

Interactive comment on “Holocene trends in the foraminifer record from the Norwegian Sea and the North Atlantic Ocean” by C. Andersson et al.

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We would like to thank Elizabeth Levac and an anonymous reviewer for their careful review and helpful comments. Our responses to the individual comments are listed below.

Comments from Reviewer I (anonymous):

The first comment addresses concerns that the sub-surface reconstructions are based on transfer function estimates rather than Mg/Ca estimates and that it would have been relevant to including results from different foraminiferal species. We agree that Mg/Ca data from MD95-2011 would indeed have improved the manuscript. We are currently seeking funding for performing Mg/Ca analyses in MD95-2011, but cannot

C1248

at this stage include any data Mg/Ca into the manuscript. Additional data of this kind are crucial for future reconstructions and comparisons of the evolution of sub-surface water masses in the North Atlantic and the Norwegian Sea. However, to date, the only foraminiferal-based SST estimates that are available from MD95-2011 are from transfer functions. Reviewer I points out that changes in the thermocline, which are likely to have occurred, may alter the relationship between surface temperature and foraminiferal population changes. We believe that the good agreement between the geochemical records from MD95-2011 and the transfer function estimates strongly suggest that the foraminifer faunal assemblage changes at MD95-2011 reflects environmental change at sub-surface depth. Due to the ability of planktic foraminifers to change depth habitat, there is always a risk that any environmental changes may be reconstructed incorrectly, both by faunal and geochemical methods. For example, the centennial to millennial scale changes in salinity south of Iceland (suggested to be the response to southward advances of the polar front and subsequent surface freshening) could, as suggested by Thornalley et al. (2009), be underestimated if *G. bulloides* migrated to a deeper, more saline environment. We have, as Reviewer I suggested, included the *G. inflata* record from RAPID-12-1K in Figure 3 and expanded the text accordingly.

Third comment from Reviewer I address the need to provide a critical assessment of the ocean component of the model used in the data-model comparisons. We appreciate the need for this, and have provided more extensive references to the model and model evaluation. However, we are also providing several new figures comparing of modelled and observed data, so that this data is more accessible for the readers. Besides having some problems resolving currents around Greenland, the model behaves well. We suggest that this model evaluation is added to the manuscript as an Appendix.

Reviewer I finally points out some technical corrections. These comments are greatly appreciated and we have made corrections accordingly.

Comments from Reviewer II (Elisabeth Levac):

C1249

The first and fifth comments concern the usage of terms such as “Holocene thermal maximum” and “early to mid-Holocene optimum”, and whether these are separate events or if the different terminology stems from temporal differences. These two terms are often used interchangeably in literature. The term early to mid-Holocene is perhaps a more appropriate term to use since the Holocene Thermal Maximum refers to a punctual event, which is indeed time transgressive, as Reviewer II points out. The time transgressive nature of many records is clear when comparing the records in Figures 2A, 2B, and 2C. We have tried to be consistent and have used the term “early to mid-Holocene” rather than Holocene Thermal Maximum in the manuscript.

Page 2083: the somewhat confusing statement about the thermal optimum in Canada, has been corrected.

Page 2085: We have added references to the Maximum Likelihood Method (ter Braak and Looman, 1986; ter Braak and Prentice, 1989; ter Braak and van Dam, 1989) in the methods section.

Page 2085: boundary conditions for the pre-industrial is AD 1750, not 1780. This had been corrected in the text.

Page 2085-2086: Yes, the records have been compared visually. Statistical tests to check how similar these types of records are highly sought after, but not included in any of the papers published recently on similar subjects as the current manuscript (e.g. Came et al., 2007; Jansen et al., 2007; Farmer et al., 2008; Thornalley et al., 2009). In general, these types of statistical tests are often lacking from many paleoenvironmental studies and this aspect should be more focused on. Recent, European initiatives (i.e. Past4Future that we are participating in) deals with interglacial climates. This project will be focusing on acquiring more new data and on comparing and synthesizing marine paleorecords from the Holocene, which will enable these types of more rigorous statistical testing.

Page 2091: We see that the description of the depth habitat of *G. bulloides* may be

C1250

misleading, as pointed out by Reviewer II. The habitat of *G. bulloides* in the eastern North Atlantic is restricted mostly to the upper 60 meters (Schiebel et al., 1997). The term “near-surface living (or even surface living) is perhaps too haphazardly used by foraminiferal experts to describe species with a depth habitat mainly restricted to the mixed-layer or at least depth above the thermocline. South of Iceland the mixed layer is deep during winter (60-700 m) and shoals to about 50 m during summer, when *G. bulloides* is assumed reproduce in the northeastern Atlantic (Ganssen and Kroon, 2000). In the eastern Norwegian Sea the winter mixed-layer is slightly shallower, but the summer mixed-layer depth is the same as south of Iceland, i.e. about 50 m (e.g. Levitus, 1994). We have tried to clarify the depth habitat and, hence, the signal *G. bulloides* represents in the manuscript.

Page 2093 and 2094: Reviewer II asks for more information on melt-water and its effect on surface currents. Indeed, melting was still occurring in the early Holocene and this had an effect on organisms living both at the very sea-surface (see for example the recently published paper by Berner et al., *The Holocene* 20(2), 2010) and organisms such as foraminifera with sub-surface depths habitats (e.g. Thornalley et al., 2009). From a foraminifera point-of-view, Mg/Ca data is needed to resolve questions related to melt-water properly. However, seas-surface salinity reconstructions from transfer function estimated based on dinocysts have been published by e.g. Solignac et al., *Quat. Sci. Rev.*, 2004; Solignac et al., *Paleoceanography* (21), 2006 and Solignac et al., *Can. J. Earth Sci.* (45), 2008. These papers present reconstructions of Holocene sea-surface conditions, including salinity, from different sites across the North Atlantic. We have expanded on this in the text, since it is important for interpreting the trends in the data included in the manuscript, especially for the early Holocene.

All technical corrections suggested by Reviewer II have been incorporated into the manuscript.