

Combining seismic arrays to image the high-frequency characteristics of large earthquakes

Eric Kiser and Miaki Ishii, GJI, 2012

Backprojection method

- Compared with other slip inversions, it doesn't assume fault plane or rupture speed.
- It does assume depth and hypocenter location.
- Here the method is extended over multiple arrays, in this case TA and Hi-net, and uses 1-5 Hz frequency band

Backprojection method

ID travel time prediction

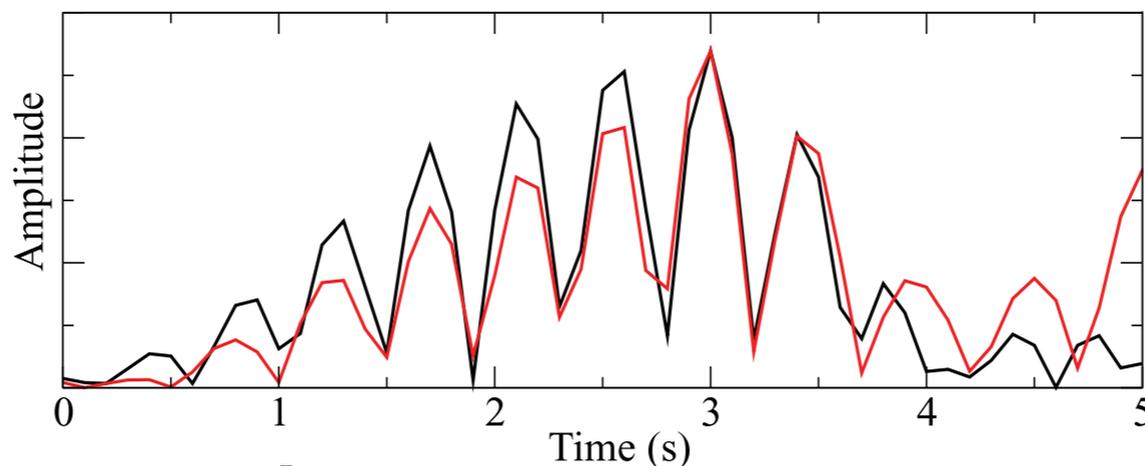
amplitude normalization

station specific 3D travel time correction

array specific stack at gridpoint:
$$s_i(t) = \sum_{k=1}^K \alpha_k u_k (t - t_{ik} + \Delta t_k),$$

- Creates stack for each grid point around the hypocenter.
- 3D travel time is corrected by cross-correlating the initial energy.
- The contribution of each station (in each array) is normalized.

Example stack
TA (red)
Hi-net (black)

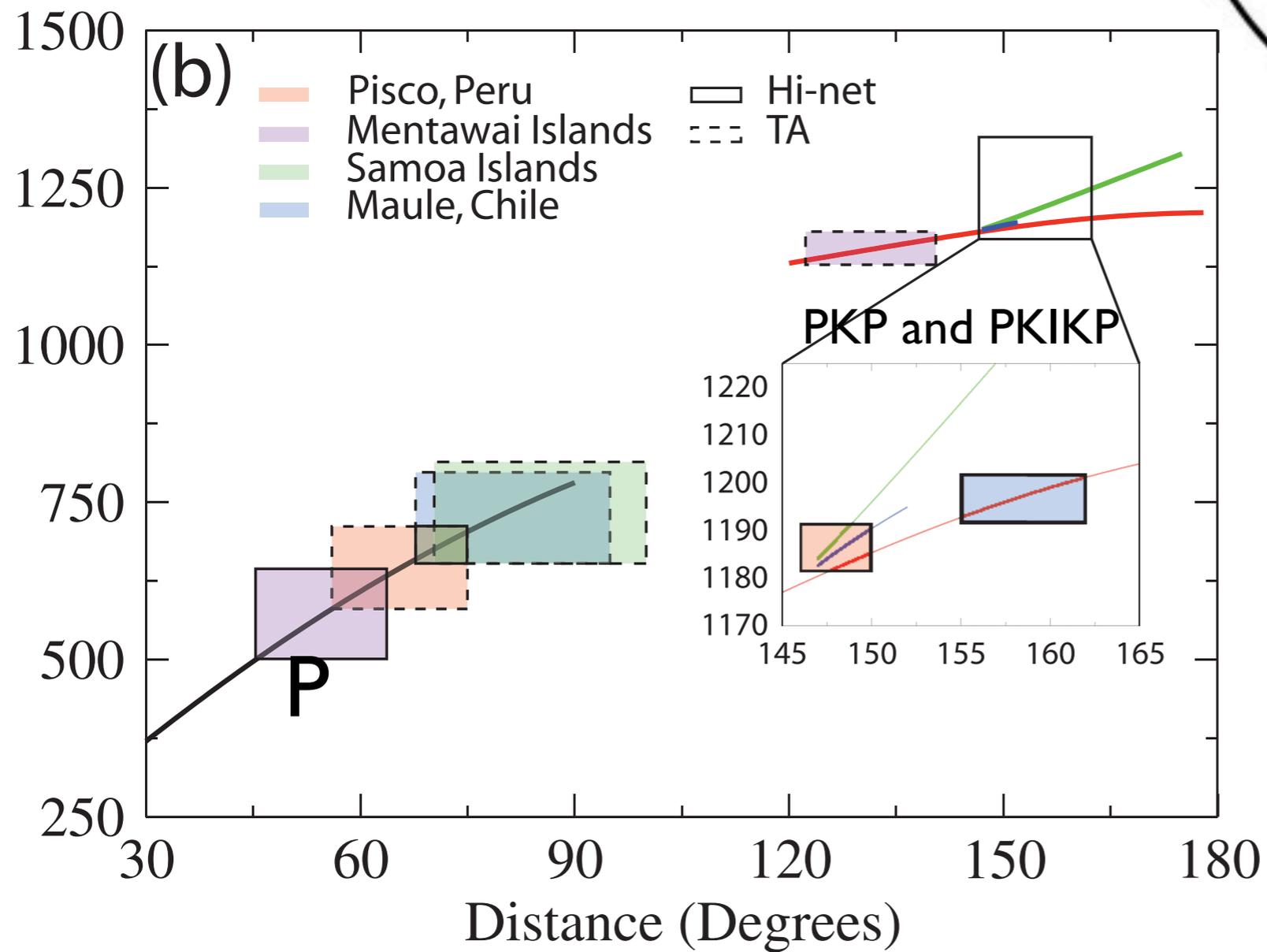
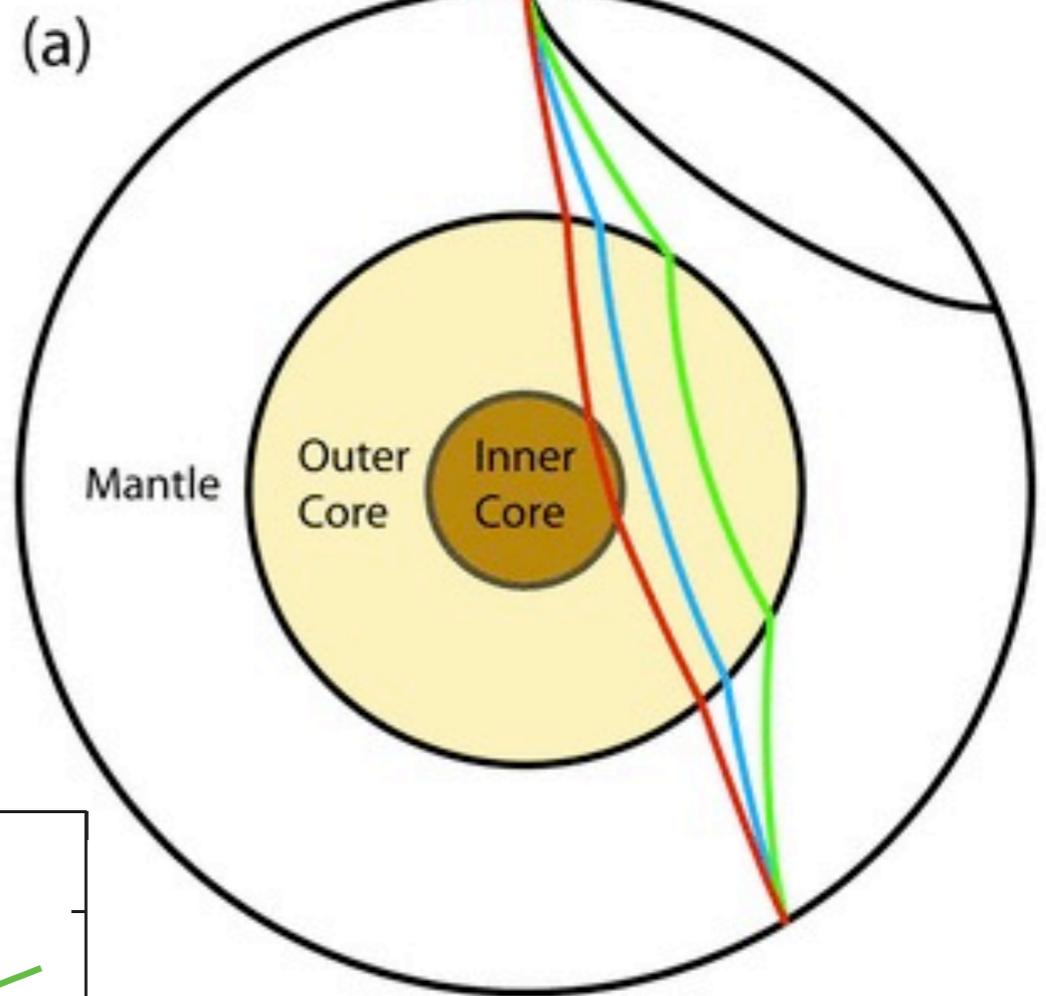


sum over arrays per gridpoint:
$$S_i(t) = \sum_{j=1}^J w_j |s_{ji}(t + \Delta t_j)|,$$

amplitude normalization

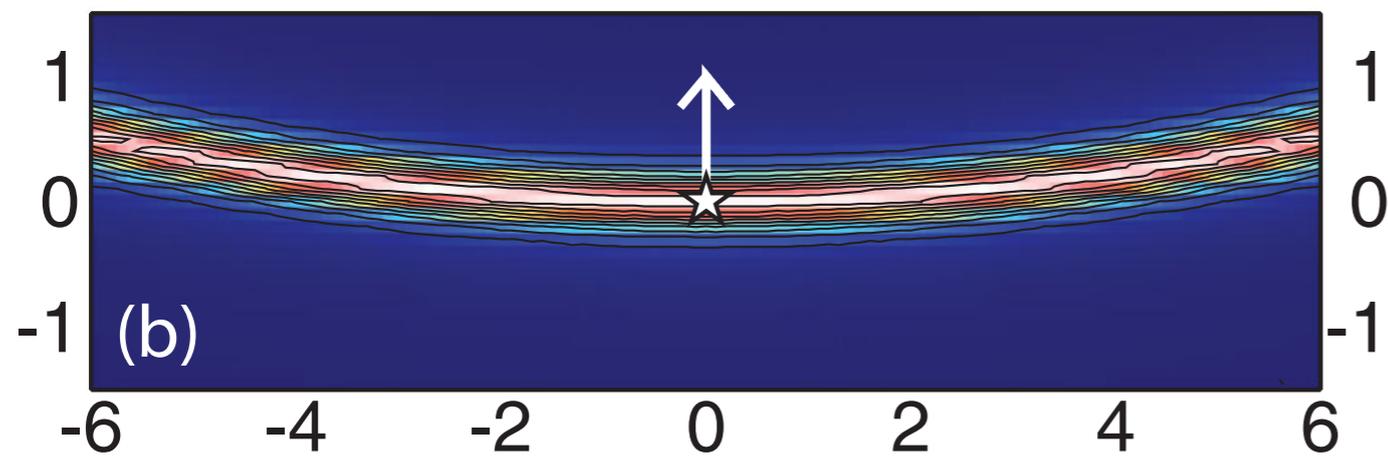
array specific 3D travel time correction

Multiple phases

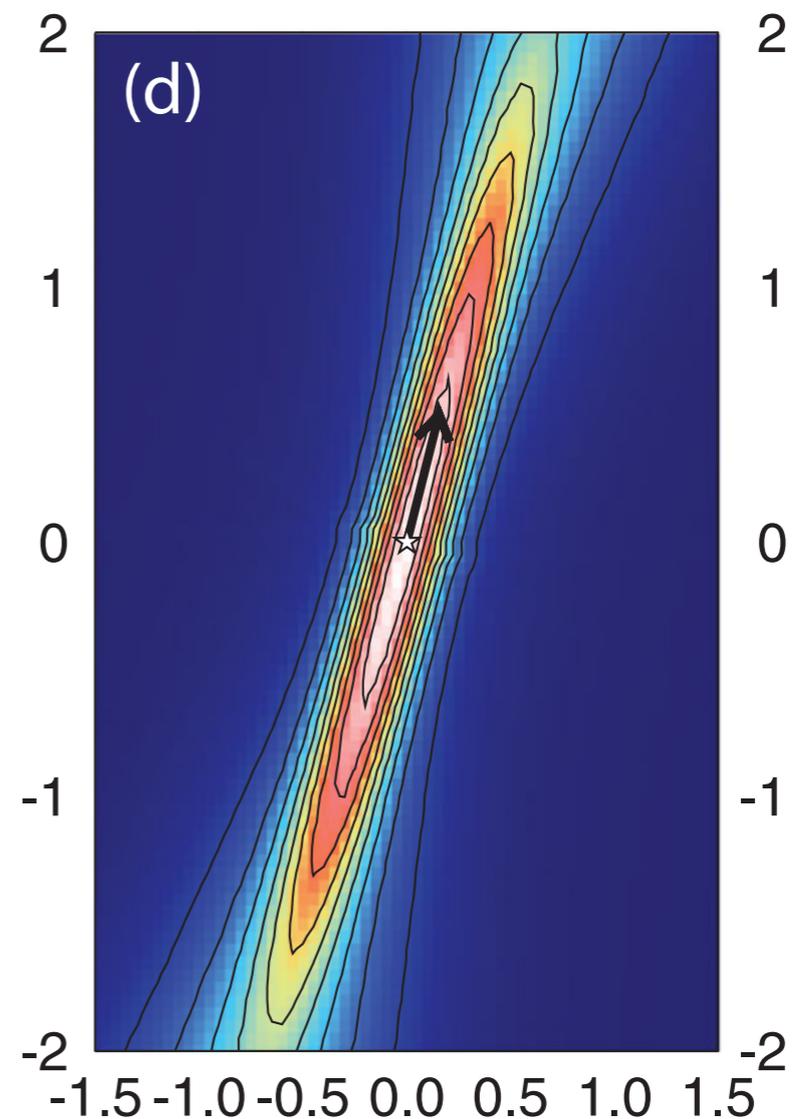


Array distribution

Array at constant azimuth



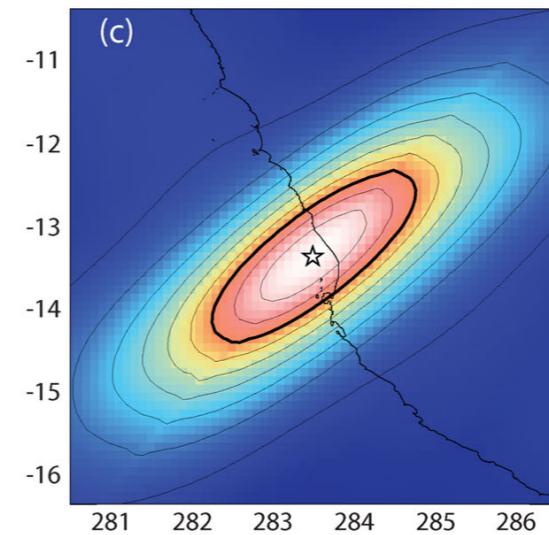
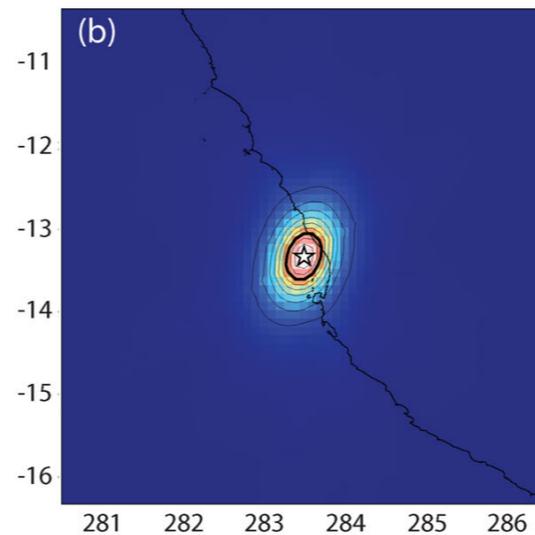
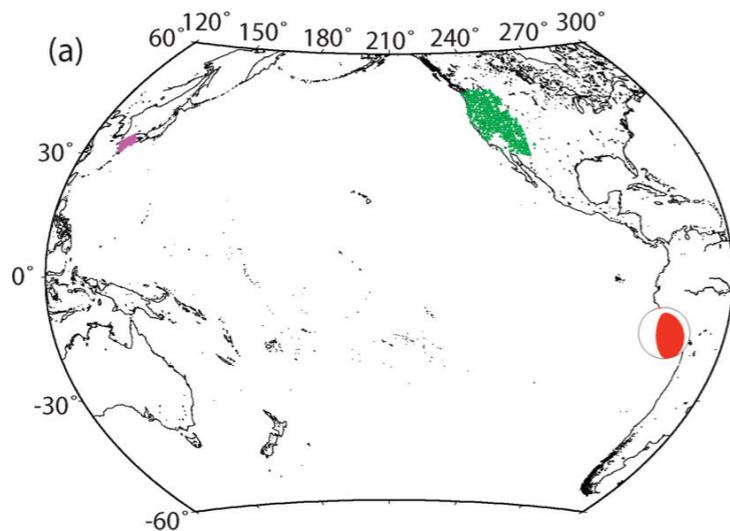
Array at constant distance



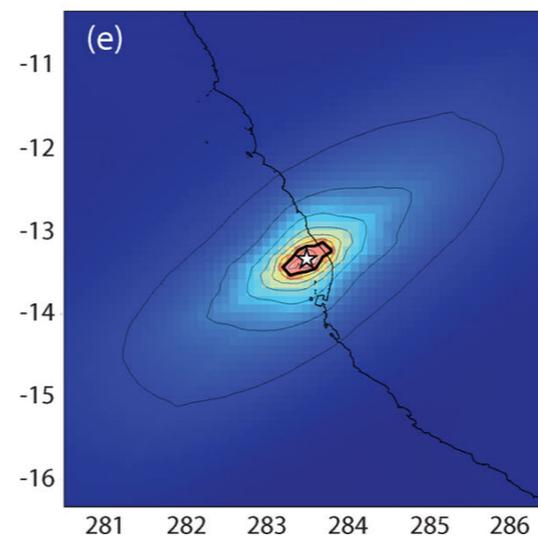
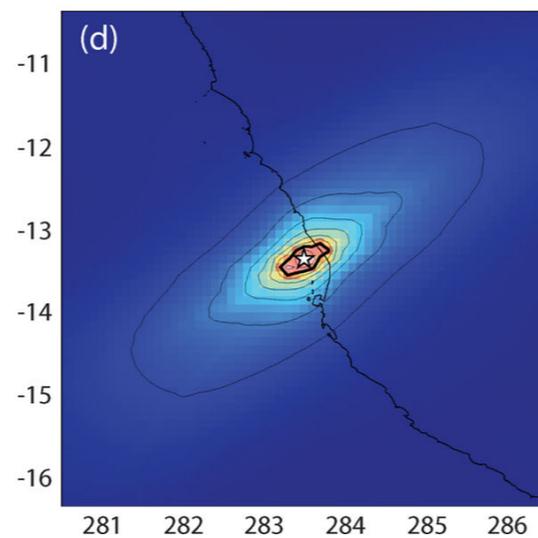
Resolution

TA
2200 km²

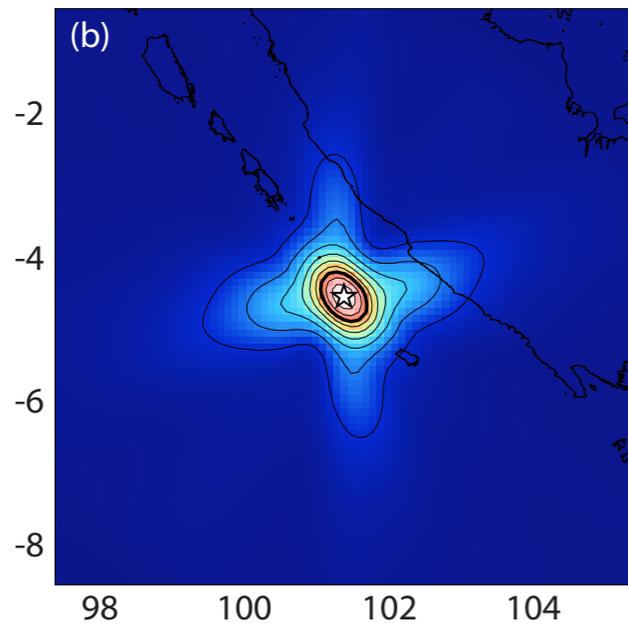
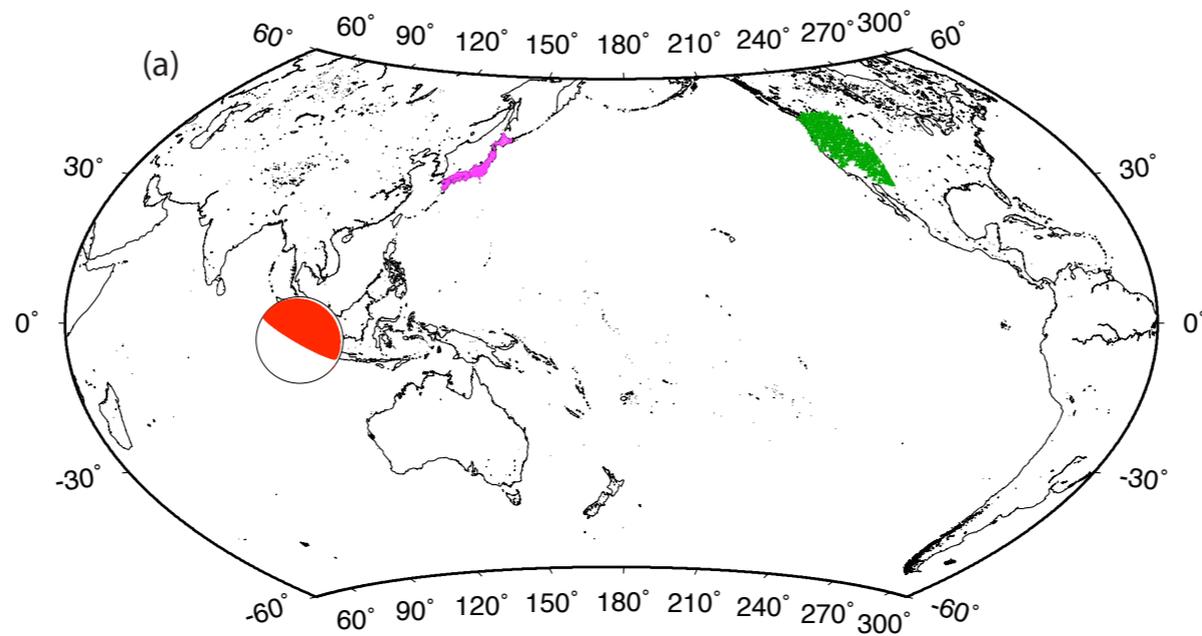
Hi-net
30000 km²



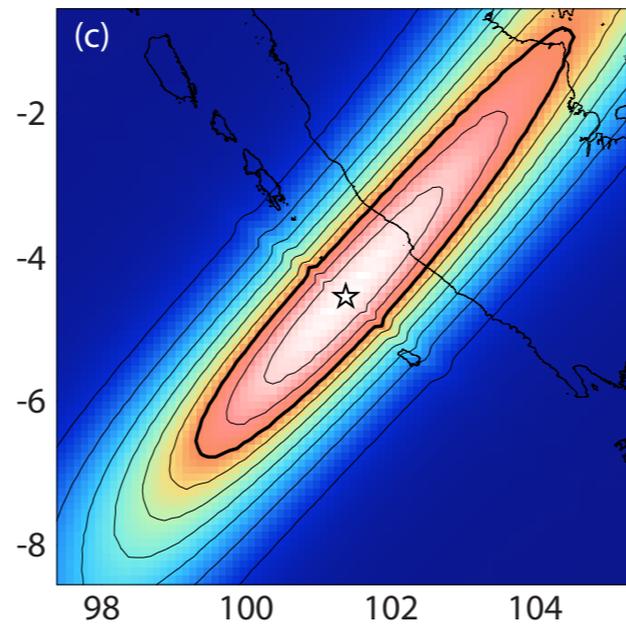
Both
1400 km²



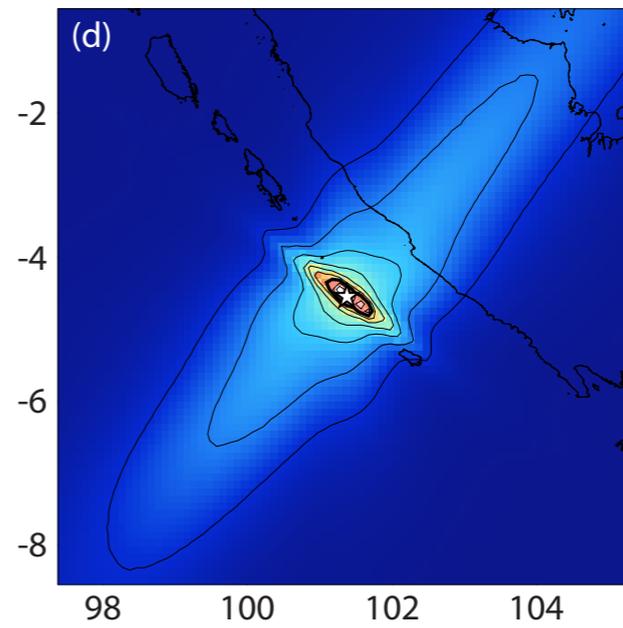
Including more
core phases



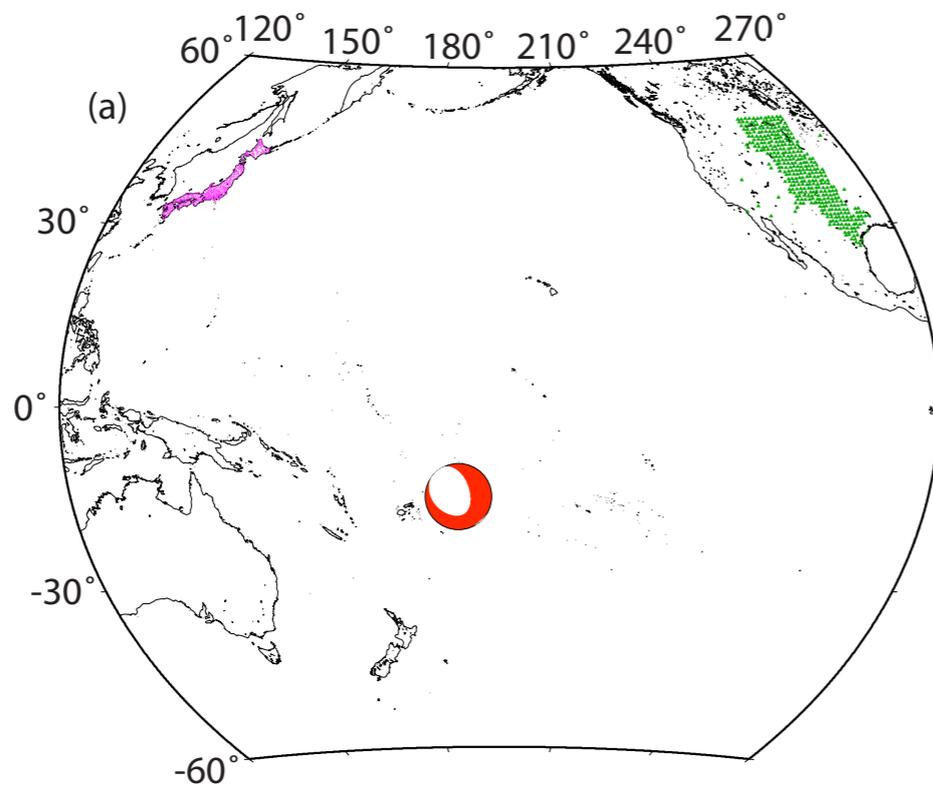
Hi-net



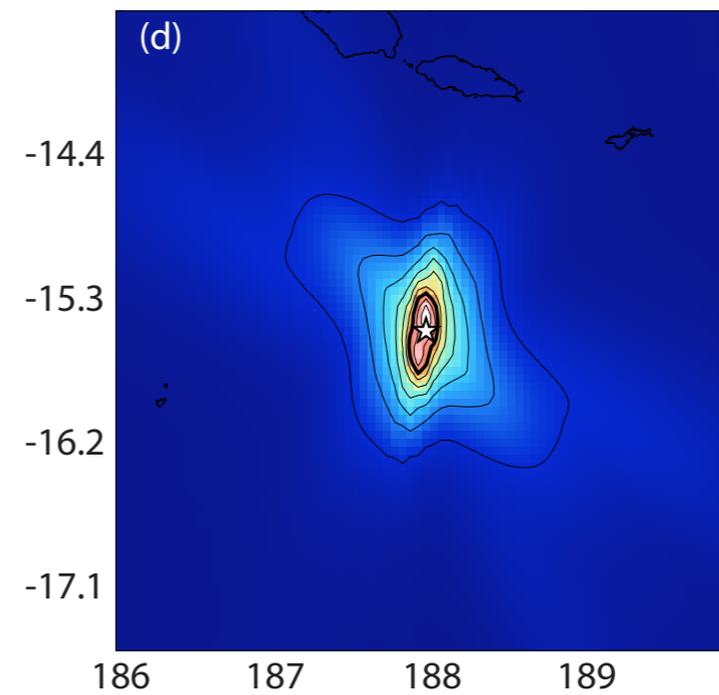
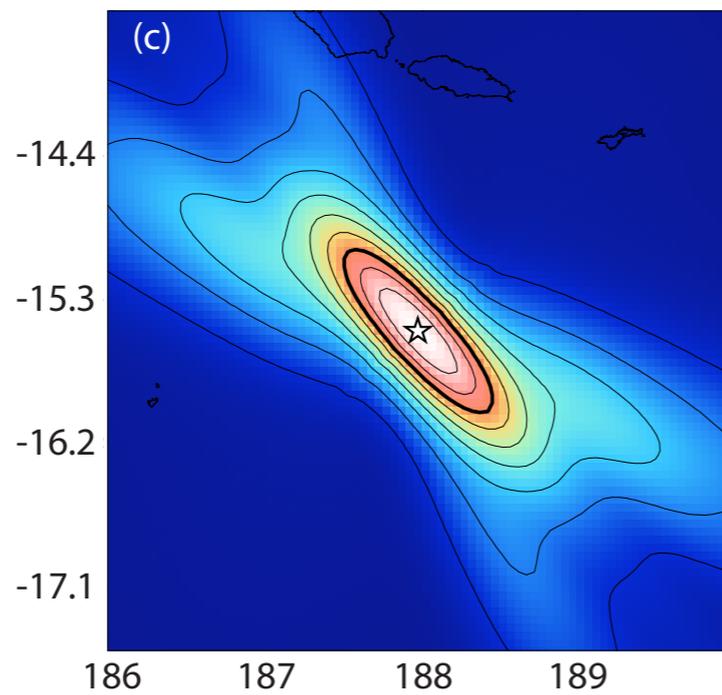
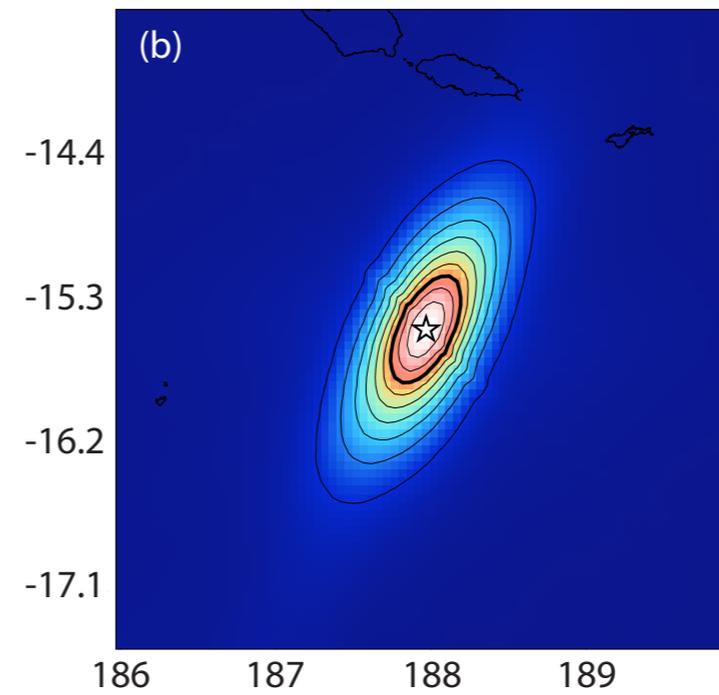
TA



Both



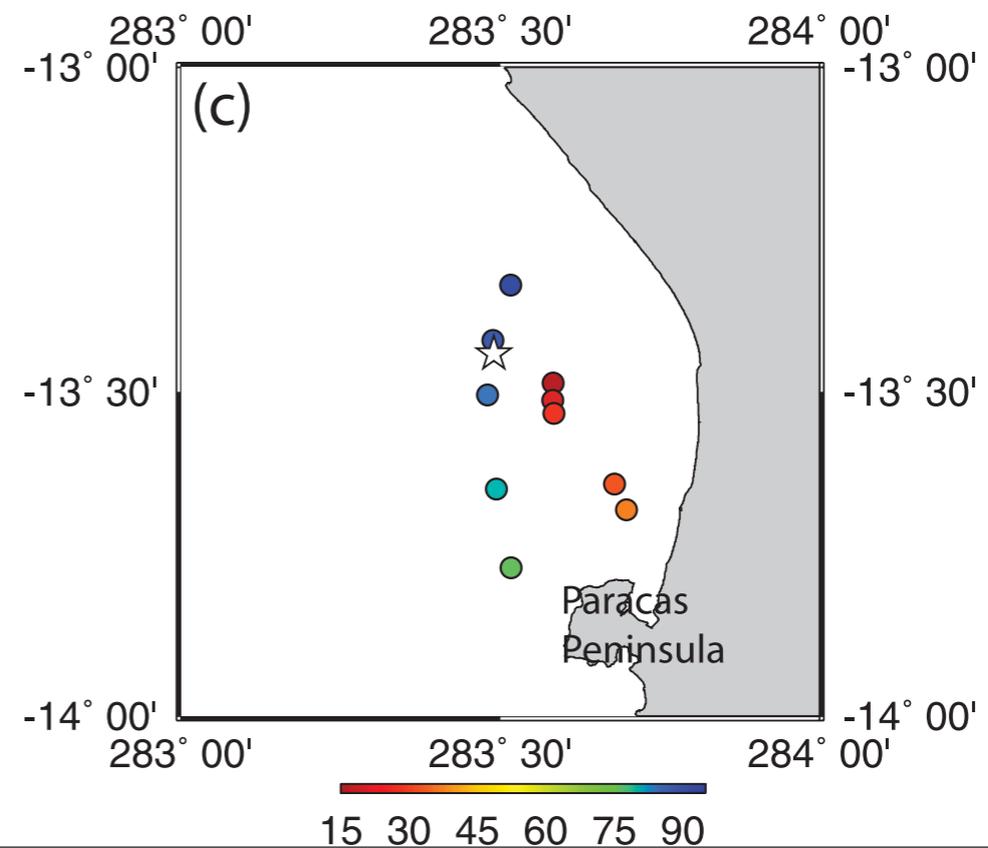
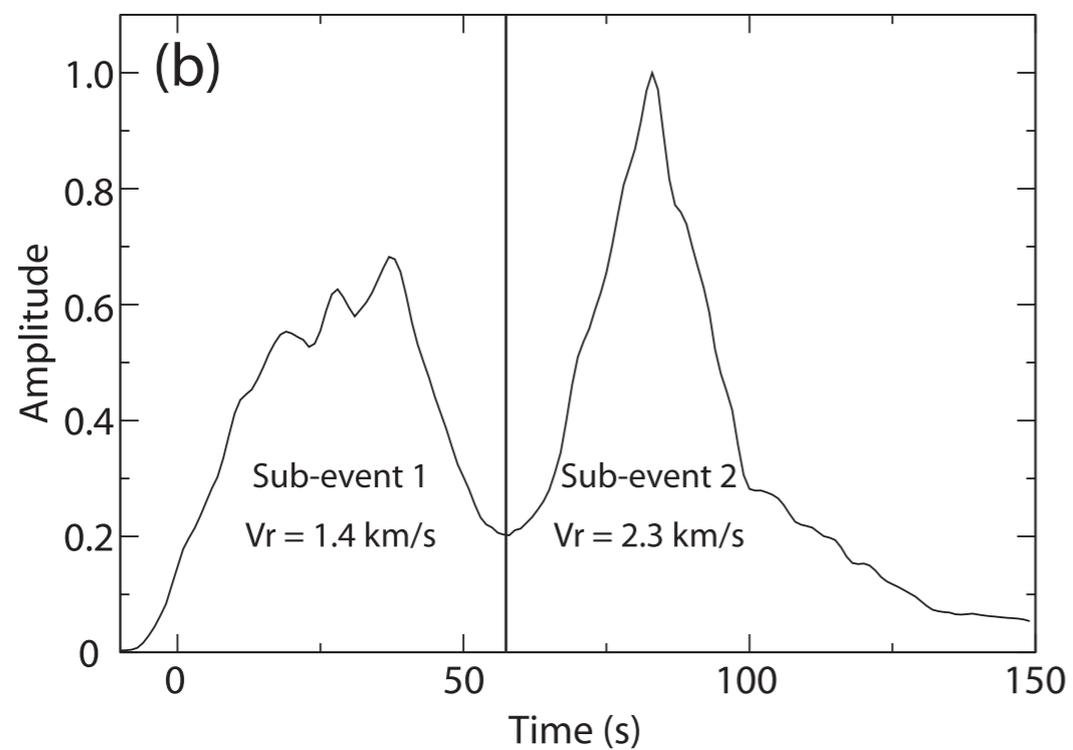
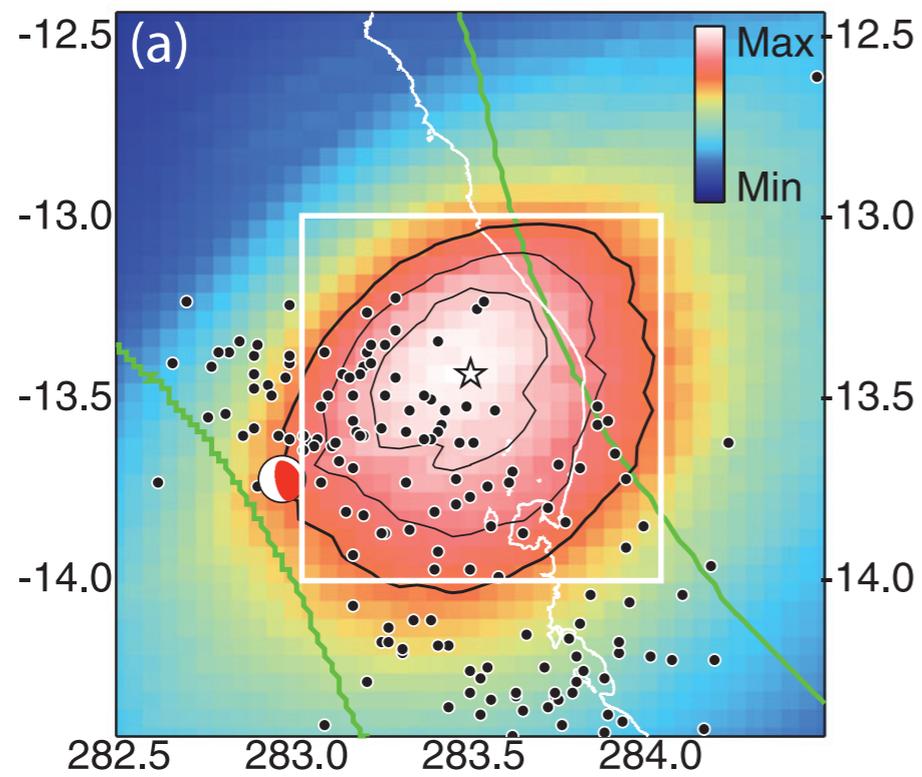
TA



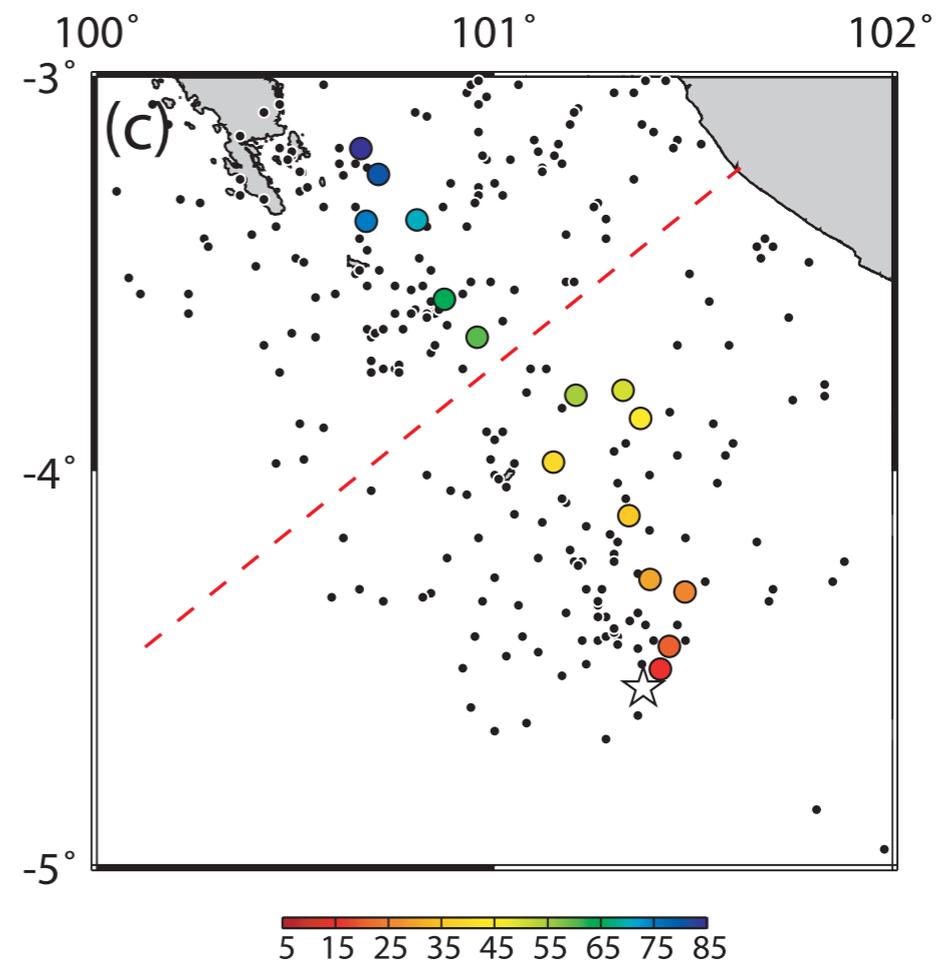
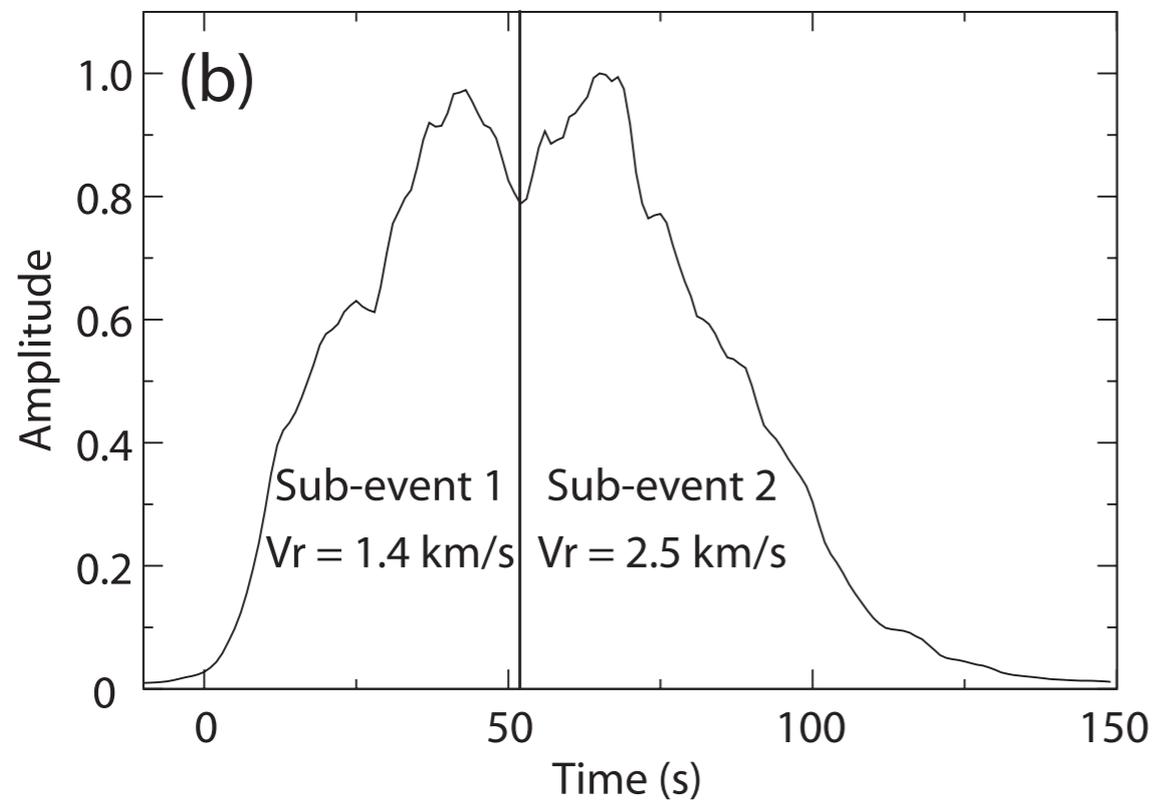
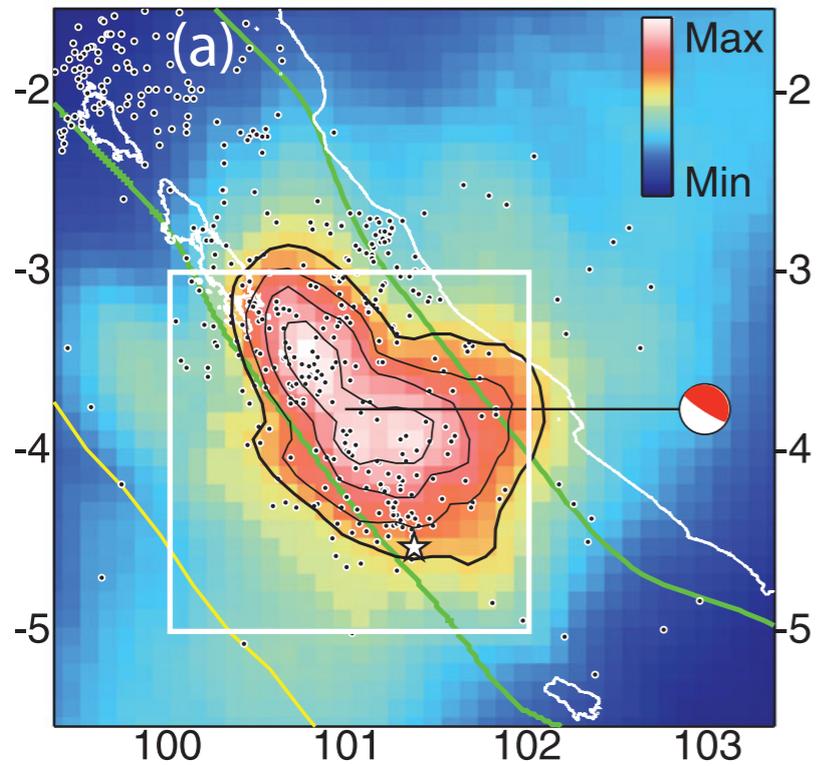
Hi-net

Both

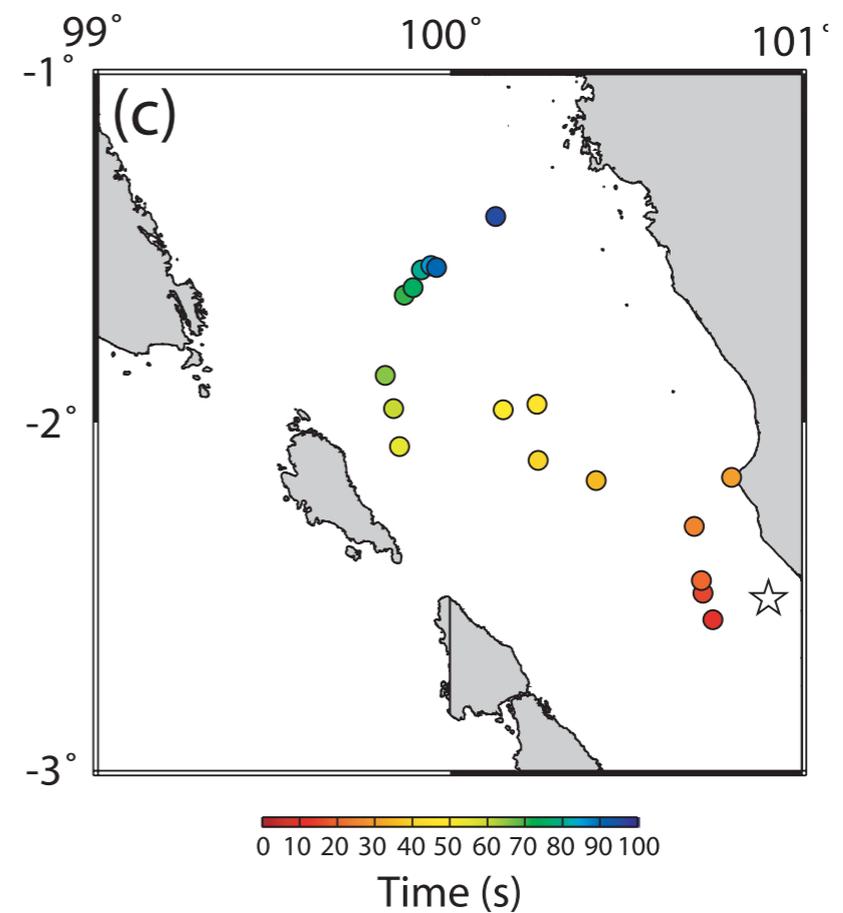
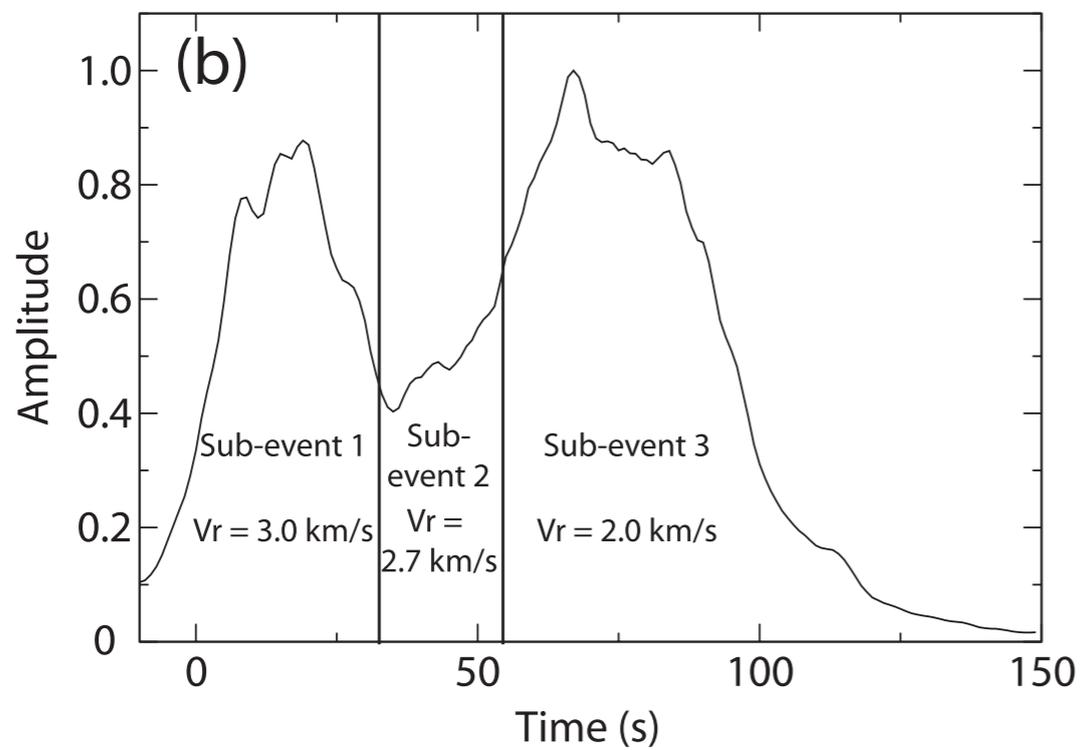
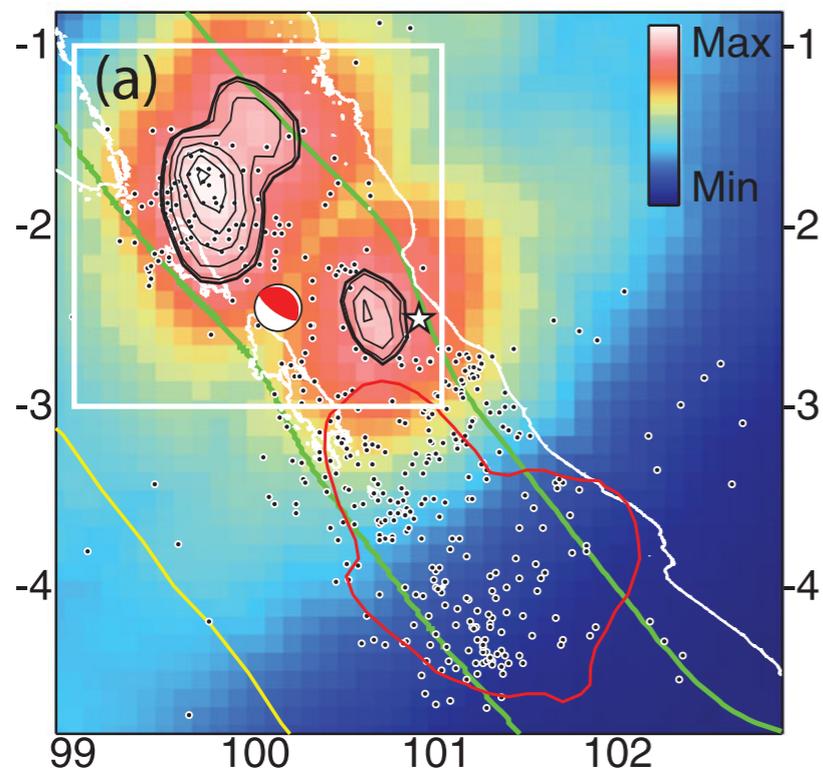
Pisco, Peru, 2007



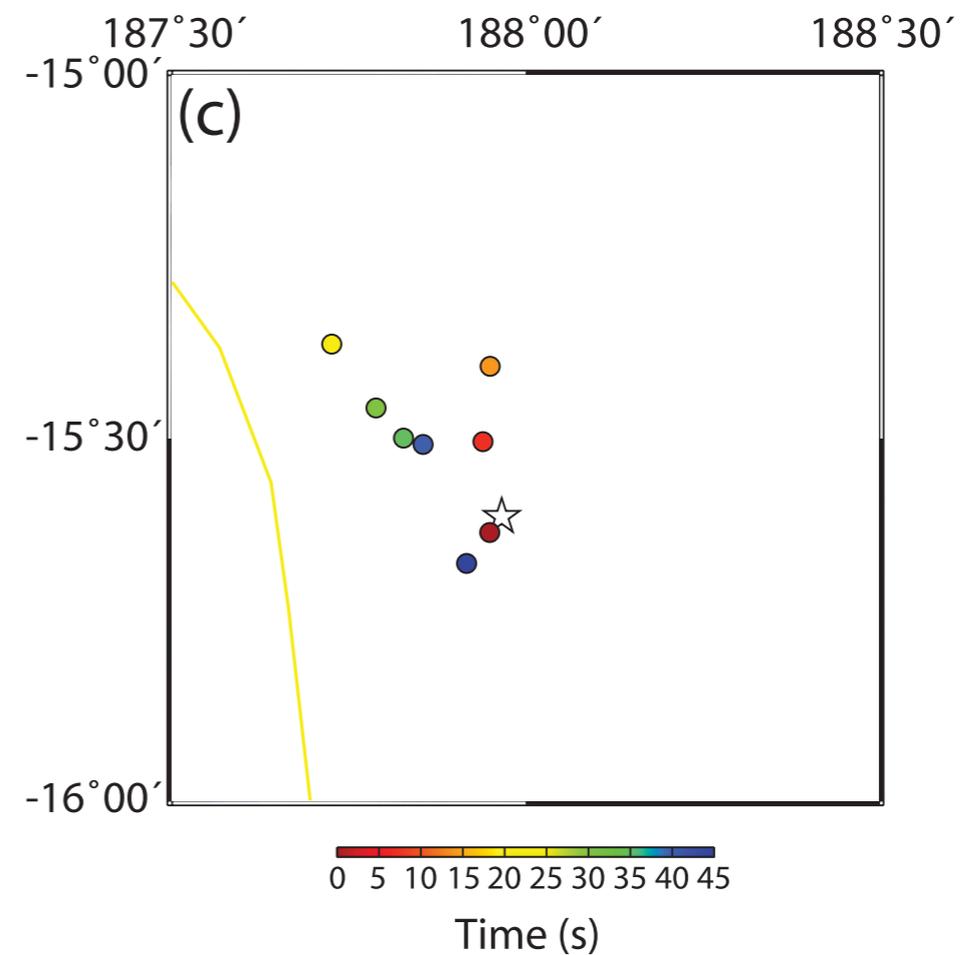
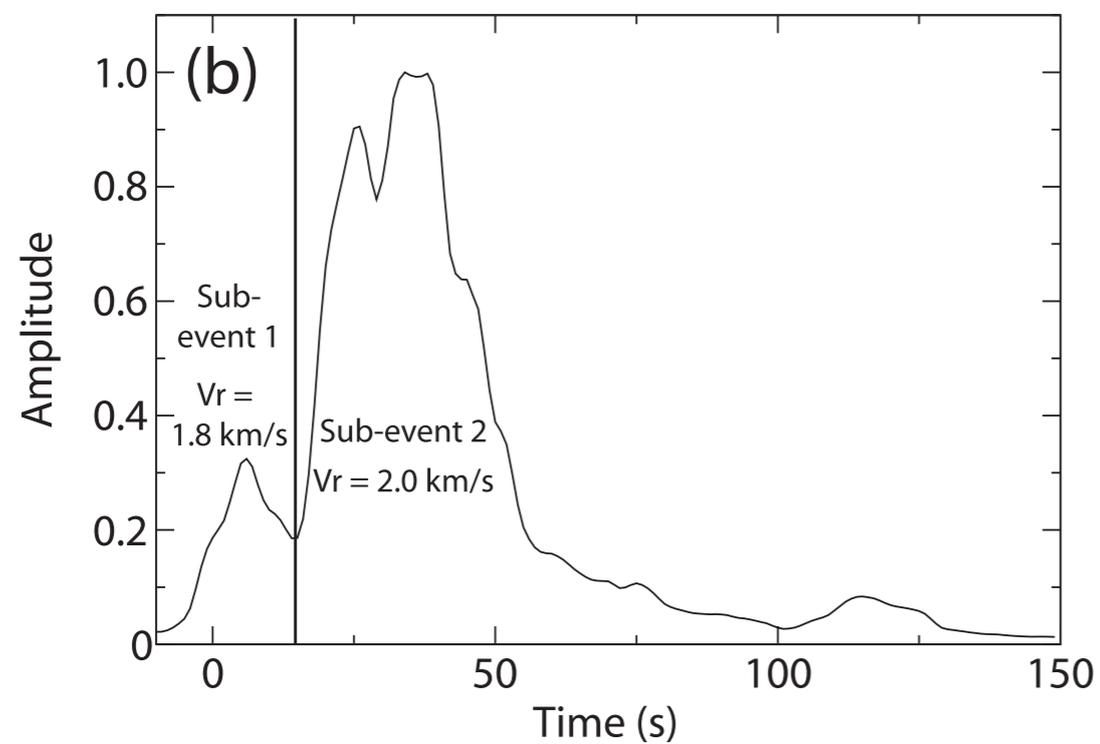
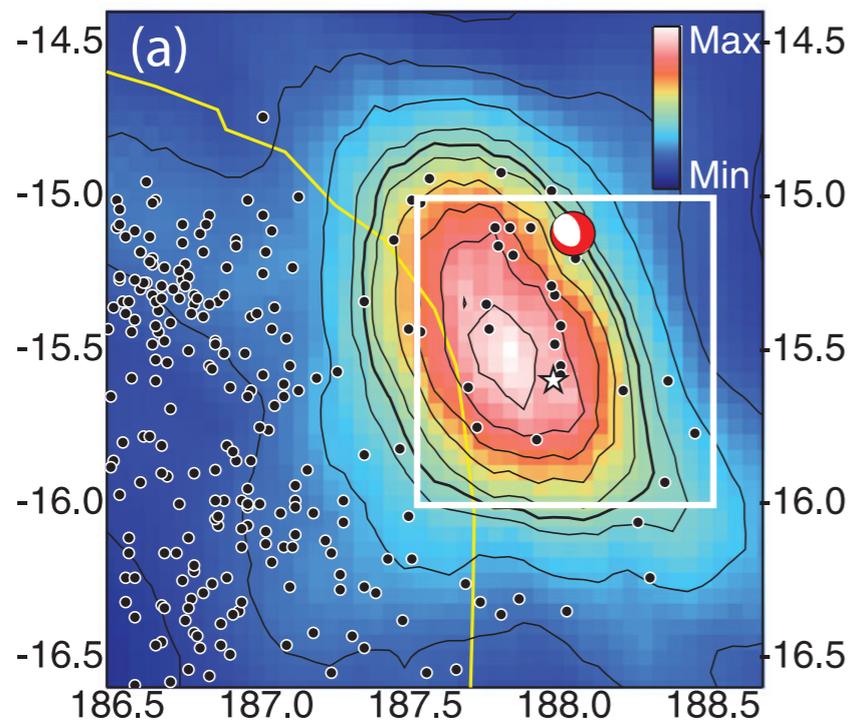
Mentawai Islands I, 2008



Mentawai Islands II, 2008

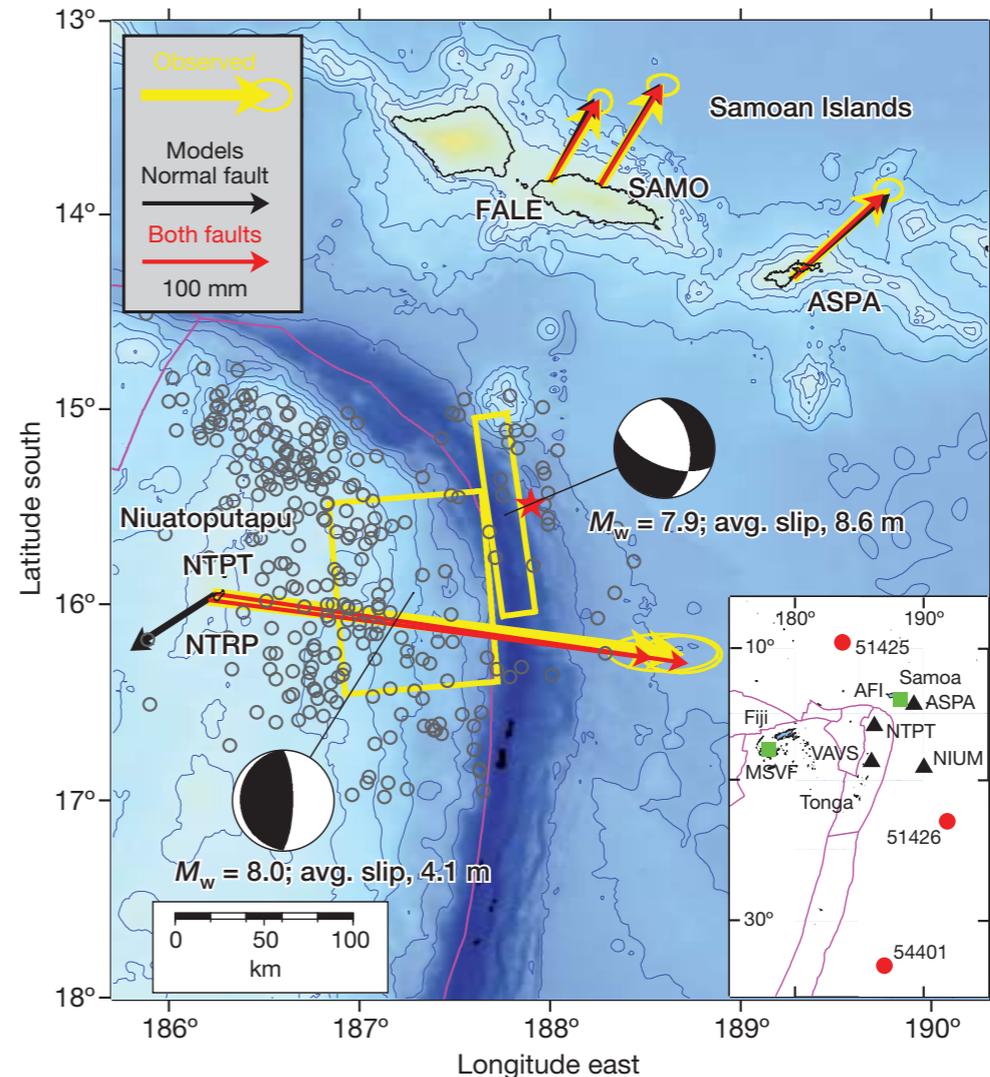
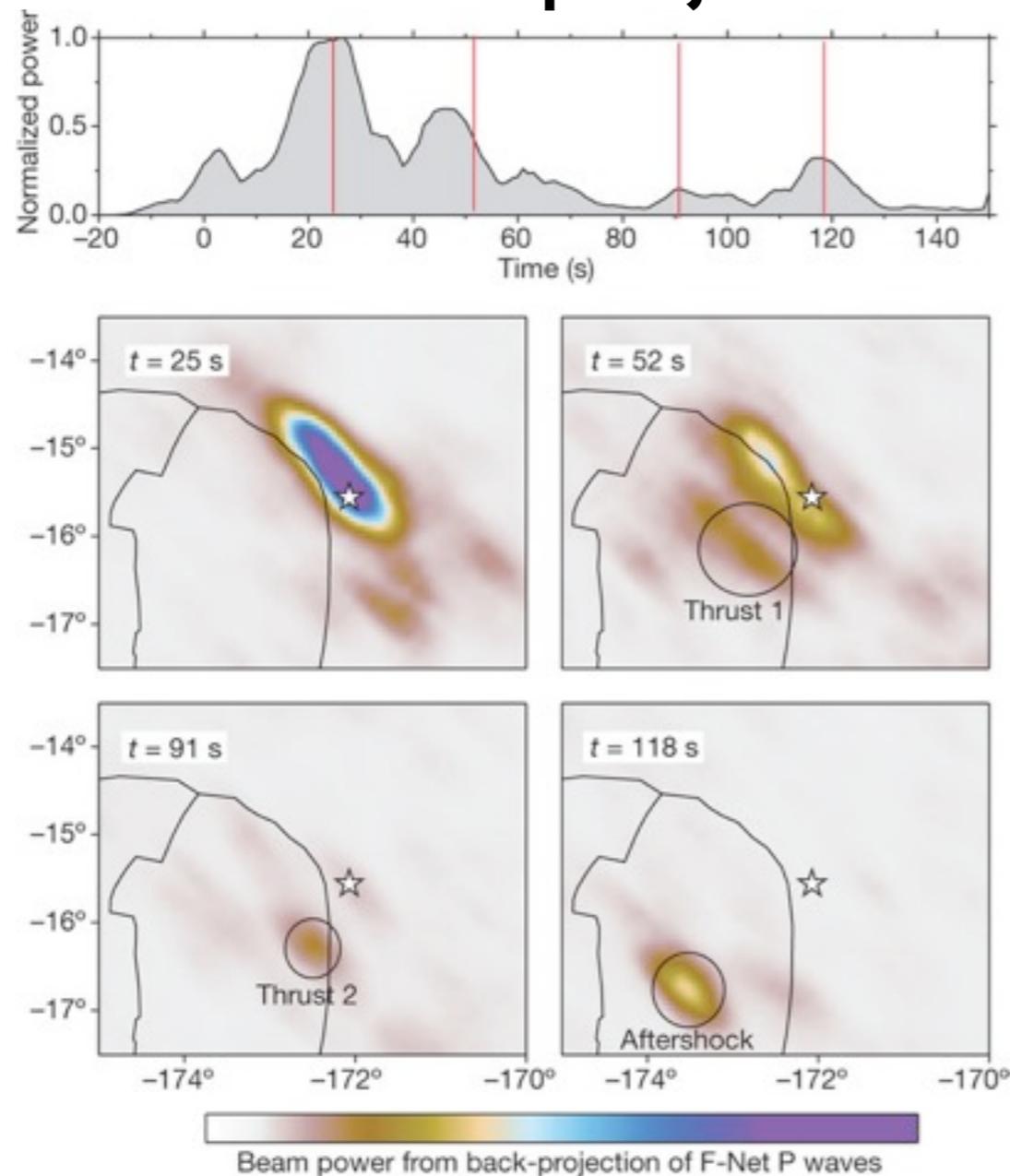


Samoa Islands, 2009



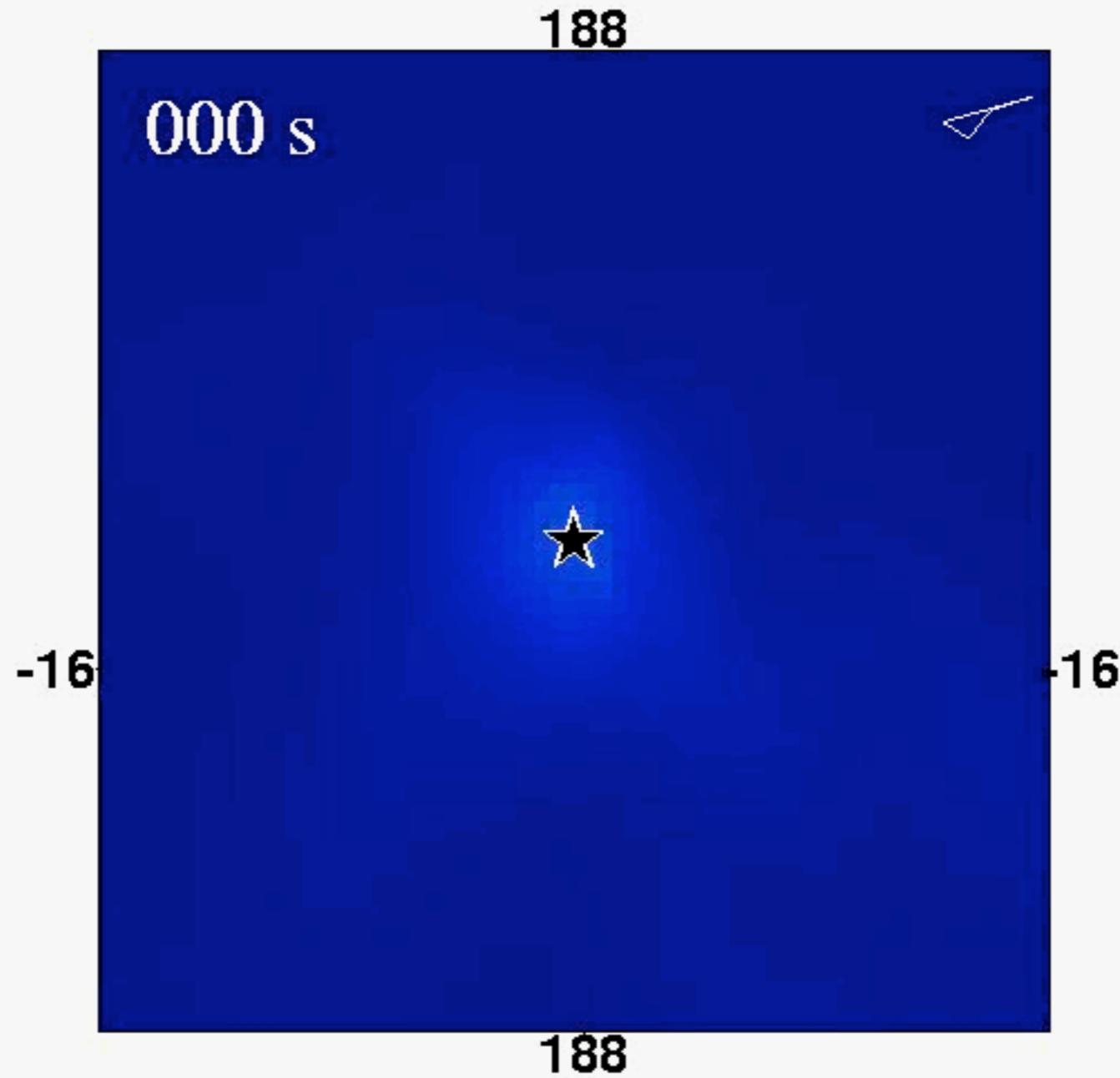
Outer rise normal + thrust events?

Lay et al. 2010
 .2-3Hz back projection

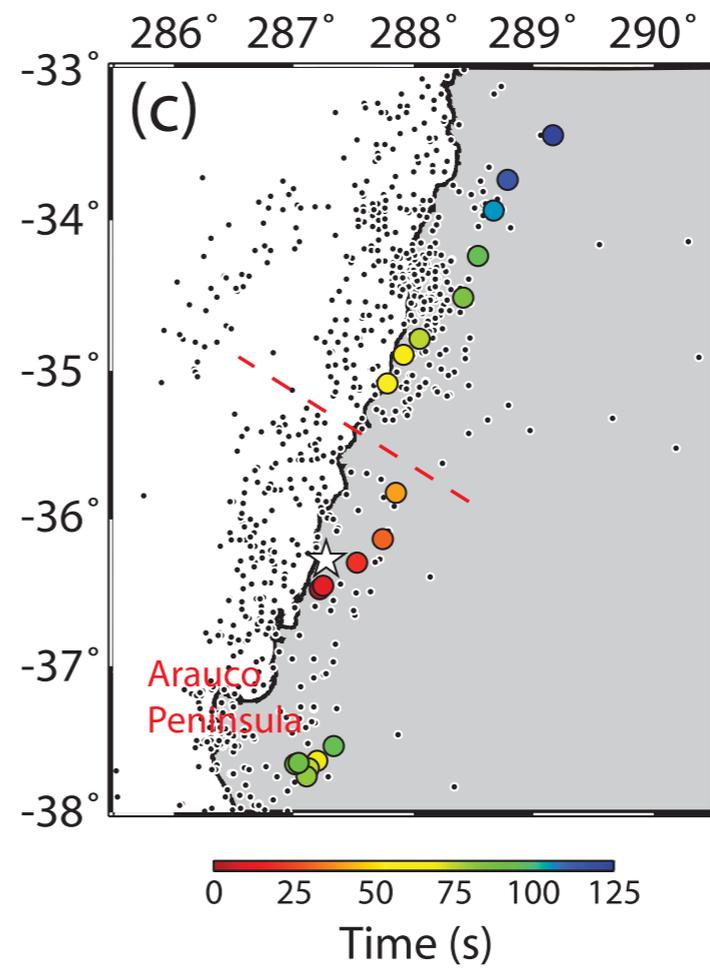
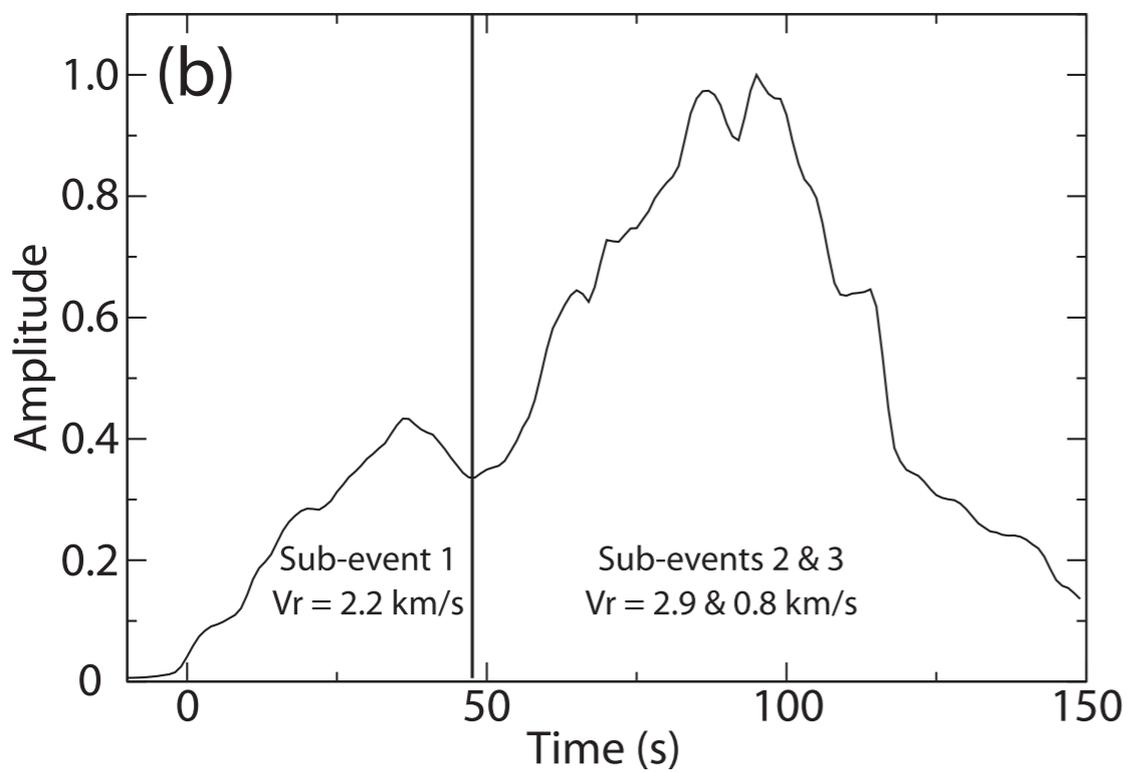
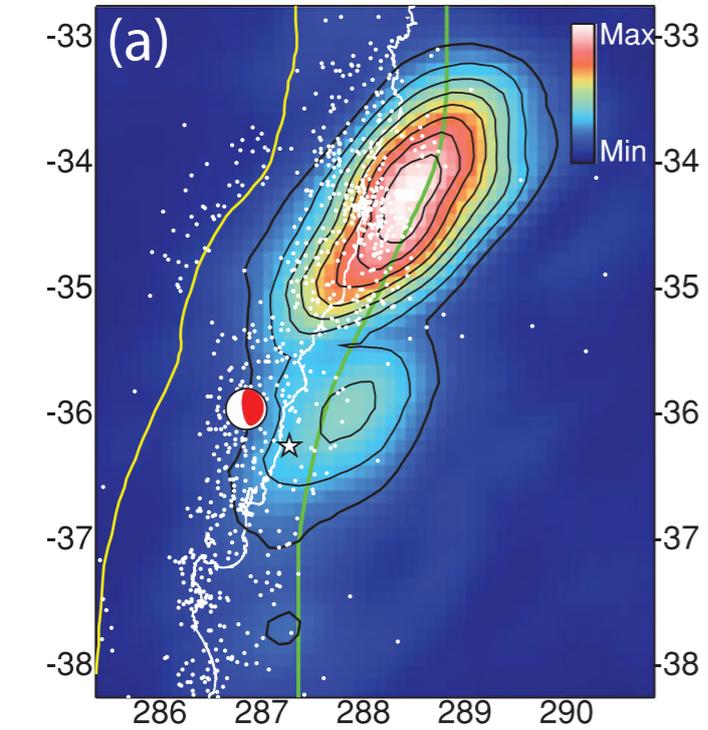


Beavan et al. 2010

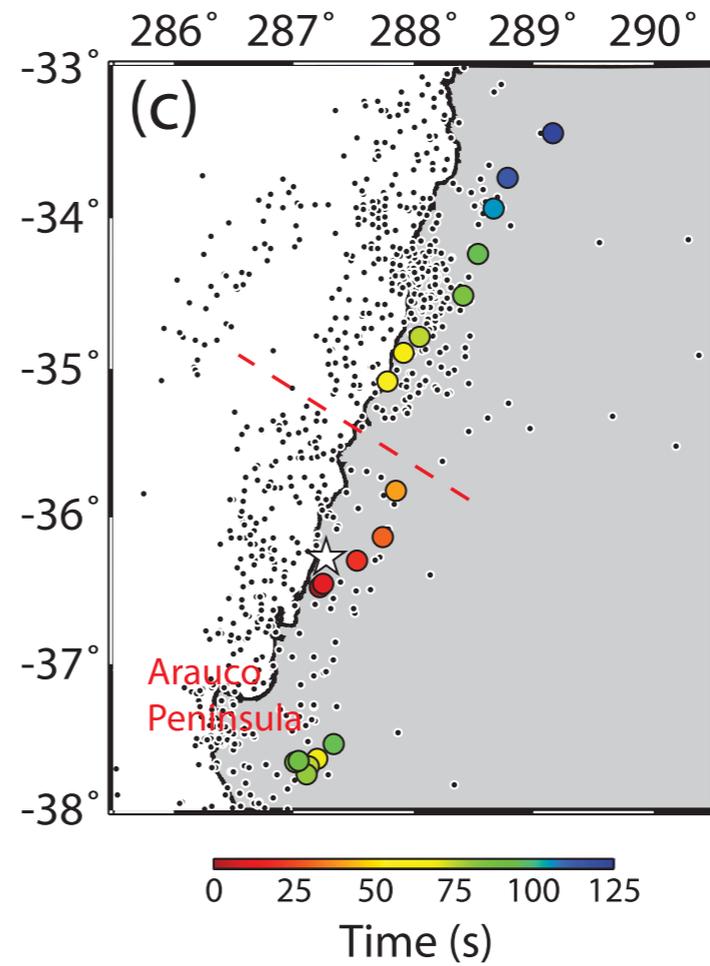
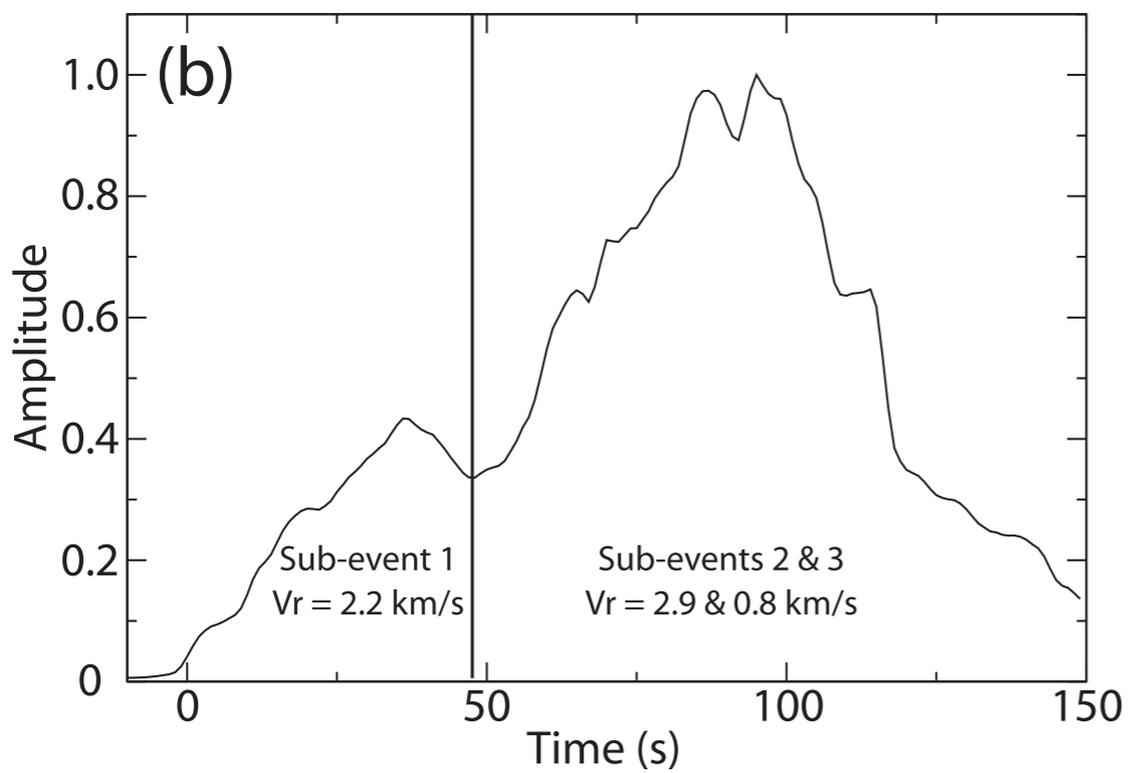
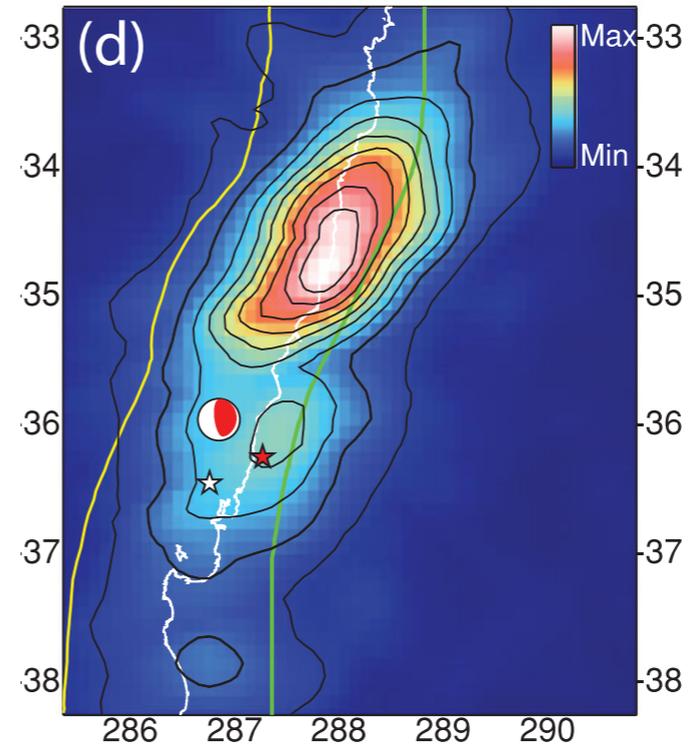
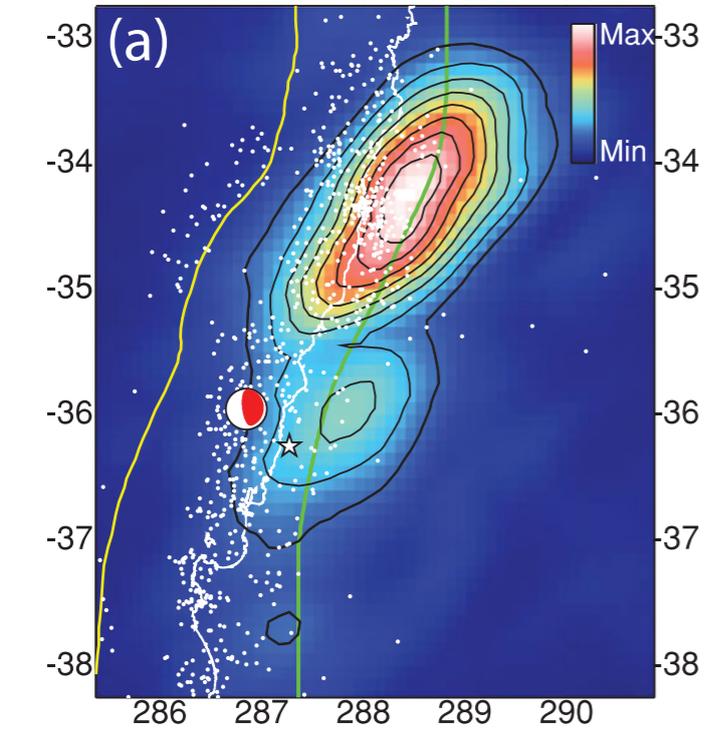
Samoa Islands, 2009



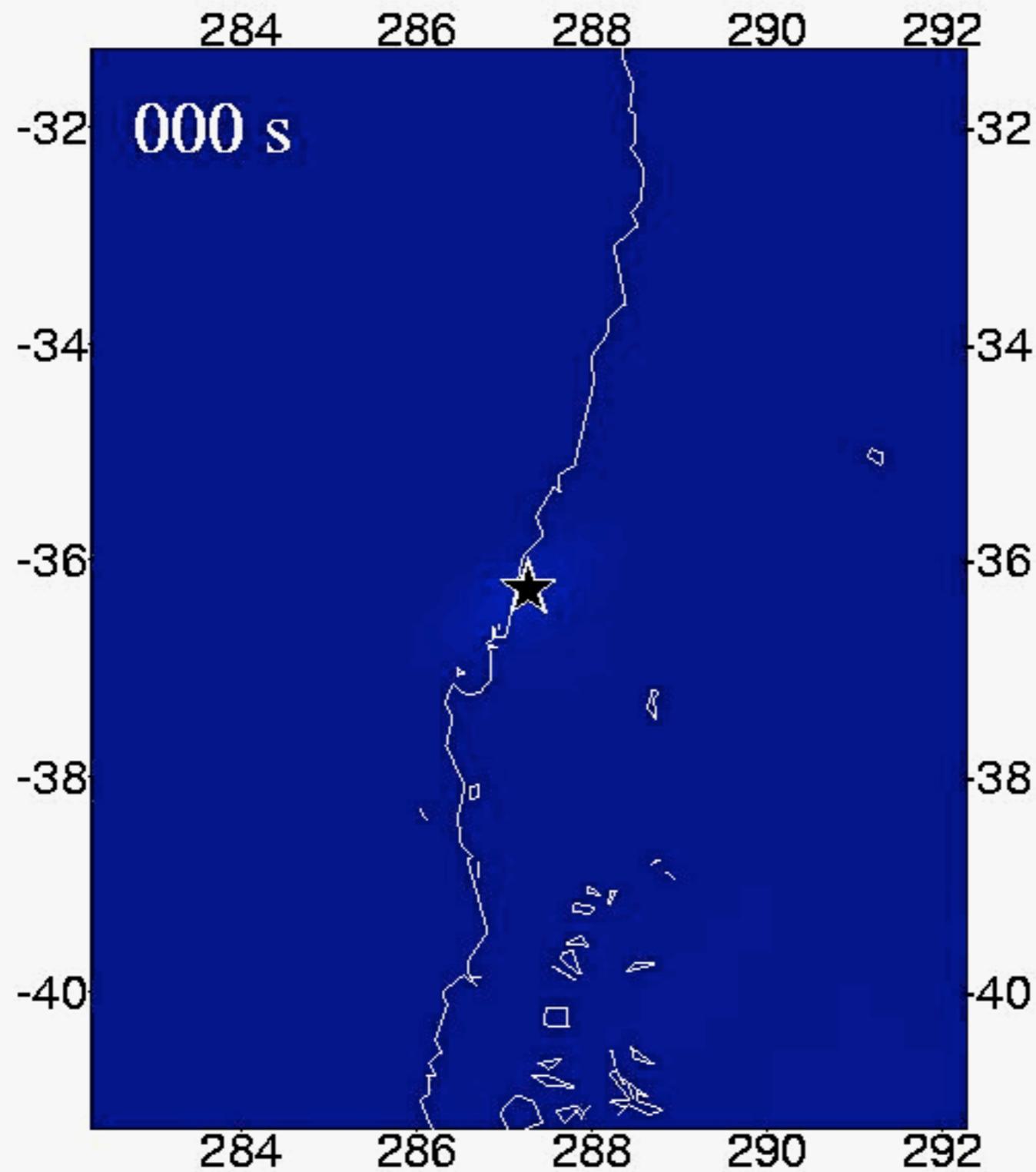
Maule, Chili, 2010



Maule, Chili, 2010



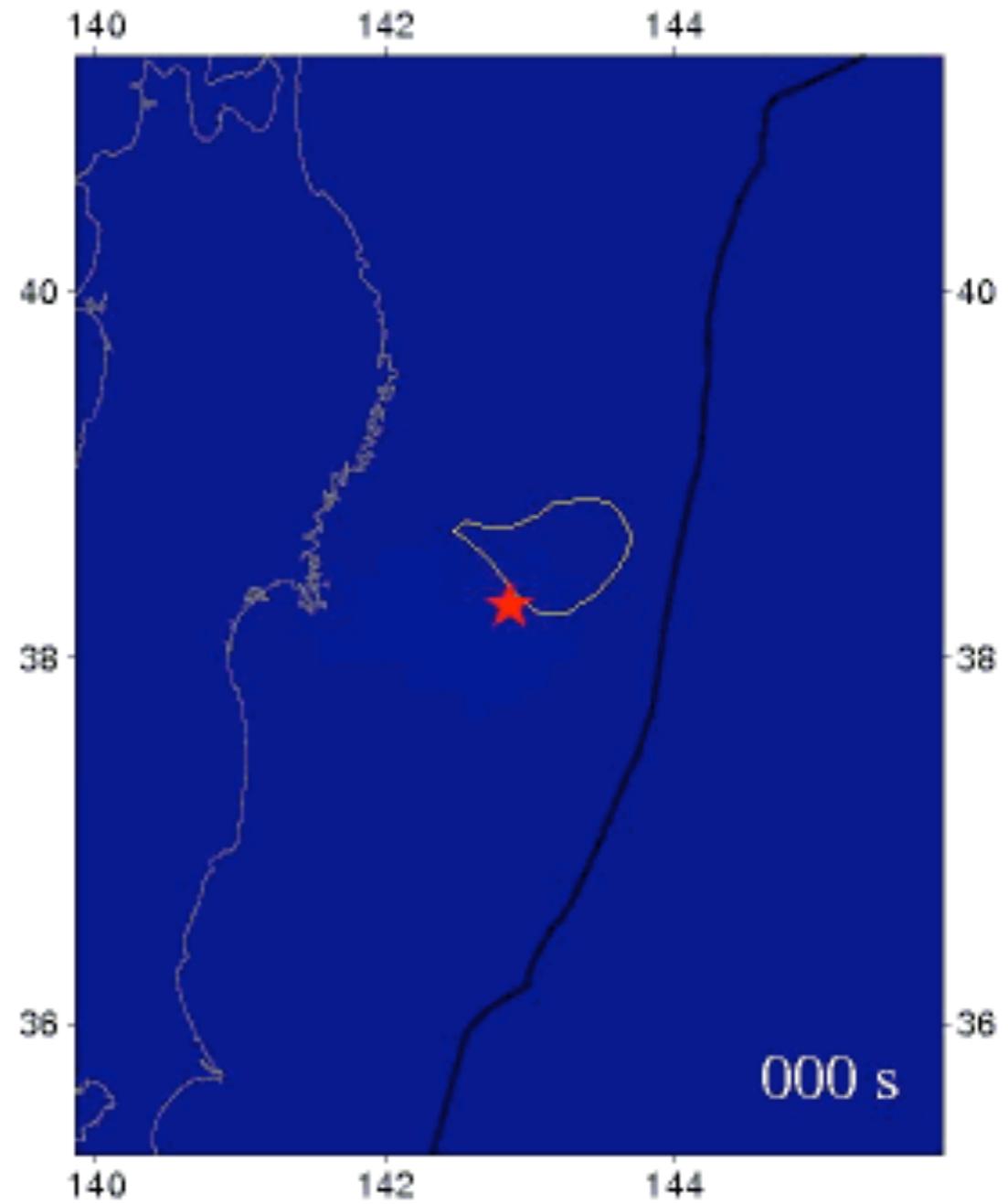
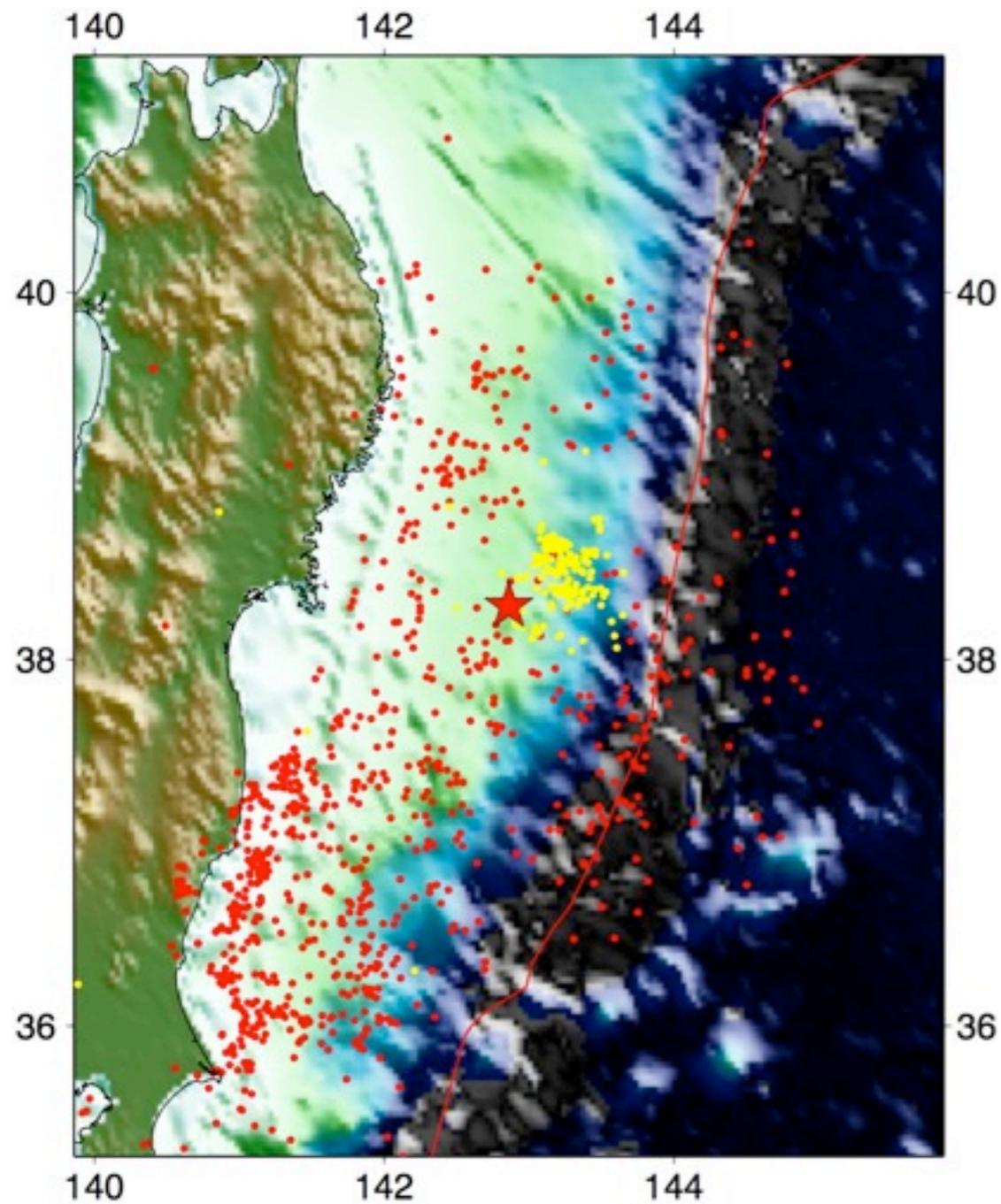
Maule, TA data only

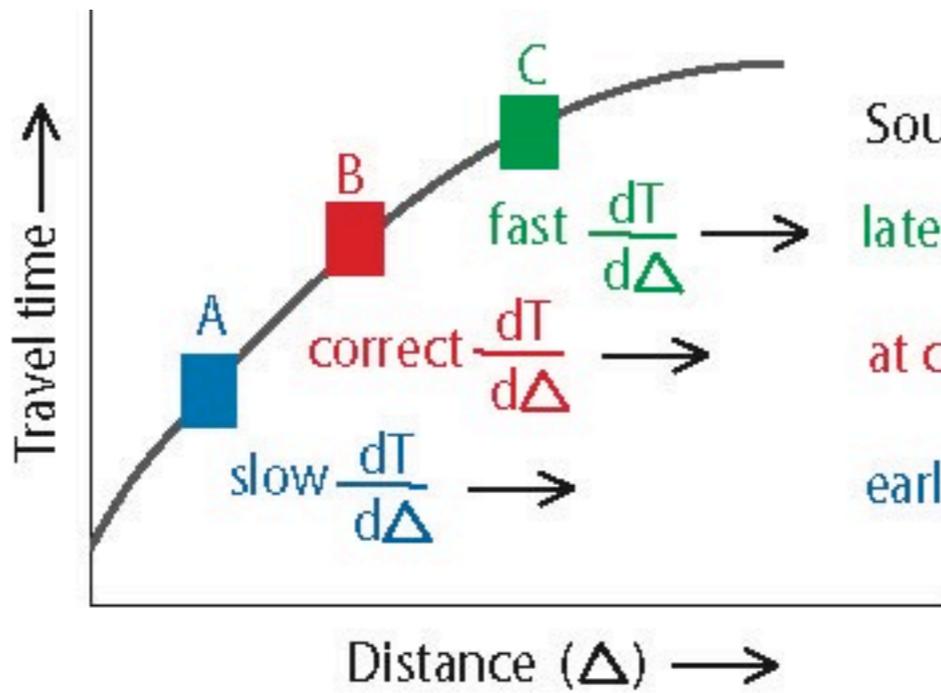


Conclusions

- Multiple arrays increase lateral resolution.
- Events are segmented in subevents with varying rupture directions and speeds.
- In some cases there is a gap in the rupture, suggesting multiple fault segments are triggered by an adjacent fault segment.
- Ruptures for the four subduction events propagate towards the bottom of the seismogenic zone.

Tohoku 2011





Source image forms:

late and close

at correct time and place

early and far

