The Cryosphere Discussions

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Comment on tc-2021-232

Samuel Kachuck (Referee)

Referee comment on "Resolving glacial isostatic adjustment (GIA) in response to modern and future ice loss at marine grounding lines in West Antarctica" by Jeannette Xiu Wen Wan et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2021-232-RC1, 2021

General Comments

The manuscript, "Resolving GIA in response to modern and future ice loss at marine grounding lines in West Antarctica" by Wan et al., addresses what computational grid is required to resolve the local sea level changes caused by solid-earth responses to changes in cryospheric loading, and how those compare to uncertainties in the solid-earth mechanisms (e.g., elastic vs. viscoelastic, poorly constrained viscosities). These questions are particularly salient for those engaged in describing and forecasting the sea level effects of changes in the cryosphere, particularly in areas, like West Antarctica, where such solid-earth feedbacks on the future dynamics of the ice are a significant source of uncertainty.

The authors find that the limiting factor for spatial resolution is the representation of the load, rather than the smoother solid-earth response, and provide a useful rule of thumb for determining what resolution is necessary to compute the elastic response of certain loads. They additionally show how uncertainties in the behavior of the mantle (in particular, the possibility of a low viscosity zone underlying parts of West Antarctica) can generate signal differences far exceeding errors caused by resolution, emphasizing how critical it is to include these processes in modeling and to encourage observational constraints of the mantle rheology.

The manuscript is well presented and I have only a handful of rhetorical suggestions to help with cohesion and flow, and one requested additional model run to resolve an apparent inconsistency in the comparison of the 3D rheologies with the 1D average rheology.

Finally, I would like to encourage the authors to release their model code source publicly, in accordance with the journal's data policy, to "guarantee integrity, transparency, reuse, and reproducibility.”

Specific comments

Comment on the 1D Viscosity: The vertically averaged GIA model you use to compare with the 3D viscosity models is for the whole of Antarctica and therefore not reflective of the viscosity underlying your region of interest (the Amundsen Sea). It makes it difficult for me to evaluate claims like the one made in Line 378 that there is a dependence on the 3D structure within the Amundsen Sea domain or in Line 404 that a 1D viscosity, rather than one with simply a long relaxation time, is closer to the purely elastic model. I appreciate that you quantify the importance of GIA from outside the Amundsen Sea (L313 and Supplemental S1) as being about 6% of the central response, and so might be hesitant to apply a lower viscosity 1D average to the globe. However, if you were to focus only on load changes in the Amundsen Sea, is there not any 1D viscosity profile or relaxation spectrum that, within other uncertainties, reproduces? This would greatly strengthen the cited arguments and the comparison you make in Figure 8.

Comment on ice dynamics and grounding lines: Though the paper’s technical scope is focused on modeling local sea level changes due to solid-earth processes, part of the justification is that these sea level processes will affect the dynamics of the ice’s grounding line, and are therefore necessary to model in tandem. I think a good place for this discussion could be surrounding the location of the grounding line under different resolutions and physical assumptions (e.g., elastic or viscoelastic mantle). And yet the final grounding lines in Figure 2, 4, 6, and 7 doesn’t appear to change at all from case to case - the variation in the sea level (almost 20 m near the grounding line in Figures 2i,f) doesn’t seem to affect where ice is floating. Is that right? In contrast, when we included the ice dynamics, we found a lag in a grounding line position of about 30 km after 100 years for a similar amount of sea level fall at Pine Island (Figure 3b in Kachuck et al., 2020). Considering this will significantly affect the resolution error near the grounding line that you show in Figure 9, and I think is worth discussing.

Line-by-line

L35: Instead of “consists of… and…”, you might indicate that a viscoelastic material’s response begins as that of an instantaneous elastic solid, and transitions to a longer-timescale viscous-like relaxation. For heuristic and analytic purposes we sometimes treat them as separable and additive.

L60: “Viscous effects due to ongoing ice loss … â□□â□□have not been included in recent high resolution coupled projections”: You could cite Kachuck et al (2020), Coulon et al.

(2021), or De Conto et al. (2021) as recent examples of coupling ice dynamics to viscous vertical land motion in projections. The first has high spatial resolution, with 500 m grid spacing near the grounding line, for projections with viscoelastic feedback of Pine Island Glacier in the Amundsen Sea Embayment. The others are Antarctic-wide and determine that the ELRA model, and modifications thereof, are satisfactory for constraining large-scale sea levels.

L246: An image of the ice load and topography would really help in understanding this description.

L255: The Scaling Factor used in Figure 3b is not introduced in the main body text and doesn’t appear again in the results focused on the Amundsen Sea. I would recommend integrating it more (see next note). Additionally, "scaling factor" is used previously to refer to the construction of viscosity profiles from seismic data (e.g., L179), muddling the usage. Another term might make this clearer.

L322: I could use more elaboration here on the differences between representing the ice load and computing the elastic response, and maybe some tie-in with the Idealized Experiments results. Is the idea that we need finer resolution for better representation of the grounding line (i.e, where the ice load disappears), but not necessarily for the smoother earth response, which is consistent with your findings in the idealized experiment? If so, could you use the Scaling Factor from Figure 3b to explain this? In those earlier experiments, though, am I right in understanding that you didn’t have any ice-ocean interaction? Does the ocean load smooth that boundary?

L353: It is hard for me to visually evaluate this statement across the different scales of the colorbars.

L369: “A viscous process” is vague. Could you specify that this is a result of assuming viscous incompressibility, or whatever other viscous consequence you are referring to?

L423: This would lead me to conclude that high resolution is not important for coupling viscoelastic deformation to grounding line motion. Do you believe that to be so? Are there conditions you can foresee in which resolution would play a larger role?

L465: Although this feedback on grounding line dynamics is not addressed in this study.

L489: see comment to L322. Clarification there will also clarify here.

Technical corrections

L136: “structure. which”

L475: “reflecting” -> “reflect”

L481: missing word in “over time our simulations”

Comments on Supplemental material

L36: The referenced plot is titled “ASE_10km-ASE_1km” rather than “ANT_10km-ASE_ANT.”

Caption to Figure S1. The grounding line appears to be a shade of green rather than the red as described in the text (which will probably be very difficult for individuals with red-green color-blindness).

Figure S2.2a) It looks like the recorded minimum of -3.21 m sea level occurs outside the domain, given the scalebar.

Figure S2.2b) max and min are written as negatives, but look on the scalebar as positive.