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. The objectives of this research are to understand and exploit the effects of the ocean state on acoustic propagation and detection.

OBJECTIVES

This work will contribute to the goals through global and regional physical ocean modeling and data assimilation. The modeling includes both model comparisons with observations, evaluating model error, and forecast and predictability studies to see the growth of uncertainty in time and space and the influences of the past ocean state on the acoustic propagation conditions on the shelf north of Taiwan.

APPROACH

The QPE DRI is a coordinated effort in which many types of measurements have been collected over the continental shelf to the north of Taiwan. The field results will be used to help characterize the rapidly varying physical environment in comparison to the models and to study acoustic propagation and scattering in the region. Two of the most important physical processes in the region of the experiment are the cold dome observed off the northwest corner of Taiwan and intrusions of the Kuroshio onto the shelf north of Taiwan.

Earlier observational studies (Yang et al., 1999; Zhang et al. 2001) reported intrusions of the Kuroshio Current into the East China Sea (ECS) to the north of Taiwan in the vicinity of the Mien-Hua Canyon (25.4°N, 122.5°E). Zhang et al (2001) analyzed observations from a moored current meter array (World Ocean Circulation Experiment PCM-1) that spanned the East Taiwan Channel between September 1994 and May 1996, and found a relationship between periods of low volume transport and those times when the Kuroshio intruded into the ECS. From surface drifter tracks they also observed a large Kuroshio meander to the south of the ETC that shifted the axis offshore and changed the flow field from its usual northward direction perpendicular to the PCM-1 array to nearly westward and parallel to the array line. Further, using altimetry data they related the low transport pulses to the arrival of anticyclonic eddies approaching the western boundary south of the PCM-1 array line. In an earlier observational study, however, Yang et al (1999) using drifters and altimetry related low transport pulses to the approach of cyclonic eddies and high transport events to the arrival of anticyclonic eddies.

Many previous studies have also focused on the cold dome, and a major hypothesis for its formation has been wind events. We used new modeling studies to evaluate these hypotheses and to understand the processes controlling both intrusions and cold dome.

WORK COMPLETED

In the past year, we have focused on writing up our results for publication. These results include detailed comparisons of OGCMs with observations and the examination of the phenomenology of key regional oceanographic processes: occurrences of the Cold Dome and Kuroshio intrusions onto the shelf northwest of Taiwan.

We examined intrusions of the Kuroshio Current into the East China Sea in three high resolution model simulations: data assimilative 1/12° global Hybrid Coordinate Ocean Model (HYCOM; http://www.hycom.org), a forward simulation of 1/10° global Parallel Ocean Program (POP), and a regional forward simulation using the 1/24°MITgcm. All models were forced with synoptic atmospheric fluxes.

Previously, we had calculated volume transport anomalies through the East Taiwan Channel from all three models. Extreme volume transport events were defined as those values that exceeded two standard deviations of the demeaned daily volume transport time series. These extreme occurrences were averaged to form high and low composites of velocities at 15 m and sea surface height anomaly (SSHA). Building on this approach, we constructed composite time series for 99 days prior to and after the low and high events for both > 2 STDs and 1<STD<2. These time series were then animated allowing us to follow the evolution of the interactions among westward propagating mesoscale eddies, the Kuroshio Current, and the Ryukyu Islands. Subsequent findings lead us to quantify the impact of the eddies on the time-mean circulation and invoke vorticity arguments to provide context for the results.

Using HYCOM output as initial and boundary conditions, regional MITgcm model runs have been conducted in a domain which extends from 116°E to 128.5°E and from 22°N to 27°N using 1/24° and 1/48° grids. Both setups used 50 layers in the vertical, including 5m spacing near the surface.

In addition to the "Cold Dome" and Kuroshio intrusion analyses performed earlier, we used similar statistical techniques as were used for the intrusions to link the cold dome to positive sea level anomalies to the East of Taiwan and strengthened Kuroshio nearer the coast. There is a significant negative correlation between the strength of the Kuroshio and the temperature in the Cold Dome region. The relationship is more linear than that for the intrusions, meaning that compositing with thresholds did not reduce the scatter or produce a clearer relationship.

RESULTS

Interactions of mesoscale eddies, the Kuroshio, and the Ryukyu Islands as depicted by our animations showed that cyclonic eddies penetrated into and coalesced with the Kuroshio only when extreme events exceeded 2 STDs. Otherwise the cyclonic eddies deformed on the offshore flank of the Kuroshio and were advected poleward with the flow losing their signature in the process. We are now quantifying the impact of eddies on the time-mean circulation as the final stage of the paper.

The 1/24° resolution MITgcm runs have shown realistic Cold Dome statistics, based on comparisons to historical Taiwanese observations and SSH observations. The MITgcm improves on HYCOM in these respects. Adjoint model runs have been used to quantify the influences on the Cold Dome region, comparing wind to Kuroshio strength. Wind is a much weaker influence than ocean state variables like temperature and current, suggesting that the Kuroshio drives the Cold Dome variability more than local winds.

The regional model was also used to simulate the ocean during the time of the intensive field program, including the effects of Typhoon Marokot, which caused significant damage to Taiwan and unleashed up to a meter of rain. In addition to older model runs using reanalysis forcing, but no runoff from Taiwan, the MIT group (led by Lermusiaux) supplied us with carefully reconstructed runoff values for the major rivers on Taiwan during the aftermath of the typhoon. The presence or absence of runoff had little effect on the southward flow along the northeast coast of Taiwan 10 days after the passage of the cyclone, as seen in the observations.. This suggests that the wind forcing dominated over the freshwater forcing in the production of this phenomenon.

A paper describing the Kuroshio intrusions as depicted by the three models and drifter data is being prepared for submission to the Journal of Marine Research QPE special issue. A second paper describing the cold dome simulations is in preparations for the same issue.

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 Dr Luca Centurioni at SIO and Dr Pierre Lermusiaux at MIT.