Clim. Past Discuss., 6, C454–C456, 2010
www.clim-past-discuss.net/6/C454/2010/

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

Anonymous Referee #1

Received and published: 18 July 2010

In this contribution, Hu and Yang address the atmospheric CO2 level required to deglaciate an ice-covered, or hard snowball, Earth. Using NCAR's CAM3, it is estimated (through extrapolation) that approximately 1 bar of CO2 is necessary. However, the main point of the paper is that this level is highly model dependent and far from certain. Comparisons with similar runs using the FOAM and LMDz models indicate that CAM3 has a CO2 sensitivity somewhere between these two models. The higher sensitivity relative to FOAM is attributed to differences in physical parameterizations of cloud and radiation schemes, and changes in surface albedo due to snow amounts.

This work essentially supports and verifies the studies of Pierrehumbert (2004) and LeHir et al. (2007), both of which conclude that the deglacial-CO2 level is likely model dependent and sensitive to model parameterizations. In this sense, the manuscript is

not new or unique, but it does present nice insights into the reasons for the differences between FOAM and CAM3.

My concern about this manuscript is the methodology. The model setup is curious and potentially flawed. The authors state (p. 1340) that sea ice is prescribed by fixing surface temperature over ice below the model freezing point (-1.8 C). Because of this approach, low-level air temperatures asymptote to the freezing point (p. 1341, Fig. 1). Another issue is that sea ice surface temperatures can and (in the real world) do fall below -1.8 C. The surface temperature of sea ice is essentially a balance between the surface heat budget and heat diffused between the sea-ice surface and the underlying ocean (which should have a temperature near the freezing point). By specifying a sea surface temperature of -1.8 C, it is very likely that an artificial heat source has been added to the sea ice surface. This could partly explain why CAM3 is warmer than FOAM at low CO2 levels, and complicates any comparisons between the models.

Both Pierrehumbert (2004) and Le Hir et al. (2007) spinup a snowball Earth using low pCO2 levels (100 ppmv), and then use this snowball state as an initial condition for higher CO2 experiments. This method alleviates the need to prescribe a fixed surface temperature and allows sea ice to melt if conditions permit. Why didn't Hu and Yang follow this approach? (A justification is warranted.) How much does it influence their comparison with the FOAM and LMDz? Additional experiments are almost certainly required to address this.

I don't completely understand the focus on FOAM and the Pierrehumbert (2004) study. It would seem that the comparison with the LMDz model is just as important. In this sense, the paper seems unbalanced. An analysis and discussion of why CAM3 and LMDz deglacial CO2 levels differ would be very welcome.

There are two comments in the Results section that could use additional explanation. On p. 1342, "...location of the maximum clear-sky greenhouse effects also shows different meridional shifts..." On p. 1343, "...cloud layer is lifted to between 300 and

CPD

6, C454–C456, 2010

500 hPa." Presumably this is because tropospheric warming at high CO2 reduces saturation at low levels. A statement to this effect should be added.

In general the manuscript reads well. Additional editing is required in some places to fix grammatical and spelling errors, and clumsy language, for example, the first sentence of the Abstract. Also, p. 1341, "faster" should be "greater". On p. 1343, "averagely" should be "on average".

The title is more accurately "Model dependency of. . ." rather than "Uncertainty of. . .". The study doesn't quantify the uncertainty, or indicate whether any of these models are approaching the true deglacial CO2 level.

On p. 1339, it is not clear what ". . .as consistent conditions are considered" means.

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