NOAA Technical Memorandum NMFS-F/NEC-17

Northeast Monitoring Program

Summary of the Physical Oceanographic Processes and Features Pertinent to Pollution Distribution in the Coastal and Offshore Waters of the Northeastern United States, Virginia to Maine

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts

December 1982

NOAA TECHNICAL MEMORANDUM NMFS-F/NEC

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3. *Definition of Management Units*. By Emory D. Anderson and Guy D. Marchesseault. October 1980. v + 4 p., 4 figs., 1 table.

4. *Fishery Management Techniques, A Review*. By Michael P. Sissenwine and James E. Kirkley. October 1980. v + 10 p.

5. *The Status of the Marine Fishery Resources of the Northeastern United States*. By Margaret M. McBride and Bradford E. Brown. December 1980. vii + 13 p., 4 figs., 3 tables.

6. *Economic and Biological Data Needs for Fisheries Management, With Particular Reference to the New England and Mid-Atlantic Areas*. By Guy D. Marchesseault, Joseph J. Mueller, and Ivar E. Strand, Jr. December 1980. v + 10 p., 1 fig., 3 tables.

7. *Methodology for Identification and Analysis of Fishery Management Options*. By Brian J. Rothschild, Richard C. Hennemuth, Jacob J. Dykstra, Leo C. Murphy, Jr., John C. Bryson, and James D. Ackert. December 1980. v + 10 p., 5 figs., 1 app.

(continued on inside back cover)

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NEMP IV 82 F 0004

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December 1982

ABSTRACT

Physical processes and features influencing the distribution and fate of pollutants in the coastal and offshore waters of the northeastern United States are identified and described. The general physical oceanographic setting of this portion of the North Atlantic is briefly presented before identifying the following relevant features and processes: estuarine effluent plumes, upwelling, warm core rings and Gulf Stream meanders, fronts, density stratification, the cold pool, bottom currents, and sediment transport. In addition, field measurements of pollutant dispersion and quantitative models and physical processes also are discussed.

Effluent plumes from the Chesapeake and Delaware bays, Hudson-Raritan Estuary, Connecticut River and the Merrimack River are seen as significant present or potential sources of pollutants or as features influencing distributional patterns of pollutants. Plume configurations are complex and dynamic, varying significantly in time scales ranging from tidal to seasonal.

Upwelling has been detected and reported seasonally present along the Virginia-New Jersey coastline, along the Rhode Island-Massachusetts coastline, near Nantucket Shoals and in Massachusetts Bay. In addition, some persistent upwelling appears to be commonly found along the northern edge of Georges Bank.

Warm core Gulf Stream rings and meanders have been frequently detected to be interacting with the water mass over the continental shelf in the Middle Atlantic Bight and invading Deep Water Dumpsite 106. Less frequently, rings have been seen interacting with the water mass on Georges Bank.

Fronts separating water bodies with considerably different properties have been studied along the northern edge of the Gulf Stream, separating shelf water from slope water, surrounding the well mixed areas on Georges

Bank and Nantucket Shoals, bounding estuarine effluent plumes, and bordering upwelling areas in a coastal active band throughout the Middle Atlantic Bight and Gulf of Maine. Most of these fronts can be detected by satellite infrared sensors.

Density stratification occurs seasonally throughout the region of interest, except in areas of strong tidal mixing such as central Georges Bank, Nantucket Shoals, and the eastern end of Long Island Sound. The presence of a thermocline during summer months acts as a barrier to the descent of many of the wastes presently dumped at sea, reducing the available mixing volume to the surface mixed layer.

The cold pool is a relatively isolated layer of cool water underlying the thermocline and mixed layer in the Middle Atlantic Bight each summer and early fall. Replenishment of dissolved oxygen in this layer is quite slow because of the density stratification of the thermocline. In 1976 a large portion of this layer suffered critically low oxygen concentrations and high mortality of benthic organisms resulted. Oxygen-demanding pollutants may have been a minor contributing factor, but the event was mainly caused by early stratification and unusual circulation patterns.

Field studies of dispersion of dumped wastes have been conducted at the 12-Mile Sewage Site and the Acid Dump Site in the New York Bight apex, the 35-Mile Dumpsite off Delaware, and the 106-Mile Site. Typically, settling velocities, mixing rates, and diffusivities were determined for selected waste materials in these studies.

Development of conceptual and numerical models for the region of interest has progressed mostly along general lines, covering broad areas. Few models are being or have been developed to deal specifically with the trajectories and dispersion of waste materials dumped in coastal and offshore waters.

CONTENTS

INTRODUCTION

What is the health of the marine ecosystem in the coastal and offshore waters of the northeastern United States? What are the impacts of man's waste disposal activities on the living marine resources in this ecosystem? These questions fall within the purview and are the concern of several Federal agencies which have a general commitment to answer them. In the Northeast, several elements of the National Oceanic and Atmospheric Administration (NOAA), with expertise to respond to this commitment, have jointly developed an integrated program, the Northeast Monitoring Program (NEMP), to provide a scientific basis for the answers. Managers and investigators involved in NEMP have selected a wide array of physical, chemical and biological variables to measure for establishing baselines and for monitoring changes at about 140 locations (Fig. 1), including areas where impact is expected, as well as those that are thought to be currently relatively uncontaminated.

Determining and understanding changes in the health or quality of living resources is not simple, because of the dynamic and complex nature of the ecosystem and the variety of ways man can or does influence this system, many of which are very subtle and difficult to measure. There are many questions that need to be answered to fully understand how significant these effects can be at the population or ecosystem level. A major area of understanding that is yet incomplete is the role of physical oceanographic processes and features in the transport, dispersion, and fate of pollutants in the coastal and offshore waters of the northeastern United States.

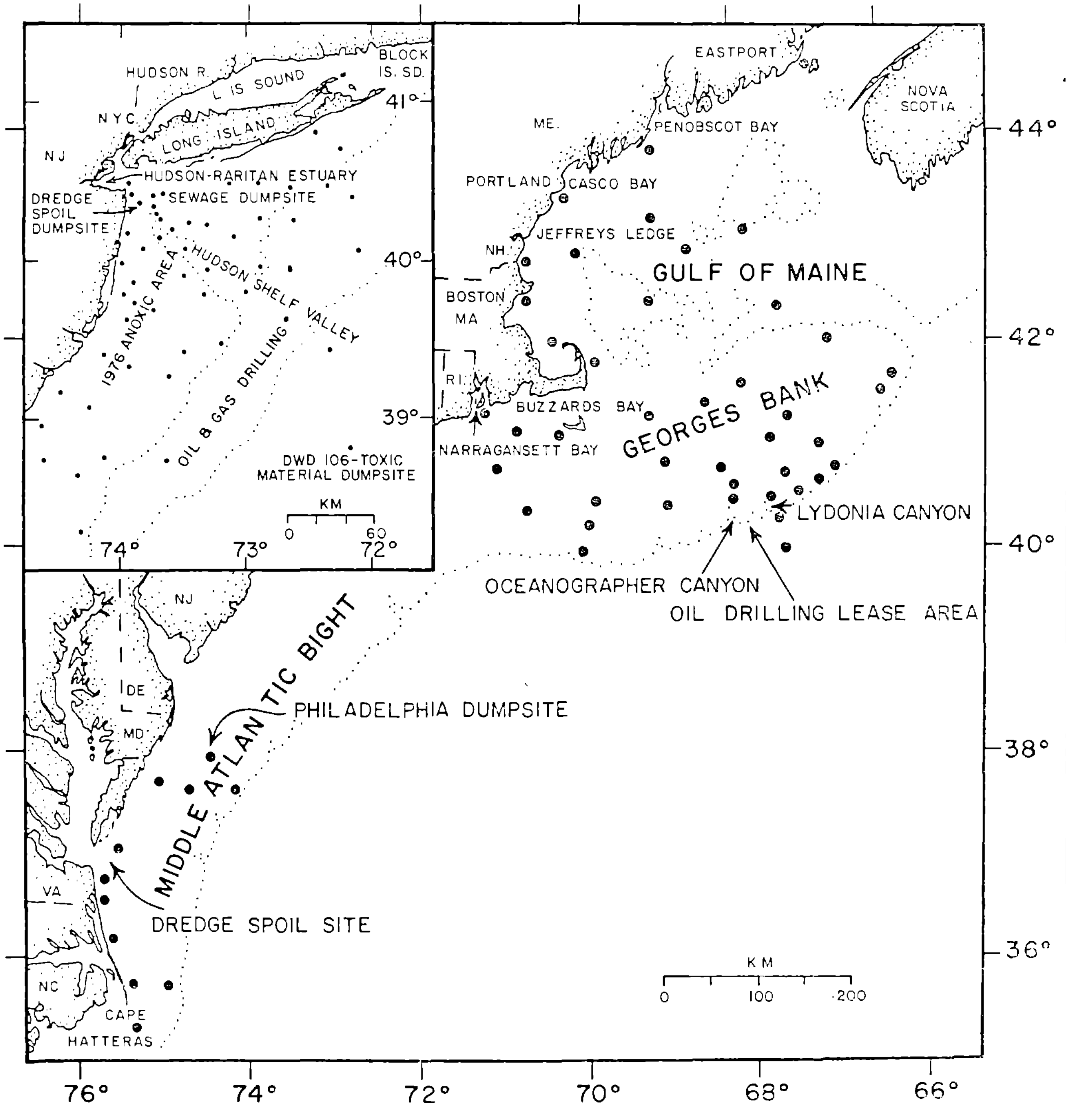

Figure 1. Northeast Monitoring Program area of interest, with major ecosystems indicated. (From Annual NEMP Report on the Health of the Northeast Coastal Waters of the United States, 1980. NOAA Tech. Memo. NMFS-F/NEC-10).

The physical oceanography of this area (the NEMP area) probably is as well studied and understood as any other coastal marine area in the world, as the number of entries in the bibliography of this summary attests. However, much of the data or information contained in these documents is often not readily available to or understood by non-oceanographers, especially those who need insights to plan research and monitoring programs or have to draw conclusions about cause and effect of pollution and are required to make management decisions on such topics as the siting of waste dumps.

In an attempt to make this information base more available and useful to researchers and managers concerned about resource health and ocean dumping impacts, a team of oceanographers was asked to work together to summarize what is known about the physical oceanographic processes of the marine waters off the northeastern United States, with special emphasis on those processes that influence the distribution of pollutants. This summary report is the result of this effort.

The organization of this summary basically treats relevant features and processes wherever they occur in the area of interest. Accordingly, chapters are devoted to estuarine effluent plumes, upwelling, Gulf Stream rings and meanders, fronts, density stratification, the cold pool, bottom currents and sediment transport, and dispersion of dumped pollutants. Following these chapters is one dealing with models of various processes. The information on models is consolidated in one chapter rather than scattered through the preceding chapters, in order to reduce the number of citations resulting from the multiplicity of applications of many of the models. The final chapter is a geographic summary composed of charts, locating the sites of the various relevant features and processes in the

NEMP area of interest. Following the last chapter is a bibliography of all pertinent publications located by the authors, listed whether they are cited in the text or not. Some of the listed entries are accompanied by abstracts or annotations.

AVERAGE CONDITIONS

Coastal and offshore waters of the United States north of Cape Hatteras (Fig. 2), can be subdivided on the basis of oceanographic characteristics into four subareas: the Gulf of Maine, Georges Bank, the Middle Atlantic Bight, and the Slope Water-Gulf Stream area. Most of the general, descriptive oceanographic reports and atlases relevant to this area deal with only one or two of these subareas, except for the summary reports by Bumpus (1973) and Hopkins and Garfield (1977). Nevertheless a general summary of average oceanographic and meteorological conditions in the whole area can be obtained from these two reports and from those prepared by Beardsley and Boicourt (1981), Williams and Godshall (1977), Godshall, et al. (1980), and Bumpus (1976).

The average circulation off the northeastern U.S. involves seasonally variable gyres in the Gulf of Maine and on Georges Bank, slow westward and southward flow on the continental shelf in the Middle Atlantic Bight, similarly slow southwestward flow in the slope water which occasionally carries one or more Gulf Stream warm core rings (eddies), and relatively rapid northeastward flow in the Gulf Stream (Fig. 3).

The gyre in the Gulf of Maine is a cyclonic (counter-clockwise) rotating feature which is strongest in the spring and early summer months, when flow into the Gulf from the Scotian Shelf and discharge from streams in Maine, New Brunswick, and Nova Scotia are the greatest. During fall and winter the gyre weakens, and its southern sector may break down allowing

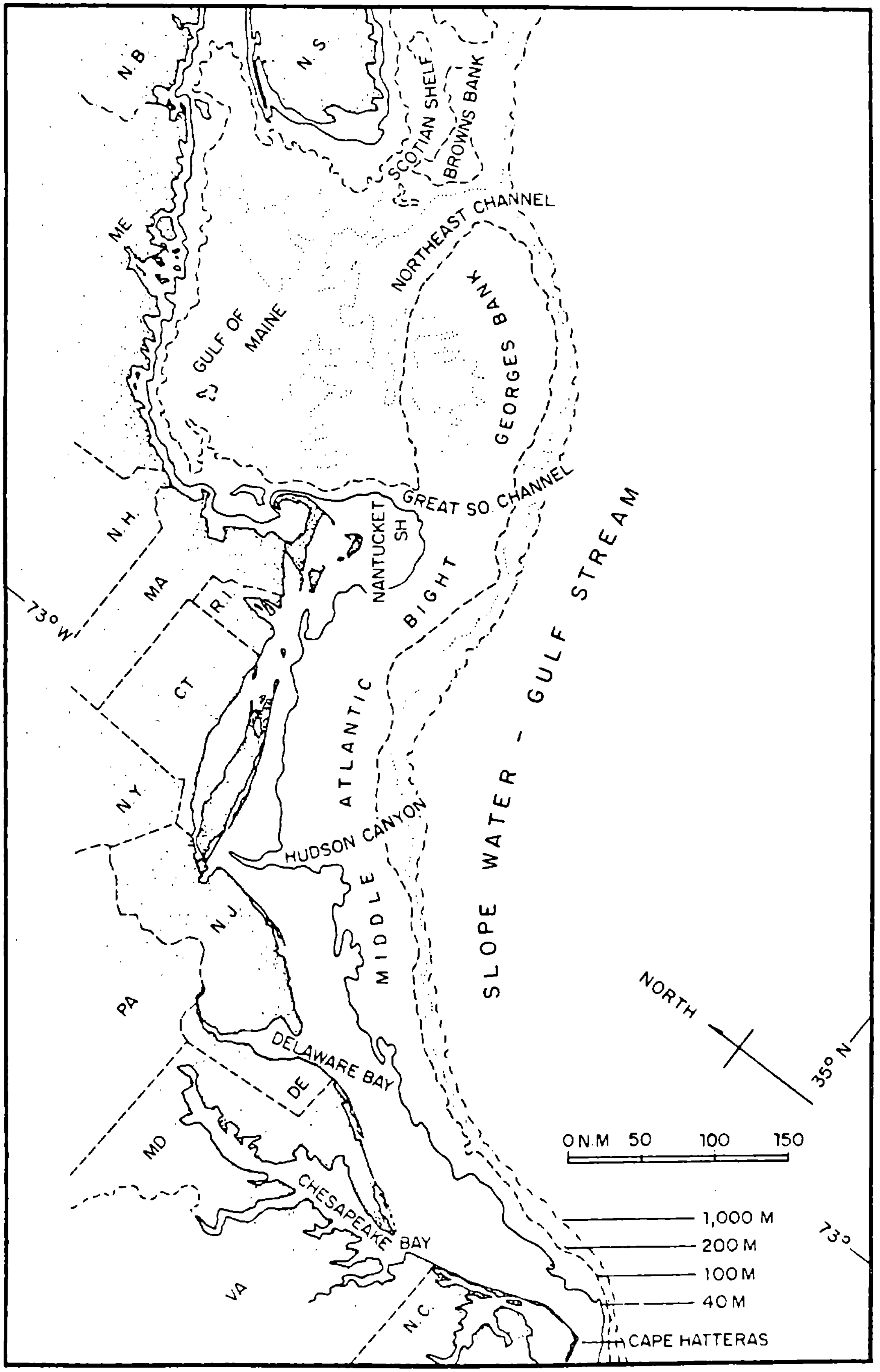

Figure 2. The North American coast and waters of the shelf and slope from Nova Scotia to Cape Hatteras, North Carolina.

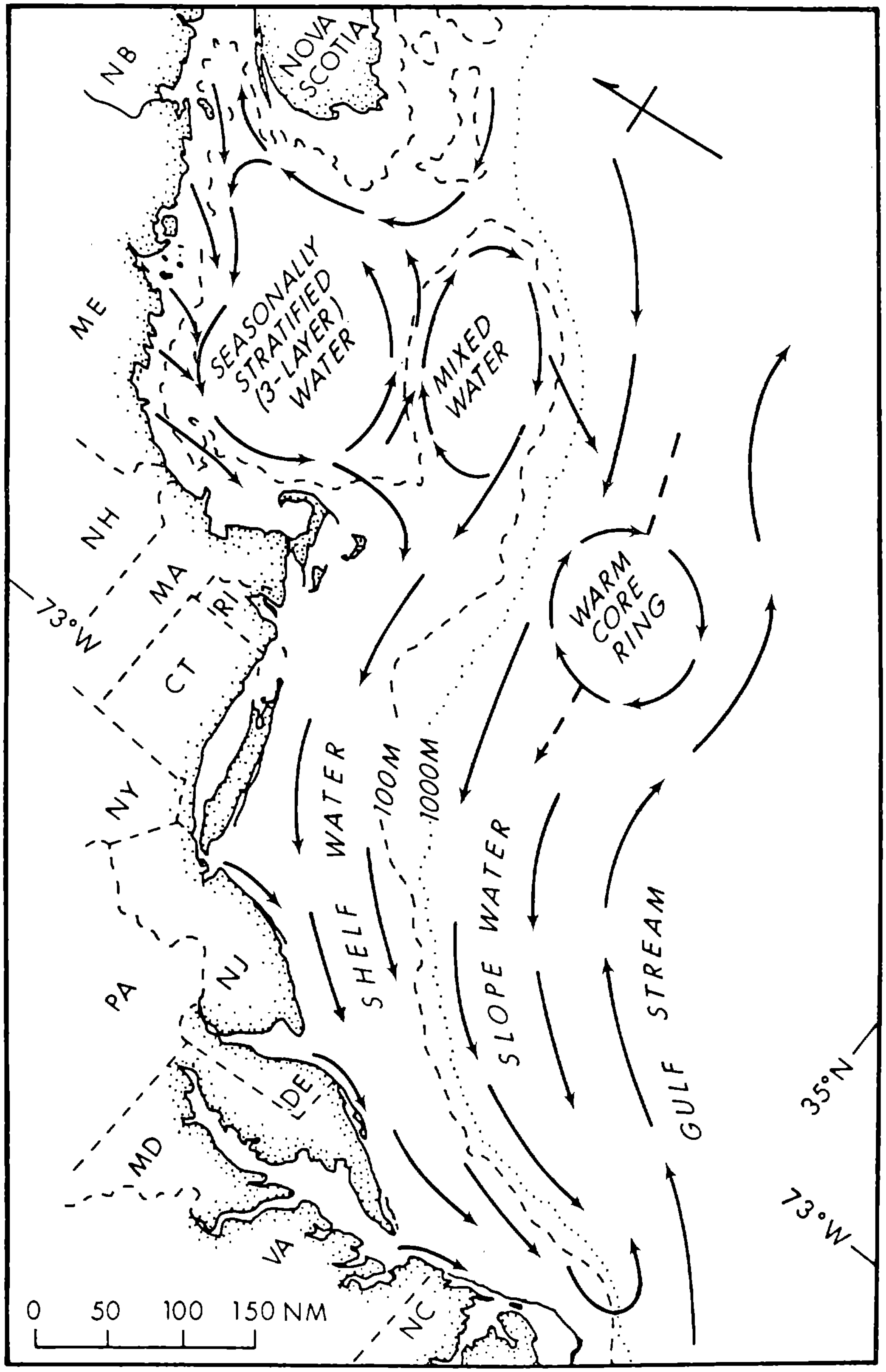

Figure 3. General surface layer circulation of northwestern Atlantic coastal and offshore waters.

water to drift southward onto Georges Bank and into Great South Channel. There are three water masses, identified by their temperature and salinity characteristics, found in the Gulf and variously involved in the gyre's motion: Maine Surface Water (MSW), Maine Intermediate Water (MIW), and Maine Bottom Water (MBW). The first two, MSW and MIW, are low salinity masses and the third, MBW, has a higher salinity derived from incursions of offshore slope water. The first two are involved in annual cycles of heating, runoff, stratification and overturn, but the third is not, and it changes only slowly, except when intrusions of warm, saline slope water occur or complete overturn happens in unusually cold winters.

The water on Georges Bank appears to be derived principally from MSW and MIW with minor additions of slope water which slightly increase its salinity. Because of strong tidal currents the water over the central, shallow (<60 m) portion of the Bank does not experience the stratification in spring and summer found in surrounding, deeper waters. Circulation on the Bank also involves a seasonally variable gyre similar to that in the Gulf, but in an anticyclonic direction (clockwise). This gyre is well developed in the spring and summer, but during the fall and winter its west side breaks down and a drift to the west and south occurs instead.

Shelf Water in the Middle Atlantic Bight undergoes stratification in the spring and summer, involving the development of a surface mixed layer of warm water underlain by a distinct thermocline. Beneath this seasonal thermocline over much of the shelf south of Cape Cod is a layer of water variously called the cool pool, cold cell, cold pool, or cold bottom water, isolated from surface heating effects by the thermocline. Deepening of the surface mixed layer and the attendant erosion of the thermocline begins in late summer and by late October-mid November thermal stratification is completely destroyed. From then until spring the water mass is vertically isothermal with the coldest water found nearshore and a weak horizontal gradient toward warmer water offshore.

An abrupt gradient to warmer, saltier water, called the Shelf/Slope Front, is usually located in the vicinity of the edge of the continental shelf. Long-term average motion of the shelf water mass is approximately parallel to the bathymetry toward the southwest, with speeds of about 5-10 $cm \cdot sec^{-1}$ at the surface and 2 $cm \cdot sec^{-1}$ or less in the bottom water (Hansen, 1977; Han and Niedrauer, 1981; EPA, 1978). Short period events, such as storms, can cause much more energetic variations in the flow field, and tidal currents on the inner shelf can range up to 100 $cm \cdot sec^{-1}$ near entrances of estuaries and generally up to 20 $cm \cdot sec^{-1}$ elsewhere.

The shelf water can be divided into two modes, low salinity (below 33.2 $^{o}/oo$ and high salinity (above 33.4 $^{o}/oo$), as revealed by the volumetric analyses of Hayes (1975) and Wright and Parker (1976). The less saline mode is generally found along the inner shelf in depths less than 60 m, and the more saline is found farther offshore in depths greater than 60 m. Nearly half the annual runoff into the Middle Atlantic Bight usually occurs during the spring (Bigelow and Sears, 1935), lowering nearshore surface salinities to less than 32 $^{o}/oo$. During the year 157 km^3 of runoff in the Middle Atlantic Bight mixes with slope water to produce about 2,400-3,400 km^3 of shelf water (Wright, 1976a; Bush, 1981). Shelf water losses from the Middle Atlantic Bight occur near Cape Hatteras where the Gulf Stream entrains it (Fisher, 1972) and across the Shelf/Slope Front in turbulent exchange processes.

The slope water mass has been thought of as a mixture of shelf water and Gulf Stream water, the masses which abut it on the shoreward and seaward sides, because its temperature and salinity ranges lie in between those of its neighboring masses. Recent work by Fairbanks (1982) using oxygen isotope ratios to identify source areas of Atlantic coastal water masses revealed that slope water mainly is derived from the Labrador Sea with some Gulf Stream water mixed in (via warm core rings). The average motion of this water mass is much like that of the shelf water, parallel to the bathymetry and toward the southwest. Aperiodically, the slope water area is invaded by meanders of the Gulf Stream or warm core rings separated from the Stream, either of which radically change the local water mass properties and circulation at any given location.

Circulation of the surface layer of shelf and slope water is strongly influenced on short (multi-day) time scales by weather conditions in the overlying air mass. Summaries of long-term mean weather conditions have been prepared for the Middle Atlantic Bight and Georges Bank (including the Gulf of Maine) by Williams, et al. (1977) and Godshall, et al. (1980). Together, the two summaries adequately cover the geographic area of concern to this study in terms of surface wind, visibility, air temperature (Georges Bank) and superstructure icing. Earlier atlases for the North Atlantic (Meserve, 1974; U.S. Naval Oceanographic Office, 1963; and Naval Weather Service Detachment, 1976) include our area of interest only in their broader portrayal of mean monthly or seasonal conditions.

According to Godshall, et al. (1980), the northern part of our area of interest falls between the normal summer and winter locations of the Polar Front, yielding two distinctly different wind regimes in the two seasons. Summer (actually May-August) is characterized by southwesterly winds associated with large-scale circulation of subtropical anticyclones (highs). Winter (October-March) winds are northwesterly or westerly, stronger, and associated more with smaller-scale circulation systems.

For the Middle Atlantic Bight, the southern part of our area of interest, Williams, et al. (1977) attribute the northwesterly wind field of winter to the dominance of the Icelandic Low (cyclonic), yielding a vector mean of 7-9 knots (3.5-4.5 $m \cdot sec^{-1}$) from the WNW-NW. The summer wind field is dominated by the Bermuda Subtropical High (anticyclonic), characterized by SW winds of 3.5-4.5 knots (1.8-2.2 $m \cdot sec^{-1}$ vector mean).

In their discussion of estuarine and continental shelf circulation in the Middle Atlantic Bight, Beardsley and Boicourt (1981) summarize what is known about atmospheric forcing over the continental shelf. They point out that synoptic scale (>2 days, >500 km) disturbances are responsible for most of the surface wind variance over the shelf and open ocean. This is manifested in the Middle Atlantic Bight as frequent, intense cyclones (low pressure systems); 2.5 per month in summer, 5 per month in winter and more intense in winter than in summer. The cyclones are produced by the interaction between warm, moist, maritime air and cooler, drier, continental air, and characteristically intensify as they move northeastward along the shelf toward Georges Bank and Nova Scotia. The mean surface wind stress is eastward-southeastward except in summer, when it is northeastward, and the mean stress is generally stronger offshore (2 to 8 times at the shelf edge) and veers cyclonically (up to 30°) with increasing distance offshore.

Air temperature in winter over the coastal water from Maine to Virginia is strongly influenced by the cold, continental air masses moving over the ocean during episodes of strong W-NW winds. Lettau, et al. (1976) prepared a plot of monthly average air temperatures along the New York and New Jersey coasts which shows a minimum of about 2°C in January-February and a maximum of about 25°C in July-August. According to the plot, fall cooling occurs more rapidly than spring warming, -4.4°C/month vs. +4.0°C/month. Farther seaward the magnitudes of the minimum and maximum would be moderated, but the profile of the annual cycle would be very similar. About 100 km off the New Jersey coast, the January-February minimum is about 4°C and the July-August maximum is about 25°C. Southward, in the vicinity of Norfolk, the same distance offshore, the minimum is about 7°C and the maximum is about 26°C. In the northern portion of our area of interest, in the Gulf of Maine, minimum average air temperatures are about 0°C and the maximum is about 18°C (Naval Weather Service Detachment, 1976).

A word of caution regarding the value of summary statements of average conditions worth noting is that offered by Hopkins and Garfield (1977) as follows:

> "An inherent danger associated with superficial reviews is a tendency towards oversimplification, thereby giving a false impression of either the detail required to understand the system or the system itself. A good example of this tendency is the use of long term mean conditions to describe a system. It is now known that these mean conditions likely have no relevance for shorter time periods or often for other equally long periods. Particularly in coastal regions where much of the energy is found at the 'event' scale (1/2 to 3 days) long term means represent only a small portion of the total energy. The state of

understanding of the physical system prevents us from providing a description covering the full frequency range at any point let alone the entire coastal zone."

ESTUARINE EFFLUENT PLUMES

Flow from coastal estuaries forms plumes of low salinity water which spread over the surface of the shelf water mass. These plumes often carry pollutants from discharges and runoff in their source estuaries, and accordingly can be regarded as major point sources for a variety of pollutants. Also, the strong salinity and temperature fronts which bound the plumes are line convergences, which tend to concentrate floating materials, including particulate pollutants which are buoyant or attached to buoyant materials. The characteristic form of the plumes provides an indication of which regions of the bottom are most likely to receive particulate materials that slowly settle from the plume waters and which portions of the shelf water mass are likely to experience unusually high levels of phytoplankton productivity resulting from the higher concentrations of nutrients carried by many of the plumes.

Hudson-Raritan Plume

Ketchum et al. (1951) provided the first extensive hydrographic survey of the apex of the New York Bight. Their salinity and temperature data showed that the volume of river water in the plume entering the Bight from the Hudson River rarely exceeded 1% of the total volume of the Bight apex. This calculation, together with knowledge of the average discharge from the river system, led them to conclude that the residence time of river water in the Bight apex was only 6-10 days, indicating relatively rapid dispersion of the plume. Han and Niedrauer (1981) extended Ketchum's analysis with more recent data and obtained residence times ranging from 5.5 to 12 days with an average of 6.8 days.

More recent work by Charnell and Hansen (1974) and Bowman and Wunderlich (1977) have shown that the Bight waters are dominated by spring season runoff. During these high discharge periods the Hudson River plume is generally parallel to the New Jersey coast due to a southwest deflection caused by the Coriolis effect and shelf currents (Fig. 4). Winter mixing due to storms can rapidly and completely mix the entire water column; re-establishment of the river plume in the Bight takes approximately 2 days. During periods of lesser discharge (summer), location of the plume becomes highly variable and strongly wind-influenced. Bowman (1978) showed from data taken in August 1976 that the set and shape of the river's plume varied widely over a 6 day time period and were influenced by wind stress. Mechanisms by which the plume is mixed into the surrounding shelf waters are not well understood at this time.

Computations of the particle flux from the Hudson River plume to shelf waters of the New York Bight, based on current meter data and water samples, were made by Young and Hillard (ms).[1] Suspended matter fluxes were highest (about 30 x 10^{-6} g·sec^{-1}·cm^{-2}) during periods of spring runoff as a consequence of increased flow, not increased concentrations of suspended particulate matter. At other times the quantity of particulate matter carried by the Hudson plume appeared to be "---negligible compared with discharge through other adjacent coastal sectors---."

They also found that suspended particulates in the surface plume of the Hudson River were present in concentrations usually higher than in

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[1] Young, Robert A. and Bruce F. Hillard, U.S. Dept. of Comm., NOAA, Atlantic Oceanographic & Meteorological Laboratories, 4301 Rickenbacker Causeway, Miami, FL 33149. "Preliminary observations of particle flux related to the Hudson River Plume, New York Bight."

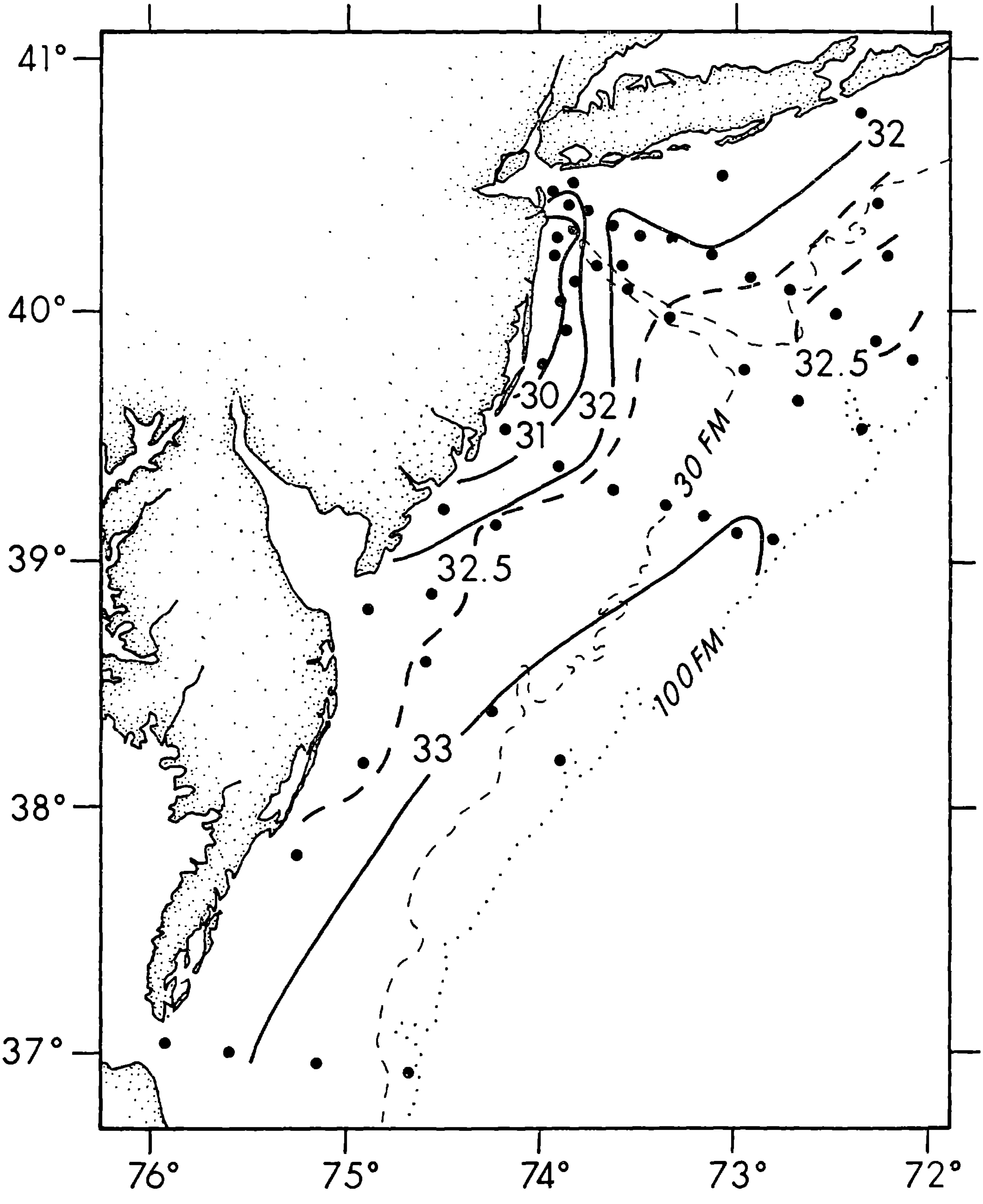

Figure 4. Effluent plume from the Hudson-Raritan estuary as revealed by surface salinity (parts per thousand). From a report of results of cruise NEMP-81-07 of the GEORGE B. KELEZ, 3-9 June 1981, by C. E. Warsh, 18 June 1981.

surface waters off Long Island or bottom waters off New Jersey. The greatest concentrations, except in high runoff periods, were found in bottom waters off western Long Island, assumedly due to resuspension of sediments from the broad, shallow shelf by wave action. Concentrations measured on eight cruises at least showed traces of the plume. During the April cruise, during high runoff, the particulate plume extended broadly southward along the New Jersey coast at least 70 km.

Drake (1974 and 1977) and Nelsen (1979) found average surface concentrations of suspended particulate matter in the plume to range from 1 to 10 $mg \cdot L^{-1}$ and the edge of the plume to generally lie 5 to 10 km offshore.

Fedosh and Munday (1982) analyzed 86 cloud-free images from satellite sensors (58 Landsat color and 28 infrared) for indications of surface configuration of the Hudson-Raritan plume. In the mouth of the estuary the turbidity plumes were typically lobed, filled the entire entrance, and curved southward in the alongshore drift. Those plumes which extended farther seaward tended to be more linear in form and spread farther laterally. Plumes extended farthest seaward under the influence of northwesterly winds. Thermally mapped plumes had longer frontal regions than turbidity plumes.

They also found that 51% of the plumes extended to the dredge spoil dumpsite (25 km) and 12% reached the sewage sludge dumpsite (35 km). None of the 82 plumes studied reached the acid waste dumpsite (45 km).

Delaware Bay Plume

Studies of surface circulation in Delaware Bay and on the adjacent continental shelf out to about 50 km offshore using drifters provide some indirect indication of effluent plume characteristics (Pape, 1981). Nine releases of surface drifters during the April 1979-March 1980 period showed predominantly out-of-bay and southward trajectories along the DelMarVa shore to the Chesapeake Bay entrance and beyond. After one deployment (July 31) drifters passed Cape Hatteras and were recovered along the coast of North Carolina. Some northward motion was indicated by a few drifters on four releases, and on one release (November 15) all the drifters moved north outside the bay entrance.

A study of 129 satellite clear-sky images, both color and infrared, conducted by Fedosh and Munday (1982) showed that the turbidity plume from Delaware Bay often was manifested in two bands. One band was located off Cape May (north of the bay) and the other off Cape Henlopen (south of the bay). The Cape May turbid zone was the larger of the two, usually filling about 70% of the bay entrance. Its configuration was highly variable, often extending southeastward, but occasionally northeastward along the New Jersey coast. The Cape Henlopen turbidity plume was more linear in shape and about one-tenth as large. Its orientation was characteristically southeastward, veering southward along the coast.

Most of the plumes detected remained within 20 km of the Delaware coast and extended southward as much as 40 km. None of the plumes reached the acid waste disposal site located 60 km southeast of Delaware Bay. The thermal images revealed a different plume pattern, occasionally showing three bands corresponding with the turbidity pattern and at other times showing only a single warm plume near Cape Henlopen.

Chesapeake Bay Plume

Chesapeake Bay receives the discharge of several rivers including the Susquehanna (50%), Potomac (18%) and the James (14%). Other lesser rivers total the remaining 18% (Hargis, 1981). The annual outflow from Chesapeake Bay to the Atlantic Ocean is estimated to be about 60 km^3 (Schubel, 1972). This constitutes over 50% of the estuarine inflow to the Middle Atlantic Bight (Beardsley, et al., 1976). Outflow of the low salinity water from the estuary results in a near-surface plume which extends seaward a highly variable distance beyond the mouth of the estuary. The offshore boundary of this low salinity, buoyant plume occurs as a sharp front.

Outflow of low-salinity water is affected by river discharge rates and by local wind and coastal current effects, but can also be affected by the setup of pressure gradients on the adjacent continental shelf (Wang, 1979; Wang and Elliot, 1978).

Discharge effects were greatest when Hurricane Agnes caused extremely high discharge in the Bay during June 1972, resulting in the extension of the low salinity plume 45 km eastward across the shelf (Schubel, et al., 1976). Because of the storm's heavy rainfall, freshwater discharge into the Bay increased from 2.1×10^3 m^3 sec^{-1} to 48.1×10^3 m^3 sec^{-1}. Salinities of less than 30 $^o/oo$ were observed (Boicourt, 1973) along the Virginia-North Carolina coast as far south as Oregon Inlet, North Carolina, about 130 km south of the bay mouth (Fig. 5).

In contrast, during the second half of 1980 a severe drought affected the northeastern United States, causing reduced discharges into the bay, with some streamflows falling to 30% of normal. Salinities less than 30 $^o/oo$ were observed no farther than the immediate vicinity of the bay mouth during October 1980 (Thomas, 1981).

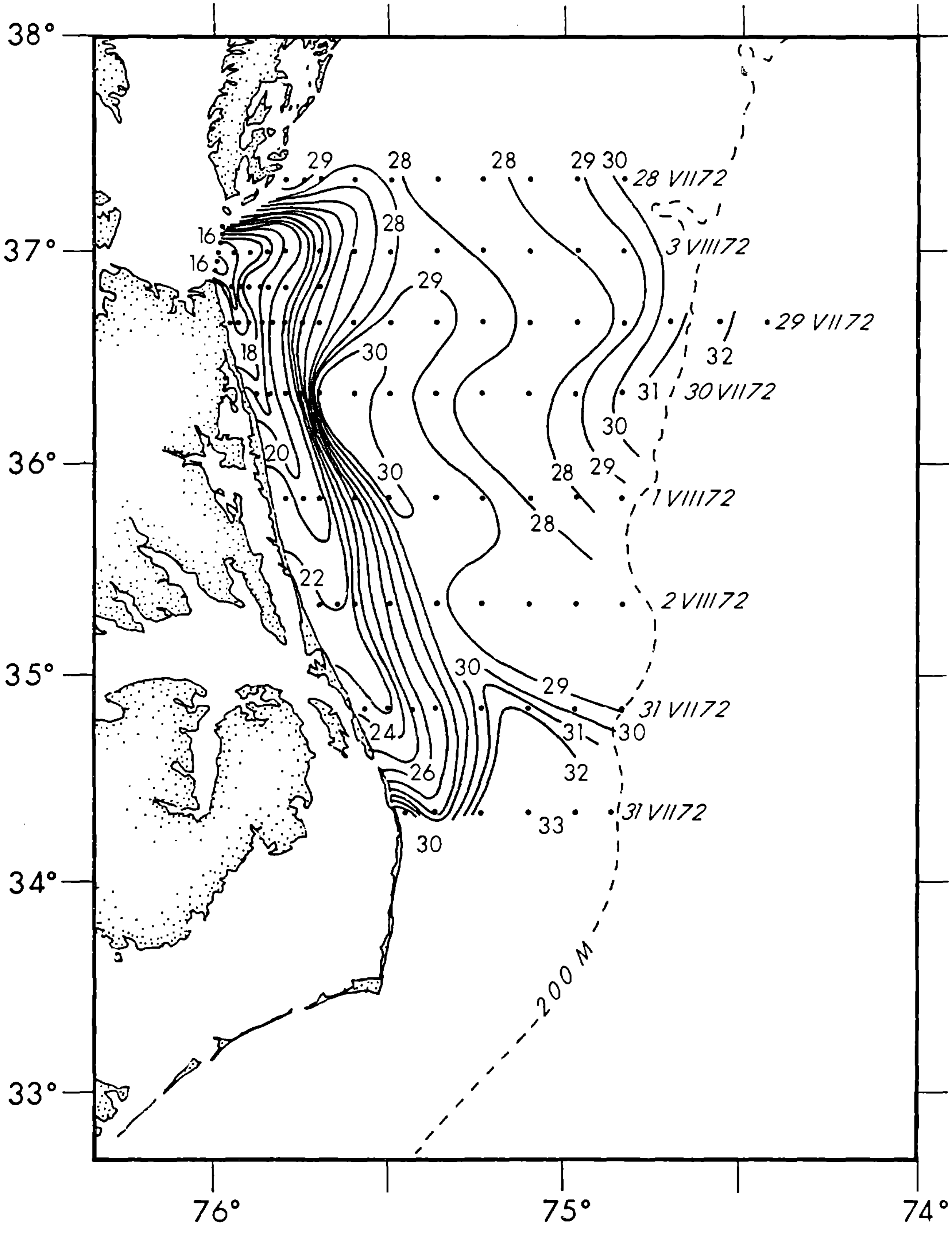

Figure 5. Effluent plume from Chesapeake Bay as revealed by surface salinity (parts per thousand) during 28 July-3 August 1972 after the passage of Hurricane Agnes in June. From Boicourt, 1973.

The estuarine circulation of lower Chesapeake Bay involves two-layer flow, with the upper layer discharging low-salinity water onto the continental shelf while the lower layer moves higher-salinity shelf water into the bay (Pritchard, 1955). Generally, over a series of tidal cycles and as a result of estuarine circulation, freshened bay water exists at the surface on the southern side of the bay mouth (Cape Henry) and is deflected to the right by the earth's rotation. Boicourt (1973) in a synoptic study following Hurricane Agnes showed that the outflow turned to the south and flowed as a quasi-geostrophic jet along the Virginia-North Carolina coast with greatest thickness nearshore, with the halocline shoaling to a high-shear lateral front 8-15 km offshore.

For a recent, time-series perspective, Munday and Fedosh (1981) examined 81 dates (1972-80) of Landsat images using enhancement and density slicing techniques and showed that the Chesapeake Bay plume usually lies off the Virginia coast south of the bay mouth. Southwesterly winds spread the plume eastward over a large area. Ebb tide images (compared to flood tide images) showed a more dispersed plume.

The remote sensing aspects of the SUPERFLUX experiments (Campbell and Thomas, 1981) further confirmed the two-dimensional structure of the plume with respect to salinity, chlorophyll, suspended solids and crude phytoplankton assemblages in much greater detail and more synoptically than the traditional sampling used to estimate its character. Of particular interest was the identification of patches of higher or lower salinity water in the plume (Kendall, 1981).

Waters emanating from Chesapeake Bay to the contiguous shelf are not homogeneous. Oertel and Wade (1981) demonstrated the lack of congruence between graphic presentations of the various constituents within the plume. They were able to define three separate subplumes emanating from the bay; one each for salinity, total suspended matter, and hydrocarbons associated with total suspended matter.

On ebb, water emerges from Chesapeake Bay and flows south along the coast, while shelf water from along the DelMarVa Peninsula is transported southward between the plume and shelf water southeast of the bay entrance (Sarabun, 1981). South of Cape Henry, the three water types interact and mix. During flood, the tidal currents off Virginia Beach are directed roughly northwest which results in the scalloping of the plume edge seen in Seasat-SAR imagery of the coast south of Cape Henry.

Upper-layer flow measurements lend further credence to the idea that the Middle Atlantic Bight shelf currents are ordered in a series of bands parallel to the coast (Boicourt, 1981). The outer shelf water is moving south in the mean, while the inner shelf is at the mercy of the winds, such that the summer flow is typically to the north. The narrow (10-20 km) band along the coast can be affected by estuarine circulation such that, along the Virginia and North Carolina coasts, the flow is to the south. The strength and spatial extent of this influence depends primarily on the magnitude of the estuarine outflow. Evidence of banding (parallel to the coast) for this area is seen also in satellite thermal imagery (Vukovich and Crissman, 1981). The southward-flowing shelf waters along with admixtures of the Chesapeake Bay plume eventually become entrained in the Gulf Stream off Cape Hatteras (Fisher, 1972; Ruzecki, et al., 1976) except on occasions when strong northeast winds force these waters around Cape Hatteras and into Raleigh Bay (Stefannson, et al., 1971).

Connecticut River Plume

Fresh water discharged by the Connecticut River (560 $m^3 \cdot sec^{-1}$ mean discharge) passes into New York Bight via the eastern end of the Long Island Sound (Garvine, 1975). The Connecticut River's mean rate of discharge is about the same as that of the Hudson River, and its plume has been shown to affect salinities of shelf waters south of Montauk, Long Island (Ketchum and Corwin, 1964). High river discharge during spring runoff results in shelf salinities about 2 $^o/oo$ less than those during low discharge periods. This effect extends to a depth of 60 m south of Montauk.

Gulf of Maine Tributary Plumes

Even though total river discharge from New England (including Connecticut) is double that of the Hudson and Delaware systems combined and about thirty percent larger than that entering Chesapeake Bay (Miller, et al., 1963), it is distributed among a large number of small rivers. This is particularly true for tributaries to the Gulf of Maine. As a consequence, distinct major plumes aren't observed there; the many small plumes blend into a relatively narrow coastal band of low salinity instead. No publications dealing with plume configurations in the Gulf of Maine were found in the literature search associated with this study.

Studies of hydrographic and current meter data collected in Massachusetts Bay reported by Butman (1978) showed that the low frequency currents in this portion of the Gulf of Maine are dominated in the spring by flow from the Merrimack River. The river enters the Gulf of Maine about 30 km north of Cape Ann, the northern edge of Massachusetts Bay, and its plume flows southward around the cape into the bay where it forms a lens of relatively fresh water. The density field associated with the lens causes clockwise circulation (geostrophic) around the lens.

UPWELLING

The process of upwelling, whether wind-driven (divergent transport of surface water by wind action) or dynamic (interaction of currents and bathymetry) involves divergent horizontal transport of surface water which is replaced by deeper water with different properties. The area of upwelled water usually is bounded by a front, where upwelled water converges on the indigenous surface water. Thus, upwelling, if occurring in polluted waters, also would transport pollutants horizontally, and the fronts created by the upwelling process could concentrate floating pollutants. Upwelling of anoxic bottom water, such as that which occurred along some New Jersey beaches in the summer of 1976, can impact on marine organisms in the nearshore area and human utilization of these waters.

Frequently, upwelling leads to increased phytoplankton productivity, because of the higher concentrations of dissolved nutrients carried by the upwelled water. If this occurs in a nearshore area that already carries high nutrient concentrations from runoff and discharges of waste materials from urban centers, it may drive the coastal ecosystem closer to eutrophication. Some of the nearshore band of high phytoplankton productivity found along the northern New Jersey coast involves the interaction of these two enrichment processes.

Northern Georges Bank

Bigelow (1927) first implied that upwelling was active along the northern edge of Georges Bank and discussed the resultant "consumption" of slope water during the spring. Since then various measurements have been made that imply that the process of upwelling occurs either continuously or intermittently. However, direct observations of upwelling have not yet been made.

Lagrangian bottom drifters released along the Northeast Channel (Lauzier, 1967) show a zone of divergence implying upwelling of bottom water along the northeastern edge of Georges Bank. Current meter moorings placed in an array across the northern slope of the bank have shown evidence of a divergence off the northern edge (R. J. Schlitz, personal communication)[2]. The meters located below 80 m on two moorings in water depths of 200 m and 220 m all showed components of current away from the bank (north). The average speeds were between 2 and 6 $\mathrm{cm \cdot sec^{-1}}$ for the duration of the records, up to 47 days. In addition to evidence from direct measurements of current, Pastuszak, et al. (1982) have concluded that there are indications of upwelling near the northeastern edge in nutrient and hydrographic data collected over the period of one year.

One mechanism that may induce upwelling has been proposed by Garrett and Loucks (1976) from a study of upwelling near the southwest corner of Nova Scotia. Centrifugal forces generated by strong tidal currents associated with features of bottom topography of small radius of curvature produce upwelling independently of the current direction. Both conditions are found at the eastern end of Georges Bank where the bottom contours turn from an east-west to a north-south orientation. A second mechanism was proposed by Loder (1980) in his model of rectification of tidal currents along the northern edge of the bank, in which cells develop in the cross-isobath direction involving flow onto the bank along the bottom above the 60 m isobath.

[2] Dr. Ronald Schlitz, U.S. Dept. of Commerce, NOAA/NMFS, Woods Hole, MA 02543

Massachusetts Bay

Analyses conducted by Kangas and Hufford (1974) of temperature profiles collected by bathythermographs on the Boston Lightship (32 m water depth) during 1964-71 revealed that upwelling commonly occurs there during summer. Prevailing winds from the southeast to west, common during the summer, provide the offshore transport of surface waters followed by upwelling of deeper, cooler water.

Middle Atlantic Bight

During the periods of prevailing southwesterly winds, mostly in the summer months, upwelling should occur along the New Jersey-Virginia coast. An analysis of surf temperatures wind velocities, and nearshore temperature sections off Monmouth Beach, N.J. by Hicks and Miller (1980) demonstrated the linkage between southerly winds and shoreward motion of the cold bottom water, which in many cases came into the surf zone.

In the analysis of data and events involved in the development of anoxic conditions in the bottom water and resulting high benthic mortalities off New Jersey in the summer of 1976, some evidence of upwelling was uncovered. Mayer, Hansen and Minton (1979) found indications of upwelling off northern New Jersey in 5 of 13 months and off western Long Island in 8 of 12 months of current meter data; in each case it was persistent enough to register in monthly mean current vectors. Analysis of wind field observations for the inner New York Bight for February-June 1976 by Diaz (1979) produced monthly mean offshore transports (computed Ekman) in the surface layer each month, but strongest off New Jersey in February. Steimle and Sindermann (1978) reported observations of dead and dying fish and hydrogen sulfide odors in the surf zone of the south central coast of New Jersey in late July and early August, indicating upwelling of the anoxic bottom layer clear into the surf zone. Nelsen, et al. (1978) and Mayer and Han (in press) have identified a relationship between local wind stress and onshore flow of bottom water in the Hudson Shelf Valley (upwelling) in the apex of New York Bight.

Upwelling conditions along the south coast of Long Island have been found to be dependent upon local winds. Scott and Csanady (1976) found that eastward wind stress caused offshore flow in the surface layer and compensating onshore flow near-bottom, during summer stratified conditions in 32 m water depth 11 km offshore. They found westward wind stress caused flow in the reverse directions. Han and Mayer (1981), however, observed offshore surface currents and onshore near-bottom currents during periods of <u>both</u> eastward and westward wind stresses, at a point 6 km offshore in 18 m water depth. Upwelling in response to westward wind stresses there is inconsistent with Ekman theory. They found offshore bottom layer flow (downwelling) only in response to <u>strong</u> westward and northward wind stresses.

Indirect evidence of upwelling south of Long Island has been reported by Walsh, et al. (1978) in distributions of chlorophyll, nutrients, and zooplankton together with some wind and current data. These data showed episodic mixing and upwelling events associated with the passage of storms. During stratified periods, storms caused upwelling along the coast as evidenced by higher nutrient concentrations. During unstratified periods storms caused increased nutrient concentrations throughout the water column over a broader area, due to mixing of near-bottom nutrients upward.

Studies with surface and bottom drifters in Rhode Island Sound (Cook, 1966) revealed surface drift to be offshore and bottom drift onshore during the fall and winter. Additional studies by Collins (unpub. manuscript)[3] showed maximum returns of seabed drifters in December 1975, January and February 1976 from releases in Rhode Island Sound during May and September 1975. In both studies the development of upwelling conditions was associated with the westerly-northwesterly winds of late fall and winter. Collins also found support for offshore drift of surface waters during this period in his analysis of sea level records.

WARM CORE RINGS AND GULF STREAM MEANDERS

Meanders and warm core rings formed in the Gulf Stream are mesoscale (100 km or more) features which exhibit relatively slow translational speeds (kilometers per day) and rapid angular speeds (kilometers per hour). Both types of motion can affect the transport or dispersion of suspended or dissolved pollutants dumped into the meanders and rings or in the water they entrain from the shelf and slope water masses. The current shear found near the high speed ($>1\ \mathrm{m\cdot sec^{-1}}$) portion of these features can be an effective dispersive mechanism, while also transporting the pollutant materials considerable distances along circuitous trajectories.

Warm core rings and Gulf Stream meanders are apparently the principal source of physical variability in the slope water region off the Northeast coast. Monitoring this variability has only been possible since the latter part of 1973, when high resolution infrared data became available rountinely from NOAA environmental satellites.

North of Cape Hatteras the Gulf Stream turns northeast into deep water and tends to meander with increasing amplitude downstream. The meanders, with wave lengths of about 320 km, have been found to propagate downstream

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[3] Collins, Barclay, Geology & Interpretation Dept., Gulf Science and Technology Co., P. O. Box 2038, Pittsburgh, PA 15230. "Upwelling in eastern Rhode Island Sound: A seabed drifter study."

at an average speed of about 6 $cm \cdot sec^{-1}$ (Halliwell and Mooers, 1979). Meanders reaching amplitudes of around 150 km or more often detach from the Stream and close into rotating masses of water called Gulf Stream rings or eddies.

Warm core rings form in slope water from meanders on the left (shoreward) side of the Gulf Stream (Fig. 6). The detached meanders close into clockwise (anticyclonic) rotating masses of water with measured velocities from as slow as 30-50 cm/sec (Saunders, 1971) to as fast as 140 cm/sec (Cheney, 1978). These rings have a warm core because they enclose Sargasso Sea water that moved shoreward with the originating meander. Greatest in area near the sea surface, when newly formed they have ranged in diameter from about 150 to 230 km and may reach depths of over 2000 m. Unlike Gulf Stream meanders which move in the direction of the Stream, warm core rings move in the slope water in a direction opposite to that of the Stream, at average speeds up to about 15 cm/sec over extended periods. However, they have been observed to stop or move in other directions for days or even several weeks. Because most warm core rings seen off New England and the Middle Atlantic coast have formed southeast of Georges Bank, where Gulf Stream meanders often reach high amplitude, many have been absorbed back into the Gulf Stream near their place of origin within a few weeks or months after formation, by encountering one of these meanders. Those which escaped such destruction and reached the longitude of Cape Cod usually have persisted for a few more months until eventually resorbed by the Gulf Stream at the latitudes of Virginia, where the Stream runs close to the continental slope. The frequency distribution of ring longevity provides more direct evidence that warm core rings tend to be either short- or long-lived. The production rate of rings occurring in the slope water west of

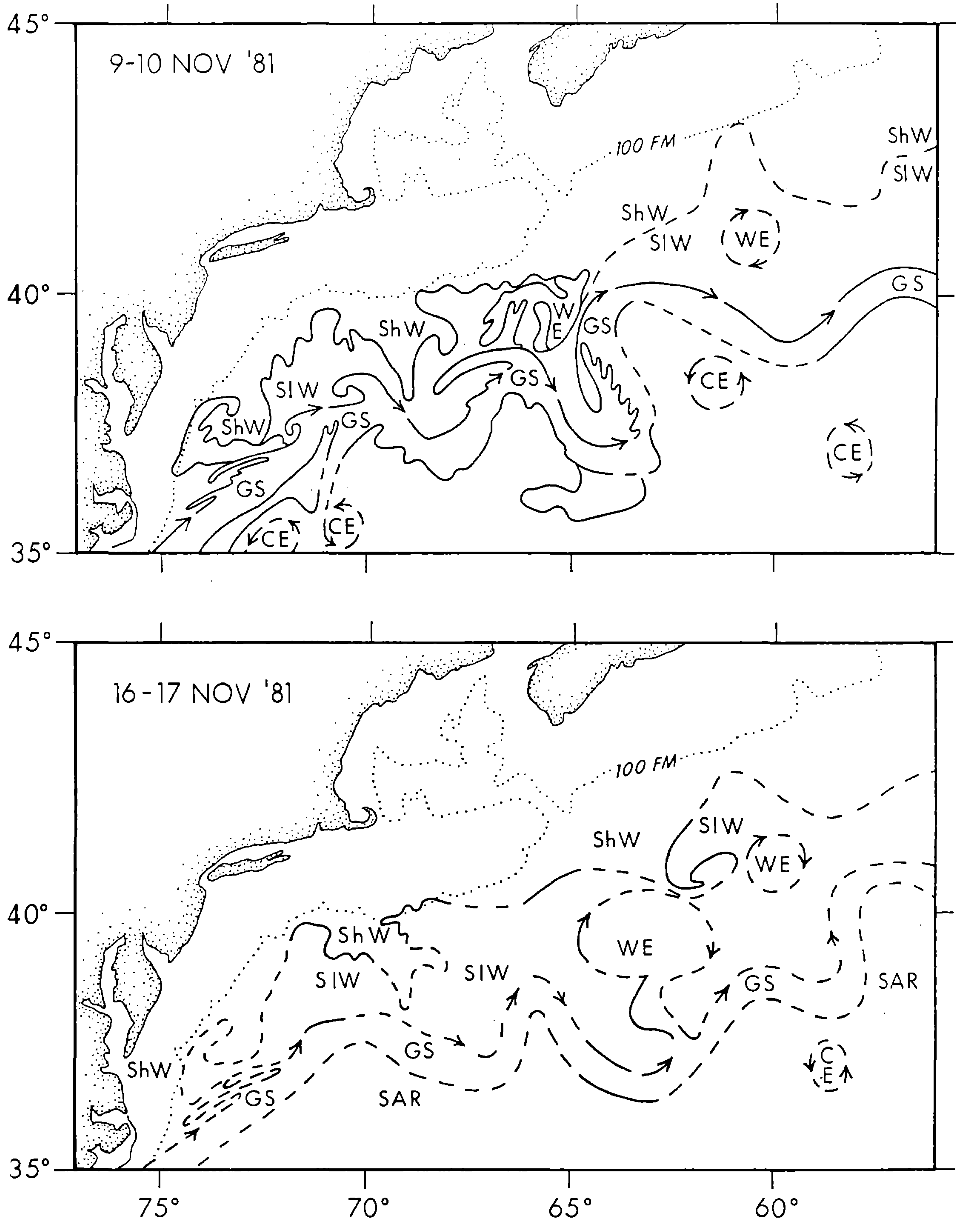

Figure 6. The birth of warm core ring (WE) from a Gulf Stream meander at about 39°N, 63°W. From weekly oceanographic analysis charts produced jointly by the National Weather Service and National Earth Satellite Service of NOAA.

60°W longitude during the past seven years has varied from six in 1974 to eleven in 1979 (Fitzgerald and Chamberlin, 1981).
During these years, variation in the number of rings simultaneously present has ranged from eight during a period of a week or two in early May 1977 (Mizenko and Chamberlin, 1979) to none during a six-week period from March to mid April, 1978 (Celone and Chamberlin, 1980).

Continental Shelf Interactions with Rings and Meanders

Warm core rings and Gulf Stream meanders and interactions between these features are not only a principal source of circulation and water mass variability in the slope water region, but also apparently the principal mechanisms for shoreward transfer of Gulf Stream water and kinetic energy into the vicinity of the continental shelf. Three kinds of interaction with continental shelf waters have been observed:

a. removal of shelf water by "entrainment",
b. injection of slope water and modified Gulf Stream water onto the shelf, and
c. modification of circulation on the shelf.

Satellite infrared data provide direct information only on the first of these influences, entrainment, because of its visibility at the sea surface, but detection of entrainment is not possible when clouds block transmission of thermal infrared from sea surface to satellite. Satellite data are not adequate for estimates of volume transport from entrainment because they measure only the surface area of entrained water and show its general direction of movement, but provide no information on either its depth or speed.

Injections of slope water and modified Gulf Stream water onto the shelf by warm core rings has been frequently observed in vertical temperature sections from shipboard data. Pronounced examples have been reported for southwestern Georges Bank (EG&G, 1978) and southern New England (Crist and Chamberlin, 1979) (Fig. 7). Because injection onto the shelf is predominantly subsurface, satellite data provide only circumstantial evidence by showing where this process may be taking place.

Information is scarce on the influence of warm core rings on shelf circulation except for what can be inferred ordinarily regarding entrainment immediately adjacent to rings. One fortuitous data set showing this sort of influence was from drogued buoys on SW Georges Bank in November 1977, which showed reversal of "the expected downcoast (southwestward) mean flow" apparently caused by a warm core ring (EG&G, 1978). Again as in the case of injections, the satellite data only indicate where such a circulation influence may be taking place.

Pronounced differences in the interaction of warm core rings and Gulf Stream meanders with shelf water are apparent between Georges Bank and the Middle Atlantic continental shelf. These differences relate primarily to the propagation characteristics of the rings and meanders. Although a number of the analyses necessary to make quantitative comparison have not been completed, the differences can be described qualitively:

a. Those which approach Georges Bank do so when younger, larger, and stronger in rotary flow than when they later enter the waters off the Middle Atlantic Shelf.

b. About 35% more rings occur in the vicinity of Georges Bank.

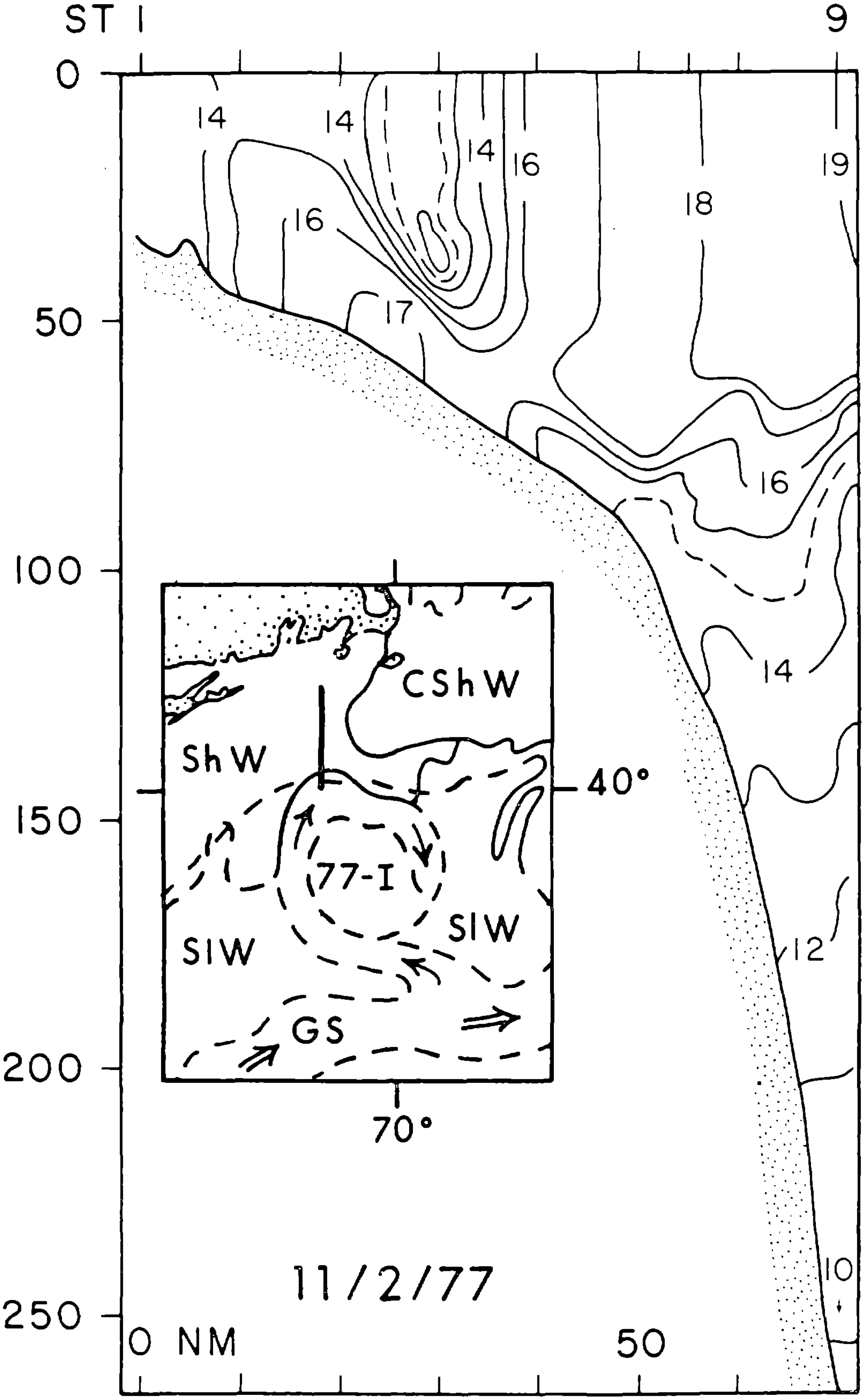

Figure 7. Injection of warm slope water, possibly mixed with Gulf Stream water, onto the continental shelf by the circulation of warm core ring 77-I, as revealed by an XBT temperature (°C) section conducted on 2 November 1977 along the 71°W meridian across the continental shelf. From Crist and Chamberlin, 1979. Inset chart shows location of temperature section and warm core ring 77-I.

c. Most rings in the Middle Atlantic maintain close contact with the continental slope, especially in the Hudson Canyon area and southward.

d. Entrainment of Gulf Stream water into the vicinity of the continental slope is characteristic of rings that occur south of Georges.

e. Longevity of rings is more variable in the vicinity of Georges than in the Middle Atlantic.

f. High amplitude meanders are common S and SE of Georges Bank but extremely rare in the Middle Atlantic.

g. Low amplitude meandering of the Stream just north of Cape Hatteras sometimes brings it close to the continental slope as far north as the offing of Chesapeake Bay causing entrainment of shelf water and the Stream may directly force warm saline water onto the shelf.

Interactions with the 106 Mile Dumpsite

Bisagni (1976) determined from two years' data (1974-75) that only about three warm core rings each year moved far enough to the west to affect the 106 Mile Dumpsite. Figure 8 shows a vertical temperature section through a ring which was centered just northeast of and covering the dumpsite in July 1975. The seasonal thermocline extended to 50 m depth across the ring, while the main thermocline began at a depth of about 500 m; much deeper than in the surrounding slope water. Between 50 m and 500 m depth in the ring's core occurred a thick layer of nearly isothermal water approximately 100 km across. Clearly the presence of a warm core ring and its currents could have profound effects on the water column and dispersion of waste dumped at the 106 mile site.

The ring shown in cross section in figure 8 apparently also has interacted with the shelf water in a relatively common manner. Water from the cold pool lying beneath the thermocline on the shelf (<10°C) has been removed and warm slope water (>12°C) has been thrust up on the upper slope by the ring. Such exchanges can involve slope water that has received wastes from dumping operations at the 106 mile site, which may be thrust well up onto the shelf.

Other workers have continued to study the production of warm core rings in succeeding years (1976-1980) and have shown 3 to 6 rings occurring per year at the 106 mile dumpsite (Mizenko and Chamberlin, 1979a, 1979b; Mizenko and Chamberlin, 1981; Celone and Chamberlin, 1980; Fitzgerald and Chamberlin, 1981, 1982 (in press). Although the occurrence of the rings in the slope water and at the 106 mile site are commonplace, there is apparently no regular seasonality or periodicity to them.

Of the three principal water masses which may occupy the upper portion of the water column of the 106-Mile Dumpsite, Sargasso Sea water in warm core rings provides the greatest mixing depths (depth to thermocline) for dissolved or slowly settling wastes. Dumping near the center of a warm core ring would provide for isolation from interaction with shelf water or slope water and would allow the greatest dilution to occur in a water mass having a relatively low average density of marine organisms. Dumping in the periphery of a ring should be avoided, however, to avoid the risk of mixing the waste-bearing water with slope water or shelf water, where the population densities of organisms are greater.

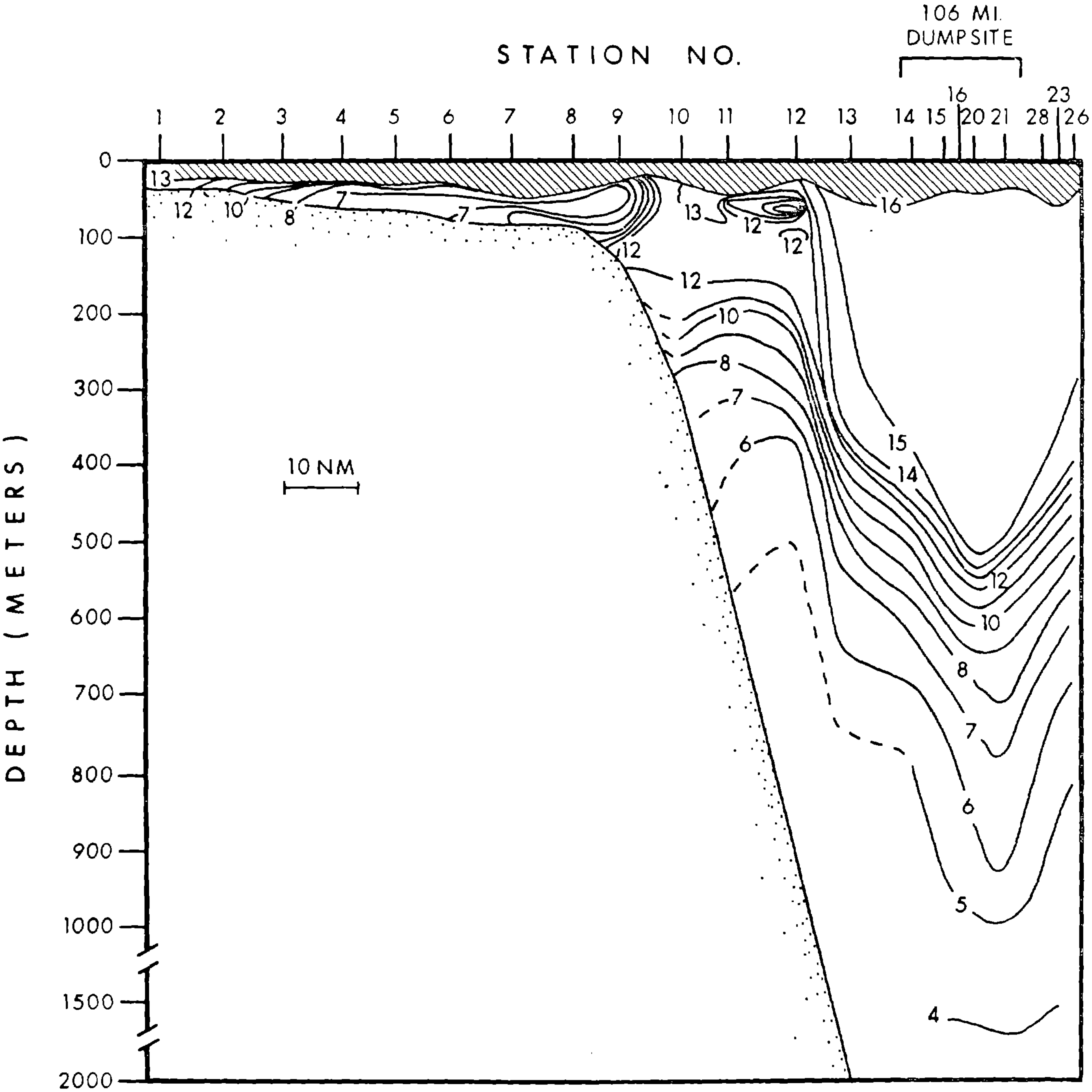

Figure 8. Warm core ring in the vicinity of the 106-Mile Dumpsite in July 1975 as revealed by a vertical section of temperature (°C). Gradients in the thermocline were too intense for contouring at this scale (shaded area). Surface temperatures ranged from 22 to 25°C. From Goulet and Hausknecht, 1977.

FRONTS

Where two water masses in the ocean meet, there is frequently a front, across which there is a sharp transition between the differing characteristics of the two water masses. Typically, major advective exchange between the water masses is restricted and occurs only sporadically across fronts. Frontal regions are commonly convergence zones, and consequently floating or suspended materials including pollutants, in the water tend to become concentrated along them. Pollutants accumulated in this fashion would be located in close association with increased biological abundance and activity, which quickly develops in the vicinity of a convergence zone.

Shelf-Slope Front

The shelf-slope front is located over or near the outer edge of the continental shelf, separating less saline and usually cooler shelf water from the slope water which lies offshore. The front is continuous from Cape Hatteras to Georges Bank and is present throughout the year. The shelf-slope front extends from the surface to the bottom, typically touching bottom at depths between 75 and 100 m and slopes seaward, with the surface intersection situated about 25 to 55 km offshore from the bottom contact (Beardsley and Flagg, 1976).

The horizontal salinity gradient across the shelf-slope front is typically 1 to 2 o/oo over 10 to 50 km and near-bottom temperature gradients are about 2-4°C throughout the year, but can be as much as 8°C (Bowman and Wunderlich, 1977). Temperature contrasts across the front at the surface normally are about 4° to 6°C, but are much less intense from late June to September as the summer thermocline and a warm surface mixed layer cuts across the front (Bowman and Wunderlich, 1977). The vertical temperature and salinity structure within the front can develop complex patterns because of inter-leaving of shelf and slope waters in the form of offshore extrusions of "cold pool" water at mid-depth, intrusions of slope water onto the shelf along the bottom and exchanges of surface waters. Gordon and Aikman (1981) hypothesized that considerable transfer of salt occurs from slope water to shelf water across this front during the summer stratified season. During this period the horizontal density gradient is minimal across the front facilitating the transfer of about half the salt required annually to balance fresh water inflow.

Examination of sea surface temperature patterns has shown that the front exhibits large wavelike motions of 100 km or more, propagating at speeds of about 5 $cm \cdot sec^{-1}$ (Gunn, 1977; Halliwell, 1978). Robinson, et al. (1974) found meanders along the front on scales of tens of kilometers with displacement speeds of 5 to 20 $cm \cdot sec^{-1}$. Such variations in the frontal position have been attributed to a dynamic response to atmospheric forcing (Stommel and Leetma, 1972; Csanady, 1973; Flagg and Beardsley, 1978), Gulf Stream meandering (Wright, 1976), to the passage of warm-core rings through the slope water (Beardsley and Flagg, 1976; Celone and Chamberlin, 1980) and because of destabilization of the front resulting from river discharge into the shelf water (Ketchum and Keen, 1955; Ketchum and Corwin, 1964).

Wind stress may be another cause of the offshore movement of the shelf-slope front due to Ekman transport (Boicourt and Hacker, 1976; Beardsley and Flagg, 1976) or interference with the normal momentum balance of the front in a direction parallel to the front, thus causing geostrophic adjustment normal to the front (Csanady, 1978). Warm core Gulf

Stream rings may also cause seaward extensions of the shelf/slope front due to the rings' currents (Morgan and Bishop, 1977). Local baroclinic instability of the front over steep topography could be another factor affecting its movement (Flagg and Beardsley, 1978).

Cresswell (1967) reported on the presence of detached parcels of shelf water within the slope water, which he believed had separated from the front by "calving", and Wright (1976) concluded that the detachment of such parcels, along with seaward excursions of the front, may account for most of the exchange required for salt balance of the shelf waters. The highly variable location (Fig. 9) of the shelf-slope front from Cape Hatteras to Georges Bank has been examined from weekly interpretations of surface thermal patterns using satellite-derived infrared imagery beginning in 1973 (Ingham, 1976). Gunn (1979) compiled five-year means of these records and found that the mean position of the surface front remains close to the location of the 200 m isobath and variability averages about 50 km around the mean position. Hilland and Armstrong (1980) examined this five-year compilation and described seasonal tendencies to the front's position, finding the front to be located more offshore during the first half of the year (maximum excursion in February to April) and more shoreward during the latter half of the year (extreme incursions in July to September). For the period of record for these analyses (1974-1979), the most anomalous offshore excursion occurred in 1978 when the front generally was positioned distinctly offshore of normal (up to 150 km off southern New England) during spring and summer (Hilland and Armstrong, 1980). This record excursion of the front in 1978 may have resulted from increased advection of shelf water from the east (Chamberlin, 1978) or from a total absence of warm core rings in the slope water (Hilland and Armstrong, 1980).

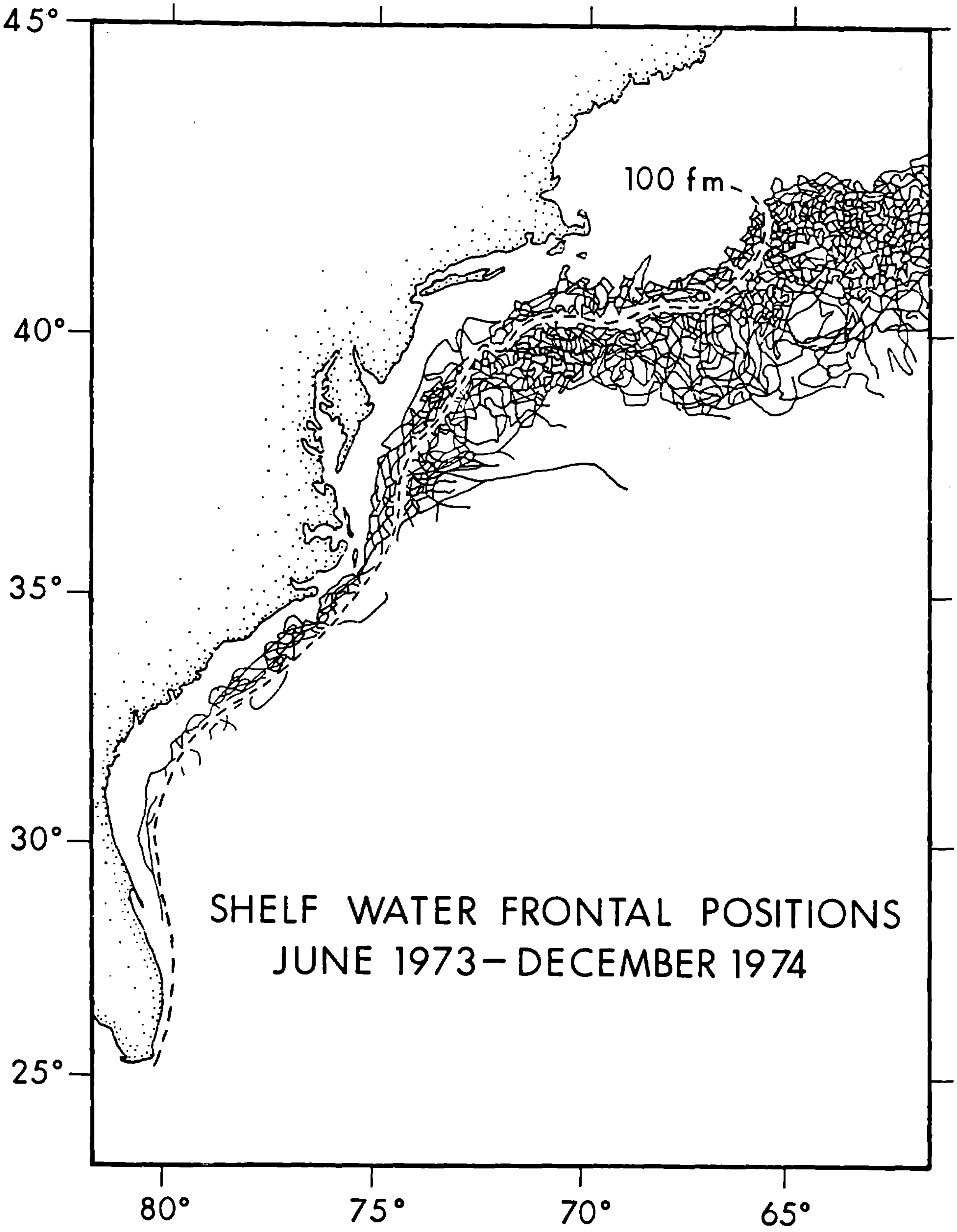

Figure 9. Composite plot of locations of the shelf-slope front during June 1973-December 1974 compiled from weekly frontal analysis charts derived from satellite infrared imagery. From "The Environment of the United States Living Marine Resources - 1974". MARMAP Contribution No. 104. NOAA, National Marine Fisheries Service. Unpublished report.

Gulf Stream Front

The Gulf Stream front is a narrow zone of abrupt horizontal change in temperature and salinity caused by the strong velocity shear between the weak, southwesterly flow in the slope water and the strong northeastward and eastward flow of the Gulf Stream. The front is continuous off the east coast of North America and has been observed to depths of 2000 m. In the upper 400 m there are distinct differences in water masses across the front, between the cooler, less saline slope water and the warmer, more saline Gulf Stream water. The front inclines downward in the offshore direction.

Along its course, large perturbations develop in the Gulf Stream front because of meandering of the Gulf Stream (Fig. 6). Hansen (1970) described the Gulf Stream meandering as "quasi-geostrophic", comprised of frontal waves which progress eastward with phase speeds of 5 to 10 $cm \cdot sec^{-1}$ and wave lengths of 200 to 400 km. The amplitude of the waves at the surface typically increases toward the east almost linearly downstream from Cape Hatteras, coursing a swath about 100 km wide off Cape Hatteras to more than 300 km wide south of the Scotian Shelf (Hansen, 1970). Current meter measurements made by Schmitz, et al. (1970) indicated that the meanders extend to considerable depth (2,585 m). Although the meandering of the front is usually limited to the slope water region, on occasion meanders may penetrate to the shelf water (Gotthardt and Potocsky, 1974).

The surface position of the Gulf Stream front has been monitored from ship reports, airborne infrared data, bathythermographs, and satellite-derived infrared imagery and shown in monthly maps since 1966 ("The Gulf Stream Monthly Summary" and "Gulfstream"). Since 1973 the U.S. Naval

Oceanographic Office and the National Earth Satellite Service of NOAA have prepared weekly charts of the Gulf Stream front position.

Nantucket Shoals Front

Most of the information on the hydrographic characteristics of Nantucket Shoals was collected in a series of cruises during May, July, and September 1978 (Limeburner and Beardsley, 1979). Along the eastern and southern side of the shoals the general characteristics of a tidally-generated front (boundary of well mixed area) were found at about the 40 m contour. The shallower region was always homogeneous since the mixing caused by the high tidal currents overcomes the heating and fresh water inputs that tend to produce vertical stability. Outside the 40 m contour the frontal structure was complicated by localized upwelling regions. These were spatially variable, but generally found in an area 15 km wide and 50 km long. Although general frontal characteristics were seen in the temperature, salinity, and density fields, the vertical difference of density defines the well-mixed zone most clearly. Within the shallow area of the shoals the vertical density differences were always 0.1 $g.l^{-1}$ or less while in the stratified area values up to 4.0 $g.l^{-1}$ were found in July.

After fall overturn of the water column the fronts along the eastern and southern side of the shoals disappeared. This was due to the atmospheric cooling and increased wind stress. Limeburner (1979) found well-mixed conditions both on Nantucket Shoals and to 100 m depth in the Gulf of Maine from data collected in January and March.

Central Georges Bank Front

Over the central portion of Georges Bank, in depths less than approximately 40-60 m, the water is well-mixed throughout the year and as a result is seasonally separated from deeper water by a front. The water enclosed by this front is approximately equal to that defined as Georges Bank Water by Hopkins and Garfield (1981), which they say owes its unique characteristics to isolation and low volume replenishment. The mechanism causing the front is identical to that for Nantucket Shoals, tidal stirring overcomes the stabilizing tendency of solar heating. During winter the increased wind stress extends the mixed water column out to the shelf-slope front on the south side and into the Gulf of Maine. In spring, as wind stess decreases and solar heating increases, the front forms at approximately the 60 m isobath around the bank. On the north side of the bank this is near the shelf break and creates a temperature front separating the relatively warm stratified waters near the surface in the Gulf of Maine from the cooler isothermal waters on Georges Bank. On the south side of the bank, however, the distance between the 60 m isobath and the shelf break (200 m) is relatively long, about 75 km, and as the season progresses the thermocline develops over the outer shelf and slope, separating the water below the thermocline from the heating source. This creates a seasonal cold pool between the tidally generated front on the south side of Georges Bank and the shelf-slope front.

The position of the front varies with the phase of the tide, moving north during flood and south during ebb. There is some variation with the spring-neap (fortnightly) cycle but less than would be expected. This has been discussed by Simpson and Bowers (1981) and attributed to variable efficiency of mixing in the cycle.

Coastal Active Band

Fronts develop because of estuarine effluent plumes, wind-driven upwelling, or mixing in a nearshore band throughout the NEMP area of interest. Their existence is highly variable in space and time and frequently depends upon weather conditions. A perusal of infrared imagery from GOES and polar orbiter satellites provides an estimate of the average width of this band of frontal features to be about 20 km. In spite of the relatively small scale of features in this band, they may have considerable influence on the distribution of water-borne pollutants, because the band receives a significant portion of the regional inputs of pollutants from estuarine effluents, outfall discharges, and dumping.

DENSITY STRATIFICATION

The seasonal development of a surface mixed layer of low density water and underlying pycnocline influences the dispersion of pollutant materials introduced into the surface waters by dumping or other means. Those pollutants which are dissolved or suspended will remain in the mixed layer above the pycnocline, which forms a virtual barrier to vertical mixing. Pollutant components which are slightly more dense than sea water in the mixed layer sink slowly to the pycnocline then accumulate there (Orr, et al., 1980) because of the sharp increase in water density encountered. As a consequence of these characteristics, the water column involved in the dispersion of dissolved or suspended pollutants is considerably shallower in the late spring and summer when stratification occurs, than in the winter when the water column is vertically isothermal in the upper 100-200 m.

Gulf of Maine

The thermal stratification of the waters in the Gulf of Maine follows an annual cycle in response to seasonal heating and cooling by the atmosphere and direct solar insolation. The thermal influence on the stratification is complemented by salinity changes in the surface waters due to the annual variation in coastal fresh water runoff. Together the temperature and salinity changes combine to yield a regular seasonal cycle of density stratification in the Gulf of Maine.

In winter the Gulf of Maine is generally well-mixed to about 100 m depth with temperatures of 2-5°C. This uniformity is due to convection induced by surface cooling and strong winter winds. In extreme years the mixing may extend to near bottom (>200 m). Below the cold mixed layer normally there is a warmer (5-8°C) and saltier layer of bottom water that originates over the continental slope and enters the Gulf through Northeast Channel. During the spring, coastal runoff reaches a maximum and begins to stratify the nearshore surface waters of the Gulf by decreasing the salinity. Increased solar insolation then warms the surface layer and a strong thermocline forms inhibiting vertical exchange and isolating a mid-depth layer as a temperature minimum region of 4-5°C, remnant from the past winter cooling. The temperature minimum slowly warms during the summer. With the beginning of fall, atmospheric cooling begins to break down the thermal stratification in the surface waters. By winter stronger winds and continued surface cooling drive convection that mixes the upper portion of the Gulf of Maine and begins again the annual hydrographic cycle.

Georges Bank

The waters around the edges of Georges Bank (depths >60 m) exhibit a seasonal cycle similar to that observed in the surface layers of the Gulf of Maine. Conditions are vertically uniform in winter. Thermal stratification with a strong thermocline develops in the spring and summer. Winter cooling reestablishes a well-mixed, vertically uniform water column.

Over the shallow portions of Georges Bank, where water depth is less than about 60 m, the strong tidal currents keep the water column well-mixed throughout the year. While the water temperature exhibits seasonal warming and cooling, no vertical stratification develops.

Middle Atlantic Bight

The water volume in the Middle Atlantic Bight is divided into a narrow, coastal, low salinity band affected primarily by outflow from three major estuaries, a shelf region ranging between 20 m and 100 m depth, and the outer shelf region at the shelf break which receives intrusions of more saline and warmer slope water and is characterized by the shelf-slope front.

The shelf region is occupied by low salinity water ranging between 30 $^{o}/oo$ near shore to 35 $^{o}/oo$ at the bottom along the shelf break. The average salinity over the shelf is around 32.5 $^{o}/oo$ at the surface to 35 $^{o}/oo$ along the bottom. Water temperature varies seasonally, ranging from 2°C in the nearshore zone during February-March to values as high as 30°C, but generally 25-26°C in late summer. In winter the water is vertically homogeneous with temperature increasing seaward at all depths. The water begins to warm by late April with a thermocline established by early June. The intensity of the thermocline increases and reaches a maximum in mid-August to early September. As the surface waters continue to warm, the thermocline deepens and increases in intensity. The warmer surface waters then begin to mix downward increasing the bottom temperature. Maximum bottom temperatures are reached approximately one month after the surface temperature has reached a maximum (Ketchum and Corwin, 1964). Cooler air temperatures by this time have produced fall overturn which breaks down thermal stratification and enhances vertical mixing.

The intensity of the thermocline varies as a function of wind and solar heating. With an early spring onset of southerly winds and atmospheric heating a strong thermocline can be set up reducing vertical mixing to near zero. Added to this can be large freshwater runoff from the estuaries creating large salinity differences further intensifying stratification. Strong southerly winds can also provide a mechanism for invasion of warm high-salinity slope water onto the shelf at mid-depths or along the bottom, compensating for offshore transport in the surface layer. During the winter when this occurs a weak thermohaline stratification appears with slope water moving in along the bottom. During the summer, the warmer, more saline water appears to move along the shelf into the vicinity of the 10 m isobath (Boicourt and Hacker, 1976).

Slope Water

Wright (1976a) subdivided the slope water into three layers: surface, permanent thermocline, and deep, based on thermal characteristics. The surface water layer exists in the upper 200 m, where seasonal changes due to surface warming and cooling and wind-mixing occur, and where shelf water incursions occur to a depth of approximately 120 m. The annual meteorological cycle leads to stratification of these waters and the development of a seasonal thermocline beginning in May and persisting until October or November when cooling and storm activity destroy it (Ingham, et al., 1977). When the seasonal thermocline is well developed, a warm (20°-25°C) mixed layer 30-40 m thick is present. Below this mixed layer in the seasonal thermocline temperature gradients can be as great as $0.5°C \cdot m^{-1}$. Figure 10 shows a vertical temperature section from July 1978 from New York City southeast to the 106 Mile Dumpsite and beyond. The near-surface mixed layer and the seasonal thermocline are shown to be well developed in both the shelf and slope water regions. When winter cooling and storm wind-mixing occur, the water column becomes nearly isothermal to approximately 100-200 m depth or the top of the permanent thermocline (Fig. 11).

Movement of the shelf-slope front into the slope water area may have different results depending on the season. Overspreading of the area by shelf water in the winter and spring would bring in colder and less saline water into the surface slope water layers. This would form an inverted thermocline (but not a pycnocline) with warmer more saline slope water underlying colder less saline shelf water. During the summer and early fall, however, overspreading by shelf water at the surface would have little effect on the thermal stratification because of uniform surface heating of both shelf and slope waters.

The second layer in the slope water, the permanent thermocline layer, exists between the depths of approximately 200 and 600 m (13°C to 5°C) where thermal gradients average about $0.02°C \cdot m^{-1}$. Water at these depths is beyond the reach of local meteorological effects and remains relatively

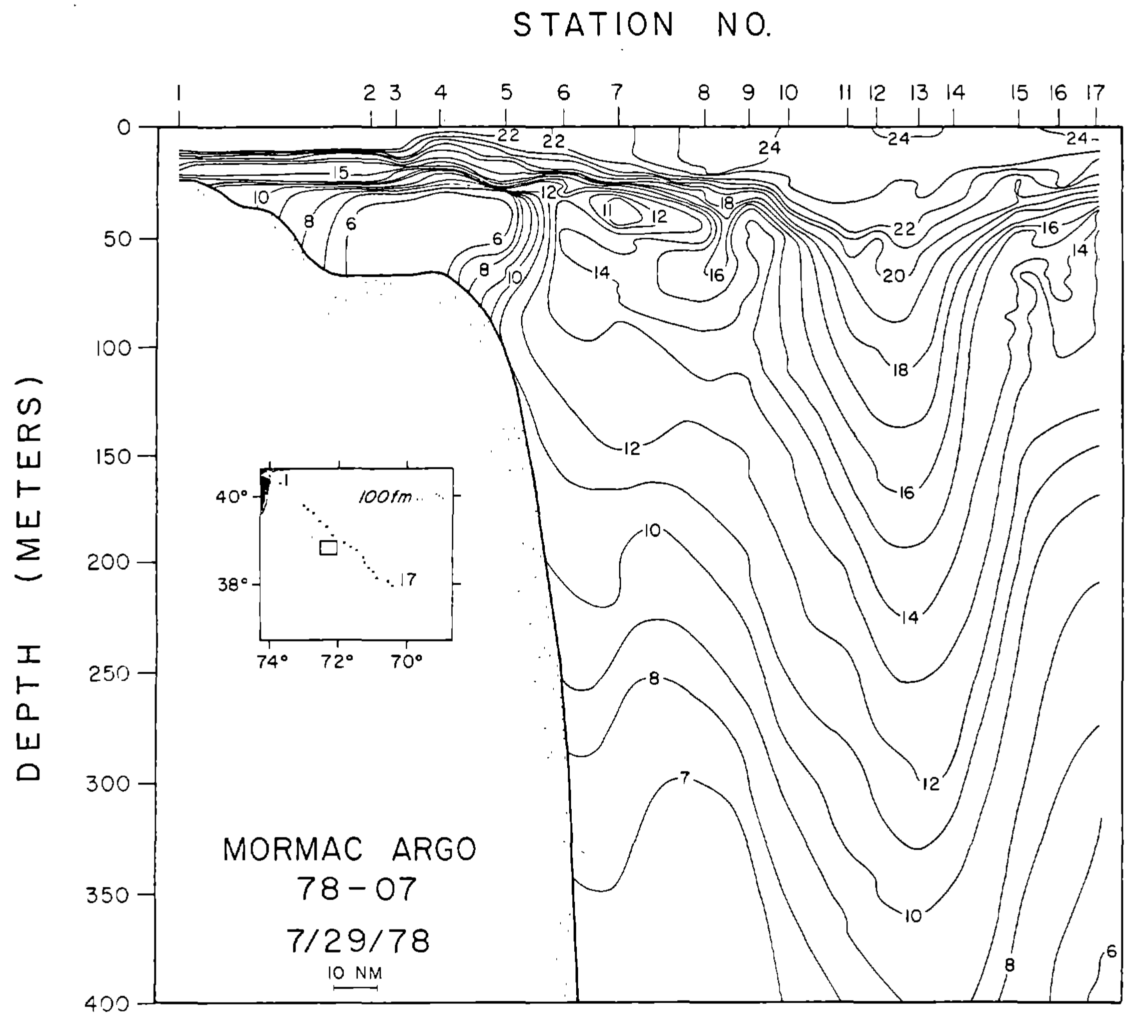

Figure 10. Vertical section of temperature (°C) showing thermocline development in shelf and slope waters. From Cook and Hughes, 1978.

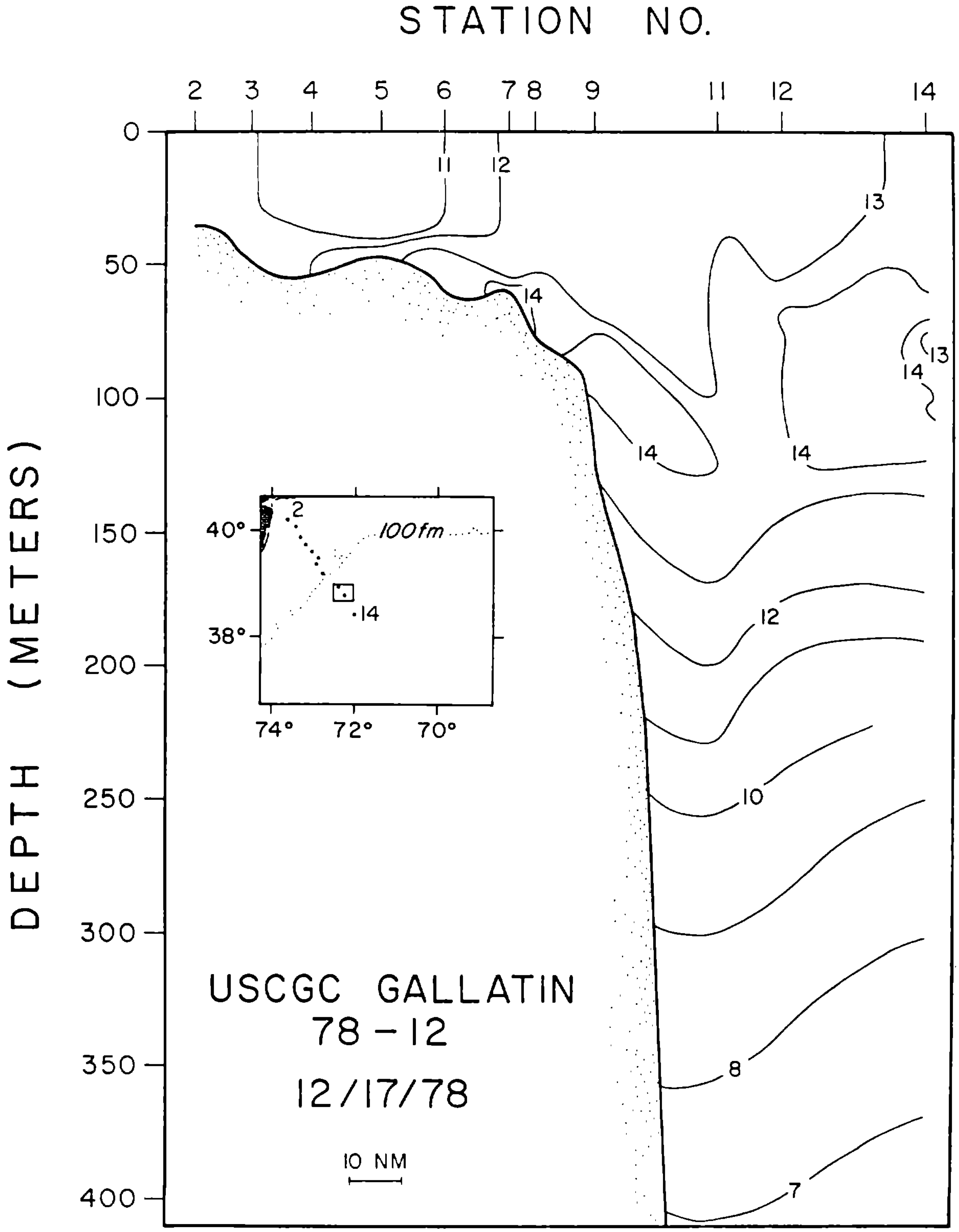

Figure 11. Vertical section of temperature (°C) showing late fall conditions in outer shelf and slope waters. From Cook and Hughes, 1980.

constant except for warping of temperature strata caused by aperiodic incursions of the north wall of the Gulf Stream or warm core Gulf Stream rings.

The third layer, deep slope water, exists from about 600 m to bottom and is a zone of very slow temperature decrease to a minimum of 2.2°C at about 4000 m. Variations in the lower portions of this layer over the continental rise may be due to the position of the Western Boundary Undercurrent, a deep geostrophic, near-bottom current.

COLD POOL

The cold pool, so named by Bigelow in 1933, is a continuous subsurface water type located on the continental shelf bottom between Georges Bank on the northeast to Cape Hatteras at the southwest. This feature was referred to as remnant "winter water" by Bigelow (1933), Ketchum and Corwin (1964), and Whitcomb (1970) who believed it to be formed from the winter cooling of mixed Middle Atlantic Bight shelf water. With hydrographic data portrayed by Colton, et al. (1968) and Limeburner et al. (1978), the feature can be traced to the north along the eastern edge of Georges Bank and into the Gulf of Maine, where temperature and salinity relationships suggest a possible source of replenishment (Beardsley et al., 1976 and Hopkins and Garfield, 1979). To the south the cold pool feature has been traced past the offing of Chesapeake Bay to Cape Hatteras where three major water masses (shelf, slope, and Gulf Stream) meet.

The cold pool becomes an identifiable feature each year beginning with spring surface warming and the onset of thermal stratification (generally in late April to early May) and lasts throughout the summer into early fall, until the normal seasonal overturn (from October to December, but mostly in November) mixes away the vertical density structure and the water column becomes vertically isothermal.

The cold pool normally covers an area on the bottom between the 40 and 100 meter isobaths (20-60 fathoms) an area of approximately 88,000 km^2 between Georges Bank and Cape Hatteras. The average thickness of the feature is about 35 meters and extends from the bottom to the base of the seasonal thermocline (within 20-30 meters of the surface). This represents a volume of 3,100 km^3, or about 30% of the total volume of shelf water in the Middle Atlantic Bight.

The cold pool is a relatively slowly changing feature (by virtue of its bathymetric location) when compared to the more active zones of lateral mixing seaward and vertical mixing shoreward, with a long-term average flow of about 1-3 $cm \cdot sec^{-1}$ southwestward (Mayer et al., 1979). However, the cold pool is in a state of constant change, and it can be acted on by several processes either singly or simultaneously, some of which are as follows:

Wind events can cause upwelling nearshore, moving the shoreward leading edge of the cold pool toward the beach and sometimes even into the surf zone (Hicks and Miller, 1980). Other wind events, if persistent enough, also can influence the offshore edge of the cold pool, forcing it and the shelf water-slope water front to move seaward (Csanady, 1978).

Gulf Stream rings migrating along the shelf edge to the southwest through the Middle Atlantic Bight can cause perturbations in the subsurface shelf-slope front and the seaward edge of the cold pool by advecting upper slope water (>12°C) shoreward over the edge of the continental shelf, sometimes moving the cold pool off the bottom and causing it to bulge seaward, leading to "calving" (Whitcomb, 1970 and Wright, 1976).

Bathymetric features such as the Hudson Shelf Valley and the submarine canyons which underlie the outer edge of the cold pool at several locations, from Corsair Canyon at the eastern edge of Georges Bank to Norfolk Canyon at the southern end of the Middle Atlantic Bight can affect the cold pool. Flow in the canyons can cause movement in the position of the cold pool. According to Mooers et al. (1979) down canyon transport of cold pool water was observed along the southwestern side of Wilmington Canyon. In contrast to this, Han and Niedrauer (1981) observed that cold pool water did not sink into the Hudson Shelf Valley, but rather stayed at the same level as on the surrounding shelf. Nevertheless, bottom water flow in the canyons and shelf valleys should act to displace the cold pool either onshore or off.

At the southern edge of the cold pool, near Cape Hatteras, where the shelf is narrow, the Gulf Stream entrains both surface shelf water and subsurface cold pool water (Ford et al., 1952; Fisher, 1972; and Kupferman and Garfield, 1977).

Seasonal and Interannual Variations

Depending on geographic location, the cold pool attains its minimum temperature in early spring to early summer (Table 1). Off southern New England the minimum is usually recorded in mid-March (1.1-3.3°C,mean 2.1°C), but off New York it is in early June (3.8-4.7°C, mean 4.1°C). Off southern New England, the minimum cold pool temperatures ranged from 1.1°C to 3.3°C averaging 2.1°C in 1977-81, while off New York they ranged from 3.8°C to 4.7°C, averaging 4.1°C (Table 1).

TABLE 1.

Maximum, minimum, average and differences in bottom temperatures at 60 meters depth (mid point of the cold pool) collected for 5 years (1977-1981) for the southern New England and New York ship of opportunity transects (from data collected by the NOAA/NMFS/Atlantic Environmental Group, Narragansett, Rhode Island).

Transect Location	Year	Min. Temp.°C	Avg. Min Temp.	Timing of Min.	Max. Temp.°C	Avg. Max Temp.	Timing of Max.	Avg. ΔT°C
Southern New England	1977	1.1			16.8			
	1978	1.6			13.6			
	1979	1.9			14.9			
	1980	2.4			17.2			
	1981	3.3			12.0			
			2.1	Mid March		14.9	Early Nov.	12.8
New York	1977	3.8			13.0			
	1978	3.8			12.0			
	1979	3.8			12.0			
	1980	4.6			12.9			
	1981	4.7			11.6			
			4.1	Early June		12.3	Late Nov.	9.1

Maximum cold pool temperatures occur when the vertical stratification of the water column is destroyed during fall overturn. The warmest temperatures off southern New England (11.6-13.0°C, mean 12.3°C) precede the maximum temperatures off New York by an average of only 20 days (usually in November). Differences between seasonal maximum and minimum temperatures are larger off southern New England (almost 13°C) than off New York (about 9°C).

Role of Convective and Advective Mechanisms

Traditionally the cold pool has been described as a stationary parcel of remnant winter water that slowly eroded away during the summer and early fall. Then, because the coldest part of the cold pool in summer often was located off New York, it was suggested that the source of the cold water was within the Middle Atlantic Bight. Recent analyses of more detailed thermohaline data and long-term current meter measurements have shown a slow (1-3 $\mathrm{cm \cdot sec^{-1}}$), mean flow of the cold pool from the northeast to the southwest (Beardsley et al., 1976 and Mayer et al., 1979).

Data collected in the cold pool from ships of opportunity along two transects in the Middle Atlantic Bight (south across the shelf along 71°W and southeast across the shelf from New York) also indicate that pulses of cooler water are advected southwestward between these two transects until mid-June with a speed consistent with current meter observations.

With the onset of spring warming and development of thermal stratification, vertical mixing processes essentially cease between the cold pool and the surface. As an indication of how weak this vertical mixing is, estimates of vertical velocities for subsurface fronts in slope water (seaward edge of cold pool) average about 1 meter·day^{-1} (Garrett and Horne, 1978). While the cold pool is easily identifiable along its lateral boundaries as a thermal feature and less so as a salinity feature, it is totally unidentifiable laterally as a density feature. Therefore, mixing could occur with surrounding water masses along density surfaces laterally (cross shelf) far easier than with overlying water.

Hypoxia

During the summer of 1976 oxygen-deficient (hypoxic) conditions developed in sub-thermocline waters, including the cold pool, on the continental shelf off New Jersey, causing mass mortalities of benthic organisms and displacements of finfish populations. These conditions persisted from July through September and extended over an area of about 8600 km^2. Because of the large magnitude of this catastrophe, considerable attention was directed toward determining the circumstances that caused the severe depletion of oxygen. A summary report was prepared of the findings (Swanson and Sindermann, 1979) in which it was concluded that (1) a combination of natural, but anomalous, events generated the low oxygen condition, (2) man's activities had little or no discernible effect, and (3) future recurrences should be expected, particularly since low oxygen-related marine mortalities had also developed in the same area in 1968, 1971 and 1974, although they were of lesser extent than that which occurred in 1976.

Factors which were identified as contributing to the hypoxia of 1976 were (1) early initiation of stratification of the waters due to early warming of the surface waters and lowering of surface salinities by high river discharge, (2) a massive bloom of the dinoflagellate *Ceratium tripos* which lasted from February to July, (3) lack of storms moving through the area in spring, and (4) disruption of the typical southwestward currents resulting in aggregation of organic particulate material (including *C. tripos*) in the area.

The role of some of these conditions in generating the hypoxia of 1976 can be seen by considering the normal annual cycle of dissolved oxygen in the bottom waters as described by Armstrong (1979) for the New Jersey shelf waters, along with the annual cycle of stratification and with conditions that were observed in 1976 (Fig. 12). During fall and winter the bottom waters on the continental shelf of the Middle Atlantic Bight become saturated with oxygen as overturn of the water column from cooling at the surface mixes oxygenated surface water with the bottom water. With the onset of stratification in spring by vernal warming and increased river discharge, vertical replenishment of oxygen to the bottom water becomes inhibited. Dissolved oxygen concentrations in the developing cold pool decline as utilization exceeds replenishment. With strengthening of stratification through summer, oxygen content near the bottom rapidly declines until fall overturn begins to break down the stratification and replenishes the oxygen.

Typically, dissolved oxygen concentrations in bottom water reach annual maximum values of about 7 $ml \cdot l^{-1}$ throughout the Middle Atlantic Shelf in March and annual minimum concentrations in August of about 3 $ml \cdot l^{-1}$ off New Jersey and about 4 ml.l-1 for the bottom waters off Long Island (Armstrong, 1979). Experiments reported by Thurberg and Goodlet (1979) indicated surf clam mortality in water of dissolved oxygen

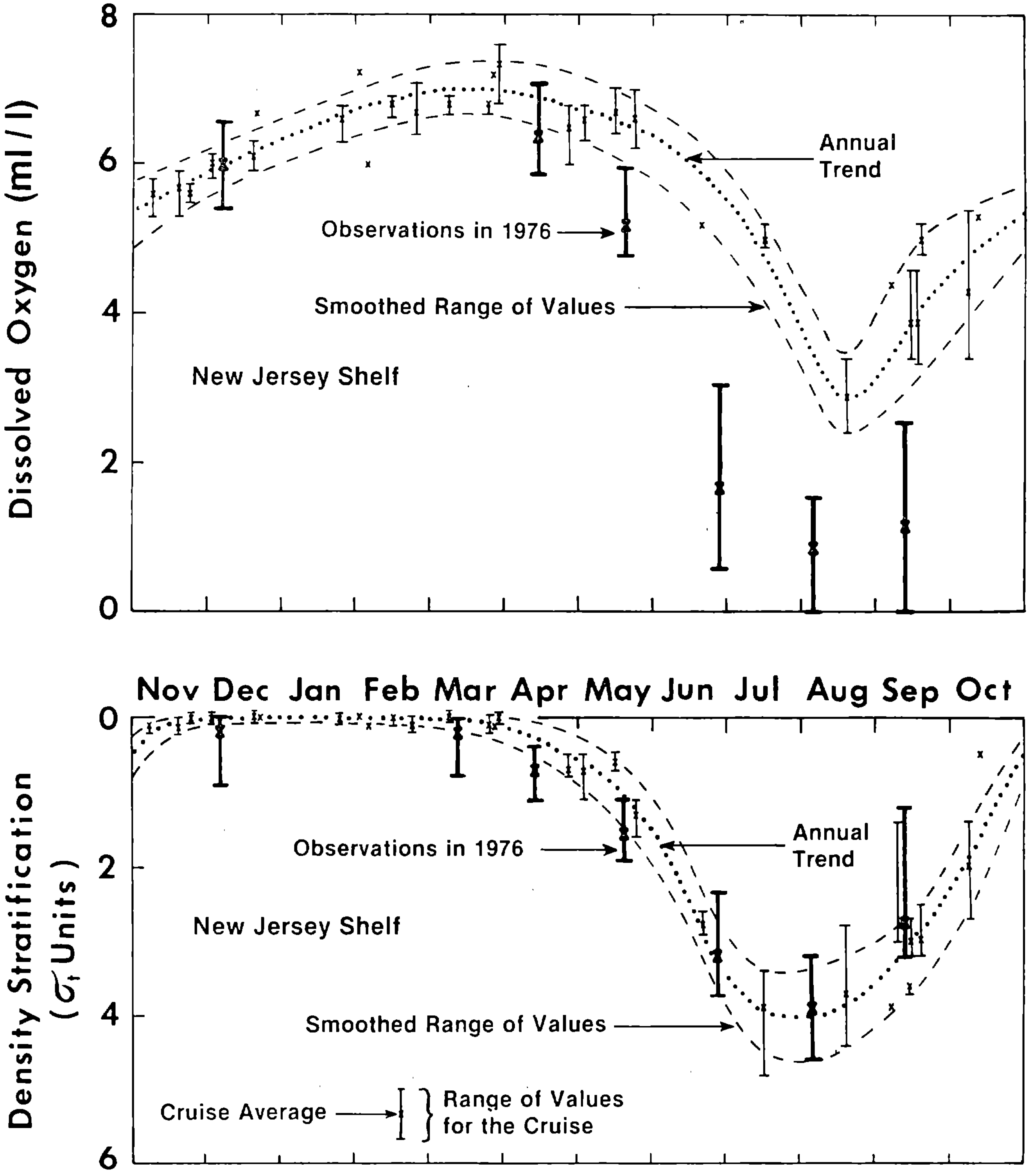

Figure 12. Seasonal cycles of dissolved oxygen concentration ($ml \cdot l^{-1}$) in bottom waters (>20 m) and vertical density stratification (surface minus subpycnocline σ_t difference) in New Jersey shelf waters. From Armstrong, 1979.

concentrations less than 1.4 ml/l and Azarovitz et al. (1979) found finfish avoidance at concentrations below 2.1 ml/l. Therefore, only small decreases in concentrations below normal August values can have deleterious effects on the marine fish and shellfish, particularly in the bottom waters off New Jersey.

The annual cycle of bottom water dissolved oxygen in figure 12 indicates that on the shelf in early spring a limited volume of oxygen becomes trapped below the developing pycnocline. As the season progresses through summer this volume is continuously diminished by utilization while strengthening stratification decreases the opportunity for replenishment from the oxygenated surface layer. During this time of the year, any condition which either increases the utilization or further decreases the replenishment, beyond normal ranges, can lead to hypoxic conditions.

It can be seen in the lower panel of figure 12 that stratification was about one month earlier than normal in 1976, and was stronger than normal through May (Armstrong, 1979; Hazelworth and Cummings, 1979). This probably had three effects: the annual maximum concentrations in the bottom water probably were not as high as normal and the volume of oxygen available below the pycnocline was less; the stratified season was lengthened so that the period when utilization exceeded replenishment was one to two months longer than normal; and with stratification stronger than normal for March-May, replenishment from vertical exchange would have been reduced and concentrations would have declined more rapidly than normal for those months. Armstrong (1979) considered the result of these effects of stratification and estimated that, if all other conditions had been normal, average dissolved oxygen concentrations over the New

Jersey shelf would have been below 2 $ml \cdot l^{-1}$ in August, with essentially totally depleted oxygen developing over some portions of the shelf. Off Long Island, average minimum concentrations would have been reduced to about 2.3 $ml \cdot l^{-1}$. Diaz (1979) found that from February through June of 1976, storm activity over the New York Bight was well below the norm. This condition would also have reduced replenishment to the bottom waters because of decreased vertical exchange with surface waters from a lack of mechanical mixing. Disruption of the normal southwesterly currents because of abnormal winds were considered to have diminished replenishment because of reduced flushing by advection and to have enhanced utilization by concentrating the bulk of oxygen-demanding material over the New Jersey shelf (Mayer et al., 1979; Han, et al., 1979). Added to these factors was increased utilization of oxygen because of the extensive bloom of the dinoflagellate Ceratium tripos. Located in the upper levels of the cold pool during spring and early summer, respiration by this population represented a significant increase above normal in oxygen demand (Malone, 1979). As the bloom collapsed in mid-summer, dead dinoflagellates coated the bottom,and the decay of this mass placed further demand on the oxygen supply in the bottom water (Mahoney, 1979).

The extensive and persistent hypoxia and mass mortalities off New Jersey in 1976 (Fig. 13) resulted from the combined occurrence of all the factors described above. More limited hypoxic events developed in the summer of 1974 and in the fall of 1968 and 1971. In each of the latter two years summer was prolonged and overturn of the water column by autumnal cooling was delayed, so that the length of the season of stratified water conditions was extended (Armstrong, 1979). Although all of these cases

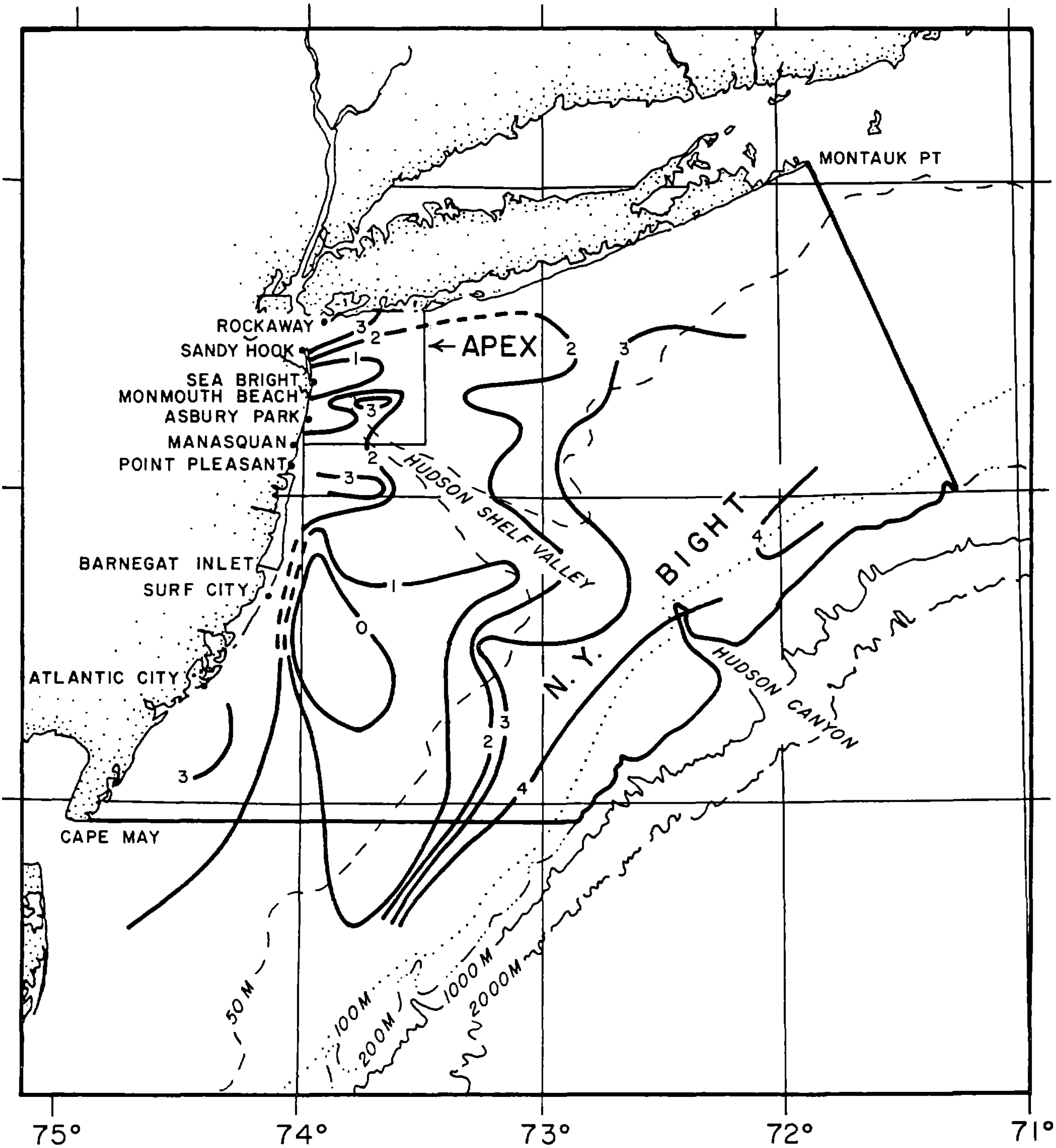

Figure 13. Dissolved oxygen concentration ($ml \cdot l^{-1}$) in bottom water in the New York Bight during August - September 1976. (From Swanson and Sindermann, 1979).

of hypoxia developed off New Jersey, 1976 summer dissolved oxygen concentrations off Long Island were also well below normal and were probably reduced in adjacent areas (Armstrong, 1979). Because of the similarity of conditions in the bottom waters throughout the Middle Atlantic Bight, a combination of factors could lead to hypoxia most anywhere in this region, although they tend to be most critically focused for the waters off northern New Jersey.

BOTTOM CURRENTS AND SEDIMENT TRANSPORT

Solid wastes with densities greater than sea water will accumulate on the sea floor, provided bottom currents are not strong enough to resuspend them. On most of the continental shelf, bottom currents are strong enough to resuspend any solids less dense than sand and transport them considerable distances. Waste particles less dense than sand dumped in such areas would be scattered widely, and only temporarily deposited in areas of ridge-and-swale bottom topography. Wastes with about the same density and grain size as sand would be moved along with sand waves which are common in many areas of the shelf.

Georges Bank

The mean circulation pattern on Georges Bank is a general clockwise motion with speeds of 15-20 $cm \cdot sec^{-1}$ on the northern side of the bank and a broad southwestward flow of about 5 $cm \cdot sec^{-1}$ along the southern side. The water motions, however, on both Georges Bank and Nantucket Shoals are dominated by strong tidal currents that are often in excess of 70 $cm \cdot sec^{-1}$.

The tidal motion is rotary with excursion ellipses of about 5 km by 10 km so that the speed of the water remains high throughout the tidal cycle. The tidal currents are fairly uniform with depth and, at the bottom, are strong enough to erode and remove fine-grained sediment by suspension and to cause bedload transport of coarser material. The direction of sediment transport is expected to follow the mean circulation pattern. As a result of this active transport, the surface sediments on both Georges Bank and Nantucket Shoals are comprised of sands and gravel, since finer grained sediments (silt and clay) are constantly winnowed away (Twichell, et al., 1981).

Middle Atlantic Bight

Sediment transport in the Middle Atlantic Bight appears to be dominated by strong, infrequent storm-induced events separated by periods of little transport. Finer sediments may remain in suspension for a long enough period of time to move shoreward in the estuarine-like gravitational circulation which is apparent, at least on the inner shelf. Some of these fines may find their way into the estuaries themselves.

Sea bed drifter studies have provided an inexpensive way to study the net bottom currents on the continental shelf. Bumpus (1973) released thousands of sea bed drifters, about 16% of which were returned from region beaches or waters. These data showed a general onshore (northward) bottom movement south of Long Island and New England at speeds of about 1-2 $\mathrm{cm \cdot sec^{-1}}$. Over the outer shelf the bottom drift was directed westward at about the same speeds. Off the New Jersey coast, currents converge towards the coast between about 38.5°N and 40°N latitude. South of this region, the drift tends towards Chesapeake Bay at about 2 $\mathrm{cm \cdot sec^{-1}}$. Hardy et al. (1976) and Charnell and Hansen (1974) found similar results in other long term sea bed drifter studies. They also noted, however, a strong near-bottom estuarine-like circulation into Long Island Sound and New York Harbor at 2 $cm \cdot sec^{-1}$. They found an apparent divergence along the Hudson Shelf Valley where east of the valley bottom drift was northward while west of the valley more westward bottom drift was observed. Bottom drifter releases during April 1979-March 1980 reported by Pape (1981) on the continental shelf in the vicinity of Delaware Bay showed predominantly onshore movement, strongly convergent on the Bay mouth.

Long-term near-bottom currents were studied in the Hudson Shelf Valley and Canyon system by Keller et al. (1973) and Nelsen et al. (1978). Current meter measurements showed flow reversals up and down canyon with velocities of 8-15 $cm \cdot sec^{-1}$, with a maximum of 27 $cm \cdot sec^{-1}$ in the upper central portion of the canyon. Sediment texture and organic carbon content of the sediments, however, indicate a long-term down canyon (seaward) transport of fines to the continental rise. Nelsen et al. (1978) concluded from current meter data and wind records that upchannel near-bottom flow was related to westerly winds driving surface waters seaward during the winter, while during the summer seaward near-bottom flow prevailed.

Biscaye and Olsen (1976) measured suspended particulate concentrations in the New York Bight and found local resuspension of fine bottom sediments due to erosional currents. These resuspended sediments were limited to near-bottom waters during the stratified seasons due to limited vertical mixing across the pycnocline.

Simultaneous measurement of near-bottom currents and sediment transport or sediment bedforms, although difficult, has been conducted by some workers. McClennen (1973) reported that sediments off the New Jersey coast in four water depths between 59 and 143 m were being reworked based on ripple marks and sedimentary structure analyses. Mean currents varied between 11.8 and 19.5 $cm \cdot sec^{-1}$ measured at 1.5-2.0 m off the bottom. Based on critical erosion velocities, he determined that the shelf sediment may be eroded and transported as much as 30% of the time by currents and eroded 8% of the time by wind waves at 30 m depth. Freeland et al. (1976) discussed similar results for linear bedforms indicating sand movement.

Swift et al. (1976) showed the importance of storm events in causing large sediment transports with sustained southwestward near-bottom currents of greater than 50 $cm \cdot sec^{-1}$ for approximately 12 hours. These short, efficient, storm-related, large scale transports are separated by longer periods of quiescent minimal transport. Data indicated westward transport off Long Island and southward transport off the New Jersey shore.

Two large depositional areas are located within the Middle Atlantic Bight and are quite different from the more common shelf relict ridge and swale topographies discussed by Swift et al. (1976) and Freeland et al. (1976). One of these areas is the so-called Christiaensen Basin located within the apex of New York Bight. This topographic low has much higher levels of clay and silt than surrounding sand areas. Although the sewage sludge (12 mile) dumpsite is located near the Christiaensen Basin, the Basin has not shown any measurable bathymetric changes which could be attributed to dumping of sludge (Freeland et al., 1976). The area outside of the Christiaensen Basin also contains a few mud-sand scour patches with linear bedforms indicating sand movement. The Christiaensen Basin may act as a "sediment trap", trapping fine sediments which are only aperiodically resuspended by major storm events.

A second depositional area is located about 110 km due south of Martha's Vineyard covering about 2500 km^2 of the continental shelf (Milliman et al., 1980). This area has been termed the "Mud Patch" and is composed largely of sand-silt-clay, sandy-silt and silty-sand (Wigley and Stinton, 1973). Measurements of excess ^{210}Pb from cores collected in the Patch and high depositional rates measured by ^{14}C dating (Bothner, et al., 1981) indicate that the fine grained sediments are modern. The Patch "-- is the only site of present-day natural deposition on the Continental Shelf off the eastern United States, exclusive of the Gulf of Maine." known to those authors. Organic content of sediments from this area is higher than in surrounding shelf areas and may have higher values of trace metals (Maurer, 1982). This is due to the natural sedimentation and sorptive processes controlling fine grained deposition. This region contains a high proportion of deposit-feeding benthos and represents a typical "soft-bottom" community. The Mud Patch is surrounded by typical clean shelf sands and the relief ridge and swale topography (Milliman, 1973).

The sediments in the Mud Patch are believed to be from recent deposition resulting from a gradient in the tidal current speed across the Patch (Twichell, et al., 1981). The material suspended by the strong tidal currents over Georges Bank and Nantucket Shoals are carried into the region by the mean southwestward flow, where tidal currents decrease in strength toward the west to less than 10 $cm \cdot sec^{-1}$ at the western edge of the Mud Patch. These slower tidal currents are not able to keep the fine-grained material in suspension, thus the material settles out and is deposited as the water moves southwestward across the Mud Patch region.

Tidal and Sub-Tidal Near-Bottom Currents

Superimposed upon the weak alongshore mean currents discussed above are currents in the tidal (6-24 hours) and sub-tidal (2 to several days) frequencies which have been measured by many workers in the past several years with current meters.

Tidal currents have regular semi-diurnal (12 hour) periods and are generally strongest near the coast. The tidal currents are generally described as rotary, constantly varying in direction, thus describing what are known as tidal ellipses. Beardsley et al. (1976) and Patchen et al. (1976) noted from current meter data that tidal currents in the Middle Atlantic Bight are related to the M_2 and K_1 tidal components. The tidal currents decrease in magnitude away from the coast and also decrease with depth. Scott and Csanady (1976) noted moderately strong (20 $cm \cdot sec^{-1}$) tidal currents 11 km south of Long Island during September 1975.

Subtidal currents are mostly barotropic (caused by changes in sea level) and constant with depth. The sea level changes are due to meteorological forcing caused by either local winds or the propagation of a shelf wave from some distant oceanic or meteorological event (Ou et al., 1981; Bennett and Magnell, 1979; Scott and Csanady, 1976; Beardsley and Flagg, 1976). Beardsley and Butman (1974) proposed a conceptual model to explain simultaneous measurements of sea level changes along the coast and current meter measurements on the continental shelf. They proposed that offshore winter storms dominate the shelf circulation by causing strong westward wind stresses south of New England which drive water shoreward (north) due to Ekman transport. This causes sea level to rise along the coast which sets up a cross-shelf (seaward) pressure gradient force causing a flow to the west due to the geostrophic force balance. This current parallels the westward wind stress which caused the initial setup. Storms located over the land, however, cause eastward wind stresses setting up a large alongshore pressure gradient force which causes large current oscillations but little net alongshore flow. These storms cause Ekman transport away from shore and cause sea levels to fall along the coast. Bishop and Overland (1977) showed that during the winter season wind-driven circulation predominates on the shelf while during the summer, density driven currents are more common.

Many workers have found that these meteorologically forced subtidal currents increase in magnitude away from the coast and decrease near bottom. Boicourt and Hacker (1976) showed near-bottom currents of between 12 and 36 cm·sec^{-1}, increasing in a seaward direction. They also showed that cross-shelf currents may be enhanced by near-bottom onshore flow along the outer shelf in response to offshore Ekman flow at the surface under certain wind conditions. Beardsley et al. (1976) showed that currents veered shoreward closer to bottom, suggesting that near-bottom materials may move shoreward, in agreement with the earlier sea bed drifter work already discussed.

Seasonal stratification due to the development of a pycnocline in shelf water has several implications for the current structure, response and sediment transport of the region. Patchen et al. (1976) determined for the apex of New York Bight that weak stratification resulted in the entire water column responding strongly to the wind, while response was limited to the upper stratified layer when a thermocline was present. Han et al. (1980) showed a decoupling of currents above and below the pycnocline in the New York Bight, with near-bottom currents varying from northward to southwestward. Shonting (1969) reported similar results for Rhode Island Sound where the surface flow above the seasonal pycnocline was strongly isolated from the lower layer.

Nearshore current meter data collected in the apex of New York Bight by Swift et al. (1976) showed a strong onshore transport component. A similar onshore transport was noted by Han and Mayer (1981) on the Long Island inner shelf near the 37 m isobath in late fall. Current records showed both tidal and subtidal forcing, while onshore near-bottom flow appeared to respond to the net offshore surface flow resulting in a zero net cross-shelf flux. Only strong onshore or easterly winds produced an offshore near-bottom component.

DISPERSION OF DUMPED POLLUTANTS

In an attempt to quantify the impact of waste materials being dumped in the ocean, measurements of spatial and temporal concentration variations and behavior of the waste materials are of the utmost importance. Regulatory agencies formulate input criteria based directly on the space-time concentration history of the waste being discharged. However, accurate spatial and temporal histories of waste dispersion and mixing are often poorly understood or totally absent, because of a lack of direct field measurements. Dispersion and mixing models may offer some alternative to the missing field measurements by providing a framework of assumptions and equations through which dispersion may be predicted. Models, however, must be thoroughly tested before they can be used reliably, requiring at least some direct measurements.

Field experiments to determine the trajectories and dispersion of waste materials have been conducted with particular classes of wastes at specific dump sites. The short-term behavior of dumped wastes depends a great deal upon the characteristics of the site at which they are dumped and on the nature of the wastes. Accordingly, the results of field studies and their applicability are limited.

12-Mile Sewage Sludge Site

The 12 mile dumpsite, situated in about 25 m water depths in the apex of the New York Bight, about 15 km off Long Island and about 20 km off Sandy Hook, New Jersey (Fig. 14), is in a highly variable marine environment. The water column in the vicinity of the site undergoes regular seasonal changes in stratification because of heating and cooling, wind mixing and influx of low salinity water from the Hudson-Raritan estuary. Average currents are toward the south-southwest, but vary widely under the influence of local wind forcing and stratification.

Summaries of currents and hydrography in the waters of the inner portion of New York Bight (Hansen, 1977; Han and Niedrauer, 1981; EPA, 1978) show long-term mean flows to the southwest, ranging from 5-6 $cm \cdot sec^{-1}$ (0.1 knot) in the surface layer to less than 2 $cm \cdot sec^{-1}$ (0.04 knot) in the bottom water. On shorter time scales the currents are stronger and highly variable in direction and speed. Wind-driven surface currents can occur in any direction and compensating flows in bottom waters can result from some wind conditions (Charnell, 1975; Nelsen et al., 1978; Hicks and Miller, 1980; and Bennett and Magnell, 1979), producing either shoreward advance and upwelling of bottom water off New Jersey and in the Hudson Shelf Valley, or

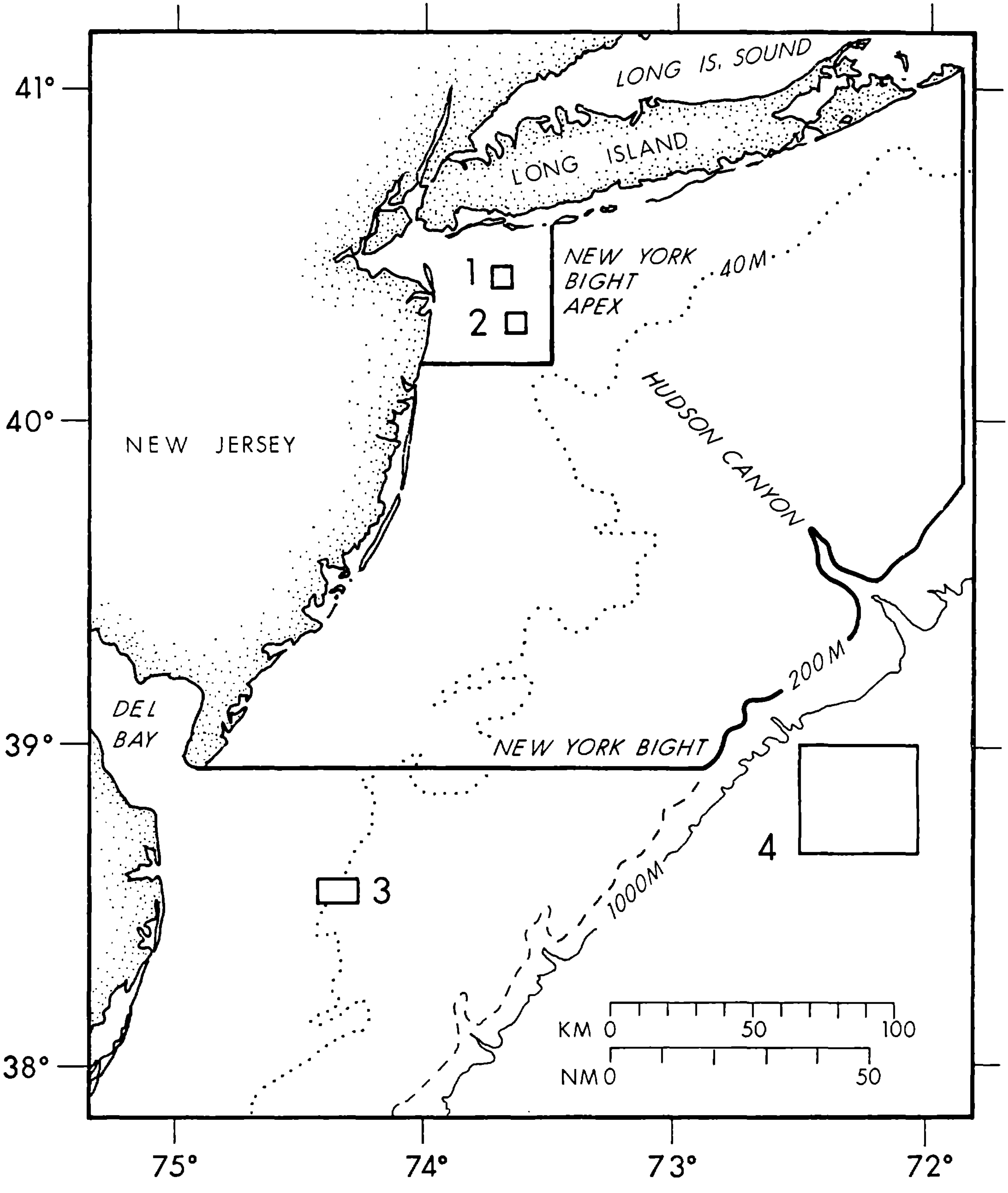

Figure 14. Middle Atlantic Bight dumpsites for which dispersion studies have been reported: 1. 12-Mile Sewage Sludge Site, 2. Non-toxic acid site, 3. Non-toxic acid (35-Mile) Site, and 4. Toxic chemical (106-Mile) Site. From Interstate Electronics Corp. (1978).

with different wind conditions the offshore retreat of bottom water. Field studies with sea bed drifters and bottom current meters (Bumpus, 1965; Charnell and Mayer, 1975; Patchen et al., 1976; Hardy et al., 1976; and Hansen, 1977) indicate the existence of a clockwise gyre in the Bight apex. However, this feature has not yet been described synoptically, and the forcing functions involved or the resulting variations in the gyre have not been defined. During the passage of "northeaster" storms, current speeds greater than 30 $cm \cdot sec^{-1}$ (0.6 knot) in the surface layer and greater than 25 $cm \cdot sec^{-1}$ (0.5 knot) in the bottom water have been recorded.

Tidal currents measured within 3 m of the bottom near the 12 mile dumpsite (Hansen, 1977) ranged up to about 10 $cm \cdot sec^{-1}$ (0.2 knot). According to EPA (1978), "Bottom tidal current velocities may be low, about 10 $cm \cdot sec^{-1}$ (4 in/sec), but when coupled with wind-driven currents during storms, they can cause resuspension and subsequent redistribution of sediments."

Numerous studies of municipal sewage sludge dumping at the 12-mile site and the impacts of such dumping have been made over a period of several years. However, specific studies of dispersion of sewage sludge at the site have been relatively few. Callaway et al. (1976) conducted some preliminary measurements of sludge dispersion at the site, including measuring physical characteristics such as bulk density, solids density and particle size, followed by an at-sea multi-parameter study of each sludge type after dumping. Their measurements showed that density of solids was always greater than seawater. Bulk density, however, was found to be always less than seawater at the 12 mile site. This was observed to limit mixing of the largest fraction of the dumped sludges to the upper portion of the water column both during underway and stationary discharges. Larger particles did settle with higher velocities ($0.5-1.0\ cm\cdot sec^{-1}$), but the sludge plume had much lower settling velocities ($10^{-3}\ cm\cdot sec^{-1}$). The sludge plumes were also noted to be very sensitive to the development and persistence of thermally-induced shallow pycnoclines. In the absence of pycnoclines, during periods of strong winds, mixing was shown to cause rapid (5.5 hr.) dispersal of the sludge to background levels. Effective vertical diffusivities were measured to be approximately $10^3 cm^2\cdot sec^{-1}$. Subsurface dilutions varied from 200:1 at a few meters depth to 600:1 at the surface.

Proni and Hansen (1981) and Duedall et al. (1981) reported from acoustic backscattering data that reflecting layers of sewage sludge appeared in the 5-10 m pycnocline after a stationary dump of the material at the 12 mile site in July 1976. These layers moved horizontally relatively rapidly ($50\ cm\cdot sec^{-1}$) away from the dump location. Their speed decreased with increasing distance from the dump. Such layering may be responsible for the widely varying concentrations observed immediately after a dump. Material shallower or deeper than the seasonal pycnocline dispersed with a rate more in agreement with traditional estimates.

These field measurements of sewage sludge dispersion, although few, clearly demonstrate the dispersive nature of the water column on the 12 mile sewage sludge dumpsite. Dispersion is most rapid when the meteorologic and hydrographic conditions include high winds and an unstratified water column. High background levels from New York Harbor contribute to the apparent "rapid dispersion" by masking the detection of dumped sludge for longer periods of time.

Acid Dump Site

Dumping of non-toxic chemical wastes from National Lead Corporation at the so-called "acid site" located 28 km east of the northern New Jersey coast near 40°20'N, 73°40'W (Fig. 14) has occurred since 1948. Some of the earliest studies of dispersion and mixing of dumped wastes were conducted there (Redfield and Walford, 1951; Ketchum and Ford, 1952). These investigators found that dilution of the waste due to the dumping barge's wake turbulence was from 250 to 500:1 immediately behind the barge. After the barge's passing, the polluted wake continues mixing with the surrounding waters, and initial widening of the wake plume continues for about 30 min., but its vertical deepening reaches the maximum extent almost immediately. Vertical measurements showed identifiable waste near bottom at 24 m, 410 m astern of the dumping barge during January 1950 (Redfield and Walford, 1951), but during April 1948 measurements showed a vertical penetration of only about 10-12 m. Increased thermal stratification (in April) leading to a decrease in density of the surface waters is believed responsible for the noted differences in vertical penetration of the waste. Discrete measurements of the iron concentrations and some simplifying assumptions allowed Ketchum and Ford (1952) to estimate mixing coefficients (effective diffusivities) for the acid waste plumes. They assumed that each unit length of the barge wake contained the same amount of dumped waste and that the concentration distribution across the wake's axis was normal. Thus, from: $Y = N/2(k_e\pi)^{-\frac{1}{2}}(t)^{-\frac{1}{2}}$, where Y = iron concentration, t = time, N = barge discharge rate, k_e = effective diffusivity, they computed k_e from data collected in the field. They found that effective diffusivities varied from 2×10^3 $cm^2 \cdot sec^{-1}$ in April and July to nearly

7×10^3 $cm^2 \cdot sec^{-1}$ in January and proposed that the higher diffusivity measured in January was due to the less stable water column present at that time relative to the other two experiments.

Gordon and Gerard (1973) more recently summarized their findings regarding the spread of contaminants in shelf water. Using a combination of dye tracer studies and free drifters in the vicinity of Ambrose Light Tower together with aerial photographs from the nearby acid site, they found large vertical and horizontal shear zones occurring in the upper portions of the water column related to wind. The largest vertical shear values, 12 $cm \cdot sec^{-1}$, were observed across the pycnocline between the surface mixed layer and underlying water during periods of highly stable (stratified) conditions, and the least vertical shear was observed during neutrally stable (unstratified) conditions. Thus, waste plumes produced during the highly stratified seasons could be expected to remain coherent for longer time periods, as long as they remained above the pycnocline. Large scale lateral discontinuities also occurred with lateral shear becoming evident by the displacement of either dye or waste plumes on either side of the shear. These discontinuities were attributed to convergence zones.

Midshelf Sites

A midshelf dumpsite for non-toxic chemical wastes exists 35 nm (64 km) southeast of Cape Henlopen at 38°30'N, 74°15'W (Fig. 14). Although the site is now deactivated, acid-iron waste from the duPont Edgemoore facility was dumped there from 1969 until early 1977, when the disposal activity was relocated to the 106 mile toxic waste dumpsite (Interstate Electronic Corp., 1978).

A report was prepared by EG&G Environmental Consultants for duPont (EG&G, 1977) concerning the dispersion of the waste at the 35 mile site. Their findings showed that during a September 1976 experiment, the thermal stratification (evidenced by a well-defined thermocline at 10 m depth) limited the vertical extent of the waste discharged. Measured iron concentrations and pH showed about a 5000:1 minimum dilution in the barge wake after 15 minutes. Minimum dilution increased through time to 20,000:1 after 2 hours and to over 250,000:1 after 6 hours. Seawater pH was lowered at the shallow depths above the observed thermocline due to the acidic waste, but returned to ambient values after about 3 hours. Klemas et al. (1977) observed several Edgemoore waste plumes in Landsat satellite and aircraft data during both the stratified (summer) and unstratified (winter) seasons. The plumes drifted generally south or southwest at about 25-30 cm$\cdot$sec^{-1}. Drogue studies on the site showed a southwest movement of about 25 cm$\cdot$sec^{-1} in the winter, while some drogues tended to move north and northeast during the summer (Klemas et al., 1977). Most important, however, were the higher drogue speeds (as great as 100 cm$\cdot$sec^{-1}) directed towards the southwest which were measured at the site during the passage of an offshore low pressure storm system. During such events, enhanced vertical wind mixing when coupled with the high advection rates may greatly increase the dispersion of an acid waste plume relative to the already high rates measured at the site.

Offshelf Sites

The only deep water offshelf dumpsite within the Middle Atlantic Bight is the 106-Mile toxic waste dumpsite centered near 38°50'N, 72°15'W

(Fig. 14). The dumpsite is located approximately 106 nm (190 km) southeast of New York City just off the continental shelf break in depths which range from about 1,700 to 2,750 m. Over several years, various types of wastes have been dumped at the 106-Mile site. A few of the wastes, however, make up a very large percentage of the total which has been discharged there. These wastes are the duPont Grasselli wastewater (a highly alkaline solution of magnesium hydroxide), the duPont Edgemoore wastewater (a highly acidic solution of iron sulfate and iron chloride) and the American Cyanamid Warner wastewater (a slightly acidic solution of organic residues from chemical and pesticide production). Because of potential future dumping needs, two experimental dumps of materials were conducted: the first in July 1977 of primary sewage sludge from Camden, N.J. and the second, a test dump of coal ash from a Consolidated Edison coal-fired power plant, September 1980.

Kohn and Rowe (1977) reported on dispersion experiments of both the duPont Grasselli wastewater and the American Cyanimid Warner wastewater conducted in August 1976. Both wastewaters were mixed with a solution of Rhodamine-WT dye before being discharged. Dispersion in both cases was measured in water pumped from depths of 5 and 10 m, which were continuously analyzed with a pair of fluorometers.

Initial dilutions of the duPont Grasselli and American Cyanimid wastes in the wake of the barge in a calm sea-state differed greatly; about 4,000:1 and 600:1 respectively. Kohn and Rowe (1977) attribute these differences in initial mixing to the density of each wastewater relative to the density of seawater. The duPont waste (1.12 $g \cdot cm^{-3}$) is denser than seawater (1.025 $g \cdot cm^{-3}$) and tended to sink while the American Cyanimid waste was less dense (1.020 $g\cdot cm^{-3}$) and tended to remain in the upper waters. Upon mixing with seawater, the duPont waste produces a white floc which was found (under laboratory conditions) to settle at 0.5 $m\cdot min^{-1}$. After 17 hours the duPont waste at 10 m was diluted to 12,500:1, while the American Cyanimid waste at 10 m was only diluted to 2,500:1 after 17 hours. These differences were again probably caused by the differences in the initial densities of the wastewaters relative to seawater. Dye concentrations decreased rapidly in the first 5 hours and then began to asymptotically approach a constant value.

Hydroscience (1978f, 1979c) studied the dispersion of American Cyanimid Warner wastewater and found dilutions after 4 hours of 25,000:1 in May, 14,000:1 in July, and 9,200:1 in October 1978. Acoustic backscattering data (Orr and Hess, 1978) indicated that Grasselli waste tended to reside in the mixed layer above the seasonal thermocline in the summer season. Winter data showed deeper penetration and uniform vertical distribution of the Grasselli waste to greater than 60 m depth (Orr et al., 1980).

Falk and Gibson (1977) reported on a dispersion study which was conducted by EG&G Environmental Consultants for duPont in September 1976 at the 106 Mile site using dyed Grasselli waste and a series of fluorometers. This study was done during calm sea conditions and with a well developed seasonal thermocline. Within 2 minutes of dumping, Grasselli wastewater dilution was 5,000:1 and increased to 15,000-30,000:1 after 11 hours. Similar results were reported by Hydroscience (1978c, 1978d, 1979b) for Grasselli waste dumped in May, July and October 1978.

Investigations of duPont Edgemoore (acid-iron) waste dispersion at the 106 Mile site began in July 1977, because earlier in 1977 the disposal operation was moved from the 35 Mile site to the 106 Mile site. Acoustic detection of the particulate phase of the waste during July 1977 showed accumulations in regions of high density gradients with occasional penetrations of the gradient to depths of 40 to 60 m. Initial sinking rates of the waste plume after release were 1-3 $m \cdot sec^{-1}$, with rapid decreases in the rate by about 20 minutes. During winter conditions, when deep mixed layers and an absence of seasonal thermoclines occur, the acid-iron waste sank farther and appeared to remain in dense patches which did not show rapid dispersion. Hydroscience (1978a, 1978b, 1979a) studied dispersion of acid-iron waste at the 106 Mile site in May 1978, July 1978 and October 1978 and found minimum dilutions of 75,000:1 after 4 hours.

Horizontal dispersion of both the Grasselli and Edgemoore wastes appeared to be generally enhanced (after initial barge-wake mixing) by current shear, such as that noted during the July 1977 study when a warm core Gulf Stream ring was located at the 106 Mile site. Csanady (1981) in an analysis of several diffusion experiments clearly differentiates between rapid "wake dispersion" caused by barge-generated eddies, and "oceanic dispersion" caused by the mean shear and turbulence in the ocean. Under stratified (summer) conditions, any further decrease in concentration after the wake dispersion phase is completed, is a result of one dimensional diffusion processes in the cross-plume direction. Csanady (1981) determined that effective diffusivity values determined from the experiments were orders of magnitude too low, meaning that other processes such as shear diffusion must be responsible for the observed dilutions. A calculated diffusion velocity of 0.25 $cm \cdot sec^{-1}$ was close to the observed value for the experiment series. Based on this work, Csanady (1981) concluded that sluggish shear diffusion would last for many days provided that conditions remained quiescent. However, meteorologic disturbances (storms and passing fronts) and hydrographic features (warm core rings and other ocean fronts) probably interrupt quiescent periods often enough that they govern the ultimate fate of barged industrial waste at the 106 Mile site.

An experimental dump of coal ash was conducted by Energy Resources Corporation at the 106 Mile site (ERCO, 1981) for Consolidated Edison Company of New York to allow the U.S. EPA permit application process to continue. Analysis of a sample of coal ash from the dump showed a bulk density of 0.94 $g \cdot cm^{-3}$, a particle density of 1.90 $g \cdot cm^{-3}$ and a settling rate of 12 $m \cdot min^{-1}$. The ash was enriched in heavy metals including Cr, Cu, Mn, Ni, Va and Zn. Approximately 84% of the sample was in the sand or silt size ranges. A strong seasonal pycnocline was present at the 106 Mile site at 20-35 m depth and exhibited increased turbidity prior to the coal ash dump on September 15, 1981. After the dump commenced, acoustic backscattering and water sample data showed that a portion of the dump had penetrated the seasonal pycnocline to a depth of 100 m in 20 minutes, while some ash still remained within it. This rapid settling rate (5.0 $m \cdot min^{-1}$) is consistent with data that showed no evidence of material within the pycnocline after 1 hour. After 1.5 hours, the acoustic system showed no evidence of the plume. Calculations showed that 55% of the discharged material (probably the sand and coarse silt-sized fractions) settled well beyond the seasonal pycnocline within 0.25 hours of discharge. It was estimated that 98% of the discharged material had rapidly settled towards the sea bottom. Some vertical shearing of the remaining surface plume by currents was noted.

The 106 Mile site already receives (or may receive in the near future) a variety of waste types with widely varying physical and chemical characteristics. These wastes may be separated based on their dispersion characteristics into four groups:

Group 1 (American Cyanimid wastewater) has densities less than seawater, will not impact the ocean bottom and are most affected by horizontal dispersion. Vertical mixing to the seasonal pycnocline may not be instantaneous although distribution of the waste throughout the seasonal mixed layer will probably occur.

Group 2 (duPont Grasselli and Edgemoore wastewaters) has densities which are close to seawater density and also will not impact the ocean bottom. Vertical barge-wake mixing to the seasonal pycnocline (if present) or deeper (if not present) is almost instantaneous; further dispersion is horizontal.

Group 3 (coal ash) has densities (particle densities) much greater than seawater, with high sinking rates and will most probably impact the bottom. This group is affected almost exclusively by its sinking rate while barge wake mixing and horizontal dispersion are almost insignificant.

Group 4 (sewage sludge) composition varies widely but usually is more than 95% water with a bulk density close to that of sea water. A small fraction of the sludge is particulate material heavy enough to sink to the sea floor quickly. The remainder is suspended or dissolved material; the former sinks very slowly, the latter sinks only if its fluid density is greater than sea water, coming to rest when dilution reduces it or when it encounters the pycnocline.

Although these four groups have different physical characteristics, their combined dumping in one area may cause some unforeseen effects. For example, rapid transport of coal ash to bottom if contaminated through sorptive processes by other chemical wastes prior to descent may provide a mechanism by which wastes from groups 1 and 2 (above) may impact the ocean bottom.

MODELS

It is quite appropriate to recall some of the ideas presented by B. H. Ketchum in his wrap-up comments to the Symposium on the Middle Atlantic Continental Shelf and the New York Bight (Ketchum, 1976) as they pertain to modeling. In particular, the following:

> "What else do we need to know? We need a useful, predictive model.... Modelers sometimes assume that if they can draw enough boxes and enough arrows on a piece of paper, they suddenly know something about the system. Actually, it works the other way around. The boxes and arrows are nonsense until something is known about the system and then you can start to build a model based on what you know. If one builds an entirely conceptual model (obviously nobody does; whatever information is available is used), one can delude oneself and others that something is known about the system.
>
> "What can a model do? It can help define the gaps of knowledge where we need more precise information. If it fails in doing this, then it fails in the first purpose of a model. Even more importantly,

> once enough is known of the forcing factors, of the flow factors, of the control factors, then a prediction can be made about the effects of a perturbation of some part of the system on some other part of the system. There may never be a complete model of the New York Bight, including the circulation, the geology, and biology, the ecology, the benthic biology, the phytoplankton, the zooplankton and all of their interactions. But that doesn't say that a model can't be useful; it doesn't have to be complete, but it does have to be realistic. Approximations or estimates can be used for some of the 'unknowns' and the results checked against reality."

These comments are quite appropriate as one reviews the state of modeling the marine environment of the northeastern United States. If one were to pinpoint a major failing of models (and modelers) for the region, it would have to be that they are not available when major environmental decisions for the marine system have to be made. This is not to indicate that the researchers have somehow failed, but rather to point out an area that has not been addressed adequately by modelers; providing our decision makers with the best scientific information available on which to base their judgments. What are needed are models that can answer the many "what if" questions that decision makers need to consider, predictive models that have a firm basis in the real world.

From descriptions of the features and processes in the preceding chapters, it is quite apparent that the marine environment off the northeastern U.S. is quite complex. It is so complex that the process of "building" models for the various systems is difficult, because many of the underlying processes and interactions are not sufficiently understood. However, much modeling work has been done, and some of it is quite useful.

Table 2 presents a summary of modeling activities that have been completed and/or are underway. The table is organized roughly in accordance with the pertinent features and processes discussed in the previous chapters.

It would be impossible in the space allotted to discuss a significant fraction of the models listed in Table 2. Instead, six modeling activities were chosen as examples to be discussed. This is not to say that those picked are the best. Rather, these particular activities serve as good examples that can be used to point out good aspects of modeling as well as problem areas.

Diagnostic Modeling in New York Bight

The term diagnostic as applied to modeling means that not all of the typically dependent variables are calculated. Instead, one or more of the dependent variables are specified, and the other dependent variables are calculated based on this specification. A good example of this type of modeling is the work of Han, Hansen and Galt (1980) and Han, Hansen and Cantillo (1979) applied to the New York Bight. They specified the currents at the boundaries and the interior density field, then "interpolated" the currents in the interior using the appropriate hydrodynamic equations. Galt (1980) provides a clear description of this "interpolation" procedure. This method is very useful for deriving a flow field over a region from a few point current measurements. One problem with this model is that it is very data intensive and is only as good as the data it uses. Also, the model is only useful during relatively steady conditions, and it is not a predictive model.

A possible alternative to requiring field data as input would be to use a coarse-grid predictive model over a much larger region. Then use the calculated values from it to drive the diagnostic model. This is similar to the technique of using a coarse grid model to determine boundary conditions for fine grid model.

The diagnostic model is a useful framework for retrospective analysis of a field program. This information could then be used to indicate a more efficient deployment/arrangement of field instruments to maximize the return of information for a given number of instruments. In fact, part of the retrospective analysis of a field program could determine the sensitivity of the calculated currents to various subsets of the actual measurements.

Box Model for Middle Atlantic Bight Transport

The box model technique is based on the concept of mass conservation. It is assumed that the area to be modeled is a well-mixed reactor, and conservation equations are written for the box. By writing equations for various independent tracers, enough equations can be obtained to match the number of unknown transports. Good applications of this to the Middle Atlantic Bight shelf are seen in the work of Bush (1981) who used mass, temperature and salinity and Garfield (1978) who used mass, salinity and Cs^{137}. The calculated transports were for the northern shelf and near-surface slope water into and the shelf water out of the shelf region. The models were used to calculate annual average transports for the region for a given year. The results agreed quite well with other independent transport estimates.

This type of model provides a good technique for analyzing year-to-year variations in transport, but it requires a good data base for successful application. Bush (1981) has performed sensitivity analyses of her results to variations in the data. This model could be used to evaluate the most efficient use of data to provide good estimates of the transport. This is not a predictive model.

Dissolved Oxygen Model

The modeling framework developed at Manhattan College has had wide application and has recently been applied to the dissolved oxygen problem in the New York Bight (O'Connor, Mancini and Guerriero, 1981; O'Connor and Mancini, 1979). Basically, their procedure is to use a model(s) of the various mechanisms they feel are relevant as a focal point to organize data, to extract water transport, and to calculate transport of constituents of concern. The model is then used to predict conditions under a variety of scenarios. These results can then be used to evaluate the various scenarios in some possible decision-making process.

This framework is heavily dependent on data for actual development of the model, for determining water transports, and for calibrating the coefficients in the model, but it makes efficient use of the data. Various verification procedures have been developed for the model parameter studies to help the analyst determine the best coefficients based on the available data (Thomann, 1980).

One of the strong points for this modeling framework is that predictions can be made assuming various physical scenarios. This framework is also a good example of how a model can be used to synthesize and evaluate data. It is not unusual in this type of modeling framework that the analyst finds that there is not sufficient information in the data to differentiate alternative mechanisms that could be occurring. The analyst can then propose measurement programs to generate the required data.

Hydrodynamic Modeling of Entire Shelf

The recent work of Beardsley and Haidvogel (1981) is an example of a systematic approach to hydrodynamic modeling of the entire Middle Atlantic shelf. Their published work is just the first part of what seems to be a very promising study. Their model is two-dimensional, and only qualitative comparisons with data have been made, but they admit that much more detail has to be added and more experimenting with the model has to be performed before detailed comparisons with data can be made.

This is the type of model that can be used as input to a finer grid model of a subregion or to a diagnostic model. Once more work has been done on this full-shelf model, it could be quite useful as a predictive tool.

Oil Spill-Fisheries Impact Modeling

An example of how hydrodynamic transports can be coupled with ecological-type models is seen in the work of Reed, Spaulding and Cornillon (1980). They were interested in predicting the effects of oil spills on the fishery on Georges Bank. The total model is composed of three components: transport, fishery and oil spill fate. The transport as discussed in their report was determined from the observed seasonal patterns, simple wind-driven dynamics and random walk dispersion. More recent work incorporates 3-D hydrodynamic calculations. Much detailed effort has gone into the fishery and oil-spill components. Various aspects of these components have foundations in experiments and observation. This is another good example of how models can be used for prediction, assuming various scenarios.

Impact of Ocean Disposal

The work of O'Connor, Okubo, Champ, and Park (1981) can be viewed as a "global" model for addressing the question of what will happen if sewage sludge is dumped at the 106 Mile dumpsite. It can be viewed as a global model because it addressed the "big picture" in terms of what will happen. They are not concerned with specific details or developing new models. Rather, they determine what the existing information base can tell them and then piece together what they hope to be a consistent picture. The various components they use can range from observations and estimates up to actual model results. A product of this type of modeling is the indication of the areas where more research is needed.

TABLE 2. SUMMARY OF NUMERICAL MODELS GROUPED BY INTEREST AREAS

MIDDLE ATLANTIC REGION CIRCULATION (INCLUDING GULF OF MAINE)

Reference	Area	Description
Han, Hansen & Galt (1980)	New York Bight	diagnostic model for circulation
Beardsley and Haidvogel (1981)	entire Middle Atlantic Bight, including Gulf of Maine, out to 200 meters	2-D wind-driven hydrodynamic model
Beardsley and Winant (1979)	Middle Atlantic Bight	determined that mean circulation caused by large scale mid-ocean circulation
Holland (1978)	idealized ocean	mesoscale eddy model including a Gulf Stream
Haidvogel and Holland (1978)	idealized ocean	linear stability theory applied to Holland (1978)
Holland and Lin (1975a, b)	idealized ocean	mesoscale eddy model
Bush (1981)	Middle Atlantic Bight shelf	box model for transport
Holland & Hirschman (1972)	North Atlantic	3-D circulation model with prescribed density field
Bishop (1980)	Middle Atlantic Bight shelf	mean summer and winter transport analytic model (combines Csanady (1976) and Bishop & Overland (1977))
Csanady (1976)	Middle Atlantic Bight shelf	analytic 2-D model for winter circulation
Sarmiento & Bryan (1982)	North Atlantic	3-D robust diagnostic model for circulation
Han, Hansen & Cantillo (1979)	New York Bight	diagnostic model of water and oxygen transport
Ou and Beardsley (1980)	continental shelf south of New England	propagation of free-topographic Rossby waves across continental margin
Loder (1980)	Georges Bank	mean current-tidal current interaction

MIDDLE ATLANTIC BIGHT CIRCULATION (cont.)

Reference	Area	Description
Csanady (1980)	Long Island coast	simple model to show offshore winds could cause longshore pressure gradient
Han & Mayer (1981)	off Long Island	tide and wind response models based on current meter records
Bennett & Magnell (1979)	New Jersey coast	use numerical model to analyze current meter data
Cornillon, Reed, Spaulding & Swanson (1980)	Georges Bank, Gulf of Maine	use SEASAT altimetry to compare with 2-D vertically averaged model
WES-COE (1982) ①	Atlantic City to Nantucket Island	2-D storm surge model (after Butler (1980))
Garrett (1974)	Bay of Fundy, Gulf of Maine	examine normal modes (after Platzman (1972))
Csanady (1978)	Middle Atlantic Bight shelf	steady-state, depth averaged 'global' model of shelf circulation
Garfield (1978)	Middle Atlantic Bight shelf	box model for transports
Ou, Beardsley, Mayer Boicourt & Butman (1981)	Middle Atlantic Bight	examine sub-tidal (wind-forced & free wave) current fluctuations in current meter data
Bush & Kupferman (1980)	Middle Atlantic Bight	show that Csanady (1976) model is sensitive to alongshore wind stress and pressure gradient
Schmitz & Owens (1979)	North Atlantic (MODE area)	compare model results (Bretherton & Karweit (1975)) with statistical properties of mesoscale eddy field from long-term moored instrument data
Csanady (1974)	Gulf of Maine	linear model of aperiodic motions over idealized shelves

MIDDLE ATLANTIC BIGHT CIRCULATION (Cont.)

Reference	Area	Description
Bishop & Overland (1977)	Middle Atlantic Bight shelf	analytic model for mean summer flow using observed density field
Talay & Whitlock (1975)	Baltimore Canyon	wave refraction modeling
Hopkins (1982)	Middle Atlantic Bight shelf	discusses role of local and external forcing using 2-D model
Hopkins & Dieterle (ms submitted to *Con. Shelf Res.*)	New York Bight	externally forced barotropic circulation model in 2-D

① Waterways Experiment Station,
Corps. of Engineers, U.S. Army
personal communication.

ESTUARINE EFFLUENT PLUMES

Reference	Area	Description
Beardsley & Hart (1978)	Hudson & Chesapeake Bay estuaries	2-D flow of estuary onto shelf, driven by runoff
Harrison, et al. (1967)	Chesapeake Bay mouth	multiple linear correlation of drifters with winds and runoff
Kao (1981)	Chesapeake Bay plume	2-D model driven by fresh water
Garvine (1979a, b, 1980)	Connecticut River plume	2-D model, integral technique

UPWELLING

Reference	Area	Description
Kangas & Hufford (1974)	Massachusetts Bay	calculate upwelling rates from upward migration of isotherms and by method of Yoshida (1955)

WARM CORE RINGS AND GULF STREAM MEANDERS

Reference	Area	Description
Ikeda (1981b)	Gulf Stream Rings	asymmetric instability of rings and evolution of shape in nonlinear case
McWilliams & Flierl (1979)	Gulf Stream Rings	idealized study of vortex behavior
Meid & Lendemann (1979)	Gulf Stream Rings	numerical simulation of ring propagation in ideal ocean
Hart (1975a, b)	Gulf Stream Rings	instability of ring on sloping bottom
Luyten & Ribinson (1974)	Gulf Stream Meandering	analyzed dynamics in terms of measurable quantities
Flierl (1979)	Gulf Stream Rings	how are size & strength of ring related? shape of isotherms
Csanady (1979)	Gulf Stream Rings	birth and death of rings
Newton (1978)	Gulf Stream Meander	compares with dynamics of atmospheric jet stream
Semtner & Mintz (1977)	Gulf Stream Rings and Meanders	numerical simulation of western North Atlantic
Schmitz & Vastano (1975)	Gulf Stream Rings	investigate entrainment and diffusion in ring using temperature data
Bretherton & Karweit (1975)	Gulf Stream Ring	6 layer, quasi-geostrophic model; try to simulate ring
Ikeda (1981a)	Gulf Stream Meanders and Eddies	2-layer, quasi-geostrophic model to study meander growth and eddy detachment
Firing & Beardsley (1976)	cyclonic vortex	numerical simulation on β plane
Saltzman & Tang (1975)	Gulf Stream Meanders	analytic model to show that asymmetric features of meandering ocean currents can develop

FRONTS

Reference	Area	Description
Chuang & Wang (1981)	continental shelf	effect of density front at shelf on internal tides
Kao (1980)	Gulf Stream front	2-D model - forced by buoyant material
Olbers (1981)	oceanic fronts	internal wave scattering at fronts
Garvine (1979a, b, 1981)	Gulf Stream front	2-D model - integral technique
Flagg & Beardsley (1978)	shelf-slope front off New England	baroclinic stability of front over variable topography
Posmentier and Houghton (1981)	New England shelf break front	simple model of springtime evolution of front
Kao & Cheney (1982)	Gulf Stream front	use SEASAT altimeter data to test models (Kao (1980), Stommel (1966, p. 109), Charney (1955))
Behringer, Regier & Stommel (1979)	Gulf Stream	simple model to explore thermal feedback mechanism for Gulf Stream formation

COLD POOL/THERMAL STRATIFICATION

Reference	Area	Description
Ou & Houghton (1981)	Nantucket Shoals to Hudson Shelf Valley	1-D model with non-uniform rates of heating and with bathymetric features
Aikman (1981)	Middle Atlantic Bight shelf and slope	1-D, 2 layer model of density stratification
Shaw (1981)	cold pool	theoretical model to investigate dynamics of cold pool movement
Anderson, et al (1979)	North Atlantic	numerical experiments to clarify role of stratification and topography on transient response to change in wind forcing
Han & Niedrauer (1981)	New York Bight cold pool	mixing model used to determine diffusion coefficients

BOTTOM CURRENTS AND SEDIMENT TRANSPORT

Reference	Area	Description
Nelson, Gadd and Clarke (1978)	Hudson Shelf Valley	empirical, semiquantitative model for wind-induced flow
Schubel & Ikubo (1972)	Chesapeake Bay mouth	how sediment gets across shelf
Hsueh (1980)	Hudson Valley Shelf	time-averaged, near bottom current as function of mean wind and mean inflow along shelf
Swift, et al (1981)	New York Bight	sediment transport by tidal, wind-driven, and wave orbital currents treated as a diffusion process

DISPERSION OF POLLUTANTS

Reference	Area	Description
Reed, Spaulding and Cornillon (1980)	Georges Bank	transport- fishery- oil spill model
Fischer (1980)	Mid-Atlantic Continental Shelf	estimated dispersion of dissolved material
Sharp & Church (1981)	off Delaware Bay	biochemical dynamics during stratification
O'Connor, Okubo, Champ and Park (1981)	DWD-106	global model for potential effects of sewage sludge dumping
Falkowski, Hopkins, and Walsh (1980)	New York Bight	analyze historical data to distinguish between man-induced & natural causes of oxygen depletion
Cornillon, Spaulding and Hansen (1979)	Georges Bank	fate model for subsurface and surface oil movement
Munday, Harrison, and MacIntyre (1970)	Chesapeake Bay	use tidal-current table date to predict oil slick movement
Miller, Bacon and Lissauer (1975)	New Jersey and Delaware coast	investigate techniques for predicting oil spill movements
Smith, Slack and Davis (1976a)	Mid-Atlantic outer continental shelf oil lease area	oil spill risk analysis to determine relative impact in oil development
Smith, Slack and Davis (1976b)	North Atlantic outer continental shelf oil lease area	oil spill risk analysis to determine relative impact in oil development
Tingle and Dieterle (1977)	New York Bight Apex	oil trajectory forecasting
Flierl (1980, 1981)	gyre or large eddy circulation	simple models of distribution and impact of waste disposal in gyre or large eddy
Swanson (1981)	12-mile, 65-mile, and 106-mile dumpsites	develop pros and cons on dumping sewage sludge at sites
Spaulding (1981)	Georges Bank	similar to Reed, Spaulding & Cornillon (1980) but with 3-D hydrodynamic component

DISPERSON OF POLLUTANTS (Cont.)

Reference	Area	Description
O'Connor & Mancini (1979)	New York Bight	steady-state evaluation of mechanisms influencing dissolved oxygen levels and of engineering solutions for existing water quality problems
O'Connor, Mancini & Guerriero (1981)	New York Bight	time-variable version of O'Connor & Mancini (1979)
Brown & Kester (1981)	DWD-106	stratified microcosm
Morel & Farley (1981)	marine dumpsites	second order rate model for particle removal by coagulation
Atwood, et al (1979)	New York Bight	determination of assimilative capacity
Csanady, et al (1979)	DWD-106	determination of assimilative capacity

GEOGRAPHIC SUMMARY

Summarizing the locations of the various features and processes significant to the distribution of pollutants can best be accomplished by a series of maps (Figs. 15-21).

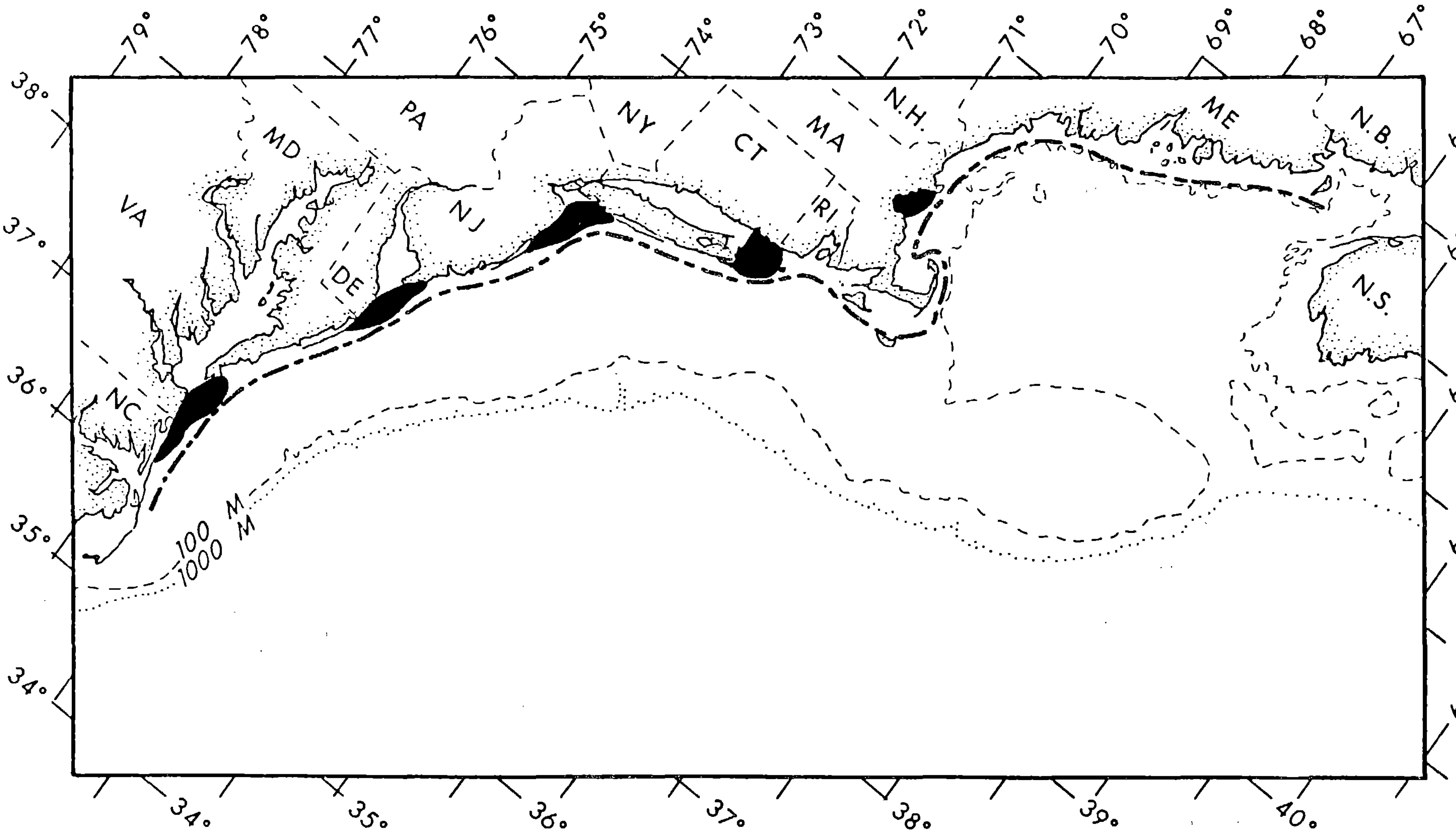

Figure 15. Estuarine effluent plumes. Shaded areas indicate the approximate regions influenced at various times, but do not represent the plumes at any specific time. Dash- dot line indicates approximate boundary of coastal active band which includes most estuarine effluent plumes and upwelling areas.

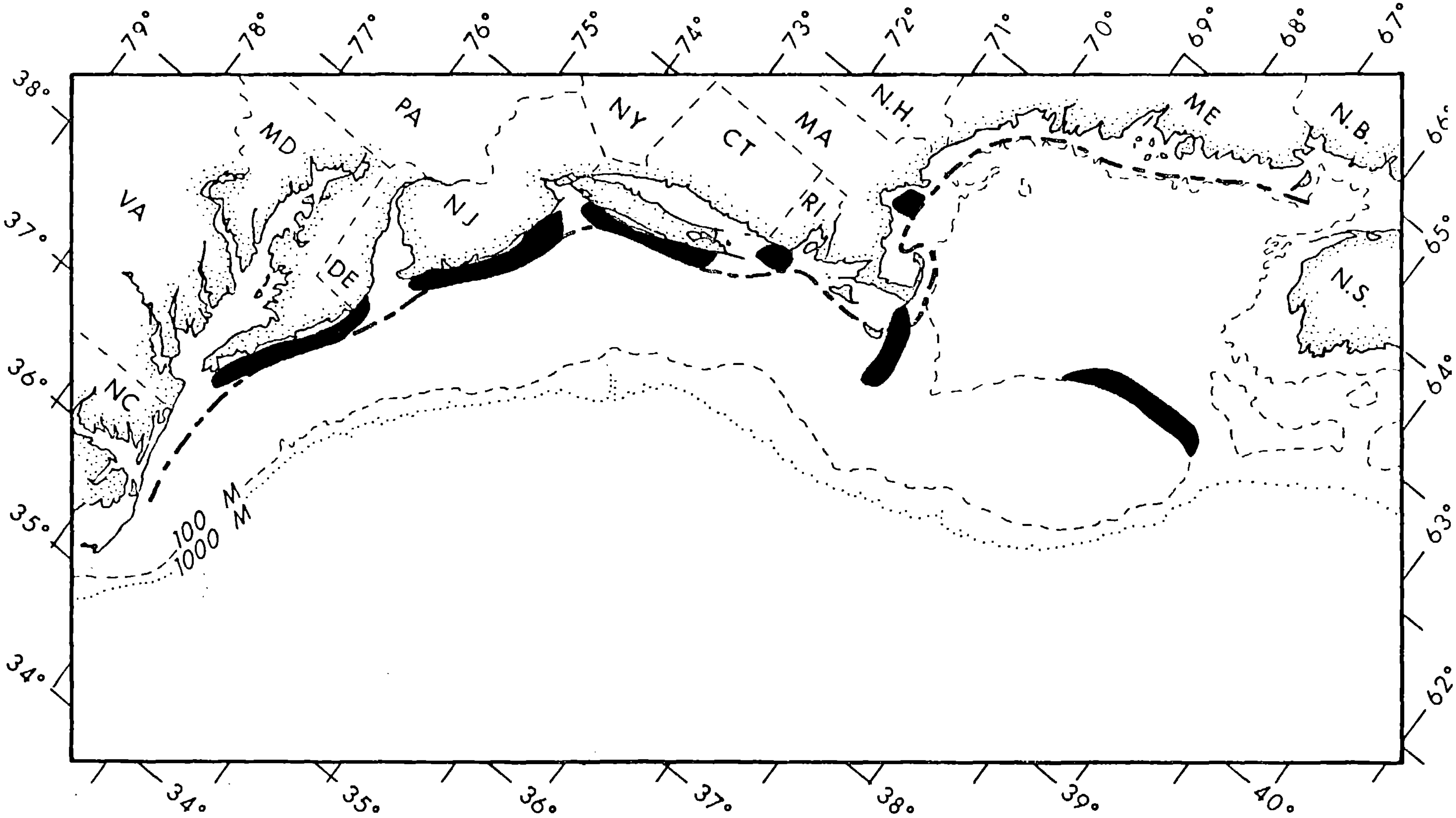

Figure 16. Upwelling areas. Shaded areas are those subject to upwelling at least part of the year. Dash-dot line indicates approximate boundary of coastal active band which includes most estuarine effluent plumes and upwelling areas.

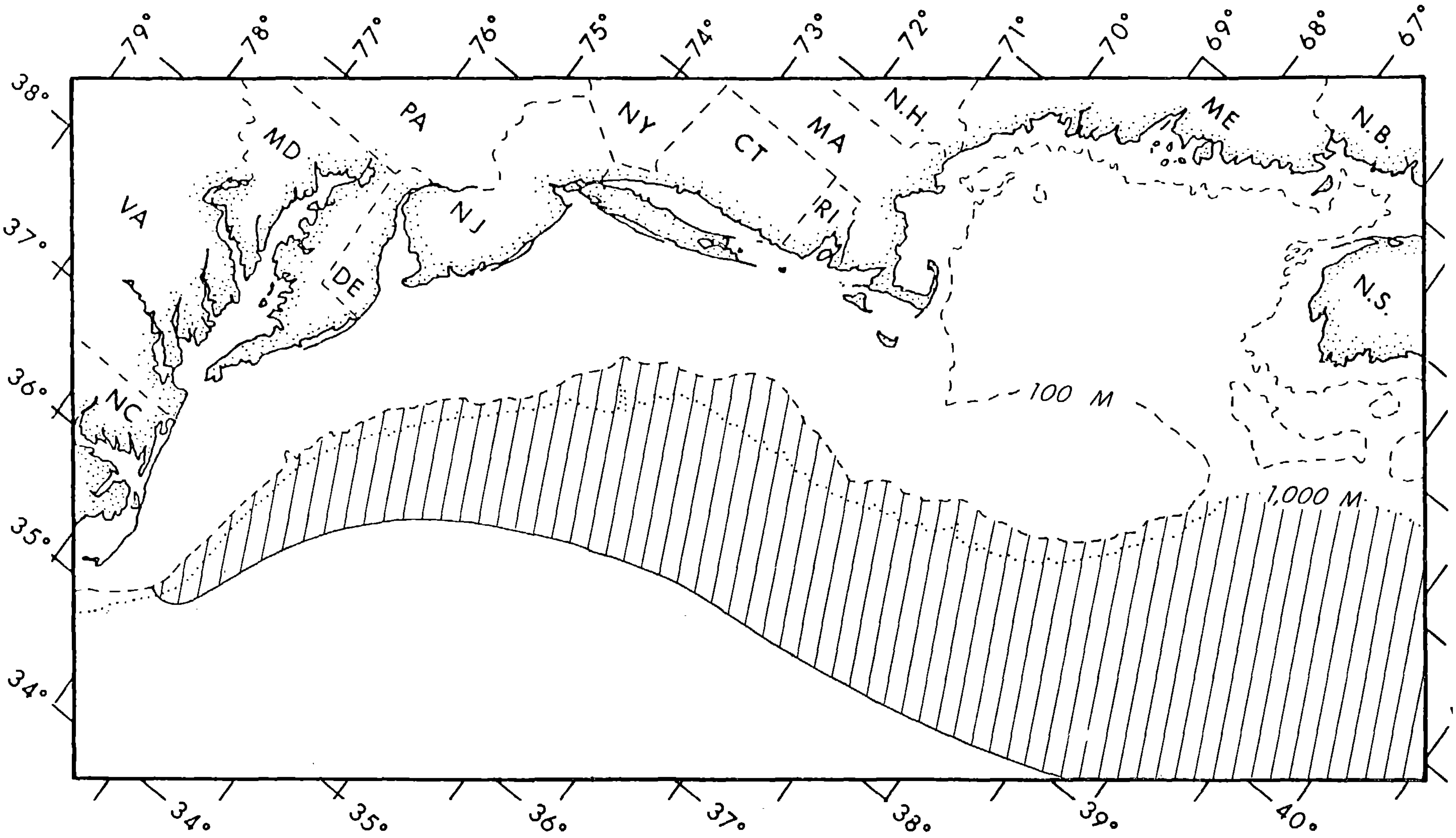

Figure 17. Slope water area through which warm core rings move southwestward and Gulf Stream meanders move northeastward.

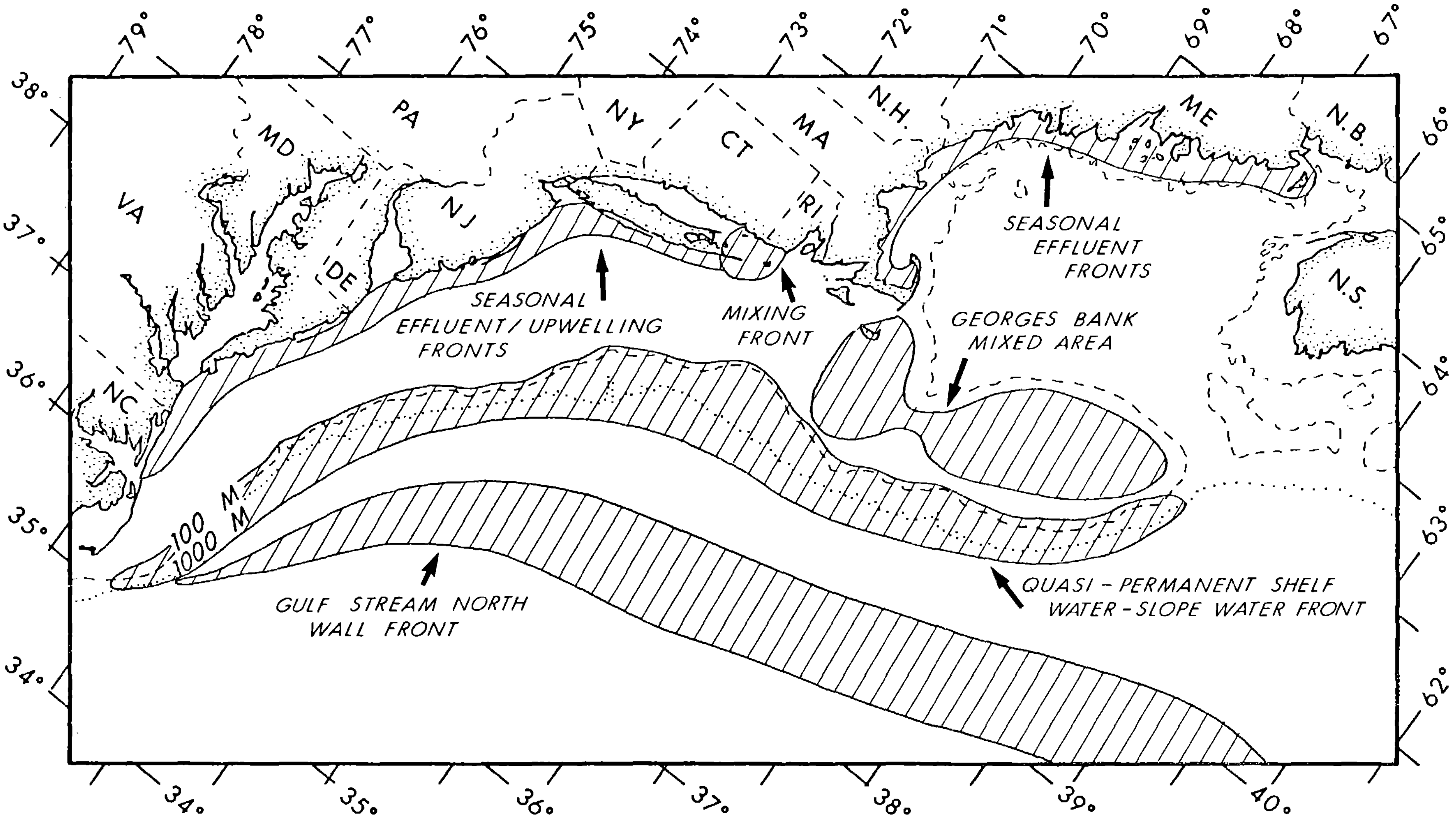

Figure 18. Zones of seasonal or quasi-permanent fronts.

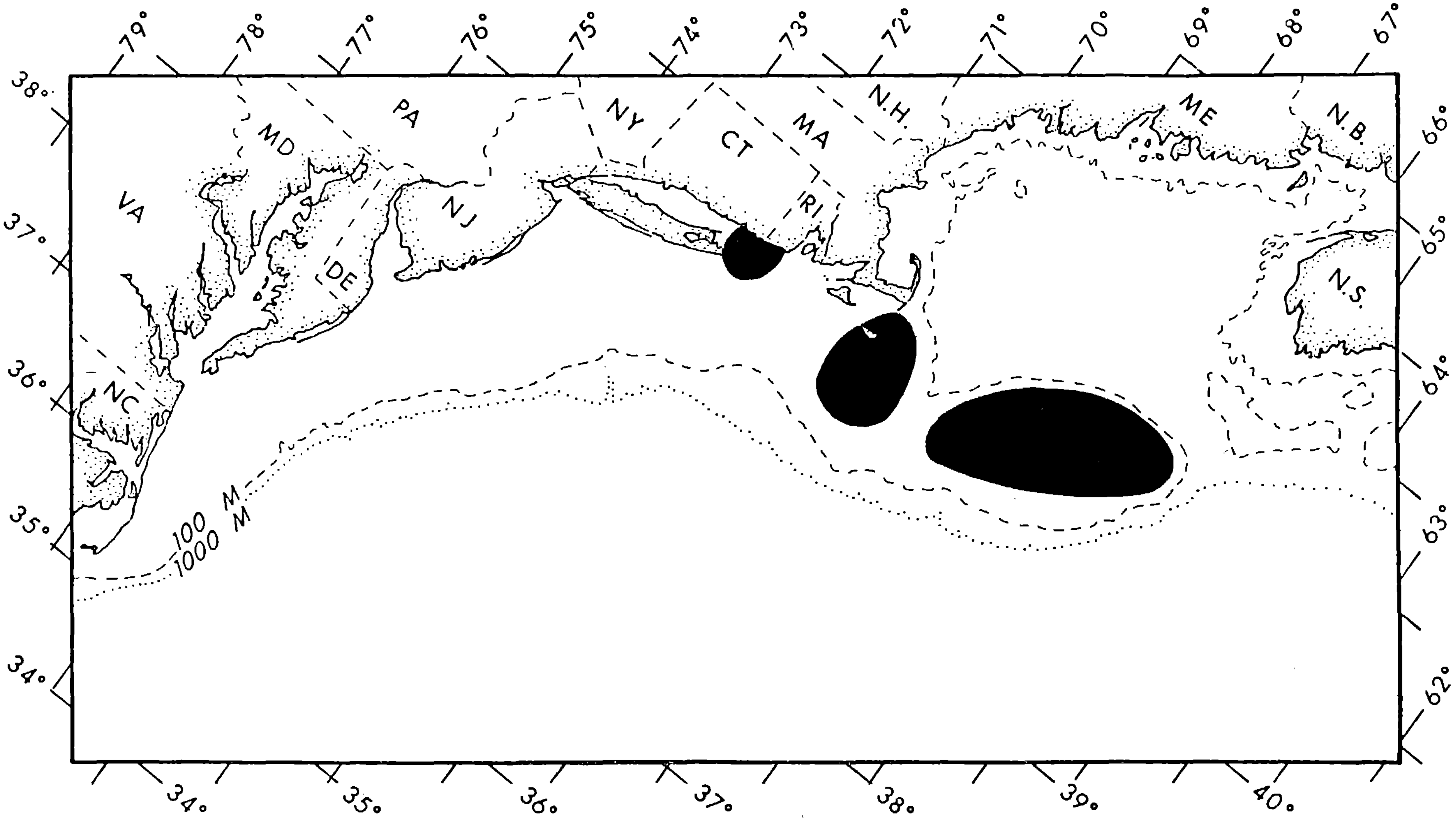

Figure 19. Areas not experiencing seasonal density stratification.

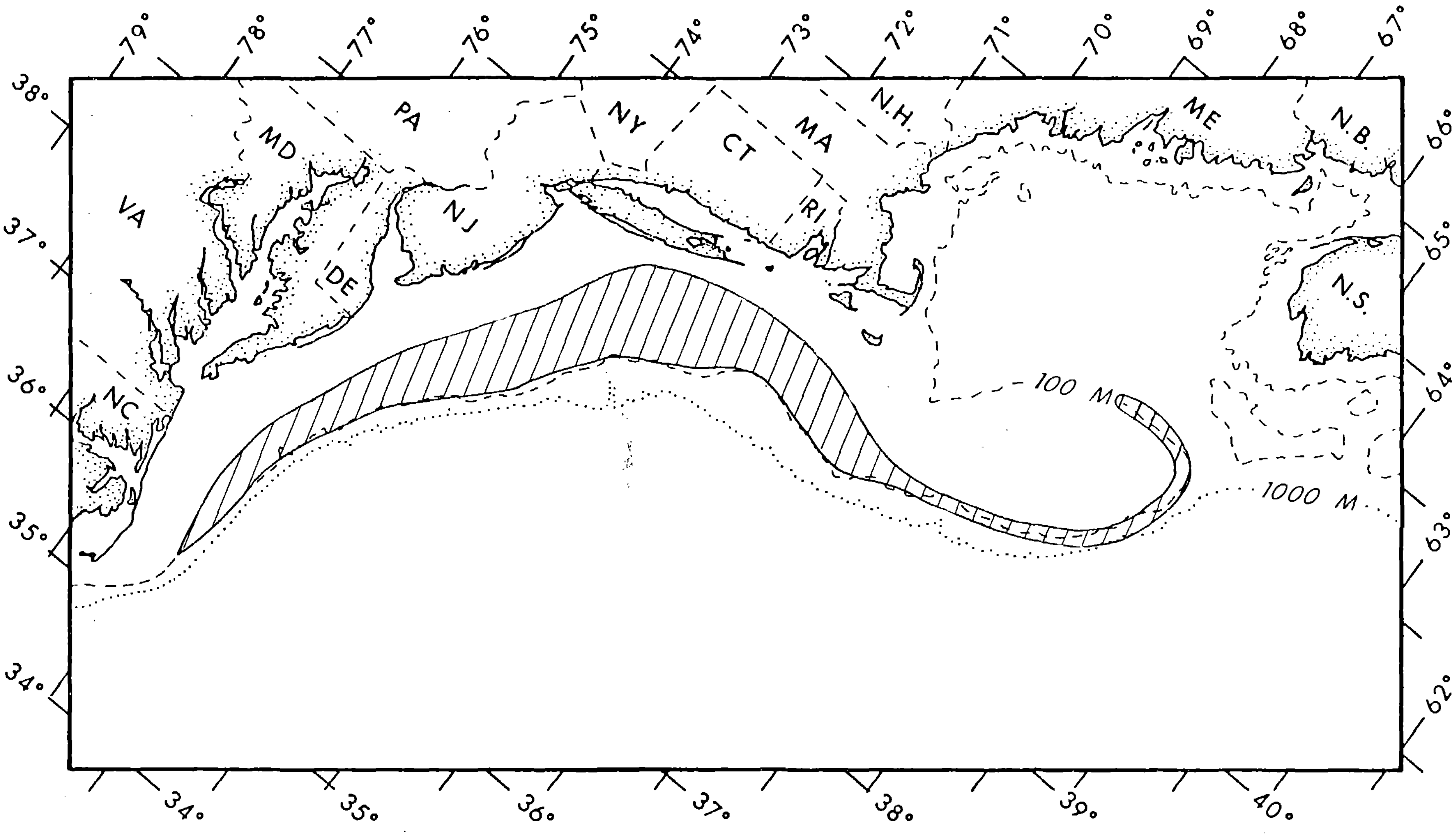

Figure 20. Composite areal extent of the cold pool.

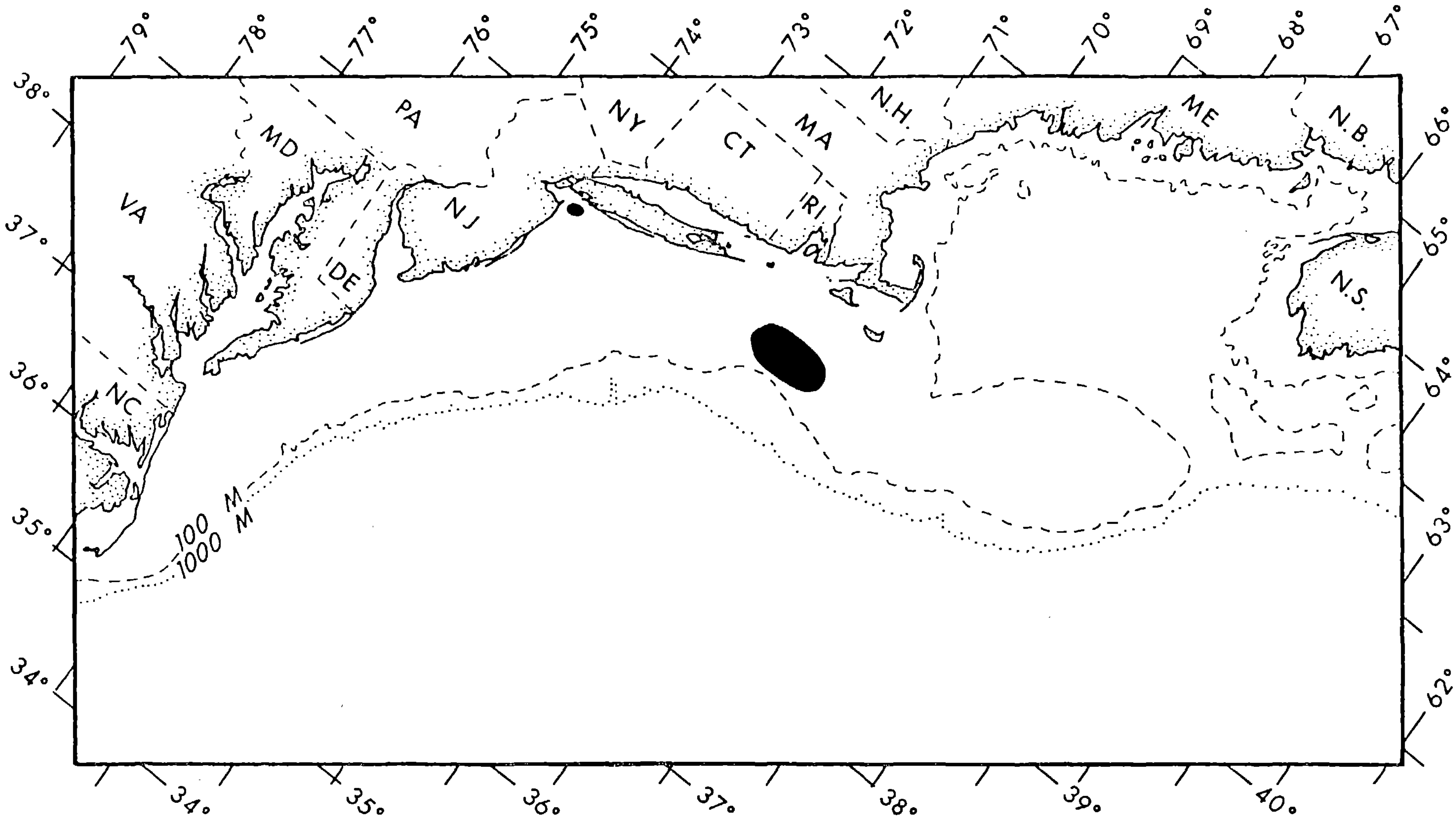

Figure 21. Long-term depositional areas on the continental shelf, excluding submarine canyons.

BIBLIOGRAPHY

The following list of references includes all relevant published items discovered by the authors of this report. It is not restricted to items cited in the text, but all cited items are listed.

When abstracts or summaries were readily available to the editor they were included. Summaries preceded by an asterisk were taken from an annotated general bibliography prepared for the Northeast Monitoring Program by the NOAA Environmental Data and Information Service.

Aikman, F. 1981. The effects of fresh water on the shelf water pycnocline: a numerical study. Paper presented at Middle Atlantic Physical Oceanography Workshop, Univ. of Rhode Island, Oct. 21-22, 1981.

Anderson, D. L.T., K. Bryan, A. E. Gill, and R. C. Pacanowski. 1979. The transient response of the North Atlantic: Some model studies. J. Geophys. Res. 84(C8): 4795-4815.

Four numerical experiments have been designed to clarify the role of stratification and topography on the transient response of the ocean to a change in wind forcing. The geometry and topography appropriate to the North Atlantic between the equator and 50°N are used to make the study more appropriate to a real ocean. In all four experiments, zonally symmetric wind stresses are 'switched on' at the upper surface of a resting model ocean. Two short experiments, 1 and 2, with a duration of 100 days, are first discussed. These are for a homogeneous ocean with and without topography. The response in the flat-bottomed case can be described either in terms of planetary waves or basin modes, but when topography is present, no obvious wave propagation was identified. Higher-frequency basin modes are detectable, but their amplitude is much lower than that in the flat-bottomed case. They are damped out on a time scale of ≲50 days. Two longer experiments, 3 and 4, are then analyzed. These are the analogs of 1 and 2, but stratification was included. The introduction of stratification for the ocean with topography leads to a new, longer time scale, not just for the baroclinic modes, but also for the barotropic. Despite the presence of topography, modal analysis was found useful in analyzing the results. Propagation effects are analyzed, both on the moderately fast time scale of internal Kelvin waves and on the slow time scale of internal planetary waves. Kelvin waves are apparent along the equator, the northern boundary, and on the eastern coast in the Gulf of Guinea from the equator to 20°N. They are not clearly visible anywhere on the west coast. Planetary waves can be detected in the interior both in the presence and absence of topography. When topography is present without stratification, the transport of the Gulf Stream is reduced from 30 to 14 million tons per second. This is a well-known result. With stratification there is no significant difference in transport between the case with or without topography.

Armstrong, R. S. 1979. Chapter 6. Bottom oxygen and stratification in 1976 and previous years. In: Oxygen Depletion and Associated Benthic Mortalities in New York Bight, 1976. R. L. Swanson and C. J. Sindermann (Eds.). NOAA Prof. Paper 11, pp. 137-148.

* Comparison of climatological conditions, dissolved oxygen content and stratification data obtained in 1976 with that obtained in previous years in the New York Bight area.

Atwood, D., D. W. Brown, V. Cabelli, J. Farrington, C. Garside, G. Han, D. V. Hansen, G. Harvey, K. S. Kamlet, J. O'Connor, L. Swanson, D. Swift, J. Thomas, J. Walsh, and T. Whitledge. 1979. The New York Bight. In: Assimilative Capacity of U.S. Coastal Waters for Pollutants. Proceedings of a workshop at Crystal Mountain, Washington, July 1979. E. D. Goldberg, (Ed.), NOAA, Boulder, Colorado.

Azarovitz, T. R., C. J. Bryne, M. J. Silverman, B. L. Freeman, W. G. Smith, S. C. Turner, B. A. Halgren and P. J. Festa. 1979. Effects on finfish and lobster. Chapter 13. In: Oxygen depletion and associated benthic mortalities in New York Bight, 1976. R. L. Swanson and C. J. Sindermann (eds). NOAA Prof. Pap. No. 11, U.S. Dept. Commerce, Rockville, Maryland

Barinov, A. A. and V. A. Bryantsev. 1972. A volumetric statistical analysis of the Nova Scotia shelf and Georges Bank water masses. ICNAF Res. Bull. No. 9:21-25.

Barrett, J. R. 1965. Subsurface currents off Cape Hatteras. Deep-Sea Res. 12:173-184.

Barrientos, C. S. and N. A. Pore. 1976. Storm surges. MESA NY Bight Atlas Monograph 6. MESA NY Bight Project and NY Sea Grant Institute, 44 p.

* A historical summary analysis of storm surges is offered in this monograph. Major storms affecting the Bight region were hurricanes of September 1938 and 1960, extratropical storms of November 1950 and March 1962.

Beardsley, R. C., W. C. Boicourt and D. V. Hansen. 1976. Physical oceanography of the Middle Atlantic Bight. Am. Soc. Limnol. Oceanogr. Spec. Symp., Vol. 2:20-34.

Kinetic energy spectra from moored current meters in the mid-Atlantic Bight reveal marked differences in current variability between the inner shelf and the outer shelf and slope regions. The nearshore subtidal current variability appears to be dominated by meteorological forcing. The amplitude of the semidiurnal and diurnal tidal peaks decreases in the offshore direction. Shallow water records show little or no inertial energy, while at the shelf break and over the slope, inertial motion contributes significantly to the current variance. A simple conceptual model is presented to explain how intense winter low pressure systems ("northeasters") drive strong alongshore currents which are coherent over much of the bight. A map of "mean" currents measured in recent moored array experiments demonstrates subsurface water flow along the shore toward the southwest. The average currents generally increase in magnitude offshore and decrease with closeness to bottom. At most sites, the mean current veers toward shore with increasing depth. The alongshore volume transport measured at three transects across the bight shows surprising uniformity, considering the possible sources for discrepancy. This transport (order 2.0 X $10^5 m^3 s^{-1}$) of water within the 100-m isobath implies a mean residence time of the order 3/4 year. Much of the shelf water observed flowing westward south of New England must originate in the Gulf of Maine-Georges Bank area.

Beardsley, R. C. and W. C. Boicourt. 1981. On estuarine and continental shelf circulation in the Middle Atlantic Bight. Chap. 7 (p. 198-235) In: Evolution of Physical Oceanography Scientific Surveys in honor of Henry Stommel. The MIT Press, Cambridge, MA 623 pp.

7.3.4 Summary and Some Remaining Problems

We have attempted here to describe the shelf response to wind forcing on three time scales. Synoptic-scale atmospheric disturbances and in particular winter cyclones can drive strong transient current fields that tend to move along the shelf in phase with the forcing. The cross-shelf momentum balance is approximately geostrophic and both the current and subsurface pressure fluctuations are generally coherent over much of the Middle Atlantic Bight, reflecting the relatively small size of this shelf region with respect to the atmospheric forcing. The synoptic-scale shelf response appears to be consistent with continental shelf-wave theory. The direct effect of wind forcing is also evident in the monthly-mean shelf circulation, although the observed currents have a complex spatial structure and other processes like runoff and offshelf forcing contribute to the variability on this time scale. The mean flow over the Middle Atlantic Bight is primarily driven not by local runoff and wind stress but by the large-scale wind stress and heat-flux patterns over the western North Atlantic. Thus the observed currents can be decomposed into a mean component driven by a steady offshelf forcing and a fluctuating component driven by the regional wind stress field acting over the shelf.

This review has focused on the wind-driven circulation components in the Middle Atlantic Bight. The actual influence of density stratification on the different components of the general circulation is still not clear, and only a crude estimate of the flushing rate of the shelf is available. The processes controlling the local position and movement of the shelf-slope water front are poorly known. As noted by Fofonoff (chapter 4, this volume), satellite infrared mapping of the sea surface temperature has greatly added to our perception of the spatial variability and complexity of the near-surface current and thermal fields.

Beardsley, R. C. and B. Butman. 1974. Circulation of the New England continental shelf: Response to strong winter storms. Geophys. Res. Letters 14:181-184.

* A brief data-modelling paper in which the authors engage in a discussion of "current measurements along with coastal sea level observations and suggest a simple model for the wind-driven response of the shelf circulation to strong winter storms".

The study "focuses on the winter circulation of the continental shelf waters on the section of the Mid-Atlantic Bight from Nantucket Shoals to Sandy Hook, New Jersey" in March of 1973.

During the period of data collection three winter storms passed through the area.

"The observations show that large westward mass transports along the shelf were produced by strong easterly winds, while westerly winds produced little alongshore flow. Significant cross-shelf and alongshelf surface pressure gradients occur during the storms."

Beardsley, R. C. and C. N. Flagg. 1976. The water structure, mean currents and shelf water/slope water front on the New England continental shelf. Mem. Soc. Royale des Sci. de Liege. 6(10):209-225.

Beardsley, R. C. and D. B. Haidvogel. 1981. Model studies of the wind-driven transient circulation in the Middle Atlantic Bight. Part 1: Adiabatic boundary conditions. Jour. Phys. Oceanog. 11(3):355-375.

A numerical model of the wind-driven transient ocean circulation in the Middle Atlantic Bight is described. The model incorporates realistic topography and covers the continental shelf between the coast and the 200 m isobath from Cape Hatteras to the southern tip of Nova Scotia. The traditional shallow-water dynamics are used, i.e., the vertically integrated and linearized equations for the flow of a homogeneous fluid driven by atmospheric pressure and wind stress fluctuations and damped by a quadratic bottom stress. The equations are integrated in time using a simple modification of Platzman's (1972) finite-difference scheme, with a 12.7 km grid spacing. At the coast, normal flow is required to vanish; at non-coastal boundaries, the equivalent surface elevation is held fixed.

Several classes of initial value experiments are used to study the free and forced modes of this model, and the damped flow driven by a spatially uniform and stationary wind stress and by an idealized traveling synoptic-scale wind-stress pattern. The numerical experiments indicate that several time scales are important in the regional adjustment process. These are an inertial time scale dependent on the regional long-wave propagation speed, a local frictional time scale dependent on the strength of the depth-averaged velocity field, and a longer time scale which reflects the adjustment process within the entire model. The transient response within the Middle Atlantic Bight proper from Cape Cod to Cape Hatteras to an alongshore wind stress is clearly dominated by friction and rotation. The effective spinup time scale for a 2 dyn cm^{-2} wind stress is about 10 h at New York. This is sufficiently short in comparison to the 4-10 day time scales characterizing atmospheric transients that the storm-driven currents should be quasi-steady. Within the deeper Gulf of Maine basin, the effective spinup time scale is much longer and the normal modes of the basin excited by the wind forcing are only weakly damped in time.

A comparison of model and observational data on current and sea level variability indicates that the model response is more realistic within the Middle Atlantic Bight section of the model domain. Differences within the Gulf of Maine are due primarily to the specific boundary condition imposed on the upcoast (Scotian shelf) boundary.

Beardsley, R. C. and J. Hart. 1978. A simple theoretical model for the flow of an estuary onto a continental shelf. J. Geophys. Res. 83(C2):873-883.

A simple theoretical model is developed to describe the steady flow of an estuary onto an adjacent continental shelf. A two-layer density stratification is assumed for the shelf water, and the fluid motion is driven by the positive (upper layer) and negative (lower layer) mass fluxes associated with a pair of point sources located at the mouth of the estuary. The dynamics are linear and include the effects of Coriolis acceleration, turbulent friction, and bottom topography. Analytic solutions for the one-layer single-source problem are found for two special depth profiles. A boundary layer solution is found for the power law depth profile $h(y) = \alpha y^{\kappa}$, and a global solution is found for the log law profile $h(y) = H_o[1 + \alpha \ln (y/L_b)]$ for small $\alpha << 1$. Both solutions indicate that the far-field flow is asymmetrically concentrated toward the right-hand coast in the northern hemisphere, a consequence of the basic balance between topographic vortex stretching and bottom friction. This mechanism also applies when a constant alongshore current is present. In the two-layer case the flow in the upper layer generally tends to be concentrated toward the left-hand coast, since the upper fluid feels (1) the interface and not the bottom topography and (2) the interfacial drag exerted by the lower fluid toward the right-hand coast. A brief comparison is made between model predictions and observations for the Hudson and Chesapeake Bay estuaries.

Beardsley, R. C., H. Mofjeld, M. Wimbush, C. N. Flagg, and J. A. Vermersch, Jr. 1977. Ocean tides and weather-induced bottom pressure fluctuations in the Middle Atlantic Bight. J. Geophys. Res. 82(21):3175-3182.

Five bottom pressure gages were deployed in the Middle Atlantic Bight during the late winter of 1974. Analysis of the resulting pressure series and neighboring coastal tide gage series shows that tides are the dominant pressure signal in this section of the continental shelf. Most of the remaining pressure fluctuations appear to be forced by meteorological transients. During March 21, 1974, a developing cyclone moving up the coast excited a coherent group of sea level oscillations with characteristic periods of 5-7 hours, which are interpreted here as coastal-trapped edge waves. Spectra of the nontidal pressure series are red, however; most of the non-tidal variability is caused by lower-frequency (subtidal) components. The subsurface pressure (SSP) fluctuations do appear coherent over the spatial extent of the array in the most energetic subtidal frequency bands, and estimates made of the relative horizontal SSP gradients indicate that cross-shelf gradient variations are significantly larger than alongshore gradient variations. Some consequences of these large weather-induced gradient fluctuations on the shelf circulation are discussed.

Beardsley, R. C. and C. D. Winant. 1979. On the mean circulation in the Mid-Atlantic Bight. J. Phys. Oceanogr. 9:612-619.

Two possible mechanisms which may drive the observed mean alongshelf flow in the Mid-Atlantic Bight are described. Runoff from concentrated sources could conceivably force this flow; however, the one-layer homogeneous model results of Csanady (1978) and Beardsley and Hart (1978) imply that the observed shelf flow is not driven by runoff alone. On the other hand, the Semtner and Mintz (1977) numerical model of the North Atlantic strongly suggests that the shelf circulation is just a boundary layer component of the ocean circulation and thus driven by the large-scale wind stress and heat flux distributions. This model result supports Csanady's (1978) conclusion that the physical mechanism which creates the alongshelf pressure gradient thought to drive the alongshelf flow must be of oceanic origin.

Behringer, D., L. Reiger, and H. Stommel. 1979. Thermal feedback on wind-stress as a contributing cause of the Gulf Stream. J. Mar. Res. 37:699-709.

A simple model is used to explore a feedback mechanism which may be significant in the formation of the Gulf Stream. The feedback operates through the drag coefficient which is a function of the sea-air temperature difference. The model is divided into interior and western boundary regions which are overlaid by an atmosphere with a constant meridional temperature gradient. The model predicts the interior sea-air temperature difference which determines, in sequence, the enhancement of the basic wind-stress distribution, the interior Sverdrup velocity, and the zonal velocity between the interior and the western boundary regions. All variables are functions of latitude only. Calculations for a two gyre ocean demonstrate the ability of the feedback mechanism to produce a "Gulf Stream" without higher order dynamics.

Bennett, John R. and Bruce A. Magnell. 1979. A dynamical analysis of currents near the New Jersey coast. J. Geoph. Res. 84(C3): 1165-1175.

A numerical model is used to analyze currents measured on the continental shelf near the shore of New Jersey. The model neglects longshore variations of current and all variations of density, but includes inertial accelerations and a nonlinear eddy viscosity. Local wind stress, sea level changes, and a constant longshore pressure gradient are the forcing terms. The model successfully reproduces most of the current variance; however, the predicted currents do not exhibit the dominant 4-hour response time of the observed currents, and the model sometimes misses energetic current events. These differences are ascribed to three-dimensional setup effects elsewhere in the New York Bight.

Betzer, P. R. 1978. A study of the sources, transport, and reactions of suspended particles in waters of the New York Bight. NOAA Tech. Memo. MESA-23. Marine Ecosystems Analysis Program, Boulder, Colo., 37 p.

Eighty-six samples of suspended matter collected on five cruises to the New York Bight have been subjected to chemical analyses. The results demonstrate that some of the major inputs of particulate matter to this system can be chemically typed and then traced. Seasonal changes in the distribution and composition of suspended materials are related to 1) river input, 2) diatom productivity, 3) sediment-water interactions, and 4) the dumping of anthropogenic materials.

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Bisagni, J. J. 1977. Physical oceanography of Deepwater Dumpsite 106, February-March 1976. In: Baseline Rep. of Environmental Conditions in Deepwater Dumpsite 106. NOAA Dumpsite Eval. Rep. 77-1, U.S. Dept. Comm., 87-115.

Bisagni, J. J. 1981. Lagrangian measures of near-surface waters at the 106-Mile Dumpsite. NOAA Tech. Memo. OMPA-11. U.S. Dept. of Comm., Washington, DC 23p.

Bisagni, J. J. and G. Behie. 1980. Water mass changes and circulation patterns in the vicinity of the 106 Mile industrial waste Dumpsite. NOAA Northeast Monitoring Program Report, No. NEMP-III-80-C-0049, 35 p.

Bisagni, J. J. and D. R. Kester. 1981. Physical variability at an east coast United States offshore dumpsite. P. 89-107. In: Ocean Dumping of Industrial Wastes. B. H. Ketchum, D. R. Kester and P. K. Park (eds.). Plenum Press, New York and London. 525 p.

Three hydrographic stations conducted during a 1977 cruise to Deepwater Dumpsite 106 inadvertently sampled an established anticyclonic Gulf Stream ring both prior to and after it interacted with the Gulf Stream. Continuous STD data and discrete dissolved oxygen measurements in the ring were analyzed using temperature-salinity (T-S) and temperature-oxygen ($T-O_2$) diagrams. These data showed good correlation with T-S and $T-O_2$ diagrams from Gulf Stream, Sargasso and Slope Waters obtained during a cyclonic Gulf Stream ring study. Apparently, a new entrainment of Gulf Stream Water around the ring occurred within the sampling period and was manifested by increased salinity and decreased levels of dissolved oxygen. Combined satellite surveillance and at-sea measurement of temperature, salinity and oxygen provide an accurate method of describing this highly dynamic and variable region in and around Deepwater Dumpsite 106.

Biscaye, P. E. and C. R. Olsen. 1976. Suspended particulate concentrations and compositions in the New York Bight. In: Special Symposia Vol. 2, Middle Atlantic Continental Shelf and New York Bight. M. G. Gross (ed.). Amer. Soc. Limnol. Oceanogr. pp. 124-137.

Biscaye, P. E., C. R. Olsen and G. Mathieu. 1978. Suspended particulates and natural radionuclides as tracers of pollutant transports in continental shelf waters of the eastern U.S.A. In: Chemical Pollution of the Marine Environment - 1st American-Soviet Symp. U.S. EPA Ecol. Res. Ser. EPA-600/9-78-038. 199 pp.

Bishop, J. M. 1980. A note on the seasonal transport on the middle Atlantic shelf. J. Geophys. Res. 85(C9):4933-4936.

A simple analytical model is proposed that adequately predicts both the mean summer and mean winter transport along the Middle Atlantic Shelf. The mean flow is modeled by using the steady Ekman and geostrophic equations driven by the mean wind stress, the mean cross-shelf density gradient, and a variable longshore sea-surface slope. It is shown that previous models, although consistent with this approach, might have to be refined to include longshore and seasonal variations in the longshore sea-surface slope. Also, seasonal variations in mean wind stress and mean cross-shelf density gradient are identified as key components in the description of flow dynamics. Calculated transports agree with the limited observations.

Bishop, J. M. and J. E. Overland. 1977. Seasonal drift on the Middle Atlantic Shelf. Deep-Sea Res. 24:161-169.

A relationship among non-tidal surface currents, seasonal density distributions, and mean wind stress is developed from the thermal wind relation and Ekman dynamics. The result can be interpreted as a simple shallow water equivalent of the dynamic method. This approach indicates that summer currents on the Middle Atlantic Shelf set southwestward on the order of 5 to 15 cms^{-1} and are maintained by the density distribution. In winter, winds predominate over the weak contribution from the density field. Winter mean wind stress implies southward flow on the order of 15 cms^{-1}. Drift estimates are consistent with atlas values.

Boicourt, W. C. 1973. The circulation of water on the Continental Shelf from Chesapeake Bay to Cape Hatteras. Ph.D. Thsis. The Johns Hopkins Univ., Baltimore, MD. 183 pp.

Boicourt, W. C. 1981. Circulation in the Chesapeake Bay entrance region: Estuary shelf interaction. p. 61-78. In: Chesapeake Bay Plume Study - Superflux 1980. NASA Conference Publ. 2188. J. W. Campbell and J. P. Thomas (eds.), 516 pp. Scientific & Technical Information Branch, National Aeronautics & Space Admn. Wash., DC.

Summary

Current meters and temperature-salinity recorders confirm that the upper layers of the continental shelf waters off Chesapeake Bay can be banded in summer, such that the coastal boundary layer (consisting of the Bay outflow) and the outer shelf flow southward while the inner shelf flows to the north, driven by the prevailing southerly winds. These measurements show that the estuary itself may also be banded in its lower reaches such that the inflow is confined primarily to the deep channel, while the upper layer outflow is split into two flow maxima on either side of this channel.

Boicourt, W. C. and P. W. Hacker. 1976. Circulation on the Atlantic continental shelf of the United States, Cape May to Cape Hatteras. Mem. Soc. Royale des Sci. de Liege, 6(10): 187-200.

Observations from two sets of experiments on the northeast continental shelf of the United States reveal details of the response of the shelf waters to strong wind forcing. Measurements of currents within a cross-shelf section show that northerly winds can move water on the outer shelf, one shelf-width to the south within a three-day interval. These observed high-velocity motions are in contrast with the long-term mean flow to the south of order 5 - 10 cms^{-1}. For both the winter (unstratified) and the summer (stratified) seasons, lateral shear is evident in the storm-driven longshore flows, with velocities increasing in the offshore direction. Cross-shelf motions during these wind events are qualitatively consistent with Ekman theory. Southerly wind events can drive offshore motion in the upper Ekman layer, requiring subsurface return flow. This return flow, which consists of high salinity Slope Water, appears to occur in a bottom Ekman layer during the unstratified season. Under stratified conditions, the return flow occurs at mid-depth, above the cold water band at the shelf break.

The second set of experiments, designed to measure the longshore variability of the response to strong wind events, were made with two current meter moorings separated along the 35 m isobath. The results show that at separations of 130 km and 235 km, the longshore component of velocity is well correlated during both high and low flow conditions. The cross-shelf component is poorly correlated, except during the highest flows. The shelf appears to respond as a unit to strong wind events over longshore scales of at least 235 km.

Boicourt, W. C., D-P Wang, and W-S Chuang. 1979. Low-frequency current variability on the southern Mid-Atlantic Bight. J. Phys. Oceanogr. 9:1144-1154, November 1979.

* "Results of this study indicate that circulation in the southern Bight is affected by local alongshore wind forcing as well as the disturbances propagating from the north. Stratification is essential in determining the cross-shelf circulation. Persistence of alongshore wind seems to be another important factor. Therefore, three-dimensionally, time dependency and density stratification are all essential in modeling the circulation of the Mid-Atlantic Bight."

This paper is an objective analysis of low-frequency current variability on the continental shelf taken during a 4 month period in 1975 (March to June). A current meter mooring located 84 km off the coast of the Chesapeake Bay collected data at depths of 10, 20, and 30 m.

Bothner, M. H., C. M. Parmenter and J. D. Milliman. 1981. Temporal and spatial variations in suspended matter in continental shelf and slope waters off the northeastern United States. Est. Coast. & Shelf Sci. 13(213-234).

Seston in waters of Georges Bank originates primarily from biological production and from resuspension of bottom sediments. The concentrations of suspended matter observed on the central shoals are more influenced by storms than by seasonal changes. Winter storms produce highest concentrations of non-combustible material throughout the water column, and summer storms appear to increase biological production by mixing additional nutrients into the photic zone. On the southeast flank of the bank, in water depths between 80 and 200 m, the concentrations of total suspended matter and non-combustible material show little variation compared with the central shoals, and storm effects are far less noticeable.

Highest concentrations (>15 mg l^{-1}) of suspended matter occur in bottom waters south of Nantucket Island after winter storms and appear to be primarily resuspended bottom sediment. Resuspended sediment is also common in near-bottom waters of the southwestern Gulf of Maine, and occasionally near the intersection of the shelf/slope water mass front and the bottom.

Seasonal variations were observed in the distribution and species composition of phytoplankton. Coccoliths are predominant on the central bank during the winter, but during the spring and summer they are concentrated on the eastern flank at deeper depths.

Bothner, M. H., E. C. Spiker, P. P. Johnson, R. R. Rendigs and P. J. Aruscavage. 1981. Geochemical evidence for modern sediment accumulation on the continental shelf off southern New England. J. Sed. Petrol. 51 (1):281-292.

An area of fine-grained sediment approximately 170 km X 74 km in size, located in water depths between 60 m and 150 m south of Martha's Vineyard, Mass., is a site of modern sediment deposition. The ^{14}C ages systematically increase with sediment depth from about 1,300 years B.P. at the surface to 8,000-10,000 years B.P. at the depth of maximum core penetration. The old age for the surface sediments probably results from a combination of deposition of old carbon and faunal mixing. In the finest sediments, the sedimentation rates were approximately 130 cm/1,000 yrs when deposition began and have decreased to about 25 cm/1,000 yrs. The decreasing sedimentation rate reflects a diminishing source of fine sediments, which presumably came from the Georges Bank and Nantucket Shoals area.

Inventories of excess ^{210}Pb in undisturbed cores average 70 dpm/cm^2 (disintegrations per minute per square centimeter), more than two times higher than the flux of ^{210}Pb from the atmosphere and from ^{226}Ra decay in the overlying water. This additional influx of ^{210}Pb either must be with new fine-grained sediment material or from solutions that are stripped of their ^{210}Pb by particulates in the bottom nepheloid layer. Stable Pb concentrations in surface sediments are about 28 ppm, as much as two times higher than concentraions at depth.

The high accumulation rates, ^{210}Pb inventories, and trace-metal profiles imply that this area is a modern sink for fine-grained sediments and for pollutants associated with particulate matter in the water column. To our knowledge, this is the only site of present-day natural deposition on the Continental Shelf off the eastern United States, exclusive of the Gulf of Maine. Because the net currents on the outer half of this Continental Shelf flow from northeast to southwest, this fine-grained deposit may receive its sediments and possible contaminants from the Nantucket Shoals and Georges Bank regions.

Bowman, M. J. 1978. Spreading and mixing of the Hudson River effluent into the New York Bight. Hydrodynamics of Estuaries and Fjords. In: Nihoul, J. C. J. (ed.). Elsevier Scientific Publishing Co., 373-386.

Results are presented from three Hudson River plume sampling cruises made in the New York Bight, in August 1976.

The data show that the set and shape of the spreading effluent vary widely over time periods ~6 days, and are clearly influenced by local wind stress.

Application of Takano's model of a steady state plume spreading into a stagnant ocean suggests a horizontal eddy viscosity $\sim 10^8$ cm^{2}sec^{-1}, and strong anticyclonic deflection of the plume. This value is considered to be an overestimate, since interfacial shear stress is neglected in the model.

More careful measurements and calculations are needed to separate out the effects of horizontal and vertical viscosities, Coriolis force, advection by a prevailing coastal current and local wind stress, on plume dynamics.

Bowman, M. J. and W. E. Esais. 1981. Fronts, stratification, and mixing in Long Island and Block Island Sounds. J. Geophys. Res. 86: 4260-4264.

Spatial patterns of bulk stratification in Long Island and western Block Island Sounds observed near the fall equinox of 1978 show a strong correlation ($\Gamma = 0.79$) with contours of the h/U^3 stratification index derived from tidal stream and depth charts. The index delineates stratified, transitional and mixed regions with apparent good accuracy, with the marginally stratified frontal zones being characterized by $\log_{10} h/U^3 \sim 1.5 m^{-2} s^3$. These results and theoretical considerations suggest that the index may be a useful parameter in corroborating and predicting frontal boundaries in other moderately stratified estuaries where local buoyancy fluxes are derived from fresh water sources.

Bowman, M. J., W. E. Esais and M. B. Schnitzer. 1981. Tidal stirring and the distribution of phytoplankton in Long Island and Block Island Sounds. J. Mar. Res. 39(4):587-603.

Phytoplankton distributions in Long Island and Block Island Sounds measured during a 1978 fall equinox cruise are interpreted in terms of tidal mixing variations and water column stratification. A stratification depth-scaled-by-light diagram is used to quantify the preferred physical environments of the two major morphological groups (diatoms and microflagellates). The success of the method in clearly distinguishing these physical regimes suggests its value as a useful biological growth index in estuarine systems.

Bowman, M. J. and D. A. Jay. 1975. The physical oceanography and water quality of New York harbor and western Long Island Sound. Mar. Sci. Res. Center Tech. Rep. No. 23, Refn. 75-7, NY Sea Grant Inst., Marine Sci. Res. Center, State Univ. of New York, Stony Brook, NY 11794.

* Interpretations of hydrography and circulation of New York Harbor and western Long Island Sound and data available from the results of studies conducted by the Marine Sciences Research Center are given in this technical report. Emphasis is placed on the transport of salt and water between the harbor and Long Island Sound through the East River tidal strait for an increased understanding of pollutant transport. "Although the available data are insufficient to produce a complete description of mixing and transport processes in the Sound and the Harbor, they are sufficient to provide preliminary answers and to guide further research."

Bowman, M. J. and P. K. Weyl. 1972. Hydrographic study of the shelf and slope waters of New York Bight. State Univ. of New York, Mar. Sci. Res. Center Tech. Rep. #1 .

This report presents results obtained from three oceanographic cruises made by the Marine Sciences Research Center during 1970 and 1971 to investigate the physical characteristics of the shelf and slope waters of New York Bight.

The existence of a sharp temperature-salinity front over the continental slope was confirmed during the months of June 1970 and April 1971. Associated with this front is a subsurface warm tongue delineated by a temperature maximum which intersects the edge of the shelf at a depth of about 150 meters.

Data obtained in August 1971 showed no evidence of any temperature front over the slope but suggested the existence of an irregular salinity gradient in this region.

Three factors appear to be important in the dynamics of the formation and dispersion of the subsurface warm tongue over the continental slope. These are the existence of the temperature-salinity front and the associated convergence zone, the meanderings of the Gulf Stream and the creation of warm eddies, and the intrusion of Labrador water into the Bight.

Bowman, M. J. and Wunderlich, L. D. 1977. Hydrographic properties. MESA NY Bight Atlas Monograph No. 1, 78 p., NY Sea Grant Institute, Albany, NY

* This monograph presents an extensive summary of original and archived data on the hydrographic properties of the New York Bight. Cycles of temperature, salinity and density characteristics are determined from seasonal patterns of insolation, river runoff, evaporation minus precipitation, winds, ocean currents and shelf/slope exchanges. Principal hydrographic features of the outer continental shelf are strong temperature/salinity fronts between shelf-water and slope-water. Shelf/slope water exchanges are dominated by small scale dynamics of which little is known and quantified.

Bretherton, F. and M. Karsweit. 1975. Mid-ocean mesoscale modeling. Proceedings of Symposium on Numerical Models of Ocean Circulation. National Acad. Sci., Wash., DC, p. 237-249.

Brown, D. W., R. E. Callaway and A. M. Teeter. 1976. Preliminary analysis of the dispersion of sewage sludge discharged from vessels to the New York Bight waters. Am. Soc. Limnol. Oceanogr. Spec. Symp. 2:199-211.

* This data report focuses on ocean disposal and the dispersion of sewage treatment plant wastes discharged into the New York Bight apex. Field experiments monitored sludge vessels during 1974-1975 aboard the R/V *Atlantic Twin*. An inter-ocean STD/beam transmissometer was used to monitor *in situ* concentrations of Total Suspended Matter (TSM). Objective analysis of each field experiment is made and alternate solutions are discussed.

Brown, M. F. and D. R. Kester. 1981. Fate of ocean-dumped acid-iron waste in a MERL stratified microcosm (abstract). Program and Abstracts, Third International Ocean Disposal Symposium, Woods Hole Oceanographic Institution, Woods Hole, MA, Oct. 12-16, 1981.

Brown, W. S. and R. C. Beardsley. 1978. Winter circulation in the western Gulf of Maine: Part I. Cooling and water mass formation. J. Phys. Oceanogr. 8:265-277.

Buller, R. J. and J. R. Webster. 1950. Drift bottle releases off New Jersey. Spec. Scientific Rep: Fisheries No. 10.

Bumpus, D. F. 1957. Surface water temperatures along the Atlantic and Gulf coasts of the United States. Spec. Scientific Rep: Fisheries No. 214.

Bumpus, D. F. 1961. Drift bottle records for the Gulf of Maine, Georges Bank, and the Bay of Fundy, 1956-58. Spec. Scientific Rep: Fisheries No. 378.

Bumpus, D. F. 1964. Residual drift along the bottom on the continental shelf in the Middle Atlantic Bight area. Limnol. Oceanogr. 10 (Suppl.):R-50-R53.

Bumpus, D. F. 1969. Reversals in the surface drift in the Middle Atlantic Bight area. Deep Sea Res. 16 (Suppl.):17-23.

Reversals in the surface drift off the Middle Atlantic States in mid-summer have been observed more frequently during the 1960s than previously. These are associated with the low runoffs of the Delaware and Hudson River watersheds during this period especially during the drought of 1963-1966. It is predicted that surface current reversals may be expected at any time, April-September, when the wind is from the southern sector and the runoff during March, April and/or May has been much below normal.

Bumpus, D. F. 1973. A description of the circulation on the continental shelf of the east coast of the United States. Prog. Oceanogr. 6:111-157.

* Interpretation of large amounts of drift bottle and sea-bed drifter data acquired during the 1960's over the continental shelf of the east coast of the United States, suggests some approaches to elicit a better understanding of the circulation problem in the future.

Bumpus, D. F. 1976. Review of the physical oceanography of Georges Bank. ICNAF Res. Bull. 12:119-134.

Previously published information on the bathymetry, rotating tidal currents, temperature-salinity distribution and general circulation of the Gulf of Maine and Georges Bank are discussed. New information on surface temperature fronts in relation to monthly Ekman transport vectors is presented. Data on the distribution of herring larvae during successive periods during the autumns of 1972, 1973, and 1974 are used as evidence of dispersion and advection. Feasible approaches toward development of a circulation model are mentioned.

Bumpus, D. F. and L. M. Lauzier. 1965. Surface circulation on the continental shelf off eastern North America between Newfoundland and Florida. Serial Atlas of the Marine Environment Folio 7, New York, Amer. Geophys. Soc.

Bunker, A. F. 1976. Computations of surface energy flux and annual air-sea interaction cycles of the North Atlantic Ocean. Monthly Weather Rev. 104(a):1122-1140.

Bush, K. A. 1981. Middle Atlantic Bight transports determined from a salinity-heat box model using historical hydrographic and meteorological data. M.S. thesis. Univ. of Delaware, College of Marine Studies, Lewes, Delaware.

A salinity-heat box model of the Middle Atlantic Bight (MAB) has been formulated to calculate volume transports of northern shelf and near-surface slope waters into, and of MAB shelf water out of, the MAB shelf region. Results were obtained for each of two years, 1967 and 1971, using tracer mean values and uncertainties determined from historical hydrographic and meteorological data. The atmospheric source term, or surface energy flux, was calculated from the bulk aerodynamic equations for latent and sensible heat exchange and from the radiational exchange equation using Bunker's (1975) technique.

Transports calculated from this model are consistent with transports determined from other MAB studies, indicating the validity of this approach to MAB circulation studies. Variations in transports calculated for 1967 and 1971 reflect variations in the hydrographic and meteorological conditions during these two years. A sensitivity analysis for each of the two years indicates that the model is most sensitive to changes in MAB shelf water salinity and temperature values and to changes in northern shelf water temperature values.

Bush, K. and S. L. Kupferman. 1980. Wind stress direction and the alongshore pressure gradient in the Middle Atlantic Bight. J. Phys. Oceanogr. 10(3):470-471.

We find that the alongshore transport in winter calculated using a circulation model based on Ekman and geostrophic dynamics (Csanady, 1976) for a shelf region similar to the Middle Atlantic Bight is sensitive both to the alongshore component of the wind stress and the alongshore pressure gradient. If the total alongshore transport in the region remains uniform along the shelf at $-2.5 \times 10^5 m^3 s^{-1}$ (positive poleward) as indicated by current meter measurements, our calculations show that the alongshore pressure gradient must decrease from 1×10^{-3} Pa m^{-1} off Montauk Point to zero south of Cape Henry, as a consequence of the change in orientation of shelf to wind stress.

Butman, Bradford. 1978.
On the dynamics of shallow water currents in Massachusetts Bay and on the New England continental shelf. Tech. Rep. WHOI 77-15. Woods Hole Oceanographic Institution, Woods Hole, MA 20543. 174pp.

Massachusetts Bay is a coastal Bay 100 km long and 40 km wide located in the western Gulf of Maine. The Bay is closed by land to the north, west and south, but is open to the Gulf to the east; the opening is partially blocked by a shallow bank. The bottom sediment distribution in the Bay is complex; fine grained material is found in the deep basin, sand and gravel on the shallow bank and mixtures of sand, gravel and fine material nearshore. Richardson current meters were moored 1 m from the bottom over a one year period at several locations in the Bay to study the bottom currents and the equilibrium between current and sediments. The current measurements suggest that the bottom sediments can be expected to move only occasionally in certain areas. The maximum bottom speeds are principally determined by the strong tidal currents in the basin.

In winter, the near bottom currents are dominated by wind stress associated with strong storms. Bottom currents in the shallow areas are generally in the direction of the wind while currents in the deep portion of the basin are often opposite to the direction of the wind. Sea surface setup in the direction of the wind is observed, as well as absolute changes in sea level as the Bay adjusts to changes in the level of the adjacent Gulf of Maine. Adjustment of the bottom currents to wind events requires approximately 12 hours.

Moored current meter measurements and synoptic hydrographic observations made in Massachusetts Bay show that freshening from the spring runoff dominates the low frequency currents and the hydrography of the Bay in the spring months. The major freshening is attributed to the Merrimack River which empties into the Gulf of Maine 30 km to the north of the Bay; discharge of the Merrimack increases by at least a factor of two in spring. Flow directly into the basin from several smaller rivers is not important. Two major features are found: a fresh surface plume confined to the upper 10 m of the water column which becomes more distinct as the seasonal thermocline develops, and a large deep fresh lens. Flow is clockwise around the deep lens and is consistent with the thermal wind relation. Sustained currents of 10 - 20 cm^{-1} with time scales of 5 - 10 days were observed as the deep lens (or lenses) slowly advected through the basin. Current observations made in the previous spring show similar low frequency behavior.

Two simple linear models of the semidiurnal tide on the continental shelf are used to estimate the vertical turbulent eddy viscosity, a linear bottom drag coefficient, and the change in the bottom drag a homogeneous water column with constant eddy viscosity to a sinusoidal body force with a slip bottom boundary condition is presented. With measurements of the tidal current at two depths, four parameters are shown to be independent of the body force: the ratio of the clockwise current at two depths, the ratio of counterclockwise current at two depths, the change in the tidal ellipse orientation, and the change in phase of the tidal ellipse. Observations of the semidiurnal tidal current on the New England continental shelf are consistent with a vertical eddy viscosity of 20 - 50 $cm^2\ sec^{-1}$ and a bottom drag coefficient of .02 - .05 $cm\ sec^{-1}$. The Ekman depth is thus 10 m and the integrated adjustment time is approximately 28 hours.

An integrated linear model with linear damping of the semidiurnal tide on the continental shelf, forced uniformly at the shelf edge, show an increasing phase lag of the tide at the coast with increased damping; amplitude remains relatively constant over a wide range of damping coefficient. Observations of the tide at the coast during storms a phase lag of as much as 10 degrees for the semidiurnal tide. For approximate dimensions of the New England shelf, this implies an increase by a factor of 3 - 5 of the bottom drag coefficient and an integrated motion adjustment time of 6 - 9 hours. Waves may be an important contribution to the increased bottom stress.

Butman, B., R. C. Beardsley, B. Magnell, D. Frye, J. A. Vermersch, R. Schlitz, R. Limeburner, W. R. Wright and M. A. Noble. 1982.
Recent observations of the mean circulation on Georges Bank. J. Phys. Oceanogr. 12(6): 569-591.

A clockwise circulation around Georges Bank was measured by means of moored current meters, aircraft-tracked surface drifters, and satellite-tracked drifters drogued at 10 m. The strongest flow was in a narrow jetlike current (30 cm s^{-1}) along the northern flank of the bank. The flow of shelf water on the southern flank was westward (10 cm s^{-1}) toward the Middle Atlantic Bight; some of this water flowed northward through the eastern side of Great South Channel and recirculated around Georges Bank. The satellite-tracked drifters and the moored observations indicate that the circulation around the bank was not completely closed and considerable variability occurs in the trajectory of an individual water particle.

Butman, B., R. C. Beardsley, and M. A. Noble. 1982. Long-term current observations on the southern flank of Georges Bank. EOS 63(3):92-93. Abstracts for AGU/ASLO Joint meeting in San Antonio, TX. Feb. 16-19, 1982.

Nearly continuous current measurements at 45 and 75 m were made from May 1975 to March 1979 at 40°51'N, 67°24'W on the southern flank of Georges Bank in water 85 m deep. The mean flow at 45 and 75 m was southwestward at approximately 8.6 and 3.5 cm/s respectively. At 45 m, an average seasonal change of approximately 6 cm/s was observed in the monthly mean flow; maximum southwestward flow was in early September and minimum flow in early March. At 75 m, there was no significant seasonal change in the monthly mean flow. Hydrographic sections suggest that much of the seasonal change in the flow at 45 m was caused by a cross-bank density gradient established by summer heating.

Loder (Jour. Phys. Oceanog., 1980, p. 1399) has suggested that part of the mean along-bank flow may be driven by tidal rectification. His theory predicts that the low-frequency along-bank flow is proportional to the squared amplitude of the cross-isobath tidal current in deep water. On Georges Bank, the squared amplitude of the surface tide varies by approximately 55% at fortnightly (355 hrs) and monthly (655 hrs) periods and thus the low-frequency flow should exhibit a similar modulation. However, no significant spectral peaks (greater than 1 cm/s above background) were observed in the along-bank flow at 45 or 75 m. The lack of coherence at 355 and 655 hours between a simulated tide (M_2, N_2, S_2 constituents) and the along-bank flow suggests that the modulation of the along-bank flow was less than .9 and .6 cm/s at 45 and 75 m respectively. Thus, assuming the predicted 55% modulation, less than approximately 30% (1.1 and 1.6 cm/s at 45 and 75 m) of the observed non-seasonal flow at this location can be attributed to tidal rectification at 90% confidence.

Butman, B. and M. Noble. 1979. Low-frequency wind-induced sea level oscillations along the east coast of North America. J. Geophys. Res. 84(C6):3227-3236.

* Report on detailed analysis of wind, tide level, and barometric pressure data for November 1973 through April 1974 for 14 coastal stations between Cape Hatteras, North Carolina and Eddy Point, Nova Scotia. Atmospherically adjusted sea level was coherent with longshore winds at low frequencies (periods 60-600 hours) over as much as 1300 km. Response of sea level to winds was 8-12 hours. Cross shore correlation was weak. Response to SW winds was twice as great as that for NE winds.

Butman, B., M. A. Noble, R. C. Beardsley, J. A. Vermersch, R. A. Limeburner, B. Magnell and R. J. Schlitz. 1980. The mean circulation on Georges Bank as measured by moored current meters. ICES Report ICES C.M. 1980/C:34 Hydrography Committee. International Council for the Exploration of the Sea, Copenhagen.

Butman, B., M. Noble and D. W. Folger. 1979. Long-term observations of bottom current and bottom sediment movement on the Mid-Atlantic continental shelf. J. Geophys. Res. 84(C3):1187-1205.

Bye, J. A. T. 1966. The wave-drift current. J. Mar. Res. 25(1):95-102.

* Using an irrotational wave-drift current model, the author shows that wave-drift current may contribute to surface-drift velocities.

Callaway, R. E., M. Clansy, and A. Stroud, 1974. Computation of tides, currents and dispersal of pollutants in the New York Bight from Block Island to Atlantic City with large grid size, single and two layer hydrodynamical-numerical models. Environ. Pred. Res. Fac. Tech. Report. No. 4-74.

Callaway, R. J., A. M. Teeter, E. W. Browne, and F. R. Ditsworth. 1976. Preliminary analysis of the dispersion of sewage sludge discharged from vessels to New York Bight waters. ASLO Spec. Symp. Vol. 2: Middle Atlantic Continental Shelf and the New York Bight. p. 199-211.

New York City sewage treatment plant wastes discharged to the New York Bight apex average 2.6% solids with an average solids density of 1.50 g cm^{-3}. Bulk waste density is about 1.000 g cm^{-3}, whereas the density of surface seawater in the sludge dumping area ranges from 1.019-1.025. Solids concentration of the wastes in the sludge vessels ranged from 5 to 50 g liter^{-1}. Correlation of extinction coefficient from a 10-cm light-path beam-transmissometer with total suspended matter (TSM) allowed continuous profiling of TSM, STD and beam transmittance profiles were made either by towing the instrument through a sludge patch or wake or by making vertical profiles. Dilution in the wake of a release ranged from 500-1000.

The time for TSM to reach background or equilibrium values (0.5-2 mg liter^{-1}) depends on initial concentration. Equilibrium time was approached exponentially for well mixed conditions in about 5.5 h. Pycnocline formation in the upper 8 m caused a similar approach to equilibrium time; below that depth TSM increased slightly with time.

Settling velocities for the larger flocculated sludge particles averaged about 0.5-1cm s^{-1}. Values of 0.01-0.3 cm s^{-1} were obtained from plots of the center of mass of the waste field. The remainder of the dispersing sludge field had velocities of 10^{-3}cm s^{-1} and less.

TSM from New York Harbor can reach the permit area, but oceanographic conditions in the apex usually prevent this.

Relocating the permit area to other deeper areas would cause the affected bottom area to increase in proportion to the increased depth, but concentrations of settled-out material would be inversely proportional, if the oceanographic environment was similar.

Campbell, J. W. and J. P. Thomas (eds.). 1981. Chesapeake Bay plume study: Superflux 1980. NASA Conf. Publ. 2188, NOAA Conf. Publ. 2188, NOAA/NEMP III 81 ABCDFG 0042. NTIS Springfield, Virginia, 522 pp.

Celone, P. J. and J. L. Chamberlin. 1980. Anticyclonic warm-core Gulf Stream eddies off the northeastern United States in 1978. Annls. Biol. Copenh. 35:50-55.

Chamberlin, J. L. 1978. Unusual offshore distribution of cold Atlantic Shelf water during the spring and summer of 1978. Coastal Oceanog. and Clim. News 1(1):1-2.

Charnell, R. L. 1975. Assessment of offshore dumping; Physical oceanography, geological oceanography, chemical oceanography. ERL MESA-1, 90 p.

* A data report which examines the physical, geological, and chemical oceanographic features of the New York Bight and their relationship to waste and sewage disposal in the area. The investigation includes studies of ocean currents, sea floor topography, sedimentation, methods of sewage disposal, and the chemical composition of sewage.

Charnell, R. L., G. Han. W. L. Stubblefield. D. J. P. Swift, H. Mofjeld, Peter E. Gadd, J. W. Lavelle, H. R. Brashear, F. N. Case, C. S. Kunselman., 1976. Preliminary results of coincident current meter and transport observations for winter time conditions on the Long Island inner shelf. Georphys. Res. Letters. 3(2): 97-100.

Data report which discusses the "preliminary results of an experiment recently completed in the New York Bight to directly measure offshore cohesionless sediment and its immediate forcing mechanism, the overlying water velocity field."

Charnell, R. L., D. V. Hansen. 1974. Summary and analysis of physical oceanography data collected in the New York Bight Apex, MESA Report No. 74-3. 44 pp.

Charnell, R. L., and D. S. Mayer. 1975. Water movements within the Apex of the New York Bight during summer and fall 1973. NOAA Tech. Memo. EORL MESA - 3. 29 pp.

Charney, J. G. 1955. The Gulf Stream as an inertial boundary layer. Proc. Nat. Acad. Sci. 41:83-92.

Chase, J. 1955. Winds and temperatures in relation to broa strength of Georges Bank haddock. Journ. Du Conseil. 21(1):17-24.

Chase, J. 1959. Wind induced changes in the water column along the east coast of the United States. J. Geophys. Res. 64:1013-1022.

* Data report which presents data from eleven lightships stationed along the U.S. late in 1955.

The survey extended from Frying Pan Shoals lightship (about 145 miles southwest of Cape Hatteras) to Ambrose Lightship just north of Sandy Hook, New Jersey.

Salinity, temperature and surface pressure was taken to determine what effect if any, did wind pattern have on the water column at these lightships. It was found that two types of changes in the water column at certain lightships are linked to the wind pattern. In one type there is a replacement of the whole water column, whereas in the other there is a fluctuation in the thickness of the upper layer.

Chase, J. 1969. Surface salinity along the east coast of the United States. Deep-Sea Res. 16 (Suppl.): 25-29.

Salinity determinations daily at 12 lightships from Savannah to Portland during 1956-1967 are descriptively analyzed using decadal means. Seasonal cycles appear well-defined. Annual minima generally follow spring thaw and run-off.

Chase, R. R. P. 1979. The coastal longshore pressure gradient: Temporal variations and driving mechanisms. J. Geophys. Res. 84(C8): 4898-4904.

Cheney, R. E. 1978. Oceanographic observations in the western North Atlantic during FOX 1, May 1978. Tech. Note 3700-79-78, V. 5 U. S. Naval Oceanographic Office, Washington, D.C.

Chervin, M. B. and Malone, T. C. 1979. The production and fate of phytoplankton size fractions in the plume of the Hudson River, New York Bight. Limnol. Oceanogr. 24(4): 683-696.

* The causes of seasonal blooms of net plankton in Feb-March, and nanoplankton in June-July are explained by changes of water column stability, phytoplankton growth, and copepod grazing. Sampling was done at six stations in the New York Bight from September 1973 through March 1978.

Net plankton blooms as correlated with periods of weak stratification.

Nanoplankton dominated during the summer when primary productivity and copepod biomass reached their seasonal maxima. These small cells were almost entirely consumed before they could sink from the surface layer.

Chuang, W. S. and D. P. Wang. 1981. Effects of density front on the generation and propagation of internal tides. J. Phys. Oceanogr. 11:1357-1374.

A numerical model is developed to study the internal tidal motion on the continental margin. The system includes irregular bottom topography and a horizontal density stratification maintained by a mean geostrophic current. Both the propagation and generation processes are examined.

In the propagation process, the topographic effect alone will scatter a significant part of the incident wave energy into higher modes, resulting in a beamlike structure for the transmitted wave. For a density front over a flat bottom, energy in the transmitted waves remains largely in the original wave mode, though the wave length, and hence wave amplitude, varies with local density stratification. When the density front is located over a sloping bottom, the topographic effect is reduced, whereas the frontal effect is not affected. Thus, scattering into higher modes becomes more restricted.

In the generation process, internal tides are produced in the upper and lower parts of the slope region due to the interaction between surface tides and bottom topography. With the presence of a density front, internal tide energy also can be derived from the surface frontal layer. In addition, the topographic effect will be modified by the front. The net effect is destructive (constructive) when the isopycnals tilt upward in the shoreward (seaward) direction.

These results indicate that on the continental margin, the density front has strong effects on the generation and propagation of internal tides, particularly when the density front is located above the continental slope. Since the internal tide provides an important energy source for mixing on the shelf, the density fronts will have a storng effect on the mixing processes.

Clarke, G. L. 1938. Seasonal changes in the intensity of submarine illumination off Woods Hole. Ecology 19: 89-106.

Clarke, G. L., E. L. Pierce and D. F. Bumpus. 1943. The distribution and reproduction of Sagitta elegans on Georges Bank in relation to hydrographic conditions. Biol. Bull. 85: 201-226.

Cohen, E. B. and W. R. Wright. 1978. Changes in the plankton on Georges Bank in relation to the physical and chemical environment during 1975-76. Int. Counc. Expl. Sea paper C.M. 1978/L:27.

Nine cruises were made on Georges Bank between September 1975 and December 1976 during which chlorophyll, nutrients and planktonic biomass were measured along with temperature, salinity and dissolved oxygen. Primary production was measured on most of the cruises. Data from these cruises are presented in vertical plots to show the relation between physical and biological variables. Primary production is calculated to be on the order of 400 to 500 gm C $m^{-2}y^{-1}$. After an initial increase in the spring primary production appears to remain at high levels with no evidence of a decrease in summer through fall. The high production seems to be maintained by mixing on top of Georges Bank and by transport of nutrient-rich deeper water toward the Bank along both the northern and southern edges. Observations that are closer in both space and time will be required to confirm this hypotheses.

Colton, John. B., Jr. 1968. Recent trends in subsurface temperatures in the Gulf of Maine and continuous waters. J. Fish. Res. Bd. Canada. 25(11):2427-2437.

A comparison was made of 1955-60 and 1961-66 monthly mean 200-m temperatures in eight 1-degree quadrangle areas in the Gulf of Maine and along the Continental Slope between Nova Scotia and Long Island. Temperatures were appreciably lower in all areas during the latter period. The subsurface temperature trends paralleled trends in surface temperatures previously documented. The distribution of temperature at 200 m along the edge of the Continental Shelf during March, May-June, and September 1965 and 1966 and the distribution of temperature, salinity, and dissolved oxygen on sections made across the Continental Shelf in September 1954, 1965, and 1966 showed that the cooling and warming trends are accompanied by changes in the composition of the subsurface water. Cold years occur when Slope Water is displaced or modified by Coastal Water of Labrador origin. Warm years occur when Slope Water borders upon the 200-m isobath and the ratio of Coastal to Central Atlantic Water is low.

Colton, J. B., R. Marak, S. Nickerson and R. Stoddard. 1968. Physical, chemical and biological observations on the continental shelf, Nova Scotia to Long Island, 1944-66. U.S. Fish and Wildlife Service Data Report No. 23. 189 pp.

Colton, John B. and Ruth R. Stoddard. 1972. Average monthly sea water temperatures - Nova Scotia to Long Island, 1940-1959. Folio 21 - Serial Atlas of the Marine Environment, American Geographical Society.

Average monthly temperatures at the surface, 10, 20, 30, 40, 50, 75 and 100 m. Also monthly temperature profiles at one-degree (longitude) intervals. Covers Gulf of Maine, Georges Bank and environs between 64° and 72°W, north of 39°N.

Colton, John B. and Ruth R. Stoddard. 1973. Bottom water temperatures on the continental shelf, Nova Scotia to New Jersey, NOAA Tech. Rept. NMFS CIRC-376. 55 pp.

Mean monthly and annual maximum and minimum bottom water temperatures, based on data collected in 1940-66, portrayed on 15 maps.

Colton, J. B. and R. F. Temple. 1961. The enigma of Georges Bank spawning. Limnol. and Oceanog. 6(3):280-291.

The drift of bottles and transponding drift buoys over the Georges Bank area show that, with the exception of midsummer when the Georges eddy is most pronounced and southerly winds predominate, surface drift is offshore in the direction of the slope water band. Indications are that the currents below the surface move at a slower rate than at the surface, but in a similar direction. The effects of offshore drift, time and location of spawning, vertical distribution of eggs and larvae, and length of pelagic life on the dispersal and survival of eggs, larvae, and juveniles of commercially important foodfishes are discussed. It appears from observations on haddock and herring that under average conditions most fish eggs and larvae are carried away from Georges Bank and lost to the fishery, that only under unusual hydrographic conditions are the eggs and larvae retained in the area, and that the year class strength of the various species inhabiting Georges Bank is dependent in part upon non-tidal drift.

Cook, G. S. 1966. Non-tidal circulation in Rhode Island Sound. Drift Bottle and Sea-Bed Drifter Experiments (1962-1963). U.S. Naval Underwater Weapons Research and Engineering Station Tech. Memorandum TM 369, Newport, RI., 44 pp and 34 illustr.

The non-tidal circulation in Rhode Island Sound shows seasonal variations at both the surface and bottom. During spring, the surface drift is primarily toward the east and north, while the bottom drift is toward the northwest. During summer, the surface drift tends northerly, with secondary components toward the east and west, reflecting the effect of a cyclonic eddy. Bottom drift during the summer is similar to that observed during the spring. During autumn and winter (little data was obtained during the winter season), the surface drift tends offshore, while the bottom drift tends onshore.

The features of the drift patterns are discussed in the light of river effluent, advection and meteorological effects. Typical drift speeds at the surface ranged from 2 to 14 km/day while the bottom drift speeds were from 0.1 to about 3 km/day.

Based on the seasonal pattern and other persistent features of non-tidal drift, a test firing area, which offers the best probability for ultimate recovery of a lost test vehicle, is suggested.

Cook, S. K. and C. E. Gardner, Jr. 1978. An example of rapid change in the summertime water column over the continental shelf southeast of Sandy Hook N. J. Gulfstream 4(5):6-7.

Cook, S. K. and M. M. Hughes. 1980. Water column thermal structure across the shelf and slope southeast of Sandy Hook, New Jersey. Annales Biol. Cons. Int. Explor. Mer. 35 (1 Hydrography): 14-25.

Cornillon, P., M. Reed, M. Spaulding, C. Swanson. 1980. The application of SEASAT-1 radar altimetry to continental shelf circulation modeling. Proceedings of Symposium on remote sensing of the environment, San Jose, Costa Rica, 23-30 April 1980.

This study investigates the applicability of high resolution radar altimetry to numerical modeling of continental shelf circulation. The Georges Bank/Gulf of Maine region, one of the richest fishing grounds in the world and currently being considered for oil exploration, was selected as the test site.

Radar altimetry is employed in verifying predictions of the continental shelf circulation model. SEASAT-1 radar altimetry has been selected over GOES-3 altimetry because of its higher resolution, a necessity for observing elevation changes on the shelf, and because of its repeating orbit, which provides a convenient means of improving the GEM-10b geoidal estimate in the Georges Bank/Gulf of Maine region.

Details of the numerical circulation model to be used in the analysis are presented elsewhere. In overview, the model is three dimensional in nature and incorporates a vertical coordinate transformation to resolve the surface and bottom layers. Although for this investigation, tidal forcing only was used, the model is capable of responding to all significant forcing mechanisms on the shelf (tides, wind, atmospheric pressure and density gradients). The model makes use of the efficient semi-implicit mode of time integration, removing the surface gravity wave time step restriction.

Verification of the predicted surface elevation is achieved through a comparison of model and altimeter derived values of this quantity on two SEASAT tracks passing through the study area. For this comparison tidal gauge data along the shelf break were used to drive the model while open ocean tidal data were used to correct for SEASAT orbital bias and tilt. The comparison is in general excellent, the only problems being in the absolute magnitudes of the sea level. This problem appears to be attributable to errors in the bias and tilt correction rather than errors in the circulation model.

Cornillon, P. C., M. L. Spaulding and K. Hanson. 1979. Oil spill treatment strategy modeling for Georges Bank. American Petroleum Inst., Oil Spill Conf. Proc., p. 685-692.

Costin, M., P. Davis, R. Gerard and B. Datz. 1963. Dye diffusion experiments in New York Bight. Columbia University, Lamont Geol. Obs. Tech. Rep. CU-2-63 (Unpub. Man.)

Cox, J. and P. H. Wiebe. 1979. Origins of oceanic plankton in the Middle Atlantic Bight. Estuarine Coastal Mar. Sci. 9:509-527.

* This article analyzes documented occurrences of oceanic and other non-indigenous zooplankton in the New York Bight as well as recent knowledge on warm core rings in order to trace the origins of plankton in this region. It presents an objective analysis of previous works in the field and provides a conceptual framework for plankton dynamics in the Middle Atlantic Bight.

Cresswell, G. M. 1967. Quasi-synoptic monthly hydrography of the transition region between coastal and slope water south of Cape Cod, Massachusetts. WHOI Tech. Rpt. 67-35.

Crist, R. W. and J. L. Chamberlin. 1979. Bottom temperatures on the Continental Shelf and Slope south of New England during 1977. Annls. Biol., Copenhagen. 34:21-27.

Csanady, G. T. 1973. Wind-induced baroclinic motions at the edge of the continental shelf. J. Phys. Oceanog. 3(3):274-279.

In a two-layer model of stratified fluid flow, motions in the internal mode are governed by the distribution of an equivalent depth h_e. For a typical continental shelf, the distribution of h_e with distance from shore may be closely approximated by two straight-line distributions patched at the shelf break, one of constant slope and one of constant (equivalent) depth. For such a simple model the forced response to a suddenly imposed wind stress (in the internal mode) is easily calculated. The component of the wind stress perpendicular to shore produces a step-like feature of the thermocline at the shelf, and a longshore Ekman drift gradually reducing to zero at the coast from the infinite ocean value far offshore. Wind stress parallel to the shore produces a thermocline step and a longshore jet at the shelf break, both of linearly increasing amplitude (in time), and an onshore or offshore Ekman drift, again reducing to sero at the coast but having the infinite-ocean magnitude far offshore.

Csanady, G. T. 1974. Barotropic currents over the continental shelf. J. Phys. Oceanogr. 4: 357-371.

We study below with the aid of linearized equations, but using a quadratic bottom friction law, the barotropic forced (aperiodic) response to wind stress or external pressure gradient of various simple continental shelf models. The frictionless response to longshore wind stress shows many of the characteristics of the classical "coastal jet" problem but is complicated by depth variations, mainly because of the generation of vorticity over a sloping bottom. Positive vorticity is generated where the depth increases to the left of wind (in the North Hemisphere) and negative vorticity where the depth gradient is opposite. Thus, in a deep gulf separated from the open ocean by a shallow bank (in the Gulf of Maine, for ezample), a double-gyre circulation tends to be established.

Friction places a definite limit on the maximum velocities which are produced by a storm of given intensity, the limit being more or less independent of depth. For typical shelf conditions the time of establishment of frictionally controlled flow is a few times 10^4 seconds, longer where the establishment of geostrophic balance requires larger influx of water into the shore zone (e.g., in a wide gulf). Outside the shelf break, frictionally controlled flow is never established by any storm of realistic duration. The response remains essentially of the frictionless transient type with a progressive development of a coastal jet that intensifies with time. A realistic, combined model may be obtained by patching a coastal jet over the open ocean to frictionally controlled flow over the shelf. This reveals the further slow change in surface level over the shelf, which, however, does not significantly influence the frictionally controlled flow pattern.

A comparison of the theoretical results with observations in the Gulf of Maine suggests that the observed double-gyre circulation (known to be most intense in May) is a barotropic response to northeasterly wind stress. It is hypothesized that these winds dominate the air-sea momentum exchange early in the season because air blowing off the continent is much warmer than the sea surface and produces only low stresses.

Csanady, G. T. 1976. Mean circulation in shallow seas. J. Geophys. Res. 81(30):5389-5399.

The mean circulation of shallow seas arises as the residue of chaotic first-order flow episodes created by winds, tides, and river inflow. The average effect of many such episodes is to generate an internal pressure and shear stress distribution which may differ significantly from a steady solution of the equations of motion. Within the coastal boundary layer (of about 10-km width), complex average effects of variable flow probably dominate. However, in mid-shelf regions of the Mid-Atlantic Bight, for example, classical steady state models adequately describe the main features of the mean circulation. The statistical effects of variable first-order flow even bring about some simplifications of the theory, i.e., linear internal and bottom friction laws and a decoupling of salt transport from the mean circulation. The mid-shelf circulation of the Mid-Atlantic Bight is thus found to consist of four additive components, each driven by offshore wind, longshore wind, longshore pressure gradient, and density contrasts caused by freshwater influx. The longshore pressure gradient enters the theory as a parameter necessary for describing the interaction of a portion of the continental shelf with the rest of the ocean. The pressure gradient driven flow component is responsible for some notable circulation features such as the line of divergence in bottom drift at about the 60-m isobath. The wind-driven and thermohaline flow components are familiar in character. Quantitatively, the four components together account satisfactorily for the observed mean shelf circulation.

Csanady, G. T. 1978. The arrested topographic wave. J. Phys. Oceanogr. 8:47-62.

Csanady, G. T. 1978. Wind effects on surface to bottom fronts. J. Geophys. Res. 83(C9):4633-4640.

In nearshore regions, water of reduced density is frequently present owing to freshwater influx or spring heating. Under some circumstances, light nearshore water is confined to one side of a density front, extending from surface to bottom, and is called 'spring thermocline' or 'shelf edge front.' The shape and permanency of this front are affected by wind stress, which may interfere with the momentum balance in a direction parallel to the front and cause geostrophic adjustment motions normal to the front. A simple geostrophic adjustment theory elucidates some of the more important effects of wind on such fronts. Winds opposing the geostrophic flow above the inclined front tend to flatten its shape and eventually destroy the front, sometimes causing the formation of a surface 'lens' or 'bubble.' Comparison with observations from Lake Ontario and from the New England continental shelves shows that the theory gives a realistic first-order description of frontal behavior.

Csanady, G. T. 1979. The birth and death of a warm core ring. J. Geophys. Res. 84(C2): 777-780.

The birth of a warm core ring is conceptualized as a catastrophic separation process governed by the strong inertial forces within a western boundary current. A frictionless theory based on this postulate and assumed geostrophic balance on completion of the separation process yields a description of ring geometry and velocity distribution in first-order agreement with observation. In particular, maximum velocities of the order of 1 $m\ s^{-1}$ are predicted to occur near the perimeter. The initial decay rate of the ring is estimated from an interface friction and entrainment model (using the above maximum velocity) to be about 0.05 day^{-1}, which reduces rapidly, however, as the ring slows down. Interface friction is found to be much more important than entrainment in producing the decay.

Csanady, G. T. 1980. Longshore pressure gradients caused by offshore wind. J. Geophs. Res. 85 (2):1076-1084.

Observations of currents 12 km south of the Long Island caost show that strong offshore winds could generate considerable longshore nontidal flow well below any surface Ekman drift. A momentum balance calculation in the longshore direction shows a surface level gradient of order 10^{-6} to be the proximate cause of the longshore flow. A very simple model of the observed phenomena is a sloping plane beach acted upon by cross-shore wind, varying sinusoidally in the long shore direction. With bottom friction parameterized by a linear law, a parabolic equation is found to govern steady state flow, expressing a balance of vorticity tendencies die to cross-isobath flow, curl of bottom stress, and any forcing. Calculated solutions for variable cross-shore wind show a trapped pressure field on the inner shelf which controls the transition between an essentially frictionless momentum balance on the outer shelf to frictionally dominated flow at the shore. Realistic estimates of the parameters entering the theory suggest that the longshore gradients associated with the trapped inner shelf field are of the correct order of magnitude to explain the generation of longshore flow by a system of cross-shore winds.

Csanady, G. T. 1981. Circulation in the coastal ocean, Part 1. Trans. Am. Geophys. Union. Vol. 62(2). Jan 13, 1981.

* This is part one of a three-part series on circulation patterns in the earth's "coastal oceans" - large shallow bodies of water with horizontal dimensions of 100 km or more such as the continental shelves. Such bodies are characterized by "oceanic" circulation, in the sense that motions in them are strongly affected by the earth's rotation. Theoretical frameworks are described for wind-driven transient currents, upwellings, downwellings and coastal jets present in these waters. Confirmation of these models are made from observations in Lake Ontario during the International Field Year on the Great Lakes, 1972-73.

The author stresses the importance of understanding patterns of residual or longer-term water particle displacements as a means of predicting the distribution of temperature, salinity, heavy metals and nutrients.

Csanady, G. T. 1981B. Circulation in the coastal ocean. Part 2. Trans. Am. Geophys. Union, EOS, Vol. 62(5) Feb. 3, 1981.

* As a continuation of part 1, current driving forces unrelated to winds are examined. Flow phenomena observed are: Current reversals and dynamic principles that govern the propagation of relevant types of trapped waves that occur cyclonically southwestward down the coast of North America, flow controlled by bottom friction and dynamics is considered, and also thermohaline circulations caused by cooling of shallow waters.

Csanady, G. T. 1981C. Circulation in the coastal ocean, Part 3. Trans. Am. Geophys. Union. EOS, Vol. 62(8), Feb. 24, 1981.

* The simple dynamic shelf circulation models from parts 1 and 2 are broadened to focus on long-term, larger-scale flow phenomena in the layer model.

Csanady, G. T. 1981D. Analysis of dumpiste diffusion experiments. In: Ocean Dumping of Industrial Wastes. B. J. Ketchum, D. R. Kester and P. K. Park (eds). p. 109-129. Plenum Press, N. Y. and London, 525 pp.

The oceanic dispersion of industrial waste barged to Deep Water Dumpsite 106 is effected in the first instance by barge-bound eddies ("wake dispersion"), then by naturally occurring mean shear and turbulence. Wake dispersion is very efficient, producing initial dilution up to a factor of 10^4, and is controlled by the dimensions and the forward speed of the barge. Subsequent dispersion by natural oceanic processes is slow under stratified summer conditions, describable by an effective diffusivity of order 300 cm^2 sec^{-1} or a diffusion velocity in the beighborhood of 0.2 cm sec^{-1}, for the first 12 hours or so after release. A comparison of the observed data with shear-dispersion theory shows that: (a) horizontal dispersion in the upper 10-20 m of a stratified ocean is mainly due to mean shear-vertical mixing interaction; (b) the low observed rates of dispersion may be attributed to the fact that an early phase of shear diffusion was in evidence. Extrapolation to diffusion times of the order of several days should be possible using a constant diffusion velocity, or an effective diffusivity increasing in direct proportion to time.

Csanady, G. T. 1981E. Long-term fate of barged waste in slopewater. P. 123-124 (abstract). In: Program and Abstracts - Third International Ocean Disposal Symposium. Woods Hole Oceanographic Institution, Woods Hole, Mass. Oct. 12-16, 1981. 156 pp.

Csanady, G., G. Flierl, D. Karl, D. Kester, T. O'Connor, P. Ortner, W. Philpot. 1979. Deepwater Dumpsite 106. In: Assimilative capacity of the U.S. Coastal Waters for Pollutants. Proceedings of a workshop at Crystal Mountain, Washington, July 1979. E. D. Goldberg, (Ed.) National Oceanic & Atmospheric Administration, Boulder, Colorado.

Davis, C. W. 1979. Bottom water temperature trends in the Middle Atlantic Bight during spring and autumn, 1964-76. NOAA Spec. Sci. Report - Fish. NOAA Tech. Rep. NMFS SSRF 739, 13 p.

Day, C. G. 1957. Drift bottle records for Gulf of Maine and Georges Bank, 1931-56. Spec. Sci. Rep.: Fisheries No. 242.

Day, C. G. 1958. Surface circulation in the Gulf of Maine as deduced from drift bottles. U.S. Fish and Wildl. Serv., Fish. Bull. 141:443-472.

Diaz, H. F. 1979. Chapter 3. Atmospheric conditions and comparison with past records. In: Oxygen Depletion and Associated Benthic Mortalities in New York Bight, 1976. Swanson, R. L. and C. J. Sindermann (Eds.), NOAA Prof. Paper 11, pp. 51-77.

* An objective comparative analysis from climatological data and relevant atmospheric forcing fields for February-August 1976 is made in this paper. The magnitude and persistence of anomalous weather patterns during the months preceding the period of bottom-water anoxia suggest a possible connection to the disruption of the marine environment. Anomalies existing in sea surface temperature, surface wind, wind stress and vertical motion calculations consisting of open-ocean and coastal upwelling estimates are examined.

Dickson, R. R. and J. Namias. 1976. Atmospheric climatology and its effect on sea-surface temperature. In: The Environment of the United States Living Marine Resources, 1974. MARMAP Contribution No. 104, pp. 3-1 to 3-12.

Dickson, R. R. and J. Namias, 1976. North American influences on the circulation and climate of the North Atlantic sector. Mon. Weather Rev. 104:1255-1265.

During the post-war period the pressure field at Greenland has been characterized by long-sustained winter regimes of alternating high and low pressure, with important effects on the winter climate of Europe. Although these alternations of pressure anomaly at Greenland may be shown to be associated with periods when the pattern of long waves in the upper westerlies showed a general reversal over much of the Northern Hemisphere, it is also suggested that within this hemispheric pattern of change, contemporary variations of winter climate along the Atlantic seaboard of North America have exerted an important influence on the pressure field at Greenland and, through teleconnections, elsewhere (e.g., the North Atlantic and Europe). Comparing months of extreme winter warmth and cold over the southeastern United States it is shown that changes in the strength of the baroclinic field at the coast are associated with major changes in the distribution of winter storms. More specifically, during winters of extreme cold over the southeastern United States and the associated enhanced baroclinicity at the Atlantic seaboard, the zone of peak winter storm frequency is drawn far to the southwest of normal, with a corresponding decrease in cyclonic activity in the Iceland-Greenland area.

Doyle, B. E. and R. E. Wilson. 1978. Lateral dynamic balance in the Sandy Hook-Rockaway Point transect. Estuarine & Coastal Mar. Sci. 6:165-174.

Currents associated with the residual nontidal flow through the Sandy Hook to Rockaway Point transect exhibit considerable vertical and lateral structure including a two-layer estuarine flow pattern over much of the transect and inflow to New York harbor at all depths near Rockaway Point. To determine the relative importance of different dynamic processes in maintaining this structure, the nontidal lateral momentum balance in the transect has been examined using current meter and hydrographic data from the 1952 and 1958-1959 U.S. Coast and Geodetic Survey field studies in New York Harbor. Results suggest that over the entire transect the lateral pressure gradient force balances the sum of the centrifugal force associated with the oscillating tidal flow and the Coriolis force due to the nontidal flow normal to the transect. This balance is maintained without significant contribution from turbulent shear stresses. Over much of the transect the primary balance is between the lateral pressure gradient force and the centrifugal force.

Drake, D. E. 1974. Suspended particulate matter in the New York Bight Apex: September-November 1973. NOAA Tech. Rept., ERL 318 - MESA 1.

Drake, D. E. 1977. Suspended particulate matter in the New York Bight Apex, Fall 1973. *J. Sedim. Petrol.* 47(1):209-228.

Duedall, I. W., T. A. Nelsen, T. A. Johnson, J. R. Glasgow and J. R. Proni. 1977. Quantitative mapping of suspended solids in wastewater sludge plumes in the New York Bight apex. J. Water Pollution Control Fed. 49:2063-2073.

* On September 22, 1975, three wastewater sludge dumps and their plumes were monitored by air remote sensing and surface vessels, the NOAA Ship KELEZ and the SUNY vessel ONRUST. Remote data was collected by a multispectral scanner, multispectral photograph, and a mapping camera. Surface water samples and acoustic profiling data are presented in another report. Results show that calibrated regression equations relate to remotely sensed data and to sea-truth measurement and can be used to provide maps of synoptic distributions of water quality parameters associated with ocean disposal of wastewater sludge.

Duedall, I. W., S. A. Oakley, J. J. Parker and J. R. Proni. 1981. Sewage sludge tracking in the New York Bight (Abstract). Third International Ocean Disposal Symposium, Woods Hole Oceanographic Inst., Woods Hole, MA. Oct. 12-16, 1981.

Duedall, I. W., H. B. O'Connor, J. H. Parker, R. E. Wilson and A. S. Robbins. 1977. The abundances, distribution and flux of nutrients and chlorophyll *a* in the New York Bight apex. Est. & Coast. Mar. Sci. 5:81-105.

Tidal, spatial and seasonal changes in salinity, temperature and concentrations of ammonium, nitrite, nitrate, phosphate, silicic acid, chlorophyll *a* and suspended matter in the waters between Sandy Hook, New Jersey and Rockaway Point, New York, were measured during five cruises which took place between November 1973 and June 1974. Over this period concentrations of nutrients and chlorophyll *a* were much greater than those found in the adjacent coastal waters. The main source of the ammonium, nitrite and phosphate is sewage effluent which is discharged into the waters surrounding the New York metropolitan region; nitrate comes mainly from the Hudson River and silicic acid is discharged in large amounts from river and sewage sources.

The largest tidal variation in salinity and nutrient and chlorophyll *a* concentrations occurs near Sandy Hook where the Hudson River discharge has the greatest influence. Near Rockaway Point, nutrient and chlorophyll a concentrations are generally lower and salinities higher than those observed near Sandy Hook because of the inflow of Bight water by non-tidal currents. During the spring freshet nutrient concentrations, especially ammonium, are low along the transect due to (1) dilution by the spring freshet and (2) utilization by the abundant phytoplankton. Flux calculations for the June observations indicate that most of the nutrients and chlorophyll *a* are being transported from the lower Hudson Estuary into the New York Bight apex.

E G & G. 1975. Summary of oceanographic observations in New Jersey coastal waters near 39°28'N latitude and 74°15'W longitude during the period May 1973 through April 1974. Rep. B-4424. E G & G Environ. Consult., Waltham, MA.

E G & G Environmental Consultants. 1977. Measurements of the dispersion of barged waste near 38°33'N latitude and 74°20'W longitude. Unpublished report submitted to E. I. duPont deNemours & Co., Edgemoore, Delaware.

E G & G. 1978. Intersection of a Gulf Stream eddy with Georges Bank. New England Outer Continental Shelf Physical Oceanography Program, Appendix D of 8th quarterly Progress Report to U.S. Dept. Int., Bur. Land Management, V:D-1 to D-56.

Eittreim, S., M. Ewing and E. M. Thorndike. 1969. Suspended matter along the continental margin of the North American Basin. Deep Sea Res. 16:613-624.

Elsberry, R. L. and R. W. Garwood, Jr. 1978. Sea-surface temperature anomaly generation in relation to atmospheric storms. Bull. Am. Meteorol. Soc., 59:786-789.

* Anomalously high or low sea-surface temperature patterns are explained by the limiting depth over which the surface heat flux is distributed. Atmospheric storms serve to determine the timing of the transition from a winter regime of deep isothermal layers to a shallow, summer layer. Years with early transition dates have high surface temperature because of the tendency to accumulate net surface heat flux in a shallow layer. Years with a late transition date show lower temperatures as heat addition is spread over greater depths.

Energy Resources Company. 1981. Demonstration of compliance of coal ash disposal at the 106-mile waste disposal site with subparts B, D and E of the ocean dumping regulations. Unpublished report prepared for the Consolidated Edison Company of New York, Inc. 155 pp.

EPA. 1978. Environmental impact statement on the ocean dumping of sewage sludge in the New York Bight - Final - September 1978. U.S. Environmental Protection Agency, Region II, 26 Federal Plaza, N.Y., NY 10007. 26 p. plus Appendices A and B.

Fairbanks, R. G. 1981. Isotope measurements identify sources of Middle Atlantic Bight water masses. Coastal Oceanogr. Climatol. News 4(1):6-7.

Fairbanks, Richard G. 1982. The origin of continental shelf and slope water in the New York Bight and Gulf of Maine: Evidence from $H_2{}^{18}O/H_2{}^{16}O$ ratio measurements. Jour. Geophys. Res. 87(c8)5796-5808.

The $H_2{}^{18}O/H_2{}^{16}O$ ratio of meteoric water in eastern North America decreases with increasing latitude. The annual weighted average $\delta^{18}O$ content of the Middle Atlantic Bight (MAB) and Gulf of Maine (GOM) rivers are -9.33% and -10.89%, respectively. The $\delta^{18}O$ compositions of the major east coast rivers are 2% enriched during summer months. By using $H_2{}^{18}O$ and salinity measurements, both conservative properties of sea water, the geographic origin of continental shelf water can be identified. The isotope-salinity tracer method, which has been used so successfully in polar regions, is also an effective method in the temperate MAB because subpolar waters are exported to this region. The apparent dilutent of slope water is -22%$\delta^{18}O$ relative to standard mean ocean water. Water of this composition is presently forming in the Labrador Sea. Melt water from sea ice has nearly the same isotopic composition as the sea water from which it formed and thus may be distinguished from meteoric water. In March 1977, the New York Bight cold pool contained as much as 2.5% sea ice melt water. The Gulf of St. Lawrence is the nearest source of sea ice. The New York Bight 'cold pool' was renewed from the north between March and July, which was the extent of our sampling period.

Falk, L. L. and J. R. Gibson. 1977. The determination of release time for ocean disposed waste waters. Unpubl. Rep. submitted to U.S. E.P.A. Region II. Edison, New Jersey. 38 pp.

Falkowski, P. G., T. S. Hopkins and J. J. Walsh. 1980. An analysis of factors affecting oxygen depletion in the New York Bight. J. Mar. Res. 38(3):479-506.

* This article is an analysis of possible factors leading to oxygen depletion within the New York Bight based on historical data extending back to 1910. The *Ceratium tripos* bloom of 1976 is given particular attention. Factors leading to its establishment and subsequent shellfish kill are said to be a warm winter with large runoff, a low frequency of spring storms, a deep summer thermocline, persistent southerly winds with few reversals, a large autochtonous carbon load and low grazing pressure by zooplankton. It is suggested that anoxia could have occurred due to this abnormal chain of biological events without any sludge dumping from New York City.

Fedosh, M. S. and J. C. Munday. 1982. Satellite analysis of estuarine plume behavior. VIMS Contr. No. 1066 6pp. Prepared for inclusion in the proceedings of OCEANS 82, IEEE, Washington, D.C., September 20-22, 1982.

Estuarine plumes at the Chesapeake, Delaware, and Raritan Bay entrances were studied in 268 Landsat MSS and 68 HCMM thermal infrared images. Turbidity or thermal boundaries were detected in nearly all images. Wind had a large influence on locations of boundaries: under strong southwest to west winds, plumes moved eastward from bay mouths into waste disposal areas. Northern winds, the Cariolis force, and net non-tidal coastal currents drove plumes southward along the coasts from bay mouths. Plume boundaries are more dispersed during ebb tide. Seasonal effects are mixed.

Firing, E. and R. C. Beardsley. 1976. The behavior of a barotropic eddy on a β-plane. J. Phys. Oceanogr. 6(1):57-65.

Fischer, H. B. 1980. Mixing processes on the Atlantic continental shelf, Cape Cod to Cape Hatteras. Limnol. Oceanogr. 25(1): 114-125.

Data from moored current meters and airborne and satellite observations are used in conjunction with analyses of shear flow dispersion to estimate the dispersion of dissolved substances in the Middle Atlantic Bight during unstratified periods. The long-shelf dispersion coefficient is estimated to be of the order of 10^4-10^5 $cm^2 \cdot s^{-1}$, and the cross-shelf dispersion coefficient of the order of 3×10^5 $cm^2 \cdot s^{-1}$ at midshelf. The cross-shelf estimate is a factor of 10 less than previous ones, which were based on the assumption that the cross-shelf flux of freshwater is equal to the inflow from tributary rivers within the bight itself.

Fisher, A. 1973. Environmental guide to the Virginia Capes operating area. U.S. Naval Oceanogr. Off. Spec. Publ. 211, 58 pp.

Fisher, A., Jr. 1972. Entrainment of shelf water by the Gulf Stream northeast of Cape Hatteras. J. Geophys. Res. 77: 3248-3255.

Entrainment of relatively cold low-salinity water by the Gulf Stream and subsequent formation of a cold filament adjacent to the northern edge of the Gulf Stream were frequently observed during a series of combined ship and aircraft surveys conducted northeastward of Cape Hatteras between October, 1968, and May, 1969. Particularly well-defined entrainment was observed during mid-May, 1969 when a band of surface water 10 to 15 km wide and 40 meters thick was observed to reach from the continental shelf to the northern edge of the Gulf Stream. Transport seaward from the outer shelf is of the magnitude 10^4 m^3/sec. Failure to observe entrainment during some of the flights agrees with the discontinuous nature of the cold filament adjacent to the northern edge.

Fitzgerald, J. and J. L. Chamberlin. 1981. Anticyclonic warm core Gulf Stream eddies off the northeastern United States during 1979. Annls biol., Copenh. 36:44-51.

Fitzgerald, J. and J. L. Chamberlin. In press. Anticyclonic warm core and Gulf Stream eddies off the northeastern United States in 1980. Annls biol., Copenh.

Flagg, C. N. and R. C. Beardsley. 1978. On the stability of the shelf water/slope water front south of New England. J. Geophys. Res. 83(C9):4623-4631.

The baroclinic stability of a Margules front over steep topography is studied in an attempt to explain some wavelike features observed on the shelf water/slope water front south of New England. During winter this front extends from the bottom hear the 85 m isobath to the surface with a typical mean slope of 2×10^{-3}, with a corresponding geostrophic shear of about 10 cm/s. A quasi-synoptic hydrographic survey of the New England shelf made during March 1974 resolved a wavelike distortion of the front characterized by a 80-km alongshelf wavelength. The associated Rossby number based upon the alongshelf wave number and the vertical shear ($Ro = k(\Delta U)/2f$) is <0.05, so that a perturbation analysis using the semigeostrophic approximation is possible. This approach allows the resulting equations to be cast into an ordinary eigenvalue problem which can be easily solved numerically. The effect of increasing the bottom slope is to destabilize some neutral modes and to stabilize other modes that had been unstable over flat topography. In general, however, the characteristic e folding times of the unstable modes increase dramatically from 2-5 days for flat topography to greater than 50 days for realistically steep topography. This rapid decrease in growth rates with increasing bottom slope implies that the observed wavelike features on the front must be generated by some mechanism other than local baroclinic instability. Once they are generated, the observed features may propagate as essentially stable frontal wave modes. We note, however, that the front would be quite unstable if it was located over flat topography. This may help explain why persistent fronts of this type appear to be found near the shelf break.

Flierl, G. R. 1979. A simple model for the structure of warm and cold core rings. J. Geophys. Res. 84(C2):781-786.

We consider the simplest model describing the shape and strength of warm and cold core rings. The Coriolis parameter is taken to be constant. The flows are strong enough so that the interface betweem the two fluids rises to the surface. We describe the velocity and interface depth profiles and compare the model to field data.

Flierl, G. R. 1980. Simple models of waste disposal in a gyre circulation. Presentation at the 2nd International Ocean Disposal Symposium.

Flierl, G. 1981. Motion and dispersion of dumped material by large amplitude eddies. P. 125 (abstract). In: Program and Abstracts - Third International Ocean Disposal Symp. Woods Hole Oceanographic Inst., Woods Hole, MA. Oct. 12-16, 1981. 156 pp.

Ford, W. L., J. R. Leonard and R. E. Banks. 1952. On the nature, occurrence and origin of cold low salinity water along the edge of the Gulf Stream. J. Mar. Res. 11(3): 281-293.

Ford, W. L. and A. R. Miller. 1952. The surface layer of the Gulf Stream and adjacent waters. J. Mar. Res. 11(3):267-280.

Freeland, G. L., G. Han, W. L. Stubblefield, D. J. P. Swift, P. E. Gadd and J. W. Lavelle. 1976. Morphologic evolution and coastal sand transport, New York and New Jersey shelf. Am. Soc. Limnol. Oceanogr. Spec. Symp. 2:69-89.

* A geological history of the continental shelf is presented in this paper along with quantitative estimates of sediment transport. The Holocene transgression of tide dominated sedimentation at estuary mouths and sand transport patterns that develop along the adjacent shoreface and inner shelf are discussed. Real-time studies of fluid motion and substrate responses are made. Reports on analysis and studies of sand transport yield fragmented reports and many more questions than initially realized.

Freeland, G. L., D. J. Stanley, D. Lambert and D. J. P. Swift. 1981. The Hudson Shelf Valley: Its role in shelf sediment transport. In: Sedimentary Dynamics of Continental Shelves. C. E. Nittrouer, (ed.). Elsevier, NY. p. 399-427.

Freeland, G. L. and D. J. P. Swift. 1978. Surficial sediments. MESA NY Bight Atlas Monograph No. 10. MESA NY Bight Project and New York Sea Grant Institute, 93 p.

* This monograph is an overview and summarization of what is currently known about surficial and suspended sediment in the New York Bight. Data are presented as maps showing tracklines and results of completed work.

Freeland, G. L., D. J. P. Swift and W. L. Stubblefield, and A. E. Cook. 1976. Surficial sediments of the NOAA-MESA study areas in the New York Bight. In: Spec. Symp. 2, Middle Atlantic Continental Shelf and the New York Bight, (M.G. Gross, ed.). Amer. Soc. Limnol. Oceanogr. pp. 90-101.

Freeland, G. L., D. J. P. Swift and R. A. Young. 1979. Mud deposits near the N.Y. Bight Dumpsites: Origin and Behavior. In: Ocean Dumping and Marine Pollution, Palmer and Gross (eds.) Dowden, Hutchinson and Ross, Inc. 73-95.

Frey, H. R. 1978. Northeastward drift in the northern Mid-Atlantic Bight during late spring and summer 1976. J. Geophys. Res. 83(C1):504-514.

* Using surface drift cards dropped from helicopters, south of Long Island, the author describes an anomalous northeastward surface current persistent over the summer of 1976.

Frye, D. and G. Williams. 1977a. Measurements of the dispersion of barged waste near 38°50'N latitude and 72°15'W longitude at the "106" dumpsite. Unpubl. Man. E G & G Environmental Consultants, Waltham, MA.

Frye, D. and G. Williams. 1977b. Measurements of the dispersion of barged waste near 38°33'N latitude and 74°20'W longitude. Unpubl. Man. E G & G Environmental Consultants, Waltham, MA.

Fuglister, F. C. 1947. Average monthly sea surface temperatures of the western North Atlantic Ocean. Pap. Phys. Oceanogr. Meteorol. 10(2):25 p.

Fuglister, F. C. 1963. Gulf Stream '60. Prog. Oceanogr. 1:265-283.

Fuglister, F. C. 1971. Cyclonic rings formed by the Gulf Stream 1965-66. In: Studies in Physical Oceanography. A tribute to Georg Wust on his 80th Birthday. Gordon and Breach, Publ.

Fuglister, F. C. and A. D. Voorhis. 1965. A new method of tracking the Gulf Stream. Limnol. Oceanogr., Suppl. 10:115-124.

Fuglister, F. C. and L. V. Worthington. 1951. Some results of a multiple ship survey of the Gulf Stream. Tellus 3:1-14.

Gadd, P. E., J. W. Lavelle, and D. J. P. Swift. 1978. Estimates of sand transport on the New York shelf using near-bottom current meter observations. J. Sed. Petrol., 48:239-252.

Galt, J. A. 1980. A finite-element solution procedure for the interpolation of current data in complex regions. J. Phys. Oceanogr. 10:1984-1997.

A finite element solution technique is introduced to develop current patterns subject to geostrophic and Ekman dynamics for an irregular continental shelf region. The interpolation bases set of functions uses triangular topology. Alternate boundary conditions are discussed and related to both the mathematical nature of the governing equation and the geophysical constraints imposed on the flow. Examples of the derived current patterns are shown for two regions of the Gulf of Alaska.

Garfield, N. 1978. A box model study of the circulation in the Middle Atlantic Bight. M.S. Thesis. University of Delaware, College of Marine Studies, Lewes, Delaware.

Garrett, C. 1974. Normal modes of the Bay of Fundy and Gulf of Maine. Canad. J. Earth Sci. 11:549-556.

Garrett, C. and E. Horne. 1978. Frontal circulation due to cabbeling and double diffusion. J. Geophys. Res. 83(C9): 4651-4656.

Garrett, C. J. R. and R. H. Loucks. 1976. Upwelling along the Yarmouth shore of Nova Scotia. J. Fish. Res. Board Can. 33:116-117.

Garside, C. and T. C. Malone. 1978. Monthly oxygen and carbon budgets of the New York Bight apex. Est. & Coast. Mar. Sci. 6:93-104.

* This paper is a compilation of source material and data gathered during 12, 3 day cruises aboard the R/V COMMONWEALTH at monthly intervals, September 1974-August 1979. The distribution of primary production salinity, temperature, dissolved oxygen and particulate organic carbon are used to establish monthly oxygen balance for the apex of the New York Bight. "The monthly regression lines of surface oxygen flux against particulate organic carbon, the monthly mean surface flux calculated from the spatially unweighted mean POC, the number of points used and the correlation coefficient of the regression line and the annual mean values of all parameters are tabulated."

Garvine, R. W. 1975. The distribution of salinity and temperature in the Connecticut River Estuary. J. Geophys. Res. 80(9): 1176-1183.

Garvine, R. W. 1979a. An integral hydrodynamic model of upper ocean frontal dynamics: Part I. Development and analysis. J. Phys. Oceanogr. 9(1):1-18.

The paper develops and analyzes a model of frontal-scale dynamics applicable to established, persistent upper ocean density fronts. The effects of interfacial friction and mass entrainment arising from turbulent dissipative processes are incorporated as well as the effects of earth rotation and wind stress. The model is of hydrodynamic character in that the circulation is not permitted to do its own mixing. The equations of motion are solved after their integration over the vertical from the pycnocline bottom to the sea surface. Two independent frontal length scales are found: one is L_t, the dissipative length scale, defined as the ratio of the asymptotic pycnocline depth to the magnitude of the interfacial entrainment coefficient; the other is the baroclinic Rossby radius, the internal wave phase speed divided by the Coriolis parameter. The ratio of these length scales forms the fundamental parameter of the model dynamics, P_r, called the rotation parameter. For large values of P_r the frontal length scale is the Rossby radius alone and the model dynamics show features in common with the inertial, inviscid Gulf Stream theories. For small values of P_r the frontal zone can have a double structure with the inner region corresponding to the nonrotational dynamics explored in a previous paper. For values of order one both dissipative and rotational effects enter the dynamics.

Garvine, R. W. 1979b. An integral hydrodynamic model of upper ocean frontal dynamics: Part II. Physical characteristics and comparison with observations. J. Phys. Oceanogr. 9(1):19-36.

The physical characteristics of a model of an upper ocean front are examined and compared to observations. The model was developed and analyzed in a companion paper. It applies to the mean circulation and hydrography of established persistent fronts. The results for a case where turbulent transport and earth rotational effects are both important are examined in detail. The circulation then contains a jet for the velocity parallel to the front including cyclonic shear but with speeds that are below geostrophic values. The circulation normal to the front shows strong two-sided convergence and sinking near the surface front. The question of upward versus downward mass entrainment is examined in terms of its impact on the model circulation. Five frontal cases are examined and compared to field observations. These cover a wide range of frontal scales from a river plume front to the Gulf Stream front. The river plume front nearly corresponds to a limiting case for the model where rotation is negligible and turbulent dissipative effects dominant, while the Gulf Stream front corresponds nearly to the opposite limiting model case where dissipation is negligible and rotation dominant. The other cases fall between these two limits.

Garvine, R. W. 1980. The circulation dynamics and thermodynamics of upper ocean density fronts. J. Phys. Oceanogr. 10:2058-2081.

This paper extends a previous hydrodynamic circulation model of established, persistent upper ocean density fronts by including a thermodynamic or buoyancy equation in the integral treatment. An analysis is also conducted of the variables related to the kinetic and potential energy budgets in the frontal zone. A comparison of the new results with previous ones shows satisfactory agreement. The new model is used to explore three frontal types of widely different scale or rotation effect, a river plume front, a Sargasso Sea front and the Gulf Stream front. As the scale increases, the influence of rotation increases and the effect of interfacial turbulent transport diminishes. Also, with increasing scale the strength of the downstream (along-front) flow increases while the cross-stream flow diminishes, but always shows a two-sided convergence near the surface front. The kinetic energy dissipation decreases rapidly with dissipation times of resident kinetic energy increasing from ten minutes for the river plume front to a week for the Gulf Stream front. The model results are examined in an attempt to answer three questions about the circulation dynamics. They indicate that the direction of turbulent mass entrainment is always downward, that fronts always spread, even if slowly, relative to the ambient fluid, and that the cross-stream flow near the surface front always shows a two-sided convergence.

Gibbs, Ronald J. 1982. Turbid horizons at mid-depth in the Wilmington Canyon area. Estuar. Coastal Shelf Sci., 14:313-324.

Turbid horizons have been discovered at depths of 20 to 40 m on top of an extension of the 'cold pool' over the Wilmington Canyon and across the continental shelf to its south. Twelve detailed profiles of salinity temperature and light scattering were obtained along with water samples at various depths. These data showed no turbid horizons in areas over the slope where the extension of the 'cold pool' was missing. Particle-size distributions showed these turbid horizons are composed of certain larger sizes of material while clay-size material is in all samples. The turbid horizons were composed mainly of dinoflagellates and silicoflagellates.

Gingerich, K. J. and G. F. Oertel. 1981. Suspended particulate matter in Chesapeake Bay entrance and adjacent shelf waters. P. 199-221 In: Chesapeake Bay Plume Study - Superflux 1980. NASA Conf. Publication 2188, J. W. Campbell and J. P. Thomas (eds.). Scientific and Technical Information Branch, NASA, Washington, DC, 516 pp.

The Department of Oceanography, Old Dominion University, participated in a 1980 NASA/NOAA Superflux program. To support the scientific objectives of the program, water samples were collected and analyzed for hydrocarbons, chlorophyll, nutrients, and suspended solid concentrations and size distributions. The program consisted of three experimental study periods (March, Superflux I; June, Superflux II; and October, Superflux III) in 1980 to study the plume of Chesapeake Bay under various seasonal conditions.

This report utilized the data collected during the Superflux II mission to describe the distribution of several component characteristics of suspended solids that may have influenced the Chesapeake Bay entrance and adjacent shelf waters.

Godshall, Frederic A., Robert G. Williams, Joseph H. Bishop, Fred Everdale and Steven W. Fehler. 1980. A climatologic and oceanographic analysis of the Georges Bank region of the outer continental shelf. NOAA/EDIS Report to the Bureau of Land Management, USDI - Interagency agreement AA551-1A8-14 (Sept. 1980), 290 pp.

Gordon, A. L., and Frank Aikman III. 1981. Salinity maximum in the pycnocline of the Middle Atlantic Bight. Limnol. Oceanogr. 26(1):123-130.

A persistent salinity maximum is observed in the upper part of the pycnocline in summer-autumn over the outer shelf of the New York Bight, induced by a nearly isopycnal transfer of slope water to the outer shelf. The transfer is possible only in the stratified seasons when isopycnals are continuous across the shelf-slope front. Estimates of the slope-shelf salt flux required to produce the pycnocline S-max suggest that it may provide about half of the salt required annually in the shelf region to balance input of river water.

Gordon, A. L., A. F. Amos and R. D. Gerard. 1976. New York Bight Water Stratification - October 1974. Am. Soc. Limnol. Oceanogr. Special Symp. Vol. 2:45-57.

Thermohaline stratification of New York Bight continental shelf water during October 1974 is basically of the summer regime. Salinity increases markedly with increased distance from the coast, yet a basic vertical structure is maintained; an upper isohaline layer; a salinity maximum at the top of the thermocline; a salinity minimum at the base of the thermocline; a deep isohaline layer associated with the cold near-bottom winter residual stratum; and (over the outer shelf) a bottom intrusion of relatively saline and warm slope water. Inversions in temperature and salinity are common within the thermocline.

The pycnocline is continuous over the shelf and slope, though some weakening and deepening occurs over the shelf break. Over the shelf it is mainly supported by the thermocline and over the slope by the halocline. The pycnocline may not be an effective barrier to isopycnal interchange of surface and deep layers in view of the relative slope of isopycnals to pycnocline.

In October 1974 oxygen distribution of the continental shelf was primarily two-layered, with a sharp division at the pycnocline. The lower cold layer has an oxygen concentration of near 60% of full saturation, with values near 3.6 ml/liter. This is low; if the deeper layer is principally a residue of the winter homogeneous condition with initial saturated oxygen values, it would represent oxygen consumption at a rate of 2.6 ml/liter during the six summer months after accounting for the low oxygen influx of slope water.

Gordon, A. L. and R. D. Gerard. 1973. Wind drift surface currents and spread of contaminants in shelf waters. U.S. Coast Guard Report CG-D-5-75. U.S. Dept. Transportation Pub., 64 pp.

From July 1972 to February 1973 a number of experiments were carried out in the vicinity of Ambrose Tower, designed to study the velocity field in the upper few meters of the water column and dependence of local environmental factors. The experiments consisted of aerial photography of a pattern of dyed water, free drifters, dye plumes from anchored generators, drogues set at 1, 3 and 5 meters and floating computer cards. Also photographed were the acid-iron discolored water pattern farther off the coast which enabled large-scale study. The basic aim of the set of experiments is to better understand the fate and behavior of oil contamination.

The results of the experiments indicate the presence of strong vertical and lateral shear within the upper few meters of the water. The upper few centimeters, the layer which would contain the oil contamination, often moves at velocities quite different from average "surface drift." The convergent zones detected by the dye also accumulate the oil and move the oil windward at accelerated rates. The oil and dye have been observed to be frequently transferred to long discontinuity lines in the velocity field, often seen running north-south in the New York Bight.

Oil spilt on the ocean does not spread laterally in a uniform way, but responds to the basic velocity field of the upper few meters (and may, in turn, influence the velocity field directly). The velocity field of the upper few meters is complex in its variants and does not appear to be related to the wind in a simple manner. Significant shearing was observed under calm wind conditions. We believe that the wind factor for oil is larger than the wind factor which is valid for average surface drift and that this difference grows as the surface heating increases.

Gordon, Robert B. 1974. Dispersion of dredge spoil dumped in nearshore waters. Est. & Coast. Mar. Sci. 2:349-358.

* This paper is an analysis of a series of turbidity measurements made at the New Haven spoil ground in the Long Island Sound. Turbidity observations during 7 different cruises were carried out with precise navigational control, permitting quantitative observation of the deposition. Turbidity profiles include convective descent, final collapse of marine silt and long term dispersion of the cloud. Details of resuspension due to the interaction of descending spoil with the bottom are unresolved.

Gotthardt, G. A. and G. J. Potocsky. 1974. Life cycle of a Gulf Stream anticyclonic eddy observed from several oceanographic platforms. J. Phys. Oceanogr. 4(1):131-134.

Goulet, J. R., Jr. and K. A. Hausknecht. 1977. Physical oceanography of Deepwater Dumpsite 106, Update-July 1975. P. 55-86. In: Baseline Rep. of Environmental Conditions in Deepwater Dumpsite 106. NOAA Dumpsite Eval. Rep. 77-1.

Griscom, C. 1968. An analysis of subsurface currents and temperature at a site on the continental shelf of the northeastern United States. Gen. Dyn. Electr. Boat Division Rep. No. U413-68-109.

Griscom, C. A. and W. T. Sommers. 1969. Tidal currents and coastal drift in the vicinity of the head of Hudson Canyon.A.I.A.A. Paper 69-411: 12 p.

Gross, M. G. 1976. Waste disposal. MESA New York Bight Atlas Monograph 26. New York State Sea Grant Institute, SUNY, Albany, NY 12210. 32 p.

Gunn, J. T. 1978. Variations in the position of the shelf water front off the Atlantic coast between Georges Bank and Cape Romain in 1976. In: Ocean Variability in the U.S. Fishery Conservation Zone, J. R. Goulet, Jr. and E. D. Haynes (eds). NOAA Tech. Rep. NMFS CIRC. 427:301-314.

Gunn, J. T. 1979. Variation in the shelf water front position from Georges Bank to Cape Romain in 1977. Annales Biol. Copenh. Vol. 34:36-39.

Gunnerson, C. G. 1981. The New York Bight ecosystem. From: Marine Environmental Pollution, 2. Dumping and Mining by R. A. Geyer (Ed.). Elsevier Sci. Publishing Co., Amsterdam, Holland.

Haidvogel, D. B. and W. R. Holland. 1978. The stability of ocean currents in eddy-resolving general circulation models. J. Phys. Oceanogr. 8:393-413.

The stability of currents generated in an oceanic eddy-resolving general circulation model EGCM (Holland, 1978) is investigated by solving the eigenvalue problem associated with the finite-difference quasi-geostrophic vorticity equations which govern the flow. In general, both barotropically and baroclinically unstable waves are shown to exist for instantaneous currents found in the EGCM. Although these simulated flows are not always quasi-steady in the sense required by the theory and are themselves modified by the presence of the finite-amplitude eddies, many characteristics of the eddy field and its interaction with the time-mean circulation can nevertheless be deduced by the linear stability analysis.

In particular, these investigations show that linear stability considerations correctly identify regions of instability in the ocean circulation model and accurately predict the low-order statistical features of the eddy field such as wavelength, period and phase speed. The effects of weakly unstable regions which are masked by global diagnostic techniques can be studied with the local stability model. The linear stability analysis also predicts, with some success, higher order statistics such as the sign and structure of intra-eddy energy fluxes that are important indicators of the dynamics of the unstable regions.

Haight, F. J. 1942. Coastal currents along the Atlantic coast of the U.S. U.S. Coast. Geod. Surv. Spec. Publ. No. 230. 73 p.

Halliwell, G. R., Jr. 1978. The space-time structure and variability of the shelf water/slope water and Gulf Stream surface thermal fronts and warm-core eddies off the northeast United States. M.S. Thesis, Univ. of Delaware, Newark, DE. 195 pp.

Halliwell, G. R. and C.N.K. Mooers. 1979. The space-time structure and variability of the shelf water-slope water and Gulf Stream surface temperature fronts and associated warm core eddies. J. Geophys. Res. 84(C12):7707-7725.

Han, G., D. V. Hansen, and A. Cantillo. 1979. Diagnostic model of water and oxygen transport. Chap. 8. In: Oxygen depletion and associated benthic mortalities in New York Bight. 1976. R. L. Swanson and C. J. Sindermann (eds). NOAA Prof. Pap. No. 11. U.S. Dept. Commerce, Rockville, Maryland. p. 165-192.

Han, G., D. V. Hansen and J. A. Galt. 1980. Steady-state diagnostic model of the New York Bight. J. Phys. Oceanog. 10(12):1998-2020.

A qualitative evaluation is made of the output from a finite-element, steady-state diagnostic model to observed time-averaged currents. The model uses a vorticity balance equation with linear bottom friction and inputs observations of near-bottom currents on the model boundary, density field and bottom topography. The output is the near-bottom (barotropic) velocity field over the entire modeled region. Velocity profiles are constructed using the thermal wind equation with the observed density field from May 1976 and a turbulent closure scheme model of Mellow and Durbin to reproduce the top and bottom Ekman layers. Transport is computed in layers above and below the pycnocline by integrating the geostrophic velocity profile and adding the Ekman layer transport.

Comparisons of the modeled bottom velocities at three moorings interior to the region and modeled vertical profiles of velocity at the interior moorings and the four boundary moorings to the observations at these points, show favorable agreement. Along-isobath flow is modeled more accurately than cross-isobath flow. Along-isobath flows, both in the shelf valley and outside the valley, are well represented, but near-bottom flows in the valley in two of the patterns are strongly ageostrophic and thus are not in agreement with model results. Errors > 100% are found for weak flow events and the accuracy of the vertical shear in the velocity deteriorates away from the time of the density observations.

The model results are useful for calculating the advective transport of dissolved and suspended constituents in the water. Though the accuracy of the point velocities have a median relative error of ~50%, the transport calculation is probably more accurate.

Han, G. C. and D. A. Mayer. 1981. Current structure on the Long Island inner shelf. J. Geophys. Res. 86:4205-4214.

Current velocity records from a deployment of 17 current meters across a ridge and swale topography with a 5 m amplitude, 6.5 km off the coast of Long Island, were analyzed to determine the interaction between the flow field and the topography which might maintain these special bottom features. No first-order interactions were found; the flow field was generally parallel everywhere. Correlation, coherence, and empirical orthogonal modal (EOM) analysis showed no significant differences between meters as a function of alongshore or cross-shore separation. EOM analysis showed that 79% of the variance was in the first barotropic mode with a strong vertical shear that was probably related to friction. Tide and wind response models can replicate about 64% of the variance in the alongshore velocity, of which about 30-40% is tidal. The residual record, uncorrelated to wind or tide, shows the effect of alongshore variations in the pressure field following a storm event by reversing the flow opposite to the diminishing wind stress. By regression of the averaged alongshore bottom velocities to wind stress, a linear bottom friction coefficient of 0.14 cm s^{-1} is found, which is in agreement with previous estimates, and a time average alongshore pressure gradient of 0.3 X 10^{-7} is found which is an order of magnitude smaller than previous estimates. By scaling the results of the wind response model, the linear bottom friction coefficient is also found to be 0.14 cm s^{-1}.

Han, G. and T. Niedrauer. 1981. Hydrographic observations and mixing processes in the New York Bight, 1975-1977. Limnol. Oceanogr. 26(6):1126-1141.

A series of 15 hydrographic cruises in the New York Bight over 1975-1977 is described and analyzed. The cruises cover all seasons but focus primarily on spring and summer. Temperature and salinity data show wide seasonal and interannual variability. Each of the three regions - inner bight, midshelf, and outer shelf slope - has distinctive properties and dynamics.

The inner bight properties are affected primarily by river flow and wind-driven flows up the shelf valley which often splits the freshwater surface layer into two plumes, one east and one west of the valley head. The "cold pool" temperature structure on the midshelf is different each year. The water with the lowest recorded temperature (2.58°C) was on the bottom after the thermocline formation in May 1977.

Mixing models of the inner bight confirmed previous estimates of residence time as 6.8 days and yielded K_x - 5 X 10^6 $cm^2 \cdot s^{-1}$ with an advective transport component of 1 $cm \cdot s^{-1}$ to the southwest. A model of the mixing of the lower layer cold pool on the midshelf with onshore, offshore, and upper layer waters yields $K_x = 7 \text{ X } 10^6$ and $K_z = 0.1$ $cm^2 \cdot s^{-1}$ as the on-offshore horizontal and vertical diffusion coefficients.

Hansen, D. V. 1970. Gulf Stream meanders between Cape Hatteras and the Grand Banks. Deep-Sea Res. 17(3):495-511.

The position of the Gulf Stream between Cape Hatteras and approximately 60°W was delineated at intervals of a few days to month using the 15°C isotherm at 200 m depth as an indicator for the thermal front associated with the stream. The dominant pattern inferred from the sequence of observations is a quasi-geostrophic wave pattern of 200-400 km wave length moving to the east with phase speeds of 5-10 cm/sec, and amplitudes generally increasing steadily to the east, except for a breakdown in summer when very large amplitude meandering between 69°W and 64°W led to extremely complicated thermal conditions in this region.

Evaluation of topographic and Coriolis effect variations along the paths indicates that for plausible current structure the mean path of the stream is consistent with the topographic control hypothesis advanced by Warren (1963). Although the meanders too must be strongly influenced by topographic variations, these variations are in general insufficient to account for the curvature of meanders in the observed paths.

Comparison of unstable wave properties inferred from the observations with results from several investigations of dynamic instability as a possible cause of the meanders shows that baroclinic instability theories yield good estimates of wave length of the fastest growing wave component, and a baroclinic theory with some topographic influences yields a good approximation to the phase speed as well. An equivalent spatial growth rate computed from the disturbance group velocity and the temporal growth predicted by all the theories is generally larger than that of the observed meanders.

Hansen, D. V. 1977. Circulation. MESA NY Bight Atlas Monograph No. 3, N.Y. Sea Grant Inst., Albany, NY. 23 p.

* This MESA monograph extracts and summarizes archived and original source current meter, sea-bed drifters and Euleran method data in an attempt to give an exact picture of circulation in the Bight. The major feature of Bight circulation is a relatively slow flow to the southwest over most of the outer continental shelf. There is evidence that this general pattern may be altered or even reversed for periods of up to 3 months during the summer over New Jersey's shallow shelf. Indications of a clockwise eddy exist in the inner Bight influenced by the Hudson/Raritan estuary, angular coastlines and the Hudson Shelf Valley topography. Mapping of the inner Bight tends to be inadequate due to temporal and spatial variability from tides and wind actions.

Harding, J., S. Larson, T. Laevastu, and K. Rabe. 1976. Ocean atmosphere interactions off the northeast coast of North America. Am. Soc. Limnol. Oceanogr., Spec. Symp. 2:35-43.

* This article summarizes data not given by the author in past literature, including objective analysis of large scale effects of sea-air interactions in the New York Bight-Middle Atlantic continental shelf, response of surface air properties to sea surface properties (micro-scale analysis of interaction within 10 m of surface); and the effects of energy feedback from the ocean to atmosphere.

Hardy, C. C., E. R. Baylor, and P. Moskowitz. 1976. Sea surface circulation in the north-west apex of the New York Bight - with appendix: Bottom drift over the continental shelf. NOAA Tech. Memo. ERL MESA-13. 132 p.

Hargis, W. J., Jr. 1981. A benchmark multi-disciplinary study of the interaction between Virginian Sea. In: Chesapeake Bay Plume Study - Superflux 1980. NASA Conference Publication 2188. J. S. Campbell and J. P. Thomas (Eds.), 516 p. Sci. and Tech. Information Branch, National Aeronautics and Space Administration, Washington, D.C.

Harrison, W., M. L. Brekmer and R. B. Stone. 1964. Nearshore tidal and nontidal currents, Virginia Beach, Virginia. U.S. Army Corps of Engineers Tech. Memo. 5, 20 p.

Harrison, Wyman. 1966. Partial correlation model for waters of the southern portion of the Middle Atlantic Bight, U.S.A. Proceedings of the 10 Conf. on Coastal Engineering, 4 p.

The model holds for waters of the Atlantic continental shelf of the United States between Cape Henlopen, Delaware, and Cape Hatteras, North Carolina. It is based upon correlations between environmental driving forces (winds and runoff) and surface and bottom drift inferred from drifter recoveries.

Harrison, W., J. J. Norcross, N. A. Pore, and E. M. Stanley. 1967. Circulation of shelf waters off the Chesapeake Bight - Surface and bottom drift of continental shelf waters between Cape Henlopen, Delaware and Cape Hatteras, North Carolina. June 1963-December 1964. ESSA Prof. Paper No. 3, 82 p.

Part I. - The coastline between Cape Cod, Mass., and Cape Hatteras, N.C., is known as the Middle Atlantic Bight. The configuration of this coastline permits distinction of two smaller bights - New York Bight in the north and Chesapeake Bight in the south. The mouth of Chesapeake Bay is found at the apex of the Chesapeake Bight. Coastal or shelf waters considered in the Study extend from the shores of the Chesapeake Bight to the 183-m isobath. These shelf waters are of interest to fisheries biologists because a number of important fish spawn in them; species whose early life stages are spent in nursery grounds of Chesapeake Bay or other coastal embayments. The present Study was designed to reveal possible modes of transport of young fishes from the offshore spawning sites to the nursery grounds.

Part I summarizes much of the earlier research on continental shelf waters off Middle Atlantic Bight. Included are descriptions of the seasonal distribution of temperature and salinity, as affected by atmospheric conditions and river discharge, and the surface and bottom circulation of shelf waters. Since 1951, knowledge of the drift of bottom water has been enhanced by use of the Woodhead seabed drifter. Recovery of seabed drifters released off the Chesapeake Bight during 1963-1964 indicated shoreward drift of bottom water which at times was oriented toward Chesapeake Bay.

Part II.-Beginning in June 1963 and lasting for 17 consecutive months, drift bottles and sea-bed drifters were released from U.S. Navy aircraft over the continental shelf off the Chesapeake Bight. Temperature and salinity variations across the shelf off Chesapeake Bay were determined in 15 monthly shipboard surveys. Results obtained did not indicate significant changes in the surface flow patterns compared to previous findings, but a complex pattern of surface circulation was noted during the summer of 1964. The effects of winds, runoff, and characteristics of the thermal structure of shelf waters are offered as explanations for variations in the surface flow.

Bottom drift of shelf waters off Chesapeake Bight, although exhibiting areal and monthly variations, tended toward the southwest, irrespective of the season and direction of the surface flow. The influence of Chesapeake Bay circulation on contingguous bottom waters of the shelf was evidenced by the recovery of seabed drifters in the Bay or near its entrance. The direction of the inferred bottom drift toward Chesakeake Bay appeared to be related to changes in river discharge and seasonal prevailing winds. The rate of bottom drift was estimated to be highest when the water column was not thermally stratified and to increase with increasing distance from shore.

Harrison et. al 1967 continued.

Part III.- Vectors of surface and bottom drift inferred from drifter recovery data are correlated with winds and runoff by means of multiple linear regression procedure. Preictands are $\bar{U}$ and $\bar{V}$ drift components for each straight line drifter trajectory. Predictors are u and v wind components for each of three lightships, averaged over the period a drifter was adrift, and 21 stream-discharge values lagged in time to provide estimates of runoff at each of three points along the coast. (The sense of the $\bar{U}$ or $\bar{u}$ components is from east to west and $\bar{V}$ or $\bar{v}$ components from north to south.)

A partial correlation model between wind or runoff and surface and bottom drift components is constructed in a series of sketches based upon the stronger correlations between $\bar{U}$ or $\bar{V}$ and the strongest predictor. The model reflects the importance of "permanent" flow on certain correlations and reveals weaknesses inherent in the two-variable correlations. The importance of developing multivariate equations for predicting surface and bottom drift is apparent after a detailed examination of the model.

Predictor equations containing four predictors are developed by subjecting 27 possible predictors to a computerized screening procedure. The resultant equations are evaluated by the R^2 criterion and by testing acceptable equations on an independent set of data that is synchronous with the dependent data. The root mean square error (RMSE) resulting from the application of a given equation to independent data is compared to the standard deviation of the observations (dependent data) from which the equation was derived. If the RMSE is less than one-fifth the standard deviation, and if the first two predictors seem physically significant, the equation is deemed acceptable for final evaluation. Some equations do not make reasonable predictions on the dependent data during periods in which drifter recovery data are sparse. These equations are considered reliable for interpolation of the drift only during those periods when most of the observations on which they are based were gathered.

Hart, J. E. 1975a. Baroclinic instability over a slope. Part I: Linear theory. J. Phys. Oceanogr. 5:625-633.

We consider the instability properties of a circular current in the upper layer of a two-layer quasi-geostrophic ocean over a unidirectional slope. This particular flow topography geometry is intended as a crude model of geophysical gyres where the variation of the Coriolis force is negligible. Such currents occur in the Arctic and in Gulf Stream rings. The slope destabilizes the flow; the critical Froude number is lowered as the slope increases. Baroclinic instabilities tend to generate time-independent or mean currents in the upper and lower layers which, because of the slope, are markedly asymmetric across the gyre.

Hart, J. E. 1975b. Baroclinic instability over a slope part II: Finite-amplitude theory. J. Phys. Oc 5: 634-641.

Baroclinic instability of a circular current is modified by the presence of a unidirectional bottom slope. An analytical theory is developed for the slightly unstable flow regime over a weak slope. The presence of the slope creates azimuthal sidebands $n \pm 1$ to the basic azimuthal wavenumber n, of the instability. The interaction of the sidebands with the slope causes a decrease in the stability of the flow compared with that in the case with a flat bottom. The interaction of the sidebands with the primary baroclinic wave produces a time-independent asymmetric current. In addition, the basic wave self-interaction produces a time-independent current which flows up the slope and generates asymmetric vorticity. This latter effect is predominant when the Rossby radius of deformation is much smaller than the radius of the basic current.

Hatcher, P. G. and P. A. McGillivary. 1979. Sewage contamination in the New York Bight. Coprostanol as an indicator. Env'l Sci. & Tech. 1225-1229.

Hayes, R. M. 1975. Oceanographic observations Nova Scotia to Cape Hatteras, North Carolina October-November 1969 and May-June 1970. Oceanographic Report No. CG 373-66. U.S. Coast Guard Oceanographic Unit, Washington, DC 13 pp.

A volumetric statistical (T-S) analysis of water masses is presented for two Coast Guard oceanographic cruises in support of the International Commission for the Northwest Atlantic Fisheries, Nova Scotia to Cape Hatteras, North Carolina from 25 October to 22 November 1969 and 19 May to 9 June 1970. The fall cruise data exhibited a 54% greater volume of Gulf Stream water in the survey area than the spring cruise, a result of a Gulf Stream meander which brought large volumes of tropical water into the slope region. Effectively the Gulf Stream meanders resulted in an exchange of water masses bringing oceanic water into the coastal zone and vice versa. Seasonal changes in the geostrophic conditions shoreward of the Gulf Stream may influence the extent of intrusion of that water mass into the continental shelf region.

Hazelworth, J. B. and S. R. Cummings. 1979. Chapter 5. Physical conditions compared with previous years. In: Oxygen Depletion and Associated Benthic Mortalities in New York Bight, 1976. Swanson, R. L. and C. J. Sindermann (Eds.). NOAA Prof. Paper 11, pp. 125-135.

* This paper compares density (sigma t), temperature, and salinity data obtained in 1976 with the same data obtained in previous years.

Heezon, B. C., C. D. Hollister and W. R. Ruddiman. 1966. Shaping of the continental rise by deep geostrophic contour currents. Science 152:502-508.

Hicks, D. C. and J. R. Miller. 1980. Meteorological forcing and bottom water movement off the northern New Jersey coast. Est. & Coast. Mar. Sci. 1980 II:563-571.

* Archive temperature, salinity and density data from NODC and standard weather observations at JFK airport and Atlantic City NJ from NCC were analyzed to determine atmospheric forcing of oceanographic conditions at a section across the New Jersey continental shelf (39 40-40N, 72 45-74W). Additional data from Monterey Beach were used to examine extent of upwelling events in the surf zone. Prolonged southerly winds created upwelling and moved "cold pool" water near shore. Prolonged north winds created downwelling conditions. Time scale of 1 day was seen in response of shelf waters to meteorological functions.

Hicks, Steacy D. 1963. Physical oceanographic studies of Narragansett Bay, 1957 and 1958. Spec. Sci. Report: Fisheries No. 457.

Hilland, J. E. and R. S. Armstrong. 1980. Variation in the shelf water front position from Georges Bank to Cape Romain in 1978. Annls biol. Copenh. 35:46-50.

Hilland, J. E. 1981. Variations in the shelf water front position in 1979 from Georges Bank to Cape Romain. Annls biol. Copenh. 36:34-36.

Holland, W. R. 1978. The role of mesoscale eddies in the general circulation of the ocean - numerical experiments using a wind-driven quasi-geostrophic model. J. Phys. Oceanogr. 8:363-392.

Results from a two-layer, quasi-geostrophic, general circulation model of the ocean with fine horizontal resolution are presented. As in Holland and Lin (1974a, b), mesoscale eddies spontaneously arise due to instabilities in the oceanic currents, giving rise to transient ocean circulations that reach a statistical equilibrium. In these final equilibrium states, the interaction of the eddy field with the mean is examined, and it is shown that the eddies determine the character of the large-scale mean flow. In particular, the eddies act to limit the amplitude of the mean flow in the upper ocean, are responsible for a downward energy propagation that fills the deep sea with eddy energy, and create a downward momentum flux which is responsible for the creation of deep, time-mean, abyssal gyres that are an important component of the vertically averaged mass transport in the ocean.

Three new aspects of the mesoscale eddy problem are discussed. First, the Holland and Lin (1975a, b) results are extended to highly nonlinear free jets, a simple but more realistic treatment of the Gulf Stream as the source for mesoscale eddy energy. Second, bottom friction is examined as the likely mechanism for energy dissipation in a quasi-geostrophic turbulent flow; lateral dissipation enters as an important enstrophy sink but not as an important energy sink. Finally, the usefulness of the quasi-geostrophic nature of the model is demonstrated; only one-tenth of the computer time needed for two-layer primitive equation experiments is required for quasi-geostrophic ones with comparable resolution.

Holland, W. R. and A. D. Hirschman. 1972. A numerical calculation of the circulation in the North Atlantic Ocean. J. Phys. Oceanogr. 2:336-354.

A series of numerical experiments are carried out to simulate the three dimensional circulation in the North Atlantic Ocean and to examine the dynamics therein. The calculations are partly diagnostic in that the density field is not predicted but is given from observations. The main predicted quantities are the velocity and pressure fields.

The results of the basic experiment are compared with observations. The surface currents are quite similar to observations based upon ship drift data, and the surface pressure field is nearly identcal to the height of the free surface constructed from a level of no-motion hypothesis. The deep pressure variations are nowhere flat or level, however, and the predicted deep currents are quite complex. They are, in fact, strongly controlled by botrom topography and tend to follow f/II contours, where f is the Coriolis parameter and II the depth. The Gulf Stream transport is quite large, reaching a maximum value of 81 X 10^6m^{3}sec^{-1} despite the lack of important inertial effects in the western boundary current. Subsidiary experiments show that this large transport value results from an important interaction between the variable density field and bottom topography in the western North Atlantic. When in one experiment the density field was a homogeneous one and in another the depth was constant, the maximum transports in the western boundary current were only 14 and 28 X 10^6m^{3}sec^{-1} respectively.

Other experiments show that the details of the wind-stress distribution are unimportant when the density field is known; the density field contains most of the information about the long term wind driving. For example, when the wind stress is set equal to zero everywhere (but the density field is maintained in its observed configuration), the Gulf Stream transport is reduced by only 5%. Thus, the pressure torques associated with bottom topography provide the main vorticity input. Finally, it is shown that the results discussed in the basic experiment are not very sensitive to the details of the density field used in the calculation. When these data are highly smoothed and used in a subsidiary calculation, the important features, such as the enhanced transport in the Gulf Stream and the topographic steering of currents in the deep ocean, are unchanged.

Holland, W. R. and L. B. Lin. 1975a. On the generation of mesoscale eddies and their contribution to the oceanic general circulation. I. A preliminary numerical experiment. J. Phys. Oceanogr. 5:642-657.

Numerical experiments on the wind-driven ocean circulation in a closed basin show that mesoscale eddies can appear spontaneously during the integration of the equations of motion for a baroclinic ocean. For some values of the basic parameters governing the flow, the solutions reach a steady state while for other values finite-amplitude eddies remain a part of the final statistically steady state. In the eddying cases the solutions can be regarded as a mean flow upon which is superimposed a set of eddies which propagate westward at a few kilometers per day. The eddies typically have horizontal wavelengths of a few hundred kilometers.

Analyses of the energetics show the eddies to be generated by the process of baroclinic instability. The potential energy of the mean flow is released to supply energy to the eddies. The computed Reynolds stresses, while small compared to the terms in the geostrophic balance of the mean momentum equations, do have a strong influence on the mean circulation and, in fact, the deep mean circulation is driven entirely by the eddies. If the flow were steady, there would be no flow in the deep layer in this model. Finally, the computed curl of the Reynolds stresses shows that the vorticity balance of the mean flow is strongly affected by the presence of mesoscale eddies.

In the first part of this report we describe the two-layer model and discuss its numerical formulation. Then the results of a preliminary eddy experiment are discussed in detail, showing the spontaneous growth of baroclinic eddies and describing the final statistical steady state that occurs. Energetic analyses and vorticity balances show the important role played by the eddies in determining the character of the oceanic general circulation.

Part II of this paper will discuss a variety of experiments which explore the dependence of results on the basic parameters and boundary conditions governing the model. In particular the dependence of results on wind stress magnitude and distribution, lateral viscosity coefficient, basin size, and boundary conditions (free slip and no slip) will be examined.

Holland, W. R. and L. B. Lin. 1975b. On the generation of mesoscale eddies and their contribution to the oceanic general circulation. II: A parameter study. J. Phys. Oceanogr. 5:658-669.

In this investigation the wind-driven ocean circulation theories are extended to include mesoscale eddies as an integral part of the general circulation of the ocean. A two-layer numerical model of ocean circulation in a simple, rectangular basin driven by a steady wind stress is used for this purpose. The equations of motion are integrated as an initial value problem until the solutions reach either a steady state or, in the case of an ocean in which eddies have appeared spontaneously as a result of baroclinic instability, a statistically steady state.

Part I of this study discussed the formulation of the numerical model and presented results from a preliminary numerical experiment. Energetic analyses showed that eddies result from baroclinic instability during the spin-up of the ocean from rest and that, in the final statistically steady state, the eddy momentum and buoyancy fluxes played an important role in establishing the mean circulation. In the particular case examined there, the region of eddy generation was in the westward return flow and not in the strong boundary jets.

In this part of the study, results from ten additional experiments are examined to understand, in a limited way, how eddy generation and the resulting eddy statistics depend upon the basic parameters describing the model ocean. In particular, the dependence of results on the coefficient of lateral viscosity, the wind stress amplitude, the wind stress distribution (one and two gyres), the basin size, and the boundary conditions (slip and no-slip) are discussed. Results show a wide range of model behavior under the conditions examined but the common result is that the mean circulation of eddying oceans is importantly altered, one might even say largely determined, by the statistical nature of the eddy field.

Hollman, R. 1970. The physical oceanography of the New York Bight. Proc. Water Pollut. Greater New York Area Symp. p. 2-12.

Hollman, R. 1973. Some features of the circulation in the New York Bight. EOS Trans. Amer. Geophys. Union 54(4):302.

Hopkins, T. S. 1982. On the sea-level forcing of the Mid-Atlantic Bight. J. Geophys. Res. 83(C3):1997-2006.

The Mid-Atlantic Bight circulation is discussed with particular comment directed toward the role of the parabathic pressure gradient. A distinction is made between external and local sea level forcing. External forcing consists of an oceanic boundary condition on the sea level gradient. The shelf response to this is geostrophic: the diabathic component drives the parabathic flow, and the parabathic component drives diabathic flow. The latter, together with the bottom stress generated by the former and the physical dimensions of the shelf, determine the degree of convergence or divergence within the shelf volume, which, in turn, determines the sea level dependence required to satisfy continuity over the shelf. Local forcing due to the wind stress, the internal field of mass, and the total bottom stress, in conjunction with local bathymetry, determines the extent of local convergence or divergence, and as a consequence, generates additional sea level distortion. Conceptually, local and external forcing can be considered as independent although they are, in fact, coupled through bottom stress and internal field of mass adjustment.

Hopkins, T. and N. Garfield. 1977. Physical oceanography. Chapter 4. In: Summary of Environmental Information - Continental Shelf-Bay of Fundy to Cape Hatteras (1977). U.S. Dept. of Interior, Bur. of Land Management.

Hopkins, T. S. and N.Garfield. 1979. Gulf of Maine Intermediate Water. J. Mar. Res. 37(1):103-139.

The thermohaline dynamics of the Gulf of Maine are analyzed from the two year, eight cruise, data set of Colton, Marak, Nickerson, and Stoddard (1968). Six water masses are described: the Maine Surface Water, Maine Intermediate Water, and the Maine Bottom Water as interior water masses; and the Scotian Shelf Water, the Slope Water, and the Georges Bank Water as exterior water masses. Particular attention is given to the formation and disposition of the Maine Intermediate Water. Salt balance, T-S volume, and T-S drift analyses are used to provide transport and mixing estimates for the year 1966. The Slope Water entered at depth through the Northeast Channel at a rate of 2600 km^3/yr; while the Scotian Shelf Water entered the surface and intermediate layers, mostly during winter intrusions, at a rate of 5200 km^3/yr. The surface and intermediate layers exported a total of 7900 km^3/yr in a 3:5 ratio, respectively. The Maine Intermediate Water tends to collect over the Wilkinson Basin during the stratified season, to exit via the Great South Channel during early spring, and to exit via the Northeast Channel during spring and summer. Comparisons are made between the estimated winter heat loss of 280 Ly/d and the observed heat losses of 230 Ly/d (surface layer) and 360 Ly/d (surface and intermediate layers). A limit for the Scotian Shelf Water contribution is about -70 Ly/d. It is concluded that the Maine Intermediate Water is produced locally and that it is exported in significant quantities.

Hopkins, T. S. and N. Garfield, III. 1981. Physical origins of Georges Bank Water. J. Mar. Res. 39(3):465-500.

The seasonal behavior of the Georges Bank Water mass is described from the context of the historic National Oceanographic Data Center file (1910-1978). The Georges Bank Water is defined as the water type most commonly found in the top 40 m of water within the 65 m isobath. Plots of its distribution show it unique within the Georges Bank/Gulf of Maine region. The uniqueness is more a result of isolation and low volume replenishment than of vertical mixing of advective inputs from adjacent stratified waters. Large scale renewal by isopycnal intrusions of Wilkinson Basin Water is only observed during late fall-early winter. These conclusions are based on an analysis of horizontal salinity gradients, on salt budget calculations, and by comparisons with T-S cycling in adjacent water masses. Horizontal salinity gradients are typically <0.2 ^{o}/oo per 100 km across the Bank and <0.1 o/oo per 100 km along the Bank, and do not reflect a mean input of fresher Scotian Shelf Water nor of saltier upper Slope Water. Evaporative heat flux is a minimum in late spring ∿50 Ly/day and a maximum in early fall ∿400 Ly/day. The Georges Bank Water has a salinity maximum of ∿32.9 ^{o}/oo in early March and a minimum of ∿32.1 ^{o}/oo in early August, making the freshening cycle shorter (5 months) than the salting cycle. The historic mean salinity is 32.5 ^{o}/oo. Some aspects of the circulation are analyzed. An explanation for the observed jet flow along the northern flank is given from a geostrophic balance with tidal pressure force. The jet is centered over the 50 m isobath with amplitudes ∿20 cm/sec. Local convergences and divergences are created by veering of the surface Ekman transports about the perimeter of the Bank (<60 m). Steady sea level response to these transport discrepancies appears to be more effectively maintained on an integrated Bank-wide scale rather than locally. A sea-level high pressure over the Bank appears to be maintained under prevailing southwesterly winds. Its existence requires local satisfaction of continuity in the perimeter barotropic and tidally rectified flows and necessitates a lack of closure in the anticyclone circulation about the high pressure. The completeness of the anticyclonic gyre is inhibited further by the lack of deep baroclinic ajustment.

Hotchkiss, F. S. and C. Wunsch. 1982. Internal waves in Hudson Canyon with geological implications. Deep-Sea Res. 29 (4A):415-442.

Data from an array of instruments in Hudson Submarine Canyon for 15 weeks are qualitatively consistent with theoretical and laboratory results concerning the concentration of internal wave energy by canyon topographies. Internal wave energy was intensified at the head and near the floor of the canyon, with phase lags suggestive of propagation of internal waves up the canyon from the deep sea. Significant diurnal and semidiurnal internal tides were present, indicating their generation at the topographic relief around the canyon. Internal wave energy is apparently dissipated by mixing at the head of the canyon. A major storm during the experiment induced strong currents in the canyon. These currents are probably more important than internal waves as carriers of sediment except in the very head of the canyon.

Howe, M. R. 1962. Some direct measurements of the nontidal flow on the continental shelf between Cape Cod and Cape Hatteras. Deep Sea Res. 9:445-455.

* Author reports measurements of drift current velocity and hydrographic properties on 2 cruises in July - August, and November 1961, covering 5 cross-shelf sections between Cape Hatteras and Nantucket Shoals. The hydrographic data are of interest but the drift measurements were made over 2 or 3 lunar days only, thus representing only spot measures of the highly variable wind-driven energy regime.

Hsueh, Y. 1980. On the theory of deep flow in the Hudson Shelf Valley. J. Geophys. Res. 85(C9):4913-4918.

The time averaged near-bottom current in the New York Bight for a selected 3-day period is idealized as a steady state response to the mean wind at the John F. Kennedy International Airport and the mean inflow condition across the Long Island shelf. The idealization invoked potential vorticity conservation in a homogeneous ocean subject to a linear bottom friction and results in shelf currents whose longshore components are in general agreement with the averages of the observed. In Hudson Shelf Valley, qualitative agreement with the observation is achieved in the the onshore component which is directed nearly along the valley axis. Nearshore, within 40 km or so of the coast, the response is, to a substantial degree, wind driven. Nearshore upvalley mean flow is due partly to shore-parallel wind stresses that are directed away from the valley and is due partly to topographic deflection of an alongshore current that is driven in part by the inflow condition and in part by the alongshore component of the mean wind stress. Because of the important role of bottom friction, an alongshore current driven by longshore winds undergoes sharper (and more realistic) deflection across the valley than does an alongshore current driven by the inflow condition.

Hughes, M. M. and S. K. Cook. 1981. Water column thermal structure across the shelf and slope southeast of Sandy Hook, New Jersey, in 1979. Annls. biol. Copenh. Vol. 36:15-25.

Hunter, J. R., W. C. Boicourt and P. W. Hacker. 1977. An analysis of the winter meteorological response at sub-tidal frequencies of the Atlantic continental shelf. Ches. Bay Inst. Spec. Rep. 57, 21 pp.

Hydroscience. 1978a. Ocean monitoring survey at "106" Site of Edgemoore barged wastewater, May 22, 1978. Submitted to E. I. duPont deNemours and Co., September 14, 1978.

Hydroscience. 1978b. Ocean monitoring survey at "106" Site of Edgemoore barged wastewater July 22, 1978. Submitted to E. I. duPont deNemours and Co.

Hydroscience. 1978c. Ocean monitoring survey at "106" Site of Grasselli barged wastewater May 19, 1978. Submitted to E. I. duPont deNemours and Co.

Hydroscience. 1978d. Ocean monitoring survey at "106" Site of Grasselli barged wastewater July 24, 1978. Submitted to E. I. duPont deNemours and Co.

Hydroscience. 1978e. Report on ocean monitoring cruise at the 106 Mile Deepwater Dumpsite. Submitted to American Cyanimid Co., August 29, 1978.

Hydroscience. 1978f. Report on ocean monitoring cruise at the 106 Mile Deepwater Dumpsite. Submitted to American Cyanimid Co., October 24, 1978.

Hydroscience. 1979a. Ocean monitoring survey at "106" Site of Edgemoore barged wastewater. Submitted to E. I. duPont deNemours and Co.

Hydroscience. 1979b. Ocean monitoring survey at "106" Site of Grasselli barged wastewater, October 25, 1978. Submitted to E. I. duPont deNemours and Co.

Hydroscience. 1979c. Report on ocean monitoring cruise at the 106 Mile Deepwater Dumpsite. Submitted to American Cyanimid Co., February 2, 1979.

Ianniello, J. P. 1981. Tidally-induced residual currents in Long Island and Block Island sounds. Est. Coast. and Shelf Sci. 12:177-191.

The tidally-induced residual currents in the Long Island Sound-Block Island Sound (LIS-BIS) tidal channel are investigated using a previously-developed analytic model. Known first order tidal properties of LIS-BIS are matched using three different models, chosen to isolate the effects of the factors potentially controlling the second order currents, either breadth, depth or eddy viscosity variations. The residual currents driven by these first order models agree to within roughly a factor of two, indicating that the model is not overly sensitive to these parameters. Tidally-induced currents on the order of observed currents in eastern LIS and BIS are predicted. The outstanding structural feature of the predicted residual currents is a region of strong surface flow divergence and bottom flow convergence centered at a sharp constriction in the channel. Eulerian and Lagrangian observations in eastern LIS and BIS are reviewed; indirect support for the theoretical results is found.

Ichiye, T., M. Inove and M. Carnes. 1981. Horizontal diffusion in ocean dumping experiments. p. 131-159. In: Ocean Dumping of Industrial Wastes. B. H. Ketchum, D. R. Kester and P. K. Park (Eds.). Plenum Press, New York and London.

During two experiments monitoring ocean dumping operations in the Gulf of Mexico and off Arecibo, Puerto Rico, a number of drifters were tracked with a ship-borne radar and aerial photographs of the plumes were analyzed by use of the results of drifter experiments in the Gulf of Mexico. Horizontal eddy diffusivity was determined from increases of the variances of the drifter positions with time and were calculated with Okubo's method (1976). The variances of drifter positions did not increase with time when the wind speed exceeded critical values off Puerto Rico. It was speculated that the wind rows caused the drifter convergence during the Puerto Rico experiments. The speculation is partially confirmed by analyzing the aerial photos of the plumes which show striations along the direction of the prevailing winds.

Ikeda, M. 1981a. Meanders and detached eddies of a strong eastward-flowing jet using a two-layer quasi-geostrophic model. J. Phys. Oceanogr. 11(4):526-540.

The process of meander growth on and eddy detachment from an eastward flowing oceanic jet, which is modeled after the Gulf Stream east of Cape Hatteras, is studied using numerical solutions of nonlinear equations. The equations express potential vorticity conservation in a two-layer quasi-geostrophic model with a weak planetary β effect. Solutions are restricted to a spatially periodic, temporally growing case. Initially, small-amplitude meanders are given, being superimposed on the jet. The solutions describe a process in which the meanders grow increasingly larger, the larger meanders are cut off, and cyclonic and anticyclonic eddies are detached southward and northward, respectively. Concurrent with the eddy detachment, an eastward flow is restored in the upper layer, and the lower layer develops an eastward flow under the restored jet and two westward flows north and south of it. A baroclinic instability is very effective in meander growth, while a weak β effect is necessary for eddy detachment; i.e., the meander grows large enough for the detachment by taking potential energy from the basic flow, and the β effect then cuts off the large amplitude meanders.

This two-layer weak planetary β case is contrasted with a one-layer case when meander amplitude is much smaller, as well as a two-layer zero β case when no eddy is detached in spite of large amplitude meanders. A topographic β effect is examined, when southward increase of depth is introduced instead of latitudinal gradient of the Coriolis parameter. In a weak topographic β case, flow patterns are very similar to those of a weak planetary β case. In a strong topographic β case, no eddy is detached. The results are compared with Gulf Stream meanders and detached eddies.

Ikeda, M. 1981b. Instability and splitting of mesoscale rings using a two-layer quasi geostrophic model of an F-plane. J. Phys. Oceanogr. 11(7):987-998.

Asymmetric instability of a circular Gaussian ring and evolution of a ring shape in a nonlinear case are studied using a two-layer quasi-geostrophic model on an f plane. Ring behavior is classified on an F-λ plane with other parameters fixed, where F is an internal rotational Froude number associated with a two-layer model, and λ is a ratio of the rotation speed in the lower layer to that in the upper layer. In the range concerned where $F < 4$ and $\lambda >$ o, the mode having an azimuthal wavenumber of 2 is the fastest growing, followed by the mode of the wavenumber 3. The ring is more unstable as F increases and as λ decreases, where larger F corresponds to smaller density difference or to a larger ring size. By numerical calculations, for which an initial perturbation of the wavenumber 2 is superimposed on a ring, ring behavior is classified into four groups from the most unstable to the most stable case: (i) a ring that splits into two small rings, (ii) a ring that rapidly becomes a slender ellipse and returns to a circle, (iii) a ring that slowly becomes an ellipse and returns to a circle, and (iv) a ring that approaches a circle from the beginning. For the groups (ii) and (iii), the ring is stabilized by nonlinear effects after the ring becomes a slender ellipse, although the ring is unstable during an infinitesimal perturbation.

Two connected rings are studied using numerical calculations. A weaker companion ring is absorbed into a stronger major ring when the distance between the two rings is identical to the radius of the ring. In contrast when the distance is doubled, the companion separates from the major ring. The theory is applied to Gulf Stream rings.

Ingham, M. C. 1976. Variations in the shelf water front off the Atlantic coast between Cape Hatteras and Georges Bank. In: J.R. Goulet, Jr. (compiler). NOAA/NMFS MARMAP contrib. 104. p. 17-1--17-21.

Ingham, M. C., J. J. Bisagni and D. Mizenko. 1977. The general physical oceanography of Deepwater Dumpsite 106. In: Baseline Rep. of Environmental Conditions in Deepwater Dumpsite 106. NOAA Dumpsite Eval. Rep. 77-1, U.S. Dept. of Comm. pp 29-54.

Interstate Electronics Corp. 1978. A summary of data pertaining to two ocean disposal sites in the Middle Atlantic Bight with recommendations for further studies. Unpublished report prepared for U. S. Env. Prot. Agency, Washington, D.C. 20460

Iselin, C. O'D. 1936. A study of the circulation of the western North Atlantic. Papers in Phys. Oceanogr. and Meteor. 4:1-101.

Iselin, C. O'D. 1939. Some Physical factors which may influence productivity of New England's coastal waters. J. Mar. Res. 2(1):74-85.

* Discussion of physical factors such as salinity, temperature, large scale mixing mechanisms, and eddies which affect the productivity of New England's coastal waters.

Iselin, C. O'D. 1955. Coastal currents and the fisheries. Deep Sea Res. 3 (Suppl.):346-357.

Johnson, D. R. 1973. The seasonal density structure and circulation on the continental shelf. EOS Trans. Amer. Geophys. Union 54(4):316-317.

Johnson, R. E. 1976. Circulation Study near Cape Henry, Virginia, using lagrangian techniques. Tech. Rep. 21, Inst. Oceanogr., Old Dominion Univ., Norfolk, Virginia.

Johnson, Ronald E. 1981. Lagrangian circulation study near Cape Henry, Virginia. In: Chesapeake Bay Plume Study - Superflux 1980. p. 175-197. NASA Conference Publication 2188. J. W. Campbell and J. P. Thomas (Eds) 516 p. Scientific & Technical Information Branch, National Aeronautics and Space Administration, Wash., DC.

Summary

A study of the circulation near Cape Henry, Virginia, has been made using surface and seabed drifters and radar-tracked surface buoys coupled to subsurface drag plates. Drifter releases were conducted on a line normal to the beach just south of Cape Henry. Surface drifter recoveries were few; wind effects were strongly noted. Seabed drifter recoveries all exhibited onshore motion into Chesapeake Bay. Strong winds also affected seabed recoveries, tending to move them farther before recovery. Buoy trajectories in the vicinity of Cape Henry appeared to be of an irrotational nature, showing a clockwise rotary tide motion. Nearest the cape, the buoy motion elongated to almost parallel depth contours around the cape. Buoy motion under the action of strong winds showed that currents to at least the depth of the drag plates substantially are altered from those of low wind conditions near the Bay mouth. Only partial evidence could be found to support the presence of a clockwise nontidal eddy at Virginia Beach, south of Cape Henry.

Joseph, E. B., W. H. Massman and J. J. Norcross. 1960. Investigations of inner continental shelf waters off lower Chesapeake Bay. Part I. General introduction and hydrography. Chesapeake Sci. 1:153-167.

Kangas, R. E. and G. L. Hufford. 1974. An upwelling rate for Massachusetts Bay. Jour. Geoph. Res. 79(15): 2231-2236.

Contours of time series bathythermograph data taken at the Boston light vessel station over several years (1964-1971) indicate that upwelling occurs in Massachusetts Bay during most summers. Cold more saline water is noted near the nottom progressing upward through the water column. Upwelling rates for 1971 of 2.0×10^{-4} cm s^{-1} and 5×10^{-4} cm s^{-1} were computed from the upward migration of isotherms and by the equations of Yoshida (1955), respectively. The upwelling period (summer) coincides with the time of predominate southeasterly to westerly winds. A definite decrease in sea level height observed during the summer of 1971 may have been due to the offshore wind-driven transport of surface water.

Kao, A. F. 1975. A study of the current structure in the Sandy Hook-Rockaway Point transect. Mar. Sci. Res. Center Tech. Report. Mar. Sci. Res. Center, SUNY, Stony Brook, L. I., NY.

Kao, T. W. 1980. The dynamics of ocean fronts. The Gulf Stream. J. Phys. Oceanogr. 10:483-492.

The establishment and maintenance of the mean hydrographic properties of large-scale density fronts in the upper ocean is considered. The dynamics is studied by posing an initial value problem starting with a near-surface discharge of buoyant water with a prescribed density deficit into an ambient stationary fluid of uniform density. The full time-dependent diffusion and Navier-Stokes equations with constant eddy diffusion and visosity coefficients and for a constant Coriolis parameter are used in this study. Scaling analysis reveals three independent length scales of the problem, vis., a radius of deformation of inertial length scale L_0, a buoyancy length scale h_0 and a diffusive length scale h_v. Two basic dimensionless parameters are formed from these length scales: the thermal (or more precisely, the densimetric) Rossby number, $\widetilde{Ro} = L_0/h_0$ and the Ekman number $E = (h_v/h_0)^2$. The governing equations are then suitably scaled and the resulting normalized equations are shown to depend on E alone for problems of oceanic interest. Under this scaling, the solutions are similar for all $\widetilde{Ro}$ sufficiently large. It is also shown that $1/\widetilde{Ro}$ is a measure of the frontal slope, so that $\widetilde{Ro}$ is large for all oceanicdensity fronts. The governing equations, in the form used in a previous paper by Kao et al. (1978), are solved numerically and the scaling analysis is confirmed. The solution indicates that an equilibrium state is established. The front can then be rendered stationary by a barotropic current from a larger scale alongfront pressure gradient. In that quasi-steady state and for small values of E, the main thermocline and the inclined isopycnics forming the front have evolved together with an intense alongfront jet and a crossfront (or cross-stream) circulation with surface discharge toward the front and return flow at greater depth. Conservation of potential vorticity is also obtained in the light water pool.

Kao, T. W. 1980. continued

The surface jet exhibits anticyclonic shear in the light water pool and cyclonic shear across the front. It is also shown that horizontal diffusive effects are unimportant. Comparisons with known hydrographic features of the Gulf Stream are made, showing good agreement, especially on the major features. It is thus seen the mean Gulf Stream dynamics can indeed by interpreted in terms of a solution of the Navier-Stokes and diffusion equations, with the cross-stream circulation responsible for maintenance of the front. This mechanism is thus suggested in this paper as a mechanism for the maintenance of the Gulf Stream Dynamics.

For large values of E, it will be shown that another type of scaling is required. That result will be shown in a subsequent paper as Part II of this series, and is relevant to the study of density and current structure on the East Coast continental shelf of North America from Newfoundland to Chesapeake Bay, a region subject to forcing by freshwater river discharges.

Kao, T. W. 1981. The dynamics of oceanic fronts. Part II: Shelf water structure due to fresh water discharge. J. Phys. Oceanogr. 11(a): 1215-1223.

In Part I of this series, a framework was introduced for the study of oceanic frontal dynamics. The dynamics was studied by posing an initial value problem, starting with a near-surface discharge of buoyant water with a prescribed density deficit into an ambient stationary fluid of uniform density. An essential aspect of the framework was the identification of the proper length scales: an inertial length scale L_o, q buoyancy length scale h_o and a diffusive length scale h_y. In Part I, the horizontal and vertical dimensions were scaled by L_o and h_o, respectively; and two dimensionless parameters were formed, viz., $\overline{\mathrm{Ro}} = L_o/h_o$ and $E = (h_v/h_o)^2$. It was shown in Part I that under this scaling the normalized equations depended on E only for $\overline{\mathrm{Ro}}$ sufficiently large. The solution for E small, i.e., for the almost inviscid case, was given in Part I; and the equilibrium state was discussed in a frame of reference in which the front was stationary.

In this paper, we present the solution for large E. It will be shown that a universal similarity (in the sense of a fully scaled set of governing equations without any parameter) is obtained, when the horizontal and vertical dimensions are now scaled by L_o and h_v, respectively, for a given dimensionless depth d;d constitutes the only parameter of the problem and enters it through the location of the bottom. The solution for $d \approx 10$ is relevant to the study of the establishment of current and density structure of the shelf water subject to forcing by freshwater discharge along the coast, such as the mid-shelf region of the east coast continental shelf of North America. It is shown that when equilibrium is reached, a frontal region can be identified, which propagates steadily but slowly across the shelf. Behind the frontal region the horizontal flow field is steady. The nature of the force balance in the cross-shelf and along-shelf directions is clarified.

This paper is totally self-contained and can be read without reference to Part I.

Kao, T. W. and R. E. Cheney. 1982. The Gulf Stream front: A comparison between SEASAT altimeter observations and theory. J. Geophy. Res. 87(C1):539-454.

In a recent paper by Cheney and Marsh (1981), SEASAT altimeter data were used to derive quantitative information on sea surface height anomalies across the Gulf Stream. In another recent paper by Kao (1980), the dynamics of the Gulf Stream front was investigated, and a similarity solution was obtained. The model gives a universal shape of the sea surface height rise and the width of that anomaly across the Gulf Stream. In this paper we present a quantitative comparison between the model and six Gulf Stream altimeter profiles representing a broad range of conditions. The remarkable closeness of fit is mutually reinforcing to both the model and to the role of satellite altimetry in ocean dynamics. Comparisons of the data with the well-known theories of Stommel (1966) and Charney (1955) are also made, and implications of these comparisons are explored.

Keller, G. H., D. Lambert, G. Rowe, and N. Staresinic. 1973. Bottom currents in the Hudson Canyon. Science 180:181-183. April 1973.

In-place measurements of the bottom currents in the Hudson Canyon reveal that the current regime is characterized by a pronounced reversal of flow up and down the canyon. Velocities are commonly of the order of 8 to 15 centimeters per second, reaching 27 centimeters per second on occasion in the upper and central portion of the canyon. Although a 2.5 day recording of currents showed a net transport upcanyon, a combination of 66 current measurements from the submersible Alvin, the analysis of sediment texture and organic carbon, and the determination of the benthic fauna-nutrient relationship indicate that over the long term there is a net transport of fine material through the canyon to the outer continental rise.

Kendall, B. M. 1981. Remote sensing of the Chesapeake Bay Plume salinity via microwave radiometry. Chesapeake Bay plume study: Superflux 1980. Campbell, J. W. and J. P. Thomas (Eds.). NASA Conf. Publ. 2188, NOAA/ NEMP III 81 ABCDFG0042, NTIS, Springfield, Virginia. 522 pp.

Ketchum, B. H. 1976. The old and the new: New York Bight research in perspective. In: Middle Atlantic Continental Shelf and the New York Bight. (M. Grant Gross, ed.). ASLO Special Symposia Vol. 2.

Ketchum, Bostwick H. and Nathaniel Corwin. 1964. The persistence of "winter" water on the continental shelf south of Long Island, New York, Linmol. Oceanogr. 9(4): 467-475.

The deep water on the continental shelf south of Montauk Point, Long Island, remains cold throughout the summer. Since this cold-water pool is surrounded by warmer water, it appears to be formed in the winter and to persist, with only gradual modification, for several months.

The temperature and salinity of the water in this area have been observed on 20 cruises made during a 3-year period. The cycle of temperature is described. The salinity changes in the deep water as it gradually warms are used to evaluate qualitatively whether the temperature change in each year was associated with admixture of high-salinity warmer off-shore waters or lower-salinity, warmer surface waters.

The average salinity of the water on the continental shelf was closely correlated with the 6-month average river flow of the Connecticut River, and it is shown that the salinity can be predicted to within error of estimate of approximagely 0.3% from this river flow.

Ketchum, B. H. and W. L. Ford. 1952. Rate of dispersion in the wake of a barge at sea. Trans. Am. Geophys. Union. 33(5):680-684.

Ketchum, B. H. and D. J. Keen. 1955. The accumulation of river water over the continental shelf between Cape Cod and Chesapeake Bay. Deep-Sea Res. Suppl. to 3:346-357.

Summary - The depth mean salinities for the waters of the continental shelf between Cape Cod and Chesapeake Bay show a seasonal variation in the concentration of river water. The spring and the winter accumulations are about the same, but about 25% more river water is present in the summer. The total volume of fresh water in spring and winter is equivalent to that produced by the rivers in about one and a half years. The extra accumulation in summer is equal to half a year's flow, and reflects, in part, the fact that the high spring flows of two successive years are present on the shelf at this time.

There is a decrease in the average content of river water in the direction of the flow of the coastal current, in spite of the addition of river water along its course. It is concluded that considerable transport of river water and of salt normal to the coast is necessary. The horizontal mixing coefficients normal to the coast are computed from the seasonal changes in salinity. They range from 0.58 to 4.96 x 10^6 cm^2/sec, with the values for the decrease in salinity from spring to summer being smaller than those for the increase from summer to winter conditions. At both times, the values decrease with increasing depth and distance from shore.

Ketchum, B. H., A. C. Redfield and J. C. Ayers. 1951. The oceanography of the New York Bight. Papers in Physical Oceanography and Meteorology. 12(1) 1046. Massachusetts Institute of Technology and Woods Hole Oceanographic Institution.

Six cruises were made at different seasons to survey the hydrographic conditions in the inner part of the New York Bight, where the effluent from the Hudson and other rivers enters the sea. The distributions of salinity, temperature, oxygen and iron are described.

Sea water diluted with river water varies greatly in distribution from the more common pattern with the diluted water confined to a narrow band along the New Jersey shore, to a pattern with the diluted sea water widely distributed over the surface.

On four of the six cruises, when the river flow was fairly great, the distribution patterns were well defined. Dynamic calculations indicated that the current velocities required to maintain these distributions in steady state were possible. Both widespread and confined patterns of distribution were included.

Ketchum, B. H., R. F. Vaccaro, and N. Corwin. 1958. The annual cycle of phosphorus and nitrogen in New England coastal waters. J. Mar. Res. 17:282-301.

Klemas, V. G., R. Davis and R. D. Henry. 1977. Satellite and current drogue studies of ocean-disposed waste drift. J. Water Poll. Control Fed. May 1977. 757-763.

Klemas, V. and W. D. Philpot. 1981. Remote sensing of ocean-dumped waste drift and dispersion. P. 193-211 In: Ocean Dumping of Industrial Wastes. Eds. B. H. Ketchum, D. R. Kester and P. K. Park. Plenum Press, New York and London.

The drift and dispersion of sixteen acid waste plumes 64 km off the Delaware coast were investigated using Landsat imagery, current drogues and ship data. The waste plumes imaged by Landsat were found to be drifting at average rates from 0.59 km hr^{-1} to 3.39 km hr^{-1} into the southwest quadrant. The plumes seemed to remain above the thermocline which was observed to form from June through August at depths ranging from 13 m to 24 m. During the remainder of the year the ocean at the test site was not stratified, permitting wastes to mix throughout the water column.

The magnitudes of plume drift velocities were compatible with the drift velocities of current drogues released over a 12 month period at the surface, at mid-depth and near the bottom. However, during the stratified warm months, more drogues tended to move in the north-northeast direction, while during the non-stratified winter months a southwest direction was preferred.

Rapid waste movement toward shore occurs primarily during storms, particularly northeasters. Duirng such storms however, the plumes are rapidly dispersed and diluted. The plume width was observed to increase at a rate of about 1.5 cm sec^{-1} during calm sea conditions, yet attain spread rates in excess of 4 cm sec^{-1} on windy days. These results indicate that by the time a waste plume would reach shore, dilution would be at least one million to one.

Koh, Robert C. Y. and Y. C. Chang. 1973. Mathematical model for barged ocean disposal of wastes. Environmental Protection Technology Series EPA - 660/2-73029. December 1973. 584 pp.

Kohn, D. and G. T. Rowe (1977). Dispersion of two liquid industrial wastes dumped at Deepwater Dumpsite 106, off the coast of New Jersey, USA. Final Report, DWD 106 Large Scale Dumping Study, NOAA, Rockville, MD.

Kuo, A. Y., E. P. Ruzecki, and C. S. Fang. 1976. The effects of the Agnes flood on the salinity structure of the lower Chesapeake Bay and contiguous waters. In: The effects of tropical Storm Agnes on the Chesapeake Bay estuarine system. Chesapeake Research Consortium, Ind. Publ. 54. The Johns Hopkins University Press, Baltimore, Maryland.

Kupferman, Stuart L., and N. Garfield. 1977. Transport of low-salinity water at the slope water-Gulf Stream boundary. J. Geophys. Res. 82(24):3481-3486.

* The author provides descriptive analysis of temperature and salinity data from two cruises of the RV EASTWARD (E-198-72, 30 October-05 November, 1972; E-GA-74, 23-30 May 1974) between Delaware Bay, Delaware and Cape Hatteras, North Carolina across the shelf and into the Gulf Stream. Two unconnected bands of shelf water were found entrained in the Gulf Stream, one at the surface and one about the 100 m depth. Transport volume of shelf water by the entrained band process is estimated at 16,000 cubic meters/s.

Laevastu, T. and R. Callaway. 1974. Computation of tides, currents, and dispersal of pollutants in the New York Bight from Block Island to Atlantic City with large grid size, single and two-layer hydrodynamical-numerical models. ENV PRED RSCH FAC Tech. Note No. 4-74. Environmental Prediction Research Facility, Naval Postgraduate School, Monterey, CA 93940.

This report describes the results of the application of Hydrodynamical-Numerical (HN) models to New York Bight. The results of computer runs with a large, two-open boundary, single-layer model, as well as with a two-layer model for the same area, are presented. Many of the problems in the application of these models are connected with the treatment of the open boundaries. The Environmental Prediction Research Facility (EPRF) has found a few satisfactory methods for the treatment of these boundaries, some of which are briefly mentioned in this report. The method is further described in Part 2 of the report series where the two-layer model is documentsd (see references).

Vertification of the New York Bight models is very brief, due to scarcity of proper observations. However, the models have been verified in other applications, to the extent that they are considered to be ready for operational and real-time use. It could be mentioned that a 3-layer version of the models have now been applied at EPRF to larger open ocean areas with considerable success. The experiences from these applications have been indirectly used in this work and are available to EPA.

Laevastu, T., J. Harding, K. Rabe and S. Larson. 1976. Ocean-atmosphere interactions off the northeast coast of North America. Am. Soc. Limnol. Oceanogr. Spec. Symp. Vol. 2:35-43.

The New York Bight-Middle Atlantic continental shelf region is typical of midlatitude continental east coast areas in the intense sea-air interaction occurring during late autumn and winter. During these seasons dry but cool air moving over warm coastal water takes up a considerable amount of heat and moisture (latent heat). The daily uptake near the coast can exceed 0.5 g of water per cm^2 on a monthly mean basis.

The response of the surface layers of the atmosphere to the properties of the sea surface is relatively rapid so that quasi-equilibrium conditions are established after surface air has traveled about 6 h over water.

The main consequences of this large heat and moisture uptake on the atmosphere are deepening of lows that pass the coastline and frequent cyclogenesis off the coast. As the heat and moisture are transported upward, a trough forms at the 850-mb level. A thermally driven cyclonic surface wind component is created along the coast, but it often escapes the attention of synoptic weather analysts.

The main effect of the atmosphere on the ocean is rapid cooling of already cool coastal waters during autumn and winter, resulting in increases in thermocline depth. The coastal southerly current is influenced by the surface cyclonic wind component.

Lambert, R. B. 1974. Small-scale dissolved oxygen variations and the dynamics of Gulf Stream eddies. Deep-Sea Res. 21:529-546.

Lauzier, L. M. 1967. Bottom residual drift on the Continental Shelf area of the Canadian Atlantic Coast. J. Fish. Res. Bd. Canada 24:1845-1859.

Lavelle, J. W., T. L. Clarke, G. H. Keller. 1975. Possible bottom current response to surface winds in the Hudson Shelf Channel. J. Geophys. Res. 80:1953-1956.

* A brief report which discusses current studies done in the Hudson Shelf Channel during the summer of 1973.

Current measurements were taken over an 11 day period. Wind data was taken at "Ambrose Tower some 34 km north-northwest of the site, and at Barnegat Light, New Jersey, some 56 km south-southwest of the site."

Although data collection occurred over a relatively short period of time, it was concluded from the observations that "there is reason to suggest a correlation between flow in the axis of the Hudson Shelf Channel and the prevailing surface winds. During the summer period, winds which blow onshore (south-southwest or south) seem to produce down-channel flow, while winds blowing offshore (west or northwest) appear to cause a current reversed and net up-channel current".

Lavelle, J. W., P. E. Gadd, G. C. Han, P. A. Mayer, W. L. Stubblefield, D. J. P. Swift, R. L. Charnell, H. R. Brashear, F. N. Case, K. W. Haff and C. W. Kunselman. 1976. Preliminary results of coincident current meter and sediment transport observations for wintertime conditions on the Long Island inner shelf. Geophys. Res. Letts: 3(2):97.

We have observed late fall and winter bedload sediment transport and the overlying current field in ridge and swale topography on the inner continental shelf south of Long Island, and can report movement of bed material at a water depth of 20 m to a distance of approximately 1500 m after several storm events. Movement over an 11-week observation period was longshore and oblique to the ridge crest at the experimental site. Currents were also predominately longshore, but long term averages demonstrate that a vertical shear existed in the fluid motion. Although the number of sediment transport "events" suggested by the current meter data is nearly balanced in eastward and westward directions, both estimates of transport from current speeds and sand tracer dispersion patterns show that several westward flowing events dominated the transport during a two and one-half month period. A quantitative upper bound of 31 cm/sec on the threshold velocity for sediment movement in this size range is also set by the data.

Lavelle, J. W., D. J. P. Swift, P. E. Gadd, W. L. Stubblefield, F. N. Case, H. R. Brashear, and K. W. Haff. 1978. Fair weather and storm sand transport on the Long Island inner shelf. Sedimentology 25: 823-842.

Lavelle, J. W. and D. J. P. Swift. 1982. Near-shore currents measured in ridge-and-swale topography off Long Island, New York. J. Geophys. REs. 87(c6):4190-4194.

Eighteen near-shore current records within an area 11 km^2 on the Long Island inner shelf have been examined for indication of small-scale topographic influence. In the frictionally influenced near-shore water column, currents over the 39-day records are generally oriented slightly clockwise of the longshore direction toward the principal axis of the local ridge-and-swale topography. This orientation angle is largest and closest to the local topographic axis when semidiurnal tidal currents dominate other flows, a result which may suggest that tidal currents play a role in molding the local topography. Viscous tidal current theory for a constant depth surface describes the observed dependence of the semidiuranl (M_2) tidal current ellipticity and ellipse orientation on depth. The inferred vertical eddy viscosity coefficient ranges from 5 to 35 cm^2/s.

Lavelle, J. W., R. A. Young, D. J. P. Swift and T. L. Clarke. 1978. Near bottom sediment concentration and fluid velocity measurements on the inner continental shelf, New York. J. Geophys. Res. 3:6052-6062.

Lear, D. W., M. L. O'Malley, W. C. Muir and G. Pence. In press. Environmental effects of sewage sludge at the Philadelphia dumping site. In: Ecological Stress and the New York Bight: Science and Management, G. F. Mayer (Ed.). Estuarine Research Federation.

The Philadelphia sewage sludge disposal site is located about 70 km east of Ocean City, Maryland. Sludge has been dumped at this site since 1973, and the environmental effects of the practice have been under detailed observation since that time. The site showed no evidence of departures from typical, temperate mid-shelf conditions prior to the onset of sludge dumping. Since then, trends of environmental modification and degradation have appeared in areas contaminated by sludge-derived materials. The changes seem limited to the ocean bottom environment and include increased concentrations of metals in organisms, elevated metals and total organic carbon levels in sediments, changes in abundance of some species, apparent mortalities of molluscan shellfishes, unique occurrences of sewage bacteria, and appearance of pathological conditions in endemic crustaceans.

Leetma, A. and H. Stommel. 1972. Circulation on the continental shelf. Pesticide Monit. Jour. 69:3380-3384.

Lesht, B. M. 1978. Field measurements of the bottom frictional boundary layer in the New York Bight. ERL MESA-28, NOAA, Wash., DC, August 1978.

A detailed field study of near sea floor frictional boundary layer of the inner continental shelf in the apex of the New York Bight was undertaken to present a coherent picture of boundary layer processes affecting sediment transport. High resolution, simultaneous measurements of turbidity were made in order to correlate sediment transport with the flow. Wave activity is discussed and relationships between wave time scales and mean flow turbulence presented. The study provides a basis for modeling long term average observations and allows for a more accurate assessment at sediment transport.

Lettau, B., W. A. Brower, Jr. and R. G. Quayle. 1976. Marine Climatology. MESA New York Bight Atlas Monograph 7. N.Y. Sea Grant Inst., Albany, NY 239 p.

* The climatology of the New York Bight is presented in narrative and atlas form, based on data collected by ships of various registry travelling through the study area, U S. Coast Guard light stations, and seven other coastal land stations. The narrative section "utilizes selected data as examples and illustrations of the seasonal variation of meteorological parameters." It is intended as an overview indicating the range and scope of the climatic variation. The atlas is a detailed presentation of wind, visibility, present weather, sea level pressure, temperature, cloud, and wave data in the form of maps and graphs.

Limeburner, R. 1979. Hydrography and circulation about Nantucket Shoals. M.S. Thesis, Massachusetts Institute of Technology, 113 pp.

Limeburner, R. and R. C. Beardsley. 1979. Hydrographic station data obtained in the vicinity of Nantucket Shoals, May, July, and September 1978. Tech. Rep. WHOI 79-30, 88 pp.

Limeburner, J. A., J. Vermersch and R. Beardsley. 1978. Hydrographic station data obtained in the vicinity of Georges Bank, May and August, 1976. WHOI Tech. Rept. 78-82. 116 p.

Loder, John W. 1980. Topographic rectification of tidal currents on the sides of Georges Bank. J. Phys. Oc. 10(9):1399-1416.

The rectification of M_2 tidal currents on the sloping sides of Georges Bank is predicted to make an important year-round contribution to its observed mean clockwise circulation. A rectification mechanism involving continuity and Coriolis effects, but regulated by bottom friction ((Huthnance, 1973), is operative. Huthnance's (1973) depth-averaged theory for the along-isobath mean Eulerian current associated with this mechanism and with a second, purely frictional, mechanism is extended to include mean current-tidal current interaction, spatially-varying bottom friction and rotary tidal currents. The ratio of cross-isobath tidal excursion L_e to topographic length scale L is found to be an important nondimensional parameter in determining the degree of nonlinearity of the Coriolis mechanism. A significant Stokes velocity is associated with both receification processes, so that, for the Coriolis mechanism, the mean Lagrangian current is only about two-thirds of the mean Eulerian current.

On the sides of Georges Bank, L_e and L are of the same order, and the rectification is sufficiently nonlinear that interaction of the mean current with the tidal current is important. The mean Eulerian and Lagrangian currents, and the cross-isobath mean sea surface slopes, are predicted for half-sinusoid representations of bottom topography on the northwestern, northern and open ocean sides of the Bank. The mean flow is clockwise and concentrated over the edge of the Bank, but smeared out onto the top of the Bank by the mean current-tidal current interaction. The predicted current speeds, which are greatest on the northwestern and northern sides, are of the same order as those observed.

Luyten, J. 1977. Scales of motion in the deep Gulf Stream and across the continental rise. J. Mar. Res. 35(1):49-74.

* An array of 15 moored current meters was deployed across the continental rise near 70°W in the western North Atlantic. Data is an examination of the space-time structure of the low frequency fluctuation field in the deep water near the Gulf Stream. Data provides the first synoptic views of spatial structure of the large amplitude fluctuation characteristics. This report addresses a few of the many aspects and implications of these observations, focusing upon the broader inferences as to the scale and character of this flow regime and its possible dynamics.

Luyten, F. R. and A.R. Robinson. 1974. Transient Gulf Stream meandering. Part II. Analysis via a quasi-geostrophic time-dependent model. J. Phys. Oceanogr. 4(2):256-269.

Simultaneous path and bottom velocity measurements made during the Transient Meander Experiment, reported in Part I, are analyzed in terms of a quasi-geostrophic thin jet model of the meandering Gulf Stream. The theory gives an explicit representation of the velocity field which may be used to decompose the observed velocities. This representation is shown to be consistent with the observations. The dynamics of this model provides an equation of the path of the Stream, a cross-sectional average of the vorticity equation. A linearized form of this equation is used to examine the relations between the space and time scales of the variability. The historical data on the space and time scales of the meandering are shown to be consistent with those implicit in the linearized form of the path equation. The contributions to the local vorticity balance are estimated from the observations reported in Part I. The data, although complicated by observational errors, suggest a balance between the local rate of change of vorticity and the advection of vorticity. The contributions from vortex stretching due to variable topography appear to be unimportant for the scales of the meandering. The local dynamics appears to be fully time-dependent.

Magnell, B. A., S. L. Spiegel, R. I. Scarlet, and J. B. Andrews. 1980. The relationship of tidal and low-frequency currents on the north slope of Georges Bank. J. Phys. Oceanogr. 10(8):1200-1212.

Measured currents at the steeply sloping north edge of Georges Bank show an unusually strong correlation between tidal and lower frequency components. The dominant current constituents are the rotary semidiurnal tides (amplitude ~ 30 cm s^{-1} ellipticity 0.6) and the mean isobath-parallel flow to the northeast (ranging from zero to 40 cm s^{-1}). At the middle water depth in the period range of 3-5 days, the along-isobath low frequency component is highly coherent ($y^2>0.8$) with the amplitude of the semidiurnal tidal current. The fact that variation of the tidal current amplitude occurs on time scales appropriate to wind-driven events suggests that the tidal structure must be significantly baroclinic, and this is supported by hydrographic data. The evidence thus suggests a local nonlinear interaction between tidal and low-frequency currents, with both the steep bottom topography and the density structure being important factors.

Mahoney, J. B. 1979.
Plankton dynamics and nutrient cycling. Part 2 - Bloom decomposition, Chap.9. In: Oxygen depletion and associated benthic mortalities in New York Bight. 1976. R. L. Swanson and C. J. Sindermann (Eds.). NOAA Prof. Pap. No. 11, U.S. Dept. of Comm., Rockville, MD

Malone, T. C. 1976.
Phytoplankton productivity in the apex of the New York Bight: Environmental regulation of productivity/chlorophyll a. Am. Soc. Limnol. Oceanogr. Spec. Symp. 2:260-272.

Malone, T. C., W. Esais, and P. Falkowski. 1979.
Plankton dynamics and nutrient cycling, Part I - Water column processes. Chap. 9 In: Oxygen depletion and associated benthic mortalities in New York Bight, 1976. R. L. Swanson and C. J. Sindermann eds. NOAA Prof. Pap. No. 11. U.S. Dept. Commerce, Rockville, Maryland.

Mannheim, F. T., R. H. Meade and G. C. Bond. 1970. Suspended matter in surface waters of the Atlantic continental margin from Cape Cod to the Florida Keys. Science 167:371-376.

Maul, G. A., P. W. deWitt, A. Yanaway, and S. R. Baig. 1978. Geostationary satellite observations of Gulf Stream meanders: Infrared measurements and time-series analysis. J. Geophys. Res. 83(C12): 6123-6135.

Maurer, D. 1982. Review of benthic invertebrates of Georges Bank in relation to gas and oil exploration with emphasis on management implications. Unpublished report submitted to NOAA/NMFS/NEFC, Woods Hole, MA

Mayer, D. A. and G. C. Han. In press. Circulation in the Hudson Shelf Valley, Part I. J. Geophys.Res.

Mayer, D. A., D. V. Hansen, and D. A. Ortman. 1979. Long-term current and temperature observations on the Middle Atlantic Shelf. J. Geophys. Res. 84(C4):1776-1792.

Nearly 2200 days of current and temperature data were collected at a midshelf location in the Middle Atlantic Bight between June 1974 and March 1977. These data were examined for the average conditions and seasonal cycles of water circulation and temperature and some statistical properties of their variation at higher frequency. The average flow is found to be toward the south-southwest at about 5 cm/s near the surface, diminishing to about 1 cm/s near the bottom. The occurrence of energetic wind-driven transient current events which can exceed a 2-month duration makes it impossible to determine a clear seasonal pattern in the sequence of monthly mean flows. There is, however, a clear seasonal pattern in the distribution of higher-frequency fluctuations. Storm wind-induced transient currents of 3- to 10-day duration appear prominently in winter records. Inertial currents appear selectively in the summer, that is, in parts of the water column well insulated from the bottom by a strong thermocline. For low-frequency motions (periods from 3 to 10 days) in both summer and winter records the preferred directions of motion throughout the water column appear to be consistent with equilibrium (mean) Ekman veering arguments. The water column response was found also to be most sensitive to the component of wind stress parallel to the bathymetry. The temperature follows a well-known seasonal cycle of heating and stratification. During the unstratified seasons, very little high-frequency temperature variation is observed, but during summer, thermal oscillations due to daily heating and inertial and semidaily tidal frequencies (3/3, 4/3, and 6/3 cpd) and a 5/3-cpd oscillation appear prominently.

Mayer, D. A., D. V. Hansen, and S. M. Minten. 1979. Water movement on the New Jersey shelf, 1975 and 1976. In: Oxygen Depletion and associated Benthic Mortalities in New York Bight, 1976 Swanson, R. L. and C. J. Sindermann (eds). NOAA Prof. Pap. 11, pp. 149-163.

Mayer, D. A., Mofjeld, H., and Leaman, Kevin D. 1981. Near-inertial internal waves observed on the outer shelf in the Middle Atlantic Bight in the wake of hurricane Belle. J. Phys. Oceanogr. 11:87-106. (January 1981).

On 10 August 1976 Hurricane Belle passed rapidly over the highly stratified shelf of the New York Bight. Records from Aanderaa current-meter moorings show that the response to the hurricane depended strongly on bathymetry. At deeper stations (~70 m depth), intense first-mode, internal near-inertial oscillations were generated at frequencies ~1% less than the local inertial frequency. At shallower stations (~50 m depth), only weak, heavily damped second-mode oscillations were observed in the current records, with no corresponsing inertial signals in temperature. In the Hudson Shelf Valley, inertial motion occurred only near the surface. This was probably due to topographic effects. The divergence and curl of the wind stress contributed equally to the forcing. The response at the deeper stations is consistent with Geisler's (1970) theory for the open ocean in which a hurricane leaves a wake of internal-inertial oscillations if it travels faster than the internal phase speed and if its horizontal scale is comparable to the internal phase speed and if its horizontal scale is comparable to the internal Rossby radius. The observed frequency shifts (subinertial motion) and observed relative vorticity are consistent with Mooer's (1975a) theory that relative and planetary vorticities combine to give an effective inertial frequency. Here it is suggested that lack of strong inertial motion at the shallower stations is due to a lack of resonance and the likelihood that frictional effects are more important in shallower water, resulting in a more heavily damped response.

McClennen, C. E. 1971. Wave and current effects on continental shelf sediments. Grad. School Oceanogr., University of Rhode Island Rep. (unpublished).

McClennen, C. E. 1973. New Jersey continental shelf near bottom current meter records and recent sediment activity. J. Sed. Petrol. 43(2):371-380.

Modern sedimentary processes associated with the ridge and depression topography of the New Jersey continental shelf were investigated with the aid of near bottom current meter measurements and also estimates of near bottom wave orbital velocities derived from classical wave theory and available surface wave observations. Four current meters were set 1.5 to 2.0 m above sea bottom in 30, 59, 74, and 143 m depths for nine to eleven days during the late springs of 1970 and 1971. The root mean square speeds of the meter records were 13.7, 11.8, 12.9 and 19.5 cm/sec in order of increasing depth, with a maximum recorded 2.5 minute average speed of nearly 40/cm/sec and net southwesterly transport. Both current and wave data indicate reworking of the surface sand cover on the shelf. In determining the relative importance of wave vs. current activity the true value of the critical erosion velocity is of primary importance. The present day physical reworking of the surface sediments is indicated independently by bottom photographs of ripples and by sedimentary structures in box cores, with reworking being generally limited to the upper meter of sediment. No mechanism for the present formation of the larger scale ridge and depression topography is indicated by the currents measured or the wave considerations.

McLellan, H. J. 1957. On the distinctness and origin of the slope water off the Scotian Shelf and its easterly flow south of the Grand Banks. J. Fish. Res. Board, Can. 14:213-239.

McWilliams, J. C. and G. R. Flierl. 1979. On the evolution of isolated nonlinear vortices. J. Phys. Oceanogr. 9(6):1155-1182.

The evolution of an isolated, axially symmetric vortex is calculated with a quasi-geostrophic, adiabatic, hydrostatic, β-plane, two vertical mode model. The circumstances of greates interest are those of weak friction and large vortex amplitude (strong nonlinearity). Systematic studies are made of the consequences of varying the frictional coefficient, the vortex amplitude, the vortex radius (relative to the deformation radius), the degree of nonlinear coupling between the two vertical modes and the initial vertical structure of the vortex

Results of note include the following. Within the approximation of a single vertical mode model (i.e., in the absence of modal coupling), a baroclinic vortex has an increased westward and a finite meridional propagation speed when its amplitude is greater than infinitesimal. Both of these speeds however, are limited by the wave speeds (as determined from infinitesimal amplitude theory) of the weak dispersion field outside the vortex. The vortex amplitude decay rate, in the limit of strong nonlinearity, is governed by the frictional coefficient rather than dispersion. When vertical modal coupling is included, the vortex propagation and decay rate can be altered. Asymptotically in time, the vortex approaches a state of deep compensation (i.e., beneath a shallow thermocline, there is no flow in phase with the upper ocean vortex), with a propagation velocity less rapid in the westward direction and more rapid in the meridional direction (compared to a single mode vortex), and with a decay rate again controlled by the friction coefficient. At earlier times, however, more bizarre behavior can occur; for example, a vortex with initially pure baroclinic mode vertical structure can behave as an eastward-propagating vortical modon for a brief interval.

This study focuses on vortices whose baroclinic component is of only one sign (a positive temperature extremum in the thermocline); however, because of a symmetry of the model chosen (in particular due to its quasi-geostrophic assumption), these solutions can be simply reinterpreted to apply to vortices of both signs.

Meade, R. H. 1969. Landward transport of bottom sediments in estuaries of the Atlantic coastal plain. J. Sediment. Petrol. 39:222-234.

* Estuaries between Cape Cod and Cape Canaveral (Cape Kennedy) are examined for streamflow (1931-1960) and sediment load (1909-1968). Sediment load of rivers is deposited in the estuaries and offshore sands also appear to be moving into the estuaries. Rate of filling or alteration is a function of both streamflow and sediment load.

Meade, R. H. and S. W. Trimble. 1974. Changes in sediment loads in rivers of the Atlantic drainage of the United States since 1900. Int. Assoc. Sci. Hydrol. Pub. 113:99-104.

Meade, R. H., P. L. Sachs, F. T. Mannheim, J. C. Hathaway and D. W. Spencer. 1975. Sources of suspended matter in waters of the Middle Atlantic Bight. J. Sedim. Petrol. 45(1):171-188.

Meid, R. P. and G. L. Lindemann. 1979. The propagation and evolution of cyclonic Gulf Stream rings. J. Phys. Oceanogr. 9(6):1183-1206.

Numerical simulations of the propagation of cyclonic Gulf Stream rings are made using a primitive equation β-plane model of a flat-bottomed two-layer ocean with a rigid lid. Initially circular eddies having upper and deep ocean maximum currents $\max U_1$ and $\max U_2$ located at radial position 1 from the center are allowed to evolve and four types of behavior have been discerned: 1) dispersing rings possess negligible nonlinearity and disperse rapidly; 2) barotropic rings ($U_1 = U_2$) are weakly dispersive, propagating recognizably for long periods of time, and nearly barotropic eddies ($U_1 \ U_2$) slowly lose coherence in the deep ocean; 3) upper ocean rings propagate with a vortex present only in the upper ocean; and 4) eastward-traveling eddies possess circulations in the upper and lower oceans which propagate together stably to the east.

Changes in viscosity are found to be more important to the longevity of the ring than are changes in $(\max U_1)/\beta/^2$. Both westward and northward speeds increase with increasing $\max U^2/\max U_1$ and increasing $(\max U_1)/\beta/^2$. Speeds to the west are found to be 2-3 km day^{-1} and those to the north are 1-9 km day^{-1} for $3 \leq (\max U_1)/\beta/^2 \leq 15$ and $0 \leq \max U_2/\max U_1 \leq 1.2$.

Meserve, J. M. 1974. U.S. Navy marine climatic Atlas of the World. Vol. 1 - North Atlantic Ocean. Naval Weather Service Detachment, U.S. Naval Weather Service Command, Washington, DC. 371 pp.

Miller, A. R. 1950. A study of mixing processes over the edge of the continental shelf. J. Mar. Sci. 9(2):145-160.

By means of T-S area diagrams, a method of analysis is developed for the study of closely spaced hydrographic data. In a transitional zone, such as that over the continental shelf off southern New England, this method is useful for following the continuity of the mixing process. Changes in salinity at the edge of the shelf are due, for the most part, to horizontal advection. There are indications of non-isentropic mixing on a smaller scale. From the turbulent features of the region, as indicated by instabilities, this condition is not unexpected.

Miller, A. R. 1952. A pattern of surface coastal circulation inferred from surface salinity-temperature data and drift bottle recoveries. WHOI Ref. No. 52-28 (unpub. man.).

Miller, A. R. 1957. The effect of steady winds on sea level at Atlantic City. Met. Monographs 2(10):24-31.

From a study of tidal records for Atlantic City, New Jersey, and daily weather maps over a period of six months, the elevation of the sea surface associated with the geostrophic wind field has been evaluated as a function of the geostrophic wind velocity. The relationships are expressed in a nomogram.

Assuming the angle of deviation between surface and geostrophic winds to be 20°, and allowing for the static effects of atmospheric pressure, maximum elevation above the predicted tide level is observed when the surface wind blows 40° from the right of normal to the coastline. In general, there appears to be a 12 hr lag between the winds and the associated state of sea level.

Miller, Arthur R. 1958. The effects of winds on water levels on the New England Coast. Limnol. Oceanogr. 3(1):1-14.

Tidal records from Nantucket Sound, Cape Cod; Montauk, Long Island; and Portland, Maine, have been studied along with wind and barometric observations from each location. Results of this study show that departures from mean sea level due to wind may be resolved into two components. The first is a component which refers to symmetrical sinusoidal variation of sea level departure as a function of wind direction and applies to the outer coast and to the general level of Nantucket Sound in particular.

The second is an asymmetrical component which refers the responses of sea level at each observing station to local wind force, direction, fetch length, and local topography. Under different circumstances these components vary in relative importance in determining the local departure from mean sea level. In addition to wind direction and velocity, duration and size of wind field may determine whether one component is more important than the other.

The varying importance of each component probably governs the time-lag between peak winds and maximum sea level departures which will vary from several hours to as much as twenty hours.

Miller, D. W., J. J. Geraghty and R. S. Collins. 1963. Water atlas of the United States. Water Information Center, Inc., Port Washington, N.Y., 40 plates.

Miller, M. C., J. C. Bacon, and I. M. Lissauer. 1975. A computer simulation technique for oil spills off the New Jersey-Delaware coastline. Report CG-D-137-75. U.S. Coast Guard Res. & Dev. Center, Groton, Connecticut.

Milliman, J. D. 1973. Marine Geology in coastal and offshore environmental inventory, Cape Hatteras to Nantucket Shoals. Complement V. 10-1 to 10-91. Marine Pub. Series No. 3, University of Rhode Island, Kingston, RI 02881.

Milliman, J. D., M. H. Bothner and C. M. Parmenter. 1980. Seston in New England Shelf and Slope Waters 1976-1977. 171 to 173. In: Environmental Geology Studies in the Georges Bank Area, U.S. New England Atlantic Outer Continental Shelf 1975-1977 (J. M. Aaron, ed.). Final report submitted to the U.S. Bur. of Land Management.

Mizenko, D. and J. L. Chamberlin. 1979a. Anticyclonic Gulf Stream eddies off the northeastern United States during 1976. In: Ocean variability in the U.S. Fishery Conservation Zone, 1976. J. R. Goulet, Jr. and E. D. Haynes (Eds.). NOAA Tech Rep. NMFS CIRC 427:259-280.

Mizenko, D. and J. L. Chamberlin. 1979b. Gulf Stream anticyclonic eddies (warm core rings) off the northeastern United States during 1977. Annales Biologiques, Vol. 34:39-44.

Mizenko, D. and J. L. Chamberlin. 1981. Gulf Stream anticyclonic eddies and shelf water at 106 mile site during 1977. In: Assessment Report on the Effects of Waste Dumping in 106 Mile Ocean Waste Disposal Site. NOAA Dumpsite Eval. Rep. 81-1. U.S. Dept. of Commerce, Pub. P.207-232.

Mooers, Christopher, N. K., R. W. Garvine and W. W. Martin. 1979. Summertime synoptic variability of the Middle Atlantic shelf/slope water front. J. Geophys. Res. 84(C8): 4837-4853.

A quasi-synoptic study of the shelf water/slope water front off New Jersey, Delaware, and Maryland in mid-July 1977 revealed an isolated body of very cold (<6°C) water in the near bottom 'cold pool'. Its volume at least halved over 10 days during which nearby shelf waters were perturbed by two anticyclonic (warm core) eddies located over the continental slope. Water colder than 6°C lay along the bottom between the 80- and 100-m isobaths and was about 30 m thick. The seaward edge of the cold pool (here denoted as colder than 8°C) marked the inshore boundary of the shelf water/slope water subsurface temperature front with 10°C variations per 2-20 km, depending upon alongshelf location. The thermocline underwent large displacements and deformations over 10 days, indicative of vigorous upwelling and downwelling and large potential vorticity changes at the shelf break. The dominant scales of variability (or correlation scales) in the thermal fields were 30 km alongshelf, 10 km cross shelf, and 1- to perhaps 20 days. (The internal radius of deformation on the outer shelf is about 15-25 km). There was substantial vertical structure on the scale of 10 m or less. A surface convergence zone coincided with a surface roughness bank ('tide rip') near the shelf break, and internal gravity wave activity seemed intense there too. Two independent estimates of vertical velocity at the shelf break suggested values of about 10^{-2} cm/s, one for a time scale of a week or longer and the other for a time scale of at least a few hours. Over Wilmington Canyon a large 'lip' of cold pool intruded into the slope water along the southwestern side of the Canyon, perhaps undergoing entrainment and 'calving' by an anticyclonic eddy located over the slope. There was further evidence of offshore entrainment throughout the water column between the two eddies.

Mooers, C. N. K., J. Fernandez-Partagas, and J. F. Price. 1976. Meteorological forcing fields of the New York Bight. University of Miami Tech. Report UM-RSMAS, TR-76-8, 151 pp.

* This paper is a report on meteorological forcing in the New York Bight. The study involved analysis of cyclones in the area at the time to determine their effect on surface pressure, temperature, dew point, and wind information. Precipitation, water flux and wind stress curl and divergence were some of the parameters studied.

Data collected is presented throughout the paper in the form of graphs and mathematical equations.

Morel, F. M. M. and K. J. Farley. 1981. The importance of coagulation in the sedimentation of waste particles in receiving waters (abstract). Program and Abstracts, Third International Ocean Disposal Symposium. Woods Hole Oceanographic Inst., Woods Hole, MA. Oct. 12-16, 1981.

Morgan, Charles W., and Joseph M. Bishop. 1977. An example of Gulf Stream eddy-induced water exchange in the Mid-Atlantic Bight. J. Phys. Oceanogr. Vol. 7, pp. 472-479.

* Data and observations for this study were collected from a cruise by the USCGC EVERGREEN in August of 1974.

The eddy was observed about 110 nm southeast of Cape May.

From the temperature and salinity data taken and current studies done while on the cruise, it was suggested that eddies may be responsible for an important portion of the mixing of shelf water with the slope water region in the Mid-Atlantic Bight.

Morton, R. W. 1970. Suspended sediment distribution in Narragansett Bay and Rhode Island Sound. Southeast Meet. Geol. Soc. Amer. GSA Memoir Symp. on Estuaries.

Mulholland, P. J. and J. A. Watts. 1982. Transport of organic carbon to the oceans by rivers of North America: a synthesis of existing data. Tellus 34:176-186.

Transport of organic carbon in rivers of North America to the oceans was assessed by compiling and anlyzing data from 82 North American rivers draining 60% of Canada and the United States. These data were collected by the U.S. Geological Survey and the Water Resources Branch of Canada's Inland Waters Directorate. Mean annual concentrations of total organic carbon showed considerably less variation than did annual specific export (gC m^{-2} yr^{-1}). Regional variation in annual specific export of total organic carbon was attributed primarily to differences in annual runoff. Transport of total organic carbon to coastal regions by North American rivers totalled about 35 X 10^{12} ± 5 X 10^{12} gC yr^{-1} in 1977 and 1978. The total organic carbon flux to the oceans associated with the long-term average annual flow in North American rivers was computed to be about 40 X 10^{12} gC yr^{-1}, slightly larger than that in 1977 and 1978 because of the lower-than-average runoff in some regions those years.

Mulligan, H. F. 1974. Oceanographic factors associated with New England red tide blooms. Proc. of the 1st Int. Conf. Tox. Dino. Blooms, Mass. Science & Tech. Foundation, 1974, pp. 517-524.

* Three red tides during the period from 1972 to 1974 were studied in the coastal region from Rye, New Hampshire to Cape Ann, Massachusetts. In addition, from April 1971 to July 1972, salinities, water temp., transmissivities, PO-4 and NO-3 profiles and chl. a concentrations were measured.

Coastal upwellings which bring cysts into the euphotic zone and provide nutrients were considered to be crucial in initiating blooms with subsequent and continuous enrichments contributed by the Merrimack R. important in sustaining the bloom. Periods of low rainfall were found to be especially important as they resulted in river runoff with high concentrations of waste which caused a stratified water column.

Munday, J. C. Jr. and M. S. Fedosh. 1981. Chesapeake Bay plume dynamics from LANDSAT. p. 79-92. In: Chesapeake Bay Plume Study - Superflux 1980. NASA Conference Publ. 2188. J. W. Campbell and J. P. Thomas (Eds.), 516 pp. Scientific and Technical Information Branch, NASA, Washington, DC

Examination of 81 dates of Landsat images with enhancement and density slicing has shown that the Chesapeake Bay plume usually frequents the Virginia coast south of the Bay mouth. Southwestern (compared to northern) winds spread the plume easterly over a large area. Ebb tide images (compared to flood tide images) show a more dispersed plume. Flooding waters produce high turbidity levels over the shallow northern portion of the Bay mouth.

Munday, J. C., W. Harrison, and W. G. MacIntyre. 1970. Oil slick motion near Chesapeake Bay entrance. Water Resource Bull. Jour. 6:879-884.

Murray, S. P. 1975. Trajectories and speeds of wind-driven current near the coast. J. Phys. Oceanogr. 5:347-360.

Myers, T. D. 1974. An observation of rapid thermocline formation in the Middle Atlantic Bight. Estuarine Coastal Mr. Sci. 2(1):75-82.

Thirty-two vertical temperature profiles were obtained in the spring of 1973 at an industrial waste disposal site 60 km off the coast of Delaware.

Initiation of the thermocline occurred rapidly in mid-April. In a 4-day period, the temperature at 3 m rose from 6.7 to 9.5 C, an average of 0.7 deg. C/day. A discrete warm water front was confirmed in surface isotherm plots. Density stratification was primarily thermally induced.

Nalwalk, A. J., D. F. Paskausky, C. Rathburn, R. Williams. 1972. Seasonal variation in temperature and salinity in Block Island Sound. EOS Trans. Amer. Geophys. Union, 53(4):396.

National Oceanic & Atmospheric Admin. 1976. Evaluation of proposed sewage sludge dumpsite areas in the New York Bight apex. Estuarine Coastal Mar. Sci. 6:93-104.

Naval Weather Service Detachment. 1976. Climatic study of the near coastal zone - east coast of the United States. Published by Director, Naval Oceanography and Meteorology. Wash., DC, 133 pp.

Nelsen, T. A. 1979. Suspended particulate matter in the New York Bight Apex: Observations from April 1974 through January 1975. NOAA Tech. Memo. ERL MESA-42. 78 pp.

Nelson, Terry A., Peter E. Gadd and Thomas L. Clarke. 1978. Wind-induced current flow in the upper Hudson Shelf Valley. J. Geophy. Res. 83(C12): 6073-6082.

Drawing from wind and current meter data, an empirical model has been developed for wind-induced current flow in the New York Bight apex portion of the Hudson Shelf Valley. Data have shown that winds from 270°T (±50°), blowing for at least 9 hours at speeds of greater than 5 m/s, can cause northward (upchannel) bottom flow in the shelf valley at velocities in excess of 40 cm/s. Southern (downchannel) flow is initiated by winds from 75°T (±35°) blowing for at least 6 hours at speeds of 4 m/s or more. Seasonal variation in the wind field results in predominant upchannel flow during October-April with downchannel flow throughout the rest of the year.

Newton, C. W. 1978. Fronts and wave disturbances in Gulf Stream and atmospheric jet stream. J. Geophys. Res.

Similarities in their basic features, including spatial variations of frontal structure along the current, suggest that Gulf Stream meanders are dynamically analogous to atmospheric jet stream waves, with descending motions upstream and ascending motions downstream from a wave trough. In a symmetrical wave with uniform speed along the current it is shown that confluence, together with the distribution of vertical motions, accounts for the greater baroclinity in the frontal zone at troughs than at crests, a necessary feature of such a wave. Gross features of the three-dimensional motions are discussed for an eddy in the process of cutting off to form a Gulf Stream ring. Prior to its detachment from the slope water mass, deduced sinking motions exceed, by 2 orders of magnitude, the vertical motions in ring eddies that have become isolated. The large downward volume flux during the formative stage is associated with the asymmetrical structure (more water pouring into a cold tongue on its west side than leaves it on its east side) and with the vertical distribution of volume transport (greater inflow than can be accommodated by horizontal expansion in the upper layers). The inflation time for a Gulf Stream ring is about a month, much shorter than the decay time.

Noble, M. and B. Butman. 1979. Low frequency wind induced sea-level oscillations along the East Coast of North America. J. Geophys. Res. 34(6):3227.

Atmospherically adjusted coastal sea level observations (ASL) and wind measurements at stations along the east coast of North America from Cape Hatteras, North Carolina, to Eddy Point, Nova Scotia, for a 6-month winter period were used to study the spatial structure of ASL and wind stress on the continental shelf and to determine the low-frequency response of ASL to wind forcing. ASL and wind stress were coherent over distances of 1300 km for motions with periods between 60 and 600 hours. Northward movement of storm systems and the associated ASL response was observed for stations north of Cape May, New Jersey. South of Cape May the phase of ASL suggested southward movement of pressure disturbances. Longshore wind accounted for 55% of ASL energy and led ASL by 8-12 hours. Cross-shore winds were generally not coherent with ASL. In the Middle Atlantic Bight (MAB), sea level response was 17 cm for a 1 dyn cm^{-2} longshore wind and symmetric in the longshore wind stress directions. In contrast, from Nantucket north, sea level response to longshore wind stress was weaker (9 cm for a 1 dyn cm^{-2} wind to the northeast). The response for wind to the northeast was twice as large as the response for wind stress toward the southwest. If coastal winds were representative of winds over the shelf, the observations imply that the wind-driven longshelf geostrophic currents were larger for unit wind stress in the MAB than in the Georges Bank-Scotian Shelf region. The regional change in ASL response may be due to the large semidiurnal tidal currents which occur in the Georges Bank region or to the rough topography on the Scotian Shelf, which effectively increases bottom friction. The regional change in ASL response suggests a divergence in longshore flow and an onshore flow on the shelf south of Nantucket for winds to the southwest. A low-frequency longshelf ASL slope was observed in the MAB that was incoherent with longshelf wind stress.

Norcross, J. J. 1960. Investigations of inner continental shelf waters off lower Chesapeake Bay, Part I - General introduction and hydrography. Chesapeake Sci. 1:155-167.

* This paper serves as an introduction to a proposed series describing the results of a series of monthly exploratory cruises into the neritic waters of the Atlantic Ocean adjacent to lower Chesapeake Bay in 1959. Twenty-two offshore stations in addition to three stations in Chesapeake Bay were sampled monthly. Routine hydrographic data were taken at each station. Data analyses show that from December through March the water column was essentially homogenous with respect to temperature. Vernal warming began in April and thermal stratification progressed through May. The distribution of salinities was generally coastal in character with isohalines parallel to the coastline.

O'Connor, D. J. and J. L. Mancini. 1979. The carbon-oxygen distribution in New York Bight Phase I - Steady State. MESA-New York Bight Project Report. NOAA Office of Marine Pollution Assessment, Biology Bldg., SUNY, Stony Brook, NY

O'Connor, D. J., J. L. Mancini and J. R. Guerriero. 1981. Evaluation of factors influencing the temporal variation of dissolved oxygen in the New York Bight - Phase II. Report from Manhattan College, Environmental Engineering and Science, Bronx, NY 10471. 81 p.

The purpose of this project is to evaluate the mechanism influencing dissolved oxygen levels in the New York Bight and to evaluate potential engineering solutions, such as nutrient control, for existing water quality problems.

The study employed existing data on Bight water quality and a nonlinear water quality model which considers oxygen-carbon-and nitrogen distributions to evaluate alternative water quality control options.

O'Connor, T. P., A. Okubo, M. A. Champ, and P. K. Park. 1981. Deep ocean dumping of sewage sludge. Presentation to Ocean Pollution '81 Conference, 19-23 Oct. 1981, Halifax, Nova Scotia.

O'Connor, T. P. and P. K. Park. In press. Consequences of industrial waste disposal at the 106-Mile ocean waste disposal site. In: Ecological Stress and the New York Bight: Science and Management, G. F. Mayer (ed.). Estuarine Research Federation.

Industrial wastes are dumped beyond the edge of the continental shelf at the 106-Mile Ocean Waste Disposal Site. These wastes are mainly liquids that, in some cases, form a precipitate floc after mixing with seawater. Rather than descending to the sea floor, wastes are distributed primarily as plumes within the upper mixed layer. The method of dumping yields a plume with a maximum initial concentration of about 200 ppm waste. Within about four hours, the maximum concentration is reduced to approximately 10 ppm with a waste plume width of about 1 km. Further dilution and plume growth proceed slowly, leading to the conclusion that storm events may be necessary to dilute extensively the waste. The average flow through the dump site seems to be sufficient, when compared to the frequency of dumping, for each dump to be an independent event so that later dumps do not occur in previously created plumes. It is estimated that, on the average, the plumes move toward the southwest along the contour of the continental shelf.

Laboratory studies have shown that oceanic strains of phytoplankton are less tolerant of waste than coastal strains of the same species, and that there is considerable variation in response to waste among species. Although no tested phytoplankton species have been found to be affected at 10 ppm waste, it is possible that within a waste plume there will be a readjustment of phytoplankton communities favoring more resilient species. Tests of this are proceeding, as are tests on the sublethal responses of zooplankton to wastes, histopathological and chemical analyses of field-collected organisms, studies of the stability of waste-derived organic compounds, and studies of the partitioning of waste constituents between dissolved and particulate phases.

Oertel, G. F. and T. L. Wade. 1981. Characteristics of total suspended matter and associated hydrocarbon concentrations adjacent to the Chesapeake Bay entrance. In: Chesapeake Bay Plume Study: Superflux 1980. J. W. Campbell and J. P. Thomas (eds.). NASA Conf. Publ. 2188. NOAA/NEMP III 81 ABCDFG0042. NTIS, Springfield, Virginia. 522 pp.

Olbers, D. J. 1981. A formal theory of internal wave scattering with applications to ocean fronts. J. Phys. Oceanogr. 11(8):1078-1099.

A concise theory for scattering of internal waves at localized inhomogeneities (i.e., topographic features, baroclinicity in the density field, variations of the mean sea level, jetlike currents) in the oceanic waveguide is presented within the formal framework of quantum mechanical scattering theory. The equations of motion of the wave system are reduced to a form resembling the Schrodinger equation with an interaction operator describing the effect of the ambient inhomogeneities. By standard Green's function techniques integral equations for the scattered field and its Fourier transform (which relates to the amplitudes of the scattered waves) are derived, both for a scattering region of finite extent (representing a two-dimensional scattering problem) and a "wall-like" scattering region of infinite extent (representing a one-dimensional scattering problem.) As an example, the theory is applied to the scattering at a straight geostrophic front. The far-field is described in the Born approximation valid for $(U/c)\ (kL_3) \ll 1$, where U is the speed of the geostrophic current of width L_3, and c and k are the phase speed and wavenumber of the incident wave. It is found that the scattering process has a significant directional signature while modal redistribution appears to be weak.

Orr, M. H., L. Baxter, II, and F. R. Hess. 1980. Remote acoustic sensing of the particulate phase of industrial chemical wastes and sewage sludge. Woods Hole Oceanographic Inst. Tech. Rep. 79-38, 153 pp.

Orr, M. H. and F. R. Hess. 1978. Remote acoustic monitoring of industrial chemical waste released at Deepwater Dumpsite 106. J. Geophys. Res. 83:6145-6154.

Ou, H. W. and R. C. Beardsley. 1980. On the propagation of free topographic Rossby waves near continental margins. Part 2: Numerical model. J. Phys. Oceanogr. 10:1323-1339.

Ou (1980, Part I) presented analytical solutions of free topographic Rossby waves propagating in an infinite wedge filled with a uniformly stratified fluid. We present here in Part 2 a numerical model incorporating more realistic topography and bottom friction to simulate the propagation of these waves across continental margins. Although the analytical solutions in a wedge can explain many of the wave properties observed in our numerical model, new features are introduced that have practical importance. It is found that the replacement of the apex by a finite nonreflecting shelf introduces at the shelf break an antinode in the pressure field, causing the kinetic energy to drop rapidly across the shelf break onto the shelf. It is also found that the baroclinic fringe waves excited near the slope/rise junction can cause an amphidromic point to form for shorter waves and reverse the direction of phase propagation above it. This changes the sign of the Reynolds stress locally and might have important implications on the mean flow structure generated by these waves. The baroclinic fringe waves also cause an offshore heat flux over the continental rise as in contrast to the onshore heat flux generated over the slope region due to the rigid upper surface. This heat flux divergence near the slope/rise junction can obviously contribute to a mean sinking motion there, accompanied by upwelling on both sides of it. Friction, however, generates an offshore heat flux near the bottom, and complicates this heat flux distribution. The model predictions are compared with the current and temperature data obtained south of New England during 1976. The comparisons are generally consistent, suggesting that topographic Rossby wave dynamics play an important role for the low-frequency motions over the continental rise and slope.

Ou, H. W., R. C. Beardsley, D. Mayer, W. C. Boicourt and B. Butman. 1981. An analysis of subtidal and current fluctuations in the Middle Atlantic Bight. J. Phys. Oceanogr. 11(10):1383-1392.

Subtidal current fluctuations in the Middle Atlantic Bight are examined from current-meter data collected in 1975 and 1976. Spectral analysis provides evidence for both locally wind-forced response and free waves that propagate downshelf which are not correlated with the local wind. A simple empirical model has been construc6ed to fit two linearly independent plane waves to the observed current spectra. Application of the model to the current data obtained at a pair of stations in the New York Bight during the period of 26 October 1975 to 4 April 1976 indicates that the two waves propagate in opposite directions along the coast, and with the additional evidence from rotary-coefficient calculations, it is suggested that they correspond to the forced and free waves speculated upon earlier. The noise level is a free parameter in the model and is determined by adjusting the phase speed of the forced wave to the translation speed of the observed wind field. This gives a 526 km day^{-1} phase speed for the free wave, and the forced wave, free wave and noise compose ~41, 39 and 20% of the total variance.

Ou, H. W. and R. Houghton. 1981. A note on the summer progression of the cold pool temperature in the Middle Atlantic Bight. Unpubl. Manus. Lamont-Doherty Geological Observatory, Palisades, NY.

Pape, Edwin H. III, 1981. A drifter study of the Lagranian mean circulation of Delaware Bay and adjacent shelf waters. Master's thesis, University of Delaware. Del - SG-18-81. Delaware Sea Grant College Program, Newark, Delaware 19711.

To document the Lagrangain mean circulation of Delaware Bay and adjacent shelf waters a series of nine deployments of surface and seabed current drifters was made. The study area, roughly 50 km up the Bay to 50 km offshore, was chosen to examine the exchange of water between estuary and shelf. Each deployment involved 28 stations and about 1000 drifters. Use of aircraft provided a synoptic release.

The presence of classical estuarine circulation in Delaware Bay can be inferred from maps of the apparent drifter trajectories. The seaward surface residual flow in the Bay is directed towards the Delaware shore, consistent with Coriolis effects, while the bottom residual flow moves upstream in the deep channels of the Bay and then spreads laterally onto the adjacent shallower areas on both sides. The estuarine circulation extends onto the adjacent shelf. The surface residual motion on the shelf is generally toward the south, although it can reverse and flow northward while the bottom residual currents converge on the Bay mouth.

Vector maps of mean speed and direction of the residual circulation, with 95% confidence intervals, show a coherent flow pattern over the study area during the period studied. The speed of the residual currents on the shelf is consistently faster than that in the Bay. However, over the entire study area, the surface residual circulation is an order of magnitude faster than the bottom circulation. Both surface and bottom current speeds in the Bay are slower than those observed in other estuaries, and currents on the shelf and slower than previously reported for the Middle Atlantic Bight.

Wind and river conditions during the study were not characteristic of their long-term means. Consequently, it was not practical to present residual curculation patterns corresponding to seasonal periods in wind and river runoff. However, the return percentages suggest that offshore surface flow and onshore bottom flow intensify in the second half of the calendar year.

Although river flow shows little correlation with the residual circulation, the wind record explains much of the variance in drifter movement. In general, offshore winds drive surface water downstream/offshore and bottom water upstream/onshore in a simple two layer flow. This pattern reverses for onshore wind. Enough of the variance in drifter movements is left unexplained, however, that other forcing, such as tidal rectification, should be considered.

Parker, B. B. and R. B. Pearce. 1975.
The response of Massachusetts Bay to wind stress. MIT Sea Grant Program Rep. MITSG 75-2. Massachusetts Inst. of Technol., Cambridge, MA. 02139. 107pp.

The effect of atmospheric stability on the wind stress coefficient (or drag coefficient), C_D, of the commonly used quadratic law is demonstrated. The method of determining values for C_D is essentially a "wind set-up" method using Doodson filtered tidal records from Boston and Sandwich, Massachusetts and similarly filtered wind and barometric pressure data. The mean values for C_D for the three stability groups are: $1.10X10^{-3}$ for stable conditions, $1.40X10^{-3}$ for neutral conditions, and $1.84X10^{-3}$ for unstable conditions. The wind set-up method has been objected to for various reasons, but all these objections are fairly well answered for as far as this particular investigation is concerned. Excellent correlation exists not only between Boston-Sandwich sea level differences and the component of wind stress along the longitudinal axis of the bay (which is necessary to carry out the above method), but also between Boston-Portsmouth sea level differences and the onshore component of wind stress. Filtering Boston, Sandwich, Portsmouth, and Eastport, Maine tidal records results in very similar non-tidal sea level curves even after pressure correction. This fact, combined with the several hour lag between changes in the onshore wind stress component and sea level changes at Boston, implies that the Gulf of Maine has an important effect on Massachusetts Bay.

Wind data at Boston is used for this study but it is corrected for the frictional effect of land using the result of comparisons with other wind stations around the bay. This has apparently not been done for many wind set-up investigations and is perhaps one reason why C_D's from wind set-up methods have usually been larger than from other methods.

Wind stress was generally much greater in the winter of 1971 than in the summer, not only because of generally higher wind speeds, but also because of greater atmospheric instability and denser air. There is however, reason to believe that wind-driven currents (in the upper layer of water) are greater in the summer due to thermal stratification. Current data off Salem harbor generally support this contention and also indicate the existence of internal waves.

A sceptical look is also taken at the basic quadratic law and an alternative approach is suggested.

Parr, A. E. 1933. A geographical ecological analysis of the seasonal changes in water along the Atlantic coast of the U.S. Bull. Bingham Oceanogr. Collect. 4:1-90.

Pastuszak, M., W. Redwood Wright, and D. Patanjo. Unpubl. One year of nutrient distribution in the Georges Bank region in relation to hydrography, 1975-1976. ICES C. M. 1981/ c:7 Hydrography Committee. International Counc. Expl. Sea, Copenhagen.

A series of nine cruises were conducted in the Georges Bank region between July 1975 and August 1976. The sampling included measurement throughout the water column of temperature, salinity, dissolved oxygen, nitrate, orthophosphate, and silicate. The distribution of the variables and their annual cycle are described for the waters on Georges Bank and in the adjacent areas of the Gulf of Maine to the north and over the continental slope to the south.

Patchen, R. C., and B. W. Gottholm. 1981.
The response of the shelf to hurricane Belle-August 1976. NOAA Tech. Rep. NOS 89, 36pp.

On 10 August 1976 Hurricane Belle passed through the New York Bight; the data set included meteorological information from the National Weather Service, water level information from the National Ocean Survey, and current meter and Salinity/Temperature/Depth (STD) information from the Marine Ecosystem Analysis Program. Hurricane Belle can be classified as a fast-moving storm translating over a two-layer density structure. The temporal and spatial responses to the hurricane were determined by spectral and residual techniques. The STD information and the temperature records obtained at the current meter locations indicate that a cooling and mixing of the surface waters was observed at stations to the right of the storm, and that only weak mixing was observed at stations directly in the path of the storm. At current meter locations on deeper areas of the continental shelf (greater than 55 m) the baroclinic response of a generation of internal inertia-gravity waves in the lee of the hurricane can be seen in the two layers. For stations of the shallower area of the shelf (less than 55 m), a strong barotropic response indicated by the generation of localized quasi-geostrophic barotropic Rossby waves, 18 to 20 hours after the hurricane entered the New York Bight, is observed. The data compared favorably with the results of Chang and Anthes for a hurricane translating at 11 m s^{-1}. The topographic restraint of the velocity field for stations located in the Hudson Canyon is described.

Patchen, R. C., B. B. Parker and E. E. Long. 1976.
Analysis of current meter observations in the New York Bight apex August 1973-June 1974. ERL 368-MESA 5, 08/73-06/74. Environmental Res. Lab., Boulder, CO., 24 pp.

* A comprehensive field program in the apex region was devised and carried out to establish the significant temporal and spatial scales and water dynamics. Data from 13 stations and 2 transects during 1973 and 1974 were studied along the outer apex boundaries. Results show a frictional bottom boundary layer 7 m above the bottom and the impacts of the principal lunar semidiurnal (m2) and Lunisolar diurnal (ki) constituents on circulation. Statistical analysis shows a fall seasonal clockwise circulation with a 30% counterclockwise deviation occurring. For the Spring season, the development of stratification and depth of thermocline and wind driven fluxes appear to determine the mean westward geostrophic current. Data is on file at NODC.

Pease, T. E. 1969. A study of temperature and salinity changes along the northern New Jersey coast. N.Y. Univ. Dep. Met. Oceanog. Geophys. Sci. Lab. Rep. TR 69-7, 51 p.

Philpot, W. D. and S. G. Ackleson. 1981. Remote sensing of optically shallow, vertically inhomogeneous waters: A mathematical model. In: Chesapeake Bay Plume Study-Superflux 1980. p. 283-299. NASA Conference Publication 2188. J. W. Campbell and J. P. Thomas (Eds.), 516 pp. Scientific and Technical information Branch, Aeronautics and Space Administration, Wash. DC.

A multiple-layer radiative transfer model of a vertically inhomogeneous, optically shallow water mass is briefly described. This model is directed toward use in remote sensing of water properties. Some preliminary results and qualitative predictions are presented.

Posmentier, E. S. and R. W. Houghton. 1978. Fine structure instabilities induced by double diffusion in the shelf/slope water front. J. Geophys. Res. 83(C10): 5135-5138.

* Analysis of temperature-salinity data from 13 stations across the shelf/slope front southeast of Long Island between 39.8 N, 71.5 W and 40.5 N, 72.2 W taken on R/V CAPE HENLOPEN in May 1977. Intervals of negative stability are found in the TS diagram at the frontal zone. Analyses indicate double-diffusion mixing with salt fingering as the mechanism responsible.

Posmentier, E. S. and R. W. Houghton. 1981. Springtime evolution of the New England Shelf break front. J. Geophys. Res. 86(C5): 4253-4259.

The shelf break frontal shape and T-S relationships in the frontal vicinity have been observed to undergo a transition in the spring. It is shown that this transition should result from two simple assumptions: (1) during the early spring, the offshore density gradient becomes reversed in a layer of intermediate depth; and (2) the front is gravitationally stable. Observations south of Nantucket preceding and following the transition during 1979 illustrate the metamorphosis from a monotonically sloping front to a convoluted shape which delineates two layers of shelf and two of slope water. The convoluted shape of both the front and the T-S curves after the transition are found to be consistent with the observed density gradients if it is further assumed that the front is Margules-type with a velocity discontinuity of 5 cm/s.

Pratt, S. D., S. B. Saila, and Polgar. 1972. Dredge spoil disposal in Rhode Island Sound. Univ. of Rhode Island Tech. Rep. 2:48 p.

* Technical report which discusses dredge spoil disposal in Rhode Island Sound. The report contains general information on the spoil disposal dumpsite, characteristics of the physical environment of the area, and reviews some direct effects of spoil dumping on marine animals and the benthic invertebrates of the Sound.

Pritchard, P. W. 1955. Estuarine circulation patterns. Proceedings of the Amer. Soc. Civil Eng. 81: Sep. No. 717, 11 pp.

Proni, J. R., H. M. Byrne, F. C. Newman and D. J. Walter. 1977. Acoustic imaging of the New England shelf-slope water mass interface. Nature, 269:790-791.

* This is an analysis of data taken from June 15-23, 1976 by the NOAA ship George B. Kelez along the New England continental shelf. Measurements were made along three tracklines. Profiles using XBT and CTD were obtained at regular intervals. Acoustics were used to detect the interfaces associated with the intrusion of cold New England shelf water into the warmer slope water during this period. It was found that the shelf-slope water transition zone apparently fluctuates significantly in location on a time scale of a few days.

Proni, J. R. and D. V. Hansen. 1981. Dispersion of particulates in the ocean studied acoustically: The importance of gradient surfaces in the ocean. P. 161-173. In: Ocean Dumping of Industrial Wastes. (B. H. Ketchum, D. R. Kester and P. K. Park, Eds.) Plenum Press, New York and London.

Knowledge of the rate of dispersion of particulate matter dumped in the upper ocean and of the processes governing that dispersion is fundamental to an understanding of the effects of dumping on the ocean environment. Accurate chemical dilution rates of dumped material cannot be determined without a knowledge of the spacial distribution of ocean dumped material and the way in which that distribution changes with time. Acoustical methods offer one approach to studying ocean dispersion of dumped material. Acoustical results presented herein show some of the complicated effects which gradients in oceanic parameters, such as temperature and density, produce in the dispersion of particulate matter dumped in the ocean.

Proni, J. R., F. C. Newman, R. L. Sellers and D. J. Walter. 1982.
New York sludge tracking experiment STAX-1. NOAA Tech. Memo. OMPA-15. National Oceanic and Atmospheric Administration, Office of Marine Pollution Assessment, Boulder, Colorado.

Sewage sludge in the ocean has been detected using a modified 200 KHz acoustic echo sounder. The three-dimensional distribution of suspended material and its rate of diffusion have been determined after digital processing of data. Increased biological activity is apparently associated with the presence of sewage sludge. The detection of internal waves in 30 m of water is reported.

Proni, J. R., D. J. Walter, and R. L. Sellers. 1982.
STAX-II Final acoustical data report. NOAA Data Report OMPA-II. Boulder, Colorado.

High frequency acoustic systems (20 and 200 KHz) have been used successfully in the detection and tracking of sewage sludge in a dumping zone in the New York Bight Apex. Observations made with these systems indicate that particulate distribution of a dumped artificial tracer is highly dependent on changes associated with the vertical density structure in the water column.

Pyle, Robert L. 1962. Sea surface temperature regime in the western North Atlantic 1953-1954. Folio 1 - Serial Atlas of the Marine Environment. American Geographical Society.

Twenty six pairs of maps of mean-monthly, annual difference (1953-54), seasonal range, seasonal warming and cooling, seasonal maxima and minima. Covers Atlantic coastal area from Bahamas to Nova Scotia.

Redfield, A. C. and L. A. Walford. 1951. A study of the disposal of chemical waste at sea. Nat. Res. Coun. Pub. 201, Report of the Committee for Investigation of Waste Disposal, 29 pp.

Redfield, A. C. 1958. The influence of the continental shelf on the tides of the Atlantic coast of the United States. J. Mar. Res. 17:432-448.

* Tidal high water intervals and mean range at 6 tide stations on U.S. east coast from Tybee Light, Fire Island, NY, given in the U.S. Coast & Geodetic Survey Tide Tables Atlantic Ocean were analyzed. Tidal behavior at the coast was dependent on numerous topographic factors of the continental shelf. Tidal range at the coast is shown to be dependent on distance from the continental slope.

Reed, M., M L. Spaulding, P. C. Cornillon. 1980.
An oil spill fishery interaction model: development and applications. Report on Contract E(11-1)4047. U.R.I. Oc. Eng. Dept., South Lab, Narr. RI, 02882.

Reid, Jr., J. L. 1962.
Distribution of dissolved oxygen in the summer thermocline. J. Mar. Res. 20(2): 138-148.

Using previously published (1937-60) oceanographic data for various cruises during 1928-1960, the following preliminary hypothesis is examined: if water in the winter mixed layer remains saturated with oxygen throughout the year, then seasonal temperature changes require the presence of a summer subsurface oxyty maximum. Both Atlantic and Pacific data are examined and appear to validate the hypothesis. Photosynthesis is shown to have little effect upon subsurface maxima of oxyty.

Richardson, P. L. 1981.
Gulf Stream trajectories measured with free-drifting buoys. J. Phys. Oc. 11(7): 999-1010.

During 1975-78, 35 free- drifting buoys measured surface currents in the Gulf Stream region. The buoy trajectories trace numerous paths of the Stream and show that the Stream is strongly influenced by the New England Seamounts. This influence is manifested as 1) a quasi-permanent, 100 km, southeastward deflection of the Stream and the frequent occurrence of a ring meander over the seamounts: 2) large-amplitude meanders beginning at the seamounts and extending eastward: and 3) small, 20 km diameter eddies which appear to be generated locally by individual seamounts.

A chart of the mean temperature field at a depth of 450 m agrees with several of the patterns seen in the buoy trajectories. West of the seamounts, the mean path of the Gulf Stream is eastward; over the seamounts, the path turns sharply northeastward and the isotherms in the Stream abruptly diverge.

Riley, G. A. 1967.
Mathematical model of nutrient conditions in coastal waters. Bull. Bingham Oceanogr. Collect. 19:72-80.

* "A mathematical model is developed to illustrate the distribution of nitrate and phosphate in coastal waters. The model depends on the existence of a deep water source of nutrients at the edge of the continental shelf and determines in relation to horizontal and vertical mixing and biological rates of regeneration and utilization. It is shown to be as applicable to the coastal region off southern New England with respect to nutrient concentrations, N:P ratios, and productivity levels."

Robinson, A. R., J. R. Luyten and F. C. Fuglister 1974.
Transient Gulf Stream meandering. Part I: An observational experiment. J. Phys. Oceanogr. 4(3):237-255.

The results from an observational experiment on the mesoscale space-time variability of the Gulf Stream are reported. Various techniques, including aerial surveys, ship trackings of the 15C isotherm at 200 m, drogues and moored current meters were used and are compared, to give estimates of the variability of the motion over a wide range scales. A two-week time series of daily tracks of the Stream near 70W are used to interpolate instantaneous paths over 2° of longitude. These paths provide the first detailed information on the small-scale variability of the path indicator of the Gulf Stream northeast of Cape Hatteras. Similarly, the long time series of triweekly aerial surveys provides a detailed picture of the evolution of a large-scale meander.

Ruzecki, Evon P. 1981.
Temporal and spatial variations of the Chesapeake Bay Plume. P. 111-130. In: Chesapeake Bay Plume Study - Superflux 1980. NASA Conference Publication 2188. eds. J. W. Campbell and J. P. Thomas, 516pp. Scientific and Technical Information Branch, National Aeronautics and Space Administration, Washington, D.C.

Historical records and data obtained during the Superflux experiments are used to describe the temporal and spatial variations of the effluent waters of Chesapeake Bay. The alongshore extent of the plume resulting from variations of freshwater discharge into the Bay and the effects of wind are illustrated. Variations of the cross-sectional configuration of the plume over portions of a tidal cycle and results of a rapid-underway water sampling system are discussed.

Ruzecki, E. P., C. Walsh, J. Usry and J. Wallace. 1976.
The use of the EOLE Satellite System to observe continental shelf circulation. Eighth annual offshore Tech. Conf., Houston, Texas. P.697-708.

Ryther, J. H. & Dunstan, W. M. 1971.
Nitrogen, phosphorus and euthrophication in the coastal environment. Science 171: 1008-1013.

Surface samples were collected from eight stations in Great South Bay, Moriches Bay, and the Forge River in one set of experiments and from coastal and open ocean regions off New York and New Jersey as part of an ocean cruise in September 1969.

Enrichment studies were done on water samples taken from both locales using nitrogen and phosphorus as variables. Results show that nitrogen was the primary limiting factor to algal growth.

High content of particulate organic matter characteristic of the New York Bight extended seaward for less than 80 km to the east and southeast, wheras pollution occurred at least 240 km to the south, along the New Jersey coast to Delaware Bay.

Saltzman, B. and C. M. Tang. 1975. Formation of meanders, fronts and cutoff thermal pools in a baroclinic ocean current. J. Phys. Oc. 5:86-92.

Using an analytical model similar to that previously applied by the authors to the atmosphere, calculations are made showing how second order, nongeostrophic effects can modify a two-layer baroclinic wave system that grows exponentially from a small perturbation in a uniform zonal ocean current. It is shown that many of the asymmetric features characteristic of meandering ocean currents develop, including "fronts" and cutoff cyclonic cold pools to the south and anticyclonic warm pools to the north of the axis of the mean current. The implication is that all of these features can be viewed as being the simultaneous consequence of baroclinic instability (with attendant second order finite amplitude effects) of a broader, more uniform current that might tend to be forced externally by the wind stress and thermohaline processes.

Sarabun, C. C., Jr. 1981. Mapping watermass boundaries using fluorosensing lidar. In: Chesapeake Bay Plume Study: Superflux 1980. Campbell, J. W. and J. P. Thomas (Eds.) NASA Conf. Publ. 2189, NOAA/NEMP III 81 ABCDFG0042. NTIS, Springfield, VA, 522 pp.

Sarmiento, J. L. and K. Bryan. 1982. An ocean transport model for the North Atlantic. J. Geophys. Res. 87(C1):394-408.

Three-dimensional solutions are obtained for the circulation of the North Atlantic using a robust diagnostic model. In contrast to previous diagnostic models the robust diagnostic model incorporates the conservation of the large-scale fields of heat and salinity as well as momentum. An approximate fit to observed fields of temperature and salinity is obtained by a closure condition. The method is robust in the sense that it does not have the extreme sensitivity to the density input fields of the classical diagnostic method. Equilibrium solutions are obtained by numerical integration of the time-dependent equations. Error estimates for the velocity field can be obtained indirectly from the numerical solutions. Temperature observations used as input have an effective resolution of 3° x 3° of latitude and longitude and a sampling error of ± 0.15°C. The equivalent vertically integrated velocity error is estimated to be ± 0.5-1.0 cm/s depending on bottom topography. The suitability of the model for geochemical work is judged by comparison with heat and salinity balance estimates. Best results are obtained for the case in which the model has a minimum observational constraint below the surface.

Saunders, P. M. 1971. Anticyclonic eddies formed from shoreward meanders of the Gulf Stream. Deep Sea Res. 18:1207-1219.

* Author uses XBT data in the area 39-40N, 68-71W and moored current meter data from 13 m, 53 m, 185 m, 207 m, 1044 m, 2066 m, at 39-12 N, 70-03 W. A Gulf Stream anticyclonic eddy formed during the period 15 September - 4 December 1969 and remained at the edge of the shelf. Energy computation indicated the eddy circulation is confined to the upper 1000 m and energy is primarily potential energy.

Saunders, P. M. 1977. Wind stress on the ocean over the eastern continental shelf of North America. J. Phys. Oceanogr. 7:555-566.

Employing one million ship reports gathered in the years 1941-72 seasonal averages of the wind stress and its standard deviation have been computed for the shelf region of the eastern North American continent (out to a depth of 200 m). A drag coefficient is assumed which increases with wind speed, from 1.0×10^{-3} at 5 m s^{-1} to 2.3×10^{-3} at 25 m s^{-1}. Atmospheric stratification is taken into account but its effect is shown to be small.

In the summer season the 32-year climatological wind stress is toward the northeast, having a magnitude close to 0.25 dyn cm^{-2} throughout the entire shelf region. In the three other seasons the stress is directed toward the south and east being strongest in winter (1-1.5 dyn cm^{-2}) and weakest in fall (0.25-0.5 dyn cm^{-2}). In addition to the expected increase in magnitude with increasing latitude remarkable small-scale variability occurs. An offshore increase in stress is widespread and dominates the mid-Atlantic Bight; in winter the stress there increases from 0.5 to 1.0 dyn cm^{-2} in going 200 km offshore. In the Gulf of Maine and especially in the Gulf of St. Lawrence local maxima occur; the tail of the Grand Banks 500 km from shore shows a minimum. Probably much of this variation is associated with the intensity (and frequency) of cyclonic activity rather than directly with changes in friction at the underlying surface. Some oceanographic consequences are commented on but the computations are principally intended as a data source for further research.

Schmitz, J. E. and A. C. Vastano. 1975. Entrainment and diffusion in a Gulf Stream cyclonic ring. J. Phys. Oceanogy. 5:93-97.

The mixing and entrainment processes present in a cyclonic ring are investigated by means of a parametric model which is fitted to serial temperature data for a North Atlantic ring. The physical model assumes an axial symmetric ring in which the temperature is presumed to governed by

$$\frac{\partial \tau}{\partial \tau} = \frac{1}{r}\frac{\partial}{\partial r}\left(rKh\frac{\partial \tau}{\partial r}\right) + \frac{\partial}{\partial z}\left(K_z\frac{\partial \tau}{\partial z}\right) + \frac{1}{r} J(\psi,\tau),$$

where K_h and K_z are the horizontal and vertical eddy diffusity coefficients and $J(\psi,\tau)$ is the (r,z) Jacobian of the transverse stream function ψ and the temperature τ. Data from two cruises curing the 1967 observation of a ring by the Woods Hole Oceanographic Institution provided estimates of the derivatives of the tempera= ture. Regression analysis was used to determine the coefficients for polynomial representations of $\psi(r,z)$ for selected combinations of K_h and K_z. The study indicates upper bounds on the order of magnitudes for the diffusivities $(k_h, K_z) = (10^5, 10)$ $cm^2 s^{-1}$ based upon near-minimum least-squares error estimates from the regression analysis. An important result is that little differentiation exists between a purely advective the regression analysis. An important result is that little differentiation exists between a purely advective entrainment regime and those regimes including both entrainment and diffusion; i.e., the entrainment circulation appears to be the dominant mechanism in the temporal changes of the ring for a time scale of at least two momths. The results provide streamline patterns for the transverse flow from the surface to 1000 m depth consistent with isotherm movement and changes in the ring water masses.

Schmitz, W. J., Jr. 1974. Observations of low-frequency current fluctuations on the continental slope and rise near site D. J. Mar. Res. 32(2):233-251.

* An array of 8 near bottom current moorings were placed on the continental rise and slope near site D in the area 70.5W - 71.5W, 39-40 N in fall of 1970. Time series of current velocity of 45 to 111 days were obtained. Authors applied spectral and cross spectral analyses of the series and suggest that the phase relationships between u and v components indicate a combination of trapping of modes and propagation near the slope-rise junction, up-slope.

Schmitz, W. J. and W. B. Owens. 1979. Observed and numerically simulated kinetic energies for MODE eddies. J. Phys. Oceanogr. 9:1294-1297.

It is demonstrated that the outcome of an inter-comparison between data and the vertical distribution of eddy kinetic energy predicted by a previously developed numerical model of the MODE area is frequency dependent. In the range of periods from 50 to 150 or even to 400 days (one definition of the temporal mesoscale, the scale that the model was designed to simulate), the comparison is quite good. For periods in the range of 5 to 50 days, the agreement is poor. For periods longer than 400 days, the comparison is indeterminate. Earlier conclusions concerning the relation of model results to the MODE data should be qualified by stipulating frequency range, and future inter-comparisons for any model in all regions should be conscious of the desirability of doing so across common frequencies.

Schmitz, W. J. Jr., J. F. Price, P. L. Richardson, W. B. Owens, D. C. Webb, R. E. Cheney, and H. T. Rossby. 1981.
A preliminary exploration of the Gulf Stream System with SOFAR floats. J. Phys. Oc. 11(a):1194-1204.

SOFAR (sound fixing and ranging) floats deployed for engineering tests during 1977-79 yield the first long-term quasi-Lagrangian observations in the subsurface Gulf Stream System. The character of these float tracks supports the premise that the Gulf Stream is a persistent, large-scale, vertically coherent jet at depths (approximately) within and above the main thermocline, where mean and eddy kinetic energies are roughly the same and lateral motions of the Stream are clearly delineated. A float track at thermocline depth is visually coherent with the track of a concurrently launched surface drifter over the larger horizontal scales traversed during the first few months of their trajectories. Below thermocline depths, fluctuation or eddy kinetic energies are normally larger than the mean and a persistent Gulf Stream is difficult to detect. However, deep motions that are visually coherent with upper level flows may be observed for an intermediate range of space and time scales.

Eddy kinetic energies based on the float data are compatible with existing Eulerian estimates to the extent comparable. The consistency of a quasi-Lagrangian eddy kinetic energy estimate in the vicinity of the thermocline, roughly 400 $cm^2 s^{-2}$, the first such observation to our knowledge, is indirect but relatively convincing. Zonal and meridional variances for the float data are also in line with existing Eulerian results. Estimates of the frequency distribution of eddy kinetic energy for the longest float trajectory available are nearly identical to comparable Eulerian results at frequencies less than about a cycle per 20 days.

Schmitz, W. J., Jr., A. A. Robinson and F. C. Fuglister. 1970. Bottom velocity observations directly under the Gulf Stream. Science 170:1192-1194.

Schopf, T. J. 1967. Bottom water temperature on the continental shelf off New England. U.S. Geol. Surv. Prof. Paper 575-D, pp. 192-197.

Schroeder, E. H. 1963. North Atlantic temperatures at a depth of 200 meters. Am. Geograph. Soc. Serial Atlas of the Marine Environment. Folio 2, 13 pp. 9 pl.

Schroeder, E. H. 1966. Average surface temperatures of the Western North Atlantic. Bull. Mar. Sci. 16(2):302-323.

Schubel, J. R., H. H. Carter and W. B. Cronin. 1976. Effects of Agnes on the distribution of salinity along the main axis of the bay and in contiguous shelf waters. In: The effects of tropical storm Agnes on the Chesapeake Bay estuarine system. Chesapeake Research Consortium, Inc. CRC Pub. No. 54. The Johns Hopkins Univ. Press. pp. 35-65.

Schubel, J. R. and A. Okubo. 1972. Comments on the dispersal of suspended sediment across the continental shelves. Chap. 15 in: Shelf Sediment Transport: Process and Pattern. D. J. P. Swift, D. B. Duane and O. H. Pilkey (Eds.). Dowden, Hutchinson and Ross, Inc., Stroudsburg, Pennsylvania.

Scott, J. T. and G. T. Csanady. 1976. Nearshore currents off Long Island. J. Geophys. Res. 81:5401-5409.

Currents were observed for a 25-day period in September 1975 at 11 km south of Long Island, where the water is 32 m deep, at three levels by using electromagnetic current meters. Tidal currents were found to be moderately strong, of the order of 20 cm s^{-1}. Nontidal flow is caused by wind stress, horizontal density contrasts due to fresh water influx, and a longshore surface level gradient sloping down southwestward. The time-averaged flow has simple characteristics, adequately described by classical Ekman models in frictional equilibrium. By suitable changes in the averaging period, quantitative estimates of a bottom friction coefficient and a longshore pressure gradient are deduced from the data. The bottom friction coefficient agrees with what one would estimate from boundary layer theory for roughness elements of about 70-cm height. The longshore pressure gradient deduced from the behavior of currents agrees with the evidence of geodetic leveling.

Semtner, A. J. and Y. Mintz. 1977. Numerical simulation of the Gulf Stream and mid-ocean eddies. J. Phys. Oceanogr. 7:208-230.

The circulation of the western North Atlantic is simulated with a primitive equation model that has 5 levels and a horizontal grid size of 37 km. The idealized model domain is a rectangular basin, 3000 km long, 2000 km wide and 4 km deep, which is oriented so that the long axis of the basin is parallel to the east coast of the United States. The nearshore side of the basin has a simple continental shelf and slope, whereas the other sides are bounded by vertical walls. The model ocean is driven by a 2½ gyre pattern of steady zonal wind stress and by a Newtonian-type surface heating. After initialization from a 15-year spin-up with a coarser grid, two experiments are carried out each of several years duration: the first uses a Laplacian formulation for the subgrid-scale lateral diffusions of heat and momentum, the second uses a highly scale-selective biharmonic formulation ofr these diffusions. Bottom friction is present in each case.

In both experiments, a western boundary current forms which separates from the coast and continues eastward as an intense free jet, with surface velocites >1 m s^{-1} for almost 1000 km downstream. In the experiment with biharmonic closure, this simulated Gulf Stream develops large-amplitude transient meanders, some of which become cold-core cyclonic rings and warm-core anticyclonic rings that drift westward. In both experments, transient mesoscale eddies also form in the broad westward-moving North Equatorial Current, where the simulated thermocline in the model ocean slopes downward toward the north. The remaining regions of the model ocean also contain transient mesoscale eddies, but they are of weaker intensity.

The dominant process of eddy kinetic energy production, in both experiments, is a baroclinic-barotropic instability which is concentrated in the part of the Gulf Stream that is over the continental slope. But where the Gulf Stream lies over the abyssal plains, there is large reconversion of eddy kinetic energy into the kinetic energy of the time-averaged flow. Eddy kinetic energy is also produced by baroclinic instability in the North Equatorial Current, but at a much smaller rate. In the biharmonic experiment, the eddies transfer considerable kinetic energy downward, and bottom friction is the dominant process of eddy kinetic energy dissipation.

An analysis of the heat transport, in the biharmonic experiment, shows that the horizontal transport of heat by eddies is much larger than the subgrid-scale horizontal heat diffusion. In the Gulf Stream region, the eddy heat transport is comparable to the effect of a lateral diffusion coefficient of 10^7 cm^2 s^{-1}.

Sharp, J. H. In press. *In situ* phosphate regeneration in Middle Atlantic coastal waters. In: Ecological Stress and the New York Bight: Science and Management, G. F. Mayer (ed.). Estuarine Research Federation.

Concern exists over man's disposal of bioactive nutrients into the marine environment. These nutrients can stimulate microbial plant production that, if not consumed in marine food chains, can cause serious oxygen demands. To understand the impact of man's input of nutrients it is necessary first to gain a better understanding of natural nutrient cycles. This paper attempts to quantify natural phosphate regeneration in bottom waters of three regions in Middle Atlantic coastal waters and to evaluate the contributions that *in situ* nutrient regeneration could make toward supporting microbial plant production. It is striking that the apex of the New York Bight, with high production, receives a much smaller proportion of its phosphate supply from *in situ* regeneration than adjacent New Jersey and Long Island coastal waters. The approach taken here is the first of its kind for quantifying and comparing coastal nutrient regeneration.

Sharp, J. H. and T. M. Church. 1981. Biochemical modeling in coastal waters of the Middle Atlantic States. Limnol. Oceanogr. 26(5):843-854.

Biochemical dynamics in coastal waters off the U.S. Middle Atlantic States are examined by applying the Redfield model of nutrient regeneration and apparent oxygen utilization. The modeling takes advantage of the comparatively uniform spatial conditions of the seasonally stratified central shelf region and follows temporal changes in the isolated bottom waters on an integrated mesoscale. A seasonally averaged rate of bottom water nutrient regeneration of 0.0044 μmol $P \cdot liter^{-1} d^{-1}$ results and this permits estimation of a nitrogen flux across the thermocline equivalent to 0.02 μmol $N \cdot liter^{-1} \cdot d^{-1}$. This nitrogen flux and an extrapolated surface water nutrient regeneration could supply at least one-third and maybe close to two-thirds of the total nitrogen requirement for the phytoplankton productivity during summer in these coastal waters.

Shaw, P. T. 1981. On the dynamics of bottom water movement in the Middle Atlantic Bight. Paper presented at Middle Atlantic Bight Physical Oceanography Workshop, Univ. of Rhode Island, 21-22 October, 1981.

Shonting, D. H. 1969. Rhode Island Sound square kilometer study 1967: Flow patterns and kinetic energy distribution. J. Geophys. Res. 74:3386-3395.

A square kilometer array of self-recording current meters was placed in Rhode Island Sound for 13 days in the summer of 1967 to monitor quasi-continuously small-scale current motions above and below the sharp seasonal pycnocline. The surface flow appeared strongly isolated from the lower layer by the pycnocline. Strong influence of the semi-diurnal tide was observed in both layers; however, a dominant mean flow to the WSW occurred in the upper layer, whereas the lower layer showed more random and rotary character. Instantaneous currents within the array show occurrences of highly meandering and unsteady motions a few hundred meters in dimension. The kinetic energy of mean motion and the turbulent (or eddy) kinetic energy of the upper layer were about 4 to 5 times that of the bottom layer.

Shonting, D. H. and G. S. Cook. 1970. On the seasonal distribution of temperature and salinity in Rhode Island Sound. Limnol. and Oceanogr. 15(1):100-112.

Sigaev, I. K. 1978. Intra-year variability of geostrophic circulation on the continental shelf off New England and Nova Scotia. ICNAF Selected Papers No. 3.

From the analysis of charts of dynamic topography based on data collected in 1963-73, seasonal types of the geostrophic current fields on the New England and Nova Scotia shelves are described and intra-year variations in the circulation pattern considered. The various types are characterized by quasi-stationary gyres of zones of rising and sinking water, some of which coincide with important biological events, such as the spawning of herring on Georges Bank in September and the spawning of silver and red hake along the southern slopes in early summer.

Simpson, J. H., C. M. Allen and N. C. G. Morris. 1978. Fronts on the continental shelf. J. Geo. Phys. Res. 83(C9):4607-4614.

* The authors report a model of frontal regimes in the ocean based on available turbulent kinetic energy from tidal currents and wind stress and on buoyancy flux input at the surface. Model validation was with sea surface temperature measurements from an airborne radiometer and velocity measurements using radio tracked drogues on 18-19 July 1973. Earlier drogue measurements near fronts are discussed. While the mean positions of fronts are predicted well by the model, detailed structure is not.

Simpson, J. H. and D. Bowers. 1981. Models of stratification and frontal movement in shelf areas. Deep-Sea Res. 28(7A):727-738.

Smith, J. D. and C. E. Long. 1976. The effect of turning in the bottom boundary layer on continental shelf sediment transport. Mem. Soc. Royale Sci. Liege 6(10):369-396.

* "In this paper a simple time-dependent analytical model with a linearly increasing eddy viscosity near the sea bed and a constant one in the interior, is developed and compared to current meter data collected in recent years during studies of circulation on the Washington continental shelf. The results indicate that reduction of the turbulent diffusion coefficient due to flow stratification and the effects of density-induced pressure gradients in the interior of the water column must be included in the model in order to explain the salient features of the measured velocity hodographs. Reasonable estimates of these parameters indicate approximately 18 degrees of turning between the center of the water column and the sea bed in a layer about 30 m thick. When combined with the observation that the direction of the vertically averaged velocity closely parallels that of the isobaths, this yields a ratio of offshore to longshore sediment transport of nearly 1:3."

Smith, K. L., Jr., C. H. Clifford and G. T. Rowe. 1974. Sediment oxygen demand in an outwelling and upwelling area. Tethys. 6:223-230.

* In situ analysis is given of oxygen demand of sediments from New York Bight outwellings and California current upwellings to evaluate the influence or organic enrichment on benthic carbon utilization and to provide a basis of comparison. Studies reveal that enrichment increases the oxygen demand of sediments. "The mud sediments of the outwelling area were high in organic carbon and infaunal abundance and biomass whereas in the fine sediments of the upwelling, organic carbon, infaunal abundance and biomass were lower. Oxygen demand, in both areas were equivalent."

Smith, R. A., J. R. Slack, and R. K. Davis. 1976a. An oilspill risk analysis for the Mid-Atlantic outer continental shelf lease area. U.S. Geological Survey Open-File Report 76-451.

An oilspill risk analysis was conducted to determine relative environmental impacts of developing oil in different regions of the Mid-Atlantic Outer Continental Shelf lease area. The study analyzed probability of spills, likely path of pollutants from spills, and locations in space and time of recreational and biological resources likely to be vulnerable. These results are combined to yield estimates of the overall oilspill risk associated with development of the lease area.

Smith, R. A., J. R. Slack, and R. K. Davis. 1976b. An oilspill risk analysis for the North Atlantic outer continental shelf lease area. U.S. Geol. Survey Open File Report 76-620.

An oilspill risk analysis was conducted to determine relative environmental hazards of developing oil in different regions of the North Atlantic Outer Continental Shelf lease area. The study analyzed probability of spill occurrence, likely path of pollutants from spills, and locations in space and time of recreational and biological resources likely to be vulnerable. These results are combined to yield estimates of the overall oilspill risk associated with development of the lease area.

Spaulding M. 1981. Oil spill fishery interaction modeling - application to Georges Bank. Paper presented at Middle Atlantic Bight Physical Oceanography Workshop, Univ. Rhode Island, October 21-22, 1981.

Spaulding, M. L. and R. Robertson. 1981. Three dimensional numerical dispersion model of acid iron waste disposal. P. 133 (abstract) in: Program and Abstracts - Third International Ocean Disposal Symposium. Woods Hole Oceanographic Inst., Woods Hole, MA October 12-16, 1981. 156 pp.

Stearns, F. 1965. Sea-surface temperature anomaly study of records from Atlantic Coast stations. J. Geophys. Res. 70:283-296.

Stearns, F. 1969. Bathymetric maps and geomorphology of the Middle Atlantic continental shelf. Fish. Bull. 68:37-66.

* "The shape of the sea floor can influence the movement of water masses on the shelf, and this movement can affect the distribution of such oceanographic properties as temperature, salinity, and nutrient elements."

Stefansson, U., L. P. Atkinson, and D. F. Bumpus. 1971. Hydrographic properties and circulation of the North Carolina Shelf and Slope Waters. Deep-Sea Res. 18:383-420.

Stefansson, U., and L. P. Atkinson. 1971. Nutrient-density relationships in the western North Atlantic between Cape Lookout and Bermuda. Limnol. Oceanogr. 16(1): 51-57.

Steimle, F. W. and C. J. Sindermann. 1978. Review of oxygen depletion and associated mass mortalities of shellfish in the Middle Atlantic Bight in 1976. Mar. Fish. Rev. 40(12):17-26.

Steimle, F. W. and R. B. Starr. 1979. Chapter 2. Temporal development of physical characteristics. In: Oxygen Depletion and Associated Benthic Mortalities in New York Bight, 1976. NOAA Prof. Paper 11. R. W. Swanson and C. J. Sindermann (Eds.). pp. 17-50.

* Data from expanded water column characterization (XWCC 8, 9, 10) cruises on NOAA ship <u>George Kelez</u> and <u>Researcher</u> are objectively analyzed. Physical oceanographic conditions of water column and associated dissolved oxygen levels for April, May, June and September 1976, are defined. Specifically, seasonal temperature, salinity, density, pycnocline, dissolved oxygen (upper and lower levels), and Hurricane Belle XBT data are studied and conclusions drawn for the 1976 oxygen depletion event in the New York Bight.

Steinhauer, W. G. 1976. Transport pathways of polychlorinated biphenyls in Atlantic water. J. Mar. Res. 34(4):561-575.

* Data from seven separate cruises between 36°S and 54°N during 1973-1975 were analyzed for PCB content. The PCB appears to concentrate in regions of high precipitation, verifying transport from the land via vapor-aerosol. The authors argue from the data that there is net northward transport of PCB in surface waters with entrainment in North Atlantic deep water and subsequent re-transport southward at depths.

Stewart, H. B. , Jr. and G. F. Gordon. 1964. Underwater sand ridges on Georges Shoal. P. 102-114. In: Papers in Marine Geology. R. L. Miller (Ed.). MacMillan Co., N.Y. 531 pp.

Stigebrandt, Anders. 1980. Cross thermocline low on continental shelves and the location of shelf fronts. Elsevier Scientific Publishing Co., New York, 1981. pp. 51-65.

The author presents a model of 2 layered water column in shelf waters with a one-dimensional thermocline. The solution for his model indicates that tidally driven turbulence in the lower layer affects the upper layer in regions beyond frontal local areas and there is water exchange even in the presence of a thermocline. Author states that knowledge of bottom tidal currents, winds, and heat exchange through the sea surface should allow calculation of exchange rates through the thermocline.

Stommel, H. 1966. The Gulf Stream. University of Calif. Press, Berkeley, California, 248 p.

Stommel, H. and A. Leetmaa. 1972. Circulation on the continental shelf. Proc. Nat. Acad. Sci. 69(11):3380-3384.

Stubblefield, W. L. 1976. Morphologic evolution and coastal sand transport, New York - New Jersey shelf. In: Special Symposia Vol. 2, Middle Atlantic Continental Shelf and the New York Bight, M. G. Gross (Ed.). Amer. Soc. Limnol. Oceanogr. p. 69-89.

Sutcliffe, W. H., Jr., R. H. Loucks and K. F. Drinkwater. 1976. Coastal circulation and physical oceanography of the Scotian Shelf and Gulf of Maine. J. Fish. Res. Bd. Canada, 33(1):98-115.

Swanson, R. L. 1976. Evaluation of proposed sewage sludge dumpsite areas in the New York Bight. NOAA Tech. Memo. ERL MESA-11. U.S. Dept. Commerce, NOAA, Wash., DC, 212 pp.

Swanson, R. L. 1976. Tides. MESA, N. Y. Bight Atlas Monograph No. 4. Albany, NY, New York Sea Grant Inst.

* Times of high and low tides and tidal ranges are mapped. Seasonal variations and accuracy of predictions from tide tables are shown. Variation in the range of tide and time of high water along the east coast can be correlated with width of the shelf. Long Island Sound, a major embayment, modifies the co-tide and co-range lines in the northeast portion of the bight.

Swanson, R. L. 1981. The pros and cons of ocean dumping sewage sludge at the 12-mile, 65-mile and 106-mile sites. Presentation to Third International Ocean Disposal Symposium, Woods Hole, MA 12-16 October 1981.

Swanson, R. L. and C. J. Sindermann (eds.) 1979. Oxygen depletion and associated benthic mortalities in New York Bight, 1976. NOAA Prof. Pap. 11. U.S. Dept. Commerce, Rockville, Maryland 345 pp.

Swanson, R. L., C. J. Sindermann, and G. Han. 1979. Oxygen depletion and the future: An evaluation. Chap. 16 In: Oxygen depletion and associated benthic mortalities in New York Bight, 1976. R. L. Swanson and C. J. Sindermann (Eds.). NOAA Prof. Pap. No. 11. U.S. Dept. Commerce, Rockville, MD.

Swanson, R. L., H. M. Stanford, J. S. O'Connor, S. Chanesman, C. A. Parker, P. A. Eisen and G. F. Mayer. 1978. June 1976 pollution of Long Island ocean beaches. J. Envl. Eng. Div. ASCE. 104(EE6): 1067-1085.

In June 1976, Long Island's ocean beaches were inundated with floating wastes including sewage-related material, trash, and garbage. The material exited the Hudson-Raritan estuary as a result of high spring runoff and intensive May rains. Once introduced into New York Bight waters, it was transported to the beaches by persistent southerly winds. The major sources of the floatable wastes were urban runoff and sewage treatment plant bypassing feeding through the combined sewer system. Assessment was accomplished by comparing waste materials found on the beaches with the types and volumes of materials associated with suspected sources. Continual washups of floatable material can be expected, particularly during summer months, until better source and screening controls are implemented.

Swift, D. J. P. 1975. Response of the shelf floor to geostrophic storm currents of the Middle Atlantic Bight of North America. 1975. Proc. of 9th International Congress of Sedimentology, Nice. 1975. Theme 6, pp. 193-198.

Swift, D. J. P., D. B. Duane, and I. F. McKinney. 1971. Topographic Rossby waves at a site north of the Gulf Stream. Deep-Sea Res. 18:1-19.

* Current velocity was sampled every 15 minutes with minimized aliasing for over 3 years at site-D (39-40 N, 70 W) at depths of 100 m, 500 m, 1000 m, and 2000 m. Following averaged subsampling over 114 hours (9.5 semi-diurnal tide cycles, 6 inertial periods), a variant of complex demodulation was used to obtain spectra, cospectra and quadrature spectura for the 4 depth series. The correlations obtained relative to the geometric arrangement of the slope and Gulf Stream forcing function are interpreted as topographic Rossby waves.

Swift, D. J. P., G. L. Freeland, P. E. Gadd, G. Han, J. W. Lavelle, and W. L. Stubblefield. 1976. Morphologic evolution and coastal sand transport, New York - New Jersey Shelf. In: Special Symposia Vol. 2, Middle Atlantic Continental Shelf and the New York Bight. (M. Grant Gross, Ed.) Am. Soc. Limnol. Oceanogr. p. 69-89.

The surface of the New York-New Jersey shelf has been extensively modified by landward passage sedimentary environments during the postglacial rise of sea level. The retreat of estuary mouths across the shelf surface has resulted in shelf valley complexes. Constituent elements include shelf valleys largely molded by estuary mouth scour, shoal retreat massifs left by the retreat of estuary mouth shoals, and midshelf or shelf-edge deltas.

The erosional retreat of the straight coast between estuary mouths has left a discontinuous sheet of clean sand 0-10 m thick. During the retreat process, a sequence of oblique-trending, shoreface-connected sand ridges formed at the foot of the shoreface. As a consequence, the surficial sand sheet of the shelf floor bears a ridge and swale topography of sand ridges up to 10 m high and 2-4 m apart.

The mechanics of sedimentation in these two nearshore environments (estuary mouth and inter-estuarine coast) are now being investigated for purposes of environmental management as well as for futher understanding of shelf history. In late fall and winter 1974, current meters were deployed on the Long Island coast and a radioisotope tracer dispersal pattern was traced over an 11-week period. Eastward or westward pulses of water were generated during this period of successive weather systems. Flows in excess of the computed threshold velocity of substrate materials were sustained for hours or days and were separated by days and weeks of subthreshold velocities, and the sand tracer pattern expanded accordingly. A single intense westward flow transported more sand than all the other events combined. The storm was anomalous with respect to the short term observation period, but it may in fact have been representative of the type of peak flow event that shapes the inner shelf surface.

Systematic observations of sedimentation in New York Harbor mouth have not yet been initiated. However, reconnaissance data reveal a complex patpern of ebb- and flood-dominanted zones that control the pattern of sand storage.

Swift, D. J. P., J. W. Lavelle, R. A. Young and T. L. Clarke. 1978. Near-bottom sediment concentration and fluid velocity measurements on the inner continental shelf, New York. J. Geophys. Res. 83(12):6052-6062.

* This paper reports a series of experiments designed to investigate the relationship between near-bottom fluid velocity and suspended matter on the inner continental shelf south of Long Island, New York during a 27 day period of October 1976. "If conditions are reasonably similar one might expect that sampling near-bottom suspended matter concentrations with conventional survey techniques in coastal areas which are wave and wind controlled is unlikely to yield representative samples in any but the most quiescent of conditions. If spatial distribution of near bottom suspended matter are sought at time of unusual wave or current conditions the results from this study pose the question as to whether a synoptic view can be gathered without an array of in situ instrumentation."

Swift, D. J. P. and T. R. McKinney. 1974. Large scale current lineations of the central New Jersey shelf: Investigations by side scan sonar. Mar. Geol. 17:79-102.

Swift, D. J. P., R. A. Young, T. L. Clark, G. L. F. Freeland, C. E. Vincent. 1981. Sediment dispersal in the vicinity of the New York Bight dumpsites (abstract). Program and Abstracts, Third International Ocean Disposal Symposium, Woods Hole Oceanographic Inst., Woods Hole, Mass., October 12-16, 1981.

Talay, T. A. and C. H. Whitlock. 1975. Wave modeling and experimental activities in the Baltimore Canyon region. In: Marine Environmental Implications of Offshore Oil and Gas Development in the Baltimore Canyon Region of the Mid-Atlantic Coast. Proceedings of Estuarine Research Federation Outer Continental Shelf Conference and Workshop. Published by Estuarine Research Federation.

Taylor, C. B. 1957. Extreme sea water temperature and densities along the North Atlantic states during summer 1955. J. Mar. Res. 16(1):1-7.

* Author presents an analysis of the record high sea water temperatures and extremely low densities observed in harbor and coastal waters of the North Atlantic states during the summer of 1955.

From observations of Weather Bureau and Coast and Geodetic Survey data collected at that time, it was determined that hurricanes Connie and Diane were responsible for the record low densities (or salinities) and the high sea water temperatures were due in large part to continued high air temperatures.

Thomann, R. V. 1980. Measures of verification. In: Proceedings of workshop on verification of water quality models. EPA-6009-80-016 April 1980. Environmental Research Laboratory. Office of Research and Development, U.S. Environmental Protection Agency, Athens, Georgia 30605.

Thomann, R. V., H. J. Salas and D. J. O'Connor. 1977. Water quality. MESA N.Y. Bight Atlas Monograph No. 27, NY Sea Grant Institute, Albany, NY, 104 pp.

* Water quality of the New York Bight is measured by the following parameters: temperature, salinity, turbidity, secchi depth, dissolved oxygen, nitrogen and phosphorus forms, silicate, pH, heavy metals, coliform bacteria and phytoplankton chlorophyll. An attempt is made to identify and monitor recent changes in water quality. The monograph does not address benthic or atmospheric boundary conditions.

Data encompasses ten data sets from 1948 to present. Gaps exist from 3 to 10 years.

Thomas, J. P. 1981. Chesapeake Bay plume studies (SUPERFLUX) relative to the biology of the contiguous shelf, fishery research and monitoring. In: Oceans '81 Conference Record, Vol. 2, IEEE Publ. No. 81CH1685-7, pp. 1216-1221.

A study was initiated in 1980 to study the influence of the Chesapeake Bay plume on the continuous shelf using both in situ and remote sensing techniques. The combined use of in situ and remotely sensed data has enabled us to define the area of the continental shelf that is influenced by the Chesapeake Bay plume. Waters emanating from the Bay contained biostimulants, contaminants and other materials as well as increased biomass and biological activity, and a different assemblage of phytoplankton. Remote sensing added to our ability to understand the complex and dynamic plume and adjacent shelf area by 1) providing synoptic and detailed information for the surface field in which in situ measurements were made and, 2) directing surface ships to key areas to maximize their sampling ability. Surface ships provided information concerning 1) the vertical structure of the water column and 2) variables not directly relatable to those measured by remote sensors.

Thomas, J. P. 1981. Assessment of Superflux relative to fisheries research and monitoring. In: Chesapeake Bay Plume Study. Superflux 1980. Campbell, J. W. and J. P. Thomas (Eds.) NASA Conf. Publ. 2188, NOAA/NEMP III 81 ABCDFG0042, 522 pp.

Thurberg, F. P. and R. O. Goodlett. 1979. Low dissolved oxygen concentrations and surf clams - a laboratory study. Chap. 11. In: Oxygen depletion and associated benthic mortalities in the New York Bight, 1976. R. L. Swanson and C. J. Sindermann (Eds.) NOAA Prof. Paper No. 11, U.S. Dept. Commerce, Rockville, Maryland.

Tingle, A. G. and D. A. Dieterle. 1977. A numerical oil trajectory forecast model used to assess the hazard to Long Island beaches from oil entering the New York Bight apex from February 11-24, 1977. BNL 50649. Brookhaven Nat. Laboratory, Upton, NY 11973.

Oil spilling into the Hudson River from a grounded barge (carrying 400,000 gallons) was observed entering the N.Y. Bight Apex on 11 February 1977. A computer model was used to forecast the subsequent trajectory of this oil and to assess the hazard to Long Island beaches. Oil was forecast to wash ashore on the 13th on Rockaway or Long Beach, depending upon the initial position of the oil in the bight. Oil was observed on Rockaway Beach on the 13th. Additional daily forecasts indicated no further hazard to Long Island, also in accordance with observations, and the forecasts were terminated on the 16th. The model was also used to assess a beaching event that occurred a week later. The complete calculations are available on microfiche in graphics format.

Twichell, D. C., C. E. McClennen, and B. Butman. 1981. Morphology and processes associated with the accumulation of the fine-grained sediment deposit on the southern New England Shelf. J. Sedim. Petrol. 15(1): 269-280.

Uchupi, E. 1967. Slumping on the continental margin southeast of Long Island, New York. Deep-Sea Res. 14:635-639.

U.S. Naval Oceanographic Office. 1963. Oceanographic Atlas of the North Atlantic Ocean - Pub. No. 700, Section IV, Sea and Swell. Wash., DC, 227 pp.

Vincent, C. E., D. J. P. Swift and B. Hillard. 1981. Sediment transport in the New York Bight, North American Atlantic shelf. In: Sedimentary Dynamics of Continental Shelves, C. E. Nittrouer (Ed.). Elsevier, New York, pp. 369-398.

Vincent, C. E., R. A. Young and D. J. P. Swift. 1982. On the relationship between bedload and suspended sand transport on the inner shelf, Long Island, New York. J. Geophys. Res. 87(C6):4163-4170.

Data obtained by a near-bottom Profiling Concentration and Velocity system (PCV), deployed in 10 m water depth at a site 1 km from the Long Island coastline, are used to examine links between bedload and suspended sand concentrations. Calculations of bedload areal concentration C* are based on the empirical results of Vincent et al. (1981) and use the theoretical formulations of Grant and Madsen (1978, 1979) to describe the interaction between wave and current boundary layers. Suspended sand concentrations were obtained directly from an Acoustic Concentration Meter (ACM). Average suspended sand profiles C_z were found to fit closely to a log-linear profile $C_z = C^1(1-A \log_e z/z^1)$, where C_1 is the sand concentration at a height $z_1=1$ cm from the bed and A is empirically determined as 0.22 ± 0.005. A linear correlation is observed between the areal bedload concentration C* (the volume of bedload per unit area of the bed) and the suspended sand concentration 1 cm above the bed C_1, with a coefficient of 0.82 (significant at the 1% level), and supports the hypothesis of Einstein (1950) that bedload and suspended load are related through bedload concentration. It is also shown that the sedment threshold criterion of Komar and Miller (1973), when expressed as a ratio (here called the Komar ratio), can be used as a useful predictor for C_1 under conditions where the wave orbital currents are much greater than the mean flow. These relationships offer the opportunity for the calculation of both bedload and suspended sand transport rates from measurements of the steady current velocity and wave parameters, combined with information defining the surficial sediments and local bottom topography.

Voorhis, A. D., D. C. Webb and R. C. Millard. 1976. Current structure and mixing in the shelf/slope water front south of New England. J. Geophys. Res. 81(21):3695-3708.

Horizontal and vertical currents in the front along the edge of the continental shelf south of New England during the late spring were measured by tracking special neutrally buoyant floats which tagged different water masses. The mean current (10-20 cm s^{-1}) was westward along the shelf and was confined completely to the overlying shelf water with a geostrophic transport of about 0.7 sverdrups between the 80- and 300-m isobaths. No mean cross-shelf or vertical currents could be reliably measured. Higher-frequency currents were detected and are described. Numerous conductivity-temperature-depth lowerings were made over the drifting floats to examine the interleaving process and possible mixing between shelf water and slope water. The layers are thinned by vertical shear, and they gain and lose both heat and salt on a time scale of 1-3 days. This plus the rich microstructure suggests the existence of vertical turbulent exchange between layers having a turbulent diffusivity of the order of cm^2s. Estimates of net annual heat and salt input to the shelf are made, and they appear to be significant in determining the heat and salt budget of the shelf water mass.

Vukovich, F. M. and B. W. Crissman. 1981. Monitoring the Chesapeake Bay using satellite data for Superflux III. In: Chesapeake Bay plume study: Superflux 1980. Campbell, J. W. and J. P. Thomas (Eds.). NASA Conf. Publ. 1980, NOAA/NEMP III 81ABCDFG0042. NTIS, Springfield, VA, 5aa pp.

Walford, L. A. 1938. Effects of currents on the distribution and survival of eggs and larvae of haddock (Melanogrammus aeglefinus) on Georges Bank. Bull. U.S. Bur. Fish. 29:1-73.

Walford, L. A. and R. I. Wicklund. 1968. Monthly sea temperature structure from the Florida Keys to Cape Cod. Serial Atlas of the Marine Environment Folio 15, Amer. Geogr. Soc.

Walsh, J. J., T. E. Whitledge, F. W. Barvenik, C. D. Wirick, S. O. Howe, W. E. Esais and J. T. Scott. 1978. Wind events and food chain dynamics within the New York Bight. Limnol. Oceanogr. 23(4):659-683.

Time series of wind, current, nutrients, chlorophyll, and zooplankton are used to examine the effect of storm events on the food chain dynamics of the New York Bight. Storms cause dilution of phytoplankton concentration in the vertical plane, but lead to aggregation of chlorophyll in the horizontal field. Nutrients are made available with onshore flow in response to wind events favorable for upwelling. A series of nutrient budgets suggest that storm-induced mixing and upwelling of nitrate may satisfy at least 33% of the productivity demand of this system. Examples of the biological response to storms are drawn from 20 cruises during January, March, April-May, and August-September 1974, 1975, 1976 and 1977 under mixed and stratified conditions of the water column. The interaction of storms and seasonal stratification suggests predictable structure and frequency of chlorophyll distribution across the shelf which may influence both the survival strategies of herbivores and the loci of energy transfer to the rest of the food chain.

Wang, D. P. 1979. Low frequency sea level variability on the Middle Atlantic Bight. J. Mar. Res. 37:683-697.

Low-frequency sea level fluctuations on the Mid-Atlantic Bight, from Cape Cod to Cape Hatteras, and their relations to wind forcing were examined over a one-year (1975) period. The dominant sea level fluctuations occurred at time scales of 4 days, and they were coherent over the entire Bight. On the other hand, sea levels were not coherent between the southern (south of Kiptopeake B.) and northern part at shorter time scales.

Local wind forcing was important from Cape Cod to Mape May; most of the sea level change was driven by the alongshore (northeast-southwest) wind. In addition, the east-west wind set up a large surface slope between Nantucket and Sandy Hook. The wind set-up may be due to the bent coastline around Sandy Hook; the frictional effect may also play a role.

South of Cape May, the local alongshore wind forcing was dominant at time scales shorter than 3.3 days (in winter). At longer time scales, contribution from free shelf waves was significant. A southward phase propagation of 600 km/day was found between Cape May and Cape Hatteras, which is consistent with the shelf wave model. The dominance of free waves apparently was due to the lack of coherent wind forcing south of Cape May.

Wang, D. P. 1979. Subtidal sea level variations in the Chesapeake Bay and relations to atmospheric forcing. J. Phys. Oceanog. 9:564-572.

Wang, D. P. and A. J. Elliot. 1978. The effect of meteorological forcing on the Chesapeake Bay: The coupling between an estuarine system and its adjacent coastal water. In: Hydrodynamics of estuaries and fjords. (P. 127-145). J.C.J. Nihoul (Ed.). Elsevier, Amsterdam.

Warsh, C. E. 1975. Physical oceanography historical data for Deepwater Dumpsite 106. P. 105-140. In: May 1974 Baseline Investigation of Deepwater Dumpsite 106. NOAA Dumpsite Evaluation Report 75-1. U.S. Dept. Comm. and Environ. Protection Agency.

Warsh, C. E. 1975. Physical oceanographic observations at Deepwater Dumpsite 106, May 1974. P. 141-188. In: May 1974 Baseline Investigation of Deepwater Dumpsite 106. NOAA Dumpsite Evaluation Report 75-1. U.S. Dept. Comm. and Environ. Protection Agency.

Webster, F. 1969. Vertical profiles of horizontal ocean currents. Deep Sea Res. 16:85-98.

* This report is an analysis of data collected by Richardson-type current meters suspended from moored buoys at Site D (39 deg. 20 min N., 070 deg. W) in the western North Atlantic. Thirty records representing 40 months of current profile data at approximated depths of 10, 100, 500, 1000 and 2000 m were taken. Conclusions from these polar derived vertical profiles are as follows: the mean velocity at Site D is to the west, with amplitude decreasing with depth; the kinetic energy of the time-dependent currents is proportional to the Brunt-Vaisala frequency; the mean speed at Site D is principally due to rectified time-dependent processes; time-dependent currents below the depth of the continental shelf show the shelf's restrictive influence; and the eddy transport of momentum changes sign at the depth of the shelf.

Welch, C. S. 1981. Mid-level intrusions at the continental shelf edge. J. Geophys. Res. 85(C11):11,013-11,019.

Observations across the continental shelf offshore from New Jersey in late summer 1976 show an intrusion of saline water at the mid-level of the water column across the shelf edge front, which appears in density only as an offshore thickening of the pycnocline. This internal density field produces horizontal pressure gradient forces within the pycnocline in the onshore direction. These forces, in the linearized equations of motion with a constant eddy viscosity, drive a circulation which resembles a double Ekman spiral for internal pressure vertical distributions which are thin with respect to the Ekman depth. For thick pressure distributions, the circulation is geostrophic. The resulting flow pattern has no net cross-shelf transport. For the continental shelf edge in the example, a northward geostrophic mid-level jet is predicted by the theory. Ekman depth, and thus the vertical coefficient of eddy viscosity, can be determined from hydrographic data describing an intrusion.

Whitcomb, V. L. 1970. Oceanography of the Mid-Atlantic Bight in support of ICNAF, September-December 1967. U.S. Coast Guard Oceanogr. Rep. No. 35, 157 pp.

Whitledge, T. E., A. Mattee, R. Waldhauer, J. J. Walsh, L. J. Castiglione, L. A. Codispoti, S. D. Howe, C. D. Wirich, and R. E. Tucker. 1976. Transient forcings of the lower trophic levels during the spring bloom within the New York Bight. Am. Soc. Limnol. Oceanogr., Spec. Symp 2:273-274.

* An objective analysis of a time series study of the spring bloom in the New York Bight across the continental shelf, south of Long Island, from March 26 to April 9, 1975 is presented. Measurements of temperature, salinity, irradiance, nutrients, chlorophyll, phytoplankton, particles, particulate nitrogen and carbon, zooplankton, primary production, respiration, and nitrate uptake over the two week period suggests maximum productivity and minimum grazing stress at midshelf.

Whitlock, C. H. and T. A. Talay. 1974. The influence of surface waves on water circulation in a Mid-Atlantic continental shelf region. NASA Tech. Note NASA TN D-7771. Langley Research Center, Hampton, VA 23665. 45 p.

The importance of wave-induced currents in different weather conditions and water depths (18.3 m and 36.6 m) is assessed in a mid-Atlantic continental shelf region. A review of general circulation conditions is conducted. Factors which perturb the general circulation are examined using analytic techniques and limited experimental data. Actual wind and wave statistics for the region are examined. Relative magnitudes of the various currents are compared on a frequency of annual occurrence basis. Results indicate that wave-induced currents are often the same order of magnitude as other currents in the region and become more important at higher wind and wave conditions. Wind-wave and ocean-swell characteristics are among those parameters which must be monitored for the analytical computation of continental-shelf circulation.

Wigley, R. L. and F. C. Stinton. 1973. Distribution of macroscopic remains of recent animals from marine sediments off Massachusetts. Fish. Bull. 71(1):1-40.

Williams, R. G. 1969. Physical oceanography of Block Island Sound. Nav. Underwater Sound Lab. Rep. No. 966.

Williams, R. G. and F. A. Godshall. 1977. Summarization and interpretation of historical physical oceanographic and meteorological information for the Mid-Atlantic region. U.S. Dept. Commerce, NOAA, Wash., DC. Final report to the Bur. of Land Management, U.S. Dept. of the Interior, Interagency Agreement AA550-IA6-12. 295 pp.

Wilson, Robert E. 1979. A model for the estimation of the concentrations and spatial extent of suspended sediment plumes. Estuarine & Coastal Mar. Sci. 9:65-68.

A simple model is presented for the spatial structure of suspended sediment plumes produced by over-board pipeline disposal of dredge spoil in shallow waters. The model is based on a solution to the advection-diffusion equation for a continuous vertical line source. It provides information on the variation of both centerline concentration and the second moment of the lateral distribution with distance from the source. The structure of the plume is described by only two parameters: one proportional to the settling velocity of the suspended material and the other equal to the ratio of a diffusion velocity to the advective velocity of the ambient flow. The model has been applied to represent the structure of observed suspended sediment plumes at three separate shallow water sites.

Winant, C. and R. Beardsley. 1979. A comparison of some shallow wind-driven currents. J. Phys. Oceanog. 8:218-220.

Worthington, L. V. 1964. Anomalous conditions in the slope water area in 1959. J. Fish. Res. Bd. Canada 21:327-333.

Wright, W. R. 1976. The limits of shelf water south of Cape Cod, 1941 to 1972. J. Mar. Res. 34(1):1-14.

Some 19,000 bathythermograms and 1,600 oceanographic stations in the region 39° to 41°N, 69° to 72°W have been examined for evidence of changes in the character and position of the shelf water/slope water boundary. Results show a) the boundary, identified by the 10° isotherm, intersects the bottom within 16 km of the 100-m curve about 80 percent of the time, with a seasonal progression from the south in the winter to north in the fall; b) at the sea surface the boundary position is much more variable, averaging 52 km seaward of the 100-m curve in winter and 72 km seaward in late summer; c) detached parcels of shelf water are found in the slope water at all times of the year, with maximum occurrence in late spring and early summer; and d) the combination of entrainment at Hatteras and production of detached parcels appears to account for the shelf water/slope water exchange required by salt balance considerations.

Wright, W. R. 1976a. Physical oceanography - The western slope water. In: Summary of Environmental Information on the Continental Slope Canadian/U.S. Border through Cape Hatteras. Manuscript submitted to U.S. Bur. Land Management, Marine Minerals Div. NTIS Publ. 2840000/AS.

Wright, W. R. and C. E. Parker. 1976. A volumetric temperature/salinity census for the Middle Atlantic Bight. Limnol. Oceanogr. 21(4):563-571.

Yentsch, C. S. 1977. Plankton production. MESA N.Y. Bight Atlas Mongr. No. 12, N.Y. Sea Grant Institute. Albany, NY. 25pp.

* Physical and biochemical factors controlling primary production in Bight waters are described. High temperatures attribute to increased vertical mixing during winter and strongly stratified waters during summer. Low productivity during summer is caused by limited nitrogen supplies in the euphotic zone. Productivity of the slope waters is limited by vertical mixing. The spring bloom stems from decreased vertical mixing induced by solar radiation and relaxation of winds. Autumn productivity is increased resulting from a breakdown in the summer thermocline induced by colder temperatures and increased winds.

Young, R. A. 1978. Suspended matter distribution in the New York Bight apex related to Hurricane Belle. Geology 6:301-304.

Young, R. A., T. L. Clarke, R. Mann, and D. J. P. Swift. 1981 Temporal variability of suspended particulate concentrations in the New York Bight. J. Sed. Petrology 51(1): 0293-0306.

Temporal variability observed in several time series of suspended matter measurements, obtained by light scattering and conventional water sampling, has been examined to identify significant time scales with respect to synoptic characterization of regional suspended matter distributions in the inner New York Bight. Processes with periods corresponding to surface waves (seconds) and storms (days) apparently make the strongest contributions to overall concentration variability, and tidal motions appear to have only a weak influence on near-bottom suspended load. An empirical model is proposed which assumes that concentration variance is linearly related to the mean concentration, both increasing in response to such processes as wind-wave mixing and boundary layer interactions with the bottom. Data obtained during the study support the model. This model is used in a numerical experiment which suggests that fair-weather variability in processes affecting near-bottom concentrations is probably not sufficient to cause serious errors in suspended matter studies in the New York Bight.

Zimmerman, Herman B. 1971. Bottom currents on the New England continental rise. Jour. Geophys. Res. 76(24):5865-5876.

Current meters were placed approximately 2 meters off the bottom at depths from 2900 to 5000 meters on the continental rise near the New England seamount chain. Current velocities greater than 15 cm/sec were recorded in a west-southwest direction, parallel to the regional contours. The greatest velocity recorded was 26.5 cm/sec toward the southwest. Spectrum analyses of the time-series curves have resolved periodic motions superimposed on secular, contour-following trends. An interaction between the contour current and the Gulf Stream is also apparent. These data suggest that the contour current, a Western Boundary Undercurrent, is competent to transport and erode continental rise sediments. A significant sediment dispersal system parallel to the regional slope is confirmed to be operative on the present-day continental rise.