Clim. Past Discuss., 8, C2054–C2057, 2012
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Climate of the Past Discussions

CPD

8, C2054–C2057, 2012

Interactive Comment

Interactive comment on "Model sensitivity to North Atlantic freshwater forcing at 8.2 ka" *by* C. Morrill et al.

Anonymous Referee #2

Received and published: 25 October 2012

Morrill et al. compare the sensitivity of the large scale ocean circulation, surface air temperature and precipitation to a large freshwater perturbation in the western North Atlantic, simulating the 8.2 ka event. The discussion focuses on four experiments from three coupled climate models of varying complexity and briefly compares these simulations with paleo proxy data. Based on this analysis, the authors conclude that a) large-scale anomaly patterns in temperature and precipitation are qualitatively reproduced by the models, b) the magnitude and duration of the anomalies are too small, and c) neglecting boundary conditions like the remnant Laurentide ice sheet and a continuous small freshwater flux associated to its melting does not significantly alter the results, at least in one of the models.

The manuscript is well-written and sufficiently illustrated. The research question concerning the sensitivity of the Atlantic Meridional Overturning Circulation (AMOC) is interesting and important, and while AMOC intercomparison studies have been carried out in the past, they mostly concerned hypothetical scenarios and not the 8.2 ka event. However, the discussion of results remains largely descriptive and concentrates on a few broad-scale similarities between models, while potentially more insightful differences are not discussed in detail. This is partly due to an unsatisfactory consideration of related work. As one example, the analysis does not take into account recent advances on the interaction of the large scale horizontal (gyre) circulation with the imposed freshwater anomaly. This is unfortunate given the mostly high quality of the model simulations. Data quality is clearly insufficient in the case of ModelE-R, for which only decadal averages are shown, with inconsistent reasoning.

Major concerns:

1) Only decadal averages are shown for ModelE-R instead of annual averages for all the other models. This is motivated by large decadal variability (p3953, l29) and the availability of model data (caption of fig. 2). Regarding the first point, I strongly feel that the same data frequency should be shown for all models. A temporal filter can be applied to deal with low-frequency variability as has been for the other models. The reader should be given the opportunity to judge for himself. If indeed annual output was not kept in the original simulation, the authors should be able to re-run it with reasonable effort. They have the expertise as one of the co-authors has published with ModelE-R in the past and given the very low resolution of the model the simulation of 200 years can not take more than a couple of hours on a modern desktop computer.

2) The discussion of circulation changes is limited to the AMOC. Several recent studies demonstrated that changes in the deep ocean circulation can not be fully understood without addressing the routing of the freshwater anomaly by surface currents. Condron and Winsor (2011) showed that more freshwater is entrained in the Atlantic subtropical gyre with higher spatial model resolution, a theory that could easily be tested in the present study. Proxy data (Lewis et al., 2012) and a coarse resolution model (Born et

al., 2010) suggest that a sizable portion of the freshwater volume did reach the Nordic Seas. In addition to the modification of the freshwater pulse by the surface (gyre) circulation, this latter study also concludes that the subpolar gyre circulation reacted to the forcing, speculating that this might have contributed to the onset of Labrador Sea deep convection. I suggest to include figures for mixed layer depth and barotropic stream function for all models.

3) Partly related to this previous point, the discussion of the role of Labrador Sea deep convection is confusing and probably too brief. What exactly causes the different response in LOVECLIM compared to ECBilt-Clio if the two models are virtually identical? Did the background freshwater flux in CCSMall shut down Labrador Sea deep convection? The motivation for CCSMog was that it was more like ModelE-R in terms of boundary conditions but would it not be worthwhile to analyze a second version of ModelE-R with Labrador Sea convection in order to compare it to CCSM3? I think this is important to discuss since Labrador Sea deep convection started at about the time of the 8.2 ka event (Hillaire-Marcel et al., 2001) and has been associated with the freshwater pulse (Born et al., 2010).

Minor comments:

p3951, l8: "...Earth system models of..." - "system" missing

p3952, l24: "pre-industrial" - with lowercase "i"

p3953, l9: "Global mean ocean..." - please include a reference.

p3955, l12: "...it appears that then a significant amount enters the Greenland-Iceland-Norwegian Seas..." - This can not be seen in the figure. Has it been quantified?

p3955, l21: "Areas of positive SSS ... are caused by the cessation of the 0.05 Sv background meltwater flux..." - Can this be quantified? This statement seems highly unlikely given the weakness of the freshwater flux and the large positive salinity anomaly. Since the subpolar front and the North Atlantic Current are also located in this region, a shift of the current provides another plausible explanation. The analysis of changes in the barotropic stream function can clarify this question as well as some of the issues mentioned above.

p3956, l19: subscript "all" and "og" misplaced

the reference for the following citations is missing (not a comprehensive list): Hoffmann et al., 2012; Winsor et al., 2012; Morrill et al., 2012.

References: Born, A. and Levermann, A. (2010), The 8.2 ka event: Abrupt transition of the subpolar gyre toward a modern North Atlantic circulation, Geochemistry, Geophysics, Geosystems 11, Q06011 Condron, Alan and Winsor, Peter (2011), A subtropical fate awaited freshwater discharged from glacial Lake Agassiz, Geophysical Research Letters 38, L03705 Lewis, C.F.M., Miller, A.A.L., Levac, E., Piper, D.J.W. and Sonnichsen, G.V. (2012), Lake Agassiz outburst age and routing by Labrador Current and the 8.2 cal ka cold event, Quaternary International 260, 83-97

Interactive comment on Clim. Past Discuss., 8, 3949, 2012.