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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To understand mountain building in the Alps, the crustal deep structure, its complex deformation, and the properties of the mantle lithosphere below have to be imaged and identified. This holds especially for the eastern Alpine domain where the Adriatic indenter caused strong up-right folding and exhumation of lower-plate units in the core of the orogen, but also lateral escape north of the Periadriatic Fault (e.g. Ratschbacher et al., 1991; Scharf et al., 2013; Favaro et al., 2017; Rosenberg et al., 2018). This project targets crustal and upper mantle heterogeneities including the Moho at the crucial junction of the Eastern Alps, western Carpathians, western Pannonian Basin and northern Dinarides. The aim is to provide high-resolution images of the deep subsurface structure and so shed better light on the forces driving subduction and collision.

Broad-band surface wave velocity measurements are ideally suited to constrain absolute shear-wave velocities in the crust and upper mantle from about 5 km to 300 km depth. Ambient noise (e.g. Stehly et al., 2009; Fry et al., 2010; Molinari et al., 2015; Behm et al., 2016; Kästle et al., 2016; 2018; Schippkus et al., 2018; Lu et al., 2018; 2020), earthquake data (e.g. Kolinsky et al., 2019; 2020; El-Sharkawy et al., 2020; Belinic et al., 2021), and also joint inversions of ambient noise and earthquake data (Kästle et al., 2016; 2018) have been used for surface wave tomography. Receiver function studies yield images of discontinuities in the crust, of the Moho and the lithosphere-asthenosphere boundary. In contrast to surface waves, receiver functions are not sensitive to absolute velocities. Examples for receiver function studies in the Alps are Bertrand & Deschamps (2000), Kummerow et al. (2004), Lombardi et al. (2008), Bianchi et al. (2014), Zhao et al. (2015), Kind et al. (2017), and Hetényi et al. (2018). Recent methodological developments relevant for the analysis of crustal anisotropy are given in Link et al. (2020).

The project addresses Theme 1 „Reorganisations of the lithosphere during mountain-building“ by joint stochastic inversion of surface wave and receiver function measurements for isotropic and anisotropic deep structure of the Alps. We focus on the Eastern Alps and the transition to the Pannonian Basin and Dinarides to resolve intracrustal discontinuities and the Moho topography. We will compile Rayleigh and Love dispersion curves for the Eastern Alps from earthquake data and ambient noise. Fig. 1 shows an example for surface wave tomography of the Alpine area using earthquake data (El-Sharkawy et al., 2020). Results of recent anisotropic P-receiver function analysis are given in Fig. 2 (Link & Rümpker, 2020). In addition, we are developing a modified version of the S-receiver function method which has no sidelobes and which preserves the wave forms of the response of the lithosphere below the seismic stations. The principle of the method is to sum unfiltered broadband P components with the S arrival time as reference. Fig. 3 shows an example for a North-South profile band crossing the Eastern Alps in the vicinity of the western central Tauern Window. The Moho topography as well as indications for a south-dipping Eurasian slab are indicated in this preliminary data example. Both P- as well as S-receiver functions will be compiled for the Eastern Alps. Specifically, we will make use of data of the PACASE experiment in the region.

Software tools for the joint inversion of receiver function results with surface wave dispersion curves for a three-dimensional radially and azimuthally anisotropic model of the shear-wave velocity will be developed and intensively tested. In addition, average Vp/Vs ratios for the crust will be determined. Analysis of radial and azimuthal anisotropy will identify different crustal domains as well as horizontal flow patterns related to lateral escape in the Eastern Alps. We are supporting the development of the Alpine Model Generator (see Coordination Project) as a platform to compare and interpret results of seismic imaging. In cooperation with other projects, we will contribute to the interdisciplinary interpretation of seismic models.

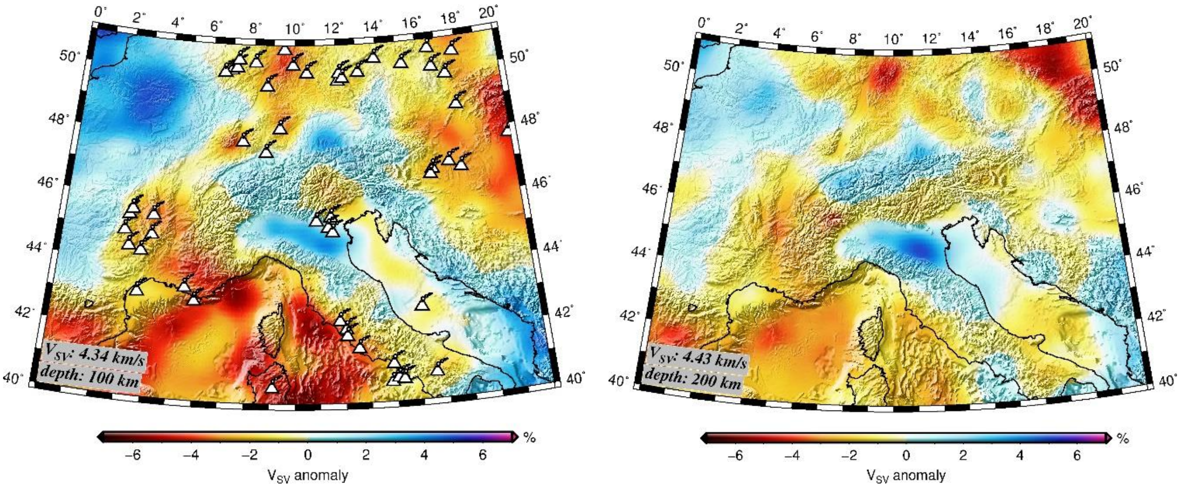

Figure 1: Horizontal cross sections through a 3D shear-wave velocity model obtained from the inversion of surface wave measurements (El-Sharkawy et al., 2020) at 100 km (left) and 200 km depth (right). White triangles indicate the location of Cenozoic volcanic fields (Meier et al., 2016).

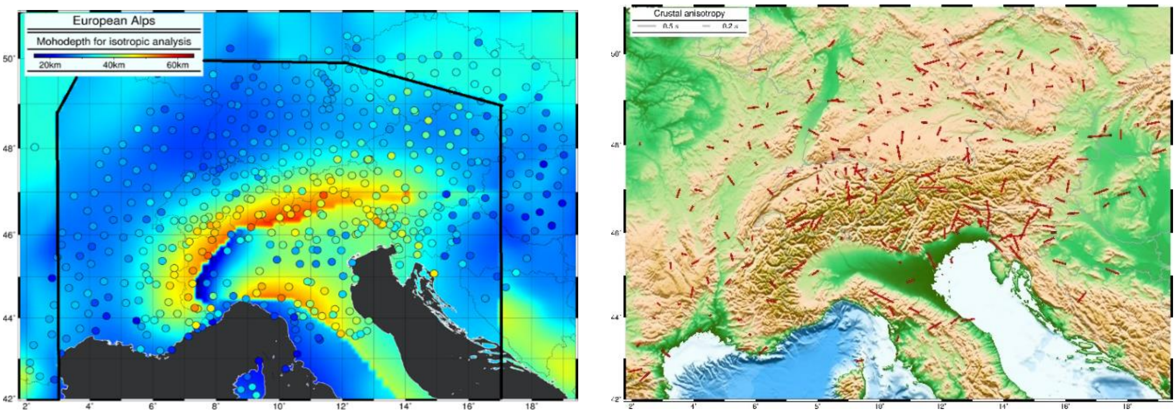

Figure 2: (Left) Moho depth estimation from receiver functions for the AlpArray temporary network and permanent stations in the region (Link & Rümpker, 2020). The background color gives Moho depth estimations from Spada et al. (2013; inlet) and Tesauro et al. (2008; surrounding region). (Right) The crustal anisotropy shows a large scatter of fast axis directions, while the splitting time, the strength of anisotropy, is increasing from the Alpine foreland to the mountain belt.

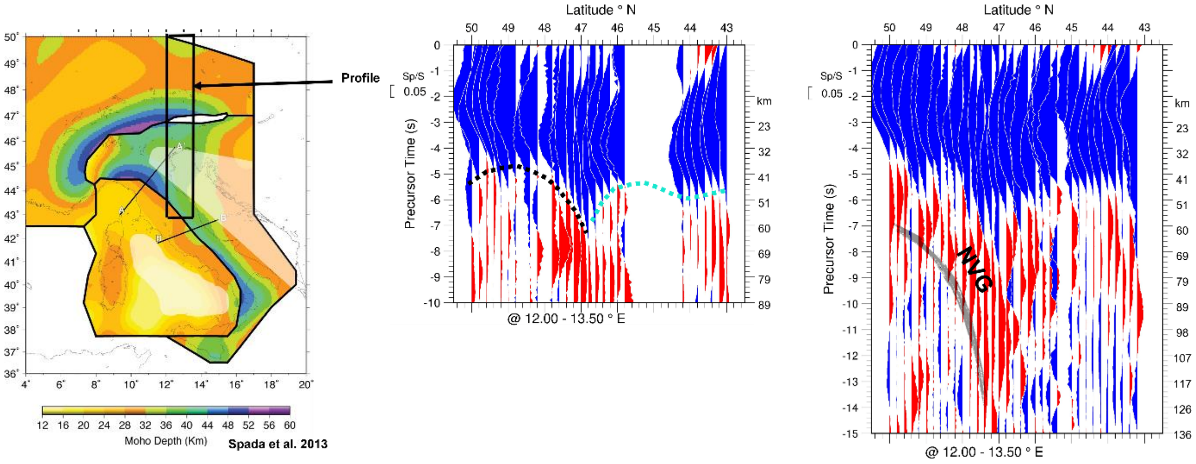

Figure 3: Stacked S-to-P converted waves for a north-south profile crossing the eastern Alps. (Left) Location of the profile. (Middle) Stacked S-to-P converted waves for piercing points at 50 km depth. The black dashed line marks the European Moho and cyan dashed line the Adriatic Moho. (Right) Stacked S-to-P converted waves for piercing points at 100 km depth. The gray lines indicate possible source regions of waves scattered at a negative velocity gradient (NVG).

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