

RESPONSE TO R2 :

R2 : "It has several problems, some of which stem from the poor documentation of CRUST1.0."

5 We agree that CRUST1.0 is poorly documented. We contacted G. Laske and asked for some details. She answered "Ice thickness was constrained using maps from the British Antarctic survey", but she did not confirm whether space gravimetric data have been included or not in the model. This is the reason why we wanted to compare with a fully independent model, like AN.1. Our aim was to show that gravimetry can constrain the crustal models and help to have a better solution than models using only seismology data.

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R2: "To have confidence in the work more assessment is needed (e.g. a comparison with receiver functions)"

We take into account this possibility. We propose to merge figure 6 and figure 7 into a new figure 6. Then, figure 8 becomes figure 7 and the new figure 8 shows the comparison with receiver functions for the crustal thickness (we respect the limit of 10 figures max.). This comparison is a very local test. Don't forget our model is a global and a rough resolution solution.

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The text of the manuscript has been changed: we added a new paragraph at the end of **5.2.2 Spatial analysis of crustal models** (page 11, line 22). This paragraph is entitled: "Comparison with seismic receiver functions »

20 Copy of the new paragraph :

Comparison with seismic receiver functions

To complete the confrontation with seismic crustal thicknesses, we compare our results to those from receiver functions. We use the Antarctic Moho compilation given by An (Figure 4 and Table S1 from An et al., 2015), who selected a list of stations under the evaluation of the quality of Moho depth (more details and sources can be found in the publication of An). On Figure 8, we plot the differences between the crustal thickness from GOCE and the value found in the fourth column of Table S1. Roughly, we obtain the same discrepancies than those observed with the profiles on Figure 7. In East Antarctica, our model

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is thinner than seismic studies (see for example Feng et al., 2014; Hansen et al., 2010). The larger disagreement is located around the Gamburtsev Subglacial Mountains region (GSM). Seismic data show a thickening up to 60-65 km in this region (see also An et al., 2016), while gravity suggest a more regular crust with thicknesses under 50 km.

5 Conversely, in West Antarctica seismic studies find between 20 and 30 km for the crust thickness which is thinner than our crust from space gravity (Figure 8). Using receiver functions from POLENET, Chaput et al. (2013) explain that this thin crust is compatible with mantle compensation, especially across MBL dome (Marie Byrd Land). During our computation at continental scale, we had to postulate the full crustal isostatic compensation of topography. In regions with mantle compensation or with density variations,
10 our results will differ from the real crustal thickness. Specific studies have to be done in such regions, based on seismic data but also on airborne (Scheinert and al., 2016) or ground gravity data, these latter having a better resolution appropriate to local studies.

15 *R2 : “And addressing non-isostatic support of topography).”*

We will reply to this comment below.

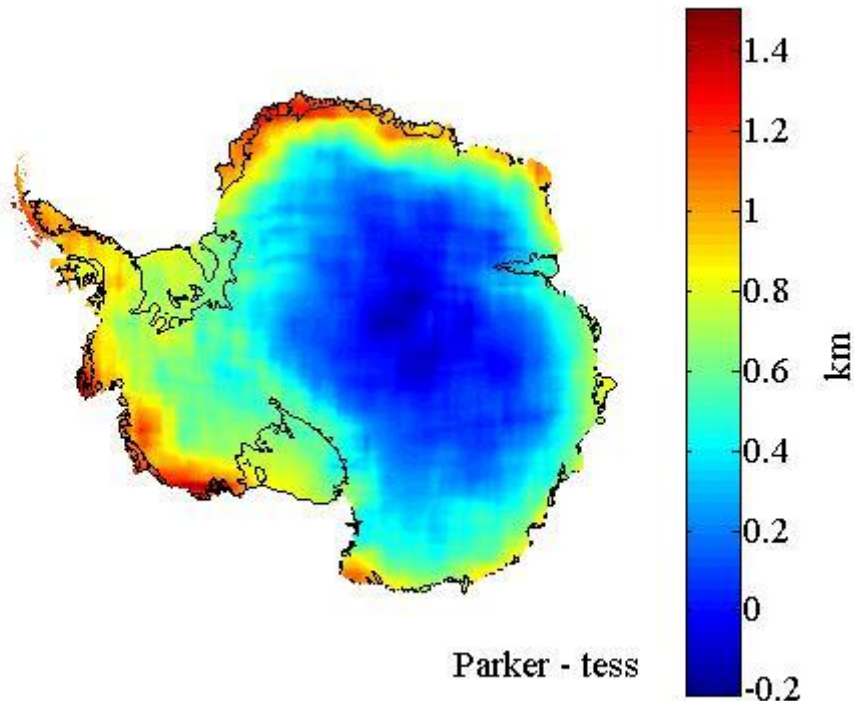
R2: “English: in general, the English is not good”

We already contacted the editing service.

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R2: “Limits of Parker’s method: the authors use Parker’s method for deriving the terrain effect, which is appropriate for a flat plane, but may become problematic at scale where curvature is important; this should be justified at this length scale”

We have also estimated terrain effects using tesserooids (Uieda, L., V. Barbosa, and C. Braitenberg (2016), Tesseroids: Forward-modeling gravitational fields in spherical coordinates, GEOPHYSICS, F41-F48, doi:[10.1190/geo2015-0204.1](https://doi.org/10.1190/geo2015-0204.1)), a method which takes curvature into account. The differences between crustal thickness estimates from Parker or tesserooids methods are shown in the figure below. The maximum reaches 1km, which is within our error bar.



10 *R2: "Airborne gravity: the new compilation of airborne gravity by Scheinert 2016, should be at least mentioned"*

We add a comment in the text and mention the publication (page 12, line 10):

"Specific studies have to be done in such regions, based on seismic data but also on airborne (Scheinert and al., 2016) or ground gravity data, these latter having a better resolution appropriate to local studies."

5 R2: "CRUST 1.0 circularity: the biggest issue is the comparison with CRUST1.0. The authors use old studies for mean crustal thickness constraint, which presumably was an input for CRUST1.0, admit that CRUST1.0 used airborne gravity for input, in some unspecified way (even though they reject Bedmap2 because of its gravity contamination) and come up with the same result as CRUST1.0 which is not that shocking in retrospect"

10 Our mean value of 35 km is consistent with old studies cited in the text but in fact it is also consistent with AN1 mean value (see table 1 of the paper). CRUST 1.0 used airborne gravity for input in complement of seismic data. This is not a problem because we have been working with GOCE which is only satellite gravity observations. In Bedmap2, GOCE data are used in some regions of Antarctica to constrain the ice thickness, and this is a problem because we are using the same data to obtain the crust thickness.

15 R2: "In general, CRUST1.0 is not well documented enough to determine how independent of the satellite gravity data it is."

Yes we agree that CRUST 1.0 is not well documented. We have answered this question in the beginning.

R2: "There is not attempt to compare with receiver functions for Moho depth."

20 As we said we have made this comparison and it is now included in a new paragraph "Comparison with seismic receiver functions" (page 11, line 22).

R2: "Given all that, the statement that CRUST1.0 is to be preferred seems to be far too strong."

25 We can make the same analysis using CRUST 2.0. This model cannot include space data like GOCE but the resolution is worse. In the text, we do not state that CRUST1.0 is the best model, we observe that CRUST1.0 is closer to our gravity crustal model.

R2: "Non Moho support: there is no attempt to address flexural or mantle support of topography, something strongly suspected for Marie Byrd Land, and likely an issued for Antarctica, given the thick lithosphere and time varying ice load."

30 We are talking here about small wavelength features, typically smaller than 200 km (usually, it is accepted that structures larger than 200 km are isostatically compensated). This comment concerns local studies

with other sources of information. Certainly, in some regions, we could find disagreement between our gravity interpretation and local studies as Chaput et al. (2013). But our work presents results at larger wavelengths, at the scale of Antarctica. We can't resolve very local structures: GOCE resolution is very close to the 200 km limit, and we want to provide a purely gravimetric, global model. Such a model will be interesting in further studies, looking at a specific region, with complementary data at smaller resolution (for example ground or airborne gravity data, seismic data). The combination of our gravity model with local data could be used to test if the signal comes from crust thickness variations or uncompensated topography. Finally, GOCE provides static gravity field then we cannot study time varying deformations.

10 The text has been changed. Page 12, line 5, we added:

Conversely, in West Antarctica seismic studies find between 20 and 30 km for the crust thickness which is thinner than our crust from space gravity (Figure 8). Using receiver functions from POLENET, Chaput et al. (2013) explain that this thin crust is compatible with mantle compensation, specially across MBL dome (Marie Byrd Land). During our computation at continental scale, we had to postulate the full crustal isostatic compensation of topography. In regions with mantle compensation or with density variations, our results will differ from the real crustal thickness. Specific studies have to be done in such regions, based on seismic data but also on airborne (Scheinert and al., 2016) or ground gravity data, these latter having a better resolution appropriate to local studies.

20 *R2: "Bedmap2: An additional issue is the use of Lythe 2001 over Fretwell 2013 for the bed topography. Figure 6 demonstrated that the authors know where Bedmap2 is using GOCE data, and certainly BEDMAP was not constrained by any data in those areas anyway. There is no value in not using Bedmap2, if you know which areas do have GOCE contamination."*

We think it is important for the reader to see easily the regions where GOCE is used into Bedmap 2 because the crustal thickness estimations in these regions are certainly affected when using Bedmap 2 in the inversion. People who are specifically working in these regions should use crustal gravity models carefully.

Technical issues: Throughout: None of the figures have spatial bars or graticals.

We added spatial bars to the figures.

We made all other technical changes suggested by the reviewer.

We added the 3 references mentioned by the reviewer and we cited them in the text.