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Interactive comment on "A high-resolution bedrock map for the Antarctic Peninsula" *by* M. Huss and D. Farinotti

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We acknowledge the reviewer for these helpful comments. As suggested, we have reformulated parts of the Introduction in order to more realistically state the (unproven) potential of our new dataset for ice flow modelling studies. A complete uncertainty map for the entire study domain is provided in the supporting online material along with the final bedrock topography.

Below, we respond to all comments, and state how we account for them in the revised version of the paper. The responses (normal font style) to the reviewer's comments are written directly into the reviews (displayed in italic font style). The corresponding revised sentences in the manuscript are given in quotation marks, including line numbers in the revised manuscript.

The difficulty with the paper, as it stands, is that the emphasis of the work is toward providing an improved dataset for modeling: this is the argument used in the introduction. Nowhere, however, is it demonstrated, even qualitatively, that the dataset they have produced will result in more robust model estimates of ice dynamics at a regional scale.
There are two possible solutions to this. The first, which I do not recommend, is that they examine the impact of their new dataset on higher-order model simulations of ice dynamics and, more importantly, predicted evolution compared with, say, Bedmap2. The second, and more practical, is to provide a more "balanced" introduction and not to over claim or over state the potential, but unproven, value of the new dataset for modeling purposes.

We agree. In fact, we just *assume* that the new dataset will be valuable to future modelling efforts on the Antarctic Peninsula. However, we are not able to *prove* its potential. Such an analysis would be beyond the scope of the present paper. We thus follow the reviewer's second suggestion and reformulate certain paragraphs in order to more realistically state the potential of the bedrock map for flow modelling.

Changes are applied to the Introduction: Our statements there, however, are already quite general and not directly related to the new dataset derived in the present study. Respective paragraphs in the Results and Conclusions were also slightly reformulated.

"Whereas for large-scale ice sheet modelling, the spatial resolution provided by Bedmap2 might be sufficient, detailed considerations of mass balance, ice flow and grounding-line dynamics necessitate the application of models that are able to cope with the high spatial variability of the governing processes. For such models, a high-resolution bedrock topography is an essential geometric constraint."

"We capture many features of small scale variability that were lost in the 1 km grid of Bedmap2 such as narrow subglacial troughs or smaller ice thicknesses around local rock outcrops."

REMOVED: "Thus, our dataset might open new possibilities for ice dynamic modelling".

"The bedrock dataset derived in the present study might be useful for calculating the future response of glaciers of the Antarctic Peninsula using ice dynamic models and, hence, to better understand the processes triggering their rapid changes. This may offer new possibilities for studying cryospheric glacier contribution to sea-level rise."

Section 4 is welcome but I missed a figure showing the error map for the whole domain. Without robust and reliable error estimates for the derived ice thickness, they are virtually unusable and uninterpretable. This is fairly critical and I do not understand why it was not included. Fig 5 indicates that the errors are not spatially homogenous, which is no surprise. It would appear that the largest relative errors occur for the smallest thicknesses, which is presumably where the glaciers are most sensitive to external forcing and where the largest dynamic changes are likely to take place. This goes back to my first point about how much more useful the dataset actually is for model prediction purposes? If relative uncertainties near the glacier terminus are, say, 100%, does this help model projections?

Apparently, we have not made it clear enough that the uncertainty map (Fig. 7) is available for the entire domain. We chose to show only one specific region here in order to focus on the small-scale spatial variability in the uncertainty and its influencing factors (e.g. distance from OIB measurement points). We provide the uncertainty map (both absolute and relative uncertainty) for the entire domain along with the final bedrock topography in the Supporting Online Material of The Cryosphere. This is clearly stated in the revised version.

"By multiplying the uncertainty grids from the approaches (i) and (ii), an error map for the entire study region is created providing information on local ice thickness and bedrock uncertainty in both absolute and relative terms (Fig. 7, see SOM for uncertainty map of the entire Antarctic Peninsula)."

Relative uncertainties are higher for small than for large ice thicknesses (see Fig. 5): This is not unexpected as a small absolute error translates into a much larger relative error for small thicknesses. In terms of usefulness for ice flow model applications the smaller relative errors for large thicknesses are actually good news as these regions are most relevant for the dynamics and the related changes.

Whether the partly significant uncertainties in our bedrock dataset are critical to the applicability of the dataset is difficult to judge. We try to give an optimal estimate using the presently available data and models which does much better reproduce spatial ice thickness variations on the Antarctic Peninsula compared to the presently available datasets (see e.g. Fig. 9).

Why have the authors limited this analysis to north of 70 degs? The AP extends considerably further south to around 75 degs (see e.g. Cook and Vaughan, TC 2010). It would be interesting to see how Bedmap2 compared further south with this approach.

We are aware of this, and have therefore mentioned the restriction of our dataset to the region north of 70°S many times in the article. The study domain is simply limited by the availablility of the indispensable input data: Most importantly, this is the digital elevation model by Cook et al. (2012), and the glacier catchments (derived from this DEM) by Cook et al. (2014). No comparable and similarly detailed / accurate dataset is yet available for the regions of the Antarctic Peninsula south of 70°S. We clarified this issue with an additional sentence.

"Due to the availability of high-resolution input data the study only addresses the Antarctic Peninsula north of 70 degree S (Fig. 1)."

Related to the point above about errors is the comparison between measured and modeled velocities (Fig 4). As stated, Fig 4a cannot be used to determine the error directly because the data were used to tune the parameters. Fig 4b provides another measure of the error because to conserve mass the velocity (times thickness) must match the observed flux. It seems that the misfit in velocity also provides, indirectly, information about the error in thickness. Here the comparison is made just at OIB points but it could also be done continuously, and spatially, for the whole domain.

This is indeed a good suggestion that we have considered as well in the course of developing our methodology. However, it is not trivial to actually apply it. In fact, methods exist to derive ice thickness directly from observed surface velocity grids (see e.g., McNabb et al., 2012; Morlighem et al., 2014). Such approaches could also be used for the Antarctic Peninsula, although their applicability would probably be limited by the poorly constrained spatial variability in sliding rates and the spatial resolution of the velocity data (450 m).

The reviewer proposes to quantify ice thickness uncertainties via observed surface velocities. This would involve many other assumptions, as well as the uncertainties inherent to the measurement of surface velocity itself and the likely non-stationary flow of glaciers on the Peninsula. We therefore decided to only rely on more robust catchment-averaged flow velocities and not to include the spatial velocity field into the uncertainty calculations. We however added an outlook stating the potential of distributed surface velocity information in the estimation of bedrock topography.

"Potential future improvements of the bedrock estimate for the Antarctic Peninsula might be directed towards more strictly enforcing mass conservation and including spatially distributed surface velocity data as an immediate constraint into the ice thickness determination (see e.g., McNabb et al., 2012; Morlighem et al., 2014)."

Fig 6a. Would be useful to add the difference in thickness in another colour.

We have the impression that adding another line for the difference (and consequently another axis) would make the figure difficult to read. Basically, Fig 6a shows profiles of surface and measured/modelled bedrock elevation. The differences are already shown (in a spatially distributed way) in Fig. 6b. Therefore, we did not change the figure.

Fig 7 shows absolute thickness errors. Not entirely clear where the grounding line/ice edge is here but assume its top right and that the relative errors for northern portion of Starbuck (200 m) are large: 100% or more? Why not provide a relative error map for the whole domain? Referring to this might help to what extent this new dataset can improve model prediction..

In response to this comment we extend Figure 7 by an additional panel for the same region showing the relative uncertainty as well. Figures for the absolute and the relative uncertainty of the entire model domain are provided in the Supporting Online Material (as requested by the above comment of the reviewer).

Additional reference:
Morlighem, M., Rignot, E., Mouginot, J., Seroussi, H., and Larour, E.: High-resolution ice-thickness mapping in South Greenland, Ann. Glaciol., 55(67), 64–70, 2014.

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