Reply to comments from the anonymous referee #2

This manuscript presents an analysis of Gulf Stream variability using gridded altimetry and an ocean reanalysis product. The primary focus is the location of the destabilization point first discussed by Andres (2016), and this manuscripts main result is an extension of Andres's calculation to later years. Andres (2016) had shown that the destabilization point was moving upstream, but Sánchez-Román et al. find that the destabilization point started moving back downstream around 2015. Further, the motion of the destabilization point is highly correlated with the NAO with a lag of 1-year. These are both fairly remarkable results, even if the manuscript's methodology is not particularly novel. A paper focused on investigating and explaining these results in greater detail would have been very interesting. Unfortunately, the present manuscript lacks focus and is not clearly written or organized. It also includes a great deal of extraneous and often unsupported material that makes it unsuitable for publication in its current form.

Dear Madam/Sir,

we appreciate your comments which have been useful in improving the manuscript. Below we have responded to each of the specific comments and trust that these clarifications and amendments meet your approval. The manuscript has been rewritten and reorganized for clarity, and now it has a more in depth discussion. In the new version, we highlighted the results representing novel knowledge related to the migration of the destabilization point at both seasonal and interannual frequencies, together with its implications in the transport of energy and nutrients in the North Atlantic Ocean. We also discussed them according to the actual knowledge of the Gulf Stream system. OSR papers are constrained to include a maximum of four figures so we added extra panels to the figures to further support the results. Please, notice that in the new version the time series have been extended to year 2022 because it is mandatory for OSR#8 publication so in this new version a time period of 30 years has been analysed. Data for year 2022 was not included in the original version due to its unavailability in the Copernicus Catalogue when submitted.

1. **Major Comments**

   There are long passages where results are quoted, but there are no figures or anything else to back them up. These results are practically meaningless without evidence. If the results are worth discussing, show a figure. If not, do not discuss them. The following passages should either be removed or be revised to include evidence:

   Lines 111–131

   Lines 235–251

Please notice that papers to be published in the OSR#8 are constrained to include a maximum of four figures. Thus, we cannot add new ones to the manuscript. We consider that the figures included in the original version are representative of the main results addressed in the text. However, we agree with the reviewer that results must be accompanied by evidence so to solve this, we added a new panel to Figure 1 to include both the 1993-2022 overall mean eddy kinetic energy in the Gulf Stream region and its temporal evolution (aggregated values) to support the results discussed in lines 111-131. The same applies to Figure 3: we added a new panel with the temporal evolution of the temperature in the water column for the Gulf Stream region to support the results discussed in lines 235-251. We decided to remove the sentences related to the EOF analysis since we cannot add more figures to the manuscript to support the results.

2. The usage of the term "Gulf Stream" is inconsistent, both internally and with oceanographic nomenclature. The current following the path shown in figure 1 is properly considered the Gulf Stream, but many things are called the "Gulf Stream" in the text that are not the Gulf Stream.

   The reviewer is right. We made a mistake in the previous version and wrongly identified the Gulf Stream path with the Gulf Stream North Wall, and also with the North Atlantic Current. This has been solved in the new version for clarity. In the following, we response to each individual comment related to this.

   1. Lines 33–34: It is stated that the Gulf Stream "becomes the North Atlantic Current". The North Atlantic Current and the Gulf Stream are geographically distinct. A fraction of the water that flows through the Gulf Stream eventually flows into the North Atlantic Current, but a large amount flows elsewhere as the North Atlantic Drift or as part of the Gulf Stream's recirculation gyres. Importantly, most of the water from the Gulf Stream ends up recirculating in the North Atlantic Subtropical Gyre and does not flow into the North Atlantic Current.

      This has been a misunderstanding. According to Stendardo et al. (2020): "The salinity import/freshwater export from/toward the subtropics is ensured by the North Atlantic Current (NAC) as a continuation of the Gulf Stream (e.g., Rossby, 1996) which supplies the subpolar gyre with warm and saline water from the subtropics as part of the upper branch of the AMOC." We understood that the Gulf Stream becomes the NAC but It is wrong. Thanks for the clarification. As the reviewer mentions, most of the water from the Gulf Stream recirculates in the North Atlantic Subtropical Gyre and not in the NAC so we removed the sentence in the new version to avoid confusion.

      Stendardo, I., Rhein, M., & Steinfeldt, R.: The North Atlantic Current and its volume and freshwater transports in the subpolar North Atlantic, time period 1993–2016. Journal of Geophysical Research: Oceans, 125, e2020JC016065. https:// 385 doi.org/10.1029/2020JC016065, 2020.

2. Line 10: “The Gulf Stream transports warm waters into the subpolar eastern North Atlantic … ” The current that transports warm water into the subpolar North Atlantic is the aforementioned North Atlantic Current. The Gulf Stream does not have a direct subpolar connection.

   Thanks for the clarification. The sentence in the abstract has been modified in the new version as follows to mention that the Gulf Stream carries warm waters from low to high latitudes in the North Atlantic:

   “The Gulf Stream transports warm waters from low to high latitudes in the North Atlantic Ocean, impacting Europe's climate”

3. Lines 112–113: The Gulf Stream does not become the Gulf Stream North Wall (GSNW). The GSNW is part of the Gulf Stream, so the Gulf Stream cannot become the GSNW.

   The reviewer is right. We mixed up the terms “Gulf Stream Extension” and “Gulf Stream North Wall”. We have solved this misunderstanding in the new version and accordingly modify the sentence as follows:

   “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°W where the Gulf Stream separates from the continental margin and becomes the Gulf Stream Extension (Fig. 1, panel b).”

3. The usage of Gulf Stream North Wall (GSNW) also inconsistent and occasionally incorrect. The GSNW is the strong temperature front on the northern flank of the Gulf Stream. It is not “the path described by the Gulf Stream Extension” (lines 34–35) as it is north of the main core of the Gulf Stream. As noted in Chi et al. (2019), the GSNW and the main core of the Gulf Stream do not necessarily even follow the same path.

   The reviewer is right. As we stated above, we made a mistake in the previous version and wrongly identified the Gulf Stream path with the Gulf Stream North Wall. This has been solved in the new version to avoid errors. The first paragraph of the introduction describing the Gulf Stream system has been reworded as follows:

   “The Gulf Stream is part of the western boundary current system. It 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). The Gulf Stream Extension carries near-surface warm waters from the subtropical to the subpolar North Atlantic (Guo et al., 2023) marking a transition from warm subtropical to cold subpolar waters (Joyce and Zhang, 2010; McCarthy et al., 2018) known as the Gulf Stream North Wall (GSNW). The GSNW is a sharp temperature front located to the north of the Gulf Stream that does not necessarily follows its path (Chi et al., 2019)."

Lines 70–71: The Gulf Stream, not GSNW, converts from a stable to an unstable jet. The GSNW is a front, not a jet. Fronts are often associated with jets through thermal wind, but they are not the same thing.

See response to the previous comment. We have modified the sentence as follows to indicate that the Gulf Stream Extension converts from a stable to an unstable jet:

"To do that, the time-varying position of the path destabilization point where the Gulf Stream Extension converts from a stable, detached jet to an unstable, meandering detached jet is investigated following the methodology described in Andres (2016)."

4. While gridded altimetry comes on a daily 1/4º grid, it does not have a temporal resolution of one day or a horizontal resolution of 1/4º. At the latitude of the Gulf Stream, the ground tracks used to construct the gridded produce are located approximately 2º apart and sampled roughly every 10 days. The values between the tracks and sample times are "filled in" using optimal interpolation. This produces smooth-looking fields, but can also invent spurious features and give the false impression of high precision. Ballarotta et al. (2019) estimates that gridded altimetry has an effective resolution of 150–200 km (e.g., 1.5º–2º) in the Gulf Stream region. As such, reporting locations obtained from gridded altimetry with sub-degree precision (as on line 107) is not meaningful. The authors reference Ballarotta et al. (2019) in noting that gridded altimetry misses some mesoscale features, but don't appear to acknowledge that the coarse resolution of altimetry may affect their estimates of the location of, for example, the destabilization point.

   The effective spatial resolution showed by Ballarotta et al . (2019) refers to the DT-2018 version of the altimeter gridded products. Our study uses the up-to-date DT-2021 version which improves the previous one, including the effective spatial resolution, which is reduced to 100-150 km in the Gulf Stream region (Pujol et al., 2023). As discussed in Ballarotta et al . (2019) the effective spatial resolution is computed for maps constructed with three altimeters (CryoSat-2, HY-2, Jason-2) over the period 12 April 2014–31 December 2015 being Saral/AltiKa data used as an independent dataset. These authors state that "we believe that this assessment of the spatial resolution based on maps constructed with three altimeter missions may be considered a reasonable averaged estimate since about three altimeter missions are used in the merging for the CMEMS products 70 % of the time over the period 1 January 1993–15 May 2017." Nevertheless, the multi-mission gridded product is computed with a satellite constellation including all the available altimeters at a given time (ranging from two to seven over the period considered in this study; see, e.g., Fig. 1 in International Altimetry Team, 2021; Morrow et al., 2023). As a consequence, the errors are not constant in time since they depend on the number of satellites used and we can reasonably consider that this error is reduced when more than 3 altimeters are used (i.e. over the last decade).

We also want to highlight that the manuscript mainly focuses on the seasonal/interannual variability and long-term longitudinal/latitudinal migration of the destabilization point rather than on its location at a given time. The text also include different elements to aware the users of the limitation of the methodology and quantify the errors of estimation of the location of the destabilization point : together with the location for the 1993-2022 mean and also for the yearly assessment, we provide its confidence interval at 95% confidence level computed from monthly-averaged and daily data, respectively (see text in the new version for details and response to the next comment). This confidence interval has a value of 1 degree in longitude and 0.24 degrees in latitude for the 1993-2022 mean path destabilization point; and ranges respectively between 0.6-2.16 degrees and between 0.17-0.47 degrees for the yearly location of the destabilization point. As we mention in lines 83-85 in the original version, “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).”

We are aware that we cannot provide such a precise location of the mean destabilization point so we modified the sentence of former line 107 as follows:

“The mean destabilization point of the monthly mean Gulf Stream paths (1993–2022) is located at coordinates close to 38°N and 66°W (Fig. 1, panel a).”

International Altimetry Team: Altimetry for the future: Build- ing on 25 years of progress, Adv. Space Res., 68, 319–363, https://doi.org/10.1016/j.asr.2021.01.022, 2021.

Morrow, R., Fu, L. L., Rio, M. H., Ray, R., Prandi, P., Le Traon, P.-Y., Benveniste, J.: Ocean Circulation from Space, Surv, Geo- phys., https://doi.org/10.1007/s10712-023-09778-9, 2023.

Pujol, M-I, Taburet G., and SL-TAC team: EU Copernicus Marine Service Product Quality Information Document for the 370 Global Ocean Gridded L4 Sea Surface Heights And Derived Variables Reprocessed 1993 Ongoing, SEALEVEL_GLO_PHY_L4_MY_008_047, Issue 8.2, Mercator Ocean International, https://catalogue.marine.copernicus.eu/documents/QUID/CMEMS-SL-QUID-008-032-068.pdf. Last access: 4 April 2023, 2023.

Sánchez-Román, A., Pujol, M. I., Faugère, Y., and Pascual, A.: DUACS DT2021 reprocessed altimetry improves sea level retrieval in the coastal band of the European seas, Ocean Sci., 19, 793–809, https://doi.org/10.5194/os-19-793-2023, 2023.

5. Lines 94–95: Without information about how the confidence interval computed there’s no way for the reader to determine if they trust it.

   The confidence interval of the yearly location of the destabilization point was computed from daily data as follows: we identified the daily path of the Gulf Stream from the 25 cm SSH contour from daily altimetry maps for the whole time period considered (30 years). Then, the 30 daily paths for a given month were separated into 0.5° longitude bins and the variance of Gulf Stream position (latitude) in each bin was calculated. The downstream distance (longitude) where the latitude’s variance first reaches $0.42(°)^2$ was defined as that month’s path destabilization point. The location (longitude and latitude) of the 12 monthly destabilization points of a given year were used to provide an estimation of the confidence interval (at 95% confidence level) of the destabilization point for that year. The same was applied to compute the confidence interval of the 1993-2022 mean destabilization point. This has been summarized in the new version as follows:

   “The confidence interval (at 95% confidence level) of the mean destabilization point was computed from the yearly destabilization point locations. A similar analysis was conducted for the seasonal assessment. Furthermore, the aforementioned computation was repeated from daily altimetry maps to compute the confidence interval (at 95% confidence level) of the yearly destabilization point location. To do that, the 30 daily paths for a given month were used to identify the month’s path destabilization point. The 12 monthly destabilization points of a given year were then used to provide an estimation of the confidence interval for that year.”

6. Figure 2b: The value given for 1994 in figure 2b is approximately 5º to the west of that in Andres (2016) figure 3. What is the source of this disagreement?

   Andres (2016) identifies the downstream distance (longitude) where the latitude’s variance first reaches $0.5(°)^2$ as the path destabilization point for a given year. Here, we use indeed the half of the maximum variance obtained for the aggregate (1993-2022), that is $0.42(°)^2$. As a consequence, we obtain a different yearly location of the destabilization point than that reported by Andres (2016). However, to check our method, we repeated the analysis using the value of $0.5(°)^2$ and we obtained quite similar locations to those reported by Andres (2016). In the following there is the paragraph explaining the method. We removed the reference of Andres (2016) to avoid confusion:

   “Following 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 1993–2022 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. This is where the Gulf Stream converts from a stable, detached jet to an unstable, meandering detached jet (Fig. 1, panel a)."

7. Section 4: This section is labeled "Discussion and conclusions", but it is almost entirely more results rather than a discussion or a conclusion.

   This point has been also raised by the reviewer #1. The section has been accordingly updated to highlight the implications of the recent eastward migration of the destabilization point following the westward migration described by Andres (2016), as well as the meridional shifts in the destabilization point together with their seasonality. In the following there are some examples of paragraphs added to this section including discussion, following also reviewer#1 comments:

   Section 4.1: Seasonal and interannual variability of Gulf Stream paths

   "the destabilization point of the detached jet exhibits a remarkable low-frequency shift westward between 1995 and 2012 accompanied by a southward shift of the jet. This promotes a shorter stable detached jet with time and thus eddying flows closer to the western boundary and the Middle Atlantic Bight (MAB) shelf that are widespread along a larger region of the North Atlantic. This proximity increases the probability of Gulf Stream-MAB interactions and have important consequences beyond a local increase in the EKE associated with the Gulf Stream (Andres, 2016). Warm core rings can spun off from the jet and bring salty and nutrient-reach deep waters to the euphotic zone at the shelfbreak front in the MAB leading to enhanced primary productivity (Zhang et al., 2013; Hoarfrost et al., 2019) and ecosystem changes (Gawarkiewicz et al., 2018). Monim (2017) reported an increase of 50% in the frequency of warm core rings formed annually in years 2000-2016 (overall, in agreement with the observed westward shift of the destabilization point) compared to 1977-1999 in the slope region south of New England having important effects on biogeochemical cycling (Hoarfrost et al., 2019).
   In 2012 the destabilization point displacement reversal exhibits a previously unreported low-frequency migration eastward accompanied by a northward shift of the jet until 2020. This translates into a larger fraction of the stable detached jet in detriment of the unstable meandering jet that is likely to promote the depletion of the frequency of warm core ring intrusions onto the continental shelf and the probability of Gulf Stream-BAM interactions, in contrast with the increased interactions from the westward displacement observed in the recent past."

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

   "The low-frequency west-southward shift of the destabilization point observed between 1995 and 2012 is accompanied by a weakening of the jet (figure not

shown) and associated mesoscale surface EKE (Fig. 1, panel b). Dong et al. (2019) attributed this velocity decrease to an increase in SSH to the north of the Gulf Stream mainly due to ocean warming.
The observed weakening of the jet over this period was explained by Renault et al. (2016) in terms of energy transfers from the ocean to the atmosphere over the Gulf Stream induced by the current feedback. It attenuates the wind surface stress inducing a positive surface stress curl opposite to the current vorticity that deflects energy from the Gulf Stream into the atmosphere and dampens eddies. It causes a mean pathway of energy from the ocean to the atmosphere (Renault et al., 2016a). Consequently, the current feedback promotes a slowdown of the jet and a drastic weakening of the EKE limiting the propagation of eddies. This mechanism could be fostered by the observed west-southward shift of the destabilization point."

"On the other hand, the previously unreported low-frequency north-eastward shift observed from 2013 until 2020 promotes an increasing velocity with larger associated EKE (see Fig.1). Guo et al. (2023), based on Empirical Orthogonal Function (EOF) analysis, found a mode that suggests an enhancement in EKE when the Gulf Stream shifts to the North. Thus, the current feedback is likely to weaken in this period allowing energy transfers from the atmosphere to the ocean and the propagation of eddies. This would suggest a connection of the current feedback and net energy transfers between the atmosphere and the ocean with the observed meridional shifts of the jet and associated velocity rather than the variations in SSH linked to the ocean warming pointed out by Dong et al. (2019). However, the aforementioned increasing frequency of warm core ring intrusions onto the continental shelf observed during the low-frequency south-westward shift of the destabilization point can contribute to sea level rise through steric effect (Gawarkiewicz et al., 2018) reflecting a decreased sea level difference across the Gulf Stream (Sallenger et al., 2012) and a slowdown jet. The opposite is likely to account during the north-eastward displacement of the destabilization point when a larger fraction of the stable detached jet is observed in detriment of the unstable meandering jet. Thus, the Gulf Stream related processes could have an impact on sea level variability in the coastal region. Furthermore, the global long-term change in surface mesoscale EKE found by Martinez-Moreno et al. (2021) might show that the Ocean EKE has experienced an increase. These changes in EKE also show that surface mesoscale diffusivities vary on climate time scales due to a coupling between large-scale climate variability and eddy mixing rates as a result of small amplitude changes in the large-scale flow (Busecke and Abernathey, 2019). These authors suggested that temporal variability in mesoscale mixing could be an important climate feedback mechanism due to the relevance of lateral mesoscale mixing for the ocean uptake of heat and carbon, and the distribution of oxygen and nutrients in the ocean, among others."

8. Section 4.1: Figure 2b shows that the destabilization points migrates by more than 10º on interannual timescales. Against this background, the ~1º seasonal shifts are not meaningful. Indeed, the confidence intervals in figure 4e are barely non-overlapping.

   The main idea of this section is to highlight the meridional seasonal fluctuations of the Gulf Stream Extension to the north in summer/fall, and to the south in winter/spring rather than the location of the seasonal destabilization point. The fact that this seasonality is only observed in the Gulf Stream extension (detached jet east of 70°W) makes a reduced longitudinal migration of the destabilization point at seasonal scales when compared with the long-term one. However, it is not negligible so we strongly think that it should be kept in the text. On the contrary, the meridional displacements of the seasonal destabilization point are negligible with respect to the longitudinal variability so we added the following sentence to the new version:

   "The seasonal meridional shifts of the destabilization point are negligible with values ranging from 38.2°N in spring to 38.3°N in summer. On the contrary, this meridional displacement of the 1993–2022 mean path is not observed upstream of 70°W. This makes the observed seasonal shifts of the jet to promote longitudinal seasonal variability of the destabilization point."

9. Lines 259–263: The fact that Andres (2016) found a 5 year lag between the destabilization point does not justify a 5-year running mean filter. A centered running mean has no effect on the phase of a time series, so a 5-year lag in the original time series would remain a 5-year lag in the smoothed time series.

   The reviewer is right. The sentence in its present form leads to confusion. We tried to explain that the uncorrelation at zero lag between NAO and the destabilization point found by Andres (2016) supports the approach followed here of assessing low-frequency variability of Gulf Stream path, which is based on a five-year running mean filter. Actually, this five-year running mean filter comes from the filter applied to the NAO by the NOAA /National Weather Service, available at:

   https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/JFM_season_nao_index.shtml

   The sentence has been removed in the new version to avoid confusion about the filter applied.

Minor Comments

1. Lines 26–27: The authors should clarify that the AMOC accounts for 90% of the heat transport at 26.5ºN (the latitude of the RAPID array). There is no reason to expect that this holds true at other latitudes.

   Thanks for the clarification. It has been included in the new version as follows:

   "The AMOC accounts for nearly 90% of the total heat transport at 26.5ºN in the North Atlantic (Johns et al., 2011)."

2. Lines 27–28: It is not clear what "subpolar planetary heat exchange" means. Is it heat exchange on a planetary scale?

   We tried to emphasize in this sentence that the AMOC is a major driver of subpolar heat changes on a planetary scale. We have reworded the sentence in the new version for clarity as follows:

   "The AMOC accounts for nearly 90% of the total heat transport at 26.5ºN in the North Atlantic (Johns et al., 2011). Thus, it is a major driver of subpolar heat content changes (McCarthy et al., 2018)."

3. Line 49: Not clear what "instability" means in this context. Why are lateral shifts more associated with instability than meandering?

   There is a misprint in the sentence. We wanted to indicate that the variations in the Gulf Stream path are due to wavelike fluctuations linked to the Gulf Stream meandering and instability; and also to large-scale lateral shifts of the path. We have modified the sentence for clarity:

   "The variations in the Gulf Stream path exhibit two main modes: (i) wavelike fluctuations linked to the Gulf Stream meandering and instability, and (ii) large-scale lateral shifts exhibiting seasonal and interannual changes."

4. Line 62–63: Joyce used the 15ºC isotherm at 200 m depth. As written, the text suggests that the 15ºC isotherm is equivalent to the 200-m temperature.

   The sentence has been reworded and added to a new paragraph describing the different methodologies to identify the location of the Gulf Stream path:

   "The time-varying location of the Gulf Stream can be identified by using a constant sea surface height (SSH) contour from mapped absolute dynamic topography (ADT) from satellite altimetry to find snapshots of the current's path (Andres, 2016). The 25 cm SSH contour is commonly used (e.g. Lillibridge and Mariano, 2013; Rossby et al., 2014; Andres, 2016; Chi et al., 2021 and Guo et al., 2023). Other methods to identify the path of the Gulf Stream are based on the location of an isotherm at a given depth. Joyce et al. (2000; 2009) used the 15ºC isotherm at 200 m depth to define the region just to the north of strong flow of the Gulf Stream that corresponds to the GSNW. This approach was followed by Frankignoul et al. (2001) and Seidov et al. (2019; 2021) to identify the latitude of Gulf Stream paths."

5. Line 63: Joyce's index locates the GSNW which, as noted previously, is not necessarily colocated with the region of strong flow.

   The reviewer is right (see response to the previous comment). We updated the sentence as follows for clarity:

   "Joyce et al. (2000; 2009) used the 15ºC isotherm at 200 m depth to define the region just to the north of strong flow of the Gulf Stream that corresponds to the GSNW."

6. Figure 3: It would help to indicate the regions discussed in the text on the figure.

   The Figure 3 has been updated and now includes the location of the regions discussed in the text.

7. Line 173: The range over which the standard deviation decreases between the two periods is tiny—only 1º, which is below the effective resolution of gridded altimetry. What is the reader supposed to take away from this result?

   The analysis of the temperature signature of the Gulf Stream path is conducted through the assessment of the reanalysis product, which has a spatial resolution of 1/12 degrees, that is enough to investigate differences in a spatial range of 1 degree.

8. Lines 210–211: Should "low-frequency remarkable shift" be "remarkable low-frequency shift"?

   Yes. It has been reworded in the new version as follows:

   "In addition to the seasonal variability of Gulf Stream paths, the destabilization point of the detached jet exhibits a remarkable low-frequency shift westward between 1995 and 2012 accompanied by a southward shift of the jet."

9. Lines 211–203: This is a very confusing sentence. What is widespread along a larger fraction of the North Atlantic? Larger fraction than what?

   We are sorry for the confusing wording of the sentence. We tried to highlight that a westward shift of the destabilization point promotes a shorter stable jet and, therefore, eddying flows closer to the western boundary that are widespread along a larger region of the North Atlantic. We reworded the sentence as follows:

“This promotes a shorter stable detached jet with time and thus eddying flows closer to the western boundary and the Middle Atlantic Bight (MAB) shelf that are widespread along a larger region of the North Atlantic.”

10. Lines 224–225: How do we see from the results presented here that the shift of the destabilization point was accompanied by a weakening of the jet?

    As it was aforementioned, we are constrained to include a maximum of four figures in the manuscript. Thus, we decided to not include the aggregated velocity associated to the jet. However, the figure 1 in the new version displays the time series of the aggregated EKE associated with the jet which is indicative of its velocity. The sentence has been reworded as follows:

    “The low-frequency west-southward shift of the destabilization point observed between 1995 and 2012 is accompanied by a weakening of the jet (figure not shown) and associated mesoscale surface EKE (Fig. 1, panel b).”

11. Lines 230–231: How do changes in EKE show that surface mesoscale diffusivities are largely influenced by climate variability?

    Busecke and Abernathey (2019) found strong evidence that mixing rates in the ocean vary on interannual and longer time scales in many regions of the global ocean. They stated that the observed mixing rates suggest a coupling between large-scale climate variability and eddy mixing rates due to small amplitude changes in the large-scale flow. They suggested that temporal variability in mesoscale mixing could be an important climate feedback mechanism due to the importance of lateral mesoscale mixing for the ocean uptake of heat and carbon, the distribution of oxygen and nutrients in the ocean, ENSO dynamics, and water mass formation.

    We have updated the sentence to clarify this issue as follows:

    “These changes in EKE also show that surface mesoscale diffusivities vary on climate time scales due to a coupling between large-scale climate variability and eddy mixing rates as a result of small amplitude changes in the large-scale flow (Busecke and Abernathey, 2019). These authors suggested that temporal variability in mesoscale mixing could be an important climate feedback mechanism due to the relevance of lateral mesoscale mixing for the ocean uptake of heat and carbon, and the distribution of oxygen and nutrients in the ocean, among others.”

    Busecke, J. J., & Abernathey, R. P.: Ocean mesoscale mixing linked to climate variability. Science Advances, 5(1), eaav5014. https://doi. org/10.1126/sciadv.aav5014, 2019.

12. The final paragraph of the manuscript (Lines 270–279) does not seem to follow from the results presented in the paper. Indeed, it mostly summarizes background material and would fit better in the introduction. It would be worth, however, ending the paper with a proper conclusion.

We have updated the sentence as follows:

"The northward shift of the Gulf Stream path observed in the latest decade is likely to continue in the near future. It will probably impact on the zonal displacements of the destabilization point and may promote its migration to the east, 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 being accompanied by a shift in the NAO index for winter. The observed time-varying Gulf Stream stability and associated ring dynamics may impact the frequency of warm core rings in the slope region south of New England and thus the upper ocean through changing events that drive the exchange of heat, nutrients and biogeochemical properties between the continental slope and outer shelf in the coming years. "

Technical Corrections

1. The word "isobath" is used to mean depth, but it does not. An isobath is a contour of constant distance between the surface and the bottom. It is equivalent to a topographic contour. Replace with "depth" on lines 62 and 100.

   done

2. Replace "inverses" with "reverses" on line 153.

   done

3. Replace "inverses" with "reversal" on line 216.

   done

References

Ballarotta, M., and Coauthors, 2019: On the resolutions of ocean altimetry maps. *Ocean Sci.*, **15** **(4)**, 1091–1109.

Chi, L., C. L. P. Wolfe, and S. Hameed, 2019: The distinction between the Gulf Stream and its North Wall. *Geophys. Res. Lett.*, **46 (15)**, 8943–8951.