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**Geoscientific
Model Development
Discussions**

Interactive comment on "

A new coupled ice sheet-climate model: description and sensitivity to model physics under Eemian, Last Glacial Maximum, late Holocene and modern climate conditions" *by* J. G. Fyke et al.

Anonymous Referee #1

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Summary:

This paper describes a significant advance in the coupled modeling of ice sheets and climate. The authors have coupled the Penn State University Ice model to the U.Vic. Earth System Climate Model and have carried out detailed control and sensitivity simulations of both the Greenland and Antarctic ice sheets for a variety of climate conditions (Eemian, LGM, late Holocene, and present-day). To my knowledge, these are the

most detailed global, coupled ice-sheet/climate simulations to date. The implementation of the coupling is reasonable and scientifically defensible, given the nature of the two models. In particular, the sub-grid surface-mass-balance scheme is a sensible approach for coupled modeling and is preferable to positive-degree-day methods.

The model results give a consistent message: that the surface mass balance and steady-state area and volume of the Greenland ice sheet are sensitive to modest atmospheric warming (and model biases), whereas the colder Antarctic ice sheet is less sensitive. The results are informative, although not surprising. The scientific value of the model could be significantly increased by coupling the Antarctic ice sheet to the ocean. This is a major task and would be an appropriate topic for a future paper.

The paper is well organized and clearly written, with a sufficient (but not overwhelming) level of detail. Earlier contributions are referenced appropriately. The tables and figures are clear and useful.

In summary, I recommend that the paper be published subject to the minor revisions listed below.

Specific comments:

(1) pp. 1228-1230: Please explain in more detail how precipitation and humidity are downscaled to subgrid elevation classes. The text states (p. 1230) that precipitation occurs when the specific humidity exceeds 0.85. (I assume this should be "relative humidity.") For humidity, do you assume that each elevation class has the same (large-scale) RH and scale the specific humidity based on temperature? Or do you hold specific humidity to the large-scale value and compute the RH based on temperature? For precipitation, do you use the same large-scale rate for all elevation classes, deciding based on temperature whether it falls as rain or snow? Or do you use the downscaled RH to decide whether precipitation falls?

(2) p. 1235: Please state more clearly how the ocean is treated in the part of the

domain covered by ice shelves. Does the ocean circulate in this region with the assumption that the upper boundary is the atmosphere? Or do you assume that there is an ocean wall at the shelf boundary?

(3) p. 1235: Please briefly describe how Pollard and DeConto (2009) prescribe melt rates and calving.

(4) p. 1238: How do you define AIS and GIS volumes and areas? The Antarctic continent and the island of Greenland are covered by large ice sheets as well as many small glaciers. Does the model distinguish between ice sheets and glaciers, and if so, how? If not, then the figures given in the text should be interpreted as the combined areas and volumes of ice sheets and glaciers. This could partly explain why the simulated GIS area and volume are greater than observed for the late Holocene.

A related question: In figure 8, do the plots show the entire ice-covered area of Greenland, or have you used a mask to remove small glaciers and show only the ice sheet?

(5) p. 1265: Figure 5 might be easier to interpret if plots in the lower row were difference plots (i.e., simulation minus ERA40). Similarly for Figure 6.

Technical corrections:

Title: Here and in the text, I would suggest changing “ice sheet-climate” to “ice-sheet/climate” for clarity.

Throughout the text: Numbers are written in scientific notation as, for example, 26 x 10 x 10ˆ6 instead of 26 x 10ˆ6. Please remove the extra “x 10”.

p. 1224, l. 3 No comma after “model”

p. 1225, l. 25 Change “explicitly represent” to “have explicitly represented”

p. 1226, l. 25 Delete second “closed and”

p. 1227, l. 6 Add hyphen in “present-day”

p. 1227, l. 19 I suggest “ice-sheet/ice-shelf”

p. 1227, l. 20 Add hyphen in “shallow-ice”

p. 1227, l. 22 Also in “shallow-shelf”

p. 1227, l. 25 “3D” -> “Three-dimensional”

p. 1228, l. 16 “sealevel” -> “sea level”

p. 1228, l. 27 “compared against” -> “compared to”

p. 1229, l. 15 Change “orders of magnitude” to “an order of magnitude” (given that the temperature changes involved are $\sim$20 degrees).

p. 1229, l. 28 I suggest starting a new paragraph with “Over ice sheets. . .”

p. 1231, l.1 Please define “total relief” here. I think it is the difference between the max and min elevations of the underlying ice-sheet grid cells.

p. 1232, l. 6 “is” -> “are”

p. 1236, l. 12 “FORTRAN” -> “Fortran”

p. 1238, l. 27 “is very likely” -> “it is very likely”

p. 1239, l. 11 Change “ice streams” to “outlet glaciers”

p. 1239, l. 25 “sealevel” -> “sea-level”

p. 1239, l. 27 “sealevel” -> “sea level”

p. 1240, l. 1 Add comma after “shelves”

p. 1241, l. 27 I think this is the first reference to Figure 4, but it appears after references to Figure 7. Please renumber the figures accordingly.

p. 1242, l. 12 Similarly, this is the first reference to Figures 5 and 6.

p. 1243, l. 23 Delete “that”

p. 1246, l. 15 “reverted a value” -> “reverted to a value”

p. 1248, l. 8 Delete “AD”

p. 1248, l.8 Did you really compute an Antarctic SMB of 22.2 x 10ˆ15 kg/yr? This would be 22,000 Gt/yr, or about ten times greater than observed values. Maybe the exponent should be 14 instead of 15? Similarly, the stated Greenland SMB on p. 1249 seems too large.

p. 1249, l. 24 Replace semicolon with “and”?

p. 1250, l. 21 Delete first “model”

p. 1251, l. 1 Delete comma after “heat”

p. 1251, l. 24 “a overestimate” -> “an overestimate”

p. 1252, l. 10 Insert “of” after “locations”

p. 1262 In l. 4 of caption, change “affect” to “effect”

Interactive comment on Geosci. Model Dev. Discuss., 3, 1223, 2010.