Numerical Hindcasts of the California Current

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LONG-TERM GOALS

The long-term goal of my research is to develop, verify, and apply numerical ocean prediction models to eastern boundary coastal regions in order to improve our scientific understanding of the structure and dynamics of such regions.

OBJECTIVES

The broad objective of this research is to aid in the development of a reliable modeling capability for eastern boundary current regions. The specific objectives are (1) to carry out and verify multi-year numerical model hindcasts of the California Current, and (2) to compare these hindcasts with those being conducted by other groups within the Navy and University communities.

APPROACH

The numerical simulations and hindcasts of the California Current are being carried out using the DieCAST regional model (Dietrich 1997). The DieCAST model is a z-level primitive equation model that uses a fully conservative fourth order space finite difference scheme, which produces high computational accuracy and especially low numerical dispersion (Sanderson 1998; Sanderson and Brassington 1998). Both of these properties are essential for an accurate simulation of fine scale processes in the coastal ocean and at the shelf break. The numerical simulations have been forced by monthly climatological winds, while the hindcasts will be driven by a two-year data set of high resolution wind fields produced by quasi-operational atmospheric prediction models, the MM5 and COAMPS models, respectively. The verifications will make use of *in situ* data from ONR's CTZ and EBC programs (for statistical and phenomenological verifications) and TOPEX/Poseidon altimeter data (for hindcast behavior).

WORK COMPLETED

During the last year we completed three diagnostic studies, two in the California Current (Haney and Hale 2000, Shearman et al. 2000), and one in the Alboran Sea (Viudez et al. 2000). In addition, we completed a collaborative review article on modeling the California Current (Miller et al. 1999) and a simulation study of the California Current (Haney et al. 2000). Work has also progressed to access the surface wind stress from MM5 model runs from October 1998 to (eventually) October 2000. This

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wind stress data, along with similar data from the COAMPS reanalysis fields that are being prepared by J. Kindle (Stennis Space Center), will be used to force the ocean model during the two-year hindcasts.

RESULTS

In our diagnostic studies, we have shown that one is able to diagnose accurately the 3-dimensional circulation and vertical velocity in the ocean by using the dynamic initialization technique of digital filter initialization (DFI). We verified the DFI method, and successfully applied it to synoptic hydrographic data from the CTZ program in the summer of 1988 (Haney and Hale 2000) and the EBC program in the summer of 1993 (Shearman et al. 2000). Figure 1, from Haney and Hale (2000), shows one of the main results of our diagnostic studies.

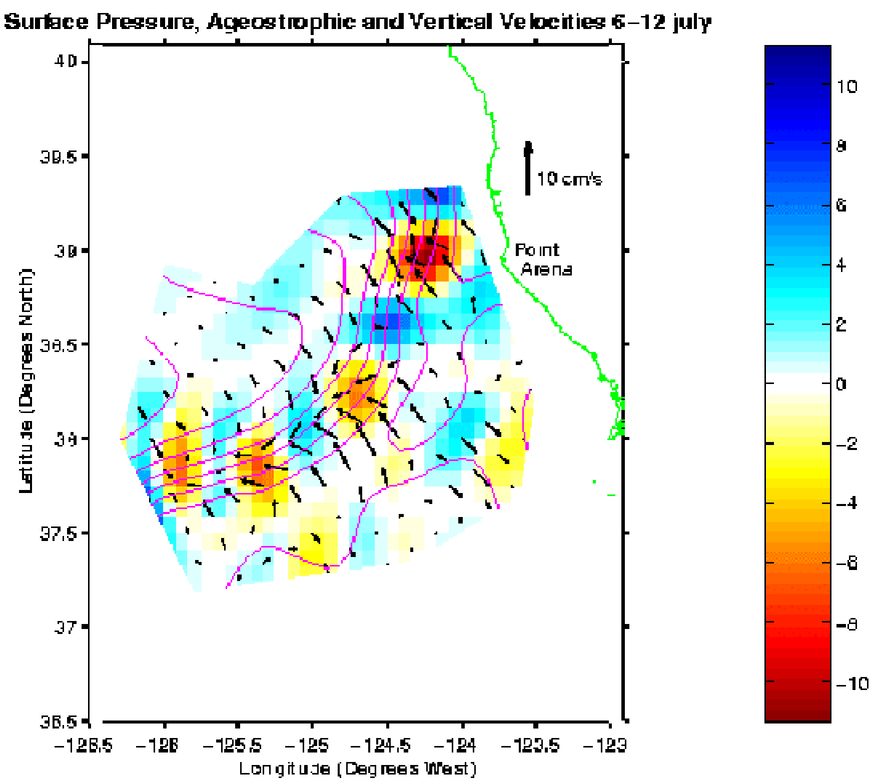

Figure 1

This is a picture of the three-dimensional circulation in an observed, offshore-directed California coastal jet. The upper ocean circulation associated with the jet is clearly seen to be both confluent (isobars becoming more closely spaced in the downstream direction) and convergent (ageostrophic velocity vectors). Along the center of the jet, there are alternating cells of rising and sinking motion, with maximum vertical velocities near 10 m/d. This result is typical of such coastal filaments, although some smaller scale features, such as those resolved by the higher resolution EBC data, have been found to have vertical velocities up to 30 m/d (Shearman et al. 2000). In our diagnostic study of the Atlantic Jet in the Alboran Sea (Viudez et al. 2000), we showed that the vertical advection of momentum is negligible in the local momentum balance even when the vertical current shear is large, as it is in the highly baroclinic Atlantic Jet.

Figure 2, from Miller et al. (1999), shows one of the results from our recent California Current simulations using monthly mean climatalogical wind forcing. With such forcing, the model reproduces many of the main features of the observed annual cycle of the California Current including the strengthening of the coastal jet in spring and the weakening of the jet in autumn and winter. Coastal eddies in the simulation form primarily off the major headlands, especially Cape Mendocino and Point Arena. Figure 2 shows a map of the model simulated sea surface height and temperature fields during the upwelling season when the eddy field is strongest. As a result of this eddy development, a region of maximum eddy kinetic energy (EKE) migrates westward from the coast on a seasonal time scale. This seasonal development, in which the EKE builds up at the coast, propagates slowly offshore, and subsequently decreases at the surface west of about 126W in the simulation, is in close agreement with the most recent satellite observations (Kelly et al. 1998, Strub and James 2000). We have recently shown in our model simulation that as the EKE propagates offshore, it spreads vertically into the deep ocean by means of a nonlinear transformation of kinetic energy from the vertical shear (baroclinic) currents to the vertical mean (barotropic) currents (Haney et al. 2000). Such an energy transformation is predicted to occur as a part of the natural up-scale transfer of kinetic energy in quasi-geostrophic turbulence (Salmon 1998). It is observed to occur in the atmosphere in midlatitudes (Winn-Nielsen 1962). Most importantly, our identification of the mechanism in our model simulation clearly explains the observed decrease of EKE in the upper ocean west of about 126W. When this work is published, we will consider it a most significant accomplishment. This is not only because it explains the satellite observations of near surface EKE, but because of its broad implications about the role of eastern boundary regions in supplying EKE to the deep ocean and the need for numerical models of the coastal oceans to simulate the process accurately.

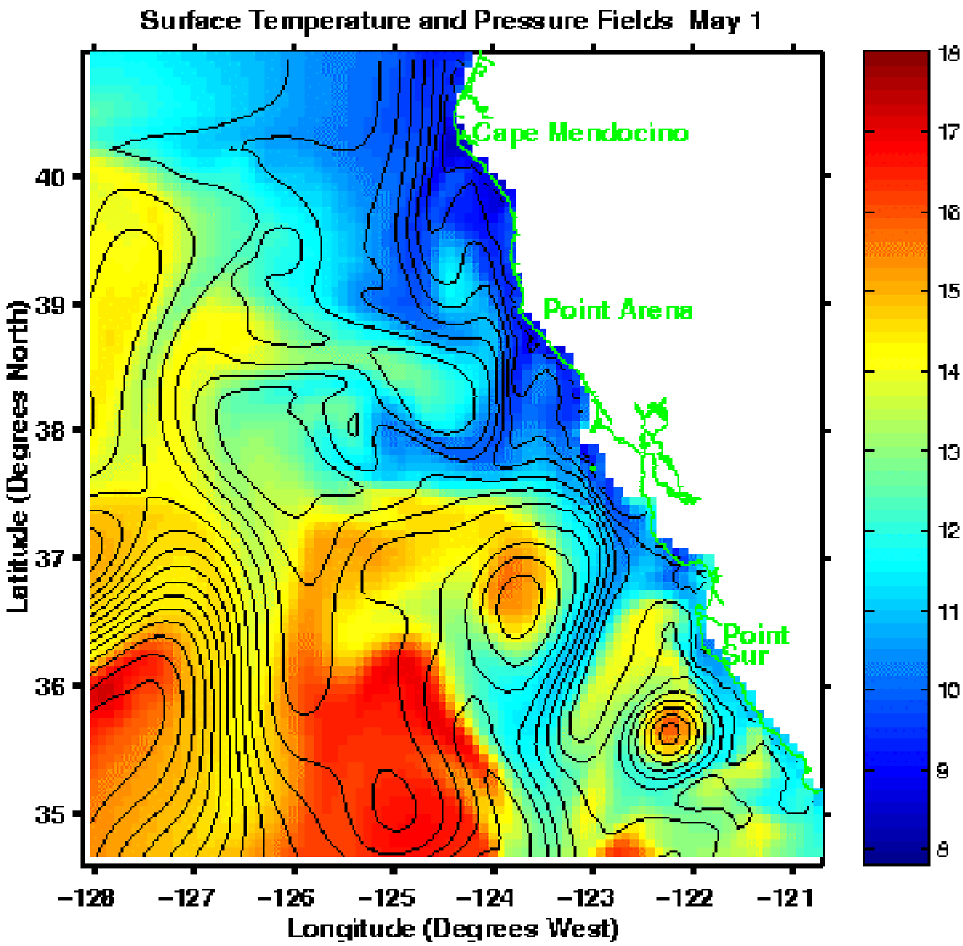

Figure 2

IMPACT/APPLICATIONS

The validation and use of DFI as a diagnostic tool in the ocean will have important impact in advancing diagnostic ocean studies and numerical ocean prediction. Our new interpretation of the offshore propagation of EKE in the California Current will have a significant impact in coastal oceanography and numerical modeling.

TRANSITIONS

Our research on modeling the California Current is in broad support of the efforts at FNMOC (M. Clancy) and NRL-Stennis (J. Kindle) to develop a real-time ocean analysis and forecasting capability, including biology, for the coastal oceans.This support manifests itself in close coordination, and timely information exchange on such topics as model properties, experimental set-up, forcing data, regional modeling difficulties, comparison and exchange of results, methods of model verification, and so forth.

The DFI methodology has been accepted as an important diagnostic tool in numerical ocean modeling in the US and abroad.

RELATED PROJECTS

I am collaborating with R. Hodur and others at NRL-Monterey to validate the Navy's high resolution coastal ocean model (NCOM) in the Mediterranean Sea. I am also collaborating with J. Tintore (UIB, Spain) in diagnostic studies of mesoscale variability in the Alboran Sea and in modeling the interanual variability in the Mediterranean Sea. Finally, I plan to participate in a National Ocean Partners Program (NOPP) to inter-compare ocean models and to synthesize ocean observations off the West Coast of North America.

FIGURE LEGENDS

1. Map of the surface pressure field in terms of the sea level height (magenta isolines with contour interval of 4 cm), the ageostrophic velocity at the surface (arrows with scale on the right) and the vertical velocity at 90 m (color, in m/d). The results are for the CTZ survey during July 6-12, 1988.

2. SST (color, in deg C) and sea level height (white isolines with contour interval of 2 cm) on a typical day in May from the DieCAST CCS model showing the types of upwelling filaments, eddy structure, and equatorward jet typical of this time of year (from Miller et al. 1999).

REFERENCES

Dietrich, D. E., 1997: Application of a modified Arakawa "A" grid ocean model having reduced numerical dispersion to the Gulf of Mexico circulation. *Dyn. Atmos. and Oceans,* **27**, 201-217.

Kelly, K. A., R. C. Beardsley, R. Limeburner, K. H. Brink, J. D. Paduan and T. K. Chereskin, 1998: Variability of the near-surface eddy kinetic energy in the California Current based on altimetric, drifter and moored current data. *J. Geophys. Res.,* **103,** 13067-13083.

Salmon, R., 1998: *Lectures on Geophysical Fluid Dynamics*, Oxford University Press, New York, 378pp.

Sanderson, B., 1998: Order and resolution for computational ocean dynamics. *J. Phys. Oceanogr.*, **28**, 1271-1286.

Sanderson, B. and G. Brassington, 1998: Accuracy in the context of a control-volume model. *Atmosphere-Ocean*, **36**, 355-384.

Strub, P. T. and C. James, 2000: Altimeter-derived variabililty of surface velocities in the California Current system: 2. Seasonal circulation and eddy statistics. *Deep Sea Res.* (in press).

Wiin-Nielsen, A., 1962: On transformation of kinetic energy between the vertical shear flow and the vertical mean flow in the atmosphere. *Mon. Wea. Rev.*, **90**, 311-323.

PRESENTATIONS AND PUBLICATIONS

Haney, R. L., R. A. Hale and D. E. Dietrich, 2000: Offshore propagation of eddy kinetic energy in the California Current. Paper presented at the European Geophysical Society XXV General Assembly, Nice, France, 25-29 April 2000.

Haney, R. L., R. A. Hale and D. E. Dietrich, 2000: Offshore propagation of eddy kinetic energy in the California Current. *J. Geophys. Res* (submitted).

Haney, R. L. and R. A. Hale, 2000: The use of digital filter initialization to diagnose the mesoscale circulation and vertical motion in the California coastal transition zone. *J. Marine Systems* (in press).

Miller, A. S., J. C. McWilliams, N. Schneider, J. S. Allen, J. A. Barth, R. C. Beardsley, T. K. Chereskin, C. A. Edwards, R. L. Haney, K. A. Kelley, J. C. Kindle, L. N. Ly, J. R. Moisan, M. A. Noble, P. P. Niiler, L. Y. Oey, F. B. Schwing, R. K. Shearman and M. S. Swenson, 1999: Observing and modeling the California Current system. EOS Trans. AGU, Vol. 80, No. 45, November 9, 1999, Pages 533, 534, 536, 539.

Shearman, R. K., J. A. Barth, J. S. Allen and R. L. Haney, 2000: Diagnosis of the three-dimensional circulation in mesoscale features with large Rossby number. *J. Phys. Oceanogr.* (in press).

Viudez, A., R. L. Haney and J. T. Allen, 2000: A study of the balance of horizontal momentum in a vertical shearing current. *J. Phys. Oceanogr.* (in press).