

Interactive comment on “Twelve years of ice velocity change in Antarctica observed by RADARSAT-1 and -2 satellite radar interferometry” by B. Scheuchl et al.

B. Scheuchl et al.

bscheuch@uci.edu

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We would like to thank D. Vaughn for his detailed review and for the encouraging feedback on our work. We appreciate his evaluation and the specific comments. Detailed responses are provided below.

This paper presents an analysis of the differences in ice-flow velocity measured over a significant portion on the Antarctic ice sheet between 1997 and 2009 using interferometric synthetic aperture radar acquired by the Canadian satellites Radarsat-1 and -2. Several areas of apparent change are identified, on and around the Ross and

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Filchner-Ronne ice shelves. Responding to the specific questions posed to reviewers. The paper is relevant and within the scope of TC, and presents some novel data. The discussion arrives at significant conclusions (I express some concerns below), and the methods appear to be sound, and the overall presentation of the paper is logical and complete.

Thank you for the general feedback and for the positive evaluation of our work.

While, it appears that the velocity fields presented are the product of well-considered and well executed analysis, and correction for the most important confounding issues has been undertaken with care, I believe that there are two areas of the interpretation and conclusion that I do not fully support, but which could relatively easily be addressed in a revised manuscript.

We will revise the manuscript with you comments and concerns in mind. Detailed responses are provided below.

1. The radar data were acquired over 24-day satellite repeat periods, separated by 12 years, and velocity fields derived from these data are representative of these epochs. The interpretation is (implicitly) based on the assumption that the differences between these epochs are capturing persistent changes in the ice-flow over this timescale, rather than, say, shorter-term variability. I am not strongly objecting to the likely validity of this assumption, but I would like to see some effort to acknowledge, and to justify it. Ronne Ice Shelf in particular is an area of daily, fortnightly (Gudmundsson, 2006), and annual (Adalgeirsdottir et al., 2008) fluctuations.

We briefly address this issue in the discussion paper (pg 1727 line 25). Our data sets were acquired 24 days apart, which means that we measure the mean surface displacement over that period. Averaging over 24 days greatly reduces sensitivity to variations with a cycle smaller than this period. The strongest variations reported are diurnal, semi-diurnal, and fortnightly. (Gudmundsson, 2006; Adalgeirsdottir et al.,

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2008). A residual effect could be present due to annual variation (Murray et al., 2007), however, looking at Figure 2 of Murray et al. (2007) and assuming similar cycles for 1997 and 2009, both acquisition periods fall in similar phases of the annual cycle and the effect should be small.

2. A statement at the end of the abstract concerns me. "Overall, we conclude that the ice stream and ice shelves in this broad region, . . . exhibit changes in ice dynamics that have almost no impact on the overall ice balance of the region". I think this needs clarification, and may well not be justified. Surely, if there is a change in the rate of ice-flow in an ice stream, across the grounding line or ice-front, then this has to be a direct impact on the out-going ice flux, and so in that sense has a one-to-one impact on the mass-balance of that glacier basin. Whether or not the change in flux is counter-balanced or overshadowed by larger changes in snowfall is not really the issue. This entire study is aimed at determining (successfully) the magnitude of the changes in flux, but then this statement (and similar ones in the conclusions section) suggest that these are unimportant, when they are clearly part of a larger picture of stable/changing mass-balance in these glaciers. Perhaps, the authors are trying to point out that the dynamic changes they have observed are generally "second-order" effects compared to those elsewhere (Amundsen Sea embayment, etc.), and perhaps that is arguable, but that is not clear in the current text.

Our results show that dynamic changes are present in the region of interest. Central Antarctica is a region that deserves continued observation, with primary focus on Siple Coast. A 25% reduction in ice velocity of Whillans Ice Stream significantly affects the mass balance of this ice stream, a similar conclusion can be drawn for Mercer Ice Stream. Changes are significant and point to a possible shutdown of these ice streams if the trend continues. Mass balance changes of West Antarctica have shown to be driven by losses on glaciers in the Bellingshausen and Amundsen seas region and on the Peninsula (Rignot et al., 2008). We do want to make the point that the changes observed here remain relatively small compared to changes reported for other areas

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of West Antarctica.

We will rephrase the sentence in question to make our point clear.

I am certainly not calling for the dynamic changes to be "hyped-up", but I would say that the study rather clearly shows that it is not just the gross changes in the Amundsen Sea and on the Antarctic Peninsula, that are worthy of further study. Indeed, these results taken at face value show that dynamic changes are present in many other glaciers. Overall, the language used in the text is somewhat informal, and consequently, in several areas, it is not as precise as one would hope.

We appreciate your emphasis the importance of the changes observed. This will help in working with international space agencies to ensure some level of InSAR data continuity in central Antarctica going forward. Given the difficulties to collect data south of 80 degrees South, it is an important point to make.

To reduce the use of informal language, we will address all specific comments provided in a revision.

The figures are generally presented in a form that is too small to review properly. This may due to the way the authors presented the figures, or the preparation processes within the editorial offices of TCD, or possibly a function of the charging structure of the journal, but the outcome is the same – I could not see the detail on the maps that was discussed in the text.

We will remove Figure 1 as suggested in a following comment. We will present the two velocity maps of Figure 2 in one line and the difference map in a second line below this allows the panels of the overview maps to be presented larger. The TC journal format would allow the figure to be presented even bigger. Figures 3 and 4 will be divided up to present maps and graphs in separate figures. Specific comments for the map presented in Figure 4 will be addressed.

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Specific comments

The title seems to promise more than is delivered – the focus of the paper is two ice shelves and their hinterlands, and the title should really reflect that.

We will change the title to:

Ice velocity changes in the Ross and Ronne sectors observed using satellite radar data from 1997 and 2009.

Pg 1719 line 3-4 The Bamber et al. 2007 citation seems an odd choice here, (Doake et al., 2002) certainly measured it directly.

We will change the citation to Doake et al. (2002) according to the recommendation. (Page 1720 in the original manuscript)

Pg 1719 line 14 "Horizontal ice velocity is. . ." Pg 1722 line 18 "flaps up and down" is not very precise language.

Pg 1719 line 14: We will modify the paragraph to provide more information on the method as suggested by H. Fricker.

Pg 1722 line 18: We will change "flaps up and down" to "moves up and down"

Pg 1724 line 8 Were any other mammals used apart from seals? If not, why not say "seals"?

We confirmed that seals only were used (Padman et al., 2010) and will change the text accordingly.

Pg 1724 line 28 Surely this statement shows that the changes in velocity are significant to the dynamics of the entire glacier and so to the mass balance, which would contradict the last statement in the abstract.

Changes observed for Whillans and Mercer Ice Streams are significant. Please also

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see our response specifically to your comment on the last sentence of the abstract for clarification.

We will rephrase the sentence in the abstract to make our point clear.

Pg 1725 line 8 Citation to "prior studies" is missing.

We will add the missing citations:

Prior studies reported on limited discrete points up to 400 km upstream for Whillans Ice Stream and 150 km upstream for Mercer Ice Stream (Joughin et al., 2002, 2005).

Pg 1726 line 8-9 In several places the terminology makes reading very difficult, and potentially misleading. In this example... "Mercer and Whillans...experience...slow down. Their 12 yr velocity difference. . . is up to 50 m yr-1. . .". Here, a value indicating the magnitude of a slow-down would be positive, but the change/difference would be negative. Personally, if I was talking about a change, I would indicate the sign explicitly (+50 or -50 etc.) to make this clear.

We will add the signs explicitly to and carefully review our wording to ensure the recommendation is taken into account in the revision.

Pg 1726 line 20 A recent paper (Brunt et al., 2010) has been through much of this identification of uncertain and erroneous errors in the MOA grounding line.

We will include the citation to Brunt et al. (2010).

Pg 1727 line 12 "Filchner/Ronne Ice Shelves proper", this is very informal, but it is also unclear. And, Filchner-Ronne Ice Shelf is I think usually given in the singular.

We will change "Filchner/Ronne Ice Shelves proper" to "Filchner-Ronne Ice Shelf itself" and make sure to use Filchner-Ronne Ice Shelf as recommended. The term "proper" will be also changed in two more cases as well (Pg 1716 line23 and Pg 1730

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line15).

Pg 1727 line 20 Mosaicking would surely be possible, it would simply highlight the mis-match between frames.

We will rephrase the sentence in question.

"If they were artifacts, the resulting mosaic combining several tracks acquired at different times would show mis-match between the frames."

Page 1728 line 8/9 Gudmundsson and Jenkins undertook an extensive ground-based study that showed no evidence of ongoing change on Rutford Ice Stream, over (I think) an overlapping interval. I would recommend citation of that study here, both to corroborate the findings of this survey, and give due precedence to the earlier work. (Gud- mundsson and Jenkins, 2009)

We will include the citation in the revised manuscript (Gudmundsson and Jenkins, 2009).

Pg 1728 line 25 Ronne Ice Shelf!

We will change the sentence as recommended.

Pg 1728 line 25-28 I don't see how this paragraph relates to the results of this study - the connection is not made explicitly.

We will change the paragraph and provide the missing connection.

Pg 1730 " which suggest that the ice dynamics of the entire region does not have a strong impact on the mass budget of the Antarctic continent". Related to previous comments, this sentence is really not correct as written. It may be that ice dynamics (i.e. the forces that control ice flow) has not changed significantly during this short

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period, but to suggest that ice dynamics (=ice-flow) is not important is surely, incorrect. Especially, where such broad concluding statements are made, their meaning must be made quite precise.

We will change the conclusion to clarify our point. Please also see our response specifically to your comment on the last sentence of the abstract for clarification.

Figure 1 – This figure seems an excessive way to demonstrate the importance of a routine correction applied in processing. I think it could be omitted, put to supplementary text, or some other technical report – unless there is citable evidence that the omission of the tidal correction by other authors has resulted in dubious results in which case those should be cited.

We will remove Figure 1 and text referring to it.

Finally, one picky point. Hyphenation is largely ignored in the text, but one repeated example jars on me as a reader. A "12-yr" change should surely be hyphenated.

We will review the manuscript with respect to hyphenation

We will include the citations that are not already part of the manuscript and mentioned here for discussion purposes.

References

Aðalgeirsdóttir, G., Smith, A. M., Murray, T., King, M. A., Makinson, K., Nicholls, K. W., and Behar, A. E.: Tidal influence on Rutford Ice Stream, West Antarctica: observations of surface flow and basal processes from closely spaced GPS and passive seismic stations, *J. Glaciol.*, 54, 715–724, doi:10.3189/002214308786570872, 2008.

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- Brunt, K., Fricker, H. A., Padman, L., Scambos, T. A., and O'Neel, S.: Mapping the grounding zone of the Ross Ice Shelf, Antarctica, using ICESat laser altimetry, *Ann. Glaciol.*, 51(55), 71-79, doi:10.3189/172756410791392790, 2010.
- Doake, C. S. M., Corr, H. F. J., Nicholls, K. W., Gaffikin, A., Bertiger, W. I., King, M. A., and Jenkins, A.: Tide-induced lateral movement of Brunt Ice Shelf, Antarctica, *Geophys. Res. Lett.*, 29, doi:10.1029/2001GL014606, 2002.
- Gudmundsson, G. H.: Fortnightly variations in the flow velocity of Rutford Ice Stream, West Antarctica, *Nature*, 444, 1063–1064, doi:10.1038/nature05430, 2006.
- Gudmundsson, G. H. and Jenkins, A.: Ice-flow velocities on Rutford Ice Stream, West Antarctica, are stable over decadal timescales, *J. Glaciol.*, 55, 339–344, 2009. doi:10.3189/002214309788608697, 2009.
- Joughin, I., Tulaczyk, S., Bindschadler, R., and Price, S. F.: Changes in West Antarctic ice stream velocities: observation and analysis, *J. Geophys. Res. (Solid Earth)*, 107, 2289, doi:10.1029/2001JB001029, 2002.
- Joughin, I., Bindschadler, R. A., King, M. A., Voigt, D., Alley, R. B., Anandakrishnan, S., Horgan, H., Peters, L., Winberry, P., Das, S. B., and Catania, G.: Continued deceleration of Whillans Ice Stream, West Antarctica, *Geophys. Res. Lett.*, 32, L22501, doi:10.1029/2005GL024319, 2005.
- Murray, T., Smith, A. M., King, M. A., and Weedon, G.P.: Ice flow modulated by tides at up to annual periods at Rutford Ice Stream, West Antarctica, *Geophys. Res. Lett.*, 34, L18503, doi:10.1029/2007GL031207, 2007.
- Padman, L., Costa, D. P., Bolmer, S. T., Goebel, M. E., Huckstadt, L. A., Jenkins, A., McDonald, B. I., and Shoosmith, D. R.: Seals map bathymetry of the Antarctic continental shelf, *Geophys. Res. Lett.*, 37, L21601, doi:10.1029/2010GL044921, 2010.
- Rignot, E., Bamber, J. L., van den Broeke, M. R., Davis, C., Li, Y., van de Berg, W. J., and van Meijgaard, E.: Recent Antarctic ice mass loss from radar interferometry and regional climate modelling, *Nat. Geosci.*, 1, 106–110, doi:10.1038/ngeo102, 2008.

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