Response to M. An (referee)

General comment

An : « *Gravity observations can offer reliable information about variations in Moho topography, but not absolute thickness values, therefore, absolute thicknesses from seismic studies are often taken as a priori constrains in gravimetric inversion. The constraints used in this manuscript are from global model, CRUST1.0, but it gives little information on Antarctic interior.* »

Yes, gravity data allow us to access crustal thickness variations with respect to an average value, and not absolute thicknesses. This is our unique constraint. We chose a 35 km value based on mean values from seismological models, not only CRUST1.0, and from literature.

Using a mean value during the inversion process has no influence on the resolution of gravimetric results. Our thickness model gives information near the coastlines as well as in the Antarctic interior. Using gravity data from space allows us to benefit from a complete coverage of equal quality, and reveals details about the crustal structure anywhere on the Antarctic continent (except inside the small zone around the south pole where GOCE data are lacking).

An: *"New results (e.g. AN1 model) showed that the crust of Antarctica is very different with those (e.g. CRUST1.0) imagined previously. However, the new results were not considered in the manuscript".*

Our aim is to propose an upgraded model for the crust thickness variations in Antarctica, using the last and most detailed available gravimetric field. It was interesting to confront the result with other models proposed by seismological studies. CRUST1.0 is one of the most famous, but it was built considering some gravimetric data. So, we completed our comparison choosing a model fully independent from gravity data, and only based on seismological data: AN1 is the most recent one. We considered this new result in our study, especially on figure 8 of our paper where differences between all models are presented.

Specific comments

Authors reply to comment (1).

An: "The text in the manuscript about the observations used in An et al. (2015) is that "in Antarctica there are very few seismological observations and the Chinese model is poorly constrained" (page5, lines 11-12). This statement is completely wrong. It is true that there had ever been few seismological observations in Antarctic *before 2007. However, since the IPY (2007–2008), intensive seismological surveys under GAMSEIS and POLENET projects have been conducted in Antarctica. Those observations significantly improved the coverage of seismic observations in Antarctica. As one work of the GAMSEIS project, An et al. (2015) not only used almost all seismological observations before the IPY, but also the observations of GAMSEIS and POLENET. Their model was constrained by the best data coverage on entire Antarctica to date."*

We have changed the text in page 5 lines 13-14 into: "in Antarctica there are very few seismological observations compared to gravity data, for example, in areas of East Antarctica as QML (Queen Maud Land) and AGV (George V land) (see Kanao et al. 2013 figure 1 to see the station distribution or An et al. 2015 figure 4) "

An : "After a comparison with AN1 of An et al. (2015), the manuscript concluded that "CRUST1.0 has a better spatial resolution" (Page 5, line 15). On the contrary, in my view, the comparison of the manuscript only demonstrated that CRUST1.0 has no valid information on Antarctic interior. Seismic studies under GAMSEIS and POLENET projects since 2007 have shown that the crust of Antarctic interior is very different from previously imagined. The results of GAMSEIS project are overviewed by An et al. (2016) (http://www.aps-polar.org/paper/2016/27/02/A160908000001). Body-wave receiver function (RF) analysis is a good method to detect Moho depth beneath seismic stations and the results are normally considered as reliable. RF studies showed that crust in central East Antarctica is thick (>50 km and even to be ˜60 km) (Hansen et al., 2010; Feng et al., 2014), in West Antarctica is thin (˜20-30 km) (Chaput et al., 2014). However, in CRUST1.0 model, the crust in west Antarctica is >30 km thick, and in East Antarctica is <42 km (Figure 8d). The text ("The comparison with the CRUST1.0 model reveals large differences between them. As seen in Figure 3, from -26 to +19 km, AN1 has higher values, mainly localized in the East Antarctic craton. West Antarctica is much thinner " in " the AN1 model") and Figure 8d in the manuscript shows that AN1 is compatible with the RF studies. From these comparison, we can just conclude that AN1 is more reliable. It is opposite with that "CRUST1.0 has a better spatial resolution".

The Hansen et al. (2010) study is local and focused on the GSM (Gamburtsev Subglacial Mountains). Their results shown that the mean crust thickness estimated in the stations surrounding the GSM is about 40-45 km and reach 55-58 km at the GSM. In our study we show that the crustal thickness over GSM derived from GOCE are around 40-50 km (see figure 5 of our paper) which is consistent with other gravimetric studies (Block et al. 2009, Von Freese et al. 1999, Llubes et al. 2006). However these results are different from those based on GAMSEIS data (Hansen et al. 2010, Feng et al. 2014) .

We have changed the text "*CRUST1.0 has a better spatial resolution"* into: " Including gravimetric observations (land and/or satellite) as constraints of the seismological model allows to improve the spatial resolution".

An:" Another comparison ("The latter seems also rougher, with a less precise coast limit. CRUST1.0 has a better spatial resolution.") is meaningless. Spatial resolution of a model is controlled by observations, but is not related with roughness of the model. More "precise coast limit" in CRUST1.0 indicates that the model around coast areas of Antarctica may be constrained mostly by topography but not seismic observations. The roughness in the model of AN1 around the coast lines is related to its resolution.

Figure S3 in Auxiliary material of An et al. (2015) can be taken as resolution-length map of crustal thicknesses of AN1. The figure shows that the resolution length for crustal thicknesses in AN1 is ~120 km in Antarctica. This resolution length is similar to that (77-~200 km) of gravity data used in this manuscript."

We have changed the text *"The latter seems also rougher, with a less precise coast limit."* into: "The roughness in the AN1 model around the coast line is related to its resolution ".
In fact, our paper shows that the crustal thickness model derived from GOCE is closer to CRUST model. But we agree with the reviewer's comment. Our purpose was just to explain models difference, but it is not the main goal of our paper.

The comparison of our results with AN1 model allows us to demonstrate the interest of taking into account gravity data as constraint in crustal thickness models, because it is the most recent model derived from only seismological observations. Firstly, we can confirm/validate spatial variations over the regions where gravimetric and seismological signals are comparable, and highlight the regions where discrepancies exist between the two approaches. Secondly, the use of gravity data improves the model resolution and makes it possible to estimate density variations. We would like to emphasize that GOCE observations have a uniform resolution and accuracy over the whole area covered by the satellite

(2) An : "The manuscript used the thickness of CRUST1 as constraints to analyze gravity observations. "In areas where there is a lack of seismic observations crustal thickness is constraint by gravity observations using maps from British Antarctic Survey (Laske private communication)" (page 5, lines 6-8). In this case, the results for those areas in the manuscript are little significant because the constraints at those areas used in this study of gravity observations are from gravity observations, and their reliability is unknown."

We have focused our approach on a regional comparison between crustal thickness models, i.e., over the entire Antarctica continent. In addition, CRUST1.0 model is not constrained by gravity observations from satellite missions. In the case of local studies, we could use complementary land gravity measurements to improve the spatial resolution but it is not the purpose of this paper.

(3) An : "The very-thick crust in central EANT and very-thin crust in WANT may indicate that Antarctica is special. Density may be also special in the areas. Gravity observations may be useful to detect this."

Yes, we agree, this is shown in figure 9 of our paper.

Biblio :

We agree to add references proposed by M. An work, and we did the technical corrections.

An: "Line 10: "another crustal model has been proposed by a Chinese team" ==> "a regional model on Antarctic crust (AN1) (An et al., 2015) has been proposed". The AN1 model is one of results of the efforts from international (US, China, France, Japan) collaborations under GAMSEIS and partly under POLENET. The model AN1 is a regional model, but CRUST1.0 is a global model."

Ok, we changed the text

An: "Lines 11-12: delete "but in Antarctica there are very few seismological observations and the Chinese model is poorly constrained" Line 15: delete "CRUST1.0 has a better spatial resolution"

We changed the text. See comment about R2 remarks.

An : "Page 7 Lines 3-5: "According to previous studies (Block et al., 2009; Ritzwoller et al., 2001), the mean depth in West Antarctica is about 40 km and in East Antarctica is about 30 km. We fix to the mean value, 35 km, as mean depth for the whole continent" ==> "According to global 1-D model of AK135 (Kennett et al., 1995), we fix to the mean value, 35 km, as mean depth for the whole continent". The studies (Ritzwoller et al., 2001; Block et al., 2009) did not use new seismic observation or results. It is not true that "the mean depth in West Antarctica is about 40 km and in East Antarctica is about 30 km". Since only a general mean value (35 km) is used, it is acceptable to cite a global 1-D model of AK135."

We do not say 35 km is the real mean thickness of the crust in Antarctica. We only use this value to start our computation. And we choose a realistic value, in agreement with scientific literature. AK135 is an old reference (Kennett et al., 1995). We prefer to cite the reference to AN's model (2015), which is in agreement with our starting value (see table 1 of this manuscript).