We thank the reviewer for the thorough and detailed assessment of our manuscript. The comments have highlighted several aspects that can be strengthened, and we outline below how these will be addressed in the revised manuscript.

Reviewer comments are shown in ***black****, and our responses are shown in* ***blue italics****.*

In addition to the revisions outlined below, the revised manuscript will include several substantial additions:

1) *The author order has been revised to reflect updated contributions to the study. In particular, Jack Wharton has been moved to the fourth author position following his contribution of the %*N. pachyderma *dataset and its interpretation.*
2) *The %*N. pachyderma *record and an assemblage-based SST reconstruction have been incorporated into the manuscript.*
3) *The comparison with Emerald Basin records has been substantially expanded, including direct comparison of the %*N. pachyderma *and assemblage-based SST reconstructions from both sites.*
4) *Additional evaluation of the δ¹⁸O–salinity relationship, alternative Mg/Ca calibrations, and age-model sensitivity will be included to provide a more comprehensive assessment of methodological uncertainties.*
5) *The age model of core OCE-326-30GGC has been added to Fig. 2, and the deglaciation chronology of Anticosti Island has been updated using the reconstruction of Couette et al. (2026).*

This manuscript presents Mg/Ca-derived sea-surface temperature and planktonic δ¹⁸O records from a sediment core retrieved at 274 m water depth taken in the St. Ann's Basin on the northeastern Scotian Shelf. The authors reconstructed ~8.6 ka of hydrographic variability and argue that episodic warm and saline anomalies after ~6.5 ka represent Gulf Stream (GS)-sourced slope water intrusions, driven by modal-state shifts in the Gulf Stream–Labrador Current (GS-LC) system linked to AMOC, the Subpolar Gyre (SPG), and solar forcing. The topic is timely, and the site is well chosen, and it's a companion paper of Matzerath et al. (2026). However, several methodological, interpretive, and structural issues reduce confidence in the conclusions as currently framed.

> *We thank the reviewer for the overall assessment of the manuscript and for recognizing the relevance of the study site and the timeliness of investigating Holocene hydrographic variability on the Scotian Shelf. We acknowledge the concerns raised regarding methodological uncertainties, interpretation of proxy records, and the structure of the discussion.*
>
> *In the revised manuscript, we plan to address these issues through a more detailed treatment of proxy limitations and ecological uncertainties, inclusion of additional assemblage-based information, further discussion of chronological and calibration uncertainties, and a restructuring of the Discussion section to more clearly separate observations from interpretations. We will also revise the wording of several conclusions to more explicitly reflect the level of uncertainty associated with the proposed hydrographic mechanisms.*
>
> *We believe these revisions will substantially strengthen the manuscript and provide a more balanced framework for interpreting hydrographic variability on the Scotian Shelf during the Holocene.*

Major Concerns

1. Single-core, single-species design limits robustness

The entire reconstruction rests on one sediment core MSM101_44-3 and one foraminiferal species (Neogloboquadrina pachyderma). This species is known to exhibit a highly variable, ecologically sensitive depth habitat — the authors themselves acknowledge it calcifies at depths ranging from ~20 to over 100 m, depending on sea-ice cover, chlorophyll concentration, and stratification. With such a dynamic depth habitat, it is difficult to disentangle true SST signals from changes in the species' calcification depth over the 8.6 ka record. The authors argue that the reconstructed temperatures are consistent with modern subsurface conditions; however, this circularity (validating subsurface temperatures against subsurface observations while referring to them as "SSTs" in the title, abstract, and throughout the manuscript) is never fully resolved. The paper would be substantially strengthened by including a companion proxy less sensitive to depth migration — foraminiferal assemblage counts, dinocysts, or a second geochemical tracer on a different species — rather than relying on a single signal from a single organism.

The authors' reliance on broader (including the Arctic) implications of using N. pachyderma rather than regional foraminiferal depth-habitat is either (1) willful ignorance or (2) disregard for other relevant data. The following three papers (including others) deal with foraminiferal assemblages in the southern Labrador Sea and Grand Banks!

Barrenechea Angeles, I., Lejzerowicz, F., Cordier, T., Scheplitz, J., Kucera, M., Ariztegui, D., Pawlowski, J., Morard, R., 2020. Planktonic foraminifera eDNA signature deposited on the seafloor remains preserved after burial in marine sediments. Scientific Reports 10, 20351.

Sahoo, N., Syed, M., Syed, S., Matul, A., Mohan, R., Tikhonova, A., Kozina, N., 2022. Planktic foraminiferal assemblages in surface sediments from the subpolar North Atlantic Ocean. Front. Mar. Sci. 8 https://doi.org/10.3389/fmars.2021.781675.

Stangeew, E. (2001): Distribution and isotopic composition of living planktonic foraminifera N. pachyderma (sinistral) and T. quinqueloba in the high latitude North Atlantic. PhD Thesis, Mathematisch-Naturwissenschaftliche Fakultät der Christian-Albrechts-Universität zu Kiel, 90 pp.

We agree that reconstructions based on a single sediment core and a single planktonic foraminiferal species require careful consideration of ecological uncertainties. However, we don not assume a fixed calcification depth throughout the record. Instead, the Mg/Ca-derived temperatures are interpreted as reflective conditions within the preferred calcification habitat of N. pachyderma, whose depth is known to vary with hydrographic conditions.

To strengthen this interpretation, we will incorporate planktonic foraminiferal assemblage data from core MSM101_44-3, including downcore %Np and an assemblage-based SST reconstruction (Fig R1). Although these proxies are not fully independent, they provide complementary information derived from different aspects of the foraminiferal record. The comparison shows that the principal hydrographic changes identified in the Mg/Ca record are also reflected in the assemblage data.

We will also extend the discussion of N. pachyderma ecology and incorporate the suggested regional literature to better address the habitat depth, seasonality and associated uncertainties. Throughout the revised manuscript, we will distinguish more clearly between sea-surface temperatures and temperature records recorded within the preferred calcification habitat of N. pachyderma. Finally, we will place greater emphasis on the site-specific nature of the reconstruction and adopt more cautious language when discussing broader regional implications.

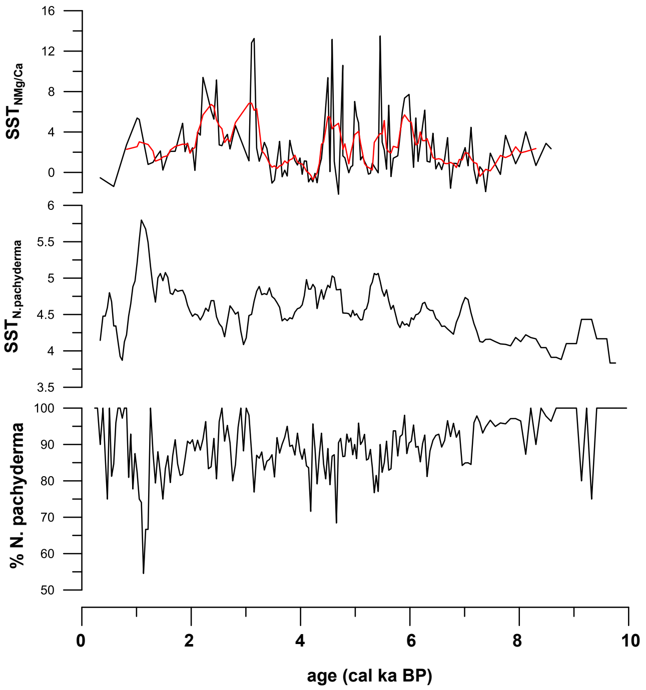

*Fig R1: Comparison of the Mg/Ca-derived SST reconstruction with the newly added assemblage-based SST reconstruction and %*N. pachyderma *record. The independent reconstructions show consistent centennial-scale variability and support the inferred hydrographic changes.*

2. The SSS reconstruction is insufficiently validated

Sea surface salinity is reconstructed from $\delta^{18}O$ of seawater ($\delta^{18}O_{sw}$) using a global mean ocean $\delta^{18}O$–salinity relationship (LeGrande & Schmidt, 2006). The Scotian Shelf sits at the confluence of isotopically distinct water masses — the cold, isotopically depleted Labrador Current and the warm, more enriched Gulf Stream — making a global mean equation a poor fit. Regional $\delta^{18}O$–salinity relationships for this margin differ substantially from the global mean, and the use of a single global equation to quantify salinity anomalies of only ~1.5 psu (the magnitude invoked to support intrusion events) is not adequately justified. Kolling et al. apply a global equation to a highly variable regional environment and then use the resulting SSS anomalies as primary evidence of intrusions. This is a notable weakness that should either be addressed through regional calibration or, at a minimum, treated with far more explicit uncertainty. Did the author consider the following relevant reference? Would the Figs. 3, 5, and 6 of Khatiwala et al. (1999) support Kolling et al.'s findings?

Khatiwala, S. P., Fairbanks, R. G., and Houghton, R. W. 1999. Freshwater sources to the coastal ocean off northeastern North America: evidence from H218O/H216O. JGR 104 (C8), 18241-18256.

The author used the generic calibration equation of Elderfield and Ganssen (2000) to convert their Mg/Ca data despite numerous calibration equations specifically developed for N. pachyderma. For example, Kozdon et al. (2009), Nürnberg (1995), Wu and Hillaire-Marcel (1996, GCA); Livsey et al. (2020).

Kozdon, R., A. Eisenhauer, M. Weinelt, M. Y. Meland, and D. Nürnberg (2009), Reassessing Mg/Ca temperature calibrations of Neogloboquadrina pachyderma (sinistral) using paired δ44/40Ca and Mg/Ca measurements, Geochem. Geophys. Geosyst., 10, Q03005, doi:10.1029/2008GC002169.

We will expand the discussion on the δ^{18}O-salinitx relationship and its applicability to the hydrographically complex Scotian Shelf. In particular, we will discuss the uncertainties associated with reconstructing absolute salinity and evaluate the regional framework of

Khatiwalla et al., (1999). A comparison of our reconstructed $\delta^{18}O_{sw}$ *values with the regional water-mass mixing relationships show that they follow the expected regional mixing trend and fall within the range defined by modern Scotian Shelf and Labrador Shelf waters (Fig R2). We will include this comparison in the supplementary material and discuss its implications for the reconstructed hydrographic variability.*

We will also expand the discussion of alternative Mg/Ca calibration, including those suggested by the reviewer. As these calibrations were developed for different hydrographic settings and analytical approaches, we will evaluate their applicability to the Scotian Shelf and compare our reconstruction with the most suitable regional alternative. These additions will provide a more transparent assessment of the uncertainties associated with both the salinity and temperature reconstructions.

These additions will strengthen the interpretation of the reconstructed hydrographic variability while providing a more transparent assessment of the uncertainties associated with both proxy calibrations.

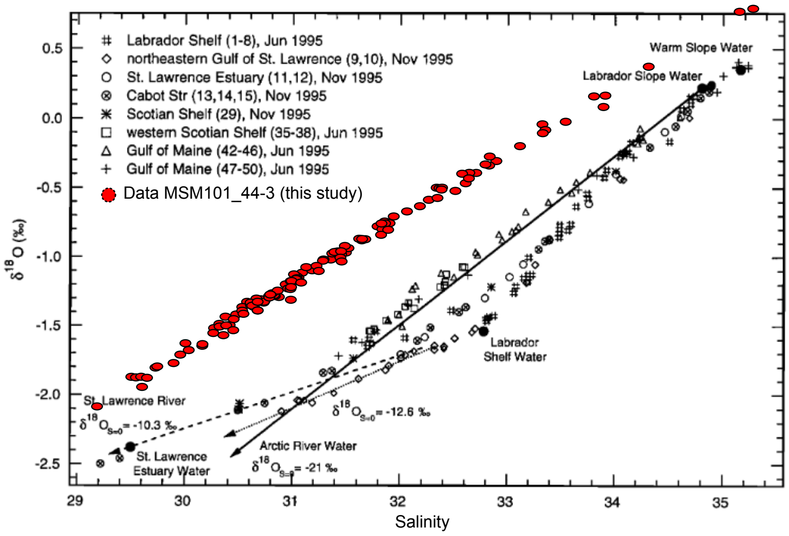

Fig R2:

Comparison of reconstructed δ¹⁸Oswsw and salinity values from core MSM101_44-3 (red circles) with the regional δ¹⁸O–salinity relationship of Khatiwala et al. (1999).

3. Chronological resolution and uncertainty are underappreciated

The age model is based on excellent 10 previously published AMS ^{14}C dates on mixed benthic foraminifera, yielding 95.4% credible interval widths of 350–530 years. The warm intrusion events the authors identify — which are core interpretive units lasting only 100–300 years — are therefore within or below the age model uncertainty. It is possible that two adjacent data points, identified as a single coherent "event," straddle an age-model uncertainty of several centuries. The manuscript does not propagate chronological uncertainties into the event timing or duration claims, and comparisons with other Holocene records (e.g., Bond events, AMOC minima reconstructions) are made with a precision the age model cannot support. A more rigorous treatment of age uncertainty, including Monte Carlo propagation or, at a minimum, a clear discussion of how age uncertainty affects event identification, is needed. Moreover, the calibration used by the authors is erroneous, as Heaton et al. (2023) revised their original “recipe” for the polar regions (see the reference below).

Kolling et al. did not consider the impact of sea ice on modifying ∆R. Their ∆R data is not convincing. Sea ice and wind are not the only modifications of ∆R, and different water masses, for example, Arctic-derived vs tropics will have a different ∆R. Also, just because there is no sea ice influence at the site today doesn’t mean it could not have happened in the past. See Wanamaker et al. (2012).

Heaton, T. et al., 2023. Marine Radiocarbon Calibration in Polar Regions: A Simple Approximate Approach using Marine20. Radiocarbon 65 (4), 848 - 875.

Lewis, C.F.M. et al. 2012. Lake Agassiz outburst age and routing by Labrador current and the 8.2 cal ka cold event. Quat. Int. 260, 83–97.

> *We agree that the age model uncertainty should be considered more explicitly when discussing the timing and duration of individual events. However, this uncertainty primarily affects the exact timing of the reconstructed variability rather than its occurrence. We will therefore revise the manuscript to place greater emphasis on the chronological uncertainty and adopt more cautious language when comparing our record with other Holocene climate archives.*
>
> *We will also evaluate the marine calibration approach proposed by Heaton et al. (2023) and discuss its implications for the chronology. In addition, we will reassess the choice of ΔR during the Early Holocene by considering the potential influence of changing water masses and sea-ice conditions. A sensitivity test using an increased ΔR for the interval prior to 7 ka BP will be included to assess its effect on the age model.*
>
> *The sensitivity (TableR1) test indicates that the resulting age differences are on the order of ±200 years and do not alter the overall interpretation of the record. Further, independent sea-ice reconstructions from St. Anns Basin indicate that seasonal sea ice was restricted to the Early Holocene, suggesting that any potential influence on ΔR would be limited to the oldest part of the record.*

Table R1: Sensitivity test of the age model using an increased ΔR (+200 yr) for samples older than 7 ka BP following the recommendations of Lewis et al. (2012) and the calibration approach of Heaton et al. (2023). The resulting age differences remain within approximately ±200 years and do not affect the overall interpretation of the record.

			Original Chronology			**Modified Δ R for <7k**		
Sample ID	**Depth (cm)**	**AMS ^{14}C age (^{14}C a BP)**	**Δ R (^{14}C yrs)**	**Standard deviation**	**Age median (cal. a BP)**	**Δ R (^{14}C yrs)**	**Standard deviation**	**Age median (cal. a BP)**
57530	26.5	920±40	-86 ± 66	93	439	-86 ± 66	93	443
57531	126.5	1737±29	-86 ± 66	94	1215	-86 ± 66	94	1221
57532	226.5	2540±40	-86 ± 66	120	2123	-86 ± 66	120	2138
58011	328.5	3370±35	-86 ± 66	120	3143	-86 ± 66	120	3149
57534	426.5	4110±40	-86 ± 66	128	4057	-86 ± 66	128	4063
58013	528.5	4715±40	-86 ± 66	123	4849	-86 ± 66	123	4854
57536	627.5	5290±55	-86 ± 66	113	5551	-86 ± 66	113	5556
57537	725.5	6040±40	-86 ± 66	104	6357	-86 ± 66	104	6355
57538	826.5	7040±45	-86 ± 66	93	7433	114 ± 50	93	7268
57539	946.5	9105±50	-86 ± 66	110	9675	114 ± 50	110	9471

4. The event-detection methodology is ad hoc

Warm events are defined as data points exceeding one or two standard deviations above the mean

SST and SSS. This is a common but statistically arbitrary approach — the threshold is not grounded in any physical or oceanographic criterion. Two single-point peaks are excluded without a fully providing statistical justification (the authors simply note they consist of "only one data point"). Moreover, the mean values used for thresholding (2.4°C and 32 psu) integrate both the cold early period and the warmer mid-to-late Holocene, which means the statistical threshold shifts depending on which part of the record is being evaluated. A more robust approach — such as a running mean baseline, a formal change-point detection algorithm, or comparison against a null hypothesis of red noise — would place the event identification on firmer ground.

If an outlier analysis of the data plotted in Fig. B1 is carried out, six data points (621, 527, 503, 495, 340, and 335 cm) in Fig. B1 and subsequent curves C-F in Fig. 3 would be beyond the 95% confidence interval or would fall beyond the trend-line. Thus, the decadal-to-centennial-scale variability discussed in the manuscript would disappear.

We agree that the event identification can be strengthened by applying additional criteria beyond a simple threshold. However, the main hydrographic features identified in the Mg/Ca and $\delta^{18}O_{sw}$ *records remain visible in the 5-point running average already presented in Figs. 4 and 5, indicating that the inferred variability is not solely controlled by individual points.*

To make the event definition more robust, we will revise the methodology by calculating the mean and standard deviation only for the interval after 6 ka, during which the events occur. In addition, events will only be defined where peaks identified in the original data are also supported by the smoothed record. We will expand the description of the event identification procedure and discuss its limitations more explicitly.

We will also compare the identified events with the newly incorporated %N. pachyderma and assemblage-based SST reconstructions to evaluate whether the main hydrographic changes are supported by independent proxy evidence.

5. The modal-state framework is applied somewhat loosely

The Pickart et al. (1999) modal-state framework was developed specifically for the Newfoundland Shelf and hinges on the relative contributions of Denmark Strait Overflow Water (DSOW) versus Labrador Sea Water (LSW) to the WBC. Kolling et al. invoke this framework for the Scotian Shelf, which lies further southwest and has a different shelf geometry, bathymetry, and water-mass exposure. The adaptation is plausible but is not rigorously tested. No proxy record from this core actually constrains WBC composition — the authors infer minimum versus maximum modal states entirely from the surface SST-SSS signal, which creates a degree of circular reasoning: the warm events are taken as evidence of maximum modal states, and the maximum modal state is then offered as the explanation for the warm events. Just a reminder that the sediment core used by Kolling et al. was retrieved at 274 m water depth bathed by the inner Labrador Current. Thus, the dynamics of the inner Labrador Current must be clearly linked to the LSW and WBC before the authors' hypothesis can be accepted, as outlined in section 4.5. I am aware that the independent constraints on deep- or intermediate-water variability at this site (e.g., benthic foraminiferal $\delta^{13}C$ or Cd/Ca) could not be achieved due to the unavailability of various proxy-carriers; however, rigorous testing is needed before accepting this mechanism rather than merely assuming it.

We agree that Pickart et al. (1999) modal-state framework was developed for the Newfoundland Shelf and cannot be directly transferred to the Scotian Shelf. Our intention is not to reconstruct modal states from our proxy record, but to use this framework as a conceptual model to discuss hydrographic variability.

We will revise the manuscript to make this distinction clearer and avoid wording that implies a direct reconstruction of water-mass or WBC composition. We will also expand the discussion of the connection between the inner Labrador Current, Labrador Sea Water and the Western Boundary Current, while explicitly acknowledging that the proposed mechanism cannot be independently verified with the available proxy data.

6. Incomplete comparison with contradicting records

Kolling et el. briefly acknowledge that their Mg/Ca SST record contradicts alkenone-based reconstructions from the nearby Emerald Basin, which show a long-term cooling trend with no centennial variability. While the authors offer plausible arguments (seasonal bias, depth habitat, bloom seasonality), they do not systematically engage with why the same intrusion events identified at St. Ann's Basin leave no signal in the foraminiferal assemblages of Emerald Basin. The proposed explanation — differences in basin geometry and proxy sensitivity — is, to be precise, speculative and underdeveloped, and thus unacceptable. Given that Emerald Basin is central to the regional Scotian Shelf literature and provides the most directly comparable record, a more thorough and spatially explicit discussion of why proxy signals diverge across basins only ~100 km apart is essential.

> *We agree that the comparison with Emerald Basin should be expanded, as it provides the most relevant regional comparison for our record. To address this, we will incorporate the Emerald Basin planktonic foraminiferal records into the revised manuscript together with Dr. Jack Wharton and Prof. David Thornalley, who have joined the author team (see author comment 28. March 2026). This will allow a direct comparison of %N. pachyderma and assemblage-based SST reconstructions between St. Anns and Emerald Basin.*
>
> *We will expand the discussion of the similarities and differences between both records and discuss how basin geometry, hydrographic setting and proxy-specific sensitivities may contribute to the contrasting proxy signals. This will provide a more balanced assessment of regional hydrographic variability and the limitations of individual proxies.*

Minor Concerns

The title refers to "8.6 ka BP" but the substantive interpretive findings largely concern the last 6.5 ka. The early part of the record (8.6–6.5 ka) is characterized as stable and essentially featureless. Readers may reasonably expect more emphasis on the older interval.

> *We agree that the main variability occurs after ca. 6.5 ka BP. However, the earlier interval provides important baseline against which the subsequent increase in variability can be evaluated. We will clarify this transition more explicitly in the revised manuscript.*

The Mn/Ca correction applied to all Mg/Ca values warrants more transparency. Kolling et al. conclude that corrected and uncorrected values do not differ; the fact that 62 of their samples exceed the Boyle (1983) threshold for diagenetic coatings is substantial and should be discussed more fully rather than given a brief note.

> *We agree that Mn/Ca correction and its implication should be described more explicitly. In the revised manuscript, we will expand the discussion of the Mn/Ca screening results. We will also provide a more explicit comparison between corrected and uncorrected Mg/Ca values. As shown in the manuscript, Mn/Ca ratios do not exhibit meaningful relationships with Mg/Ca values, and application of the Elderfield et al. (2012) correction produces only negligible changes to the reconstructed SSTs. Consequently, the principal patterns of hydrographic variability and its interpretation of the record are unaffected by the correction. We will clarify these points in the revised manuscript and appendix.*

XRD determined Calcite (wt%); it would have been useful to obtain dolomite to identify the Lake Agassiz or 8.2 ka event robustly.

> *We have quantified dolomite abundances as part of the XRD analyses and will incorporate the downcore dolomite record into the revised manuscript to evaluate its relationship to the 8.2 ka event, see Figure R3 below.*

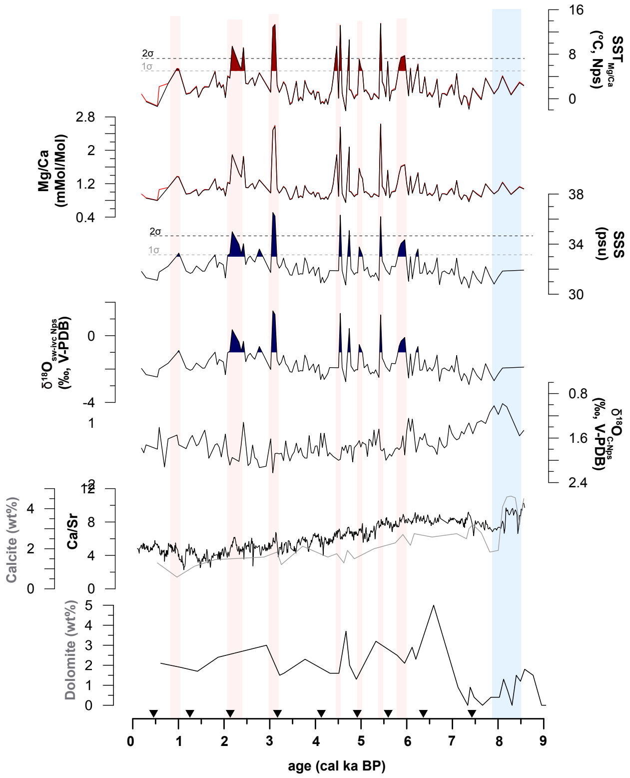

Fig R3: Revised results figure including the XRD-derived dolomite record. A distinct increase in dolomite content is observed at ~8.5 ka BP, consistent with enhanced detrital input during the 8.2 ka event.

The spectral analysis section makes claims about solar forcing (the de Vries cycle and the 1500-year Bond cycle) based on a record spanning only ~8.6 ka and unevenly sampled. The spectral significance thresholds (95% confidence intervals) are reported, but the bandwidth and degrees of freedom in the Blackman-Tukey analysis are not, making it difficult to assess the robustness of the spectral peaks independently.

> *We agree that the spectral analysis should be presented more cautiously given the length and sampling structure of the record. In the revised manuscript, we will provide the missing methodological details of the Blackman-Tuckey analysis, including bandwidth, number of lags, degrees of freedom, interpolation procedure and significance testing. We will also tone down the interpretation of spectral peaks and avoid presenting them as direct evidence for solar forcing. Instead, the revised text will describe these periodicities as broadly consistent with previous reported solar- and Bond-scale variability, while explicitly acknowledging the limitations imposed by the 8.6 ka record length and uneven sampling.*

The SSS-to-δ^{18}O conversion implicitly assumes no change in regional ice volume correction beyond the Siddall et al. (2003) global sea-level correction. For a near-coastal site influenced by variable glacio-isostatic adjustment and proximity to the retreating Laurentide Ice Sheet, this assumption should be explicitly acknowledged as a potential source of error. Could the authors not find reasonable references for the Holocene sea-level changes surrounding the North Atlantic than the far-field of the Red Sea? How about Walker et al. (2021)?

Walker, J.S., et al., 2021, Common Era sea-level budgets along the U.S. Atlantic coast: Nature Communications, v. 12, p. 1841, https://doi.org/10.1038/s41467-021-22079-2.

> *We agree that regional sea-level change and glacio-isostatic adjustment may represent an additional source of uncertainty in the reconstruction of δ^{18}O$_{sw}$, particularly during the Early*

> *Holocene. We will expand the discussion of the assumptions associated with the applied ice-volume correction and include a discussion of regional sea-level evolution and glacio-isostatic adjustment using the available North Atlantic literature, including Vacchi et al. (2018), while acknowledging the potential influence of regional sea-level variability on our reconstruction.*

A lot is riding on the Wharton (2022) thesis in this manuscript; however, access to the thesis is restricted to UCL open-access staff until 1 March 2027. Therefore, we have to accept Kolling et al. statements at face value rather than verify them.

> *Wharton and Thornalley have joined the author team which will ensure that statements previously based primarily on the thesis are more fully documented and supported within the manuscript itself.*

We thought the German research institutions had made progress in dissuading chain authorship; however, it appears to be a spurious attempt, as shown by the current authorship.

> *We respectfully note that all authors meet the journals authorship criteria and have made substantially contributions to the study. Author contributions are provided in accordance to the journals guidelines and can be clarified further, if necessary.*

Overall Assessment

The paper addresses a genuinely important problem — the paleoceanographic history of a rapidly warming and poorly understood margin — and provides what is, to date, one of the few high-resolution foraminiferal records from the Scotian Shelf. The (poor) identification of episodic warm intrusions and their tentative linkage to North Atlantic circulation modes is a potentially significant contribution. However, in its current form, the study overreaches in several places: (1) the event-detection approach is underdeveloped, (2) the SSS reconstruction rests on an inappropriate calibration, (3) the claimed chronological precision in event timing exceeds what the age model supports, and (4) the mechanism invoked (modal-state transitions) is inferred rather than independently tested. Substantial revision is needed before the interpretations can be accepted with confidence. The paper is recommended for major revision or rejection.

> *We thank the reviewer for the detailed assessment of the manuscript and for recognizing the value of the new Scotian Shelf record. We acknowledge the concerns raised regarding event identification, salinity reconstruction, chronological uncertainty and the interpretation of circulation mechanisms. As outlines in our responses above, we will address all of these points through additional analyses, expanded discussion, new proxy data and more cautious interpretation of the underlying mechanisms in the revised manuscript.*