2019 SCEC Proposal FINAL REPORT

Detailed space-time variations of shallow velocity changes from dense array data

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***Proposal Categories*:**

Integration and Theory

SCEC Research Priorities:

Science Priorities: P2.c, P4.a, P2.b

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Summary

The research provides high-resolution results on temporal changes of seismic velocities in the shallow crust generated by small earthquakes and other sources. The results are based on continuous waveforms recorded a dense array of 1,108 vertical ZLand nodes at the Sage Brush Flat (SGB) site in the trifurcation area of the San Jacinto fault zone (SJFZ) southeast of Anza, California. The dense array covered ~ 600 m x 600 m region around the Clark branch of the SJFZ, with 1108 sensors separated nominally by 10-30 m, and recorded earthquake and noise data continuously at 500 samples/sec. The recordings include signals generated by small earthquakes and various other sources of ground motion (e.g. air/train traffic, wind shaking obstacles above the ground). We examine velocity changes with autocorrelation functions of moving time windows using different frequency bands (10-40 Hz) related to different depth sampling. The results show that nearby M < 3 earthquakes can produce over 10% transient changes of velocities at the subsurface that recover on a timescale of minutes. The derived values reflect a combination of nonlinear behavior and changes of material properties. The response of the network is highly variable and is likely related to the local structure underneath the array. The spatial distribution of velocity changes is similar for all cases examined so far. However, the time of the recovery process following velocity drops strongly depends on the used frequency band. Non-earthquake sources of ground motion produce similar changes as seismic events. Additional analyses of earthquakes and other sources of motion can improve the knowledge on velocity changes at shallow depths.

Intellectual Merit

The preformed analyses reveal surprising changes of seismic velocities at the subsurface generated by small earthquakes and other ongoing sources of weak ground motion. If substantiated by additional work in progress, the results have important implications on the dynamics of the subsurface and its susceptibility to failure in relation to weak ground motion, and expected amplitudes of ground motion at the surface.

Broader impact

The research provides important knowledge on nonlinear elasticity and failure of shallow materials. The results may be used to test and refine assumed models on the rheology and behavior of the shallow crust and near-surface soils, and are relevant to reliability of underground facilities. The techniques developed in the project may be used to derive high resolution results on variations of seismic velocities in other locations.

Publications supported by the project

Bonilla, L. F. and Y. Ben-Zion, 2020. Detailed space-time variations of shallow velocity changes from dense array data, manuscript in preparation.

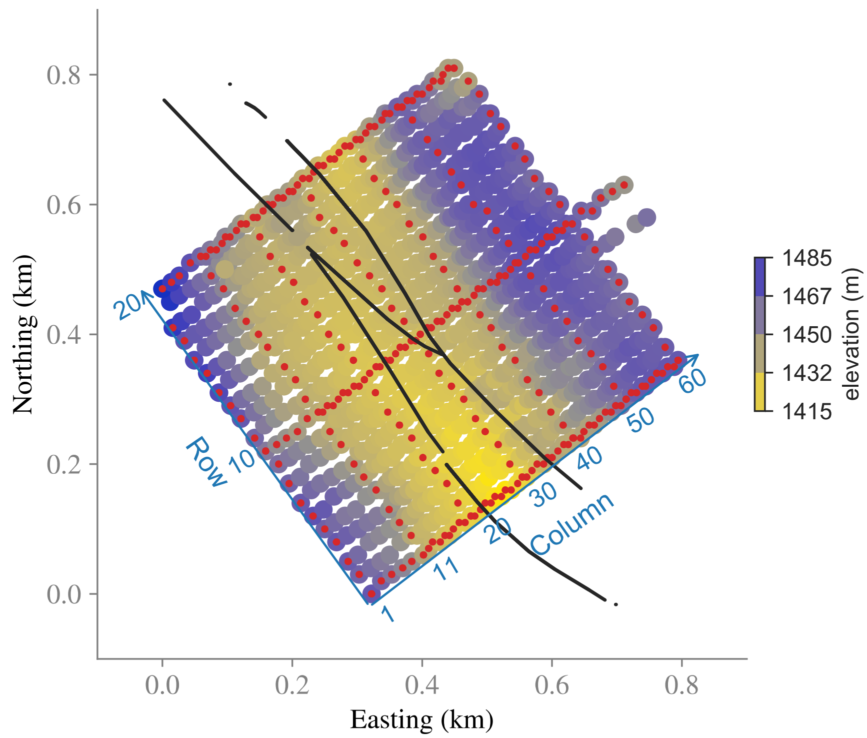

Figure 1. A spatially-dense array with 1108 vertical- component geophones at the SGB site on the San Jacinto Fault Zone. Red dots show the row and column intervals every 10 sensors. Black lines indicate fault surface traces including the main Clark fault (MCF). The row and column numbers of the dense array start from the SW corner and increase toward the NW and NE (blue arrows), respectively. Modified from Ben-Zion et al. (GJI, 2015).

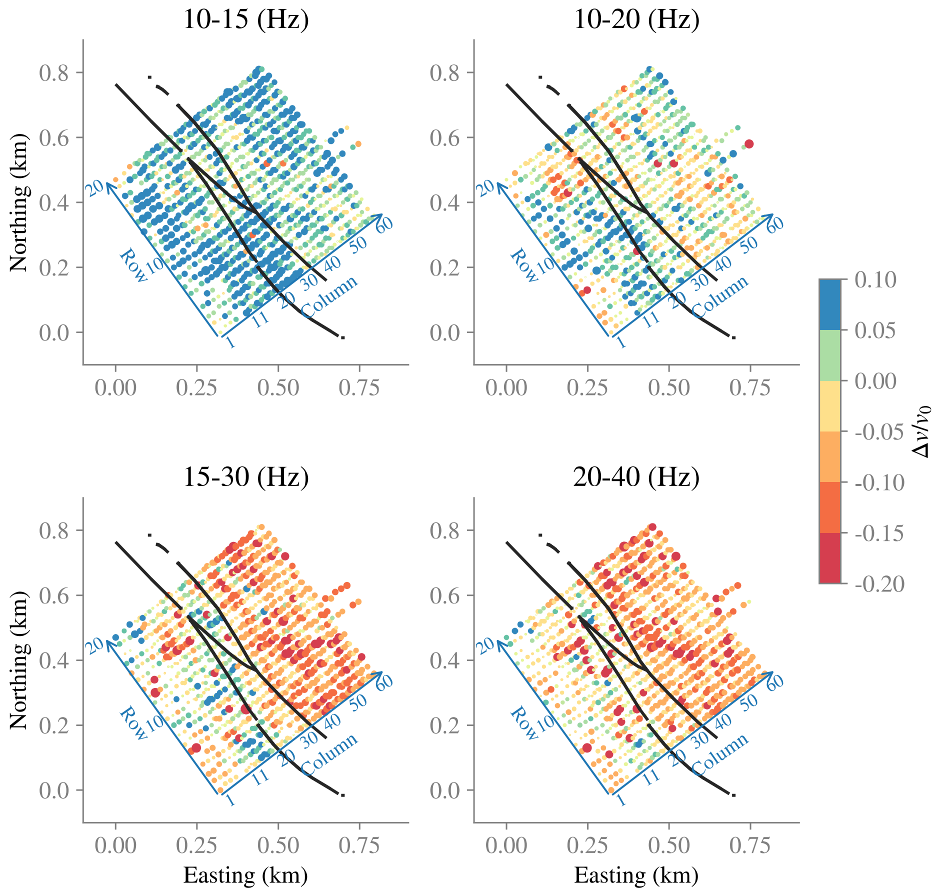

Figure 2. Spatial distribution of temporal changes of seismic velocities across a dense array at the SGB site on the San Jacinto Fault Zone for four frequency bands. The results are based on the autocorrelation function of a stack of P waves generated by 31 M<2.5 events with respect to the autocorrelation of the ambient noise. The derived values reflect a combination of nonlinear behavior and changes of material properties. From Bonilla and Ben-Zion (ms. in prep., 2020).