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The resolution of reservoir dynamics with noise based technologies: A case study from the 2006 Basel injection experiment

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We explore the applicability of noise-based monitoring and imaging techniques in the context of the 2006 Basel stimulation experiment using data from five borehole velocimeters and five surface accelerometers located around the injection site. We observe a significant perturbation of medium properties associated with the reservoir stimulation. The transient perturbation, with a duration of 20-30 days, reaches its maximum about 15 days after shut in, when microseismic activity has ceased; it is thus associated with aseismic deformation. Inverting relative velocity change and decorrelation observations using techniques developed and applied on laboratory and local to regional seismological scales, we can image the associated deformation pattern. We discuss limits of the the frequency- and lapse-time dependent resolution and suggestions for improvements considering the 3-D network geometry together with wave propagation models. The depth sensitivity of the analyzed wave field indicates resolution of perturbation in the shallow parts of the sedimentary layer above the stimulated deep volume located in the crystalline base layer. The deformation pattern is similar to InSAR/satellite observations associated with CO_2 sequestration experiments, and indicates the transfer of deformation beyond scales associated with the instantaneously stimulated volume. Our detection and localization of delayed induced shallow aseismic transient deformation indicates that monitoring the evolution of reservoir properties using the ambient seismic field provides observables that complement information obtained with standard microseismic approaches. The results constitute a significant advance for the resolution of reservoir dynamics; the technology has the potential to provide critical constraints in related geotechnical situations associated with fluid injection, fracking, (nuclear) waste management, and carbon capture and storage.