# International Hydroacoustics Workshop 2017

# Report of Contributions

ID: Type: **Oral**

# telemetry services and products for ocean observation programs: potential use cases by CTBTO hydrophones networks?

The presentation will be an overview of the main satellite telemetry solutions dedicated to ocean data collection programs: Drifting Buoys Cooperation Panel (DBCP), Argo floats program, Ship of Opportunity (SOT), and other observation programs based on new autonomous vehicles: gliders, Remotely Operated Vehicle (ROV), Autonomous Underwater Vehicle (AUV), and Unmanned Surface
Vehicle (USV).

CLS, as the historical and exclusive operator of the Argos system, on behalf of its governance agencies (French Space agency, National Oceanic and Atmospheric Administration (NOAA), and National Aeronautics and Space Administration (NASA), has been involved since 1978 in these programs and has been building strong links with the meteorological & oceanographic community. The Argos system data collection capabilities will be presented together with potential use cases for
CTBTO oceanic networks (subsurface or surface moored buoy monitoring).

Then, CLS Iridium products & services will be presented as a more and more frequently used telemetry solution used by the oceanographic and meteorological community for transmitting high
volumes of data, in real-time (minute). Iridium different telemetry solutions: Short Burst Data (SBD),
Rudics, Circuit Switched Data (CSD), and Pilot will be presented together with Iridium data rates capacities and CLS added-value services such as real-time data and position decoding, archiving, automatic distribution via FTP or email, Web-mapping interface, CLS support & expertise, etc.

**Primary author:** BAUDEL, Sophie (C.L.S.)

**Presenter:** BAUDEL, Sophie (C.L.S.)

**Track Classification:** Technology and engineering trends in Ocean Observatories, with emphasis on technologies and trends pertinent to the IMS hydroacoustic network

ID: Type: **Oral**

# -frequency calibration of hydrophones and acoustic recording systems

For absolute measurement of sound in the ocean, and for assurance of stability in long-term monitoring applications, the performance of the measurement system is a crucial factor governing the quality of the measured data. In validating that performance and providing traceability to the measurements, calibration is of vital importance to ensure noise monitoring strategies and in-situ source characterisations are underpinned by robust metrology. The need for enhanced traceability is particularly acute at frequencies below 1 kHz where high-amplitude anthropogenic sources of greatest concern radiate much of their sound energy, where regulation and international directives mandate that environmental monitoring shall be made, and where long-term monitoring applications such as those of the CTBTO focus their measurement strategy. Here, a description is given of the calibration methods and facilities available for low-frequency calibration of hydrophones and recording systems. The description covers the methods outlined in international standards such as IEC60565:2006, and novel methods and facilities which may be used. Consideration is given to the challenges involved in undertaking calibrations at very low frequencies, and how these calibrations may be validated through the international metrology infrastructure.

**Primary author:** ROBINSON, Stephen (National Physical laboratory)

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**Track Classification:** Technology and engineering trends in Ocean Observatories, with emphasis on technologies and trends pertinent to the IMS hydroacoustic network

ID: Type: **Oral**

# achievement of DONET seafloor observatory network

The Dense Ocean-floor Network system for Earthquakes and Tsunamis (DONET) is the real-time seafloor observatory network developed in Japan. In this study, scientific and engineering trends of DONET are addressed, which may contribute to the IMS hydroacoustic network. The large undersea volcano's eruption took place in the central Mariana Islands in the Pacific Ocean in 2010 and series of T-phase from the eruption were recorded by the IMS's water-column hydrophones (e.g., Green et al., 2013; Heaney et al., 2013). The same signals could also be detected by the first deployed DONET hydrophone and its characteristics were similar to the IMS's records. DONET uses the state-of-the-art technologies in the system in order to achieve sustainable seafloor observatory network, for which three major functional components are separated; "backbone cable system", "science node (junction box)", and "observatory". Hybrid wet-mate connectors assemble between each component, which allows us to lead easy maintainability of the DONET by ROV. Science node which plays an important role as a hub-to-spoke function can also make it possible to add/separate stations flexibly. 51 stations in total are now in operation by two DONET systems, and among which two stations have already been replaced successfully without interruption of other stations.

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

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

**Track Classification:** Technology and engineering trends in Ocean Observatories, with emphasis on technologies and trends pertinent to the IMS hydroacoustic network

ID: Type: **Oral**

# practices and technologies for maintenance of modular deep-sea observing systems

The advent of deep-sea cabled observing systems and related installation and maintenance requirements has driven the development of new practices and new capabilities in subsea intervention. Since 2006 Ocean Networks Canada and its partners have led innovations that range from modular sensor platform designs to major rebuilds of scientific ROVs and the development of sophisticated instrument lifecycle workflows. A key component of ONC's deep-water networks are ROV-deployable instrument platforms or 'pods' that support onboard and satellite sensors through connections to a central junction box. A wet-mate optical-electrical link to the observatory backbone network simplifies the recovery and redeployment of individual instrument platforms and their sensor suites. Adding heavy-lift capability to scientific ROVs whose highly maneuverability and dexterity are essential for observatory servicing, has been a transformative development. Through-frame lifting, first developed for the ROV ROPOS, permits the controlled placement of instrument platforms on the seafloor and their rapid recovery for maintenance and upgrades. Observatory support requirements extend beyond field logistics. ONC's Oceans 2.0 software environment includes an integrated instrument workflow, from procurement through calibration, testing, deployment, commissioning and decommissioning, plus tools for monitoring instrument health and data QA/QC, all aimed at maximizing the scientific value of the data archive.

**Primary author:** JUNIPER, Stanley KIM (University of Victoria)

**Presenter:** JUNIPER, Stanley KIM (University of Victoria)

**Track Classification:** Sustainability of modular ocean observation systems and maintainability challenges with focus on the use of Remotely Operated underwater Vehicles (ROV) and environmentally challenging locations

ID: Type: **Oral**

# in the Studies on the Next Generation Cabled IMS Hydroacoustic Stations

In 2016, a study on the design of the next generation cabled hydroacoustic (HA) stations was conducted with the objective of evaluating viable architectures for the sensor package of the underwater system (UWS). The goals of this project were to: (i) improve sustainability by reducing the impact of events that may negatively affect data availability, (ii) facilitate reparability through modular designs and (iii) develop options for non-interfering instrumentation able to improve the scientific value of International Monitoring System's (IMS) hydroacoustic data. The overriding requirements for all proposed concepts were the minimum 20-year design life and the fulfilment of all other CTBT operational manual specifications. Wet- and dry-mateable connector technologies which have a proven track record in ocean engineering, make it possible to introduce different levels of modularity in order to achieve the above goals. The range of technical solution options that emerged from the study are presented together with the trade-offs vis-à-vis technical/operational complexity and related risks. The successive steps envisaged for this effort are the down-selection of options to fully meet CTBT operational manual specifications and extensive prototype testing.

**Primary author:** ZAMPOLLI, Mario (CTBTO)

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**Track Classification:** Sustainability of modular ocean observation systems and maintainability challenges with focus on the use of Remotely Operated underwater Vehicles (ROV) and environmentally challenging locations

ID: Type: **Oral**

# OOI Regional Cabled Array - a model for upgrading IMS hydroacoustic stations

In 2014, the University of Washington (UW) completed the deployment of the Ocean Observatories Initiative Regional Cabled Array (RCA), a state-of-the-art cabled ocean observatory off the central Oregon coast. The RCA was designed, and constructed by the Applied Physics Lab-UW for a 25-year service life, in conjunction with the UW School of Oceanography. Powered from shore by an 860 km backbone of telecom-grade electro-optical cable, the RCA supports 14 seafloor instrument platforms operating at depths of 80 to 2900 m, as well as six innovative mooring-based profilers. The instrument platforms and profilers are located on the offshore littoral zone, at the base of the continental shelf, and in and around the caldera of an active undersea volcano, 480 km offshore. Approximately 140 oceanographic instruments are connected to this observatory in any given year, including nine hydrophones and 13 seismometers. The University of Washington conducts annual ROV-supported operation and maintenance cruises to service all elements of the observatory. The RCA is modular and flexible, utilizing many hybrid and electrical wet-mate connectors for efficient installation and servicing by ROV, and exhibits a number of advanced features that are highly applicable to potential upgrades of IMS hydroacoustic stations.

**Primary author:** CRAM, Geoffrey (Applied Physics Laboratory - University of Washington)

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**Track Classification:** Sustainability of modular ocean observation systems and maintainability challenges with focus on the use of Remotely Operated underwater Vehicles (ROV) and environmentally challenging locations

ID: Type: **Oral**

# Ocean floor network observatories and their applications

In Japan, S-NET and DONET as real time monitoring system on Earthquakes and Tsunamis have deployed off Tohoku and off Nankai Trough. However, DONET and S-NET are different systems, DONET is a cable system with nodes, on the other hand, and S-NET is an in-line cabled system. DONE i.e. the Dense Ocean-floor Network system for Earthquakes and Tsunamis, and S-NET i.e. Seafloor observation Network for Earthquake and Tsunamis along Japan Trench. These systems have been in operation. At April 1st 2016, the earthquake occurred in DONET array, the hypocenter of this earthquake is determined at boundary on Philippine plate. It means that this earthquake as the plate boundary earthquake on Philippine plate occurred for the first time since 1944 Tonankai Earthquake. DONET detected this earthquake precisely. On the other hand, S-NET observed earthquake and tsunamis at November 22nd 2016, then contribute to Tsunami warning. We recognized the importance and significant of ocean floor network. So, MEXT as Japanese government is starting to discuss about the new ocean floor network around western part of Nankai trough. We will introduce Japanese ocean floor networks, observed data and applications.

**Primary author:** KANEDA, Yoshiyuki (Kagawa University)

**Presenter:** KANEDA, Yoshiyuki (Kagawa University)

**Track Classification:** Sustainability of modular ocean observation systems and maintainability challenges with focus on the use of Remotely Operated underwater Vehicles (ROV) and environmentally challenging locations

ID: Type: **Poster**

# -establishment of the IMS Hydroacoustic Station HA04, Crozet Islands, France.

The incorporation of the hydroacoustic station HA04, Crozet Islands, France, into the International Monitoring System (IMS) of the Comprehensive Nuclear-Test-Ban Treaty Organisation (CTBTO) was successfully completed on 29 December 2016. HA04 was Certified and Promoted into Operations on 19 June 2017. Similarly to most other cabled hydroacoustic stations in the IMS, HA04 is comprised of two triplets of moored hydrophones deployed on both sides of Possession Island (Crozet Islands) sending uninterrupted data to a shore facility via submarine fiber optic cables. The designed frequency pass-band is 1 – 100 Hz. Data are relayed to Vienna via a shore based satellite link in real time. According to CTBTO's standard requirements, the design life of HA04 is at least 20 years, maintenance-free for the underwater system. An outline of the main phases of this project, highlights from the installation operations and examples of received hydroacoustic signals associated with underwater seismic activity in the Indian Ocean as well as vocalizations from marine mammals acquired by the new HA04 are presented here. The integration of HA04 into the operational platform of IDC will enable registered researchers to access archived monitoring data and processing software, or via the National Data Centres (NDCs).

**Primary author:** HARALABUS, Georgios (CTBTO)

**Presenter:** HARALABUS, Georgios (CTBTO)

**Track Classification:** Risk mitigation in design, installation and operation of submarine cabled systems

ID: Type: **Oral**

# installation of IMS hydroacoustic station HA04 Crozet

The CTBTO's International Monitoring System (IMS) includes 6 hydrophone based monitoring stations. During 2016 the Engineering and Development Section within the IMS Division installed the final hydroacoustic station at the Crozet Islands, France.
The weather at Crozet which is situated in the Southern Indian Ocean is such that marine operations have to be carefully planned and can only be conducted during the short Austral summer weather window, and even during this period hurricane force winds and large swells are encountered.
The requirement for 20 years of operation of the underwater system without a maintenance interaction was a key driver in the station's design and its installation. To maximise the chances of a successful installation in the harsh maritime conditions it was necessary to collect high quality bathymetry, acquire an in-depth understanding of the prevailing ocean currents, adopt robust and well qualified engineering designs, and pay close attention to risk management and the use of a state of the art cable ship as the deployment platform.
An overview of the above engineering and operational approaches will be presented, together with some video footage of the installation.

**Primary author:** STANLEY, Jerry (Comprehensive Nuclear-Test-Ban Treaty Organization)

**Presenter:** STANLEY, Jerry (Comprehensive Nuclear-Test-Ban Treaty Organization)

**Track Classification:** Risk mitigation in design, installation and operation of submarine cabled systems

ID: Type: **Poster**

# undersea observatory based on Ethernet

In 2015, the University of Tokyo deployed 4th seafloor cabled system. It is 2nd cabled system in the off-Sanriku region, the northwest Pacific, and 2nd generation of Internet Protocol (IP) based observatory. We employed standard Transmission Control Protocol/Internet Protocol (TCP/IP) with a speed of 1 Gbps for system control and monitoring, and data transmission. It helps us to reduce cost and brings flexibility and expandability. It is also important to achieve availability and reliability. Redundant system is an easy and effective way. The new system has 3 observation nodes with one external port, which use Underwater Mateable Connector and Power over Ethernet technology. Each node has a CPU, FPGAs and dual switching hub. The system has dual-ring and partial mesh topology with 4 fibers. IEEE-1588 (PTP) is also implemented to synchronize a real-time clock. Furthermore, other 2 fibers are dedicated for precise timing. This system works well, and record many events such as 2016 off Fukushima earthquake (M7.4) and its tsunami.

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**Track Classification:** Risk mitigation in design, installation and operation of submarine cabled systems

ID: Type: **Oral**

# Multidisciplinary and Water-Column Observatory - European Research Infrastructure Consortium (EMSO ERIC): Challenges and opportunities for Strategic European Marine Sciences

EMSO (European Multidisciplinary Seafloor and water-column Observatory, www.emso-eu.org) is a European large-scale distributed Research Infrastructure (RI) with the essential scientific objective of real-time, long-term observation of environmental processes related to the interaction between the geosphere, biosphere, and hydrosphere, for multidisciplinary and interdisciplinary investigation of deep ocean processes related to Marine Ecosystems, Climate Change and Marine Geo-hazard. The geographic locations of the EMSO observatory nodes represent key sites in European waters, from the Arctic, through the Atlantic and Mediterranean, to the Black Sea, as defined through previous studies performed in FP6 and FP7 EC projects. EMSO is one of the environmental RIs included on the roadmap of ESFRI (European Strategic Forum on Research Infrastructures) since 2006, and it is included as Landmark in the last ESFRI roadmap 2016 (www.esfri.eu/roadmap-2016). EMSO in October 2016 became ERIC (European Research Infrastructure Consortium), the legal body that will be in charge of running EMSO observatory nodes as a unique integrated marine infrastructure. EMSO ERIC will be hosted by Italy with participation of Italy, France, The United Kingdom, Greece, Spain, Ireland, Portugal and Romania. Many other countries are interested to be part of this RI.

**Primary author:** FAVALI, Paolo (Istituto Nazionale di Geofisica e Vulcanologia (INGV))

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**Track Classification:** Ocean Observatories as ”platforms of opportunity” for IMS sensor prototypes and temporary replacement sensors

ID: Type: **Poster**

# APPROACH TO ENHANCING THE UTILIZATION OF HYDROACOUSTIC DATA AND PRODUCTS IN WEST AFRICA

The Hydroacoustic Monitoring Stations are essentially established to monitor the oceans for underwater explosions. In total, there are 11 stations with six underwater hydrophone stations and five T-phase stations on land in eight countries at entry into force of the CTBT. Despite the fact that all States Parties have open, equal, timely and convenient access to all raw and processed IMS data, IDC products, over the years, utilization of hydroacoustic data and products from members of the African Scientific community has been very low when a comparison is made with other waveform technologies. This may largely be attributed to a number of factors including the fact that there is no single African State responsible for any of the stations and the complexity of the monitoring station. It is on this basis that we carried out survey in order to understand the extent of awareness of the hydroacoustics technology within the region and to put forward strategy that will ensure greater involvement of researchers and scientists across the globe to eventually enhance the use of hydroacoustics data and products in the region. Awareness on the use and benefits been has been found to be generally low.

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**Presenter:** BISALLAH, Awwal (Nigeria Atomic Energy Commission)

**Track Classification:** Civilian applications of IMS data

ID: Type: **Poster**

# of IMS seismic / hydroacoustic data in civilian applications

On 25/04/2017, the Burkina Faso NDC found an extremely rare event that occurred in the Atlantic Ocean northwest of the Ascension Islands near the West African coast (943 km Monrovia Liberia), a non-seismic zone . What led us to conduct a study on this event in order to know exactly what is happening in the area. This is how, we used seismic and hydroacoustic data and also referred to the IDC REB and SSEB bulletins in order to complete our study. IMS hydroacoustic Facilities are not only important in monitoring Oceans but also significant in the aspect of small Islands Disaster warning and tsunami Hazard Investigation.

**Primary author:** TIENDREBEOGO, Sombewindin Emile (National Center of Scientific and Technological Research (CNRST))

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**Track Classification:** Civilian applications of IMS data

ID: Type: **Oral**

# Capacity to enhance the use of IMS data and IDC products in Ghana

The National Data Centre (NDC) in Ghana is part of the global network under the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO). The Data Centre has technical expertise in the monitoring and verification technologies of the Comprehensive Nuclear-Test-Ban Treaty and provides technical advice and support on issues pertaining to the verification of the Treaty. The main work of the data centre is collation of seismic, hydroacoustic, infrasound and radionuclide data for monitoring nuclear explosions. The Centre has access to certified data as well as transfer of technology and global communications systems from the CTBTO. Over the years, the Centre has benefited from training programs, workshops and conferences organized by the CTBTO around the globe. To impart the knowledge gained, the centre also periodically organizes local training programs to build and strengthen its human resource capacity. Our stakeholders have benefited immensely from our local training programs. Research students in the oceanography department in tertiary institutions are taught the benefits of the hydroacoustic technology. The Centre also provides information on earthquake safety measures to our stakeholders for earthquake disaster risk reduction using the data received from the International Data Centre.

**Primary author:** AMPONSAH, Paulina Ekua (Ghana Atomic Energy Commission)

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**Track Classification:** Civilian applications of IMS data

ID: Type: **Oral**

# -Seismic Airgun Signals in Hydroacoustic Data.

Marine-seismic airguns are used in oil and gas exploration and reservoir monitoring. High-pressure air is rapidly released from submerged airguns, usually towed a few metres from the sea-surface as part of an array that is designed to concentrate sound transmissions vertically downwards. Although the primary use-case of airgun arrays is probing deep into the seabed, the sound they transmit may travel to large horizontal distances, particularly if they are operated close to seabed slopes such as seamounts and shelf edges. In such circumstances, the sound produced by airguns may become trapped in the ocean's deep sound-channel where low attenuation and separation from reflection and scattering losses at the sea surface and seabed allow sound to travel thousands of kilometres while still remaining detectable above background noise. The fundamentals of sound generation in airguns are discussed and examples are provided showing how signals may propagate over ranges covering entire ocean basins. Examples of airgun signals in CTBTO hydroacoustic datasets are provided. The impact of airgun sound on the marine life is discussed and possibilities for using CTBTO data to study this impact are outlined. The potential for an 'opportunistic' use of airgun signals in ocean-acoustic experiments is also considered.

**Primary author:** PRIOR, Mark Kevan (TNO)

**Presenter:** PRIOR, Mark Kevan (TNO)

**Track Classification:** Civilian applications of IMS data

ID: Type: **Poster**

# visualization and annotation of open access and confidential passive acoustic monitoring data archives.

The impact of underwater noise on marine life is a rapidly increasing focus for research, regulatory change, and conservation actions. Digital hydrophone records from Ocean Networks Canada's cabled observatory systems represent the largest data volume delivered to the science community, supporting research into marine mammal responses to vessel traffic, seasonal use of ocean habitats by whales, fish sound emissions, and the development of automated classification algorithms. Access to the online archive is facilitated by ONC's Oceans 2.0 interface. Individual hydrophone records can be reviewed for length, contiguity, and instrument specifications. Quick view spectrograms permit rapid scanning of data records for events of interest prior to data downloads. The archive will soon support hydrophone data searches based on time-stamped annotations (from manual or automated classification), and linking with online analytical tools. ONC's open data policy applies to all hydrophone records collected by the observatory network but the data acquisition system and archive also accommodate military security and third party data ownership requirements. For example, during naval exercises near ONC seafloor listening stations, shore-based military computers divert real-time hydrophone data streams, for review and redaction before release. Password access to third party hydrophone data was introduced in 2017.

**Primary author:** JUNIPER, Stanley KIM (University of Victoria)

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**Track Classification:** Civilian applications of IMS data

ID: Type: **Poster**

# of changes in the acoustic environment of the southern Indian Ocean using long term trend analysis on CTBTO data collected at Cape Leeuwin

Monitoring of deep-ocean low-frequency sound is challenging, but data have been reported for the Northeast Pacific Ocean and Indian Ocean in a number of recent publications. The CTBTO (Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization) has made available data from their deep-ocean hydro-acoustic stations, so that researchers may examine the existence of trends and features in the recorded sound. In the case of some of the stations, the data cover more than ten years of recordings. Here, we present trend analysis of data from one CTBTO observatory at Cape Leeuwin (Australia) to examine the rate and magnitude of change in low frequency sound (5-105 Hz) over the period 2003 - 2015. The analysis involves the application of regression to percentile levels in limited frequency bands and employs bootstrap resampling as a non-parametric approach for the necessary quantification of the uncertainties associated with the estimated trends. Results obtained by linear and more complex regression models are compared and the effect of aggregating data over various time intervals is also examined. Finally comparisons are drawn between trends observed in adjacent frequency bands.

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**Track Classification:** Civilian applications of IMS data

ID: Type: **Oral**

# situ onset time estimation of the explosion events by classical statistical methods and wavelet analysis

The topic of this paper is algorithm for in situ estimation of the time of arrival, or TOA, which origin are events that have sudden rise of the pressure and may occur in different environments such is air, water or ground. The algorithm is adaptive and based on specific approach that generally means using two-step method. The first is wavelet decomposition of the signal in purpose to rough estimate existence and time position of the described events, and the second understands detailed analyze of the data segment, which is identified by wavelet analysis, and automatic onset time estimation. Such approach enables very precise estimation of the onset time, or TOA. In many cases, such approach enables to reject false events that are consequence of multipath transmission of the pressure waves (infrasound, sound, underwater sound and seismic waves). In this paper, tens of experiments that concerned artillery gun projectiles verify the quality of proposed method.

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**Track Classification:** Signal processing techniques for hydroacoustic event detection and evaluation

ID: Type: **Oral**

# hydroacoustic data associated with earthquakes in Chile and Ecuador

The South American continental shelf and territory is covered by 16 (primary and auxiliary) IMS seismic stations and 1hydroacoustic station. The data from both the hydroacoustic station and seismic stations were used to analyse the two events that occurred in Chile on September 16, 2015 and Ecuador on 16 April, 2016 to assess the efficiency of these stations. This research effort is devoted to using Geotool software to gain experience from the synergy between hydroacoustic and seismic observations. In this paper, the result obtained by using correlation, spectrum and energy analysis to study the seismic waves produced by ground motion and associated hydroacoustic data is presented.

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**Track Classification:** Signal processing techniques for hydroacoustic event detection and evaluation

ID: Type: **Oral**

# applications of hydroacoustic devices in Costa Rica

Costa Rica is bordered by the Pacific Ocean on its western side and by the Caribbean Sea on its eastern side, with a total of 1,290 km of coastline. Scientific research and monitoring of physical properties of the ocean in Costa Rica is largely done by the oceanography group of the Department of Physics (DP) at Universidad Nacional. Many of the observations are made with hydroacoustic instruments operated on either moving vessels or moored at the seabed near the coast. The DP leads hydrographic and hydrodynamic studies in coastal areas using both echosounders to create bathymetry maps and Acoustic Doppler current profilers (ADCP) to characterise the circulation and wave properties in areas of interest. This talk will describe observations and results using hydroacoutic instruments in the Pacific and Caribbean coasts of Costa Rica.

**Primary author:** VARGAS HERNANDEZ, Jose Mauro (Laboratorio de Oceanografía y Manejo Costero (LAOCOS))

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**Track Classification:** Signal processing techniques for hydroacoustic event detection and evaluation

ID: Type: **Oral**

# activity monitoring along the Nankai Trough using DONET

The Nankai Trough area is one of important targets to monitor crustal activities due to the potential of future huge earthquakes and tsunamis. To monitor crustal activities, the Dense Oceanfloor Network system for Earthquakes and Tsunamis (DONET) was installed in rupture areas of the Tonankai/Nankai earthquakes. The installed area has generally low seismicity but slow slip events have occurred. Various signals from crustal displacement to slow slip, tsunami and earthquakes were detected.by many types of sensors of DONET to realize observation with broadband and large dynamic range. One of the good examples for the observations is the earthquake of off southeast Mie prefecture in 2016 (M6.5). The focus distributed on the place boundary using high accuracy crustal structure. The aftershocks concentrated far away 10 km north from the main shock and the migration of the aftershocks were also observed. After that, the slow slip events were activated between the trough axis and the main shock. Tsunami and crustal displacement of a few centimeters each were also detected and the fault size was estimated to be 4 km x 8 km using these signals. In this presentation, we introduce the examples of the observations using DONET.

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**Track Classification:** Signal processing techniques for hydroacoustic event detection and evaluation

ID: Type: **Oral**

# -phase observations in the offshore area of northeastern and southwestern Japan

Permanent seafloor seismic and tsunami observation networks were deployed near the Japan trench and the Nankai trough, Japan. We can monitor seismic waves and tsunamis at the stations in real time and also T-phase signals propagating via the SOFAR channel in the ocean. In this study, we investigated the acoustic source location of the T-phase energy with the travel-time analysis using short-period (3-8 Hz) seismic data at the stations at the depths of 1,000 to 4,500 m. The epicenter dominantly distributes around the Izu-Bonin and the Kuril subduction zones where steep seafloor slopes are developed from forearc areas and island chains to the trench axis, indicating that seismic waves at seismic activities in the subduction zones and volcanic activities in the islands are efficiently converted into acoustic waves in the slope. Our analyses using seafloor station data as a large array in the conjugate depth of the SOFAR channel may contribute to developing our understandings of the mechanism of T-phase generation and also to monitoring small seismic and volcanic events in ocean areas where the present land station network is insufficient for their detection and coverage.

**Primary author:** NAKAMURA, Takeshi (National Research Institute for Earth Science and Disaster Resilience)

**Presenter:** NAKAMURA, Takeshi (National Research Institute for Earth Science and Disaster Resilience)

**Track Classification:** Signal processing techniques for hydroacoustic event detection and evaluation

ID: Type: **Oral**

# Seismometers to Supplement the IMS Hydrophone Network

A hydrophone station in the International Monitoring System (IMS) network can breakdown which can result in reduced monitoring coverage. Seismic data may be used to mitigate this reduction. Here, two examples of how seismic data can be used for the detection, location and characterisation of hydroacoustic signals are presented. In the first of these, signals from a series of underwater explosions near Florida are analysed. Bubble pulses characteristic of underwater explosions are identified at seismic stations in the United States and the estimated explosion depths and yields are shown to be consistent with published ground-truth information. In the second example, we assess the proportion of T-phases recorded on IMS hydrophones from seismic disturbances published in the Reviewed Event Bulletin (REB) that are observed on nearby seismometer stations at Ascension Island and Diego Garcia. At Ascension Island, seismometer stations record around 20% of hydrophone detected phases published in the REB. At Diego Garcia, the seismometer detection capability is lower due to the Chagos-Laccadive Ridge blocking some signal propagation paths.

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**Track Classification:** Signal processing techniques for hydroacoustic event detection and evaluation

ID: Type: **Oral**

# of distant quiet man-made sources and shadow zone arrivals of earthquakes

The ocean is nearly transparent for acoustic propagation at low frequencies (< 100Hz), leading to the detection of signals (seismic events, volcanoes and man-made signals) at distances as large as the ocean basin. Observations of a low level source transmission from Guam to Wake Island will be presented. Historically, basin acoustic modeling has neglected out-of-plane effects and has been performed with the model computed in the range/depth plane for multiple radials following geodesics (Nx2D). Out-of-plane effects include refraction and diffraction - which have different effects as well as different approaches to modeling. Experiments where 3D propagation effects were significant will be presented within this context, including Perth-Bermuda (1960), the Heard Island Feasibility Test (1993) and a recent seismic tomography test off the coast of Japan (2015). Three physics mechanisms will be addressed : horizontal deflection due to mesoscale eddies and fronts, reflection from islands (refraction) and diffraction behind bathymetric edges.

**Primary author:** HEANEY, Kevin (Applied Ocean Sciences)

**Presenter:** HEANEY, Kevin (Applied Ocean Sciences)

**Track Classification:** Signal processing techniques for hydroacoustic event detection and evaluation

ID: Type: **Oral**

# and results from cabled hydrophone arrays deployed in deep sea off East Sicily (EMSO ERIC node)

Since 2005 a cabled deep-sea infrastructure is operative at 2100 m water depth, 25 km off the port of Catania (Sicily). The infrastructure, under continuous improvement, is the first operative cabled node of the EMSO ERIC, hosting several multidisciplinary observatories built in Collaboration by the Italian Institutions INFN, INGV, CNR, CIBRA and other scientific partners. Hydrophone antennas, sensitive in the range of frequencies between 1 Hz and 90 kHz, have been installed on seafloor observatories. Acoustic data are continuously digitized in situ at very high resolution, time-stamped with absolute GPS time and sent to shore in real time, through optical fibre link. Together with bioacoustics (cetaceans sounds), noise pollution study and monitoring were the main goal of the research activity. Results on multi-year monitoring of anthropogenic noise will be discussed. Focus of the analysis is the noise level in the 63 Hz and 125 Hz noise bands in compliance with the EU Marine Strategy Framework Directive. The contribution of ship noise was modelled, based on their recorded routes, and compared to data. Noise in the high frequencies domain was also investigated.

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**Track Classification:** Signal processing techniques for hydroacoustic event detection and evaluation

ID: Type: **Poster**

# data analysis of earthquake signals received on the newly installed HA04 hydro-acoustic station of the CTBTO International Monitoring System.

During December 2016, the Comprehensive Nuclear-Test-Ban-Treaty Organization (CTBTO) re-established the hydro-acoustic station HA04 close to the Crozet Islands in the Indian Ocean as part of the International Monitoring Systemâ□□s (IMS) world-wide, multi-technology sensor network. The station is composed of two triads of hydrophones located to the north and south of Possession Island. High quality hydro-acoustic data are being received continuously at CTBTO since the deployment of the station where signals from whale calls, earthquakes and anthropogenic sources have been detected. In this poster, emphasis is given to signals generated by earthquake events located on the Indian Ocean Ridge at relatively close distance to the north of the HA04 station. Preliminary analysis of the propagation paths and received signal levels from the events to the station has been performed considering the complex local bathymetry and spatio-temporal variations in the water column sound speed. An assessment will be performed, to the extent possible, concerning the impact of these environmental factors on the propagation in this particular scenario with the aim of examining potential improvements to the International Data Centreâ□□s (IDC) automatic processing algorithms.

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**Track Classification:** Signal processing techniques for hydroacoustic event detection and evaluation

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# -phase signals from events with epicentres in 'blocked' locations.

T-phase signals generated by earthquakes with epicentres in or close to ocean areas may be detected after oceanic propagation over distances of tens of thousands of kilometres. Ocean environments are close to being horizontally stratified but lateral variability in water depth or sea-water sound-speed can lead to out-of-plane propagation. This can result in T-phases being detected in locations at which the geodesic path between receiving station and epicentre is blocked by land or water too shallow to act as an efficient waveguide. Data from the International Monitoring System of CTBTO is used to illustrate the detection at hydro-acoustic stations of T-phases from seismic events with epicentres in the "acoustic shadow" of land masses A fully three-dimensional parabolic equation model is used to demonstrate that lateral variability of the bathymetry can explain this phenomenon. The implications of this are that the CTBTO network has greater coverage than predicted by 2-D models and that inclusion of diffraction in future processing can improve the automatic global association of hydroacoustic events.

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