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Climate of the Past Discussions

Interactive comment on "Uncertainty of the CO_2 threshold for melting a hard Snowball Earth" *by* Y. Hu and J. Yang

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This paper addresses an interesting question, namely, recovery from a hard Snowball Earth, but it is deficient on two key points:

1. First, and most importantly, the model assumes a constant, 1-bar surface pressure (as far as I could tellâĂŤI did not see this pointed out explicitly). This same invalid assumption was made by Pierrehumbert (2004, 2005), and it is the main reason why his model failed to deglaciate from a hard Snowball. When you outgas a few tenths of a bar of CO2 into a 1-bar atmosphere, the surface pressure does not remain at 1 bar. It increases! This makes a substantial difference to the amount of greenhouse warming that is predicted. I pointed this out in my review of Abbot and Pierrehumbert (JGR, 2010), referenced in this manuscript, and my comment is acknowledged in their paper

as a personal communication. What they say, actually, is that the change in surface pressure doesn't make much difference below 0.1 bar of added CO2. But what this implies, and what the figure I sent to them shows, is that it does make a big difference above 0.1 bars. The present calculation goes to 0.2 bars, and the underestimate of the greenhouse effect is significant. If I had access to the figure that I sent to Dorian Abbot, I would attach it here. Unfortunately, I'm off on sabbatical, and I don't have access to my home computer. Perhaps the authors could obtain this from Dorian.

Related issues: i) What surface pressure assumption did LeHir et al. (2007) use? This should be checked. ii) ii) (p. 132) "Indeed, further increasing CO2 results in T_Bot asymptotic to 271.35 K." This result is misleading, as it is entirely the result of the constant 1-bar surface pressure assumption. Note that the variation in surface pressure was done correctly by Caldeira and Kasting (1992). They based their EBM on 1-D calculations published by Kasting and Ackerman (Science, 1986). In that calculation (which was not for a Snowball Earth), we ran pCO2 up to 100 bar for both present and early Earth. The greenhouse effect of CO2 does not become asymptotic at high CO2 levels. Rather, it accelerates as the atmosphere becomes thicker. Venus is a good example of this phenomenon.

2. Second major point: The authors do not acknowledge the existence of a second type of Snowball Earth solution, namely, the "thin-ice" model. This model was first proposed by Chris McKay (GRL, 2000) and later elaborated by Pollard and Kasting (2005, 2006). This model, which is discussed also by Abbot and Pierrehumbert, deglaciates at a much lower CO2 level than any of the hard Snowball models. The reason is that the ice is thin in the tropics, allowing sunlight to penetrate (and thereby keeping alive the algae and subsurface biota), and also lowering the surface albedo. It is disingenuous to write a paper about the difficulty in deglaciating a hard Snowball Earth without pointing out that there is a competing model that does not have this problem.

Interactive comment on Clim. Past Discuss., 6, 1337, 2010.