universität wien

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Dear Professor Jan Kratochvil

please find enclosed my referee report on the doctoral Thesis “Anisotropic tomography of the European upper mantle” by the candidate Ms. Helena Zlebcikova.

Eligibility. The present doctoral Thesis clearly demonstrates the ability of the candidate, Ms. Helena Zlebcikova, in conducing creative scientific research in the field of Geophysics.

Summary of the main findings. In this Thesis, the candidate developed a new algorithm for solving the geophysical inverse problem of defining the anisotropic structure of the Earth's upper mantle. The new methodology strictly overcomes a long-standing “trick” used by seismologists in the past, i.e. solving such inverse problem in two steps with several approximations, demonstrating the novelty and originality of the candidate's research. The new algorithm simultaneously solves for the full elastic model of the upper mantle, both in its isotropic and anisotropic components, and can be used to analyse in details the well-known trade-off between anisotropy and heterogeneities in the rock volumes. Moreover, assumptions on the anisotropic fabric of the rocks (i.e. geometrical properties of the seismic wave propagation) are weak, indicating the possibility of reconstructing more realistic rock properties than those considered in previous approaches. The algorithm is presented in details, allowing for high-level of reproducibility, and tested on a number of theoretical and conceptual models. Finally, the candidate applied the new algorithm to seismic measurements recorded in Northern Europe, and compare the new knowledge on the elasticity of the upper mantle with previous studies.

Importance. The new methodology developed by the candidate will have a strong impact on the wide community of Earth scientists, given the potential link of anisotropy with a number of geophysical process occurring in the Solid Earth. The new methodology gives the possibility of modelling realistic anisotropic rocks in the lithosphere, not limited to horizontally-oriented crystals of olivine, and open to multi-disciplinary studies of the lithospheric mantle.

Style of the Thesis. The present doctoral Thesis represents a valuable document. I found a clear and reasonable structure of the chapters. The presentation style is appropriate for a scientific product. The figures are in a relevant number, but all necessary. The quality of the graphics meets the high-standard required in top-level publications.

Comments/Questions. I have three main comments/questions for the candidate:

(1) *Linearized scheme for solving the inverse problem.* The simultaneous inversion of the isotropic/anisotropic structure is completed using a widely-used linearized inversion scheme (Page 17, Equations 51). I would consider this as a first step. To better assess the trade-off between isotropic and anisotropic structures, a stochastic approach to the solution of the inverse problem is more appropriate. Stochastic methods, like Monte Carlo sampling, allow to investigate coupled variations of model parameters, and to quantitatively estimate their covariance. Did the candidate consider this option for improving the methodology? Can the candidate foresee advantages and weaknesses for such potential further step in the development?

(2) *Seismic tomography is usually non-linear.* As far as I can appreciate from Equation 42 (Page 16), the candidate opted for an implicit linearisation of the seismic tomography inverse problem, where the candidate dropped the dependance of the ray-paths of the P-wave velocity field (and anisotropic field too). While I recognize that it is a widely-used approximation, I would argue that such choice could have an impact (limited impact?) on the trade-off between heterogeneities and anisotropy in the upper mantle. Ignoring the ray-path dependance on the velocity field could force the introduction of additional heterogeneities and/or anisotropy into the model, for fitting the data adequately. Did the candidate consider to use a more sophisticated approach to ray-tracing for solving the inverse problem?

(3) *Comparison with previous methodologies.* In the past, anisotropic body-wave tomographies have generally considered horizontal or vertical symmetry axis. Here, a more general orientation of the anisotropic symmetry axis is possible. Given the fact that, using the present AniTomo code on the data recorded in Fennoscandia, the retrieved symmetry axes are steeply dipping, it would be interesting to see the results of the inversion of the LAPNET data imposing the symmetry axes to be horizontal or vertical. These results should illustrate which are the potential artefacts introduced using a fixed inclination for the symmetry axis and could help to interpret previous studies based on approximated methods.

Best regards,

Dr. Nicola Piana Agostinetti

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