

## ***Interactive comment on “Traces of the crustal units and the upper mantle structure in the southwestern part of the East European Craton” by I. Janutyte et al.***

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We thank the anonymous referee for the constructive comments, and provide our corrections and replies below:

1) In order to set the optimal damping value we investigated the trade-off between the data variance and model variance (Fig. 9 in paper), and concluded that damping value 80 is an optimal, and it was used in our studies. We also made inversions with higher damping value (120) which in result gave about  $\pm 1$  to  $\pm 1.5$  % lower velocity contrast. But as our study area is 800 km in longest direction and we aim to resolve smaller scale structures we think that damping value 80 is reasonable. The W-E smearing dipping to

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the east is probably due to the seismic rays coming mainly from the NE-E-SE direction, because we use (due to natural conditions) more earthquakes (EQs) from the region to the east compared to the region to the west from the study area. The resolution kernel elements are presented in Fig. 1 where we plot the values for every inverted layer from 60 to 350 km. The values in general are very small and close to zero (from about -0.04 to +0.09). We suggest that the results are reasonably resolved in the parts with good station coverage and further from the outskirts (i.e. in the central part) of the study area. Of course, we face a lack of ray-crossing in some areas close to the Kaliningrad District of Russia and Belarus due to absence of the stations there, which increases the W-E smearing as well. The Fig. 10 (in paper) shows that we have quite good ray coverage in the area, and Fig. 11 (in paper) shows that in horizontal directions the structures can be fairly resolved (as the vertical smearing is always much larger compared to the horizontal one) in the central part of the study area.

2) The referee is right that the amplitudes resolved in our results are too large (up to about 12 % – i.e. about  $\pm 6$  % – velocity contrast). The geological conditions could explain the contrast maybe up to about  $\pm 3$  %. The TELINV is a relative teleseismic tomography code which means that the high and the low amplitudes should be compensated. The referee suggests that the high velocity contrast could be due to a) temperatures, b) anisotropy or c) "flat-Earth" model used. We partly agree with all the suggestions, but we think that there are also other factors, like d) the effect from "significant" crustal structures, and e) the influence from the compiled crustal travel time (TT) corrections which still may have an additional component to the final result. a) In the study area beneath W Lithuania we have an increased heat flow (up to 55-100 mW/m<sup>2</sup>) which is significantly higher than that of the surrounds, thus, the effect due to temperature should be quite significant in the results. b) The studies by Wüstefeld et al. (2010) and Sroda et al. (2014) show relatively small anisotropy for the EEC, thus, its effects on the results may not be large. c) We agree that the "flat-Earth" transformation has an effect for the apparent velocities when dealing with large areas. In our study we used the TELINV code which uses "flat-Earth" model. We did not correct our results

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for spherical model. Our study area is 800 km in longest direction and the model is set to the depth of 700 km. Assuming incidence angle of 30 degrees (most of the angles in our study are smaller than 10 degrees), our model is stretched at the bottom (i.e. 700 km) about 11 %, which means that in average for the whole distance the horizontal stretch is 5.5 % (vertical is not changed). For an incidence angle of 30 degrees that gives about 1.4 % longer raypaths. For most of our observations (which have smaller incidence angles) this effect would be smaller than 1 %. d) We invert the layers from 60 km, which coincides almost with the Moho depth in some places (in the eastern part). There are also large granite bodies present in the study area which, as showed in some studies, may have some influence (cause low velocity anomalies) on the results of the tomography inversion. Moreover, we observe the highest amplitudes in the uppermost inverted layers which imply possible effects from the crustal structures, while going deeper the amplitudes are smaller. The significant crustal structures may modify the signal strength and add-up to the observed velocity contrast as well. e) As we know, the proper crustal TT corrections are essential in teleseismic tomography in order to eliminate (or to "reduce" would be the more precise saying) the leaking from the crust. As we presented in our paper, "the crustal TT corrections for individual seismic stations do not take into account the bending of the seismic rays in the crust", this also may cause some minor, however, additional effects. Also, the crustal models which we used for calculations of the crustal TT corrections have their own limits of precision. In conclusion, we think that all the reasons listed above may have (smaller or larger) cumulative effects to the data, that is why we observe such a high velocity contrast in our results of the teleseismic tomography inversion. In our paper we do not speculate what could be the real velocity contrast due to geological conditions, because we do not know how much we have additional effect due to the above mentioned reasons, but it may be useful to provide some information about it.

3) In the inversion we use 4195 picks of P wave arrivals and 2040 inverted nodes which result in a matrix of approximately 8.5 mln. elements. A singular value decomposition (SVD) of the G matrix, would require a good computer with the number of model and

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data parameters used in the study. We did not perform the SVD for this study.

Answer to P4 paragraph 2.1. Motuza (2005) summarized the various studies and results of the deeps seismic sounding profiles carried out around Lithuania and concluded, that "the seismic velocities in the uppermost part of the mantle vary between 8.65 and 8.9 km/s and the corresponding density is 3374-3406 kg/m<sup>3</sup> increasing from the west to east along the profile (insertion: EUROBRIDGE profile) (...) In the marginal parts of the WLGD local reflectors appear at a depth of 82–73 km in the mantle. The origin of these reflectors is not clear and various explanations are possible. R. Giese interpreted them as bodies of higher density, where seismic velocity increases up to 9.2 km/s (Giese, 1998). The density was modeled by L. Korabljova using GM SYS software as 3622 kg/m<sup>3</sup> (Motuza et al., 2000). The high density of the bodies points to the presence of high density minerals, possibly garnet and pyroxene. These bodies can potentially represent delaminated slices of the crust, which sank in the mantle (e.g. Defant and Kepezhinskis, 2002)." In our case we do not question results of the other studies.

Answer to P6 paragraph 2.3 line 10. Our mistake occurred most likely during the text editing. The sentence should be "The boundary between the EEC and the TESZ in NW Poland is near vertical (Grad et al., 2005)." The original study by Grad et al. (2005) includes reinterpretation of some deep seismic sounding profiles carried out in Poland, but nothing related with EQ analysis.

Answer to P8 line 10. EQs of large magnitudes are generated on large tectonic faults. During the EQ the rupture migrates for a certain period of time generating different types of the seismic waves, thus, the wave-train recorded at the station is long and complex. In our study we dealt with the first P wave arrivals only, so, for us it was not so important, but to be sure that no errors would occur we limited the magnitude range.

Answer to Fig. 11. The smearing visible on the vertical slices in Fig. 11 (in paper) is most likely due to rays coming mainly from the NE-E-SE direction. The distribution of

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EQs used in our study is presented in Fig. 5 (in paper), where we have most of the EQs from Indonesia, Japan and Kamchatka regions, and there were not so many EQs during the given period of certain magnitude to the west of the study area. Moreover, there were no stations in the Kaliningrad District of Russia and Belarus, which also reduces the ray-crossing in the area. We think that for resolution estimation it is quite enough to use the hit matrix (to observe the ray coverage) and the checkerboard test (to observe how well the structures in the upper mantle can be resolved with the real station configuration).

As for the table with additional information about the inversion parameters, we think that the model is fairly described in the section 4.3. In this section we provide a number of layers (i.e. 16), the depth of our model (i.e. 700 km), spacing between model nodes (i.e. 50 km) and inverted layers (i.e. from 60 to 350 km). Usually in teleseismic tomography the lower layers of the input model ensure the stability and are not inverted. Also, the nodes of the model grid at the edges (which usually are set much further from the study area in order to "collect" the seismic rays) are also not inverted. If someone is interested in the number of inverted nodes in the layer, the mathematics is easy: we have 17 nodes along the main transect (from 0 to 800 km every 50 km) and 12 (from -250 to 300 every 50 km) nodes transverse to the main transect, which give 204 inverted nodes in a layer. The only information missing is the structure of the input model, thus, a number of inverted layers. We have 10 layers between 60 and 350 km, which give 2040 inverted nodes in total. In general we think that this information might be interesting, but it is not a must, thus, we did not provide in a separate table.

Additional references used in the response: i) Sroda, P., and the POLCRUST and PASSEQ Working Groups: Seismic anisotropy and deformations of the TESZ lithosphere near the East European Craton margin in SE Poland at various scales and depths. EGU General Assembly 2014, Geophysical Research Abstracts, Vol. 16, EGU2014-6463-1, 2014. ii) Wüstefeld, A., Bokelmann, G., and Barruol, G.: Evidence for ancient lithospheric deformation in the East European Craton based on mantle seis-

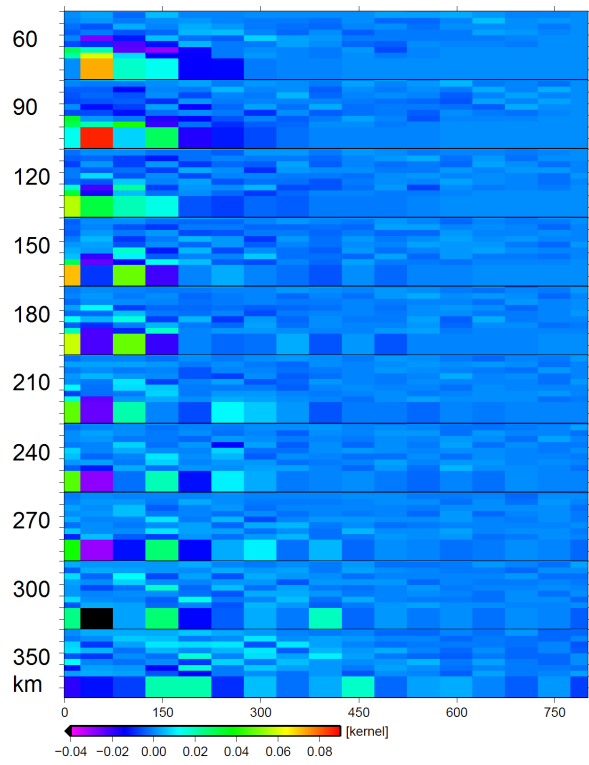
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**Fig. 1.** Kernels for inverted layers.

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