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Surface wave tomography of central and northern Europe from automated inter-station dispersion measurements

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With the rapid growth in the number of seismic stations globally, automated analysis routines are inevitable to extract seismic observables from these large data volumes. For surface wave tomography, phase velocity dispersion curves of fundamental mode surface waves yield information on the isotropic as well as anisotropic structure of the crust and upper mantle. We have developed an algorithm that enables automated, accurate measurement of inter-station phase velocity dispersion curves through cross correlation of vertical (Rayleigh wave) and transverse component (Love wave) seismograms.

After testing various parameters for automation of the procedure we find that the automated selection of segments of a given phase-velocity curve requires three parameters only, namely (1) difference of the measured phase velocity curve from a background model, (2) a smoothness constraint and (3) a length criterion. Furthermore, before averaging all measurements for one path, outliers are rejected. We performed rigorous tests to optimize the selection parameters. Interestingly, rough perturbations in the phase velocity curves do not bias the average phase velocities towards larger values. This indicates a rather random perturbation of the phase velocities by noise and complicated non-plane wave propagation.

We successfully applied the method to more than seventy thousand inter station paths in central and northern Europe, involving more than one million cross correlations on more than 20 years of data from permanent networks.

After inversion of the fundamental mode phase velocity dispersion curves for both Rayleigh and Love waves, we obtain high resolution anisotropic phase velocity maps for periods between 10 and 250 seconds. We performed series of the tests to obtain the optimal values of the regularization (smoothing and damping). Resolution tests indicate a resolution in Central to Northern Europe of 50 to 200 kilometers.

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At shorter periods the North-German and Polish sedimentary basins are clearly imaged. At lower crustal depth the Alpine crustal root is characterized by low velocities. At longer periods a shallow asthenosphere beneath the regions of Cenozoic volcanism is found in Central Europe. The transition zone between the shallow Central European asthenosphere and the thick mantle lithosphere beneath the East European Craton along the Trans-European Suture Zone shows a distinct internal 3D structure. At depths between about 70 km to 100 km the strongest lateral heterogeneity is found in the region of the Elbe lineament, whereas at larger depths below about 120 km a very sharp boundary is present beneath the Tornquist-Teisseyre-Zone. Azimuthal anisotropy at lower crustal depths across central Europe allows to differentiate between crustal and lithospheric domains created during the Variscan, Caledonian and Cadomian orogenies. Fast direction are interpreted as reflecting syn-orogenic deformation processes, as the fast directions of azimuthal anisotropy in the underlying asthenosphere are different.