Détection et caractérisation des glissements lents dans les zones de subduction par intelligence artificielle appliquée aux données GNSS

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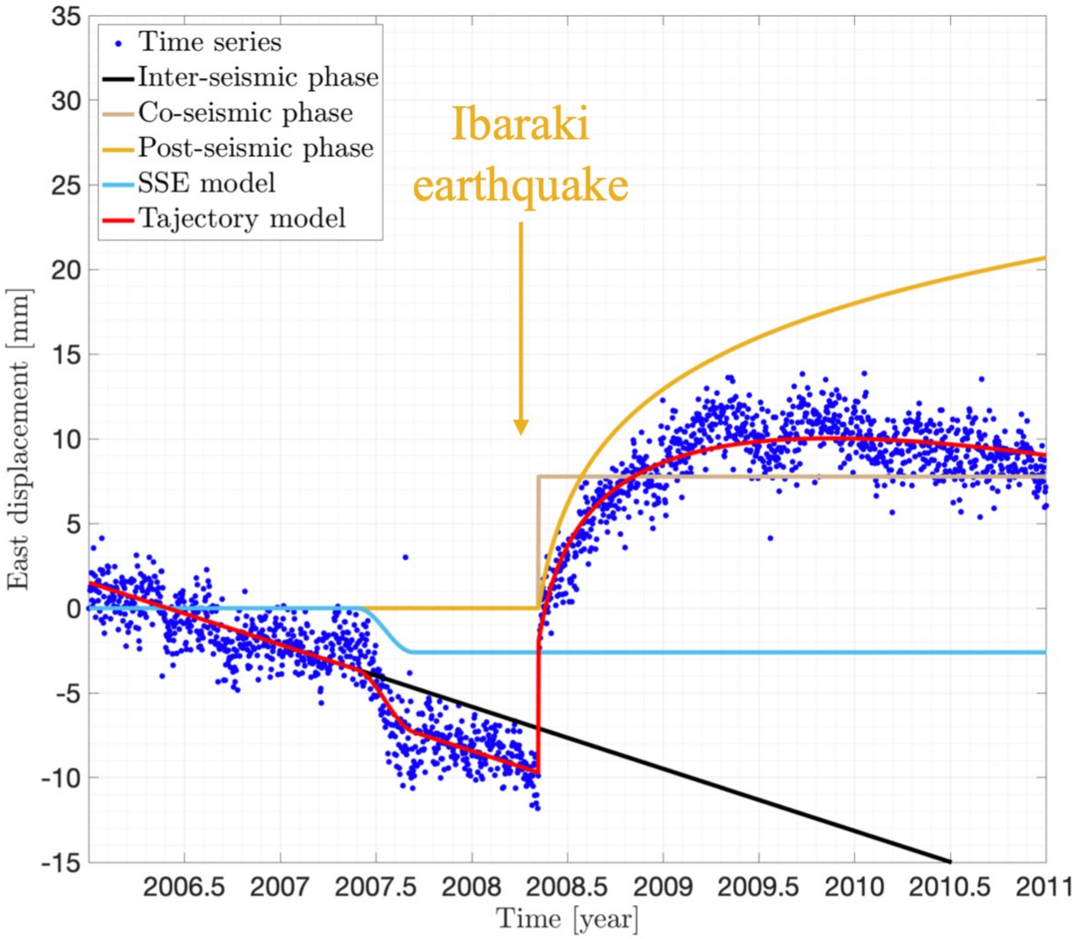
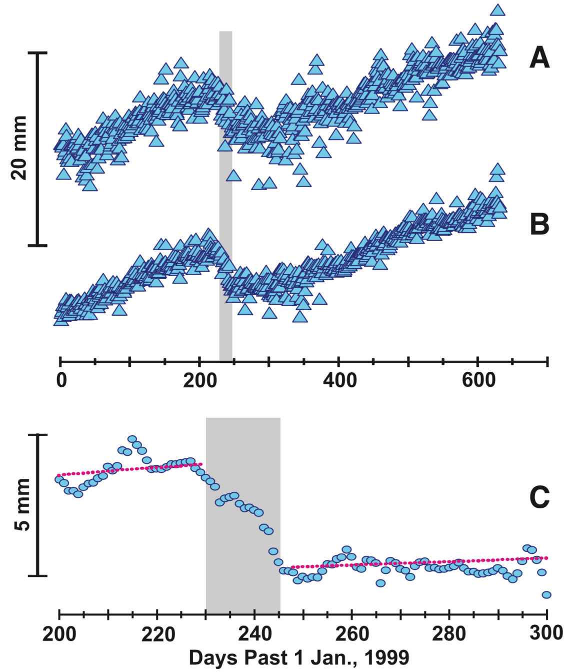
Dragert et al., 2001

Slow slip events?



Courtesy of L. Marill

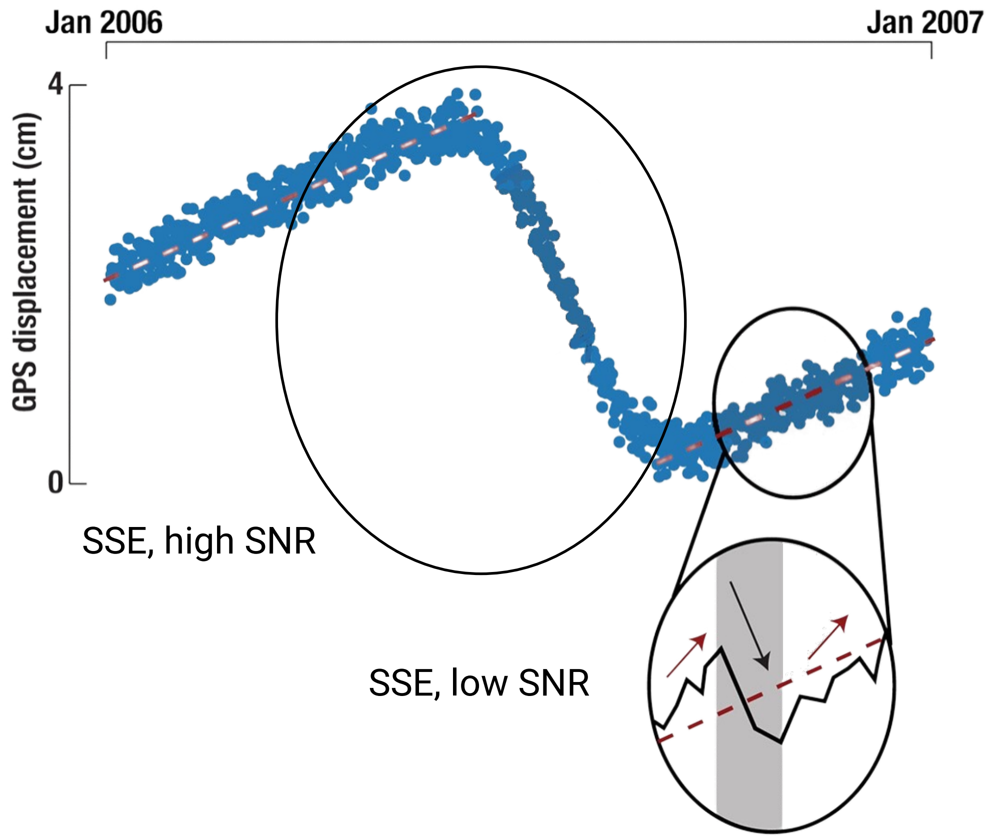


- No seismic wave radiation

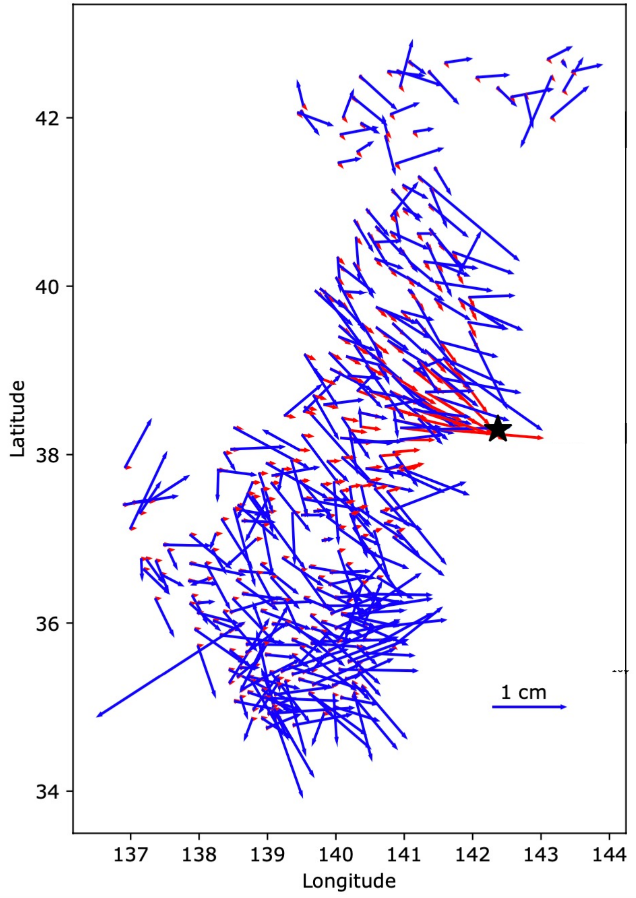
- duration of days to months

Help better understand the role of aseismic slip in earthquake cycle → insights into the fault mechanics

Slow slip events are hard to detect



Simplified after Jolivet, Frank, 2020, *AGU Advances*



Bletery and Nocquet, 2023, *Science*

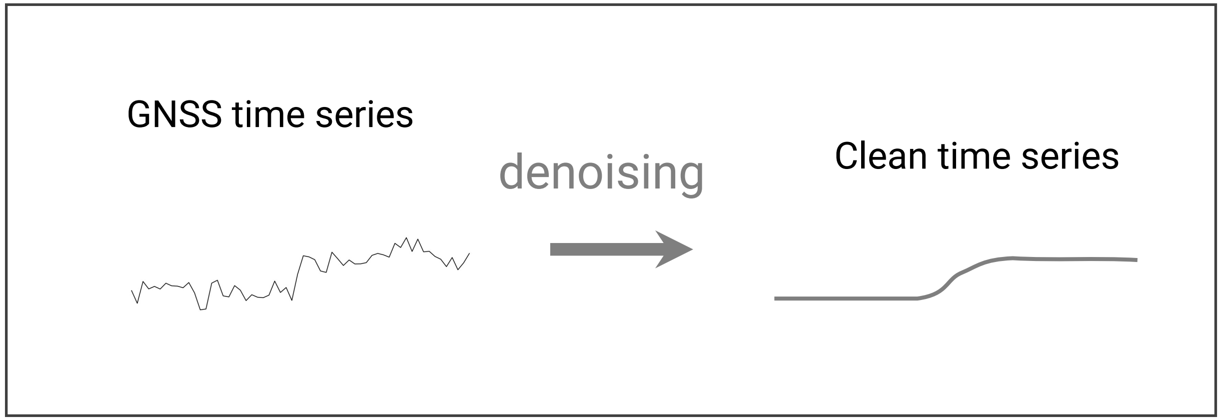
Slow slip events are **hidden** in the noise of GNSS time series…

Slow slip events have been observed worldwide, yet catalogues are still **sparse** and **incomplete**

Detecting slow slip events through **denoising**

Systematic SSE detection still hindered by the noise in GNSS time series

Denoising as intermediate step



GNSS time series → **Denoising** → Clean GNSS time series → Detection + Characterization

Objective

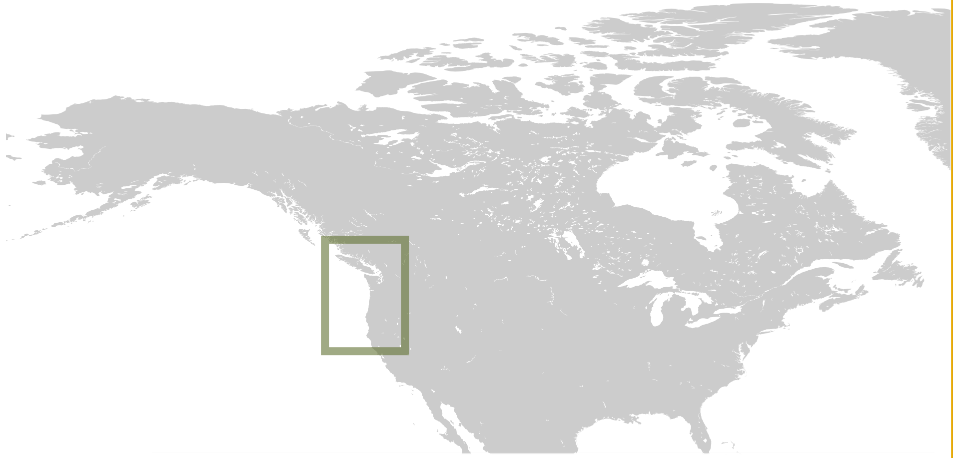
Multi-station spatiotemporal denoising method based on deep learning

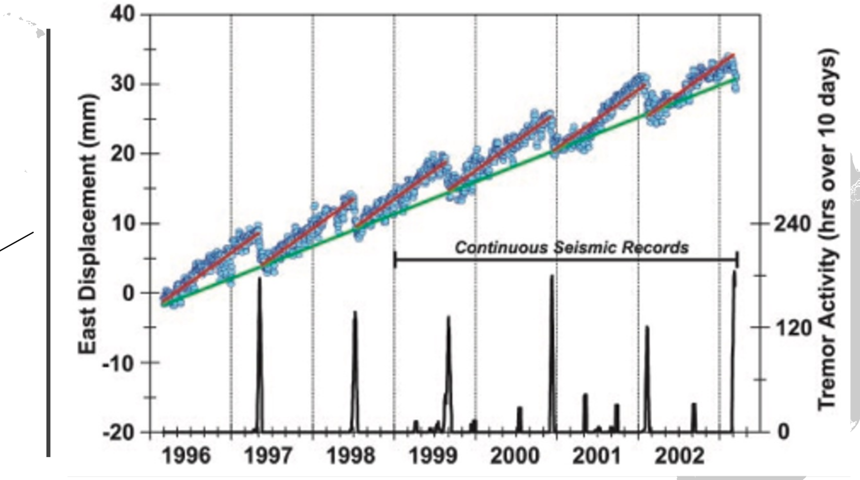
Area of study: Cascadia (North America)

No major earthquakes affecting the GNSS time series

Correlation between slow slip events and tremors: validation

SSE catalogue[1] : further comparisons

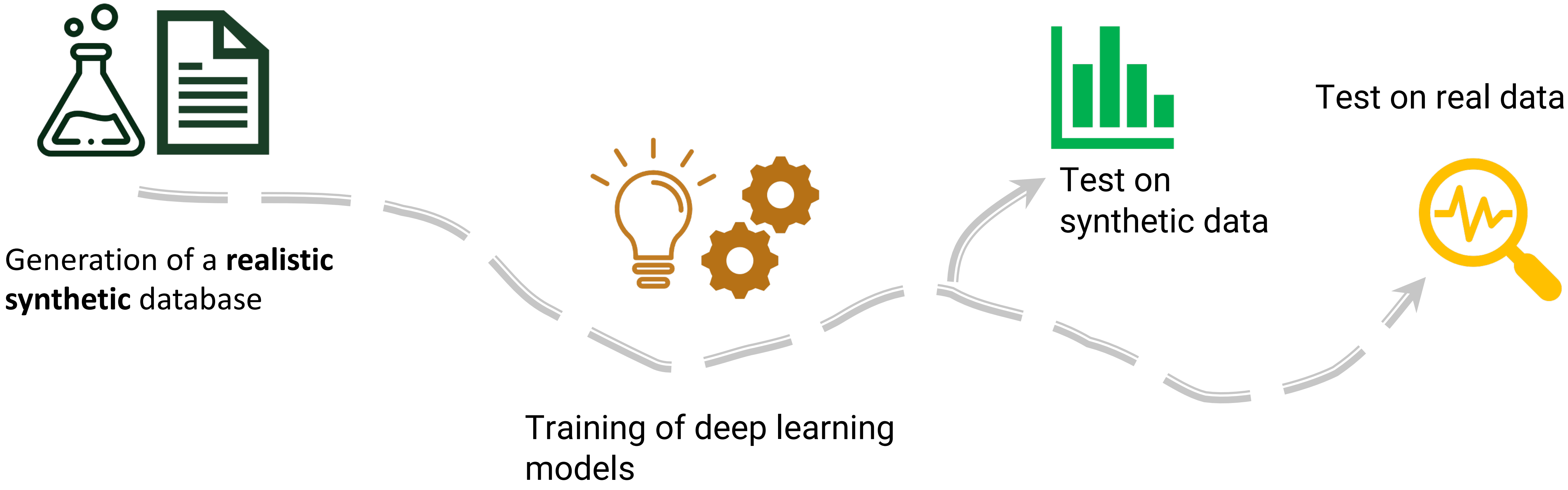




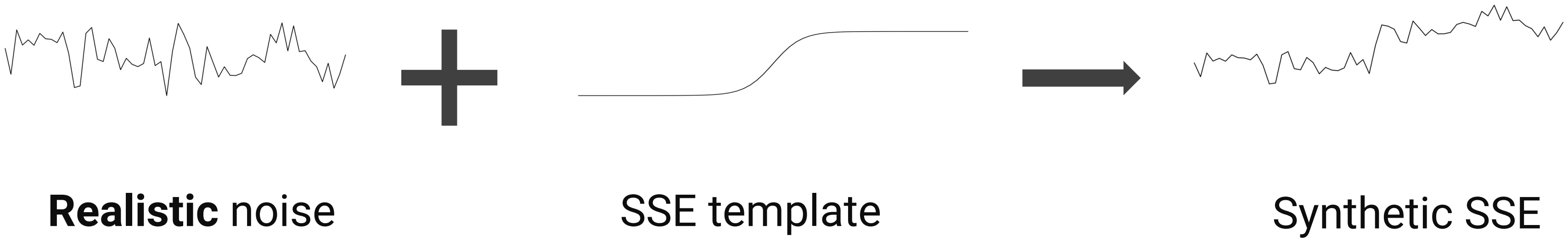
Rogers and Dragert, 2003, *Science*

[1] Michel et al., 2019, *Nature*

Proposed approach



Synthetic data generation



SSEgenerator: generation of realistic noise

Non-post-processed GNSS time series → Principal Component Analysis → Fourier phase randomization → (FFT^{-1}, PCA^{-1}) → Artificial time series

improved[1]

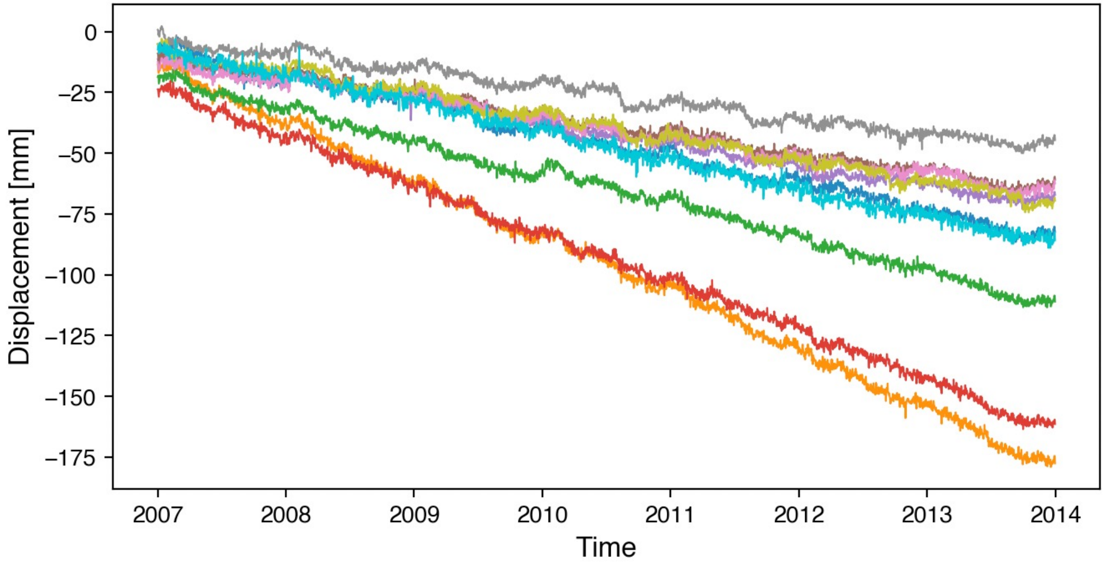
Iteratively adjust the amplitudes to match the original ones

Better statistical similarity

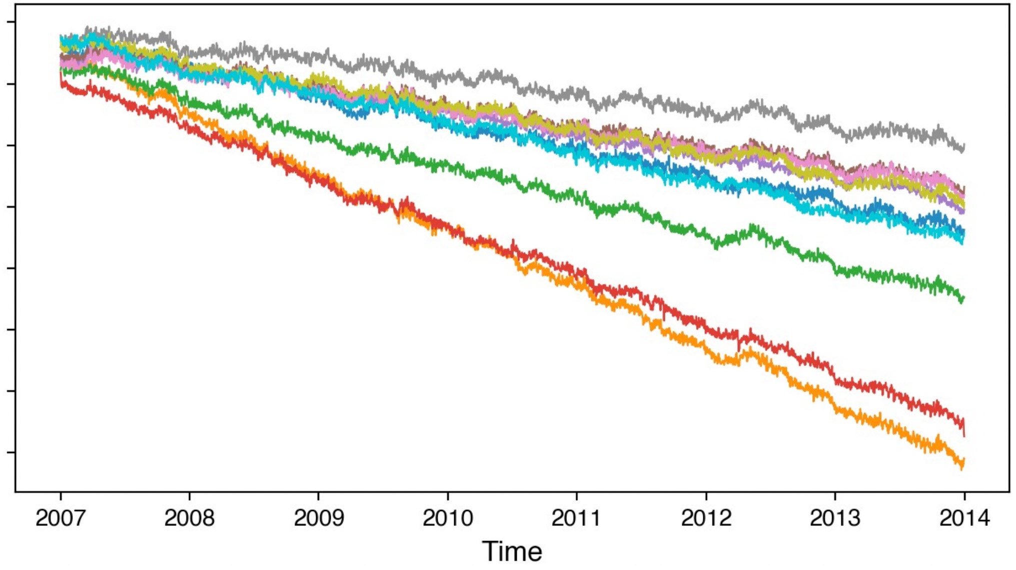
Principal Component Analysis: Preserves the spatial variability

Fourier phase randomization: Preserves the temporal coherency

Real GNSS time series



Artificial GNSS time series



Costantino et al., 2023, *Nat. Comms. Env.*, accepted

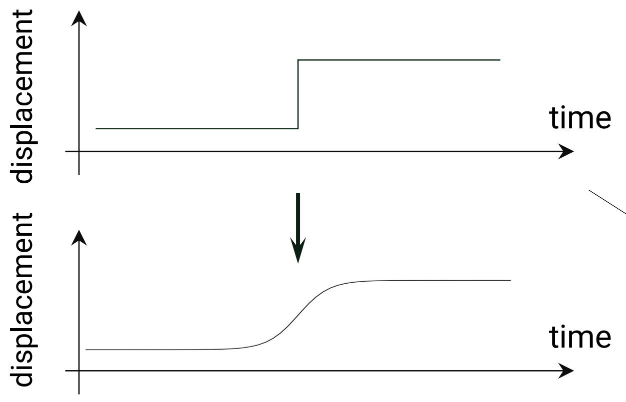
[1] Schreiber, 2000, *Physica*

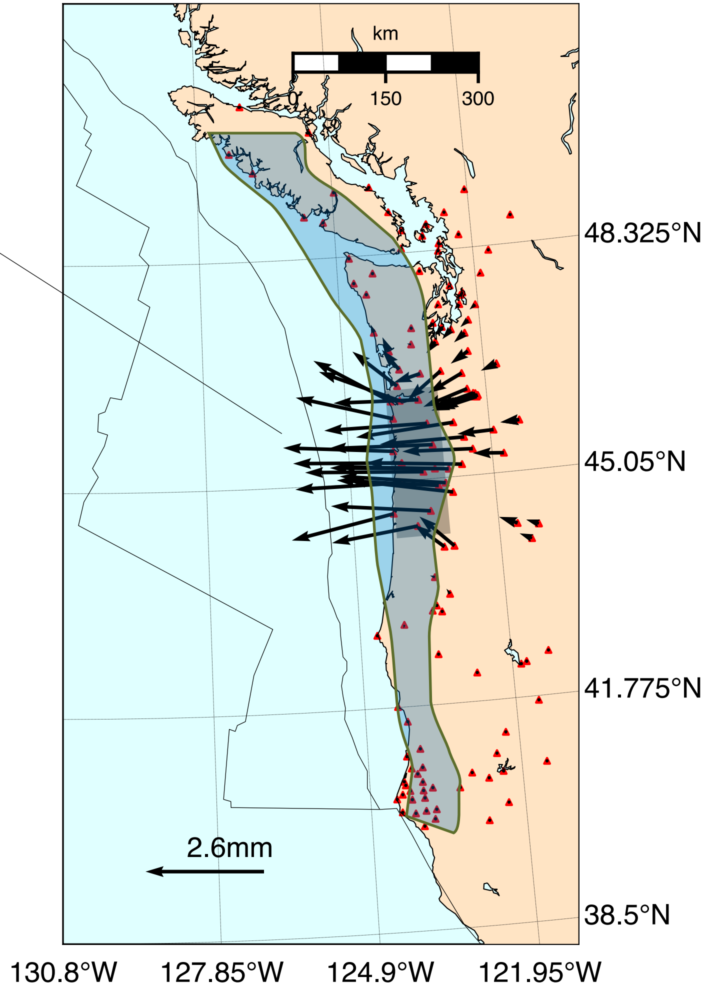
SSEgenerator: generation of synthetic slow slip events

Model of the **elastic** ground **response** associate with an earthquake of given physical parameters[1]

Physical parameters → Okada → Modeled displacement

(fault position, orientation and size, amount of slip)





Different nuances of SNR (magnitude) and event durations

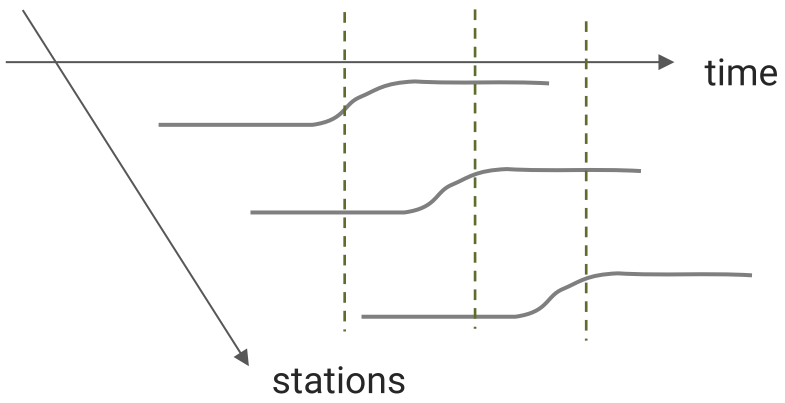
Randomly generated physical parameters (fault position and orientation, amount of slip)

[1] Okada, 1985, *BSSA*

Costantino et al., 2023, *Nat. Comms. Env.*, accepted

SSEgeneratorV2: generation of realistic slow slip patterns

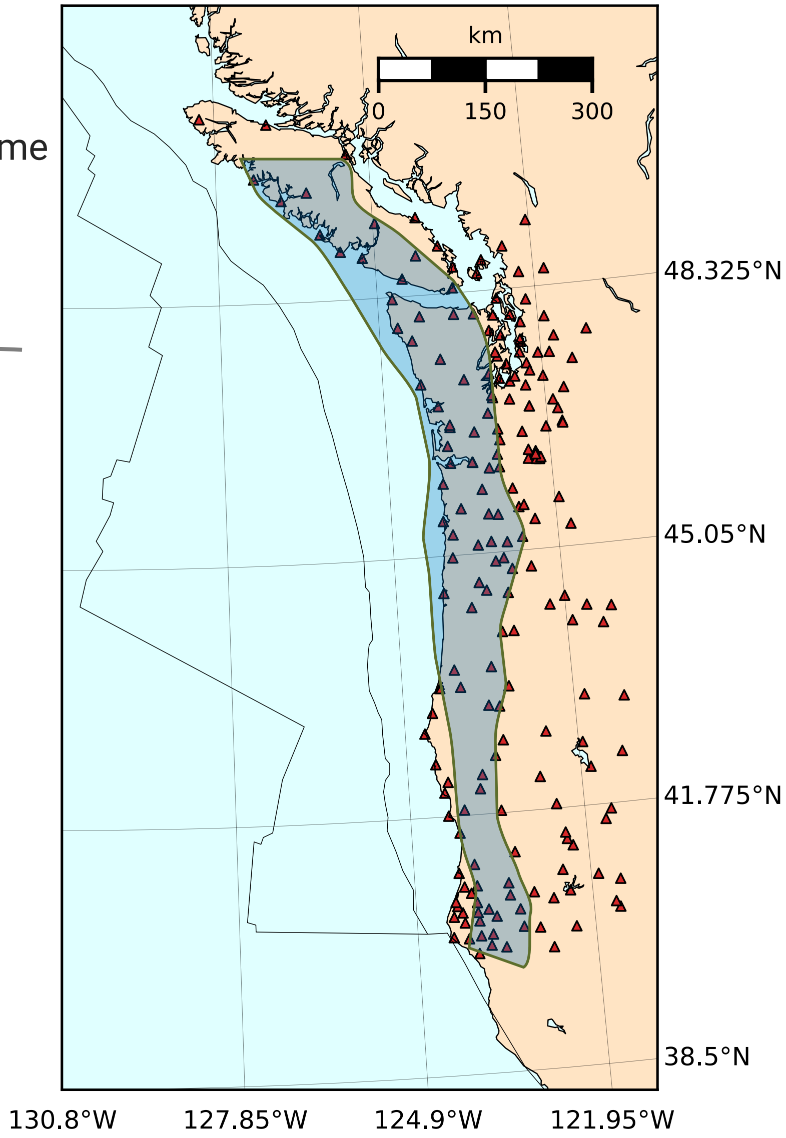
One template per event is **not enough**



e.g., slow slip events can propagate in space and time

- No signal → **Zero displacement**: SSEdenoiser can better understand what noise look like

- Up to three signals | More realistic signals, better modeling slow slip propagation



Costantino et al., in prep.

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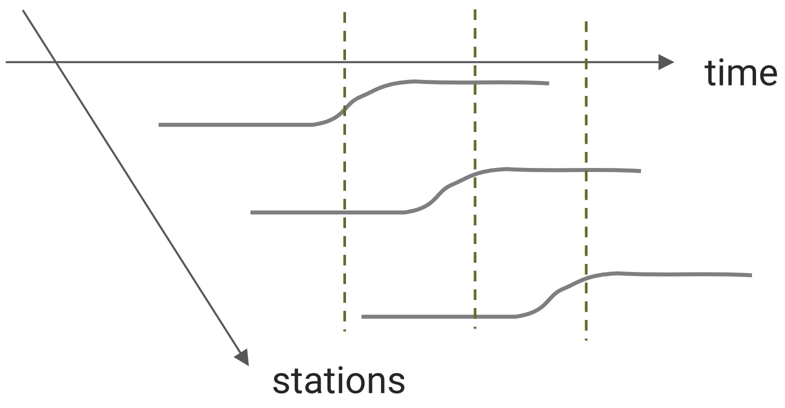

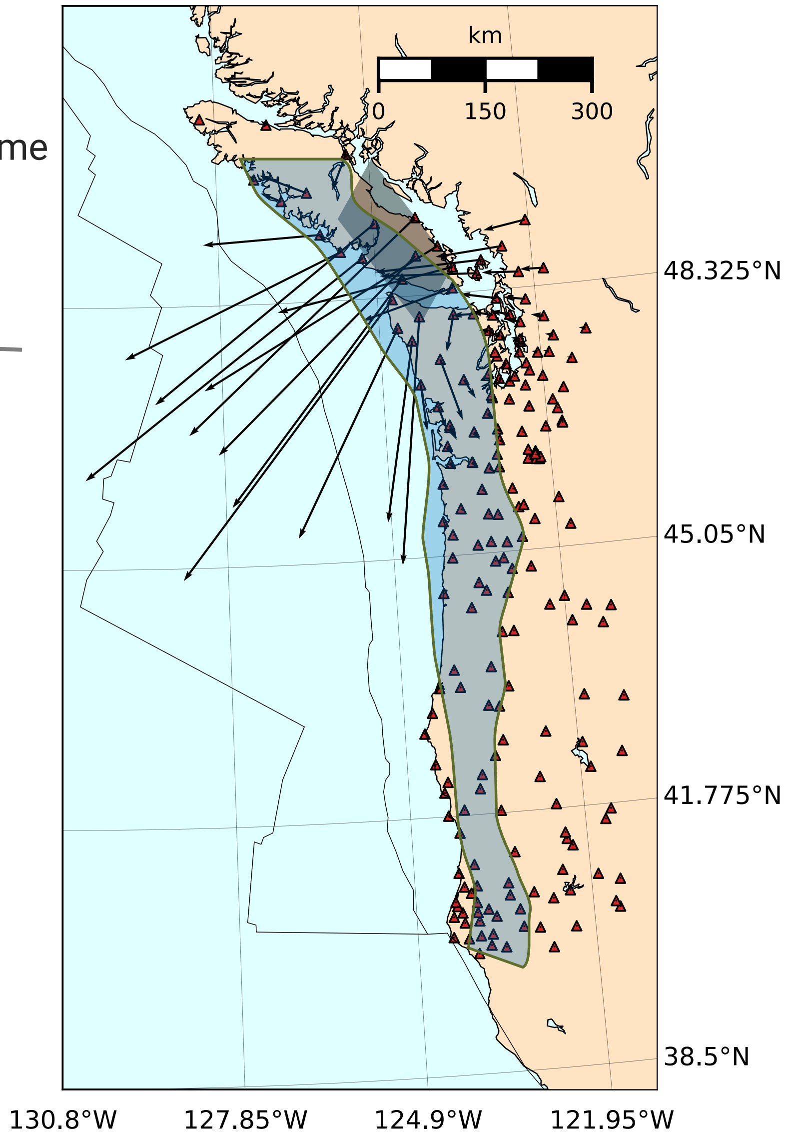

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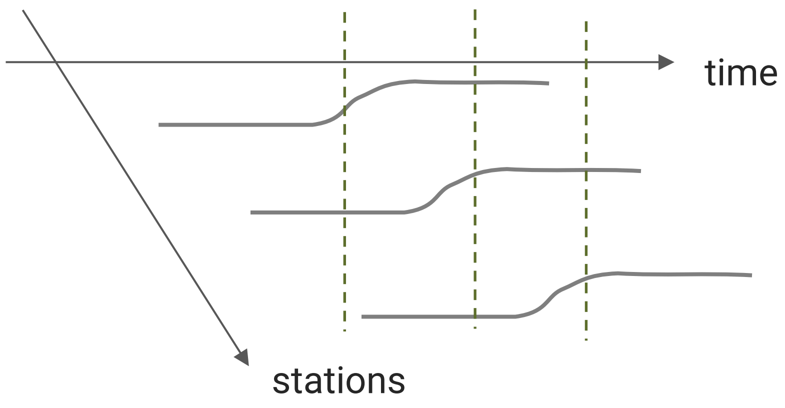

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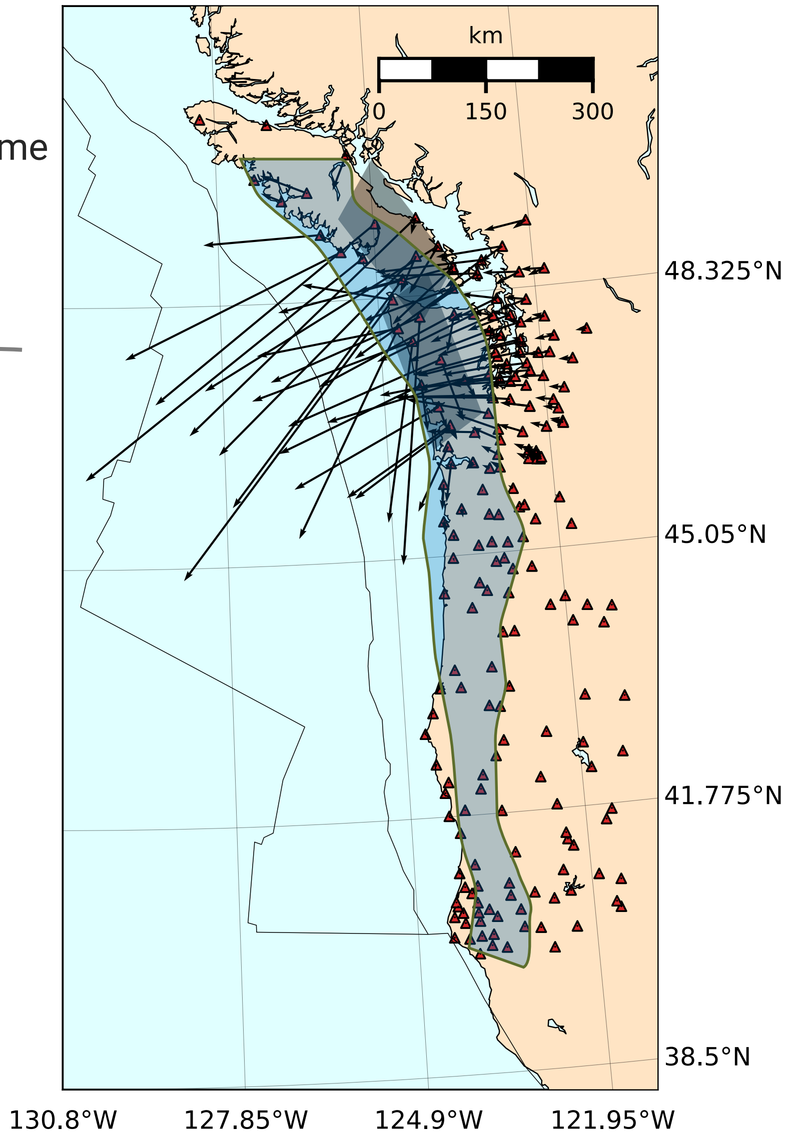

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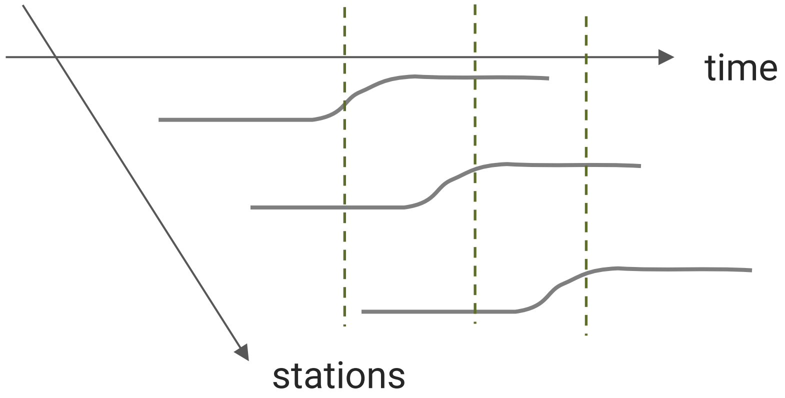

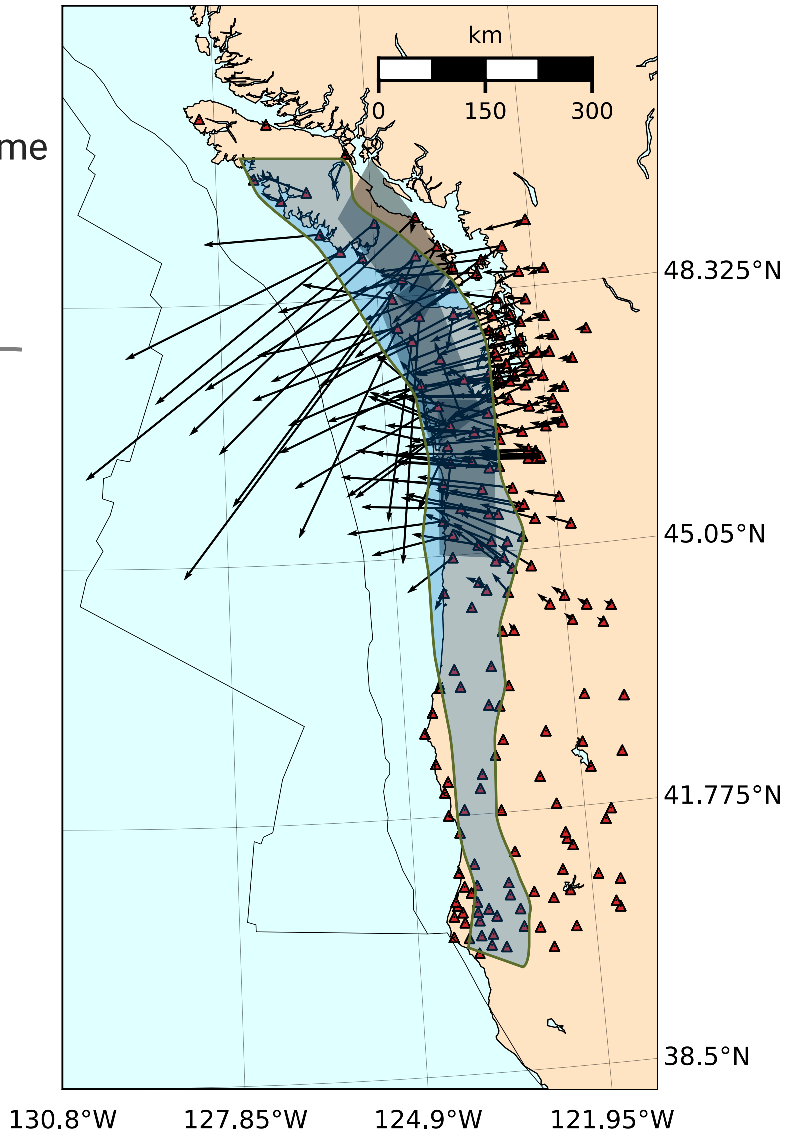

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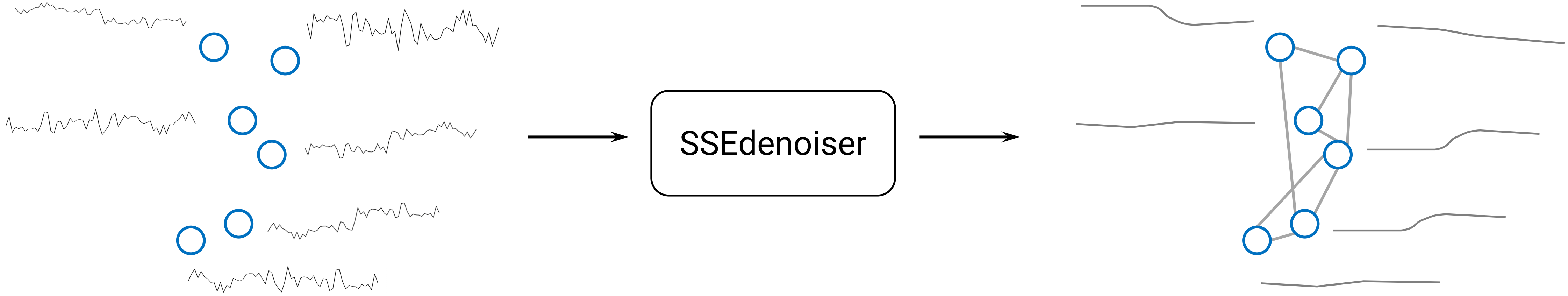
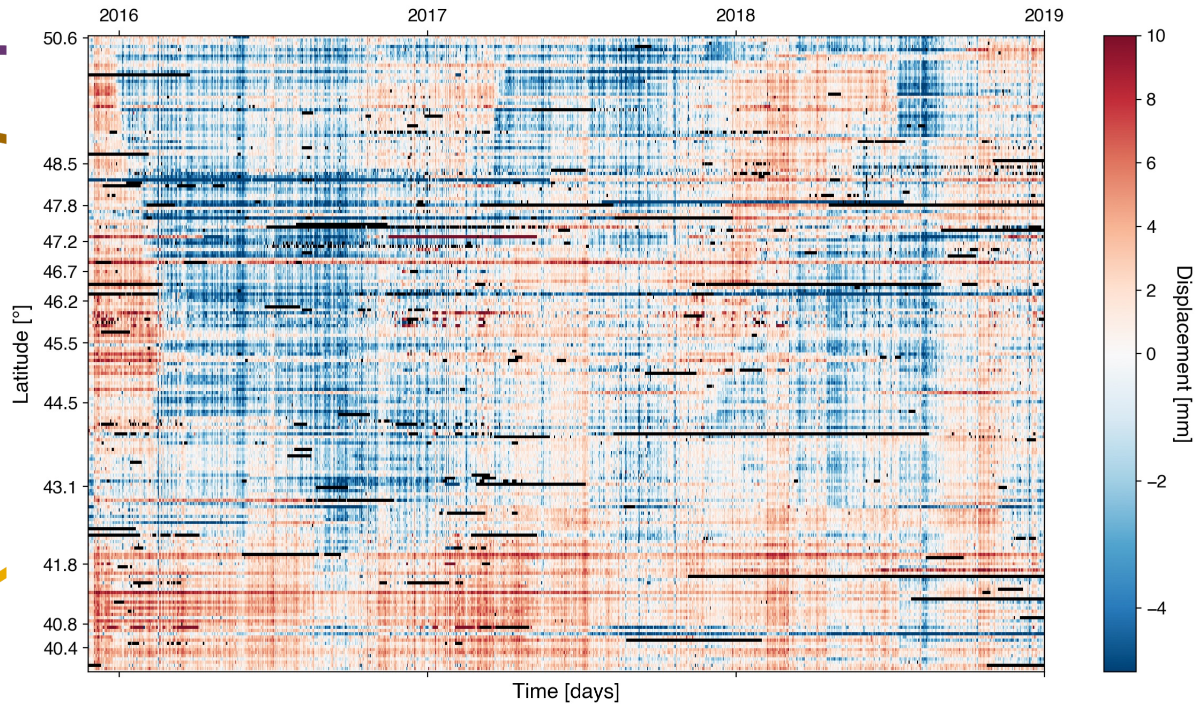
SSEdenoiser – high level architecture



Costantino et al., in prep.

Denoising of real data in Cascadia



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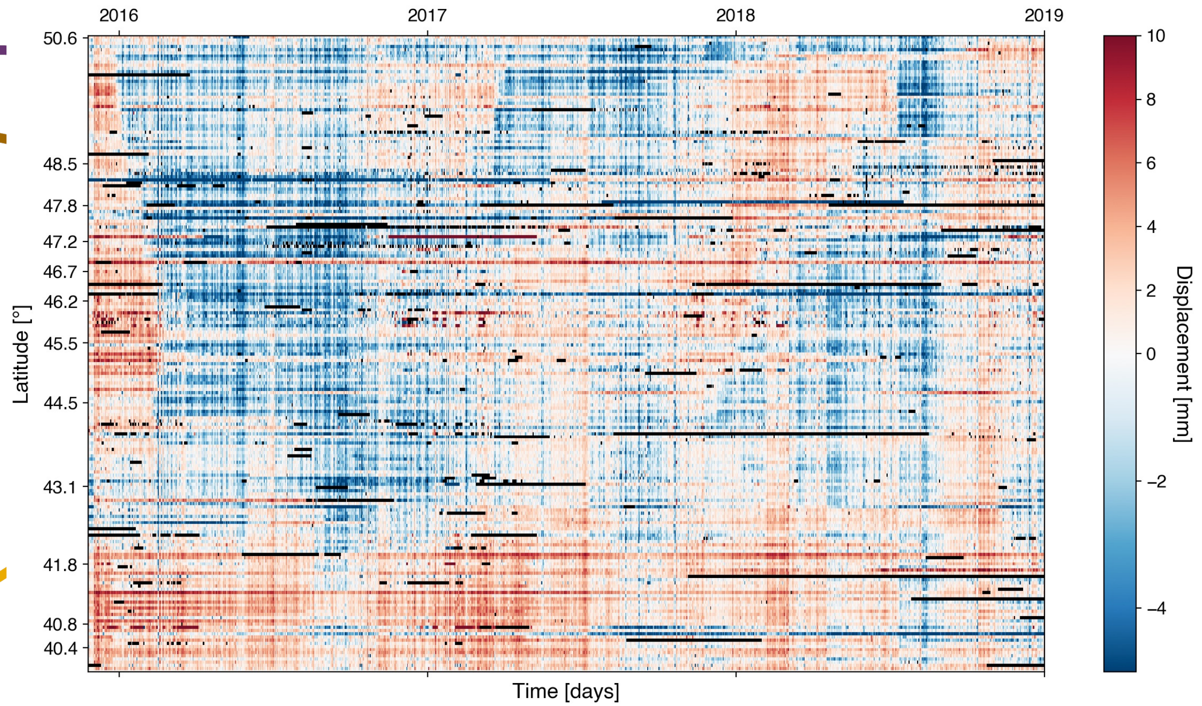
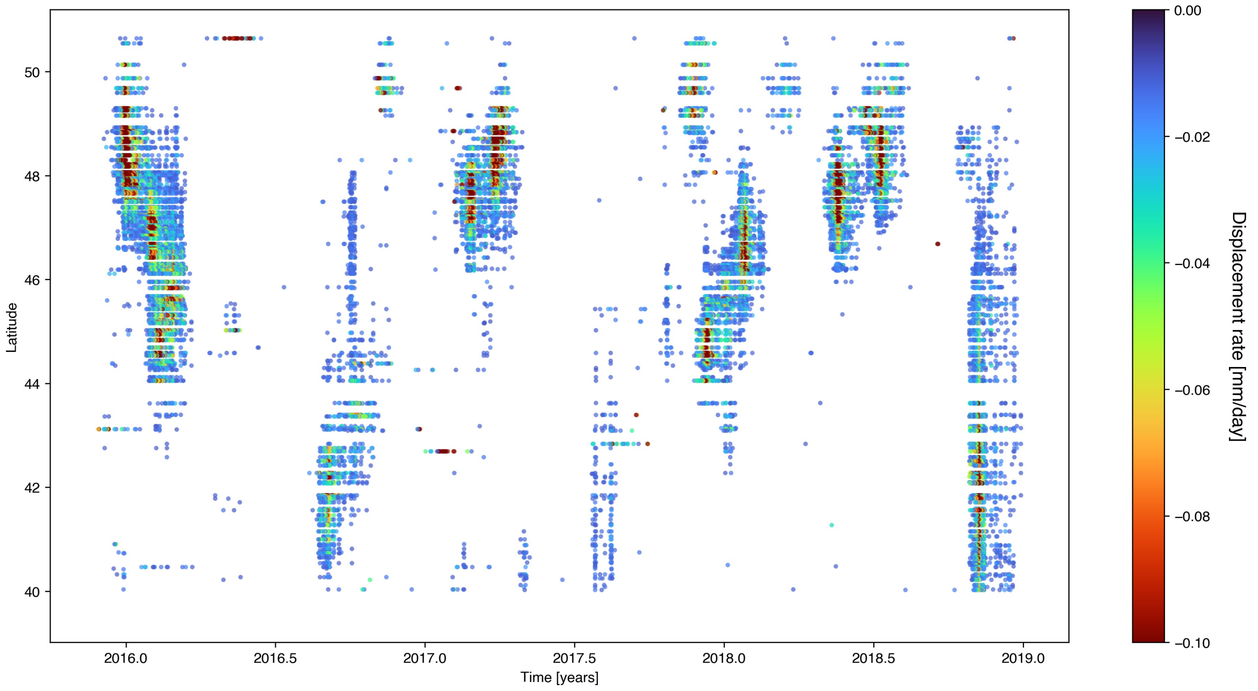


SSEdenoiser



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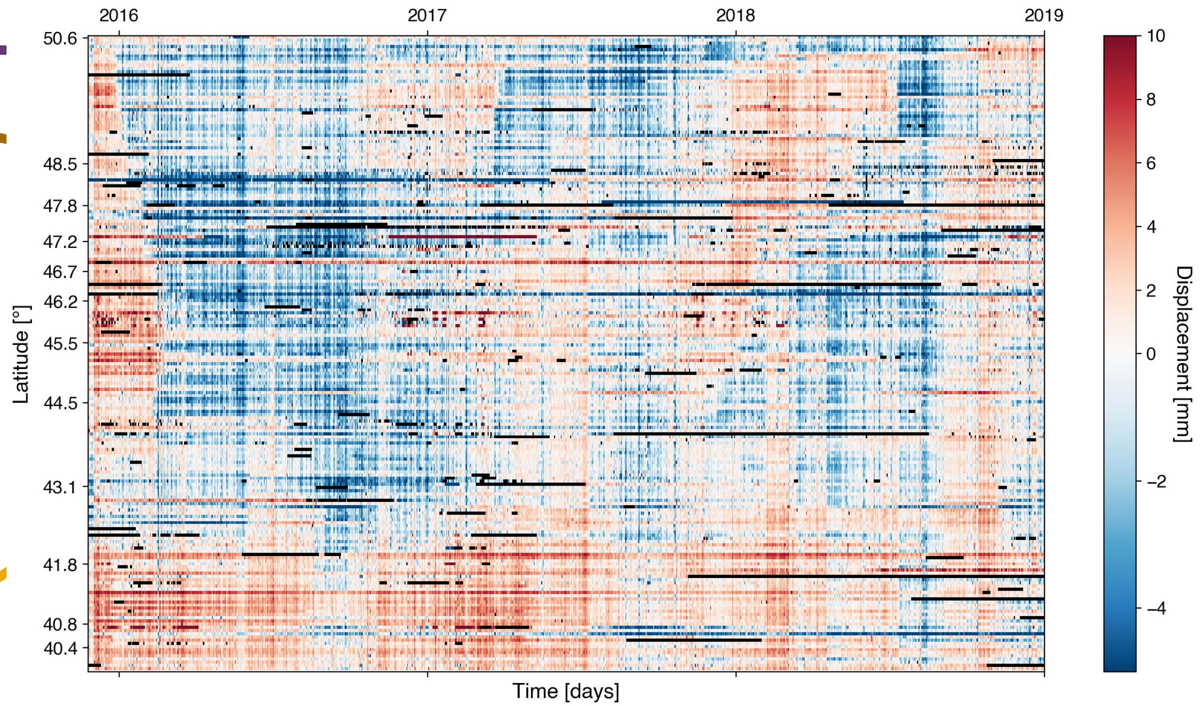

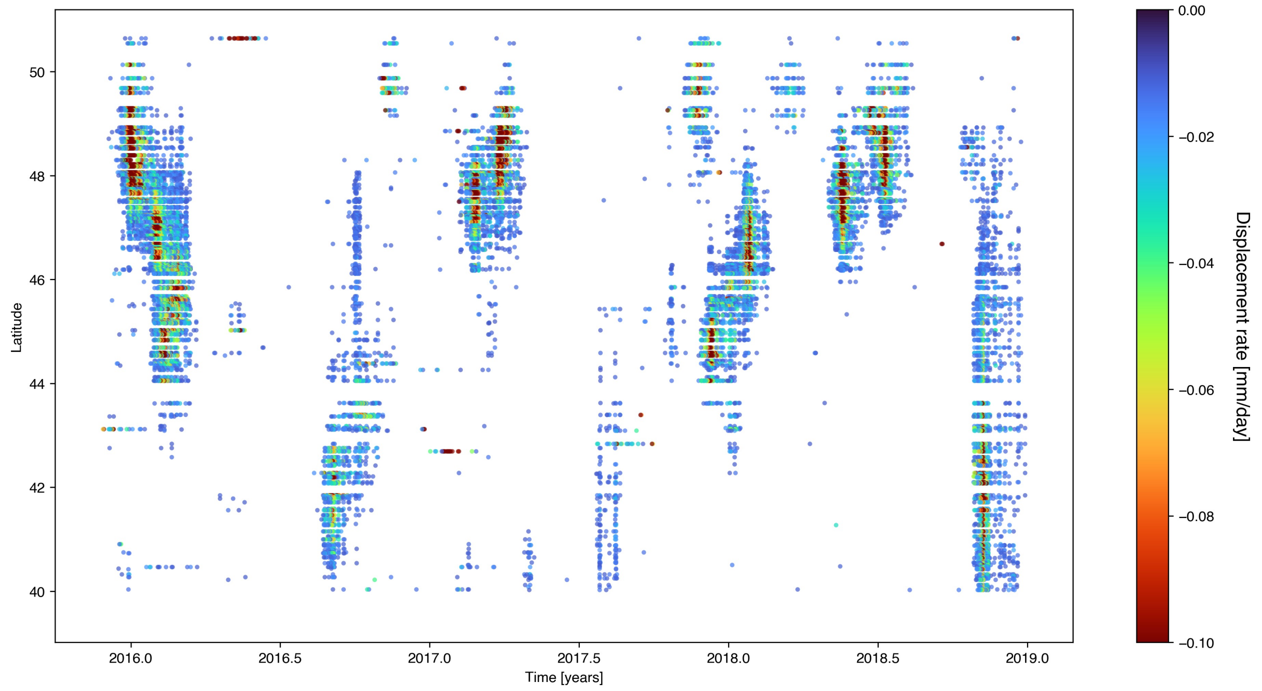

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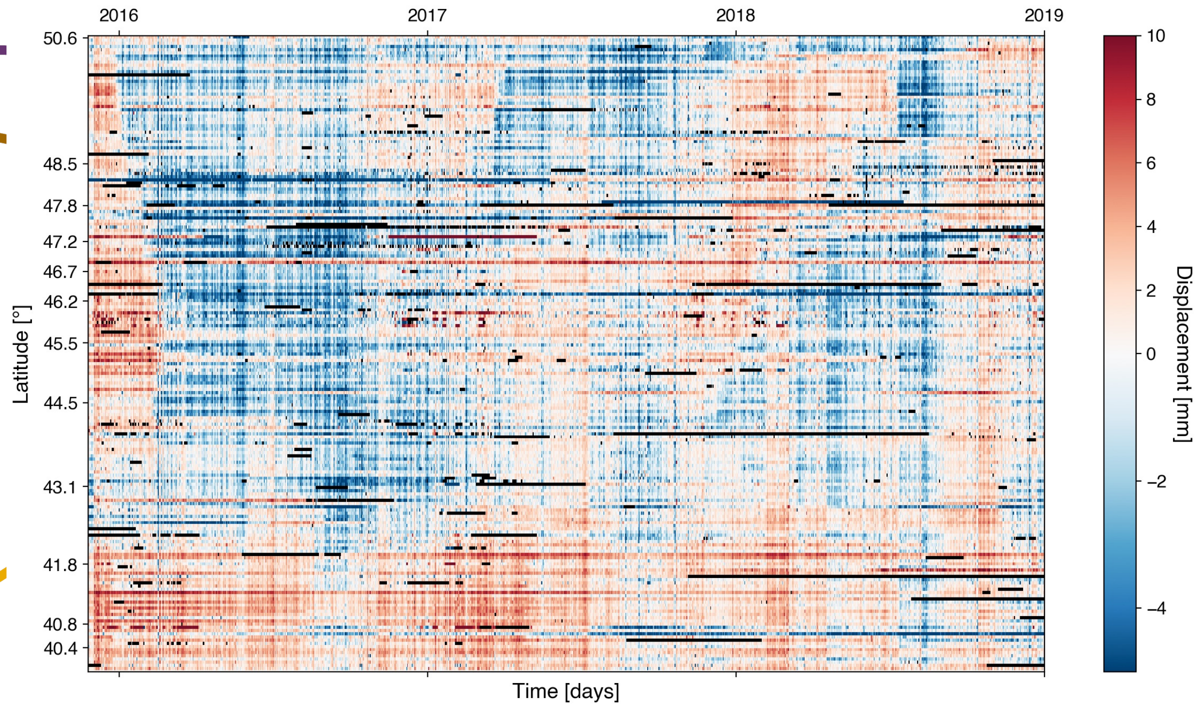

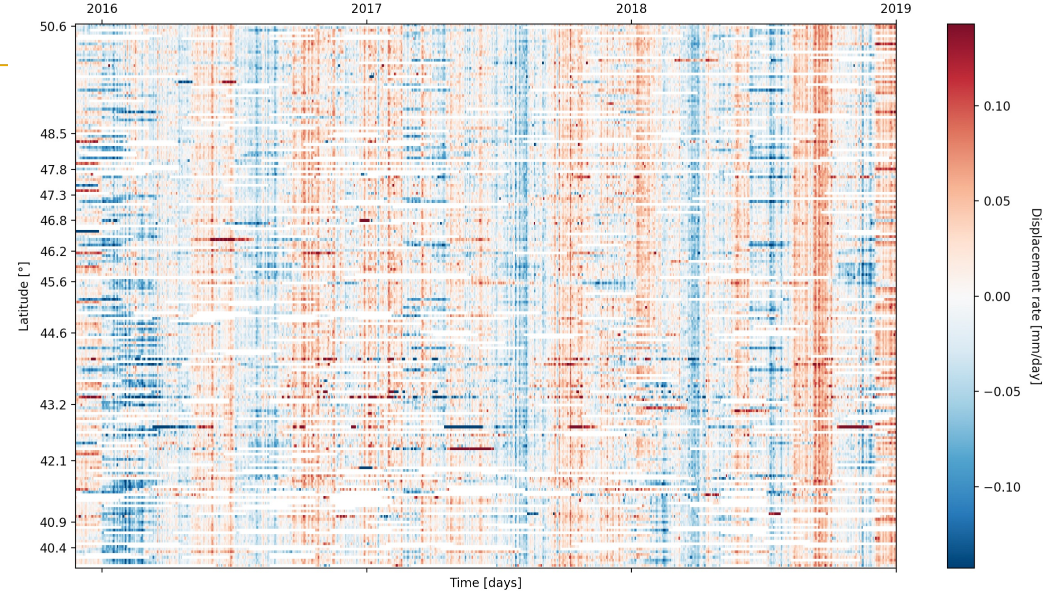

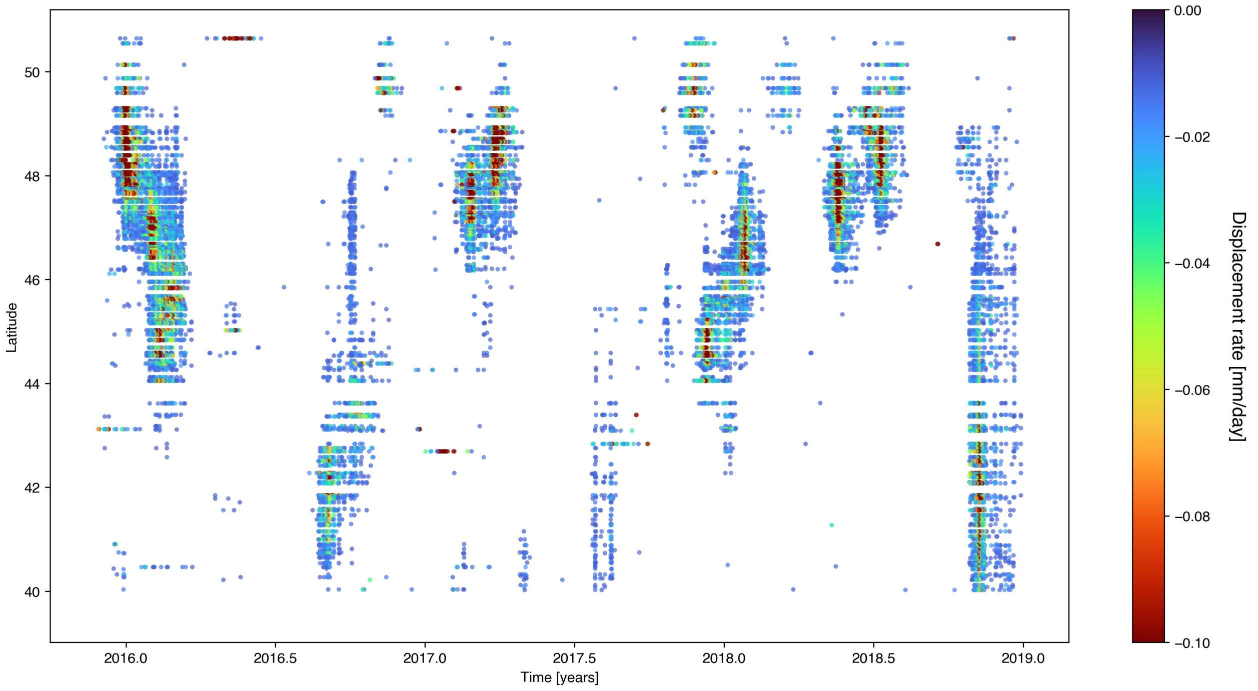

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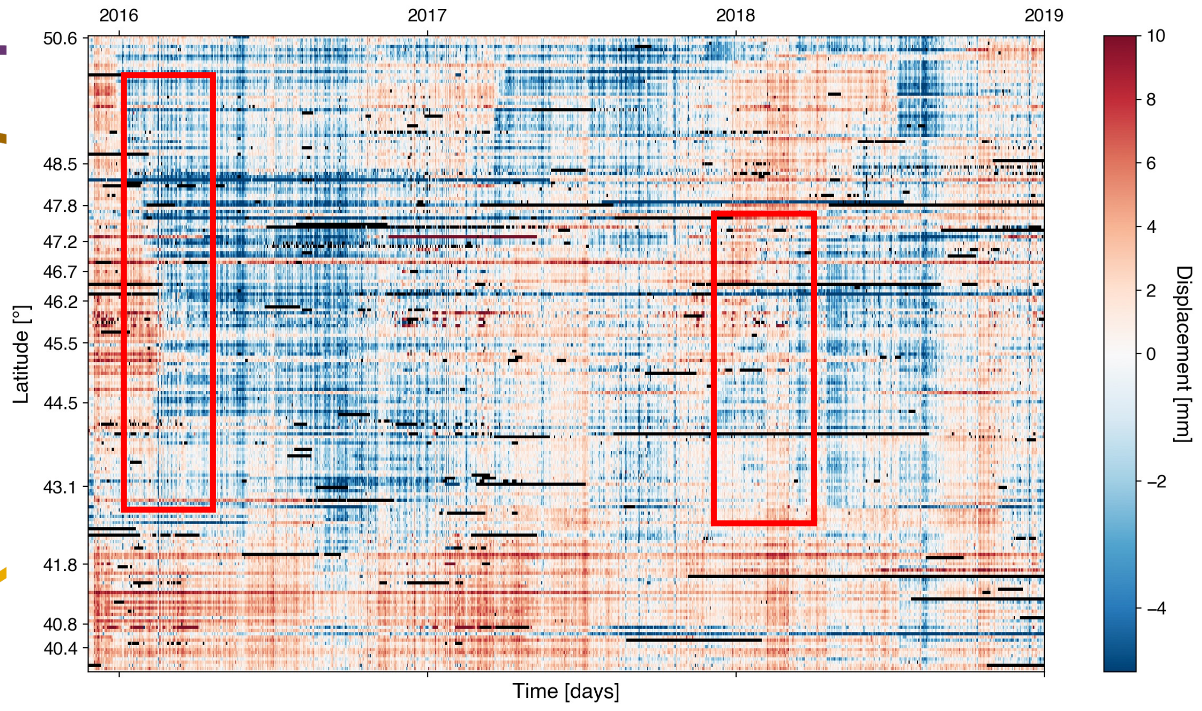
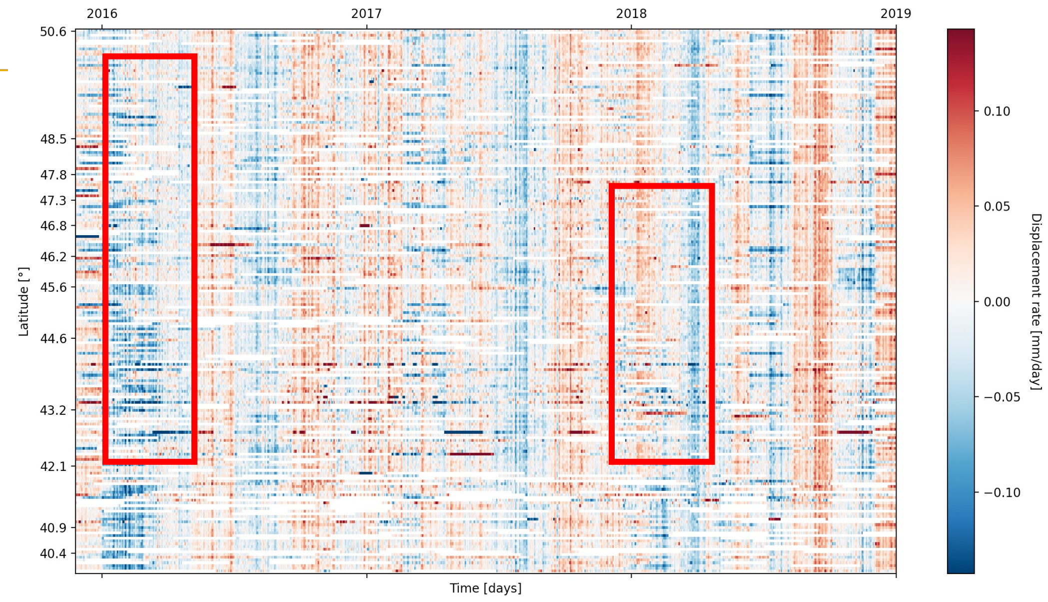
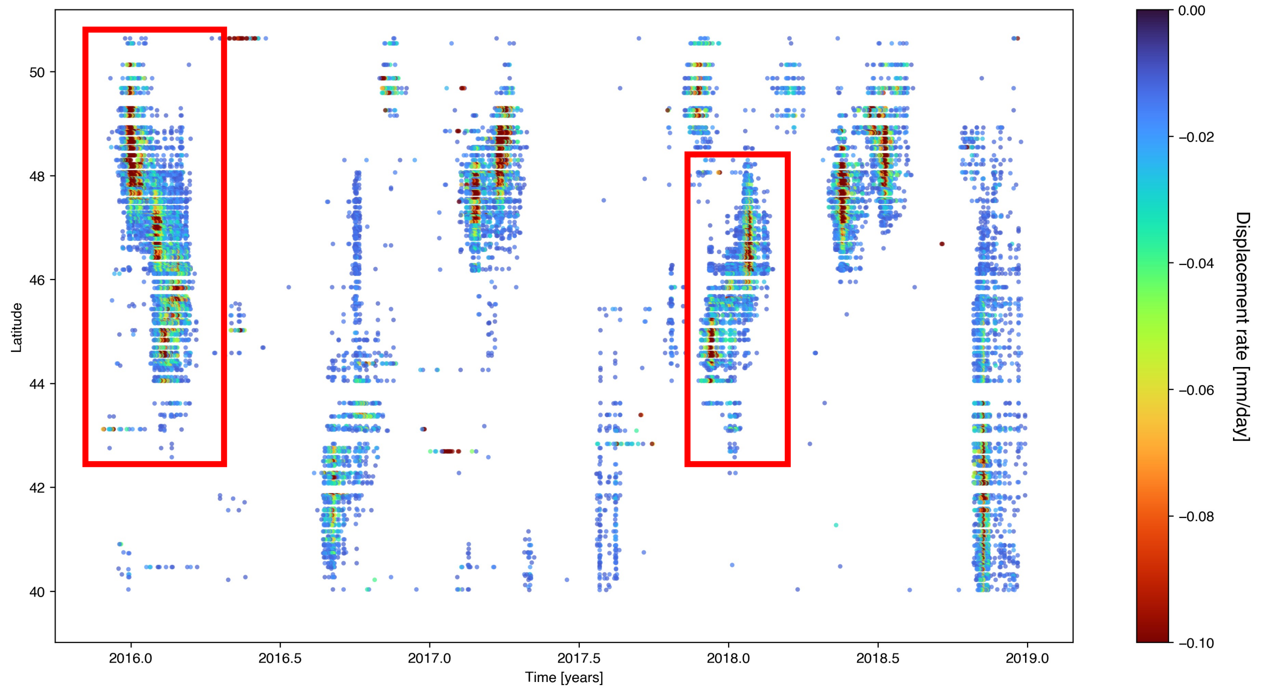
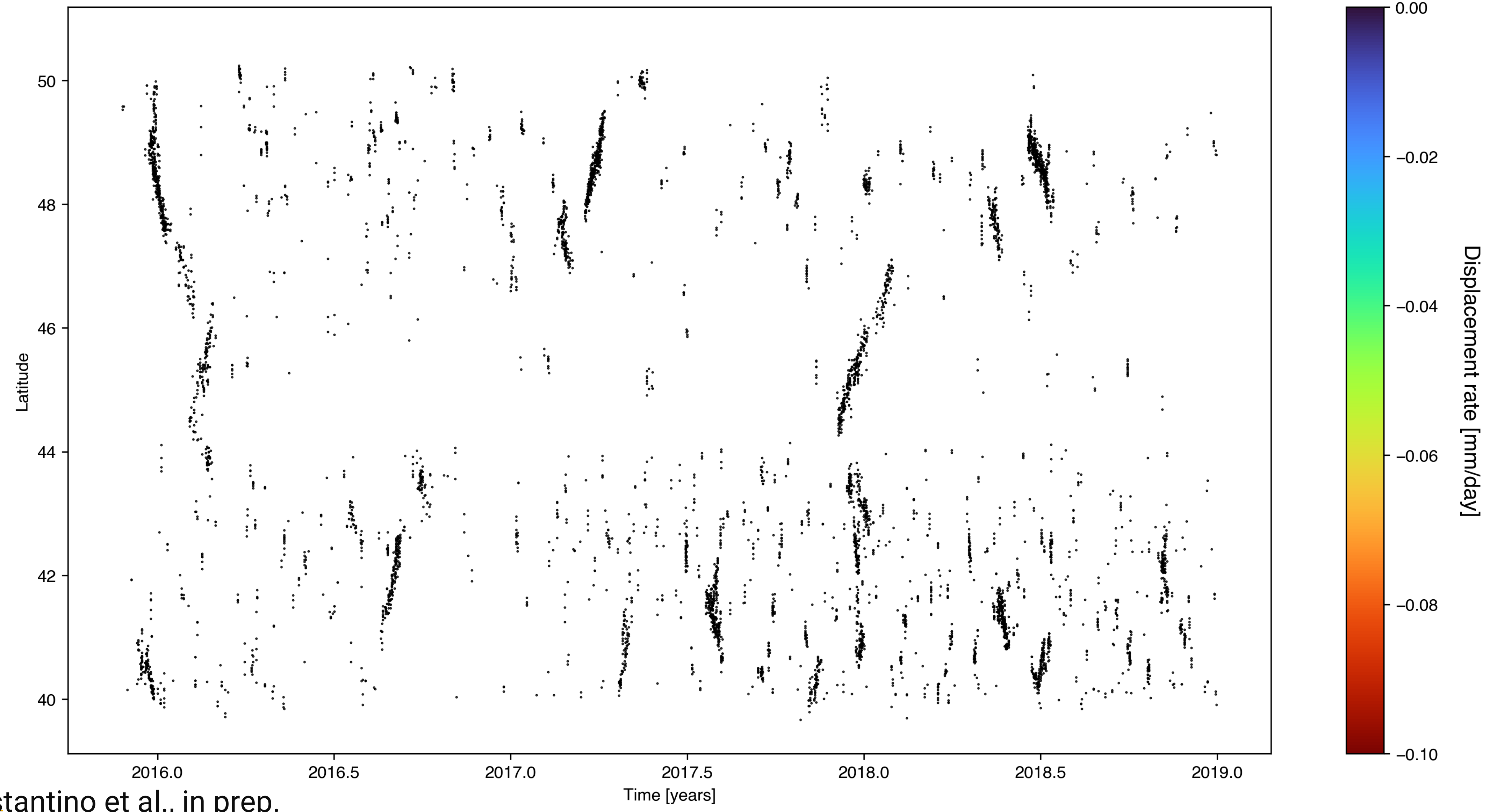






Costantino et al., in prep.

Validation against tremors in Cascadia



Costantino et al., in prep.

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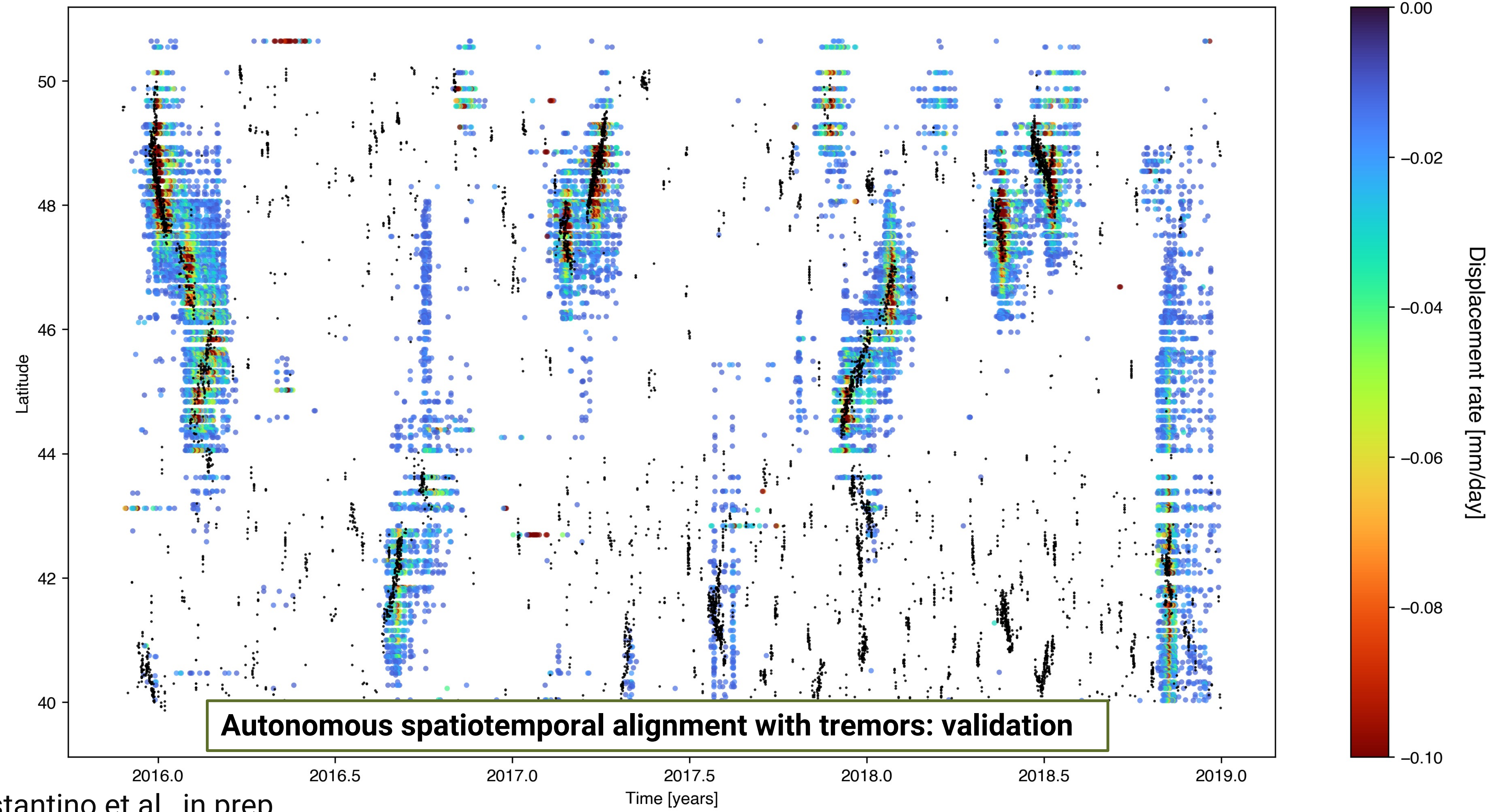
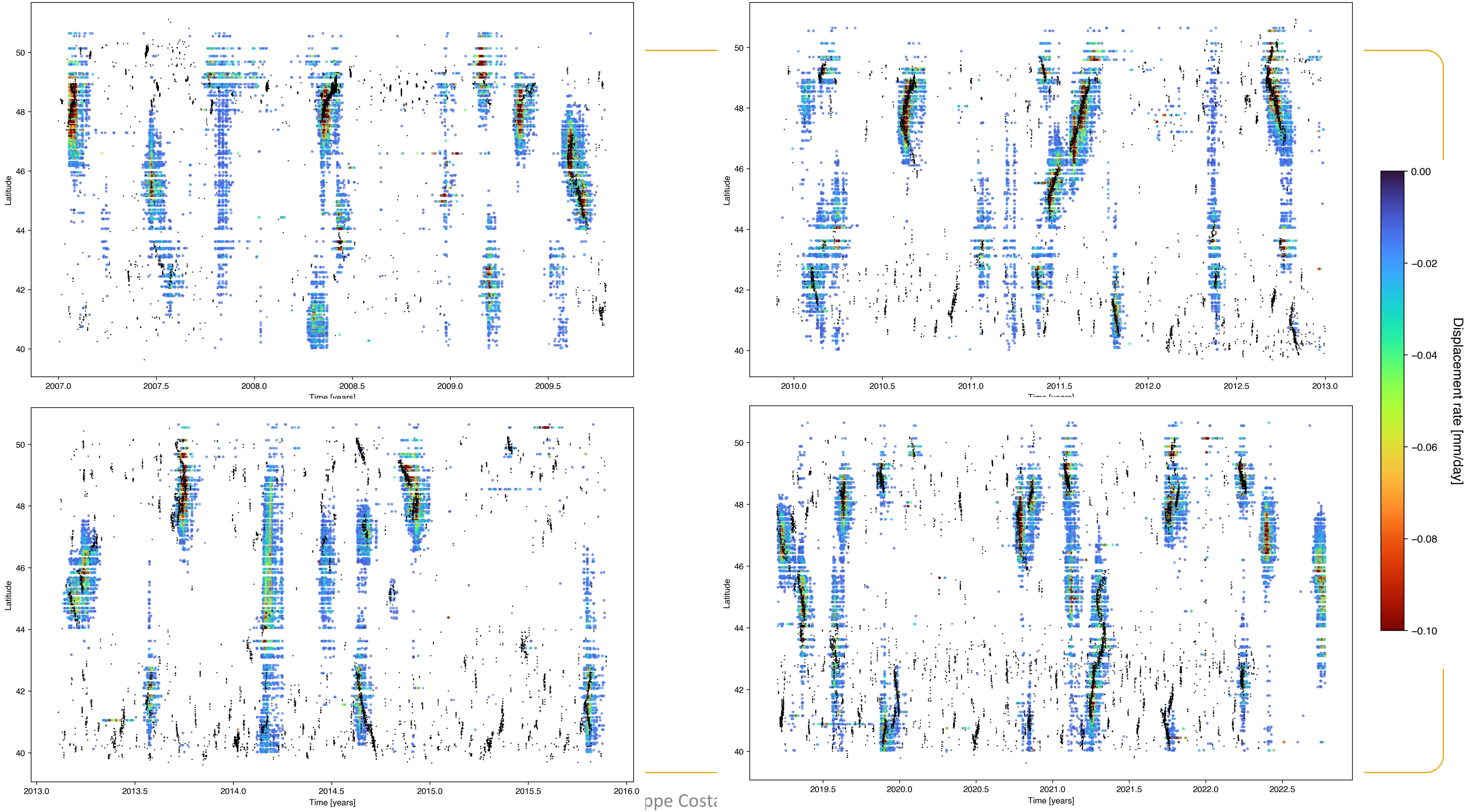


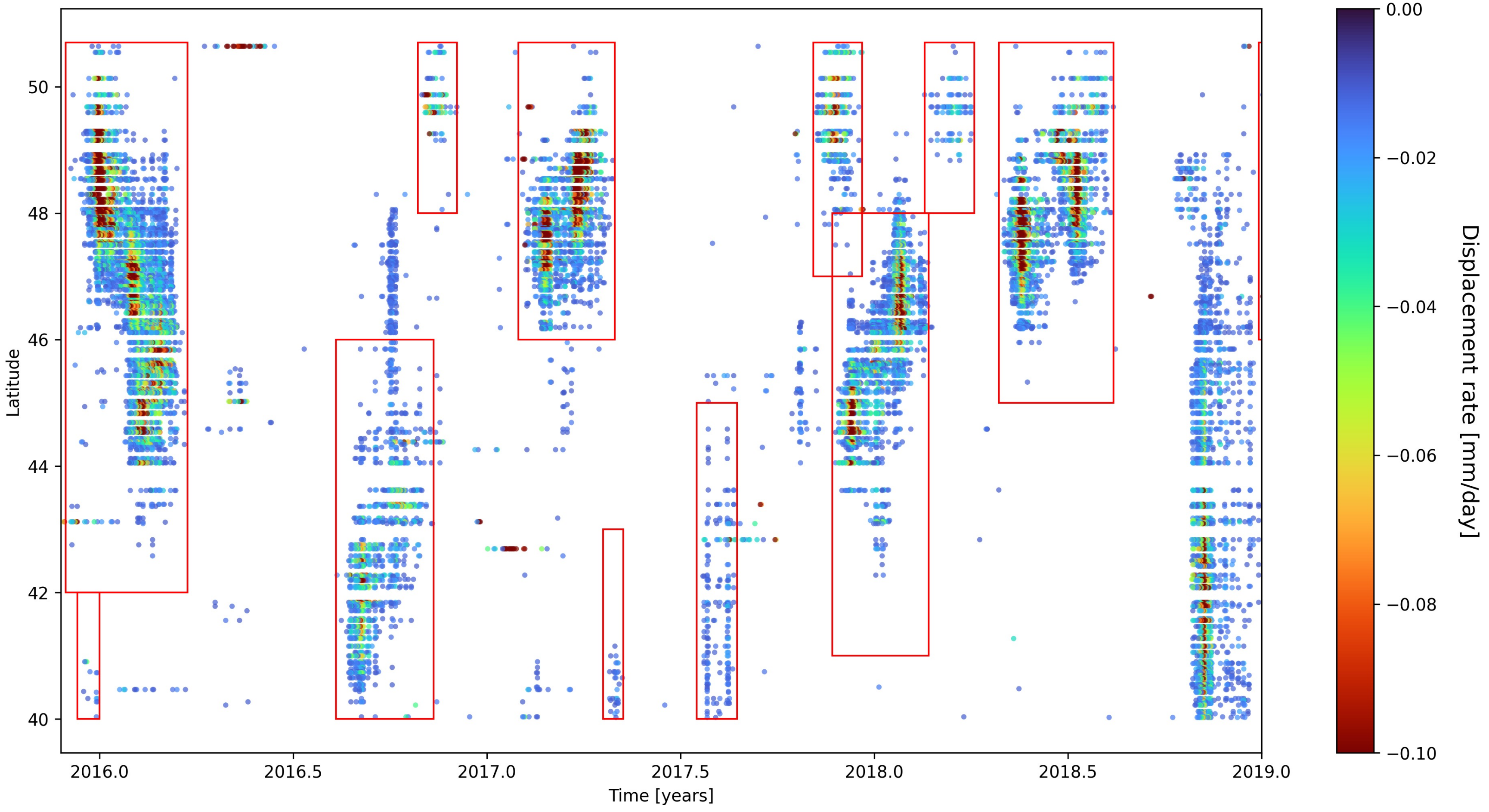
Costantino et al., in prep.

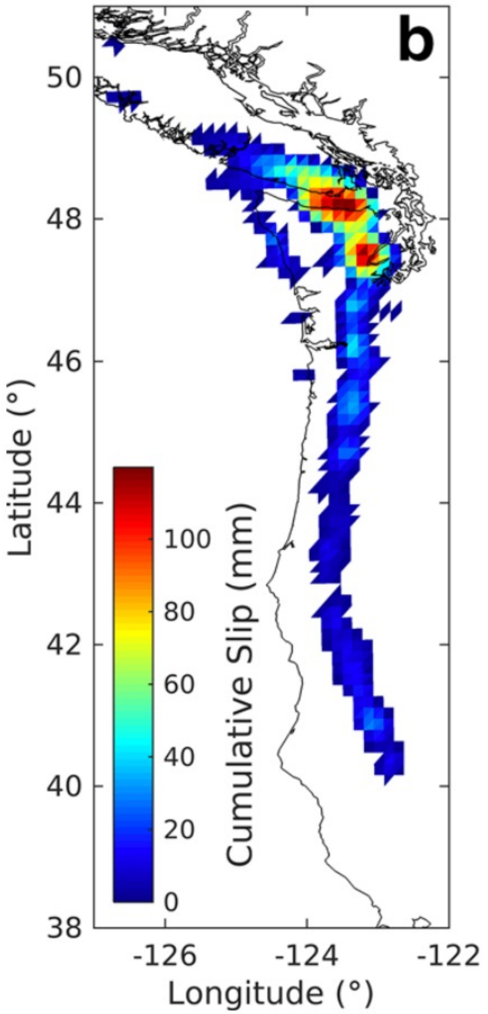


Latitude
Time [years]
2007.0
2007.5
2008.0
2008.5
2009.0
2009.5
2010.0
2010.5
2011.0
2011.5
2012.0
2012.5
2013.0
2013.5
2014.0
2014.5
2015.0
2015.5
2016.0
2019.5
2020.0
2020.5
2021.0
2021.5
2022.0
2022.5
40
42
44
46
48
50
Displacement rate [mm/day]
0.00
−0.02
−0.04
−0.06
−0.08
−0.10

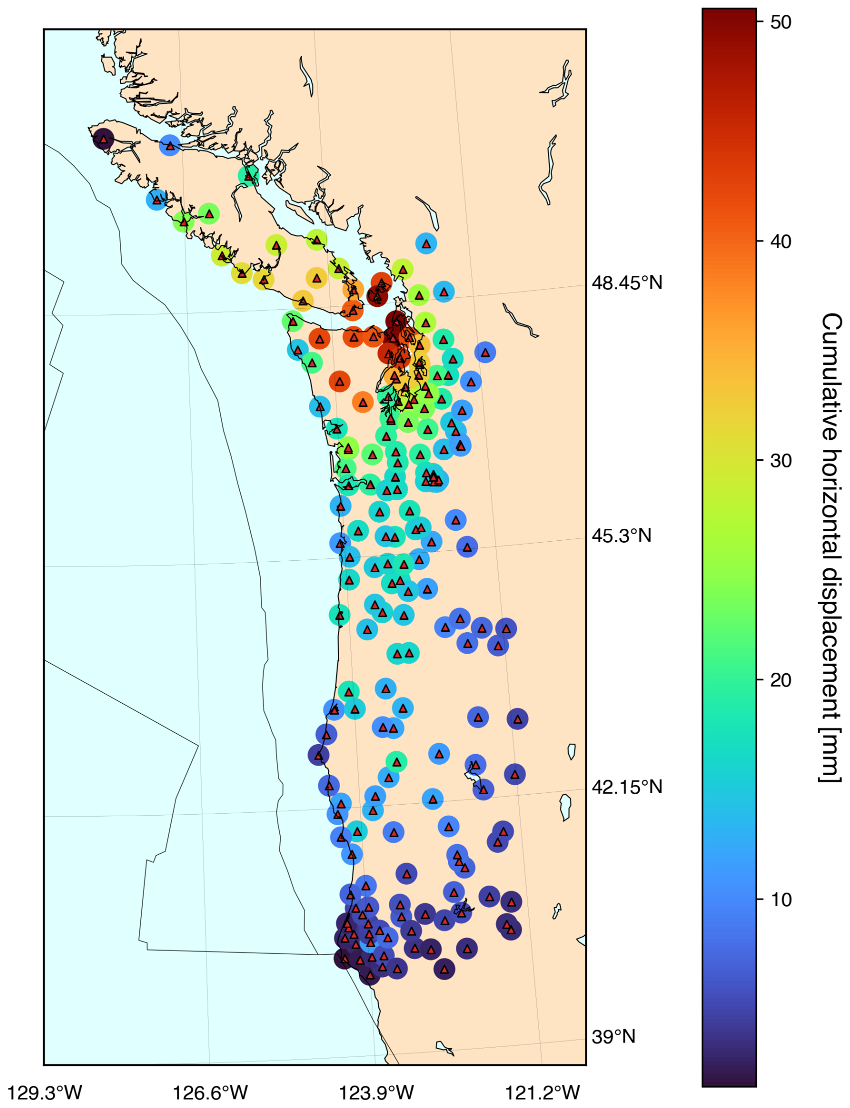
ppe Costa

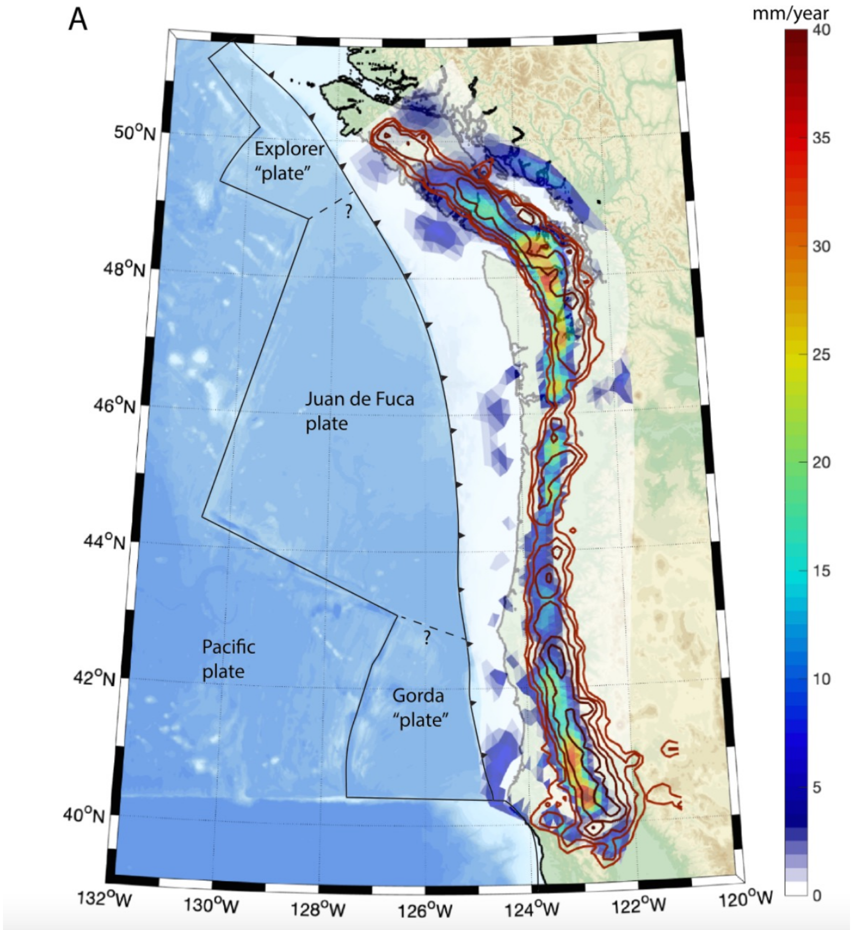
Detection and characterization on denoised time series



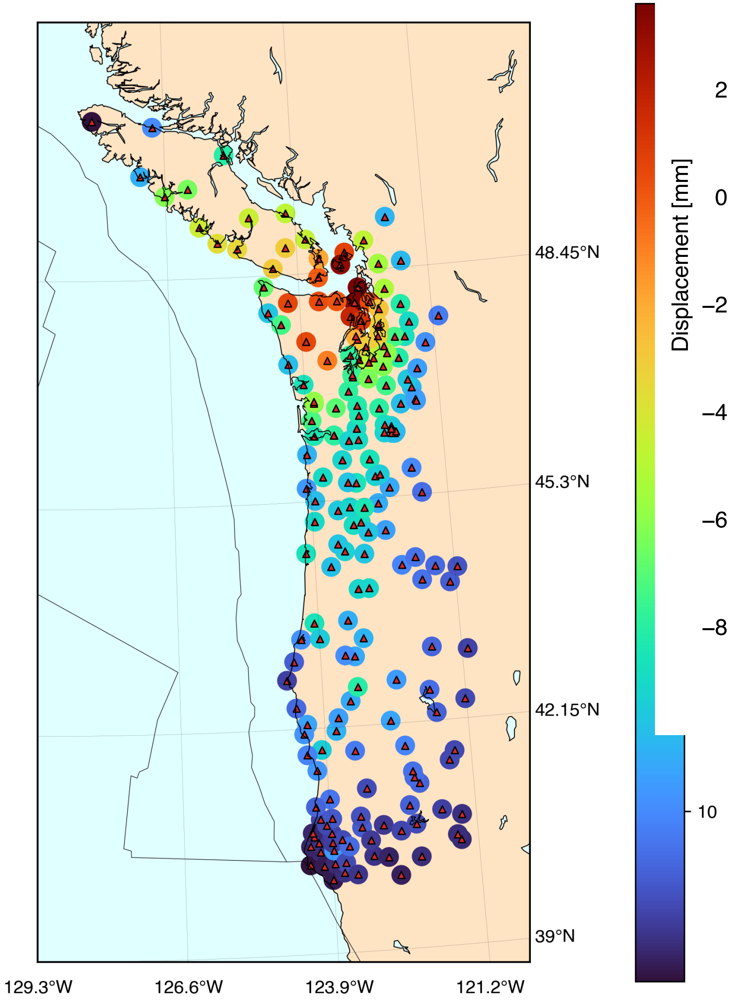


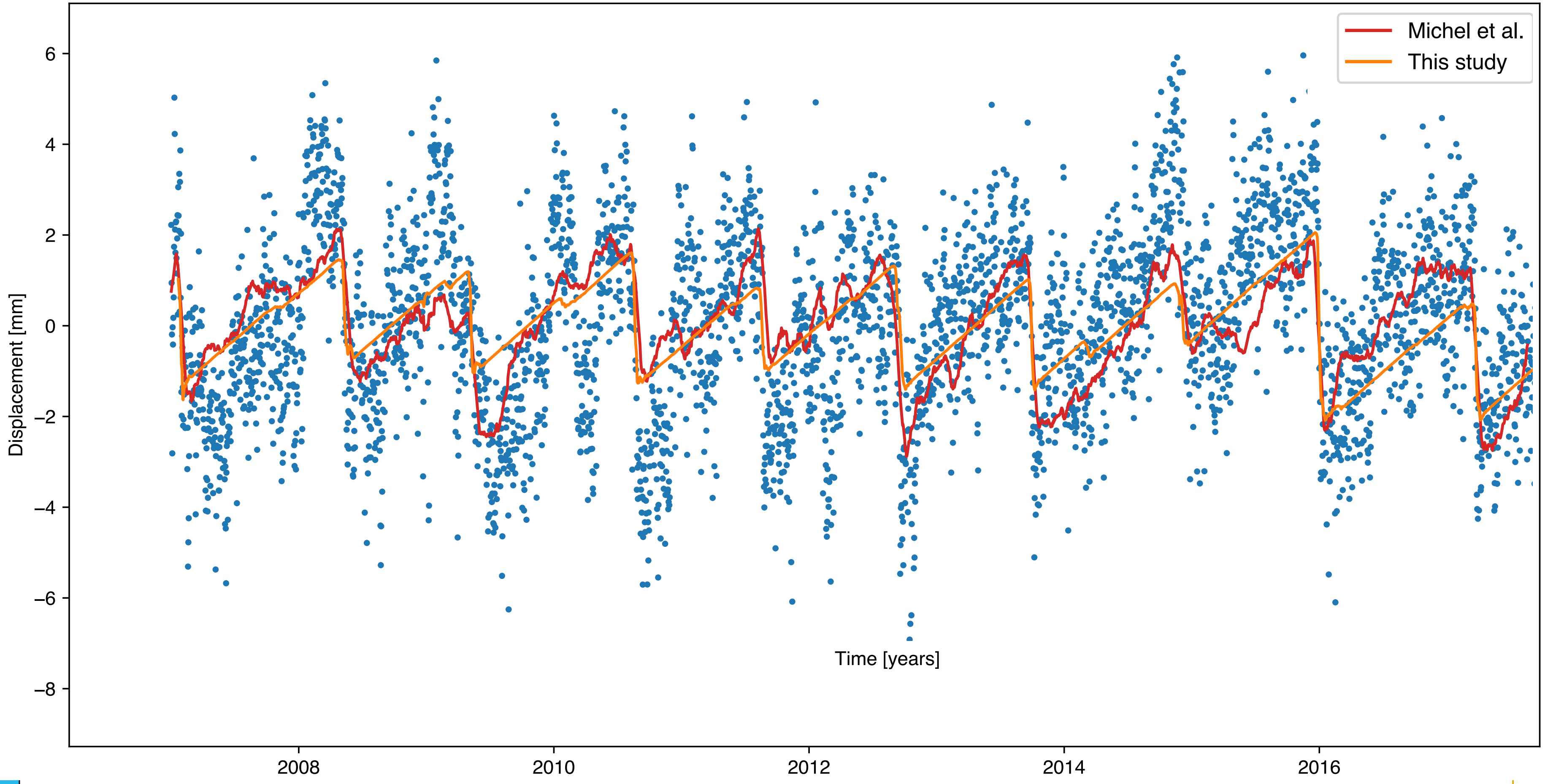
Michel et al., 2019

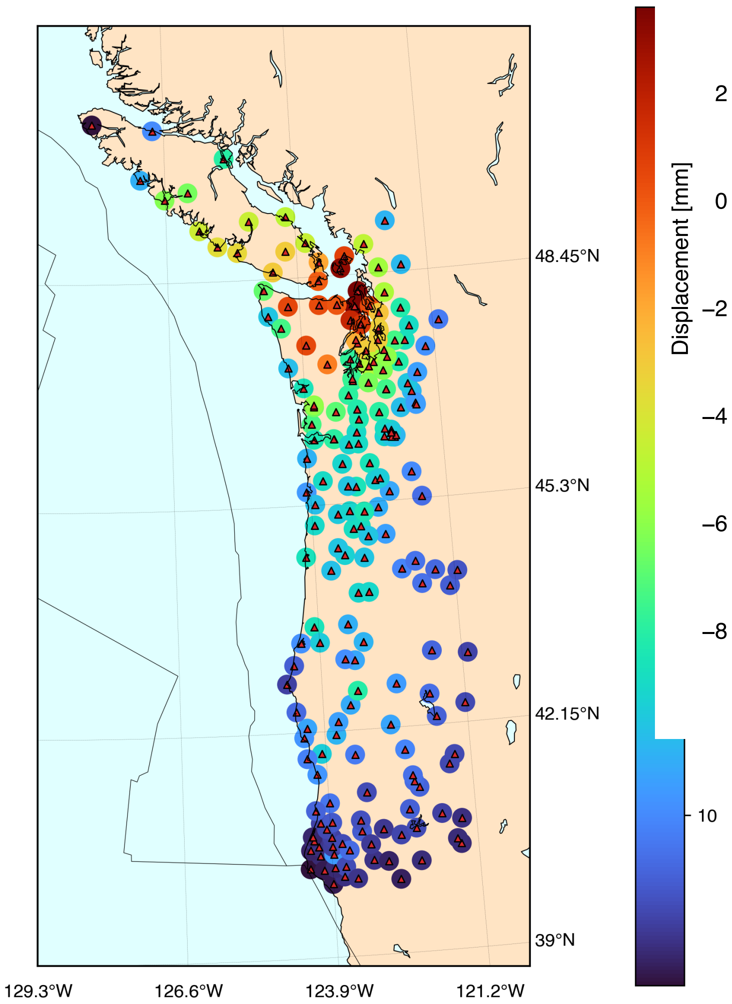


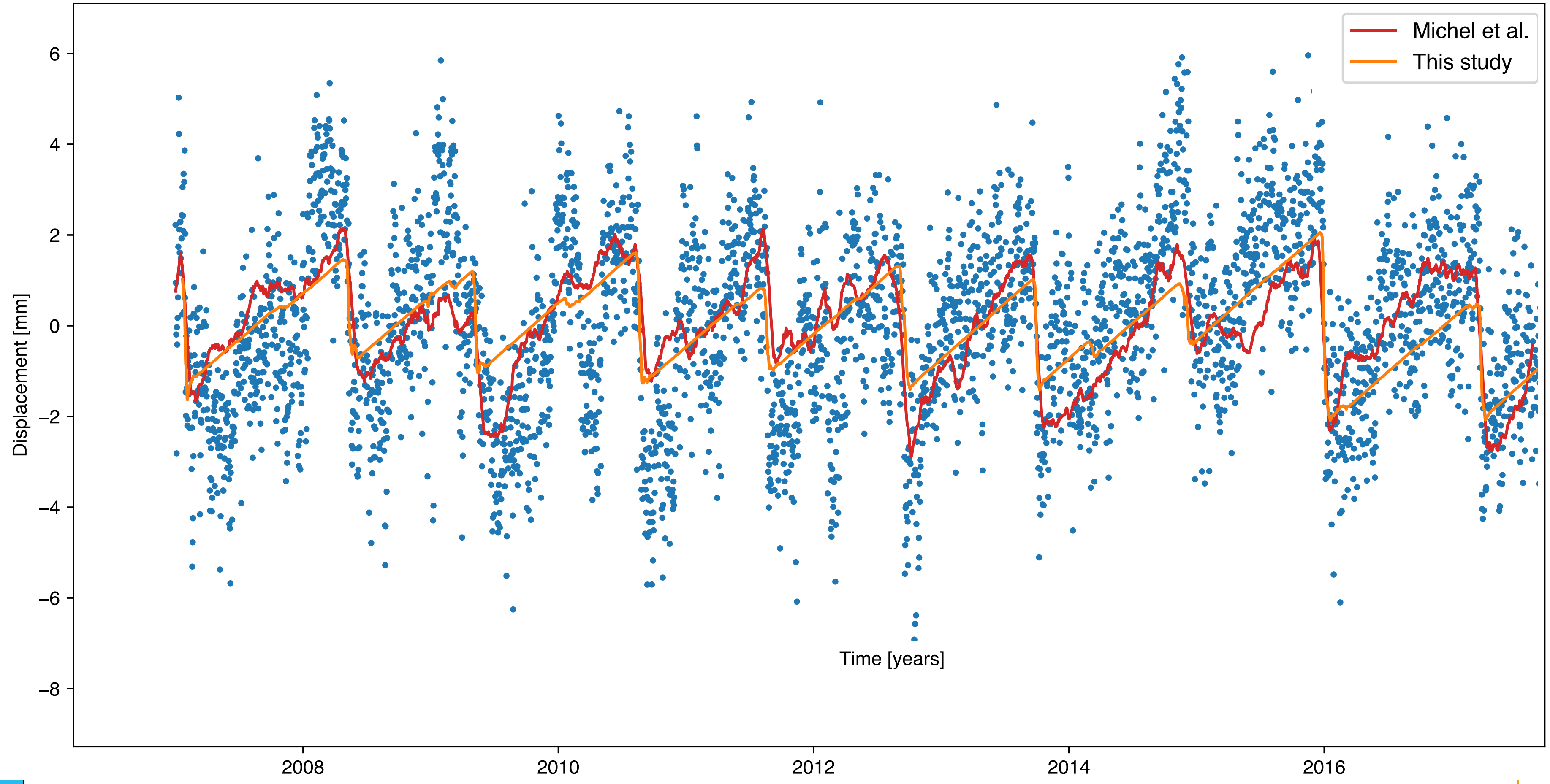


Bartlow, 2020


48.45°N
45.3°N
42.15°N
39°N
129.3°W
126.6°W
123.9°W
121.2°W
Displacement [mm]
10


Michel et al.
This study
Time [years]
6
4
2
0
−2
−4
−6
−8
2008
2010
2012
2014
2016





Merci pour votre attention !