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Climate of the Past Discussions

Interactive comment on "Freshening of the Labrador Sea as a trigger for Little Ice Age development" *by* Montserrat Alonso-Garcia et al.

Anonymous Referee #3

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Alonso-Garcia and coauthors present high-resolution sediment data from Eirik Drift off the southern coast of Greenland. They analyze the amount and mineralogy of ice-rafted debris (IRD), covering approximately the last 2000 years. The primary results are several episodes of increased deposition of IRD and an increase in hematite stained grains after about 1400 AD. This leads the authors to suggest that Arctic sea ice export strengthened and the Atlantic subpolar gyre (SPG) weakened. As a consequence, less Atlantic waters were present in Greenland fjords, changing the stability of tidewater glaciers, their calving rates and thus the amount of IRD transported to the core site. The original data is compared with several older records from the same region in the subpolar North Atlantic.

I think this study contains very valuable new data and that it is a good addition to the existing literature (Copard et al., 2012; Moffa-Sanchez et al. 2014a, Moreno-Chamarro et

al., 2016). Text and figures are mostly clear. Previous works are referenced adequately. I do not fully agree with the interpretation of the data, which is rather speculative on several occasions and likely incorrect in some aspects. I will summarize my criticism in 4 major points:

1) Several of the claims made in the discussion are not well supported by the data. In my opinion, the sediment record does not warrant statements about the stability of the calving front of Greenland glaciers. Fjord environments are extremely complex and heterogeneous in their dynamics so that no robust conclusions can be drawn from a single sediment core several hundreds or thousands of miles away. Ice-rafting occurs both during 'cold' and 'warm' episodes, for which two different and only weakly supported explanations are given. Furthermore, whether the MCA and the LIA periods really had a temperature signal in the relevant regions has not been shown in the manuscript. I think they are better characterized as high and low sea ice periods.

2) Throughout the paper, references are made to an outdated reconstruction of the North Atlantic Oscillation (NAO) (Trouet et al., 2009). It has been shown that the method of this reconstruction is flawed and that its results are not trustworthy (Lehner et al., 2012). A new and more advanced method shows very different results (Ortega et al., 2015). It is clear that "some" change in the atmospheric circulation took place at 1400 AD that led to changes in the proxy records (Trouet et al., 2009; Olsen et al., 2012), but that change is probably unrelated with the NAO. I really do not see the necessity to relate the original data of this manuscript with the NAO and thus recommend to remove this link altogether.

3) The delay between the onset of the stronger freshwater forcing at ∼1000 AD and the weakening of the SPG ∼1250 AD, as well as the further lag of 200 years before the cooling of Atlantic waters in the fjords (page 12) are not reasonable and not well supported by evidence. Present-day observations and modeling show that a slowdown of the SPG after weakening the convection in the Labrador Sea takes place within a single season or at most some few years. There is no physical reason to

assume a delay of multiple centuries. I believe the same is true for the cooling of Greenland fjords, although I do not know that for certain. I suggest the authors estimate the energy balance and fluxes to support their claim or remove this part. On a more general note, the authors seem to expect a strict determinism underlying their data, which is probably not correct. In the highly variable North Atlantic and due to the strong positive feedbacks associated with the SPG, abrupt changes can happen suddenly and in response to rather minor forcing pulses (Moreno-Chamarro et al., 2016). Not every wiggle will have an easily identifiable cause.

4) While a weakening of the SPG at about 1400 AD is consistent with findings by Copard et al. (2012), Moffa-Sanchez et al. (2014a) report more frequent changes in the strength of the gyre. How can these views be reconciled? This should be included in the discussion.

minor comments: l 77: These numbers refer to the last interglacial and are not relevant here. I think the mechanism is reasonable and should be kept, but either specify that these percentages are for a different climatic period or remove them.

l 95: Say when this shift occurred.

l 137: Add a reference.

l 146: How can robustness be claimed when the key publication by one of the co-authors has not even been submitted?

l 215: This argument is not convincing. If the westerly winds prevented dust from being transported upwind to the sedimentation site, they would also have avoided dust from reaching Greenland glaciers as well. However, the climatological wind direction is irrelevant here, because volcanic eruptions are usually short-lived events and dust is transported in the direction of wind at that time. It can not be ruled out that a volcano erupted during a week of predominantly easterly winds, even though that may be the less common situation.

l 229: In this paragraph, I was quite confused whether the individual statements referred to glacier ice or to sea ice. Please be more explicit.

l 246: This argument shows that while the small recent variations in Arctic sea ice export correlated with the NAO, large anomalies in export probably have a different cause, like the GSA. Maybe sea ice during the LIA was thicker in the Arctic and so more ice (volume) was exported without a faster flow? This view would be consistent with findings from Miller et al. (2012) and Lehner et al. (2013). Also, I am unsure whether the manuscript discusses the impact of freshwater forcing from sea ice.

l 358: A more detailed study on this effect is Born et al. (2016).

References (not already included in the manuscript): Lehner et al. (2013), Amplified inception of European Little Ice Age by sea ice-ocean-atmosphere feedbacks, Journal of Climate 26, 7586-7602 Born et al. (2016), Transport of salt and freshwater in the Atlantic Subpolar Gyre, Ocean Dynamics (online), DOI: 10.1007/s10236-016-0970-y

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