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Simultaneous inversion for 3D crustal and anisotropic lithospheric structure and regional hypocenters beneath Germany

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There is now ample evidence from both refraction seismic studies, done already a quarter century ago and from more recent local earthquake traveltime analysis of some of the authors above that large sections of the upper mantle underneath Europe and Germany, in particular, are anisotropic.

Employing a modified version of the method of simultaneous inversion for structure and hypocenters (SSH) of the first author, including a priori known upper mantle anisotropy, the investigations of Song et al. [2001] and Song et al. [2004] by means of a 1D time-term analysis and a full 2D Pn anisotropic inversion of regional traveltime data are extended here to a full 3D SSH-inversion underneath Germany. Regional traveltimes from local events occurring between 1975 - 2003 are used which, after application of several selection criteria, results in $\sim$1300 events with a total of $\sim$30000 P- and S-phases for the SSH inversion.

Because many of the recorded events appear to suffer from relatively poor hypocentral depth locations a full SSH analysis becomes an intricate undertaking. To alleviate the problem the SSH procedure is carried out in several incremental steps of increasing complexity. First of all improved vertically inhomogeneous velocity (1D) models are derived assuming an isotropic as well as an anisotropic upper mantle. In addition of a slightly better model fit for the anisotropic than for the isotropic model, the latter gives also a somewhat lower Pn-velocity of $\sim$7.90 km/s, compared with $\sim$8.0 km/s for the former. This indicates that inclusion of upper mantle anisotropy into the model is required to obtain physically reasonable Pn-velocities. The results for the P-velocity in the lower crustal layer of the model are less clear, as there appears to be some trade-off in the velocity of that layer and that of the upper mantle.

During the course of this part of the study the 3D models have been increasingly refined, starting with a lateral discretization into 15 x 15 blocs (lateral extension of about 40 x 40 km per bloc) and finally going up to 35 $\times$ 35 blocs, (lateral extension of about 16 x 16 km). For each of the models, the inversion solutions for the isotropic, as well as the anisotropic case (i.e. incorporating the anisotropic velocity correction for the Pn-phases) are examined and the sensitivity of the solution to the data is estimated by means of various tests for resolution, covariance and other trade-off characteristics of the data- and the model-space.

Significant improvements for both the isotropic and anisotropic upper mantle cases are obtained for full 3D SSH inversion models. Similar to the 1D Pn-velocity models there are remarkable differences in the lateral Pn-velocities, depending whether the lithosphere is corrected for anisotropy or not. Namely, for an anisotropic upper mantle the median ellipse velocities are generally higher, laterally smoother and behave also more stable throughout the inversion than those obtained assuming an isotropic upper mantle.
Checkerboard resolution tests are performed indicating a rather well-resolved upper crust und upper mantle and a less-resolved lower crust. Additional tests with theoretical generated anomalies show the power of the resolution capability of the available dataset. From these initial theroetical inversion tests the need for the elliptical anisotropic Pn-velocity correction in the real subsequent 3D tomographic study beneath Germany has also been recognized, as the anisotropic inversion test models are consistently better resolved than the isotropic ones.

As for the geological and tectonical interpretation of the seismo-tomographic crustal velocities obtained,

there appears to be congruence of the latter, namely, in some portions of the upper crust, with some of the important features, suture zones and lineaments defined by the Central European Variscides.