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The Cryosphere Discussions

Interactive comment on "Greenland ice sheet surface mass balance: evaluating simulations and making projections with regional climate models" *by* J. G. L. Rae et al.

Anonymous Referee #4

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The paper provides a detailed comparison of the surface mass balance simulated for the Greenland Ice Sheet by the regional climate models HadRM3P, HIRHAM5, MAR, and RACMO2. All four models have been evaluated for the recent past, and three models have been run forward to 2099 using output from global climate simulations. The authors find that MAR and RACMO2, which have sophisticated sub-models of snow physics, give the most realistic simulations of the recent past. The SMB of HadRM3P has a positive bias, mainly because of a near-coastal cold bias associated with high albedos. The HIRHAM5 SMB, on the other hand, has a negative bias, in large part because it does not include meltwater refreezing and simulates too much runoff. The temperature increase required to obtain a negative total SMB forthe ice sheet is esti-

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mated as $\sim 1^{o}$C for HIRHAM5, $\sim 2^{o}$C for MAR, and $\sim 9^{o}$C for HadRM3P. The MAR value is likely the most realistic.

A key conclusion is that high model resolution is not sufficient to yield a realistic SMB for the Greenland ice sheet. It is also necessary to have a detailed multilayer snow physics schemes that includes processes such as meltwater percolation and refreezing, snow metamorphism, and albedo evolution.

The paper is thorough, carefully written, and well organized. The authors do a good job of exploring model biases, with numbers and physical reasoning to back up their explanations. There are detailed tables and figures to support the arguments in the text. The authors have gone beyond a cursory intercomparison ("Model A says this, while model B says that") to give a reasoned assessment ("Model A gives a more realistic simulation than model B, and here are the reasons why.")

This paper will be useful for researchers interested in projecting future contributions of the Greenland Ice Sheet to sea-level rise. I recommend that it be published with minor revisions as detailed below.

Suggested revisions

On p. 2061, the authors say that an aim of the paper is to provide GrIS surface-mass-balance projections "with greater accuracy than is possible from coarser-resolution general circulation models." On p. 2062, they state that GCMs "generally have insufficient resolution to represent the orography at the margins of the ice sheets." On p. 2081, they say that "RCMs can resolve the steep topography at the margin of the ice-sheet better than GCMs, and thus produce a more realistic simulation." These statements reflect the conventional wisdom that high grid resolution is necessary for a realistic simulation of Greenland's SMB. The RCM results, however, suggest that surface physics is critical, without showing that grid resolution is equally important. For example, the MAR, HIRHAM5, and HadRMP3 models have similar grid resolution, but very different SMB simulations.

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I suggest that the authors qualify these statements, citing the manuscripts submitted recently (after the Rae et al. paper was written) by Vizcaino, Lipscomb, and co-authors to the *Journal of Climate*. This work shows that the Greenland SMB simulated by a global climate model (the Community Earth System Model, CESM) compares well with that of RACMO. CESM has sophisticated snow physics, along with a sub-grid tiling scheme for downscaling atmospheric forcing to different elevation ranges in each grid cell. The success of this approach is consistent with the findings of Rae et al. on the importance of surface physics, while suggesting that lower grid resolution can be compensated to some degree by sub-grid tiling.

On p. 2080, and again on p. 2082, the authors cite the ranges found by Gregory and Huybrechts (2006) and Robinson et al. (2012) for the temperature at which Greenland's total SMB becomes negative. They simply state that the various MAR, HIRHAM3, and HadRM3P results lie at the edge of or outside these ranges. It would be helpful they could assess whether the new RCM results (for MAR in particular) are more credible than the previously published ranges, and if so why.

As stated in Table 1 and elsewhere, RACMO was not used for simulations of the 21st century. Given that it has arguably the best SMB simulation for the recent past, I am curious to know why it was not used for the 21st century projections, and whether there are plans to use RACMO for such projections.

Figure 2 is hard to read and should be reformatted.

Some figures should be renumbered to be consistent with the order cited in the text. In the submitted manuscript, for example, Fig. 3 is mentioned (p. 2067) before Fig. 2 (p. 2068).

I noticed a couple of typos: On p. 2069, l. 29, "was" should be "were". On p. 2082, l. 23, the word "are" is missing.

Interactive comment on The Cryosphere Discuss., 6, 2059, 2012.