As the Project Executives of the CTBT: Science and Technology 2019 (SnT2019) conference, it is our pleasure to welcome you to this important seventh gathering of the nuclear-test-ban research community. As with past SnT conferences, this event in the stunning Hofburg Palace provides an opportunity to collaborate and innovate for the future.

This SnT conference expands discussion on the CTBT verification system in the broader context of international organizations, global policy making, international collaboration and citizen awareness. As before, the continued vitality and credibility of the monitoring regime is based upon the advancement and broad understanding of methods to measure relevant signals from around the globe.

The effective verification of a comprehensive nuclear test ban is founded on the scientific and technical capacity of the world’s experts in nuclear test detection and on the infrastructure that underpins it. This capacity is ever advancing, and we at the CTBTO must remain at the forefront of this advancement if the effectiveness and credibility of our Treaty’s verification regime are to be maintained.

With SnT2019, the conference series is again expanding quantitatively: more than 1000 participants are expected, and more than 120 oral and 500 poster presentations will take place. The quality is enhanced with more stringent acceptance criteria for abstracts and more expert panels than ever before. Throughout the week, one room will be dedicated to hosting only panels, giving participants the opportunity to discuss some of the most inspiring topics with high relevance for the future scientific and technological developments that will have an impact on CTBT implementation and its entry into force.

We look forward to your active participation in this conference. Whether you are presenting results, learning of recent advances by others, sharing practical experiences or discussing new initiatives and plans, your involvement adds to the dynamism and progress of the CTBT community.

We wish you a collaborative and invigorating experience at SnT2019 and a pleasant stay in beautiful Vienna.

Tammy Taylor
Director, International Data Centre Division
CTBTO Preparatory Commission

Nurcan Meral Özel
Director, International Monitoring System Division
CTBTO Preparatory Commission
Tammy Taylor is the Director of the International Data Centre Division. Before joining the CTBTO, she was the Chief Operating Officer of the National Security Directorate at the Pacific Northwest National Laboratory (PNNL) in the United States of America, where she led the mission execution, capability development and project management of the three divisions and four project management offices representing the National Security Directorate. Prior to joining PNNL in 2013, she served in a number of positions over 14 years at Los Alamos National Laboratory (LANL). She served as the Deputy Associate Director of Chemistry, Life and Earth Sciences, the Division Leader of Nuclear Engineering and Non-Proliferation, a group leader, project leader, staff member and Director’s Postdoctoral Research Fellow.

From 2007 to 2010, Taylor was an Intergovernmental Personnel Act assignee from LANL to the Office of Science and Technology Policy (OSTP) in the Executive Office of the President within the National Security and International Affairs Directorate of OSTP, serving the Science Advisors to President Barack Obama and President George W. Bush. She managed the national science and technology portfolio on nuclear defence issues including non-proliferation, nuclear detection, nuclear forensics and nuclear detonation response and recovery, dealing with issues such as preparedness, planning, medical counter measures, decontamination and long term recovery.

Taylor has a PhD and a Master’s degree in Environmental Engineering from the Georgia Institute of Technology in the United States of America. Her undergraduate degree is in Civil Engineering from New Mexico State University in the United States of America.

Nurcan Meral Özel is the Director of the International Monitoring System Division. Before joining the CTBTO, she was Head of the Geophysics Department at Bogazici University (BU) and Vice-Director of the BU-Kandilli Observatory and Earthquake Research Institute (BU-KOERI) in Turkey from 2009 to 2014. Özel was responsible for and coordinated all seismological operations at BU-KOERI, which hosts the Regional Earthquake and Tsunami Monitoring Center and the Istanbul Earthquake Early Warning System.

From 2010 to 2015, Özel led the National Tsunami Warning Center establishment project, which implemented real time tsunami monitoring at BU-KOERI as well as the first tsunami communication system in Turkey. She is the founding coordinator of the National Tsunami Warning System in Turkey, which has been operational since 2012 and provides services to the eastern Mediterranean, Aegean and Black Seas.

Özel was the Director of the Turkish National Data Centre from 2006 to 2014. She has made significant scientific and operational contributions to earth science and to earthquake, tsunami and nuclear test monitoring and research in her country. Özel has developed expertise in earthquake source mechanisms, global seismology, deep and moderately deep earthquakes in subduction zones, strong ground motion, seismic array methods of monitoring nuclear tests, tsunami hazard and early warning systems, and tsunami modelling.

Özel was also a Professor of Geophysics at BU from 2005 to 2014. She has supervised 10 Master’s and 8 Ph.D. students and has more than 60 scientific publications. Özel holds a Geophysical Engineering degree from Istanbul University in Turkey and a PhD in Seismology from Hokkaido University in Japan.
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Eligible for the Young Scientist Award.
Theme 1:
The Earth as a Complex System
Accurate meteorological modeling is critical for obtaining realistic atmospheric transport and dispersion (T&D) predictions. There are several data assimilation (DA) techniques used to improve meteorological results. Two common philosophies are nudging and variational DA. Traditionally, nudging is used in T&D, whereas more sophisticated variational techniques are used in weather forecasting. Here, these two DA techniques are investigated in order to assess their specific impacts on T&D results and to determine if the more advanced DA techniques used in weather forecasting can be employed for T&D applications. The two methods are applied in the Weather Research and Forecasting (WRF) model for the Colorado Springs Tracer Experiment (COSTEX). First, WRF results are verified and validated against available measurements of temperature, wind speed, and wind direction. Next T&D simulations for COSTEX are performed with the Hybrid Single-Particle Lagrangian Integrated Trajectory model. Using the COSTEX tracer observations, the correlation, fractional bias, figure of merit in space, and Kolmogorov-Smirnov parameter are computed to evaluate the robustness of the T&D simulations and identify which DA technique provides the most realistic results. Overall, this study provides guidance for the meteorological community as to which DA techniques provide the most value for T&D applications.

In routine processing of IMS infrasound data at the IDC, microbaroms with dominant frequencies ranging from 0.1 to 0.5 Hz appear in overlapping frequency bands and are considered as noise. In this study, microbarom signals were used as calibration signals, and their amplitudes at the German infrasound station IS26 were modelled based on operational ocean wave interaction simulations and a semi-empirical attenuation relation. This relation strongly depends on the middle atmosphere (MA) dynamics; however, vertical temperature and wind profiles, provided by numerical weather prediction (NWP) models, have exhibited significant biases when compared with high-resolution LiDAR soundings. A fully autonomous LiDAR for MA temperature measurements was installed at IS26 for estimating uncertainties in the modelled amplitude. Temperature and wind perturbations, considering observed biases and deviations, were added to the operational high-resolution atmospheric model analysis produced by the European Centre for Medium-Range Weather Forecasts. Such uncertainties in horizontal winds and temperature explain 97% of the actual detections, compared to 77% when using the direct NWP model output. Incorporating realistic wind and temperature uncertainties in NWP models, obtained by high-resolution LiDAR measurements, can thus significantly improve the understanding of a station's detection capability throughout a year, especially during the hemispheric summer seasons.
T1.1-O3  **Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound Propagation and Scattering in the Atmosphere**

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The experimental results of studying the effect of a fine-scale layered structure of a stably stratified atmospheric boundary layer (ABL) on fluctuations of the parameters of acoustic pulses generated with a certain period (1 min) by an artificial detonation source are presented. The vertical profiles of wind velocity fluctuations in the thin layers of the ABL have been retrieved using the wave forms and travel times of the recorded arrivals of pulses from the source. It is shown that the mechanism of scattering of pulse signals in a stably stratified ABL is similar to the mechanism of scattering of signals from ground surface explosions by layered nonhomogeneities of wind velocity and temperature in the stratosphere and lower thermosphere. The role of similarity parameter here place the dimensionless thickness of the reflecting nonhomogeneous layers, which is the vertical scale of the layer multiplied by the relative difference in effective sound velocity and normalized by the vertical wavelength. The effect of such inhomogeneities on the temporal fluctuations of the azimuth and arrival times of the signals is studied. The estimation of the error in localization of pulsed sources is given. Acknowledgement: This work was supported by RFBR N 18-55-05002

T1.1-O4  **Climate Change Through the Eyes of Radioisotopes**

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Cosmogenic radionuclides beryllium-7 and sodium-22 are known atmospheric tracers and can be used together in a lock-in technique to effectively trace vertical air masses based on surface measurements. This technique allows to study progression and speed of atmospheric cells. Data show that the cells are decelerating during the summer period which is extending in time. This is caused by warming of the whole troposphere and increased tropopause height due to rising CO2 concentrations. Aestival episodes of persistent high-pressure systems over Europe with low pressure gradients that led to almost stationary thunderstorms are correlated with the observed deceleration of atmospheric cell movement. This demonstrates that 7Be and 22Na can be used as indicators for confirming several side effects of climate change while providing a new modelling tool in seasonal weather forecast.

T1.1-O5  **Detection Efficiency of the IMS for Bolides**

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In this study we examined 344 bolides (airbursts) reported on the JPL CNEOS website (https://cneos.jpl.nasa.gov/fireballs/) between 2007-2018 and attempt to correlate these with infrasound detections. We found 206 of these bolides were detectable by at least one infrasound station while only 42 were automatically registered as part of the Reviewed Event Bulletin (REB) issued daily by CTBTO. However, this global REB detection rate of ~10% averaged from 2007-2018 is less than the "modern" rate (from 2014-2018) which approaches 20%. Above the 1 kT CTBTO design threshold, we find that 40% of airbursts are reported in the REB, while more than 90% are detectable at one or more infrasound stations. All airbursts with energy > 2 kT reported on the JPL fireball site since 2007 have been detected infrasonically. However, the REB is only complete above 15 kT with the automated detection system not having reported at least four airbursts with
**Theme 1: The Earth as a Complex System**

energies between 8 – 14 kT during 2007-2018. We will present details of the IMS airburst detection efficiency by season, airburst energy and other detection variables.

**T1.1-O6**  
**NEMO - A Global Near Real-Time Fireball Monitoring System**

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The Near real-time Monitoring system, called NEMO, is a project for world-wide and near real-time monitoring of bright fireballs, currently under development. NEMO is based on an alert system collecting information on fireball events and will be a combined world-wide database for large fireball events with the goal to analyse and combine data of these events from various data sources to maximize the scientific output. Based on social media, the alert system can provide very fast notifications for fireball events. Furthermore, diverse data sources are investigated like witness reports, meteorological satellite data, or the IMS infrasound data. There is still a lack of knowledge on extra-terrestrial objects in the intermediate size range (decimetres to metres). These objects cause bright fireballs when they impact the Earth’s Atmosphere, which they do frequently, but are too small to be detected by NEO (near-Earth object) surveys. To close this gap between large meteoroids and small asteroids is one of NEMO’s aims. In this talk a brief introduction on NEMO and its working principle will be given, illustrated by an example of a NEMO event: the Russian daytime fireball from 21 June 2018.

**T1.1-O7**  
**Recording of Internal Gravity Waves and Infrasound Waves from the Warm and Cold Fronts in Moscow Region**

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The results of recording internal gravity waves and infrasound waves from the warm and cold fronts associated with the atmospheric storm passing through Moscow on May 29, 2017 are presented. The waves were recorded by a network of 4 microbarographs IFA-MGU-M SR - ZNS located in Moscow and Moscow region. It shows the temporal changes in the characteristics of IGWs and infrasound waves such as coherence, direction of propagation, phase velocities, characteristic periods and frequency spectra with the passage of warm and cold fronts through the network.

**T1.1-O8**  
**Remote Monitoring Volcanic Eruptions Using IMS Infrasound Data**

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The European Research Infrastructure project ARISE demonstrated that infrasound is an efficient method for remote volcano monitoring up to distances of several thousand kilometers. Near field infrasound observations can be used to reconstruct in detail the eruptive chronology and to provide near-real time notification of ongoing activity to civil protection authorities. At larger distances recent work showed that infrasound parameters could constraint the source strength and eruptive chronology. Such parameters are useful to model the ash plume dispersion which is strongly controlled by source term information that is often missing, especially for volcanic
eruptions from poorly instrumented volcanoes. ARISE project perspective is to cover this gap, providing near-real time information on the source terms to the Volcanic Ash Advisory Centre (VAAC). The prototype system Volcanic Information System (VIS) was recently integrated in the virtual Data Exploitation Centre (vDEC) of CTBTO and first tested using remote infrasound observations from Etna. In order to consolidate the notifications, confidence levels are calculated using accurate atmosphere specifications. Once validated, VIS is planned to further be evaluated by considering other regions worldwide.

**T1.1-O9**  
**Temperature and Wind Atmospheric Lidars as Tools for the Validation of Infrasound Propagation Models**

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Rayleigh temperature and Doppler wind lidars are powerful instruments to monitor the vertical profile of atmospheric parameters up to the upper mesosphere. Such instruments are operated routinely at Haute-Provence Observatory (OHP) in South-East France and at Maïdo Observatory in Reunion Island in the frame of the Network for the Detection of Atmospheric Composition Change (NDACC) and they are included in the ARISE (Atmospheric dynamics Research InfraStructure in Europe) project. They allow to monitor the long-term evolution of the middle atmosphere in relation with global climate change and to study the role of atmospheric waves (gravity waves, planetary waves, sudden stratospheric warmings) in the variability of this region at various scales. Using the lidar profiles of wind and temperature, it is possible to reconstruct the vertical profile of effective sound velocity and to compare it with the prediction of infrasound propagation simulations using Numerical Weather Prediction models. The co-location of temperature and wind lidars and microbarometer arrays at OHP and Maïdo ARISE sites offers a great opportunity to evaluate the added value of such lidars for the interpretation of infrasound detection.

**T1.1-O10**  
**The Effect of Atmospheric Boundary Layer on the Detected Radionuclides in Kuwait**

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The atmospheric planetary boundary layer (ABL) plays a major role in the detected radionuclides concentrations at the ground level; it can describe the dynamic and the behavior of the air movement in the region of interest. In this work, data collected from the CTBTO/IMS RN40 station for the years 2013-2018 along with the measurements of the upper air temperature using MTP-5H microwave temperature profiler were used to study the influence of Kuwait ABL on the concentrations of Be-7 as a natural and Cs-137 as an anthropogenic radionuclides in atmosphere. Results showed that the height and the frequencies of the formation of the surface temperature inversion were linked with the high concentrations of both radionuclides detected in Kuwait.
The middle and upper atmosphere is a highly variable environment at subseasonal time scales. This variability influences the general atmospheric circulation especially through the propagation and breaking of planetary and gravity waves in the stratosphere and mesosphere. The ARISE (Atmospheric dynamics Research InfraStructure in Europe) project integrates complementary instruments such as infrasound stations of the International Monitoring System developed for the verification of the Comprehensive Nuclear-Test-Ban-Treaty, lidar and radar networks and satellites. One main objective is to determine the origin of the uncertainties in Numerical Weather Forecasting (NWP) models, such as the operational analyses distributed by the European Centre for Medium-Range Weather Forecasts (ECMWF) used for infrasound propagation modeling. It is shown that the variability from tropical convection, wind over mountains, stratospheric warming events and gravity wave activity strongly contribute to the uncertainties. The different scales of the disturbances and their seasonal evolution are studied. Significant differences in the uncertainties are observed in regions that are subject to different conditions, depending on wave activity. The ARISE perspective is to provide new data sets for model assessment, assimilation in medium range weather prediction models and in operational infrasound simulations.

**Poster Presentations**

**T1.1-P2 Analysis of Multiple Detections of May 2011 Grímsvötn (Iceland) Eruptive Activity at Different IMS Infrasound Stations and its Correlation with Local Observations**

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Grímsvötn volcano, located under the Vatnajökull glacier on the center of the active NE rift zone of Iceland, is the most active volcano of Iceland. Its last eruption, in May 2011, broke the ice cover and became subaerial explosive, ejecting volcanic ash into the atmosphere, causing major impact in air traffic in the Northwestern Europe and in the North Atlantic. We present long-range observations of the May 2011 Grímsvötn eruptive activity recorded at IS18, IS26, IS42, IS43, IS31, IS10, IS53 and IS17, at source-to-receiver distances ranging from approximately 2,250 km to 6,500 km, with a maximum azimuthal gap of approximately 210°. We relate those volcanic sources of infrasonic waves to events listed in the Reviewed Event Bulletin (REB) of the CTBTO International Data Center (IDC), based on the detections associated back azimuths and on the local volcanological observations from the Icelandic Meteorological Office (IMO) published reports.
**T1.1-P3** Analysis of Multiple Detections of Mount Etna Eruptive Activity at Different IMS Infrasound Stations Compared with Near Source Observations

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Mount Etna, the largest and most active volcano of Europe, is located on the NE region of Sicily Island, southern Italy. Its recent volcanic activity is typically explosive with explosive episodes and lava fountaining able to produce high (up to 15 km) eruptive plumes. In the framework of the ARISE2 project, the Universities of the Azores (UA) and Florence (Unifi), carried out a collaborative research on the IS42 infrasound detections of explosive volcanic activity. A comparison of infrasound detections of the IMS station IS42, located at a distance of 3,700 km from Etna with data recorded near the source (around 5 km) by the ETN local UniFi infrasonic array for the Etna volcanic activity in 2011 and 2016 has been performed. In the present study we extend the long-range observations to the IMS infrasound stations at IS48, IS26, IS42, and IS17, at source-to-receiver distances ranging from approximately 550 km to 3,980 km, with a maximum azimuthal gap of approximately 200°. We compare the detections obtained with the near field detections of the ETN and the long range observations with the events listed in the Reviewed Event Bulletin (REB) of the CTBTO International Data Center (IDC), in order to evaluate the potential of the IMS network in detecting and identifying sources of volcanic activity.

**T1.1-P4** Application of Information Technologies for Detecting, Analyzing & Determining the Atmospheric Dynamics

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The unprecedented growth in the information technologies has opened the gates to explore the atmosphere, in a greater depth, for detecting, locating and determining the spatial or temporal pattern of any natural or anthropogenic change occurring in its layers. The Infrasound technologies, in the recent years, have been exponentially evolved to a much broader discipline encompassing multidimensional domains such as geology, climatology, geo-informatics engineering, wireless communication and remote sensing technologies. These technologies can be used for continuous observations of the sub layers of atmosphere particularly stratosphere and mesosphere, to analyze any climatological change caused by any natural or man-made processes. Systematic assessment of low-frequency infrasound signals and utilization of satellite imageries play a pivotal role to investigate the dynamics of middle atmosphere. These information, if aptly used, can help in multi hazard, vulnerability and risk assessment of hydro-meteorological and climate change induced hazards and help to develop a continuous monitoring of atmospheric processes.

**T1.1-P5** ARISE Project: Infrasound Monitoring for Civil Applications

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The ARISE (Atmospheric dynamics InfraStructure in Europe) project combines the International infrasound Monitoring System developed for the verification of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) with lidar and radar networks and satellites for an improved description of the atmospheric dynamics. Civil applications are the following: - Weather forecasting: It is demonstrated that a better knowledge of the stratosphere, for example at the onset of stratospheric warming events, improves forecasts at time scales of
**Theme 1: The Earth as a Complex System**

several weeks. Gravity waves observed in the lower part of the infrasound spectrum can also be parameterized for improved representation in models. - Climate change: The long duration infrasound time series are relevant to determine the evolution of disturbances with the climate change. This concerns tropical convection, lightning activity, cyclones and ice breaking in polar regions. - Civil security: Infrasound remote monitoring is well adapted to automatically detect and notify volcano eruptions at global scale. The impact for civil aviation is large especially for unmonitored volcanoes. The Volcano Information System (VIS) is proposed in cooperation with CTBT organization and the Toulouse Volcano Ash Advisory Center (VAAC). A prototype is included in the ARISE data Center. Infrasound observations are also relevant for the monitoring of thunderstorms and meteors.

**T1.1-P6 Assessing Middle Atmosphere Weather Models Using Lidar and Ambient Noise: A Case Study for IS02**

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In routine processing of IMS infrasound data at the IDC, microbaroms with dominant frequencies ranging from 0.1 to 0.5 Hz appear in overlapping frequency bands and are considered as noise. In this study, microbarom signals were used as calibration signals, and their amplitudes at the Argentinian infrasound station IS02 were modelled based on operational ocean wave interaction simulations and a semi-empirical attenuation relation. This relation strongly depends on the middle atmosphere (MA) dynamics; however, vertical temperature and wind profiles, provided by numerical weather prediction (NWP) models, have exhibited significant biases when compared with high-resolution LIDAR soundings in altitudes where infrasound signals propagate. Here, the fully autonomous LIDAR for MA temperature measurements was installed in Rio Grande, Argentina, which is around 60 km north of IS02. Temperature measurements have been carried out since November 2017. The poster provides first results of collocated LIDAR and infrasound measurements covering a time period of more than one year. Due to the extended duration of the LIDAR campaign at IS02, compared to the one at IS26 in 2016 (seven months), the results are expected to be more significant and highlight the seasonal differences with enhanced accuracy.

**T1.1-P7 Atmospheric Dynamics**

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Atmospheric Dynamics involves observational and theoretical analysis of all motion systems of meteorological significance, including such diverse phenomena as thunderstorms, tornadoes, gravity waves, tropical hurricanes, extratropical cyclones, jet streams and global scale circulation. When there is a nuclear explosion, all the particles comes out and travel to the oceans, earth and atmosphere. Another area is atmospheric dynamics relevant to the transport of radionuclides and the propagation of atmospheric infrasound. All elements released into the atmosphere changes the atmospheric dynamics. Particles that stay in the atmosphere influence the weather and also lead to climate change. Gases released from a nuclear event can damage our greenhouses that protect our earth. This means that we will have weather extremes, for example: higher temperatures (heat waves), colder winters and sea level rise. With all the data it is very easy to analyze the events and detect upcoming events.
**T1.1-P8** Characterizing Ocean Ambient Noise Using Infrasound Network

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The ability of the International Monitoring System (IMS) global infrasound network to detect atmospheric explosions and events of interest strongly depends on station specific ambient noise signatures which include both incoherent wind noise and coherent infrasonic waves. To characterize the coherent ambient noise, broadband array processing has been performed on continuous IMS recordings since 2005. Obviously, ocean wave interactions contribute to the atmospheric coherent ambient noise field, therefore we apply wave action models to compute these microbarom sources. We use two-dimensional energy spectrum ocean wave products to build a global reference database of oceanic noise sources. Overall, we compare observed and modeled directional microbarom amplitudes at several stations worldwide distributed. Such studies aim to better characterize the coupling mechanisms at the ocean-atmosphere interface. In return, an improved knowledge-base on ambient ocean noise sources opens new perspectives for enhancing the characterization of explosive atmospheric events as well as for providing additional integrated constraints on middle atmosphere dynamics and disturbances in sparsely covered regions of the world.

**T1.1-P9** Climate Change Impact & Adaptation Studies Using Radionuclide Data

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CTBTO has Radionuclide Stations deployed at various parts of the world as part of its verification regime. These stations are collecting data by sampling atmospheric air. The data produced by these stations can be used for studying climate change and its impacts. This data can be projected using pattern informatics techniques to map isotopes production indicating spatial and temporal distributions across climatic zones. These distributions can be correlated to other indicators particularly climatological to form related hypothesis. These hypothesis can be further tested using latest samplings from regional meteorological outfits while duly incorporating historical data. Climate change phenomenon and its impact in terms of variability of related observed data in relation to other factors can accordingly be structured in the form of a matrix indicating trends. This quantitative analysis helps in finding precise intricate impacts followed by identification of causal factors at both micro and macro level. Different correlation techniques can be applied to determine boundary conditions and forming thresholds for predicting climate change patterns. Models for developing simulations can accordingly be developed based on study findings. This briefly explained concept is challenging yet interesting as it may help us in understanding future of our habitat.

**T1.1-P10** CORAL – An Autonomous Middle Atmosphere Lidar in Southern Argentina

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The Compact Rayleigh Autonomous Lidar (CORAL) is a high-power Rayleigh backscatter lidar designed for profiling the middle atmosphere and studying gravity waves from the troposphere to the mesopause region at around 90 km altitude. It was deployed to Rio Grande, Tierra del Fuego, Argentina in November 2017 and has since then collected more than 1300 h of high-resolution data. Using local weather data and forecasts, the lidar operates autonomously and measurements are obtained on average on two out of three nights. The region of Tierra del Fuego is known for the largest stratospheric gravity wave activity on Earth, where gravity waves are
Theme 1: The Earth as a Complex System

excited by strong zonal winds crossing the Andes mountains. Averge potential energy densities of 60 J/kg at 40-50 km altitude are reached during winter, and significantly higher values are observed during intermittent extreme gravity wave events. We present the lidar instrument technology, measurement statistics, an overview of the temperature and gravity wave datasets and selected examples of large-amplitude mountain waves.

T1.1-P11  Estimating Tropospheric and Stratospheric Large-Scale Wind Components Using Infrasound from Explosions

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We study large-scale wind effects on infrasound propagation to the seismic array ARCES, Norway, utilizing 30 years of data from around 600 ground truth events at the Hukkakero military blast-site in Finland, which all are well-constrained in location and origin time using seismic data. The wind component perpendicular to the infrasound propagation (cross-wind) will translate the wave a distance proportional to wind magnitude and travel time. Using observed deviations from the true azimuth to the explosion site, combined with the observed travel time, we demonstrate that an average large-scale cross-wind can be estimated solely from infrasound data. Our analysis shows that the infrasound-based estimation of the cross-wind has a high degree of correlation with the cross-winds extracted from ERA-interim atmospheric re-analysis models. We suggest using this approach for estimating the tropospheric and stratospheric large-scale wind components. These results also confirm that in an event localization context, without ground truth information, knowledge of the average cross-wind is of great value for event location improvement.

T1.1-P12  EUNADICS-AV Tracer Experiment: Modelling and Model Evaluation

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Aircraft travel is one of the most critical modes of transport in this century. Even short disruptions of flight schedules result in major economic damages as was proven by the aftermath of the 2010 Eyjafjallajökull-eruption in Iceland. Air traffic safety is another important aspect. The focus of the ongoing project EUNADICS-AV (European Natural Airborne Disaster Information and Coordination System for Aviation) is on developing methods and systems which guarantee a safe air traffic and at the same time low economic damages in case of a possible natural hazard or a possible nuclear accident. In September 2018 an experiment took place in Germany and Austria in order to simulate a real emergency situation. Small amounts (5 to 10 kilograms) of a non-toxic, inert tracer gas (Perfluorcarbon-PFC) were released in Oberpfaffenhofen/Germany and Langenlebarn/Austria into the atmosphere to be transported by the wind. Altogether three aircrafts with specific measurement devices were flying through assumed regions affected by the dispersed tracer gas, which had been predicted by the atmospheric transport and dispersion models FLEXPART and HY SPLIT, to measure its distribution. In this presentation we will compare FLEXPART and HY SPLIT qualitatively for one of the tracer releases and evaluate FLEXPART based on the measurements.

T1.1-P13  Filling a Gap in the Wet Scavenging Scheme in FLEXPART 10.3

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Recently an improved wet scavenging scheme was released for FLEXPART 10.3 (April 2017). It focuses on physically-based improvements by using 3D cloud water fields which allow to better distinguish between in- and below-cloud scavenging. Even though this procedure shows much better realistic results than previous schemes, improvements with respect to numerical aspects (interpolation in time of clouds/cloud water and the falsification
of precipitation disaggregation) and fall-back options for missing cloud water fields are still pending. Therefore, we introduce a new disaggregation method for precipitation data and linearly interpolate the cloud information. Additionally, the relationship between clouds and precipitation and the impact of different scavenging parameters are studied. Missing cloud information can be substituted with parameterizations based on precipitation rates and relative humidity, distinguishing between large-scale and convective clouds. To ensure consistent quality for future FLEXPART versions, the testing environment introduced in FLEXPART 10.3 is extended by some automated test cases to allow regression testing. The methodology together with, idealised and real case tests are presented.

**T1.1-P14  IDC Infrasound Technology Developments**

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The IDC advances its methods and continuously improves its automatic system for the infrasound technology. The IDC focuses on enhancing the automatic system for the identification of valid signals and the optimization of the network detection threshold by identifying ways to refine signal characterization methodology and association criteria. An objective of this study is to reduce the number of associated infrasound arrivals that are rejected from the automatic bulletins when generating the reviewed event bulletins. A number of ongoing projects at the IDC will be presented, such as: - improving the detection accuracy at the station processing stage by introducing the infrasound signal detection and interactive review software DTK-(G)PMCC (Progressive Multi-Channel Correlation) and by evaluating the performances of detection software; - development of the new generation of automatic waveform network processing software NET-VISA to pursue a lower ratio of false alarms over GA (Global Association) and a path for revisiting the historical IRED. The IDC identified a number of areas for improvement of its infrasound system, those will be shortly introduced.

**T1.1-P15  Improving Propagation-Based, Stochastic Models for Bayesian Infrasonic Localization and Characterization**

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Bayesian methodologies have been developed for network level analysis of infrasonic signals including association, localization, and characterization. In the case of localization and characterization, the underlying propagation models utilized in computing the source parameters can be simplistic and generalized or include propagation-based, stochastic models unique to a given spatial and temporal scenario such as the western US during winter. Previously, these propagation-based, stochastic models have been constructed using archived atmospheric specification data and large-scale propagation simulation campaigns. Statistical analysis of the underlying seasonal variability in the atmosphere has led to refinement in the profiles needed for use in the simulation campaigns and methods are being developed to further refine the construction of propagation models for events of interest using atmospheric updating techniques. An overview of the construction and use of these propagation models will be presented along with discussion of several applications including standard signal analysis for localization and characterization of infrasonic events as well as optimization of network configuration for signal detectability.
**Theme 1: The Earth as a Complex System**

**T1.1-P16 Improving the Infrasound Monitoring Capability in Europe Incorporating CEEIN**

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Established in 2018, the Central and Eastern European Infrasound Network (CEEIN) consists of six national microbarograph stations in Hungary, Romania, Austria, and Czechia. This joint experiment aims to contribute both to advanced understanding of infrasound sources in Central-Europe and to the ARISE design study project, as an enhancement of the European infrasound network. Several events of interest including accidental explosions, bolides, North Sea sonic booms, volcanic eruptions and severe weather phenomena have been studied. Data processing and analysis have been performed by using the latest version of DTK software (GPMCC and DIVA). Network performance modeling were undertaken and proved that the European detection capability is significantly improved by incorporating data from the CEEIN.

**T1.1-P17 Infrasound Monitoring for Global Climate Model Calibration: A Two-Way Collaboration**

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While stochastic parameterizations in Global Climate Models (GCMs) are promising for improving longstanding climate predictions, there is no consensus regarding the values of tunable parameters. Further, in infrasound studies randomness is often described as a disturbance superimposed onto given atmospheric specifications, without feedback effect on climate/weather. This work shows how stochastic schemes in a GCM can be calibrated with data provided by the IMS infrasound network and full-wave acoustic modeling, using the FLOWS platform, developed at CEA. FLOWS’ concept of propagation is expressed in the form of a reduced model, a concept that was first introduced at the Science and Technology conference 2013. The performance of the method is demonstrated by comparing the updated climatology and variability of the middle atmosphere with the reanalysis. Including IMS data in the GCM is shown to compensate the warm bias compared to observations, and to reevaluate the frequency of sudden stratospheric warmings. Ultimately the aim of this work is to answer the questions of whether, to what extent and at what cost the use of updated atmospheric data, using the IMS infrasound background noise and machine learning, helps improve association and localization.

**T1.1-P18 Infrasound Propagation in Multiple-Scale Random Media Using Surrogate Models**

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Infrasound propagation in realistic environments is highly dependent on the information to specify the waveguide parameters. For real-world applications, there is considerable uncertainty regarding this information, and it is more realistic to consider the wind and temperature profiles as random functions, with associated probability distribution functions reflecting phenomena that are filtered out in the available data. Even though the numerical methods currently-in-use allow accurate results for a given atmosphere, high dimensionality of the
random functions severely limits the ability to compute the random process representing the acoustic field, and some form of sampling reduction is necessary. In this work we use polynomial chaos (gPC)-based metamodels to represent the effect of large-scale atmospheric variability onto the acoustic normal modes. The impact of small-scale atmospheric structures is modelled using a perturbative approach of the coupling matrix. This multi-level approach allows to estimate the statistical influence of each mode as the frequency varies. An excellent agreement is obtained with the gPC-based propagation model, with a few realizations of the random process, when compared with the Monte Carlo approach, with its thousands of realizations. Further, the gPC framework allows computing easily the Sobol indices without supplementary cost, which is essential for sensitivity studies.

T1.1-P19 **Large Events Recorded at the IMS Infrasound Network**

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Infrasound is one of three waveform technologies used by the Comprehensive Nuclear-Test-Ban Treaty verification regime. Events detected by infrasound stations of the International Monitoring System (IMS) are included in the International Data Centre (IDC) bulletins. According to the IDC analysis rules, events are considered large if they are detected by at least six primary stations. There are only a few infrasound seed events per year which fulfill this criterion. Pure infrasound events are characterized by a small number of associated phases, due to sparse network, high winds at recording stations, or unfavourable propagation conditions. The largest infrasound seed event reported in the Reviewed Event Bulletin (REB), which was detected by 20 infrasound stations, was generated by the meteor which fell close to Chelyabinsk in Russia in 2013. Large seismic events may also generate infrasound signals, which under favourable propagation conditions may be seen at distant infrasound stations. This presentation will provide examples of REB events recorded at many stations of the IMS infrasound network.

T1.1-P21 **Look-Up Tables with Empirical Climatologies for Infrasound Detection, Location, and Characterization of Long Range Volcanic Eruptions**

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Energetic volcanic eruptions emit exceptional infrasonic signals (frequency below 20 Hz) to the atmosphere, because eruptions have a punctuated duration and its signals can travel up to thousands of kilometers due to their low frequency nature and atmospheric ducting effects. Because of this, IMS stations can be used to locate and characterize the surface activity of volcanoes. Unfortunately, atmospheric effects (e.g., crosswinds) along the raypaths can change the apparent direction of the incoming signals in the IMS stations, which needs to be addressed in a robust and fast manner to make use of infrasonic data in real time. Empirical climatologies and 3D ray tracing can be used with this purpose to have an a priori value of azimuth deviation to improve the source location (e.g., Matoza et al., 2018). Furthermore, the IMS network can be used to significantly enhance the signal-to-noise ratio (e.g., Matoza et al., 2017). In this work, look-up tables to estimate atmospheric propagation effects have been developed with empirical climatologies. Three test cases of VEI 4 eruptions along the Chile-Argentina Andean Cordillera have been used: Chaitén in 2008, Puyehue-Cordón Caulle in 2011, and Calbuco in 2015. Our results for the source location improvement are showed and analyzed.
**Theme 1: The Earth as a Complex System**

**T1.1-P22 On the Use of Infrasound Observations from Volcanoes for Improving the Weather Forecasts**

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Infrasound waves are emitted by various geophysical sources such as volcanoes, northern lights and ocean swell. In many situations, the middle-atmosphere can behave as a waveguide and infrasound can propagate up to thousands of kilometers. In such cases, infrasound signals can be recorded by stations of the International Monitoring System (IMS). Reliable simulation-based predictions of acoustical arrivals, however, need a so-called atmospheric specification, which describes the atmospheric state in terms of temperature, wind fields, and other meteorological-related variables. Such data can be obtained from products that are currently provided by the operational meteorological centers. The goal of this study is to use ray tracing simulations and observations made at the IMS stations, in terms of trace velocity and back azimuth, to select the atmospheric states that explain best the acoustical observations. Here these states are given via ensembles of short-range forecasts and analyses, using the global Numerical Weather Prediction (NWP) model ARPEGE of Météo-France, and a Bayesian approach is adopted for selecting the most likely members of the ensembles. The method is assessed using infrasound signals associated with a sequence of eruptions of Mount Etna in May 2016, and detected at the Tunisian infrasound station IS48.

**T1.1-P23 Probabilistic Predictions and Uncertainty Estimation Using Adaptively Designed Ensembles for Radiological Plume Modeling**

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Better characterization of meteorological uncertainty is needed within a dispersion modeling framework so that plausible ranges of predictions from radiological releases to the atmosphere (e.g. nuclear power plant, nuclear detonation) can be accurately communicated to decision makers. Largely for computational reasons, atmospheric model ensembles typically utilize a reduced set of physics configurations that often fail to fully explore the uncertainty range of atmospheric phenomena key to dispersion modeling processes, such as surface energy exchange, cloud formation, precipitation, and atmospheric stability. To address this research need, we use machine learning and adaptive statistical methods to optimize the ensemble design to capture the key sources of meteorological uncertainty specific to a region, period, and atmospheric release scenario. Without having to run a full ensemble, this methodology samples and iteratively learns about the atmospheric model physics options that affect plume predictions. Statistical methods are used to quantify the contributions to the ensemble variance in radiological deposition and recommend additional model physics configuration to run. This work will develop a computationally efficient and statistically robust method to provide probabilistic plume predictions for real-time consequence management and expert assessment of airborne radiological material.

**T1.1-P25 Temporal Variations of the Intensity Spectra of Atmospheric Pressure Fluctuations in Different Frequency Ranges and Their Possible Connection with Climate Change**

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The possibility of using data from the registration of atmospheric pressure fluctuations obtained on a microbarograph network to study the problem of climate change is studied. The study of atmospheric pressure fluctuations in the range of periods of infrasonic and internal gravity waves (periods from 10 seconds to 3 hours) recorded in 2009-2018 at the network of OIAP microbarographs located in the region of Moscow was conducted. The average distance between microbarographs is about 7 km. Additionally, data on the recording of
In this study, we are going to present results of global coherent infrasound measured at IMS infrasound stations and its correlation with atmospheric dynamics. A new implementation of the Progressive Multi-Channel Correlation (PMCC) algorithm enables characterization, with a single processing run, of coherent noise in log-spaced frequency with one-third octave bands from 0.01 to 5 Hz. Such a new array processing algorithm enables a better characterization of all received signals in their wave parameter space (e.g., frequency-azimuth space, frequency-trace-velocity space). This, in turn, enables more accurate signal discrimination, and source and propagation studies. We are currently performing re-processing of the entire previous IMS infrasound database covering the time period from April 2005 to November 2018; whereas the number of stations has increased from 30 to 50. The obtained results clearly indicate a continuous spectrum of coherent signals at IMS stations within the 0.01 to 5.0 Hz frequency range; especially when comparing the recent results with those of previous re-processing approaches as well as the standard IDC products.

T1.1-P27 The Global and Coherent Infrasound Field: Revisiting the Reprocessing of the Full International Monitoring System Infrasound Data, Part 2: Examples

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In this study, we are going to present results of global coherent infrasound measured at IMS infrasound stations and its correlation with atmospheric dynamics. A new implementation of the Progressive Multi-Channel Correlation (PMCC) algorithm enables the characterization, with a single processing run, of coherent noise in log-spaced frequency with one-third octave bands from 0.01 to 5 Hz. Such a new array processing algorithm enables a better characterization of all received signals in their wave parameter space (e.g., frequency-azimuth space, frequency-trace-velocity space). This, in turn, enables more accurate signal discrimination, and source and propagation studies. We are currently performing a re-processing of the entire previous IMS infrasound database covering the time period from April 2005 to November 2018; meanwhile, the number of stations has increased from 30 to 50. The obtained results clearly indicate a continuous spectrum of coherent signals at IMS stations within the 0.01 to 5.0 Hz frequency range. In this part of our study, examples of globally detected microbarom sources and hotspots for generating mountain-associated waves are shown, as well as benchmarking events like volcanic eruptions and bolides.
**Theme 1: The Earth as a Complex System**

**T1.1-P28  The Influence of Tropospheric Ducts on Long Range Infrasound Propagation**

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The troposphere is generally thought of as the lowest 15 kilometers of the atmosphere. In the simplest case it is characterized by a more or less linear decrease in temperature and a relatively thin elevated wind jet called the jet stream. The jet stream is typically centered about 10 kilometers from the ground surface and is mostly eastward flowing, but can vary from north-eastward to south-eastward. In addition, the troposphere is the region of the atmosphere that interacts directly with the Earth's surface which can lead to near-ground temperature inversions over cool ground and low altitude wind jets induced by ground topography. What results is a potentially complex and variable environment in which infrasound can propagate efficiently, ensonifying the ground from tens to well over a thousand kilometers. Further, at infrasonic frequencies, the acoustic wavelength can be comparable to the vertical extent of the atmospheric structures in the troposphere, causing the resulting ducts to be highly dispersive and leaky leading to complex interactions between the tropospheric ducts and ducts in the middle/upper atmosphere. In this presentation numerous observations of infrasonic signals propagated in the troposphere will be presented, their features discussed and compared to theoretical predictions.

**T1.1-P29  Tropical Cyclones Activity in Southwest Pacific and Their Link to ENSO and Sunspot**

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The influence of the El Nino-Southern Oscillation (ENSO) and sunspots on tropical cyclone intensity in the Southwest Pacific is examined. The research is built on work in the study between sunspots, ENSO, and tropical cyclone intensity with different variables using ACE (Accumulated Cyclone Energy) and tropical cyclone frequency intensity. It has found that sunspots determine if a link is present between solar irradiance and tropical cyclone. The correlations in sunspot extreme years (maximum and minimum) increased from those over the entire cycle, with minimum years having the highest correlations to tropical cyclone intensity. Regression model show that increased sunspots number actually decrease tropical cyclone frequency and ACE. ENSO have also been examined to find the relation between tropical cyclone season and sunspot. The result shows that El Nino contribute >30% of TC frequency. Also, strong El Nino on 2015-2016 and 1996-1997 contribute high tropical cyclone frequency and ACE (more than 20 and more than 100x10^4 knot) in Southwest Pacific. Moreover, sunspot need time lag to effect the La Nina and El Nino phenomena about 2-3 years. Sunspots should be considered for increased pre-seasonal tropical cyclones forecast accuracy and the inter-annual variability of tropical cyclones.

**T1.1-P30  Using Infrasound Mobile Array (I68CI) Data to Characterize Tropical Thunderstorm over West Africa**

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Côte d’Ivoire NDC in collaboration with CTBTO deployed from January to December 2018, a mobile infrasound array (I68CI) in North-East (Comoe Reserve) of Côte d’Ivoire. This portable array had 5 sensors and had been sampling at 50Hz. I68CI detected local, regional and distant infrasound sources. In this tropical region, during monsoon season, the main sources detected by the portable array are thunderstorms. They are moving...
from East to West and have several cells. Shortly before midnight, on 2018 April 9, I68CI detected infrasound from a big thunderstorm. This thunderstorm is located in northern Ghana at 200 km far from the station and with 0.33 km/s as mean speed. During his displacement, the thunderstorm divided into two cells with two different azimuths, which can be seen on the precipitation satellite image. It is a characteristic of thunderstorm in this region.
T1.2 Solid Earth Structure

Oral Presentations

T1.2-O1 3-D Seismic Velocity Model of the Eastern Mediterranean Region Using Body-Wave Tomography

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The Israeli National Data Center monitors and characterises the seismicity of the Eastern Mediterranean region as part of its mandate with the Comprehensive Nuclear-Test-Ban Treaty. The seismic velocity model is one of the factors that affects most the location accuracy. Three-dimensional tomographic studies of the area have been conducted in the past, but are patchy with inhomogeneous resolution, due to limited data sets and irregular data quality. We developed a new, high-resolution body-wave velocity model of the Eastern Mediterranean region. Major efforts were applied into producing a high-quality body-wave traveltime dataset, essential in order to obtain a high-resolution velocity model. We gathered seismic data from local events, as well as from man-made explosions, mostly quarry blasts in Israel and Jordan. We used both Pg and Pn phases to constrain the crust and uppermost mantle. The work was done in the Regional Seismic Travel Time framework. Our velocity model will not only enhance the CTBT organisation’s seismic location capabilities, it will also be of significant importance for earthquake monitoring in the region and for the Earthquake Early Warning System being implemented in Israel.

T1.2-O2 Earthquake Swarms and Reactivation of Seismicity Associated with the 2015 Mw 7.8 Gorkha Earthquake in Nepal

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The earthquake activity of central Himalayas is monitored continuously since 1994 by the national seismic network of Nepal (NSC) comprising of 21 seismic stations. Most of the recorded seismicity nucleates along the downdip-end of the locked fault segments of the Main Himalayan Thrust fault, the shallow dipping mega-thrust between Indian plate and Tibetan Plateau. After the April 25, 2015, Gorkha earthquake, more than 40,000 events were located within the study area and there were 30,462 events with ML >= 2.3, including 7 events with ML >= 6.0, and one large aftershock with Mw 7.3 on May 12, 2015. There is no clear evidence of foreshocks or other pre-seismic patterns. In 2018, the seismicity rate in the ruptured area is still about 5 times higher than the background seismicity before the Gorkha Earthquake. The Gorkha earthquake is the first large Himalayan earthquake allowing a detailed analysis of its aftershocks and the associated relaxation processes. Several global reactivations and anomalous bursts of earthquakes, sometimes organized in clusters. Some of these clusters are located outside the rupture zone either in Nepal or on the Tibetan Plateau. Most of them appear to be controlled by geological structural complexities of the Main Himalayan Thrust fault.
T1.2-O3 Estimation of Local Seismic Activity by Deterministic Hazard Assessment. A Case Study in North-Eastern of Azerbaijan

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Site-specific deterministic hazard assessment at respective locations of the north-eastern region of Azerbaijan provides estimates of the amplification factor on local soil conditions. Topics of interest include moment magnitude, seismic energy, b-value, simulated earthquake scenario-based Peak Ground Acceleration (PGA), site effects, rock site characterization and intensity. This study is a large scale seismicity analysis for seismic source zone clarification and estimation of maximum earthquake magnitude. The earthquake catalogue from the Republican Center of Seismological Survey (RCSS) at Azerbaijan National Academy of Sciences (ANAS) was used. The intensity distribution classifies regions in the highest hazard level with intensity value of 7 and above in the western and also in the eastern part of the area. The b-value result shows that a decrease is observed in the western part of the region and in some areas of the northern part which is an indication of higher stress in those areas. The very high PGA is scattered also in the western and eastern parts. It may have significant impact on engineering design, especially for critical facilities in those areas. Independently from the epicenter of scenario earthquakes, the low and very low PGA is scattered in the central part of the study area.

T1.2-O4 Revised Local- and Regional-Scale Velocity and Attenuation Models for Canada for Improved Earthquake/Explosion Location, Magnitude and Yield Estimates

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The Canadian National Seismic Network (CNSN), covering one of the largest single-network areas worldwide, plays an important role in global nuclear explosion monitoring. As such, and in light of the recent CNSN refurbishment program, we present two national-scale models of local and regional velocity and regional frequency-dependent attenuation relations for 3-D crustal and upper mantle structure. We make significant advancements in Regional Seismic Travel Time (RSTT) tomography (Myers et al., 2010) for Canada using natural and mining-related seismic event data from the Canadian National Earthquake Data Base (NEDB) in addition to a newly-assembled ground truth database of locally and regionally recorded mining events and refraction explosions of known location, depth and timing. For the attenuation model, we use regional Lg amplitude–distance relations in narrow frequency bands in the range 0.5-16 Hz across various regions of Canada and systematically invert for frequency-dependent Q. Improved velocity and attenuation models are of multifaceted interest to the nuclear explosion monitoring community as they have the potential of 1) reducing earthquake/explosion location errors through improved travel time predictions of regional and local phases, 2) improving explosive yield estimates and 3) reducing regional magnitude bias across adjacent geologic provinces.
Theme 1: The Earth as a Complex System

T1.1-O1 Application of Advanced Data Assimilation Techniques to Improve
T1.1-O2 Assessing Middle Atmosphere Weather Models Using Lidar and Ambient

Oral Presentations

Integrated Trajectory model. Using the COSTEX tracer observations, the correlation, fractional bias, figure of

In routine processing of IMS infrasound data at the IDC, microbaroms with dominant frequencies ranging from

First, WRF results are verified and validated against available measurements of temperature, wind speed, and

techniques used in weather forecasting can be employed for T&D applications. The two methods are applied in

Accurate meteorological modeling is critical for obtaining realistic atmospheric transport and dispersion (T&D)

There are several data assimilation (DA) techniques used to improve meteorological results. Two

The Regional Seismic Travel Time (RSTT) tomography model has been developed to improve travel time predictions for regional phases (Pn, Sn, Pg, Lg) in order to increase seismic location accuracy, especially for explosion monitoring. The RSTT model is specifically designed to exploit regional phases for location, especially when combined with teleseismic arrivals. The latest RSTT model (version 201404um) is located on the Sandia National Laboratories web site (http://www.sandia.gov/rstt). We are in the process of updating the RSTT model to include new features. The original model used CRUST2.0 combined with an a priori model in Eurasia from US National Laboratories. The newest crustal update will use the CRUST1.0 version that includes more detailed and realistic structures. New event data are also being compiled that include global ground-truth (GT) information from local, regional, and teleseismic bulletins as well as data obtained through various RSTT workshops in South America, Latin America, Asia, and Africa. Using the new crust and available data, the tomography will be updated for improved coverage and accuracy, including new path-dependent uncertainty estimates for all regional phases. We also demonstrate validation of the new model and uncertainty estimates using the International Monitoring System stations and Reviewed Event Bulletin events.

Poster Presentations

T1.2-P1 22 New Focal Mechanism Solutions for Shallow Earthquakes and Stress Observations for Bolivia (Plurinational State of)

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On this research we present 22 new focal mechanism solutions for shallow earthquakes (<70km depth) located at Bolivia region, most of them were felt by people and caused some damage to structures. Until 2016 the way of data processing with a small network did not allow us to get focal mechanism solutions for magnitudes below 4.5 M L. After 2016 with the seismic network enhanced and the data merging from LP AZ - PS06, SIV - AS08 and Penas-IS08 under the NDC-in-a-BOX Seiscomp 3 - Seisan software allow us to have accuracy data to implement the focal mechanism procedure. We applied the Double Couple method which takes the elastic wave radiation from an earthquake and they can be modeled in two equivalent ways, it means that there is a point force which applies exactly to a point in an elastic medium that is represented as pairs of point forces, so the result can be used to show a shear faulting. Our solutions were tested numerically and verified in situ, all of them are coherent with the geology and stress system maps for the region, all solutions were presented to Civil Defense Minister to contribute to National Hazard Map.

T1.2-P2 3D Dynamic Earthquake Fracture Simulations Considering the Nonplanar Fault Geometry and Heterogeneous Stress States in the Sea of Marmara

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The main objective the study is to determine 3D dynamic earthquake rupture scenarios in the Sea of Marmara, considering non-planar fault geometry and heterogeneous stress structures, since the Marmara region is prone to a large earthquake (M>7.0) with its >15 million inhabitants in Istanbul. We adapt creeping and locked parts of the segments of the Main Marmara Fault (M M F) via results of recent repeating earthquake and seismicity studies. We constrain initial shear and normal stresses through recent interseismic strain rates and regional stress orientations. Additionally, previous rupture extensions are estimated from the investigations related to historical data and turbidity records. Due the requirement of high computational demand, the most accurate and largest
mesh size (200m) and the time step (0.01s) values are verified for planar (simple) and non-planar (complex) test geometries. Tetragonal mesh is used in order to increase the sensitivity of the rupture propagation within the generated fault geometry. As a result of this study, we obtain realistic 3D dynamic earthquake rupture scenarios for the non-planar and heterogeneous fault structure of the Marmara Sea. Hence, we consider under what conditions whole of the unruptured segments of the Main Marmara Fault can rupture and which scenarios are more realistic.

**T1.2-P3**  
**A Comparative Study on the Tectogenesis of 2015 Mt. Kinabalu Earthquake of Sabah Malaysia and Tsunamigenic 2018 Sulawesi Indonesia Earthquake**

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The 2015 Mount Kinabalu Earthquake of moment magnitude (Mw) 6.0 and focal depth 10 km located 6.014°N 116.563°E in the Kinabalu Mountain of Sabah lasted for about 30 seconds. This earthquake occurred well away from the nearest plate boundary in the region of very low historical seismicity mainly because of the rupture of a northwest-dipping normal fault that did not reach to the surface. However, seismological and morphotectonic evidences suggest that the rupture occurred on a normal fault that splays upwards from the brittle-plastic transition in the interface décollement. Proposed thermo-tectonic model further suggests slow build-up of strain due to the on-going lower crust melt, delamination and sinking of lower crust, spontaneous instability, and sudden sub-crustal collapse. The recurrence time of 2015 Kinabalu Earthquake having magnitudes ≥5, ≥6 and ≥7 has been calculated which is about 20 years, 150 years, and 1300 years respectively. On the other hand, moment magnitude (Mw) 7.5 Sulawesi Earthquake struck north of Palu, Indonesia on September 28, 2018 that ruptured north-south trending Palu-Koro fault with left-lateral strike-slip motion. Tectonic mechanism here bears character of subduction tectonics. Subducting slab along Minahassa Trench in the Selebes Sea below Sulawesi Island is undergoing partial melting in the upper mantle.

**T1.2-P4**  
**A Computer Code for Determining Composite Focal Mechanism Solutions**

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In general, determination of focal mechanism solutions for individual events with a sparse recording network is difficult due to low S/N and poor azimuthal coverage. For areas with frequently repeating small to medium-size seismic events, composite focal mechanisms are constructed by superimposing data from events that rupturing the same fault segment and have similar or identical source mechanisms (Lee et al., 2014). In this study a computer code is developed which is used in the process of determining composite focal mechanism solutions to objectively sort earthquakes into sets in which the P-wave first-motion data are compatible. A comparison is made between the observed first-motion data from a sequence of aftershocks in the rupture zone and surrounding areas in southern Iran to each of the 2^n mathematically possible patterns for the recording network of stations. The comparison results in two parameters being assigned to each of the patterns: (1) the number of earthquakes which have first motions compatible with the pattern; (2) the number of actual first-motion data for those earthquakes. Generally, one finds only a few patterns with high parameter values (Billington, 1982) and these few patterns are physically possible; i.e., they are compatible with double-couple focal mechanism solutions.

**T1.2-P5**  
**A Three-Dimensional Crustal Velocity Model of the Javakheti Highland from Local Earthquake Tomography**

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The objectives of this study are to determine P and S wave velocity model in the crust and to characterize seismic wave propagation in the Javakheti Highland and surrounding areas, including north-western part of Armenia. The 3D crustal velocity model is constructed using the local seismic events recorded by seismic
Theme 1: The Earth as a Complex System

stations from newly established Armenian network. Above mentioned stations are installed due to the cooperation between the Institute of Geological Sciences (IGS) of NAS RA and the Institute of Earth Sciences, Academia Sinica and cooperation between the IGS and the Department of energy of the USA. The broadband and near broadband (Guralp-6TD, 3T, STS2) seismometers are installed in the seismic stations. Additional information from the surrounding stations was also extracted from the database of IRIS (Washington, http://ds.iris.edu/ds/). In the past several years the number of high quality seismic stations has increased because of new and expanded networks in Armenia and Georgia. This provides high-quality P and S wave travel-time data. The upgraded 3-D velocity structure from this study will significantly improve event location accuracy in the region. Tomographic results show a velocity structure up to Moho depth and evidence of anomaly zones in the territory of the study area.

T1.1-O1 Application of Advanced Data Assimilation Techniques to Improve Atmospheric Dynamics

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T1.1-P124 SALSA3D Software Tools for Model Interrogation, Event Location and Travel-Time

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The development of the SALSA3D (SAndia LoS Alamos 3D) tomographic velocity models has made available to the monitoring and seismological communities a 3D velocity model useful for event location and uncertainty estimation. We discuss the research products that have resulted from this effort, including the models themselves, model uncertainties, a set of 2D and 3D travel time tables and an associated software suite. Included in the software is a single-event locator (LocOO3d) that can use a variety of velocity models, including the SALSA3D models, either alone or in combination to provide location and location uncertainties. A second program, pCalc is capable of computing travel-time estimates through the SALSA3D models for a rich set of seismic phases and is also compatible with several community velocity models. These two software packages, along with the previously-released model representation framework (GeoTESS) provides a suite of tools for working with the SALSA3D models that will be useful to monitoring agencies and academic institutions throughout the seismological community.

T1.2-P6 African Geodetic Reference Frame and First Results from GNSS Networks in Africa

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The African Geodetic Reference Frame (AFREF) is conceived as a unified geodetic reference frame for Africa. It will be the fundamental basis for the national three-dimensional reference networks fully consistent with ITRF. When fully implemented, its backbone will consist of a network of continuous, permanent GPS stations such that a user anywhere in Africa would have free access to such stations. Full implementation will include a unified vertical datum and support for efforts to establish a precise African geoid. AFREF has vast potentials for geodynamics, geodesy, mapping, surveying, geoinformation, earthquakes, natural hazards mitigation, earth sciences, etc. AFREF is, therefore, an African initiative to unify the geodetic reference frames of Africa based on the ITRF through a network of GNSS base stations at a spacing within ~1000 km between station. First Reference Frame Solution of about 80 GPS stations has been started in February 2014 at some processing centers in Europe and Africa. Results of independent solutions by various African scientific teams: Hart RAO, South Africa, Ardhi University, Tanzania and SEGAL, University of Beria Interior, Portugal, show an accuracy of aligned ITRF 2008 using 42 IGS stations in E and N components with 3.0 mm and in U component 7.5 mm.
**T1.2-P7**  
**Amplification of Earthquake Magnitude and Sediment Thickness Correlation in Palu Region and Surrounding Areas**

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Palu, Sigi and Donggala areas were devastated by a large earthquake on Friday September 28, 2018 at 10:02:43,674 UTC. Information released by Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG) shows the strength of the earthquake at magnitude 7.4 with a depth of 10 km, epicenter at coordinates of 0.22 S and 119.85 E. This earthquake is based on focal mechanism data is a strike-slip fault. The strength of the earthquake triggered an underwater landslide which generated a tsunami up to 11.31 meters and inundation 468.8 meters. The intensity of the earthquake on scale III-VIII MMI has resulted in massive liquefaction in several places, among them Balaroa, Petobo and Siderajono Oge. Field measurements were conducted at 350 points throughout at the Palu area to determine rock conditions and sediment thickness. Morphology of the Palu area and its surroundings is in the form of plains where the cover of sediment layer is generally in sediment quarter consisting of fluviatile and alluvium sediment. Data analysis shows sediment thickness at some points even reaching more than 600 meters. The results of the research in the Palu area showed a positive correlation of sediment thickness with maps of earthquake damage patterns.

**T1.2-P8**  
**An Active Tectonics of the Tien Shan and Dzungaria**

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The paper is devoted to the study of active tectonics of the Tien Shan and Dzungaria - the area of interaction of the two largest lithospheric plates: the Indo-Australian and Eurasian. Interest in this area is due to the fact that its study can provide materials for answering some questions of the modern theory of tectonics of lithospheric plates, among which the problem of intra-continental mountain building. Indeed, the newest orogeny of these major structures develops at a distance of more than 2000 km from the direct interaction of these plates, which began about 55 million years ago. This distinguishes it from the situation that exists in the subduction zones and the situation in typical conflict zones, where one continent sinks under the other along the main thrust. Despite the detailed study of the Tien Shan and Dzungaria, many questions of its modern geodynamics remain unlighted or poorly illuminated. Among them: what is the distribution of current stresses within the orogenic belt? Are the main stresses within the marginal parts of the orogenes concentrated or evenly distributed within the belt? What is the slip rate of Late Quaternary tectonic displacements in the zones of active faults?

**T1.2-P9**  
**An Improved Velocity Model for Routine Hypocenter Location in Central Brazil**

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Brazil is located in the stable continental interior of South American plate. The seismicity distribution is not uniform and in general it is characterized by low seismicity (M <3.5). In the last century occurred only two dozen events of magnitudes above 5, two of which with magnitudes larger than 6. The Brazilian Seismic Catalog was initially compiled by Berrocal et al. (1984) and it is maintained by a pool of institutions SIS-UnB, IAG-USP, UFRN, CPRM and ON. The catalog is very heterogeneous and the location quality for some events is unknown. A better and more uniform monitoring started after the establishment of the Brazilian Seismograph Network, after 2014, the detection threshold in the Amazon region dropped from M 4.5 to M 3.5. In this study, we propose a new 1D velocity model for the central Brazil. From the catalog, we have selected 77 well-locatable events with a total of 812-P wave observations from 57 stations. A series of coupled hypocenter-velocity-model non-linear
Theme 1: The Earth as a Complex System

Inversions were performed with the code VELEST searching the model space for best performing results. While previously the seismicity exclusively was located at very shallow depth, with the new model we do find evidence for some hypocenters located down to 20km depth.

T1.2-P11 Analysis of Time Domain Airborne Electromagnetic (TDEM) Data for Evaluating Gold Mineralization Potential of Ilesha Schist Belt, Southwestern Nigeria

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The analysis of filtered and enhanced Time Domain airborne Electromagnetic (TDEM) data acquired over Ilesha Schist Belt in southwestern Nigeria with the desire to characterize the subsurface in terms of rock distribution and structural framework for the purpose of evaluating the gold mineralization potential of the region, indicate high amplitude conductive subsurface (60,000 – 120,000 mS/m) in the western part of the study area which is underlain by amphibolites, amphibolites schist, and schist inter-layered with pegmatites, while medium to low amplitude conductivity signatures were recorded east of the study area where porphyritic granites, granite gneiss, migmatites, granulites and quartzites are the dominant rocks. Structural analysis of the enhanced TDEM data amplified salient subsurface pattern that defined the mineralized regional and local structural features hosting the gold deposits. Major conductive (> 2000 mS/m) linear structure which trends NE - SW and traversed the study area, dividing it into two, with the Ifewara - Iwaraja fault system. Other linear and curve-linear conductive features which also trend NE-SW, NNE - SSW, NNW - SSE established the structural framework that controlled mineralization and hosting of the gold deposits.

T1.2-P12 Analysis of Unusual Seismic Events in Northwestern Madagascar

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On the 15th of May 2018, an unusual seismic event of magnitude 5.9 has been detected in North-West of Madagascar. Following that event, thousands of earthquakes were detected from that zone. By combination of data recorded from the local seismic network and the seismic stations of the International Monitoring System, the NDC Madagascar have an inventory of more than fifty seismic signal per day from that same zone. Seismic data analysis and focal mechanism study has been performed in this study to explain the source of those triggering events. Analysis showed that most of those earthquakes are generally located between 11.8373°S to 14.1798°S in latitudes and 44.4773E to 46.7782E in longitudes and has 10 to 35km in depth. Moreover, on 11th November, another earthquake of 5.7 in magnitudes has been detected. Following that day, an extension of North-West to South-West of those earthquakes has been remarked. In addition, the focal mechanism analysis shows that 58% of the event are generated from slip faults, 39% are from normal fault and 3% are from reverse fault. The two main events are from slip faults with one that shows reverse fault. In this study we interpret those events as originated from a magma shift under the seabed.

T1.2-P13 Are We Able to Detect Viscoelastic Inconsistencies in the Earth?

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The frequency responses of loss moduli of a linear viscoelastic or anelastic continuum shall be consistent with the frequency responses of the respective storage moduli. The same applies to quality factors and the corresponding seismic wave velocities. Our recent reprocessing of earlier laboratory viscoelastic experiments on basaltic lavas shows a general tendency to ideal consistency of the viscoelastic shear modulus with increasing temperature under the atmospheric pressure. Nevertheless, in some samples at some temperatures, we
encountered truly large inconsistencies in terms of the ratios of relaxation time spectra. To identify the mechanisms leading to such behaviour, more laboratory experiments are needed. The role of pressure shall also be examined. In parallel, the seismomotographic experiments searching for viscoelastic inconsistencies within the Earth are worth to be considered and their feasibility assessed. If there are any inconsistency spots prominent enough to be detected by seismic tomography, it would be interesting to see whether they coincide with tectonically active zones.

**T1.2-P14** Armenian Seismic Network and Earthquake Catalogue

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Seismic networks are source of valuable data for seismological research. Since 2010 in cooperation with French CEA/DASE broadband seismic network in Armenia has been upgraded. Among various tasks in seismological research, modern network allows to improve the quality of the catalogue. The seismicity of Armenian Upland relates to the Arabian-Eurasian plates’ collision, which is characterized by diffusive distribution of shallow earthquakes of various magnitudes. The strong shallow earthquakes are expressed by well pronounced active surface faulting. Comparison of seismicity of Armenia and the Caucasus with tectonic setting shows that all the strong earthquakes are associated with the active blocks, their edges and junctions. The analysis of the focal mechanisms of earthquakes with various magnitudes shows the presence of all fault types in Armenia: strike-slip, normal, reverse, thrust, oblique, normal faulting with various components, and with prevailing strike-slip faulting. The combinations of exposure depend on the relatively neighboring blocks’ movements. The quality of the Armenian National Catalogue is discussed and the representativeness is described. A unified and homogeneous earthquake catalog is a base for analysis—determination of catalogue completeness, recurrence and activity rates etc., which are the key input parameters for probabilistic seismic hazard assessment.

**T1.2-P15** Changes of Seismic Structure Beneath Jailolo Region During June-July 2017 Inferred from P-Wave Tomography

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At the end of 2015, a seismic swarm occurred in Jailolo region, West Halmahera, Indonesia. GFZ Germany collaborated with BMKG Indonesia to monitor seismic activities in Jailolo by installing a temporary network of 35 seismic stations. Here we present the results of a local earthquake tomographic inversion beneath Jailolo region corresponding to two time periods, June and July 2017. About 6,000 P-wave phases from 567 events were used to invert for the 3-D P-velocity structure of the crust beneath Jailolo region. The calculations were based on tomographic inversion of P arrival time data using the local earthquake tomography code LOTOS. We performed a thorough analysis of the results in each of the time periods and compared them. The resulting tomographic images shows differences for each period. The June period shows low P-velocity anomalies for depths of 4-14 km with anomaly values up to -6%. However in the July period the anomalies have lower values than the June period, P-velocity anomalies value up to -1.5% in 7-10 km depth. Low P-velocity anomalies can be associated with high content of fluids and partial melts or magma reservoir within the crust beneath long-dormant Jailolo volcano. This magmatic activities are assumed as a source of seismic swarm activities in Jailolo region.
T1.1-O1 Application of Advanced Data Assimilation Techniques to Improve
Earthquake Predictions: The Comoro seismicity study
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A simple model for controlling stick-slip friction and implications for effects of tides on earthquakes irregular stick-slip friction of slowly sheared rocks, or granular materials is affected by small applied oscillatory stresses. Neural Networks (NNs) Modeling such systems is important (1) to predict and control the timing of large slips during friction, and (2) to resolve whether or not lab experiments can predict analogous effects of tides on large earthquakes. Recent experiments, contradict traditional friction models and the connection of lab-experiments to earthquakes is controversial. Here we present a simple model that predicts (I) observed experimental results, (II) new ways to control stick-slip motion, (III) the need for higher oscillation-frequencies than previously used in experiments to mimic the effect of tides on large earthquakes, and (IV) the need for ten-thousands of large earthquakes by NNs simulation to observe significant correlations with tidal or seasonal stress variations (while lab experiments require only a few large slips). Our results thus resolve the long-standing controversy about the applicability of experiments to earthquake observations.

T1.1-O2 Assessing Middle Atmosphere Weather Models Using Lidar and Ambient Temperature Measurements
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The volcanic patterns before and after the last eruptions in Gde-Comoro Island, noticing Mayotte-island by seismic extent magnitude. Recent experiments, contradict traditional friction models and the connection of lab-experiments to earthquakes is controversial. Here we present a simple model that predicts (I) observed experimental results, (II) new ways to control stick-slip motion, (III) the need for higher oscillation-frequencies than previously used in experiments to mimic the effect of tides on large earthquakes, and (IV) the need for ten-thousands of large earthquakes by NNs simulation to observe significant correlations with tidal or seasonal stress variations (while lab experiments require only a few large slips). Our results thus resolve the long-standing controversy about the applicability of experiments to earthquake observations.

T1.2-P16 Clustering Geometry of Aftershocks in Earthquakes
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T1.2-P17 Comoro-Islands, Source of May-June 2018 Earthquake Swarm in the East of Mayotte-Island
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Comoro-Islands experienced infrequent earthquake swarm that started on May 10, 2018 to June 30, 2018 in the east of Mayotte, the oldest volcanic island. From this sequence, roughly 122 events in the range of 3.5-5 mb Magnitudes recorded by CTBT-IMS have been identified to evaluate the seismic patterns, as well as additional international catalogues (USGS). This East-African region is known active with multiple sources including an evolving crust. Our research includes two main aspects: - The spatiotemporal patterns of the subsequent earthquakes after we assess the Comoro seismicity within the Region, considering the July-October events. For these temporal characteristics, we use Scordilis empirical global relations to convert the original IMS-mb-Magnitudes to Moment Magnitudes-Mw≥4 in order to obey the mainshock-aftershocks Omori’s illustration. - The volcanic patterns before and after the last eruptions in Gde-Comoro Island, noticing Mayotte-island by 3.65±0.1 million years roughly dated, has been considered as an extinct volcanism. Results showed Mainshock-aftershocks study was not elucidating a fault slip mechanism. Additionally to our volcanic findings with the likelihood estimates from (BRGM) data, and, the absence of other factors such as the presence of an iceberg in the region, we suggest that magma may have drained from a volcanic chamber under the seafloor.

T1.2-P18 Comparison of Mainshock and Aftershock Energy Release (Case Study: Earthquake in Sumatera and Java Subduction)
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We calculated some devastating earthquake energies for events that occurred in subduction zone and followed by aftershocks. We compared the amount of energy released between mainshock and aftershock with the empirical formula from the Gutenberg- Richter relation. Historical data with three months aftershocks after five major earthquakes (Bengkulu, Pangandaran, Simeulue, West Sumatra, and Tasikmalaya) were obtained from the International Seismological Center. From analysis and energy calculations of earthquake aftershocks from major earthquakes with a magnitude larger than 5.0, energy aftershocks ranging from 0.1% to 33%, with a random pattern. By comparing the energy aftershocks of earthquakes, the results are generally 10%, it is estimated that the earthquake with strike-slip mechanism having earthquake aftershocks with total energy less than 10%. The
earthquakes which have aftershocks and thrust mechanism make a total energy more than 10%. By obtaining these comparisons, this research is based on scientific studies can be used as a reference to providing information on the possible impact of an occurrence of the earthquake and its aftershocks.

**T1.2-P20**  **Crustal Composition and Moho Characteristics Beneath Northern African Region: New Contribution for Seismic Hazard Assessment**

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Three different techniques will be used to investigate the composition of crust and Moho characteristics beneath the northern African region, including Egypt, Libya, Tunisia, Algeria, and Morocco. These methods are the receiver function (RFs), the joint inversion of RFs and surface wave dispersion (SWD), and seismic tomography. The RFs results will give us the crustal thicknesses (Moho depths) and the composition of the crust beneath each country region. While, by using the joint inversion and seismic tomography, the shear wave velocity model and the characteristics of Moho discontinuity, (sharp or gradational) beneath each country will be obtained. In fact the depth of Moho is an important parameter to characterize the overall structure of a crust and can often be related to the geologic and tectonic evolution of the region. Its lateral variation has strong influence on the seismic wave propagation in the crustal waveguide and controls the strong shaking from damaging earthquakes in certain distance range. As a result, damage could occur due to these coming waves. The work will be focused on how to obtain a significant information not only on the Moho depths or undulations beneath some regions in Morocco but also the characteristics of the Moho discontinuity.

**T1.2-P21**  **Crustal Seismic Structure of Gheshm Region, Southeast Iran**

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Inversion of local earthquake travel times were used to derive a simple model for the crustal velocity structure beneath the Gheshm Island. The P-wave and S-wave travel times from 112 well-located aftershocks of the 2005 Gheshm earthquake (Mw 5.8) sequence recorded by the IIEES local seismic network were inverted to determine a 1D velocity model of the upper crust. The network was operational from December 2005 until March 2006 and for the recorded events average ratio of P-wave to S-wave velocity is calculated as 1.78. The limited range of earthquake depths (between 8 km and 22 km) prevents any reliable determination of velocity interfaces deeper than 20 km. The resulting P-wave velocity model comprises an upper crust with 8 km and 4 km thick sedimentary layers with P-wave velocities (Vp) of 5.43 and 5.92 km s⁻¹, respectively, above 8 km thick layer of upper crystalline crust (Vp 6.19). Depth of the Moho was estimated based on the variation of average coda Q at 1 Hz (Q0) as a function of maximum sampling depth. A sharp rise around 40 km depth is most likely an indicator of lower attenuation of Moho.

**T1.2-P22**  **Crustal Structure and Seismogenic Zone of Cameroon: Integrated Seismic, Geological and Geophysical Data**

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This study describes the seismo-tectonic evolution of Cameroon. It is noticed that seismic activity is largely related to the Cameroon volcanic line (CVL) and many of the tectonic phenomena follow the previous structural lines. Although the area is that of a relatively low seismicity, the effects of a given earthquake could be considerable. This study combines seismic records, from 1952 to 2002 and from 2005 to 2007, with the integration of existing structural information to better define the seismogenic zones. An important identified cluster of epicenters in S-W defines the first seismic source region where events characteristics show a weak
seismicity related to volcanic activity. The second seismogenic zone, in the north of Mount Cameroon volcano, illustrates the activity of Central Cameroon Shear Zone (CCSZ) faults; its seismicity is considered weak to moderate with maximum magnitude recorded which 5.1 Mb is. The area of "Sanaga Shear Zone" (SSZ) constitutes the third seismic source region with moderate seismicity in which maximum magnitude recorded is 5.8 Mb; Depth of its faults segments is evaluated at 33 km.

**T1.1-O1** Application of Advanced Data Assimilation Techniques to Improve Atmospheric Transport and Dispersion Predictions

**T1.2-P23** Crustal Structure of Some Tectonic Regions in West Africa

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New estimates of Moho depth, Poisson's ratio and shear-wave velocities for fourteen seismological stations in Nigeria, Ghana, Mali and Côte d'Ivoire were obtained. The data used for this study was from teleseismic earthquakes recorded at epicentral distances between 300 and 900 and with moment magnitudes greater than or equal to 5.5. P-wave receiver functions were modeled using the Moho Ps arrival times, H-k stacking, and joint inversion of receiver functions and Rayleigh wave group velocities. The average Moho depth of the stations in the Neoproterozoic Nigeria basement complex is 36 km, and 23 km for the stations in the Cretaceous Benue Trough. The crustal structure of the Paleoproterozoic Birimian and Neoproterozoic Dahomeyan terrain and Togo Structural Unit in southern Ghana is similar, with an average crustal thickness of 43 km. Poisson's ratios for all the stations ranged from 0.24 to 0.26. The crustal structure of the Nigerian basement complex is similar to the average crustal structure of Neoproterozoic terrains in other parts of Africa, but the Neoproterozoic terrains in southern Ghana have a thicker crust with a thick mafic lower crust. The crustal thickness of the Birimian in Côte d'Ivoire and Taoudeni basin is 40 km and 36 km respectively.

**T1.2-P24** Crustal Structure Study in Mongolian Altai

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Mongolian Altai is western part of Mongolia and it is considered seismically active region. There are several active faults such as Sagsai, A-K hutzul and effect of movement on these active faults cause earthquakes along these faults. In order to study detailed seismotectonics and crustal structure in Mongolian Altai range, 12 broadband seismic stations were installed in Mongolian Altai range, starting from September 2017, by Institute of Astronomy and Geophysics. Distribution of temporary seismic station covers relatively large area. Currently, hundreds local and teleseismic events detected and recorded on temporary seismic network and study on detailed seismicity in this region and crustal structure study are going on. Preliminary result of seismicity shows relatively improved location of epicenters which concentrated along the active faults in this region. Moreover, results from teleseismic receiver function analysis for crustal structure implies that thickness of crust reaches about 60 kms in this mountainous region.

**T1.2-P25** Crustal Thickness Estimates Beneath Four Seismic Stations in Ethiopia Inferred from P-Wave Receiver Function Studies

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Moho depths beneath four Ethiopian Seismic Station Network (ESSN) are estimated from P-wave receiver functions (RF). We used high quality seismic data recorded at ANKE (Ankober), DILA (Dilla), HARA (Harar) and SEME (Semera) stations for earthquakes located at epicentral distances ranging from 30 to 100º with magnitude mb ≥ 5.5. We applied a frequency domain deconvolution technique to remove source and propagation
path effects. The minimum number of teleseismic earthquakes used is 14 for HARA while the maximum is 39 for SEME station. We achieved a reasonably good fit between the observed and synthetic RFs. The lowest Moho depth is observed at Semera station which implies a thinned crust while the highest crustal thickness is observed at Ankober, which lies along the North western plateau margin. Our results agree with previous observations which strengthen the hypothesis that Moho depths estimated for stations that lie within the rift and rift margins are lower than those located in the plateaus. Our RFs inversions show a low velocity gradient at about 16 km depth at Semera station, interpreted as evidence for lower crustal storage of partial melt.

T1.2-P26 Database from a Seismic Network to Monitor the 2018 Enhanced Geothermal System Stimulation in Espoo/Helsinki, Finland

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We discuss several topics associated with a stimulation experiment in the Helsinki, Finland, area. In June and July 2018 the St1 Deep Heat company stimulated a rock mass between 6 km and 7 km depth in Otaniemi/Espoo, Finland, to establish an Enhanced Geothermal System (EGS) to support district heating. Three-component instruments (10) were installed between 238 m and 1620 m depth and 7 broadband stations on surface. ISUH also installed a temporary network consisting of 100 4.5-Hz three-component geophones. The sampling rate was 400 Hz. The cube-stations operated for 106 days during the stimulation. The 100 stations were organized in 3 large arrays (100 m x 100 m) consisting of 25 stations, 3 small 4-station arrays, and 8 single stations. The large arrays were intended to resolve propagation properties of body waves from earthquakes in the ~M0.5 to ~M2.5 range. The stimulation resulted over 4000 micro-earthquakes with M -1.0 - 1.7. We compare noise levels, signal-to-noise ratios, and detection thresholds from different networks. We study source mechanisms, evaluate hypocenter locations from different methods. Using double-beamforming, we discuss further the properties of noise-based P waves propagating between arrays and the potential for monitoring the rock properties above the stimulated volume.

T1.2-P27 Deformational Style in North-Western Part of the Punjab Foreland

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We analyzed seismic events occurring in Thal region at northwest (NW) margin of Punjab Foreland basin south of the Himalayan Frontal Thrust. For this study, focal mechanism solutions of moderate to small sized events were determined. We performed Moment tensor inversion for recent 23 events occurring during time period 2010-2017, while for older events (i.e. 1981, 1982, 1996 and 1999), first P-wave polarity technique was used. The study shows that strike-slip faulting prevails in the area as observed in 19 events for which the waveform inversion has been performed. Strike of the faults, depicted on the basis of these events, is nearly consistent direction i.e. north-south, but, dip of the faults and depth of the events is increasing northwards representing a north-dipping slab. We observed that movement of the blocks, along depicted strike-slip faults compensates effect of each other. The low occurrence of larger earthquakes in this region may be due to cumulative slip absorbed aseismically in the decollement of Salt Range in the north.
**Theme 1: The Earth as a Complex System**

**T1.1-O1 Application of Advanced Data Assimilation Techniques to Improve Atmospheric Dynamics**

Oral Presentations

We present high-resolution seismicity imaging after studying earthquakes which occurred around the Tripa fault. The Tripa fault is a segmented fault of SFZ, actively moving, characterized by a strike-slip fault and located in southern part of Aceh. We used 10 years the earthquake catalogue and continuous seismic waveform from BMKG, including P and S arrival times. We did manually picking of inspections to get arrival times and compare it with BMKG results. The earthquake hypocenters, which trapped on 10 km depth, were relocated by using inversion with double difference method based on arrival times in each station. We used 6 local velocity model, and compare each of them to get the best RMS result. From 70 events of the BMKG catalogue 50 events were manually relocated and 40 events with BMKG arrival times. With RMS <0.1, the results show a clear separation of seismicity areas into 3 cluster. Hypocenters were located deeper, more precise than before, and separated into 2 clusters on the left and right side. The strike focal direction from Global-CMT follows the distribution of hypocenters relocation. The left and right sections of clusters must be further investigated, both had generated a devastating earthquake.

**T1.2-P29 Discriminating Between Induced, Triggered and Natural Seismicity**

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To discriminate between recent seismicity around Lake Nasr Aswan region, whether it is induced or triggered by Lake Reservoir or is of natural origin, we analyze moment tensor solutions and source spectra of recent recorded earthquakes in the area. The earthquake focal mechanisms including source mechanism parameters and source spectra can give important information to assist in discriminating between natural and induced seismic events. In this work, we computed moment tensors and stress drop values for five recent induced events recorded by the Egyptian National Seismic Network (ENSN) around Lake Nasr, Aswan Area with magnitudes between 3.0 and 4.5 as well as five nearby earthquakes from Red Sea with magnitudes ranging from 4.0 to 5.5, events that are interpreted as natural events. We performed full waveform inversion for the studied seismic events including complete moment tensor and dominant double-couple (DC) signature. Our results exhibited that most induced events demonstrate significant non-double-couple components. The estimated focal depths of most Induced events are significantly shallower than focal depths for inter-plate and intraplate earthquakes in and around area under investigation. On the other hand, stress drops and source spectra of studied events are used as another key to differentiate between natural and induced events.

**T1.2-P30 Dissecting Hearts of the Continent in Southern Africa Using First P-Wave Tomography Based on Local, Regional, and Mining-Induced Earthquakes**

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In the present study, the anatomy of the uppermost subcontinental lithosphere (USCL) under southern Africa is explored through the application of seismic tomography. The Kwaapvaal and Zimbabwe cratons, which constitute the Precambrian hearts of the continent around which southern Africa was formed, are sliced using P-wave tomography to improve our understanding of the seismological structure of the USCL beneath the continent. The tomograms of the USCL beneath the study area were determined from first P-wave arrival times generated by local, regional and mining-induced earthquakes recorded by 82 stations of the 1997–1999 Southern Africa
Seismic Experiment that were supplemented by 3 International Monitoring System (IMS) stations located in the study area. The geotomograms provide a key constraint for understanding better the thermal, density and compositional variations in the region, and in advancing our knowledge of the assembly and modification history of continents through time. The present tomograms can be correlated with results from previous seismic studies in the area to detail the already known structural features and to find new structures. The results indicate that the P-wave structure in the study area is heterogeneous, and bring insight into the P-wave velocity anomalies associated with the USCL in southern Africa.

T1.2-P31 Earthquake and Radioactivity, Its Application in Indonesia

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Indonesia is an area that is very prone to earthquakes. Research needs to be done in an effort to minimize the impact of earthquakes. One of them is monitoring physical parameters that occur before, during, and after an earthquake. One parameter is the concentration of radon gas which has certain radioactivity and is considered capable of representing one of the parameters of the lithosphere dynamics when an earthquake occurs. Some results of the study indicate an increase in gas concentration before an earthquake. In Indonesia, monitoring devices for radon gas concentrations are installed in several regions, including in Sumatera (Medan dan Liwa), Jawa (Lembang dan Yogjakarta), and Central Sulawesi (Palu). Some temporary results from the earthquake case study show that there was an increase in the concentration of radon gas before an earthquake occurred in more than 50% of the cases. This increase was observed by the standard deviation method, median absolute deviation, and also daily inconsistencies. This indicates that radon can be used as a physical parameter that can be observed to analyze physical phenomena other than seismic parameters, before, when and after earthquakes occur.

T1.2-P32 Earthquakes Re-Location, GT Events Identification and PSHA in Parts of Sub-Saharan Africa to Boost CTBT’s Verification Capability and its Scientific Applications

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Phases from regional and local earthquakes contribute significantly to velocity model errors on the accuracy of earthquake location. This, the dearth of data, poor network of seismic stations, poorly located and well-defined events, absence of a reliable velocity model etc., have hindered meaningful seismological research in parts of sub-Saharan Africa. In this study, prominent events were relocated and some which include the 2009 Benin event, 2017 Botswana earthquake, 2015 Namibian event, 2016 and 2018 events in Nigeria were screened for Ground Truth events using Geotool, Regional Seismic Travel Times and iloc stringent procedures. Secondly, in collaborations with relevant institutions, probabilistic seismic hazard assessment was carried out using data from NDCs, local seismic stations, and ISC to compute earthquake hazard parameters. The results show a b-value of 0.79 ± 0.05, activity rate of 3.047 ± 0.747, M max of 6.88 ± 0.26 and PGAs for a 10% probability of exceedance in 50 years range of 0.05 - 0.2g. The results aim to contribute to the regional velocity model development, enhancement of verification compliance with the CTBT and its civil and scientific applications, improvement of seismicity, seismic hazard assessment, and seismotectonic outlooks of the entire region covered.
**Theme 1: The Earth as a Complex System**

**T1.2-P33  Estimation of 2D and 3D Shear Wave Velocity Structure of Crust and Upper Mantle of Northern Part of Iranian Plateaus**

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Determination of shear wave velocity structure is important to interpret the tectonic activities in this region. For this goal, we conducted a tomographic inversion of Rayleigh wave dispersion to obtain group velocity tomographic images for the north part of Iran. Estimated group velocity dispersion curves using frequency time analyzing of surface wave have been processed to obtain tomographic. The shear wave velocity structure has been estimated beneath each station by using joint inversion of P-waves receiver functions and dispersion curves of Rayleigh waves. The depths of Moho and the Lithosphere-Asthenosphere Boundary have been estimated. Based on derived results, Moho depth is increasing from southern to northern part of Alborz region, whereas the lithosphere-asthenosphere boundary depth is decreasing from southern to northern part. Our results reveal strong heterogeneity in the upper mantle beneath Alborz region. High velocity anomalies have been observed at depth of ~120 to ~180 km in the upper mantle, which is consistent with the presence of under thrusting of Caspian lithosphere beneath Alborz. We have observed almost well correlation between the thickness of under thrusted high velocity layer and surface topography.

**T1.2-P34  Estimation of Local Site Effects Using Microtremor Testing in Erdenet City**

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Site effects associated with local geological conditions constitute an important part of seismic hazard assessment. This work was done in the framework of the project "Seismic micro zoning 12 aimag centers" funded by Ministry of Construction and Urban development. In order to estimate site effects we used seismic weak motion, seismic noise survey and seismic array measurement data. The weak motion survey was applied for 15 sites including 1 outcropping rock site used as reference site with a duration of 14 days. Other 14 site locations were selected based on different geotechnical conditions. Seismic microtremor measurements were done in a 500 meter distance grid and in total 527 sites were measured for a duration of one hour. All measurements were done with a Guralp CMG3EPS seismometer and REFTEK 130b digitizer. For all noise and weak motion measurement sites we obtained the amplified frequency using Horizontal to Vertical noise spectral ratio (HV). With this ratio we defined for each site a geological condition area. Based on this we created a deduced amplified frequency map.

**T1.2-P35  Estimation of Moho Depth under the MDT Seismic Station (Midelt, Morocco) Using Receiver Function Technique**

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It is well known that the receiver function method can provide a very good local measurement of crustal thickness under a three component broadband station. In order to investigate crustal thickness beneath the MDT broad band seismic station located in Midelt region (Morocco), which forms part of the PTS International Monitoring System, we applied the H-k stacking technique proposed by Zhou and Kanaomi based on stacking several receiver functions computed from different teleseismic events. This technique is based on a stacking algorithm which sums the amplitudes of receiver functions at the predicted arrival times of the Moho P-to-S converted phase and the later multiple converted phases PpPs and PpSs+PsPs by different crustal thicknesses H and Vp/Vs ratios. The best estimations of crustal thickness H and Vp/Vs ratio are found when the three phases are stacked coherently. We used more than 60 teleseismic events recorded by MDT seismic station during the years 2016 and 2017, located between 30° and 90° and having magnitude greater than 6. After the computation of receiver functions, only 20 events which showed coherent results were selected to be used in the H-k stacking technique. The estimated depth of the moho beneath MDT seismic station is about 40 kilometers.
T1.2-P36  Estimation Sources, Path and Site Effects from 2018 Lombok Earthquakes Sequences

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The earthquakes sequences that struck the north part of Lombok Island are of the thrusting earthquake type as interaction of the back-arc Flores thrust tectonic system. This earthquake sequences is initiated by significant earthquakes with magnitude M 6.4 (29 July 2018), M 6.9 (05 August 2018) and M 7.0 (19 August 2018). Using hybrid simultaneous displacement spectrum inversion for determining the physic of source characteristic, path effect and amplification effect at the recording seismic sites (PLAI, JAGI, SRBI and TWSI) reveals that the median static stress drop is 28.4 MPa and the Q-factor parameterise is about 64 f0.8. Processing of 8 significant earthquakes ranges from M. 4.9 to M. 6.4 also indicates amplification factor of the SRBI and TWSI stations to be app. 4 - 6 Hz and 15 - 18 Hz respectively. PLAI is assumed as reference station due to its MASW measurement of app. 1385 m/s (rock site category).

T1.2-P37  Flow Plane Orientation in the Upper Mantle under the United States from SKS Shear-Wave Splitting Observations

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The cause of seismic anisotropy is still an open question, e.g., to which degree it is due to more recent geodynamic activities in the asthenosphere, or to frozen-in deformation in the lithosphere. We show that these two endmember cases can in principle be distinguished using shear-wave splitting observations from SKS waves. This is illustrated by the simple example of pure olivine with horizontal a-axis, and differing orientations of the other two axes, namely vertical b and vertical c. The azimuthal dependence of shear-wave splitting measurements is described by two parameters, which can provide additional information about subsurface deformation. In particular the oscillation parameter d1 constrains the orientation of foliation. We demonstrate that shear-wave splitting in Western and Central United States indeed shows the predicted azimuthal dependence, related to a mainly subhorizontally-oriented flow plane of deformation in the upper mantle. This has important implications for asthenospheric flow.

T1.2-P40  Geometrical Definition of the Boconó Fault in the Sector Las Gonzalez Mérida, from the Simultaneous Relocation of Seismic Events Occurring in a Burst of Seismicity During 2015-16

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On November 11, 2015 a seismic event, Mw=5.1, took place in the Las Gonzalez sector of the Boconó fault in western Venezuela region. This event was followed for an intense seismic activity mounting up to almost one thousand events until March 31, 2016. This was recorded by the permanent FUNVISIS seismic network in Venezuela. During those dates an important project, GIAME, with a significant number of temporal stations, were also in place and running, collecting seismic data for the given region. For this work, we will relocate the captured population of events with different techniques. 1. that accounts for the correlated travel-time predicted errors, with the usage of the ILOC code (Bondar et al., 2011), and 2. that involves the simultaneous calculation of hypocenters of the given set of seismic events based on the difference of residuals between previously located neighbors events to achieve an improved relative location, with the usage of the HypoDD code (Waldhauser et al., 2000). We expect that the reached better accuracy with the new solutions will shed light on the presence of the smaller secondary faults present in the area, at the surface and in its dipping to the depths.
**Theme 1: The Earth as a Complex System**

**T1.2-P41 Gravity Derived Crustal Thickness Map of Botswana: Implication to the Mw 6.5 April 3, 2017, Botswana Earthquake**

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Botswana has been experiencing a rise in seismicity since 2010 which culminated in the 2017 Mw 6.5 April 3, Botswana earthquake, the second largest earthquake event in recorded history. This earthquake occurred ~350 km southeast of the Okavango Rift Zone (ORZ), in an area previously not known for large magnitude earthquakes or active faults. The occurrence of this earthquake made it clear that the crustal structure of Botswana is not yet fully understood. To address this, we utilized gravity data to construct a crustal thickness map of Botswana, which has enabled us to study the crustal structure underneath the thick Kalahari cover. Our results also show some localized zones of slightly-thinned crust within intraplate regions. We find that the Mw 6.5 earthquake occurred within a region underlain by relatively thin crust suggesting this as a possible region of tectonic and possible incipient rifting zone. The study also identified regions where earthquake activity can occur relatively to known earthquake regions. The approach can also be used to determine if the earthquake is the result of a nuclear test or an interplate earthquake in continental stable areas.

**T1.2-P42 Ground Response of Kathmandu Valley Sediments During 2015 Gorkha Earthquake**

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The Kathmandu Valley was strongly rocked at 11:56 local time by an Mw 7.8 earthquake on 25th of April 2015. This earthquake was followed by a large number of aftershocks including the 12th May 2015 (Mw 7.3) Dolakha Earthquake. Largest peak ground acceleration (PGA) was observed at a rock site during the M 7.8 earthquake, however velocity was smaller. On the other hand, the soil sites have recorded smaller acceleration but the velocity was comparatively large during the M 7.8 earthquake. The large velocity at the soil sites is the reason for strong shaking of the multi storey apartment buildings and the damage they sustained and comparatively smaller accelerations are responsible for the small damage of engineered low rise buildings. During other (M >6.0) earthquakes the PGA at rock site are smaller and are large at soil sites. Fourier amplitude spectrum of the acceleration data reveals the predominant frequency at soil sites ranges between 0.2 to 0.3 Hz for the Mw 7.8 earthquake. However, during its strong aftershocks the predominant frequency moves towards high frequency. Fourier amplitude spectrum reveals that, on horizontals, the high frequencies are damped rapidly above 1 Hz.

**T1.2-P43 Heterogeneities of Short-Period S Wave Attenuation Field in the Earth's Crust and Uppermost Mantle of the Eastern Tien Shan**

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Studying attenuation field characteristics is important for analysis of geodynamical processes and for solving the problem of underground nuclear explosions and earthquakes discrimination. We have carried out mapping shear wave attenuation field in the Eastern Tien Shan lithosphere including the area of Lop Nor nuclear test site. We used recordings of seismic stations MKAR and KKAR, located at regional distances, for the mapping. The methods based on the analysis of Lg and Pg, Sn and Pn wave amplitude ratios, and Lg coda were used. Zones of high attenuation, first of all to the west of Urumqi city and in the area of Lop Nor nuclear test site were picked out. No large earthquakes (M≥7.0) were recorded in these zones during the past 200 years. It is supposed that processes of large earthquake preparing can occur in the first zone. Relatively weak attenuation corresponds to the earth's crust of the second zone. At the same time, essentially high attenuation is observed in the uppermost mantle of this zone. We believe that the attenuation anomaly in the area of test site is connected with mantle fluids ascending due to protracted intensive artificial influence, like in the areas of other nuclear test sites.
**T1.1-O3** **Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound**

The determination of hypocentral locations and fault plane solutions and estimation of the seismic hydraulic diffusivity will be estimated using the equation of linear growth of seismicity in the particular period of time. The fine-scale seismicity in combination with geomorphic data sets and focal mechanism solutions proposes that the whole fault system comprises a mix of EW trending sinistral and N20° trending faults on a combination of east-west compression with some right-lateral strike slip motion.

**T1.2-P46** **Implication of Volcano-Tectonic and Fluid Movements on Seismic Activity in the Paka Geothermal Prospect**

Abundant seismicity is recorded instrumentally for a sufficiently long period of time in the region of Deren, 180km south of Ulaanbaatar. These earthquakes have been roughly assigned to Deren fault which expresses NS trending thrust morphology. In order to define and accurately characterize active faults in the region, we used 2 different datasets from 2 distinct temporary seismic deployments. The datasets, particularly 55 events within the magnitude 1.5 to 4.5 from the regional temporary seismic array that has a station spacing of about 50km and 1111 events from a temporary local network that adapted to the size of seismicity have been separately analyzed by means of precise relative location. The relative hypocenter locations reveal new features about crustal structures of Deren, particularly EW trending structure of about 50km long and its eastern end bifurcated at N20° and N70°. Equally, relocation reveals 3 parallel N20° oriented structures that roughly 10km detached one another on the west of total seismicity. The fine-scale seismicity in combination with geomorphic data sets and focal mechanism solutions proposes that the whole fault system comprises a mix of EW trending sinistral and N20° trending faults on a combination of east-west compression with some right-lateral strike slip motion.

**T1.2-P47** **Interdependence Among Earthquake Magnitude, Ground Motion Attenuation and Consequences for the Central Asia Derived from Pamir-Hindu Kush Deep Earthquakes Data**

The tectonics of Central Asia are dominated by the spectacular collision between India and Asia. For the Central Asia region the largest center of seismic activity is the deep-focus (90-300 km) Pamir-Hindu Kush earthquake zone. The spatial placement of earthquake foci in the area (100-150 km by 700 km), the high level of seismicity and repeatability of events and the compactness displayed by the various focal zones, provides a unique opportunity to study natural events that have different source parameters but nearly the same ray paths. We revised strong motion attenuation specifically from Hindu Kush and Pamir seismic zones by searching the records of seismic stations of Uzbekistan, Tadjikistan and Kyrgyzstan. Variation in time delays with azimuth and
**Theme 1: The Earth as a Complex System**

epicentral distance appears to be due to the varying angles between the ray path and the principal axes of the anisotropic system. We have found a significant number of repeating earthquakes with reversed polarity waveforms, which may suggest repeating rupture on sub-parallel faults but with reversed slip directions. Comparative analysis of the time of Pamir-Hindu Kush earthquakes and the formation of large landslides in the period from 1969 to 2018 showed agreement for more than 200 cases of landslides formed in South Kyrgyzstan, Uzbekistan and Tajikistan.

**T1.2-P48 Investigate Seismic Sites Using Microtremor Studies and Elliptical Curve Inversion of Horizontal-to-Vertical Spectral Ratio in Sleman, Yogyakarta**

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This study aims to investigate seismic parameters based on the dominant period and elliptical curve inversion of Horizontal-to-Vertical Spectral Ratio (HVSR). The data used as many as 20 sites, was taken using a seismometer portable short period in the span of a minimum of 50 minutes of data recording in the Sleman, Yogyakarta. The Nakamura method (Nakamura Y., 1989) as known as Horizontal-to-Vertical Spectral Ratio (HVSR) is used to obtain the value of the dominant frequency and amplification factor. The dominant frequency is changed to the dominant period which can indicate the type of soil. HVSR processing uses a guide from the SESAME Project. The results of processing 20 sites show that the dominant frequency ranges from 0.629 Hz to 15.298 Hz. While the amplification factor has a range of 0.015 to 6.613. The waveform can be inverted based on the elliptical curve of HVSR datasets to produce a velocity model. From the velocity model, we can know Vs30 to determine the type of soil too. From inversion process, Vs30 obtained has a range of 140 m/s to 2050 m/s. In addition, from the velocity model data obtained, it can be seen the sediment thickness in site.

**T1.2-P50 Investigations of the 2018 Earthquake Swarm in Mamasa (Sulawesi), Indonesia**

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In early November 2018, an earthquake swarm took place in the Mamasa Region, West Sulawesi and resulted in moderate damage in the villages. BMKG reported more than 600 events within the first month with four of them having magnitude Mw > 5.0. The seismicity was accurately relocated by using double difference with cross-correlation data. A template matching technique was also utilized to provide catalog completeness for lower magnitudes. We show that the earthquakes concentrated on a 12-km length intensive plane and distributed irregularly along very shallow to about 15 km depth. This relocated seismicity suggests a ~90 km fault plane generated by the strike-slip fault. We propose it confidently as the source parameters of 29 earthquake (Mw > 4.0) using moment tensor inversions exhibit a dominant strike-slip mechanism trending NNE-SSW (average strike = ~200, average dip = ~80). Both our relocation and template matching techniques provided 4,170 events starting from 31 Oct - 27 Nov 2018 and from the westernmost part, moving gradually and diffusely to the east during early November 2018; eventually slowly decaying with time lasting for months. Our findings suggest the invaluable chance to elucidate the presence of active fault zone in this region.
T1.2-P51  Jordan Seismological Networks

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Real time monitoring systems around seismogenic zone are very important for early detection of earthquake and seismic hazard and seismic risk assessments. Furthermore, these systems are also indispensable to understand crustal activities and phenomena as precursor. In Jordan, Dead Sea Transform system is responsible for earthquake activities in the region. Two seismic networks were installed in Jordan by Jordan Seismological Observatory (JSO). These networks are running telemetry stations and strong motion stations. These networks include one station which belongs to the CTBTO international Monitoring Stations and two stations which belongs to GEOFON Global Seismic Network. In this presentation, we explain Jordan seismic networks and advanced seismic hazard applications.

T1.2-P52  Kinematics of the Suez-Sinai Area from Combined GPS Velocity Field

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A combined GPS velocity solution covering a wide area from Egypt to Middle East allowed us to infer the current rates across the main tectonic features. We have estimated 126 velocities from time series of 90 permanent and 36 non-permanent GPS sites located in Africa (Egypt), Eurasia and Arabia plates in the time span 1996–2015. We combined our velocity solution in a least-squares sense with two other recent velocity solutions of networks located around the eastern Mediterranean, obtaining a final IGb08 velocity field of about 450 sites. Then, we have estimated the IGb08 Euler poles of Africa, Sinai and Arabia, analyzing the kinematics of the Sinai area, particular velocity profiles, and estimating the 2D strain rate field. The estimated relative motion with respect to Africa is of the order of 2–3 mm/yr, however there is a clear mismatch between the modeled and the observed velocities in the southern Sinai sites. We have also assessed the NNE left shear motion along the Dead Sea Transform Fault, estimating a relative motion between Arabia and Africa of about 6 mm/yr in the direction of the Red Sea opening.

T1.2-P53  Lithospheric Scattering and Structure from Teleseismic P Waveforms

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Subsurface heterogeneities with scale lengths on the order of the seismic wavelength scatter the seismic wavefield, transferring energy from the main arrival to the coda and generating traveltime and amplitude fluctuations. Understanding the effect of these heterogeneities on the wavefield is important for the characterization of natural and man-made seismic sources and to improve our knowledge of Earth structure. Here, we combine an energy flux model with the analysis of the incoherent coda wavefield to a dataset of over 350 teleseismic events recorded at the Pilbara, Alice Springs and Warramunga seismometer arrays in Australia. This combination allows us to determine heterogeneity (correlation length, RMS velocity fluctuations of the heterogeneities and thickness of the scattering layer) that quantify the scale and magnitude of the lithospheric heterogeneities present beneath the arrays. Our new results show similar heterogeneity structure for all three arrays, despite the fact that they are located on different geological provinces with different crustal thickness and tectonic histories. These results are the first step in the development of a technique aiming to remove the effect of the small-scale, near receiver structure from recorded wavefields, thus enabling us to improve our source characterization and more clearly image the Earth’s interior.
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**T1.2-P54  Local Magnitude Formula Determination of Seismic Swarm at the Long-Dormant Jailolo Volcano, West Halmahera, Indonesia**

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In 2015 - 2016 there was an attack of Seismic swarms in Jailolo region, West Halmahera, Indonesia. GFZ Germany collaborated joint research with BMKG Indonesia after those disasters to install a temporary seismic network, called 7G network during August 2016 – July 2017. Then, we determined the local magnitude formula for this network. We used 3387 amplitude records from 150 earthquakes event with focal depth less than 30 km. Those data recorded by 6 broadband and 29 short period stations in the 7G network from August to December 2016 and end of June till July 2017. The results from this study were the distance correction function, \(-\log A = 1.742\log R - 0.00184R - 0.113\), and the magnitude local formula for 7G network, \(M_L = \log A + 1.742\log R - 0.00184R - 0.113\), where A and R are maximum amplitude and hypocentral distance, respectively. The stations' correction also found in this study. We found that the stations' correction for the 7G network was among -2.478 - -0.996 for 33 stations and anomalies for 2 stations because of their values was out of the range of those 33 stations. The negative values of stations' correction indicated high amplification meanwhile the positives indicated low amplification.

**T1.2-P57  Moment Tensor Solutions of Earthquakes in South of Sumba Island (Indonesia)**

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Potential of earthquake hazard in the south of Sumba Island (Indonesia) is poorly investigated. Tectonics of this region is proposed into two debatable models i.e. related to the subduction zone or due to collisional tectonics. During the year of 2015-2018, we find that the earthquakes in this region were sensitive to small stress perturbation dynamically imparted by large distant earthquakes. The earthquakes located in isolated ~60x30 km and secluded from most of the seismicity in the west of the Island. All of the seismicity analyzed here was activated after the occurrence of the 2018 Mw 7.5 Palu (Sulawesi) earthquake. We provided the source mechanism of M >4.8 earthquakes by means of moment tensor inversion utilizing three component local seismograms of BMKG. The method based on multiple-point source representation and iterative deconvolution. Our results required variance reduction between synthetic and observed seismograms should be > 70%. Our results indicated most of the earthquakes were shallow reverse faulting with the low dipping to the north and were generally agreed with the slab model and relocated seismicity by the previous study. Our study supported evidences that the shallow low dipping thrust faults are slightly more susceptible to surface wave triggering.

**T1.2-P58  Monitoring of Crustal Activities Using Oceanfloor Network System for Disaster Resilience**

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Recently, there are many disasters related earthquakes and tsunamis in the world, for example, the 2011 off Tohoku and 2018 Palu Indonesia. These sources are located in the sea, therefore it is important to utilize data of seafloor observations for disaster resilience. We have considered how to use real-time data by oceanfloor network systems like the Dense Oceanfloor Network system for Earthquakes and Tsunamis (DONET) to reduce these damages. We have two strategies, which are monitoring crustal activities using statistical technique for long term evaluation of huge earthquakes with a magnitude over eight, and real-time tsunami prediction considering tsunami propagation. DONET has ability to determine focus of small earthquakes with a magnitude
0.8 and we understand in situ stress field around the subduction zone using temporal-spatial seismicity map. We consider that real-time tsunami prediction based on the propagation is effective, because it is easy to reflect the real-time amplitude of the seafloor pressure data of coming tsunami to the coast on the prediction. It is useful to use it for tsunami by seafloor landslide. Convenient forward tsunami modeling is helpful for far field tsunami. In this presentation, we introduce our attempt using the oceanfloor network system for disaster prevention.

**T1.1-O3 Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound**

In this study we examined 344 bolides (airbursts) reported on the JPL CNEOS website which approaches 20%. Above the 1 kT CTBTO design threshold, we find that 40% of airbursts are reported in the layer multiplied by the relative difference in effective sound velocity and normalized by the vertical pulses from the source. It is shown that the mechanism of scattering of pulse signals in a stably stratified ABL is the signals is studied. The estimation of the error in localization of pulsed sources is given. Acknowledgement:

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**T1.1-O4 Climate Change Through the Eyes of Radioisotopes**

Strong earthquakes cause numerous human losses and infrastructure damages. The earthquake occurrences jeopardize cities, villages, state critical facilities, constructions (oil-gas pipeline, terminals, water reservoirs and others). The studied area is situated in the complex zone from the viewpoint of geodynamics and tectonics, included in the Alpine folded system. The seismic activity in the area is characterized by uneven seismicity with periodic format. The goal of the research is seismic hazards analysis in the eastern Caucasus (Azerbaijan) with the use of multi-parametric integrated method. The integrated method with the multidisciplinary character includes mathematical and statistical estimation of seismic parameters and probabilistic approach and also mapping of the area in peak ground acceleration value. In this study, the earthquake occurrences based on probabilistic theory was assessed, peak ground acceleration maps for scenario earthquakes were prepared using the interpolation algorithm and compared with the map of lithology. Clear correlation was observed between the distribution of peak ground acceleration and soil amplification maps. The results can be applied not only in the construction of hydro-technical structures, oil and gas pipelines, but also in the early stage projection of civil and industrial objects. Besides, the results can be used in the mid-term seismic prognosis researches. This work was supported by the Science Development Foundation under the President of the Republic of Azerbaijan-Grant № EIF/GAM-4-BGM -GIN-2017-3(29)-19/08/2

**T1.1-O5 Detection Efficiency of the IMS for Bolides**

In this study we examined 344 bolides (airbursts) reported on the JPL CNEOS website which approaches 20%. Above the 1 kT CTBTO design threshold, we find that 40% of airbursts are reported in the layer multiplied by the relative difference in effective sound velocity and normalized by the vertical pulses from the source. It is shown that the mechanism of scattering of pulse signals in a stably stratified ABL is the signals is studied. The estimation of the error in localization of pulsed sources is given. Acknowledgement:

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**T1.2-P59 Multi-Disciplinary Views on Seismic Hazard Analysis in the Eastern Caucasus (Azerbaijan)**

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Strong earthquakes cause numerous human losses and infrastructure damages. The earthquake occurrences jeopardize cities, villages, state critical facilities, constructions (oil-gas pipeline, terminals, water reservoirs and others). The studied area is situated in the complex zone from the viewpoint of geodynamics and tectonics, included in the Alpine folded system. The seismic activity in the area is characterized by uneven seismicity with periodic format. The goal of the research is seismic hazards analysis in the eastern Caucasus (Azerbaijan) with the use of multi-parametric integrated method. The integrated method with the multidisciplinary character includes mathematical and statistical estimation of seismic parameters and probabilistic approach and also mapping of the area in peak ground acceleration value. In this study, the earthquake occurrences based on probabilistic theory was assessed, peak ground acceleration maps for scenario earthquakes were prepared using the interpolation algorithm and compared with the map of lithology. Clear correlation was observed between the distribution of peak ground acceleration and soil amplification maps. The results can be applied not only in the construction of hydro-technical structures, oil and gas pipelines, but also in the early stage projection of civil and industrial objects. Besides, the results can be used in the mid-term seismic prognosis researches. This work was supported by the Science Development Foundation under the President of the Republic of Azerbaijan-Grant № EIF/GAM-4-BGM -GIN-2017-3(29)-19/08/2

**T1.2-P60 On the Relationship Between Floods and Earthquake in Southern Africa**

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In recent years, the Southern African Region has faced an increase in the frequency and magnitude of natural hazards such as floods and earthquakes. This marked increase in seismicity is believed to be partly associated with the propagation southwards of the East African Rift System (EARS). The heavy rainfall triggered by extreme weather events caused by climate change affecting Southern Africa has led to widespread flooding in the region. A preliminary analysis of the temporal and spatial relations between extreme flood events and the largest recorded earthquakes in the four Southern African countries of Botswana, Malawi, Mozambique and Namibia for the period 2000 to 2018, suggests that there is a relationship between these two natural hazards. Damaging earthquakes such as the 2006 Mw 7.0 Mozambique (Machaze), 2009 Mw 5.6 Namibia (Kunene), 2009 Mw 6.0 Malawi (Karonja) and 2017 Mw 6.5 Botswana (Moiyabana) coincided with some of the worst flooding to hit these areas in decades.

**T1.2-P61 P and S Wave Tomography of the Central Tien Shan from Inversion of Local Earthquake Arrival Time Data**

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Detailed tomographic images of the crust under the Central Tien Shan, Kyrgyzstan, are determined by using P and S wave arrivals data from local earthquakes and applying tomography method. The Tien Shan is one of the tectonically and seismically active intracontinental mountain ranges in the world sandwiched between stable...
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areas, Kazakh Shield to the north and Tarim Basin to the south. The tomography method by Zhao et al. (J GR, 1992) has been used in this study. We selected earthquakes as uniform as possible in the study area. Most of the earthquakes are located at depths of 0-20 km. We set all layers of grid net up to 65 km in the upper and lower crust with a spacing of 5 km and 10 km, respectively. The Moho discontinuity is set at a depth of 50 km. The spacing between grid nodes is 0.3-0.5 degrees in horizontal direction. The study area is characterized by an alternation of high-V and low-V layers beneath ranges and basins. The tomographic results exhibit considerable amount of crustal heterogeneities, which confirms the tectonic complexities of the study area. Earthquakes are located either in or on the edge of low-V layers in the Tien Shan, respectively.

T1.2-P63 Prediction of Earthquake Hazard in the Northeast India Himalaya

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The Himalayan region, the zone of collision of the Indian and Eurasian plates is most earthquakes prone. Based on the observed positive correlation between the inter-event times and the magnitude of the preceding mainshocks, the time- and magnitude- predictable model is found to be applicable in study region. The earthquakes with magnitude Ms ≥5.5 since 1906 to 2008 occurred in 19 delineated seismogenic sources in northeast India Himalaya have been used to predict the future earthquake hazard. It is found that, the probabilities for the occurrence of moderate to large size earthquakes in some of the seismogenic sources of northeast India and its adjoining southeastern Tibet is significantly high ranging from 0.81 to 1.0 for the next decade. Using the estimated conditional probabilities for occurrence of moderate to large size earthquakes, we report that eight such expected magnitude range 6.0-7.1 would occur till 2019 of which six will be located in Arakan-Yoma region (three intermediate and three shallow) and remaining two shall focus one each in the Himalayan Frontal Arc and the Eastern Syntaxis. It has been advocated that these vulnerable seismogenic sources be monitored for multi-hazards in real time for future development and planning.

T1.2-P65 Preliminary Results of Continuous Monitoring and Surface Condition of an Active Fault in the Southeast Aceh

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Southeast Aceh is one of the most seismically active regions due to the existence of the subduction zone and the Great Sumateran Fault. Some historical devastating earthquakes with magnitude range 5 – 7 occurred in 1965, 1980, 1997, 2008 and 2010, and could make intensity 4 – 7 MMI. To know the seismic activity, we have deployed 7 seismometers, 3 short periods and 4 broadbands, adding to the stations from BMKG and CTBTO network for 6 months from August 2018 until March 2019. Data were downloaded every 2 months. After 4 months of recording, to get the preliminary results, we downloaded, investigated and analysed the waveform and found 900 events using the STA/LTA method. In the result we found that the hypocentre distribution occurred and spread more in the southern part than in the northern part. Because of that, we rotated 3 sensors close to the southern part, to minimize the azimuth coverage and get a high raypath. We also conducted a microtremor survey to know the surface condition. We took 25 point and analysed the H/V to get the dominant parameter. From H/V results it is seen that the surface condition can be inhabited and is not too influenced by microwaves.
T1.2-P66  Preliminary Study of Seismic Hazard Along the Cameroon Volcanic Line (CVL)

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Earthquakes frequently occur along the Cameroon Volcanic Line (CVL), with magnitudes ranging between 2 and 6. These events are from tectonic and volcanic origins. An experiment called the Cameroon Broadband Seismic Experiment (CBSE) was conducted in the country between 2005 and 2007. The data collected was used in this work to compute the seismic hazard and therefore highlight the most risky areas around the CVL. We applied a pass band filter on to the data with frequency ranging from 1 to 5 Hz. We then picked the first P and S arrivals. This allowed the location of the earthquakes. The located events were distributed along the Congo Craton margin. This provided an update of the Cameroon neoseismicity. From the seismicity map and seismic hazard computation, we distinguished four risky areas: The mount Cameroon area, considered to be the most seismically active; the southern Cameroon area's seismicity is associated with the Kribi-Campo fault and also the presence of the Congo Craton, known for its high magnitude tectonic activity. The area along the Sanaga fault is the third risk zone; and the last one is the western Cameroon characterized by a network of large faults.

T1.2-P67  Preliminary Study of the Impact of Directivity for Strong-Motion Effective Duration on High-Rise Building

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For buildings most scientists assume that the maximum amplitude and longest duration of strong motion are in the highest structures. Contrary, this study used three waveform of events which were recorded on an accelerometer array in a 12-store building in Jakarta. Those are the M 6.5 Kebumen, M 5.6 Pandeglang, and M 4.7 Lebak earthquakes. It shows that the effective duration of the M 6.5 Kebumen is shortest and high amplitude is in the highest structure. But the M 5.6 Pandeglang, and M 4.7 Lebak are in different. Based on source mechanism data, seismic waves of the M 6.5 Kebumen directly traveled to Jakarta, in one direction on strike. Ruptures release high amplitude and short duration of strong motion on forward direction or contrary for strike indirectly. According to this study, it is shown that the object of energy compensation of M 5.6 Pandeglang and M 4.7 Lebak is on duration, whereas the object of energy compensation of M 6.5 Kebumen is on amplitude. This study was strengthened by similar method and result on the Aceh Sumatra earthquake.

T1.2-P68  Present-Day Stress Field in NW Himalaya and Surrounding Regions Based on Inversion of Earthquake Focal Mechanisms

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Stress field inversion is performed in NW Himalaya and surrounding regions on the basis of 584 earthquake focal mechanisms listed in the data bulletin of the International Seismological Centre (ISC) for the area between latitudes 25°-40°N and longitudes 65°-85°E. Earthquakes in the period of July 1974 to March 2018, with focal depths 10-248 km and magnitude range (Mw 4.7–7.9) have been selected and the inversion of all available solutions is applied to determine the best fitting stress tensors. Focal mechanism of most of the earthquakes indicates thrust faulting, which confirms northward under thrusting of the Indian Plate along the Main Boundary Thrust (MBT) and Main Central Thrust (MCT) system, and eastward under thrusting along the Burmese Arc. Fault-plane solutions indicate left-lateral motion along the Kirthar-Sulaiman Range and right-lateral motion along the Karakoram Fault, which are in agreement with the expected sense of lateral mass movement for the continental collision model. A predominant compressional stress regime in the NW Himalaya is represented by a
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Accurate meteorological modeling is critical for obtaining realistic atmospheric transport and dispersion (T&D) simulations. There are several data assimilation (DA) techniques used to improve meteorological results. Two common philosophies are nudging and variational DA. Traditionally, nudging is used in T&D, whereas more forecast guidance for the meteorological community as to which DA techniques provide the most value for T&D simulations and identify which DA technique provides the most realistic results. Overall this study provides guidance for the meteorological community as to which DA techniques provide the most value for T&D simulations.

T1.1-O1 Application of High-Resolution LiDAR Measurements to Assess Uncertainties in NWP Model Outputs

Obtaining by high-resolution LiDAR measurements, can thus significantly improve the understanding of a station's detection capability throughout a year; especially during the hemispheric summer seasons. Incorporating realistic wind and temperature uncertainties in NWP models, uncertainties in horizontal winds and temperature explain 97% of the actual detections, compared to 77% when atmospheric model analysis produced by the European Centre for Medium-Range Weather Forecasts. Such wind perturbations, considering observed biases and deviations, were added to the operational high-resolution model output. Using the direct NWP model output. Such measurements was installed at IS26 for estimating uncertainties in the modelled amplitude. Temperature and vertical wind field are modelled based on operational ocean wave interaction simulations and a semi-empirical attenuation relation.

T1.1-O2 Assessing Middle Atmosphere Weather Models Using Lidar and Ambient Noise: A Case Study for IS26

This relation strongly depends on the middle atmosphere (MA) dynamics; however, vertical temperature and horizontal winds were used as calibration signals, and their amplitudes at the German infrasound station IS26 were determined. Signals were used as calibration signals, and their amplitudes at the German infrasound station IS26 were determined. The network, noise is mainly generated by cars on streets, trains on railways, activity in town centers, and also from military activities. Inside the network, noise is mainly generated by cars on streets, trains on railways, activity in town centers, and also wind turbines. Outside the network, we map the city of Vienna as a major contributor to noise.

T1.2-P69 Probabilistic Seismic Hazard Assessment in Kenya and Its Vicinity

Seismic hazard assessment in Kenya is very crucial due to great and rapid spread of large development programs especially, the nuclear power plants and oil and gas, stations that are envisaged to be established under the Vision 2030. Although Kenya is considered a country of low to moderate seismic activity, it has experienced numerous historical large earthquakes and damage has been reported ranging from minor to great. In the past, because of under-development, the effects of major earthquakes in Kenya have been deceptively low. However, this situation is rapidly changing, with development programs moving into the earthquake-prone areas, which will bring vulnerability to damaging earthquakes. The tectonic activity of Kenya has been reviewed. All magnitudes were homogenized to moment magnitude scale and declustered. Seismic source zones parameters have been modeled from 103-year catalogue. Appropriate ground motion prediction attenuation equation is adopted. Then seismic hazard was computed using 50 km interval grid points, utilizing PSHA approach using Openquake program. The results shows high hazard levels in southwestern regions as compared with regions in northeastern part of the study area. Result provides information about earthquake prone areas and seismic risk potentials and, therefore, can be utilized for future earthquake mitigation and preparedness.

T1.2-P71 Properties of the High-Frequency Ambient Seismic Field Recorded on a Large-N (N=10,530) Seismic Deployment in the Vienna Basin

The Vienna Basin is the largest petroleum basin in Austria. As part of the ongoing seismic exploration for hydrocarbon resources in the basin, a large-N (N=10,530) dataset of continuous seismic recordings of the ambient seismic field was acquired in early 2018. Data were recorded on geophones (10-Hz corner frequency) and each location was made up of 12 or 24 densely clustered geophones, which were stacked to increase signal-to-noise ratio. Data were collected by these geophone clusters for up to 6 days, recorded only during day time. The station locations are distributed on a grid of roughly 40m by 400m and cover an area of about 500km2. Here, we present the first insights into the ambient seismic field in the Vienna Basin retrieved from this dataset. We perform beam-forming to detect noise sources outside of the study area, as well as Matched Field Processing to detect and locate noise sources at the surface inside of it. The wave-field is dominated by cultural noise. Inside the network, noise is mainly generated by cars on streets, trains on railways, activity in town centers, and also wind turbines. Outside the network, we map the city of Vienna as a major contributor to noise.

T1.2-P72 Receiver Function Analysis of the IMS Stations Located in Africa

The International Monitoring System of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) is now composed of 18 seismic stations all over Africa. Initially, those stations has been installed to detect any nuclear explosion in the region and from all over the world. The States Signatories of the treaty has access to those data in near real time and gets the opportunity to use them for their research and analysis. In this regard, we performed receiver function analysis. 9 of those 18 stations were used, to obtain an average seismic velocity Vp model in the direction North-East South-West of Africa. The result shows that the average depth of the upper...
mantine with the lower mantle \((\text{Moho})\) is around 30km. The result from the stations installed in the North-East of Africa shows a shallower \(\text{Moho}\) than those installed in the South-West. It can be explained by the geological structure of the Somali plate at the East African rift. Further research is ongoing to provide more explanation regarding this fact.

**T1.1-P73**  **Recent Seismicity Along the Davie Ridge/Fracture Zone**

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Davie Ridge/Fracture Zone, considered as the seaward extension of eastern branch (Kenya Rift Valley) of the East African Rift System (Mougenot et al., 1986), is a 2200 km-long prominent relic fracture zone that cuts across the West Somali Basin (Coffin and Rabinowitz, 1987, 1988; Grimison and Chen, 1988). It ranges between 30 and 120 km wide, with a west-facing scarp along the lower half of its length, that rises as much as 2300 meters above the sea floor (Scrutton, 1978; Mougenot et al., 1986). Earthquakes as deep as 40 km have been recorded below Davie Ridge (Grimison and Chen, 1988). However, evaluation of recent seismic data for the purpose of this study shows that \(M \geq 5.0\) earthquakes at relatively shallow depths of 10 - 30 km are a common occurrence along the Davie Ridge in the Mozambique channel. The earthquake focal mechanism indicates that the Davie ridge is characterized by normal faulting with occasional oblique faulting. Since early 2018 through 2019, the Davie ridge has been characterized by high frequency of earthquakes occurrence. This paper presents a review of these earthquakes and their implications on the stress changes along the Davie ridge/fracture zone.

**T1.2-P74**  **Relevance of National Data Centres Established in Southern Africa, the Case Study for Zambia**

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The establishment of National Data Centers by states members has really helped in the monitoring and verification efforts of the CTBTO Preparatory Commission, Vienna, Austria (CTBTO). The core mandate of the CTBTO is to ban all nuclear test explosions. Almost all the central and East African countries have signed and ratified the CTBT. To monitor nuclear test explosions, systems built on the principles of seismic, infrasound, radionuclide and hydroacoustic technologies are installed around the globe to record and monitor man-made and natural events. Zambia, being is a beneficiary of the seismic data from the International Data Centre (IDC) to monitor earthquake activities in the country complementing the efforts of the government of the republic of Zambia. Earthquake activity around Zambian areas is more diffused and with surface wave magnitudes ranging from 1 to 4.9. However, depending on the site conditions, the damage to the structures may be increased due to the effects of large earthquakes emanating from the Lake Kariba area and Earthquake activity within and around the Copperbelt may sometimes be triggered (induced) by mining activities, which may also have an increased and sustained damage on the structures, because of the frequent vibrations caused by mining blasts.
Theme 1: The Earth as a Complex System

T1.1 Atmospheric Dynamics

Oral Presentations

T1.1-O1 Application of infrasound arrays for the characterization of atmospheric wave signals: a case study in the Atlantic Ocean

T1.1-O2 Analysis of uncertainties in horizontal winds and temperature explain 97% of the actual detections, compared to 77% when wind perturbations, considering observed biases and deviations, were added to the operational high-resolution guidance for the meteorological community as to which DA techniques provide the most value for T&D simulations and identify which DA technique provides the most realistic results. Overall this study provides merit in space, and Kolmogorov-Smirnov parameter are computed to evaluate the robustness of the T&D Integrated Trajectory model. Using the COSTEX tracer observations, the correlation, fractional bias, figure of merit in space, and Kolmogorov-Smirnov parameter are computed to evaluate the robustness of the T&D Integrated Trajectory model. Using the COSTEX tracer observations, the correlation, fractional bias, figure of

T1.1-P71 Atmospheric Inversions using the Hybrid Single-Particle Lagrangian Integrated Trajectory model. Using the COSTEX tracer observations, the correlation, fractional bias, figure of

T1.1-P72 Development of a mission that will provide a new understanding of a station's detection capability throughout a year; especially during the hemispheric summer seasons.

T1.1-P73 Accurate meteorological modeling is critical for obtaining realistic atmospheric transport and dispersion (T&D) predictions. There are several data assimilation (DA) techniques used to improve meteorological results. Two sophisticated variational techniques are used in weather forecasting. Here, these two DA techniques are investigated in order to assess their specific impacts on T&D results and to determine if the more advanced DA techniques used in weather forecasting can be employed for T&D applications. The two methods are applied in simulations based on operational ocean wave interaction simulations and a semi-empirical attenuation relation.

T1.1-P74 Seismic Geohazard Monitoring in the Baringo Silali Geothermal Prospect in Northern Kenya

T1.1-P75 Revisiting the 2018 Kalibening Earthquake Sequence in Central Java: Call for the Revision of Earthquake Hazard

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As moderate devastating earthquake that impacted the economic loss was about $ 1.68 million US, the 2018 Kalibening earthquake quite shocked where the faulting mechanism still unconfirmed. There was no reference indicating the existence of the faulting zone exactly on the earthquake sequence. We take a benefit from seismic temporary network with the density ±2 km, which deployed while a macroseismic survey in purposing to evaluate the 2018 Kalibening earthquake sequence. Earthquake relocation using double difference combined with cross-correlation and determining earthquake moment tensor inversion solution using near source seismograms were applied. We suggested the deformation scheme of this earthquake with a thrust faulting with 307.5/ 28.8/ 118.5 (Strike/ Dip/ Rake) as a result from mainshock and supported by aftershock moment tensor solutions. This parameter consistent to aftershocks relocation results which formed a lineation trending NW-SE appropriate with Strike = 307.5. The cross-section exhibits aftershocks pattern which elongated deeper and formed a slope from SW to NE approximately fit to Dip = 28.8. The results from investigating the background seismicity in Banjarnegara Region using combined catalog (ISC-USGS-BMKG) compared to BJ1 (single station) showed the sparse and the lacking of InaTEWS seismic network configurations.

T1.2-P76 S-wave Velocity Structure Beneath PS14-ROSC Station Using Microtremor Arrays

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The PS14-ROSC station was certified as a CTBTO Primary Seismic Station since 2003. The station is located in Rosal close to the Colombian National Seismological Network headquarters. The ambient seismic noise around the station has increased since it was installed. With the purpose of improving the signal-to-noise ratio, reducing noise and improving seismic data quality we have proposed to deepen the seismometer vault. In order to estimate the S-wave velocity structure beneath the vault we conducted microtremors arrays measurements (radius from 60 cm up to 25 m). We calculated the dispersion curve, the Vs velocity profile and H/V ratio at the site. We estimated an average Vs30 value of 203 m/s that classifies the soil as a Soil Type D or stiff soil according to Colombian Building Code NSR-10. The H/V noise ratio exhibits a peak around 6.65 Hz corresponding with Vs 400m/s at a depth of 20m in the S-wave velocity profile. Other geophysical measurement are required to know more characteristics of the bedrock.

T1.2-P77 Seismic Geohazard Monitoring in the Baringo Silali Geothermal Prospect in Northern Kenya

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Plans to develop geothermal resources in the Baringo-Silali Block in the northern segment of the Kenya Rift by Geothermal Development Company (GDC), is at an advanced stage. The company has installed ten seismic stations around Paka and K orosi volcanoes, within the Kenyan rift system, to monitor seismicity for sustainable development of the resource and as part of geohazard monitoring prior to, and following the exploitation of the geothermal resources hosted in the prospects. The geohazard monitoring work entails obtaining and analyzing seismicity data, and determination of how pulses of activity are distributed over time. Monitoring of seismic events is also being done in order to obtain insights on the intensity, size, type, and distribution of micro-
earthquakes (MEQs), which will aid in subsequently determining associated hazards. Double difference relocations were used to obtain high earthquake locations and identify major swarms located in both crater summits. The swarms showed a pipe-like pattern of seismicity on the southwestern part of Paka crater summit, while Korosi, displayed minor seismicity around the volcanic center. This paper, therefore, presents the seismic monitoring report for data obtained from August 2012 up to July 2018 in Paka and Korosi prospects that lie in Baringo-Silali geothermal block.

T1.2-P80 Seismic Hazard Scenario in Western Himalaya, India
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In the present study Deterministic Seismic Hazard Analysis (DSHA) has been carried out for the states of Himachal Pradesh & Uttarakhand. Study investigates the seismicity data from the year 1963 to 2017 with $M_w \geq 4.0$ in the region bounded by $29^\circ N$ - $33^\circ N$ latitude and $75^\circ E$ - $81^\circ E$ longitude. Data have been taken from the catalogue of USGS and ISC. The study region is one of the most seismically active regions of western part of Himalaya, India and there are numerous major seismic faults present in this region. Eighty-nine seismo-tectonic sources in and around Himachal Pradesh & Uttarakhand were identified. Using an appropriate attenuation model the peak horizontal accelerations, peak vertical accelerations and ratios of peak vertical to horizontal accelerations were computed. For this purpose the study region was divided into grids of $0.5^\circ$ by $0.5^\circ$. The estimated peak horizontal accelerations vary from 0.02g to 0.60g and peak vertical accelerations vary from 0.01g to 0.47g. The ratios of vertical to horizontal accelerations vary from 0.27 to 0.78. The PGA contour maps prepared for the region show that larger Peak Ground Accelerations are present in the region where there is a higher density of larger faults and vice versa.

T1.2-P81 Seismic Impact from Earthquakes of Different Distance upon the Territory of Belarus
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The analysis of data and information about strong distant, regional and local occurred earthquakes was performed. Seismological monitoring in Belarus represents the system of continuous round-the-clock observations, on-line data transfer, obtained data multilevel storage, processing and analysis, control of natural and artificial seismic events in a wide energy and distance range. All works are performed by the Centre of Geophysical Monitoring of the National Academy of Sciences of Belarus using up-to-date seismic equipment.
Theme 1: The Earth as a Complex System

Accurate meteorological modeling is critical for obtaining realistic atmospheric transport and dispersion (T&D) predictions. There are several data assimilation (DA) techniques used to improve meteorological results. Two sophisticated variational techniques are used in weather forecasting. Here, these two DA techniques are investigated in order to assess their specific impacts on T&D results and to determine if the more advanced DA techniques used in weather forecasting can be employed for T&D applications. The two methods are applied in simulations and identify which DA technique provides the most realistic results. Overall this study provides merit in space, and Kolmogorov-Smirnov parameter are computed to evaluate the robustness of the T&D Integrated Trajectory model. Using the COSTEX tracer observations, the correlation, fractional bias, figure of merit in space, and Kolmogorov-Smirnov parameter are computed to evaluate the robustness of the T&D Integrated Trajectory model. Using the COSTEX tracer observations, the correlation, fractional bias, figure of

T1.2-P84 Seismicity Along the Seismogenic Zone of Algarve Region (Southern Portugal)

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The seismicity of the Portuguese territory increases in intensity from north to south, with a spatial distribution concentrated in the south and its adjacent Atlantic margins. The present seismological study, focused around Algarve region, was carried out through a cooperation project between the Universities of Évora (Portugal), Lisbon (Portugal), Strasbourg (France) and the IPMA (Lisbon, Portugal). To locate the seismic events and find the local velocity structure of epicentral area, the P and S arrival times at 38 stations are used (Geostar stations, telemetered network, U. Lisbon and IPMA stations). The data used in this study were obtained during the Algarve campaign, which worked, from January/2006 to July/2007. The preliminary estimate of origin times and hypocentral coordinates are determined by the Hypoinverse program. Linearized inversion procedure was applied to comprise the following two steps: 1) finding the velocity model using Velest and 2) simultaneous relocation of hypocenters and determination of local velocity structure. This work is expected to produce a more detailed knowledge of the crust structure over the region of Algarve, being able to identify seismogenic zones, potentially generators of significant seismic events and also the identification of zones of active faults.
**T1.1-O3** Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound

Detection Efficiency of the IMS for Bolides

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Egypt has suffered from a number of destructive earthquakes such as Kalabsha earthquake (1981, Mag 5.4) near Aswan city, Cairo earthquake (1992, Mag 5.9) and Aqaba earthquake (1995, Mag 7.2). The Egyptian authorities do a great effort to mitigate the earthquake disasters. The seismicity at the zones of high activity is investigated in details to report the active source zones. Since the year of 1997 till now, the geodetic observations by means of GPS were applied to cover some other regions of the country. These regions include Sinai, Gulf of Suez, Greater Cairo, Aswan and the Middle part on the River Nile. Data adjustment and analysis of repeated GPS campaigns using Bernese Software prevailed significant movements which may help in understanding the geodynamics of these regions. In the meantime, GPS measurements of crustal motions for 200 sites extending east-west from the Caucasus Mountains to the Adriatic Sea and north-south from the southern edge of the Eurasian plate to the northern edge of the African plate were carried out and estimate of plate motions at stations were determined. From the previous results, we could find there are some correlations between the computed surface deformation and the earthquake occurrences.

**T1.2-P85** Seismicity and GPS Observations for Studying Crustal Deformation and Geodynamics In and Around Egypt

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**T1.2-P88** Seismicity of the Okavango Delta Region: Contribution of IMS and Local Stations

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The Okavango Delta region (ODR) in Botswana is one of the largest alluvial fans on earth and is hosted in a graben structure that could be the terminus of a southwesterly extension of the East African Rift System (EARS). The delta comprises the upstream panhandle and the downstream mega-fan situated in the middle of the Kgalagadi Basin. The ODR has been observed to be characterized by the highest level of seismicity compared with other regions of Botswana. Data from the online bulletin of the International Seismological Centre (ISC) shows that many of the seismic events in the ODR have been detected by distant seismic stations at distances beyond 500 km from the heart of the delta, thus resulting in relatively poor location determinations. We present the results based on the data recorded by seismic stations deployed in the Network of A utonomously Recording Stations (NARS)-Botswana Project. The station distribution during this project allowed for better computation of focal mechanism and characterization of fault system of the region. We also use IMS in the region (LBTB, LSZ, BOSA, MATP, TSUM, and SUR) and other regional stations to review the location of seismic events that occurred before installation the local monitoring stations.

**T1.2-P89** Seismo-Tectonic Evaluation of December 13, 2009 Chittagong Earthquake

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The December 13, 2009 earthquake and its aftershocks were generated near the Chittagong folded belt. This active earthquake source structure is located near the subduction zone of the India-Myanmar plates boundary. The generation of earthquakes larger than 5 indicates that the region is tectonically active and as such thrust faults are capable of generating future large earthquakes. Chittagong and Chittagong hill tracts districts are located on the folded sedimentary rocks of tertiary age. The focal mechanism analysis bears information on the seismic fault and tectonics of the earthquake source region. The tectonic movement along Point Chittagong is 5.5 cm/y with direction NNE. Using the data set from the event area same areas have b = 0.71 and some b = 0.61. This b-value may indicate the situation of crustal deformation of the area. Low b-values of the event area suggest that the ground has large potential for future large earthquake. The subduction structure of Bangladesh, Myanmar continues to Andaman Islands area and to Sumatra. So the background of historical earthquake and recent low to medium magnitude earthquakes in this area indicate that the possibility of damaging earthquakes cannot be ruled out.
Theme 1: The Earth as a Complex System

T1.1 Atmospheric Dynamics

Oral Presentations

T1.1-O1 Application of Advanced Data Assimilation Techniques to Improve Atmospheric Transport and Dispersion Predictions

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Assessment of seismic hazard is challenging especially for low seismicity regions like southern Africa, where association of seismicity to causative faults is difficult as these faults are buried and show no surface rupture. However, the availability of good quality data from improved monitoring of earthquakes, recent geological, geodetic and geophysical studies, have made it possible to prepare an updated seismotectonic map of the region. The recognition and detailed mapping of historical and quaternary surface faulting in many zones of neotectonic activity have led to recent improvements in seismic hazard studies. The seismotectonic map assists in the delineation of seismic hotspots and potential earthquake sources in order to carry out a proper seismic hazard assessment using state of the art methodologies. Thus, in the study to prepare the seismotectonic map, concerted efforts were made to identify active faults and characterize them. To assist in that effort, stress data compiled mostly from fault plane solutions, were also obtained and could be used in characterising faults and seismic source zones. It is hoped that the information in the seismotectonic map will contribute to the preparation of more accurate seismic hazard assessments for South Africa.

T1.2-P92 Seismotectonics of Southern Africa

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T1.2-P95 Sinkhole Process Interpretation Based on Shear Wave Seismic Reflection Results at Ghor Al-Haditha, Dead Sea

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Since nearly 30 years - apparently contemporaneous to the rapid decrease of the Dead Sea level - ongoing unknown sinkhole processes in the subsurface continuously compromise farming areas, housings, industrial sites, and infrastructure at the investigation site, resulting in massive destructions. Similar processes are observed also at the western border of the Dead Sea. Although many geophysical studies have been carried out at the site since more than 20 years, the subsurface structure and the process itself is quite unknown until yet. In recent years, a massive salt layer at 35-400 m depth was proposed below alluvial fan deposits, which was originally the target of this reflection seismic pilot study. In October 2013 and October 2014, a shear wave reflection seismic study was carried out at the most destructive sinkhole site in Jordan, close to the village of Ghor Al-Haditha at the southeast border of the Dead Sea. Our interpretation, supported by two boreholes, is that sequences of unconsolidated alluvial fan deposits dominate all of the seismic depth sections, starting from the top soil used by farming to a depth of at least 200 m.

T1.2-P98 Source Process Analysis of the 28 September 2018 Palu Earthquake (Mw 7.4) Using Teleseismic Waveform

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On Friday, 28 September 2018 (10:02:45 UTC) a large, damaging earthquake occurred in Palu, Central Sulawesi, Indonesia. Based on BMKG analysis, the earthquake has a magnitude Mw 7.4, depth 11 km, and epicenter of 2.2°S - 119.89°E. This event caused destructive secondary effects such as a tsunami, landslides, liquefaction, and collapsed structures in many place in Palu city. Slip distribution and Source Time Function (STF) were determined to investigate the causes of the earthquake. The investigation used 37 teleseismic waveforms obtained through IRIS. The result of STF graphic modelling showed that 3 peaks of Moment Rate Function (MRF) appeared during 35 seconds. This MRF is consistent with 3 asperity zones in the fault plane, that consist of 2 asperities near the hypocenter and 1 shallow asperity located around 60 km south of the hypocenter. Those asperities were presumably cracked and became the new sources of shaking while movement of the strike-slip Palu earthquake Mw 7.4 was not yet finished. This phenomena was suspected to cause a submarine landslide that generated the tsunami after the earthquake of Mw 7.4.

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**T1.1-O3 Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound**

We process continuous data downloaded from the IRIS Data Management Center and recorded at the TA array in Alaska to detect and locate P-wave microseisms using a backprojection method. We backproject the energy to a series of grid points covering the entire Earth, with ~400 km spacing. For each grid point — and an assumed origin time — 10 min data from each element of the Alaska TA array is extracted, starting with the predicted P-wave arrival time by the 1D ak135 velocity model. For each trace, the processing involves, in succession, removing the trend and applying a filter and a taper. All traces in the array, at distances of 30–90 deg from the grid point, are stacked using a fourth-root stacking method, and the root-mean-square amplitude of the stack is assigned as the power of the specific stack. The procedure is repeated for each grid point and for origin times incremented by 5 min. The backprojection method is applied to data recorded at the Alaska TA array during 2018. We estimate the sources of P-wave microseisms in the Atlantic and Pacific Oceans and compare them with predictions of wave-wave interactions from ocean models developed under the WAVEWATCH III framework.

**T1.1-O4 Climate Change Through the Eyes of Radioisotopes**

In recent studies, the seismic activity in Ulaanbaatar region has been active since 2005. Therefore, this is a need for a more comprehensive study on the structure of this region where the highest density of population of Mongolia lives. The aim of this study is to obtain a map of structure of Ulaanbaatar region by gravity data and to estimate the thickness of the sediments and the morphology of the basement of this area. This region includes Ulaanbaatar basin, Nalaikh basin, and Bogduul granite massif. Since 2013, we have carried out the ground gravity survey, using the gravity meter CG-5 and has collected more than 2000 gravity data. Result shows that Ulaanbaatar region is a complex block structure, thickness of sediments in Ulaanbaatar basin is 150-400m, in Nalaikh basin- 800m and thickness of the Bogduul granite massif- 9 km. The results are useful for engineering seismological studies to evaluate the seismic hazard of the Ulaanbaatar region.
**Theme 1: The Earth as a Complex System**

**T1.1-O1 Application of Advanced Data Assimilation Techniques to Improve Atmospheric Model Analysis**

Oral Presentations

Application of Advanced Data Assimilation Techniques to Improve Atmospheric Model Analysis

Oral Presentations

Obtained by high-resolution LiDAR measurements, can thus significantly improve the understanding of a station's detection capability throughout a year; especially during the hemispheric summer seasons. Uncertainties in horizontal winds and temperature explain 97% of the actual detections, compared to 77% when atmospheric model analysis produced by the European Centre for Medium-Range Weather Forecasts. Such wind perturbations, considering observed biases and deviations, were added to the operational high-resolution guidance for the meteorological community as to which DA techniques provide the most value for T&D simulations and identify which DA technique provides the most realistic results. Overall this study provides merit in space, and Kolmogorov-Smirnov parameter are computed to evaluate the robustness of the T&D Integrated Trajectory model. Using the COSTEX tracer observations, the correlation, fractional bias, figure of merit in space, and Kolmogorov-Smirnov parameter are computed to evaluate the robustness of the T&D Integrated Trajectory model. Using the COSTEX tracer observations, the correlation, fractional bias, figure of

**T1.1-O2 Assessing Middle Atmosphere Weather Models Using Lidar and Ambient**

Oral Presentations

Atmospheric Dynamics

Oral Presentations

Accurate meteorological modeling is critical for obtaining realistic atmospheric transport and dispersion (T&D) predictions. There are several data assimilation (DA) techniques used to improve meteorological results. Two common philosophies are nudging and variational DA. Traditionally, nudging is used in T&D, whereas more recent applications utilize variational techniques.

**T1.2-P106 Tectonic Activity and Its Influence in the Increase of Earthquakes in Iraq**

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Iraq is a country subject to seismic activity associated in a belt Zacros-Taurus which is caused by the collision of the Arabian plate and the Eurasian plate. Where Arabian plate is affected by three types of tectonic boundaries: divergent boundaries, convergent boundaries, and plate boundaries. Under these attractions the Arabian plate moves north-east, leading to the expansion of the area of the Red Sea and the Gulf of Aden on one hand and increasing the collision at the mountains of Makran, Zacros and Taurus on the other hand. We note this motion from time to time being represented by light, medium and strong earthquakes. The CTBTO Preparatory Commission, Vienna, Austria (CTBTO) provides Member States, in accordance with the requirements of the verification regime, the data from seismological monitoring stations, one of the four techniques used by the organization to achieve its goals of making the world free of Nuclear weapons and supporting the scientific and practical side concerned with the monitoring of earthquakes and their effects. In this poster the level of seismic activity witnessed in Iraq between (2017 - 2018) and define mb, MI to determine Mw which was signal of increasing seismic activity is shown.

**T1.2-P107 Tectonic Plates Interactions and Detection Capabilities of the IMS Seismic Stations in the Africa Region**

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Monitoring seismicity and appropriately analysing the data are important for both scientific and civil applications. Correct analysis forms the premise for estimating the risks in intercontinental seismicity occasioned by tectonic plate interaction. The International Monitoring Stations (IMS) seismic stations in the African region consist of 9 primary and 15 auxiliary stations. Two earthquakes occurred in Indonesia (Indo-Australian plate) on 12 August, 2010 and 16 April, 2016. The IMS stations in Africa (African plate) are of teleseismic distances from the two Indonesian events. The ability of these stations to be deployed for scientific purposes was assessed using the two Indonesian events. The data from these stations were analysed using the Geotool software to locate both events. Parameters studied were spectrum, fk, ray-tracing and azimuth for phase, magnitude, time and slowness. This analysis of both events is presented in this study.

**T1.2-P109 The B-Value of Local Seismicity Around Seymareh Dam (Zagros region-Iran), Before and After Impoundment**

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Earthquakes began to occur in Seymareh dam - Central Zagros region, in Iran- soon after the filling of Seymareh Dam in April 2012, with magnitude 4.7. In the present study, three datasets 2006/08-2011/04 (60 months before impoundment), 2011/04-2016/03 (60 months after impoundment) and 2011/04-2018/10 are analyzed to study the b-value. The b-value is calculated using the Gutenberg-Richter relationship. The estimated b-value of this region before impoundment are found to be in good agreement with previously reported studies (b-value = 0.62, 60 months before impoundment). In the subsequent years after impoundment, the b-value shows an increase (b-value = 0.72, 60 months after impoundment and b-value= 0.83, after impoundment). Also, the pattern of spatial clustering of earthquakes show increase in clustering and migration along the dam site and two faults near it, called Vizenhar and Gavar faults near North-East of dam site. The results of this investigation indicated that reservoir-induced earthquakes might have resulted from the release of energy accumulated by impoundment of the reservoir, although we are just in the beginning of our long-term study.
The Caucasus is one of the most active segments of Alpine-Himalayan system. High seismicity of the area reflects the active tectonics of the region. In 2016, Caucasus countries started a joint Probabilistic Seismic Hazard Assessment (PSHA) supported by LLNL (Lawrence Livermore National Laboratory). The major goal of the project was to compile regional seismic catalog in order to provide reliable input for the seismic hazard assessment. The Caucasus has a documented historical catalog stretching back to the 2000 years. Instrumental period started in 1899, when the first seismograph was installed in Tbilisi. Seismic network grew over the years and number of stations increased in the region, providing better network coverage. Data recorded by the regional network were stored as the seismic bulletins in a paper form. We digitized bulletin data from former Soviet Union monitoring network (1955-2004) with combined arrivals from neighboring countries to improve location accuracies. We measured direct Mw’s using coda calibration method for magnitude relationship. Number of events in the compiled catalog is significantly higher than the existing local and international catalogs (e.g. International Seismological Center (ISC)). We combined this with alternative source and ground motion models in probabilistic framework to modernize the building codes in Georgia.

The one of the main segment of South Hangay fault systems, the Bayanbulag left-lateral strike-slip fault, was activated by moderate sized earthquake with Ml=5.4 on 2012/10/03. The earthquake was recorded by the 72 station BB seismic network deployed in the Hangay dome (44°-51°N, 95°-104°E) during 2012–2014 as part of the scientific collaboration with Lehigh University under frame of the project “Intracontinental Deformation and Surface Uplift- Geodynamic Evolution of the Hangay Dome, Mongolia, central Asia”. We performed inversion to estimate a 1-D velocity model with station corrections for the crust and uppermost mantle under South Hangay Dome of central Mongolia. The simultaneous inversion for structure and hypocenters was carried out, using 198 selected events with local magnitude more than 1.5 from over 925 local events recorded by the BB experiments. We determined both, P-wave and S-wave velocity models, compare hypocenter locations and travel-time residual distribution for South Hangay fault systems. Using this new model, we relocated the ~2000 selected events. This new model is expected to improve the accuracy of the routine hypocenter determination and as initial reference models for seismic tomography and also seismic hazard studies in future.
**Theme 1: The Earth as a Complex System**

**T1.1-O1 Application of Advanced Data Assimilation Techniques to Improve Atmospheric Dynamics**

Incorporating realistic wind and temperature uncertainties in NWP models, wind perturbations, considering observed biases and deviations, were added to the operational high-resolution simulations and identify which DA technique provides the most realistic results. Overall this study provides accuracy meteorological modeling is critical for obtaining realistic atmospheric transport and dispersion (T&D) predictions. There are several data assimilation (DA) techniques used to improve meteorological results. Two techniques used in weather forecasting can be employed for T&D applications. The two methods are applied in the WRF model for the Colorado Springs Tracer Experiment (COSTEX).

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**T1.2-P114 The Role of Geochemical and Petrographic Properties of Rocks on the Rheology (Viscosity) of Magmatic Systems: Involvement in Wave Spread and Internal Dynamics of the Earth, Case of the Nyiragongo Volcano Field in the Virunga Volcanic Province (East African Rift)**

In this work, we are studying samples from lava collected following successive eruptions on the side of the Nyiragongo volcano, between 1977 and 2002, as well as the inside of the crater in 2016. First part of the work concerns the petrographic and geochemical (major and traces elements) analysis of these samples. In a second part, geochemical data are used to calculate the viscosity of these lavas. Viscosity is an important parameter influencing the effusion rate, lava flow speed and wave spread. Petrology analysis results points to andesites samples as previously mentioned in previous studies of the same volcano. The logarithmic value of viscosity, for lava’s temperatures around 1000°C to 1200°C is around 2.5 Pa.s in average for lavas collected from 2002 to 2016 eruptions, while it is 2.8 Pa.s in average for the lavas from 1977’s eruption. So the viscosity from Nyiragongo’s lava seems to decrease with time. The average lava flow speed of Munigi and Bitungulu vents (2002 eruptions) are respectively 6 m/s et 5 m/s.

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**T1.2-P115 The Seismic Network of Zambia**

This work provides an up-to-date overview of modern instruments used in earthquake seismology as well as a description of theoretical and practical aspects of seismic instrumentation. The main presentation describes the Zambian Seismic Networks [ZSN]. This network has undergone three major phases in its digitization processes from single analog station to the current three components: - Choosing and installing equipment for seismic stations - Designing and setting up seismic networks and arrays - Maintaining and calibrating seismic instruments, digitizers, seismic recorder, communication systems and Software used for seismic stations and networks. The aim of the network is to monitor seismic activities in Zambia and surrounding areas to inform the accurate understanding of a station’s detection capability throughout a year; especially during the hemispheric summer seasons.
Government of the Republic of Zambia on earthquake activity. The sensor types installed include the STS1/2 with Q330 digitizers interfaced with the CTBTO GCI. The rest of the stations are either Guralp Tellurium, Nanometrics with all digitized, Reftek 130s, some Guralps compact types with inbuilt DM 24 digitizers which operates using SCREAM software.

**T1.2-P117 Understanding Pamir-Hindukush Seismicity**

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Located on the northeastern part of the Asia-India continental collision zone, Afghanistan is one of the seismically most active countries in the world. Destructive earthquakes occur frequently, mostly beneath the Afghan Hindu Kush mountains at crustal and sub-crustal levels, and pose a large threat to the Afghan community. Sub-crustal seismicity forms a worldwide unique zone of intense intermediate depth seismicity, which has been interpreted as intracontinental subduction with different polarity beneath the Tajik Pamir and the Afghan Hindu Kush mountains. The lithospheric slab currently subducting beneath the Hindu Kush seems to be in the state of breaking-off as all large sub-crustal Mw≥7 earthquakes within the last century occurred exclusively beneath the Hindu Kush. It is unclear how and if earth’s surface reacts to these deep lithospheric processes. seismic stations are operating within the Hindu Kush Mountains within a joint project, forming the largest seismic network in Afghanistan. The network is situated on top of the nest of intermediate depth seismicity and further west in the Afghan platform, aiming to resolve the crustal structure and seismicity within this remote region. Here, we present the purpose of the project, goals and station description alongside with the first results on seismicity distribution.

**T1.2-P118 Updating the Egyptian Earthquake Source Parameters Database**

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Focal mechanism and source parameters are an essential input for many seismological applications including source characterization, discrimination, and Seismic Hazard Assessment. In this study, we constructed new database for updated Earthquakes Focal Mechanism and Source Parameters for Egypt. Data coverage for the catalogue extends 2012 to 2018 events with Magnitude ≥ 3.5. The catalogue compromise quality weighted Focal mechanism Solution and different source parameter including seismic moment, fault radius, corner frequency, stress drop, and moment magnitude. The Database is regularly updated with the solution for events with magnitude ≥ 3.5 using data from Egyptian National Seismological Network, Egyptian Strong Motion Network, IMS, ORFEUS, and ISC data.

**T1.2-P119 Upper Crustal Structure at the KTB Drilling Site from Ambient Noise Tomography**

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In this study, we show results from ambient noise tomography at the Continental Deep Drilling Project (KTB) drilling site, Germany. During the KTB project crustal rocks have been drilled down to 9 km depth and several active seismic studies have been performed in the surrounding. The aim of this study is to present a new shear-wave velocity model of the area while comparing the results to the previous velocity models and hints for anisotropy depicted by former passive and active seismological studies. We use a unique data-set composed of two years of continuous data recorded at nine 3-component temporary stations installed from July 2012 to July
**Theme 1: The Earth as a Complex System**

2014 located on top and vicinity of the drilling site. Moreover, we included a number of permanent stations in the region in order to improve the path coverage and density. Cross correlations of ambient noise are computed between the station pairs. Dispersion curves of surface waves are extracted in the 0.07 to 3 Hz frequency band and are then inverted to obtain group velocity maps. We present here a new velocity model of the upper crust, which shows that velocity variations at short periods correlate well with geology of the region.

**T1.1-O1 Application of Advanced Data Assimilation Techniques to Improve Forecast Accuracy in Regional Weather Models**

Accurate meteorological modeling is critical for obtaining realistic atmospheric transport and dispersion (T&D) predictions. There are several data assimilation (DA) techniques used to improve meteorological results. Two methods are applied in this study: nudging and variational DA. Traditionally, nudging is used in T&D, whereas more advanced data assimilation (DA) algorithms are also employed. In this study, we investigated the performance of different DA techniques and identified the most promising ones for practical applications.

**T1.2-P120 Upper Mantle Imaging with Surface Wave Diffraction: AlpArray Seismic Network and the Cameroon Volcanic Line**

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The AlpArray seismic network stretches hundreds of kilometers in width and more than thousand kilometers in length over the greater Alpine region (Europe) consisting of around 250 temporary and 400 permanent broadband stations. We utilize an array beamforming technique identifying the frequency dependence (40-150 s) of the surface-wave phase-velocity vector. We observe deviations of backazimuths with respect to the great circles, which form intriguing stripe-like patterns throughout the region. These stripe-like arrival-angle deviation patterns can be caused by interference of diffracted wavefield after passing a single small-scaled velocity anomaly. Using Rayleigh waves from two earthquakes under the Southern Atlantic Ocean and a grid search inversion scheme, we located the anomaly at 10.5°N/15.0°E. Its width is 320 – 420 km, and its length matches the 2500 km long upper mantle low-velocity region under the Cameroon Volcanic Line. The observation serves not only as a detector of upper mantle heterogeneities, but it also allows to determine how phase and group travel time delays and wavefront healing can affect global and regional tomographic studies. This has important consequences for the local phase-velocity measurements as well.

**T1.2-P122 Using HV Method for Imaging of Fault Zones (the Baikal Rift)**

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We use of the modified Nakamura's method of H/V spectral relations for investigation of inner structure of the Tunka basin (the Baikal rift system). The depression is a half-graben bounded from the north by the steeply dipping Tunka fault. The sedimentary cover of the basin is represented by rift lacustrine, alluvial, volcanoclastic sediments and basalt flows. The measurements of ambient noise were made for long profiles crossing the basin, as well as for profiles oriented across the strike of fault zones. The interpretation of submeridional section across Tunka fault shows the vertical displacement of basement surface with amplitude at about first tens meters along the fault plane. Further to the south on 5 km the inclined step is traced. The surface of this step is covered with a basalt flows. Obviously, the main displacement which forms a deepest part of the basin is located to the south of the end of the profile. The use of the method made it possible to establish the position of individual fault branches in the zones of the seismically active Baikal-Mondy and Tunka faults under the Cenozoic sediments and allows to determine the thickness of the sediments.
T1.2-P123  Velocity of Seismic Waves in the Earth’s Crust and Upper Mantle of the Siberian Platform and Baikal Folded Region According to Underground Nuclear Explosions

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During 1976–1987 in the former USSR in the territory of the Eastern Siberia and Yakutia ten peaceful nuclear explosions (PNE) were conducted. PNEs were measured by regional analog seismic stations located in the Baikal rift at distances from 246 to 1407 km. Based on these data the regional velocities of seismic waves in the Siberian platfrom, Transbaikalian block and Baikal-Patom highland were determined. According to the PNEs records obtained on the Yakutia network, the P and S wave velocities in the crust and upper mantle of the Siberian Craton were calculated [Mackey et al. 2005, Burkhard et al., 2016]. The P and S-wave velocities in the upper mantle obtained the Baikal region are lower than in Yakutia area, while in the crust, on the contrary, they are higher. Such a spatial distribution of the velocities of seismic waves agrees well with the SibCrust model [Cherepanova et al., 2013]. Low velocities of seismic waves indicate the presence of low-velocity anomalies in the region under the crust. The presence of low velocity anomaly under the Moho in the Baikal rift was noted according to the deep seismic sounding data [Krylov et al. 1981] and seismic Q-factor calculations [Dobrynina et al., 2016].
T1.3 Properties of the Ocean

Oral Presentations

T1.3-O1 Analysis of Hydroacoustic Signals Associated to the Loss of the Argentinian ARA San Juan Submarine

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On 15 November 2017, the loss of the Argentinian ARA San Juan submarine was detected by three IMS hydrophone stations, ranging from 6,000 km in the Atlantic Ocean to 12,400 km in the Indian Ocean. The great data quality and high signal to noise ratio on the two closest stations allow to identify direct and several reflected paths on different types of bathymetric structures. An original location method will be presented, which jointly utilizes a small subset of arrivals associated to both submarine event and a controlled depth charge realized by the Argentinian Navy close to the last known position of the submarine. Location results and associated uncertainties will be compared to the recovered wreck position. Broadband full waveform modelling and cepstral analysis techniques were also performed to try to separate source and propagation effects.

T1.3-O2 Calculation of Hydroacoustic Propagation and Conversion to Seismic Phases at T-Stations

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The IMS Hydroacoustic network consists of 6 Hydrophone stations and 5 T-stations. The T-stations are high-frequency seismic stations (sample rates of 100 Hz) situated on islands or coastal stations and intended primarily to capture signals from in-water explosions. However, while there are numerous recordings of impulsive-like signals at the hydrophone stations, recordings of this type of signal at the T-stations are relatively rare. This is because the conversion of the in-water acoustic signal as it propagates from ocean to land is both complex and characterized by strong attenuation. To improve the understanding of this phase conversion at T-stations, we are performing numerical calculations using the spectral element code SPECFEM2D, modelling the underwater propagation along a path leading towards each T-station and the phase conversion through the ocean/land interface to the seismometer. Environmental information from a variety of sources was gathered to construct the earth and ocean models used in the calculations. The goal of this part of the work is to provide a set of calculated waveforms to complement the limited set of observed waveforms and to assist in the characterization of arrivals from explosion-generated hydroacoustic waves at T-stations.

T1.3-O3 CTBTO’s Contribution to the Search of the Missing Argentine Submarine ARA San Juan

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The Argentine submarine ARA San Juan went missing on 15th November 2017. The last confirmed contact was from a location around 600 kilometres offshore the San Jorge Gulf, Argentina. In order to provide information which could potentially help in the search for the ARA San Juan, CTBTO analysed data recorded by its International Monitoring System (IMS). Two IMS hydroacoustic hydrophone stations, namely HA10 in the

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Atlantic Ocean and HA04 in the southern Indian Ocean, recorded an unusual signal of unknown nature which originated at the vicinity of the last known location of the ARA San Juan. On 1st December 2017, in order to confirm the accuracy of the location of this acoustic anomaly, the Argentine Navy deployed a depth charge to the North of the last known position of the submarine. This signal was also detected by the same two IMS hydrophone stations and localized to within 37 km of the declared depth charge location. On 17th November 2018, the ARA San Juan was found on the seabed at 900 metres depth, very close to the location originally indicated by CTBTO. This presentation reviews the equipment and signal analysis employed by the scientific team at CTBTO to accomplish this feat.

**T1.3-O4  Hydroacoustic Signatures “Petition” for Social Change: Curating Hydroacoustic Data to Strengthen the Implementation of Environmental Dimensions of the SDGs**

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Ocean acoustic data from the IMS hydroacoustic (HA) station network can be used to support climate research, and study global trends and characteristics of ocean soundscapes across the world. Meanwhile, assessing anthropogenic marine impact and its relation with ocean soundscapes is gaining traction and appreciation across broad sectors of society. With the objective of proposing linkages between the CTBT and the Sustainable Development Goals, this project investigates how hydroacoustic data can be utilized by audiences to assess the state of health of the oceans, and provide key indicators for the sustainable use of their resources. This will be developed through efforts to build: 1) a technical understanding of how acoustic signatures are isolated and interpreted, 2) strategies to design a data product platform that is also value-driven, 3) an identification of gaps in the current global policy practice related to the assessment of marine ecosystems. The outcome of this project shows how the CTBTO IMS HA network could be leveraged in this context. With special emphasis on SDGs 11, 12, 13 and 14, this work explores critical linkages within and between environment-related SDG goals and targets, and the development of indicators to support their implementation.

**T1.3-O5  Distributed Detection Framework and Three-Dimensional Propagation Model for Acoustic Detection of Baleen Whales**

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The HA08 hydrophone triads to the north and south of Diego Garcia constantly record low frequency whale calls. This work develops detectors for different types of blue whales, the Antarctic, Sri Lankan, Madagascar, and an unidentified type. There are significant challenges for constructing detectors. The calls are complicated, and show variations in intensity across frequency bands, and within the three hydrophones of a triad. There is hence a variability to the Signal to Noise Ratio (SNR) available for detection. A major cause for the variability is the scattering due to the island bathymetry. This work proposes a robust framework to overcome these issues in two stages. The first stage uses subspace approaches to detect calls across respective frequency bands. The second stage compensates for the SNR variability to improve the detection rates. In this stage, a distributed approach fuses detections across call frequencies, and the hydrophone triads. The other focus of this work is building a three dimensional propagation model to predict sound scattering, which helps suggest improvements to the detector. Finally, the work uses a subset of calls (recorded over a year) to estimate the probability of detection. The new method has higher detection rates than results previously published in the literature.
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T1.1 Atmospheric Dynamics

Oral Presentations

T1.1-O1 Application of Operational Global Atmospheric Model Analysis to the Detection of Oceanic Infrasound

The existing infrastructure of the six Hydroacoustic Systems spans remote locations of the world. The first of these systems at Diego Garcia is reaching its 20 year life and consideration to the maintenance and replacement of the systems is ongoing. This presentation will discuss opportunities to incorporate advancements in active junction box design, facilitating the inclusion of wet-mate underwater fiber optic connections in any future upgrade, replacement, or repair of these systems. Recent analysis of the in-water triplet has shown that these units are likely to last much longer than the 20 year life objective. During any future maintenance or repair, the inclusion of a junction box with wet-mate fiber optic connectors could help to improve the serviceability of the system and could provide opportunity to expand the system to new co-located science research.

T1.1-O2 Assessing Middle Atmosphere Weather Models Using Lidar and Ambient Winds

Accurate meteorological modeling is critical for obtaining realistic atmospheric transport and dispersion (T&D) simulations. Sophisticated variational techniques are used in weather forecasting. Here, these two DA techniques are investigated in order to assess their specific impacts on T&D results and to determine if the more advanced DA techniques used in weather forecasting can be employed for T&D applications. The two methods are applied in combination for the Colorado Springs Tracer Experiment (COSTEX) and signal the potential for improved T&D simulations.

T1.1-O3 Improved T&D Simulations for the Tracer Experiment Using Hybrid Single-Particle Lagrangian Approaches

Conducting successful and timely at-sea installation and sustainment of International Monitoring System (IMS) hydroacoustic (HA) stations requires proactive management of the risks associated with challenging ocean environmental conditions, such as those which prevail at remote IMS HA sites. To support the planning of maritime operations for the establishment of hydroacoustic station HA04 at the Crozet Islands located in the Southern Ocean, one of the world’s most challenging ocean environments, the IMS HA team used an in-house Monte Carlo simulation tool to estimate installation weather delay days using as input a database of historical ocean weather records available from the local meteorological station, together with a breakdown of maritime operational steps. The model’s predictions were found to be in good agreement with the actual outcome of the installation. Based on this experience APL-UW were approached for the development of a sophisticated Monte Carlo Mission Time Simulation (M MTS) tool for more general at-sea operations performed at various locations. M MTS uses NOAA WaveWatch III oceanographic re-analysis data for the assessment of ocean weather together with a detailed mission planner for all stages of the maritime operations. The M MTS has potential applications to other missions associated with the CTBTO Preparatory Commission, Vienna, Austria.

T1.1-O4 Enhanced Understanding of T&D Simulations for the Tracer Experiment Using Hybrid Techniques

The Ocean Observatories Initiative Cabled Array (OOI-CA) commenced operation in 2014 with two trunk cables extending offshore from the central Oregon Coast, that incorporate multiple science nodes which host approximately 140 commercial and custom oceanographic instruments. With an operational life of 25 years, this undersea network delivers ample power and real-time data acquisition to support sustained, continuous observations of a wide range of oceanographic parameters over long periods of time. While many of these instruments are installed on the seafloor, the Cabled Array includes three novel winched profilers, designed and constructed at APL-UW, located on subsea moorings on the continental shelf, the abyssal plain, and flanking an active undersea volcano. These highly capable profilers can each host up to 15 instruments and transit vertically from 200 m to just below the surface up to nine times per day, unattended for one year between servicing missions. Among the data provided by these systems are CTD observations made at 1 Hz. Temperature and salinity profiles will be presented over the five-year operation of these profilers and related to the large scale oceanography off the coast of Oregon. Adding ancillary instrumentation to CTBTO assets could allow similar insights in other oceans.
Reducing Ambiguity in Hydroacoustic Triangulation Through Consideration of Three-Dimensional Propagation Features

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Ambiguity in triangulation of events recorded on the IMS hydroacoustic network depend on the accuracy in knowing when these events occurred. Considering only the direct "line-of-sight" propagation path to a station, three stations are needed to pinpoint an event time. To overcome this requirement, consideration of additional signal features relating to the propagation characteristics can improve triangulation. Two such signal features are: (1) modal dispersion characteristics of the direct path; and (2) delayed out-of-plane arrivals caused by bathymetric refraction. Detection of out-of-plane arrivals effectively add additional "virtual" stations, while characteristics of modal dispersion correspond to the propagation distance. Thus when such signal features are present in combination with the back-azimuth information, source triangulation can be accomplished from a single station. An examination of these signal features within two impulsive acoustic events, one associated with the loss of the Argentine submarine San Juan and the other a planned depth charge deployed two weeks later as part of the initial search, demonstrate the ability to triangulate with limited receiving stations (note both of these events were detected at HA10 and HA04). Furthermore, the propagation models used to capture these signal features also provide an assessment of triangulation error caused by uncertain oceanography.

Poster Presentations

Climate of the Upper Ocean Layer in Stations of Ecuadorean Sea

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The seasonal and monthly sea temperature time series profiles (0-100m) were analyzed in four points 10 miles off the Ecuadorean coast located in the equatorial eastern Pacific. The data are of high spatial resolution (1m) and different duration; two of them have 20 years and the other two, only five years. The main objective was to identify the depth of the upper layer of the ocean until the end of thermocline (width of the mixed layer plus width of thermocline). For the determination of the thickness of the mixture layer, the method of the temperature change rate with depth was used, and for the thickness of the upper layer, the depth where the temperature was equal to the minimum sea surface temperature of the time series was considered. In general, seasonality was found, both in the mixed layer and upper layer width, but a clear relationship with the ENSO events could not be established. The variation of the thickness of the mixed layer showed a direct relationship with the dry and rainy periods, being higher during the dry season (September-October). The depth of the thermocline showed an annual cycle, but not related to the known seasonality.

IMS Discrimination Between T-Phases Originating from Volcanic Tremors Versus H-Phases Induced by Volcanic Eruptions in the Northwestern Pacific Ocean

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Hydrophone triplet data recorded by the Wake Island IMS hydroacoustic station HA11 was examined with the intent to determine the directivity and number of event arrivals from undersea eruptions originating from the Japanese volcanic island of Ioto (formerly named Iwojima). Ioto is located 2700 km northwest of HA11 and is categorized as an active above-surface volcano. In-situ measurements of volcanic tremors showed that volcanic activity increased during the month of September 2018, when up to 772 detections per day were recorded. Local flyover observations identified that undersea eruptions were occurring in the nearshore shallow-water area during this time. However, there remained the difficulty with regard to discriminating between in-situ seismic
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arrivals corresponding to volcanic tremors, and ones corresponding to undersea eruptions. The analysis of the
data recorded at HA11 made it possible to discriminate between T-phase arrivals from volcanic tremors
originated from Ioto and arrivals from the eruptions, which more closely resemble H-phase arrivals. The arrivals
from Ioto at HA11 and the in-situ observations showed good correlation. Our results suggest that two-thirds of
the arrivals can be associated with volcanic tremors and one-third with the undersea eruptions.

T1.3-P4  Long-Range Ocean Sound Propagation Effects Related to the Search for the
Argentine Submarine ARA San Juan

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The CTBTO IMS hydrophone stations HA10 (Ascension Island in the Atlantic Ocean) and HA04 (Crozet Islands
in the southern Indian Ocean) detected an unusual impulse-like event on 15th November 2017, which originated
from the vicinity of the last known position of the Argentine submarine ARA San Juan. The location accuracy
was confirmed by a depth charge deployed by the Argentine Navy two weeks later, which was detected by the
same two hydrophone stations. Both impulse-like signals propagated out to a distance of approximately 7000
kilometres along different geodesic paths from the event origin through different underwater environments. The
impact of the ocean waveguide propagation on these signals is analysed. Strong low-pass filtering and time
dispersion are observed at the receiving end. Simulations of signal propagation along geodesic paths from the
impulse-like event locations to HA10 and HA04 are performed by two-dimensional parabolic equation
modelling of full time-series, utilizing spatial and temporal oceanographic database information. The modelling
results broadly agree with bandwidth and time-dispersion features observed at HA10 and HA04 for the 15th
November 2017 signal. These results suggest that inclusion of long-range propagation effects is beneficial for
the detection and classification of distant signals from underwater impulsive events.

T1.3-P5  Scenario-Based Tsunami Hazard Assessment for Karpathos Island,
Southeastern Aegean Sea

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Karpathos is the second largest of the Greek Dodecanese islands. Historical data indicate that this area is prone
to earthquakes and tsunamis. In this study we evaluate the tsunami hazard for the Karpathos Island (Karpathos,
Arkasa and the Airport) by means of a scenario-based technique. We take into account tsunamis generated by
three seismic sources in agreement with local tectonics and historical records: one placed near Crete in the
Eastern Hellenic Arc (EHA), with reference to the 1303 A.D., Mw=8.0 event), another near Rhodes
(hypothetical scenario earthquake, Mw=7.3), and one near the coast of Karpathos, based on the 1948, Mw=7.3
earthquake. The code UBO-TSUFD, developed by the Tsunami Research Team from University of Bologna, is
used for all numerical simulations. Tsunamis are computed in several domains with different resolution for a
better calculation of the maximum coastal wave height and tsunami inundation. Tsunami parameters for each
individual scenario are used to construct aggregated scenario, which help us to evaluate the buildings in the
inundation zone. The contribution of all scenarios along the coast of Karpathos is studied via synthetic
mareograms. It is found that seismic source EHA dominates and that the southern part of Karpathos is more
exposed to tsunami.
T1.1-O3 Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound

The Dahlia Tropical Cyclone occurred during the period November 27th until December 2nd, 2017, with increasing strength in the West Indian Ocean near the Bengkulu Sea. Altimetry satellite data was used to determine the condition of sea level anomaly and showed an increased sea level anomaly of about 0.3-0.4 meters, but experienced a less significant change from the previous conditions caused by the distance of cyclone trajectories which are quite far from the verification station area. Delft-3D simulation modeling was conducted to determine the condition of the ocean and atmospheric dynamics during the Dahlia Tropical Cyclone phase. The peak of the significant wave height reached a value of 3.24 meters at the Ciwandan Station which was caused by wind induction from the Dahlia tropical cyclone. The peak of swell height reached a value of 3.0 meters with the direction of propagation towards the Sunda Strait. Automatic weather system data shows that wind direction is mostly from the Southwest with speeds reaching 11-17 knots during Dahlia Tropical Cyclone. The study presented here proves the important role of wind induction on swell propagation from tropical cyclones which causes maximum significant wave heights and sea level anomalies. The Delft-3D model results compare favorable with observations from the Geospatial Information Agency revealing a strong correlation of 0.86 indicating that the Delft-3D model in this case provides trustworthy predictions.

T1.3-P7 Subspace Detection of Seismic Survey Signals Observed on the IMS Hydroacoustic Network

Background hydroacoustic signals resulting from marine air-gun surveys impact the detection capability of the CTBTO hydroacoustic stations and their automated processing (Brouwer et al., 2018). For surveys close to hydroacoustic stations or with favourable coupling into the SOFAR channel, the periodic air-gun shots stand out clearly as a fishbone pattern in the time trace. It is desirable to automatically detect and characterize these survey signals, even when they have a low SNR. The purpose of the automatic detection is to mitigate their impact, to complete the characterization of all hydroacoustic signals, and for those surveys where the location and timing of the sources are available to verify and improve the environmental and propagation models available to the CTBTO. To this end, we developed a subspace detector (Harris, 2006) that can bootstrap from temporally co-located signals. We discuss the means of bootstrapping, the azimuth selectivity, and assess performance relative to ground-truth data. Brouwer, A., Le Bras R., Nielsen P. L., Bittner P., Wang H. Assessing and Mitigating the Impact of Seismic Surveys on CTBTO Hydroacoustic Detections, EGU General Assembly PICO presentation EGU2018-8367. Harris, D. B. (2006). Subspace detectors: Theory. Lawrence Livermore National Laboratory Internal Report UCRL-TR-222758.

T1.3-P8 Suprapodal Hydroacoustic Observations of Earthquakes Along the Middle America Trench

Large-magnitude (>5 mb) earthquakes occur regularly along the northern Middle America Trench, a major subduction zone located offshore the Pacific coast of Mexico. Time-difference-of-arrival calculations suggest that low-frequency acoustic phases generated by these events couple into the Sound Fixing and Ranging (SOFAR) channel and can be recorded as far as Diego Garcia, Indian Ocean, where a hydrophone station (H08)
is operated as part of the International Monitoring System (IMS). Transmission loss modeling indicates that hydroacoustic propagation between the epicenter region and the IMS station is feasible and matches observed travel times. At more than ~21,300 km, arrival ranges exceed the source-receiver distance of any previously documented, artificial or naturally occurring underwater signal, making them the furthest hydroacoustic transmissions to have ever been observed on Earth. Implications for test-ban monitoring and the potential of the H08S hydrophone array for further studying seismic activity along the Middle America subduction system will be discussed. These preliminary findings show that the detection of oceanic events relevant to the CTBT verification regime is possible even beyond the antipodal range, thus highlighting the exceptional capabilities of the IMS hydroacoustic network.

Tectonic Structure Identification at Pidie Aceh Sea with Geo-Marine Survey

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As part of the Indonesian PRIMA 2017 sea trial, a geophysical survey was conducted from the research vessel Baruna Jaya VIII along a track named leg #1 from Jakarta to Sabang via Indian Ocean, and along a track named leg #2 from Sabang to Jakarta via Malacca Strait. The objective of this research is to observe the tectonic structure of Malacca Strait in the North of Pidie. The methods used in this research include observations of the seabed topographic with single-beam echo sounder, the seabed geological condition with a sub-bottom profiling (SBP) tool, and modelling of gravity anomalies from topex satellite data. In the gravity modelling, the second vertical derivative (SVD) analysis was used to determine the type of fault, and the grav3D inversion modelling was implemented to estimate the density distribution. From this research, the survey area has at least four different slopes, i.e., a relatively flat region with almost no slope, somewhat steep, sloping, and slightly sloping. For the geological condition, the seabed is composed of hard rock and sediments that reach 30 meters in thickness, typically for the normal fault. The SVD modelling confirms the existence of this normal fault. The grav3D inversion modelling shows a basin structure with soft rock on the top layer and hard rock in the lower layers with an oblique structure.
T1.4 Interaction Among the Earth’s Subsystems

Oral Presentations

**T1.4-O1 Atmospheric Events Energy Estimation Based on Seismic Data**

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The estimation of the released event energy is part of the CTBTO Preparatory Commission, Vienna, Austria analysis. For events occurring underwater and underground the methods for energy estimation are well developed. However, for atmospheric events the accuracy of the methods which rely on data recorded by infrasound stations is not good enough. In the past few years the passage of energy between earth, ocean an the atmosphere is investigated. It is shown that underground events are recorded by infrasound stations and atmospheric events by seismic stations. The use of the seismic records for estimating the atmospheric event energy release seems promising as it reduce the dependency on the varying atmosphere. In the fifties of the twentieth century, there were theoretical works on the energy transfer between the atmosphere and the earth. But, as the monitoring networks were undeveloped, the number of observations to support the calculation was limited. In this work, we investigate, using the data recorded by the International Monitoring System, if more reliable energy estimation of an atmospheric event, can be achieved based on seismic data.

**T1.4-O2 Complex Propagation of Explosion-Generated Infrasound Revealed by the Large-Scale AlpArray Seismic Network**

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On September 1st, 2018 a devastating explosion occurred on the facility of an oil refinery near Ingolstadt, Germany. We analyzed data of 400 permanent and temporary seismic stations and find strong seismo-acoustic signals on more than 80 seismic stations. The infrasound signal is detectable on seismic stations within 10 - 400 km from the source, with 40 km spatial resolution. We confirm the explosion site both by the seismic and seismo-acoustic arrivals. A part from seismic P- and S-waves, we identified three separate acoustic phases with celerities of 332, 292, and 250 m/s, respectively, each of which has a particular spatial pattern of positive detections at the ground. Seismo-acoustic amplitudes are strongly affected by the type of seismic installation but still allow insight into regional infrasound attenuation. Our observations likely represent tropospheric, stratospheric, and thermospheric phases. We performed 3D acoustic raytracing to validate our findings. Tropospheric and thermospheric arrivals are to some extent reproduced by the atmospheric model. However, raytracing does not predict the observed acoustic stratospheric ducts. Our findings suggest that small-scale variations had considerable impact on the propagation of infrasound generated by the explosion.

**T1.4-O3 Modulation of Gas Fluxes at the Soil-Atmosphere Interface Due to Coupled Physical, Chemical and Biological Effects**

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Following an underground nuclear explosion, emission of radioactive gases to the atmosphere is controlled by properties of the geological media and the applied pressures and temperatures. These conditions are highly
variable in space and time, leading to modulations of gas fluxes at the soil-atmosphere interface that must be understood for proper detection of nuclear events both through the IMS and during OSI. We focused on the soil system, characterized by variable water content and plant growth. We developed an improved set-up to conduct gaseous tracer experiments under controlled conditions mimicking natural ones. Although a constant tracer gas flux was applied at the base of a soil column, the measured gas fluxes at the surface varied by ca. +300% to -100% within hours to days compared to the injected one. This is due to changes in the water distribution in the soil, controlled by multiple effects of physical, chemical and biological origins. Modulations of the radioxenon or argon-37 fluxes to the atmosphere must then be taken into account for better determinations, especially when these fluxes are integrated in space and time. This can be predicted by numerical modeling knowing the environmental conditions.

Poster Presentations

T1.4-P1 7Be in South America: Detection by IMS Radionuclide Stations and Possible Applications for Climate and Environmental Studies

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7Be is one of the cosmogenic isotopes most efficiently produced in nuclear spallation reactions induced by the interaction of cosmic rays and atmosphere constituents, then it rapidly attaches to suspended aerosols and its fate is governed entirely by atmospheric dynamics. With a relative short half-life of 53.22(6) days, it decays via electron capture and one of the byproducts of this transition is a gamma ray of 477.6 keV. Due to its abundance, 7Be concentration is quantified with a high degree of precision by the IMS radionuclide network. The focus of this work is to characterize the spatial and temporal variability of 7Be concentration in South America analyzing the data collected by several IMS stations provided under a vDEC collaboration over the 2005-2016 time period. 7Be concentration in air is dominated by a seasonal cycle for which the stronger effects are more evident around mid-latitudes, with periodicities closely related to the ones found in climate. Anomaly time-series were compared with climate parameters of interest and a conceptual model was developed to explain 7Be interannual variability. Anomalous 7Be high concentration events were identified and using retro-trajectory analysis the enriched 7Be air masses were traced back to their source.

T1.4-P2 An Earthquake Precursor Using the Anomalous Radon Concentration: Study Case Palu Earthquake, Indonesia, Magnitude 7.2, September 28, 2019

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An earthquake precursor is a phenomenon which takes place sufficiently prior to the occurrence of an earthquake. Agency for meteorology, climatology and geophysics (BMKG) have earthquake precursor monitoring system in Palu, Indonesia. This system monitor and record some physical parameter such as: radon content, groundwater level, humidity and temperature. Its monitoring has been used as a possible tool for earthquake precursor, because the distribution of radon concentration is closely related to the geological structure, fracture, nature of rocks and distribution of sources. We clearly observed of increasing trend of radon concentration, since August 2018 before Palu earthquake, magnitude 7.2, September 28, 2018. High radon concentration because of opening of cracks, increases the diffusion of pore fluid and change of strength and pore pressure, causes variations in the chemical and physical characteristics of the rocks. The increase of the radon concentration happens when the cracks start to form in the rocks of the involved area in the possible earthquake. The problems related to the identification of anomalies are: the characteristic of the anomaly; the distance between the epicentre and radon site; and the estimation of the time between the radon anomaly and the earthquake occurrence.
**T1.4-P3**  
**Anomaly of Total Electron Content Associated with Earthquakes and Tsunamis Observed from GPS Data in Indonesia**  

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We conducted research to study the main characteristic features of the seismo-ionospheric variations derived from GPS data called Total Electron Content (TEC). TEC is a quantity for the ionosphere of the earth. It is the total number of electrons integrated between two points, along a tube of one meter squared cross section. We have analyzed some earthquakes (M $>$5) that occurred within 2018 to study the changes in TEC associated with these earthquakes. A monthly standard deviation of the TEC and spatial variation are utilized to identify anomalous signals before an earthquake. The results show anomalous in the TEC before some big earthquakes (Lombok, Palu, and Krakatau eruption). The TEC derived from the global positioning system (GPS) at Balikapapan (latitude 25.38 N, longitude 82.998 E), Indonesia has been observed during Palu’s earthquake 2018. These pre-earthquake ionospheric anomalies appear within about 2-5 weeks prior to earthquakes. A possible mechanism responsible for ionospheric anomalies before big earthquakes is proposed.

**T1.4-P4**  
**Combined Electromagnetic (EM) and Electrical Resistivity Tomography (ERT) Geophysical Studies of Environmental Impact of Awotan Dumpsite in Ibadan, Southwestern Nigeria**  

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This study established the level of contamination caused by the decomposition of wastes by defining the lateral distribution and the vertical limit of leachate induced zone of anomalous conductivity distribution within the subsurface through the analyses of Electromagnetic (EM) and Electrical Resistivity Tomography (ERT) data, generated from the integrated geophysical survey over Awotan landfill dumpsite, in Ibadan, southwest Nigeria. Nine (9) EM and ERT profiles each were established within and around the Awotan landfill site. EM data were acquire at 5 m station interval using 10 m, 20 m and 40 m inter-coil spacings, while ERT stations were occupied at 2 m electrode spacing using dipole-dipole electrode configuration. The near perfect agreement between the two sets of data generated from the EM and ERT surveys over the Awotan landfill site as well as the subsurface imaging ability of these geophysical methods to delineate the region of elevated contamination presented in the form of anomalously high apparent ground conductivity and low subsurface resistivity distribution, suggest the importance of integrating electromagnetic and electrical resistivity investigation techniques for environmental studies and more importantly for selecting appropriate landfill dump site location such with ability to retain the generated contaminants and thus prevent environmental pollution.

**T1.4-P5**  
**Detection of Traveling Ionospheric Disturbances from an Earthquake and a Volcano Eruption: Case Study**  

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Literatures introduced ionospheric responses to earthquakes and volcanic eruptions in several decades. These events induce the Traveling Ionospheric Disturbances (TIDs) which can be detected by monitoring the temporal and spatial variation of electron content in the ionosphere. On 23 January 2018, multiple geophysical events along the ring of fire were reported. Although a few studies revealed there was no strong correlation between the events, it is still worth to observe the ionospheric reaction from those events for comparison. In this study, we selected the 7.9 Mw earthquake in the Gulf of Alaska and the Kusatsu-Shiranesan volcanic eruption in Japan as a case study. Analyzing the waveforms of TIDs generated from two types of events with the same space weather condition (as they happened on the same day) provides results of less uncertainty due to external conditions. The
**Theme 1: The Earth as a Complex System**

TIDs were extracted and detected from GNSS carrier phase observations recorded at nearby GNSS stations of each event. By a coherent analysis, a notable similarity and dissimilarity among the TIDs from the two events were revealed. This study suggests the effective approach to discriminate the signatures of ionosphere from a specific type of the Earth geophysical event.

**T1.4-P6 Can Climate Change Predict and Trigger the Earthquake Activity?**

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It is very correct that earthquakes are associated with different tectonic, physical, astronomical, climatic and other events. Earthquakes result from geodynamics produced by Earth's stress fields which is a process of Earth's interaction with the Sun and other celestial bodies as well as the climate results from this. One general connection between climate and the Earth's stress field is that climate change may lead to increased erosion with mass redistribution. Such mass redistribution may increase the probability of stress release in a pre-stressed domain that may happen because the mass or stress unloading due to erosion decreases the overall or principle stress in the system which may have just been high enough to stabilize the system before. Mohr's circle of stress analysis would be the physical context behind this. And, in addition, deglaciation could be a significant factor: it decreases lithostatic loading with less stabilization. And, fluids in a stressed system always play a role, as they influence relative stresses. The lithosphere is very close connected with the atmosphere. There is relationship between precipitation and earthquakes on the short-term scale, and between solar irradiation and stress field in the upper crust.

**T1.4-P7 Monitoring and Verification Systems for Nuclear Tests with Biological Indices**

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Humankind since its inception has tried to reduce the risks of natural or anthropogenic disasters. Remote sensors, mathematical models, numerical simulations, automatic stations are among the mechanisms used to monitor and infer the study parameters. However, anomalous events such as accidents or nuclear tests in a climate change scenario present serious predictive difficulties. As a result, mechanisms for monitoring and controlling the peaceful use of nuclear energy, among other applications, are now being questioned. On the other hand, the scientific community is making great efforts to combine technology with information obtained directly from living creatures or ecological systems. Developing biological indexes to monitor water quality levels, soil or air, as well as, microbial biosensors of various types. Due to their short life cycles, greater sensitivity to radiation, the ease of quantifying the diversity and frequency of macroinvertebrates and microorganisms, it will become an indispensable input in mathematical models. Tools that influence the design of policies to reduce the risk of nuclear disasters.

**T1.4-P8 Monitoring of Naturally Occurring Radionuclides in Santa Cruz - Galapagos Islands, in Relation to Atmospheric and Ocean-Atmosphere Interaction Processes over the Galapagos Islands and the Ecuadorian Coast**

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The IMS radionuclide particulate station at Santa Cruz - Galapagos is located in an area where various oceanographic and atmospheric processes converge. An assessment of the radionuclide activity concentrations in relation to atmospheric and ocean-atmosphere interaction processes serves as reference for temporal analysis of atmospheric processes in the Equatorial East Pacific. With this regard, activity concentrations of 7Be and 212Pb were continuously measured using HPGe high resolution gamma spectrometry. Daily and monthly data collected
from June 2017 to December 2018 are presented and discussed in this study by means of statistical analysis of radionuclide activity concentration, atmospheric parameters and ocean-atmosphere interaction indices. The results showed less variable values of 7Be concentration over wet season, as well as, higher concentrations during the season transition month and lower values at the end of the wet season. The analysis of 212Pb distribution revealed clear seasonal behavior, with minimum activity concentrations during dry season and maximum values during wet season. Moreover, each radionuclide showed significant correlation with atmospheric parameters and climate indices. This poster summarizes the baseline of activity concentration of 7Be and 212Pb and its response and interaction with atmospheric and ocean-atmosphere interaction processes over the Galapagos Islands and the Ecuadorian coast.

**T1.1-O3**  
Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound

The Geophysical Survey of the Academy of Sciences of the Republic of Tajikistan has modern seismic stations for seismic monitoring and also for monitoring of nuclear explosions. The seismic stations of Tajikistan registered the sixth nuclear test of North Korea on September 3, 2007 at 03:38:09 (S. H. Negmatullaev, F. Yu. Devonashoev, T. P. Ulubaeva). Modern system of seismic monitoring // Dushanbe, 2018, 21p). In recent years phenomena occurring in the atmosphere in advance of the upcoming earthquakes have been actively studied: changes in air temperature and atmospheric pressure, anomalous change of atmospheric transparency (optical thickness), water vapor content, Ångstrom parameter, aerosol optical thickness of the fine and coarse fraction, ozone and nitrogen dioxide content in the vertical column of the atmosphere. The results of the investigation of the isotope distributions of TI-208, Pb-212, Ac-228, Pb-214, Bi-214, Th-234, Ra-226, Pb-210, Cs-137, Be-7 and K-40 in the atmospheric aerosol samples of the southern, central and northern parts of Tajikistan are also presented.

**T1.1-O4**  
Climate Change Through the Eyes of Radioisotopes

**T1.1-O5**  
Detection Efficiency of the IMS for Bolides

**T1.4-P9**  
Monitoring Seismic Events and Content of Isotopes on Atmospheric Aerosol of Tajikistan

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The Geophysical Survey of the Academy of Sciences of the Republic of Tajikistan has modern seismic stations for seismic monitoring and also for monitoring of nuclear explosions. The seismic stations of Tajikistan registered the sixth nuclear test of North Korea on September 3, 2007 at 03:38:09 (S. H. Negmatullaev, F. Yu. Devonashoev, T. P. Ulubaeva). Modern system of seismic monitoring // Dushanbe, 2018, 21p). In recent years phenomena occurring in the atmosphere in advance of the upcoming earthquakes have been actively studied: changes in air temperature and atmospheric pressure, anomalous change of atmospheric transparency (optical thickness), water vapor content, Ångstrom parameter, aerosol optical thickness of the fine and coarse fraction, ozone and nitrogen dioxide content in the vertical column of the atmosphere. The results of the investigation of the isotope distributions of TI-208, Pb-212, Ac-228, Pb-214, Bi-214, Th-234, Ra-226, Pb-210, Cs-137, Be-7 and K-40 in the atmospheric aerosol samples of the southern, central and northern parts of Tajikistan are also presented.

**T1.4-P10**  
Observations of Interactions Among Earth’s Subsystems from the EarthScope Transportable Array

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Large-scale seismological networks record diverse and complex signals resulting from interactions among Earth’s subsystems. The signals vary in strength and may be unintentionally observed. For example, acoustic energy from sources such as bolides or volcanoes can propagate in the atmosphere then couple into seismic energy that is recorded by seismometers. Processes in the hydrosphere (seasonal storm activity) and cryosphere (presence of sea ice) modulate the ambient microseismic background noise. Long-period tilt signals on horizontal seismic components are driven by variations in atmospheric pressure. Finally, the weak magnetic susceptibility of broadband seismometers yields long-period signals during geomagnetic storms. These various signals provide valuable insight into interactions between the solid Earth, oceans, atmosphere, and magnetosphere. The scientific value of these observations is enhanced through the use of dense networks with standard station design, substantial geographic extent, and long duration deployments. Augmenting existing seismic networks with weather sensors, microbarometers, infrasound microphones, etc. produces complementary data that can be leveraged to best characterize the observations. We present examples from the EarthScope Transportable Array deployments in the conterminous United States and Alaska. Global geophysical networks such as the International Monitoring System and Global Seismographic Network present similar opportunities for unique observations.
Theme 1: The Earth as a Complex System

T1.1-P11 Optimistic Monitoring Earthquake Precursor in Sumatra
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Since 2016 BMKG has been monitoring earthquake precursors in Sumatra. Observation of these precursors used geomagnetic data that we installed along the Sumatra fault and Megathrust Sumatra in stages, in 2012 install 3 stations namely Gunung Sitoli (GSI), Nias; Siccincin (SCN), Padang; and Liwa (LWA), Lampung. Then in 2017 and 2018 the BMKG installs in Mueloboh (MLB), Ache; Sabang (SBG), Ache; Simalungun (SML), Lake Toba; Kepahiyang (KPY), Bengkulu and Muara Jambi (MRJ), Jambi. Currently in Sumatra we have 8 earthquake precursor stations. The method we developed is processing Geomagnetic data using ULF emission to obtain earthquake precursor anomalies. The result is an earthquake precursor parameter consisting of when? That is obtained from an onset time anomaly that has a range of 30 days after onset time, then Where? That is obtained from the direction of azimuth source conductivity in the earthquake preparation zone with a susceptibility of ± 22.50 from the azimuth and the last one is How Big is the Impact? That is by statistical calculation of the predicted magnitude to be produced. During the period of 2016-2018 the results of the validation of the earthquake precursors that we made produced a very optimistic value of 63%.

T1.4-P12 Seasonal Variations of Microseisms in the Baikal Rift
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The report presents the results of a study of seasonal variations in the spectral characteristics of seismic waves in the Baikal rift from earthquake and microseism records based on the H/V-ratios. We used records of seismic waves from regional earthquakes (P and S-waves), as well as records of microseismic vibrations. To account for seasonal variations, data were considered in different seasons (warm season: July, August, September and cold season: December, January, February, March). By the type of H/V-curves, seismic stations in a region can be divided into three groups: (1) with a stable characteristic, regardless of the season; (2) with seasonal variations of H/V; (3) with an unstable H/V curve. For most stations of group 2, seasonal variations in the frequency response may be due to tidal effects on the lake Baikal – stations are located on the coastline. A comparison of the obtained H/V-curves for earthquakes and microseisms shows their good agreement in the low-frequency region (up to 3.5 Hz) for all stations. For some stations, an increase in the level of the H/V-curve is observed in the region of medium and high frequencies, which may be due to the influence of the earthquake source.

T1.4-P13 Seismo-Acoustic Observation of the Ocean Swell Sources at BURAR Site
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A four-element seismo-acoustic array of 1.2 km aperture is deployed in northern Romania, at BURAR site, under a joint effort of AFTAC (USA) and NIEP (Romania). To characterize the site detection background, typical sources observed by both types of sensors are investigated. Generated from non-linear interactions between ocean waves, the ambient noise – atmospheric (microbaroms) and crustal (microseisms) – could be recurrently detected, indicating that ocean swell can be considered as a seismo-acoustic source leaving imprint on both seismic and infrasonic recordings. Seismo-acoustic data have been processed and analyzed in the 0.1Hz to 0.8Hz frequency band using DTK-GPMCC and DTK-DIVA software (CTBTO NDC-in-a-Box). F-k analysis has been applied for signal interactive analysis. Two main ocean swell sources have been identified: North Atlantic Ocean and Mediterranean Sea. Microbaroms detections are strongly influenced both by seasonally dependent stratospheric winds and local turbulence-induced pressure fluctuations. Microseisms power spectral noise amplitudes correlate well at the microbarom peak (around 0.2 Hz), seismo-acoustic detections showing similar frequencies and backazimuths for the same source. Microseismic noise level varies from low during summer to high during winter, whilst a shift of the Double Frequency Peak from lower to longer periods could be correlated to seasonal atmospheric conditions.
T1.4-P15  ThunderSeis: Seismic Analysis of Thunder Infrasound

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Thunder represents an important source of seismic and infrasound recordings. Yet they also serve as signal to better understand infrasound propagation and seismoacoustic ground coupling. Infrasound stations have been sparse so far, but the spatial coverage has recently improved dramatically, and we have made striking observations of infrasound propagating across Eastern Austria in 2018, using the seismological AlpArray network. We have observed strong signals of thunder, e.g. during the severe convective weather event on May 2, 2018 in the Viennese region. In combination with the comprehensive Austrian lightning database ALDIS a multiyear time span is available which allows a systematic investigation of lightning detections with thunder recorded on the seismic stations of the AlpArray network. The seismoacoustic observations also illuminate meteorological processes in the troposphere during a thunderstorm event - including the lowest layers of the atmosphere where large parts of human, animal and plant lives take place. This may perhaps also allow to better constrain the mechanisms behind thunder generation and propagation. Indeed, studies suggest that infrasound observations can provide detailed insight into the mechanisms of thunder generation.

T1.4-P16  Use of IMS Facilities for Monitoring Hazardous Geophysical Phenomena and Climate Change in the Antarctic Peninsula Region

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In the Antarctic Peninsula region a number of research stations are measuring seismic and infrasound signals and some are also part of the CTBTO IMS. The region is exposed to earthquakes, tsunamis and cyclonic activity. The measurements are ongoing for a long time allowing an assessment of climate change. Satellite observations have made a tremendous breakthrough in the study of the continent but ground-based measurements are still lagging behind. There are perennial datasets of microseismic and acoustic noise, which are associated, for example, with cyclonic activity in the region and the presence of ice cover in the water area. Additional local monitoring of cryoseismic over the years can also contribute to climate research.
T1.1-O3 Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound Propagation and Scattering in the Atmosphere

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The experimental results of studying the effect of a fine-scale layered structure of a stably stratified atmospheric boundary layer (ABL) on fluctuations of the parameters of acoustic pulses generated with a certain period (1 min) by an artificial detonation source are presented. The vertical profiles of wind velocity fluctuations in the thin layers of the ABL have been retrieved using the wave forms and travel times of the recorded arrivals of pulses from the source. It is shown that the mechanism of scattering of pulse signals in a stably stratified ABL is similar to the mechanism of scattering of signals from ground surface explosions by layered nonhomogeneities of wind velocity and temperature in the stratosphere and lower thermosphere. The role of similarity parameter here place the dimensionless thickness of the reflecting nonhomogeneous layers, which is the vertical scale of the layer multiplied by the relative difference in effective sound velocity and normalized by the vertical wavelength. The effect of such inhomogeneities on the temporal fluctuations of the azimuth and arrival times of the signals is studied. The estimation of the error in localization of pulsed sources is given.

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T1.1-O4 Climate Change Through the Eyes of Radioisotopes

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Cosmogenic radionuclides beryllium-7 and sodium-22 are known atmospheric tracers and can be used together in a lock-in technique to effectively trace vertical air masses based on surface measurements. This technique allows to study progression and speed of atmospheric cells. Data show that the cells are decelerating during the summer period which is extending in time. This is caused by warming of the whole troposphere and increased tropopause height due to rising CO2 concentrations. Aestival episodes of persistent high-pressure systems over Europe with low pressure gradients that led to almost stationary thunderstorms are correlated with the observed deceleration of atmospheric cell movement. This demonstrates that 7Be and 22Na can be used as indicators for confirming several side effects of climate change while providing a new modelling tool in seasonal weather forecast.

T1.1-O5 Detection Efficiency of the IMS for Bolides

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In this study we examined 344 bolides (airbursts) reported on the JPL CNEOS website (https://cneos.jpl.nasa.gov/fireballs/) between 2007-2018 and attempt to correlate these with infrasound detections. We found 206 of these bolides were detectable by at least one infrasound station while only 42 were automatically registered as part of the Reviewed Event Bulletin (REB) issued daily by CTBTO. However, this global REB detection rate of ~10% averaged from 2007-2018 is less than the "modern" rate (from 2014-2018) which approaches 20%. Above the 1 kT CTBTO design threshold, we find that 40% of airbursts are reported in the REB, while more than 90% are detectable at one or more infrasound stations. All airbursts with energy > 2 kT reported on the JPL fireball site since 2007 have been detected infrasonically. However, the REB is only complete above 15 kT with the automated detection system not having reported at least four airbursts with...
**T2.1 Characterization of Treaty-Relevant Events**

**Oral Presentations**

**T2.1-O1**  **Infrasound Records Associated with the Western of Yunnan Fireball on October 4, 2017**

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A bright fireball was reported at 12:07:05 UTC on October 4, 2017 at a height of ~37 km above 28.1N, 99.4E near Shangri-La, the western of Yunnan of China. It had a TNT yield equivalent of 0.54 kilotons (kt). Infrasonic signals were observed by the 116 infrasound array that is part of the International Monitoring System (IMS) and Tengchong infrasound array located in the western province of Yunnan, China. The PMCC method was used to estimate the wave parameters at the two infrasound arrays, and the source location (99.28E, 27.99N) was determined by the back azimuth intersection, which is only 17 kilometers away from NASA’s location. According to the empirical formula of equivalence between yield and period, the explosion equivalent is estimated to be about 0.2 kilotons.

**T2.1-O2**  **Physical Characterization of Filters from German and Sweden Radiological Monitoring Networks with Ru-106 from 2017**

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In late September and early October 2017, the International Monitoring System and several national radiation surveillance networks in Eastern and Western Europe reported low levels of the airborne radionuclide contaminants ruthenium-106 and ruthenium-103, with both species being CTBT relevant. Filters from the national networks of Sweden operated by the Swedish Defence Research Agency, Totalförsvarets forskningsinstitut (FOI), and of Germany operated by the German meteorological services Deutscher Wetterdienst (DWD) containing ruthenium-106 were characterized physically, including coincident gamma high resolution gamma spectrum, electron microscopy, autoradiography, and species solubility. The filters were very radiopure, with no other radioisotope component in excess of 0.002 fraction of the ruthenium activity. Electron microscopy and autoradiography indicate the ruthenium was highly dispersed in domains likely less than a micron in size. Solubilization studies discount the possibility of ruthenium existing as tetroxide (RuO₄) on the filter and demonstrate that 50 to 60% of the species present can be extracted in polar solvents including water. The initial conditions of the aerosolized material prior to dispersal are considered in a discussion of this important CTBT verification scenario, including the analytical techniques available for event characterization.

**T2.1-O3**  **Possibilities to Identify Cavity Due to UNE Using Seismic Wave Fields**

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The resonance seismometry is one of the CTBT’s permitted techniques during OSI. Numerical modeling of seismic wave fields makes it possible to investigate resonance phenomena and their signatures in free-surface records. The necessary condition for reasonable results is an optionally accurate and computationally efficient numerical-modeling tool together with a sufficient set of realistic structural models. Based on extensive review
of the available literature we have developed 3D realistic models of the underground structure after an UNE. The most general model consists of cavity, chimney with apical void, crushed zone, fractured zone, environment and free surface. We performed extensive numerical modeling of seismic wave fields due to plane-wave excitation (representing regional and distant events), near point double-couple sources (representing aftershocks) and seismic ambient noise. We then comprehensively analyzed the simulated wave fields in the time, frequency and time-frequency domains. In a seismic wave field due to a distant source it was possible to identify and locate cavity. A seismic wave field generated by an aftershock was much more difficult to interpret in terms of the cavity presence due to strong effects of a radiation pattern. Analysis of seismic noise makes it possible to identify cavity at least for relatively shallow cavities.

**T2.1-04 Seismic Full Moment Tensor Analysis of Nuclear Explosions in North Korea**

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We estimate seismic full moment tensors and their uncertainties for seven events at the North Korea nuclear test site, consisting of six declared nuclear tests and one event, interpreted as a cavity collapse, that occurred 8 minutes after the declared test. We also analyze two earthquake events that occurred to the south and were recorded by the same set of stations. We perform a grid search over the six-dimensional space of moment tensors, generating synthetic waveforms at each moment tensor grid point and then evaluating a misfit function between the observed and synthetic waveforms. For each moment tensor we characterize its uncertainty in terms of the variation in waveform misfit on the eigenvalue lune, a probability density function for moment tensor source type, and a confidence curve for the probability that the true moment tensor lies within the neighborhood of the best-fitting moment tensor. We find that the moment tensor source types are clearly separated for the six declared nuclear test events, the collapse event, and the two earthquakes. Moment tensors for the six explosion events can be represented as a sum of a double couple and a crack tensor whose plane is near horizontal.

**T2.1-05 Seismic Spectral Ratios Between North Korean Nuclear Tests: Implications for Their Seismic Sources**

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Seismic spectral ratios between the 2017 North Korean nuclear test (NKT2017) and four other Korean tests conducted in 2009 (NKT2009), 2013 (NKT2013), January, 2016 (NKT2016) and September, 2016 (NKT2016S) are investigated. All the observed teleseismic P-wave spectral ratios exhibit a unique notch at approximately 2.5Hz that is not observed for regional P- and Lg-wave spectral ratios. Meanwhile, the network-averaged Lg-wave spectral ratio is similar to that of regional P-wave, but with the source corner frequencies significantly reduced. We demonstrated that the observed notch of teleseismic P-wave spectral ratios may be well modeled by interference between pP- and P-wave, while regional P-wave spectral ratios may be well fitted with source spectral ratios predicated by classical explosion source models including MM71, DJ91 and their two hybrids. Results obtained indicate that for NKT2017’s buried depth in the range of 600-1100m, the MM71-related models give a yield estimation about 100-300kt for NKT2017, 3-7kt for NKT2019, 6-15kt for NKT2013 and NKT2016J and 10-25kt for NKT2016S, while yield sizes obtained by model DJ91 are much smaller.

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Theme 2: Events and Nuclear Test Sites

T2.1-O6  The 2017 North Korean Nuclear Test - A Comprehensive Multi-Technology Analysis

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On September 3rd 2017 official channels of the Democratic People’s Republic of Korea announced the successful test of a fusion bomb. This would be a major step in the nuclear program of North Korea. This study provides a multi-technology analysis of the 2017 North Korean event and its aftermath using a wide array of geophysical methods (seismology, infrasound, remote sensing, radionuclide monitoring, and atmospheric transport modeling). The depth of the event, its strength in terms of radiated high- and low-frequency seismic energy, the contribution of possible faulting or slope instability processes, the near-surface damage in the test area, explosive yield and the proof of whether fission products are detected as atmospheric tracers are key questions to be answered. The multi-technology and multi-methodology analysis presented in this study clearly indicates that the September 2017 North Korean event was in fact a nuclear test and that even in the phase of before its entry into force, the CTBTO verification regime has again demonstrated its readiness with respect to the recent North Korean nuclear test.

T2.1-O7  UK NDC Analysis of IMS Radionuclide Events near to North Korea

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The UK National Data Centre (NDC) has developed a custom radionuclide analysis pipeline that has been integral to the NDC’s capability to utilise data from the IMS. A number of novel software tools have been conceived to aid review of IMS events and these have been put to use in a study of the North Korean Region. By considering known emitters of radionuclides and relating these to detections at JPX38 (Takasaki), it has been possible to demonstrate the sensitivity of JPX38 to North Korean underground nuclear tests (UGT), as well as other sources of radioxenon in the region.

Poster Presentations

T2.1-P1  A Seismo-Acoustic Analysis of the 2017 North Korean Nuclear Test

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Underground nuclear tests give rise to seismic and infrasound signals that can be detected on International Monitoring System (IMS) stations. The infrasonic signals are due to seismo-acoustic coupling. The radiation of infrasound is dependent on source depth. Recent studies have demonstrated the added value of seismo-acoustic analyses, for example, to improve depth-yield estimates of (nuclear) explosions. In this study, we present a seismo-acoustic analysis of the 2017 North Korean Nuclear Test that has been detected on IMS microbarometer array I45RU. We analyze the seismo-acoustic coupling by making use of array processing and back-projection techniques. The back-projections show that infrasound radiation is not confined to the epicentral region. More distant regions are found to be consistent with locations of topography, sedimentary basins, and underwater evanescent sources. The back-projections can be used to estimate the average infrasonic propagation speed through the atmosphere. We discuss these findings in the context of infrasound propagation conditions during the sixth nuclear test. It is suggested that propagation from the test site to I45RU may have occurred along unexpected paths instead of typical stratospheric propagation. We present several scenarios that could be considered in the interpretation of the observations.
T2.1-P3 Analysis of Moment Magnitude (Mw) to Compare the Energy of Six North Korea’s Nuclear Test with Plutonium-240

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From 2006 to 2017 seismic monitoring noted that North Korea conducted nuclear tests six times, namely on October 9, 2006 (M 4.3), May 25, 2009 (M 4.7), February 12, 2013 (M 5.1), January 6, 2016 (M 5.1), September 9, 2016 (M 5.3), and September 3, 2017 (M 6.3). The purpose of this study is to compare the seismic radiation values and Plutonium-240 energy. The waveforms used are from INCN Station, Incheon, South Korea (October 9, 2006, May 25, 2009, September 9, 2016, and September 3, 2017) and MDI Station, Mudanjiang, Heilongjiang Province, China (February 12, 2013 and January 6, 2016). Data were downloaded from IRIS. We use the Seismic Analysis Code to process the waveform data. The result of this processing get the highest of moment magnitude (Mw) is 6.4, seismic moment (Mo) = 6 x 10^18 N.m, seismic radiation energy (Es) = 3 x 10^14 Joule. Energy Q = 4.18 x 10^6 Joule is energy that can be produced by 1 kg of TNT. Then the energy released by 72 kt TNT is equal to 72 times the energy released by a nuclear explosion on spontaneous fission of Plutonium-240.

T2.1-P4 Applying Radioxenon Isotopic Ratios for Nuclear Explosion Monitoring

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For nuclear explosion monitoring, isotopic ratios of xenon are used for characterizing an event. Civilian sources of radioxenon have an isotopic signature that may appear different from the one resulting from a nuclear test. This becomes most evident in the four-isotope plot where the nuclear reactor and nuclear test domains are clearly separated from each other. If only one pair of isotopes is detected it may still be possible to draw conclusions about the relevance of an observation for nuclear explosion monitoring. For certain isotopic ratios, screening flags are defined and applied in the IDC products. A theorem approach is to show the isotopic ratios in scatter plots and look for outliers and clusters. More generally, isotopic ratios can be compared to the history of background observations at a given station, to determine whether it is anomalous or not. It may also be used for event origin time determination, to test the hypothesis that the observation of interest may indicate a prompt or delayed release that is associated with a seismic event at a certain time and location. This presentation will demonstrate selected visualizations and statistical tests that have the potential to be applied for CTBT monitoring purposes.

T2.1-P5 Automatic Computation of MSVMAX Magnitude at the French National Data Center

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One robust and rapid discriminant between tectonic and treaty-relevant events is based on the discrepancy between seismic wave magnitudes: the surface wave magnitude (MS) and the body-wave magnitude (mb). A better alternative is to consider the MSVMAX, a frequency varying MS between 8 and 40 s period. Such approach opens up the limited frequency range and helps improve event detectability and characterization. Studies led the French National Data Center to develop and implement an operational tool to calculate the MSVMAX on Rayleigh and Love waves. Such tool is now running in an automatic mode and quickly returns magnitude information for events within a region of interest. This operational software is being used to process seismic data from different networks and sensor types, select time windows of interest based on the wave propagation according to an Earth velocity model, and apply several tests (azimuth and wave polarization) before providing a weighted MSVMAX value. It can also access a seismic database, which makes it a very...
Theme 2: Events and Nuclear Test Sites

valuable tool. We present this newly designed operational tool with illustrations on selected events of interest. Its high value for event discrimination is shown and the goodness of available discrimination laws is discussed.

T2.1-P6 Candidate Methods for the Implementation of OSI Resonance Seismometry

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The Treaty mentions Resonance Seismometry (RS) as a method for the continuation period of the OSI. RS shall use resonant seismic wavefields generated inside the explosion cavity, the rubble zone, or up to the surface to map the suspected subsurface test site. However, RS is not yet an established method in the scientific community, and a variety of different source signals and interpretation methods may fill its role. We compare the practicability of some different methods for their implementation as part of the OSI. Test case of our analysis is the Kyllylahti mine dataset of 2016 in Finland, where we implemented two candidate methods for RS: (1) The H/V method resolves near-surface changes of soil properties by relating the horizontal and vertical portions of ground motion. (2) The calculation of minor variations in the planar wavefield from larger earthquakes at teleseisms distances, i.e. more than 3,000 km away, visualizes local subsurface anomalies. Results of both methods will be presented and discussed for relevance in RS.

T2.1-P8 Comparative Analysis of the Waveforms of the North Korean Nuclear Tests Obtained by the Seismological Method at the Alibek Station

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The article is devoted to a comparative analysis of the waveform of nuclear tests based on data obtained the Alibek station. The station successfully registered nuclear tests that took place at North Korea and made a significant contribution to the detection and evaluation of explosion parameters at International Data Centers. In the waveform picture of the explosions, both similar and distinctive features are observed, which, among other things, is determined by different power and mechanisms of conducting nuclear explosions. Similar features in all cases are: intense secondary wave Pg; practical absence of pronounced Sn waves; the presence of Lg-wave. Distinctive features are associated with the Rayleigh surface wave - for one event, the wave is almost absent, and for others it has different intensities. The analysis of waveform and assessment of the dynamic characteristics of the waves suggest that the records of the seismic event not only correspond to the known general characteristics of the records of underground nuclear explosions, but also complement the data obtained in other regions of the Earth.

T2.1-P9 Comparison of the DPRK Aftershocks Observed in 2019 with the Aftershocks Between September 2016 and April 2018

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Several seismic stations of the International Monitoring System (IMS), as well as non-IMS stations detected seismic signals from an extensive series of low-magnitude aftershocks which followed the DPRK underground tests. We investigated these events using the waveform cross correlation (WCC) method. One of the principal results is aftershock clustering. Using signals measured by IMS stations KSRS and USRK, one is able to distinguish between aftershocks similar to that observed on September 11, 2016 and those similar to the collapse events following the DPRK6. Since May 2018, there was no significant aftershock measured by IMS stations. On January 1, 2019, the IDC found a relatively large aftershock detected by two array stations KSRS and USRK. Several smaller events were detected using the multi-master WCC method combining waveform information from six practically co-located DPRK explosions and 23 largest aftershocks. The January 1, 2019 event has
higher similarity with the DPRK 6 aftershocks and is characterized by the P/S spectral ratio, which belongs to the population of the DPRK aftershocks.

T2.1-P10 Data History from Nuclear Power

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The history of nuclear testing began early on the morning of 16 July 1945 at a desert test site in Alamogordo, New Mexico when the United States exploded its first atomic bomb. Designated as the Trinity Site, this initial test was the culmination of years of scientific research under the banner of the so-called “Manhattan Project”. North Korea conducted the sixth nuclear test in its history on September 3, 2017, according to officials in South Korea and Japan. The Japanese Foreign Ministry also concluded that North Korea had conducted a nuclear test. The US Geological Survey reported an event measuring 6.3 on the Richter scale, near the Punggye-Ri site where the nuclear test was conducted. The South Korean authorities said the event seemed to be man-made. Both the US Geological Survey and the Chinese Earthquake Administration reported a smaller second earthquake at the same site that followed the initial event several minutes later, which was described as a collapse of a cavity.

T2.1-P11 Detection of Nuclear Explosions by Remote Regional Seismic Network

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Objective of these studies was to test the possibility of identifying nuclear explosions using a remote seismic network and to evaluate effectiveness of some parameters for identification nuclear explosions. Regional seismic network BAVSEN (Baltic Virtual Seismic Network), which unites 10 seismic stations, was used to identify distant nuclear explosions in North Korea. BAVSEN being a part of the GEOFON network (GFZ Potsdam), has been operational since 2008. We registered 5 nuclear explosions. Three nuclear explosions were used for analysis. The following parameters were used to identify nuclear explosions: 1) amplitude spectra of P and S waves group; 2) spectral ratios P/S; 3) Ms/Mb magnitude ratio. The first two parameters are based on well-known property of S-wave amplitude exceeding over P-wave amplitude for earthquakes and inverse amplitude ratio for explosions. Testing has shown that most effective criterion for identification is Ms/Mb magnitudes ratio. Linear approximation gave following results: Ms = 1.329M b - 1.530 (for earthquakes); Ms = 1.447M b - 3.907 (for nuclear explosions). Spectra of P and S waves group, as well as P/S spectral ratios are less effective parameters for identifying nuclear explosions using remote seismic network. Testing has shown the possibility of using remote seismic networks for monitoring nuclear explosions.

T2.1-P12 Determination of Body-Wave Magnitudes of the North Korean Underground Nuclear Tests

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We determined teleseismic short-period body wave magnitude (mb) for the six underground nuclear explosions (UNE) at the North Korean test site by using globally distributed seismographic stations in the epicentral distance range of 30° to 95°. Most of the stations selected for the magnitude determination are located in central Asia, Europe, Australia, and North America, but none from South America and Africa. Data from about 40 common stations that recorded most of the six explosions are used to simulate the analog World-Wide Standardized Seismograph Network (WWSSN) records in an attempt to utilize conventional mb and yield relations developed during WWSSN era — early 1960s through mid-1980s, for the UNEs at similar site conditions. We also determined root mean square (RMS) amplitudes of Lg waves from the six known North Korean UNEs by using waveform data from seismic stations situated on continental crustal paths from the UNEs. Six stations in Asia produced useful data. The RMS Lg amplitude measurements show consistency
The Nevada National Security Site conducts experiments aimed at increasing capabilities in explosion monitoring. The Source Physics Experiment (SPE) objectives are understanding the prompt-signal phenomenology of the explosion source, including shear wave generation, and improving numerical modeling codes. Since 2010, the SPE project has conducted eight (8) chemical explosions in both well-characterized granite and alluvium emplacement media. The SPE experiments have been recorded on a wide range of diagnostics, including borehole accelerometers, seismic, infrasound, magnetic, video, and photogrammetry. SPE is incorporating state-of-the-art diagnostics systems, including Large-N and distributed fiber optics, to provide unprecedented resolution of the seismic phenomena. The Underground Nuclear Explosion Signatures Experiment (UNESE) is an NNSS project that has focused on improving models for late-time signals produced by underground explosions. The UNESE research included studying remote sensing and geophysics methodologies to detect change in the surface and subsurface after historic explosions. UNESE also conducted experimental studies to measure and model tracer gas migration in different emplacement scenarios of previous nuclear explosions. This work was done by Mission Support and Test Services LLC, under Contract No. DE-NA-0003624 with the U.S. Department of Energy. DOE/NV/03624— 0357.

**T2.1-P14**  
**Focal Mechanism of 2017 DPRK Nuclear Explosion and Its Collapse Event**

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Unlike the previous DPRK nuclear explosions, a rare collapse event followed the 2017 nuclear explosion after about 8 minutes and a half. As two kinds of special shallow depth seismic events with different source properties, the accurate inversion of the focal mechanisms of them is of great significance for the identification of CTBT events. In this study, the inversion of the moment tensor of the nuclear explosion and collapse event is carried out with the waveform data of the dense regional seismic stations. After that, the focal mechanisms of the two events with small waveform residual are compared from the surface wave amplitude ratio. The results show that the surface wave amplitude ratio has a certain screening effect on the waveform inversion. The resolution of the optimal solution of the nuclear explosion is higher, which is close to the crack source. Meanwhile, the solution resolution of the collapse event is lower and the source type cannot be accurately determined. One reason for the lower solution resolution of the collapse event may be the limitation of the observed data and also the complexity of the source process itself.

**T2.1-P15**  
**Identification of Quarry Blasts near BRMAR Seismic Array: An Application of Multichannel Cross-Correlation Detector**

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With the increasing population of many quarries around the BRMAR array, the data quality of the stations is polluted by the blasts. There are more than 10 operational quarries spread across the city and in the vicinity of the array. BRMAR is a circular shaped 7 elements array with a diameter of approximately 40 km located in the city of Ankara. The array consists of borehole type medium period instruments installed at 60 to 40 m depth from the surface. Long period array data is important for nuclear explosion monitoring, especially for measuring the mb/MS discriminant. Therefore, monitoring of the quarry activities has become an important task for the Turkish NDC. Multichannel waveform cross-correlation method accurately and reliably detects and classify the quarry blasts using a repository of template events. Occurrence rate of the mining blasts between the time period
of January 2016 - September 2018 was examined. More than 2 templates for each of the mining quarries were selected to detect the blasts at different sites for MWCC method. The results show that the number of blasts displays an increasing trend over the years, as much as on average at least 2 to 3 mining blasts occurring every weekday.

**T2.1-P16** Infrasound Signals from the 2017 North Korean Underground Nuclear Explosion and the Subsequent Collapse Event

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This study focuses on the assessment of infrasound signals from North Korean underground nuclear explosion at 03:30:01 UTC and the subsequent collapse event at 03:38:31 UTC on September 3, 2017. We use infrasound observations from ten infrasound arrays in and nearby to the Korean peninsula. The explosion generated local, diffracted, and epicentral infrasound, while only epicentral infrasound accompanied the collapse. Infrasound phases were identified and used to constrain the locations of the two events. Detection results for the closest stations to the sources are used to constrain differences in source phenomena between the explosion and collapse. Arrival times for the explosion and collapse are compatible with stratospheric propagation times, while a variety of current atmospheric models do not predict such arrivals during the period leading up to the equinox. In order to reconstruct an atmospheric model that predicts the infrasound observations, we search the best-fit atmospheric profile from historical G2S model using empirical orthogonal function analysis. We also constrain the possible source location from all arrays based on a backward ray tracing technique using an ECMWF model. The data and analysis highlights the need to understand the transitional nature of the atmosphere at the time of the September 2017 explosion.

**T2.1-P17** Overview of North Korean Nuclear Tests Based on Data from Modernized Slovak National Network of Seismic Stations

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The Slovak National Network of Seismic Stations (NNSS) has been considerably modernized and enhanced during the years 2001 - 2004. At the present, the NNSS represents the principal and the most important infrastructure designated for monitoring of seismic activity on our territory. The primary function of the NNSS is to monitor and localize earthquakes with macroseismic effects on the territory of Slovakia. Besides, the seismic stations of NNSS are also capable of recording weaker local and regional earthquakes as well as teleseismic earthquakes and nuclear explosions. The NNSS fulfill its duties also within the framework of the technical cooperation between the Slovak Republic and CTBTO by providing seismological data to the Slovak Academy of Sciences (SAS), which has been designated as the Slovak National Data Centre (NDC) for CTBTO. Until today, the Democratic People’s Republic of Korea (DPRK) has conducted six nuclear tests (in 2006, 2009, 2013, two in 2016, 2017). The ability of the NNSS to detect the seismic signal generated by the DPRK nuclear events and the estimates of locations and magnitudes of the events are presented. The results are compared to the International Data Centre estimations.
**Theme 2: Events and Nuclear Test Sites**

### T2.1-P18 Overview of TIMETool, a Software for Nuclear Event Timing

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TIMETool is a smart application system allowing to evaluate the nuclear event zero time using radioxenon isotopic activity ratios. The nuclear events of interest are nuclear explosions under in-growth condition, releases from nuclear power plants or from medical isotope production facilities. TIMETool allows setting the time of fractionation in the case of a nuclear explosion. The plots generated by this software, including the measurement data, give an estimate of the origin time of the release. TIMETool could be a promising tool in support of the CTBT to help in nuclear event timing.

### T2.1-P19 Radionuclide Signatures of Molten Salt Reactors

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Molten salt reactors (MSRs) utilize a molten salt mixture as the primary coolant, and some systems also have fuel dissolved in the coolant. Whilst the concept is not new, and was established in the 1950s, there has been renewed interest as part of the development of Generation IV reactor designs. In particular they are seen as a promising technology for utilizing thorium or spent light water reactor (LWR) fuel. Their unique molten design has important implications for the radionuclide signatures that could be detectable by the International Monitoring System (IMS). As the fuel is not encapsulated like LWR systems, short-lived gaseous and volatile radionuclides could more readily escape, producing emissions with a different radioxenon isotopic signature, and also potentially a variety of long-lived particulate decay products. This effect could be further enhanced by the online removal of accumulating fission products in MSR designs. This research examines these effects and discusses the potential impacts on the IMS.

### T2.1-P20 Relative Location of DPRK Test Events

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Relative locations of the six declared DPRK nuclear test events are presented. Given a well azimuthally distributed dataset of common stations, each with sufficient time-bandwidth product, precise relative arrival times are produced through manual alignment (e.g., Fisk, 2002). These relative arrivals are subsequently used to calculate a network specific travel-time correction via a master event, which is then applied to all events yielding relative master-event locations. The observable test site infrastructure and the geometry of the relative locations are useful in further constraining the absolute location of the cluster of events.

### T2.1-P21 Relative Location of North Korean Nuclear Tests Using IMS Data: How Do Different Techniques Compare?

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Here we apply three relative location techniques (double-difference, hierarchical clustering, and station corrections), to the six reported North Korean nuclear tests using IMS data. The aim of this study is to better understand how each technique performs with respect to the others, and to compare with independently published results, as well as the official North Korean nuclear test site map. A nuclear test site can be thought of as a single, independent seismic event cluster with strong, highly-correlated P-waves, and relatively weak S-
waves; whereas natural earthquake clusters often vary in mechanism and can be widely spatially distributed. Nuclear tests are often recorded at local, regional, and teleseismic stations, whereas most earthquake relative location studies are limited to local phases. Because of these differences and others, previous studies comparing relative earthquake location methods may not relate to relative nuclear test locations, further motivating this study. While the goal of this project is to understand how different relative location methods perform at North Korea’s Punggye-ri test site, a future goal is to adapt the most suitable methods into a set of tools for the Australian NDC.

T2.1-P22 Relocation of Seismic Events in South Africa for Ground Truth Identification and Classification

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In an effort to improve the velocity models used in the calculation of travel time corrections for regional phases, well-located earthquakes are being relocated and classified as ground truth (GT). The events were prepared by first reassessing their source parameters using available collected phase data. The first step in identifying possible GT events was to preselect events that were going to be further analysed to see if they satisfy the GT595% criteria. A set of eight events recorded by more than five stations located within a distance of 150 km of the event epicentre were relocated using the ISC location algorithm, iLOC, and a 3D global velocity model made compliant with the Regional Seismic Travel Times parameterization. Solutions of two of the eight preselected events were found to satisfy the conditions for GT595% candidacy whilst four events satisfied the criteria for GT2090% candidacy. The P wave path coverage for the two identified GT595% events shows that both events were well recorded by 106 and 542 stations respectively, which were well distributed azimuthally. It is hoped that these GT595% events are going to be useful in the improvement of the RSTT models for our region.

T2.1-P23 Representation of Complex Seismic Sources by Orthogonal Moment Tensor Fields

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Complexity of seismic sources can be represented by space-time variations of stress gluts. We present a new representation theorem of seismic sources that exactly and uniquely decomposes any stress-glut density into a set of up to six orthogonal tensor fields of increasing degree (Juarez & Jordan, GJI-2018). The moment tensor fields are ordered by their first nonzero polynomial moments. The representation theorem generalizes the point-source approximation to a sum of multipoles that features the centroid moment tensor (CMT) as its 0th-degree term. We define the total scalar moment MT to be the integral of the scalar moment density, and we use the representation theorem to estimate moments for each degree. If the source is complex, MT is larger than M0, the Akai moment. We decompose seismic source models of earthquakes and explosions to illustrate how the higher-degree terms characterize the source complexities. We compute synthetic seismograms to illustrate the radiation patterns of the higher-degree fields and their frequency dependence. Our results indicate that the radiation from the higher-degree fields was large enough that it may be possible to estimate low-order multipoles directly from seismic data.
Theme 2: Events and Nuclear Test Sites

**T2.1-P24  Seismological Investigations of the 2017 North Korean Nuclear Test**

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On September 3rd 2017 official channels of the Democratic People’s Republic of Korea announced the successful test of a nuclear device. Only minutes after the alleged nuclear explosion at the Punggye-ri nuclear test site at 03:30:02 (UTC), hundreds of stations distributed all around the globe picked up strong and distinct seismic signals associated with an explosion. Our investigations locate the event within the test site at a depth of 0.6 km. The radiation and generation of P- and S-wave energy in the source region are significantly influenced by the topography of Mt. Mantap. Inversions for the full moment tensor of the main event reveal a dominant isotropic component accompanied by significant amounts of DC and CLVD terms, confirming the explosive character of the event. The analysis of the source mechanism of an aftershock around 8 min after the test in the direct vicinity suggests a cavity collapse. Measurements at seismic stations of the IMS result in a body wave magnitude of 6.2, which translates to a yield estimate of around 400 kT TNT equivalent. The explosive yield is possibly overestimated, since topography and source mechanism both tend to enhance the peak amplitudes of teleseismic P-waves.


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North Korea conducted underground nuclear explosions on October 9, 2006 (mb 4.3), May 25, 2009 (mb 4.7), February 12, 2013 (mb 5.1), January 6, 2016 (mb 5.1), September 9, 2016 (mb 5.3) and September 3, 2017 (mb 6.3). We estimated source depths at 2.12 km, 2.06 km, 2.05 km, 2.06 km, 2.05 km and 1.97 km respectively based on the azimuth averaged spectral minima using pP+P/sP+P and pPn+Pn/sPn+Pn including spectral holes of the fundamental-mode Rayleigh wave amplitude spectra. It is also noticeable that the synthetic spectral nulls of P-wave spectra in the near-field and in the far-field including Rayleigh waves are in good agreement with those of observations. We show particle motions of surface waves which represent the generations of Rayleigh and Love waves depending upon the different raypaths. The raypaths through the subduction zone of the Pacific slab shows poor Love waves indicating that the low Q with high attenuation generates little Love waves in addition to the less trapped SH waves in the explosions. In particular, we should also note that the possibility of the over-burial detonation would affect magnitudes and seismic yields for North Korean underground nuclear tests.

**T2.1-P26  Source Time Functions of North Korean Nuclear Tests**

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I compute the source time functions of North Korean nuclear tests directly from seismograms. Because the events are located close to each other, the spectral ratio of the seismograms of two events measured at the same seismic station is the spectral ratio of the reduced velocity potential (RVP) source time functions: the path effect between the test site and the seismic station cancels. A scaling law relates the RVP of two events via two independent parameters: the yield ratio and the source depth ratio. The tests of 2009 and 2013, the two tests of 2016 and the test of 2017 have source time functions that are scaled versions of each other, suggesting they were
detonated in the same rock formation. The 2006 event does not share the same source characteristics. The form of the RVPs is similar to a damped sine wave, in agreement with theory. The natural frequency and damping factor is proportional to the cube-root of the radial stress at the elastic radius and inversely proportional to the cube-root of the yield; the amplitude is proportional to the square of the cube root of the yield. Calibration for yield is via published data from Nevada Test Site.

**T 2.1-P27 Space Borne Optical and Radar Data to Characterize North Korean Nuclear Test 2017**

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To visualize and characterize the surface imprint of the 2017 test, radar data from the ALOS-2 satellite and multispectral optical data from the Pleiades satellite are investigated. Data from the ALOS-2 satellite in the L band are analyzed by SAR Interferometry to investigate surface deformations correlated with the 2017 test and its aftershocks. The method of change detection analysis based on vegetation changes is applied. Space borne InSAR nowadays allows for the detection of surface displacements with a precision on the order of a few millimeters. Repeat pass interferometry is based on the registered interferometric phase per ground cell (pixel) and is related to the distance differences between the scatterer and the synthetic aperture radar (SAR) sensor between two acquisitions separated in time. For the analysis of the surface displacement due to the 2017 test, data from 29 August and from 12 September 2017 are used. InSAR analysis based on the ALOS-2 satellite data reveal strong surface deformations in the epicenter region, the resulting map of resolvable displacements clearly shows an area of subsidence of up to 10 cm 3 km north of the main support area and clear uplift of up to 10 cm west of the Mt. Mantap.

**T 2.1-P28 Summary of Common Exercise (Waveform Portion) at the 6th East Asia Regional NDC Workshop 2018**

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Ten National Data Centers (NDCs) and CTBTO PrepCom’s International Data Center (IDC) exchanged their waveform analyses on six North Korea-declared nuclear tests at the sixth East Asia Regional NDC workshop (EARNW) held September 17-21, 2018, in Ulaanbaatar, Mongolia. Cross correlation technique is clearly becoming popular among the workshop participants for a variety of purposes including detection, location, and even for size estimation. Some relative location results presented at the workshop exhibit geometric patterns of five epicenters matching - at least qualitatively - fairly well with a cartoon-depicted pattern shown to the invited journalists who were present at North Korea-declared “Punggye dismantlement ceremony”, albeit the accuracy of North Korea LtG. Kang's poster itself is not verified yet. The latest event of September 3, 2017, which was the largest North Korea-declared nuclear test so far, prompted a couple of NDCs to re-investigate the procedure of seismic magnitude scaling relationships between teleseismic and regional phases. Two NDCs provided extensive lists of aftershocks following the 6th test, demonstrating the robustness of cross-correlation technique. As designed, the EARNW’s have facilitated convenient discussions on cooperation, including the sharing of some non-IMS data on specific events discussed during Common Exercises, among the participating NDCs.
Theme 2: Events and Nuclear Test Sites

T2.1-P29  The Detection of Underground Nuclear Explosions by Natural Signatures

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The detection of low-yield underground nuclear explosions (UNEs) is challenging due to containment measures undertaken to prevent escape of radioactive signatures. These signatures include fission and activation products generated from the explosion. Measures may also be undertaken to restrict generation of seismic and infrasound signatures. A new approach is proposed to detect such tests using natural signatures produced from the increased release of radon gas isotopes (222Rn and 220Rn) from the disturbance and pressurization of the sub-surface flow regime caused by a UNE. Whilst physical barriers can be constructed to ensure containment, measures are not typically implemented to restrict radon escaping from beyond the containment cage around the cavity. It is envisaged such soils, rock and pore waters are placed under significant stress and agitation by the explosion, and would be subject to increased radon release. The resulting anomalous radon concentrations (and associated progeny) could be useful for UNE detection.

T2.1-P30  Three-Dimensional Space Analysis of Radioxenon Isotopic Activity Ratios for Characterizing a Nuclear Event

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This study on the nuclear release timing aims at analysing radioxenon isotopic activity ratios in three-dimensional space. When real data from nuclear tests are used, the first results obtained are promising for nuclear event zero time determination and nuclear release discrimination. This presentation focuses on the methodological approach. Obviously three isotopes are less likely to be detected simultaneously than two isotopes are. However, if three isotopes are available, making use of all three together offers a much more powerful analysis mechanism than with only two isotopes. In the three-dimensional space the analysis of timing and event screening can be separated. A time-independent screening can be achieved through the projection along the decay axis and the time of the event origin can be determined for each kind of source scenario by projecting the isotopic ratios on the decay axis and scale it in units of time. The time-independent screening is most useful for CTBT monitoring purposes since the time of origin of a remote detection is in general not known.

T2.1-P31  Towards an Improved Catalogue of Shallow Ground Truth Events in Eastern North America

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Depth estimation is an important part of discriminating anthropogenic from non-anthropogenic events. For small events in sparsely instrumented regions, there are few methods available for depth estimation. Ground-truth (GT) events at shallow depths will be a key part of any scheme to validate new methods. Although the ISC catalog contains more than a thousand GT events with 1 km < depth < 5 km, just four of these are in Canada and just two more are in eastern North America. Rock bursts and other mining-related events in underground mines can be considered shallow ground truth events, inasmuch as the hypocentre can be constrained by direct observation. At CHIS we have good working relationships with many mine operators. In mid-2016, we began requesting depth information when confirming events. Up to now, we have assembled a catalogue of shallow GT blasts and mining-related events consisting of 161 events 2 ≤ MN < 3 and 25 events 3 ≤ MN ≤ 3.9 (MN ≈ MW + 0.5). These events form eight clusters, spanning 1600 km across Ontario and Quebec. We present this catalogue, and a preliminary investigation into methods of depth estimation using it, including regional depth phase and crustal Rayleigh wave modeling.
For practically 30 years of its existence, the KNET seismic network, located in Kyrgyzstan and Kazakhstan, registered on regional and teleseismic distances nuclear tests conducted at test sites: Nevada, Mururoa and Fangataufa, Lop Nor, Pokharan, Chagay and Punggye-ri. Currently, it includes 10 stations that transmit data in real time to the Institute of Seismology of the National Academy of Sciences of the Kyrgyz Republic and the Research Station of the Russian Academy of Sciences. KNET data is used by regional and international seismological centers for scientific research and different type of seismic bulletins compilation. Despite on the fact that the KNET stations were located on teleseismic distances from the North Korean nuclear test site Punggye-ri (in the range of 4300-4515 km), they registered 6 North Korean nuclear tests for 2006-2017. In the paper, a comparative analysis of the waveforms of the North Korean tests according to the KNET data is carried out, and the dynamic and kinematic parameters of the explosions are estimated.

The mb 6.1 event related to the 2017 DPRK’s sixth nuclear test occurred in DPRK’s Punggye-ri test site on September 3, 2017. After 8 minutes 32 seconds from the origin time of the event, the second event of mb 3.6 followed. Three-dimensional surface deformations from the ascending and descending satellite radar observations were retrieved for the nuclear test. From the upward deformation component, we could clearly identify the collapse of the Punggye-ri test site’s facilities as well as the collapse related to the second event. And, from the horizontal deformation component, we were also able to recognize that the shape of the nuclear source is spheroidal. The location, depth and cavity radius of the event were calculated from the horizontal component by using Yang’s dislocation model after the landslide-feasible deformations were removed from the horizontal deformations. The epicenter of modeled explosion was similar to those calculated from previous studies. However, the depth and cavity radius were slightly different, which were about 492 m and 68 m, respectively. The yield calculation from compressive strength of Cretaceous Bulguksa Granite and the estimated cavity radius was 298±27 kton which was bigger than results of other studies by approximately 100 kton.

The Democratic People’s Republic of Korea (DPRK) conducted six announced nuclear tests between 2006 and 2017 however the only time that the international monitoring system detected radioxenon, that could be related to the DPRK3 nuclear explosion, occurred on February 12, 2013. About eight weeks after the DPRK3 test, the IMS stations measured abnormal concentrations of 133Xe and 131mXe. The source terms were estimated with Flexpart atmospheric transport model. The predicted release profile consisted of three 3-hours plumes on 7 and 12 April. The radioxenon concentrations are in better agreement with JPX38 and RUX58 measurements than the previous study that was done with the Hysplit model. Finally, explosion yield has calculated by analytical data and estimated release profile. The explosion yield with assuming 10% leakage has predicted about 7.89±1.3 kt and 9.98±1.2 kt for 239Pu and 235U fissile materials respectively.
T2.2 Challenges of On-Site Inspection

Oral Presentations

T2.2-O1  A Rapid and Non-Destructive Method for Determining In-Situ Uniaxial Compressive Strength (UCS) of Rocks During On-Site Inspections

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The On-Site Inspection Action Plan (OSI-AP), CTBT/PTS/INF.1343, serves as a tool for furthering OSI capabilities towards the establishment of a balanced, coherent, and robust verification regime at entry into force (EIF) of the CTBT. In furtherance to the objectives of OSI-AP, an experts meeting was held on 7-9 March 2018 to consider issues relating to OSI GVOB and position finding. Petrographic techniques to examine thin sections of rocks during initial inspection period (IIP) was proposed. However, rock sample collection, thin section preparation and petrographic analysis, herein considered a destructive method, was not adopted as an OSI technique. The in-situ Uniaxial Compressive Strength (UCS) test technique was proposed as a viable alternative. UCS is a non-destructive test for rapid assessment of condition of rocks and concrete structures. The tests are easier to undertake because they necessitate less/no sample collection, and thin sections preparation and petrographic analysis. Results of UCS tests during geological and geophysical investigations for dam site in Kenya will be presented during the Science and Technology Conference (SnT 2019). The UCS results as well as use of the technique during OSI enable rapid decision making as to the nature and characteristics of in-situ rocks thus allowing investigations/inspections using intrusive techniques.

T2.2-O2  CHAOS During an OSI (Applying Measurement Restrictions to Sample Characterisation at the BOO)

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A ruggedised, gamma-gamma based system for in-field, real-time measurements of environmental samples has been developed at GBL15. This is specifically designed to enable measurement restrictions, such that it can support OSI activities envisaged under the CTBT. In restricted mode, only the 17 OSI relevant radionuclides are measured, with zero information recorded regarding other radionuclides. All data acquisition, analysis, and reporting is automated, and implemented within a CAEN S.p.A. HEXAGON dual-input Multi-Channel Analyser (MCA). Multiple analysis streams are deployed on the system, including traditional analysis of a histogram for each detector channel (in both full and restricted modes), and coincidence analysis based upon real-time sorting of time-stamped, list-mode events stored in the buffer of the MCA. This multi-faceted approach allows for far greater confidence in the reported results, as all data streams report fully quantified radionuclide activities and uncertainties. The software is fully configurable depending on the level of measurement restriction required; the detail available ranges from the full analysed histograms (with embedded peak fitting, efficiency and shape characterisations) to a simple yes/no traffic light system to denote the presence or absence of an OSI relevant radionuclide.
T2.2-O3 **C-137 Background Measurement in the Marine Environment of the Asia-Pacific Region to Support Emerging Challenges of On-Site Inspection (OSI) in Seas**

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Under the Comprehensive Nuclear-Test-Ban Treaty (CTBT), On-Site Inspection (OSI) is the final CTBT tool to be used for proofing suspicious nuclear explosions after entry-into-force of the treaty. Over a decade, a huge attention has been paid on the development and testing of OSI procedures, techniques, and equipment to reveal whether or not underground nuclear testing actually occurred. New challenges causing concerns over international peace and security have recently been emerged and discussed. There is a possibility of suspicious events other than underground and underwater testing and marine & coastal seas is among them where nuclear explosions could take place. Not only further capacity building of potential on-site inspectors and development of appropriate OSI techniques but also the radioactivity database of the OSI-relevant gamma-emitting radionuclides in marine & coastal environment is needed. This recent work aims to review and summarize C-137 radioactivity in seawater, sediment, and biota from several countries in the Asia-Pacific region. These data would play a vital role as a reference/background data in case of any future underwater nuclear explosions. Through skill-enhanced inspectors, well-developed procedures, and comprehensive radioactivity data, the CTBT’s goal to end nuclear testing could be achieved.

T2.2-O4 **Environmental Radioxenon Activity Concentration Monitoring by OSI Radioxenon Processing System**

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Since 2002, Northwest Institute of Nuclear Technology (NINT) has begun to do research work and has developed three-generation OSI radioxenon processing system (XESPMs), including XESPM-I, XESPM-II and XESPM-III, which are composed of sampling, purification and measurement units, and the three units are independently operated. The final sample prepared can be measured either by HPGe γ spectrometry or β-γ coincidence counting system. The high sensitivity radioxenon automatic processing system (XESPM-II) was used to monitor the radioxenon activity concentrations natural background under high radon concentrations and radioxenon activity concentrations in Beijing atmosphere after Fukushima nuclear power plant accident. The rapid radioxenon processing system (XESPM-III), detecting radioxenon isotopes, played an important role in IFE14. Some further works related to radioxenon system development are proposed based on the research experiences.

T2.2-O5 **Gamma Imaging for On-Site Inspection: Reconstruction of an Extended Source in a Restricted-Access Zone**

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Under the Comprehensive-Nuclear-Test-Ban-Treaty a State Party can request an on-site inspection to establish whether or not a nuclear explosion has been carried out. Gamma radiation measurements would form a key component of the operation. However, the inspected State Party may declare up to 50 km² of restricted-access sites (RAs) each of area up to 4 km². We have developed the Silicon photomultiplier-based Compton Telescope for Safety and Security (SCoTSS) gamma imager and survey spectrometer. In a mobile survey along the perimeter of a restricted-access site, SCoTSS can perform a kind of triangulation to work out the distribution of radioactivity inside. This scenario has been enacted experimentally with controlled distribution of 10 GBq of radioactive lanthanum in an L-shaped pattern of area 3,200 m² followed by perimeter survey using the SCoTSS imager. We have developed tomographic methods to reconstruct the distribution of radioactivity using the
Theme 2: Events and Nuclear Test Sites

images from multiple points of view. Despite the imager being constrained to locations on the ground over 200 m from the source, it is possible to localize the distribution of the radioactivity. These experimental results and methods will be presented and their potential application to restricted-access sites in on-site inspection will be discussed.

T2.2-O7  How to Develop a Credible Scenario for Large Field Exercises - Scenario Task Force Activities

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Exercises play an integral role in efforts to build up the on-site inspection (OSI) element of the verification regime established by the CTBT, as they allow various inspection activities, techniques, processes and procedures to be tested in a manner against a robust and realistic scenario. The OSI Exercise Plan 2016-2020 foresees the conduct of three Build-up Exercises (BUE) covering all inspection phases. The development of a technically realistic, scientifically credible, rationally coherent and intellectually motivating scenario is crucial for testing OSI capabilities. Therefore, a Scenario Task Force (STF) was established, comprising selected technical experts from various State Signatories who, supported by the PTS, have been developing a contiguous scenario for all three exercises. The scenario shall aim to facilitate the testing of recently developed inspection techniques, updated procedures, new infrastructure, such as the Equipment, Storage and Maintenance Facility (ESMF) and the Operations Support Centre (OSC) and information management systems such as the Geospatial Information Management system for OSI (GIMO). The poster provides an overview of the objectives, scope and method of work of the STF, the challenges faced in creating a complex scenario, and the means by which an OSI scenario may stimulate the application of inspection techniques and inspection elements.

T2.2-O8  The Potential Use of Interferometric Techniques in the Location and Estimation of Suspected Test Sites

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Interferometric techniques using radar signals to map the elevation of the Earth’s surface or to map differences in the topography as a function of time have surged in applications in the last few years. Satellite interferometry, using successive radar images of the Earth's surface are now routinely used to monitor subsidence of sedimentary basins due to water or oil extraction. Similar interferometric instrumentation is now also available to be mounted in drones at relatively low elevation, allowing a very dense cloud of observations leading to a very high spatial resolution. One of the main challenges of an on-site inspection is the rapid location of the potential test site within a relatively large area. For this purpose, a number of geophysical and geodetic techniques have been proposed for use at Entry into Force. Here, we propose and demonstrate that with the current availability of open-source satellite images and the low cost of drone-borne interferometry, the location of the suspected site where the nuclear test may have taken place will be revealed by subsidence or deformation of the ground surface. Thus interferometry may be the more economical method of a first order mapping the location of a suspected test site.

T2.2-O9  Utilization of Unmanned System for Environmental Sampling in CTBT OSI

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Areas contaminated with high or lethal radioactivity are deemed as the highest risk for the OSI inspectors if they stay or work there. Besides, other harsh environments, tough conditions, limited personnel also makes the challenge for an OSI system. These circumstances call for an advanced approach to deal with those problems. In this case, an unmanned system equipped with sampling gears could make the most of its advantages. We developed an unmanned OSI environmental sampling system prototype, and the laboratory and field tests have
been carried out based on this prototype. The test results indicate that the system has the advantages of robust and functioning properly in harsh conditions with the capability of perception, communication, navigation, reliability, persistence, maintainability, mobility, etc. Using this system, the efficiency of OSI environmental sampling are greatly improved and the personnel security is guaranteed.

T2.2-O10 UNE’s Subsurface Signatures, Detected by Active Seismic Surveys at the Semipalatinsk Test Site

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One of the problems in OSI subsurface techniques development is the uncertainty of potential target objects. In a general approach (which includes OSI modelling) the zones of explosive disintegration are presented in simplified form – as a vacuous cavity with areas of active crush around it. The real situation is described by more complicated models with presence of other disrupted areas, including spall zones and common fracturing areas, which could be detected using near-surface seismic surveys. At the Semipalatinsk Test Site, where borehole UNEs were conducted, an active seismic survey using diving waves method was carried out. In the UNEs epicenters the spall zones were detected to the average depth of 85 m. Their thickness depends from the yield of the nuclear charge. P-wave velocity was less than in the surrounding rocks with 1.0-1.5 km/s, S-wave with 0.5 km/s. Under the spall zones to the average depth of 150 m the common fracturing layer was revealed. Parameter of cracks density changes from 0.15 to 0.45. Upper se disintegrated zones may also be used as indicators of conducted UNEs. Herewith the spall zones allow to define UNE’s hypocenter position and its yield. In this presentation we give methodical recommendations on active seismic technique applying during the OSI continuation period.

Poster Presentations

T2.2-P1 Application of Complex Geophysical Research for the On-Site Inspection of Nuclear Tests

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Carrying out nuclear explosions underground (UNE) significantly reduces the display of radioactive contamination on the surface. That is why the CTBT foresees a number of geophysical methods during on-site inspections. It is important to continue improving the geophysical methods for on-site inspections, especially under the conditions of limited access to the sites that raise suspicions in carrying out nuclear tests. We present the results of the development of a new representation on mountain rocks and water interaction using various parameters (dynamic, structural and material) determined at a distance by electrical survey methods. This allows to establish bleached zones and migration and deposits of materials (including radioactive ones) in real geological media. In order to detect hydrodynamic structures that pass through the focal points of an UNE, tritium exhalation measurements are used as the main marker of radioactive contamination distribution. The validity of these presentations is proved theoretically, experimentally and by geophysical survey in real conditions at the Semipalatinsk Test Site. In addition to on-site inspection we propose to use this method to study radioactive contamination in other nuclear facilities.
Theme 2: Events and Nuclear Test Sites

T2.2-P2 Application of the Radionuclide Method Using Tritium as an Indicator for On-Site Inspection

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Within the framework of the CTBT, both global monitoring and on-site inspections are conducted. The task of the on-site inspection is an evidence reliable assessment of the fact that nuclear tests have done. In this paper, a verification method for identification of nuclear explosions using the tritium content in the environment is proposed to consider. The possibility of event screening using this method was showed based on observations in the places of nuclear tests. It was established that during nuclear tests 3H enters environmental objects, regardless of the specific features of an explosion. The Semipalatinsk test site example showed that in the field of ground testing tritium was only fixed in the top layer of soil with content was about 10E5 Bq/kg. However, in the places of underground nuclear tests, tritium can be contained in surface and underground waters, in snow, in plants, in soil and in air, in concentrations of 10E1+10E5 Bq/kg. Experimental studies of air contamination suggested that the concentration of tritium in soil air decreases exponentially with distance from the test venues. Investigations of the tritium/Eu-152 ratio in soil found that using such data could give a potential information about the nature of an explosion.

T2.2-P3 Business Approach to Finish an Unsolved Dilemma of the OSI

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Under CTBT, an On-Site Inspection (OSI) is the final measure to verify compliance with the Treaty and can be used to verify whether a suspicious event was, in fact, a nuclear explosion. But that measurement tends to get a false detection from medical radioisotope production released Xe. It has been an unsolved dilemma between CTBTO and the MRP. A business approach is one of the choices for this dilemma. The concept is there must be a company that will buy and utilize the released Xe from MPRs. As we know, Xe-135 can be used in medical or other industry needs. So, the released Xe can be re-commercialized. This concept is expected to offer a solution for the false-detection of nuclear weapon test from CTBTO and engage the medical radioisotope production for fulfilling the world demand. Further research will be needed to develop an effective technology for transferring the Xe from the MRP s to Xe based industry companies.

T2.2-P4 Challenges in Hosting an On-Site Inspection Regional Course

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The specific requirements for a course of On-Site Inspection (OSI) of the CTBTO Preparatory Commission, Vienna, Austria (CTBTO) place some exceptional challenges in terms of venue and scenarios, equipment transportation and coordination among different agencies, companies and suppliers. Due to its extent there is no other course like it in the framework of the CTBTO. In April 2018 the OSI regional introductory course - known as RIC23 - took place in Argentina and the Nuclear Regulatory Authority (ARN) was the main Point of Contact for local organization. This presentation intends to describe the key challenges encountered in organizing a regional OSI introductory course from the point of view of the hosting country and how they were tackled in the case of the RIC23. We anticipate that the remarks and lessons learned from this experience may be useful for preparing similar courses in the future.
**T2.2-P5**  **Challenges of On-Site Inspection in Extreme Climatic Conditions**

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This work presents a brief review of the documents determining the progress of on-site inspections, as well as an analysis of the current status of the development of procedures and methods of on-site inspections under the CTBT. In this study we made an overview of the field of nuclear testing in different climatic conditions and made examples of potential difficulties encountered by the inspectors in such conditions. The report concludes that it is necessary for the CTBTO PC to consider that these possible difficulties may affect the inspector training cycles.

**T2.2-P6**  **ESI 2007 Earthquake Intensity Scale in Help of CTBT OSI’s Verification Regime**

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The Environmental Seismic Intensity Scale (ESI-2007) is a recent intensity scale designed, implemented and tested to measure the damage level of an earthquake. ESI-2007 solely focuses on the impact of a seismic event on nature. In other words, it intends to establish the level of damage from observable Environmental Earthquake Effects (EEE) that a particular earthquake can generate on ground surface around the epicenter, which include: mass wasting/sliding, cracks, water changes, etc. In that sense, ESI was proposed with two main aims: 1) to refloat the observational study of natural effects, which past scales used to include or use; 2) to evaluate the effect of earthquakes in sparsely populated to unpopulated areas. Additionally visual observation (VOB) is a prime approach of the OSI Verification Regime to narrow down and ultimately define the location of a nuclear explosion "ground zero". Since test sites are placed at remote sites and tests are performed VOB must look for "suspicious" man-made installations and/or land/ground modifications, as well as for surface ground modifications characteristic of explosions. These latter ground observables are a commonality between ESI and OSI-VOB. Furthermore, both also targets remote areas with scarce to no population.

**T2.2-P8**  **Studying the Suspected Site of Nuclear Test by Using Microtremor Method**

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Microtremor are continued vibrations of the ground, having small amplitudes in the range of 0.1 to 1 micron. Their origin is related to natural and artificial disturbances, such as wind, sea waves, traffic industrial noise, and similar causes. Observation of microtremors can give useful information on dynamic properties of the site such as predominant period, and amplitude. By taking advantage of the change (Anomaly) in the dominant frequency measurements at the site of study, it is possible to develop a probability of identifying the area, where a nuclear test might have occurred. Microtremor observations are easy to perform, and inexpensive method. According to Nakamura (1989) methods, some assumptions are considered: 1. The microtremor of frequency ranged between (0.5 to 20 Hz.). 2. The artificial noise is mostly propagated as Raleigh wave. 3. Horizontal and vectoral motions are related to the soil conditions of the observation point and (AH/AV) is close to 1 for the firm soil. 4. The microtremor motion is due to nearby sources and all deep sources are Neglected.
Theme 2: Events and Nuclear Test Sites

T2.2-P10  The Family of the OSI
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The OSI courses have many benefits for the participants whether they are in the course of the inspectors, the beginners' courses or local workshops. They can develop the personal skills of the trainee through practice which will be useful for the trainee and future OSI member. Working together with individuals as a team helps to build strong bonds between them and allows new ideas to flourish and thus achieve goals faster, feel confident and respectful and thus make strong friendships that will grow among all. This will always motivate them to give more and become a strong family. After the beginning of the ongoing 3TC training program, started in 2016 with many courses, the OSI started to work as one team benefiting from the expertise of specialists (trainers) to use the latest technologies and equipment for the inspection process. This experience built a single integrated and interrelated family despite the different traditions and countries. They celebrate their birthdays, grieve with their sorrows and communicate with different social media not only in training times but also outside training. This helps the inspectors to perform training in harsh environments, remote areas and under different conditions.

T2.2-P11  The Identification of Ground Zeros of Nuclear Events of the Semipalatinsk Test Site
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In the territory of the "Experimental Field" ground of the Semipalatinsk test site there are a great number of ground zeros of nuclear events. In case there is a crater, a ground zero is quite easy to identify. However, in case of no technogenic disturbances it is impossible to spot it visually. A detailed analysis of Cs-137 and Am-241 has shown that due to these meteorologically transported products, this forms a displacement of the real ground zero, and in some cases, a ground zero cannot be detected. In this context, neutron activation products, in particular Eu-152, are assumed to be the most effective to reveal ground zeros of nuclear events. For the technique to be processed, surface soil samples were collected at different distances from the supposed ground zero of a nuclear event. Fractional sample analysis was carried out; extra deep-earth soil sampling was made. Based on the mineralogical analysis, sampling should be made at a depth of 5-10 cm rather than on the surface, as the surface layer is subjected to contamination due to radionuclides fallout after the explosion. For research one should use a coarse fraction because it is less subjected to transfer.

T2.2-P15  VNIIA Major Activities Related to the CTBT Technologies
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VNIIA is the leading organization of ROSATOM in implementing the CTBT and is currently performing a set of research activities: -provides scientific and methodological support and develops hardware and software solutions to ensure the CTBT OSI activities, carries out an integral assessment and forecast of technical capacities within the verification regime for compliance with the CTBT, analyzes the effectiveness of control means and the informative value of IDC data; -participates in the analysis of events evidencing a possible non-compliance with the Treaty by States Parties; collects geophysical and radionuclide data based on IDC products; -improves the information and analytical system in order to use it in the applied research for the activities of Rosatom within the CTBT verification regime and other treaties limiting nuclear tests; -studies and improves processes for detection and localization of weak seismo-acoustic events at distances on a regional scale (using
T1.1-O3 Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound Propagation and Scattering in the Atmosphere

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The experimental results of studying the effect of a fine-scale layered structure of a stably stratified atmospheric boundary layer (ABL) on fluctuations of the parameters of acoustic pulses generated with a certain period (1 min) by an artificial detonation source are presented. The vertical profiles of wind velocity fluctuations in the thin layers of the ABL have been retrieved using the wave forms and travel times of the recorded arrivals of pulses from the source. It is shown that the mechanism of scattering of pulse signals in a stably stratified ABL is similar to the mechanism of scattering of signals from ground surface explosions by layered nonhomogeneities of wind velocity and temperature in the stratosphere and lower thermosphere. The role of similarity parameter here place the dimensionless thickness of the reflecting nonhomogeneous layers, which is the vertical scale of the layer multiplied by the relative difference in effective sound velocity and normalized by the vertical wavelength. The effect of such inhomogeneities on the temporal fluctuations of the azimuth and arrival times of the signals is studied. The estimation of the error in localization of pulsed sources is given.

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T1.1-O4 Climate Change Through the Eyes of Radioisotopes

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Cosmogenic radionuclides beryllium-7 and sodium-22 are known atmospheric tracers and can be used together in a lock-in technique to effectively trace vertical air masses based on surface measurements. This technique allows to study progression and speed of atmospheric cells. Data show that the cells are decelerating during the summer period which is extending in time. This is caused by warming of the whole troposphere and increased tropopause height due to rising CO2 concentrations. Aestival episodes of persistent high-pressure systems over Europe with low pressure gradients that led to almost stationary thunderstorms are correlated with the observed deceleration of atmospheric cell movement. This demonstrates that 7Be and 22Na can be used as indicators for confirming several side effects of climate change while providing a new modelling tool in seasonal weather forecast.

T1.1-O5 Detection Efficiency of the IMS for Bolides

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In this study we examined 344 bolides (airbursts) reported on the JPL CNEOS website (https://cneos.jpl.nasa.gov/fireballs/) between 2007-2018 and attempt to correlate these with infrasound detections. We found 206 of these bolides were detectable by at least one infrasound station while only 42 were automatically registered as part of the Reviewed Event Bulletin (REB) issued daily by CTBTO. However, this global REB detection rate of ~10% averaged from 2007-2018 is less than the “modern” rate (from 2014-2018) which approaches 20%. Above the 1 kT CTBTO design threshold, we find that 40% of airbursts are reported in the REB, while more than 90% are detectable at one or more infrasound stations. All airbursts with energy > 2 kT reported on the JPL fireball site since 2007 have been detected infrasonically. However, the REB is only complete above 15 kT with the automated detection system not having reported at least four airbursts with...
Theme 2: Events and Nuclear Test Sites

T2.3 Seismoacoustic Sources in Theory and Practice

Oral Presentations

T2.3-O1 Analysis Result of DPRK’s Nuclear Test Using Korea Meteorological Administration (KMA) Infrasound Network

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KMA has been operating infrasound array stations at Cheorwon(CW) and Yanggu(Y G) since 2011. KMA’s infrasound stations successfully detected the azimuthal directions of the arrivals of the infrasound signals generated from DPRK’s underground nuclear explosions. Recently, we tested ray tracing simulation of infrasound wave propagation in the atmosphere generated from the calculation methods of Ray tracing method, Normal mode method, Parabolic equation method. Analysis results from 4th to 6th DPRK’s tests of ray tracing simulation using KMA’s atmospheric data and numerical simulation results pointed out proper azimuthal directions from test site to CW and Y G. KMA’s mission is to detect precise azimuthal direction and origin time generated from DPRK’s explosion, ICBM missile launching and Nuclear test. Since current network is located in eastern part of DMZ(demilitarized zone) to monitor DPRK’s nuclear test, three new infrasound arrays will be installed at western part of DMZ in 2019 to fill the gap of monitoring area and increase detection rate. Currently, we are finding the potential sites to deploy the sensors which are made up array networks and to find proper configurations to improve detection rate. Installing the sensors that meet the CTBTO’s standard regulations and find optimal wind-noise reducing systems are also important.

T2.3-O2 Analyzing the Reduced Displacement Potentials of DPRK Nuclear Explosions Using Waveform Equalization Technique

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We equalize regional P, surface, and the P+surface waves simultaneously to estimate reduced displacement potential (RDP) and depth of burial (DOB) of DPRK nuclear explosions, using waveforms from the stations at IRIS DMC. RDPs are predicted using the formula in Saikia (2017). The algorithm starts with the initial RDP and DOBs for two explosions. RDP of one explosion S1 is convolved with the other explosion recorded data O2, and vice-versa (i.e., S2 with O1), which generates two convolution seismograms: S1*O2 and S2*O1. The objective is to minimize the differential error between the two convolution seismograms, and achieve an optimization by cycling through the parameter space. Next we fix the RDP and DOBs of these two explosions using the derived optimized values and continue the process to include the next explosion. Thus, we have two additional source convolved seismograms: S3*O1 and S3*O2 to minimize the global error between these constructed differential seismograms. We continue the process until the last explosion is included. The investigation resulted RDP and DOB parameters consistent with those established by other investigators except for the September 3, 2017 explosion, which is caused by the influence of non-isotropic seismic sources, and which is a topic of current investigation.
Data Analysis and Simulations of the Source Physics Experiments: Impact on Explosion Discrimination & Monitoring

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The Source Physics Experiments (SPE) are a series of controlled chemical explosions at the Nevada National Security Site to gather observations to verify and validate explosions physics-based numerical models, and to understand, in particular, the genesis of shear waves to improve nuclear monitoring capabilities. Executed between 2011 and 2016, SPE Phase I included six chemical explosions conducted in the same Climax Stock granite borehole with different yields and different depths. Phase II, however, includes only four chemical explosions and are being conducted in dry alluvium geology (DAG). The first two, DAG-1 and DAG-2 have been successfully executed in 2018. In a multi-laboratory effort, we developed a comprehensive nested numerical framework to simulate from end-to-end, source-to-receivers, the waves generated from the non-linear explosion source-region to linear-elastic seismoacoustic distances. We present the analysis of all SPE collected data, summarize how modeling predictions compare to observed data and draw lessons learned. We also share insights on the main mechanisms of generating shear motions in granite and alluvium. Moreover, the team has developed schemes of uncertainty propagation of the geological characterization and geophysical parameters pertinent to denied access and remote sites. We present the impacts of those uncertainties on enhancing source discrimination.

Poster Presentations

Near-Source Mechanism for Creating Shear Content from Buried Explosions

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The buried chemical explosion tests of the Source Physics Experiment (SPE) includes a near-source three-axis borehole accelerometer array. Data analysis combined with numerical modeling promotes a better understanding of ground shock phenomenology with particular emphasis on anomalous shear motion. SPE includes Phase I tests in a jointed medium (granite) and Phase II tests in a relatively homogeneous medium (alluvium). Both phases included a wide range of yield-scaled depth-of-burial (SDOB). Inspection of Phase I velocity traces indicated initially quiescent non-radial components which undergo a sudden amplitude surge immediately following the peak radial pulse. We describe our hypothesis of a granite joint slip mechanism resulting from loading and subsequent unloading of the joints. Data traces and results of explicitly-jointed finite element calculations are presented to illustrate the mechanism. We illustrate that this phenomenon is evident only in Phase I tests within a range of SDOB. We contrast these results to the Phase II data where there are no natural joints, and where data indicate an absence of non-radial motion. We correlate the relation between Phase I SDOB and shear release observations to the DPRK announced tests, also in granite, and the likelihood of those tests to confuse MS:mb earthquake/explosion discrimination.
T2.3-P1  A New GT5 Event in a Previously Aseismic Region of the Brazilian Phanerozoic Parnaiba Basin

L. Vieira Barros, M. Sousa de Assumpcao, J. Carvalho

Seismicity in Brazil is at a low level, with only three continental earthquakes of magnitude five in the last three decades. Until recently there has been a low number of seismic stations in the region. Both factors explain why it is very difficult to detect events at regional distances that can be classed as Ground Truth 5 (GT5). In the first PTS - CTBTO RSTT meeting (in 2012) seismologists from South America were encouraged to cooperate in identifying GTx events. At that time, Brazil appeared completely empty in the world map of GT events. With the deployment of the Brazilian Seismographic Network (RSBR) and using aftershock sequences well recorded by local and regional stations as reference events, it was possible to relocate mainshocks which would fulfill GT5 event criteria. We studied aftershock activity induced by a 4.6 mb mainshock on January 3, 2017. This event was registered by 25 regional stations of the RSBR. A local seismic network, which consisted of 5 stations, enabled to relocate this earthquake with an accuracy of a GT5 event. For hypocentral location an accurate velocity model was determined using phase conversion, which was clearly identified on the interface sediment-basement. In this work, we present a new GT5 event in order to better define the 3D velocity model for Brazil.

T2.3-P2  A Post Sunda Strait Tsunami Survey of Sunda Strait Tsunami, December 22nd 2018

S.D. Anugrah, I. Gunawan, M. Fadhillah, A. Aprilyanto, A. Sugiharto, R. Rudianto, L. Somali, T. Yatimantoro

Sunda Strait Tsunami took place on 22 December 2018. Two days later a post survey was conducted in the area surrounding the strait, along the coast of the Banten and the coast of Lampung. The results of 28 measurement points revealed that the tsunami height varied from 0.75-6.22 m. The maximum height was measured at the area of Carita in Banten, based on a tsunami trace which left broken tree branches. Tsunami height measurements took the tide level into consideration. In some areas the distance of tsunami inundation was investigated by means of the post tsunami survey. In general the average of inundation distance was approximately 200 m from the coastline to inland. The Krakatau Volcano tsunami modeling was simulated to reconstruct the tsunami propagation and to verify tsunami modeling method. The model was generated considering a flank collapse of the Volcano. Based on the eyewitness interviews no earthquake shaking was felt before the tsunami.

T2.3-P3  Analysis and Modeling of the Infrasound Signals from the 2017 DPRK Nuclear Explosion at IMS Station IS45

C. Pilger, K. Koch

Strong infrasound signals from the Democratic People’s Republic of Korea (DPRK) underground nuclear test on 3 September 2017 were observed at IMS infrasound station IS45 in Russia around 25 minutes after the explosion, consisting of 2 distinct high-amplitude peaks about 1 min apart. From Progressive Multi-Channel Correlation (PMCC) processing and frequency wave-number analysis these arrivals yield distinctly different estimates for back azimuth and apparent (trace) velocity indicating different propagation paths. Furthermore, we were able to identify some weaker precursory arrivals as well as an infrasound arrival about 8 minutes later, thus presumed to be associated with the explosion's aftershock, i.e. collapse event. For the numerical modeling of the identified infrasonic phases we applied two-dimensional (2D) ray-tracing and 1-D parabolic equation methods with atmospheric velocity profiles derived from an ECMWF forecast model augmented by empirically deduced velocity variations. These propagation calculations indicate for epicentral seismic-acoustic wave conversion that
both stratospheric and thermospheric ducting has occurred explaining well the major peaks and the aftershock signal. For the precursory signals we applied grid search calculations for backtracking the likely source regions where additional conversions of seismic waves into acoustic energy occurred.

**T2.3-P4  Analysis of Kosti Meteorite Using Infrasound Data: A Case Study in Sudan**  
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A meteorite fell in Kosti city located in the White Nile State of Sudan on June 20, 2017. The meteor entered the Earth’s atmosphere at 12:03 midnight local time. The meteor’s light was very intense, images of this explosion were captured by mobile devices as lighting falling balls. Infrasound signals originating from the meteorite were detected at IMS stations in Kenya (1S32KE) and Tunisia (1S48TN). Event was part of SEL3 bulletin. Data recorded by these IMS stations were analysed using GPMCC. Analysis results agreed with the known back azimuth of the event. The result of the study is presented in this paper.

**T2.3-P5  Analysis of the Infrasound Signals from a Bolide over the Bering Sea**  
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In the current work we discuss IMS infrasound observations from a bolide occurring over the Bering Sea in December 2018 recorded at eight infrasound IMS arrays at distances from 2,000 up to nearly 8,000 km. We use the Bayesian Infrasound Source Location (BISL) procedure to obtain a source location and an origin time. Detection patterns and celerity observations validate the presence of a strong stratospheric waveguide north and east of source location, in agreement with the expected state of the atmosphere at the time of the event. The observed frequency range of the signals are variable, with the furthest stations exhibiting higher frequency than the closer stations. Using the standard deviation of the measured periods, and the Revelle 1997 period/yield relationship, the release of energy for this event is between 5 and 103 kt.

**T2.3-P6  Complex Seismological Investigations near Bulgarian Antarctic Base**  
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Bulgarian Antarctic seismic station LIVV was operational during three astral summers between 2015 and 2018 on Livingston Island, Antarctica. The estimated performance of the seismic equipment shows the capability of the station to register seismic events of different nature. More than 12000 seismic events were recorded, most of them related to the seismicity of glaciers. A big number of local earthquakes was also registered. Two methods were used for earthquake location. First one used data from only one station and was based on Golitsyn’s method and Vincenty formula. Second one applied DHypo software with different velocity models and seismic phases from four Spanish stations deployed on Deception Island volcano and two Argentinian-Italian (AI) stations. To study the glacial seismicity we used different technics and procedures: 1) for epicenter estimations of one type of icequakes a developed code for a single station location was applied; 2) GNSS measurements at the surface of glacier Perunika were conducted and meteorological data were collected.
**Theme 2: Events and Nuclear Test Sites**

**T2.3-P8  Deployment of Temporal Infrasound Array in Ecuador**

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In 2018, a four element portable infrasound array was deployed in the Ecuadorian Amazon region, near Reventador volcano. This experiment was carried out as a collaborative effort between the CTBTO and the Instituto Geofísico, Quito. Due to the amount and frequency of local infrasound sources (e.g. active volcanoes), the mainland portable array installation provides a large amount of data useful for comparisons against permanent IMS stations, such as the relatively nearby IS20, and also other regional IMS infrasound stations (e.g. IS14, IS08, IS13, etc.). In addition, the proximity of the both IS20 and the portable array to active volcanoes in the region, allows the Instituto Geofísico and the CTBTO to continue to assess local volcano hazards and to gain knowledge of the region.

**T2.3-P9  Detection and Interpretation of Seismoacoustic and Seismic Events at NDC Iraq**

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We study explosions and earthquakes which occur in our region and worldwide to contribute to stopping nuclear explosions and support the Comprehensive Nuclear-Test-Ban Treaty (CTBT) verification regime. The National Data Center (NDC) in Iraq was established to enable the country to have access to the International Monitoring System (IMS) data and the International Data Center (IDC) products. In our capacity we are helping to verify compliance with the CTBT. Our center has technical expertise in seismic and radionuclide technologies. Recently we started working with IMS infrasound data. We analyzed an explosion in Ukrainian ammunition depot, which took place on 9 October 2018. We used IDC products and data from infrasound stations to analyze this event with software DTK-(G)PMC (Progressive Multi-Channel Correlation). Also, we applied the NDC-in-a-Box software package (Geotool, SeisComP3) to analyze a seismic event that occurred at the Iran-Iraq border on 06-01-2019. Recently a Capacity Building System (CBS) was installed by the CTBTO team in our NDC. We are using IDC data and products and CBS data for the purpose of developing our capacity to receive, analyze and investigate incident events.

**T2.3-P10  Determine the Relationship Between Seismic and Acoustic Signals**

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There are hundreds of mines and quarries in the territory of Mongolia using blasts with varying yields and firing schemes. These mining-related explosions occupy a large part of the seismic catalogue issued by the IAG. To discriminate between the earthquakes and explosions is more difficult as the sizes and distances are different for all events. This study is designed to quantify the Baganuur mining explosions using seismic and infrasound station data. The study uses ground truth coal mining explosion data from 2016 which were obtained from the Baganuur mine company. In total data from 167 explosions were used for this analysis. Using infrasound station data, we estimated a minimum explosive level that can be detected at infrasound stations. We also included a seasonal variation in the detectable levels of explosive. For seismic acoustic data, we estimated a relationship between the mining explosions total explosive yields with peak amplitude, magnitude and Arias intensity. A waveform cross correlation technique was used in order to find the detection threshold level using a master event of the Baganuur mining area.
**T2.3-P11** Discrimination Between Quarry Blasts and Local Earthquakes in Aswan, Egypt

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A modern and sensitive seismic network (ASN) for monitoring the earthquakes beneath Nasser Lake has been operating in Aswan since June 1982. It is comprised of 23 field stations distributed south of Aswan High Dam. ASN records are clear and high quality digital waveform seismograms. In that region, seismic disturbances are also generated by the ongoing quarry blasts carried out mostly during the day time. Sometimes they are mistaken for the micro-earthquake activity of the area. Thus, the discrimination between quarry blast and local earthquake seismograms is important. In fact, multi-criteria investigations are now well known for identifying features which distinguish natural events (earthquakes) from explosions. This study presents a comparison between source properties of the quarry blasts and natural events (i.e., amplitude, periods and waveform). The P to S spectrum and logarithmic amplitude values of 15 quarry blasts and 15 micro-earthquakes of magnitude (ML) < 3 were compared with an attempt to examine the short-period discriminants on those events from Aswan area. Aswan seismic events are of near-source effects, which allows neglecting the propagation correction. The comparison between a quarry blast and an earthquake involves the source effects parameters (i.e., dynamic characteristics of waves, amplitudes, periods, and waveform).

**T2.3-P12** Distributed Acoustic Sensing Observations and Modeling of the DAG Series of Chemical Explosions

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The Dry Alluvium Geology (DAG) series of chemical explosions aim to increase our understanding of explosion-source seismic, acoustic, and electromagnetic phenomenology. The explosion series takes place on the Nevada National Security Site (NNSS) in an alluvium geology. As of December 2018, two of the planned four explosions have been detonated in a common borehole on Yucca Flat: 1,000 kg TNT-equivalent at 385-m depth-of-burial and 50,000 kg TNT-equivalent at 300 m. A component of the DAG diagnostic instrumentation consists of surface-laid and downhole fiber optic distributed acoustic sensing (DAS) cables. A helically-wound fiber installed in two vertical boreholes 80-m from ground zero (GZ) and a traditional surface-laid straight fiber extending from GZ to 2 km recorded the explosions. We present both modeling and observations of the explosions. Phenomenology observed thus far include near-source generated S waves, post-event microseismicity, and surface spall.

**T2.3-P13** Estimating Seismic Source Depths Using Body and Surface Wave Observations

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The ability to confidently estimate the depths of small-to-medium sized (mb < 5) seismic disturbances is important when monitoring compliance with the CTBT. Source depths can be determined by identification of teleseismic depth phases pP and sP, and by modelling surface-wave amplitude spectra. The radiation pattern of pP and fundamental-mode Rayleigh amplitudes show the effectiveness of these methods for earthquake depth estimation depends on the orientation of the focal mechanism, local source structure, and recording station locations. For some focal mechanisms, predicted amplitudes of pP will only be large for stations in certain locations, and Rayleigh wave spectral nulls that tightly constrain the depth often only occur for a limited range of azimuths. We show that for sources where Rayleigh wave spectral nulls are not observed and the source depth cannot therefore be well constrained, the focal mechanism obtained can be used to predict the locations of stations where pP should have a large amplitude, and hence has the potential for positive identification by analysts. These stations could be IMS seismic stations, and/or open seismometer stations in other networks.
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These estimated source depths can also be used in a joint inversion of body and surface-wave data for the focal mechanism.

**T2.3-P15** High-Precision Teleseismic Double-Difference Earthquake Relocation of Palu - Koro Earthquake M 7.4

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The Sulawesi region has complex tectonic conditions. One of the main sources of seismicity in the study area is the Palu-Koro fault activity with the application of left lateral strike-slip. On September 28, 2018, at 17.02.45 WIB (GMT +7), an earthquake of M 7.4 occurred to cause a tsunami hazard in the areas of Palu and Donggala. BMKG sensor recorded 835 aftershocks until November 25, 2018. In this study we use 3D seismic wave velocity model with a grid size 1°×1° in the travel-time calculations. The results of the relocation show the earthquake patterns along the Palu-Koro fault, and the Malano fault with shallow depth (d> 70km).

**T2.3-P16** Hybrid Waveform Modeling for Small-Scale Source Complexity at Teleseismic Distances

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In order to improve event detection, location, and identification, we need to better understand the complexities governing high frequency teleseismic wavefields. However, despite rapid hardware and software developments, capturing a broad range of heterogeneities with conventional seismic wave propagation remains computationally prohibitive on the global scale. To bridge the gap between complexity and computational cost, we present a global Instaseis-based (van Driel et al. 2015, www.instaseis.info) injection type hybrid method. The modified Instaseis interface couples the global wave-propagation solver, AxiSEM (Nissen-Meyer et al. 2014, seis.earth.ox.ac.uk/axisem), with an arbitrary three-dimensional solver of choice (in this work we use WPP), and thus embeds a heterogeneous 3D domain within a spherically symmetric Earth model either around the source, at depth or on the receiver side. Complex structures can be accounted for in the source region in order to model specific seismic observations that are caused by near-source phenomenology, like topography and 3D geology. Such hybrid simulations provide more insight into understanding and quantifying how structures contribute to waveform characteristics at teleseismic distances (such as amplitude, dominant frequency, onset form and pulse duration), and thus could refine our detection, location and identification capacities in nuclear explosion monitoring using seismology.

**T2.3-P17** Implications for S Wave Generation from Subsurface Chemical Explosions Using Large Arrays of Sensors


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The Source Physics Experiment (SPE) is a series of instrumented chemical explosions at the Nevada National Security Site (NNSS) designed to improve understanding of seismic wave generation and propagation from explosions. In April 2016 a temporary deployment of 996 geophones was installed at distances of 400 to 3000 m from a buried (76.5 m) 5000 kg TNT equivalent chemical explosion. The explosion was situated in a weathered...
granite body surrounded by volcanic tuffs, Paleozoic carbonates, and alluvium. The experiment included an active source campaign using a weight drop. In December 2018 a similar deployment (~500 sensors) was installed around a 50,000 kg TNT equivalent chemical explosion at a depth of 300 m. The geologic setting was alluvium over basement. Results show substantial differences in waveforms and associated particle motions over small spatial distances. Characterization of the velocity structure was conducted using first arrival P wave analysis, interferometry, and inter-station correlation. Statistical estimations of the spatial heterogeneity based on the recorded data led to improved modelling of the waveforms using 3D numerical models and demonstrated that path conversions account for a significant component of the observed S waves.

T2.3-P18 **Infrasonic Bulletin to Station IS41**

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The National Data Center (NDC) in Paraguay produces a monthly bulletin of event detections picked by infrasound station IS41. The project of bulletin production began after the upgrade of IS41 in July of 2018. The bulletin is based on the raw data analysis using the software GPMCC on a virtual machine, which processes data received in real time on the CBS (Capacity Building System). A statistical report of events published in the newsletters is presented from August to December 2018 using the WEKA software. We also present a spectral analysis of the most relevant sources of recurring events such as thunderstorms, microbaroms, dam and fall, using the GPMCC.

T2.3-P19 **Infrasonic Monitoring of Deorbiting Soyuz Crafts on the Territory of Central Kazakhstan**

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Since 1994, a contemporary digital network of seismic and infrasound stations of the IGR NNC RK located throughout the perimeter of the Republic territory has been operating successfully in Kazakhstan. At the present time, KNDС receives in real time mode and processes data from 4 infrasound arrays: Aktyubinsk IS31, Kurchatov KURIS, Makanchi MKIAR, and Russian station Zalesovo IS46. Since May 2011, the bulletins of infrasound detections of signals are made using the data of KURIS station, since March 2012 by Zalesovo 146 station, since 2007 by 131 station, and since 2017 by MKIAR. At the present time the bulletin of infrasound events is created on a regular basis, a huge work is conducted on the source type discrimination. The work shows the infrasound and seismic records of deorbiting Soyuz crafts for the territory of Central Kazakhstan. The peculiarities of the wave pattern of infrasound and seismic signals generated during the deorbiting crafts entering the sensible atmosphere and supersonic motion are considered. These signals were compared with bolide signals. The obtained results can be used for improving the reliability of the KNDС infrasound bulletin events discrimination and replenishment of the reference events database.

T2.3-P20 **Measurement of Rotational Ground Motions for CTBT**

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Following classical theory in elasticity, the entire seismic wave-field caused by an infinitesimal deformation has three components of translation – standardly used in seismology - but also six components of strain and at least three components of rotation. Since decades the collocated measurement of translational and rotational ground motion is demanded. So far, it was hampered mainly due to the very small amplitudes of rotations. However, for about a decade, some strong-motion and quite very recently the first broadband rotational instruments have been becoming available. In several publications it has been shown that collocated measurement provides huge benefits in almost all research areas of observational and exploration seismology. Possible applications include...
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sub-soil analysis and characterisations on various scales, wave-field separation and reconstruction, improved S-wave identification, source location and discrimination, as well as determination of the source mechanism (point and kinematic source). Furthermore, the studies showed that even single station analyses provide significantly more information on structure and source when data of six components are measured collocatively compared to only the three components of translation. In our presentation we are going to compile some of the major advantages and provide an outlook for possible applications within the framework of CTBT.

T2.3-P21 More Precise Location of Aswan Seismicity Based on Waveform Analysis

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Accuracy of the hypocentral location of Aswan seismic events is not satisfactory and was one of reasons for upgrading the local Aswan Seismic Network (LASN). LASN is now composed of 23 filed stations distributed in a relatively narrow area (80 km X 80 km) south of Aswan High Dam. The network provides data as digitally-recorded waveforms of seismic events. This study aims to improve the hypocentral location accuracy based on waveform analysis by applying the Cross Correlation method. Results demonstrate that there are ± delays in the P-wave and the S-wave arrival times of the examined events in relation to the master event at the same station (i.e., Δ Pt ranges between 0.15 and 0.11 second, while Δ St ranges between 0.17 and 0.11 second). The reason for this could be an error in the manual picking of arrival times. We assumed that the P- and S- velocity distribution remains constant during this sequence of events. Relocated events are more closely distributed around the master event. This demonstrates that they originate from almost the same location, rather than the zone identified from the preliminary locations based on manually picked onset times.

T2.3-P22 Seismic Moment Tensor Inversion for Source-Type Identification

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The use of regional distance long-period, complete waveform data to determine the seismic moment tensor is now a routine and reliable approach in determining the source mechanism of natural and man-made seismicity and may be used to identify or discriminate different types of seismic sources. Such source-type identification is important for better understanding the physics of earthquakes, geothermal and volcanic seismicity, seismicity in ice, as well as seismicity induced by anthropogenic activities such as mining, oil and gas operations, and explosions. The successful applications of the regional moment tensor method at the past nuclear test sites and the North Korea nuclear tests show that the method is robust and capable for source-type discrimination of nuclear explosions at regional distances. The goals of this project are to study the uncertainty in regional distance seismic moment tensor estimation due to the effects of limited station coverage, assumptions in subsurface Earth structure for Green’s function estimation, effects of shallow source depth and free-surface conditions, as well as expanding the seismic moment tensor database to low-magnitude chemical shots (Source Physics Experiment) and regions with limited data (Middle East and Eastern Caucasus).

T2.3-P23 Simultaneous Relocation of the Seismicity of the Pannonian Basin Using Bayesloc

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We relocated all events in the Pannonian Basin with the iLoc location algorithm using travel-time predictions from RSTT, a global, three-dimensional velocity model of the crust and upper mantle to provide accurate single event locations and to identify ground truth events. Using the iLoc locations as initial hypocenters and several hundred confirmed quarry blasts and mine explosions that qualify for ground truth as benchmark locations we
relocate the entire seismicity of the region simultaneously with the bayesloc multiple event location algorithm. We show that the results present an improved view of the seismicity of the region.

**T2.3-P24 Source Models and Scattering Origin of Regional Phases from Coda Spectral Ratios**

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The Source Physics Experiment (SPE) chemical explosions provide ground truth, and near-source recordings that are unavailable in typical monitoring scenarios. We examine coda source spectral ratios of near-source, local and regional distance recordings to isolate source and propagation effects, and to potentially improve monitoring at distance. Classical source models (Mueller and Murphy, 1971, MM71; Denny and Johnson, 1991, DJ91) predict the source ratios poorly; however, a hybrid model (MM71 with DJ91 cavity radii) performs better, and by varying cavity and elastic radii we obtain models that fit spectral ratios to within measurement precision. Based on this, the best predictive model for the SPE suite is the hybrid model with cavity and elastic radii decreased to 95% and 75% of their original values, respectively. Finally, we observe a distinct spectral modulation at 6-9 Hz that is not predicted by classical models, most likely caused by short period surface waves, such as Rg, interfering with those produced by spallation of near surface layers. The same modulation is observed for compressional (P) and shear (S) waves at distance, indicating that local and regional phases originate as near-source Rg that is scattered into body waves.

**T2.3-P25 Study of Seismoacoustic Signatures of the September 28th 2018 Sulawesi Earthquake**

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A magnitude 7.5 earthquake with subsequent tsunami occurred on September 28th 2018 at 10:02:45 UTC near the city of Palu on the Indonesian island of Sulawesi. Clear and long-lasting infrasound signatures related to this event were observed by at least two IMS infrasound arrays. Although these IMS stations IS39 and IS07 in Palau and northern Australia are more than 1800 and 2700 km away from the earthquake’s epicenter, distinct signals including seismic and acoustic arrivals were recorded at the infrasound arrays and associated to the event. Nevertheless, the precise infrasound generation mechanism is still not well understood. The super shear nature of the rupture, the following landslides and tsunami as well as the seismoacoustic coupling to nearby terrain features may have an impact on the infrasound emitted and subsequently observed. A detailed study of the event-related observations and the potential infrasound generation mechanisms is presented covering range- and time-dependent infrasound propagation modeling, realization and variation of the atmospheric background conditions as well as comprehensive data analyses of a large number of infrasound stations in the area, some of them showing additional signal features possibly related to the event.

**T2.3-P26 The Annual Hungarian Seismo-Acoustic Bulletin of Ground Truth Events**

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The first infrasound array in Hungary (PSZI) started operation in May 2017. On its recordings several different natural and man-made sources have been identified, including quarry blasts, bolides, thunderstorms, volcano eruptions and microbaroms. Between June 2017 and December 2018 the Hungarian National Seismological Network recorded seismic signals from more than 1000 surface explosions in approximately 70 quarries in Hungary, Slovakia, Romania, Croatia and Austria. 25% of them was also detected by the PSZI infrasound array.
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The back-azimuth and velocity gained from the infrasound detections are used as a completion to the seismic arrivals for the relocation of these events by the iLoc location algorithm. These explosions form the core of the first Hungarian Seismo-Acoustic Bulletin which is planned to be published in February 2019. The HSAB will include all the identified seismo-acoustic and acoustic-only events detected by the PSZI array since its installation. The Central and Eastern European Infrasound Network (CEEIN) was established in 2018 and includes 6 infrasound stations in Hungary, Romania, Czechia and Austria. In case of the events recorded by more CEEIN stations all the CEEIN detections are included in the Bulletin. From 2019 the Hungarian Seismo-Acoustic Bulletin will be published yearly.

T2.3-P27  The Baumgarten and Ingolstadt Explosions: Infrasound Observations from Ground Truth Sources in Eastern Austria and Southern Germany

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Two heavy explosions occurred in Eastern Austria and Southern Germany at gas/oil facilities within less than one year, being detected at dense surrounding seismic networks and remote infrasound arrays. The Baumgarten explosion on 12 December 2017 showed clear seismoacoustic arrivals to distances of 150 km at the seismic AlpArray network and sparse, and hence weak, seismic signals, and an isolated infrasound arrival at an Hungarian array. The Ingolstadt explosion on 1 September 2018 generated clear seismic phases at the nearby Grauenberg Array (GRF) as well as AlpArray network stations to larger distances. Infrasound phases at several arrays in Central and Eastern Europe complemented these observations. In our presentation we report on the analyses of the available infrasound signals using frequency-wavenumber techniques as well as cross correlation analysis to extract relevant waveform parameters of the observed arrivals. With 3D propagation modeling using the ECMWF forecast model for atmospheric specification these parameters are validated as belonging to the respective source. Furthermore the seismic arrivals are used to estimate the seismic magnitude of each explosion to finally compare the seismic and acoustic features generated by both explosions in order to assess our capability for accurately modeling the acoustic arrivals.

T2.3-P28  Tropical Cyclones Monitoring in the Indian Ocean Basin Using Seismic and Infrasonic Stations

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Tropical cyclones occur from December to April in the South-Western of Indian Ocean. They generate both seismic and infrasonic sources, respectively secondary microseisms (SM) and microbaroms. Standing waves issued from the interaction of two swells in opposite directions with same periods generate a source of noise. Such waves generate pressure variation to the ocean floor and create seismic waves called Rayleigh waves, that may be recorded by seismic stations (at frequency band 0.1- 0.35 Hz) even at large distance (Longuet-Higgins, 1950). In the meantime, these stationary waves generate microbaroms that travel in the atmosphere and that are well recorded by infrasound stations at frequency around 0.2 Hz (Benioff & Butenberg, 1939). These two independent detections are combined to track and monitor tropical storm during their lifetime.

T2.3-P29  Understanding Seismicity Catalog and Their Problems in Zambia

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Earthquake activity in Zambia is closely associated with the Zambian Area of East Africa Rift system (EARS). Seismicity level in southern Africa is normally low. In Zambia seismicity is diffuse, earthquakes of magnitudes
Ms>5.0 may occur. Seismicity catalogues are one of the most important products of seismology. They provide a comprehensive database used to assess seismicity, applied in seismo-tectonics earthquake physics or seismic hazard analysis. Issues with investigation of seismicity in Kaputa and Nsama area were caused by lack of regional seismic stations, low frequency of earthquake occurrence in the area and problems with source azimuth and magnitude estimation.

**T2.3-P30** *Waveform and Dispersion Modeling Using DPRK Regional Seismograms Recorded by the High Sensitivity Seismic Network of Japan*

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In this study, we analyze long-period (5-20s) surface waves recorded from all DPRK nuclear explosions by the open stations of the High Sensitivity Seismic Network of Japan (HSSNJ), including the stations in region around the DPRK nuclear site. The purpose of this study is to understand the influence of the Sea of Japan (SOJ) on surface waves, the effect of multi-path due to the three-dimensional structure, and how these effects influence the source parameters determination. Both Rayleigh and Love wave dispersion curves were processed after removing the instruments response and rotating the horizontal traces. We invert the Rayleigh-wave dispersion curves using a fixed water layer on the top and those of the Love waves without. The HSSNJ stations cover an azimuthal range from 65° to about 195° over the distance range from 670 to 1465 km. We also use these surface waves to investigate source parameters i.e., the RDP (reduced displacement potential) and depths of individual explosions by implementing the waveform equalization technique. We are combining both path model and source parameters to model the P waves observed at the stations in this dataset.
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T2.4 Atmospheric and Subsurface Radionuclide Background and Dispersion

Oral Presentations

T2.4-O1 Analysis of High Time-Resolution Observations of Radioxenon Releases from BWRs Compared to Stack Data and Reactor Operation Parameters

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The newly developed SAUNA III – radioxenon system prototype has been running in Stockholm since 2016 and provided a rich data set of atmospheric radioxenon observations with 6 hour time resolution. A large part of the observed plumes originates from releases from the nuclear power plant Forsmark, located 110 km north of the system, and includes many observations/releases with three or even four isotopes. To gain better understanding of the observed plume shapes and isotopic ratios, data has been compared with stack- and other operational data provided by the plant, in combination with different atmospheric transport models as well as calculations of different nuclear production- and separation scenarios.

T2.4-O2 Application of Computational Fluid Dynamic in the Atmospheric Dispersion of Radionuclides at Fukushima Disaster

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Atmospheric dispersion modeling is used to predict radionuclide concentrations worldwide, modeling is useful to study the impact of an accident or nuclear event on the environment. This kind of simulations provides ways to find better decisions in case of some event may occur, Gaussian model is the most used model but it has some limitations as time scales and wind direction changes, while CFD is a powerful tool to calculate the concentration of particulates including parameters of wind velocity and presence of obstacles. The Fukushima disaster is one of the most significant nuclear incident since Chernobyl, a monitoring network from CTBTO Preparatory Commission, Vienna, Austria (CTBTO) found information about the spread of radioactive particles related to Fukushima accident in more than 35 radionuclei stations. This work aimed to compare the Gaussian model dispersion with Computer Fluid Dynamics (CFD) simulations and some monitory system CTBTO radionuclides data related to Fukushima disaster.

T2.4-O3 Assessment of Temporal Variations of Natural Radionuclides Beryllium-7 and Lead-212 in Surface Air in Tanay, Philippines

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Physico-chemical processes occurring in the atmosphere play an important part in the global distribution of radionuclides. In this study, radionuclide concentrations of cosmogenic and terrestrial radionuclides Beryllium-7 and Lead-212 in surface air and meteorological data collected by the CTBTO Radionuclide Monitoring Station
PHP52 in Tanay, Philippines were assessed to understand the atmospheric conditions involved in radionuclide distribution in tropical climates. Daily activity concentrations of Pb-212 and Be-7 and daily meteorological data from 2012 to 2017 were retrieved and plotted against sample collection date using Microsoft Excel and evaluated for possible correlations. Surface air concentrations of Be-7 and Pb-212 were found to range from 0.00779±0.00188 to 11.2±0.116 mBq/m3 and from 1.37±0.036 to 106.6±1.075 mBq/m3, respectively, and show a consistently similar trend annually. Positive and negative correlations were observed between radionuclide concentrations and meteorological data, supporting observations from other literature that radionuclide concentrations in surface air are affected by atmospheric conditions such as temperature, humidity, and amount of precipitation, which varies depending on the season. This is further supported by the observed annual trends on radionuclide activity concentrations which follow the dry and wet season observed in tropical climates such as the Philippines.

T2.4-O4 Contribution of All Nuclear Research Reactors to the Global Radioxenon Emission Inventory

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Radioactive xenon isotopes provide the most likely observable radioactive signatures of underground nuclear explosions. These isotopes are frequently detected by IMS noble gas systems as a result of normal operational releases from different types of nuclear facilities including nuclear power plants (NPPs) and medical isotope production facilities (MIPFs), reprocessing facilities and nuclear research reactors (NRRs). Improving the knowledge about the impact of different emission sources on IMS observations leads to strengthen the screening of radioxenon detection results. The contribution of NPPs and MIPFs to the global radioxenon emission inventory is fairly well understood. NRRs are the only source type of which contributions to IMS observations have not yet been systematically assessed. This study is the first attempt to assess the total emission inventory of nuclear research reactors expressed as annual total discharges. The results can be used for guiding future studies and enhancing the understanding of the impact of known sources on the IMS background observations.

T2.4-O5 Half a Century of Krypton-85 Measurements in the Atmosphere of Central Europe

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Large quantities of the radioactive noble gas krypton-85 (85Kr) are released into the atmosphere as a result of reprocessing of used nuclear fuel rods. Reprocessing started in the 1940s mainly to separate plutonium for military purposes. Emissions from civil reprocessing activities have steadily been increasing since and impede on the use of 85Kr as an indicator for clandestine plutonium production. For almost half a century weekly samples of surface air have been collected by the Bundesamt für Strahlenschutz (BfS), Germany, for the measurement of 85Kr. Sampling at Freiburg started in 1973, Mt Schauinsland in 1976 and Jungfraujoch in the Swiss Alps in 1990. The complete time series will be presented and discussed, as well as results from particular weeks. Weekly and average 85Kr activity concentrations in the atmosphere of Central Europe were modeled from almost 12,000 individual measurements at 11 stations and will be presented. The baseline and average have continuously increased, interrupted by a relatively stable period from 2009 to 2013. Since then 85Kr activity concentrations have increased and are currently at a baseline level of approximately 1.45 Bq/m3.
T2.4-O6 High Resolution Stack Data from Fission Based Mo-99 Production

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The Source Term Analysis of Xenon (STAX) project is a new effort to better understand the radioxenon background in the environment. This project is using high resolution stack detectors to directly measure the radioxenon emissions from fission-based Mo-99 production facilities. Currently, two experimental high purity germanium (HPGe) based detector systems reside at the Institute for Radioelements (IRE) in Fleurs Belgium and at the Australian Nuclear Science and Technology Organisation (ANSTO) in Australia, which are two of the large suppliers of worldwide Mo-99 for medical uses. Direct measurement of the four treaty relevant radioxenon isotopes (Xe-131m, Xe-133, Xe-133m and Xe-135) is being measured every fifteen minutes using these HPGe detector systems. A discussion of the detector technology and example data sets will be presented.

T2.4-O7 Measurement of Background Observations Using Mobile Detection System of Four Radioxenon Isotopes in 2017-2018

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The capability of the Mobile Detection System to detect xenon from underground nuclear explosions is dependent on the radioactive xenon background. Medical isotope production (MIP) by nuclear fission releases xenon isotopes including xenon-133 and iodine-133. The amount of xenon released from MIP facilities is equivalent to that released from an underground nuclear explosion. This work recognizes the signals of MIP emissions from a nuclear explosion using a model to calculate the Xe from MIP facilities that differs from nuclear explosion due to other accompanying isotopes. This paper is based on measuring Xe isotopes concentration in the lower atmosphere in Iraq in specific condition and the transport of these isotopes. It confirms the hypothesis that MIP facilities are at present the major emitters of radioxenon to the atmosphere. Suspension of operations of these facilities indicates the scale of their normal contribution to the Iraqi radioxenon background. This gives an opportunity to investigate the influence of other local and long distance sources on the radioxenon background. It means, comparing with past background, an increase of radioxenon (reduced from the MIP background) may refer to a nuclear explosion in air or underground.

T2.4-O8 Search for Radioxenon Signals at IMS Stations Possibly Associated with Announced DPRK Nuclear Tests

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Since the provisional operation of the International Monitoring System (IMS) started, six announced underground nuclear tests were conducted by the Democratic People's Republic of Korea (DPRK) at the Punggye-ri Nuclear Test Site. For the first test (9 October 2006) and the third one (12 February 2013), radioxenon observations were made by IMS stations that were immediately reported to State Signatories as associated with the time and location of the relevant seismic events and, therefore, consistent with the assumption that the observations are reflecting a radioxenon emission from the DPRK test site. The isotopic ratios recorded in April 2013 are considered a strong evidence for the nuclear nature of the seismic event of 12 February 2013. Further investigation by various authors with in-depth scientific analysis, partly applying new methodologies in the domain of atmospheric transport modelling, have revealed that potentially more IMS samples than initially thought may contain traces from the same hypothetical emissions that were already identified or even additional potential emissions occurred and were captured at IMS stations. The applied
The Detection of Ar-39 Above UNEs Decades Later as a Signature

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During the conduct of the Underground Nuclear Explosion Signatures Experiment (UNESE), which involved the injection of Ar-37 into UNE chimneys at the Nevada National Security Site, we detected the unanticipated presence of Ar-39 in gas samples taken from the shallow (0 – few m deep) subsurface. This long-lived UNE observable was present in all of our measurements in the vicinity of UNE sites, spanning different geologies, vertical- and horizontal-emplacement scenarios, and yields less than 20 kt. This implies that the detectability of UNEs by radionuclides at the surface is likely much longer than previously thought. The detection of Ar-39 and Ar-37 rely on low-background, internal-source proportional counters built at Pacific Northwest National Laboratory. We discuss the measurements, natural backgrounds, and implications.

Underground Nuclear Explosion Signatures Experiment (UNESE) Phase 2: Gas Migration Studies in a Tunnels Test Location

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Phase 2 of the Underground Nuclear Explosion Signatures Experiment (UNESE) included the injection of tracer gases into the chimney of a historic horizontally-emplaced nuclear test at the Nevada National Security Site. The purpose of these injections was to observe the migration of gases from the chimney to the adjacent tunnel complex and their migration within the surrounding geology. Two tracer injections occurred – one of a single stable tracer gas (freon) in January of 2018, and a second of two radioactive tracers, Ar-37 and Xe-127, and the stable tracer sulfur hexafluoride (SF6) in June 2018. Measurements were made of gas collected from multiple locations within the tunnel and two locations were monitored semi-continuously using gamma-ray detectors to measure gas recirculated from the measurement points. Samples were also collected at various depths within an adjacent borehole that was drilled from the surface to emplacement level in May and June 2018. The injections, subsequent monitoring and sample collection, and results will be presented and discussed.

Backgrounds, False Negatives and False Positives: Dealing with RN Detection in 2019

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Detection of relevant radionuclides in the International Monitoring System absent a nuclear test, and especially radioactive xenon isotopes, has been the subject of concern for over a decade. These relevant radionuclide detections are usually called "backgrounds," and they are unavoidable due to the peaceful production of radioactive isotopes and other manmade phenomena. However, how we deal with these detections has not been clearly understood. This presentation seeks to explain at a high level how the detection of backgrounds may lead to both false positive alarms and false negative results, if the detections are not understood and accounted for in some way. We will give several easy to grasp examples, as well as report on a detailed study of the false positive rate that could be seen if fission-based isotope production occurred in the United States.
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Poster Presentations

T2.4-P1  Aerosol Dynamics and Dispersion of Radioactive Particles

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Traditionally dispersion models have quite rudimentary descriptions of the processes that change the aerosol size distribution and composition throughout the transport. These processes, aerosol dynamics, include wet and dry deposition, coagulation, condensational growth, chemical interactions, nucleation of new aerosols and the interaction between the released aerosol and the ambient atmospheric aerosol. Using the trajectory box model CALM the importance of aerosol dynamics has been studied. The target of this study is to analyse the relevance of including more advanced aerosol dynamics into dispersion models that are used to track released radioactive particles. When all aerosol processes are involved a clear transformation of the radioactive particles can be seen towards the accumulation mode, approximately particles of sizes between 0.1 and 1 μm. If, for example only dry and wet deposition were modeled and the rest of the processes were left out, this is not the case. The time it takes for this transformation to occur differs from site to site and from trajectory to trajectory. However, we conclude that a certain care of addressing the aerosol processes is required especially near the sources of the dispersion.

T2.4-P2  Application of Source Detective System for a Fukushima Accident

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Some radionuclides were detected in monitoring stations in Korea from a Fukushima accident occurred in March 2011. In particular, the maximum concentrations of I-131 and Cs-137 were shown on the 6th and 7th of April at Gunsan and Busan in Korea, respectively. A source detective system has been applied to investigate the transport pathway of radionuclides measured in the air sampling in Korea from the Fukushima accident. A source detective system is composed of trajectory, atmospheric dispersion, and source term estimation models. Six stations measured in Korea were used to estimate pathway of radionuclide from the Fukushima in the early of April. From the simulations, radionuclides released into the air from the Fukushima were transported directly from April 4 to April 8. In overall, I-131 and Cs-137 reached Korea after travelling around the world due to the westerly winds from Fukushima, but some of the I-131 and Cs-137 entered the Korean Peninsula directly owing to the variations of wind during the 4th through the 8th of April. A source detective system can be used as good tools to detect unknown source regions and release rates of radionuclides released into the air from covert nuclear activities and accidents.

T2.4-P3  Argon-37 Variability in the Low Troposphere

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Argon-37 is produced in the high troposphere by spallation of argon through 40Ar(n,4n)37Ar and by neutron capture, 36Ar(n,γ) 37Ar. The resulting natural equilibrium concentration of Ar-37 in the mixed troposphere is about 0.5-1 mBq/m3. This value may define the background level for the use of Ar-37 for search area reduction by means of atmospheric Ar-37 measurements in downwind direction of a potential test area in the course of an OSI. In order to investigate long term atmospheric activity levels of Ar-37, bulk air samples were collected close to the CTBTO IMS Radionuclide station located in Takasaki, Japan. In the years 2016-2018 in total 105 air samples were taken and analyzed for their Ar-37 activity concentrations with no value exceeding 10 mBq/m3.
Slight variations are most likely caused by neutron activation of stable argon in facilities such as nuclear power plants and research reactors, venting of soil gas where Ar-37 is produced by neutron activation of Calcium or less likely Stratosphere to Troposphere (STT) transport. In this study the potential geographical source location of the air masses sampled in Japan, are determined by atmospheric transport modelling.

**T2.4-P4** *Assessment of Radionuclides Present in Atmospheric Aerosol in Dar Es Salaam, Tanzania by Using Gamma-Ray Spectrometry*

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The presence of Natural Occurring Radioactive Materials (NORMs) and artificial radionuclides in the atmosphere is of special interest to the public health. The fallout of artificial radionuclides from nuclear activities and emissions of NORMs present in the earth’s crust can access the atmosphere. The possibility of air to be contaminated with aerosols and radionuclides is very high. When these aerosols are inhaled directly or ingested through food and water, serious health problems may occur. This study aims to assess radionuclides presents in atmospheric aerosol collected from CTBTO Radionuclides station in Dar es Salaam, Tanzania by Gamma – Ray Spectrometry and background radioactivity level of the atmosphere can be established. Aerosol samples will be collected on the roof of Physics Department at University of Dar es Salaam by High volume air sampler with the flow rate of 830 m3 h-1 in discrete segments for 24 hours in one month by a filter with particulate efficiency of 80% for aerosols of ≥ 0.2μm in diameter. The results may be useful to the Government and other authorities to formulate rules and regulations for monitoring radioactivity level. Also to take action for elevated levels of activity concentration in the atmosphere.

**T2.4-P5** *Atmospheric Dispersion and Ground Level Deposition of Cs-137 Released from Chernobyl Nuclear Power Plant Accident*

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Even though many studies have been carried out to calculate the effects of the Chernobyl Nuclear Power Plant accident of 26 April 1986, even today, major uncertainties about impact of the accident exist. None of the available source term, used in atmospheric transport models, produces a good representation of the atmospheric dispersion and ground level deposition of radionuclides. In this study, atmospheric dispersion and ground level deposition of Cs-137 released from Chernobyl nuclear power plant was simulated with the Lagrangian particle dispersion model FLEXPART. The source term estimated by Evangeliou et al. (2017) was used with ECMWF and NCEP reanalysis datasets as meteorological input data. The results were visualized with the Quicklook plotting tool and then compared with each other and with the Cs-137 contamination map of Europe after the Chernobyl accident (Cs-Atlas, EC / IGCE / Roshydromet/ Minchernobyl / Belhydromet, 1998). Some differences were observed between meteorological datasets. Moreover, the comparison with Atlas demonstrated that while in some regions the Cs-137 depositions are reproduced well, while in other regions significant deviations are found.

**T2.4-P6** *Atmospheric Dispersion Assessment of Radioxenon After North Korea’s 6th Nuclear Test Using LADAS Model*

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North Korea conducted the sixth underground nuclear test on 3 September 2017 at Punggye-ri Nuclear Test Site (NTS). Since North Korean government shut down the site in 2018, this event may be the last nuclear test carried
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out at the Punggye-ri NTS. We performed atmospheric dispersion simulations on some radioxenon emission scenarios for this event using our Lagrangian Atmospheric Dose Assessment System (LADAS) model utilizing Numerical Weather Prediction (NWP) data based on the Unified Model (UM) produced by the Korea Meteorological Administration (KMA). Also, for explosion information such as location and estimated test yield, we followed announcement of KMA. For the case of immediate radioxenon emission, it was expected that a near surface radioxenon plume passed to northeast through Chongjin and Rason in North Korea and, after 5 September, arrived at Hokkaido in Japan via Vladivostok in Primorsky Krai in Russia and northeast of the East Sea. Therefore, for this event, radioxenon was undetectable in Korea and southern Japan. The RUX58 station, one of the International Monitoring System (IMS) stations operated by the Comprehensive Nuclear-Test-Ban-Treaty Organization (CTBTO), was expected as a strong candidate for detection of radioxenon but unfortunately it was not on normal operation at that time.

T 2.4-P8  Atmospheric Dispersion for Gaussian Straight Line Plume Model During Normal & Accidental Release

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The first step in the process of dose evaluation is the computation of air concentration of the released radio nuclides using appropriate atmospheric dispersion models. Ground contamination level due to dry and wet deposition can also be computed for such models. The second step is to compute inhalation, immersion and external gamma doses due to the passage of the plume (in case of continuous and short time release). This requires the use of an appropriate dosimetric model. Also the ingestion dose due to ground contamination needs the use of an appropriate environmental model. In practice computation of air concentration and ground contamination uses input data on source term, meteorological data and site characteristics. The dose can then be computed easily by multiplying the (time integrated) concentration by precalculated dose factors for the particular nuclides and route. Typical input information required for the first step – are the source term which specifies the quantity of nuclides and the mode of release (height, velocity, etc.). Meteorological parameters, the concentration and doses are directly proportional to source strength and inversely to the wind. Once the plume enters the atmosphere it is subject to transport by wind and diffusion. Atmospheric dispersion is then the combination of transport and diffusion.

T 2.4-P10  Atmospheric Dispersion of Radionuclides Originating from Hypothetical Accidents and Normal Operation in Research Reactors and Medical Production Facilities

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Analytical and Commercial Gaussian Plume Dispersion Models are used at INVAP as an efficient tool for the design and optimization of Research Reactors, Medical Production Facilities (MIPFs) and Fuel Elements Manufacturing Plants, already operations in different countries. INVAP has relevant experience related to the atmosphere radionuclide emission, monitoring and mitigation, at each stage of the design of nuclear facilities. In this work, results of emission from Normal Operation and different examples of hypothetical accidents, considered in Preliminary and Detailed Design Stages, for Research Reactors and MIPFs, are presented. The different contributions of the radionuclides released to the atmosphere are analyzed, in the frame of International and National Regulatory requirements. The contribution from Noble Gases, Iodine/Bromine and Aerosols are presented and evaluated also from a radio-protection point of view.
T2.4-P11  Atmospheric Dispersion of Radionuclides Originating from Hypothetical Accidents at Rooppur Nuclear Power Plants in Bangladesh

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Nuclear power is considered as one of energy sources in electricity generation. Although nuclear power is considered to be economically beneficial, it has serious risks for environmental and human health due to various nuclear accidents like Chernobyl and Fukushima. The Fukushima Nuclear Accident resulted in a large amount of radionuclides released into the atmosphere, which has greatly raised public concerns. The atmospheric impacts of the nuclear accidents were evaluated by many researchers from three aspects including radioactive baseline of the atmosphere, the concentration limits in standards and radiological protection. Bangladesh is going to build two nuclear power plants at Rooppur site. Different accident scenarios were considered to assess potential consequences of a nuclear accident under distinct atmospheric conditions. Among the main background sources, there are Nuclear Power Plants (NPPs), which may release Xenon radioisotopes during normal operation. In this study, atmospheric dispersion model is presented for the evaluation of radioxenon release to the atmosphere and to evaluate the health impact of other radionuclide emissions, like: Cs-137, I-131, Kr-85 and Kr-88. The atmospheric dispersion of these radionuclides to be released from potential nuclear accidents in Rooppur nuclear power plants were modeled and total ground deposition of these radionuclides were estimated.

T2.4-P12  Atmospheric Radioactivity Over State of Kuwait: Fission and Activation Radionuclides Availability and Concentrations During the Last Five Years

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The State of Kuwait signed the Comprehensive Nuclear-Test-Ban Treaty (CTBT) in 1996, and the signature was ratified in May 2003. The Treat specifies one Kuwait-based Radionuclide Station RN40 (KW40). The task of KWP40 is to gather data on radionuclides and to provide such data to the IDC. The station monitors a lot of fission and activation products and the topic of this study is therefore to consider fission and activation product availability, frequencies and concentrations using the data gathered by the station. This study also looks at the key fission and activation radionuclides which are above abnormal levels in the air (level 4 and 5) and compares its ratios between the last five years and assesses its causes.

T2.4-P13  Atmospheric Transport Modelling for Dispersion Conditions After the DPRK 2017 Nuclear Test and the Origin of Regional Xenon Detections

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For the definite proof of the nuclear origin of an explosion it is necessary that traces of radioactive fission products are released into the atmosphere and measured by radionuclide monitoring stations. The nuclear explosion conducted and announced by the DPRK on 3rd September 2017 was the strongest so far as the seismological analysis shows (see other presentations). The dispersion of potential releases emitted after the September 2017 explosion is investigated using the Lagrangian Particle Dispersion Model HYSPLIT operated in forward mode with GFS/GDAS meteorological data provided by NCEP. In the weeks after the DPRK test explosion occasionally the radioactive isotope xenon-133 was measured at various locations in the region by national means of South Korea. If measured without other isotopes xenon-133 is not specific for nuclear explosions as it is also produced by other nuclear facilities. Backward Atmospheric Transport Modelling is used to assess the potential source regions of those detections. Most of the xenon-133 occurrences in September 2017 seem to originate from background sources but some in October at the IMS station RNS8 according to atmospheric backtracking may have emerged from the DPRK test cavity by a small delayed leakage.
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**T2.4-P14 Atmospheric Transport Study of Japan Noble Gas Systems**

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Understanding atmospheric xenon backgrounds is of paramount importance in interpreting IMS xenon data, specifically in screening out uninteresting sources and detecting/locating interesting sources. We simulated atmospheric transport near JPX38 (Takasaki, Japan) to determine the kinds of impact that the limited term regional network of systems there could have on interpreting JPX38 data, even after the temporary network is removed. The key is to simulate detection of known backgrounds and possible interesting sources, then compare to measured backgrounds to extrapolate how well a future unknown xenon source could be detected, located, and nuisance backgrounds screened out.

**T2.4-P15 Backward Atmospheric Transport Modelling Coincidence Localization of Single Sources and Repeating Emitters**

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In the framework of CTBT monitoring the application of atmospheric Lagrangian Particle Dispersion Models is well established to confine source regions of radionuclide detections. For that Source Receptor Sensitivity (SRS) fields are regularly calculated in backward mode for air samples. Various localization approaches for combining SRS fields for detections at multiple stations caused by an assumed single source in space and time were introduced over the last decade. Especially a simple additive coincidence approach overlapping SRS fields for multiple detections has shown to be quite promising in several test cases. This method was expanded to evaluate source regions of repeating xenon detections at single stations. The simulated source regions of air samples with elevated xenon-133 activity concentrations are stacked in space in order to evaluate a region of potential common origin. Examples from recent years are shown for different IMS radionuclide stations. Especially highlighted is the potential source area of recent radionuclide activity concentration peaks at the German station RN33, Schauinsland, which is operated by BfS.

**T2.4-P16 Characterization and Evolution of Global Xe Background Between 2016 and 2018**

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Monitoring atmospheric xenonis is essential for confirming an underground nuclear weapon test. Accordingly, it is crucial to the international monitoring system (IMS) of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) to monitor xenon worldwide. Four of the xenon isotopes are of interest for CTBT verification; 131mXe, 133mXe, 133Xe and 135Xe. In a nuclear explosion, the four isotopes are produced in sufficient quantities and have half-lives long enough to allow an appreciable amount to travel and reach IMS xenon stations. Therefore, understanding the xenon background at the IMS stations is important to CTBT verification process. In this work, a comparative study between the global xenon background in 2016, 2017 and 2018 is conducted to determine the evolution of Xe background for all the available IMS stations. The stations with pronounced changes in its Xe background were identified and the ratios between different Xe isotopes were calculated and analyzed.
T2.4-P18  Development of Compact Xenon Adsorption System for Medical Radioisotope Production Facilities to Mitigate Global Radioxenon Background

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KAERI launched new research reactor project in 2012. The project covers reactor and fission-based medical radioisotope production facilities. Research activities related with fission Mo-99 target and process development have been also initiated in 2012 in Korea. In this report, management scheme for the xenon and iodine emission from the fission Mo-99 process was presented. Additionally, KAERI’s contribution to the development of compact xenon reduction system was presented. Concept and experimental data of the prototype xenon reduction systems with chilled activated carbon column was exhibited. Based on the result, new system has been designed and fabricated with integrated gas mixer and cryogenic cooler in the carbon column. Finally, conceptual design of the practical in-cell xenon reduction system was presented to be installed as an installation in the KAERI’s new research reactor was proposed. Developed xenon mitigation system will contribute to minimize global and local radioxenon background originated from the medical radioisotope facilities, such as fission Mo-99 production facilities.

T2.4-P19  Devices to Reduce Emission of Radioactive Noble Gases via Hydrogen

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The Fission Radioisotope Production Plant of Argentina, located at the Ezeiza Atomic Center, produces Mo-99 since 1985, irradiating targets with High Enrichment Uranium. In 2002 the targets have been changed by Low Enrichment Uranium. Facilities that produce radioisotopes by fission are considered one of the largest emitters of radioactive noble gases into the environment. The increase of the background of radioactive noble gases and particularly the Xe-133 does not favor the rapid detection of an undeclared nuclear explosion, a task carried out by the monitoring stations of the CTBTO in different parts of the planet. The poster describes the process of production of radioisotopes by fission, the dissolution of the targets with uranium in an alkaline medium and the generation of hydrogen. The emission of noble gases via hydrogen will be analyzed, the different devices to retain it and/or reduce it and a comparative study of them, its characteristics, advantages and disadvantages.

T2.4-P20  ECMWF Data Sets as Input for the ATM FLEXPART Prepared by a New Version of the flex_extract Tool

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A tool called flex_extract has been developed over many years, partly on behalf of the CTBTO/PTS, to retrieve meteorological data from ECMWF’s MARS archive for driving FLEXPART or the WRF model. Its functionality includes the generation and execution of MARS requests, calculation of the vertical winds for FLEXPART, and transformation to a latitude-longitude grid. Additionally, it disaggregates accumulated flux data, such as precipitation, and prepares the final FLEXPART input files. In 2018, several changes occurred with respect to ECMWF data, such as the replacement of grib_api by ecCodes, of emoslib by the new interpolation library MARS-MIR, and also in the Web API. Furthermore, more data can now be accessed by non-member-state users. The latest reanalysis, ERA5, with many improvements compared to the previous ERA-Interim, is currently available from 1979 on. The diversity of data sets, the possible combinations of MARS request settings and ways of accessing MARS can be confusing for less experienced users. Therefore, an overview of the available ECMWF data sets and the ways how they can be accessed with the latest version of flex_extract is presented.
T2.4-P21  Establishment of the National Baseline Using Data from IDC

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The radionuclide levels from the selected IMS stations have been studied, in order to establish the national baselines. The study has focused on specific radionuclides including nuclides from medical production and fission products from nuclear reactors or nuclear power plants, as well as existing particulate and gaseous nuclides from nuclear tests from the past. The data obtained from IDC products for the region of East Asia have been analyzed from year 2010. Then, geostatistic analysis has been performed to study the probability distributions of the radiation from the nuclides of interest across the country. The radiation baselines will be used as a new measure supporting the decision making in case of nuclear incidents in the region.

T2.4-P22  Estimation of the CTBT-Relevant Radionuclides Sources by Ensemble Adjoint Atmospheric Transport Modeling

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This work describes the recent development of Egyptian-NDC approach for the source estimation of CTBT-Relevant Radionuclides (RN) by using an ensemble of Adjoint atmospheric transport and dispersion modeling (ATM). A new deterministic method is developed for simultaneous estimation of the possible source location, time of release, and source strength. This method is based on the least square linear regression. The verification of this method, in case of a simplified perfect adjoint ATM and error-free concentrations measurements, shows that the method provides the exact source parameters. Since, in the real atmospheric dispersion of RN, there are many sources of uncertainty, and the deterministic methods fail. Therefore a system of ensemble adjoint ATM and Bayesian inference approach was developed to address the uncertainty in the source term estimation. Some examples by using synthetic measurements experiments, for real atmospheric conditions, illustrate the ability of this combined method to retrieve the possible source parameters and quantify the uncertainty in this estimation. This approach is currently running over regional scale due to the lack of computing power, but it is applicable also to global scale.

T2.4-P23  Estimation of Xenon Background for the IMS Stations Located in the Pacific Ocean

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In the process of verification whether a given detection can be caused by an event like a nuclear explosion, the knowledge about civil sources like nuclear power plants or isotope production facilities is extremely important because they contribute to the background signal. To estimate the xenon background the Atmospheric Transport Modelling (ATM) results were combined with Xe-133 observations. The study period covers 9 months, from April to December 2014. This study shows the monthly changes in the Xe-133 background for 3 IMS stations: JPX 38 in Takasaki, Japan, USX 77 in Wake Island and USX 79 in Oahu, Hawaii. It is demonstrated that NPP emissions can significantly contribute to the Xe-133 measurements even at remote locations like IMS stations USX 77 in Wake Island or USX 79 in Oahu, Hawaii.
Fractional Release of Argon from Activated Rocks and Powders

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Neutron activation products, such as Ar-37 and Ar-39, comprise an important component of the radionuclide signature from an underground nuclear explosion (UNE). While the production of activation products from a UNE can be predicted based on relevant cross-sections and geologic composition, uncertainty still remains as to what fraction of the activation products are released from the geologic matrix into air-filled pore space - the emanation fraction. A system was developed at Pacific Northwest National Laboratory to quantify the emanation fraction of argon from samples ranging in size from powder to small (multiple centimeter) rocks. To date, seven materials, two powders and five rock types, have been irradiated with neutrons and the emanation fraction of Ar-37 been measured. Additionally, the emanation of Ar-39 for four of those materials was also measured. These measured emanation fractions of both Ar-37 and Ar-39 will be presented along with a brief description of the system used to measure them.

Global Observations of Radioiodine by the CTBT International Monitoring System

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For the purpose of global monitoring for nuclear explosion signatures under the Comprehensive Nuclear-Test-Ban Treaty (CTBT), a unique International Monitoring System (IMS) with 80 radionuclide stations is being established. The daily samples are analysed with focus on the 83 CTBT-relevant radionuclides including I-130, I-131, I-133 and I-135, being all fission products. In addition, separate systems of noble gas detectors at initially 40 sites analyse the atmospheric air for radioxenon isotopes of interest. I-131 is of special interest for nuclear explosion monitoring because it is a direct precursor of Xe-131m that is most relevant for possible detection of underground nuclear tests. This paper summarizes the observations made at all IMS stations since their beginning of operation. It discusses the trends and global radioiodine distributions with a special emphasis on the nuclear debris observed as a consequence of the Fukushima accident when multiple radioiodine isotopes were observed, including I-132. The implications of radioiodine observations for CTBT verification are investigated. The isotopic activity ratios are an opportunity to distinguish nuclear explosion signatures from normal anthropogenic background.

Global Radioxenon Emission Inventory for 2014 by Normal Operational Releases from Nuclear Power Plants and Medical Isotope Production Facilities

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Global radioactivity monitoring for the verification of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) includes the four xenon isotopes 131mXe, 133Xe, 133mXe and 135Xe. These four isotopes are serving as important indicators of nuclear explosions. Various peer-reviewed publications establish the global radioxenon emission inventory by normal operational releases from certain types of facilities: nuclear power plants, medical isotope production facilities, and most recently also for nuclear research reactors. The integrated emission inventory presented here collects the best estimates for all relevant sources world-wide. As much as possible it presents the real 2014 emissions with variations over time as reported by the facility operators. Otherwise, it applies the best available estimated for a generic year. This emission inventory can be used for source-receptor studies with atmospheric transport models and for comparing the simulated and observed radioxenon concentrations at the locations of the noble gas systems that are part of the CTBT International Monitoring System (IMS). The purpose is to provide a scientific solid data set to be used for calibration of screening IMS noble gas observations and to assess the performance of IMS stations.
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T2.4-P28 Hemispheric Atmospheric Dispersion Analysis of Radionuclides Released from the Fukushima Daiichi Nuclear Power Plant

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We analyzed hemispherical atmospheric dispersion of Cs-137 released from the Fukushima Daiichi Nuclear Power Plant (FDNPP) due to the accident in March 2011, by comparing simulations with observation data from CTBT International Monitoring Systems. We used WSPEEDI-II (Worldwide version of System for Prediction of Environmental Emergency Dose Information version II), which consists of the atmospheric dynamic model WRF and particle dispersion model GEAR, developed by Japan Atomic Energy Agency for atmospheric dispersion simulations. It was shown in our simulations that calculated Cs-137 concentrations generally agreed well with the measurements. By using atmospheric dispersion simulations with limited release period, we investigated release time of Cs-137 observed at CTBT stations. It was found that the Cs-137 released from March 14 to 14 was dispersed almost all over the northern hemisphere and the most of Cs-137 observed in Europe is due to the release during this period. Meanwhile, the Cs-137 released from March 17 to 19 mainly reached around the Pacific Islands area and the West Coast of the USA. These results might be useful for re-estimation of the release amount of Cs-137 from the FDNPP.

T2.4-P29 How the UK National Data Centre Utilises Stack Monitoring Data in Support of the Comprehensive Nuclear-Test-Ban Treaty

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The Comprehensive Nuclear-Test-Ban Treaty (CTBTO) International Monitoring System (IMS) provides a network of 120 Radionuclide detection systems, strategically positioned around the globe with the aim of detecting radionuclide emissions from nuclear explosions. Scientists at the UK National Data Centre (NDC) based at AWE Aldermaston, work to support the UK’s obligation to The Treaty by monitoring the IMS, providing expert interpretation and advice to the UK government. This talk covers recent developments in radiometric data analysis for particulate and noble gas radionuclides - specifically an automated atmospheric transport modelling (ATM) pipeline utilising prototype stack monitoring data from IRE as part of the STAX project.

T2.4-P30 Impact of CRL Shutdown on CTBTO North-American Noble Gas Stations

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The monitoring of atmospheric radioxenon is a key aspect of the unambiguous identification of an underground nuclear explosion by the CTBTO. However, the detection capability of the CTBTO’s noble gas network is impacted by the presence of a radioxenon background produced by nuclear civil activities. Radiopharmaceuticals production facilities have been identified in the past as significant contributors to the radioxenon background. Despite their very limited number, their releases during normal routine operations can be up to several orders of magnitude above those attributed to other civil nuclear facilities. On 1st of November 2016, the NRU multipurpose reactor in Chalk River Nuclear Labs halted production of medical radioisotopes. The cessation of the production affords a special opportunity to assess the impact of the releases on the detection at some North-American noble gas stations of the CTBTO network. ATM is used as a supporting tool to identify the measurements associated with the emissions from NRU. Preliminary results showing this impact are discussed.
T2.4-P31 **Impacts of the Thorium-Based Nuclear Fuels to the CTBTO Monitoring System**

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As the development of thorium-based nuclear fuels for long-term sustainability of electricity generation have reached a step to closer commercial approval in some countries, the future impacts to the CTBTO's radionuclide monitoring regime need to be taken into account. Its potential sources of radioxenon and other fission products are a real challenge and need to be considered. We have made initial estimation of the products through fission yields of 233U and 235U data. To support and validate this analysis we have made measurement and analysis of 233U from irradiated 0.1g ThO2 samples by using the fission-induced delayed neutron counting method. The amounts of 233U produced was 17.2 +/- 1.9 µg after 50 hours irradiation by the Kartini reactor at an average neutron flux of $10^{13}$ n cm$^{-2}$ s$^{-1}$, cooled down for 55 days, and re-irradiated for 100 hours. This value is in a good agreement with the measurement results through the strongest gamma line of 233Pa by using a gamma spectrometry system i.e $(16.8 +/- 1.2$ µg) and with the calculated amounts of 233U using ORIGEN2 computer code (14.3 µg). For better estimation, the ThO2 samples will be re-irradiated again by the Siwabessy reactor at neutron flux of $10^{14}$ n cm$^{-2}$ s$^{-1}$. In future activities, the 135Xe and 233Pa build-up of thorium based fuel will be analyzed.

T2.4-P32 **Impacts of Tropical Climate on Radioactivity Measurement in Particles Collected at the Recently Certified RN65, Thailand**

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It has been widely known that climate factors such as ambient temperature potentially influence transportation of particles and gases in surface air and soil. This impact is even larger under circumstances of extreme climate in the tropical zone. IMS Radionuclide and Noble Gas monitoring stations are operated by sampling particulates and gases at surface air level. This could be affected by those factors resulting in fluctuation of background radioactivity measured from gamma-emitting radionuclides and Minimum Detectable Concentration (MDC). This study aims to reveal impacts of tropical climate factors including ambient temperature and humidity on background radioactivity levels of interested radionuclides. The results obtained from this work would be used for more accurate analysis and more reliable interpretation of gamma spectrum gain from the newly certified RN65 and other stations located in the tropical area. In addition, these high-quality scientific data would help strengthen the environmental radioactivity databases at the national and international levels.

T2.4-P33 **Inhalation Dose Assessment of 212Pb and 7Be Using Data of IMS RN65**

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Every year during December and January high pressure covers the capital of Thailand and provinces in the central part resulting the air ventilation is limited in vertical direction. Air pollution occurring in Bangkok has been horizontal flown to neighbor provinces including Nakhon Pathom where RN65 located. Very high density of PM 2.5 dust has been continuously reported by the Pollution Control Department. Health problems experienced by people due to dust inhalation increased significantly. Internal exposure dose from inhalation of dust attached with natural radionuclides is also expected to be increased in areas of dust pollution. Activity concentrations of natural radionuclides such as 7Be and 212Pb reported in RRR during the period are used for assessing the inhalation dose for people living near the RN65 station. Finally, statistical analysis of 7Be and 212FPb activity concentrations with interesting factors were analysed and reported in this study.
T 2.4-P34  Introducing Geomechanics and Discrete Fracture Capabilities into STOMP to Understand the First 10-100m of UNE Signal Transport

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Substantial effort has gone into research on the evolution of underground nuclear explosion (UNE) signatures within the subsurface and above ground environments as a result of natural, relatively slow transport mechanisms. Dynamics of signature evolution in the subsurface just after UNE detonation (e.g. fractionation of volatile noble gas precursors) have been increasingly demonstrated to have critical influence in determining eventual noble gas signatures exploited by monitoring technologies. Traditionally, subsurface transport modeling using the Subsurface Transport Over Multiple Phases (STOMP) code and other similar simulators have largely treated the early-time UNE environment very simplistically as an ill-defined, high temperature and pressure "energy pill" or have even begun simulations with some generic initial distribution of the radionuclides under the assumption that the early time dynamics took place rapidly and have concluded. In an effort to bridge this gap in UNE signature simulation capability, geomechanical and discrete fracture simulation capabilities have been implemented in STOMP to more directly assess the impact of early time rock damage and high temperature and pressure induced transport on UNE signature evolution. An overview of these implementations along with results of initial scenario simulations and projected future work will be presented.

T 2.4-P35  Inverse Modelling Applied to the Xe-133 Background

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Inverse atmospheric transport modelling allows to locate the origin of airborne radionuclides. Worldwide, the International Monitoring System (IMS) monitors for the presence of specific airborne radionuclides in order to verify compliance with the Comprehensive Nuclear-Test-Ban Treaty. Certain radioactive noble gases such as Xe-133 are attractive tracers as they are more likely to be detected after an underground nuclear explosion than particulates. The regular IMS detections of Xe-133 that originate from civil sources, in particular medical isotope production facilities, complicate Treaty verification. In this study, we make use of these Xe-133 detections (and non-detections) at specific stations in the Northern Hemisphere and apply inverse modelling. We compare the results, such as location and emission, with the properties of a major medical isotope production facility. As such, our study allows to test the inverse modelling capability in a real-world environment, with a single dominant source but where detections are contaminated by contributions from other radioxenon emitters, in particular other medical isotope production facilities and nuclear power plants. We have selected several time-consecutive cases covering a long period of time. Therefore, our results benefit from a wider applicability compared to studies dealing with a specific case only.

T 2.4-P36  Investigation of Emission of 37Ar from All Nuclear Research Reactors Worldwide

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37Ar is an indicator of an underground nuclear explosion on-site inspection. This radioisotope is produced via 40Ca (n, α) 37Ar reaction through neutron activation of 40Ca included in the rocks near to the nuclear explosion location. The relatively long half-life of 35 days compared to short-lived CTBT-relevant radioxenon isotopes results into 37Ar activity becoming stronger than radioxenon activity approximately 50 days post-detonation. In addition to nuclear explosions, 37Ar can also be produced via neutron activation of air within a neutron emitting facility such as nuclear power plants or research reactors. In recent years, efforts were started to investigate the contribution of specific sources to the radiargon background. In this presentation, the emission of 37Ar from
research reactors is investigated based on specific reactors and then extrapolated to all nuclear research reactors worldwide.

T2.4-P37 Investigation of Specific Historical Radioxenon Background Detections in the IMS

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The noble gas component of the IMS has considerably grown and improved since the certification of the first noble gas system. Since then, additional noble gas systems were certified in the IMS and are continuously sampling and measuring radioxenon in the atmosphere. During the operation of these systems, a worldwide radioxenon background originating from civilian facilities has been observed, which is composed especially of Xe-133. This worldwide civilian radioxenon background makes the CTBT verification work of NDCs very challenging. In some regions of the world, the noble gas systems are detecting Xe-133 almost every day. This high radioxenon background is blurring and limiting the detection capability, for CTBT related events, of the noble gas component of the IMS. It is thus crucial to understand the radioxenon background observed by each system so as to allow a better discrimination between potentially CTBT related detections and the detections from the civilian background. In this study, the radioxenon background detections at CA X17 are used as a benchmark case to test different alternative approaches to the current use of the operational SRS fields provided by the IDC. These approaches are then applied to specific IMS systems where the radioxenon background sources are not well known.

T2.4-P38 Isotopic Signature of Radioargon Released from the FRM-II Reactor

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Both radioargon isotopes 37Ar and 39Ar could be useful signatures for an underground nuclear explosion (UNE). Therefore, an On-Site Inspection team will sample and analyse soil gas to verify compliance with the Comprehensive Nuclear-Test-Ban Treaty once it has entered into force. This report studies the potential interferences of a civilian facility on both radioargon isotopes by calculating the annual releases and evolution of the isotopic ratio at a research reactor. It is also focusing on the time variation of the stack emissions and isotopic ratios. Prior to release, the hot water layer system and mechanisms of diffusion are affecting the radioargon ratios. Analysis of the 37Ar to 39Ar found that similarly to an UNE the ratio is mainly a function of both half-life ratios. 39Ar stack releases are very low compared to other argon isotopes. Therefore, the impact on the background is believed to be limited to the vicinity of the nuclear facility. On the other hand, considering that the first nuclear test took place in 1945, 39Ar due to its long half-life can be utilised as a signature for legacy test sites.

T2.4-P39 Magmas in Nuclear Cavities and Their Potential Effects on the Source Term and Its Migration

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Underground nuclear explosions lead to the formation of cavities partly filled with magma contributed by the surrounding volatilized rocks during cooling. The distribution of magma inside a given cavity depends on its viscosity, on the relative density of the rocks incorporated from the rubble zone and on the thermal evolution of
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The cavity. Bubbles and foam can form, creating pumice-like zones of melt under certain circumstances. The potential interactions of the fission products with the magma, their trapping in bubbles and their transport through a complex matrix made of blocks of rocks surrounded in part by some bubble-bearing magma are evaluated here in order to determine whether this is likely to diminish the activity or modify the source term and the fraction of it that is eventually released to the atmosphere.

**T 2.4-P40 Measurement of Radioargon and Radioxenon in Soil Gas**

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The most important indicators for a UNE during an OSi are the radioactive xenon isotopes X-e-131m, X-e-133 and X-e-133m and the radioactive argon isotope Ar-37. In the assessment of a detection of these nuclides it is important to have knowledge about the levels that can be expected due to the natural background. Therefore, it is interesting to measure the background levels of radioxenon and radiogeo in soil gas, along with other components (i.e. radon, CO₂, O₂). The relationship between these constituents are also of interest. Sub soil sampling has been carried out in the region of Kvarntorp (Sweden), a location with known elevated uranium content in the ground. Almost 40 samples has been taken from ten different sites. The preliminary results from analyzing these will be presented.

**T 2.4-P41 Medical Isotope Production in Argentina: Status of the Construction of Ra-10 Research Reactor**

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The RA-10 M multipurpose Argentine Nuclear Reactor Project is located at the Ezeiza Atomic Center, near Buenos Aires city. The construction license for this facility has been granted by ARN in 2014 and the building has started in 2016. This modern reactor is conceived as a multipurpose facility suitable for radioisotopes production, materials and fuel irradiation and neutron techniques applications. The planned expansion of radioisotopes production will put the National Atomic Energy Commission in the ranking of large-scale producers in the global market. Neutron techniques will allow the developing of fuel elements for research reactors and biotechnology and radiopharmacy studies among others. Argentina leads the OPAL Project, which follows the technological evolution of research reactors for the production of radioisotopes, like the one that was built in 2007 in Australia. The RA-10 is a 30 MW power reactor. The reactor design is open pool type and fuel elements with low enrichment low-enriched uranium. The initial operation license is planned for the second half of 2020. To calculate the radionuclide discharges, the ARN uses optimized discharge values following the philosophy of "as low as reasonably achievable concept". The producer has the responsibility for evaluating the necessary improvement in engineering to minimize them.

**T 2.4-P42 Model-Based Assessment of Radionuclide Migration in the Geosphere by Using Different Type of Data - Northern Bulgaria Case Study**

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Modeling of radionuclide transport is concerned as a key issue of the evaluation of environmental and people safety in connection with eventual release of radionuclides into the geosphere. The classical assessment of the transport is based on convection-diffusion equation (CDE), which terms describe mathematically the infiltration and solute transport into the soils. In the most cases considering variably saturated medium, the infiltration rate is the leading force of the radionuclides movement. There are different methods of estimation of the infiltration rate, e.g. by direct measurements with lysimeters, by expert’s decision based on the annual precipitation or by
water-balanced models. The aim of the study is to represent an approach for assessment of vertical migration of key radionuclides from the soil surface subject to differently determined infiltration rates, i.e. by expert’s choice over literature data, and by in situ measurements of meteorological data (water balance approach) both for the case of Northern Bulgaria including the vicinity of Kozloduy NPP. The results from the simulations are analyzed from the viewpoint of the radionuclide flux extend in the soil and respectfully from the environmental and human risk prediction.

T2.4-P43 Nb-95 and Zr-95 Background from IMS Particles Stations

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This work focuses on detections of Nb-95 and Zr-95 from particles stations of International Monitoring Stations IMS. These two isotopes are part of relevant radionuclides of CTBT and are sometimes detected. The mapping of this background and the analysis of their time series level is a helpful tool that can be used to characterize the activity background of both parent-daughter radionuclides in the world.

T2.4-P44 Noble Gas Signature Adsorption in a UNE - Bridging the Gap Between Laboratory and Field Scale Models

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In an effort to better understand the processes that impact noble gas transport in the subsurface, the Underground Nuclear Explosion Signatures Experiment (UNESE) conducted multiple field campaigns in which tracers such as Xe-127, Ar-37 and chemical surrogates were released underground and monitored as they migrated toward the surface. A significant result was that the tracers reached sampling locations with different dilutions, indicating that these "largely non-interacting" gases were being differentially influenced by the environment. These results have spurred a number of laboratory scale experiment efforts to improve models of how UNE-relevant noble gases and common surrogates interact with geologic material under variable conditions. This presentation focuses on bridging the gap between models based on small-, even pore-scale transport physics and field-scale radionuclide signature migration models. Specifically, laboratory experiments demonstrating the capacity of volcanic tuff to variably adsorb xenon and argon gas versus chemical surrogates are used to inform field-scale models and ultimately depict how even small effects can result in large radionuclide signature discrepancies over large distances.

T2.4-P45 Plants as Indicators of Radioactive Contamination at Nuclear Test Sites

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In some cases, after conducting a nuclear test can be carried out the necessary measures to eliminate surface contamination due to which radionuclides will be buried under the bulk of anthropogenic soil. In this situation, the traditional methods used to obtain evidence of the fact of nuclear testing would be inadequate. Additionally, due to the natural migration of radionuclides with groundwater can be increased area of contamination. Indicators of radioactive contamination of the buried layers of soil and groundwater can serve plants with deep penetrating roots that can accumulate radionuclides. The authors present the results of research conducted at the Semipalatinsk test site in the area of tunnels for underground nuclear testing. The specific activity of Cs-137 (=1000 Bq/kg) in plants of about tunnels in some cases higher than in the surface layer of soil (=100 Bq/kg). The maximum content of Sr-90 (350 Bq/kg), Pu-239+240 (13 Bq/kg), Cs-137 (6.7 Bq/kg) in plants is higher than in groundwater – Sr-90 (14 Bq/kg), Pu-239+240 (0.002 Bq/kg), Cs-137 (<0.03 Bq/kg). Thus, it is shown that the
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plants in this case are indicators of contamination of the buried layers of soil and groundwater and can be used to identify the locations of nuclear tests.

T 2.4-P46 Progress over 2014 Baseline on the Match Between Observations and Simulations of Radioxenon Concentrations at IMS Stations

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Normal operational releases of radioxenon make the discrimination between radioxenon detections from civil nuclear applications and from nuclear testing a very complex task. The objective on the short to medium term is to develop algorithms and tools that facilitate the understanding of the background. The longer-term vision is to eventually develop robust methodologies for determining to what extent radioxenon detections at International Monitoring System (IMS) stations can be explained based on the impact of civil sources. The 2014 baseline is updated in two ways. On one hand, the radioxenon emission inventory has been updated. On the other hand, observed radioxenon activity concentrations at the IMS noble gas sites have been further reviewed. The update involves offline reprocessing of the spectral data using a new NCC configuration. The potential xenon contribution from civil sources was estimated using the output of Atmospheric Transport Modelling (ATM) so called source-receptor-sensitivity (SRS) fields. The presentation compiles achieved results for simulated concentration estimates and observations at IMS stations. The statistical analysis of simulated vs. observed data is repeated and compared with the 2014 baseline that was set in a previously published study.

T 2.4-P48 Radioactivity Characteristics of Atmospheric Aerosol Samples in Guangzhou

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Aerosol radioactivity analysis plays an important role in environmental radiation monitoring. The set up of CNP22 in Guangzhou, China allows station operators to log in a continuous radioactivity data and find radioactivity characteristics. The concentrations of Pb-210 and Be-7 give seasonal variation and show a maximum in winter times. A relationship between Pb-210, Be-7 and PM 10, PM 2.5 were analyzed.

T 2.4-P49 Radionuclides Monitoring Along the Brazilian Coast

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The Brazilian Navy is monitoring the concentration of the radionuclides Cesium 137 and Strontium 90 in samples of water, sediment, fish, and mussels from the marine environment along the Brazilian Coast since 1996. The aim of this work is to establish the background of these radionuclides to assess possible increase of the values due to human activities with nuclear test, nuclear power station accident or other event. The results are stored in a database at the Admiral Paulo Moreira Marine Research Institute. Twenty three sites are annually monitored, between the latitudes of 0° 36‘ 49”S and 32° 02‘ 06”S and longitudes of 34° 50‘ 0”W and 52° 05‘ 55” W. The highest values of Cesium 137 measured were 4.1 Bq.m-3 in seawater at Atafona, in 2001; 4.14 Bq.kg-1 in the sediment at Santos, in 1998; 1.72 Bq.kg-1 in fish at Macae, in 2000; and 1.75 Bq.kg-1 in mussels at Angra dos Reis, in 2000. The highest values of Strontium 90 measured were 0.23 Bq.kg-1 in fish at Santos, in 2000 and 0.175 Bq.kg-1 in mussels at Vitoria, in 2006. The only source known of these radionuclides is probably from the nuclear atmospheric tests made before the end of the II World War.
T2.4-P50 Revisiting Assessment of Radioactive Gases Emanated in the Storage Area of Spent Nuclear Fuel at BN-350 Reactor

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A comprehensive radiation assessment and possible long-term predictive estimates of the radiation situation at places of long-term storage require oversight of radioactive gas emanation. For this reason it is necessary to develop and implement respective recommendations for research and future oversight of the content of radioactive gases in air of SNF storage areas. Experimental research was undertaken to fulfill the task that was set during IVG.1.M physical start-ups. Air was sampled from the conduit of reactor ventilation system using two devices: ‘Purga’ - a cryogenic device and ‘OS1700’ - a tritium manifold. Air sampled collected by ‘Purga’ was measured with a gamma-spectrometer. Air samples collected with the tritium manifold were analyzed with a beta-spectrometer. Experimental studies conducted registered the major radioactive gases: 41Ar 30 to 4,500 Bq/m3, 85Kr up to 280 Bq/m3, - 87Kr up to 720 Bq/m3, 88Kr up to 840 Bq/m3, 135Xe up to 140 Bq/m3. Experimental studies undertaken have shown applicability in principle to use sampling and analytical equipment for assessing radioactive gases emanated in a SNF storage area at BN-350.

T2.4-P51 Risk Estimates Migration of Radionuclides After Flooded Klivazh Facility

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In September 1979 industrial underground nuclear explosion rocked Ukraine, in the frame program #7 "Nuclear Explosions for the National Economy". The nuclear experiment was conducted in the suburb of the Y enakiyev town, the "Y unyi Kommunar (Y unkorn)” coal mine. The nuclear explosion formed a vitrified glass-ceramic melt chamber containing about 95% of the radioactivity of the explosion to assure that would be insoluble in water. Due to the lack of official information on the state of the environment all available sources were analyzed. With the coal production shut down the mine’s pumps continued to pump shaft waters out for more than a decade to prevent flooding of the "Klivazh" facility. The main goal of the presentation is to provide objective information regarding uncontrolled leakage of contaminated water from flooded mines. A significant uncertainty associated with the present mining-geological state of the “Klivazh facility” dictates a need to validate assessments of the geological environment’s protective ability. Preliminary recommendations environmental monitoring to reducing risk associated with migration of radionuclides after flooded “Klivazh” facility have been primarily made as conservative assessments.

T2.4-P52 Statistical Study of the Atmospheric Background and Anomalous Values of the Radioxenon Activity Concentrations at Some IMS Stations

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The main goal is to perform a detailed statistical analysis of the atmospheric background and of the “Abnormal Concentrations” of radioxenon, measured at some IMS stations. For each IMS station considered, a descriptive statistical analysis of the empirical distribution was performed and two types of “Statistical Process Control Charts” were applied to the measured values. The Shewhart “Control Chart for Individual Measurements”, sensitive to large variations and the “Exponentially Weighted Moving Average (EWMA) Control Chart”, sensitive to small variations, were used to analyze the overall chronology of the observations and to identify and study those values that significantly deviate from the average value. The “Control Charts” method were then
Theme 2: Events and Nuclear Test Sites

Compared with the "Inter-Quartile Range" method currently used by the IDC, the results show that the "Control Chart for Individual Measurements" is particularly meaningful for the periodic monitoring of IMS stations in order to identify large variations of radio-xenon activity concentrations, while the "EWMA Control Chart" is more suitable for specific studies on the atmospheric background and on the "anomalies" of radioxenon activity concentrations. The use of "Control Charts" method as a possible complement to the "Inter-Quartile Range" method, could be further investigated.

T2.4-P53 Tajikistan and CTBTO

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On October 7, 1996 Tajikistan signed the "Comprehensive Nuclear-Test-Ban Treaty (CTBT)" and on December 2, 1998 the mentioned treaty was ratified. Tajikistan has borders with China, Pakistan and India, where nuclear tests were previously conducted. Taking into account the proximity of these countries, some work is being done in Tajikistan to continuously improving monitoring in various zones of the country. In addition, Tajikistan supported and signed the "Treaty on Nuclear Weapon Free Zone in Central Asia". Tajikistan stands for that all countries ratify the CTBT. The completion of ratification procedure of this important document gives new impulse for the complete prohibition of nuclear tests in the world. Tajikistan has a number of stations in the system of Academy of Sciences for detecting airborne radionucleides. In addition, there is a network of seismic stations, some of which are equipped with equipment for radionucleides detection. These stations are in the high mountain gorges of Tajikistan, find out places of abnormally high levels of deposition of technogenic radionuclide cesium-137 and its subsequent migration to edible wild plants. The dependence of deposition process of radionucleides from composition of brought aerosols on geological features and isolation of mountain gorge has been shown.

T2.4-P54 The Characteristic Release of Noble Gases from an Underground Nuclear Explosion

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Releases of noble gases at the ground surface resulting from explosively propagated vents or large operational releases have typically been considered to be the only modes of transport from an underground nuclear explosion (UNE) which are capable of producing detectable levels of radioxenon in atmospheric sampling at significant standoff distances. For thermally and barometrically driven post-detonation transport across the broad surface of a simulated UNE site, we show that even deep, well-contained UNEs, without prompt vents or operational releases, are potentially detectable at least tens of kilometers downwind with current technology. From our simulations, we find that broad-area surface fluxes of radioxenon exhibit exponential dependence on bulk permeability resulting in order-of-magnitude enhancements of surface flux for small increases in permeability. UNEs characterized by a canonical depth-to-yield relationship generally resulted in larger atmospheric signals for shallower, lower-yield explosions allowing downwind detection at distances greater than 1000 km. Additionally, simulations suggest that atmospheric sampling at night produces detections at the greatest distances downwind.

T2.4-P55 The Rapid Radionuclide Isotopic Ratio Determination Technique to Assess Nuclear Event Debris

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Radionuclide detection is a further step to complement any abnormal event data recorded by seismic, hydro acoustic and infrasound station network prior asking for the approval of the On-Site Inspection (OSI).
Radionuclides can travel away from a source of event for thousands of kilometres under favourable meteorological conditions and still can be detected. In this work a rapid comprehensive method that optimises man-work hours, materials and activities such as a rapid radiochemical radionuclide separation, gamma- and mass-spectrometry measurement techniques combined together for radionuclide determination and source assessment is demonstrated. Gamma spectrometric measurements were performed with the state-of-the-art "Ortec" alpha spectrometer and gamma spectra were recorded by SILENA gamma-spectrometric system with a HPGe coaxial detector. Radionuclide isotopic ratios were measured by a sector field mass spectrometer combined with a high sensitivity APEX sample introduction system. It is demonstrated how an environmental sample analysis could be performed within 72 hours from arriving to the analytical laboratory. Elevated 137Cs/239,240Pu, 238Pu/239,240Pu, 240Pu/239Pu isotopic "finger print" values reliably reveal a nuclear event and assess its source by fusing these values with atmospheric transport modelling. What is more, analysis of soil profiles in depth clearly distinguish the new nuclear event debris from the previous ones.

T2.4-P56 Trends in Worldwide Background of CTBT-Relevant Xenon Isotopes Based on IMS Data

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The CTBTO operates 25 certified Noble Gas (NG) systems of the International Monitoring System (IMS). The data is routinely processed in the International Data Centre (IDC) operations. Data from these certified NG systems are reviewed by IDC Analysts on a daily basis. Automated and reviewed products are generated and made available to Member States via the IDC secure web portal (SWP) and through the Verification Data Message System (VDM S). IDC products include a 3-level based categorization scheme as a first screening layer of CTBT relevant xenon isotopes. IDC reviewed results over a long term period at various locations further contributed to a reliable characterization for better understanding the worldwide background of xenon isotopes. The presentation aims at compiling results on radio-xenon detections at IMS NG systems, based on all data from June 2011 to December 2018. Covered aspects include major categories of observed trends in terms of detection frequency and air activity concentration.

T2.4-P57 Validation Study of the Flexpart-WRF Model with Episodes of Xe-133 Releases and Detections in Europe

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The International Data Centre (IDC) of the CTBTO is developing the capability to conduct High-Resolution Atmospheric Transport Modelling (HRATM) using the Numerical Weather Prediction model WRF and the Atmospheric Transport Model (ATM) Flexpart-WRF. The performance of Flexpart-WRF at the IDC is assessed by using source terms from a medical isotope production facility in Belgium to simulate the resulting concentration time series at IMS noble gas station DEX33 in Germany. Seven episodes of elevated Xe-133 concentrations at DEX33 were selected; each episode consists of 6 to 11 subsequent samples with each sample being taken over a 24-hour period. For each sample a high-resolution backward simulation was performed with nests of increased resolution around the source and the receptor. The simulated concentrations were produced by HRATM for different output resolutions (10, 30 and 50 km) and are compared to simulated results by the conventional Flexpart model as well as verified by the available measurements for DEX 33. The comparison includes similar statistical metrics as established during the first ATM challenge in 2016 are applied for the comparison of the model outputs against the measurements.
T2.5 Historical Data from Nuclear Test Monitoring

Oral Presentations

T2.5-O1 Digitization and Analysis of Printed Seismograms from Aftershocks of the Novaya Zemlya Explosion on October 27, 1973

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In October 1973, a nuclear explosive with a yield of about 4 megatons was detonated underground at the Novaya Zemlya test site. The explosion was followed by a series of aftershocks, a phenomenon that had previously not been observed at Novaya Zemlya. Today, very few short period seismic recordings of these aftershocks exist. At the Swedish Defence Research Agency (FOI), printed short period seismograms from the Hagfors station have been preserved, and in this paper we present the results of scanning these seismograms and digitizing the signal. The digitization process as well as the associated difficulties are explained together with an analysis of the properties of the seismic signals from the aftershocks. Finally, a comparison with the aftershocks following the nuclear test on Sep 3, 2017 in North Korea is made. The region of Novaya Zemlya is a very low seismicity region. In the ISC catalogue between 1960 and 2016 only 57 earthquakes are found. The identification of the aftershocks is quite easy in both time and space.

T2.5-O2 Noble Gases Release After Underground Nuclear Explosions

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Underground nuclear explosion may be followed by noble gas releases. 493 underground nuclear tests and explosions of different purposes and in the different rocks were conducted in the Soviet Union over the period of 1961-1990. A total of 340 underground nuclear tests were conducted at the Semipalatinsk Test Site. 179 explosions (52.6%) among them were classified as these of complete containment, 145 explosions (42.6%) as explosions with weak release of radioactive noble gases (RNG), 12 explosions (3.5%) as explosions with nonstandard radiation situation. Thirty-nine nuclear tests had been conducted at the Novaya Zemlya Test Site; six of them – in shafts (vertical boreholes) and 33 tests in the horizontal tunnels. In 14 tests (36%) there were no RNG release. Twenty-three tests have been accompanied by RNG release into the atmosphere without residual contamination. Nonstandard radiation situation occurred in two tests. In incomplete containment explosions both early-time RNG release (up to ~1 h) and late-time release from 1 to 28 h after the explosion were observed. Sometimes gas release took place for several days, and it occurred either through tunnel portal or epicentral zone, depending on atmospheric air temperature and pressure. Figures of stemming complexes will presented.

T2.5-O3 Using Satellite Imagery to Map Russia’s Underground Nuclear Test Site on Novaya Zemlya

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In 1997, the United States accused Russia of conducting a secret nuclear test at its underground test site on Novaya Zemlya. Despite admitting later that the August 17, 1997, event was an earthquake in the Kara Sea, U.S. officials maintained that activity observed at the test site prior to the earthquake was similar to activity observed before previous nuclear tests. The activity the United States observed was actually preparations for a subcritical
nuclear experiment on August 14, highlighting the need to better differentiate between observables associated with subcritical and full-scale nuclear tests. CNS used a combination of declassified historical satellite imagery and contemporary high-resolution commercial satellite imagery to map the evolution of the Soviet Union’s underground nuclear test campaign on Novaya Zemlya, as well as record signatures associated with underground nuclear tests at the site. Establishing a visual baseline of historical activity allows for better assessment of ongoing activity and potential treaty-relevant events at the test site.

**Poster Presentations**

**T 2.5-P1**  
**A Catalogue of Nuclear Test Explosions Recorded by Slovak National Network of Seismic Stations**  
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An important part of historical seismographic data research is data archiving and digitization. In the second half of the 20th century the monitoring of seismic events caused by nuclear explosions was an essential goal of each seismological service. More than 400 of them were recorded by the Slovak National Network of Seismic Stations. So far no special catalogue of seismic events caused by nuclear test explosions recorded by Slovak National Network of Seismic Stations was compiled. To reach this goal, the historical data from the archives of the Slovak National Network of Seismic Stations and bulletins of Czechoslovak and Slovak seismic stations have been investigated. The analog seismograms from the Slovak seismic stations have been checked for presence of data from nuclear test explosions, preserved and prepared for digitization. The catalogue can be integrated to the worldwide database of nuclear test explosions.

**T 2.5-P2**  
**A Comprehensive Central Asia Seismological Bulletin**  
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Central Asia is located in a tectonically active and complex region. The area is characterized by high levels of seismicity, and many catastrophic earthquakes have occurred. Central Asia also contains or is within regional distances of many of the world’s nuclear test sites. Seismic networks in the region were developed during Soviet times, with each republic operating independent networks with standardized processing and analysis. The current distribution of seismic networks generally remains the same, though networks are now national and operated by independent countries. From Soviet times until today, most bulletin and event data were not fully exchanged between Central Asian networks. The fact that only subsets of event data were routinely exchanged and used has hindered all aspects of seismological research in the region, such as investigation into regional Earth structure, calculation of event parameters, incomplete seismic risk assessment, etc. To improve all aspects of seismological research and knowledge in Central Asia, we are merging bulletin data from the networks of Kyrgyzstan, Tajikistan, and Kazakhstan into a single database. Following completion of the database, all events will be relocated, and the completed comprehensive bulletin will be submitted to the International Seismological Centre for inclusion into the global database.
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T2.5-P3  Detectability of the UNE Wigwam by Radionuclide Stations of Today’s IMS

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The Comprehensive Nuclear-Test-Ban Treaty (CTBT) bans all nuclear explosions, including those detonated underwater. To improve the understanding of the radionuclide signatures of such an event, and whether it would be detectable under the verification regime of the CTBT, the 1955 Wigwam underwater nuclear explosion has been modelled. Inventory calculations and atmospheric transport modelling have been performed to estimate the activity at the radionuclide stations of the International Monitoring System (IMS). This has utilized reported release values (0.92%) and meteorological data from the event. The research shows that there is a high probability that Wigwam would have been detectable at U.S. IMS stations at Wake Island (RN77) at 8.4 days, Guam (RN80) at 10.7 days and Sand Point, AK (RN71) at 13.7 days. At these locations, the majority of IMS relevant radionuclides were fission products, such that additional radionuclides from the seawater activation had largely decayed before reaching the stations. The presentation will describe the Wigwam event and data, the phenomenology of underwater nuclear explosions, and our plume projections of where Wigwam’s radionuclides would have been measured by IM S stations, had they existed at the time.

T2.5-P4  Digitization of Soviet Era Peaceful Nuclear Explosion Seismograms from Regional Stations

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The crustal structure of Eastern Siberia is poorly known due to its inaccessibility and the sparseness of seismic stations and larger earthquakes. Peaceful Nuclear Explosions (PNEs), detonated by the former Soviet Union are seismologically significant because they are Ground Truth events, wherein the depth and geographic coordinates of energy release (the detonation) are precisely known. The PNEs are therefore excellent data sources for crustal studies. Analog seismograms from regional stations for PNEs in eastern Siberia were collected and scanned to create a seismogram database. This database contains over 25 PNE, that when incorporated together, provides data coverage better than what is possible using only earthquakes. The scanned seismograms were hand digitized using the computer program WaveTrack. Digitizing PNEs allows modern processing techniques to be applied to each seismogram and provides the opportunity to enhance studies that were previously done using analog techniques. Digital data manipulation allows further analysis of crustal, velocity, and attenuation models.

T2.5-P6  Discrimination of Nuclear Explosions and Earthquakes at Regional Distances for the Lop Nor Test Site According to the KNET Network Data

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Data of seismic monitoring network KNET, located in Kyrgyzstan and Kazakhstan, which is began its operation in 1991 are actively used by researchers around the world. Over the years, the KNET network has recorded a large number of seismic events of various nature occurred in the area of the Lop Nor test site. In addition, on several stations of KNET network such as AAK, EKS, BKG, CHM and TKM stations, during the Soviet era analog stations have operated. A comparative analysis of the waveforms of underground nuclear explosions conducted at regional distances at the Lop Nor test site in 1975-1996, as well as tectonic earthquakes from 1991-2018 with epicenters located near the test site, was carried out. The spectral ratios of the longitudinal and shear wave’s amplitudes (Sn/Pn, Lg/Pg) of underground nuclear explosions and earthquakes are investigated.
**T2.5-P7**  
**Historical Records of Nuclear Explosions in Archives of the Institute of Geophysical Research**

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The Institute of Geophysical Research of the Republic of Kazakhstan possesses a large archive of analog records of nuclear explosions. The whole IGR archive can be conditionally divided into three parts: the records of former SSC MD USSR the archive of Borovoye Observatory (1966 - 1990) and Kurchatov Observatory (1973 - 1996), and the records of the CSE IPE AS USSR the archive at KNDC (Almaty) (1951 - 1996). The KNDC archive contains records of nuclear explosions conducted in different mediums at different Test Sites of the world and recorded by stations installed on the USSR territory. The archive also contains the records of large chemical explosions, earthquakes and other events. In addition to seismic records, the archive contains the records of microbarograph, strainmeter, tilometer. The total amount of analog seismograms at KNDC archive exceeds 300 000. The report shows the description and history of the IGR archive compilation, presents some examples of different nature events. One of the priority tasks of the IGR is saving of available historical seismograms. During past twenty years, under support of different foreign Organizations, the Institute has been conducting works on records scanning and digitizing. To date, about 10000 seismograms were digitized.

**T2.5-P8**  
**New Stage of Works on Nuclear Explosions Historical Records Digitization**

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The IGR during the past twenty years has been conducting a work on digitizing of nuclear explosions records and scanning of seismograms recorded on photo- and ordinary paper and stored at archives of different related Organizations. This work in different years was conducted under some projects financed by: ISTC (1998 - 2000), LDEO (2013-2014), NORSAR (2012), CM R (2000-2002), and under the Kazakhstan grant (2005-2011). Under the different projects, the records of nuclear explosions conducted at different Test Sites of the world were digitized as well as "peaceful" nuclear explosions. It was managed to digitize the records of Central Asia stations that recorded the explosions from Semipalatinsk Test Site, Novaya Zemlya, peaceful nuclear explosions on the USSR territory, Lop Nor, Nevada et al. Currently there is a new project with AFTAC. In addition to seismic records, the project is also aimed at digitizing of microbarograph records that has recorded infrasound signals from the regions of the STS, Lop Nor, Novaya Zemlya Test Sites. The works on digitizing of analog seismograms result in unified format records, metadata generalized by common formats allowing creating a united database of digitized nuclear explosions by Central Asia stations.

**T2.5-P9**  
**Nuclear Test Monitoring History in the North-East of the USSR**

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In 1946 U.S. government invited Soviet scientists to nuclear tests on the Bikini atoll. USSR sent nuclear physicist academician Skobelitsyn and director of Dalstroil Gold and Rare Metals Institute Aleksandrov, engineer colonel of NKVD. The institute focused on uranium deposits search and uranium ore mining and concentrating technologies development. Skobelitsyn’s and Aleksandrov’s trip report was never published. Presumably, one of the tasks assigned to them was detection of nuclear explosion site and its power estimation. By that time the U.S. was already using seismographs for that purpose and this method was also obvious for Russian scientists. In order to hide seismic signs of nuclear explosions American scientists proposed performing the tests in Alaska, where seismicity was high enough for concealing nuclear explosions with energy lower than that of earthquakes. In the USSR it was decided to open a seismic station in a place with low seismicity.
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closest to nuclear test sites on the Pacific. Considering secrecy, Aleksandrov proposed placing the station in Dalstroi territory, restricted even for Soviet people. Jan 1, 1952 Magadan seismic station with just two seismologists started operating. Arrival times were sent to Moscow without processing. Sometimes seismograms were requested, mostly at days of nuclear-weapon testing.

T2.5-P10 Semipalatinsk Test Site Usage for Effectiveness Check of New Detection Methods of Underground Nuclear Explosions

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At site "Balapan" of Semipalatinsk test site (STS), 105 underground nuclear explosions (UNE) were carried out in vertical wells with power up to 150 kt and depths up to 500 m, at the site "Degelen" - more than 200 UNEs were carried out in horizontal tunnels at depths up to 200 m. Actual locations determination of UNEs on STS by existing methods is complicated by depth of UNEs at "Balapan", and by mountainous terrain conditions at the site "Degelen". Diversity of geological conditions of UNEs locations determines different effectiveness of regulated technologies and determines the need to improve it and study of additional methods possibilities. It is proposed to conduct research for effectiveness assessment of new detection methods of UNEs. The feasibility of the proposed methods allow using them to conduct the first phase (tritium content in the atmospheric air for localization of inspection area) and the second phase (concentration of gases in soil air and heat measurement to detect underground-loosened zones). These methods have shown its high efficiency in studies on STS, they are not officially part of the in-situ methods now, but it can be quite successfully used to detect "fresh" UNEs and explosions conducted several decades ago.

T2.5-P12 Waveforms from Nuclear Explosions (WFNE)

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Waveforms From Nuclear Explosions (WFNE) data repository will be open for the research community’s access to source parameter data and associated waveforms from worldwide nuclear explosions. It is based on the former NEDB, which had contained data collected, analyzed and assembled by SAIC/Leidos, using a very large number of sources and ground truth information. It will now contain newly published or revised information, including the recent DPRK events. WFNE is a comprehensive repository on all 2157 nuclear explosions that were detonated in various locations of the world, and includes waveforms from atmospheric, underground and underwater detonations. Also available are raw and parametric data, meta-data summaries for the explosions detonated on different test sites, as well as information on the data providers that have been sourced. All events have parametric data collected from alternative publications and a preferred solution. Over 65,000 waveforms are associated to 678 of the nuclear explosions, ranging from digitized analog recordings for the oldest explosions to recent IMS data. The waveform data have associated station information, including available calibration and instrument responses. The information will be accessible via a web interface with a user account. The waveforms can be viewed, selected and downloaded from the web site.
T1.1-O3 Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound Propagation and Scattering in the Atmosphere
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The experimental results of studying the effect of a fine-scale layered structure of a stably stratified atmospheric boundary layer (ABL) on fluctuations of the parameters of acoustic pulses generated with a certain period (1 min) by an artificial detonation source are presented. The vertical profiles of wind velocity fluctuations in the thin layers of the ABL have been retrieved using the wave forms and travel times of the recorded arrivals of pulses from the source. It is shown that the mechanism of scattering of pulse signals in a stably stratified ABL is similar to the mechanism of scattering of signals from ground surface explosions by layered nonhomogeneities of wind velocity and temperature in the stratosphere and lower thermosphere. The role of similarity parameter here place the dimensionless thickness of the reflecting nonhomogeneous layers, which is the vertical scale of the layer multiplied by the relative difference in effective sound velocity and normalized by the vertical wavelength. The effect of such inhomogeneities on the temporal fluctuations of the azimuth and arrival times of the signals is studied. The estimation of the error in localization of pulsed sources is given.

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T1.1-O4 Climate Change Through the Eyes of Radioisotopes
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Cosmogenic radionuclides beryllium-7 and sodium-22 are known atmospheric tracers and can be used together in a lock-in technique to effectively trace vertical air masses based on surface measurements. This technique allows to study progression and speed of atmospheric cells. Data show that the cells are decelerating during the summer period which is extending in time. This is caused by warming of the whole troposphere and increased tropopause height due to rising CO2 concentrations. Aestival episodes of persistent high-pressure systems over Europe with low pressure gradients that led to almost stationary thunderstorms are correlated with the observed deceleration of atmospheric cell movement. This demonstrates that 7Be and 22Na can be used as indicators for confirming several side effects of climate change while providing a new modelling tool in seasonal weather forecast.

T1.1-O5 Detection Efficiency of the IMS for Bolides
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In this study we examined 344 bolides (airbursts) reported on the JPL CNEOS website (https://cneos.jpl.nasa.gov/fireballs/) between 2007-2018 and attempt to correlate these with infrasound detections. We found 206 of these bolides were detectable by at least one infrasound station while only 42 were automatically registered as part of the Reviewed Event Bulletin (REB) issued daily by CTBTO. However, this global REB detection rate of ~10% averaged from 2007-2018 is less than the "modern" rate (from 2014-2018) which approaches 20%. Above the 1kT CTBTO design threshold, we find that 40% of airbursts are reported in the REB, while more than 90% are detectable at one or more infrasound stations. All airbursts with energy > 2kT reported on the JPL fireball site since 2007 have been detected infrasonically. However, the REB is only complete above 15kT with the automated detection system not having reported at least four airbursts with
T3.1 Design of Sensor Systems and Advanced Sensor Technologies

Oral Presentations

T3.1-O1  Description and Results from a Feedback Digital Infrasound Detector System

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Since the signing of Comprehensive Nuclear-Test-Ban Treaty (CTBT) in 1996 and the establishment of International Monitoring Systems (IMS) stations for the verification of nuclear explosions significant improvements have been achieved in monitoring systems. The improvement in seismic detection systems and the technology has substantially surpassed the development and the sophistication of infrasound monitoring systems. A feedback infrasound system based on a new topology and concept is described. Design details and results will be presented. The described feedback Infrasound system eliminates all the shortcomings of existing infrasound detection technology. The designed low noise digital Infrasound (micro-barometer) system provides an improved method of calibration. The frequency response and gain of the feedback detector is dependent only on the electrical parameters of the feedback- loop providing a stable and highly accurate detector. It will be shown that the digital Infrasound detector response to seismic signals is virtually eliminated. The system provides three independent outputs, these being: output proportional to pressure, derivative of pressure and second derivative of pressure.

T3.1-O2  Establishment of a Network of Political and Scientific Cooperation Between CTBTO and the Great Lakes Region to Contribute to Sustainable Development

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The Great Lakes region is hit by geological hazards that disrupt sustainable development in the region. Most of the cities in the region are located in the East African Rift. This is the case of some cities in which the vulnerability is on a high level. CTBTO has installed two seismographic stations in Kenya and one in Uganda. The ongoing maintenance of these stations by CTBTO has provided a good scientific contribution to the understanding of this region. However, the part of the Great Lakes remains empty, so that, it would be very important that the network be extended by establishing stations in the DRC, Rwanda and Burundi, which can help to allow the region and contribute to sustainable regional development. This regional collaboration will contribute to: - A wakening of the consciousness of those governments that seem to have forgotten CTBT, - The establishment of some seismic stations in the region which can help now to assess weakness areas in which buildings must be restricted, and to assess the seismic risks in the region. - Strengthen peace in the region through the inter-institutional and intergovernmental cooperation network.

T3.1-O3  Estimation of Antineutrino Registration as a Method of Monitoring Nuclear Explosions

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In many respects, the antineutrino burst emitted by a nuclear test is the ideal signal for a nuclear detonation. Modern technologies and methods allow hiding radioactive isotopes after an explosion or camouflage seismic signals, but means and methods of masking antineutrinos do not exist. In each nuclear explosion about 1024

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antineutrinos are produced per kilowatt energy released during the fission in a time interval of about 10 seconds. The emission of antineutrinos is unaffected by the environment in which the explosion occurred. The antineutrinos signal spreads long distances from the location of the detonation through different environments.

We propose to build a 1 km$^3$ detector at the South Pole for the purpose of detecting nuclear tests. The introduction of antineutrino sensors into the International Monitoring System could help to unequivocally detect nuclear weapon tests.

**T3.1-O4 Exploiting the Tailorable Nanoporosity of Metal-Organic Frameworks for In-Situ Identification of Radioisotopes**

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Radioactive xenon isotopes are signatures of clandestine underground nuclear tests. Their low concentrations remote from the event require collection and separation from large quantities of air using porous carbon sorbents. Unfortunately, due to their short half-lives, large dilution factors, and the long times required to remotely acquire samples, information concerning the time, location, abundance of specific isotopes produced in the event can be lost. Consequently, detection strategies are needed that enable much more rapid isotope identification. We will describe in-situ radioisotope identification by beta-gamma coincidence in a portable system enabled by Metal-Organic Frameworks (MOFs), a new, highly tailorable class of sorbents with surface areas as high as 7000 m$^2$/g. MOFs possess a combination of properties unique among nanoporous materials. First, their ultrahigh surface areas facilitate selective adsorption of weakly interacting gases such as xenon. Second, established structure-function relationships governing MOF gas uptake enable rational design of materials optimized for specific applications (e.g., to selectively adsorb Xe). We demonstrate that MOFs enable the identification of radioactive xenon isotopes virtually in real time when used in a novel high-pressure detection system we designed. Our MOF-enabled detection concept could dramatically improve the reliability, timeliness, and information content of systems used for CTBT verification.

**T3.1-O5 High Sensitive Xe Measurements**

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Unfortunately only Xe133 is usually detected in the air samples on IMS Noble Gas installations. Due to its relatively higher concentration in comparison with metastable xenon isotopes. The metastable xenon concentrations are a few orders of magnitude lower and it is therefore only possible to detect them within short distances. The new proposed method uses Xe samples of large volume for each measurement (>100 ccm of pure Xe) resulting in MDCs for Xe131m, Xe133, Xe133m and Xe135 in every sample of less than 10$^{-5}$ Bq/m$^3$. We developed a system to purify the Xe sample from a Xe-Kr mixture which is accumulated as a by-product during oxygen and nitrogen production from atmospheric air at different types of air separation plants. During the presentation the design of the sample preparation unit, the beta-gamma spectrometer suitable for big sample measurement together with the first achieved practical results will be presented.

**T3.1-O6 High Throughput Argon-37 Field System**

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PNNL is exploring the use of 37Ar for detecting nuclear explosion, including for use in the International Monitoring System (IMS). A high throughput 37Ar separation and measurement system was developed at Pacific Northwest National Laboratory (PNNL) to detect 37Ar activity generated from an underground nuclear explosion. Argon-37 is an activation product generated when neutrons interact with calcium in the soil surrounding an underground nuclear explosion. As a noble gas, argon is unreactive and migrates through the
earth and can be released into the atmosphere with the radioxenon fission gases that are also produced during a nuclear explosion. Detection of 37Ar can be a confirmatory measurement for a nuclear test, and when combined with radioxenon isotopes from the same sample the confidence that a nuclear explosion occurred improves significantly. PNNL has performed a large number of soil gas and atmospheric background measurements to understand gas migration of naturally occurring Ar-37 in the soil and for experiments where 37Ar and 127Xe were injected into a nuclear test cavity. PNNL will present on the newly developed Argon-37 High Throughput system as well as discuss measurements made at locations throughout the northwest region of the United States.

**T3.1-O7**  **How Useful Are (Quantum Technology) Gravity Measurements for On-Site Inspection?**

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Gravitational field mapping is permitted by paragraph 69 of the CTBT Treaty (1996; UN A/50/1027) to be deployed during the continuation period of an on-site inspection (OSI) to look for features relevant to underground nuclear explosions (UNES). Examples of features of interest include tunnels used for horizontal emplacements, and underground voids and collapse features caused by vertical emplacements. Whilst current spring based gravity instruments used are limited both by their resolution and by sources of environmental noise superimposed on the measurements, the imminent arrival of quantum technology (QT) gravity sensors based on atom interferometry promise both a far greater resolution and the ability to suppress environmental noise by measuring a gravity gradient, creating a sensor useful in field applications such as during an OSI. This paper will present computer simulations based on mathematical forward modelling of buried UNEs relevant targets and realistic noise sources to explore the potential uses of these new sensors in an OSI context. This will allow quantification of the overall improvements to detectability of UNEs observables in terms of the depth and size of resolvable features when utilising QT sensors.

**T3.1-O8**  **Seismically Cued Antineutrino Detectors Have Limited Potential to Monitor Nuclear Explosions**

R. Carr\(^1\), J. R. F. Dalnoki Veress\(^2\), A. Bernstein\(^3\)  
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In this presentation we discuss findings from a study to test the sensitivity of large gadolinium-doped water detectors to antineutrinos released by nuclear-fission explosions, using updated signal and background models and taking advantage of the capacity for seismic observations to provide an analysis trigger. We find that advances in seismic monitoring and neutrino physics have made the detection of explosion-derived antineutrinos more conceivable than previously asserted, but the size and cost of sufficiently sensitive detectors continue to seriously limit applications. Under certain conditions, the antineutrino signature of a 250-kton pure-fission explosion could be identified several hundred kilometers away, in a detector about the size of the largest module proposed for a basic physics experiment. However, for an explosion two orders of magnitude less yield and more of interest because it is harder to verify as being nuclear in nature, the standoff distance shrinks by an order of magnitude likely requiring locating the detector in-country. In principle, such an observation could provide rapid confirmation that the seismic signal coincided with a fission event, possibly useful for cooperative monitoring of nuclear-weapon test sites but unlikely for detecting explosions at long stand-off distances.
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**T3.1-O9**  **The Feasibility of Using MEMS Technology for Monitoring Large Earthquakes**

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Small low-cost microelectromechanical system (MEMS) triaxial sensors provide ground-acceleration measurements of moderate to large earthquakes. However, the common challenge of such sensors is low dynamic range which is because of high self noise of these systems. In this paper, a new configuration for reducing self-noise of MEMS acceleration sensors is provided. Using this configuration, a three-axial acceleration sensor was built. Five sensors of this type were installed at a concrete dam to monitor the response of the dam against large earthquake. During 12 November 2017 Mw 7.3 Sarpol-e Zahab (Iran-Iraq Border) earthquake, this system recorded the earthquake in different locations of the dam. In this paper, the results of such recordings are presented. Moreover, the results of shaking table tests of this acceleration recording system collocated with other acceleration sensors are also presented. The results shows that new configuration of MEMS acceleration sensors could be used to record the seismic motion of large earthquakes.

**T3.1-O10**  **Using the Existing Telecommunication Optical Fiber Cables as Underwater Seismic Events Detectors**

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Detecting ocean-floor seismic activity is crucial for our understanding of the interior structure and dynamic behavior of the Earth. However, 70% of the planet’s surface is covered by water and seismometers coverage is limited to a handful of permanent ocean bottom stations. It can be shown that existing telecommunication optical fiber cables can detect seismic events when combined with state-of-the-art frequency metrology techniques by using the fiber itself as the sensing element. As it was found, the existing underwater telecommunication optical fiber cables could be used in this way without disruptions to service and without having to make any changes to the cables. All that would be needed would be to gain access to one of a group of channels on both ends of a cable. Each side would be fitted with a special laser-based detector to continually monitor the signal. The researchers suggest that if enough of the cables under the oceans were used as seismic monitors they could offer access to unprecedented types of information—information that could be used to predict tsunamis, for example, or to better understand global seismic activity as it relates to plate shifting and volcanism.

**Poster Presentations**

**T3.1-P1**  **A Differential Highly Sensitivity Sensor for Accounting of Seismic Devices Instrumental Thermal Noise**

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One of the main factors causing noise in the records of precision long-period seismometers is the temperature fluctuations of the mechanical elements of the seismometers and their sensitive sensors caused by temperature fluctuations in their internal space due to the presence of local heat sources. Electronic components, for example, operational amplifiers, resistors and inductances that are part of the electronics of such devices, can be act as local heat sources. Heat is generated during the operation of mechanical elements too. A very complex dynamic temperature pattern is created in the internal volume of the device. To reduce the effect of this type of noise, we suggest using adaptive and optimal filtering of seismic signals based on high-precision temperature recording of key elements of seismic instruments. To date, there were not so small systems capable of recording temperature
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changes inside seismic instruments with sufficiently high accuracy. The highly sensitive thermometer developed by us is capable of simultaneously monitoring the temperature at several of the most important points of any seismic device with an accuracy of up to 0.005 degrees Celsius.

T3.1-P2  A New Gamma Camcorder

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Nowadays, gamma dose rate images are created by "gamma cameras", commercially available, unsuitable to be used in many cases of verification of undeclared activities and detection of radioactive hot spots. The new gamma camcorder developed by INVAP, change the way you see gamma radiation fields, allowing to scan and film a gamma radiation field at 1 frame/second, with a compact, affordable, lightweight and highly efficient device. Unlike current gamma cameras, the device is not used to form the classic concepts of lens and focus. INVAP concept was tested using experimental measurements in a nuclear reactor. Design flexibility enables the use of several types of detectors. The gamma field was reconstructed with very good resolution in those gamma dose rate ranges suitable for Nuclear Power Plants, namely from 10μSv/h up to 15Sv/h. But the technology does not limit camcorder velocity, and presented results shows that a real time image could be obtained from nuclear reactor up to natural background. Camera concept could be applied to neutron fields also. Using this concept, production of a remote equipment for mapping and monitoring high gamma radiation fields is currently in progress, aiming to provide real time information of radiation fields inside Nuclear Power Plants.

T3.1-P3  A New Process Design for Compact Radioxenon Separation System

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In the context of the Comprehensive Nuclear-Test-Ban Treaty, the CEA developed the SPALAX system about 15 years ago. It is currently implemented in the International Monitoring System to detect and characterize xenon releases following a nuclear explosion. This system is still under continuous improvement; in order to reduce the footprint and the energy consumption, the separation and purification steps can be optimized further. The internally developed Ag@ZSM-5 zeolite adsorbent can be an ideal candidate given its site of strong interaction with xenon at low partial pressures. This zeolite has unmatched capacity at partial pressures of xenon in air. This material is now tested with a new and more compact design of the process. This system can separate directly xenon from air without any nitrogen membranes, and thus with a limited working pressure and energy requirement. System and its performances will be illustrated.

T3.1-P4  A New Three-Component Optical Accelerometer

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This experimental study demonstrates a new three-component accelerometer that is based on the moiré technique. Our goal was to build an optical accelerometer whose performance is similar to that of seismic sensors yet can operate. The oscillation system of the sensor is a spring-suspended mass whose position is monitored by moiré technique. We used two similar overlaid gratings at a small angle that, one of them is fixed to the frame and the other one is attached to the suspended mass. The gratings are installed close to each other with no physical contact. Moiré pattern is illuminated with a 1 mW diode laser and its beam passes through the moiré pattern and a narrow slit and hits on a light detector. Due to a typical impulse and the fringes movements, the light intensity on the detector varies and is recorded as voltage. A digital signal processor samples the interference fringes signal and produces a 200 samples/sec record of the accelerometer output signals. Experiments to test this idea have been performed on our optical accelerometer and a calibrated accelerometer as a reference accelerometer in identical conditions. Investigations and Comparisons show that, our accelerometer is quite reliable and has some advantages.
T3.1-P5  **Antineutrino Detectors: An Evaluation of Their Use for Monitoring of Nuclear Explosions**

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Historically, nuclear explosion monitoring has been performed via atmospheric transport of radionuclides. In this paper, we aim to answer the question “Is there a role for antineutrino detectors for monitoring of nuclear explosions?” The International Monitoring System (IMS) is a network of detectors established under the Comprehensive Nuclear-Test-Ban Treaty that continuously monitors the world for nuclear explosions. While the IMS utilizes conventional detection techniques (seismic, infrasound, hydroacoustic, and airborne radionuclides), there is often discussion of the potential for antineutrino detectors to detect a nuclear explosion. We suggest that the current generation detector capabilities and cost associated with antineutrino detectors make their use within the IMS-like monitoring infrastructure prohibitive at this time, especially when compared to an expanded capability of current IMS technologies. Throughout this paper, we discuss the capabilities and requirements of antineutrino detectors and provide the information utilized in arriving at the above conclusion.

T3.1-P6  **Application of Optimal Filtering to Take into Account the Influence of Baric and Temperature Fluctuations of the Seismic Instrument and the Environment**

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This paper is devoted to the use of the optimal filtering technique for the correction of seismic signal records, where there may also be some noise associated with both fluctuations in atmospheric pressure and temperature. It is not possible to record seismic true information about the movement of the soil by modern seismic instruments due to the considerable sensitivity of these instruments to fluctuations in atmospheric pressure and temperature both of the surrounding space and within the instruments themselves. Consideration of changing the internal temperature of seismic instruments is a very difficult task too, since uneven heating of the internal volume caused by local heat sources, which may be electronic components, for example, operational amplifiers, resistors and inductances that are part of electronics any modern device, must be taken into account. The effect of this kind of noise of non-seismic origin on the instruments increases with the expansion of its frequency response for longer periods. In the course of research, we have demonstrated that the use of optimal filters for the correction of long-period channels records of seismic instruments can significantly improve the signal-to-noise ratio, which will allow the detection of seismic signals masked by similar types of noise.

T3.1-P7  **Applying an Anti-Coincidence System Plastic-HPGe to Lower the MDA of Radioxenon Measurement**

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The systems developed to detect the emissions of xenon isotopes, for the verification of the CTBT treaty are required to have a very sensitive detection limit, having to reach specific values of minimum detectable activity (MDA). To improve the sensitivity of the measurements and to decrease the minimum detectable activity (MDA) values it is important to reduce, among other factors, the background detected by the system. At ENEA Noble Gas laboratory an anticoincidence system has been developed to support the measurement of radio xenon isotopes in atmospheric samples. The system consists of a HPGe coaxial detector p-type installed inside a low-
background shield of old lead (150 mm) with a layer of electrolytic copper (35 mm). Two NUVIA plastic scintillators were placed above the shielding to detect coincident cosmic-ray interactions. The electronics associated with the detector amplifies the signal and passes it through an analogue-to-digital converter. Tests conducted with the anticoincidence system have shown a reduction of the Compton continuum that contributes to the spectrum background. In addition, the measured MDA values, compared to those obtained using the standard system, decreased for all the radioxenon isotopes.

T3.1-P9  Calibration of Infrasound Sensors in a Long-Term Field Study

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A long-term field study is being performed at Sandia National Laboratories (SNL) Facility for Acceptance, Calibration, and Testing (FACT) to compare the performance of five infrasound sensors in active use. The goal of this study, which was initiated at the beginning of 2018 and is continuing into 2019, is to evaluate the relative performance of the sensors in a field environment in which the sensors are subject to dynamic environmental conditions and to evaluate changes in the sensor’s absolute performance under controlled laboratory conditions. The results of the laboratory calibrations, performed at 3-month intervals, are presented here. We examine the laboratory measurements of self-noise, sensitivity, and amplitude and phase response to determine to what extent the sensor performance has changed over the course of the field study.

T3.1-P10  Characterization of the Microbarometer’s Sensitivity to the Environment

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The French Atomic Energy Commission (CEA) has developed microbarometers to measure infrasonic waves in the atmosphere. To characterize its sensors and validate their requirements, several test equipment have been developed. An infrasound generator is used to determine the sensitivity of the microbarometer in the frequency range from 0.0001 Hz to 300 Hz. In addition, a sealed enclosure regulated in static pressure as well as a temperature regulated enclosure allows to characterize the microbarometer’s sensitivity to the environment. The covered temperature range is -10°C to 50°C and the covered static pressure range is 650 hPa to 1030 hPa. Results obtained with microbarometers type MB3 and MB2005 are presented.

T3.1-P11  Comparison of PSD Methods in Simultaneous Discrimination of Alpha-Gamma Radiations

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Radiation spectroscopy of radionuclides is of concern in various applications. Many radionuclides of interest can be attributed as alpha-gamma-emitters which makes it possible to be distinguished by alpha-gamma coincidence methods. Phoswich is a technique which is based on making a coincidence between different time behaviors of sandwiched fast and slow scintillators. Here, a phoswich system is presented constructed by making use of a BC400 scintillator as the fast signal, and a CsI(Tl) for the slow signal. A GEANT4 application has been developed for simulation studies in the design phase to optimize various factors dealing with the efficiency and resolution of detector. Pulse shape discrimination (PSD) is an essential part of the procedure and can be performed with analog or digital methods. In this project alpha and gamma discrimination was performed using phoswich detector and digital PSD method. Three different digital PSD methods have been compared: Rise Time Discrimination (RTD), Constant Time Discrimination (CTD), and Charge Comparison method (CC). Experiments have shown that the CTD method with less than 0.25% error has a better performance in gamma classification than other methods.
T3.1-P12  **Deployment of Portable Infrasound Array in Costa Rica**

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The proposed collaboration will be an important contribution from OVSICORI-UNA to the volcanic monitoring in Costa Rica as it will expand the spatial coverage beyond that of the permanent International Monitoring System infrasound component in Latin America and the Caribbean. The installation of the portable infrasound array station by PTS-CTBTO and OVSICORI-UNA in the month of November 2018, in the North-East Zone of Costa Rica in the Selva Biological Station Reserve. The deployment and installation of CTBTO infrasound mobile system in Costa Rica (I69CR), would be beneficial for advancing the understanding of infrasonic sources in Central, Latin American and Caribbean regions. Some data analyzes of seismic events near Costa Rica and volcanic activity detected close to the place of the portable infrasound station I69CR are presented with software DTK-GPMC 5.7.3, NDC in box SHI-NIAB Mar 2018, CentOS 6.9, ver 4.3.

T3.1-P14  **Development of a Mobile Radiation Detection System**

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Following the success of AT6101C Backpack-based Radiation Detector ATOMTEX SPE developed a highly sensitive system AT6103 that can be used for locating the sites of nuclear incidents among other applications. The System was supposed to be easily movable. The decision was to use detection devices based on protected cases integrating up to three gamma and/or neutron radiation detection units and a communication device. The maximum number of detection devices in one System is six. Connection between the cases and the tablet PC is realised by wireless technology. It was possible to build the required high response instrument by increasing the number of detection units in the System and applying special data consolidation algorithms. To date the System has been developed and certified. The System is designed for radiation detection on land, cargo or facilities with GPS mapping. The System functions include measurement with GPS mapping, detection, alarm, identification of radionuclides, extended analysis of data by GARM software, and online data transfer by ARMS software. Test operation of the System on board a helicopter and a vehicle were successfully held as part of field tests of CTBTO in radiation contaminated area due to Chernobyl NPP accident (Polesye Radiation Ecological Reserve, Belarus).

T3.1-P15  **Development of a New Compact Photon/Electron Detector for Radioxenon Measurement**

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An ultra-compact lightweight unshielded spectrometer for detection and analysis of atmospheric radioxenons has been developed. This system works at ambient temperature and has a 58 cm³ inner active volume. Atmospheric radioxenon activities are determined with beta/gamma coincidence technique using both NaI(Tl) detectors and large pixellized Si-PIN detectors. The concept of this detection system, especially the gas cell, is partially inspired by the PIPSbox detector integrated into the SPALAX-NG (SPALAX New Generation). Carbon window suppression allows to operate over atmospheric pressure (~2 bar) in order to enhance the detection sensitivity at the price of a slight decrease of the energy resolution. The performances of the detection system in terms of Minimal Detectable Activities are below 20 mBq (12h acquisition, unshielded), for all radioxenon of interest (131m-X,e,133-X,e,133m-X,e and 135-X,e). Coupled with the SPALAX-NG gas enrichment system, Minimal Detectable Concentrations of this spectrometer are lower than 1 mBq/m³ for the four radioxenon of interest (12h acquisition, 60 m³ sampled volume). This new system and its performances will be presented.
**Theme 3: Verification Technologies and Technique Application**

**T3.1-P16 Development of an Electrostatic Precipitator System for Radionuclide Particle Collection**

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Electrostatic precipitation offers an approach to aerosol collection that can provide greater operational flexibility and improved instrument sensitivity to accommodate future radionuclide aerosol monitoring requirements. Due to inherently low pressure drops through the aerosol collector, an electrostatic precipitator (ESP) can accommodate much higher sample flow rates than comparable filter-based systems. The performance can be dynamically adjusted by controlling independent parameters, such as flow rate and the electric field strength within the precipitator. This control allows operators to enhance or reduce particle collection in real time, adjusting to changing radionuclide load conditions, and operate in a low-power mode during times of limited power availability. We present the development of a new radionuclide collection system that employs a custom electrostatic precipitator and sample handling system to interface with existing and new detector systems. Our aerosol collector realizes significant power savings over existing radionuclide aerosol collection systems, minimizes sample cross-contamination, and provides opportunity to enhance detection instrument sensitivity through more compact samples and higher sampling flow rates.

**T3.1-P17 Distributed Fiber Optic Seismic Sensors with Seismic Noise Floor Performance**

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Fiber Optic Sensors for Seismic monitoring are commonplace in the oil and gas community and are used for understanding seismic profiles in well bores and from one dimensional surface measurements. Recently they have been used in high profile academic work to monitor and measure the effect of earthquakes with the proposal being to exploit existing the infrastructure of telecommunications fiber optics as an early warning systems in the San Andreas fault, California. Current advances in interrogator design bring the performance of such devices down to the seismic noise floor in the sub Hz region with dedicated designs indicating a route to performance significantly below the seismic noise floor. Additionally, over 30,000 km of installed monitoring capability now exists of installed vibrational monitoring capability in a wide range of geographic locations with extended baselines that routinely delivers earthquake evidence to asset owners such as pipelines or railroads. We present the concept of using this sensing base as a potential, additional, lower performance but widespread and growing resource of listening sensors.

**T3.1-P18 Experimental Setup and Results of Xenon Sorption Characteristics Research for a Number of Adsorbents**

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A comparative study of methods for extracting xenon from atmospheric air led to the choice of Pressure Swing Adsorption (PSA) technology as the basis for development of a prototype system for noble gas field sampling directly on traps during on-site inspection. The choice of sorbent to use in the system prototype was proposed to be carried out experimentally, by comparative measurements of the sorbing properties of various sorbents. A description of the test bed and research program is provided. The results of the experiments, which make allow evaluating the sorbing properties of a number of sorbents for xenon, are given. Conclusions have been made that allow proceeding to the development of appropriate design and technological solutions for the design of a prototype system for noble gas field sampling directly on traps during on-site inspection.
T3.1-P19  Fault Identification Using Seismic Data Monitoring in Jakarta, Indonesia

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For the seismic activity monitoring and verification of the existence of faults in the Jakarta area, site surveys have been conducted, signal background noise test (signal feasibility monitoring), permission and installation of 17 seismograph type Lennartz in DKI Jakarta, South Tangerang and Bekasi Regency were performed. Activities started with site surveys (location selection coordinates placement of seismograph Lennartz equipment for earthquake monitoring) from June 26 2018 to November 30 2018. Data processing was carried out using signals from 26 microtremor signal samples along the location of fault fault management from Tangerang Selatan, South Jakarta and Bekasi Regency. Until December 3, 2018, the earthquake monitoring data were processed and searched for earthquake events using Lassie software and quality control was carried out using SeiscomP. The results of this data processing were verified with results from the research of Landsat imagery from Harisolumakso, 2001, and verified also with Baribis fault identification from Koulali, 2016 and validated with contour of microgravity density and geological and fault conditions in Jakarta from Koulali, 2017.

T3.1-P20  Future of Aerosol Radionuclide Monitoring

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In the 1990s, Pacific Northwest National Laboratory (PNNL) developed the Radionuclide Aerosol Sampler Analyzer (RASA) for worldwide aerosol monitoring. For the last several years, staff of PNNL and Creare have made investigations into aspects of upgrading the RASA. Key themes have been a modular approach to additional radionuclide measurements, optimizing the sampling/analyzing times to improve detection and location capability, and improving the power consumption via the use of electrostatic collection versus classic filtration. These individual efforts have been made in the context of retrofits to the existing RASA. In this work, we consider a complete RASA redesign at a notional level. Individual studies reported here contain theory and experimental investigations, but none of these has been tested with the others, and further work is needed to verify these gains. With these caveats, this work shows that substantial optimization of detection and location capability of a network of RASA systems is possible, multiple mission spaces can be addressed with additional measurements, and electrostatic collection is a practical advantage, although more work is needed. The quite unexpected result of this study is that some optimization of the existing RASA is possible without any hardware changes at all.

T3.1-P22  Hyper-Sensitive Gamma Spectrometry – Approaching the Ultimate Limit

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The Comprehensive Nuclear Test-Ban Treaty (CTBT) International Monitoring System (IMS) provides a network of 120 Radionuclide detection systems, strategically positioned around the globe with the aim of detecting radionuclide emissions from nuclear explosions. The UK CTBT Laboratory (GBL15, based at the Atomic Weapons Establishment, UK) routinely monitors this network for the UK government, assessing events, reviewing data, and re-measuring IMS samples from around the world. The laboratory also undertakes substantial research, with the aim of increasing the overall sensitivity of the monitoring regime. This submission will discuss the improvements possible for the monitoring regime, and the potential gains that are yet to be made.
**Theme 3: Verification Technologies and Technique Application**

**T 3.1-P23 Improvement of Energy Resolution of Beta Detector in Radioxenon Detection System (INGAS)**

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The INGAS detection system for measurement of radioxenon isotopes has been developed. In this system, gamma-rays and beta particles are detected by a well-type NaI(Tl) crystals and plastic scintillator, respectively. The beta detector is a hollow cylindrical plastic scintillator that contains gaseous radioactive source. This geometry can affect the energy resolution of the beta detector. The capability of GATE 7.0 to transport the optical photon was used to study and improve the energy resolution. The effects of main optical parameters such as reflector type and detector dimension on the energy resolution were considered by injection of 131mXe in the beta cell. The results show that the improved energy resolution of beta detector at the energy of 129 keV conversion electron is 37%.

**T 3.1-P25 Investigating New Detection Mediums for Atmospheric Radioxenon Measurements**

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Several radioxenon isotopes (Xe-131m, Xe-133, Xe-133m, Xe-135) are characteristic byproducts of nuclear explosions, and the presence of these isotopes in specific ratios in the atmosphere acts as a clear tracer which allows the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) to verify the nuclear nature of a clandestine explosion. These isotopes can be discriminated from background and detected at extremely low concentrations (< 1 mBq/m3 air) via exploitation of their distinct beta-gamma coincidence decay signatures. At Oregon State University, we have recently developed three compact and relatively low-cost radioxenon detectors to improve reliability and maintainability of current radioxenon detection systems employed at the International Monitoring System. Our detectors utilize new detection mediums (Stilbene+SiPM, SrI2+SiPM, co-planar CZT, and PIPS detectors) to measure xenon radioisotopes via beta-gamma coincidence technique. In this presentation, we will present the design of detectors and also discuss our preliminary experimental results using (1) Stilbene-CZT, (2) PIPS-CZT, and (3) PIPS-SrI2 radioxenon detectors.

**T 3.1-P26 New Lobular Detection Technology and Possible Applications**

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Accurate knowledge of gamma radiation fields generated either by strategic materials, orphan sources, environmental natural radiation (NORMS), decommissioning activities, as well as monitoring of radiation leakages, is essential for national regulatory agencies, border safety controls and customs administrations. Currently existing gamma cameras are not yet fully useful to meet the necessary conditions for most of these activities. A new concept of "gamma vision", developed by INVAP, uses lobular detection geometry for real time reconstruction of gamma radiation fields. This technology enables the application of the main design concept with several types of detectors, which allow to actually see dose rate from the background levels, typically 0.1μSv/h, up to values of 15Sv/h. In this work, some applications using the presented technology are shown and described, among them: Radiation Image Portal Monitors, to detect illicit traffic of radioactive sources. Our new concept allows to detect said sources and reconstruct, on real time, the image of the radiation field and accurately locate smuggled radiation sources. Gamma Handheld or Mobile Camcorders allowing to know the real time absorbed dose and to track hot spots in real time, triggering a paradigm shift in radiological protection as we know it today.
T3.1-P27  Next Generation Low-Power HPGe Gamma-Ray Spectrometer to Improve IMS Particulate Radionuclide Station Reliability

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LLNL developed a low-power and long-lifetime solution to improve reliability of high-purity germanium-based (HPGe) gamma-ray detectors in International Monitoring System (IMS) particulate radionuclide stations. HPGe is a semiconductor that must be operated under high vacuum at cryogenic temperatures (77 - 100 K) for energy-resolution analysis of gamma-rays emitted by radionuclides. The challenge is that HPGe detectors often fail after a station power outage because, with the return of power/cooling, impurities condense on the semiconductor surface inside the vacuum cryostat. One solution is to not let the detector warm up during power failures, however, existing HPGe detectors require too much power. LLNL has developed a high-efficiency (140%) HPGe detector which requires as little as 12-20 W cooling and could replace the higher-power-requiring detector component in IMS stations. The LLNL system requires only 10-25% of the power of current mechanically-cooled HPGe of similar size and could be kept cold via a small solar cell and battery, thereby improving the likelihood the IMS station will fully recover with restoration of power. Engineered for space applications and environments, this poster will discuss the current state of the HPGe systems, the operational characteristics, and possible application to the IMS.

T3.1-P28  Project PIM: A Low-Cost Mobile Seismo-Acoustic Sensor for Geophysical Deployments

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In this work, we present the "Pressure and Initial Measurement" (PIM) measurement board. The goal of project PIM is to develop a low-cost measurement board with multiple seismo-acoustic digital sensor and to compare them with existing high-fidelity equipment. PIM is designed using Micro-electromechanical Systems (MEMS) sensors. The sensors on the measurement board are an absolute pressure sensor, differential pressure sensor and an accelerometer. The board can be placed on top of a Raspberry Pi which serves as a datalogger. Printed circuit boards (PCB) have been designed to connect MEMS to the Raspberry Pi. All components of PIM are cheap, have a low energy consumption and have a small dimension. This allows for a versatile sensor that can be used for geophysical field studies, i.e. as mobile sensor arrays or in areas where the security of a deployed sensor is less guaranteed. Besides introducing a low-cost seismo-acoustic mobile sensor, we present the outcome of several calibration tests. The calibration protocol for PIM is based on the calibration protocol of the Royal Netherlands Meteorological Institute.

T3.1-P29  PVA Nanofibers Based Microfluidics Chip for Detection and Absorption of Nuclear Radioactive Solutions

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Radioactive wastes are usually by-products of nuclear power generation and other applications of nuclear technology, such as research and medicine. Previous sampling techniques required sample volumes ranging in the tens of milliliters and poses a high level risk of radiation exposure to analytical personnel and equipment. Nanotechnology has provided various structures which reduce oxidative damage in engineering applications with great efficiency. Here we have developed water stable PVA nanofibers and used them for two purpose, adsorption of nuclear radioactive waste by coating their surface with a natural zeolite (clinochlore) to treat contaminated water and second we patterned PVA nanofibers in nano rods and labeled them with radiotracer [2-[18F]fluoro-2-deoxy-D-glucose ([18F]FDG)] and closed them in microfluidics chip for the testing of positron emission tomography (PET) radiopharmaceuticals. When fluid baths these nano roads emit positrons and they
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The emission of antineutrinos is unaffected by the environment in which the explosion occurred. The detection of $^{37}$Ar can be a confirmatory measurement for a nuclear test, and when combined with on-site inspections, and in other applications where nuclear and radioactive material has to be detected, localized and possibly identified. Therefore replacement materials need to be considered, selected, implemented in corresponding detectors, and thoroughly tested. A notable development in the field of hand-held radiation detection devices focuses on simultaneous neutron and gamma ray detection with a single scintillator. This may lead to a new type of small and efficient hand-held devices, utilizing non-He-3 neutron detection. The outcome of a study of the scintillators CLYC and CLLB which allow a simultaneous measurement of gamma and neutron radiation will be presented in this contribution. Additionally, results with a neutron detector implemented in a wearable Radiation Isotope Identifier Device (RIID), the D3S from Kromek, will be shown. Differences in the detection of neutron radiation will be explored and analyzed regarding their potential use in on-site inspections.

**T3.1-P30 Radiation Detection for OSI - A Study of Non-He-3 Neutron Detectors**

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Within the past decade a significant shortage of He-3 and consequently an enormous increase in cost has occurred. Detectors equipped with He-3 are widely used in neutron detection applications, e.g. by first responders, during on-site inspections, and in other applications where nuclear and radioactive material has to be detected, localized and possibly identified. Therefore replacement materials need to be considered, selected, implemented in corresponding detectors, and thoroughly tested. A notable development in the field of hand-held radiation detection devices focuses on simultaneous neutron and gamma ray detection with a single scintillator. This may lead to a new type of small and efficient hand-held devices, utilizing non-He-3 neutron detection. The outcome of a study of the scintillators CLYC and CLLB which allow a simultaneous measurement of gamma and neutron radiation will be presented in this contribution. Additionally, results with a neutron detector implemented in a wearable Radiation Isotope Identifier Device (RIID), the D3S from Kromek, will be shown. Differences in the detection of neutron radiation will be explored and analyzed regarding their potential use in on-site inspections.

**T3.1-P31 Radioactive Gas Metrology at NPL and the Development of Short-Lived Gas Standards**

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NPL maintain the UK’s primary standards of radioactivity; including radioactive gas standards. Gas standards of $^3$H, $^{14}$C, $^{11}$C-11, $^{85}$Kr and $^{133}$Xe are realised by means of absolute counting using a series of length-compensated internal-gas proportional counters. These standards are used for the calibration of stack, area and environmental monitors. Presented is an overview of NPL’s capability in the areas of radioactive gas measurement and radioactivity-in-air monitoring. The overview will include details of planned inter-comparison of $^{133}$Xe and recent work to produce and standardise the short lived fission and activation product gases $^{41}$Ar, $^{85m}$Kr, $^{87}$Kr, $^{88}$Kr and $^{135}$Xe for the calibration of a Fukushima NPP criticality monitor.

**T3.1-P32 Radioxenon Collection Using Synthesized Xenon-Adsorbing Material for Nuclear Test Monitoring**

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LLNL is researching a metal-organic framework material for collecting radioactive xenon isotopes from atmospheric raw air for applications in the context of nuclear test monitoring. By using a recently-synthesized xenon-adsorbing material, in combination with an advanced adsorption processing cycle in a structured adsorbent bed, the LLNL concept has the potential of reducing the footprint and improving the energy-efficiency.
of radioxenon systems by allowing operation at room temperature and with no pre-processing. The high-xenon selectivity of the adsorbent material and its insensitivity to water are key enabling features in adsorbing xenon from raw unprocessed air at room temperature. This poster will discuss the current state of the material characterization, the system modeling, and possible applications of relevance to CTBT.

**T3.1-P33** Report on SPALAX-NG Validation Tests and Performances  
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The first industrial prototype of the new Generation SPALAX system (SPALAX-NG) has been delivered at CEA in December 2017. This system is dedicated to continuous detection and measurement of xenon radioisotopes in the atmosphere. It has been designed to upgrade the current SPALAX system on the IMS network. After several months of optimization, an official validation test period has been launched with PTS in October 2018 for 6 months at the developer facility (CEA/DIF). After completion of this first period, the outstanding performances of the system are well established with detection limits of ~ 0.2 mBq.m⁻³ (8 hour collection) for the four relevant radioxenon isotopes. Taking benefit of the high resolution and the low background of the new spectrometer, the system is able to separate unambiguously the contribution of each isotope. These performances give a new perspective on the radioxenon background knowledge in Western Europe.

**T3.1-P34** Results from a 6-Month Acceptance Test of the SAUNA III - Prototype  
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In compliance with the acceptance process for the next generation noble gas systems, the SAUNA III - prototype at FOI has undergone a six-month evaluation in cooperation with the PTS. The system was allowed to run in routine operation, and was also further tested using radioactive xenon injections at the beginning and at the end of the test period. Results from the tests will be presented.

**T3.1-P35** SAUNA-CUBE: The First Prototype for a Noble Gas System Adapted for an Array-Network  
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A detection network consisting of arrays of less complex noble gas measurement systems at selected sites, would, at comparable cost, have a verification capability superior to the current IMS noble gas network configuration. Such a network would also be more reliable, redundant, and easier to maintain. The first industrial prototype of a noble gas system adapted for an array network - SAUNA-CUBE - has been manufactured and tested. Although the system design is based on many years of operation of the SAUNA concept, the concept is in many ways new, and presented many challenges. The system design and functionality will be presented, along with the initial test results and further plans.
Theme 3: Verification Technologies and Technique Application

T 3.1-P36  Status of Infrasound and Seismic Metrology at CEA

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The level of confidence expected by the measurement produced by geophysical measurement chains is a guarantee of quality for the data that are processed in the subsequent analysis process and the elements necessary for the resulting decision-making. The CEA’s metrology activity in the infrasound and seismic fields has historically contributed to the development of this confidence. The fields of low-frequency dynamic environmental metrology are not for the most part covered by the international metrology organizations, both private and public, responsible for materializing and ensuring the connection of measurements to the international system of units, although this is a fundamental part of the guarantee of measurement control. In order to respond to this lack, the CEA has been developing for several years an R&D activity in metrology aimed at equipping itself with laboratories, standards and calibration methods designed to meet current and future metrological challenges. This presentation will focus on CEA’s metrology activity through its new measurement and testing facilities dedicated to infrasound and seismic sensors as well as its R&D work in metrology.

T 3.1-P37  Status of the Stack Monitor for the STAX Project

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We present the manufacturing status of INVAP’s stack monitor for the STAX (Source Term Analysis of Xeon) project. INVAP has designed a stack monitor based on a HPGe detector that meets the Hardware and Software requirements defined by STAX project. Emphasis is put in the fact that it can be adapted to broad emissions regimes of the different MIPFs. The monitor has a modular design which allows for an easy installation, fulfilling the different requirements that facilities that already have a system for the monitoring of the stack may have. In the framework of a contract with PNNL, INVAP is manufacturing the stack monitor. The hardware is described, and the status of the manufacturing of the measuring chamber, shielding and sampling system is shown.

T 3.1-P38  Study of Materials for Improved Adsorption of Xenon at IMS Radionuclide Stations

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A crucial part of the verification system of the CTBT are the radioxenon monitoring systems that are monitoring the atmosphere for potential xenon releases from nuclear explosions. The efficient adsorption and desorption of radioxenon in adsorbent materials is essential for the detection capability of these systems. Recent studies on xenon adsorption in porous materials have shown promising results for the further improvement of the detection capability of the IMS noble gas systems. In the framework of the two previous EU JA programs, SCK•CEN developed a laboratory set-up to perform breakthrough experiments on different adsorbent materials and developed a model for the simulation of the adsorption process. Although this research was in another context, it was obvious that the studies performed and the methods developed were also very promising for xenon monitoring purposes. The SCK•CEN has been contracted by the CTBTO under the EU JA VII program to perform a fundamental study of xenon adsorption materials (activated carbons, silver doped zeolites, metal-organic frameworks) for a more efficient noble gas monitoring at IMS stations, which could be translated in lower detection limits or shorter collection and processing times. The project as well as the first results will be presented.
T3.1-P39  Testing of Cosmic Veto for RASA Background and MDC Reduction

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One factor affecting Radionuclide Aerosol Sampler/Analyzer (RASA) detector minimum detectable concentration (MDC) is the level of background counts in the spectrum. Interactions between cosmic rays and high-purity germanium detectors result in increased detector background counts, which reduce detector sensitivity. Anti-coincidence systems eliminate counts which originate outside the detector shielding. By eliminating these counts, significant improvements in MDC could be achieved. To investigate the possible effects of cosmic veto on RASA performance, General Dynamics Mission Systems (GDMS) tested an off-the-shelf Canberra CosmicGuard system on a testbed RASA system in Chantilly, Virginia. After tuning the system, GDMS performed 72-hour blank filter measurements to measure the effect on detector sensitivity. Using a Canberra Lynx multi-channel analyzer, GDMS captured both gated and ungated spectra for direct observation of the effect of the cosmic veto. Using an unmodified RASA geometry, GDMS measured a 3% reduction in background counts, and a 2% reduction in MDC. Further improvement could be seen with a custom scintillator design to more fully surround the RASA detector, or testing at a location with a higher cosmic background.

T3.1-P41  The Gas Processing System of SAUNA CUBE

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A new concept in radioxenon detection, based on the deployment of smaller and less complex systems compared to the ones presently used in IMS, is being developed at FOI. The new radioxenon systems, named SAUNA CUBE, will be deployed in an array configuration consisting of 4-5 units. A first prototype of the CUBE gas processing system has been constructed in the laboratory and its performance has been tested and evaluated. The xenon yield was determined using a thermal conductivity detector, showing a fairly stable result of about 80%. The removal of carbon dioxide and water from xenon was analysed using a mass spectrometer and the peaks were found to be clearly separated, indicating an effective separation process. The gas system has been operated in continuous mode for about 40 days in order to investigate system stability. The retention time and the peak widths showed small variations. In addition, the radon removal capability was studied.

T3.1-P42  The Güralp Affinity as a Replacement for the DM 24SxAM

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The Affinity is presented as a replacement for the long-running DM 24-based digitizer products incorporating Authentication capability. A key design concept is that the operator experience should be the same as far as possible, in order to minimise the learning curve, and maximise the existing investment in knowledge and experience. Both devices are compared, and the commonalities and differences highlighted in the areas of the hardware interfaces, the software usage, the features and the performance. The Affinity is a drop-in replacement for the existing digitizers, whilst adding new functionality. Therefore, it is ideally suited to the long term sustainment and technology refreshment of IMS stations.

T3.1-P43  The Radiation Dose Monitoring Network System in a Coastal Area

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We propose a real time monitoring radiation dose network of marine area by using buoys and drones. This system will provide 2-dimensional dose distribution and estimation of health risk for people who move in the
Theme 3: Verification Technologies and Technique Application

area covered by the system. This system has been developed to keep safety of evacuees from radiation accident and resident around nuclear power plant in case. There is also the possibility to use this system for monitoring of nuclear tests by additional analysis of data from this sensor network. The monitoring network consists of buoys and drones equipped with a spectrometer for radiation and environmental sensors. These components are connected each other by IoT network and satellite communication. The program for nuclear identification from energy spectrum should be optimized for nuclides which are assumed to be detected. Additionally, the correction function for dose calculation needs to be optimized because buoys and drones will move. These optimization and predicted usability of the system will be shown in this presentation.

T3.1-P44 Three Future Filters for IMS Radionuclide Particulate Operations

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The radionuclide segment of the IMS is required to achieve a minimum of 95% data availability while maintaining high sensitivity for detection of nuclear explosions. These consistent levels of performance can only be achieved with the continued use of high-quality and reliable equipment and consumables. To manage and ensure the future supply of filter media needed to sustain longer-term IMS radionuclide particulate sampling, the PTS is preparing for the testing and qualification of the future supply of IMS filter materials. In preparation of identifying and validating future suppliers, an optimised test protocol for the acceptance testing of filter materials and for batch testing have been developed. Requirements, test protocols and test results for existing and candidate material will be presented.

T3.1-P45 Towards Disaster Mitigation on Earthquakes and Tsunamis Using Off Shore Real Time Monitoring Data

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Recently, many destructive earthquakes and tsunamis occurred in the world such as 2011 Tohoku earthquake in Japan, 2018 Palu earthquake/ tsunami at Sulawesi Island in Indonesia etc. Therefore, off shore real time monitoring systems around seismogenic zones are very important for early detection of earthquake and tsunami. Furthermore, these systems are also indispensable to understand crustal activities and phenomena as precursors. In Japan, Ocean floor network systems as DONET and S-NET already deployed for early warning and prediction researches. Recently, N-NET will be developed and deployed around western part of Nankai trough seismogenic zone in southwestern Japan. In DONET system, DONET1 and DONET2 are focusing on the Nankai Trough seismogenic zone southwestern Japan, S-NET is focusing on off east Japan based on lessons learned from 2011 Tohoku earthquake. The system of N-NET will be developed as the highbrid system of DONET and S-NET. For disaster mitigation, not only real time data but also advanced simulation are indispensable. We developed the recurrence simulation of mega thrust earthquakes, data assimilation and real time inundation simulation using real time data in Nankai trough seismogenic zone. In this presentation, we explain Japanese ocean floor networks and advanced simulation researches.
**T 3.1-P46 Ultra-Sensitive Measurements of Large-Volume Radioxenon Samples Using an Ultra-Low-Background Proportional Counter**

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The PTS and the international community have expressed interest in the ability to obtain xenon samples using the output of industrial oxygen plants, which could be three orders of magnitude or more larger than xenon samples currently collected by International Monitoring System (IMS) stations. Precise characterization of regional backgrounds is a motivation for very large volume samples and the enhanced sensitivity they could provide. Such samples would be too large for measurement in the existing detection systems and, as such, a new optimized method for analysis needs to be investigated. For many years the Pacific Northwest National Laboratory (PNNL) has been developing ultra-low-background internal-source gas proportional counters (ULBPCs) for use in a variety of applications; these ULBPCs function as beta spectrometers and have the capacity to analyze significantly larger gas samples than the traditional detectors used in the IMS and the potential to offer significantly improved sensitivity. PNNL has investigated the use of ULBPCs for measuring large-volume radioxenon samples to assess optimal performance parameters (e.g. operating pressure, count gas blend, etc.), sensitivity levels, and ability to discriminate multiple radioxenon isotopes. Results from these investigations will be presented.

**T 3.1-P47 Unmanned Aerial Vehicles in On-Site Inspection: New Techniques for Gamma Spectroscopy Survey**

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Under the Comprehensive-Nuclear-Test-Ban-Treaty a State Party can request an on-site inspection (OSI) to establish whether a nuclear explosion has taken place. Gamma spectroscopy measurements are key to OSI and aerial radiometric survey has been demonstrated to provide efficient coverage of large areas. We have developed the Advanced Radiation Detector for Unmanned Aerial Vehicle (UAV) Operations (ARDUO). This gamma spectrometer can point out the direction to a radiation source while in flight to permit real-time evolution of flight plans. We have collected data with this system flown over a variety of point and extended sources including a controlled release of 40 GBq of 140La in an L-shape pattern covering 3,200 m². Here we will present these results and show how the directional information from the system can be used to improve the spatial precision of an aerial survey map. In an OSI UAV's can provide advantages over manned vehicles by keeping the pilot out of hazardous situations, flying lower and slower for improved sensitivity and by removing the need for the Inspected State party to supply an aircraft. We will discuss how directional techniques could be applied to improve the spatial precision of traditional manned aerial survey in on-site inspection.

**T 3.1-P48 Updated Results from Long-Term Infrasound Sensor Comparison**

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Previous testing has shown that infrasound sensors deployed in the field can exhibit notable deviations from their lab-based calibrations. These variations may in part be due to changes in environmental conditions, long-term sensor drift, or other unresol ved features. In early 2018 we installed two identical test elements at the Sandia National Labs FACT site with five infrasound sensors (Chaparral M 50A, Chaparral M 64, M B 2005, M B 3, and Hyperion IFS-5100) connected to a single port to the atmosphere, as well as internal and external temperature, humidity, and absolute pressure sensors. Using the M B 2005 as the reference, we examine the sensor response a
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The emission of antineutrinos is unaffected by the mass of the detector and can be detected in the atmosphere surrounding an underground nuclear explosion. As a noble gas, argon is unreactive and migrates through the earth and can be released into the atmosphere with the radioxenon fission gases that are also produced during a nuclear explosion. Detection of $^{37}$Ar can be a confirmatory measurement for a nuclear test, and when combined with the detection of antineutrinos, it can provide a powerful tool for verifying that a nuclear explosion has occurred.

T3.1-P49 Xenon International

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Xenon International is a next-generation ground-based radioxenon measurement system developed by Pacific Northwest National Laboratory in collaboration with Teledyne Brown Engineering (TBE). Xenon International processes samples every 6 hours and collects more than 2.5 times the amount of xenon gas over first-generation systems, improving detection sensitivity by nearly a factor of two. During a one-year field test at the International Monitoring System (IMS) station RN75 in Charlottesville, VA, U.S.A., Xenon International measured atmospheric radioxenon samples while located next to the U.S. IMS system USX75—a SAUNA system—from July 2018 through July 2019. The goal of the field test was to determine system reliability and uptime, and data flow to the U.S. National Data Center (NDC) of the system while operated by U.S. IMS station operators. This presentation reviews the field testing results and data evaluation between the Xenon International system and the USX75 system as part of the development process to achieve manufacturing maturity. Comparison of the data from the two systems are presented that highlight the significance of shorter processing time and lower detection limits.
T3.2 Laboratories Including Mobile and Field Based Facilities

Oral Presentations

T3.2-O1 Investigations of the Characteristics of Installation for the Measurement of Low Activities of 37Ar Based on the Detection of Liquid Argon Scintillation

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One of the most conclusive evidences of a violation of CTBT is the presence in the subsoil air of elevated concentrations of 37Ar radionuclide, which is formed in large quantities in the interaction of neutrons with calcium in rocks. Traditionally, to measure the activity of 37Ar, proportional gas counters are used, which are filled with a counting gas prepared from samples of argon with the addition of methane. Further reduction of the detection limit of 37Ar is limited by the difficulty of a significant increase of argon sample volume placed in a proportional counter. Installation for the detection of argon-37 low activities based on the liquid scintillation principle is being developed at the Radium Khlopin Institute under contract with the CTBTO. The role of the scintillator in this installation is performed by the liquefied preparation of extracted from soil air argon itself. The use of liquefied argon samples allows one to multiply the volume of the measured samples without increasing the size of the measuring cell and shield elements, and allows significant reduction of detection limits of 37Ar. Installation is currently being tested and the results are given in this presentation.

T3.2-O2 More Sensitive Measurements that Radionuclide Laboratories Can Do for Special Studies

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Advanced gamma-spectrometry systems have potential for higher-sensitivity analysis of CTBT relevant radionuclides in IMS samples. These systems include sophisticated multi-detector configurations that are capable of coincidence measurements with Compton and cosmic rejection. They can provide detection sensitivity 2-4 orders of magnitude higher than conventional gamma-spectrometry used for IMS samples. Such systems could be utilized for the re-analysis of selected IMS samples, to provide more accurate measurements with lower uncertainty, improved isotopic ratios, and potentially detect radionuclides not detectable using station or laboratory systems. The advantages of these next-generation systems has been investigated by a collaboration between the Pacific Northwest National Laboratory (PNNL, U.S.A.) and Atomic Weapons Establishment (AWE, UK), host to USL16 and GBL15.

T3.2-O3 Sample Throughput Improvements for the U.S. Noble Gas Laboratory

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As radioxon samples are collected around the world at the CTBT IMS stations, a subset of those are sent to radionuclide laboratories around the world for re-analysis. PNNL operates the U.S. Noble Gas Laboratory (US-NGL), which was certified in December of 2016. The laboratory currently has one certified detector, but there are potential scenarios where additional throughput is desired. Two examples of this desired throughput are when multiple samples arrive at once, such as during a Proficiency Test Exercise (PTE) or from an event at a
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station. Alternatively, if there was a calibration or PTE performed shortly before station samples, it is desirable to have a subset of pristine detectors with no additional backgrounds from the radioxenon spikes. We have installed a detector bank of four additional detectors for US-NGL. The gas handling system for these detectors has been optimized to minimize the dead volumes, allowing the detectors to meet the CTBT verification requirement for transfer efficiency. The detectors have undergone initial testing and are in the process of being certified for operation. We present the detector calibration and gas handling mechanism for the new detector bank. Additionally, we present operational scenarios for the added sample throughput of the US-NGL.

Poster Presentations

T3.2-P1  **Accuracy of Particulate Sample Analysis with a BEGe Detector**

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Accurate gamma spectrometric measurements depended on correct values of several parameters. One of these is corrections for true summing coincidences of the gamma radiation emitted by the assayed radionuclides. Coincidence summing correction factors are nuclide specific and should be applied to relevant measured peak areas to obtain accurate activity results. In the study several radionuclides for CTBTO International Data Centre (IDC) event screening from particulate samples were analysed looking at summing coincidence effects. These samples contain fission and activation products measured using BEGe detector. Correction factors are obtained by software based on Monte Carlo calculations. A comparison of coincidence summing correction factors were made between an available commercial software package (LabSOCS) and a specifically developed software package (VGSL), developed by Radionuclide Development Unit of the IDC. VGSL is designed to provide quality assessment of the data delivered by eighty (80) international monitoring stations around the world to monitor nuclear emissions after nuclear tests, in the atmosphere or underground. The results of the coincidence summing correction factors from relevant radionuclides of particulate samples indicate the accuracy of the activity results, if the factors generated by LabSOCS are identical or may be complemented by VGSL software factors.

T3.2-P2  **Developing a Laboratory-Based Beta-Gamma Coincidence Detection System**

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Beta-gamma coincidence detection methods have become an integral part of the International Monitoring System (IMS), particularly with regard to radioxenon detection. The UK Radionuclide Laboratory (GBL15) is currently working with partners at the University of Surrey and NPL in developing a laboratory-based system for beta-gamma coincidence measurements, aiming to reduce detection limits for radionuclides of interest, as well as future-proof the UK Noble Gas analysis capability in support of the Verification Regime.

T3.2-P4  **Efficiency of Ion Exchange Columns for Precipitation Sampling**

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As a complement to measurement of radioactivity in air, collection and measurement of radioactivity in deposition is performed within many national surveillance systems. Deposited radioactivity can give an estimate of external dose to the public and can also be used to calculate transport factors for radionuclides. The system used in Sweden consists of a collection funnel, from which the precipitation is passed through an ion-exchange column. The contents of the column are ashed and measured by gamma spectroscopy to determine deposited radioactivity. In order to have control of the method used within the national surveillance system, and a possible
future modification of the method, the collection efficiency of the ion exchange columns has been investigated together with tests of a new ion exchange resin. The effects of ashing at different temperatures have also been investigated for the two types of ion exchange columns. The collection efficiency was high for all tested nuclides. For most nuclides, losses during ashing were small, but loss of iodine could be seen at temperatures as low as 60 °C. Deposition of Ru-106 during autumn 2017 revealed that activity can remain in the funnel and lead to cross-contamination of subsequent samples.

T3.2-P5 Further Development of the SAUNA-FIELD System for Rapid Deployment and Improved Operation

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The measurement of xenon was successfully incorporated in an on site inspection (OSI) exercise for the first time during the integrated field exercise in Jordan 2014 (IFE14). One of the systems used was the SAUNA-FIELD, designed to process and analyse radioactive xenon from sub-soil samples with the purpose of detecting nuclear explosions. During the last years FOI has, built on experience, lessons learnt from exercises and outputs from workshops, re-designed the system to improve the functionality during an OSI. The aim has been to simplify the deployment of the system and to further improve the automation of the process when handling sub-soil samples to reduce the amount of manual labour needed. A new design, enabling the system to be installed in a container suitable for air transport, has been made which drastically simplifies the deployment of the system. The software and gas handling capacity has also been improved for the operator.

T3.2-P6 Quality Assurance for the OSI Field Radionuclide Laboratory

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The sole purpose of an on-site inspection is to clarify whether a nuclear weapon test explosion has been carried out in violation of the CTBT. To ensure that credible results are delivered from the in-field analysis of the environmental samples collected during an inspection, the On-Site Inspection Division are developing the underlying processes, identifying key performance indicators, and documenting the equipment and resource preparation steps of the Field Radionuclide Laboratory, in close coordination with other Divisions. This poster reviews the challenges faced, describes the status of progresses made in the development of the Field radionuclide Laboratory, and documents the objectives for the training of surrogate inspectors and readiness for the 2020 Buildup Exercises.

T3.2-P7 Radioxenon Spiked Air for Field Testing

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A trusted known test sample is vital to working with measurement systems regarding diagnostics and quality control. In the laboratory setting, diagnostic and quality measurements have been essential to troubleshooting and performance demonstration, respectively. The ability to make these types of measurements is just as powerful and necessary in the field. The measurement of radioactive xenon by the International Monitoring System (IMS) of the Preparatory Commission for the CTBTO Preparatory Commission, Vienna, Austria (CTBTO PrepCom) could benefit from the ability to make diagnostic and quality control measurements at established monitoring stations. The test sample or measurement sample must be available at the field locations to take advantage of the power of diagnostic and quality control measurements. Idaho National Laboratory (INL) has demonstrated the ability to prepare test and quality samples of radioactive xenon in various matrices. Partnering with the Swedish Defence Research Agency (FOI) has led to the demonstration of the measurement of an air sample spiked with radioactive xenon provided by INL. The preparation, measurement and results of
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The emission of antineutrinos is unaffected by the environment in which the explosion occurred. The detection of 37Ar can be a confirmatory measurement for a nuclear test, and when combined with other diagnostic techniques, it can be used to support the PTS review of Lab capabilities and compliance. Recent activities related to Xe PTEs as well as Xe PTE results will be presented.

T3.2-P9  Status and Results of Xenon Proficiency Test Exercises

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One key element of the quality assurance/quality control (QA/QC) program for IMS Noble Gas systems of the Radionuclide network will be based on sample re-analyses at International Monitoring System laboratories. Station and Radionuclide Laboratory results of measurements of Xenon activity concentrations and isotope ratios will be compared since these parameters are independent of gas losses. To ensure the credibility of IMS Laboratories as providers of noble gas analysis results, the Laboratories require certification to perform the analysis of noble gas samples, as well as their regular participation in a QA/QC program. Regular Xenon Proficiency Test Exercises (Xe PTEs) are a key part of the laboratory QA/QC program, and these exercises support the PTS review of Lab capabilities and compliance. Recent activities related to Xe PTEs as well as Xe PTE results will be presented.
T3.3 Remote Sensing, Satellite Imagery and Data Acquisition Platforms

Oral Presentations

T3.3-O1  Continuous and Unattended Spectroscopic Operation and Analysis with the Mirion Data Analyst

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A number of applications benefit from continuous and repeated gamma ray spectral acquisition, analysis, and reporting. In these cases, important criteria include: no lapses in data acquisition during monitoring, full data analysis and reporting can be applied in real time, the spectra and results are stored for post analysis review, and notifications are available when concentration levels rise above predetermined limits. The Data Analyst is a small device designed to accommodate these needs and provide the flexibility needed to configure measurement, data collection, and data analysis for a variety of applications. Continuous acquisition is accomplished with novel software and hardware which allows for unattended acquisition, analysis, and storage of data over multiple measurement workflow definitions. Since multiple averaging times are allowed for a single data stream it is possible to attain swift reaction times in parallel with very low minimum detectable concentrations. The analysis protocol leverages existing Genie 2000 analysis algorithms and applies them in real time to each workflow as it completes an averaging interval. The device also accommodates the use of analog inputs, GPIO communication, GPS location, and either wired or wireless communications. The capabilities of the device as well as a number of applications will be discussed.

T3.3-O2  International Radiation Monitoring Information System (IRMIS)

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The Incident and Emergency Centre (IEC) of the International Atomic Energy Agency (IAEA) has developed a web application, the International Radiation Monitoring Information System (IRMIS) through which the Member States can share and visualize large quantities of radiation monitoring data (viz. gamma dose rate, isotope specific ground depositions and air concentrations in a nuclear or radiological emergency). The geo-referenced radiation monitoring data maps produced by the IRMIS can assist Member States to take appropriate protective actions during an emergency. The IRMIS may be used to assist official Contact Points, designated under the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, in the decision-making process following a nuclear or radiological emergency irrespective of the cause.

T3.3-O3  Mapping Radioactive Minerals Using Satellite Data

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Most developing nations depend on the exploration of minerals for economic growth and development. Reliable information in terms of geological and mineral prospective maps is therefore important for full exploration. Remote sensing, as a direct adjunct to a field, lithological and structural mapping and GIS plays an important role in the study of mineralized areas. It has huge importance in both geological surveys and for potential investors, as it helps in reducing the time spent in field work, cost and human labor especially in
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inaccessible areas. A application of remote sensing and GIS for radioactive mapping are not fully integrated into the activities of geological survey. This study was aimed at applying remote sensing techniques and GIS to map radioactive minerals in mirima hills. The data used in the study area was Landsat 8 and 7 obtained from (https://earthexplorer.usgs.gov/) 5 website which was processed by using ENVI5.3 and ArcMap 10.3 software by means of the color composite, band rationing, principal component analysis and supervised classification. Different types of minerals /rocks were mapped by studying spectral anomalies in processed Landsat 8 and 7 data using band ratio 6/7, 6/5, 4/2, color composite, PCA and supervised classification.

Poster Presentations

T 3.3-P1 A New Method to Identifying Radioactivity in the Region of Infrared

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Last theoretical study on the effect of gamma radiation on natural rocks show that the spectrum in the infrared region will be affected by radiation (Ejtehadi et al., SNT 2017). Infrared spectrometry works by analyzing the amount of energy found in infrared photons absorbed by the molecule which depends on the energy of the vibrational molecules. Gamma ray is one type of photon with high energy which changes another molecules' energy. So the changing of energy in molecules would be detected by infrared spectroscopy. It is very useful for detecting a region with radioactivity when the gamma ray affects the surrounded material (a major part of the CTBTO activity). The recent laboratory and field study on K-Feldspar granitic rock sample (a rock capability contains Uranium) with natural irradiation in the warm spring of radium radiation level of 86 in Talesh-Mahale (Ramsar Province in Iran) has shown significant changes in 500 to 2500 wavelength/nm area and peaks of 1450, 1950 and 2300 nm. Some satellites and airborne sensors may be used to show the gamma ray affects by changing the infrared spectrum. This method is very applicable in absence of a gamma detector or can be used to limiting scanning purpose area.


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The study aimed to produce landslide susceptibility maps based on GIS and Remote Sensing modeling and to conduct field surveys to get the local community’s view about the landslides in Rawalakot, Azad Kashmir. Landslide susceptibility index (LSI) maps were prepared utilizing different parameters namely topographic (slope, aspect, elevation, plan curvature, land use/land cover etc.); hydrological (distance from streams, SPI, TWI, precipitation etc.) and geological parameters (lithology, distance from faults, distance from roads etc.) in GIS environment. All the parameter layers were assigned weights with 0.04 threshold consistency ratio (CR) values using an analytical hierarchical process (AHP) and weighted overlay combination (WLC) for the identification of four different landslide susceptibility zones i.e. low, moderate, high and very high. Results showed that these zones covered 3 %, 33%, 45 % and 18% of the total area, respectively. Local community based field survey revealed that standard building codes should be adopted for construction of infrastructure in the area.
T3.3-P3  **Application of Weather Radar Data for Volcanic Ash Dispersion of Anak Krakatau Eruption on 27 December 2018**  
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Operational weather radar data from eruption of Mt. Krakatau in Sunda Strait located between Sumatra and Java Island Indonesia in 27 December 2018 is analysed to identify Mount Krakatau eruption and its dispersion by using a direct product in the form of CAPPI-MAX (Constant Altitude Plan Position Indicator – Maximum) retrieved from reflectivity factor (dB z). The radar can capture the reflectivity of Mount Krakatau eruption and its dispersion. Larger material size named lapilli with 45 – 50 dBz tends to locate in the nearby volcanic area. The medium size of the material like coarse volcanic ash with 30 – 35 dBz of reflectivity detected surrounding the center of the volcanic area and carried away by the wind to the south direction. Volcano eruption patterns begin suddenly as a high reflectivity factor appears in the middle and the spreads around it with lower value as increasing distance.

T3.3-P4  **Applying Multispectral and Hyperspectral Imagery Analysis to Monitor and Verify Front-End Uranium Production**  
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We are arguably approaching an era where more and more states may be interested in pursuing nuclear weapons. While export controls limit the sharing of technology and knowledge related to nuclear weapons development, much of the science behind these weapons can be found in the open-source. Because nuclear weapons designs are easier to obtain, the most effective strategy to prevent new states from building and testing such weapons is to restrict the acquisition or production of fissile material. The production of fissile material is often a closely held state secret; even for states that report production levels to the IAEA. Having a firm grasp on a state’s fissile material production, capabilities, and activities can further inform whether a state has or is planning to develop and test nuclear devices. Uranium production can be difficult to verify without on-the-ground inspections. As more multispectral (MS) and hyperspectral (HS) sensors are developed and launched, data from these sensors can help verify uranium mining and milling activities. We did a proof-of-concept study on how MS and HS data can be used to monitor front-end uranium production and the potential for this to be implemented as a verification mechanism.

T3.3-P5  **Comparison of Satellite Earth Observation and Seismic Data to Analysis the Effect of Nuclear Tests in 2017 North Korea**  
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An underground nuclear test can produce a shockwave that lofts surface material. In 1996, a new phase in stopping all types of nuclear tests began with the Comprehensive Nuclear-Test-Ban Treaty Organization. However, the nuclear tests are still being performed by some countries, one of them is North Korea on September 3, 2017. The earthquake is one of implication from the nuclear test that can affect a few factors in the sub-surface. Furthermore, the explosions also influence in the atmosphere and the surface of the nuclear test. In this research, we use the thermal and panchromatic band from LANDSAT 8, ASTER and also combined with the seismic data to analyses the characteristic effect of a nuclear test for more comprehensive monitoring. In a seismic method, the explosion energy will be converted to magnitude moment and distance that possible to refer the secure range of the nuclear test. While in satellite, the wide area of nuclear test is clearly shown from the ASTER data, and the emissivity from the thermal band also increase after the test was executed. The comparison of both methods is potentially used to develop change detection techniques to support a CTBT on-site inspection.
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T3.3-P7  Design and Construction of an OSI Airborne Techniques Simulator


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To support the development of airborne OSI equipment configurations in a realistic setting prior to actual testing on board an aircraft, an airborne techniques simulator has been designed and constructed. As well as providing a means to support the development of OSI airborne techniques, the simulator offers significant potential to train OSI surrogate inspectors on the application of visual observation, multi-spectral, gamma and magnetic surveys on the ground before embarking on in-flight training. The simulator has the look and feel of an actual helicopter, with appropriate seating and harnesses as well as cabin hard points. The simulator is built on an Mi-2 helicopter airframe but has been heavily customised to simulate different aspects of various airframes. For example, a hatch has been created inside the cabin to simulate openings in the Sikorsky UH 60 Black Hawk and Eurocopter AS332 Super Puma. Similarly, external hard points have been added to allow the mounting of utility pods designed for the Bell 212 and Eurocopter AS350, which are typically used to house multi-spectral sensors. The flexible nature of the simulator allows different OSI scenarios to be tested and trained, which can incorporate interactions with pilots and OSI representatives on-board the airframe.

T3.3-P8  Improvements to the Standard Station Interface (SSI) Software: State of Health and Authentication with ECDSA

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CTBTO Standard Station Interface (SSI) is a set of executable programs and application programming interfaces for acquisition, authentication, archiving, and telemetry of seismic, infrasound, and hydroacoustic data acquired by the stations of the IMS nuclear monitoring network. The State of Health (SoH) module of the SSI is the interface which allows station operators to monitor and control parameters of the SSI operation. This module collects State-of-health information related to the SSI, underlying hardware and software layers and presents this information to the station operators in a user-friendly format. The objective of the module modification is to provide the station operator with a modern means to access SoH information of the running station. This includes meaningful measurements provided by the digitizers, by SSI, the CRF and by supporting equipment. Authentication with ECDSA (Elliptic Curve Digital Signature Algorithm) has also been integrated to the SSI. This algorithm is supported by the tokens used at stations, and a software/firmware update has been done to enable its use. SSI Configurator is updated to include the ECDSA option. SPYRUS Links Series II HSM and the SmartCard HSM are the supported HSM devices.

T3.3-P9  Optimizing the OSI Operation by Employing Drone Mounted Aerial Gamma Monitoring System

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Mapping of radionuclide contamination in a large area to search for radionuclides of interest for an OSI may be undertaken by several methods, the mapping for covering area of about 1000 km² will need several days of helicopter operation and longer days for ground operations. The use of drone (unmanned aerial vehicle)-mounted gamma monitoring system may give some advantages of saving a lot of time and resources including more rapid of preparation and operation, fewer operators, better access coverage area that cannot be reached by conventional ground-based operation, more flexible adjustment of flight speed and altitude compared to helicopter, better detection efficiency due to the shorter distance to the ground and more detailed coverage area compared to aerial-based operation, and others. We propose a prototype of drone-mounted gamma monitoring system that consists of a lightweight gamma detector equivalent to one inch of NaI(Tl) in efficiency with a simpler pulse
processing system, a GPS, a lightweight smart phone size battery, a video camera and a data acquisition and telemetry system for collecting data of radiation level, position coordinates and visual data location and IOT-based real-time sending using wireless communicator to a receiver station located in base-camp or field inspection area.

T3.3-P10 Potential Ways for Optimization of Multispectral Including Infrared (MSIR) Imaging for On-Site Inspection (OSI)

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According to the Protocol stipulated techniques for inspection activities provide multispectral including infrared (MSIR) imaging during an additional overflight (AO) to search for anomalies or artifacts as features of potential underground nuclear explosion (UNE). Modern MSIR systems may be used for OSI purposes with application of multispectral and infrared sensors. Since the Protocol has no definition of the "multispectral" term the Treaty and the Model Text for the draft OSI Operational Manual have no limitations for these sensors in regard to number and parameters of spectral regions. But MSIR equipment should be used solely for OSI purposes in full compliance with the Treaty and therefore practical application of specific spectral regions should be well-grounded. Based on the IFE-2014 the CTBTO Preparatory Commission developed the OSI Action Plan for 2016-2019 which includes Project 3.1 for examination of integrated airborne systems for MSIR, gamma spectroscopy and magnetic field mapping. One of the problem issues is optimization of all such equipment within a limited space of an aircraft. Therefore MSIR equipment optimization for OSI purposes is critical task. This paper examines potential ways for optimization of MSIR equipment with account of well-grounded selection of specific regions.

T3.3-P11 Several Key COTS Equipments’ Potential Application to CTBTO OSI

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Position-Finding/Navigation, Field Communication, UAVs and Near-Field - Communication are all commercial-off-the-shelf equipment, which are widely used in everyday life. This work is dedicated to the potential use of such equipment in the CTBT technical framework and real OSI scenarios and to provide some system engineering solutions. Essential philosophy of keeping balance between OSI mission efficiency and least intrusiveness must be kept in mind. - Position-Finding/Navigation: 4-mode navigation system solution involving GPS, GLONASS, BEIDOU and GALILEO GNSS systems, customized for OSI. The system solution would bring political awareness and technical reliability together to meet the factual OSI requirements. - Field Communication: Customized field communication system solutions meeting the fundamental requirements of individual inspectors, inspection teams, base-of-operation, and headquarters, including potential encryption capability. This would provide an additional option for OSI equipment selection. - UAVs: Potential system solution and customization based on OSI to keep balance between technical efficiency and least intrusiveness. While the arguments in meetings are taking place from session to session, technical discussion could continue in parallel. - Chain of Custody solution: Customized embedded micro-chips and Near-Field Communication system solution to meet the requirements of OSI operational concept development for OSI samples Chain-of-Custody.
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T3.3-P12 The Significance of Publicly Available Commercial Satellite Imagery for Monitoring Nuclear Weapons Nonproliferation and Natural Disasters

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Low-earth-orbiting satellites have long been used for imagery analysis since the Cold War era. Now that satellite imagery is within the reach of anyone with internet access, it’s important to explore the benefits of this technology for our scientific and social interactions. This paper explored the benefits of satellite imagery for nuclear weapon nonproliferation by providing insights on imagery analysis and the use of some commercial geospatial tools. Technology has helped to see the inception of commercial satellites with electro-optical sensors having ground sample distances (GSDs) of one meter or less. Large volumes of some of these satellites are cost-free and available to anyone with Internet access. Many of these satellite tools including WorldView, Gaofen, and Google Earth have proved effective in monitoring activities on the earth surface and visually exposing many clandestine facilities and unlawful activities worldwide and are therefore capable of monitoring nuclear weapon proliferation and natural disasters. Visual imagery from these satellites can work along with the IMS data in monitoring nuclear weapon test activities and natural disasters. Therefore, satellite imagery, big data analytics and social media reporting could be put into proper use to improve nuclear weapon nonproliferation and natural disasters monitoring.

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T3.4 Augmented Reality and Fusion of Data from Different Monitoring Technologies

Oral Presentations

T3.4-O1 Recreating and Exploring the DPRK Nuclear Test Site in 3D to Calculate Possible Overburdens for Detonations

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In 2018 the Democratic Peoples Republic of Korea invited selected journalists to its nuclear test site where they photographed and videoed the destruction of some features. The imagery revealed detail previously unseen by the outside world, including a map showing the tunnel entrances (adits) and test locations. We have used that imagery and other data to recreate the test site in 3D; explore it in virtual reality and make estimates of indicative minimum overburdens for the tests. We geolocated the map then extracted locations for the tests and adits by using imagery from the event, a digital elevation model and satellite imagery. During the process 3D visualisation software was used to reconstruct the test site, geolocate the adits and explore the site in immersive virtual reality. Virtual poster boards showing some of the photographs were created and positioned to replicate the original photograph locations, which helped to geolocate the adits and understand the wider site layout. Previous work that calculated the tests’ locations, using seismic data was repeated using the locations from the map. The two datasets were compared and the minimum overburden for each test was calculated assuming a straight line between the adit and test location.

Poster Presentations

T3.4-P1 Data Fusion of Electromagnetic and Infrasound Measurements

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Measurements of electromagnetic (EM) fields have been proposed as a means of supporting and aiding infrasound (IS) signal analysis. As opposed to nuclear explosion, other natural and man-made IS sources do not produce an EM signal. Thus, if an IS signal is not accompanied by an EM pulse, it is known that it is not originated from a nuclear explosion. Lightning discharges are the main source of EM pulses. Due to their high abundance, fortuitous coincidence of lightning with an IS signal are a common situation. These events may be mistakenly assumed as a nuclear explosion. To avoid this obstacle, a reliable method for lightning detection and identification is required. In this work we present results of continuous measurements of EM fields, adjacent to IAMR IS array at Mt. Meron, Israel. Lightning discharges are detected and analyzed, and their abundance is compared with theoretical predictions. We show how information about lightning location can be deduced from recorded waveform. Correlation with IS events is being examined as well. We conclude that lightning signals can be identified and filtered out, and thus the EM signal can be fused with the IS records to provide better performance of the CTBT monitoring system.
T3.4-P2  **Detection and Interpretation of Explosive Events by Seismic and Infrasound Networks of Ukraine**

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In recent years, Ukraine and the adjacent territory has been shaken by a large number of explosions. These are industrial explosions, fireball explosions, man-made accidents and the consequences of military actions. The geophysical network of the Main Center for Special Monitoring (MCSM) confidently records the signals from all these events. Additionally, data of the IMS and national networks of neighboring states are connected for processing. In addition, satellite images of emergency regions are actively used to refine data verification methods. At the same time, there is an urgent need to identify an event and calculate its spatial and energy parameters. Joint monitoring of seismic and infrasound data is the most effective for monitoring explosions. In this case, with a ground explosion, the location of the event by the seismic method is confirmed by infrasonic data. At the same time, the presence of only an infrasonic response indicates an air explosion. In addition, such explosions are important for network calibration. To determine the energy of the explosions, empirical dependences were constructed based on hundreds of signals from career explosions, for which the coordinates and the amount of explosives are already known in advance. Subsequent evaluations for accidental explosions confirmed their viability.

T3.4-P3  **Detection and Location of an Earthquake Using Seismic, Infrasound and Hydroacoustic Data: A Case Study of Botswana**

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Strong earthquakes are rare in southern Africa. Botswana is located in the Southern Region of Africa. Botswana experienced an earthquake on April 3, 2017 that was felt in South Africa, Zimbabwe and Swaziland. Data collected from seismic, infrasonic and hydroacoustic (SHI) stations that were at local, regional and teleseismic distances were analysed to determine the epicentre of the event. The data were analysed using GPMCC. The waves were extracted and studied by methods of spectrum, azimuth and correlation between the acoustic and seismic signals for phase, magnitude, time and slowness. Results from the analysis showed that the foreshocks and aftershocks of the earthquake were detected using SHI stations. The results also showed the operational readiness of the SHI stations towards achieving nuclear test monitoring goal for which they were set up.

T3.4-P5  **National Seismic Network of Samoa**

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Technical advances in computer vision, FreeBSD and JOPENS system have produced a considerable improvement in Augmented Reality. However local tremors were not been able to monitor, JOPENS software is a seismic network data processing system which based on network platform. We extend the functionality of AR JOPENS by integrating seismic stations to record vibration data. Seismic stations objective is to record the ground motion in real-time and transmit data to the server via Radio Link (MDS iNET-300 Transceiver). The application of AR based on JOPEN software is a hot interest topic for computer application and human-machine interaction. The seismometer is installed and connected to a digitizer to record specified frequency, amplitude, accuracy of direction and other parameters from the output waveform. The levels of vibration created by the shaking are measured accurately by laser interferometer or grating ruler. NDC Network consists of one existing station (ASO95)-USGS, three broadband and three short period stations.
We explored joined analysis of seismic and infrasonic signals for improvement in automatic monitoring of small events using collocated seismic and infrasonic networks operating in Israel during 2012-2017 within the Bional USA-Israel Science Foundation (BSF) project. The network covering Israel territory comprised 14 stations hosting a microphone and a seismic sensor (seismometer or accelerometer) plus a temporary small infrasonic sensor array LEVY and the two permanent infrasonic arrays of the National Data Center: one in the South IOB and one in the North of Israel IMA, collocated with the secondary CTBTO seismic array on Mt. Meron, MMAI. The main project results are: 1) Large database of continuous seismo-acoustic recordings have been accumulated and processed including many GT0 events; 2) The new seismo-acoustic software for automatic detection and location of seismo-acoustic events have been created and tested, based on Bayesian probabilistic approach and the database of explosions from the Utah Test and Training Range; 3) Regional infrasound propagation characteristics have been assessed via a combination of the local meteorological sounding information with global meteorological specifications and GeoAc raytracer of Los Alamos making the unique Israeli database of meteorological specifications for the range of altitudes from 0 to 150 km.
The emission of antineutrinos is unaffected by the environment in which the explosion occurred. The detection of $^{37}$Ar can be a confirmatory measurement for a nuclear test, and when combined with the design of the sample preparation unit, the beta-gamma spectrometer suitable for big sample sizes, can be used to determine the presence of noble gases such as oxygen and nitrogen produced from atmospheric air at different types of air separation plants. During the measurement together with the first achieved practical results will be presented.

MOF-enabled detection concept could dramatically improve the reliability, timeliness, and information content of systems used for CTBT verification. PNNL is exploring the use of $^{37}$Ar for detecting nuclear explosion, including for use in the International Monitoring System (IMS). A high throughput $^{37}$Ar separation and measurement system was developed at Pacific Northwest National Laboratory (PNNL) to detect $^{37}$Ar activity generated from an underground nuclear explosion. Argon-$^{37}$ is an activation product generated when neutrons interact with calcium in the soil. Unfortunately only $^{133}$Xe is usually detected in the air samples on IMS Noble Gas installations. Due to its relatively higher concentration in comparison with metastable xenon isotopes, the new proposed method uses Xe samples of large volume for each measurement (>100 ccm of pure Xe) resulting in MDCs for $^{131m}$Xe, $^{133}$Xe, $^{133m}$Xe and $^{135}$Xe in every sample of less than 10$^{-5}$ Bq/m$^3$. We introduce of antineutrino sensors into the International Monitoring System could help to unequivocally detect nuclear explosion. The decision that a given detection level corresponds to the effective presence of a signal (i.e. a radionuclide activity) is currently widely made on the basis of a classic hypothesis test. However, the classic framework suffers several drawbacks, such as the impossibility to provide a probability of a given level of signal or a limitation on the type of distributions (ISO 11929). Furthermore, for heterscedastic distributions, simulations have underlined the poor performance of these methods (Strom et al, Health Physics, 81(1), 2001). Several attempts have been made in the past to use a bayesian framework in detection and decision problems. Most have not been able to overcome some hurdles in the definition of hypothesis testing with a point like null hypothesis. We propose a method having good performances in terms of false positive rates, which can be applied to various type of distributions (analytically in some cases and at least numerically) and whose underlying principles are easy to understand. It relies on the interval estimation of the difference between two signals (noise versus noise added to the potential signal).

In this study we describe an improved semi-automatic cepstral method for estimating the depth of very shallow earthquakes (depth < 3km) and explosions. To estimate yield and location, this method is crucial, especially for explosions, for which the depth phase (pP) is not easily discernable from the first arrival (P). Unlike previous cepstral studies, our novel procedure utilizes the Power and the Complex Cepstrums, and homomorphic deconvolution in performing these estimates. The analysis includes two steps: at first, an optimal window is chosen, using a reduced set of metrics; second, metrics related to homomorphic deconvolution are applied on the best data windows, and a statistically most probably signal-echo delay is chosen. The metrics quantify: scalloping and unwrapping, power and complex cepstrum similarity; liftering adequacy; and success of the homomorphic deconvolution, which includes delay lag recovery, and deconvolved waveform comparison to the initial signal. Weights applied to each metric are set empirically, or based on the adequacy of the minimum – phase signal approximation. The algorithms are tested on a ground-truth database, with well-known depth events and on synthetic waveforms.
T3.5-O4  Can High-Precision Methods of Seismic Monitoring for Earthquakes and Explosions Find Application for Broad Areas?

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Numerous studies have shown for small regions monitored by a sparse network, that modern methods of detecting and locating clusters of seismic events are orders-of-magnitude more effective than traditional methods (which analyze events one-at-a-time). But can modern methods be effective over broad areas? We describe practical experience answering this question in application to a large region of mainland East Asia, including a project to study the seismicity of Mongolia, and parts of southern Siberia, involving vigorous earthquake and mine-blasting activity, for a 5-year period (2012 to 2016) using open stations with significant archives. We report on experience gained with the many choices involved in: (1) identifying well-recorded seismic events; (2) obtaining their waveforms for use as templates; (3) cross-correlating templates against the continuous archive, to detect thousands of plausible new events having a pre-determined false alarm rate; (4) validating such detections; (5) measuring their relative arrival times as recorded at common stations; and then (6) relocating as many events as possible using double-difference methods. We report successful reduction of detection thresholds for parts of mainland East Asia, and substantial improvements in location precision.

T3.5-O5  Continuous Assessing of the Reviewed Event Bulletin with Waveform Cross Correlation

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The Reviewed Event Bulletin (REB) of the IDC includes more than 550,000 events with associated seismic and infrasound phases. Continuous comparison of the event hypotheses tested as REB events during routine interactive analysis with these historical events allows for significant improvement of the REB consistency. We use the method of waveform cross correlation (WCC) for assessment of the similarity between events on station-by-station basis. A list of master-events (MEs) for the WCC currently includes ~450,000 REB events with high and intermediate quality of waveforms templates. For automatic event hypotheses, only MEs within 15 degrees are used. To corroborate a daily REB, which includes events reviewed after automatic processing and those added manually, we also test all these events for similarity with MEs within 5 degrees. Two instances of the WCC-based assessment implemented: (1) automatic dual REB-based comparison with the historical REB events, and (2) an interactive spot check aimed at specific area, time period, event characteristics, stations, etc. The latter can be used as a tool for the IDC interactive review, as well as an instrument for the Special Studies and Expert Technical Analysis conducted under State’s Party and PTS, or On-Site Inspection request.

T3.5-O6  Earthquake Detection with Convolutional Neural Network and Precise Earthquake Location with 3-D Velocity Model in the Southwest Sichuan, China

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We present an earthquake detection algorithm on the basis of convolutional neural network (CNN) for a local seismic network in the southwest Sichuan, China. The seismic network is composed of 30 stations. The CNN is trained over 2900 regional earthquakes. The performance is tested with 5-month continuous waveforms and compared with manually picked phase arrivals. About 85% arrival differences of CNN predicted phase onsets versus original manual picks for the test dataset is less than 0.1s. We construct a 3-D initial velocity model with joint inversion of surface wave dispersion curves and teleseismic P-wave receiver functions. We then determined a fine 3-D velocity model with body wave travel time tomography method. The lateral velocity model is about 20km*20km, which is improved greatly compared with previous studies. Then we relocated 30 years’ regional earthquakes with the 3-D velocity model. The location software takes station elevation, topography and the Earth’s ellipticity into consideration, and can use Pg, Pn, PmP, Sg, Sn, SmS and sPn phases simultaneously. The
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average absolute location error is less than 1 km. The precision of the earthquake location is calibrated by a dense seismic array and repeating earthquakes. Our research enhances the scientific community's ground truth data collections.

T3.5-O7 Identification of Repeating Seismic Events Using Diffusion Maps

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In this work, an advanced machine learning technique named diffusion maps is applied for automatic identification of repeating seismic event clusters such as an aftershock sequence. Identification of such a sequence will help to lighten the analysts' burden and to allow for timely production of reviewed bulletins. The proposed methods begin with a pre-processing stage in which a time-frequency representation is extracted from each seismogram while capturing common properties of seismic events and overcoming magnitude differences. Then diffusion maps are used in order to construct a low-dimensional model of the original data. In this new low-dimensional space, classification analysis is carried out. The algorithm's performance is demonstrated on several seismic data sets that were recorded at the IMS stations, as the identification process can be carried out with no need of master templates for detecting new aftershocks. Moreover, the proposed method can be used together with the waveform cross-correlation detector as a verification tool for reducing the number of false alarms.

T3.5-O9 Machine Learning for Emulation of Seismic-Phase Travel Times in 3-D Earth Models

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We develop a machine learning approach to emulate seismic-phase travel time calculation through a 3-dimensional (3-D) Earth model. Our goal is to establish a computationally efficient way to implement 3-D Earth models in real-time monitoring systems and enable routine utilization of 3-D models in basic research. Seismic-phase travel times computed using a 3-D Earth model can reduce travel-time prediction error to approximately 0.6 seconds on average, leading to median event epicenter error of approximately 6 km for a network with azimuth gap less than 120°. Computation of travel times through a 3-D model can take 0.1 to 1.0 seconds, which is orders of magnitude too slow for real-time monitoring systems. We train a gradient-boosted regressor using travel times computed through the LLNL-G3D model. The training set is millions of travel times from randomly selected event locations to each network station, as well as randomly selected station locations. Preliminary tests find that machine learning effectively captures global effects like ellipticity and event depth. The effects of the 3-D model can be emulated with resulting errors dominated by the 3-D model itself, and computation time on the order of 10 micro-seconds. On-going research efforts include optimization of training-set sampling.

T3.5-O10 NET-VISA: Evaluation of Event Location Performance Compared to SEL3, and NEIC PDE

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The CTBTO's International Data Centre is in the final stages of implementing NET-VISA, a new algorithm to perform the automatic association and location steps in the next generation IDC software. NET-VISA applies a Bayesian approach with a forward physical model using probabilistic representations of the propagation, station capabilities, background seismicity and noise statistics to obtain the maximum a posteriori solution to the highly
nonlinear problems of phase association and event location. NET-VISA has been running operationally at the IDC in parallel with SEL3 since August 1, 2017. We compared 17 months between August 1, 2017 and January 1, 2019 of NET-VISA and IDC Standard Event List (SEL3) bulletins to the USGS Preliminary Determination of Earthquakes (PDE) bulletin as well as relocations of NET-VISA and IDC SEL3 bulletins with the iLoc location algorithm using travel-time predictions from the global 3D Regional Seismic Travel Times (RSTT) model to assess the performance of NET-VISA in terms of completeness of the automatic events and location accuracy. We demonstrate that NET-VISA achieves improvements over the IDC SEL3 on both accounts and thus provides a more complete and accurate starting bulletin for the IDC analyst review.

**T3.5-O11** **Peak Identification in EDS Measurements Using Multiple Subset Sum Problem Formulation**

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In the framework of the everyday activity of NDCs analysts, accurate EDS analysis is generally achieved through a correctly identification of various spectral peaks and other features of the spectrum. In practice, however, it is easy to misidentify X-ray peaks based on preconceptions of the result and due to presence of cumulated peaks. In fact, one of the most common errors made by EDS novices is the failing to identify X-ray peaks. One of the main reasons for the misidentification of X-ray peaks is due to the presence of the cumulated peaks. Cumulated peak are generally caused by accumulation of different possible values of emitted energies for a certain nuclide present. The matching of unidentified or cumulated peaks with adequate nuclides can be viewed as a combinatorial problem. To solve this problem and to identify peaks, we propose in this work a compact formulation of the problem as an integer linear program. The problem can be equivalently formulated as the well-known decision problem called the multiple subset sum problem which it can easily be solved in pseudo-polynomial time using dynamic programming.

**T3.5-O12** **Recent Improvements on the Broadband Seismic Network of Iran (Implementing Tuned Seiscomp3 and Automatic Online Moment Tensor Inversion)**

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Iran plateau is known as one of the highest seismic active regions in the world. Therefore, it is very important to know quickly about the location and the source mechanism of large earthquakes. The broadband seismic network of Iran was established since 1998 with 4 broadband seismic stations by International Institute of Earthquake Engineering and Seismology (IIEES). During last few years the total number of active seismic stations reaches 28. This number is expected to be increased up to 48 stations by the end of 2030. The increasing amount of seismic data receiving by the IIEES Data Center, has taken us to install and use the Seiscomp3 as an acquisition system to process the real-time data since 2017. Seiscomp3 leads to decreasing the time of 25 minutes manual event location to 5 minutes automatically. Moreover, we have utilized the Automatic Online Moment Tensor Inversion code (AOMTI) successfully, since 2018. Within 30 min after occurrence of an event with Mw > 4.5, the AOMTI starts to calculate the source. The final results including main-shock epicenter, last one month seismicity, focal mechanism, and waveform fits as a map will be sent immediately to predefined organizations.
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**T3.5-O13**  
**Statistical Analysis to Advance Common Understanding on SAUNA False Positives Hypothesis**  
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The Preparatory Commission for the CTBTO, Vienna, Austria (CTBTO) is establishing an International Monitoring System (IMS) including 80 radionuclide stations, of which 40 will also be equipped with capabilities for measuring CTBT relevant xenon isotopes (Xe-131m, Xe-133, Xe-133m and Xe-135). The CTBTO International Data Centre (IDC) operates dedicated analysis software for processing spectral data from the IMS noble gas systems. The analysis of beta-gamma coincidence Noble Gas data is based on Net Count Calculation (NCC) method which, in its standard implementation, only performs interference corrections if a positive net signal is present. A retrospective analysis of reported detections seems to show overestimated rate of false positives for some isotopes. With the aim of improving the analysis results, a new configuration of the NCC method that systematically performs interference corrections was tested and the results are statistically compared with the standard method. Data for the period 2014-2016 from 7 SAUNA systems was used for the analysis of detection rates per detector and per isotope. Achieved results based on the normality test, skewness and kurtosis are visualized through QQ plots and probability density graphs. The presentation will compile the findings based on these statistical Figures Of Merit.

**T3.5-O14**  
**The Machine-Learning Tool NET-VISA from Cradle to Adulthood - The Next Generation System of the IDC and the SNt Process**  
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A research concept presented on a poster at the very first SNt conference in 2011 has resulted in a fully-fledged operational software product named NET-VISA. It has become one of the tools used by the International Data Centre (IDC) waveform analysts to review and improve the SEL3 bulletin and produce the REB, one of the finest global seismological bulletins, and the only one to combine seismic and hydroacoustic sensing. The basic scientific concepts will be presented but the emphasis will be on the process of adopting, developing, adapting, testing, bulletproofing, and operationalizing the initial prototype. Extensive off-line testing involving State Signatories experts has shown that one of the expected benefits of NET-VISA -- a substantial reduction in missed events compared to Global Association (GA) -- has been realized. Currently, NET-VISA generates an automatic bulletin VSEL3, in parallel to SEL3. To take advantage of the reduced missed event rate, only the events which are complementary to the reviewed SEL3 are presented to the analysts. VSEL3 has been in place since January 2018 and tracing the origin of the REB events confirmed the significant reduction in missed events. If sufficient confidence is established, NET-VISA will replace GA in producing the SEL3.

**T3.5-O15**  
**Unified Implementation of NCC Analysis Algorithms for Both Current and Next Generation Beta-Gamma Coincidence Based Noble Gas Systems**  
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Among the most promising technologies for next generation of noble gas systems are those based on Silicon PIN diodes for beta. It has been demonstrated that the high electron energy resolution of these detectors can significantly improve the discrimination power between Xe-131m and Xe-133m. The first next generation noble gas (NG-NG) systems SAUNA-III and SPALAX-NG developed, respectively, by FOI (Sweden) and CEA
(France) are currently undergoing the one-year acceptance testing by CTBTO. Xenon International (USA) and MIKS (Russian Federation) are following. Each system has specific design features that improve on current operational systems, which require customized software solutions to process resulting spectral data. In order to ensure smooth integration of NG-NG systems, the IDC initiated a new unified software development project for timely deployment into the production environment. The software is based on the Net Count Calculation (NCC) method. The implementation allows data from all systems to be automatically processed using the same software tool, taking into account inherent specificities. The new software has been rapidly developed and is available already during the acceptance testing period. The contribution presents the key features of the new unified implementation of NCC algorithms, for handling both current and next generation technologies.

**T3.5-O16 Machine Learning to Categorize Radionuclide Spectra**

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The presentation describes work using one- and two-dimensional Convolutional Neural Networks (CNNs) to categorize radionuclide spectra. The aim of this work is to automatically recognize ‘normal’ spectra and thus possibly reduce the work of the human analysts, which would need to focus on the unusual spectra which are more difficult to categorize.

**Poster Presentations**

**T3.5-P1 A Demonstration of the RKF Solution Method for Multi-Physics Analysis of Radionuclides Evolved in Nuclear Testing**

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The prediction of radionuclide source term values generated from a nuclear test, and discriminating those radionuclides from a competing background activity, including medical isotope production, is an important metric in treaty monitoring activities. To properly quantify the various fission products and other radioactive materials generated in a nuclear explosion, capturing the effects of nuclide production, decay, transmutation, and chemistry, etc., involves a multi-physics approach that fundamentally requires the solution of the production Bateman equations. These constitute a coupled set of linear differential equations that, depending upon the radionuclides of interest, can have radically diverse time dependencies spanning many orders of magnitude, making their solution numerically stiff at best. An "on the fly" approach to achieving correct isotopic solutions with certified accuracy is possible via the Runge-Kutta-Fehlberg (RKF) solution methodology. RKF employs a variable time step with error control to maintain a targeted error Residual (R). The thrust of this work is to evaluate the efficacy of employing the RKF methodology to dynamically solve for a set of radionuclides important to treaty monitoring, and assess the multi-physics options that can be incorporated in this approach.

**T3.5-P2 A New Analysis Method for Beta-Gamma Radioxenon Spectra, Including Improved Calculation of Decision Limits**

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A new method for analysis of beta-gamma coincidence radioxenon spectra has been developed. The problem is formulated as a linear equation system, solved by matrix inversion. This makes the analysis procedure simpler compared to the NCC method, including the calculation of covariances. Furthermore, only 6 instead of 10 regions of interest are needed. In addition, the estimation of the decision limits is modified compared to the NCC-method using a Bayesian correction to adjust for the fact that the estimated background can be negative, which in turn can lead to undefined decision limits. This modification allows the decision limits to always be...
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defined, and they also come closer to the assumed confidence level, which reduces the number of false
detections, in particular for the metastable isotopes 131mXe and 133mXe, as shown by Monte-Carlo
simulations.

T3.5-P3 A New Approach for Calculating 1D Local Velocity Model Using Particle
Swarm Optimization Technique

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A new method for calculating 1D local seismic velocity model is proposed by using one of the powerful methods
in global optimization techniques named Fuzzy Self-Tuning Particle Swarm Optimization (FST-PSO). It
generates random particles (velocity models) in a pre-defined solution space in which after number of iterations
they lead to a model that yields best fits to the data. Not using the partial derivatives of travel-times respect to
model parameters and performing no matrix inversion, it enables to speed up the calculations. In addition,
because the PSO family members use only random processes to generate new models, they are inherently stable
and avoid all numerical problems encountered in deterministic methods. Taking advantage of fuzzy logics
implemented, no parameters are needed to be adjusted including social, cognitive and inertia for running the
program. The proposed methodology is very easy-to-use, effective and powerful. Its proficiency was checked on
both synthetic and real datasets. This method was applied to calculated 1D velocity model of the Southern-part
of central Alborz Iran, which its velocity model has already been calculated. The comparison between these two
models shows a good correlation between them, while the reductions of RMS and hypocentral errors using the
FST-PSO-model are obvious.

T3.5-P4 A New Blind Deconvolution Approach for the Separation of Seismic Waves

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In this paper we propose a new approach for the separation of different seismic waves (mainly P and S) which is
based on the blind deconvolution of the signals provided by an array of seismic sensors. For this, we model the
signal provided by each sensor by a noisy convolutive mixture of different seismic waves, where the noise
signal, which we consider a source in its own right, is not necessarily stationary and white as in most works
existing. In addition, unlike most of these recent works, which proposed for our mixing model (which is a model
of a MIMO system) methods of blind separation of sources that require several assumptions about the sources
and filters of mixing, we use a method of blind deconvolution based on subspace techniques for a SIMO (Single
Input Multiple Output) system only, which requires a lot less assumptions and is more efficient. The results of
our tests on artificial mixtures and some real mixtures of seismic signals are very encouraging.

T3.5-P5 A Novel Approach for Signal Sparse Time-Frequency Representations

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By exploiting the fact that most real-life signals are sparse in the time-frequency (TF) domain, a significant
suppression of the unwanted cross-terms can be achieved in the signal TF representation. In this work, we
propose a sparse reconstruction algorithm, based on the two-step iterative shrinkage/thresholding (TwIST)
algorithm, in which the soft-thresholding value is adaptively determined by the fast intersection of the
confidence intervals (FICI) rule. Firstly, the TF region with the lowest mean value is determined, and then the
thresholding value is set to the largest sample within the region. Examples of synthetic and real-life (seismic)
signals confirm that the performance of the proposed reconstruction algorithm is competitive to the performance
of its state-of-the-art counterparts.
T3.5-P6 A Semi-Automatic Method for Extraction and Interpretation of Reflection Green's Functions from Ambient Noise and Signal, for IMS Seismic Station Crustal Reflector Characterization

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Seismic interferometry is applied, for the first time, to extract reflector Green's Functions (GFs) at PDAR, Pinedale, Wyoming, USA, a well-calibrated IMS primary seismic array. For improved event location, a semi-automatic method is developed to extract and interpret crustal reflector structure beneath each station. To address challenges related to phase identification, we use synthetic waveform modelling, an F-statistic detector and Cepstral analysis. High frequency loss by extracting GFs from stacks of years of continuous waveform autocorrelations is addressed by extraction of reflections with higher frequency content (and thus, improved resolution) when applying the same method to several days of high teleseismic activity. We discuss promising results, when compared to existing geophysical information beneath PDAR, and the possibility of deep mantle observations.

T3.5-P7 A Simplified Fuzzy ARTMAP Neural Network Based-Approach for Seismic Signal Discrimination Between Earthquakes and Quarry Blasts

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Seismic source recognition based on acquired signals is a complex analysis and a difficult task to model using classical mathematical methods. In fact, seismic signals are affected by complex geological conditions and several types of noise sources. Nowadays, artificial intelligence techniques have attracted increasing attentions among scientists to handle real world problems which cannot be modeled using traditional mathematical techniques. The aim of this study is to propose a neural network based approach for discrimination between earthquakes and quarry blasts. This neural network, namely simplified Fuzzy ARTMAP, has several advantages over many other neural network models, which make it an attractive model for investigation into the problem of seismic signal classification. The performance of this approach was examined on a variety of real seismic data. Additionally, a comparative study with the mostly used multilayer perceptron neural network classifier was conducted. Each seismogram is represented by the most important features that are mainly used by seismic analysts. To further improve the Fuzzy ARTMAP performance, genetic algorithms were used. Classification results showed that this approach improves classification performance, training speed and generalization. Furthermore, it provides other appealing features, including flexible configuration and incremental learning capability.

T3.5-P9 Analyzing Seismic Explosion Records Using SEISAN

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This presentation gives an overview of the seismic analysis software package SEISAN. Initially SEISAN was developed to analyse seismic records of earthquakes in local networks, but the package has undergone a steady development so that it today can be applied to seismic sources at all distances including possible nuclear explosions. SEISAN is used in more than 30 countries, mainly in small seismology groups and primarily on Windows or Linux platforms. SEISAN is also used at NDCs in many parts of the world. The architecture of SEISAN is based on a database structure where the three main parts are the parametric data, the waveform data and the metadata. The parametric data are based on the well-established Nordic format, the International Seismological Centre reports that app. 25% of the bulletins they received are in the Nordic format. SEISAN reads a number of waveform formats, but miniseed is preferred. Waveform-data can be in stored in SDS, BUD or a SEISAN structured file systems. SEISAN reads instrument metadata in an internal format, but also in SEED
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and GSE format. Data examples showing how SEISAN can aid smaller NDCs are given based on data from the IMS and on data from local a seismic network.

**T3.5-P11 Applying Waveform Correlation to Aftershock Sequences Using a Global Sparse Network**

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Studies have shown that waveform correlation is effective in detecting similar seismic waveforms from repeating earthquakes, including aftershock sequences. Monitoring agencies have shown interest in adopting techniques to quickly characterize aftershock sequences to reduce the amount of effort required by analysts to add aftershocks to event bulletins. Our experiment uses waveform templates recorded by multiple stations of the IMS network during the first 12 hours after the main shock to detect and identify aftershocks that occur during the subsequent week. We present methods for station and template selection, threshold setting, and event detection that are specialized for aftershock processing in a sparse, global network. We apply the methods to several aftershock sequences to evaluate the potential for establishing a set of standard aftershock waveform correlation processing methods that can be effective for operational monitoring systems with a sparse network. We compare candidate events detected with our processing methods to the LEB bulletin to develop an intuition about potential reduction in analyst effort.

**T3.5-P12 Automatic Characterization of Phase Type at Three-Component Seismic Stations Using Neural Networks**

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Determination of initial phase type of arrivals is an important step in automatic processing of seismic waveforms. The goal is to classify each STA/LTA detection as either regional S phase, regional P phase, teleseismic phase or as a noise. Correct characterization of arrivals improves automatic event formation in the subsequent steps of automatic processing. In the International Data Centre (IDC) processing pipeline, the initial wave type of three component stations (3-C stations) is currently being determined on basis of a set of features extracted from all three channels in the time domain. Our goal is to investigate if the initial phase type of 3-C station arrivals can be accurately determined via direct processing of sampled waveforms using convolution or recurrent neural networks and thus skip the step of feature extraction. The methods are tested on a set of approx. 300k arrivals labeled by analysts. To implement the neural network architectures we use TensorFlow and train them on GPUs.

**T3.5-P13 Automatic Machine Learning Methods for Analyzing Radioxenon Isotopes Spectra**

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One of the verification methods used for the Comprehensive Nuclear-Test-Ban-Treaty (CTBT) is the measurement of environmental radioxenons. Measuring the activity concentration of radioxenon isotopes (131mXe, 133mXe, 133Xe, 135Xe) and discrimination from each other and from 214Pb which is daughter of 222Rn as interference factor in the nuclear detector is a challenge and interesting area of research for the CTBT. Different systems have been developed to detect and measure the activity concentration of these isotopes including beta–gamma coincidence spectroscopy. In this work, a range of robust classification machines (CM) such as MLP_BP, KNN, RNN, etc. were selected amongst various families of learner algorithms in order to analysis of beta–gamma coincidence spectra with different activities that were simulated with GATE V6.2 code. For this purpose, we considered a feature extraction algorithm (FEA) such as FCM (Fuzzy C means) for initial
feature extraction. Eventually, the accuracy for each method was reported and compared. The results showed that, employing appropriate optimization tools (such as Q-learning) and hybrid system can prepare intelligent analyzing radioxenon spectra hence accuracy of 97% and 99% for prediction of presence of radioxenon isotopes and determination of activity concentration were achieved, respectively.

**T3.5-P14 Automatic Systems for Accurate Tracking of Aftershock Sequences**

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Aftershocks from very large earthquakes cause significant difficulties and delays in producing seismic event bulletins. Not only are there many more events to process in a given time, the cost function of generating a reviewed bulletin increases greatly due to poorer automatic event lists. The phase-association algorithms which form the automatic bulletins operate best under normal background conditions. The aftershock scenario generates rapid sequences of arrivals which are often misassociated, increasing human analyst effort significantly. We propose an advanced, iterative, processing pipeline in which arrivals associated with well-defined events in one iteration are removed from the parametric data-streams, prior to being processed by the phase-associator in the next iteration. The intention is to generate a robust and accurate automatic event bulletin which adapts according to the context of current seismicity. This will provide a far better starting point for human analyst review. For any given aftershock sequence, we demonstrate how most of the seismic events in a target region encompassing the likely extent of aftershocks can be detected and located by a focused region-optimized algorithm. Removing all phases associated with these events from the detection lists provides phase-association algorithms with the near-normal background state in which they are optimal.

**T3.5-P15 Bayesian Approach to Localization of Atmospheric Release with Demonstration on the Case of Ruthenium-106 Release in 2017**

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Localization of an unintended atmospheric release is crucial in atmospheric monitoring as well as in verification strategy of organizations such as CTBTO or national authorities. To find the location is, however, complex task with many involved uncertainties composed in measured data and technique, usage of an atmospheric transport model, selected weather reanalysis, and used inversion technique. In continental scale, the localization can be formulated as the linear inverse problem on a grid and solved as an optimization problem. We study the Bayesian formulation where the uncertainties can be incorporated directly into the model and thus can be estimated together with all other parameters. It is shown that the quality of the resulting estimates strongly depends on quality of measurements and their spatial and temporal distributions. These findings will be demonstrated on the case of the ruthenium-106 observation in the fall of 2017 over the Europe and Asia.

**T3.5-P16 Can artificial Intelligence Help Detect Nuclear Explosions?**

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The field of artificial intelligence has had an exponential growth in its application in recent years. In particular, machine learning is an effective tool to solve problems that seek to find patterns of behavior from large databases. This boom was largely due to the new and increasingly powerful computing capabilities and a large amount of data available. The IMS has 306 stations installed, 6 under construction and 25 planned. This represents a large volume of data that is published daily. The application of machine learning can improve the search of patterns in this data to optimize the processing and improve the automatic response to a possible nuclear explosion. A review of the applications of machine learning techniques for improving the processing of data from different types of IMS stations is presented.
**T3.5-P18** Comparing REB and SSEB (IDC Products) with Other Seismic Data Centers

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Work at the JSO (Jordan Seismological Observatory) identified some differences in the result of seismic data analysis in most of international seismic data centers and the results of IDC products (REB and SSEB). Seismic data (origin time, Latitude, Longitude, Depth and magnitude) were compared for some events in the International Data Center products REB (Reviewed Event Bulletin) and SSEB (Standard Screened Event Bulletin) with the data for same events from other International Seismic Data Centers like: EMSC (Euro-Med Seismological Centre), GFZ (German Research Center for Geosciences), KOERI (KANDILLI Observatory and Earthquake Research Institute), JSO (Jordan Seismological Observatory), GII (Geophysical Institute of Israel) and others. It was found that there is not a big difference in the results especially in the ORIGIN TIME, LATITUDE, LONGITUDE and MAGNITUDE but there is a difference in the DEPTH. Further studies are needed to identify the reason for this cases. It may be from the analysis algorithm or from the velocity model used at the IDC, from travel time tables or from other logic reasons.

**T3.5-P19** Comparison of Pick-Based and Waveform-Based Event Detectors for Local to Near-Regional Distance Data from Utah

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We compare a pick-based seismic event detector (PEDAL), to a waveform-based detector (WCEDS). Both algorithms were tested on data from 3-component stations in the University of Utah network. We chose to focus on Utah because the region is tectonically complex and includes both regularly occurring earthquakes as well as various types of anthropogenic sources, hence it presents a variety of challenges for event detection. The 2 week interval of time processed (January 1-14, 2011) includes a significant aftershock sequence near the town of Circleville. The data set also includes a huge number of mining induced events from a coal mining region. The events built by our two methods are scored against a master catalog, carefully built by an expert analyst who found a total of 7883 events for the 14 days. Comparison of the 3 catalogs is done using a Venn diagram, to investigate areas of overlap and isolation. Our results suggest that when tuned to achieve a comparable level of recall, the waveform-based method has better precision (i.e. fewer false events). We also found the waveform-based method to be more stable and easy to configure due to the lack of an additional processing step to generate signal detections.

**T3.5-P20** Contribution of Kazakhstan's Stations of the International Monitoring System into Global and Regional Monitoring

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This work discusses the contribution of IMS stations in Kazakhstan into the REB in terms of the number of associated phases as compared to other IMS stations. It is shown that all Kazakhstan stations are effective in monitoring, and are among the most efficient IMS stations. This observation is also confirmed by global mapping of event epicenters as well as by threshold magnitude and the proportion of events with arrivals at the Kazakhstan stations in the REB. A detailed comparison of the REB and the KazNDC bulletins, seismic and infrasound, are carried out within Central Asia (CA). The number of events in the KazNDC bulletins is larger than that in the REB as the KazNDC bulletin is obtained using the regional network with a larger number of stations. There are 398 seismic events in the REB for the investigated territory. The KazNDC seismic bulletin contains a significantly larger number of events - 13839. A actual location accuracy for the CA events in the REB can be estimated by GT events only. We present such examples using locations obtained by a special local monitoring network and those in the REB for the events within western Kazakhstan.
T3.5-P21  **Data Processing Modular Software for Real-Time Stack Monitor**  
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The processing of the measurement of nuclear facilities stack emissions (Research Reactors and Radioisotopes Production Facilities) has evolved from first monitors based on embedded systems to the latest industrial PCs based systems. The Software has been re-designed for the new stack monitor. This new software version is based in a modular architecture that allows to adapt it to the specific project requirements. The software to be implemented for STAX project is presented. Its architecture and the relational data base model used in this development are also shown.

T3.5-P22  **Detecting Low Magnitude Seismic Events Using Convolutional Neural Networks**  
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Detection of arrivals at seismic stations in a network is the first step in building seismic events. Improving the ability to accurately identify seismic arrivals for three-component stations in adverse signal-to-noise environments is vital to improving detection and location of seismic events. Waveform correlation and other template matching methods are modern techniques that may be used, yet, each have limitations. They lack compatibility between stations, require significant data, and accumulate large template databases, reducing performance. In this work, we present updated results using convolutional neural networks (CNNs). CNNs have been shown to significantly improve performance at local distances under conditions such as induced seismicity.

We expand the use of CNNs to more remote distances and lower magnitudes. We explore the tradeoffs of certain architectures of CNN and update previous results. We describe performance results of our method tuned on a new dataset with expert defined picks. The dataset used is from the Dynamic Network Experiment 2018 (DNE18) and comes from sensors in Utah. We demonstrate the ability to train the CNN on these events and achieve significantly higher test set performance than standard methods. Furthermore, we validate performance on streaming data, including very low magnitude expert picked arrivals.

T3.5-P24  **Detection and Classification of Lightning Events**  
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Electromagnetic pulse has been excluded from the IMS technologies because its high false alarm rate due to lightning discharges. Here we examine a possible method of overcoming this obstacle by merging infrasound data with electromagnetic measurements. The proposed method is based on the fact that all known sources of infrasound, with the exception of a nuclear event, do not emit an electromagnetic signal except for lightning. Therefore, the ability to detect and classify lightning events is a necessary condition for the use of an EM signal for the purpose of the IMS. The data set is taken from an antenna that has been located adjacent to the Mt. Meron infrasound array, and the measured EM fields have been recorded for several days in times of lightning storms. Then we used methods of spectral analysis and machine learning in order to detect and classify lightning events in EM signal. We present here examples and statistical analysis of the results. These results give hope that the proposed data fusion method can be implemented to enhance both detection and discrimination capabilities of the IMS.
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**T 3.5-P25  Detection Performance of Dynamic Correlation Processors Using De-Noised Signal Space-Spanning Templates**

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Correlation detectors are often used in a context in which detections are implicitly assumed to be identifications. This assumption is valid at sufficiently high detection thresholds. But we often wish to set thresholds as low as possible in order to detect signals obscured by noise. By doing so, we introduce the possibility of detecting signals not from the source of interest. In this work I study the performance of dynamic correlation processors in two scenarios: close-in monitoring of an active coal mine using single channel detectors, and global monitoring using 3-component detectors. In both scenarios a first pass through the data is used to create sets of detectors that span the space of high-SNR signals. Detections from these detectors are used to create de-noised templates using singular value decomposition. The new suites of detectors are then used to re-process the data. The new templates have large projections on one another, so it is common to produce many triggers per signal. For most detections there are tens to hundreds of triggers considered, showing that the signal space was well sampled. Where interevent separations are known, the detectors are shown to be highly specific.

**T 3.5-P26  Developing a Deployable, Flexible Radionuclide Analysis Pipeline**

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The UK NDC Radionuclide analysis pipeline has been designed to be collapsed and rebuilt as required. Whilst the current pipeline is built across a number of high-performance computing systems at AWE Aldermaston, there was a requirement to produce a flexible system that can be deployed at short notice. Taking inspiration from the IDC’s NDC-in-a-Box (NIAB), installation code and documentation has been compiled such that the system can be installed on a virtual machine, running a variety of operating systems. This opens up the radionuclide analysis pipeline capability for use externally, on a contained system. All of the radionuclide analysis and review tools (including BeGAX, GRINDER & GBL15 GUI) are accessible from within the virtual machine and the performance is similar to that of the UK NDC integrated solution. This poster showcases some of the features of the tools used to interact with the radionuclide data as well as the results of a recent NDC collaboration.

**T 3.5-P27  Discrimination Between Earthquakes and Explosions by Using Scaling Parameter Hurst Parameter**

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In this paper, we investigate the long-range correlations and trends between consecutive earthquakes and Explosions by means of the scaling parameter so-called locally Hurst parameter, H(t), and examine its variations in time, to find a specific pattern exists between events. The long-range correlations are usually detected by calculating a constant Hurst parameter. The multi-fractal structure of earthquakes caused that more than one scaling exponent is needed to account for the scaling properties of such processes. Thus, In this paper, we consider the time-dependent Hurst exponent, to realize scale variations in trend and correlations between consecutive seismic activities, for all times. We apply the Hilbert-Huang transform to estimate H(t) for the time series extracted from seismic activities occurred in world. The superiority of the method is discovering some specific hidden patterns exist between consecutive earthquakes, by studying the trend and variations of H(t). Estimation H(t) only as a measure of dependency, may lead to misleading results, but using this method, the trend and variations of the parameter is studying to discover hidden dependencies between consecutive earthquakes. Keywords: Long-range dependence, Time-dependent Hurst exponent, Hilbert-Huang transform, Empirical mode decomposition, Seismic activities.
T3.5-P28  **Discrimination Between Nuclear Explosions and Natural Earthquakes**  
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Seismic discrimination between underground nuclear explosions and earthquakes is an important component of the Comprehensive Test Ban Treaty (CTBT) verification regime. Complexity, Spectral ratio, amplitude ratio of P/S and mb-Ms (body wave and surface wave magnitudes) discrimination methods were applied for identifying natural events from nuclear explosions in China, India, Pakistan, North Korea, and USA. The waveform data were collected from different sources i.e. IMS and IRIS for a set of 16 nuclear explosions and 16 earthquakes with $4.5 \leq mb \leq 6.5$ using broadband stations. The complexity of natural events is higher than of artificial events. The spectral ratio is larger for explosions than of the earthquakes due to the higher frequency content in the seismogram of explosions. The amplitude ratio of P/S shows larger amplitude in the case of explosions compared to earthquakes. mb-Ms discriminant method shows that mb is larger than Ms in the case of explosions. Based on the results of our study, the amplitude ratio of P/S and mb-Ms techniques are the most effective seismic methods for identifying the nature of the source. Keywords: Amplitude ratio of P/S, mb-Ms, CTBT, Discrimination, complexity

T3.5-P29  **Disturbing Incidents Signal Character Analysis in Nuclear Explosion Infrasound Detection**  
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This paper analyzes the characteristics of disturbing incident in the infrasound detection of nuclear explosion. After data preprocessing, such as mean removal, atmospheric disturbance removal, filtering and normalization, etc., the infrasound signal characteristics of lightning, chemical explosion and satellite launch events are analyzed through spectrum and statistical methods. Finally, spectrum characteristics of disturbing incident infrasound signal are obtained according to statistical conclusions. The analysis results show that the acquired infrasound signal characteristics of lightning, chemical explosion and satellite launch event are different from those of nuclear explosion, and this characteristic value can be used as one of the feature vectors of nuclear explosion infrasound detection and recognition.

T3.5-P30  **Dynamic and Agnostic State of Health (SOH) Analysis Tools for Noble Gas Systems**  
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Careful analysis of SOH data can provide critical information about the operating status of an International Monitoring System (IMS) station and the data being reported. Pacific Northwest National Laboratory (PNNL) with support from the Defense Threat Reduction Agency (DTRA) Nuclear Arms Control Technology (NACT) Program has been developing tools to analyze SOH data reported from noble gas systems within the IMS network. The current version of the tool was tested against the Swedish Automated Unattended Noble Gas Analyzer (SAUNA) and the PNNL-developed Xenon International system. The SOH tool uses a modular framework where the SOH data, using IM S2.0 format, is written to a database. The analysis uses a modular format, whereby different algorithms can be used, in parallel, to analyze SOH data. For system alerts and testing, for example, a simple limits algorithm as well as exponential weighted moving average (EWMA) were implemented and tested. An analysis daemon also uses these algorithms to summarize the station health in a station summary page. PNNL is working closely with the U.S. IMS radionuclide station operator, General Dynamics (GD), for feedback and testing of the tool. The tool, implementation framework, and current status will be presented.
**T 3.5-P31  Enhancement on the Algorithm of Characterization Limits of the Net Count Calculation Method for Low Counts of IMS Beta-Gamma Coincidence Noble Gas Samples**

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The beta/gamma coincidence spectra are analyzed at the International Data Centre (IDC) using the so-called net count calculation (NCC) method based on a number of Region of Interest (ROI) and interference ratios between isotopes and ROIs. The gross counts in each ROI follow a Poisson distribution. Therefore, the true value and variance of the gross counts are estimated as the gross counts of a single measurement. That works fine for the samples with high counts. However, it could be a problem when the samples are on the detector background level. The critical level could be underestimated in case there is a negative value of the net counts, therefore probably resulting in false positive. The net counts with a negative value are replaced as 0 based on the prior knowledge that the true value of the amount of radioactivity is non-negative. For the samples on the detector background level, characterization limits of the net count are estimated based on the detector background measurement instead of the single measurement itself. This paper presents results of the new algorithm compared with the current NCC method for noble gas samples from IMS beta-gamma coincidence systems and Monte-Carlo simulated samples on the detector background level.

**T 3.5-P32  Exploiting Bayesian Inference Priors to Form Synthetic Waveform Events or to Validate Events Formed by Automatic Processing**

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The Preparatory Commission for the CTBTO Preparatory Commission, Vienna, Austria (CTBTO) has been developing and testing NET-VISA, Bayesian automatic event detection and localization software package. In our preliminary testing at the CTBTO, NET-VISA shows better performance than its currently operating automatic association program. This implies that the priors of Bayesian inference built within the NET-VISA framework have a good ability to depict the relationship between sources of waveform events and detections on CTBTO’s stations. At the same time, synthesizing a good event, or evaluating and validating events quantitatively are important topics to improve the performance of detecting waveform events, and therefore, detecting a nuclear explosion. In this context, we have been building methodologies to apply the NET-VISA priors onto the synthetic event generation and the event evaluation. In the presentation, the quality of synthetic events and the feasibility of validating events formed by the currently operating association program will be discussed.

**T 3.5-P33  Global and Local Scale High-Resolution Seismic Event Catalogs for Algorithm Development and Testing**

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When developing new seismic data processing methods, the verification of potential events and associated signals can present a significant problem, especially as detection thresholds are lowered to include anthropogenic signals from surface and shallow underground sources. In particular, we note that without a complete and accurate catalog, it is not possible to accurately calculate either precision or recall. Here we present two 14-day seismic event catalogs, one developed in Utah for local-scale event processing using data from the University of Utah Seismic Station network, and the other developed for global-scale processing using data from the International Monitoring System (IMS). Each catalog was built manually by an expert analyst to comprehensively identify events from all sources that were locatable using phase arrival timing and (when available) directional information, resulting in a number of event increases compared to existing catalogs of 4300% in Utah and 650% globally. The catalogs additionally contain challenging event sequences (prolific aftershocks and small events at the detection/location threshold) and novel event types and sources (infrasound aftershocks and small events at the detection/location threshold) and novel event types and sources (infrasound aftershocks and small events at the detection/location threshold) and novel event types and sources (infrasound aftershocks and small events at the detection/location threshold) and novel event types and sources (infrasound aftershocks and small events at the detection/location threshold) and novel event types and sources (infrasound aftershocks and small events at the detection/location threshold) and novel event types and sources (infrasound aftershocks and small events at the detection/location threshold) and novel event types and sources.
Implementation of a Fast Infrasonic Spectrum Sensing System Based on Fisher-Statistics Detection Method

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Fisher statistics-based signal detection is a widely used powerful multi-sensor infrasound spectrum sensing strategy. However, this method requires the repeated computation of test statistics for each element of a grid of slowness vectors, which imposes a high computational complexity and leads directly to a raised processing time. Since conventional systems often have very stringent speed requirements for real-time surveillance applications, this disadvantage leads a limited application of Fisher detectors (FDs) for several infrasonic sensing purposes. In this presentation, we report a strategy for implementation of FD with reduced time-consumption. This strategy is based on the fact that the detection process for slowness-grid elements can be performed in a parallel manner using powerful graphics processing units (GPUs), in contrast with conventional FDs. The results of our simulations as well as empirical works show that our strategy promises very significant time-savings compared with conventional FDs, which enables it as a good candidate for real-time applications. Accordingly, we have implemented the algorithm in Visual Studio environment to produce a special fast infrasound detection software.

Improvements of Phase Detection and Identification Using 3C Array Processing

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Seismic arrays traditionally are made of vertical sensors co-located with a single three-component (3C) seismometer. The deployment of fully 3C seismic array offers the possibility to use the coherency of the horizontal components in addition to the vertical ones. Indeed, the horizontal component traces give the opportunity to improve the detection and the characterization of the S-phases that have a greater amplitude on the horizontal component than on the vertical one. Yet, 3-C arrays are currently poorly exploited in automatic S-phase detection, classification and identification algorithm. Our work focuses on the use of horizontal components in array processing technique, which is PMCC (Progressive Multi-Channel Correlation), to identify complex seismic wavefield features using data from the LSBB (Low Noise Underground Laboratory located in Rustrel, Southern France) 3C broadband seismic array. The influence of horizontal trace rotation on the consistency of this array is investigated using several recent local and regional events. A campaign of measurements was performed to precisely establish the orientation of each station in the LSBB 3C seismic array using Fiber Optic Gyrocompass. These measurements have also permitted to investigate the influence of the stations orientation errors on the array consistency.

InfraPy - An Open Source Signal Analysis Toolkit for Infrasound Research

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Infrasound researchers at Los Alamos National Laboratory have been actively developing and evaluating signal analysis tools for detecting, associating, localizing, and characterizing infrasonic signals and sources. The algorithms developed during these efforts have been combined into a suite of Python libraries and recently made available as an Open Source software toolkit. The detection methods are based on adaptive Fisher detection methods previously developed for inclusion in the InfraMonitor tool, while the association, localization, and characterization methods leverage Bayesian algorithms and statistical propagation models to accurately identify and characterize infrasonic events. A number of interface options have been developed including a command line interface (CLI) for large-scale batch processing and a graphical user interface (GUI) for interactive analysis.
The emission of antineutrinos is unaffected by the environment in which the explosion occurred. The 37Ar emission can be a confirmatory measurement for a nuclear test, and when combined with the design of the sample preparation unit, the beta-gamma spectrometer suitable for big sample areas facilitate selective adsorption of weakly interacting gases such as xenon. Second, established structure-function relationships governing MOF gas uptake enable rational design of materials optimized for specific applications (e.g., to selectively adsorb Xe). We demonstrate that MOFs enable the identification of radioactive xenon isotopes which are signatures of clandestine underground nuclear tests. Their low concentrations are a few orders of magnitude lower and it is therefore only possible to detect them within short distances. The new proposed method uses Xe samples of large volume for each measurement (>100 ccm of pure xenon). The event definition criteria for the SI events requires reliable detections reported by at least one infrasound station together with one or more detections at primary seismic stations. Using various sets of defined parameters, we have cross-correlated seismic signals recorded at the IMS stations from thousands of historical seismic-infrasound events reported in the IDC's Reviewed Event Bulletin (REB). For the WCC method, we have optimized these defining parameters by balancing the rate of detection and false alarms. The most important parameters are the frequency band and the template length. We will present examples of historical cross-correlations of data from selected seismic and infrasonic IMS stations and preliminary results of the automatic cross correlation bulletin (XSEL), in comparison with the REB, for the period February to May 2019.

The International Monitoring System (IMS) comprises four technologies: seismological, radionuclide, hydroacoustic, and infrasonic. An important limitation of these technologies is due to the fact that the structure of the propagation medium is partially known. This is especially true for infrasound and indeed, a current trend is to take into account the impact of random atmospheric small-scale structures on the waveforms using computational models. On the other hand, the last decade has been the success of stochastic parameterizations in short-term, medium-range and seasonal atmospheric model ensembles. Operational weather centers now...
routinely apply stochastic schemes to better represent model uncertainty and to improve the forecast quality. The goal of this work is to better constrain these stochastic schemes using IMS infrasound records, and to improve our knowledge about atmospheric small-scale randomness, on a daily basis. It is shown that recurrent explosive events can be exploited for this task, through combining models of gravity wave turbulence with machine learning techniques. The performance of the method is demonstrated using signals observed at the Norwegian station 137NO in August-September every year. These signals are known to be generated by the well-characterized daily ammunition destruction explosions that occur at the Hukkakero site, in northern Finland.

**T3.5-P40 Leveraging Powerful Artificial Intelligence Abstractions of IMS Data**

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Artificial Intelligence (AI) has developed at a rapid pace in recent years and has found widespread usage in many applications and services that we use in our daily lives. One emergent domain in Artificial Intelligence is generative modeling i.e. the process of learning statistical abstractions of observed phenomena. These abstractions are powerful not only in allowing AI systems to generate near-realistic examples of the observed phenomena (e.g. generating highly realistic pictures of human faces) but also in allowing researchers to learn rich statistical representations of the phenomena that can serve as the basis of further analysis and interpretation of said phenomena. This presentation will provide a review of generative modeling techniques and discuss how they can be applied to the gigabytes worth of seismic, hydroacoustic, infrasound and radionuclide data that the International Monitoring Systems captures each day. Specifically, this presentation will demonstrate how generative modeling can learn statistical abstractions of the data and how these abstractions can be leveraged to augment the CTBT’s verification capabilities and to support spin-off analyses (e.g. monitoring climate change) of the data.

**T3.5-P41 Long-Term Infrasound Monitoring of Volcanic Activities of Kyushu Region in Japan**

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Tokyo VAAC (Volcanic Ash Advisory Center) issued more than 10,000 advisory reports describing volcanic activities in Japan over the past ten years (2009-2018). Around 98.5% of advisory is related to the volcanic eruption/explosion of five volcanoes of Kyushu area, Aso-san, Kirishimayama, Sakurajima, Kuchinoerabujima and Suwanosejima. Infrasound signals produced by these volcanoes are well detected at the Korean Infrasound Network (KIN) which is consisted of eight infrasound array stations. Epicentral distance ranges from 502km to 1,034km. We have analyzed the infrasonic records by using PMCC with a reference to the event origin time of advisory reports, focusing on the Sakurajima which is most active. Analysis results show that the annual variations of arrival time and back-azimuth of infrasound signals are well matched to the annual change of atmospheric condition in regional scale. It shows also effects of winter stratospheric sudden warming in 2011/2012 and 2012/2013 in infrasound propagation. To examine possibility of characterizing each volcano, spectral features of beam-formed waveforms of representative infrasound signals are compared each other. It is confirmed that continuous volcanic activities in Kyushu region are excellent sources for infrasound study as well as atmospheric study in regional scale.
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T3.5-P43  **Matrix Operation of the Net Count Calculation Method for Beta-Gamma Coincidence Spectrum Analysis of IMS Noble Gas Samples**

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Activity concentrations of CTBT relevant radioxenon isotopes are determined by using liner equations of the net count calculation (NCC) method based on a number of Region of Interest (ROI) and interference ratios between isotopes and ROIs for noble gas samples from IMS beta/gamma coincidence systems. Regarding the coincidence counts in X-rays region, different analysis algorithms were developed by introducing ROI-4 to -10. The interference ratios between ROI-3 to ROIs of 4 to 10 could be different between algorithms like 7-ROI and 10-ROI approaches. That is dependent on whether the coincidence counts of X-rays and electrons from Xe-133 is processed as the independent measurement of ROI-4 or the interferences of ROI-3 to ROI-4 and metastable xenon ROI-5/6. The definition of the interference ratio with respect to calculation algorithms was discussed in this presentation. The NCC equations can be resolved concisely by using matrix operation. Calculation procedures of the net counts, their uncertainties and critical limits were investigated, and the configurations were optimized for samples from noble gas systems of SAUNA II/III, Xenon International and SPALAX NG. It is flexible to compose the interference matrix according to specified analysis algorithm and configurations, and to add additional interference corrections.

T3.5-P44  **Mel Cepstrom Techniques for Event Identification**

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The goal of this study is to outline the advantages, applicability and performance of Mel Cepstrum (MC) techniques for seismic and infrasound event identification. MC has been traditionally used for speech recognition at Mel Frequencies (MF), which are equally spaced frequencies on a logarithmic scale. In this study, MC coefficients are used for feature extraction on seismic and infrasound signals. It is assumed that some types of event sources have frequency-power signatures which may be visible in the MC coefficients. To estimate the MC, in each data window the log energy is computed in twenty triangular, overlapping band pass filters, centered on each MF, which are applied to the Fourier transform spectral magnitude. A discrete cosine transform is applied to convert the log power spectrum from MF domain to time domain, and the MC coefficients are estimated. Preliminary results using MC for event identification are promising, and suggest that some event categories, such as atmospheric nuclear explosions (Operation Dominic in the 1950’s), have consistent MC, especially consistent differential MC coefficients in neighboring MF bands.

T3.5-P45  **Multilayer Neural Network Architecture Optimization and Performance Amelioration for Seismic Signal Classification Using Genetic Algorithms**

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Artificial Neural Networks ANNs, inspired by the biological neurons in the human brain, are recently showed great results on a variety of classification problems. The main advantage of ANNs is their ability to learn easily and directly complex non-linear mappings from data without requiring mathematical models of the problem. However, the main difficult task in using ANNs is to determine an optimal topology that achieves the best results. Frequently, this task is performed using a trial-and-error process. Nevertheless, this method demands enormous amount of time and effort, and it may not lead to the best performance. Therefore, in this paper, we propose an automatic genetic optimization algorithm for seismic signal classification using the Multilayer Perceptron neural network. This methodology was applied to real seismic data, composed of four classes. The result is an optimized MLP that achieves good performance. Furthermore, the most important thing is the fact that the algorithm searches for the best configuration by testing a large number of configurations without the
intervention of the user and in less amount of time, and thus it reduces the designing effort and time compared to the classical method.

T3.5-P46  **Optimization Algorithm for Synergy of CTBT Verification Techniques in Addressing IMS and OSI Tasks**

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We have developed an algorithm for CTBT verification methods synergy that ensure an optimal Neumann-Pearson operating characteristic of nuclear explosion detection based on a set of standard discriminants used in addressing IMS and OSI tasks. The algorithm is based on the structuring of observation space on the basis of likelihood ratio (ratio of probabilities to get this set of discriminant values in case of a nuclear explosion or its absence). We have determined conditions for applicability of the proposed algorithm and the its field of application and have given examples of possible discriminants when addressing IMS and OSI tasks. We have substantiated the dependence of false alarms on the nuclear explosion detection probability and shown that this algorithm is optimal based on Neumann-Pearson criterion.

T3.5-P47  **Platform for Rain Monitoring and Flood Prevention Risk Oriented Citizen in Dakar**

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Senegal, like other Sahel countries, has experienced a very long and persistent drought from the 1970s to the 1990s impacting dramatically society and economy. Since the 2000s, annual rainfall amount has recovered with an increase of extreme events and floods mainly in most populated urban areas like Dakar and its suburbs. In addition, the existing infrastructure for weather and environmental observation as well as the present local rainfall and hydrology process knowledge are far from sufficient. To fight against floods and ensure good protection and mobility for people during rainy seasons, we propose to set up a centralized monitoring platform with our meteorological observation network, integrated with Satellite data and IMS data to be able to mitigate heavy rain events and ensure real-time rain monitoring allowing good mobility by indicating low risk areas in Dakar and as such helping addressing SDGs 6, 10 and 11. It consists of a central system (data storage and processing), a web application (real-time visualization) and a mobile application for citizens (rainfall and floods map, alert system for possible heavy rain, ...). Machine Learning will be used for analysis taking into account physical environment and rain spatio-temporal variability.

T3.5-P48  **RASA Filter Jam Detection Algorithms**

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General Dynamics Mission Systems (GDMS) is seeking methods to reduce downtime due to filter advance failures for the Radionuclide Aerosol Sampler/Analyzer (RASA) system. The primary concern during filter advances are filter jams, which occurs when the filter media wraps itself around the driver rollers. Filter jams often lead to hardware damage to the advance motor gear assembly, thus requiring manual intervention. Damage to the filter media can also occur due to tension stress or from actions taken to restore the system. To address this concern GDMS is investigating ways to leverage existing RASA sensors to detect and mitigate filter jams. One such sensor is the filter advance motor current transducer. This state-of-health sensor has in the past only reported its minimum, maximum, and average values during a filter advance. However, GDMS has been able to successfully identify patterns indicative of a filter jam by observing minute fluctuations in the current values while the motor is engaged. An algorithm was then developed to search for these patterns in real-time and take appropriate actions to prevent catastrophic component failures. Further corrective actions are also being investigated to automatically restore the system using existing hardware and without human intervention.
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T 3.5-P49 Recent Advances and Status of Generative Modeling for Network Processing at the CTBTO

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NET-VISA is a physics-based generative model of global-scale seismology designed for network processing at the IDC, i.e. building an event bulletin based on waveform data. The model includes a probabilistic description of event formation in multiple media (underground, ocean, and atmosphere), the propagation of energy within and across the media along multiple paths or phases, the detection and mis-detection of these phases at the IMS stations, the detection of coda energy, and finally the false, or noise, detections at the stations. Further, the model is continuously trained on historical data using machine learning techniques, and an inference algorithm based on greedy heuristic search scans the incoming data stream to generate a continuous event bulletin. In this presentation, we will describe the ongoing efforts to make NET-VISA results available to the analysts and the measured improvements on standard IDC products such as the REB bulletin (+10% additional events). We will also describe some recent advances: inclusion of infrasound detections and the corresponding atmospheric medium in the model, modeling of oceanic explosions generating detections at seismic stations, improvements for regional seismic events (+10% overlap with the analyst-reviewed LEB bulletin), and real-time noise modeling to improve processing of large aftershock sequences (+5% overlap).

T 3.5-P50 Reduction of Wind Noise Impact Based on the Use of Data from a Weather Station in Recording Infrasound Signals at IS43

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We have developed a method of reducing wind noise impact on recording of infrasound signals by considering wind speed at IMS infrasound stations. Approximation of developed algorithms was performed at IS43. The likelihood ratio \( \Lambda \) for a model signal corresponding to a 10 kiloton atmospheric nuclear explosion (ANE) at the distance of about 3000 km from the infrasound station was used as a discriminant. \( \Lambda \) was assessed by a pair of values – a root-mean-square deviation of pressure pulsations \( \sigma_p \) and a mean value of wind speed module \( v \) that were averaged by the duration of an ANE model signal. We used data for 3 years of different seasons and different time of the day, the total duration of 36 hours. Over 20 thousand ANE model signals were included in the background. 2D distributions of conditional probability \( P(\sigma_p,v) \mid H) \) and \( P(\sigma_p,v) \mid H\) were generated for hypothesis \( H \) (ANE) and its alternative \( H^\prime \) and an operating characteristic of meteoselector was constructed on their basis. The analysis of the operating characteristic, which is a dependence of false alarms on the detection probability, allows to make a conclusion about the efficiency of the proposed method.

T 3.5-P51 RNIAC: A Cloud-Based Approach of the Radionuclide National Data Centre (NDC) in a Box Software (RNIAB)

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The introduction of the Radionuclide NDC-In-A-Box (RNIAB) was a milestone in the treaty verification. The software is helping the Radionuclide community to get the latest and utmost of the Radionuclide data, analysis and review. However, maintaining and operating such complex software is a complex task and lacks the means of exchanging information and data analysis among the state parties. The aim of this research is to study the possibility of adopting, implementing and operating a cloud-based version of the RNIAB. The research benefits from the rapid and growing advances in communications and cloud solutions and services. Implementing such approach may increase the usage and operability of the Radionuclide software remotely and efficiently. Also, it can increase the exchange of information and Radionuclide data analysis among the National Data Centers as well as reduces efforts and time of maintainability of the software. The challenges to such approach will be
presented. Also, the different cloud-based solutions and databases will be discussed. The methodology, models and techniques to achieve the proposed research will be introduced as well as future directions.

T 3.5-P52 RSTT Validation Studies in the Middle East, Central Asia and the Caucasus

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Travel-time predictions from RSTT, a global three-dimensional velocity model of the crust and upper mantle are tested and validated in the Middle East, Central Asia and Caucasus regions. In cooperation with the CTBTO, we organized workshops (e.g. Kazakhstan) to conduct training on RSTT. Using the iLoc location algorithm and ground truth events as benchmark locations we relocated events both with ak135 and with RSTT predictions and compared the accuracy of the locations with respect to the ground truth. We demonstrate that RSTT brings an overall improvement in location accuracy.

T 3.5-P53 Scientific Evaluation of the Benefits of Increase in Resolution for IDC’s ATM Tools and Launching Interface

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It is generally considered that guidance resulting from ATM usually benefits from an increase of spatial and temporal resolution. Under funding from the European Union Council Decisions VII, our group has initiated a scientific evaluation of that assumption. CTBTO mainly uses ATM guidance in backward mode to link a measurement from an IMS station to a possible source location. However, ATM is also used in forward mode to predict which of the IMS radionuclide stations are likely to be affected given a potential radioactive release. These two aspects will be considered in this study. Increasing resolution implies additional computing resources. A third secondary aspect will be to evaluate the relative cost of running at higher resolution taking into consideration the steady decrease in CPU cost over the years. Results of this study will contribute to define the future evolution of the ATM system within the CTBTO. This presentation will describe the project and present initial results.

T 3.5-P54 SeisComP3 iLoc Integration Applied to Array Processing

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With the recent SeisComP3 release the already available seismic event locators including LocSat, Hypo71 and NonLinLoc have been extended with iLoc. iLoc is the expansion of the ISC locator algorithm optimized for seismic event monitoring by local and regional networks, NDCs and global event location studies. With iLoc the open source SeisComP3 system is able to integrate results from array processing modules like GEMPA’s commercial software package LAMBDA. To support array processing the graphical user interfaces of the open source SeisComP3 package have been extended to consider phase picks for event localization with slowness and backazimuth in addition to the detection time. Therefore iLoc as a native SeisComP3 locator allows to use the
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full capacity of array processing in LAMBD A and SeisComP3 during real-time automatic and interactive analysis. LAMBD A provides several array processing techniques as static and dynamic F-K analysis, beam packing and backprojection along traveltime curves. As infrasound phases are supported by iLoc, the seismic and infrasound phases derived by LAMBD A can be used within the localization. Here we present the array processing results for the nuclear weapons tests of North Korea and other induced seismic events applying the iLoc implementation compared to the existing locators like LocSat.

T3.5-P55 Seismic Instrument Response Representation Using Poles and Zeros in Laplace Domain

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This presentation focuses on instrument responses representation using poles and zeros in the Laplace domain. Poles and Zeros of a transfer function are the frequencies for which the value of the denominator and numerator of the function becomes zero respectively. There are basically three (3) types of seismometers used in Transportable array (TA) namely Guralp CMG-3TB, Streckeins STS-2, Trillium 240. The study used PS42, which is a primary seismic station of the International Monitoring systems (IMS) in Tunisia with broad-band channels and a Guralp CMG-3TB. The seismometer has six (6) poles and three (3) zeros with a normalization factor of 4.395259E+10. The sensitivity of the channel is 20.0 counts/(nm/s) at a frequency of 1.0 Hz. A Python algorithm was developed to do Wiener-Levinson deconvolution and plot instrument responses using poles and zeros data set. The set of six (6) poles and two (2) zeros which are complex numbers with frequency vectors were inputs of the algorithm to output amplitude and phase at these frequencies. One set of zeros was ignored in order to have a response in velocity. The algorithm displayed frequency response curve which is almost the same as a seismometer response curve of a Guralp CMG-3TB and therefore validates the algorithm.

T3.5-P56 Seismic Phase Identification with Deep Learning in Frequency Domain

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Identifying different seismic phase of a seismograph has been the cornerstone in earthquake processing and location. Most of the efforts of the seismic phase identification is the obligation of the analyst. Deep learning is offering a powerful tool for analyst experience transfer by learning form the events data already processed. Then, these gained knowledge can be used for upcoming processing and extract missing small events. Most of the previous seismic waveform processing for phase detection and identification were done in time domain. In this study we suggest using frequency domain in form of spectrogram of the event. Spectrogram is used to represent the varying of the seismic signal power for different frequency bands though time. Using frequency domain allows the deep learning to extract more sensitive, robust and stable features from the signal which can lead to better classification result. Earthquakes recorded by the SCSN (Southern California Earthquake Data Center) are used as training and validation data sets which were used in previous similar studied to provide a stable benchmark. The three channels waveform were used to enrich the deep learning algorithm and increases the ability for phase type discrimination.

T3.5-P57 Sensitivity Analysis and Disaggregation of Recent Seismic Hazard Assessment in Egypt

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A recent probabilistic seismic hazard analysis for Egypt is performed of the Peak Ground Acceleration (PGA) and Spectral Acceleration (SA) for 475 and 2475 years return periods. In the current study, an earthquake catalog of Egypt and its surrounding from 2200 BC to 2016 AD is used for identifying the seismic sources and calculating their seismicity parameters. Two de-clustering algorithms, three seismotectonic models, and four
Ground Motion Prediction Equations (GMPEs) are implemented through the logic-tree framework to overcome the epistemic uncertainties. Sensitivity analysis shows that seismic hazard results of the cities located at the unstable shelf are highly affected with variation in the de-clustering algorithms. The sensitivity analysis of the used GMPEs shows wide variations of the values obtained by each model and this reflects the urgent need for evaluating the recent developed GMPEs using the Egyptian seismological database. The results of the disaggregation show that Newbie City is highly exposed to high levels of ground motion in 475 and 2475 years return periods and at the short and long spectral periods (1 sec.) but, cities located in the NW part of Egypt are highly affected by the long period seismic waves generated by earthquakes initiating at the Hellenic Arc.

**T 3.5-P58  Sensitivity of a Bayesian Source-Term Estimation Model to Spatiotemporal Sensor Resolution**

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Source term estimation (STE) methods calculate the most-likely source characteristics of an atmospheric release given concentration observations. The confidence in the STE depends on the time and space scales of the observations, sensor locations, and release parameters. In previous work, we developed and validated a probabilistic STE algorithm that was validated using high-resolution spatiotemporal data collected during a controlled tracer release experiment. Here, the STE algorithm receives significant improvements, which extend applicability to coarser-resolution observational datasets. Improvements include the addition of a fully-connected deep neural network model emulator with dynamically optimized architecture and more robust and resilient goodness-of-fit (GOF) metrics, used to measure the discrepancy between model and observational data. Using synthetically generated observations over East Asia, the skill of the improved algorithm is quantified over a broad range of sensor configurations and release scenarios. The evaluation is broken into three experiments. First, a validation study. Next, data-denial techniques are applied to a single release scenario over the Korean peninsula, where the skill of the inversion is shown to be highly sensitive to the number of deployed sensors but less sensitive to temporal resolution. Finally, the STE algorithm is tested for many release locations throughout the geographic model domain.

**T 3.5-P59  Signal Character Analysis of Lightning in Nuclear Explosion Infrasound Detection**

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This paper analyzes the characteristics of interference event in the infrasound detection of nuclear explosion. After data preprocessing, such as mean removal, atmospheric disturbance removal, filtering and normalization, etc., the infrasound signal characteristics of lightning, chemical explosion and satellite launch event are analyzed through spectrum and statistical methods. Finally, spectrum characteristics of interference event infrasound signal are obtained according to statistical conclusions. The analysis results show that the acquired infrasound signal characteristics of lightning, chemical explosion and satellite launch event are different from those of nuclear explosion, and this characteristic value can be used as one of the feature vectors of nuclear explosion infrasound detection and recognition.

**T 3.5-P60  Simulations of Gamma Ray Spectra of Fission Samples**

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Radionuclide laboratories affiliated with the CTBTO use high-resolution gamma-ray spectrometry to determine the presence of certain fission and activation products, which indicate the occurrence of a nuclear explosion. Annual proficiency tests are used to assess the performance of the radionuclide laboratories. While proficiency
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Test samples are usually quite expensive to prepare and allow only limited radionuclide content (due to radioactive decay and safety issues), synthetic spectra can be used to model practically any scenario at relatively low cost. Gamma-ray spectra of fission samples of varying ages were accurately modeled using a combination of two tools: (i) Koala code was used to calculate the time-dependent activities of fission products. (ii) GEANT4 software was used to simulate the response functions of a germanium detector to photons of varying energies. The numerical simulations were validated experimentally by irradiation of HEU samples in a reactor and later measuring them periodically. Synthetic spectra were used to test an algorithm for measurement restrictions within the framework of OSI. The numerical method and obtained results, as well as possible applications (e.g. nuclear forensics), will be presented and discussed.

T3.5-P61 Source Spectral Discrimination Between Shallow Earthquakes and Quarry Explosions in Northern Egypt

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In this study, the P- and S-wave observed velocity and displacement source spectra from earthquakes and Quarry explosions with similar magnitudes were analyzed and compared. We have examined 1755 vertical component seismograms of 244 earthquakes and 239 Quarry explosions with magnitudes M d=1.5-3.3 between 2009 to 2015 recorded by the Egyptian National Seismic Network (ENSN) in northern Egypt at epicentral distances of up to 200 km in order to develop a criteria for qualitative and quantitative discrimination between shallow earthquakes and quarry explosions based on differences in their spectral properties. The computed spectra were corrected for site, propagation path and instrumental effects for each recorded station. Based on omega-square fitting Brune's model, the source parameters of seismic moment (M o), corner frequency (f c) and moment magnitude (M w) were determined from corrected displacement spectra then the quantitative analysis is performed. Results of this study show that the quarry explosions spectra decrease more sharply at high frequencies than earthquakes of the same estimated magnitudes, leading to lower corner frequency estimates. Moreover, earthquake velocity spectra contain high-frequency energy compared with the spectrum of the quarry explosions. A scaling relations were constructed successfully between M o(P,S)-fc(P,S), fc(P)-fc(S) and f c(P)/fc(S)-M w(P,S); it reflect an effective separation between earthquakes and explosions.

T3.5-P62 Source Term Estimation in the Presence of Nuisance Signals

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Many source-term estimation algorithms for atmospheric releases assume the measured concentration data are influenced only by the releases of interest. However, there are situations where identifying a short-term release from an unknown location in the presence of long-term releases from a different location is of interest. One such example is determining if part or all of a typical magnitude concentration of a radioactive isotope in a sampler came from a nuclear explosion, such as the explosion announced by DPRK in 2013, while medical isotope facilities and nuclear power plants were also operating in the region. An estimation algorithm has been developed for the case where a short-duration release is confounded by a long-term nuisance signal associated with one or more additional release locations. The technique is demonstrated using synthetic release data for a hypothetical medical isotope production facility and a hypothetical puff release from a different location. The algorithm successfully determines the location and time-varying release rate from the medical isotope production facility and the location, time, and release magnitude of the puff release.

T3.5-P63 Source Term Estimation Using Multiple Isotopes in Atmospheric Samples

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 Algorithms that estimate the location and magnitude of an atmospheric release using remotely sampled air concentrations typically involve a single constituent. A new algorithm is presented that makes discrimination between possible types of releases (e.g., nuclear explosion, nuclear power plant, or medical isotope production facility) an integral part of the analysis for samples that contain multiple isotopes. Algorithm performance is demonstrated using synthetic data and shows promise in discriminating between different hypotheses on the release type, especially if data are available on 3 or more isotopes.

**T3.5-P64  Source Term Estimation with a Simple Weak-Constraint Inverse Modeling Scheme**

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It is well known that weak-constraint variational data assimilation (4D-Var) performs better than its strong-constraint counterpart by including model uncertainty terms in the cost function. However, model uncertainties have been rarely considered in the inverse modeling applications. In this study, a simple weak-constraint inverse modeling scheme is designed to include model uncertainties using NOAA’s HYSPLIT Lagrangian dispersion model. The Cross Appalachian Tracer Experiment (CAPTEX) data are used in the initial tests so that the results can be easily evaluated with the known release sources. In this simple scheme, model uncertainties are added to the observational covariance matrix. Before the model uncertainty terms are introduced, the inverse tests using concentration differences in the cost function results in severe underestimation while those using logarithm concentration differences in the cost function results in overestimation of the release rate. Adding model uncertainty terms improves results for both choices of the metric variables. This weak-constraint HYSPLIT inverse modeling system is further tested with the Fukushima nuclear accident case. In the tests, the daily average cesium-137 air concentration measurements around the globe are used to estimate the release of the radionuclide.

The results are then compared with the results using a strong-constraint HYSPLIT inverse modeling system.

**T3.5-P65  Spectral Region-of-Interest Methods Used in Net Count Calculations**

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There are multiple approaches to radioxenon data analysis using the net count calculation (NCC) method. This presentation focuses on the 10- and 7-regions-of-interest (ROI) approaches. Analysis of radioxenon data from the Xenon International, a new system developed by Pacific Northwest National Laboratory in partnership with Teledyne Brown Engineering, uses the 7-ROI approach, whereas the Swedish Automatic Unit for Noble gas Acquisition uses the 10-ROI approach. The similarities and differences between the two approaches will be presented, along with considerations for improvements and standardization for software sustainability.

**T3.5-P67  Stack Data Processing Pipeline**

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The Source Term Analysis of Xenon (STAX) project is a new effort to better understand the radioxenon background in the environment. This project aims to use high resolution stack detector systems to measure the four IMS relevant radioxenons (Xe-131m, Xe-133m, Xe-133 and Xe-135) from fission based M0-99 production facilities. The data pipeline from the collection of the raw data to the automatic analysis of the data at a centralized data repository involves many steps. Some of these steps include data conversion to a standardized format, secure data transmission, encryption, data receiving and parsing, and automated spectral analysis. The
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overall data pipeline will be described, as well as a graphical user interface for basic viewing of stack release data.

T3.5-P68  Study of Variants for Seismic Data Pre-Processing Which Are Not Leading to Significant Losses of Information that May Be Needed

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Seismic data processing algorithms are constantly being improved. Most algorithms demands preliminary processing. Typically, this processing is either very simple, such as frequency filtering, or highly specialized for highlighting specific features of the signal and can not be used with other post-processing algorithms. We are considering solutions which are not leading to significant losses of information that may be needed. The basic purposes of the preprocessing are the reduction of noise, elimination of obvious noise (mostly of anthropogenic origin) and decrease the dimensionality of the data, i.e., the removal of their redundancy. As a post-processing we intend using neural networks of one or another architecture, but it does not exclude a possibility of application of other algorithms. In our work we are considered Wavelet transform, Autoencoder, and Compressive Sampling as preprocessing.

T3.5-P69  SVM Classification of Explosions and Earthquakes Using Seismic Features

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Among methods for big data exploration, machine learning is becoming more reliable solution in decision making systems and figure out trends in data or testing new models and algorithms on specific data sets. Support vector machine is a supervised learning method in classification and regression analysis. This research was conducted to evaluate the application of support vector machine (SVM) classifier on classification of explosions and earthquakes from recorded seismic signals. The dataset used to train the model comprised of 500 earthquakes and 40 explosion which occurred in the region of Rudbar Lorestan dam in the time span of 4 years. These data was randomly divided to two sections; the training section with 75%, and the testing section with the 25% of total number of events. The features used as predictors were time domain, frequency spectrum, magnitude, depth, length and STA/LTA of each record. The results indicated that SVM successfully learned the relationship between the inputs and outputs, and classified the output classes of explosions and earthquakes.

T3.5-P70  Testing IMS/CTBT Verification Capability Using July 2013 Lake Albert Seismic Activity in Western Rift, Uganda

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Lake Albert is located at the western border of Uganda with the Democratic Republic of Congo. The lake is bounded by active faults of the western branch of the East African Rift System (EARS). The western branch of the EARS is very seismically active on the African Continent. On 2nd, 3rd and 4th July 2013, the Albertin Lake region was hit by moderate earthquake activity. The seismic events were recorded by the International Monitoring Stations (IMS) of the Preparatory Commission of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO). The data from the IMS station network in the region were used to study the seismic events and advise the Government and the public in Uganda. Our National Data Centre (NDC180) efforts in the analysis of the seismic activity demonstrates the readiness of CTBTO/IMS infrastructure towards entry into force of Comprehensive Nuclear-Test-Ban Treaty (CTBT). The seismic activity on a known active zone is therefore useful in testing the IMS/CTBT verification capability.

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T3.5-P71  **The Application of Multi-Criteria Synthetic Method in Discrimination of Nuclear Explosions from Earthquakes**

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Doubtful earthquake events in Standard Screened Event Bulletins of the International Data Center are focus events to every states signatories. The complexity of waveform, spectral ratio, and composite ratio were selected as the three criteria for discrimination of nuclear explosions from earthquakes. A method has been developed using the difference between the focal mechanisms and the study of multi-criteria synthetic methods. The three criteria and multi-criteria synthetic method were applied to six nuclear explosions and five natural earthquakes, which happened in Punggye-ri nuclear test site of North Korea. The results of application indicated that multi-criteria synthetic method came to an accurate conclusion for these events, even if one of the criteria provided a wrong decision, which verified the effectiveness of multi-criteria synthetic method.

T3.5-P72  **The Challenge of Quantitative Comparison and Quality Assessment of IDC Waveform Bulletins**

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The issue of comparing different catalogs and identifying identical events in the waveform catalogs is of great importance. In the context of CTBT, this issue is important in several situations. Firstly, in assessment the quality of Reviewed Event Bulletin (REB) and automatic waveform products of IDC versus different baseline catalogs. Secondly, in comparison the results of National Data Centers (NDCs) with IDC and evaluating the degree of consistency of these results to each other. Thirdly, in evaluating performance of new analyzing algorithms, like NetVISA, in comparison with national seismic catalogs, as baseline catalogs. In all of these cases, it is very important to use one unified procedure as a unique basis of comparison, otherwise, it is not logical to compare results of different studies. So far, different criteria have been used by different researchers to identify identical events in different catalogs. Diversity of these criteria indicates diversity of results and notices the caution for judgment amount the results of different studies. In this paper, it is intended to propose a unified method of comparison among different catalogs. It is also intended to use magnitude of events, as another parameter of comparison, in the process of evaluating quality of different catalogs.

T3.5-P73  **The Identification and Determination of Small Peaks and the False Positive Alarm in RN Particulate Spectra Analysis**

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The peak detection criteria (D) is defined in IDC RN analysis software SAINT to identify peaks in spectra. If \( D \geq 1.0 \) peaks are confirmed and if \( D < 1.0 \) peaks not confirmed. Many peaks with \( D \) around 1 in RN particulate spectra make the spectra analysis and nuclide associations very difficult. Cases of peaks identification with \( D \) around 1 may result in missing nuclide detections or false positive nuclide detections. In this paper some cases of spectra analysis and laboratory reanalysis are summarized.
The emission of antineutrinos is unaffected by the environment in which the explosion occurred. The detection of $^{37}$Ar can be a confirmatory measurement for a nuclear test, and when combined with systems used for CTBT verification.

In traditional data processing pipelines, the signal associator links the detections to the fitting event hypotheses to generate an event bulletin. Most of the time, this traditional pipeline requires heavy human analyst involvement to improve the quality of the resulting event bulletin. We propose an Iterative Processing Framework (IPF) that incorporates automatic analyst behaviors (Auto Analyst) into the event building pipeline. In the proposed framework, Auto Analyst takes over many of the tasks traditionally performed by human analysts. These tasks include searching for expected signal detections for validated event hypotheses at lower thresholds, in optimized detection bands that are informed by historical data; validating and refining signal detections by performing multiple f-k analyses with varying parameters; and locating events based on unassociated signal detections from single array stations. To test the proposed pipeline, we processed a two-week period (May 01-14, 2010) of the signal detections dataset from the IDC. Comparison with an expert analyst-reviewed ground truth bulletin for the same time period suggests that IPF performs better than the pipeline currently in use at the IDC. Most of the additional events built by the Auto Analyst are low-magnitude events that evaded the traditional pipelines of event building.

The Source Term Analysis of Xenon (STAX) project is a new effort to better understand the radioxenon background in the environment. The project aims to deploy new high-resolution stack detector systems at facilities that routinely release radioxenon, such as fission based medical isotope production facilities. As radioxenon is detected every day in the International Monitoring System (IMS), the ability to directly measure the releases from these civilian sources contributing to the background could greatly aid in attributing IMS detections. In conjunction with atmospheric transport modeling (ATM), this new STAX data could be used by treaty monitoring scientists to better understand the worldwide radioxenon background that the IMS routinely detects. This presentation will give an overview of the STAX project, including status, detector technology, and data security methods that are being developed.
T3.5-P77  Toward Reliable Certainty for Seismic Processing Tasks with Deep Learning

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Machine learning is a powerful way to accomplish a variety of seismic processing tasks, outperforming state-of-the-art for many traditional discrimination techniques in terms of broad applicability and performance. However, self-reported certainty from learned models can be unreliable, especially for data with characteristics outside of training distributions. While these cases can be rare, or go unnoticed during controlled experiment set-up and testing, real-world situations, production settings, and monitoring objectives require reliable estimates of certainty for decision making. In this work, the goal is to focus on understanding the current limitations of certainty from model output on a simple seismic event discrimination task using deep convolutional model architectures. With an understanding of the limitations on our current methods, can we improve upon the trustworthiness of a model’s reported certainty through data augmentation, model adaptations, or external trust metrics?

T3.5-P78  Towards Automatic Noble Gas Data Processing at the Canadian NDC

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With the maturation of noble gas monitoring technology and the widespread deployment of this technology throughout the International Monitoring System (IMS), the Canadian NDC receives a large number of noble gas spectra daily. The ability to analyse this data accurately and timely becomes more important for the verification mission as noble gas emissions from recent Democratic People’s Republic of Korea nuclear tests has demonstrated. An automatic pipeline has been set up to process the high resolution gamma spectra from Spalax missions. Two years historic data collected in Ottawa have been processed by the pipeline, and the results are demonstrated. An automatic pipeline has been set up to process the high resolution gamma spectra from Spalax missions. Two years historic data collected in Ottawa have been processed by the pipeline, and the results are compared with the reviewed Atami results. The feasibility of this pipeline is analysed and discussed. A spectrum fitting tool for automatic Beta-Gamma coincident spectrum processing will be presented and the particular advantages of this approach described.

T3.5-P79  Towards Real-Time Association of Infrasound Events Using Full-Wave Modeling

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One important limitation of infrasound technology is due to the uncertainties that are associated to any available atmospheric specifications. While these uncertainties should be implemented in operational products, the problem of calculating plausible waveforms requires a high CPU load that exceeds available resources. For this reason, the current association procedure neglects some important physical aspects of wave propagation, which leads both to high false alarm rates and incomplete events. The latter often occurs when a candidate event sufficiently close to a true event is lacking. In this work, we present a new statistical model for analyzing and interpreting the data from the International Monitoring System. The method is based on Bayesian inference using a parallel Markov chain Monte Carlo algorithm and a computationally efficient full-wave propagation model. The method provides simulation-based probabilities of detection in a random atmosphere and can associate detections when multiple, interacting events are present in the data along with both sources of coherent and incoherent noise. In turns, the posterior probability of no association can be estimated, thereby providing a way to reduce the false alarm rate in operational-like environments such as that encountered by the International Data Center.
**T3.5-P80**  **Using Spectral Ratios to Discriminate Between Low-Magnitude Earthquakes, Explosions and Mining Events in Canada**

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Many regions in Canada contain a mixture of natural seismicity of variable depth, low-magnitude explosions (arising from construction and/or mining activity) and mining induced events. Their correct classification is critical for seismic monitoring and for ensuring that anthropogenic events do not inflate seismic hazard calculations. Recently, local- to regional-spectral ratio discriminants across multiple phases and frequency bands have successfully been used in Canada to improve the accuracy and efficiency of event screening, particularly at low magnitudes (M < 3) where other explosion discriminants often fail. This work will present results from several case studies where spectral ratio discriminants have been used with varying degrees of success. In a test study in the New Brunswick, Canada, both high-frequency Pg/Lg and low-frequency Lg/Rg spectral ratios consistently discriminated between small (M < 2) blasts and earthquakes. In the mining-rich district of Sudbury, Canada, successful discrimination was possible for roughly 80% of a test sample of M 2 to M 3 blasts and rockbursts. However, no single spectral ratio consistently provided adequate discrimination, and optimal spectral ratios needed to be calculated/tuned for particular stations. Preliminary results from other regions in Canada will also be presented.

**T3.5-P81**  **Weather Support and Application of ATM During an OSI: Development Perspectives**

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As part of the current 4 year Action Plan (2016-2019) to develop on-site inspection (OSI) capabilities, the OSI and IDC Divisions of the CTBTO conducted a feasibility study to define the needs and applications of atmospheric transport modelling for use during all phases of an inspection. This poster presents the key findings for AP Project "ATM for an on-site inspection" and the work tasks recommended to develop the required capabilities for a timely and efficient support of the inspection team, in areas of health and safety, mission planning and interpretation of inspection data collected.

**T3.5-P82**  **When Can the Combination of Seismic and Infrasound Data Improve Event Location?**

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Events near the boundary between the solid earth and atmosphere, such as the recent DPRK nuclear tests, generate both seismic and infrasound observations. This presentation explores the combined use of seismic and infrasound observations for joint localization of events based on a Bayesian framework. We explore the value of combining both types of observation in terms of the precision of the subsequent event location and origin time that is possible, relative to the precision using seismic or infrasound data alone. We use ground truth data that include repeated sources with regular basis in time such as mining activities and surface explosions. Using a combination of real and synthetic data, we explore when combining the two types of observation can improve the precision as a function of the numbers and distributions of stations, and of the spatial scale (local, regional, or global). This work highlights the importance a priori estimates of uncertainty in observations as well as models.
**T3.5-P83 Application of Nonlinear Echo State Network (Machine Learning) in Daily Streamflow Forecasting**

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The number of water-related challenges are expected to increase in the future. They can differ from the impact of floods, droughts, glacier dynamics and economic to population growth, etc. To tackle these challenges, hydrological models have developed to explore the solutions for sustainable water management. Streamflow forecasting as one of the crucial topic in hydrology is essential for water resources engineers. The high-quality forecasting can support their decisions about hydroelectric power programming, flood mitigation and agricultural/domestic water supplies. The existing dynamicity and chaotic feature in the hydrological models may obstruct the accurate prediction process. Furthermore, the performance of any hydrological model is correlated to the set of model parameters. In the view of current understanding and incomplete research to date, this study is conduction to determine a novel method of NESN-MP (None Linear Echo State Network-Multivariate Polynomial) forecasting engine for predicting daily streamflow in large catchments attribute. This study develops a non-parametric and user-friendly model to yield optimal forecasting up to several months ahead of its lead time as follows: (1) Problems corrupted by noise; (2) Complex systems that may not be dittoed; and (3) Circumstances where the input is incomplete or ambiguous by nature producing bad data (inaccurate input).
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We have developed 3D realistic models of the underground structure after an UNE. The most general model consists of cavity, chimney with apical void, crushed zone, fractured zone, environment and free surface. We performed extensive numerical modeling of seismic wave fields due to plane-wave excitation (representing regional and distant events), near point double-couple sources (representing aftershocks) and seismic ambient noise. We then comprehensively analyzed the simulated wave fields in the time, frequency and time-frequency domains. In a seismic wave field due to a distant source it was possible to identify and locate cavity. A seismic wave field generated by an aftershock was much more difficult to interpret in terms of the cavity presence due to strong effects of a radiation pattern. Analysis of seismic noise makes it possible to identify cavity at least for relatively shallow cavities.

T2.1-O4 Seismic Full Moment Tensor Analysis of Nuclear Explosions in North Korea

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We estimate seismic full moment tensors and their uncertainties for seven events at the North Korea nuclear test site, consisting of six declared nuclear tests and one event, interpreted as a cavity collapse, that occurred 8 minutes after the declared test. We also analyze two earthquake events that occurred to the south and were recorded by the same set of stations. We perform a grid search over the six-dimensional space of moment tensors, generating synthetic waveforms at each moment tensor grid point and then evaluating a misfit function between the observed and synthetic waveforms. For each moment tensor we characterize its uncertainty in terms of the variation in waveform misfit on the eigenvalue lune, a probability density function for moment tensor source type, and a confidence curve for the probability that the true moment tensor lies within the neighborhood of the best-fitting moment tensor. We find that the moment tensor source types are clearly separated for the six declared nuclear test events, the collapse event, and the two earthquakes. Moment tensors for the six explosion events can be represented as a sum of a double couple and a crack tensor whose plane is near horizontal.

T2.1-O5 Seismic Spectral Ratios Between North Korean Nuclear Tests: Implications for Their Seismic Sources

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Seismic spectral ratios between the 2017 North Korean nuclear test (NKT2017) and four other Korean tests conducted in 2009 (NKT2009), 2013 (NKT2013), January, 2016 (NKT2016J) and September, 2016 (NKT2016S) are investigated. All the observed teleseismic P-wave spectral ratios exhibit a unique notch at approximately 2.5Hz that is not observed for regional P- and Lg-wave spectral ratios. Meanwhile, the network-averaged Lg-wave spectral ratio is similar to that of regional P-wave, but with the source corner frequencies significantly reduced. We demonstrated that the observed notch of teleseismic P-wave spectral ratios may be well modeled by interference between pP- and P-wave, while regional P-wave spectral ratios may be well fitted with source spectral ratios predicted by classical explosion source models including MM71, DJ91 and their two hybrids. Results obtained indicate that for NKT2017's buried depth in the range of 600-1100m, the MM71-related models give a yield estimation about 100-300kt for NKT2017, 3-7kt for NKT2019, 6-15kt for NKT2013 and NKT2016J and 10-25kt for NKT2016S, while yield sizes obtained by model DJ91 are much smaller.
T1.1-O3 Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound Propagation and Scattering in the Atmosphere

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The experimental results of studying the effect of a fine-scale layered structure of a stably stratified atmospheric boundary layer (ABL) on fluctuations of the parameters of acoustic pulses generated with a certain period (1 min) by an artificial detonation source are presented. The vertical profiles of wind velocity fluctuations in the thin layers of the ABL have been retrieved using the wave forms and travel times of the recorded arrivals of pulses from the source. It is shown that the mechanism of scattering of pulse signals in a stably stratified ABL is similar to the mechanism of scattering of signals from ground surface explosions by layered nonhomogeneities of wind velocity and temperature in the stratosphere and lower thermosphere. The role of similarity parameter here place the dimensionless thickness of the reflecting nonhomogeneous layers, which is the vertical scale of the layer multiplied by the relative difference in effective sound velocity and normalized by the vertical wavelength. The effect of such inhomogeneities on the temporal fluctuations of the azimuth and arrival times of the signals is studied. The estimation of the error in localization of pulsed sources is given.

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T1.1-O4 Climate Change Through the Eyes of Radioisotopes

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Cosmogenic radionuclides beryllium-7 and sodium-22 are known atmospheric tracers and can be used together in a lock-in technique to effectively trace vertical air masses based on surface measurements. This technique allows to study progression and speed of atmospheric cells. Data show that the cells are decelerating during the summer period which is extending in time. This is caused by warming of the whole troposphere and increased tropopause height due to rising CO2 concentrations. Aestival episodes of persistent high-pressure systems over Europe with low pressure gradients that led to almost stationary thunderstorms are correlated with the observed deceleration of atmospheric cell movement. This demonstrates that 7Be and 22Na can be used as indicators for confirming several side effects of climate change while providing a new modelling tool in seasonal weather forecast.

T1.1-O5 Detection Efficiency of the IMS for Bolides

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In this study we examined 344 bolides (airbursts) reported on the JPL CNEOS website (https://cneos.jpl.nasa.gov/fireballs/) between 2007-2018 and attempt to correlate these with infrasound detections. We found 206 of these bolides were detectable by at least one infrasound station while only 42 were automatically registered as part of the Reviewed Event Bulletin (REB) issued daily by CTBTO. However, this global REB detection rate of ~10% averaged from 2007-2018 is less than the "modern" rate (from 2014-2018) which approaches 20%. Above the 1 kT CTBTO design threshold, we find that 40% of airbursts are reported in the REB, while more than 90% are detectable at one or more infrasound stations. All airbursts with energy > 2 kT reported on the JPL fireball site since 2007 have been detected infrasonically. However, the REB is only complete above 15 kT with the automated detection system not having reported at least four airbursts with...
T4.1 Network Optimization

Oral Presentations

T4.1-O1  Adaptable Turnkey Solution for Infrasound Station

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In collaboration with the CTBTO engineering division, Enviroearth acquired step by step experience and expertise in the whole understanding of the infrasound monitoring station infrastructure. With the objective to homogenize existing and future IMS Infrasound stations, Enviroearth technical division contributed to redesign the infrasound station as a set of optimized, interchangeable and interconnected modules. Some module design comes from the Commission’s field experience, when the others are the result of our own research and development studies. According to the specifications of the end-user and to the station environment, it will be necessary to select between several modules for: Wind-Noise Reducing System/ Communication and the Power Supply systems/ Sensors /Digitizers, etc. Each module is the result of a technical studies and feedback of our long experience of stations upgrade on field and will be composed of: - A complete and optimized technical solution - A set of data sheet - A list of pros and cons depending of the station particular environment. The aim of this complete study is to present a simple, adaptable and turnkey solution for the installation of an Infrasound Monitoring Station, always targeting a continuous improvement of the robustness and sustainability of the IMS network.

T4.1-O2  Latest Development of the Standard Station Interface Calibration Module

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The SSI calibration module is a tool that extends the Standard Station Interface (SSI) for intuitive execution of instrumental calibrations and review of calibration results. It aims to (1) support the complex planning, technical execution, evaluation and reporting of the calibration of IMS seismic and T-phase stations (2) provide a single, standard interface that masks the heterogeneity of the hardware/software used at different IMS stations and (3) standardize the communication through full implementation of IMS $2.0$ format to dramatically ease the exchange, parsing and review of calibration messages, for both the Station Operator and PTS staff. The module was deployed at a few pilot stations and the PTS currently continues the deployment at other stations.


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Nuclear treaty monitoring is dependent upon a reliable sensor network to achieve mission capability. However, a failure to effectively plan, execute or manage your network through its entire life cycle will result in performance degradation potentially threatening successful event detection. AFTAC’s Center of Engineering Excellence has developed a comprehensive approach to total life cycle management to optimize network performance while minimizing total ownership cost and risk. This holistic approach focuses on rigorous understanding of key performance parameters, robust system design principles and detailed support concepts that are required to ensure desired mission capability objectives are met. AFTAC Systems Engineers successfully implemented this technical management framework with tremendous results including increases in network data availability, quality and timeliness while achieving unprecedented levels of cost savings across the organization.
Poster Presentations

**T4.1-P1 Troubleshooting Indonesian CTBTO Stations**

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CTBTO auxiliary seismic station network in Indonesia has one data center and six auxiliary seismic stations. Each station has different categories requiring troubleshooting. At the NDC we have Power, Communication and Server problems requiring troubleshooting. Meanwhile at auxiliary seismic stations we may have Power, Communication and Seismic Sensor problems. Some of those problems are independent but others are coupled. With more and more data we can study faults, which allows us to better understand what happening at the NDC or auxiliary stations when data is not flowing. Nevertheless observations by station operators may be helpful if somehow all the supporting data is not available. This could enhanced by supporting data that we already have at NDC. After a study, effective tools and procedures could be developed and applied.

**T4.1-P2 Bulgarian NDC and Network – New Achievements and Challenges**

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The first big steps to bring Bulgarian seismology to digital age was made in the end of 2005 when first data transfer from each seismic station to Bulgarian data center was fact and the operation seismologist works directly with digital seismograms. All seismic stations were equipped with 3C broadband seismometers and digitizers DAS 130 of Reftek, brand of Trimble Inc. Automatic EQ processing is based on SNDM software package. As fast as possible location, magnitude and depth are performed within 8 minutes. Information for felt EQ as soon as possible is sent to authority, civil protection and public mas media. For seismic event of interest we provide information to IDC of CTBTO in Vienna Now the end of 2018 we started with a new step to integrate Seiscomp3 in seismic data processing in our NDC with modules - scanloc for detection clustering and association and sceval for Realtime event evaluation.

**T4.1-P33 Next Generation Power Systems of CTBTO’s International Monitoring System (IMS)**

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With the strong mandate to sustain high annual data availability throughout the network in face of harsh environmental, logistical, and meteorological challenges, it becomes imperative to design power systems with increased resiliency, added redundancy and trusted components, which passed the test of time. The design and deployment of the next-generation IMS power systems thus creates a window of opportunity to modernize station design, minimize catastrophic failures at the existing stations, and incorporate the latest technological advancements at new installations or station upgrades as part of the forthcoming IMS network recapitalization period. The next-generation IMS power systems are based on the open system architecture concept, utilizing ad-hoc selection and substitution of various power sources and power system components derived from the environmental demands and logistical restrictions present at the station location. These purpose-built, yet standardized power systems thus adapt to the site-specific input and output requirements, without requiring extensive redesign and cost when deployed at other stations throughout the IMS network. The high degree of standardization simplifies installation, maintenance and future upgrades as components can be freely interchanged throughout their life cycle without impacting the overall system.
Theme 4: Performance Optimization

T4.1-P5  Cybersecurity Analysis on Satellite Network Vulnerability

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Satellites play a significant role in communication, especially in situations where it is impossible to utilize conventional cellular networks. Satellites have been used in early warning systems, meteorology, navigation and, broadcasting, and surveillance. To this effect, satellites are a strategic asset for CTBTO and any cyber attack on them would have disastrous impact. The security of the satellite should be a pillar of the cybersecurity strategy for CTBTO since the transmission of data from the base stations to the IDC is through the satellite system. The wave of cyber threats has evolved rapidly in the last years in the pace of technological evaluation, therefore, mitigation factors need to be in place to protect the satellite systems from hackers. In this study, we explore the importance of security, satellite network architecture operation design and technologies, satellite network threats and security analysis, satellite network vulnerabilities, deployed security tools, limitations to be considered while deploying such security techniques and protocols for securing satellite communication, as well as statistics on recent attacks on satellite infrastructure. We then propose best practices for each of the above scenario.

T4.1-P6  Designing the Control System for Air Conditioning and Dehumidifier to Optimize the Performance of Gamma Spectrometer at RN42 Station

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The Radionuclide Monitoring Station RN42 is owned by CTBTO Preparatory Commission, Vienna, Austria (CTBTO) and managed by Malaysian Nuclear Agency. Radionuclide Monitoring Station RN42 Station is a place to detect radioactive particle in the atmosphere located in Cameron Highland Pahang, Malaysia which is 240km far away from Malaysian Nuclear Agency office. The station is operated continuously 24 hours everyday with minimum downtime. The mean annual temperature in Cameron Highlands is 18°C and means annual relative humidity is 87.0%. The target specification for operating temperature in RN42 station is below 22°C and relative humidity is 40% to ensure the gamma spectrometer inside the station can be operated at optimum condition and safely. The objective of this study is to design the control system for air conditioner and dehumidifier to ensure the gamma spectrometer inside RN42 station can be operated at optimum condition. This study is important to ensure the gamma spectrometer working at the best performance without major problem so that the station’s operator can operate the station smoothly and the data can transfer to International Data Centre (IDC) on time.

T4.1-P7  Fair Spectral Access in Cooperative Cognitive Radio Networks

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Cooperative Communication in Cognitive Radio Network (CRN) is emerging Communication prototype that provides enhanced capacity and improved reachability. Such cooperation can generally be achieved using Secondary Users (SUs) as intermediate relays in order to provide benefit to Primary Users (PUs) in exchange of sharing spectrum in either time domain or frequency domain. This arrangement is commonly referred as Overlay CRN. Furthermore, Cooperative communications can be employed to resolve fairness constraints by supplying optimal average transmission rate to the users or through other resource optimization techniques. Such schemes result in an increased transmission rate of PUs and an access of spectrum to SUs. Furthermore, for fair spectral access, it is necessary to adopt a scheme that maximizes the average rate of transmission of both PUs and SUs. Various schemes exist in the literature which have focused on resolving fairness issues in CRNs. However, in such schemes the PUs improved performance does not necessarily translate into a satisfactory performance for the SUs. Existing cooperative distribution algorithms such as Conventional Distribution Algorithms (CDA) and Pragmatic Distribution Algorithms (PDA) cannot improve the transmission rate of both PUs and SUs simultaneously and thus should be revised to address the fairness issues in the assignment algorithms.
T4.1-P8  **Free-Space-Optical Communication as Back Up in Case of Non Functioning of the GCI-III**

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For a modulated beam of visible, the Free-Space-Optical (FSO) communication is a method for a range of application. For this paper we will focus the Free-Space-Optical communication as back up in case of non functioning of the GCI-III. Taking into account the effects of extreme weather conditions of ten years from 2003 to 2012 we have determined the performance of a FSO system. The determination of the power received for a range of distance from 1 to 15km deepened the analysis and the discussion of the effects of weather conditions. The rain attenuation distribution was calculated taking into account geometric losses and indicating the availability of the system. In this paper we establish percentages of availability, the power margins and optimal link ranges of some FSO systems, for weather conditions in Dakar. We have made a FORTRAN program for this work. We used M graph software on LINUX to draw the graphs outlines. The results were performed by a lognormal distribution with good precision of the tests of correlations. The availability of optical link for weather conditions are established with high precision. We have highlight the advantage of free-Space-Optical communication as a back-up in the case of non-functioning GCI-III in the region of Dakar.

T4.1-P9  **Geodynamic Network of Seismic and Volcanic Monitoring OVSICORI-UNA: a Possibility of Data Integration with the Costa Rica National Data Center (NDC-CR)**

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OVSICORI-UNA is a University Research Institute dedicated to research of volcanoes, earthquakes and other tectonic processes, in order to find useful applications that help society to mitigate the adverse effects of these events to economic and social development. The purpose of the seismic network was to obtain information on the location of the generators of volcanic tremors and characterize sources. Our Data Center has been expanded with a contribution of CTBTO with a National Data Centre installed in September 2010, to acquire seismic data from stations in the region and the globe, which will be very useful to improve the precision of the location parameters provided by the OVSICORI -UNA to national and international scientific community. The country last 3 decades has faced significant seismic and volcanic events which thanks to a seismographic- volcanic as operating the OVSICORI-UNA network has allowed to go steadily monitoring, recording and orderly documenting each of these events, which allowed significant knowledge of the volcanic-seismic-tectonic conditions in the country forward and that in the past were unknown for lack of a good seismic and volcanic monitoring and seismic-volcanic data bank.

T4.1-P10  **Geography Information System Capabilities: GeoEvent Method to Improve Network Optimization of CTBTO Operation Data**

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Network optimization plays an important role as information technology is growing at exponential rates especially with CTBTO Operations and computer centre producing large volumes of data and thus consuming larger network bandwidths. However, if proper network optimization is not in place, the continuous growth can add strain to the network architecture of the concerned environment or organization. This paper, proposes Geography Information System (GIS) capabilities, a GeoEvent method as a tool to monitor traffic data, improve network performance and eliminate data redundancy of real time continuous data from end to end.
T4.1-P13  Implementation of a QA/QC Programme for Noble Gas Monitoring in the IMS Network

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There are currently 25 of 40 radionuclide stations with noble gas capabilities which are certified for operations in the IMS network. To gain confidence in results reported from these stations an annual QA/QC programme has been developed ensuring the quality of the radioxenon sampling, gas processing and measurement processes. Reference gas samples spiked with radioxenon isotopes are sent to the certified IMS noble gas stations. After measurement of the reference samples at the station they are sent to IMS radionuclide laboratories and re-analyzed. Results of the QA programme are presented. Furthermore, challenges with regard to a network wide QA/QC programme involving short-lived isotopes and remote station locations are also presented.

T4.1-P14  Implementing Process Oriented Knowledge Management: Lessons Learned from an Application in the OPCW

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The Chemical Weapons Convention (CWC) is an international disarmament treaty to achieve the vision of a world free of chemical weapons. The Convention prohibits the development, production, acquisition, stockpiling, retention, transfer or use of chemical weapons, and provides for the destruction of existing stockpiles. The Chemical Demilitarisation Branch (CDB) provides support to the States Parties by technically assess compliance with their obligations and by implementing a credible verification regime in relation with the chemical weapons and chemical weapons production facilities. CDB has initiated a pilot project to identify improvements on its activities based on the evaluation of its knowledge products. The methodology used is “Process Oriented Knowledge Management” where CDB processes are mapped and its knowledge intensive tasks and products are identified. The study presents the methodology and proposes initiatives to address knowledge gaps to improve processes efficiency.

T4.1-P15  IMS Station Management in Argentina

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The Nuclear Regulatory Authority (ARN) of Argentina has three stations of the International Monitoring System (IMS) already established and certified. Two new IMS stations: RN02 for radionuclide monitoring in Salta and IS01 for infrasound monitoring in Rio Negro will be built during the period 2019/2020 to complete the Argentine Network under ARN responsibility. An update of the existing IMS stations to latest technologies, RN01 Buenos Aires and IS02 Tierra del Fuego, is expected in the near future. The Argentine National Data Center (NDC) is under development. The aim of this presentation is to share ARN’s experience in IMS Station Management considering administrative and technical factors and also existing limitations related to: maintenance planning, response to an urgent repair need considering long distances between stations and ARN Headquarters, Local Operators capabilities and training, importation of equipment, bidding processes, quality assurance and good practices.
**T 4.1-P16  Infrasound Detection Capability Improvement on Noise Reduction System**

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Argentina is a Member State of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) and as such has stations that form part of the International Monitoring System (IMS) network, part of which consists of Infrasound Stations. As part of corrective maintenance measures, two agents/operators from the Nuclear Regulatory Authority (ARN) performed tests on the noise reduction system on one array of the IS02 Infrasound Station. A week of testing the array, implementing various resources, including apparently ridiculous ones such as checker game parts, bath-mat fragments and silver tape, concluded in identifying the leakages and amending them, including some improvised techniques that enhanced and improved the performance of the noise reduction system on the H5 array. This improvement was reached as a product of knowing and understanding how the station is set up and works.

**T 4.1-P17  Key Factors that Improved Data Availability at IMS RN Stations**

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This poster will describe key factors that led to improved Data Availability at IMS stations. Work was implemented to move away from corrective Maintenance to preventative Maintenance. Our focus was to improving station infrastructure; power, grounding, lightning protection and climate control. We strengthened Station Operator technical training's by targeting stations in need, improving training content and delivery. A targeted sparing program was implemented at the stations to provide critical spares when needed and to mitigate long lead times from shipping and procurement. Optimization of the overall sustainment was achieved by equipment standardization and improved documentation. Detectors are the key element of a Station, secure Shipping and handling procedures were implemented to reduce damage to sensitive instruments. For RN detectors we introduced vacuum evacuation to extend detector life in the field.

**T 4.1-P18  Maintenance Visit to Radionuclide Station FJ P26 and Auxiliary Seismic Station AS031/M SVF**

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The HPGe detector at FJP26 had vacuum and noise problems which lead to performance below operational requirements and unsustainable operation. An urgent trip to the station was conducted by PTS staff to restore detector vacuum and performance was restored. Other issues at the station were also resolved, authentication was enabled and the station operator was trained on equipment and configuration issues. The AS031/M SVF station is an IRIS/IDA configured seismic station. The SSI computer was down for a long period of time for an unknown reason and could not be restored remotely or by the station operator. The IRIS/IDA network was receiving data. A visit to the station was planned to troubleshoot this problem and replace the SSI computer. Troubleshooting showed problems with the power configuration after a battery change. Due to sufficient supply of on-site spares, correct availability of tools, cables, etc., the power system could be repaired and reconfigured on-site during a one-day visit to this station. The station was restored. The station operator was involved during the on-site visit and helped fixing the power problem.
**Theme 4: Performance Optimization**

**T4.1-P19  Major Upgrade at IS41 Villa Florida, Paraguay**

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After 15 years of operation, IMS infrasound station IS41 Villa Florida, Paraguay, had to face several technical issues due to equipment aging and infrastructure deterioration. In order to mitigate those problems major upgrade of the station took place in June 2018. At each remote element the power supply and lightning protection systems were improved. The wind-noise reducing system has been replaced, MB3 microbarometers and Guralp DM-24 were deployed. Reference pressure sensors were installed in parallel with the operational MB3 sensors, allowing continuous passive on-site calibration at each site. Net improvement was observed in the data quality, and continuous, authenticated data are received at the IDC. The upgrade allowed also much more reliable maintenance, remote monitoring and efficient troubleshooting of the station.

**T4.1-P20  New High Quality VBB Borehole Sensor Upgrades and Additional Atmospheric Sensors at Global Seismographic Network (GSN) Stations**

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In order to improve network reliability and data quality, the GSN has begun deploying newly available VBB borehole seismometers to replace the aging KSS4000 and some poorly performing STS-1 sensors over the last two years. Considerable effort has also been made to address problems with deteriorating infrastructure that suppressed data return and increased background noise. This includes adopting new borehole sensor installation techniques that maximize the performance of seismic instruments deployed at GSN sites. The new seismometers have improved self-noise characteristics and broader bandwidth than the generation of sensor they are replacing and meet the pass-band sensor specifications for IMS primary and auxiliary seismic stations. The GSN is also diversifying the instruments installed at the stations to broaden the variety of geophysical data collected. These instruments include meteorological stations and infrasound sensors intended to augment the infrasound network already deployed as part of the CTBTO’s International Monitoring System and the IRIS Transportable Array.

**T4.1-P23  Parallel Processing in the GDM S Analysis Pipeline**

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General Dynamics Mission Systems (GDMS) employs a single server to process and analyze a variety of incoming data files. The server’s ability to process these files in a timely and accurate manner is of critical importance. However, the server has been overwhelmed at times with the sheer number of files it receives, resulting in delays and skipped processing of files. It has also been plagued with reliability issues, and requires constant attention to remain operational. To address these shortcomings, GDMS is building a next generation system to process incoming files in a faster and more reliable manner. It uses multiple processing nodes to process multiple files simultaneously. Multiple redundancies are built-in to ensure reliability. “Smart” processing algorithms will result in faster processing of higher priority files. An alert system will notify staff of any issues; resulting in faster recovery times should an error occur.
The loss of power to station equipment is one of the major causes of station downtime, but it is a difficult issue to troubleshoot without data. To address this issue, General Dynamics Mission Systems investigated the use of commercially available products to monitor power quality and generator state-of-health. Two monitoring devices were procured, installed, and tested. The first is a generator monitor currently installed at IMS radionuclide monitoring station RN75. The device monitors the generator’s state-of-health and sends real-time alerts and data which allows GDMS to ensure the generator is mission capable at all times. The second is a power quality meter installed in the GDMS testbed. The device provides enhanced functions for monitoring power consumption and quality. This device quantifies the power quality using industry standard metrics, and can perform sub-cycle transient waveform capture in the event of voltage spikes or harmonics. GDMS can receive alerts remotely or view events of interest through the device’s web interface. These improvements seek to increase visibility into power quality trends and events which may affect station health and premature equipment failure.

Instrumental seismology is based mainly on the precision of the recording instruments and their operating states. It is important to know the response of the association digitizer-sensor to the ground excitation. For the purposes of the CGS, aftershocks recording seismic array, we suggest a simple method to evaluate the operation of the short seismic stations to each other. Ten seismometers have been installed inside a gallery of flow-through dam for a period of one week, the sensors are 50cm apart from each other. The dam offers the possibility of earthquakes recording in a short time and in an environment of low noise. The test shows that the stations have a similar response for the same excitation. The time is an important parameter for seismology without it the locations may take a significant error. In order to observe the behavior of the instrument internal clock, two stations was installed at the same place, the first station operated for one month without clock correction (GPS time), a second one is installed for a 24h duration. During this time, an earthquake was recorded allowing the drift rate evaluation of the internal clock, thus offer the possibility to correct the clock drift if necessary.

As part of its monitoring activities, the CGS Algeria includes a National strong motion accelerometers network and a National Broadband seismic network (five stations) located in northern part of the country. In the effort to install the Broadband stations a methodology was adopted, inspired from the international standard and adopted with local needs. As a first step administrative contacts was made with the local authorities in concerned Wilaya, then in sites visit and primary site selection, followed by geophysical field studies, then shelter building and final installation. Biskra, located south east of Algeria is the first studied site; we installed two broad band seismological stations for continuous recording during four weeks, enabled us to calculate daily Power spectral density (PSD) for each station and signal to noise ratio (SNR) using local and regional seismic event recorded by the stations. For under ground recognition at selected site we applied geophysical methods (seismic, electric, gravimetry and H/V technique). The results allowed us to establish an underground profile below the site planned for future station installation. The seismic shelter was built under four meters deep, divided in two levels and the external reinforced concrete walls are surrounded with a stone wall to improve thermal isolation.
Theme 4: Performance Optimization

T4.1-P31  The New Botswana Seismological Network (BSN): Developments in Detection of Seismic Events in Southern Africa and Beyond

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Launched during the period between 2000 and 2001, the Botswana Seismological Network (BSN) project involved the installation of seven accelerometric stations distributed across the seismically active Okavango delta region (ODR) in northwestern Botswana. The network was deployed for long-term monitoring of seismic activity in the ODR to improve our understanding of the causes of earthquakes and enable better assessment of seismic-related hazards and risks in the area. Due to operational challenges, those BSN stations were de-installed in 2016. Currently, the BSN system has been revitalized through the deployment of a set of 21 new broadband seismographic stations nationwide. The digital network was installed through a collaborative project between the Botswana Geoscience Institute (BGI) and the Netherlands based University of Twente (UT) and the Utrecht University (UU). At the end of the project in March 2018, ownership of the stations was transferred to the BGI to reconstitute the BSN. The new BSN is telemetered continuously to the BGI server via the Seiscomp3 acquisition system and integrated with IMS and other regional stations to enhance detection of regional and teleseismic events. Both data and bulletins are shared to the Incorporated Research Institutions for Seismology (IRIS) and the International Seismological Center (ISC) respectively.

T4.1-P32  Upgrading of PS11 and Establishment of IS12 as well as the National Data Centre of Bangui Project in Central African Republic

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After ratifying the Treaty on 26 May 2010, an agreement has been signed between the Preparatory Commission for the CTBTO and the Government of the Central African Republic on 31 December 2010, on the “Conduct of Activities, Including Post-certification Activities, Relating to International Monitoring System Facilities PS11 and IS12”. PS11 and IS12 are both part of 337 IMS facilities for the Comprehensive Nuclear-Test-Ban Treaty. PS11 is the existing station, which was operational under BGCA code for GTSN from 1994 to 2004. Unfortunately, it was destroyed during the trouble situations in Central African Republic and needed to be upgraded. However, the IS12 station is a new one to be established as well as the National data Centre of Bangui. The reliability of the raw data provided in the past by the previous BGCA/GTSN station contributed at the International Data Center to detect the world parameters of nuclear explosions, natural disasters, the understanding of earth influence. The control of the non-proliferation of mass destruction weapons: their disarmament as well as the protection of the environment. The optimization of above facilities will contribute to the implementation of monitoring network of CTBT verification regime for the control of the international security and peace.
**T4.2 Systems Engineering**

**Oral Presentations**

**T4.2-O1**  
* A New Approach to Supportability Analysis for the IMS, Based on the Cross-Industry Standard Process for Data Mining (CRISP-DM).  
  
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Sustaining a technically complex and globally distributed network such as the International Monitoring System (IMS) presents multiple challenges, particularly when combined with the high levels of data availability required. To this end, the IMS Analysis Team has already developed several components of an integrated support system, including various data gathering methods, supporting analysis and modeling capability, for decision making. Building on this earlier work and the lessons learned, the need for a standardized data mining approach to supportability analysis was recognized. The poster shows how the Cross-Industry Standard Process for Data Mining (CRISP-DM) framework as a best practice can be applied in IMS.

**T4.2-O2**  
* FaultNet: A Deep-Learning Framework for Data-Gap Analysis  
  
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Each year, National Data Centers (NDCs) experience thousands of data gaps, often requiring human intervention to restore timely data. Understanding the source of these gaps is critical for maintaining mission capabilities. To address this, we present a three-tiered framework for real-time automated data-gap analysis. First, we present an Internet of Things (IoT)-based equipment suite, providing low-overhead status-of-health (SOH) monitoring capabilities at every instrument. We next describe an open-source infrastructure monitoring tool capable of collecting and trending the SOH-streams in real-time. Finally, we present FaultNet, a deep neural network algorithm that analyzes the raw SOH streams and produces a probabilistic model for source-fault analysis. Deep Neural Network-based analysis is currently responsible for revolutionary advances in equipment maintainability, and the FaultNet framework has the potential to both reduce outage response-time for NDCs, and improve data availability at the IDC.

**T4.2-O3**  
* Geophysical Monitoring System (GMS) Development for IDC Re-Engineering  
  
  **J. M. Harris, K. Rivera, J. Burns, J. Coram, J. DuBois, L. Kidd, R. Prescott, C. Young**  
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Sandia National Laboratories is developing the Geophysical Monitoring System (GMS) for modernization of the United States National Data Center waveform processing system. Concurrently, the International Data Centre (IDC) has begun the development phase of their IDC Re-engineering project to improve capabilities and maintainability of their waveform processing system. GMS has substantial overlap with IDC system requirements, so the United States is providing the common architecture and processing components of GMS as a contribution-in-kind to accelerate progress on IDC Re-engineering. GMS is a substantial re-implementation of the waveform processing system using modern software languages and patterns. High level objectives include improving configurability and flexibility, capture of data provenance to provide insight into processing results, and extensibility to accommodate new processing and analysis components based on innovations emerging from the monitoring research community. GMS is being released as open source for use by the IDC and member states. The first release was made available in December 2018 for IDC review. The next release (2019) will
**Theme 4: Performance Optimization**

provide a generic runnable system including basic components for data acquisition, automated processing, and interactive analysis. This presentation describes GMS project goals and milestones, system architecture and design, and new user interfaces for waveform and event analysis.
**T4.3-P2  CTBTO Link to the ISC Database**

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The Link to the database of the International Seismological Centre (ISC) provides both PTS and National Data Centres a dedicated access to datasets maintained by ISC using specially designed graphical interfaces and database queries. This service gives access to several products: the ISC/ISS bulletins of natural seismicity of the Earth, mining induced events, nuclear and chemical explosions; the ISC-EHB bulletin and the IASPEI Reference Event list (GT) and ISC Event Bibliography. The database searches are tailored to the needs of the monitoring community and divided into four major categories: the Area based spatio-temporal search (based on ISC Bulletin), the REB based spatio-temporal search (based on specific REB events), the GT event based search and the IMS station based search (historical reporting patterns of stations close to IMS sites). We recently completed a major overhaul of the whole system, streamlined the database queries and user interfaces. The service has been extensively used by the NDCs and PTS and proved useful during a number of CTBTO Exercises.

**T4.3-P3  CTBTO’s Seismic Data Products**

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A good deal of seismic data is acquired, processed, analysed and stored by CTBTO’s IDC. A number of times CTBTO has issued tsunami early warnings based on its seismic data acquisition systems and sensors deployed across the world. The data products though available can be made more sophisticated in terms of providing pre-analysed GIS based products for disaster impact estimation more precise hazard analysis. Focal Mechanisms (Moment Tensors) and waveforms data can also be shared using an open portal platform for public access at least for major seismic activities. It will augment available products besides providing independent data set for correlation and comparative analyses including estimation of uncertainty. At present, USGS is the only organization producing focal mechanism for events larger than 5 Mw. However, moment tensors and waveform data of an independent source like CTBTO will help in advancing related science. Focal mechanism helps in studying shifting of thrust in active seismic regions and can lead to the most demanded analysis. This can subsequently lead to the formation of reports on regional seismicity helping in saving precious human lives and properties. This humanitarian cause falls in line with the moral cause of banning nuclear testing, both aiming at saving precious human lives.

**T4.3-P4  Development of Information Technologies at Kazakhstan National Data Centre (KNDC) in Support of the CTBTO**

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Kazakhstan National Data Centre (KNDC) is upgrading the automated system of data acquisition and analysis to extend its capabilities, and support the IMS stations and local stations operation to ensure their long term sustainability. The upgrade includes adoption of several contemporary systems and technologies, such as: open source ZABBIX monitoring system, and Proxmox Virtual Environment (Proxmox VE) virtualization system. ZABBIX is a monitoring solution for services of computer network, servers and network equipment. In KNDC, ZABBIX is providing the integrated control of the processes on data acquisition, and its volume from seismic and infrasound stations of Kazakhstan network, and from IMS stations, as well as control for physical state of...
Theme 4: Performance Optimization

equipment and power systems. A doption of Proxmox VE virtualization system allows to place on one hardware platform the tens of virtual, isolated container (servers and workstations). This reliable system allows decreasing the expenditures on creating and maintenance of the park of physical servers and workstations. This system already provides operation of several servers at KNDC, such as web-server, database server, and ZABBIX monitoring system server. Adoption of this new technologies will ensure the high level and quality of KNDC products and enhance the reliability and stability of information infrastructure operation.

T4.3-P5  Expanding National Data Centres to Provide High Performance Computing (HPC)

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Various countries are building National Data Centres (NDCs) to consolidate their Information and Communication Technology (ICT) activities and in the process reducing costs, improve efficiencies and security, and stimulate economic growth. The high costs associated with building resilient data centres that meet Tier III/IV standards pose a challenge in accommodating higher densities making it difficult for such environments to scale. These data centres become legacy environments as soon as they are built as they can only accommodate densities of up to about 3 – 5 kW per rack. The high volume of data that is generated every millisecond calls for dynamic data centres that will accommodate mixed densities up to 30kW without costly customization, and to improve competitiveness while performing High Performance Computing (HPC). The Royal Science and Technology Park (RSTP) in the Kingdom of Eswatini is upgrading their National Data Centre to a mixed density environment to accommodate HPC activities. This research will investigate how to upgrade the current NDC at RSTP and position it to participate in global HPC activities and further to be part of the CTBT ecosystem supporting various research activities.

T4.3-P6  Improved Method for the Testing and Verification of the Sierra Instruments 620S Mass Flow Meter

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Fluid flow represents one of the most significant process variables in an aerosol sampling system. The use of mass flow meters provides improved system control, easy maintenance, and reduced environmental influence. To ensure that flowmeters provide accurate data after initial certification and upon equipment replacement, a rigorous testing and validation process is critical. The system must include components of the manufacturer’s test procedures, system and station specific applications, and verification against a trusted reference. General Dynamics Mission Systems (GDMS) performed a study of both population deviation in meter measurements and the effects of operational conditions on meter output. The Sierra 620S population shows good flow relationship to the differential pressure meter used. Additionally, it was shown that meter alignment is very forgiving in relation to the output measurement. For long-term, consistent compliance, GDMS has developed a multi-faceted flow meter verification process using National Instrument’s LabVIEW architecture, Sierra Instruments verification methods, and in-house built tests and components. The results are stored within the GDMS logistics database in an easy to read format and directly associated with the device under test. This method allows subsequent testing repeatable with minimum error or deviation; and expandable to new systems and devices.
T4.3-P7  **Low Cost Transmission and State of Health for NDC’s**

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Transmitting live data from a seismic station has a cost. The Observatorio San Calixto (OSC) based in La Paz, Bolivia, developed a low cost (<50US$) solution for 3G live data transmission system, based on a Raspberry Pi, and a 3G dongle. A homemade State of Health (SoH) daughter board connected on top of the Raspberry Pi was designed to connect intrusion, battery voltage and temperature sensors. Minisedd data format is being used, based on IRIS tools. This system can thus be connected with most of off-the-shelf digitizers. Data is stored locally allowing for backfilling in case of network shortage, and transmission is done through VPN to secure the access. For the NDC, a web-based graphical interface was developed to monitor of the live-SoH of each station, with charts and records of the station history. Mail alerts are sent when a station is missing or a parameter is out of range. Though it cannot be used for alert system, as it depends on the mobile network, it is of good help as a complement of the existing CTBTO network for research topics, and it is easily movable. This system has been successfully deployed today on five stations on the Bolivian network.

T4.3-P9  **NDC in the Cloud: Example of Performing Seismic Processing in the Cloud**

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The capabilities of National Data Centers (NDC) vary greatly based upon national resources and infrastructure but the capacity-building vision is to have all NDCs capable of obtaining IDC data and performing calculations and analysis to come to the same result regardless of their infrastructure. Cloud computing resources may provide a path for performing these analyses using a scalable infrastructure located regionally allowing even the most resource-poor NDCs to fully participate in the CTBT and advise their National Authority concerning events. For another-poor, scientists at LANL utilized Amazon Web Services (AWS) to download a year’s worth of U.S. transportable array seismic data (1690 arrays) from IRIS and processed the data in the cloud. The results of the data analysis and the sorted data were downloaded to a local PC. This can be viewed as a case study for what can be done in remote or smaller NDCs. The cloud services were utilized for a short time and the calculation power was right-sized to the computing power and cost.

T4.3-P10  **Quantifying the State of Health of a Detection System Remotely with LabPulse**

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A real-time monitoring system for state of health (SoH) information can be an important part of maintaining radiological instrumentation in a laboratory, in the field and in remote locations. This session will discuss the concept of Lab-Pulse which is a live SoH monitoring system for radiological instrumentation to ensure system performance, increase up-time, improve timing of instrument maintenance, watch for faults, reduce time to solve problems, and improve overall system reliability. There are many components of a radiological measurement system including detectors, electronics, software, communications, periodic quality checks, and data storage. All of these play a vital role in having a functional and accurate system. Lab-Pulse monitors SoH data from sensors within these devices and sensors of the surrounding environment that could influence instrument performance. Tracking of SoH data can help ensure all components are functioning within specifications. We will discuss the tools used for a modern SoH monitoring system, and how this data can later be used for advanced analytics to find irregularities, predict potential failures before they occur, schedule maintenance, and improve the design of future instruments. We will also share our vision and what we have learned so far from our system on the instruments we monitor.
**Temporary Installation of Seismo Wave MB3d with Raspberry Pi at Nanyang Technological University**

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To assess the feasibility of the installation of an infrasound array on the campus of Nanyang Technological University (NTU) a temporary deployment of the Seismo Wave MB3d microbarometers is being designed and carried out. This system uses Raspberry Pi 3 B (RPi) microcomputers for data collection, archiving, and data streaming via Wi-Fi and Ethernet. The use of RPi allows for a real-time stream from deployed sensors into the main infrasound data processing systems at NTU and allows for comparison between the NTU sites and the established infrasound site at MacRitchie Reservoir. In order to achieve real-time data transmission, the RPi is configured to access the MB3d USB connection using Ser2net and Earthworm software. This current configuration has provided a solution for temporary deployments, but there are limitations that impact its use for further deployments including high power consumption and reliability relative to other stations. For a practical and inexpensive solution for easily accessible sites, the RPi has worked well, but these few technical issues keep it from being an ideal solution for a permanent installation. Further work is being done to determine if a similar solution can be designed to work with the serial connection for the MB3ds.
T4.4 Performance of the Full Verification System

Oral Presentations

T4.4-O1 3rd ATM Challenge 2019

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Two ATM challenges were successfully performed in 2015 and 2016. However, they did not address the more practical aspect of estimating radioxenon background at selected IMS stations. This estimation is needed for calibration and performance assessment of the verification system as described in the Treaty. Estimating the radioxenon background is the main goal of the 3rd ATM Challenge. In the frame of multi-model ensemble modelling a training approach will be used to define the optimal set of ensemble members, specific to each station. Xe-133 stack emission data for the time period June - November 2014 from the IRE (Belgium) and CRL (Canada) radiopharmaceutical plants will be used as well as estimates for nuclear power plants and research reactors. The annual emissions from the Mallinckrodt facility (The Netherlands), the NIIAR facility (Russia) and the Karpov Institute (Russia) will also be considered to refine predictions. The ultimate goal of the atmospheric transport modelling exercise is to provide an ensemble analysis of radioxenon background levels at IMS stations frequently impacted by industrial emissions. The presentation will deal with the design and development of the exercise scenario. First results will be shown if already available.

T4.4-O2 International Monitoring System's Detection and Screening Capability in Australia

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The completeness and accuracy of the CTBT Reviewed Event Bulletin (REB) is assessed in the Australian region through comparison with a local bulletin. We compare the REB to Australia's National Earthquake Alerts Centre (NEAC) bulletin for all events in Australia between May 23rd and December 31st 2018. Australia is an intra-plate tectonic environment and as such experiences around 100 magnitude 3 earthquakes every year. The continent is also home to a multitude of mining facilities and NEAC’s seismologists locate mining blast events daily and, where possible, confirm these events with local mines. The bulletins are compared to quantitatively show the IMS performance in a setting with sparse station coverage; the benefits of using 3D travel times in Australia and how well the REB events are screened. In addition the contribution of the NET-VISA bulletin to the REB is examined. Both feedback and suggestions are provided, not only on the performance improvement but also on the NET-VISA’s prior probability distribution functions.

T4.4-O3 Near Real-Time Monitoring of the IMS Event Detection Capability

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The primary seismic network of the International Monitoring System (IMS) forms the backbone of the CTBT verification regime. The average event detection capability of the primary seismic network is estimated to be within the range mb 3.1 to 3.4 for the northern hemisphere, and between mb 3.4 and 3.7 for the southern hemisphere. However, it is understood that the detection threshold can vary significantly with time during
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situations such as high station noise levels, large earthquakes or outages of key stations. The continuous threshold monitoring method was developed to address the temporal and spatial variability in network detection capability, and an operational implementation has been running at the International Data Center for several years. The current system provides hourly averaged estimates of the three-station detection capability, as well as the point-wise maxima (worst-case) for each hour. Recent advances in computer technology has allowed for increased temporal and spatial resolution in the calculations, as well as new graphical presentation options of capability estimates. Additionally, the steadily increasing IDC event database is used to obtain higher accuracy and improved uncertainty estimates. We will in this presentation demonstrate new approaches and applications of the threshold monitoring method for continuous assessment of IMS performance.

Poster Presentations

T4.4-P1  A Framework for Performance Optimization

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The verification systems described in arms control treaties are the products of negotiations that involve compromises. As a result, the end product may not be optimal. Nevertheless, the associated technical organizations are expected to provide assurances that information generated through monitoring will be sufficient to detect non-compliance. To evaluate the performance of a verification system, one needs to take into account not only the associated technologies and methodologies, but also the constraints imposed by each treaty. These limit the types and number of measurements that can be performed as well as the outcomes of the analyses of the monitoring data. This paper presents a framework for optimizing the performance of treaty verification systems. It is based on the observation that arms control treaties that incorporate monitoring, verification and enforcement of compliance are in effect feedback control systems. Consequently, the approaches and techniques used in evaluating such systems are also applicable to the treaty verification systems. Using the CTBT as an example of a feedback control system, the paper will emphasize the measurement, analysis and evaluation components for the purpose of identifying potential improvements and inherent limitations in their performance within the constraints imposed by the treaty.

T4.4-P2  An Assessment of XSEL Bulletin as Produced Through the Cross Correlation Technique

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An assessment of the Cross Correlation bulletin (XSEL) was performed for two data days in October 2018. 208 and 449 events were used for REB and XSEL bulletins, respectively. The objectives were: 1) investigate XSEL new events; and 2) assess the quality of XSEL. For the first objective, waveform data for the 244 XSEL new events were investigated. Of these 10 (4.1%) were found to build legitimate events. For the second objective REB and XSEL bulletins were compared. Matched and unmatched events were identified based on the number of common defining phases (≥ 2) and the arrival time differences between common phases (≤ 6 sec). Events not meeting these conditions are considered as unmatched events. The number of matched, unmatched REB and unmatched XSEL were 125, 83 and 324 events, respectively. About 61% of the matched events have location difference < 1 deg. Arrival time differences between common phases showed that in most cases they were picked earlier in XSEL than in REB. The results indicate that the Cross Correlation technique needs additional criteria to reduce the number of bogus and new seed events; and create proper arrival time picks to produce a bulletin that can be comparable to the REB.
T4.4-P3  **Build Up Exercises to Validate OSI Capability Development**

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On-Site Inspection (OSI) capabilities comprising inspection methodology, equipment and techniques development, training of surrogate inspectors and infrastructure, have been considerably developed within the framework of the comprehensive OSI Action Plan 2016-2019 approved by State Signatories. The application of various techniques including data analyses and integration is at the heart of an OSI. Field exercises, conducted on a regular basis, are a true testing ground for the application of OSI technologies close to real-life conditions. In 2016, the Preparatory Commission approved an ambitious OSI Exercise Plan including the conduct of three Build-up Exercises (BUE) covering all inspection phases, aimed at validating key deliverables of the Action Plan projects. Two field BUEs will be held in Slovakia in 2020, with – for the first time – aspects of all 17 inspection techniques permitted under the Treaty being exercised. Preparation and conduct of such a major undertaking requires both close coordination with the host country and support from States Signatories. Surrogate inspectors will participate as Inspection Team or Inspected State Party members. The poster provides an overview of the objectives and scope of the BUEs, information on preparations for this PTS-wide endeavour and elaborates on inspection activities and techniques that shall be tested.

T4.4-P4  **Data Availability and Quality at IMS Stations and Local Networks**

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Experience gained through capacity building activities of the CTBTO in the use of IMS data and IDC products has greatly influenced many developing countries to introduce policy measures to support and invest in the verification regime of the CTBTO through science, technology and innovation. The participation of more states parties through workshops, training’s, on line modules etc. has greatly strengthened the deployment of the CTBTO verification technologies and similar technologies for civil and scientific gains. Kenya hosts two IMS stations as part of the verification regime of the CTBTO. Besides that the government has also invested in similar technologies throughout the country to capture smaller events which are not necessarily recorded by the global networks. This has helped to integrate treaty monitoring functions into the national operations and procedures to enhance performance. The aim of this study therefore is to highlight the measure put in place to enhance and optimize the performance of IMS stations and the local networks and its impact on the performance of the NDC, and the social and economic livelihood of the local communities nearby through participation.

T4.4-P5  **Effective Management of OSI Equipment and Software**

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The On-Site Inspection Division has long-operated an off-the-shelf asset management system to record and track items. While such systems have their place, the need for cross platform integration and Treaty specific considerations has led to the development of a bespoke system for managing OSI equipment and software that is fully integrated with other OSI data management systems. The system is in line with the standard operating procedure on equipment certification, which includes equipment authentication, calibration, testing and certification for OSI deployment. RFID tags are employed to record and track items as they move around the Equipment, Maintenance and Storage Facility in Seibersdorf and also out of the facility for maintenance, training, testing and exercise purposes. The system incorporates the concept of alternative configurations to meet a particular OSI capability e.g., the airborne multi-spectral system is comprised of up to five sensor systems that can be installed on different airframes i.e., several different possible configurations of the same sensors. The system hierarchically identifies current status and logs all activities performed on an individual item or system and provides a ticketing interface for preventative and reactive maintenance. It is a browser-based system and is fully deployable for OSI activities.
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T4.4-P6  **High-Density Configuration Experiment of Noble Gas Measurement Systems in Japan**

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In early 2018, two mobile noble gas measurement systems were deployed and have started measurement at Horonobe and Mutsu in Japan. Together with a third mobile system that will be deployed at Fukuoka, Japan, in spring 2019, and the operating IMS noble gas system at station RN38, Takasaki, Japan, this creates a high-density configuration of noble gas measurement systems. The objective of this configuration is to generate a database of detections which will be used to develop and test methods for better understanding the contributions of known sources from across Eurasia. Contributions from these sources are frequently observed at IMS station RN38. The high density configuration will provide a framework to test and optimize source location algorithms and to better understand Level C episodes, specifically at JPX38. The three mobile noble gas measurement systems used in this experiment and their operation are externally funded. The planned duration of this experiment is two years.

T4.4-P7  **National Data Centre Preparedness Exercise 2017 - Exploring Real IMS Data for Casual Connections**

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The objective of NPE 2017 was to enhance the use of real IMS data an IDC products and services in the everyday-work of NDCs. Starting point of three proposed independent NPE 2017 tasks were selected real radionuclide detections. The tasks of NPE 2017 did not necessarily require the identification of the real source of radionuclide emissions which were generating the detections. The idea of this exercise was to deal with the hypothetical bridging between radionuclide detections and waveform events. Task A was on Level C detections of the gamma-spectroscopic noble gas system of RN29 with events in the source region generating hydroacoustic arrivals at IMS stations. Task B was a series of beta-gamma coincidence measured radionuclide detections at RN04 and RN46 in November 2017. The question related to source localization by backward atmospheric transport modelling and source characterization by means of isotopic ratio analysis. Task C dealt with a Level 5 particulate detection at RN63 which had just by chance in its field of regard a series of powerful explosions of an ammunition depot with many seismo-acoustic recordings in. Thus the NPE 2017 tasks covered all IMS technologies and could be used by participants as suggestions for detailed review.

T4.4-P8  **Quality Assessment of REB Through Comparison with NEIC Bulletin for the Month of September 2018**

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The quality of the IDC REB was assessed by comparing it with an international bulletin viz., NEIC. To accomplish the task, NEIC (NEIC located events) and IDC REB events for the month of September 2018 were utilized. During this period, 2268 and 2976 events were considered for NEIC and IDC, respectively. The comparison was performed using the BULCMP software to identify matched and unmatched events of the two bulletins. The results showed that a total of 1444 events could be matched between the two bulletins. The percentage of matched events with location difference (D) < 1° is about 97.0% while the percentage of events with D ≥ 5° is about 0.1%. The percentage of matched events without intersecting error ellipses is 18.2%. There were 18 events with magnitude (M) ≥ 4.0 and D ≥ 3°. Of these events, waveform investigation showed that the locations of 11 events were closer to the NEIC solutions. 13 unmatched NEIC events with M ≥ 4.0 were found during the comparison. Waveform investigation for these events revealed that 1 REB and 4 LEB only events
were legitimate LEB/REB events. The results showed that available data should be utilized not to miss and mislocate events.

T 4.4-P9  **Quantifying Uncertainties and Confidence Level in ATM Simulations**

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The main task of the CTBTO Preparatory Commission, Vienna, Austria is to establish a global verification regime to monitor compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT). The Commission has developed an atmospheric transport modelling (ATM) pipeline in order to produce source-receptor-sensitivity (SRS) fields to indicate possible source regions for potential releases of radionuclides (RN) related to hypothetical or actual detections at RN stations. CTBTO mainly uses ATM guidance in backward mode to link a measurement from an IMS station to a possible source location. However, ATM is also used in forward mode to predict detections related to a potential radioactive release. Different ATM systems will generally produce different solutions because a) the input meteorological fields are different, b) the transport and dispersion models are different or configured differently, and c) the source term is specified differently. CTBTO in collaboration with Zentralanstalt fuer Meteorologie und Geodynamik (ZAMG), under funding from European Union Council Decisions VII, has initiated a project to study the impact of different meteorological input coming from an EPS to better estimate the source location and to quantify the level of confidence. This presentation will describe the project and present initial results.

T 4.4-P10  **Quantifying Uncertainties in the Atmospheric Modelling (ATM) Simulations Resulting from Different Emission Time Resolution**

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The International Monitoring System (IMS) developed by the CTBTO Preparatory Commission, Vienna, Austria (CTBTO) is a global system of monitoring stations, using four complementary technologies: seismic, hydroacoustic, infrasound and radionuclide. The radionuclide network comprises 80 stations, of which more than 60 are certified. These radionuclide stations provide global monitoring of radioactive aerosols and radioactive noble gases supported by atmospheric transport modelling (ATM) to allow detected radioactivity to be attributed to a source. Recent studies suggest that the ATM performance using different emission time resolutions is not significantly different. The availability of emission data for IRE (Belgium) and ANSTO (Australia) for the full year of 2014 gave an opportunity to verify the aforementioned statement for different atmospheric conditions. For the purpose of this study, the simulated activity concentrations of Xe-133, calculated using four different emission time resolutions (daily, half-daily, 3 hours and 1 hour), were compared with the available measurements collected by the IMS noble gas stations influenced by these facilities.

T 4.4-P11  **Successes in Improving Data Availability to RN Station with Long Term Issues**

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Some RN stations and for years suffered from long term problems that affected their data availability. These problems were temporarily fixed and were reappearing after a certain time. The strategy of dealing with these long term issue was to identify the root cause and try to tackle. The poster present various stations where a good
Theme 4: Performance Optimization

diagnostic of the root cause and proper and prompt measures were taken leading to a successful restoration of the data availability. The examples presented are KWP40 in Kuwait City, Kuwait. KIP39 in Kiribati, MXP44 in Guerrero Negro, Mexico, PTP53 in Ponta Delgada, Portugal and TZP64 in Dar es Salaam, Tanzania.

T4.1-P1 Troubleshooting Indonesian CTBTO Stations

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With the strong mandate to sustain high annual data availability throughout the network in face of harsh environmental demands and logistical restrictions present at the station location. These purpose-built, yet standardized power systems thus adapt to the site-specific input and output requirements, without requiring extensive redesign and cost when deployed at other stations throughout the IMS network. The high degree of standardization simplifies installation, maintenance and future upgrades as components can be freely interchanged throughout their life cycle without impacting the overall system.

The COPC is a contemporary version of the International Data Centre (IDC) Operations Centre. The new facility provides a centralized focus for monitoring and oversight of all PTS Operations and Maintenance (O&M) activities. The COPC ensures that: IT infrastructure is functional; IMS (authenticated) raw data reaches the IDC within Data Availability Specifications; continuous automatic data processing; data and products are distributed in timely fashion; necessary corrective actions are taken to maintain data quality and efficient cost-effective network operations. It provides timely reporting on the overall performance and operational status of the IMS verification system and provides a location for the core ad hoc OSI-OSC.

T4.1-P2 Bulgarian NDC and Network – New Achievements and Challenges

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The Operations Centre (COPC) of the Provisional Technical Secretariat (PTS) of the Preparatory Commission, Vienna, Austria (CTBTO) is a facility where the International Monitoring System is supervised by staff and is a potential deployment location for an ad hoc On-Site Inspection Operations Support Centre (OSI-OSC). The COPC is a contemporary version of the International Data Centre (IDC) Operations Centre. The new facility provides an integrated environment for supporting the technical teams of the PTS and a workbench for development of sustainable operations while in preparation for Entry into Force of the Treaty. The COPC provides a centralized focus for monitoring and oversight of all PTS Operations and Maintenance (O&M) activities. The COPC ensures that: IT infrastructure is functional; IMS (authenticated) raw data reaches the IDC within Data Availability Specifications; continuous automatic data processing; data and products are distributed in timely fashion; necessary corrective actions are taken to maintain data quality and efficient cost-effective network operations. It provides timely reporting on the overall performance and operational status of the IMS verification system and provides a location for the core ad hoc OSI-OSC.

T4.1-P33 Next Generation Power Systems of CTBTO’s International Monitoring System

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CTBTO auxiliary seismic station network in Indonesia has one data center and six auxiliary seismic stations. Each station has different categories requiring troubleshooting. At the NDC we have Power, Communication and Server problems requiring troubleshooting. Meanwhile at auxiliary seismic stations we may have Power, Environmental, Logistical and Meteorological issues. With more and more data we can study faults, which allows us to better understand what is happening at the NDC. Diagnostic of the root cause and proper and prompt measures were taken leading to a successful restoration of the data availability. The examples presented are KWP40 in Kuwait City, Kuwait. KIP39 in Kiribati, MXP44 in Guerrero Negro, Mexico, PTP53 in Ponta Delgada, Portugal and TZP64 in Dar es Salaam, Tanzania.
T1.1-O3 Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound Propagation and Scattering in the Atmosphere

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The experimental results of studying the effect of a fine-scale layered structure of a stably stratified atmospheric boundary layer (ABL) on fluctuations of the parameters of acoustic pulses generated with a certain period (1 min) by an artificial detonation source are presented. The vertical profiles of wind velocity fluctuations in the thin layers of the ABL have been retrieved using the wave forms and travel times of the recorded arrivals of pulses from the source. It is shown that the mechanism of scattering of pulse signals in a stably stratified ABL is similar to the mechanism of scattering of signals from ground surface explosions by layered nonhomogeneities of wind velocity and temperature in the stratosphere and lower thermosphere. The role of similarity parameter here place the dimensionless thickness of the reflecting nonhomogeneous layers, which is the vertical scale of the layer multiplied by the relative difference in effective sound velocity and normalized by the vertical wavelength. The effect of such inhomogeneities on the temporal fluctuations of the azimuth and arrival times of the signals is studied. The estimation of the error in localization of pulsed sources is given.

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T1.1-O4 Climate Change Through the Eyes of Radioisotopes

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Cosmogenic radionuclides beryllium-7 and sodium-22 are known atmospheric tracers and can be used together in a lock-in technique to effectively trace vertical air masses based on surface measurements. This technique allows to study progression and speed of atmospheric cells. Data show that the cells are decelerating during the summer period which is extending in time. This is caused by warming of the whole troposphere and increased tropopause height due to rising CO2 concentrations. Aestival episodes of persistent high-pressure systems over Europe with low pressure gradients that led to almost stationary thunderstorms are correlated with the observed deceleration of atmospheric cell movement. This demonstrates that 7Be and 22Na can be used as indicators for confirming several side effects of climate change while providing a new modelling tool in seasonal weather forecast.

T1.1-O5 Detection Efficiency of the IMS for Bolides

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In this study we examined 344 bolides (airbursts) reported on the JPL CNEOS website (https://cneos.jpl.nasa.gov/fireballs/) between 2007-2018 and attempt to correlate these with infrasound detections. We found 206 of these bolides were detectable by at least one infrasound station while only 42 were automatically registered as part of the Reviewed Event Bulletin (REB) issued daily by CTBTO. However, this global REB detection rate of ~10% averaged from 2007-2018 is less than the "modern" rate (from 2014-2018) which approaches 20%. Above the 1 kT CTBTO design threshold, we find that 40% of airbursts are reported in the REB, while more than 90% are detectable at one or more infrasound stations. All airbursts with energy > 2 kT reported on the JPL fireball site since 2007 have been detected infrasonically. However, the REB is only complete above 15 kT with the automated detection system not having reported at least four airbursts with...
T5.1 Science in Policy Discussions and Lessons Learned from Other Arms Control Agreements and Arrangements

Oral Presentations

T5.1-O1 Chemistry and Diplomacy: The Provision of Scientific Advice for Disarmament and Non-Proliferation Treaty Organisations

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Decision makers serving in policymaking organs of international arms control, disarmament and non-proliferation instruments often consider and review information with significant scientific underpinning. This includes approval of lists of new inspection equipment; approving the addition of scientific content for validated databases; budgeting and/or resource allocation for relevant scientific research; and/or reviewing analytical results from inspections or investigations of non-compliance. Engagement with scientific communities helps to ensure that an organisation remains abreast of developments in science and technology, and can continue to develop capabilities that enhance operational effectiveness. At the technical level this interaction proceeds through running experiments, analyzing data and speaking in scientific jargon - yet the same key technical information must also be conveyed to decision makers, many of whom have no formal scientific training, but require adequate levels of scientific literacy to carry out their duties. The connection of science to policy is commonly facilitated through a scientific advisory mechanism which sits at an interface between science and international diplomacy. Taking the Chemical Weapons Convention as an example, we will discuss challenges, successes and lessons learned from the provision of scientific advice to disarmament treaty policymakers facing a variety of routine and non-routine issues in treaty implementation.

T5.1-O2 Comparative Assessment of CTBT with International Arms Control and Disarmament Treaties: Strengths and Limitations of Science in Enforcement and Addressing Security Driven Actions

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In a world transiting through a changing global order with ongoing geopolitical realignments and reasserting behavior of certain states, nuclear weapons and delivery system appear to be becoming relevant currency of national and cooperative power by certain states. Citing this influx in security environments, where some states in past undertook demonstration of nuclear capability, while some have threatened to modernize its forces, certain states indicated reserving the prerogative to test further systems. The central significance of security environment and centrality of threat perceptions to develop and test nuclear capabilities, there remains a need to critically analyze the emphasis on science-driven approaches in strengthening efficacy of non-proliferation treaties such as CTBT. This paper also takes a comparative analysis of other treaties, and in understanding the role of scientific and non-scientific factors that rendered those treaties effective. It also takes a look at non-scientific elements that rendered other international non-proliferation, disarmament and arms control treaties effective vis-a-vis others. This paper analyzes strengths of science-driven mechanisms, role of security environment-driven factors that challenge non-proliferation and disarmament treaties along with "taboo" of certain weapon systems which have rendered their use unacceptable. It also examines factors that strengthened and made durable non-proliferation treaties.
**T5.1-O3  North Korea and the CTBT**

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Conventional wisdom has long held that North Korea would quite likely be the most difficult case among the eight remaining states that must ratify the CTBT for it to enter into force. The recent personal involvement of the Presidents of the U.S., South Korea and North Korea may make this achievement less distant than previously believed. In view of North Korea’s stated willingness to give up its nuclear weapons, it would not be logical for it to refuse to join the CTBT and insist on preserving a right to test such weapons. At least signing the CTBT would be a logical and effective early step for North Korea, in what looks to be a long and difficult process to a broader political settlement. This could be accompanied by North Korea’s support for, and participation in, the activities of the CTBTO, including verification. Lessons from the negotiation of earlier arms control agreements, as well as from the cessation of the former Soviet Union’s nuclear testing program, can help guide the orderly and verifiable transition of North Korea to a Non-Nuclear Weapon State and party to the CTBT.

**Poster Presentations**

**T5.1-P3  CTBT Entry into Force: Breaking the Stalemate**  
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Despite differences on nuclear weapons as being the cause of unending arms race or linchpin of deterrence, there has been general consensus on the need for nuclear disarmament. Putting a ban on nuclear tests remains one of the oldest yet hardest fought items on disarmament agenda. Given their perceived security interests and diverging nuclear ambitions, the abstaining states continue to point fingers at each other for not being politically sincere towards Treaty’s entry into force. This stalemate has not only halted any progress on the Treaty but also undermines the prospects of global disarmament that are already marred by differences on mutually agreeable mechanism to pursue it. This scenario calls for exploring innovative ideas on how to convince abstaining states to get into legally-binding mechanism. Drawing inference from the idea of Nuclear Weapons Free Zones, a region oriented approach may prove useful in finding solution to the global problem. Through verifiable legally binding bilateral, or even multilateral, agreements on non-testing of nuclear weapons, the goal of CTBT may be pursued gradually. Given that some states, like Pakistan, have expressed willingness to enter into legally binding bilateral agreement with India, the prospects of this graduated regional approach appear bright.

**T5.1-P4  Leveraging the CTBT’s Verification Provisions for Promoting Entry-Into-Force**  
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The CTBT’s verification provisions- especially the IMS -are unparalleled in arms control agreements. Yet, verification concerns were key in the 1999 US Senate rejection of the CTBT. More generally, the role of effective verification has not been not been sufficiently acknowledged recently. The Treaty on the Prohibition of Nuclear Weapons, for example, reduces verification to Comprehensive Safeguards Agreements, thus taking a step back from the more rigorous Additional Protocol. Similarly, the demise of the Intermediate-Range Nuclear Forces Treaty underlines the importance of verification of treaties, with ‘disarmament verification’ having become a buzzword in the framework of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). We argue that the CTBT’s contribution to arms control verification should be leveraged not only for strengthening the NPT in trying to work out what verification would look like in a nuclear disarmament context, but also for achieving entry-into-force of the CTBT itself. The nuclear tests conducted by the Democratic People's Republic
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of Korea (DPRK) demonstrate that the IMS works and that the CTBT is verifiable. Now is the time to highlight the CTBT’s unparalleled verification contribution to arms control, its expertise to verify the closure of the DPRK’s test site, and to persuade the United States and China that they could strengthen a weakened NPT by showcasing their fidelity to NPT Article 6 through CTBT ratification.

T5.1-P5  On-Site Inspection: A Multidimensional Example of Science Diplomacy

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As the concept of science diplomacy has evolved and is becoming consolidated in the wider epistemic community, a taxonomy of this concept has been developed. This taxonomy for science diplomacy consists of three dimensions: 1. diplomacy for science; 2. science in diplomacy; and 3. science for diplomacy. This concept has also more recently come into the purview and parlance of the political and multilateral diplomatic community including International Organizations such as the CTBTO. Despite the broad use of the science diplomacy concept as an overarching theme and approach, a gap exists in effectively translating and providing more practical examples of the various dimensions of science diplomacy. Our presentation will apply and operationalize these three dimensions of science diplomacy to a key specific element—On-site Inspection (OSI)—of the verification regime of the CTBT. By applying and fleshing out these dimensions of the four phases of an OSI, the aim is to provide a more tangible and practical overview of the interactions and interface between science and diplomacy that are required in this one specific element of the CTBTO’s verification mandate.

T5.1-P6  Strengthening the NPT Through CTBT Entry-Into-Force: Is There a Link Between the Comprehensive Test-Ban Treaty and the Non-Proliferation Treaty?

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A half-century has passed since the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) embedded into international law a normative and legal barrier prohibiting the horizontal proliferation of nuclear armaments. Once praised by President Lyndon B. Johnson ‘as the most important international agreement since the beginning of the nuclear age’, the NPT has come under intense pressure in recent years, due to a mosaic of endogenous and exogenous dynamics. Despite a plethora of propositions for strengthening the NPT the international community and the academy have paid little attention to the Comprehensive Nuclear-Test-Ban Treaty (CTBT) as a viable NPT stabilizer. This is puzzling for two reasons. First, the prospect of the CTBT appeared to play a major role in effecting the unconditional and indefinite extension of the NPT at the 1995 Review and Extension Conference. Second, support for the CTBT is stronger than ever, with 184 signatures and 167 ratifications. This thus begs the following these research questions: is there a link between the CTBT and the NPT? Why is the CTBT often at the fringes of arms control discussions, despite its near-universality? Therefore, this paper focuses on finding answers to the above questions.

T5.1-P7  Testing Customs: The CTBT and Customary International Law

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Treaties like the Comprehensive Test Ban Treaty (CTBT) create binding obligations on States once they enter into force: for example, the obligation not to engage in nuclear weapons testing. But under international law, customs can also create binding obligations. Although the CTBT has yet to enter into force, does it nevertheless strengthen the formation of a customary law prohibition on nuclear testing? What are possible risks and impacts
on customary law if entry into force is not achieved? And what is the role of the scientific community in shaping customs? This presentation assesses the required elements of customary international law—state practice and opinio juris—based on research into standards employed by the International Court of Justice, expert interviews, and comparisons to the role of custom in the Chemical Weapons Convention and the Biological Weapons Convention. Also considered are the role of women and youth in making international law, as the CTBTO’s inclusion of these groups paves the path for a more equitable understanding of who determines legal customs. Through this analysis, the presentation seeks to answer pressing questions relating to the position of the CTBT within the international legal landscape.

T5.1-P8  The Development of Arms Control Agreements and Arrangements

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Despite the fact that arms control agreements and arrangements cannot come into action without a holistic approach, there has been no study completed that used a rigorous metadata analysis and synthesized related studies to review the overall scene on the topic. This paper aims to apply a science-based profile and assessment to analyze the trend of arms control agreements and arrangements research within the broader context as they relate to the CTBT and nuclear explosion monitoring. By investigating 2,500+ arms control related research publications and citation data from the year 1956 to 2019, this study explores who is doing what in the field, when, where and with what implications. The analysis includes comparisons of countries, organizations, authors, and fields of study, and investigates their individual work and collaborations on arms control agreements and arrangements. In addition, for a ‘whole-of-government’ approach, this research brings in publications of multiple sectors, including academia, government, commercial, and nonprofit actors as a way of collaborative approaches to arms control efforts.
T5.2 Experience with and Possible Additional Contributions to Issues of Global Concern such as Disaster Risk Mitigation, Climate Change Studies and Sustainable Development Goals

Oral Presentations

T5.2-O1 CTBTO for UN 2030: Empowering Diplomacy Through Science in South Asia

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This project proposal will consider the instrumentalisation of diplomacy through scientific investigation to strengthen support for the Comprehensive Nuclear-Test-Ban Treaty (CTBT) and its verification regime. It will look at CTBT ratification through a step-by-step, non-traditional security approach by showcasing the International Monitoring System’s (IMS) civilian potential and its benefits to a country’s security objectives, whether it is tsunami warnings off India’s southern coast or landslides in the Himalayas. It will involve a demonstration of how states that have pledged to the UN 2030 Agenda on Sustainable Development can be incentivised to translate intent into action by utilising information from the IMS’ radionuclide, hydroacoustic and infrasound technologies for climate change and disaster risk knowledge and monitoring. It will attempt to document learnings and benefits accruing to neighbouring states that host IMS stations on data use for environment and climate change monitoring that are of relevance to India given the geo-physical similarities. The objective reality of the scientific benefits of CTBTO resources for a country’s sustainable development goals will be instructive in making the the foreign policies of those that oppose the CTBT more politically aligned with it, with the eventual goal of contributing to narrative change in South Asia.

T5.2-O2 CTBTO IMS Contribution to SDG 14 Life Below Water

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Tsunami waves, volcano eruptions, underwater explosions, whales, cyclones are the major sources of hydroacoustic signal from all around the world. Those signals are verified by the CTBTO IMS, having 3 out of 11 HA IMS stations located in the Indian ocean. Surprisingly, insufficient research has been conducted regarding the area’s sustainability, particularly incorporating CTBTO capacity to contribute. In this study, the notable records of HA04, HA08, HA01 (IMS) have been analyzed between 2016 and 2018 pursuing the purpose to define the sources of hydro-acoustic signals. There are more than 4 Cyclones in the Indian Ocean annually and combined with the local seismic stations they are now able to track the cyclones path like the accurately spotted 22/12/18 Tsunami wave. Previous research shows IMS capacity to detect whales and other species. Annual Whale Festival (June-August) has also been monitored in the eastern part of Madagascar. In this regard the diverse dimensions of IMS contribution to SDG14: Life below water are discovered.
T5.2-O3  Feasibility Assessment for Geothermal Potential in Las Trincheras - Mariara, Venezuela

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The purpose of this research is to investigate the potentiality for a geothermal system that could be in place in the locality of Las Trincheras-Mariara, Carabobo State, Venezuela. In the context of, CTBT and the Sustainable Development Goal. The area is characterized by the presence of hot springs and extensive low-intensity seismicity. The main events magnitude are 4.7 and 4.9, respectively. In addition, understanding of the high swarm seismicity observed in the area in the year 2018, would derive on a better-constrained localization of the seismic events with the implementation of a more robust localization technique that will involve simultaneous multiple event locations with traditional focal mechanism analysis. Moreover, with our results we should impact on another important area of social interest such as the Seismic Microzonation studies for the cities of Valencia and Maracay. Therefore, this project involves the incorporation of PTS temporal local seismic stations to densify the stations in the area and the update of geological and geophysical information in order to accomplish a better scientific understanding of the given geothermal process.

T5.2-O4  Hazard Mitigation Analysis of the Anak Krakatau Eruption and Its Tsunami (22 December 2018)

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Krakatau volcano formed as impact of Indo-Australian and Eurasian plate activity during millions years. It’s located at Sunda strait, between Java and Sumatra islands. Krakatau volcano was erupted in 1883, with eruption scale estimated 30 times atomic bombs of Hiroshima and Nagasaki. The eruption cause more than 36,000 casualties and generate tsunami with maximum run-up around 30 meter in Java and Sumatra. The devastating eruption in 1883 made Krakatau volcano collapse. The top of Krakatau volcano destroyed and cause new smaller volcano appear that called Anak Krakatau volcano. Every year, Anak Krakatau volcano spouting volcanic ash on small scale and grows 0.5 meter in average per month. On 22 December 2018 occurred eruption Anak Krakatau volcano that generate large tsunami in Banten and Lampung and cause hundreds casualties. Based on Geospatial Information Agency of Indonesia (BIG), tsunami arrived in the land on 21:30 local time. We made analysis and simulation by difference origin time (OT) of Anak Krakatau eruption and tsunami arrival to proposed a tsunami early warning for local people in Banten and Lampung. We used the CGJI (InaTEWS) and LEM (CTBTO) seismic sensors in this research.

T5.2-O5  Infrasound Monitoring of Active Volcanoes at Local and Regional Scale

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Infrasound has great potentials to monitor ongoing volcanic explosive eruptions at source-to-receiver distances up to 1000s of km. However, while at short distances (< few 10s km) its operational use is feasible and well demonstrated, at long range its efficiency is still debated, mostly because of time varying propagation effects and the ubiquity of infrasound signals produced by multiple sources. We present infrasound array analysis of eruptive activity at Etna volcano, Italy, performed at local (< 10 km) and regional distances (> 500 km) and apply detection algorithm to identify in real-time ongoing eruptions. We show how frequency-dependent semi-empirical relationships derived from parabolic equation simulations coupled with realistic atmospheric profiles allows to correct for attenuation and reconstruct the pressure time history with great accuracy. This allows applying the same threshold parameters defined for the local array. We show how regional arrays at distance of >1000 km are able to pick eruptive activity of Etna with an efficiency of 87% and no false alerts. Considering
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the latency of ~1 hour related to propagation time, we show that remote infrasound detection of eruptive activity would be available before the actual notification, thus opening new perspective of real-time volcano monitoring at regional scale.

T5.2-O6 Amplifying the Impact of CTBTO Data for Emergency Response and Climate Change Monitoring

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The CTBTO Preparatory Commission, Vienna, Austria’s (CTBTO) International Monitoring System is a unique resource of reliable data that can be utilized to monitor many climate and man-made catastrophes. Our project aims to magnify the impact of this data by exploring new relationships between the CTBTO and social media platforms that include crisis and emergency response programs, which often have a broader and more immediate reach than governments or NGOs in the face of disasters. Specifically, we will first identify the range of incidents that the IMS system is capable of monitoring and exactly how this monitoring can bolster emergency response planning. Subsequently, we will identify accessible and high-impact platforms with which the CTBTO can partner, such as the Twitter Alerts program or Facebook’s emergency safety check. We expect the layering of CTBTO IMS data, social media, and crisis response tools to enhance the efficiency of emergency response and evacuation. Additionally, by collecting first-hand accounts of these catastrophes on social media platforms through the partnership, the CTBTO can paint a more holistic picture of the impact of these events on the ground. In turn, this could enrich ongoing climate change and natural disaster monitoring efforts being conducted across the United Nations.

T5.2-O8 Renewable Energy and Sustainable Development in the Light of Environmental Security

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Renewable energy is one of the most efficient ways to achieve sustainable development, there are several opportunities for Renewable Energy Sources, as well as for nuclear technologies to contribute to mitigating climate change and to promote sustainable development (SD) the picture of nuclear power’s role is significantly different within different countries and different world regions. In a few countries large numbers of nuclear power plants are playing a key role in supplying their countries’ electricity, the employment of this energy in a peaceful splitting is synonyms with sustainable development which is the other takes into account the current needs of the community without touching the rights of future generations but this link must take into account the important aspect to the environment with environmental safety system so that there becomes integration between peaceful nuclear industry and sustainable development in the light of environmental security, in this framework, the main scope of the present study is we will highlight through this study, the role played by the alternative energies in achieving sustainable development, and discuss the most important environmental and security challenges of nuclear plants and the importance of their peaceful use as a source of sustainable development and environmental security.

T5.2-O9 The Catastrophic Failure of the Iron-Ore Tailings Dam: The Worst Environmental Disaster in Brazil

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The dam break of the Fundao dam on November 5th 2015, in the municipality of Mariana, Minas Gerais State, produced the worst environmental disaster ever observed in Brazil. A huge mud flow destroyed a nearby town,
causing 19 deaths and leaving a trail of destruction as it advanced along the Doce River up to the ocean for 680km. This flood of slurry resulted in a lack of potable water and challenging environmental impacts. Moreover, one hour before the dam break, four small events with M2.5 occurred approximately 1 km from the dam. This occurrence renewed Brazil’s interest in reservoir-triggered seismicity. Since then, inspections have been intensified on mining companies that have tailings dam, especially regarding the follow-up of technical safety standards and handling of toxic material. The surveillance process has become increasingly important in particular during the monitoring of detonations in the quarries since they can trigger fractures and/or weak zones and increase the failure rate of the dams. The explosions in mines produce seismic and infrasonic signals and this work aims to verify the synergy between the seismic and infrasonic technologies using data of the Brazilian IMS stations PS07 and IS09.

T5.2-O10 The CTBTO and Goal 11: Using the IDC to Make Cities Safer and More Inclusive Through Disaster Preparedness Laws (CTBTO x SDGs Innovation Challenge)

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Our project seeks to explore how the IDC can be incorporated into disaster preparedness laws, to promote safer and more sustainable cities in furtherance of SDG 11. Noting that disasters disproportionately affect slums, we will also explore how advocates for slum upgrading and affected communities can utilize IDC data as evidence to advocate for more inclusive preparedness laws. First, we will determine whether disaster preparedness laws in affected and at-risk countries include a component of risk detection and early warning systems. We will then assess how the IDC can serve as a resource to strengthen risk detection and early warning provisions—for example, by utilizing moment magnitude estimates to predict disaster risk. Based on this assessment, we will propose ways to explicitly reference the IDC in disaster preparedness laws through model legislation. As an attachment to our model law, we will include recommendations on how slum upgrading advocates and affected communities can utilize IDC data in urban risk assessments, to advocate for more inclusive preparedness laws. Specifically, we will explore how seismic hazard maps, combined with slum mapping by organizations like the World Bank and UN, can better assess risk.

T5.2-O11 The Invisible Link Between the Sendai Framework for Disaster Risk Reduction and CTBT

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Natural disasters are increasing in frequency and intensity, becoming extreme and complex and have been affecting many countries over recent years. The need for a modern, multi-hazard, disaster response system to strengthen the national and collective ability to prevent and prepare for emergencies is evident. Early warning is a major component of disaster risk reduction with the potential to prevent loss of life and reduce the economic and material impacts of disasters. The Sendai Framework for Disaster Risk Reduction 2015-2030 recognizes the benefits of multi-hazard early warnings systems and places them in one of its seven global targets. The EU Civil Protection Mechanism plays a key role in coordinating the response to disasters in Europe and beyond through its Emergency Response Coordination Centre. ARISTOTLE-European Natural Hazard Scientific Partnership Project, funded by the European Commission’s Directorate-General for Humanitarian Aid and Civil Protection and relying on a solid partnership with expertise in volcanoes, earthquakes, tsunamis, severe weather, flooding and forest fires, has been launched to support the EUCPM and ERCC in their global natural disaster impact assessment. This presentation will focus on how the ARISTOTLE-ENHSP functions and how the CTBTO data can assist multi-hazard early warning systems, thus support the Sendai Framework.
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Poster Presentations

T5.2-P1  Activities of the Ghana Nuclear Data Centre (NDC)

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The National Data Center in Ghana was established in February, 2010 at the Ghana Atomic Energy Commission. The Center is mandated to collate seismic, radionuclide, infrasound and hydroacoustic data for monitoring nuclear test explosions for global peace. The data are obtained from our neighboring country Cote d’Ivoire and the International Data Center in Austria. The objectives of the Data Center include the following: receive and use data from the International Monitoring System (IMS) stations and products derived from the IMS from the International Data Center for verification and compliance of the Comprehensive Nuclear-Test-Ban Treaty and for disaster mitigation studies.

T5.2-P4  Contributions to Issues of Global Concern such as Disaster Risk Mitigation

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The data of IDC, properly interpreted may predict or prevent some disasters. A n earthquake for example, starts with annunciators signals before the event itself. The objective of this study is to show that in areas of high tsunami risk it is often possible to give alert or make an emergency evacuation using IDC data. In addition, the infrasound stations of the CTBTO can detect the entry of a meteorite in the atmosphere and estimate its probable drop point helping to take emergency measures. The presentation will be based on two concrete cases.

T5.2-P5  CTBT in Global Context: Nepal’s Scenario

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Nepal is a non-nuclear weapon state. As a peace loving country Nepal has already signed Nuclear Non-Proliferation Treaty (NPT) in 1970 and a signatory of the CTBT in 1996 with the commitment of using nuclear techniques in improving human health, world’s peace, prosperity and security and not for military purposes. In this run, Nepal has also become a member state of UN’s body, the IAEA for the peaceful use of nuclear applications in the country. The ‘Nuclear Law of Nepal’ has been drafted with cooperation of the IAEA which is currently in the parliamentary process for approval and that will open the door for the extensive use of nuclear applications for the benefit of the country. In the other hand, Nepal is surrounded by several nuclear installations of neighboring countries and remains in the threat of nuclear weapons menace and nuclear accidents that may occur in its neighborhood. The early ratification of the treaty should be in priority to maintain world’s peace and prosperity. Moreover, CTBTO has proposed for hosting an Auxiliary Seismic Station to be established in the Mt. Everest of Nepal. I will share how Nepal can use the IMS data for disaster risk and climate change mitigation.
**T5.2-P6**  
**CTBT Technology for Securing SDG 6: Ensure Availability and Sustainable Management of Water and Sanitation for All**

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The Comprehensive Nuclear-Test-Ban Treaty (CTBT) was adopted by the United Nations General Assembly in New York on 24 September 1996. The International Monitoring System is a global network of facilities for detecting evidence of possible nuclear explosions. With 321 monitoring stations and 16 radionuclide laboratories around the world, using seismic, hydroacoustic and infrasound monitoring technologies, the commission is able to locate energy released by an explosion caused by nuclear or natural events taking place underground, underwater or in the atmosphere. In 22 countries, the water stress level is above 70 per cent, indicating the strong probability of future water scarcity, if any nuclear testing is given, water would be in risk of having radioactive waste. Protecting our water is key to achieve SDG 6 The International Data Center processes the data collected by the IMS as soon as they reach Vienna, and through a National Data Centre, provide technical advice to the United Nations Commission and the competed authorities. Therefore be part on the decision making to avoid any risk of nuclear testing polluting clean trans boundary waters.

**T5.2-P8**  
**Earthquake Tectonics, Sustainability of Cities and Infrastructure, Seismic Hazard Assessment and Mitigation. A Case Study in North-East of Azerbaijan**

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The worldwide-known seismic hazard assessment methods and approaches are regenerated according to the modern seismic requirements. Strong earthquakes cause numerous human losses and infrastructure damages. Earthquakes are a threat to the sustainability of the cities, critical facilities, oil-gas pipeline, terminals, dams and others. The existence of oil and gas pipelines is important to Azerbaijan for intensifying the economy, strengthening oil and gas potential, also politically and strategically in the Caucasus. The regional main oil and gas pipelines pass through seismic active areas (Georgia, Turkey) in line with the seismically active north-east part of Azerbaijan. The objective of the project is to estimate seismic hazard in the north-eastern part of Azerbaijan with the use of modern multi-parametric integrated methods considering the importance of national strategic objects and facilities to the economical development of the country which might lose sustainability as a result of earthquakes. The outcome is to estimate seismic activity and plot models of seismic hazard based on the configuration of the multi-parametric values and make advises on establishing early-warning system in the country.

**T5.2-P9**  
**Economic Uses of Previous Nuclear Test Grounds (Semipalatinsk Test Site)**

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This project is aimed at analyzing alternative ways in which previous nuclear test sites can be used economically and be beneficial in the long run. Any methods have to take into consideration the effects that radiation has on life. Therefore techniques used should be able to minimize human contact with these areas. The work compromises the following steps: first review the levels of radiation still being emitted from the area, second, review the amount of radiation dosage with or without protection lastly determine the economic activity that can be used.
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T5.2-P12 How National Young Academies Can Help CTBTO Implementing Relevant Sustainable Development Goals

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They are numerous examples of ways in which national young academies can support the processes of test ban monitoring, including opportunities to support the work of the United Nations Commission Human Resources Science and Technology. A voluntary national work plan in short, mid-term and long term period can be performed to support the exchange of knowledge and ideas between the CTBTO and the broader scientific community.

T5.2-P13 Identification of Mass Movements Using the CTBTO IMS Data: Seismo-Acoustic Technology

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In densely populated areas, mass movements such as debris flows, landslides, and rock falls have been for a long period of time subjects that so many engineers, both practitioners and researchers have been focused on, trying to figure out how they can be detected and mitigated. The losses caused by these hazards are generally spectacular, often destructive and sometimes murderous. Generally, mass movements are preceded by the propagation of characteristic seismic and acoustic waves in low-frequencies (< 20Hz), roughly audible to humans. Beyond their scope of continuously monitoring Nuclear explosions, the 150 seismic and 48 infrasound sensors of the CTBTO IMS are capable of traveling efficiently through the earth surface, screening out the entire planet in 40 hours, and detecting pre and post soundings or shakings related to a particular event. Combining infrasound and seismic data has appeared to be one of the very powerful tools that can be used to detect, characterize, and extract quantitative information from signals of mass movements in order to set up early warning systems (EWSs) for a sustainable risk management.

T5.2-P14 Integrating the CTBTO IMS and NDC into the NNREP as a Tool for Enhancing Radiological Emergency Response and Preparedness in Nigeria

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The National Nuclear and Radiological Emergency Response Plan (NNREP) describes the capabilities, responsibilities and authorities of government and international agencies. It also provides a conceptual basis for integrating the activities of these agencies to protect public health and safety. The CTBTO International Monitoring System verification technologies, together with the data, technologies and products of the International Data Centre, have potential civil and scientific applications which can provide significant benefits to States and the international scientific community. These work is to integrate CTBTO capabilities into the NNREP in collaboration with the National Data Center and other National agencies like the Nigerian Geodesy and Geodynamics Agency, to help detect radionuclides and to provide results on radionuclide air concentrations from the CTBTO global monitoring network and related expertise; as well as advice on atmospheric transport and dispersion predictions as a result of a nuclear and radiological accident. If these capabilities are enhanced and integrated in to the NNREP it would go a long way to protect public health and safety through the useful information's provided to the emergency response organizations in Nigeria as stipulated in the NNREP from the relevant IMS monitoring stations.
The recent destructive earthquakes and associated tsunamis in Indonesia, Japan and Haiti, which killed more than half a million people, remind the world that we must be more proactive in developing ways to mitigate tsunami impact on our global society. The area around the Marmara Sea, as one of the most intensely populated parts of Europe, is subject to a high level of seismic hazard. The North Anatolian fault, one of the most active seismic zones in the world, runs within a few miles of the city under the Sea of Marmara. The 1999 İzmit earthquake, which is one of the most devastating earthquake to strike Turkey, caused enormously high damage and losses. Scientific researches shows that there is a 65% probability that Istanbul will be hit by a catastrophic earthquake within 30 years. Previous studies show that the tsunamigenic impact of submarine landslide in the Marmara Sea is one of the major hazards to take into account. The goal of this study was to explore the power of integration of MaRDiM SATREPS project which aims to raise the preparedness for possible large-scale earthquake and tsunami disasters in Marmara Region and Smart City Istanbul and potential benefits to Sustainable Development Goals.

Usage of data from seismic stations of the unique network of the CTBTO can be very useful for seismologists to derive realistic information about the earth’s core and layers. Especially contribution of the stations at teleseismic distances (>1000 km) is significant for each country. As a result of such studies, realistic urban transformations and immediate emergency responses can be obtained. Therefore, sustainable cities and communities can be achieved which is the 11th goal of the sustainable development. Moreover, living in strong buildings both secures lives and lets people to continue to live in their homes during secondary events. In addition, immediate interference after a disaster can save health and supply well-being, contributing to the 3th SDG. Furthermore, urban transformation requires not only construction of stronger buildings but also new infrastructures. Hence, new industrial areas also may be generated and the 9th SDG may be achieved. Also, by renewing old and vulnerable structures, where people with weak economic conditions live in, everyone can live in safe buildings in equal conditions which can contribute to the 10th SDG. Consequently, open use of seismic data of the CTBTO can be very important for the four the sustainable development goals.

In the last 500 years, more than 75 tsunamis have been documented in the Caribbean and the adjacent regions. Since 1842, 3446 deaths associated with tsunami waves have been reported. Since the mid-1990s, UNESCO’s Intergovernmental Oceanographic Comission has focused on the development of a tsunami warning system for the Caribbean (von Hillebrand-Andrade, 2013), enabling many countries in the region to implement warning systems, including the National Seismological Service and Tsunami Warning Center of Venezuela manage by FUNVISIS. The main objective is the inclusion of the Caribbean tsunami warning centers and NDCs to the CTBTO disaster warning initiatives. Tsunami warning centers in 14 countries receive data from around 100 IMS stations, particularly those covering the Pacific and Indian Oceans. This "tsunami agreement" only includes data from seismic and hydroacoustic stations, the inclusion of infrasound stations is introduced taking as a reference the experience of Garcés et al. with Sumatra earthquake in 2004, who propose that the initiation and
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propagation of a tsunami can produce low frequency sound near the source, as well as along the coastline and basins.

T5.2-P18 Investigation of the Catchments Sensitivity on the Observed Climate Change Signal

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Understanding the spatiotemporal variability of basin hydrological response in the context of a changing environment plays a crucial role in meeting future challenges towards a sustainable environment. This study aims at investigating the temporal dynamic of basic water cycle components and disentangling the relative importance of land use/land cover change and climate variability on the observed increased streamflow. Trends in observational data, precipitation and streamflow, are detected using Mann-Kendall statistical trend test. Non-observational component, actual evapotranspiration (ET) rate, is estimated with a Rainfall-Runoff model. We also examine ANOVA attribution concept to search for signals of change in climate variability and/or land use land cover (LULC) that could be attributable to the observed increased streamflow over the study watersheds. The ANOVA statistical approach reveals that the climate variability is the dominant factor on increased streamflow in all study watersheds than that of LULC change. However, in the disturbed watersheds there is evidence of a possible combined impact of LULC and climate variability on increased streamflow. This possible combined impact could be addressed by temporal decrease in ET over the second period, which can subsequently lead to an increase in streamflow volume.

T5.2-P19 Microgravity Survey to Evaluate Earthquake Effects on a Dam Site in Iraq

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A total of 324 microgravity measuring points were carried out on Derbendikhan rockfill Dam, 230km NE Baghdad, to evaluate the possible effects resulted in 7.3 magnitude earthquake hit the Iraqi-Iranian borders, 40km from the site, on Nov. 12, 2017. The site lies within the high folded zone which is a part of the Western Zagros Fold - Thrust Belt. A gravimeter Model CG-5 was used in this survey, where all the necessary corrections were applied on the raw data to calculate the Complete Bouguer Anomaly map. A 2m upward continuation filter was applied on Bouguer map for regional field determination that used to calculate the residual anomaly map. The residual map showed numerous negative and positive gravity anomalies that reflect subsurface heterogeneity in density distributions. Power spectrum analysis of Bouguer map showed six depth slices of gravity sources; 0.95m, 1.75m, 5.5m, 12.5m, 21m and 55m. The results showed two prominent anomalies appear close to the right bank on 21m depth; the first is a positive anomaly of 8m long, and the second is a negative anomaly of 14m long. These positive and negative anomalies suggest high and low-density zones coincide with compression and extension stresses resulted in the earthquake energy.

T5.2-P22 Modern Seismic Network Development in Iraq

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Iraq lies in an area prone to intense earthquake activity. Global networks recorded nearly one hundred Mw > 5.0 earthquakes in nearby regions since 2000. The Iraq Seismic Network was established in the late 1970s and
became operational in the early 1980s. However, recording and reporting of seismic data has been intermittent, leading to a large gap in regional seismic data collection. Seismic research in Iraq did not advance during a long period of national instability. In 2014, the U.S. Department of Energy's Seismic Cooperation Program, through Lawrence Livermore National Laboratory (LLNL), re-engaged and trained local scientists in Iraq to install stations, improve the quality of seismic monitoring, and modernize seismic hazard mapping in Iraq. Currently, the Iraq Seismological Observatory, including participants from Iraqi universities and other research organizations, operates eleven broad-band seismic stations in Iraq. Six of these stations provide open data to the international community (three in real-time) through the Incorporated Research Institutions for Seismology's Data Management Center. LLNL has collaborated extensively with Iraqi experts on modernizing seismic hazard maps based on a new Probabilistic Seismic Hazard Assessment. In 2017, the Iraqi government incorporated the updated hazard maps into new seismic design criteria in the national building code.

T5.2-P24 Operational Readiness of CTBT Hydroacoustic Stations in Achieving Sustainable Development Goal 14

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Oceans, rivers and streams according to the United Nations serve as the world’s largest source of protein, with more than 3 billion people depending on them as their primary source of protein. Close to half (45 per cent) of deaths in children under five each year causes associated with malnutrition. Hydroacoustic methods which are non-invasive provide data which can be applied in various ways for monitoring and studying the dynamically changing aquatic ecosystems exuberated by climatic changes. CTBTO have hydroacoustic stations that monitor the world’s oceans. This study investigates the operational readiness of these hydroacoustic stations. Literature in the past ten years was examined to collate data for the study. The result of the study showed that 90% of the hydroacoustic stations are ready to contribute data that could used for achieving the sustainable development goal 14.

T5.2-P25 Prediction of Major Earthquakes Using 4-D Seismic Attenuation Tomography

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The crucial loss amplitude of seismic waves is attributed to the anelasticity that known as the intrinsic attenuation in comparing to scattering, geometrical spreading and the other amplitude effects. The tectonic driven forces cause accumulation stress in time along the fault region which followed by changes in the elasticity properties of the media until reaching the failure point and the energy released in the form of seismic waves that caused vital earthquake hazards. The attenuation tomography has been used successfully to scale the anelastic anomalies in high resolution 3-D image. This research aims to develop a novel technique to predict major earthquakes using 4-D seismic attenuation tomography based on measuring the changes in 3-D attenuation over interval-time scale to detect the rate of changes in the anelasticity within the seismic source zones of major earthquakes. Local, dense and well configured seismic array records will be used with high accuracy data processing tools to detect any variation in the attenuation values along the interval time. The developed novel technique expected to use the 4-D attenuation tomography as a measurable tool for strain changes due to stress accumulation along the active fault zones to predict major earthquakes.
T5.2-P27  Promotion of Civil and Scientific Applications of Data and Techniques Used for Nuclear-Test-Ban Verification

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During the process of monitoring the globe for signs of nuclear explosions, the CTBTO monitoring network generates large amounts of data which has potential to be used for civil and scientific applications in many areas. Data and spin-offs from the International Monitoring System (IMS) stations are being used by scientists and policy makers among others to better understand our planet and manage our environment, and are being applied in diverse fields, ranging from atmospheric and climate science, monitoring of tsunamis to recording of earthquakes and tracking marine mammals. Civil and scientific applications of the data and spin-offs of the IMS stations can, therefore, significantly contribute towards improving human welfare and need to be promoted. The CTBTO, national governments and international research institutions, among others, can play an important role in the promotion of civil and scientific applications of data and spin-offs of IMS stations. Wide promotion of techniques arising from nuclear test ban verification through different approaches is being recommended.

T5.2-P28  Recent Seismic Activities in Ghana: The Role of the National Data Centre (NDC)

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Ghana is far from the major earthquake plate boundaries. However, the region has experienced devastating earthquakes in the past. Two major earthquakes of magnitude 6.5 on the Richter scale were recorded in the country in 1862 and 1939 and numerous earth tremors thereafter. On 24 March, 2018 and 9 December, 2018 a series of earth tremors of magnitude ranging from 3.0 to 4.8 on the Richter scale hit parts of Accra the capital city, and caused a lot of panic among the populace. The National Data Centre established in Ghana eight years ago is playing a key role in the dissemination of seismic information. The data received from the International Data Centre in Vienna is used to complement the efforts of the Ghana Geological Survey Authority in monitoring earthquake activities in the country. The earthquake events are catalogued at the National Data Centre for earthquake hazard studies. The data is also made available to our stakeholder agencies for earthquake disaster risk mitigation. Periodically, the Centre organizes awareness programmes to educate the public on earthquake safety measures. This is done with the objective of minimizing any disasters or casualties that might occur in the event of an earthquake.

T5.2-P29  Remote Sensing Earthquake Ground Motions Using Seismo-Acoustic Coupled Signals

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A key component in the initial relief efforts following an earthquake disaster is the ShakeMap, which depicts the distribution of shaking intensity in the struck region and is usually available within minutes of an earthquake. In regions where seismic instrumentation is limited, such ShakeMaps are poorly constrained. In Haiti for example, there were no seismometers operating during the 2010 Mw 7.0 Port-au-Prince earthquake. After days of surveying the damage on the ground an estimated ShakeMap was available. This dramatically hampered the post-disaster response and proved costly in societal terms. In this study, we develop a backprojection technique to infer earthquake ground motions using infrasonic signals generated by the earthquake and recorded at one or more infrasound arrays. Due to the low frequency nature of such signals and the existence of waveguides in the atmosphere, these signals are hardly attenuated during propagation and can be detected over long ranges. We show that infrasonic signals recorded during the 2010 Haiti earthquake by an IMS array IS51 in Bermuda, more
than 1700 km away from Haiti, could have been used to generate a ShakeMap minutes, not days, after the earthquake.

**T5.2-P30 Scientific Applications of IDC and IMS Products: Earthquake Research and Tsunami Warning in Sri Lanka**

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Although the primary purpose of the products of International Data Center (IDC) and the International Monitoring System (IMS) of Comprehensive Nuclear-Test-Ban Treaty (CTBT) verification regime is to verify compliance with the Treaty effectively, those products can be used in scientific and civil applications such as research on earth structure, earthquake monitoring and tsunami warning. The Seismic Data Monitoring Center at GSMB, Sri Lanka also benefited by the products of IDC and the IMS data. The main function of the Seismic Data Monitoring Center at the GSMB is to provide accurate and prompt seismic activity data for relevant authorities especially of impending tsunamigenic events and to be used later for research purposes. Presently, it retrieves raw seismic data from IDC and GFZ servers and analyses them using Seiscomp3 software. The national data center receives raw data from seismic stations around Indian Ocean from the IDC and these data are being analyzed to determine the earthquake parameters including location, depth, magnitude etc. The accuracy of these results is compared with the products of the IDC and used for tsunami warning and later in research on seismicity in and around Sri Lanka.

**T5.2-P31 Seismic Hazard Assessment for Northern Malawi**

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By virtue of its tectonic position on the southern tip of the East African Rift System, the northern region of Malawi often experiences earthquakes of varied sizes. These earthquakes are a significant hazard to the communities in the area. The December 2009, Karonga earthquake of moment magnitude Mw 6.0 (USGS, 2009), caused significant damage and disruption to local communities which are already poor. It is therefore a societal and scientific interest to understand the seismicity of the region since this helps in formulation of appropriate policies for disaster risk reduction measures such as national seismic safety regulations and building standards. Earthquake catalogs, which records earthquakes, explosions, and seismic disturbances, play a key role in seismic hazard assessment. Seismic monitoring data is one of beneficial service the CTBTO offers to its signatory states which can be used for disaster management among other uses. This study intends to identify and define seismic sources for northern Malawi which will be used to produce seismic hazard maps with different probabilities of exceedance. The study will use the Probabilistic Seismic Hazard Analysis methodology which quantifies the rate of exceeding various ground motion levels, given all possible earthquakes in an area of interest (Anza et al., 2011).

**T5.2-P32 Seismic Intensity Map of 5.5 Mozambique Earthquake**

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A magnitude 5.5 earthquake occurred in the Mossurize District, Manica Province, Mozambique. The National Institute of Mines used IMS data in their analysis to improve the location and depth of the earthquake. Further studies of intensity using Mercalli scale were used to estimate the coverage of damaged areas and infrastructures within. Combining both methods, seismology and imaging with drones, helped the civil protection agency to relief and mitigate the impacts of the earthquake.
**Theme 5: CTBT in a Global Context**

**T5.1-O3 North Korea and the CTBT**

E.M. Ifft  
Stanford University, CA, USA, ... also for achieving entry-into-force of the CTBT itself. The nuclear tests conducted by the Democratic People's Republic of Korea have not been a good example in trying to work out what verification would look like in a nuclear disarmament context, but also for the efforts made by the IAEA in this regard. It has been argued that the CTBT's contribution to arms control verification should be leveraged not only for strengthening existing prohibitions, but also for new initiatives that could help achieve collective security. For example, the CTBT's verification mechanisms, as well as its role in promoting nuclear disarmament, could be more effectively utilized to guide the orderly and verifiable transition of North Korea to a Non-Nuclear Weapon State and party to the NPT. At least signing the CTBT would demonstrate a commitment to non-proliferation, and participation in, the activities of the CTBTO, including verification. Lessons from the negotiation of earlier arms control agreements, as well as from the cessation of the former Soviet Union's nuclear testing program, can help in understanding the complexities and challenges associated with the current situation. The CTBT provides a blueprint for how verification can be used to contribute to global security and stability.

For the Patients of the U.S., South Korea and North Korea may make this achievement less distant than previously believed. In view of North Korea's stated willingness to give up its nuclear weapons, it would not be logical for it to refuse to join the CTBT and insist on preserving a right to test such weapons. At least signing the CTBT would demonstrate a commitment to non-proliferation, and participation in, the activities of the CTBTO, including verification. Lessons from the negotiation of earlier arms control agreements, as well as from the cessation of the former Soviet Union's nuclear testing program, can help in understanding the complexities and challenges associated with the current situation. The CTBT provides a blueprint for how verification can be used to contribute to global security and stability.

**T5.1-P4 Leveraging the CTBT's Verification Provisions for Promoting Entry-Into-Force**

Poster Presentations

**T5.1-P3 CTBT Entry into Force: Breaking the Stalemate**

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Stanford University, CA, USA

**T5.2-P33 Seismicity Study of Botswana from 1966 to 2012**

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Not much is known and well documented about the seismicity of a larger coverage of Botswana primarily because over the years, local seismic stations were biased to the north-western part of Botswana, to monitor the more seismogenic Okavango Delta Region. The objective of this study is to estimate the relative size distribution of seismic events (b-value), the rate of seismic activity (a-value), and associated stress condition prevailing in Botswana to assist in the quest of hazard mitigation. This study shows that micro-seismic activities of magnitude ranging from 1.3 to 5.7 are distributed not only on the northern part of Botswana, but also in other parts of the country such as the Southern (including Kweneng East and West), Central and Eastern Botswana. The b-value and a-value for the entire catalogue was found to be 1.2 and 6.3, respectively, implying a region of low stress dominated by small to moderate events. The minimum completeness magnitude (MC) was found to be 3.8. From this analysis, annual probabilities of occurrence for M4 and M5 events were found to be 67.2 % and 4.3 %, respectively, while M6 or larger event has an annual probability of 0.3 %.

**T5.2-P38 Swedish Biodiversity in Time and Space**

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FOI has been collecting and archiving weekly air filters from six locations throughout Sweden for ~50 years ( >15,000 filters in total); the original goal of this project was to detect radioactive fallout. In cooperation with Umeå University and Swedish University of Agricultural Sciences, these filters have been utilized to examine biodiversity in Sweden through time by sequencing the DNA captured in these filters. Due to the special design of the filters and downstream packaging and storage, the DNA is remarkably well preserved, allowing long time series to be studied. In fact, using shotgun sequencing we can detect virtually all known organisms in Sweden; e.g. bacteria, viruses, plants, insects and even mammals along with the parasitic flatworms living in their intestines. Sequences associated with antibiotic resistance genes are also readily detected as well as known genes involved in virulence. We are now using these filters to study how the ecosystem is responding to a changing environment as well as tracking important pathogens to humans, agriculture and livestock. The goal is to make forecasts on future changes to ecosystems and pathogen distributions.

**T5.2-P40 The Changes in the Wildlife of a Region as an Indicator of the Effect of the Radiation Caused by the Nuclear Tests**

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The relation between the human kind and the environment in which it develops has been changing during time and has been always depending on the speed and the efficiency of the technological advances of our species. We have now entered to a new stage in the history were we need to produce big amounts of energy in a very short time. To achieve this we began to use more efficient sources. The use of nuclear energy, based on the nuclear fission can be very dangerous if it is not managed with the right measurements. In order to meet the objective of guaranteeing a healthy life and promote the well-being in the population of a country, we need to know the effects that this kind of energy has on the wildlife and in this way know the effects it will have in the human population. A way to monitor the effect of nuclear tests in certain areas is by measuring the effect it has on life, allowing us to know not only how life does this process of natural selection based on the mutation, but also present evidence of the risk that runs the life by the exposure of this radiation.
The occurrence of Earth tremors and earthquakes in Nigeria has been a source of concern to emergency managers and government of Nigeria. Although Nigeria was not generally suspected to be prone to major earthquakes, over the years, several of minor tremors had been experienced in some parts of the country. Now the story is different, as a threat has been confirmed, it should be seen as an opportunity to get forward with strategic planning and to explore opportunities from the CTBT IMS through the NDC. Incidentally, when some of those tremors occurred, there were no functional seismological observatories in Nigeria. But that has now changed. The Nigerian Government has also established a seismographic network managed by the Centre for Geodesy and Geodynamics (CGG), Toro, Nigeria, with four operational stations equipped with 24-bit 4-channel recorders and broadband 30-second seismometers. These networks could be integrated into the CTBTO NDC if there is awareness of the civilian application of the IMS and the opportunities from the use of the CTBTO NDC in Abuja. Earth tremor and earthquake would be detected, measured in Nigeria and data could be exchanged, disaster and risk would be mitigated life and property would be saved.

Climate is changing and the weather focusing is become a major focus on bringing a new weather pattern for citizens and everyone to follow up. Global warming is the main alteration of climate changes. To curb this, the United Nations sustainable development goals aim at developing and strengthening the future aims at solving the challenges we face. The IMS data with 337 facilities that monitor the entire planet, produces information useful for not only the nuclear test-ban-treaty organization but also the meteorological stations. In collaboration with the Comprehensive Nuclear-Test-Ban-Treaty Organization (CTBTO), it has established a verification regime capable of contributing to the UN’s efforts in the area of meeting the UN objectives of climate change. The IMS data which produce up to 26 gigabytes of data daily, is used in additional to nuclear test, to detect changes in the weather like tsunamis, increasing levels of water in the oceans due to movement of glaciers. It is not only used for climate changes but also in underground detection of earthquakes, sound waves in the oceans, the sound of whales in the oceans which bring a relaxing experience for the tourists all over the world.

The national data centre (NDC) in Namibia assists the IMS I35NA infrasound station with daily data quality monitoring. Although infrasound is relatively new, the Namibian NDC has taken on the challenge to analyse and interpret both infrasound and seismic data sets from the Namibian IMS station. It remains challenging, but one objective of the NDC is to identify most cultural and static infrasound sources in the I35NA spectrum. Another objective is to monitor the influence of mining activity on the I35NA station using infrasound data and satellite imagery. Another objective is to build strong NDC cooperation ties with different NDCs on civil problems faced in Namibia. One such cooperation is with the Austrian NDC to do forensic analyses on IMS seismic data to better understand seismic activity in the Kunene Region of Namibia. Another project is
cooperation of the Namibian NDC with the Young Professional Network (YPN) to produce a seismic hazard map using IMS data and to communicate the information to rural communities. The Namibian NDC is also active in public awareness of the CTBT with regular articles and student engagements.

T5.2-P45  The WHO and the CTBTO: Joint Initiatives to Address Air Pollution in the Cities

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Air quality plays a pivotal role for the achievement of SDG 11 which is aimed at making cities inclusive, safe, resilient and sustainable. Having taken into consideration adverse effects of air pollution, the WHO issued the Air Quality Guidelines which cover four air pollutants. But the list lacks radionuclides which are air pollutants as well. The objective of the research is to examine a possible contribution of the radionuclide monitoring technology of the IMS to the WHO studies. The results suggest that cooperation between the CTBTO and the WHO could be an important step forward in addressing air pollution. Initially, the CTBTO could provide the WHO with information on radionuclide levels. Secondly, it could facilitate the WHO research on recognizing health impacts of radionuclides. Likewise, joint study could pave the way for the update of the Air quality Guidelines and putting radionuclides on the list or drafting new legal documents. Next, cooperation could give an impetus to raising awareness of people about air pollution and encouraging state authorities to follow standards. Overall, cooperation between the CTBTO and the WHO will help to alleviate the problem of air pollution and make cities a safer place to live in.

T5.2-P46  Tsunami Evacuation Map in Padang, West Sumatra for Disaster Risk Mitigation

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Based on historical earthquake, West Sumatra had occurred destructive earthquake in 1833 with estimation moment magnitude (Mw) 8.8 - 9.2. Theoretically, large earthquake has return period and possibility to occur in future. Therefore, for reducing the earthquake impact, we made tsunami evacuation map in Padang city, West Sumatra. We choose this city as our research because it has dense population. We made tsunami evacuation map based on tsunami inundation modelling. In our tsunami simulation scenario, we used not only 1833 event parameter but also potential earthquake in seismic gap around Sunda strait (Mw 8.7). The final inundation is composite between both of those scenarios. We used ComMIT software from NOAA to simulate tsunami propagation and inundation. The detailed bathymetry and topography data from Big (resampling grid 1 arc sec) was used in this research. We applied QGIS software to make tsunami evacuation map in detailed. Our results show that the inundation distance reach around 1.5 km. To anticipate error of tsunami modelling we applied buffer 100 meters in our results. We made clustering of population and considering demographic condition to make evacuation route and evacuation shelter.

T5.2-P47  Tsunami Risk Assessment in South-Eastern Mediterranean

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Along with history, the southern-eastern Mediterranean coasts have experienced several historical tsunamis triggered by the earthquake from both far and near field sources (e.g., Hellenic, Cyprian arcs). The most
hazardous tsunami events were 365 AD in Crete with Mw8.5, 1222 in Cyprus with Mw 7.7 and 7.5 and 1303 in Rhodes Island with Mw8.0. The tsunamis caused widespread destruction and victims along the coastal cities as evidenced by available historical reports, geomorphology and paleo-tsunami investigations accomplished recently. On the other side potential mechanisms to generate tsunami would be a local underwater landslide, mass movement due to Volcanic eruptions and local earthquakes. These potential sources pose a higher risk due to short travel times for tsunami waves that limits the alarming time. Furthermore, a case study for tsunami impact was applied in details in the city of Alexandria. By combining hazard and vulnerability levels for residential buildings, a qualitative risk assessment has been performed. The urge for the implementation of early warning system for the coast of eastern Mediterranean is becoming an essential and urgent need.

T5.2-P48  Urban Seismic Risk Evaluation for Georgia

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Seismic hazard and risk assessment directly link to sustainable development of country. Here we are presenting the main elements of the newly developed seismic hazard model of Georgia. The starting point in seismic hazard assessment is the updating of the regionally harmonized datasets with focus on data that become available within the recent years. From this point of view international seismic monitoring systems playing greater role to solve indicated task. One of the biggest advantage of global monitoring network is that, the data are available freely without any barriers. National agencies are often focused on their own interests and do not freely sharing data, or the data are limited by national boundaries. This is why networks like International Monitoring System (CTBTO/IMS) extremely important for future development of science. Based on this data earthquake catalog for Caucasus updated up to 2017. That allow parameterization of newly developed seismic sources and probabilistic seismic hazard assessment for the entire region. Detail investigation of Building inventory allowed us to investigate intensity based vulnerability for city-museum Mtscheta in Georgia. Finally seismic risk in terms of damage and economic loses were estimated for this city. The results were delivered to scientific community and local end users.

T5.2-P49  Waiting to the Eight: Billions People and CTBTO Committed for a Safer World

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As of September 2018, 184 states out of 196 signed the nuclear test ban treaty with 167 ratifications. In other hand, this means that more than 4.3 billions people residing in the ratifying countries are committed to the treaty principles. On the other hand, it is mandatory to have the ratification of countries listed in the annex 2, for the entry into force of the treaty. 8 states out of the 44 mandatory ratifications are still remaining. In this paper, we highlight with statistical analyses the engagement in favor of the treaty and in a safer world and draw the attention of the other countries that the world is waiting of their prompt action to go straight for a safer world. We underline, based on 2019 projections, that near 55% of the world population and representing more than 83% of habitable land ban nuclear tests. To generalize for the whole earth including ocean and land, we can say according to our analyse that 95% of the planet area are under nuclear test ban. The results are also a call to the 8 countries to join the path being drawn for nuclear test ban and peace by the world.
T5.3 Capacity Building, Education and Public Awareness

Oral Presentations

T5.3-O1 CTBT and Role of the CYG in the Korean Peace and Denuclearisation Process

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The nuclear crisis in the Korean peninsula is a long-standing problematic issue which constitutes a threat and challenge to global peace and security order. DPRK’s nuclear tests have demonstrated the increasing technical capacity of their nuclear weapons program and served as acts of provocation and conflict escalation. Conversely, the recent steps by DPRK to place a moratorium on nuclear testing and destroy a nuclear testing facility serve as confidence building measures which have helped the Inter-Korean peace process. However, these steps have not been sufficient to overcome suspicions from the USA or the international community, nor to free up the blocks in the DPRK-USA process. Further progress by DPRK to verifiably proscribe further nuclear testing would be of enormous benefit to the diplomatic processes, and serve as incremental steps towards full denuclearisation. The CTBT and CTBTO can play important roles in this process, possibly even resulting in DPRK signing the treaty, so long as there is public and international support for such incremental measures as well as incentives for DPRK to join the CTBT. A helpful factor will be to engage youth in public promotion of the role of the CTBT in the Korean peace process. The CTBTO Youth Group could help in this regard.

T5.3-O2 Examining How the United Nations Sustainable Development Goals Mutually Reinforce CTBT’s Mission and Moves the Momentum of the Treaty Forward

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There is an intrinsic linkage between the United Nations Sustainable Development Goals (SDGs) - Peace and Justice Strong Institutions, Gender Equality and Quality Education -with the mission of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO). In the following, I will explain how these three SDGs are mutually reinforcing and bolsters the mandate of the CTBTO. Simultaneously, I will also explore how the Preparatory Commission of the CTBTO can become active on issues like Quality Education and Gender Equality at various levels of government and non-governmental bodies which would be a significant way for the CTBTO to gain greater salience. The Treaty ratification is one of the ultimate goals of the CTBTO. However, prior to ratification, there are several issues that the CTBTO can have a more pronounced voice in which will not only augment the cause of the CTBTO but also provide the CTBTO with a prominence that it deserves in the world of peace and security issues. Working on some of the SDGs like quality education and gender equality will lay the groundwork and facilitate CTBT’s entry into force. It would allow and move the momentum of the treaty forward.
Nowadays the struggle for feminism is becoming increasingly important. Despite the fact that much has already been achieved in this case, in many areas it is extremely rare to meet women. This is not due to the reluctance of women to occupy certain positions, but the obstacles raised by society for a long time, prejudices that still live in the minds of many people. It is worth noting that this is an erroneous model of behavior, because for a comprehensive solution of problems the view of both men and women is necessary. It has been scientifically proven that their thinking is fundamentally different from each other, so why not to take this fact into service to achieve more advanced objectives, including in terms of the global transformation of our world, reflected in the UN sustainable development goals. In our research, we touch upon two goals: Quality education (goal 4) and Gender quality (goal 5). We will try to create a training program on the subject of the radionuclide nuclear test verification method. The results of the research work will help us to understand which distinctive features of this program will contribute to better and more effective learning of female representatives.

The abstract examines the contribution of NRNU MEPhI to the work of the CTBTO Youth Group and the potential for further cooperation. MEPhI students have been active participants in various activities of the Youth Group since its foundation: The First International Conference of the CTBTO Youth Group was held on the basis of MEPhI in October 2017. Participants of the Youth Group from MEPhI were active during the CTBT Science Diplomacy Symposium in May 2018 and the GEM-Youth International Conference in August 2018. Today MEPhI is a leading university that trains specialists to work with nuclear technologies. The Institute of Nuclear Physics and Engineering, Institute for Laser and Plasma Technologies, Institute of Cyber Intelligence Systems, Institute of Physical and Technical Intellectual Systems, and Institute of Engineering Physics for Biomedicine provide the main areas of technical education in which MEPhI has long conducted educational programs to train specialists for the IAEA. In addition, much work is being done on training in the field of scientific and technical cooperation on the basis of the Institute of International Relations. This experience can be actively and effectively applied in the training of young professionals for the benefit of the CTBTO.

The CTBT Science Diplomacy Generation is a diversified capacity building project of MEPhI aiming to train and nurture the next generation of Science Diplomacy experts who will address daunting problems facing the Treaty. The project CTBTxSDG comprises regional outreach and education activities including a comprehensive training course in English with the engagement of CTBTO online materials, skype conferences with CTBTO staff, presentation and poster contests, gamification activities, on-site visits to the National Data Center in Dubna and Dukhov All-Russia Research Institute of Automatics. The project is expected to provide a platform for interdisciplinary, multicultural and inter-institutional collaboration to broaden and strengthen the engagement of various scientific communities working in test ban monitoring as well as to enhance their geographical gender representation, involving MEPhI students, pre-university students, academia, legal and technical experts. We use the occasion of the SnT2019 to introduce the modules of the proposed project, its interdisciplinary teaching methods and a multilingual CTBT glossary elaborated by joint efforts. Moreover, we will present the initiative to launch on the margins of the SnT2019 a presentation contest 'CTBT Science
**Theme 5: CTBT in a Global Context**

Diplomacy Generation to Promote the SDGs' to reinforce linkages between the CTBT and the SDGs, with a 17-slide presentation format.

**T5.3-O7  Promoting CTBT Through Capacity Building, Education and Public Awareness**

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Scientific and technological input is essential to the CTBT decision-making processes, implementation and acceptability of its policies. Access to information while important, may lose the intended universality if methods and findings are inconsistent with stakeholders' concerns. CTBT non-compliance challenges emerge in its structural inadequacies. Issues of ratification and entry into force can be addressed by raising awareness through capacity-building workshops, meetings, international forums etc. among the stakeholders like arms control lobbies, conference on disarmament, governmental institutions, UN General Assembly First Committee etc. Scientific-advisory and policy-making roles are critical to efficient compliance and demand regular consultation and information sharing between scientific and policy institutions. Scientific innovation coupled with sagacious and bold leadership help mitigate the challenges of arms control arrangements like CTBTO. CTBTO must improve the engagement of national and international stakeholders within the policy-making circles through various capacity-building programs to educate them. Public awareness towards negative impact of radioactive environmental contamination from nuclear testing generates pressure on the government in favor of arms control measures. This would be useful in information dissemination and may enhance CTBT's universal appeal. Greater understanding of stakeholders' security and legal obligations is needed through robust program of consultation, collaboration and capacity building.

**T5.3-O8  Raise the Nuclear Awareness for the Public Across Culture**

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The CTBTO should raise public awareness about nuclear, while ordinary people maintain their fear of the nuclear for war purposes, skeptics pursue their knowledge for peaceful nuclear use. Both sides of the nuclear goal must be very well aware of most people in the world. The limited of nuclear knowledge will make people reject everything about nuclear which will endanger the development of peaceful nuclear use. While we know that a country's decision to support or reject international organizations is strongly influenced by the opinions of its people. With sufficient knowledge about nuclear benefits and threats, the public will play a major role in the development and global network for peaceful nuclear use and active supervision of the potential for nuclear use for war purposes, especially for the nuclear test ban. Cultural differences of the nations sometimes brought the low acceptance of global preference, with the active participation of CTBTO for nuclear education to the member's states peoples, cultural barriers among nations will be eliminated and allow the CTBTO to be fully implemented into force. The contribution will be effective when CTBTO work together with a local institution.

**T5.3-O9  Raising Public Awareness Among Students About CTBT in Nuclear Age**

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The CTBT has languished for so long, that now we must not only revitalize the actors currently responsible for treaty entry-into-force, but also energize the upcoming group of advocates and scientists, many of whom are unaware of the treaty and its benefits. In order to bridge this gap, the youth generation has become the very important role in nuclear age. This paper examines how the CTBT serves as useful tool with which to learn and/or discuss a variety of topics, including the threat of nuclear proliferation, the use of diplomacy, the art of negotiation, the functioning of international organizations, and the impact of the Science and Technology (SnT)
on International Relations. Students in Myanmar and Cambodia are unfamiliar with the intergovernmental organizations and regimes in place to reduce the dangers of nuclear weapons, tend to hold an ethnocentric perspective on nuclear weapon issues. Therefore, the CTBTO educational resources such as Knowledge and Training Portal whose various courses help students from Technological University (Kyaukse), Myanmar and Pannasatra University, Cambodia learn about the CTBT was introduced in 2018. Moreover, students were introduced the CTBTO youthgroup platform which involving the next generation have natured and encouraged young people who would play an important role in the future.

**T5.3-O10 Role of Civil Society Organizations for Education and Public Awareness**

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Role of Civil Society Organizations for education and public awareness in NIGER. The role of the CTBTO is to detect an atomic explosion on the planet to take steps to prevent the current nuclear-armed countries from continuing their tests, and the States that do not have nuclear weapons not to acquire them. In addition to this mission, the CTBTO, through IMS data and IDC products, can make available to scientists data for civilian applications, such as nuclear and radiological applications and emergency preparedness. The CTBTO also ensures that countries and institutions have a science-policy interface for wide dissemination of scientific knowledge to both decision-makers and the general public in general. In the face of the emerging arms race and the heightened risks of a terrorist nuclear attack, the insecurity of nuclear weapons systems in the face of cyber risks, as well as the use of emerging technologies, poses risks to systems that are associated with them. It is imperative that we civil society organization, mobilize ourselves to influence the authorities for the introduction of the knowledge of the missions of the CTBTO into our education system from primary to university for a general culture of peace and a life without arms and nuclear tests.

**T5.3-O11 The Intrinsic Value of CTBTO Workshops, Training Programs, and Expert Meetings**

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The Workshops, Training Programs and Expert Meetings of the CTBTO contribute significantly to optimizing the monitoring and verification of the CTBT, exchanging knowledge, strengthening the engagement of the scientific community, and identifying how scientific developments and cooperation can support national needs and the CTBT, all of which are goals of the 2019 SnT. Few people outside of Vienna know about these valuable workshops and programs. They have included a recent workshop on drilling in on-site inspections, and some of the many upcoming programs in 2019 include: NDC capacity building on analysis of radionuclide and waveform IMS data and IDC products, radionuclide training for station operators, Latin America and Caribbean infrasound training for NDCs. The workshops aim to achieve an understanding of the verification regime, build capabilities of the National Data Centres, provide expertise about using IMS data and IDC products, support practical experience in analyzing IMS data, build up national and regional capacities in implementing the Treaty, and increase participation in the verification regime. This presentation will describe the many workshops and training programs, the added value that they have imparted in the regions addressed, the significance of transmitting knowledge to future generations, and their contribution towards entry into force of the Treaty.
T5.1-O3 North Korea and the CTBT
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T5.3-P2 Awareness Activities Related to CTBT Undertaken by HANEA
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A awareness activities related to CTBT undertaken by HANEA SnT 2019, 24-28 June 2019 in Vienna, Austria To better participate in the activities of treaty, to popularize the treaty’s benefits and derive profits from treaty, Niger established a national data center (NDC) in 2014. Niger, through its NDC, has established a multidisciplinary team of potential users of IMS data and IDC products. Niger will create conditions to build capacity of this team in order to better use these data and products for all useful purposes. Niger receives in its NDC data from PS26 (TORD) stations and soon data from the RN48 (NEP48), which is under installation. Niger makes public awareness activities relating to treaty and the benefits of accessing and using IMS data and IDC products, through regular organization of workshops; sessions; seminars and open days. Thus, the Niger authorities are committed to advocate for the entry into force of the treaty both at the level of the United Nations and the International Union of Parliamentarians. The poster will present the High Authority of Niger to Atomic Energy and then all the awareness-raising actions conducted in the direction of the Government, parliamentarians, scientists and engineers, media men and civil society.

T5.3-P3 Awareness of the Radionuclide Monitoring Technology for Myanmar’s Students
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The radionuclide monitoring technology, one of the four monitoring technologies used by the CTBTO for detection nuclear explosion, was introduced to the undergraduate students at Technological University. The main objectives of the presentation is to increase knowledge how the CTBT is carrying out the treaty of nuclear weapons test and how the air sample are monitored, detected and sent to the International Data Center (IDC) in Vienna to know the radioactive particles content. About two years ago, introducing of the CTBT’s educational
T1.1-O3 Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound

In this study, we examined 344 bolides (airbursts) reported on the JPL CNEOS website which approaches 20%. Above the 1 kT CTBTO design threshold, we find that 40% of airbursts are reported in the each step of the function in Radionuclide Monitoring Station Rn-42 such as air sampler collect the radionuclides from the environment with a filter, sample filter is prepared to count in Gamma detector and the result data in computer are sent directly with satellite, VSAT to IDC. This discussion is the first step of sustainable learning for undergraduate students who will continue studying about the CTBT’s performance.

T5.3-P4 Capacity Building and Public Awareness Creation by National Data Centre in Ghana, West Africa

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The Republic of Ghana signed the Comprehensive Nuclear-Test-Ban Treaty (CTBT) on October 3, 1996 and ratified the CTBTO on June 14, 2011. In February 2010, Ghana commissioned its CTBT National Data Center (NDC) so that it can support international efforts to monitor nuclear weapons testing more effectively. Seismic data received from the International Data Centre is one of the benefits the CTBT offers in the area of earthquake hazard assessment for Ghana. Experts at the NDC-Ghana access and compile seismic events data registered on the seismo-acoustic networks of International Monitoring System for the country. This data in addition to the national earthquake monitoring means will be used to update and identify seismically prone areas of the country. The Center in collaboration with other agencies intermittently organise public lectures on earthquake disaster risk mitigation thereby creating public awareness. The Center also makes recommendations to the government of Ghana on earthquake safety measures and assist government institutions to develop appropriate land and building policies. Capacity building undertaken by the Provisional Technical Secretariat (PTS) empowers signatory states including Ghana with equipment, software and training. Knowledge is further imparted in individuals who visit the center for educational tours and others through periodic internal trainings.

T5.3-P5 Capacity Building for Expertise for Non-Proliferation Rules and Instrument

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The Comprehensive Nuclear-Test-Ban Treaty (CTBT), the unique and comprehensive verification to ban nuclear explosions is essential for human beings, animals, plants and environment. Policy makers, scientist, technician, academia, students and media members from many countries is implementing to enhance the capabilities of the Treaty’s verification regimes and to become a universal law with comprehensive approaches. Myanmar signed Comprehensive Nuclear-Test-Ban Treaty (CTBT) in 1996 and ratified in 2016. As a developing country, Myanmar needs to raise awareness and advance science and technology for verification methods and Myanmar is actively participating in CTBTO’s comprehensive innovative programs. Myanmar was a party to Partial Test-Ban Treaty in 1963. Myanmar signed Nuclear Non-Proliferation Treaty in 1992 and an additional protocol in 2013. In addition, Myanmar signed Bangkok Treaty in 1995 and Treaty on the Prohibition of Nuclear Weapon in 2018. To support CTBT, Myanmar has linked CTBTO’s website for public awareness and participating in policy makers, scientists, students and technical level for expertise in CTBTO’s verification systems. To strengthen legislative and regulatory framework and to support political commitments for non-proliferation obligations of international organizations, Myanmar is drafting new Nuclear Law and the existing Atomic Energy Law will be replaced.


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**T5.1-O3 North Korea and the CTBT**

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The nuclear tests conducted by the Democratic People’s Republic of Korea in trying to work out what verification would look like in a nuclear disarmament context, but also for achieving entry-into-force of the CTBT itself. The contribution of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) to arms control verification should be leveraged not only for strengthening verification concern were key in the 1999 US Senate rejection of the CTBT. More generally, the role of the CTBT’s verification provisions—especially the IMS—are unparalleled in arms control agreements. Yet, effective verification has not been sufficiently acknowledged recently. The Treaty on the Prohibition of Nuclear Tests (PTNT) and the Nuclear Non-Proliferation Treaty (NPT) are the main international nuclear weapons control agreements, as well as from the cessation of the former Soviet Union’s nuclear testing program, can help guide the orderly and verifiable transition of North Korea to a Non-Nuclear Weapon State and party to the NPT. Participation in, the activities of the CTBTO, including verification.

This scenario calls for exploring innovative ideas on how to convince abstaining states to join. The CTBT would be a logical and effective early step for North Korea, in what looks to be a long and difficult process to a broader political settlement. This could be accompanied by North Korea’s support for, and participation in, the Comprehensive Nuclear-Test-Ban Treaty (CTBT), as well as on education in seismology and research for an improved seismic and infrasonic monitoring of Central Asia. During the first year, the cooperation focused on the modernization of the National Data Centers in Kazakhstan and Kyrgyzstan and training courses on interpreting and processing of seismic records conducted at the KNDC in Almaty for specialists from Kyrgyzstan, Tajikistan, and Kazakhstan. To improve the monitoring capabilities and the regional cooperation between the countries in Central Asia, the compilation of a regional bulletin has started by collecting seismic data or seismic onset readings from more than 50 stations in Central Asia. In addition, methods are under development to classify different source types (natural, man-made) of the events in the new bulletin.

**T5.3-P6 Capacity Building in Central Asia to Monitor the CTBT**

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In 2018, a new joint project started between NORSAR, the Institute of Geophysical Research ME of the Republic of Kazakhstan, and the Institute of Seismology of the Academy of Science of the Republic of Kyrgyzstan. The project focuses on capacity building in Central Asia in relation to technical verification of compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT), as well as on education in seismology and research for an improved seismic and infrasonic monitoring of Central Asia. During the first year, the cooperation focused on the modernization of the National Data Centers in Kazakhstan and Kyrgyzstan and training courses on interpreting and processing of seismic records conducted at the KNDC in Almaty for specialists from Kyrgyzstan, Tajikistan, and Kazakhstan. To improve the monitoring capabilities and the regional cooperation between the countries in Central Asia, the compilation of a regional bulletin has started by collecting seismic data or seismic onset readings from more than 50 stations in Central Asia. In addition, methods are under development to classify different source types (natural, man-made) of the events in the new bulletin.

**T5.3-P9 Challenges to Innovative Solutions, Transparency and Application of Verification Technologies in Non-Signatory, Annex 2 States in the Modern Era**

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Non-signatory Annex 2 states are embroiled in difficult geopolitical situations, prone to conflict and misunderstandings. The arms race in the subcontinent and tensions on the Korean peninsula has exacerbated challenges towards sustainable peace and made instant signing of the CTBT elusive. However, there is still room for innovative solutions to be explored given the enormous literature which exists on weapons development in both regions and the international community acknowledging that de-escalation is preferred. The necessity to exercise restraint and promote greater transparency between adversaries puts into perspective how innovative solutions can be implemented and what challenges to verification technologies exist. Irrefutable evidence on the sea leg to India’s deterrence as well as Tactical Nuclear Weapons from Pakistan exists. Without transparency, the risk of accidents from domestic political considerations, escalation of bellicose rhetoric, or tensions on the Korean Peninsula or the Line of Control can take place. In light of these realities, this paper lays out challenges to the application of verification technologies in both regions and the impediments towards innovative solutions by making a case that geopolitical scenarios, right wing governments and escalating tensions pose significant challenges towards de-escalation and mitigation of conflicts for non-signatory, Annex 2 states.

**T5.3-P10 Cloud Platform as Instrument to Enhance Capabilities of Remote Users (Data Processing and Training)**

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In 2016, the cloud platform for the processing of geophysical data was deployed in NDC-UA. NIAB package is used as a base, which can be installed entirely or partially, for example separately Seiscomp3 or Geotool. However, it is possible to install another software. The deployment of the cloud platform in NDC-UA solved the problem of software installation on a large number of users and substantially reduced the cost of software deployment and maintenance. In 2018, a new joint project started between NORSAR, the Institute of Geophysical Research ME of the Republic of Kazakhstan, and the Institute of Seismology of the Academy of Science of the Republic of Kyrgyzstan. The project focuses on capacity building in Central Asia in relation to technical verification of compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT), as well as on education in seismology and research for an improved seismic and infrasonic monitoring of Central Asia. During the first year, the cooperation focused on the modernization of the National Data Centers in Kazakhstan and Kyrgyzstan and training courses on interpreting and processing of seismic records conducted at the KNDC in Almaty for specialists from Kyrgyzstan, Tajikistan, and Kazakhstan. To improve the monitoring capabilities and the regional cooperation between the countries in Central Asia, the compilation of a regional bulletin has started by collecting seismic data or seismic onset readings from more than 50 stations in Central Asia. In addition, methods are under development to classify different source types (natural, man-made) of the events in the new bulletin.
issue of technical resources, greatly reduced the time for the installation and maintenance of software, and if necessary, allowed the rapid migration of the system. Taking into account that M CSM, which includes the NDC-UA, has a territorially distributed structure, the use of the cloud platform has made it possible to effectively involve remote staff, including experts, who can now conduct a full analysis of the emergency situation wherever where the Internet is available. In addition, the platform turned out to be an effective way of conducting of trainings with universities students, which has proven itself for several years. Having a positive experience of using of the cloud platform in NDC-UA, we offer it for testing and subsequent use in other NDCs. Also, it would be appropriate to use the cloud platform in the Capacity building system during trainings and in the work of CTBTO experts.

T5.3-P12 Contending the Security Dilemma: Policy and Science

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Even-though the Peloponnesian war ended in 404 B.C, the legacy it left is significant; a security dilemma. In the Middle-East, even though state-to-state large-scale conventional warfare has theoretically ended in 1973, states are still tied to this security dilemma. This dilemma led some states like Israel to formulate national security policies based on a nuclear deterrent, or Iran to pursue nuclear ambitions, or other states like Egypt to maintain ballistic capabilities. Ultimately, the CTBT’s entry into force became a hostage to this security dilemma of mistrust. The purpose of this abstract is to go beyond the security dilemma and introduce tentative CBMs based on both policy and science through win-win scenarios in the present status-quo that lacks minimal favorable conditions to sign and ratify the CTBT in the Middle East. Policy-wise, regional cooperation to fight militant non-state actors, a common threat to the state survival through the coordination of intelligence and information on one hand. On the other, scientifically, through establishing a Middle-Eastern platform that allows the transfer of science and technology. Indeed, creating a status-quo of joint-dependency based on common survival and science can end the dilemma and ultimately pave the way for the CTBT entry into force.

T5.3-P14 CTBT and Evolving Nuclear Order

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The advent of nuclear weapons was a great shift of paradigm in the global politics and nuclear testing is associated with it. Therefore, it further leads to the concerns of nuclear proliferation (vertical/horizontal) and nuclear safety and security matters. This poster is organized in three parts. I) It analyses and reviews the scope of CTBT, II) it examines the CTBT phases over the years, III) it discusses discourse regarding the treaty at multiple levels and possibilities of the way forward. It also aims to provide and map the challenges related to the CTBT in comparison of non-proliferation treaties at the international level, which include difficulties of achieving objectives of the treaty with reference to evolving nuclear order and growing strategic ground realities. Furthermore, it analyses the systems developed by the CTBTO consisting of the International Monitoring System, International Data Centre and their contribution to the value of the Treaty in relation to the broader non-proliferation regime. This poster also proposes suggestions to address some challenges, at the working level by development of systemic capacity building to introduce various aspects of technological support which the CTBTO may provide for global security issues such as climate change.

T5.3-P15 CTBT Enforcement

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CTBT is comprehensive for its scientifically acceptable parameters which are are working even without CTBT’s coming into force. The Treaty was adopted more than twenty two years back yet it lacks formal enforcement.
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The formal enforcement has not been possible so far because of Eight States (UCIPINI) which have not ratified it. Ratification of a Treaty is entirely different from its enforcement in international law. To this date there is no State in the world who is not enforcing this Treaty in the territories it occupies. Education is the sine-qua-non for channelizing a movement towards awareness and capacity building. In shrunk in world where education is required hardly is the situation of full literacy. Education enters and grows itself with a tool not available to the whole mankind. This need to be addressed. The paper looks into two broad based approaches for bringing CTBT in force reliably and in a time bound manner.

T5.3-P16 CTBT the Next Global Agenda Toward Peaceful Planet

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The CTBTO is on track to make the world free from testing the nuclear weapons in future. ‘No’ to nuclear testing is the only prerequisite to the nuclear debate. There is a need to advocate the youngsters on the role of the CTBTO, its mandate and prepare them for the years ahead in countering the challenges ahead. The initiatives like bringing CTBT as a subject in curriculum and the positive role played by the CTBTO in promoting science technology will motivate the youngsters, and students to play a better role.

T5.3-P17 CTBT-SDG 5-Innovation-Challenge: Building Resilient Communities Through CTBT Science Information Sharing

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The Kunene Region in north-western Namibia is a geological laboratory for continental break-up whereby the region is littered with faults and thrusts and seismic activity has often been reported. In 2018, an unprecedented number of earthquakes has been recorded. Due to the remoteness of the region, very few people have been able to communicate their experiences to the relevant authorities and the media. Remote communities feel disempowered and fearful of their environment. Their understanding of natural occurring events, such as earthquakes are also tested and requires engagement by experts with effective communication tools. The Young Professionals Network in cooperation with the Namibian National Data Center (NDC) is taking on this challenge to build resilience of the poor and those in vulnerable situations applying effective communication strategies and tools to transmit information to vulnerable groups. Scientific results and useful information produced by the Young Professionals Network and the Namibian NDC using International Monitoring System (IMS) data and processed with NDC-in-a-box software is shared and communicated to the affected rural communities. The project aims to measure how well useful scientific information using IMS data and IDC products is relayed to affected rural communities using novel communication techniques.

T5.3-P18 CTBT Educational Programme and Sustainable Development Goal 5 in Nigeria

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At a glance participants in e-educational activities differ strongly based on gender. Men tend to be motivated to participate in work-related learning more than women. Women on the other hand are drawn to responsibilities in the home and participate more in work-related training that allow them to perform their responsibilities in the home. One of the targets of the Sustainable Development Goal 5 (SDG5) is to enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women.
The CTBTO has developed some educational resources to increase the participation of women in its programme. It has been reported that in Nigeria only 17% of science researchers are women. This study examined the CTBTO educational programme and SDG5. Personal interviews were conducted and questionnaires were administered randomly to female researchers to test whether findings from interviews were correct. The result of the study indicated that what is being learned and how it is being learned is adequate. But factors like constrained time, infrastructural resources (electricity, internet and funds) and conflicting priorities are limitations to increased participation of women in CTBTO educational programme.

**T5.3-P19** *CTBTORS the Global Heroes of Sustainability: A Collaborative Online Game for Schools and Citizens*

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It has been demonstrated that education, health and income are the three more important capacity generators for human beings. It is proposed the design and implementation of an educational collaborative online game, mission-oriented, to increase awareness on SDGs, to promote CTBT and CTBTO and to strengthen democratic, local and global values. It simulates the organization of the CTBTO, uses the scientific and technical capacity of this organization, the different kind of information available at CTBTO and related, for carrying out and solving different mission in which SDGs and targets are involved. But in the same way there could have specific missions related to onsite inspections, negotiations for abandoning a clandestine or declared nuclear programme by a country, among others. It is designed to complement classroom and homework activities. It provides means for mission designing, solution process and reporting. It should be designed taking into account the common ethical values that underlie school curricula of different countries. Although students are the main audience of the game, it is important to include people outside school.

**T5.3-P20** *Curriculum Development on CTBTO Verification Regime*

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CTBTO over the years has emerged as one of the leading scientific data repositories around the world. It has compatible systems including accreditation systems and sizeable footprint at the global level. This elaborate infrastructure and expertise is a result of innumerable efforts of both scientific and diplomatic communities. The lessons learnt, therefore, are immense, all-encompassing and worth codifying for adoption in terms of best practices and technologies by other organizations responsible for research in related areas. Case studies, books, and literature on the processes, technologies, related experiences and above all operation of the data centers including IDC and remote stations need to be recorded and shared for forming part of the related curriculum for teaching at different levels. This knowledge intervention will enable CTBTO to reach out to the universities around the world. The great work of preventing nuclear testing will pave way for establishing similar infrastructure at an appropriate scale for other scientific purposes. The innovation will accordingly take roots through engagement of academia and students focusing at new possibilities.

**T5.3-P21** *Deploying a Radionuclide Monitoring Station in Kazakhstan*

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On November 29, 2017 a Memorandum was signed between the Department of Foreign Affairs, Commerce and Development in Canada and the Ministry of Energy of the Republic of Kazakhstan (ME RK), which implies a property deposit on the part of Canadian partners as a radionuclide noble gas monitoring station in order to strengthen supervision of the Comprehensive Nuclear-Test-Ban Treaty. This station is designed for strengthening enforcement of the Comprehensive Nuclear-Test-Ban Treaty (CTBT). To deploy a radionuclide
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station NNC RK specialists preselected 3 potential sites in the territory of Kurchatov. Comprehensive studies were conducted on each site selected that involved: collection and analysis of general information on a site, the analysis of meteorological data, radiological survey, identification of available engineering communications and types. In the course of research every possible source of radionuclides entering the air environment has been assessed in the area of interest. Background characteristics of radionuclide contamination in the area of interest are estimated. The mean concentration of natural and man-made radionuclides in the environment was found to be at the background level of global fallout for this region in Kazakhstan. Based on activities, materials on the comprehensive survey of selected sites were prepared.

T5.3-P22 Engaging Young Generation: The Case of Ural Federal University in Russia

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Since 2013, Ural Federal University has been promoting the Comprehensive Nuclear-Test-Ban Treaty and its verification regime. This has been done via educational and research programs. Over the past three years, an annual survey on CTBT has been conducted by 100 students of International Relations at Ural Federal University. The survey shows that between 30 to 40 percent of IR students know about the CTBT, although this is the percentage of students who attend the nuclear non-proliferation course. The survey provides results about the future role of younger generation in decision-making and personal contribution to promote the CTBT. Moreover, the survey shows the importance of the CTBT dissemination of information, and about the various institutions of nuclear non-proliferation regime. Despite the patriarchal mentality and little belief in the personal contribution to nuclear non-proliferation regime, more than half of the respondents assert that the role of youth is becoming increasingly essential in the modern world, and the young generation should have the upper hand in forming a safe and sustainable world.

T5.3-P23 Enhancing Public Awareness of the CTBTO/CTBT Using Social Media

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Social media has become a very important part of our lives over the past decades, from interacting with people all over the world to selling products and even creating awareness for various campaigns. Social media campaigns have proved to be very effective methods to capture people's attention, with the ALS ice bucket challenge being one of the most significant one, but over the past couple of years social media challenges have evolved from the ice bucket challenge and planking type to more creative and artistic challenges. Some examples of these are the kiki challenge in 2018 which involved dancing, the invisible challenge which involves acting and the lip sync challenge which involves singing along to popular songs just to mention a few. Coming up with such a social media challenge for the CTBTO could capture the people's attention and create an avenue for more serious conversations about ratifying the treaty and spreading the CTBT's agenda especially to the youth.

T5.3-P24 Equipping the Next Generation of Nuclear Explosion Watchers - CTBT Educational Materials a Useful Resource

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The CTBT, like any other international agreement, require public knowledge of its existence for universal acceptance and promotion of its primary goal. For the CTBT to remain relevant to the next generation, there should be consistent effort at providing adequate information on the technical, scientific, legal and political aspects of the Treaty. Mindful of this fact, the CTBTO has a number of public educational resources available to
increase the knowledge of the general public. These educational resources are to create understanding of the Treaty’s relevance and contribution to international peace and security thereby enhancing the nuclear test ban verification compliance as desired. The CTBTO also employ a couple of public web-portals such as Knowledge and Training Portal (KTP), CTBTO Youth Group (CYG), CTBTO on iTunes U for educational purposes. The CTBTO Youth Group platform is one of such useful platforms, that engages the next generation of nuclear explosion watchers and build their interest in the verification regime. It is now the turn of NDCs at the local level of individual State Signatories to publicize the Treaty and its verification regime as well as the continuous role it is playing in non-verification-related applications to mitigate disasters.

T5.3-P25 Establishment of an Academic and Research Network Under the CTBTO Umbrella

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Science in the modern world is increasingly interdisciplinary. The CTBT: Science and Technology conference is a great example with its five sections. In order to broaden and strengthen the engagement of the scientific communities working in the monitoring ban test, including young scientists, and to enhance the geographic and gender representations of these communities, there is a strong need for a suitable platform for partnership through which CTBTO, educational and research institutions, as well as other stakeholders to cooperate and to promote the core mandate’s objectives of the CTBTO and additional sustainable social and economic goals. My proposal to CTBTO governing bodies is to prepare the establishment of an academic and research network under the CTBTO umbrella which can serve in the best way to the goals of the organization. Best practices of other organizations might be used. IAEA for example has several academic, research and training networks – among them INSEN (International Nuclear Security Educational Network) and NSSC Network (Nuclear Security Support Centers Network). Similar networks exist at OSCE, EU European network of independent non-proliferation think tanks in support of the implementation of the European Union strategy against Proliferation of Weapons of Mass Destruction, UNODC ACAD network, etc.

T5.3-P26 Estimation of Ionizing Radiation Risk and Their Effects as a Method of Approach to Data Products

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Introduction: Releases of radionuclides produce events and their characteristics can be estimated based on the data products collected (characterization of the source and signals), but this is a proceeding that shows huge risks and is not always possible. Objective: To ensure compliance with the Treaty, describe the scientific basis of risk estimation (RE). Methodology: The most important source of data to RE of ionizing radiation is the group of atomic bomb survivors. Considering the characteristics of this group and the epidemiological data of low LET radiation (medical exposures of thyroid and breast, patients undergoing radiotherapy in the UK to relieve pain associated with ankylosing spondylitis and data on secondary cancers in women treated for cervical cancer) quantitative RE is performed. Results: Relevance of the origin of data on the effects of radiation, transport of risks between populations, dose-response function and risk projection models are showed. Conclusion: Occasionally interpretation errors occur due to sample size, lack of controls, strange effects different from those produced by radiation, inadequate dosimetry and lack of a sufficiently large dose range. Since radiation risks may be diverse for another population, it’s necessary to establish a procedure that allows results extrapolation to other human populations.
T5.3-P27  Evidence Based Proposition to Make IMS and IDC Data Available for Use Through Climate Change Education in the Context of Education for Sustainable Development, Promoting Peace and Climate Change Resilience in Africa

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Evidence based propositions are developed using a thematic analysis of the data set. Adaptation related projects are those that help reduce the vulnerability of human and natural systems to the current and future impacts of climate change and climate-related risks, increasing or maintaining adaptive capacity and resilience in the targeted regions and countries through use of IMS and IDC data. A large number of observation associated with project implementation experience are reviewed to identify good practices that have significant implications for practice, for which there is robust evidence which might be expected to be worth considering in other circumstances and initiatives. The resulting proposition are statements of good practices with some aspects of strategies to educate the policy makers and general population on availability and applicability of IMS and IDC data sustainably through non-formal learning spaces, theoretical perspectives of disaster mitigation for sustainable development that if adopted are expected to improve biodiversity conservation efforts, bend the curve of conflict and food security outcomes. The propositions are intended to inform design decisions, improve implementation but also structure debate and learning on effective practice. Each proposition is supported by explanations that expands proposition, summary of public evidence, example of projects that ground the proposition in context and practice, design implications of proposition for new interventions, hypothesis consequences for environmental education, summary of assumption underpinning the proposition and a summary of counter views and counter evidence to the proposition. They are grouped into: values and principles, theoretical perspectives, strategies for integration in non formal learning and partnerships and networks.

T5.3-P28  Extended-NDC-in-a-Box Experience at the Israel National Data Center

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The Extended-NDC-in-a-Box (ENIAB) is an integrated data acquisition, processing and analysis platform for NDCs, which was developed by the IDC. ENIAB contains several software packages including SeisComP3 and Geotool. In the poster we will summarize our experience of implementation and adaptation of ENIAB at the Israel NDC. The Israel NDC has installed the ENIAB on three separate computers instead of as a single virtual machine. The package was divided so that one machine holds the SeisComP3, another runs Geotool, and the third holds PostgreSQL databases. We have installed two databases- a database which serves the SeisComp3 automatic event parameters, and an osdb database which serves Geotool. We use ENIAB tools such as proc2css to export data from one database to the other. The ENIAB package enables us to combine data of IMS stations and IDC processing results with data from national and other networks. All waveforms and automatic arrivals and origins are imported into Geotool for further manual processing.

T5.3-P29  Feminist Perspective on Disarmament

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Nuclear weapons represent the unparalleled risk of catastrophic destruction to human civilization. An underrated aspect of nuclear weapons is the idiosyncratic gendered nature of it which makes the prospect of a nuclear weapon detonation especially devastating to women. Women are critically underrepresented in negotiations and high level decision making positions. This imbalance has led to the quagmire the disarmament community finds itself in. The lack of female perspective and input on the discourse and debate of nuclear weapons and disarmament is especially egregious. Nuclear politics sits at the intersection of the sciences and international
relations, two fields which have struggled with gender parity and issues of representation. As a result of the lack of meaningful representation and the relative youth of the field discourse has become inundated with gendered language. The abundance of masculine gendered language in use has made it an unwelcoming field for women who are face adversities unless they utilize masculine gendered language speak in their terms. Meaningful progress towards disarmament cannot occur until issues of gendered language and gender parity are dealt with. Disarmament, as it is generally conceived, is a feminine act and as long as normative masculine values are favoured, total disarmament is impossible.

**T5.3-P30** Goal 9. Build Resilient Infrastructure, Promote Inclusive and Sustainable Industrialization and Foster Innovation

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The CTBT can make a major contribution to the achieving of the 9th of the SDG by bringing of groundbreaking technologies to developing countries. The paper reviews 5 proposals for CTBT that would pave the way for accomplishment of the 9th goal. All proposals were chosen after analysis of the CTBTO sphere of activities and review of global problems which are impedeing the achievement of the 9th goal. The first two proposals related to IMS system and its capacity to build resilient infrastructure. Two next proposals are connected with the usage of CTBTO Data Centre. The fifth proposal bounded up with the global promotion of innovations among the youth. It is hoped ideas in this proposals may help the CTBTO contribute to fulfillment of the 9th goal of the SDG.

**T5.3-P31** How the CTBTO Activities Increases and Develops the NDCs Technical Staffs Knowledge, Experiences and Skills, JO-NDC as an Example

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**T5.3-P32** Implementation of Capacity Development and Public Awareness for CTBT Verification Regime in Myanmar

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Myanmar signed the CTBT in 1996 and ratified it in 2016. As a CTBT ratifying state, Myanmar needs to implement the capability development and public awareness concerning with CTBT verification activities. When implementing the CTBT verification regime, Myanmar considered the linkage between CTBT and sustainable development goals (SDGs). A National Data Centre (NDC) is needed in the country for characterization of the
source, correctly analyzing and interpretation of the collected signals. The seismic, hydroacoustic, infrasound and radionuclide technologies are important technologies for understanding the signals generated by a nuclear explosion. Various capacity development and public awareness are important. Civil society, change school curriculum, participation in process, organizing workshops and seminars are carried out by policy makers' decision. International collaboration and citizen awareness is needed to understand the CTBTO verification system for monitoring the nuclear explosions in a global context. The Atomic Energy Division (AED) will collaborate with external funding agents to get human resource for NDC implementation in Myanmar. Young scientists, science administrators and representative will be achieved from this national development initiative. This is focused on research and development in areas potentially relevant to the Treaty's verification regime.

**T5.3-P33 Implementation of Research and Development Obligations of the Republic of Kazakhstan on CTBT**

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Kazakhstan has been actively supporting the activity of Preparatory Commission (PC) for the Comprehensive Nuclear-Test-Ban Treaty (hereinafter - the Treaty) in virtually all fields of creating and improving main elements of the verification regime. The Treaty has been signed by Kazakhstan in 1996 and ratified by the Parliament in 2001. In 2007 an Agreement has been ratified with PC of the Treaty Organization "On implementation of activities, including post-certification ones, at the facilities of international monitoring in support of the Treaty". Within the framework of the above mentioned governing documents five stations of the International Monitoring System (IMS) have been created - a network of 4 seismic monitoring stations, an infrasound monitoring station, Kazakhstan National Data Center and a corresponding communications system in Kazakhstan during the period from 1999 till 2006. Based on the initiative from Kazakhstan and in accordance with the resolution of PC of the Treaty Organization four field experiments on on-site inspections held on the territory of former STS during the period from 1999 till 2008. The report presents the results of longstanding work of IMS and their impact on the regime of nuclear tests control.

**T5.3-P34 In a Hope of Non Nuclear World**

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As an aspirational youth of 21st century, I am guided by the visions of Mahatma Gandhi to create a world, which is free from want and free from fear, a world shaped by the ideas free of violence. Hence, after working for nearly a decade as a senior software engineer, I quit my job to pursue this vision and devoted myself to the cause envisaged by Gandhi Ji. I am currently co-founder and chairman of Incredible Bharat Foundation (http://www.ibfonline.org). At IBF, we aim to promote communal harmony, universal brotherhood and global peace including propagation of cultural heritage, arts and literature. Here, we strive to promote and advocate human rights and fundamental freedoms for all without any discrimination of race, religion, color, sex and language. As a member of CTBTO Youth Group (CYG), I aim to undertake, organize, conduct and facilitate conferences, lectures, research and education on various aspects of nuclear non-proliferation and against destructive impacts of nuclear explosions. CYG shall also give an opportunity to engage and interact on a common platform with youth leaders. I am also technologically skilled to develop solutions for propagation and perpetuation of the afore-mentioned objectives.
**T5.3-P36  Increasing Role of the CTBT**

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50 years after first use of nuclear bombs, and testing of nuclear explosions in open atmosphere, the Comprehensive Nuclear-Test-Ban Treaty (CTBT) was opened for signature on 24 September 1996, and an absolutely unique international norm on nuclear testing was established. The Treaty bans nuclear explosions by everyone, everywhere: on the Earth's surface, in the atmosphere, underwater and underground. Now, the CTBT makes it very difficult for countries to develop nuclear bombs for the first time, or for countries that already have them, to make more powerful bombs. It also prevents the huge damage caused by radioactivity from nuclear explosions to humans, animals and plants. However, CTBTO's monitoring stations picked up an unusual seismic event in the Democratic People's Republic of Korea (DPRK) on 3 September 2017. In this presentation we are considering some aspects of the present international policy, possible reasons of newly challenges in the international area, the importance to reinforce a joint call for the prompt entry into force of the CTBT, and increasing role of the Treaty in a global policy context.

**T5.3-P37  Internal Management Software for Station Managers**

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Thanks to CTBTO we have a complete platform where we can record many of the activities carried out by local operators, station operators or station managers every day. However, there are many other internal aspects involving only managers that we need to automate for all that involve administration of CTBT in each country regarding; management of contracts, land lease, finance, invoicing, equipment tracking, internal reports, internal maintenance, training of our personnel, applications in science, agreements with other institutions, etc. The development of this Software is to make the management process easier together with all that involves all
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aspects related to CTBT monitoring stations and National Data Centers in only one platform. Another important aspect is to be able to unite Spanish-speaking countries and be interconnected to solve common problems that we must solve day by day. This software will start from our NDC website through a personal account, it is intended that all countries can better organize the management of their stations and the National Data Center.

T5.3-P38  International Outreach and Training on the Regional Seismic Travel Time (RSTT) Method
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The Regional Seismic Travel Time (RSTT) model reduces travel time prediction errors for phases (Pn, Pg, Sn, and Lg), which are commonly used for seismic event location. Reduction of travel time prediction errors leads directly to reduction of event location errors, which is critical to CTBT verification. The CTBTO-PTS has incorporated RSTT into 8 international training activities since 2012. In addition, RSTT has been the focal point of 10 special sessions at scientific conferences. As a result, NDC personnel and academic researchers from Africa, Asia, Australia, Europe, North America, South America, The Middle East, and Oceana, have been trained in the use of RSTT. Training sessions and professional conferences foster international collaborations that have contributed geophysical information and data that improve the RSTT earth model. These improvements extend the geographic coverage of RSTT tomography and supply important ground-truth data that make travel time calculations more accurate in areas where scientific collaboration has taken place. These data contributions and the RSTT model are openly available to all NDCs and the broader research community. The presentation will review RSTT international training sessions and detail the effort to establish RSTT as a standard for the calculation of regional seismic travel times.

T5.3-P39  It Is Not About the "Know-How", It Is About "Why" and "How-To" Spread the Knowledge.
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Spreading the knowledge acquired for more than 100 years in seismic and hazard monitoring to society was not an easy task to fulfill because we are a nonprofit institution with small budget compared with another non-governmental institution that works with other hazards. Despite the financial issue, we decided to start the Knowledge Spreading using low cost methods and the most important part of the plan we applied our imagination and the importance of the IMS network in order to have more attention from the local authorities and of course the society. Taking advantage of the importance role of our institution on the operation and maintenance of three IMS stations (PS06, AS08 and IS08) and the civil application to the data we could catch the attention from Civil Defense vice Minister who included us as the main point of information for teaching about the earthquakes in our country. Later we could produce a document called "Seismic Culture" addressed to child and teenagers who diffused the knowledge to their homes and then to the neighborhood. Finally we had a seismic simulation on a school and five towns, because we showed the importance of IMS network.
T5.3-P40  KAIST NEREC for Developing Human Capital for Global Nuclear Nonproliferation

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While the global community continues much efforts to reduce the threat of nuclear weapons, nuclear proliferation remains one of the top international security concerns. Given various challenges in nuclear nonproliferation, KAIST started a new human capital development program in 2014 called, NERE (Nuclear Nonproliferation Education and Research Center) Summer Fellows Program in collaboration with world-class nuclear nonproliferation experts. So far the program has produced 123 alumni students from 30 countries and 54 Universities in the world. The program aims at developing nuclear nonproliferation specialists in key regions and countries of strategic importance. The program is an intensive 6-week training course including lectures, seminars, group discussions, research work, field trips, participation in an international conference, and various activities for professional networking and development. The multicultural mixture of the students strengthens our collective ability to see issues from rich diverse perspectives and appreciate different cultures. Engineers work together with social scientists experiencing synergistic learning in their problems solving while integrating science, technology and policy. By raising people who can responsibly guard the technology with meaningful knowledge and connections with the global community, we may have better opportunities to deal with future global nuclear challenges.

T5.3-P42  Monitoring Compliance with the CTBT - Contributions by the German NDC

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"Monitoring Compliance with the CTBT - Contributions by the German NDC" is the title of a book on various CTBT related topics by authors from the German National Data Centre (Federal Institute for Geosciences and Natural Resources in Hannover, BGR) and national partner institutes. Studies on institutional, technical and scientific aspects in the CTBT context are described to highlight recent, current and future work at the German NDC and to contribute to the CTBT monitoring and verification tasks. Nevertheless, this book focuses primarily on those aspects of the verification regime where BGR has expertise as well as BGR’s activities and responsibilities as the German NDC and an IMS station operator during the last twenty years. After the general introduction the DPRK events including 2016 are analysed, and the National Data Centre Preparedness exercises until 2015 are described. The chapters on the global test-cases of Tohoku-Fukushima, and the Chelyabinsk Fireball are followed by studies on quality control, remote sensig, and OSI, with a focus on seismic aftershock monitoring. The book serves as first overview for newcomers in the field and interested public but may be also interesting for experts and diplomats.

T5.3-P44  National Data Centre's Training Cycle Approach

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The overarching objective of the Capacity Building and Training (CBT) programme is to support the participation of the States Parties in the CTBTO verification regime, by providing the necessary tools, training and equipment for the NDCs. This is envisaged by, inter-alia, assisting the States Parties in developing the technical capabilities in receiving, processing and analysing International Monitoring System data at the National Data Centres, and use of IDC products. In its efforts to optimize its training program within the available resources, the Capacity Building and Training Section in The International Data Centre has adopted the Training Cycle Approach (TCA). The objective of the Training Cycle Approach is to efficiently conduct a series of interrelated training activities that help the States Parties in building and enhancing their capacity in using the IMS technologies and IDC products, and at the same time to promote networking among different
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NDCs. The focus of the TCA is on improving the NDC staff analytical skills by providing them with the different tools prepared by the IDC.

**T5.3-P45 NDC Establishment and Operation**

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Before Establishment of NDC in any country we need to know: What is an NDC, Need for an NDC, Tasks of and Functions of an NDC, NDC Capacity Building, and Data Access - Secure Signatory Account and to answering NDC Frequently Asked Questions. NDC is an organization with technical expertise in the monitoring and verification technologies of the CTBT, working under the guidance of, or as an integral part of a national authority, a data center operated and maintained by a State Party whose functions may receive data and products from the IDC. A State Party’s NDC should inter alia: Provide technical advice and support to the national authorities, Receive and use IMS data and IDC products: For Treaty verification and compliance and for country’s benefit in its natural disaster management and other civil and scientific applications. The Functions of an NDC will be defined by the national authorities is: - Advice the National Authority by: Providing technical advice and support on all matters pertaining to the verification of the Treaty, Verifying the nature of the events and their (non) compliance with the Treaty. - Use IMS data and IDC products as needed according to National needs.

**T5.3-P46 NNRA Information Dissemination Strategies**

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The nuclear industry is a global enterprise that grows and achieves quality in a global environment. There is need to be effective and efficient in their operational and strategic process. Findings have shown that many organizations will achieve great purpose when they can share knowledge through education, training and creating awareness activities. One of the visions of the Nigerian Nuclear Regulatory Authority (NNRA) is to achieve effective communication within the organization and to the general public. NNRA demonstrates existing strategies that enable them interact with appropriate international organizations for effective and efficient dissemination of information which will be discussed in this paper. However, this work will include key ideas which the NNRA is ensuring effective capacity building, education and public awareness for both decision makers and the general public using science policy. Fortunately, this created ideas can be possible solutions for the improvement of nuclear activities, achieve internal and external performances, with reduced limitations. There are practical examples set up that can support CTBT and nuclear international bodies in achieving reliability and conformance practice for framing policy objectives on the environment, health and safety standards of scientific communities.

**T5.3-P47 Non-Proliferation Culture as a Subject for Master Degree Curriculum in Technical University of Moldova**

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The political instability in the Black Sea region, the lack of territory control and the serious violation of international treaties and agreements, underline the need for active participation of all international actors in the non-proliferation of AMD. An invaluable role is the continuous education with the objective to make non-proliferation treaties universal. A curriculum for the Nuclear Safety and Security subject (ECTS 4) was developed at the National Nuclear Security Support Center (NNSSC). The curriculum was designed for Master’s students and includes lectures, seminars and the writing of a paper. The NNSSC puts special emphasis on
developing the teaching staff through the synergy of nuclear safety, non-proliferation and cyber security. As CTBT and NPT are inextricably linked, the curriculum has been updated recently with topics on non-proliferation, and the role and importance of these international treaties. The cyber-security as a pillar of nuclear safety and security, as well as non-proliferation, was included in this optional curriculum. The results have shown that master students possessed a greater degree of awareness of nuclear safety and non-proliferation than Bachelor graduates did. An important fact to mention is that the optional discipline was requested by more than 25 graduates of other universities.

**T5.3-P48  Plan to Develop CTBTO Network in Vietnam**

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The plan to develop the CTBTO knowledge in Vietnam includes the following: - learn about techniques used in the verification regime of CTBT - exploit IDC data for verification purpose and for scientific research and civil application - improve the knowledge and experience on the techniques so that can give the government the advice on the technical issues when necessary - enhance the knowledge on CTBT and technical issues by exploiting E-learning, CTBTO forum on internet - participate in the exercises held by PTS or state parties such as NPE exercise, common exercise as doing in this such as NPE exercise, common exercise ... - strengthen the knowledge technical skill of NDC staffs through technical training course, workshop, either domestic or abroad, hold by CTBTO, IAEA ... - exploit software of NDC-in-a Box provided by CTBTO to analyze IMS data for improving NDC analysis skills of NDC staffs, including: - carrying out the analysis of spectra of RN stations of IMS by using Openspectra for particulate radionuclide and Norfy for radioxenon - practicing the Atmosphere Transportation Modeling ATM software (web grape) and Geotool (for analysing seismic data) to gain experience and skill in operating them to build technical ability.

**T5.3-P50  Promoting Civil and Scientific Applications of International Monitoring System (IMS) Data and Spin-Offs**

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During the process of tracking the globe for signs of nuclear explosions, the monitoring network of the CTBTO generates huge amounts of data that assist scientists to understand our Earth in a better way. IMS data and spin-offs can be applied by scientists and other interested parties in diverse fields, ranging from atmospheric studies to recording of earthquakes, warning of impending tsunamis and storms and tracking movements of marine mammals among others. With support from scientists, policy makers can use the data to warn people of impending disasters and therefore save lives. These efforts can contribute significantly towards expansion of human knowledge and development. A broad range of outreach initiatives and science communication including public lectures, print and electronic media, social media, training courses and conferences can be used to promote civil and scientific applications of IMS data and techniques used for nuclear test ban verification. The CTBTO, national governments, national and international organisations, academic institutions, among others can play an important part in the promotion process. Measures aimed at promoting wide civil and scientific applications of IMS data and spin-offs by relevant stakeholders are being recommended.

**T5.3-P52  Proposal for a Clean and Sustainable Energy Policy in Bolivia**

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Bolivia is a country that is recently venturing into nuclear issues such as: • Nuclear Research Reactor • Food irradiator • Cyclotron and pharmacy radio Through the creation of the ABEN Bolivian Nuclear Energy Agency in 2016, which is promoting the three points mentioned above in a single complex in an urban area of the city of...
E1 Alto in District 8 in an area of 100 hectares. In this way participation with stations of the CTBTO of radionuclides in national territory is required, through the agreements signed by Bolivia in the United Nations and being part of the CTBTO it is necessary to implement and enforce the policies in this regard through a structured plan and from within the country, that is, proposed through a bill issued by the Bolivian authorities themselves. This initiative will be possible through the technical and scientific cooperation that the CTBTO can provide to the country.

**T5.3-P53** Public Awareness and Safety

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Capacity building, education and public awareness are sorely needed for understanding and mitigating the effects of global change and nuclear explosion. Likewise, for the compliance with the CTBT and contribute for Global Peace and Security in the all regions. To heighten public awareness campaign on nuclear explosion matters, long-term and locally-based training and awareness are relevant to students, villagers, decision-makers, journalists, and other local people to better be able to deal with the nuclear explosion challenges. My research findings indicate that the capacity building, education and public awareness are powerful new approach to the design, implementation, monitoring, management, and evaluation of development technical challenges of the CTBT in the context of nuclear arms control treaties. As noted, lack of capacity building, education and public awareness address several criticisms of capacity development work, including the lack of a coherent partnerships and an effective monitoring of results. By researching the impact of a nuclear explosion, it was found out factor, like Wind, that can affect the successful detection of atmospheric radionuclide emissions from a nuclear explosion. These issues, including detection and identification Seismic sensitivities and radionuclides from nuclear power are very important in the process of technical capabilities, education and public awareness.

**T5.3-P55** Raising Awareness of Nuclear Nonproliferation Through the Capacity Building System (CBS) in Iraq NDC

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In November 2018, CTBTO staff came to Iraq to set up and install the capacity building system for our national data center. It includes analysis programs that have improved our analysis and allowed us to pinpoint the earthquakes that occurred in Iraq on the 25 November 2018. We, therefore, need to differentiate between earthquakes and events of human origin. The importance of implementing CBS is to enable us to continuously monitor and coordinate seismic activities in our region, receiving data using the International Monitoring System (IMS) data and IDC products for the region, verification of the treaty. By accessing and analyzing the seismic waveform we can educate the public about the CTBT and its verification regime by involving university students and youth interested in nuclear non-proliferation research by providing them with knowledge about CTBTO and data. We share our experiences with the Organization to promote non-proliferation goals and scientific applications. Our earthquake detection in Iraq is an example of scientific applications related to non-proliferation. The proposed paper will focus on the role and comparison between the earthquake in Iraq in 2017 and 2018 and how CBS enhances IHS data processing capabilities.

**T5.3-P56** Raising Public Awareness of the CTBT: Measuring Success, Addressing Challenges

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In recent years, the CTBTO Preparatory Commission has been very active in raising global public awareness about the dangers associated with nuclear testing and the need for the CTBT ratification, as well as the treaty’s
technical aspects. Recognizing the importance of these activities, the study evaluates, through a systematic and comparative analysis, as well as an expert survey, how successful the campaign is in communicating its message, generating positive interest, developing public support and producing behavior change among its target audiences. The study also looks at why the CTBT promoting activities are more successful in some countries than others and if they are tailored to the context, values, capacities and other attributes of local audiences, including youth. It is also useful to explore which communication tools and media provide creative and innovative ways of increasing the success of the awareness raising efforts. Based on the lessons learned, the study provides recommendations on approaches to maximize the effectiveness of the CTBTO outreach initiatives and to engage relevant national and international stakeholders with the aim to create a global culture against nuclear testing and to facilitate the treaty’s entry into force.

**T5.3-P57 Regional Training Centre-South African Perspective**

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South Africa has been a regional training centre for the Organisation for the Prohibition of Chemical Weapons (OPCW) Assistance and Protection Course and Analytical Chemistry Course since 2005. In the Assistance and Protection Course, participants dealing with the emergency response and protection against chemical weapons and toxic industrial chemicals are invited. The course covers theoretical and practical training on the usage of individual and collective protective clothing, monitoring, detection and decontamination techniques, as well as the handling of casualties after a chemical incident. In the Analytical Chemistry Course, participants are trained in sample preparation, basic analytical techniques and the use of certain laboratory equipment required for the analysis of toxic chemicals. South Africa possess skill in organising, hosting and in case of the above-mentioned conducting non-proliferation related training interventions using minimal resources and equipment that developing countries do possess. South Africa hosted the first Introductory Training Programme for African States of the CTBTO IMS in December 1995, and has been sporadically hosting CTBT training courses culminating in the Advanced Course of the On Site Inspection Third Training Cycle and the Ground and Airborne Visual Observation Course in October 2018.

**T5.3-P58 Role of CTBT in Order to Achieve SDG**

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It is impossible to achieve sustainable development in absence of peace. Nepal is a peace loving country and has already signed the CTBT. It always advocates nuclear technology for peaceful purposes and has supported the nuclear disarmament and non-proliferation. It is a landlocked country between two nuclear giants; China and India. Though Nepal has no nuclear plant and any sort of nuclear weapons, it cannot be isolated from any nuclear disaster that may happen in the neighboring countries. Thus it is a high time to establish monitoring system of background radiation level in order to assure safety to the countrymen. Up to now, there is no CTBT related activities in Nepal and many Nepalese are unaware about this treaty. It needs more popularization program to make it universal. In this context, CTBTO can penetrate in Science and Technology lagging countries like Nepal by offering some technical assistance.

**T5.3-P59 Saving Lives through Third Stream Activities and Fulfilling CTBT Objectives**

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CTBT member countries appointed technical tasks to institutions that already monitor national seismological networks. In some South American states, seismological research organizations also promote the awareness of
seismic culture in their countries, associating threat and vulnerability in delivering sound contents, i.e. best practices during earthquakes. Col & Chu established that 92% of earthquakes fatal victims can be reduced thanks to the implementation of tailored-made seismic contents. Research shows the advantages of using analogies of energy released of nuclear explosions as an appropriate mechanism to better understand seismic events and establishing an appropriate educational correlation. Third stream activities of universities and research centres have special impact among communities. This research demonstrates through case studies two folds: (1) how local scientific work and cooperation support national needs in support of CTBT objectives and (2) identify tangible solutions improving nuclear test monitoring whilst increasing earthquake culture thanks to the plethora of advantages that this investigation demonstrates.

**T5.3-P61 Strengthening Nonproliferation Norms in South Asia**

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The emerging trends in South Asia’s nuclear politics are running contrary to global non-proliferation norms. The developing trends not only have the tendency to make the nuclear norms more vulnerable, but also undermine the security of the region as a whole. The emerging trends include preferential treatment of India in civil nuclear agreements and its potential membership in the NSG, growing nuclear material stockpiles and the consistent opposition of Pakistan and India to a Fissile Material Cut-off Treaty (FMCT) and to the CTBT. Historically, India and Pakistan have developed some confidence building measures and despite hostilities have honored those norms. Likewise, India and Pakistan have honored their unilateral moratorium on nuclear testing till date, notwithstanding nuclear developments. While efforts should be made for a formal ratification of the CTBT by India and Pakistan, it is important to strengthen the norm by encouraging any step in that direction, such as a bilateral test ban treaty.

**T5.3-P62 Technical Support Provided to States Parties and Its Impact on Process of Promoting Ratification of Treaty**

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Comprehensive Nuclear-Test-Ban Treaty was adopted in 1996. It is one of the fundamental mechanisms in the field of non-proliferation and nuclear disarmament and one of the pillars of global nuclear non-proliferation regime. According Annex II Treaty shall be subject to ratification by 44 States to enter into force. Situation remains pending of the ratification of eight States (China, Egypt, Iran, India, Pakistan, North Korea and United States of America). Sudan ratified Treaty in 2004, after accession to Treaty, had many opportunities to participate in various activities organized by the Preparatory Commission (PC), training and qualification of the researchers, lawyers. In 2013 National Data Center was established, under Seismological Research Institute, National Research Center and was designated as a national authority. National Nuclear & Radiological Regulatory Act was issued in 2017. Technical support plays an important role by implemented various activities through international monitoring system and to monitor data which provides for purposes of scientific research and disaster prediction to work towards their mitigation. State Parties can enhance this role by organizing seminars; workshops raise awareness of benefits of Treaty, also to influence international community to support requirements for ratification.
T5.3-P63  The Application of International Monitoring System Data (IMS) and International Data Centre (IDC) Products at the Jordanian National Data Centre

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Jordan has established the (NDC-JO) within Jordan Seismological Observatory (JSO) under the umbrella of Ministry of Energy and Mineral Resources; this poster aims to present the application of (IMS) data and (IDC) products at (NDC-JO) and (JSO). Since its establishment, JO-NDC received data from a few IMS seismic stations, JO-NDC also utilizes the IDC Secured Website to retrieve the IDC products from time to time. For analysis activity, JO-NDC used a software package provided by CTBTO (NDC in Box). JO-NDC uses the IMS data and IDC products for various purposes such as relocate the regional seismic events by requesting waveform data from IDC product (REB and SSEB) and use it to relocate the events by using different software’s. As a result from the application of IMS data and IDC products, JO-NDC is able to strengthen its in-house capability particularly in data analysis as well as participate in any NDC related exercises organized by the CTBTO. The IDC products have enable JO-NDC to compare the accuracy of its analysis findings. JO-NDC has greatly benefited by the application of IMS data and IDC products in the aspect of building up its capability as well as enabling its participation at the international level.

T5.3-P64  The CTBT’s Relevance to the SDGs: A Virtual Education Platform for Capacity-Building

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This project aims to educate American high-school and university STEM students about the CTBT and its contributions to the 2030 Agenda for Sustainable Development, specifically focused on SDG goals 11, 13, and 14. Students in the United States are not aware of the CTBT, despite the United States’ standing as the largest financial supporter of the Treaty’s verification regime. The project participants will develop an educational tool in the form of a virtual workshop that incorporates new and existing information on how the CTBT helps advance the SDGs. Leveraging the CTBTO Youth Group network in the United States, the project leaders will establish contact with teachers and professors at the target high schools across the United States, scheduling “virtual classroom” sessions with students that will take place between March to May. In addition to the “virtual classroom” settings, the project participants will identify schools which will welcome in-person presentations. The expected outcome of this project is an increased awareness among students about the contribution of the CTBT’s verification regime to the SDGs. Once the educational tool is formed and prototyped in American classrooms, other regions would be able to adapt the workshop presentations and target them to their domestic audiences.

T5.3-P65  The Education and Public Awareness of the CTBT Through Web Application Mexico

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It is important that people is aware of the potential damages that nuclear explosions can cause not only on the land but also in the environment and health of human beings and other living species. It is also important for them know that there exists a Treaty that pretends to prohibit these practices. Sadly in Mexico most of the people is not aware of these practices of nuclear explosions and the damage that they produce in our environment. This proposal aims to promote the awareness of the CTBT as well as the labor of the CTBTO by the creation of a web application which could include information of the CTBTO and the CTBT and different resources for citizens to be aware of the importance of stopping nuclear explosions. The application may include...
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simulators, games or whatever could make it interactive and educate citizens regarding the problematics of nuclear explosions and the CTBTO/CTBT. It is also intended to give a promotion of this application through social media like YouTube, Facebook or Instagram. This application aims to be first implemented in Mexico, but in a future it is planned to implement it globally.

T5.3-P66 The Effect of Art Students’ Awareness of Nuclear Weapons on Their Artistry

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The aim of the study is to find out that nuclear weapons awareness of students who are educated in art teacher program by reflected in the pictures. The study group consist of art students at Cumhuriyet University, faculty of education in 2019 spring semester. The study is quantitative research and was carried out with quasi-experimental method. Data were collected by nuclear power plants scale which developed by Gül, Demir and Yeşilyurt (2016) and by the paintings of the students about the topic. In the first week of the process of the experimental study, the students were asked to paint the feelings they awakened about nuclear weapons. After that, students were provided with the seminars of experts in the field of nuclear weapons for three weeks. In the fourth week, students were asked whether they wanted to change the paintings they made about nuclear weapons, or whether they wanted to make a different painting again. Those who want to review their paintings or the points they want to correct in the paintings are analyzed. How increasing student awareness about nuclear weapons affects their artistic products.

T5.3-P67 The Importance of Coordination of Scientist and Policy Makers

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The National Data Center (NDC) of the Comprehensive Nuclear-Test-Ban Treaty was commissioned in Ghana in February 2010 basically to enhance and support international efforts to monitor nuclear weapons testing efficiently. The CTBTO Preparatory Commission’s education and activities aim at providing knowledge and training to experts on the treaty that bans all nuclear explosions. The CTBTO relies on innovations to strengthen the capabilities of the treaty’s verification regime. The NDC assesses areas in Ghana that are hazardous to earthquake by receiving seismic data from the International Data Center. This assists the experts at the NDC to continually update and help frame policy objectives on land and building on seismically prone regions and areas in Ghana through recommendations made to the government. CTBT discussions revitalized among policy makers, scholars, experts, students and media will create more awareness about the nuclear test ban; transferring knowledge among younger generation and integrating new technologies in CTBT promotion. The center in collaboration with other bodies and organizations often hold seminars and lecture series on earthquake disaster risk alleviation. The Provisional Technical Secretariat (PTS) take up capacity building when they empower signatory countries like Ghana with the right equipment, software and training.

T5.3-P68 The Importance of Promoting the CTBT Locally and the Benefits of Doing So

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Widespread awareness and understanding of the Comprehensive Nuclear-Test-Ban Treaty still remain a challenge. Namibia, a country of only 2.5 million people and fifth largest exporter of nuclear source material, the promotion and widespread understanding of the CTBT is continuously given attention. In a long-term effort to gain public awareness of the CTBT, the Namibia National Data Centre together with the IMS Infrasound
I35NA station actively promotes the CTBT in a variety of ways in Namibia. Public information seminars are held to explain and promote the CTBT, regular articles on CTBT, IMS, NDC and OSI related activities and training that staff members engaged in, teaching university modules on geophysical methods for non-exploration purposes, and regular visits by schools to the Tsumeb IMS station. Over the past years these efforts have resulted in increasing support from central Government to carry out CTBT related activities, the 2017 RSTT workshop held in Namibia, more students using IMS data and regular high-level visits by Namibian delegations to the Executive Secretary’s office. Most important impact is an increased understanding and appreciation for the data of the IMS and potential services and relevance of the Namibia NDC in everyday life of Namibian citizens and institutions.

T5.3-P69 The Italian CTBTO CNF: Readiness Test Status
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The National Institute for Oceanography and Experimental Geophysics (OGS) in Trieste (Italy) in cooperation with the Italian CTBTO National Authority is offering its Cludinico (CLUD) seismic station as a Cooperating National Facility (CNF) to the CTBTO; as outlined in Pesaresi and Horn (2015) the additional data from the Italian CNF improve the CTBTO location capabilities in the Europe/Middle East area of about 21%. In this presentation we will illustrate technical details of solutions adopted to incorporate the Italian CNF into the CTBTO IMS: evaluation of data acquisition systems, CTBTO Standard Station Interface (SSI) hardware and software procurement, operation and tests, UPS upgrade, anti-tamper device operations, CTBTO GCI installation and test, security measures installation. Reference: Pesaresi, D., and Horn, N.: Improving CTBTO monitoring capabilities: the Italian proposal for a CNF, CTBT Science and Technology 2015, Vienna, Austria, 22-26 June 2015, T4.1-P31, doi:10.13140/RG.2.1.2862.1927, 2015.

T5.3-P70 The Necessity of Academia-Industry-Political for Nuclear Awareness
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We live in an interconnected world characterized by the emergence of new actors and a fast pace technological environment. Prevention and awareness are critical if we wish to prevent rapid escalation of crisis and massive retaliation with Nuclear Weapons from one state to another or the use of so called “Backpack Nukes” from individual persons. Arms control should be sought within the broader scope of technology policy along with collaboration from the political and educational realms. In the 1990s the Triple Helix Concept of academia-industry-government interactions was introduced by Etzkowitz and Leydesdorff. The Comprehensive Nuclear-Test-Ban Treaty is the opportunity to bring policy-makers and engineers working together on alternative technological tools with a dual-use component, using this concept. For instance, the CTBT verification systems also contributes to environmental threat prevention. This talk will seek to first give an overview of current dual-use activities and assess their success in raising awareness. We will then explore possible case studies of synergies between the three sectors and expected positive outcomes on the CTBT and the economy. Thus, the case studies will include a political and engineering component to encompass the whole subject matter. We will conclude with recommendations and challenges to overcome.

T5.3-P71 The Role Media Can Play in Raising Awareness of the CTBTO Goals
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Media is powerful, and we should take advantage of its worldwide reach to communicate the scientific knowledge to both decision makers and the public. This will help the CTBTO in achieving its goals and its accomplishing essential mission; that’s to make The Comprehensive Nuclear-Test-Ban Treaty enter into force. Media and journalists can simplify the multitude of linkages science, technology and society have among the
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general public, by creating a compelling form of stories. Hence, engaging more young sci-journalists will attract people's attention to the benefits and importance of having the CTBTO. For instance, the IMS data and IDC products can be utilized for civil purposes (apart from their main purposes). Moreover, digital media can act as a facilitating bridge between people and nuclear science, the thing that can contribute to making the complex concepts more comprehensible to people. This needs well-trained journalists that believe in the CTBTO values and have the ability to analyze the data carefully and present them in an interesting, direct and professional way to the audience. While our audience could be policy, decision-makers or the general public. Like any other organization, the CTBTO can support this form of journalism in order to achieve its collective goals.

T5.3-P72 The Role of Member States in Providing Insight into the Substance of the CTBT: The Linkage Between ARN and the Local Community

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Argentina is bound by the Treaty to host eight monitoring stations and one radionuclide laboratory. The Nuclear Regulatory Authority (ARN) is responsible of the radionuclide and infrasound stations, and the laboratory. At present, ARN is working on the installation of two remaining stations, and foresees to make them fully operational soon. Outreach activities are conducted in parallel with technical activities, aimed at gaining the acceptance from the local community and focusing on raising awareness of the obligations of the Treaty, and on the benefits of the civil and scientific applications of the Treaty. In this endeavor, ARN needs to interact with the local authorities, in order to obtain the necessary permits for the land use, and also with a wide range of stakeholders including local supplying companies, local residents, NGOs, general public, etc., so to engage them, as appropriate. This presentation is intended to show the liaison role of ARN between the CTBTO and the local community, facilitating mutual understanding and agreement.

T5.3-P76 Travelling School

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The project is the Travelling School. This is an educational and inclusive travelling life-course for people of different age, affiliation and level of education from different countries, primarily for those Annex 2 that haven’t ratified the Treaty yet. The concept of this school is different to what we have already been doing due to its inclusiveness and equality in terms of participants. We need to approach the grassroots giving them an opportunity to contribute educating them. The education course would include the historical background, possible hazards, political framework, region’s involvement and technical side of the issue. The focus would be centered at the four SDGs: Peace, quality education, gender equality and partnership. The best solution for project implementation is to involve CYG members as mentors who would travel to countries and hold the schools for different groups of population. The expected outcome is raising people awareness and concern about the issue, making them understand the whole groundwork which would make their approach to their government solid and trustworthy. We will make them prepared for promoting our general idea by carrying out the project work during the school allowing them to propose ideas and concerns on the topic.
T5.3-P77 Two Courses on Comprehensive Nuclear-Test-Ban Treaty: Political, Legal and Technical Aspects’ and Intensive Policy Course on “Comprehensive Nuclear-Test-Ban Treaty: Political, Legal and Technical Aspects”

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1. Keeping in view this concept, I believe that the courses which I attend at the Preparatory Commission for Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) namely: CTBT’s Advanced Science Course and Diplomacy and Public Policy, built my understanding to comprehend the complex debate surrounding nuclear non proliferation and disarmament in general and the politics behind nuclear testing in particular. Additionally, Theoretical and practical experience which I gained from field visits, Table-top exercise and Executive Council simulations helped me to formulate a course titled: Comprehensive Nuclear-Test-Ban Treaty: Political, Legal and Technical Aspects’ for MY University. It is a three credit course and offered as a part of bachelor’s programme for international relations to university students. This course enables the students to confront the challenges of the twenty-first century’s shifting security landscape and also promotes recognition of the importance of the CTBT. 2. a two-week Intensive Policy Course on “Comprehensive Nuclear-Test-Ban Treaty: Political, Legal and Technical Aspects”. The central theme behind this endeavor is to increase the awareness and stimulate understanding of the Treaty in order to promote its entry into force and universalization.

T5.3-P79 Understanding of Nuclear-Weapons-Related Issues Among Practitioners in Indonesia

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Indonesia has consistently supported nuclear non-proliferation: Despite this, the Indonesian public still perceives all 'nuclear issues' in the pejorative, limited sense of 'nuclear weapon issues'. Therefore, it is important that both stakeholders and practitioners are familiar with the aspects surrounding nuclear weapons, most importantly the treaties which constrain them, in order to answer the most common topics of public inquiry without misleading. Correct information pertaining the issue is important, both to raise public awareness and counter negative perceptions on nuclear issues. This study aims to measure the degree of understanding about nuclear weapons and non-proliferation issues, as held by the stakeholders and practitioners belonging to nuclear-related institutions within Indonesia. The study was conducted using a dichotomous answer questionnaire with True/False answers consisting of 12 questions, split into 4 sections: nuclear weapons testing, the CTBT and Indonesia's role in non-proliferation treaties, detection methods for nuclear tests, and the use of nuclear weapons. The questionnaire was distributed among the personnel of the National Nuclear Energy Agency (BATAN) and the Nuclear Energy Regulatory Agency (BAPETEN). The results show that cursory understanding of 'popular' issues among nuclear-related personnel is still lacking, despite said personnel being the most likely targets of public inquiry.

T5.3-P81 Verification Regime Versus Sustainable Development Goals: How Can Ghana Benefit from the Radionuclide Technology in Achieving Sustainable Development Goals

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The CTBTO is setting up 337 facilities to monitor nuclear explosions in the world. The technologies used by the CTBTO in monitoring include seismic technology, infrasound technology, hydroacoustic technology and radionuclide technology. The radionuclide technology measures radioactive particles and noble gases. It is also referred to as the ‘smoking gun’. It is the confirmatory test for all the waveform technologies. The Sustainable
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Development Goals (SDGs) are a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity. This work seeks to identify ways to merge the activities of CTBTO to the SDGs with respect to the radionuclide technology which can further help with national development. How can a country like Ghana benefit from the radionuclide technology such that at least one SDG is achieved? Monitoring stations can be set up in the country as this will help the country monitor the radionuclides in the atmosphere. The awareness of the role of CTBTO in radionuclide monitoring can be created through symposia, fora and media engagement. Predictive models can be used to assess the potential health impacts of radiation. Job opportunities and improvement in the health sector may be expected upon work completion.

**T5.3-P82  Wake Up Pakistan!**

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Today’s youth is going to be the next generation of policy makers, politicians, and bureaucrats and thus in order to push Pakistan closer to ratifying the CTBT we need to educate its youth. Many of my peers in Pakistan don’t know about the CTBT and this worries me. For this reason, my project proposes a 4-stage plan that can be put into effect for capacity building of Pakistani Youth. The first stage requires the introduction of courses related to nuclear weapons and arms control in the top universities of the country. These courses will serve to unite like-minded students that support the cause of CTBT. In the second stage, these group of intellectuals can be encouraged to form a branch of the Youth Group in Pakistan. Third, this group will go from city to city spreading its message in different schools and universities. This will encourage the formation of more branches of the youth group. For the final stage, these youth activists will meet with government officials in the Ministry of Foreign Affairs to have larger conversations about the proposed bilateral moratorium on nuclear testing with India. Thus, this initiative will bring the issue of CTBT ratification into public discourse.

**T5.3-P83  West African Countries Collaborate on the Promotion of Joint Research Projects and CTBT Academic Curricula**

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Low level of research collaborations has been the bane of scientific development within West African region. However, an unprecedented milestone was achieved in 2017 as researchers from Cameroon, Nigeria, Benin Republic, Togo, Ghana and Senegal have joined forces to work towards advancing research activities and promote integration of CTBT Academic curricula in the region. The group met during the last quarter of 2017 to work out modalities for rapid attainment of its resolutions. The meeting which attracted researchers, academia and students cutting across most disciplines from higher institutions, gave rise to fundamental research prospects in the region which include the use of IMS products for integrated research, ambitious data sharing, joint research projects and knowledge exchange, overall diversification and integration of knowledge-based CTBT academic curricula in key institutions in the region. One of the strategies adopted by the group include involvement of ECOWAS as a regional block for quick policy implementation. The group equally identified some challenges that may hinder meaningful research and prospect of incorporation of CTBT academic curricula which include ease of access to CTBT materials, internet-based tools, and CTBT course accreditation etc. Region-based solutions have also been proposed to address the aforementioned constraints.
T1.1-O3 Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound Propagation and Scattering in the Atmosphere

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The experimental results of studying the effect of a fine-scale layered structure of a stably stratified atmospheric boundary layer (ABL) on fluctuations of the parameters of acoustic pulses generated with a certain period (1 min) by an artificial detonation source are presented. The vertical profiles of wind velocity fluctuations in the thin layers of the ABL have been retrieved using the wave forms and travel times of the recorded arrivals of pulses from the source. It is shown that the mechanism of scattering of pulse signals in a stably stratified ABL is similar to the mechanism of scattering of signals from ground surface explosions by layered nonhomogeneities of wind velocity and temperature in the stratosphere and lower thermosphere. The role of similarity parameter here place the dimensionless thickness of the reflecting nonhomogeneous layers, which is the vertical scale of the layer multiplied by the relative difference in effective sound velocity and normalized by the vertical wavelength. The effect of such inhomogeneities on the temporal fluctuations of the azimuth and arrival times of the signals is studied. The estimation of the error in localization of pulsed sources is given.

Acknowledgement: This work was supported by RFBR N 18-55-05002

T1.1-O4 Climate Change Through the Eyes of Radioisotopes

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Cosmogenic radionuclides beryllium-7 and sodium-22 are known atmospheric tracers and can be used together in a lock-in technique to effectively trace vertical air masses based on surface measurements. This technique allows to study progression and speed of atmospheric cells. Data show that the cells are decelerating during the summer period which is extending in time. This is caused by warming of the whole troposphere and increased tropopause height due to rising CO2 concentrations. Aestival episodes of persistent high-pressure systems over Europe with low pressure gradients that led to almost stationary thunderstorms are correlated with the observed deceleration of atmospheric cell movement. This demonstrates that 7Be and 22Na can be used as indicators for confirming several side effects of climate change while providing a new modelling tool in seasonal weather forecast.

T1.1-O5 Detection Efficiency of the IMS for Bolides

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In this study we examined 344 bolides (airbursts) reported on the JPL CNEOS website (https://cneos.jpl.nasa.gov/fireballs/) between 2007-2018 and attempt to correlate these with infrasound detections. We found 206 of these bolides were detectable by at least one infrasound station while only 42 were automatically registered as part of the Reviewed Event Bulletin (REB) issued daily by CTBTO. However, this global REB detection rate of ~10% averaged from 2007-2018 is less than the “modern” rate (from 2014-2018) which approaches 20%. Above the 1 kT CTBTO design threshold, we find that 40% of airbursts are reported in the REB, while more than 90% are detectable at one or more infrasound stations. All airbursts with energy > 2 kT reported on the JPL fireball site since 2007 have been detected infrasonically. However, the REB is only complete above 15 kT with the automated detection system not having reported at least four airbursts with...
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T1.1-O3 Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound

This demonstrates that 7Be and 22Na can be used as indicators for deceleration of atmospheric cell movement. This confirms several side effects of climate change while providing a new modeling tool in seasonal weather forecasting.

In this study we examined 344 bolides (airbursts) reported on the JPL CNEOS website between 2007-2018 and attempt to correlate these with infrasound detections. We found 206 of these bolides were detectable by at least one infrasound station while only 42 were the REB, while more than 90% are detectable at one or more infrasound stations. All airbursts with energy > 2 kT reported on the JPL fireball site since 2007 have been detected infrasonically. However, the REB is only complete above 15 kT with the automated detection system not having reported at least four airbursts with the REB.
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In this study we examined 344 bolides (airbursts) reported on the JPL CNEOS website. We found 206 of these bolides were detectable by at least one infrasound station while only 42 were automatically registered as part of the Reviewed Event Bulletin (REB) issued daily by CTBTO. However, this allows to study progression and speed of atmospheric cells. Data show that the cells are decelerating during the deceleration of atmospheric cell movement. This demonstrates that 7Be and 22Na can be used as indicators for allows to study progression and speed of atmospheric cells. Data show that the cells are decelerating during the

The experimental results of studying the effect of a fine-scale layered structure of a stably stratified atmospheric boundary layer (ABL) on fluctuations of the parameters of acoustic pulses generated with a certain period (1 wavelength. The effect of such inhomogeneities on the temporal fluctuations of the azimuth and arrival times of the layer multiplied by the relative difference in effective sound velocity and normalized by the vertical

It is shown that the mechanism of scattering of pulse signals in a stably stratified ABL is similar to the mechanism of scattering of signals from ground surface explosions by layered nonhomogeneities pulses from the source. It is shown that the mechanism of scattering of pulse signals in a stably stratified ABL is similar to the mechanism of scattering of signals from ground surface explosions by layered nonhomogeneities
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The experimental results of studying the effect of a fine-scale layered structure of a stably stratified atmospheric boundary layer (ABL) on infrasound wave propagation are presented. Specifically, the influence of the ABL on infrasound wave propagation is investigated using both theoretical and experimental approaches. The theoretical analysis is based on the linearized acoustic wave equation, while the experimental study involves the measurement of the vertical profiles of wind velocity fluctuations in the ABL.

The findings indicate that the ABL significantly affects infrasound wave propagation due to the presence of thin layers with different sound velocities. The role of similarity parameter in the decay of infrasound waves is also highlighted. The results are consistent with the theoretical predictions and provide insights into the processes that govern infrasound wave propagation in the ABL.

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T1.1-O3 Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound

The Atmospheric Boundary Layer (ABL) is crucial for understanding infrasound propagation, which is vital for monitoring low-yield nuclear tests. It plays a significant role in the detection efficiency of infrasound stations.

The ABL is characterized by vertical fluctuations of wind velocity, which impact infrasound propagation. These fluctuations are due to the instability of the boundary layer, which can affect the detection of infrasound signals.

In this study, we examined the ABL to understand the mechanisms of infrasound propagation and detection. The vertical profiles of wind velocity fluctuations in the ABL on fluctuations of the parameters of acoustic pulses generated with a certain period (1 min) by an artificial detonation source are presented.

The effect of such inhomogeneities on the temporal fluctuations of the azimuth and arrival times of pulses from the source is investigated. It is shown that the mechanism of scattering of pulse signals in an ABL is influenced by the vertical scale of the reflecting nonhomogeneous layers.

The dimensionless thickness of the reflecting nonhomogeneous layers, which is the vertical scale of the boundary layer multiplied by the relative difference in effective sound velocity and normalized by the vertical wavelength, is a key parameter in the scattering of pulse signals in the ABL.

Cosmogenic radionuclides beryllium-7 and sodium-22 are known atmospheric tracers and can be used together with infrasound detection to study climate change. These radionuclides are produced in the atmosphere by cosmic-ray spallation of nuclei and can be used as indicators for changes in the tropopause height due to rising CO2 concentrations.

This work was supported by RFBR N 18-55-05002.
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In a lock-in technique to effectively trace vertical air masses based on surface measurements. This technique allows to study progression and speed of atmospheric cells. Data show that the cells are decelerating during the summer period which is extending in time. This is caused by warming of the whole troposphere and increased tropopause height due to rising CO2 concentrations. Aestival episodes of persistent high-pressure systems over the summer. The infrasound detection of these events is crucial for understanding the atmospheric dynamics and for modeling purposes.

The signals is studied. The estimation of the error in localization of pulsed sources is given. Acknowledgement:

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T1.1-O4 Climate Change Through the Eyes of Radioisotopes

Cosmogenic radionuclides beryllium-7 and sodium-22 are known atmospheric tracers and can be used together with other techniques to study climate change. These isotopes are produced in the atmosphere by the interaction of cosmic rays with atomic nuclei. Their subsequent decay produces a set of radioactive daughters that can be tracked over time.

The distribution of these isotopes can be used to infer past climate conditions, such as temperature and precipitation. For example, increases in the concentration of 7Be and 22Na can be correlated with periods of increased volcanic activity or changes in ocean circulation. Additionally, the production of these isotopes is sensitive to changes in solar activity, which can also influence climate.

The global REB detection rate of ~10% averaged from 2007-2018 is less than the "modern" rate (from 2014-2018) of about 30%. This suggests that infrasonic detection is effective but not complete. However, the REB, while more than 90% are detectable at one or more infrasound stations. All airbursts with energy > 2 kT reported on the JPL fireball site since 2007 have been detected infrasonically. However, the REB is only complete above 15 kT with the automated detection system not having reported at least four airbursts with energy > 2 kT. This indicates that there is a gap in detection at lower energies, and further improvements are needed to capture a wider range of events.

The infrasound detection of these events is crucial for understanding the atmospheric dynamics and for modeling purposes. For example, the infrasound data can be used to infer the location and size of the source, which can then be compared with other data such as seismic and optical observations. This can help to improve our understanding of the sources of infrasound, such as volcanic eruptions, earthquakes, and meteorite impacts.
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T1.1-O3 Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound...

The experimental results of studying the effect of a fine-scale layered structure of a stably stratified atmospheric boundary layer (ABL) on fluctuations of the parameters of acoustic pulses generated with a certain period (1 min) by an artificial detonation source are presented. The vertical profiles of wind velocity fluctuations in the ABL are measured in a lock-in technique to effectively trace vertical air masses based on surface measurements. This technique allows to study progression and speed of atmospheric cells. Data show that the cells are decelerating during the austral episodes of persistent high-pressure systems over Europe with low pressure gradients that led to almost stationary thunderstorms are correlated with the observed tropopause height due to rising CO2 concentrations. Aestival episodes of persistent high-pressure systems over Europe with low pressure gradients that led to almost stationary thunderstorms are correlated with the observed tropopause height due to rising CO2 concentrations. Aestival episodes of persistent high-pressure systems over Europe with low pressure gradients that led to almost stationary thunderstorms are correlated with the observed tropopause height due to rising CO2 concentrations. Aestival episodes of persistent high-pressure systems over Europe with low pressure gradients that led to almost stationary thunderstorms are correlated with the observed tropopause height due to rising CO2 concentrations. Aestival episodes of persistent high-pressure systems over Europe with low pressure gradients that led to almost stationary thunderstorms are correlated with the observed tropopause height due to rising CO2 concentrations. Aestival episodes of persistent high-pressure systems over Europe with low pressure gradients that led to almost stationary thunderstorms are correlated with the observed tropopause height due to rising CO2 concentrations. Aestival episodes of persistent high-pressure systems over Europe with low pressure gradients that led to almost stationary thunderstorms are correlated with the observed tropopause height due to rising CO2 concentrations. Aestival episodes of persistent high-pressure systems over Europe with low pressure gradients that led to almost stationary thunderstorms are correlated with the observed tropopause height.
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T1.1-O3 Atmospheric Boundary Layer as a Laboratory for Modeling Infrasound Propagation and Scattering in the Atmosphere

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The experimental results of studying the effect of a fine-scale layered structure of a stably stratified atmospheric boundary layer (ABL) on fluctuations of the parameters of acoustic pulses generated with a certain period (1 min) by an artificial detonation source are presented. The vertical profiles of wind velocity fluctuations in the thin layers of the ABL have been retrieved using the wave forms and travel times of the recorded arrivals of pulses from the source. It is shown that the mechanism of scattering of pulse signals in a stably stratified ABL is similar to the mechanism of scattering of signals from ground surface explosions by layered nonhomogeneities of wind velocity and temperature in the stratosphere and lower thermosphere. The role of similarity parameter here place the dimensionless thickness of the reflecting nonhomogeneous layers, which is the vertical scale of the layer multiplied by the relative difference in effective sound velocity and normalized by the vertical wavelength. The effect of such inhomogeneities on the temporal fluctuations of the azimuth and arrival times of the signals is studied. The estimation of the error in localization of pulsed sources is given. Acknowledgement: This work was supported by RFBR N 18-55-05002

T1.1-O4 Climate Change Through the Eyes of Radioisotopes

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Cosmogenic radionuclides beryllium-7 and sodium-22 are known atmospheric tracers and can be used together in a lock-in technique to effectively trace vertical air masses based on surface measurements. This technique allows to study progression and speed of atmospheric cells. Data show that the cells are decelerating during the summer period which is extending in time. This is caused by warming of the whole troposphere and increased tropopause height due to rising CO2 concentrations. Aestival episodes of persistent high-pressure systems over Europe with low pressure gradients that led to almost stationary thunderstorms are correlated with the observed deceleration of atmospheric cell movement. This demonstrates that 7Be and 22Na can be used as indicators for confirming several side effects of climate change while providing a new modelling tool in seasonal weather forecast.

T1.1-O5 Detection Efficiency of the IMS for Bolides

P. Brown, N. G...