Infrasound Technology Workshop 2015

BOOK OF ABSTRACTS

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1. IMS, IDC and NDC Infrasound Projects

Oral Presentations

T1-O1. IDC Infrasound technology developments

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The IDC advances its methods and continuously improves its automatic system for the infrasound technology. The IDC focuses on enhancing the automatic system for the identification of valid signals and the optimization of the network detection threshold by identifying ways to refine signal characterization methodology and association criteria. An objective of this study is to reduce the number of associated infrasound arrivals that are rejected from the automatic bulletins when generating the reviewed event bulletins. A number of ongoing projects at the IDC will be presented, such as: - improving the detection accuracy at the station processing stage by replacing the infrasound signal detector DFX-PMCC (Detection and Feature eXtraction – Progressive Multi-Channel Correlation) and by evaluating the performances of detection software; - separating infrasound data from other waveform technologies at the automatic network processing stage for technology development and for preparing the implementation of next generation of waveform association algorithm. Infrasound rules in Global Association (GA) and NET-VISA implementation are explored to pursue a lower ratio of false alarms; - network capability estimations as a tool to monitor performances. The IDC identified a number of areas for improvement of its infrasound system, those will be shortly introduced.

T1-O2. Overview of IMS infrasound station and engineering projects

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The infrasound component of the International Monitoring System (IMS) consists of sixty stations, including forty-seven certified stations transmitting continuous data to the International Data Centre (IDC) in Vienna, Austria. Each infrasound station is composed of an array of infrasound sensors capable of measuring micropressure changes produced at ground level by infrasonic waves. The Provisional Technical Secretariat (PTS) of the Comprehensive Nuclear-Test-Ban Treaty (CTBTO) is continuously working towards the completion and sustainment of the IMS infrasound network. The objective of this presentation is to review the main activities performed in the IMS infrasound network over the last year. This includes construction, installation, certification, major upgrade and revalidation activities. Major technology development projects to improve the reliability and robustness of IMS infrasound stations as well as their compliance with IMS Operational Manual requirements will also be highlighted.

2. Infrasound Instrumentation

Oral Presentations

T2-O1. Evaluation of infrasound in-situ calibration method on a 3-month measurement campaign

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This work is devoted to the signal processing algorithm developed for the on-site calibration of infrasound stations in accordance with the draft IMS operational manual. This algorithm is based on the comparison of the spectral contents between the sensor under test and a known reference sensor. However because the large signal variability, mainly due to the wind effects, the requirements are very challenging. The presented study has led to use a log-scale filter bank approach and a weighted estimator based on the coherence level. The algorithm as well as the numerical results obtained for several weeks of measurements at IS26 (Germany) will be presented. The results confi rm the capability of the method to provide results within IMS minimum requirements. It also appears that the method is able to provide useful information on the performance and response of the noise reduction system.

T2-O2. Evolution of Distributed Infrasound Sensor Networks

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Infrasound sensor and array networks on the ground and aloft permit acoustic remote sensing for diverse natural and man-made events. This paper discusses the evolution of monitoring systems for both natural and man made hazards, including (but not limited to) volcanoes, earthquakes, tsunamis, typhoons, explosions, and industrial accidents.

T2-O3. Improved Approach towards IMS Equipment and Service Contracts (Call-Offs)

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Together with the guidance of the PTS 2014-2017 Midterm Strategy, Draft IMS Operational Manuals and historical experience throughout the International Monitoring System, IMS/ED has begun an earnest effort to improve the quality of future equipment and service support contracts put forth within the IMS. In order to benefit IMS stations, targeted equipment and service support contracts will include intra-site communications, station power systems, grounding/lightning protection and data acquisitions systems. With these planned actions, along with the recently implemented Wind Noise Reduction System contract, IMS/ED will focus on meeting station Data Availability (DA) requirements, improving Timely Data Availability (TDA) and reducing any future station failures, through the supply of quality goods and the sourcing of reliable services. The authors are Alfred Kramer, Marian Jusko, Julien Marty, Pavel Martysevich and James Robertson (alphabetical order, if possible)

T2-O4. Infrasound station : Renewal considerations

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On the French Polynesian infrasound station I24FR, the wind noise reducing system is based on an 18 m diameter star array with 32 low impedance inlets. In the framework of the station upgrade, the question to use 96 air inlets instead of 32 air inlets is tackled. Global assessment on performances, investment and maintenance will be considered with respect to WNRS.

T2-O5. Long Duration Wind Noise Abatement Study at the University of Mississippi Field Station

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Long duration measurements have been obtained at the University of Mississippi Field Station. These tests compared bare sensors to sensors treated with porous hoses, and sensors under circular domes of different diameters (1.15, 1.50, 2.40 and 6.00 m). The domes used a variety of external claddings, including 2.5cm thick foam and perforated aluminum meshing (typically the holes had a diameter of 3mm, with a 5 mm spacing and 30% effective opening). The sensors were recorded continuously, allowing measurements to be obtained over a wide range of weather conditions. As expected, the frequency of maximum wind noise attenuation decreased with increasing diameter of the dome, and the maximum attenuation obtained increased commensurately with diameter. Tests were also performed with nested domes, which were shown to provide greater attenuation than just the larger of the two domes. While porous horses typically provided superior wind noise attenuation at lower frequencies, these also attenuated sound at higher frequencies, and there were number other issues (temperature dependence of the transfer function, pores getting clogged in rainy weather), which made them less than ideal for longer period unattended observation.

T2-O6. Mitigating Power Supply Problems at IMS Infrasound Stations

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A large number of IMS infrasound stations are installed at remote locations without reliable grid coverage and stable power supply. One of the commonnly used sources of electricity is photovoltaic system and battery bank. Although the use of solar energy is not a new concept, there are no off-the-shelf packages ready to be deployed at all the stations. In addition, complicated access and logistics, equipment failure and difficult weather conditions are among the challenges that we have to overcome during the operation and maintenance of the stations. This paper describes the installation and maintenance of the power supply systems at some IMS infrasound stations, where the installations were adapted to the particular local conditions, allowing reliable power source, efficient remote monitoring, operation and maintenance.

T2-O7. Pilot Interlaboratory Comparison Study - Process and main results

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The Pilot Interlaboratory Comparison Study (the "Pilot Study") was initiated based on recommendations of the Infrasound Expert Group Meetings 2013 and 2014. The scope of the Pilot Study includes the review of the state-of-the-art methods used in the characterization, testing and evaluation of infrasound sensors with the long-term objective of performing Interlaboratory Comparisons. The Pilot Study Group includes three Participants (CEA, SNL, UMiss) and one Coordinator (PTS). In this work, we present the scope and the process of the Pilot Study, including the agreed upon definitions of quantities measured (Self-noise, Dynamic Range, Sensitivity, Frequency Response and Passband), the Technical protocol and the circulation of a set of sensors between Participants. Preliminary results of the Pilot Study will also be discussed based on reports from Participants.

T2-O8. Progress in the integration of onsite calibration capability at IMS stations - Towards measurement quality assurance

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Progress in the integration of onsite calibration capability at IMS stations - Towards measurement quality assurance B. Doury1, A. Kramer1, T. Grasse2, J. Marty1, S. Nikolova1 1Comprehensive Nuclear-Test-Ban Treaty Organization 2Bundesanstalt für Geowissenschaften und Rohstoffe In the report of its 43rd session published in September 2014, Working Group B recommended the PTS to integrate a passive calibration technique based on side-by-side comparison into the IMS infrasound network. IS26 (Freyung, Germany) was selected as a pilot station, and the technique was implemented there in May 2015. In this work, the integration of the calibration technique at station IS26 will be presented. The need for Measurement Quality Assurance will be then discussed. This includes a set of processes, methods and procedures to ensure that calibrations meet IMS quality management criteria. This also entails the allowable limits of measurement error, the reference base to which the measurements must be related, the properties of the measurement process and a means of assigning uncertainty to our measurements.

T2-O9. Russian IMS Infrasound Stations: Issues of Operation and Modernization

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The Comprehensive Nuclear-Test-Ban Treaty was ratified by the Russian Federation on 30 June 2000. According to the Treaty there are four IMS infrasound stations in Russia, which are located in Dubna (IS43), Petropavlovsk-Kamchatskiy (IS44), Ussuriysk (IS45) and Zalesovo (IS46). During operation Russian IMS infrasound stations there are different problems, such as flooding of station's equipment, necessity of using special transport to achive some sites, absence of spare digitizers and microbarometers because of shipment problems to RF etc. The solution of some issues can be simplified with using equipment produced in RF. For example, microbarometer ISGM-03M, which was developed by Scientific Technical Center "Geophysical Measurements" (Novosibirsk, Russia). Microbarometer ISGM-03M meets PTS certification requirements. Calibration of microbarometer can be provided with the aid of automated equipment ISCGM-2. The use of this microbarometer will make it possible to reduce time of repair and alleviate logistic and customs problems.

T2-O10. Status of Meteorological Observations at IMS Infrasound Stations

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The 2012 Infrasound Expert Group Meeting Report includes number of recommendations to the improvement of meteorological observations at CTBTO / International Monitoring System (IMS) infrasound stations, including investigation of the possibility of IMS observations to get closer to to World Meteorological Organization (WMO) standards, use of absolute pressure sensors at infrasound stations instead of MB2005 absolute pressure data and decreasing meteorological data sampling. The Engineering and Development Section of the IMS presents the results of following the recommendations of the report, containing study of the WMO requirements and their applicability to IMS standards and practice, first installations of absolute pressure sensors, quality improvement of meteorological data and implementation of State-Of-Health monitoring software.

T2-O11. Wind noise reducing system: complementary results

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In the framework of incoming IS stations recapitalization, it is mandatory to improve our knowledge on wind noise reducing system. For that, some simulations and on field experiments were carried out. The results are discussed according to different multi inlets configurations. These elements will provide some useful information in the choice of the future new WNRS.

3. Infrasound Data Processing and Station Performance

Oral Presentations

T3-O1. A global view on the coherent infrasound field

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Systematic characterization of coherent infrasound detection is important for quantifying the recording environment of each station which influence the detection probability of specific signals of interest. We present results of global coherent infrasound measured at IMS infrasound stations and its correlation with atmospheric dynamics. The processed database covers the time period from 2005 to 2015; whereas the number of stations has increased from 30 to 48. Following Matoza et al. (2013), the new implementation of the Progressive Multi-Channel Correlation (PMCC) algorithm enables the characterization, with a single processing run, of coherent noise in the log-spaced frequency bands from 0.01 to 5 Hz. Such experiment enables a better characterization of all received signals (e.g. frequency, azimuth, trace velocity). This, in-turn, allows more accurate signal discrimination, source and propagation studies. The multi-year processing so far indicates a continuous spectrum of coherent signals. It emphasizes continuous signals such as mountain associated waves, oceanic microbaroms, as well as persistent transient signals such as repetitive volcanic, surf, thunder, or anthropogenic activity. From these results, coherent ambient infrasound detection models station, frequency and time dependent could be derived and used to make more accurate and realistic network detection capability models.

T3-O2. Enhancing the association of infrasound events using a probabilistic categorization of clutter.

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The IDC collects waveforms from a global network of infrasound sensors maintained by the IMS, and automatically detects signal onsets and associates them to form event hypotheses. However, a large number of signal onsets are due to local clutter sources such as microbaroms (from standing waves in the oceans), waterfalls, dams, gas flares, surf (ocean breaking waves) etc. These sources are either too diffuse or too local to form events. Worse still, the repetitive nature of this clutter leads to a large number of false event hypotheses due to the random matching of clutter at multiple stations. Previous studies, for example [1], have worked on categorization of clutter using long term trends on detection azimuth, frequency, and amplitude at each station. In this work we continue the same line of reasoning to build a probabilistic model of clutter that is used as part of NET-VISA [2], a Bayesian approach to network processing. References: [1] Infrasound categorization Towards a statistics-based approach. J. Vergoz, P. Gaillard, A. Le Pichon, N. Brachet, and L. Ceranna. ITW 2011 [2] NET-VISA: Network Processing Vertically Integrated Seismic Analysis. N. S. Arora, S. Russell, and E. Sudderth. BSSA 2013.

T3-O3. Five Years of Infrasound Arrivals in the International Data Center Bulletins: A Review

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Infrasound re-entered automatic processing at the International Data Center, Vienna, on 11th February, 2010. This presentation provides a review of the infrasound arrivals that have been incorporated into the automatically generated Standard Event Lists (SEL's) and the analyst-reviewed Reviewed Event Bulletin (REB) over the past five years. The analysis focuses upon events in western Eurasia; significant numbers of events are recorded in this region, in part due to a higher density of International Monitoring System (IMS) infrasound arrays. In particular we focus upon the geographical clustering of events that contain only infrasound arrivals (and not

seismic arrivals). One example is an analysis of an event cluster within the REB over the North Sea, a known area of sonic boom generation. Data recorded across the LOFAR microbarograph network in the Netherlands provides a method of comparison between arrivals recorded across the sparse IMS network with data recorded at near-regional ranges (

T3-O4. Global Infrasound Network Detection and Association

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We apply infrasound pipeline processing algorithms to multiple years of International Monitoring System infrasound data. The results are summarized to identify trends in detection bulletins at each IMS infrasound array. Automatically formed events are compared with the CTBTO Reviewed Event Bulletin for the same time period. By identifying both false positives and false negatives, we identify improvements that are required to automatic algorithms.

T3-O5. I39PW Real-Time Station Performance Monitoring

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The collection of usable infrasound station data is a pragmatic performance requirement. Infrasound array I39PW, Palau, is located near the Asian-Pacific Ring of Fire and within the Northwestern Pacific typhoon basin. These natural source regions provide abundant ambient signals for assessing station performance and streamlining processing routines. The University of Hawaii Infrasound Laboratory (ISLA) operates and maintains I39PW and runs several automated processes for real-time station performance monitoring. The Infrasonic Energy, Nth Octave (INFERNO) framework is used to select the frequency bands and time windows used in real-time spectral analyses, signal to noise, and PMCC4 array processing. Selected case studies will be presented.

T3-O6. Identification infrasonic signals with very low frequency

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The problem of identification of infrasonic signals with frequency (0.002-0.02 Hz) was studied. Such infrasonic signals can be obtained from atmospheric storms. Signals amplitudes comparable with a noise. The data obtained from IMS station IS 43 were analyzed. Two identification methods of infrasonic signals were used. The first based on the Fourier and morphological analysis and the second based on correlation analysis. The obtained direction of arrival for the selected infrasound signals were compared with the direction of propagation of atmospheric fronts. Weather maps of atmospheric fronts were presented as well. The quite good correlations between calculated direction of infrasonic arrivals and that ones for atmospheric fronts was observed.

T3-O7. KSIAR, the Korea Seismo-Infrasound Array installed at PS31

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Korea Institute of Geoscience and Mineral Resources (KIGAM) has installed an infrasound sensors since May 2014 on the existing eight seismic stations of PS31 called KSRS which is composed of 26 seismic sensors with a 40-km aperture. The installed acoustic sensors are collocated with the seismic stations of KSRS. This changes part of KSRS into a seismo-infrasound array, the Korea Seismo-Infrasound Array (KSIAR). The aperture of KSIAR is 6.8 km. The data from KSIAR except that from the site KS06 is being transmitted in real time to

KIGAM with VPN and internet line. The analysis on seismo-acoustic signals has been performed since the installation of acoustic gauges. The utilization of an array process called Progressive Multi-Channel Correlation (PMCC) detects seismo-acoustic signals caused by various sources including small explosions in relation to constructing local tunnels and roads as well as large scale surface explosions in regional distance ranges. The seismo-acoustic signals recorded by KSIAR are supplying useful information for discriminating local and regional man-made events from natural events.

T3-O8. Loss of coherence influence on the detection capabilities of the IMS network

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The loss of coherence in the infrasonic arrays have been introduced by Mack & Flinn (1971) and have since been heavily studied (Blandford, 2002) , (Nouvellet, 2013), (Green, 2013). The loss of coherence (LOC) is derived from uncertainties on the source wavefront. This leads to a loss of coherence that is function of both the distance between the sensors, and the frequency. In this study, we propose an algorithm to simulate the LOC which is used to compute the performance of the usual detectors (consistency, MCCM, F-Detector) in presence of loss of coherence. We show that in case of strong LOC, the choice a small subset of sensors can increase the detection capabilities of a IMS station. However, in case of strong noise it is recommended to use the maximum number of sensors for the detection. We finally give a strategy to select the optimal subset of sensors based on the amplitude of the loss of coherence and the SNR.

T3-O9. Observation and studying of local infrasound coupled by seismic wave on wide spread infrasound network

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A kind of least-squared-error localization algorithm applied on wide spread infrasound network is proposed in this article. Model of cross correlation between distant sensors and atmosphere infrasound propagation are analyzed. The localization error caused by quantity and distribution structure of network and ray tracing of local infrasound in real atmosphere are also calculated. Infrasound coupled by local seismic Rayleigh wave of Lushan (Ya'an) Earthquake on April 20th 2013 is detected by infrasound network and could prove the algorithm and analysis above. Comparing infrasound signals with seismic recording of IRIS global network, we found that they were well correlated for the corresponding time period in signal travel time, signal correlation (0.6-0.9), particle motion trajectory analysis, etc. the zone of infrasound source calculated by the least-squared-error localizing algorithm is not compact but its center (minimum value determined by least-squared-error method) is less than 150km distant from the epicenter. Due to the less absorption and refraction in atmosphere propagation, local infrasound is easily detected and recognized and could be a possible and feasible way to monitor earthquake.

T3-O10. Progress of Infrasound Events Location and Source Discrimination in Central Eurasia Region

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Kazakh NDC provides infrasound signal detection and event localization since 2013. Data come from a network consisting of two Kazakhstani infrasound arrays IS31 and Kurchatov and also Russian station IS46. Construction of another infrasound array at Kazakhstan is at the final stage. It is at the East of Kazakhstan. The station collocates with seismic array at Makanchy, PS23. For the moment event bulletins are available for almost three years of observations. Analysis of these data allows to extract regions with high density of infrasound sources. It is possible to study seasonal changes at the network detectability. Initial discrimination of some frequently acting sources is resolved. Unseasonable detectability changes are also preliminary explained.

T3-O11. Towards a Probabilistic Infrasound Detection Scheme using the Hough Transform

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Due to the sparse nature of the 60 station International Monitoring System (IMS) infrasound array network, correctly associating multiple signals with an acoustic source is challenging. The process is made more difficult by detection schemes that struggle to distinguish between small local sources and the large distant sources of interest to the Comprehensive Nuclear-Test-Ban Treaty Organization. At telesonic distances (>1000km) signals from point explosions appear to have stable backazimuths and long durations (hundreds of seconds). One detection scheme that exploits both the backazimuth stability and the long signal duration is the Hough Transform detector (applied to infrasonic data by Brown et al., 2008). This detector scheme takes a series of short-window estimates of signal backazimuth and identifies linear features consistent with long duration stable signals. To assess the quality of a detection we apply a probabilistic framework, developed by the radar community, to construct a combined F-statistic and Hough transform detector. The F-detector provides the initial backazimuth estimate, while the Hough transform exploits the signal duration and stable backazimuth. Examples are shown of applying the scheme to IMS data, and the suitability of the probabilistic framework for long-range infrasound detection is discussed.

4. Infrasound Modelling and Network Performance

Oral Presentations

T4-O1. A Statistical Framework for Estimating Atmospheric Winds using Continuous Infrasound

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Infrasonic energy is known to propagate into the upper atmosphere before returning to the ground surface. A number of researchers have shown that transient infrasonic signals observed at spatially separated points can be used to estimate characteristics of the atmospheric winds. A statistical framework will be presented to demonstrate the extension of such methods to continuous infrasonic signals. Using this formulation, the inversion can be applied to a number of types of infrasonic "noise" such as microbaroms and wind farm infrasound to continuously monitor variations in the local atmospheric winds. The primary limitations of the application to such an approach are due to 1) the precision to which ground-to-ground propagation times can be identified and 2) the level of complexity allowed in the atmospheric model. The second of these concerns will be discussed in detail and compared with current atmosphere inversion methods and results.

T4-O2. ANTARES explosion observed by the US-ARRAY : an unprecedented collection of infrasound phases recorded from the same event

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The 28th October 2014 in Wallops Flight Facility, orbital's Antares launch vehicle failed and heavily exploded onto the launch pad area. At that time, the US transportable array of more than 200 operating stations (all equipped with microbarometers), was located on the east coast of the US and surrounded the accident. A large amount and variety of infrasound phases were observed at some stations, highlighting interesting propagation effects. The variety of recorded signals on such a dense network is unprecedented and offers the opportunity to better understand some propagation features, such as (1) the frequency content changes of stratospheric phases; (2) the dispersion of tropospheric phases propagating over thousands of kilometers within a stable and thin waveguide at fast phase speeds (350m/s) with low attenuation; (3) the non-linear effects associated with slow thermospheric phases (180m/s), especially in terms of shape, amplitude and duration. These 3 points will be addressed, and pieces of interpretations will be given thanks to the different propagation techniques: full waveform modelling (Normal Modes, finite element method), parabolic equation and ray tracing technique. Location issues of such an acoustic event based on tens of infrasound arrival times only will also be shown and discussed.

T4-O3. Atmospheric infrasound propagation modelling using the reflectivity method

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A realistic modeling of infrasound propagation is necessary for acoustic event detection and location, and for evaluating models of the state of the atmosphere. Infrasound arrivals are typically predicted using ray-tracing although full-waveform modeling is frequently necessary. The reflectivity method generates synthetic seismograms for point sources in a layered medium. For an accidental explosion in northern Norway, we demonstrate using effective sound speed that reflectivity in a layered model of the atmosphere predicts all the observed phases at 410 km distance. Ray-tracing using the same atmospheric model fails to predict one of these arrivals which, comparing reflectivity and ray-tracing output at closer distances, is demonstrated to be a first bounce stratospheric arrival. We advocate using reflectivity in parallel with ray-tracing for providing a more complete view of the infrasound wavefield including head-waves and shadow zone arrivals.

T4-O4. ECMWF SSW forecast evaluation using infrasound

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Accurate prediction of Sudden Stratospheric Warming (SSW) events is important for the performance of numerical weather prediction due to significant stratosphere--troposphere coupling. In this study, for the first time middle atmospheric numerical weather forecasts are evaluated using infrasound. A year of near continuous infrasound from Mt. Tolbachik (Kamchatka, Russian Federation) is compared with simulations using high resolution deterministic forecasts of the European Centre for Medium-range Weather Forecasts (ECMWF). This study focuses on the period around the 2013 major SSW, and shows that while the SSW onset is better captured by the ten day forecast, the duration and recovery is better captured by the nowcast. As such, this study demonstrates the use of infrasound in the evaluation of middle atmospheric weather forecasts and therefore its potential in the assessment of tropospheric forecast skill.

T4-O5. FLOWS: Stochastic propagation models for decision analysis

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While long-range infrasound propagation modeling is a useful tool in geophysics and nuclear treaty verification, the inherent unpredictability of subgrid-scale atmosphere dynamics results in a poorly constrained propagation medium. This work reports on the project FLOWS (Fast Low Order Wave Simulation) that begun in 2013 and whose aim is to reformulate the problem in a probabilistic framework by using stochastic reduced models. Signal statistics are obtained by computing a few propagating modes over large ranges of frequencies, along with probabilistic inference to incorporate atmospheric data. Such a probabilistic model enables integrating the uncertainties associated with a hypothesized event and the atmosphere. A stochastic parameterization of gravity waves (GWs), currently in use in a general circulation model, is adapted to estimate the GW field unresolved in the large-scale atmospheric specifications. By examining how the GW field manifests statistically within the waveforms, it is shown how we can update the numerically obtained signals from the underlying probabilistic GW field. Applied in the context of the International Monitoring System (IMS), FLOWS achieves uncertainty quantification of the continuous stream of recorded signals and enables associations based on a Bayesian framework. It also predicts signals that are missed by the classical high-frequency techniques.

T4-O6. Infrasound study of the vertical atmospheric structure

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The vertical structure of wind field in the upper stratosphere and mesosphere obtained by infrasound probing method is studied. The method is based on the effect of infrasound scattering from highly anisotropic wind velocity and temperature inhomogeneities in the atmosphere. The vertical wavenumber spectra and coherences of the retrieved vertical profiles of wind velocity fluctuations are obtained. Particularly, such profiles were retrieved from the signals recorded for different azimuths at a range of 100-120 km from volcanoes in Kamchatka. The infrasound propagation from volcanoes and surface explosions through the atmosphere with the retrieved profiles of the effective sound speed is modeled by using parabolic equation method. The obtained consistency between modeled and recorded infrasound signals at different ranges from the infrasound source shows that real-time retrieval of the fine-scale wind velocity structure allows us to better predict infrasound field and localize its source as compared to the case when such structure is not taken into account in the existing atmospheric models. The possibility of using retrieved wind velocity structure for improving the models of long-range infrasound propagation in the atmosphere is discussed

T4-O7. The method of decomposition of infrasonic signals from pulsed sources

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The proposed method is based on the decomposition of infrasonic signals from pulsed sources. The recorded infrasonic signal is decomposed on a sequence of the acoustic pulses having the forms of U and N waves. Each U and N wave corresponds to the reflection of sound from the atmospheric inhomogeneities at different altitudes in the atmosphere. By determining the time intervals between such waves it is possible to determine the vertical gradients of the effective sound speed at different altitudes in the atmosphere. The vertical profiles of the vertical gradients of the effective sound velocity in the atmosphere by using infrasound signals recorded from different pulsed sources are obtained. The obtained data are interpreted with the theory of fine structure formation in the upper atmosphere.

T4-O8. Three-Dimensional Finite-Difference Time-Domain Simulation of Explosion Infrasound in Rough Topography

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We investigate the impact of rough surface topography on atmospheric infrasound propagation by means of full 3D numerical simulations. The geometry of the reflecting surface and/or structures near the acoustic source strongly influences the development of acoustic waves, thereby affecting the sound radiation patterns in the far field. The linearized Euler equations, describing acoustic overpressures in the presence of background flows, are solved by Finite-Difference Time-Domain (FDTD) method. The FDTD method has advantages to account for complex wave phenomena such as reflection, diffraction, and scattering by arbitrary objects, which may not be properly handled by acoustic rays. Parallel algorithms are implemented to distribute large workload across CPU/GPU clusters. Surface topography, sound speed variation, and wind profiles are taken into consideration for realistic atmospheric propagation. We characterize sound propagation patterns in a series of numerical simulations with different surface topographies and investigate the topographic propagation effects in combination with atmospheric sound speed and wind gradients. Finally, the result of numerical modeling is compared to the acoustic overpressures observed from chemical explosion experiments for verification. By understanding sound propagation in realistic emplacement conditions and atmospheric properties, we expect to improve acoustic source characterization substantially (e.g., yield and explosion mechanisms).

5. Analysis of Infrasound Sources and Scientific Applications of Infrasound

T5-O1. Airborne infrasound: A new way to explore the 3D acoustic wavefield

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As a part of the Source Physics Experiment (SPE) site characterization and explosive test series, we developed and deployed an airborne octocopter infrasound platform. Traditionally, infrasound data is collected with sensors and arrays that are installed on the ground. For most applications this is sufficient but can be limiting when observing non-isotropic sources, such as underground explosions, at close range. To develop and test the airborne infrasound platform we recorded data from the HK Exploration Seismo-Acoustic Hammer at the Nevada National Security Site. During early field-testing of the hammer source we found that, as the 13 metric ton mass hit the ground, a significant downward deflection of the surrounding surface imparted an observable infrasound pressure wave into the atmosphere. We compared waveforms collected at various vertical and horizontal offsets from the hammer source and found that the peak frequencies differed when observed directly above the source compared to the horizontal offsets. This work was done under award number DE-AC52-06NA25946. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

T5-O2. An effort to utilize the infrasound observation network data for reducing damage from convective storms and lightning

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In order to understand regional infrasound sources and improve the accuracy of the discrimination for the nuclear test, the development of the infrasound monitoring system with a low-cost and compact size has been started and the portable infrasound observation kit by using the nano-resolution digital quarts resonator sensor (Paroscientific, Inc., USA) was developed in 2011. Until now, in order to limit damage caused when a disaster strikes associated with explosive volcanos, tsunamis, snow avalanches, convective storms and lightning, several portable kits have been deployed in array configuration in Japan. In the summer and early fall every year, many thunderstorms occur and pass near the infrasound station and many interesting infrasound signals associated with these thunderstorms are detected by the infrasound observation network. In this presentation, we would demonstrate the signal generation mechanism by comparing the information obtained from X band multiparameter radar with the characteristics of these infrasound signals.

T5-O3. Atmospheric Characterization from Repeating Seismoacoustic Events: Exploiting the Synergy of Seismic and Infrasound Data

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Remote event detection and location using infrasound requires high quality temporal and spatial atmospheric models. Large industrial blasts and military explosions are tightly constrained in time and space using seismic data and can generate infrasound recorded both regionally and globally. The most useful seismo-acoustic sources are repeating sources with relatively frequent explosions, sampling the infrasonic wavefield over many time-scales. An extensive database of explosions from many sites in Fennoscandia and northwest Russia has been compiled, dating

back to the late 1980s. Each event is associated confidently with a known source, with an accurately determined origin time, usually by applying waveform correlation or similar techniques to the characteristic seismic signals generated. For selected repeating sources and infrasound arrays, we have assessed the variability of infrasonic observation: including the documentation of lack of observed infrasound. These observations provide empirical celerity probability distributions. Such empirical distributions have been demonstrated in numerous recent studies to provide infrasonic event location estimates with significantly improved uncertainty estimates. Tropospheric, stratospheric and thermospheric returns have been observed, even at distances below 200 km. This information is now providing essential input data for studies of the middle and upper atmosphere.

T5-O4. Automated detection and cataloging of global explosive volcanism using the IMS infrasound network

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Explosive volcanic eruptions are among the most powerful sources of infrasound observed on earth, with recordings routinely made at ranges of hundreds to thousands of kilometers. These eruptions can also inject large volumes of ash into heavily travelled aviation corridors, thus posing a significant societal and economic hazard. Detecting and counting the global occurrence of explosive volcanism helps with progress toward several goals in earth sciences and has direct applications in volcanic hazard mitigation. This project aims to build a quantitative catalog of global explosive volcanic activity using the International Monitoring System (IMS) infrasound network. We are developing methodologies to search systematically through IMS infrasound array detection bulletins to identify signals of volcanic origin. We combine infrasound signal association and source location using a brute-force, grid-search, cross-bearings approach. The algorithm corrects for a background prior rate of coherent infrasound signals in a global grid. When volcanic signals are identified, we extract metrics such as location, origin time, acoustic intensity, signal duration, and frequency content, compiling the results into a catalog. This work represents a step toward the goal of integrating IMS data products into global volcanic eruption early warning and notification systems.

T5-O5. Emergency launches of carrier rockets from Baikonur cosmodrome recorded by infrasound and seismic stations of KZNET network

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Starting from 1957, Baikonur cosmodrome located in Central Kazakhstan launches rockets on a regular basis. The flight traces pass over the territory of Kazakhstan where the infrasound and seismic stations of KZNET network are installed. KNDC Data Centre conducts detailed analysis of seismic and acoustic records of events of different nature round-the-clock; among them there are some associated with launch, flight, accident falls and burst of carrier rockets. The records of Kazakhstan seismic and infrasound stations were studied on availability of signals connected with accident falls of rockets for the period 1994.06-2015.06. Seismic and acoustic records from stations ABKAR, AKTO (AS59), BRVK, BVAR(AS57), IS31, KKAR, OTUK, VOS connected with large accidents of carrier rockets Dnepr (July 26, 2006), Proton (September 5, 2007 and July 2, 2013) were studied in details.

T5-O6. Gravity waves observed through measurements of the uncorrelated tropospheric noise between 0.5 and 6 Hz

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The coupling between gravity waves and the turbulence-generated atmospheric noise has been studied from the beginning of 1970:ies. The uncorrelated atmospheric noise, normally considered as an obstacle when detecting weak infrasonic signals, may be, studying its envelope, used to extract gravity waves passing through the turbulent medium. Dimensions of arrays of the Swedish-Finnish Infrasound Network (SFIN) are to small (75 x 75 meters) to determine the angle of arrival and the phase velocity of detected gravity waves. However, the frequency spectrum of observed gravity waves and its temporal variations may be determined. Examples of gravity wave spectra generated by large meteoroid entries, rocket launch and major explosions are presented.

T5-O7. Infrasonic waves from marine storms –"voice of sea"

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Some data on a high-frequency infrasound recorded within a range of 2--16 Hz ("voice of the sea") in the water area of the Black Sea are given. Different parameters of the recorded infrasonic signal - the direction and phase velocity of arriving infrasonic waves, spectral composition, and coherence - have been studied. Wind and wave conditions in the water area of the Black Sea were studied in detail. The collision of two atmospheric vortices was observed a few hours before the first arrivals of infrasonic waves, and the collision of differently directed sea waves was observed during the recording of infrasound. The direction of the arrivals of infrasonic waves coincided with the direction between the zone of collision of sea waves and the point of infrasound recording. The assumption was made that, in order to explain the observed infrasonic waves, it is necessary to use the mechanism responsible for the emission of infrasound into the atmosphere by standing surface waves formed due to the nonlinear interaction of surface waves propagating in opposite directions and to take into account the frequency-filtering properties of both wind-velocity and temperature stratifications of the atmosphere itself along the path of infrasound propagation.

T5-O8. Infrasound Waveform Inversion and Mass Flux Validation from Sakurajima Volcano, Japan

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Recent advances in numerical wave propagation modeling and station coverage has permitted robust inversion of infrasound data from volcanic explosions. Complex topography and crater morphology has been shown to substantially affect the infrasound waveform, suggesting homogeneous acoustic propagation assumptions are invalid. Volume flux estimates from the infrasound waveform inversion provide an exciting tool for accurate characterization of both volcanic and non-volcanic explosions. Mass flux, arguably the most sought-after parameter during a volcanic eruption, can be determined from the volume flux if the volcanic flow is well-characterized. Thus far, infrasound-based volume and mass flux estimates have yet to be validated. In February 2015 we deployed six infrasound stations around the explosive Sakurajima Volcano, Japan for 8 days. Here we present our waveform inversion method and volume and mass flux estimates of numerous explosions using a high resolution DEM and 3-D Finite Difference Time Domain modeling. Several ground-based instruments and methods are used to independently determine the volume and mass flux of individual volcanic explosions. We compare the volume and mass fluxes estimates and discuss sources of error and future improvements. Our technique may produce realistic estimates of mass flux and plume height and extent necessary for volcanic hazard mitigation.

T5-O9. Propagation effect on MAWs from Drakensberg Mountain using IS35 and IS47

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IMS Infrasound stations detect mostly signals from Mountain Associated Waves at frequency range [0.015 - 0.1Hz]. MAWs are generated as hydrodynamic oscillation in the turbulent wind-stream in the lee of high mountain ranges (Meecham, 1971). Amplitude attenuation of MAWs from Drakensberg Mountain range is studied. Observed attenuation at two IMS infrasound stations IS35 and IS47 was compared with Raytracing technique using Bass & Sutherland, 2003 absorption model. PMCC method is used to process infrasound data. IS47 detects signal from Drakensberg Mountain almost over the year. However, in IS35 bulletin this source is observed only from December to March and between June and July. Amplitude attenuation is due to atmospheric absorption of acoustic energy along its propagation. At first approximation, amplitude decreases with range.

T5-O10. Signals from the October 28, 2014 Antares Rocket Detonation

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On October 28, 2014 the launch of an Antares rocket from the Wallops Island Air Force Base in northern Virginia on the US eastern seaboard failed. To prevent the uncontrolled damage that could result from an uncontrolled launch the rocket was detonated. The detonation occurred at about 18:22:45 local time, producing a large explosion. Propagation conditions at the time were ideal: there was a temperature inversion and a well developed jet stream flowing up along the eastern seaboard providing a good ground duct for the near field propagation. In addition there was a well developed, eastward flowing stratospheric jet allowing the signal generated in the near field to propagate efficiently far up the east coast. Fortuitously, many of the USArray stations had been left in place providing a network of infrasound stations covering the full 180 degrees of azimuth available on the mainland. Details of the signal as it was generated in the near field and launched to the far field will be discussed.

T5-O11. The Spatial Coherence Structure of Infrasonic Waves in the European Arctic from Regional Events

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The spatial correlation of infrasound signals influences both infrasound array design and signal detectors. Previous atmospheric acoustic studies have identified anisotropic coherence loss across infrasound arrays, with greater loss for sensor-separations perpendicular to the direction of propagation than parallel. A recent study confirmed this anisotropy for International Monitoring System (IMS) infrasound array data. It is, however, difficult to identify the source of the coherence loss due to the differences in source-to-receiver paths. Therefore, we investigate the coherence structure of multiple signals recorded between one ground-truth source (munitions explosions in Hukkakero, Finland) and one station (the 10 element array at IS37, Norway). The source-to-receiver range is 320 km, with signals expected to be first bounce stratospheric. In agreement with previous studies we observe anisotropic coherence loss across the array. Initial results suggest coherence loss increases with decreasing celerity: lower celerities correspond to longer paths and hence greater coherence loss. The coherence loss for this range agrees well with the global study results that suggest the coherence loss depends on source-to-receiver range. The relationship between the boundary layer windspeed and coherence loss will also be investigated.

T5-O12. The infrasound data portal

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To be updated to: The infrasound data portal J.D. Assink(2), L. Frobert(2), A. Le Pichon(1), N. Brachet(1), C. Mendelewski(1), E. Blanc(1) (1) CEA, DAM, DIF, F-91297, Arpajon, France (2) EMSC-CSEM, CEA, DAM, DIF, F-91297, Arpajon, France In the context of the ARISE research infrastructure project, an infrasound data portal has been developed. The portal will provide access to raw infrasound data from European stations as well as advanced data products that are useful for civil applications and the study of atmospheric structure using infrasound data. In this presentation, the current features and future developments of the portal are discussed.

Posters

T6-P1. Analysis of Seismo-Acoustic Events in International Data Centre Operations

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A system based on four technologies has been established to monitor compliance with the CTBT. Three of them, so called waveform technologies (seismic, hydroacoustic and infrasound), help to detect and locate events. Seismic seed events with associated detections at hydroacoustic stations (T phases) are the majority of seismo-acoustic events. This study will focus on another group of seismo-acoustic events, i.e. events recorded at both seismic and infrasound networks of the International Monitoring System (IMS).

T6-P2. Analyze of the latitudinal migration of Gravity waves detected at IS17

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The IS17 Station is located at 6.67N in central Côte d'Ivoire in West Africa. This geographical location is central to both quasi-stationary locations of the rainy season (ITCZ) over West Africa. These quasi-stationary locations are 5N in May-June (first location) and 10N in July-August (second location). Using their azimuthal locations, the ten years observations of GWs in the south and north of the station were analyzed. The study showed an abrupt shift from their southern location (5N, Gulf of Guinea region) to the north (10N, Sahelian region) of the station. The average date of this abrupt shift is arrow June 16. This abrupt shift is made in less than one week and is called "West African monsoon Jump". The historical date of the abrupt shift of the ITCZ is June 23 (+- 7 days).

T6-P3. Burkina Faso NDC: Challenges to use Infrasound data

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The government of burkina faso throught the ministry of foreign affairs in a billateral agreement with the PTS for CTBTO established a NDC in Burkina with the aim of monitoring the testing of nuclear explosions. Seismic, hydro acoustic, radionucleide and infrasound methods are used for the monitoring. The NDC was commissioned in February 2010 and currently has nearly 5 technicians who treats only the seismic data received directly from IMS. Burkina Faso is a landlocked and mining country and as such we hope to be able to use infrasound data in the civil application order to prevent and see the impacts of mining explosions. Thus to increase its resources, participate in various debates and make our contribution we are looking for these kinds of forums to enjoy the experiences of others to build our emergent NDC.

T6-P4. CHALLENGES OF INFRASOUND DATA ANALYSIS,TECHNIQUES AND APPLICATION

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The infrasound I32KE is located about 10KM to the NNE of the city of Nairobi within Karura forest in Kenya.This station together with Ps24 are part of the global verification regime of the CTBTO.These stations are managed by the University of Nairobi which also serves as the NDC Kenya.These stations have continued to perform well in fulfilling their obligation to the CTBT by maintaining the rquired levels of data availabilty ,data procesing and siesmic data analysis.Together with an upgraded NDC,we look forward to additional capacity biulding in both seismic and infra sound data analysis. In the poster,we present the station performance as well as the challenges of infrasound data analysis and scientific application of infrasound,

T6-P5. Design, provision and installation of infrasound station Wind Noise Reduction Systems

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EnvirOconsult is an Infrasound Station Wind Noise Reduction System manufacturer since 2014. We have developed a new system only made of stainless steel offering robustness & reliability over long period of time. It has been designed to facilitate the onsite installation reducing the time wasted for leakage detection and cancellation. All parts (manifolds, inlet ports, ball valves…) have been specially designed for this project and high quality press fittings used.

T6-P6. Detectability of IMS infrasound station IS35

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IMS infrasound network in the southeast of Africa are operational since 2005.It's now composed of 4 continental stations IS32, IS35, IS47, IS19 and 2 oceanic IS33 and IS52. The characteristics of this African network is not fully known. In this study, detectability of IS35 station is done. Generally, the detection is dominated by natural sources MAW [0.015 – 0.1 Hz], microbaroms [0.1 – 0.5 Hz] and thunderstorm activities above 0.5 Hz. Signals from quarry and open mine are also detected and identified. PMCC method is used to process infrasound data and results are correlated with European Centre for Medium-Range Weather Forecasts (ECMWF) data and National Oceanic and Atmospheric Administration (NOAA) Wave Watch III model. MAWs sources identified are Eastern Arc Mountains, Ethiopian Highlands, Drakensberg Mountains. Microbaroms are generated mostly by the Antartic Circumpolar Current (ACC). In the high frequency, continental and oceanic thunderstorm activities are detected.

T6-P7. Detectability of IMS infrasound station IS47

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IMS infrasound network in the southeast of Africa are operational since 2005.It's now composed of 4 continental stations IS32, IS35, IS47, IS19 and 2 oceanic IS33 and IS52. The characteristics of this African network is not fully known. In this study, detectability of IS47 station is done. Generally, the detection is dominated by natural sources MAW [0.015 – 0.1 Hz], microbaroms [0.1 – 0.5 Hz] and thunderstorm activities above 0.5 Hz. Signals from quarry and open mine are also detected and identified. PMCC method is used to process infrasound data and results are correlated with European Centre for Medium-Range Weather Forecasts (ECMWF) data and National Oceanic and Atmospheric Administration (NOAA) Wave Watch III model. MAWs sources identified are Eastern Arc Mountains, Ethiopian Highlands, Drakensberg Mountains. Microbaroms are generated mostly by the Antartic Circumpolar Current (ACC). In the high frequency, continental and oceanic thunderstorm activities are detected.

T6-P8. Detection capabilities of the IMS Infrasound array and Seismic stations in West Africa

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The IMS has two infrasound array stations (IS11 and IS17) and three seismic stations (DBIC, TOROD and KOWA) located in West Africa. The ability of these stations to be deployed for civil and scientific purposes was assessed during the air crash of an Algerian airline on 24 July 2014, while travelling from Burkina Faso to Algeria. Local waveforms associated with the air-crash were studied from the infrasound and seismic waves produced by ground motion. The waves were extracted and studied by methods of spectrum, wave propagation, ray-tracing, and correlation between the infrasonic and seismic signals. The result showed that waves' source located were near the epicentre.

T6-P9. Dynamical Calibration and Identity Validation for Microbarometers

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The results of dynamical microbarometer calibration are presented. An original methodic of the calibration was performed. The methodic bases on step pressure changes in a small piston attached to a microbarometer altogether with 50 liter damping volume. The calibration of the MB2000 and MB2005 microbarometers allowed to get their frequency responses. The method also allowed to disclose units failures that are not seen by regular IMS diagnosis procedures. It is also possible to validate microbarometers identity using the same method. The method was tested with I31KZ microbarometers and also during field infrasound experiments conducted by the Institute of Geophysical Researches of the Atomic Energy Agency of the Kazakhstan Republic.

T6-P10. Establishment of Local Infrasound Network Infrastructure East Africa

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Whereas our additional efforts are to use Infrasound data from Nairobi Station (IS32) of the Preparatory Commission for Comprehensive Nuclear Test Ban Treaty organization (CTBTO) in the International Monitoring System (IMS) for civil and scientific application especially in the landslides and lightening studies, there is lack of local infrasound network density. The relevance of the local network is to improve our data detection, processing and interpretation of the infrasound sources and research. The challenge above has been understood by the government of Uganda in establishment of disaster preparedness and early warning systems. Thus, plans are underway to complement the IMS Nairobi Station (IS32) by establishment of three (3) infrasound stations in Uganda in order strengthen local infrasound network density for research.

T6-P11. Evaluation of the first 4 years of data from the Israel Infrasound Network

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The Israel Infrasound Network (IIN) consists of two arrays of microbarometers: one near Dimona, in the Negev Desert, and the other near Meron, on the Lebanese border. The arrays have been set up to record continuously for approximately the past four years. Certain phenomena, like the clear connection between average azimuth and season, we expected; others, like Mt. Etna's complete dominance of our winter-time observations, we did not. We also learned several important lessons about how the aperture of the arrays affects observations across the different frequency ranges. The Dimona array, being of much wider aperture, could observe signals from sources much lower than 1 Hz: gravity waves and very near-field events, for example. The Meron array, on the other hand, was much better at making observations across the full range of infrasound frequencies, and as such, was ideal for identifying paroxysmal explosive events such as nearby sprites. Here, we show these and other observations, and summarize what we have learned so far.

T6-P12. Feature extraction and Classification of infrasound signals Based on IMF Components Analysis

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The discrimination problem among different infrasound sources is a key issue to CTBTO infrasound monitoring station, in order to improve classification performance of various types of infrasound signals, this paper propose a new feature extraction method which is based on the component ratio of IMF. To evaluate of the classification performance of the proposed features, dichotomy classification method is firstly applied to each IMF component ratio, that is IMF1/IMF2, IMF1/IMF3, IMF2/IMF3, and then these features are combined to form a new feature vector and the SVM (Support Vector Machine, SVM) method is applied to evaluate the classification performance of the novel feature vector. Experimental results show that: the novel feature vector is valid to discriminate these different infrasonic sources, and the best recognition rate is over 80%.

T6-P13. Framework for detection software evaluation: refinements to the user-interface

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The IDC operates a number of automatic signal detection algorithms for seismic, hydroacoustic and infrasound time-series data recorded in real time by the International Monitoring System (IMS). It is of interest to assess the performance of an individual detection algorithm on signals of relevance to the PTS. This project extends the earlier work of Charbit et al. (ITW2014) that established metrics and methodologies for quantifying the performance of signal detection algorithms of the kind that are in regular use at the IDC. The matlab code formulation of the earlier work has been edited and a more user-friendly interface developed. The toolkit allows the user to: a. generate a synthetic data set with pre-determined values of SNR, signal duration and inter-sensor decorrelation b. call a choice of detection algorithm c. generate precision and recall plots The work presented here will describe the implementation and use of the software, and present precision/recall results for the current DFX detector.

T6-P14. IMS INFRASOUND STATION MONITORING PERFORMANCE IMPROVEMENT AFTER WNRS MAINTENANCE – I09BR BRASILIA, BRAZIL

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The Infrasound Station I09BR, installed in 2001 at Brasilia, Brazil, is composed by four elements, equipped with 18 meters wind noise reducing systems (WNRS). Each WNRS is composed by four rosettes of 24 graveled inlet ports, constructed with buried commercial galvanized pipes, brass summing manifolds and resonance suppressors. Despite the high data availability, the system is showing data quality problem, affecting the monitoring capability. The problems are associated to the pipe array deterioration, due to the age and lack of maintenance, and the main issues are related to junction's leakages, blocked inlet ports and pipes and bad connection to the microbarometer nozzle. The implementation of a routine data analysis from the local data center as well as a data quality follow up from CTBTO IDC could help in detecting data quality problems and trigger timely maintenance actions (PRs) to keep the station collecting quality data. The present work will produce some statistics on the events detection from before and after the station WNRS maintenance.

T6-P15. Identification of infrasound sources of South-American using IDC bulletins.

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In this study it is going to be presented preliminary results of study infrasound source from South-American using data provided by the IDC bulletins along the years and using data mining tool, and present a method for discern near sources using one data station.

T6-P16. Infrasound Signal Records Made by Borehole Seismometers

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The seismic array KURK located in Kurchatov, North-East Kazakhstan, consists of 21 elements with borehole seismometers. The array records multiple mining blasts from a nearby quarries. The analysis of the data shows presence in the blasts records non-typical phases. Along with well-known seismic arrivals, some phases come significantly later and have very slow apparent velocities. Having those arrivals compared with infrasound data, recorded at Kurchatov infrasound array we propose an infrasound nature of some seismometer records. The physics of the seismo-acoustic arrivals is discussed.

T6-P17. Infrasound Technology in Indonesia

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For more than 30 years, the BMKG and the French CEA institutes have been collaborating to implement and improve geophysical networks for detection and characterization of natural phenomena such as earthquakes. This scientific cooperation in the field of seismology started in the 1980's, and more recently in the domain of infrasound with the set-up of an experimental station in three different locations across the Indonesian archipelago. Composed of 4 MB2005 sensors, the Indonesian experiment confirmed the value of infrasound observations for major natural hazard monitoring such as large earthquakes and tsunamis, severe weather episodes and the volcanic activity at regional scale. An automated method to estimate the location of regional infrasound sources has been developed in order to merge these records with data provided by the International Monitoring System (IMS). The output of the location process also represents valuable information in evaluating the influence of the atmosphere between the source and infrasound stations, which may contributes to a better description of dynamics of the atmosphere in a region of the world where stratospheric models are poorly constrained.

T6-P18. Infrasound Technology, a CTBT vision for Civil and Scientific Purposes: Related hazards case in Comoros

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Various Karhala eruptions were noticed from known years 1808 to 2007. Some of the Volcano Observatory recorded with sensitive seismic-volcanic activities as for 2005-2006 periods, generated phreato-Magmatic eruptions, reacting as explosive eruptions. Such ground-atmosphere coupling process has a major interest in regard of understanding and interpreting the route of source generating and outcomes linked to it: the related Effects. From this aspect, the CTBT Infrasound Technology is to play important role on event investigations similar to 20/01/2010 and 24/11/2014, in the surrounding areas of Comoros. Consequently, in an historical view, Comparable events reported by IDC Infrasound Expert, realised that 3sequences of Karthala volcano have been observed and recorded in IRED (Infrasound Reference Event Database) in 16 and 17 April 2005, and 28 May 2006. These eruptions have been reported in the Database of Smithsonian, at that time, the Infrasound Technology hasn't been yet considered among the Reviewed event Bulletin REB records of the IDC. However, continuous efforts would be of great Interest, not only concerning the IDC increasing performance but also supporting other member States Issues concerning Research and other civil and scientific needs.

T6-P19. Infrasound signals from the blasting sources in Dobrogea seismogenic region, Romania

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Acoustic data recorded with infrasound IPLOR array were analyzed and combined with seismic observations in an attempt to blast decontaminate Romanian seismic catalogue, (ROMPLUS) by discrimination between quarries explosions and tectonic earthquakes in Dobrogea seismogenic region. Seismo-acoustic analysis was carried out for two years, 2011 and 2012, 520 events in ROMPLUS catalogue being investigated. Diurnal and seasonal variations of the number of located events show significant peaks during the time intervals with higher quarries' activity. By using WinPMCC software, infrasonic signals detected by IPLOR array are characterized in terms of direction, horizontal phase velocity and frequency content. The observed backazimuths and arrival times of infrasonic signals were compared with expected backazimuths and theoretical arrival times of catalogue's locations. 128 infrasonic signals were associated with seismic events located in the Dobrogea region in a distance range between 110 and 230 km from the IPLOR array and backazimuth interval from 110 to 160 degrees. In the absence of information regarding the controlled explosions detonated at the mines and quarries (origin time, location, amount of explosives discharged), association of infrasonic signals with seismic detections represents a reliable method to identify blasting sources in seismic catalogues and to distinguish them from natural earthquakes.

T6-P20. Integration of the Infrasound Technology for Civil and Scientific Application in Ghana

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The National Data Centre in Ghana was established to enable the country have access to International Monitoring System (IMS) data and International Data Centre (IDC) products to monitor nuclear test explosions and verify compliance of the Comprehensive Nuclear Test-Ban Treaty (CTBT). The Centre has technical expertise in the monitoring and verification technologies of the CTBTO. It is mandated to collate seismic, radionuclide, infrasound and hydroacoustic data for monitoring nuclear test explosions for global peace. The Centre has been actively involved in seismic monitoring and uses the seismic data obtained from the IMS stations to compile earthquake catalogue for the country and the West African region. The radionuclide technology was introduced in the country last year. Five years after its inception the infrasound technology is the next the centre is bringing on board due to its vast usefulness in the aviation sector and for meteorological studies since a range of meteorological events can emit infrasound and in climate change research. This paper gives an overview of strategies and activities envisaged as well as the potential impact of this technology in the country.

T6-P21. Measuring Infrasound from the Maritime Environment

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Wide global infrasound coverage is obtained using the CTBTO land-based network. However, two thirds of the earth's surface is composed of oceans, and no capability yet exists to monitor infrasound from sensors fielded in the maritime environment. The challenges of developing such a capability may be significant, however, if overcome, could provide infrasound coverage where it does not exist, or is not reliable. In addition, event detection redundancy achieved by multiple monitoring stations along different propagation paths may potentially improve detection confidence, classification and localization performance. It may also provide more complete characterization of the

infrasound propagation environment and other factors important for understanding infrasound performance worldwide. This poster will focus on efforts taken to overcome one of the technical challenges in fielding a maritime-based infrasound sensor: compensating for the degrading effect of ocean motion (heave) on the sensor. Heave-induced vertical motion will induce ambient atmospheric pressure changes on the sensor, which may overwhelm and obscure infrasound signals of interest. This poster will present progress made in compensating for the interference signal. Promising, preliminary data is presented from an at-sea experiment using a microbarometer and motion tracking system installed onboard a ship.

T6-P22. Melcepstral Coefficients Used as Input to a Neural Network for Identification of an Expanded Set of Atmospheric Nuclear Explaoions and Bolides

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In our previous research, Melcepstra coefficients were extracted from a number of infrasonic hand-digitized atmospheric explosion waveforms from the 1962 Operation Dominic series of atmospheric nuclear tests. These explosions were shown to have a distinctive pattern of Melcepstral coefficients which can be modeled with synthetically-generated waveforms. In this follow-on research, the authors have accomplished two major additions: the first being the expansion of the database to include additional atmospheric nuclear explosions, and a significant number of additional bolides, as well as a number of surface chemical explosions. More importantly we are designing a Neural Network that takes these coefficients and outputs the class that fits best (explosions or bolides). Finally we have done a preliminary investigation on how the Melcepstrum/neural network identifies underground nuclear and chemical explosions which are also detected by one, or more, infrasound arrays.

T6-P23. Monitoring of infrasound phenomena in Cameroun (Central Africa)

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Many events include earthquakes, volcanoes and lakes explosions which can radiate infrasound often occur in Cameroon. The infrasound emitted by volcanic eruptions and lakes explosions, as it occurred in Nyos and Monoum lakes, is discussed in terms of what are their potential and what they actually are in Cameroun. The phenomena influencing infrasound are analyzing, interpreting, and modeling for the area of central Africa. The atmospheric background conditions such as the pressure, temperature and wind profiles are integral parts for the propagation calculations for infrasound to know. Thus, it appears that annual average temperature is about 78.8°F with main fluctuation from July to August. Maximal wind speed Simulation model at an altitude of 50 meters and a resolution of 50 km is less than 4 m/s. The average air pressure is about 985 hPa. These parameters and wind direction are influenced by the Harmattan, a northeasterly wind blowing from the Sahara desert into the Gulf of Guinea between.

T6-P24. Monitoring of local events by Ukrainian NDC infrasound network and problems of dynamic calibration of microbarographs.

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Over the past year in Ukraine increased the number of events of technogenic origin, which generate infrasound. This is especially due to the increased number of man-made accidents in industrial plants - an explosion at a chemical

plant, a fire at an oil storage facility, etc. During the summer, to work actively extractive industries which leads to an increase in the number of quarry blasts. Such point sources allow qualitatively evaluate the performance of funds infrasound monitoring of MCSM. Means of MCSM infrasound monitoring recorded most of these signals. Also, MCSM is working to improve the quality of microbarographs dynamic calibration and seek the possibility of modernization of calibration process. For a comparative analysis proposed parallel simultaneous calibration of several microbarographs.

T6-P25. New optical microbarometer

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Transducers implemented in microbarometer are mainly composed of two associated elements. The first one converts the external pressure variation into a physical linear displacement. The second one converts this motion into an electrical signal. According to this configuration, MB3, MB2000 and MB2005 microbarometers are using an aneroid capsule for the first one, and an electromagnetic transducer (Magnet-coil or LVDT) for the second one. We think that changing the electromagnetic transducer by an interferometer is a solution to increase the dynamic and the resolution of the sensor. Firstly, we will present the new transducer principles, considering the aneroid capsule and the interferometer using integrated optics technology. Secondly, we will present the first part of this project in which the interferometer is positioned outside the aneroid capsule. In this configuration, interferometer mechanical adjustments are easier, but measurement is directly disturbed by environmental effects like the thermal variations. Six prototypes and an optical digitizer were specifically designed. Then, we will present the first sensitivity and self-noise measurement results compared to those of a MB2005 microbarometer. Finally, a new design of the optical microbarometer will implement the interferometer into the aneroid capsule under vacuum to protect the optical measurement from environmental effects.

T6-P26. Project of improvement of characterization and localization of phenomena detected by IS17 station using a infrasound portable array

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A better localization of infrasound events in West Africa and on the African equatorial band requires fairly close infrasound station data. This improvement of locatisations is possible due to the zonal organization of altitude wind jet over this region. In Africa, Cote d'Ivoire has an infrasound station (IS17) certified by the CTBTO since 2002. The few existing infrasound stations in this continent (Tunisia, South Africa, Djibouti, Central African Republic (non-operational station)) are quite far thereof. In West Africa, we note the lack of other infrasound station that could allow improvement of events localization with IS17. Thus, an infrasound portable array facility with CTBTO in Cote d'Ivoire will improve the detection of events and their locations. Note that Cote d'Ivoire has expertise in infrasound equipment. This project will also establish a collaboration with neighboring countries such as Burkina Faso, Mali, Ghana, etc.

T6-P27. Quarry blasts acoustic signature in near-field infrasound records

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Seismometers is widely used in recording quarry blasts, whereas the relatively new technology of using infrasound detector is not widely used especially in near field recordings. In near field records infrasound could be very good discriminator between natural and artificial seismic sources (e.g. blasts vs earthquakes). The near-field records could be also used as a good estimator of the explosive charge used in the blast through the pressure drop measurement. The seismic records in near-field is contaminated with the direct air-shock along with first arrivals of P-waves where it is not easy to differentiate between the two effects however in infrasound records the only recorded effectis the pressure drop of the air-shock. This work is a first step for better understanding of the near-field infrasound records and the investigations of the silence zone.

T6-P28. Real-time version of the Bayesian Infrasonic Source Localization method

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The Bayesian Infrasonic Source Localization method(BISL), introduced by Mordak et. al, (2010) and upgraded by Marcillo et al., (2014) is destined for the accurate estimation of the atmospheric event origin at local, regional and global scales by the seismic and infrasonic networks and arrays. The BISL is based on probabilistic model of the source-station infrasonic signal propagation time, picking time and azimuth estimate merged with a priory knowledge about celerity distribution. It requires at each hypothetical source location, integration of the product of the corresponding source-station likelihood functions multiplied by a priory probability density function of celerity over the multivariate parameter space. The BISL is now based on the numerical integration, which is generally a rather time-consuming procedure. The computational scheme proposed simplifies the target function so that the integrals are taken exactly and are represented via standard functions. This makes the procedure much faster and realizable in real-time without practical loss of accuracy. The procedure executed as PYTHON+FORTRAN code demonstrates high performance on a set of the model and real data.

T6-P29. River as the Infrasound Medium and Detection of Infrasound Events

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Infrasound generated in the ground penetrates through the boundary surface between ground and river and transmits through the river water environment. That enables using underwater hydroacoustic sensors, or (UWHS), in detection, identification, and localization of the infrasound events in rivers, which origin is in the ground. The main contribution to the infrasound waves in the river gives seismic activity of the earth, and various types of explosions. The waves through the ground and water transmit at higher speeds than in the air, and therefore information about characteristics infrasound events are more quickly available. Generally, research in the field of the river infrasound should be organized in three directions: detection, identification, and localization all types of ground activities using hydroacoustic technology. To perform quality hydroacoustic detection it is necessary define hydroacoustic measuring lines suitable for detection infrasound events that take place at the ground. In this paper are presented some experimental data about infrasound events in the river water environment obtained by hydroacoustic measuring techniques.

T6-P30. Super Gaussian non-Stationary near-Infrasound Noises Sparse Representation

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Abstract: In accordance with the results of the experience of IDC (CTBTO International Data Center) automatic infrasound processing software in its current form, there are some difficulties as the automatically identifying and classifying infrasound phases, and the rejection and no classification of the smallest detected signals in the very low SNR (Signal-to-Noise) ratio data capturing times. Due to the non-stationarities and discontinuities, SGnSnINs (Super Gaussian non-Stationary near-Infrasound Noises) could not be well representing, feature extracting, and then classifying in stationary transform domains as STFT (Short Time Fourier Transform). DWT (Discrete Wavelet Transform) is the most common used and conventional transform for representing, feature extracting, and then classifying of non-stationary signals using data independent kernels. But the simulations confirm that the sparse representation transforms could be well representing SGnSnINs than DWT because of using data dependent kernels (Atoms). In the proposed method, MP-TFD (Matching Pursuit Time Frequency Decomposition) technique is used for SGnSnINs representing, and then NMF (non-Negative Matrix Decomposition) technique is applied for decomposing the TFM (Time Frequency Matrix) into its significant components. Finally, MFCCs (Mel-Frequency Cepstral Coefficients) are extracted as the features, and these features are used for sources classifying.

T6-P31. precursor infrasound waves monitored before several strong earthquakes

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Study on precursor infrasound wave monitored before several strong earthquakes. With the infrasound microphone CASI-ICM-2011, a kind of infrasound wave was received before a series of earthquakes over Ms6.0 with frequency among 0.001 to 0.01Hz, peak sound pressure level 50 to 200Pa, continuous time period half hour to 4 hours, propagation speed 10 to 30m/s. A sensors network was spreaded in north-east China with automatic data uploaded to a central server computer in Beijing. Source of the precursor infrasound wave emitted 4 days before Ms7.0 Lu-san earthquake and 12 days before Ms7.7 Pakistan earthquake have been located perfectly. Mechanism of this infrasound generation has been discussed that it could be radiated by a large scale surface vibration near 1 million square kilometer in earthquake developing. Two signals received after Ms8.8 Chile earthquake and Yu Shu earthquake were provided to prove this suggestion. The detected signal shows the infrasound waves arrived companying with S waves at the same time. One model was provided as a piston source to simulate very low frequency infrasound radiated by large surface vibration. All the presented signals in this paper should be useful for precursor information obtaining to close earthquake prediction.