Modeling and analysis of Distributed Acoustic Sensing (DAS) data in Geothermal environments

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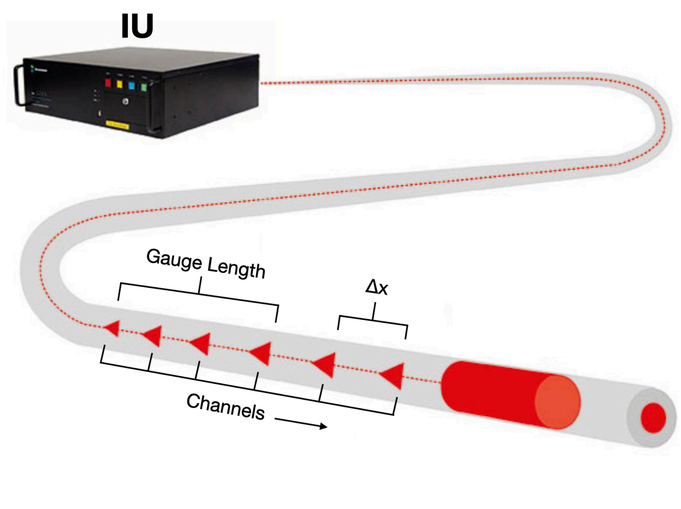
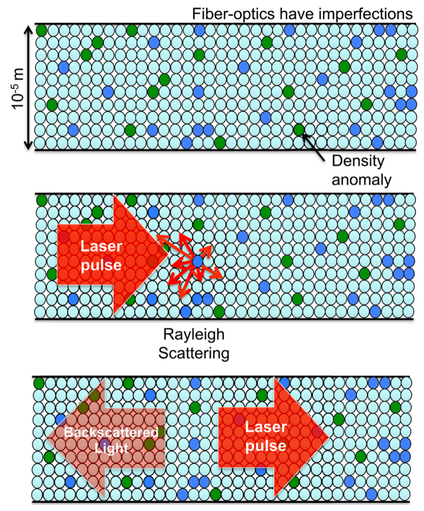
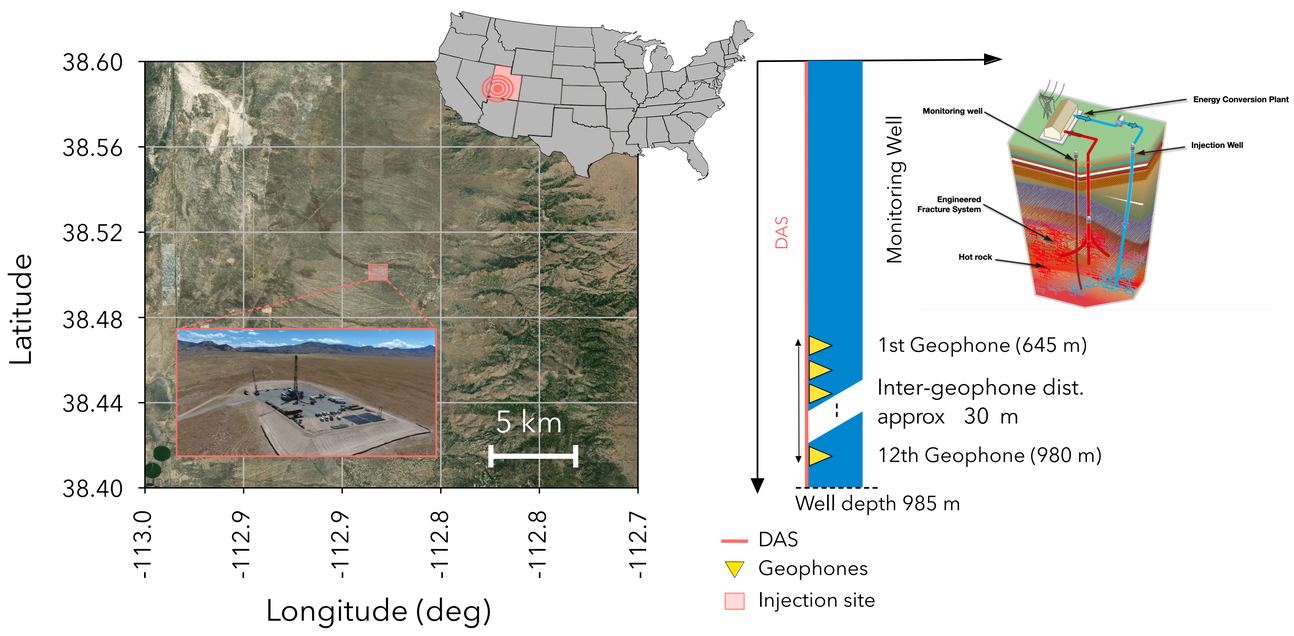
Distributed Acoustic Sensing (DAS)

DAS systems are based on the principle of the Optical Time-Domain Reflectometry (OTDR). This technology consists of an interrogator unit (IU) that sends a laser pulse along a fiber optic cable. A portion of this light pulse, due to defects along the fiber, is back-scattered (**Rayleigh back-scattering**) and recorded by the IU. Phase differences in back-scattered arrivals allow a measure of the dynamic **strain** occurred along the entire fiber, thus can be used for seismic monitoring. This instrumentation can resists to high temperatures (up to about 100° or more), allowing the fiber to be located very close to the reservoir. For this reason, DAS is particularly useful for induced seismicity monitoring of Enhanced Geothermal System.





Lindsey et al. (2020)

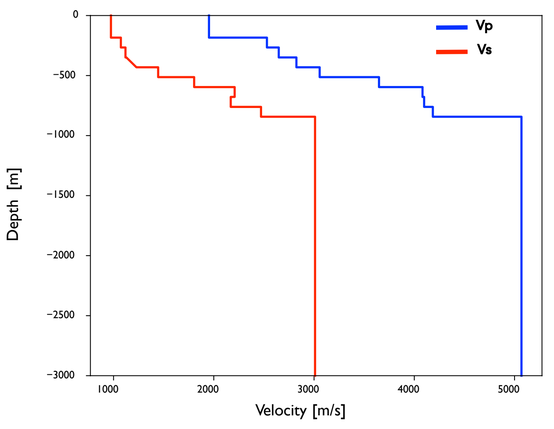


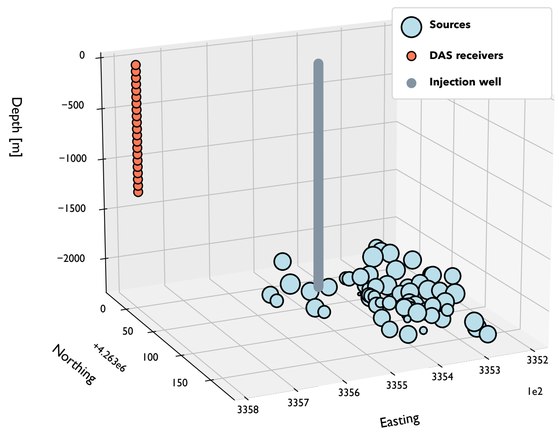
Enhanced Geothermal System (EGS)

EGSs are artificial geothermal reservoirs in which dry rock formations are characterized by high temperatures. EGSs require a fracture network that works as an heat exchanger, this is done by injecting large volumes of fluids at high pressure in the subsurface (hydraulic stimulations). Although EGSs have unquestionably great potential for future low-carbon energy production, still remains the problem of **induced seismicity** associated with these operations (Grigoli et al., 2018). To address this problem, the U.S. Department of Energy started the Frontier Observatory for Research in Geothermal Energy (**FORGE**) experiment, in Utah, whose purpose is developing and testing new methodologies for **microseismic monitoring** of induced seismicity in geothermal environments (Lellouch et al., 2020).

Synthetic Workflow

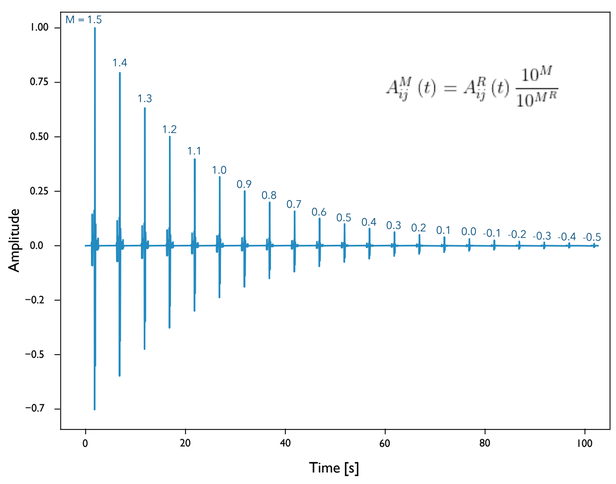
Modeling of earthquake and micro-earthquake sources for synthetic simulations with Salvus (Mondaic) software based on spectral element method.



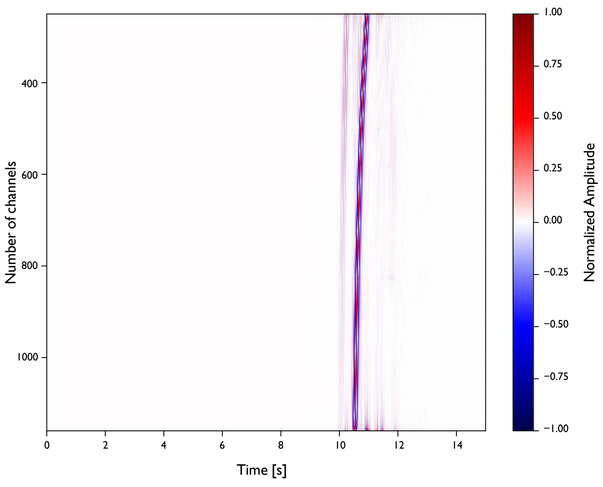


Left) 1D Velocity model used for simulation; Right) Sources and receivers configuration for each event.

Synthetic waveform amplitudes re-scaled according to the real magnitude of the reference event.



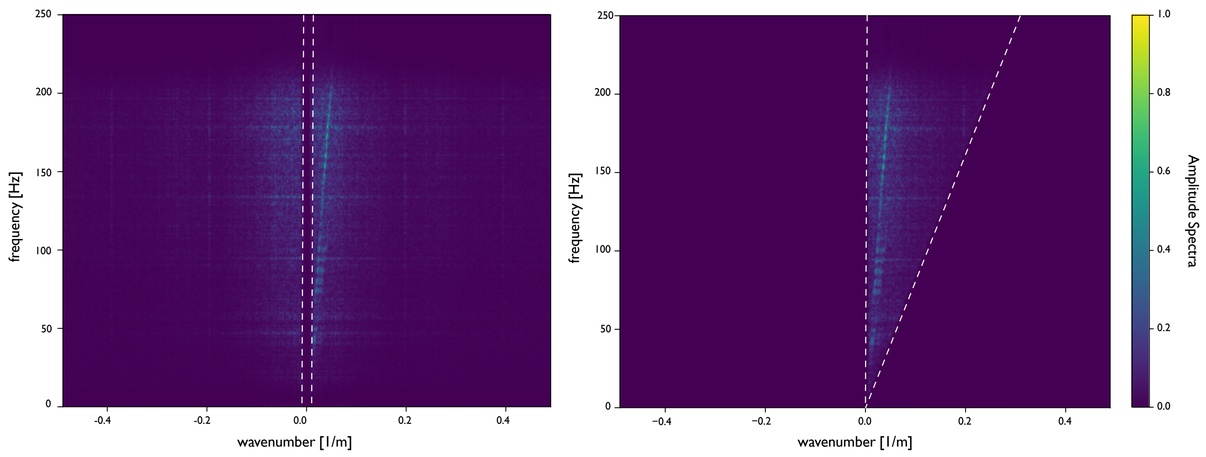
Re-scaling of synthetic waveform amplitude for different magnitudes;



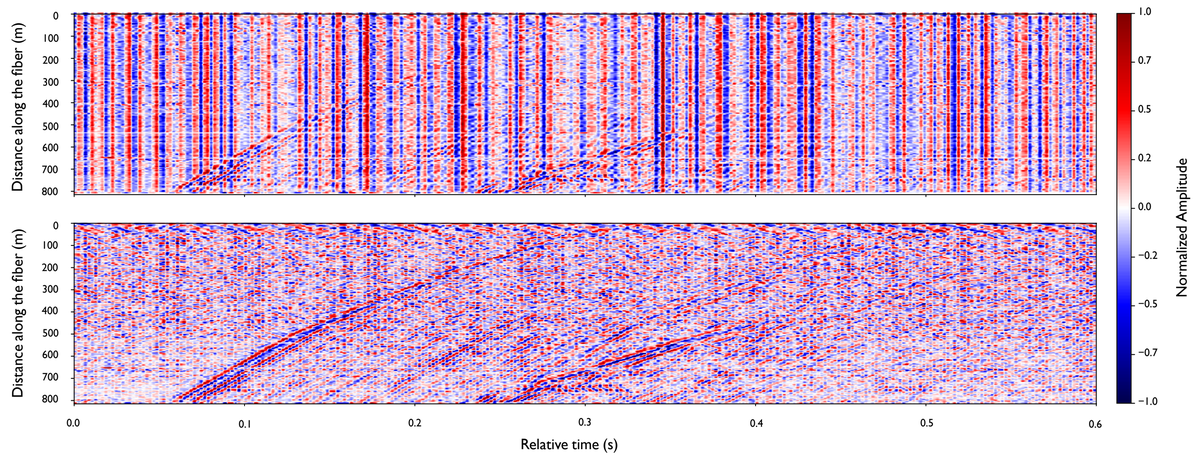
Synthetic DAS event

Real data analysis

Frequency-wavenumber analysis and filtering to de-noise real data.



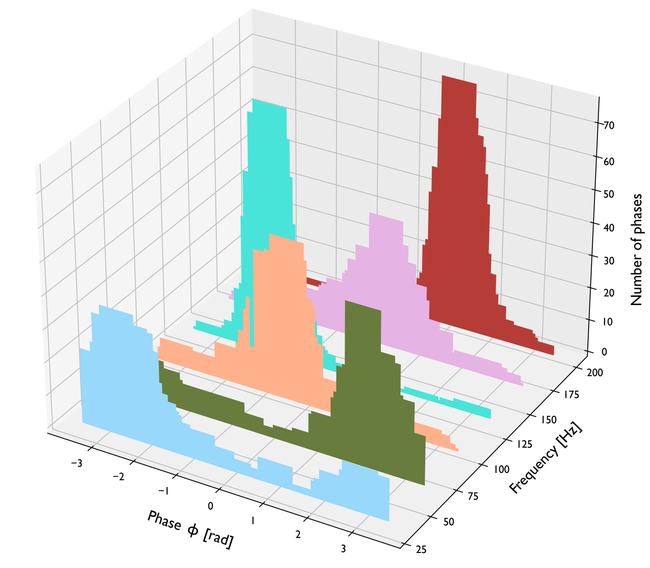
F-K spectrum of: (left) pre-processed DAS data, (right) F-K filtered DAS data.



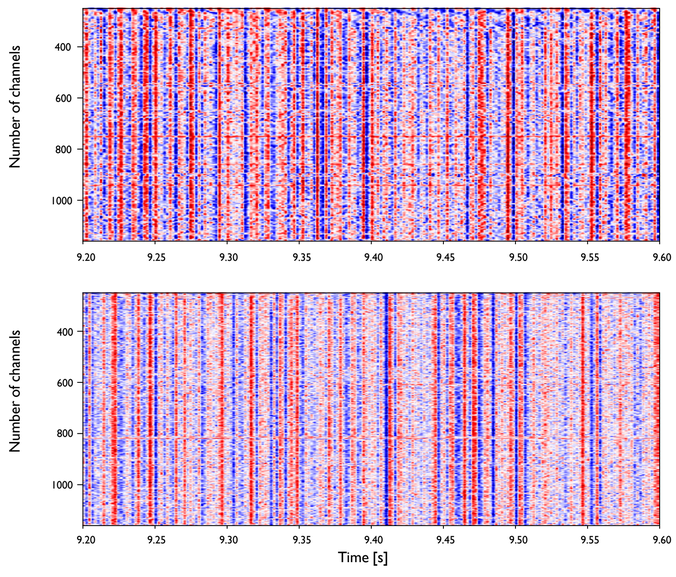
DAS data before (up) and after (down) the application of F-K filter.

Sthochastic simulation of noise and comparison with real DAS data

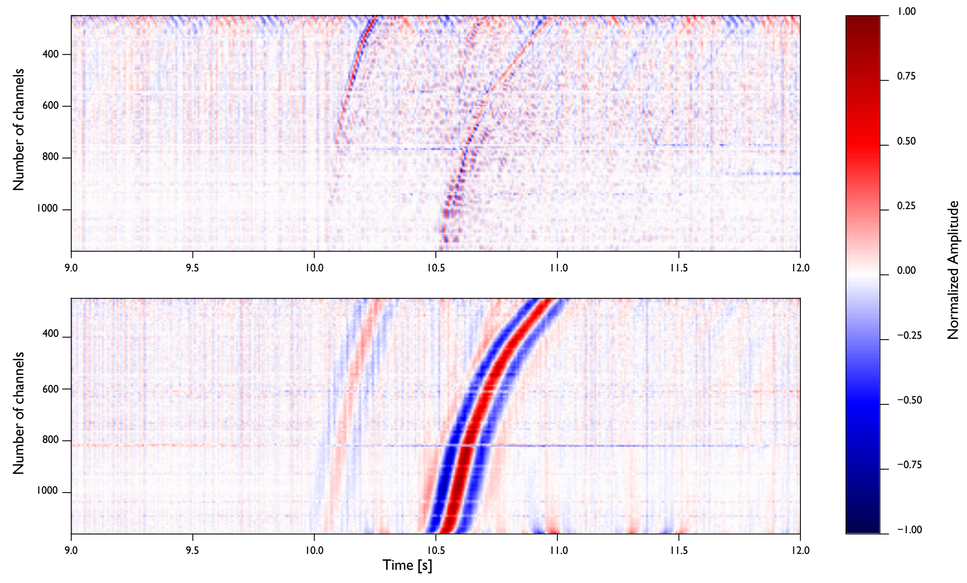
Analysis of phase distributions for each frequency in order to reproduce the real noise affecting DAS data.



Different phase distributions per frequency.



Real DAS noise (up) and synthetic DAS noise (down).



Comparison between real data (up) and synthetic data (down).

References

Grigoli F., Cesca S., Rinaldi A., Manconi A., López-Comino J., Clinton J., Westaway R., Cauzzi C., Dahm T., Wiemer S., (2018). The November Mw 5.5 Pohang earthquake, a possible case of induced seismicity in South Korea. Science 360:1003–1006.

Lellouch A., Schultz R., Lindsey N. J., Biondi B. L., and Ellsworth W.L. (2021). Low-magnitude seismicity with a downhole distributed acoustic sensing array-Examples from the FORGE geo- thermal experiment, J. Geophys. Res. 126, e2020JB020462.