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# Direct modelling of the mechanical strain influence on coda wave interferometry

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Coda Wave Interferometry (CWI) aims at tracking small changes in solid materials like rocks where elastic waves are diffusing and so intensively sampling the medium, making the technique more sensitive than those relying on direct wave arrivals. Its application to ambient seismic noise correlation, referred to as Ambient Noise Interferometry (ANI), has found a large range of applications over the past years like for reservoir monitoring or regional fault evolution. Physically, the changes in phases observed are typically interpreted as small variations of seismic velocities. However, this interpretation remains questionable. The goal of the present work is to show from a direct numerical modelling that deformation signal also exists in CWI measurements, which might provide new outcomes for the technique.

For this purpose, we model seismic wave propagation within a diffusive medium using a spectral element approach (SPECFEM2D) during an elastic deformation of the medium. The mechanical behavior is obtained from a finite element approach (Code_ASTER) keeping the mesh grid of the sample constant during the whole procedure to limit numerical artefacts. The CWI of the late wave arrivals in the synthetic seismograms is performed using both a stretching technique in the time domain or a frequency cross-correlation method. Both show that the CWI is sensitive to the elastic deformation of the scatterers differently from an acoustoelastic effect, which is not included in the model.

As an illustration, the CWI monitoring of the deformation is simulated at the laboratory scale where a distribution of scatters in a block intends to mimic the behavior of a granite sample with its mineral grains. The modelled sample is chosen to mechanically and acoustically reproduce a typical reservoir rock like the granite of the deep geothermal site of Soultz-sous-Forêt, France. The mean free path inverted by comparison of the energy density function with a simple multiple diffusion model by least square fitting satisfies the criterion necessary for strong scattering and the computed function fits well a diffusion model. The relative time-shift measured along the coda signal is shown to vary with the displacement imposed with a linear trend. The increase of the relative time-shift with strain shows that elastic deformation is fully correlated to time shifts. Numerous tests show that the time shifts measured in the seismograms carry a real deformation signal and are not numerical artefacts. Our results provide new outcomes for the application of the technique in particular at field scale like the monitoring of fault deformation.