CORRESPONDENCE

Comments on "Reconstruction of the Gulf Stream from 1940 to the Present and Correlation with the North Atlantic Oscillation"

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ABSTRACT

The path of the Gulf Stream as it leaves the continental shelf near Cape Hatteras is marked by a sharp gradient in ocean temperature known as the North Wall. The latitude location of the Gulf Stream North Wall (GSNW) has previously been estimated by subjective analysis of daily maps of sea surface temperatures. Recently, Watelet et al. (2017) presented an objective procedure by fitting an error function to the SST profile across the Gulf Stream at 81 longitude positions. The fit smooths over not only the GSNW but also the much colder waters from the Labrador Sea on the continental shelf. Watelet et al.'s procedure is therefore likely to misidentify the shelf-slope front as the Gulf Stream North Wall, leading to a systematic northward bias the in North Wall position.

The path of the Gulf Stream (GS) as it leaves the continental shelf near Cape Hatteras is marked by a sharp gradient in ocean temperatures known as the Gulf Stream North Wall (GSNW). Fluctuations in the meridional position of the GSNW have attracted much interest because they have large impacts in the distribution of heat in the North Atlantic that affect local climate (Joyce et al. 2009; Kwon and Joyce 2013; Taylor 1996) and also marine populations (Nye et al. 2011; Saba et al. 2015).

The meridional position of the GSNW at particular longitudes is operationally estimated via subjective analysis of SST charts by the U.S. Naval Oceanographic Office and the National Oceanic and Atmospheric Administration (Taylor and Stephens 1980, 1998; Drinkwater et al. 1994). Recently Watelet et al. (2017, hereinafter WBB17), presented an objective method for detecting the position of the North Wall and computing an index for the latitude position of the GSNW. The authors developed a sea surface temperature (SST) dataset by analyzing a large number of in situ observations. They computed a GSNW index from their SST product for 1940–2015 based on the latitude of maximum SST gradient at 81 equally spaced zonal positions at intervals of 0.25° longitude. They find the latitude of the GSNW at each longitude by fitting the SST to the error function

$$f(y) = p_2 + p_3 \mathrm{erf}\frac{y - p_1}{p_4},$$

where the p_i are parameters determined by the fit.

The analysis was carried out over a rectangular domain spanning 32°–47°N and 70°–50°W (approximately, see Fig. 2 of WBB17). Note that this domain contains substantial regions of shelf as well as part of the Gulf of St. Lawrence north of Nova Scotia.

Examination of their results shows that the GSNW index WBB17 computed is in error. The domain used in their analysis includes a large part of the continental shelf and extends to the Grand Banks in the north. This region is occupied by cold water originating from the Labrador Current, which is distinct from the Gulf Stream. A comprehensive discussion of the shelf-slope front (SSF) is given by Bisagni et al. (2006). The SSF extends from the tail of the Grand Banks southeast of Newfoundland to the southern Middle Atlantic Bight near Cape Hatteras, North Carolina. Similar to the GSNW, the SSF is readily observable in SST data as seen for the week centered on 18 May 1998 in Fig. 1 of Bisagni et al. (2006). Long-term mean positions (1973–92)

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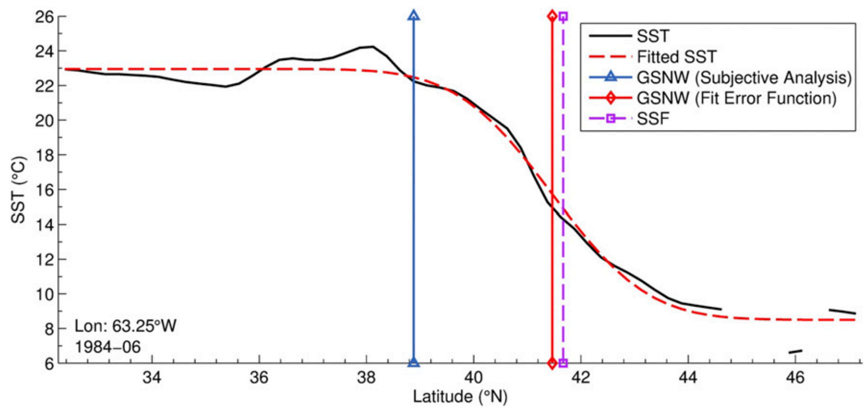

FIG. 1. The SST profile at 63.25°W in June 1984. The solid black line shows the SST profile from OI-SST v2, the dashed orange line shows the fitted error function, and the vertical blue, red, and violet lines indicate the latitudes of the North Wall from subjective analysis, the North Wall from fitting the error function as in Watelet et al. (2017), and the SSF from the subjective analysis, respectively.

of SSF and GSNW are shown in Fig. 2 of their paper. The monthly averaged positions of the GSNW and SSF from subjective analysis are also available on the website of Fisheries and Oceans Canada (http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-pmza/climat/gulf-golfe/slope-plateau-eng.htm).

It should be noted that the SSF has large meanders. Halliwell and Mooers (1979) report that the standard deviation of the displacements of the SSF around the mean position is ~30 km near Cape Hatteras and it increases to ~65 km near the Northeast Channel located east of Georges Bank. From 1974 through 1976 the SSF was observed to be displaced as far as 100 km shoreward and 300 km seaward of the shelf break (Ingham 1976; Gunn 1979). Eastward excursions of cold shelf water would be smoothed over by the procedure used by WBB17 and impact their estimate of the GSNW position. Figure 3 in WBB17 shows their SST profile in June 1984 at 63.25°W and the error function fit. The estimated latitude of the GSNW at this specific longitude is about 41.6°N. This is close to the mean position of the SSF at 63.25°W, far to the north of the GSNW in Fig. 2 of Bisagni et al. (2006). In Fig. 1, we reproduced WBB17's Fig. 3 from NOAA's optimally interpolated SST version 2 (OI-SSTv2; Reynolds et al. 2007). OI-SSTv2 is available in a horizontal resolution of 0.25°, which is the same as the SST dataset developed by WBB17. Latitudes of the GSNW and SSF from subjective analysis are also marked as reference. The GSNW latitude we get from fitting an error function is ~41.5°N, which is close to WBB17's result (~41.6°N). However, it is clear that this latitude is closer to the SSF than the GSNW from subjective analysis.

We have followed the procedure described by WBB17 to compute the GSNW latitude at the same domain between 1982 and 2014 from OI-SSTv2. We fitted the monthly SST profiles at the 81 longitudes between 70° and 50°W with the error function as given in Eq. (3.1) of WBB17. The 81 latitudes of the GSNW are then found as the locations of the maximum gradient in the error function.

As another illustration of the problem in the WBB17 method, Fig. 2 shows comparisons of the GSNW latitude computed by their method with the location of the GSNW estimated from subjective analysis for February 1993 and August 1993. The location of the maximum current velocity in the Gulf Stream, which we estimated from the 25-cm sea surface height (SSH) from satellite altimetry,[1] is also shown for comparison, as well as the position of the SSF. The North Wall front and the SSF can be seen in the SST profiles in the four panels of Fig. 2. The WBB17 method smooths over the two fronts by fitting the error function and identifies the location of the maximum gradient in the fitted line as the latitude of the GSNW. The GSNW thus estimated is biased north of its location from the subjective analysis and is sometimes close to the SSF.

Figure 3 compares the long-term averages (1982–2014) of the locations of the

[1] A (more than 1 m) permanent SSH drop can be found across the GS. The 25-cm SSH contour from satellite altimetry is located at the middle of the drop and thus used as a proxy of the maximum velocity location (Rossby et al. 2014; Andres 2016). The comparison between them can be found in Fig. S1 of Andres (2016).

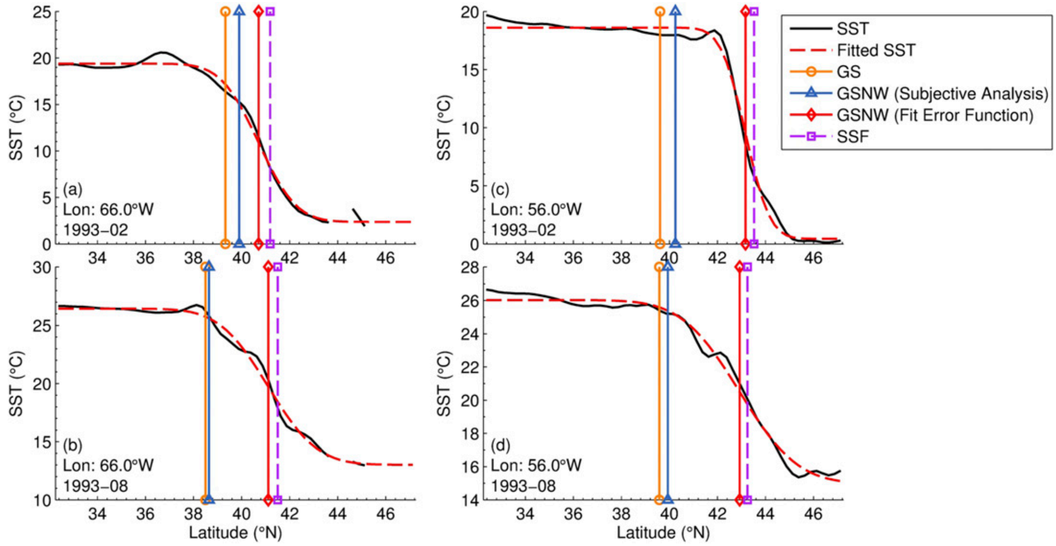

FIG. 2. Temperature profiles of SST and the fitted error function for (a) 66°W in February 2006, (b) 66°W in August 1993, (c) 56°W in February 1993, and (d) 56°W in February 2006. The vertical lines indicate the positions of the Gulf Stream maximum velocity (yellow line), GSNW from subjective analysis (blue line), GSNW estimated from the error function fit (red line), and the shelf-slope front (dashed red line). Please note that the SST peak between the GS and the SSF in (c) is due to a warm eddy north of the GS.

1) GSNW latitude calculated by the WBB17 procedure (red line),
2) GSNW estimated by subjective frontal analysis of SST maps (yellow line) given by Fisheries and Oceans Canada at the link given above, and
3) SSF estimated by subjective analysis of frontal SST maps (black line) given by Fisheries and Oceans Canada at the link given above.

The figure makes it apparent that the long-term average of the North Wall obtained by the WBB17 method is close to the SSF front, considerably north of the GSNW obtained by subjective analysis of SST data.

In the weekly satellite-based snapshots of SSTs, as in Fig. 1 of Bisagni et al. (2006), we can see the cold waters from the shelf distinct from the warmer waters of the Gulf Stream. However, the two water masses are intertwined in a complex juxtaposition because of the inevitable presence of meanders and eddies. The subjective frontal analysis is thus likely to be more suitable for detecting the position of the North Wall and the SSF from SST compared with

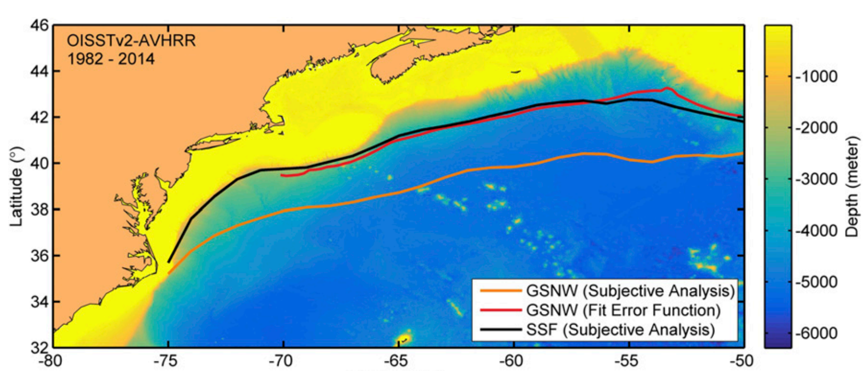

FIG. 3. Climate mean path between 1982 and 2014. The subjective fronts are downloaded from Fisheries and Oceans Canada (http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-pmza/climat/gulf-golfe/slope-plateau-eng.htm). The background color indicates topography from the General Bathymetric Chart of the Oceans (GEBCO; Becker et al. 2009).

an ''objective'' method that smooths over the temperature gradients.

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