International Hydroacoustics Workshop 2019

Report of Contributions

ID: Type: **Poster**

seismic observatories along the Japan Trench and their data

The Japan Trench is one of the most unique zones covered dense seismic networks in a wide area. National Research Institute for Earth Science and Disaster Resilience operates 150 seafloor seismic observatories, and Earthquake Research Institute, the University of Tokyo has 6 seismic stations. Each seismometer is linked with optical fiber cables, and the data are transmitted to Japan Meteorological Agency and other organizations in real-time. We present seismic records propagated through ocean and originated from both natural earthquakes and controlled-sources.

Primary author: YAMADA, Tomoaki (Japan Meteorological Agency)

Presenter: YAMADA, Tomoaki (Japan Meteorological Agency)

Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Oral**

trends and features in deep-ocean noise determined from the CTBTO hydroacoustc stations

This paper describes the results of applying a statistical method for long term and seasonal trend analysis and uncertainty evaluation from deep-ocean noise data. The analysis method uses a flexible discrete model that incorporates terms that capture seasonal variations in the data together with a moving-average statistical model to describe the serial correlation of residual deviations, with uncertainties validated using bootstrap resampling. The measured data originate from a number of the CTBT hydro-acoustic monitoring stations and span up to a maximum of 15 years. The analysis focuses on data from Cape Leeuwin, Wake Island, and Ascension Island, but also looks at Juan Fernandez and Diego Garcia. The features of the data are described, including differences observed in the seasonal variation and long-term trends, with the latter often exhibiting negative gradients. A tentative discussion is initiated of the potential causes of some of the variations, including changes in the acoustic output of individual anthropogenic sources (such as ships and seismic surveys), drift in the sensitivity of the sensing technology, changes in the sound transmission paths due to changing environmental conditions (for example, sea temperature), and changes to natural sound sources such as ice (especially in the Southern Ocean) and baleen whales.

Primary author: ROBINSON, Stephen (National Physical laboratory)

Presenter: ROBINSON, Stephen (National Physical laboratory)

Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Oral**

anomalous seismoacoustic event offshore northern Honshu, Japan

On 9 April 2019, flight control of the Japanese Air Self-Defense Forces lost contact with a F-35 fighter plane deployed on a training exercise off-coast northern Honshu, Japan. Floating debris recovered during the initial phase of the search and rescue mission suggests that the plane may have crashed, its last known position being communicated as approximately 135 km east of Misawa Airbase, Aomori Prefecture. Here, we investigate an arrival recorded by the hydrophone triplet arrays of IMS station H11, Wake Island, after contact was lost. Both timing and back azimuth of the signal distinctly match the location and source time of an anomalous seismic event that was registered by cabled seafloor seismometers in the vicinity of the presumed crash site, and that might be linked to the impact of the plane onto the sea surface. In addition to signal localization, we investigate the spectral composition and source-receiver paths to relate seismic and hydroacoustic recordings. Alternative source mechanisms will be discussed. Our findings show that the detection of small-scale events relevant to the CTBT verification regime is possible even over megameter distances, and that the capabilities of the IMS network extend beyond the realm of test-ban treaty monitoring.

Primary author: METZ, Dirk (Japan Agency for Marine-Earth Science and Technology (JAMSTEC))

Presenter: METZ, Dirk (Japan Agency for Marine-Earth Science and Technology (JAMSTEC))

Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Oral**

CTBTO hydroacoustic data to evaluate long-term trends in deep-ocean noise in the Southern Ocean

This paper describes a statistical method for performing long term trend analysis and uncertainty evaluation of the estimated trends from deep-ocean noise data. The measured data used originate several of the hydro-acoustic monitoring stations of the CTBTO and span up to a maximum of 15 years. The analysis method uses a flexible discrete model that incorporates terms that capture seasonal variations in the data together with a moving-average statistical model to describe the serial correlation of residual deviations, with uncertainties validated using bootstrap resampling. The main features of the approach used include (a) using a model that includes terms to represent explicitly seasonal behaviour, (b) using daily aggregation intervals derived from 1 minute SPL averages, and (c) applying a non-parametric approach to validate the uncertainties of trend estimates that avoids the need to make an assumption about that distribution of those differences. The trend analysis is applied to time series representing monthly and daily aggregated statistical levels for five frequency bands to obtain estimates for the change in sound pressure level with associated coverage intervals. Statistically significant trends in SPL are observed for all percentiles in the frequency bands. Seasonal variation is also observed, with correlation with relevant climatic factors.

Primary author: ROBINSON, Stephen (National Physical laboratory)

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Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Oral**

deep-ocean thermometry using IMS hydroacoustic arrays

We develop a method to retrieve phase-velocity in the SOFAR channel between two neighboring IMS hydroacoustic arrays (HA) for the purpose of monitoring deep- ocean temperature variations which are sparsely sampled. Previous studies Wolf et al., 2015; Evers et al., 2017; Sambell et al., 2019) have used an ambient acoustic field cross-correlation approach to resolve lag time as a proxy for temperature. Classical interferometry is not possible since the ambient avefield is not sufficiently equipartitioned. Moreover, as IMS HA are linked to a shore facility on a nearby island, part of the field is blocked, intrinsically preventing uniform illumination. In addition, such an approach is sensitive to mechanical interactions with the hydroacoustic sensor though the anchoring system to the ocean floor, thus resolving the surface wave propagation velocity instead of the water column acoustic propagation velocity.

In this study, we use acoustic signals from impulsive events, i.e., earthquakes and volcanic eruptions, that have a direct line of sight to two HA on either side of the shore facility island. We use array processing to: (1) distinguish between mechanical interactions with the hydroacoustic sensor and pressure-wave interactions due to acoustic propagation in the water column and the SOFAR channel, and (2) Retrieve wavefront parameters and beamform in the back-azimuth direction. In the next stage we cross-correlate 16 traces ((3 + 1)^2; 3 elements/array + 1 bestbeam, 2 arrays) using only the part of the signal associated with SOFAR channel propagation to retrieve lag time. We correct for the back-azimuth offset relative to the great circle path connecting the two arrays and calculate the temperature.

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Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Poster**

estimation for early warnings using pressure perturbation data

Deployments of real-time offshore observatory stations could contribute to enhancing early signal detection of hydroacoustic, seismic, and tsunami phases and also to improving accuracies for source analyses of the phases. We investigated pressure gauge data recorded at offshore stations in northeast and southwest Japan to develop an estimation method of providing rapid and reliable magnitude for early warnings. We focused on amplitude in a period band of less than 6 s at moderate to large earthquakes. In the case of stations deployed in deep ocean areas, the amplitude of pressure waveforms in this period band is roughly consistent with the vertical amplitude of water particle velocity. We constructed an empirical equation between the catalog magnitude and the observed maximum amplitude at the stations and estimated the magnitude for each event data. Our results show that the estimated magnitude correlates well with that in the catalog. The two sigma standard deviation is 0.70, which is almost the same value as that estimated from using amplitude data recorded at seismometers. Real-time monitoring of pressure perturbations at offshore stations may be a practical, effective way of estimating magnitude as well as that of seismometer data at suboceanic earthquakes.

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Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Poster**

real-time monitoring system and data application

In Japan, some offshore real-time monitoring systems have been deployed off the coast of the Pacific Ocean including the Nankai Trough Seismogenic zone and the Tohoku Seismogenic zone (i.e., the Japan Trench). DONET and S-NET have been deployed in the Nankai Trough and the Japan Trench, respectively, since the 2010s. Now, new development of next generation real-time monitoring system namely N-NET has been launched, which is focusing on the western part of the Nankai Trough. Many catastrophic earthquakes, volcanic eruptions and tsunamis bring destructive disasters in the world. In Indonesia, for example, the Palu earthquake and the Krakatau volcanic eruption brought tsunami disasters in 2018. Therefore, we should realize that offshore real-time monitoring systems are very important and effective for early warning. The Japanese offshore real-time monitoring system such as DONET and S-NET are used for earthquake early warning (EEW) and tsunami warning, and they have contributed to understanding of seismic activities in the region. At the same time, we could examine the in-situ data acquired by the system for the purpose of scientific studies. In the presentation, we introduce the Japanese offshore real-time monitoring system and the utilization of their data.

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Presenter: KANEDA, Yoshiyuki (Kagawa University)

Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Oral**

# of long-range propagation of acoustic waves generated by different types of impulsive sources.

When considering acoustic events of impulsive nature in the ocean that generate shock waves as detonation of explosive charges (especially those close to free surface or seabed), air-guns, electric shocks or collapses of metallic objects or glassware, we should be especially careful verifying the conditions of validity of equations used in the range of distances, depths and frequencies of interest. A range-dependent model based on Parabolic Equation Method (RAM v1.5) was used to estimate Transmission Loss along acoustic paths of thousands of kilometres. Effects of source-depth, physical properties of sound channel and several formulations to quantitatively describe sound attenuation in water column were considered. The feasibility of inferring distinctive features of impulsive acoustic sources from the corresponding pressure levels received at long distances was examined through spectral and cepstral analysis techniques. Analyses of signals generated by impulsive sources are presented. Different types of impulsive signals taken from semi-empirical models were used as input with the aim of analysing acoustic propagation effects over long source-receiver distances, assuming linear acoustics validity. Reported pressure pulses for implosions of small aluminium cylinders were scaled up to evaluate implosions of larger objects. Some anisotropic characteristics of the sources could be inferred from the analysis performed.

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Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Oral**

# of IMS hydrophone triplet data associated with undersea volcanic activity of Ioto Island

Real-time monitoring and early detection of undersea volcanic activity are indispensable in relation to disaster reduction, however it remains difficult to implement continuous in-situ observation of undersea volcanoes due to their difficult accessibility compared to above-surface volcanoes. International Monitoring System (IMS) hydroacoustic stations, which are equipped with triplets of hydrophones, are installed at six locations in the world's oceans. A Hydrophone triplet makes it possible to detect and determine the direction-of-arrival (DOA) of hydroacoustic signals. In the present study, data from HA11 Wake Island (a U.S. Territory in the Pacific) is examined to investigate the association of hydroacoutic signals with undersea volcanic activity at Ioto (formerly called Iwojima) volcanic island in the northwestern Pacific Ocean. The cross-correlation analysis indicates that the DOA of recorded hydroacoustic signals can be associated with sources at Ioto with a high degree of confidence. Temporal evolution of the detected hydroacoustic signals makes it possible to establish a direct association with in-situ seismic observations obtained with equipment which is permanently deployed at Ioto. Our study shows that the IMS hydrophone triplets can contribute to the identification and far-field monitoring of hydroacoustic signals generated by undersea volcanic activity.

Primary author: MATSUMOTO, Hiroyuki (Japan Agency for Marine-Earth Science and Technology (JAMSTEC))

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Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Oral**

and interpretation of variability in long-range, underwater acoustic signal propagation recorded on CTBT IMS hydrophone stations

On 15th November, 2017, the CTBT IMS hydroacoustic stations HA10 (Atlantic Ocean) and HA04 (southern Indian Ocean) detected an unusual impulse-like event whose estimated location was in the vicinity of the last known position of the missing Argentine submarine ARA San Juan (EGU2018-18559, 2018). This detection and localization was further confirmed by a controlled air-dropped depth charge deployed by the Argentine Navy, on 1st December 2017, close to the estimated location of the unusual event. The focus of this presentation is on the signal from these impulse-like events propagating out to a distance of more than 6000 kilometres along geodesic paths from the event origin through two very different underwater environments (EGU2019-9253, 2019). The impact of the ocean waveguide on the signal propagation is manifested by strong frequency low-pass filtering and time dispersion of the signal recorded on HA04 compared to the recordings on HA10. An interpretation of the signal characteristics recorded on HA10 and HA04 from the impulse-like events is performed by two-dimensional propagation modelling of full time-series including spatially dependent oceanographic database information. The modelling results broadly agree with observed features and point to the importance of adapting detection and classification algorithms to specific propagation paths.

Primary author: NIELSEN, Peter Louring (CTBTO Preparatory Commission)

Presenter: NIELSEN, Peter Louring (CTBTO Preparatory Commission)

Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Oral**

Hydroacoustic component of the IMS: Status and applications with emphasis on hydroacoustic detections pertinent to the case of the Argentine submarine ARA San Juan

The International Monitoring System (IMS) of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) comprises eleven hydroacoustic stations to monitor the world's oceans for nuclear explosions. Five of these are T-phase seismometer stations while six use water-column hydrophones cabled to shore providing real-time data to Vienna. The hydroacoustic network is the only of the four CTBT technologies that is fully certified. Nonetheless, significant effort is put into repairing and sustaining the IMS hydroacoustic network.
This presentation has two parts: a) it provides an overview of the hydroacoustic component of the IMS and summarizes major projects in hydroacoustics and b) provides highlights of recent civil and scientific applications based on hydroacoustic data with emphasis on detections pertinent to the Argentine submarine ARA San Juan that went missing offshore the San Jorge Gulf, Argentina, on 15th November 2017. CTBTO analysed data acquired by the hydroacoustic stations HA10 in the Atlantic Ocean and HA04 in the southern Indian Ocean with the intent to contribute information relevant to the search for the missing submarine. The night between the 16th and 17th November 2018, the ARA San Juan was found on the seabed at 900 metres depth, very close to the location indicated by CTBTO.

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Presenter: HARALABUS, Georgios (CTBTO)

Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Oral**

the use of subspace detectors for seismic survey signals observed on the IMS hydroacoustic network

Marine seismic surveys make use of a ship-towed air-gun array. The compressed-air shots fired into the water generate impulsive sound wave fronts whose reflections are recorded to map the oceanic crust. These intense sounds cause depletion of the local zooplankton [1], and can impact the detection capability of the CTBTO hydroacoustic stations and their automated processing [2]. It is desirable to detect the presence of these surveys, also when at great remove and low SNR. To this end, we explore adaptation of the subspace detection method [3] from seismology to hydroacoustics. In implementing the requisite algorithms, use was made of the ObsPy framework [4]. [1] McCauley, R.D. et al. (2017) Nature Ecology & Evolution 1, 0195. https://doi.org/10.1038/s41559-017-0195 [2] Brouwer, A., Le Bras R., Nielsen P. L., Bittner P., Wang H. (2018) Assessing and Mitigating the Impact of Seismic Surveys on CTBTO Hydroacoustic Detections, EGU General Assembly PICO presentation EGU2018-8367. [3] Harris, D. B. (2006). Subspace detectors: Theory. Lawrence Livermore National Laboratory Internal Report UCRL-TR-222758. [4] M. Beyreuther, R. Barsch, L. Krischer, T. Megies, Y. Behr and J. Wassermann (2010). ObsPy: A Python Toolbox for Seismology, SRL, 81(3), 530-533, https://doi.org/10.1785/gssrl.81.3.530

Primary author: BROUWER, Albert (International Institute for Applied Systems Analysis)

Presenter: BROUWER, Albert (International Institute for Applied Systems Analysis)

Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Poster**

Modelling of Rakhine Coast, Myanmar

Myanmar has long coastal areas and need to set up ocean observation systems. Department of Meteorology and Hydrology set up sea level observation stations at along the coastal areas of Myanmar and also monitoring the disaster including the tsunami disaster. Myanmar have been suffered many times of earthquake disasters and four times of tsunami by known the historical data. The purpose of this study is to estimate the tsunami arrival time and maximum tsunami wave amplitude for Rakhine coast of Myanmar by TUNAMI F1 model. In this study, I calculating the tsunami arrival time and maximum tsunami wave amplitude based on a tsunamigenic earthquake source of moment magnitude 8.5 in the Arakan subduction zone off the west-coast of Myanmar and selecting eight outpoints of Rakhine coast by TUNAMI F1 model. The model result indicated that the tsunami waves would first hit the Kyaukpyu of Rakhine coast about 0.05 minutes after generate the earthquake of moment magnitude 8.5 and the maximum tsunami wave amplitude was 2.37 meters.

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Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Oral**

# of very low frequency long term ocean ambient noise from CTBTO sites.

Long term ocean acoustic noise data from CTBTO sites at Wake Is., Ascension Is. and Diego Garcia, spanning periods of up to 15 years, have been analyzed through an effort sponsored by the US Office of Naval Research. Data were Fourier Transformed in 10-sec segments to provide noise spectra with a resolution of 0.1 Hz. Low-frequency spectrum level time series data were then examined for two purposes: (1) to identify long term statistical trends that might signal changes in climate, and (2) to identify natural or man-induced processes that drive observed fluctuations in noise spectral level. Noise levels at frequencies from 1 to 5 Hz appear relatively free of noise from shipping and marine life, and noise fluctuations in this band tend to be driven by natural processes such as wind, seismic activity and lunar and solar positions. Investigation of the statistical properties of the noise at very low frequencies, coupled with detailed modeling of low-frequency acoustic propagation, has resulted in confidence that the noise due to specific forcing functions, wind for example, can be isolated thereby allowing interpretation of the time change of oceanic sea noise. Propagation at these frequencies can be impacted by conversion to seismic/infrasound energy.

Primary author: ELLER, ANTHONY (Applied Ocean Sciences)

Presenter: ELLER, ANTHONY (Applied Ocean Sciences)

Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Oral**

and Hydroacoustic Observations from Recent Small Underwater Events in the South Atlantic Ocean

Small underwater events are often detected by the seismometer and hydrophone stations of the International Monitoring System (IMS) and the Global Seismographic Network. In this study, signals from the 15 November 2017 Reviewed Event Bulletin hydroacoustic event in the South Atlantic Ocean that occurred around 550km east of Argentina are analysed along with signals from a nearby depth charge detonation on 1 December 2017. The 15 November 2017 event was of interest as the epicentre is in the vicinity of the last reported position of the ARA San Juan, an Argentine Navy submarine. The epicentre estimate in this study, calculated with standard methods, is 46.0426S, 59.8096W, and is located close to the location of the wreck of the ARA San Juan. Hydroacoustic signals observed at two IMS hydrophone stations for the 15 November 2017 event contain significant energy at high frequencies which is inconsistent with an earthquake source. Frequency modulations are also observed in the amplitude spectra from both events and for the depth charge detonation these modulations are consistent with those expected from the known depth and yield. Modulations observed from the 5 November 2017 event differ from those observed for the depth charge event.

Primary author: HEYBURN, Ross (AWE Blacknest)

Presenter: HEYBURN, Ross (AWE Blacknest)

Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Oral**

processing with DTK suite of software: Application to hydroacoustic data

The CEA/DAM has developed the DTK (Dase ToolKit) suite of software dedicated to array processing, which is available in the NDC-in-a-Box package delivered by the PTS since 2016. Originally designed for processing infrasound and seismic data, the software package has evolved during the past two years, with significant efforts carried out to extend the existing functionalities to hydroacoustic technology. To illustrate the capability of last released DTK-DIVA and DTK-(G)PMCC software to process triplets of hydrophones data and display results over large periods of time, several examples will be presented. First, routine analysis of several years of detections from stations in Indian and Pacific Oceans will be shown. Acoustic events from the obtained detections have been built and results will be discussed in terms of location accuracy and low level monitoring of oceanic seismicity. For the biggest events, expert analysis is performed to efficiently map zones of T-wave excitation from P/S to T wave conversion and T wave reflection. Finally, special focus will be made on the location results associated to the loss of Argentinian ARA San Juan submarine.

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

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

Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Oral**

waves traveling along Antarctica, observed from long distance: Travel time as a function of the seasons

Activities of Monowai Volcanic centre have been observed as seismic waves recorded at Rarotonga station (RAR), as well as hydroacoustic waves recorded at Ascension Island (H10). Beamforming has been performed on the hydroacoustic data to verify the source and study the effect of performing calculations with a best beam. The lag time that is calculated by cross correlating seismic and hydroacoustic data corresponds to the known source-receiver distances and the calculated velocity. Finally, the lag time is studied as a function of time in order to observe seasonal change. Travel times between the source and hydrostation H10 do generally increase with decreasing temperature. In the Southern Hemisphere winter however, a sudden decrease of lag time is observed. This might be explained by a different velocity profile of the ocean around the poles, and the formation of sea ice.

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

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Track Classification: 2. Data analysis and signal processing methods for CTBT verification purposes

ID: Type: **Oral**

use of symmetry in 3D propagation

Solving propagation in a three-dimensional environment is one of the most challenging problems in computational physics. However, for cases where the environment possesses some kind of symmetry be it rotational or translational, the propagation problem can be simplified considerably. It can be shown that in problems where the environment is translationally invariant, the 3D wave equation can be Fourier transformed along the direction of translational symmetry to reduce it to a 2D equation for each spectral component. The 3D solution can be obtained by solving the 2D wave equation for each spectral component and performing the inverse Fourier transform. In this paper we use translation symmetry to compute propagation in an ideal and a penetrable wedge. For the ideal wedge, the pressure-release boundary condition is applied to both boundaries and for the penetrable wedge, the pressure-release boundary condition is applied to the horizontal surface and the continuity of pressure and normal velocity is imposed on the sloped interface. To obtain a numerically exact solution, we use the virtual source technique to solve the corresponding 2D problems. We use azimuthal symmetry in the framework of boundary element method to compute propagation in a Pekeris waveguide in the presence of conical seamount.

Primary author: ABAWI, Ahmad (Private Company)

Presenter: ABAWI, Ahmad (Private Company)

Track Classification: 3. 3-D modelling for long-range hydroacoustic signal propagation

ID: Type: **Oral**

# of CTBT IMS Hydroacoustic hydrophone station underwater system electronics calibration sequences

The end-to-end calibration from the hydrophone ceramic element input to the digitizer output of CTBT IMS Hydroacoustic (HA) hydrophone stations is measured in a laboratory environment before deployment. After the hydrophones are deployed permanently with the Underwater System (UWS) hydrophone triplets, the response of the digitizer component can be measured by activating remotely a relay which excludes the hydrophone ceramic, preamplifier and riser cable, and feeds a pre-stored known waveform into the digitizer circuit via a digital-to-analogue converter. Analysis of these underwater calibration sequences makes it possible to verify the stability of the digitizer response over time and obtain useful information for investigations which require an accurate knowledge of the system response. Results are presented showing the stability of the UWS electronics response over time and one case, pertaining to the H10S triplet of HA10 Ascension Island, where changes in the calibration response appeared after the onset of electronic noise in one hydrophone channel with cross-talk to the other two channels.

Primary author: ZAMPOLLI, Mario (CTBTO)

Presenter: ZAMPOLLI, Mario (CTBTO)

Track Classification: 3. 3-D modelling for long-range hydroacoustic signal propagation

ID: Type: **Oral**

modular hydrophone triplet options for sustainable IMS hydroacoustic stations

Each of the six IMS HA hydrophone stations consists of two triplets (one north and one south triplet), except for HA01 Cape Leeuwin (Australia) which has only one triplet. The hydrophone triplets are designed for a minimum 20 year-life, with no scheduled maintenance required. In the current robust design, triplet nodes and components are linearly interconnected in such a way that the repair of any failing component necessitates the replacement of the entire triplet. The complete lack of modularity does not allow component replacement. Wet-mate connectors (WMC's), which have found widespread use in Ocean Observatories and in the Oil-and-Gas sector over the past decade, can be a game-changer: placed at strategic locations in the triplet which are accessible to a Remotely Operated Vehicle (ROV) controlled from a surface ship, WMC's can enable the targeted repair of components. Triplet design options, with varying degrees of modularity and complexity, have been examined vis-à-vis reparability, operational risk and sustainability. This down-selection process has led to the identification of a hybrid modular triplet concept which strikes a balance by maintaining the reliable deployability of the present linear system whilst enabling the targeted replacement of failed components.

Primary author: ZAMPOLLI, Mario (CTBTO)

Presenter: ZAMPOLLI, Mario (CTBTO)

Track Classification: 3. 3-D modelling for long-range hydroacoustic signal propagation

ID: Type: **Oral**

3-D long-range modeling of underwater sound triggered by submarine earthquakes

Underwater low-frequency sound triggered by submarine earthquakes (5 to 20Hz) can travel great distances in the oceans, and it can be detected at thousands of kilometers from the epicenter. As a variety of geological and physical oceanographic features can cause horizontal refraction, reflection, and diffraction, 3D underwater sound models are required for accurately predicting global scale sound propagation. However, solving accurately the long-range propagation of sound from submarine earthquakes in fully 3D environments involves important scientific challenges. In this work, based on the simulation of sound propagation triggered by a Southern Mid-Atlantic Ridge earthquake, a set of recommendations to improve 3D global scale underwater sound modeling are proposed. A comparison between single frequency and broad-band 3D parabolic equation (PE) model results with sound recorded by IMS hydroacoustic network near Ascension Island and SW06 experiments (1000 and 8600 km from the earthquake epicenter, respectively) is presented. Likewise, single frequency results from a 3D Normal Mode model (Kraken 3D) are discussed. Overall, model results show the importance of 3D effects induced by the Mid-Atlantic Ridge and Atlantic Islands on low-frequency long-range sound propagation.

Primary author: OLIVEIRA, Tiago (University of Aveiro)

Presenter: OLIVEIRA, Tiago (University of Aveiro)

Track Classification: 3. 3-D modelling for long-range hydroacoustic signal propagation

ID: Type: **Oral**

Dimensional Hydroacoustic Propagation on Basin Scales

The ocean is nearly transparent to acoustic energy at low frequencies, particularly those sampled by the United Nations Comprehensive Nuclear-Test-Ban Treaty Organizations (CTBTO) hydroacoustic network (sample rate 250 Hz). This phenomenon is specifically what makes global coverage in support of the test-ban successful. Low frequency sound is less well trapped in the global sound channel and therefore interactions with the seafloor are more significant. Lateral bathymetric changes, with seamounts, continental shelf's and mid-ocean ridges makes out of plane propagation a significant factor in determining the International Monitoring System (IMS) coverage capability. A brief overview of three-dimensional modeling will be presented including the opportunities for putting 3D modeling into the event localization system.

Primary author: HEANEY, Kevin (Applied Ocean Sciences)

Presenter: HEANEY, Kevin (Applied Ocean Sciences)

Track Classification: 3. 3-D modelling for long-range hydroacoustic signal propagation

ID: Type: **Oral**

Modeling and the CTBTO Network

The oceans are generally not quiet places. Sound sources are ubiquitous and include surface wind including storms, distant and local shipping, seismic surveys, earthquakes, marine mammals and lightning. In the low frequency band (below 125 Hz), sound travels to very long distances. In this paper, we present a modeling approach based upon the efficient Parabolic Equation that can generate the basin soundscape for low-frequency sound. Satellite Automatic Identification System (AIS) data provides real-time high-resolution full global coverage of the shipping distribution. This coupled with surface wind measurements and model forecasts permits near real-time soundscape (or ambient noise) modeling. The challenge is to improve our understanding of sound source levels. This is best done through a comprehensive comparison of sound predictions and measurements taken from the International Monitoring System (IMS) hydroacoustic data. For this talk the Wake Island and Ascension Island data will be compared with the soundscape model simulations

Primary author: HEANEY, Kevin (Applied Ocean Sciences)

Presenter: HEANEY, Kevin (Applied Ocean Sciences)

Track Classification: 3. 3-D modelling for long-range hydroacoustic signal propagation

ID: Type: **Oral**

-Low Frequency seismic source for Ocean tomography and long-range propagation research

There is a growing interest for a very low frequency sound source in the frequency range below 40 Hz for such applications as Arctic under-ice thermometry, long-range navigation, sub-bottom seismic profiling, and etcetera. A coherent ultra-low frequency sound source is a quieter and more benign to marine mammals than air-guns, used for the oil exploration. Teledyne Marine recently developed infrasound source for the Marine Vibrator Joint Industry Project. The coherent source is based on the application of an underwater, gas filled bubble resonator covered by an elastic membrane. The membrane supports high volume displacement. The sources are not sensitive to cavitation and to coupling effects. The fluid dynamics and acoustics of a sperical resonator are defined by the Rayleigh-Plesset equation. The buoyancy deforms the shape of a real bubble from spherical. The 3D simulation and experiments have shown that a cylindrical form is a practical engineering solution. It performances similar to a spherical bubble, keeps its shape and can be towed with a high speed. The Q-factor of a practical bubble resonator is ~ 10. The experimental bubble resonator has shown good performance with a maximum SPL close to 205 dB and frequency in a range of 5-20 Hz.

Primary author: MOROZOV, Andrey (Teledyne Marine)

Presenter: MOROZOV, Andrey (Teledyne Marine)

Track Classification: 1. Technological advancements in marine engineering pertinent to the sustainability and improvement of the hydroacoustic component of CTBT's International Monitoring System (IMS)

ID: Type: **Oral**

weather-based Monte-Carlo simulations for identifying the weather risk of maritime operations

Ocean weather can have a dramatic impact on maritime operations, particularly in areas where weather conditions change rapidly and in extreme ways. Several locations where International Monitoring System (IMS) Hydroacoustic (HA) hydrophone stations are located are characterized by such rapid and extreme variability. For this reason, weather conditions have always been monitored carefully throughout the execution of HA station installation projects. In the special case of HA04 Crozet Islands, located in one of the world's most challenging oceans where the weather is extremely volatile, CTBTO developed an ad-hoc weather risk estimation Monte-Carlo simulation tool which relies on available historical meteorological data, task breakdowns and weather thresholds for the envisaged maritime operations. As this approach proved to be applicable and useful for the estimation of the HA04 installation's weather delay risk, a more widely applicable Monte-Carlo Mission Time Simulation (MMTS) tool was developed in a project with APL University of Washington, in which high-resolution oceanographic hind-cast data are used in conjunction with maritime mission task breakdowns and thresholds to produce predictions of the duration of at-sea operations including weather delays. MMTS was a key instrument in supporting the down-selection of Modular Design Options for Sustainable HA triplets.

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Track Classification: 1. Technological advancements in marine engineering pertinent to the sustainability and improvement of the hydroacoustic component of CTBT's International Monitoring System (IMS)

ID: Type: **Oral**

-Dimensional Global Scale Underwater Sound Propagation Modeling

A three-dimensional (3D) parabolic-equation (PE) model has been created to simulate global scale underwater sound propagation. This 3D PE model utilizes a map project to transfer the surface of the Earth to a Cartesian plane, which enables an efficient solution marching algorithm. This model also incorporates a data-assimilated global ocean model, the HYbrid Coordinate Ocean Model (HYCOM), and a high precision bathymetric database. Comparisons with a vertical-mode horizontal-PE model will be shown to demonstrate the need of the 3D PE model in the case where the mode coupling effect is strong due to rapid environmental variations. An example of low-frequency sound propagation across the Atlantic Ocean will also be shown and compared with a real-world data collected during the Shallow Water 2006 Experiment. Future research plans on analyzing the CTBTO hydroacoustic monitoring data will be discussed.

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Track Classification: 1. Technological advancements in marine engineering pertinent to the sustainability and improvement of the hydroacoustic component of CTBT's International Monitoring System (IMS)

ID: Type: **Oral**

Technology to Extend Life and Utility of Hydroacoustic Systems

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

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Track Classification: 1. Technological advancements in marine engineering pertinent to the sustainability and improvement of the hydroacoustic component of CTBT's International Monitoring System (IMS)

ID: Type: **Oral**

, Construction and Qualification of a Modular Prototype Hydroacoustic Node

The concept of a modular alternative for the current linear hydroacoustic triplet design has been the focus of significant development by the University of Washington Applied Physics Laboratory (APL-UW) in recent years. A number of options have been studied from the perspective of two key criteria: the desirability of maintaining the existing highly effective linear deployment method, and the strategic introduction of modularity to reduce servicing cost and to increase servicing efficiency. A Monte Carlo-based statistical tool was developed that integrates detailed deployment and servicing scenarios with historical wave or wind data to provide probabilistic estimates of elapsed time to complete a given scenario at any site and time of year. Output from this tool, named the Monte Carlo Mission Time Simulation (MMTS), clearly points to one design option that has the shortest deployment time and also the shortest ship time on site for servicing operations. The steps required for the detailed design, construction and qualification of a prototype of the most promising option will be presented. Also presented will be the characteristics of the optimum test site and a survey of existing test facilities that have been investigated for this purpose.

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Track Classification: 1. Technological advancements in marine engineering pertinent to the sustainability and improvement of the hydroacoustic component of CTBT's International Monitoring System (IMS)

ID: Type: **Oral**

of the CTBTO's Hydrophone Based Hydroacoustic Stations

The Engineering and Development Section of the International Monitoring System (IMS) Division is responsible for the installation and maintenance of the hydrophone based hydroacoustic stations within the CTBTO's IMS. All hydroacoustic stations are now installed, certified and providing near real-time hydroacoustic data to the International Data Centre in Vienna, Austria. Five of these stations are based in remote island locations, and one station is located in Australia. The stations comprise of hydrophones suspended in the water column which are cabled to shore with electro-optical trunks. Some stations are in their second decade of operation, the newest station was certified in 2017. High data availability from these stations is achieved by identifying and mitigating station specific risks. This presentation will consider some current risk mitigation issues with respect to the in-water component with particular emphasis on HA01 Australia.

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Track Classification: 1. Technological advancements in marine engineering pertinent to the sustainability and improvement of the hydroacoustic component of CTBT's International Monitoring System (IMS)