Infrasound Technology Workshop 2018 (ITW2018)

Report of Contributions

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ID: Type: **Oral**

Classification of natural and man-made infrasound events

Infrasound sources could be classified as man-made and natural sources. The first category includes explosions while the second includes earthquakes, volcanoes, fireball, and meteorites. In this paper the different sources are processed using the Progressive Multi-Channel Correlation algorithm (PMCC) which is a very effective technique in array analysis. This technique correlates the signals recorded by the different collocated elements of the array. The obtained correlation function reflects different patterns depending on spectral characteristics of the infrasound source. In this study, we analyzed different infrasound man-made and natural sources, including The October 7, 2008, TC3 meteor fallen over the north Sudan Nubian Desert, the February 15, 2013, Russian fireball, and February 6, 2016, Atlantic meteor near to the Brazil coast. Additionally, the volcanic eruption of Etna, Sakurajima and Hawaii volcanoes. Furthur more the rocket launching events of the Dnepr rocket which launched in 2006 from Baikonur, Kazakhstan. , finally, the earthquake of the Tohoku earthquake in 2011. The study showed a unique signature for each set of events that may be used for an automated algorithm for signal classification

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Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

-driven parameterization for CLEAN beamforming

Ambient noise varies both in space and time, resulting in multiple source locations with varying strength. Interfering sources are not always correctly resolved when classical beamforming methods are applied. Various beamforming methods exist in literature for a better discrimination of multiple continuous sources. One of these methods, CLEAN, is discussed here. The CLEAN method iteratively selects the maximum of the f/k spectrum, removes it and stores it in a new spectrum. Nonlinear ocean wave interaction generates signals that radiates in ocean, atmosphere and solid earth. These low frequency signals dominate the ambient noise field, around 0.2Hz (microbaroms(atmosphere) and microseisms(solid earth)). To detect and characterise these continuous signals, infrasound and seismic arrays of the International Monitoring System (IMS) are used. Those arrays are build to monitor nuclear test, for the verification of the Comprehensive Nuclear Test Ban Treaty (CTBT), failing to exclude the ambient noise field consequentially increase the false-alarm rate. This research tests CLEAN elaborately and proposes a data-driven method to parameterise the beamforming algorithm. The use of Fisher statistics is proposed to help determine the stopping condition for CLEAN and to indicate the source strengths. Results are obtained by applying CLEAN on synthetic data and on IMS data.

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Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

on a Method for Improving the Accuracy of the Traveltimes Difference Surveying of Infrasound Detection Array

The traveltimes difference surveying of infrasound detection array is one of key factors that affects the accuracy of infrasound source localization. In this paper, the main methods of calculation the traveltimes difference of infrasound detection array are introduced, and then analyze on common method for improving the accuracy of the traveltimes difference calculation. Based on the infrasound wave signal influence factors in the case of long distance transmission, the correlation function fitting curve and resampling technique are proposed to improve the accuracy of traveltimes difference surveying.
Keywords: infrasound, array, the traveltimes difference

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Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

climatology of ocean ambient noise using the IMS infrasound network

The ability of the International Monitoring System (IMS) global infrasound network to detect atmospheric explosions and events of interest strongly depends on station specific ambient noise signatures which include both incoherent wind noise and coherent infrasonic waves. Understanding the detectability of coherent noise in the frequency range of explosions is important for successfully applying infrasound as a verification technique. To characterize the ambient noise, broadband array processing has been performed on continuous IMS recordings since 2005 using a standardized fractional octave band schemas. Ocean wave interactions contribute to the atmospheric coherent ambient noise field. For the source term modelling, the operational ocean wave interaction model distributed by Ifremer has been updated to characterize coupling mechanisms at the ocean-atmosphere interface. The observed and modeled directional microbarom amplitudes at several IMS stations worldwide distributed are compared, accounting for both frequency dependent source and propagation effects. This study aims to build a global reference database to provide an improved knowledge-base on ambient ocean noise sources. In return, it opens new perspectives for enhancing the characterization of explosive atmospheric events as well as for providing additional constraints on middle atmosphere dynamics and disturbances in sparsely covered regions.

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Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

Infrasound Array Processing with Robust Estimators

Infrasound signal detection and source characterization relies on high-quality array processing parameter estimates. Physical and statistical assumptions in conventional array processing techniques sometimes fail due to propagation effects or station degradation. Unlike conventional least squares, robust regression estimators are relatively insensitive to data that deviate from the assumed model. We compare two such estimators, M-estimators and least-trimmed squares (LTS), to conventional array processing methods (fk, PMCC, L1 regression, and ordinary least squares (OLS)) using synthetic and real infrasound data. Evidence from synthetic testing suggests robust estimators are resistant to single station contamination by noise, sinusoidal waves, and timing errors. Additionally, evaluation of LTS residuals enables outlying inter-station differential times to be flagged automatically, providing a potential data quality tool. Initial testing on IMS data suggests that these techniques produce more stable and accurate back-azimuth and velocity calculations than conventional techniques. For example, we note improved estimates at IS57 for a case where the plane wave assumption breaks down at a single element. We will present additional case studies applying our robust estimators to real data. Lastly, similar to OLS, the robust estimation methods also quantify uncertainty as a covariance matrix, providing a useful estimate of station and detection quality.

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Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

OF MICROBAROM AND MICROSEISM SOURCE REGION FOR THE KAZAKHSTAN TERRITORY AND COMPARISON WITH THE OBSERVATIONS OF THE KAZAKH SEISMO-ACOUSTIC NETWORK

The Kazakh monitoring network consists of five seismic and three infrasound arrays. Seismic arrays are ABKAR, BVAR, KKAR, MKAR and Kurchatov Cross. Infrasound arrays are I31KZ, Kurchatov and Makanchi infrasound arrays. KazNDC also processes data of the Russian infrasound array I46RU. All the arrays record low-frequency signals mostly from North-West. A dominating source region of microbarom/microseism signals for Kazakhstani area is located in North Atlantic [Smirnov et al., 2010]. Time-dependent simulations of the microbarom/microseism source regions were made using a hydrodynamic model of ocean wave interactions developed by IFREMER. Comparisons between observations at the Kazakh monitoring network and modelling results are carried out.

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Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

Event Categorization Using Machine Learning and Deep Learning

It is nearly impossible for an analyst to categorize regional and global infrasound events by eye. Currently, categorizing these events requires removing false detections and using seismic or other forms of data as ground truth. We explore two machine learning approaches, support vector machine (SVM) and deep learning (Convolutional Neural Network) to determine their potential for high-accuracy automated infrasound event categorization. We leverage a training catalog of 36,000 events, detected and manually labeled by the International Data Centre (IDC). The catalog consists of events from a variety of both natural and anthropogenic sources located around the world. Features relating to the physical characteristics of the data are used in SVM, while for the deep learning approach we use both spectrograms and raw data as the model input. Performance of the two methods is compared using 10-fold cross validation to determine their individual advantages. 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.

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Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

infrasonic wavefronts over large aperture sensor arrays

The apparent velocity and backazimuth of infrasound signals on arrays can be estimated in many ways. Estimates can vary significantly with the methods and parameters used, and with signal coherence. Larger arrays, with many sensors, allow measurement of the slowness on many different subsets of sensors. On IMS infrasound arrays with aperture 1-2 km, and with over 8 sensors, we can form parametrized slowness maps for the incoming wavefront as a function of location within the array. In most cases, the best parametrization is a plane wavefront. For near-field sources, the wavefield parametrization captures the wavefront curvature, allowing accurate distance estimates. At over 3 km aperture and with 25 sites, the ARCES seismic array is significantly larger than most IMS infrasound arrays. Strong ground-coupled airwaves from repeating explosions at 180 and 250 km allow the measurement of slowness on different parts of the array. We demonstrate that backazimuth variability resulting from atmospheric factors greatly exceeds variability from measurement uncertainty, and that the deviation from a plane wavefront varies from event to event. We conclude the shape of the infrasonic wavefront at these distances is influenced by atmospheric features with length scale comparable to the dimensions of the array.

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Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

# of acoustic standards in PMCC detector for fine-tuned infrasound detection and categorization

The completion of IDC event bulletins requires that infrasound array detector be tuned to detect wide variety of acoustic signals, often buried in the background noise. Dominant frequencies of signals of interest can span over 3 decades (from 0.01Hz to 10Hz), depending on source energy, frequency-dependent attenuation along different propagation paths and noise conditions which can vary significantly from one station element to another. Consequently, assessing correctly the detection capability of an infrasound station relies on the ability to detect both broadband transient as well as narrow band signals, and to estimate precisely wavefront parameters in separated frequency bands. In this context, the configuration of a broadband detector is tricky, especially in determining the optimal filter banks and associated window lengths. An optimal adjustment is proposed from an extension of fractional octave frequency scales used in acoustic metrology extended to infrasound frequency ranges (Garcès, 2013). A multi-resolution algorithm has been implemented in DTK-PMCC with a standardization of the window lengths and the frequency bands in third octave bands, which adapts automatically to the geometry of each station. Results demonstrate how the quality of the obtained detections are adapted to more efficient categorization and more precise event locations.

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Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

False Alarm Rate of the International Monitoring System Infrasound Network

The International Monitoring System (IMS) infrasound network has been designed to acquire the necessary data to detect and locate explosions in the atmosphere with a yield equivalent to 1 kiloton of TNT anywhere on Earth. A major associated challenge is the task of automatically processing data from all IMS infrasound stations to identify possible nuclear tests for subsequent review by analysts. This presentation is the first attempt to quantify the false alarm rate (FAR) of the IMS network, and in particular to assess how the FAR is affected by the numbers and distributions of detections at each infrasound station. The results show that the FAR for events formed at only two arrays is extremely high (ranging from 10's to 100's of false events per day across the IMS network, depending on the detector tuning). It is further shown that the FAR for events formed at three or more IMS arrays is driven by ocean-generated waves.

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Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

the presence of tonal noise in infrasound records

Industrial activity has a significant impact in the local and regional seismic-acoustic wavefield. The repetitive nature of industrial processes generates persistent elastic energy that can be observed at distances of several 10's of kilometers. The signature of this activity is observed as a mixture of both broadband and tonal noise (TN) in seismic and acoustic/infrasonic records. TN is generated by machines with rotating parts and is often characterized by sharp spectral peaks at the frequency of rotation and its integer harmonics. For example, large modern wind turbines (power > 1 megawatt) can produce TN with fundamental frequencies between 0.5 and 3 Hz. We are developing an algorithm for the detection and localization of TN. This detector operates in three steps: (1) temporal normalization to prevent the interference of transient signals, (2) estimation of the power spectral density and peak identification, and (3) peak categorization within TN sequences. We are testing the performance of the detector using infrasound stations of the International Monitoring System. The identification and characterization of TN (e. g.: number of TN sequences, fundamental frequencies, and number of harmonics) in infrasonic records can provide information to reduce its potential effects in the performance of sensor arrays.

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Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

and azimuth estimation based on two-dimensional subspace algorithm in the infrasound monitoring

Infrasound monitoring is an effective method for monitoring the atmosphere and shallow explosions. And during the infrasound monitoring, the slowness and azimuth are very important for the infrasound signal propagation, location and infrasonic sources recognition. The common method for the slowness and azimuth is the frequency-wavenumber(FK) method, but when the FK is applied to the infrasound signal processing, the accuracy and resolution are not high, furthermore, this method can't identify multiple infrasound signals effectively. Based on the uncorrelation characteristic between the infrasound signal subspace and the noise subspace, the infrasonic two-dimensional subspace model is constructed, and then, a high-resolution calculation algorithm is proposed. The comparative analysis and the simulation experiments show that the proposed algorithm has better performance than the FK method in terms of resolution and has good discrimination results among two simultaneous infrasound sources.

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Track Classification: Data Processing and Station Performance

ID: Type: **Oral**

Analysis and Propagation Modeling of Dynamic Sources of Opportunity

Sources of opportunity play a key role in expanding our understanding of source physics and validating propagation models. For dynamic sources, such as rockets, the modeling is complicated by the body's motion through the propagation medium. Supersonic sources pose the additional challenge of introducing nonlinear propagation effects. Previous research efforts in this area have successfully modeled arrival time, azimuth and waveform observations using eigenrays (Blom et al., "Analysis and Modeling of Infrasound from a Four-Stage Rocket Launch," Jour. Acous. Soc. of Am., 139, 3134-3138, 2016) and full-wave modal analysis (Waxler et al., "The Stratospheric Arrival Pair in Infrasound Propagation," Jour. Acous. Soc. of Am., 137, 1846-1856, 2015). In this study, observations from recent heavy-lift rocket launches are analyzed to further quantify our model capabilities. Booster separation from the main rocket body may introduce distinct, separated sources, and it is included in the analysis as ground truth will support. Prediction limitations for arrival time, azimuth, and dominate waveform features are compared to observations. Event-to-event comparisons are also made to identify features that can be attributed to source type.

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Track Classification: Modelling & Network Performance

ID: Type: **Oral**

Source Models

It is a daunting task to frame the fearful symmetry of a blast. Properties and defining characteristics of theoretical source pressure functions representative of detonations and deflagrations are considered, and criteria for defining reference blast pulses are discussed. A new impulse-balanced blast pulse is proposed as a reference signature for propagation model initialization, the design of detection and feature extraction algorithms, yield uncertainty quantification, and transfer function evaluations.

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Track Classification: Modelling & Network Performance

ID: Type: **Oral**

atmospheric updating to construct high precision models of propagation effects for source localization and event characterization

The dynamic and poorly sampled nature of the atmosphere has posed an ongoing challenge in infrasound propagation modeling applications due to the associated uncertainty in the acoustic propagation medium. Propagation-based, stochastic models defining seasonal trends in path geometry and travel times as well as transmission loss have been constructed using archived atmospheric specifications combined with ray tracing and normal mode simulation capabilities, respectively, and produced promising improvements in relevant applications. Improving the precision of these models requires refinement of the suite of atmospheric states considered in the stochastic formulation, which can be accomplished via atmospheric updating analysis. Such analysis aims to identify perturbations to an initial estimate of the atmospheric state that improves agreement between observed and predicted propagation characteristics. Several approaches to atmospheric updating for infrasonic propagation modeling will be discussed and evaluated in cases with and without ground truth source locations and origin times using a combination of synthetic and real-world data sets.

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Track Classification: Modelling & Network Performance

ID: Type: **Oral**

effects of stability of the atmospheric boundary layer on the propagation of acoustic waves

The experimental data on the amplitude-time parameters p+, p-, t+, t- of the first positive and negative phases of acoustic waves in the atmosphere generated by pulse sources of different nature are analyzed. By comparing these data with the results of numerical simulation of spherical and cylindrical propagation of blast waves in homogeneous atmosphere, the effects of stability of the atmospheric boundary layer (ABL) on the parameters of acoustic signals were found. More than 6300 experimental values of p +, p-, t +, t- were analysed.It was explained for the first time the qualitative and quantitative influence of the stability of the ABL on the parameters of the acoustic waves propagating in the ABL. As a result, the average values of its parameters p +, p-, t + and t- increase by 1 - 2 orders with respect to the case of wave propagation in the unstable or neutral boundary layer of the atmosphere. The approximations of the experimental values of the p- and t- recorded acoustic signal ob-tained in the wide energy ranges of the sources 10(-8) < Q < 10(+10) kg of TNT and the reduced distance 1 < R/Q(1/3) < 4·10(4) m/kg1/3 are given.

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Track Classification: Modelling & Network Performance

ID: Type: **Oral**

# of Infrasound Waveform Inversion: Application to Explosion Yield Estimation

Waveform inversion techniques are widely used to constrain source dynamics of infrasound. The methods exploit full-waveform information and provide further constraints on source parameters than other inversions using only a few observation parameters. Infrasound waveform inversion was recently applied to volcanic eruptions and chemical explosions and showed promising results for source parameter estimations. The method can improve the accuracy of the estimated yield by using full 3-D numerical Green's functions and incorporating the propagation path effects into the inversion. However, the inversion results are often given without any uncertainty estimation, which is critical for quantifying the reliability of the inversion solution. In this study, we present probabilistic framework for waveform inversion method and describe the uncertainty of inversion parameters by the posteriori distribution and the priori data covariance. We apply the method to ground-truth explosion experiments and evaluate the yield estimation errors associated with mismodelling and source uncertainty. The presented probabilistic statements can be generalized for other infrasonic events (e.g., volcanic explosion, bolide explosions) and provides quantifiable uncertainty analysis.

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Track Classification: Modelling & Network Performance

ID: Type: **Oral**

3-D Acoustic Multipole Waveform Inversion at Yasur Volcano, Vanuatu

Well-constrained acoustic waveform inversion can provide robust estimates of explosion source parameters, increasing our ability to monitor anthropogenic and natural explosions. Previous volcanic studies have generally assumed a simple acoustic source (monopole), however more complex source reconstructions can be estimated using a combination of monopole and dipole sources (multipole). We deployed an acoustic network around Yasur volcano, which has eruptions every 1-4 minutes. The deployment included acoustic sensors along a tethered aerostat, allowing us to better constrain the acoustic source in three dimensions. We follow the methods of Kim et al. (2015) using Finite-Difference Time-Domain modeling to obtain the full 3-D Greenâ□□s functions for each propagation path. We then invert for the location and multipole source-time functions for 80 events to examine the source characteristics of the vents, including an infrasound-derived volume flow rate and dominant dipole direction. We perform the first multipole inversion that accounts for topography and find that a monopole is a good approximation, but a small dipole component remains that is consistent with ballistic trajectories. Furthermore, accounting for topography helps reduce the overestimation of both the monopole and dipole strengths. This inversion method could be extended to anthropogenic explosions and monitoring efforts, potentially in near-real time.

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Track Classification: Modelling & Network Performance

ID: Type: **Oral**

effect of along-path variability in stratospheric waveguide structure upon infrasound signal duration.

The duration of infrasonic signals recorded by sensors on the Earth's surface increases with source-to-receiver distance, due to the increased separation of the fastest and slowest portions of the wavefield. 43 infrasound signals exhibiting high signal-to-noise ratios within the 0.32 to 1.28Hz passband, and generated by well-constrained ground truth events, have been analyzed using an algorithm developed to consistently measure signal durations. The signal database contains recordings from microbarograph arrays of the International Monitoring System at distances of between 20 and 6300km from the source. The results indicate that signal duration is dependent upon both source-to-receiver distance and the along-path variability in the strength of the stratospheric waveguide, as measured by the ratio of effective sound speeds in the stratosphere and at the ground. For paths with low along-path waveguide variability the signal duration, D (s), exhibits a weak linear relationship with source-to-receiver distance, r (km), such that D can be estimated as D = 0.278r+122. The signal durations are reduced when the propagation paths exhibit waveguide strength variability. Ray-tracing simulations indicate that horizontal gradients in waveguide strength act to restrict the signal celerities that can be supported by stratospheric waveguide propagation.

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Track Classification: Modelling & Network Performance

ID: Type: **Oral**

-wind effects on infrasound propagation

The cross-wind effect on infrasound propagation has been studied on the seismic array ARCES, Norway, utilizing 30 years of data from explosions at the Hukkakero military blast-site in Finland. Around 99% of the seismically identified explosions at Hukkakero (around 600 in total) are detected as seismo-acoustic signatures around 10 minutes after the arrival of the original P- and S-waves, indicating a good ducting through the stratosphere between the two sites. Despite these observations, ray-tracing of infrasound through re-analysis model atmospheres (e.g., ERA-Interim and ERA5) typically shows that ARCES lies in the shadow zone for these explosions. The total cross-wind effect, throughout the whole propagation path, has instead been estimated along a simplified ray-path model. The observed back azimuth deviation of the infrasound arrivals for each event is then analyzed in light of the calculated cross-wind effect, to get a statistical estimate on the effect the cross-wind has on infrasound propagation. Our results verify that both the tropospheric and stratospheric cross-wind contributions affect the propagation. Therefore, the tropospheric winds need to be considered when using these data to characterize the stratosphere.

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Track Classification: Modelling & Network Performance

ID: Type: **Oral**

Transmission Loss Maps for Regional Infrasound Propagation

A general method for producing a statistical model for infrasound signal transmission from a large sample of atmospheric specifications has been developed. Applying this method to historical archives of atmospheric specifications, statistical transmission loss maps are developed. These depend on season of the year. It is found that propagation characteristics divide the year into four seasons, winter, summer, autumnal equinox and vernal equinox. The separation into seasons depends on location, and the particular months in each season can vary slightly. The statistical sampling method and the obtained results for a few examples are shown and potential extensions of the method are discussed.

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Track Classification: Modelling & Network Performance

ID: Type: **Oral**

# of laser measurements of a pressure driver in infrasound laboratory calibrations

Infrasound chambers are commonly used to calibrate infrasound sensors using a dynamic piston to generate pressure variations and a calibrated reference sensor against which to compare the observations of pressure. The reference sensor that is used in such a calibration system requires periodic recalibration in order to maintain traceability. As an alternate approach to traceability, the 1400 Liter infrasound calibration chamber at Sandia National Laboratories has recently been improved to include a laser on each of its two 10" diameter pressure drivers that measures the absolute displacement of the piston surface. By incorporating traceable measures of the piston surface area, chamber volume, chamber surface area, and absolute pressure, the displacement measurements of the laser-piston should be able to be used to predict the dynamic pressure observed within the infrasound chamber. Empirical measurements of the laser-piston displacement relative to calibrated reference sensors are compared with both adiabatic and isothermic models of the infrasound chamber.

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Track Classification: Measurement systems and calibration

ID: Type: **Oral**

Noise Reduction at Infrasound Frequencies Using Large Domes

One ongoing challenge to the use of infrasound for long-range monitoring applications (e.g., remote explosions or natural sources of infrasound such as tornados, volcanos or hurricanes) continues to be the high noise floors experienced at many permanent infrasound stations. International Monitoring System (IMS) infrasound stations typically address this problem using large pipe arrays as wind noise filters. However, these arrays generate significant distortion of higher frequency signals, making them non-ideal signals with significant frequency content above a few Hz. Further, they do not produce sufficient noise reduction during windy (typically daytime) measurements, making their utility generally limited to very quiet wind-noise periods (typically nighttime). Here we report on the development history of a 20-foot dome intended for permanent infrasound installations, and on measurements collected from arrays at the University of Mississippi Biological Field Station and at the Sandia National Laboratory Facility for Acceptance, Calibration, and Testing (FACT) site. The 20-foot dome at the FACT site is collocated with an IMS 18-m rosette filter and a University of Alaska Fairbanks experimental array, and more than a year of data has been collected, allowing for detailed comparisons of the efficacy of these different wind-noise reduction schemes.

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Track Classification: Measurement systems and calibration

ID: Type: **Oral**

passive on-site calibration at IMS infrasound arrays

The challenge for infrasound calibration is to measure the response of the operational microbarograph sensor connected to the wind-noise reduction system (WNRS). Gabrielson (2011) proposed a passive method using a calibrated reference sensor with no WNRS located beside the operational sensor. This passive on-site calibration technique at certified IMS stations has been implemented in the forests of Germany in 2015 (IS26) and Norway in 2016 (IS37) and on the ocean islands of Galapagos (IS20) and Tahiti (IS24) both in 2017. We attempt to follow the method presented by Charbit et al., (ITW 2015), and analyse data from these four locations in the frequency passband 0.02 – 4 Hz to determine the variation in the operational element sensitivity through time. Of interest is how the results of the passive calibration methodology vary between array elements and between different station locations across the passband of interest. Power spectral density (PSD) plots can be used alongside the passive on-site calibration method to identify possible data quality issues (Martysevich, ITW 2017) especially due to problems with the WNRS, or its connection to the operational microbarograph.

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Track Classification: Measurement systems and calibration

ID: Type: **Oral**

in reciprocity calibration of infrasound sensors

Reciprocity calibration is a well-established primary calibration technique, a technique that does not require an independently-calibrated acoustic reference. In its most general form, reciprocity requires two transducers in addition to the sensor being calibrated; however, the responses of these transducers do not need to be known. The transmitting and receiving responses of the two reciprocal transducers and the receiving response of the sensor are derived from voltage-to-current ratio measurements, by physical characteristics of the apparatus—volume, surface area, and electrical resistance, for example—and physical characteristics of the air inside the apparatus. The calibration chamber, designed and built by the National Center for Physical Acoustics at the University of Mississippi, then modified and operated by Sandia National Laboratories, incorporates commercial moving-coil loudspeakers as the reciprocal transducers. These loudspeakers are attached to a closed volume containing the sensor under test. This presentation describes measurement of the magnitude and phase response over frequency of several infrasound sensors using the reciprocity-based calibration procedure. The dominant sources of uncertainty and auxiliary measurements used to verify proper operation are described.

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Track Classification: Measurement systems and calibration

ID: Type: **Oral**

# of Nonlinearity in Microbarometers

Accurate element-to-element correlation of incoming signals is important for good infrasound-station performance. For example, mismatches in phase response can result in errors in azimuth estimation. These mismatches can be identified through in-situ calibration. Although the impact of nonlinearity on array performance is not as well known, waveform distortion has the potential to affect classification of acoustic events. Furthermore, characterization of nonlinearity (including signal clipping) should be a part of the specification for microbarometer performance to avoid acceptance of new sensor types that might have good small-signal performance but poor large-signal performance and to establish limits for existing-sensor applications. In a previous task, Penn State developed a portable apparatus for on-site measurement of acoustic impedance of pipe- or hose-based wind-noise reduction systems. Since this probe can generate high acoustic pressure amplitudes, the probe has since been modified to measure departures from linearity in microbarometers. The actual transfer curve of the microbarometer (voltage out as a function of pressure in) can be measured directly, which avoids the difficulties in interpretation of indirect methods like harmonic distortion or two-tone intermodulation. This paper describes preliminary experiments in nonlinearity determination for several microbarometer types.

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Track Classification: Measurement systems and calibration

ID: Type: **Oral**

results from long-term infrasound sensor comparison

Previous testing has shown that infrasound sensors deployed in the field can exhibit notable deviations from their lab-based calibrations. These variations may in-part be due to changes in environmental conditions (e.g. temperature), long-term sensor drift, or other unresolved features. In early 2018 we installed two identical test elements at the Sandia National Labs FACT site with five infrasound sensors (Chaparral M50A, Chaparral M64, MB2005, MB3, and Hyperion IFS-5100) connected to a single port to the atmosphere, as well as internal and external temperature, humidity, and absolute pressure sensors. Using the MB2005 as the reference, we examine the sensor response a function of time and compare it to lab-based calibrations and environmental conditions. Preliminary results show that all sensors exhibit some variability, with the amplitude variations often >5%. The variations occur on both long-term (months) and short-term (diurnal) timescales. The short-term variability appears related to changes in environmental conditions, and is very significant (up to 20%) for the Chaparral 50A and somewhat for the MB3 (~5%). The other sensors show some long-term sensitivity offsets. Here we present the results of 6 months of testing and discuss potential sources of response variability and how they may affect station performance.

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 and calibration

ID: Type: **Oral**

# of Seismo Wave MB3d with Raspberry Pi at Nanyang Technological University

In order to assess the feasibility of the installation of an infrasound array on the campus of Nanyang Technological University (NTU) a temporary deployment of the Seismo Wave MB3d microbarometers is being designed and carried out. This system uses Raspberry Pi 3 B (RPi) microcomputers for data collection, archiving, and data streaming via Wi-Fi and Ethernet. The use of RPi allows for a realtime stream from the deployed sensors into the main infrasound data processing machine at NTU and allows for comparison between the NTU sites and the established infrasound site at MacRitchie Reservoir. In order to achieve realtime data transmission the RPi is configured to access the MB3d USB connection and is also running the Earthworm software. This current configuration has provided a solution for temporary deployments, but there are limitations that impact its use for further deployments including high power consumption relative to other elements of the station. For a practical and inexpensive solution for easily accessible sites, the RPi has worked well, but these few technical issues keep it from being an ideal solution for a permanent installation. Further work is being done to determine if a similar solution can be designed to work with the serial connection for the MB3ds.

Primary author: WHILLDIN, David (Nanyang Technological University, Earth Observatory of Singapore)

Presenter: WHILLDIN, David (Nanyang Technological University, Earth Observatory of Singapore)

Track Classification: Measurement systems and calibration

ID: Type: **Oral**

-Borne Barometers for Aero-seismometry with Planetary Science Applications

JPL and its partners are in the process of developing new technology for the detection of infrasonic waves generated by seismic activity from a balloon in order to achieve the aim of performing geophysical experiments from an atmospheric platform. This technique is being developed for application on planetary bodies with significant atmospheres, such as Titan and Venus. In particular, the remote sensing of quakes on Venus avoids the technological challenge of landing and surviving in harsh conditions on its surface for long periods of time. In this presentation, we will examine the potential of balloon-borne infrasound sensors to act as seismometers from the air, and their ability to detect and characterize seismic events on the surface. We will present a detailed analysis of data gathered in a first-of-its-kind experiment in Pahrump, Nevada in June 2017, where artificial seismic signals were generated using a seismic hammer and infrasonic signatures were recorded using balloon-based barometers. Our results demonstrate the ability of our infrasound sensors to not just detect, but also geolocate and examine the spectral content of ground motion produced by the hammer. We continue to develop this innovative technique to study the subsurface of planets without needing to land on them.

Primary author: KRISHNAMOORTHY, Siddharth (NASA Jet Propulsion Laboratory)

Presenter: KRISHNAMOORTHY, Siddharth (NASA Jet Propulsion Laboratory)

Track Classification: Measurement systems and calibration

ID: Type: **Oral**

-going research in Infrasound at Georgia Tech Research Institute (GTRI)

This presentation discusses on-going research in Infrasound at Georgia Tech Research Institute (GTRI), the applied research arm of Georgia Institute of Technology. In particular, results of a study that compared a number of commercially available infrasound sensors with and without a wind screen loaned to GTRI by NASA Langley and described by Ahuja and Shams in the 2017 Infrasound Workshop are presented. Sources of producing controlled infrasound under consideration at GTRI are also discussed. These include a sonic boom simulator, a low frequency acoustic driver, oscillating jets, and door opening and closing. Each source was most effective in a given frequency range. Controlled infrasound at 0.1 Hz was obtained by varying the exit Mach number of exit Mach number of a cold plume from very low Mach number to a high Mach number at a nominal frequency of 0.1 Hz. It is expected that the amplitude of this signal will increase by heating the jet. Preliminary results of successful attempts at removing wind noise using Wavelet methodology are also shown. This talk will also describe planned collaborative work on the topic of infrasound between researchers at Georgia Tech and those at CTBTO.

Primary author: AHUJA, Krishan K (Georgia Institute of Technology)

Presenter: AHUJA, Krishan K (Georgia Institute of Technology)

Track Classification: Measurement systems and calibration

ID: Type: **Oral**

# of MB3d in operationnal condition in tropical area

I68CI is an infrasound portable array deployed in the North-East of Cote d'Ivoire since January 2018. This project is the result of collaboration between CTBTO and the Station Geophysique de Lamto, the ivorian NDC. The sensor used is the MB3d, developped by the French Renewable and Atomic Commission (CEA) and manufactured by SeismoWave. It is made of a MB3a microbarometer with a digitizer in one device. This is the first time that the MB3d is run for a long period and in tropical environment. This presentation will report observations made on this sensor during the first months of this project. It will talk about the influence of local temperature, wind noise reducing system used, seismic sensitivity and its internal state of health.

Primary author: YAO, Oka Palmer (CTBTO)

Presenter: YAO, Oka Palmer (CTBTO)

Track Classification: Measurement systems and calibration

ID: Type: **Oral**

from the 2009 and 2017 DPRK rocket launches

Supersonic rockets generate low-frequency acoustic waves, i.e., infrasound, during the launch and re-entry. Infrasound is routinely observed at infrasound arrays from the International Mon- itoring System, in place for the verification of the Comprehensive Nuclear-Test-Ban Treaty. Association and source identification are key elements of the verification system. The moving nature of a rocket is a defining criterion, in order to distinguish it from an isolated explosion. Here, it is shown how infrasound recordings can be associated, which leads to identification of the rocket. Propagation modeling is included to further constrain the source identification. Four rocket launches by the Democratic People's Republic of Korea in 2009 and 2017 are analyzed, in which multiple arrays detected the infrasound. Source identification in this region is impor- tant for verification purposes. It is concluded that with a passive monitoring technique such as infrasound, characteristics can be remotely obtained on sources of interest, i.e., infrasonic intelligence, over 4500+ km.

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

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

Track Classification: Analysis of Sources and Scientific Applications

ID: Type: **Oral**

-field source localisation of Greenland glaciers at infrasound station I18DK

This paper considers infrasonic characterization of run-off and calving events from glaciers using I18DK data (Qaanaaq, Greenland). We seek to localise observed near-field sources of infrasound. The estimated curvature of the spherical wavefront may provide information on the location of the source. We suggest the Q-tau parameter as a tool to discriminate between far-field (plane) waves and near-field (spherical) waves. This parameter measures the misfit in time difference of arrivals (TDOA) compared to a plane wave. The sources are then localised using linear inversion based on the TDOA, as well as with a forward approach. Both algorithms produce accurate source location estimates when applied to synthetic data. The Q-tau values suggest a near-field glacier source located north-east of the station. The inverse source localisation shows a clear source direction, however, it is challenging to estimate exact locations. By comparison, the forward problem approach provides directions in agreement with the localisation. We conclude that the Q-tau parameter is meaningful when discriminating near-field from far-field sources. A localisation based on the TDOA and the forward approach is only possible near the station. Higher sampling rate, larger arrays and a modified array orientation will enhance the discrimination of spherical waves and the localisation.

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

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

Track Classification: Analysis of Sources and Scientific Applications

ID: Type: **Oral**

-acoustic signals of the Baumgarten (Austria) gas explosion detected by the AlpArray seismic network

On December 12, 2017 a devastating gas explosion occurred at the Baumgarten gas hub in Eastern Austria. We detected the resulting seismo-acoustic signal on permanent and temporary broadband seismic stations at distances between 30 and 175 km from the gas hub, most prominently in the 2-4 Hz range. Two distinct phase arrivals correspond to acoustic waves traveling through the troposphere and stratosphere. The passing of a cold front shortly before the explosion created several temperature inversions at low altitude, and acoustic waveguides within the troposphere that facilitated our infrasound detections at distances as close as 50 km from the source, in addition to the commonly observed stratospheric reflections. 3D acoustic raytracing using temperature and wind velocities from the from the high-resolution forecast model of the European Center for Medium Range Weather Forecast has allowed to precisely relate the spatial distribution of our detections with calculated surface bounce points of infrasound rays. This has provided a precise and independent estimate of the time of the accident, to be used in forensic investigations. After the first explosion signal, we also detect a prolonged coda of elevated noise, which is probably due to ongoing gas release and/or the fire from the escaping gas.

Primary author: FUCHS, Florian (University of Vienna)

Presenter: FUCHS, Florian (University of Vienna)

Track Classification: Analysis of Sources and Scientific Applications

ID: Type: **Oral**

the ground motion distribution of the 2016 Mw 6.2 Amatrice, Italy earthquake using remote infrasound observations

The Mw 6.2 Amatrice earthquake that struck central Italy on 24 August 2016 was recorded by 7 infrasound arrays in the Euro-Mediterranean region at distances up to 1260 km, recordeding long lasting coherent wave trains characterized by large back-azimuth variations. The back projection of the stratospherically ducted infrasound illuminates radiating regions over ~600 km along the Apennines from Po basin to Gulf of Naples. A comparison between acoustic surface pressure derived from infrasound records and the seismic source pressure derived from measured seismic ground motion shows first order agreement in the attenuation with the epicentral distance. From these observations, seismic quality factors in Central Italy are estimated. The northernmost reconstructed source region comprises the Po Valley where seismic amplification occurred within plain alluvial sediments. These results show that infrasound records at hundreds of kilometers from a shallow moderate-magnitude devastating earthquake can provide ground shaking information as well as local amplification caused by topographic and geological features. Overall, these results give evidence of the surplus of the International Monitoring System for addressing issues being relevant for civil purposes and scientific research as well as for providing additional information as a complementary multi-technology network on potential natural hazards, especially in remote areas.

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: Analysis of Sources and Scientific Applications

ID: Type: **Oral**

Heavy Case Study

Infrasonic signatures associated with the maiden flight of SpaceX Falcon Heavy are presented. IMS and open source data (Twitter, YouTube, RedVox) are integrated to examine various aspects of the complex sequence.

Primary author: GARCES, Milton (Defense Threat Reduction Agency, Nuclear Arms Control Technology Program)

Presenter: GARCES, Milton (Defense Threat Reduction Agency, Nuclear Arms Control Technology Program)

Track Classification: Analysis of Sources and Scientific Applications

ID: Type: **Oral**

-Resolution Observations of a Meteo-Tsunami

In the early morning of 29 May 2017, unusually large waves of over 2 m height hit the west coast of the Netherlands, leading to some property damage. The waves were due to a meteo-tsunami, which is a tsunami of meteorological origin, unlike seismogenic tsunamis. This particular event was caused by a rapidly moving cold front which featured a sharp squall line that moved towards the coast. Associated was a large perturbation in air pressure of 5 hPa which, along with Proudman resonance effects and the upsloping seabottom lead to the tidal surge. While the meteorological conditions leading up to such an event are relatively common, the more extreme events appear to happen under specific conditions only. As a result of the meteo-tsunami, gravity waves were observed over the Netherlands with a variety of meteorological instruments, including weather radar, ceilometers and a network of micro-barometers that are typically used for the detection of infrasound. The high resolution gravity wave observations show characteristic waveforms that provide enhanced insight in the storm processes and that may be missed when averaged meteorological quantities are considered. The observations are found to be in good agreement with forecasts obtained from the non-hydrostatic HARMONIE model.

Primary author: ASSINK, Jelle D. (KNMI - Royal Netherlands Meteorological Institute)

Presenter: ASSINK, Jelle D. (KNMI - Royal Netherlands Meteorological Institute)

Track Classification: Analysis of Sources and Scientific Applications

ID: Type: **Oral**

Dependent Backprojection of Seismo-Acoustic Signals

Recent earthquakes in the Alaska region have generated a set of interesting seismo-acoustic coupled signals that have been detected by an International Monitoring System (IMS) array, I53US, local infrasound arrays of the Alaska Volcano Observatory (AVO), and some stations of the EarthScope Transportable Array (TA) that is currently deployed in Alaska and western Canada. In this study we analyze the seismo-acoustic coupling by making use of array-processing and backprojection techniques. Specifically, we beam-form and backproject the detections in narrow frequency bands to outline locations where seismic waves couple to the atmosphere to generate infrasound. Whereas some infrasound sources are broadband, others are band limited and are detectable only when processed in the right frequency band. We show that different features are illuminated at different frequencies. At low frequencies, < ~1 Hz, large topographical features such as entire mountain ranges and large basins are visible. At higher frequencies, > 1.5 Hz, individual mountain peaks and small alluvial valleys are illuminated. The ability to correctly associate infrasound detections with source locations is important for the verification of the Comprehensive Nuclear-Test-Ban Treaty. The above technique provides a tool for better understanding the seismo-acoustic coupling process and more accurate location of remote infrasound sources.

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

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

Track Classification: Analysis of Sources and Scientific Applications

ID: Type: **Oral**

# of a signal detected at a Hungarian infrasound array on 12 December 2017

On 12 December 2017 a heavy detonation occured near Baumgarten about 30 km east of Vienna, Austria, around 9 am local time. Seismo-acoustic signals were detected at AlpArray seismic stations up to 150 km distance (Schneider et al., 2018) providing evidence from 3D raytracing for both tropospheric and stratospheric arrivals and inferring an origin time of 7:44:16 UTC. The infrasound array PSZI deployed in May 2017 by the Hungarian NDC consists of 4 elements within 400 m, located at the Piszkes Observatory (48.32 N, 16.87 E) at a range of ~230 km east-southeast from Baumgarten. From PMCC processing and F-K analysis an acoustic signal at 7:57:55 UTC is found with backazimuth of 296-300 degrees and slowness of 273 s/degree, respectively, resulting in extraordinarily high trace-velocity (>400 m/s) and azimuth residual. With 3D raytracing through the ECMWF model for the particular date we are able to explain a trace-velocity in excess of 400 m/s from stratospheric winds exceeding 100 m/s along the travel path. The azimuth residual is in part explained by these winds, but also results from array element altitude differences. Thus, the case is made that the PSZI signal is indeed associated with the Baumgarten explosion.

Primary author: KOCH, Karl (Federal Institute for Geosciences and Natural Resources (BGR))

Presenter: KOCH, Karl (Federal Institute for Geosciences and Natural Resources (BGR))

Track Classification: Analysis of Sources and Scientific Applications

ID: Type: **Oral**

infrasound data to monitor atmospheric impacts from extra-terrestrial material

An estimated average of 54 tons of extra-terrestrial material enter Earth's atmosphere per day. If the objects are large enough they can produce very bright meteors, called fireballs. NEMO (NEar real-time MOnitoring system) will analyse fluxes and characteristics of extra-terrestrial material by globally searching for fireballs in near real-time. Ground-based networks exist for meteor/fireball observations on a local scale, but there is no world-wide database yet. By combining data we can reach the aspired coverage and maximize the amount of scientific knowledge. Social media is a fast source for world-wide information and NEMO's fast-alert-system is based on them. However, this is biased to populated areas and daytime events. The IMS (International Monitoring System) can provide information without these biases for large objects. The IMS's infrasound stations monitor our atmosphere during day and night. They can detect energy released by entering objects. With NEMO we want to improve the detection and analysis of fireballs with the IMS and explore certain automation processes to accelerate the fireball examination. Our talk will introduce NEMO and its detection procedure using the ca 4-m-sized Russian day-time fireball on 21 June 2018 as an example. This is a CTBTO, ESA, BGR, and Oldenburg University cooperation.

Primary author: OTT, Theresa Lisel Maria (Carl von Ossiertzky University of Oldenburg)

Presenter: OTT, Theresa Lisel Maria (Carl von Ossiertzky University of Oldenburg)

Track Classification: Analysis of Sources and Scientific Applications

ID: Type: **Oral**

concurrent microbarom signals to constrain atmospheric infrasound propagation conditions: case study of the 2017 DPRK nuclear test

The 2017 North Korean nuclear test gave rise to seismic and low-frequency acoustic signals, that is, infrasound. The infrasonic signals are due to seismo-acoustic coupling and have been detected on microbarometer array I45RU in the Russian Federation at 401 km from the test site. We analyze the seismo-acoustic coupling by making use of array-processing and backprojection techniques. The backprojections show that infrasound radiation is not confined to the epicentral region. More distant regions are found to be consistent with locations of topography, sedimentary basins, and underwater evanescent sources. The backprojections can be used to estimate the average infrasonic propagation speed through the atmosphere.

During the 2017 North Korean nuclear test, the stratosphere was in a state of transition from summer to winter, and the stratospheric vortex was relatively weak. Because long-range infrasound propagation is largely conditioned by the strength and the direction of the stratospheric vortex, this implies that propagation from the test site to I45RU may have occurred along unexpected paths. The mode of propagation can be difficult to decipher from the seismo-acoustic signals alone.
To supplement our understanding of infrasound-propagation conditions during the test, it can be insightful to analyze concurrent infrasonic signals that were detected at the infrasound array. Indeed, all signals must have propagated through the same atmosphere, albeit from different directions. In particular, continuous signals in the microbarom band (0.1–0.4 Hz) may provide some additional evidence about the mode of propagation, be it stratospheric or thermospheric.

During the 2017 North Korean nuclear test, Typhoon Sanvu was active in the Pacific basin, leading to continuous microbarom observations on array I45RU. The semidiurnal variation in best beam amplitudes suggests that these signals have propagated through the thermospheric waveguide. This independent observation is in line with the weak stratospheric vortex conditions.

Reference: https://doi.org/10.1785/0220180137

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

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

Track Classification: Analysis of Sources and Scientific Applications

ID: Type: **Oral**

mechanism of generation of infrasound signal from earthquake 5 December 2014, Mongolia

Moderate shallow earthquake occurred December 5, 2014 (MW=4.9) in the north of Lake Hovsgol (Mongolia). The infrasonic signal with duration 140 seconds was recorded for this earthquake by infrasound station "Tory". Source parameters of the earthquake (seismic moment, source radius, displacement) were received by spectra analysis of direct body waves. The analysis of seismograms and amplitude variations of the surface waves allows finding the effect of the propagation of the rupture in the earthquake focus, the azimuth of the rupture propagation direction and the velocity of displacement in the earthquake focus are determined. The results of modeling of the surface displacements caused by the earthquake, and high effective velocity of infrasound signal (~625 m/s) indicates that its occurrence is not caused by the down movement of the earth's surface in the epicentral region, but by the effect of the secondary source. The position of the secondary source of infrasound signal is defined on the northern slopes of the Khamar-Daban ridge according to the data about the azimuth and time of arrival of acoustic wave at the station "Tory". The interaction of surface waves with the region topography is proposed as the most probable mechanism of formation of the infrasound signal.

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: Analysis of Sources and Scientific Applications

ID: Type: **Oral**

SIGNAL CHARACTERISTICS FROM OCEAN WAVE SPECTRA STUDY DURING CYCLONE PERIOD

In the South-West Indian Ocean, tropical cyclones occur every year from December to April which can generate infrasonic signals in the 0.1-0.5 Hz frequency band and propagate into thousands of kilometers. Generation mechanism of microbarom signals is attributed to the nonlinear interaction of surface ocean waves and radiated acoustically only if the swells are almost opposite in direction and of a near identical frequency. The Infrasound station I33MG, Madagascar from the International Monitoring System (IMS) is used for this study with selected cyclones in the Indian Ocean. National Oceanic and Atmospheric Administration's (NOAA's) Wavewatch 3 (WW3) model is run to estimate the spatial and temporal distribution of the acoustic source spectra induced by nonlinear ocean wave interactions, then coupled with empirical amplitude scaling relationships to predict microbarom signal levels and peak frequencies (M. Garcés, 2014). Results are presented following the sea-state evolution and microbarom frequency band.

Primary author: RAKOTOARISOA, Andriniaina Tahina (Institute and Observatory of Geophysics of Antananarivo (IOGA))

Presenter: RAKOTOARISOA, Andriniaina Tahina (Institute and Observatory of Geophysics of Antananarivo (IOGA))

Track Classification: Analysis of Sources and Scientific Applications

ID: Type: **Oral**

Infrasound technology developments

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

Primary author: MIALLE, Pierrick (CTBTO Preparatory Commission)

Presenter: MIALLE, Pierrick (CTBTO Preparatory Commission)

Track Classification: IMS, IDC and NDC Infrasound 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: IMS, IDC and NDC Infrasound Projects

ID: Type: **Poster**

years of operation in Romania of the I67RO PTS portable infrasound array

PTS portable infrasound array (I67RO) has been deployed in September 2016, in western Romania, for one-year experiment, within a collaboration project between National Institute for Earth Physics (NIEP) and PTS/CTBTO. Operated and maintained in the framework of Romanian infrasound monitoring network, I67RO array has been proven effective in supporting NIEP efforts for monitoring of natural and anthropogenic acoustic sources. Therefore, NIEP expressed the strong interest to continue this collaboration, and PTS agreed to extend the period of the array deployment in Romania for a second year – until October 2018. I67RO four-element array covers a 0.9 km aperture area, being equipped with CEA/DAM MB2005 microbarometers and Reftek RT 130 data loggers. Data are processing 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. station monitoring performance (array detection capability, types of sources detected). A chronology of I67RO operation and maintenance since array deployment is showed as well. This joint experiment contributed both to advance the understanding of infragenic sources in Central-Europe and to support ARISE project in order to expand the spatial coverage of the European infrasound network.

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

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

Track Classification: Poster session

ID: Type: **Poster**

# of Man Made Seismo-acoustic Events

A series of events originating from Balakliia and Kalynivka both in Ukraine were recorded by the IMS network on 23 March 2017 and from the evening of September 26, 2017 to September 27, 2017 respectively. The location of events was estimated with seismic (AKASG, FINES) and infrasound (I43RU, I26DE, I31KZ, I37NO) monitoring data obtained from these IMS stations that recorded these events using GPMCC. The results obtained from analysing the seismic and infrasound data at NDC-NG for phase, magnitude, time and slowness were compared with that from IDC analysis. NDC-NG results were in substantial agreement with that of the IDC. The data availability and timeliness for the event from the IDC were also satisfactory. The Spectrogram for the stations shows wave energy covering a broad frequency range (0.5-20.0 Hz). The results from the analysis of infrasound data were consistent with the known back azimuth of the event and characterisation of the event pointed to a man-made event possibly an explosion.

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

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

Track Classification: Poster session

ID: Type: **Poster**

Implementation Project Infrasound Portable Array in Costa Rica by PTS-CTBTO and OVSICORI-UNA and Analysis of Volcanic Source of Infrasound by NDC Costa Rica (Mt. Sinabung Volcano).

Collaboration between OVSICORI-UNA and the Provisional Technical Secretariat of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO). The deployment and installation of a CTBTO infrasound mobile system in Costa Rica, would be beneficial for advancing the urderstanding of infrasonic sources in Central, Latin American and Caribbean regions. The proposed collaboration will also be an important contribution from OVSICORI-UNA to the volcanic monitoring in Costa Rica as it will expand the spatial coverage beyond that of the permanent International Monitoring System infrasound component in Latin America and the Caribbean. The Infrasound Portable Array will be installed in the North of country to have a quality signal monitoring from active volcanoes: Turrialba Volcano, Poas Volcano and Rincon de la Vieja Volcano. NDC of Costa Rica conducted a volcanic analysis of the infrasound source, the volcanic eruption event of Mt. Sinabung on February 19, 2018 at 01:53 UTC (08:53 local time). We correlate data from IMS infrasound stations: I52GB (BIOT/Chagos Archipelago, United Kingdom of Great Britain and Northern Ireland), I06AU (Cocos Islands, Australia), I19DJ (Djibouti).

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: Poster session

ID: Type: **Poster**

and scientific use of infra sound and seismic data from NDC Kenya

IS32 is a seven element primary array station situated about 10KM outside the capital city of Nairobi. Because of its location, the station faced major operation and maintaince challenges in the past. Having addressed most of the life cycle challenges ,we have now embarked on the civil and scientific application of data that is collected and transmitted to both the IDC in Vienna and the NDC-KE in Kenya for analysis. Educating the community and sharing of the analyzed data from the NDC has led into the participation of both the government and the local community in using infra sound as well as seismic data for both civil and scientific gains. In my presentation, i highlight the importance of infra sound technology and how it is being applied In Kenya. Although major gains have been made ,there is still need for more capacity building in infra sound data analysis and techniques .

Primary author: AKECH, John Opiyo (National Council for Science & Technology)

Presenter: AKECH, John Opiyo (National Council for Science & Technology)

Track Classification: Poster session

ID: Type: **Poster**

OF BOLIDE INFRASONIC OBSERVATION, on June, 2nd, 2018 in BOTSWANA

On June 2nd, 2018, around 16h44 UT, Bolide impacted the Earth atmosphere over Botswana, near South Africa border. This event was recorded at some IMS infrasound arrays in Southern Africa. Data analysis were performed using WinPMCC software (CEA/DASE) based on PMCC method (Y. Cansi,1995). A pass-band frequency between 0.1 Hz and 4 Hz is applied to detect the source. Results using I47ZA station show the azimuth is arround 357.5° for the coming infrasound signals. Infrasound processing gave an estimated energy of 3.09 kT. Acoustic simulation of propagation using Raytracing technique (Virieux, 2004 Hamiltonian mathod ; Bass & Sutherland, 2003 absorption model) shows dominant stratospheric phases.

Primary author: ANDRIANAIVOARISOA, Jean Bernardo (Institute and Observatory of Geophysics of Antananarivo (IOGA))

Presenter: ANDRIANAIVOARISOA, Jean Bernardo (Institute and Observatory of Geophysics of Antananarivo (IOGA))

Track Classification: Poster session

ID: Type: **Poster**

records associated with the western of Yunnnan fireball on October 4,2017

A bright fireball was reported at 12:07:05 UTC on October 4, 2017 at a height of ☒37 km above 28.1N, 99.4E near Shangri-La, the western of Yunnnan of China. It had a TNT yield equivalent of 0.54 kilotons (kt). Infrasonic signals were observed by I16 infrasound array that is part of the International Monitoring System (IMS) and Tengchong infrasound array located in the western of Yunnnan of China. The PMCC method was used to estimate the wave parameters of two infrasound arrays, and the source location (99.28E,27.99N) was determined by the back azimuth intersection,which only 17 kilometers away from NASA's loaction.

Primary author: SU, Wei (Institute of Geophysics, China Earthquake Administration)

Presenter: SU, Wei (Institute of Geophysics, China Earthquake Administration)

Track Classification: Poster session

ID: Type: **Poster**

IMS Regional Infrasound Network to Monitor Atmospheric Explosion Events Detection

Monitoring the atmosphere and shallow underground phenomenon for low frequency acoustic waves is the CTBT's infrasound sensors deployed to detect any nuclear explosion signatures anywhere by anyone around the planet. This network also monitors and detects infrasound signals from non-verification-related explosion events either from man-made or natural sources. Such a data has been of immense benefit to society through its wide spread civil and scientific applications. Atmospheric explosion events detection from 2007 - 2010 at the IMS infrasound stations (I11CV, I17CI, I19DJ, I32KE, I33MG, I35NA, I47ZA and I48TN) which form part of the regional network for Africa were studied using IDC database. These stations commonly detect atmospheric explosion signals from sources such as volcanic eruption, bolide and meteor, supersonic aircrafts, rocket launches and re-entries, microbaroms and explosions (chemical). This study highlights (using the case of detections from volcanic eruption at Mt. Etna in 2007 and rocket launch at KSC, Florida in 2008) the significant capability of the regional IMS infrasound network to detect atmospheric explosion event source(s) at regional and global levels to contribute to the verification regime and its compliance.

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

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

Track Classification: Poster session

ID: Type: **Poster**

Graphical User Interface for Interactive Infrasound Time Series Analysis

InfraPy is a Python-based infrasound analysis toolkit being developed at Los Alamos National Lab for detection, association, localization, and characterization using infrasonic signals. The software is intended to eventually provide a complete suite of tools for infrasonic signal analysis. The use of the Python language allows for fast development through a wealth of built in libraries and ease of use through rapid development of documentation. In addition to continued development and evaluation of the analysis algorithms, a Graphical User Interface (GUI) is being developed to make many of the tasks associated with array analysis easier and less time consuming. The primary focus of this GUI development has been on implementing methods for interactive time series analysis enabling rapid analysis using the built-in Bartlett, Capon, and MUSIC beamforming algorithms to identify coherent signals recorded across an infrasonic array. Continued development is ongoing and intended to lead to an open-source version of the InfraPy toolkit including the GUI. The software is aimed to be utilized by and accept contributions from the general infrasound research community. An overview of the capabilities of the time series analysis GUI as well as examples of its application to a number of data sets will be presented and discussed.

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

Presenter: WEBSTER, Jeremy (U.S. Department of Energy, National Nuclear Security Administration)

Track Classification: Poster session

ID: Type: **Poster**

study about location of Infrasound Permanant station.

For the permanent station in South-Korea, we try to expand our Government infrasound station in the future. About past experience on the running permanent station, the Government face several problem related atmospheric activity. It was lighting and weathering from the nature. For the acceptable location as good as possible, we pick the several feature which makes station more stable from the atmospheric activity.

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

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

Track Classification: Poster session

ID: Type: **Poster**

Autonomous, Maritime Infrasound Sensing Capability

Wide infrasound coverage is obtained using fixed, land-based monitoring stations. However, two-thirds of the earthâ□□s surface is composed of oceans, and while some sensing stations are located on islands, no capability yet exists to monitor infrasound from sensors fielded directly in the maritime environment. We investigate the potential of fielding microbarometer sensors on persistent, autonomous, unmanned surface vehicles (USVs), yielding the potential of an expansive, new, remote environment from which infrasound signal detection can be made. To enable such a USV-hosted infrasound sensing capability, numerous unique challenges need to be solved including motion-induced noise, wind noise, water intrusion, and survivability amidst salt water in the harsh maritime environment. A scheme for reducing interference signals due to heave motion has been developed and tested utilizing an auxiliary IMU in conjunction with an adaptive filter. Recent work has focused on the development of a unique, compact wind reduction approach using closed-cell foam that also protects the sensor from water intrusion. Following development and testing of a single platform, a small fleet of vehicles and sensors will be developed and deployed enabling the configuration of a sensor array in order to improve detection capability and provide directionality information.

Primary author: PLATE, Randall (Spawar Systems Center)

Presenter: PLATE, Randall (Spawar Systems Center)

Track Classification: Poster session

ID: Type: **Poster**

# of IS24 upgrade : focus on calibration capabilities

A major upgrade has been carried out during 2017 at French Polynesian infrasound station IS24. The station is operational from November 2017, and is planned to be re-validated in October 2019. The renewals and changes of hardware are described. Among those upgrade actions, the most significative one is the installation of 2 infrasound sensors at each element of the station. The new operational sensor (MB3) is connected to the wind noise reducing system. The former operational sensor (MB2000) is now installed has a reference sensor. This “two-sensor configuration” allows the computation of the frequency response of the operational element including the WNRS. In addition, the MB3 response can be checked using its built-in calibration capability. After one year of station operation, a description of calibration techniques and associated results are presented.

Primary author: NIEF, Guillaume (CEA/CENTRE Ile-de-France)

Presenter: NIEF, Guillaume (CEA/CENTRE Ile-de-France)

Track Classification: Poster session

ID: Type: **Poster**

and monitoring of the MB3, MB2000 and MB2005 calibration process at Seismowave

SEISMO WAVE has designed and developed a new facility and the environmental conditions suitable for a laboratory dedicated to the infrasound metrology activity. Since September 2017, an infrasound sensor calibration bench designed by CEA and some reference sensors are installed in this laboratory.
A qualification of the calibration process has been carried out in collaboration with CEA in three steps: qualification of the bench to define the correction model to be applied to the measurements, short-term assessment of the stability of the measurement environment and the bench and finally the calibration of SEISMO WAVE reference microphone.
Since this initial qualification, SEISMO WAVE has set up an internal process to monitor its bench using reference microbarometers, an external process to monitor the bench, including intercomparison with CEA, and a calibration process for its measuring instruments and measurement standards to maintain metrological traceability of its measurement results.
This poster presents the different steps of the bench qualification, the results related to the stability of the measurement environment, the calibration bench since 2017, and finally, some information about the monitoring processes implemented.

Primary author: HUE, Anthony (SEISMO WAVE)

Presenter: HUE, Anthony (SEISMO WAVE)

Track Classification: Poster session

ID: Type: **Poster**

infrasound propagation followint the Ingolstadt explosion (September 1, 2018) recorded by the AlpArray seismic network with high (40km) spatial resolution

On the first of September 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 within 400 km radius from the explosion site and find strong seismo-acoustic signals on more than 80 seismic stations. Thanks to the dense spatial coverage of the AlpArray seismic network, the infrasound signal generated by the explosion is detectable within 10 - 400 km from the source, with high spatial resolution. The high spatial sampling reveals a pronounced spatial pattern. The event can be localized both by seismic and seismo-acoustic picks, yet the seismo-acoustic location results are significantly more precise. Seismo-acoustic amplitudes are strongly station-dependent, and are affected by the type of installation. Still, the uniform spatial coverage allows us to study the regional infrasound attenuation. We identified three separate acoustic phases with celerities of 332, 292 and 250 m/s, respectively; they probably represent tropospheric, stratospheric, and thermospheric phases, with each of them having its particular propagation direction. Our findings highlight that regional infrasound propagation can be strongly anisotropic due to winds, and that the detection of such events strongly depends on station density and geometry

Primary author: FUCHS, Florian (University of Vienna)

Presenter: FUCHS, Florian (University of Vienna)

Track Classification: Poster session

ID: Type: **Poster**

eruptions recorded in the IDC bulletins

Infrasound is one of the three waveform technologies of the Comprehensive Test Ban Treaty (CTBT) verification regime. Its primary application is to detect and locate atmospheric nuclear tests. The International Monitoring System (IMS) network also records other sources of infrasound signals like bolides, spaceflight activity, sonic booms, volcanic eruptions, quarry blasts, earthquakes, etc.
Volcanic eruptions listed in the International Data Centre (IDC) bulletins were typically detected by infrasound IMS network as pure infrasound events. In cases of seismo-acoustic events, seismic and infrasound signals were normally related to different processes related to volcanic activity. As volcanic ash poses danger to aviation, remote observation of active volcanoes is an important civil application of the CTBT verification regime.
Volcanic events included in IDC bulletins were recorded either as a sequence of short duration signals (e.g. Sakurajima) or long-lasting activity (e.g. Eyjafjallajökull). Long-lasting activity is more difficult to be included as events in the IDC bulletins but may be more interesting for civil applications. The aim of this presentation is to show examples of volcanic eruptions recorded at the IMS network to facilitate future analysis of these sources of infrasound signals.

Primary author: BITTNER, Paulina (CTBTO Preparatory Commission)

Presenter: BITTNER, Paulina (CTBTO Preparatory Commission)

Track Classification: Poster session

ID: Type: **Poster**

evaluation of the pressure-to-seismic transfer function according data broadband seismic stations

The results of the evaluation of the pressure-to-seismic transfer function for periods between 1 to 100 s obtained on the base of the seismic and acoustic waves associated with the 2013 Chelyabinsk meteorite, Russia, are presented. According to NASA report, the meteorite's breakup was fixed around 03:20 UTC. In previous study was shown that coupling between the meteorite's shock wave and Earth's surface produces Rayleigh waves that were observed at distances up to 4000 km. Both the meteorite's shock wave and surface Rayleigh wave generated by it were registered by the nearest broadband sesimic station ARU (Iris/Ida global network) at the distance ~ 250 km. The transfer function was determined as a ratio of the spectra of vertical ground motion velocity and the shock wave. The comparison of the transfer function obtained and the local site-effect (H/V-ratio) shows the satisfactory agreement of the resonance frequencies. In the Baikal rift the seismic waves were registered by the broadband seismic stations MOY, YLYR, ZAK (BAGSR network) and TLY (Iris/Ida global network). Local H/V-curves were used as a transfer function. The acoustic signal calculated are well correlated with the signal measured by the infrasound station Tory located in the same region.

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

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Track Classification: Poster session

ID: Type: **Poster**

wind influence to the detection ability of permanent and mobile infrasound station.

The theory of the infrasound wave propagation states that the acoustic waves of infrasound sources, related with wind and temperature conditions, can be detected in distance of 200-250 km (McKenna, 2005; Golden et al., 2007). From our seasonal observations (winter and summer monitoring) and research studies, we would like to determine a detection level of infrasound waves in the north hemisphere at a distance of 250 kilometers from the source, because of topography, continental location and height, and it is much windy in the territory of Mongolia. Therefore, the goal of our study is to reduce the wind noise detected in the array station, and then to improve the detection ability of the infrasound array stations. In the context of the above study, we will determine the noise level by spectrum analysis of the mobile barometer without any filters on two different sites' deployment: nearby the infrasound array station and in a forest. Also, we will determine seasonal variations depending on the site's position, by using comparable data of mobile infrasound station in the forest and IS34MN infrasound mini array during 6 to 12 months.

Primary author: CHIMEDTSEREN, Bayarsaikhan (Institute of Astronomy and Geophysics, Mongolian Academy of Science (MAS))

Presenter: CHIMEDTSEREN, Bayarsaikhan (Institute of Astronomy and Geophysics, Mongolian Academy of Science (MAS))

Track Classification: Poster session

ID: Type: **Poster**

of the Infrasound Monitoring System and data transfer

The infrasound technology system has been designed for the detection of atmospheric nuclear explosions and/or Natural disaster and pressure fluctuations produced in the frequency range. The majority of the monitoring chains used in this network also record pressure fluctuations at lower frequencies. Also, the infrasound technology is the one of the International Monitoring System (IMS) network of Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) for transfer the data from the station to the International Data Center (IDC). In this study, I want to demonstrate that the pressure fluctuations recorded by most IMS infrasound stations could be used to study GWs. Since IMS stations are regularly calibrated and record pressure fluctuations all over the Earth's surface, they provide an accurate and reliable stream of data useable to study the entire GW band on a worldwide scale.

Primary author: TOUCH, Mungkol (Ministry of Mines and Energy (MME))

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Track Classification: Poster session

ID: Type: **Poster**

infrasound portable array (I68CI) in Cote d'Ivoire data processing

After six months deployment (January to June), CTBTO infrasound mobile array (I68CI) data has been processing in three frequencies bands. The frequencies bands are the following 1 to 0.1Hz for the distant detections, 2.5 to 0.5Hz for the regional detections and 4 to 2Hz for the local detections. From January to February, the local, regional and distant detections azimuths are from Northwest. In March, there are detections in 20° azimuth. Indeed, March is the beginning month of African monsoon installation over the Gulf of Guinea. During the months of April and May, there are detections in all directions. In June, the detections azimuths are from northeast direction. In general, most of the distant detections are from the Northwest (300° to 330°), West (270°) and Southwest (210° to 190°).

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

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

Track Classification: Poster session

ID: Type: **Poster**

and analysis of explosions in an outdoor pyrotechnic site

Acoustic pressure signals recorded for numerous explosions and several azimuths in the vicinity of an outdoor pyrotechnic site of the South of France are used to validate a fully nonlinear numerical code. This code, based on direct simulation of Euler equations with a detonation model and state of the art numerical schemes, allows classifying relative effects of topography, vegetation, and meteorological conditions on blast-wave propagation in the near field of the source (~5km). To save computational time, the coupling between this full nonlinear model and a simpler linear acoustic model is shown to be efficient at long range. This tool is used to perform parametric studies to determine the most unfavorable meteorological conditions from an acoustic annoyance point of view. Indeed, anomalous propagation is present and observed toward the East. Furthermore, records at an experimental infrasound station about 300km away are analyzed.

Primary author: LARDJANE, Nicolas (CEA)

Presenter: LARDJANE, Nicolas (CEA)

Track Classification: Poster session

ID: Type: **Poster**

acoustic signals generated by the Kilauea Volcano

Volcanic infrasound is generated during the explosive release of fluid into the atmosphere. Several acoustic signals were recorded between May and August 2018 at the IMS-station IS59 on Hawaii during explosive eruptions at Kilauea Volcano. The sequence started with an earthquake at May 4th 2018. Detected signals are either based on elastic body waves or as infrasound generated by the explosion. The data analysis was carried out using DTKGPMCC-Software, part of the latest distribution of the extended NDC-in-a-Box and experience gained during the Infrasound-Training in Tunisia 2017 were applied. The comprehensive analysis of signals allowed to distinguish several sources.

Primary author: MITTERBAUER, Ulrike Helene (Central Institute for Meteorology and Geodynamics)

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Track Classification: Poster session

ID: Type: **Poster**

analysis of Japanese rocket launching events using I30JP observation data

Japan's satellite and probe carrying rocket (H-IIA, H-IIB and Epsilon) have been launched by JAXA (Japan Aerospace Exploration Agency) at Tanegashima or Uchinoura Space Center in southern Japan. Multiple infrasonic signals generated by these launched rockets are detected at I30JP from 2005, when the operation started. We have been organizing the data and the knowledge by accumulating the analysis results. Flight path of rockets are mainly categorized two directions, eastward and southward. For instance, when rockets fly eastward, infrasonic signals derived from the liftoff, detachment of the solid rocket motors and payload fairing could be discriminated by the difference of back-azimuth calculated from I30JP array data. Moreover, the signal from payload fairing drop tends to be detected firstly because the rocket speed is quite faster than infrasound propagation. We would deliver the poster presentation about our analysis stored since I30JP operation in 2005 and the past records of Japanese rockets.

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

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

Track Classification: Poster session

ID: Type: **Poster**

OF BOLIDES BY KAZAKHSTAN INFRASOUND STATIONS

Kazakhstan has established and is successfully operating a contemporary digital network of seismic and infrasound stations located throughout the perimeter of the Republic. Currently, KNDC transmits in real time and processes data from 4 infrasound arrays: Aktybinsk, Kurchatov, Makanchi, Zalesovo (Russia). This data allows for automated detection of infrasound events, and creating infrasound events bulletins on regular basis. At the present time there is a huge work on discriminating sources type; most of recorded infrasound events are mining blasts, large earthquakes, rocket launches, etc. However, many of the events hardly can be related to any of the known types, among them there are records of small bolides recorded by Kazakhstan stations quite often. For its identification, it is reasonable to use independent information of mass media, event witnesses, and records of video recorders. The work shows the records of bolides recorded on the territory of the East Kazakhstan and Ural, and comparison with records of Chelyabinsk bolide of 2013, and with sources of other nature. Location parameters of these events are compared by data of KNDC and IDC bulletins. The obtained data can be used to improve the quality of KNDC infrasound bulletin and supplement of the reference events database.

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

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Track Classification: Poster session

ID: Type: **Poster**

projects for better exploitation of IMS data for scientific and civil applications.

In the frame of its activities in exploiting the IMS Data for civil and scientific applications including security ones, the Tunisian NDC is initiating some projects at national level like the acquisition of an infrasound portable station (to be deployed in several sites in order to discriminate events sources) as well as the reinforcement of the cooperation at the national level in order to acquire data and information such as mines and queries activities that may help, by eliminating known sources, to better streamline detected events analysis and improve their results interpretation.

Primary author: ZOUHAIER JENDLI, Zouhaier (CNCT)

Presenter: ZOUHAIER JENDLI, Zouhaier (CNCT)

Track Classification: Poster session

ID: Type: **Poster**

Central and Eastern European Infrasound Network

A new regional collaboration between four countries has been founded for the establishment of the Eastern European Infrasound Network. The network is formed by three infrasound arrays in Romania, two in Czechia and one in Hungary, and one more array is to be deployed later in this year in Austria. A Memorandum of Understanding for the collaboration was signed by the representatives of the member states in June 2018. All the parties are members of the Atmospheric dynamics Research InfraStructure in Europe (ARISE) project. The infrasound sources and propagation conditions in the region were insufficiently studied in the past due to poor coverage of infrasound arrays. This regional network aims to contribute to advanced understanding of infrasound sources in Central Europe and to the continuation of the ARISE project as an expansion of the spatial coverage of the European infrasound network.

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: Poster session

ID: Type: **Poster**

Sensor Testing Capability Advancements at Sandia National Laboratories

The Facility for Acceptance, Calibration and Testing (FACT) at Sandia National Laboratories has been a valued resource for the U.S. monitoring community for decades. The FACT site hosts a number of capabilities focused on component evaluation including a recently added acoustic chamber, which provides superior isolation for sensors-under-test from the acoustic and pressure environment, and has the ability to be pressurized to sea-level conditions and evacuated to pressure levels found in the stratosphere. We also have recently installed a Spektra CS18 seismic calibration system, which we have leveraged for the purpose of determining seismic susceptibility of infrasound sensors. We have operated this chamber and seismic calibration system, conducting infrasound sensor evaluations and seismic susceptibility evaluations, for nearly one year. This work has included repeated calibrations, approximately once every three months for the past year, of ten infrasound sensors (two sets of five sensors), which are installed in the FACT site array as part of a separate sensor field evaluation effort. We have also utilized our seismic calibration system for evaluating the seismic susceptibility of an infrasound sensor. Here we present the preliminary results of quarterly calibrations of these sensors-under-test and the seismic susceptibility results of the infrasound sensor under test.

Primary author: SLAD, George (Sandia National Laboratories)

Presenter: SLAD, George (Sandia National Laboratories)

Track Classification: Poster session

ID: Type: **Poster**

NDC experience on the field of infrasound analysis

As part of signatory states and despite the absence of International Monitoring System (IMS) stations in its territory, Iraqi National Data Center (NDC) as an organization working under the Treaty Verification and an integral part of national Authority in monitoring to implement this Treaty we took benefits from Comprehensive Nuclear-Test-Ban Organization (CTBTO) and its four technologies especially on civil and scientific researches which looks the main of our purposes. Iraqi NDC has gained with the well trained specializes staff a considered experience in the field of SHI analysis. in order to promote the infrasound technology at the national data centers and due to the inclusion of infrasound data analysis software (DTK-GPMCC) in NDC-in-a-Box. In this poster, we will display an example of events analysis that occurred at the Iran -Iraq border last year and The sixth Korean test and we focus on infrasound analysis using DTK-GPMCC. Iraqi NDC staff tries to work on that technology to understand and benefits from it in order to define the events detected and to categorize and classify sources suspected. In our National Data Centre, we still work continuously to develop our expertise and analysis capability.

Primary author: SHAMKHI, Yasameen Hameed (Iraqi National Monitoring Authority)

Presenter: SHAMKHI, Yasameen Hameed (Iraqi National Monitoring Authority)

Track Classification: Poster session