Relaxation timescales after small and large earthquakes:

Similarity and controls from seismic velocity changes estimated in Patache, Chile

Luc Illien, *Christoph Sens-Schönfelder, Jens Turowski, Kuan-Yu Ke & Niels Hovius*

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lillien@gfz-potsdam.de

GFZ
Helmholtz-Zentrum
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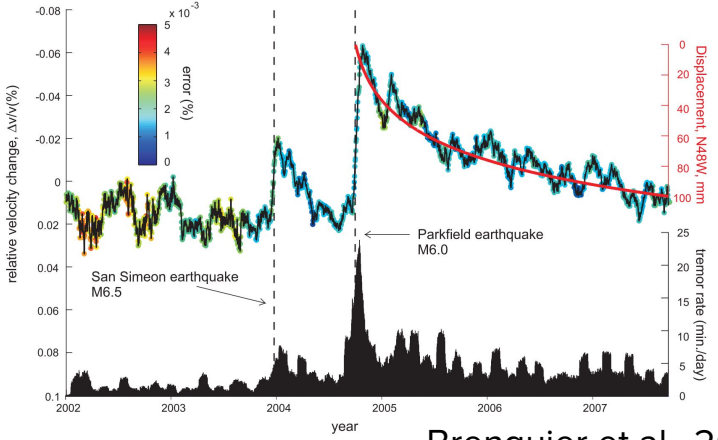
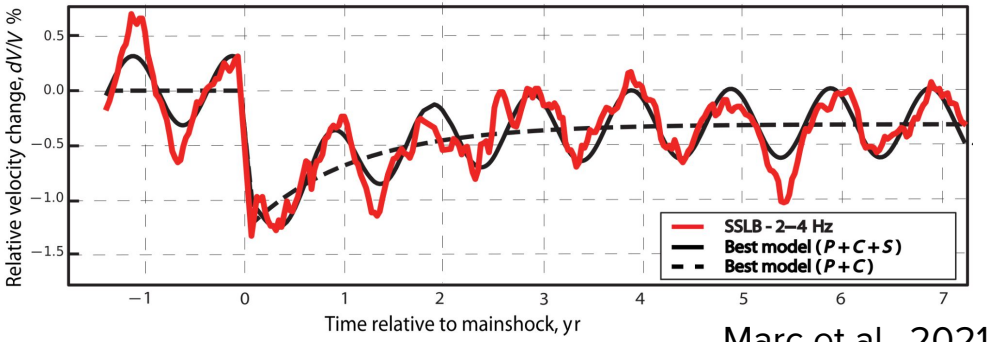
What controls the timescales of recovery/relaxation after ground shaking ?



Brenguier et al., 2008



Marc et al., 2021

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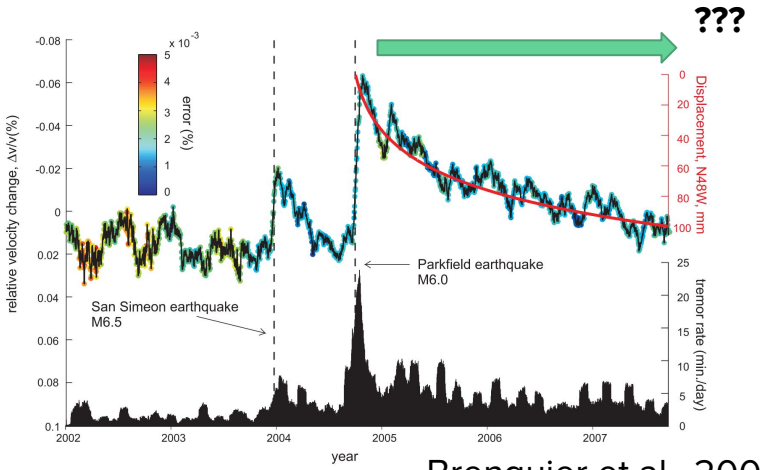

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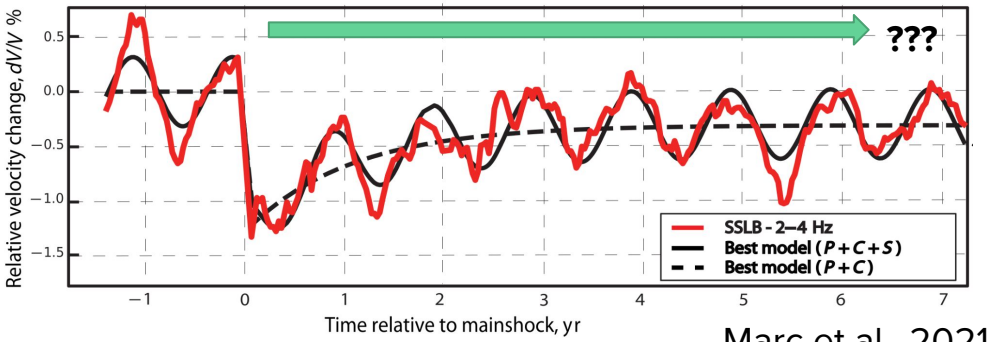

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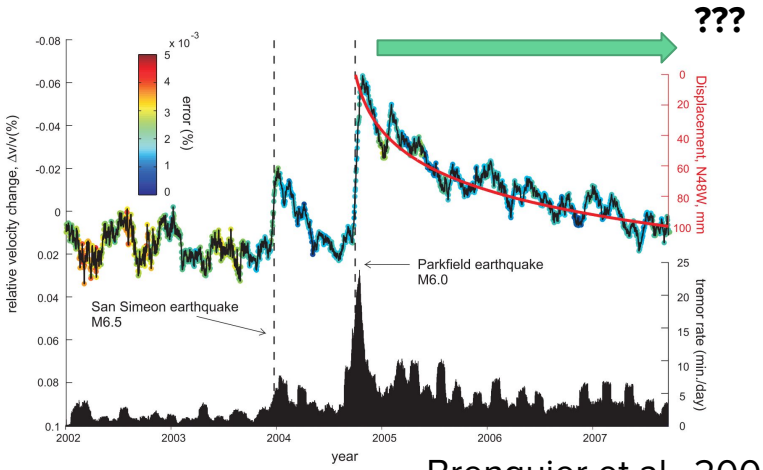

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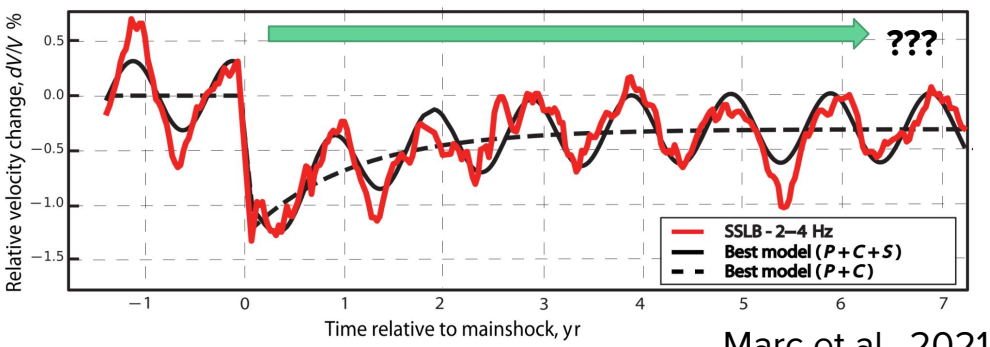

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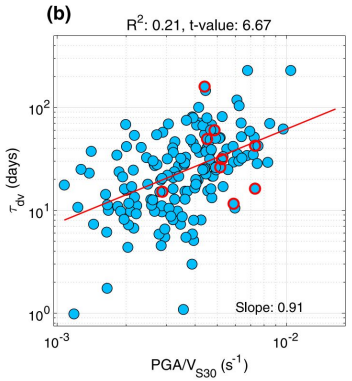
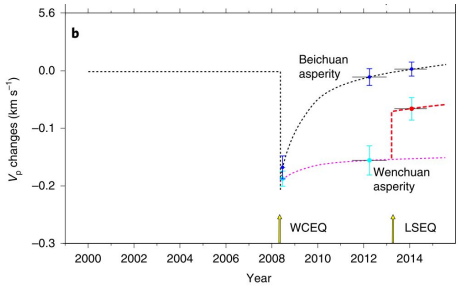
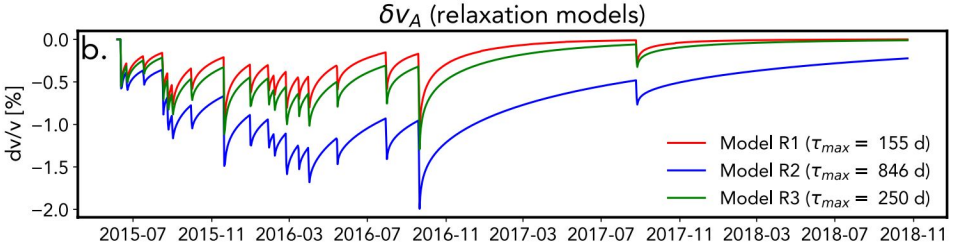
Recovery linked to other transient observations: friction/strength in fault zones, permeability disturbance, landslides rates ...

Controlled by ground shaking intensity ?
(Viens et al, 2018)





Controlled by strain at depth ?
(Pei et al, 2019)



Recovery timescale independent of ground shaking ?
(Illien et al, 2022)

To cite a few...

Recovery timescales are not well constrained.

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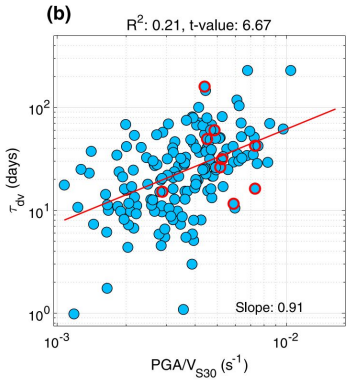

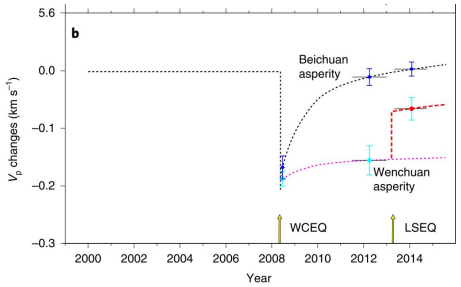

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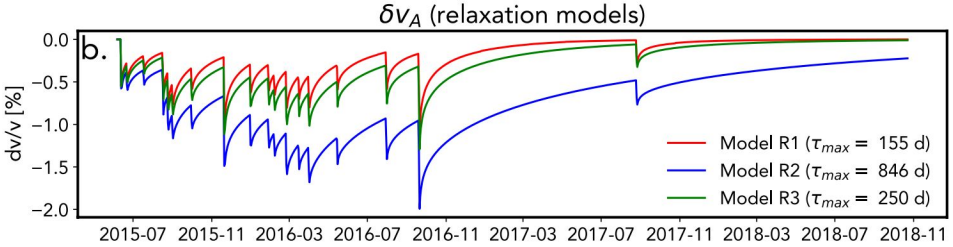

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Recovery timescales are not well constrained.

Need for better-resolved dv/v measurements

Let’s use the ergodic hypothesis.

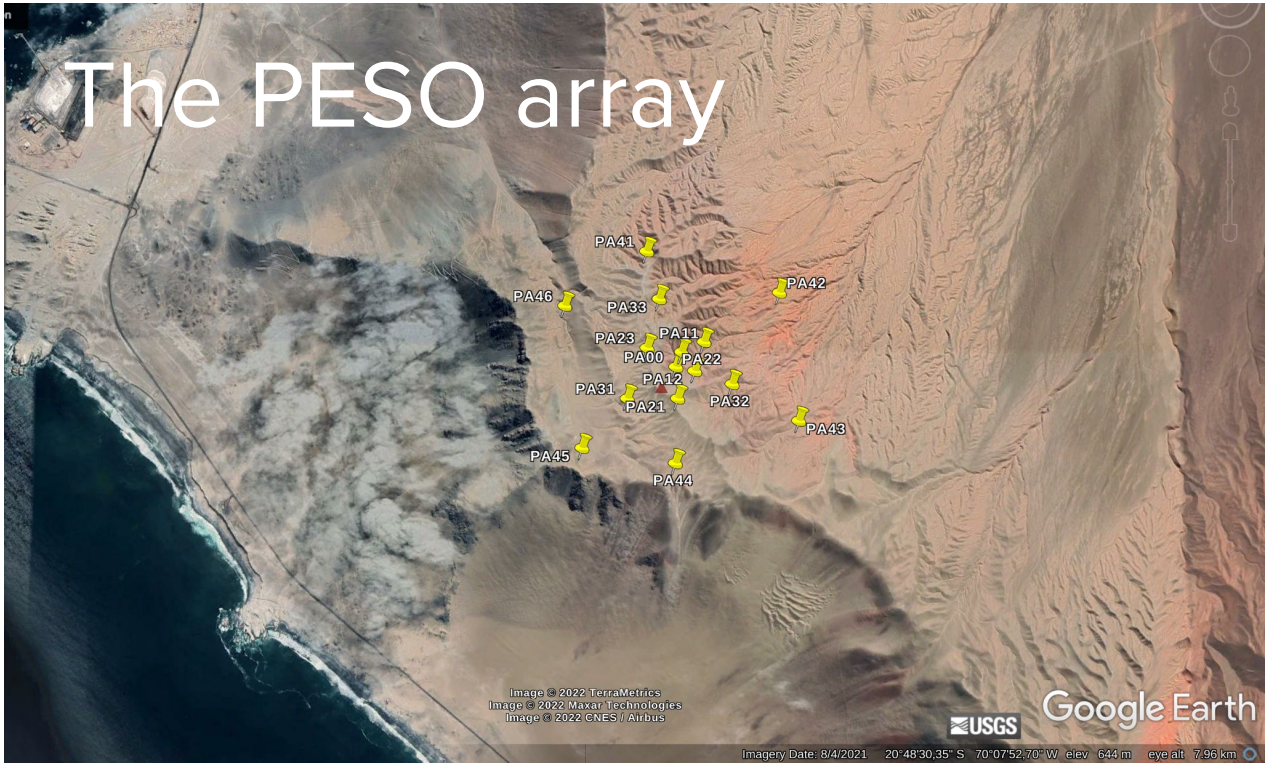
We may constrain well-resolved minute relaxations.

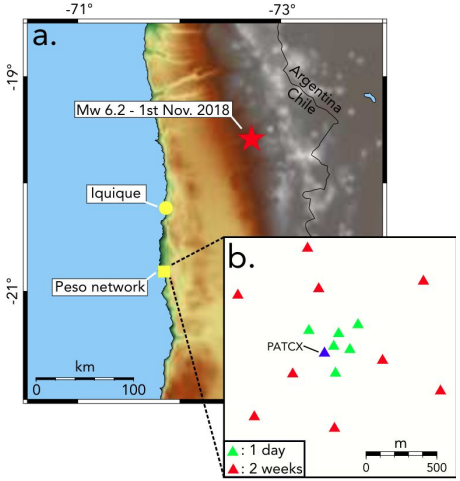
Principle

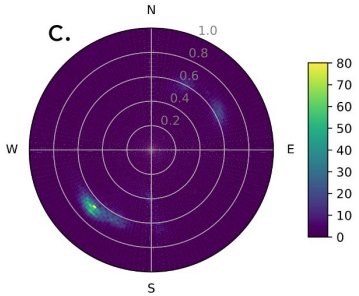
If the ambient noise wavefield is random, cross-correlations measurements may have the same ensemble (spatial) average than the time-average ones.

➜ stack results of several stations to lower the resolution of the temporal stack and reduce the noise in dv/v measurements.

The PESO array







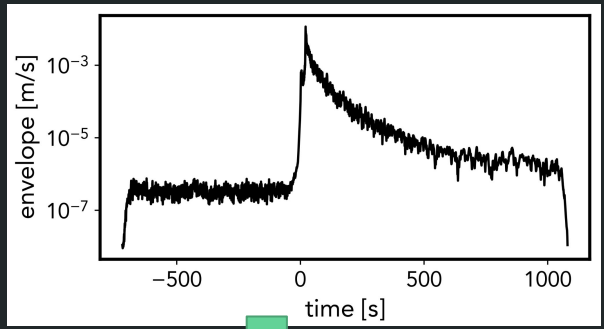
- 10 3-components BB stations set-up for 15 days
  - Noise coming from the shore at 3-6 Hz
    - Recorded one seismic event

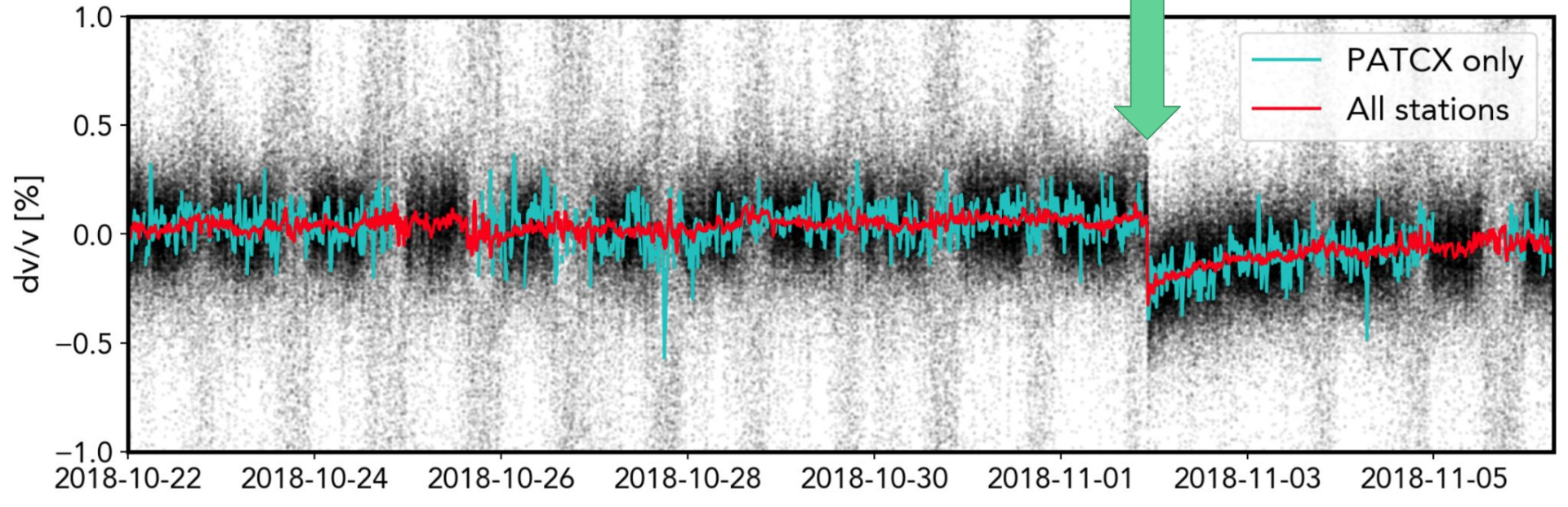
Seismic processing

From seismic traces to relative velocity changes (dv/v)

- Pre-processing: muting of segments that do not plot on a theoretical random amplitudes distribution
- Compute all CC, SC, AC (465 combinations)
- Estimate dv/v with the stretching technique
- Scheme to jointly average the stretching estimates

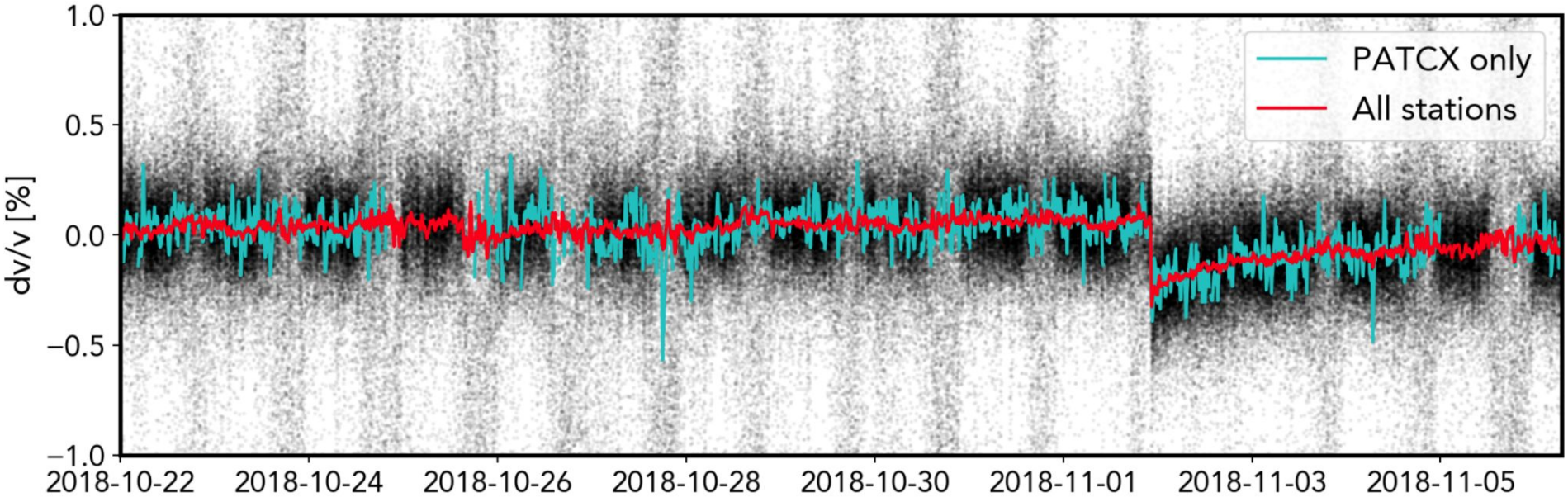
Seismic velocity changes





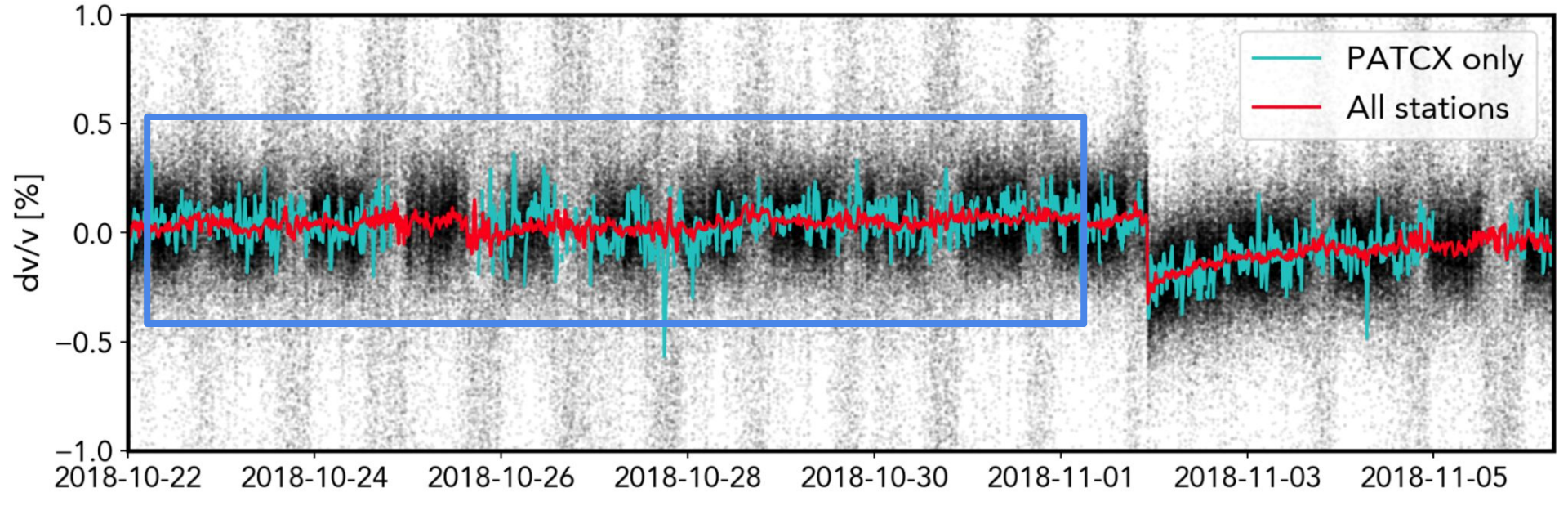
Seismic velocity changes

- well resolved 0.4 % drop (3-6 Hz)
- recover to 50% of the initial value in 2 days
- 10-minutes resolution



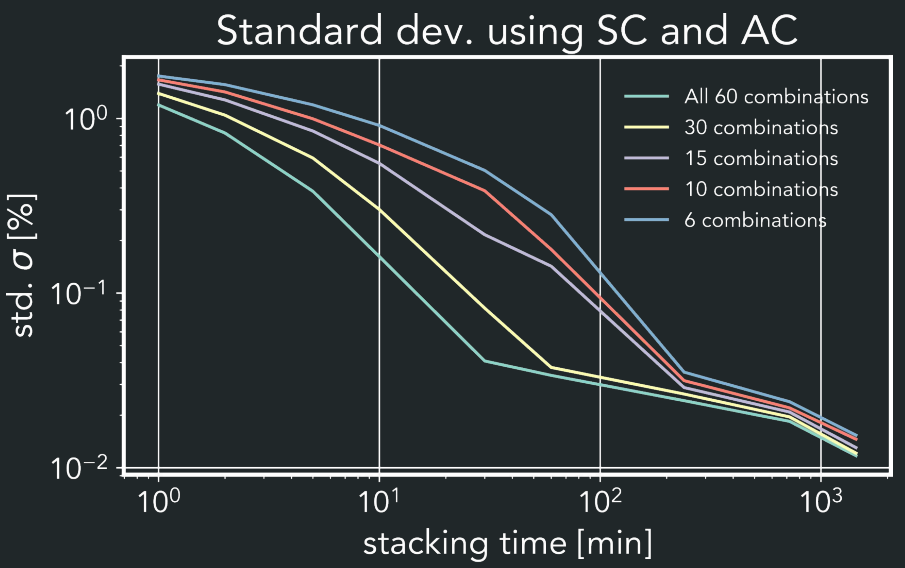
Seismic velocity changes

- What can we hope to achieve using more stations ?
- Let's use the standard deviation of the week before the earthquake



Using more seismic stations ?

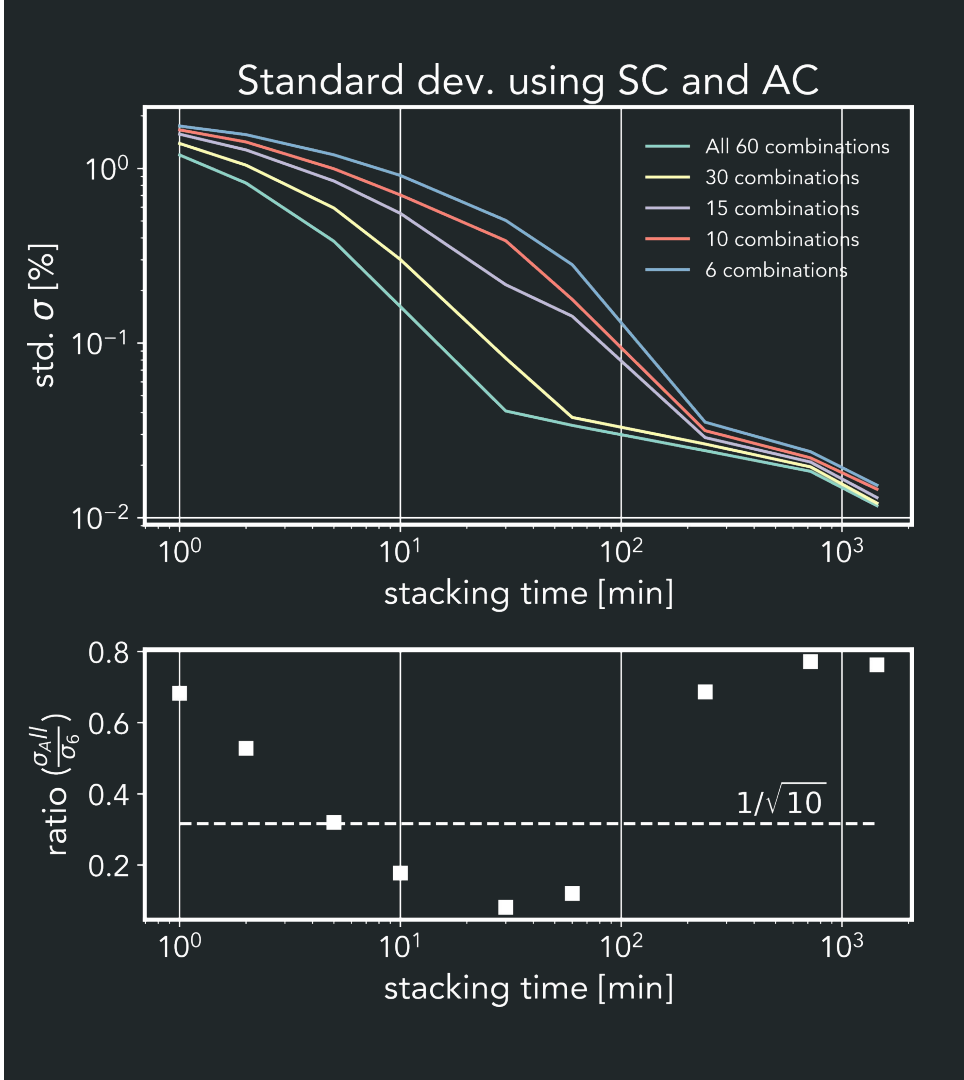
Random shuffle of the 60 single station combinations (AC + SC)



Using more seismic stations ?

Random shuffle of the 60 single station combinations (AC + SC)

If the measurements at the 10 stations can be considered independent with same variance, we may expect a reduction of the deviation ∝ sqrt(10)



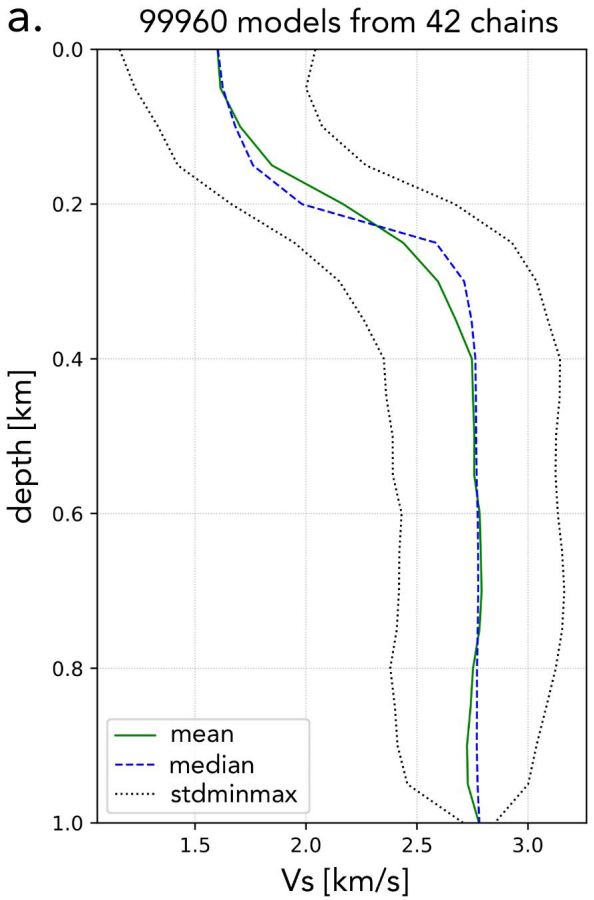
Use more stations.

Bonus

Inversion of a local 1D shear-velocity profile

- Performed with the focal spot imaging technique and a McMC transdimensional Bayesian inversion scheme
- Suggests that relaxation occurred in a hard-rock site

Contact me if you want to know more about this part



Conclusions

- Averaging station measurements is worth it in a specific stacking-time duration window (although with some deviation of the ergodic hypothesis)
- We observe a 0.4 % drop after a PGV of 1 cm/s with half of the drop recovered in 2 days
- Our observation of relaxation happened in a hard-rock site

More in ‘Resolving minute relaxation-induced seismic velocity changes: The more station, the merrier ?’ Illien et al., in prep

Ongoing work

We will compare our results with a longer-term time-series to derive an effective field-based law (or attempt to…)