DATA FEATURES FROM LONG-TERM MONITORING OF OCEAN NOISE

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1 INTRODUCTION

The International Monitoring System (IMS) is a global network of sensors operated by the comprehensive nuclear-test-ban treaty organisation (CTBTO). It includes hydroacoustic stations designed to detect signals propagating through the ocean [1]. The hydroacoustic sub-network of the IMS uses hydrophones deployed in the ocean deep-sound-channel in a two-kilometre-side, triangular configuration in the horizontal plane. This configuration, known as a triad, allows the arrival time and azimuth of signals to be determined. This information is used to help determine the location of the source responsible for generating those signals.

Data are recorded on hydrophone triads continuously and transmitted in near real-time to CTBTO's International Data Centre (IDC) in Vienna, Austria. At the IDC, discrete signals are identified within the data and associated with seismic, infrasound and other hydroacoustic data to produce lists of events that are hypothesised to have generated the signals. Initial processing is done by automatic algorithms and the results of these are subsequently refined by human analysts [1] to produce a Reviewed Event Bulletin (REB). All waveform data are stored at the IDC. The times, azimuths and other properties of all detected signals are also stored in database tables. A significant archive has been built up during the decade for which the IMS has operated and this represents a valuable resource for understanding underwater acoustic noise conditions.

2 EQUIPMENT AND DATA DESCRIPTION

Each hydrophone station consists of two major sub-systems: a) the underwater segment that incorporates acoustic sensors, undersea electronics and undersea cable that connects the facility to shore, and b) the data acquisition and storage segment that consists of shore-based utilities, data storage, state-of-health monitoring and data communication systems. Of the six hydrophone stations in the IMS, five are located on islands and have a northern and a southern triad to provide omni-directional coverage. The only hydrophone station with a single triad is at Cape Leeuwin, Australia.

The general technical requirements of hydrophone stations dictate a passband from 1-100 Hz with a flat sensor response over this band. For Cape Leeuwin, the sampling frequency is 250 Hz with a -3 dB bandpass from 1.2-103 Hz and -4 dB at 1 Hz to ensure the minimum operating requirements. The system self-noise is more than 10 dB below Urick's deep ocean low noise curve [2] throughout the passband. The system's dynamic range, defined as the difference between the rms clipping level and system noise, is 120 dB. For 1 Hz the system sensitivity is better than 42 dB re 1V/μPa while for broadband it is better than 59 dB re 1V/μPa. Signals undergo 24-bit digitisation before transmission to IDC where calibration information is stored in database tables to allow reconstruction of absolute, in-water pressure levels.
Upon reception at the IDC, data are first processed by algorithms that identify discrete signals [1]. Two sliding windows are convolved with the data – a large window for the background noise and a short window for the signal. The ratio of the windows' mean-square sums is taken as a measure of signal-to-noise-ratio (SNR) at the time of the smaller window. Times with SNR greater than a threshold are identified as having a signal present. Signal properties such as energy distribution among frequency bands, duration and cepstral features are then calculated to aid signal characterization. Signals recorded at the three hydrophones of a triad are correlated to determine

the inter-hydrophone lags. If the sum of these lags over all hydrophone pairs is less than a threshold value, the three signals are assumed to be measurements of the same acoustic wave passing over the three hydrophones. Lag values are then combined with hydrophone position data to determine the arrival azimuth of the signal. Signal arrival times, azimuths and characterisation information are then stored in database tables and used in subsequent routines that associate them with other signals to produce lists of events that are hypothesised to have caused the observed signals.

The processing described in the preceding paragraph is designed to help identify events that might be relevant to the monitoring of a global nuclear-test-ban treaty. In addition to this standard processing, waveform data is routinely processed at IDC to produce background noise spectra for every sensor in the IMS. In the case of hydrophones, these spectra give the noise in dB re 1 μPa in a 1-Hz band over the entire bandwidth of the sensor. No signal-identification algorithms are used in this processing and the entire waveform is treated as "noise". The spectra resulting from this processing are analysed to identify problems such as calibration-drift or signal "spiking".

IMS hydrophone data include signals from earthquakes, submarine volcanic eruptions, ocean-swell-induced noise, marine mammal noise, ice-breaking noise and signals from human sources such as seismic surveys and underwater explosions.

3 DATA DISPLAY METHODS

When attempting to understand acoustic conditions at IMS hydrophone stations, the sheer volume of measured data is a challenge that must be overcome. The full hydroacoustic network gathers approximately 3 gigabytes of data every day and detailed inspection of all waveforms is not feasible. Instead, data display techniques have been developed that allow high-level summaries to be produced for acquisition periods of over a year. Features shown by these summary displays can then be identified and more detailed inspection performed on only the most interesting subsets of the total dataset.

The times and azimuths at which discrete signals arrive at a given station are extracted and sorted into a two-dimensional histogram showing the numbers of arrivals in bins with a time-width of one day and an azimuth-width of five degrees. When these histograms are displayed as shaded images, patterns characteristic of certain noise sources become apparent. Days with large numbers of received signals from seismic aftershocks appear as bright spots in the image. As the intensity of the aftershock sequence decays with time, the brightness of the feature reduces, forming a "shooting star" pattern along a line of constant azimuth pointing towards the seismically active region. Periods in which a station records high numbers of marine-mammal signals appear as bright lines that cover a wide range of azimuths but are present only for a short time. This time corresponds to the passage of migrating mammals over the location of the hydrophone station. South-pointing azimuths often show high levels of activity for Indian Ocean hydrophone stations because of the presence of noise generated by ice-breaking and iceberg-calving activity along the coast of Antarctica.

When ambient noise spectra are displayed as surfaces showing spectral level as a function of time and frequency, the effects of diverse noise sources can be seen. In the sub-Hertz region, high levels of noise are observed due to non-linear interactions between sea-surface waves. This interaction is responsible for the generation of "microseisms" ubiquitously observed on seismometers but the signals recorded on hydrophone stations are direct, in-water measurements, made before the sound has coupled into the crust across the seabed. Marine mammal noises appear as peaks in the spectral level as a function of time and frequency. These peaks are centred around 20 Hz and occur during particular times of the year when migratory whale species are present in the vicinity of the recording station. The presence of ice noise is observed during spring and summer periods when sea ice is not present but icebergs may calve and break up under wave action.

4 SUMMARY

Data gathered on IMS hydrophone sensors allow underwater acoustic noise conditions to be characterised in deep-water environments. Continuous acquisition makes the data particularly suitable for studies associated with long-term monitoring of underwater ambient noise.

Analysis of arrival times and azimuths of discrete signals allows periods rich in particular types of signal to be identified straightforwardly. Regions of high seismicity and ice-breaking activity show up as azimuths from which signals are consistently received. The passage of marine mammals close to a station results in the detection of signals over a wide range of azimuths within a short period. This form of “quick look” analysis allows rapid identification of these events and helps target more detailed data analysis efforts.

Analysis of ambient noise spectra derived from IMS hydrophone data allow absolute noise levels to be calculated and monitored over extended periods. Patterns in time-stacked spectra allow identification of periods of high microseismic, ice-breaking and marine-mammal noise.

5 DISCLAIMER

The views expressed are those of the authors and do not necessarily reflect the view of CTBTO Preparatory Commission.

6 REFERENCES

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2. Urick, R. J., Principles of Underwater Sound; 3rd edition. McGraw-Hill, 1983, Chapter 7.