Distinguishing Spatial Variations in California Earthquake Dynamics Using a High- to Low-Frequency Spectral Ratio

Ian Vandevert, Peter Shearer, and Wenyuan Fan

Scripps Institution of Oceanography, UC San Diego (ivandevert@ucsd.edu, pshearer@ucsd.edu, wenyuanfan@ucsd.edu)

Why do earthquakes differ from each other?

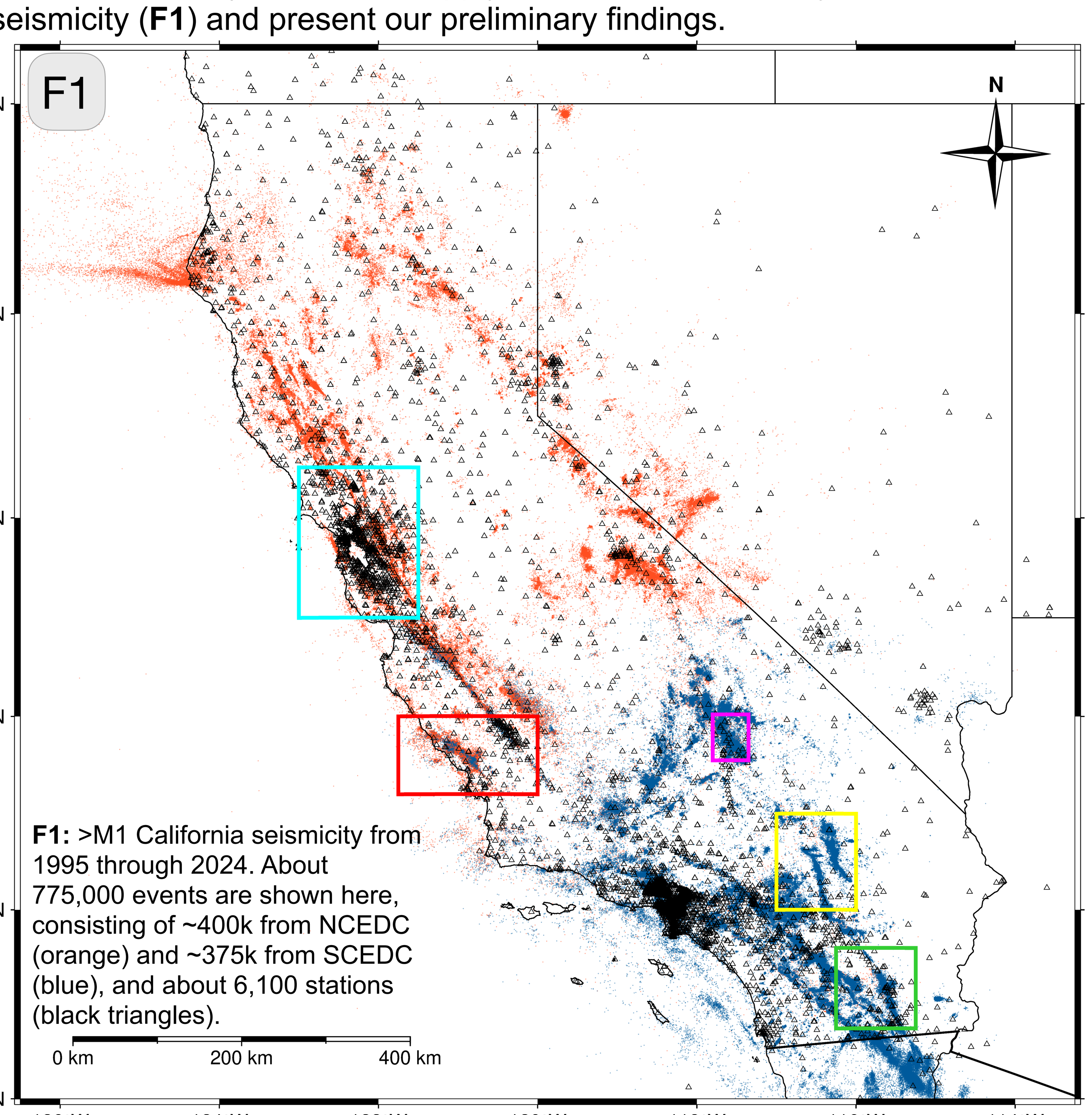
Earthquakes of similar magnitude can cause different amounts of shaking. These differences reflect varying earthquake source characteristics, which is **critical for studying hazard**. Stress drop ($\Delta\sigma$) is related to the amount of damaging high-frequency radiation, but their **estimates often have large uncertainties** (see Baltay et al., 2024).

For earthquakes of similar size, **variation in ground motion is due to the relative amount of high-frequency energy compared to low-frequency**. We define a parameter $\log\beta$ to quantify this:

$$\log\beta = \log A_{HF} - \log A_{LF}$$

where A_{HF} is the high-frequency spectral amplitude and A_{LF} is the low-frequency spectral amplitude (**F2**). We correct for station, path, and magnitude effects to obtain $\Delta\log\beta^*$, which **correlates strongly with $\Delta\sigma$.**

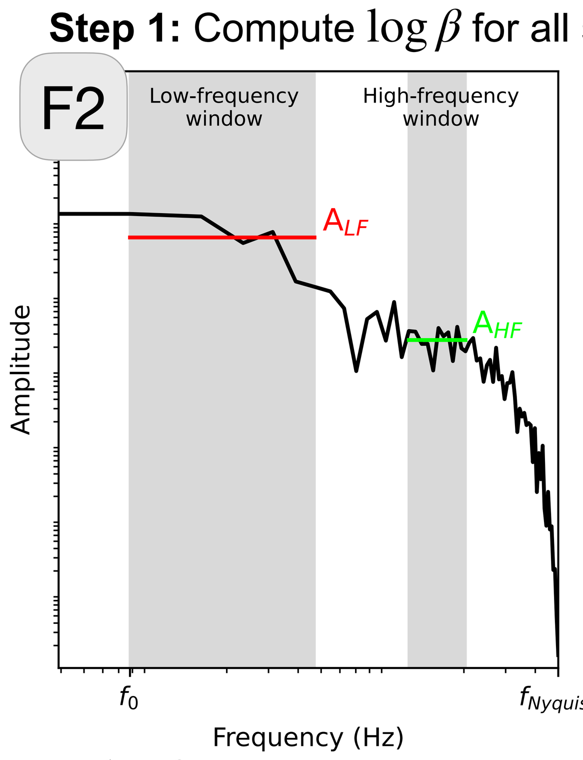
We have submitted our results applying this method to P- and S-wave spectra from the 2019 Ridgecrest earthquake sequence (Vandevert et al., 2025, *submitted*). Here, we apply this method to 30 years of California seismicity (**F1**) and present our preliminary findings.



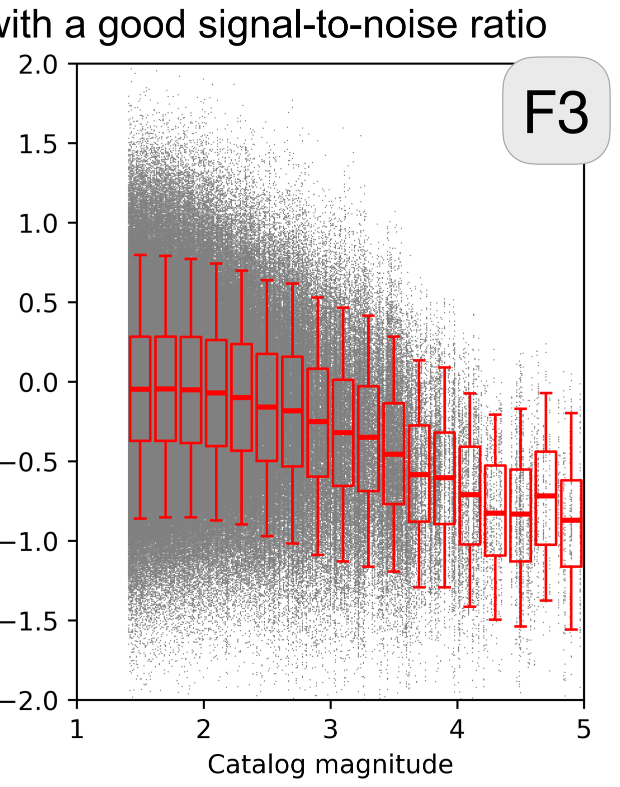
F1: >M1 California seismicity from 1995 through 2024. About 775,000 events are shown here, consisting of ~400k from NCEDC (orange) and ~375k from SCEDC (blue), and about 6,100 stations (black triangles).

How does it work?

Step 1: Compute $\log\beta$ for all seismograms with a good signal-to-noise ratio



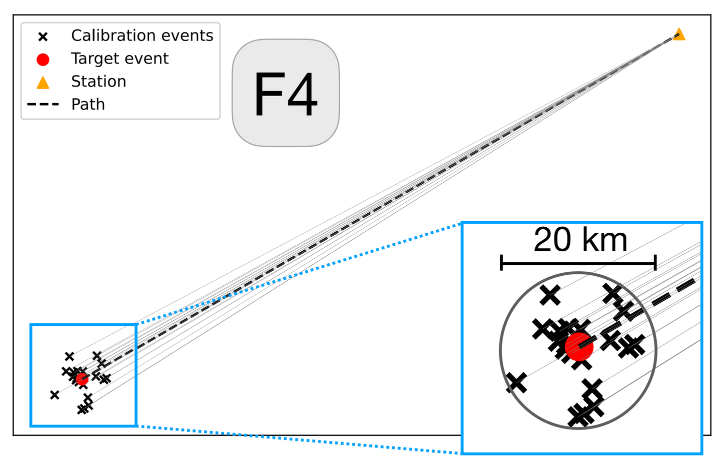
F2: $\log\beta$ computation. Low- and high-frequency amplitude levels (A_{LF} and A_{HF}) are computed as the median of their band. Bands of about 1-5 Hz and 12-20 Hz produce good correlation with previously estimated stress drop.



F3: $\log\beta$ vs magnitude for a subset of the data

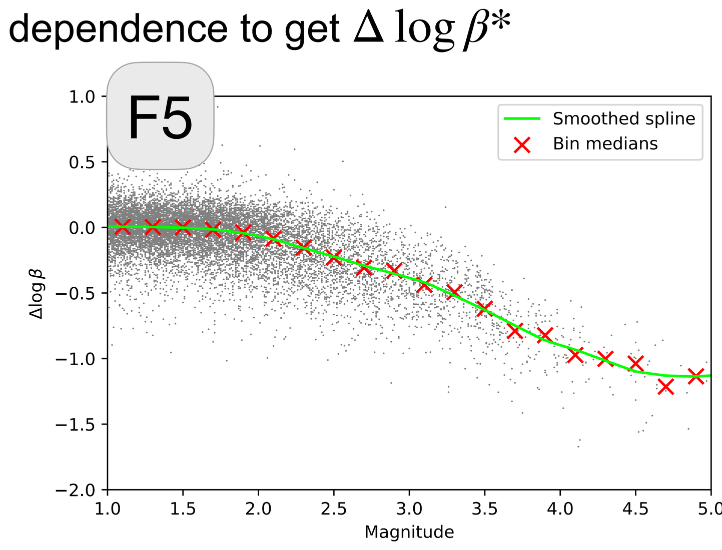
How does it work? (continued)

Step 2: Correct for station and path effects to obtain $\Delta\log\beta$



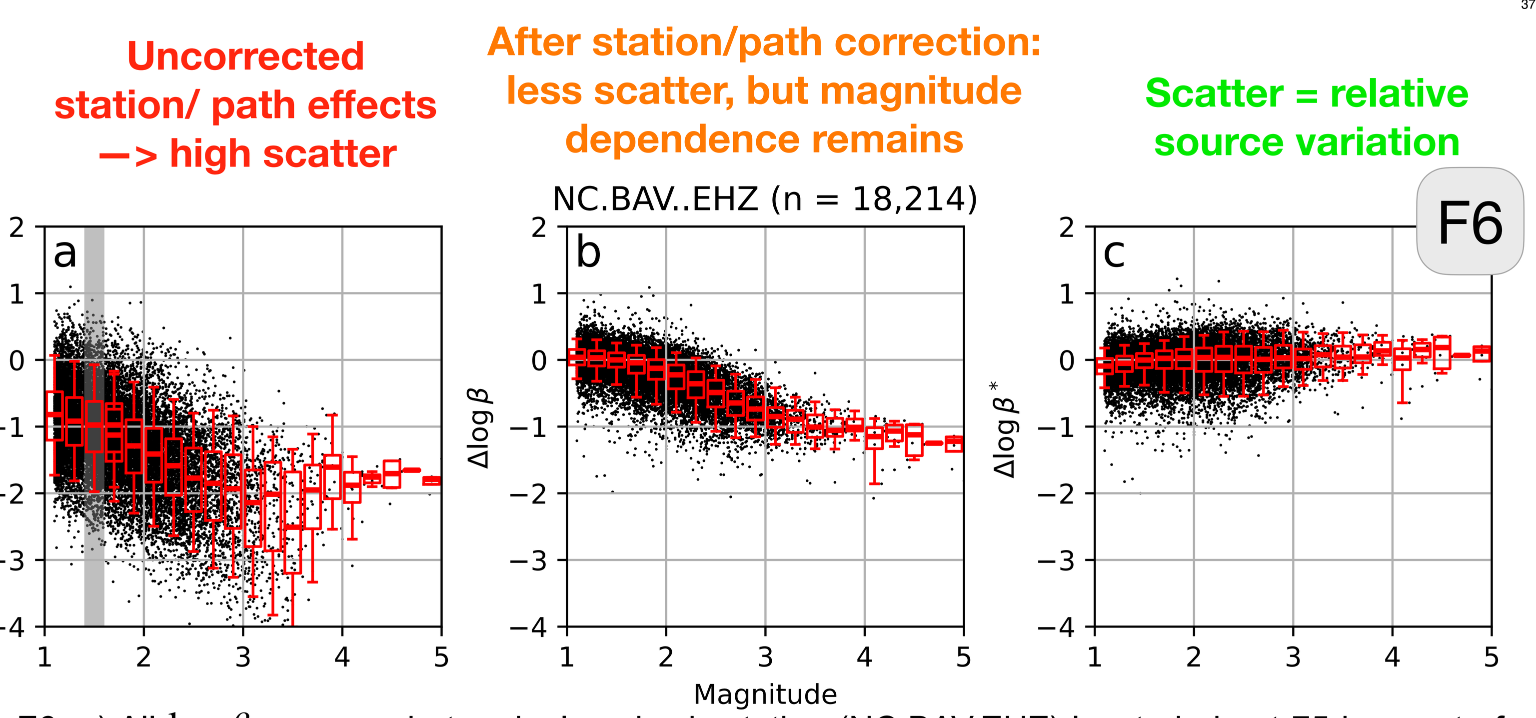
F4: Station and path corrections using small, nearby calibration events. This is analogous to the spectral decomposition method in Shearer et al. (2022), where f_c of calibration events are fixed

Step 3: Correct for magnitude dependence to get $\Delta\log\beta^*$



F5: Magnitude correction of $\Delta\log\beta$. A spline is fit to the bin medians, smoothed, and then subtracted from $\Delta\log\beta$ to get magnitude-corrected $\Delta\log\beta^*$

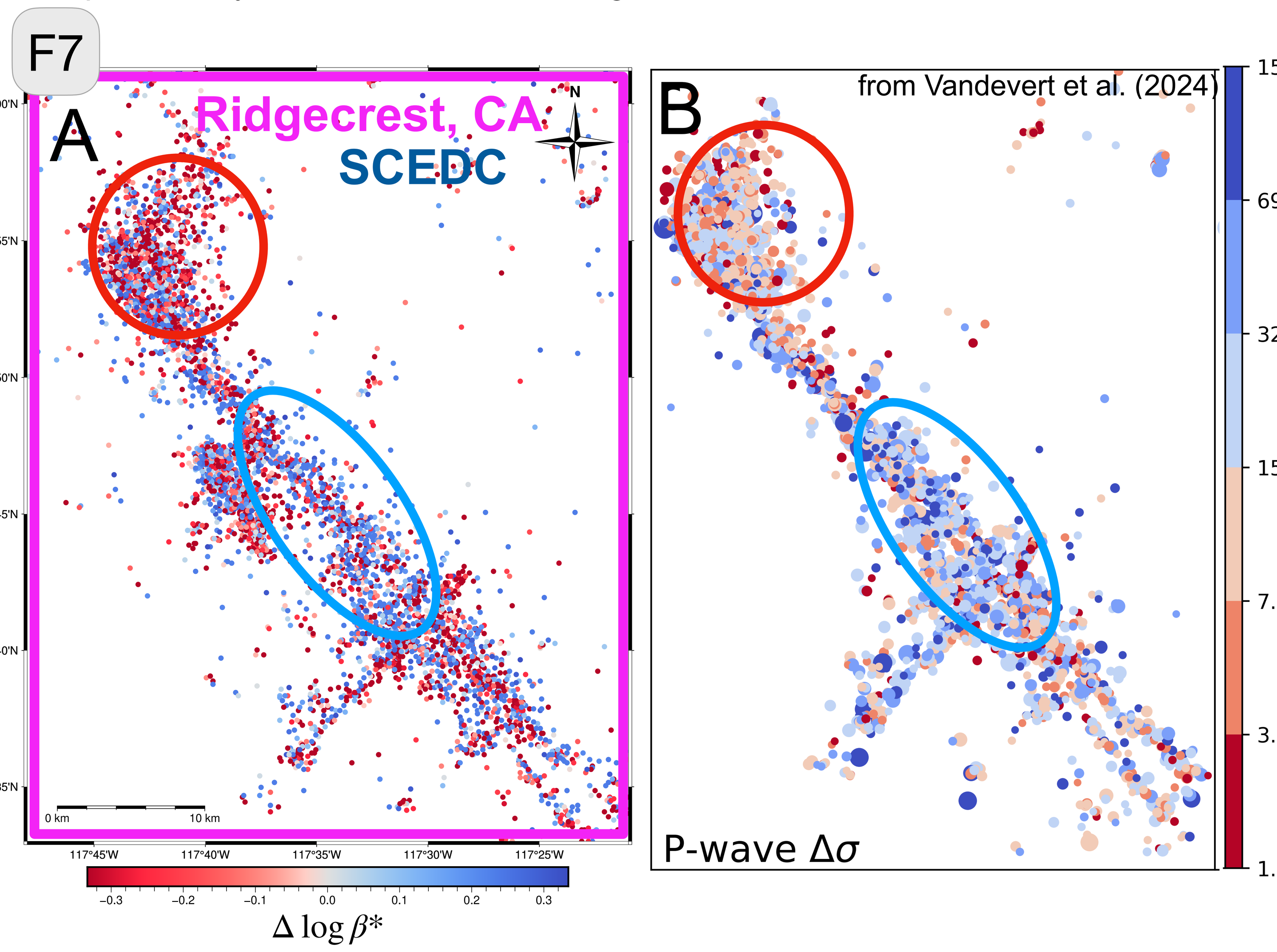
Example corrections (single station):



F6: a) All $\log\beta$ measured at a single seismic station (NC.BAV.EHZ) located about 75 km east of Monterey Bay; b) Station- and path-corrected $\Delta\log\beta$ for this station; c) Magnitude-corrected $\Delta\log\beta^*$ for the same earthquakes. Note the larger scatter in the M2-3.5 earthquakes.

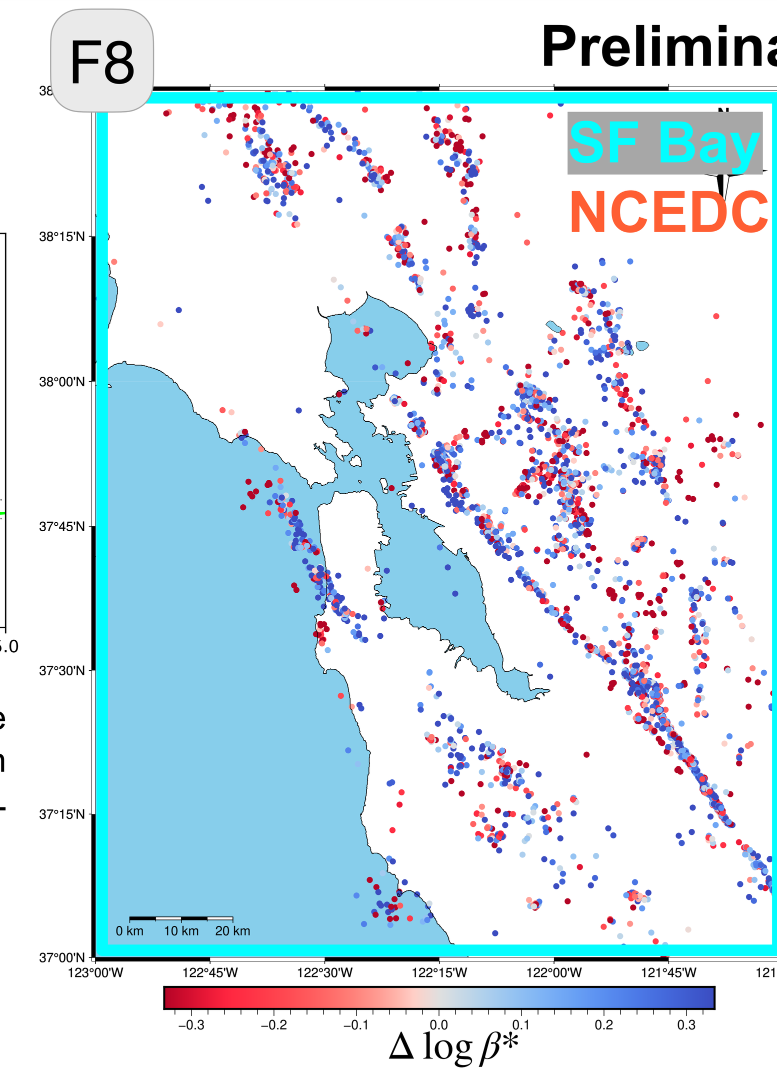
Preliminary Results

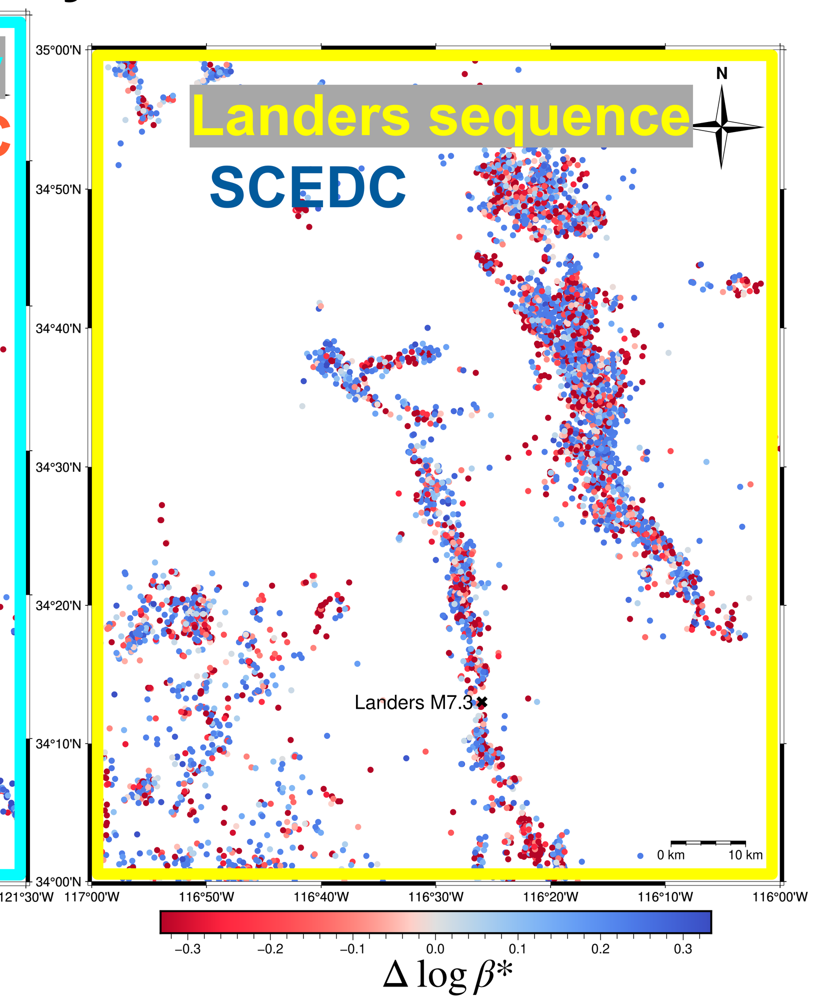
We apply the above method to the entire NCEDC dataset for 1995-2024 and the SCEDC dataset for 1995-September 2019. We find spatial patterns consistent with the findings of Vandevert et al. (2024) near Ridgecrest, CA. We also present our preliminary results for the boxed regions in **F1**.

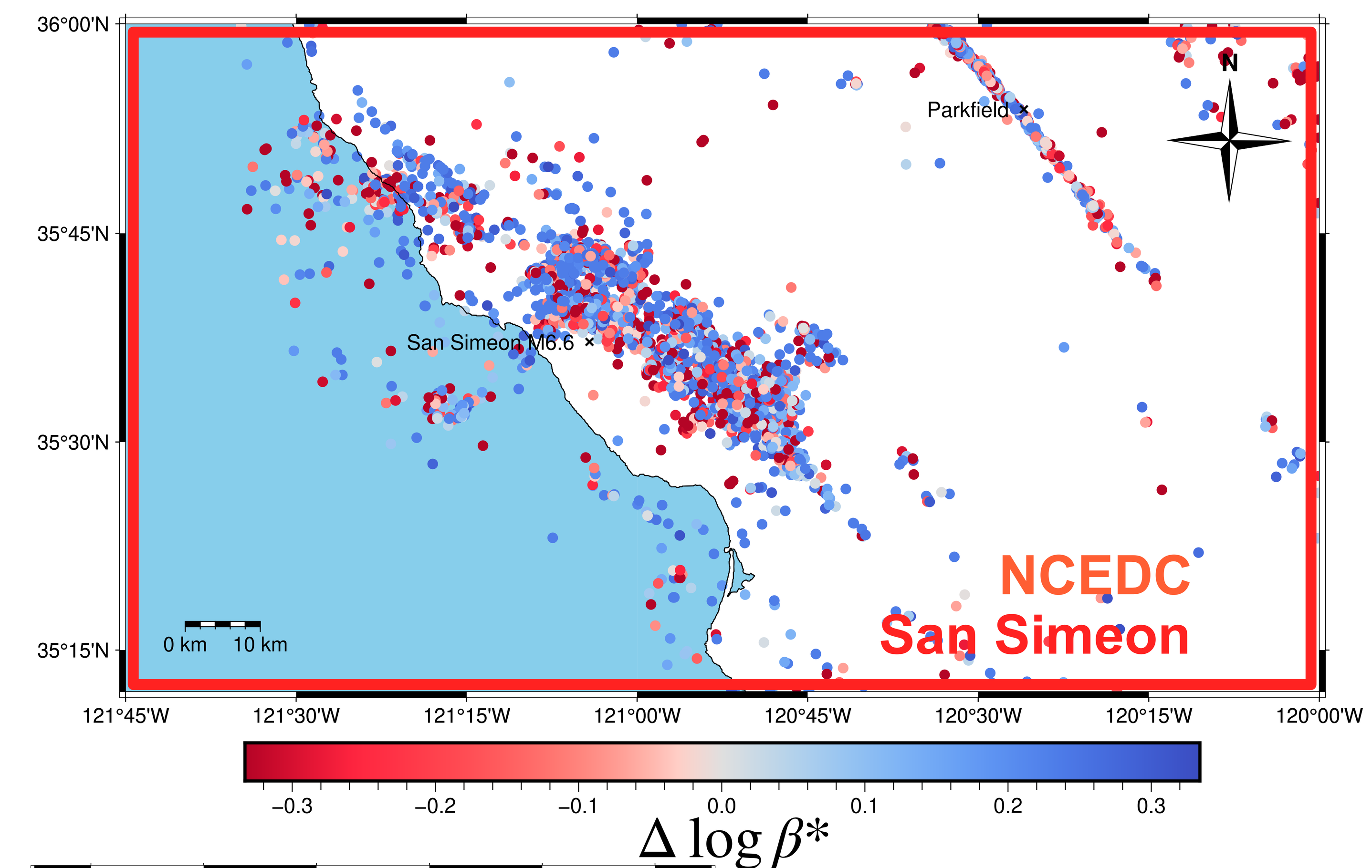


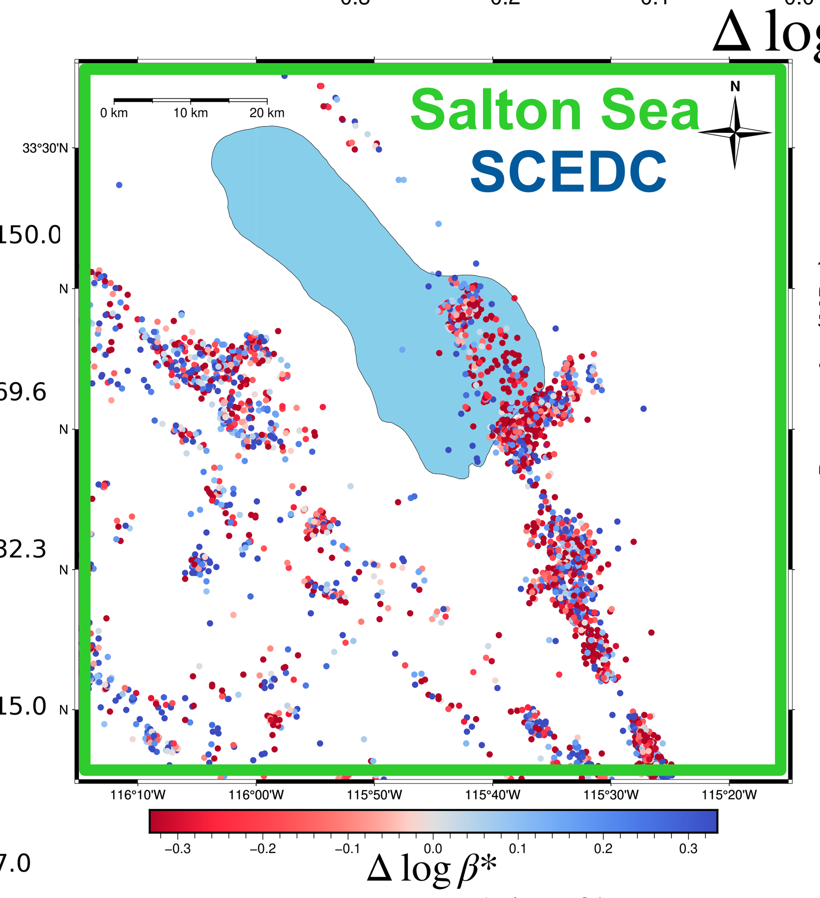
F7: A) Spatial distribution of $\Delta\log\beta^*$ for P-waves in the SCEDC dataset. B) Spatial distribution of stress drop from Vandevert et al. (2024).

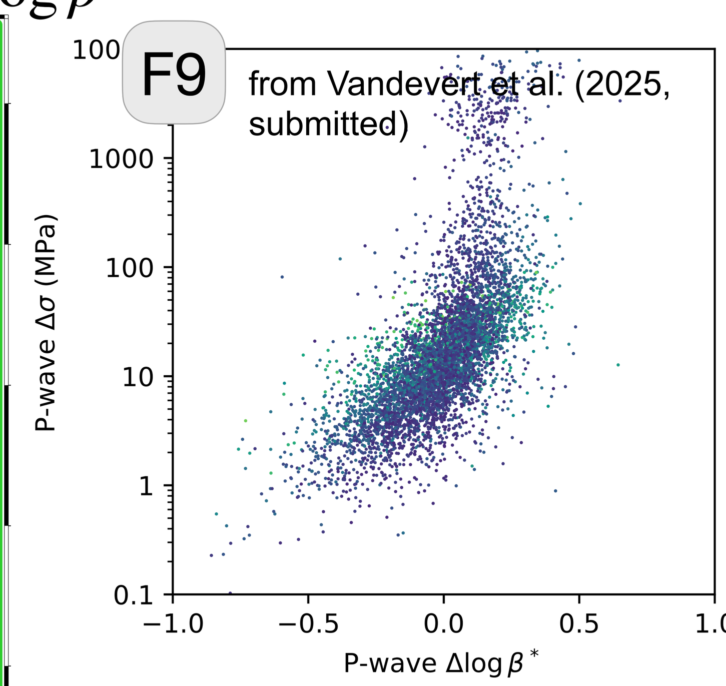
Preliminary Results











$\Delta\log\beta^*$ correlates with $\Delta\sigma$

F8: Spatial distribution of $\Delta\log\beta^*$ for select California regions. See inset for data source. Frame color corresponds to box color in **F1**.

F9: Correlation of $\Delta\log\beta^*$ with $\Delta\sigma$ in Ridgecrest from Vandevert et al. (2025, submitted)

Takeaways

- We compute **P-wave $\Delta\log\beta^*$ for the NCEDC and SCEDC datasets.**
- We find results that are consistent with our previous smaller-scale study in the Ridgecrest area.
- We find **coherent spatial variation** in $\Delta\log\beta^*$ in many regions, which seems to be consistent with previous stress drop studies

Acknowledgements

Funding for this research was provided by USGS and SCEC. Data was downloaded from SCEDC and NCEDC services.

References

Baltay, A., Abercrombie, R., Chu, S., Taira, T., The SCEC/USGS community stress drop validation study using the 2019 Ridgecrest earthquake sequence. *Seismica*, 2024

Shearer, P. M., R. E. Abercrombie, and D. T. Trugman, Improved stress drop estimates for M 1.5 to 4 earthquakes in Southern California from 1996 to 2019, *J. Geophys. Res.*, 2022.

Vandevert, I., P.M. Shearer, and W. Fan, Using a High- to Low-Frequency Spectral Ratio to Distinguish Variations in Earthquake Source Properties, *submitted*, 2025