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Interactive comment on "The phase space of last glacial inception for the Northern Hemisphere from coupled ice and climate modelling" *by* Taimaz Bahadory et al.

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Review: Climate of the Past

It is 44 yrs since Molly Mahaffy and I attempted the first model simulation to test how to rapidly grow the LIS and mimic the sea-level responses during MIS5. It is also 44 yrs since, working with Dick Peltier, an effort was made to combine an integrated approach to the world's ice sheets volumes, retreat, related changes in sea level, and glacial isostatic adjustment (ICE-1). The present paper by Bahadory et al shows how far the community has come in tackling this problem. My discussion is more along the lines of a comment rather than a review, although my response is also limited by the

fact that, like many, I am not able to access my office and references. The models used in the paper grow the ice sheets vary the climate parameters—the check on the results is the estimated change in sea level. But for many readers the important point that this paper make is in section 4.4 "Brief comparison to past geological inferences"âĂŤit is indeed brief a mere 8 lines but this statement outlines the other important, indeed critical, verification of the modelled ice sheets and their expansion and retraction, that is the aerial extent of the ice sheets, a necessary but not sufficient parameter in the calculations of ice volume an global sea level. It is a call for action to the glacial geological community, however, the problems have not changed significantly since the Clark et al 1993 paper—that is the ability to provide a date on buried stratigraphic units, primarily tills, that are older than the ∼50,000 radiocarbon dating limit—this problem remains. Generally, the Early Wisconsin Glaciation is correlated with MIS4. Figure 4 is important as it shows the sea level estimates 119-105 ka, but I had a hard job distinguishing the "purple" colors; critically these estimates varying by 20 m, or equal to several Greenland Ice Sheets. It is, however, important to note that these reconstructions do not include the MIS 5d history of the Antarctic ice sheet. I will comment on four conditions that emerge from the model studies in this paper and that I have some knowledge about: namely 1) ice coverage across Denmark Strait between Iceland and East Greenland; 2) the ice bridge between West Greenland and Baffin Island, i.e. across Davis Strait; 3) the fact (their Fig. 5) that the modelled growth indicates that a large glacial lake would be dammed in southern Hudson Bay by 116 ka; and 4) the rate of ice growth versus retreat. Core MD99-2323 is at 1 km depth on the Snorri Drift just south of Denmark Strait—the core extends into MIS7 (Dunhill, 2005, PhD Univ. Colorado). The bedrock of both Iceland and East Greenland is predominantly basalt with high weight % of plagioclase and pyroxene and no quartz (Andrews and Vogt, 2020). If the strait was covered by an ice shelf/grounded ice, this would limit the export of sediment through Denmark Strait and specifically would curtail the export of quartz. A significant peak in quartz occurs at ∼106 ka (Andrews and McCave, in prep) but this is relatively minor compared to large peaks at 80 and 30-40 ka. Many glacial studies indicate that the LGM was more extensive than during the LIG so these data raise the question of what would the modelled ice extent look like during MIS4 and MIS2? It is not clear whether the ice bridge across Davis Strait was grounded or not, if it was that would mean a huge lake behind the damn and a catastrophic flood event when it was finally broken. Along the eastern coast of Baffin Island are several complex cliff sections that record the advance and recession of ice and dated as early as the late Pliocene (Refsnider et al., 2013). A re-assement of the glacial succession using a combined amino acid racemization and cosmogenic radionuclides resulted in units previously assigned to MSI 5 and MIS 5/4 to be allotted ages > 130 cal ka BP. U-series dates (Szabo et al., 1981) on marine molluscs indicated a minimum age of $\sim$70 ka for the Kogalu member compared to 160 $\pm$ 140 ka based on the amino acid/radionuclide calculations (Refsneider et al., 2013). The main point here being to stress the considerable difficulties in verifying any MIS 5d glacial configuration solely on the basis of land-based stratigraphic sequences. A solution may exist in the form of marine cores. In Baffin Bay, core HU200829016 extends back to an estimated 120 ka (Simon et al., 2012). The basal unit (MIS 5d?) is a detrital carbonate-rich unit that represents glacial erosion of Paleozoic carbonate bedrock laying on and in the Canadian Arctic Islands and Channels. This would support that the 116 ka scenario (Fig.5) but it is worth noting that calls for an LGM ice shelf in Baffin Bay are not supported by marine evidence (Jennings et al., 2019). No fine-grained (lake sediments) were noted in the core logs (Simon et al., 2014). The MIS 5d reconstructions (Fig. 5) show ice extending NE-SW across Keewatin to Ungava and across Hudson Strait, a consequence of which is that a lake is dammed in Hudson Bay, as was speculated by Adam (1976). The terrestrial record of the last interglacial south of Hudson Bay, the Missinaibi Formation, records a succession from isostatic recovery to glacial inception (Skinner, 1973). On Adam Creek, for example, Missinaibi glaciolacustrinerhythmites underlie early Wisconsinan Adam Till, which might be used to validate the situation in Fig. 5, although a) it is not known whether the glaciolacustrine sediments are extensive, and b) Adam Till indicates a flow from the Quebec/Labrador dome (Thorleifson et al., 1992), which is

contrary to the inferred ice build-up. However, the ages of the Wisconsinan sequence in Hudson Bay remains uncertain as shown by the discussion between Dalton et al (2019) and Miller and Andrews (2019). The authors note that contrary to the general pattern of sea level change (saw-toothed curve) this is not apparent in the MID 5d sea level reconstructions. It is far from clear why this should be the case as to have ice sheets advancing into fiords, straits, and marine embayments should be faced with the same issues that we see happening today, i.e. rapid calving, so it is difficult to see why the growth and decay should be more symmetrical. Global sea levels might be decreasing as the ice sheets grow but relative sea level around the ice fronts were probably increasing due to glacial isostatic loading. These comments highlight both the importance of this paper and the difficulties that validation faces in terms of the glacial stratigraphic evidence. A partial answer might lie in the use of provenance proxies (e.g. Licht and Hemming, 2017; Verplank et al., 2009; White et al., 2016) in strategically located marine cores from trough-mouth fans or ice sheet proximal deep-sea areas (i.e. Greenland, Labrador, Norwegian Seas). Dating, however, will have to rely on correlations to isotope or paleomagnetic stacks, and the absence of Antarctica in the equation will leave a question mark regardless of the outcome. The authors are to be congratulated on a paper that will give the Quaternary community much food for thought and a very difficult challenge. Some figures are too small.

References cited:

Adam, D. P. 1976. Hudson Bay, Lake Zissaga and the growth of the Laurentide Ice Sheet, Nature, 261, p. 679–680. Andrews, J.T. and Vogt, C. 2020: Variations in felsic-versus mafic-sources in the Western Nordic Seas during MIS 1 to MIS 4. Marine Geology, 424, 106164. Clark, P.U. et al., 1993; Initiation and development of the Laurentide and Cordilleran Ice Sheets since the Last Interglacial. Quaternary Sci. Review, 12, 79-114. Dalton, A.S., Finkelstein, S.A., Forman, S.L., Barnett, P.J., Pico, T., and Mitrovica, J., 2019. Was the Laurentide Ice Sheet significantly reduced during Marine Isotope Stage 3? Geology, https://doi.org/10.1130/G45335.1 Jennings, A., Andrews, J., O' Cofaigh, C., St-Onge, G. ,Belt, S., Cabedo-Sanz, P., Pearce, C., Hillaire-Marcel, C. and Campbell, C. (2018) Baffin Bay paleoenvironments in the LGM and HS1 : resolving the ice-shelf question.', Marine Geology., 402 . pp. 5-16. Miller, G.H. and Andrews, J.T. 2019. Hudson Bay was not deglaciated during MIS-3. Quaternary Science Reviews, Licht, K. J., and Hemming, S. R., 2017, Analysis of Antarctic glacigenic sediment provenance through geochemical and petrologic applications: Quaternary Science Reviews, v. 164, p. 1- 24. Refsnider, K.A., Miller, G.H., Fréchette, B., Dylan H. Rood, D.H., 2013. A chronological framework for the Clyde Foreland Formation, Eastern Canadian Arctic, derived from amino acid racemization and cosmogenic radionuclides. Quaternary Geochronology, 16, 21-34. Skinner, R. G., 1973, Quaternary stratigraphy of the Moose River basin, Ontario: Geological Survey of Canada Bulletin 225, 77 p. Simon, Q. , Hillaire-Marcel, C., and St-Onge, G. 2012: Late Quaternary chronostratigraphic framework of deep Baffin Bay glaciomarine sediments from high-resolution paleomagnetic data. Geochemistry Geophysics Geosystems DOI: 10.1029/2012GC004272 Simon, Q., Hillaire-Marcel, C., St-Onge, G, and Andrews, J.T. 2014. North-eastern Laurentide, western Greenland and southern Innuitian ice stream dynamics during the last glacial cycle. Journal of Quaternary Science 29(1). DOI: 10.1002/jqs.2648 âĂć Szabo, B.J., Miller, G.H., Andrews, J.T., Stuiver, M., 1981. Comparison of uranium- series, radiocarbon, and amino acid data from marine molluscs, Baffin Island, Canada. Geology 9, 451-457. Thorleifson, L. H., P. H. Wyatt, W. W. Shilts, and E. Nielsen. 1992. Hudson Bay Lowland Quaternary stratigraphy: evidence for early Wisconsinan glaciation centered in Quebec. in P. U. Clark and P. D. Lea, eds., The Last Interglacial-Interglacial Transition in North America. Geological Society of America Special Paper 270, p. 207-221

Verplanck, E.P., Farmer, G.L., Andrews, J., Dunhill, G., Millo, C., 2009. Provenance of Quaternary glacial and glacimarine sediments along the southeast Greenland margin. Earth and Planetary Science Letters 286, 52-62. White, L.F., Bailey, I., Foster, G.L., Allen, G., Kelley, S.P., Andrews, J.T., Hogan, K., Dowdeswell, J.A., Storey, C.D., 2016. Tracking the provenance of Greenland-sourced, Holocene aged, individual sand-sized

ice-rafted debris using the Pb-isotope compositions of feldspars and Ar-40/Ar-39 ages of hornblendes. Earth and Planetary Science Letters 433, 192-203.

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