Gulf Stream Characteristics

June 2002

Note No.2

W.Frank Bohlen

It's less than two weeks to the start of Newport-Bermuda 2002 so I?m sure that many of you are beginning to develop an "interest" in the characteristics of the Gulf Stream as they may affect your routing and the associated strategic planning. Hopefully some time has already been devoted to a study of Stream features as shown by several of the WEB sites listed on the Race homepage. If so, I'm sure that you are thoroughly familiar with the problems posed by cloud cover. Since the Newport Safety at Sea Seminar in early March there have been several 7 to 10 day periods of unbroken cloud cover. Such cover complicates analysis of the evolution of Stream characteristics and leaves much to "artful interpretation". The best way to minimize the effect of cloud cover on Race planning and to guard against the possibility that such dense cover might occur during the week before the Race is to begin observations as early as possible (i.e. now !).

In addition to examining the variety of WEB based data sources and beginning examination of Stream characteristics, I also hope that you have had the opportunity to review the entire series of my Gulf Stream Notes posted on the Bermuda Race web site (www.bermudarace.com) as part of the Gulf Stream and Weather links. These provide a discussion of most of the major features of the Stream and governing factors as well as providing some indication of the sources of error in the variety of available data. An understanding of this latter factor is of particular value to the small boat navigator and minimizes the potential for stress and disagreement when features shown on the data plots aren?t located as reported and seemingly produce set and drift contrary to that anticipated.

Very briefly, the Notes discuss the factors governing the location of the main body of the Gulf Stream - a boundary current formed along the north western margin of the North Atlantic between the warm waters of the Sargasso Sea (surrounding Bermuda) and the colder waters flowing along the New England continental shelf . The sharp thermal gradients characteristic of this system result in horizontal pressure differences in the waters which in combination with the drag on the ocean surface produced by winds serve to produce an energetic and dynamic flow regime. Long term observations have shown the maximum velocities in the Stream to be remarkably constant (2.07 m/sec +/-

0.24m/sec - meters/sec or approximately 3.5 to 4.5 knots) (see Note 3, 2000). Maxima are generally located in the vicinity of maximum thermal gradients typically located approximately 20 nm to the south and east of the northern boundary of the Stream. Keep these characteristics in mind as you review the Navy thermal plots showing speeds of 1.2 kts (or so) in the vicinity of the rhumb line!

While speed maxima may be relatively constant the direction of flow in the Stream can be expected to display significant time variability. After leaving the coast in the vicinity of Cape Hatteras the Gulf Stream proceeds along a generally northeast tending track and becomes progressively more sinuous and meandering. As meanders form they tend to increase in amplitude and drift to the northeast. Meandering can result in near reversals of flow direction in the vicinity of the rhumb line. On occasion the growth in amplitude leads to instabilities and the "pinching off" of a portion of the main body of the Stream resulting in the formation of eddies or rings. Rings formed to the north of the main body of the Stream retain a segment of the warmer Sargasso Sea water in their interior while rings formed to the south tend to capture masses of the colder continental shelf water prior to breaking off. Both the "warm core rings" or warm eddies and the "cold core rings" or cold eddies drift to the west following formation , if clear of Stream influence or drag, at rates of approximately 1-2 nm/day. Individually, warm core rings rotate clockwise (WC - with the clock) while cold core rings display counterclockwise rotation (CC - counterclockwise). Since both warm core and cold core rings are formed from fragments of the Stream and as a result display relatively sharp thermal boundaries each feature has associated with it a distinct velocity field. Maximum velocities for both are to be found near the outer limits of the annular ring in the area of maximum thermal gradients. Peak speeds in these areas range from 2 to 3 knots. In addition to simple velocity effects the presence of rings has the potential to affect local sea state both due to wind against current factors and the enhancement of local weather produced by gradients in atmospheric heating associated with sea to air exchange. Given this range of potential effects an examination of the presence, structure and progress of rings must be considered an essential part of small boat route planning to Bermuda.

With these comments as background let's turn our attention to the structure of the Stream over the past month or so. Through most of the month of March the Stream in the vicinity of the rhumb line maintained a relatively linear form with flows in the main body proceeding from the southwest to the northeast. The warm core ring which was observed to form in early February proceeded to the west at a rate of approximately 2 nm/day and dissipated following contact with the continental shelf to the east of the entrance to Chesapeake Bay. This represents a typical progression for many of the warm core rings. In early April water temperatures were slowly warming and the Stream structure became progressively more complex. The main body broadened substantially to the east of the rhumb line and deformed into a series of deep meanders. This meandering favored the formation of a number of warm and cold core rings to the north and south of the Stream, respectively. Over the next three weeks the cold core rings displayed only slight westward drift remaining in the vicinity of 62 W and 57 W along approximately 37N (see Fig.2).

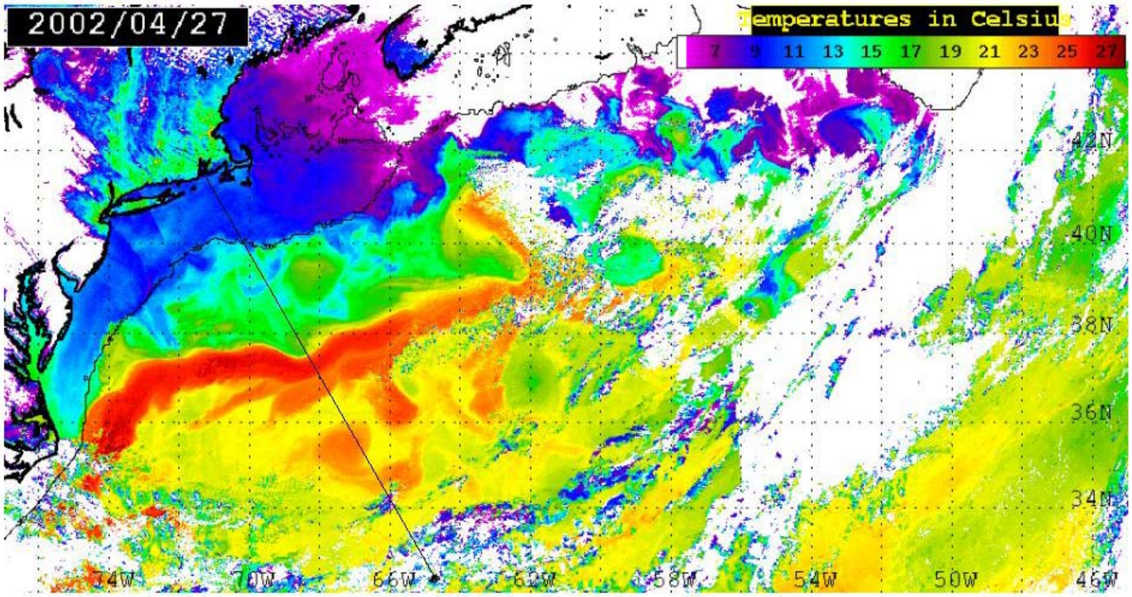

Figure 1 Sea Surface Temperatures – Composite Satellite Image
Rutgers University Site April 27, 2002

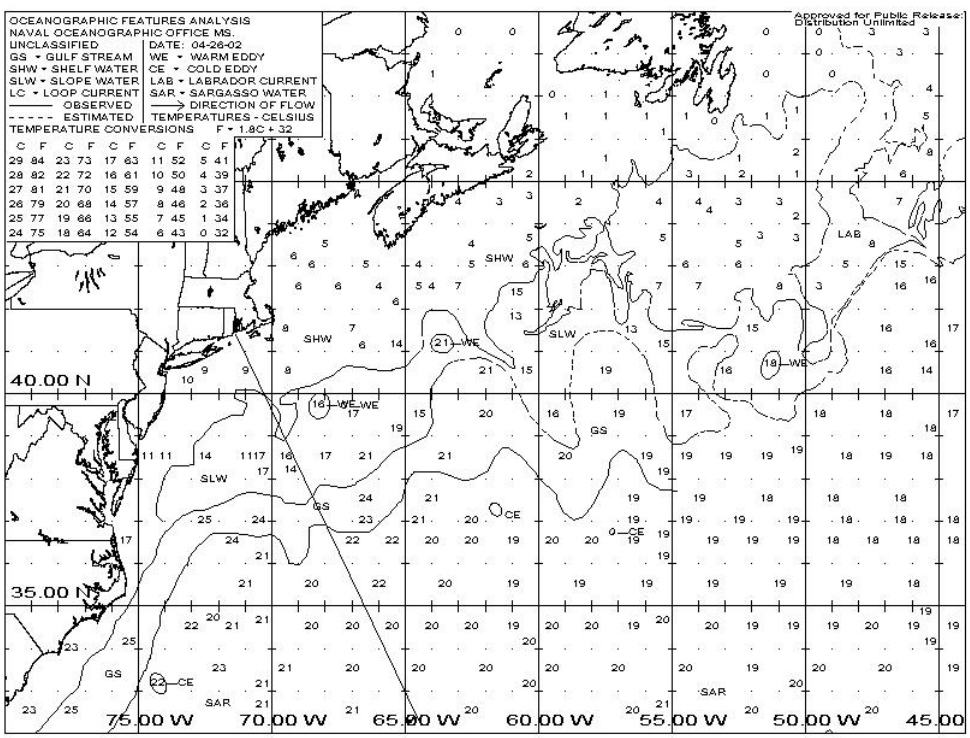

Figure 2 USN Sea Surface Temperature Analysis 4/26/02

In contrast,the warm core rings drifted steadily to the west. By the first week in May the ring observed at 68W ~ 40N was contacting the rhumb line near 70W 39N well to the north of the main body of the Stream (compare positions in Figs 1 and 2 with those in Figs 3 and 4). Examination of the satellite composite (Fig 3) shows only minor entrainment of the main body Gulf Stream water by this ring (study the blue-green patterns) implying that a small area clear of ring influence might exist between the southern limit of the ring and the northern edge of the Stream. Obviously, at this time the ring was beginning to produce a substantial flow to the north along the rhumb line. Boats enroute Bermuda during this period would have tried to avoid this countercurrent.

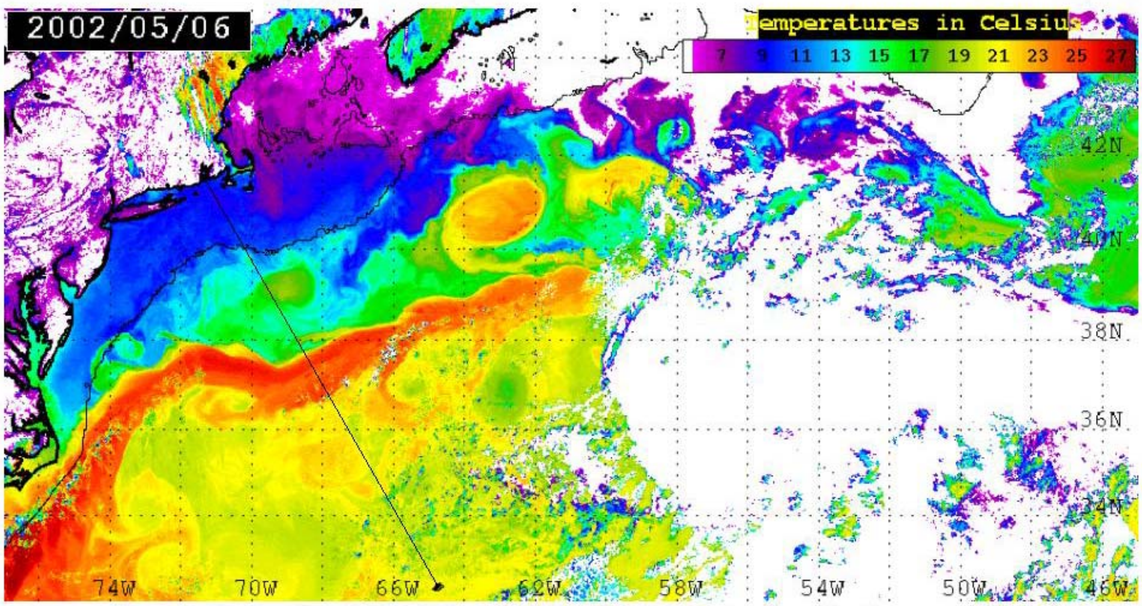

Figure 3 Sea Surface Temperatures – Composite Satellite Image
Rutgers University Site May 6, 2002

(figure 4: missing)

Proceeding through the month of May, the ring in contact with the rhumb line continued its westerly drift while the meander in the main body of the Stream deepened (Fig 5 and Fig 6). The area to the south of the Stream on to Bermuda appeared relatively free of organized rings although the variety of thermal gradients shown on the satellite images appear sufficient to produce some measurable flows with varying strength and direction which in the future might consolidate into a more well-defined feature. Routing for this period might favor a rather sinuous track proceeding first along the eastern side of the rhumb line to intercepting the warm core ring near 69W 39N (or so). Following the ring associated currents (as the winds permit) the track would then slowly proceed back to the west across the rhumb line to enter the main body of the Stream near 69W 37.5N.

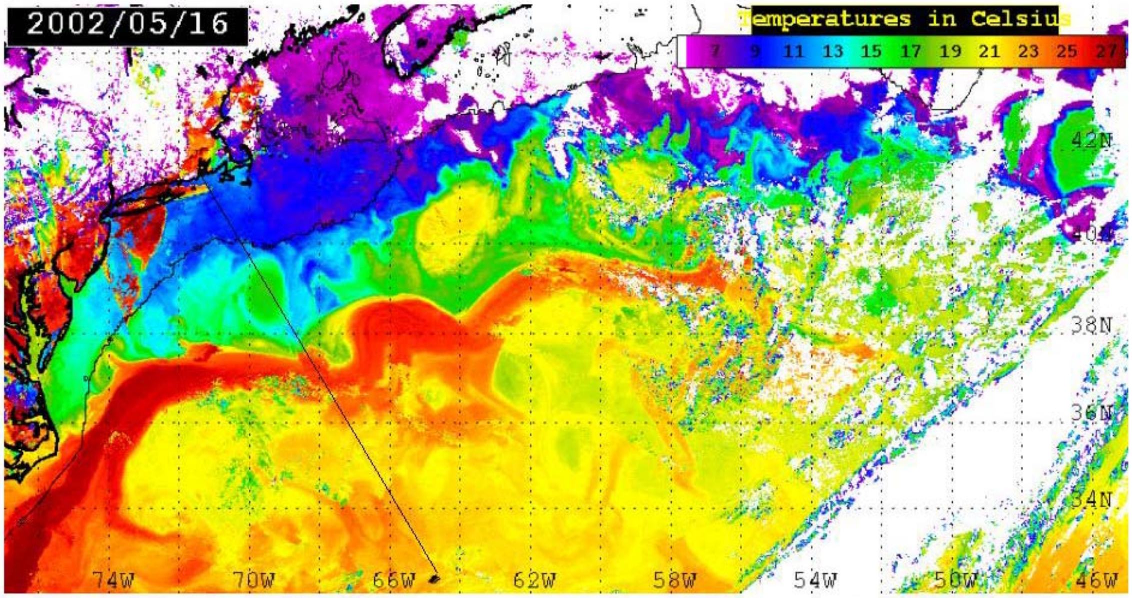

Figure 5 Sea Surface Temperature – Satellite Composite Image
Rutgers University Site May 16, 2002

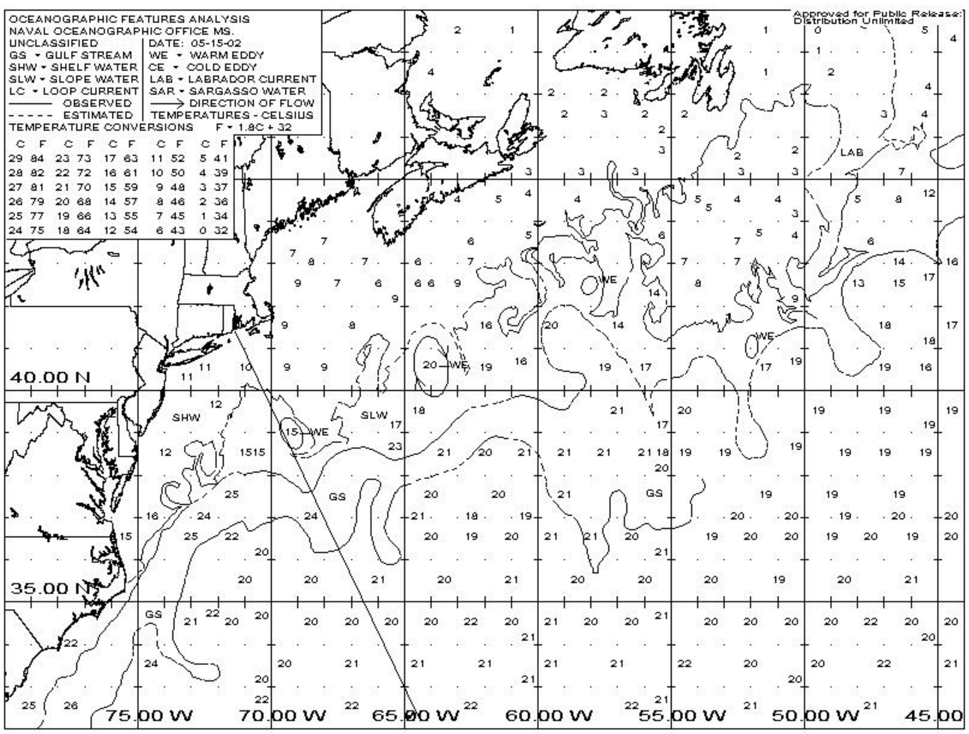

Figure 6 USN Gulf Stream – Sea Surface Temperature Analysis

Following the crossing of the Stream (approximately 90nm wide at this point) the track would closely follow the rhumb line to Bermuda. By May 31st the above warm core ring had drifted further to the west resulting in only slight contact with the rhumb line. The meander to the west of the rhumb line had deepened substantially resulting in a sinuous Stream trajectory across the line and some indication of a developing instability that may shortly result in the formation of several new rings. Despite this progression the distance between Newport and the northern limit of the main body of the Stream remained essentially constant during this period (~ 250nm). Total Gulf Stream width however, has decreased substantially (~ 50nm). The meander pattern observed over the past few weeks has displayed several unusual characteristics. First, the pattern has deepened to the west of the rhumb line resulting in a progressive increase in the distance between the south going limb of the feature and the Stream. This appears to be contrary to the normal progression that would see developing features moving downstream to the east. Second, the developing feature does not appear to be accompanied by significant downstream meandering. In planview, the feature appears to be very nearly a right angle in Stream trajectory. The beginnings of some meandering to the east of the rhumb line evident in the May 31st satellite image (see Fig 7) suggest that it's unlikely that this nearly "linear" feature can be sustained.

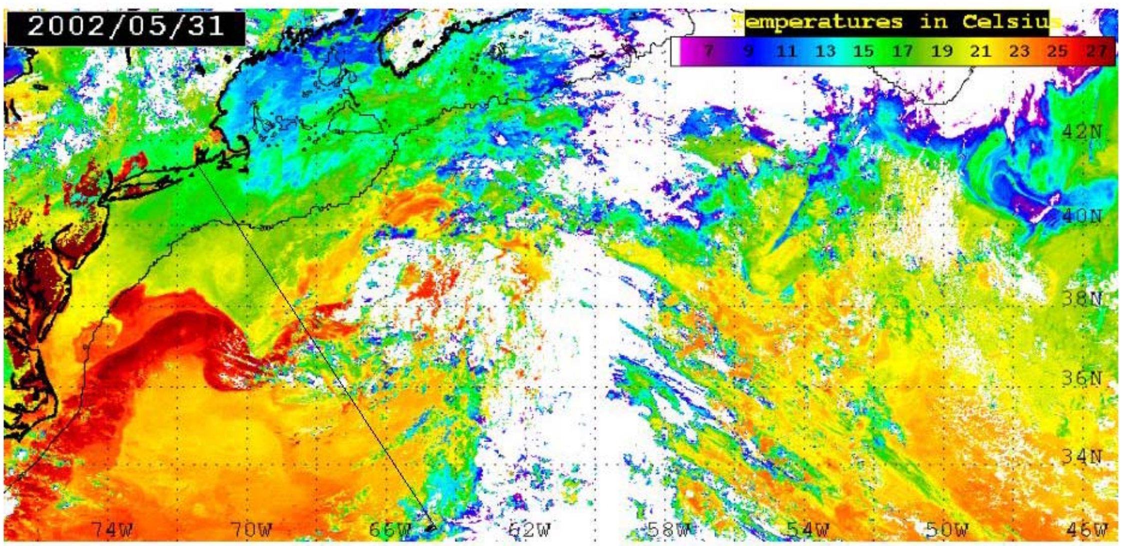

Figure 7 Sea Surface Temperature – Composite Satellite Image
Rutgers University Site – May 31, 2002

Using the past as some indication of the future, the development observed during April and May suggest that the warm core eddy will over the next two weeks continue to drift to the west resulting in a progressive reduction in associated flow effects in the vicinity of the rhumb line. Given the present form of the Stream to the west it's also possible that this ring will be absorbed within the main body of the Stream during this time. The elimination of ring effects leaves only the main body of the Stream to affect flow conditions in the way of the rhumb line. The deepening of the meander near 70W shown in the May 31st image (see Fig 7) suggests that the direction of flow across the rhumb line may become increasing oblique over the next two weeks leading to nearly northerly flows as the Stream crosses the line. Such a development might have profound implications relative to optimum routing to or from Bermuda.