

Interactive comment on “Temporal variations in the flow of a large Antarctic ice-stream controlled by tidally induced changes in the subglacial water system” by S. H. R. Rosier et al.

Anonymous Referee #1

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General comments:

This is a well-written manuscript that describes a “milestone” in ice-stream research: the ability to explain the M_{sf} amplitude in the Rutford Ice Stream’s horizontal flow. Prior to this study, the notion that an ice stream could have horizontal flow variations driven by tides at the M_{sf} frequency was understood; but was not well-reproduced in models, because of difficulty reaching the high-level of amplitude. This study finally adds the key ingredient to overcome this problem: the tidally driven fluctuations in the water pressure below the ice stream, driven by water pressure fluctuations at the grounding line caused by the ocean tide is what does it.

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I have no substantial comments that would lead to clarifications, and believe the paper to be of great value and interest to the community of researchers studying ice stream phenomena.

Specific comments:

p 2398, line 10 - “tidal subglacial water pressure variations”. . . It would seem to be better to say “subglacial water pressure variations with a tidal period” or “subglacial water pressure variations caused by the tide”. . . as it is unclear what “tidal subglacial water pressure” refers to. . .

line 16 & 17 - “. . .show that the presence of tides. . .” Again, possibly being more specific might help. Tides in the ocean beyond the ice stream? Tidal variations in the subglacial water pressure?

p 2399, line 21: “provides a window into the mechanisms that. . .” I would prefer ending this phrase with “. . .mechanisms that influence basal sliding. Saying that “observing and modeling tidally-induced modulation . . . provides a window into the mechanisms . . . causing these effects” sounds sort of self-apparent, and I think the abstract, in the last sentence, has already pointed out that the value in studying this phenomena is to “see the bed”. . .

p 2300, l 4: “tidal stresses” An oceanographer might get confused by what was meant here, e.g., are tidal stresses “frictions” from the ocean water flowing on the bottom of the ocean? I think that what is meant are the variations in stress caused by all the effects of the ocean tide seaward of the grounding line.

p 2402, l 17 : Just a comment (based on my own ignorance): I think that in the present case, where the actual movement of the ice through a cycle of interest is relatively small (i.e., flow is only a few meters or tens of meters over a 14-day cycle) the upper convected time derivative may be replaced with the regular time derivative. (I have a very fuzzy idea about what the upper convected time derivative is relative to other

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types of time derivatives; and wonder what a “lower convected” time derivative would be. I should probably learn this stuff.)

p. 2403, l 13: Is there an estimate of how far the grounding line is expected to migrate (is that known from interferometry?) It is not an important detail, but the question occurred to me.

l 21: add “the” after the word “between” . . .

p. 2405, l 10-11: Why is a distinction being made between hydraulic head and (in the parentheses) water pressure. . .? Are they not the same?

p. 2405, l 16-18: Is it being said that the basal slipperiness is being “linearized”, i.e., that the tidally varying head is accommodated in an approximate way by accounting for its mean and the perturbation?

p. 2407, l 10: replace “slap” with “slab”

p. 2408, subheading 1.5: “initialisation” should be “initialization”

p. 2408: question of clarification. If only the largest 6 tidal constituents are used to force the model, is it really possible to study the M_{sf} response? Is what is referred to as the M_{sf} response simply the “harmonic beat” that is commonly referred to as the “spring to neap” tidal amplitude envelope?

p. 2411, l 2: They are not really “tidal observations” that are being matched, they are the ice-stream velocity observations that show influence of the tide. . . tidal observations are different entities: they are observations of the vertical height of the effective sea surface with time. . .

l 3: change “Mechanism” to “mechanism”

A further question of clarification: the CATs model is used to provide the tidal forcing, is the forcing expressed entirely by the change in effective sea surface elevation at the grounding line? or are other aspects of the CATs model (e.g., involving currents below

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the ice shelf out in front of the gl) involved? Finally, have the tides ever been observed at the grounding line, i.e., with an accurate GPS measuring vertical elevation changes with time? If so, how do they compare with CATs, and if not, why not?

p. 2414, l 5-6: GPS receivers that originally made the measurements. . . Is this a reference to measurements of the M_2 amplitude (tide height) at the grounding line? or is it a reference to the ice stream’s horizontal flow response at the frequency of M_2 ? It would clarify (including some of the comments above) to have a paragraph early on that lays out what GPS measurements have been taken and how they are used (this may repeat what is in other papers, but is apparently worth it to clarify this one).

l 11: should “optimised” be “optimized”

l 14: sometimes semi-diurnal is used and sometime semidiurnal is used. I think the latter is best.

l 21: no hyphen in ice-stream.

p. 2415, l 3: change re-run to rerun

l 19: ice-stream, remove the hyphen

p. 2418, l 10-11: I think that this is also suggested by Arbic et al. see:

Arbic, B. K., J. X. Mitrovica, D. R. MacAyeal, and G. A. Milne (2008), On the factors behind large Labrador Sea tides during the last glacial cycle and the potential implications for Heinrich events, *Paleoceanography*, 23, PA3211, doi:10.1029/2007PA001573.

Figure 1: y-axis label: it is not clear that horizontal displacements are plotted (surface displacement alone could be vertical).

Figure 2: I’m not sure that the term “clamp” is used in the text, so it would be useful to explain that this is a boundary condition (or condition needed to reduce dimensionality) in the caption.

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Figure 3: explain what the blue zone is and also the region of interest for the study in the caption, as a casual reader might be confused by seeing the other processes that are unrelated in the figure.

Figure 4: change "lenght" to length, also "interpolation" in the last sentence.

Figure 5: just a comment: very impressive and convincing!

Figure 6: ditto about the y-axis label as with Fig. 1

Interactive comment on The Cryosphere Discuss., 9, 2397, 2015.