Extended Analysis of the PhilSea10 Data Set from the Western Tropical Pacific and Transitioning Results to the Operational Navy

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LONG-TERM GOAL

The long-term goal is to enhance our understanding of coastal oceanography by means of applying simple dynamical theories to high-quality observations obtained in the field. My primary area of expertise is physical oceanography, but I also enjoy collaborating with biological, chemical, acoustical, and optical oceanographers to work on interdisciplinary problems. I collaborate frequently with numerical modelers to improve predictive skill for Navy-relevant parameters in the littoral zone.

OBJECTIVES

a) To understand the environmental variability in the western tropical Pacific and its impact on acoustic propagation. This work period will focus on model/data comparisons and the high-frequency (internal waves and tides) portion of the energy spectrum. b) To continue transitioning recent basic research results from the western Pacific region to the operational Navy.

APPROACH

The ONR North Pacific Acoustic Laboratory (NPAL) deep-water acoustic propagation experiments in the Philippine Sea (DWAPS) were conducted during 2009-2011 to investigate deep-water acoustic propagation and ambient noise in the deep sea. There was an engineering test in 2009, pilot study with just two moorings in 2010, and the full-on experiment with seven deep-sea moorings and extensive shipboard observations during 2011. While primarily targeted at understanding the acoustics, the moorings supported a densely-instrumented environmental array as well sensing currents, temperature, and salinity. Several works by individual investigators have been completed and published in a special issue of the *J. Acoust. Soc. Am.*, **34**, 2013. Much work still remains to be done however to produce results across disciplines including how the environmental variability at all scales, from internal waves to the mesoscale eddies, impacts the acoustic propagation. This project is to facilitate those analyses and transition the results to the operational Navy.

WORK COMPLETED

The field portion of the program during April 2010-April 2011 was a big success [Worcester et al., 2013]. Seven moorings were deployed in a star pattern spanning roughly 17 – 23°N by 23 – 130°E. The six "transmit" moorings had an ADCP in the upper ocean spanning 260-360 m depth and many TSP instruments to 600 m depth. Additionally, the DVLA (receive) mooring observed current from 200-500 m and temperature to 4400 m depth. The UNOLS vessels used to conduct the work operated hull-mounted ADCPs throughout the many cruises to the area. Several partner PIs (P. Worcester, SIO; J. Mercer, APL/UW; A. Baggeroer, MIT) collected CTDs are part of their work. The satellite altimetry data, now easily available on the web (see for instance the Colorado Center for Astrodynamics Research, http://eddy.colorado.edu/ccar/data_viewer/index) have also been very helpful in establishing context for the field experiment. An array of Seagliders was also deployed which collected temperature and salinity profiles to 1000 m depth [Van Uffelen et al., 2013]. One manuscript has been submitted to date, a physical description of the mesoscale eddies in the Philippine Sea using all available data [Ramp et al., 2015].

A Philippine Sea data analysis workshop was held during 15-17 October at Borrego Springs, CA. This investigator gave one of only two PO talks at the meeting. A list of papers in preparation or planned was assembled. A few of the priority items are highlighted below.

RESULTS

Since funding was receive only last month, this constitutes a list of planned activities rather than results. The list indicates the directions we intend to move in.

Scientific Analysis

1. Revise and resubmit Ramp et al., [2015] on the mesoscale variability in the Subtropical Countercurrent (STCC).
2. Assess the impact of high-frequency internal Waves and tides on acoustic propagation (with J. Colosi, NPS and L. van Uffelen, UH). This work is an extension of [Colosi et al., 2013] that examined the high-frequency variability using just two moorings from the month-long PhilSea09 Pilot Study during spring 2009.
3. Model analysis and model/data comparisons (with B. Cornuelle, SIO): Complete state estimates for the entire experiment have now been run using the MITgcm model (initialized from HYCOM/NCODA) both with and without assimilation of the acoustic tomography data. Using the dynamically-consistent model fields (T, S, u, v, w) on a high-resolution uniform grid will allow computation of derived parameters such as potential vorticity and the eddy fluxes of heat, salt, and momentum.
4. Acoustic propagation through a random field of closely-packed mesoscale eddies (with K. Heaney, Oasis; J. Colosi, NPS; and P. Worcester, SIO): Impact of thermal perturbations in a closely-packed eddy field on acoustic propagation. Impact of spice in the warm eddies only on acoustic propagation. The reciprocal problem. How does placing a source in a cold eddy and receiver in a warm eddy compare to vice-versa? How about propagation across three eddies, or four eddies? The project will also explore the impact of varying the source and receiver depths and frequencies used.

Transitioning to NRLSSC

5. Acoustic provincing (with J. Fabre, NRLSSC and J. Colosi, NPS): The Philsea10 experiment provided the ideal in-situ data set to test the acoustic provincing concept. The TL data along the five radials in the star pattern permit the search for commonality and increased computational efficiency for the operational models. The results can be understood by understanding the oceanography that sound is propagating through, and its variability.
6. (Separate project): Sediment re-suspension by non-linear internal waves (with J. Calatoni, NRLSSC, D. B. Reeder, NPS; P. Diamesis, Cornell): Joe is conducting tank experiments to study this problem which is being studied numerically by Peter and observationally by the ONR Sand Dunes team.

IMPACT/APPLICATION

This analysis is expected to break new ground in the field of blue-water deep-sea acoustic propagation. The array is also the first of its kind in the STCC, one of the most energetic mesoscale eddy regions of the world. Observing the eddy energetics and propagation speeds and directions will improve the quality of the oceanographic and acoustic nowcasts and forecasts for the region.

TRANSITIONS

The collaborations with Dr. Josette Fabre at NRL Stennis on acoustic provincing and uncertainty reduction are continuing. J. Colosi has made the acoustic travel time data available. The PI also works with Dr. Dong-Shan Ko, Dr. Pat Gallacher, and Dr. Martin Buijsman who are working on numerical models of the western Philippine Sea region. The PI retains a courtesy appointment at the Naval Postgraduate School and has regular contact with the U.S. Navy via officer-students and faculty there.

RELATED PROJECTS

Peter Worcester, Scripps Institution of Oceanography, project leader

John Colosi, Naval Postgraduate School, deep water acoustics, internal waves

Bruce Cornuelle, Scripps, mesoscale modeling

Kevin Heaney, Oasis, sound propagation through packed eddies of varying sign

Brian Dushaw, APL/UW, internal waves

Lora Van Uffelen, UH, acoustic tomography from mobile nodes (gliders)

Kathleen Wage, George Mason, ambient noise

REFERENCES

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PUBLICATIONS

Ramp, S. R., J. A. Colosi, P. F. Worcester, F. L. Bahr, K. Heaney, J. A. Mercer, and L. J. Van Uffelen, 2015: Direct observations of the mesoscale variability in the western Philippine Sea. *J. Phys. Oceanogr.*, submitted.

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