OCEAN ACOUSTIC OBSERVATORIES: DATA ANALYSIS AND INTERPRETATION

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Long-Range Propagation

LONG-TERM GOALS

The ultimate limits to the coherence of long-range acoustic transmissions are imposed by ocean processes, including internal waves, mesoscale variability, interior ocean boundaries (fronts), and bathymetric scattering. An understanding of the effects of these processes on acoustic signals is crucial to the use of acoustic remote sensing methods for a broad range of purposes, including undersea surveillance, ocean acoustic tomography, and large-scale acoustic thermometry. The long-term goals of this research are to enhance our understanding of the ocean processes that ultimately determine the limits of useful long-range acoustic transmissions and to improve our capability to both generate and detect very long-range transmissions.

OBJECTIVES

Theoretical considerations suggest that acoustic scattering due to internal-wave-induced sound-speed perturbations will be small at very-low frequencies, i.e., below about 30 Hz, even at multi-megameter ranges. The objective of this research is to understand the frequency dependence of scattering from internal waves and other oceanographic features at multi-megameter ranges.

APPROACH

A short term transmission test, named the Alternate Source Test (AST), was conducted during June-July 1996 to compare broadband transmissions at 28 Hz and 84 Hz from an HLF-6A acoustic source suspended from shipboard near Pioneer Seamount off central California to two autonomous vertical line array (AVLA) receivers and to ten horizontal line array (HLA) receivers, at ranges from 150 km to about 5 Mm. The combination of temporal and spatial resolution makes it possible to isolate individual rays and, at the AVLA receivers, low order modes, in order to elucidate the basic scattering physics. The data collected on the AVLA and HLA receivers will be used to compare a variety of measures of the scattering at the two frequencies, including coherences in time, frequency,

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and space, emphasizing the unique capabilities of the AVLAs to provide information on vertical coherence and modal structure and of the HLAs to provide information on the horizontal coherence and spatial variability of the scattering. The computed statistics will be compared with theoretical predictions. SIO investigators will play the leading role in analyzing the data from the AVLA receivers, while APL/UW investigators will take the lead in analyzing the data from the HLA receivers.

WORK COMPLETED

Analysis of the data collected during FY96 continued throughout FY97. Signal processing of the dual-frequency receptions has been completed and routine clock and mooring motion corrections have been applied.

The dual-frequency data have been used by Dzieciuch, Worcester, and Munk (manuscript in preparation) to test a modified vertical beamformer that explicitly takes account of the depth dependence of the sound-speed profile at the VLAs, using a local WKBJ approximation. The modified beamformer, called a turning-point filter, permits a uniform treatment of the arrival pattern, from the early ray-like arrivals to the late mode-like arrivals.

RESULTS

Preliminary results indicate that internal-wave-induced acoustic scattering is less important at 28 Hz than at 84 Hz, as anticipated. The ray-like arrivals at the HLAs are more stable at the lower frequency. The vertical structure of the near-axial energy received at the AVLAs, which is confused and variable at 84 Hz, is less complex at 28 Hz, but is still not simple.

In simulations without internal waves the turning-point filter collapses the acoustic arrival pattern at low vertical angles into a single energy-containing curve in vertical arrival angle - travel time coordinates, where vertical arrival angle can be interpreted in terms of ray and mode turning point depths. Using real data the arrival pattern does not collapse at low angles, however, suggesting that internal-wave-induced scattering is still non-negligible even at 28 Hz.

The path integral theory of internal-wave-induced scattering in the ocean predicts that travel time bias is proportional to the logarithm of the acoustic frequency. The dual frequency AST data should therefore give information on the relative bias at the two frequencies. In preliminary calculations, the differences in travel times for simultaneous transmissions at 84 Hz and 28 Hz are found to be of order ± 50 ms. There is no clear pattern as a function of upper turning point depth, however, as one might have anticipated. Simulations by Colosi and Flatté give biases that are less than 50 ms at 3 Mm range, suggesting that the observed differences may simply represent the travel time precision for the relatively narrowband signals transmitted. Further analysis is needed.

IMPACT/APPLICATIONS

Existing systems, whether active or passive, are not anywhere near the limits of what can be done in underwater acoustics. A full understanding of the ultimate limits to acoustic coherence at long range in the ocean is essential to the design of any acoustic system for remote sensing of the ocean interior, whether it be for measurement of ocean temperatures, tracking of whales, detection of submarines, or the study of volcanic processes at mid-ocean ridges. At the conclusion of our analyses we expect to have a much fuller understanding of the frequency dependence of acoustic scattering from ocean features at multi-megameter ranges, and of the potential for exploiting the anticipated reduction in scattering, and corresponding increase in coherence, at very low frequencies.

TRANSITIONS

None.

RELATED PROJECTS

This work has been closely coordinated with, and partly supported by, the Acoustic Thermometry of Ocean Climate (ATOC) project.

REFERENCES

None.