Towards an integrated model of the Western Alps geophysical and geological data: seismic tomography of the Alpine lithosphere by ambient noise tomography and full waveform inversion

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Introduction

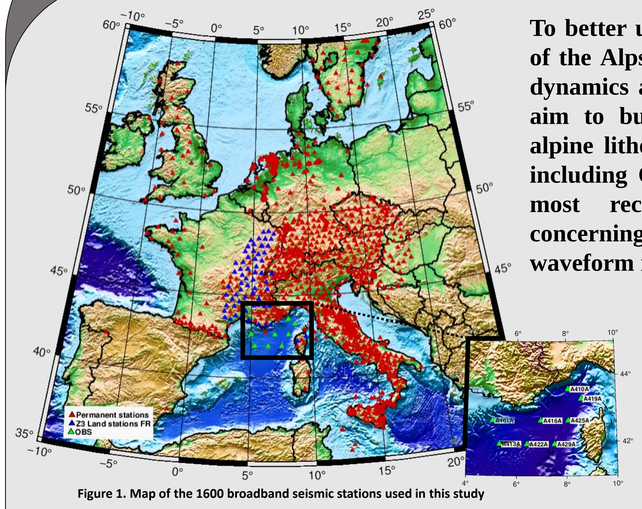

Figure 1. Map of the 1600 broadband seismic stations used in this study

To better understand the geodynamic processes of the Alps and the interaction between mantle dynamics and surface structural variations, we aim to build a high-resolution model of the alpine lithosphere using an exceptional dataset including Ocean-Bottom-Seismometers and the most recent methodological developments concerning seismic noise correlations and full waveform inversion (ISTerre).

The obtained 3D velocity model will be integrated into a Geomodeller for joint interpretation of geophysical and geological data. This multi-parameter tomography will be an important contribution to the 3-D geological models which is one of the objectives of the "Alps and Peripheral Basins" RGF project.

Surface Wave Group Velocity Tomography

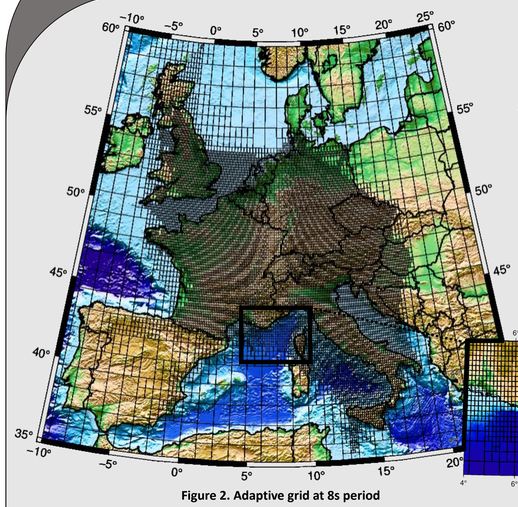

Figure 2. Adaptive grid at 8s period

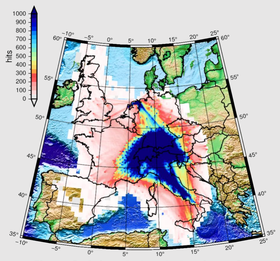

Figure 3. Azimuthal path density at 8s

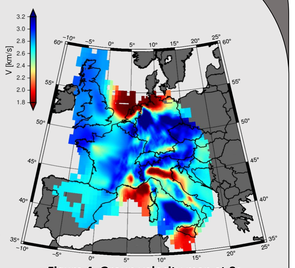

Figure 4. Group velocity map at 8s

- Signals from **3 years of seismic noise** (**2015-2018)** are **pre-processed,** then **correlated** and **filtered** in different period bands.
- The **best paths** are selected according to **distance**, **SNR** and **symmetry criteria**.
- Over **400 000 individual Rayleigh wave velocity measurements** are **inverted to 2*D* group velocity maps between 4*s* and 80*s***.
- **Automatic pixel-size parameterization** is used to obtain the **Damped least squares solution.**

High-resolution Semi-Bayesian shear wave tomography

- A **probabilistic model** is obtained by **comparing the observed local dispersion curves with the dispersion curves associated with a library of 40 million 1-D Vs models** from grid search.
- The **Vs probability distribution and the layer boundary presence probability** are calculated for **each pixel** in the **6-50 s** period band.
- A **unique 3-D shear-wave velocity model** is derived from **linear inversion** of the **100 000 best probabilistic models in 6-80 s**.

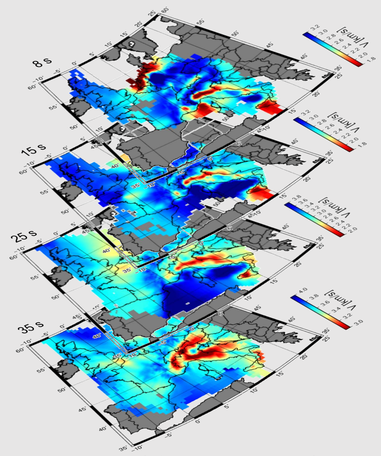

Figure 5. Group velocity maps at 8s, 15s, 25s and 35s

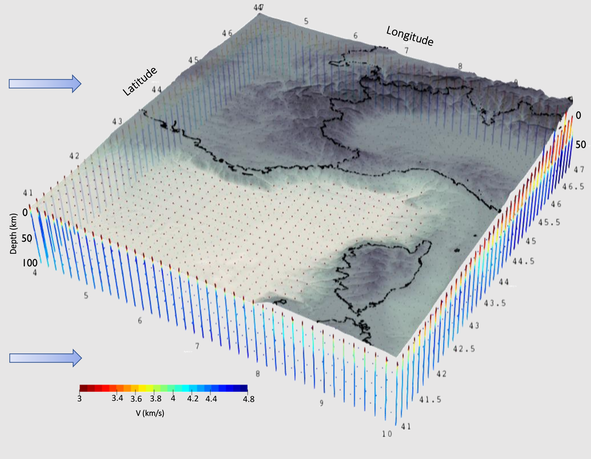

Figure 6. 1-D local Vs models derived from the corresponding dispersion curves and merged in a quasi-3D model

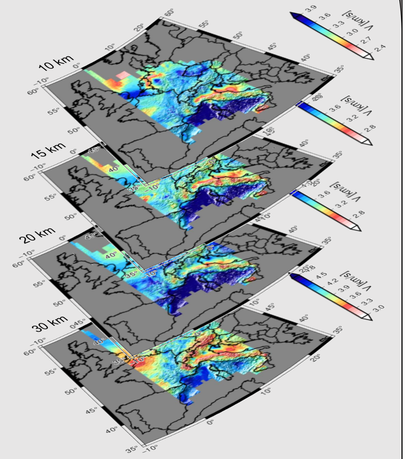

Figure 7. Depth slices in the final 3-D model at 10, 15, 20, 30 km

Misfit function

$$\Phi(m) = (\mathbf{g}(m) - \boldsymbol{d_{obs}})^T \boldsymbol{C_e}^{-1}(\mathbf{g}(m) - \boldsymbol{d_{obs}})$$

Likelihood function

$$\mathbf{p}(\mathbf{d_{obs}}|m) = \frac{1}{\sqrt{|\mathbf{C_e}|}} \exp\left(-\frac{\Phi(\mathbf{m})}{2}\right)$$

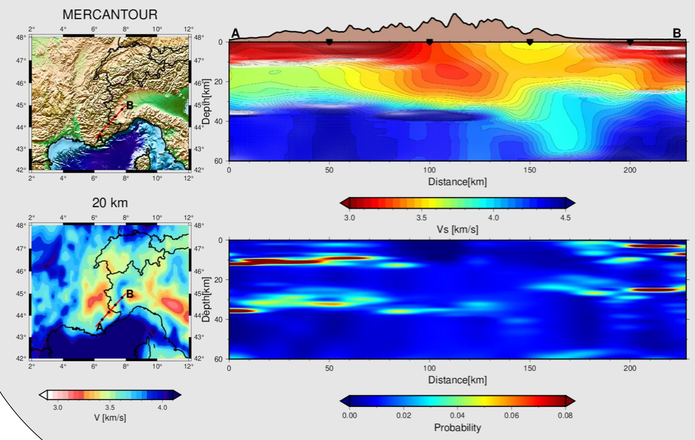

Figure 9. Depth section along the MERCANTOUR seismic profile in the final model

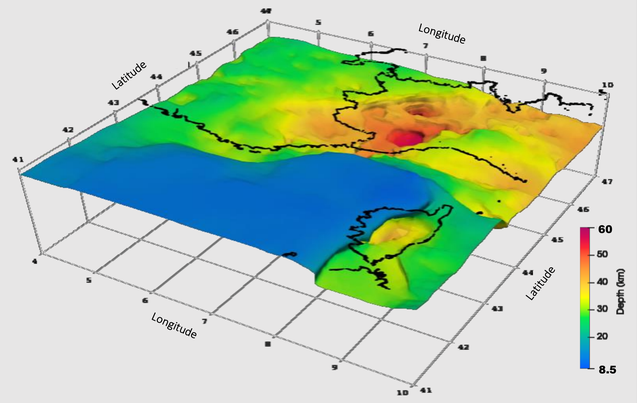

Figure 8. 3-D view of the Moho depth represented as 4.1 km/s isovelocity derived from the final model

Perspectives

- **3-D Vp model from FWI of regional earthquake records with the Vs final model as starting model.**
- **Integration of geophysical, topographic and geological data in a 3-D lithosphere geomodel of Western Alps using Geomodeller (BRGM).**

Schaefer, J. F., Boschi, L., and Kissling, E. (2011). Adaptively parametrized surface wave tomography: Methodology and a new model of the European upper mantle. Geophys. J. Int., 186(3) :1431-1453 | Y. Lu, A. Paul, L. Stehly, R. Brossier, S. Guillot, M. Malusa, and the AlpArray Working Group. (2018). High-resolution surface wave tomography of the European crust and uppermost mantle from ambient seismic noise, *Geophys. J. Int.*, 214 (2), 1136-1150.