Climate of the Past Discussions

Clim. Past Discuss., referee comment RC1
https://doi.org/10.5194/cp-2021-180-RC1, 2022

Comment on cp-2021-180

Anonymous Referee #1

Referee comment on "Climate and ocean circulation in the aftermath of a Marinoan snowball Earth" by Lennart Ramme and Jochem Marotzke, Clim. Past Discuss., https://doi.org/10.5194/cp-2021-180-RC1, 2022

The authors present an analysis of coupled GCM simulations of the aftermath of a snowball Earth event, with an emphasis on the ocean response including the consequences of the melting of continental ice sheets and sea ice/glaciers and the resulting fresh water layer that is expected to develop over the ocean. This seems to be the first GCM study of the process, the problem is very interesting, the analysis very well done, and the writing is especially clear, including of the model description, analysis, and the implications of the results. Some minor comments are suggested below, and I recommend the paper for acceptance after a minor revision.

Specifics:

The motivation in terms of cap carbonate formation, effects on ocean life, comparison with previous estimates of the de-stratification timescale of the fresh water layer is very helpful and well written.

The model description is especially helpful. The authors seem to have identified all weaknesses in their experiment design, anticipated all possible caveats/criticisms and addressed them very well. As part of this they discuss the coarse atmospheric and oceanic resolution, flat ocean topography, the unavoidable arbitrariness of the vertical mixing scheme that is addressed by sensitivity experiments, inability of the model to simulate full-thickness ice layer that is addressed via a readjustment of the salinity stratification upon melting of sea-ice to 35% area extent, the inability of the model to represent sea ice/glacier dynamics for a thick ice cover (sea ice dynamics is appropriately turned off then, leaving only the thermodynamics active), our incomplete knowledge of CO2 after snowball events that is addressed via 3 different sensitivity scenarios, and more.

Figure 2: perhaps show also the overturning for the fully glaciated state (and the

temperature and salinity for both states), so that it can be compared with the following simulated times shown later.

Figure 3: may want to show sea ice instead/also in units of thickness/equivalent sea level, volume seems less easily interpreted here.

I agree with the authors that their circumpolar current is a weak point, and that this is a result of the flat topography. A mid-ocean ridge across the circumpolar opening would indeed have helped. It seems to me that the authors address this deficiency reasonably well in their analysis and discussion.

The thick snowball sea ice cover is sometimes referred to as sea glaciers, to distinguish it from the very different present-day sea ice. I don't know that this terminology is necessarily better than sea ice, admittedly.

Lines 240-245: Interesting finding of distinct MOC cells in the freshwater and salty layers.

Figure 5: given the focus on stratification/re-stratification, it would make sense to show the temperature and density too. Perhaps another column of panels for temperature, with density contours over both temperature and salinity.

Around line 255: the density is not shown, but sloping and then vertical circumpolar salinity contours suggest that the circumpolar current is initially baroclinic and then mostly barotropic once adjusted, likely a result/artifact of the flat bottom as the authors mention. Is it? The relevance of this baroclinicity is mentioned below.

Section 6: nice analysis of the overall warmth of climate and a useful comparison to previous studies.

Lines around 320 and 395: a very important and helpful discussion of the de-stratification timescale, and its causes, and a useful contrast with previous 1D vertical model results. This seems one of the highlights of this work. A comment on this: the important part is not the strength of the circumpolar current but its baroclinicity, given the thermal wind balance: drho/dy~du/dz. The sloping iso-halines shown at some stage of the deglaciation suggests a baroclinic current and later barotropic. The sloping lines should help the de-stratification process. Would be interesting to compare the top-to-bottom vertical shear in the circumpolar current simulated here vs in present-day and thus the implications on the sloping isolines of salinity and their contribution to the destruction of the fresh water layer.