Temporal Variations and In-situ Shear Modulus-strain Behavior of Shallow Materials During the Kumamoto Earthquake Sequence

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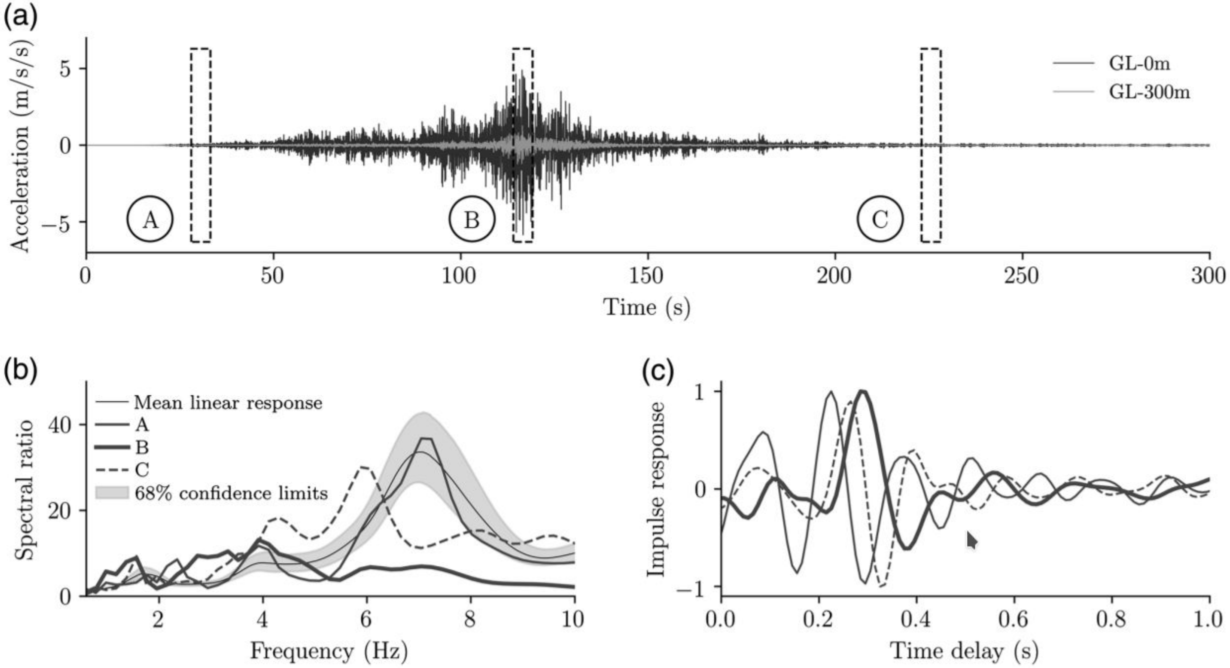
Nonlinear response of near-surface materials

- Decrease in seismic shear wave velocity
- Shift of resonance frequency
- Increase in attenuation

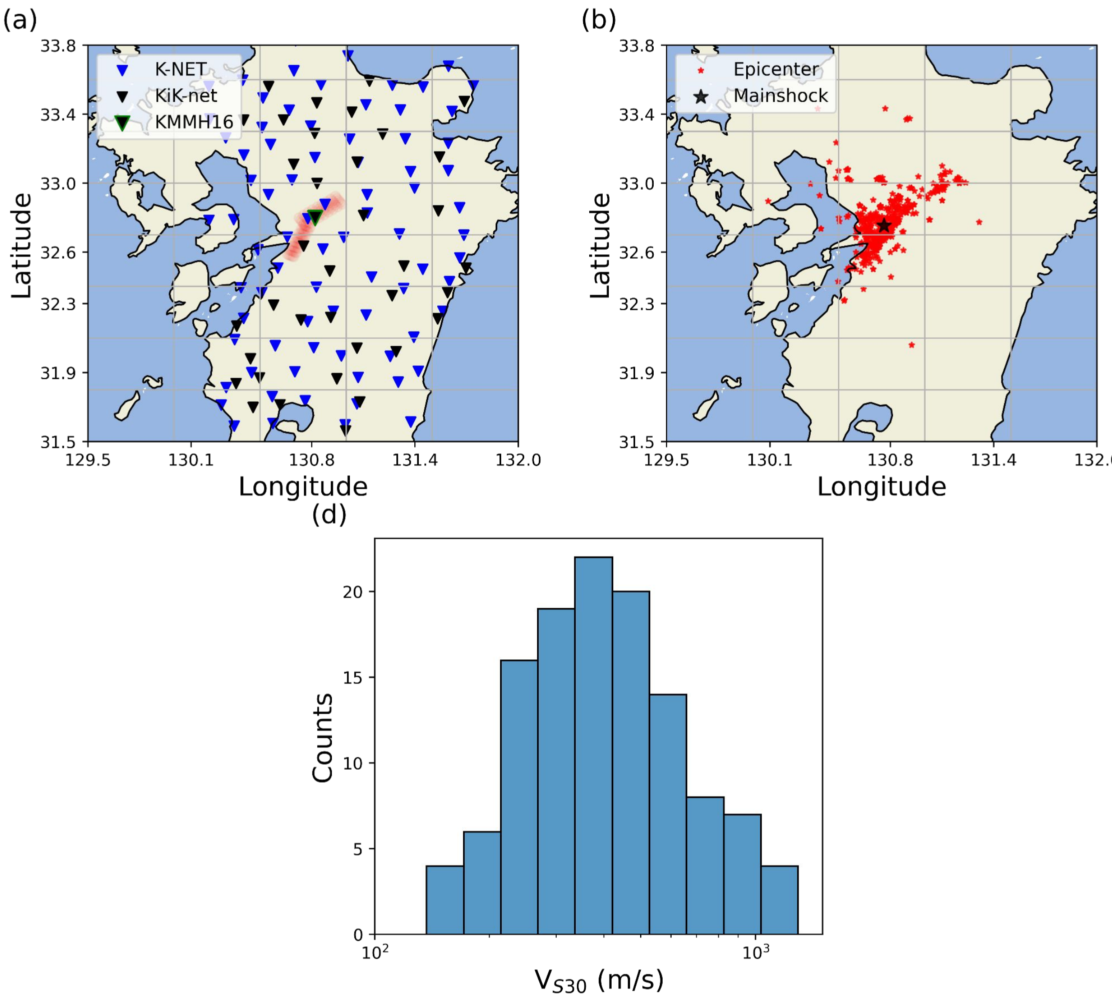


Bonilla and Ben-zion, 2019

Goal of our study

- Estimate coseismic velocity changes during the Kumamoto earthquake based on **autocorrelation function** (ACF, Claerbout, 1968, Bonilla and Ben-zion, 2019)

- Quantify **“in situ”** shear modulus-strain degradation curve for different site classes

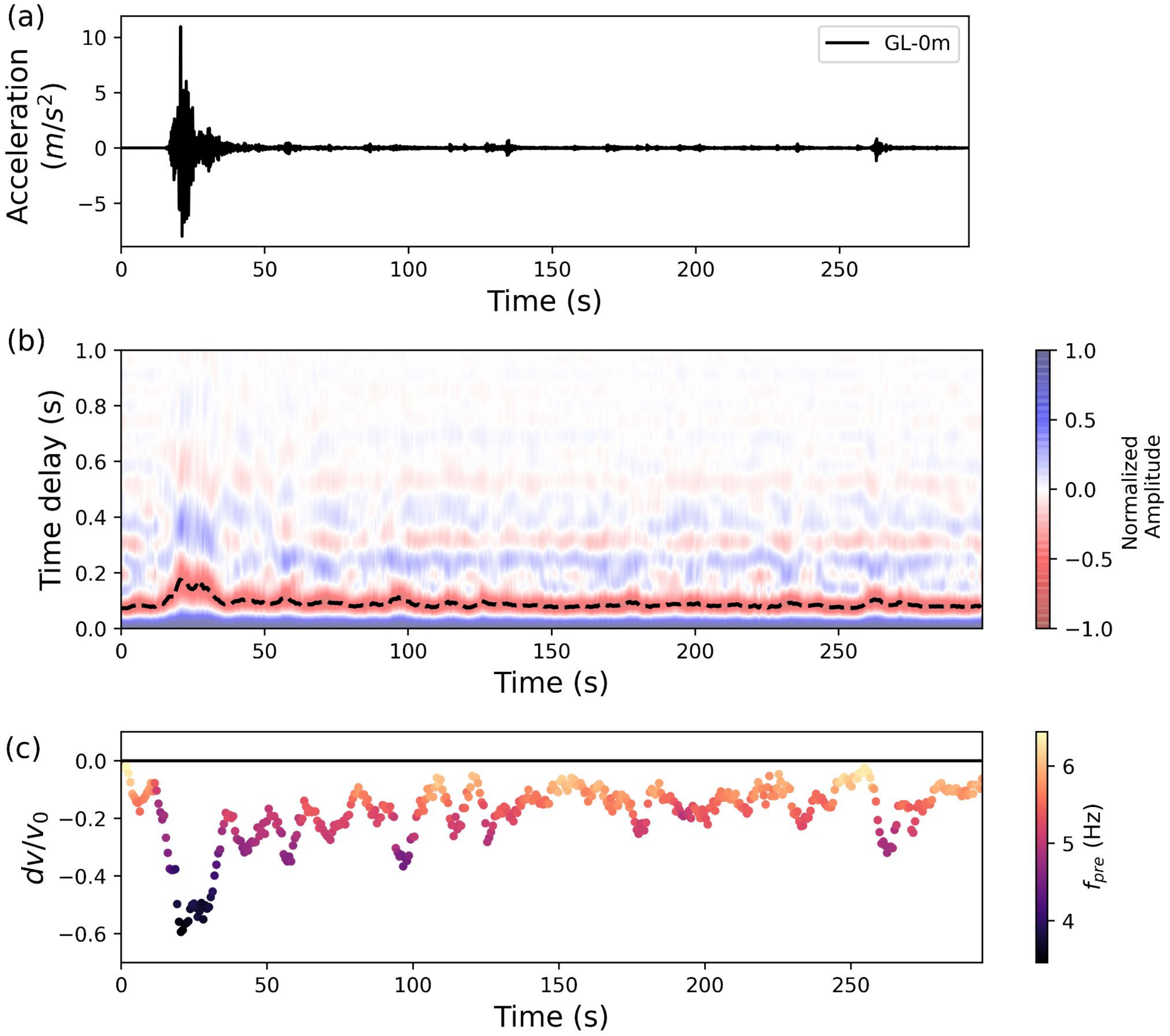


ACF for Mainshock

- The ground motion record at the surface station KMMH16

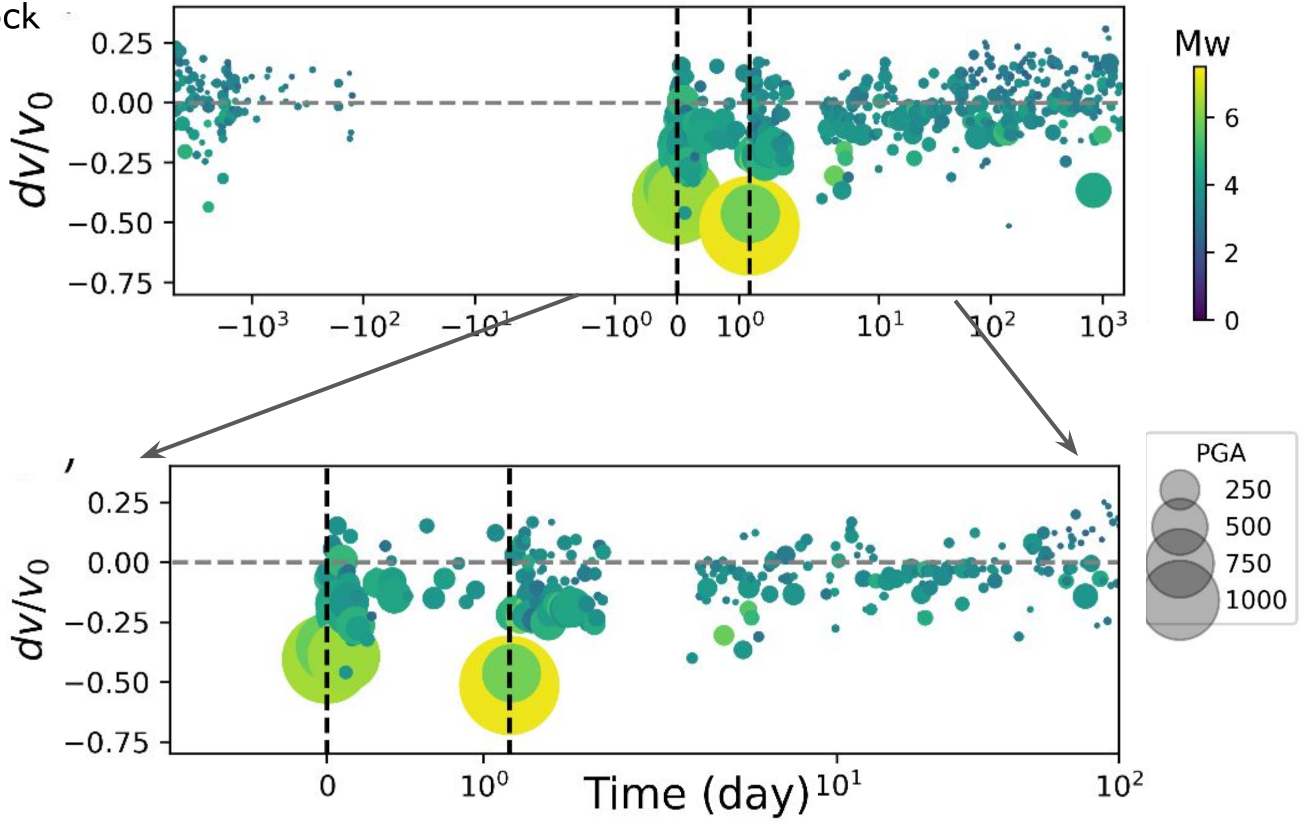
- Estimated zero-offset travel time
  - window length= 5.12s
  - 75% window overlap

- Coseismic velocity changes
  - Reference travel time is estima
    by the events with PGA<20gal



Coseismic velocity changes of the sequence

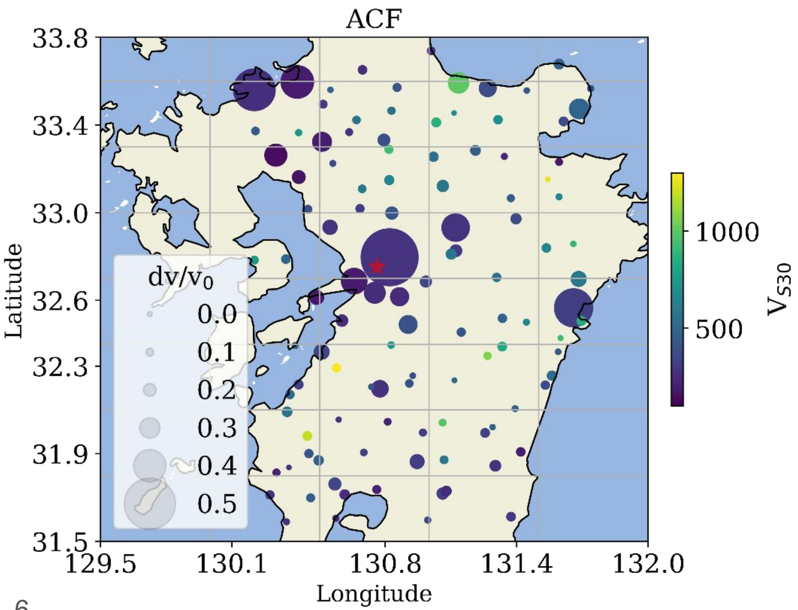
- 1st dot line: 1st foreshock
- 2nd dot line: Mainshock



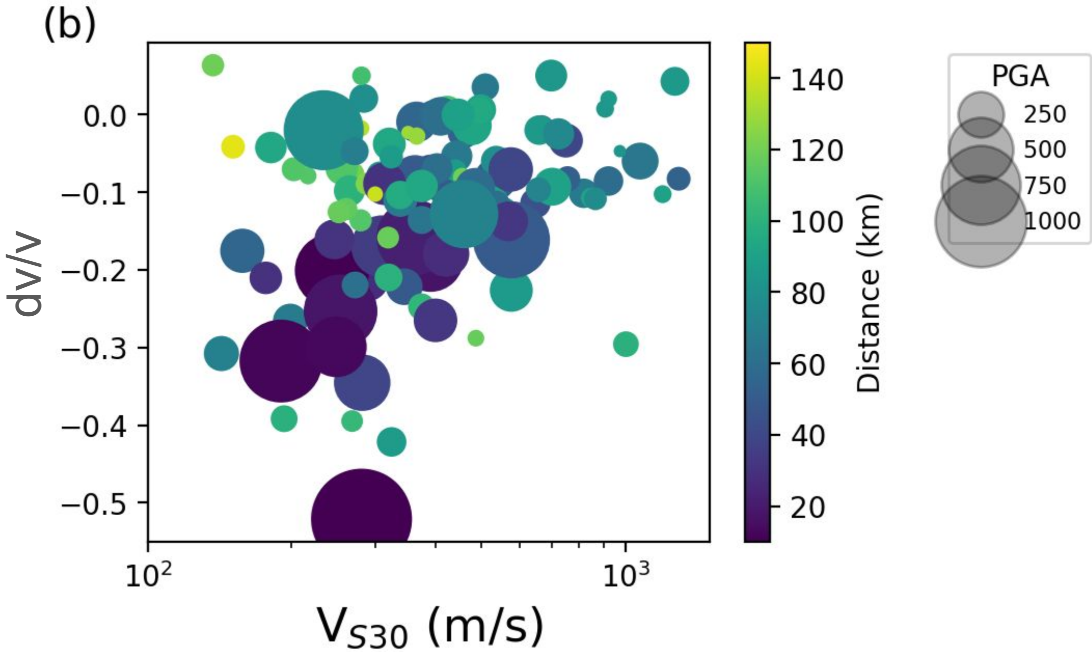
Vs30-velocity changes relation (all stations)

- Larger acceleration, soft soil conditions, and short distances to the source control the amplitude of dv/v
- dv/v are larger for low values of Vs30; however, they are also present in Vs30 > 800 m/s

KiK-net+ K-NET stations (ACF)



KiK-Net+ K-Net stations (ACF)



In-situ shear modulus-strain curve analysis (Events before and after the Mainshock)

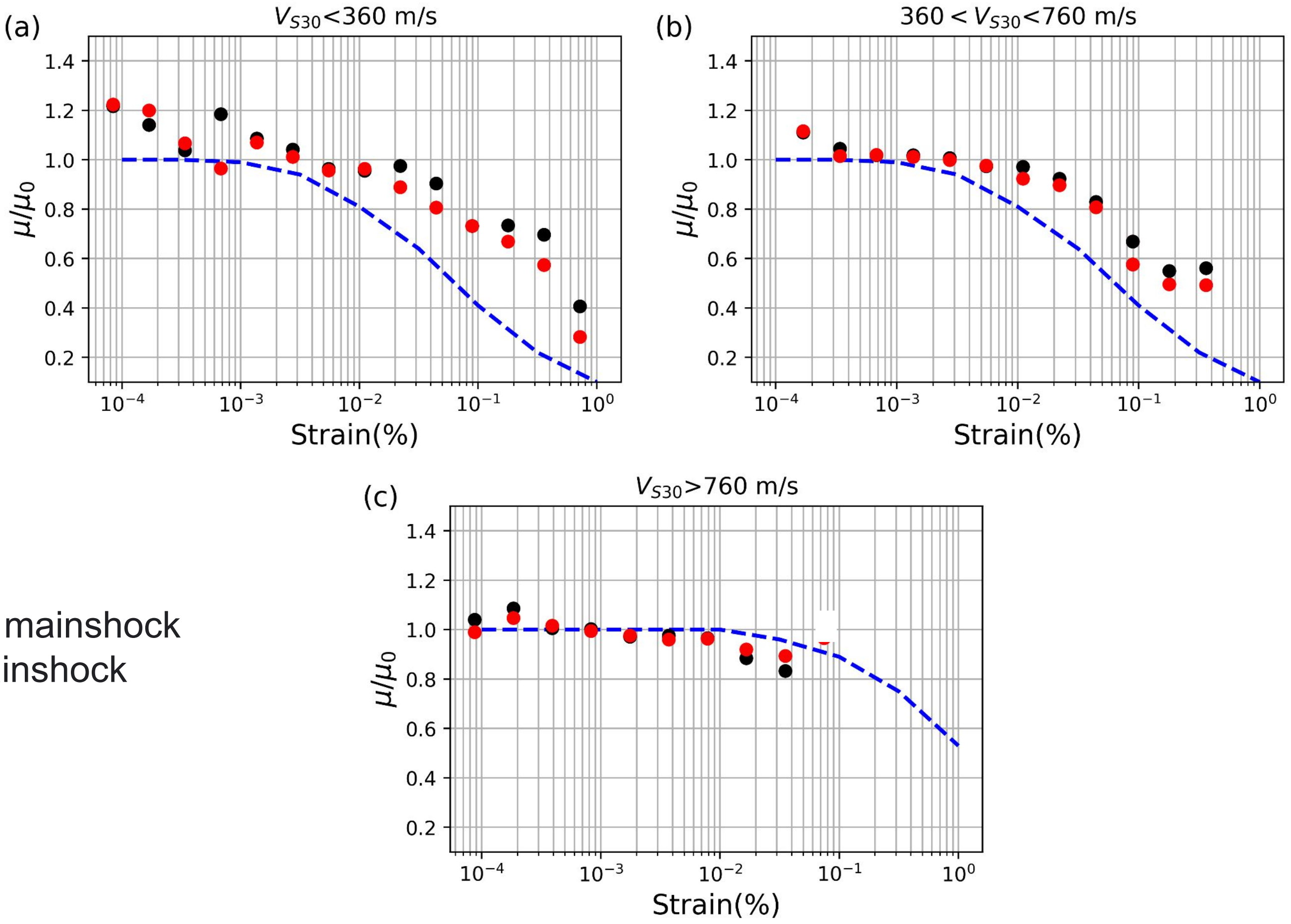
- Shear modulus proxy

$$\mu/\mu_0 = (1 + \Delta v/v_0)^2$$

- Shear strain proxy (Guéguen, 2016)

$$PGV/(V_{s30} \cdot v/v_0)$$

  - Black: Events before the mainshock
  - Red: Events after the mainshock



Conclusions

- Shear wave velocity decrease (nonlinearity) is occurring mainly close to the surface during strong ground-shaking. **This decrease is dependent on Vs30.**

- A nonlinear response is observed for **hard rock sites** (probably due to the soil layer in the top near-surface). **Vs30 alone is not enough to choose a reference site.**

- We have measured “in situ” the relationship between shear-modulus and strain changes degradation curves. **The degradation curves changes after a large earthquake.**

- The time-dependencies of site response shown in this study may be one key factor controlling the **within-station ground-motion variability.**

Thank you

References

Claerbout, J. F. (1968). Synthesis of a layered medium from its acoustic transmission response, Geophysics 33, no. 2, 264–269.

Guéguen, P. (2016). Predicting nonlinear site response using spectral accel- eration versus PGV/Vs30: A case history using the Volvi-Test site, Pure Appl. Geophys., doi: 10.1007/s00024-015-1224-5.

Bonilla, F., P. Guéguen, and Y. Ben-Zion (2019). Monitoring Coseismic Temporal Changes of Shallow Material during Strong Ground Motion with Interferometry and Autocorrelation. Bull. Seismol. Soc. Am. doi: https://doi.org/10.1785/0120180092

In-situ shear modulus-strain curve

Shear modulus proxy

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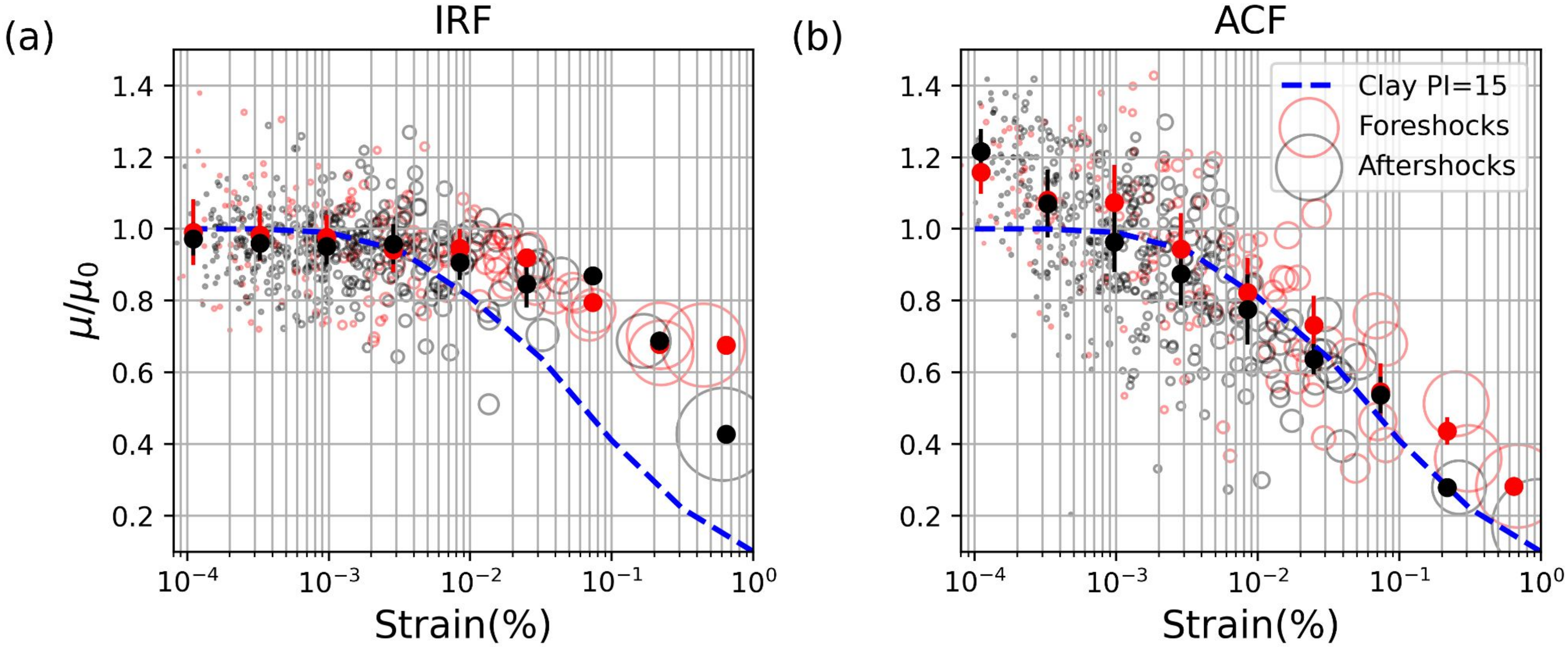
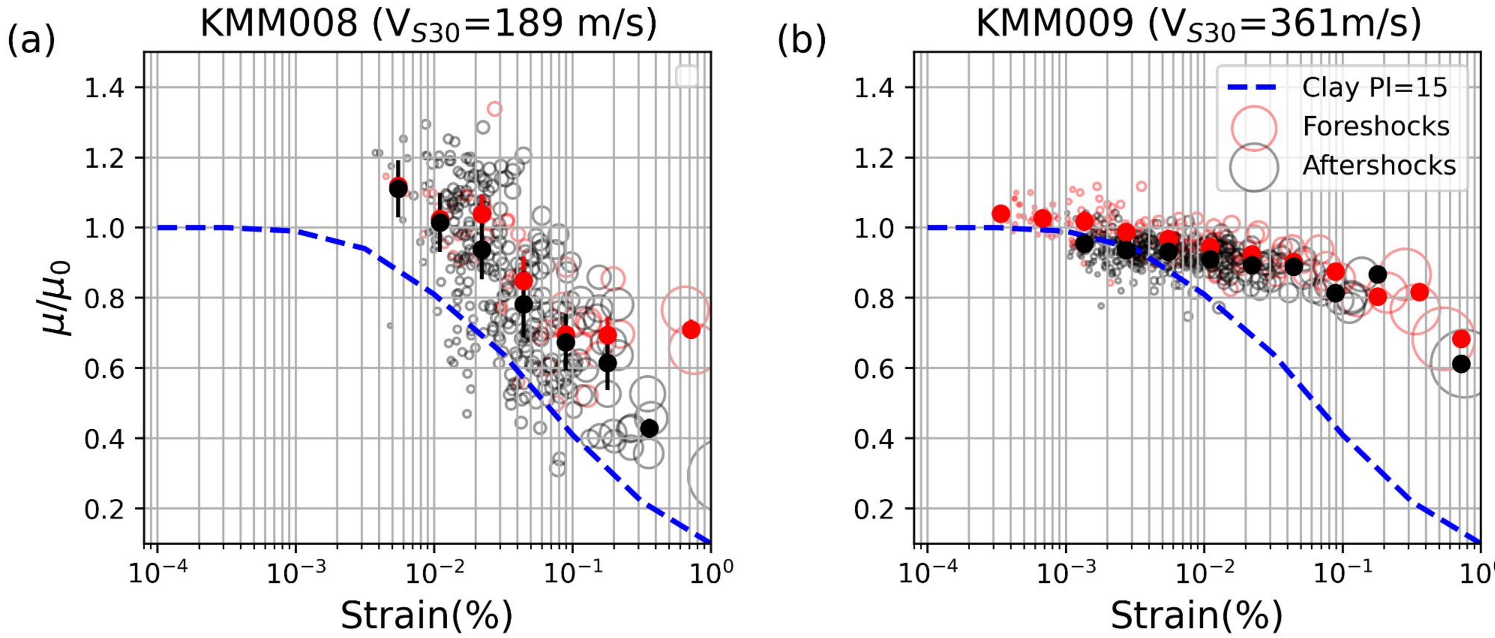
Shear strain proxy

$$PGV/(V_{s30} \cdot v/v_0)$$



In-situ shear modulus-strain analysis (soft soil)



In-situ shear modulus-strain analysis (Hard rock)