Supporting information for *Geophysical Research Letters*

On the Recent Destabilization of the Gulf Stream Path downstream of Cape Hatteras

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Supporting Text

Different methods can be used to identify the time-varying location of a western boundary current extension like the Gulf Stream east of Cape Hatteras or the Kuroshio east of Japan. One method uses a constant SSH contour in the mapped absolute dynamic topography from satellite altimetry to find snapshots of the current's path. The 25-cm SSH contour is commonly used to identify the Gulf Stream east of Cape Hatteras [e.g., *Lillibridge and Mariano*, 2013] and the 170-cm contour to identify the Kuroshio Extension east of Japan [e.g., *Qiu and Chen*, 2006]. Since Gulf Stream rings can also contain a closed 25-cm SSH contour, it is the longest contiguous SSH contour that is used here to delineate the Gulf Stream's path in each SSH map (**Figure 1**, blue contours).

The other method to identify the current's location uses the SSH gradient (∇SSH) from altimetry. Typically, the maximum meridional SSH gradient (δSSH/δy) at each longitude—which is where the zonal surface geostrophic velocity is maximum—is used to identify the current [e.g., *Kelly et. al*., 2010]. This maximum SSH gradient is generally close to the location of the constant SSH contour (e.g., see *Qiu and Chen* [2006] for the Kuroshio Extension and **Figure S1** for the Gulf Stream) though there can be differences when the flow is oblique to the direction along which the gradient is calculated. The constant SSH contour method tends to capture better the currents' steep meanders [e.g., *Kelly et al.*, 2010] where the current is oblique to the meridians and the meridional SSH gradient (δSSH/δy) is small relative to the zonal SSH gradient (δSSH/δx).

Here the along-track gradient (rather than the meridional gradient), which identifies the maximum cross-track velocity, is used to identify the location of the Gulf Stream at Line W. This method capitalizes on the satellite's high along-track resolution and is effective since track 126 is nearly orthogonal to the mean Gulf Stream path. There are a few instances when the Gulf Stream does cross Line W obliquely and there is also a strong Gulf Stream ring present on Line W. In these cases, the maximum gradient can be associated with the ring rather than the Gulf Stream. These instances are identified here by using the concurrent SSH map to distinguish the location of the ring (overall maximum in the along-track gradient) and the location of the current's axis (a secondary maximum in the along-track gradient).

At Line W, the position of the 25-cm SSH contour tracks the position of maximum SSH gradient throughout the 22-year satellite record (**Figure S1**). The orange to red shaded regions generally identify the high-velocity Gulf Stream core. The width of the high velocity region of the Gulf Stream at any time is narrow (< 0.5˚ latitude) relative to the amplitude of the Gulf Stream meanders (which can swing by more than 2˚ latitude at this satellite track).

The match between the 25-cm SSH contour and the high velocity core does not degrade over time (as might be expected if mean sea level rise were a significant factor in the best choice of SSH contour for identifying the Gulf Stream axis). Variability in the position of the 20-cm and 30-cm contours—not plotted in **Figure S1**—is hardly distinguishable from that of the 25-cm contour. However, during 2006 there is an extended period with multiple 25-cm SSH contours at Line W and alternating velocity maxima and minima. During this period there was a massive anticyclone on the shoreward side of the Gulf Stream and it is the southernmost expression of the 25-cm SSH contour that corresponds with a local velocity maximum and the Gulf Stream axis.

Both methods used to identify the position of the Gulf Stream here (SSH in **Figure 1**, blue contours and SSH-gradient in **Figure 3**, black curve) account for the presence of rings.

Other methods that are independent of satellite altimetry have also been used to identify the location of the Gulf Stream east of Cape Hatteras. These are compared in Sanchez-Franks et al. (2014) and include the location of the 15˚C isotherm at 200-m depth, a 2˚C temperature drop in sea surface temperature, and ADCP-measured velocity at 55-m depth.

Supporting Figure

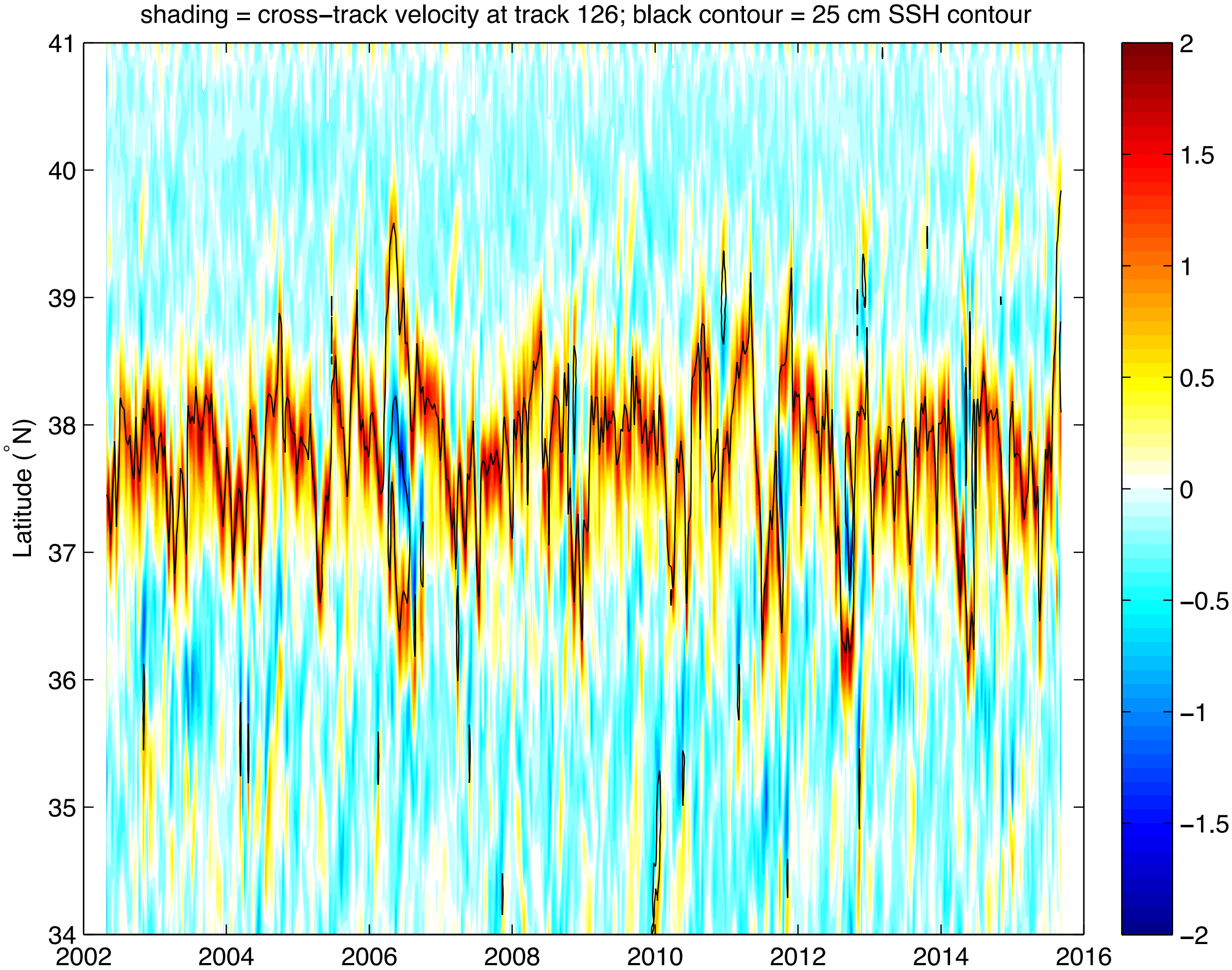

Figure S1. Time-latitude plot along Line W (track 126) showing the evolution of the cross-track velocity (m s^{-1}, shading), which is proportional to the along-track SSH gradient, and the location of the 25-cm SSH contour along Line W superimposed (black contour).

Supporting References

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