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The Cryosphere
Discussions

Interactive comment on "Exploring mechanisms responsible for tidal modulation in flow of the Filchner-Ronne Ice Shelf" *by* Sebastian H. R. Rosier and G. Hilmar Gudmundsson

Anonymous Referee #2

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In this study, the authors use a sophisticated 3D viscoelastic model of ice shelf flow to calculate the horizontal flow response of the Filchner-Ronne Ice Shelf (FRIS) to tidal forcing. The study is meant to be a comprehensive examination of the many theories that have been put forth to explain the large amplitude response of ice flow at FRIS at both M_2 and M_{sf} tidal frequencies, all within a single modeling framework. In this goal, I think the authors have generally been successful, and this is an impressive achievement which brings together many ideas and observations spanning the last decade or so. What is perhaps most interesting, is how many theories (including

their own) the authors are able to rule out for explaining the conundrum of the large amplitude M_{sf} signal at FRIS. This study provides what I think is a valuable "refocusing" of the conversation around low frequency tidal signals in ice shelf flow and how to explain/model them.

Though I am generally happy with the scientific content of this study, in what follows, I mainly point out some issues regarding information that is missing, information that could be condensed, and general textual edits that could be made to the manuscript.

Major points:

1. The manuscript has a narrative quality that takes the reader through the process of trial-and-error followed by the authors in eliminating possible explanations for the observations and coming to a final conclusion. This is fine and I think actually helpful to bring negative results into the literature in a way that is rarely done nowadays. That being said, the discussion in section 3.2 is often a bit cumbersome and overly detailed and will sometimes talk about the results of certain experiments (more on this in comments below) before they have been described. It would be worth it to condense the discussion on pages 11-13 a bit and spend more time talking about the details of the successful GLmigration experiments (which are currently a bit light on detail). I have a similar critique of the discussion and conclusion sections which re-hash many of the details right after they are discussed in section 3.2, these could also be streamlined to focus on what you learned from the successful simulations.
2. In all the figures (3-5) comparing modeled amplitudes to observed amplitudes, the reader must guess the correspondence by eye. This is not really feasible and doesn't permit an easy identification of spatial vs. constant-offset mismatches.

What would enable this comparison better is a scatter plot of the modeled amplitude vs. observed amplitude at the GPS sites for all simulations. This could be done by adding a single panel to each figure with markers for each experiment distinguished by color and/or marker type.

3. Overall, you do a nice job of constructing clean experiments that test the role of individual mechanisms in generating the tidal signal of interest. I think it is fair to say that you find the only mechanism which can really generate anything near the observed M_{sf} amplitudes for reasonable parameters is GL migration. But then you go off on this exploration of how you could have slightly less GL migration if you also increase the Glen's law nonlinearity. This is true, but you could also slightly boost the amplitude using many of the other mechanisms that you tried as well. The point isn't necessarily that the other processes (including a high value of n) aren't happening, its just that they likely aren't playing much of a role in generating the M_{sf} signal. I think the $n = 5$ experiment in Figure 5 muddies this point by selectively picking one of the "failed" mechanisms to bring back into the conversation. It would be better to leave it out (or to a supplement) I think.

4. When you describe the model in section 2, you specify certain choices (e.g., boundary conditions) which you later loosen or change. It would be helpful if you said up front, we set X for the default simulation, but we will loosen this assumption in later simulations. Just so that the reader is prepared to know what choices are constant across all experiments, and which are changed.

5. You do a nice job of reviewing the literature on proposed mechanisms for the FRIS M_{sf} signal early in the manuscript. However, later when you discuss the experiments you try and which are successful there is less attribution of ideas to previous studies. In particular, the idea that asymmetries in grounding line migration can produce a large M_{sf} signal through changing basal contact and pinning points was originally put forward in Robel et al. (2017). Yet there is no

discussion of what that study gets right and wrong in any of sections 3.2, 4 or 5. It would be helpful to discuss and evaluate these previous studies in more detail, as you have done for some of the other mechanisms discussed.

Minor points:

P. 1 Line 6: entire Filchner-Ronne

P. 1 Line 11: tidal ice flow response

P. 1 Line 5-11: this is a bit detailed for the abstract, perhaps compress this discussion somewhat

P. 1 Line 19: flows, on average, 21%

P. 1 Line 21: floating ice shelves

P. 1 Line 23: who is the "us" here? did you do this work?

P. 1 Line 24-25: Ice shelves are not thought to modify upstream flow, and also to have a fundamental effect on the. . ..

P. 2 Line 4: delete sentence: "Ice shelves. . .viscous processes" - more confusing than illuminating

P. 2 Line 4-5: increasing quantity of GPS and InSAR observations

P. 2 Line 8: delete "while. . .as such"

P. 2 Line 12: ones -> frequencies

P. 2 Line 12: delete "long-periodic"

P. 2 Line 14: several times in the paper you state that a nonlinear mechanism is needed to transfer tidal energy from short to long periods. Why? Readers not versed in this literature (or the idea of frequency mixing) will not find this to be an obvious statement. Could be helped by a brief explanation here of heterodyning/freq mixing.

P. 2 Line 16: models that only include elastic flexure

P. 2 Line 17: delete "with exact numbers dependent on location"

P. 2 Line 23-24: explain "the mechanical coupling between vertical ocean tides and ice flow occurs in the grounding zone"

P. 2 Line 24: our modelling and observational efforts

P. 2 Line 27: using a viscous
P. 2 Line 31: will be to replicate
P. 2 Line 34: suggested in previous studies as responsible
Figure 1: there's about 5 different types of information on this map? Are all of them strictly necessary (i.e. is elevation)? Would be helpful if you simplified.
P. 4 Line 7: constituents have the largest amplitude in this region
P. 4 Line 12: motion, but not
P. 4 Line 14: constituents, these do not rotate around an amphidromic point, and instead
P. 4 Line 22: signal and the (horizontal) ice shelf flow response
P. 4 Line 23: in the Weddell Sea, the semidiurnal
P. 4 Line 29: tidal cycle, periodically causing direction
P. 4 Line 33: diurnal
P. 5 Line 22: also these studies have shown that the M_{sf} signal occurs in the ice shelf first (using phase information)
P. 6 Line 4: processes using a X, Y, Z model
P. 6 Line 5: focus on modelling the two strongest responses observed in horizontal
P. 6 Line 13: angular momentum (respectively):
P. 7 Line 8: what does upper-convected mean in this context
P. 7 Line 5: explain the i, j indices
P. 7 Line 14: from what observation is the rate factor inverted? using what inversion approach? I know the detail is in appendix, but summarize in one sentence here
P. 7 Line 15: what are the other parameters(a table would be helpful) and how are they set. You get at these details somewhat (regarding E) later, but would be more useful here.
P. 7 Line 19: At the ice surface, a stress-free boundary
P. 8 Line 1: are u_{obs} and v_{obs} constant in time?

P. 8 Line 3: here is one place where it would be helpful to explicitly state that vertical clamping at grounding effectively prevents GL migration in the default setup, but this assumption will be loosened later on to allow grounding line migration to occur
P. 8 Line 15: interpolation is used to
P. 8 Line 5: the other benefit of only including principal diurnal and semidiurnal constituents is that you ensure that the presence of any other constituents in the ice shelf response has to do with processes in the flow and not the forcing itself
P. 8 Line 24: how do you generate the mesh?
P. 8 Line 30: this implies that the mechanisms which produce M_2 and M_{sf} flow variability are not the same. Perhaps it is worth saying this explicitly?
P. 9: Please provide more details on what you mean by "processing surface model displacements using the Tide MATLAB package"
Figure 3 and elsewhere: you often say things like "ice shelf motion" - this is really vague. Is this horizontal displacement? is it detrended? please be more specific on this
P. 10 Line 14: you refer to $RF_{streams}$ here before even describing what it is. Either do that here, or remove this reference
P. 10 Line 18: its it's
P. 11 Line 6-10: why was no M_2 signal generated in the grounding zone
P. 11 Line 13-15: delete "we start by. . .fig 4" sentence - or move down, it doesn't make sense here
P. 11 Line 20: rheology which is the source of nonlinearity in this mechanism
P. 11 Line 24-25: how can we tell the origin from the plots in figure 4? Are you relying on phase information that isn't plotted? It may be useful to say something about phasing.
Figure 4: the colorbar of observed amplitudes is inconsistent with the modeled colorbar (and pretty much every other figure). I can see that there will be a large discrepancy, but that's the point, isn't it? Also, plot observed filled circles on all

panels.
P. 13 Line 4: model assumes hydrostatic
P. 13 Line 30-35: you introduce the gammas, but don't explain how they are calculated so we have no context for what these numbers mean, or that they come from Tsai and Gudmundsson (I know its in the appendix, but since this mechanism is important for this study, its worth explaining in the main text)
P. 16 Line 2: exploring the processes and parameters that play a role in generating M_{sf} signal
P. 16 Line 11: found that the amplitude of the M_{sf} signal in observations
P. 16 Line 14: difference
P. 18 Line 5: tidal modulation

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