PROPAGATION, ATTENUATION AND BLOCKAGE OF HYDROACOUSTIC WAVES IN THE EARTH'S OCEANS

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ABSTRACT

We are investigating the nature of hydroacoustic wave propagation in the Earth's oceans, with a focus on the attenuation of signal over long distances and the blockage of signal by shallow features and islands along the source-receiver path. The objective of this research is to enhance discrimination capabilities for events located in the world's oceans. Two research and development efforts are needed to achieve this: (1) improvement in discrimination algorithms and their joint statistical application to events, and (2) development of an automated and accurate blockage prediction capability that will identify all stations and phases (direct and reflected) from a given event that will have adequate signal to be used in a discrimination analysis. Our current research involves measuring signal amplitude at hydroacoustic stations and comparing the results to predictions for a variety of models. To this end, we are continuing with the development of the Hydroacoustic Blockage Assessment Tool (HABAT) which is designed for use by analysts to predict which hydroacoustic monitoring stations can be used in discrimination analysis for any particular event. HABAT has been upgraded to allow measurements of the spectra and the signal amplitude from oceanic sources. Waveform data are read in and the signal and noise amplitudes are measured for a number of frequency bands. Several measures are taken. First, can the event be observed at a station above background noise? Second, can we establish backazimuth from the station to the source? Third, what is the decibel drop at one station relative to other stations? Finally, how do the measurements vary among the individual elements of each hydroacoustic array? From these results we can create blockage maps as a function of frequency that are then compared with the model-based blockage maps generated by Hydroacoustic Coverage Assessment Model (HydroCAM) to assess blockage criteria.

OBJECTIVE

The objective of this research is to enhance discrimination capabilities for events located in the world's oceans. We intend to characterize the propagation of acoustic waves across the oceans, estimate the attenuation of seismic signals along the source-receiver path, and establish whether the signal will be blocked by obstacles along the way. Once the physical processes are understood, we will be able to define the sensitivity of each hydroacoustic station to sources occuring at any point in the ocean. The strategy for improving source detection in the world's oceans is to improve model-based prediction of blockage and to develop a ground-truth database of reference events to assess blockage. Currently, our research is focused on the development of a hydroacoustic assessment software tool and the measurement of signal and noise amplitudes for earthquakes and experimental sources. The tool is envisioned to develop into a sophisticated and unifying package that optimally and automatically assesses both model and data-based blockage predictions in all ocean basins for all National Data Center (NDC) stations, and to account for reflected phases (Pulli et al., 2000).

RESEARCH ACCOMPLISHED

We are continuing with the development of the Hydroacoustic Blockage Assessment Tool (HABAT) which is designed for use by analysts to predict which hydroacoustic monitoring stations can be used in discrimination analysis for any particular event. HABAT employs both a model-based and a data-based approach to establish hydroacoustic station resolution. Originally written to interact with HydroCAM results to evaluate propagation models, the code has been upgraded to allow measurements of the spectra and the signal amplitude from oceanic sources. Waveform data are read in and the signal and noise amplitudes are measured for a number of frequency bands. A source is considered detected in a specific frequency band if the signal amplitude is noticeably above the pre-event noise amplitude. The amplitude measurements for specific sources are compared from one station to the next to assess how well an event is characterized by the entire network. Differences in resolution are affected by scattering and attenuation along the different paths. From these measurements we create frequency-dependent blockage maps which are then compared with the model-based blockage maps generated by HydroCAM to assess blockage criteria.

An example of the differences in source detectability is illustrated in Figure 1. The 2003 Indian Ocean cruise sailed along a track from Cape Town, South Africa to Darwin, Australia (Harben et al., 2004; Figure 1). The experiment resulted in 13 ground truth events which were detected at 1 or more of the hydroacoustic stations, including 40–50 individual waveforms of both stationary uncorrelated scattering or signals, underwater sound (SUS) and imploding sphere sources. We measured the spectra from each of the explosive source charges at each of the Indian Ocean stations (Diego Garcia North (DGN) and South (DGS), Cape Leeuwin, and Crozet Island). Because a nondetection of a source could be due either to blockage along the source-receiver path or attenuation of the signal over distance, it's helpful to have measurements at several stations to compare with one another. DGN and DGS are an excellent pair of stations to evaluate blockage criteria because they are located close to one another, but are in a region with significant bathymetric features which result in very different blockage predictions for each. An event that is observed at one site should be observed at the other, unless there is a true blockage along the path. This allows us to evaluate blockage as a function of frequency and bathymetry.

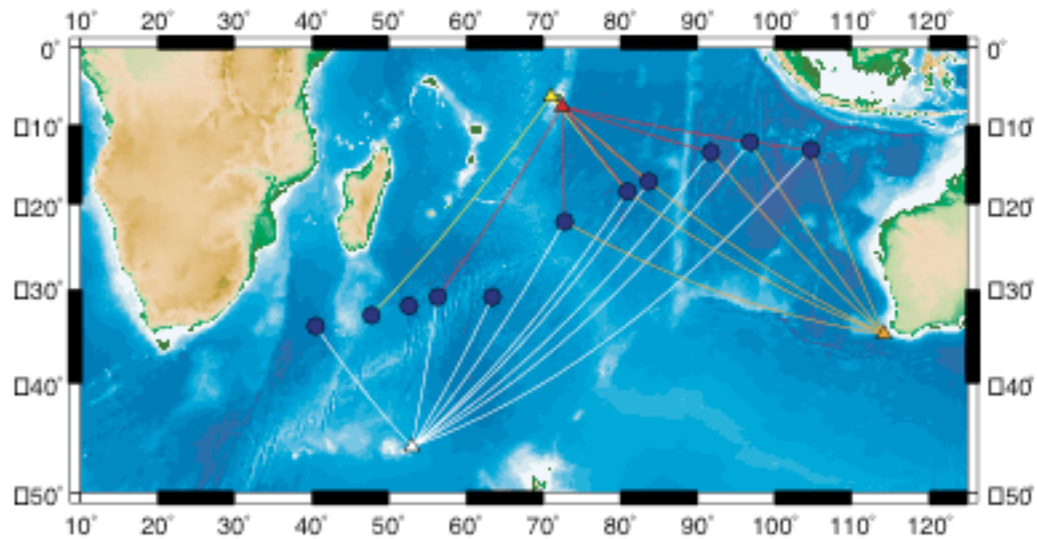

Figure 1. The 2003 cruise sailed along a track from Cape Town, South Africa to Darwin, Australia (Harben, et al., 2004). The experiment produced a series of ground truth events that were detected at 1 or more of the hydroacoustic stations; 40–50 individual waveforms for both SUS and imploding sphere sources resulted. We measured the spectra from each of the explosive source charges at each of the Indian Ocean stations (Diego Garcia North (yellow triangle), Diego Garcia South (red triangle), Cape Leeuwin (orange triangle) and Crozet Island (white triangle)). Source locations are indicated by blue circles (A01 on the left, through A11 on the right). Paths for which there was a detection are illustrated in color (white to Crozet, orange to Cape Leeuwin, yellow to DGN and red to DGS). Note that most of the paths were blocked to DGN.

Since we have only a limited number of small experimental sources available, we also take measurements of waveform data from oceanic earthquake events. These larger events are much more likely to be detected over long distances and comparisons between stations still let us evaluate attenuation and propagation criteria. Figure 2 illustrates the differences in detection of T-phases at DGN and DGS for a collection of oceanic earthquake sources. Here we've plotted signals detected above the noise at 20 Hz, which is on the lower end of the frequencies of interest (usually between 5–120 Hz). Note the significant differences in detection due to near station bathymetry. Notice, however, that a simple ray-based blockage criteria is not correct. Energy from a large source can get past an island, although it will be significantly attenuated (Figure 3). Blockage becomes more significant at higher frequencies with islands and shallow bathymetry changing from highly attenuating features into true barriers to detection (Figure 4).

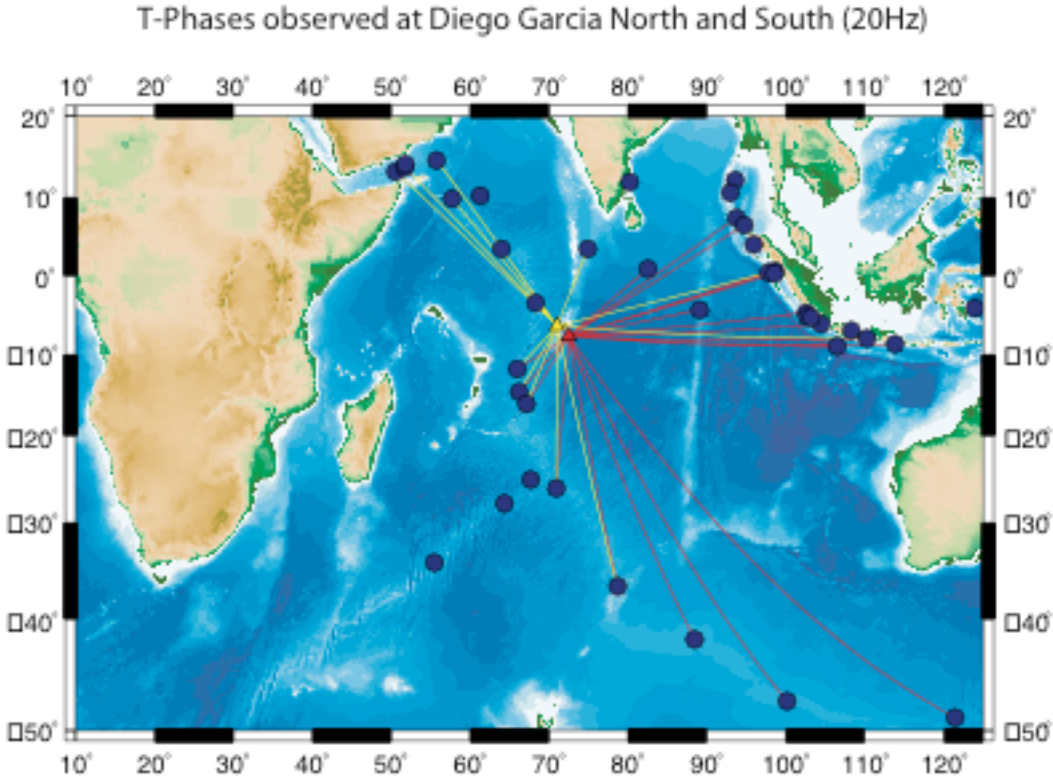

Figure 2. T-phases observed at Diego Garcia North and South. Blue circles indicate the locations of earthquake sources in the Indian Ocean in 2001 (courtesy BBN). Diego Garcia North (yellow triangle) and Diego Garcia South (red triangle) have different coverage due to the nearby bathymetry. By comparing measurements at each station to the same sources, we can define the blockage effects of the near station region. Above, we have drawn source-receiver paths for each event observed at 20 Hz.

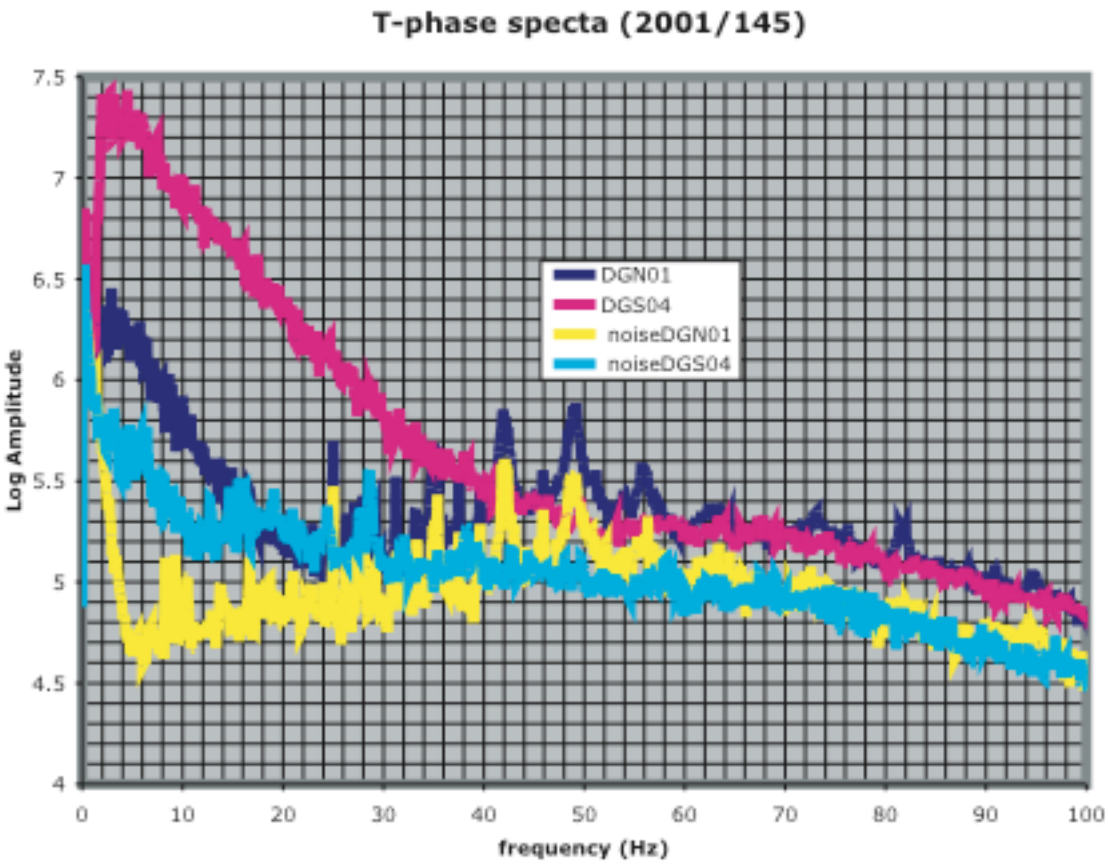

Figure 3. Spectra for a T-Phase event observed at DGN and DGS. This source was located in Java along a path expected to be blocked to DGN (it passes through the island itself). Not that there is a significant drop in amplitude at DGN relative to DGS, but the signal is still well above the noise even at 20 Hz.

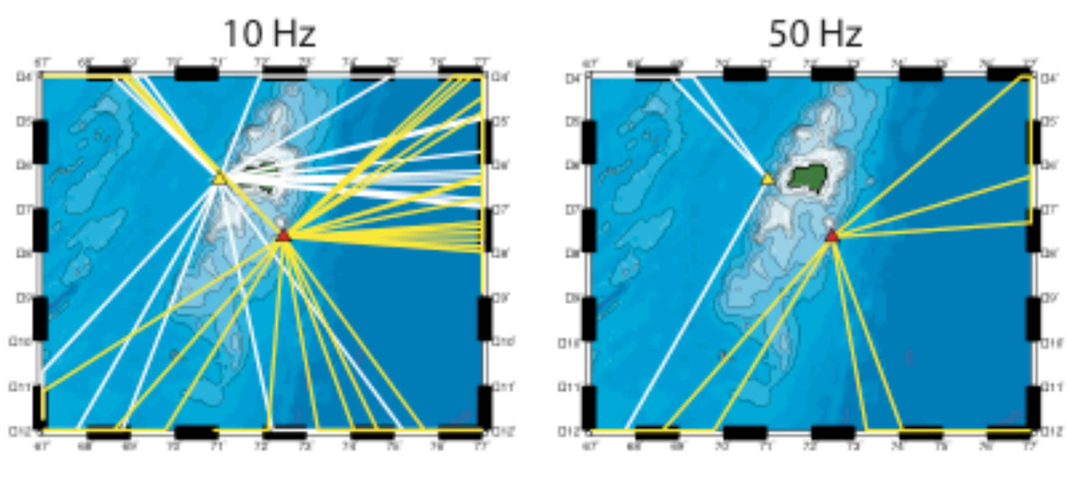

Figure 4. Here we have plotted the sensitivity of DGN and DGS to earthquake sources as a function of frequency. Each panel illustrates the local portion of the source-receiver path for sources that were observed at DGN (yellow triangle) and DGS (red triangle). The paths are plotted in white for DGN and yellow for DGS respectively. Depth contours are plotted at 0, 100, 500, 1000, 1500 and 2000 m.

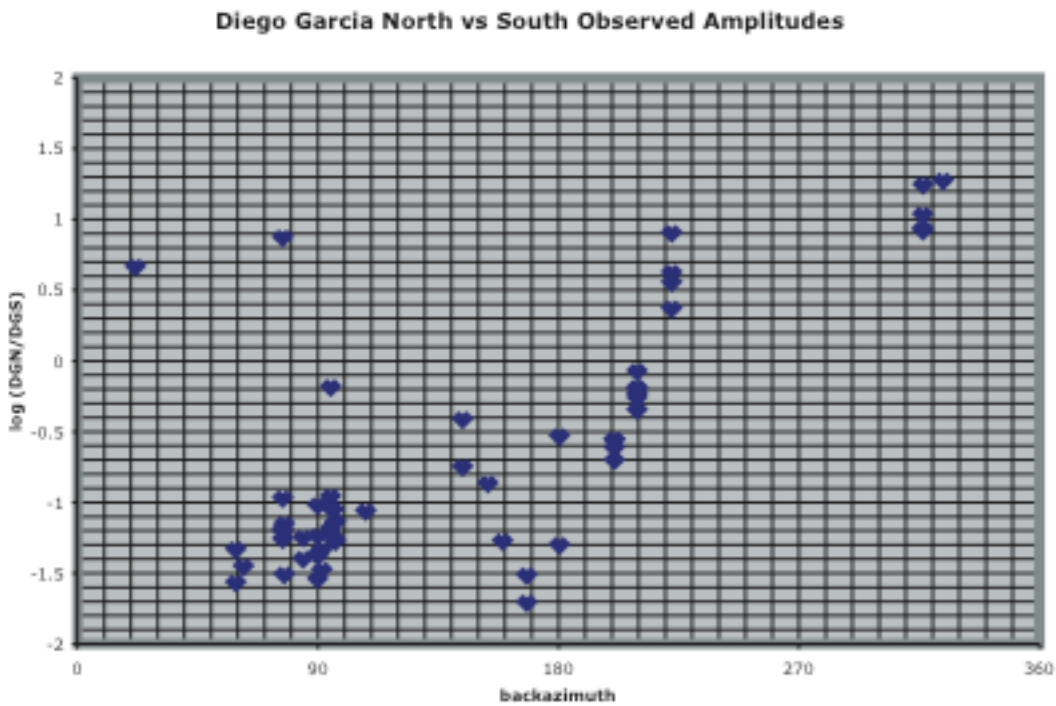

Figure 5. T-phase observations at DGN and DGS as a function of backazimuth from DGN to the source. (Only points for signals detected at both stations are plotted.)

CONCLUSIONS AND RECOMMENDATIONS

We are continuing the development of the Hydroacoustic Blockage Assessment Tool and using it in conjunction with data to define propagation, attenuation, and blockage properties of acoustic waves in the ocean. The fundamental objective is to provide a robust prediction about which hydroacoustic monitoring stations can be used in discrimination analysis for any particular event. Currently, we are limited by the small set of ground-truth data and the limitations of ray theory in defining path-stop conditions. It is apparent that blockage is not a simple phenomenon, but as we continue to collect network data we should be able to develop coverage, propagation and attenuation maps for each of the hydroacoustic stations and develop the basic criteria for establishing blockage in the ocean at large.

REFERENCES

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