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Anticyclonic warm core Gulf Stream eddies off the Northeastern United States during 1978

By

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This report summarizes for the fifth year, 1978, the movements of anticyclonic Gulf Stream eddies in the slope water region off the New England and Middle Atlantic coasts. Similar reports were prepared by Bisagni (1976) for the years 1974-75, and by Mizenko and Chamberlin (1979a, b) for 1976 and 1977.

INFORMATION SOURCES AND ANALYSIS METHODS

Methods are as described in Mizenko and Chamberlin (1979a) in regard to delimiting the surface boundaries of the eddies to include rings of entrained shelf, slope, and Gulf Stream water which often appear around the periphery, as seen in infrared satellite imagery.

The positions and surface boundaries of the eddies were estimated (1) during January to June from the Experimental Ocean Frontal Analysis charts, issued weekly by the U.S. Naval Oceanographic Office, (2) during July to December 1978 from the satellite derived Gulf Stream Analysis charts, which are issued weekly by the National Environmental Satellite Service, and (3) during the entire year from infrared imagery from the NOAA Geostationary Operational Environmental Satellite (GOES-4).

In the reports for 1976 and 1977, eddy positions were plotted only when visible in infrared imagery. In the present report, interpolated weekly positions are also plotted (open circles) for the periods when the imagery was cloud-obscured. Through inclusion of the interpolated positions, the maps give a ready impression of where there were large changes in the rates of eddy movement.

EDDY HISTORIES:

Eleven eddies were identified and tracked during 1978. Their formation and destruction dates, as well as lifetimes, are listed in table 1. Two of the eleven eddies (77-D and 77-I) originated in 1977, and nine in 1978. The movements of 77-D and 77-I during 1977 were charted by Mizenko and Chamberlin (1979).

Eddy 77-D (fig. 1), which formed east of Georges Bank about 29 March 1977, had already entered the slope water area south of New England at the beginning of 1978. Its surface diameter was about 220 km (120 nm). After moving southwest to the latitude of Delaware, the eddy was destroyed about 17 February by encroachment of a broad Gulf Stream meander that approached the continental slope north of Cape Hatteras.

Eddy 77-I (fig. 2), which formed south of Georges Bank about 16 July 1977, was southwest of Hudson Canyon at the beginning of 1978, and its surface configuration abnormally stretched out adjacent to the continental shelf. Its greatest diameter was about 220 km (120 nm) and its least diameter about 93 km (50 nm). It decreased greatly in size during January as the Gulf Stream meandered shoreward and appeared to squeeze it against the continental slope. The last remnant of the eddy was visible in satellite imagery on 12 February in the vicinity of Washington Canyon (37.7°N).

Eddy 78-A (fig. 3) formed from a large westward extending Gulf Stream meander south of Georges Bank on about 21 April, with its center at about 67.0°W, and surface diameter ≈165 km (about 90 nm). During the second and part of the third week of May, 78-A was surrounded and then overridden by Gulf Stream water, but by 23 May, the eddy had again become totally detached, although entrainment of eddy water by the Stream was apparent. During the third week of August when 78-A was in the offing of

Hudson Canyon, it was again overridden by Gulf Stream water. Its subsequent separation from the Stream was not observed, because of cloud obscured satellite imagery during the following 30 days, but clear imagery on 20 September showed it located southeast of Delaware Bay. Eddy 78-A then moved south to the latitude of southern Virginia and was destroyed by the Stream during the latter part of October.

Eddy 78-B (fig. 4) lived less than a month. Forming about 21 April from a northward extending Gulf Stream meander centered at about 64.5°W, it had a surface diameter of approximately 185 km (100 nm). 78-B moved only about 55 km (30 nm) westward until overridden and resorbed about 17 May by another Gulf Stream meander in the vicinity of 65.0°W.

Eddy 78-C (fig. 5) was even shorter lived than 78-B. Forming about 20 May from a Gulf Stream meander in the vicinity of 61.8°W, it had an apparent surface diameter of ≈220 km (120 nm). By June 1, 78-C had moved about 55 km (30 nm) westward to a position centered at 62.3°W, where it was enveloped by the same Gulf Stream meander that had resorbed 78-B.

During early June the meander that had resorbed 78-B and 78-C became elongated toward the west, and on about 12 June, a new eddy, 78-D (fig. 6), centered at about 39.0°N 65.5°W, formed from it. 78-D, with an initial surface diameter of about 240 km (130 nm), moved westward at a steady rate until about 6 September, and then remained rather stationary in the vicinity of 69.8°W until 10 October. The eddy moved generally westward during the balance of October, then to the southwest during the period from mid-November to mid-December, and was finally destroyed by the Stream east of southern Virginia (36.5°N), at the end of the year.

Eddy 78-E (fig. 7) first appeared immediately to the northeast of 78-D and only a few days after the latter eddy had detached from the Stream. Although its origin was somewhat obscure in satellite imagery, it presumably derived from the same huge meander that formed 78-D. It was initially centered at about 40.0°N 64.0°W, with an initial surface diameter of about 220 km (120 nm). 78-E moved generally westward until 22 August, when it was centered at about 66.8°W. It then remained rather stationary until 6 September when it was resorbed by a northward extending meander of the Gulf Stream, which simultaneously resorbed eddy 78-F.

Eddy 78-F (fig. 8) formed at about 60.5°W, on about 17 June, with a surface diameter of about 175 km (95 nm). It moved to the west and then southwest through the summer until about 6 September when it was at about 65.0°W and coalesced with the east side of the same Gulf Stream meander that resorbed eddy 78-E farther to the west on the same day.

The origin of eddy 78-G (fig. 9) was not clear in satellite imagery, but it apparently formed on about 11 July from a Gulf Stream meander that had propaged rapidly in a northwest direction in early July. It was initially centered at about 40.9°N 57.4°W and had a surface diameter of about 165 km (90 nm). It moved westward to about 61.0°W by 23 August and was enveloped by a northward extending Gulf Stream meander.

Eddy 78-H (fig. 10) appears to have formed at about 66.3°W on 10 October from the same large Gulf Stream meander that had resorbed eddies 78-E and F over a month earlier. This eddy was apparently short lived, and neither large nor strong. The apparent surface diameter was initially about 150 km (80 nm), but a week later, only about 110 km (60 nm). Its surface configuration was at no time well defined, even in clear satellite imagery, and its movements were minor. Last visible in satellite imagery at about 67.7°W, on 8 November, it presumably dissipated soon thereafter.

Although eddy 78-I (fig. 11) was first observed on 25 October centered at about 58.0°W, with a surface diameter of about 150 km (80 nm), its date and location of origin are unknown. It moved generally southward during the first month, and then westward to the end of 1978, when it was centered at about 60.5°W.

ZONAL ANALYSIS

Movements of all the eddies observed during 1978 are summarized in table 2, which includes the position of each eddy at the middle of each month with respect to the zones diagrammed in figure 12. The total eddy occurrences for all zones combined during 1978 was 32, while the average number of eddy occurrences for the previous four years was 33.

Envelopes of surface center positions and surface boundaries of eddies during 1978 appear in figure 13. Methods are as explained in Mizenko and Chamberlin (1979). Most eddy surface centers are found in the area between 38.5°N and 39.5°N latitude.

NUMBER OF EDDIES, TIMES OF FORMATION, AND LONGEVITY:

Production of anticyclonic Gulf Stream eddies off northeastern North America (west of 60.0°W) in 1978 followed a 9 month period, from mid-July 1977 to mid-April 1978, when no eddies were produced (table 1). Since 1974, when eddy tracking was started, the second longest interval between times of formation was 6 months. After the last of the 1977 eddies was destroyed in mid-February 1978, there was a 60-day period, ending in mid-April, when no anticyclonic eddies were apparent off the northeast coast (table 1). At all other times since 1973, when availability of high resolution infrared satellite imagery made eddy tracking practical, there have always been one or more eddies present off this coast.

The formation of 9 anticyclonic eddies in 1978 equaled the high production of 1977. In the earlier years for which eddy tracklines have been compiled, the numbers formed were 4 in 1974, 8 in 1975, and 7 in 1976. Production in 1978 was especially high from mid-April to mid-June, when 6 of the 9 formed (table 1). It is noteworthy that this production followed a record cold winter, much as was the case in 1977. There are significant differences as well as similarities between 1977 and 1978 in the timing of eddy production relative to the cold weather. The high rate of eddy production in 1977 occurred from January to mid-April, during which period 8 of the year's total of 9 were formed (Mizenko and Chamberlin 1979); the preceding period of abnormally cold weather extended from September 1976 to January 1977 (Diaz and Quayle 1978). In 1978, the high rate of eddy production, as noted above, occurred later than in 1977, and the preceding period of abnormally cold weather was also later, occurring predominantly during January and February, following a fairly normal fall (Wagner 1978).

Shipboard oceanographic observation in the northwestern Sargasso Sea during spring of both 1977 (Worthington 1977) and 1978 (Cheney 1978) further suggest a possible linkage between the high rates of eddy production and preceding cold weather. The 1977 observations revealed record deepening of the permanent thermocline and provided "the largest volume transport ever calculated for the Gulf Stream". A similarly great thermocline depth was again found in 1978, indicating that 1978 may also have been comparable to 1977 regarding volume transport of the Stream.

The 1978 eddies had much shorter lifetimes than those of 1977. Average longevity of 1978 eddies was only 84 days, but of 1977 eddies, 152 days. Maximum longevity of a 1978 eddy was 199 days, whereas the four longest lived 1977 eddies lasted about 185, 211, 273, and 334 days. The differences in longevity were clearly reflected geographically. Only two 1978 eddies lasted long enough to enter the waters off the Middle Atlantic States, but five 1977 eddies passed through this region. Because the eddies form from Gulf Stream meanders, and early destruction of eddies is also usually caused by these meanders, both the high rate of eddy production and the high rate of early destruction in 1978 indicate strong meandering of the Stream during the year.

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Table 1. Eddy formation and destruction dates, and life spans.

Eddy	Dates*	Life Span (Days)
77-D	(3/29/77) - 2/17/78	355
77-I	7/16/77 - 2/12/78	211
78-A	4/21/78 - 10/19/78	181
78-B	4/21/78 - 5/17/78	28
78-C	5/20/78 - 5/31/78	11
78-D	6/12/78 - 12/28/78	199
78-E	6/15/78 - 9/6/78	83
78-F	6/17/78 - 9/6/78	81
78-G	7/11/78 - 8/23/78	41
78-H	(10/10/78)- (11/8/78)	29
78-I	10/25/78 - into 1979	>68

* Dates in parentheses could be off by greater than one week. Dates not in parentheses are accurate to within one week, and generally are accurate to within several days.

Table 2. Eddy positions at mid-month with respect to zone during 1978.

	J	F	M	A	M	J	J	A	S	O	N	D
1.						78-F		78-G				78-I
2.					78-C	78-E	78-F	78-F				
3.				78-B	78-B	78-D	78-E	78-E				
4.				78-A	78-A		78-D			78-H	78-H	
5.						78-A	78-A	78-D	78-D			
6.	77-D	77-D						78-A		78-D	78-D	
7.	77-I	77-I							78-A			78-D
8.										78-A		

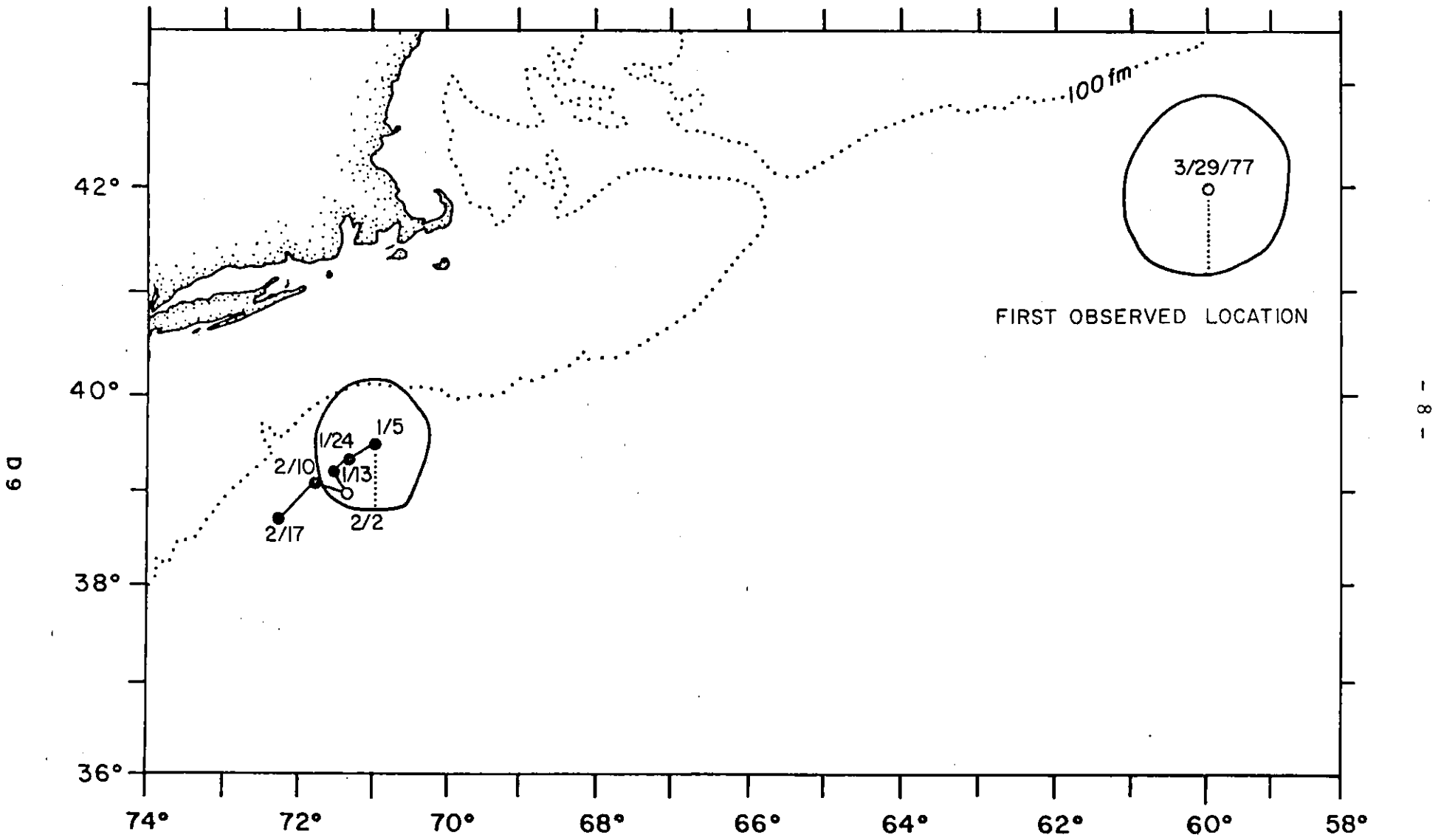

Fig. 1. Trackline for eddy 77-D (3/29/77-2/17/78). Solid circles represent positions obtained from infrared imagery; open circles represent interpolated positions for periods when the imagery was cloud-obscured.

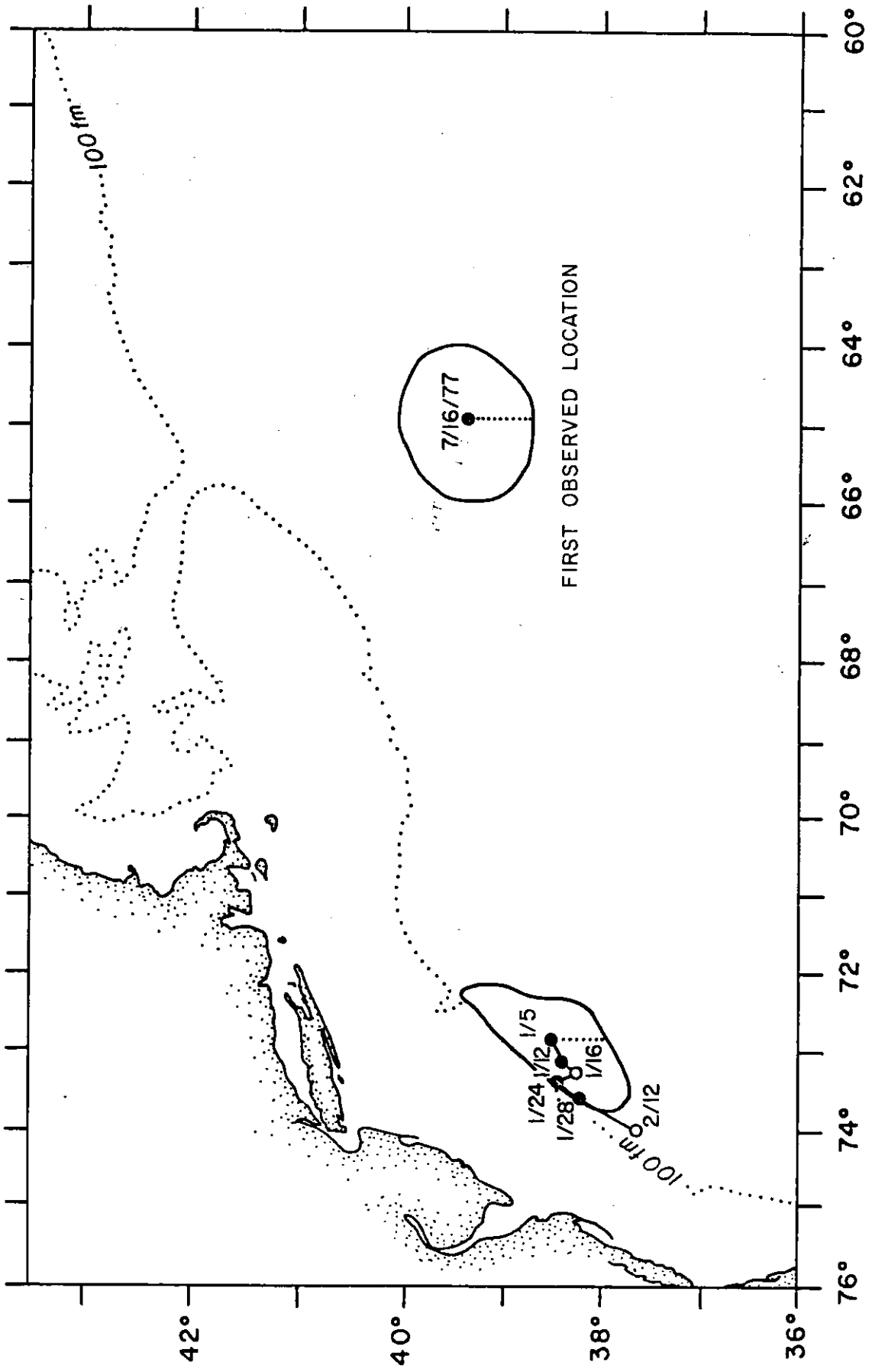

Fig. 2. Trackline for eddy 77-I (7/16/77-2/12/78). See also fig. 1.

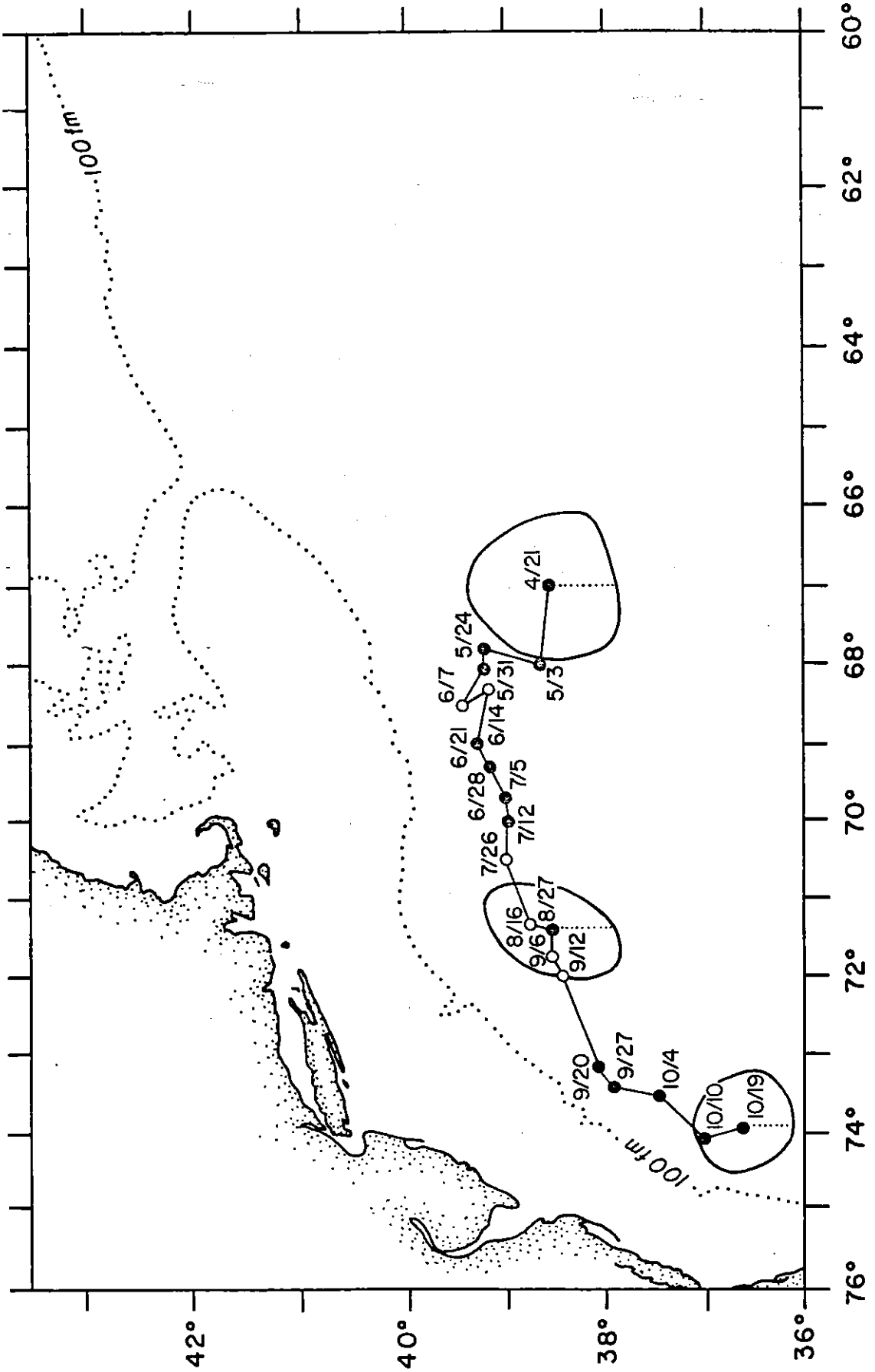

Fig. 3. Trackline for eddy 78-A (4/21/78-10/19/78). See also Fig. 1.

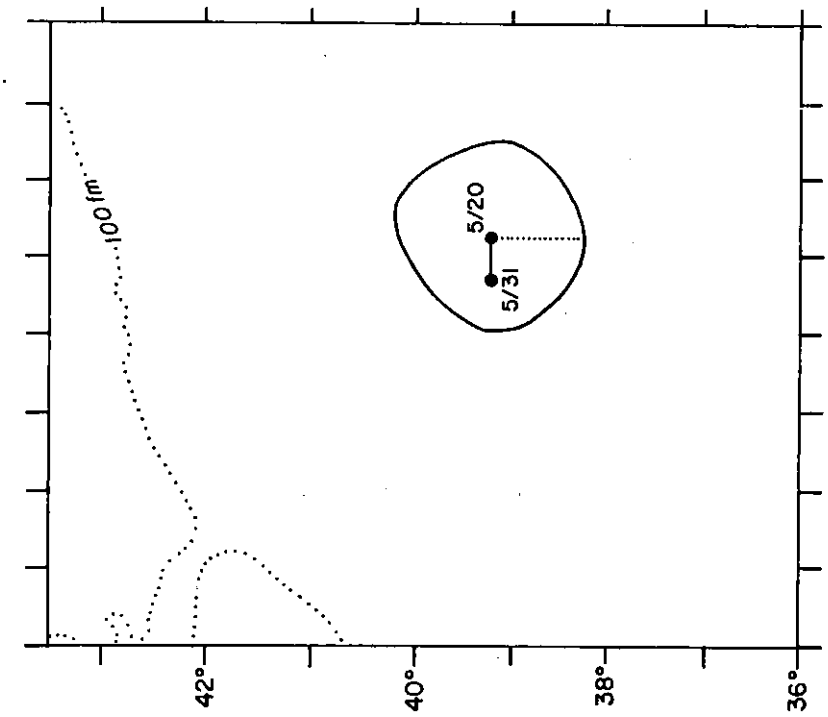

Figure 5. Trackline for eddy 78-C (5/20/78-5/31/78). See also Fig. 1.

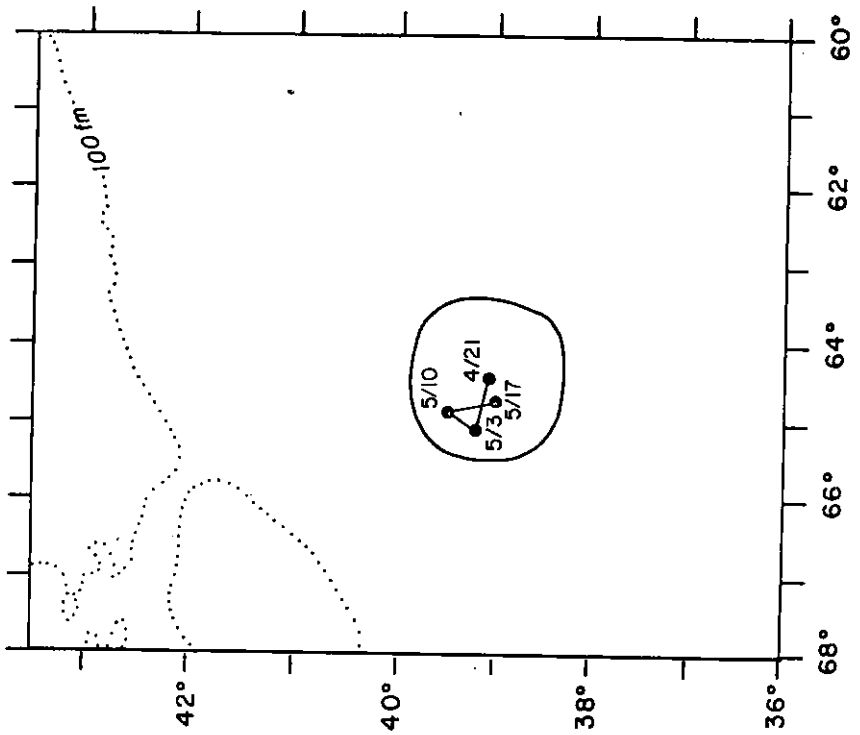

Figure 4. Trackline for eddy 78-B (4/21/78-5/17/78). See also Fig. 1.

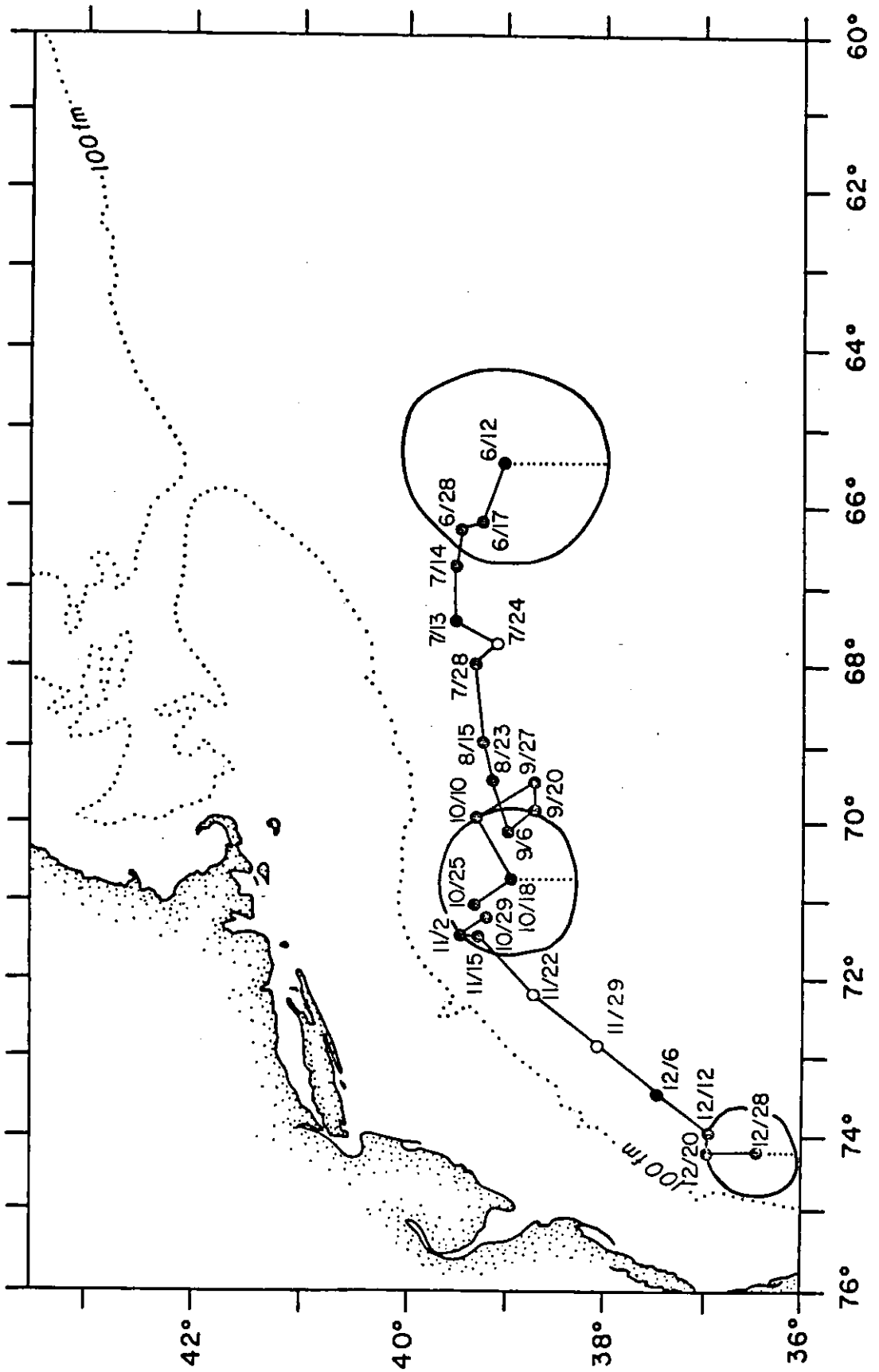

Fig. 6. Trackline for eddy 78-D (6/12/78-12/28/78). See also Fig. 1.

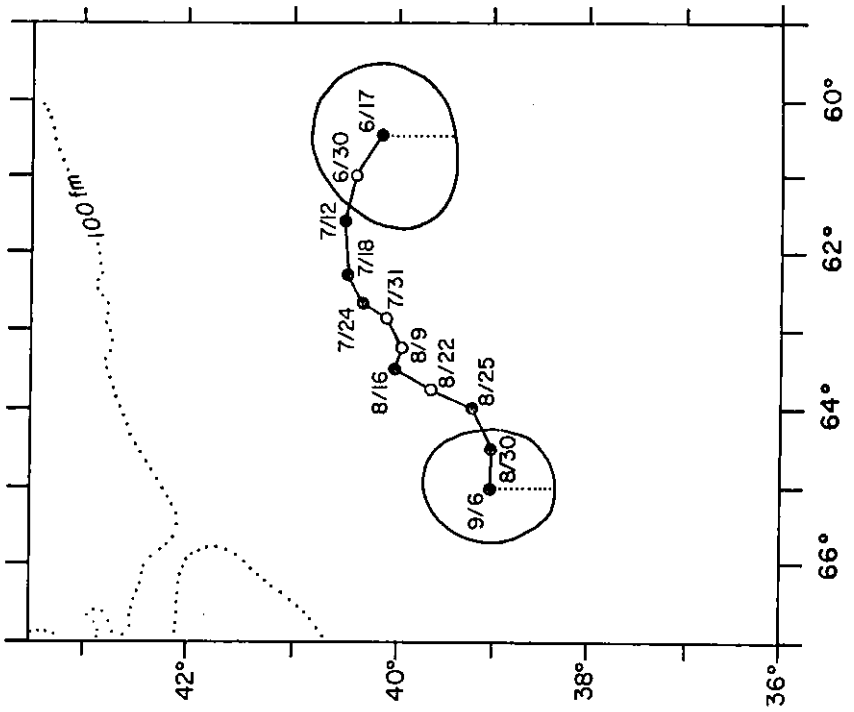

Fig. 8. Trackline for eddy 78-F (6/17/78-9/6/78). See also Fig. 1.

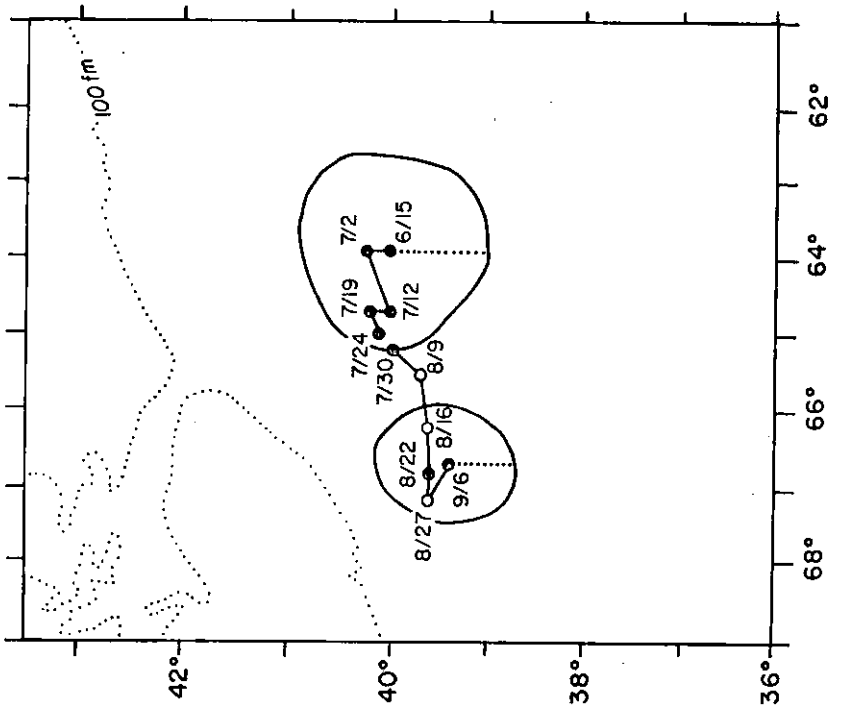

Fig. 7. Trackline for eddy 78-E (6/15/78-9/6/78). See also Fig. 1.

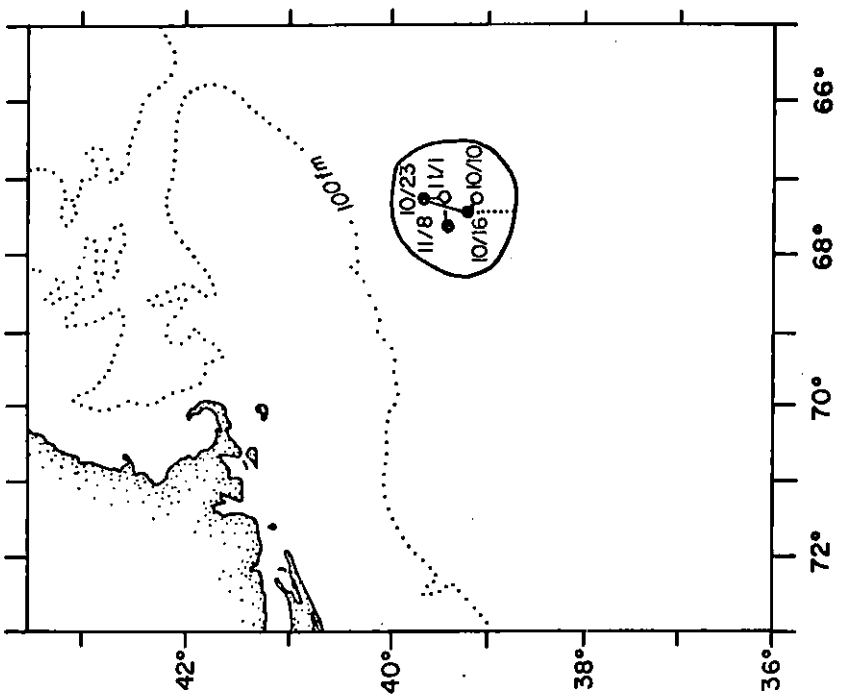

Figure 10. Trackline for eddy 78-H (10/10/78-11/8/78). See also Fig. 1.

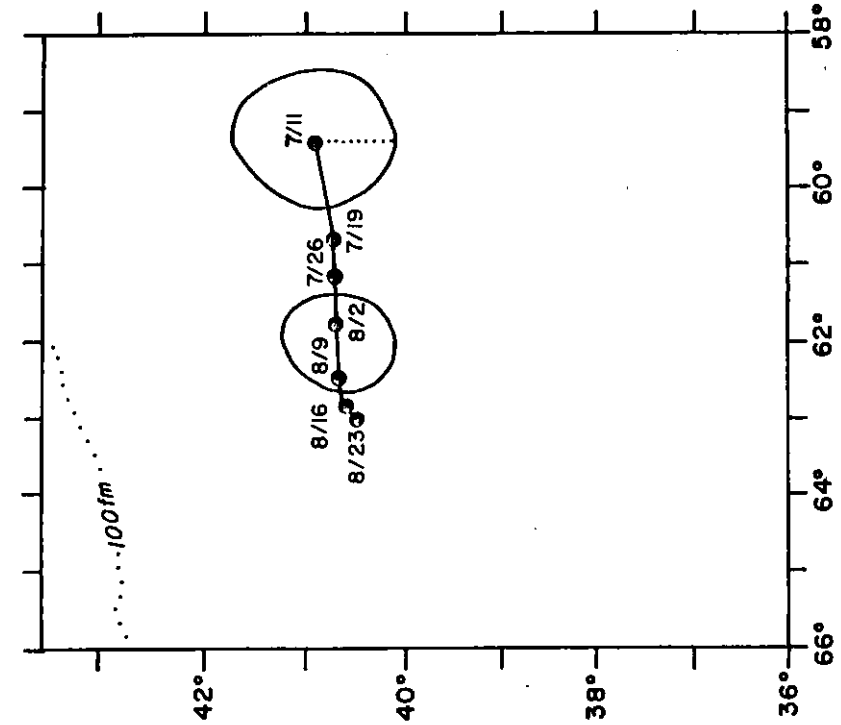

Fig. 9. Trackline for eddy 78-G (7/11/78-8/23/78). See also Fig. 1.

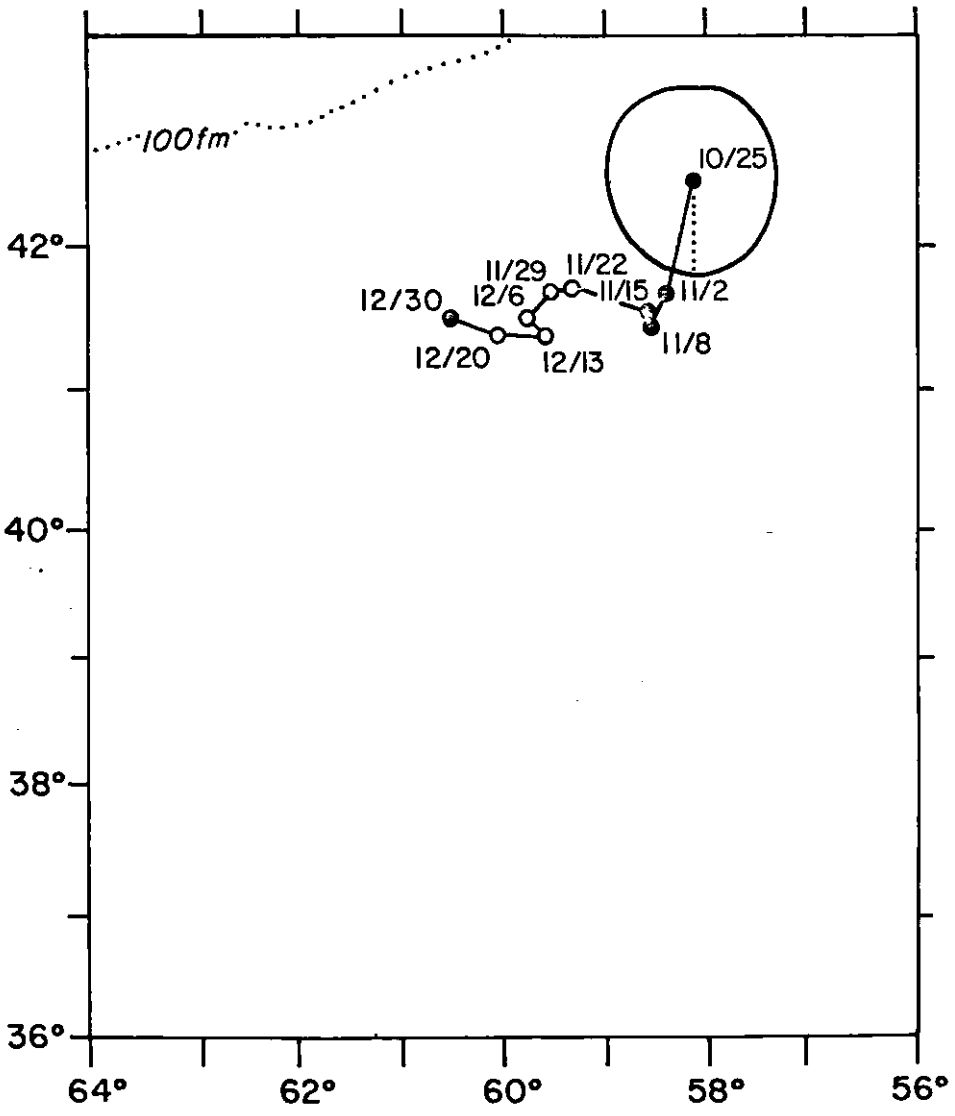

Figure 11. Trackline for eddy 78-I (10/25/78 into 1979). See also Fig. 1.

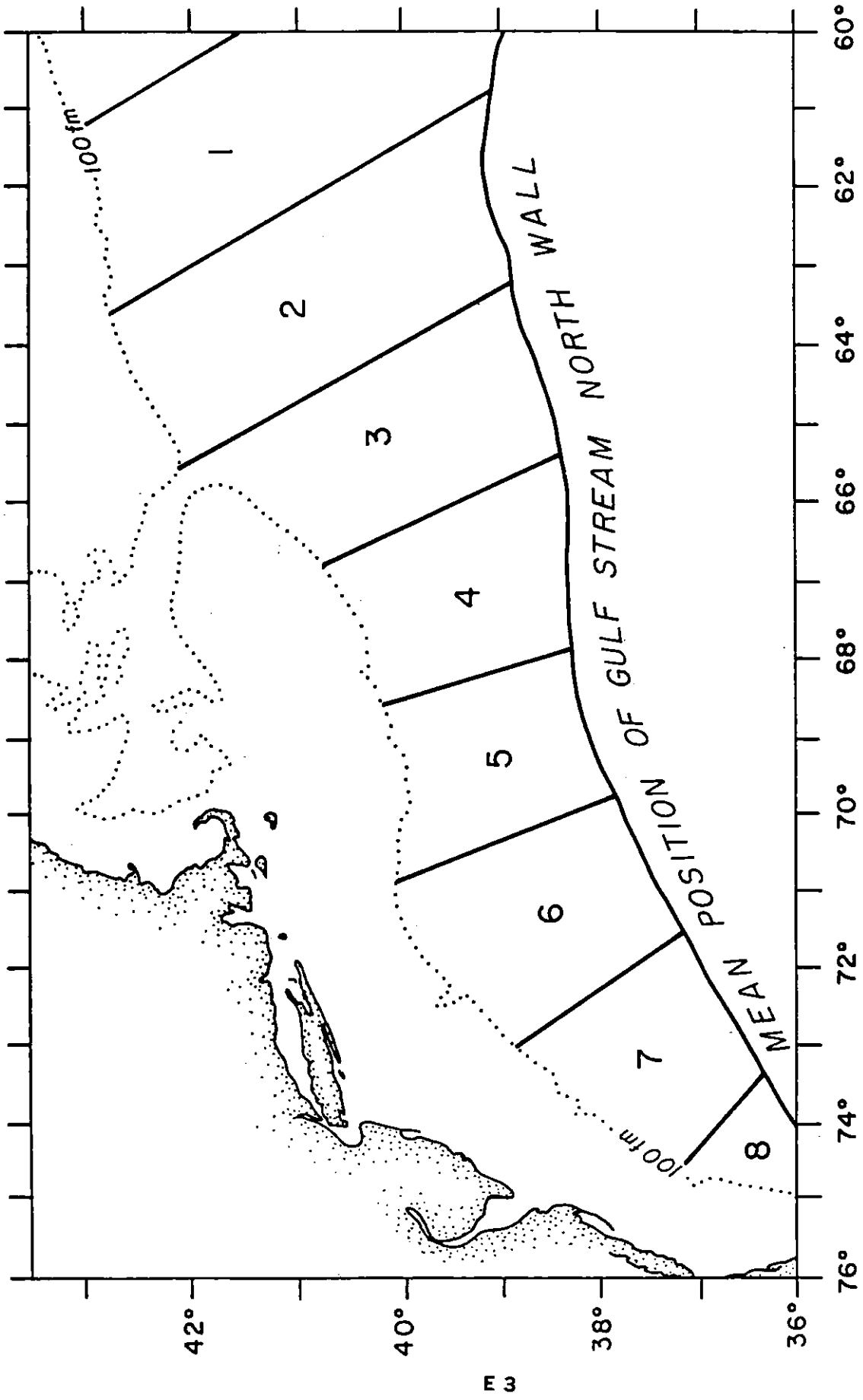

Figure 12. Zones used for table 2.

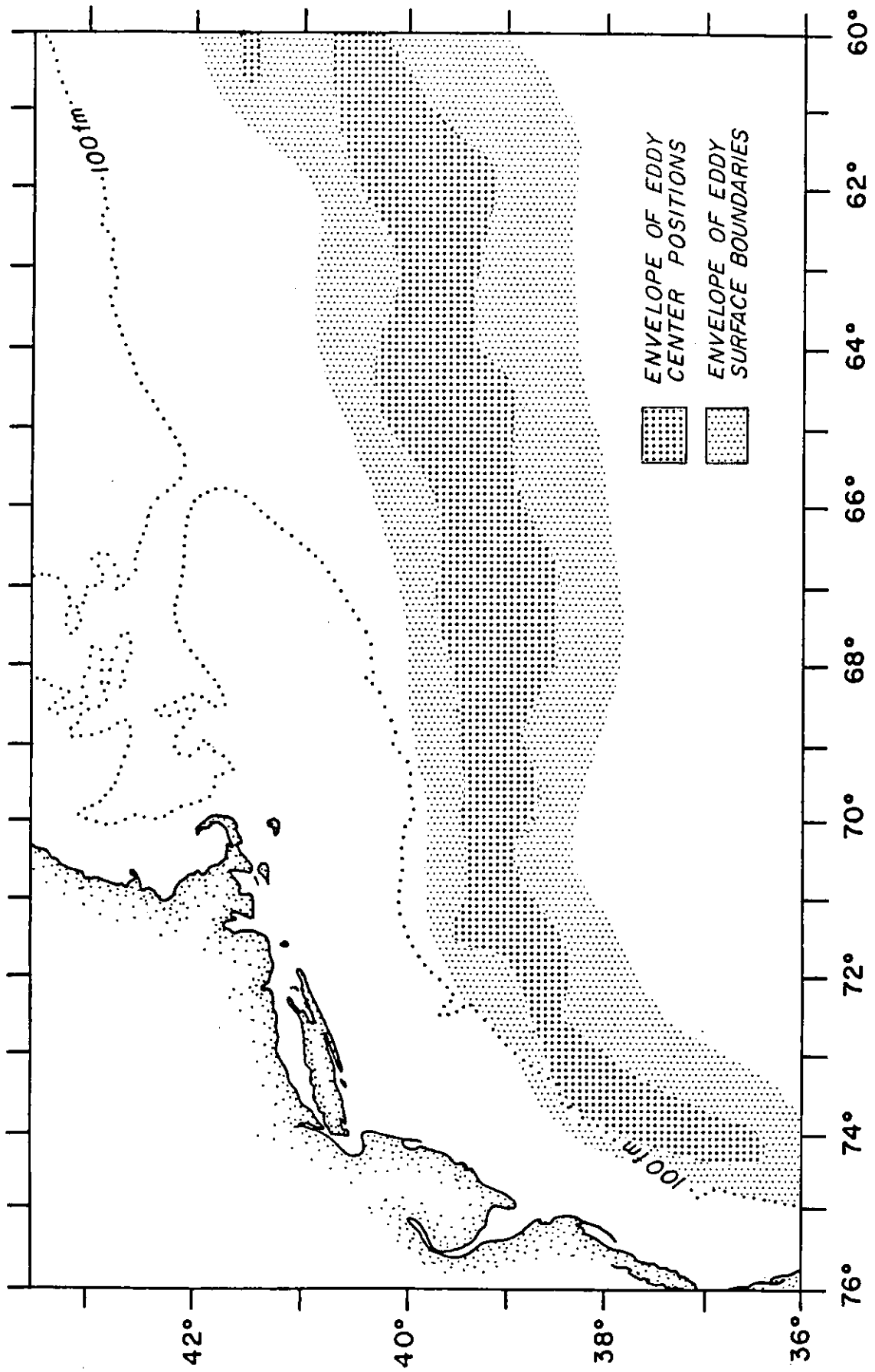

Figure 13. Envelopes of surface boundaries and center positions for eddies during 1978.