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Multiple Constituents of Solid Earth Tides Observed with Ambient Seismic Noise

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Elastic moduli of geologic materials are not constant. Due to the elastic nonlinearity of heterogeneous materials they change with the applied strain. This makes the seismic waves whose velocity depends on the elastic moduli an ideal tool for remote monitoring of subsurface strain variations – an observation that is of fundamental importance in underground operations from construction to mining, and for the monitoring of geological processes in volcanoes and fault zones. However, the strain sensitivity of the seismic wave velocity is a parameter that is hard to measure in-situ. The laboratory approach to probe the sensitivity in an active deformation test cannot be transferred to the field where controlled strain cannot be applied. Using the laboratory estimates for interpretation on the field scale requires access to representative samples and involves significant uncertainty in the upscaling. Here we show that improved processing of data from a single seismic station allows to measure the strain sensitivity of the seismic wave velocity in a natural experiment that uses the deformation induced by tidal forces as perturbations and the ambient seismic noise to measure the velocity response. We observe multiple tidal constituents, a thermal strain signal and nonlinear coupling between tidal and thermal strain perturbations.