Teleseismic P-wave travel time tomography of the Alpine upper mantle using AlpArray seismic network data

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We perform a teleseismic P-wave travel time tomography to examine geometry and slab structure of the upper mantle beneath the Alpine orogen. Vertical component data of the extraordinary dense seismic network AlpArray are used which were recorded at over 600 temporary and permanent broadband stations deployed by 24 different European institutions in the greater Alpine region, reaching from the Massif Central to the Pannonian Basin and from the Po plain to the river Main. Mantle phases of 370 teleseismic events between 2015 and 2019 of magnitude 5.5 and higher are evaluated automatically for direct and core diffracted P arrivals using a combination of higher-order statistics picking algorithms and signal cross correlation. The resulting database contains over 170,000 highly accurate absolute P picks that were manually revised for each event. The travel time residuals exhibit very consistent and reproducible spatial patterns, already pointing at high velocity slabs in the mantle.

For predicting P-wave travel times we consider a large computational box encompassing the Alpine region up to a depth of 600 km within which we allow 3D-variations of P-wave velocity. To account for influences of the strongly heterogeneous crust that cannot be resolved with teleseismic data, we integrate a complex three-dimensional crustal model directly into our model. Outside the box we assume a spherically symmetric earth and apply the Tau-P method to calculate travel times and ray paths. These are injected at the boundaries of the regional box and continued using the fast marching method (Rawlinson et al. 2005). We invert differences between observed and predicted traveltimes for P-wave velocities inside the box. Velocity is discretized on a regular grid with a spacing of about 25x25x15 km. The misfit reduction reaches values of over 80% depending on damping and smoothing parameters.

The resulting model shows several steeply dipping high velocity anomalies following the Alpine arc. The most prominent structure stretches from the western Alps into the Apennines mountain range reaching depths of over 500 km. Two further anomalies of high complexity extending down to a depth of 300 km are located below the central and eastern Alps, both being detached from the lithosphere and separated by a clear gap below the western part of the Tauern window. The central anomaly shows mainly southwards dipping, whereas the eastern anomaly is mainly dipping to the northeast. We compare our results to former studies, confirming lateral positions of the anomalies. However, the new results can benefit from the superior resolution capabilities of
the dense AlpArray seismic network, providing more accurate insights into depth extent, dip angle and directions. We perform various general, as well as purpose-built resolution tests, to verify the capabilities of our setup to resolve slab gaps as well as different possible slab dipping directions.

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