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Interactive comment on "Effect of land albedo, CO_2, orography, and oceanic heat transport on extreme climates" *by* V. Romanova et al.

V. Romanova et al.

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We thank the reviewer for the recommendations. We took into account the proposed changes and in this letter we answer to the questions.

Our study concentrates on the sensitivity study of the climate to changes of the land albedo, orography, oceanic heat transport and CO2 concentration. We used some extreme and idealized configurations to investigate the climate response to the boundary and initial conditions.

Response to the major reviewer's concerns:

1.My main concern is the sea-ice model used in this study and more generally the absence of an ice albedo feedback in their model. Indeed, at p.263, they investigate the sensitivity of the ice-planet simulation. Leaving from an initial state of SST close to freezing point (hence, equivalent to a global oceanic sea-ice cover with an albedo of 0.6), their model generates a deglaciation just because of the land albedo which

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is left free to evolve. This contradicts every modeling study which clearly and cleanly demonstrates the stability of the climate once the ocean is globally ice-covered. Budyko was the first to demonstrate that with a globally ice covered ocean, due to the high albedo of the sea-ice, the Earth is completely locked in this state. The only way to initiate a deglaciation is to leave the atmospheric CO2 to increase in the atmosphere during several million years (Caldeira and Kasting, 1992). Land surface covers a third of the planet and then it is the albedo of the ocean which is the most important driver of the climate. So, maybe, their simulation has a problem with the albedo of the ocean at -1.9°C which should be at 0.6 ... It must be clarified.

Starting the experiment, the climatic state is not in equilibrium. It takes around 10 to 15 years for the meteorological fields to adjust. The albedo for sea, ice glaciers, and snow covered areas is a linear function of the surface (0.20 m over the surface) temperature (not of SST). After the 1-st year integration, the ocean areas around the equator in ExpIP_albfree and in Exp_IP are ice free. In the first case (ExpIP_albfree), the low values of the land albedo forbid more ice formation and even cause the withdraw of the sea ice to the poles. In the second experiment (Exp_IP) the high land albedo and the positive albedo feedback is the reason for the sea ice to close at the equator and this leads to a stable global glaciated state. To investigate the ice-albedo feedback we performed several experiments. We presented only two of them in the manuscript, namely the Exp_alb02 and Exp_alb08. The signal of this change was considerable high, as could be seen from Fig. 1b,c.

2.Other concern comes from the weak sensitivity of their model to the atmospheric CO2 level. How it is possible that with one ppm you do not simulate a global glaciation. The global temperature is around -7°C. Calculating the equilibrium temperature in a very simple way, it is easy to show that the Earth temperature should be around -18°C with no greenhouse gases. Once again, it is as they are no ice-albedo feedback in their climate model.

It was found that thermal response to change of the CO2 concentration is logarithmic by many studies (e.g. Budyko, 1982; Manabe and Bryan, 1985; Oglesby and Saltzman, 1990a).The response in the CO2 experiments and the logarithmic behavior of the global temperature (Fig. 5) show that PUMA performs similarly to other models. The three lowest values of the carbon dioxide are not often simulated and is difficult to compare, but they show a good linear fit also for those extremely low values of 25 ppm 10 ppm and 1 ppm in the log plot (Fig. 5). Indeed, calculating the present-day surface temperature with fixed planetary albedo and empirical values for present-day conditions and then using the Stefan-Boltzman law for calculation of the Earth's effective radiative temperature for a planet without atmosphere, subtracting these two values, the difference yields 33°C (from 15°C to -18°C). However, all the feedback related to the water vapor absorption, cloud formation and albedo feedback are neglected in such a simple approximation. The global temperature change simulated by PUMA from the present-day experiment to the experiment with CO2 set to 1 ppm, shows 24°C (from 17°C to -7°C), which we think is a reasonable result.

3.While they cite and the know up-to-date snowball Earth references, it is somehow frustrating that they do not compare their results to other model studies. I know that each modeling study differs from another, and then, the comparison is hard. But, if they carefully read the modeling papers on snowball Earth, they will figurate that their model is the warmest and the less sensitive I've ever seen to the sea-ice albedo and to atmospheric CO2 levels. They must explain why.

We do not like to compare our simulations to those of Neoproterozoic glaciations. Simulating a snowball Earth the modelers take into account the geological particularities of the Neoproterozoic period, and that is the reduced to 6% solar constant, reduced by 40% land mass, and altered land configuration accompanied by change of the orography (could be also increase in the Earths rotation rate) and so on. The Neoproterozoic set-up is completely different than our present-day set-up. Our study was intended as nothing more but a sensitivity study. We think that we emphasized more than is necessary on the snowball Earth hypothesis which could mislead the reader. Therefore, we change our motivation in the introduction part and avoid (where it is possible) the 'snowball Earth' notation. However, it is interesting to perform a simulation with a Neoproterozoic set-up, which undoubtedly will produce lower global temperatures, and compare it to the already done simulations. This could be a subject of our further research.

4.In the paragraph (3.4), the authors investigate the effect of the orography and of the CO2 on the present-day distribution of the precipitation. Even if it is interesting, I do not figure why such a part in their paper which is introduced a modeling study on global glaciation.

Even though that a big part of the study concerns global glaciation we investigate also extreme and idealized climates, e.g. Exp_glac, in which we used the LGM orography and Laurentide Ice Sheet (given by Peltier, 1994), or Exp_flat in which the orography is neglected. Analyzing winter and summer precipitation patterns we assess the movement of the ITCZ, which is very important factor for the global atmospheric circulation change.

Changes in the text: Introduction (1.): we modified the first paragraph and deleted the second paragraph, the 'snowball Earth' is replaced by 'global glaciation' in the third paragraph.

Model design (2.1): on line after the formulas (1) '... where , Ts is the land surface temperature and Ti is the ice surface temperature' is changed to '... where, Ts and Ti are the surface temperatures over land and sea-ice.'

Sensitivity to CO2 (3.1.3): the last sentence is changed to ' The dependence of the annual mean surface temperature on the log(CO2) shows a good linear approximation consistent to, e.g., Budyko (1982), Manabe and Bryan (1985), and Oglesby and Saltzman (1990a), and is valid not only for the CO2 values near the present-day concentration but also for the extreme concentrations as 1 ppm and 1440 ppm.

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Interactive Comment

Discussions (4.) We modified the first paragraph of the discussion part, reducing of the citations connected to simulation of the Neoproterozoic glaciations.

References are corrected according to the last modifications of the text.

Interactive comment on Climate of the Past Discussions, 1, 255, 2005.