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STUDY TITLE: A Physical Oceanographic Field Program Offshore North Carolina

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BACKGROUND: The present study is part of a sequence of programs designed to provide MMS with a basis for evaluating the potential environmental impacts of oil and gas exploration in Cape Hatteras region. Mobile proposed in the late 1980's to drill for gas in Manteo Block 467 and conducted engineering studies at the proposed drill site. These studies were determined by a review panel of physical oceanographers to be insufficient to serve the purposes of a comprehensive impact statement for the region. In keeping with the finding and in accordance with Congressional requirements, two studies were identified as necessary (1) a thorough literature and data review (OCS Study MMS 93/0031); and (2) this program, a detailed field measurement study.

OBJECTIVES: (1) To develop an adequate understanding of the physical oceanography of the Cape Hatteras region in a study area which extended from 34°30'N to 37°00' and from the coast eastward to 73°00'W (but excluding Chesapeake Bay); (2) the extent to which contaminants released over the continental slope can penetrate onto the shelf and thus shoreward; and (3) to address processes associated with flow between the slope area and the shelf break, flow across the shelf break, alongshore flow on the shelf, and cross-isobath flow towards the beach in the inner shelf zone.

DESCRIPTION: The study encompassed two years of field work from February 15, 1992, through February 22, 1994. Nine cruises were competed to perform mooring placement, servicing and recovery, and hydrographic measurements. Field measurement techniques included (1) 15 current meter moorings on the shelf and in deep water; (2) quarterly hydrographic surveys concurrent with current meter servicing cruises; (3) three special event surveys, which consisted of detailed hydrographic and shipboard acoustic doppler current profiler (ADCP) surveys of offshore flow or Virginia coastal water intrusions into Raleigh Bay, and two nearshore experiments with global positioning system (GPS) drifters during June and September 1993; (4) seven sets of langrangian drifter deployments designed to evaluate the potential for materials discharged near the shelf break to reach the nearshore region; and (5) collection of satellite infrared imagery of sea surface temperature, and meteorological and water level data along the coast within 500 km of Cape Hatteras, to support analysis and synthesis of the primary data.

SIGNIFICANT CONCLUSIONS: Data from this program confirm many notions about the nature of the complex circulation of the Cape Hatteras region, including the dominant role of the Gulf Stream and its meanders on Raleigh Bay and the shelf break just north of Diamond Shoals. Export of water from the Middle Atlantic Bight shelf occurs here in a band whose location can shift depending on the location of the Gulf Stream. Material released on the shelf outside a nearshore frontal zone, approximately 2-4 km from the beach, appears likely to be eventually entrained along the Gulf Stream.

STUDY RESULTS: The dominant oceanographic feature of the region is the Gulf Stream and it associated meanders and frontal eddies; while Slope Sea influences appear to be limited in the study area. Gulf Stream rings also appear to have little affect on regional circulation patterns except indirectly during interactions near Cape Hatteras between cold core rings and the Gulf Stream. Cold core ring interactions in April, June and December 1992 reduced Gulf Stream currents to practically zero at the slope moorings: C4, during all three events; B4, in April and December and A5, only in December. There were few current reversals above 300 m at the three moorings; the strongest reversal was at B4 during the December cold core ring interaction. The Gulf Stream path has its least variability, after leaving the confines of the Straits of Florida, in the area just southeast of Cape Hatteras. No seasonal patterns in the Gulf Stream path were discernible but there were clear one- to four-month trends and a possible 10 km annual shift in position. Gulf Stream currents were observable on the shelf consistently at moorings C3 and B3. Gulf Stream water was identifiable at mooring A3, the

northernmost shelf and generates marked contrasts in the temperature-salinity characteristics of the shelf region. Hydrographic data show possible interannual variability resulting from changes in Gulf Stream position, spring runoff, and winds.

Wind-forced currents on the shelf in winter present a classic Ekman response. Currents at all levels north of Diamond Shoals and at C1 and C2 surface were highly coherent with winds and sea level. Large wind-forced current fluctuations on the inner shelf north and south of Cape Hatteras had important contributions from pressure gradients caused by sea level differences around Cape Hatteras. Currents at lower levels in Raleigh Bay were less coherent with the winds and more coherent with the Gulf Stream. Gulf Stream forcing on the shelf is almost absent in winter because of the insulating affect of a strong shelf break front and stratification and stronger wind forcing. During summer the wind stress and sea level fluctuations are about half the magnitude of those in winter. Winds in summer 1993 were weaker than in 1992. In the summers of 1992 and 1993 there was evidence that Gulf Stream fluctuations were as far as the coast in northern Raleigh Bay (Line C).

Seasonal progression of stratification in the Middle Atlantic Bight, primarily through vernal warming, was observed; this process was augmented in 1993 by an anomalous high and early buoyancy flux from Chesapeake Bay. Stratification decreases spatially from north to south as a punctuated change concentrated at cross shelf front separating Middle Atlantic Bight and South Atlantic Bight shelf waters in the vicinity of Diamond Shoals. Stratification in Raleigh Bay is, in general, weak and may be driven by either temperature or salinity fluctuations.

Export of water from the Middle Atlantic Bight Shelf occurs in the region just north of Diamond Shoals, generally between moorings B3 and D2 when the Gulf Stream was away from the shelf but between D2 and D1 when the Gulf Stream was closer. This shifting region is where direct export to the Gulf Stream takes place. Some Middle Atlantic Bight water may also be exported to the Gulf Stream from Raleigh Bay after first instruding into Raleigh Bay over Diamond Shoals. A second mechanism for shelf water export is past the northern boundary of Gulf Stream north of Diamond Shoals is estimated to be about the same magnitude as the volume transport along the continental shelf north of Cape Hatteras. Raleigh Bay shelf water also appears to be exported by entrainment along the Gulf Stream front just south of Diamond Shoals. There often are converging shelf flows in the region of Diamond Shoals from the southward flowing Middle Atlantic Bight and northward flowing Raleigh Bay water.

A series of drogued drifters were recovered ashore in the Cape Hatteras region; while seven were found beached in England (1), France (3), the Canary Islands (1), and the Bahamas (2) 14-35 months after deployment. Estimates of residence time on the shelf ranged from less than eight to more than 27 days. In general the drifters deployed in Raleigh Bay had the shortest residence time.

Drifters tracks during the nearshore experiments reveal vigorous and highly variable coastal currents near the sea surface, which are clearly influenced by the wind to a

large degree. Comparison of the drifter velocities with the wind records from the Corps of Engineers facility at Duck, North Carolina show occasional departures from a classical nearshore wind response. Buoyancy-driven and surface wave-induced currents may also affect drifter motions. With regard to the former, cross-shore motion of the drifters appears to often have been influenced by the nearshore front common to the study area. Drifter convergence to the front is indicated by the tracks of two drifter deployments. On two other occasions, the front appears to have been the outer boundary of a zone of surface transport onto the beach. This transport is attributed to driving by the onshore wind component with likely assistance from surface wave-induced currents. On two occasions during these experiments ARGOS tracked drifters were eventually entrained in the Gulf Stream.

STUDY PRODUCT: Berger, T.J., J.O. Blanton, W.C. Boicourt, J.H. Churchill, P. Hamilton, D.R. Watts, and R.J. Wayland. 1994. A Physical Oceanographic Field Program Offshore North Carolina, Final Synthesis Report. OCS Study MMS 94-0047. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, Louisiana. 375 pp.

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