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Transient change of seismic velocities in the San Jacinto fault region following the 2010 M7.2 El Mayor-Cucapah earthquake observed with ambient noise monitoring

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The 4 April 2010 M7.2 El Mayor-Cucapah earthquake occurred in on the Laguna Salada fault system in Baja California, Mexico and terminated near the U.S. Mexican border. Geological mapping, radar interferometry and creepmeter data reveal that the earthquake triggered widespread shallow slip on many fault segments in the greater Salton Trough area, including segments of the Southern San Andreas fault, Coyote Creek fault, Elsinore fault and Imperial fault. Here we report evidence in support of a triggered slip episode on the San Jacinto fault using noise-based estimates of temporal seismic velocity variations dv/v, thereby extending observations of triggered slip further north and hence further away from the main shock.

We use seismic records from 20 three-component stations of a regional seismic network around the Anza region. We discuss the filtering and data analysis strategies that are necessary to resolve the transient dv/v reduction and to rule out potentially biasing effects of wave field changes associated with the El Mayor-Cucapah earthquake aftershock sequence. We find that the transient duration is about 100 days, and the peak amplitude is one third of the seasonal dv/v signal. Peak dv/v reduction occurs 40 days after the onset. That is, the temporal evolution differs significantly from the 'instantaneous drop and slow recovery' pattern of the seismic velocities that is widely observed in many earthquake source regions, suggesting the observed velocity reduction does not result from the ground shaking associated with the El Mayor-Cucapah event. Instead, these results support the hypothesis that the dv/v pattern reflects deformation that is governed by motion on the San Jacinto fault.

A positive relation between wave period and dv/v amplitude obtained from a frequency dependent analysis indicates that the dv/v changes are not confined to the near-surface layers, but are more likely distributed in the upper few kilometers. Our results are compatible with deformation episodes along the central portion of the San Jacinto fault that have been inferred from local seismicity patterns, and from records from Plate Boundary Observatory borehole strainmeters and the Pinyon Flats Observatory (PFO) strainmeter. Notably, the timing of the peak dv/v reduction coincides with the peak strain rate observed at PFO.

These findings constitute an important contribution to our understanding of fault interactions and transient deformation patterns. They clearly demonstrate the potential of ambient noise-based techniques as a powerful, complementary building block for active fault monitoring. These claims are further supported by observations of additional weak dv/v transients in response to regional earthquakes between 2011 and 2015 that we can also associate with signals in the PFO strainmeter data.