An Automated Complete Catalog of Cascadian Slow Slip

Brendan Crowell, University of Washington

Motivations

- Characterizing interseismic deformation in subduction environments is critical for classifying hazard due to megathrust slip
- GNSS time series contain a combination of long-term tectonic deformation, seasonal modulations, coseismic and postseismic deformation from earthquakes, and transient motions due to other sources (volcanoes, slow slip events, groundwater, etc.)

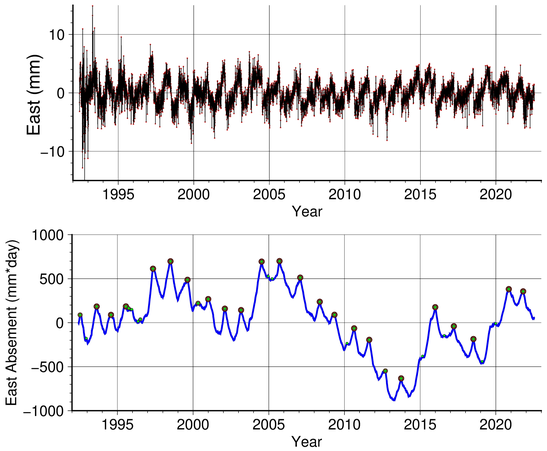
Primary Questions

- Can we classify transient motions on a single-station basis in an automated manner?
- Can we classify the level of transient behavior for these events?
- What insights can we obtain from systematically categorizing transient deformation?
- By looking in Cascadia, what role do smaller and smaller transient events play in the long-term tectonic behavior of subduction zones?

Method - Detections

The integral of displacement is absement (units of mm*day here), which is a measure of sustained displacement of an object from its initial position

Computing the absement of detrended GNSS time series produces a very clean time series with strong peaks which coincide with reversals in the motion



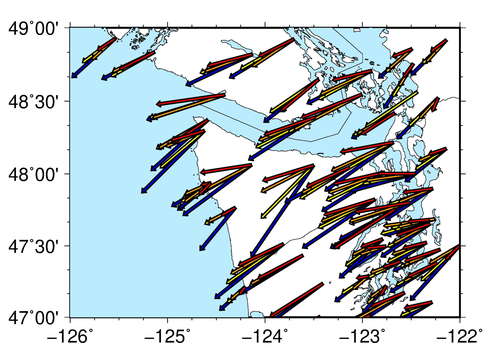
Example displacement (top) and absement (bottom) time series for ALBH. The prominence detections are shown for the 4 levels based on the size of the circles.

The prominence of these peaks gives the level of transient behavior. Here, I use 4 levels of prominence: 100, 50, 25, and 10 mm*day

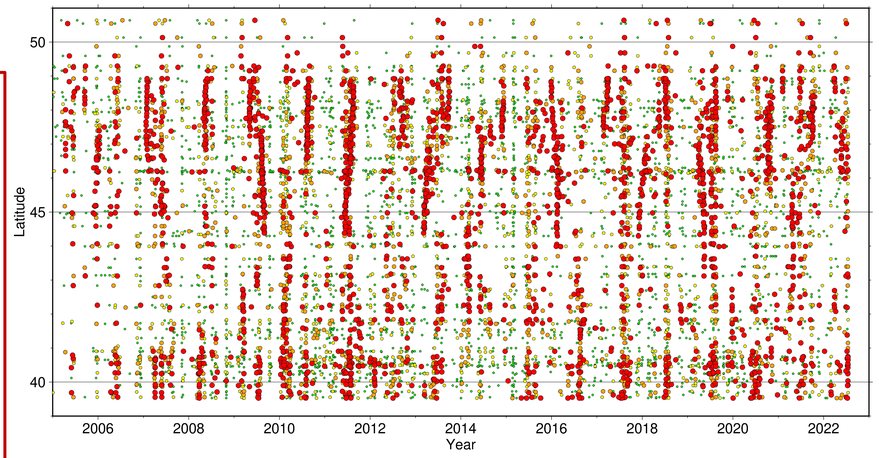
Method – Transient Velocity Field

From the detections, I stack the previous 20 days and the following 20 days and perform a weighted average of these time windows.

This gives the average displacement per transient episode, which is converted to velocity by knowing the number of detections and the total length of the time series

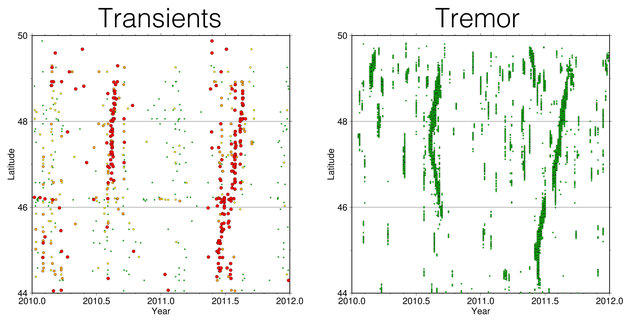


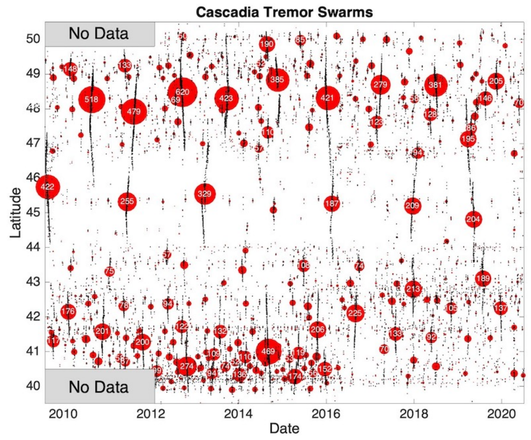
Transient velocity field for the 4 detection levels. For the smaller prominence levels, the velocities are larger and start to rotate towards the south

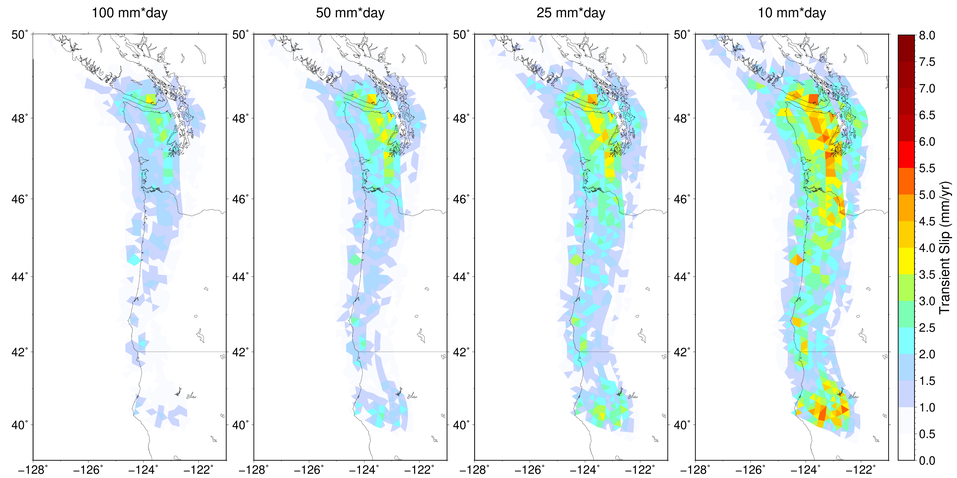


Transient Catalog

- Transient detections correlate well with the PNSN tremor catalog
- The automated transient detections show similar propagation speeds and extent to the tremor catalog
- The smaller transient detections fill in the inter-ETS time periods

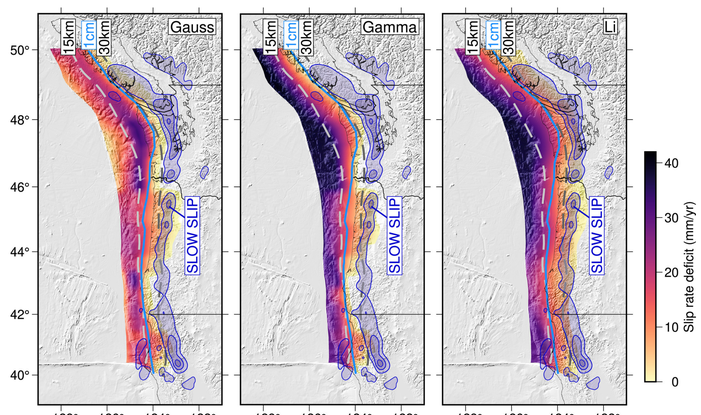






Transient Velocity Fields

- For smaller transient levels, we obtain more and more slip (figures to the left)
- A larger fraction of slip is occurring up-dip of the major ETS zone near the eastern Olympics as we go to smaller transient levels.
- The entire margin of Cascadia is accommodating some level of transient slip, implying that more interseismic strain is being released in slow earthquakes.



The locking models, while different, tend to show that the highly locked zones and the slow slip zones are slightly different. The models above for lower transient levels shows that the slow slip zone is encroaching in the up-dip direction, well into the locked zone. Figure from Melgar et al. (2022), models from Schmalzle et al. (2014) and Li et al. (2018)

Conclusions

- Absement-based detections can operate on a single-station basis, can give the absolute level of transient-ness, and is computationally light
- Applying this to all stations in Cascadia, we revealed a rich catalog of transient events that qualitatively matches the tremor catalog
- Inverting for slip along the megathrust from the different transient levels reveals that smaller transients add more slip in the up-dip direction and possibly add additional rotation that mimics the general block kinematics in the region
- A more complete catalog of smaller slow slip events has implications for locking models, adding an additional constraint to potential megathrust slip in the future