Observations and Theory of Ocean Fronts: Diagnostic Models of Ocean Straits

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LONG-TERM GOALS

The long-range purpose of these efforts is to improve our understanding of nonlinear mesoscale systems in the ocean and their role in determining the spatial/temporal distribution of environmental properties. Of particular interest are the ways these features are coupled both to the larger scale ocean circulation and to smaller submesoscale features. The efforts combine various suites of observations including Lagrangian and Eulerian current measurements, hydrography and satellite data with both analytical and numerical models to describe these features. One emphasis is on methods of combining different data sets to produce diagnostics and feature models. On the theory side the focus is on taking the results of the data analysis into a set of simple analytical models and then considering both the models and data against a range of numerical simulations. The ultimate goal of the effort is to advance not only the understanding of these features as physical entities, but to also understand the biophysical coupling taking place, their role on property dispersal, and in the long term their effects on different sedimentary environments.

OBJECTIVES

The specific objectives of the present research is to quantify the nature of flows within straits and passages such as those in the Bahamas and bounding Southeast Asian waters. Initial efforts involved an expansion of an earlier study to provide the geometry of thermoclines and mixed layers through relatively broad straits using direct current measurements, historical hydrographic data, and satellite data. The idea was to produce a set of feature models for flows in these settings and to attempt to understand the temporal adjustments in straits to changes in the bounding circulation fields. Finally, the resulting models and insights are compared to various numerical models including the North Atlantic MICOM simulations and various Navy models. The resulting suite of diagnostic models and simulations will be compared to a survey of the Bahamian passages on a NAVO cruise in March 2001 and weekly ADCP surveys from the Royal Caribbean vessel Explorer of the Seas.

APPROACH

The diagnostic model for thermoclines in straits involves three layers separated by an upper permanent thermocline that occurs in all of the equatorward limbs of subtropical gyres and a lower main thermocline. The model allows mapping of the thermoclines through straits based on either detailed transport measurements or remotely sensed temperature and surface height anomaly. Continuity of through strait flow is obtained by mapping the thermocline geometries onto bottom depth. Mixed layer

depths are also estimated by using SST imagery and historical temperature profiles. The result is a diagnostic model that can reconstruct the three-dimensional temperature, salinity (though T/S relation), and sound speed through the strait. The resulting model is compared to CTD surveys in the Bahamian straits and current meter data in Indonesian waters. Currently the model is being used to provide a diagnostic tool for reconstructing conditions in the straits from the cruise ship ADCP data. The results of the diagnostic and data analysis effort are then compared to the results of numerical simulations.

WORK COMPLETED

- Further work on the diagnostic model for the Providence Channel to verify its performance and add recirculation in inter-strait eddies.

- Publication of the application of the three-layer model to the Makassar Strait (Waworuntu et al., 2001).

- Water mass analysis of the near surface waters in the subtropical North Atlantic to estimate the large-scale sources and degree of water mass modification in the Bahamian passages and Florida Straits (O'Connor, 2001).

- Participation on R/V Walton-Smith cruise in the Bahamas in March 2001 (Olson and Samuels).

- Preliminary analysis of the Explorer ADCP data and surface currents from MICOM simulations. (Olson, Kearns)

RESULTS

The major new accomplishment is the production of the feature model for straits and its application to Makassar (Waworuntu et al., 2001) and the Providence Channels. The Makassar work shows that the strait acts as a three-layer system with much of the steady flow confined to the second layer. The surface layer flow varies with the monsoon forcing. The model demonstrated ways of combining inverted echo sounders, bottom pressure gauges and satellite altimetry to complete three layer diagnostics of the flow. The Bahamian passage extends the model to provide a three dimensional depiction of a strait. This model is currently being compared to measurements taken this year and to the MICOM model results. Given a successful comparison it will form an avenue for assimilation of data into models of strait environments.

The results of the water mass based evaluation of the origin of the surface waters in the Bahamian passages forms a chapter in a Ph.D. dissertation (O'Connor, 2001). The analysis suggests that the waters on the eastern side of the Florida Straits originate through the Old Bahama Channel and an inflow through the Providence Channel. The waters in the southern side of the latter channel are flowing out of the Florida Straits. This flow also shows up in the diagnostic model above and in the MICOM simulations (Chassignet and Garraffo, per. comm.). This work forms the basis of a successful NSF Biocomplexity Program proposal that will extend the models to understanding the dispersion of larval forms in the Bahamian ecosystem. The data is also being used to provide a chart of possible billfish habitats in the region.

Results of earlier funded ONR work are also appearing in publications. These include work on subduction (O'Connor et al., submitted) and several biophysical papers. Three of these consider the dynamics of fronts. Olson (2001) compares the physics and biology of western boundary currents and their extensions into temperate ecosystems. Computations of upwelling rates in the Florida Current demonstrate that the Gulf Stream and Kuroshio involve upwelling into the photic zone at rates that meet or exceed those in eastern boundary currents. A review of the ecosystem, however, suggests that the air-sea interaction over these currents and the rapid advection associated with them leads to very different results. A review of the biophysics of oceanfronts at different trophic levels will appear in the next volume of The Sea. A model of the ecosystem response in fronts in oligotrophic waters such as found in the Straits of Florida is in press. A companion manuscript uses the same biological model to consider the nature of the deep chlorophyll maximum. Finally, a paper of coastal flows in the lee of Barbados is currently in revision.

IMPACT/APPLICATIONS

Although is premature to state with certainty the new view of western boundary currents as upwelling systems should have lasting impact on the way we look at western boundary ecosystems. The feature model has promise in terms of assimilation of data into models of straits, but will take several years of scrutiny before reaching this goal. The work on biophysics of frontal environments funded by ONR was the primary contributor to two short courses in Latin America under the sponsor ship of the Inter-American Institute for Global Change (IAI). These provide interdisciplinary training for 50 students.

TRANSITIONS

The biophysical model in Lima et al. (In press) has been provided to the Federal University of Rio Grande, Brazil and is being used to model the Argentine, Uruguay, and southern Brazil shelf.

RELATED PROJECTS

This work is closely associated with the MICOM group's North Atlantic model (http://www.rsmas.miami.edu/micom). The new Biocomplexity program involves a wide group of investigators working on the impact of Marine Protected Areas (MPAs) in the Bahamas. These and other research efforts are closely linked to Robert Cowen's group (http://chromis.rsmas.miami.edu) and the new Center for Sustainable Fisheries at the University of Miami (http:www.rsmas.miami.edu/groups/cfsf).

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PATENTS

None