Gulf Stream Characteristics

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Note No. 2

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While the Gulf Stream is well known to be a weather generator most studies of the Stream place primary emphasis on its flow structure. To the racing navigator the currents associated with this flow can significantly affect course and speed over the ground (COG and SOG, respectively) as well as sea state. Optimizing this combination represents one of the real challenges of dealing with the Gulf Stream.

The flows forming the Gulf Stream represent the resultant of interactions between the winds acting over the North Atlantic, horizontal variations in water column density, produced by variations in water temperature and salinity, and the earth's rotation. The resulting stream is thoroughly turbulent and displays significant variability in space and time. This multiplicity of factors and the associated variability complicates computer modeling making accurate predictions of Gulf Stream velocities on the small spatial and temporal scales of interest to the sailor beyond the current "state of the art". A comparison of the output from one of several numerical models of the Gulf Stream (e.g. the U.S. Navy Research Lab. layered ocean model NLOM -see http://www7320.nrlssc.navy.mil/global_nlom/) to a satellite image of the Stream (e.g. from the Rutgers University site at http://marine.rutgers.edu/mrs/) provides graphic illustration of the relatively imprecise nature of present computer modeling.

Given these limitations the most effective way for the sailor to estimate currents associated with the Gulf Stream remains careful evaluation of sea surface temperatures and in particular, sea surface temperature gradients. Over much of the continental shelf and within the adjoining ocean basin water temperature represents the primary determinant of water density. This fundamental relationship is similar to that found in the atmosphere where air temperature affects the density of an air mass. Just as in the atmosphere where air mass density affects pressure (the familiar highs and lows) variations in water column density affect pressure at depth in the ocean. Ultimately, the distribution of water column pressures can induce currents just as the spatial distribution of atmospheric pressure leads to the generation of winds. The direction of flow in both the atmosphere and ocean is influenced by the rotation of the earth - the coriolis force. In the northern hemisphere this force causes moving particles to be deflected to the right of their initial trajectory. In the open ocean where friction is nearly negligible this results in flows essentially parallel to lines of equal pressure (isobars). Atmospheric flows behave similarly but tend to be more oblique because of increased frictional influence.

What these physical principles mean in practical terms is simply that variations in water temperature can induce flows. The speed and direction of these flows will vary as a function of temperature gradients (their sense, amplitude and rate of change) and location. In the northern hemisphere, an observer positioned with warm water to the right and cold to the left will be looking downstream towards the point to which the flow is proceeding. Applied to the main body of the Gulf Stream where warm offshore waters are bounded by the cooler inshore this relationship explains why the mean flows proceed to the north and east. It also serves to explain the flows associated with warm and cold core eddies or rings. For the case of cold core ring, the interior cold is bounded by exterior warm water. Placing the warm water to his right, an observer moving downstream with the flow would follow a counter-clockwise trajectory. The situation would be simply reversed for the warm core ring. Flow speed in all cases would be a function of magnitude of the temperature gradient and its rate of change. It's important to realize that these simple principles can be applied to all water temperature gradients not simply those associated with prominent currents such as the Gulf Stream. Without regard to origin or structure, each observed thermal gradient has the potential to affect local flows to some extent.

This functional relationship between water temperatures and current speed and direction can be illustrated by comparing direct measurements of flow with concurrent sea surface temperature (SST) patterns. Since 1992 scientists at the University of Rhode Island have maintained a current meter on the M/V Oleander which makes weekly trips between Port Elizabeth, New Jersey and Bermuda. A sample of these data from the October5, 2002 transit (Fig.1) shows significant spatial variability in the current field with speeds ranging from near zero to more than4 knots (kts) and directions from nearly all points of the compass.

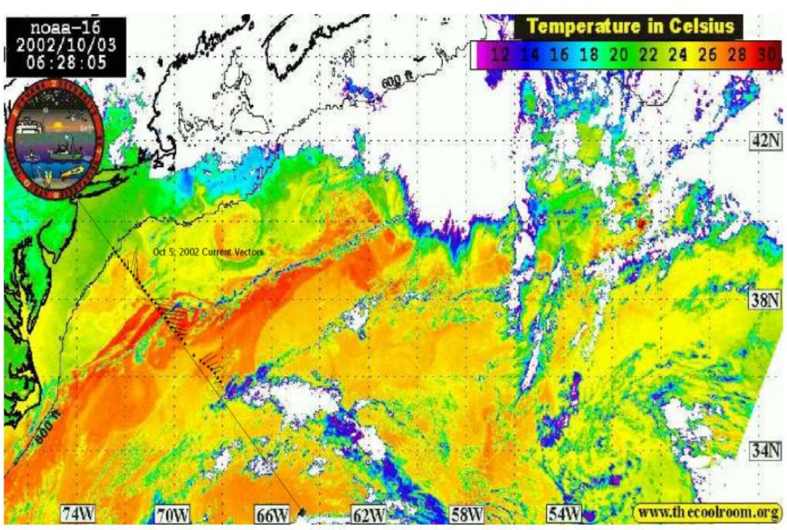

Figure 1 A Comparison of Surface Currents and SST – Northwest Atlantic – October 3, 2002
Source: SST Rutgers University, Currents courtesy of Dr. T. Rossby, URI

Placing these data over a satellite SST image from October 3, 2002 shows a close correlation between this variability and the spatial variations in water temperature. The main body of the Gulf Stream crosses the ship's track to Bermuda in the vicinity of 38N-71W. Water temperatures along this boundary increase abruptly from 22-24C to 28C coincident with the onset of an energetic east-going current. The current maximum of slightly more than 4 kts (2 m/sec)was observed at a point approximately 20 miles to the south of the boundary in the vicinity of both maximum temperature and maximum temperature gradient. To the south of this location speeds progressively decrease as the southern limit of the Stream is approached. This represents the typical surface velocity pattern for the main body of the Gulf Stream. Reviews of the long term data provided by Oleander indicate that the maximum current in this distribution is essentially constant equaling approximately 2 m/sec +/- 0.24 m/sec or 4 kts +/-0.48kt.

Significant flows were also observed to occur outside of the main body of the Stream (Fig.1). To the north near 39N-71.5W a flow from south to north was observed with speeds in excess of 3.5 kts affecting an area of approximately 30 nm along the ship’s track. This relatively discrete feature appears to be the result of a thermal feature produced by the disintegration of a warm core ring. The slight displacement between the velocity vectors and the SST pattern is most probably the result of westerly drift of the feature during the two days between the satellite pass and the ship's transit (October 3 - satellite - October 5 - ship).Notice that once again the current maximum is encountered at a point within the pool of warm water, most probably in the region of the maximum temperature gradient, and not at the outer edge of the feature.

Another interesting flow feature is evident to the south near 37N-69W. Here a tongue of warm water attached to the main body of the Gulf Stream has produced a sharp thermal boundary which results in the development of some additional flows to the east-northeast. Flow speeds within this feature are somewhat less than those observed in the main body of the Stream despite similar water temperatures most probably due to a weaker thermal gradient. Although the current observations shown in Figure 1 are not continued to Bermuda the variety in SST pattern evident in this area suggests that numerous small area patches of current with varying speed and direction should be expected in this region.

To summarize, the currents encountered along the rhumb line to Bermuda result from the combined effects of winds, water column density distributions and the earth’s rotation. The flows are turbulent and display significant spatial and temporal variability. These factors complicate modeling particularly on the small spatial and time scales of interest to the sailor. The close correlation between sea surface temperatures (SST) and flow speeds and directions makes careful study of the variety of SST data one of the best ways for a sailor to estimate current characteristics.

Moving now to the present condition of the Gulf Stream. When last viewed in mid May the northern edge of the main body of the Stream was crossing the rhumb line to Bermuda from northwest to southeast (see Note #1). A deep meander was in place to the east and there was only limited indication of significant ring development. Over the past few weeks cloud cover limited satellite views on many days pointing again to the importance of continuing and early observation. As the cover lifted in early June the Stream in the vicinity of the rhumb line was holding its position just to the south of 38N and retaining a northwest to southeast track. A meander remained to the east. This relatively benign pattern remained in place until approximately June 4th when a new wave formed along the northern edge of the Stream resulting in a series of small amplitude meanders. These features resulted in a progressive rotation in the trajectory of the flows crossing the rhumb line. At present these flows are crossing the rhumb line from southwest to northeast. The thermal data ([Fig.2](#))indicate some obliquity resulting in a slight foul current along the rhumb line to Bermuda. Satellite observations however, indicate a more nearly perpendicular crossing suggesting minimal adverse current (Fig.3).

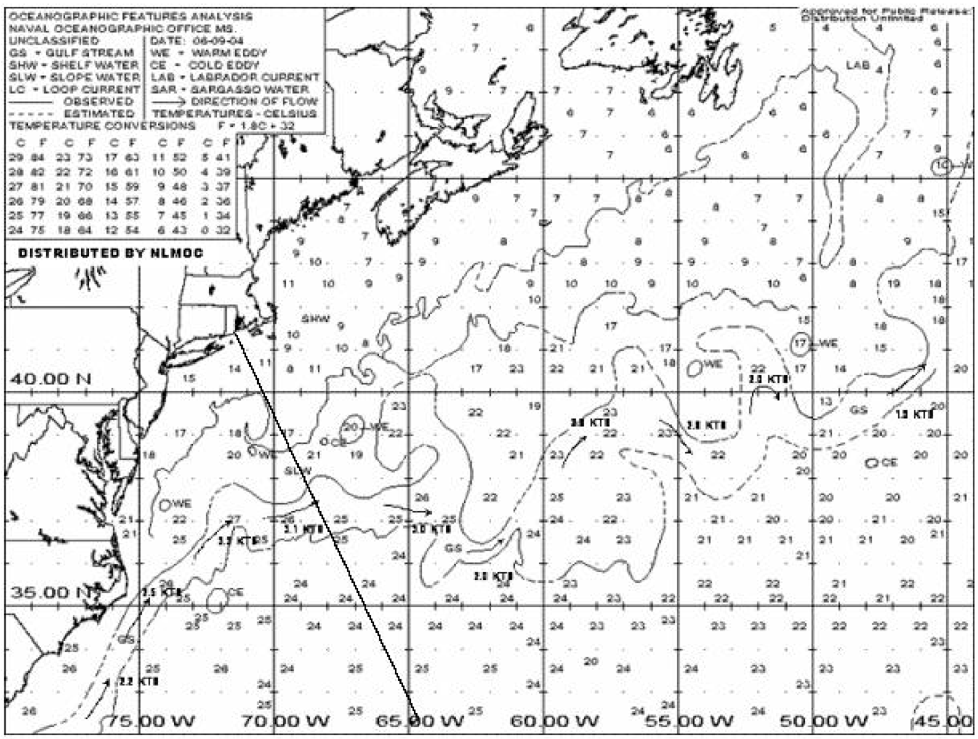

Figure 2 Sea Surface Temperatures – Northwest Atlantic Ocean – U.S. Navy Data

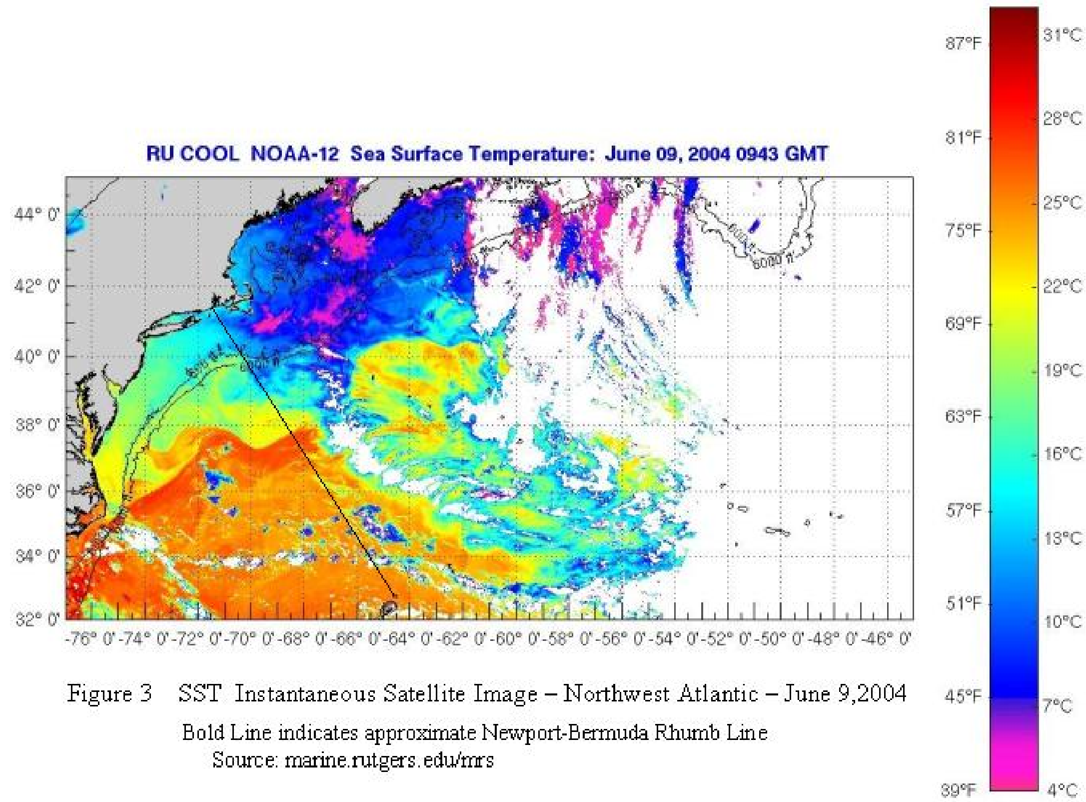

Figure 3 SST Instantaneous Satellite Image – Northwest Atlantic – June 9,2004

Bold Line indicates approximate Newport-Bermuda Rhumb Line

Source: marine.rutgers.edu/mrs

This latter view is considered the more accurate. It's also interesting to note that the warm core ring observed several weeks ago in the vicinity of 66W has moved slightly to the we stand now resides near 67W. None of the observations indicate significant cold core ring development.

The rate with which the Stream boundary has evolved over the past week indicates a need for careful observation in order to define precisely the conditions in place at the start of the Race on the 18th and their probable evolution during the course of the Race. Finally, the sharp boundary shown in Figure 3 seems ideal for the estimation of the associated current field. Applying the above criteria, where might the maximum current be found ? What is it's probably speed and direction ? We all hope to test the accuracy of these estimates in little more than a week.