Gulf Stream Characteristics

May 17, 2006

Note No.1

W. Frank Bohlen Mystic, Connecticut, Bohlen@uconn.edu

With slightly less than one month to go until the start of the Centennial Newport to Bermuda Ocean Race I hope that all navigators and tacticians have initiated some study of the Gulf Stream and had the opportunity to review some, if not all, of the notes which I prepared for the past four Races. This site also provides a reasonably comprehensive listing of web sites dealing with the Gulf Stream and North Atlantic weather. This list is by no-means complete but it does include many of the most popular and useful sites for analysis of weather and oceanographic conditions that might be encountered enroute to and/or from Bermuda. Please let me know of any recommendations you might have or errors encountered.

By way of introduction let me begin this discussion by repeating what I said in the 2004 Note #1: *"The Gulf Stream is an energetic boundary current separating the warm waters of the Sargasso Sea (the area of the North Atlantic surrounding Bermuda) from the cooler continental shelf waters adjoining New England. The resulting thermal boundary represents one of the most striking features of this major ocean current and one that is most easily measured. From Florida to Cape Hatteras the Gulf Stream follows a reasonably well defined northerly track along the outer limits of the U.S. continental shelf . Beyond, to the north of Hatteras, Stream associated flows proceed along a progressively more northeasterly tending track with the main body of the current separating gradually from the shelf. Horizontal flow trajectories in this area becomes increasingly non-linear and wavelike often forming large amplitude meanders that propagate downstream towards Europe and grow in amplitude. On occasion these meanders will become unstable and "pinch-off" forming independent rotating rings or eddies in areas north and south of the main body of the Stream. This combination of features has the potential to affect a significant portion of the rhumb line between Newport and Bermuda. It's important to realize that the influence of the Gulf Stream on conditions affecting Race strategies is not limited to water currents. The marked difference in sea surface temperatures along the inshore edge of the Stream also affects atmospheric conditions. Air warmed over the waters of the Stream rises transporting heat and water vapor aloft. Subsequent cooling of this air often favors the formation of a prominent cloud* *mass paralleling the course of the Stream. This discrete formation is often visible from some distance and is for many the first indication of the presence of the Gulf Stream (or large discrete masses of warm water). In addition to the clouds however, this rising air mass may significantly affect local wind conditions particularly during frontal passage. Conditions, such as the passage of a cold front, sufficient to increase the speed with which the warm, moisture laden, air moves upward can lead to conditions favoring the formation of thunderstorm cells often accompanied by heavy rains and locally intense and variable winds. The spatial and temporal features of these systems (i.e. small size-limited duration) and their sensitivity to heat transport rates makes accurate modeling and prediction of their characteristics difficult. This factor represents one of the primary reasons for the often significant differences between forecast conditions and those actually encountered in the vicinity of the Stream. A comparison of expected wind/wave conditions, as shown by broadcast weather maps, to those observed by satellite (see the Gulf Stream and Weather listing - e.g. the NWS surface analysis and compare to the wind data provided at http://manati.orbit.nesdis.noaa.gov/quikscat/) represents a useful and informative exercise and often provides clear illustration of the influence of the Gulf Stream on local meteorology.*

Given the prominence of thermal gradients within the structure of the Gulf Stream studies of Stream characteristics typically begin by the examination of sea surface temperature (SST) data. Historically this was only available in text format (delimiting the position of the north "wall" and the position of major features such as "rings") or fax to a selected few. The emergence of web based communications and public access satellite data has changed all of this over the past ten years. There are now an abundance of sources providing SST data for the northwest Atlantic. The problem is more the matter of selection and interpretation than an absence of information."

This summary implies that the currents associated with the Gulf Stream are to a large extent driven by gradients in water column density resulting from the spatial differences in water temperature and the associated horizontal pressure gradients. The physics governing this process are exactly the same as those affecting atmospheric circulation or winds. Just as variations in air temperature are often accompanied by changing wind speeds and/or directions, any change in water temperature will have associated with it some finite change in flow speed and direction. These density driven currents are not confined to the immediate vicinity of the Gulf Stream and can be observed to a greater or lesser degree across the entire continental shelf and beyond. Along the shelf their magnitude is typically small (due to weak thermal gradients) relative to tidal currents and as a result they are often ignored. Along the Newport to Bermuda rhumbline such a practice might lead to substantial cross-track errors however, due to the potential in this area for sharp localized thermal gradients associated with the mixing of the inshore and offshore waters. This fact adds to the importance of close monitoring of water temperatures along the entire route to Bermuda.

A schematic view of global oceanic water temperatures for mid-May,2006 is shown in Figure 1.

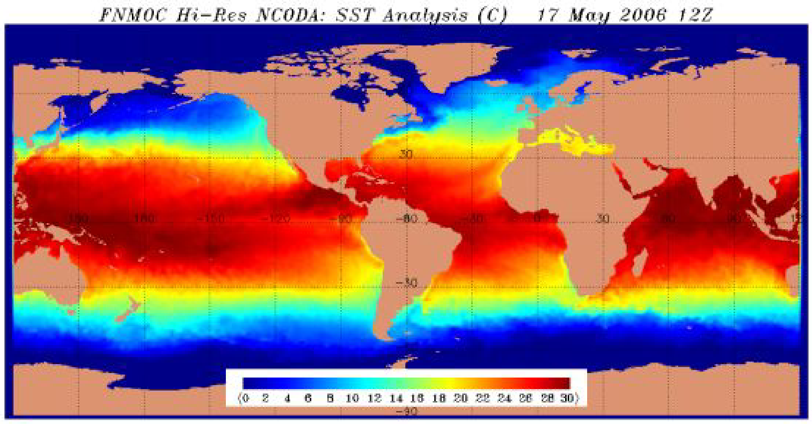


Figure 1 Global Sea surface Temperatures – Computer Simulation May, 2006

This image, produced by a U .S. Navy computer model, provides a graphic illustration of the influence of the Gulf Stream on water temperatures within the mid to northeast Atlantic, approaching Europe, and the relatively sharp thermal gradient separating the New England continental shelf waters from those to the south and east (i.e. the region of the Sargasso Sea). It is the structure of this thermal gradient along and adjacent to the rhumb line that must be carefully analyzed by the Newport - Bermuda navigator. Particular attention should be paid to the spatial structure and temporal changes. Accurate definition of the scale of these characteristics can often have immediate tactical benefit.

The variety of available satellite observations can provide a comprehensive view of Gulf Stream structure and, cloud cover permitting, an excellent way to track change. A view in February, 2006, for example, obtained from the Rutgers University site provides an fine example of the Stream structure and a variety of associated features (Fig.2).

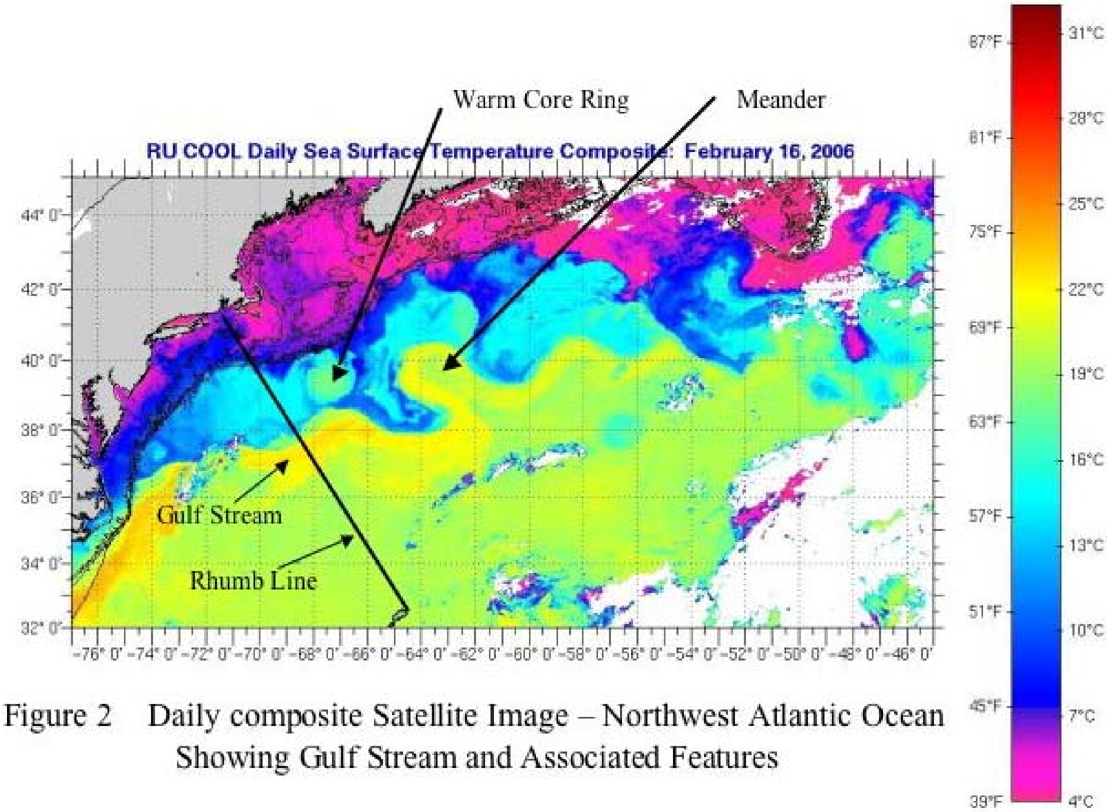


Figure 2 Daily composite Satellite Image – Northwest Atlantic Ocean Showing Gulf Stream and Associated Features

Source: Rutgers University

Proceeding southeast along the rhumbline, water temperatures in this image progressively increase from a low of approximately 5 oC nearshore to a high of 22oC. This maximum is encountered at a distance of approximately 250nm from Newport and marks the core of the Gulf Stream current which on this day crossed the rhumbline along the perpendicular and proceeded to the north and east. Average current speeds were in the range of 2 to 3 kts.

It's important to realize that this point is located along a line approximately 30 to 40 nm to the southeast of the point where water temperatures begin to rapidly increase (i.e. the so-called "north wall" of the Gulf Stream). This is understandable given the relationship between thermal gradient, water column densities, and flow speeds discussed above. Beyond this point temperature gradients weaken and in time reverse resulting in a slight fall in temperature (see Fig.2). This reversal in gradient often has associated with it a flow to the southwest countering, for some time, the usual northeasterly flow of the Gulf Stream.

The flow of the main body of the Gulf Stream beyond Cape Hatteras shown in the satellite image displays an evident sinuous structure in planview which in the vicinity of 38N 63W becomes quite pronounced with flows first undergoing a counterclockwise rotation to the north and west followed by a clockwise rotation back to the north, then east and southeast. Under usual circumstances this meander would be expected to migrate slowly downstream to the northeast. On occasion meanders can pinch-off trapping a parcel of warm water to the north of the main body of the Stream. The resulting “warm-core” ring can display a marked thermal gradient resulting in a well defined clockwise rotation with flow maxima of approximately 2 kts.. These features tend to slowly drift to the west and in time will breakdown as reducing water depths along the continental shelf favor increased vertical mixing. Such a feature is evident in the February 16 th image.

Over the next several weeks the structure of the main body of the Gulf Stream progressively changed as the meander moved to the east. The warm core ring remained in place with only a slight westerly displacement over a two week period (see Fig.3 and Fig.4).

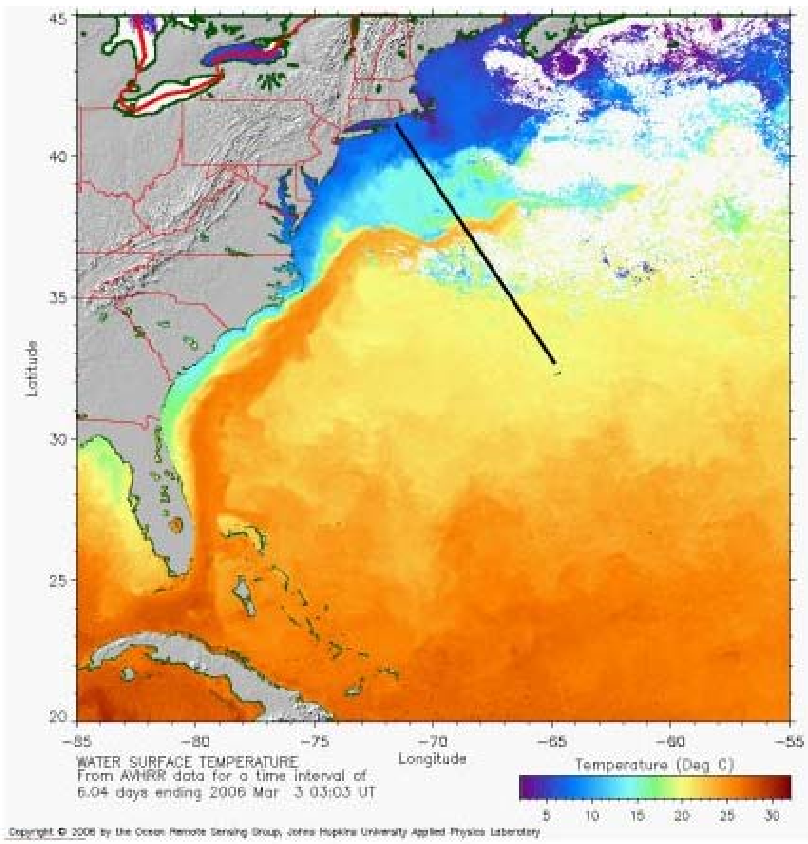


Figure 3 Six Day Composite Satellite Image – Northwest Atlantic Ocean

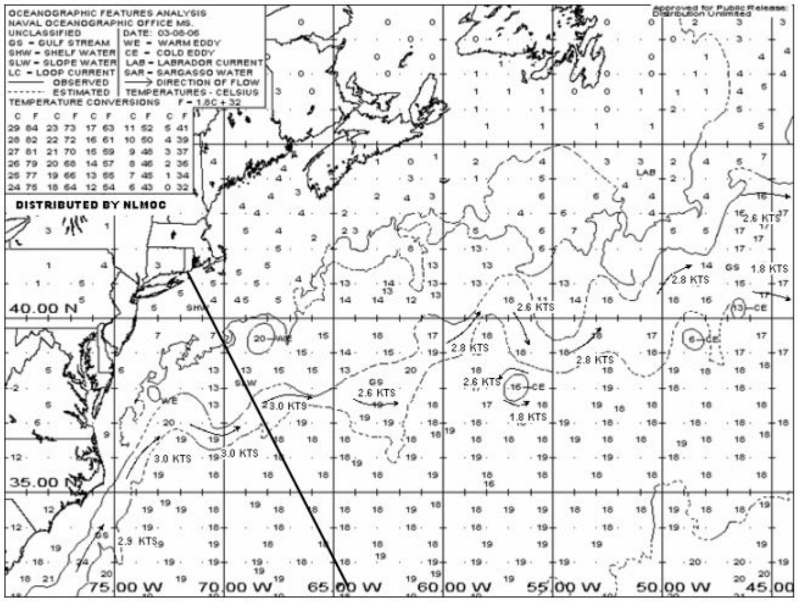


Figure 4 U.S. Navy Analysis of Sea Surface Temperature Features – March 8, 2006

This rather quiescent state changed abruptly in early April as a large amplitude meander developed in the vicinity of the rhumbline (Fig. 5).

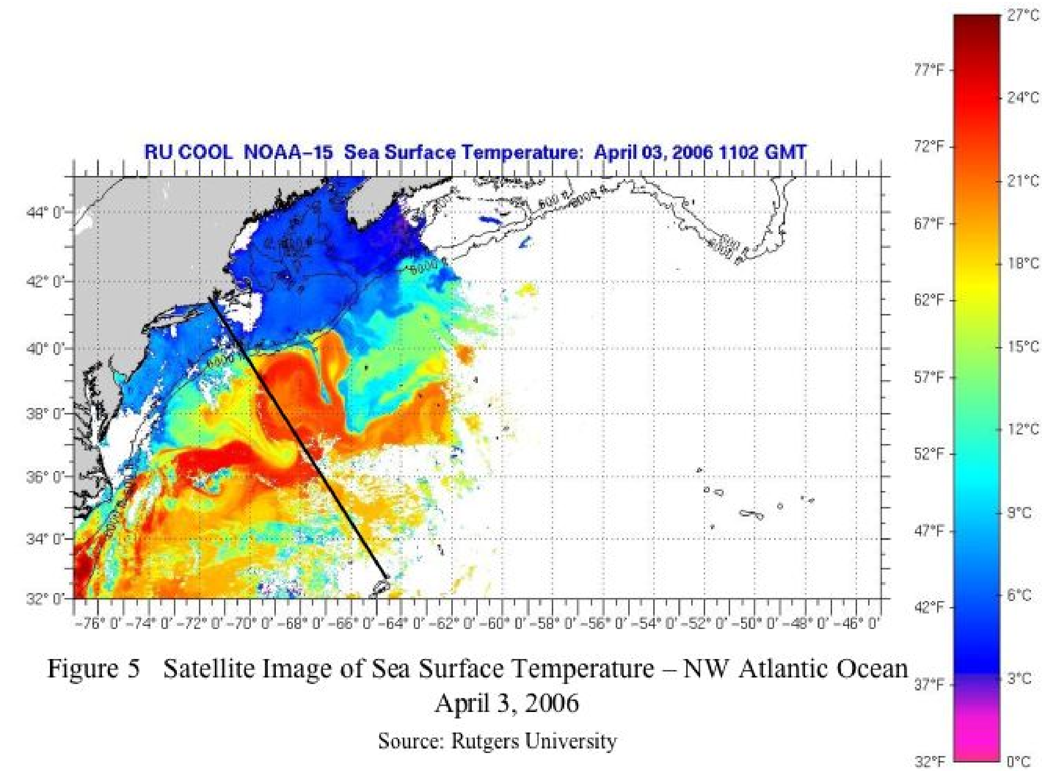
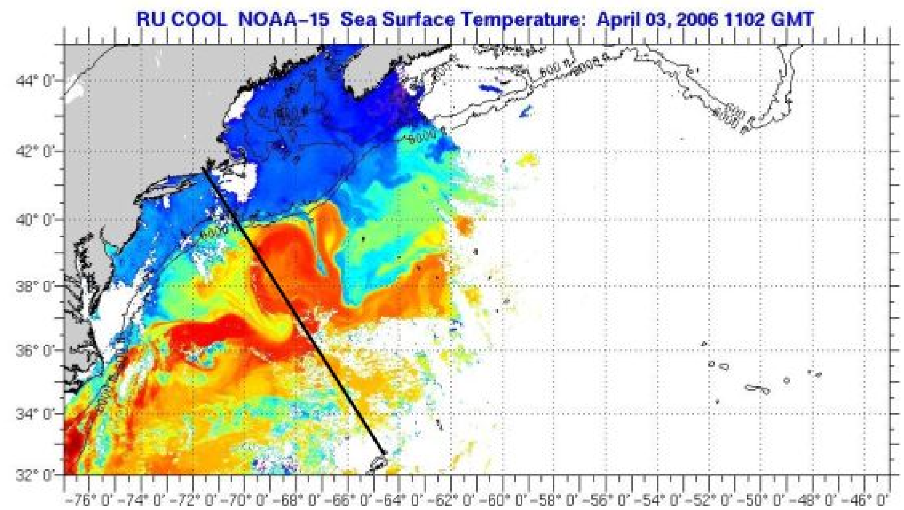


Figure 5 Satellite Image of Sea Surface Temperature – NW Atlantic Ocean
April 3, 2006
Source: Rutgers University

This impressive feature resulted in northly flows along nearly 150nm of the rhumbline and bought the warm waters of the main body of the Stream to within 90nm of Nantucket.

By early May, 2006 the April meander had migrated leaving behind a large mass of warm water (Fig.6) affecting water temperatures to within approximately 60nm of Montauk.



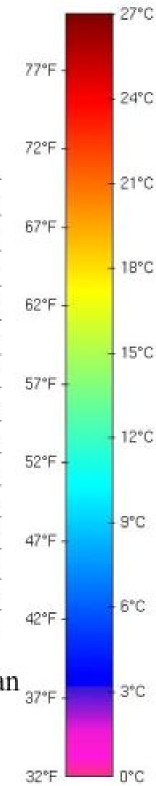


Figure 5 Satellite Image of Sea Surface Temperature – NW Atlantic Ocean
April 3, 2006
Source: Rutgers University

The thermal gradients associated with this feature produced a generally clockwise flow (i.e. the rule might read- in northern hemisphere - warm waters to the right of an observer looking downstream). This situation is slightly more complicated however, due to the fact that the feature appears to remain attached to the main body of the Stream in the vicinity of 37 50 N - 70 W and possibly also within the vicinity of 68 30 W (Fig. 6). This structure implies that when first encountered by a boat proceeding from Newport to Bermuda the warm water mass (warm core ring ?) would produce flows to the east followed by weaker to no flow as one proceeds down the rhumbline. Stronger southerly flows are to be found approximately 40nm to the east of the rhumbline. As one approaches 38 N flows would progressively shift to the south and west favoring a track proceeding westerly to encounter the main body of the Stream and the associated northeasterly flow at a point west of the rhumbline and south of 38 N.

Detailing of the evolution of the early May Gulf Stream features has been impeded by nearly continuous cloud cover. This began to break over the past few days. Satellite views from the 14 th to the 17th of May (Fig.7 and Fig.9; note that these are a combination of instantaneous and daily composite images. It's interesting to assess the differences in detail provided by both. The averaging associated with compositing seems to reduce spatial resolution and contrast) indicate little substantive change in structure along and adjacent to the rhumbline.

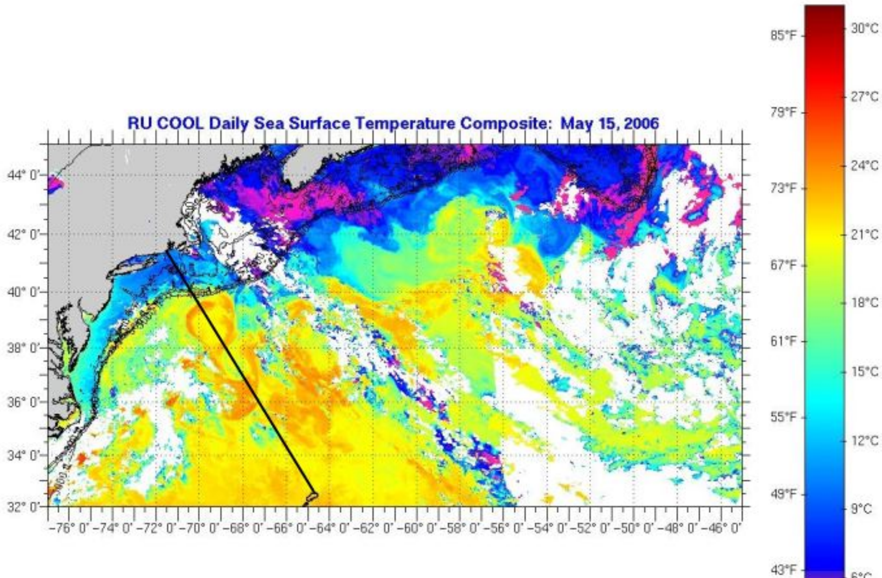


Figure 8 Daily Composite Image of Satellite Observed Sea Surface Temperatures May 15, 2006

Source: Rutgers University

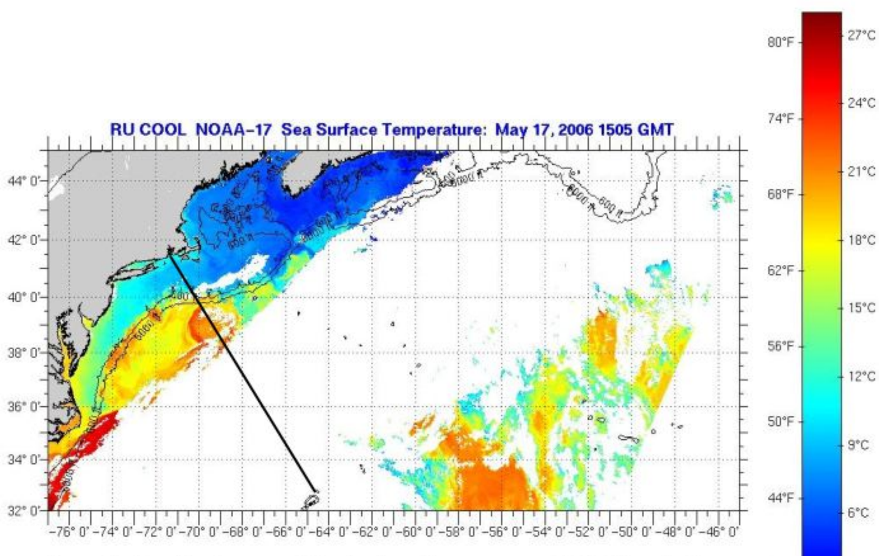


Figure 9 Satellite Image of Sea Surface Temperature – NW Atlantic Ocean May 17, 2006

Source: Rutgers University

The warm water mass remains in place with some slight change in definition. In particular, its northern limits appear more well defined as a result of some reduction in the along shelf limb observed on May 5 (Fig.6). Examination of the 14 th to 17th sequence of images indicates that the warm water mass has drifted slowly to the east. This appears consistent with a feature in close contact with the main body of the Stream. The ultimate behavior is however, not possible to predict at this time due to a lack of detail regarding the actual structure of the main body of the Stream. The image of 14 th indicates a deepening in the meander observed in early May. If this were to continue it's possible that the warm water feature will detach completely and begin a drift westward. Alternatively the warm water might be completely assimilated by the Stream. The actual progression obviously will have major tactical implications for Newport-Bermuda racers. We'll be looking to resolve this issue as well as attempting to obtain a more detailed view of the features that might exist to the south of the Stream to Bermuda over the next couple of weeks. After the experience of the 2004 race when many encountered a major flow feature just north of Bermuda, this latter area deserves particular mention.