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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 would like to thank J. Oerlemans for this critical assessment. Although we understand the main criticism made and we acknowledge that more discussion on this point is needed, we respectfully disagree in a series of aspects.

First, we do not agree that an initial estimate of bedrock topography obtained from a relatively simple approach is not useful as boundary condition for ice flow models: Complete bedrock datasets for both Greenland (Bamber et al., 2013) and Antarctica (Fretwell et al., 2013) have been derived only recently, and are exclusively based on the direct interpolation of (regionally scarce) ice thickness observations. In particular, no sort of ice flow model for improving and constraining the result in regions not covered with measurements has been used, and no additional information for the surface (i.e.

estimates of the surface mass balance, or the ice flow velocity field) has been included. Nevertheless, there is no doubt that the above mentioned studies are highly valuable to the ice sheet modelling community. In fact, the data sets are now regarded as the reference estimate for the corresponding regions.

Second, our study has the aim of providing the first high resolution ice thickness map of the Antarctic Peninsula, since the rugged topography of the region is – quite obviously – not sufficiently resolved by the 1 km grid of Bedmap2 (Fretwell et al., 2013). Basically, we present a refined interpolation approach that is able to make use of all information available so far (Operation IceBridge ice thickness, surface topography, RACMO surface mass balances, ice flow velocities), and have combined all this spatially distributed (!) information within a relatively simple framework. We are convinced that the combination of these individual data sets allows the generation of a much better constrained estimate of local ice thickness compared to the direct interpolation of unequally spaced ice thickness observations. We are well aware that our results may not be the final solution, and certainly do not exclude that studies using more complex approaches might come up with different and maybe more precise results. We are, however, confident that at present our study is a significant step ahead in the characterization of the bedrock topography of the Antarctic Peninsula and argue that our methodology – albeit its limitations – represents a valuable and still unique tool for applications at the scale of >1000 individual glaciers. In this respect, the claim that the use of our methodology is "really out of date", seems inappropriate to us.

Third, the fact that recently more comprehensive methods for inverse determination of glacier ice thickness based on thermodynamically coupled higher order models have been developed (e.g. van Pelt et al., 2013; Morlighem et al., 2013) is acknowledged several times throughout the manuscript. We fully agree with J. Oerlemans that such methods better capture the complex processes and the variations in viscosity and sliding driven by thermodynamics than our model does. However, just asking that the study is repeated with a higher order model lacks consideration of the scale of such an undertaking, and would not be as easy as suggested in the comment: van Pelt, Oerlemans et al. (2013) applied an iterative higher order approach for one glacier with 3400 grid cells. For our study region and the resolution provided this requires an increase in computation time by almost four orders of magnitude! This would simply not be feasible at present. Furthermore, van Pelt et al. (2013) used direct field observations, long-term time series of multi-century climate variability and accumulation rates, and a thoroughly validated mass balance model for constraining their flow model for the study site. All of which would not be available for a single of the >1000 glaciers of the Antarctic Peninsula we have considered. As far as we understand, the application of a thermodynamically coupled higher order model for iteratively determining ice thickness is possible for individual, well characterized glaciers but it is everything else than a trivial task when applied to a large number of glaciers, especially in a data scarce region like Antarctica.

Fourth, it is correct that our approach is indeed not able to capture the spatial variability in basal sliding and the viscosity of ice in the same way as a higher order model, but as discussed in our paper, the sensitivity of the final results on very significant changes in the assumptions on sliding is about 1 percent. Using 'a more sophisticated model' as claimed by J. Oerlemans would therefore maybe allow some improvements of the ice thickness estimate in that regard, however at the cost of a loss in flexibility to match the direct observations of ice thickness that represent the tying point of our bedrock map. We thus consider our interpolation scheme as a first order approach to generate a reasonable ice volume and bedrock estimate for the Antarctic Peninsula. We anticipate that this data set will be valuable for the initialization of flow models, as no comparable data with sufficient resolution is available for the region at present. Moreover, even models that estimate the bedrock topography iteratively, such as the model by van Pelt et al. (2013), need an initial ice thickness. Our results could thus serve as initial condition if such iterative methods were to be applied to specific study sites.

In the revised version of our manuscript we will extend the discussion on the limitations

of our approach, and provide more details on the possibilities for future improvements of regional-scale bedrock estimation using more complex models. Previous applications of the SIA for ice thickness calculation will be more properly acknowledged, and most importantly, we will clarify the main aim of our study: we here present an approach to interpolate ice thickness for a large and complex region by including all available observational data sets via a simple but flexible model framework. Although our methodology might not include all relevant processes in full physical detail, we are able to provide a bedrock estimate unprecedented in its spatial resolution accounting for all available sources of information.

References:

Bamber, J. L., Griggs, J. A., Hurkmans, R. T.W. L., Dowdeswell, J. A., Gogineni, S. P., Howat, I., Mouginot, J., Paden, J., Palmer, S., Rignot, E., and Steinhage, D.: A new bed elevation dataset for Greenland, The Cryosphere, 7, 499–510, doi:10.5194/tc-7-499-2013, 2013.

Fretwell, P. and many more: Bedmap2: improved ice bed, surface and thickness datasets for Antarctica, The Cryosphere, 7, 375–393, doi:10.5194/tc-7-375-2013.

Morlighem, M., Rignot, E., Mouginot, J., Wu, X., Seroussi, H., Larour, E., and Paden, J.: High resolution bed topography mapping of Russell Glacier, Greenland, inferred from Operation IceBridge data, J. Glaciol., 59, 1015–1023, 2013.

van Pelt, W. J. J., Oerlemans, J., Reijmer, C. H., Pettersson, R., Pohjola, V. A., Isaksson, E., and Divine, D.: An iterative inverse method to estimate basal topography and initialize ice flow models, The Cryosphere, 7, 987–1006, doi:10.5194/tc-7-987-2013.

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