Combining Acoustic, In-Situ, and Remotely-Sensed Data with Regional Ocean Models in the East China and Philippine Seas

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LONG-TERM GOALS

The long-term scientific objective of the Quantifying, Predicting, and Exploiting (QPE) Uncertainty Directed Research Initiative (DRI) is to improve the assessment of uncertainty in observations and predictions of sound propagation in littoral regions.

OBJECTIVES

The goal of this research is to understand and exploit the effects of the ocean state on acoustic propagation and detection. This work will contribute to that goal through regional ocean modeling and data assimilation. The modeling will include forecast and predictability studies to see the growth of uncertainty in time and space and the predictability of the propagation conditions on the shelf north of Taiwan from the ocean state.

APPROACH

The DRI will be a coordinated effort in which many types of measurements will be made during the demonstration experiment in FY09 over the continental shelf to the north of Taiwan. The field results will be used to help characterize the rapidly varying physical environment and to study acoustic propagation and scattering in the region.

The technical approach will center on using the Frechet derivative (adjoint) of a regional ocean model to explore the sensitivity of critical environmental features of the shelf region to the ocean in the region, to forcing, and to boundary conditions. In the longer term, acoustic remote sensing data, together with data from direct measurements and satellite remote sensing, will be assimilated into a regional ocean model to estimate the evolving ocean state using the adjoint technique.

Initially we will configure a fine-resolution (0.1°) regional general circulation ocean model, using the MIT general circulation model (MITgcm), for a region some 6°x6° encompassing Taiwan. This model will provide lateral boundary conditions to a smaller regional model to the northeast of Taiwan to be run by Lermusiaux (MIT). Initial and lateral boundary conditions for our model will be obtained from

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14. ABSTRACT
The long-term scientific objective of the Quantifying, Predicting, and Exploiting (QPE) Uncertainty Directed Research Initiative (DRI) is to improve the assessment of uncertainty in observations and predictions of sound propagation in littoral regions.

15. SUBJECT TERMS

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a global 1/12° Hybrid Coordinate Ocean Model (HYCOM) assimilation product. The choice of lateral boundary conditions is central to the issue of uncertainty. HYCOM is forced with daily Navy Operational Global Atmospheric Prediction System (NOGAPS) fluxes and uses the Navy Coupled Ocean Data Assimilation (NCODA) to assimilate data. First we need to determine the fidelity of the output in the larger northwest Pacific region by considering the representation of those processes that will be felt at the boundaries of our regional model. These are primarily westward propagating mesoscale eddies. We also need to consider the variability of the surrounding waters such as the annual cycle, mean flows, stratification and mixed layer depths.

In preparation for the regional modeling/data assimilative effort we are gathering both in-situ and remotely sensed data for the larger northwest Pacific region. These data include temperature and salinity vertical profiles from Argo floats, Expendable Bathythermograph (XBT) temperature data, velocity and temperature at 15 m from surface drifting buoys, sea surface height from altimetry, and sea surface temperatures. The data will be quality controlled and manipulated as appropriate for insertion in the data assimilation scheme.

Once the regional model and data assimilation machinery is working, Observing System Simulation Experiments (OSSE) will be conducted prior to the FY09 experiment to aid in the design of the experiment and to understand the sensitivity of the models to the various data types and geometries. The intent is to be ready to combine the data obtained during the FY09 experiment with realistic ocean models as soon as the observations become available in order to provide accurate estimates of the ocean state.

WORK COMPLETED

The ocean processes over the shelf and slope water northeast of Taiwan are inherently multi-scale and pose a challenge to predictability. Zhang et al. (2001) found low transport events as measured by an array of current meters in the East Taiwan Channel (ETC) to be co-incident with the arrival of anticyclonic mesoscale eddies at the western boundary that had propagated westward from the basin interior. During these events, surface drifter tracks showed that the Kuroshio Current developed a large offshore meander to the east of Taiwan and then intruded into the South China Sea to the northeast of Taiwan.

As part of the planning phase for the QPE DRI (FY07), Niiler and Kim correlated the current meter transport time series of Zhang et al. (2001) with sea surface height anomaly (SSHA) from the AVISO altimetry product in the waters surrounding Taiwan. They obtained a maximum correlation of 0.7 just to the east of the island (123.32°E, 23.82°N) and found that low volume transports corresponded to periods of low SSHA. They formed composites of trajectories of surface drifting buoys at 15 m that coincided with low and high sea surface height anomaly events at this location. They found that the high sea level composite trajectories were more tightly packed adjacent to the continental shelf while during low sea level events the Kuroshio Current intruded extensively over the shelf into the South China Sea.

During the planning stage for the DRI we started analyses to ascertain if eddy-resolving ocean simulations were able to reproduce this predictable ocean response. We calculated Kuroshio Current volume transport anomalies through the ETC for the period 1994-2003 from the global 0.1° Parallel Ocean Program (POP) forced with synoptic NCEP/NCAR atmospheric fluxes. We released numerical drifters to the east of Taiwan during selected low and high transport anomaly events during that period. The outcome was that during the low transport event the Kuroshio Current meandered offshore of Taiwan and then intruded into the East China Sea while during the high transport event the drifter trajectories closely followed the continental shelf. The intrusions into the ECS however occurred further to the north than is observed. Consequently, we decided to repeat the numerical drifter exercise using HYCOM/NCODA output. Since SSHA is assimilated into the model, we used low and high sea level events off Taiwan to gauge the extent to which the Kuroshio intrudes into the ECS. During low sea level events the Kuroshio Current is seen to intrude further into the SCS and its intrusion location is closer to that observed.

In the interests of time the HYCOM analyses were conducted with very limited time series of sea level and velocities at 15 m. This year we have extracted the full three-dimensional time series of output in the northwestern Pacific from both the global HYCOM/NCODA simulation (November 2003 to September 2008) and the equivalent non-assimilative HYCOM simulation (2003-2005). We are repeating the detailed calculations made with POP that will be used to provide an overall assessment of the depiction of the space and time scales of ocean processes being introduced into our regional model at the lateral boundaries. We will compare results from the forward HYCOM and HYCOM/NCODA simulations to understand the role of data assimilation in regard to the nature of the Kuroshio intrusions into the East China Sea. We are preparing a manuscript describing the results from POP and HYCOM and the results will be presented at the Fall 2008 AGU meeting in San Francisco. We have surface drifting buoy and sea surface height from altimetry available for assimilation into our regional model. Other deep data such that from Argo floats is being obtained for our study region.

Since the start of this current award, we have attended a planning meeting in Taipei, Taiwan and have begun work with Pierre Lermusiaux at MIT to create a MITgcm simulation that can be compared to his Harvard Ocean Prediction System (HOPS) runs. We still need an updated grid in latitude/longitude space as well as his boundary conditions and forcing.

IMPACT/APPLICATIONS

This study will lead to the improvement of the assessment of uncertainty in observations and predictions of sound propagation in littoral regions.

TRANSITIONS

Methodology and data results can be made available to Navy scientists.

RELATED PROJECTS

The work described here is in collaboration with Professor Peter Niiler at SIO and Dr Pierre Lermusiaux at MIT.

REFERENCES

Zhang, D., T. N. Lee, W. E. Johns, C.-T. Liu, R. Zantopp, 2001: The Kuroshio east of Taiwan: modes of variability and relationship to interior ocean mesoscale eddies, *Journal of Physical Oceanography*, **31**, 1054-1074.