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Geoscientific Model Development Discussions

Interactive comment on "The GRISLI ice sheet model (version 2.0): calibration and validation for multi-millennial changes of the Antarctic ice sheet" *by* Aurélien Quiquet et al.

Anonymous Referee #1

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Overall:

This paper provides a description of the current GRISL1 ice sheet model, focusing on modifications and extensions from the previously described version in 2001. The model is designed for relatively coarse-resolution long-term paleo applications. Main change from 2001 include the specification of grounding-line fluxes (Schoof, 2007), and a basal hydrology model. A large ensemble with Latin Hypercube sampling is used to constrain and calibrate four uncertain model parameters. The paper is clear and provides useful supporting documentation for GRISL1 users and background for other papers on GRISL1 applications.

Specific comments:

1. There is considerable scatter in Fig. 7, showing pair-wise parameter correlations with the results (here, rms error in modern ice thickness). This may be because the Latin Hypercube (LHC) sampling of the large ensemble (LE) may be too coarse to meaningfully detect pair-wise dependencies. The quasi-random distribution of red, blue and green stars in these panels is reminiscent of corresponding figures in Applegate et al. (2012, The Cryo., their Fig. 1). Chang et al. (GMD, 2014) subsequently found that the scatter in the Applegate study is due to inadequate sampling in the high-dimensional parameter space, and they used additional statistical analysis with Gaussian emulation to extract meaningful dependencies (their Fig. 4a vs. 4b). That study had a similar number of parameters (5) and ensemble members (100) as here (4 and 150). In a similarly sized Antarctic LE, Pollard et al. (GMDD, 2016) found that meaningful dependencies could only be found with "full-factorial" sampling, i.e., a run for every possible combination of parameter values, requiring 5^4 = 625 runs for 4 parameters and 5 values each. If that many runs could be performed here, it might yield much more meaningful pair-wise results than in Fig. 7. However, if that would be too computationally expensive, it could be left to future work, and the above caveats could just be noted.

2. The simulations here use uniformly prescribed basal drag coefficients, and do not use an inversion method to deduce a spatial map. There is discussion on the pros and cons (pg. 6, 15, 17), which makes good points for not using inverse methods. But it does not mention the primary motivation (I think) for using them: that without them, modern errors in ice thickness are much larger (as in Figs. 5,6), and can be made much smaller using an inverse procedure. Since these errors are the primary metric here for evaluating the model, this could help to make the calibration of model parameters more meaningful. I think the whole issue depends on whether the inverse-produced map captures real bed variations at all, or if it just cancels with and obscures other physical errors in the model. I suggest mentioning this within the existing discussion. Also, the

point made on pg. 17, line 16, on the desirability of making basal coefficients a property solely of internal model parameters (such as N here, in Eq. 14), is debatable: apart from basal temperatures and water amount of course, spatial variations in basal sliding can also depend importantly on geologic bed type, roughness, and the distribution of deformable till, which are outside the scope of the model.

3. In Eq. 14 on pg. 6, and section 2.2.1 (Eqs. 24-26, pg. 9), it is not clear how some variables for basal hydrology are determined: h_w or p_w (which are related, line 24), and effective pressure N needed for Eq. 14. Presumably there is a prognostic equation in the hydrology model for h_w, i.e., d(h_w)/dt = ..., that is not shown here. Perhaps it is the equation mentioned on pg. 9, line 23. Also N possibly depends on p_w. This information, and the equation for h_w, should be included. (Incidentally, if N depends on depth below sea level as in several other models, I would question how can it reasonably depend on that, at distances 10's or 100's km inland from the grounding line).

4. The determination of buttressing factor phi_bf in Eq. 15 (pg. 7) is an important part of the use of the Schoof flux equation, but the procedure is unclear to me from lines 21-25 on that page. Perhaps the first solution provides the back-stress-free solution...does that solution use Eq. 15 with phi_bf = 1? Then what is the second solution, and where does its value of phi_bf come from? These questions may not make sense, and just show my confusion. Hopefully this paragraph can be clarified, and perhaps expanded if that would help.

5. pg. 16, lines 5 to 7: Perhaps, the timings of the deglacial retreat in AN40T vs. AN40S can be assessed vs. papers in the RAISED reconstruction volume (Bentley et al., 2014), or other data, in order to determine which one is more realistic. The paper seems to decide rather arbitrarily that the AN40T case is more realistic (pg. 18, line 25).

6. pg. 13, lines 9-10: The pairs of values "1.5 to 3" and "1.5 to 5" do not seem to relate

to the bottom-right panels in Figs. 3 and 4, for basal-drag coefficients K0 (which are being discussed in that sentence). They seem to relate better (but still fuzzily) to the bottom-left panels for enhancement factors E_sia.

Technical comments:

The English usage is generally good, but isolated words or phrases could be improved/corrected, some of which are noted below.

pg. 1, line 19: Change "are evidences" to "is evidence".

pg. 1, line 23: Change "An other" to "Another".

pg. 2, line 7: I think "prograde" should still be "retrograde", for MICI as well as for MISI.

pg. 2, line 23: The word "diffusion" should probably be removed (?).

pg. 3, line 14, and several later places: "Tab. 1" should perhaps be "Table 1".

pg. 4, line 1: The use of two "respectively"'s in the same sentence is confusing - perhaps divide into 2 separate statements for sigma_i and tau_ij.

pg. 4, line 26: Change "Alike" to "Like".

pg. 4, lines 27-29: The word "reduces" in line 27 seems to contradict the word "favour" in line 29. Or perhaps "longitudinal" should be "shearing" in line 29 (?).

pg. 5, line 24: What does "see also numerical feature" mean?

pg. 16: I would suggest emphasizing, as a positive note, that if the (interpolated) grounding line position is known, then all that is required to obtain ice thickness H_gl at the grounding line for Eq. 15 is (1) bedrock bathymetry interpolated to the grounding line position, and (2) sea level. (This is because of the floatation criterion at the grounding line of course).

pg. 10, line 23-24: Explain the need for the artificial extension (to get an ice front parallel to x or y).

pg. 11, line 20: Misspelled "projet".

pg. 12, line 15: "in 150" should be "of 150".

pg. 12, line 20: Perhaps change "are discarded from" to "are not included in" ?

pg. 14, line 6: Change "somehow" to "somewhat".

pg. 15, line 16: Does this mean that a 100-kyr long spinup is performed with perpetual modern climate for every ensemble member? If so, say that more clearly.

pg. 15, line 24: The range of 10 to 20 m eustatic sea level drop here is actually a bit larger than several recent model studies. This might be due to larger basal drag coefficients used here on modern continental shelves, so when grounded ice expands onto them at LGM, the expanded ice is thicker there.

pg. 16, line 4: Change "In turns" to "In turn".

pg. 17, line 2: "using an inverse method" sounds like one is used here. Make it clear that one is not, and that phrase refers just to the references earlier in the sentence.

Table 1: Some of these variables do not seem to be used in the text, e.g., those under "Deformation". Others may have a different name, e.g., h_till.

Fig. 2: The relationship between the sector boundaries (left-hand panel) and the contour divisions for basal melt rates (right-hand panel) is confusing, not as one might expect. That is, there seems to be some divisions between the colors in the right-hand panel that are not present in the left-hand panel, and vice-versa.

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