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Imaging elastic deformation with coda wave interferometry

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The sensitivity of coda waves to small changes of the propagation medium is the principle underlying coda waves interferometry (CWI). These waves are intensively sampling the medium, making the technique much more sensitive than those relying on direct arrivals. Application of CWI to ambient seismic noise has found a large range of applications over the past years like for multiscale imaging or monitoring of complex structures. The interpretation of the changes measured in the waveforms remains still questionable. These changes are typically interpreted as small variations of seismic velocities, owing to several factors such as water saturation related to rainfalls, air pressure, stress or temperature changes, micro-crack developments, etc.

Here, we focus on the influence of the elastic deformation of the medium on CWI measurements. The goal of the present work is to compare an experimental approach and a numerical modelling of CWI measurements during mechanical deformation. It aims at a better understanding of the CWI records. The numerical approach allows to test the effect of the material deformation independently of intrinsic wave velocity variations which is an important contribution to laboratory experiments where both effects are generally very difficult to distinguish.

In the laboratory, an Au4G (Dural) plate is loaded with a servo-controlled press, imposing a rigid step by step displacement of its upper face. A specific distribution of holes is drilled in the sample enabling to strongly diffract the wavefield. Seismic wave propagation in this setup during the elastic deformation of this medium is replicated numerically using a 2D spectral element approach (SPECFEM2D). 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. In both approaches, we correlate the elastic deformation with the CWI of the late-wave arrivals in the measured or synthetic seismograms. Both a stretching technique and a cross-correlation method are used. They both show that the elastic deformation of the scatters is correlated with time-shifts of the CWI. Experimental and numerical results of the strain influence on CWI are consistent even if the magnitude of the observables measured are different, highlighting the partitioning between a strain signal and velocity changes in CWI. These results could support a new interpretation of coda wave interferometry and have new implications for ambient seismic noise monitoring.