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THREE-DIMENSIONAL VIEW OF A GULF STREAM MEANDER BETWEEN SAVANNA--ETC(U)  
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# THREE-DIMENSIONAL VIEW OF A GULF STREAM MEANDER BETWEEN SAVANNAH, GA. AND CAPE HATTERAS, N.C.

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Synoptic views of large regions of the ocean are difficult to obtain. Conventional shipboard techniques require such long periods of time for data collection and ship travel that severe temporal aliasing can adversely affect a data set. This is the case with measurements made in the Gulf Stream along the southeastern United States, because the Stream has significant variations with periods ranging from a few days to many weeks. Recent synoptic observations of the sea-surface temperature field, made possible through the advent of satellite-borne thermal infrared sensors, indicate that the dominant mesoscale fluctuations in the Gulf Stream in that area are wavelike meanders. They have alongshore wavelengths of about 150 km and progress in the northeasterward, or downstream direction at about 40 km day<sup>-1</sup> (Legeckis, 1979). These properties of the surface thermal variability compare well with Webster's (1961) analysis of subsurface temperature data collected during 1 month off Onslow Bay, N.C. He showed the two dominant meander periods to be near 7 days and 4 days. The consistencies between these two sets of observations make a three-dimensional, synoptic picture of the Gulf Stream quite desirable.

To rapidly map the surface and subsurface thermal structure, a series of aircraft surveys of the Gulf Stream frontal zone between Savannah, Ga., and Cape Hatteras, N.C.,

was made during February 1979. The most extensive of the series was on 14 February, with 94 AXBT's deployed over the grid shown in figure 1. Sea-surface temperature was also measured along each of the stream flight lines with a precision radiation thermometer (PRT). The set of horizontal and vertical temperature profiles obtained from this day's survey provide an essentially synoptic picture, because the total time required for the survey was less than 8 hours. This article describes the spatial features of the Gulf Stream thermal zone observed during that flight.

The surface temperature field measured by the PRT is composed of two prominent, alongshore thermal features. The front closer to shore is centered approximately 15°C isotherm and separates a very cool, nearshore water mass (occasionally referred to as "Shelf Water") from a slightly warmer water mass (sometimes called "Slope Water"). Somewhat seaward of this is the Gulf Stream surface thermal front, which is about coincident with the 15°C isotherm. The surface expression of a filament of Gulf Stream water parallels most of the inshore front. The filament at the time of the measurements had elongated and broken into a discontinuous "shingle" structure, with the separated warm water centered at about 33°N, 78°W.

Just upstream of the filament and immediately adjacent to the Stream is a narrow "ribbon" of relatively cool water which has surface temperatures less than 18°C. This ribbon occurs in the area of a persistent seaward deflection of the Stream off Charleston, S.C. (Brooks and Legeckis, 1979). It is possible that the ribbon is formed from upwelling along the shoreward Gulf Stream conjunction with the deflection process. Alternatively, lateral entrainment of shelf/slope water may produce this feature. Measurements of temperature and salinity downstream of Cape Hatteras show very narrow bands of cool, low-salinity water along the Stream's inshore front, implying lateral entrainment, which could have occurred upstream of the point of observation (Ford, Long Banks, 1952). Should simultaneous salinity and temperature observations off Charleston provide corroborative results, then lateral entrainment would be the most likely mechanism for producing the cool ribbon.

The temperatures immediately below the surface as measured by the AXBT's, reveal similar pattern to that of the coarser resolution of the AXBT data.

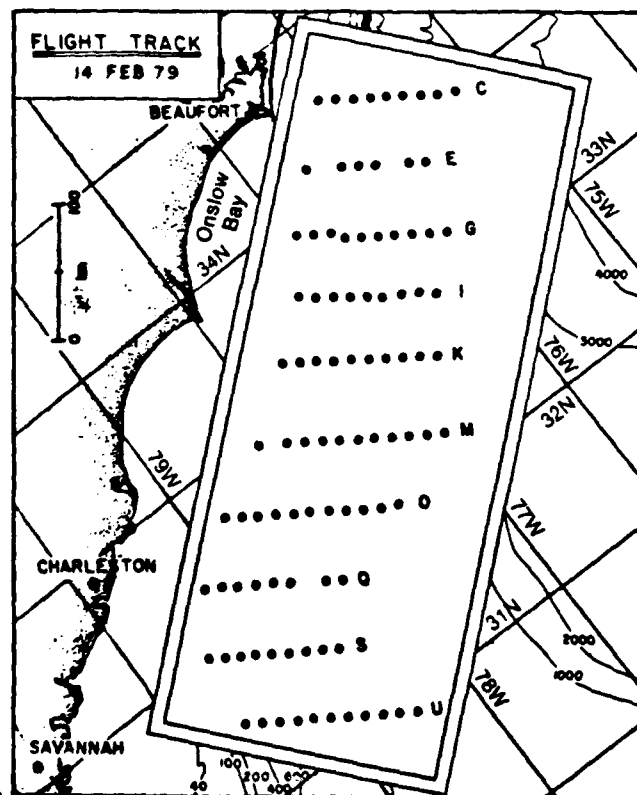


Figure 1. AXBT stations for the 14 February flight. Circles indicate station locations. Station spacing is 12.5 km, and alongshore spacing is 100 km. Occasional "dud" AXBT's cause gaps in the lines (e.g., stations are missing on line E). Total duration of the survey was 7 hours 30 minutes.

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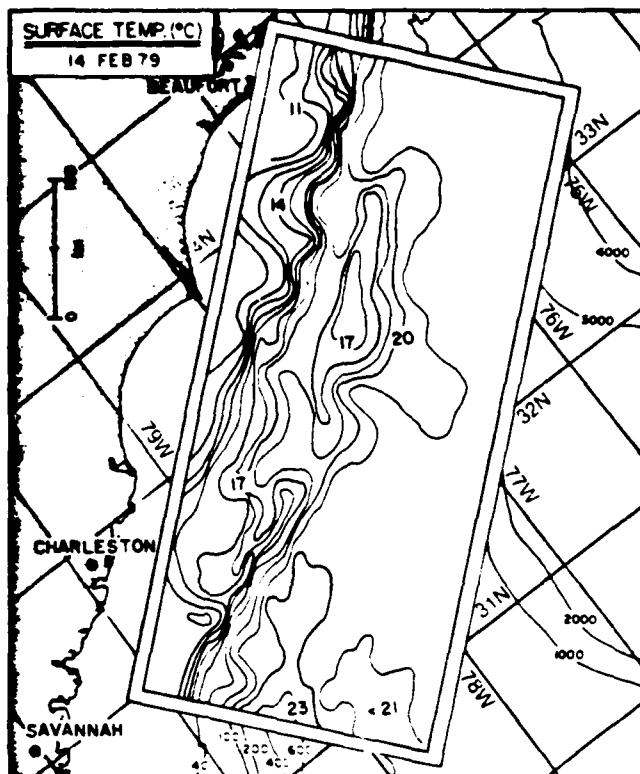
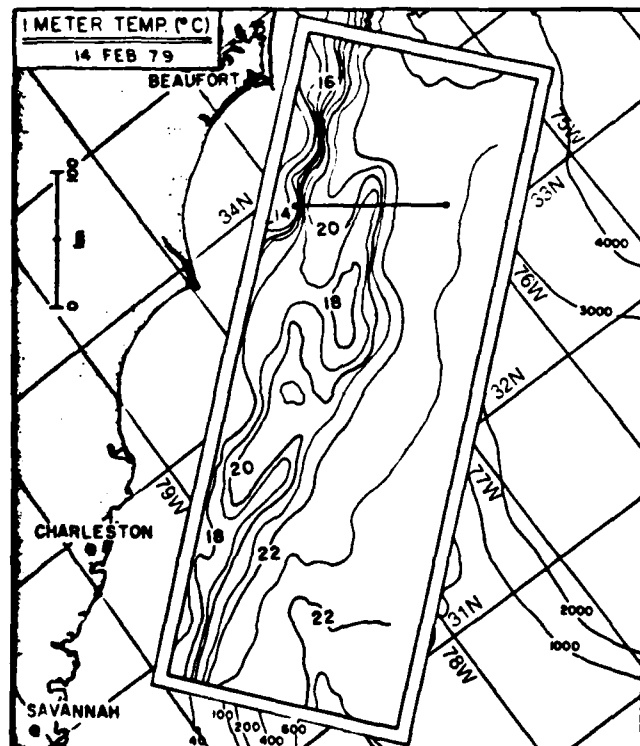


Figure 2. Surface temperature measured by the Barnes PRT-5 IR thermometer. Temperature calibration information collected between cross-stream lines has been used to give an estimated accuracy of  $\pm 0.5^\circ\text{C}$ .



define the narrow cool ribbon off Charleston definite meander pattern is evident in the Stream front ( $21^\circ\text{C}$  isotherm at this level), with a crest\* occupying the northeastern one-fifth of area. The water in the meander trough\* is cooler at this level. Figure 4 shows a vertical section at line G which "slices" through the warm filament water in the trough, and into the main body of the Severe "doming" of the isotherms has resulted upwelling of cool, deep Gulf Stream water to volume between the upper continental slope and body of the Gulf Stream in the meander trough. filament over the outer continental shelf is quite extending only to a depth of about 40 m.

Temperature patterns at the 100-m and 250-m levels (and 6) reflect the meander pattern apparent in the surface fields, with a crest in the northeastern port area, and a trough occupying most of the center. This vertical coherence of the meander thermal is consistent with current fluctuations measured in area. The velocity variations above the 400-m is Onslow Bay, which are associated with the passing meander, are vertically in-phase, with maximum eastward ("downstream") velocity occurring during passage (Brooks and Bane, 1980).

From the single, daily view provided by the AXBT data described here, the Gulf Stream frontal zone is seen to have a complex thermal structure, with features in size from a few kilometers (e.g., the width of a cool ribbon) to a few hundred kilometers (alongshore length of a meander). Similar temperatures collected during seven other flights in February flights in November 1979 are now being processed should provide further enlightenment, especially areas of meander evolution and propagation.

\*A meander crest (trough) is taken here to be the shoreward-most (seaward-most) excursion of the Gulf Stream front meander wavelength.

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Figure 3. The temperature 1 m below the sea surface measured by the AXBT's. The patterns at this level are essentially the same as those seen in the PRT data; however, AXBT 1-m temperatures are consistently higher than PRT temperatures, probably due to surface cooling caused by evaporation and conduction. AXBT-PRT temperature difference  $\pm$  one standard deviation found to be  $1.3 \pm 0.3^\circ\text{C}$  for the 94 stations.

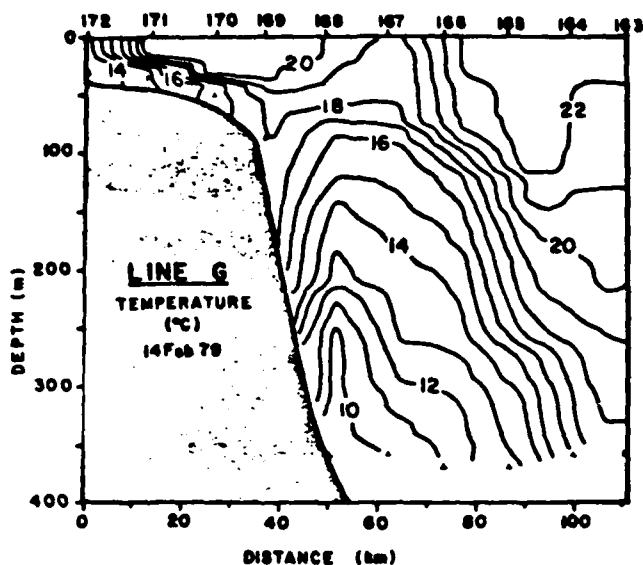


Figure 4. Vertical temperature section along line G, the position of which is indicated by the solid cross-stream line in fig. 3. The main Gulf Stream subsurface thermal front, centered approximately around the 19°C isotherm, is about 45 km offshore of the upper continental slope. This is typical of a meander trough. The vertical structure of the warm filament extending along the in-shore edge of the main body of the Stream is clearly seen over the outer continental shelf.

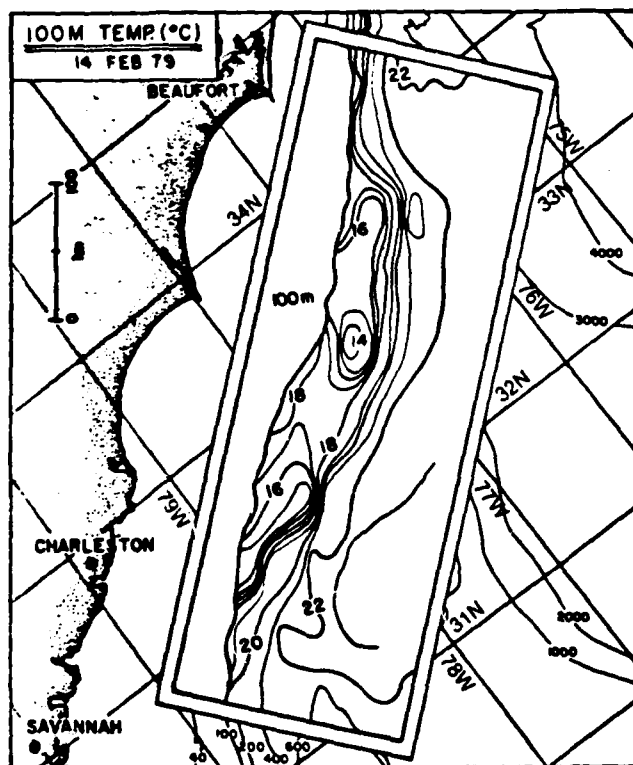


Figure 5. Temperature on the horizontal surface at 100 m depth. The skewed meander pattern is apparent at this level, with the subsurface thermal front (~19°C isotherm) trending gently offshore in the downstream direction, then turning back sharply onshore. Cool water fills the trough between the front and the 100-m isobath; the lowest temperature at this level is less than 14°C.

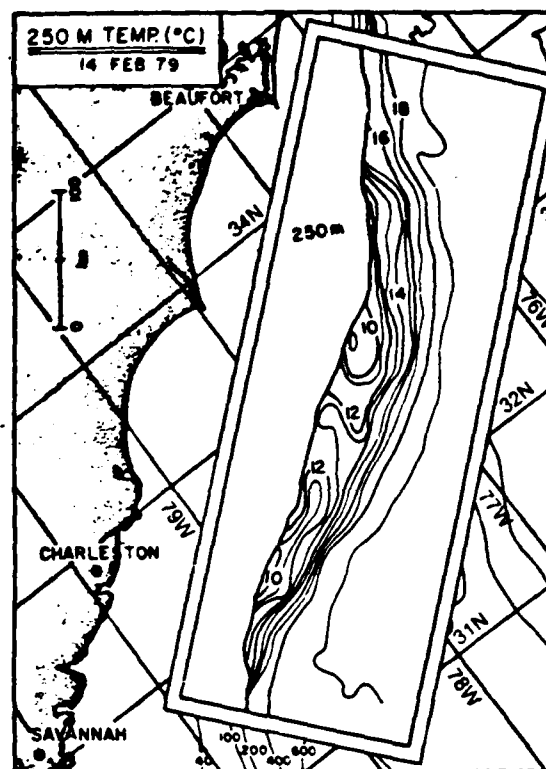


Figure 6. Temperature on the horizontal surface at 250 m. The meander pattern at this level is quite similar to that at 100 m, providing an indication of the vertical coherence of the motions.

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