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Changes in the Gulf Stream path over the last three decades

Antonio Sánchez-Román[1], Flora Gues[2], Romain Bourdalle-Badie[2], Marie-Isabelle Pujol[3], Ananda Pascual[1], Marie Drévillon[2]

[1]Mediterranean Institute for Advanced Studies, C/Miquel Marqués, 21, 07190 Esporles, Spain
[2]Mercator Ocean International, 2 Av. de l'Aérodrome de Montaudran, 31400 Toulouse, France
[3]Collecte Localisation Satellites, Parc Technologique du Canal, 8-10 rue Hermès, 31520 Ramonville-Saint-Agne, France

Correspondence to: Antonio Sánchez-Román (asanchez@imedea.uib-csic.es)

Abstract. The Gulf Stream transports warm waters into the subpolar eastern North Atlantic, impacting Europe's climate. Over the next century the Gulf Stream is expected to both reduce its speed and displace northward in response to climate change. This study investigates the changing pattern of the Gulf Stream over the last three decades as observed in the altimetric record (1993–2021) using monthly-averaged altimetry maps together with the outputs from a numerical model. The yearly evolution of the coordinates (destabilization point) where the Gulf Stream starts to meander and to convert from a stable to an unstable detached jet is investigated. The location of this destabilization point shows variations at interannual scale and has varied by more than 1400 km in longitude and 300 km in latitude over the altimetric era. Changes in the Gulf Stream path impact both associated mesoscale Eddy Kinetic Energy and waters transported towards the subpolar North Atlantic. The observed shifts of the path destabilization point seem to be linked to North Atlantic Oscillation variability during winter that may play an important role: it presents a negative trend associated to a shift from a positive to a negative phase between 1993 and 2011; and an opposite behavior from a negative to a positive phase from 2011 until 2021 in agreement with the associated south-westward and north-eastward observed migration of the destabilization point.

1 Introduction

The Gulf Stream is part of the western boundary current system and carries near-surface warm waters from the subtropical to the subpolar North Atlantic (Guo et al., 2023). The balance between these northward-flowing warm and shallow waters as part of the Gulf Stream and a southward cold and deep return waterpath describes the Atlantic Meridional Overturning Circulation (AMOC, e.g., Buckley and Marshall, 2016; Lozier, 2019; Swingedouw et al., 2022). The AMOC accounts for nearly 90% of the total heat transport in the North Atlantic (Johns et al., 2011). Thus, it is a major driver of subpolar planetary heat exchange (McCarthy et al., 2018). This makes the Gulf Stream to play a paramount role in North Atlantic climate variability and change (Frankignoul et al., 2001, Joyce and Zhang, 2010; Srokosz et al., 2012; McCarthy et al., 2015; Lozier et al., 2019).

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The Gulf Stream originates in the Gulf of Mexico and flows poleward close to the North American coast from the Straits of Florida to Cape Hatteras (Fig.1). Then, it leaves the continental margin and becomes a detached western boundary current flowing eastward as the Gulf Stream Extension (e.g., Joyce et al., 2009; Greatbatch et al., 2010). From approximately 55°W onwards, and across 38 - 42°N, it becomes the North Atlantic Current (Stendardo et al., 2020). The path described by the Gulf Stream Extension is known as the Gulf Stream North Wall (GSNW) marking a transition from warm subtropical to cold subpolar waters (Joyce and Zhang, 2010). Direct estimates of the GSNW are available from 1955 (Joyce et al. 2000) and 1966 (Taylor and Stephens, 1980) onwards, allowing the analysis of the North Atlantic ocean circulation variability from decadal and multidecadal scales (McCarthy et al., 2018).

Decadal and multidecadal variability is an outstanding feature of North Atlantic sea surface temperatures (Buckley and Marshall, 2016, Sutton et al., 2017, Guo et al., 2023). In particular, the Atlantic multidecadal variability is mainly due to internal ocean-driven variability associated with global and regional variations in precipitation and temperature, sea level fluctuations and hurricane activity (Delworth and Mann, 2000). However it could be also generated as a response to natural atmospheric variability (Clement et al., 2015) which is mainly associated with the North Atlantic Oscillation (NAO). The NAO is the first mode of Atlantic atmospheric forcing and describes surface sea-level pressure differences between the Azores high and the subpolar low, and varies at quasi-decadal and multidecadal timescales (Da Costa & Colin de Verdiere, 2002; Gray et al., 2016; Årthun et al., 2017), impacting North Atlantic sea surface temperature patterns via air-sea heat exchanges (Hurrell et al., 2003; McCarthy et al., 2018; Osman et al., 2021).

The variations in the GSNW path exhibit two main modes: (i) wavelike fluctuations linked to the Gulf Stream meandering, and (ii) instability and large-scale lateral shifts exhibiting seasonal and interannual changes (Frankignoul et al., 2001). Actually, western boundary currents are identified as eddy-rich regions where mean kinetic energy and available potential energy from the mean flow are converted into mesoscale eddy kinetic energy (EKE) from baroclinic and barotropic instabilities. The low frequency, interannual variability of the lateral shifts in the GSNW position impacts on the global climate system as a whole (Guo et al., 2023) and can be linked to changes in climate-related oceanic phenomena such as El Niño-Southern Oscillation (Taylor et al., 1998), the AMOC (Joyce and Zhang, 2010) or the aforementioned atmospheric forcing (Wolfe et al., 2019) among others. Taylor et al. (1998) found that the Gulf Stream shifts were correlated with the wintertime NAO during the time period spanning from 1966 to 1996 with high values of the NAO index (stronger westerlies) favoring a northerly path 2–3 years later. Joyce et al. (2000) observed north shifts of the Gulf Stream during positive phases of the NAO with lags of 1 year between 1954 and 1990. More recently, McCarthy et al. (2018) reported shifts in the GSNW path coincident with NAO variations over both quasi-decadal and multidecadal timescales, having implications for linking the GSNW and AMOC.

The path of the Gulf Stream in the water column and its variability can be assessed by tracking the location and direction of an isotherm at a given depth. Kim and Watts (1994) used the 12ºC isotherm (iso12) at the 400 m isobath whilst Joyce et al. (2000; 2009) used the temperature at 200 m depth (i.e., the 15ºC isotherm) to define the region of strong flow of the Gulf

Stream. This approach was followed by Frankignoul et al. (2001) and Seidov et al. (2021) to identify the latitude of Gulf Stream paths.

GSNW variability can be seen in gridded satellite altimetry and also in derived surface velocities as meridional shifts in the path of the Gulf Stream after Cape Hatteras (McCarthy et al., 2018). In this study, altimetry maps are used together with the outputs from an ocean reanalysis to assess the changing pattern of GSNW over the last three decades, impacting both associated mesoscale EKE and waters transported towards the subpolar North Atlantic. To do that, the time-varying position of the path destabilization point where the GSNW converts from a stable, detached jet to an unstable, meandering detached jet is investigated following the methodology described in Andres (2016). Furthermore, interannual variability of the GSNW is assessed to investigate possible causes and consequences of observed Gulf Stream changes.

2 Methods

Daily maps of both Absolute Dynamic Topography (ADT) from satellite altimetry (product ref. no. 1, Table 1) and sea surface height (SSH) from model outputs (product ref. no. 2, Table 1) were averaged to produce monthly maps from January 1993 to December 2021. These maps have a spatial resolution of 1/4° and 1/12°, respectively. Then, the Gulf Stream path was identified with the 25 cm SSH contour according to e.g. Lilibridge and Mariano (2013); Rosby et al. (2014); Andres (2016), Chi et al. (2021) and Guo et al. (2023) from detrended ADT (SSH) time series (Fig.1). The annual and semiannual cycles were kept in the time series in order to allow the analysis of the seasonal signal. Also, monthly-averaged geostrophic velocity fields derived from both ADT and sea level anomaly (SLA) maps (product ref. no. 1, Table1) were used to estimate the surface velocity associated with the Gulf Stream paths. Geostrophic velocity anomalies derived from SLA maps were then used to compute the Gulf Stream surface EKE. EKE presents greater values in the vicinity of the main jets and currents such as the western boundary currents whereas it rapidly decreases elsewhere (von Schuckmann et al, 2016). Satellite gridded products miss part of the mesoscale variability due to coarser effective dynamical resolutions (Ballarotta et al., 2019). However, the interannual variations in EKE can still be captured (Guo et al., 2022; 2023).

Variability of Gulf Stream paths was assessed on a yearly basis. According to Andres (2016), the 12 monthly mean paths for a given year were separated into 0.5° longitude bins and the variance of Gulf Stream position (latitude) in each bin was calculated. It can happen that the path in a given longitude bin describes a twisted route providing two or more latitudes. To overcome this, the most northerly latitude of the 25 cm SSH contour was used in the variance calculation (Andres, 2016). This computation was also done for the Gulf Stream mean paths computed for 1993–2021 as a group (Fig. 1). The downstream distance (longitude) where the latitude's variance first reaches $0.42(°)^2$ (half of the maximum variance obtained for the aggregate) was defined as that year's path destabilization point (Andres, 2016). This is where the Gulf Stream converts from a stable, detached jet to an unstable, meandering detached jet (Fig. 1). The confidence interval (at 95% confidence level) of the destabilization point was computed. Finally, a five-year running mean filter was applied to time series of the position of the destabilization point to avoid spurious signals due to changes in higher-frequency Gulf Stream variability.

Table 1: data products used.

Product ref. no.	Product ID & type	Data access	Documentation
1	SEALEVEL_GLO_PHY_L4_MY_008_047; Satellite observations	EU Copernicus Marine Service Product (2023)	Quality information Document (QUID): Pujol et al. (2023) Product User Manual (PUM): Pujol (2022)
2	GLOBAL_MULTIYEAR_PHY_001_030; Ocean reanalysis	EU Copernicus Marine Service Product (2022)	Quality information Document (QUID): Drévillon et al. (2022a) Product User Manual (PUM): Drévillon et al. (2022b)

Also, the iso12 at the 450 m isobath was identified from the product ref. no. 2 (Table 1) according to Joyce et al. (2000; 2009) and used to track the path of the Gulf Stream in the water column. This isotherm was chosen because it makes it possible to both limit short-term surface variations and follow the trajectory of the Gulf Stream more at depth.

3 Results

3.1 Transition of the Gulf Stream path to an unstable jet

The datasets and methods described above were used to characterize the mean and time-varying Gulf Stream path, and identify its transition to an unstable detached jet. The mean destabilization point of the monthly mean Gulf Stream paths (1993–2021) is located at coordinates 38.15°N and 66.11°W (Fig. 1). West of this location (i.e. near cape Hatteras), the path is stable exhibiting a relatively straight, detached jet and thus low variance (inset in Fig. 1). Downstream from the destabilization point the path becomes unstable showing meanders that translate in high variance and associated mesoscale EKE.

The Gulf Stream is one of the regions with the strongest mesoscale energy in the global ocean (Chelton et al., 2011; Guo et al., 2023). It presents mean values larger than 2000 cm^2/s^2 downstream from 75°N where the Gulf Stream separates from the continental margin and becomes the GSNW (not shown). This area has an energetic mesoscale activity exhibiting strong eddy-mean flow interaction with significant along-stream variability (Kang and Kurchitser, 2015, Guo et al., 2023). The mean EKE (1993–2021) core, with values larger than 3000 cm^2/s^2, is observed in the surroundings of the Gulf Stream mean path. In addition, the zonally-maximum mean EKE exhibiting values larger than 4000 cm^2/s^2 is located close to the

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destabilization point where the Gulf Stream becomes unstable. These features are consistent with previous observations both in the upstream and downstream parts of the flow (e.g., Kang and Kurchitser, 2015).

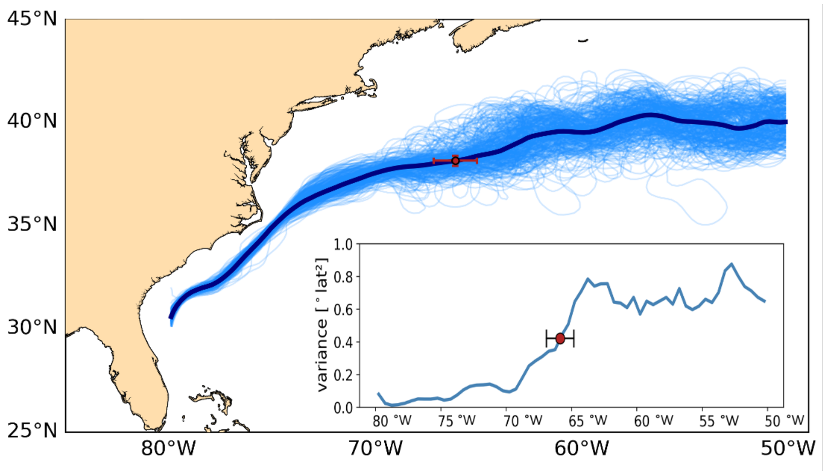

Figure 1: Gulf Stream paths based on the 25 cm SSH contour from altimetry (product ref. no. 1) showing monthly (pale-blue), and a 1993–2021 overall (blue) mean. The inset displays the variance in latitudinal position of the monthly mean Gulf Stream paths (1993–2021) as a function of downstream longitude. Red dot indicates the destabilization point where that latitude variance first reaches 0.42 (°)^2 (see text for more details). The confidence interval (at 95% confidence level) of the destabilization point in both longitude and latitude is also displayed.

The aggregated (zonally and meridionally averaged) 1-year low-pass filtered surface geostrophic velocity associated with the Gulf Stream paths (figure not show) presents an overall negative linear trend over the period 1993–2012 with reduced speed exhibiting strong interannual variability at decadal and sub-decadal scale. This agrees with results reported by Chi et al (2021) from along-track altimetry data for the same period. This fact translates into a recurring EKE decrease with values ranging from around 3000 cm^2/s^2 at the beginning of the altimetric era to close to 2200 cm^2/s^2 in 2012. From 2013 there is an inversion in the temporal evolution of the surface velocity linked to the Gulf Stream with an increasing speed until 2016 that promotes aggregated EKE values close to 3300 cm^2/s^2. This enhanced speed and associated EKE is kept until 2021 also showing interannual variability.

3.2 Interannual displacement of Gulf Stream

Figure 2 shows the yearly evolution of the destabilization point in latitude (panel a) and longitude (panel b). Over the last three decades, the location of this destabilization point (red dots) has varied by more than 1400 km in longitude (i.e., between 57°W and 70°W) and 300 km in latitude (i.e., between 37.7°N and 40.6°N) showing strong interannual variability. In addition, there has been an overall evolution of the destabilization point of the Gulf Stream towards western longitudes and southern latitudes particularly from 1995 to 2014, which agrees with the findings of Andres (2016) over the same period. On the contrary, from 2014 until 2021 an inversion in the temporal evolution of the destabilization point towards eastern longitudes and northern latitudes is observed. These new findings expand the results reported in Andres (2016) and might have an impact on the physical properties of waters transported towards the subpolar eastern North Atlantic.

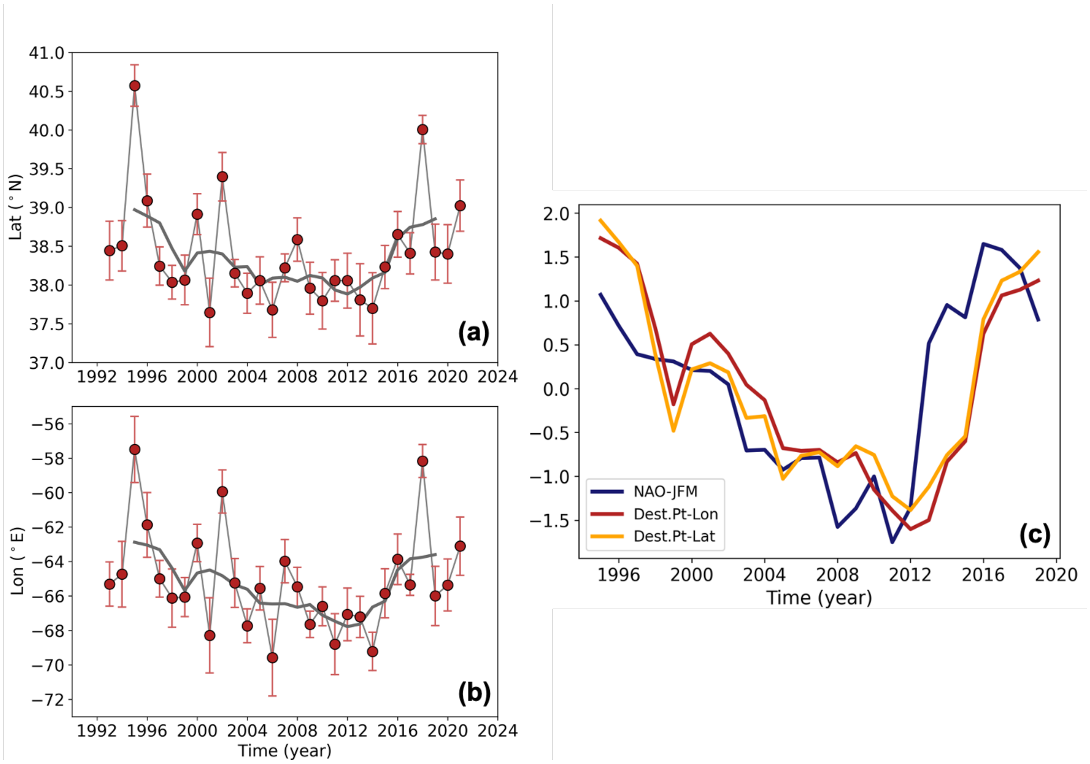

Figure 2: yearly evolution of the destabilization point computed from altimetry data (product ref. no. 1) showing the latitude (panel a) and longitude (panel b) where the Gulf Stream becomes unstable. Solid grey line indicates the five-year running mean of the destabilization point. The confidence interval (at 95% confidence level) of the yearly position of the destabilization point in both longitude and latitude is also displayed. Panel c shows the standardized five-year running mean of the position (longitude - red line, latitude - orange line) of the destabilization point and the standardized five-year running mean of the seasonal mean NAO index during cold season (blue line).

However, these results might be affected by spurious signals due to changes in higher-frequency Gulf Stream variability. To avoid this, the five-year running-mean of the position of the destabilization point was investigated (grey line in Fig. 2, panels a & b). The low-frequency variability of the Gulf Stream path indicates a westward and southward shift of the destabilization point from 1995 to 2012 that inverses towards northward and eastward shift from that year until 2021. This pattern agrees with the temporal evolution of the standardized five-year running mean of the annually averaged wintertime (January–March) NAO index (Fig. 2, panel c), that shows a Pearson linear correlation with the time-varying longitude (latitude) of the destabilization point of 0.68 (0.72). This temporal variability also matches the aforementioned time-varying surface velocities and derived mesoscale EKE associated with the Gulf Stream path giving support to the assessment of the low-frequency variability of the Gulf Stream.

3.3 Temperature signature of Gulf Stream pathway

Figure 3 panel a shows the mean Gulf Stream pathways estimated using the iso12 at 450 m depth for two representative two-year periods before (2008-2010) and after (2014-2016) the change of destabilization point, together with Gulf Stream trajectories estimated with the method based on SSH data for the same periods. The iso12 estimate of the Gulf Stream pathway is located north of the sea level estimate because the iso12 is a signature of the GSNW rather than of the center of the pathway (Seidov et al., 2021). The good correspondence between mean pathways estimated with the altimeter data and with the temperature data, indicates that the signal detected at the surface is also present in the subsurface. On both diagnostics a separation of the average Gulf Stream pathway between the two periods occurs near 66°W, which corresponds to the detected destabilization point, then downstream of 63°W the mean pathways for the two periods converge. In the subsurface near 450 m, this convergence seems to occur earlier (near 63°W) on the Gulf Stream path than at the surface (east of 58°W).

The distribution of monthly mean pathways before and after the change of destabilization point also reflect the variation observed at the surface with the method based on sea level variations. The spatial extent of the standard deviation north and south of the average pathways decreases between 66.9°W and 65.9°W between the two periods (Fig. 3, panel b). This signature of a more stable pathway at this longitude thus confirms that the change in the destabilization point diagnosed from altimetry also has a signature in subsurface on the temperature field.

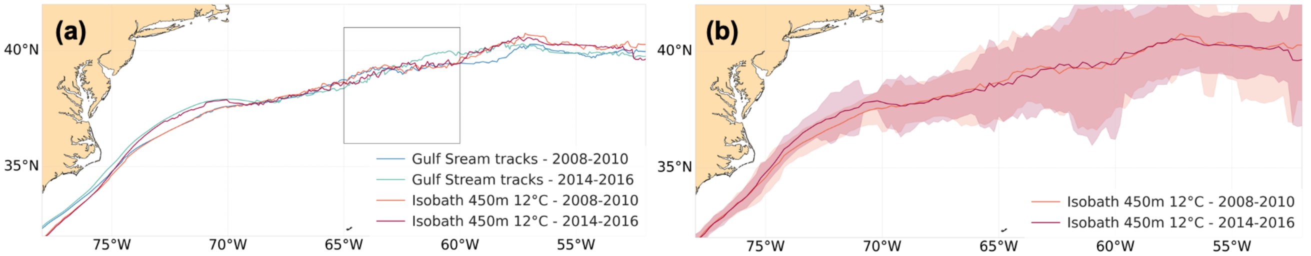

Figure 3: panel a, the mean 12°C isotherm (iso12) for 2008-2010 (orange) and 2014-2016 (red) computed from ocean reanalysis data (product ref. no. 2) superimposed to the SSH derived Gulf Stream pathway computed from altimetry data (product ref. no. 1) for the same periods, blue and green respectively. Panel b, the mean and standard deviation (2 sigma) of monthly pathways computed from ocean reanalysis data (product ref. no. 2) for the periods 2008-2010 and 2014-2016.

4 Discussion and conclusions

4.1 Seasonal and interannual variability of Gulf Stream paths

Consistent with previous studies (e.g., Andres, 2016), variance in Gulf Stream latitude increases abruptly around 65°W in the neighboring of the destabilization point and spreads around 1400 km out along the detached jet (e.g., downstream of the current's separation from the western boundary close to Cape Hatteras). In addition, a local minimum in variance is found to the west at around 70°W close to a node reported by e.g., Joyce et al. (2000). Fluctuations in GSNW position have important consequences for regional climate because the Gulf Stream transports considerable heat from the ocean at low latitudes to the atmosphere at high latitudes (Johns et al., 2011) and contributes to the distribution of energy and biogeochemical properties in the North Atlantic Ocean (von Schuckmann et al., 2016).

Tracey and Watts (1986) found that the Gulf Stream Extension displaces to the north in fall (exhibiting a relatively low baroclinic transport), and to the south in spring reaching its maximum baroclinic transport in early summer (Sato and Rossby, 1995). This seasonal pattern is observed here in Gulf Stream monthly-averaged paths and 1993–2021 overall mean from both mapped altimetric data (Fig. 4, panels b,d, e; product ref. no. 1 in Table 1) and model outputs (figure not shown; product ref. no. 2 in Table 1) corroborating previous results. These outcomes are extended here to summer (panels a & e) and wintertime (panels c & e), respectively. This is a novelty with respect to previous estimations having an impact on the location of the destabilization point (inset in panel e): it shifts eastwards until 65.05°W in winter and 65.35°W in spring, the unstable meandering detached jet being located more to the south whereas it remains close to 66°W in summer (66.21°W) and fall (66.09°W), the unstable Gulf Stream being located more to the north. On the contrary, this meridional displacement of the 1993–2021 mean path is not observed upstream of 70°W. This fact has an impact on the mesoscale EKE monitored in the Gulf Stream region that shows a clear seasonal variability, with maximum levels in the summer period (May to September) and minimum levels in winter (January), as reported by von Schuckmann et al. (2016).

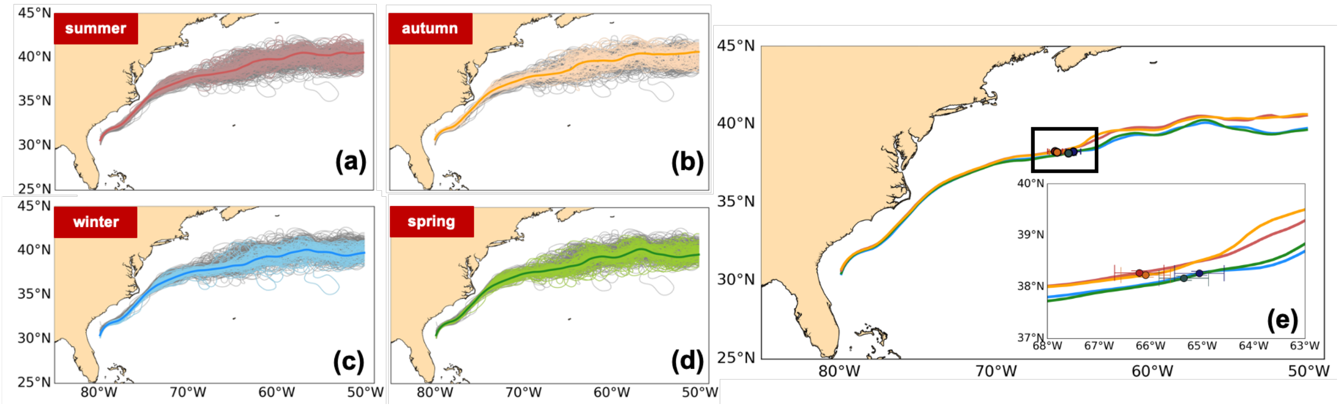

Figure 4: Gulf Stream paths based on the 25 cm SSH contour from altimetry (product ref. no. 1) showing monthly and a 1993–2021 overall seasonal mean for (a) summer (red, JAS), (b) autumn (orange, OND), (c) winter (pale-blue, JFM) and (d) spring (green, AMJ). Panel (e) displays the 1993–2021 overall seasonal means with the mean location of the seasonal destabilization point. The inset displays a zoom of the region inside the black box. The confidence interval (at 95% confidence level) of the destabilization point in both longitude and latitude is also displayed.

In addition to the seasonal variability of Gulf Stream paths, the destabilization point of the detached jet exhibits a low-frequency remarkable shift westward and southward between 1995 and 2012. This promotes both a shorter stable detached jet with time and eddying flows closer to the western boundary and the Middle Atlantic Bight (MAB) shelf that is widespread along a larger fraction of the North Atlantic. This proximity increases the probability of Gulf Stream-MAB interactions and may have important consequences beyond a local increase in the EKE associated with the Gulf Stream (Andres, 2016) such as the heat, energy and biogeochemical properties transported towards the subpolar North Atlantic. In 2012 the destabilization point displacement inverses exhibiting a previously unreported migration eastward and northward that translates into a larger fraction of the stable detached jet in detriment of the unstable meandering jet. The observed varying Gulf Stream stability may impact the upper ocean through changing events that drive heat exchange between the continental slope and outer shelf (Andres, 2016).

4.2 Impact of varying Gulf Stream stability on associated EKE and temperature at subsurface

Guo et al. (2023) found a dominant component in mesoscale EKE associated with the Gulf Stream that co-varies with the meridional shift of the jet. Thus, migration of the destabilization point may have an impact on both the Gulf Stream's surface velocity and associated EKE. The west-southward shift of the destabilization point observed between 1993 and 2012 is accompanied by a weakening of the jet (and mesoscale surface EKE), corroborating previous results reported by Dong et al. (2019). These authors attributed this velocity decrease to an increase in SSH to the north of the Gulf Stream mainly due to ocean warming. On the other hand, the previously unreported north-eastward shift observed from 2013 until 2021 promotes an increasing velocity with larger associated EKE. These outcomes agree with results reported by Guo et al. (2023) based on Empirical Orthogonal Function (EOF) analysis. These authors found a mode that suggests an enhancement in EKE when the Gulf Stream shifts to the North. Furthermore, the global long-term change in surface mesoscale EKE shows that the Ocean EKE has experienced a statistically significant increase (Martínez-Moreno et al., 2021). These changes in EKE also show that surface mesoscale diffusivities vary on climate time scales and are largely influenced by climate variability (Guo et al 2022). However, the underlying dynamics for the changes in the North Atlantic are not well understood and the mechanism behind correlations between EKE variability and Gulf Stream shifts are still unclear and further investigations are needed (Guo et al., 2022; 2023).

On the other hand, the time evolution of the temperature in the upper part of the water column in the surroundings of the Gulf Stream's destabilization point exhibits homogeneous variations over the first 1000 m and down to 2000 m (figure not shown). In addition, a strong negative hiatus was found in 2010, followed by a significant increase in temperature to become a positive anomaly in 2014. This increase may be due to both a long-term climate change and a change in the characteristics of the water masses. To analyze the possible variations induced by this change in the Gulf Stream path characteristics, a decomposition of temperature variations into EOF was applied at different depths. The explained variance of mode 1, that essentially characterizes the trajectory of the jet, and mode 2 rather representing the temperature variations to the east of the studied domain, computed at 450 m depth (figure not shown) is 30% and 10%, respectively. The principal component of the first EOF shows positive values (warm temperature) essentially at the beginning of the period (before 1996) and after 2014. This corresponds to the heat anomaly variations observed. The main component of the second EOF does not show a clear signal at the beginning of the period but from 2009-2010 there is a very strong decrease until 2014 followed by a strong increase.

https://doi.org/10.5194/sp-2023-17
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Thus, the analysis of the destabilization point of the Gulf Stream from SSH data could be a good indicator of the subsurface conditions (in the upper 1000 m of the water column) in the northeastern part south of the Grand Banks. In addition, the agreement with the EOF analysis would seem to indicate a link between the length of the Gulf Stream's detached stable jet and the temperature conditions over the first 1000 m of the water column further east, downstream of the stable jet. The eastern the destabilization point, the larger the heat transport towards the subpolar eastern North Atlantic.

4.3 External forcing of the Gulf Stream path destabilization

The observed shifts of the path destabilization point might either be due to an external forcing or reflect internal variability (Andres, 2016). The regimes of the Gulf Stream paths described above seem to be linked to NAO variability during winter (external forcing) that may play an important role: it presents a negative trend from positive to negative phase between 1993 and 2011; and an opposite behavior from negative to positive phase from 2011 until 2021 in agreement with the respectively south-westward and north-eastward observed migration of the destabilization point (panel c in Fig. 2). Andres (2016) found that the NAO index was uncorrelated at zero lag with the destabilization point of the detached Gulf Stream stating that the large- and regional-scale winds may not be directly responsible for the stability of the Gulf Stream jet. However, they found a positive linear correlation of 0.64 (significant at 90% level) when considering a time lag of five years supporting the approach followed here of assessing low-frequency variability of Gulf Stream path based on a five-year running mean filter. In addition, a maximum linear correlation of 0.78 (0.76) was found between the NAO during winter and the time-varying longitude (latitude) of the destabilization point lagging by 1 yr (figure not shown). Thus, the Gulf Stream path seems to respond passively to the variability of the NAO during winter with a delay of a year at low frequencies. This is consistent with results reported by Joyce et al. (2000) based on temperature data at 200 m depth to define the yearly position of the Gulf Stream between 1954 and 1990. Frankignoul et al. (2001) stated that this delay is much shorter than expected from linear adjustment to wind stress changes and baroclinic Rossby wave propagation whereas it seems consistent with the assumption that the latitude of separation of the stable Gulf Stream is controlled by the potential vorticity of the recirculation gyres in the region.

The Gulf Stream is expected to slow (Chen et al., 2019) and shift poleward (Caesar et al., 2019) over the next century as a consequence of the weakening of the AMOC (Cheng et al., 2013) due to climate change (Chi et al., 2021). This northward shift will probably impact on the zonal displacements of the destabilization point and may promote its migration to the east, according to results reported here, and thus a larger fraction of the stable detached jet in detriment of the unstable meandering jet. Such changes in the position of the destabilization point seem to be observed in the latest years of the altimetry era being accompanied by a shift in the NAO index for winter. However, the consequences of the observed time-varying Gulf Stream stability are far to be understood, being the altimetric record at present (1993–2021) insufficient to detect significant trends (Chi et al., 2021). According to these authors, an additional 20 years of observations are required to detect statistically significant trends in latitude assuming that the future variability in Gulf Stream paths will be consistent with the actual one.

Competing interests

The contact author has declared that none of the authors has any competing interests

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