

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

### **Anonymous Referee #2**

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The recent paper pair by the authors using CCSM3, currently (as of 2012/04/09) in press in J. Climate [Yang and Peltier, in press a,b], constitutes a veritable tour-de-force in model uncertainty assessment of the role and importance of albedo feedbacks in influencing the existence of different cold climatic states as a function of reductions in  $S_0$  and/or  $pCO_2$ . The influence of snow and ice albedo, the occurrence of melt ponds, and modelled resolution of sea-ice were all explored in the context of thresholds of entry to different snowball climates and the dynamics of the climate system detailed . . .

Having written such a comprehensive first pair of (CCSM3 based) papers, the ‘worth’ of the current paper using CCSM4 is not as obvious to me as it should be, particularly given that the results are reported as ‘quantitatively consistent’ with and only ‘moderately different’ from their previous work. The current paper, in context of the very recent

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J. Climate papers, hence tends to appear as a rather narrow model version test of the main CCSM3 vs. CCSM4 cryospheric model differences. Indeed, the extensive albedo sensitivity analysis in the earlier work was explicitly carried out to address deficiencies in the cryospheric parameter and parameterization choices in CCSM3, which qualitatively is effectively going over the same ground. I don't doubt that the implications of the differences in CCSM3 vs. 4 cryospheric parameterizations (in particular) for exploring the dynamics of past systems such as 'snowball Earth' are very important to assess and present, but without additional (paleo) 'science' results, I must question whether this paper is really suitable, or rather, does it contain sufficient new paleo-orientated findings, for subsequent publication in *Climate of the Past*?

What I am missing is the next step in understanding the Neoproterozoic climate system and potential for and nature of extreme glacial states, rather than learning more about the occurrence of extreme glacials only in the \*modern\* Earth system. In particular: what is the role of continental configuration? Both the current, and previous J. Climate papers, as well as several (but not all) previous fully coupled GCM studies, start from the modern continental configuration and associated ocean (and atmospheric) circulation. At least from the ocean perspective: this is a pretty unusual world today, including a narrow almost pole-to-pole basin (Atlantic) characterized by a strong overturning and net inter-hemispheric heat transport. Even before we get to explicit reconstructions of Neoproterozoic continents and oceans: in this advanced and cryosphericly more realistic coupled model (CCSM4): what role does the distribution of continents play? E.g. what is the difference between polar and equatorial super-continent (if any) in terms of sea-ice thresholds, what is the the position, response, and influence of the Hadley Cell in cooling feedbacks? What is the importance (if any) of fragmented landmasses vs. a super-continent.

As part of such a step in exploring further model sensitivity and the importance of paleo uncertainty in boundary conditions, I would fully expect a substantive section, just like this paper, that first fully evaluates in the context of previous (vs. 3) model experiments,

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the consequences of upgrading to the version 4 model. Without this (exploring the next key boundary conditions assumptions and uncertainties), this paper is not really going anywhere new in terms of paleo understanding. I could envisage a paper similar to this being published, but there would need to be a 'part II' paper focussed on reporting substantive wholly new science findings (and they would ideally need to be considered together as a pair).

I am afraid I don't have any helpful short comments – I really enjoyed the J. Climate papers. The current manuscript is well written and a fine CCSM3 vs. CCSM4 update on the issue, but simply: is this enough on its own? I am really keen to see the authors push our conceptual knowledge of extreme Neoproterozoic glacial states further. Please!

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