Strong Body-to-Surface Wave Scattering off the Southern California Continental Borderland

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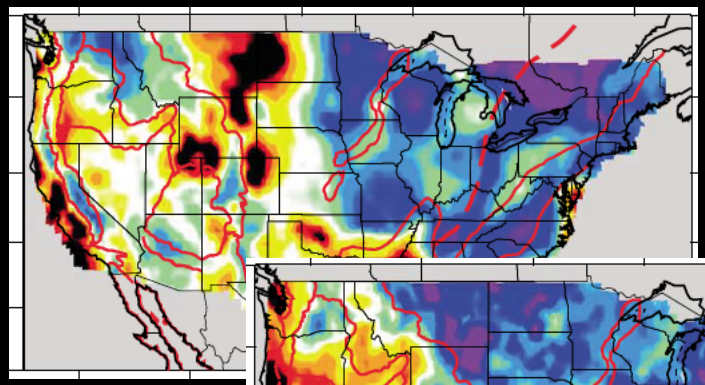
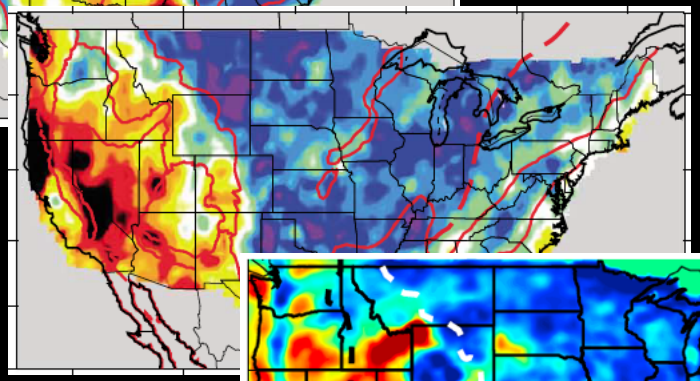
Seismic Tomography

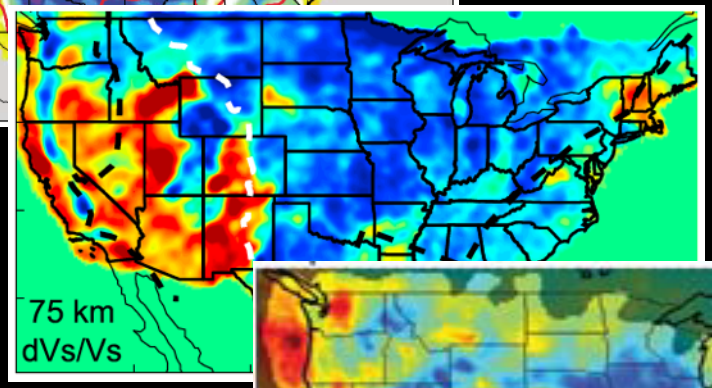


Near surface



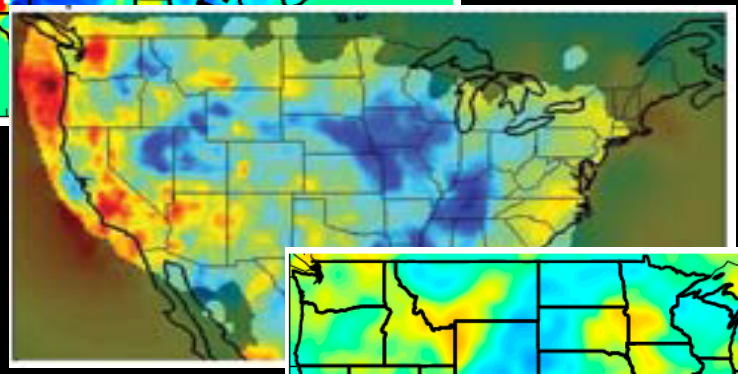
Lower crust

Shen & Ritzwoller, 2016



Upper mantle

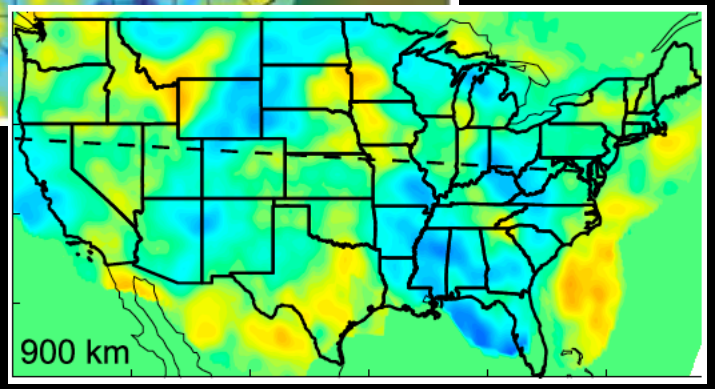
Schmandt & Lin, 2014



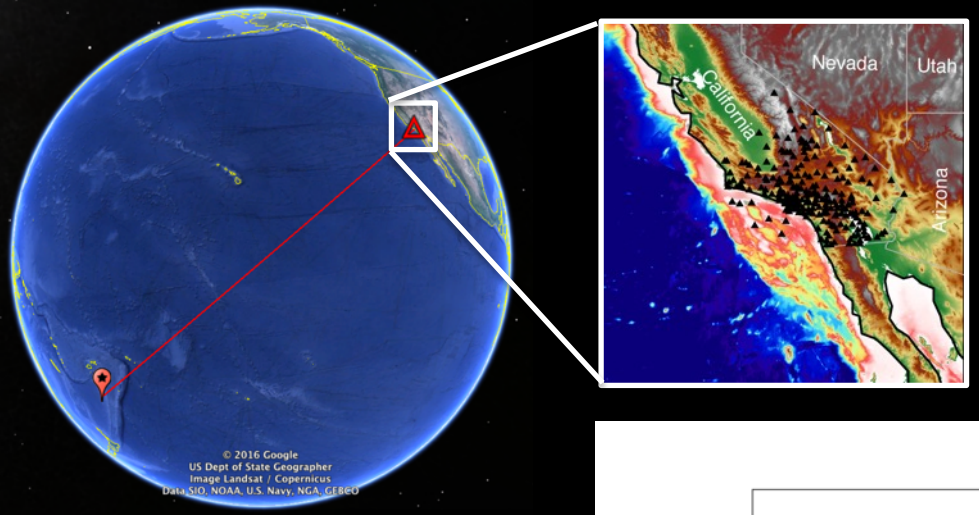
Transition zone

Burdick et al, 2016

Lower mantle



Schmandt & Lin, 2014



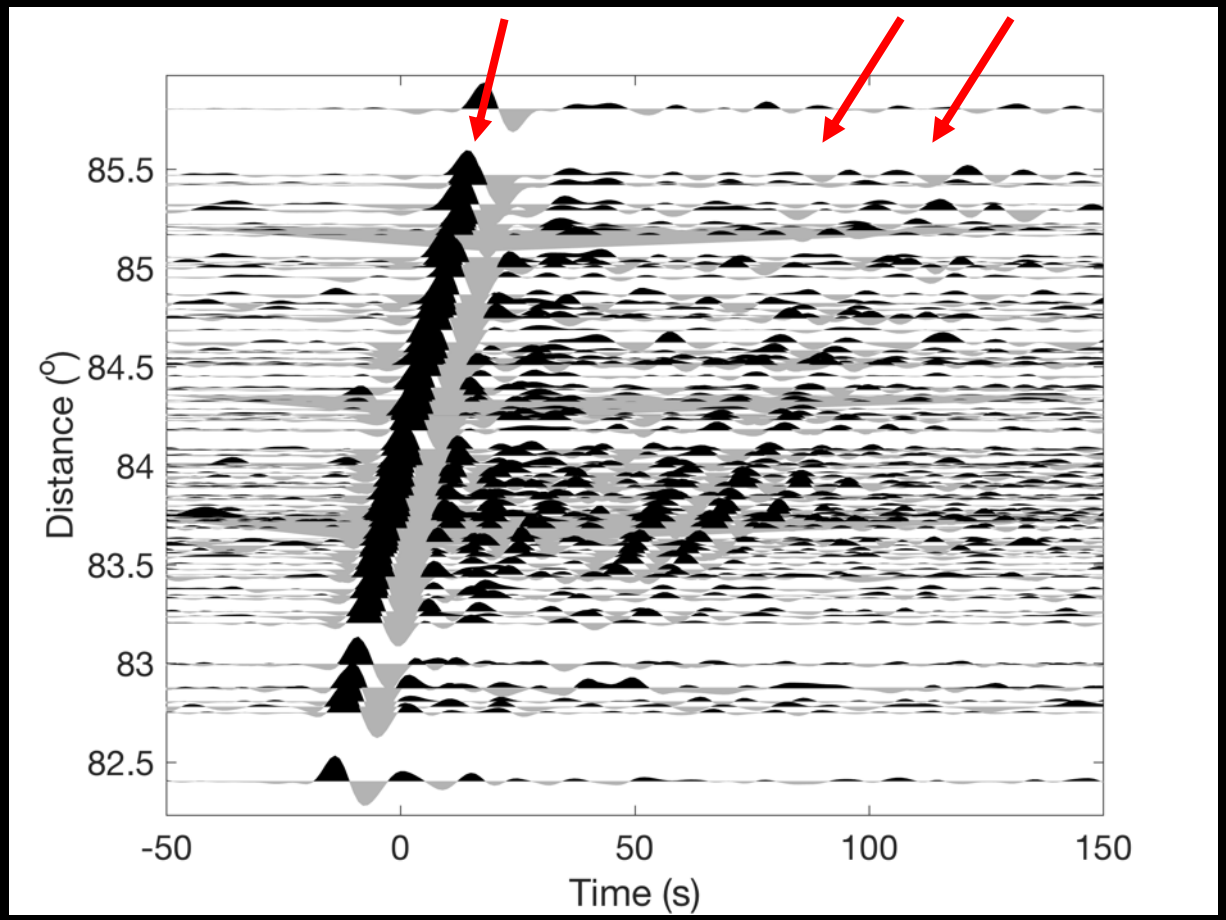
1. What are those phases?
2. Where are their sources?
3. How are they generated?

A M_w 6.5 deep event (depth=510 km) form Kermadec subduction zone

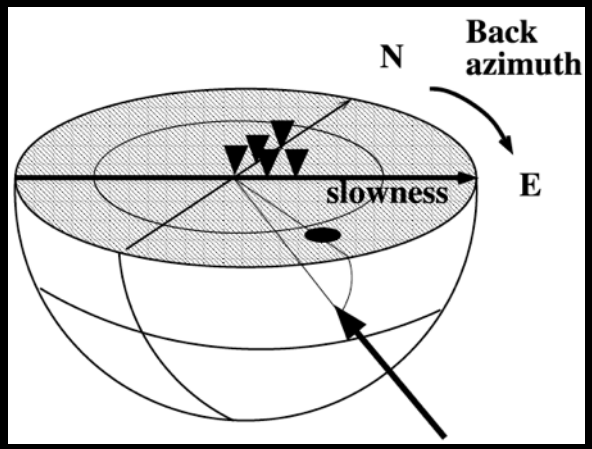
Transverse component

Bandpass: 0.02 ~ 0.1 Hz

Time reduced by *S*-wave arrival at the reference station (1281 s from earthquake origin time)



Array analysis



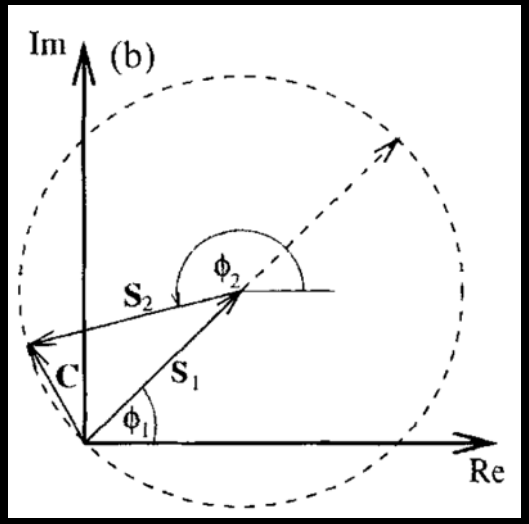
Rost & Thomas, 2002

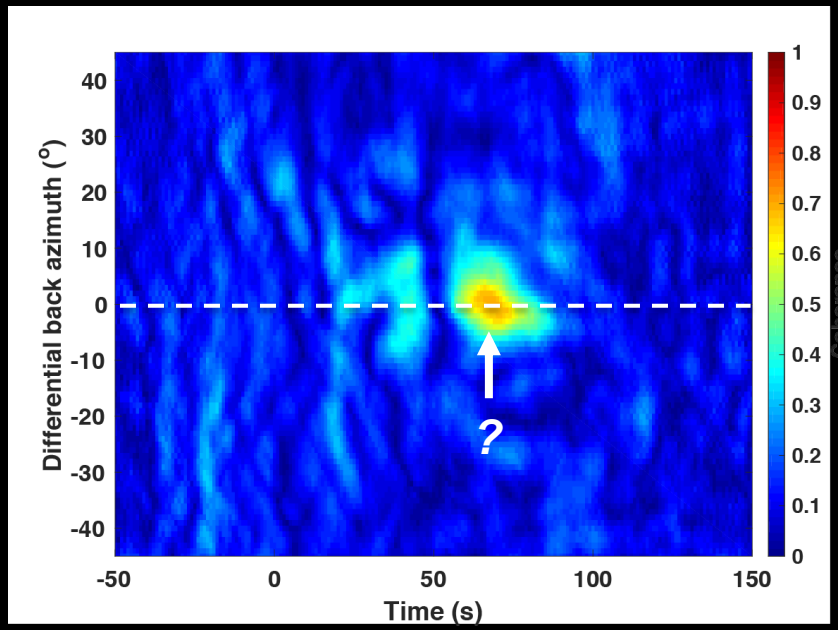
phase stack

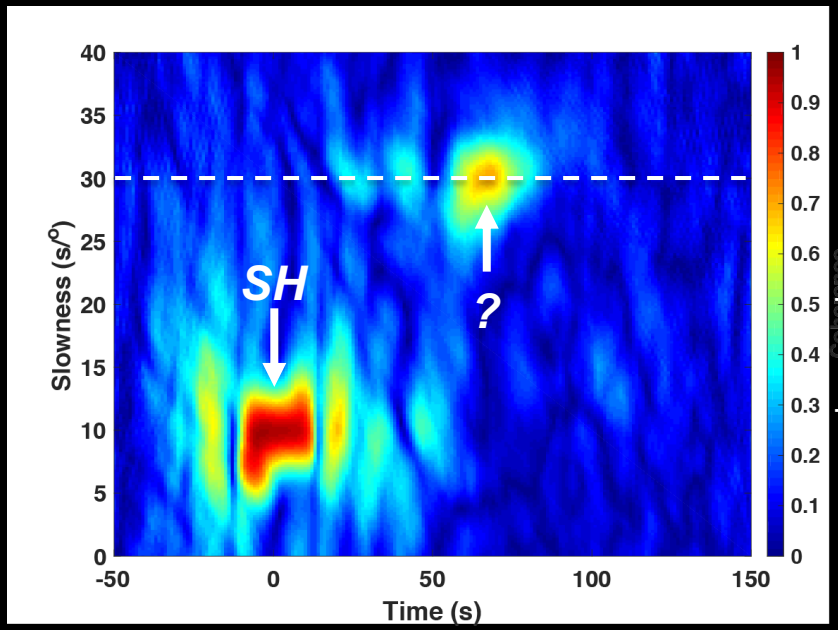
(Schimmel & Paulssen, 1997)

$$c(t) = \frac{1}{N}\left|\sum_{j=1}^{N} e^{i\Phi_j(t)}\right|,$$

$$0 \le c(t) \le 1$$

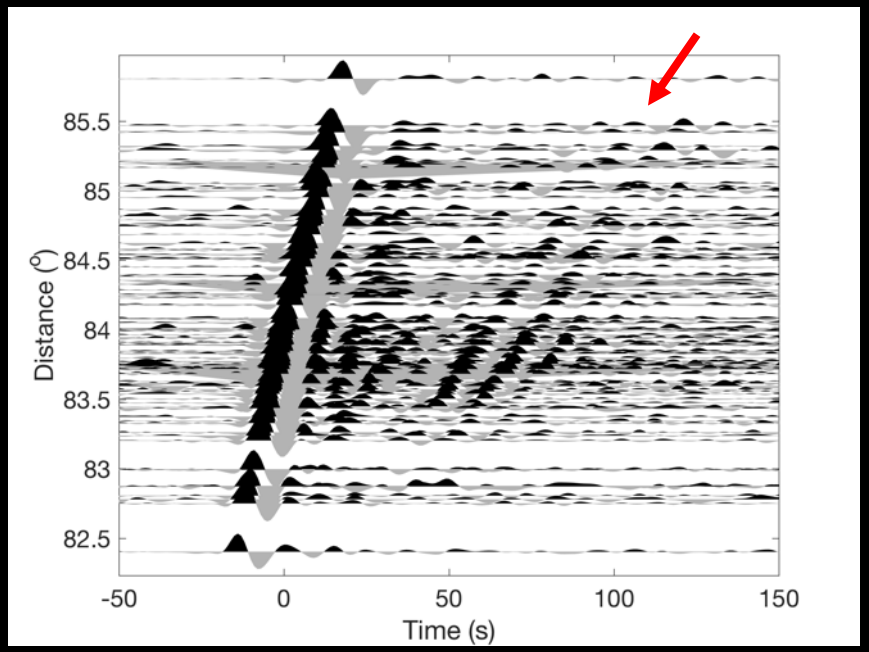


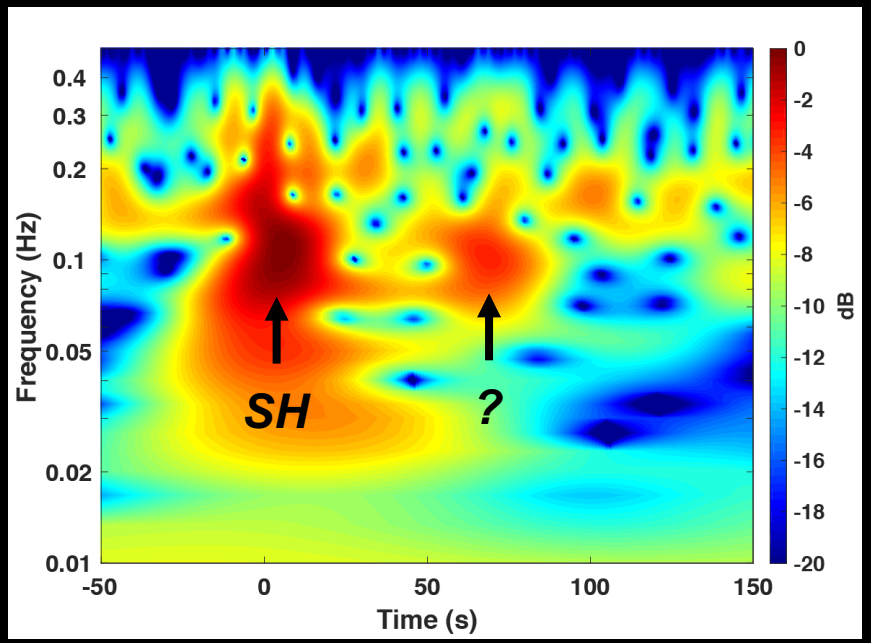




1. Same back azimuth as the earthquake source
2. Horizontal slowness ~30 s/° (apparent velocity ~3.7 km/s)

Time-frequency analysis
(S transform [Stockwell et al., 1996])

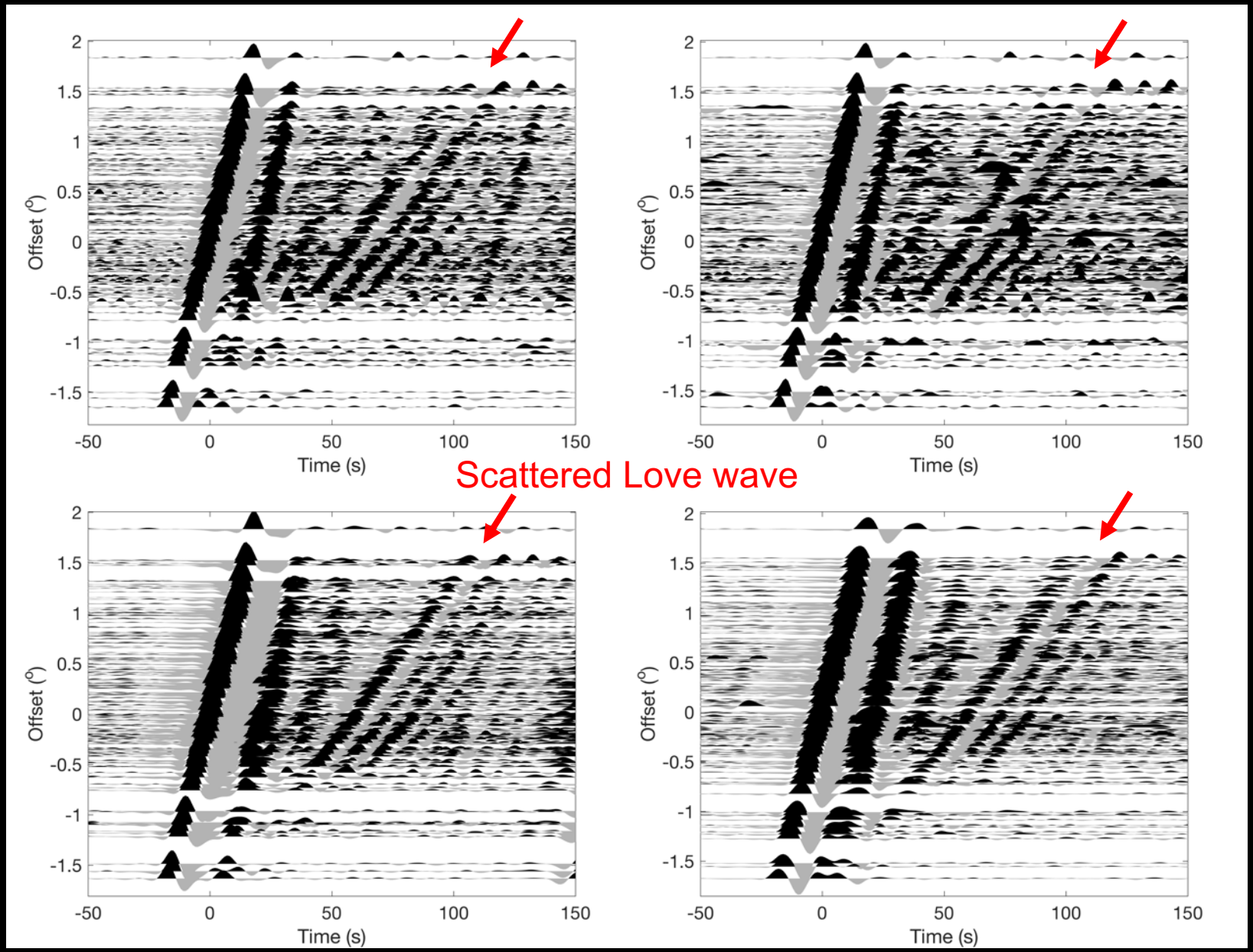




1. Same back azimuth as the earthquake source
2. Horizontal slowness 30 s/° (apparent velocity ~3.7 km/s) ⋯⋯▸ P wave
3. No apparent amplitude decay with distance ⋯⋯▸ S wave
4. Central frequency ~0.1 Hz
5. Transverse component ⋯⋯▸ Rayleigh wave

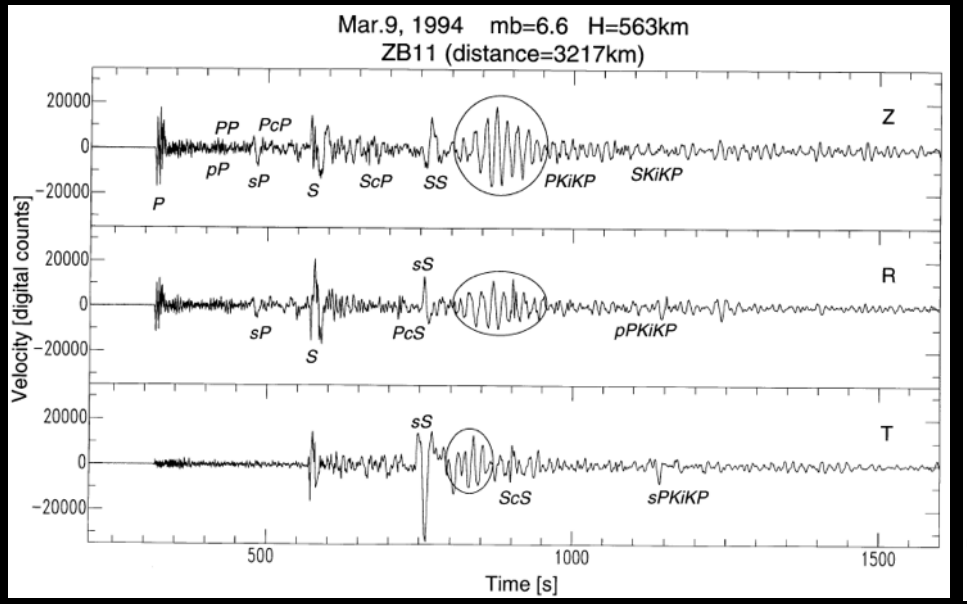
Scattered Love wave

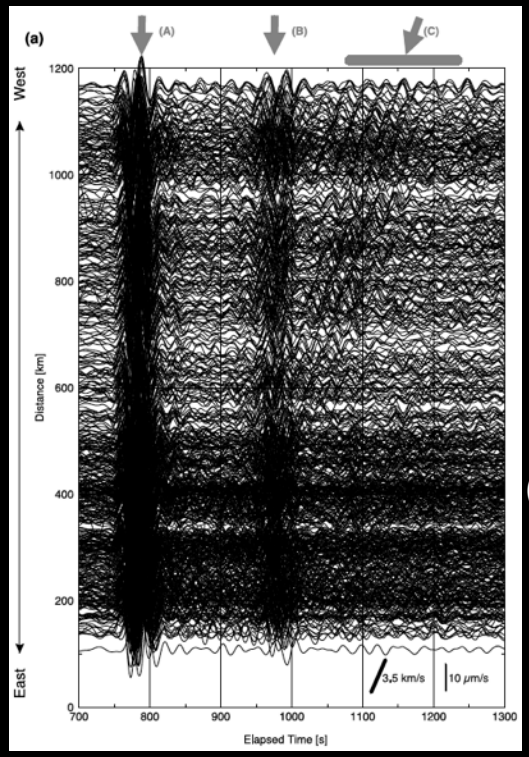
Four other deep events from the Kermadec-Tonga subduction zone



East of Australia

Strongly scattered Rayleigh and Love waves observed at the SKIPPY array from a regional deep earthquake (Furumura et al., 1998 GJI)



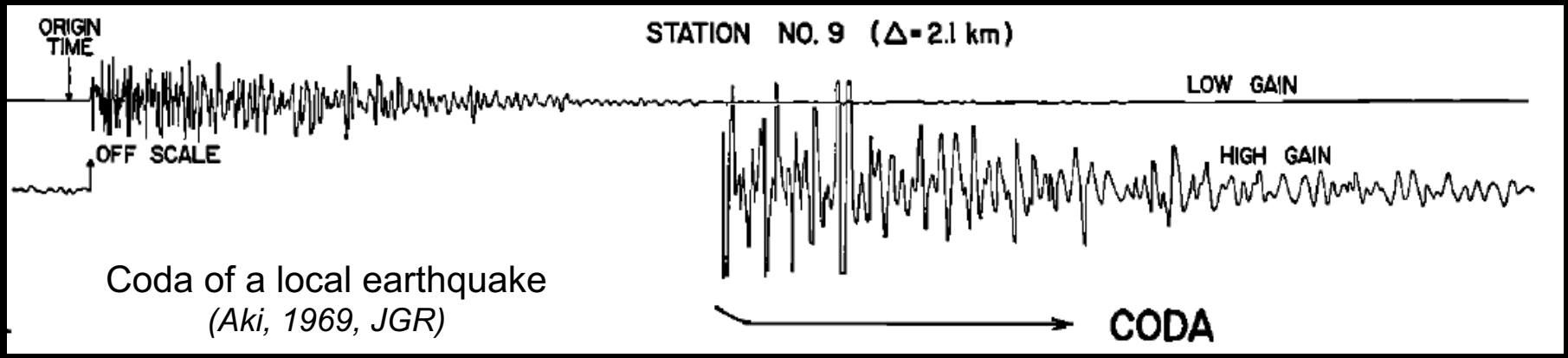


Japan Trench

Scattered Rayleigh wave following the arrival of teleseismic P waves recorded at the *Hi-net array*

(Maeda et al., 2014 EPSL)

"The modification of seismic wave caused by the three-dimensional heterogeneities is broadly called **seismic wave scattering**." – Wu & Aki, (1988)

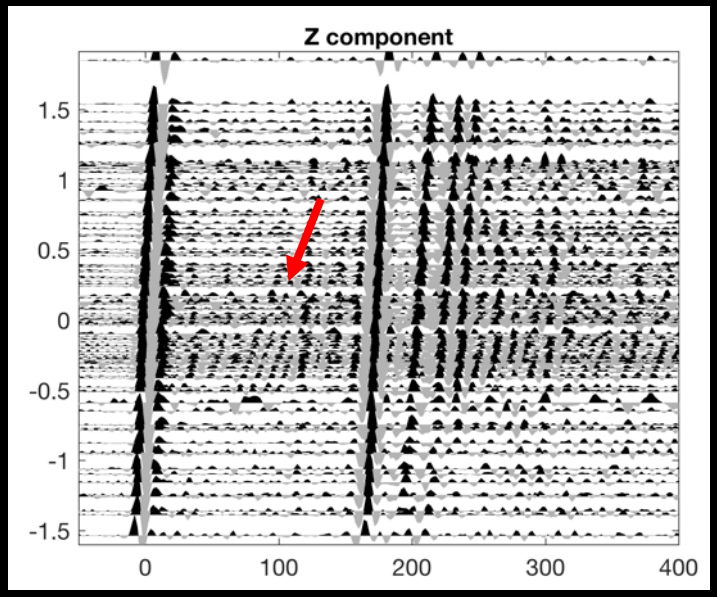


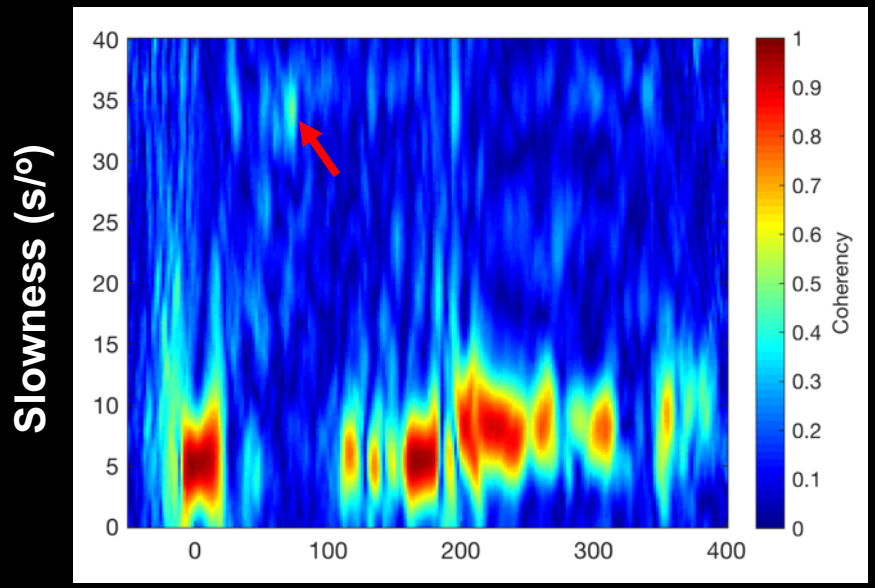
Coda of a local earthquake

(Aki, 1969, JGR)

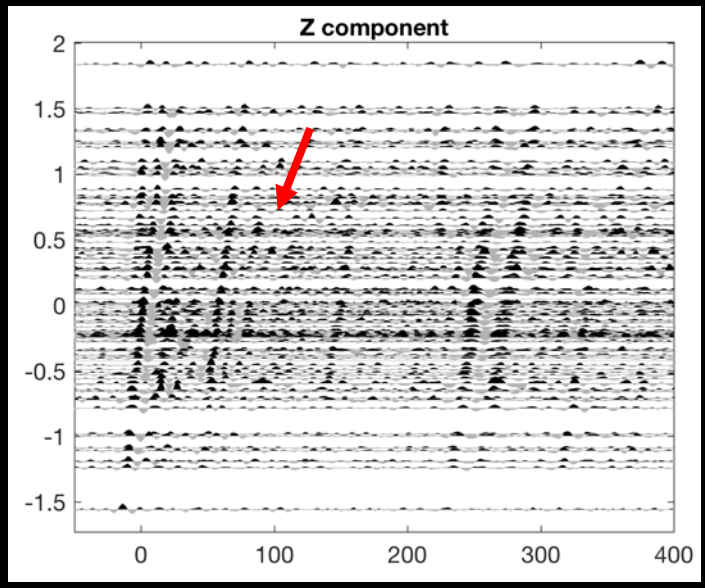
Weaker *P-to-Rg* and *SV-to-Rg* scatterings

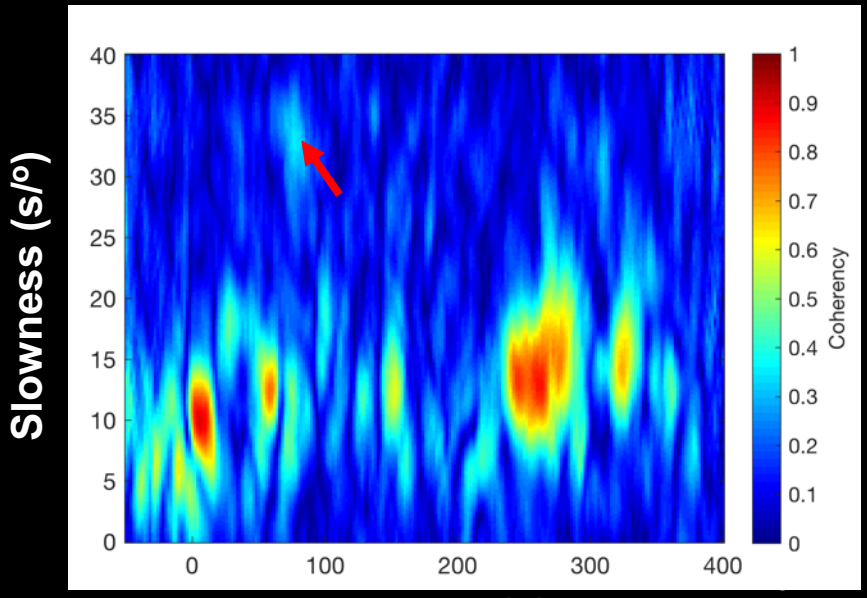
P wave (vertical)





SV wave (vertical)

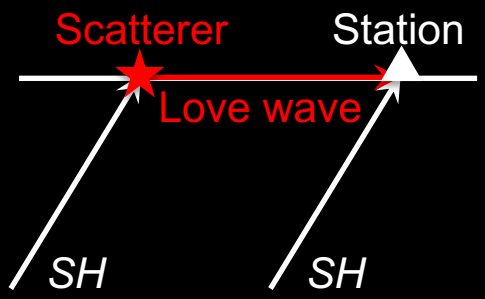




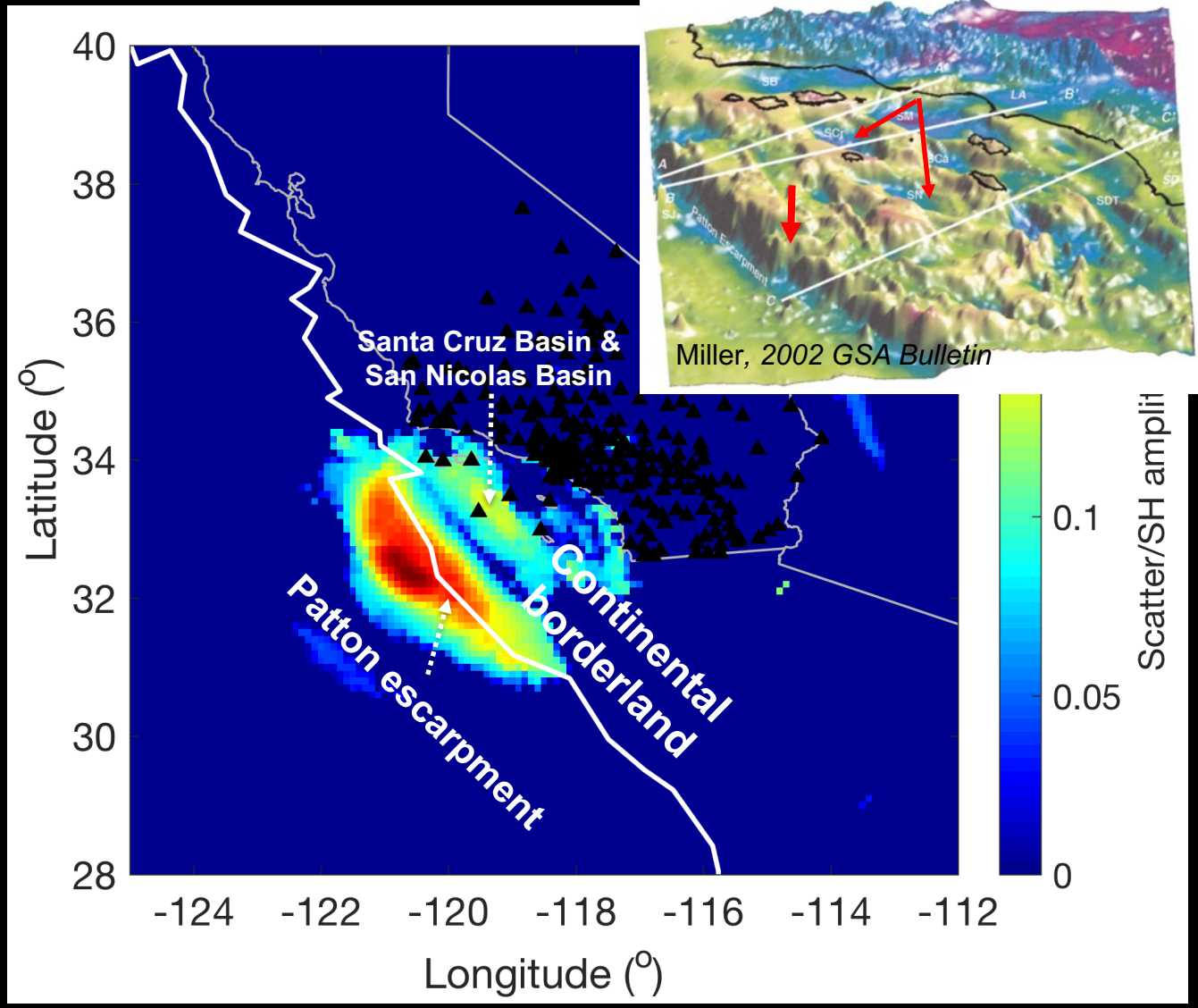
Location of *SH-to-Love* scatterers

Back projection

Cross section



Map view



assume constant Love wave velocity 3.2 km/s

How scatters are generated?

Waveform modeling

Global 2D finite-difference using GPU
(Li et al., 2014)

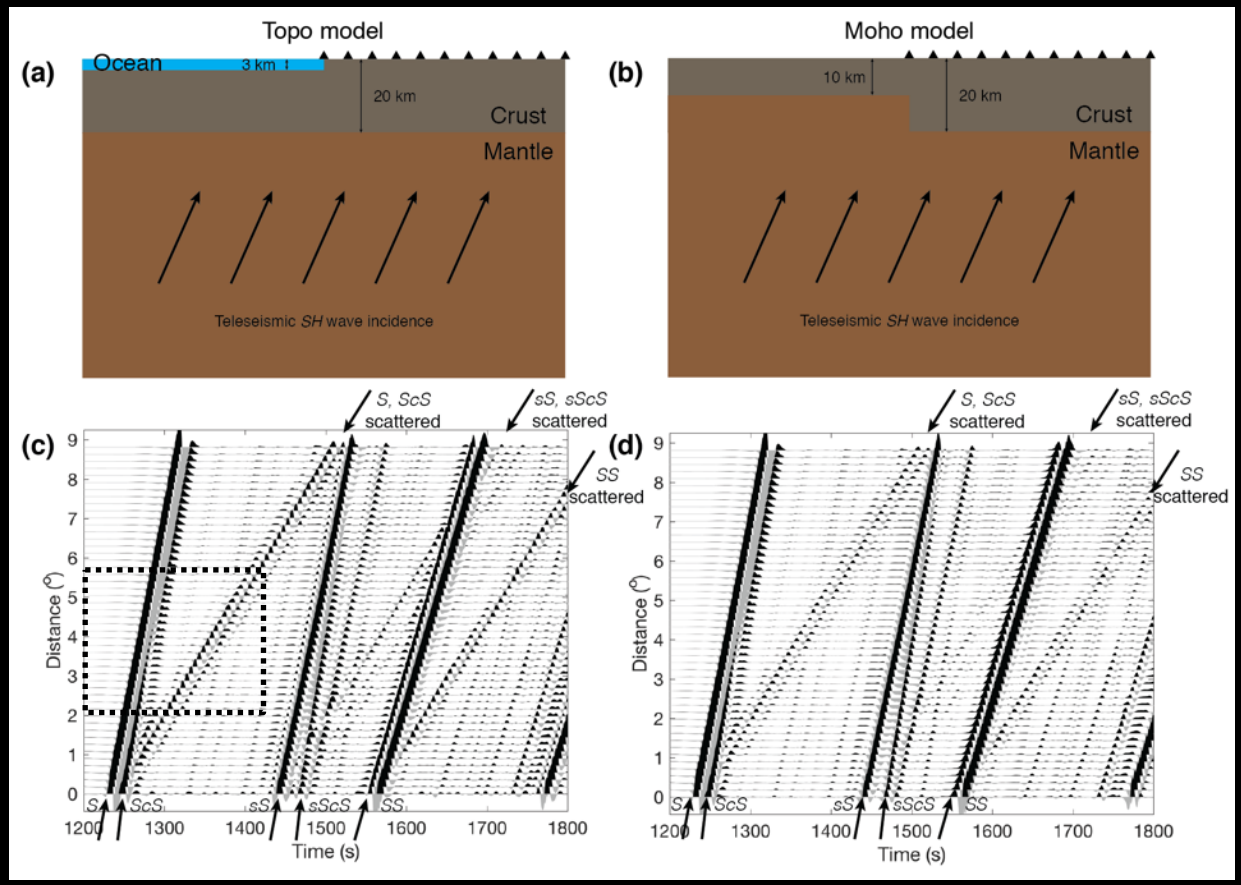
1 km grid size

Highest frequency ~0.5 Hz

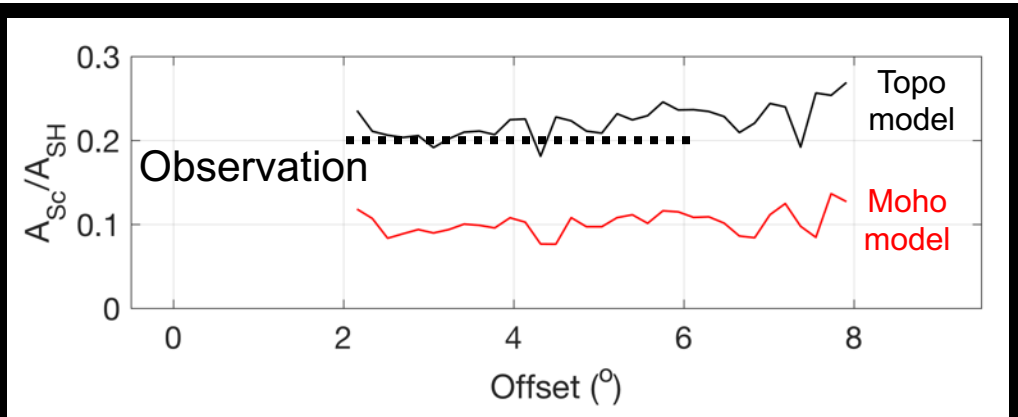
Line → point source correction

GCMT moment tensor

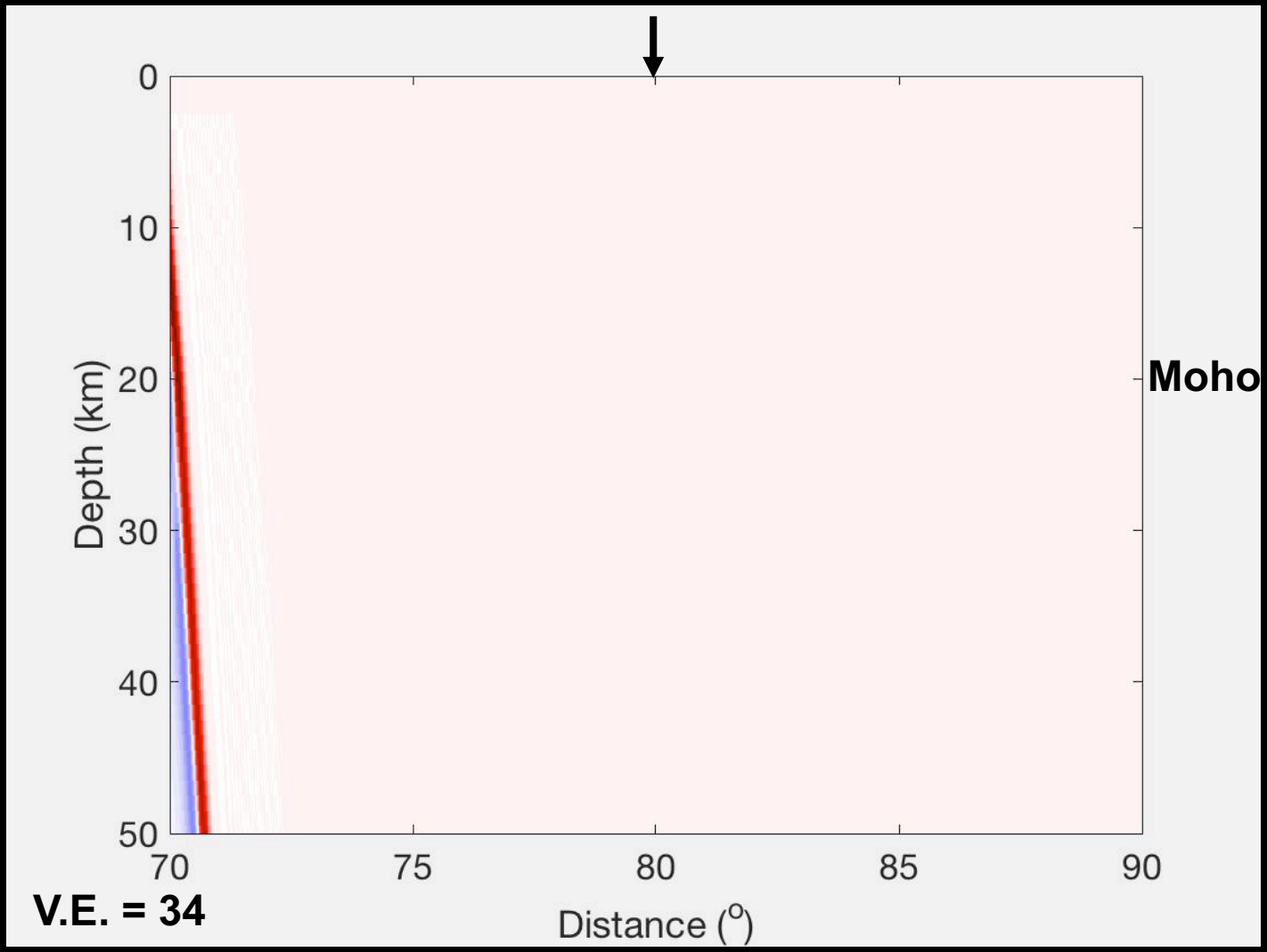
2 GPUs ~ 20 minutes



3 km change in bathymetry well predict the amplitude of scattered Love wave

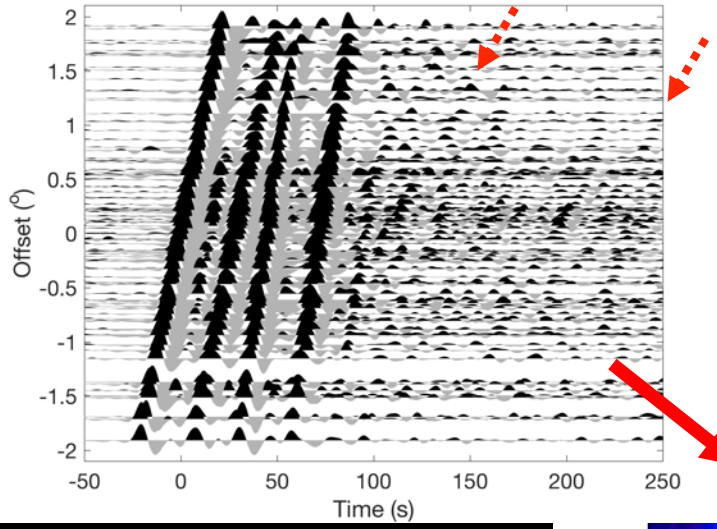


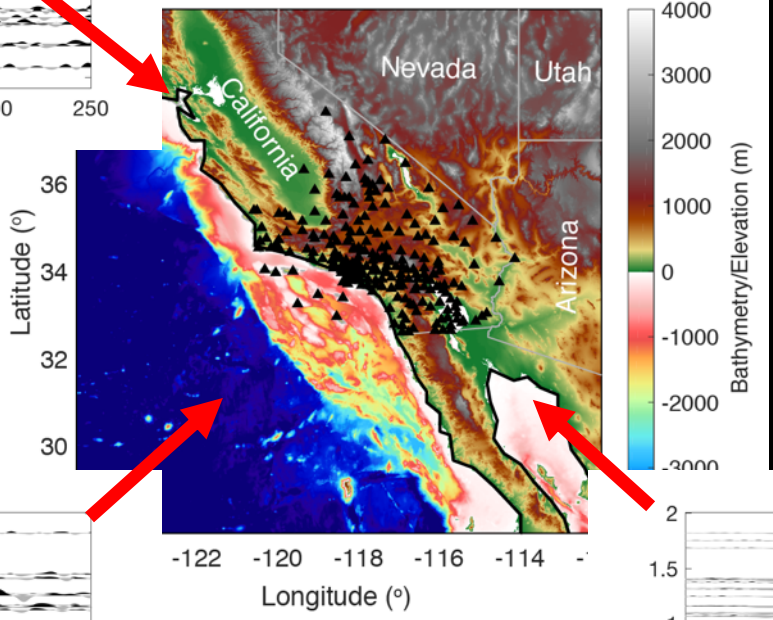
SH-to-Love wave scattering

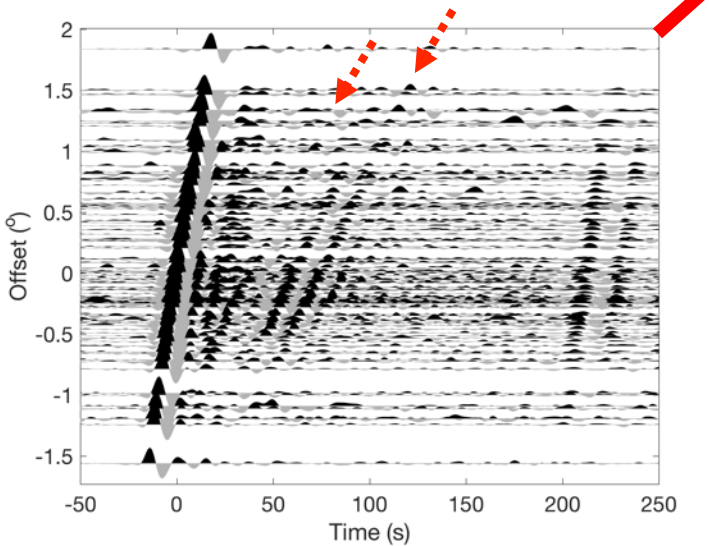


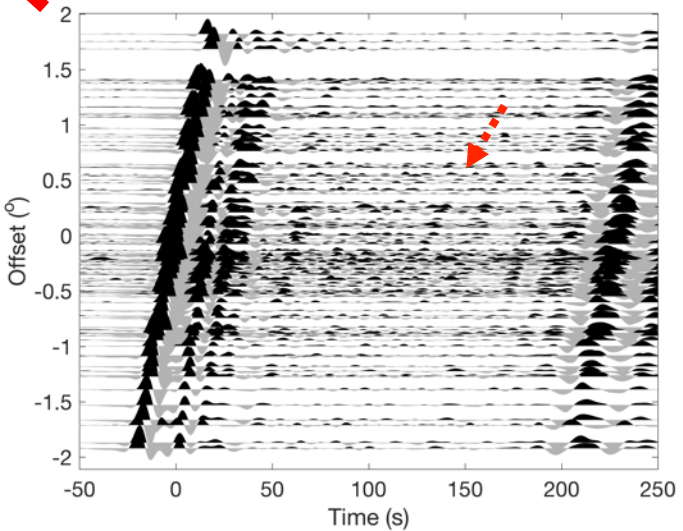
Azimuthal variations in scattering

1. *SH*-to-Love wave scattering widely exists
2. Strongest for events from SW

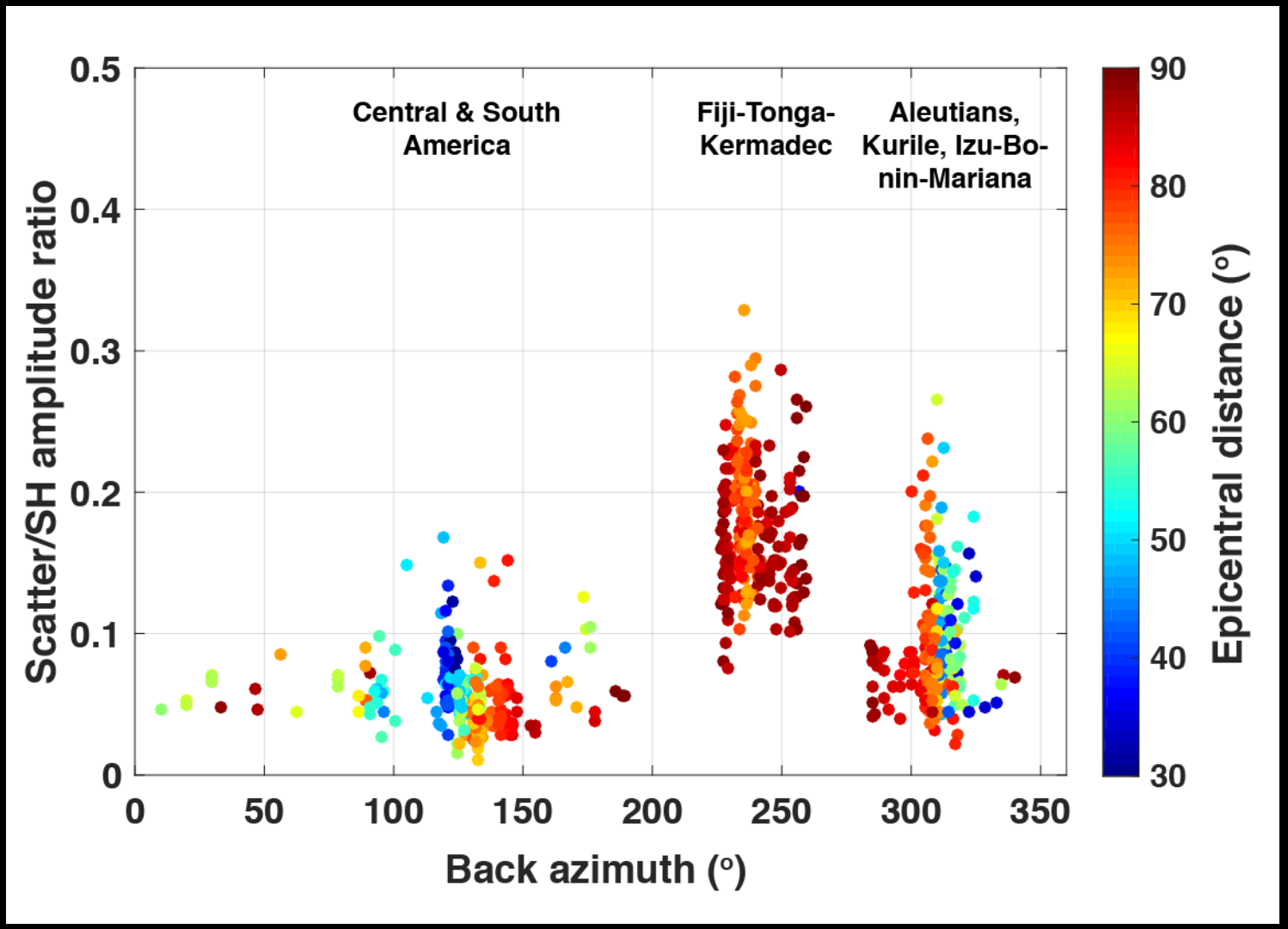








Azimuthal variations in $A_{scatter}/A_{SH}$

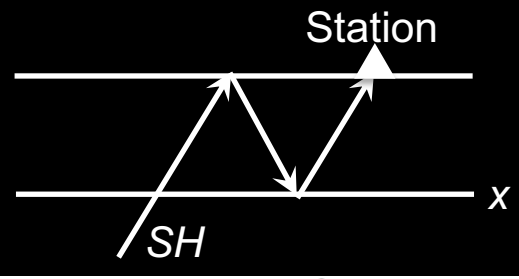


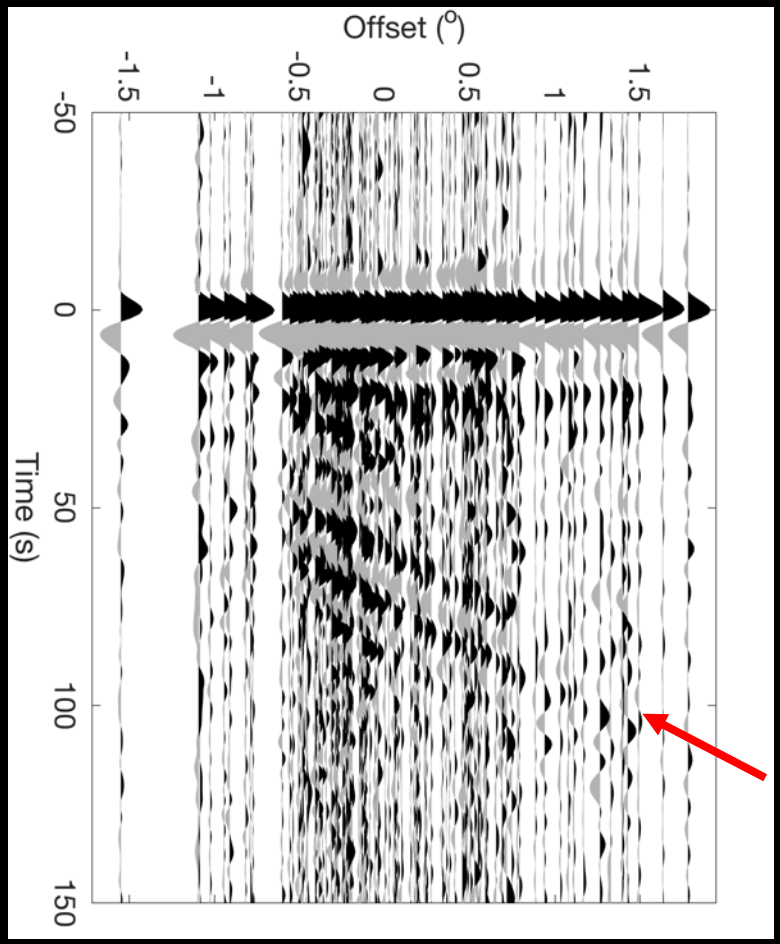
1. SH-to-Love wave scattering widely exists

2. Strongest for events from Fiji-Tonga-Kermadec subduction zone

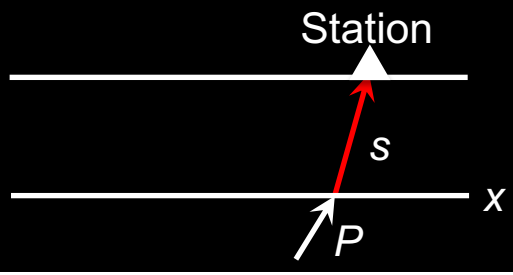
Scatters can potentially cause artifacts in structural images

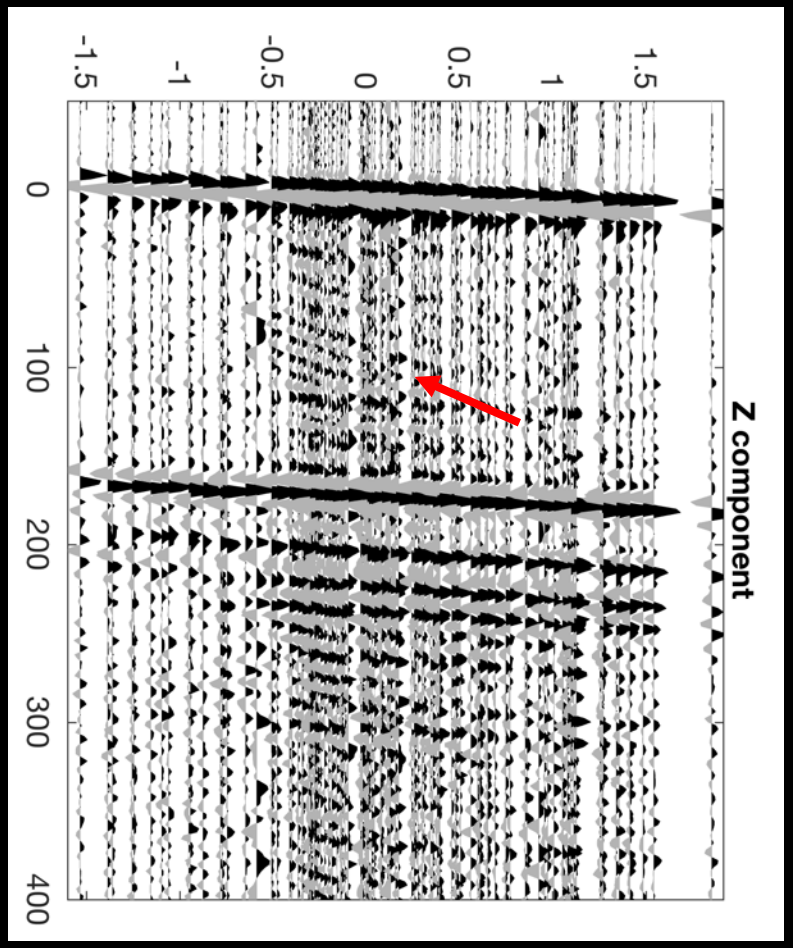
Top-side Ssxs reflection imaging





Receiver functions

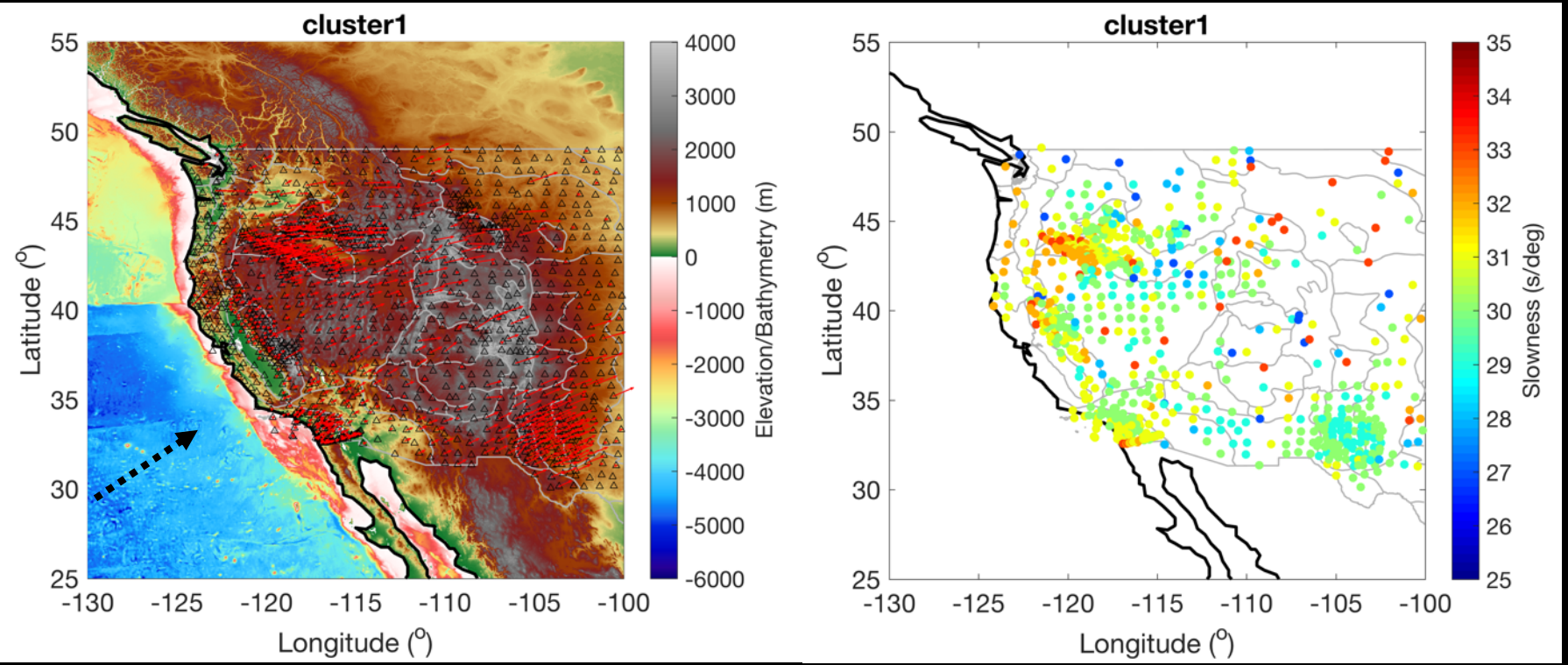




Potential application to Love wave tomography

Scattered Love wave propagation direction & time delay

Measured slowness at each station



Event cluster from Tonga-Kermadec subduction zone

Summary

- *SH-to-Love* wave scattering can be a prominent feature on seismic waveforms.
- Strong scattering from regions with pronounced bathymetric/topographic relief, such as Patton escarpment.
- Scatterings can potentially cause artifacts in subsurface images.
- Scatterings can potentially be used to constrain subsurface velocity structures.

Thank you!
Questions?