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Earth System Dynamics Discussions

Interactive comment on "A conceptual model of oceanic heat transport in the Snowball Earth scenario" *by* D. Comeau et al.

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We would like to thank Reviewer #1 for the helpful and insightful comments on the manuscript.

Major Comments 1. We certainly appreciate the importance of atmospheric heat transport in the global energy budget and climate system. Our modeling approach for the atmosphere was to simply provide a parameterization to express the net forcing of the atmosphere on the ocean and ice system, which was done through the radiative balance forcing in the effective emissivity parameter ϵ. Including atmospheric heat transport explicitly would require additional state variables of temperature at some atmospheric level, and then additional coupling parameterizations to the ocean and ice state variables of interest, which were the primary focus of the study. The Held &

Suarez reference is certainly an appropriate one to include in the discussion of our model's bistability. The response of the ocean circulation in the bistability experiments shown in Figs 7 & 8 also responded with a hysteresis loop (with the exception of Figure 8b), though it is a good point to also depict the associated ocean heat transport in these figures, which can be done in the revision.

2. Our hemispheric setup is similar to that of Griffies \& Tziperman 1995, from which we get the reference hydraulic constant k. The comparison is just to state that our results are in a reasonable range, and we explore the model's sensitivity to this parameter governing the circulation strength in Section 4.

3. Convective instability at the ocean ice interface is a small scale process well below our model's resolution, and the role of the boundary layer parameter D is precisely to parameterize this unresolved process.

4. This is a valid point, and new figures for the global glaciation experiment at true equilibrium will be revised. The climate state in Figure 3 is changing much slower than its transition towards this state, though clearly not at equilibrium with net ice accumulation everywhere. Running the model further results in net melting in the tropics.

5. The ice edge is stabilized by ice production/melting term (Eq. 10), is sufficiently negative as to overpower any ice advancing through advection. It would certainly be worth an examination of the two competing terms that make up this equation individually - perhaps a plot showing the contribution of each, noting what happens at or just before ice edge.

6. Rather than the statement that ocean heat transport works against Snowball initiation, we clarify that an appropriate statement would be poleward heat transport works against Snowball initiation. The non-monotonic impact of D in Figure 5c can be seen as a monotonic influence on ocean circulation as switches direction.

7. Perhaps a similar hysteresis example in large ice cap regime (Fig 7, 8) with D

varying would illustrate this.

Minor comments In general we agree with the minor comments and will revise accordingly., with the exception of #2. Even though our model is zonally averaged, integrating out longitude in the insolation equation results in a much messier looking expression that seems unnecessary.

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