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FLOW ALONG THE CONTINENTAL SHELF SOUTH OF NANTUCKET ISLAND

by

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ABSTRACT

Current meter data and associated hydrography were collected for one year across the continental shelf and upper slope south of Nantucket Island. Comparisons between velocities calculated from the density field and measured by current meters indicated that the baroclinic flow was in geostrophic balance. A mean volume transport of Shelf Water for the first six months was found to be 0.39×10^6 m^3/sec to the west - northwest along the contours of the local bathymetry.

RÉSUMÉ

Données de compteur de courant et d'hydrographie associés ont été rassemblés pendant un ans au travers le plateau continental et la pente supérieur au sud de l'isle Nantucket. Comparisons entre vélocitées calculées du champ de densité et mesurées par compteurs de courant indiquent que le flot baroclinque est en équilibre géostrophique. La moyenne de transport volumétrique d'eau de plateau pour les premiers six mois était 0.39×10^6 m^3/sec vers le ouest - nordouest le long des contours bathymétrique local.

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INTRODUCTION

For the past five years oceanographers in the United States and Canada have made current measurements at critical locations on the continental shelf of eastern North America from Cape Hatteras to Nova Scotia in an effort to determine the general circulation of this economically important region.

As part of this enterprise the Nantucket Shoals Flux Experiment was carried out from March 1979, to April 1980, to measure the flow between the Gulf of Maine - Georges Bank region and the Middle Atlantic Bight, two major interconnected components of the shelf system. The principal objectives of the experiment were 1) to measure flux of heat, salt, and nutrients between the two regions; 2) to determine cross-shelf flux in the vicinity of Nantucket Shoals; 3) to observe the effect of any warm-core rings of Gulf Stream origin which might pass through the area; and 4) to investigate hypotheses about transport of sediments, fish eggs, and larvae along the shelf.

The experiment was a joint effort by oceanographers from the National Marine Fisheries Service's Northeast Fisheries Center (NEFC), the Woods Hole Oceanographic Institution (WHOI), the U.S. Geological Survey (USGS), and the University of New Hampshire (UNH) involving two major efforts: 1) an array of moored current meters and other instruments across the shelf south of Nantucket Island; and 2) a series of hydrographic sections along the transect to identify shifts in the characteristics and positions of water masses. Both types of measurements were collected for a year to obtain some idea of seasonal variability.

This paper presents a calculation of the mean flow of shelf water measured by current meters during the first six months of the experiment and a comparison of directly measured flow with geostrophic velocities calculated from data obtained during hydrographic sections.

Mooring Array Design

Six moorings designated N1 through N6 were deployed 15-23 km apart along the transect shown in Figure 1. The schematic cross section (Figure 2) shows the total instrumentation: 19 Vector Averaging Current Meters (VACMs), three Conductivity-Temperature-Pressure recorders (CTPs), and one tripod to measure bottom sediment transport. Meters were not placed shoreward of the 45 m isobath because Beardsley et al. (1978) estimated that very little transport occurs there due to damping by large tidal currents. The single current meter at N6 was set beyond the shelf in an attempt to include the entire Shelf Water - Slope Water front within the transect and to obtain observations in warm-core rings. It was reasoned from past observations that the front would remain north of N6.

The Shelf Water - Slope Water Front

The front separating Shelf Water from warmer, more saline Slope Water was monitored by temperature and salinity data gathered throughout the year. The example in Figure 3 shows that either the 10°C isotherm or the 35‰ isohaline can be used to define the front following Wright and Parker (1976). Salinity was chosen to position the front because it is conservative in the surface layer while temperature can vary seasonally.

The intersection of the front and the ocean floor varied between the 95 m and the 160 m isobaths throughout the year but commonly stayed near the 100 m isobath in agreement with Wright (1976). The front surfaced most often between N5 and N6 except in three sections where the intersection was south of N6. Extrapolation of the isohalines in those cases suggests that the front surfaced within 10 km of N6.

Gordon and Aikman (1980) postulate that shoreward movements of the front are attributable to intrusions of Slope Water along isopycnal surfaces. These are closer to horizontal in summer than in winter due to the development of the seasonal thermocline. Temperature and salinity sections drawn for each cruise made during the year of the Nantucket Shoals Flux Experiment (Table 1) indicate slight Slope Water intrusion at the surface on May 30, 1979, a large mid-water intrusion to the 100 m isobath on July 8, 1979, and a near-surface intrusion on July 23, 1979. Other patterns of intrusions and seasonal variations are not apparent.

Six Month Mean Volume Transport of Shelf Water

Direct measurements from the first six months of the experiment have been used to calculate mean transport of Shelf Water. Original time series of 15-minute averages for east velocity component, north velocity component, and temperature were vector averaged to form time series of one hour then low-pass filtered to eliminate periods shorter than 33 hours. The velocity components were rotated 15 degrees clockwise to resolve the current into components perpendicular to the transect (parallel to the bathymetry) and along the transect. The six-month means calculated from these series are shown in Figure 4. Velocity estimates for missing data due to the failure of three current meters were made by studying coherence between adjacent instruments (Figure 4).

The area covered by the transect was divided into boxes with a current meter at the center of each. It was then assumed that the flow through each box could be represented by the mean velocity of the enclosed current meter.

Details of the assignment of the boxes appear in Figure 5. Volume transport was calculated for the individual areas by multiplication of the perpendicular component of the mean velocity by the area, then summed for the entire section. To obtain only Shelf Water volume transport it was necessary to subtract the area of Slope Water on the seaward side of the front. A mean position of the front was determined from ten salinity sections (Figure 5). The net transport of Shelf Water for the period of six months from March 1979, to September 1979, was determined to be 0.39 x 10^6 m^3/sec (0.39 sv.).

A Comparison of Geostrophic Velocities with Velocities from Current Meters

Stations on four of the ten hydrographic sections made during the first six months were positioned so that geostrophic velocities could be compared to the velocities from the current meters. Direct comparisons were possible because the areas between adjacent stations were the same areas that the velocities from current meters represented (Figure 5). The geostrophic velocities were calculated by classical methods with the level of no relative motion chosen to be the deepest common depth between two stations. This was always within 5 meters of the bottom of the shallower stations. For each comparison an average of VACM velocities corresponding to the length of time it took to complete the hydrographic section was taken from the filtered time series. These averages ranged from 12 to 24 hours, over at least one semidiurnal tidal cycle.

The two methods were compared by plotting velocity against depth, assuming the geostrophic velocity acted at each mooring site. Four examples shown in Figures 6 and 7 indicated very reasonable correlations. The geostrophic velocity profiles could be closely aligned to the current meter profiles by adding an individual barotropic component for each comparison. The baroclinic velocities across the line of the Nantucket Shoals Flux Experiment appear to be in geostrophic balance.

DISCUSSION

The calculated mean transport may slightly underestimate the true mean flux of Shelf Water through the transect of the Nantucket Shoals Flux Experiment. Near the shallower end of the transect, volume transport did not decrease as significantly as expected. Mean flux through the area around N1 was 0.07 x 10^6 m^3/sec, or 18% of the total flux through only 17% of the total area. The indication is that volume transport between N1 and Nantucket Island could add perhaps 10% to our measured total. However, water depth decreases rapidly north of N1 so friction and large tidal currents may significantly reduce the flux through that area.

Our mean number of 0.39 x 10^6 m^3/sec is comparable with previous estimates of mean flux on the continental shelf of eastern United States and Canada. Beardsley et al. (1976) used current meters to measure velocity through a transect about one-half of a degree of longitude west of the present transect during March 1974. The mean transport inside the 100 m isobath was calculated as 0.17 x 10^6 m^3/sec to the southwest. VACM data from the Nantucket Shoals Flux Experiment show a mean transport of 0.25 x 10^6 m^3/sec inside the 100 m isobath for the first six months.

Using direct current measurements to adjust geostrophic estimates, Flagg (1977) calculated transport on the New England continental shelf to be 0.62 x 10^6 m^3/sec, but estimated 0.4 x 10^6 m^3/sec as a more reasonable long-term mean. He also estimated that one-third of the total Shelf Water transport occurs in the wedge above the front. Our measurements support this estimate. Thirty-five percent, or 0.14 x 10^6 m^3/sec of the calculated total flux of Shelf Water passed through this wedge.

Hydrographic data has been collected since 1950 approximately once every season along a transect southeast of Halifax, Nova Scotia. Drinkwater et al. (1979) calculated an annual mean of geostrophic volume transport over the Scotian Shelf to be 0.35 x 10^6 m^3/sec to the southwest which is similar to our figure.

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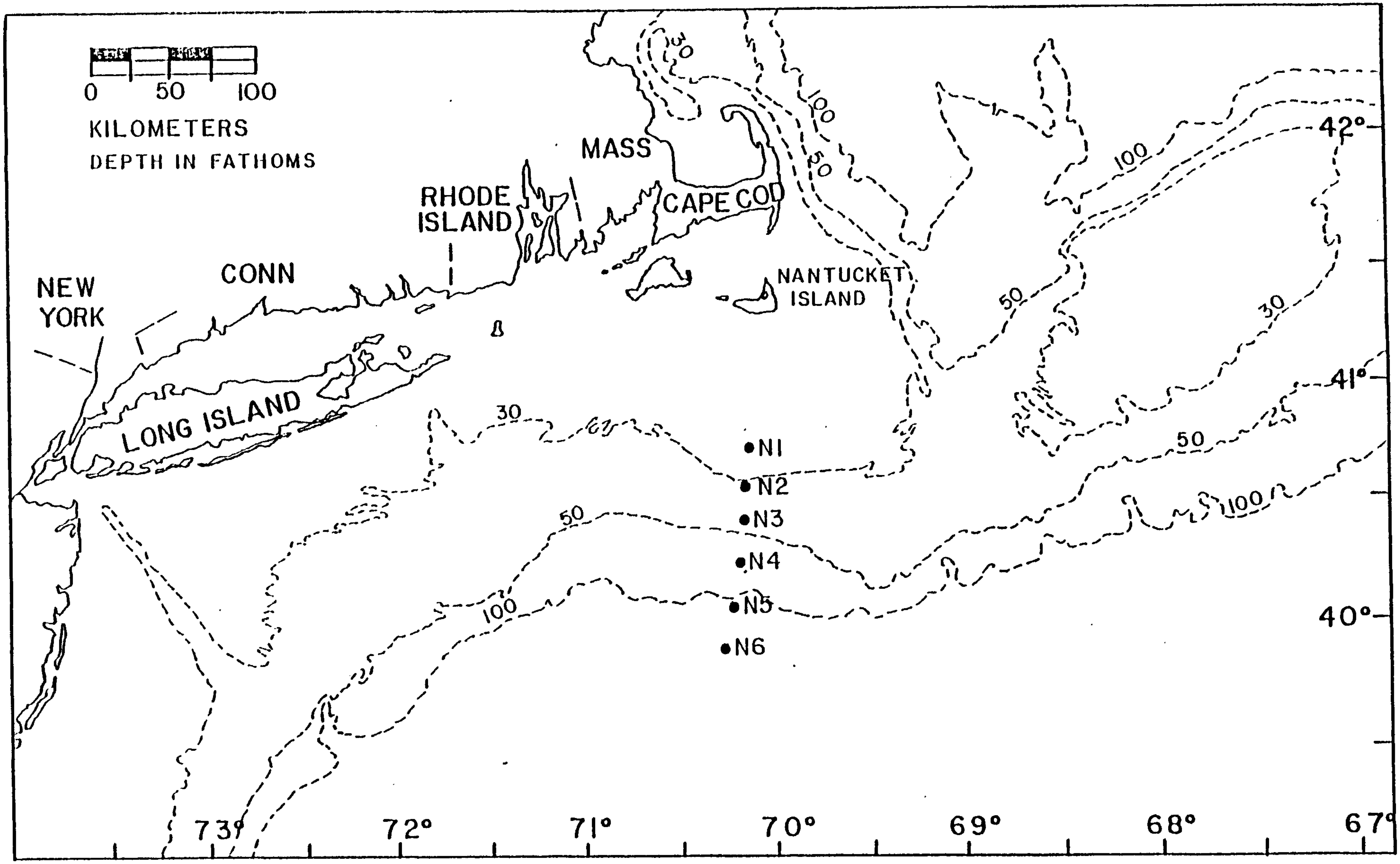
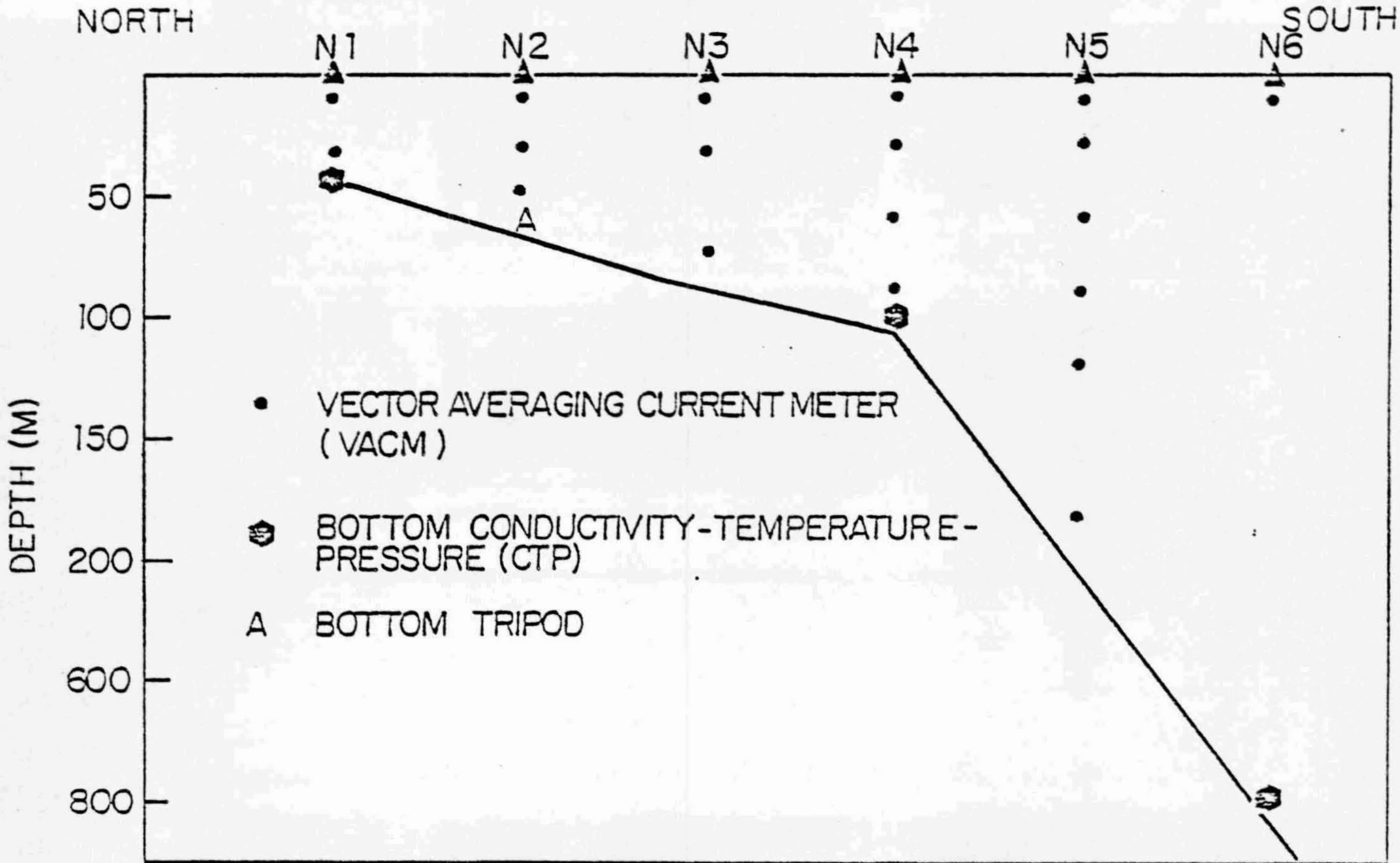


Figure 1. Positions of moorings for the Nantucket Shoals Flux Experiment array from March,1979, to April,1980.



MOORING DESIGNATION	LAT/LONG	WATER DEPTH(m)	INSTRUMENTATION
N1	40°41.7' 70°08.6'	46	10m VACM/NEFC 32m VACM/NEFC Bottom CTP/UNH
N2	40°30.0' 70°13.0'	66	10m VACM/USGS 31m VACM/USGS 51m VACM/USGS Bottom Tripod/USGS
N3	40°20.7' 70°16.1'	88	10m VACM/NEFC 32m VACM/NEFC 72m VACM/NEFC
N4	40°12.9' 70°18.2'	105	10m VACM/NEFC 29m VACM/NEFC 59m VACM/NEFC 89m VACM/NEFC Bottom CTP/UNH
N5	40°02.2' 70°22.3'	198	10m VACM/WHOI 29m VACM/WHOI 59m VACM/WHOI 89m VACM/WHOI 118m VACM/WHOI 182m VACM/WHOI
N6	39°51.18' 70°25.4'	810	10m VACM/NEFC Bottom CTP/UNH

Figure 2. Schematic cross section and data of the mooring array for the Nantucket Shoals Flux Experiment.

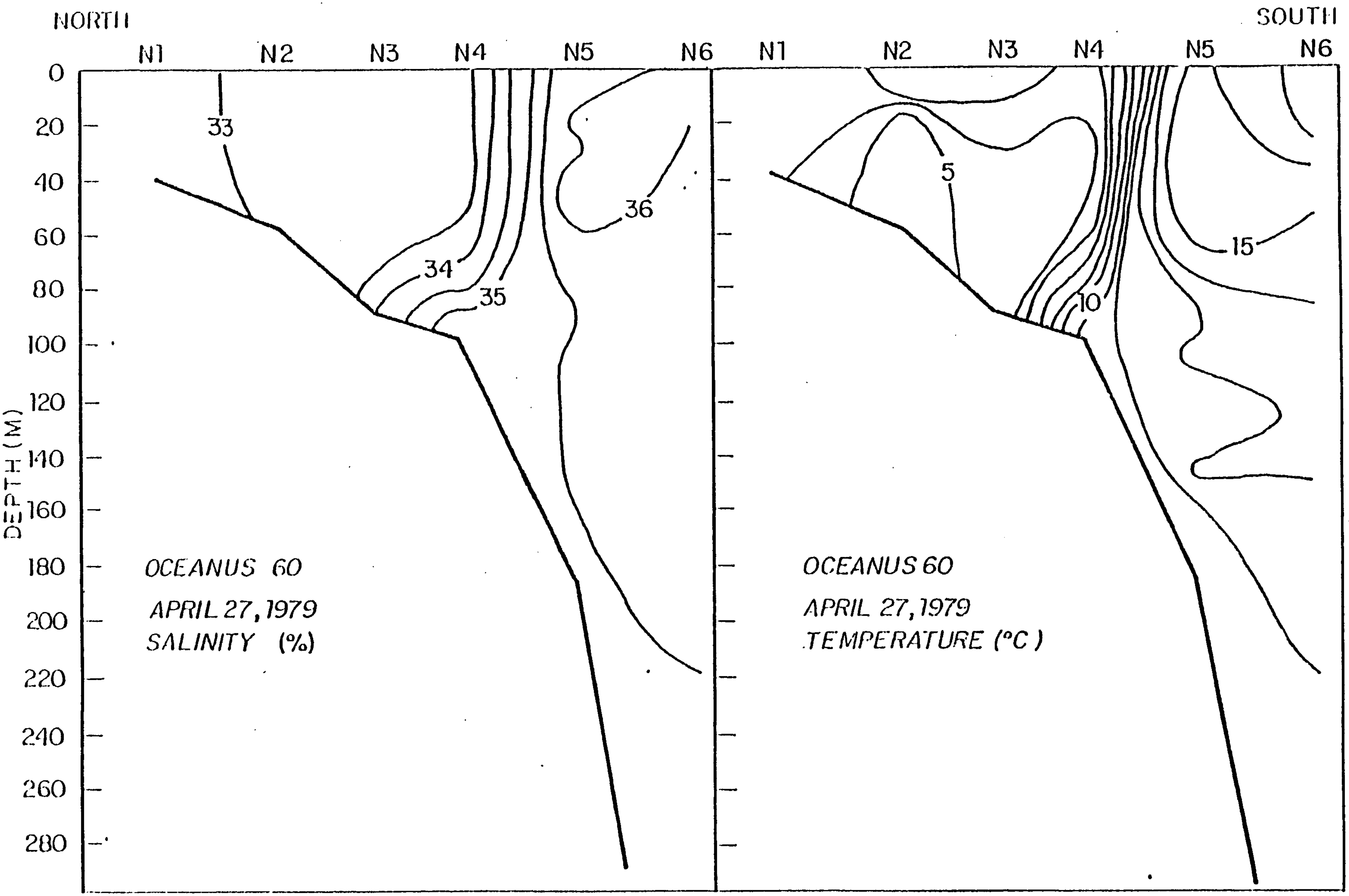


Figure 3. Temperature and salinity sections along the line of current meters from the Nantucket Shoals Flux Experiment showing the Shelf Water - Slope Water front. Note the warm, saline water of a warm - core Gulf Stream ring between N5 and N6.

Table 1. Dates of hydrographic sections along the line of moored instruments used to compute geostrophic velocity. The starred cruises made stations positioned so that the resulting geostrophic velocities could be directly compared to the current meter velocities.

DATE	CRUISE
Mar. 20-21, 1979.	OCEANUS 57*
Mar. 25,26, 1979.	EASTWARD, SWIG I, LEG 1*
Mar. 28-29, 1979.	EASTWARD, SWIG I, LEG II*
Apr. 7, 1979.	OCEANUS 60
May 18, 1979.	DELAWARE II 79-05
May 30, 1979.	WHITING 79-01*
July 8, 1979.	ALBATROSS IV 79-06
July 23, 1979.	ALBATROSS IV 79-07
Aug. 22, 1979.	BELOGORSK 79-01
Sep. 7, 1979.	ALBATROSS IV 79-09
Oct. 18, 1979.	ALBATROSS IV 79-11
Oct. 25, 1979.	ANTON DOHRN - LEG I
Nov. 13, 1979.	ANTON DOHRN - LEG II
Dec. 19, 1979.	ALBATROSS IV 79-13
Mar. 7, 1980.	WIECZNO 80-02
Mar. 19, 1980.	ALBATROSS IV 80-02
Apr. 16, 1980.	ALBATROSS IV 80-04

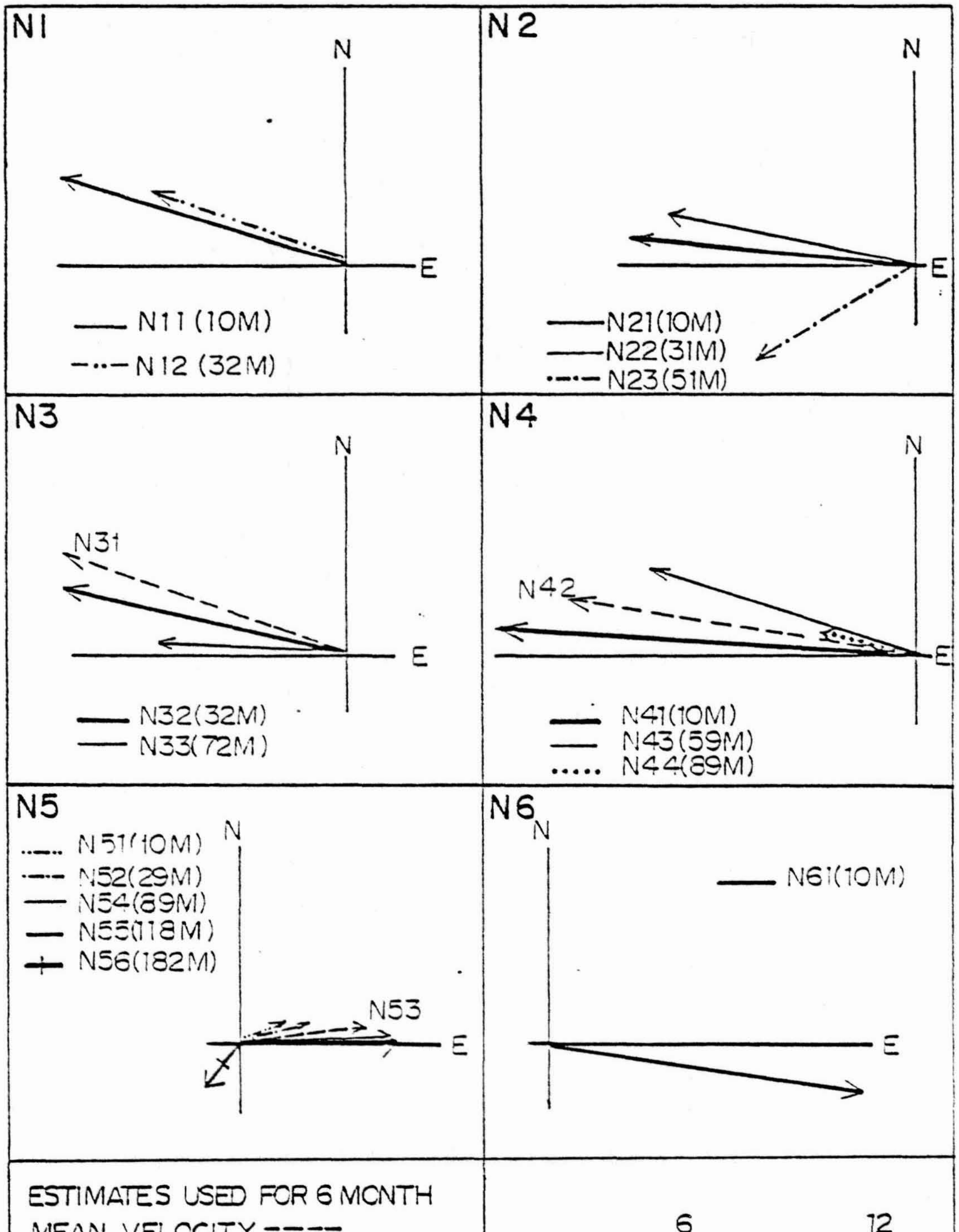


Figure 4. Mean velocities from current meters for the first six months of the Nantucket Shoals Flux Experiment.

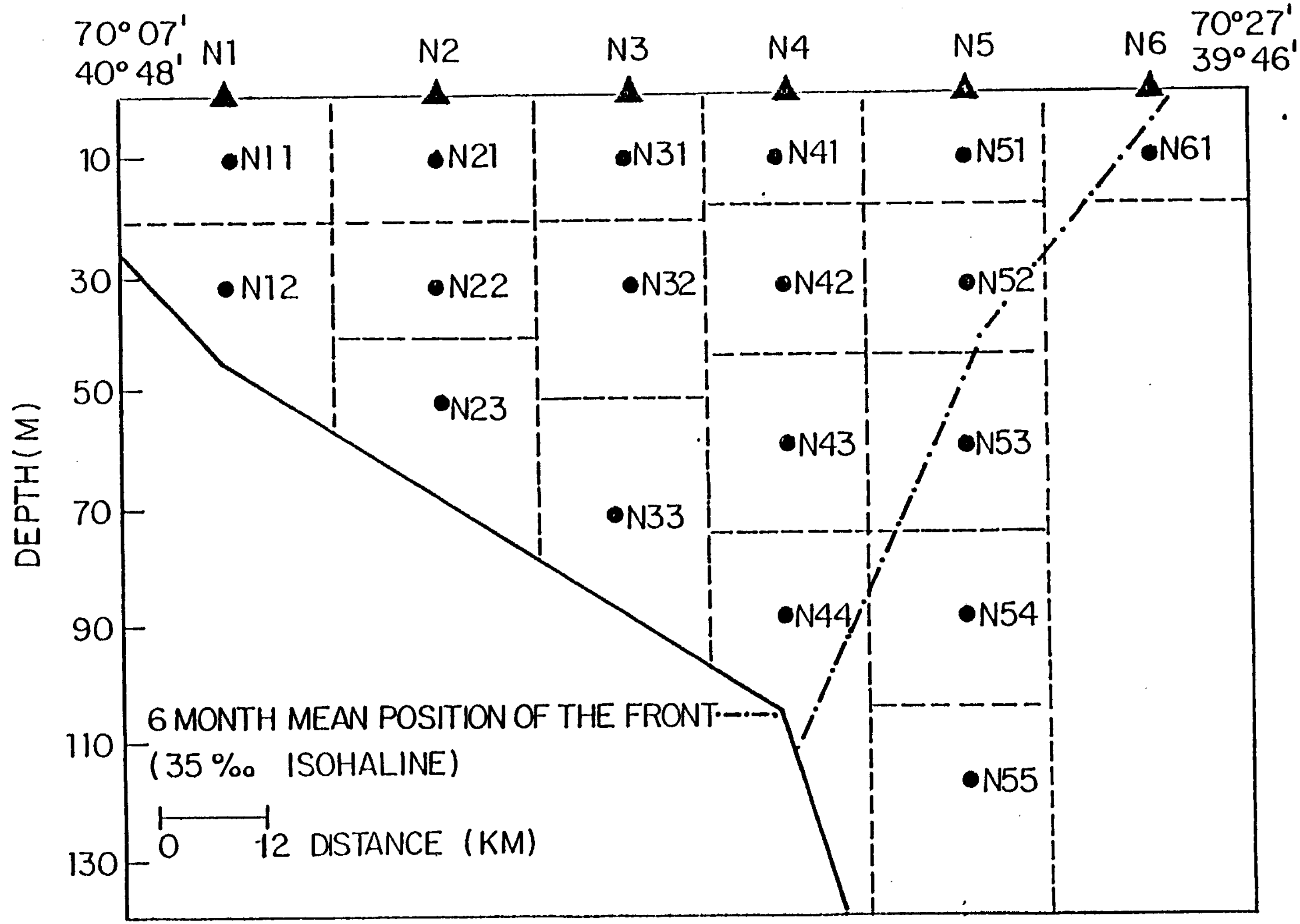


Figure 5. Areas assigned to each current meter for volume transport calculations. Only areas shoreward of the mean front were included in the estimate of Shelf Water transport.

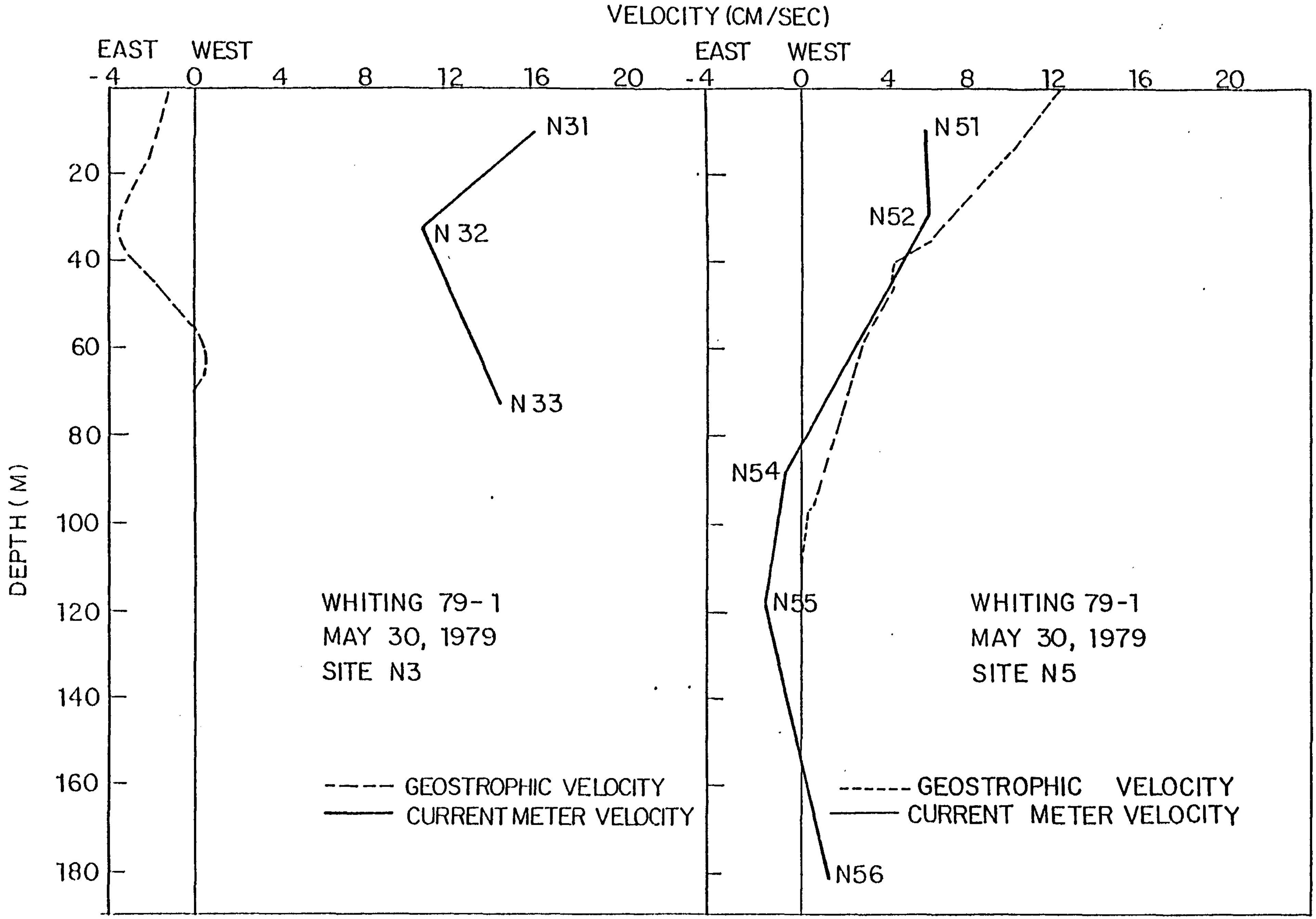


Figure 6. Comparisons of directly measured velocities with geostrophic velocities for the Nantucket Shoals Flux Experiment. The bottom depth of the dashed line is the depth of the level of no motion.

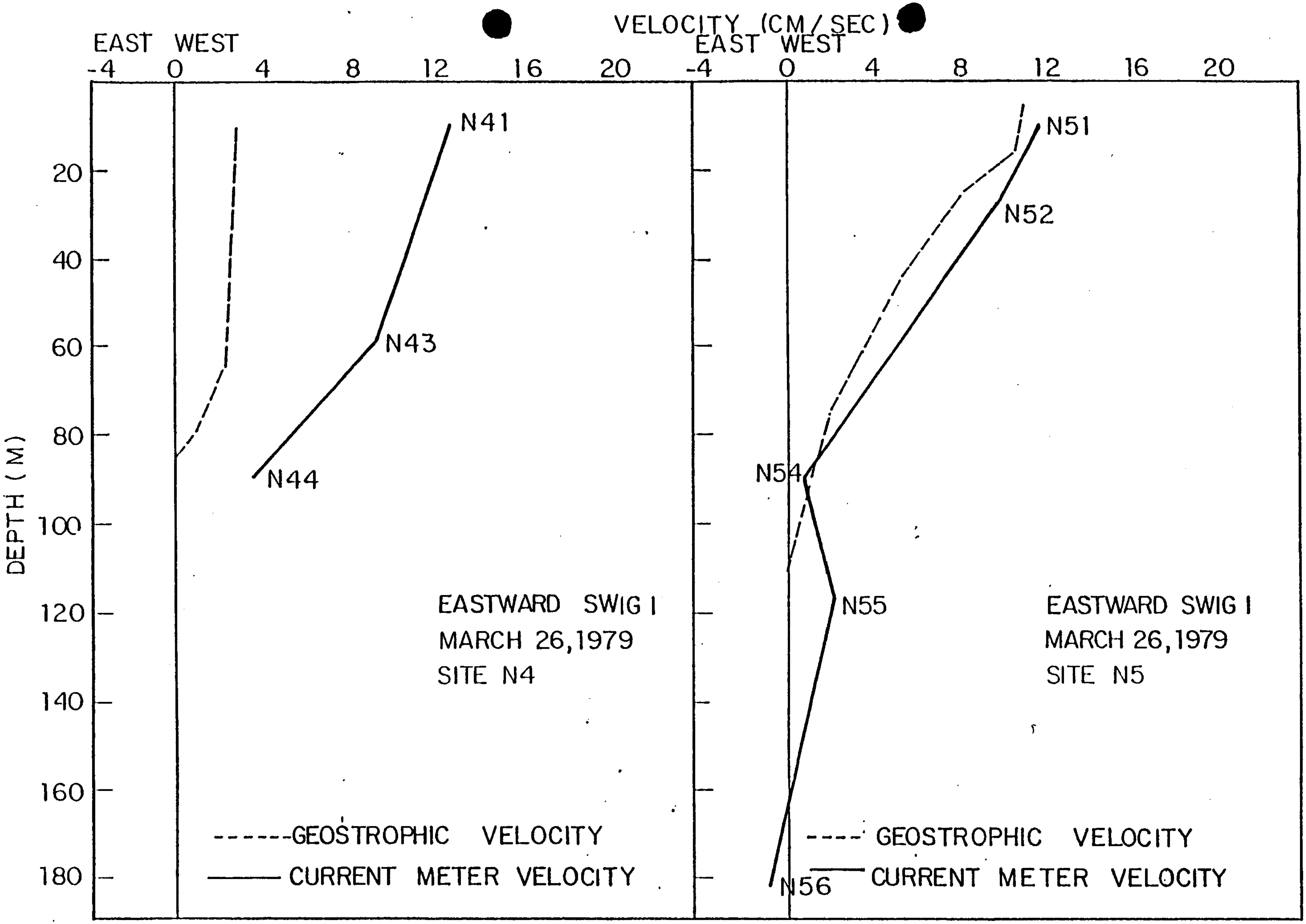


Figure 7. Comparisons of directly measured velocities with geostrophic velocities for the Nantucket Shoals Flux Experiment. The bottom depth of the dashed line is the depth of the level of no motion.