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Interactive Comment

Interactive comment on "Glacier response to North Atlantic climate variability during the Holocene" *by* N. L. Balasacio et al.

Anonymous Referee #3

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The manuscript "Glacier response to North Atlantic climate variability during the Holocene" by Balascio et al. uses a simple proglacial lake system in southeastern Greenland to asses whether small glaciers throughout the North Atlantic region advance and retreat synchronously, suggesting that climate forcing was similar throughout the North Atlantic. The study concludes that after brief advances, likely in response to early Holocene cool events, small glaciers in southeastern Greenland retreated to their minimum extents from 7.8 to 4.1 ka, constraining the local Holocene Thermal Maximum. This study also concludes that glaciers and ice caps on southeastern Greenland, Iceland, and Baffin Island advance and retreat synchronously on centennial timescales during the late Holocene.

The authors choose an ideal site for this study, a simple system with minor non-glacial allochthonous inputs to the study lake, and use proxies (grain size and magnetic susceptibility) that are generally accepted to represent glacier activity, especially in a simple system such as this. The new approach of using ITRAX data and principal components analysis is interesting, but yields slightly different results than the other more 'proven' methods, and still contains variability during a period when the glaciers are interpreted to be small or absent. The data support the broad conclusions, but a few details would be good to clarify, described below. Overall, this manuscript represents a strong contribution to the paleoclimate community. This manuscript addresses a relevant question, within the scope of Climate of the Past, and is well written, so I recommend this for publication as long as some moderate comments, described in more detail below, are addressed.

Holocene Thermal Maximum:

p. 2019, lines 22-24: this study "...refines previous estimates for [the HTM] onset and termination", but does not clarify in what way these estimates are refined. Does the 7.8 to 4.1 ka HTM in Kulusuk align with estimates of HTM, as described in Kaufman et al. (2004)? It would be informative to address whether the Kulusuk data align with the body of work examining North Atlantic glacier and Greenland Ice Sheet response to early Holocene warmth (e.g., Briner et al., 2014; Funder et al., 2011; Larsen et al., 2015; Lecavalier et al., 2014; Solomina et al., 2015; Tarasov, 2003).

There is some signal and variation in the XRF PC1 data from 7.8 to 4.1 ka, so there must be some source of allochthonous minerogenic material, even though the glaciers were small or absent. What is the source of this material? Could the source be permafrost and periglacial processes? Or snowmelt and rainwater runoff? Or something else?

Interpreting centennial-scale variability after 1.3 ka:

Because small-scale variability exists in the XRF PC1 from 7.8 to 4.1 ka, when the authors assume that the Kulusuk glaciers were small or nonexistent, it is unclear to me how the small-scale PC1 variability after 1.3 ka, which is of a similar magnitude to the PC1 variability from 7.8 to 4.1 ka, can be interpreted to represent changes in glacier size. Could this variability be related to other sources of allochthonous minerogenic material?

Synchrony of glacier & climate response:

I agree with Reviewer 1 about interpreting synchrony. It could be helpful to use probabilistic methods (an example is Anchukaitis and Tierney (2012)) to determine the likelihood of synchrony between the different glacier and climate records.

Minor comments:

p. 2010, lines 6-9: Perhaps “continuous records of variations in glacier size” is more appropriate than “higher frequency variations in glacier size”: sites in the Arctic that do have early Holocene moraines (e.g., Alaska) don’t necessarily have centennial resolution.

Geochronological data:

How do the authors deal with terrestrial vs. aquatic 14C ages? There is often a reservoir effect in arctic terrestrial 14C ages, due to storage in permafrost.

Some geochron. information that is important to provide for recalculation if necessary in the future: Raw 210Pb activity data used to model the age of surface sediments. Fraction Modern for 14C measurements

p. 2020 line 19-p. 2021, line 7: It seems to me as if there are two separate mechanisms being called upon here as the main driver of glacier change: insolation and North Atlantic cooling. Right now the following two statements seem rather disparate:

p. 2020 line 20-23: “each episode of glacier advance was followed by a period of retreat. . .possible suggesting that the glaciers repeatedly grew out of equilibrium with external insolation forcing and then retreated back toward an equilibrium state”

p. 2021 line 5-7 (following discussion of synchronous ice rafting/cooling events in the North Atlantic and ice cap advances in Iceland and Greenland) “continuous records of glacier activity. . .reveal synchronous glacier response to abrupt episodes of climate change”.

These two statements are not necessarily independent from each other, but it would be helpful to clarify which mechanism is most likely causing the observed changes. Or are both mechanisms at play? This would be good to clarify.

Fig. 1: Would it be possible to add bathymetry of Kulusuk Lake? This would help clarify if there are bathymetric highs related to glacier deposition (e.g. moraines) that may have been deposited during the period studied and therefore influence the “glacial” signal in the lake sediments.

Fig. 2. What does percent sand indicate? Could it be a signal of IRD? Why is Holocene maximum percent sand not at maximum glacial extent inferred from other proxies (approx. 10 cm)?

Fig. 3: Add a, b, c labels and dashed line on PC1 indicating absence of ice.

Fig. 4: What data are yellow and blue shading based on? The Kulusuk record, or previous publications?

Figs. 4 and 5: Why use different data in Fig. 4 and 5 to represent Langjökull? Do the C/N and sedimentation rate data in Fig. 4 reveal the same patterns as varve thickness in Fig. 5?

It would be informative to show the full Holocene magnetic susceptibility record from Big Round Lake. The timing of minimum Holocene glacier extent from the Big Round Lake record is different than at Langjökull and Kulusuk glaciers, but that is interesting information, which perhaps tells us something about regional climate and glacier variability.

It seems important to mention the different glacier-lake systems shown in Figs. 4 and

5. The transport path between Kulusuk glaciers and Kulusuk Lake and Langjökull and Hvítárvatn is much shorter than the transport path between the glacier and Big Round Lake, so there could be more sediment storage and other related processes influencing the Big Round Lake record. For example, MS seems to reflect thickness of sand layers deposited in late summer, so higher MS at 1250-1300 AD is perhaps not solely due to glacier activity. Big Round Lake varve thickness was originally interpreted to represent temperature, the opposite interpretation is used here. It seems important to at least mention the differences between these sites, and to mention the difference in interpretation from the original publication.

References

Anchukaitis, K.J., Tierney, J.E., 2012. Identifying coherent spatiotemporal modes in time-uncertain proxy paleoclimate records. Climate Dynamics 41, 1291–1306. doi:10.1007/s00382-012-1483-0

Briner, J.P., Kaufman, D.S., Bennike, O., Kosnik, M.A., 2014. Amino acid ratios in reworked marine bivalve shells constrain Greenland Ice Sheet history during the Holocene. Geology 42, 75–78. doi:10.1130/G34843.1

Funder, S., Kjeldsen, K.K., Kjær, K.H., Ó Cofaigh, C., 2011. The Greenland Ice Sheet During the Past 300,000 Years: A Review, in: Developments in Quaternary Sciences. Elsevier, pp. 699–713.

Larsen, N.K., Kjær, K.H., Lecavalier, B., Bjørk, A.A., Colding, S., Huybrechts, P., Jakobsen, K.E., Kjeldsen, K.K., Knudsen, K.-L., Odgaard, B.V., Olsen, J., 2015. The response of the southern Greenland ice sheet to the Holocene thermal maximum. Geology G36476.1. doi:10.1130/G36476.1

Lecavalier, B.S., Milne, G.A., Simpson, M.J.R., Wake, L., Huybrechts, P., Tarasov, L., Kjeldsen, K.K., Funder, S., Long, A.J., Woodroffe, S., Dyke, A.S., Larsen, N.K., 2014. A model of Greenland ice sheet deglaciation constrained by observations of relative sea level and ice extent. Quaternary Science Reviews 102, 54–84. doi:10.1016/j.quascirev.2014.07.018

Solomina, O.N., Bradley, R.S., Hodgson, D.A., Ivy-Ochs, S., Jomelli, V., Mackintosh, A.N., Nesje, A., Owen, L.A., Wanner, H., Wiles, G.C., Young, N.E., 2015. Holocene glacier fluctuations. Quaternary Science Reviews 111, 9–34. doi:10.1016/j.quascirev.2014.11.018

Tarasov, L., 2003. Greenland glacial history, borehole constraints, and Eemian extent. Journal of Geophysical Research 108. doi:10.1029/2001JB001731

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