What AlpArray tells us about stress and water resources under the Alpine Region

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The seismological AlpArray has shed much light on Earth`s structure and earthquakes in the Alpine region. Beside these two classical seismological applications ("events" and "structure"), a dataset of this kind can also be used for other purposes, and the geophysics group at the University of Vienna has been interested in extending the range of applications also into non-classical domains over the last years.

The data have helped us understand non-tectonic phenomena that generate seismic waves in the region, both of natural (such as water, wind, rockfalls, etc.), and of human origin (such as explosions, fires, trains, etc.). This has also extended the use of seismic data across the Earth`s surface, using seismic wave coupling with infrasound.

In this presentation, we focus on new applications of seismic data that extend the "structural" portfolio of seismological techniques, based on nonlinear elasticity (temporal velocity changes). "Pump-probe" approaches use a known test signal to infer subsurface properties. One such test signal is given by tidal stress, which we use as "pump" and ambient noise as "probe", to infer the orientation of mechanical stress acting at crustal depth throughout the Alpine region. This complements the World Stress Map in regions, where we have previously not had stress data - allowing us, for example, to understand why certain major faults in the Eastern Alps (the Periadriatic Line and the Giudicarie Fault) do not rupture seismically, different from less mature, but more favorably-oriented faults.

A particularly promising new application of seismic waves is the study of water in the shallow subsurface, which affects seismic wave velocities. We show that seismic waves can be used to constrain the hydraulic properties of ground water reservoirs from seismic data. Ground water level is often sensitive to air-pressure variations, and we can use the latter as "pump" to explore ground water reservoir characteristics throughout the Alpine region. The large regional variation in observed admissivity throughout Central Europe indicates the effects of thermally-related and air-pressure-related influences.

The study of seismological AlpArray data shows that also changes of soil moisture can be made visible by seismic imaging. Such variations occur periodically, but there are also important long-term trends, which show different characteristics in different regions. Seismic data can fill the observational gap in soil moisture, in a wide range of distances, and importantly, in the depth range that is relevant for plant growth. This shows that seismology can give rather useful constraints for understanding the consequences of climate change.