

## ***Interactive comment on “Stratification of surface waters during the last glacial millennial climatic events: a key factor in subsurface and deep water mass dynamics” by M. Wary et al.***

### **Anonymous Referee #1**

Received and published: 25 June 2015

Wary and co-authors present a study combining various proxy records to understand hydrographic changes during the millennial-scale climate oscillations of the last glacial period in the northern North Atlantic. The paper shows interesting new data and concepts that are interesting for the paleoclimate community and merit publication. However, the paper needs major revisions before it could be accepted for publication in *Climate of the Past*.

First of all, a manuscript should focus on the new data produced and added to the already published data. Thus –as far as I can tell– the methods and results sections should purely focus on the planktonic foraminifer derived records and on the grain size data. The dinocyst reconstructions have been published previously and should

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therefore only be integrated into the discussion. Deleting the dinocyst-relevant text from the methods and results section will also shorten the manuscript.

One of the major problems of the paper is that it is treating the planktonic foraminifer reconstruction data as indicator for subsurface water conditions. Currently, I, as a reader, can support this assumption only for the  $\delta^{18}\text{O}$  and  $\delta^{18}\text{O}_w$  data because those two values are truly related to the living/ calcification depth of *N. pachyderma* (s), although the authors never mention which depth range they assume the *N. pachyderma* (s)-derived data reflect [the authors could include the following reference to strengthen their interpretation on a regional level: Peck et al. 2008. Millennial-scale surface and subsurface paleothermometry from the North East Atlantic, 55-8 kyr BP. *Paleoceanography* 23, PA3221, doi:10.1029/2008PA001631]. For the temperature reconstruction the authors are referring to a publication by Eynaud et al. (2013) that for most readers (including me) is impossible to access. Because the manuscript does not mention from which water depth the modern analog data for the Eynaud transfer function is, I can currently not support the statement of the authors that the planktic foraminifer derived temperatures are subsurface temperatures. Most modern analog files for planktic foraminifer reconstructions are for a water depth of 10 m – the same depth as used for the dinocysts transfer function. Even if the planktonic foraminifers themselves might live over a wider depth range, by using the transfer function you relate all the information to the water depth provided by your modern analog data, i.e. 10 m???. In case the Eynaud et al. (2013) modern analog database is for a water depth deeper than 10 m not only the water depth chosen needs to be clearly stated but there should also be some additional information provided on why that exact water depth was chosen and how reliable reconstructions for the chosen water depth are in the region of the study area. See for example: Telford, R.J., Li, C., Kucera, M., 2013. Mismatch between the depth habitat of planktonic foraminifera and the calibration depth of SST transfer functions may bias reconstructions. *Clim. Past* 9, 859-870.

In the methods and results, the authors list biodiversity indices/data. What is impor-

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tance of this data is for the current study? The data are mentioned nowhere in the discussion and thus treated by the authors themselves as not relevant. I therefore recommend deleting this data from the paper.

Issues related to “stratigraphy”: 1) I recommend using GI as abbreviation for Greenland Interstadials because for the scientists from the ice-core community GIS stands for Greenland ice sheet. GI is also used within the INTIMATE community and the nomenclature of GI/GS (e.g., Rasmussen et al., 2014 in QSR “A stratigraphic framework for abrupt climatic changes during the Last Glacial period. . .”).

2) The interval marked for Heinrich event 3 is too broad. Normally, only the last cold phase is linked to H 3 (e.g., Hall et al., 2011 for a nearby record). With the broad interval used by the authors they are including a Greenland Interstadial = GI 5.1 (e.g., Rasmussen et al., 2014) into H3 and it is therefore not astonishing that they see a three-phased pattern in their paleoclimatic records.

3) H 2 timing: the general view is that Heinrich events precede a GI (e.g., Bond et al., 1993; van Kreveld et al., 2000; Hall et al., 2011). So H 2 should directly precede GI 2 and not fall into the middle of GS 3 as marked by the authors in their figures and previously by Caille et al. (2013). Grousset et al. (2000) showed that deep-sea cores from the European margin recorded an earlier event with European-sourced IRD (and thus in the strictest sense is not a Heinrich event) that sometimes is referred to as H 2.2. So from the timing in relation to the NGRIP record the authors seem to have marked and are discussing this older H 2.2. event and not H 2 per se. However, looking at the % *G. bulloides* record shown in Fig. 2 I am not sure if there is not a problem in the core’s age model. Normally, I would contribute the % *G. bulloides* peak following the marked H 2 interval to GI 2. Thus in the paleoclimate records the H 2 level might be correct; it is just too old in relation to the NGRIP chronology. To clarify this issue the authors might try to align their % *N. pachyderma* (s) record with those shown Austin, W.E.N., Hibbert, F.D., Rasmussen, S.O., Peters, C., Abbott, P.M., Bryant, C.L., 2012, The synchronization of palaeoclimatic events in the North Atlantic region

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during Greenland Stadial 3 (ca. 27.5 to 23.3 kyr b2k). *Quaternary Science Reviews* 36, 154-163.

Issues related to the modern (past) oceanography: 1) I recommend using the term of ISOW = Iceland Scotland Overflow Water instead of NSOW. ISOW is the term used by oceanographers and includes contributions by both the Norwegian Sea Deep Water and the intermediate/deep waters formed north of Iceland. I would like to see a reference to a modern oceanography study included in the reference list on page 2082 line 5. It would also be important to mention that only a minor part of the ISOW exiting through the Faeroe-Shetland Channel crosses the Wyville-Thompson ridge (see Hansen and Østerhus 2000) and therefore affects the core site. This aspect is highly important for the past records when convection in the Nordic Seas was reduced or shallower and thus the overflow potentially weaker.

2) Terminology: the authors use several time the phrase “Atlantic inflow” in relation to the NAD but this is not correct for the location of their core site. Inflow refers to the waters entering the Nordic/Norwegian Sea and thus to the Atlantic water current north of the Faeroer islands.

3) Convection: for the discussion of the past hydrographic conditions the authors are also mixing up regions or convection depths. Modern and likely GI deep convection took place in the Nordic Seas and thus way north of the studied site and not above/close to the site as implied by the text and the schemes in Fig. 6. Nowadays, the site is, however, located at the northern edge of the area where subpolar mode (central) water is formed/convected (see for example Brambilla, E., Talley, L.D., Robbins, P.E., 2008. Subpolar Mode Water in the northeastern Atlantic: 2. Origin and transformation. *Journal of Geophysical Research* 113, doi:10.1029/2006jc004063), but this an subsurface/intermediate depth water mass. On the other hand, the Rockall Plateau south of the core site is the area indicated where deep convection might have taken place during the last glacial maximum (e.g., Sarnthein et al., 1994, Changes in east Atlantic deepwater circulation over the last 30,000 years: Eight time slices reconstruc-

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tions. *Paleoceanography* 9, 209-267. or Gherardi, J., Labeyrie, L., Nave, S., Francois, R., McManus, J.F., Cortijo, E., 2009. Glacial - interglacial circulation changes inferred from  $^{231}\text{Pa}/^{230}\text{Th}$  sedimentary record in the North Atlantic region. *Paleoceanography* 24, doi:10.1029/2008PA001696.) So overall, the authors need to be more precise in indication how deep and where the convection took place they are mentioning in the discussion.

4) you cannot per se assume that the NAD was also present/flowing over/near your core site, in particular during Heinrich events and may be some of the GS. The NAD as a surface current might have been diverted to the south, i.e. towards the area(s) where deep convection took place, by the expanded subpolar gyre. Thus I would be very careful to use the term intensity in relation to a paleo-NAD. It might also be good to give evidence from cores along the NAD flow path or along the British margin (such as Hall or Peck papers) to support a NAD presence throughout the intervals discussed. The subsurface Atlantic inflow seen by Rasmussen and co-workers does not necessarily have to be a subducted NAD but could also be in the form of a mode water –although we currently cannot distinguish this in the past. So I am currently not sure if the water mass signals (NAD vs/plus meltwater) as outlined in the top paragraph of page 2094 are fully correct or not –but this also goes back to the water depth reconstructed with the planktic foraminifer transfer function. Based on the modern oceanographic conditions around Greenland I would associate iceberg-calving with fresher surface waters and thus the existence of a halocline.

Additional comments in order of page numbers: 1) in the abstract and following pages it should be “the Faeroers/ Faeroer Islands”

2) page 2080 top: the base of the Holocene was defined as 11.65 ka BP or 11.7 b2k in Walker et al. (2009; Formal definition and dating of the GSSP (Global Stratotype Section and Point) for the base of the Holocene using the Greenland NGRIP ice core, and selected auxiliary records. *Journal of Quaternary Science* 24, 3-17.) so the top age for the glacial period should be adjusted to 11 ka BP at minimum.

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3) page 2080, 2082 and 2091 the word “preconized” does not exist in English; at the bottom of page 2082 it should be “combined with”

4) page 2085 paragraph on  $\delta^{18}\text{O}_w$  calculation: the correction of  $-2.5^\circ\text{C}$  was introduced to adjust for the 10 m depth estimate for the planktic foraminifer transfer function based temperatures. So if the modern analog temperatures used by Eynaud et al. (2013) would be from a deeper water depth, this correction might no longer be valid.

5) page 2088: following the genotype analyses *N. pachyderma* (d) is now referred to as *N. incompta*.

6) page 2090: header should be changed to Deep-water proxies

7) page 2093 line 8: substitute “comforts” with “supports”

8) page 2096 line 23: I assume you mean “shallower” instead of “deeper” AMOC

9) page 2098 a) line 13: NAD re-intensification or being present again? b) line 14: you don't have a surface halocline; do you mean “near surface”? c) line 15 ff: what depth of convection do you mean? Mode water or deep water??? You get density increases with colder temperatures and higher salinity; so even if your water might be “too warm” they could have a higher salinity that could allow convection. Anyhow for the GI this whole process takes place in the Nordic Seas and you can therefore not use evidence –but there is data out there from the Nordic Seas that you can refer to. In line 19: heat exchange between what? Surface and subsurface? Surface and atmosphere (thus enabling atmospheric cooling)? For the GS/HS did you think about that some of the bottom current evidence might be related to an Atlantic-sourced water mass? Hansen and Østerhus mention on page 167 that in your study region a large Atlantic water component was observed. So if you would have deep convection over the Rockall Plateau, could that water not influence your site as well? In particular, if convection in the Nordic Seas was diminished and thus the overflow?

10) page 2100 line 13: add “water” after “fresh”

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11) page 2102 line 4 ff: is there evidence for this from any of the cores along the British ice sheet margin? E.g. papers by Peck; Hall; Knutz; Austin etc.

12) figures 3 and 5: add arrows indicating direction of salinity change for  $\delta^{18}\text{O}_w$  data and increase in LLG. Mention in legends when data is shown on reversed scale (such as  $\delta^{18}\text{O}$  N. pachyderma (s)).

There are additional minor language mistakes throughout the text that a spell/grammar check of the manuscript should pick up.

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Interactive comment on Clim. Past Discuss., 11, 2077, 2015.

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