The Gulf Stream in the Vicinity of the Rhumb Line Newport to Bermuda May 15, 2014
An Analysis of Conditions

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With slightly more than one month to go until the start of the 2014 Newport/Bermuda Race it is not too early to begin assessment of the location, form, and probable evolution of the Gulf Stream and its attendant features in the vicinity of the rhumb line. These characteristics are essential to the development of winning race strategy and ultimately (after due consideration of wind and sea state) the selection of an optimum route for each boat. To begin this process I would recommend reading the brief Gulf Stream Primer that I have posted on the Race website (Bermudarace.com –see Resources/Gulf Stream Tutorials). This provides a synopsis of primary Gulf Stream features and their dynamics as well as an introduction to a number of web sites useful to the navigator. This variety of information is intended to assist in the analysis of current existing conditions.

When cloud cover permitted, satellite views of Northwest Atlantic sea surface temperature (SST) distributions in early April showed the main body of the Gulf Stream crossing the Newport-Bermuda rhumb line at a point approximately 345 nm (nautical miles) from Newport (Fig. 1). This unusually distant point was near the bottom of a deep meander which caused the typically southwest to northeast flow of the Stream to proceed first to the southeast towards the line followed by an abrupt counterclockwise rotation after crossing the rhumb line. In a short distance this rotation resulted in near line parallel flows to the northwest over a distance of nearly 150 nm before a clockwise rotation had flows again proceeding to the east. As indicated in the Primer, maximum current speeds in this meander are located in the area approximately 30 nm in from the inshore edge of the sharp temperature boundary. With the potential for strong adverse current (maxima of 5 kts +/-) in the area east of the rhumb line this pattern clearly favors routes to Bermuda well to the west of the line.

Under typical conditions the meander in the vicinity of the rhumb line on April 14th (Fig. 1) would be expected to migrate slowly to the northeast at speeds of approximately 10 to 20 nm/day. Although cloud cover prevented detailed observation the few sightings of the Stream that were provided during late April indicated relatively little movement. This appeared to be the result of the depth or amplitude of the meander and lead to a progressive decrease in the width of the meander trapping a parcel of cold water between the warmer water boundaries and a progressive “pinching off” of the feature. By May 6th this process was nearly complete (Fig.2) resulting in a substantial increase in the area of foul currents adjoining the rhumb line. In addition the waters in the area north of the main body of the Stream extending to the edge of the continental shelf experienced significant warming. This affects water column densities sufficient to produce some amount of current with a variety of speeds and directions prior to entry into the main body of the Stream. On occasion, such distributions of temperature and currents can complicate determination of position relative to the main body of the Stream.

By May 12th the "pinch off" process was complete resulting in a new, smaller amplitude, meander of the main body of the Stream just west of the rhumb line and a cold core ring centered near 37° N 68° 30' W extending north across the rhumb line (Fig.3). The meander should proceed slowly to the northeast across the line resulting in a time variant pattern of current directions ranging from east to northeast to south to southwest as the meander proceeds across the rhumb line. Currents associated with the ring follow a clockwise pattern around the center with maxima of approximately 3 kts. With time, the ring should slowly drift to the west at a rate of 2-3 nm/day. It's important to remember that due to the fact that the waters forming the ring are colder and therefore more dense than the bordering water some amount of sinking may occur allowing warmer water to move over the cold ring. As a result the presence of the ring will become progressively more difficult to determine using satellite SST imagery since these measurements are confined to the immediate surface of the water column (< 1cm) possibly dominated by warmer less dense water overlying the cold ring. Despite this sinking and stratification however, the ring can be expected to continue affecting small boat set and drift since sinking depths are typically small relative to boat draft. We should watch this feature carefully over the next month.

The reformed Gulf Stream and ring as well as the variant SST pattern north of the main body of the Stream can be expected to produce a complex of currents with varying speeds and directions. The SST imagery of May 12, 2014 (Fig.3) continues to favor routes to Bermuda intersecting the main body of the Stream west of the rhumb line in the vicinity of 38°N 70°W. Whether this will remain the favored solution in late June is obviously dependent on the evolution of the Stream and attendant features over the next month. The extent to which this evolution can be monitored using SST satellite observations depends on the extent of cloud cover over the period. There have been years when dense clouds dominated through May and much of June. Fortunately there a number of alternatives that will not be affected by clouds.

Many routing routines make use of computer models of the Stream its structure and location. Perhaps the most popular is the Global Real Time Ocean Forecasting System (RTOFS) model developed by NOAA's National Centers for Environmental Prediction in close collaboration with the U.S. Navy Oceanographic Office. Although I find the spatial resolution (1/12th of a degree) a bit coarse for small boat navigation and the simulations often failing to accurately reproduce the SST patterns shown by the satellites the model results can provide a valuable indicator of Stream evolution during periods of dense cloud cover. If models are to be used to any great extent it's essential to gain confidence in them and to develop a personal understanding of their accuracy for the task to which they will be applied. NOAA now provides a site to assist in this process showing comparisons of model output to other data sources including the Navy monitoring and models (Fig.4). These images of simulations also permit comparisons with SST satellite imagery (e.g. compare Fig 4 to Fig 3). These can provide clear indication of the model skill at simulating complex flow regimes.

An alternative to RTOFS is the altimetry based model developed by NOAA which relies on direct satellite based measurement of sea surface elevations relative to a reference surface. Changing water column densities due to variations in temperature and salinity, the effects of winds and the influence of the earth's rotation can all affect sea surface elevation. For example as we proceed from Newport to Bermuda we encounter an increase in elevation of approximately 1m as we cross the Gulf Stream. That slope, largely the result of the difference in water column densities between the cold continental shelf water inshore and the warmer Sargasso Sea waters offshore directly affects current flow. As a result measurement of slopes can be used to infer currents. In addition since the measurements are independent of cloud cover they are continuously available often providing more detail on Stream structure than can be inferred from the SST images. The typical spatial resolution of this model is .25 degree so the results may better be used for pattern rather than small area detail. Experience gained over the past three Newport-Bermuda Races however, indicates that there is a high degree of accuracy in this model's simulations and that it has real value as a navigational tool.

The altimetry based model results for May 14, 2014 provide clear indication of the complexity of the surface currents near the rhumb line associated with the near shelf flows north of the Stream, the main body meander and the cold core ring (Fig.5). The model also indicates several areas of organized flow in the area south of the main body of the Stream to Bermuda. These latter results may be of particular value to raceers since this area is often difficult to resolve in satellite images. Overall the model patterns are reasonably similar to what is shown by the composite SST image on May 12, 2014 (Fig.3) which is consistent with the typical two day delay in the delivery of results due to processing. The warm mass of water north of the main body of the Stream does induce some amount of easterly flow across the rhumb line with speeds of approximately 0.5 kt increasing on approach to the sharp thermal boundary. The meander flows are well defined geographically although indicated maximum current speeds are significantly less than the expected 5 kt range. This is the result of a number of factors computational and graphic and provides clear indication why these model results are best used to establish patterns, i.e. where the currents are, rather than flow magnitudes.

Within the meander the cold core ring is well defined with a diameter of more than 120 nm nearly centered on the rhumb line (Fig.5). In combination with the flow patterns associated with the eastern portion of the meander along 38^{o} N (showing some area of adverse current along the rhumb line) as well as the easterly flow in the area between the shelf and the Stream, the ring and its counterclockwise flow favors a course to Bermuda to the west of the rhumb line at this time. As indicated above, two processes will likely determine whether this remains true at the start of the Race. First, the meander can be expected to move slowly to the east-northeast. This would tend to produce favorable Stream currents closer to or along the rhumb line. Second, the cold core ring is expected to drift to the west. It's possible that it will be clear of the area by 20 June. Alternatively, it may be sited just west of the rhumb line forcing consideration of an easterly track to Bermuda or a distant flyer to the west. With this rather wide range of possibilities it should be clear why close careful attention to Gulf Stream conditions is particularly important this year. Periodic examination of the available SST satellite imagery in combination with the altimetry based model results will allow accurate definition of the rate at which the Stream features evolve and the overall effects on flow speeds and directions. Such information is essential both for pre-race planning and ultimately tactical decision making during the Race. We will be discussing these characteristics in more detail in the next Gulf Stream Note in early June.

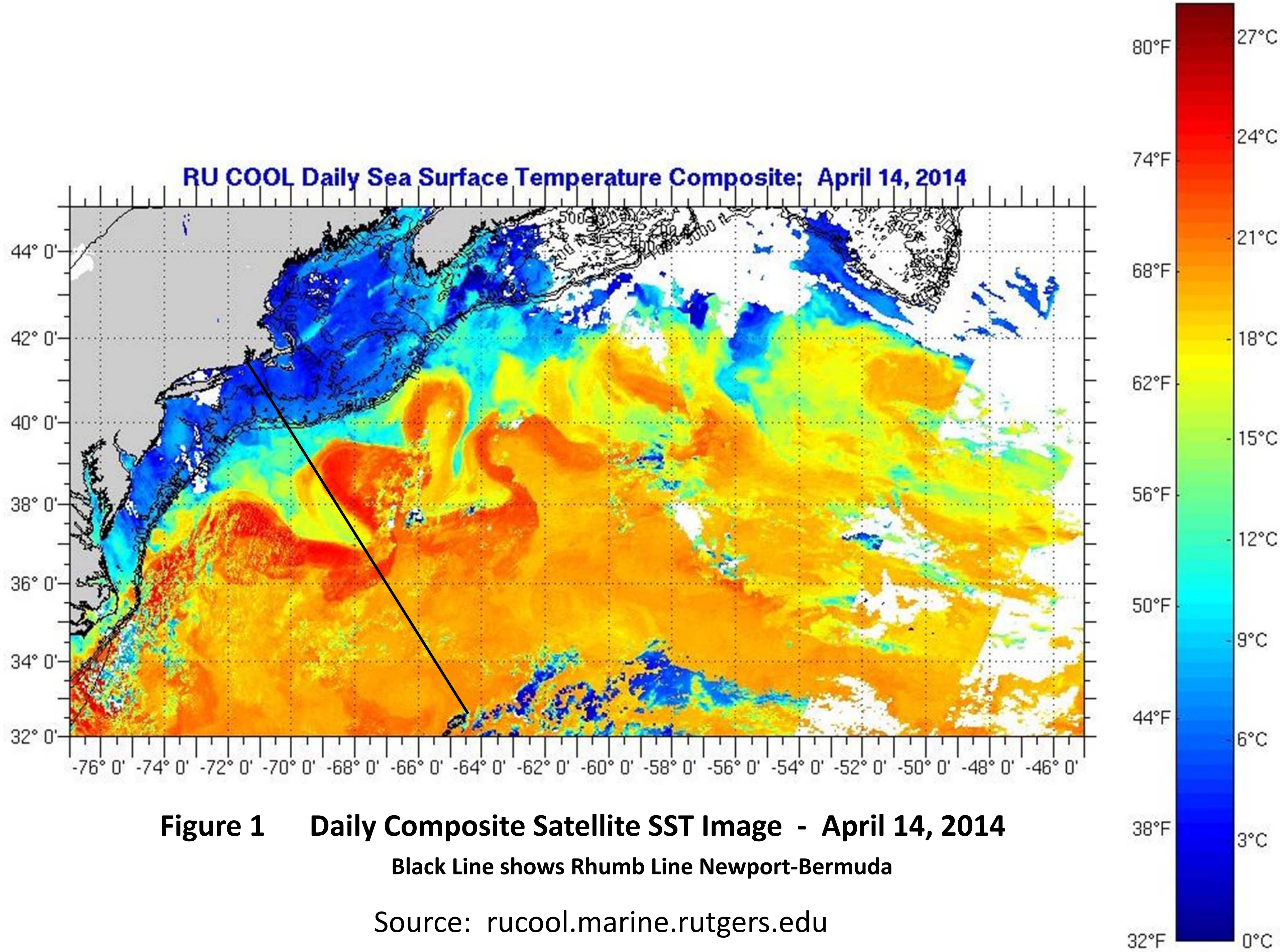


Figure 1 Daily Composite Satellite SST Image - April 14, 2014

Black Line shows Rhumb Line Newport-Bermuda

Source: rucool.marine.rutgers.edu

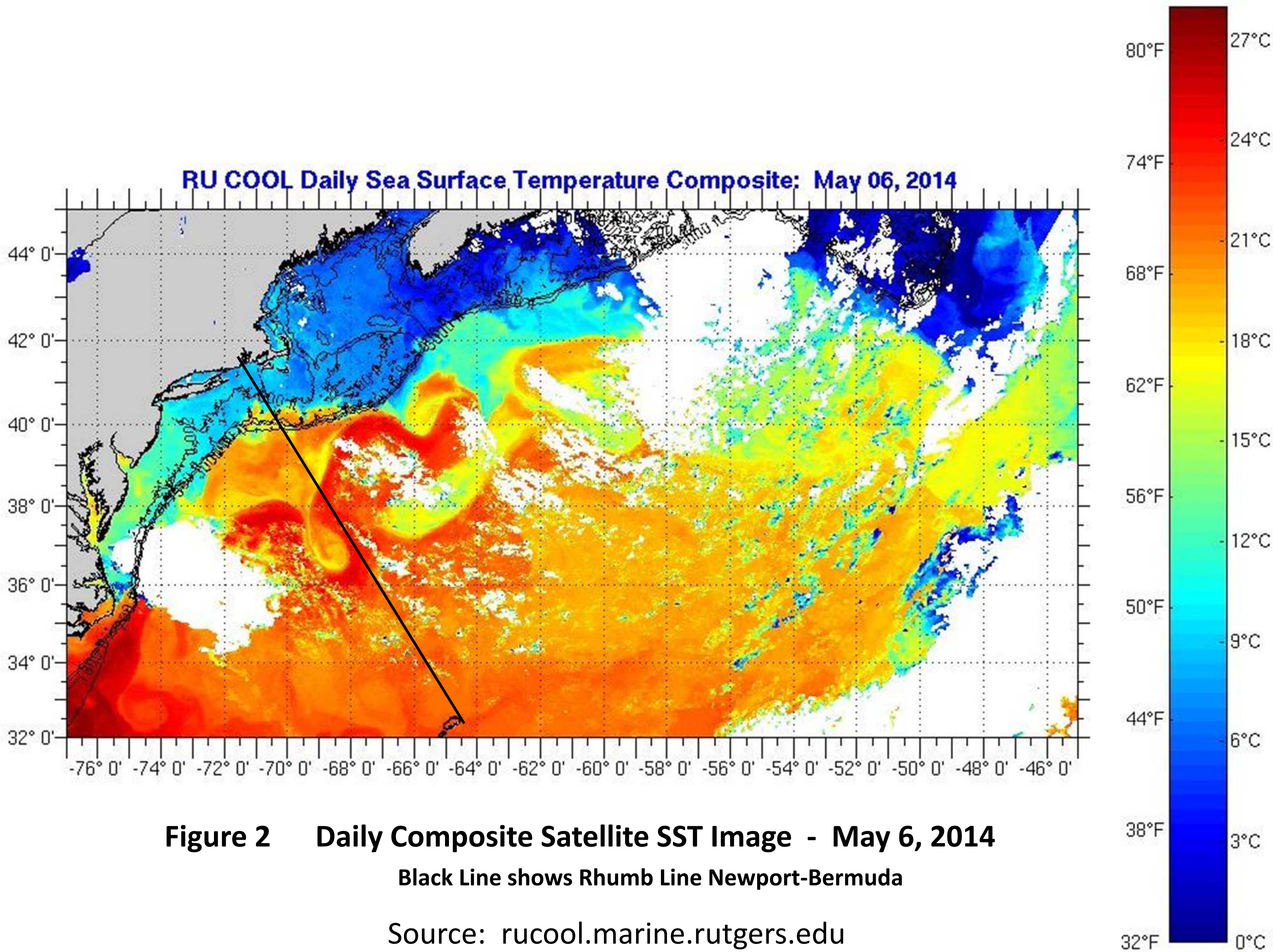
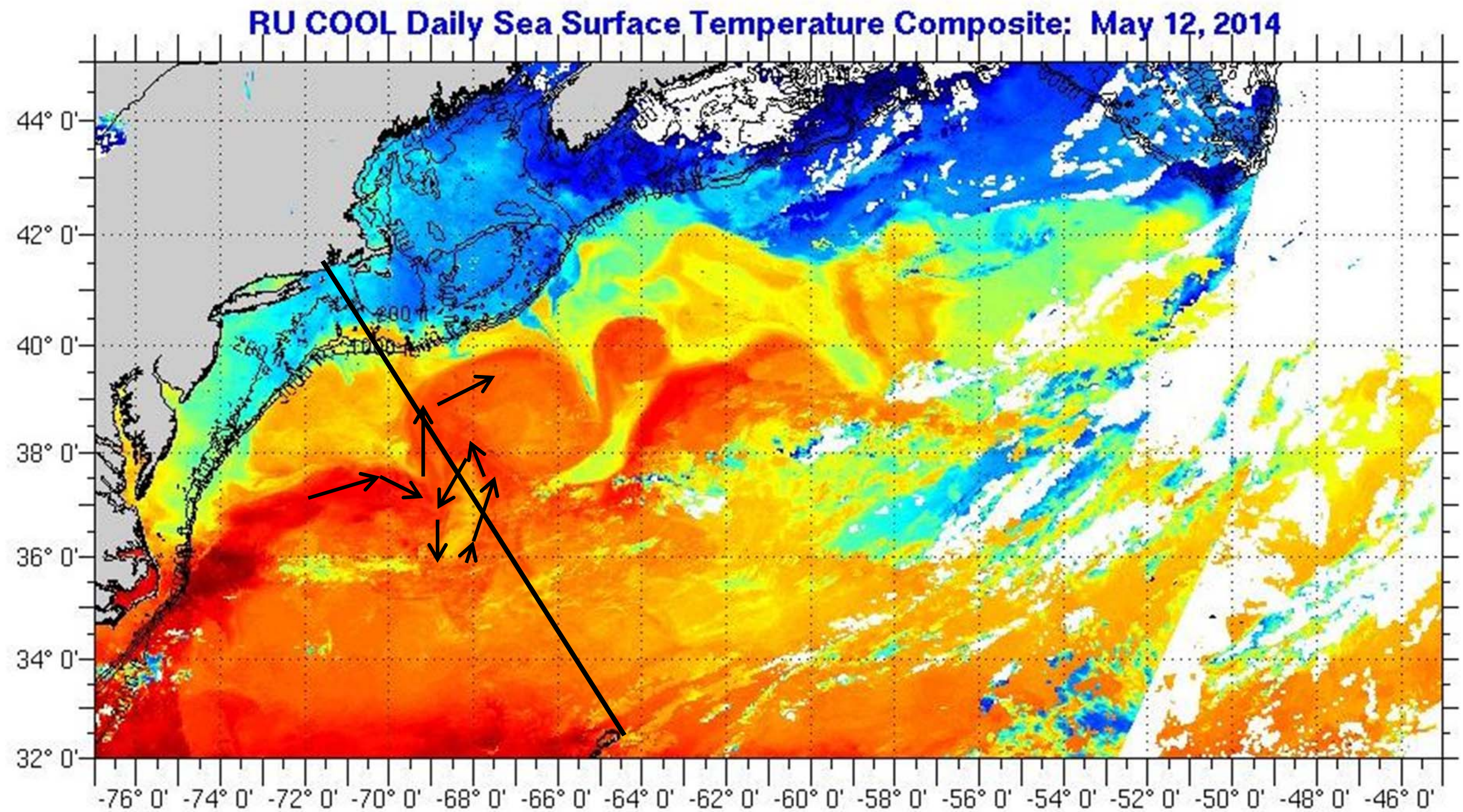


Figure 2 Daily Composite Satellite SST Image - May 6, 2014

Black Line shows Rhumb Line Newport-Bermuda

Source: rucool.marine.rutgers.edu



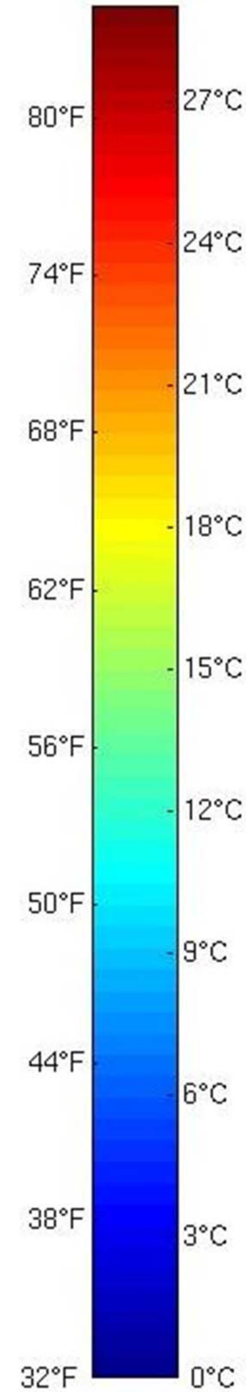


Figure 3 Daily Composite Satellite SST Image - May 12, 2014

Black Line shows Rhumb Line Newport-Bermuda

Black arrows indicate probable flow directions

Source: rucool.marine.rutgers.edu

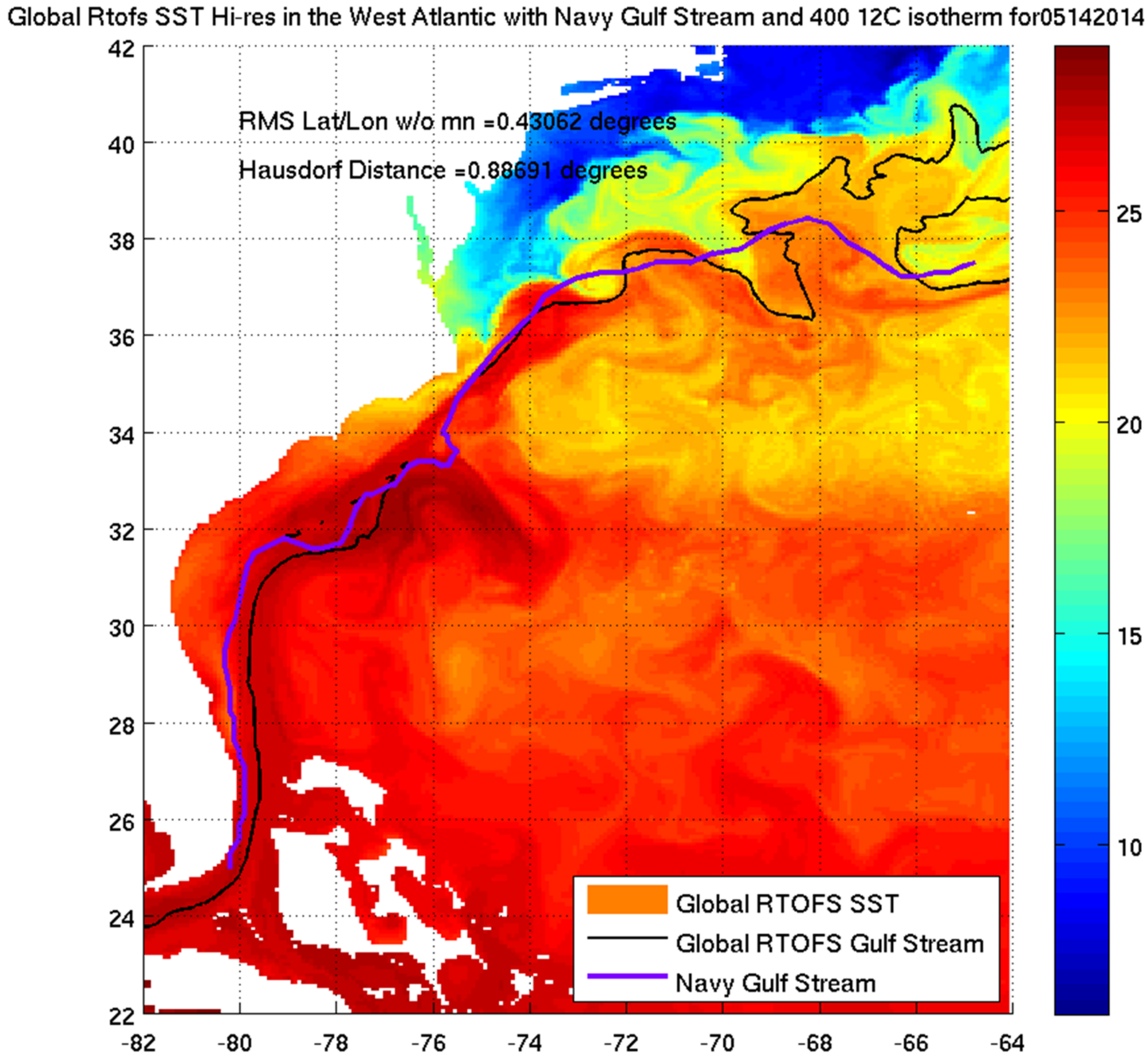


Figure 4 Global Real Time Ocean Forecast System model results - May 14, 2014 Showing Comparison with Navy Representation of Gulf Stream

Source: http://www.opc.ncep.noaa.gov/sst/GulfStream_compare.shtml

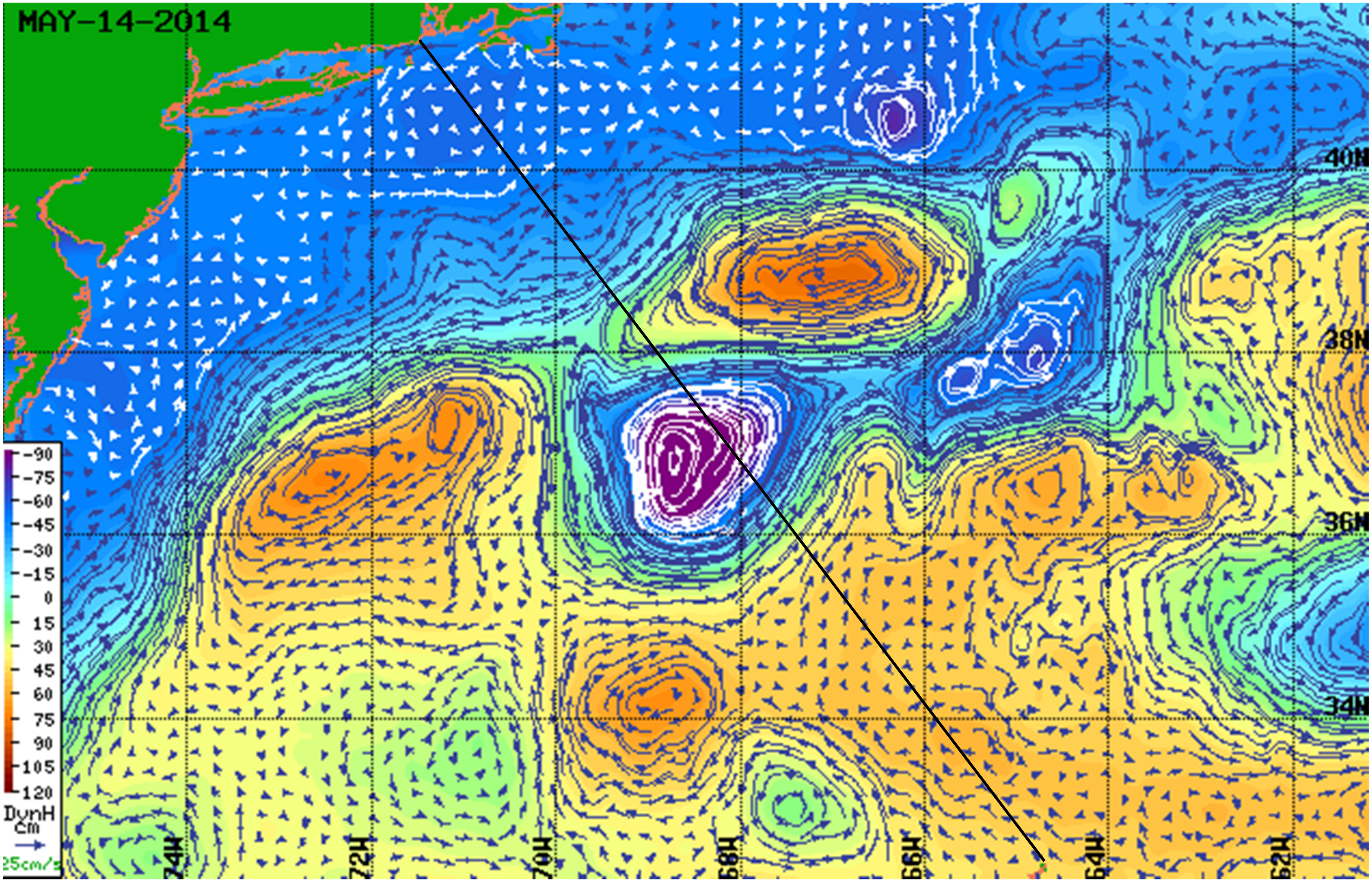


Figure 5 Satellite Altimetry Derived Surface Currents- NW Atlantic Region – May 14, 2014

Black Line shows Rhumb Line Newport-Bermuda

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