The Gulf Stream Near the Rhumb Line Newport-Bermuda May 10, 2010
An Analysis of Conditions

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As we get into this year's analysis of the state of the Gulf Stream in the vicinity of the rhumb line between Newport and Bermuda please take a few minutes to review the short "primer" or tutorial published in this year's Notice of Race and posted on the Race homepage. It provides an introduction to the major features of the Stream that is intended to help navigators understand some of the factors affecting Stream currents and the tools available to evaluate them for tactical purposes. The majority of Stream studies make use of two primary characteristics, the evident spatial variations in sea surface temperatures (SST) and the associated patterns of sea surface heights. Direct current measurements are relatively rare and, since they tend to be of short duration and site specific, are generally of little use to the small boat navigator.

Examination of SST satellite data provided by a number of sites including those maintained by Rutgers University (http://rucool.marine.rutgers.edu/) and Johns Hopkins University (http://fermi.jhuapl.edu/sat_ocean.html) shows water temperatures in April along the rhumb line increasing progressively from lows near 40^{o} F within Block Island Sound to highs in excess of 70^{o} F in the vicinity of 37^{o} N (Fig.1). Bermuda waters display only slightly lower temperatures than these highs. The abrupt change in SST near 37^{o} 30' N marks the northern boundary of the Gulf Stream. The meandering nature of this boundary shown in the image results in flows across the rhumb line proceeding from the northwest to the southeast. This trajectory can be expected to progressively change with time as the meander moves to east-northeast in a manner similar to a wave. The rates of advance display some variability but are generally on the order of miles per day. In this case, the pattern provided by the April 23rd image (Fig.2) shows that the meander moved approximately 40 nm to the east in 10 days or ~4nm/day bringing the northern boundary of the main body of the Stream at the rhumb line nearly 75 nm closer to Newport. Flows across the rhumb line during this period remained northwest to southeast with some backing or anti-clockwise rotation. The trend favors the development of flows that are increasingly perpendicular to the rhumb line. This change in flow direction as the meander progresses may have significant effect on both speed of advance and sea state making knowledge of the probable rate of change of value to the small boat navigator. These rates are best estimated using a time series of satellite views. This necessarily requires some time and is one of the reasons that early study of Gulf Stream prior to a Newport Bermuda passage is recommended.

In addition to the meandering pattern, the April SST images show several reasonably well organized thermal features to the north and to the south of the main body of the Gulf Stream. The most prominent feature to the north was, on April 13th located near 39^{o} 30' N and 68^{o} W. The temperature pattern suggests that the flows associated with this feature will be clockwise characteristic of a warm core ring. Such rings can support significant flows with maximum speeds in excess of 2 knots (100 cm/sec). In a manner similar to the main body of the Stream these maxima are located at some distance in from the edge of the ring in the vicinity of the maximum thermal gradients.

Warm core rings, free of direct Stream influence, will tend to migrate to the west. Examination of the April 23rd SST image (Fig.2) indicates that the ring centered near 68^{o}W on the 13th has migrated to the southwest and is now centered near 68^{o} 15' W suggesting a migration rate of approximately 1.5 nm/day. Such a rate will bring the ring in close contact with the rhumb line within approximately 20 days favoring the development of northerly flows near the line. Continuation of this westerly migration will necessarily result in the movement of the ring across the rhumb line in approximately 60 days implying that this feature may affect conditions in June, at least to some extent.

To the south of the main body of the Stream the composite SST images show several areas where warmer water surrounds a patch of cooler water (see Fig.1&2). Such distributions favor counterclockwise flows in a manner similar to those associated with a cold core ring. The lack of consistency in these features from image to image however, indicates that they are most probably an artifact of the compositing process used to produce the image and not embryonic cold core rings. There are techniques other than simple thermal imaging that might be used in the search for cold core rings, such as altimetry, which will be discussed in a moment.

By early May the meander in the main body of the Stream near the rhumb line had progressed an additional 40 nm to the east resulting in nearly east-west flows across the line (Fig. 3). This rate of progression was slightly less than the previously estimated 4 nm/day. To the north, the warm core ring is now in close contact with the rhumb line resulting in north-northwest flows towards Newport in the vicinity of 39^{o} N. This indicates a drift slightly greater than the previous estimate suggesting that this feature should be clear of the rhumb line by the 18th of June and the start of the Race. This ring however, has also shown some increase in diameter since the 23rd of April which in combination with its trajectory and the migration of the meander brings it closer to the main body of the Stream. Contact and the possible entrainment within the Stream could significantly affect ring trajectory and ultimately integrity.

To the south of the main body of the Stream the SST image of May 6 provides no indication of organized features such as cold core rings except in the vicinity of 38^{o} N 62^{o} W or well to the east (Fig.3). Again, this may be the result of the averaging associated with the daily composite image.

The utility of the satellite images is often compromised by cloud cover over our area of interest. It's an additional reason for early study of the Stream. In the absence of visual images one is forced to rely on models. Of the variety of models available (see e.g. USN and NOAA models at websites listed under *GS and Weather* on the Race homepage) perhaps one of the most useful relies on satellite measurements of the height of the sea surface above a specified datum. This height varies as a function of the density of the water column which in turn varies as a function of a number of factors including water temperature and salinity. In general, a warmer column of water stands a bit taller than a cooler one over the datum. Since these spatial differences in height and associated density can affect horizontal pressure gradients they can produce flows just as spatial differences in atmospheric densities/pressures can produce flows i.e. winds. The fact that these satellite measurements can be taken frequently allows regular updating of model estimates and a continuing progression of flow predictions.

Examination of the NOAA altimetry based model data for May 6th (Fig.4) shows the main body of the Stream crossing the rhumb line just to the south of 38° N, or approximately 30nm to the south of the marked thermal boundary shown on Figure 3, in the area expected to display maximum thermal gradients. This location of maximum flows is consistent with a variety of historical data provided by direct current measurements. The maximum speeds indicated appear to be on the order of 3 knots which is low when compared to direct measurements. Maximum Stream speeds typically approach 4 to 4.5 kts with occasional higher speeds during extreme wind events. These differences between modeled and measured appear to be primarily associated with model criteria and should be kept in mind when applying the altimetry based data for tactical purposes.

In addition to main body details, the May 6th altimetry based model also shows the warm core ring to the north of the Stream centered near 38° 45' N 68° 30' W close to the position indicated on the SST image. The model results suggest that the ring is in close contact with the Stream and may very well be entrained. This possibility bears watching. Ring associated flows influence a portion of the rhumb line with speeds in excess of 2 kts to the northwest near 38° 30'N.

While difficult to impossible to see on the SST satellite image, the altimetry model shows two counterclockwise features to the west of the rhumb line (Fig.4) similar in structure to a cold core ring. Maximum flows in these features are generally less than 0.5kts. Despite low speeds the features warrant some attention due to their position and the potential to adversely influence Newport to Bermuda speed of advance. It’s likely that they are not as well organized as a cold ring and are simply the result of the spatially variant water temperature/salinity field over the continental shelf. If so they will tend to be short lived and/or transient.

To the south of the main body of the Stream the altimetry based model shows two cold core rings on either side of the rhumb line one centered near 34° N 68° W and the other near 35°N 65° W(Fig.4). Both of these will tend to drift to the west at speeds of approximately 2-4nm/day. By race time such drift will have moved the westerly ring clear of the route to Bermuda while moving the easterly ring towards the rhumb line. We’ll be following this latter track with some interest.

Similar to the unusual cold features shown to the north of the main body of the Stream, the altimetry based model shows two relatively well organized warm features to the south, one near 35° 30' N 69° 30'W and the other near 36° N 67° W in close proximity to the rhumb line. Again these are expected to be transient but, due to their locations, bear watching and some study over the next month or so.

Reviews of the past two months provide clear indication of the dynamic nature of the Gulf Stream and its associated features. It’s evident that a number of these characteristics can change over times equal to or shorter than the duration of the typical Newport- Bermuda Race and the passage home. These changes may alter flow speeds and directions affecting set and drift as well as sea state. As a result they may have both tactical and safety implications. The variety of data available today allows every navigator to develop the personal understanding or “feel” for these dynamics essential for reasoned decision making over the course of the Race and/or homeward passage. These individual talents are best developed by personal study of Stream characteristics using the sources discussed in this note or other similar sources. It’s my hope that these notes help in this process.

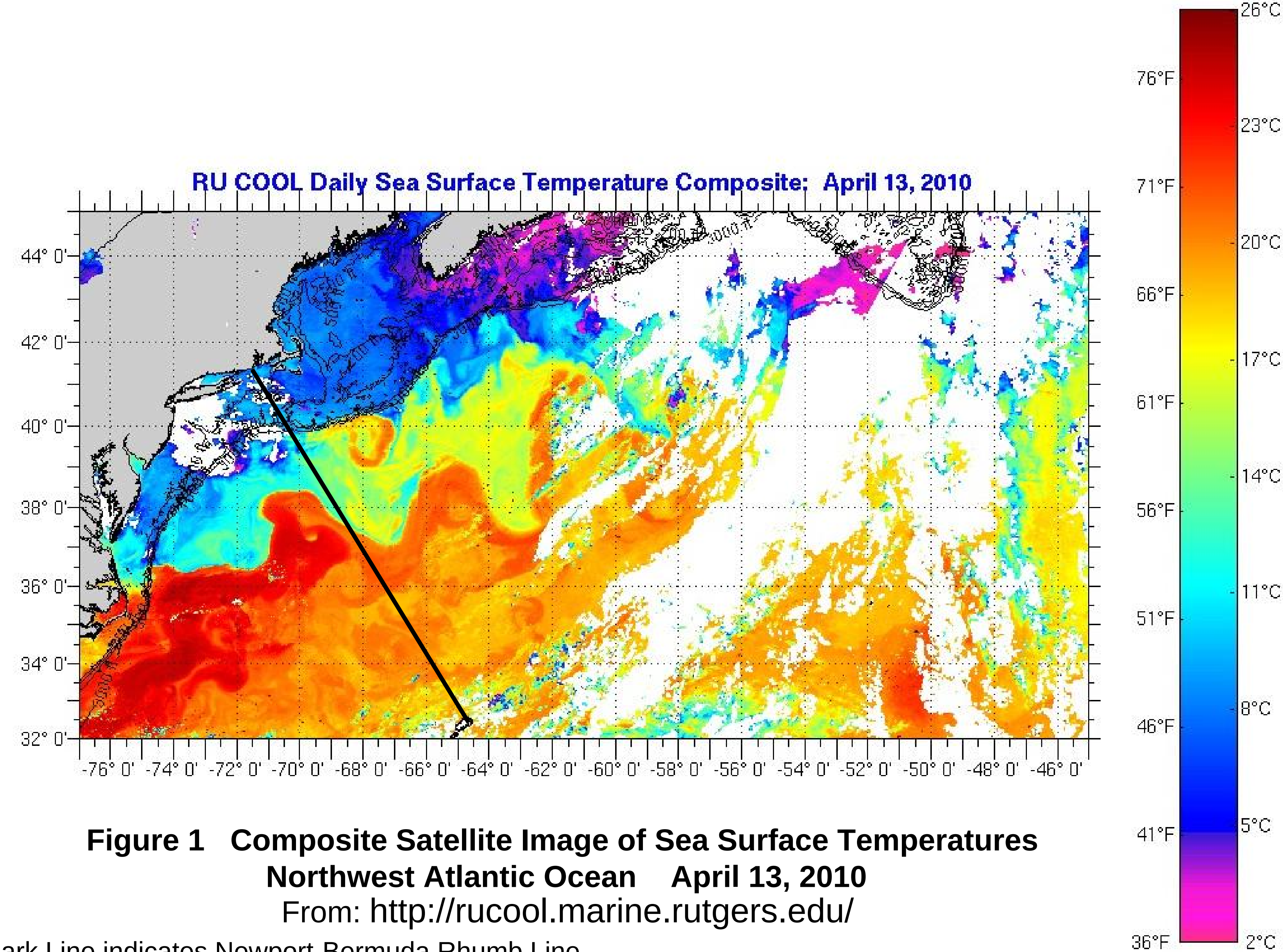

Figure 1 Composite Satellite Image of Sea Surface Temperatures
Northwest Atlantic Ocean April 13, 2010
From: http://rucool.marine.rutgers.edu/

Dark Line indicates Newport-Bermuda Rhumb Line

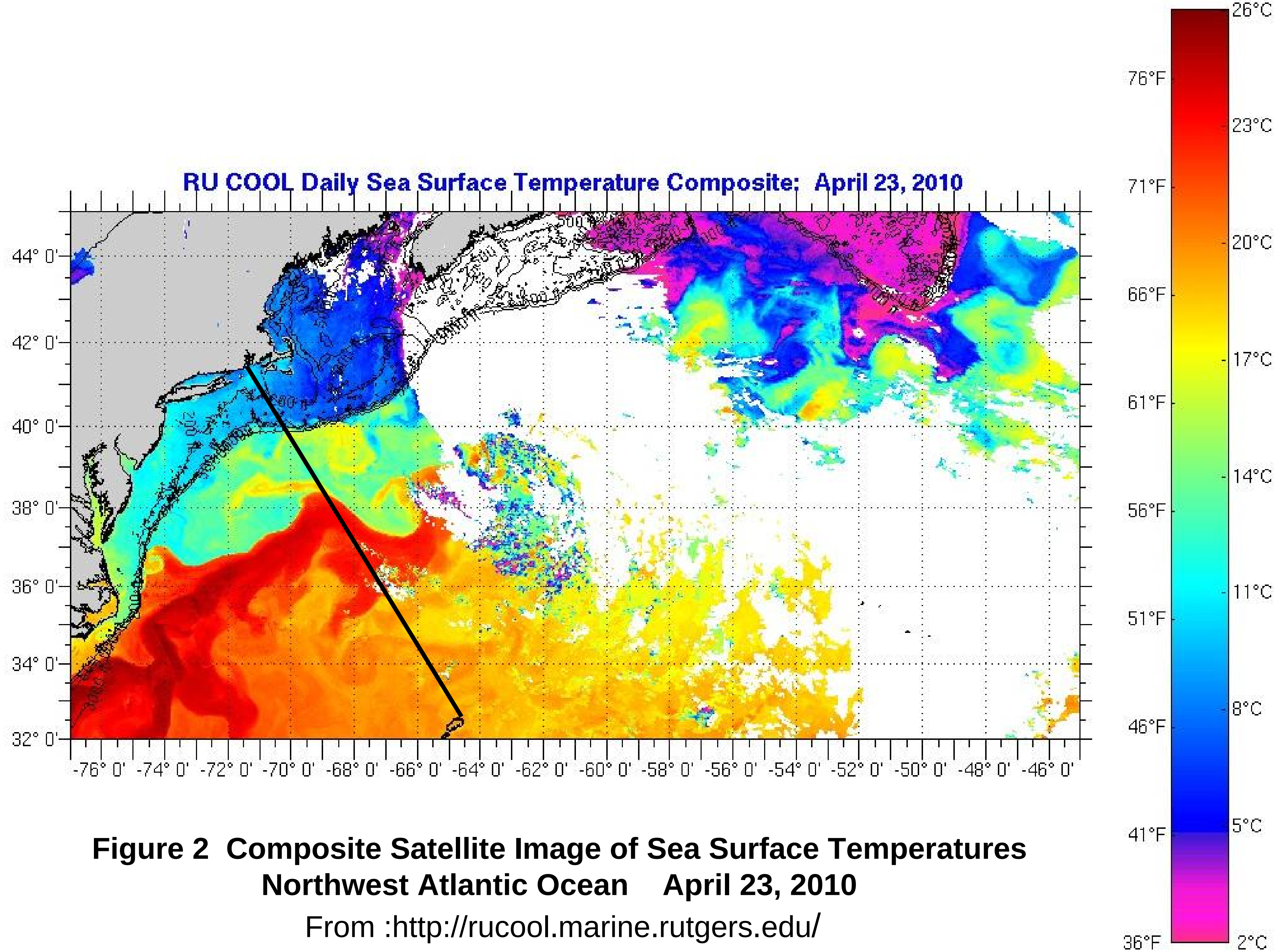

Figure 2 Composite Satellite Image of Sea Surface Temperatures
Northwest Atlantic Ocean   April 23, 2010

From :http://rucool.marine.rutgers.edu/

Dark Line indicates Newport-Bermuda Rhumb Line

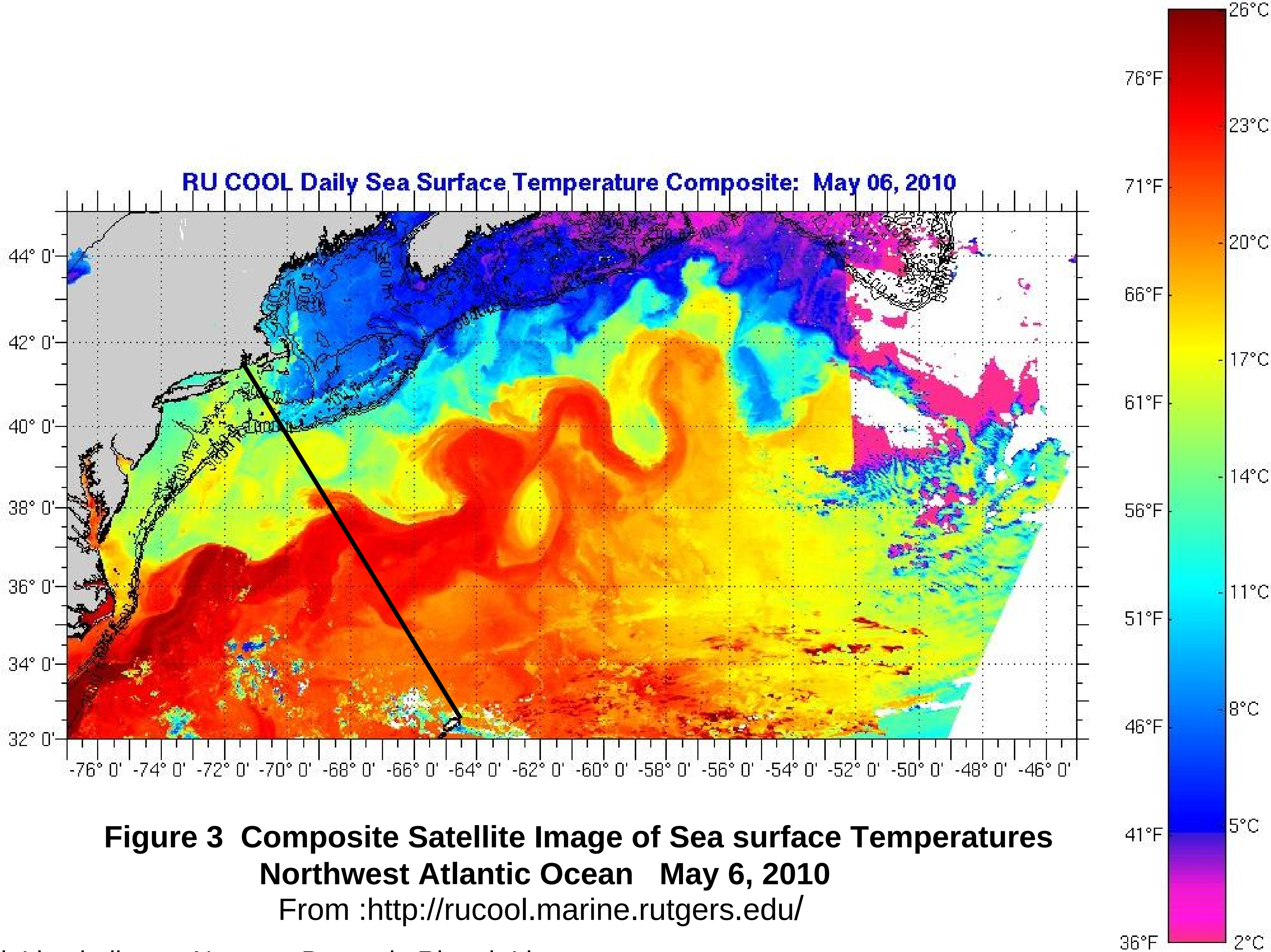

Figure 3 Composite Satellite Image of Sea surface Temperatures
Northwest Atlantic Ocean May 6, 2010
From :http://rucool.marine.rutgers.edu/

Dark Line indicates Newport-Bermuda Rhumb Line

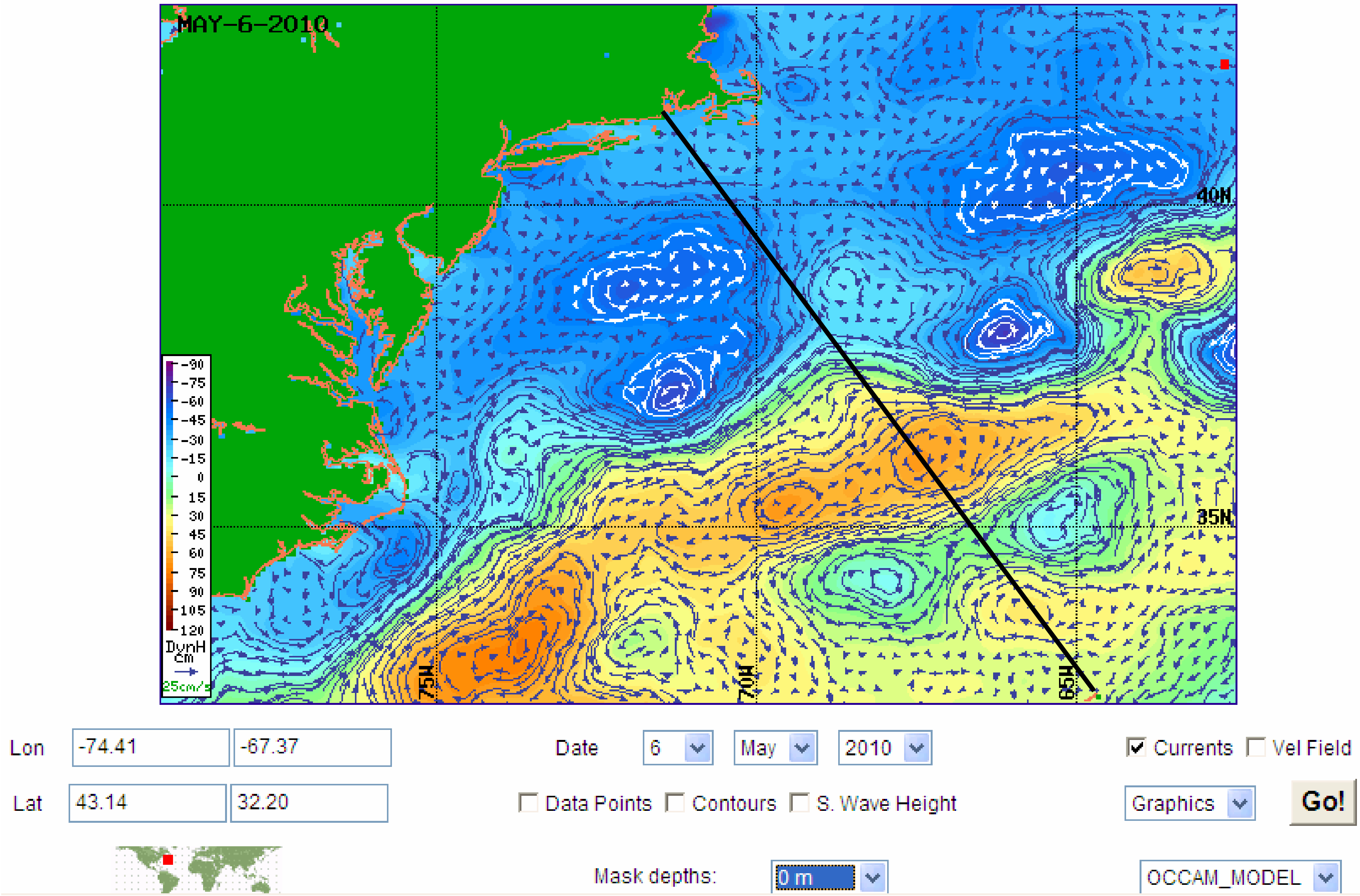

Figure 4 Current Speeds and Directions in the Vicinity of the Newport-Bermuda Rhumb Line Based on NOAA/AOML Altimetry Data

http://www.aoml.noaa.gov/phod/dataphod/work/trinanes/INTERFACE/index.html

Dark Line indicates Newport-Bermuda Rhumb Line