



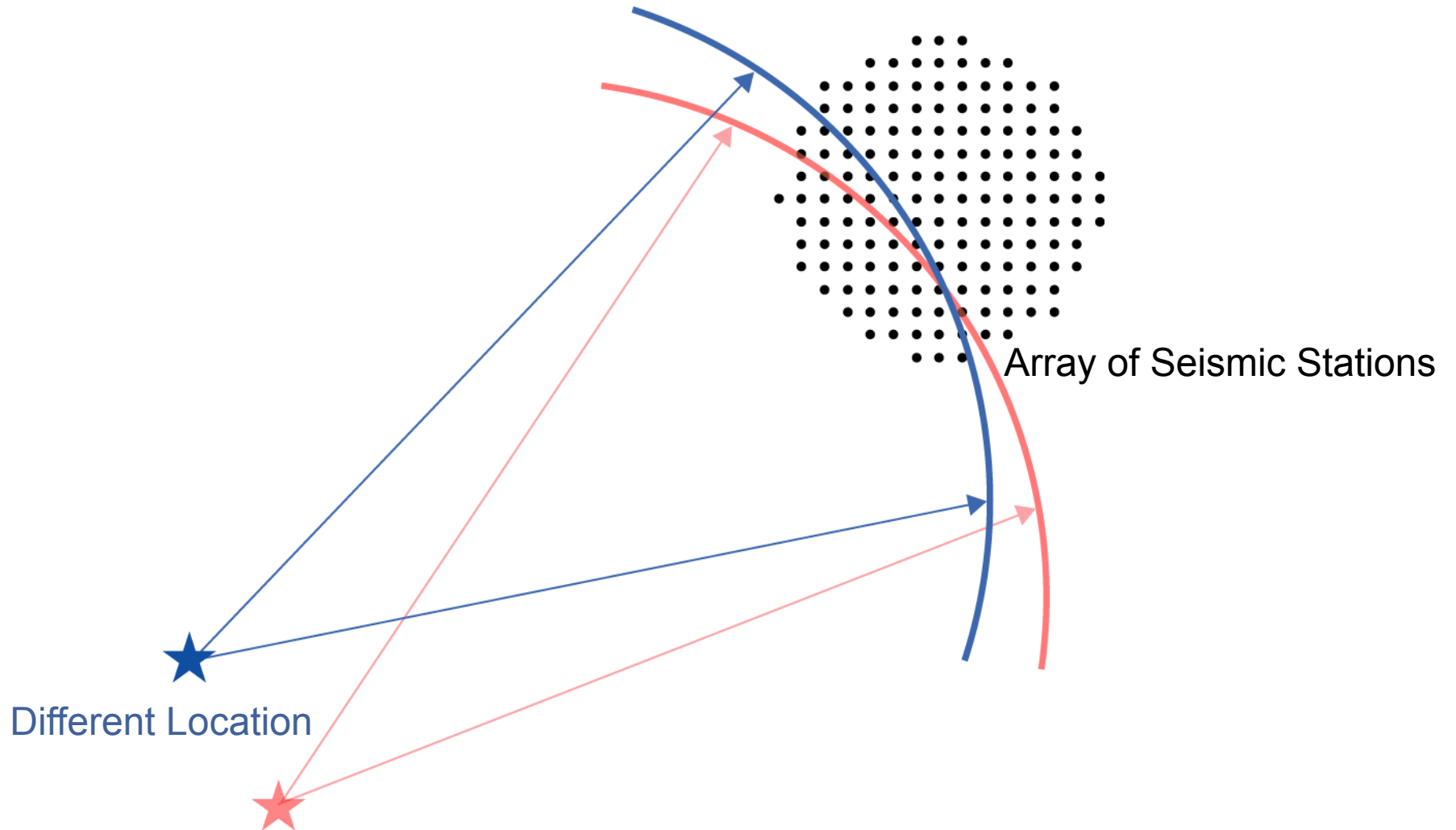
How to Hide Earthquakes

- Hidden Earthquakes
 - Back-Projection Method
 - 2011 Japan Sequence
 - Spatial Distribution
- Why Are They Hidden?

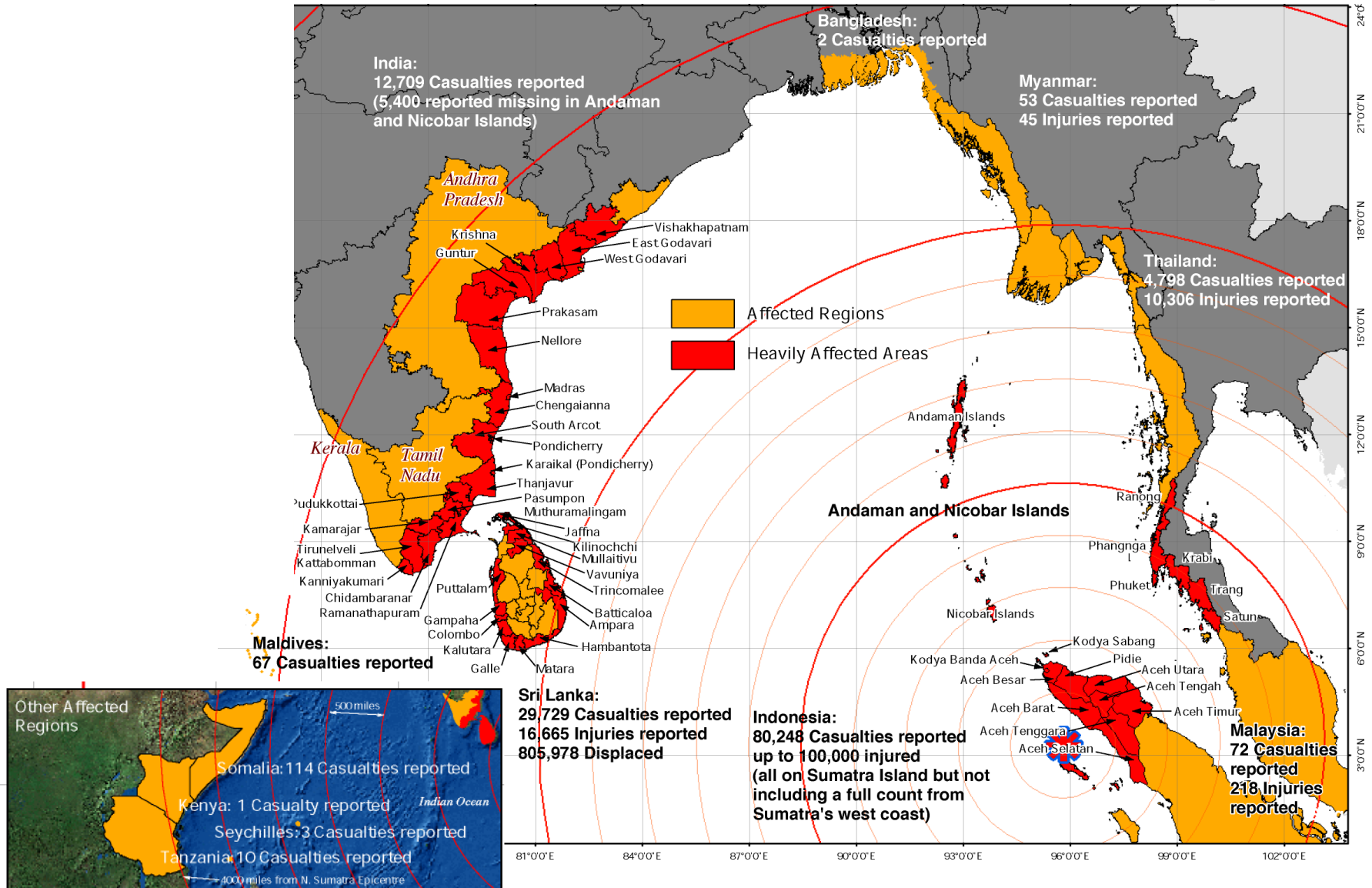
Miaki Ishii, Eric Kiser & Petros Bogiatzis
Dept. Earth & Planetary Sciences, Harvard University
Dept. Earth Science, Rice University

4th QUEST Workshop
May 22, 2013

Seismic Wavefront and Seismic Array

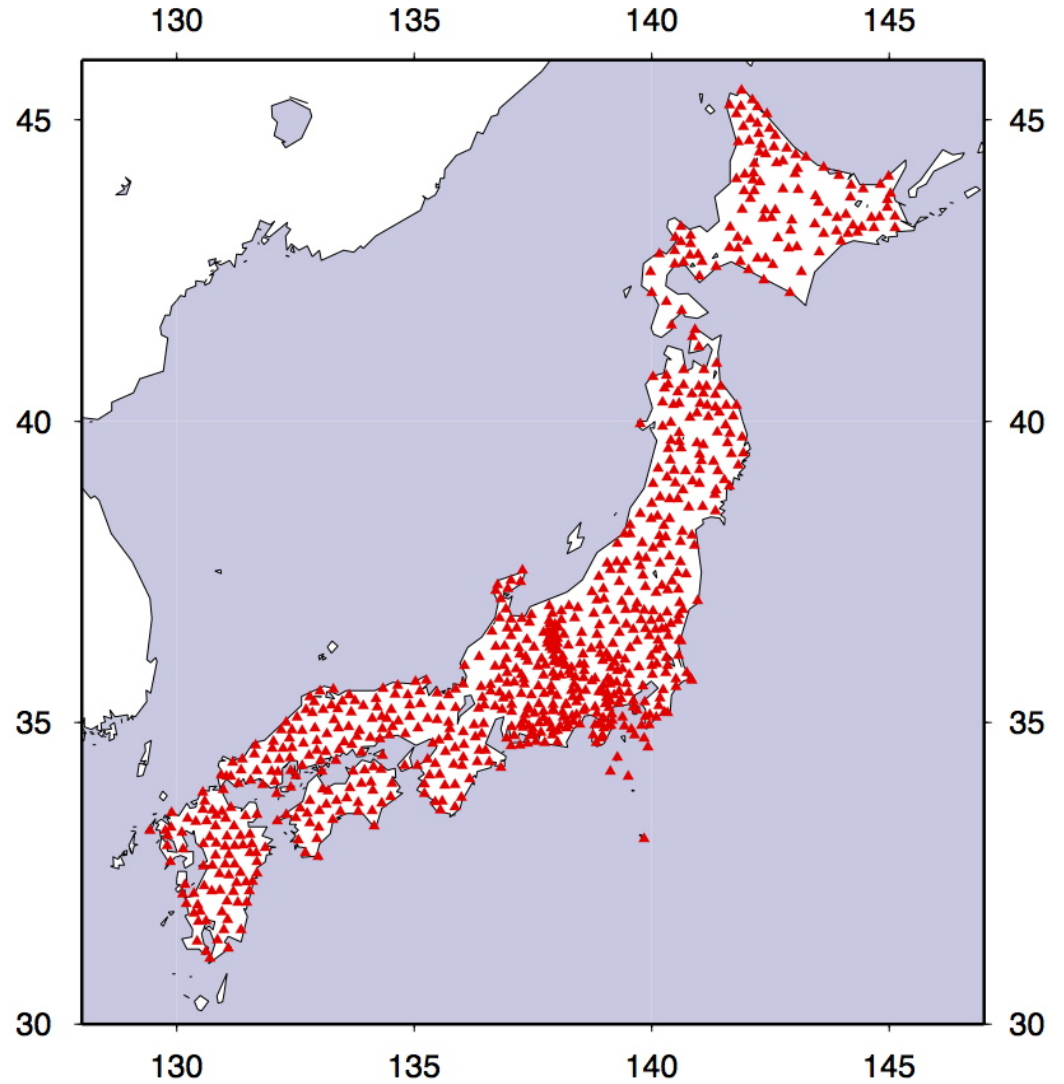


2004 Mw 9.3 Sumatra-Andaman Earthquake

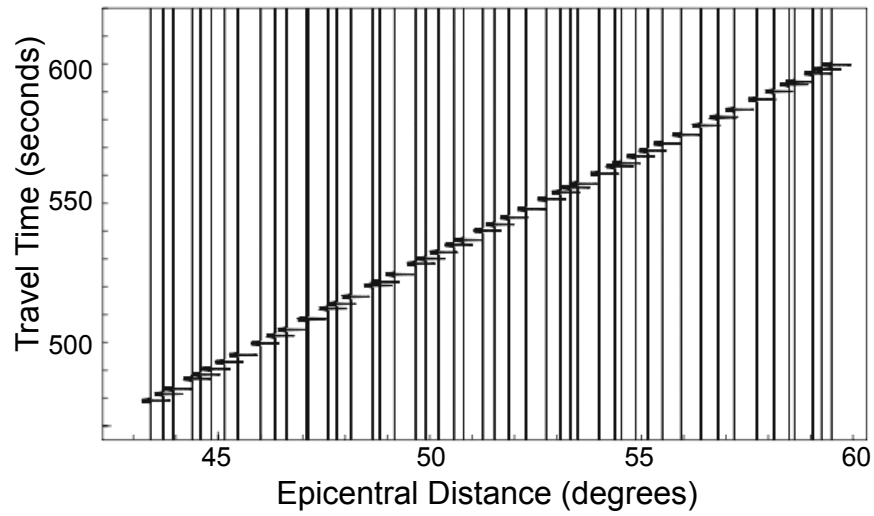


Hi-net Array in Japan

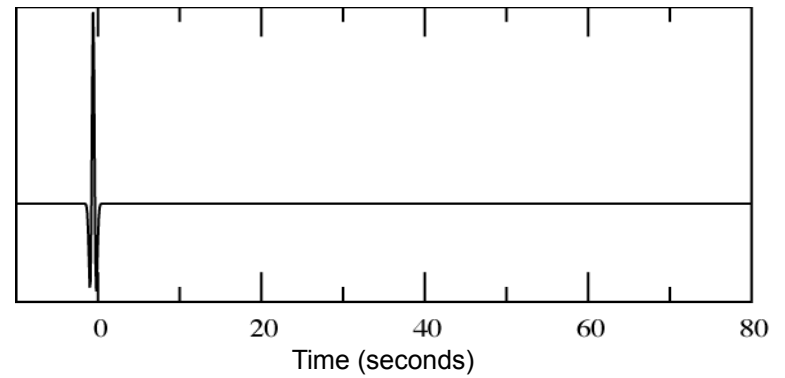
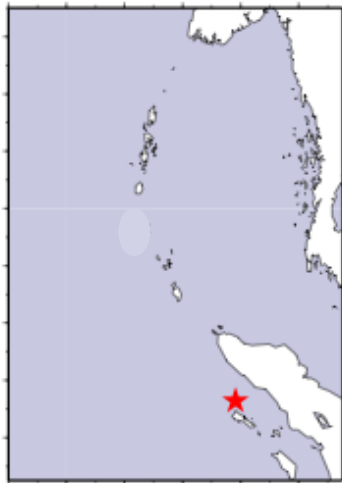
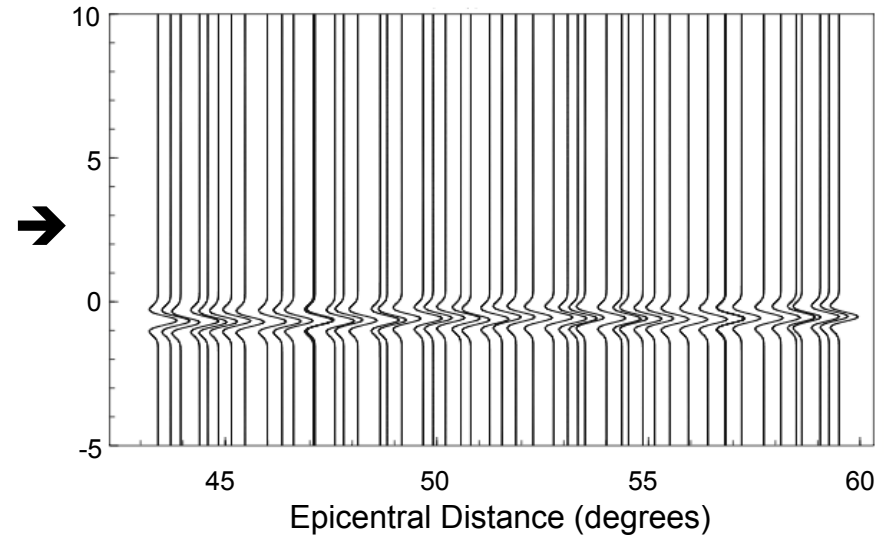
- ~800 stations
- Borehole
- Short-period
- 3 component
- $43^\circ - 60^\circ$ from Sumatra



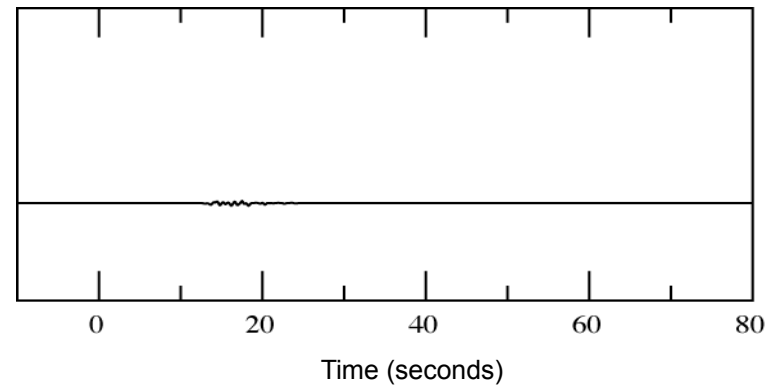
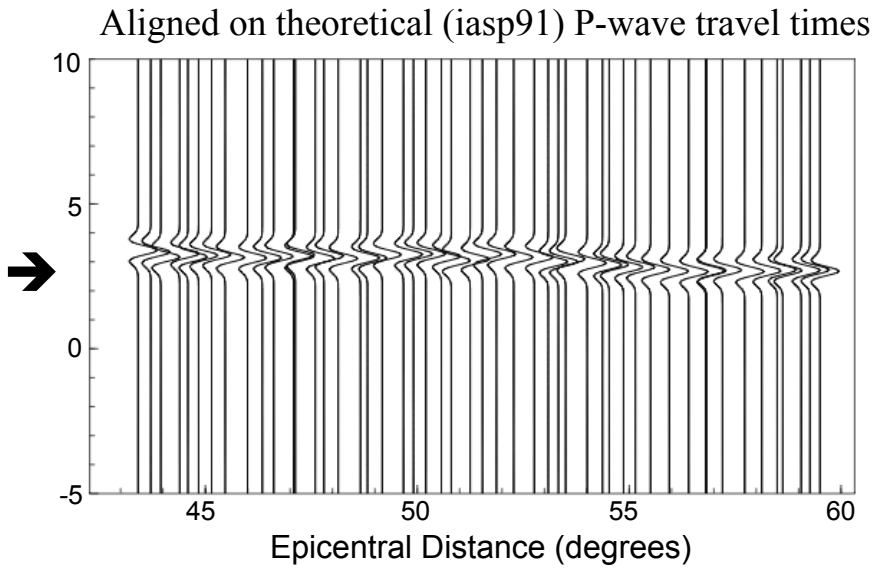
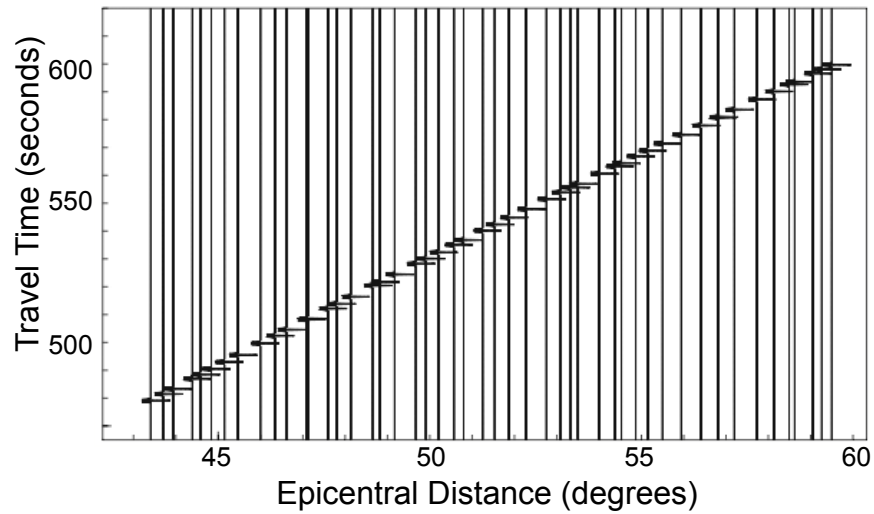
Synthetic Data



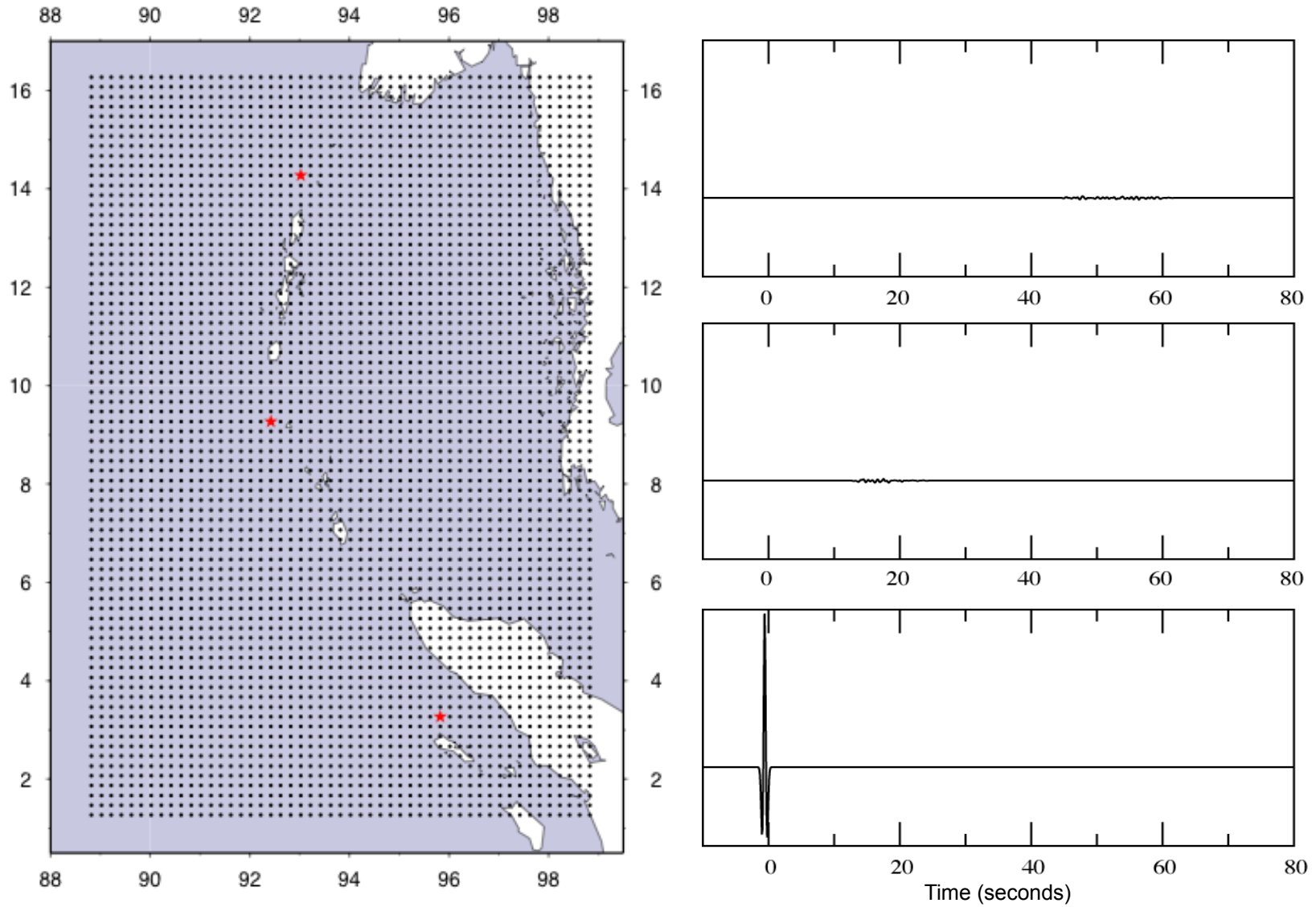
Aligned on theoretical (iasp91) P-wave travel times



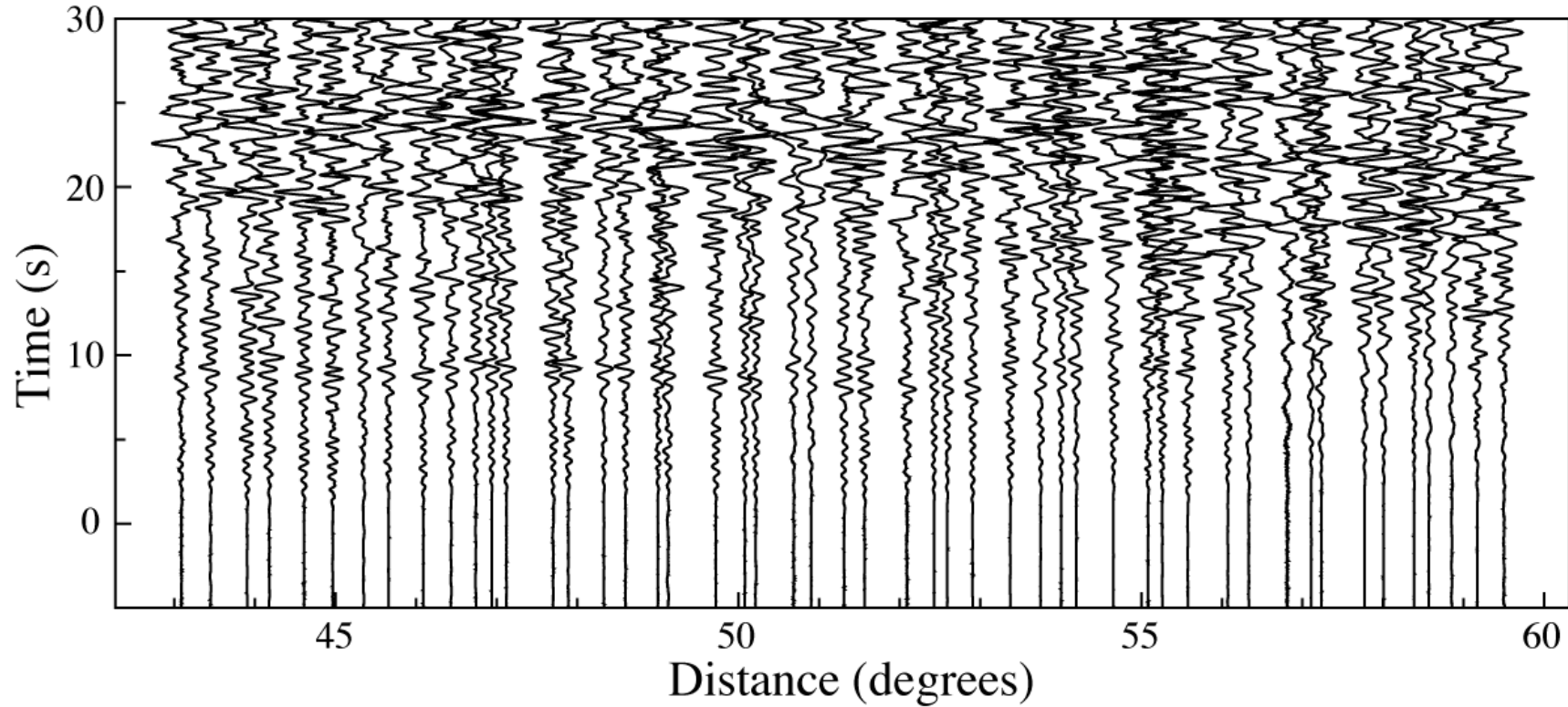
Synthetic Data (Incorrect Location)



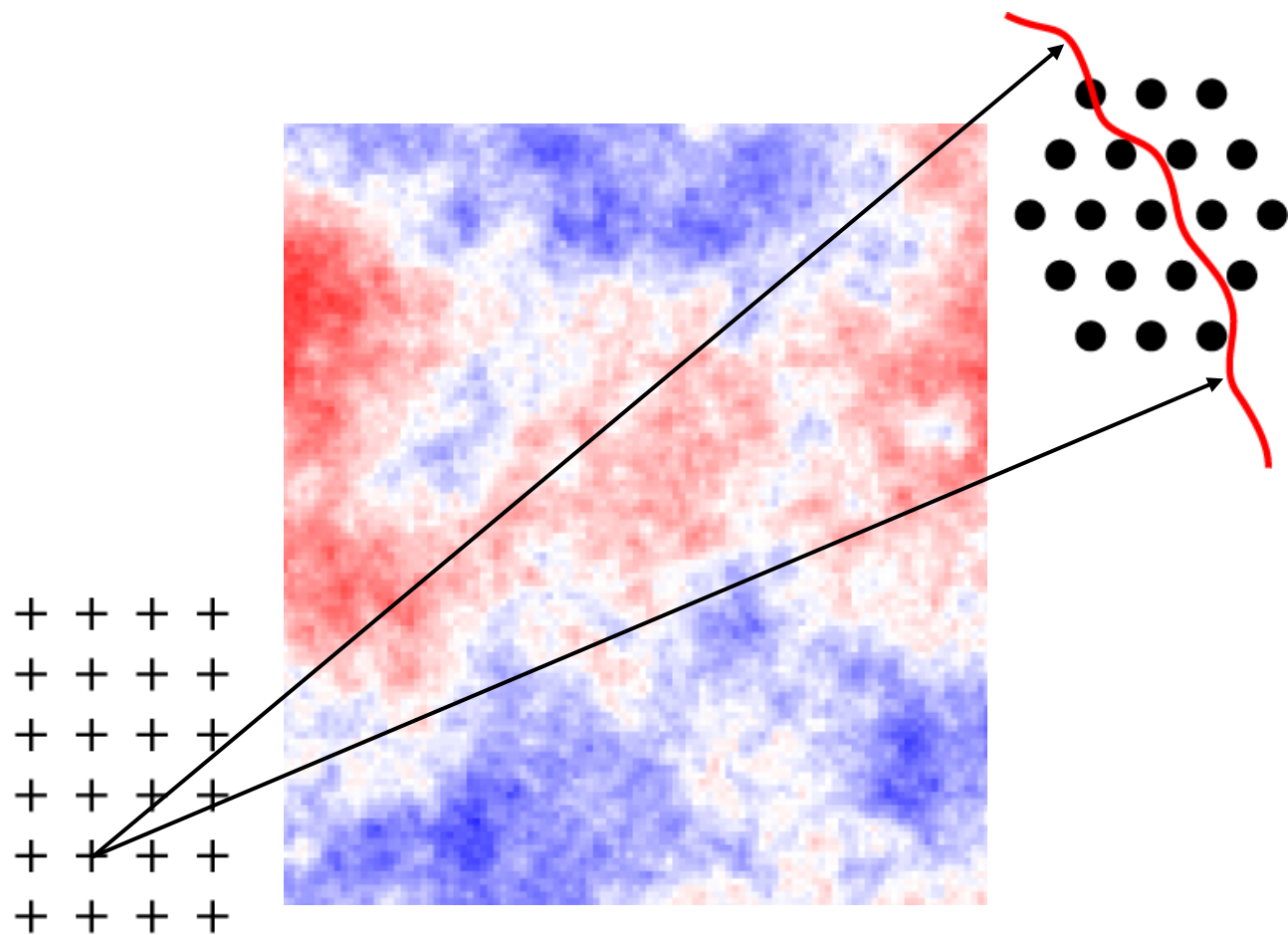
Synthetic Stacks



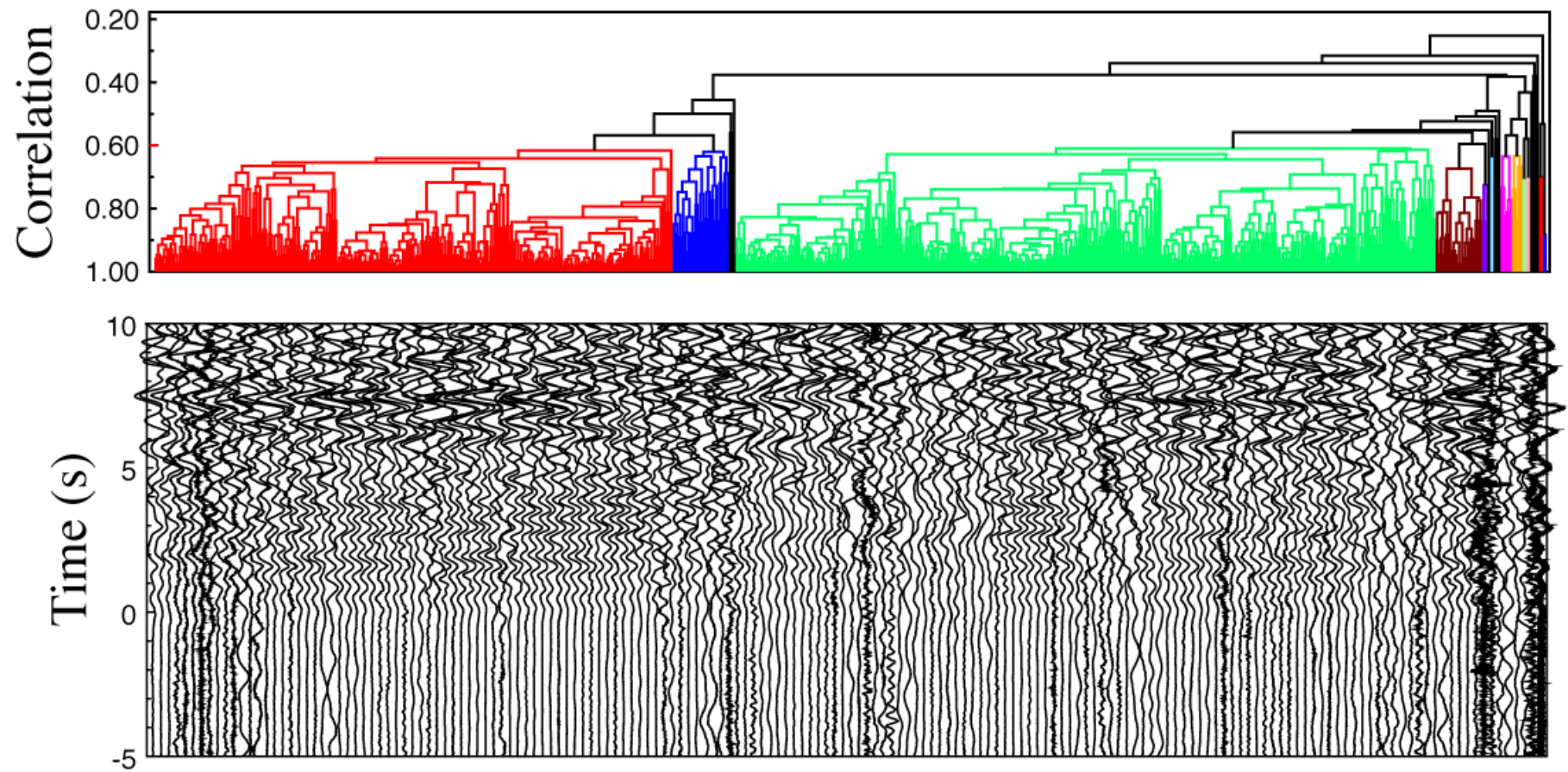
P Wave Alignment (IASP91)



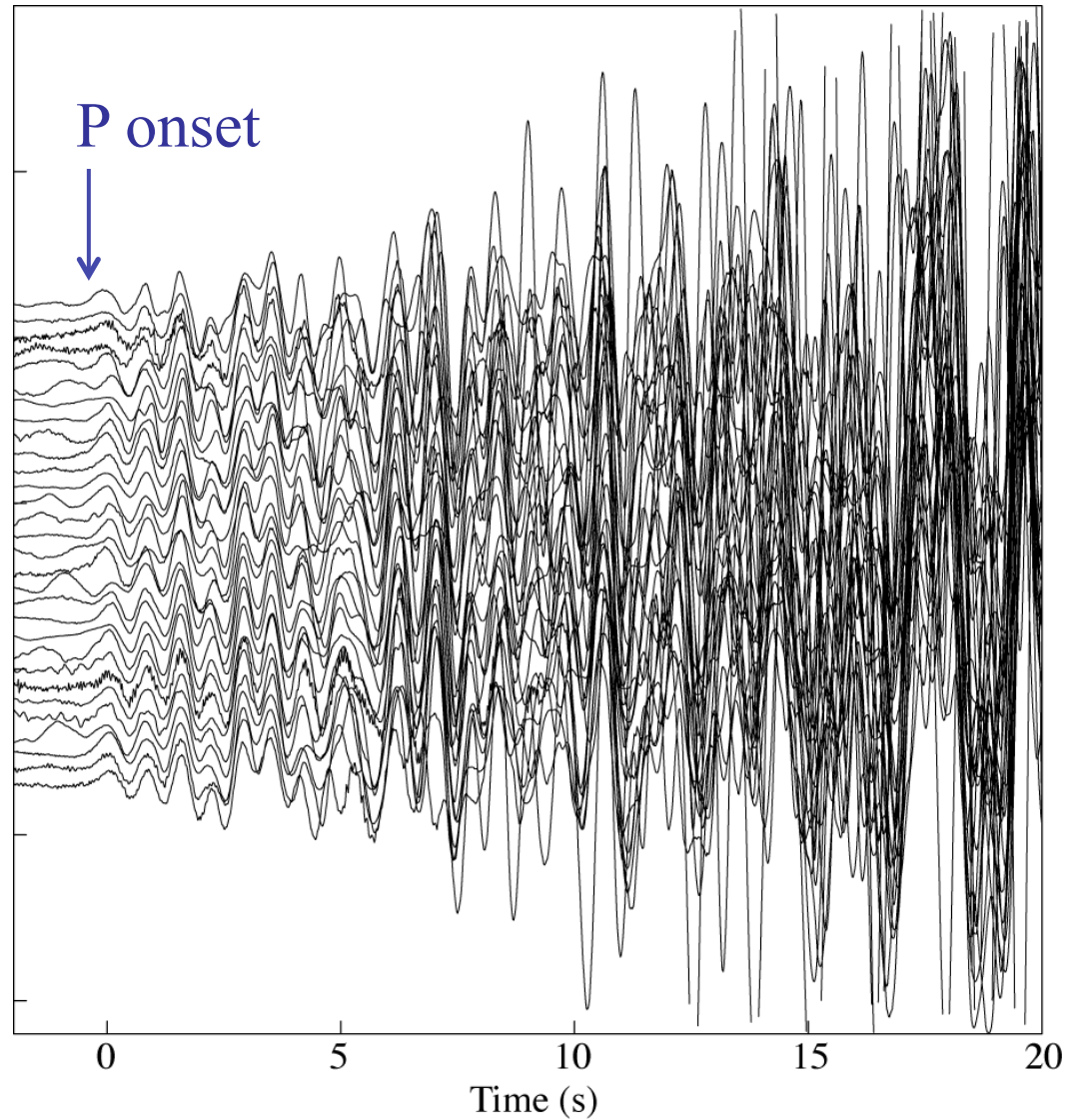
3-D Structure



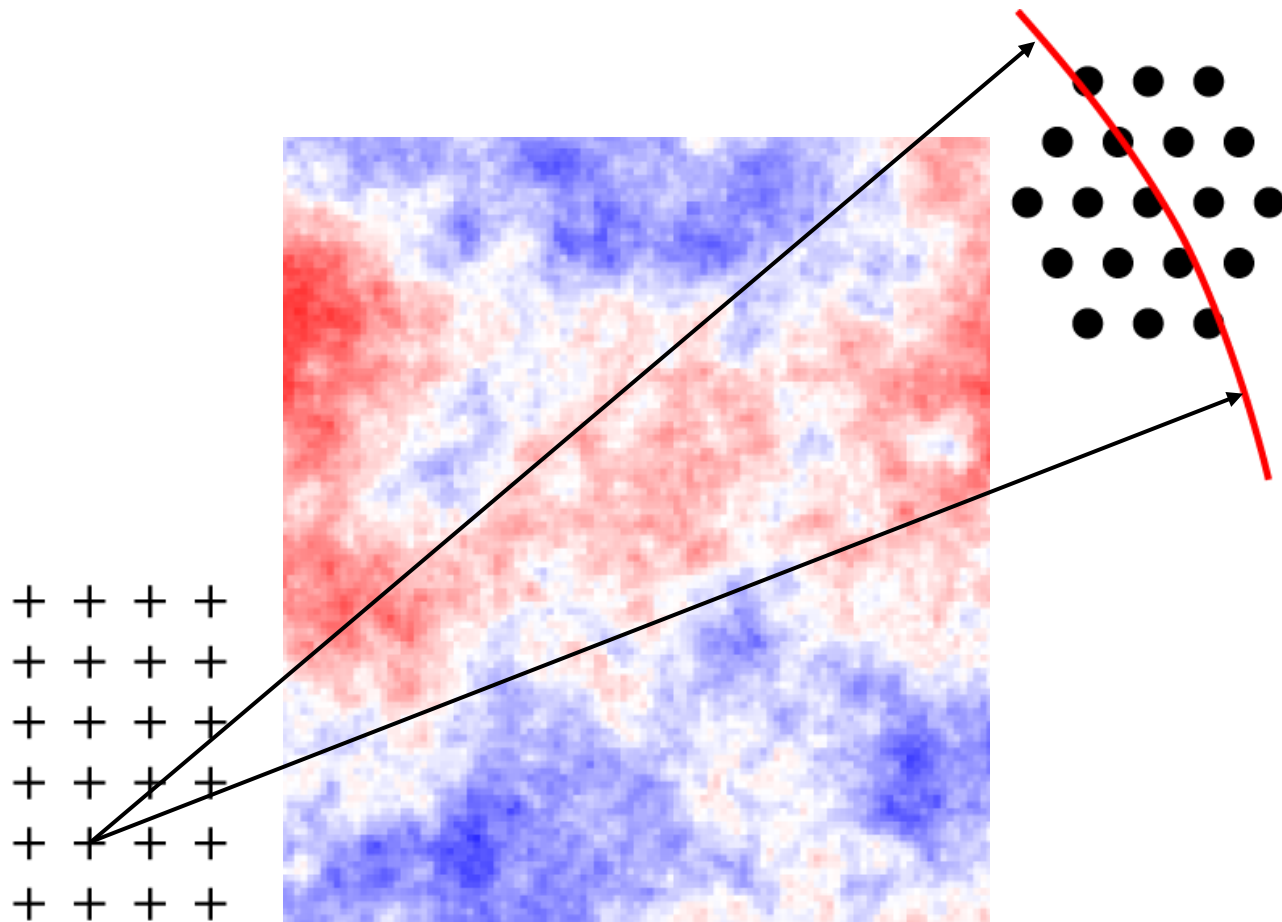
Waveform Cross Correlation



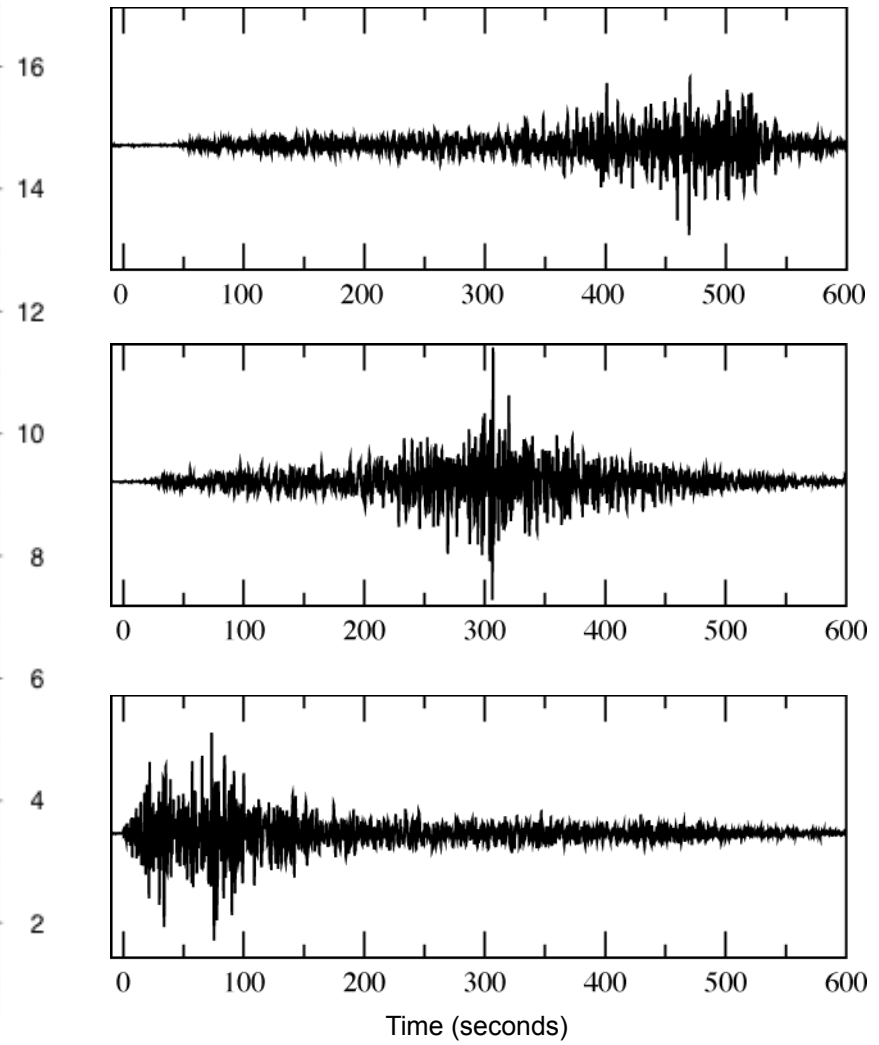
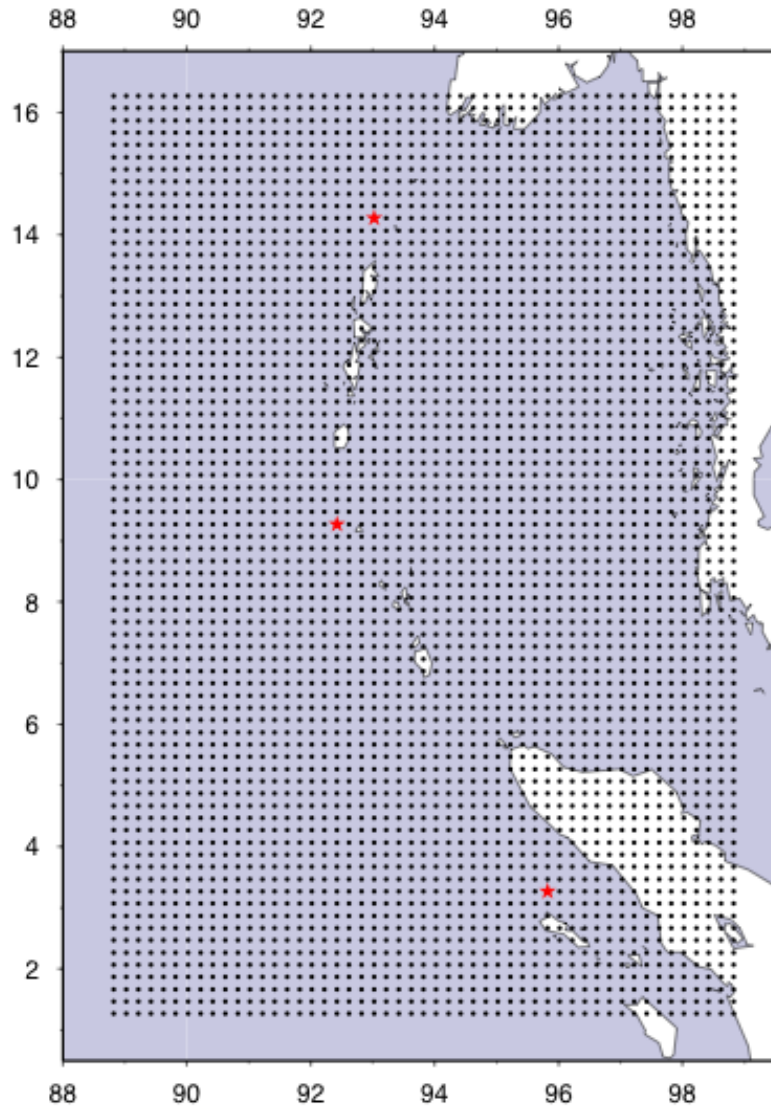
P Wave Alignment (Cross Correlation)



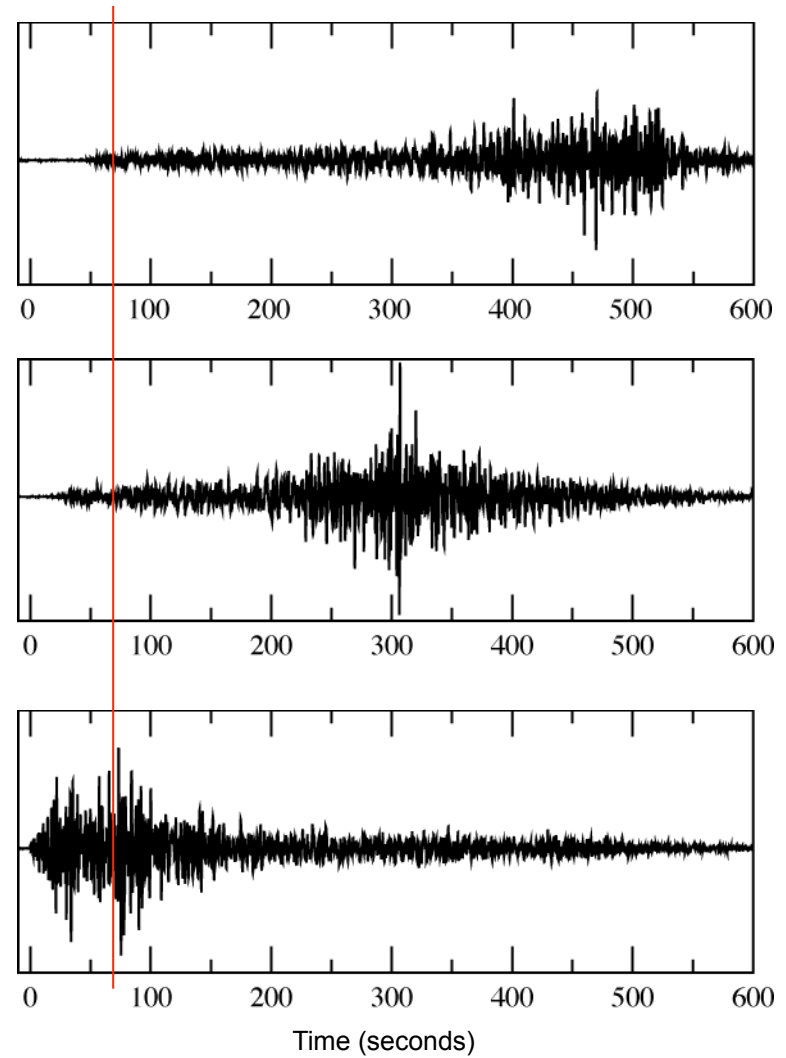
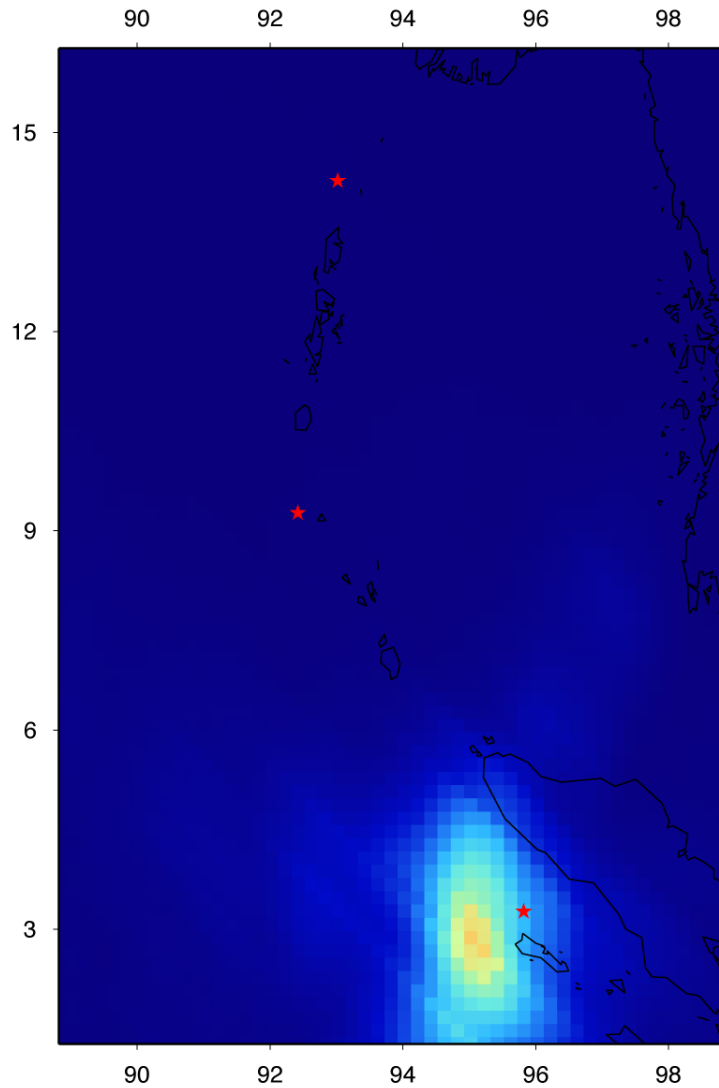
Empirically Corrected Wavefront



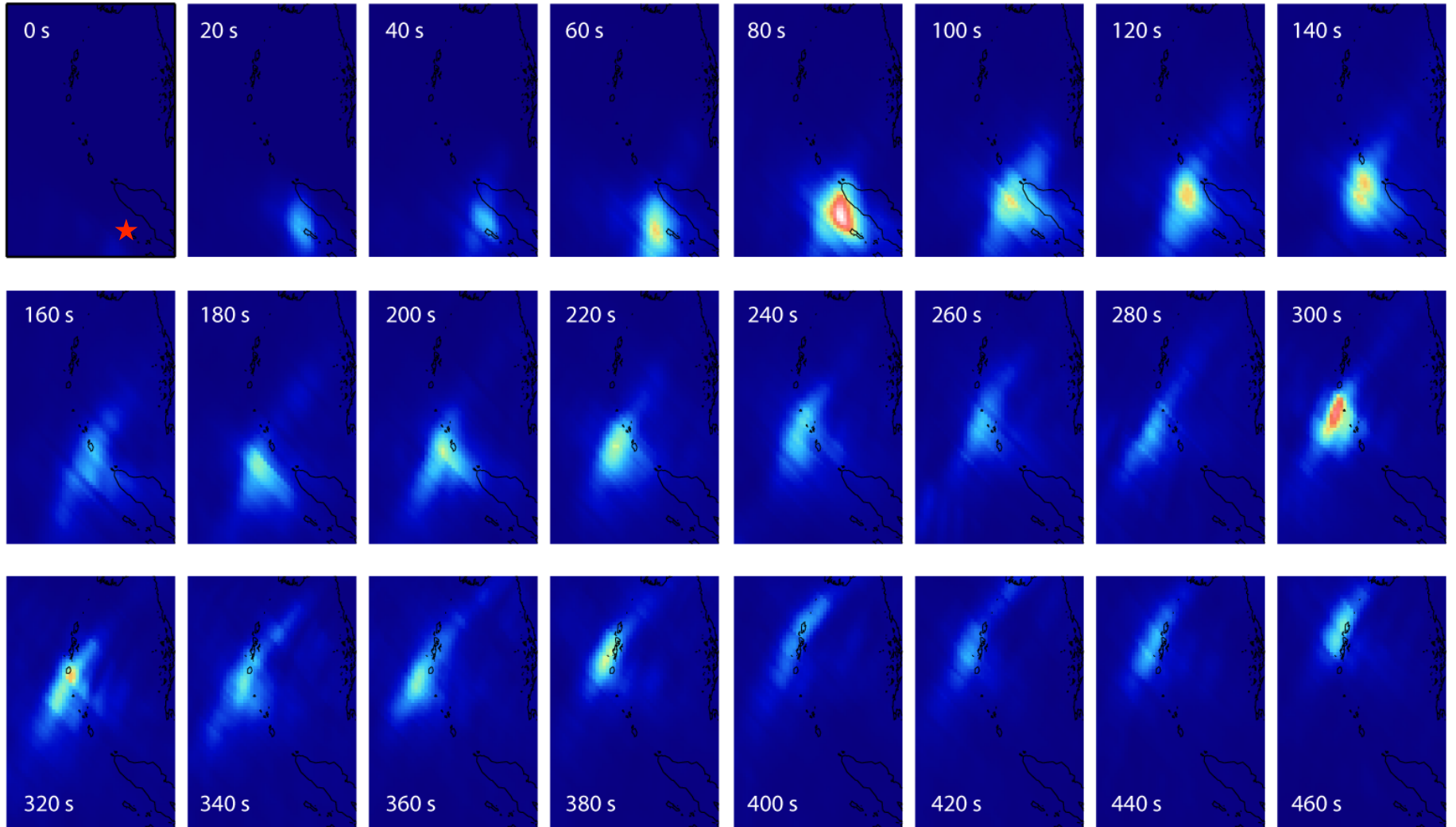
Stacks

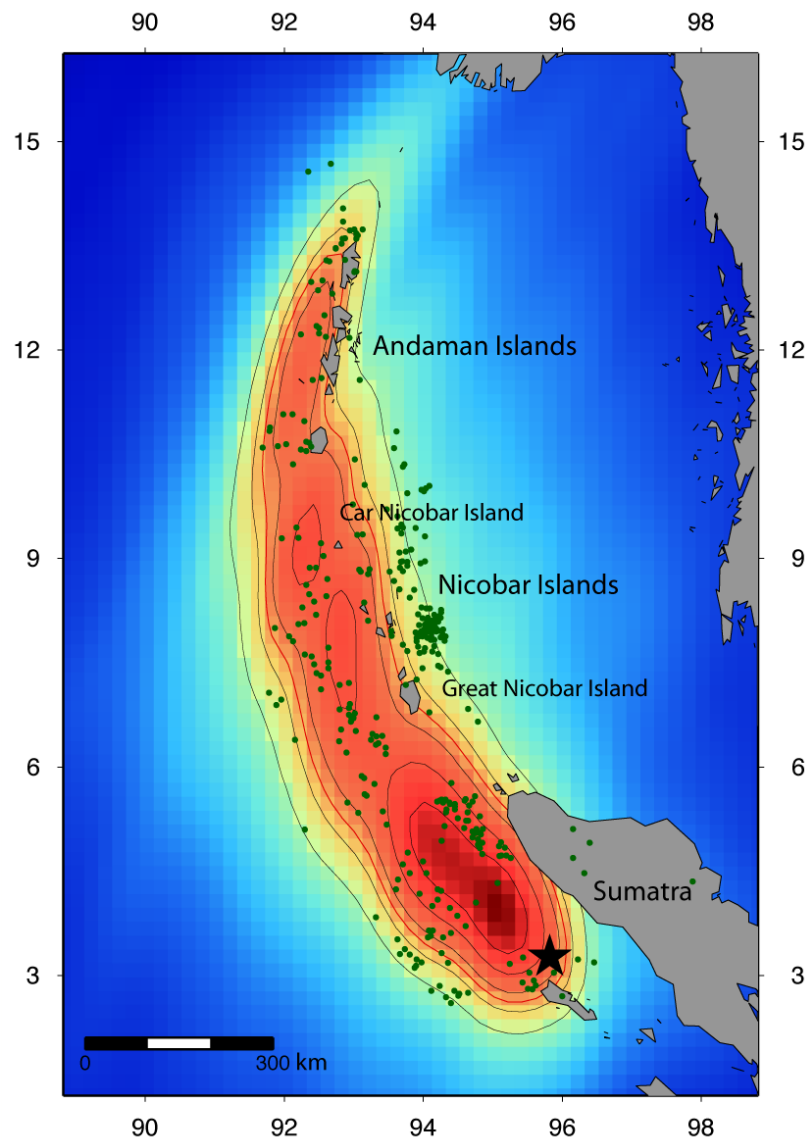


Stacks and Time Slice (60 seconds)



Time Slices



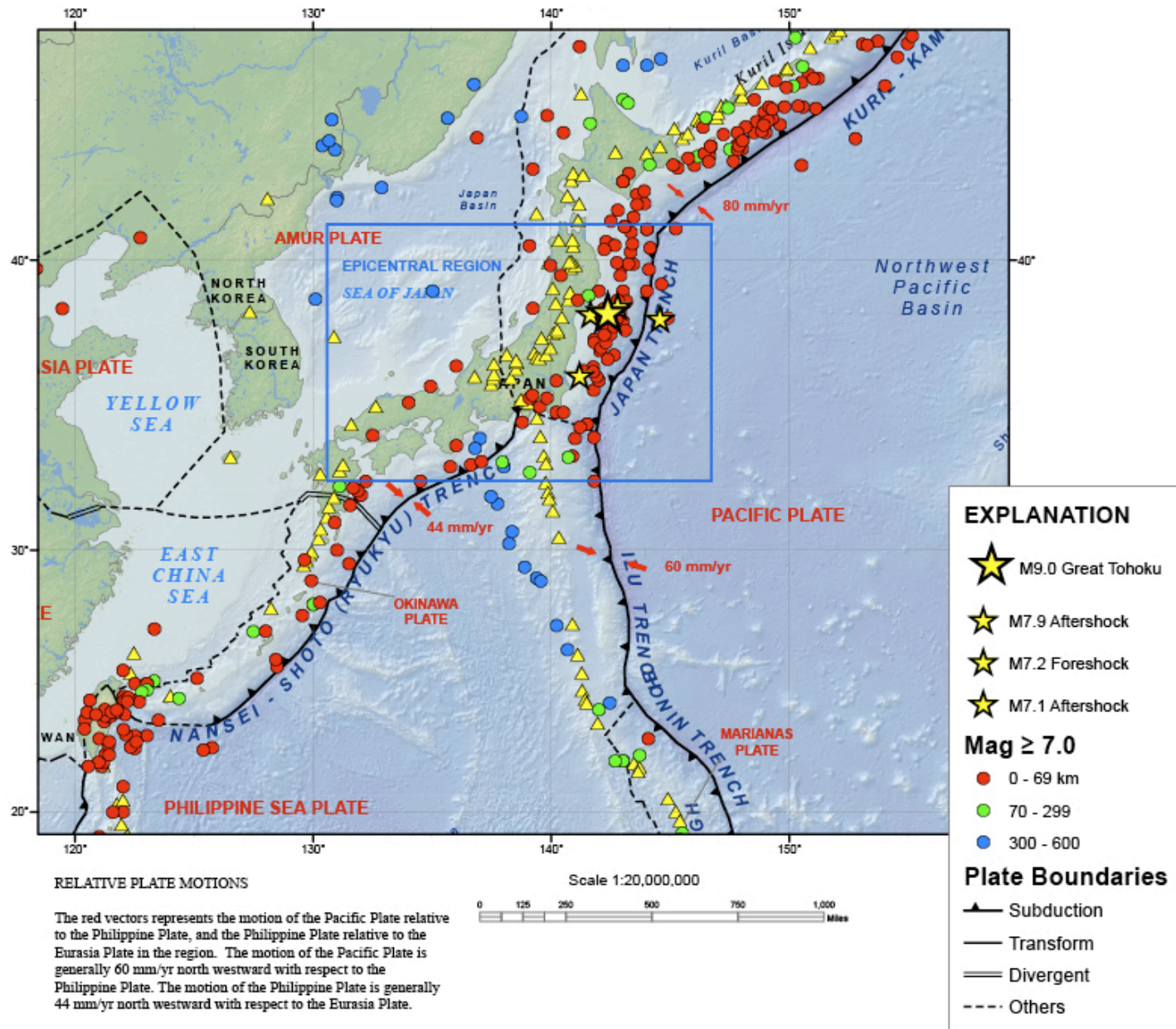


Rupture Propagation

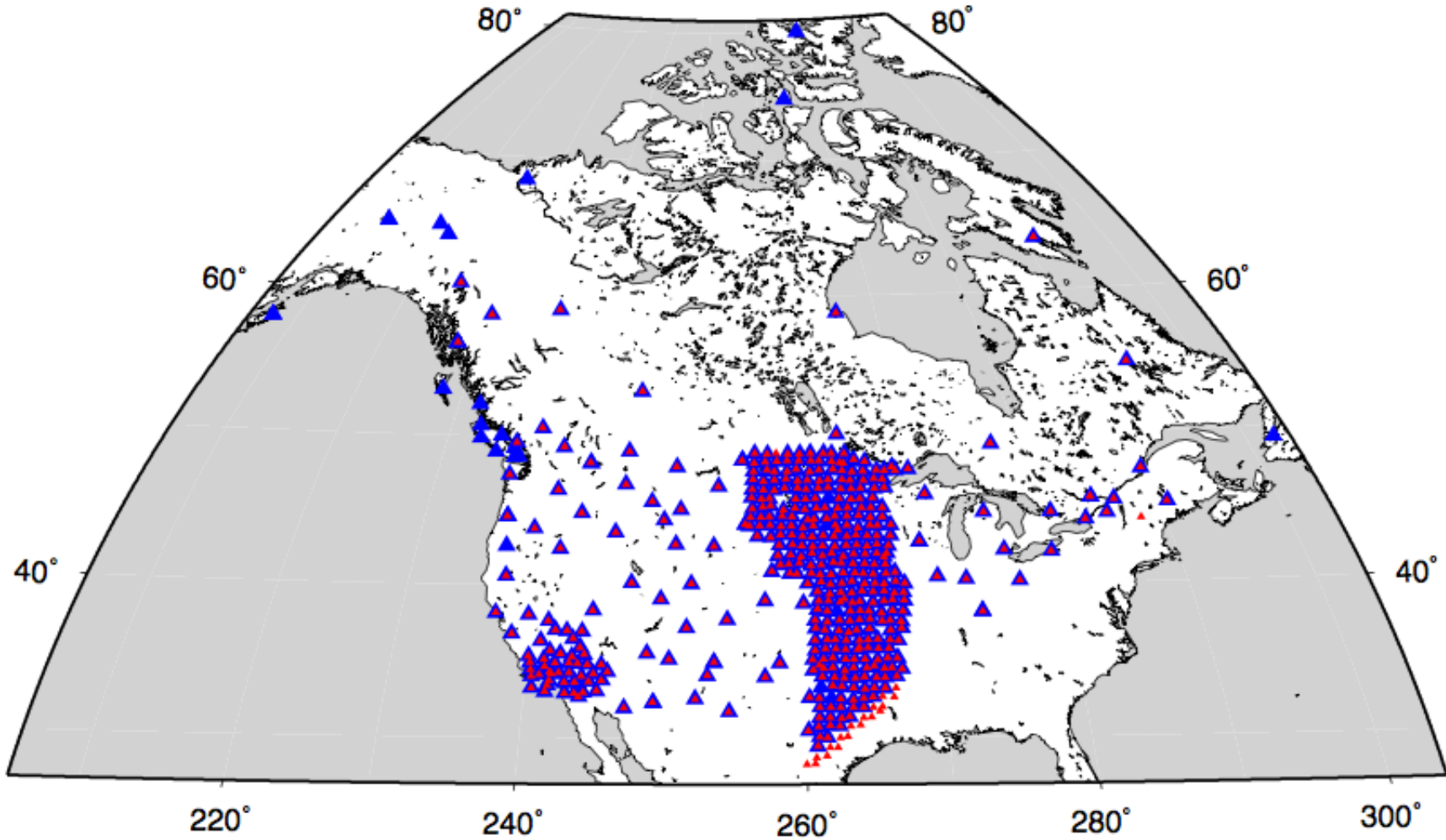
- 0-120 seconds
- Greatest energy release north-west of the northern part of Sumatra Island
- ~220 seconds
- Large energy release north-west of Great Nicobar Island
- ~300 seconds
- Large energy release around Car Nicobar Island
- Change in direction
- Duration ~ 540 s
- Rupture extends from northern Sumatra to northern end of Andaman Islands

animation available at <http://seismology.harvard.edu/resources.html>

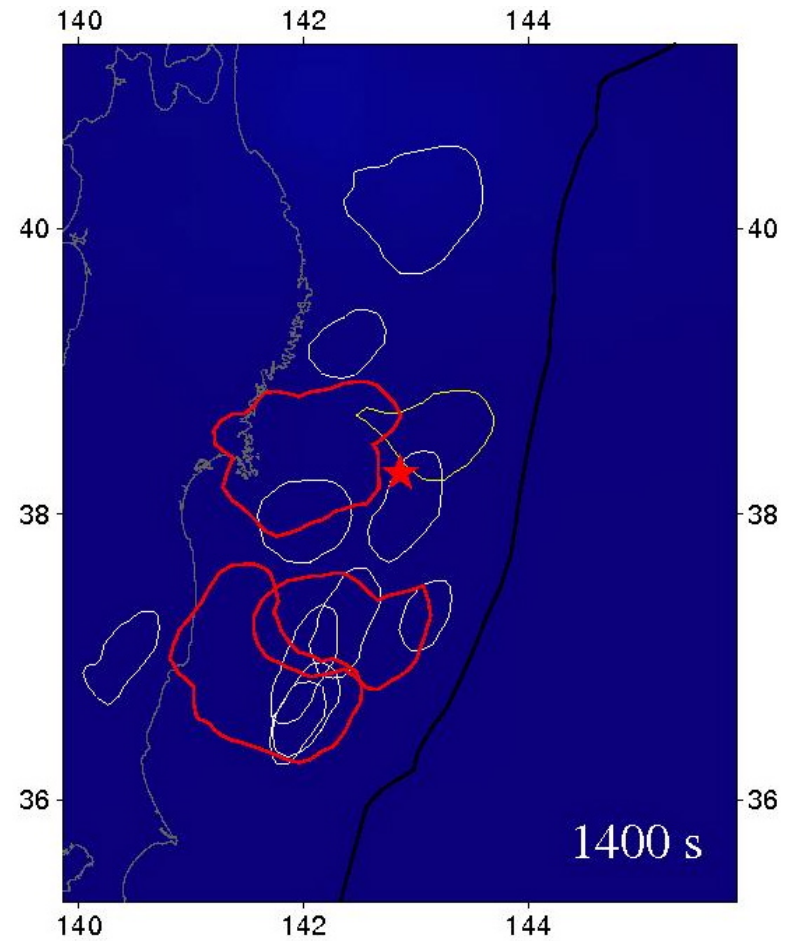
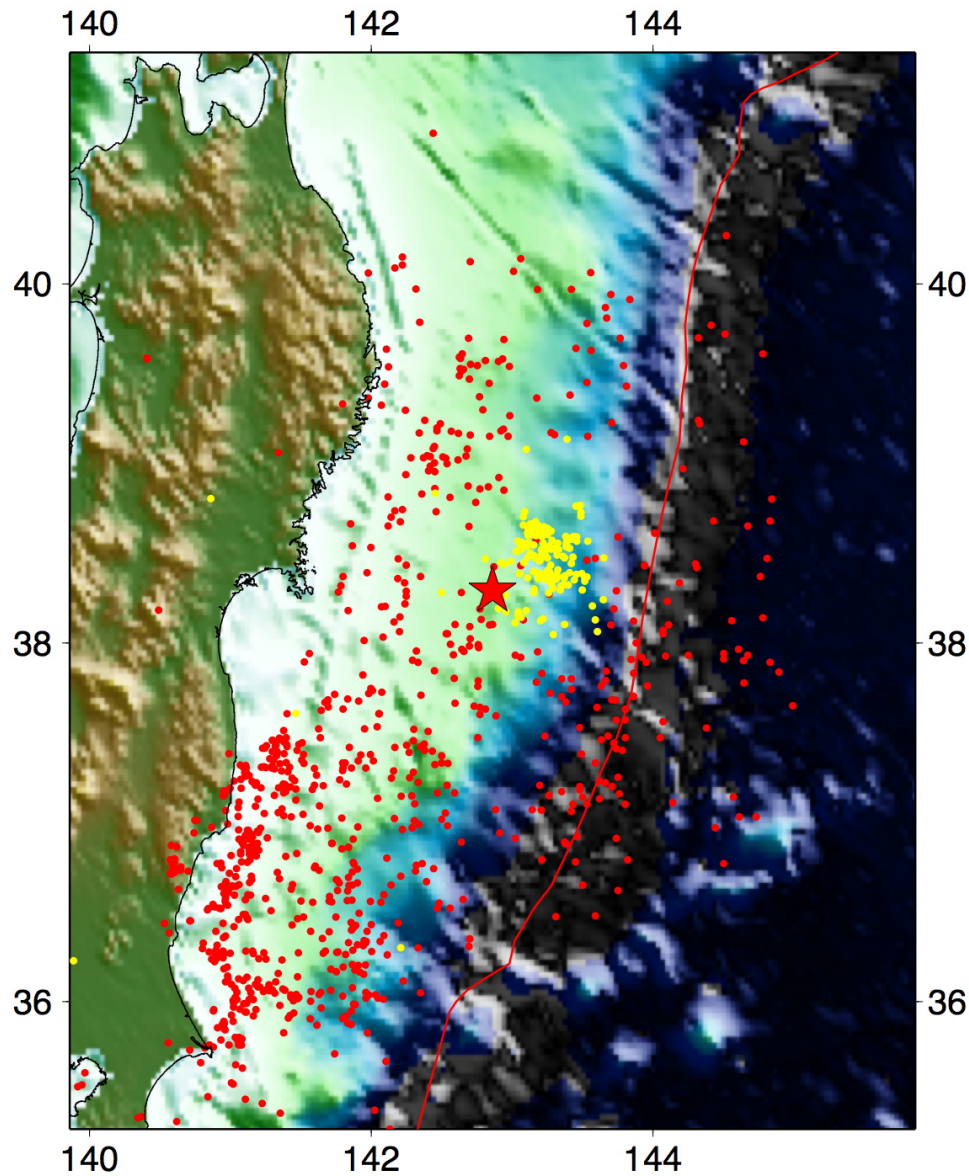
2011 Mw 9.0 Japan Earthquake



North American/USArray Stations

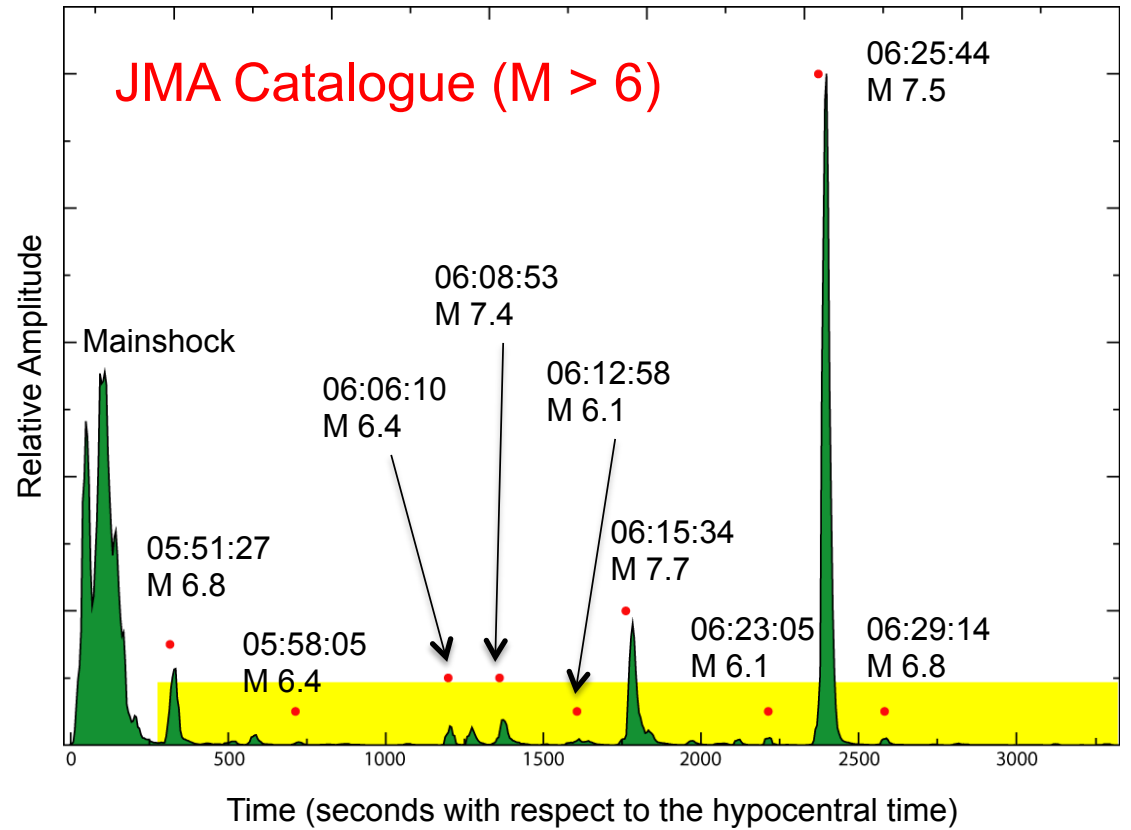
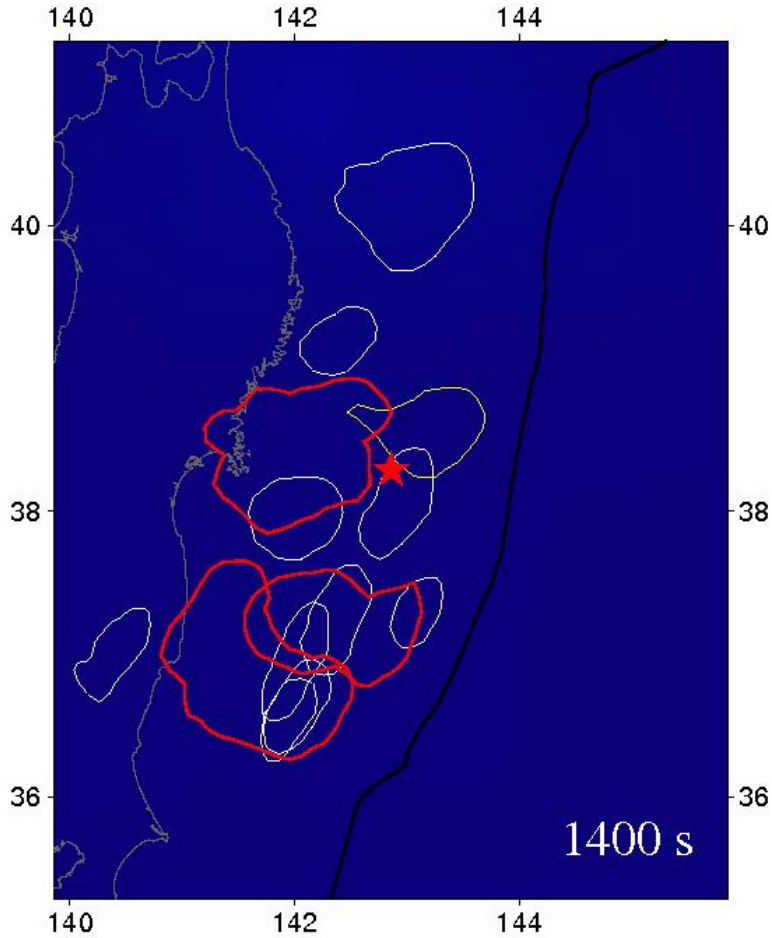


Continuous Back-Projection: 25 Minutes

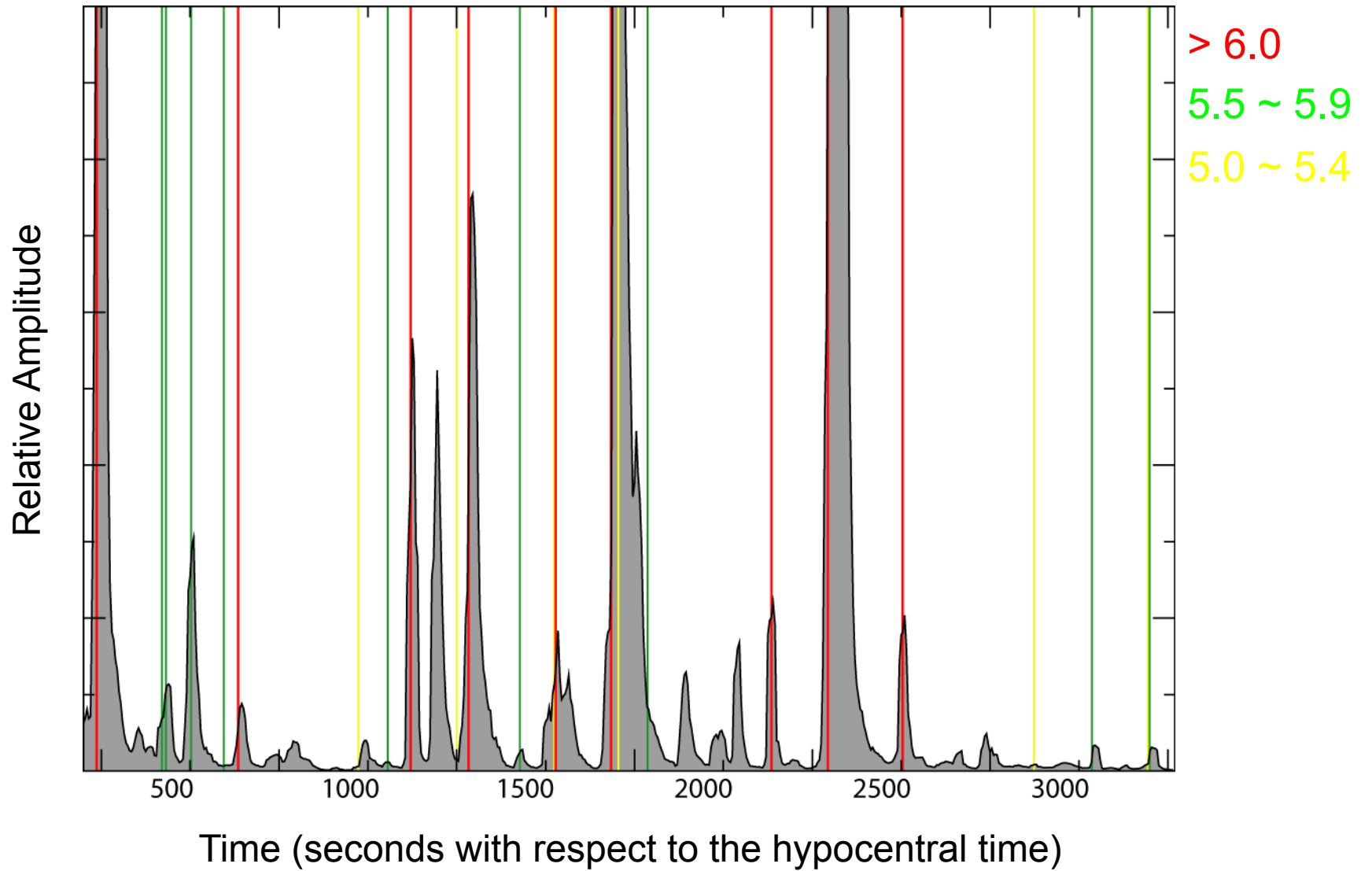


animation available at
<http://seismology.harvard.edu/resources.html>

Hidden Earthquakes

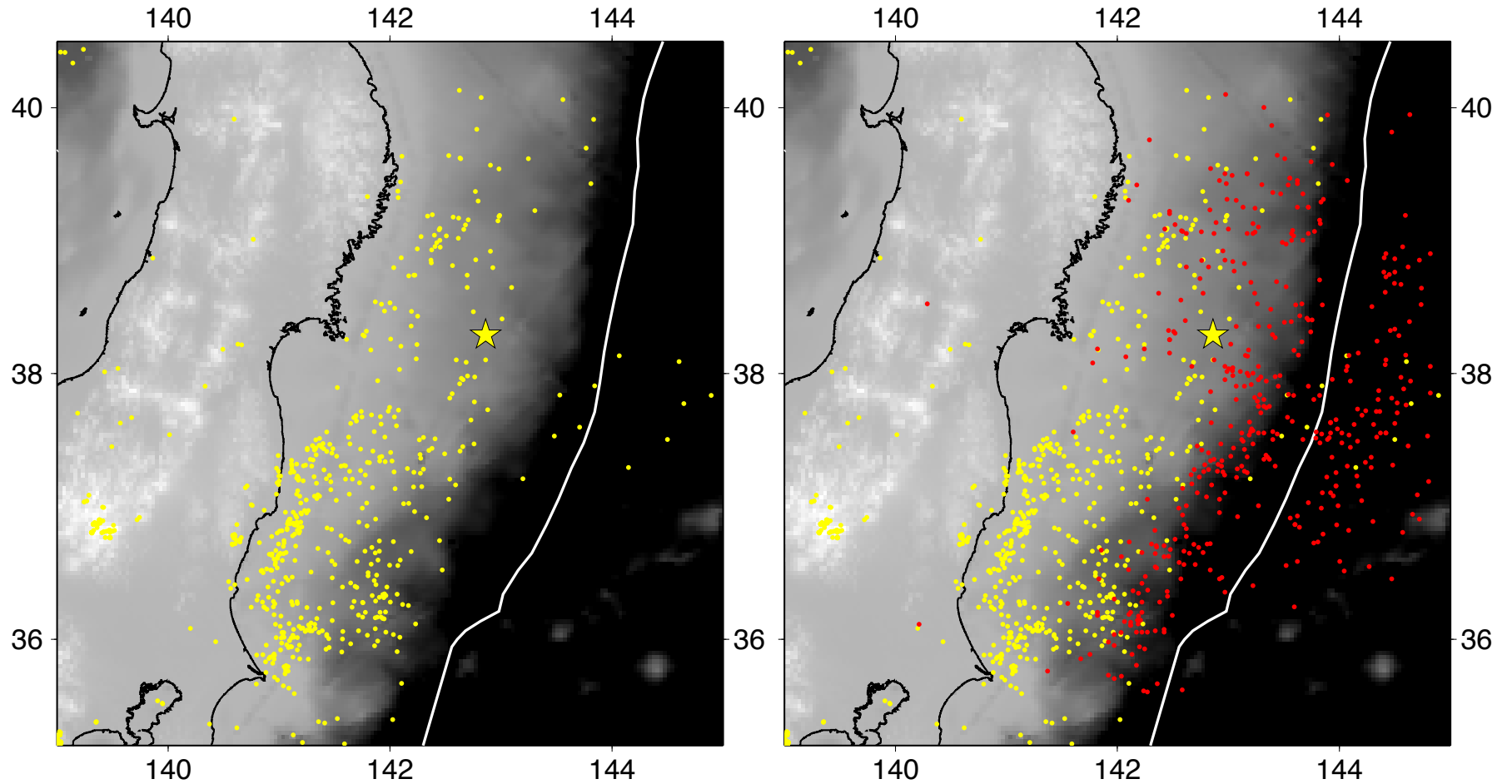


Earthquake Detection: Comparison with JMA

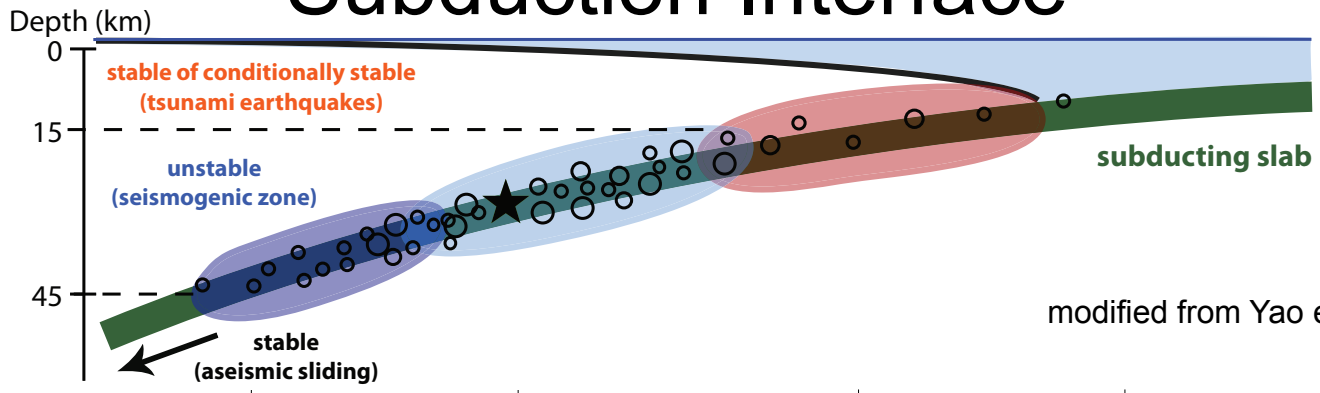


Distribution of Detected & Undetected Events

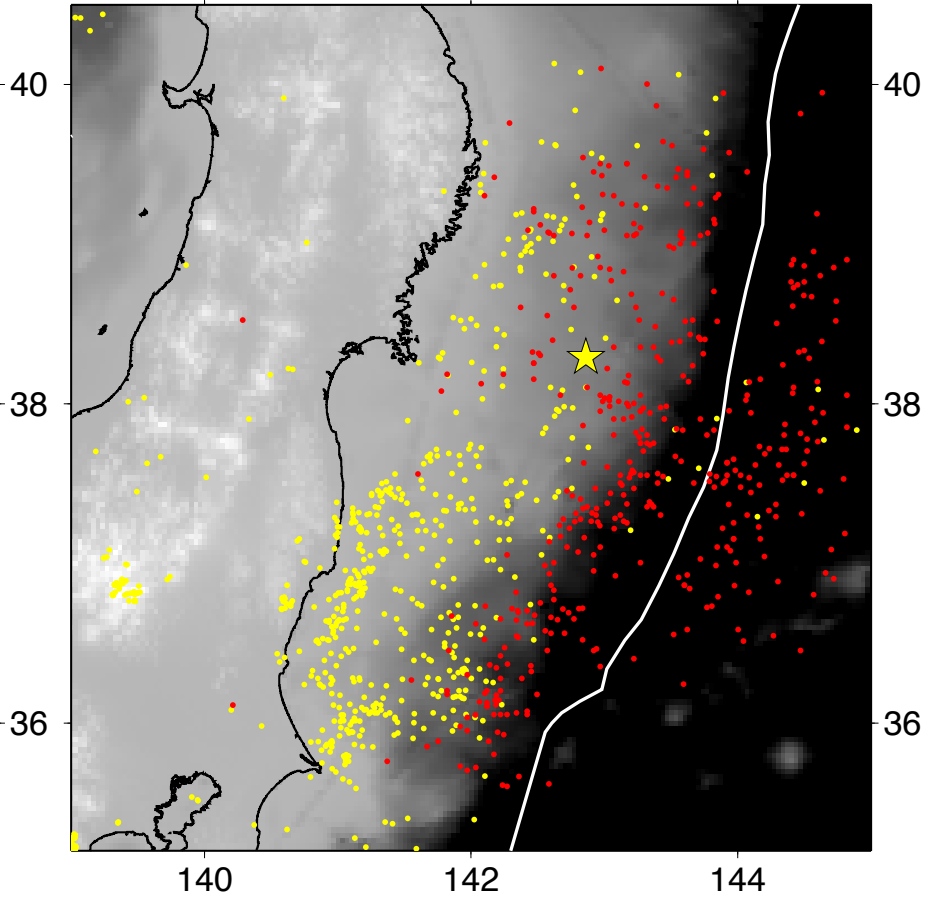
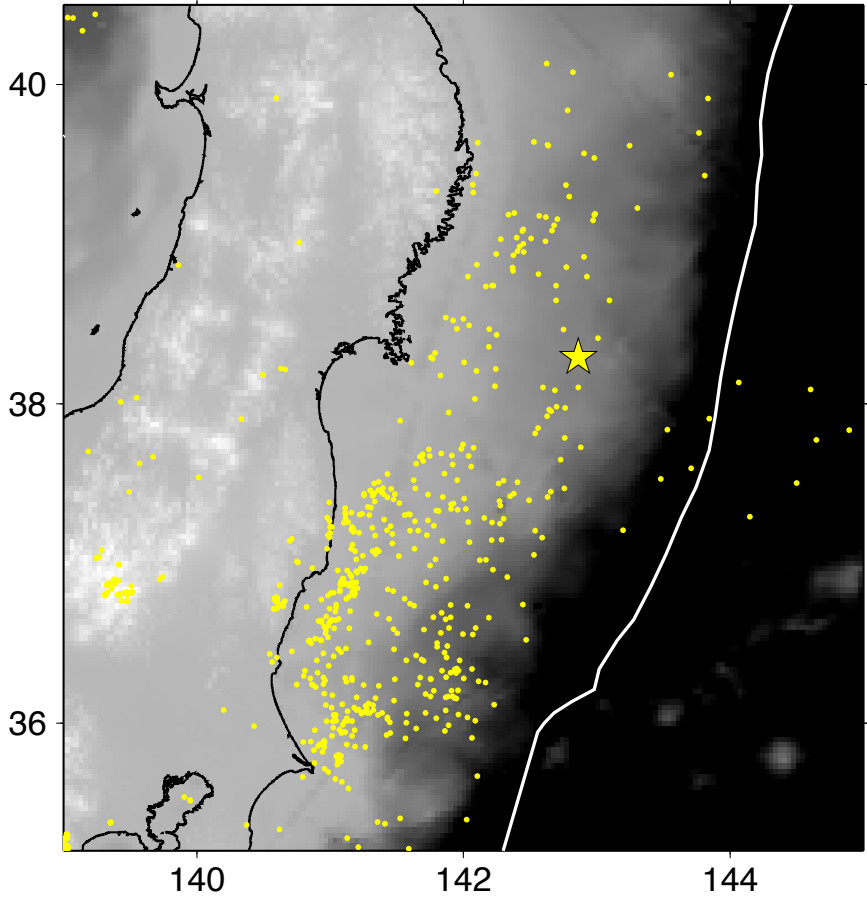
first 25 hours



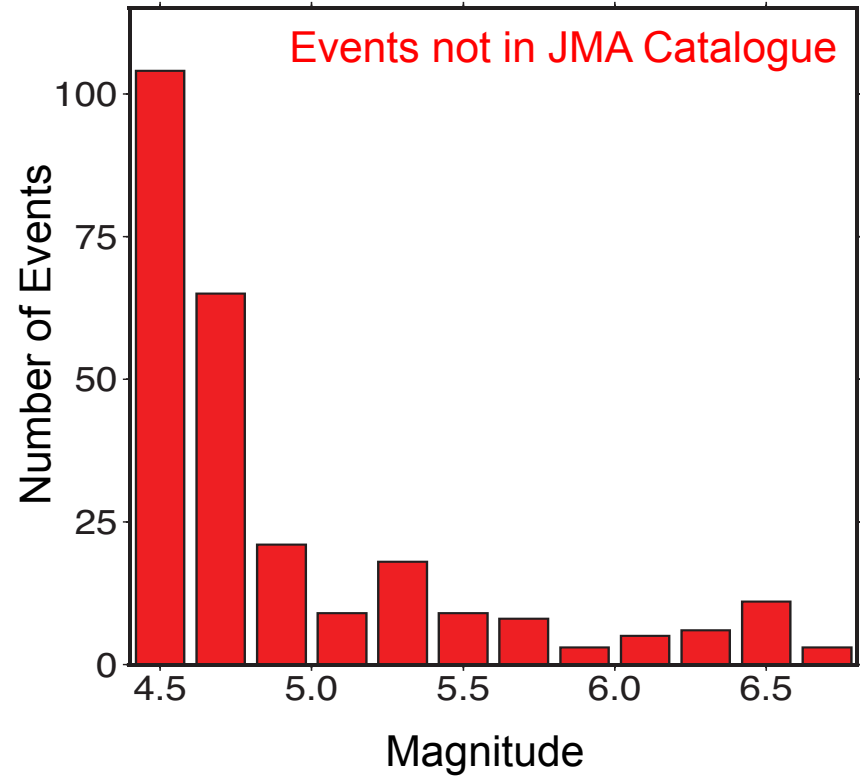
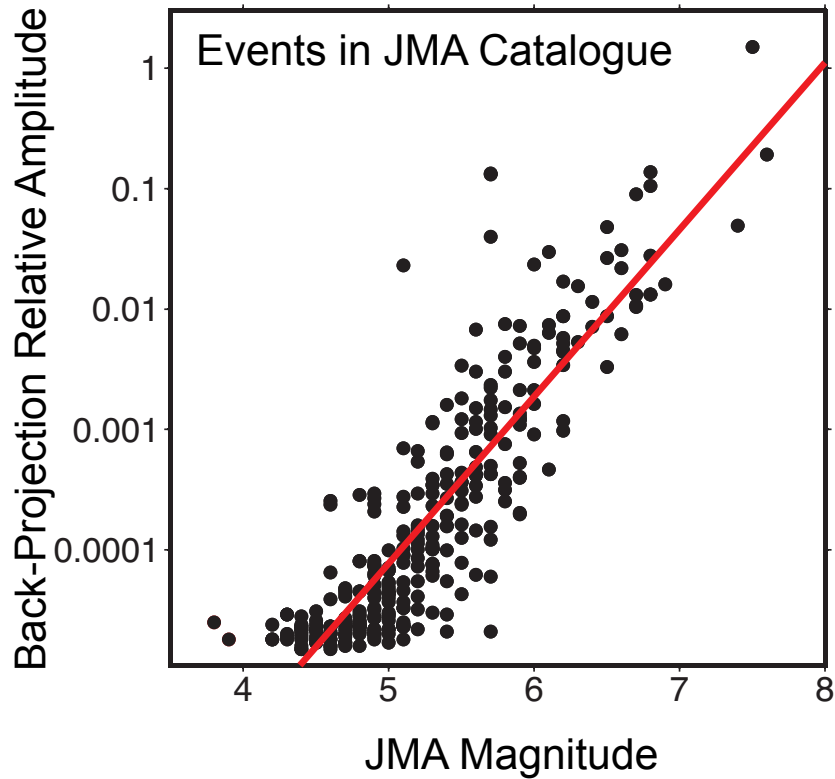
Subduction Interface



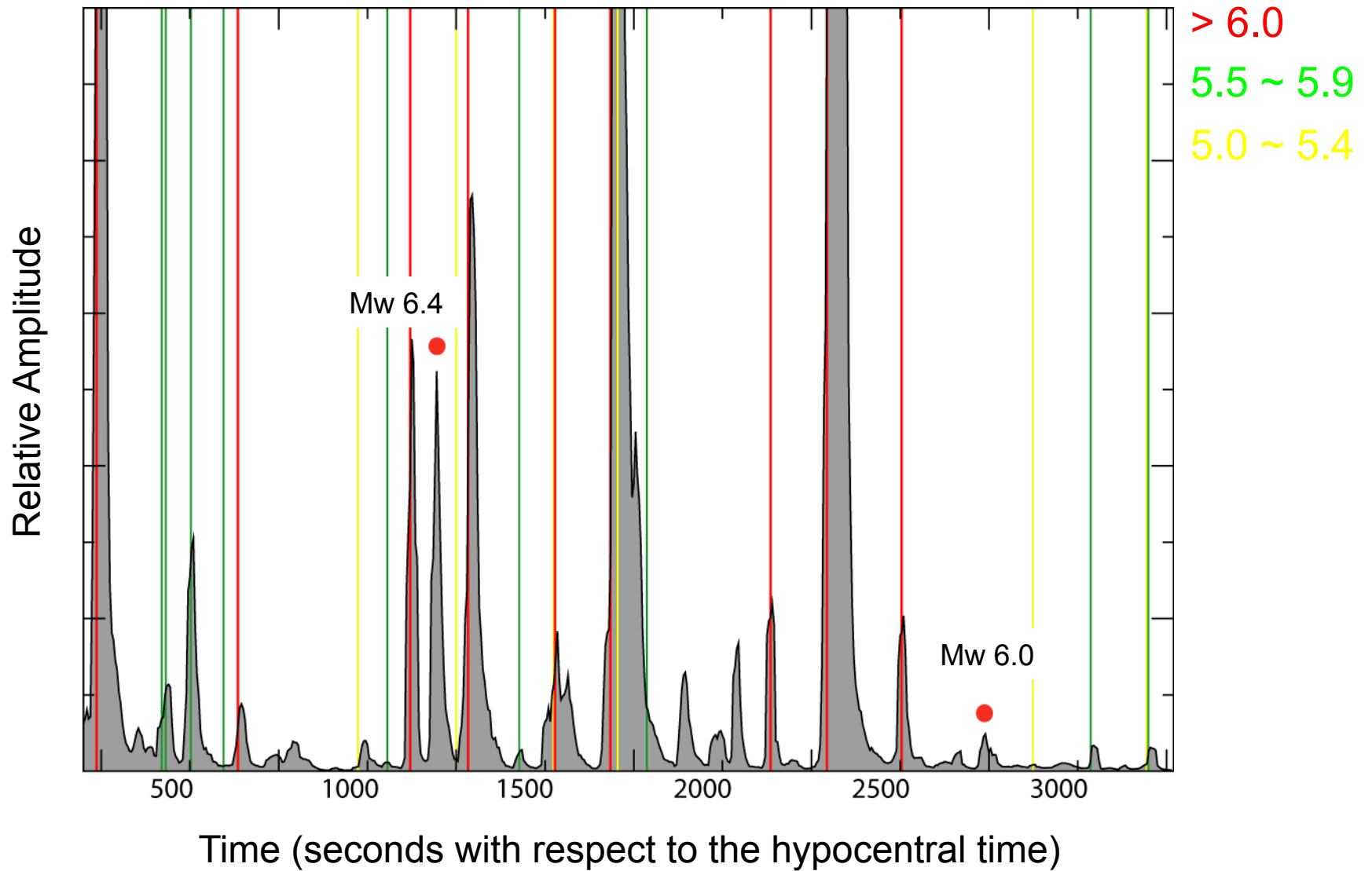
modified from Yao et al. (2013)



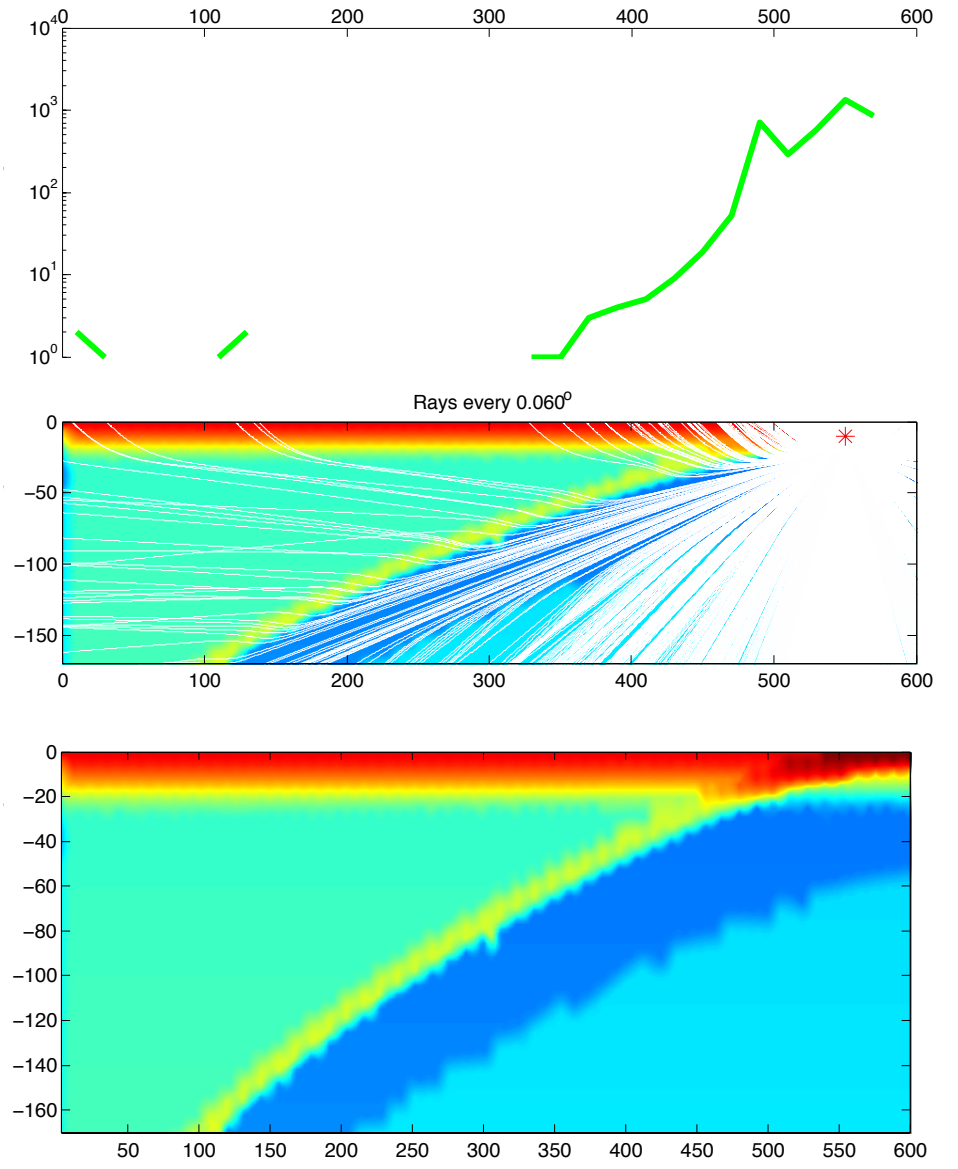
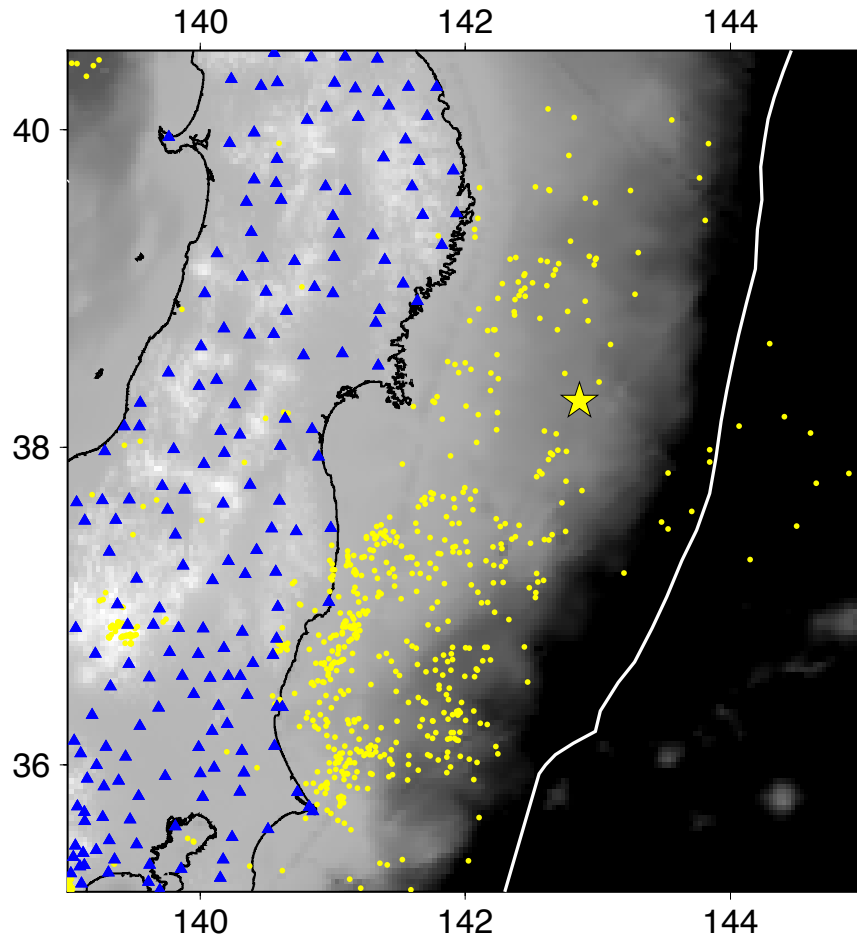
Comparison with JMA Earthquakes

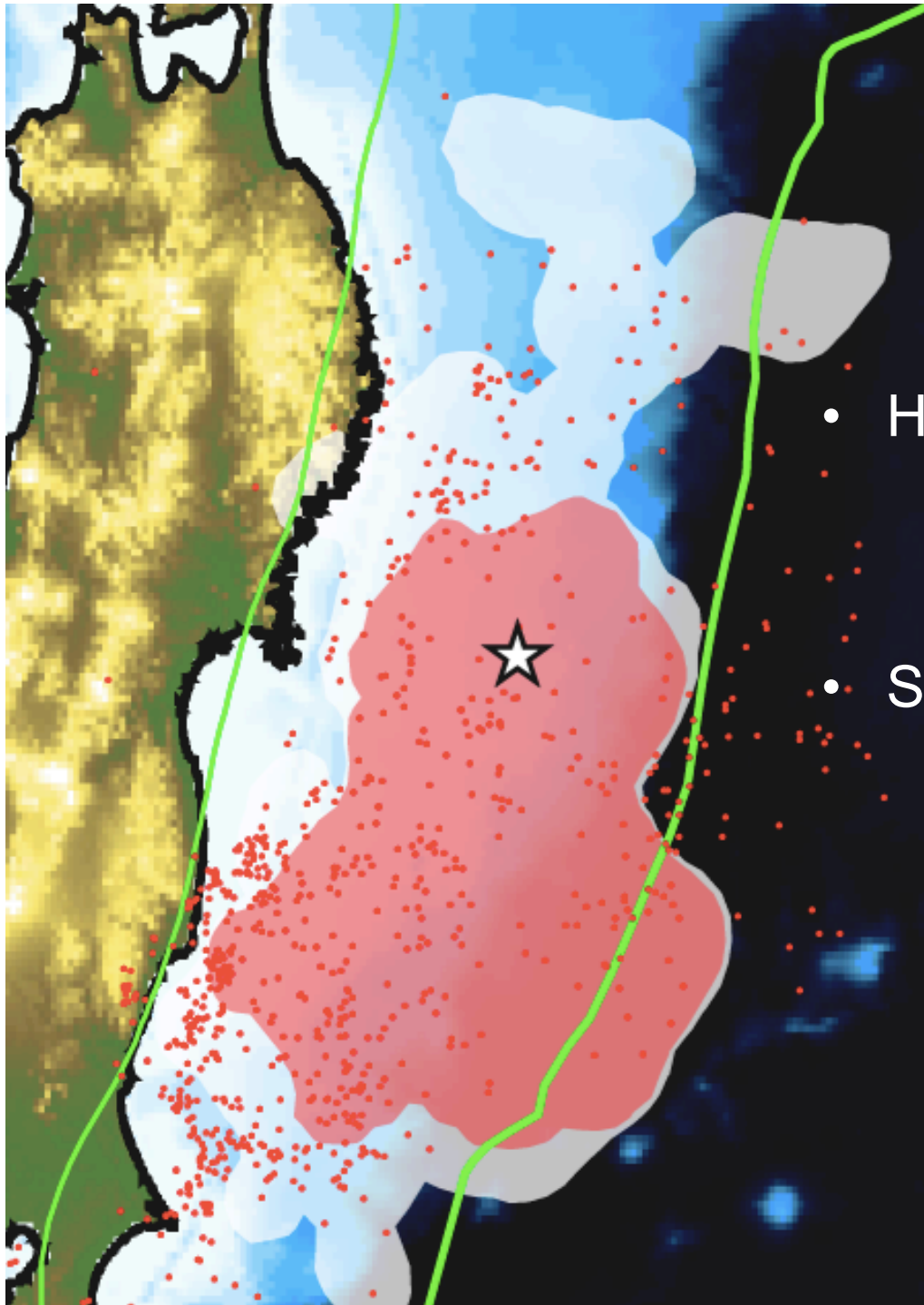


Earthquake Detection: Comparison with JMA



Hidden Earthquakes





Summary

- Hidden Earthquakes
 - Subduction Interface
 - Potential Hazard
- Shadow Zone Effect
 - Internal Structure
 - Incomplete Catalogue