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Office of Health and Environmental Research
FINAL REPORT

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Project Title

***A Study of Sediment Motion and Bottom Boundary Layer Dynamics
over the Middle Atlantic Bight Shelf and Upper Slope***

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Objectives

As the project title indicates, our principal objective was to examine fluid and sediment dynamics over the shelf and upper slope off North Carolina (the Hatteras Shelf and Slope). A secondary objective was to study the circulation and export of shelf water in the region.

Approach

To meet these objectives, we conducted two field studies over the Hatteras shelf and slope. The first was done in 1994 within the inner shelf region off Duck, North Carolina. A collaborative effort with S. Lohrenz, V. Asper and E. D'Sa of Univ. of S. Mississippi and J. Largier of Scripps, this study involved acquiring a suite of measurements (water velocity, temperature, salinity, optical backscatterance, and fluorescence) from sensors attached to a tripod deployed at the 20 m isobath. We also took advantage a large set of ship-board measurements (CTD, ADCP and Fluorescence) acquired as part of the North Carolina CoOP Study.

Our second field study was done in 1996 as part of the OMP mooring array deployment over the Hatteras shelf. This was also a collaborative effort with Lohrenz et al. of the Univ. of S. Mississippi, L. Pietrafesa of N.C. State Univ., and G. Weatherly of Florida State Univ.. It was aimed at quantifying sediment and organic matter transport of the edge of the Hatteras Shelf. Towards this end, we deployed two heavily instrumented tripods at the shelf edge, and contributed CTDs, with optical sensors, to two moorings. Our instrumentation included optical backscatter sensors (OBSs) and miniature fluorometers. These were calibrated by Lohrenz to relate their signals to total suspended particulate mass, suspended pigment concentration and organic carbon concentration.

DOE Patent Clearance Granted

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Results to Date

Dynamics of organic material transport over the inner Hatteras Shelf

Analysis of the data from the 1994 study reveals several interesting features of the chloropigment distribution over the inner Hatteras Shelf. Two dominant scales of chloropigment variation are observed. On numerous occasions, small-scale (order m) structure in the near-bottom fluorescence field is seen, even in the absence of identifiable structure in the temperature and salinity fields. Over larger time/space scales, variations in fluorescence are related to changes in water mass properties that could be attributed to alternating events of upwelling and downwelling. This view is reinforced by shipboard measurements that reveal correlations between fluorescence and hydrographic fields, both of which are modified by wind-forced upwelling and downwelling and by the advection of low salinity water from Chesapeake Bay. During the study period, local sediment resuspension of sediments is not a significant contributor to the near bottom pigment load seen at the tripod. This is an upshot of the low bottom stresses that are likely typical of the Hatteras region during late summer. Estimates of chloropigment flux indicated a net shoreward transport of chloropigments in the lower boundary layer. These results have been summarized in a paper accepted for publication in the *Journal of Geophysical Research* (D'Sa *et al.*, in press).

Export of shelf water from the Hatteras Shelf

The export of Mid-Atlantic Bight shelf water from the Hatteras Shelf is believed to be a principal mechanism for removal of organic carbon produced on the shelf. We have examined this phenomenon using the moored instrument and shipboard CTD data acquired in the Hatteras Shelf and Slope region. Our analysis indicates two fairly distinct zones of export in this region. Shelf water loss in the northern zone, over $35^{\circ}40' - 36^{\circ}10'N$, occurs principally seaward of the shelf-edge. Seaward movement of shelf water into Gulf Stream meanders and into the circulation of water discharged from the Gulf Stream are identified as important agents in effecting this loss. Export of shelf water in the southern zone occurs over middle and outer shelf and is indicated by $5-10 \text{ cm s}^{-1}$ mean offshelf velocities measured by moored current meters. This loss is due in part to transport of shelf water in a strong offshelf current at the edge of the front separating MAB shelf water from the more saline shelf water of the South Atlantic Bight. The offshelf export of shelf water at the edge of the front is principally observed when the front is moving shoreward across the shelf. The intermittency of the seaward transport of shelf water at the front may be partly responsible for the variability of the presence and transport of shelf water seen at the edge of the Gulf Stream. These results are summarized by Churchill and Hamilton (1998).

Export of organic carbon from the Hatteras Shelf

Our analysis of the bottom boundary layer time-series data from the OMP tripods has produced some unexpected results. In contrast to our findings over the inner Hatteras Shelf, local sediment resuspension is found to be an important contributor to the near-bottom suspended pigment load seen at the Hatteras shelf-edge. Three principal processes are found to effect sediment resuspension at the shelf-edge. One is the expected onshelf intrusions of the Gulf Stream current. These produce 2-4 day episodes of strong near-bottom currents, directed to the northeast, with magnitudes in excess of 50 cm/s . Our velocity records suggest that such episodes occur over the outer Hatteras Shelf near Diamond Shoals at a period roughly 40 days. A second phenomenon

producing strong currents (>50 cm/s) and sediment resuspension over the outer shelf is a pulsing of the southwestward flow of MAB shelf water. This appears to be a part of a shelf-wide response to southwestward winds (G. Weatherly, pers. comm.). Bottom currents generated by strong local storms, common in the Hatteras region, constitute the third process responsible for sediment resuspension at the outer shelf. Currents associated with surface gravity waves are an important contributor to bottom stress production during storm events. This range of processes effecting sediment resuspension, results in an unexpectedly large variations in near-bottom pigment fluxes at the shelf edge. Nonetheless, a statistically significant offshore flux is calculated from the data.

Project Impact

Understanding of lateral transport of organic matter in benthic boundary layers is critical to determining linkages of carbon budgets between inner and outer shelf regions and between shelf and deep ocean environments. Our study has led to a better understanding of the suite of processes impacting near-bottom chloropigment transport in the Cape Hatteras region, where a significant export of organic carbon has been documented (DeMaster et al., 1994).

References

- Churchill, J. H. and T. J. Berger (1998) Transport of Middle Atlantic Bight shelf water to the Gulf Stream near Cape Hatteras. *J. Geophys. Res.*, **103**, 30,605-30,621.
- DeMaster, D. J., R. H. Pope, L. A. Levin and N. E. Blair (1994) Biological mixing intensity and rates of organic carbon accumulation in North Carolina sediments, *Deep-Sea Res. Part II*, **41**, 735-753.
- D'Sa, E. J., S.E. Lohrenz, J. H. Churchill, V. L. Asper, J. Largier and A. J. Williams, III Chloropigment distribution and transport on the inner shelf off Duck, North Carolina, USA. *J. Geophys. Res.*, in press

Project Outcomes-Deliverables

Scientific Publications

- Churchill, J. H. and T. J. Berger (1998) Transport of Middle Atlantic Bight shelf water to the Gulf Stream near Cape Hatteras. *J. Geophys. Res.*, **103**, 30,605-30,621.
- D'Sa, E. J., S.E. Lohrenz, J. H. Churchill, V. L. Asper, J. Largier and A. J. Williams, III Chloropigment distribution and transport on the inner shelf off Duck, North Carolina, USA. *J. Geophys. Res.*, in press

Published Abstracts

Churchill, J. H., P. Hamilton, L. J. Pietrafesa, and G. L. Weatherly (1995) Export of Middle Atlantic Bight shelf water near Cape Hatteras. *EOS, Transactions, American Geophysical Union*, 75, 43.

D'Sa, E. J., S. E. Lohrenz, J. H. Churchill, A. J. Williams, III, and V. L. Asper (1996) Pigment distribution and transport in the benthic boundary layer at the Cape Hatteras inner shelf, *EOS, Transactions, American Geophysical Union*, 76, 3.

D'Sa, E. J., S. E. Lohrenz, V. L. Asper and J. H. Churchill (1996) Observations of pigments and sediment suspensions in the benthic boundary layer at the Cape Hatteras inner shelf. *Journal of the Mississippi Academy of Sciences*, 40, 1, 65.

Presentations at National/International Meetings

Churchill, J. H., P. Hamilton, L. J. Pietrafesa, and G. L. Weatherly (1995) Export of Middle Atlantic Bight shelf water near Cape Hatteras. American Geophysical Union Spring Meeting, May 30-June 2, Baltimore, Md.

D'Sa, E. J., S. E. Lohrenz, J. H. Churchill, A. J. Williams, III, and V. L. Asper (1996) Pigment distribution and transport in the benthic boundary layer at the Cape Hatteras inner shelf, American Geophysical Union Ocean Sciences Meeting, February 12-16, San Diego, CA.

D'Sa, E. J., S. E. Lohrenz, V. L. Asper and J. H. Churchill (1996) Observations of pigments and sediment suspensions in the benthic boundary layer at the Cape Hatteras inner shelf," Mississippi Academy of Sciences, Sixtieth Annual Meeting, February 22-23, Jackson, MS.