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Ambient noise wave-equation tomography of the Alpine crust: outcomes of the new Vs model on the structure of the deep crust

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With the advent of the AlpArray seismic network, the broad Alpine region is instrumented since 2016 by a large number of (rather) homogeneously distributed permanent and temporary stations. They provide a unique wealth of high-quality seismic data at the scale of a mountain belt, which paves the way for a significant improvement in seismic models through the application of innovative tomographic methods. We present a pioneering application of ambient noise wave-equation tomography to improve the present-day 3-D shear-wave velocity model of the Alpine crust and uppermost mantle. This so-called « ambient noise wave-equation tomography » is a new methodology for inverting seismic ambient noise data using 3-D elastic wave-equation based tomography.

In the last decade, ambient noise tomography has become a well-established seismic imaging tool widely applied from local to global scale. However, most applications still rely on the two-step 2D-1D surface-wave inversion approach based on ray theory. Meanwhile, wave-equation tomography (WET) has become feasible following rapid advances in computational facilities and numerical methods. Our WET is based on minimization of tapered cross-correlation between observed data and synthetic data computed through full 3-D wave field modelling using the spectral element code SEM46 developed by the SEISCOPE group (https://seiscope2.osug.fr/). It is expected to provide higher-quality seismic images than standard tomography techniques as it fully accounts for 3-D and finite frequency effects.

We used cross-correlations of up to four years of continuous vertical-component ambient seismic noise recordings from 304 high-quality broadband stations in the Alpine region. We used WET to iteratively improve the initial model LSP_Eucrust1.0 obtained by « standard » ambient noise tomography (Lu et al., 2018) in the period range 10-55s. The fit of simulated phase travel times of Rayleigh waves to observations is significantly better in our new Vs model than in the initial one. The resulting crustal model has, in general, stronger velocity contrasts than the initial model. It also reveals several new features that we will discuss in detail, in particular at lower crustal and Moho depth.