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Ambient noise tomography of a deep geothermal reservoir in non-uniform noise conditions

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Passive imaging from the correlation of ambient seismic noise is of great interest for the exploration, the characterization and the monitoring of deep geothermal sites. It can probe the subsoil with no natural or induced seismic sources and at much lower costs than active methods. Here, we want to apply this method to the geothermal sites of Rittershoffen and Soultz-sous-forêts, Alsace, France. The data is provided by several seismological networks installed in the area over the last years and initially dedicated to the monitoring of the induced seismicity.

The implementation of ambient noise tomography in such context have some specificities. We show that in this region, both the fundamental and the first overtone of the Rayleigh waves are present in the empirical Green functions and should be unambiguously identified. The period band is restricted to the range 1-7s due to the depth of the targeted structures (first 5 kilometers). This requires working with a noise dominated by the secondary micro-seismic peak whose spatial distribution is highly non-uniform in this region. Furthermore, the small aperture of the networks forces us to include station pairs whose distance is less than the 3 wavelengths rule, in order to maintain a proper lateral resolution of the tomographic images.

The analysis of the noise correlation functions indicate that the non-uniform distribution of the noise sources and the short inter-station distances induce significant errors on the tomographic maps. To overcome this issue, we propose an inversion scheme based on the full correlation waveforms to estimate the group and phase speed dispersion maps together with the azimuthal distribution of the noise sources. The method is first applied to synthetic data showing that the procedure produces accurate velocity measurements. The method is then applied to real data to estimate the velocity structure around the two geothermal sites.