Rupture directivity from energy envelope deconvolution: Application on 70 Ridgecrest M 3.5-5.5 earthquakes

Zhe Jia, Peter Shearer, Wenyuan Fan

Multi-fault rupture challenges hazard assessment

2012 Sumatra M 8.6/8.2

2016 Kaikoura M 7.8

2018 Alaska M 7.9

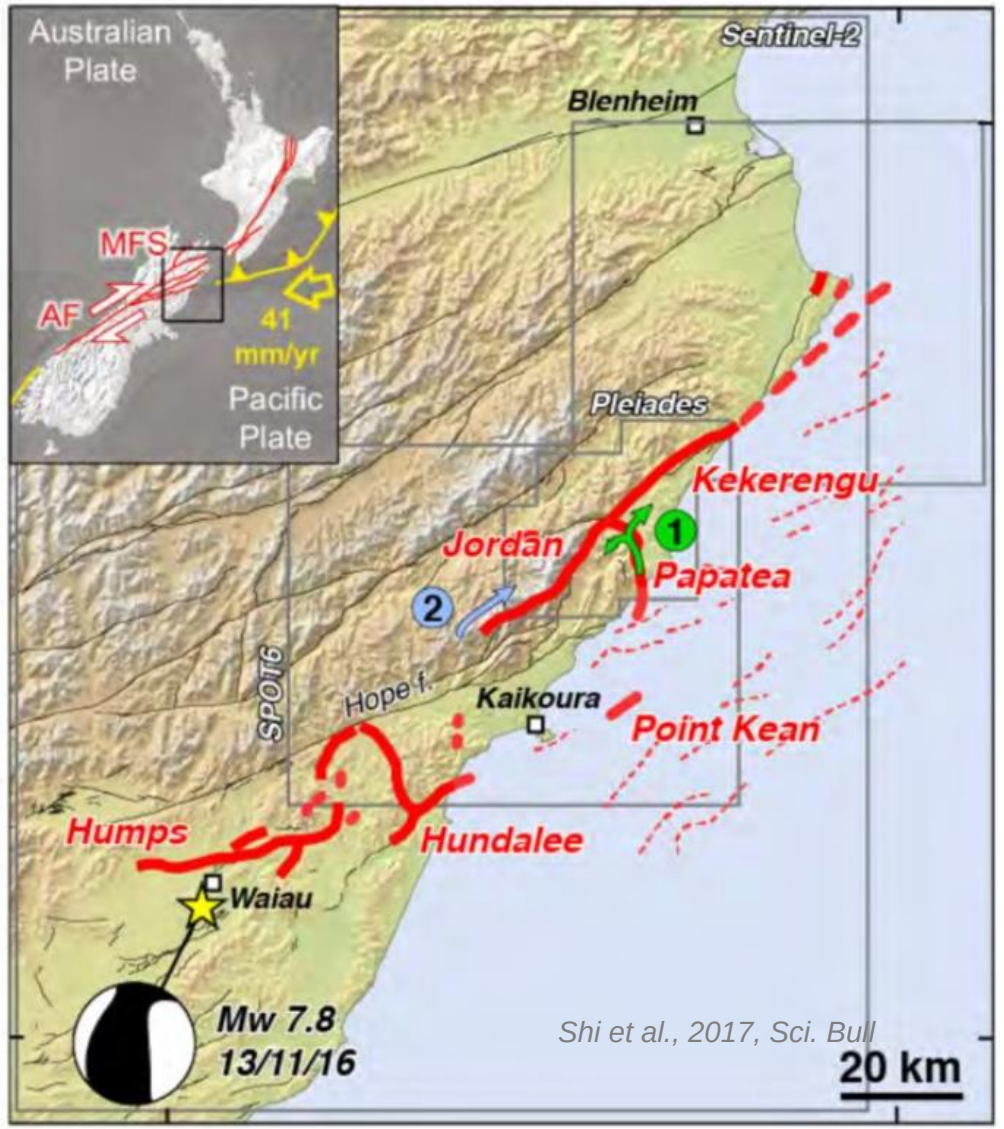
2019 Ridgecrest M 6.4/7.1

2020-2021 Alaska M 8 Sequence

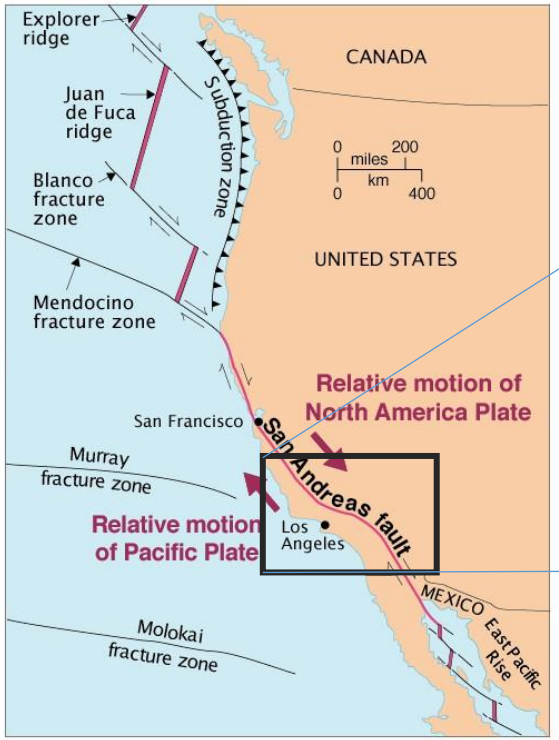
2023 Turkey M 7.8/7.7

…

>=20 fault segments

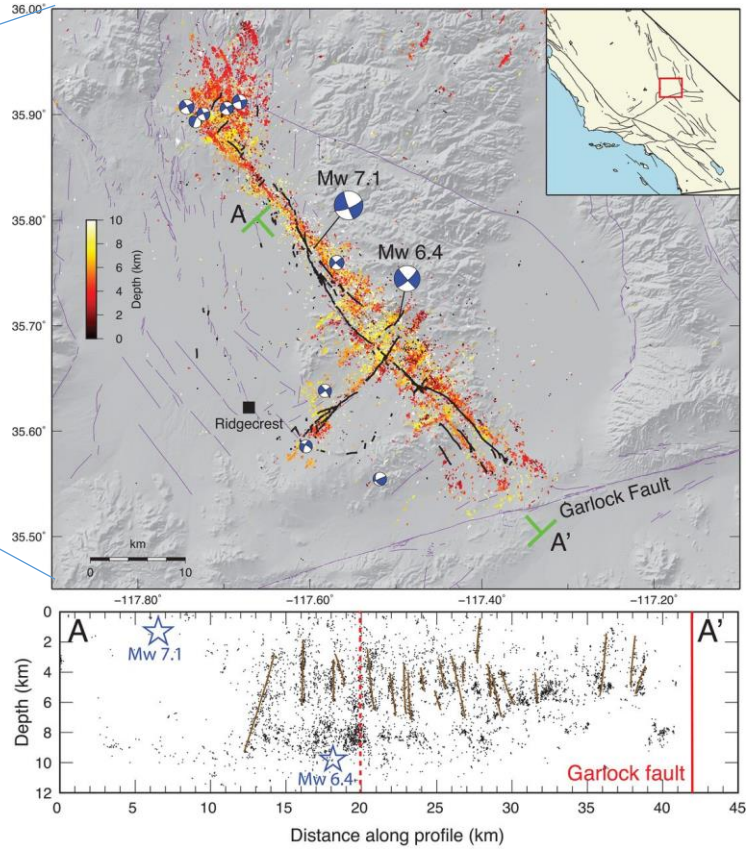


How many faults are still unknown?



usgs.gov

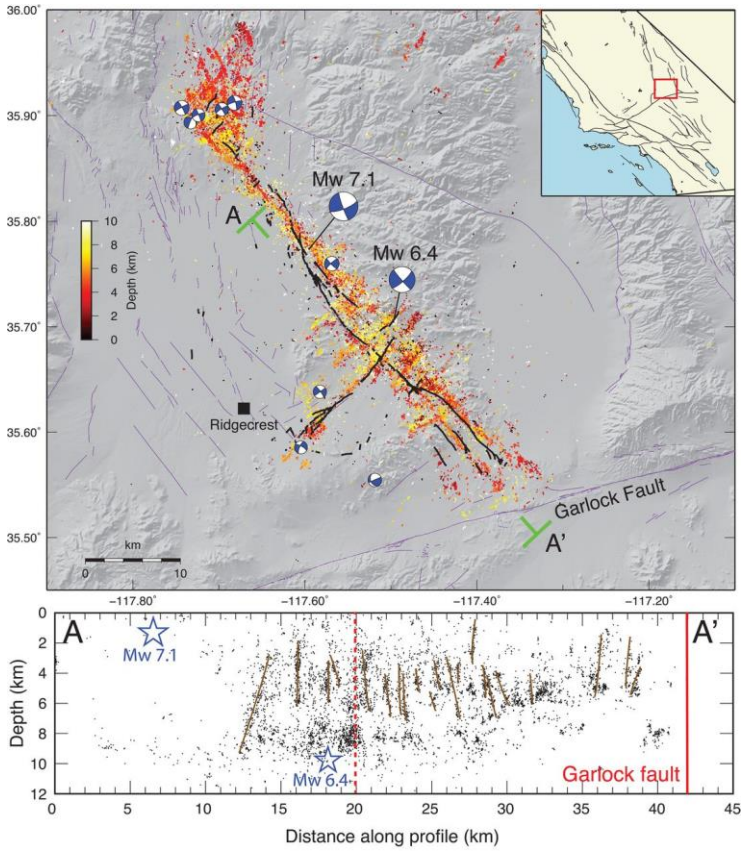
Plesch et al., 2007



Ross et al., 2019

What does the finest fault delineation need

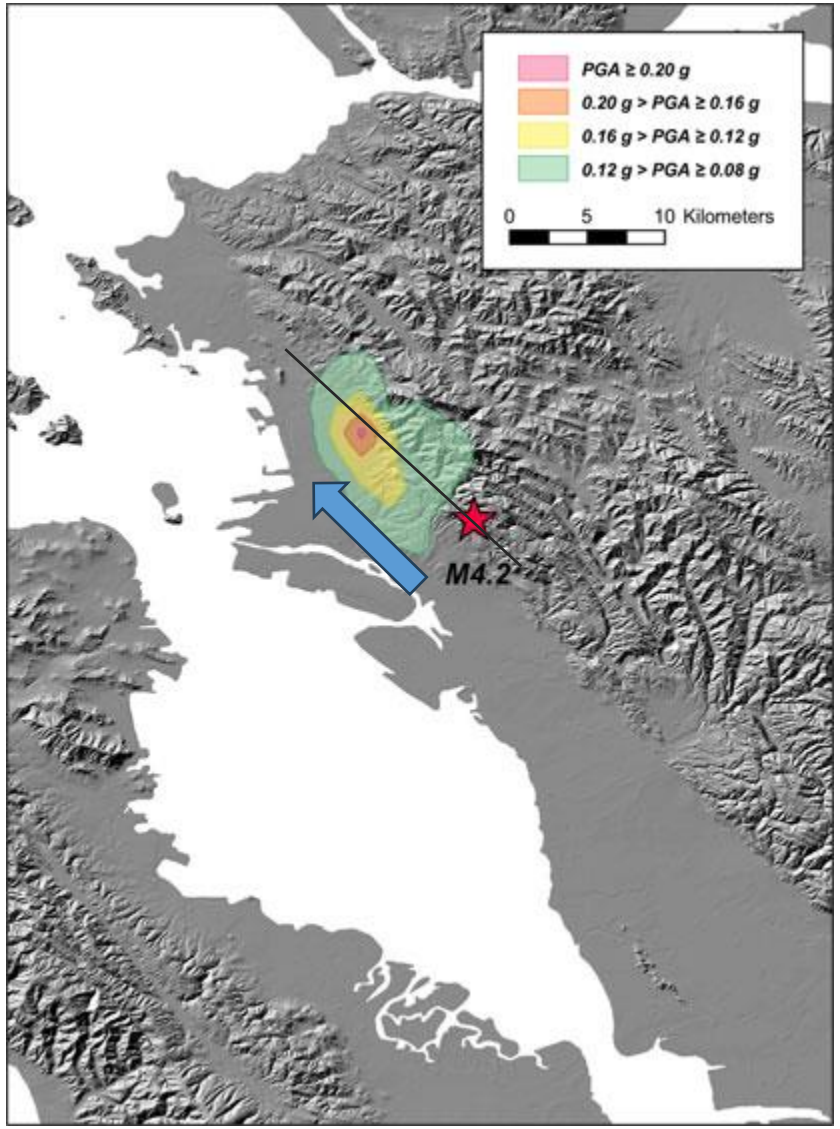
- **Numerous earthquakes**
- **Very precise location**
- **Aligned for one fault branch**



Ross et al., 2019

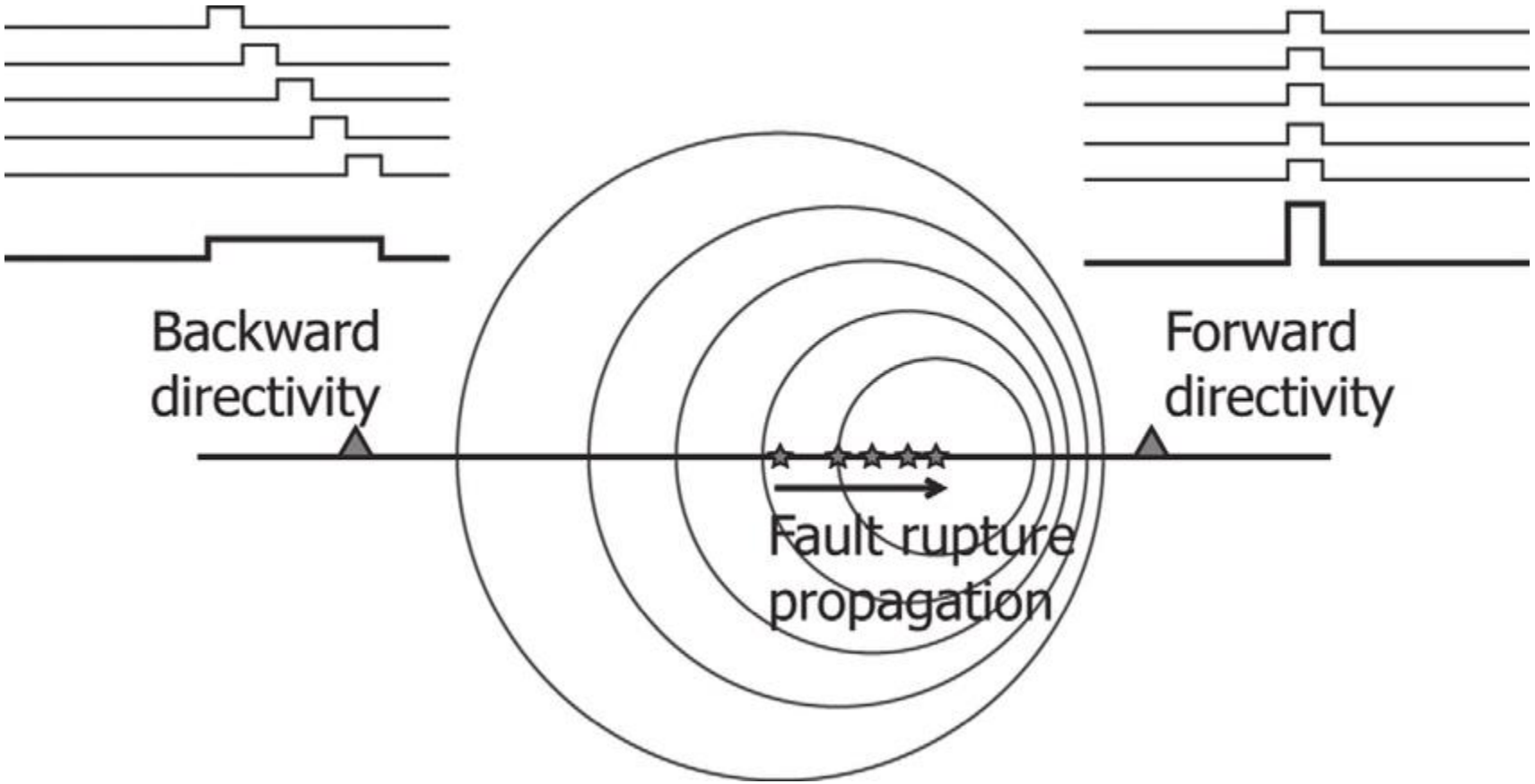
Beyond locations: the rupture directivity

- **One earthquake for one fault branch**
- **Need directivity determination**



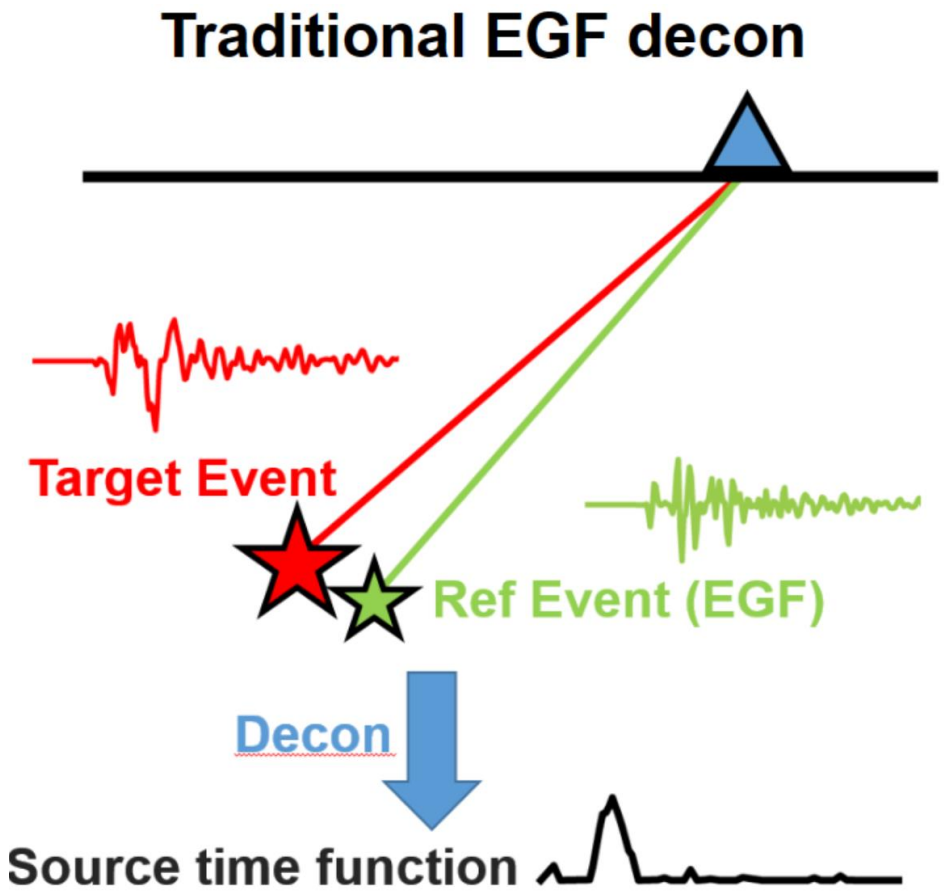
usgs.gov

The directivity effect cause duration variations



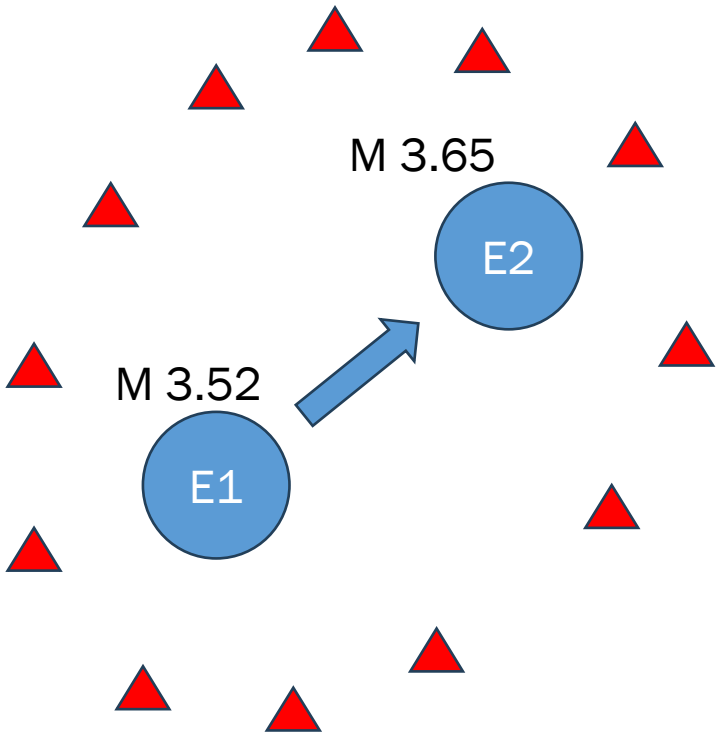
Grimaz and Malisan, 2014

Empirical Green's function method to resolve the durations

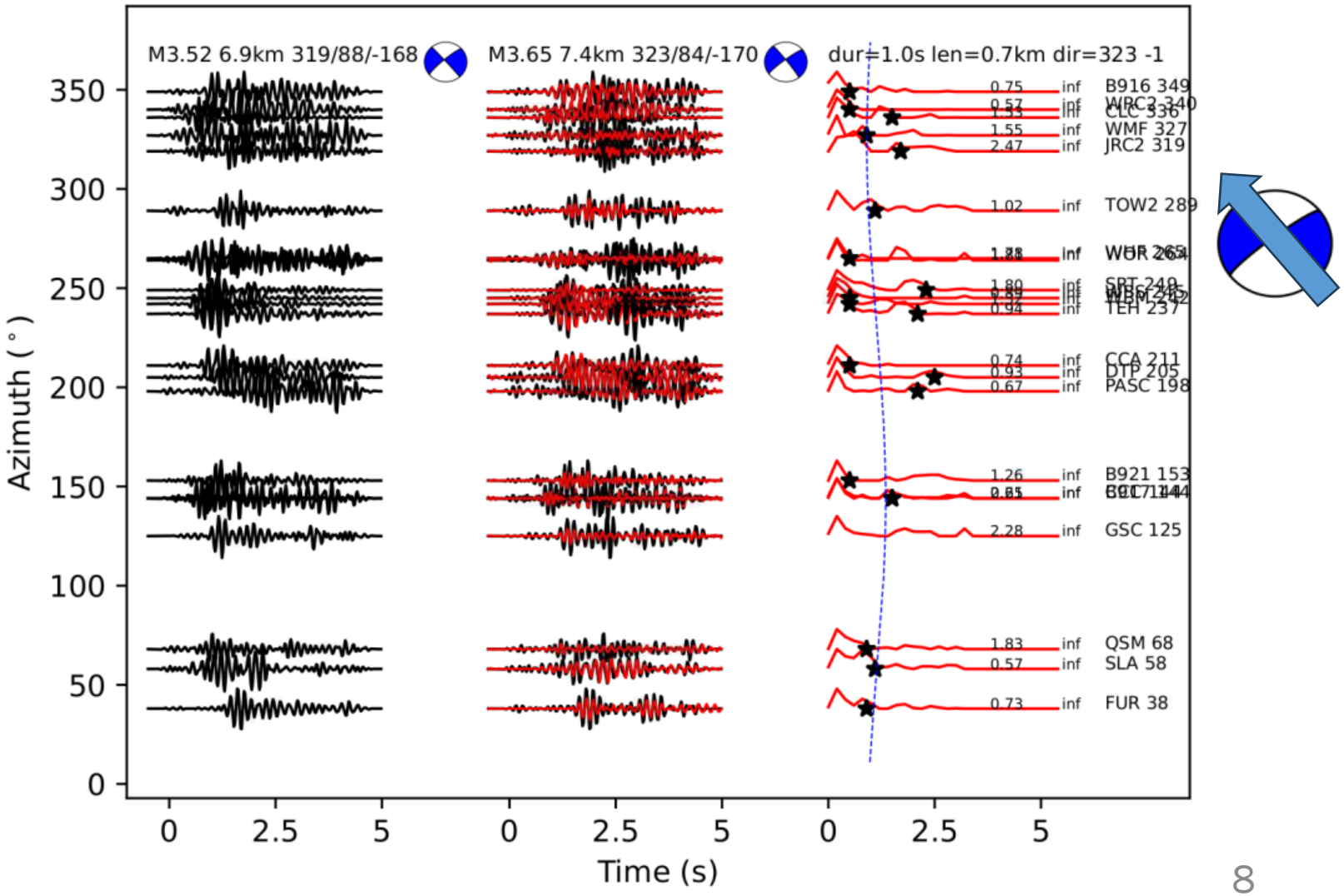


Cycle-skipping biases directivities at high frequencies

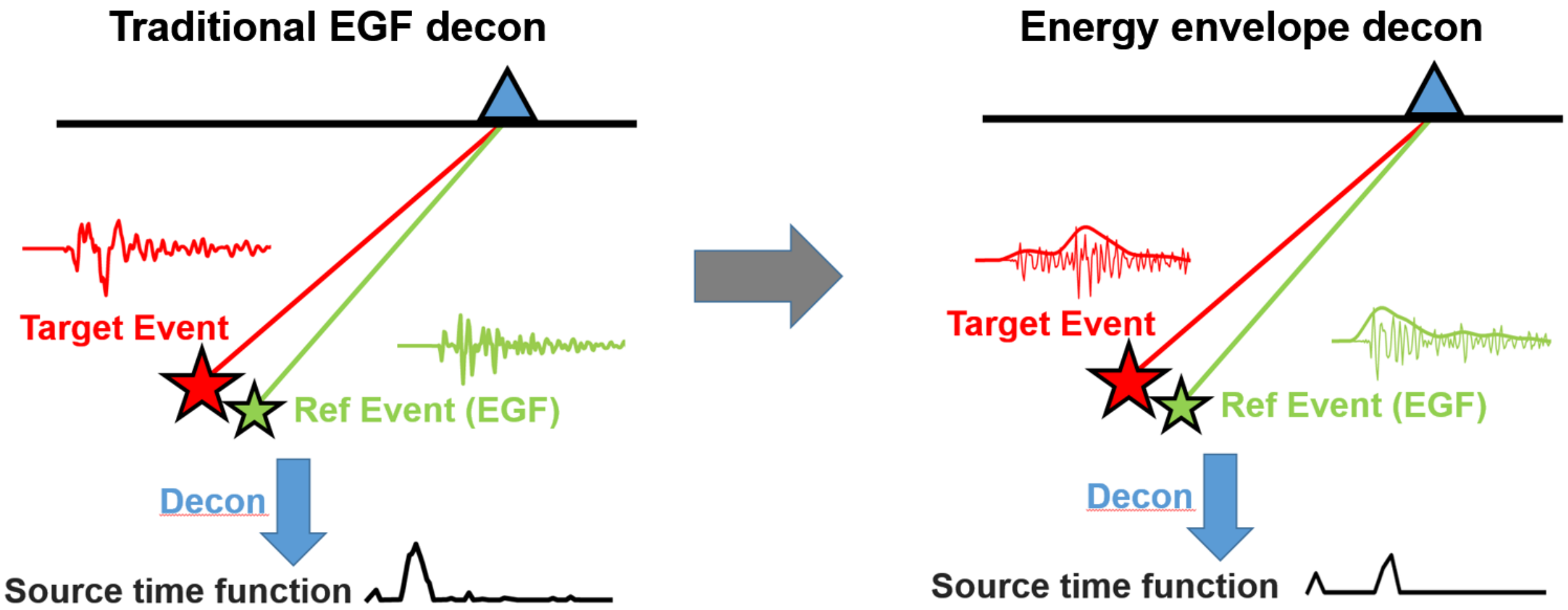
A man-made NE rupture



EGF deconvolution shows NW directivity

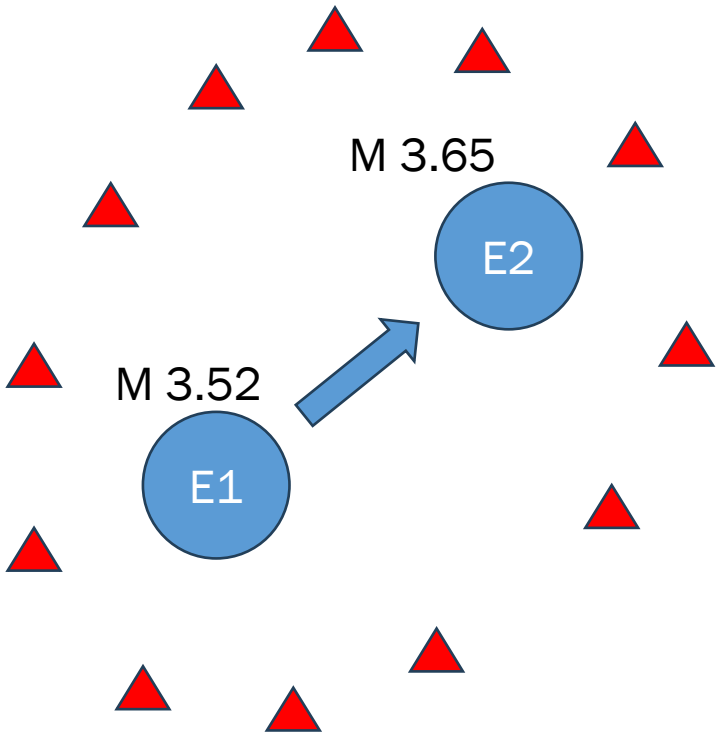


Energy envelope deconvolution

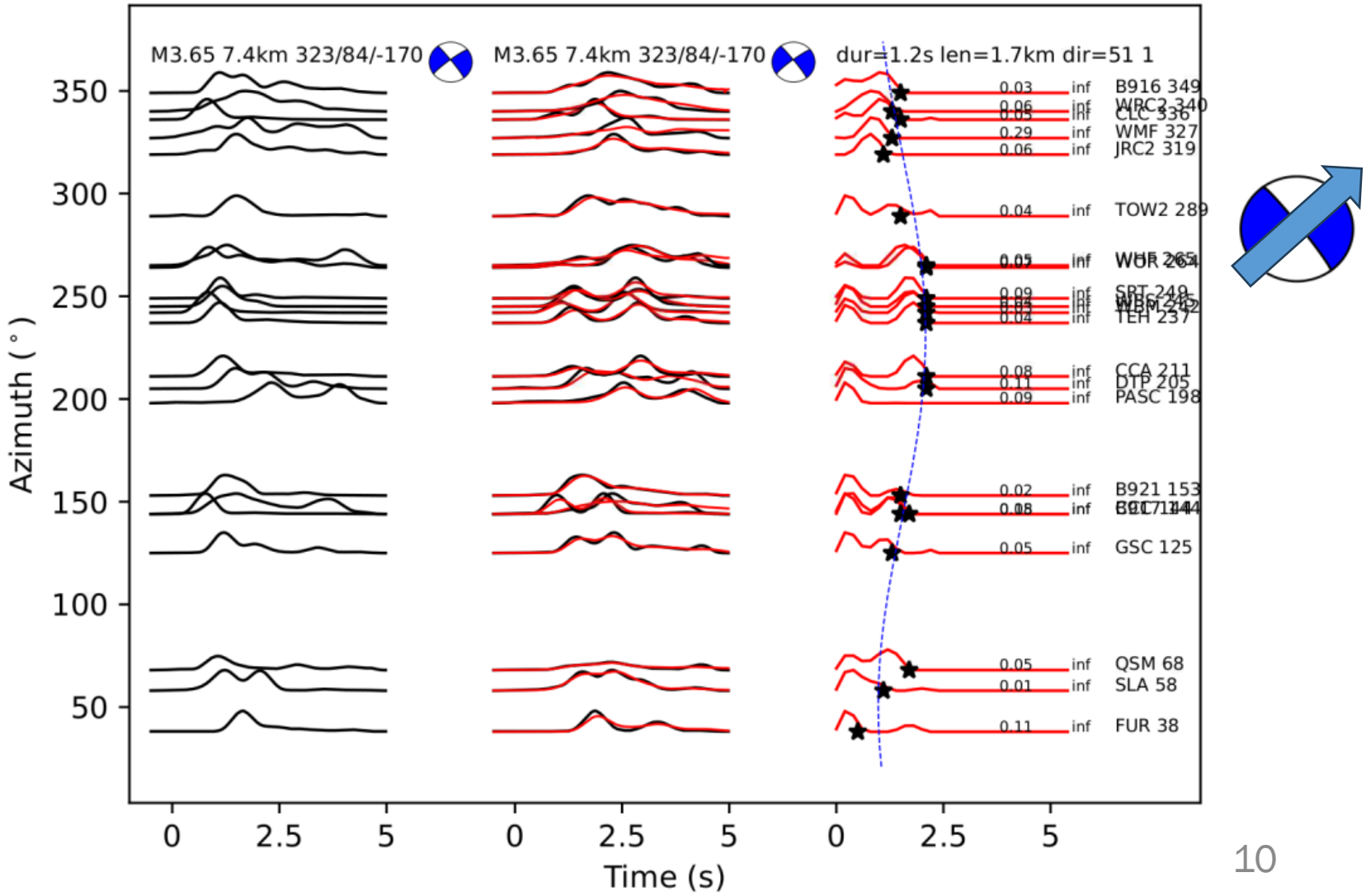


Our method recovered the truth

A man-made NE rupture

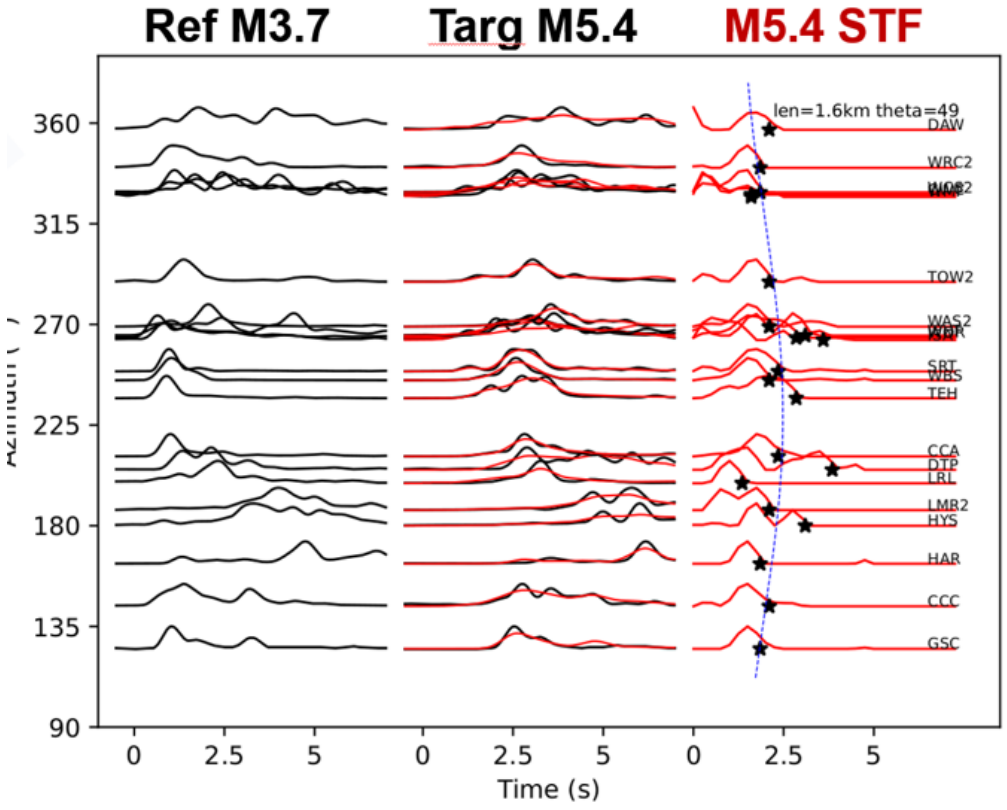


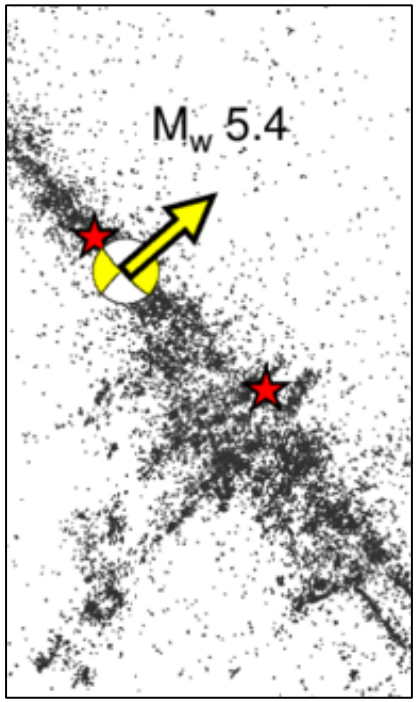
EE deconvolution shows NE directivity



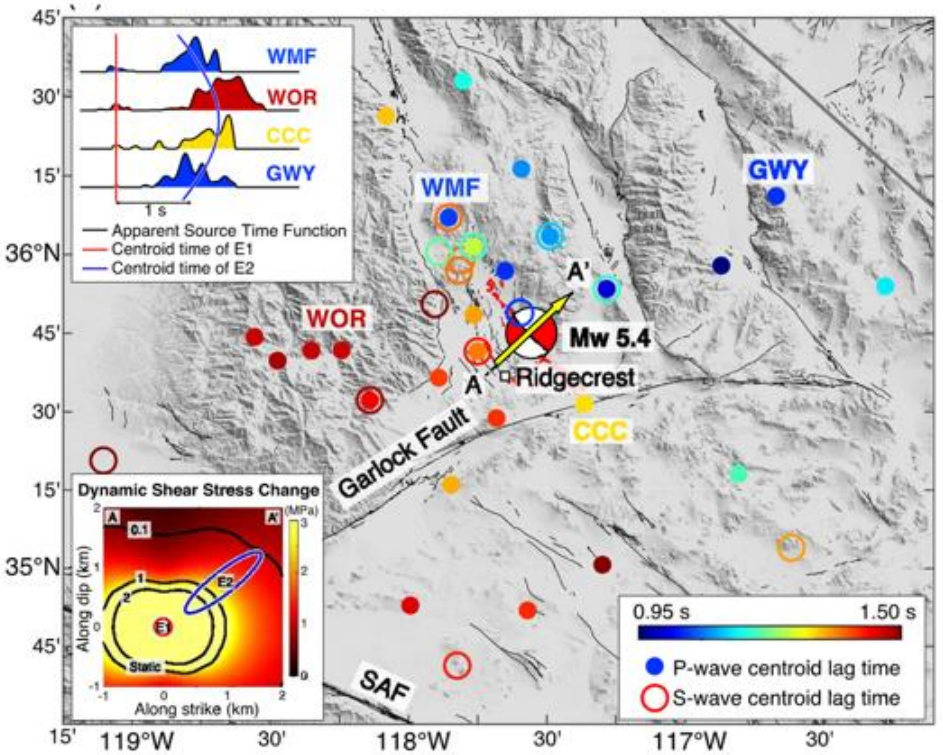
Validation on the Mw 5.4 earthquake

EE deconvolution



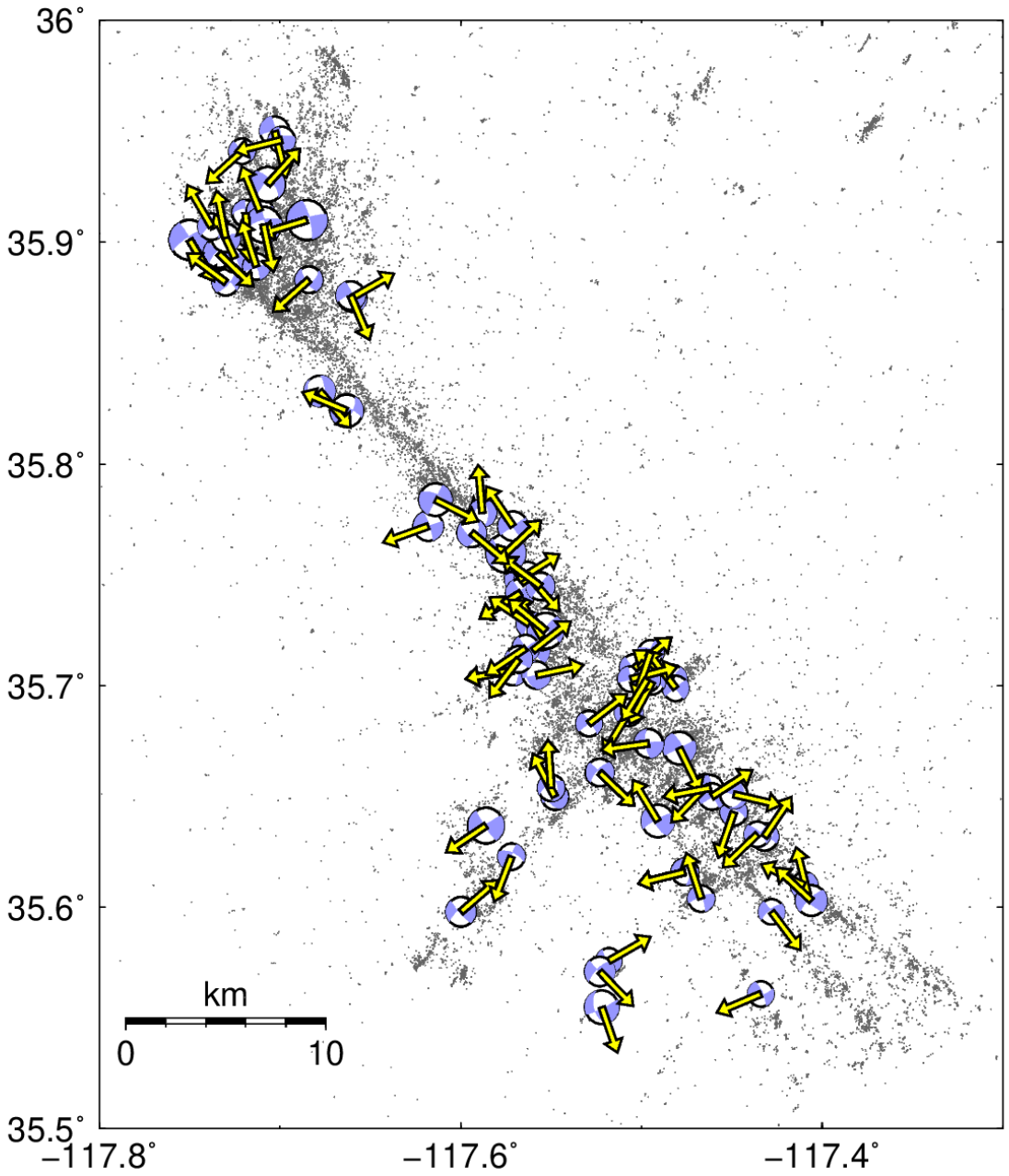


Previous analysis

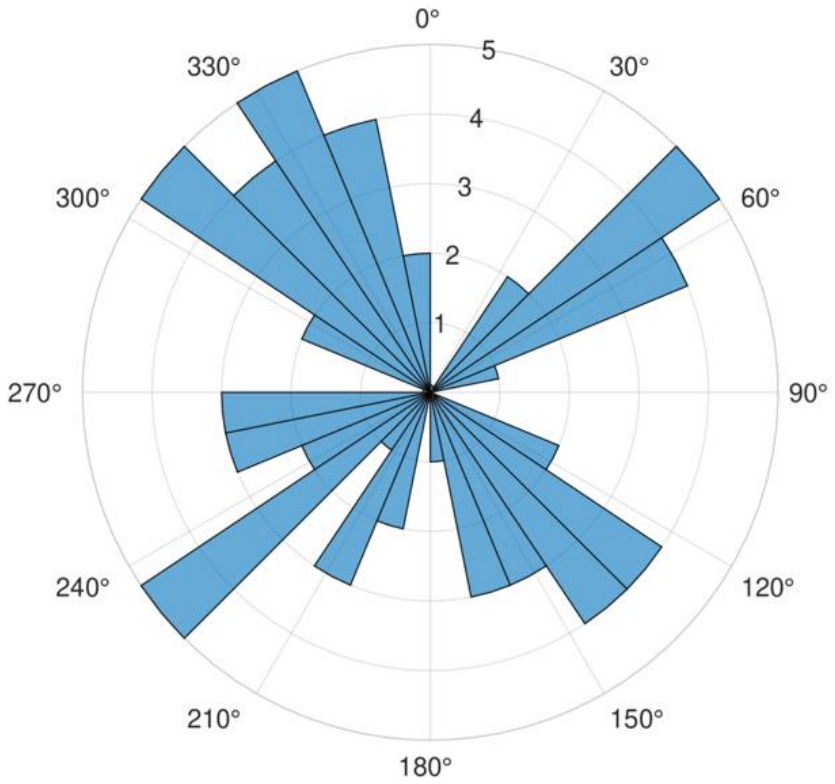


Meng and Fan, 2021

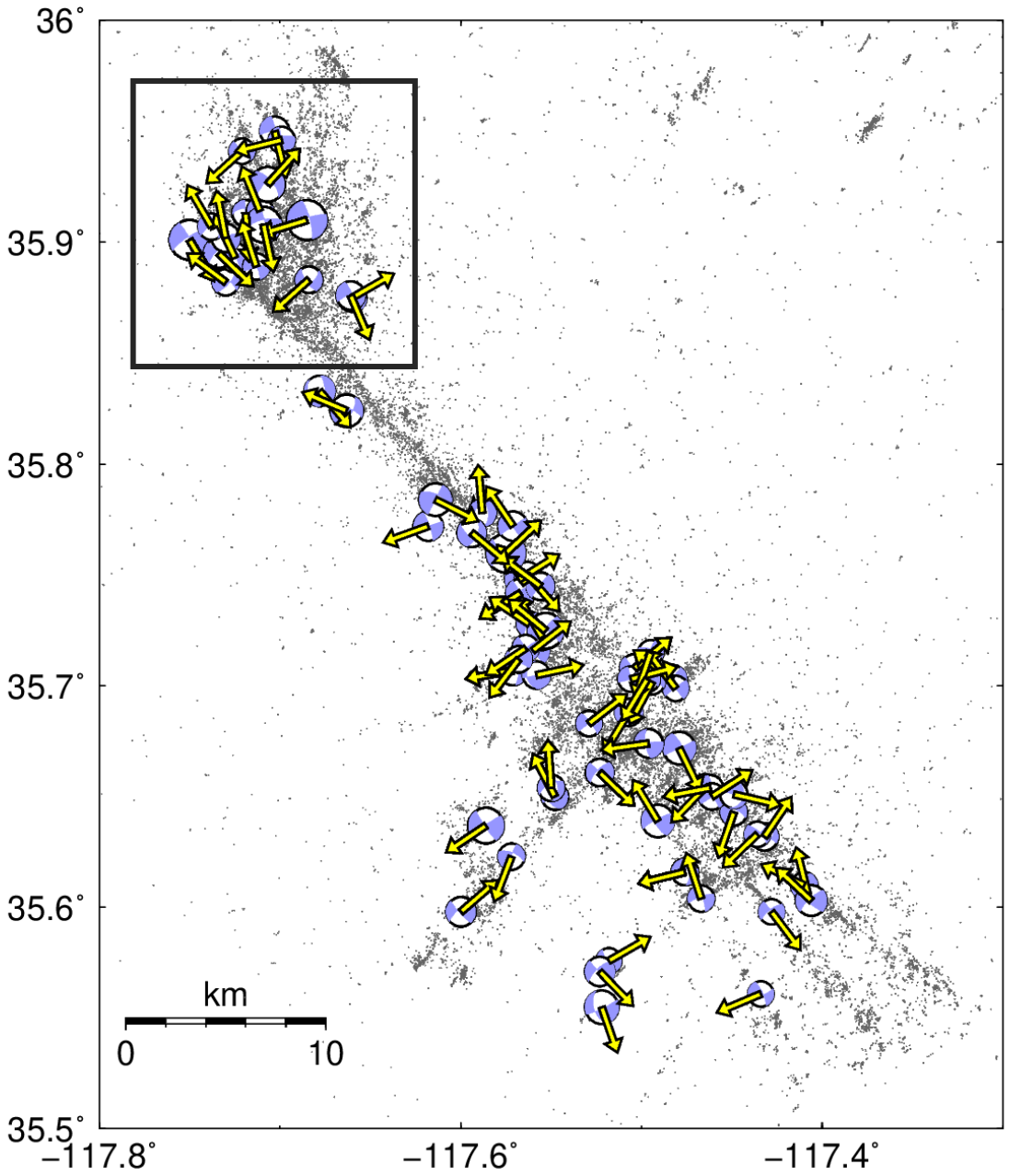
Scale it up: rupture directivities of 70 M 3.5-5.5 earthquakes

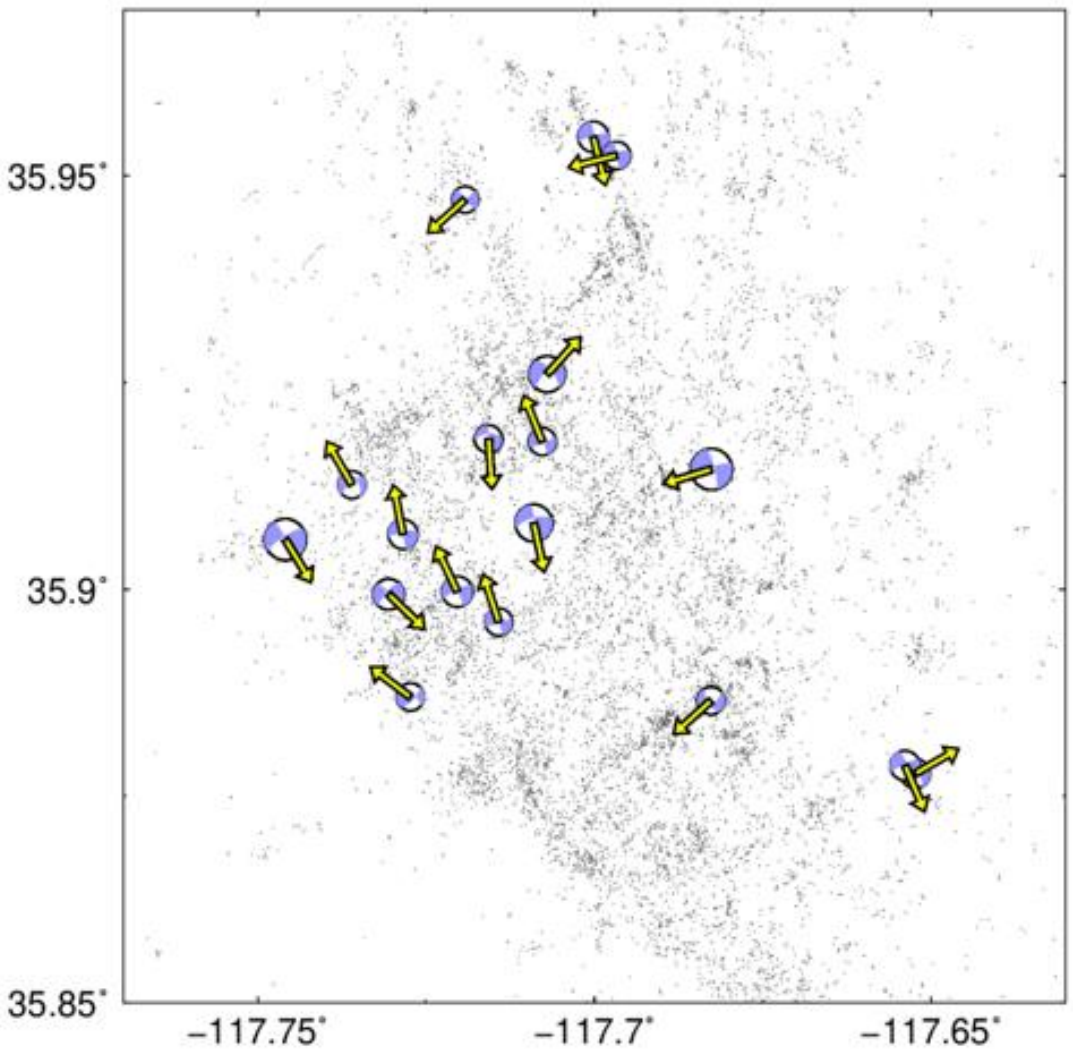


No preferred single direction

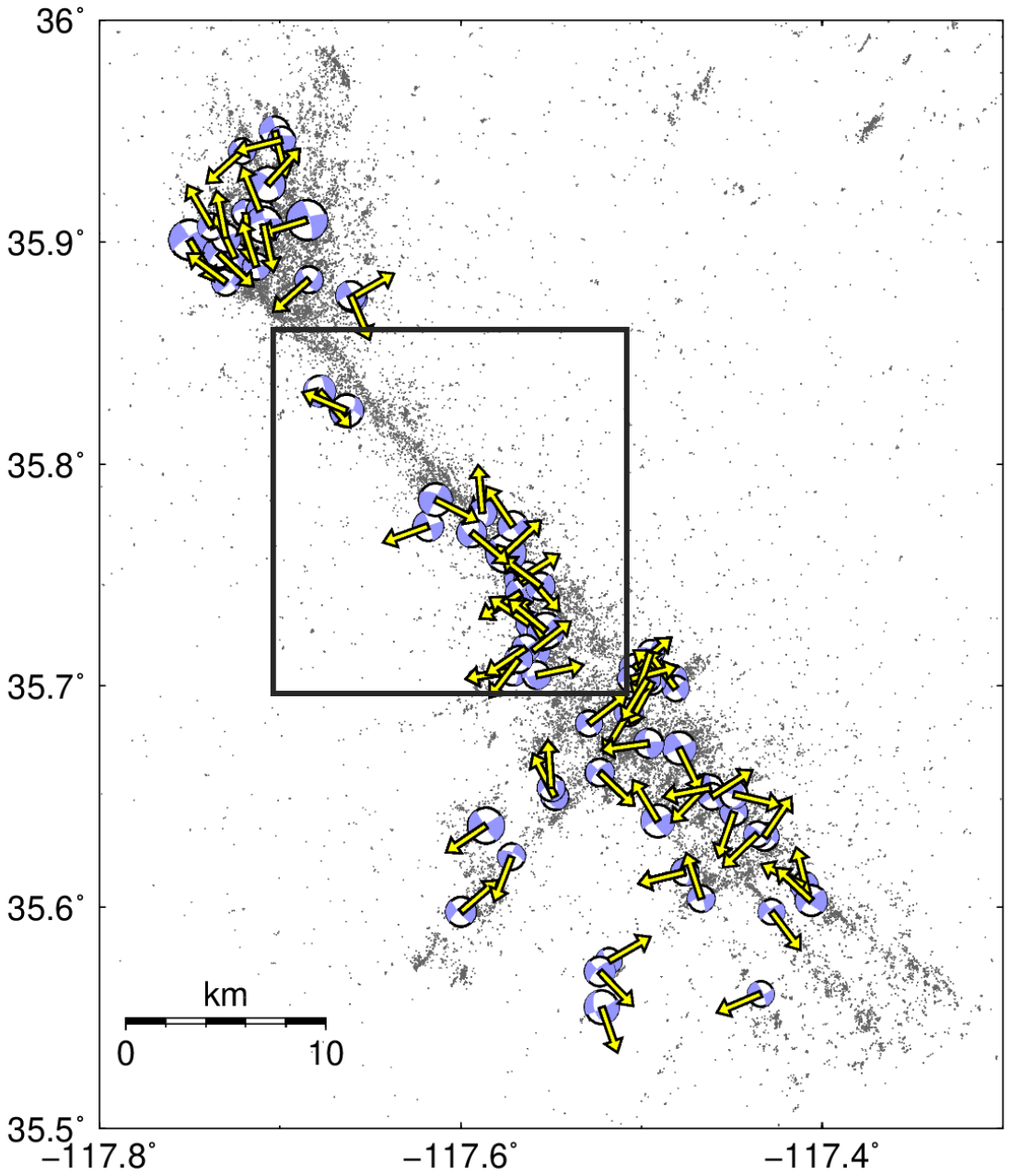


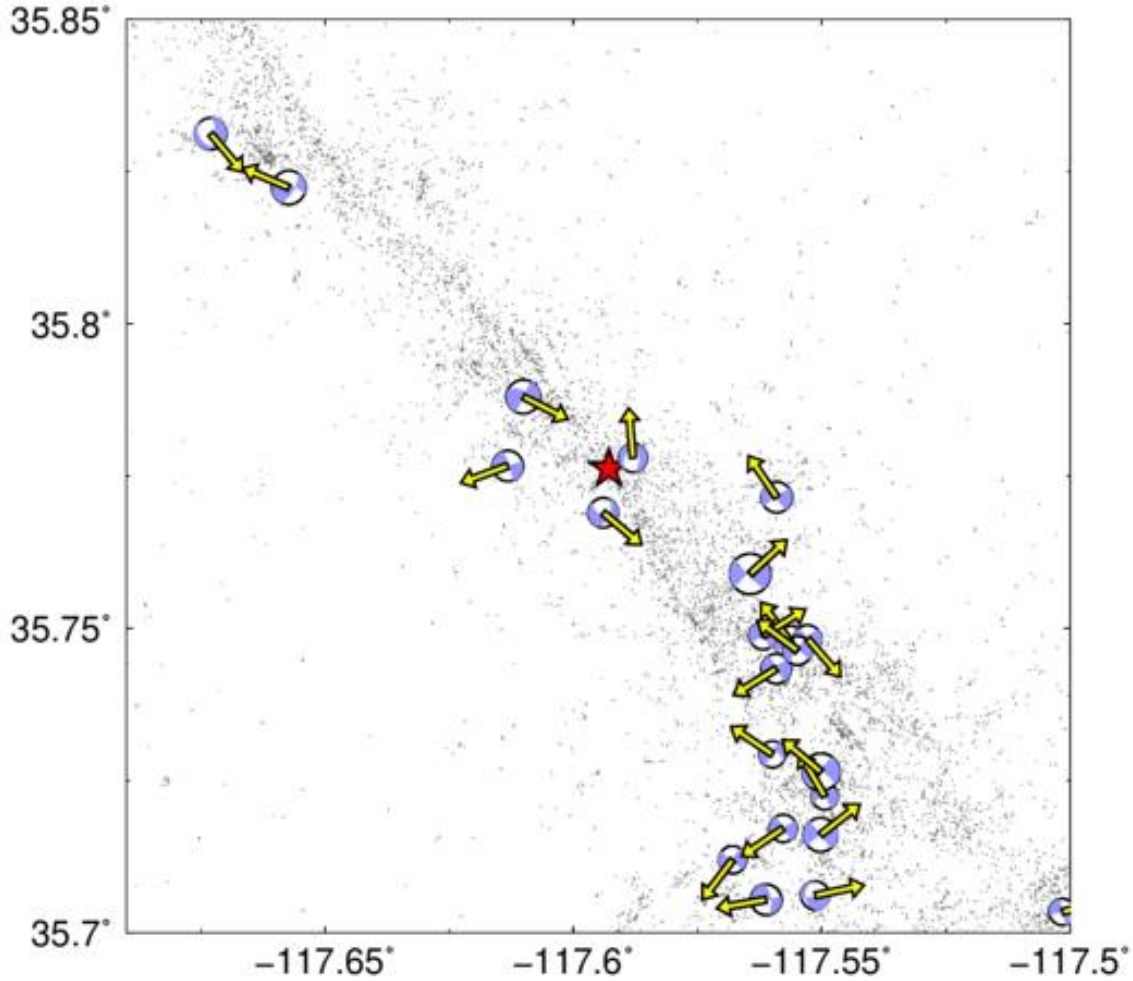
NW section: relatively simple



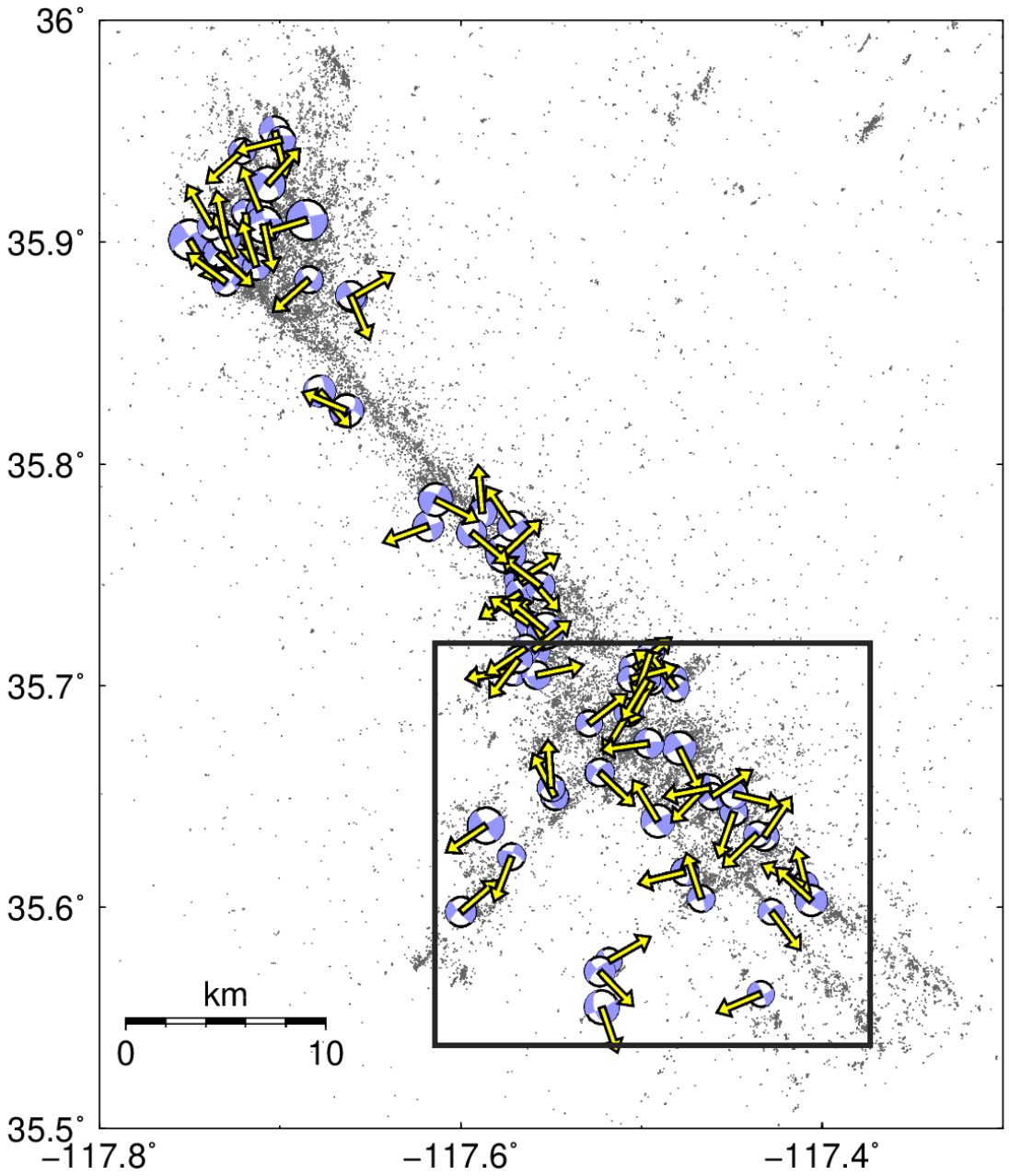


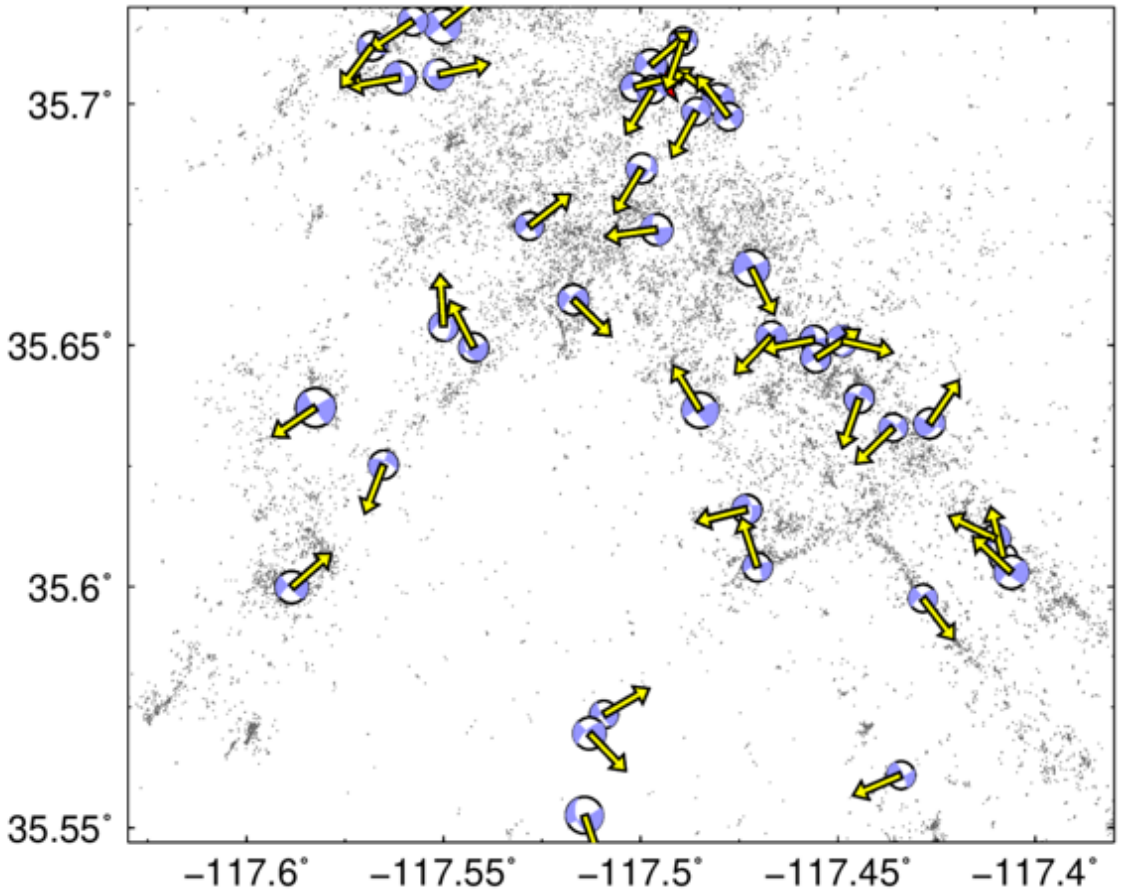
Middle section: relatively simple





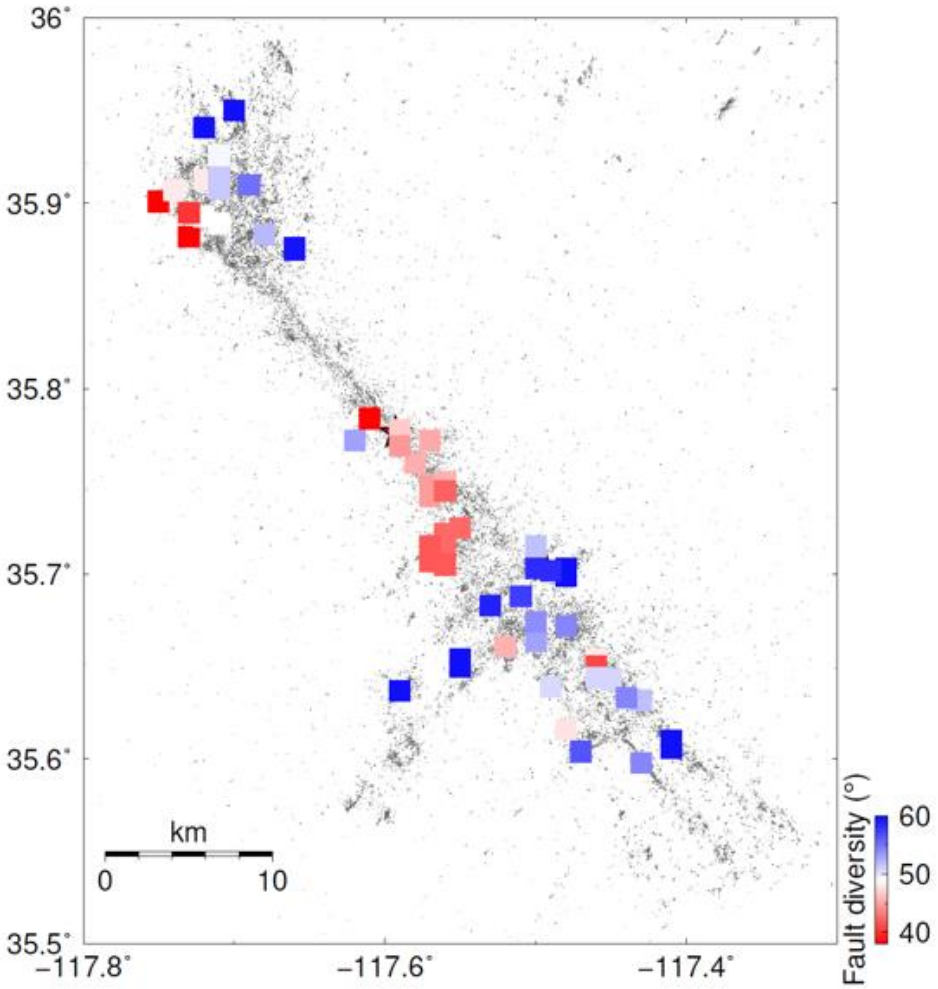
Southern section: more complex



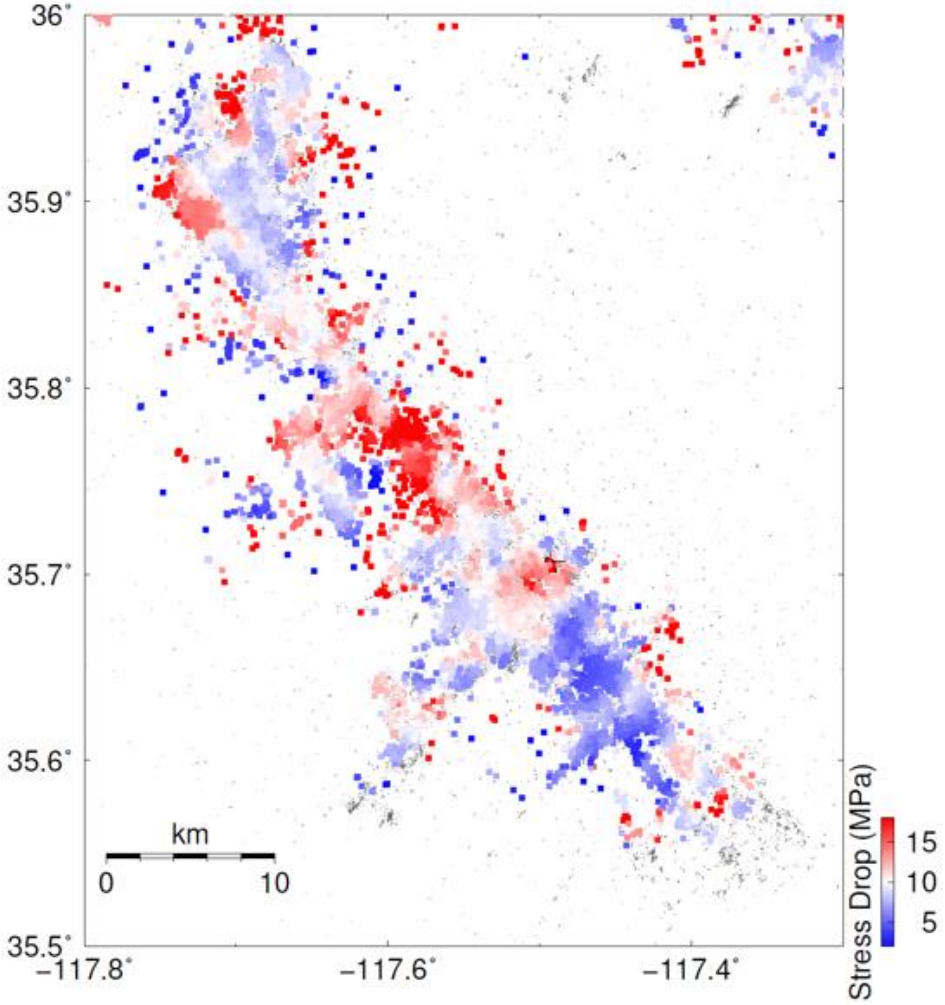


Fault structure complexity correlated to stress drop?

Fault strike diversity

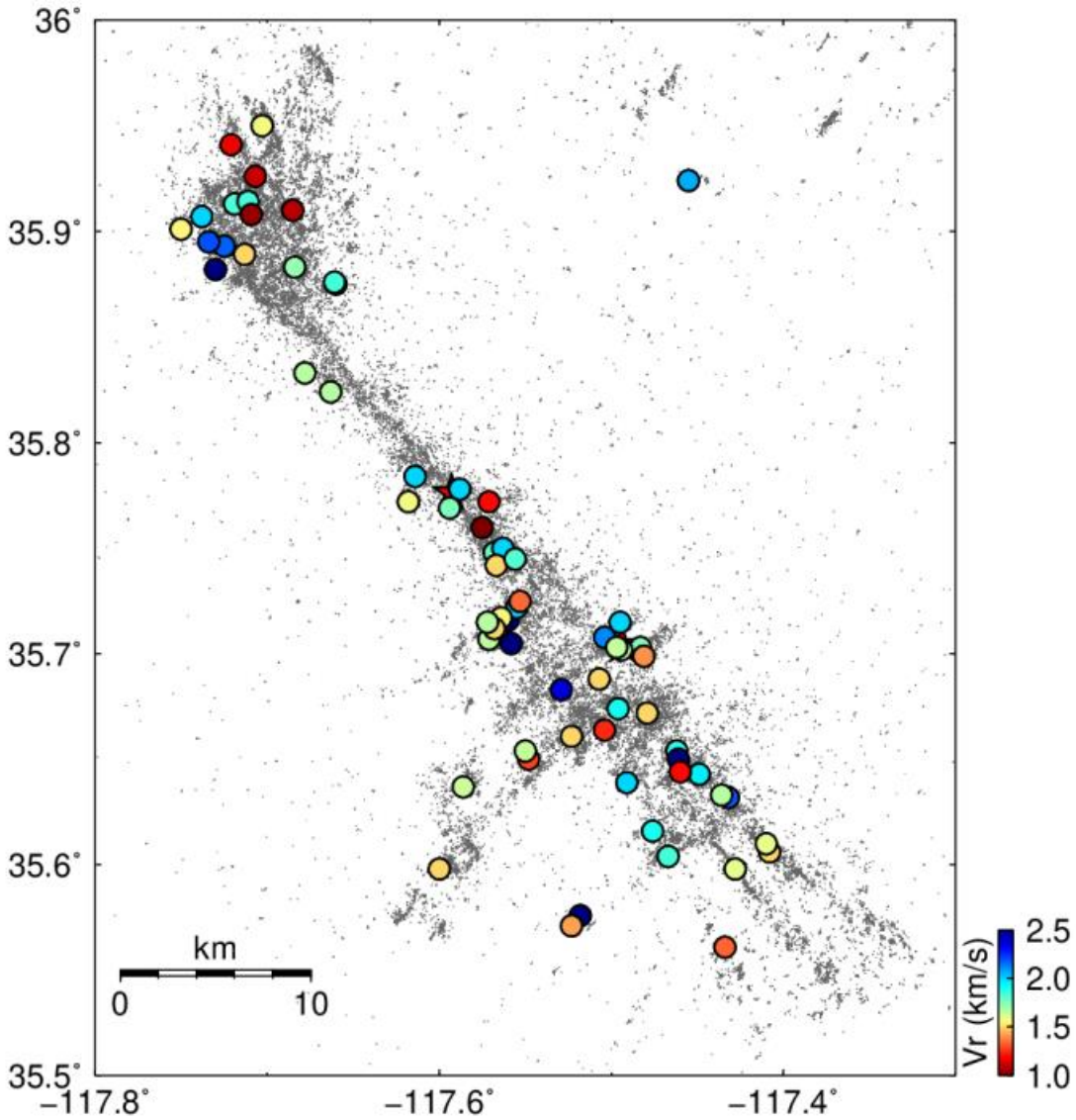


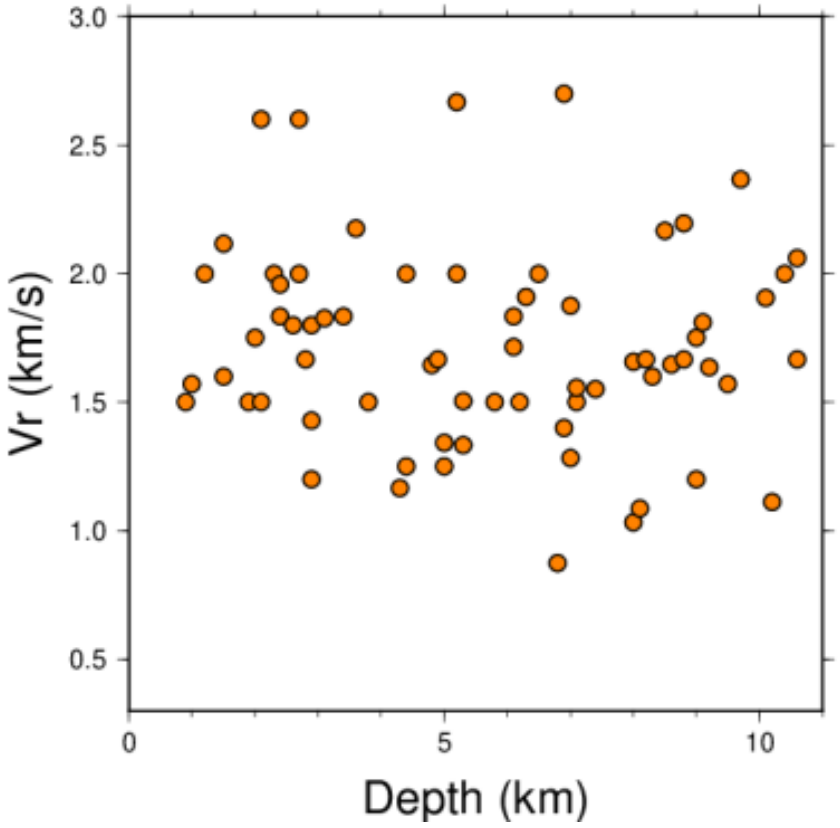
Earthquake stress drops



Shearer et al., 2022

Low of rupture velocities: mostly 1-2 km/s





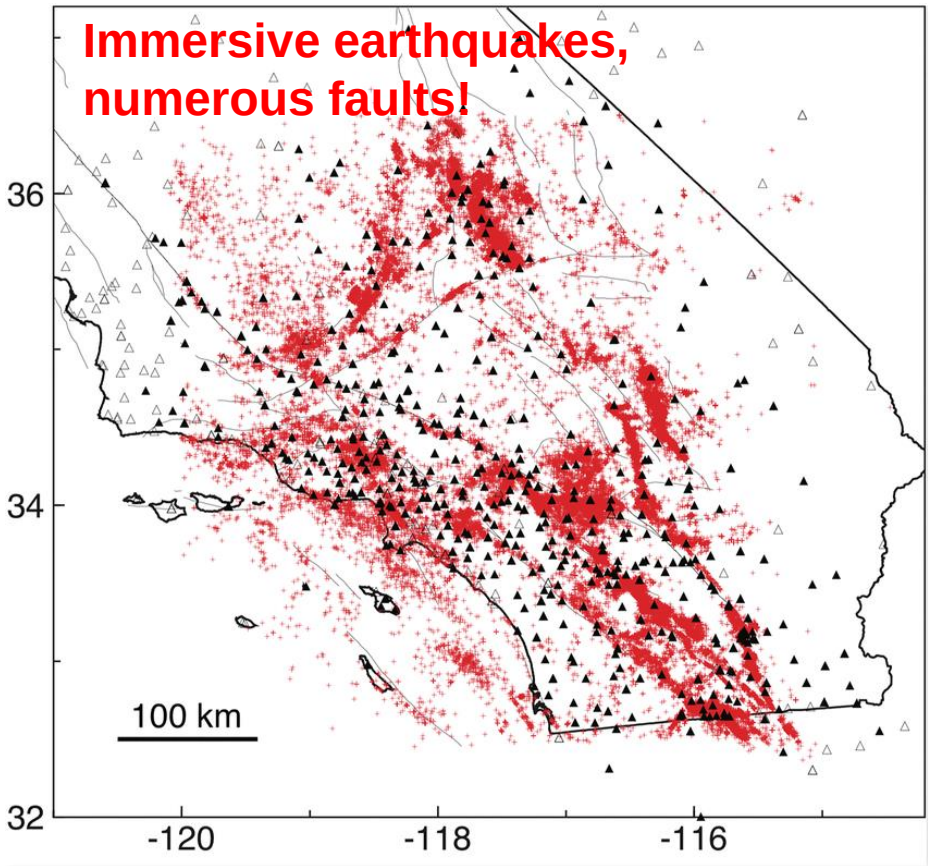
Takeaways

- **Energy envelope deconvolution illuminates detailed fault structure**

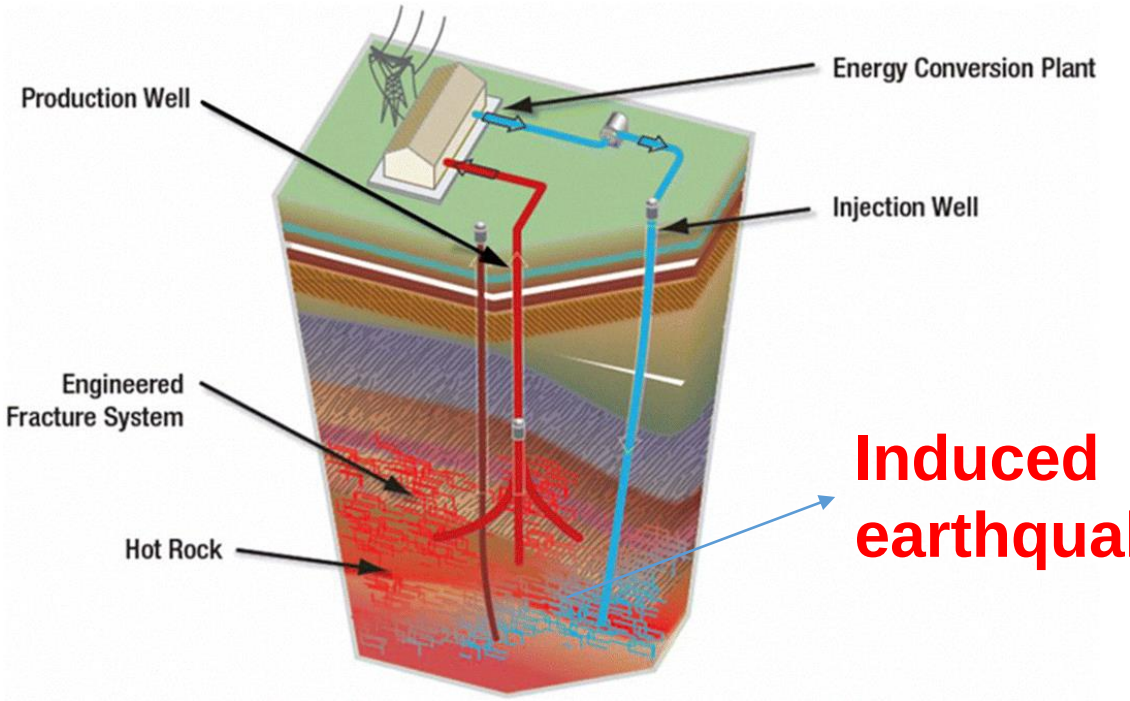
- **Fault structure may influence small earthquake stress drops**

Future applications

Much more faults to be detected



Geothermal: monitor faulting process



Olasolo et al. 2016, Renew Sustain Energy Rev.