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A Detached Eddy and Subsequent Changes (1965)

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Abstract

An isolated eddy which was observed in the Gulf of Mexico in August, 1965, is described. The velocity at the core of the current in the eddy, 113 cm/sec, was comparable to that in the East Gulf Loop Current itself. A month later, following the passage of Hurricane Betsy, the eddy was considerably modified in shape and the volume transport had decreased from 40 to 19 million m^3/sec. The velocities decreased from 113 to 73 cm/sec in the core of the current.

Nowlin, Hubertz and Reid (1968) reported on a cruise in June, 1967, and established the existence of a major eddy which had evidently become detached from the Loop Current in the eastern Gulf of Mexico. Such a phenomenon also occurred in 1965 and has been described in technical reports by Leipper (1970) and Cochrane (1966). In this case, a month after the isolated eddy was observed, another cruise was conducted and a marked change was found to have occurred in the eddy. Hurricane Betsy had passed over the area in the interim.

Three successive cruises conducted in August and September, 1965, defined the isolated eddy and indicated its anticyclonic circulation. Hydrographic stations were made at selected critical positions. BTs were obtained hourly on the first two cruises at the positions shown in Figure 5-1, taken from Leipper (1970). This figure presents the topography of the 22°C isothermal surface, the surface used also by Nowlin et al. to represent partial results of their cruise. The topography shown in Figure 5-1 indicates clearly the separation of a

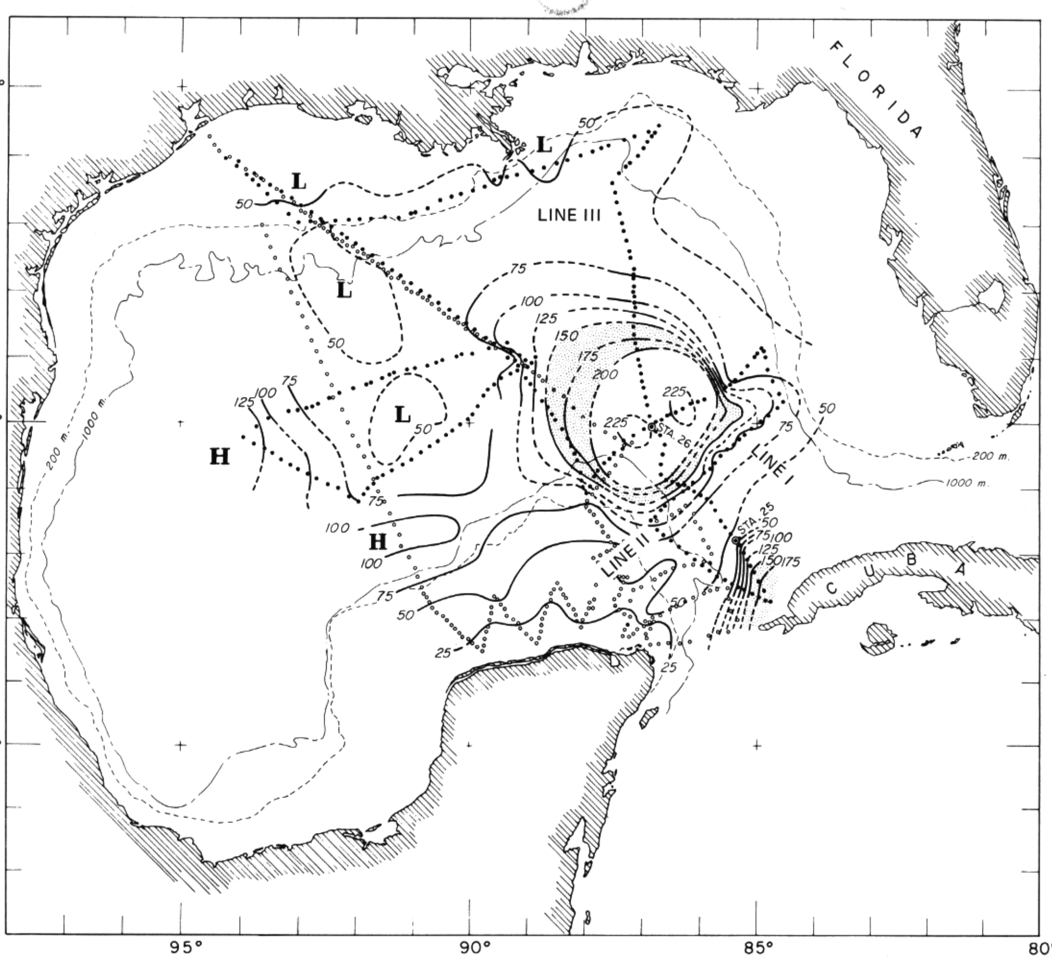

Figure 5-1. Station locations and topography of the 22°C isothermal surface for two cruises, 10-24 Aug. and 31 Aug. - 8 Sept. 1965.

major eddy from the Yucatan Current. Interpretation of the isothermal surface topography in terms of the current pattern in the Gulf is discussed by Ichiye (1962) and Leipper (1970).

Considerable additional evidence was obtained supporting the separation of the eddy from the Loop Current near Cuba. On the first cruise, as shown in Figure 5-1 by solid black dots, two lines of observations cut northwestward from Cuba across the Loop Current and show that current to be between St. 25 and the island. One of these lines extends farther and crosses the detached eddy to the northwest, centered near St. 26. On these lines, between the loop around Cuba and the eddy, the 22°C surface rises to less than 50 m, indicating that the cold ridge defining the left side (to an observer looking downstream) of the Loop Current has been reached.

The thermal structure along Line III, the most nearly north-south line in Figure 5-1, from near Panama City, Florida, to the west tip of Cuba and passing through Sts. 25 and 26 is given in Figure

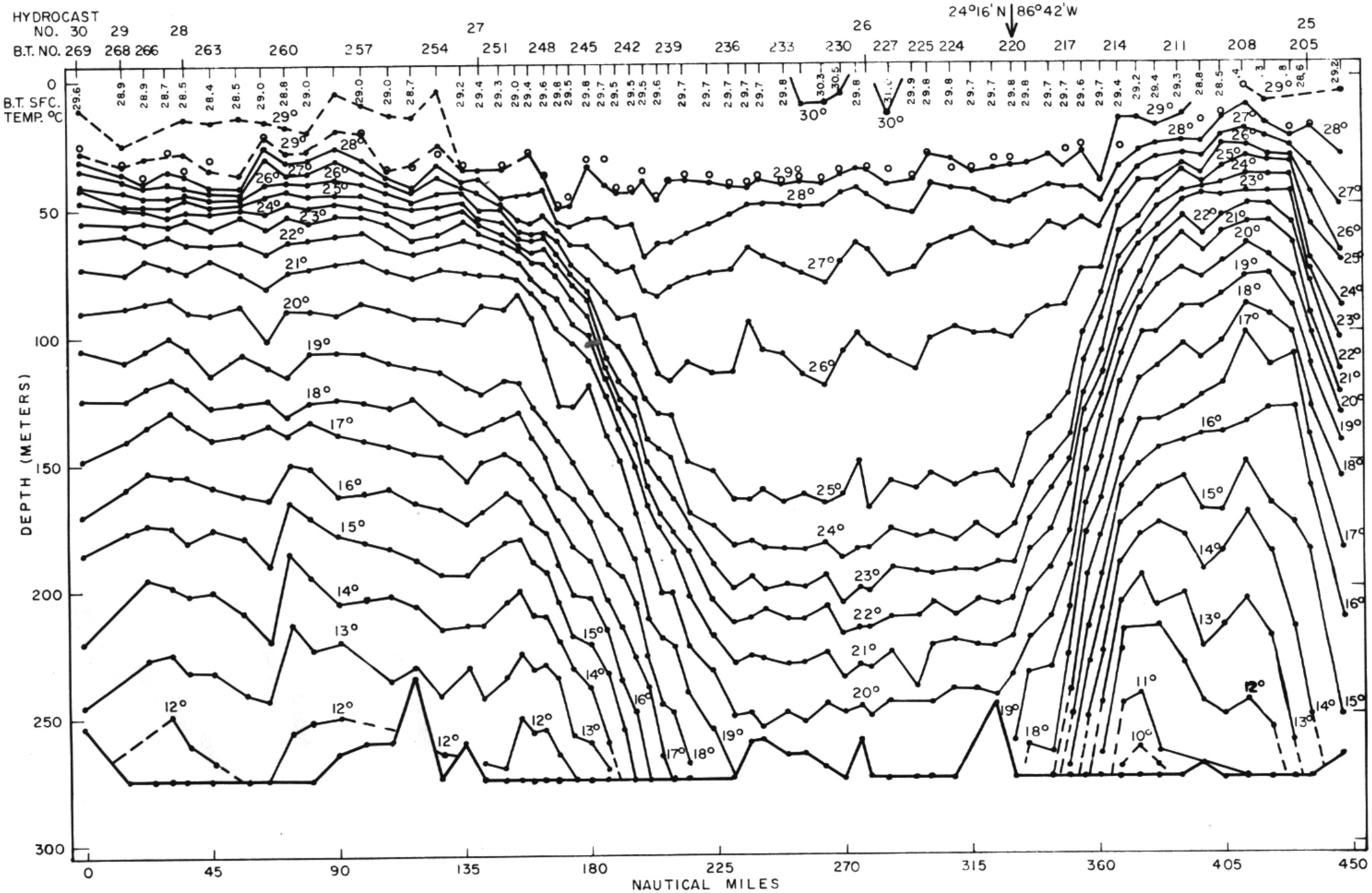

Figure 5-2. North to south temperature section (°C) across the detached eddy and the Loop Current along Line III, 20-22 Aug. 1965.

5-2. The separation between the southwesterly flowing portion of the eddy and the northeasterly flow along the coast of Cuba is shown by the rise and fall in isotherms as they reach and pass a minimum depth at BTs 207 and 208, about 35 nautical miles from the Cuban coast. The BT sections were plotted as the cruise progressed.

Since the separation of the eddy from the Loop Current was suspected, a decision was made to test the separation by making a line of observations which would hopefully fall between the two features. This test line was that marked Line I in Figure 5-1, running from northeast to southwest. The line turned out to be on the north edge of the cold ridge separating the two circulations. Line I extended fully across the deep basin north of the Yucatan Strait. The relatively flat temperature structure observed along this line (Figure 5-3) precludes the possibility of any significant flow of water across it. The 22°C isotherm dips only some 20 m, whereas in a crossing of the loop it dips more than 125 m, as in Figure 5-2. Experience on many cruises has demonstrated, as first mentioned by Ichiye (1962), that the thermal structure is a dependable indication of the presence of strong flows in the Gulf.

From August 31 to September 8, beginning a week after the cruise just discussed, the Western portion of the Yucatan Strait region was surveyed. Locations of BT observations for this cruise are also shown in Figure 5-1 (open circles). These observations indicated, since the 22°C surface was less than 50 m deep, that the cold ridge between the eddy and the loop flow extended well onto the Yucatan Shelf at that time and that the loop and the eddy flow were not connected in this area. Also, systematic observations were made with the GEK. These are shown in Figure 5-4 as reproduced from Cochrane (1966). These direct measurements of current confirm the strong southwesterly flow in the southern portion of the eddy (near top of Figure 5-4) and the unusual northeasterly flow from the Yucatan Strait in the Loop Current. The area between the eddy and the loop shows only weak and variable flow.

St. 25 of the first cruise, taken between the eddy and the loop at the position shown on Figure 5-1, was typical non-Caribbean water, the type called left-hand water by Leipper (1970) and in the Gulf found only outside the East Gulf Loop. This station position is one which in our experience is always encircled by any unbroken loop current extending farther north and which has Caribbean water present in such cases. The present data thus indicate the loop current to be broken. The maximum salinity at St. 25 was at 75 m depth and was less than 36.5 per mil. The temperature was lower than at St. 26 by 1-8°C at all depths above 1000 m. This fact and the low maximum salinity show that Caribbean water was not present at the time of the August, 1965, cruise. On the other hand, St. 26 (see Figure 5-1), which was in the center of the eddy, had a maximum salinity of 36.82 per mil which occurred at about 200 m. It also has the high temperature characteristic of water inside the East Gulf Loop or in its derivatives. A comparison of temperature and salinity values at these stations is shown in Figure 5-5.

Finally, direct current estimates for the first cruise were made independently by *Alaminos* Captain Lewis Newton. Ship speed was about 10 knots. Since most current crossings were at right angles to the current, the set was in the direction of flow and the drift should have been nearly equal to the speed of the current. On the August cruise along Line III (Figure 5-1) from Florida toward Cuba, Captain Newton's calculations showed a drift of 63 cm/sec as the ship crossed the northern side of the eddy and 96 cm/sec in the opposite direction as it crossed the southern side. These drifts persisted 9 hours and 7 hours, respectively, and their reliabilities were 60 and 80%. (The estimate of reliability depended, among other things, on the performance of the Loran.) Geostrophic computations for these same two crossings were 65 cm/sec where the drift was 63 cm/sec and 120 cm/sec where the drift was 96 cm/sec. The three other crossings of the eddy gave geostrophic values between 123 and 129 cm/sec. The

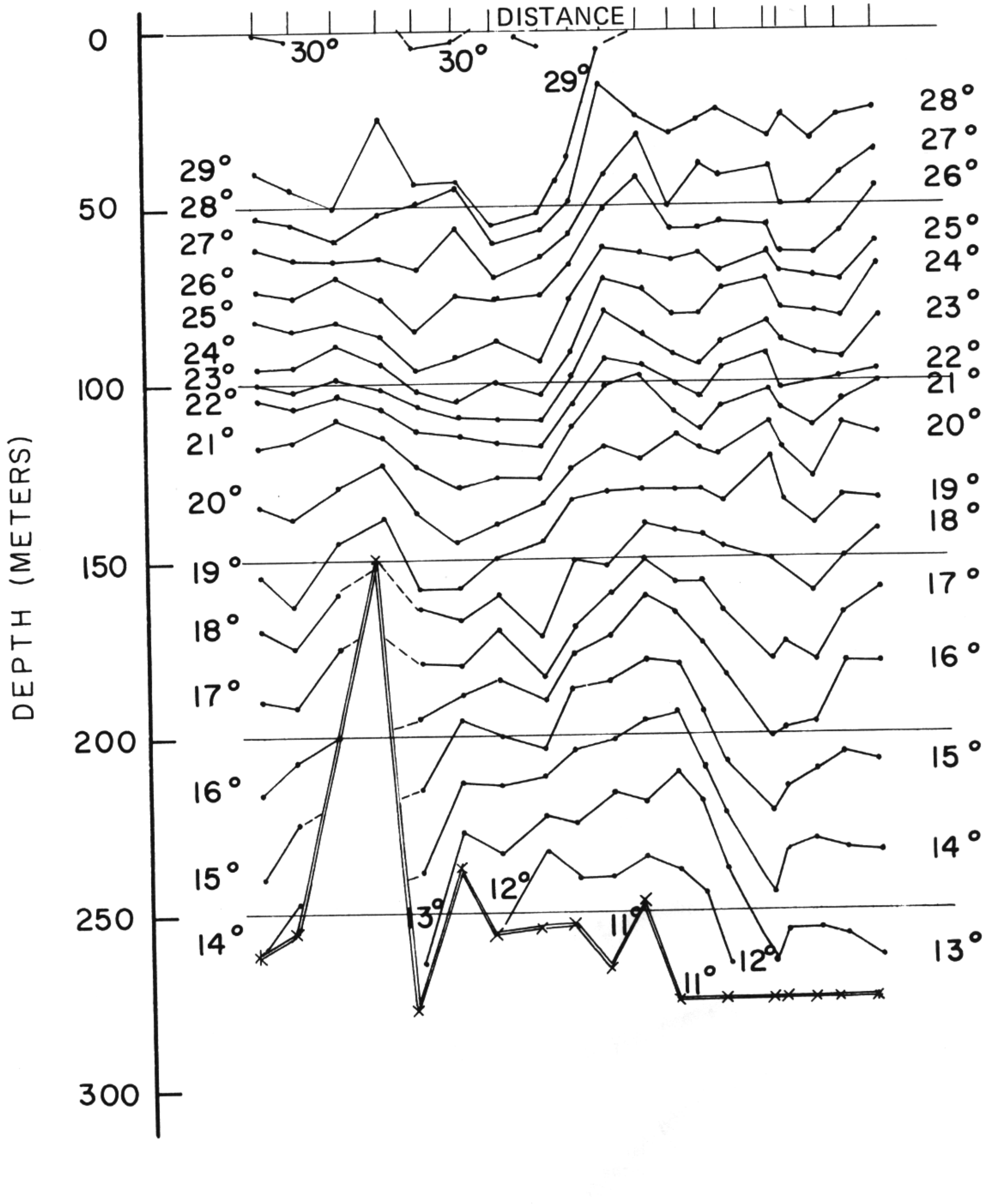

Figure 5-3. Southwest to northeast temperature section (°C), along Line I indicating no significant flow across the deep basin between Yucatan and Florida (Aug. 1965).

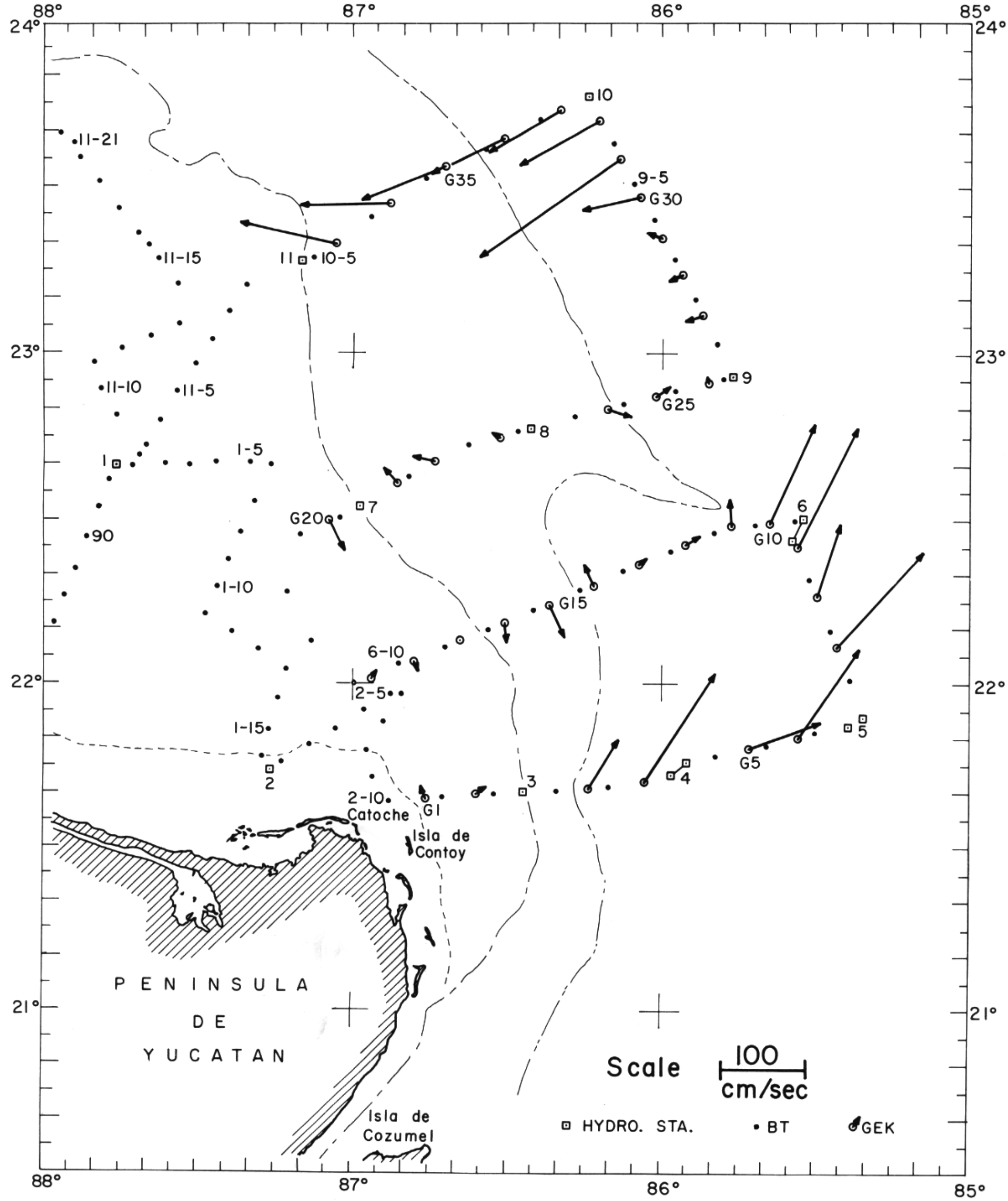

Figure 5-4. Surface current vectors from GEK measurements, 31 Aug. - 8 Sept. 1965.

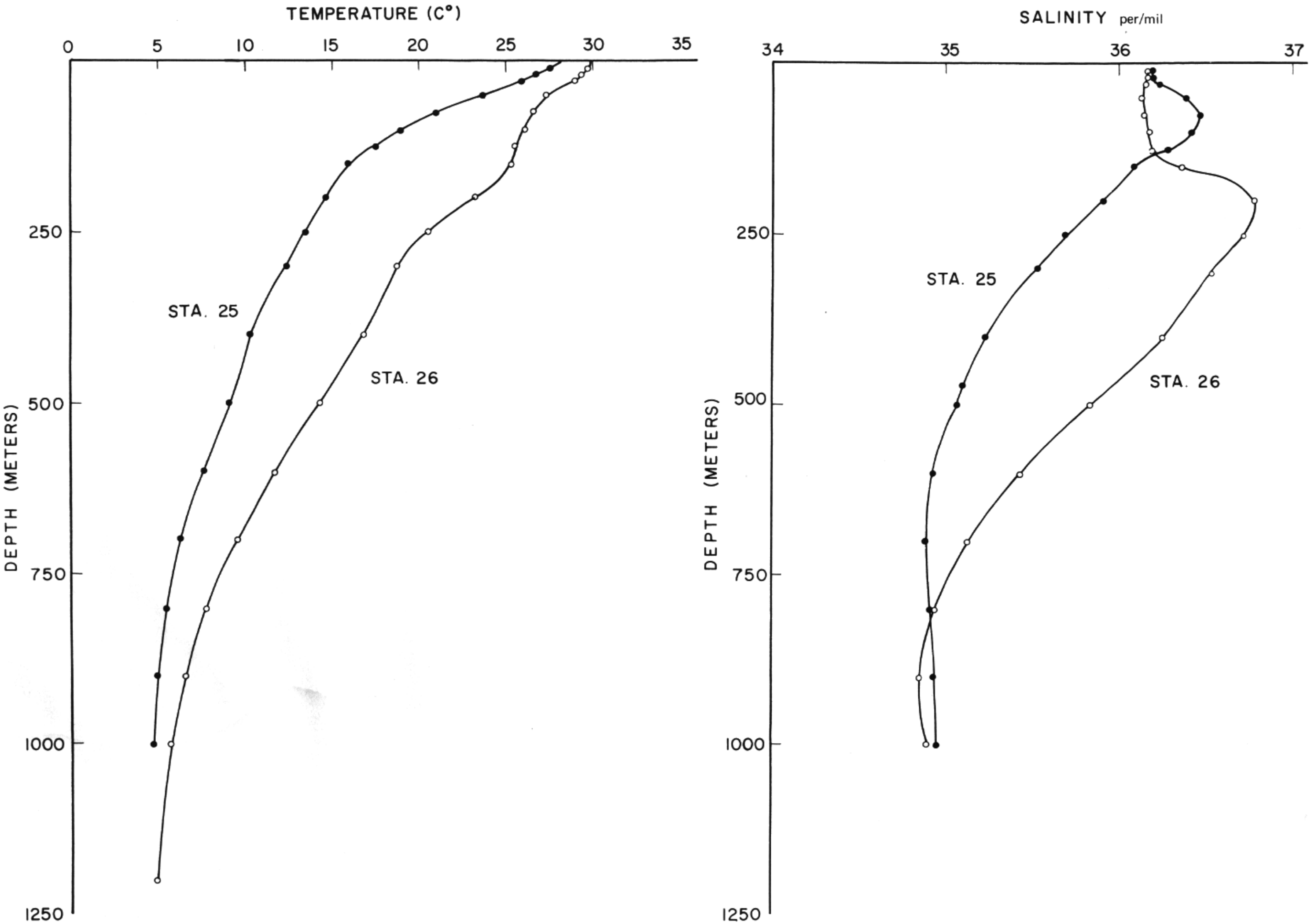

Figure 5-5. Comparison of (a) temperature, and (b) salinity values at Stations 25 and 26, Aug. 10-24, 1965.

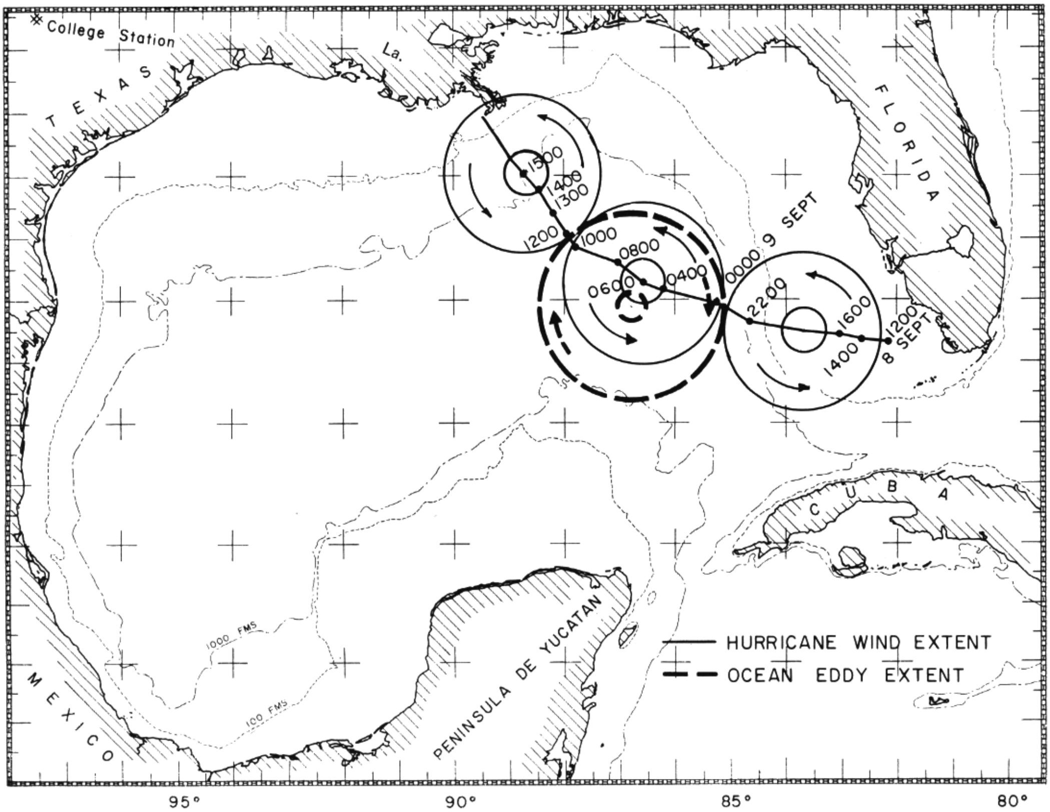

Figure 5-6. Path of Hurricane Betsy and size of the hurricane force wind area over the detached ocean eddy.

low value of 65 at the one northern crossing apparently was related to a broadening of the flow there.

As the ship traversed the center of the eddy along Line III Captain Newton observed a drift of only 13 cm/sec, reliability 50%, over a 16-hour period.

In the two crossings of the Loop Current near Cuba the drift was calculated to be 40 cm/sec for 9 hours, reliability 90%, on the western leg (Line II) and more than 103 cm/sec for 4 hours, 11 minutes, reliability 70%, on Line III. On St. 25 on the northern edge of the loop a drift of 91 cm/sec was calculated with a set toward the northeast over a 4-hour period, reliability 50%. Geostrophic velocity across the loop was 121 cm/sec but was questionable since the data were not complete.

On Line I, positioned hopefully to fall between the loop and the eddy, the Captain, as he left the Florida Shelf and headed southwest, estimated a drift of 52 cm/sec with a set to the left for the first 4 hours, reliability 50%. However, for the 14 hours needed to complete this line he calculated that there was no drift whatsoever and estimated the calculation to have an 80% reliability.

Turning toward Cuba from the Campeche Bank along Line II, Captain Newton estimated a drift of 26 cm/sec with a set to the right for 9½ hours, reliability 50%, before he entered the Loop Current which then set him in the opposite direction.

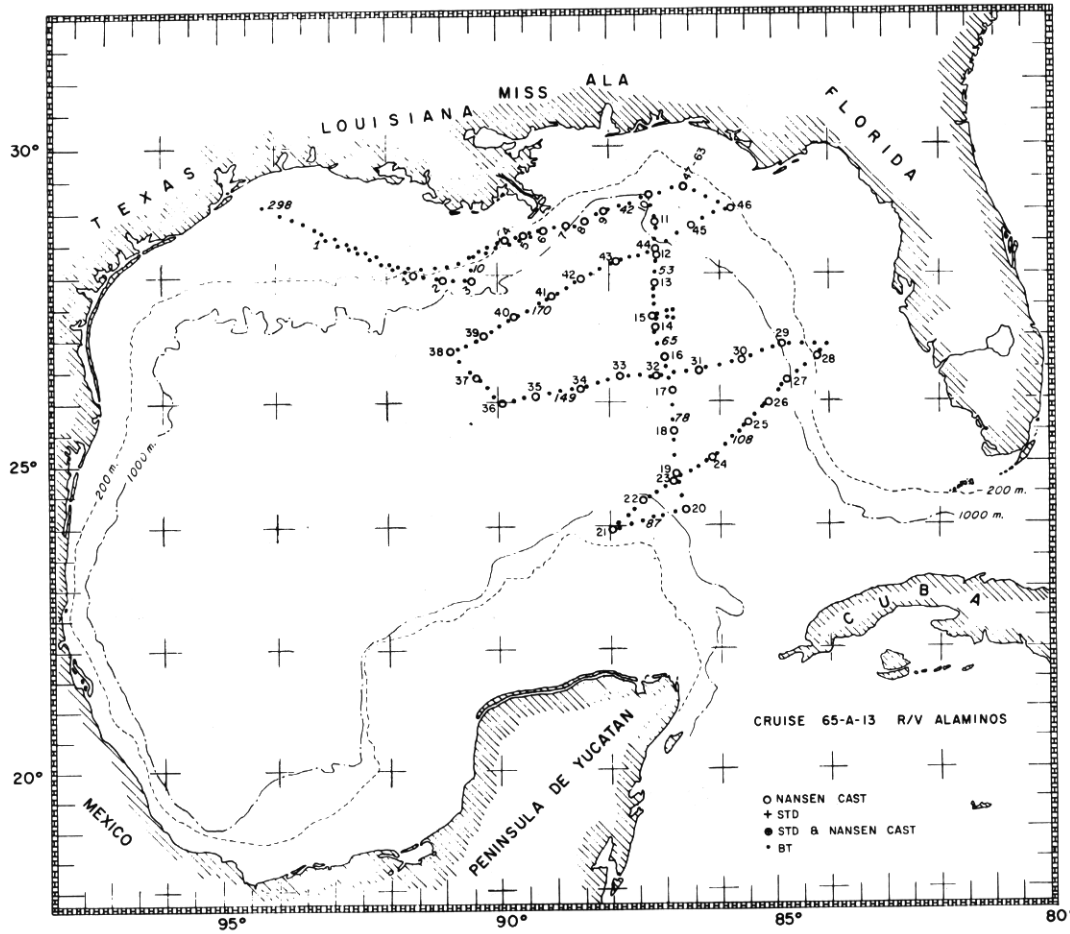

Figure 5-7. Station locations after Hurricane Betsy, Sept. 12-24,1965.

These various lines of evidence indicate clearly that the eddy was detached from the loop. Observations were close together. They were not made in the usual survey grid pattern but were planned in the light of what was known about the area to give maximum information with minimum ship time. Since many of the observation lines were run directly across the current and perpendicular to the flow, a minimum of time was used in each crossing. Although additional hydrographic stations would have been desirable to supplement the BT data more fully, the position and character of the flow were accurately determined.

When Hurricane Betsy (on September 8) crossed the area just described, the original ship plans were canceled and the *Alaminos* became available for 12 days. The path of the storm is shown in Figure 5-6. The ship days were used to repeat the lines of the cruise shown in Figure 5-1 crossed by the hurricane, i.e., the line from Galveston to Panama City, the pertinent northern portion of Line III and the northeast to southwest

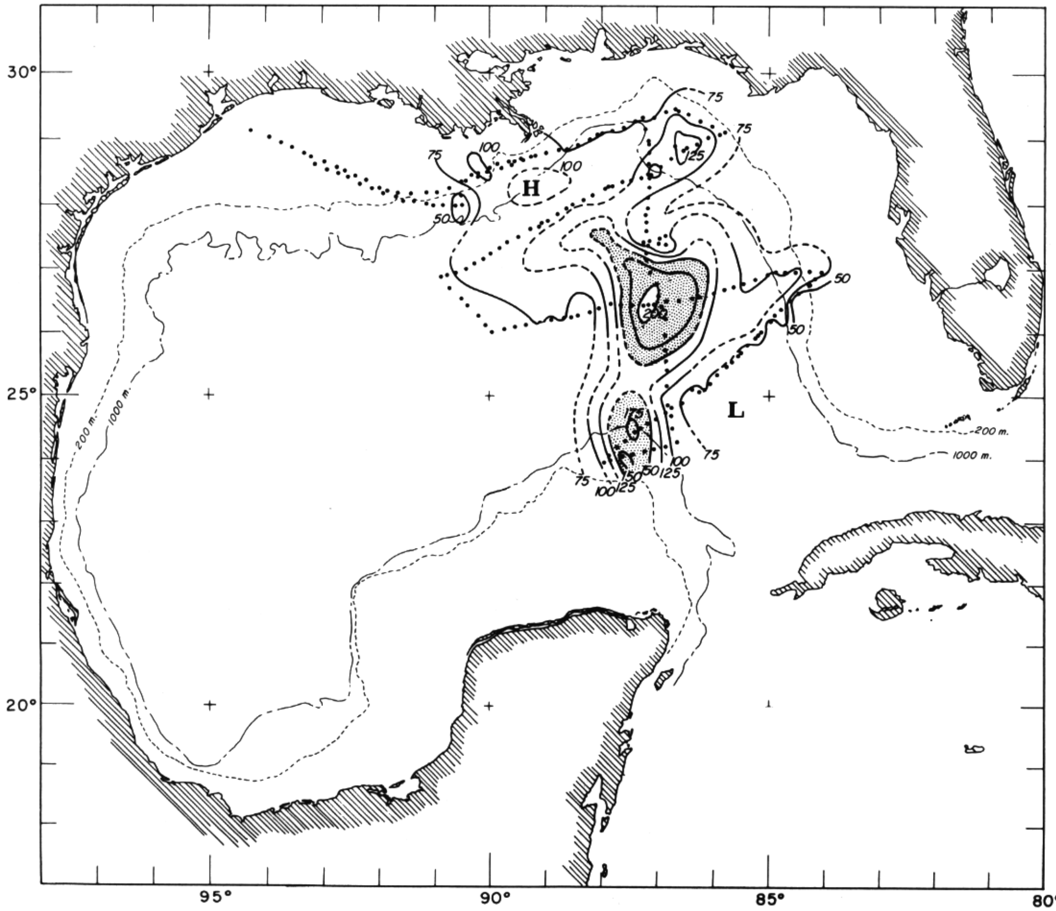

Figure 5-8. Topography of the 22°C isothermal surface, Sept. 12-24, 1965.

line through the center of isolated eddy, Figure 5-1. Two additional northeast to southwest lines were run to more fully cover the hurricane area, Figure 5-7.

At one position the hurricane was centered very close to the center of the isolated eddy, a strong cyclonic circulation in the atmosphere overlying a strong anticyclonic ocean circulation. Figure 5-6 shows the relative sizes of the eddy of the area of winds greater than 75 mph at this time.

A measurement of ocean heat loss to Hurricane Betsy based on the above cruises showed a total loss of 5×10^{18} gm cal from the Gulf and an average loss of 3750 calories per square centimeter in the areas crossed by hurricane winds (Whitaker, 1967). The beginning of the upwelling process which takes place in hurricanes (Leipper, 1967) was noticeable on the temperature sections but did not greatly alter the temperature structure because of the rapid passage of this particular storm.

In the post-hurricane survey September 12-24 the well-defined eddy of Figure 5-1 had split into two smaller eddies, one centered 100 km south and one 140 km north-northeast of the initial eddy, Figure 5-8. The two new eddies were surrounded by a flow of some 7 million m^3/sec and the volume transport was 12 million m^3/sec in each eddy, making a total flow of 19 million m^3/sec. This compares to a calculated average volume transport of 40 million m^3/sec in the initial eddy in August.

The geostrophic velocity averaged 113 cm/sec on the five crossings of the initial eddy and 73 cm/sec on seven crossings of the split eddy. At the sea surface the range of the dynamic height anomaly referred to 1000 m was 1.0555-1.8739 dyn m for the initial eddy and 1.0305-1.6331 for the eddies observed after the hurricane.

Although the small number of hydrographic stations on the initial surveys in August made the geostrophic portion of that analysis difficult, there were sufficient data of various kinds to describe the isolated eddy situation. The post-hurricane cruise was much more complete in the area of interest and the description of rapid change in the eddy which was observed may be useful in future work on circulation in the Gulf.

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