Evidence for Nonlinear Behavior of the Soil at the ARGONET site

Zafeiria ROUMELIOTI[1], Fabrice HOLLENDER[2], Philippe GUEGUEN[3]

[1]Research Unit of Soil Dynamics and Geotechnical Earthquake Engineering, Dept. Civil Engineering, Aristotle University of Thessaloniki
[2]CEA/DEN, 13108 Saint Paul Lez Durance, France // ISTerre, University Grenoble-Alpes / CNRS / IFSTTAR / IRD / USMB, France
[3]ISTerre, University Grenoble-Alpes / CNRS / IFSTTAR / IRD / USMB, France

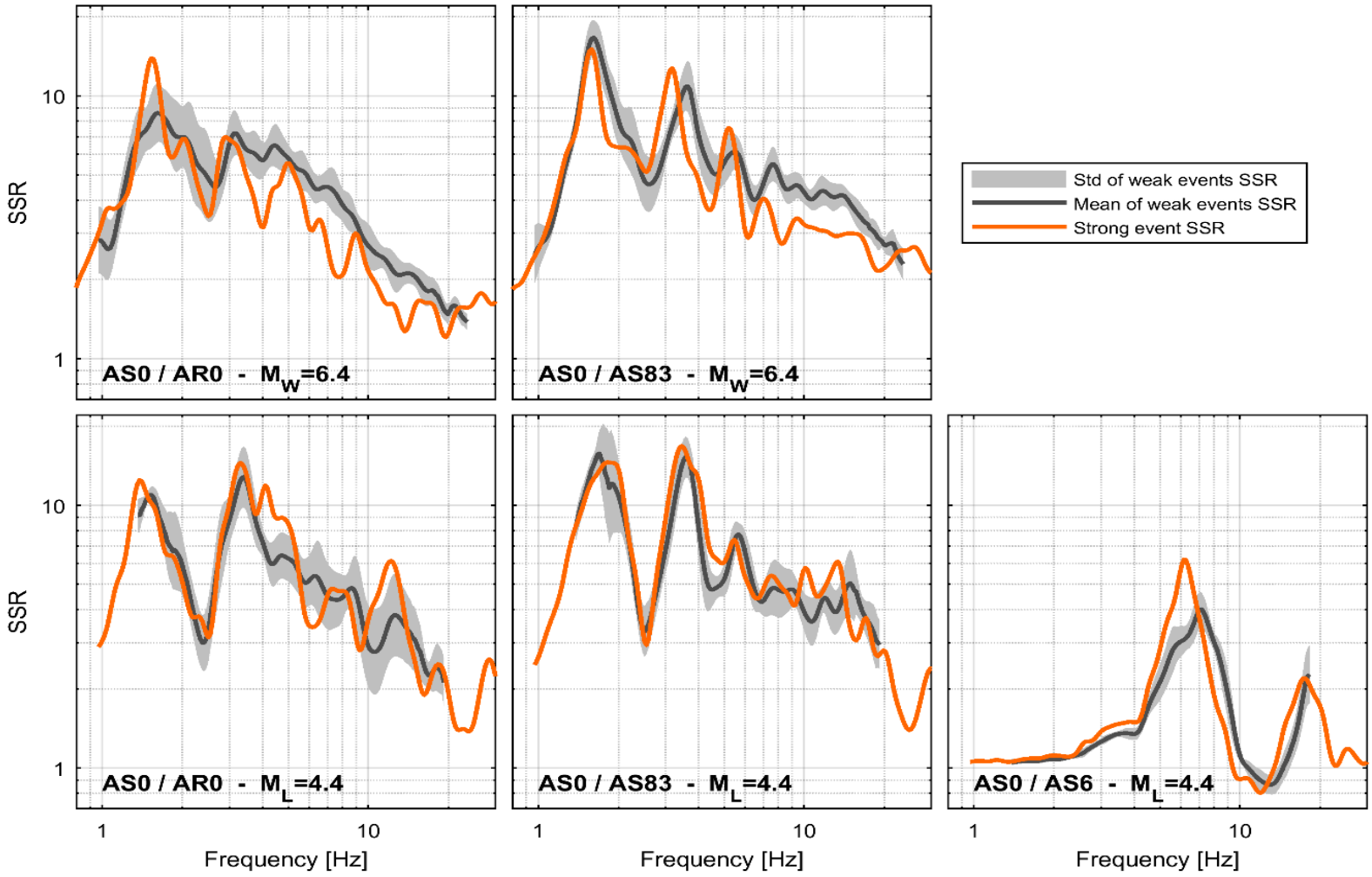
Approaches

- Standard Spectral Ratios (comparing ratios from weaker and stronger records)
- Time Variation of interferometry inferred Vs (during the strong shaking)
- Through stress-strain proxies

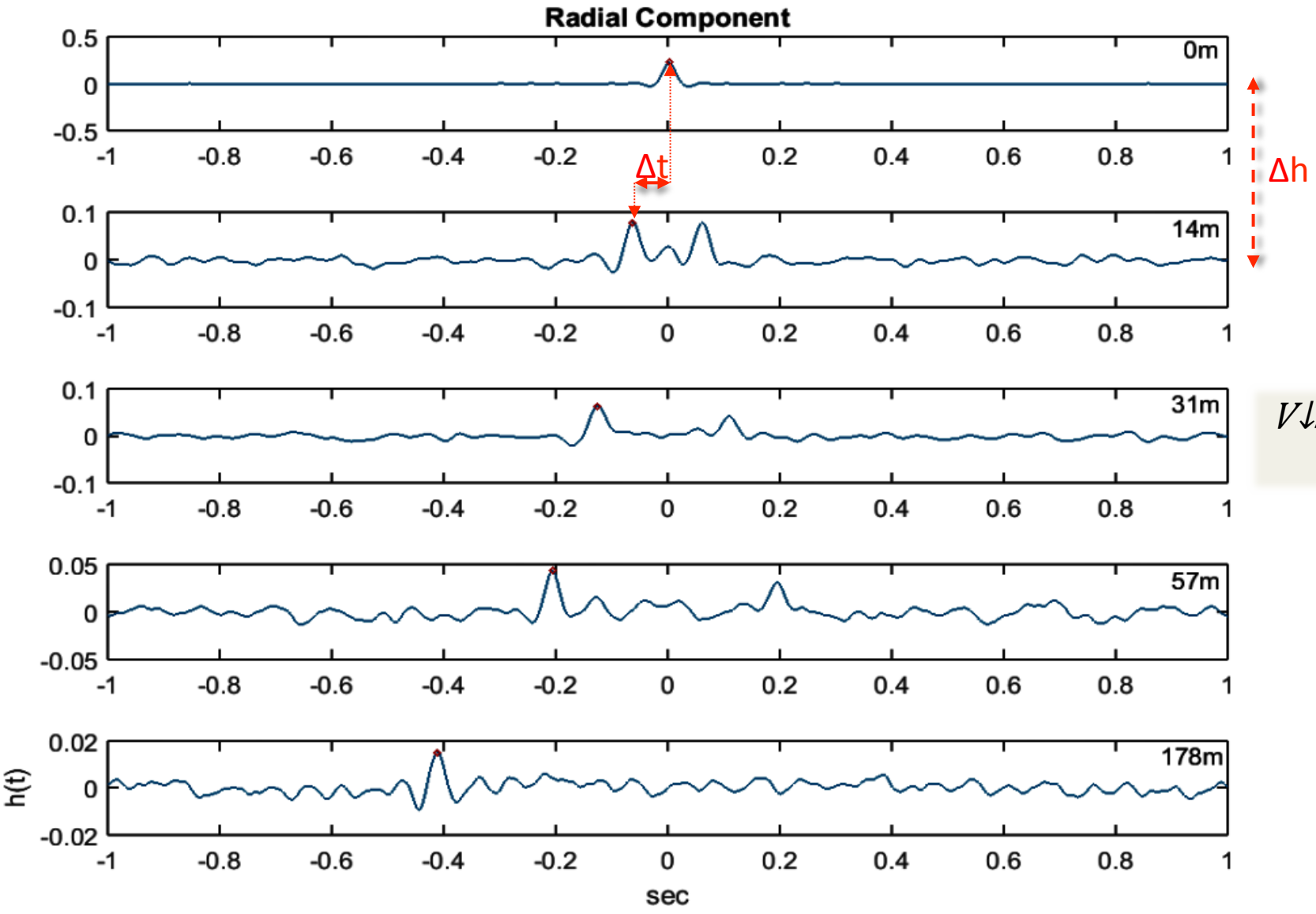
Standard Spectral Ratios

Nov 17, 2015
R=56km
Mw=6.4
PGA=143 cm/s^2

Sep 19, 2016
R=14km
Mw=4.4
PGA=138 cm/s^2

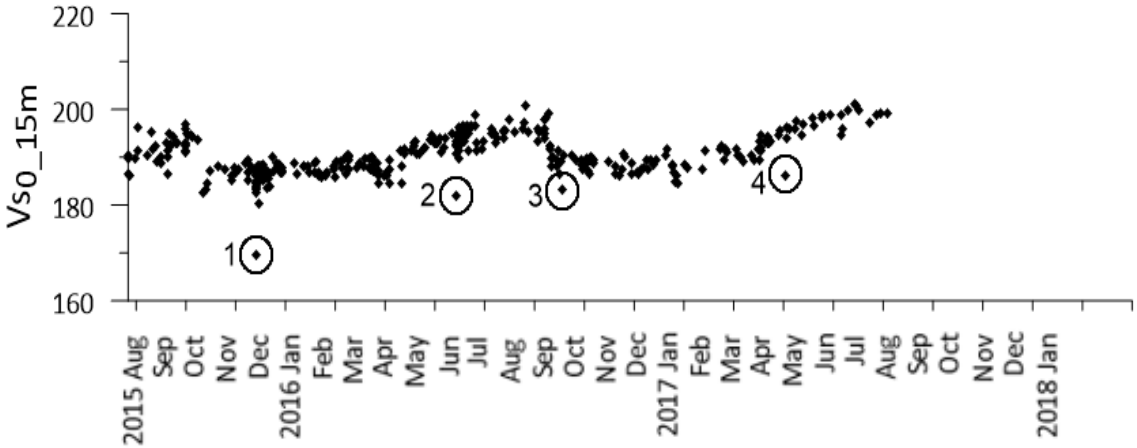


Time Variation of Interferometry Inferred Vs

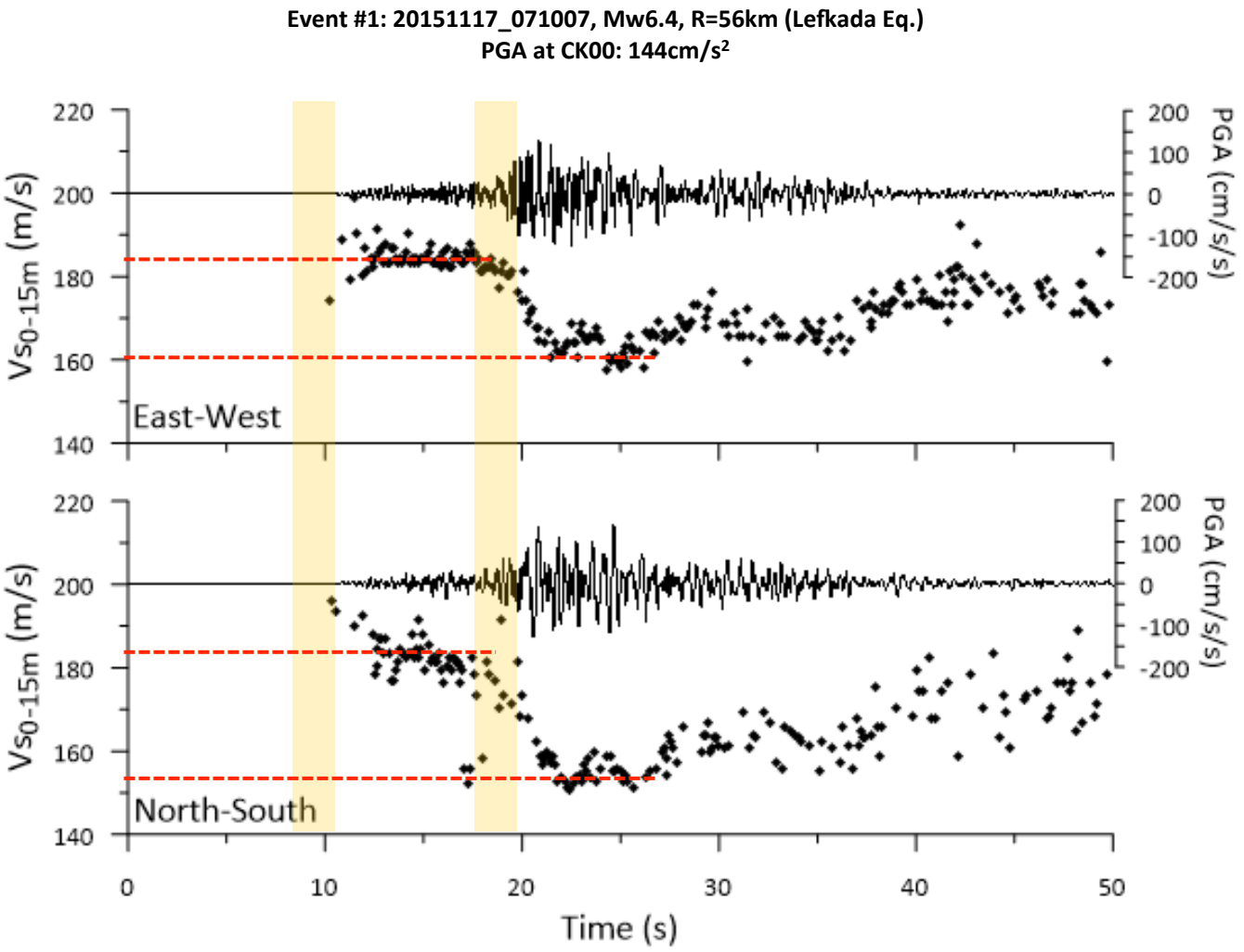


$$V_S = \Delta h / \Delta t$$

Time Variation of Interferometry Inferred Vs

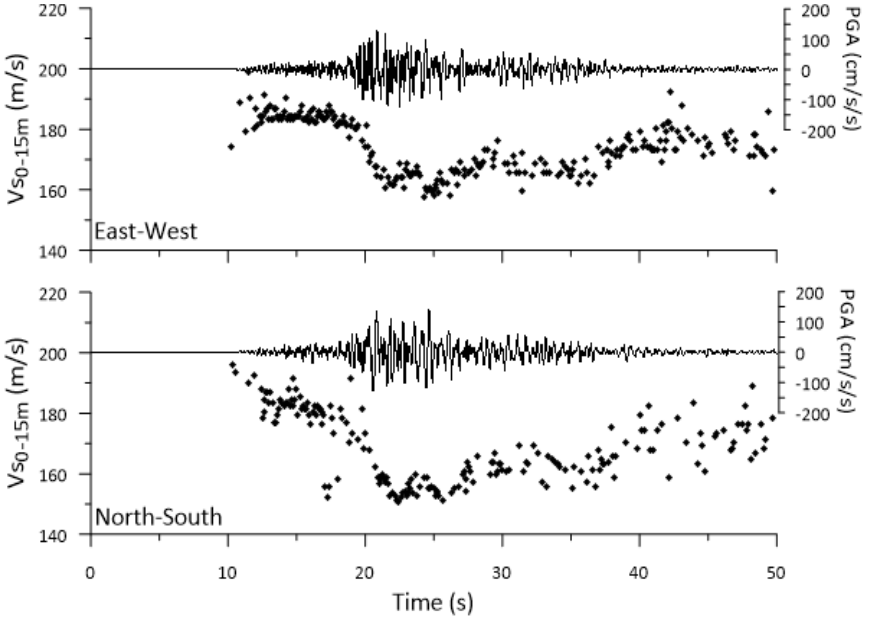


Time Variation of Interferometry Inferred Vs

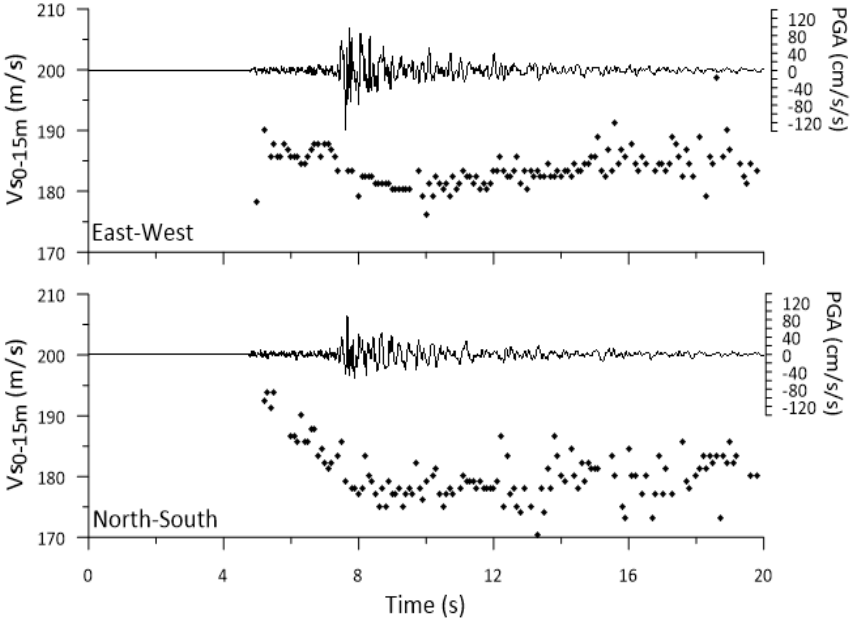


Time Variation of Interferometry Inferred Vs

Event #1: 20151117_071007, Mw6.4, R=56km (Lefkada Eq.)
PGA at CK00: 143cm/s²

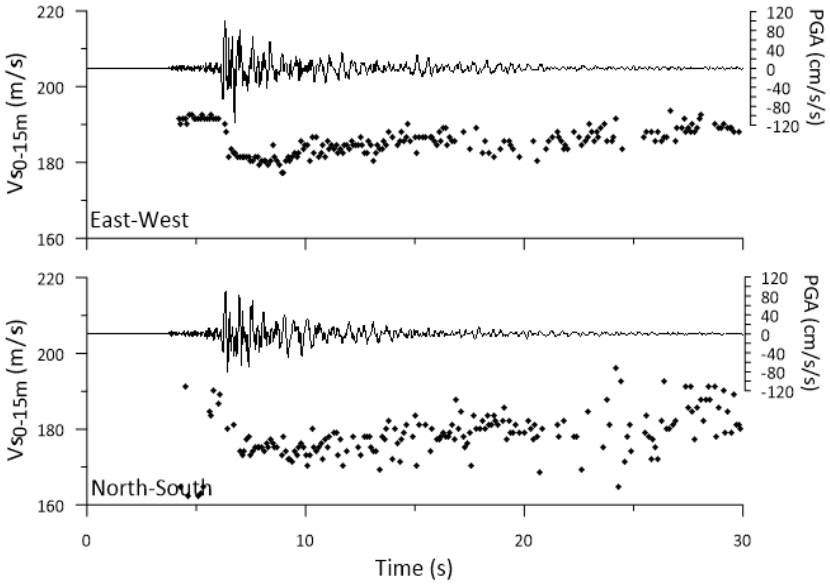


Event #3: 20160919_035945, M_L4.4, R=14km
PGA at CK00: 138 cm/s²

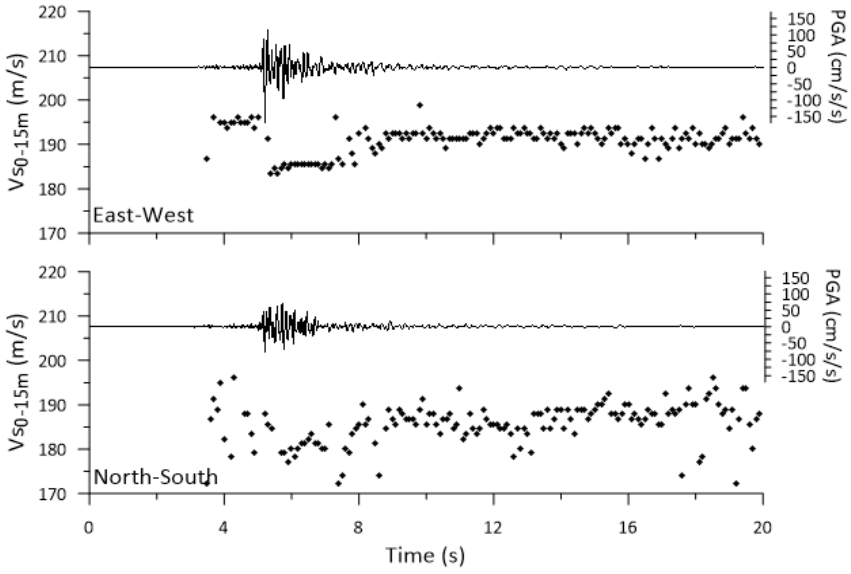


Time Variation of Interferometry Inferred Vs

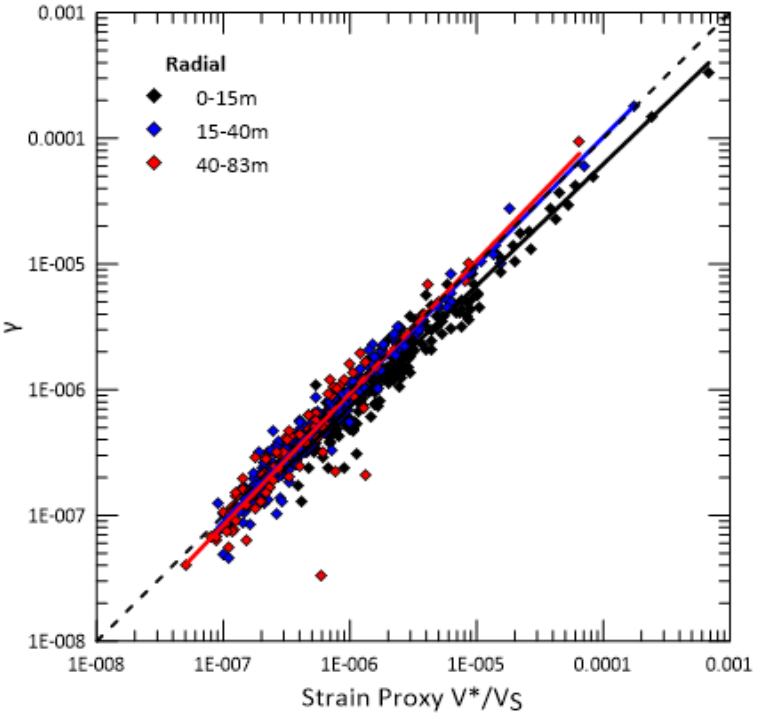
Event #2: 20160604_163825, Mw4.5, R=14km
PGA at CK00: 115cm/s^2

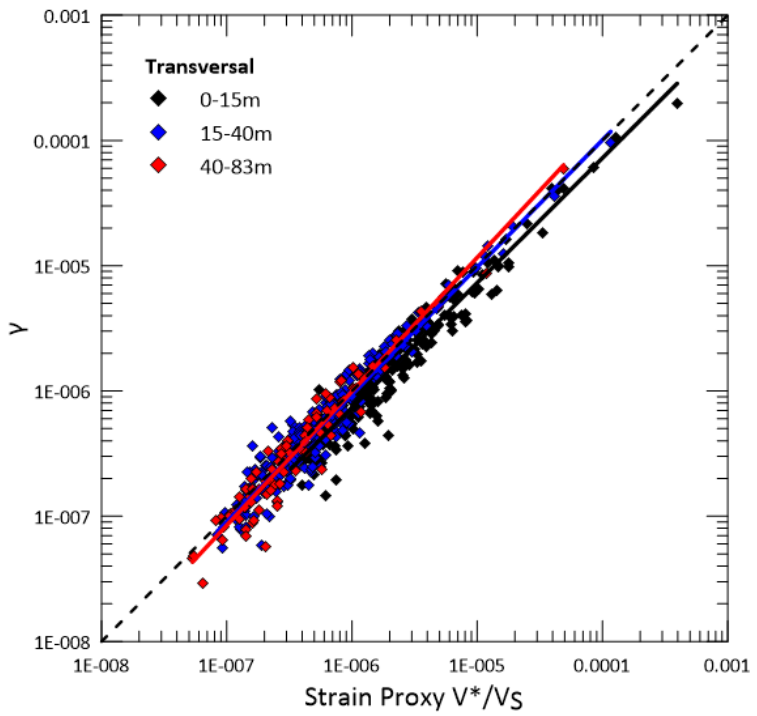


Event #4: 20170501_110241, M_L3.7, R=8km
PGA at CK00: 169 cm/s^2



Study of Nonlinear Behavior of the Soil based on Stress and Strain Proxies





STRAIN: maximum relative displacement between two successive sensors in the ARGONET borehole divided by the sensors' distance (γ)

$$\gamma_1 = \left| \frac{u_i(t) - u_j(t)}{(z_i - z_j)} \right|_{\max}$$

STRAIN PROXY V^*/V_S: the maximum absolute of the average peak particle velocities at two successive sensors/the V_S value for the in-between the sensors layer as derived from the interferometry procedure (e.g., Chandra et al., 2015; Gueguen, 2015).

$$v^* = \max\left[\left| \frac{v_i(t) + v_j(t)}{2} \right| \right],$$

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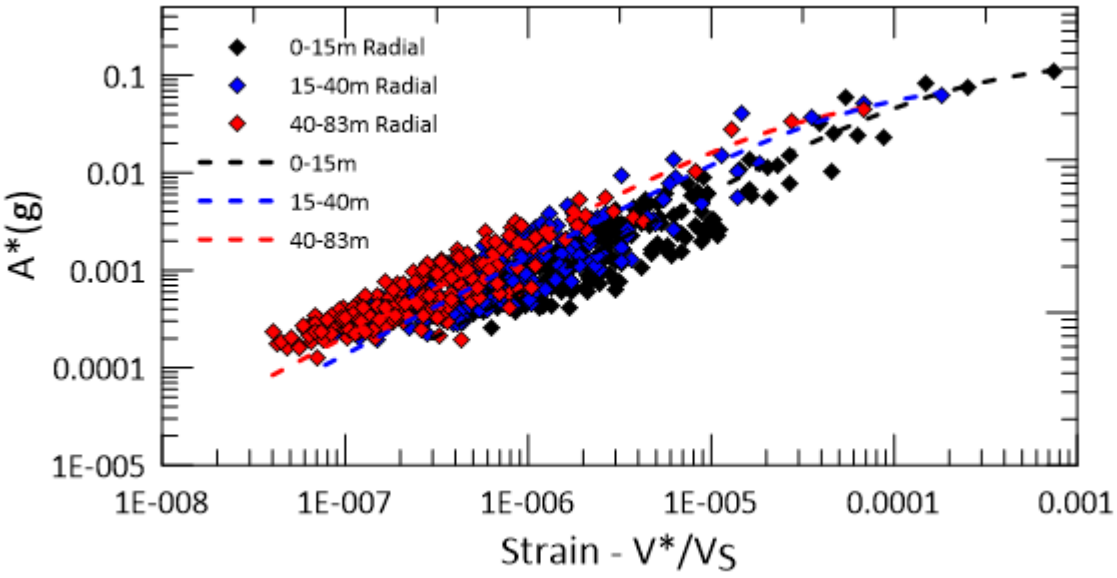
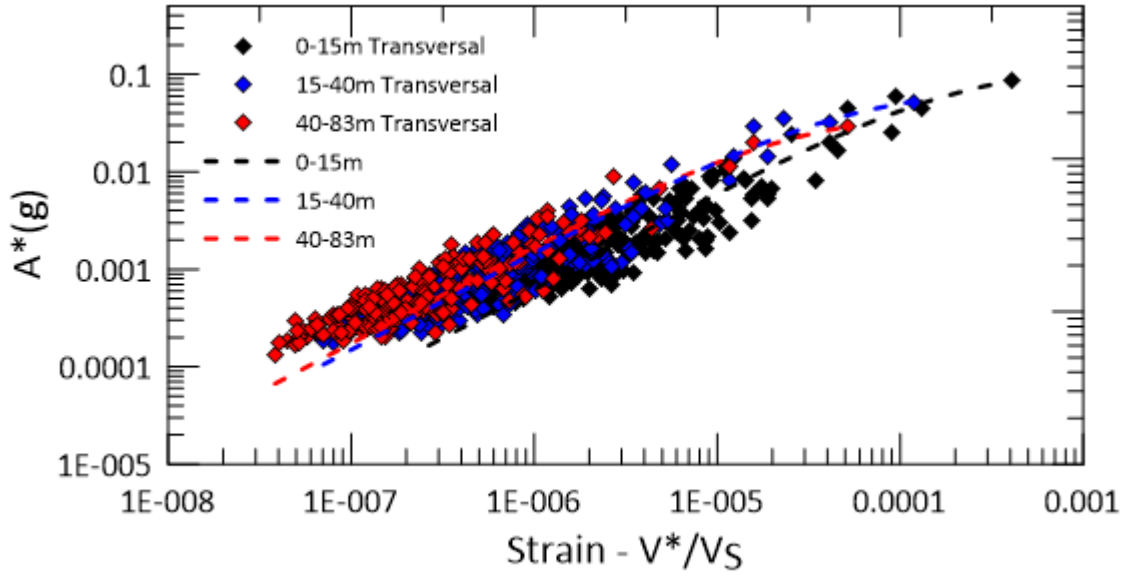
STRESS, A*: maximum absolute of the average peak particle accelerations at two successive sensors in the borehole $a^* = \max\left[\left|\frac{a(t) + a_j(t)}{2}\right|\right]$





Conclusions

- All three tested methods provide evidence for non-linear behavior of the soil
- SSRs using surface/surface or surface/deepest_downhole sensors may not reveal non-linear behavior at depth; incorporation of intermediate_depth sensors is required
- More strong events' records are required to quantify the effect