Bermuda 1-2
Gulf Stream Note No. 3
May 28, 2009
W.Frank Bohlen - Bohlen@uconn.edu

Aerial views of the rhumb line to Bermuda including the areas adjoining the Gulf Stream continue to be limited due to the abundant cloud cover. Over the past three weeks there have been occasional views of portions of the area resulting in some number of reasonably accurate composite images of sea surface temperature distributions. These in combination with the NOAA altimetry data, discussed in the previous two Notes, indicate that the Stream as it crosses the rhumb line remains an essentially linear feature although there are a number of "interesting" changes in progress. These include a developing meander to the west of the rhumb line, a circular feature or "ring" to the east north of the main body of the Stream and variety of small, less organized, thermal patches bordering the northern limit of the Stream. Our various sources of data each show these features with differing detail.

The U.S. Navy data (Fig.1) show the northern edge of the Gulf Stream to be located approximately 230nm southeast of Newport. The waters inshore of this limit appear to be relatively iso-thermal (constant water temperature) with minimal to no organized structure. A warm core ring rotating clockwise is shown centered on 39^o 20'N 67^o 40'W. Stream boundaries are marked by dashed lines indicating an "estimated" location consistent with the amount of cloud cover shown to exist during this period by the satellite views. The lack of detail in this figure and the degree of estimation associated with its preparation suggest that it is of limited navigational utility.

Reviews of composite data seem to further justify this conclusion. While the seven day composite from the Johns Hopkins site (http://fermi.jhuapl.edu/sat_ocean.html) shows the main body of the Stream crossing the rhumb line at a point approximately 240nm from Newport (Fig.2), consistent with the Navy data, the image also shows an abundance of thermal features inshore of this point leading into the rotary feature shown in the Navy image to the east of the rhumb line. This combination suggests that there will be flows to the north and east prior to entry to the main body of the Stream beginning at a point approximately 140nm southeast of Newport. In this area water temperatures should be seen to increase rapidly from approximately 18 to slightly more than 20^{o}C. These higher temperatures then appear to remain essentially constant until entry into the main body of the Stream where a relatively rapid increase to ~ 25^{o}C is expected.

In addition to this spatial thermal structure the seven day composite suggests that there is a small meander developing in the main body of the Stream just to the west of the rhumb line. This may be an artifact of the compositing process but given its proximity to the rhumb line and the potential for deepening and easterly migration the feature bears watching. It may be more easily discerned in higher resolution composite data and/or the altimetry data which we'll discuss shortly.

With regard to the rotary feature to the east of the rhumb line, the seven day composite shows a jet-like flow structure emanating from the Stream. This image suggests that the feature is attached to the Stream or at least in close contact with the Stream which would favor an easterly migration away from the rhumb line. This is another characteristic that can only be resolved using higher resolution data.

The 24 hour composite for the 22nd of May from the Rutgers University Coastal Ocean Observation Lab site (http://rucool.marine.rutgers.edu) shows many of the same features found on the Johns Hopkins seven day composite with some added detail particularly in the vicinity of the main body of the Stream (Fig.3). Once again the surface thermal data indicate that the main body of the Stream is to be found near 38°N or approximately 240nm southeast of Newport. The inshore thermal patterns in this figure however, differ from those shown on the seven day composite with warmer waters encountered near 40°N followed by a slow increase along the rhumb line to 38° 30' N where an abrupt increase in surface water temperature to approximately 23° C (from 18°C) occurs. This sharp increase occurs prior to that associated with the main body of the Stream and favors flows to the northeast reinforcing the flows produced by the initial inshore increase in water temperature. This latter gradient appears to favor a general clockwise flow much in the manner of a warm core ring resulting in a south going current along the rhumb line until the thermal boundary is encountered near 38° 30' which forces a counter-clockwise rotation resulting in the northeasterly flows across the rhumb line. Overall this image suggests that there will be a variety of currents affecting a Newport to Bermuda track well before the main body of the Stream is encountered.

To the east of the rhumb line the composite of May 22nd shows a rotary feature quite similar in structure to that shown on the seven day composite (compare Figs2 and 3). The thermal structure favors clockwise rotation and general easterly migration due to its contact with the main body of the Stream. This latter supposition is contradicted however, by the May 26th composite which shows the rotary feature moving west resulting in positioning closer to the rhumb line. If this migration continues the westerly margin of the feature could be contacting the rhumb line by the June 5th start of the Bermuda 1-2. This would result in north going currents along the rhumb line favoring a track to the west of the line in this area for boats heading to Bermuda. Given that the diameter of this feature is approximately 90nm it has the potential to affect a significant portion of the track to Bermuda and must be considered another feature to carefully watch over the next week or so.

The thermal gradients along the northern limits of the main body of the Stream as well as those associated with the boundary found to the north (Fig.3) show that a relatively shallow meander has developed in the vicinity of the rhumb line from what was seen earlier in the month (ref. Note #2). On the 22nd this resulted in main body flows crossing the rhumb line at nearly right angles. A deepening or easterly migration might significantly alter this pattern. The altimetry model results for the 28th of May (Fig. 5) show a significantly deeper meander located near 37° N 69° 40' W with no evidence of the meandering near the rhumb line suggested by the thermal data (i.e.Fig.3). Earlier altimetry results provided little indication of this feature suggesting that it may be an artifact of the computational process. Once again however, the feature warrants attention due to its potential to affect the character and structure of the flows

along the rhumb line.

In addition to introducing a meander in area not apparent in the thermal data, the altimetry plot also suggests that the feature to the north and west of the main body of the Stream thought to be producing the clockwise flow discussed above has in fact a cold core resulting in a counter clockwise flow. There is some slight indication of this possibility in the thermal data - but only slight ! Along the rhumb line the resulting flows are weak but generally adverse to boats bound to Bermuda from Newport. The resolution of the currently available thermal data makes it impossible to verify this result. Hopefully we'll get a clear day between now and the 5th of June. Absent that, prudence would appear to favor a near rhumb line course in this area to avoid the possibility of stronger adverse currents to the west while following a line to Bermuda that is at least short and takes advantage of some amount of favorable current in the event that the altimetry estimates are inaccurate.

To the east of the rhumb line the altimetry model results provide no indication of a discrete rotary feature or ring. Instead it shows the Stream as a single coherent flow which abruptly changes direction near 38^{o}N 68^{o}W or quite close to the center of the thermal feature shown in Figure 4 and previously designated as a warm core ring (Fig.1). Within this change in direction there is a clockwise rotating feature slightly south and west of the ring shown in Figure 4 . This suggests that the ring has been absorbed by the main body of the Stream. If this is the case we would expect the feature to migrate to the east away from the rhumb line over the next week or so. Again the available data limit our ability to evaluate the accuracy of these model results but they are plausible. We should add this feature to the list of those that bear watching over the next week. Here's to a clear day on Wednesday next !

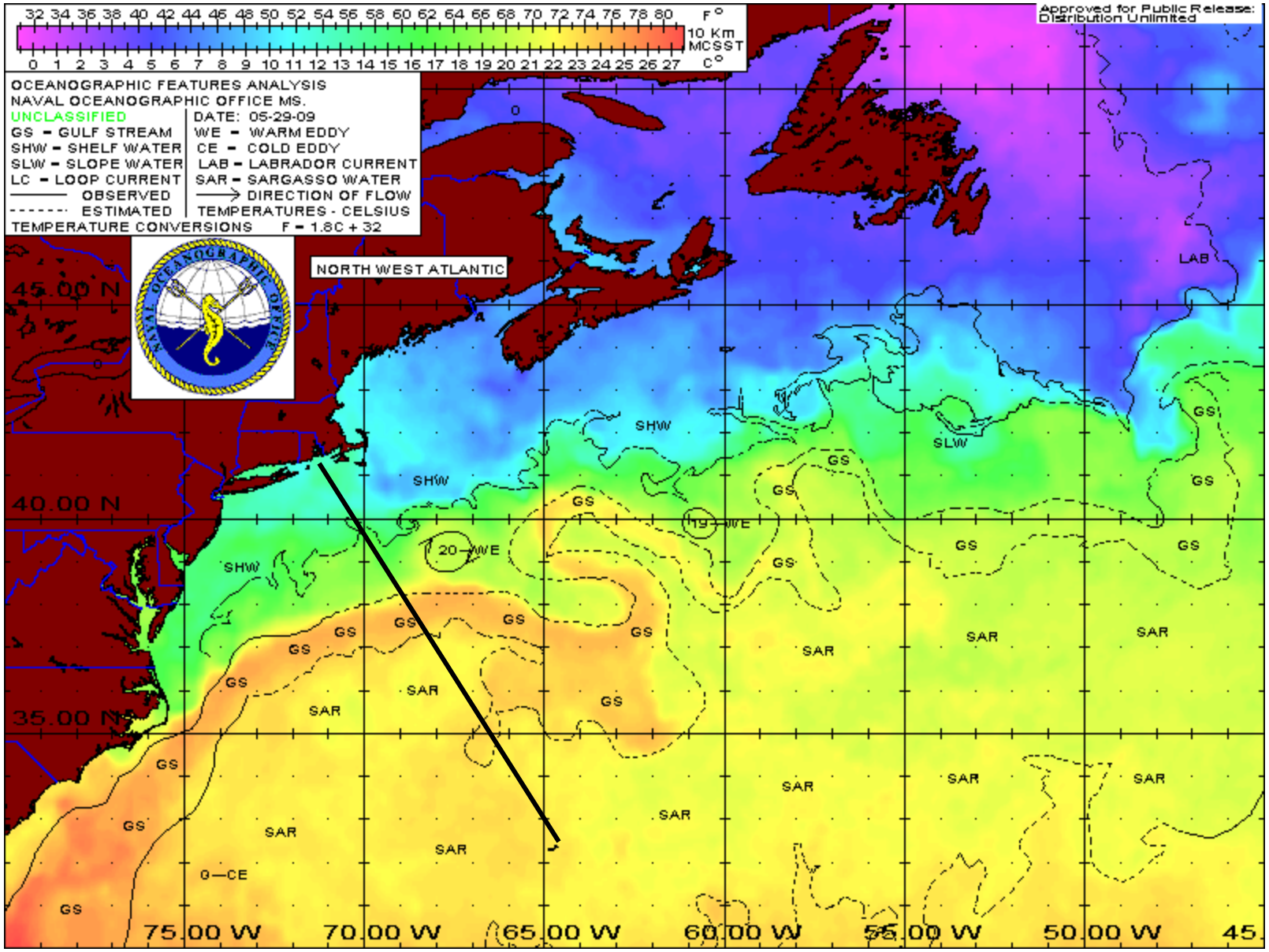

Figure 1 U.S. Navy Surface Thermal Image – May 29, 2009

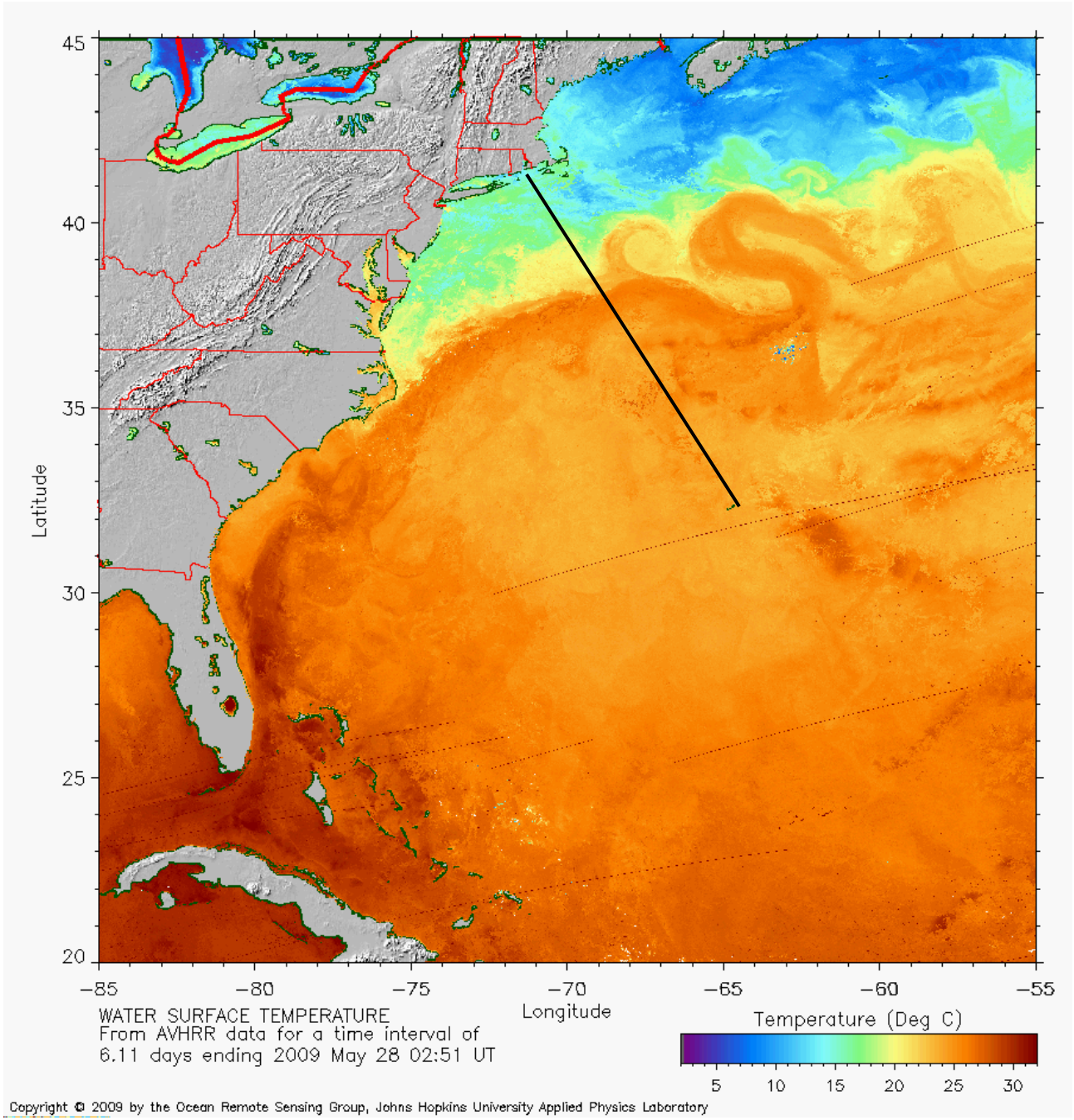

Figure 2 Seven Day Composite Satellite SST Image – May 28, 2009

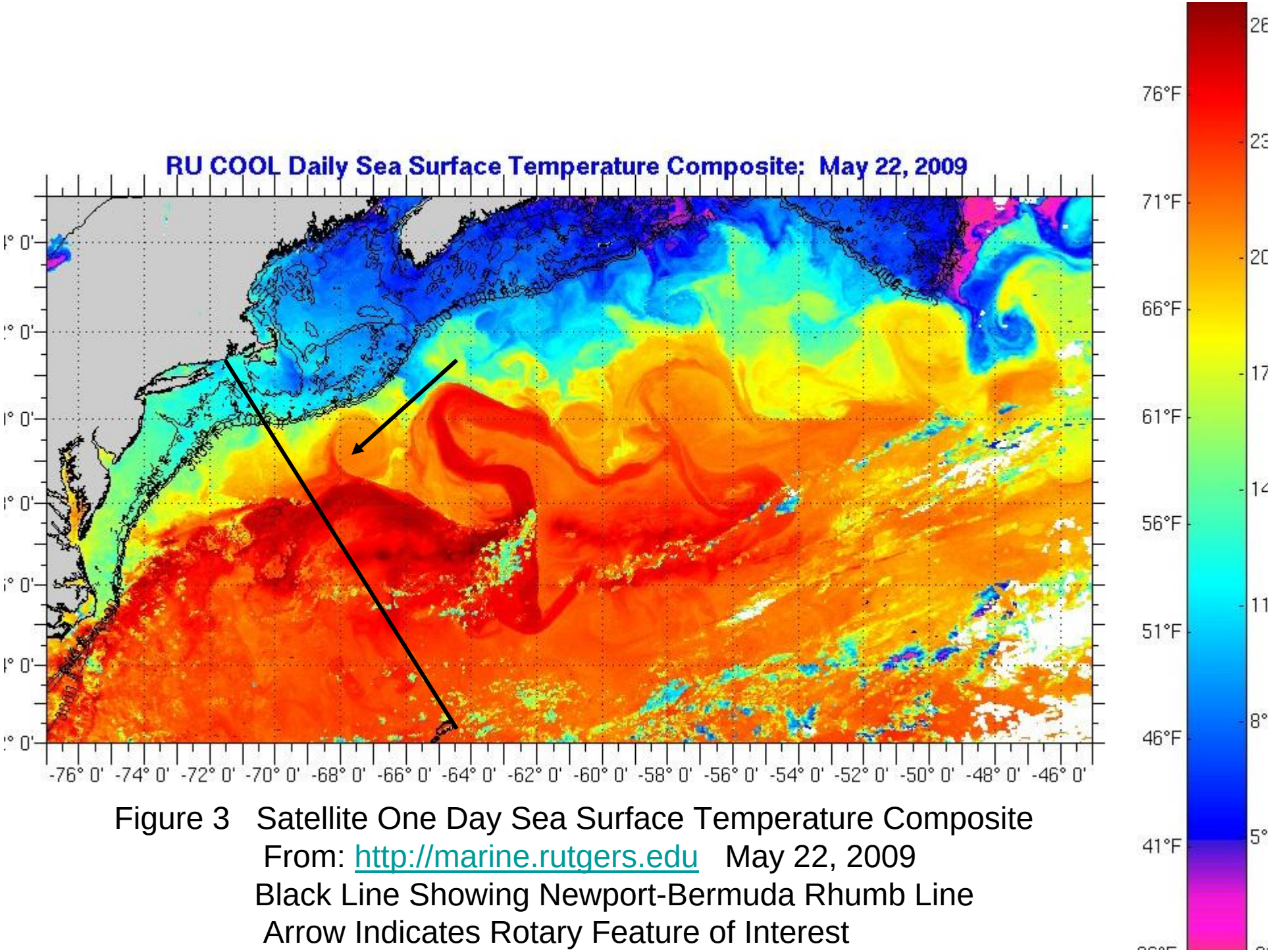

Figure 3 Satellite One Day Sea Surface Temperature Composite
From: http://marine.rutgers.edu May 22, 2009
Black Line Showing Newport-Bermuda Rhumb Line
Arrow Indicates Rotary Feature of Interest

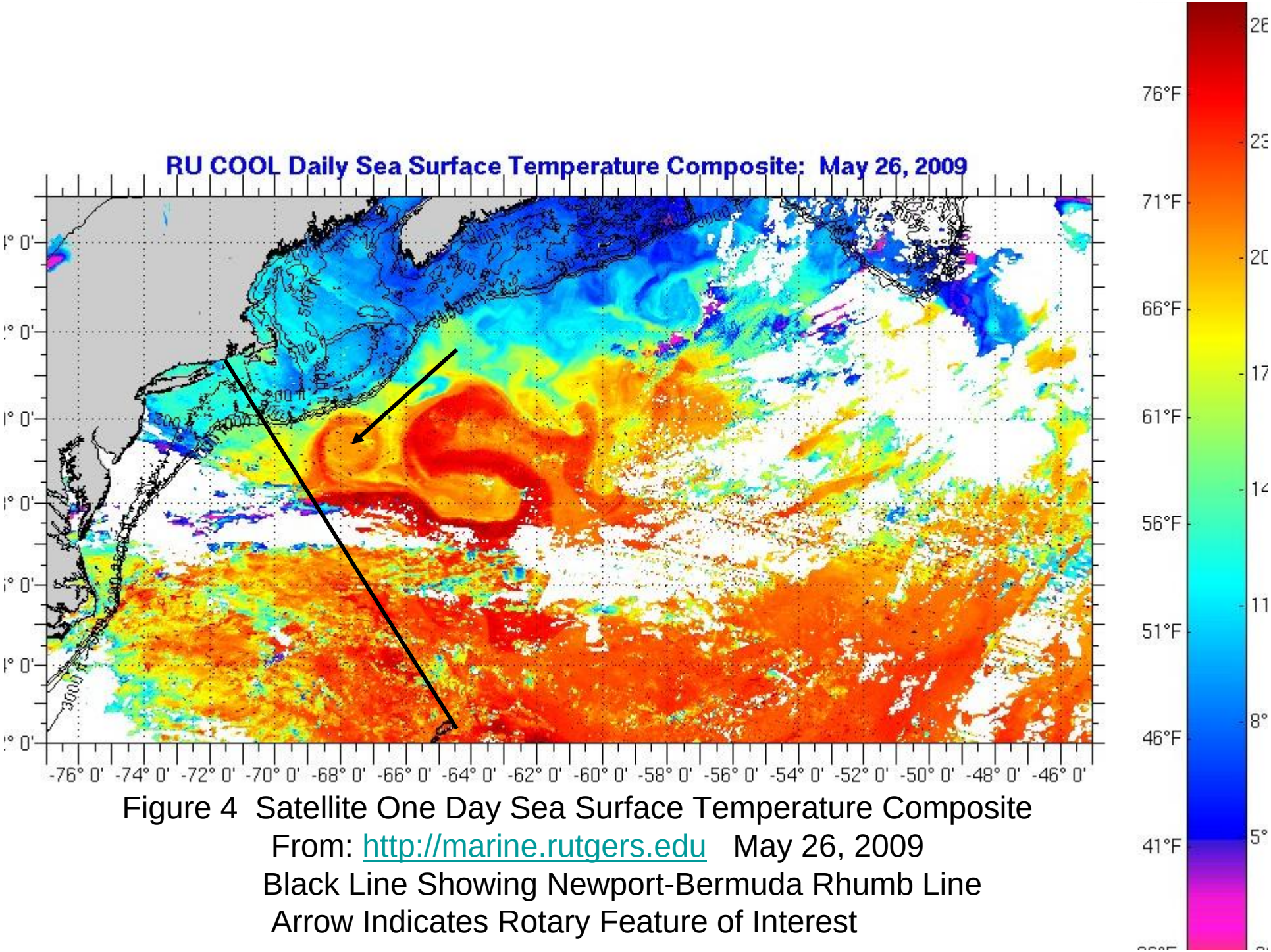

Figure 4 Satellite One Day Sea Surface Temperature Composite
From: http://marine.rutgers.edu May 26, 2009
Black Line Showing Newport-Bermuda Rhumb Line
Arrow Indicates Rotary Feature of Interest

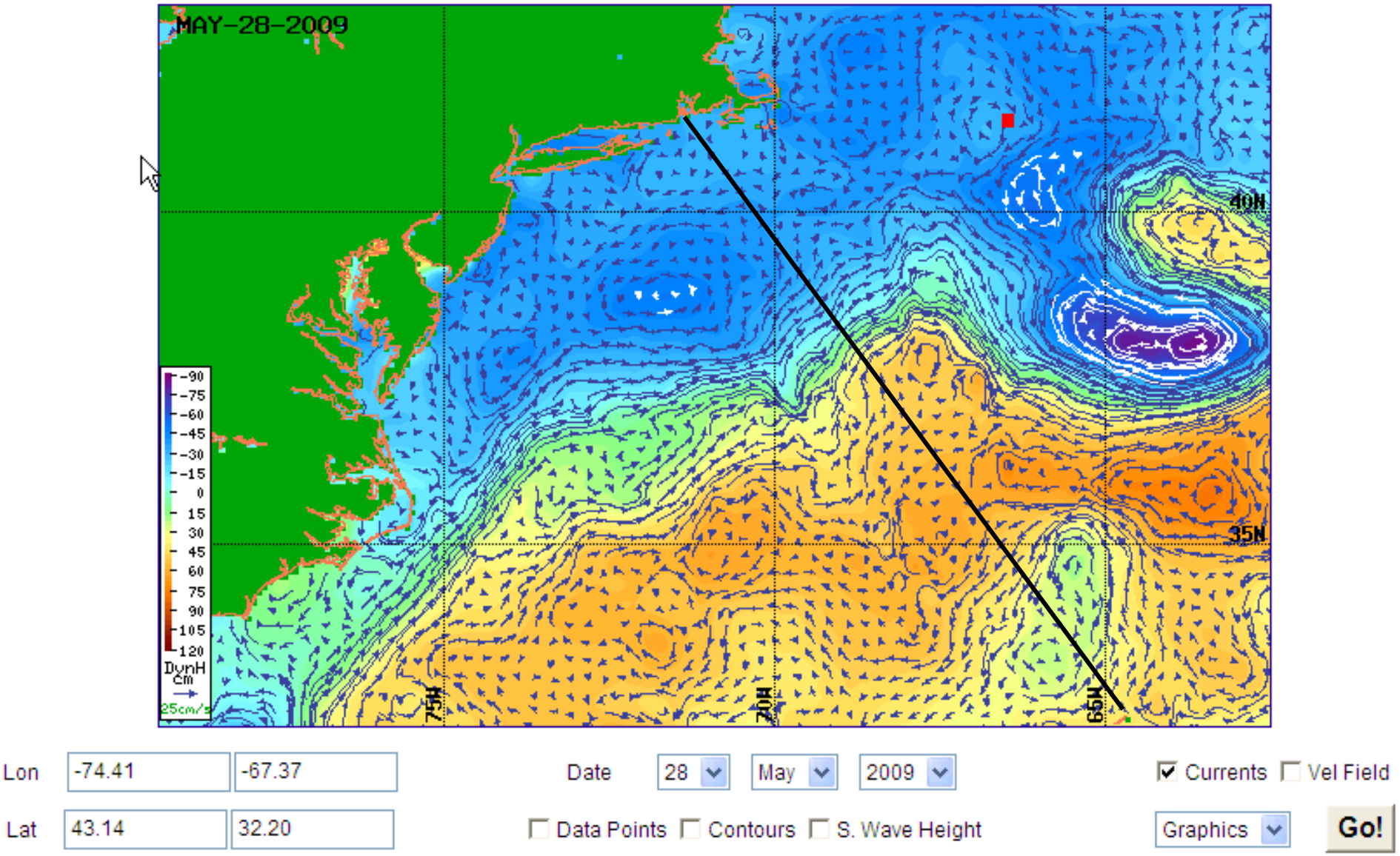

Figure 5 Satellite Altimetry Derived Surface Currents-NW Atlantic Region
Source:http://www.aoml.noaa.gov/phod/dataphod/work/trinanes/INTERFACE/index.html