Identifying Main Lithospheric Structures in the Eastern Alpine Domain by Joint Inversion of Receiver Function and Surface Wave Measurements for Seismic Anisotropy

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Rayleigh-wave phase velocity measurements from both earthquakes and ambient noise were combined to image the 3-D shear-wave velocity structure beneath the eastern Alps and in the transitions towards the Pannonian Basin and the Dinarides. This allows us to resolve crust and upper mantle structures down to 300 km including the Moho topography. Continuous waveforms were collected from 1254 stations within a 9° radius for the time period from 2006 to 2018. More than 164,464 inter-station Rayleigh wave phase-velocity curves were automatically extracted after applying a strict quality control. Using the combined dataset, a period and distance dependence correction was applied to account for the bias observed between phase velocities from both datasets that amounts to ~1 % and increases towards longer periods. 2-D anisotropic phase velocity maps were then constructed spanning periods from 5 s to 250 s. 33,981 local dispersion curves were extracted and inverted for a 3-D shear-wave velocity model (PanREA2023) encompassing crust and mantle using a non-linear stochastic particle swarm optimization.

At shallower crustal depths, the horst and graben structure of the Pannonian Basin is imaged, characterized by two NE-SW trending horsts and three graben systems. A pronounced crustal low-velocity anomaly extending to the Moho is found beneath the surrounding Carpathian orogen. A shallow south-dipping Eurasian slab was imaged beneath the eastern Alps down to only 150 km depth. Adriatic lithosphere is near-vertically dipping beneath the northern Apennines and northern Dinarides. The Adriatic slab is short reaching depths of around 150 km.

Seismic discontinuities down to the mantle transition zone are analysed using S-to-P converted phases from teleseismic earthquakes. We stack broadband teleseismic S waveform data to retrieve S-to-P converted signals from below the seismic stations. In order to avoid processing artefacts, no deconvolution or filtering is applied. The Moho signals are always seen very clearly. In addition, a negative velocity gradient below the Moho depth is evident in many regions. A Moho depression is visible along larger parts of the Alpine chain reaching its largest depth of 60 km beneath the Tauern Window. The Moho depression ends abruptly near about 13°E below the eastern Tauern Window. East of 13°E the Moho shallows all the way to the Pannonian Basin. A prominent along-strike change was also detected in the upper mantle structure at about 14°E. There, the lateral disappearance of a zone of negative S-wave velocity gradient in the uppermost mantle is interpreted to indicate that the S-dipping European slab laterally terminates east of the Tauern Window.

Joint inversion of surface wave dispersion curves and Moho travel times inferred from S-to-P converted phases allows to determine shear-wave velocity models consistent with both measurements. The uncertainty of the Moho depth estimates decreases from about 5 to 10 km considerably to 2 to 5 km depending on the depth of the Moho. The joint inversion further enables the determination of the sharpness of the negative discontinuity associated with the lithosphere-asthenosphere boundary. It appears to be rather sharp in the northern Alpine foreland and the Pannonian Basin.