

Observing seismic signatures of slow slip events with unsupervised learning

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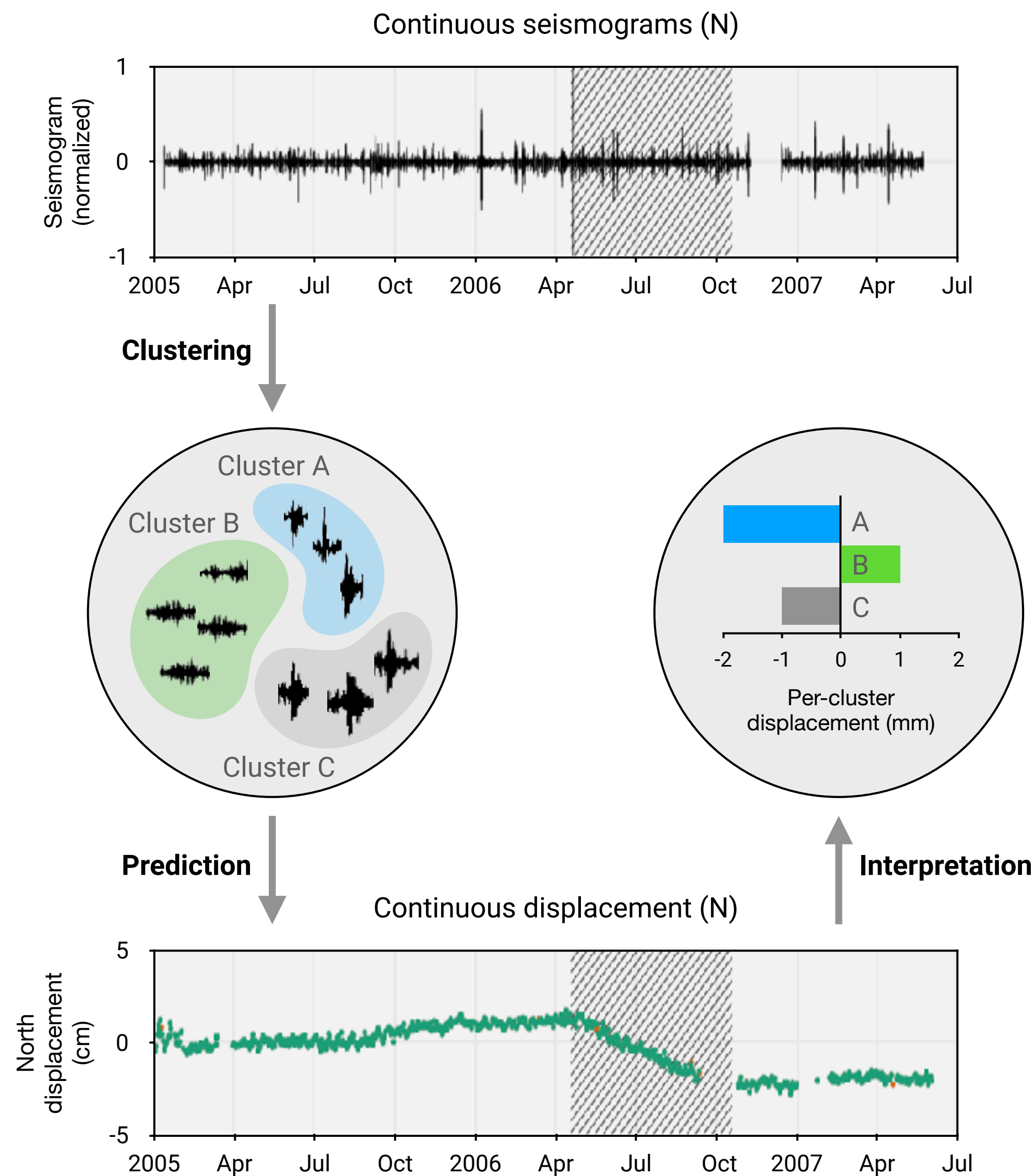
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Solicited abstract

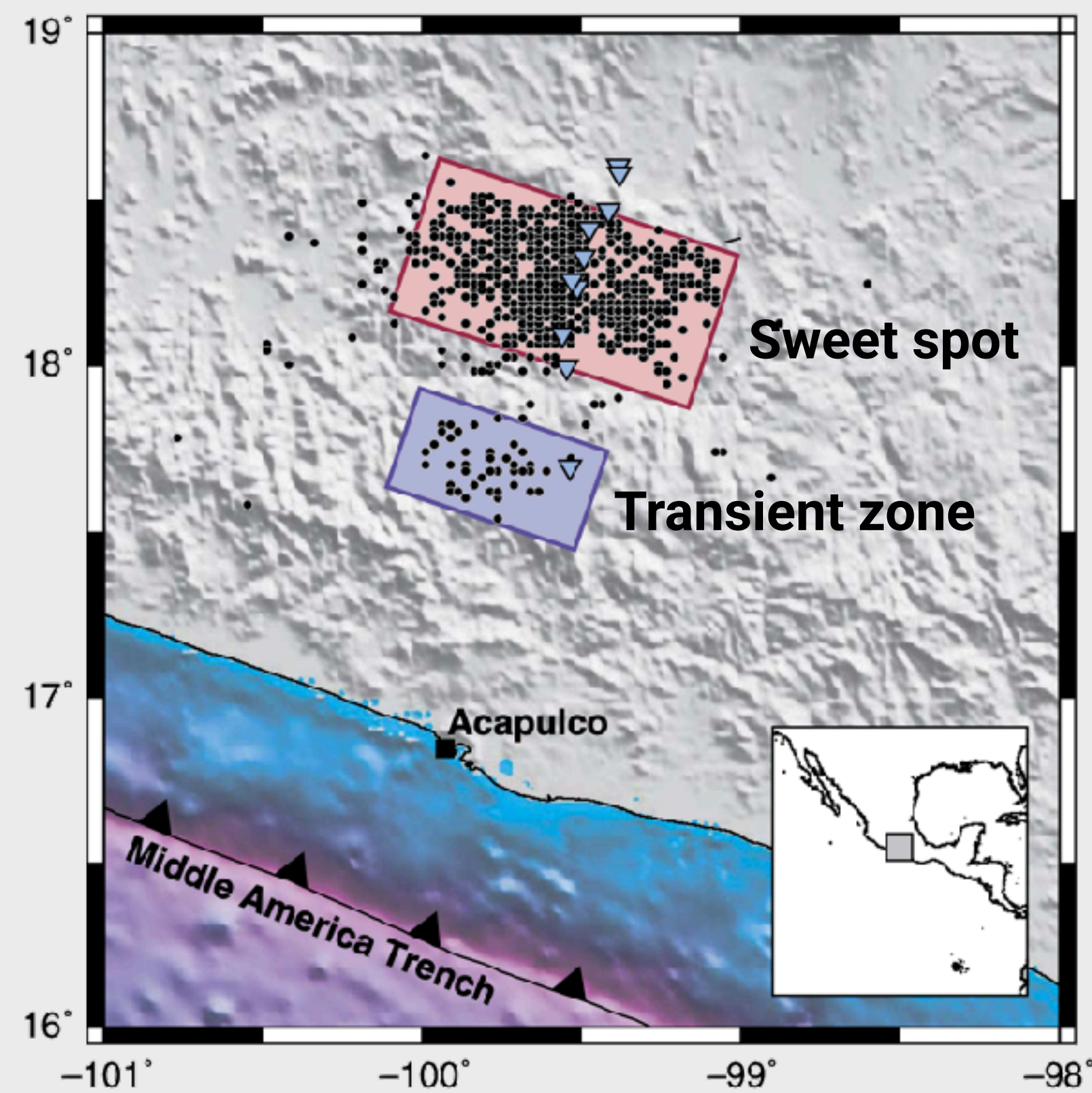
EGU21-5603



Observation of slow-slip events

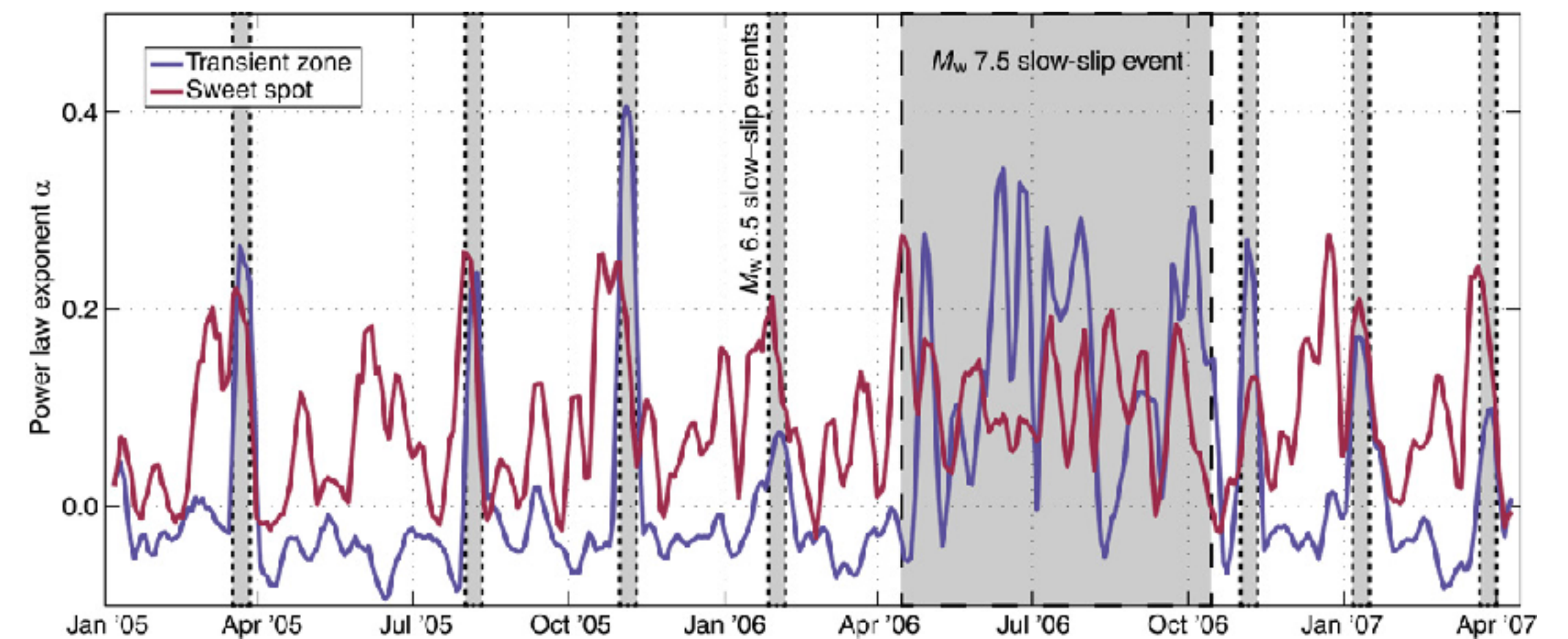
Geodetic data and associated seismicity

Low-frequency earthquakes
Guerrero, Mexico

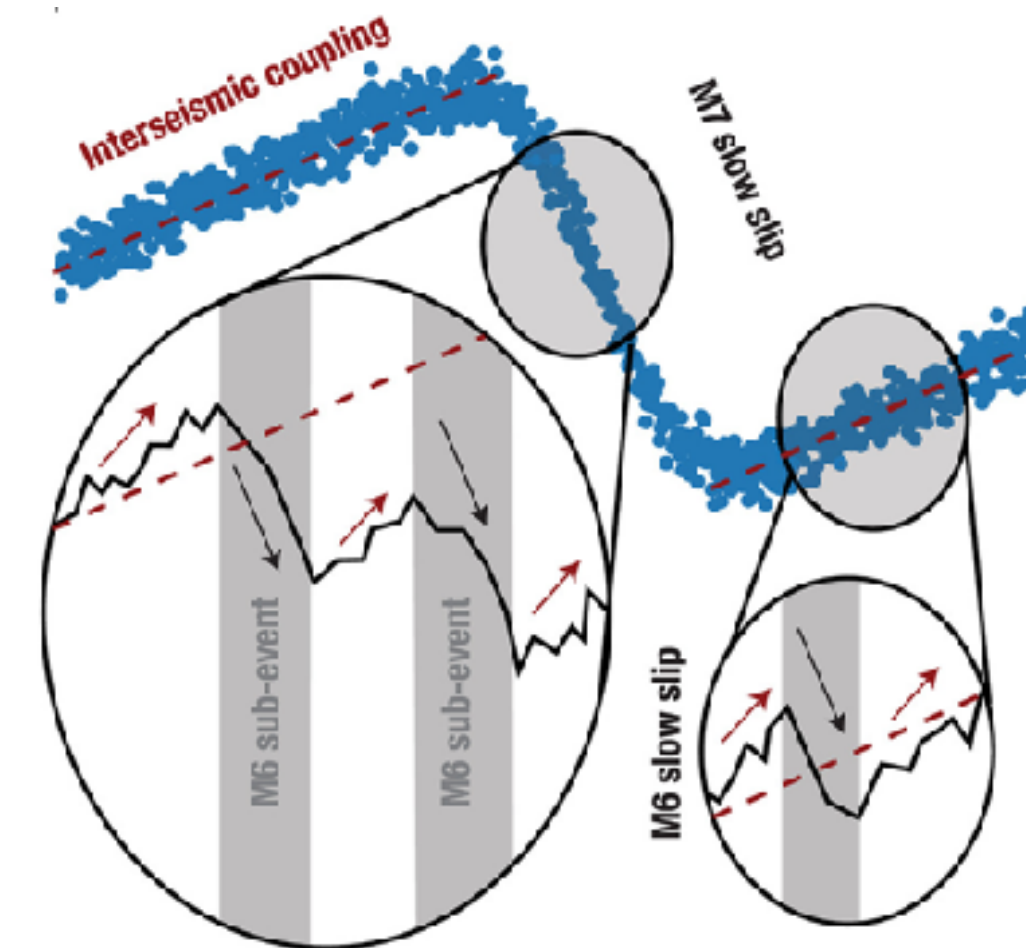


Frank et al. *Sci. Adv.* (2016)

Slow-slip events and low-frequency earthquakes swarms



Intermittency



- **Slow-slip events** visible in GPS signal
- Are intermittent
- Occur with **slow earthquakes** (LFE, tremors)

Frank et al. *Sci. Adv.* (2018)

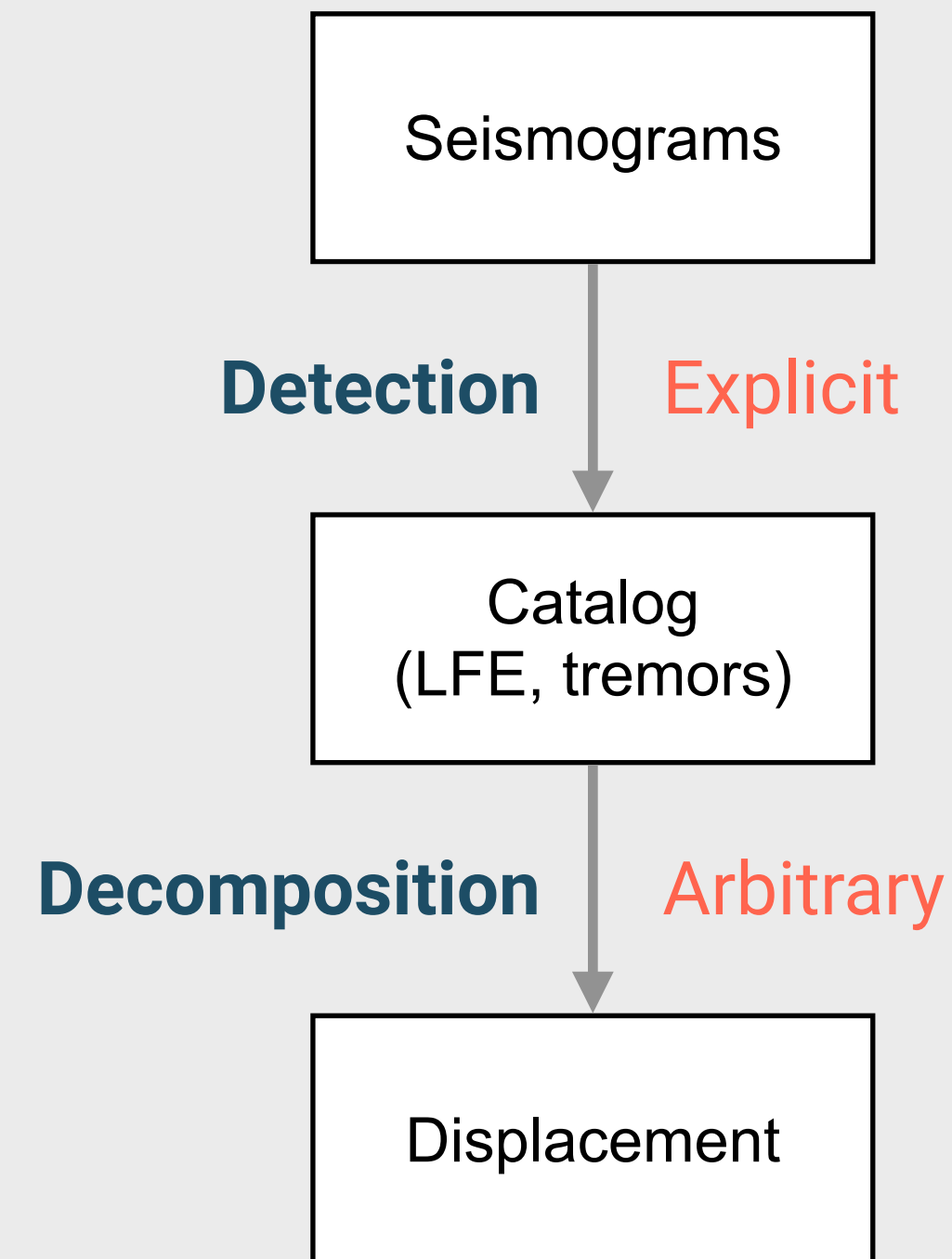
Jolivet & Frank. *Comm.* (2019)

Initial workflow

Slow-slip events and associated seismicity

Husker et al. (*G³* 2012, *GRL* 2019)

Frank et al. *Sci. Adv.* (2016, 2018)



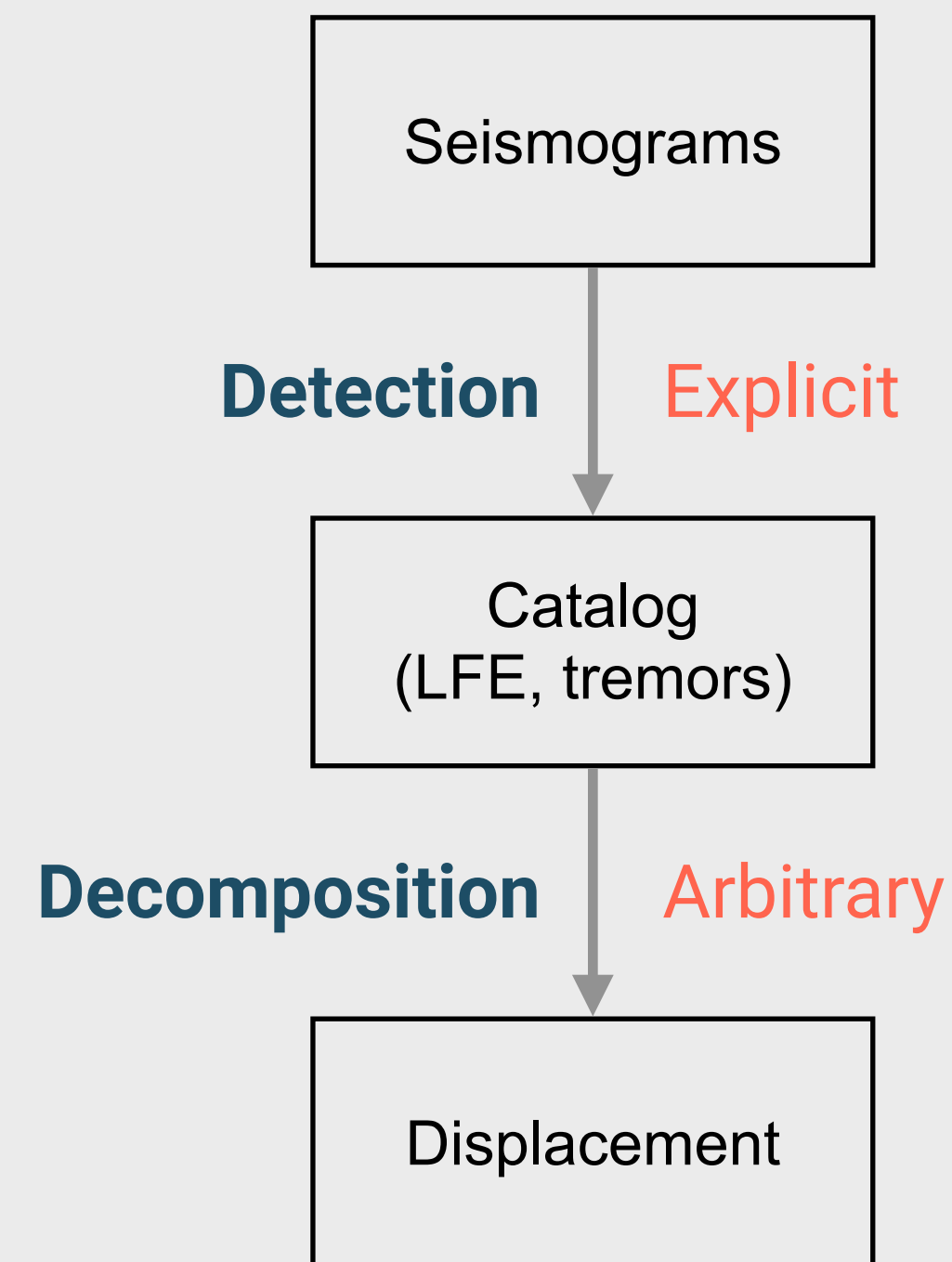
Definition of a tremor signal?
Decomposition threshold?

Initial workflow

Slow-slip events and associated seismicity

Husker et al. (*G³* 2012, *GRL* 2019)

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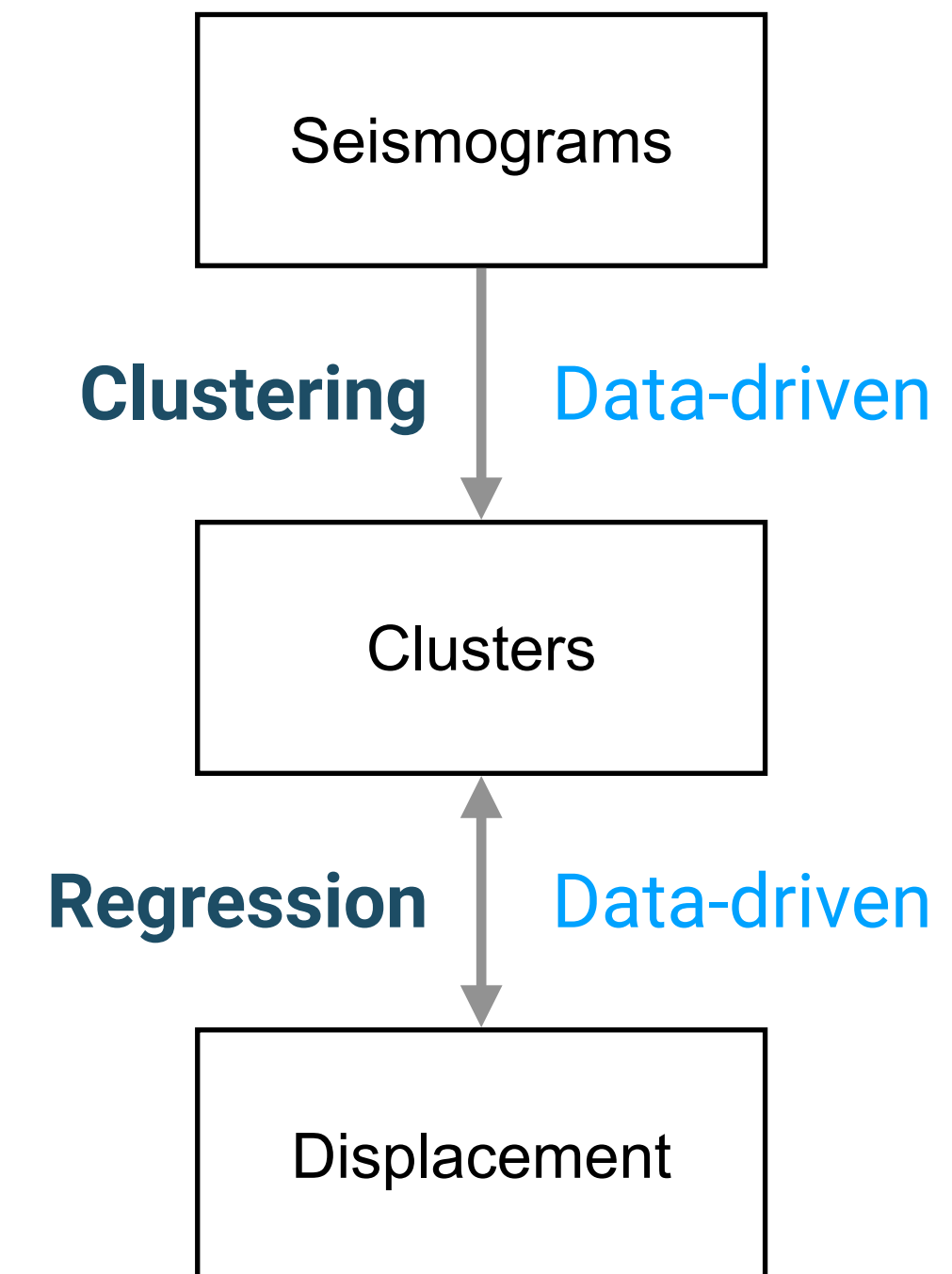


Definition of a tremor signal?
Decomposition threshold?

Proposed workflow

AI-based analysis of seismic & geodetic data

Seydoux et al. (in prep)

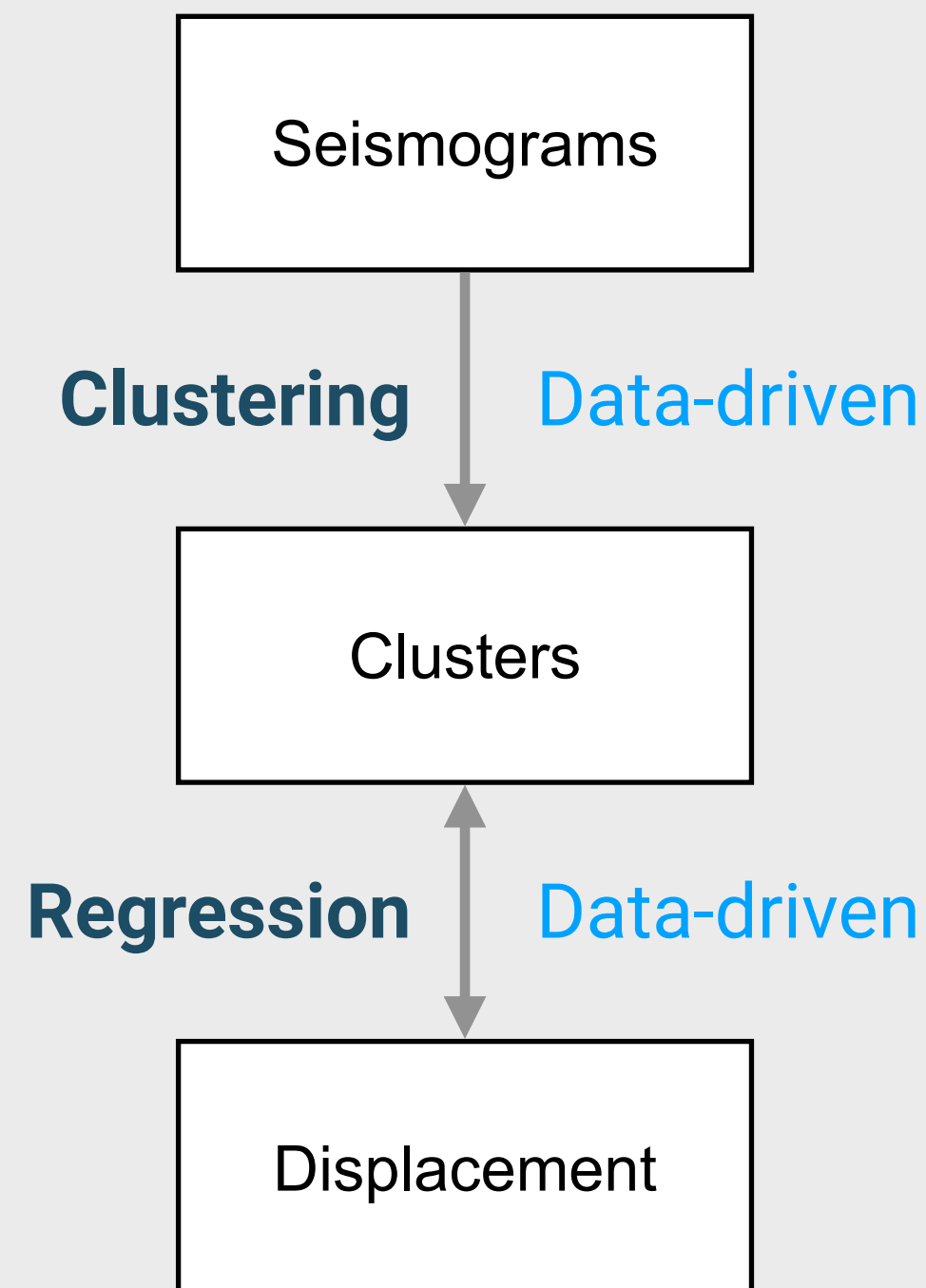


Unsupervised detection of
associated seismic signals

Proposed workflow

AI-based analysis of seismic & geodetic data

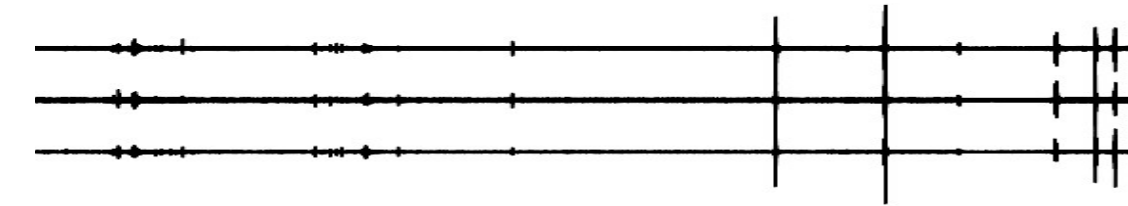
Seydoux et al. (in prep)



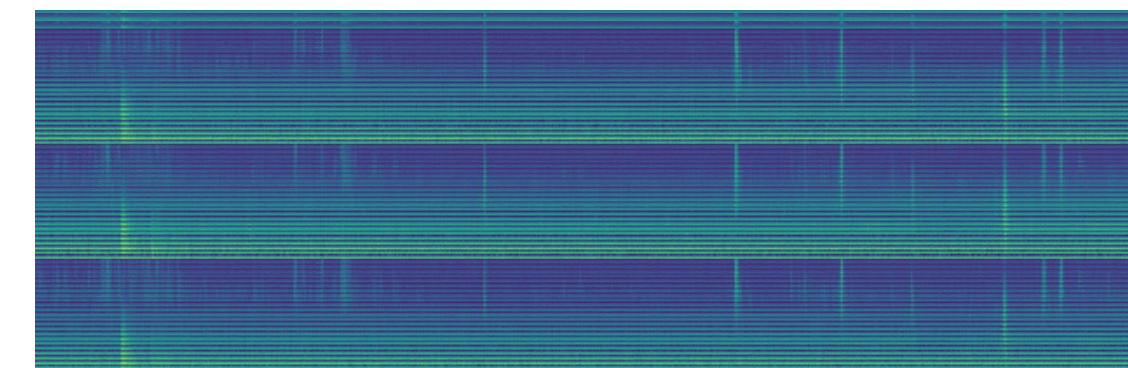
Unsupervised detection of associated seismic signals

Clustering strategy

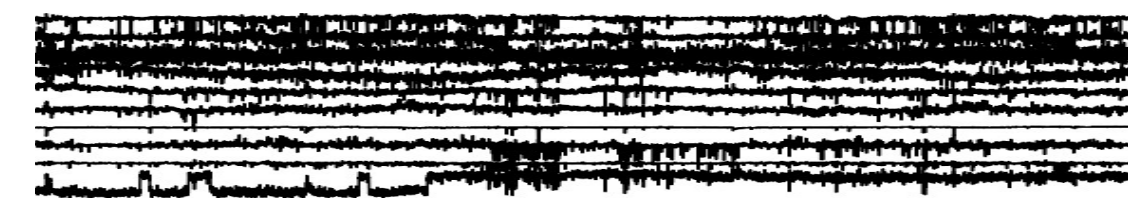
Continuous seismograms (3C)



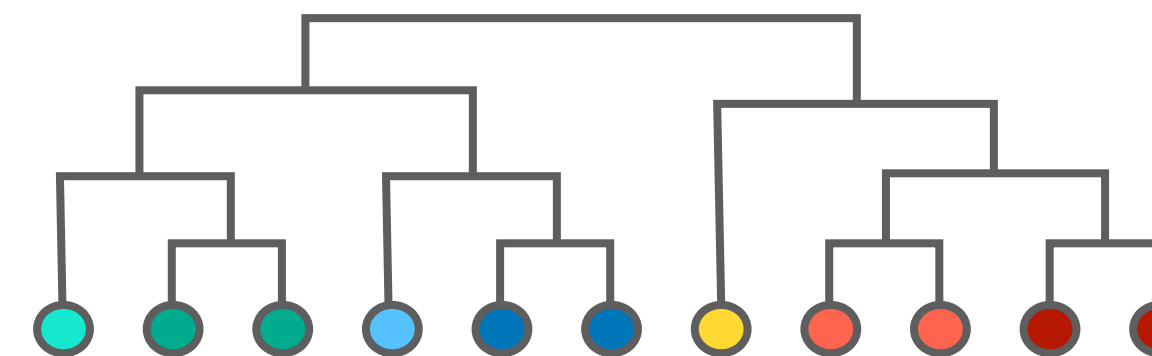
Basic waveform features



Relevant features



Dendrogram



Clusters



Seydoux et al. *N. Comm.* (2020)

Steinmann et al. (in prep)

Deep scattering network features
(Physics-driven)

Relevant features extraction with ICA

Hierarchical clustering

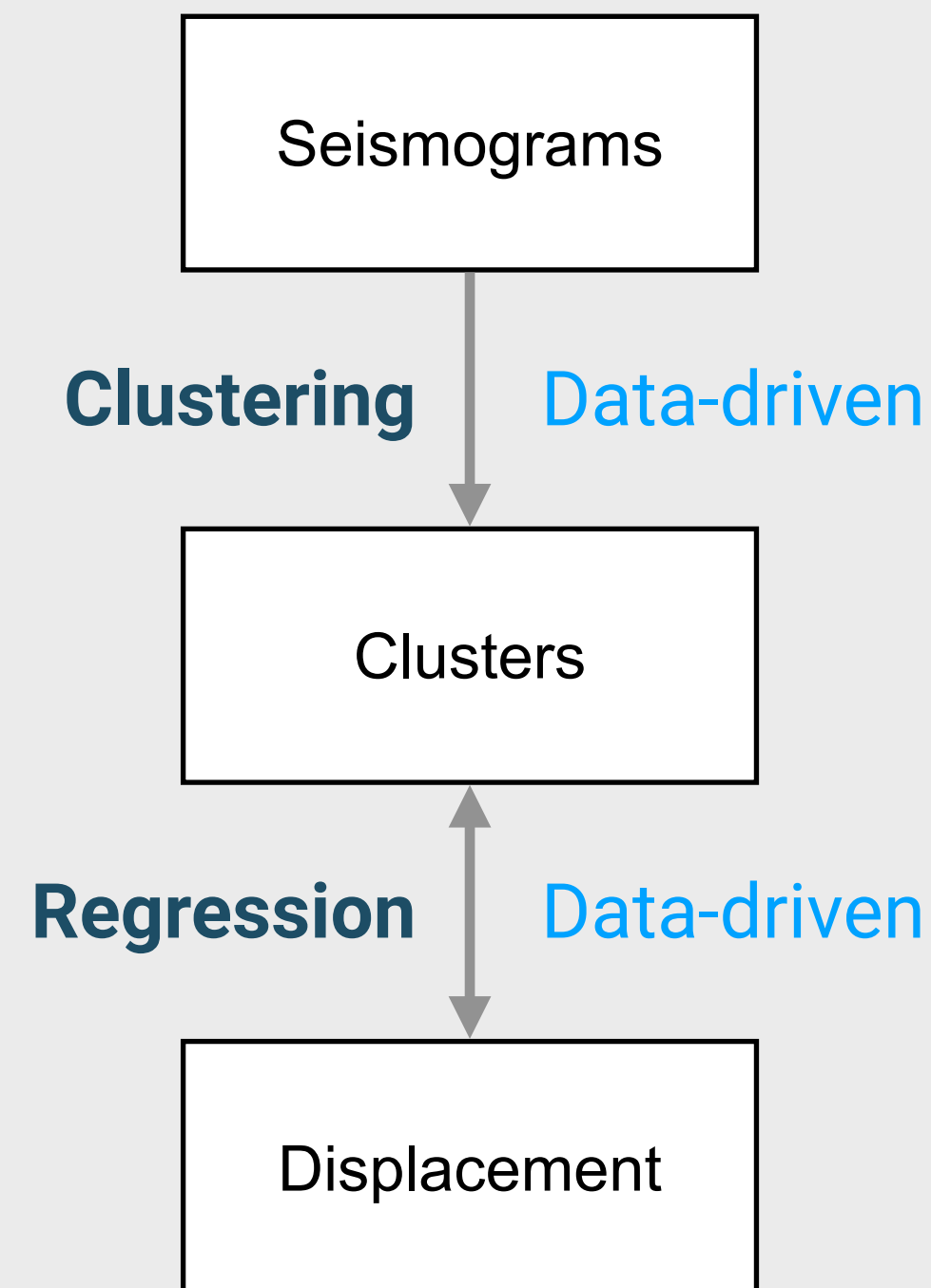
Cluster sequence

See also
Steinmann et al.
(EGU21-2788)
Thu, 29 Apr
11:49

Proposed workflow

AI-based analysis of seismic & geodetic data

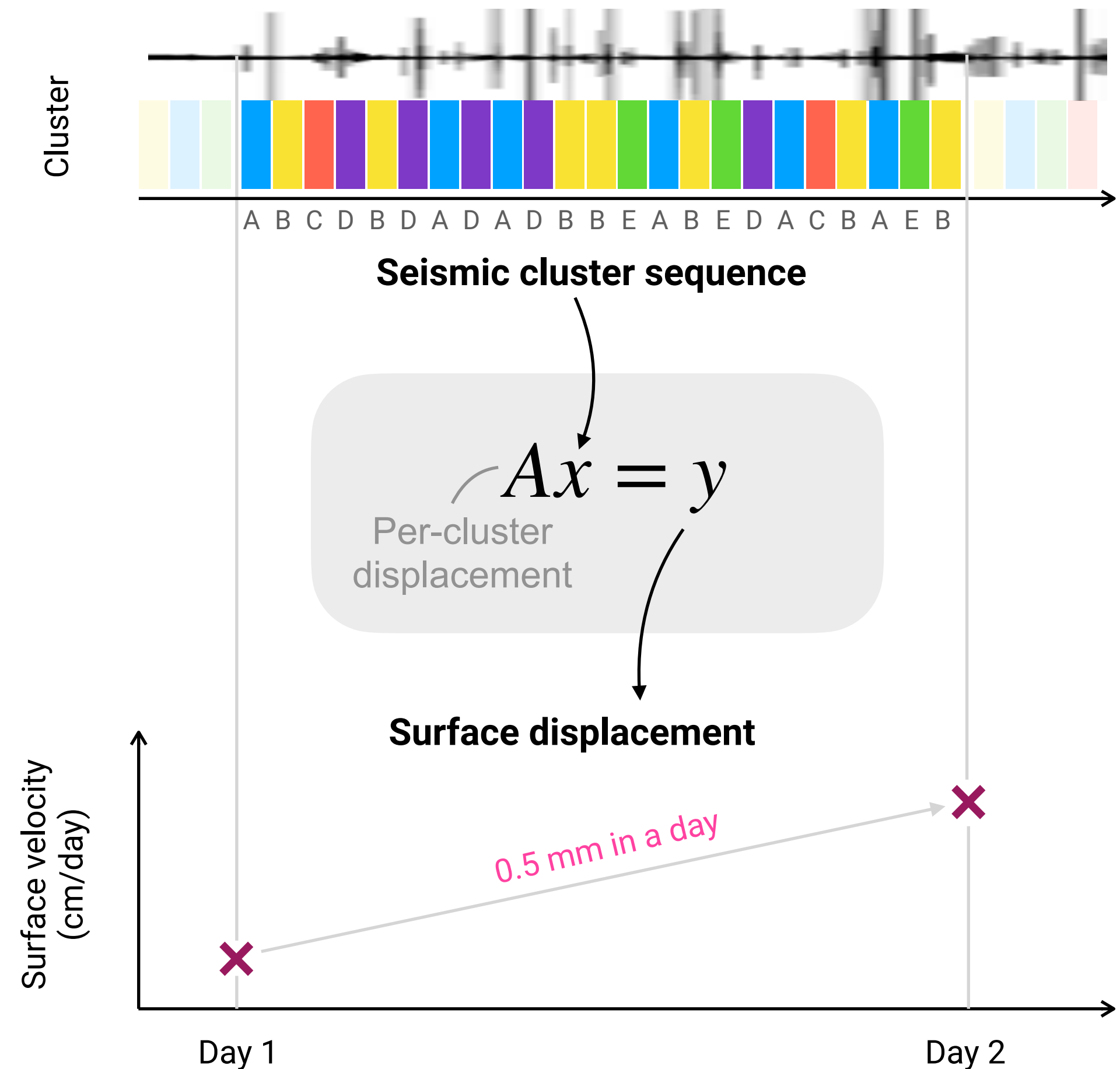
Seydoux et al. (in prep)



Unsupervised detection of associated seismic signals

Regression strategy

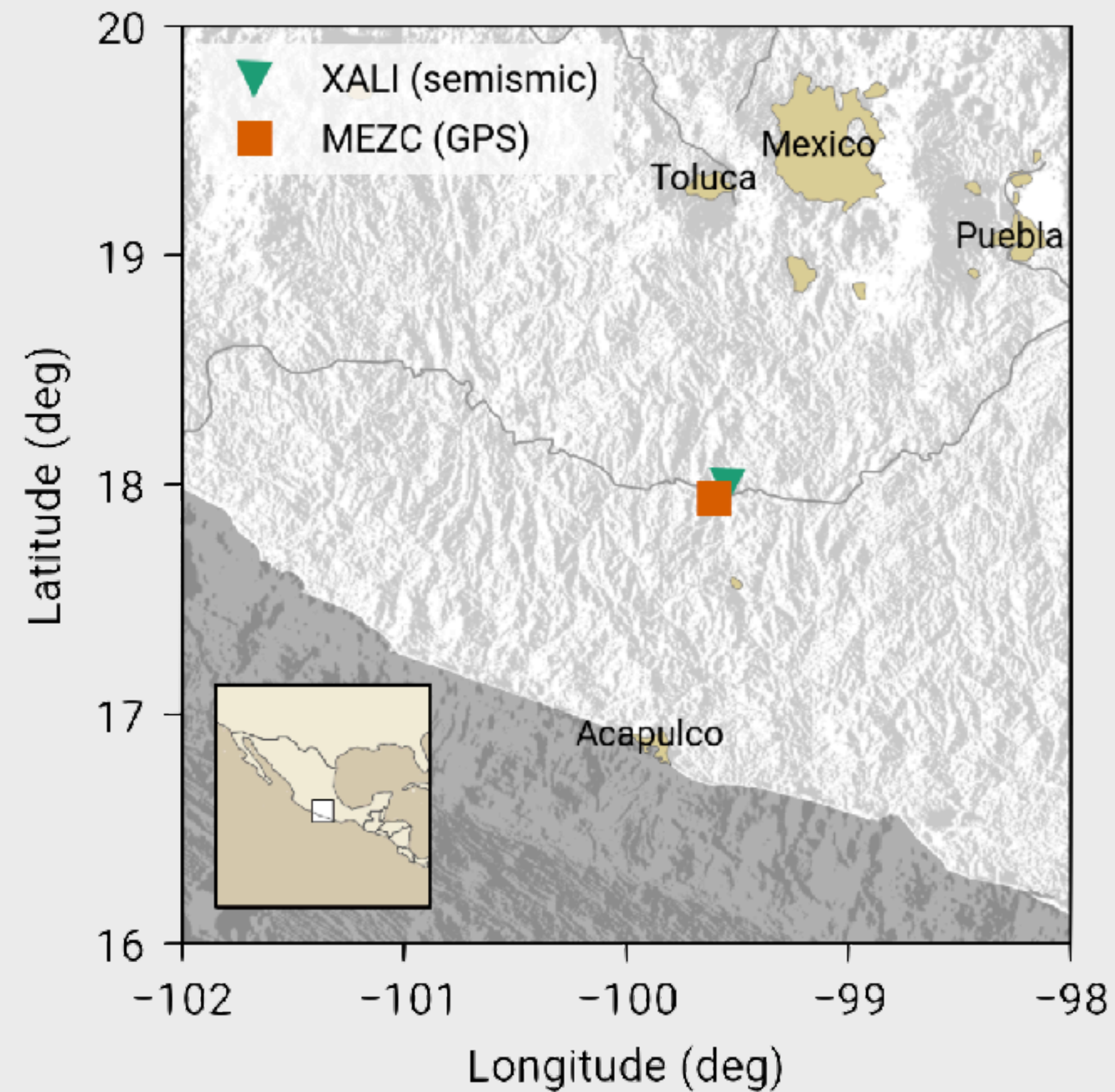
Linear regression illustration



Application

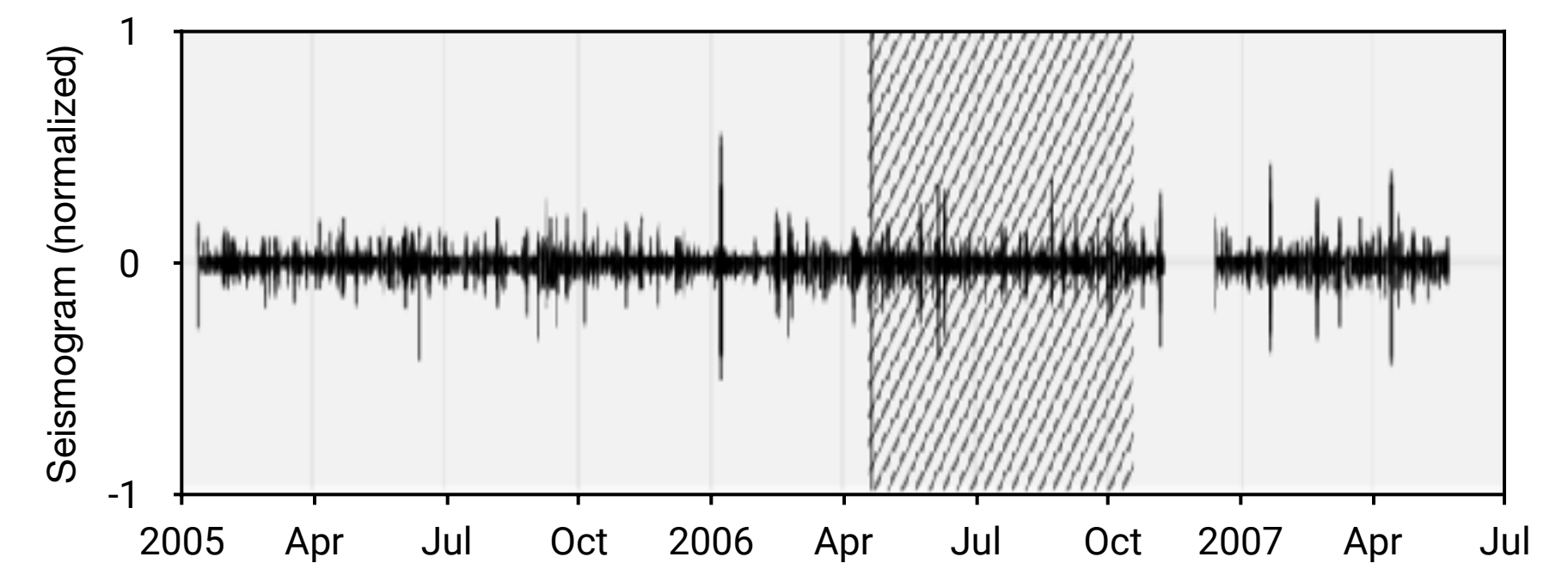
Geodetic and seismic data in Guerrero, Mexico

Seydoux et al. (in prep)

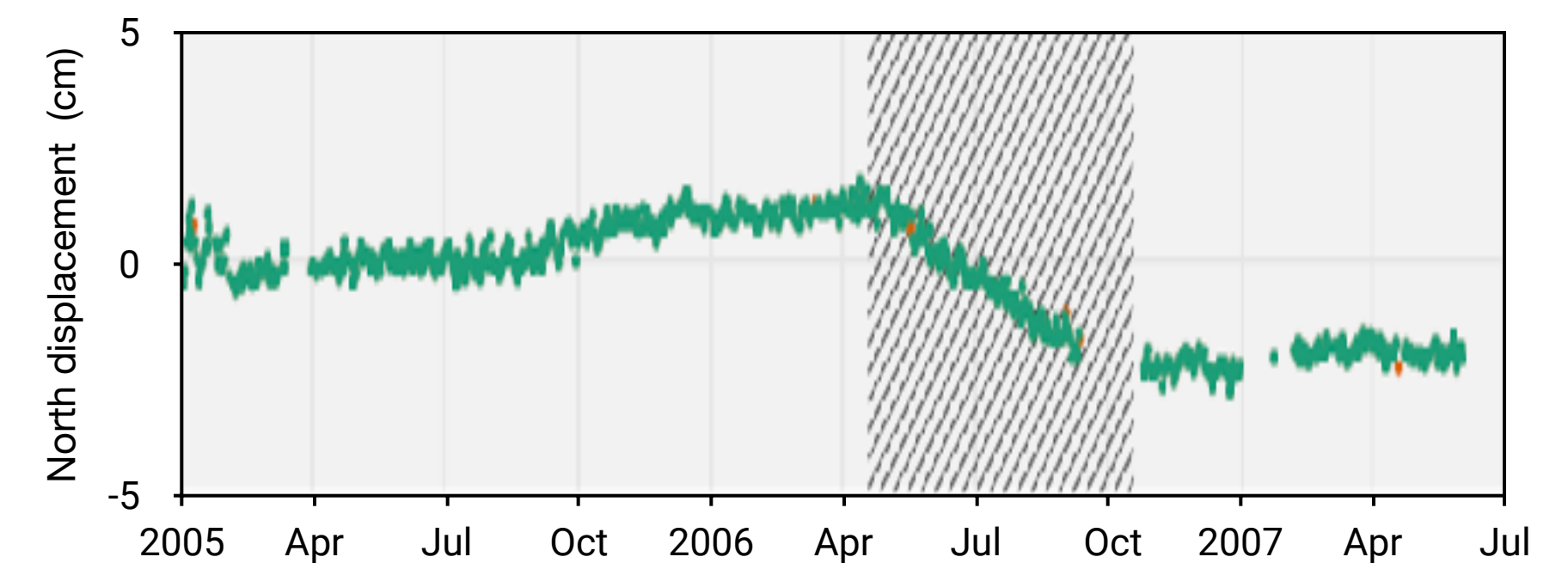


Analysis of 2.5 years of continuous data

Continuous seismograms (3 components, 100 Hz)

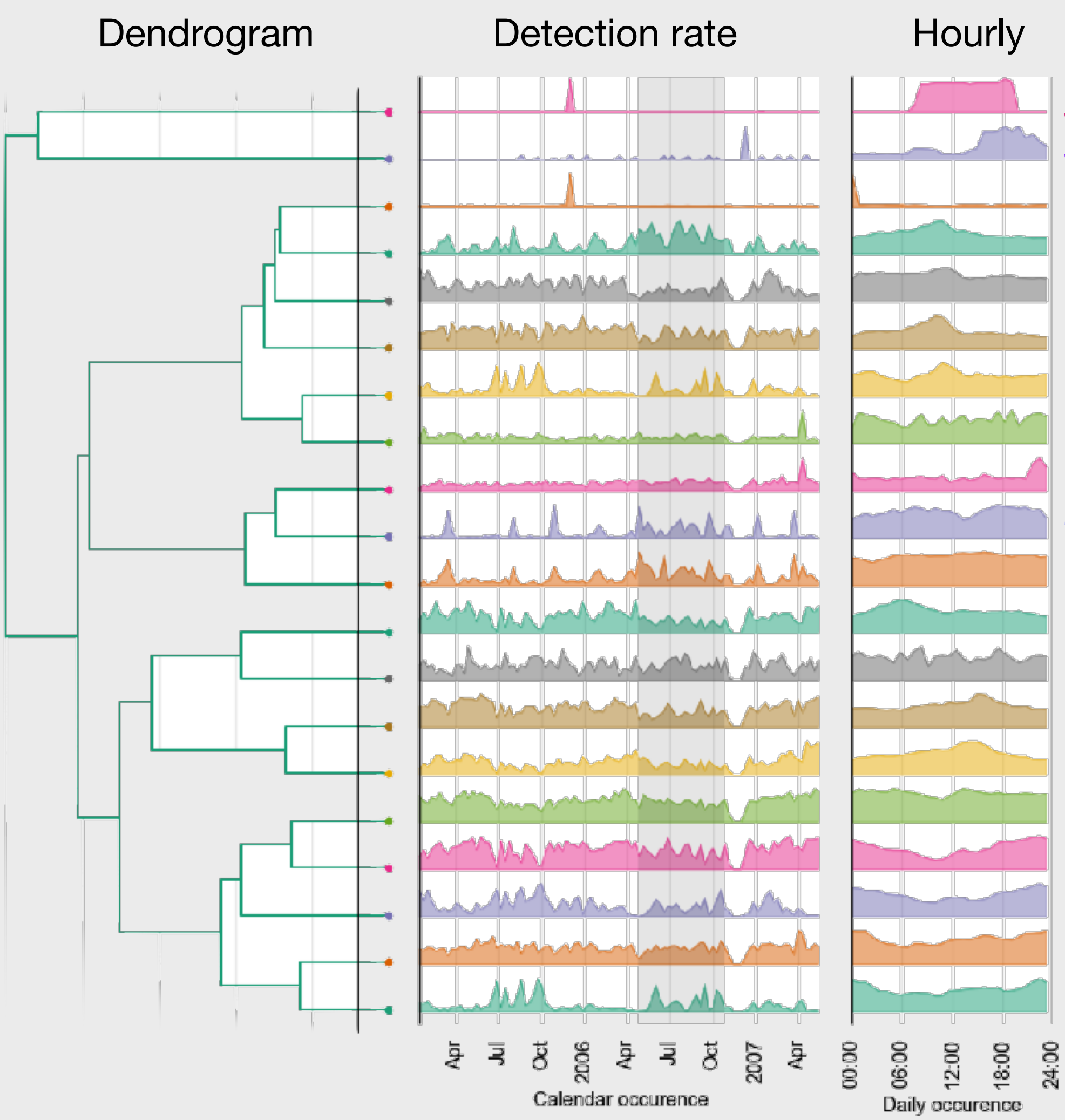


Continuous displacement (2 horizontal components, daily)



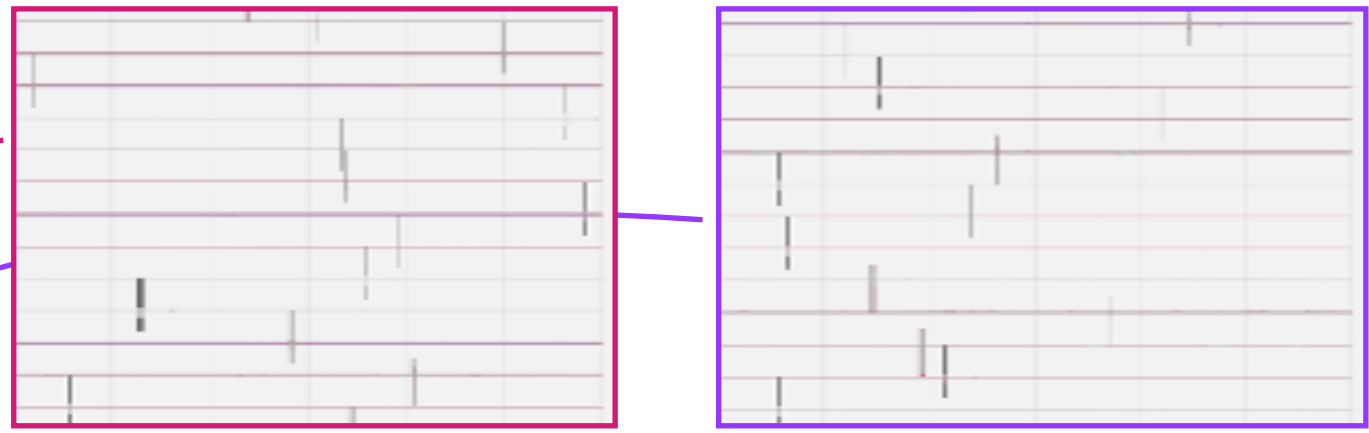
Clusters of seismic signals

From 2.5-years of continuous 3C seismic data



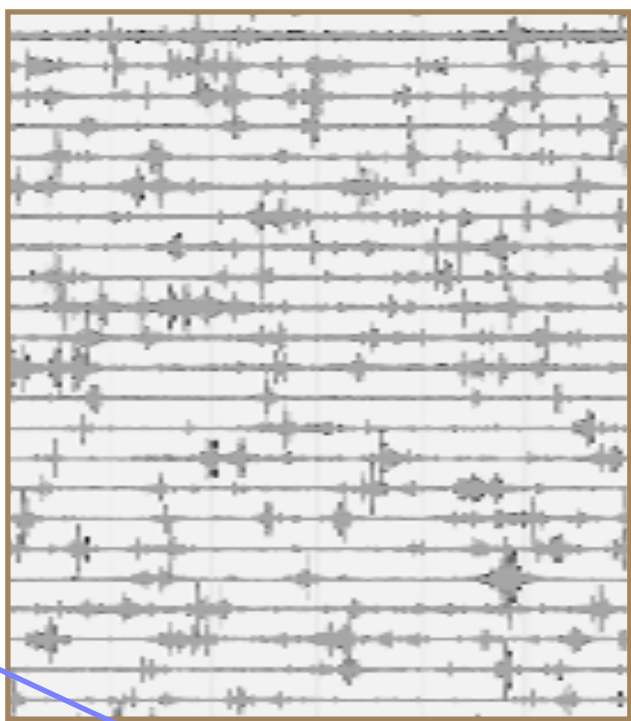
Visual inspection of seismic signal clusters

Electronic glitches and data gaps

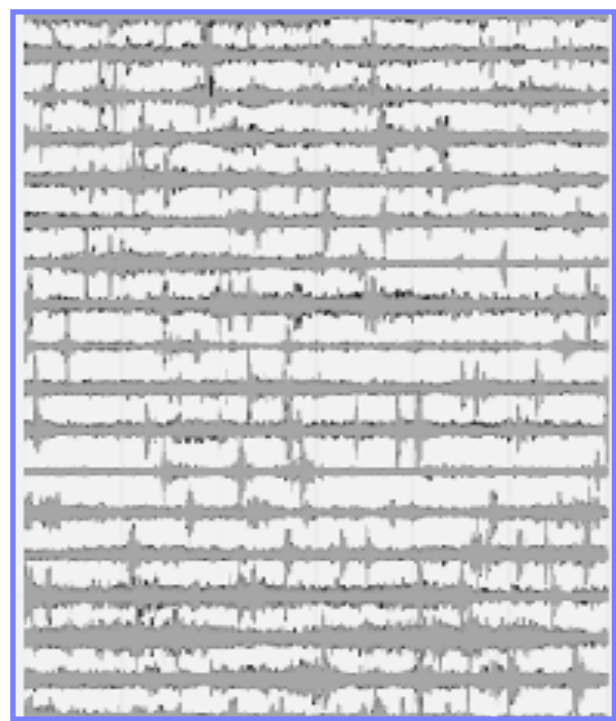


High waveform similarities

Anthropogenic noise

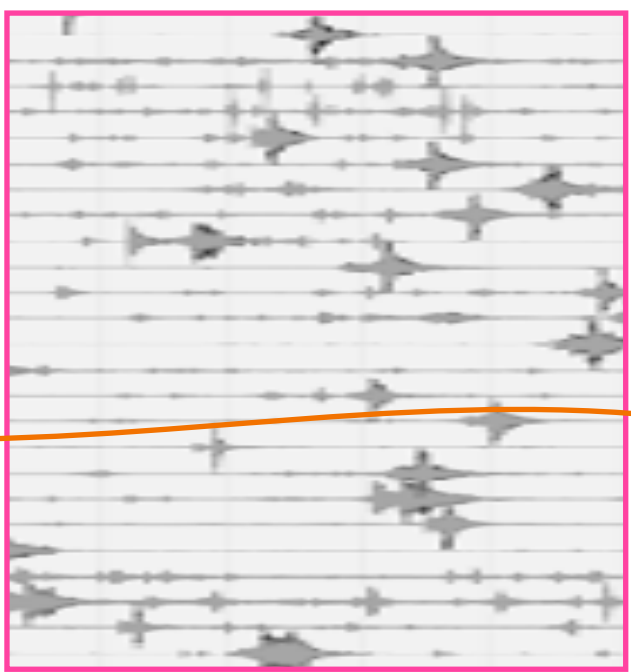


Tremor episodes



Long-duration emergent signals

Distant earthquakes



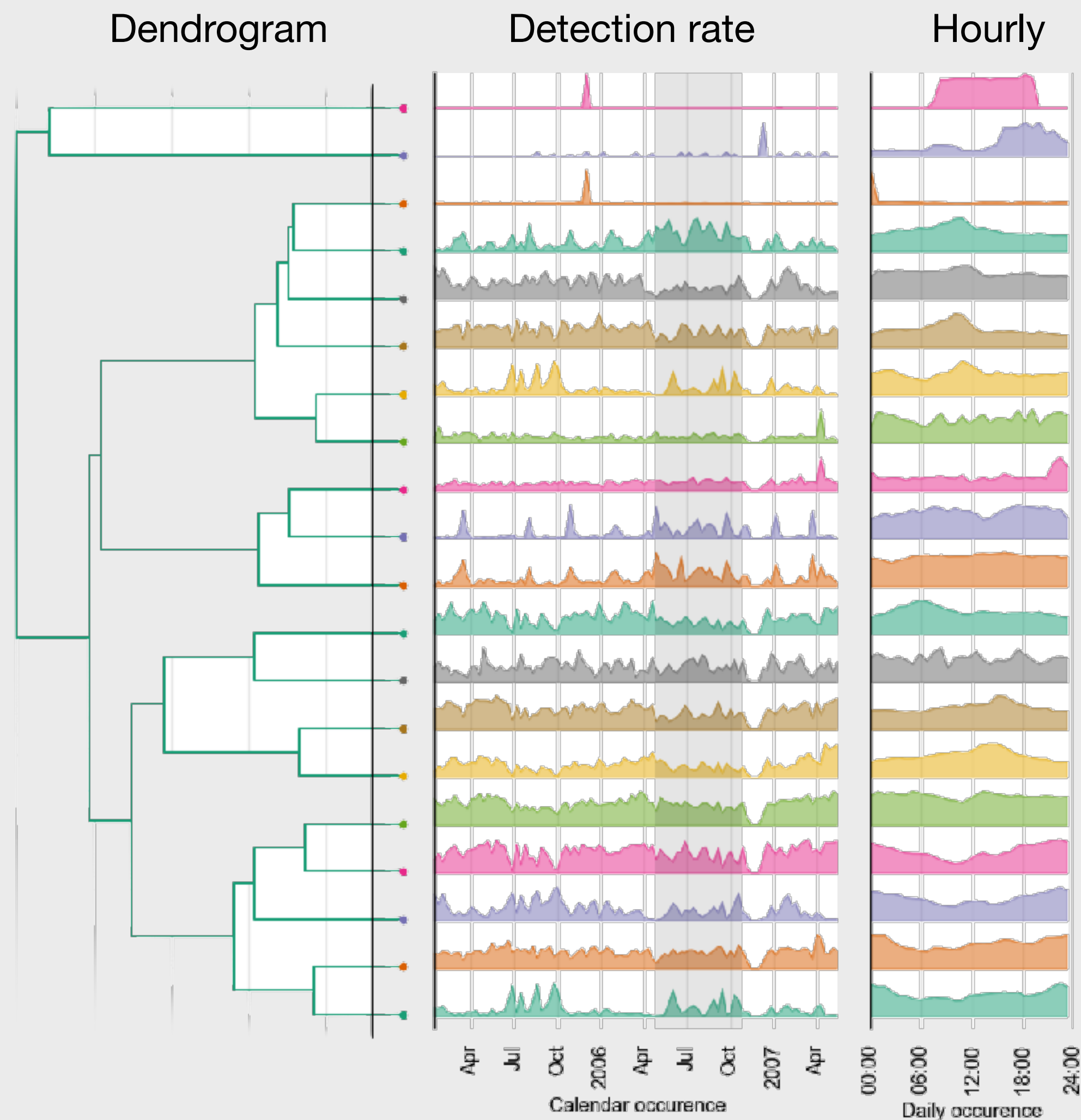
Local earthquakes



Short-duration pulse-like events

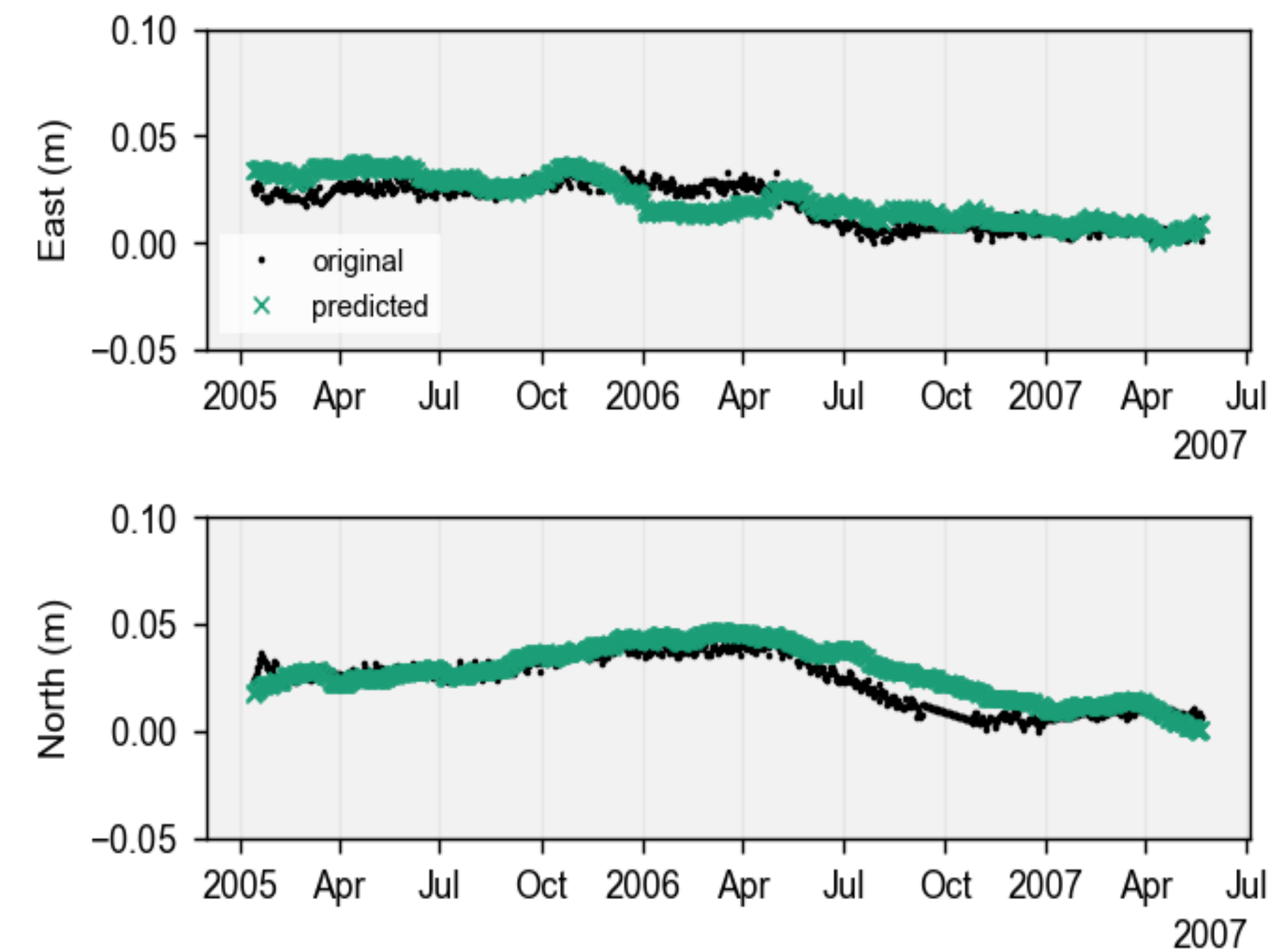
Displacement regression results

From 2.5-years of seismic clusters



GPS signal prediction from the cluster sequence

Seydoux et al. (in prep)



- **82%** accuracy of prediction
- Automatic selection of the clusters contribution

Conclusions

- We cluster 2.5 years of seismic data with an unsupervised deep-learning method
- We find seismic signals that occur preferentially during slow-slip events
- We predict the horizontal displacement from the cluster sequence of seismic signals

Perspectives

- Cross-validate meta-parameters
- Interpret the displacement contribution of each cluster
- Apply to geodetic and seismic arrays and to longer time series

