Response to reviewer comments:

Editor Decision: Reconsider after major revisions (03 Mar 2021) by Bjørg Risebrobakken
Comments to the Author:
Dear Nora Richter et al.,

Thank for very much for submitting your revised “Winter-spring warming in the North Atlantic during the last 2,000 years: Evidence from Southwest Iceland” manuscript. I have now received two evaluations of the revisions done. One still recommends major revisions, and both raise questions that I recommend you to address carefully. In part these comments reflect issues raised by both reviewers in the first review round, but not taken into account. There are also questions raised with respect to the interpretation relative to the strength of the suggested forcing.

I would also like to ask for more background information to be provided with respect to the model setup. According to Dee et al., 2018, lake specific tuning of parameters is necessary, in addition to the user defined initial conditions. Please provide information on choices made for local tuning of the model, as well as specification of individual input variables and sources of these. And how well does your control simulation represent the known lake conditions? As far as I can see you show no validation of the model set up for your lake? In part this links back to one of the main concerns of the reviewer, related to assessment of the model.

I will ask for a revision of the manuscript, taking into account the concerns still raised. I will look forward to seeing the revised version and your responses to the reviewer’s comments. Please provide responses to each comment raised and a version of the revised manuscript including track changes highlighting how the changes have been implemented.

Thank you very much for submitting your work to Climate of the Past.

Best regards,
Bjørg Risebrobakken
Editor, Climate of the Past

Response: Thank you for taking the time to review our paper and for your feedback. We have included a more detailed description of the lake model parameterization and validation of our control run in the manuscript. Please see our response to reviewer 1 below for a more detailed description of what we modified. We hope you that you will consider our manuscript for publication with the corrections outlined below.

Reviewer 1
Dear authors,

Reviewer: I have now read your rebuttal to my comments and those made by another reviewer. In light of these, I have additional suggestions that ought to be reflected before publication in my opinion:

Response: Thank you for taking the time to review our manuscript and for your feedback

Reviewer: RIK38E: my previous comment concerning the use of this index may have been mis-read. I did not suggest to use RIK38E to calibrate your samples, but merely to (better) distinguish between Group I and 2 producers (see Longo et al. 2016/2018). As I said in my initial comments, separating them is quite critical for robust temperature inferences, and using RIK38E values may significantly refine this distinction.

Response: We agree that it is crucial to distinguish between Group I and II alkenones, and we apologize for misinterpreting your previous comment. We included an additional figure in our appendix that compares the RIK_{37} and RIK_{38E} values (Fig. A1). Unfortunately, the concentrations of the $C_{38:3}$Et and its isomer were sometimes too low to reliably identify and quantify those compounds, therefore we only included the samples where we were able to reliably quantify $C_{38:3}$Et and its isomer. As you will observe in our figure, all of the samples that we include in our manuscript fall within the range of Group I Isochrysidales as previously determined by Longo et al. (2018). We updated section 2.3 to include the RIK_{38} equation and we added the following text:

"RIK_{38E} values of 0 to 0.57 were empirically shown to correspond to Group I alkenone distributions, whereas Group II alkenone distributions correspond to values between 0.75 to 1 (Longo et al., 2016, 2018)." (section 2.3, lines 131-133)

We also added the following text to section 3.1:

"To further validate our results, we also did an additional comparison using both the RIK_{37} and RIK_{38E} indices (Fig. A1). Due to lower abundance of $C_{38:3}$ Et and its isomer we had fewer datapoints for comparison, but our results still demonstrate that datapoints used in our study are predominantly produced by Group I Isochrysidales." (section 3.1, lines 226-228)

Reviewer: Ice-off dates: both me and the other reviewer of this manuscript encourage the authors to assess their model by using free and easily available observational data to assess the potential impact of variable ice-off dates. Yet, no steps have been undertaken in the revised manuscript to do so, while the authors do use observational data to justify their calibration. I strongly encourage the authors to take this comment to heart, especially in light of the high-amplitude temperature shifts that they infer.

Response: We think it is important to understand that we are not attempting to argue that the lake model precisely constrains the timing of ice-out nor spring temperatures at our study site. Rather, we use the model to explore the sensitivity of ice-out and temperature to different forcings. We modified Fig. 5 and the outputs from our sensitivity tests to reflect temperature anomalies and changes in ice-off dates relative to our control simulation.

Nevertheless, to address these concerns we have included a table with the lake-specific parameters used to calibrate our lake model in the appendix (see Table A1). As you will see in the table, the parameters were constrained based on data in Blair et al. (2015) and a previous simulation by Longo et al. (2020) on lakes in Northern Alaska where the lake model was validated with limnological data from the Toolik Environmental Data Center and the Arctic Long-Term Ecological Research program over a 6-year period. Lake E5 in Northern Alaska is similar in size and with a similar catchment area to VGHV (Longo et al., 2020). Similar to Longo et al. (2020), we also found that the neutral drag coefficient has the largest influence on outputs from the lake model simulation. In addition, we summarized the available data in the literature and the few observations we were able to make using satellite data in Tables A2 and A3, respectively. However, our study site was often obscured by clouds during the spring season, imposing significant limits on this exercise. We recorded the last day ice was observed on the VGHV and the first day where the lake was completely ice-free. We also included a comparison of the simulated lake surface temperatures and changes in ice-cover from our control run with air temperature data from a nearby meteorological station (Hella Station), since lake temperature time-series data is not available from our study site. Based on the available data in the literature, meteorological data, and satellite imagery our lake parametrization reflects the general conditions observed in southwest Iceland. To further refine the lake model simulation for VGHV and use the proxy system model developed by Dee et al. (2018) we would need a much longer observational dataset (see Longo et al. 2020).

We have updated the text in sections 2.4 and 3.2 to reflect these changes:

“We investigated the controls on spring lake water temperatures and the timing of ice-melt in VGHV using a lake energy balance model (Dee et al., 2018). The purpose of the lake model was to determine the sensitivity of our proxy to different forcing mechanisms by assessing the temperature response and timing of ice-melt relative to our control simulation. Due to the lack of extensive observational datasets from VGHV to test our model, we adjusted the initial parameters using available data in the literature and parametrizations determined by Longo et al. (2020) for lakes in Northern Alaska where the lake model was validated using limnological data from the Toolik Environmental Data Center and the Arctic Long-Term Ecological Research program over a 6-year period (see Table A1). Lake E5 in Northern Alaska is similar in size and with a similar catchment area to VGHV (Longo et al., 2020). The neutral drag coefficient was set to 0.002, and the albedos for slush and snow were set to 0.4 and 0.7, respectively. Note that volcanic eruptions in Iceland can result in ash deposits on the snow, and lower the albedo of the resulting slush and snow cover on VGHV and lead to earlier ice-off dates (Landl et al., 2003). However, we expect this to only be important during volcanic eruptions that occurred during the winter and/or spring season and would only influence the lake water temperatures and ice-cover during that year. As our purpose is to understand how the lake responds on longer-timescales, we keep the values for albedo constant. The model was initialized using ERA-Interim daily data (1979-2018 CE; ECMWF; Dee et al., 2011) averaged over grid cells covering southwest Iceland (18.25° W-22.75° W by 63.00° N-64.50° N for a 0.75° x 0.75° grid). An initial control simulation was run for 39 years, followed by sensitivity tests where various perturbations were introduced. Results from the control simulation were compared with available meteorological data, ice-off dates from nearby lakes in Iceland, and the few observations we were able to make using satellite imagery when our study site was not obscured by clouds (Tables A2 & A3; Fig. A2). The lack of extensive observational data from VGHV prevents us from validating the outputs from the lake model simulation, therefore we use the outputs from the lake model to highlight what processes could lead to variations in ice-off dates and lake water temperatures during the spring season, but not to quantify the number of days or degrees that ice-off dates and temperatures, respectively, changed in the lake over the last 2,000 years." (section 2.4, lines 166-187)

"Currently there are no extensive datasets on changes in lake water temperatures and/or ice-off dates for lakes (in particular lakes that are not influenced by geothermal activity or are glacial lakes that are subject to sea water intrusions) in Iceland to validate the control simulation from our lake model. However, a comparison with existing data in the literature and satellite images that were not obscured by cloud-cover suggests that the timing of the ice-out dates in our lake model (mid- to late April) and mean monthly temperatures of the surface lake water are reasonable (Tables A2 & A3; Fig. A2). We use the results from the lake model to infer what processes could drive large changes in ice-off dates and lake water temperatures, and thereby the determine the seasonal sensitivity of our proxy." (section 3.2, lines 240-246)

Reviewer: Group I studies: both me, but especially the other reviewer, ask for a bit more regional context about the regional application of the UK37 proxy. But instead of adding certain relevant recent studies, a number of papers have been left out. As some of these are mentioned in the rebuttal, I suspect something as gone awry here. I urge you to have a look at this: the most striking examples (previously mentioned, but now somehow missing) include 1) Harning et al. 2020 GRL, and 2) van der Bilt et al. 2020 GRL.

Response: We added additional text to section 2.3 to further discuss the application and seasonality of the U_{37}^{K} index in lakes:

"Temperature calibrations using the U_{37}^{K} index were applied to develop high resolution records of summer temperatures in Greenland (c. 5,600 yrs BP; D'Andrea et al., 2011) and Svalbard (1,800 yrs BP; D'Andrea et al., 2012 and 12,000 yrs BP; van der Bilt et al., 2018, 2019), as well as a winter-spring temperature record in Alaska (16,000 yrs BP; Longo et al., 2020). The main timing of ice-off, and the corresponding alkenone bloom in VGHV, occurs in April to May in southern Iceland and May to June in northern Iceland (see Tables A2 & A3). In contrast, studies in Svalbard report ice-off dates between late June to mid-August and show that alkenones primarily record summer (JJA) temperatures (D'Andrea et al., 2012; van der Bilt et al., 2019). In Northern Alaska ice-off dates primarily occur in June and reflect temperature changes during the winter and spring season (Longo et al., 2018, 2020). The regional variability in the relationship between the U_{37}^{K} index and temperature, as well as differences in the timing of the alkenone bloom requires the development of local temperature calibrations and validation of the seasonal sensitivity of the proxy for each region (Wang and Liu, 2013; D'Andrea et al., 2016; Longo et al., 2016). Unfortunately, there is currently no local calibration for Icelandic lakes, but in the following section we will describe how we use a lake model to test what drives changes in ice-off dates and lake water temperatures, and therefore the seasonality of temperature recorded by alkenones, in VGHV." (section 2.3, lines 146-158)

We would also like to explain why we chose not to elaborate on the study by Harning et al. (2020 GRL) in our discussion. The study by Harning et al. (2020) does not include an in-situ calibration to determine the seasonality of alkenones at the study site, Lake Skorarvatn, in Iceland, although it was mentioned as future work. The seasonality of alkenones is assumed to be summer based on the seasonality of alkenones produced in

Svalbard and Greenland (ice-out in late June to August; D’Andrea et al., 2011, 2012), even though ice-off at Lake Skorarvatn occurs in mid-April to mid-May (Harning et al., 2020). In Northern Alaska, where ice-off occurs in June, alkenones were rigorously shown to record winter-spring temperatures (Longo et al., 2018, 2020). This highlights the need for a more rigorous validation of how spring lake water temperatures and the timing of ice-off in Skorarvatn, and therefore the temperatures recorded by alkenones, respond to seasonal changes in air temperature. The calibration used for reconstructing temperatures downcore relies on the slope for Group I Isochrysidales determined by D’Andrea et al. (2016) and is used to calculate temperature anomalies over the Holocene. The record consists of 10 datapoints for alkenones over the last 10,000 years and only two data points over the last 2,000 years. Unfortunately, this makes it difficult to draw any concrete conclusions on the seasonality of the proxy or what is driving long-term changes in Icelandic temperatures. Hopefully, future studies will be able to expand on both our study and the work by Harning et al. (2020) to develop new calibrations for alkenones in Iceland and better constrain the production and seasonality of this proxy.

Reviewer: Calibration: you argue that most alkenones in your site derive from Group I producers, remove samples that (also) contain Group II, and yet opt for a Group III temperature calibration because these values are “more reasonable”. I don`t find this a particularly strong line of argumentation, and think you need to discuss this decision in more detail. Key element: available Group I calibrations now derive from many NH lakes and produce calibration slopes that are rather similar, so why would VGHV be so different?

Response: We thank the reviewer for pointing this out, and we apologize for not clarifying this statement. None of the existing calibrations generate reasonable temperatures at our study site. It is unclear why VGHV behaves differently. However, it is important to note that there are very few studies on Group I alkenones, and even in the Northern Hemisphere temperature calibration developed by Longo et al. (2018) there is considerable variation in the proxy (i.e., only 60% of the variability is explained by changes in spring temperatures). Further, differences in lake temperature sensitivity to air temperatures relative to previous studies could influence the resulting U^{K}_{37} -temperature relationship. This is why we encourage the development of local alkenone calibrations for lakes in Iceland. We have modified the text in section 3.3 to make this clearer:

“The U^{K}_{37} index can provide temperature estimates using linear relationships that are calibrated in lakes with Group I alkenone-producers (D’Andrea et al. 2011, 2016; Longo et al., 2016, 2018). Existing temperature calibrations, except for the Northern Hemisphere calibration by Longo et al. (2018), for Group I are site-specific and therefore cannot be readily applied to VGHV (e.g. calibrations give estimates of 10.2 to 33.5 °C (D’Andrea et al., 2011), 7.1 to 34.4 °C (Longo et al., 2016), 4.4 to 24.5 °C (D’Andrea et al., 2016), -1.4 to 18.3 °C (calibration for Northern Hemisphere lakes by Longo et al., 2018; see Fig. A4). Most of the variation between sites is accounted for by the y-intercept of the calibration, so the slope of Group I calibrations was suggested as a better determinant of relative temperature changes for sites lacking a site-specific calibration (D’Andrea et al., 2016). However, the slopes determined for Group I calibrations still result in a very large and likely unreasonable temperature range of 26.9 °C for $U^{K}_{37} = 0.0219T$ (D’Andrea et al., 2016). The amplitude of the reconstructed temperature is still relatively large considering that each sample is an average of 5-19 years, and most likely stems from the lack of a local calibration. These discrepancies are highlighted by the variability observed in the Northern Hemisphere calibration developed by Longo et al. (2018), where only 60% of the U^{K}_{37} index is explained by temperatures during the spring isotherm. In VGHV, the U_{37}^{K}-temperature relationship could highlight the differences in the sensitivity of VGHV lake water temperatures to air temperature relative to previous studies on Group I Isochrysidales (Longo et al., 2018). Despite these differences, the U_{37}^{K} index is known to be highly sensitive to temperatures in NH lakes and both the millennial and multidecadal variability in our U_{37}^{K} index exceeds the range of our analytical uncertainty. We assume that, after correcting for species mixing, there are no environmental parameters other than temperature that affect our U_{37}^{K} record, and we therefore use the U_{37}^{K} index to infer and evaluate qualitative changes in temperature trends and variability during the past 2,000 years." (section 3.3, lines 268-285)

References

Blair, C. L., Geirsdóttir, Á., and Miller, G. H.: A high-resolution multi-proxy lake record of Holocene environmental change in southern Iceland. J. Quat. Sci., 30, 281-292, https://doi.org/10.1002/jqs.2780, 2015.

D'Andrea, W. J., Huang, Y., Fritz, S. C., and Anderson, N. J.: Abrupt Holocene climate change as an important factor for human migration in West Greenland. Proc. Natl. Acad. Sci., 108, 9765-9769, https://doi.org/10.1073/pnas.1101708108, 2011.

D'Andrea, W. J., Vaillencourt, D. A., Balascio, N. L., Werner, A., Roof, S. R., Retelle, M., and Bradley, R. S.: Mild Little Ice Age and unprecedented recent warmth in an 1800 year lake sediment record from Svalbard. Geology, 40, 1007-1010, https://doi.org/10.1130/G33365.1, 2012.

D'Andrea, W. J., Theroux, S., Bradley, R. S., and Huang, X.: Does phylogeny control U_{37}^{K} -temperature sensitivity? Implications for lacustrine alkenone paleothermometry. Geochim. Cosmochim. Acta, 175, 168-180, https://doi.org/10.1016/j.gca.2015.10.031, 2016.

Dee, D. P., Uppala, S. M., Simmons, A. J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M. A., Balsamo, G., Bauer, P., Bechtold, P., Beljaars, A. C. M., van de Berg, L., Bidlot, J., Bormann, N., Delsol, C., Dragani, R., Fuentes, M., Geer, A. J., Haimberger, L., Healy, S. B., Hersbach, H., Hólm, E. V., Isaksen, L., Kållberg, P., Köhler, M., Matricardi, M., McNally, A. P., Monge-Sanz, B. M., Morcrette, J. J., Park, B. K., Peubey, C., de Rosnay, P., Tavolato, C., Thépaut, J. N., and Vitart, F.: The ERA-Interim reanalysis: configuration and performance of the data assimilation system, Q. J. Roy. Meteor. Soc., 137, 553–597, https://doi.org/10.1002/qj.828, 2011.

Dee, S. G., Russell, J. M., Morrill, C., Chen, Z., and Neary, A.: PRYSM v2. 0: A Proxy System Model for Lacustrine Archives. Paleoceanogr. Paleocl., 33, 1250-1269, https://doi.org/10.1029/2018PA003413, 2018.

Harning, D. J., Curtin, L., Geirsdóttir, Á., D'Andrea, W. J., Miller, G. H., & Sepúlveda, J.: Lipid biomarkers quantify Holocene summer temperature and ice cap sensitivity in Icelandic lakes. Geophys. Res. Lett., 47, https://doi.org/10.1029/2019GL085728, 2020.

Landl, B., Björnsson, H., & Kuhn, M.: The energy balance of calved ice in Lake Jökulsarlón, Iceland. Arct., Antarct., and Alp. Res., 35, 475-481, 2003.

Longo, W. M., Theroux, S., Giblin, A. E., Zheng, Y., Dillon, J. T., and Huang, Y.: Temperature calibration and phylogenetically distinct distributions for freshwater alkenones: evidence from northern Alaskan lakes. Geochim. Cosmochim. Ac., 180, 177-196, https://doi.org/10.1016/j.gca.2016.02.019, 2016.

Longo, W.M., Huang, Y., Yao, Y., Zhao, J., Giblin, A.E., Wang, X., Zech, R., Haberzettl, T., Jardillier, L., Toney, J., and Liu, Z.: Widespread occurrence of distinct alkenones from Group I haptophytes in freshwater lakes: Implications for paleotemperature and paleoenvironmental reconstructions. Earth Planet. Sci. Lett., 492, 239-250, https://doi.org/10.1016/j.epsl.2018.04.002, 2018.

Longo, W. M., Huang, Y., Russell, J. M., Morrill, C., Daniels, W. C., Giblin, A. E., & Crowther, J.: Insolation and greenhouse gases drove Holocene winter and spring warming in Arctic Alaska. Quat. Sci. Rev., 242, 106438, https://doi.org/10.1016/j.quascirev.2020.106438, 2020.

van der Bilt, W. G., D'Andrea, W. J., Bakke, J., Balascio, N. L., Werner, J. P., Gjerde, M., and Bradley, R. S.: Alkenone-based reconstructions reveal four-phase Holocene temperature evolution for High Arctic Svalbard. Quat. Sci. Rev., 183, 204-213, https://doi.org/10.1016/j.quascirev.2016.10.006, 2018.

van der Bilt, W. G., D'Andrea, W. J., Werner, J. P., and Bakke, J.: Early Holocene temperature oscillations exceed amplitude of observed and projected warming in Svalbard lakes. Geophys. Res. Lett., 46, 14732-14741, https://doi.org/10.1029/2019GL084384, 2019.

Wang, Z., and Liu, W.: Calibration of the $U_{37}^{K'}$ index of long-chain alkenones with the in-situ water temperature in Lake Qinghai in the Tibetan Plateau. Chinese Sci. Bull., 58, 803-808, https://doi.org/10.1007/s11434-012-5527-y, 2013.

Reviewer 2

Reviewer: Richter et al. present a revised and nicely improved manuscript, with the major accomplishments of the manuscript in place from the initial submission and many of my primary concerns from the original manuscript addressed. In particular, I find the modified discussion around the seasonality of the alkenone proxy to be very clear and convincing, given the available calibration data.

Response: Thank you for taking the time to review our manuscript and for your feedback

Reviewer: While I would suggest some further revision for clarity, my criticisms of the current manuscript are mostly minor and I recommend the manuscript for publication:

One of the primary conclusions reads as that increasing winter-spring insolation over the common era drove significant cold-spring warming at VGHV. However, the lake model they generate shows very little ice-off date/water temperature response to the amount of winter-spring insolation change over the common era. While this model does show a strong response to temperature, they haven't really explained how that change in insolation could drive that kind of temperature change (do they attribute the trend then to local feedbacks? Other climate process? driven by insolation). In my opinion, it would improve the manuscript if the authors are able to explain this aspect of their interpretation in very clear way. On this point, I find the discussion around drivers of climate around Iceland and the NH (section 4) somewhat meandering. It was a little bit of a challenge for me to tease out the important take-aways, and I think the section could be improved with a little bit of restructuring for clarity and flow.

Response: Thank you for pointing this out. To improve the clarity of our discussion, we decided to split section 4.1 into two different discussion sections. The first section (now 4.1) focuses on regional drivers of seasonal climate change in Iceland, and in particular how this impacts our study site and what implications this has for the interpretation of our proxy record. The next section (now 4.2) aims to put our record into the context of broader changes in seasonal climate changes observed in the NH both during the Holocene and the last 2,000 years.

Reviewer: -Given the qualitative nature of the proxy, I am somewhat unconvinced that relatively small trends outside of the long-term warming trend are climatically meaningful. The authors dedicate a good amount of text to discussing multi-decadal to centennial scale trends (section 4.2) but do not put these into the context of error on the proxy (are these changes larger than the error on any of the calibration data? Even if they are, can we trust that error range in a region that has no local calibration data?). It strikes me as an unnecessary and under supported component of the paper. It seems to me like it would be a better use of available space to clearly explain why, if the primary driver is insolation, from 0-400 CE does not seem to actually track with winter-spring insolation.

Response: We thank the reviewer for bringing this to our attention. Although we are unable to quantify the amplitude of temperature change in our record, the U^{K}_{37} index is known to be sensitive to changes in temperature in NH lakes on millennial and multi-decadal timescales (see sections 2.3 and 3.3). The variability observed in the U^{K}_{37} index in our record falls well outside the analytical uncertainty of the alkenone standard that was measured throughout our analyses ($\sigma = 0.0040$, n=28). Therefore, after correcting for species-mixing affects, we assume that temperature is the only environmental factor that will lead to significant deviations in the U^{K}_{37} index. We added the following sentences to section 2.2:

"An alkenone standard was injected twice every 8 to 10 samples to assess the analytical precision of the alkenone measurements. The standard deviation for the calculated U^{K}_{37} index (see equation 1) was 0.0040 (n = 28)." (section 2.2, lines 100-102)

We modified the text in section 3.3 as follows:

"Despite these differences, the U^{K}_{37} index is known to be highly sensitive to temperatures in NH lakes and both the millennial and multidecadal variability in our U^{K}_{37} index exceeds the range of our analytical uncertainty. We assume that, after correcting for species mixing, there are not environmental parameters other than temperature that affect our U^{K}_{37} record, and we therefore use the U^{K}_{37} index to infer and evaluate qualitative changes in temperature trends and variability during the past 2,000 years." (section 3.3, lines 281-285)

We use section 4.3 (formerly section 4.2) to discuss the variability of the U^{K}_{37} index in the context of forcings that are important in the North Atlantic region and to compare our record with existing summer and mean annual paleoclimate records. We have shortened section 4.3 and modified the text to focus on larger climate anomalies during the last 2,000 years and discuss how these are manifested in our record and offer a possible explanation as to why we observe cooling or warming during these time intervals. To address your point concerning the observed cooling between 0-400 CE followed by warming in our record, we have added the following sentences to section 4.3 as a possible explanation:

"The heterogenous temperature response in the North Atlantic region could be associated with a strengthening of the SPG between c. 200-400 CE, resulting in increased oceanic meridional heat transport to Northern Europe and colder SSTs near southern Iceland (Miettinen et al., 2012; Moffa-Sánchez and Hall, 2017). After c. 400 CE there is evidence of increased salinity and warming SSTs south of Iceland, that are associated with a gradual weakening of the SPG and contributed to a return to warmer temperatures in our VGHV record (Thornalley et al., 2009; Moffa-Sánchez and Hall, 2017; Moreno-Chamarro et al., 2017). A weaker SPG after c. 400 CE would also result in cooler Nordic waters and contribute to the cooler climate conditions observed in Northern Europe c. 500-650 CE (Miettinen et al., 2012; Helama et al., 2017; Moffa-Sánchez and Hall, 2017)." (section 4.3, lines 420-427)

Reviewer: And finally, a note to the authors to check the caption on Fig. 5 prior to final publication.

Response: Thank you for pointing this out. We fixed the caption in Fig. 5.

References

Helama, S., Jones, P. D., and Briffa, K. R.: Dark Ages Cold Period: A literature review and directions for future research. Holocene, 27, 1600-1606, https://doi.org/10.1177/0959683617693898, 2017.

Miettinen, A., Divine, D., Koç, N., Godtliebsen, F., and Hall, I.R.: Multicentennial variability of the sea surface temperature gradient across the subpolar North Atlantic over the last 2.8 kyr. J. Clim. 25, 4205-4219, https://doi.org/10.1175/JCLI-D-11-00581.1, 2012.

Moffa-Sánchez, P., Born, A., Hall, I. R., Thornalley, D. J., and Barker, S.: Solar forcing of North Atlantic surface temperature and salinity over the past millennium. Nat. Geosci., 7, 275-278, https://doi.org/10.1038/ngeo2094, 2014.

Moreno-Chamarro, E., Zanchettin, D., Lohmann, K., Luterbacher, J., and Jungclaus, J.: H. Winter amplification of the European Little Ice Age cooling by the subpolar gyre. Sci. Rep., 7, 9981, https://doi.org/10.1038/s41598-017-07969-0, 2017.

Thornalley, D., Elderfield, H. and McCave, I.: Holocene oscillations in temperature and salinity of the surface subpolar North Atlantic. Nature, 457, 711–714, https://doi.org/10.1038/nature07717, 2009.