Clim. Past Discuss., 9, C1333–C1337, 2013
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Climate of the Past
Discussions

CPD
9, C1333–C1337, 2013

Interactive Comment

Interactive comment on “Long-term variations in Iceland–Scotland overflow strength during the Holocene” *by* D. J. R. Thornalley et al.

D. J. R. Thornalley et al.

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We thank Reviewer 2 for their positive comments and suggestions, which have helped improve our manuscript. Below we provide our response to specific queries and comments raised.

REVIEWER 2: General comments The manuscript presents estimates of the strength of the Iceland Scotland Overflow (IS) by analysing the grain size of "sortable silt" (SS) in 13 sediment cores located South of Iceland, which are grouped into four depth intervals, and a "stack" of all intervals. The SS stack suggests increasing I-S overflow during early Holocene with a maximum at _7 ka and a gradually declining overflow strength thereafter. Simulated deep convection from a set of transient Holocene climate model experiments is found to be in general agreement with the reconstructed trends. In the simulations a late Holocene shoaling trend of deep convection is related to an increase in sea-ice in the Nordic Seas. This relationship is also discussed in context with the projected future decline in Arctic seaice.

I enjoyed reading this manuscript. The meridional overturning strength exhibits a huge spread in climate simulations of the past and future and the I-S overflow is an important component of this complex. The presented data are valuable to constrain the millenial scale variability of the I-S overflow throughout the Holocene. Both, text and figures are mostly clear and understandable and the method seems to be generally suitable. I recommend the paper to be accepted for publications in "Climate of the Past" with minor revisions outlined below. Title: OK

REVIEWER 2: Abstract The result that the axis of I-S overflow seems to be shallower in the early Holocene should be incorporated. REPLY: Added to revised version.

REVIEWER 2: 1. Introduction: p. 1629, ll. 16-20: Here a reference to the detailed review in "previous studies" sections would be helpful, otherwise this citation seems too unspecific. REPLY: OK, added.

REVIEWER 2: p. 1629 ll. 27/28 I would recommend to distinguish here between data and modelling studies REPLY: OK, added.

REVIEWER 2: 2. Previous studies Maybe some more literature on how I-S overflow relates to wind forcing and density on the sill would be helpful. REPLY: We have added a short comment on the mechanisms driving I-S overflow and refer the reader to the work of Hansen and Osterhus (2001) and Olsen et al 2008 who examine variability and driving mechanisms of the overflows.

REVIEWER 2: 3. Proxy reconstruction of I-S overflow strength p. 1632, l.20 Fig. 1 should be referenced here. It is nicely illustrating the different stacking strategies which were considered- otherwise the subsection about the sensitivity tests is the only place where it is made clear that the "stack" is not only an unweighted average of all cores.

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REPLY: We agree, and have added the reference to figure 1 and a brief mention to the different stacking techniques.

REVIEWER 2: p. 1633, l. 22 this is misleading as it suggests that an unweighted average of all cores was taken. REPLY: OK. We have reworded noting our weighted stack (and additional alternate stacking approaches)

REVIEWER 2: p. 1634 l. 5 what is the difference of sortable silt and silt? REPLY: Sortable silt is defined as the 10-63 ïĄ■m size silt, which behaves non-cohesively as individual particles. Finer material aggregates. Silt is the 2-63 ïĄ■m size range. (Definition added to revised manuscript.)

REVIEWER 2: 4. Results and discussion p. 1636 l. 22: unnescessarily ambiguous: is velocity reducing from _8cm/s to _6.5cm/s or is the reduction _8cm/s to _6.5cm/s ? REPLY: OK, clarified. It is reduction from ∼8 cm/s to ∼6.5 cm/s

REVIEWER 2: p. 1638 It would be disirable to provide some information on the meridional overturning in LOVECLIM: How is meridional overturning strength changing during Holocen? Is convection depth tightly related to meridional overturning strength?

REPLY: We have added the following information to the revised manuscript: In the LOVECLIM simulations, the AMOC strength is reduced by 20-30% in the early Holocene due to the impact of the melting LIS and GIS, consistent with the reduction in Nordic Seas convection depth shown in Figure 6b. However, after 7 ka, the AMOC strength remains relatively stable unlike the convection depth that is decreasing. This stable AMOC strength implies that convection activity increased at locations outside the Nordic Seas, such as the Labrador Sea, similar to the results reported by Renssen et al. (2005).

p. 1639/1640 The LOVECLIM simulation should be discussed with reference to other, state-of-the-art IPCC models. In particular the strongly diverging sensitivities of meridional overturning to IPCC scenarios should be mentioned.

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REPLY: have added the following information to the revised manuscript: Compared to state-of-the-art general circulation models, the modern maximum AMOC strength of 24 Sv simulated by LOVECLIM is at the higher end of the spectrum. However, the AMOC's sensitivity to future greenhouse gas forcing scenarios in LOVECLIM is comparable to that of other models (Weaver et al. 2012).

Additional reference Weaver, A.J., Sedlacek, J., Eby, M., Alexander, K., Crespin, E., Fichefet, T., Philippon-Berthier, G., Joos, F., Kawamiya, M., Matsumoto, K., Steinacher, M., Tachiiri, K., Tokos, K., Yoshimori, M., Zickfeld, K., 2012, Stability of the Atlantic meridional overturning circulation: A model intercomparison. Geophysical Research Letters 39, L20709, doi:20710.21029/22012GL053763.

REVIEWER 2: p. 1641 The main axis of flow changes strongly in the early Holocene but not so much after 7 ka. Can this indicate that Early Holocene I-S overflow change was thermohaline driven while after 7 ka it was (also) wind driven?

REPLY: As mentioned in response to Reviewer 1 (Fagel) there is some hint that shoaling of the I-S overflow may have occurred during the late Holocene, possibly in response to the shoaling of deep convection caused by freshening of the Nordic Seas, although the errors limit our confidence in this assertion. In which case, this seems analogous to the early Holocene.

However, the shoaling is less marked than the early Holocene. This may be related to the very different circulation regime of the high latitude North Atlantic during the early Holocene (until ∼7-8 ka), when there was significant freshwater input from decaying glacial ice-sheets. There appears to have been a weaker subpolar gyre allowing warmer, more saline (and denser) subsurface water to penetrate the region south of Iceland, as well as weak or absent Labrador Sea Water formation (Hillaire-Marcel et al 2001), with a greater contribution of dense SSW. Both these processes will have altered the density structure of the water column south of the G-S ridge and therefore possibly contributed to a shallow I-S overflow during the early Holocene. The proxy records suggest that similar late Holocene changes were smaller in amplitude. Therefore the shallow I-S overflow during the early Holocene may have been caused by the various effects of deglacial melt water input, superimposed on changes in I-S overflow strength driven partly by convection changes in the Nordic Seas.

However, we also welcome the reviewer's suggestion regarding wind forcing, which certainly warrants inclusion in our revised manuscript. Given the inability of the intermediate complexity model to accurately represent small-scale processes such as the I-S overflow we are unable to assess this hypothesis in the model simulation. We also do not have comprehensive and reliable proxy datasets for reconstructing past wind patterns (not withstanding isolated records such as Greenland ice-core dust records (O'Brien et al 1995), or Iceland loess records (Jackson et al 2005)) with which to assess whether the mid-late Holocene weakening of I-S overflow strength was wind driven, although work by Rimbu et al (2003) based on North Atlantic alkenone SST records suggests a possible shift through the mid-late Holocene to lower NAO/AO index conditions which may have contributed to the decline in I-S overflow. We therefore identify this as a subject to be explored in future studies.

We include a brief summary of these points in the revised manuscript.

REVIEWER 2: p. 1640 l. 10 remove bracket REPLY: OK

REVIEWER 2: References: OK Figures: p. 1650 correct to "map of core sites" REPLY: OK

Interactive comment on Clim. Past Discuss., 9, 1627, 2013.