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

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Response to Reviewer#2 on “Freshening of the Labrador Sea as a trigger for Little Ice Age development” by Montserrat Alonso-Garcia et al.

We would like to thank John Andrews for his interest in our work and his insightful comments about ice-rafting issues. In order to provide context to our replies, the referee’s comments have been copied below preceded by “RC” and our replies are preceded by “REPLY”.

RC

I read the paper with considerable interest. I would make two comments to start: 1) I have worked on the “upstream” issues of ice-rafting and sediment provenance

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Discussion paper

for nearly 3 decades hence feel reasonable confident to comment on the paper (e.g. Andrews and Jennings, 2014), and 2) I was a co-author on the 2013 Alonso-Garcia et al. paper.

The basic premise behind the paper is that changes in the amount and source of icerafted material (IRD) explicitly contain information about changes in the flux of freshwater, hence can potentially provide information on deep water formation. This premise requires that the proxy provides an unambiguous signal linked to freshwater exports, and of course the link is that the IRD is exported to the Erik Drift either in icebergs or in sea ice. The paper provides no information on the chronology other than to say it is discussed in a paper that is listed as "in press" but it is not in the reference list. It is also important, in my view, to state what has been used for the ocean reservoir correction and was an error attached to the value? This issue limits how well the chronology can be defined, hence the reliability of correlations with other records. It is a difficult issue that bedevils all of us (see ref. to Sjerup et al. 2010, their ref list). The authors note that Jennings et al (2014) were not able to identify a specific Icelandic tephra in the last 1 cal ka or so, hence it is difficult to constrain the possible ΔR.

REPLY

We decided to publish the chronology in this article since it may be published before the one cited in the text (Kleiven et al in prep). We obtained a total of 12 accelerator mass spectrometry (AMS) 14C dates, based on the calcareous shells of the planktonic foraminifera Neogloboquadrina pachyderma (sinistral). The dates were analyzed on the Accelerator Mass Spectrometer at the Leibniz Labor für Altersbestimmung und Isotopenforschung in Kiel, Germany. Radiocarbon ages have been converted into calendar years using the CALIB (rev 5.0.1) software (Stuiver and Reimer, 1993) in conjunction with the Marine04 calibration dataset (Hughen et al., 2004). All dates were calibrated with a constant surface reservoir age of 400 years. The sample at 0 cm showed erroneous age because of severe addition of more than 100% modern carbon (pMC) and is assumed to be post-AD 1962 (relative to the increase in bomb radiocarbon levels in the North Atlantic region). The core was collected in 2006 and the Cesium spike in 210Pb in the upper 12 cm of the core sediments confirms post-AD 1964 age. A table with the uncorrected 14C ages and calibrated ages is provided in the revised version.

RC

I feel quite strongly that there needed to be more discussion on rationale for choosing the > 63 μm fraction as an IRD signal (Andrews, 2000). I think the only really unambiguous IRD grain-size signal are clasts > 2 mm (Grobe, 1987), although a solid case can be made for a $\geq$ 250 μm. When the fine sand and greater fractions are being identified, especially on a Drift, then I think an initial analysis should include the entire grain-size spectra (Prins et al., 2002) as this, typically, indicates IRD as a distinct hump at the coarse end of the grain-size spectra.

REPLY

In this case, we wanted to compare our IRD records with Gerad Bond's records and therefore we chose the 63-150 μm fraction, as he did for his publications. Bond's technique (Bond et al., 1997) was robustly tested using several multicores in the polar-subpolar region and it was compared to counts in the >150 μm fraction. We acknowledge that grains >250 μm are the best fraction to claim transport by icebergs and sea ice because wind and deep currents can be ruled out. Unfortunately, the study interval does not contain enough grains of this fraction to develop a sound analysis, not even a preliminary one to show trends in the IRD, we will probably need larger amounts of bulk sediment to perform a decent count of IRD >250 μm. Even though it has been suggested that within the 63-150 μm fraction some grains might be transported by other means (see discussion in (Andrews et al., 2014)), given the location of the study site (in the outer part of Eirik Drift) we think meltwater plumes are very unlikely and deep currents hardly transport sediments >63 μm, and therefore we can assume the 63-150 μm fraction we studied is mainly composed of IRD grains.

RC

I also note that there is no discussion on iceberg history (e.g. (Bigg, 1999; Bigg et al., 2014; Bigg and Wilton, 2014)) or on sea ice, especially the export of the "storis" (Schmith and Hanssen, 2003).

REPLY

This will be added to the discussion, thanks for the suggestion.

RC

Finally, the discussion of the provenance of the > 63 μm fraction might have usefully identified (on their Fig. 1?) the major tidewater ice streams/glaciers of SE/E/NE Greenland and have referenced the likely annual flux (km3/yr) versus that of sea ice, this would help in trying to establish provenance. For example, coal outcrops in the area of Nansen Fjord, East Greenland, and it has been recorded in sediments on the inner shelf (Jennings, person. Commun. 2010) but I am not sure if this was stated in any of her publications. The issue of the source(s) HSG is an important one given the attention it achieved through Gerard Bond's work. The most probable source is the Devonian outcrop ca 73°N, NE Greenland (Larsen et al., 2008) in the area of Kasjer Franz Joseph Fjord. Several cores were taken from this area during a Polarstern cruise (Evans et al., 2002; Hubberten and al., 1995; Stein, 2008) although evidence for significant IRD output over the last millennium is muted and the number of tidewater glaciers on the outcrop is limited.

REPLY

Figure 1 was modified to show the main tidewater ice streams we refer in the text: Helheim (H), Kangerdlugssuaq (K), Nansen (N), and Scoresby Sund (SS).

This discussion is very interesting, particularly regarding to the HSG sources, which is one of the main evidences here to show Arctic ice export. The relative abundance of coal is significantly low and we decided it was not solid enough to discuss possible sources, plus there is not much work done with this type of rock, and therefore, we may be missing important sources. About the HSG sources, indeed in Alonso-Garcia et al. {Alonso-Garcia, 2013 #1646}, we showed the potential sources within Greenland, and we also suggested the potential input from Arctic sea ice transporting HSG from Northern Greenland and Canada as well as from the Svalbard-Franz Josef Land region.

We are extending the discussion in order to provide a more solid context for our hypothesis about the linkage between Arctic ice export and HSG deposition.

References

Andrews, J. T., Bigg, G. R., and Wilton, D. J.: Holocene ice-rafting and sediment transport from the glaciated margin of East Greenland (67–70°N) to the N Iceland shelves: detecting and modelling changing sediment sources, Quat. Sci. Rev., 91, 204-217, 2014. Bond, G., Showers, W., Cheseby, M., Lotti, R., Almasi, P., deMenocal, P., Priore, P., Cullen, H., Hajdas, I., and Bonani, G.: A Pervasive Millennial-Scale Cycle in North Atlantic Holocene and Glacial Climates, Science, 278, 1257-1266, 1997.

Interactive comment on Clim. Past Discuss., doi:10.5194/cp-2016-80, 2016.

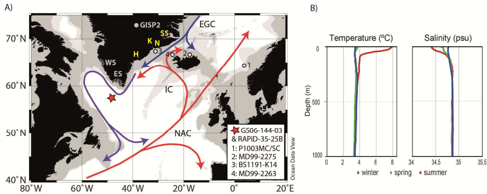

Figure 1. A) Location of multicore GS06-144-03 (red star) and other sites in the Northern North Atlantic whose records have been used to support the hypothesis proposed in this work. General North Atlantic circulation is shown according to Schmitz and McCartney (1993). The location of Norse settlements in Greenland is shaded and indicated with ES (Eastern settlement) and WS (Western settlement). The location of the main tidewater ice streams at present in SE Greenland is also depicted: Helheim (H), Kangerdlugssuaq (K), Nansen (N), and Scoresby Sund (SS). B) Temperature and salinity profiles of the first 1000 m at site GS06-144-03 obtained though Ocean Data View (http://odv.awi.de/en/home/) from the World Ocean Atlas 2013 (Locarnini et al., 2013; Zweng et al., 2013).

Fig. 1. Revised version of figure 1

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