

Interdisciplinary Research Program

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LONG-TERM GOAL

The long-term goals of this program are to foster interdisciplinary research efforts which combine the research interests of several investigators. In addition, the ARL Program provides partial Laboratory support for post-doctoral students and new academic appointments.

RESEARCH COMPONENTS

Ocean Sound Speed Variations in GPS-Acoustic Measurements (D. Chadwell)

The purpose of this project is to examine coherent variations of about 20 cm to 40 cm over periods of 15 minutes to tidal evident in GPS-acoustic residuals. These are likely caused by internal waves. Existing GPS-acoustic data sets are being analyzed to better understand these effects. Two goals are in mind: (1) the possibility of exploiting these measurements as a sensor of internal waves on moored, buoy-mounted continuously operating GPS-acoustic systems that are currently being implemented by our group and (2) possibly improving the precision of the positioning of the seafloor points. To date efforts have focused on isolating the oceanographic signal from systematic errors in the data and modeling by implementing several improvements to the analysis technique. First, modeling of the acoustic signal propagation has been enhanced to include ray tracing through a three-dimensional sound speed structure. This is a refinement over the initial approach of a 1-D sound speed structure. Second, the GPS processing has been enhanced to allow relinearization of the solution to insure better convergence, improved editing to remove data outliers, better identification of phase breaks to remove their effects from the solution, and fixing of ambiguity biases to improve the positioning component. Six of the nine existing data sets have been reprocessed with these new enhancements and the results are encouraging.

Simultaneous Infrasonic Air Acoustic and Ocean Bottom Compliance Measurements (W. Crawford and G.D'Spain)

This project examines the coherence between the infrasonic air acoustic field just above the ocean surface and the ocean acoustic pressure field on the ocean bottom in shallow water. Several natural sources (earthquakes and volcanic eruptions, at-sea storms and hurricanes and large-scale weather systems, comet explosions in the atmosphere, etc) as well as manmade sources (e.g., nuclear tests) create signals detectable by both types of sensors. The properties of these sources and the physics of propagation in the ocean and atmosphere are of interest, as are the natural background noise levels at infrasonic frequencies in both of these media. One application of this work is in monitoring infrasound sources using seafloor measurements in areas where atmospheric measurements are impractical. The

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water column filters out short wavelength turbulent fluctuations that plague atmospheric infrasound measurements, and thus may provide signal-to-noise ratio gain. To accomplish these goals, an industry-standard infrasound air acoustic sensor was acquired from the French Commission for Atomic Energy (CEA). At the same time, a new-design infrasound sensor was developed and built at MPL. It is based on the very-low-noise seafloor differential pressure gauges developed at MPL and the SIO Physical Oceanography Research Division. Both infrasound sensors were put on R/P FLIP during an August – September 1998 experiment. Simultaneously, the seafloor pressure field and the three components of seafloor motion were measured below FLIP using two autonomous deep ocean instruments. Two weeks of data were collected successfully by the two air acoustic sensors and the two ocean bottom instruments, along with ancillary environmental and FLIP motion data. These data currently are being analyzed.

The Influence of El Niño on Ocean Mixing (R. Pinkel)

The scientific objective of this project is to document the scattering of the surface tide from the undersea topography and the resultant ocean mixing. This process is expected to be unusually violent at sites where the topographic slope is equal to the ray-slope of the internal tide. The ray-slope is determined by the vertical density gradient of the water at the depth of the seamount. This gradient is modulated by El Niño, with the result that sites of strong upper ocean mixing migrate between El Niño and non El Niño years. The mixing associated with the scattering process can affect the density and sound speed profiles locally. This is of relevance to those planning to install acoustic systems on seamounts. A spring-neap variation in system performance might result. Using the Smith-Sandwell digital topographic data base, a site near the Mexican border was located. The R/P FLIP was moored at the site for an August – September 1998 experiment. A high resolution Doppler sonar and two rapid profiling CTD's were operated continuously throughout the cruise. The CTD's profiled from top to bottom (~ 800 m at the site) every 4 minutes. Roughly 10,000 profiles were collected. The sonar, mounted on FLIP's stern, profiled from 120 to 400 m. As per expectation, extremely large currents (1kt) and isopycnal displacements (100 m) were observed around the seamount. Curiously, the strong currents and strong displacements did not happen at the same time.

Noise Impact on Blue Whales (J. Hildebrand)

The objective of this project is to study the impact of low frequency noise on blue whales -- relevant to issues of environmental compliance for the Navy. Blue whales, the largest mammals on earth, are an endangered species. They produce loud low frequency (20 Hz) acoustic calls, presumed to be for communication and/or to sense their environment. The Marine Mammals Protection Act and the Endangered Species Act are laws which are designed to provide blue whales, and other marine mammals, with protection from excessive sound exposure which might be injurious to their hearing or disruptive to other behaviors. A key question is what level of underwater sound exposure is appropriate for regulation. Current standards for marine mammal sound exposure are poorly documented because of the difficulty in monitoring underwater effects of sound exposure. Our goal is to develop acoustic techniques for monitoring both underwater sound exposure and the vocal behavior associated with exposure for blue whales. In particular, we are developing a system for recording and rapidly analyzing arrays of fixed or floating sonobuoys to detect and localize blue whale calls, as well as environmental noise sources, such as nearby ships. We conducted a field program to record blue whale calls in the California continental borderlands to study the impact of low frequency noise on these calls. The continental borderlands near shore is the site of extensive shipping, a source of low frequency noise. Using sonobuoys, many blue whale calls and associated noise from shipping were recorded near the

Channel Islands National Marine Sanctuary. Typical blue whale calls are low frequency tones with fundamental frequencies near 20 Hz. The Channel Islands recordings from this past summer showed an unusually large number of short-duration downswept-frequency calls, relative to the more typical tonal type calls. We suggest that these calls may be related to near-by ranging by the blue whales, in analogy to chirped sonar. We recorded several instances where a blue whale could be identified both from visual observations and from acoustic recordings of vocalizations, with good correspondence in localization. Analysis continues on the impact of low frequency noise from ships and other sources on the character of these calls.

Long Time-Scale Ambient Noise Measurements in the Surf Zone (G. Deane)

The objective of this project is to develop an empirical model for surf noise by recording ambient noise over the band 50 Hz to 20 kHz, wave height and wind speed in very shallow water over a 12 month period. An autonomous data collection system has been built and deployed in 8 m of water, 200 m southwest of Scripps Pier, La Jolla and approximately 200 m from the surf line. The surf monitoring array consisted of 4 broad-band hydrophones and a pressure sensor which recorded ambient noise and wave height for 9 minutes every hour from July 1997 to mid June 1998. The noise recordings provide data through a wide range of incident wave fields and weather conditions, including several winter storms. Each of the 9 minute segments in the data set have been analyzed into 6 octave bands covering the frequency range 32 - 1024 Hz. The octave band averages from the surf-dominated data segments have been cross-correlated against the measured environmental conditions, which included the RMS height and dominant frequency of the incident surface wave field, the wind speed and direction, and the mean water depth, which varied with the tidal cycle. The correlation analysis shows that the single most important predictor of surf noise level is the RMS height of the incident wave field and that the noise level is proportional to the square of the RMS wave height. There is a simple physical interpretation of this result. The available mechanical energy in the incident wave field per unit cross-sectional area of ocean surface is proportional to the RMS wave height squared. Since the surf noise level is also proportional to RMS wave height squared we can conclude that the percentage of mechanical energy converted to acoustic noise is, to first order, constant.

A Study of the Bubble Size Distribution Beneath Breaking Waves in the Open Ocean (G. Deane)

The objective of this project is to measure the bubble size distribution and its evolution in time in the high void fraction plumes generated beneath breaking waves in the open ocean. An optical instrument to measure bubble size distributions in high void fraction plumes generated beneath breaking waves (Bubblecam) has been developed and was deployed from the R/P FLIP, 100 miles southwest of San Diego, California in August 1998. The instrument was mounted on a surface following frame and tethered to a boom deployed over the side of FLIP. Video recordings of the ocean's surface, wind speed and direction, FLIP's heading and surface wave elevation measurements were made simultaneously with the measurements from Bubblecam. Although weather conditions were calm during most of the deployment, approximately 50 breaking waves events occurring over Bubblecam were recorded. A preliminary examination of this data set indicates that high-quality optical images were obtained that will yield bubble size distributions within wave induced bubble plumes and will facilitate a qualitative study of bubble formation mechanisms within waves.

Undergraduate Summer Internship (J. Hildebrand)

A summer undergraduate internship component of the ARL program was established in FY97 with the objective of introducing undergraduates to oceanographic research relevant to the Navy. In FY98, four undergraduates were selected from a number of applicants across the country and they spent 10 weeks in residence at SIO working with MPL research groups.