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February 14, 1995

Dr. Thomas Kinder, ONR Code 321CD
Office of Naval Research
Ballston Tower One
800 N Quincy St
Arlington VA 22217-5660

ONR Grant # N00014-92-J-1177
OSU Acct # 30-262-3154

Dear Dr. Kinder:

In order to complete my ONR grant entitled "Equatorward Jets, Poleward Undercurrents, and Coastal Upwelling", I am sending three copies of the *Final Technical Report* to you with copies distributed as indicated below.

Sincerely,

Robert L. Smith

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FINAL TECHNICAL REPORT
ONR GRANT # N00014-92-J-1177

Robert L. Smith

Equatorward Jets, Poleward Undercurrents and Coastal Upwelling

The focus of the research was on the ocean along its eastern boundaries. A review of recent developments in our understanding of coastal upwelling was prepared based primarily on the several major oceanographic experiments were conducted over the continental margins in coastal upwelling regions during the past decade. These studies extended farther seaward than the continental shelf and often extended over the seasons. Our understanding of the processes associated with coastal upwelling, especially the Ekman transport in the surface layer and the processes affecting the ocean farther seaward, has increased. The wind-driven cross-shelf transport in the surface mixed layer agrees well in magnitude and variability with the Ekman transport estimated from the wind stress. The cool 'filaments' conspicuous in satellite images of SST during the coastal upwelling seasons off northern California, Portugal and Africa, have been studied and shown to usually be jets along the boundary (front) between recently upwelled water and the warmer adjacent ocean water. Sverdrup wrote more than 50 years ago: "One may ... raise the question whether a boundary region of the nature described can exist on a long horizontal distance ... it appears indeed likely that on a long distance it must be broken up owing to the intensive mixing processes, and that horizontal eddies of considerable dimensions may break away from the boundary region." Although the question remains, observations with new techniques suggest that the boundary is maintained over long horizontal distances as the jets meander equatorward, but that eddies may break away. The upwelled water (and the front associated with coastal upwelling) can extend farther offshore than previously realized. Cross-isobath flow, although generally small compared to the along-isobath flow over the continental margins, is of crucial importance to the physics and ecology of both the coastal ocean and the ocean boundary currents seaward of the shelf; this topic, especially over the inner shelf and in the bottom boundary layer, will be the focus of much future research, as will the problems of cross-frontal exchange.

In addition to preparing the review of studies in the eastern boundary regions associated with coastal upwelling, we continued the analyses of data from two of the experiments undertaken with ONR support:

Data from moored and shipborne Acoustic Doppler Current Profilers in the 1988 CTZ (Coastal Transition Zone) experiment were analyzed to obtain a more accurate estimate of transport in the CTZ jet by removing the tides from the ADCP data. Using the detided ADCP together with CTD data, the application of mass and salt conservation improves our view of the flow field around the box surrounding the 1988 CTZ surveys. One useful result is a fairly accurate estimate of the geostrophic transport carried by the CTZ jet (5.6-5.9 Sv in late June-early July). Noteworthy is a strong poleward undercurrent >20 cm/s centered about 100-200 m in depth, carrying at least 2.1 Sv of 'spicy' (warmer, more saline) water into the region in late July. This feature is only detectable if properly referenced geostrophic velocities are available; if the 500 dbar pressure field is assumed to be a level-of-no-motion, the undercurrent is hardly detectable.

Using data from moored ADCPs in the Gulf of Tehuantepec experiment, we investigated the extent to which it is possible to use the surface bin from the ADCP data to infer the wind speed and direction. The backscatter from the surface bin was found to be a significant predictor of wind speeds from nearby met buoys and the ship. Direction was more problematic, with the direction inferred from the ADCP surface bin falling between the direction of current in deeper bins and the wind observed from the ship.

LIST OF PUBLICATIONS (ONR GRANT # N00014-92-J-1177):

Smith, R. L., 1992: Coastal upwelling in the modern ocean. In: Upwelling Systems: Evolution since the Early Miocene, C. P. Summerhayes, W. L. Prell, and K. C. Emeis, Eds. Geological Society (London) Special Publication No. 64, 9-28.

Brown, J., E. D. Barton, P. M. Kosro, R. L. Smith, A. Trasvina and H. S. Velez, 1992: Estimation of surface winds from upward looking acoustic Doppler current profilers. J. Geophys. Res. 97: 17925-30.

Smith, R. L., 1992: Upwelling. In: McGraw-Hill Encyclopedia of Science and Technology, 7th edition, Vol. 19: 80-82.

Pierce, S. D., 1992: Structure and Transport of a Coastal Transition Zone Jet: The View from the "D" Line. Eos Trans. AGU, 72(51), 91. (Abstract)

Smith, R. L., J. A. Barth, A. Huyer and P. M. Kosro, 1992: The Coastal Jet: Its separation from the coast and its effect on an eastern boundary current. Eos Trans. AGU, 72(51), 50. (Abstract)

Barton, E. D., et al. including R. L. Smith, 1993: Supersquirt: Dynamics of the Gulf of Tehuantepec, Mexico. OCEANOGRAPHY 6: 23-30.

Pierce, S. D., 1994: Removing Tides From Shipboard Acoustic Doppler Current Profiler Data in the Coastal Transition Zone Experiment. Eos Trans. AGU, 75(3), 124. (Abstract)

Smith, R. L., 1994: On the process of upwelling: New observations and understanding. Rapp. P. v. Reun. Cons. int. Explor. Mer. Submitted in July 1994.

Smith, R. L., 1994: The physical processes of coastal upwelling systems. In: Upwelling in the ocean: Modern processes and ancient records. (Dahlem Konferenz). John Wiley & Sons. Submitted June 1994, revised November 1994.

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FINAL REPORT
N00014-92-J-1177
TITLE: EQUATORWARD JETS,
POLEWARD UNDERCURRENTS, AND
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