LET - Local Earthquake Tomography

A comprehensive high resolution 3D P- and S-wave velocity model for the Alpine mountain chain using local earthquake data:
Constraining crustal structure, lithologies and mountain-building processes

PI: Andreas Rietbrock[1], Christian Haberland[2]
PostDoc: Jack Woollam[1]
PhD: Benedikt Braszus[1]
1 - KIT Karlsruhe, 2 - GFZ Potsdam

The main goal of this project is to develop a comprehensive 3D P- and S-wave velocity model for the Alpine region using Local Earthquake Tomography (LET). Such a model is needed to relate surface structures to mountain building processes in the mantle, bridging the gap between geological orientated studies and geophysical images of lithospheric slabs in the mantle. It will also be useful for high-resultion teleseismic studies. Therefore, the study is relevant to the SPP and timely due to the current increase in data availability. The following specific objectives will be addressed in this project:

A) High resolution 3D P- and S-wave velocity model and Vp/Vs (Poisson ratio) for the Alpine region

B) High resolution 3D earthquake event locations and associated uncertainties

C) 3D crustal correction terms (both P and S) for the AASN deployment based on our new crustal model

D) Waveform data base with associated open accessible arrival times for the AASN

It should be noted that the last orogen wide crustal P-wave velocity model was compiled by Diehl et al., 2009 only using data up to 2007. At that time it was not feasible for Diehl et al. (2009) to develop a 3D S-wave velocity model due to the lack of high quality three-component seismic S-wave recordings. Data availability and quality has improved dramatically over the last decade, especially within the AlpArray Seismic Network (AASN, AlpArray Seismic Network, 2015), and now provides a unique opportunity to develop the first comprehensive P- and S-wave velocity model and associated Poisson ratio (vp/vs-ratio) for the Alps.

We will utilize the wealth of seismological data that has been collected during the last six years by the AASN and its complimentary EASI (AlpArray Seismic Network, 2014) and SWATH-D (Heit et al., 2017) experiments as depicted in Figure 1. Based on seismic data from the SWATH-D project Jozi Najafabadi et al., 2020 calculated hypocentral parameters of a subset of local earthquakes as well as the velocity structure of the eastern Southern Alps. We will collaborate closely with the corresponding working group in order to implement their results into our own

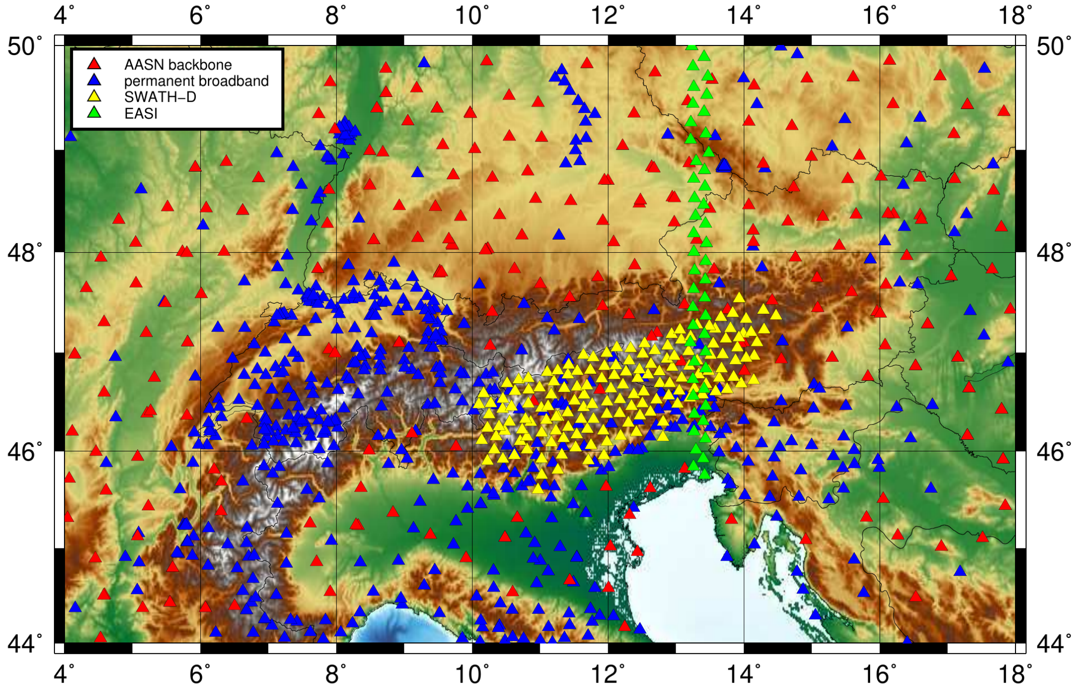

Figure 1: *Locations of seismic stations used in this project comprising permanent broadband stations (blue triangles) and the AlpArray backbone network (AlpArray Seismic Network, 2015, red triangles) as well as the complimentary SWATH-D (Heit et al., 2017, yellow triangles) and Eastern Alpine Seismic Investigation (EASI) stations (AlpArray Seismic Network, 2014, green triangles).*

work. Furthermore, a close collaboration with the group of Dr. Diehl at ETH Zürich is anticipated to ensure that efforts are not duplicated and to use available resources effectively.

Recently, our working group introduced convolutional neural networks for seismic phase detection and showed that an innovative approach in machine learning and artificial intelligence can be used to identify wave arrival times by automatic procedures even more consistently than manual picks from analysts (Woollam et al., 2019). This approach will be pursued further to obtain a set of onset times from various crustal seismic phases. Following Ryberg and Haberland, 2019 a Markov chain Monte Carlo (McMC) approach will be applied to simultaneously invert travel times for earthquake hypocentres and the velocity structure.

References

AlpArray Seismic Network (2014). *Eastern Alpine Seismic Investigation (EASI) - AlpArray Complimentary Experiment. AlpArray Working Group.* DOI: 10.12686/alparray/xt_2014.

— (2015). *AlpArray Seismic Network (AASN) temporary component. AlpArray Working Group. Other/Seismic Network.* DOI: 10.12686/alparray/z3_2015.

Diehl, T., S. Husen, E. Kissling, and N. Deichmann (2009). "High-resolution 3-D P-wave model of the Alpine crust". In: *Geophysical Journal International* 179, pp. 1133–1147. DOI: 10.1111/j.1365-246X.2009.04331.x.

Heit, B., M. Weber, F. Tilmann, C. Haberland, Y. Jia, C. Carraro, G. Walcher, A. Franceschini, and D. Pesaresi (2017). *The Swath-D Seismic Network in Italy and Austria. GFZ Data Services.* https://doi.org/10.14470/MF7562601148.

Jozi Najafabadi, A., C. Haberland, T. Ryberg, V. Verwater, E. Le Breton, M. R. Handy, M. Weber, and AlpArray the working group (2020). "Relocation of earthquakes in the Southern and Eastern Alps (Austria, Italy) recorded by the dense, temporary SWATH–D network using a Markov chain Monte Carlo inversion". In: *Solid Earth Discussions* 2020, 1–35. DOI: 10.5194/se-2020-192. URL: https://se.copernicus.org/preprints/se-2020-192/.

Ryberg, T. and C. Haberland (2019). "Bayesian simultaneous inversion for local earthquake hypocentres and 1-D velocity structure using minimum prior knowledge". In: *Geophysical Journal International* 218.2, pp. 840–854. ISSN: 0956-540X. DOI: 10.1093/gji/ggz177.

Woollam, J., A. Rietbrock, A. Bueno, and S. De Angelis (2019). "Convolutional Neural Network for Seismic Phase Classification, Performance Demonstration over a Local Seismic Network". In: *Seismological Research Letters* 90. DOI: 10.1785/0220180312.