Web links to the author's journal account have been redacted from the decision letters as indicated to maintain confidentiality.

27th Nov 20

Dear Mr Gonçalves Neto,

Please allow me to apologise for the delay in sending a decision on your manuscript titled "Changes in the Gulf Stream precede rapid warming of the Northwest Atlantic Shelf". It has now been seen by 2 reviewers, and I include their comments at the end of this message. They find your work of interest, but some important points are raised. We are interested in the possibility of publishing your study in Communications Earth & Environment, but would like to consider your responses to these concerns and assess a revised manuscript before we make a final decision on publication.

We therefore invite you to revise and resubmit your manuscript, along with a point-by-point response that takes into account the points raised. Please highlight all changes in the manuscript text file.

In addition, please ensure that the revised manuscript addresses the following editorial concerns:

Fully take into account the influence of other mechanisms for NW Atlantic warming over the study period and soften or caveat your interpretations regarding the importance of shifting currents within this context

Ensure that your findings are placed firmly in the context of relevant literature, in particular on NW Atlantic temperature anomalies

We are committed to providing a fair and constructive peer-review process. Please don't hesitate to contact us if you wish to discuss the revision in more detail.

Please use the following link to submit your revised manuscript, point-by-point response to the referees' comments (which should be in a separate document to any cover letter) and the completed checklist:
[link redacted]
** This url links to your confidential home page and associated information about manuscripts you may have submitted or be reviewing for us. If you wish to forward this email to co-authors, please delete the link to your homepage first **

We hope to receive your revised paper within six weeks; please let us know if you aren't able to submit it within this time so that we can discuss how best to proceed. If we don't hear from you, and the revision process takes significantly longer, we may close your file. In this event, we will still be happy to reconsider your paper at a later date, as long as nothing similar has been accepted for publication at Communications Earth & Environment or published elsewhere in the meantime.

We understand that due to the current global situation, the time required for revision may be longer than usual. We would appreciate it if you could keep us informed about an estimated timescale for

resubmission, to facilitate our planning. Of course, if you are unable to estimate, we are happy to accommodate necessary extensions nevertheless.

Please do not hesitate to contact me if you have any questions or would like to discuss these revisions further. We look forward to seeing the revised manuscript and thank you for the opportunity to review your work.

Best regards,

Joe Aslin

Associate Editor,
Communications Earth & Environment
https://www.nature.com/commsenv/
Twitter: @CommsEarth

EDITORIAL POLICIES AND FORMATTING

We ask that you ensure your manuscript complies with our editorial policies. Please ensure that the following formatting requirements are met, and any checklist relevant to your research is completed and uploaded as a Related Manuscript file type with the revised article.

Editorial Policy: Policy requirements

Furthermore, please align your manuscript with our format requirements, which are summarized on the following checklist:
Communications Earth & Environment formatting checklist

and also in our style and formatting guide Communications Earth & Environment formatting guide .

*** DATA: Communications Earth & Environment endorses the principles of the Enabling FAIR data project (http://www.copdess.org/enabling-fair-data-project/). We ask authors to make the data that support their conclusions available in permanent, publically accessible data repositories. (Please contact the editor if you are unable to make your data available).

All Communications Earth & Environment manuscripts must include a section titled "Data Availability" at the end of the Methods section or main text (if no Methods). More information on this policy, is available at http://www.nature.com/authors/policies/data/data-availability-statements-data-citations.pdf.

In particular, the Data availability statement should include:
- Unique identifiers (such as DOIs and hyperlinks for datasets in public repositories)

- Accession codes where appropriate
- If applicable, a statement regarding data available with restrictions
- If a dataset has a Digital Object Identifier (DOI) as its unique identifier, we strongly encourage including this in the Reference list and citing the dataset in the Data Availability Statement.

DATA SOURCES: All new data associated with the paper should be placed in a persistent repository where they can be freely and enduringly accessed. We recommend submitting the data to discipline-specific, community-recognized repositories, where possible and a list of recommended repositories is provided at http://www.nature.com/sdata/policies/repositories.

If a community resource is unavailable, data can be submitted to generalist repositories such as figshare or Dryad Digital Repository. Please provide a unique identifier for the data (for example a DOI or a permanent URL) in the data availability statement, if possible. If the repository does not provide identifiers, we encourage authors to supply the search terms that will return the data. For data that have been obtained from publically available sources, please provide a URL and the specific data product name in the data availability statement. Data with a DOI should be further cited in the methods reference section.

Please refer to our data policies at http://www.nature.com/authors/policies/availability.html.

REVIEWER COMMENTS:

Reviewer #1 (Remarks to the Author):

This is a very interesting paper about a topic that is of great interest and relevance with Marine Heatwaves very much in the news at the moment. The figure are very well done and the analyses are robust. I have only a few minor points for clarification and some small edits, and recommend that the paper be published.

Line 50. Maybe replace “at its center” with “along its axis” or “marking its axis”

Line 61-62. Maybe reword this: “The average SSH difference” for clarity (it sounds like a spatial average, but then the sentence goes on to describe the spatial structure…) Maybe something like “The difference in average SSH before and after 2008 shows a dipole pattern with large positive…”

Line 65. Maybe replace “all-time mean” with “the overall (1993-2018) mean” …or whatever the time range is
Also, maybe replace “center of the Gulf Stream” with “axis of the Gulf Stream”

Line 70-72 and Figure 1. It is worth mentioning in the text (and considering in your explanation) recent findings from Chen et al., 2020, who report that temperature (albeit surface, not water-column averaged) IS increasing all over the place, including along the route of the Lab Current…see

their figure 3. I would have thought that at least some of the warming on the shelf is due to warming LC (not only reduced LC transport as you suggest)….perhaps you should consider this? (As an aside: this figure also has a very interesting cold hole in box F, right where your research indicates a northward shifted GS – that's pretty interesting!!).

Chen, Z., Kwon, Y.-O., Chen, K., Fratantoni, P., Gawarkiewicz, G., & Joyce, T. M. (2020). Long-term SST variability on the northwest Atlantic continental shelf and slope. Geophysical Research Letters, 47, e2019GL085455. https://doi.org/10.1029/2019GL085455

Line 76-93. I'm not too familiar with the currents and topography in this region and the naming conventions, but I think the shelf break is much shallower than the 1000m isobath?…are the authors thinking about a "Labrador Current" at the shelf break (i.e. a shelf break jet) or a "Labrador Current" at the 1000 m isobath (i.e. a slope jet)? They are different currents, I think, with different drivers and variability (at least they are off of NJ: see Flagg et al., 2006). Fratantoni and Pickart, 2007 might help clarify.

Line 157 remove "ref"

Line 173 Maybe replace "have gotten" with "have become"

Reviewer #2 (Remarks to the Author):

General: This paper by Neto et al. explores the relationship between changes in the Gulf Stream near the Grand Banks and warming in the NW Atl Shelf. I think the authors are on to something really interesting here in terms of mechanisms of warming and the potential of ocean temperature forecasting in the region. My main concern is the interpretation of the results. The authors note in the abstract that two events over the last century are responsible for the rapid warming of the region. No detection/attribution analysis was conducted here and statements like these cannot be made without such a test. I'd also like to see more discussion of how their results relate to previous studies that have analyzed atmospheric forcing, AMOC, and anthropogenic climate change in the NW Atlantic. I think this paper will make a valuable contribution to the field after revision.

Abstract: The statement "Historical observations suggest this recent shift was preceded by a similar phenomenon in the 1970s, indicating that just two events are responsible for much of the dramatic warming of the Northwest Atlantic Shelf over the past century" is completely unfounded. This statement would need to be backed up by a rigorous detection/attribution analysis using climate models. How can one completely exclude changes in radiative forcing due to greenhouse gas emissions? What about air-sea fluxes (see comments below regarding Chen et al. papers), changes in AMOC, changes in Greenland ice sheet melt?

Figure 1: Both Gulf Stream Slope Water and Labrador Slope Water (ATSW and LSSW) enter the Gulf of Maine at depth through the Northeast Channel but this figure makes it look like only LSSW enters the Gulf of Maine. I suggest including both a blue and red arrow entering the Northeast Channel. Recent NOAA measurements show a dominance of ATSW (Gulf Stream Slope Water entering the Gulf of Maine over the last 10 years. It would also be useful to show circulating red/blue areas in the shelf slope indicating the slope sea recirculation gyre, which is a mix of ATSW and LSSW.

Line 83: Please add text describing the flow of both Labrador Sub-Arctic Slope Water (colder, fresher) and Atlantic Temperate Slope Water (warmer, saltier) that enter the Gulf of Maine via the Northeast Channel at depth. You can refer to the latest NOAA NEFSC State of the Ecosystem Reports (SOEs) that show the time-series of slope water intrusions in the Northeast Channel and that the majority of slope water is now comprised of Gulf Stream water (ATSW). SOE report is citable and can be downloaded here: https://repository.library.noaa.gov/view/noaa/23890

In the section entitled "Temperature anomalies on the Northwest Atlantic Shelf", why is there no mention of the warmest marine heatwave on record for the NW Atlantic that took place in 2012? Chen et al. 2015 suggest the 2012 record warming in the NW Atlantic had a large influence from air-sea heat flux. Chen et al. 2014 suggest that jet stream variability also plays a role in the ocean warming of the region. Therefore, previous research suggests a combination of regional ocean circulation change (as your paper shows) combined with atmospheric forcing (Chen et al. 2014, 2015), which is attributed to a synergy of natural climate variability and anthropogenic climate change. Please discuss how your results fit into previous research that suggest air-sea flux and jet stream variability, particularly in the year 2012, which is the warmest year on record in the NW Atlantic.

Chen, K., G. Gawarkiewicz, Y.-O. Kwon, and W. G. Zhang (2015), The role of atmospheric forcing versus ocean advection during the extreme warming of the Northeast U.S. continental shelf in 2012, J. Geophys. Res. Oceans, 120, 4324–4339, doi:10.1002/2014JC010547.

Chen, K., G. G. Gawarkiewicz, S. J. Lentz, and J. M. Bane (2014), Diagnosing the warming of the Northeastern U.S. Coastal Ocean in 2012: A linkage between the atmospheric jet stream variability and ocean response, J. Geophys. Res. Oceans, 119, 218–227, doi :10.1002/2013JC009393.

Climate Change: I am perplexed as to why there is no discussion about the impacts of anthropogenic climate change on the warming of the NW Atlantic. While previous studies have investigated the impacts of AMOC on the ocean temperature of the NW Atlantic in the context of climate change, this study seems to mostly neglect those results. While I understand this analysis is looking into the mechanisms between a northern shift in the current and warming, which I greatly appreciate, I am not convinced (based on this analysis) that just two Gulf Stream events are responsible for the enhanced warming of the NW Atlantic as stated in the abstract. It seems more reasonable that the enhanced warming of the NW Atlantic is due to a synergy of regional circulation change (as studied here), changes in thermohaline circulation (AMOC) in the North Atlantic, changes in atmospheric circulation (i.e. jet stream studies), and the changes in radiative forcing (climate change). One would need to conduct an attribution/detection study to determine which specific dynamics are mostly responsible for the enhanced warming of the NW Atlantic. It is likely a perfect storm of multiple factors.

The work by Seidov et al. 2019 suggests stability in the Gulf Stream in the last 50 years with the exception of the extension zone near the Grand Banks: "the GS northward shift is noticeable—more than 2.6° (based on 5-year average GSNW positions) in latitude over ~50 years"

https://www.nature.com/articles/s41598-019-48011-9#Sec4 This corroborates well with your results but the shift near the Grand Banks has been gradual over 50 years. Again, my concern is your attribution of the warming to two events.

The analysis in Saba et al. 2016 shows a retreat of the Labrador Current around the TGB and a northern shift in the Gulf Stream after a doubling of atmos. CO_2 in the GFDL's CM2.6. I'd like to see more discussion regarding how your results compare with these results in the context of historical climate change.

Lines 222-225: The enhanced warming reported in Saba et al. 2016 and Caesar et al. 2018 is not just in the Scotian shelf but in a large portion of the NW Atlantic shelf, including the Mid-Atlantic Bight and Gulf of Maine.

Dear Dr. Aslin, Reviewer #1 and Reviewer #2,

We would like to thank you all for your thorough and thoughtful review of our manuscript, especially at such difficult times. Both reviews touched on very important aspects of our work, many of which we have thought about before, so we are pleased to have the chance to explore those points in more depth. In response to Reviewer 2's suggestion, we have revised the schematic (Figure 1). Below, you will find a detailed response to each of the questions and suggestions raised by both reviewers. Reviewer quotations are shown in ***bold italics***, and responses in regular font.

Reviewer #1:

- ***This is a very interesting paper about a topic that is of great interest and relevance with Marine Heatwaves very much in the news at the moment. The figures are very well done and the analyses are robust. I have only a few minor points for clarification and some small edits, and recommend that the paper be published.***
- ***Line 50. Maybe replace "at its center" with "along its axis" or "marking its axis":*** Fixed (currently Line 58).
- ***Line 61-62. Maybe reword this: "The average SSH difference" for clarity (it sounds like a spatial average, but then the sentence goes on to describe the spatial structure…) Maybe something like "The difference in average SSH before and after 2008 shows a dipole pattern with large positive…":*** Fixed (currently Line 70).
- ***Line 65. Maybe replace "all-time mean" with "the overall (1993-2018) mean" …or whatever the time range is. Also, maybe replace "center of the Gulf Stream" with "axis of the Gulf Stream":*** Fixed (currently Line 73).
- ***Line 70-72 and Figure 1. It is worth mentioning in the text (and considering in your explanation) recent findings from Chen et al., 2020, who report that temperature (albeit surface, not water-column averaged) IS increasing all over the place, including along the route of the Lab Current…see their figure 3. I would have thought that at least some of the warming on the shelf is due to warming LC (not only reduced LC transport as you suggest)….perhaps you should consider this? (As an aside: this figure also has a very interesting cold hole in box F, right where your research indicates a northward shifted GS – that's pretty interesting!!):*** Yes, we do agree that Chen et al. (2020) provided important evidence of surface warming in the entire Northwest Atlantic, mostly driven by natural climate variability and associated with fluctuations in the entire basin. To address this point, we have modified this sentence (originally Lines 70-72, currently Lines 78-80) to reinforce that it is the depth-integrated temperature that did not change and to acknowledge the observed surface warming reported by Chen et al. (2020). To address the importance of other forcing factors and make a clear differentiation between the surface and subsurface warming on the NWA Shelf (reported by Friedland et al, 2020), we have added two sentences to the first paragraph of the manuscript (currently Lines 21-25): "The

Northwest Atlantic surface warming during at least the past four decades has been attributed to both natural and anthropogenic forcing (Chen et al., 2020), and has been enhanced in recent years by atmospherically-driven extreme events (Chen et al., 2014, 2015). Shelf bottom waters have also warmed in recent decades, but with distinct temporal and spatial patterns when compared to the surface warming, suggesting that different forcing factors are likely at play here (Friedland et al., 2020)."

- ***Line 76-93. I'm not too familiar with the currents and topography in this region and the naming conventions, but I think the shelf break is much shallower than the 1000m isobath?…are the authors thinking about a "Labrador Current" at the shelf break (i.e. a shelf break jet) or a "Labrador Current" at the 1000 m isobath (i.e. a slope jet)? They are different currents, I think, with different drivers and variability (at least they are off of NJ: see Flagg et al., 2006). Fratantoni and Pickart, 2007 might help clarify:***
  This is a good point. In the original text, we referred to the current between the Tail of the Grand and the Great South Channel as Labrador Current and, for the sake of our methodology, define it as the "along-slope velocity". The choice for the 1,000-m isobath (as opposed to the 100-m isobath, for example) was that this isobath continuously follows the continental slope between Flemish Pass and Cape Hatteras (i.e., this isobath does not enter the Gulf of St. Lawrence or the Gulf of Maine). We have now changed this to the 500-m isobath (currently Line 86 on), which is the shallowest isobath to meet this criteria—text and figures 2a and 3a have been changed accordingly. We have also changed the definition of the current from "along-slope velocity" to "velocity along the shelf break" and have replaced its name from "Labrador Current" to "Shelf Break Jet", as in Fratantoni & Pickart, 2007. These changes did not alter the results, interpretations, or conclusions.
- ***Line 157 remove "ref":***
  We have included "ref" here to avoid that the numbered reference was placed directly after a number (the year "1912").
- ***Line 173 Maybe replace "have gotten" with "have become":***
  Fixed (currently Line 194).

Reviewer #2:

- ***This paper by Neto et al. explores the relationship between changes in the Gulf Stream near the Grand Banks and warming in the NW Atl Shelf. I think the authors are on to something really interesting here in terms of mechanisms of warming and the potential of ocean temperature forecasting in the region. My main concern is the interpretation of the results. The authors note in the abstract that two events over the last century are responsible for the rapid warming of the region. No detection/attribution analysis was conducted here and statements like these cannot be made without such a test. I'd also like to see more discussion of how their results relate to previous studies that have analyzed atmospheric forcing,***

AMOC, and anthropogenic climate change in the NW Atlantic. I think this paper will make a valuable contribution to the field after revision.

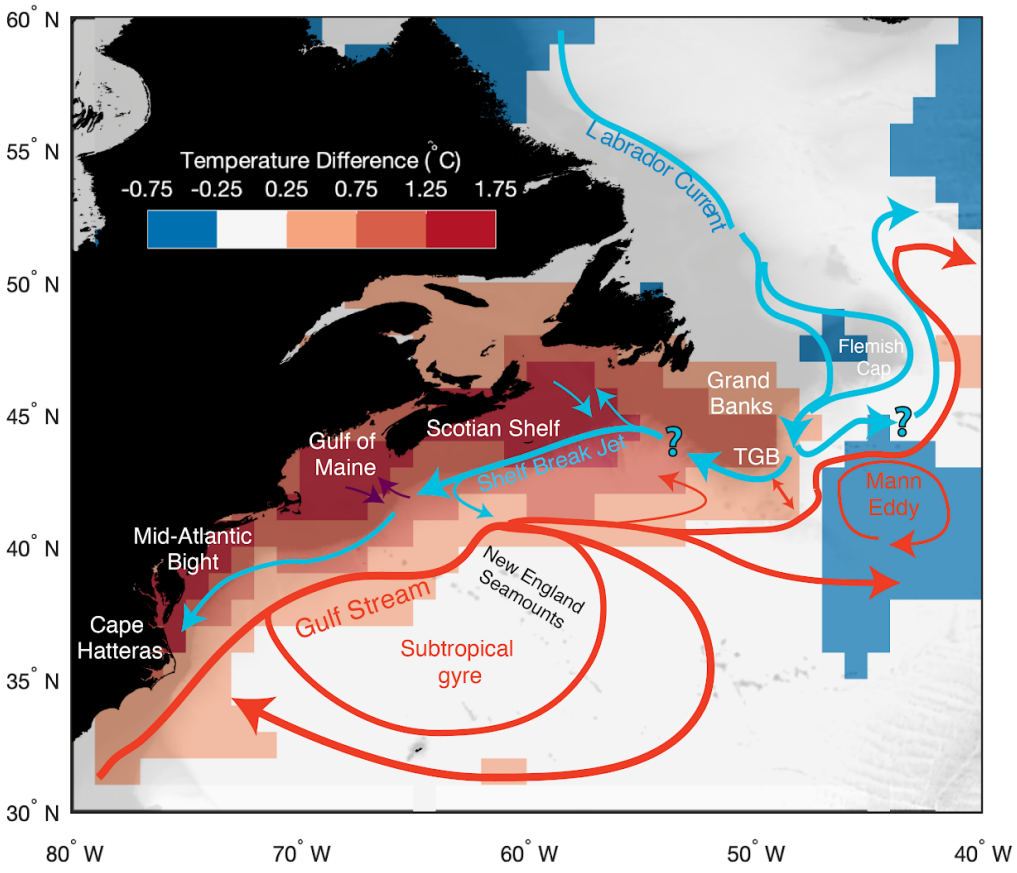
Thank you very much for all of your comments and suggestions. Below, in response to the detailed comments, we address each point individually, including the concern about the abstract's statement describing centennial scale warming.

- ***Abstract: The statement "Historical observations suggest this recent shift was preceded by a similar phenomenon in the 1970s, indicating that just two events are responsible for much of the dramatic warming of the Northwest Atlantic Shelf over the past century" is completely unfounded. This statement would need to be backed up by a rigorous detection/attribution analysis using climate models. How can one completely exclude changes in radiative forcing due to greenhouse gas emissions? What about air-sea fluxes (see comments below regarding Chen et al. papers), changes in AMOC, changes in Greenland ice sheet melt?:***

  This is a very good point. It was not our intention to resolve the entire history of shelf warming in the Northwest Atlantic and therefore we agree that this statement was too broad. We have softened this sentence to be more precise in our intention to show the contribution of the two shifts in ocean circulation to the NW Atlantic warming (currently Lines 14-17): "Historical observations suggest this recent event was preceded by a similar phenomenon in the 1970s, indicating that two shifts in ocean circulation have contributed to the dramatic warming of the Northwest Atlantic Shelf over the past century." In the last paragraph of the conclusions (currently Lines 255-257), we have also softened our statement that "Accurately simulating Gulf Stream-Labrador Current interactions at the TGB (...) will likely help govern the future properties in this region." We have acknowledged and discussed the contributions of the other factors throughout the manuscript, as detailed in the answers below.

- ***Figure 1: Both Gulf Stream Slope Water and Labrador Slope Water (ATSW and LSSW) enter the Gulf of Maine at depth through the Northeast Channel but this figure makes it look like only LSSW enters the Gulf of Maine. I suggest including both a blue and red arrow entering the Northeast Channel. Recent NOAA measurements show a dominance of ATSW (Gulf Stream Slope Water entering the Gulf of Maine over the last 10 years. It would also be useful to show circulating red/blue areas in the shelf slope indicating the slope sea recirculation gyre, which is a mix of ATSW and LSSW:***

  Thank you for these suggestions. Figure 1 has been updated to include these points. The inflow and outflow at the Northeast Channel is now purple, to reflect the mixture of warm and cold slope waters, which is explained in the caption.



- ***Line 83: Please add text describing the flow of both Labrador Sub-Arctic Slope Water (colder, fresher) and Atlantic Temperate Slope Water (warmer, saltier) that enter the Gulf of Maine via the Northeast Channel at depth. You can refer to the latest NOAA NEFSC State of the Ecosystem Reports (SOEs) that show the time-series of slope water intrusions in the Northeast Channel and that the majority of slope water is now comprised of Gulf Stream water (ATSW). SOE report is citable and can be downloaded here:***
  https://repository.library.noaa.gov/view/noaa/23890:
  Thanks a lot for this suggestion. Indeed, the results from the report corroborate our results and provide stronger evidence of the observed temperature changes in the Gulf of Maine. We have also included a reference to Friedland et al (2020) that recently reported changes in bottom temperature in the region (currently Lines 129-133): "In agreement with the observed warming on the shelf, a recent analysis inferred that the proportion of Labrador Slope Water entering the Gulf of Maine has been below average since 2010 (except for 2014) and reached a record low in 2017 and 2019, when essentially all of the Gulf of Maine slope water in the Northeast Channel was Warm

Slope Water (NOAA, 2020). Simultaneously, the Gulf of Maine and George's Banks experienced rising bottom temperatures (Friedland et al., 2020)."

- ***In the section entitled "Temperature anomalies on the Northwest Atlantic Shelf", why is there no mention of the warmest marine heatwave on record for the NW Atlantic that took place in 2012? Chen et al. 2015 suggest the 2012 record warming in the NW Atlantic had a large influence from air-sea heat flux. Chen et al. 2014 suggest that jet stream variability also plays a role in the ocean warming of the region. Therefore, previous research suggests a combination of regional ocean circulation change (as your paper shows) combined with atmospheric forcing (Chen et al. 2014, 2015), which is attributed to a synergy of natural climate variability and anthropogenic climate change. Please discuss how your results fit into previous research that suggest air-sea flux and jet stream variability, particularly in the year 2012, which is the warmest year on record in the NW Atlantic:***

  Yes, we agree that Chen et al. (2014, 2015) provide very important evidence of the atmospherically-driven surface warming event on the Northwest Atlantic Shelf in 2012 and that this was lacking in the original version of this manuscript. To address this point, we have linked their results with the new discussion NOAA (2020) and Friedland et al. (2020) described below (currently Lines 133-136): "The increased proportion of Warm Slope Water in the Gulf of Maine at the expense of Labrador Slope Water may reinforce atmospherically-driven marine heat waves, like the unprecedented surface warming in the first half of 2012 (Chen et al., 2014, 2015)."; and included it in our brief discussion of subsurface warming in the Mid-Atlantic Bight (currently Lines 146-149): "For example, the warming after 2011 in this region may be linked to the increased frequency of warm core rings shed by the Gulf Stream and/or northward shifts in the Gulf Stream orientation downstream of the separation point near Cape Hatteras (Gawarkiewicz et al., 2012; Forsyth et al., 2015; Gangopadhyay et al., 2019), in addition to anomalies in surface heat flux (Chen et al., 2015)."

  Additionally, as mentioned in response to Reviewer 1, we have added two sentences to the first paragraph of the manuscript to address the importance of warming forcing factors other than changes in ocean circulation (currently Lines 21-25): "The Northwest Atlantic surface warming during at least the past four decades has been attributed to both natural and anthropogenic forcing (Chen et al., 2020), and has been enhanced in recent years by atmospherically-driven extreme events (Chen et al., 2014, 2015). Shelf bottom waters have also warmed in recent decades, but with distinct temporal and spatial patterns when compared to the surface warming, suggesting that different forcing factors are likely at play here (Friedland et al., 2020)."
- ***Climate Change: I am perplexed as to why there is no discussion about the impacts of anthropogenic climate change on the warming of the NW Atlantic. While previous studies have investigated the impacts of AMOC on the ocean temperature of the NW Atlantic in the context of climate change, this study seems to mostly neglect those results. While I understand this analysis is looking into***

the mechanisms between a northern shift in the current and warming, which I greatly appreciate, I am not convinced (based on this analysis) that just two Gulf Stream events are responsible for the enhanced warming of the NW Atlantic as stated in the abstract. It seems more reasonable that the enhanced warming of the NW Atlantic is due to a synergy of regional circulation change (as studied here), changes in thermohaline circulation (AMOC) in the North Atlantic, changes in atmospheric circulation (i.e. jet stream studies), and the changes in radiative forcing (climate change). One would need to conduct an attribution/detection study to determine which specific dynamics are mostly responsible for the enhanced warming of the NW Atlantic. It is likely a perfect storm of multiple factors:

Yes, we agree. As shown by Saba et al. (2016), the AMOC slowdown is tied to shifts in the Gulf Stream and the Labrador Current, and therefore our results certainly corroborate their findings (and those by Caesar et al. 2018). We hope to have addressed this point with the revisions made to the abstract, introduction, discussion and conclusion, and shown in detail in the other responses here.

- ***The work by Seidov et al. 2019 suggests stability in the Gulf Stream in the last 50 years with the exception of the extension zone near the Grand Banks: "the GS northward shift is noticeable—more than 2.6° (based on 5-year average GSNW positions) in latitude over ~50 years":***
  https://www.nature.com/articles/s41598-019-48011-9#Sec4 This corroborates well with your results but the shift near the Grand Banks has been gradual over 50 years. Again, my concern is your attribution of the warming to two events:
  We considered the work by Seidov et al. (2019) while writing this manuscript, and now include a reference to their article. On page 4 (Lines 74-75), we have added a note about the consistency of our results with their observation of the expansion of the envelope of Gulf Stream North Wall positions after 2005 east of 50°W: "This pattern coincides with an increased amplitude of the Gulf Stream North Wall position east of 50°W after 2005 (Seidov et al., 2019)". As you mentioned, their proxy for the mean Gulf Stream North Wall gradually shifts northward between 50°W and 40°W over about 50 years, in contrast to our observation of a more abrupt change point in SSH at the Tail of the Grand Banks. We suspect that a possible cause of this difference is that they take the annual average of the position where the 15°C crosses 200 m as a canonical measure of the position of the Gulf Stream North Wall, which may not capture the increased probability of meanders and/or eddies impinging on the bathymetry. While this is rather speculative at this point, we are pursuing related questions in a follow-up work using a high-resolution model.
- ***The analysis in Saba et al. 2016 shows a retreat of the Labrador Current around the TGB and a northern shift in the Gulf Stream after a doubling of atmos. CO2 in the GFDL's CM2.6. I'd like to see more discussion regarding how your results compare with these results in the context of historical climate change:***
  We are happy that this point was raised, and agree that a stronger discussion on this topic was missing in the original version of this manuscript. In fact, we had considered

expanding this discussion, but kept it out at first for the sake of space. In the revised manuscript we now address this point in the introduction and in the conclusions. In the first paragraph of the introduction, we make the link between observed warming of the Northwest Atlantic and AMOC slowdown, with a lookout to the future and the implications for fisheries (currently Lines 25-32): “In one high-resolution model, simulated warming events on the Northwest Atlantic are strongly correlated with negative anomalies in the strength of the Atlantic Meridional Overturning Circulation (AMOC), leading to the interpretation that recent and historic warming in this region is an indicator of AMOC slowing in the twentieth century (Caesar et al. 2018). Under continuous greenhouse gas emissions, the AMOC slowdown and the associated warming of the Northwest Atlantic (Saba et al. 2016) are expected to increasingly alter historically-exploited stocks in this region, demanding adaptation of fisheries risk assessments to maintain resilience in a changing climate.”

In the conclusions, we modified the sentence where Saba et al is cited to relate the shelf warming with the shifts in the Gulf Stream and Labrador Current (currently Lines 241-247): “This long-term record may lend support to the hypothesis, based largely on climate modelling, of a 20th century slowdown in the Atlantic Meridional Overturning Circulation (AMOC) that is correlated with the warming of the Northwest Atlantic Shelf (Caesar et al., 2018) and associated with a northward shift of the Gulf Stream and a retreat of the Labrador Current (Saba et al., 2016). Idealized models predict a northward migration of the Gulf Stream accompanying AMOC slowdowns (Zhang & Vallis, 2007) in line with our observation of the Gulf Stream increasingly impinging on the TGB during shelf warming.”

- ***Lines 222-225: The enhanced warming reported in Saba et al. 2016 and Caesar et al. 2018 is not just in the Scotian shelf but in a large portion of the NW Atlantic shelf, including the Mid-Atlantic Bight and Gulf of Maine:***
  Currently Lines 243-244: We have replaced “Scotian Shelf” with “Northwest Atlantic Shelf”.

Sincerely,
Afonso Gonçalves Neto and co-authors.

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variability and ocean response: DIAGNOSING THE COASTAL WARMING IN 2012. J. Geophys. Res. Oceans 119, 218–227 (2014).

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12th Feb 21

Dear Dr Gonçalves Neto,

Your manuscript titled "Changes in the Gulf Stream precede rapid warming of the Northwest Atlantic Shelf" has now been seen by our reviewers, whose comments appear below. In light of their advice I am delighted to say that we are happy, in principle, to publish a suitably revised version in Communications Earth & Environment under the open access CC BY license (Creative Commons Attribution v4.0 International License).

We therefore invite you to revise your paper one last time to address the remaining concerns of our reviewers. At the same time we ask that you edit your manuscript to comply with our format requirements and to maximise the accessibility and therefore the impact of your work.

EDITORIAL REQUESTS:

Please review our specific editorial comments and requests regarding your manuscript in the attached "Editorial Requests Table". Please outline your response to each request in the right hand column. Please upload the completed table with your manuscript files.

If you have any questions or concerns about any of our requests, please do not hesitate to contact me.

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We hope to hear from you within two weeks; please let us know if you need more time.

Best regards,

Joe Aslin

Associate Editor,
Communications Earth & Environment
https://www.nature.com/commsenv/
Twitter: @CommsEarth

REVIEWERS' COMMENTS:

Reviewer #1 (Remarks to the Author):

I recommend the paper be accepted. I have only one tiny minor comment: on line 127 change "of our analysis(December/2018)" to "of our analysis (December 2018)" (remove the "/")

Reviewer #2 (Remarks to the Author):

The authors did a nice job revising the paper but there is still one statement in the abstract that needs to be revised before publication:

Abstract Lines 15-17: This sentence has not been revised to reflect my concern. You cannot attribute the impact of these two events without using global climate models. Either delete this sentence or substantially rephrase it to state that your analysis shows two events that occurred since 1970 that caused warming but it is unclear how much of the NW Atlantic decadal- and century-scale warming is attributed to just these two events.

Dear Dr. Aslin, Reviewer #1 and Reviewer #2,

We would like to thank you all again for your thorough and thoughtful review of our manuscript, especially at such difficult times. We have addressed the two points raised by the reviewers, as described below:

Reviewer #1:

- ***I recommend the paper be accepted. I have only one tiny minor comment: on line 127 change "of our analysis(December/2018)" to "of our analysis (December 2018)" (remove the "/")***
  Fixed.

Reviewer #2:

- ***The authors did a nice job revising the paper but there is still one statement in the abstract that needs to be revised before publication: Abstract Lines 15-17: This sentence has not been revised to reflect my concern. You cannot attribute the impact of these two events without using global climate models. Either delete this sentence or substantially rephrase it to state that your analysis shows two events that occurred since 1970 that caused warming but it is unclear how much of the NW Atlantic decadal- and century-scale warming is attributed to just these two events.***
  We have accepted the suggested abstract, which addresses this point.

Sincerely,
Afonso Gonçalves Neto and co-authors.