Status Report on the project “Imaging structure and geometry of Alpine slabs by full waveform inversion of teleseismic body waves” Q2, 2019

PIs: Wolfgang Friederich, Thomas Meier, Boris Kaus

PhDs: Marcel Paffrath, Johannes Stampa

Fundamental aim of the project is a full waveform inversion of teleseismic body wave data from the AlpArray network for mantle structure beneath the Alpine region with focus on slab structure and geometry. Initial work focused on the generation of a quality-controlled database of waveforms suitable for ensuing full waveform inversion. Based on an empirical lower bound of magnitude versus epicentral distance, records of about 700 teleseismic earthquakes in the distance range between 30 and 180 degrees were selected and downloaded. These records were then subjected to an automatic quality control based on a comparison with synthetic seismograms. In order to create a starting model using travel time tomography, P- and S-arrival times were automatically picked and a database of arrival times created.

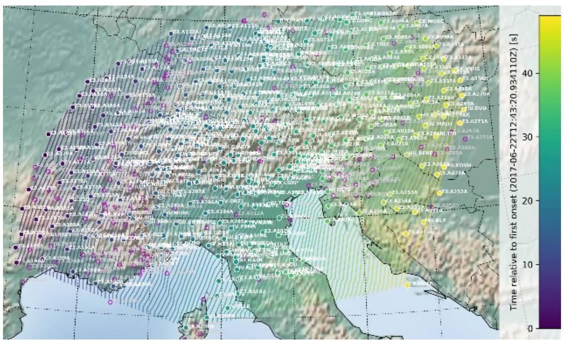

Figure 1: Map of correlation corrected P arrival times for a selected event. The P-wave arrives from the west. Interpolated arrival time isolines indicate individual wave fronts.

Closer inspection of these arrival times revealed that their absolute error is too high to obtain meaningful travel time differences across the array. For this reason, the travel times were corrected using a waveform cross-correlation of each trace with a stacked reference trace (Fig. 1). In this way, highly accurate and spatially consistent travel time residuals could be determined (Fig. 2).

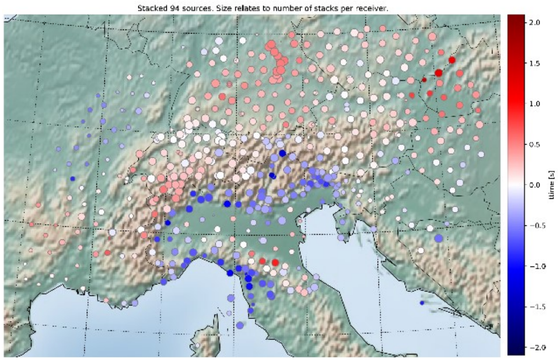

Figure 2: Map of travel time residuals relative to standard earth model AK135 averaged over 94 events.

The travel time residuals for these 94 events were inverted for P-wave-velocity perturbations beneath the array down to a depth of 500 km using FMTOMO with grid cells of dimensions 50x50x20 km^3 (Fig. 3).

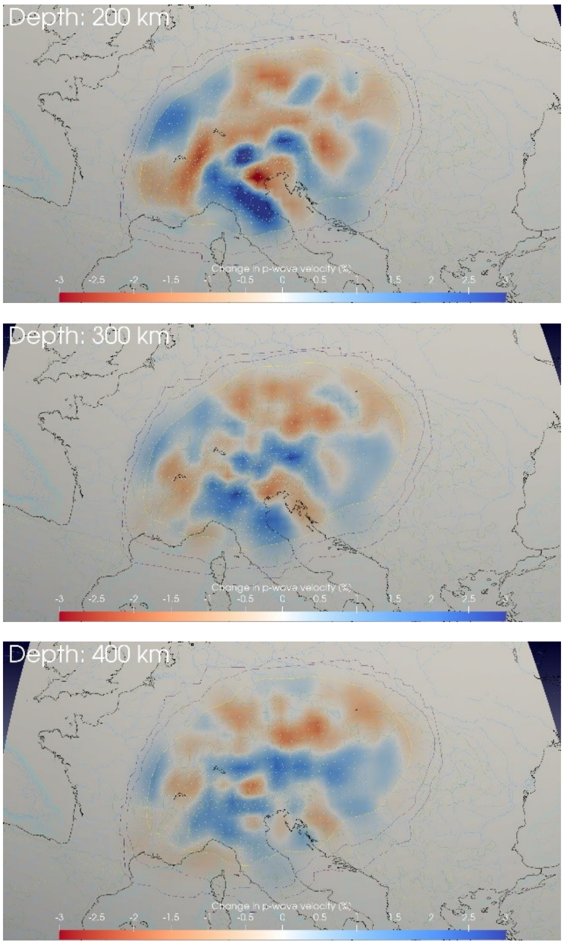

Figure 3: Depth slices through the inverted P-wave velocity model at 200 km, 300 km and 400 km.

Effects of non-resolvable crustal heterogeneities were corrected using the 3D-P-wave model of the Alpine crust by Diehl et al., (2009). Our model explains the observed travel time residuals very well. Misfit reduction is around 70 percent (Fig. 4).

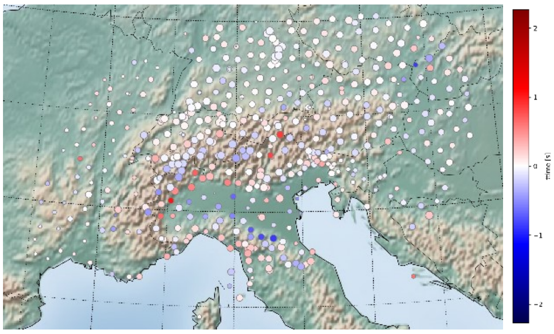

Figure 4: Map of travel time residuals averaged over 94 events after 8 iterations. For most stations, they are on the order of a fraction of a second.

Our model compares very well with the model by Lippitsch et al. (2003), especially in the central region where the Alpine slabs are located. First vertical cross sections indicate that the eastern Alpine slab indeed dips toward the northeast. However, it remains to be checked whether we can exclude artefacts introduced by the ray geometry. The model is still preliminary as we intend to add data from SwathD and the OBS experiment and extend the number of considered events. In addition, we will reduce the size of the FMTOMO inversion grid cells to 25x25x20 km^3 as there seems still to exist some potential for higher resolution.

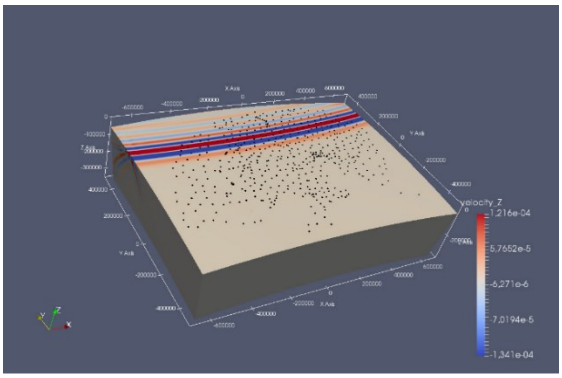

Figure 5: Snapshot of a teleseismic P-wave entering the SPECFEM3D computational domain after having been propagated from the hypocentre through the remainder of the earth model using AXISEM. Black dots indicate locations of the AlpArray backbone stations.

With regard to full waveform inversion, we implemented a hybrid approach to compute synthetic waveforms of teleseismic body waves in the Alp Array network.

This involves the coupling of a fast wave equation solver (AXISEM), that assumes a laterally homogeneous earth model and is used to handle global wave propagation, to the 3D wave equation solver SPECFEM which is used for modeling regional wave propagation through the 3D heterogeneous mantle and crust beneath the Alps (Fig. 5). Once initial models are available, this hybrid code will be used to solve the forward problem and to start the machinery of full waveform inversion.

References

Own work:

Hetenyi, G. et al., The AlpArray Seismic Network: A Large-Scale European Experiment to Image the Alpine Orogen, Surveys in Geophysics, 2018.

Other references:

Diehl, T., Husen, S., Kissling, E. and N. Deichmann, 2009. High resolution 3D-P-wave model of the Alpine crust, Geophys. J. Int., 179, 1133-1147.

Lippitsch, R., Kissling, E. & Ansorge, J., 2003. Upper mantle structure beneath the Alpine orogen from high-resolution teleseismic tomography, J. geophys. Res., 108(B8), 2376.