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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 #3

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

Summary:

This paper describes a new version of the GRISLI ice sheet model, including new model development since an earlier version many years ago (Ritz et al., 2001). While there are no major scientific advances relative to the state-of-the-art manifested with this update, documenting the current state of the model and the individual progress that has been made is well appreciated. The paper is generally well written and clear. Nevertheless, I believe there could be more detail given in some of the descriptions to

make it a better reference and make the paper more accessible for other modellers. I consequently recommend publication in GMD with some corrections as detailed below.

General comments:

I believe it is a good practice to (regularly) publish model description papers like the present one, to document the applied models, increase transparency and allow for other modellers to learn, improve upon and critically evaluate the applied techniques. One point I find regrettable with the present paper is that the authors seem to not plan to publish the model code alongside with the manuscript. I know that this may not be common practice in our community, but I believe it would be an important step forward. I would applaud if the authors would think about how to make the code publicly available, possibly with certain restrictions.

While the applied modelling techniques are mostly well described in words and equations (textbook style), the numerical implementation is often not possible to determine. I invite the authors to make an additional effort to increase the precision. This is even more important when the model code cannot be consulted. The ultimate goal should be that someone who does not know the model would be able to implement a specific feature from the given information. See also specific points below.

Reference to textbooks and earlier works is mostly in order. However, in some cases it would be useful for the reader to have some additional ('meta') information for the specific descriptions. E.g. who else is using the same technique, or does the applied technique represent a notable difference/novelty compared to other models used in the community. If other approaches exist, do you have reasons to choose this approach compared to another and why (simplicity, better results, tried other approach but didn't work ...). Again, the motivation should be to make the paper a useful reference and interesting resource for another modeller trying to implement a specific feature.

Specific comments:

P1 L14 Which time scales or time scale range, be more specific.

P1 L15 "surface albedo" is not a feedback, nor "freshwater flux". Please clarify.

P1 L18 Not sure about the connection between the two sentences implied here.

P1 L21 I would suggest rewording to avoid drastic terms "rapid" and "destabilisation".

P1 L22 "The surface mass balance-height feedback has ..."

P2 L1-3 Not all bedrock in the Antarctic shows a retrograde slope. More precision needed.

P2 L4 MISI driven retreat does not have to be very fast. Suggest removing "fast and"

P2 L7 Add "ice" before "cliff"

P2 L7 Buttressing already decreases when the ice shelve is removed and a reason for ice cliffs to fail. Reformulate.

P2 L10 What is the range of temporal and spatial scales, specify.

P2 l10 "temporal and spatial scales" of what exactly?

P2 L14 There are also state of the art models that are not FS, clarify.

P2 L19 Remove "Conversely".

P2 L21 add "e.g." before Hindmarsh

P2 L23 Reformulate "temperature and surface mass balance perturbations diffusion"

P2 L26 New sentence with "GRISLI was in the late nineties ..."

P3 L4 Not only MISI, but also GL movement in general. Reformulate.

P3 L15 "2.1 Ice thermo-mechanics". I didn't find the "thermo" aspect in this section. Reword?

P3 L21 Add equation number after "mass conservation equation".

P3 L23 "the vertically integrated velocities in x and y-direction u_x and u_y".

P4 L1 "where sigma ... and tau ... are the longitudinal and shearing stress tensor terms, respectively".

P4 15 Add an equation, explanation or reference how B_AT is calculated.

P4 L27-28 SIA and SSA are not yet defined.

P5 L5 "horizontal derivatives" and "vertical derivatives" of what? Clarify.

P6 L16 How is the water pressure defined? Add equation or reference.

P6 L25 So "beta = C*N" for temperate ice. What is assumed for the rest? Clarify.

P6 L25 I expected to get some information on how C_f is calibrated in this paragraph, maybe just a list of options that could be used, then you get back to that later.

P6 L29 Avoid use of "flux correction" as it has a specific meaning in coupling climate models. Use e.g. "flux calculation" as on top of the next page.

P7 L18-19 Here it would be good to already know how the grid is laid out. Where is the velocity defined compared to the ice thickness nodes. You later state that you are using a "staggered Arakawa C-grid", but it may not be clear to all what that implies. Could you add a clear description or figure where the different quantities are defined? This would also help in the following to explain the numerical implementation of certain schemes.

P7 L19. So the flux is imposed on two grid points in both x and y direction and applied there simultaneously? More precision is needed to make clear how to implement this.

P7 L22 Wouldn't this give back force at the places where velocities are calculated, not at the GL where it is needed?

P7 L27 Replace "Ice front" by "Iceberg" in front of "calving".

P8 L1 The section header states "Temperature coupling". There is no description of coupling in this section, only how the temperature is calculated. Maybe change title to "Thermodynamics" or "Ice temperature calculation".

P8 L2 Could give a sentence of introduction to state that this is the classic way to solve thermodynamics and similar to many other models (references). Or is there anything special here that I have overlooked?

P8 L2- Consider to give some indication on how all of this is solved numerically. How are the differential equations discretised? Which numerical schemes are used for advection and diffusion (upwind, second order, Lax)?

P10 L12 Hardly any information is shared on how the given equations are solved numerically. I believe it would make the paper a much more interesting reference for other modellers and even people in your own group if some details would be added on the practical side of the modelling.

P10 L13 More precision is needed to understand what variables are defined where on which (staggered) grid, also in the vertical. How is the vertical grid laid out? Is the order up-down or down-up? Is the first vertical grid point from the top where T is solved assumed at the boundary or representing the middle of a first layer? How is that at the base?

P10 L17 "the resolution is *reduced* to ...".

P10 L19 Replace "computes" by "uses" or "computes with". Add "which is dynamically calculated" after "(Eq.2)" or similar.

P10 L24-29 Could this be visualised for clarity?

P10 L28 How small is "small" in this context? Clarify

P11 L1 Add a reference for OpenMP.

P11 L15 Add a short overview what is coming next before going into details.

P11 L20 Add reference for ISMIP6 initMIP-Antarctica (ISMIP6 paper, website).

P12 L6 Is K0 changing the basal drag, or the basal drag coefficient? Clarify.

P12 L10 How does the BMB field keep the ice shelves stable? Clarify.

P12 L15 In my mind, the basic idea of LHS is to *sample* the hypercube and not perform all possible experiments. Maybe reword to avoid "the whole cube" if this is correct.

P12 L19 How is the low resolution data set produced from the original Bedmap2 data? Direct subsampling or smooth interpolation? This is a crucial part of preparing the input data and should be treated with detail and precision.

P12 L20 Reword "discarded from the ensemble" to "not explored in this ensemble"

P13 L12 If differences are below 500, why does the scale go to 1000 in the figures?

P13 L18 Do all these models use the same data, the same processing to get to the final input data and have similar resolution? Do you know if this is an error in the data or a problem of coarse resolution? What is different in models that do not show these features, if there are any?

P13 L20 If the last point is resolved, maybe "... suggesting a common source of error related to the coarse model resolution". Or similar to add some interpretation to this comparison.

P16 L3 How can you be sure that the parameter range is sufficient/optimal for the transient experiments? Please add a short discussion on that.

P16 L10 Maybe "post-LGM retreat"?

P17 L4 "relative to observations ... in this case, where ..." and briefly remind us what is different in the present experiments.

P17 L5 Where is the northern part of East Antarctica? polewards = south!,

north=towards the margin?

P17 L15 Inversion of what? Specify.

P17 L23 This comes a bit unexpected. Has vertical temperature been worked on in this paper? Why only the vertical?

P17 L33 "lead to a more dynamic grounding line position"

P17 L34 Has sensitivity to SL changes really been discussed in the paper?

P17 L34 Add sensitivity to sub-shelf melt rates?

P18 L11 Basal hydrology and semi-lagrangian tracking are described in "2.2 Additional features" next to other aspects that are not mentioned here in the conclusions. It may be useful to make it clearer already in the main text which of the described features are new developments in GRISLI.

P18 L26 Why does validating a model for the Antarctic give confidence to also use it for the NH. A bit more information is needed here to bridge that gap.

P18 L30 Replace "and" by "or", unless all three have to be contacted to get the model code.

Tables and figures

P26 in the middle. Replace "N.m" by "N m"?

P27 caption Table 2. Write out LHS.

P27 Figure 2. Left panel cold have additional contours to delineate the regions and a colour bar. Why does the grounding line have different melting rates than the shelf?

P29 Figure 5. Use a colour for the GL contour that does not appear in the colour map, e.g. black or dark gray.

P30 Figure 6. Same as for figure 5.

P32 Figure 8. Suggest to move the parameter values to a table or the main text.

P34 Figure 12. "materialised" –> "shown" or "indicated" Why is the GL so patchy here compared to the steady state case?

P35 Figure 13. Same as for figure 5.

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