The Gulf Stream Near the Rhumb Line Newport-Bermuda May 8, 2018
An Analysis of Conditions

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With little more than one month to go until the start of this year's Newport Bermuda Race it's beyond time for all serious navigators to be studying the form and structure of the Gulf Stream and its probable evolution in the vicinity of the rhumb line. The data necessary for this exercise are readily available on the web. In these Notes I will use a number of these sites but you should feel free to explore others. This abundance is a luxury that was not available only a few years ago.

To begin, recall that the Gulf Stream is an energetic western boundary current separating the cooler waters of the New England continental shelf from the warmer waters of the Sargasso Sea (see Gulf Stream Primer under GS Tutorials in *Resources* at http://bermudarace.com) . The boundary between these water masses is marked by an abrupt change in surface water temperatures forming the northern or inshore edge of the Stream. This evident change in temperature is often the first indication of arrival at the Stream. Maximum currents approaching 5 knots are typically found approximately 30nm to the south of the northern margin associated with maximum temperature gradients. Flows on average proceed to the east and northeast but often display a significant meandering pattern. On occasion these meanders can grow to a point of instability resulting in a cut-off similar in form to that observed in meandering rivers that produce "ox-bow" features. This process can result in the formation of discrete standalone eddies or rings of water with circulation dependent on whether the cut-off process trapped a parcel of warm or cold water. Warm core rings rotate clockwise producing maximum speeds of +/- 3 kts along a margin located approximately one-third of the way in from the outer perimeter of the ring. These features tend to be found to the north of the main body of the Stream along the edge of the continental shelf. Cold core rings rotate counterclockwise producing speeds similar to the warm core ring and dominate the region to the south of the main body of the Stream in the deeper waters of the Sargasso Sea. Once formed and clear of direct Stream influence, both classes of rings tend to drift slowly to the west towards Cape Hatteras. Warm core rings are relatively short lived (on the order of months) and are often dissipated by interactions with the bounding continental shelf. In contrast cold core rings can persist for several years before re-entrainment in the Stream.

From the navigational standpoint the speed and direction of the currents associated with each of the components of the Gulf Stream have the potential to directly affect optimum routing between New England and Bermuda . Add to this the fact that the Gulf Stream's warm waters makes it a "weather breeder" and it should be clear why the Stream warrants careful study in support of tactical decisions. In addition, the Gulf Stream is characterized by significant spatial and temporal variability. This makes early study to define rates of change of particular features and their significance in routing an absolute necessity.

Satellite images of sea surface temperatures (SST) in early January, 2018 show the main body of the Gulf Stream crossing the rhumb line – Newport to Bermuda – at a point approximately 240nm from Newport (Fig.1). A large meander is located to the west of this point with a main limb extending for more than 90 nm to the southeast nearly parallel to the rhumb line but separated by 90nm. Cloud cover (shown in white) affected much of the route to Bermuda and obscured Stream and areas south detail.

By February the meander had moved nearly 90nm to the east reducing the distance between Newport and the main body of the Stream to approximately 180nm. The associated flow crossed the rhumb line from the northwest to the southeast and the main limb of the meander was now to the east of the rhumb line (Fig.2). The observed migration of the meander from west to east is generally representative behavior but should not be assumed to always occur. Meander migration and change of form is to some extent capricious, as we will see.

Observations throughout March were limited due to persistent cloud cover. A partial SST image in Late March (Fig.3) at least suggested that there had been little meander migration since late February. The main body crossing of the rhumb line appeared to be about 210nm from Newport. This structure looks essentially identical to that shown in the composite satellite image of April 28, 2018 (Fig. 4). In contrast to the progressive migration observed during January and February the images for March and April show nearly no easterly movement and only slight change in the amplitude of the meander. For the moment the meander appears to be nearly stationary. Previous year's satellite views have observed similar conditions with all ultimately ending in easterly migration or simple dissipation or straightening of the meander. The timing of this evolution however, differed each year and provides little help in predicting how this year's meander will behave. One thing of importance given the existing location of the main limb of the meander to the east of the rhumb line is the fact that historical data provide very little indication of occasions when the meander moved to the west. However, this is not to say that it will never happen and this possibility should to be considered carefully in route planning.

Between April 28 and May 4 the meander remained in place (Fig.5) with the main body of the Stream crossing the rhumb line at a point approximately 240nm from Newport resulting in flows from the northwest to the southeast across the line. The prominent parcel of warm water to the north of the main body shown in the late April image was less evident and the May image provided no indication consistent with the formation of a warm core ring. The gradients in SST shown in the May image suggest that there will be some amount of flow due to spatial variations in water column density with the majority going from the north to the south with varying directions at speeds of generally less than 1 kt. Beyond and south of the northern margin of the Stream the compositing process required to reduce the effects of clouds effectively obscures Stream detail making it impossible to discern any cold core features. For this purpose we turn to the altimetry based model product.

Altimetry, or radar based measurements of sea surface elevations above a defined gravitational reference surface, is an all-weather system that operates reliably independent of cloud cover allowing the development of a computer model of surface currents based on the gradients in sea surface height. This product is very similar in form to a number of atmospheric models showing winds associated with gradients in pressure. Model results for May 6, 2018 (Fig.6) clearly show the meander and the associated currents affecting nearly 120nm of the rhumb line. Maximum speeds appear to be on the rhumb line and within 30nm to the east. To the west, speeds drop off quickly with flow trajectories tracing a nearly circular pattern. To the north of the Stream the altimetry provides no indication of organized rings or eddies. To the south however, there is clear indication of a counterclockwise rotating cold core feature centered near 35^{o} 15’ N 69^{o} 30’ W. Maximum current speeds in this ring will approach 3kts with flows along the eastern edge proceeding to the north and northwest with the potential to adversely affect speeds of boats heading to Bermuda. The ring’s proximity to the main body flow may slow, stop or even reverse its tendency to drift to the west. We will be watching this feature carefully over the next month. Beyond the ring below 35^{o} N there is no indication of organized development to the west of the rhumb line. Several features appear east of the line and may drift west over the next month. These should be carefully watched.

In addition to the altimetry based models Stream location and structure and the associated current field can be assessed during periods of persistent cloud cover using computer models such as the RTOFS model developed by NOAA in collaboration with the U.S. Navy. Stream structure and associated sea surface temperatures (SST) from this model (Fig.7) are reasonably similar to those shown in the satellite image of May 4^{th} (Fig.5). The meander depicted in the model however, is more pronounced than shown by either the satellite imagery or the altimetry based model. Similarly, the RTOFS current field (Fig.8) affects a larger area of the rhumb line than shown in the altimetry based model with substantial differences in flow directions. These differences are important to keep in mind since the RTOFS model is typically used in many of the most common routing programs including Expedition. The extent to which these differences matter for any individual boat must be carefully considered. Comparisons based on all available data are always worth the effort.

In summary, as of early May the Gulf Stream in the vicinity of the Newport-Bermuda rhumb line crossed at a point approximately 240nm from Newport. Stream structure in the area of the crossing was dominated by a large amplitude meander that was displaying little tendency to migrate to the east. To the south of the northern margin of the Stream there was a cold core ring centered nearly 120nm to the west of the rhumb line which affected flows over much of area east to the line. The altimetry based model shows the flow field of the ring interacting with main body meander suggesting that the ring is not clear of Gulf Stream influence and as a result may not drift progressively to the west. Under these conditions it is possible for the ring to remain in place or even move to the east if the meander migrates in that direction. Such displacement would have significant implications for routing to Bermuda. We will be looking at each of these possibilities over the next month.

As always if there are any questions please don't hesitate to send them along to Bohlen@uconn.edu

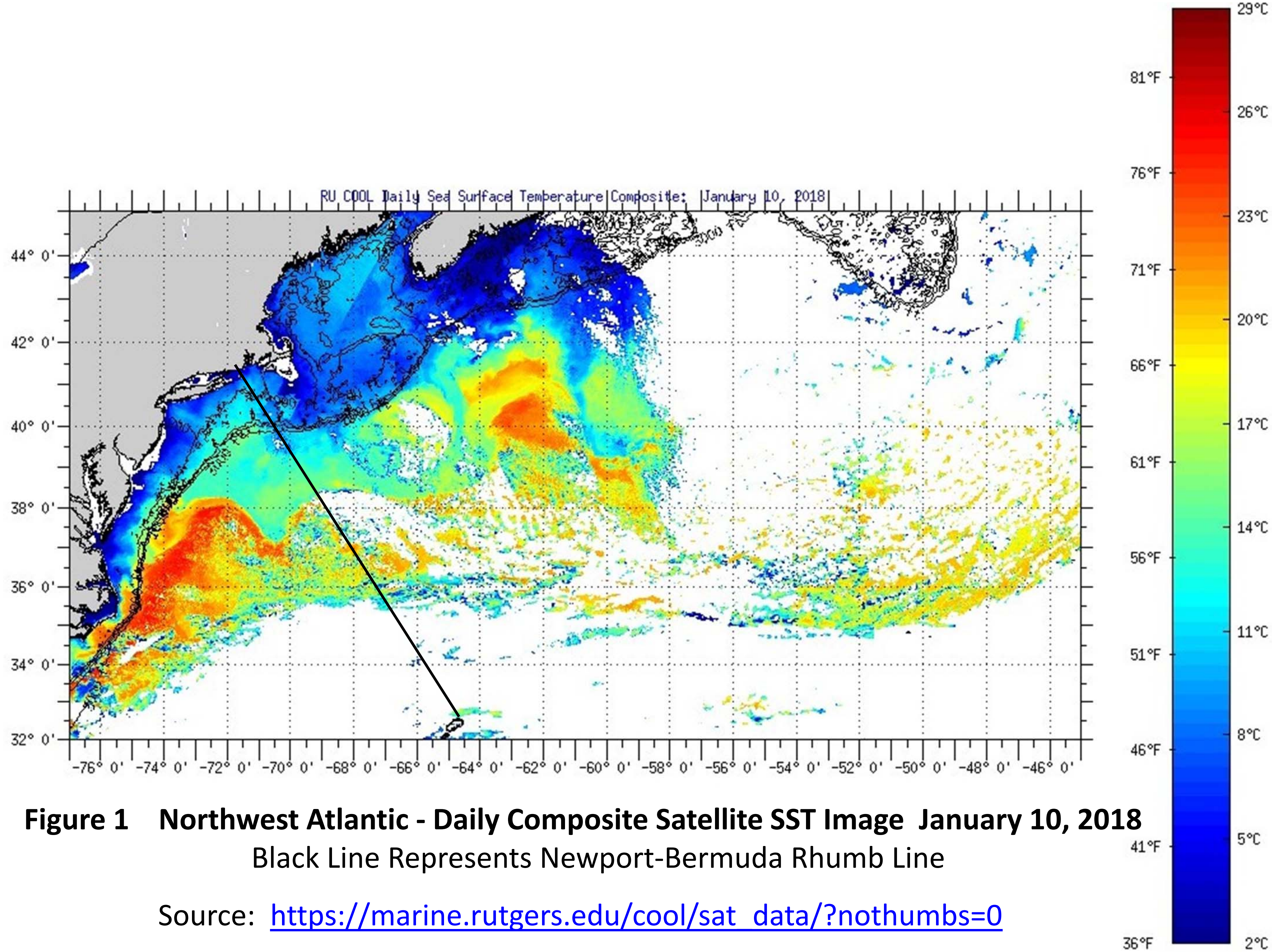


Figure 1 Northwest Atlantic - Daily Composite Satellite SST Image January 10, 2018

Black Line Represents Newport-Bermuda Rhumb Line

Source: https://marine.rutgers.edu/cool/sat_data/?nothumbs=0

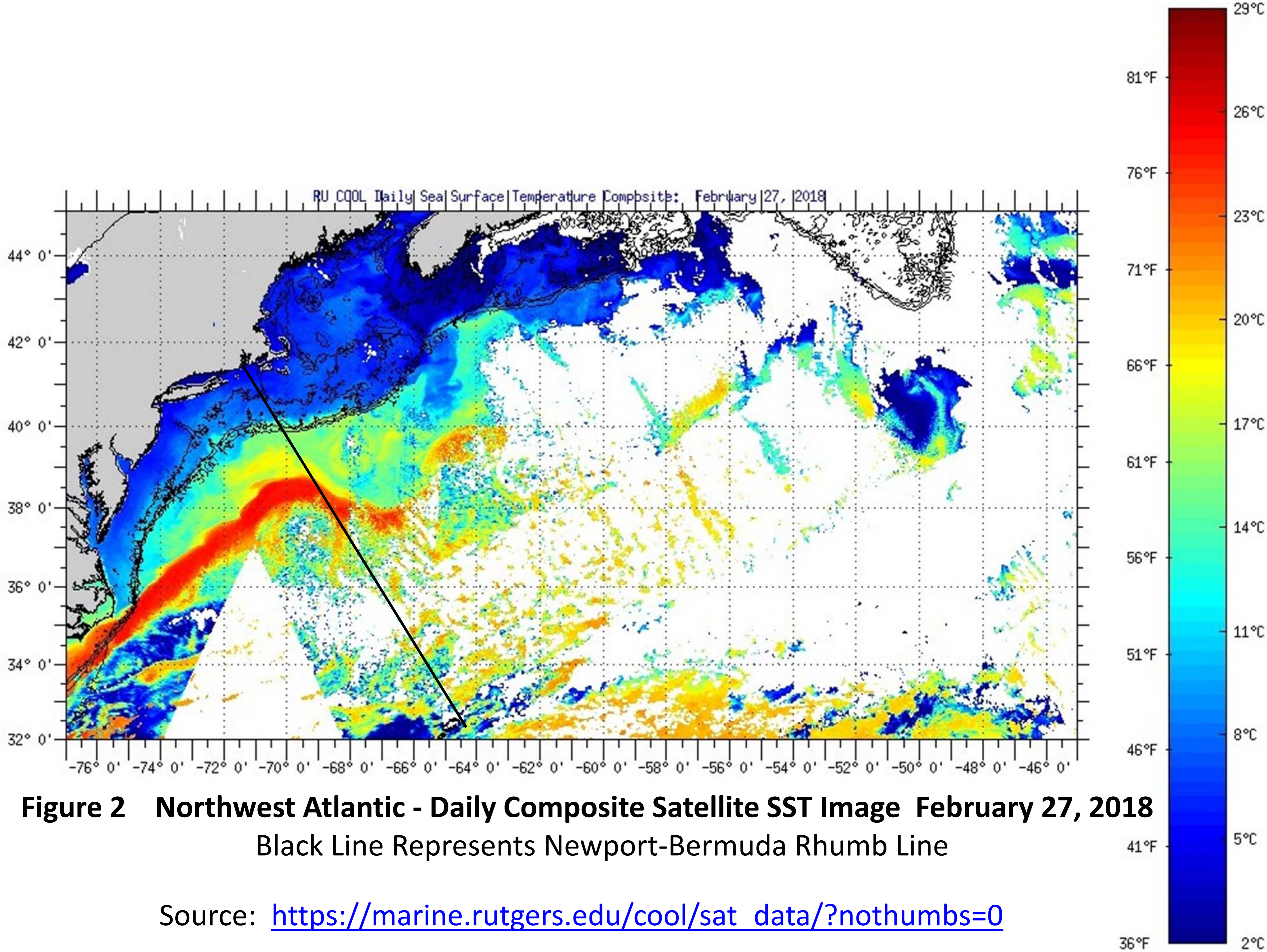


Figure 2 Northwest Atlantic - Daily Composite Satellite SST Image February 27, 2018

Black Line Represents Newport-Bermuda Rhumb Line

Source: https://marine.rutgers.edu/cool/sat_data/?nothumbs=0

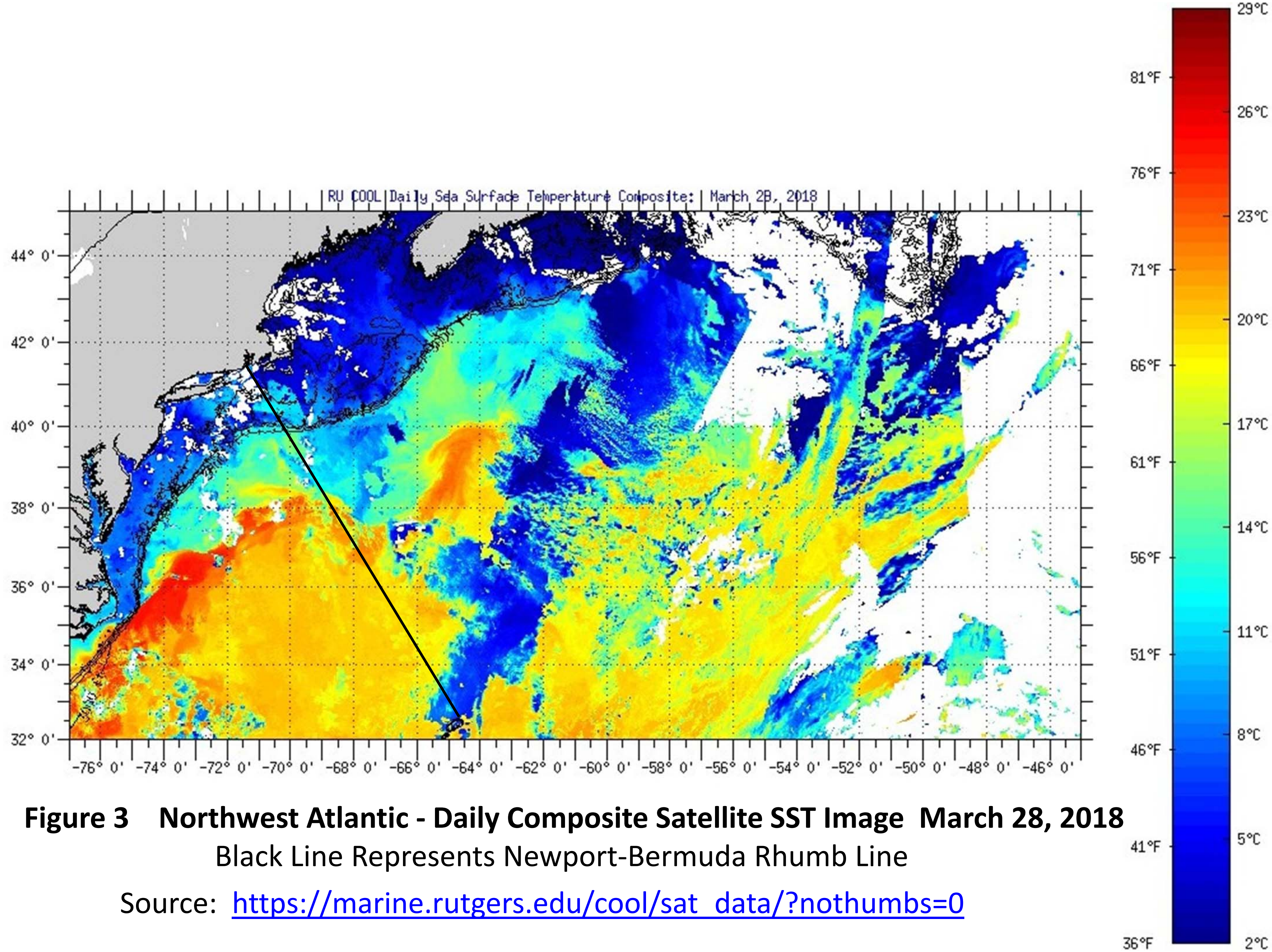


Figure 3 Northwest Atlantic - Daily Composite Satellite SST Image March 28, 2018

Black Line Represents Newport-Bermuda Rhumb Line

Source: https://marine.rutgers.edu/cool/sat_data/?nothumbs=0

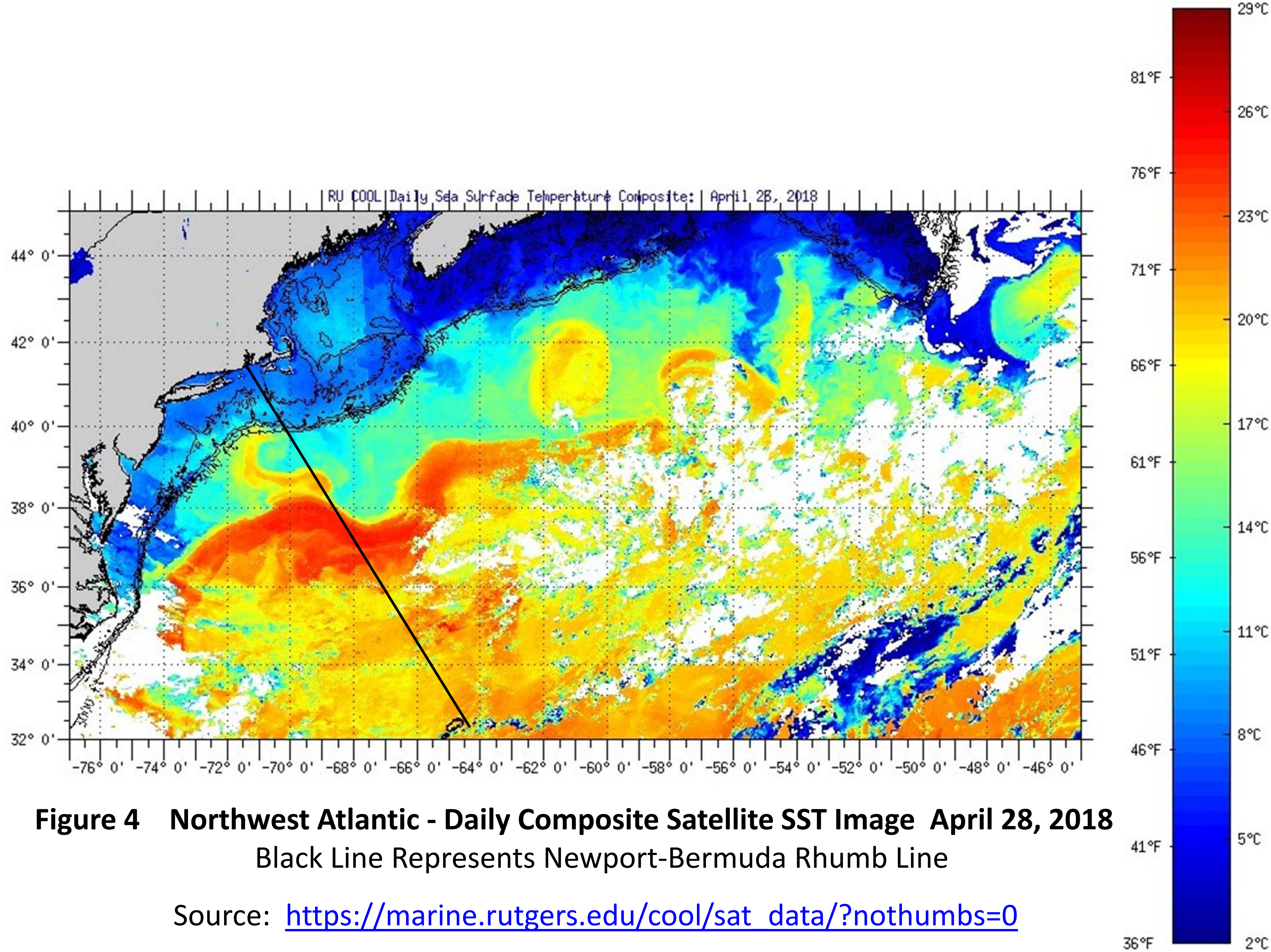
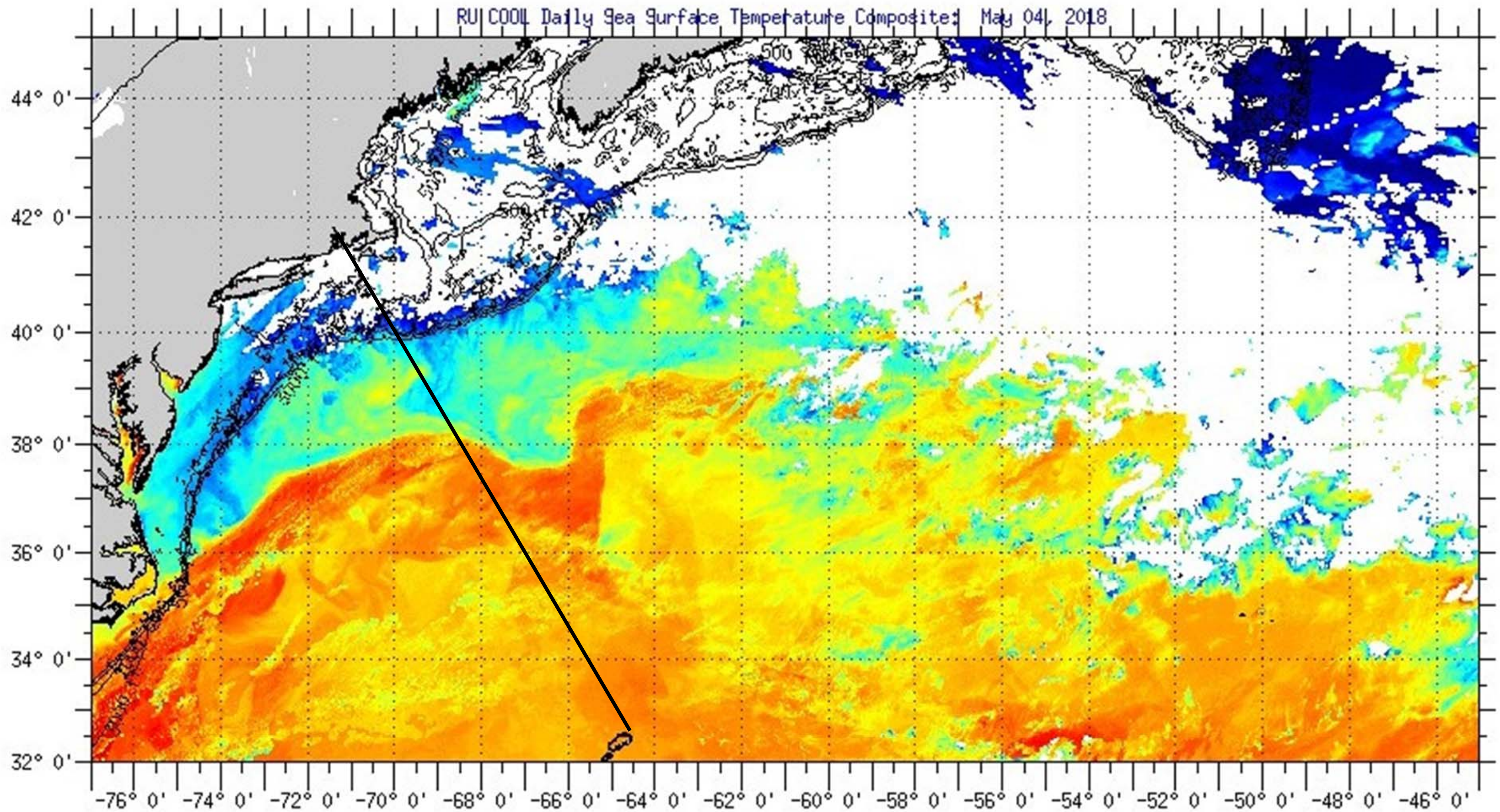


Figure 4 Northwest Atlantic - Daily Composite Satellite SST Image April 28, 2018

Black Line Represents Newport-Bermuda Rhumb Line

Source: https://marine.rutgers.edu/cool/sat_data/?nothumbs=0



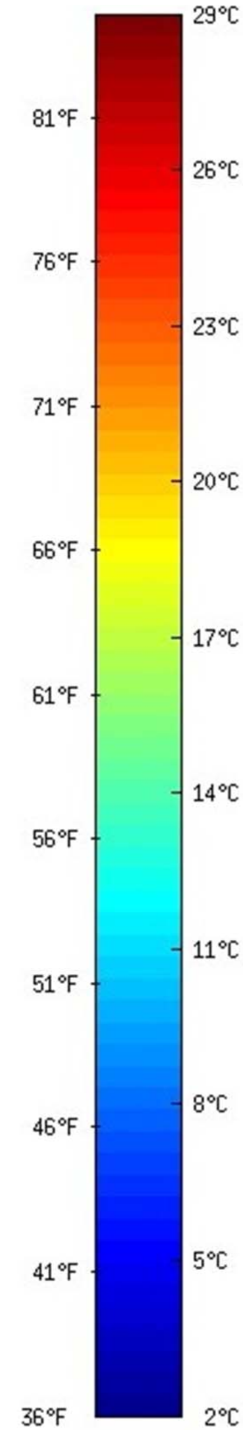


Figure 5 Northwest Atlantic - Daily Composite Satellite SST Image May 4, 2018

Black Line Represents Newport-Bermuda Rhumb Line

Source: https://marine.rutgers.edu/cool/sat_data/?nothumbs=0

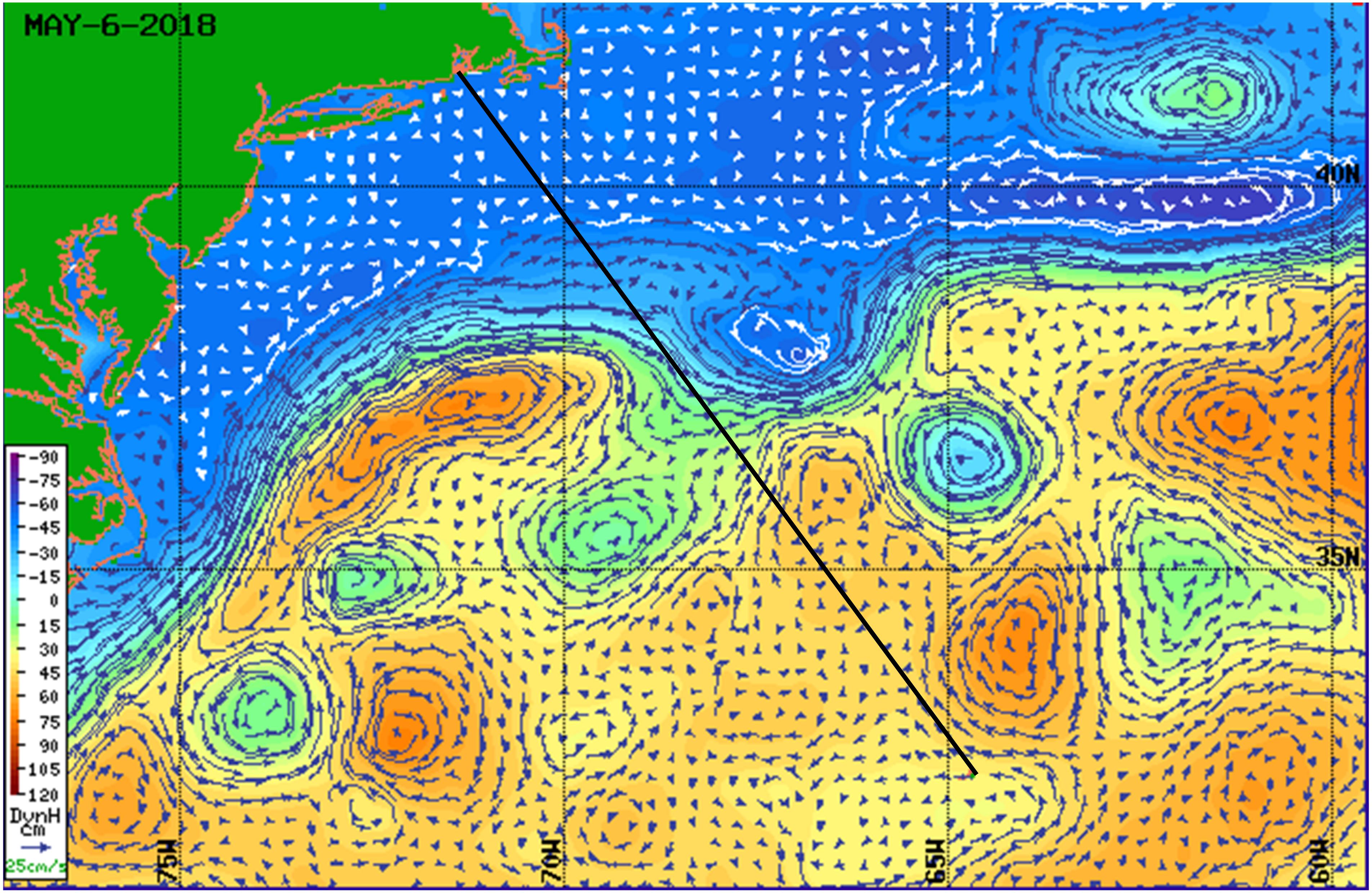


Figure 6 Satellite Altimetry Derived Surface Currents- NW Atlantic Region- May 6, 2018

Black Line shows Newport-Bermuda Rhumb Line

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

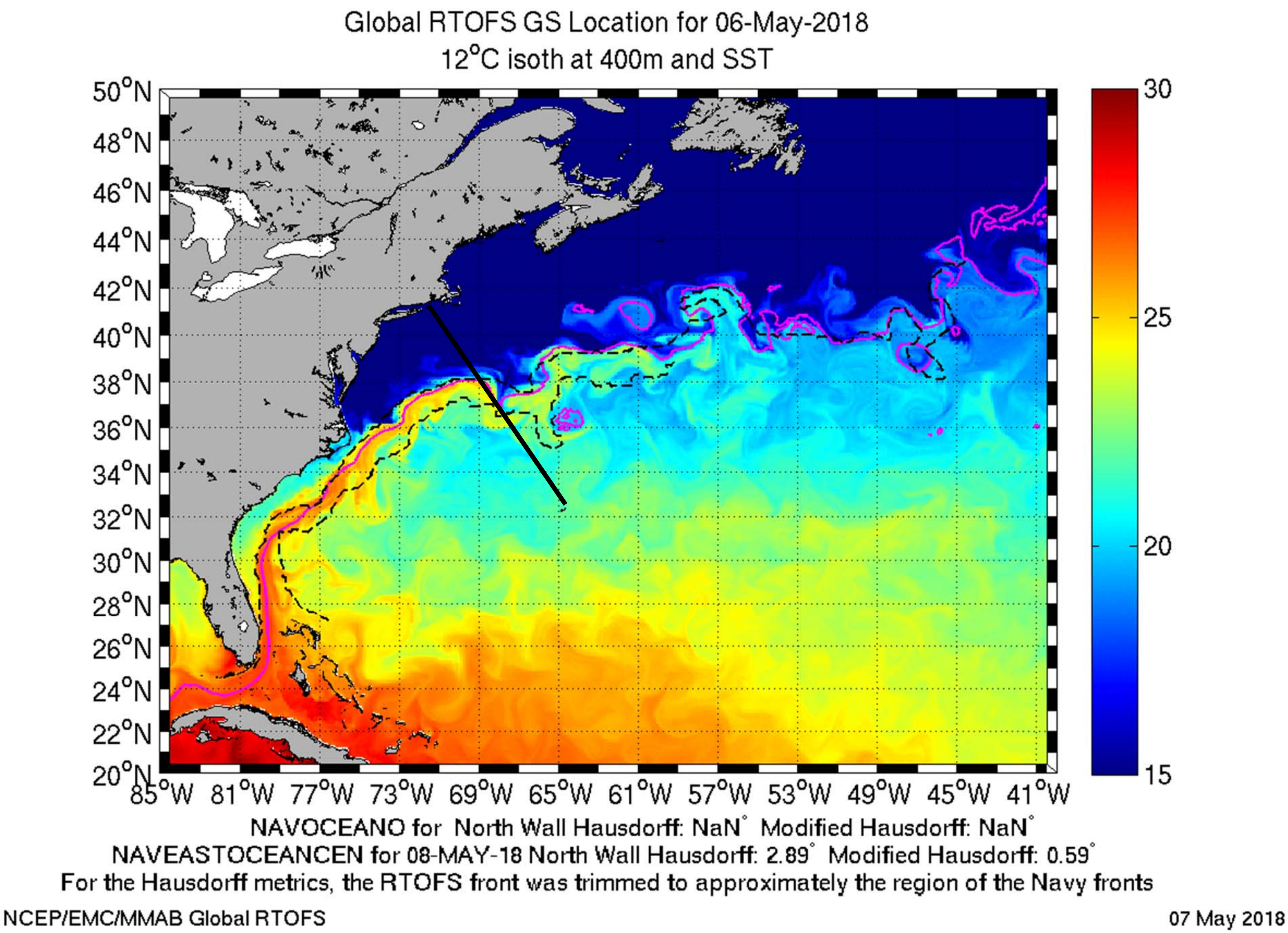


Figure 7 NOAA Numerical Model of Sea Surface Temperatures - May 6, 2018

Black Line Shows Newport-Bermuda Rhumb Line

http://polar.ncep.noaa.gov/global/monitor/

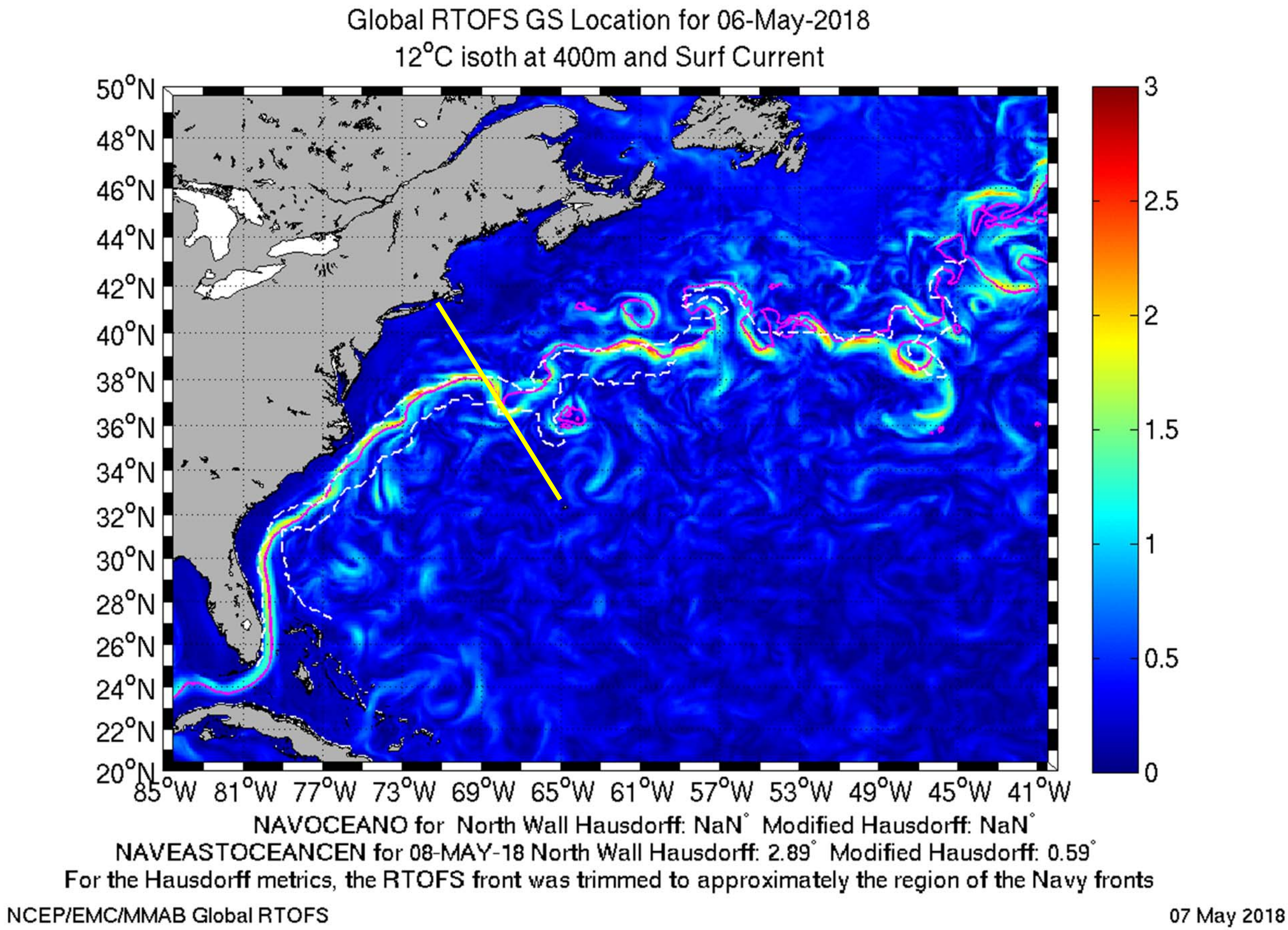


Figure 8 NOAA Numerical Model Gulf Stream Surface Currents - May 6, 2018

Yellow Line represents Newport-Bermuda Rhumb Line

http://polar.ncep.noaa.gov/global/monitor/