Detailed space-time variations of shallow seismic velocities at the San Jacinto fault zone based on autocorrelation analysis of dense array data

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Introduction

The Sage Brush Flat (SGB) site in the trifurcation area of the San Jacinto fault zone (SJFZ) southeast of Anza, California, had a dense array of 1,108 vertical ZLand nodes recording continuous waveforms for ~30 days in spring of 2014. The dense array covered ~ 600 m x 600 m region around the Clark branch of the SJFZ with a core grid of 20 rows perpendicular to and centered on the fault trace. Each row had 50 sensors at a nominal 10 m inter-station spacing and 30 m between rows (Figure 1). The array recorded earthquake and noise data continuously at 500 Hz. We compute high resolution space-time variations of subsurface seismic properties from autocorrelation functions (ACF) of noise and 31 local earthquakes recorded at the array.

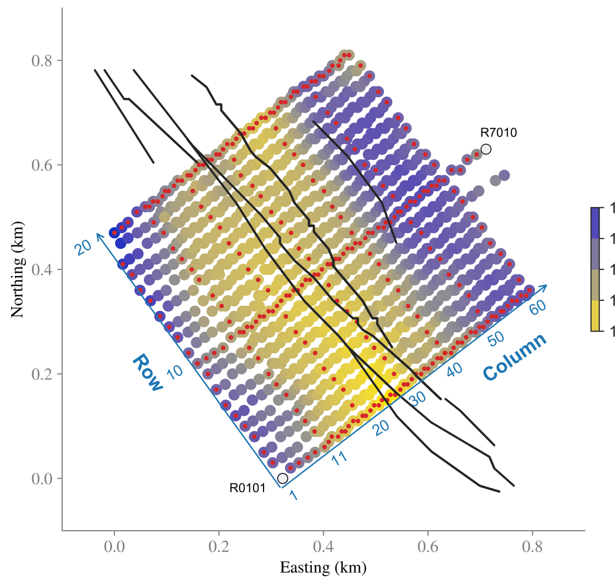
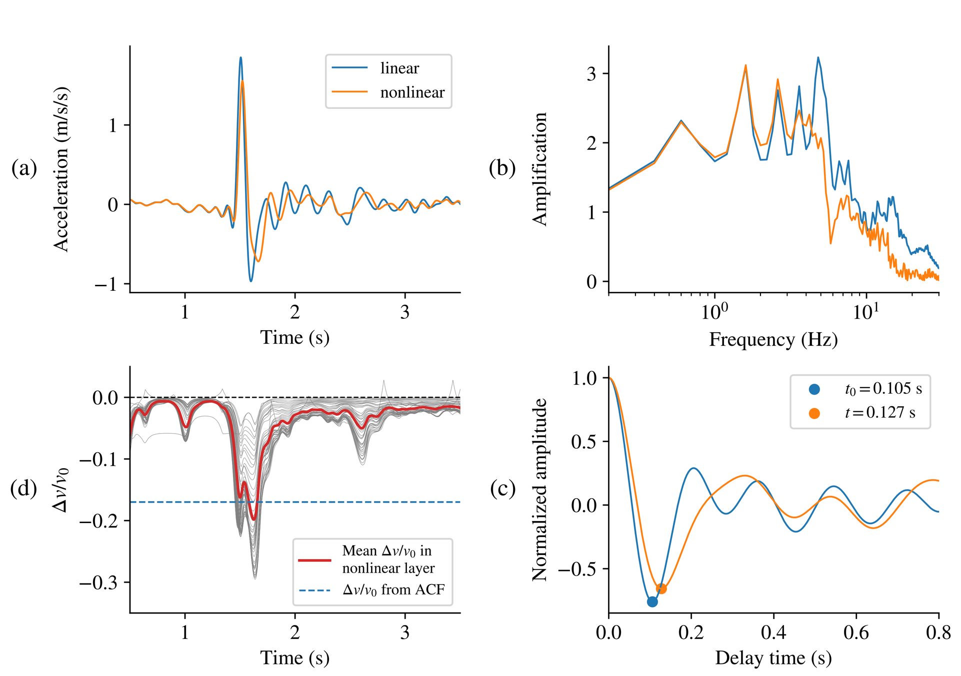


FIGURE 1: SGB dense array. The colour dots represent the topography elevation. The fault traces are shown by the black lines (Share et al., 2020).

Velocity changes and nonlinear site response



- Nonlinear soil response reduces the amplification and frequency content (Fig 2a and 2b).
- ACF's from accelerograms at the surface show different time delays due to the affected medium velocity (Fig 2c).
- Instantaneous slope of stress-strain space is the shear modulus *u* at time *t*.

$$v/v_0 = \sqrt{\mu/\mu_0}$$

$$\Delta v/v_0 = v/v_0 - 1$$

which is shown in Fig 2d

FIGURE 2: Computed velocity changes from time delays as:

$$\Delta t/t = -\Delta v/v_0 \text{ and } \Delta t = t - t_0$$

t_0 is the reference time delay

Effect of the frequency band

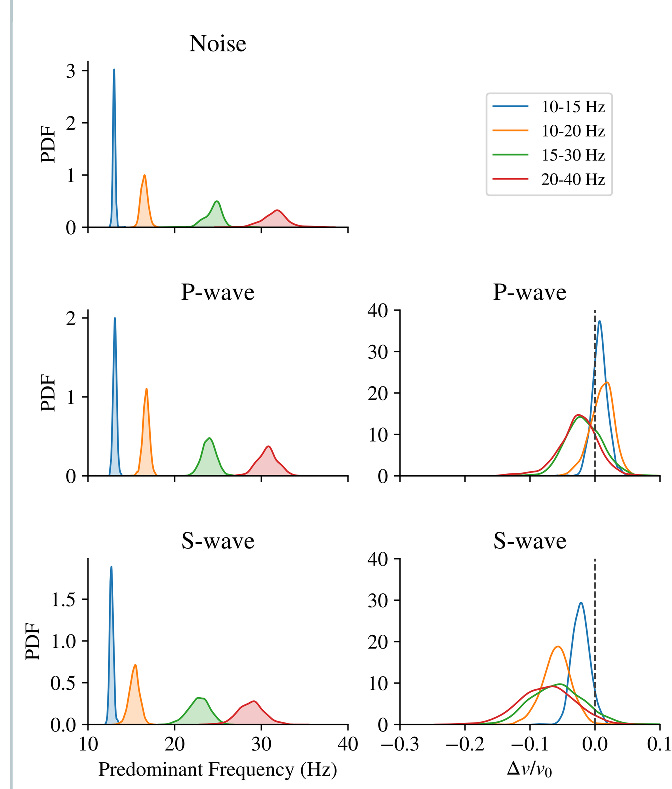


FIGURE 3: PDF of predominant frequency (left) and relative velocity changes for P and S-wave windows of *earthquake data w.r.t.* mean ACF's, at each station, of 1H *noise* at 4 frequency bands (right). This is the behavior of the whole array. P and S-waves produce 2.5% and 6% velocity changes at f > 15 Hz.

Spatial variability of dv/v changes

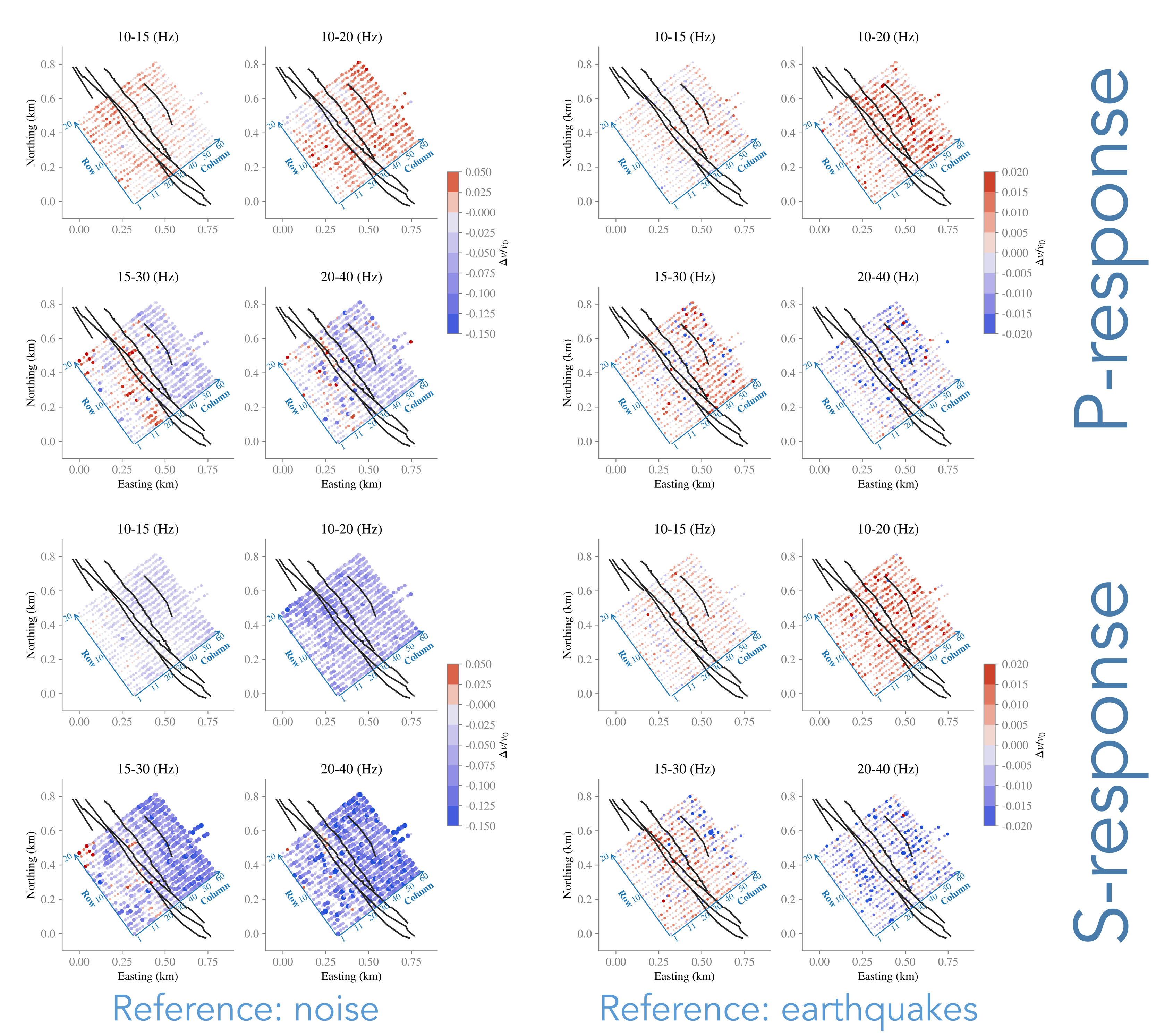


FIGURE 4: P and S-array response w.r.t. noise (left) and earthquake data (right). Relative dv/v values are higher for noise. In both cases there is a strong spatial variability at all frequency bands. Frequencies > 15 Hz clearly show a different behavior between the areas separated by the fault traces, where the NE section has lower dv/v values than the SW.

Temporal variability of dv/v changes

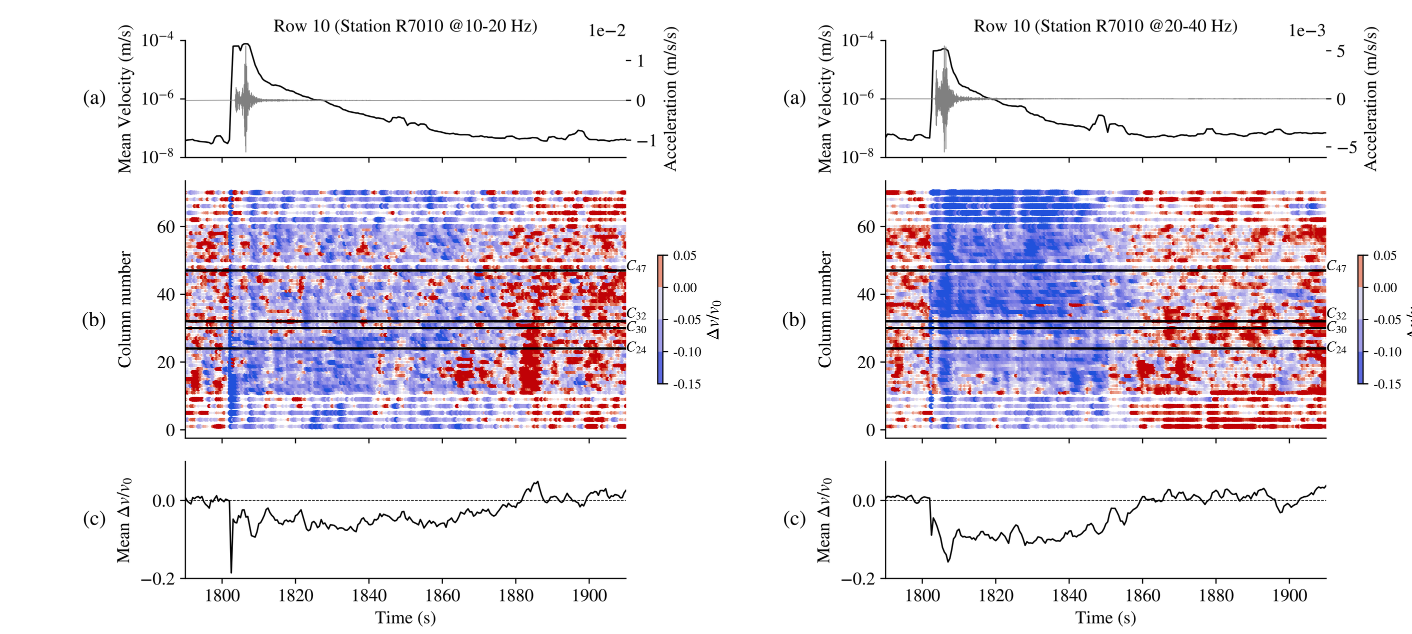


FIGURE 5: Relative velocity changes w.r.t. noise for one event along row 10 (Fig 1) at two different frequency bands. The top panel shows the acceleration and mean PGV of all stations. The middle panel shows the spatial variability of dv/v at row 10. Note the coherent response of the array to the P and S-wave arrivals. The bottom panel shows the mean dv/v of the line array. Time recovery is longer at lower frequencies and closely follows the PGV temporal evolution.

Summary

Velocity changes strongly depend on the frequency band used. The healing phase lasts longer at low frequencies. The different frequencies sampling reveals a very heterogenous media having a strong space-time variability response at shallow depths. The use of noise as reference produces relatively strong dv/v values for such small events (M < 3.1). Yet it can be useful to map the local heterogeneities of the shallow crust.

References

Share, P.-E., P. Táborík, P. Štěpančíková, J. Stemberk, T. K. Rockwell, A. Wade, J R. Arrowsmith, A. Donnellan, F. L. Vernon & Y. Ben-Zion, (2020). Characterizing the uppermost 100 m structure of the San Jacinto fault zone southeast of Anza, California, through joint analysis of geologic, topographic, seismic and resistivity data, *Geophys. J. Int.*, doi: 10.1093/gji/ggaa204.

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LFB and YBZ were funded by SCEC Award #19072 "Detailed space-time variations of shallow velocity changes from dense array data"

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