POLYMODE NEWS

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In this issue:

SATELLITE MEASUREMENTS OF GULF STREAM MEANDERS

by George Maul and Steve Baig

Several POLYMODE investigations are concerned with the role of the Gulf Stream in the interior dynamics of the ocean. A time series of the Stream's meandering, eddy production, and subsequent behavior contributes to those studies if the frequency of observation provides an unambiguous record. Inasmuch as sea-surface temperature patterns (T_s) can be interpreted in terms of circulation, weekly observations of the Stream's entire cyclonic edge and associated eddies can be made from spacecraft. The technique employs geostationary satellite data to identify regions of temperature gradient maximums, thus avoiding the difficult task of determining absolute values of surface temperature.

The Geostationary Operational Environmental Satellite, GOES-1 , provides full disk infrared imagery of the earth every 30 minutes across the Atlantic Ocean. In the infrared wavelength band of GOES (10.5-12.5 μm), the ocean and atmosphere behave nearly as blackbodies. Measured at the spacecraft, the radiance of clouds and water closely approximates their thermodynamic temperature, when allowance is made for the effect of the intervening atmosphere. When an area of the ocean is cloud-free, relative patterns in sea-surface temperature are displayed as varying densities in a photographic image.

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BEAUFORT-BERMUDA GEK, XBT, AND SHIP'S DRIFT SECTIONS

by Nelson Hogg and John Dunlap

On the way to studying mixing processes near Bermuda in October, 1975 aboard R/V Eastward, we took the opportunity to do a detailed section combining two-hourly XBT's with a continuously towed GEK (Geomagnetic Electro Kinetograph), while monitoring the side-slip of the ship with Loran-C navigation. Results of this study are presented here along with a similar, less detailed section taken on the return voyage to Beaufort.

We had been forewarned by Phil Richardson and Randy Watts that a ring was in the vicinity of 34°30'N, 70°W, and we proceeded east along 34°30'N until this eddy was encountered (the cruise track is shown in Figure 1). After deploying a satellite drifter for Richardson, we continued east-south-east toward Bermuda, arriving there on 17 October, 1975. Our work there was completed on 5 November, and we headed directly for Beaufort on a more southerly course. We had only enough XBT's left to take them about every four hours on the return voyage.

We towed a GEK on both legs that was constructed and described by Williams et al (1972). The GEK we used is a sophisticated version of earlier GEK's. It employs a "salt bridge" switching circuit to obtain directly

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NOTES from the Editor

There is no *POLYMODE OFFICE NOTES* in this issue. Paradoxically, this is not because nothing is going on in POLYMODE these days, but because too much is going on. We have just finished the U. S. POLYMODE Assembly III. We are beginning, as I write this, to commence a new round of bilateral negotiations on POLYMODE between the U.S.A. and the U.S.S.R. Most significantly, there is a thorough review now underway of POLYMODE objectives and scientific plans. This includes a reconsideration of the plans for POLYMODE Array III and a reformation of the Local Dynamics experiment.

Amidst all this discussion and thought, it is premature today to report on the results. We hope that in the near future we will be able to provide a summary of the results of these activities in POLYMODE News, and perhaps encourage further discussion of the long-range objectives of POLYMODE.

-- F. W.

The POLYMODE* News is produced at the Woods Hole Oceanographic Institution. It is edited by Ferris Webster and Leigh Stoecker.

If you have material of interest for this newsletter, please get in touch with either of the above at the Woods Hole Oceanographic Institution, Woods Hole, MA, 02543, Telephone (617) 548-1400.

*POLYMODE is derived from the names of the U.S.S.R. POLYGON experiments and the Mid-Ocean Dynamics Experiment (MODE).

BEAUFORT-BERMUDA GEK, XBT, AND SHIP'S DRIFT SECTIONS (continued)

the electrode offset voltage and eliminates the necessity of turning the ship through 180°. As the GEK only obtains the component of velocity transverse to the direction of the ship's track, periodic course changes must be made to obtain complete velocity vectors. We did this infrequently, and these measurements will not be reported here.

Our interest is in showing the degree to which the temperature field, ship's drift, and GEK reveal similar transverse velocity structure. The XBT sections are shown in Figures 2a and 3a. They are remarkably different, although only separated in time by one month, and in latitude by less than 3°. The earlier, more northerly section shows two rings--the one reported to us by Richardson and Watts, and another broader one (Big Baby?). To our surprise, no such features were observed on the return trip.

These temperature measurements were converted to "geostrophic" transverse currents by integrating the temperature from 0-700 m. We obtained an effective expansion coefficient ($\alpha' = 1 \times 10^{-4}$ $(°C)^{-1}$) from typical values of temperature (T) versus salinity (S) in the region. Geostrophic current differences were then computed from the relation:

$$\Delta V = \frac{g\alpha'}{f} \frac{\partial}{\partial x} \int_0^{700} T \, dz.$$

This quantity is indicated by the dashed lines in Figures 2b and 3b.

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SATELLITE MEASUREMENTS OF GULF STREAM MEANDERS (continued)

The problem of cloud detection is greatly simplified in GOES data because the frequency of observation is so high. After careful geographic registration, each image can be considered as the equivalent of a single frame in a motion picture. A motion picture film loop is made and projected onto a base map. Since advective rates of clouds are at least an order of magnitude higher than ocean features, sea-surface temperature patterns appear quasi-stationary for the length of one loop (which is typically nine hours long). The maxima in ΔT_s are sketched on the map and interpreted as boundaries between water masses.

The procedure discussed above is a simplification of the analysis to be done for POLYMODE, but it does allow a demonstration of the potential results. The proposed two-year study (1977-1978) will incorporate oceanographically dedicated and processed data, measurements that account for the satellite's orbit, incorporation of ship and buoy observations of T_s, and perhaps advanced video presentation technology. An example of a single analysis for one week is given in Figure 4.

Figure 4 covers the area bounded by 60°-90°W and 20°-40°N. The most prominent feature is the cyclonic edge of the Gulf Stream from off Cape Canaveral to south of the Grand Banks. Several eddies are interpreted to lie east of Cape Hatteras; the anticyclonic edge of the Stream is seen from Ft. Lauderdale to south of Cape Hatteras; and the entire Loop Current in the Gulf of Mexico is clearly outlined. The map covers the period 3-9 March, 1976. Note that the isopleths are a composite of this one-week period. Periods of cloudiness usually prevent all areas from being seen continuously and compositing is necessary. Dates of observation of each section are labeled on the figure. Independent at-sea observations in the Gulf of Mexico and off the Mid-Atlantic Bight have confirmed the validity of the analysis there; in fact, these charts have been used for cruise planning and sampling strategy. Similitude would suggest that the analysis is valid for the whole Gulf Stream system.

A composite of the period 10 February-16 March, 1976 is shown in Figure 5. The complexity of patterns in the offing of the southeast Atlantic Bight, eddy motions south of the Grand Banks and east of Cape Hatteras, and the "spring intrusion" of the Gulf Loop Current are the most striking features. How well the surface manifestation reflects the deeper thermal structure is a continuing debate; studies have shown that the horizontal separation of ΔT_s-max and ΔT_{200}-max is 14.7 ± 11.8 km. Although the standard deviation is almost as large as the mean, it is still an order of magnitude less than the width of the Stream. Within the uncertainty, the features shown in Figure 5 probably represent fluctuations such as those mirrored in Webster's (1961) Onslow Bay study.

It should be emphasized that Figures 4 and 5 were constructed using data not specifically designed for oceanographic interpretation and were obtained on a time-available basis. These data probably represent a maximum permissible departure from the meteorological mission of the Miami Satellite Field Service Station, at present. The dedicated GOES system, by providing 24-hour imagery, will deliver the maximum amount of data. This will be a significant improvement over the present nine-hour daily data take which occasionally is "out of phase" with clear views of the ocean. Periods shorter than weekly may be possible with a dedicated GOES system, and there will be times

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SATELLITE MEASUREMENTS OF GULF STREAM MEANDERS (continued)

when a near-continuous observation sequence for as long as a fortnight will be obtained. Thus, the final analysis will be made on a randomly-spaced time series, with a mean Nyquist period of two weeks. That synthesis will incorporate all available ship data. Properly annotated continuous records of T_s will be a vital adjunct to the XBT information; all POLYMODE investigators are requested to obtain such observations, if possible.

If this work continues as proposed, the Miami Satellite Field Services Station will provide information to all interested scientists. Investigators who wish up-to-date information on these observations during the field year should be in touch with either of the authors of this article.

Reference

Webster, Ferris (1961) A description of Gulf Stream meanders off Onslow Bay. Deep-Sea Res., *8*, 130-143.

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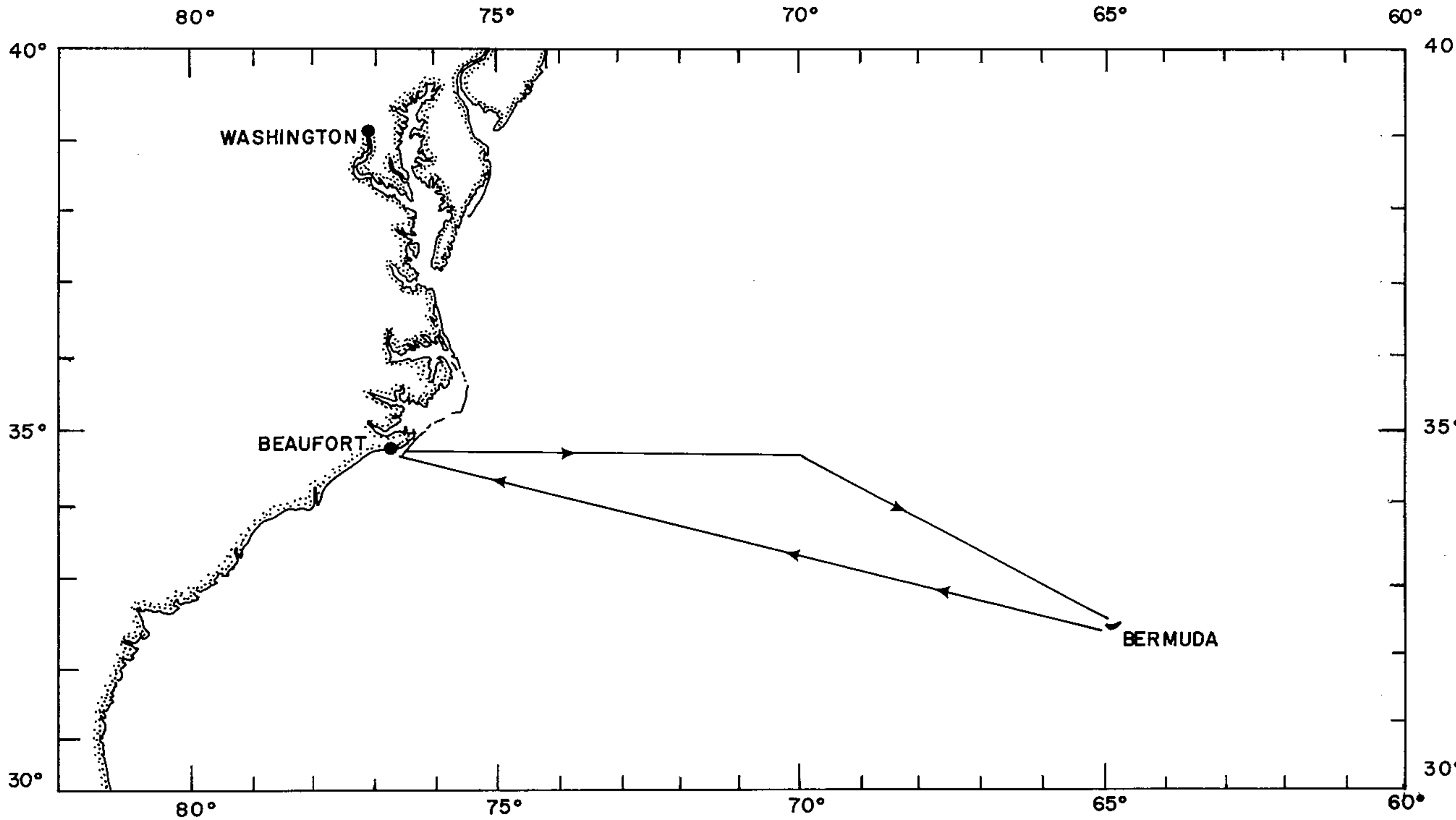
BEAUFORT-BERMUDA GEK, XBT, AND SHIP'S DRIFT SECTIONS (continued)

Also presented in Figures 2b and 3b are measurements of surface current, as measured by the side-slip of the ship from its planned course, and the transverse currents indicated by the GEK.

There is a high visual correlation between the different methods of observation. Certainly the large-amplitude rings stand out, but smaller features (those between the ring and the Gulf Stream in Figure 2b, for instance) seem to be present in all three measurements. The strong northerly flow to the west of the Richardson-Watts ring is a puzzling feature of each curve. Amplitudes are comparable. Because it is a continuous and direct current measurement device, the GEK could have promise as a survey tool for ring and mesoscale velocity fluctuations. However, a word of caution must be made. According to the XBT section on our return voyage, conditions were calm. However, both the ship's drift and the GEK measured a large anticyclonic feature at about 67°30'W, 33°N. The only hint of this in the XBT section is a slight, near-surface depression of the isotherms, which translates into a small-amplitude feature in the geostrophic computation.

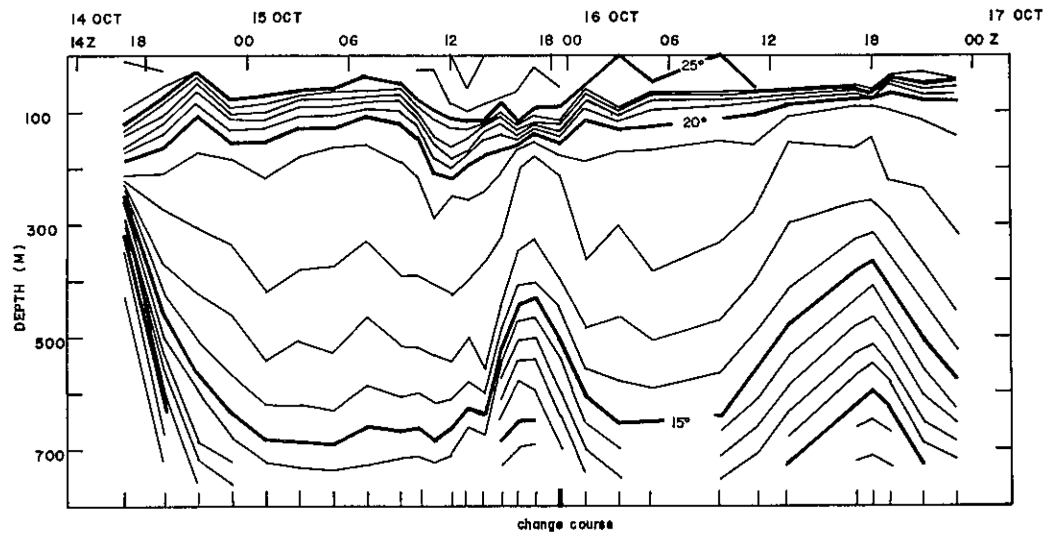
Reference

Williams, Albert J. III, Richard J. Jaffee, Peter F. Poranski, Paul J. Simonetti (1972) Short arm electric field measurements of ocean currents. Woods Hole Oceanographic Institution Technical Report No. 72-13 (unpublished manuscript).



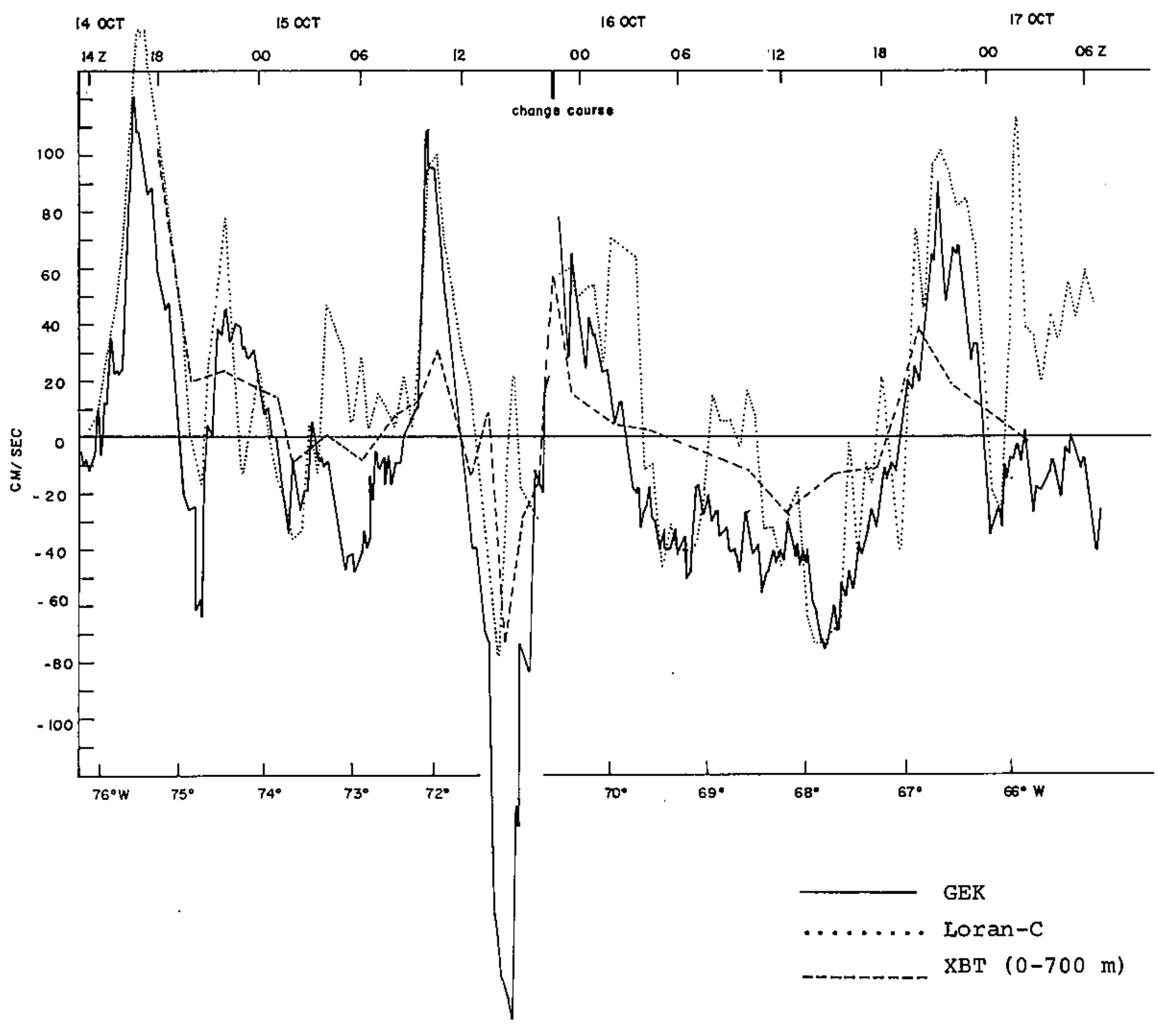
Cruise track of R/V Eastward, October, 1975.

Figure 1 (Hogg and Dunlap)



XBT isotherms from Beaufort, N. C. to Bermuda, October 14-17, 1975

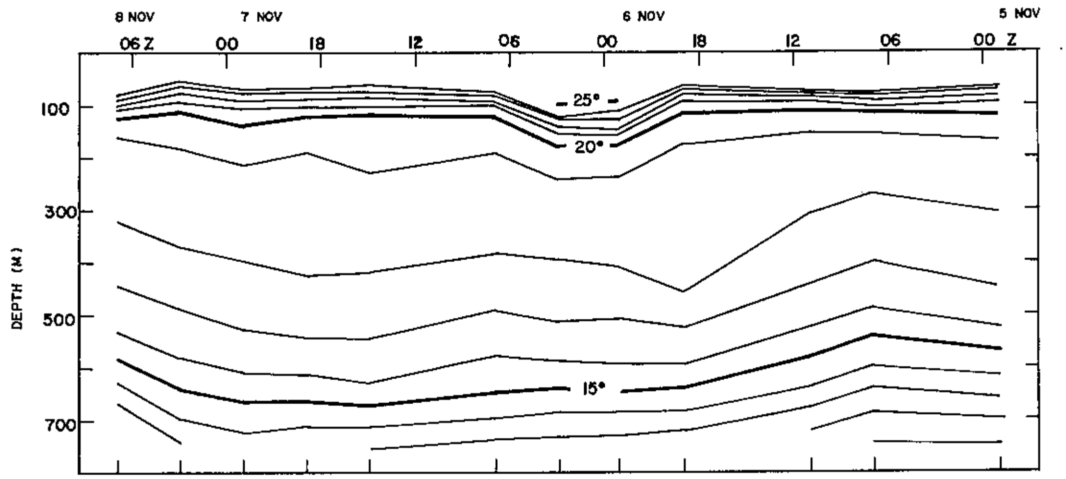
Figure 2a



Transverse velocities from Beaufort, N. C. to Bermuda, October 14-17, 1975.
(Note different sampling intervals.)

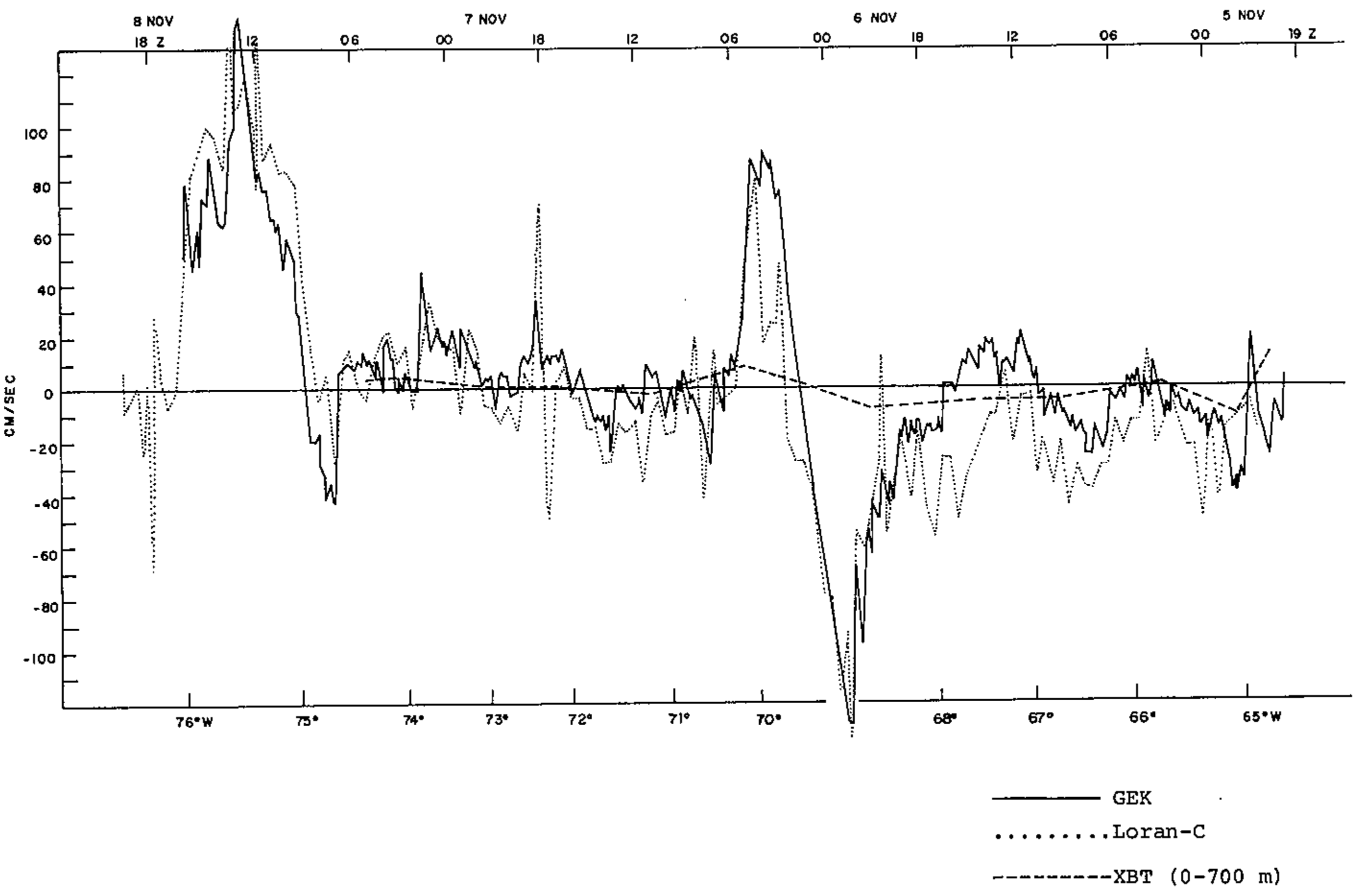
Figure 2b

(Hogg and Dunlap)



XBT isotherms from Bermuda to Beaufort, N. C., November 5-8, 1976.

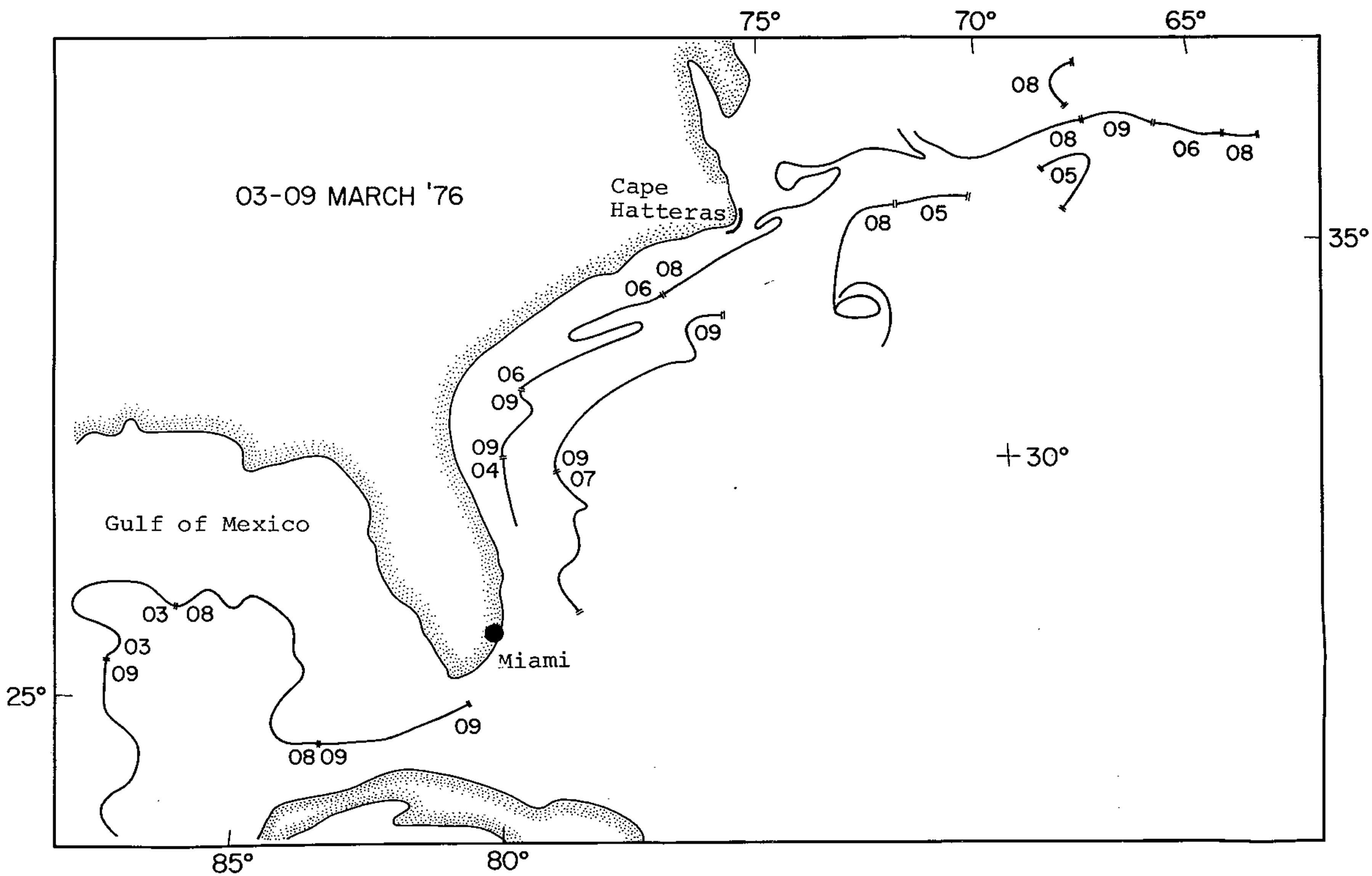
Figure 3a



Transverse velocities from Bermuda to Beaufort, N. C., November 6-8, 1975.

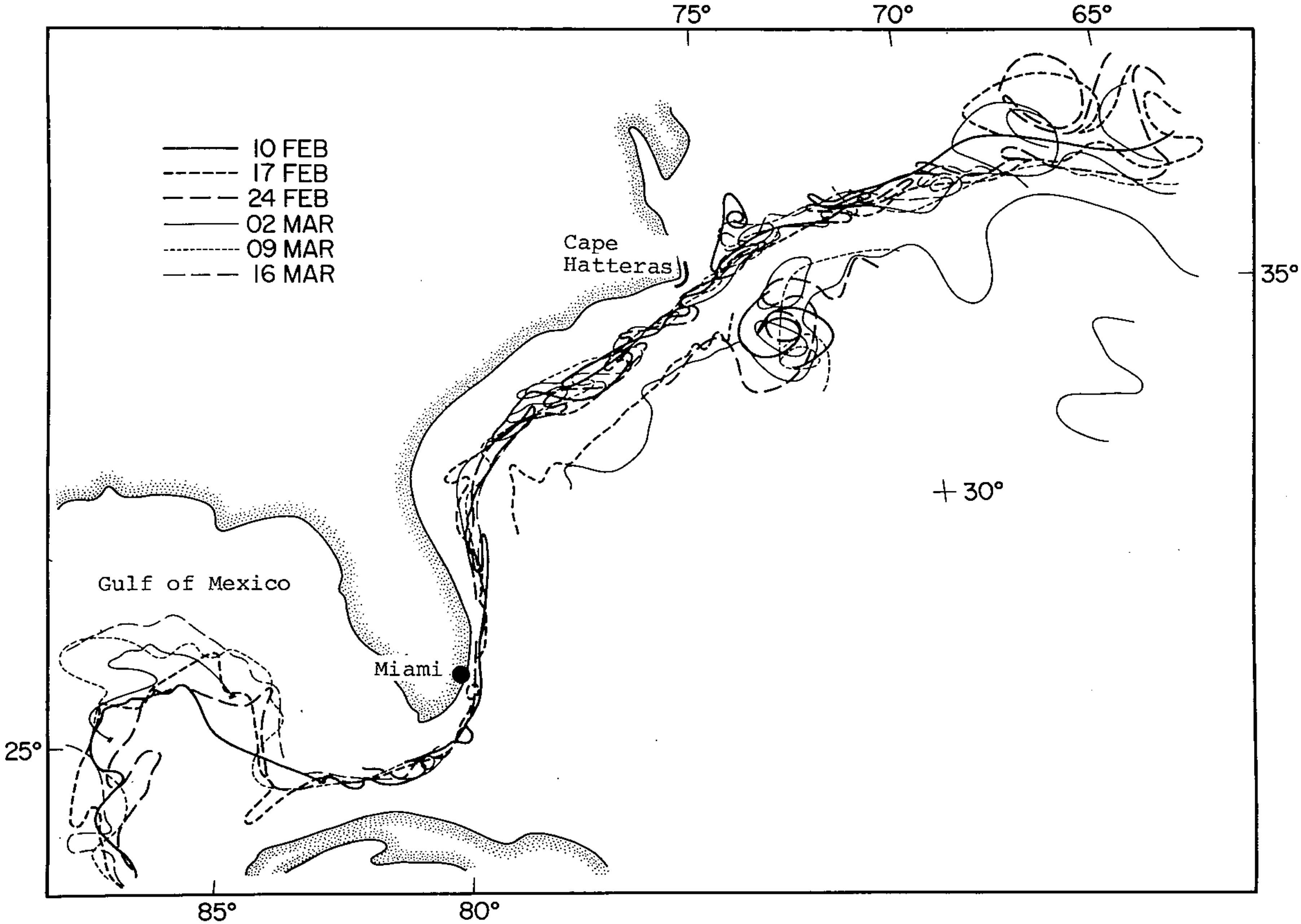
Figure 3b

(Hogg and Dunlap)



Analysis of satellite infrared imagery of the Gulf Stream for the period 3-9 March. Note the cyclonic edge of the Stream from off Cape Canaveral to south of the Grand Banks, and its anticyclonic edge from Ft. Lauderdale to south of Cape Hatteras. The Loop Current in the Gulf of Mexico is also clearly outlined. Several eddies lie east of Cape Hatteras.

Figure 4 (Maul and Baig)



A composite of the Gulf Stream satellite imagery for the period 10 February-16 March, 1976. Note the complexity of patterns in the offing of the southeast Atlantic Bight, eddy motions south of the Grand Banks, and the spring intrusion of the Gulf Loop Current.

Figure 5 (Maul and Baig)