Clim. Past Discuss., 8, C4–C6, 2012
www.clim-past-discuss.net/8/C4/2012/

Climate of the Past Discussions

Interactive comment on "The initiation of modern soft and hard Snowball Earth climates in CCSM4" *by* J. Yang and W. R. Peltier

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Received and published: 17 January 2012

This paper is a useful addition to the literature. The authors carefully compare the performance of their new model, CCSM4, with their old model, CCSM3. They show that CCSM4 is somewhat more susceptible to global glaciation than was CCSM3, largely due to the adoption of a higher sea-ice/snow albedo in the new model.

That said, the authors fail to point out an important difference between their "soft Snowball" model and the "Jormungand" model of Abbot et al. (2011). These two models differ significantly in the percentage of the ocean covered by ice and presumably in the way that they would deglaciate. Generally, the big criticism of the soft Snowball model is that it exhibits either weak, or no, hysteresis with respect to CO2 levels; hence, it makes it more difficult to account for the presence of cap carbonates. If pCO2 does not

overshoot its orginal concentration during the recovery phase, then there is no reason that such cap carbonates should exist. The Jormungand model, on the other hand, exhibits significant hysteresis because it is much closer to a full Snowball state. The hard Snowball model of Hoffman et al. exhibits the most hysteresis, i.e., it requires the highest CO2 levels to deglaciate, because the albedo is assumed to be high everywhere.

The place where this difference matters in the present manuscript is on p. 13, line 25. There, the authors state: "In Pierrehumbert et al. (2011) and Abbot et al. (2011), it was argued that low sea-ice/ snow albedo is a necessary condition for the existence of a soft Snowball solution, which is to some degree in contrast to the results obtained using CCSM3 or CCSM4. It is found in fact that, after including an active ocean, a soft Snowball state exists in circumstance in which the sea-ice albedo may be as high as 0.60 in CCSM3 (Yang et al., 2011a) or 0.61–0.65 in CCSM4 and the snow albedo may be as high as 0.71–0.91 in CCSM4." I would argue that the soft Snowball model described here and the Jormungand model described by Abbot et al. are, in fact, qualitatively different solutions, for the reasons mentioned above.

I will make one other substantive point. The fact that CCSM4 does not predict global glaciation for reasonable Late Proterozoic solar luminosity and CO2 does not imply that global glaciation is impossible, or even unlikely. CCSM4 may be better than CCSM3, but it is not a perfect climate model, and it does not even include simulated Late Proterozoic geography. The authors are aware of these limitations, and they are careful to state their conclusions with appropriate caution. I see the utility of this paper in elucidating the differences between different versions of CCSM, not in convincing people that soft Snowballs are the right solutions.

One other minor point: Doesn't it seem weird that CO2 needs to have been only 12 times higher than today in the early Neoproterozoic, but 15 times higher in the early Cambrian when solar luminosity was higher (p. 12, line 25 ff.)? What kind of climate does CCSM4 predict under these circumstances? This might be a way to test whether

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this climate model is really appropriate for simulating the glaciations in between.

Some typos:

1. (p. 5, l. 8) “gird” –> “grid”

2. (p. 9, l. 10) “pervious” –> “previous”

Interactive comment on Clim. Past Discuss., 8, 1, 2012.