Infrasound Technology Workshop 2019 (ITW2019)

Report of Contributions

https://conferences-test.ctbto.org/e/19

ID: Type: **Oral**

Infrasound technology - status and projects

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. Alongside these efforts, the IDC and its partners also focuses on expanding the capabilities in NDC-in-a-Box (NiaB), which is a software package specifically aimed at the CTBTO user community, the National Data Centres (NDC).
An objective of this presentationis to illustrate the latest efforts by IDC to increase trust in its products, while continuing its infrasound specific effort on reducing 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 presentation also focuses on a number of areas for improvement that the IDC identified for its infrasound system.

Primary author: MIALLE, Pierrick (CTBTO Preparatory Commission)

Presenter: MIALLE, Pierrick (CTBTO Preparatory Commission)

Track Classification: PTS Infrasound Technology Projects

ID: Type: **Oral**

IMS Infrasound Network – Station and Engineering Projects

The infrasound component of the International Monitoring System (IMS), often referred to as the IMS infrasound network, is composed of sixty stations. Fifty-one of these stations are already certified and transmit data in near real-time to the International Data Centre, Vienna, Austria. The Provisional Technical Secretariat (PTS) of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty (CTBTO) is actively working on the completion and the sustainment of the IMS infrasound network. In this presentation, the recent achievements related to the installation and major upgrade of IMS infrasound stations will be presented. The main infrasound engineering and development projects carried out by the PTS will also be reviewed. This includes projects to improve station reliability and resilience, data availability and measurement quality with the objective to reach compliance with all the requirements defined in the IMS Operational Manual.

Primary author: MARTY, Julien (CTBTO)

Presenter: MARTY, Julien (CTBTO)

Track Classification: PTS Infrasound Technology Projects

ID: Type: **Oral**

Assurance/Quality Control Processes at the National Center for Physical Acoustics (NCPA) Infrasound Calibration Facility

The NCPA has developed an infrasound calibration facility capable of calibrating sensors over frequencies from 0.002-20 Hz and amplitudes from a few milli-pascal to 40 Pa. The static pressure in the tank can be varied from 40 kPa to 120 kPa, and the effects of temperature can be tested for variations from -20℃ to ±45℃. Here we discuss quality assurance (QA) evaluation of different types of sensors as well quality control (QC) testing used in screening of individual sensors before being deployed. Typical results will be presented, as well as specific methodologies for QA and QC. One sensor that is of particular interest is the Hyperion sensor, a variant of which is being considered for use in International Monitoring System (IMS) infrasound arrays. The Hyperion sensor is an outgrowth of sensor development at the NCPA. Under a licensing agreement between Hyperion and the University of Mississippi (UM), the NCPA is involved in QA testing of any variant on the Hyperion sensor, as well as QC testing of each sensor shipped under the UM licensing agreement. Results from QA/QC testing of the Hyperion sensor as well as QA/QC processes adopted by the NCPA will be a particular focus of this talk.

Primary author: TALMADGE, Carrick (University of Mississippi/NCPA)

Presenter: TALMADGE, Carrick (University of Mississippi/NCPA)

Track Classification: Measurement Systems

ID: Type: **Oral**

# of a gas-combustion infrasound source

An invaluable tool in characterizing any receiver is a source with known and repeatable signal characteristics. This talk discusses development and characterization of a non-explosive, coherent source within the IMS infrasound band for the purpose of on-site calibration and detection system testing. Development of an infrasound band source is challenging because of the requirement to move a large volume of air to generate useful signal levels. According to the simple source equation, as frequency decreases, the volume velocity must increase by the inverse factor of the frequency in order to maintain an equal pressure amplitude at equal range. For this reason, a novel method is being developed using the large energy density available in gas combustion for periodic thermal expansion of an air mass. This engineering development builds on previous academic work (funded in part by the Graduate Program in Acoustics at Penn State) by the authors (Smith and Gabrielson, J. Acoust. Soc. Am.137, 2407(2015) and Smith and Gabrielson, Proc. Mtgs. Acoust. 176 ASA, Vol.35, 045004(2018)). Measurements from a large liquid-propane burner system from a hot air balloon, comparisons with a first-order thermodynamic model, and design and development of a purpose built propane burner for infrasound generation will be discussed.

Primary author: SMITH, Chad (The Pennsylvania State University, Applied Research Laboratory)

Presenter: SMITH, Chad (The Pennsylvania State University, Applied Research Laboratory)

Track Classification: Measurement Systems

ID: Type: **Oral**

reference sensors for in-situ calibration

One approach for meeting the on-site calibration requirements for infrasound stations of the International Monitoring System (IMS) involves installation of one or more reference sensors at each element. Sandia National Laboratories (SNL) has equipped two of its Facility for Acceptance, Calibration and Testing (FACT) Site Array (FSA) elements with reference sensors – two at each of the two elements – to evaluate various implementations of permanent reference sensors. The performance of these references has been studied for more than a year. The principal goal of the project is to recommend a reference-sensor configuration for operational IMS infrasound elements to enable reliable, remote determination of element response by in-situ calibration. In this presentation, several issues will be addressed: (1) limitations of a single reference sensor balanced against the cost of two references at each element; (2) number and orientation of inlet pipes for the reference sensor; (3) potential for response errors using permanent references. [Funded by the US Defense Threat Reduction Agency. Approved for public release]

Primary author: SMITH, Chad (The Pennsylvania State University, Applied Research Laboratory)

Presenter: SMITH, Chad (The Pennsylvania State University, Applied Research Laboratory)

Track Classification: Measurement Systems

ID: Type: **Oral**

Generation Power Systems of CTBTO's International Monitoring System (IMS)

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.

Primary author: ROBERTSON, James (CTBTO)

Presenter: ROBERTSON, James (CTBTO)

Track Classification: Measurement Systems

ID: Type: **Oral**

Assurance Infrastructure of IMS Infrasound Measurements

A quality assurance infrastructure for IMS infrasound measurements has been developed to comply with the certification, revalidation and calibration requirements defined in the Operational Manual for Infrasound Monitoring and the International Exchange of Infrasound Data (CTBT/WGB/TL-11,17/17/Rev.6). This quality assurance infrastructure follows guidance from the Report of Working Group B to the Third Session of the Preparatory Commission for the Comprehensive Nuclear Test-Ban Treaty Organization (CTBT/PC/III/1/Add.2) on the development of a quality assurance programme. This infrastructure is based on international standards and best practices in the field of infrasound metrology, and resulted from international collaborations with experts in the fields of infrasound technology, infrasound sensor development, infrasound sensor testing and calibration, laboratory and field metrology, quality assurance, and international standardization. The objective of this presentation is to summarize the advances made on this work programme over the last two years. The presentation will also highlight how the significant work carried out by the expert community (work to be presented in the 10+ presentations of the ITW 2019 session on "Measurement Systems and Calibration") actively supports this programme.

Primary author: MARTY, Julien (CTBTO)

Presenter: MARTY, Julien (CTBTO)

Track Classification: Measurement Systems

ID: Type: **Oral**

experiences with passive on-site calibration made at IMS infrasound array IS26

As part of the International Monitoring System a dedicated 60-element infrasound network is currently under construction to monitor compliance with the Comprehensive Nuclear-Test-Ban Treaty. As of now, 51 out of these 60 stations are certified and operational. The infrasound signals of interest are typically in the range from 0.02 to 4 Hz. The measurement of these acoustic signals takes place outdoors and even weak acoustic background noise, such as light winds, might overwhelm the signal of interest. To average spatially over the short wavelength acoustic background noise field, an infrasound element consists of a transducer connected to a wind-noise-reduction system consisting of multiple inlet pipes. For being able to fully understand the systems' ability to detect and identify acoustic events, it is crucial to obtain knowledge about the complete frequency response of the system.
Therefore, a passive calibration method has been deployed at IMS station IS26, Germany, in 2015; whereas at each of the eight array elements a calibrated reference microbarometer with a single inlet port is located beside a regular microbarometer being connected to a wind-noise reduction system. Following Gabrielson approach (2011) we have analyzed data from all array elements in the frequency range of interest to estimate the variation in the operational element sensitivity, considering the coherency in the background noise, through the seasons and years. Moreover, for long period background noise we have studied inter-site correlation for both the reference and standard sensors. This work is part for establishing traceability in on-site calibration of an infrasound array following international standards in metrology.

Primary author: GAEBLER, Peter Jost (Federal Institute for Geosciences and Natural Resources (BGR))

Presenter: GAEBLER, Peter Jost (Federal Institute for Geosciences and Natural Resources (BGR))

Track Classification: Measurement Systems

ID: Type: **Oral**

# of infrasound metrology and testing at CEA

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 and the elements necessary for the resulting decision-making. The CEA's metrology activity in the infrasound field has historically contributed to the development of this confidence. The fields of low-frequency dynamic environmental metrology are not the most part covered by the international metrology organizations, responsible for materializing and ensuring the traceability 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 acquiring laboratories, standards and calibration methods designed to meet current and foreseen metrological challenging needs. This presentation will focus on CEA's metrology activity through its new measurement and testing facilities dedicated to infrasound sensors.

Primary author: VINCENT, Paul (Commissariat à l'énergie atomique et aux énergies alternatives (CEA))

Presenter: VINCENT, Paul (Commissariat à l'énergie atomique et aux énergies alternatives (CEA))

Track Classification: Measurement Systems

ID: Type: **Oral**

long-term infrasound sensor comparison results and application to I53US and US IMS arrays

Comparison of infrasound sensor responses from field-based testing at the Sandia National Labs FACT site has revealed notable deviations from lab-based calibrations under standard conditions of temperature and pressure. All sensors tested have exhibited amplitude variations occurring on both long-term (months) and short-term (diurnal) timescales. Here we present results from continued field testing over the past year, including the response of five infrasound sensors (two MB3a's, a Hyperion IFS-5100, a Chaparral M64LN, and a Chaparral M64Plus) connected to a single port to the atmosphere, as well as internal and external temperature, humidity, and absolute pressure sensors. We examine the sensor response and performance as a function of time and compare it to lab-based calibrations and environmental conditions. As a result of this testing, the U.S. is in the process of replacing the Chaparral 50A at US IMS arrays and installing a reference sensor at each element. We will present the installation and testing of the replacement Hyperion sensors at I53US and how the reference sensors will be implemented and used.

Primary author: FEE, David (Defense Threat Reduction Agency, Nuclear Arms Control Technology Program)

Presenter: FEE, David (Defense Threat Reduction Agency, Nuclear Arms Control Technology Program)

Track Classification: Measurement Systems

ID: Type: **Oral**

Calibration of Infrasound Sensors in a Long-Term Field Study

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 several 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. Observations from field tests indicate that changes in sensor sensitivity are correlated with environmental conditions, such as temperature and barometric pressure. Work has been performed to evaluate the sensor's sensitivity under controlled laboratory conditions as a function of similar changes in temperature and barometric pressure. These laboratory measurements are compared against the field comparisons to determine if they are sufficient to predict what has been observed in the field

Primary author: MERCHANT, Bion John (Sandia National Laboratories)

Presenter: MERCHANT, Bion John (Sandia National Laboratories)

Track Classification: Measurement Systems

ID: Type: **Oral**

of the temperature coefficient of microbarometers

In operational condition, infrasound sensors are subject to extraneous disturbances including environmental variations and in particular variation of the ambient air temperature. Susceptibility of sensors to these variations is considered to be a key point that contributes to the overall level of expected performance and confidence in measurement in complement to basic calibration. A new evaluation of that influencing quantity associated with the temperature coefficient of the microbarometers was carried out by CEA in laboratory and on field with several MB3, some reference microphones and a MB2005. The presentation will show a consistent competitive analysis of the NACT experiment data, then it will focus on the similar experiment conducted at CEA: set-up, analysis methodology, preliminary results and some perspectives in this new field of measurement.

Primary author: VINCENT, Paul (Commissariat à l'énergie atomique et aux énergies alternatives (CEA))

Presenter: VINCENT, Paul (Commissariat à l'énergie atomique et aux énergies alternatives (CEA))

Track Classification: Measurement Systems

ID: Type: **Oral**

PTS Activities Related to IMS Network Infrasound Sensors

The PTS has made a concerted effort over the last 10 years to explore and test multiple infrasound sensors, which could be approved for deployment within the IMS infrasound network. Approving a sensor model for use in the IMS network (type approval) involves many steps including, but not limited to, sensor testing at accredited laboratories, testing within operational conditions, assessment of manufacturer's quality management (including calibration and testing capabilities) and engineering assessment of sensor integration into IMS network infrastructure. This presentation will review the steps included in IMS sensor type approval and present the latest testing observations made of sensors currently under this process.

Primary author: ROBERTSON, James (CTBTO)

Presenter: ROBERTSON, James (CTBTO)

Track Classification: Measurement Systems

ID: Type: **Poster**

# of Experimental Hyperion Infrasound Shrouds as an Improved Means of Wind Noise Attenuation

We evaluate experimental shrouds mounted on Hyperion IFS-5201W digital infrasound sensors. The experimental shrouds were designed by Doug Seastrand and Gary Walker of the Nevada National Security Site, National Nuclear Security Administration, as a means to further reduce wind noise. The shrouds inter-mix air pressure sampled, around the axially-symmetrical sensor body, through specially-machined plates integral to the shroud. Our evaluations take place at Sandia National Laboratories' Facility for Acceptance, Calibration and Testing (FACT) site, in Albuquerque, New Mexico, USA. Our evaluations include both laboratory acoustic isolation chamber tests and field tests. The acoustic isolation chamber tests utilize a MB2005 infrasound sensor as a reference throughout the evaluation process while ambient conditions, such as temperature, pressure and relative humidity are held nearly constant. These tests sample frequencies over the International Monitoring System (IMS) infrasound passband (0.02 Hz to 4 Hz) as a means to compare the instrument response of the sensors utilizing the experimental shrouds to that of a sensor with the standard open-port shroud. The field tests compare in-situ data collected from sensors utilizing the experimental shrouds with data collected from a sensor mounted with a standard open-port Hyperion shroud. We present preliminary results of these evaluations.

Primary author: SLAD, George (Sandia National Laboratories)

Presenter: SLAD, George (Sandia National Laboratories)

Track Classification: Measurement Systems

ID: Type: **Oral**

# of Infrasound Wind Noise Reduction Systems for Use in Temporary Deployments

Low frequency sound between 0.01-20 Hz, known as infrasound, is produced by a variety of natural and anthropogenic sources. Within this frequency band, wind is a persistent source of infrasonic noise. Infrasound sensors measure pressure fluctuations, which scale with the ambient density and velocity fluctuations of ground winds. Therefore, reducing wind velocity works to lower the signal detection threshold. Robust wind noise reduction methods have been extensively studied, but systems such as these are not ideal for temporary deployments. Here we compare four different wind noise reduction systems and make recommendations for temporary infrasound deployments. Our results show that there are two systems that are especially effective at reducing wind noise on Hyperion IFS-3000 series microphones: 1) a Hyperion high frequency (HF) shroud with a 1 m diameter metal mesh dome placed on top of it and 2) a Hyperion Four Port Garden Hose shroud with 4 Miracle-Gro Soaker System garden hoses. We also find that placing a 5-gallon bucket over the HF wind shroud provides a negligible decrease in noise up to 8 Hz and then an increase in noise. Both the soaker hose system and the Hyperion HF shroud and metal mesh dome perform the best, but it is up to the researcher to determine the which system is best for their needs based on location and funding for upkeep. We anticipate this study will be used as a resource for future infrasound deployments. For example, when a wind noise reduction method is necessary, but is only needed for a limited time period.
This research was funded by the National Nuclear Security Administration, Defense Nuclear Nonproliferation Research and Development (NNSA DNN R&D). The authors acknowledge the important collaborations with interdisciplinary scientists and engineers from LANL, LLNL, SNL, PNNL and MSTS. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Primary author: ALBERT, Sarah (U.S. Department of Energy, National Nuclear Security Administration)

Presenter: ALBERT, Sarah (U.S. Department of Energy, National Nuclear Security Administration)

Track Classification: Measurement Systems

ID: Type: **Oral**

# of traceability to the International System of Units of infrasound measurements

The primary standard for sound pressure is defined through the reciprocity calibration method specified in the International Electrotechnical Commission (IEC) Standard 61094-2:2009. This method is based on the use of closed couplers and is routinely applied by the National Metrology Institutes for a large frequency range; however, infrasonic frequencies below 2 Hz have not been explored until recently. This is revealed by the absence of calibration and measurement capabilities (CMCs) in the Bureau International des Poids et Mesures (BIPM) database for frequencies below 2 Hz. Although the extension to infrasound frequencies of the reciprocity calibration method can be achieved theoretically, this extension implies implementation problems because of the reciprocity calibration setup (microphones and couplers), initially not intended for such use. In particular, the low signal-to-noise ratios and the acoustic leakages involved at very low frequencies limit the use of the reciprocity method requiring an alternative method. In this paper, is presented first the international organisation of the metrology ensuring a single coherent system of measurements throughout the world. In a second step, is presented an alternative method based on a laser pistonphone aiming to achieve the traceability to the International System of Units (SI) of infrasound measurements and how this traceability can be recognised internationally.

Primary author: RODRIGUES, Dominique (LNE)

Presenter: RODRIGUES, Dominique (LNE)

Track Classification: Measurement Systems

ID: Type: **Oral**

time periods during which to undertake in-situ infrasound calibration using across-array coherence measurements

In-situ reference sensors (without wind noise reduction systems) are being installed at IMS infrasound arrays, next to each operational sensor. Without additional information, coherence measures between the reference and operational sensor recordings are unable to separate time periods for which the ambient pressure fluctuations across both sensors are dominated by either long wavelength acoustic waves or shorter wavelength wind-generated turbulence. We show, using data from four IMS arrays, that a combination of across-array coherence (semblance) and power measurements can assist in separating acoustic and turbulent pressure regimes. Such measures may allow automatic identification of time periods for which the proposed in-situ calibration technique is applicable across the 0.02 to 4Hz passband. We report on progress towards constructing a statistical signal model that may underpin an objective methodology for identifying such time periods.

Primary author: GREEN, David (AWE Blacknest)

Presenter: GREEN, David (AWE Blacknest)

Track Classification: Measurement Systems

ID: Type: **Oral**

component of the Hyperion type approval testing and recapitalization

As a result of the long term sensor comparison testing at the Sandia National Labs FACT site, the U.S. is in the process of replacing the Chaparral 50A at US IMS arrays and installing a reference sensor at each element. We will present the installation and testing of the replacement Hyperion sensors at I53US and how the reference sensors will be implemented and used.
This work was supported by the Nuclear Arms Control Technology (NACT) Program at Defense Threat Reduction Agency (DTRA). Approved for public release; Distribution is unlimited.

Primary author: FEE, David (Defense Threat Reduction Agency, Nuclear Arms Control Technology Program)

Presenter: FEE, David (Defense Threat Reduction Agency, Nuclear Arms Control Technology Program)

Track Classification: Measurement Systems

ID: Type: **Oral**

results of the (Infrasound-Seismoacoustic) ”Ground Coupling Experiment”

The Ground Coupling Experiment was performed in May 2019 at the CTBTO test site near the Conrad observatory in Austria - to study propagation and coupling of mechanical waves above and below ground. Signals were generated by hammer shots, explosives, rockets, steps, and wind. Infrasound was recorded by seismically-decoupled infrasound sensors (4 Hyperion IFS-5111 with wind shielding buckets), and seismoacoustic waves by three-component seismic sensors (99 Fairfield 5Hz geophones) in a 2D-configuration (at ground level and buried). Meteorological conditions were also recorded for the site (temperature, atmospheric pressure, wind speed, and wind direction). The goal is to study the propagation characteristics of the (infrasound and seismic) waves, and how they couple across the surface (infrasound-to-seismic and seismic-to-infrasound). The experiment also serves to optimize the sensor installation. We also determine coupling coefficients, characterize the sources from the measurements, and study the interference from wind. We will report the first results of the experiment.

Primary author: NOVOSELOV, Artemii (University of Vienna)

Presenter: NOVOSELOV, Artemii (University of Vienna)

Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

48 data: processing and exploiting

In the frame of its activities in exploiting and processing IS48 data using DTK-tools , NDC-TN initiated a project which aims to produce a regional infrasound sources catalogue. As first part of our study and in order to gain in time and effort, an Infrasound Data Daily Automatic Processing was developed based on the exploitation of DTK-PMCC in order to produce a daily bulletin of the IS48 station . The second part is dedicated to process detected events by IS48 and try to better streamline and interpret them based on information from cooperation at the national level and using Infrasound Reference Event Database (IRED).

Primary author: MEJRI, Chourouk (National Data Centre)

Presenter: MEJRI, Chourouk (National Data Centre)

Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

middle atmosphere weather models using LiDAR and ambient noise

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.

Primary author: CERANNA, Lars (Federal Institute for Geosciences and Natural Resources (BGR))

Presenter: CERANNA, Lars (Federal Institute for Geosciences and Natural Resources (BGR))

Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

2019 July Stromboli volcano paroxysm event: Infrasound long-range detections at IS42 station and other IMS stations.

Stromboli volcano (918 m a.s.l.) is located in a small Italian island of the same name that belongs to the Aeolian archipelago, in the Mediterranean sea. Its continuous explosive activity and persistent degassing since at least 3-7 AD (Rossi et al., 2000) makes it probably the world's best-known volcano due its spectacular basaltic explosions interspersed by lava fountains up to 250 m occurring every ≈10 minutes (Ripepe et al., 2002). On 3rd July 2019 a very strong explosive event (paroxysm) occurred at 14:45:43 UTC associated with two explosions (first one from SW crater and the second from Central crater). This event was detected in various IMS infrasound stations, including IS42, located in the Azores islands in the middle of the North-Atlantic. We present here the IS42 infrasound detections from this event, at a source-to-receiver distance of ≈3,700 km and a back-azimuth of ≈76°, as well as from other IMS infrasound stations and its correlation with the local observations.

Primary author: MATOS, Sandro Branquinho de (Instituto de Investigação em Vulcanologia e Avaliação de Riscos (IVAR))

Presenter: MATOS, Sandro Branquinho de (Instituto de Investigação em Vulcanologia e Avaliação de Riscos (IVAR))

Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

of the European infrasound network performance incorporating CEEIN

The Central and Eastern European Infrasound Network was established in 2017 and it joins 9 recently installed infrasound arrays located in Hungary, Romania, Czechia, Austria and Ukraine. The collaboration 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. The arrays significantly improve the infrasound station coverage of the Central European region. 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.

Primary author: CZANIK, Csenge (Research Center for Astronomy and Earth Sciences, Geodetic and Geophysical Institute,)

Presenter: CZANIK, Csenge (Research Center for Astronomy and Earth Sciences, Geodetic and Geophysical Institute,)

Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

the infrasound ambient noise in two hemispheres using the dense seismo-acoustic Kazakh network

Kazakh national Data Center operates three infrasound and five seismic arrays. Detection of the microbarom and microseism has been done in the arrays records for the years 2014 - 2017. On the basis of the search and also the source and propagation modelling for microbaroms, two basic conclusions were made concerning the nature of microseism and microbarom recorded within Kazakhstan. It was proved that major portion of energy arriving to Kazakhstan in winter months which falls within the frequency band of microseisms and was recorded by seismic arrays originates in the North Atlantic Ocean.Virtually always it is true for the infrasound arrays. The only exception is the periods when SSW events occur. At these time, infrasound stations record microbaroms originated in the North Pacific. Predicted changes in the signal amplitudes match well with the variations in observations for the microbaroms. However, the picture is not so simple for summer months. Some stations apparently record microseisms and microbaroms from the regions surrounding Antarctica, and this idea matches well with our prediction for microbaroms. Nevertheless, other stations record signals which could be hardly explained with the described simulation method.

Primary author: SMIRNOV, Alexandr (Kazakhstan National Data Centre)

Presenter: SMIRNOV, Alexandr (Kazakhstan National Data Centre)

Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

”Ground Coupling Experiment”: Comparison of firework acoustic signals on co-located pressure and seismic sensors

We performed a seismo-acoustic “Ground Coupling Experiment” at the CTBTO infrasound test site near the Conrad Observatory, Austria. Seismic and acoustic signals were generated by hammer beats, fireworks (rockets and crackers), human steps and wind. Seismo-acoustic signals were recorded by 99 Fairfield ZLand geophone nodes and four Hyperion IFS 5111 seismically decoupled infrasound sensors, as well as by several smartphones using the RedVox app. In this work we present a first comparison of seismo-acoustic records from co-located pressure and seismic sensors. Using the Hyperion IFS 5111 as reference sound sensors we evaluate the sensitivity of nodal geophones to acoustic perturbations and compare buried vs. surface installations. We also study how we can characterize stationary and moving sources and we analyze the impact of wind noise. By comparing seismo-acoustic records of surface sources (~1m height) with those of sources at height (~40 m height) we investigate the effect of incidence angle on the seismo-acoustic coupling efficiency.

Primary author: FUCHS, Florian (University of Vienna)

Presenter: FUCHS, Florian (University of Vienna)

Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

-associated waves and their relation to orographic gravity waves

Low-frequency infrasound observations (0.01-0.1 Hz) of so-called mountain-associated waves (MAWs) were initially reported in the 1970s. Those observations were limited to sets of regional microbarometer arrays. Different theories on the source generation mechanism evolved; however, the atmospheric variability seemed to complicate assessing the exact mechanism. Nowadays, the infrasound network of the International Monitoring System (IMS) allows the detection of MAW events globally. In this study, the Progressive Multi-Channel Correlation algorithm (PMCC) is used for detecting such events, based on up to 15 years of observations. A cross-bearing method is applied to the PMCC results to identify global source regions of MAWs. The significant hotspots are analysed, focusing on the seasonal variability in the detection parameters and both the meteorological source and propagation conditions. Moreover, satellite observations of gravity waves (GWs) reveal similarities between MAW and orographic GW occurrence. Based on these observations, the question is discussed of whether orographic GWs are involved in the source generation of MAWs. If such a link becomes evident, the IMS infrasound network will provide a unique ground-based opportunity for estimating the source regions of orographic GWs globally.

Primary author: HUPE, Patrick (Federal Institute for Geosciences and Natural Resources (BGR))

Presenter: HUPE, Patrick (Federal Institute for Geosciences and Natural Resources (BGR))

Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

coherent ambient noise in the North Atlantic and Barents sea regions

The ability of the International Monitoring System (IMS) network to detect atmospheric explosions and events of interest strongly depends on station-specific ambient noise signatures. Around 0.2 Hz, a persistent source of signals that radiate microbaroms over spatially extended regions is generated by the second order non-linear interaction of ocean waves, mostly during severe storms. A two-dimensional energy spectrum ocean wave model accounting for bathymetry and source directivity effects is used to build a global reference database of oceanic noise sources. Classical broadband array processing method and conventional beamforming approach have been implemented on multi-year continuous IMS recordings. To evaluate the source model at regional scales, comparisons between the observed and modeled directional microbarom amplitudes are carried out at station IS37 in Norway. Metrics are defined to further evaluate the capability of the developed source and propagation models to characterize continuous active source regions in the North Atlantic and Barents sea.

Primary author: LE PICHON, Alexis (CEA/CENTRE Ile-de-France)

Presenter: LE PICHON, Alexis (CEA/CENTRE Ile-de-France)

Track Classification: Modelling and Network Processing

ID: Type: **Oral**

calibration of global climate models using infrasound events

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. In this work, we propose a Bayesian hierarchical approach to calibrate the input parameters of a stochastic multiwave gravity wave (GW) scheme, which is currently in use in the LMD GCM. The GW field is obtained as a combination of individual wavepackets, whose horizontal wavenumber, direction and phase speed are chosen randomly. These parameters are inferred using ground-based infrasound records as tracers of small-scale GW variability. In a sense, the acoustic signals are "back propagated" to adjust the GW sources on a daily basis, using for this a WKB approximation of the Taylor-Goldstein equation to represent the upward-propagating GWs. The method is applied using acoustic signals observed at the Norwegian station 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. The performance of the method is demonstrated by comparing the updated climatology and variability of the middle atmosphere with the reanalysis provided by the European Centre for Medium-Range Weather Forecasts.

Primary author: MILLET, Christophe (Commissariat à l'énergie atomique et aux énergies alternatives (CEA))

Presenter: MILLET, Christophe (Commissariat à l'énergie atomique et aux énergies alternatives (CEA))

Track Classification: Modelling and Network Processing

ID: Type: **Oral**

Source Characterization for Chemical Explosions in Air

Explosive events in the atmosphere create significant pressure waves in the air. Those pressure waves propagate as shock waves near the source and quickly transitioned into acoustic waves in the far-field. Since low-frequency acoustic waves, so called infrasound, propagate long distances without significant loss of energy, acoustic signals induced by explosions are used to determine explosion energies of the events in terms of an explosion yield. In order to estimate the explosion energy accurately, the relationship between acoustic energy and explosion yield must be understood. However, explosion energies are often measured by non-linear shock waves in the near-field, and it is not clear how much acoustic energy accounts for the explosion energy. In addition, acoustic signals typically have lower-frequency contents than shock waves in the near-field, and hence frequency-dependent explosion energy should be understood to accurately infer explosion yields based on acoustic observations. In this study, we investigate the relationship between acoustic energy and explosion yield based on ground-truth explosion data. A standard acoustic source waveform will be determined by acoustic observations, and frequency-dependent energy will be explored for yield estimation. We will demonstrate that this frequency-dependent acoustic source characterization can improve the accuracy and confidence of explosion yield estimation.

Primary author: KIM, Keehoon (Lawrence Livermore National Laboratory)

Presenter: KIM, Keehoon (Lawrence Livermore National Laboratory)

Track Classification: Modelling and Network Processing

ID: Type: **Oral**

Reconstruction and Infrasound Propagation Modeling Using AVO-G2S for Explosive Sources in Alaska

Long-range infrasound propagation is greatly affected by winds and temperature gradients in the atmosphere. To understand these effects and accurately determine acoustic source information, detailed characterization of the spatial and temporal variability of the atmosphere is vital. Alaska Volcano Observatory Ground-to-Space (AVO-G2S) is an open source atmospheric reconstruction model that smoothly characterizes atmospheric conditions using multiple numerical weather prediction models and reanalysis products as well as empirical models for the upper atmosphere. We present on the implementation of AVO-G2S both as a reanalysis and forecasting tool for the Alaska Volcano Observatory (AVO). High temporal and spatial resolution atmospheric models are automatically generated in real time every 12 hours for volcanoes with elevated activity in relation to each of AVO's six dedicated infrasound arrays. We use a combination of array processing and propagation modeling to refine interpretations of infrasound detections, differentiate between possible atmospheric propagation paths, and understand detection performance at each array. We show an example for the 2016-2017 eruption of Bogoslof Volcano, where model simulations were consistent with observations from the six arrays (either a detection or lack of detection) on more than half of the 70 explosions, with long range detections aligning well with seasonal propagation variability.

Primary author: IEZZI, Alexandra (University of Alaska Fairbanks)

Presenter: IEZZI, Alexandra (University of Alaska Fairbanks)

Track Classification: Modelling and Network Processing

ID: Type: **Poster**

the use of infrasound observations from volcanoes for improving the weather forecasts

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.

Primary author: MILLET, Christophe (Commissariat à l'énergie atomique et aux énergies alternatives (CEA))

Presenter: MILLET, Christophe (Commissariat à l'énergie atomique et aux énergies alternatives (CEA))

Track Classification: Modelling and Network Processing

ID: Type: **Oral**

Empirical Models for Infrasonic Signal Celerity, Backazimuth and Duration from Ground Truth Data

Recent developments in infrasonic event association and location methods rely on prior probability distributions for infrasound signal parameters. Whilst numerical acoustic propagation modelling through atmospheric specifications may be used to provide both range dependent and time specific priors for signal parameters (e.g., celerity), analyses of ground truth data sets are necessary to validate these models. Previously, we developed a regional range-dependent celerity model for the US summer using both air-to-ground coupled waves and acoustic arrivals at distances < 1000km from summertime explosions at the Utah Test and Training Range during 2004-2008. We have now developed a software suite which allows for consistent analysis of a global ground truth database, allowing estimation of global empirical models for celerity, backazimuth and duration. The results have implications for the prior distributions constructed for the NET-VISA association algorithm (Arora et al., 2013). The major improvement on previous models is that the underlying dataset is not biased by assumptions about the signal property populations.

Primary author: GREEN, David (AWE Blacknest)

Presenter: GREEN, David (AWE Blacknest)

Track Classification: Modelling and Network Processing

ID: Type: **Poster**

Infrasound, Seismic and Hydroacoustic Technologies to Enhance Velocity Model in Jordan and Surrounding Areas

The Poster : Intrduction The modern area of infrasound studies was ushered in by the nuclear age, and the attendant needs to monitor the Earth and its atmosphere for clandestine nuclear test. Monitoring requirements became more eargent with the initiation of the Comprehensive Nuclear Test Ban Treaty CTBTO, Which sought to ban all nuclear tests.The IMS dat could become an important archive for researcher of the atmospheric phenomena that can undergo significant changes as a consequences of climatic change. There is a host of potential civil and scientific applications beyond using the data and their analysis to monitor compliance with the treaty as well as .These Applications can help mitigate the effects of natural or man made disasters, increase the weath of knowledge about our planet.

Primary author: SWEIDAN, Ghassan Ahmad (Jordan Seismological Observatory)

Presenter: SWEIDAN, Ghassan Ahmad (Jordan Seismological Observatory)

Track Classification: Sources and Scientific applications

ID: Type: **Oral**

# of infrasound from Brazilian thunderstorms

The International Monitoring System infrasound network dedicates to the verification of the Comprehensive Nuclear Test-Ban-Treaty. However, due to its high potential for scientific applications as well as the clamor for the access international scientific community, data from IMS stations were made available for use in other applications, like investigations about thunderstorms. Some studies have been conducted to understand the impact of lightning flashes in the infrasound signals. Following this, some of the stations, such as that one's located in South America, where the lightning activity is high and more appropriate for these investigations. Moreover, studies have already indicated visible increases in lightning in urban areas. This incidence of lightning is related to the increase in temperature and pollution. Brazil is one of the largest countries in the tropical zone of the planet. Thus, its climate is warmer and more favorable to the formation of storms and lightning. Around 77.8 million lightning discharges happen every year. The weather in Brasilia city, where the infrasound station operates, has two distinct seasons: a rainy summer, and dry winter. On the rainy months, thunderstorms typically occur and can produce infrasound waves. This work intends to show how thunderstorms affect infrasound signals detected in Brazil.

Primary author: NERI, Brandow (University of Brasilia, Seismological Observatory)

Presenter: NERI, Brandow (University of Brasilia, Seismological Observatory)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

permanent and seasonal infrasound sources detected by I17CI station over West Africa form 2009 to 2016

The characterization of infrasound sources detected by I17CI station was carried out using CEA infrasound bulletins from October 2009 to June 2016. The signals were processed in the frequency range [1 - 2] Hz. Two types of regional infrasound wave emitting sources were found. The emitting sources are seasonal and permanent sources. Seasonal sources are mainly convective systems over West Africa. Infrasound waves are generated by the deep convection of thunderstorms, lightning. The seasonality of these infrasound waves is related to the latitudinal shift of the Inter-Tropical Convergence Zone (ITCZ) over West Africa. Permanent stationary sources are mainly industries, hydroelectric dam mines and airports located in southeast Côte d'Ivoire and west Ghana.

Primary author: KOUASSI, Komenan Benjamin (Station Geophysique de Lamto)

Presenter: KOUASSI, Komenan Benjamin (Station Geophysique de Lamto)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

CTBTO Infrasound monitoring system

Infrasound monitoring is one of the three waveform technologies utilized by the CTBT (Comprehensive Nuclear-Test-Ban Treaty) verification regime. The International Monitoring System (IMS) of the CTBT verification regime contains a global network of 60 infrasound stations, situated in 35 countries around the world.The infrasound station consists of 10 measurement points, each with one microbarometer and an array of steel pipes placed on the ground. Noise from wind masks the infrasound waves of interest to CTBT monitoring and is suppressed by the application of such pipes. A Central Recording Facility (CRF) supplies all sites with electric power through buried copper cables. Intra-array communication uses fiber optic cables. Each of the 10 sites has a power and fiber cable to the CRF. Data from this station are transmitted continuously in real time to the International Data Centre of the CTBTO in Vienna.

Primary author: ALHOMAIMAT, Murad (Jordan Seismological Observatory)

Presenter: ALHOMAIMAT, Murad (Jordan Seismological Observatory)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

IMS Infrasound Network: the potential studies for South East Asia region

Traditionally, infrasound research has been driven largely by defense needs, namely to monitor nuclear and chemical explosions. However, there are growing numbers of potential scientific and civil applications for infrasonic observing systems. This field of very low frequency acoustics is globally well developed, which the world nowadays has an extensive worldwide network of infrasound sensors to monitor underground and atmosphere nuclear explosions under the Comprehensive Test Ban Treaty (CTBT). Natural infrasound sources such as avalanches, earthquakes, geomagnetic activity, meteors, ocean waves, severe weather, turbulence, and volcanoes offer great resources for comprehensive and interactive research programs. The evolving CTBT International Monitoring System offers exceptional opportunities to make this infrasonic data sets widely available and to explore their uses particularly in synergistic studies with seismic and hydroacoustic systems where diverse data sets can be readily melded. This study will review the broad range of research and studies possible using infrasonic observing systems, as well as its combination with other remote sensing systems in the context of South East Asia, and particularly Malaysia.

Primary author: ZOLKAFFLY, Muhammed Zulfakar (Malaysian Nuclear Agency)

Presenter: ZOLKAFFLY, Muhammed Zulfakar (Malaysian Nuclear Agency)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

# of Infrasound Data of International Monitoring System in Studying Marine and Earth Studies

Infrasound technology uses to detect very low-frequency sound waves in the atmosphere produced by events such as nuclear explosions, movements of glaciers, marine storms, hurricanes and tornadoes, mines and chemical explosions and landslides and avalanches. The IMS consist of no. of infrasound stations at Indian Ocean Region and record valuable information which helps in identifying different sources. As an island surrounded by an ocean, these information are very useful in research on different disciplines such as marine studies (marine storms, wind pattern changes) and earth studies (local earth tremors and landslides). Although the detail studies on these fields are not yet implemented, preliminary studies are going on how IMS data on infrasound technology could be used for such civil and scientific applications.

Primary author: THALDENA, Sanjeevani Nilmini Bandara (Geological Survey and Mines Bureau (GSMB))

Presenter: THALDENA, Sanjeevani Nilmini Bandara (Geological Survey and Mines Bureau (GSMB))

Track Classification: Sources and Scientific applications

ID: Type: **Oral**

from glaciers in Greenland and its relation to climate change

Inaudible sound, i.e., infrasound, is generated by glacial run-off and during calving events. Such sounds can be continuously monitored with microbarometer arrays. Changes in the rate of events can be retrieved with a resolution of a few seconds. Applying array processing techniques enables the identification of individual glaciers over ranges of tens of kilometers. We concentrated on the remote region around Quanaq in northwestern Greenland and found coherent infrasound of at least five glaciers over a period of 16 years. Knowledge on the dynamical behavior of these remote glaciers is rare, but important for sea level rise. Here we use the novel technique involving passive infrasound measurements to show that remote land and sea terminating glaciers behave differently in terms of their temporal behavior seasons and years. Strong fluctuations in infrasonic activity are found over time. Increased activity over the years of the land-terminated glacier is retrieved and also diurnal variations through a spectral analysis. We anticipate that monitoring glacial infrasound can contribute to a better understanding of the behavior of remote glaciers in the future, as the glacial dynamics can be passively observed on a fine temporal scale.

Primary author: EVERS, Läslo (KNMI - Royal Netherlands Meteorological Institute)

Presenter: EVERS, Läslo (KNMI - Royal Netherlands Meteorological Institute)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

that caused an infrasound signals in East Siberia

Seismoacoustic effects of the Hovsgol earthquake of December 5, 2014 (51.37N, 100.63E, MW=4.9) and Khoitogol earthquake of March 29, 2019 (51.71N, 101.54E, MW=4.7) were studied. Earthquakes occurred in the south-western part of the Baikal rift system: the first event located in the Hovsgol basin at 3 km depth, the second – in the Khoitogol basin at the depth 10 km. An acoustic signals were registered by the infrasound station "Tory" located 175 km from the Hovsgol event and 100 km from Khoitogol events. The results of modelling of the surface displacements caused by the Hovsgol earthquake and high effective velocity of propagation of infrasound signal indicate that its occurrence is not caused by the downward movement of the Earth's surface in the epicentral region but by the effect of the secondary source locared on the northern slopes of the Khamar-Daban ridge. The interaction of surface waves with the regional topography is proposed as the most probable mechanism of formation of the infrasound signal. In opposity, the simple waveform of the second signal, its travel time and duration give reason to believe that the signal observed was caused by surface movement in the epicentral region of the Khoitogol earthquake.

Primary author: DOBRYNINA, Anna (Institute of the Earth's Crust, Siberian Branch, Russian Academy of Sciences; Geological Institute, Siberian Branch, Russian Academy of Sciences)

Presenter: DOBRYNINA, Anna (Institute of the Earth's Crust, Siberian Branch, Russian Academy of Sciences; Geological Institute, Siberian Branch, Russian Academy of Sciences)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

# of Deployment of Portable CTBTO Infrasound Array in Jordan

The infrasound portable array deployment in Jordan is proposed in this research. The deployment and installation of CTBTO infrasound in active tectonics in Jordan would be beneficial for advancing the understanding of infrasound sources in the Dead Sea Transform (DST) region and around. In the region including Jordan, the DST system is responsible for the earthquakes as well as the previous old volcanic activities. The quality signal monitoring in the proposed portable array in Jordan is important to improve the understanding of local and regional infrasound sources observed by the CTBTO, IMS infrasound network.

Primary author: AL-QARYOUTI, Mahmoud Yousif Mahmoud (Jordan Seismological Observatory)

Presenter: AL-QARYOUTI, Mahmoud Yousif Mahmoud (Jordan Seismological Observatory)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

Mine blast using infrasound and Remote Sensing Technologies

Namibia, rich in resources has a number of open pit mines. We have an infrasound station 15 km North of Tsumeb that forms part of the International Monitoring System, (IMS). Explosions used in mining operations have similar signal forms to that of nuclear explosions. Change in the topography is monitored by remote sensing techniques (satellite images).The objective is to know if the Geophysical station in Tsumeb can pick up local mine blasts and if it is possible to distinguish land subsidence by using satellite images. Henning Crusher and B2Gold were the two known mines used. For the infrasound a filter of 0.4 to 0.5 Hertz were used to see if both blasts can be identified. Sille and RUS Copernicus was used for both areas to analyse for land subsidence. A clear infrasound signal was obtained for Henning Cursher but not for B2Gold mine. For the Remote sensing, Sille indicated clear subsidence especially for B2Gold, however, RUS Copernicus using Sentinel images has to large resolution to indicate the small mine blast. In conclusion due to the distance and size of mine blast it may or may not be recorded by Infrasound. High resolution images are need for detailed indication of Subsidence.

Primary author: HIMARUA, Feruschka (Ministry of Mines and Energy)

Presenter: HIMARUA, Feruschka (Ministry of Mines and Energy)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

the Fireballs Wave Parameters and Location Using the IMS Infrasound Stations and IDC Products vs. NASA Record.

According to NASA agency there are 789 fireballs were recorded from 1988 to 2019, there are two fireballs recorded as greatest fireballs in the world (greater than 100 kilotons of TNT) and detected by the International Monitoring System (IMS). One of these largest fireballs recorded over the RUSSIA On February 15, 2013 with 440 kilotons of TNT with extreme range reached to 20 IMS infrasound stations, and the second one recorded over Bering Sea on December 18, 2018 with 173 KT of TNT with extreme range reached to 19 IMS infrasound stations. The IMS data and IDC product were used to analyze the infrasound waveform by GEOTOOL to estimate the wave parameters and the events location then compared the result with NASA record.

Primary author: ALHOMAIMAT, Murad (Jordan Seismological Observatory)

Presenter: ALHOMAIMAT, Murad (Jordan Seismological Observatory)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

Calibration Experiments and its correlation with Jordan NDC Station

Infrasound is one of three waveform technologies used in the CTBT verification regime and the Commission has an interest in advancing the capability of the IMS to detect explosions in the atmosphere. On 26 August 2009, 24 and 26 January 2011, the CTBTO make three large-scale explosives had equivalent TNT yields of 96.0, 7.4, and 76.8 t for infrasound experiments. In Jordanian NDC the local station is detected the three explosion in all station and we get the all data from IMS data, IDC products and Jordan NDC and its correlation the infrasound station and seismological station (IMS station) with local station, and the result we used for improve the local model velocity.

Primary author: ALHOMAIMAT, Murad (Jordan Seismological Observatory)

Presenter: ALHOMAIMAT, Murad (Jordan Seismological Observatory)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

Activities as a Source of Infrasound Proposed Station in Jordan

Jordan is a relatively small country situated at the junction of the Levantine and Arabian areas of the Middle East. The Dead Sea fault zone is a major left-lateral strike-slip fault. South of the Dead Sea basin, the Wadi Araba fault extends over 160 km to the Gulf of Aqaba. The Dead Sea fault zone (DSTF) is known to have produced several relatively large historical earthquakes. However, the historical events are unequally distributed along the fault and only four events have been reported in the Araba valley over the last few thousands of years. The DSTF can be the main source of Infrasound waves. The Jordanian Phosphate mines are mainly located in Central East part of Jordan and Southern East part. Their mining explosions and activities may play important role as a source for proposed Infrasound Station in Jordan. The other main source may be the explosions (WAR in Syria and Iraq). In The last few years two many suspected (Events) Earthquakes has been Recorded due to this War. Beside the CTBTO seismic Station in Jordan (Tal Al Asfar) The major benefits will be for Jordan NDC and its staff to upgrade their knowledge in both technologies,

Primary author: SWEIDAN, Ghassan Ahmad (Jordan Seismological Observatory)

Presenter: SWEIDAN, Ghassan Ahmad (Jordan Seismological Observatory)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

Experiments with Jordan NDC Station

Infrasound is one of four technologies used in the CTBT verification regime and the Commission has an interest in advancing the capability of the IMS to detect explosions in the atmosphere. On 26 August 2009, 24 and 26 January 2011, the CTBTO make three large-scale explosives had equivalent TNT yields of 96.0, 7.4, and 76.8 t for infrasound experiments. In Jordanian NDC the local station is detected the three explosion in all station and we get the all data from IMS data, IDC products and Jordan NDC and its correlation the infrasound station and seismological station (IMS station) with local station, and the result we used for improve the local model velocity.

Primary author: SHRADGAH, Ghaith (Jordan Seismological Observatory)

Presenter: SHRADGAH, Ghaith (Jordan Seismological Observatory)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

infrasound mobile array (I68CI) data to characterize tropical thunderstorm over West Africa

Cote d'Ivoire NDC in collaboration with CTBTO deployed from January to December 2018, a mobile infrasound array (I68CI) in North-East (Comoe Reserve) of Cote 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.

Primary author: KOUASSI, Komenan Benjamin (Station Geophysique de Lamto)

Presenter: KOUASSI, Komenan Benjamin (Station Geophysique de Lamto)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

state-of-the-art network of Automatic Weather Stations in Cyprus: from weather sensors to web publishing

The Cyprus Department of Meteorology (DoM) has developed a state-of-the-art network of Automatic Weather Stations (AWS). Each station can accommodate virtually any kind of sensor and is also equipped with an industrial computer, capable of data pre- and post-processing. Station measurements are available in real time to end users and end up in DoM's climatological database for further quality control, post-processing and report generation. All communications take place in an end-to-end encrypted VPN tunnel, thus maintaining both security and integrity, without putting either the stations or the departmental infrastructure at risk. In addition to the stations, the AWS network is supported by the on-premise departmental IT infrastructure, where the stations are continuously monitored and their data are backed up and published in near real-time on the departmental website.

Primary author: CHRISTOU, Natasa (Cyprus Department of Meteorology)

Presenter: CHRISTOU, Natasa (Cyprus Department of Meteorology)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

evaluation of SPECFEM3D for local infrasound propagation over topography

Accurate infrasound propagation modeling is important for both understanding atmospheric processes and detailed infrasound source studies. Recent research has shown that over local distances (<15 km), topography is often the dominant influence on recorded infrasound signals. In addition to reflection or diffraction from interference with the topographic surface, infrasonic waves may also couple into the ground. For simplicity, seismo-acoustic coupling is typically ignored through a rigid boundary condition between the air and ground surface. Here we evaluate the 3D Spectral Finite Element Method (SPECFEM3D) for infrasound propagation over local distances. SPECFEM3D is widely used in seismology and is a promising tool for infrasound studies. At the fluid-solid interface, SPECFEM3D ensures continuity of traction and velocity normal to the interface between the two media, and solves the acoustic and elastic equations over split domains. We compare the effects of these two free surface conditions over a wide range of frequencies, starting with a well-studied 10 by 10 km region surrounding Sakurajima volcano, Japan. Comparisons with previously published Finite-Difference Time-Domain modeling results are also shown.

Primary author: BISHOP, Jordan (University of Alaska, Fairbanks)

Presenter: BISHOP, Jordan (University of Alaska, Fairbanks)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

meta-model based localization of infrasound events in multivariate atmospheres

The International Data Center operates in real time, performing network processing to localize events. In this context, the relevance of full-wave modeling is unclear for two reasons. First, atmospheric specifications are necessarily statistical in nature, whereas sound propagates through a particular atmospheric state, which is indeed not known. While a current trend is to undertake the impact of atmospheric uncertainty on the waveforms using Monte Carlo simulation, such an approach, however, drastically increases the number of model runs. Second, many thousands of detections are recorded per day and thus, the problem of calculating plausible waveforms for subsets of detections often leads to computational demands that exceed available resources. In this work, we propose a new approach of the localization problem, using stochastic full-wave modeling and non-intrusive generalized Polynomial Chaos (gPC). The main difference with the standard Monte Carlo method is the fact that the sampling is carried out over the gPC metamodel, which is calibrated over a few realizations of atmospheric fluctuations. The performance of the method is demonstrated through reanalysis of the meteor explosion over the Bering sea, on Dec. 18, 2018, using as many meta-models as there are IMS stations that have presumably recorded the bolide.

Primary author: GOUPY, Alexandre (CMLA, ENS, F-94230 Cachan, France)

Presenter: GOUPY, Alexandre (CMLA, ENS, F-94230 Cachan, France)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

The 2018 Kalibening Earthquake Sequence In Central Java: Call for the Revision of Earthquake Hazard

As moderate devastated earthquake that impacted the economic loss was about $ 1.68 million U.S, the 2018 Kalibening earthquake quite shocked where the faulting mechanism still unconfirmed. So do with any reference that did not indicated the existence of faulting zone exactly on the earthquake sequence. We take benefit from temporary network with density 2 km which deployed while macroseismic survey for earthquake relocation using double difference combined with cross-correlation. Next, determining earthquake moment tensor inversion solution using near source seismograms in purposing to evaluate the 2018 Kalibening earthquake sequence. We suggested the deformation scheme of this earthquake with a thrust faulting with 307.5/ 28.8/ 118.5 (Strike/ Dip/ Rake) as result from mainshock and aftershock moment tensor solutions. This parameter seemingly consistent to aftershocks relocations results which the formed lineation trending NW-SE appropriate with Strike = 307.5. The cross section exhibits aftershocks pattern in which elongated more deeper and formed a slope from SW to NE approximately fit to Dip = 28.8. In this study we also found that the sparse and lacking of InaTEWS seismic network configurations impacted losses in earthquake cataloging and leads the low area coverages around Banjarnegara region.

Primary author: PRAYOEDHIE, Setyoajie (NDC Meteorology Climatology and Geophysics Agency (BMKG))

Presenter: PRAYOEDHIE, Setyoajie (NDC Meteorology Climatology and Geophysics Agency (BMKG))

Track Classification: Sources and Scientific applications

ID: Type: **Oral**

NDC analysis for Sunda Strait Tsunami using Numerical Modelling and Infrasound Data from IMS Station

Saturday, Desember 22th 2018, 09.27 PM western indonesian time, Lampung Province region (South Lampung District) and Banten Province (Pandeglang and Serang District), struck by devastating tsunami landslide caused by Anak Krakatau eruption. We conduct seismic waveform analysis and several tsunami modelling scenario caused by landslide to find the source of tsunami and the effect to the region and also using infrasound data from IMS station to validating the Anak Krakatau eruption.

Primary author: PRAYOEDHIE, Setyoajie (NDC Meteorology Climatology and Geophysics Agency (BMKG))

Presenter: PRAYOEDHIE, Setyoajie (NDC Meteorology Climatology and Geophysics Agency (BMKG))

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

learning for atmospheric turbulence modeling using seismo-acoustic signals

The International Monitoring System comprises four technologies: seismological, radionuclide, hydroacoustic, and infrasound. 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 atmospheric small-scale structures on the waveforms using computational models. The goal of this study is to learn about these structures using infrasound stations that have recorded the same event. Recurrent explosive events can be exploited for this task, through combining full-wave modeling with Convolutional Neural Networks (CNNs). A previously derived stochastic Gravity Wave (GW) model for the small-scale structures is used to generate ensembles of atmospheric states, from a common atmospheric specification. CNNs are designed and trained to predict synthetic signals that are provided by the FLOWS platform and real-world signals are used to determine the parameters of the GW model. The performance of the method is demonstrated using seismo-acoustic signals that were recorded at Norwegian stations in August-September, over the last couple of years. It is shown that the resulting CNNs, together with the updated GW model, possess a good generalization ability in predicting new seismo-acoustic signals.

Primary author: MILLET, Christophe (Commissariat à l'énergie atomique et aux énergies alternatives (CEA))

Presenter: MILLET, Christophe (Commissariat à l'énergie atomique et aux énergies alternatives (CEA))

Track Classification: Sources and Scientific applications

ID: Type: **Oral**

propagation of explosion-generated infrasound revealed by the large-scale AlpArray seismic network

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 - 350 km from the source, with 40 km spatial resolution. We confirm the explosion site both by the seismic and seismo-acoustic arrivals. Apart 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 ray tracing to validate our findings. Tropospheric and thermospheric arrivals are to some extent reproduced by the atmospheric model. However, ray tracing 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.

Primary author: FUCHS, Florian (University of Vienna)

Presenter: FUCHS, Florian (University of Vienna)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

infrasound analysis of a large fireball in Zambia

At approximately 10:08 UTC on February 18th, 2019, a large atmospheric explosion originating over Zambia was detected at 8 infrasound arrays belonging to the International Monitoring System (IMS) of the Comprehensive Nuclear Test-ban Treaty Organization (CTBTO). This explosion, later associated with a bolide, was detected as far away as Alaska, at a range of more than 15,000 km. Here we show the infrasound analysis performed at the International Data Centre (IDC) of the CTBTO. We also show that the high altitude wind pattern produced favorable conditions for long-distance propagation of infrasound. This contributed to the excellent results seen here, including our calculated location being only 150km different from the location estimated by the NASA Center for Near Earth Observation Studies.

Primary author: APPLBAUM, David

Presenter: APPLBAUM, David

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

bench development dedicated to microbarometers run-in

In accordance with our ongoing quality approach, a running-in step for infrasound sensors has been investigated and implemented. Once the metrology process is completed, objective is to keep monitoring on sensitivity of MB3a sensors during several days, using the in-situ electrical calibration capability. For this purpose, a bench has been designed and characterized. Different sensitivity assessment methods have been compared. Testing conditions, bench design, methodology, and results are laid out in this poster.

Primary author: EL RHAZ, Samir-Sharif (SEISMO WAVE)

Presenter: EL RHAZ, Samir-Sharif (SEISMO WAVE)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

and location of infrasound events close to Latin America and the Caribbean using nearby IMS stations and I69CR portable infrasound station and local infrasound arrays in Costa Rica

Recent developments of portable infrasound arrays I69CR and IVTCR. It has been possible to locate some infrasound events near the Latin American and Caribbean area. On April 23, 2019, at 21:07:22 (local time), infrasound stations in Costa Rica detected and located Aguas Zarcas meteorite, that fall in the territory of Costa Rica, this event was possible to detect by infrasound stations I69CR, IVTCR, I20EC. On June 22, 2019 at 21:25 UTC was a bright fireball over the Caribbean near south of Puerto Rico. This event was detected by station I69CR at 23:06 UTC and was detected by I51GB and I20EC stations. This event is the fourth time an asteroid is seen before it enters the atmosphere. This asteroid was named as 2019 MO.

Primary author: VILLALOBOS VILLALOBOS, Hairo (Observatorio Vulcanológico y Sismológico de Costa Rica (OVSICORI))

Presenter: VILLALOBOS VILLALOBOS, Hairo (Observatorio Vulcanológico y Sismológico de Costa Rica (OVSICORI))

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

Infrasound Station Suggestion in JORDAN

Infrasound monitoring is a key technology in the CTBT verification regime and the Commission has an interest in advancing the capability of the IMS to detect explosions in the atmosphere. In the past the PTS is sponsoring an infrasound calibration experiment in the eastern Mediterranean region. The experiment is to calibrate and validate the processing methods used by the CTBTO to detect and locate infrasound events. An earlier,similar experiment was carried out in the summer of 2009. The next one was occurred in winter 2011,when the winds are in the opposite direction. The large explosion was detected over a wide region and to distances up to 3500 km. The PTS was collaborated to deploy additional sensors in Qatar, Kuwait,Oman, Kazakhstan, Georgia, Russia, Cyprus, Greece, in addition to Jordan. A site survey is recommended to locate as quiet an environment as possible. The sites should be protected from wind noise by vegetation and as far as possible away from local infrasound sources (heavy industries, dams, wind farms, sea coast) that increase the observed infrasound noise levels at distances up to tens of kilometers. We need the PTS experiences to do this project because we have not any experiences in this field.

Primary author: OLIMAT, Waleed (Jordan Seismological Observatory)

Presenter: OLIMAT, Waleed (Jordan Seismological Observatory)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

# of Portable infrasound Station in Jordan

In Jordanian National Data Center (NDC-JO) we are looking forward to a PTS portable infrasound array which will deploy for one year or more, within a collaboration project between JSO and PTS of the Preparatory Commission for CTBTO. This joint experiment aims to contribute in many important and interesting objects like: advanced understanding of infrasound sources in Middle East, training NDC-JO staff and to increasing and understanding the infrasound technique from the specialist and design makers. Through NDC-JO (Instruments and well trained technical staffs) and PTS helping, the data recorded by the infrasound arrays which will deploy in Jordan will process into detection arrival bulletins applying CEA/DASE PMCC algorithm embedded in DTK-GPMCC (extended CTBTO NDC-in-a-box) and WinPMCC software applications. The results will plot and analyze using DTK-DIVA software (extended CTBTO NDC-in-a-box), in order to assess detectability of each station, as well as the capacity of fusing detections into support of infrasound monitoring in general.

Primary author: OLIMAT, Waleed (Jordan Seismological Observatory)

Presenter: OLIMAT, Waleed (Jordan Seismological Observatory)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

-Acoustic Analysis of California Earthquake

California a State in the United States of America is covered locally and regionally by the CTBTO IMS network of infrasound and seismic (primary and auxiliary) stations. An earthquake occurred in Coso Junction outside of Ridgecrest on July 6, 2019 (3:19 GMT). The location of event was estimated with seismic and infrasound (I57US) data obtained from local and regional IMS stations that recorded the event. These analyses were done to test the operational readiness of these IMS stations. Results were obtained from the analyses for phase, magnitude, arrival time, azimuth and slowness. The Spectrogram for the stations shows wave energy covering a broad frequency range (0.5-10.0 Hz). At local and regional distances these seismic and infrasound stations were observed to be consistent with the known back azimuth of the event, thus are operational ready by contributing data to the IMS network in a timely manner.

Primary author: MADU, Uchenna Onwuhaka (Nigeria Atomic Energy Commission)

Presenter: MADU, Uchenna Onwuhaka (Nigeria Atomic Energy Commission)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

# of infrasound signals before earthiness landslide sliding

The motion and friction between soil particles and the crack propagation in the soil mass will generate infrasound waves before earthiness landslide sliding. In order to analysis the characteristics of infrasound signals of earthiness landslide critical-sliding, six groups of landslide simulation experiments are carried out on the soil slope model, at the same time, acquiring the infrasound signals that generated in the experiments. Analyzing the time-frequency characteristics of the signals using the Short Time Fourier Transform, then, studying the energy feature of the signals in each frequency band by wavelet decomposition. The result shows that there are special infrasound signals generated before earthiness landslide sliding, and the frequency of the signals is mainly concentrated in 0.5 ~ 6Hz and 12.5Hz around. According to the development law of creeping stage of earthiness landslide, the infrasound signal of 0.5 ~ 6Hz is the intermittent motion and friction of the slip surface; and ,the infrasound signal near 12.5Hz is generated by the crack propagation of the sliding body. The infrasound characteristics obtained by the experiments can be used as an important reference for the infrasound monitoring of earthiness landslide.

Primary author: LYU, Jun (Institute of Acoustics, Chinese Academy of Sciences)

Presenter: LYU, Jun (Institute of Acoustics, Chinese Academy of Sciences)

Track Classification: Sources and Scientific applications

ID: Type: **Oral**

# of seismic waveforms observed by co-located seismometer and barometer installed indoors

Surface vertical vibration arising from earthquake is considered to excite sound and it has been observed by barometer or microphone. Pressure change after earthquake is mainly generated by following three reasons. 1) Air vibration (compressional wave) is excited by earthquake ground motion around barograph. 2) Internal mechanical response is accelerated by earthquake. 3) Barograph itself moves vertically by earthquake and hydrostatic pressure is change. (However, the impact is small) We have started special observation with co-located seismometer and barometer in I30JP from Dec 2018. We installed two barometers, one of which port was close. The earthquake event of magnitude 5.1 (seismic intensity scale: 3) occurred near I30JP (40km northwards and depth is 38km) in May 2019. The port-closed barometer recorded pressure change and mechanical response was appeared when seismometer recorded S-wave. In the meanwhile, magnitude 4.5 (seismic intensity scale: 2) event occurred in Jan 2019 didn't make any pressure change to barometer.

Primary author: FUJII, Takanari (Japan Weather Association (JWA))

Presenter: FUJII, Takanari (Japan Weather Association (JWA))

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

PECULIARITIES OF THE WAVE PATTERN OF ATMOSPHERE AND SURFACE EXPLOSIONS FORM THE REGION OF LOP NOR TEST SITE BY DATA OF SEISMIC AND INFRASOUND OBSERVATIONS

At the moment, the researches in the field of seismic and infrasound monitoring are very interested in historical air nuclear tests. This interest is first of all connected with the task on detecting and discriminating nuclear tests within the CTBT, calibration and creation of reference events database for the existing IMS network et al. Lop Nor Test Site is located at Xinjiang province, about 600 km south-eastward of Kazakhstan-Chinese border. In 1964-1996 there were 47 nuclear tests, including 3 surface, 19 atmospheric and 25 underground explosions. During the nuclear tests conducting period, on the territory of Central Asia there was a monitoring network consisting of sensitive seismic stations and microbarographs with analog and digital recording. The records of atmosphere and surface explosions from Lop Nor region recorded by analog seismic stations at regional distances were analyzed as well as records of a microbarograph installed on the territory of Talgar Observatory (northern Tien Shan). Interesting is that infrasound signals from large atmosphere explosions were recorded by the microbarograph and long-period seismometer, and sometimes by a strainmeter. The dynamic parameters of seismic and infrasound records of nuclear explosions depending on the explosion yield and source type were analyzed.

Primary author: SOKOLOVA, Inna (Institute of Geophysical Researches)

Presenter: SOKOLOVA, Inna (Institute of Geophysical Researches)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

Survey for Portable Infrasound Station in Jordan

Sound waves with frequencies less than 10 Hz are referred to as infrasound. These waves have long wavelengths ranging from tens of meters at 10 Hz t several tens of kilometers near 0.01 Hz. Natural Sources of infrasound in Jordan include: earthquakes, aircraft and machinery such as wind turbines. Infrasound Technology is to detect and locate explosions in the atmosphere. It can be used in Jordan by station installation in well studied location, then connect it with National Data Center (NDC) in Jordan Seismological Observatory to receive data and signals. Suggested locations may include northern parts of Jordan in Ajloun area of lower Cretaceous such as Barqash or Eshtafina forests. These areas are recommended since they are flat areas with low surface wind, government protected and have low background noise.

Primary author: HAMMAD, NIDA'A (Ministry of Energy and Mineral Resources)

Presenter: HAMMAD, NIDA'A (Ministry of Energy and Mineral Resources)

Track Classification: Sources and Scientific applications

ID: Type: **Oral**

and seismoacoustic signatures of the 28 September 2018 Sulawesi super shear earthquake

A magnitude 7.5 earthquake occurred on 28 September 2018 at 10:02:43 UTC near the city of Palu on the Indonesian island of Sulawesi. It was a shallow, strike-slip earthquake with fractures up to the surface and a rupture length of about 150 km. Moreover, this earthquake was identified as one of very few events having a super shear rupture speed. Clear and long-lasting infrasound signatures related to this event were observed by four IMS infrasound arrays. Although these infrasound stations I39PW, I07AU, I40PG and I30JP are located in large distances between 1800 km and 4500 km from the earthquake's epicentral region, the observed infrasound signals associated to this event were intense, including both seismic and acoustic arrivals. The seismic-to-acoustic coupling at nearby terrain features is shown to generate distinct infrasonic signatures clearly recordable at remote infrasound arrays. A detailed study of the event-related infrasound observations and the potential infrasound generation mechanisms is presented covering range-dependent infrasound attenuation and propagation modeling, characterization of the atmospheric background conditions as well as identification of the regions of seismoacoustic activity by applying a back projection method from the infrasound receivers to potential source regions.

Primary author: PILGER, Christoph (Federal Institute for Geosciences and Natural Resources (BGR))

Presenter: PILGER, Christoph (Federal Institute for Geosciences and Natural Resources (BGR))

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

# of station IS41.

The station IS41 is located in Paraguay, in the middle of South America. It is composed by 4 elements and was certified in December 2003. The environment features stand out for the frequent occurrences of electric storms, high temperatures, copious rains and sometimes the access to the log elements becomes very complicated. It is presented the most common and recurrent problems of the station verified along 15 years, and this experience was reflected in an upgrade carried out around middle year 2018. In the frame of these instrumental modifications, was included the improvement of power system, grounding system, data acquisition system, wind noise reduction system and instrument vaults. It is also presented the project of the enlargement of the station to 8 elements, with a proposal of new emplacement and access to the sites.

Primary author: FUGARAZZO VELAZQUEZ, Rafael Jose (Universidad Nacional de Asuncion, Facultad de Ciencias Exactas y Naturales)

Presenter: FUGARAZZO VELAZQUEZ, Rafael Jose (Universidad Nacional de Asuncion, Facultad de Ciencias Exactas y Naturales)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

Signals from the Sinabung Volcanic Eruption on 19 February 2018

Monitoring our global environment with the infrasound array network to verify compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT), has also proved useful in several other man-made and natural phenomena, particularly in geo-hazards applications. Infrasound waves emissions from natural phenomenon such as volcanic eruption travel through the atmospheric layers resulting in pressure and temperature perturbations. Infrasound due to its low frequency acoustic waves has a very low attenuation rate when propagated in the atmosphere, and can be detected from long distances. An infrasonic array data collected after the eruption of Sinabung Volcano, Indonesia on the 19 February 2018 indicated that the vents of the eruption emitted infrasound waves. The low frequency signals were recorded by three International Monitoring System (IMS) infrasound stations such as I06AU, I19DJ and I52GB which were associated with the eruptive event of the Mount Sinabung. These infrasound signals propagated over a long distance >6000 km to be observed as far as the I19DJ station in Djibouti.

Primary author: AMARTEY, Edmund Okoe (Ghana Atomic Energy Commission)

Presenter: AMARTEY, Edmund Okoe (Ghana Atomic Energy Commission)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

capability

For infrasound station capability related.

Primary author: LEE, Seok-tae (KITValley INC.)

Presenter: LEE, Seok-tae (KITValley INC.)

Track Classification: Sources and Scientific applications

ID: Type: **Oral**

shaking intensity and source mechanism passively retrieved from remote infrasonic signals

The ShakeMap is a key component in the initial relief e_orts following an earthquake disaster. It depicts the distribution of shaking intensity in the epicentral region and is used to guide emergency responders to the region. In regions where seismic instrumentation is limited, such ShakeMaps are poorly constrained and can take days to generate. We show, that pseudo-ShakeMaps that indicate the relative shaking intensity, can be generated, within minutes, from enhanced processing and modeling of infrasound. Furthermore, the source mechanism can be retrieved. This is illustrated with infrasound from the 2010 MW 7.0 Port-au-Prince, Haiti earthquake, detected in Bermuda, over 1700 km away from Haiti. The pseudo-ShakeMap and focal mechanism retrieved in this study are in good agreement with the USGS estimated ShakeMap and the Global CMT moment tensor.

Such observations are made possible by: (1) An advanced array processing technique that enables the detection of coherent wavefronts, even when amplitudes are below the noise level, and (2) Backprojection of observed pressure perturbations to ground motions in the epicentral region while accounting for advection e_ects in the atmosphere. We support our observations with an example using the Rayleigh integral to generate synthetic waveforms from four quadrants of an earthquake focal mechanism. Synthetics are then processed to retrieve the relative sense of motion in each quadrant.

The current infrasound networks routinely detect earthquakes and allow for an unprecedented global coverage. This makes infrasound as an earthquake mitigation technique feasible for the first time.

Primary author: SHANI-KADMIEL, Shahar (Delft University of Technology)

Presenter: SHANI-KADMIEL, Shahar (Delft University of Technology)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

Auroral Signatures at the IS37 Station on 24 October 2017

Variations in acoustic pressure in the event of an atmospheric phenomenon such as auroral arcs occurrence generate infrasonic signals that are sensitive to microbarometer sensors of the infrasound network deployed globally. The International Monitoring System (IMS) infrasound network monitors and detects these non-verification-related low frequency acoustic signals periodically. These auroral electrojet arcs are often observed at the polar latitudes regions (i.e. Northern and Southern Hemispheres) of the Earth. The IMS infrasound station IS37 on 24 October 2017 detected the infrasound signals associated with the auroral electrojet arcs occurrence in the atmosphere. The observed infrasound waves were found to be within the frequency content <0.1 Hz, typical of the infrasound signals associated with auroral electrojet arcs. These aurora infrasound signals were observed with high trace velocity around 1km/s and showed quasi-continuous signals which have duration around 3 hours.

Primary author: AMARTEY, Edmund Okoe (Ghana Atomic Energy Commission)

Presenter: AMARTEY, Edmund Okoe (Ghana Atomic Energy Commission)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

Infrasound detections from Meteor events in 2019

Meteorites that penetrate the atmospheric layers can cause horror and may have an impact on population and infrastructure. When meteorites explodes in upper atmosphere it produces infrasound waves that can travel long distances with considerable no lose. The data of IMS infrasound stations used with PMCC algorism for interpretation, detecting the location and statistical analysis of two meteorites events. Two events in 2019 were well recorded at International Monitoring System IMS. The first one was a meteorite that exploded on 22 June 2019 detected in three stations (I08, I20, and I51). The second event was also meteorite penetrated 21 May 2019 detected with stations (I05, I22, I36, and I39). The IMS data were capable of locating both events with considerable resolution the first event was located over the Caribbean Sea at (21:30:43) GMT, 170 miles south of Puerto Rico .The second event was located over South Australia near Victoria (13:17:37) GMT. Although these events are irrelevant to the Comprehensive Nuclear Test Ban Treaty CTBT but location and identification of the nature of event is much helping in improving screening event in the verification System. Key Words: Meteorites -Fireball-Infrasound –International Monitoring System

Primary author: ELBEHIRI, Hani Saber Abdelsalam Farag (National Research Institute of Astronomy and Geophysics (NRIAG))

Presenter: ELBEHIRI, Hani Saber Abdelsalam Farag (National Research Institute of Astronomy and Geophysics (NRIAG))

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

performance and data quality of Infrasound station IS32 post major upgrade

The Infrasound Station IS32, herein referred to as "the station", is located about 10 km to the NNE of the city of Nairobi within Karura forest in Kenya. The thick forest canopy offers an excellent environment for the station by significantly minimizing cultural noise. In July-August 2019, the station underwent a major upgrade at all the seven element array sites and the Central facility (CF) involving installation of: - (i) 18 m of IMS standard stainless steel WNRS, (ii) MB3a microbarometers connected to the WNRS, (iii) MB2000 reference microbarometer connected to a single inlet port, (iv) Digitizer cables and integration boxes, (v) digital unit for the MET station, and (vi) upgrade of the processing computer from nmx to SSI. Additionally, passive calibration of the sensors was undertaken in accordance with WGB-43 request. During the infrasound technology workshop, we present data depicting the performance of the Infrasound station I32KE post-upgrade.

Primary author: MULWA, Josphat Kyalo (University of Nairobi, Department of Geology)

Presenter: MULWA, Josphat Kyalo (University of Nairobi, Department of Geology)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

23, a noisy infrasound array in the Southern Ocean

The International Monitoring System (IMS) is in place for the verification of the Comprehensive Nuclear-Test-Ban Treaty (CTBT). Part of the IMS are 60 infrasound arrays, of which 51 currently provide real-time infrasound recordings from around the world. Those arrays play a central role in the characterization of the global infrasonic wavefield and localization of infrasound sources (e.g., earthquakes, lightning, meteors, (nuclear) explosions, colliding ocean wave-wave and surf) [Campus and Christie, 2010].
In addition to the data provided by the IMS, the International Data Centre (IDC) in Vienna provides knowledge regarding the sensor noise levels for infrasound stations. Power Spectral Density functions (PSD), made several times per day, determine the sensor noise per station [Merchant and Hart, 2011]. Based on the minimum and maximum of the individual PSD's, the global low and high noise curves as a function of frequency are determined [Brown et al., 2014].
The IMS global noise curves are widely accepted and used [Peterson, 1993; McNamara and Bulard, 2004; Brown et al., 2014]; it is worth mentioning that the IMS infrasound array I23 is excluded from the atmospheric ambient noise curves. IS23 is located at Kerguelen Island and exist of 15 elements, divided into five triplets, making it the largest infrasound array of the IMS. Due to extreme conditions (e.g., a windy island with low vegetation), the array is known as noisy, and thus often excluded from infrasonic studies or analyses.
This research contains a detailed study of IS23. Meteorological and topographical conditions, and their effect on the infrasound recordings, are presented. Furthermore, various data processing techniques are applied, to suppress the wind noise, which could lead to an improvement of the beamform resolution.

Primary author: DEN OUDEN, Olivier Frederik Constantinus (KNMI)

Presenter: DEN OUDEN, Olivier Frederik Constantinus (KNMI)

Track Classification: Sources and Scientific applications

ID: Type: **Oral**

the use of acoustic waveforms for localizing bolides: the large 2018/12/18 Bering Sea event

The 18 December 2018, a large bolide exploded over Bering Sea. More than three months after the event, NASA reported its geographic location, its altitude and velocity at peak brightness, so that this event can be considered as a ground truth event. Bolide-generated acoustic signals were detected by 18 IMS infrasound stations up to more than 15000 km at I55US (Antarctica), tens of microbarometers of the Transportable USArray (TA) located in Alaska, seismic stations of the Aleutian Islands, and possibly on the North triplet of hydrophones of Wake Island, H11N. The dominant frequency of detected infrasound signals is centered on 0.2Hz, which offers the opportunity to study very long range propagation from full-waveform modeling at low computational cost, using for this the FLOWS platform developed at CEA. Various effects, such as the source altitude, the horizontal variability of the atmosphere and the unresolved gravity wave component, will be discussed in terms of their impacts on the station-dependent velocity models and the event location.

Primary author: VERGOZ, Julien (CEA/CENTRE Ile-de-France)

Presenter: VERGOZ, Julien (CEA/CENTRE Ile-de-France)

Track Classification: Sources and Scientific applications

ID: Type: **Oral**

Three-Dimensional Array for the Study of Infrasound Propagation Through the Atmospheric Boundary Layer

The Royal Netherlands Meteorological Institute (KNMI) operates a three-dimensional microbarometer array at the Cabauw Experimental Site for Atmospheric Research observatory. The array consists of five microbarometers on a meteorological tower up to an altitude of 200 m. Ten ground-based microbarometers surround the tower with an array aperture of 800 m. This unique setup allows for the study of infrasound propagation in three dimensions. The added value of the vertical dimension is the sensitivity to wind and temperature in the atmospheric boundary layer over multiple altitudes. In this study, we analyze infrasound generated by an accidental chemical explosion at the Moerdijk petrochemical plant on 3 June 2014. The recordings of the tower microbarometers show two sequential arrivals, whereas the recordings on the ground show one wavefront. This arrival structure is interpreted to be the upgoing and downgoing wavefronts. The observations are compared with propagation modeling results using global-scale and mesoscale atmospheric models. Independent temperature and wind measurements, which are available at the Cabauw Experimental Site for Atmospheric Research, are used for comparison with model output. The modeling results explain the signal arrival times; however, the tower wavefront arrivals are not explained. This study is important for understanding the influence of the atmospheric boundary layer on infrasound detections and propagation.

Primary author: SMETS, Pieter (KNMI - Royal Netherlands Meteorological Institute)

Presenter: SMETS, Pieter (KNMI - Royal Netherlands Meteorological Institute)

Track Classification: Sources and Scientific applications

ID: Type: **Poster**

Detection Capability Improvement on Noise Reduction System in IS02 H5 Array

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 technics 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.

Primary author: PANTIN, Andres Sebastian (Autoridad Regulatoria Nuclear (ARN))

Presenter: PANTIN, Andres Sebastian (Autoridad Regulatoria Nuclear (ARN))

Track Classification: Sources and Scientific applications

ID: Type: **Oral**

monitoring and study on infrasound from water dam

The characteristics of infrasound waves (such as frequency spectra, amplitudes, attenuation over ground surface) generated by a water dam are presented in this paper. A possible infrasound generation mechanism is proposed based on earlier models of infrasound generation by large objects falling into water. The mechanism suggests that the water falling through dam's ducts into absorption pool causes local elevations of the water surface (surges) surrounding by rings of descending water levels, which generate infrasound in the air like dipole-like pistons. The attenuation of the amplitude of infrasound waves with increasing range from a dam along different directions is analyzed as a function of a water flow speed through the ducts. The infrasound characteristics estimated from the model developed here are consistent with those obtained from the experimental data.

Primary author: TENG, Pengxiao (Institute of Acoustics,Chinese Academy of Sciences)

Presenter: TENG, Pengxiao (Institute of Acoustics,Chinese Academy of Sciences)

Track Classification: Sources and Scientific applications

ID: Type: **Oral**

monitoring in Romania

Three infrasound stations has been deployed on the Romanian territory by National Institute for Earth Physics (NIEP): IPLOR 6-element array of 2.5 km aperture, in operation since 2009 in the central part of the country, BURARI 4-element research array of 1.2 km aperture, installed in July 2016, in the northern Romania, under a joint effort with Air Force Technical Application Center AFTAC (USA), and I67RO – a PTS portable 4-element array of 0.9 km aperture, installed in September 2016, in western Romania for two-year experiment, within a collaboration project with PTS/CTBTO. Infrasound data are processed and analyzed on routinely basis at NIEP by using a duo of infrasound detection-oriented software (DTK-GPMCC and DTK-DIVA) packaged in the CTBTO NDC-in-a-Box. We present the results of these activities, i.e. array monitoring performance: detection capability assessment, types of sources observed, capacity of fusing the detections into support of understanding various infragenic sources. Infrasonic signals generated by anthropogenic explosive sources and detected with the three arrays deployed on the Romanian territory are presented.

Primary author: GHICA, Daniela Veronica (Romania National Data Centre)

Presenter: GHICA, Daniela Veronica (Romania National Data Centre)

Track Classification: Sources and Scientific applications