SHmax orientation in the Northern Alpine foreland from stress-induced anisotropy in nonlinear elasticity

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Motivation

- The state of stress in the Earth’s crust is often described by the orientation of maximum horizontal compressive stress (SHmax).

- Conventional methods:
  - Borehole-based measurements → expensive, local measurement
  - Inverting earthquake focal mechanisms → limited to seismically active areas

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- The state of stress in the Earth's crust is often described by the orientation of maximum horizontal compressive stress (SHmax)

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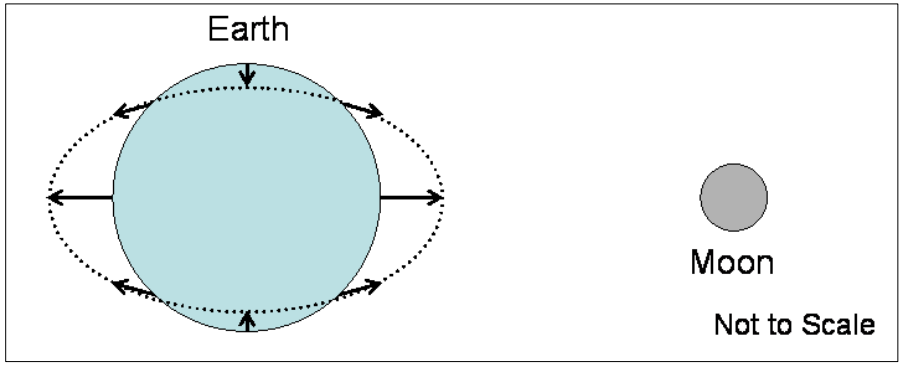
- Utilize → ambient noise recordings

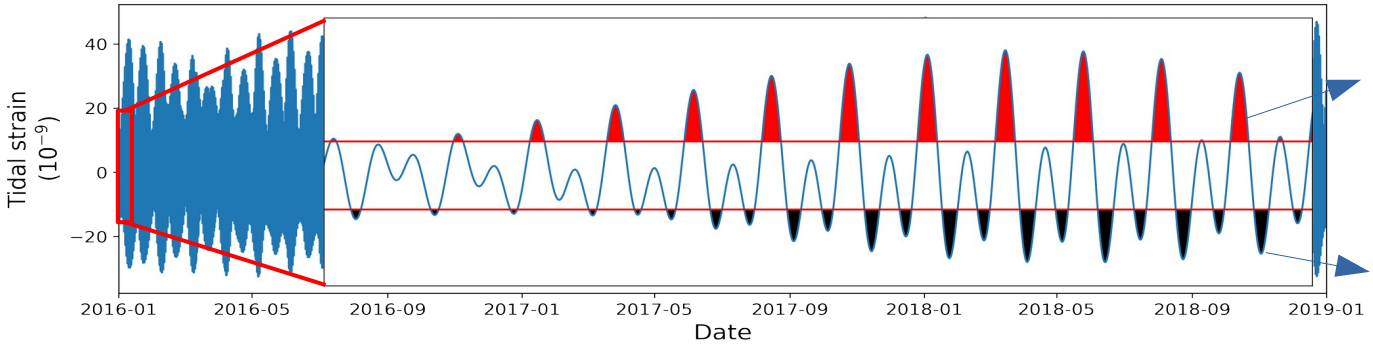
“Natural” pump-probe technique

Seismic velocity variation due to solid earth tides

- Seismic velocities tend to be faster when rocks are compressed → closing of cracks and stiffening of internal contacts
- Slower velocities → weakening of internal contacts



Graphic by: R. Pogge

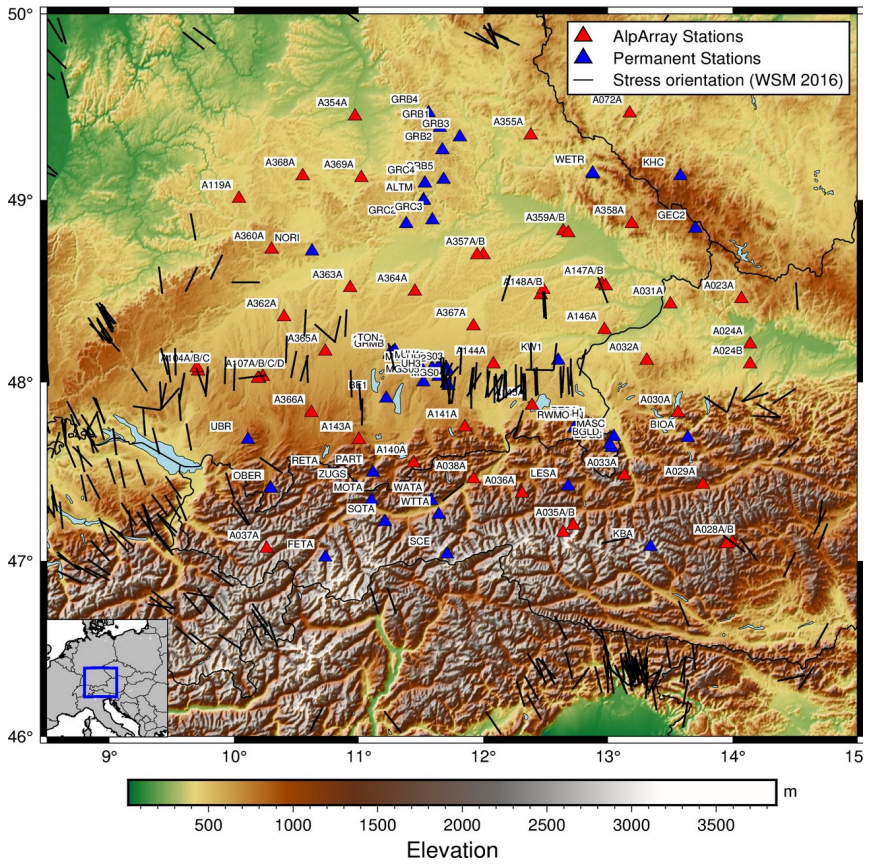


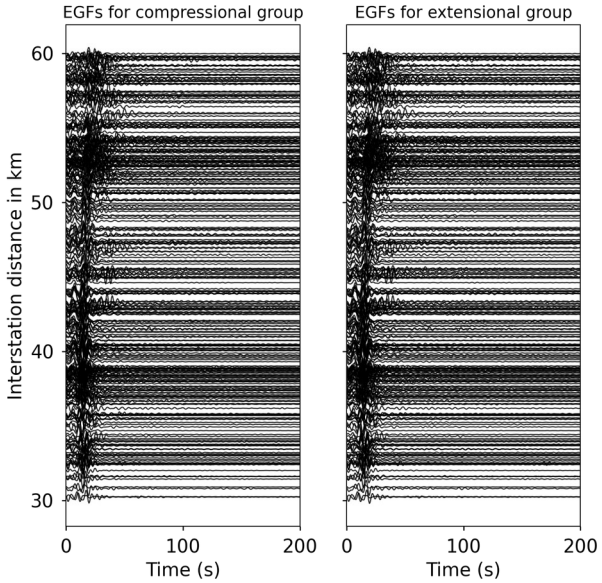
Extensional group

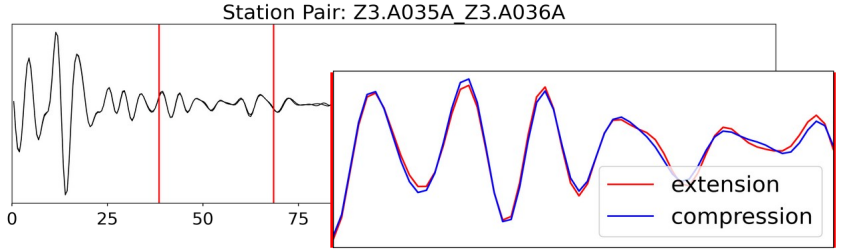
Compressional group

SPOTL package (Agnew, D.C.)

Case: Northern Alpine foreland



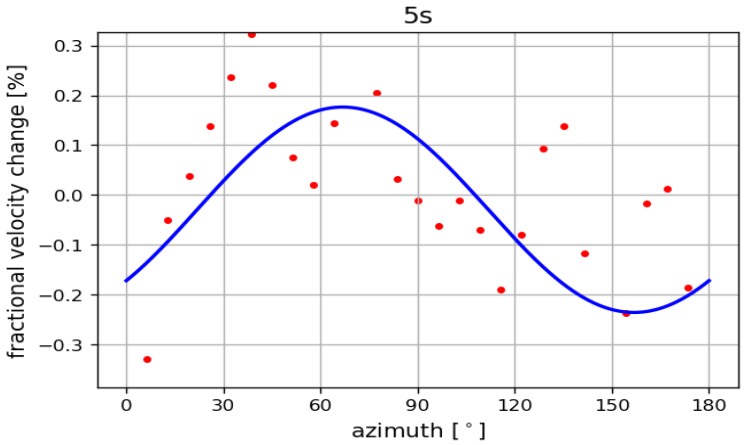




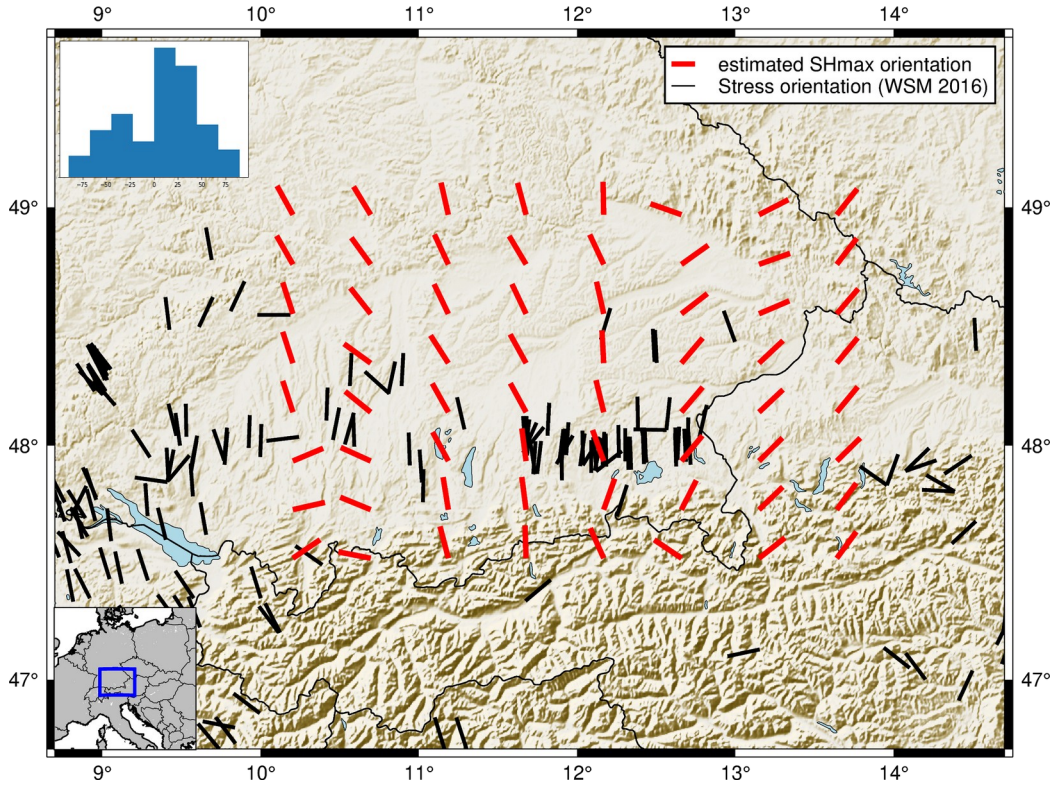
- Coda waves of 30 s time window
- 5 s period
- dv/v is calculated with the wavelet method (Mao et al., 2019)

Azimuthal dependency of fractional velocity changes

- dv/v was the greatest (negative magnitude) in the direction of SHmax



Spatial distribution of SHmax orientation



SHmax orientations derived from ambient seismic noise are in a good agremeent with SHmax reported by WSM database

Summary

- We have demonstrated that the orientation of SHmax can be estimated from ambient seismic noise
- Velocity sensitivity to strain is measured by “natural” pump-probe method where solid-earth tides serve as low-frequency pump and EGFs as high-frequency probe
- Spatial distribution of the estimated SHmax in a good agreement with SHmax from WSM database

Selected references:

- Agnew, D. C. SPOTL: Some programs for ocean-tide loading. Scripps Institution of Oceanography, La Jolla, CA. SIO Ref. Ser. 96-8, 35 pp. (1996)
- Delorey, A., Bokelmann, G., Johnson, C., Johnson, P. Estimation of the orientation of stress in the Earth's crust without earthquake or borehole data. Nature Commun Earth Environ. 2, 190 (2021)
- Mao, S., Mordret, A., Campillo, M., Fang, H., van der Hilst, R. D. On the measurement of seismic travel-time changes in the time-frequency domain with wavelet cross-spectrum analysis. Geophys. J. Int. 221, 550-568 (2019)
- Reinecker, J., Tingay, M., Mueller, B., Heidbach, O. Present-day stress orientation in the Molasse Basin. Tectonophysics. 482(1-4):129-38 (2010)

Thank you!