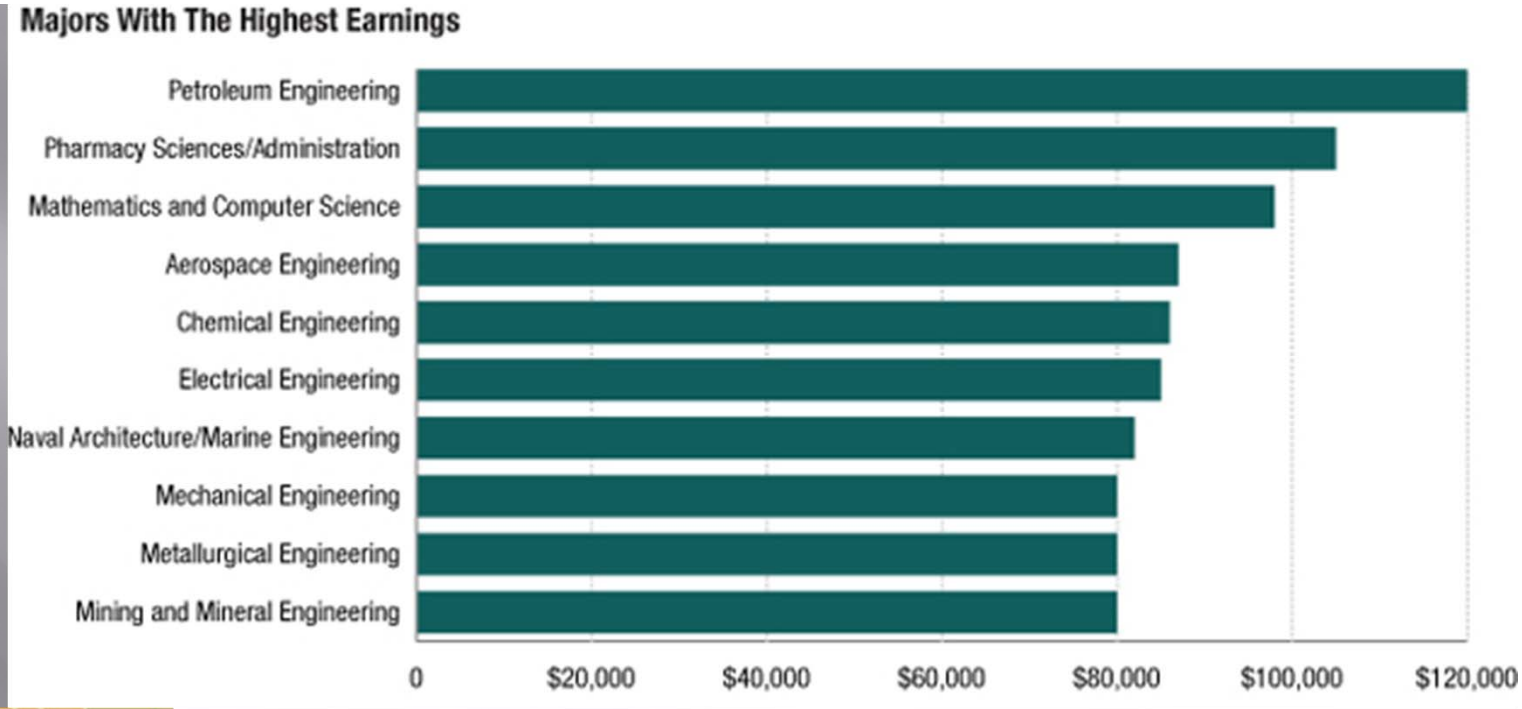
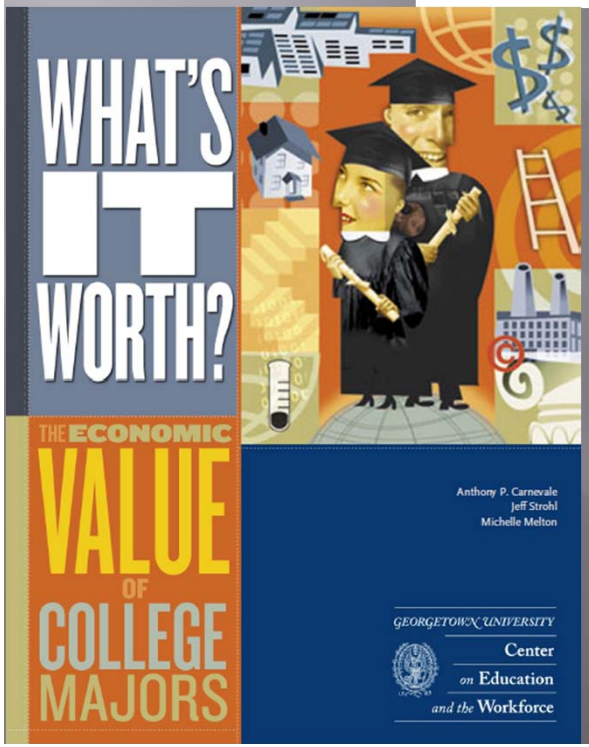




Some majors have virtually no unemployment, including Geological and Geophysical Engineering, Military Technologies, Pharmacology, and School Student Counseling.

http://www9.georgetown.edu/grad/gppi/hpi/cew/pdfs/whatsitworth-complete.pdf

Seismic tomography and interferometry: from shallow to deep

Fan-Chi Lin

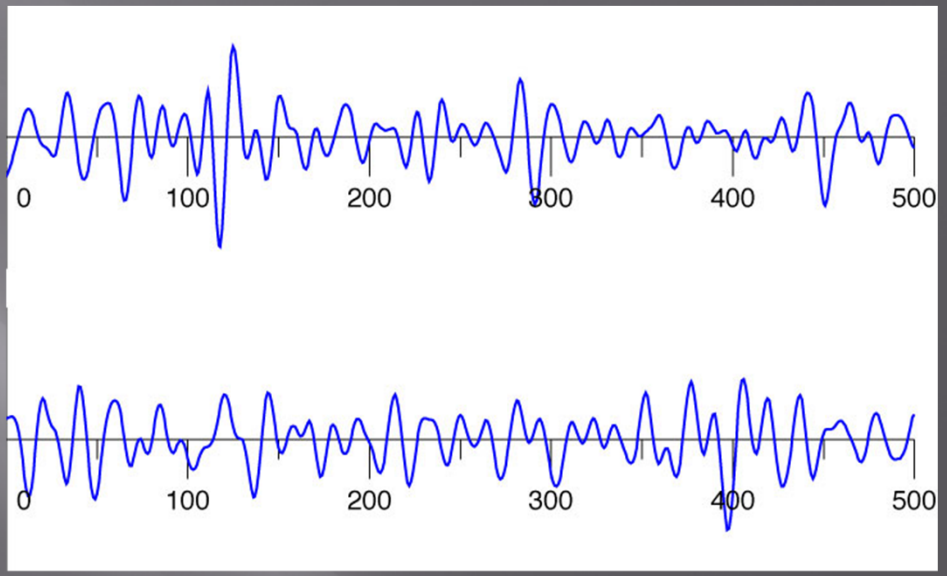
Seismological Laboratory
Caltech*

September 17, 2013
NCU

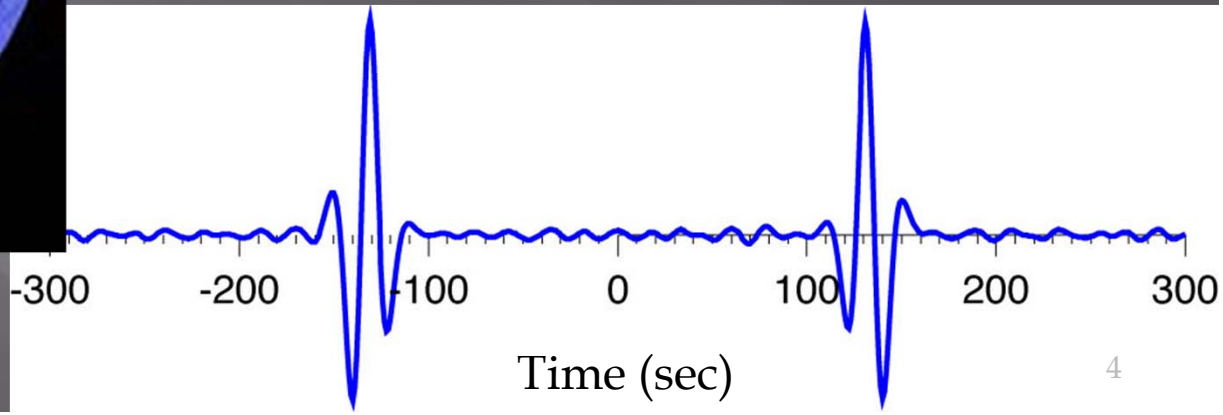
Acknowledgments

- Michael Ritzwoller (CU Boulder)
- Victor Tsai (Caltech)
- Rob Clayton (Caltech)
- Dunzhu Li (Caltech)
- Brandon Schmandt (UNM)

Seismic interferometry

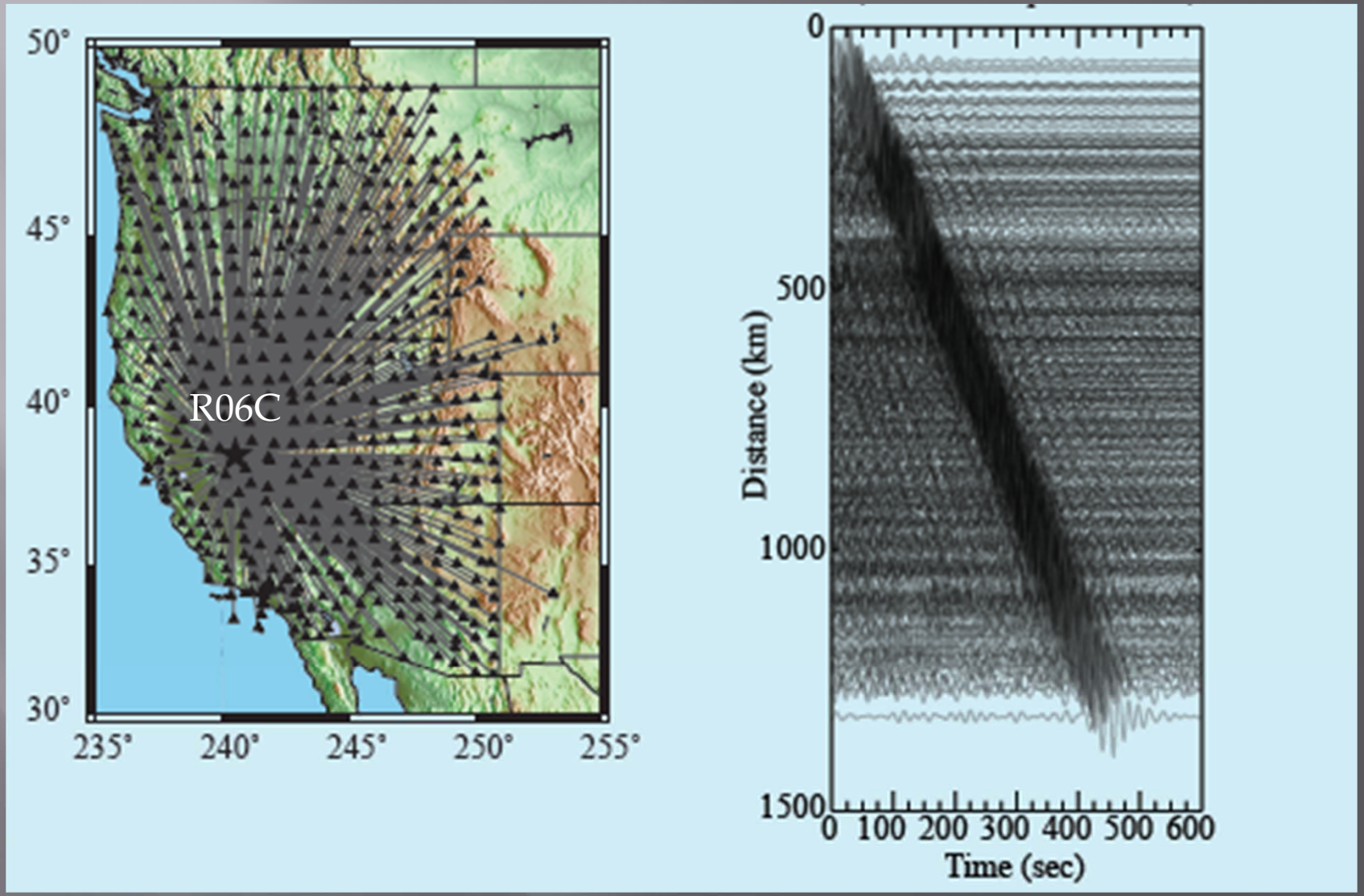


$$\int u_1(t)\,u_2(t+\tau)\;dt = C(\tau)$$



Ambient noise virtual source

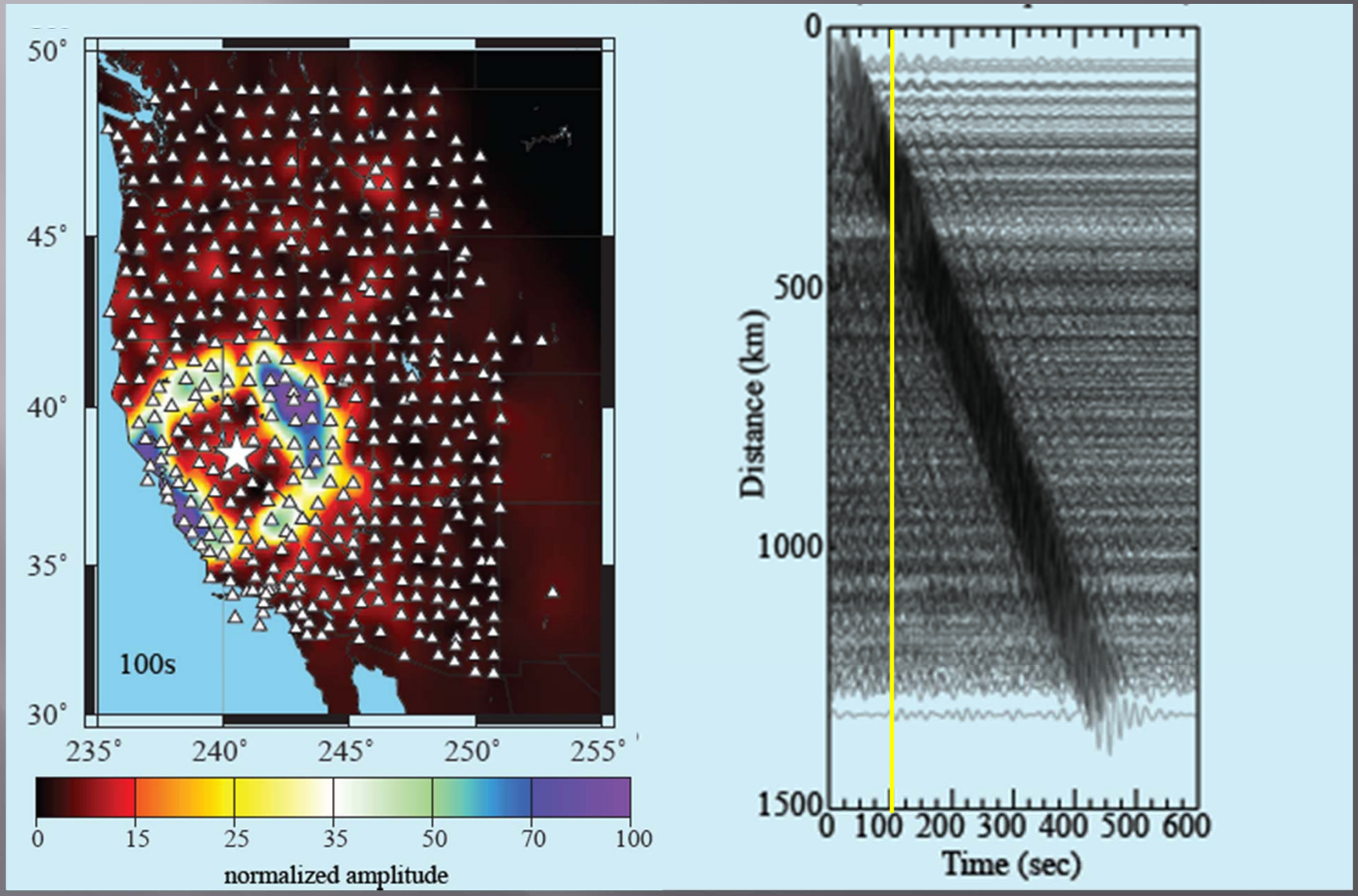
15-30s bandpass filtered



Lin et al. (2009)

Ambient noise virtual source

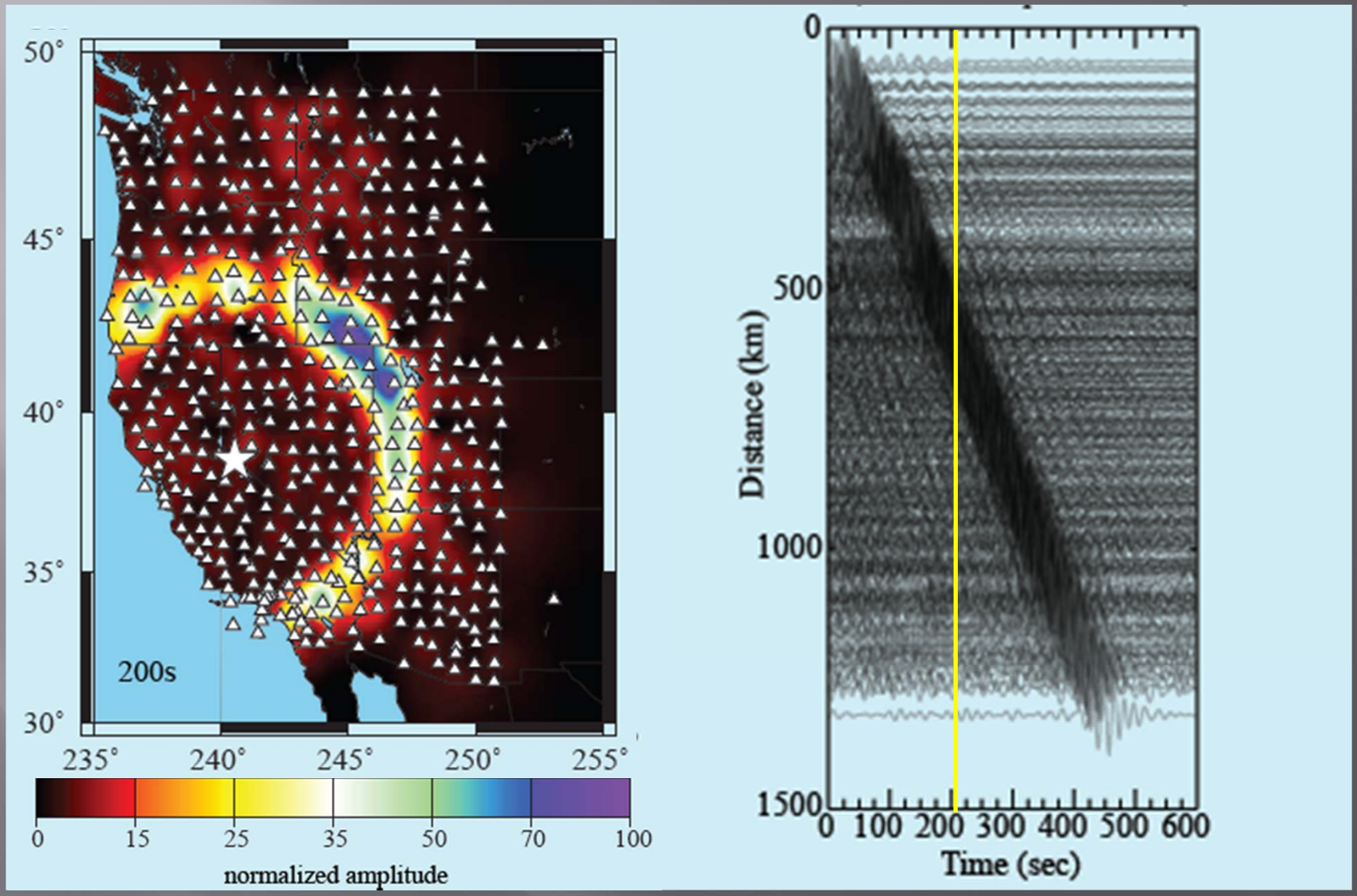
15-30s bandpass filtered



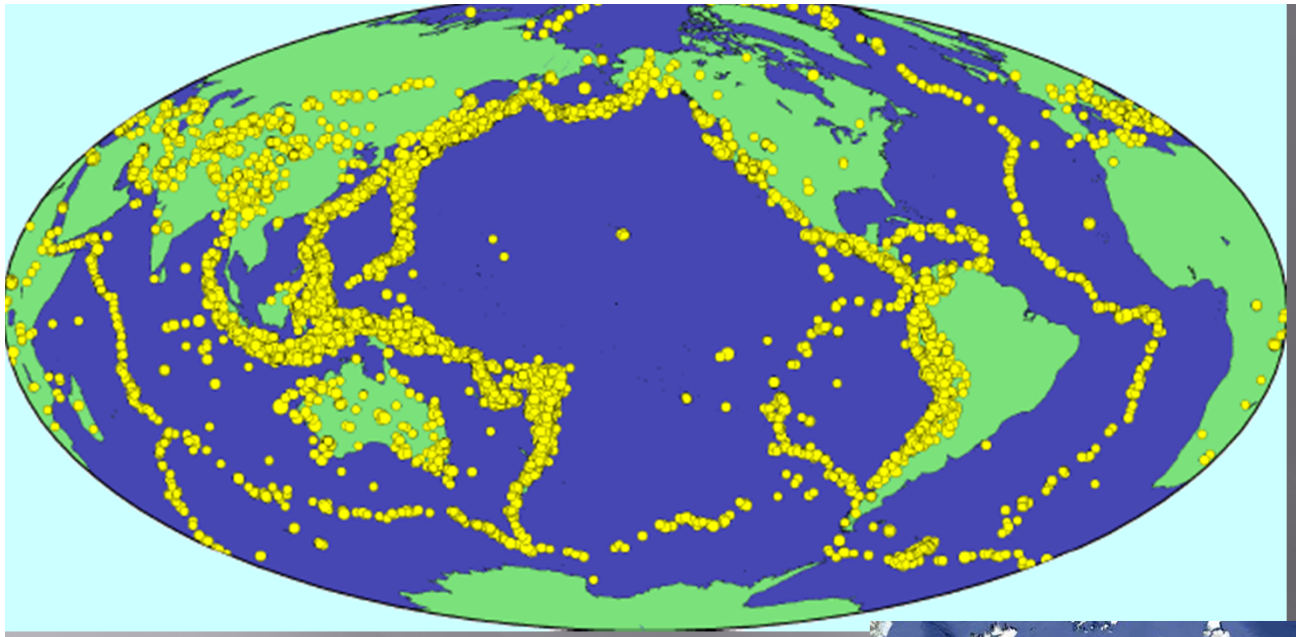
Lin et al. (2009)

Ambient noise virtual source

15-30s bandpass filtered



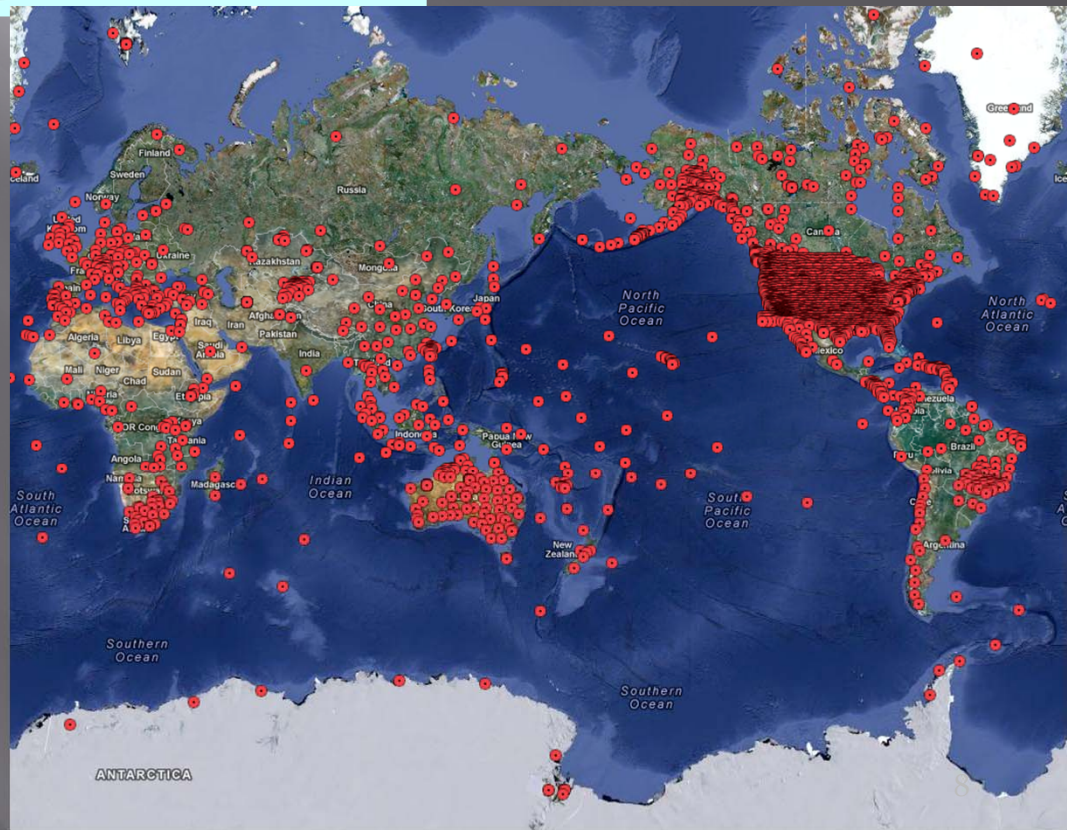
Lin et al. (2009)



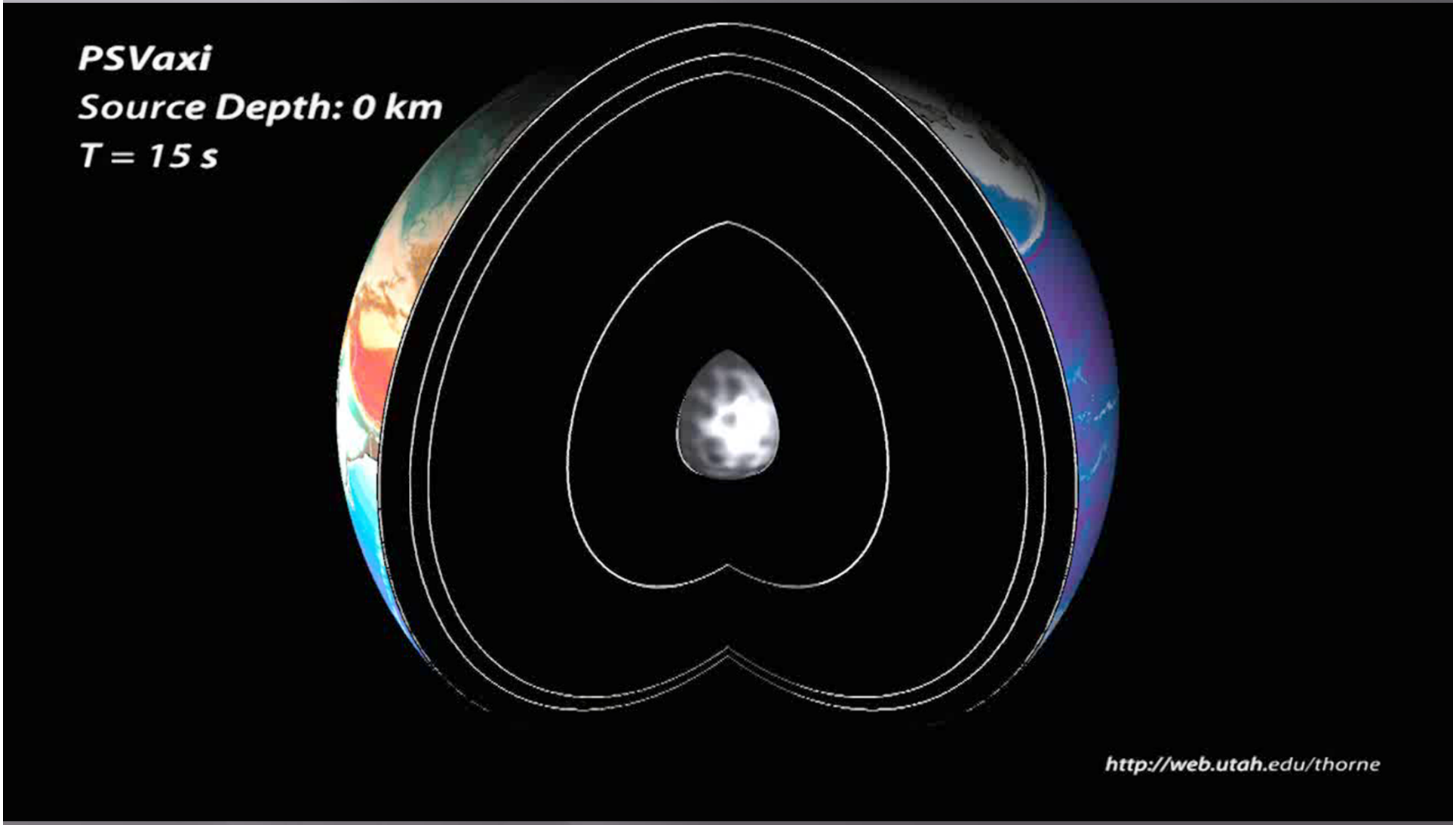
Global seismicity

Seismic station distribution

http://www.iris.edu/

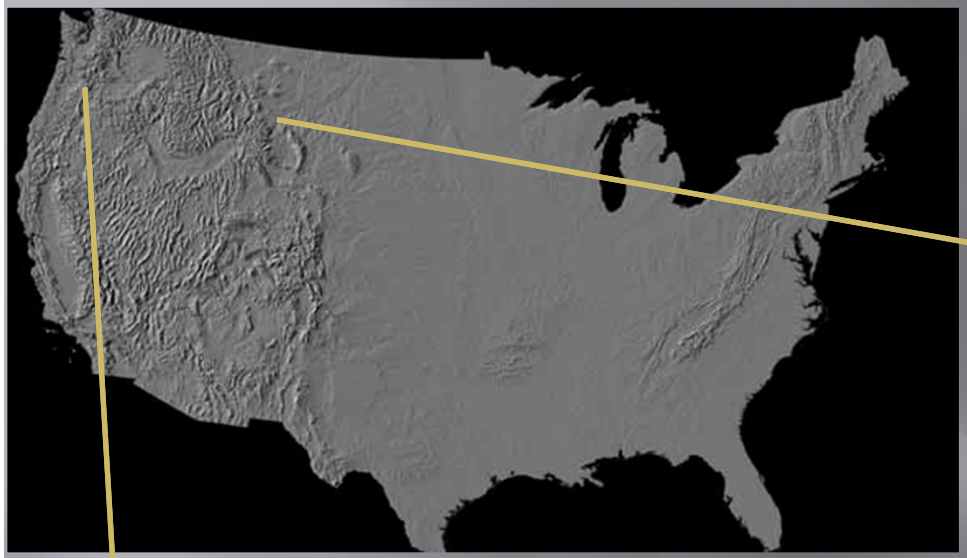


Seismic waves



http://web.utah.edu/thorne/animations.html

Ambient noise tomography



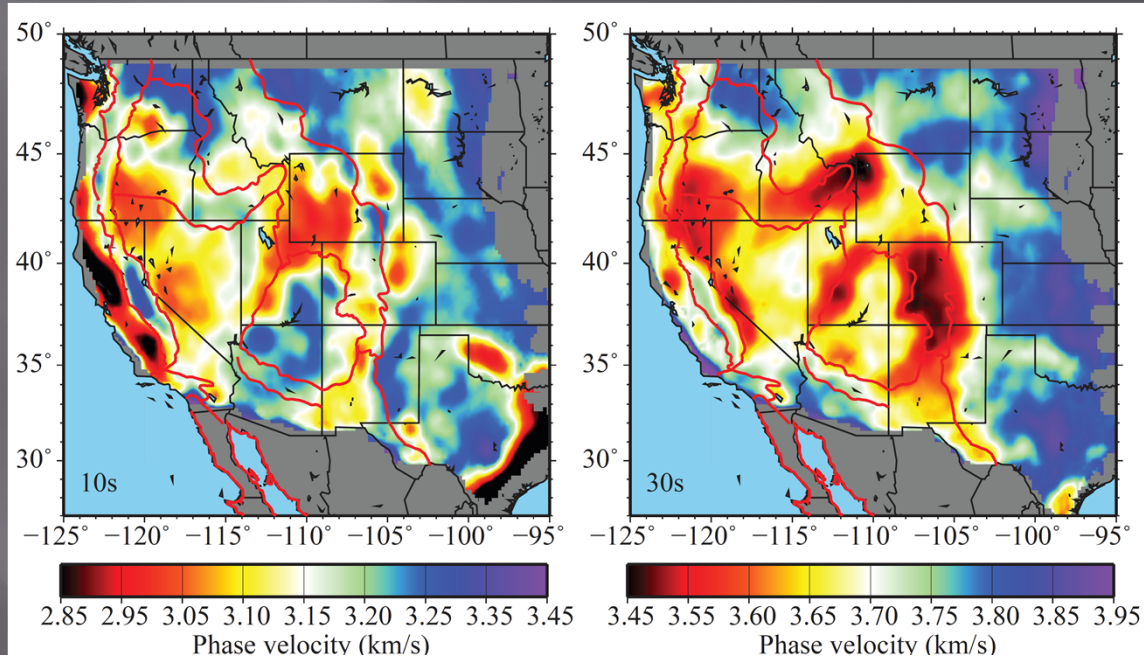
US Topography

Mt. St. Helens, Washington

Yellowstone, Wyoming

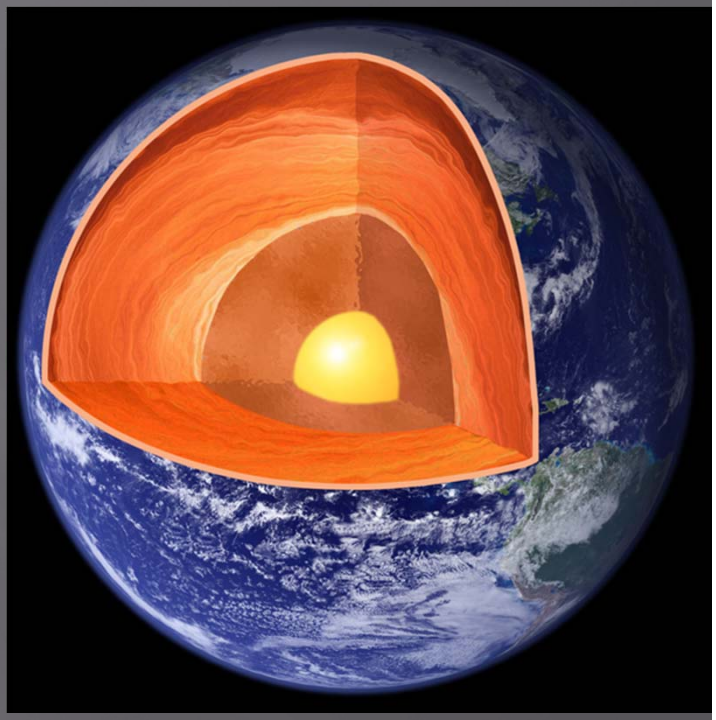
Rayleigh wave phase speed maps

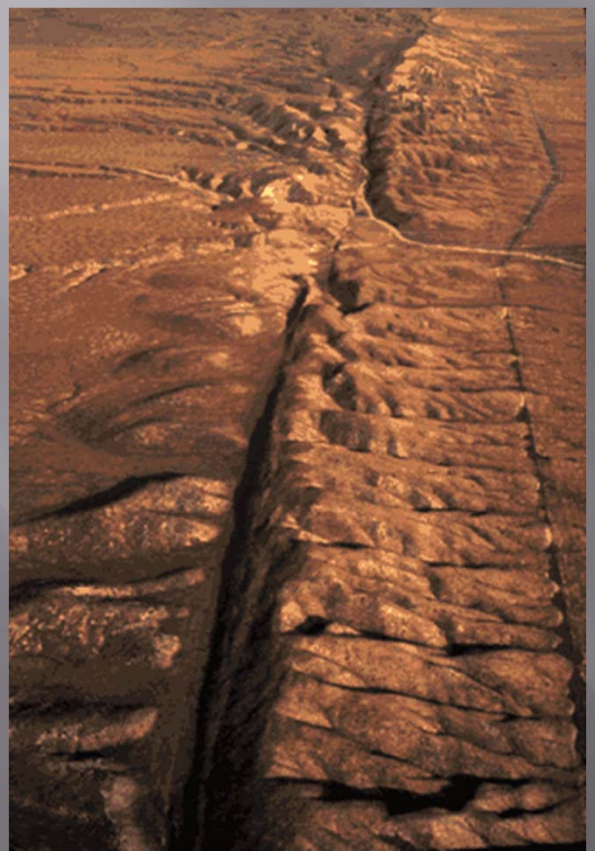
10s 30s



New directions

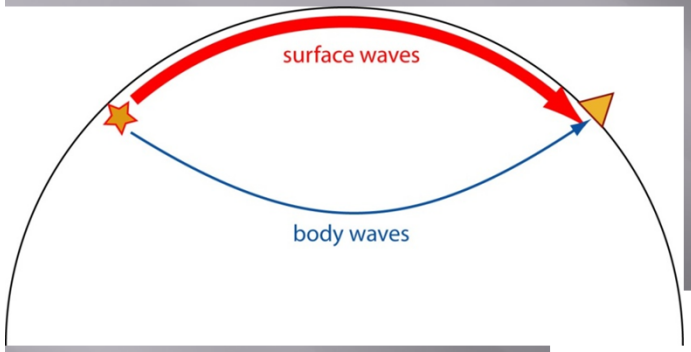
- Shallow
- Deep

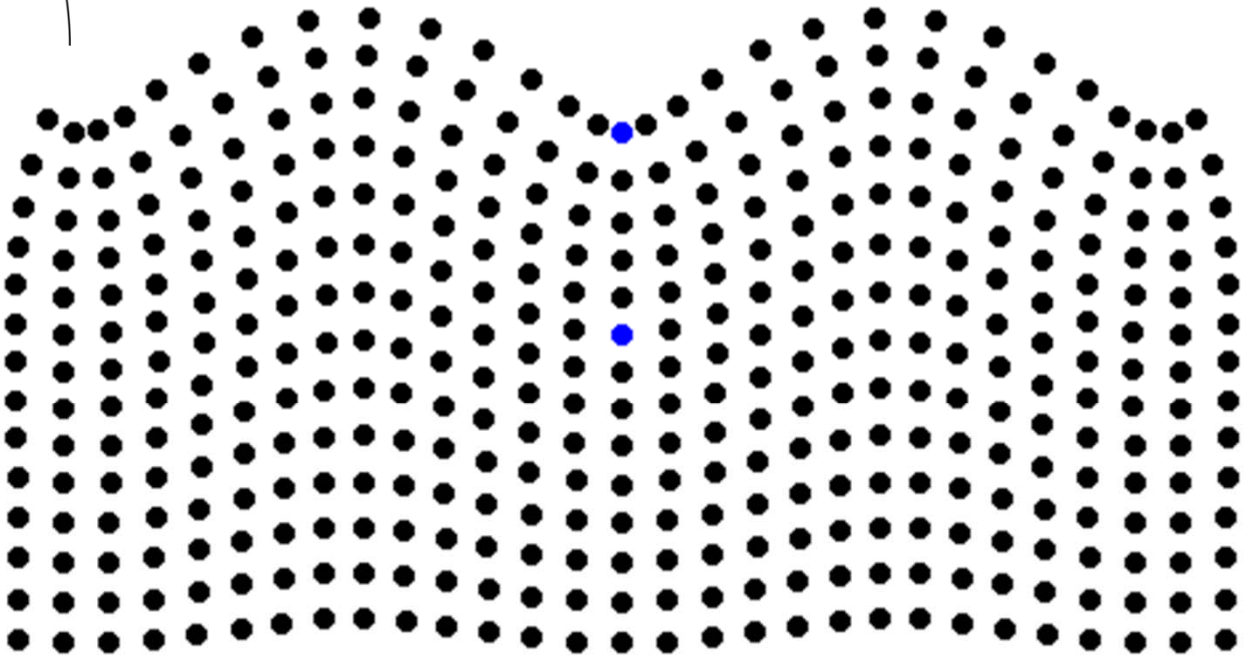




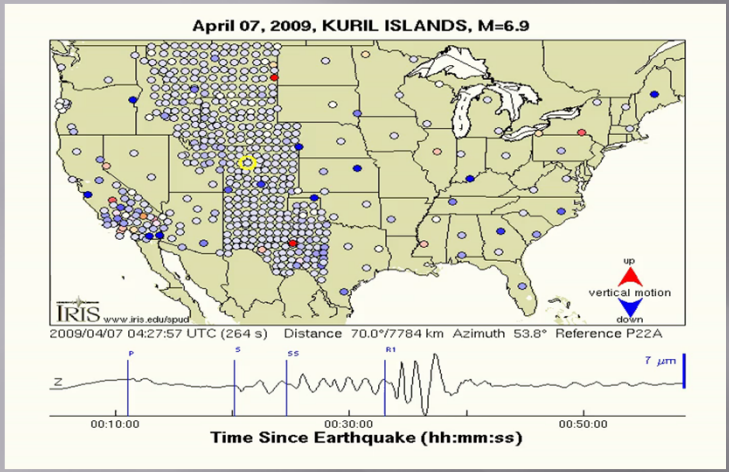
Shallow

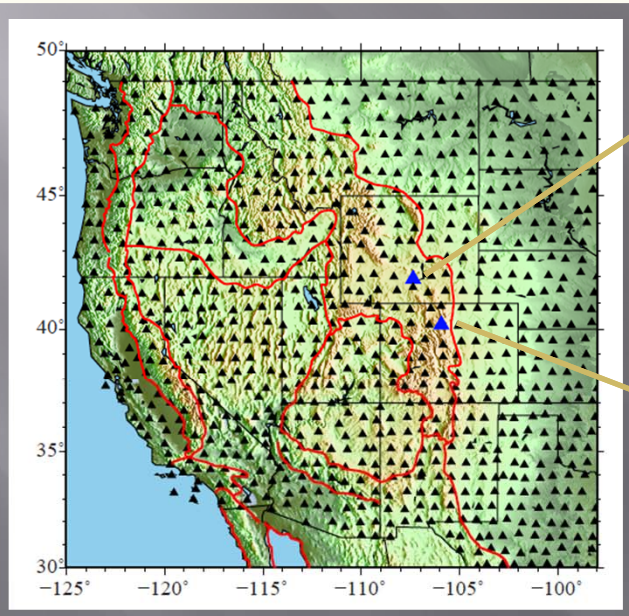
Rayleigh wave ellipticity



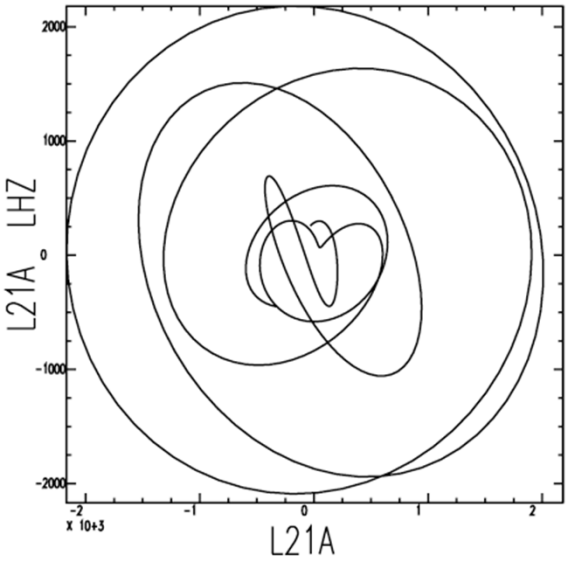


Rayleigh wave ellipticity

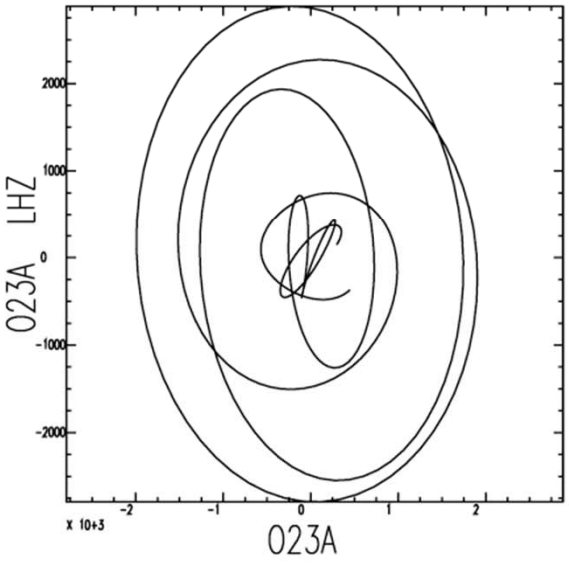




60-sec Rayleigh wave, Apr 7th 2009
Kuril Islands earthquake

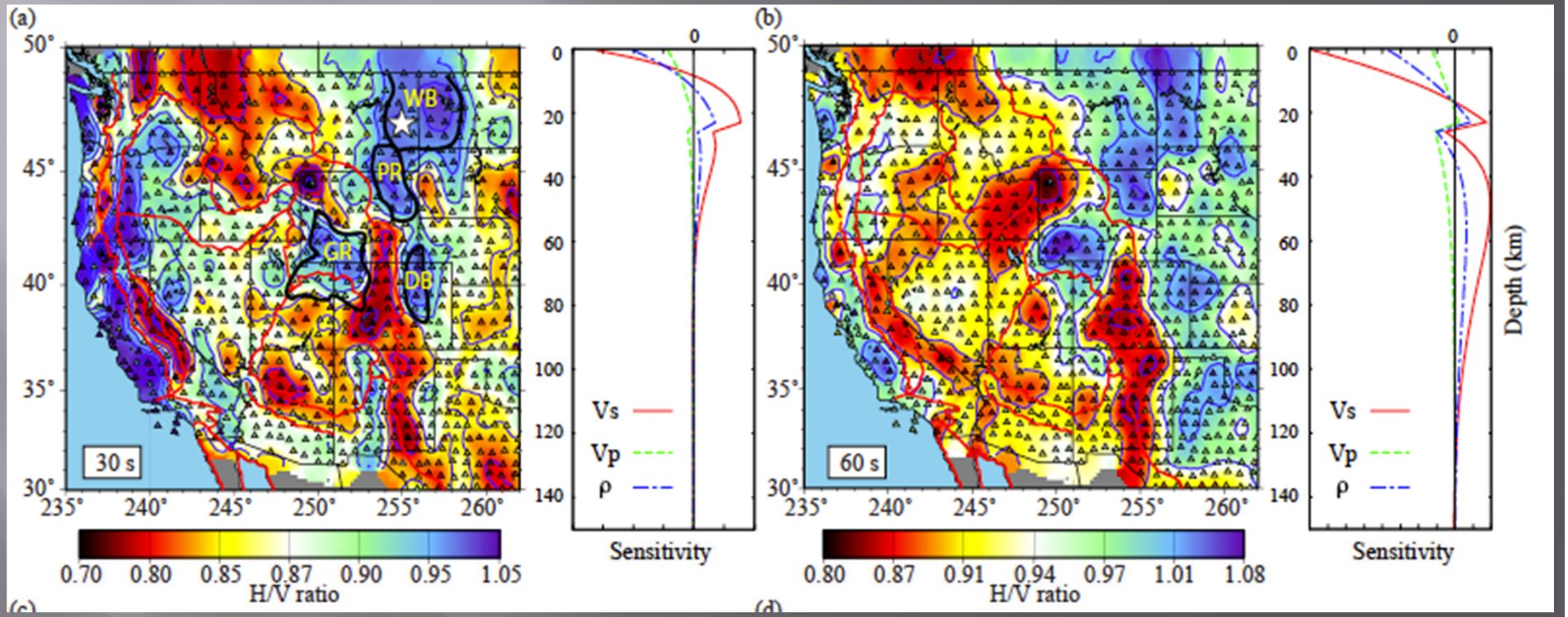


High H/V ratio



Low H/V ratio

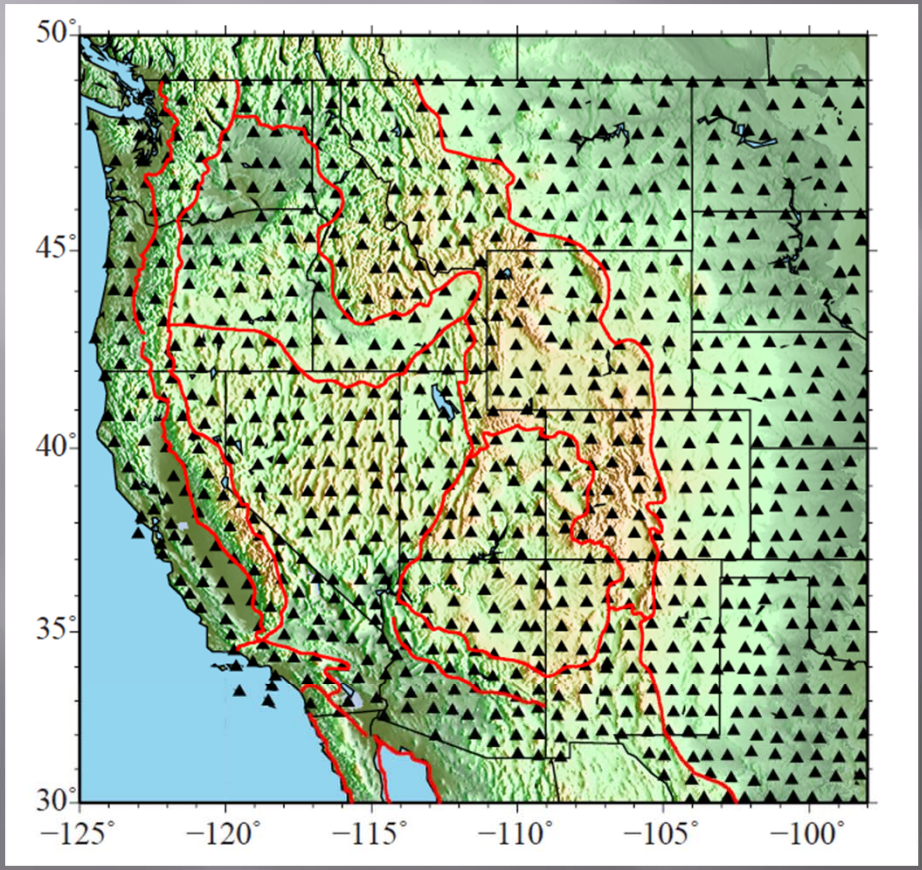
H/V ratio maps



30 sec Rayleigh wave

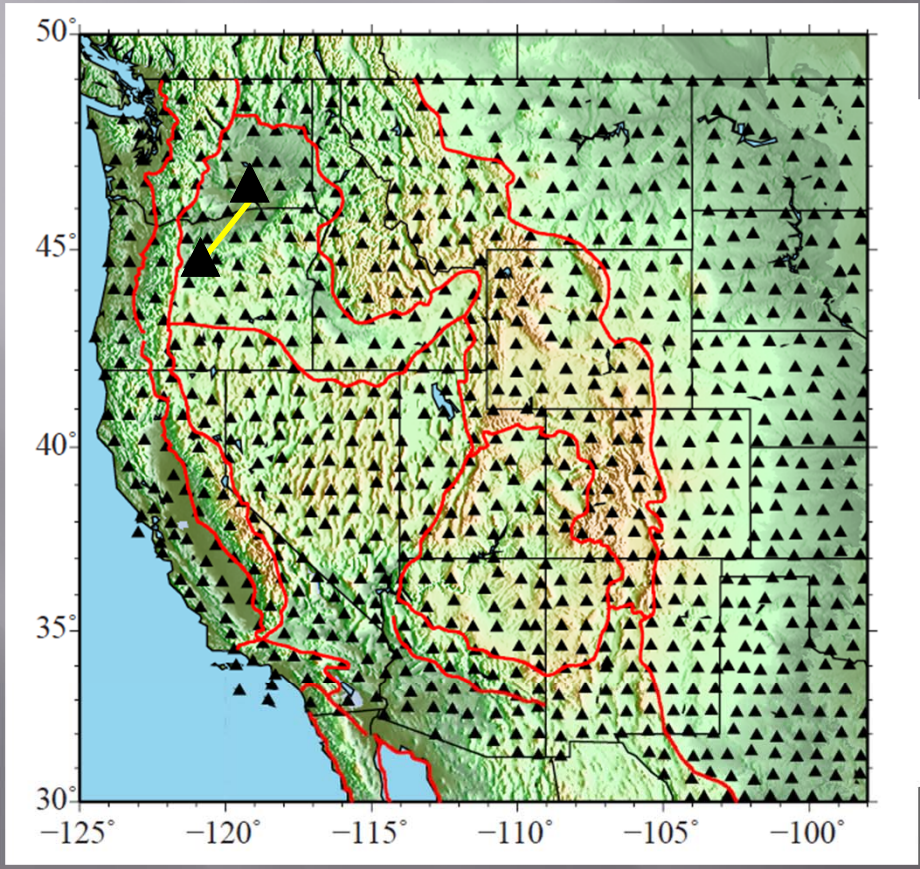
60 sec Rayleigh wave

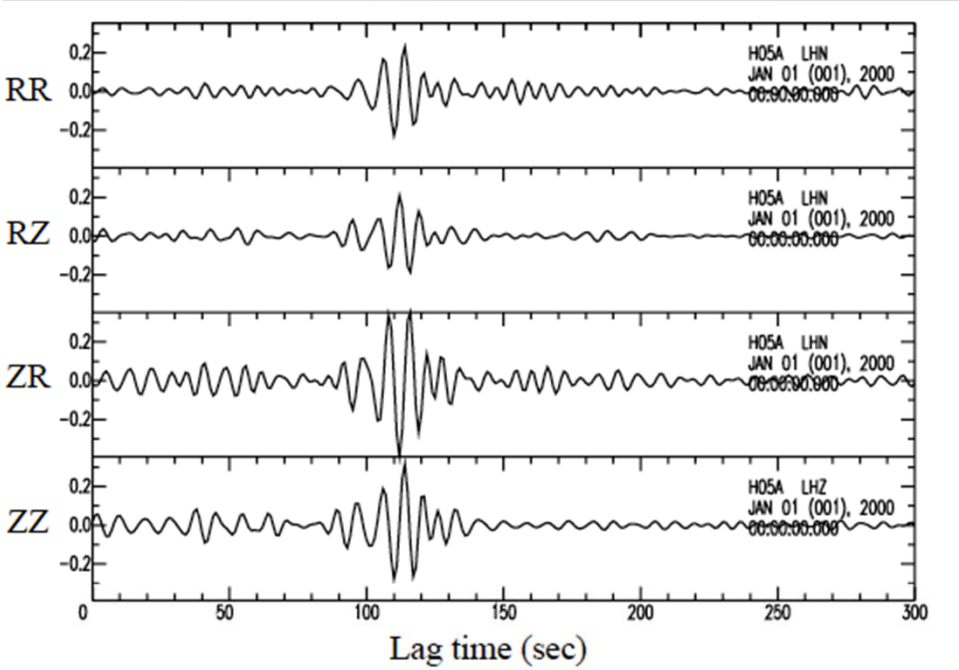
Rayleigh wave ellipticity based on ambient noise



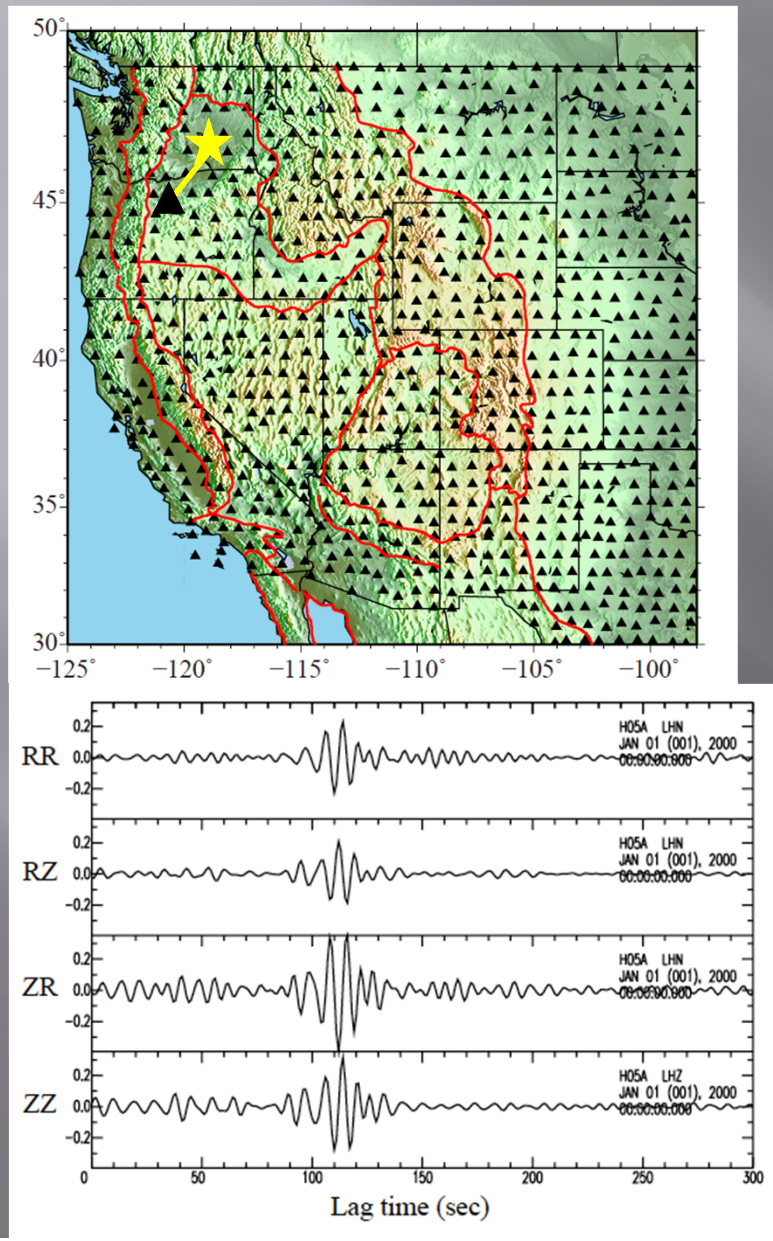
For each station, apply same temporal and spectrum normalization on vertical and horizontal component noise records to keep the amplitude ratio information.

Multi-component ambient noise cross-correlations

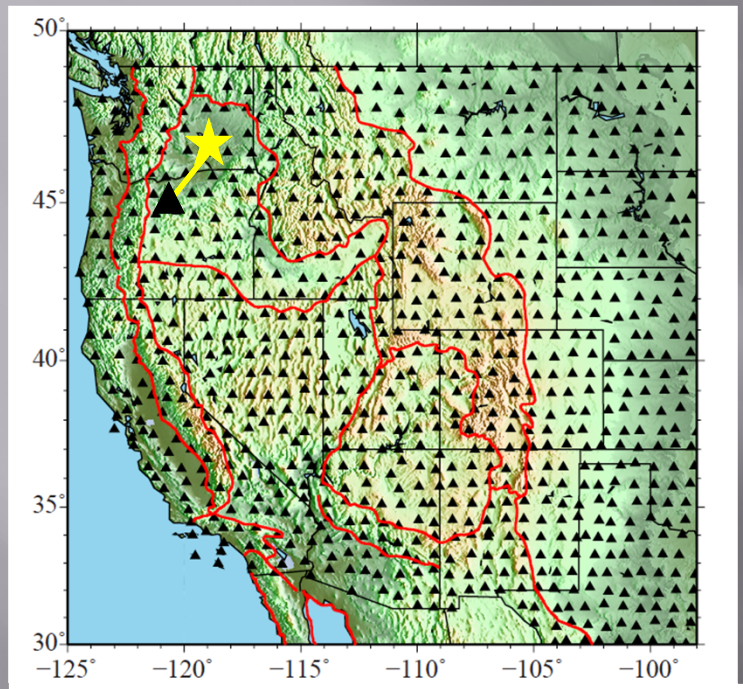


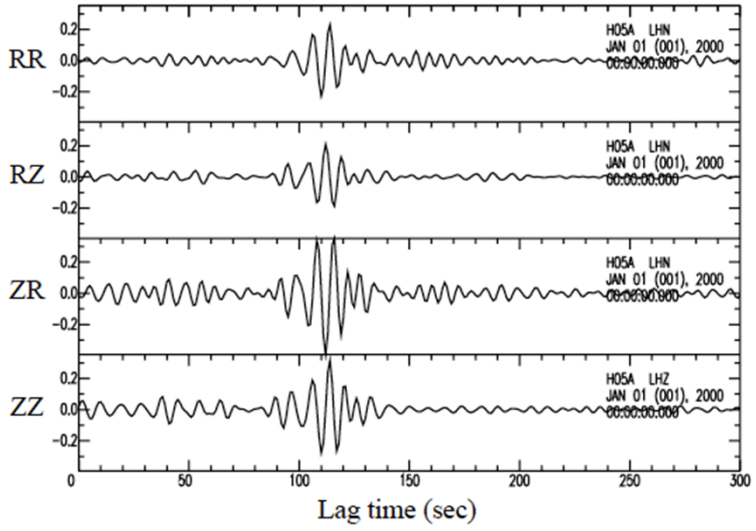


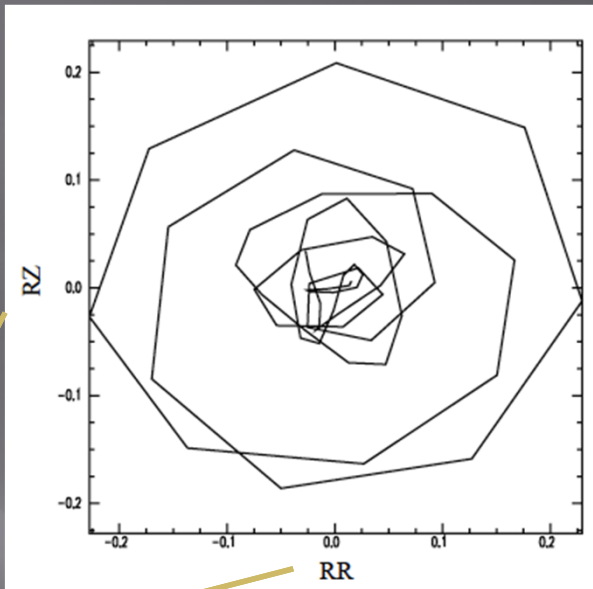
Rayleigh wave ellipticity



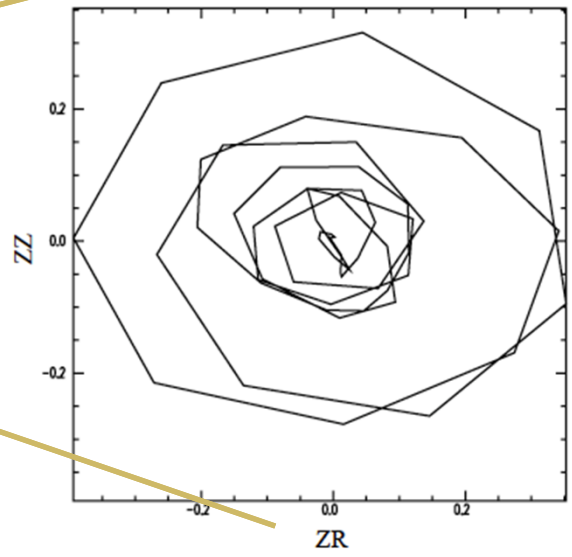
Rayleigh wave ellipticity





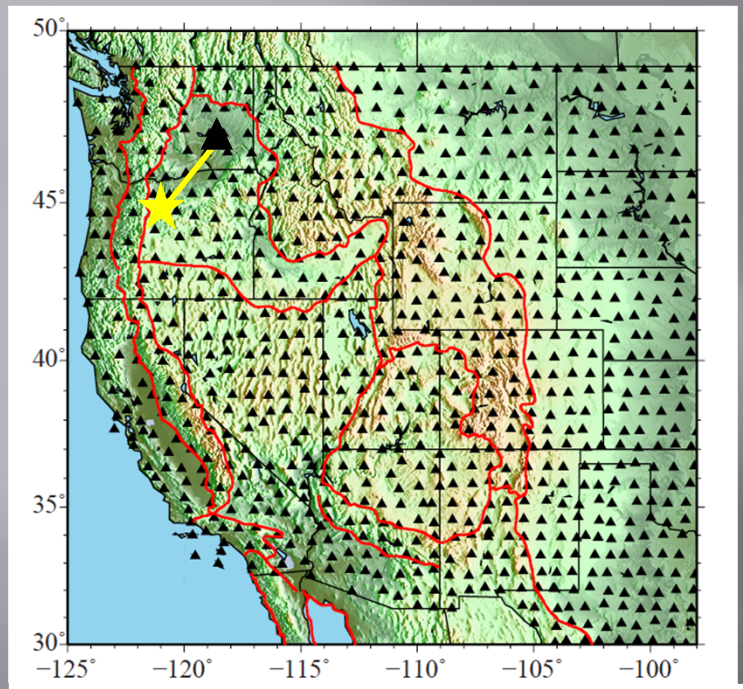


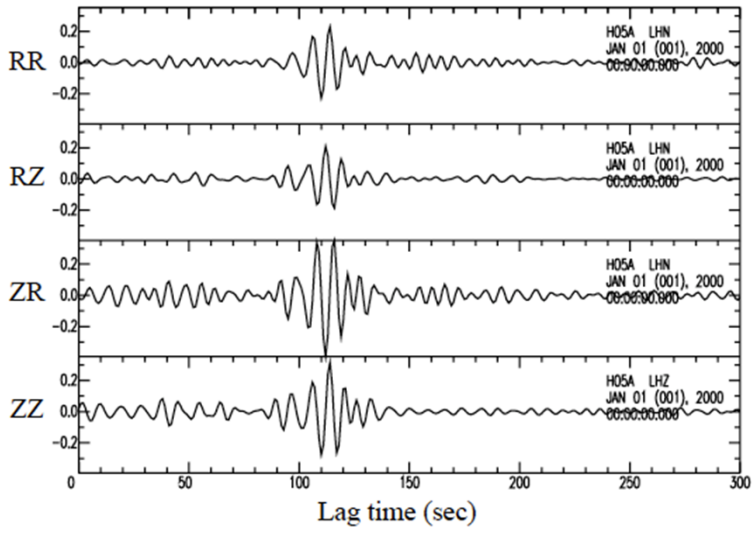
8 s Hori-zontal force

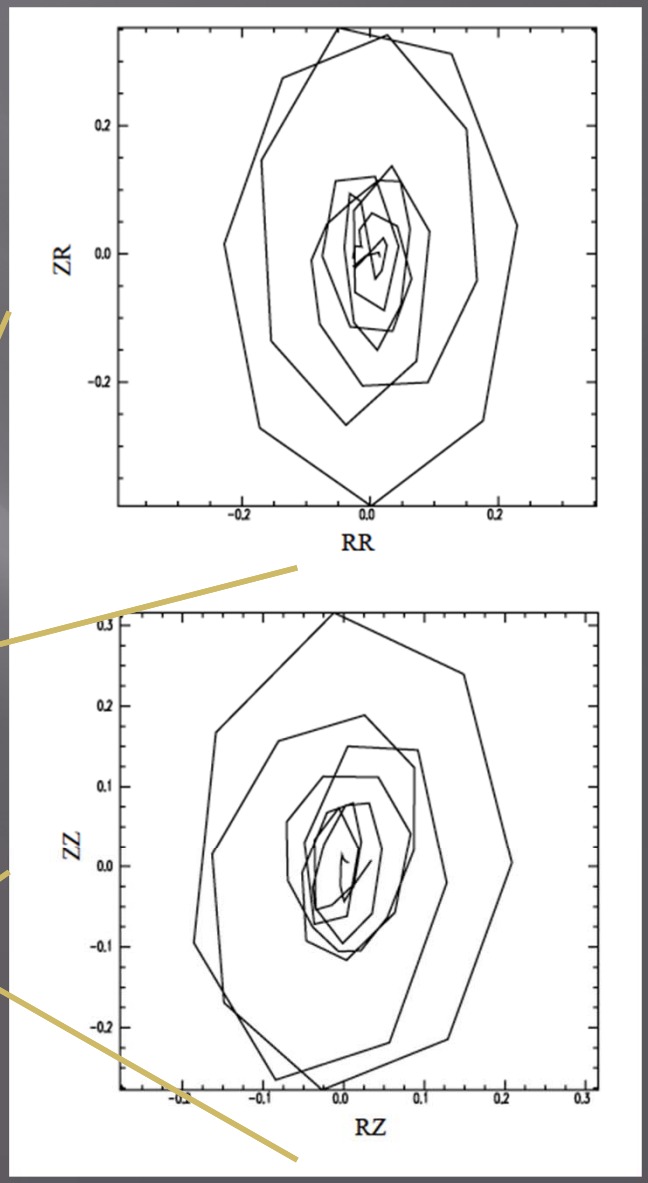


8 s vertical force

Rayleigh wave ellipticity



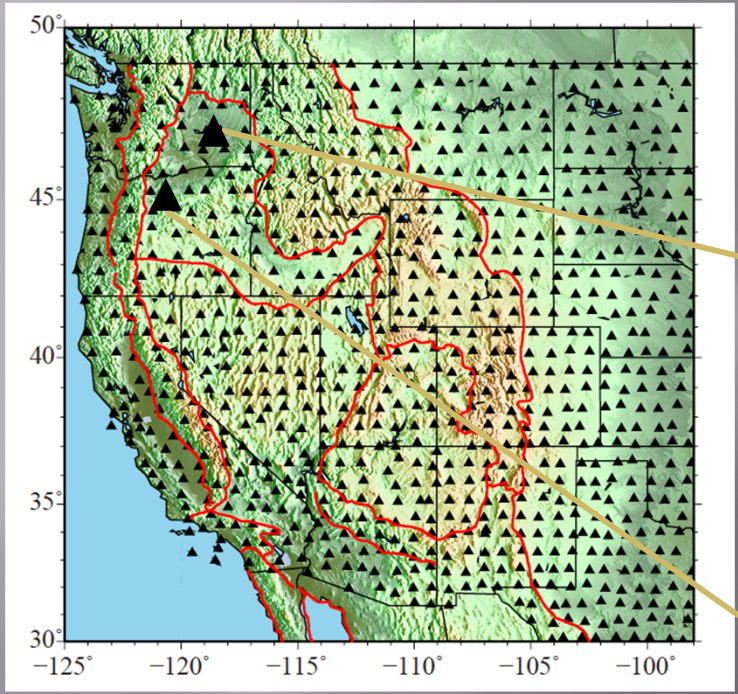


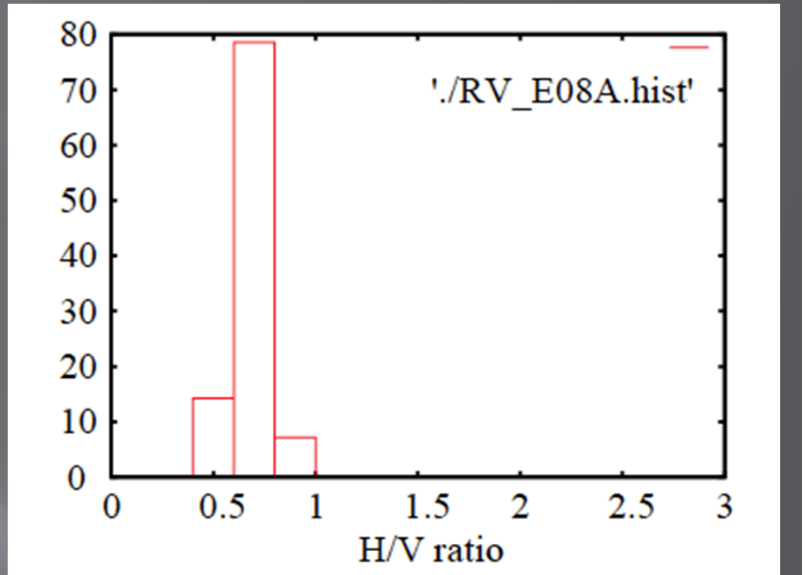


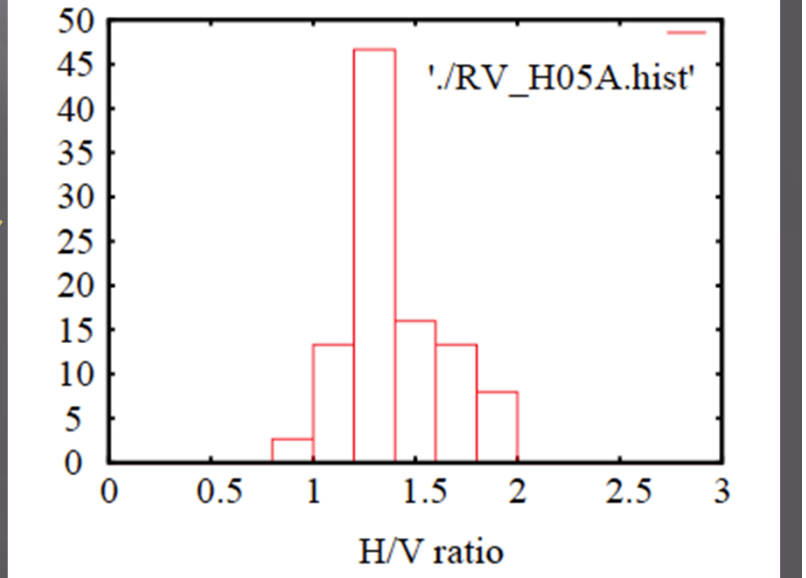
8 s Horizontal force

8 s vertical force

H/V ratio


50°
45°
40°
35°
30°
−125°
−120°
−115°
−110°
−105°
−100°


'./RV_E08A.hist'
80
70
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
H/V ratio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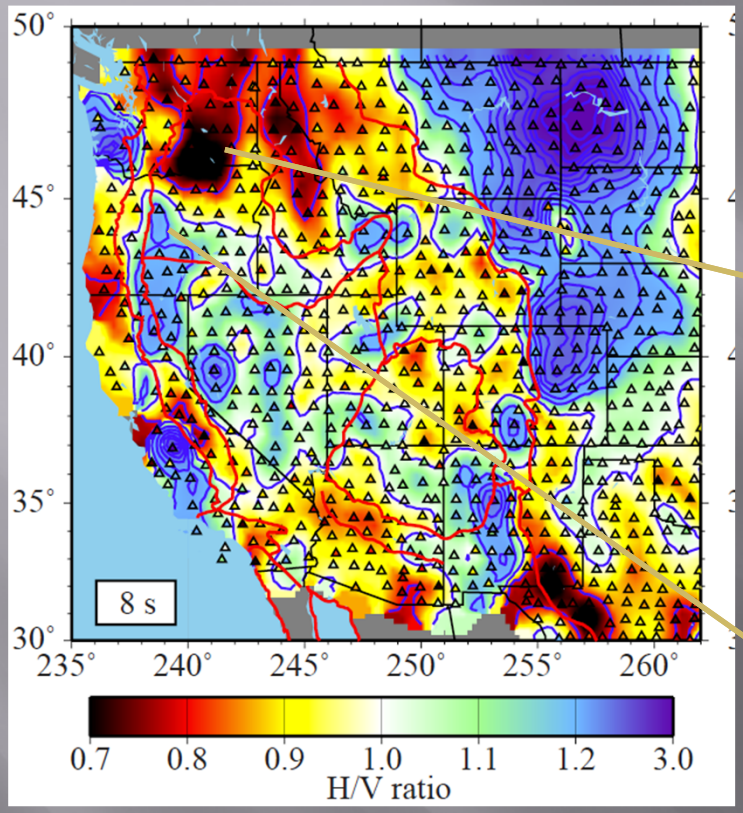
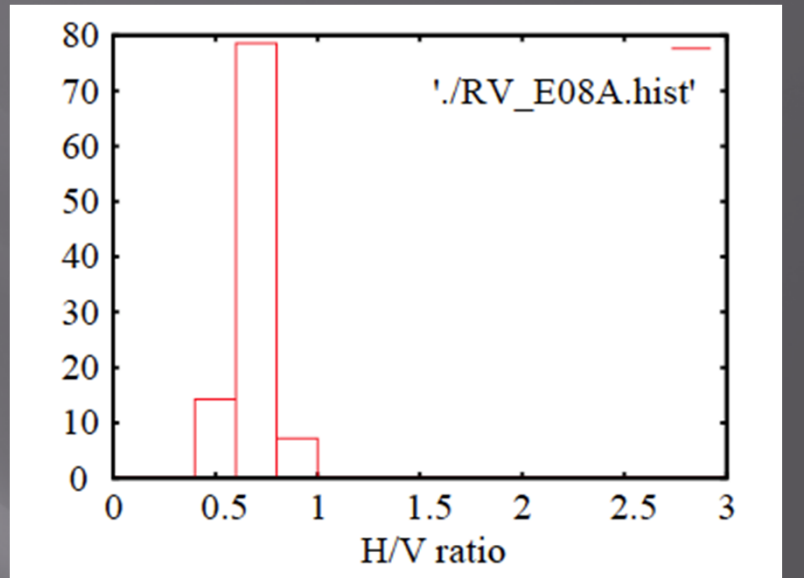
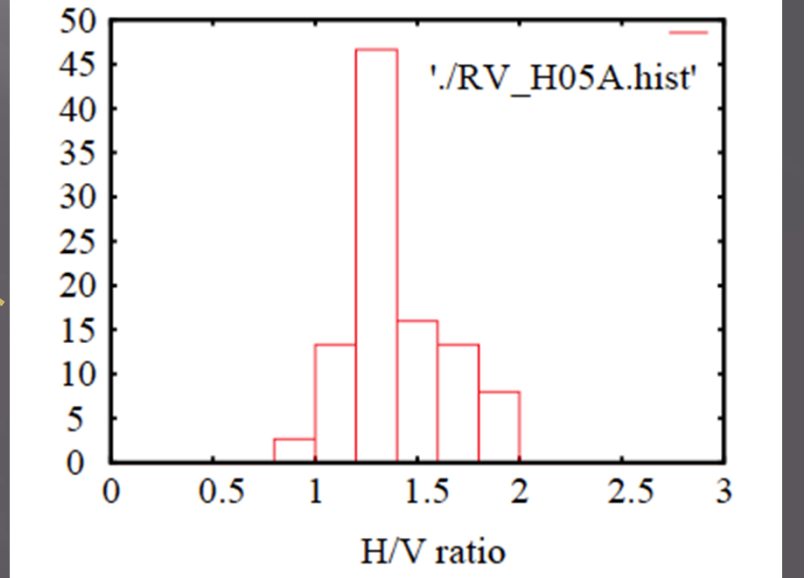
50
45
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
H/V ratio

H/V ratio

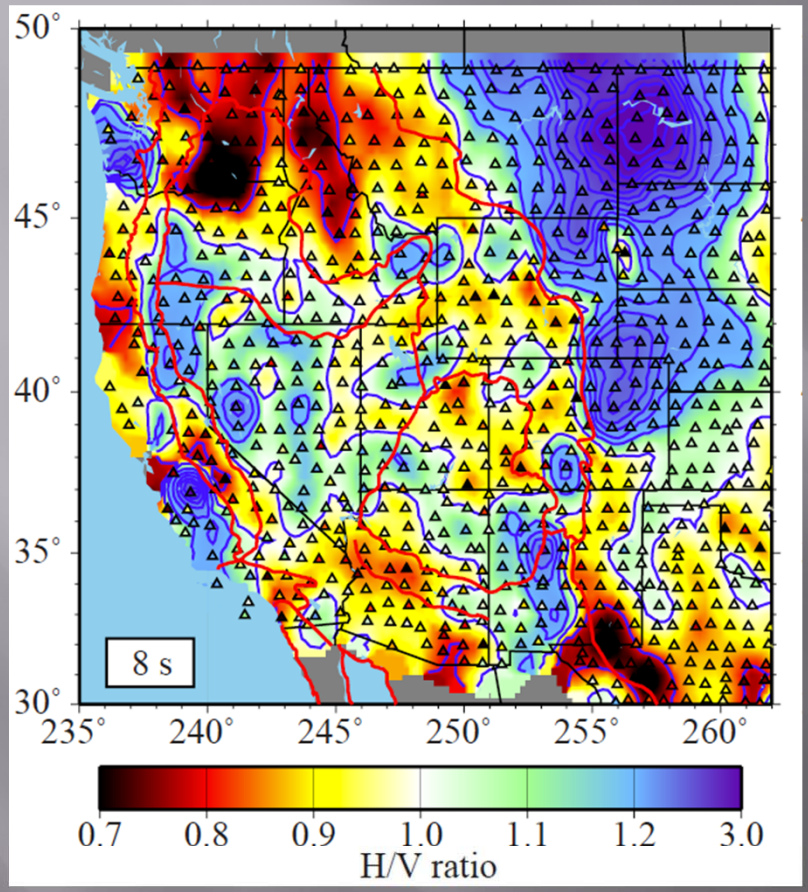


8 s H/V ratio

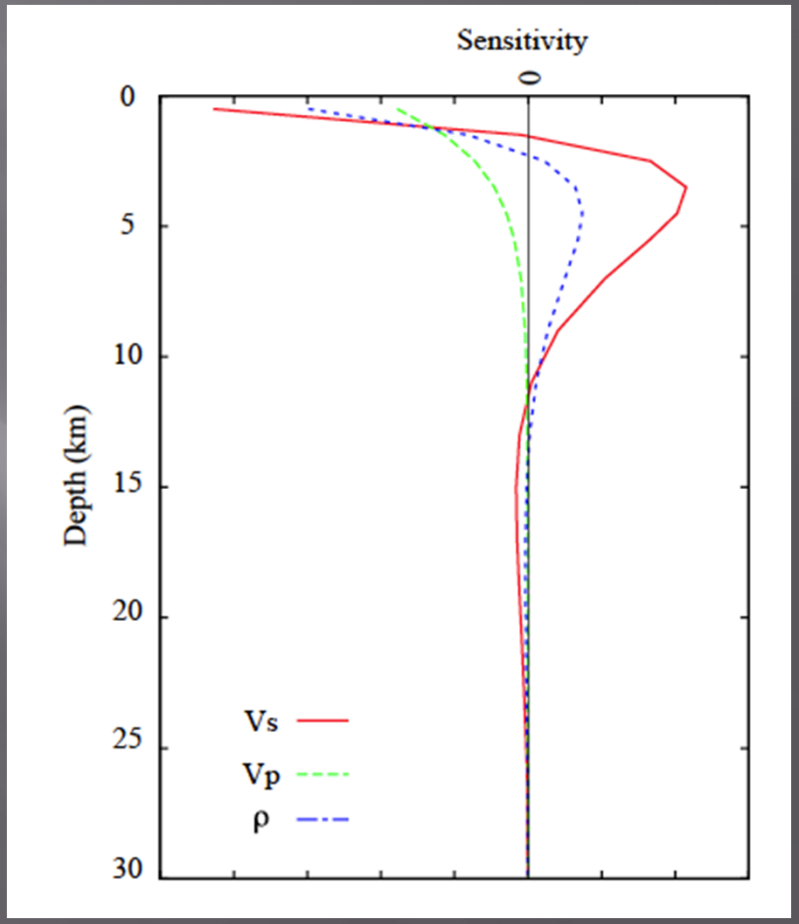




H/V ratio maps



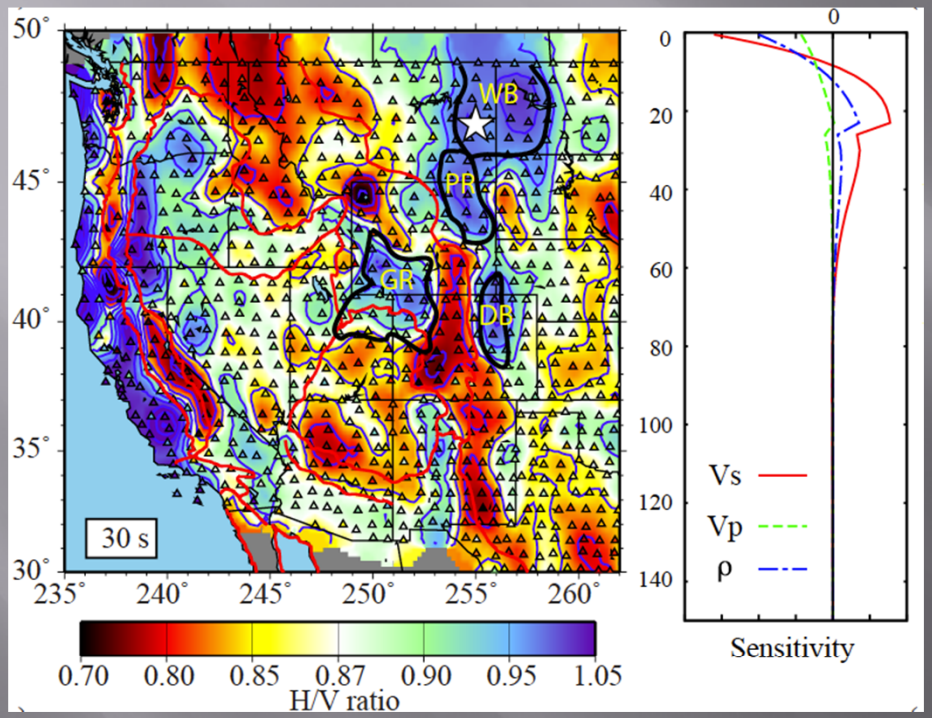
8-sec Rayleigh wave



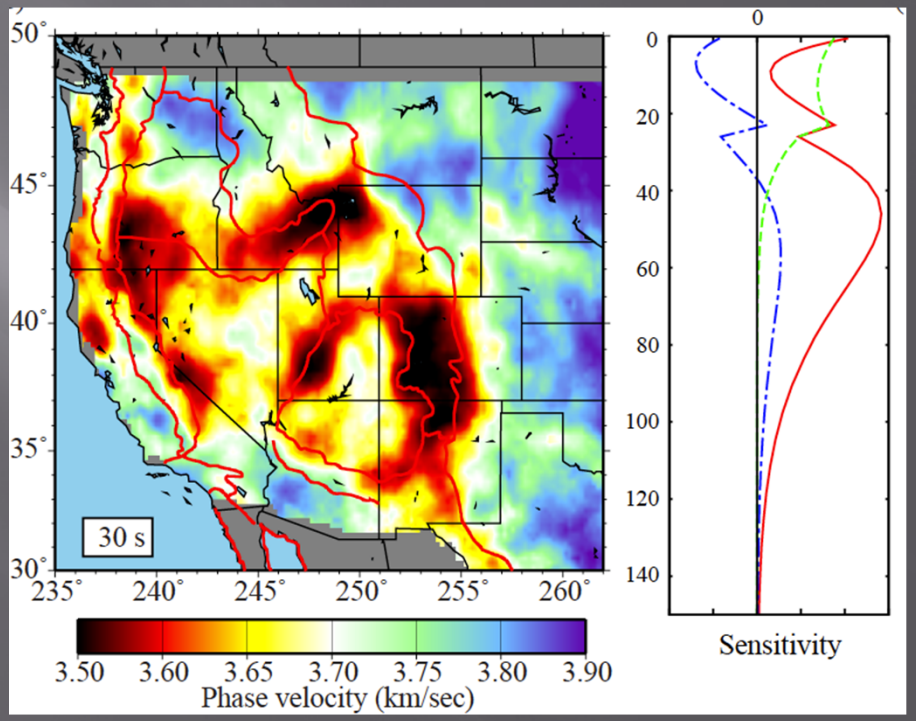
Depth Sensitivity

H/V ratio vs. phase velocity

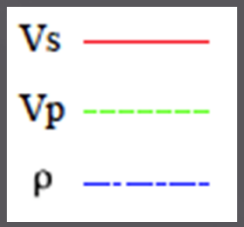
H/V ratio



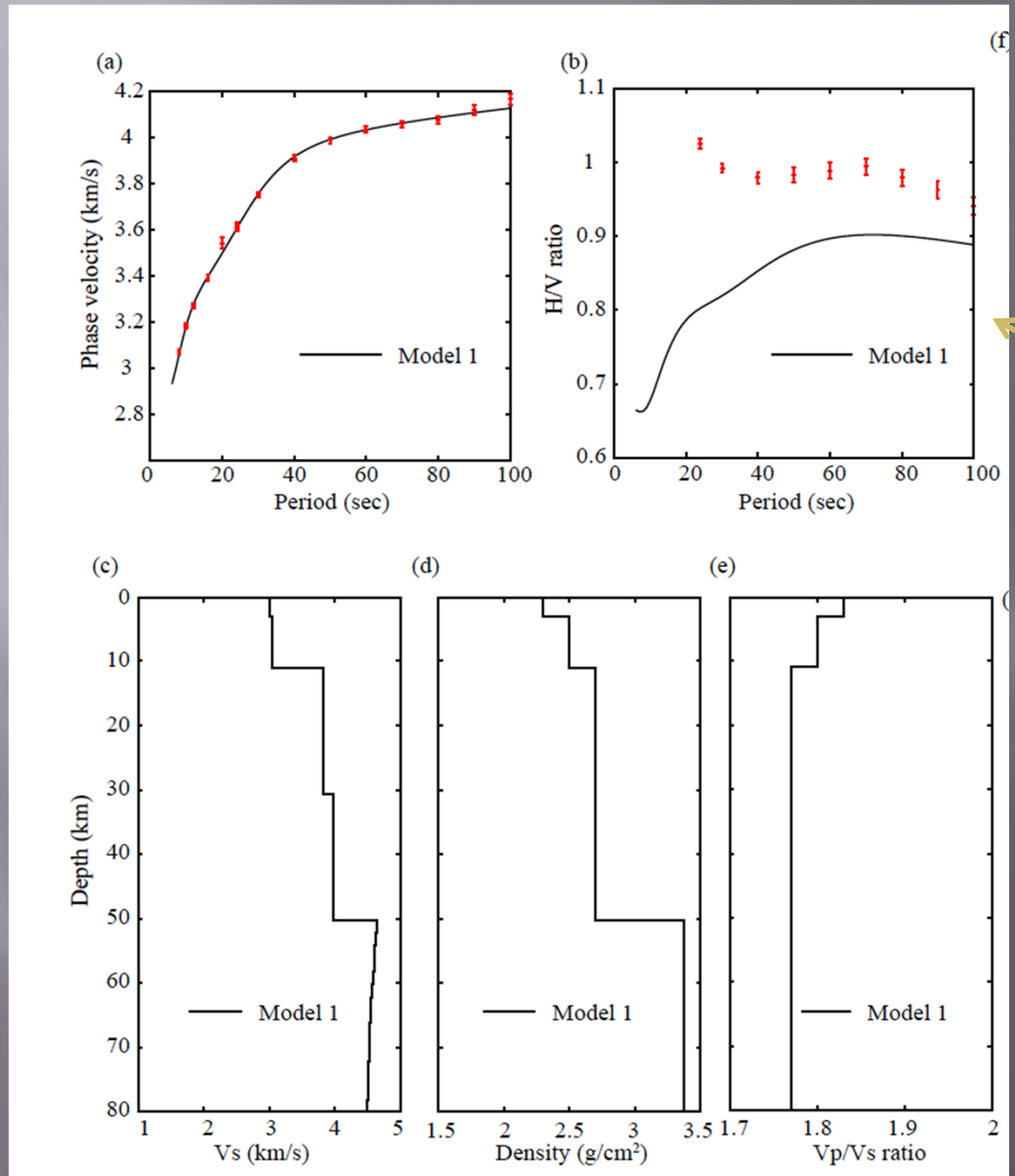
Phase velocity



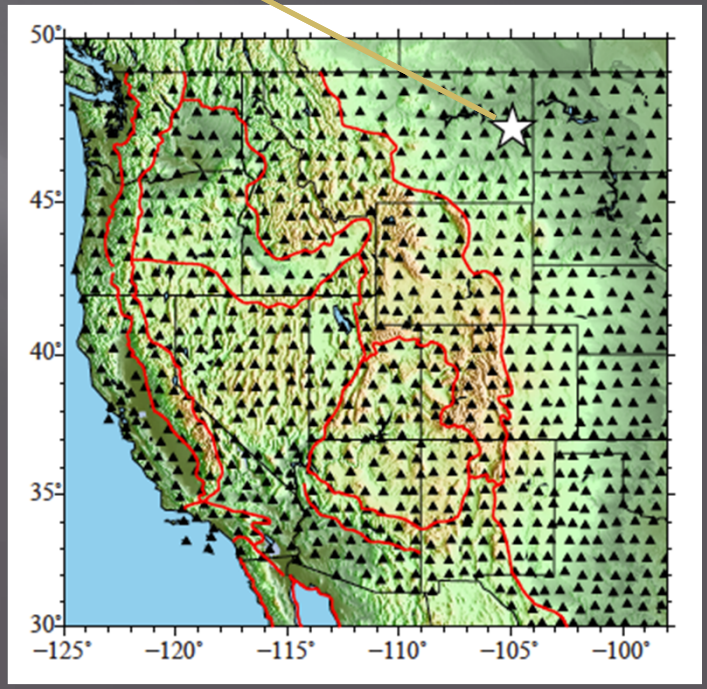
30-sec Rayleigh wave



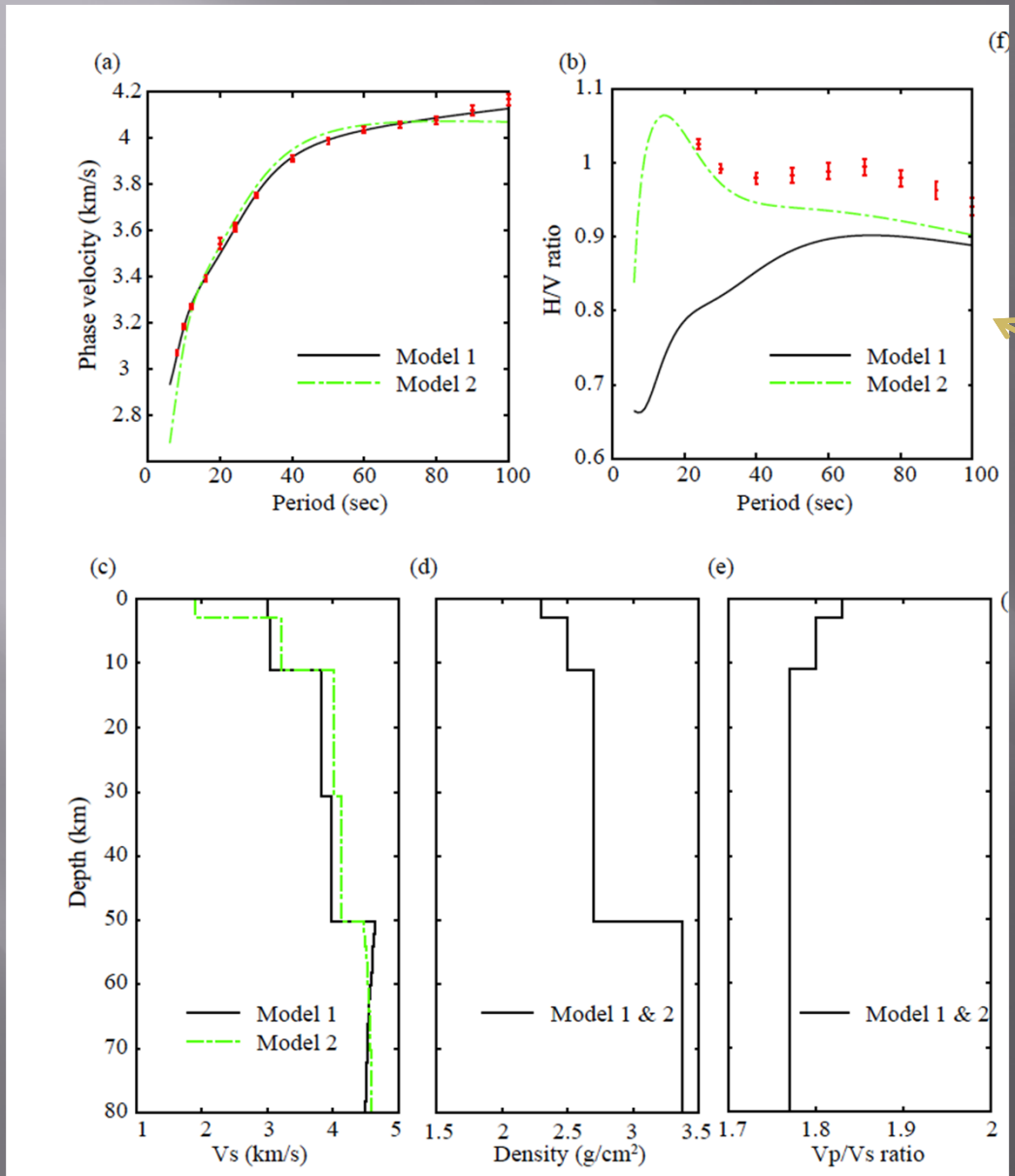
Phase velocity & H/V ratio joint inversion



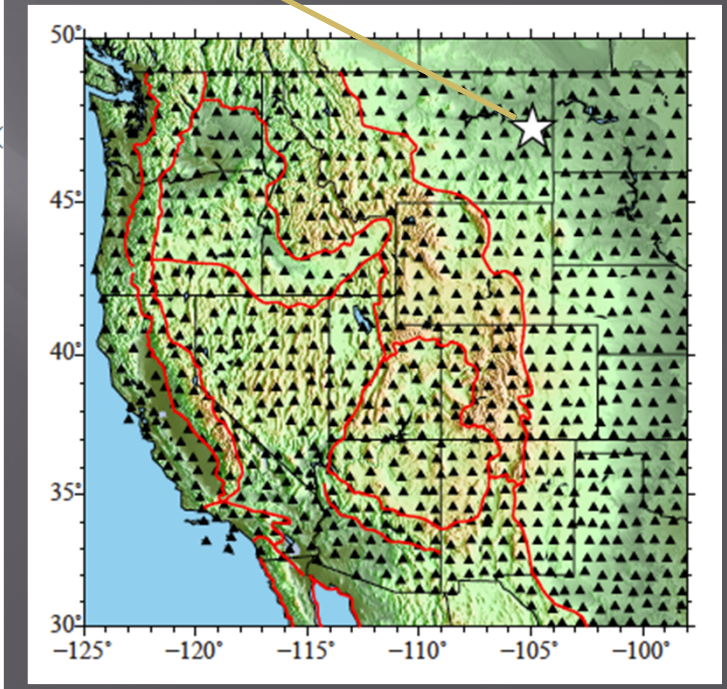
Model 1



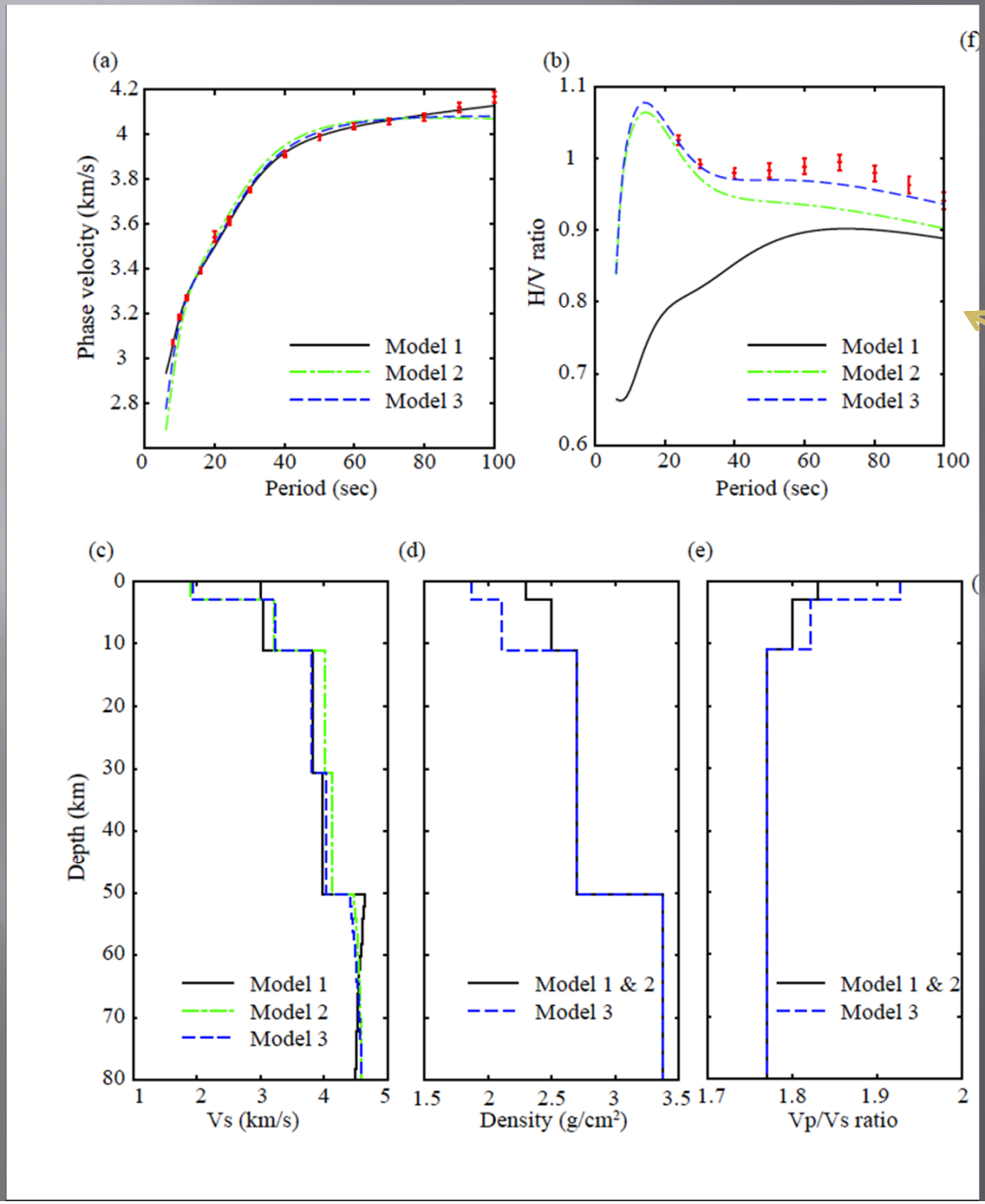
Phase velocity & H/V ratio joint inversion



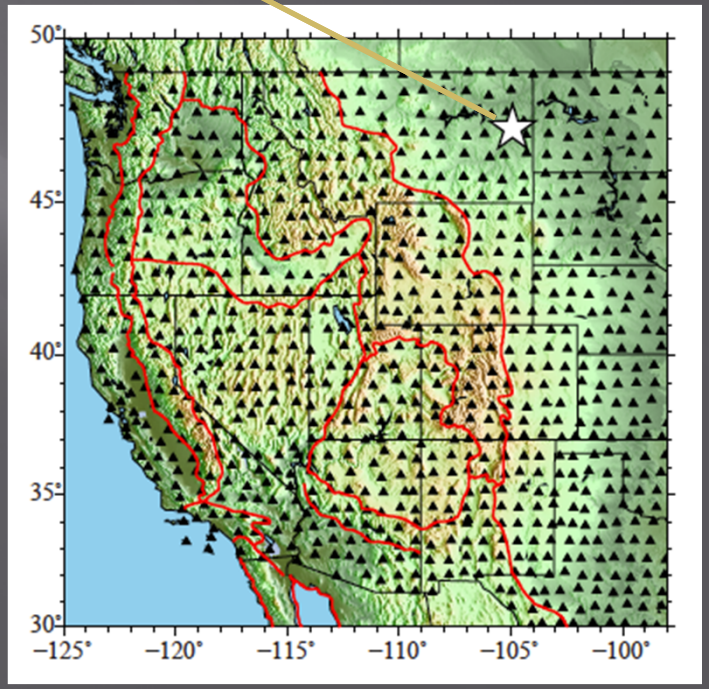
Model 2



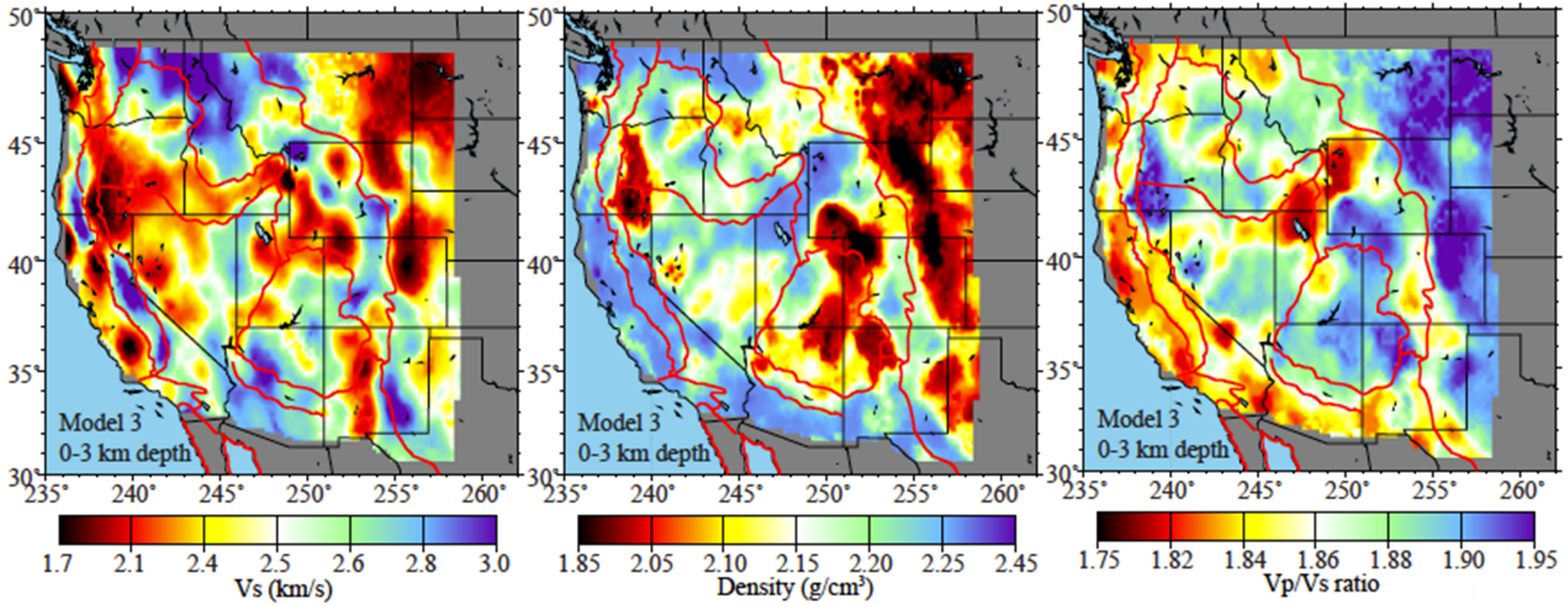
Phase velocity & H/V ratio joint inversion



Model 3



Upper 3 km crustal model



Shear velocity

Density

Vp/Vs ratio

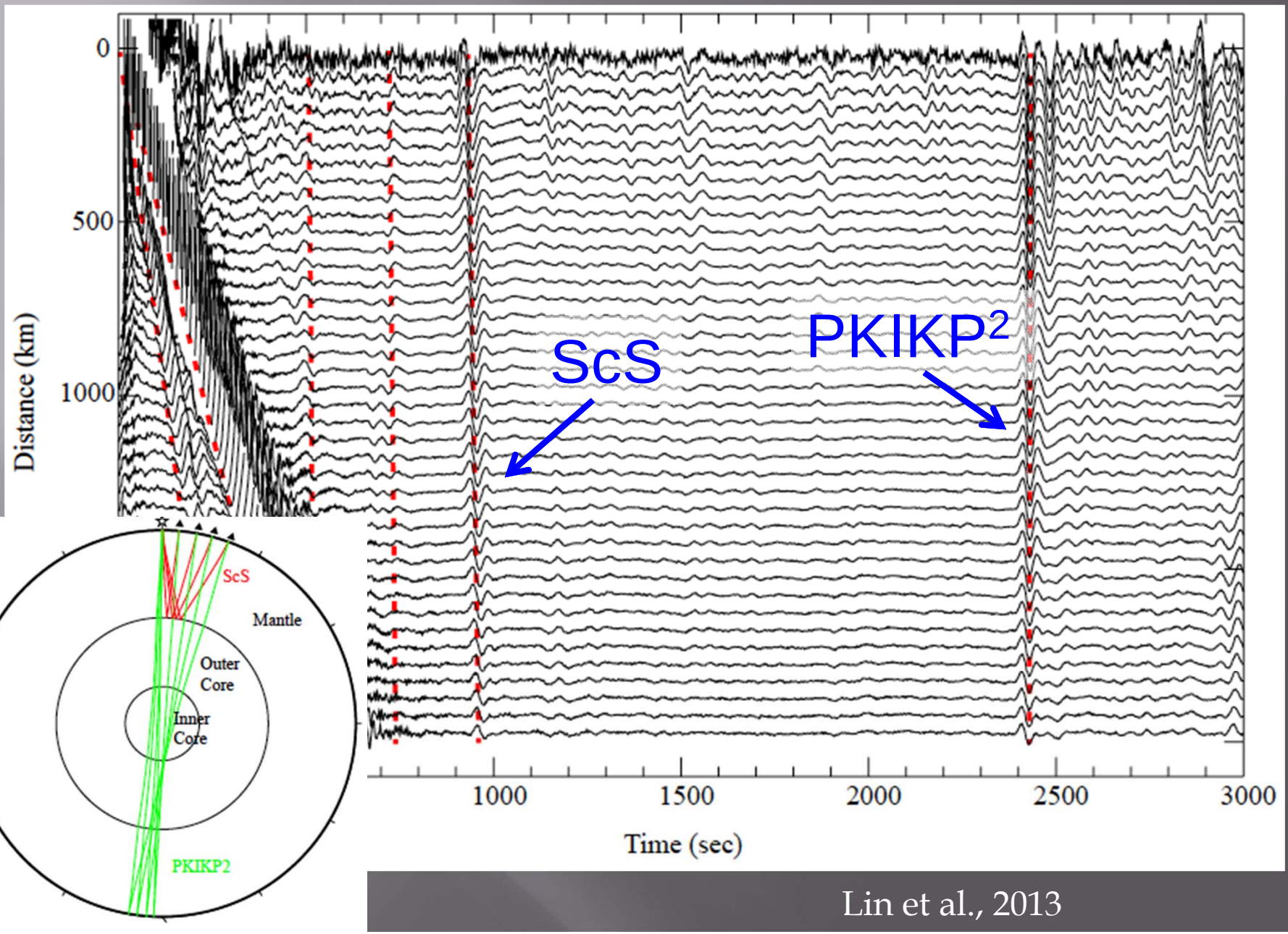
Lin et al. (2012)

Deep

Stacked USArray cross-correlations

- Process all records from Jan 2007 to May 2011 with standard ambient noise processing (Bensen et al. 2007)
- Stack all cross correlations into 50-km distance bins
  - 10,000 traces per stack

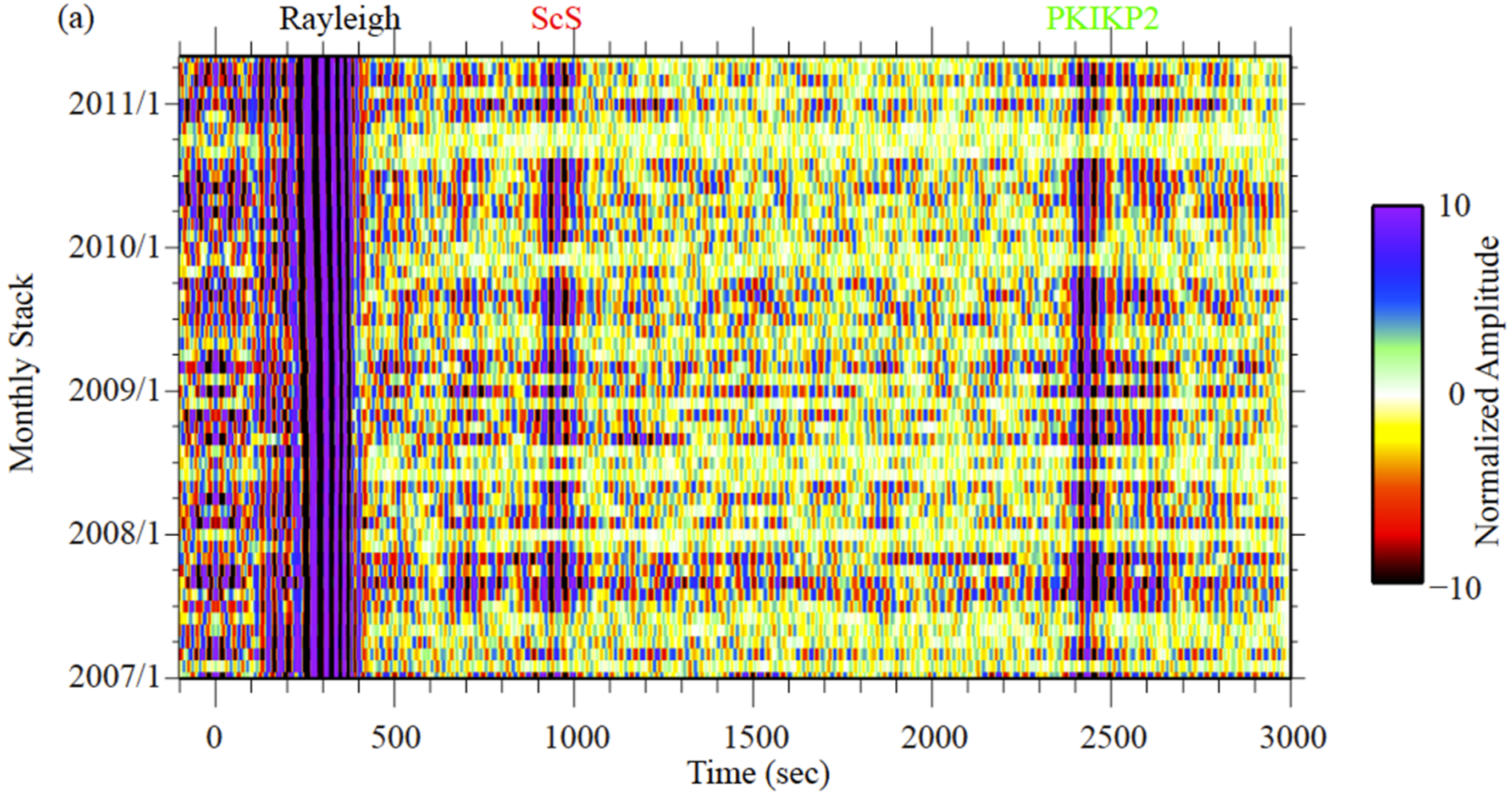
Observation of body waves



Lin et al., 2013

Why does it work?

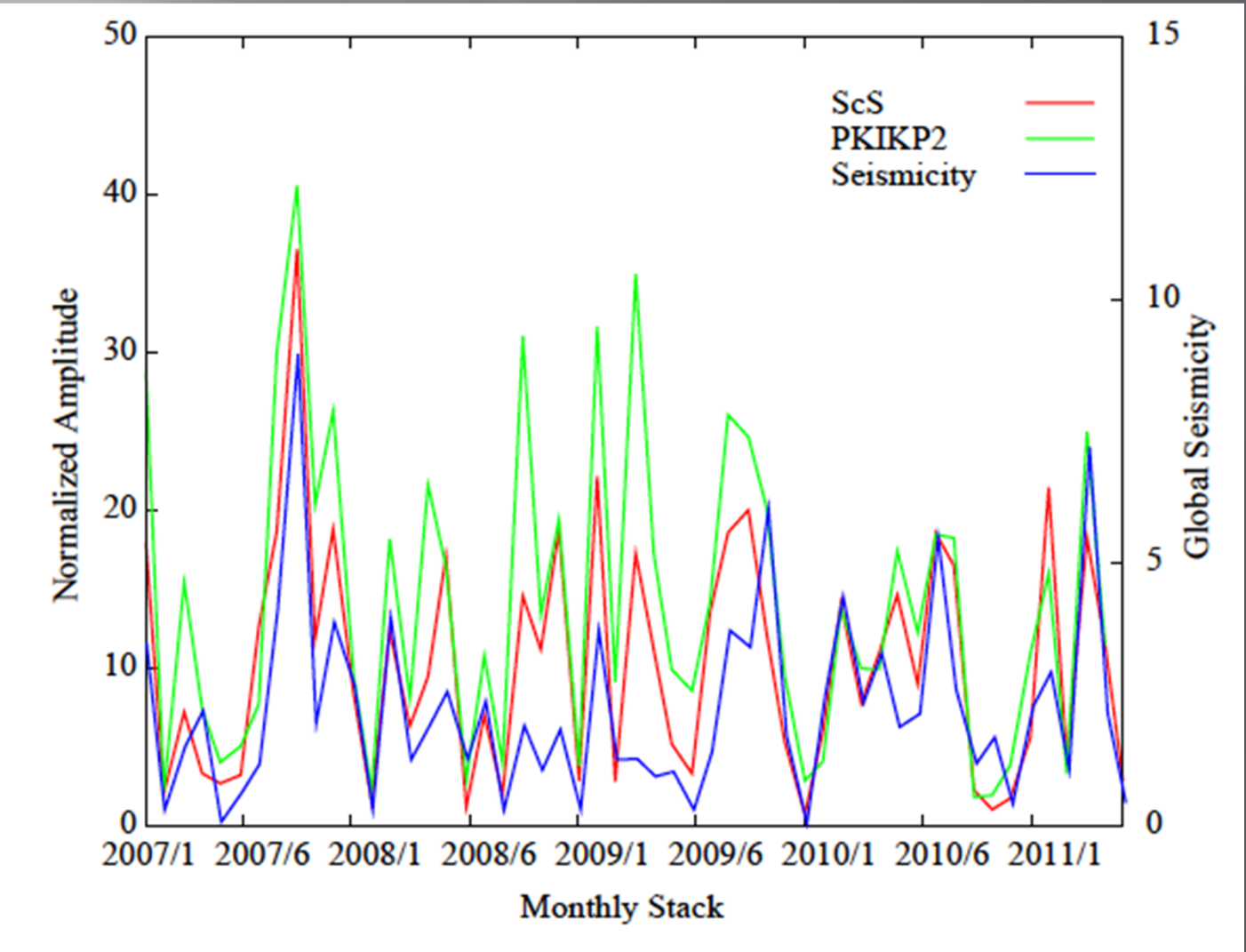
- Examine temporal variability



Distances between 1000 and 1050 km. Bandpassed between 20 and 50 sec period.

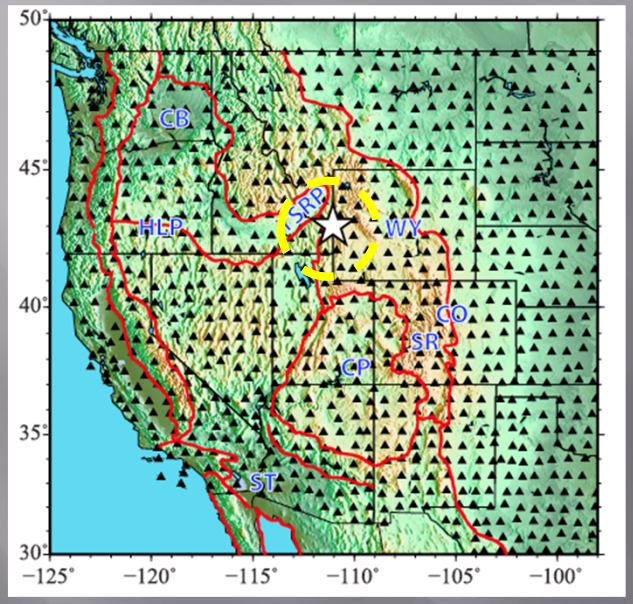
Why does it work?

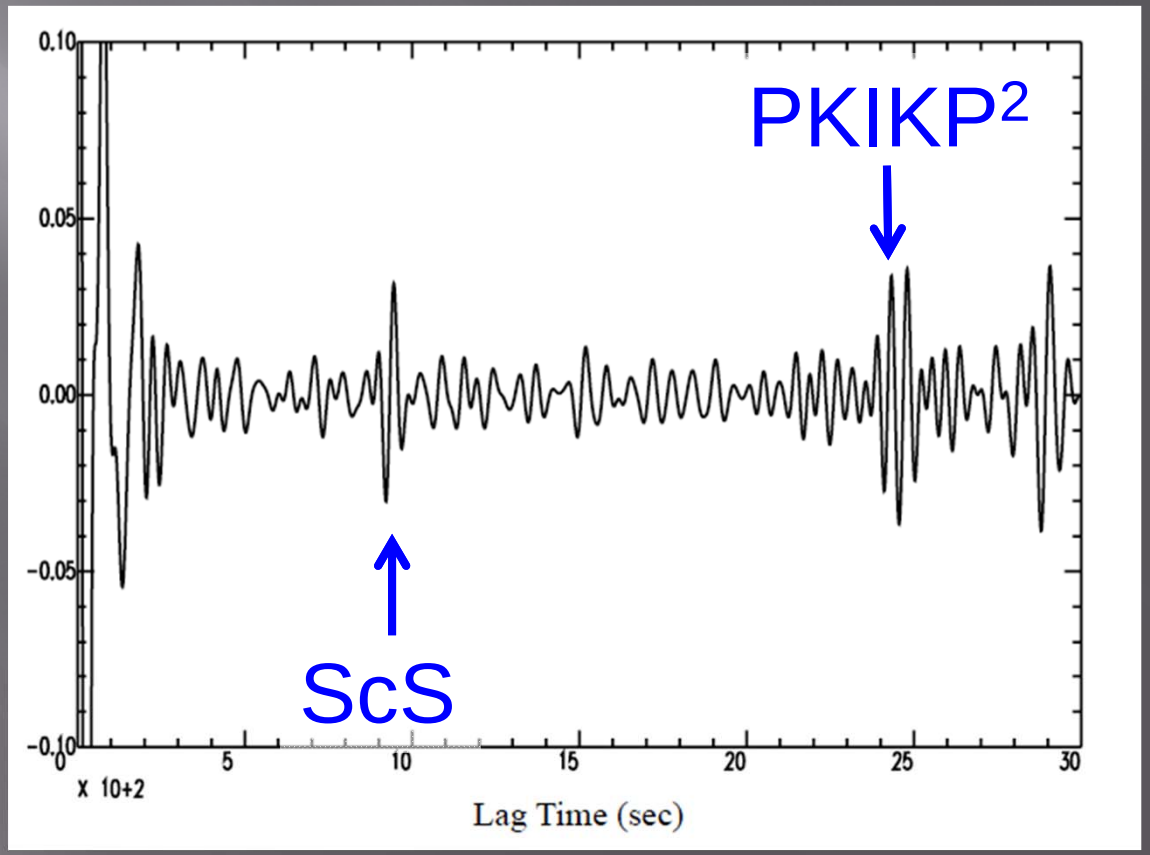
- Examine temporal variability



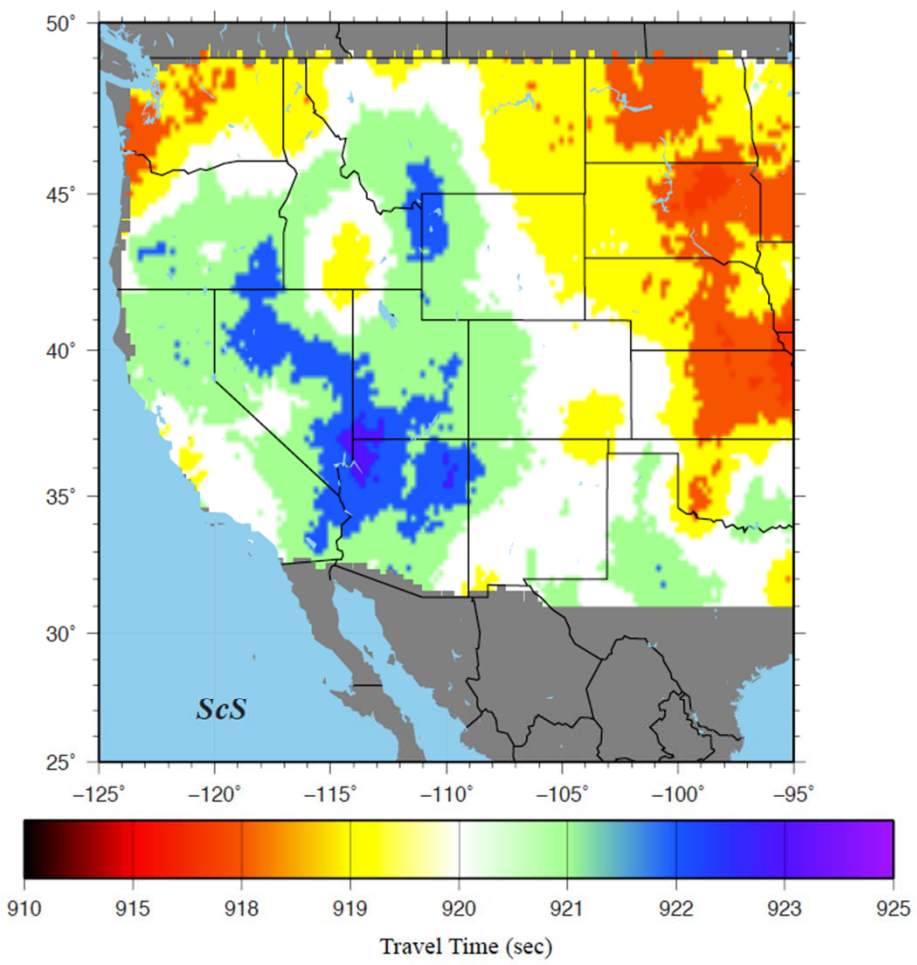
- Correlation with occurrence of M_w>6.3 eqs.

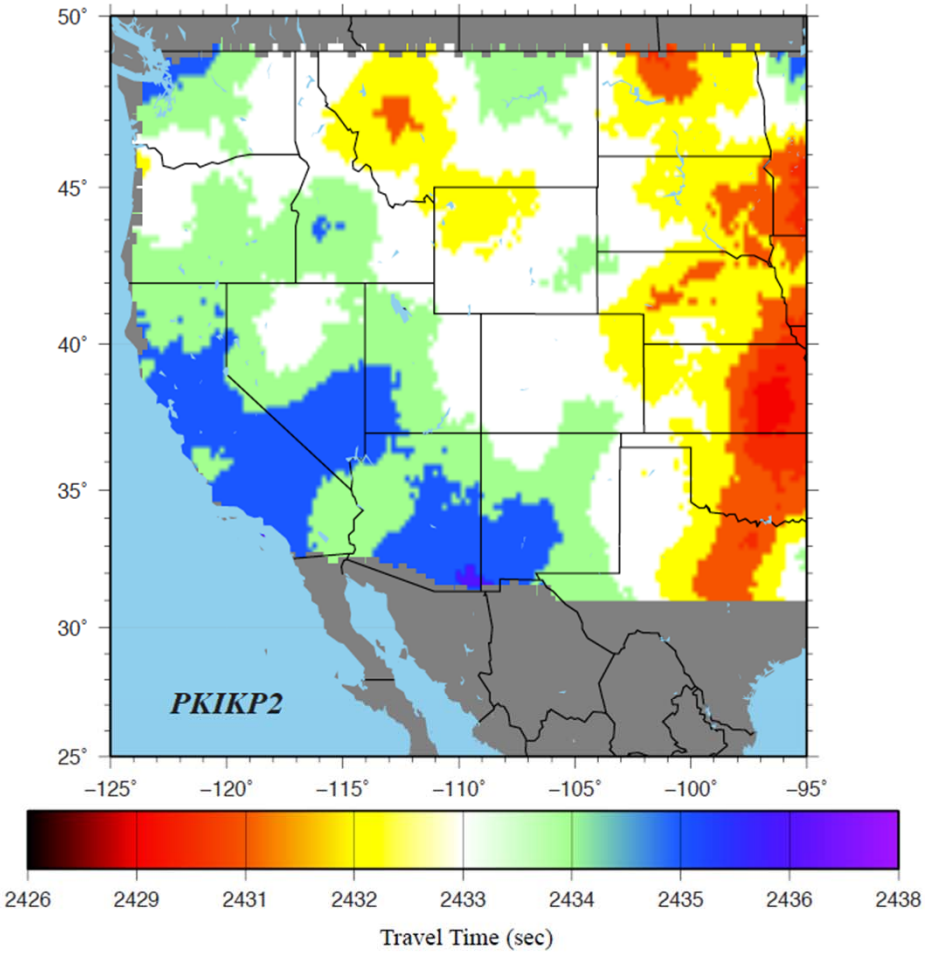
Sub-Array


50°
45°
40°
35°
30°
−125°
−120°
−115°
−110°
−105°
−100°
CB
HLP
SRP
WY
CO
SR
CP
ST

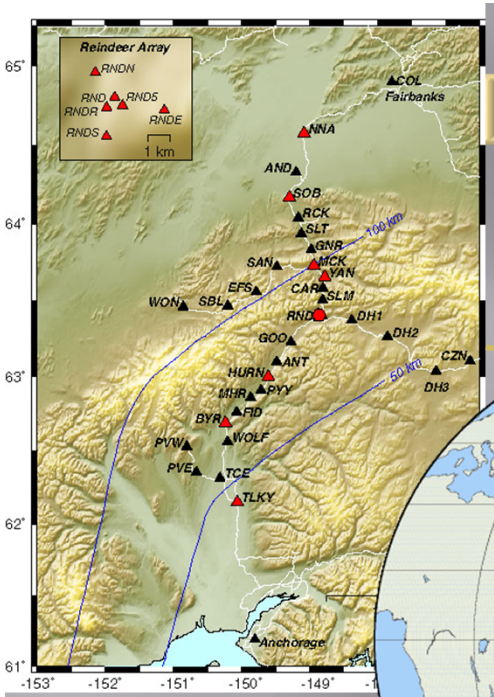

PKIKP2
ScS
0.10
0.05
0.00
-0.05
-0.10
0
5
10
15
20
25
30
X 10+2
Lag Time (sec)

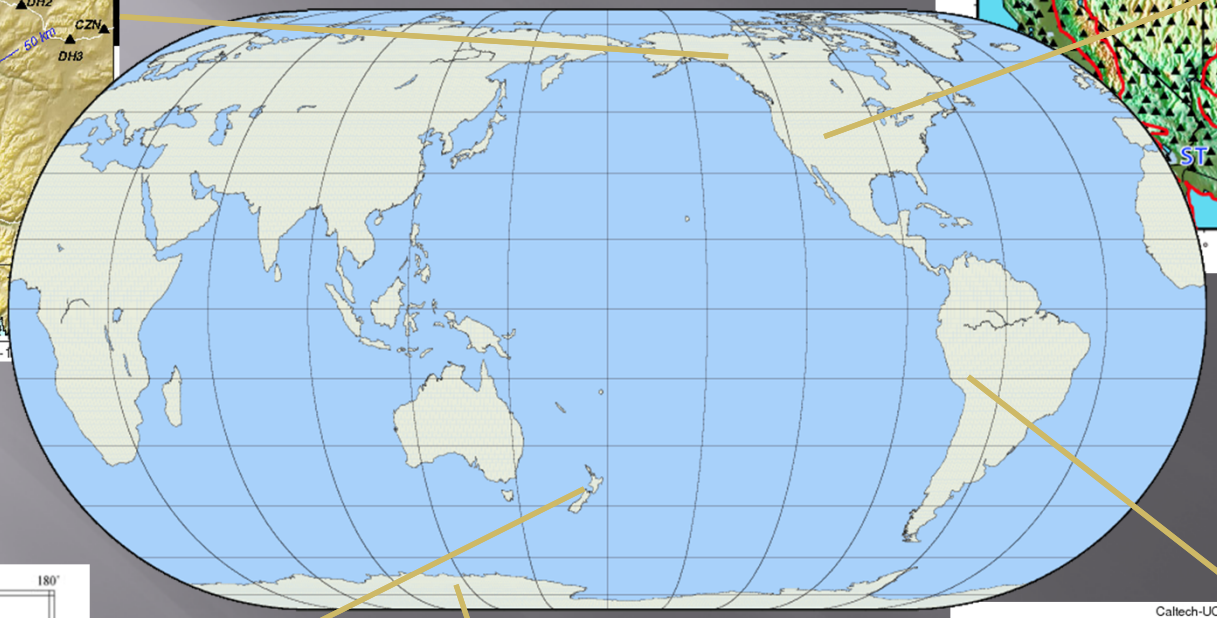
Lateral variation

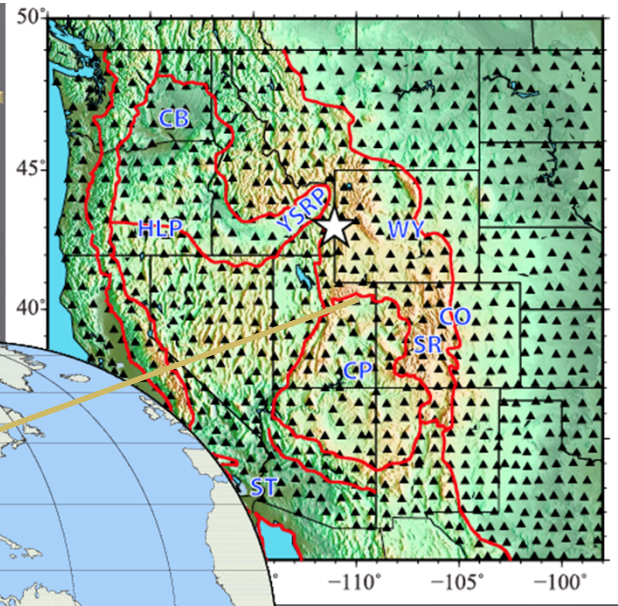


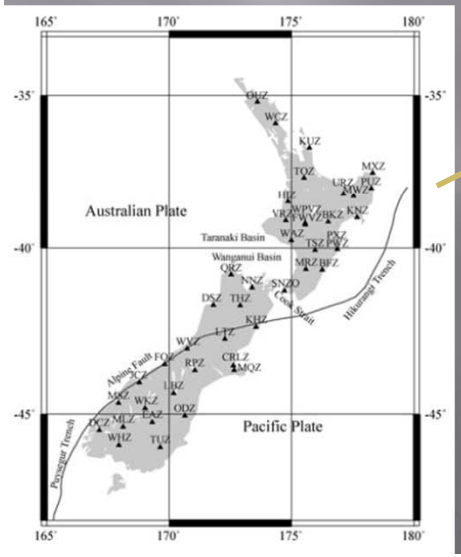


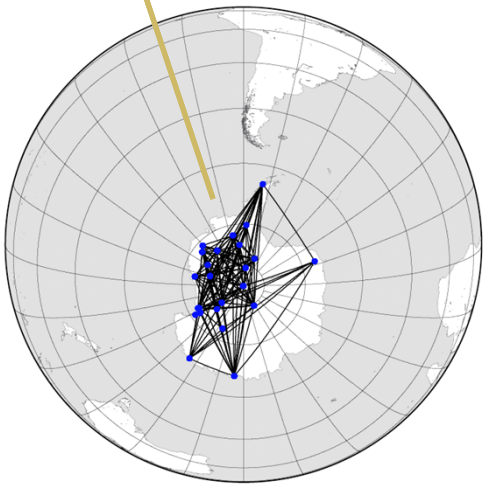
Does it work for other arrays?

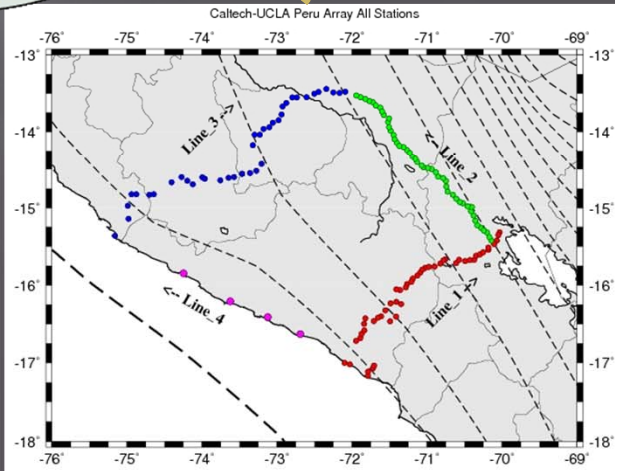






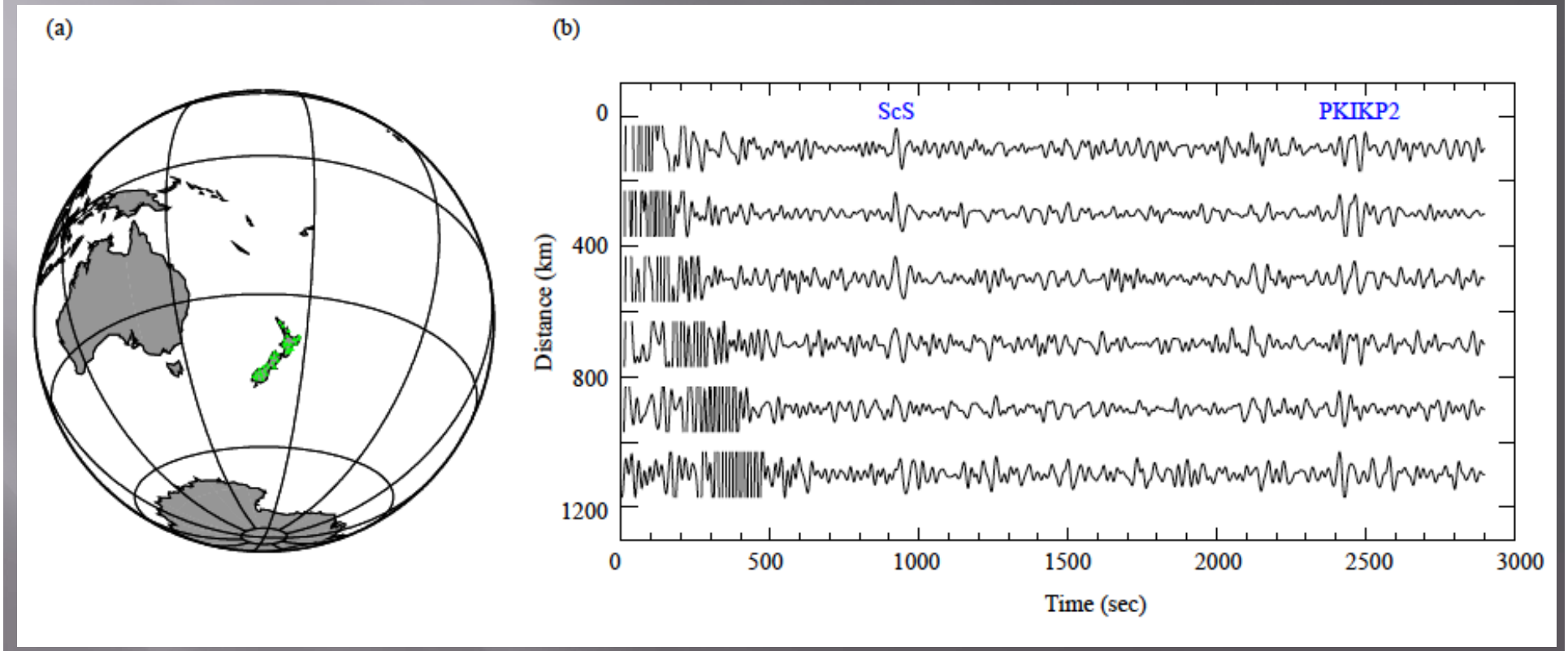




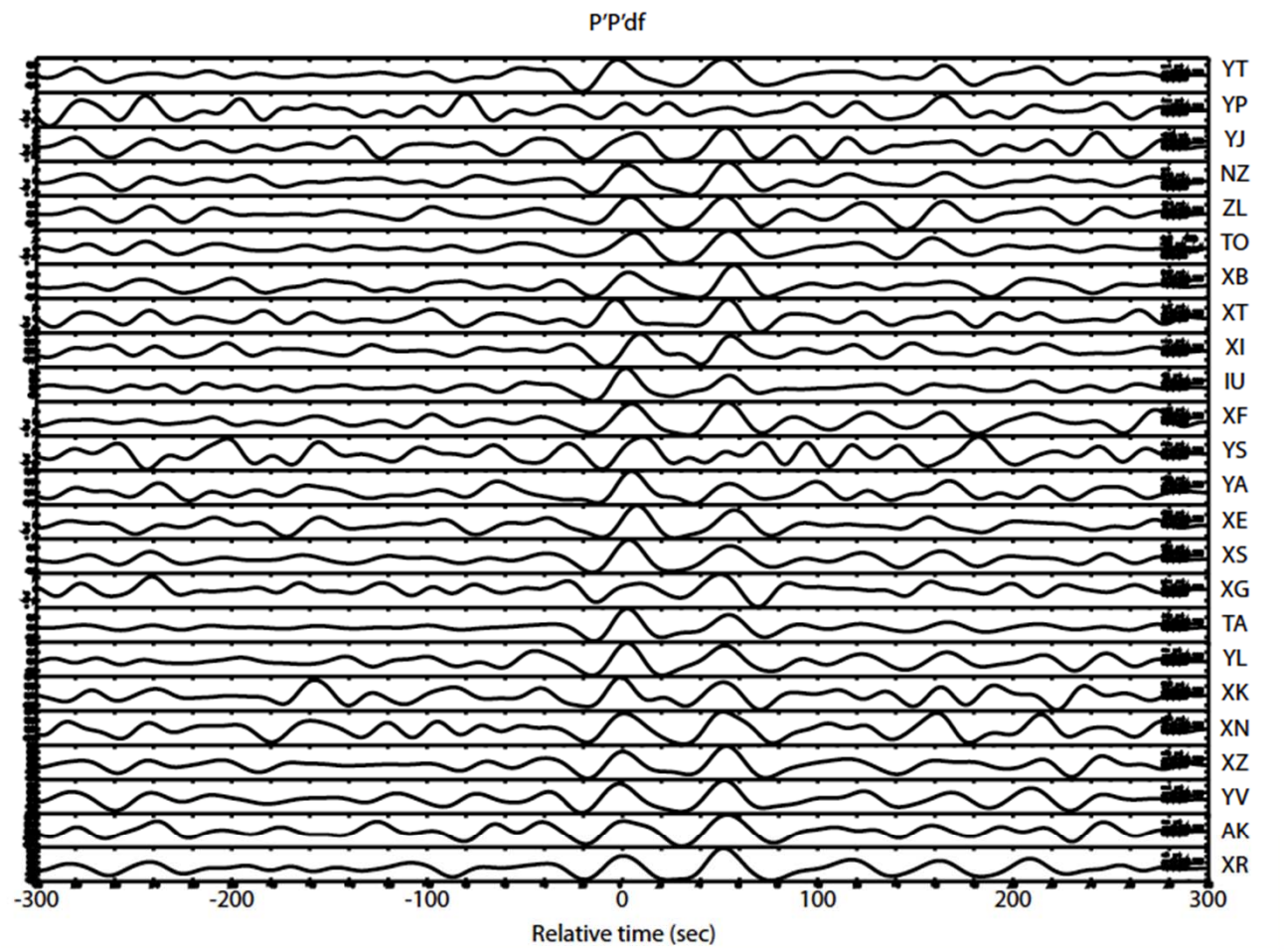


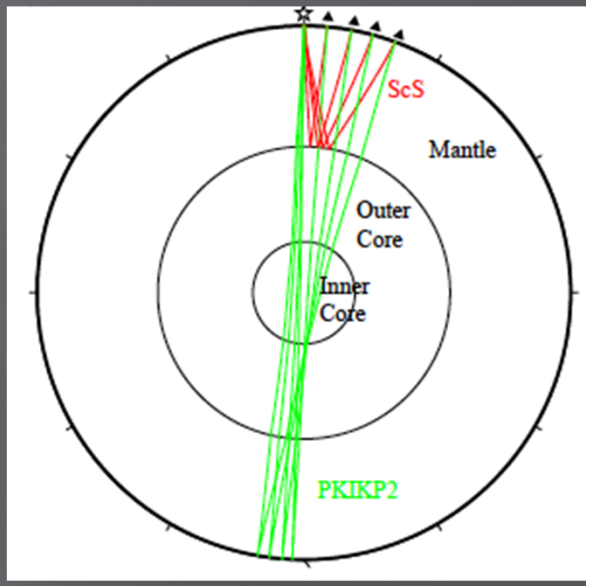
Does it work elsewhere?

- New Zealand national seismic network (42 stations)

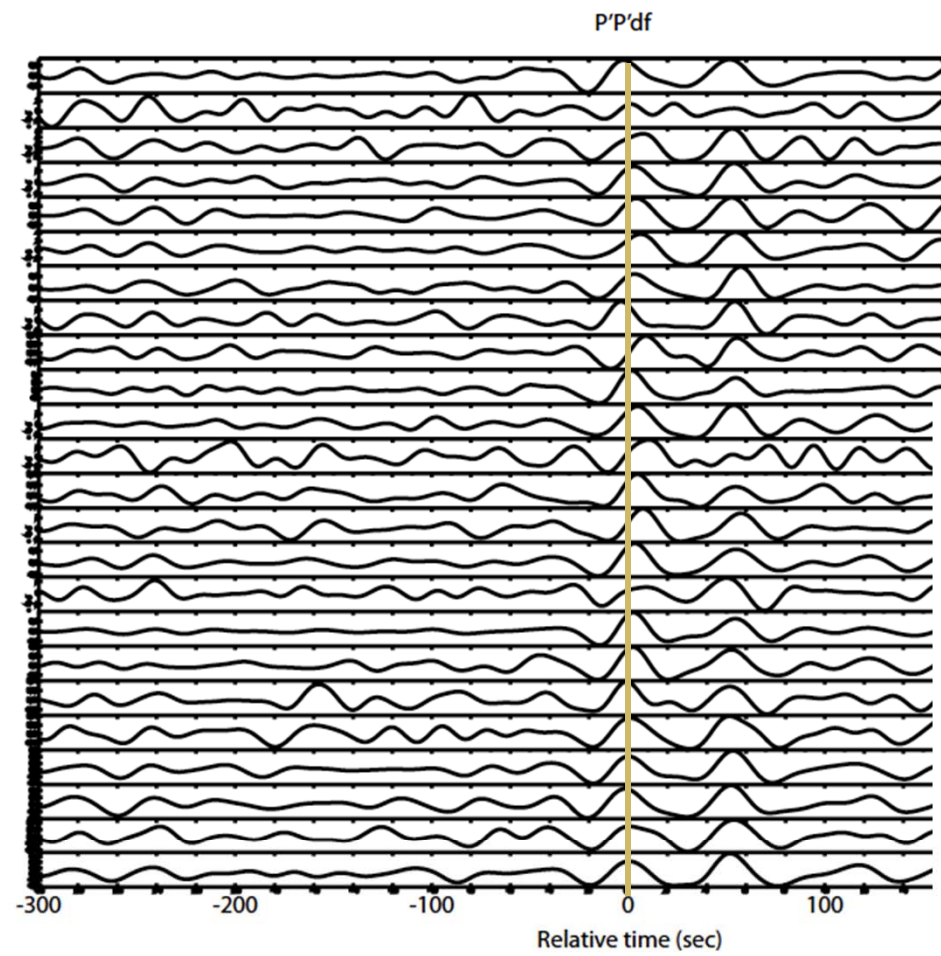


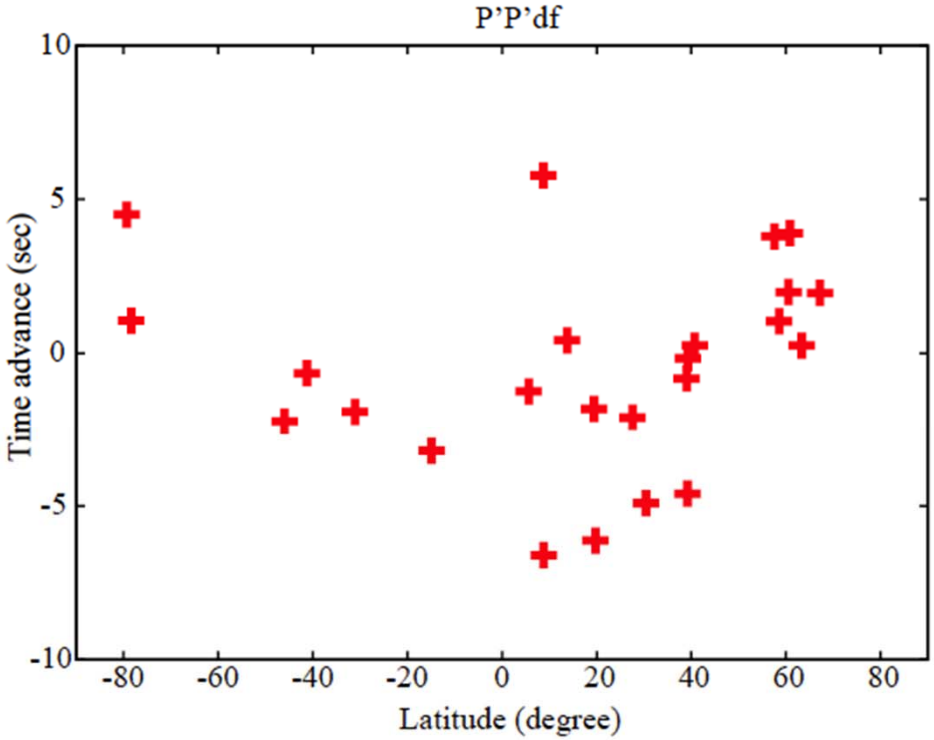
PASSCAL and other arrays





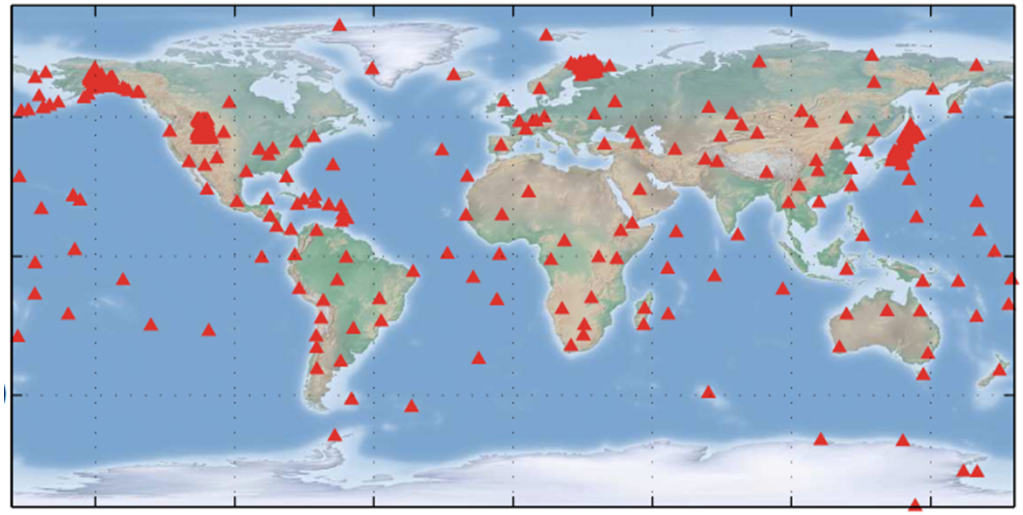
PASSCAL and other arrays

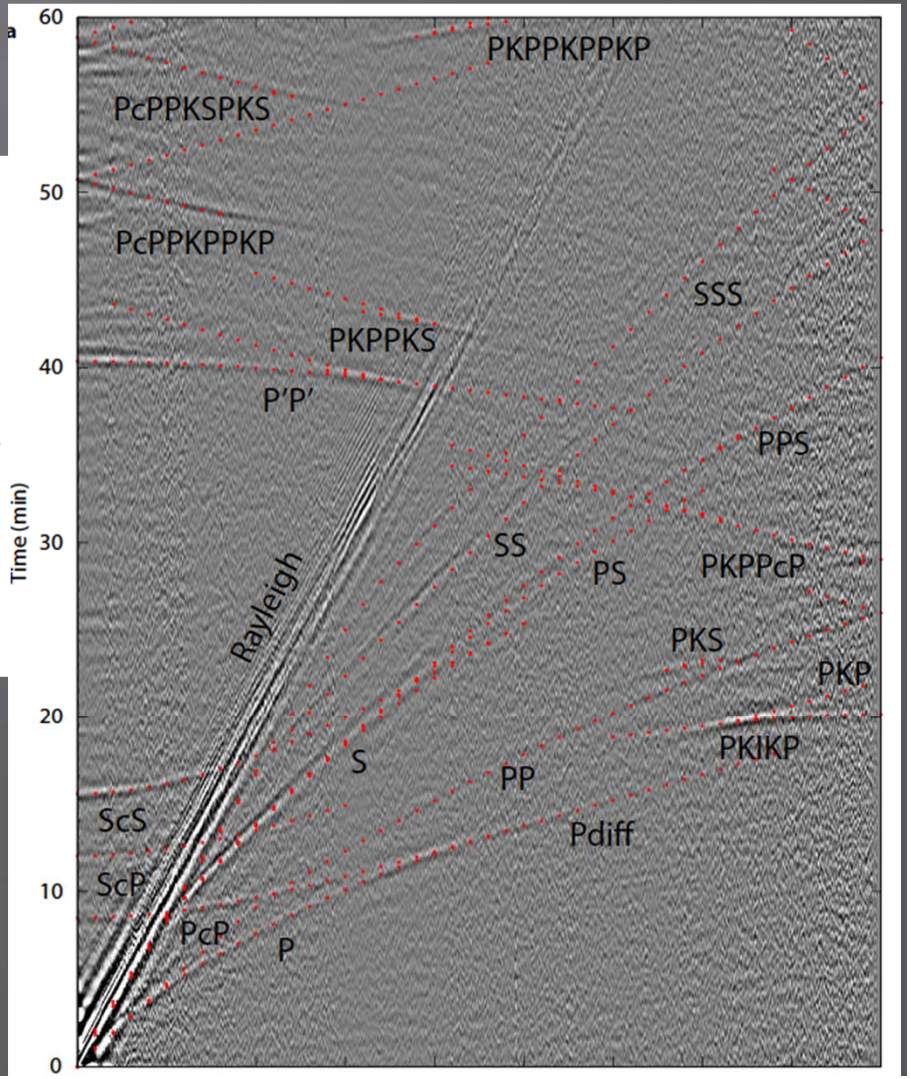




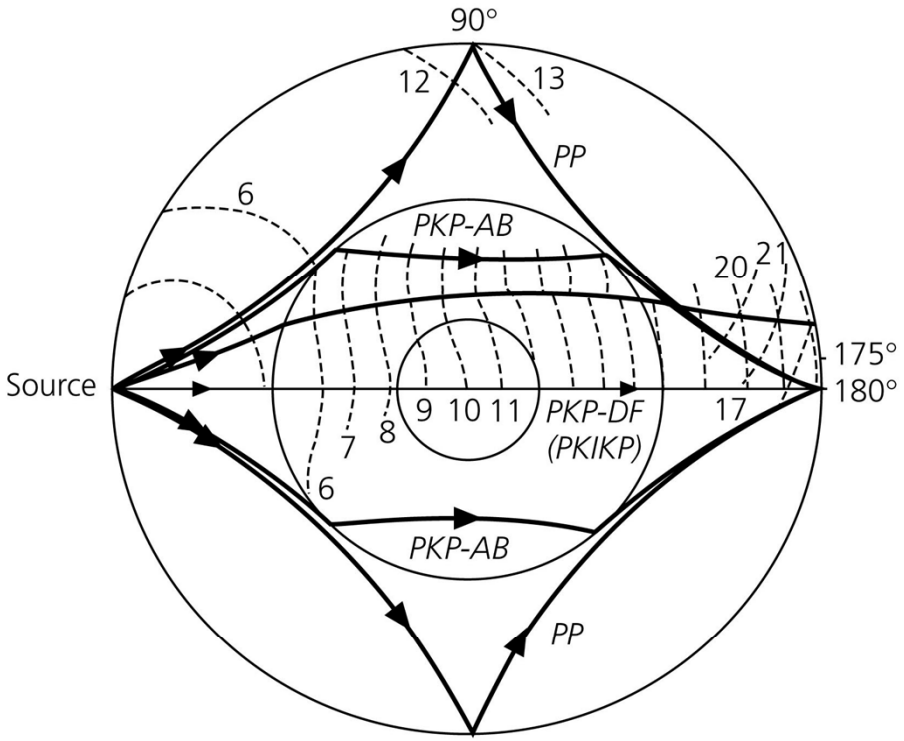
Global stack

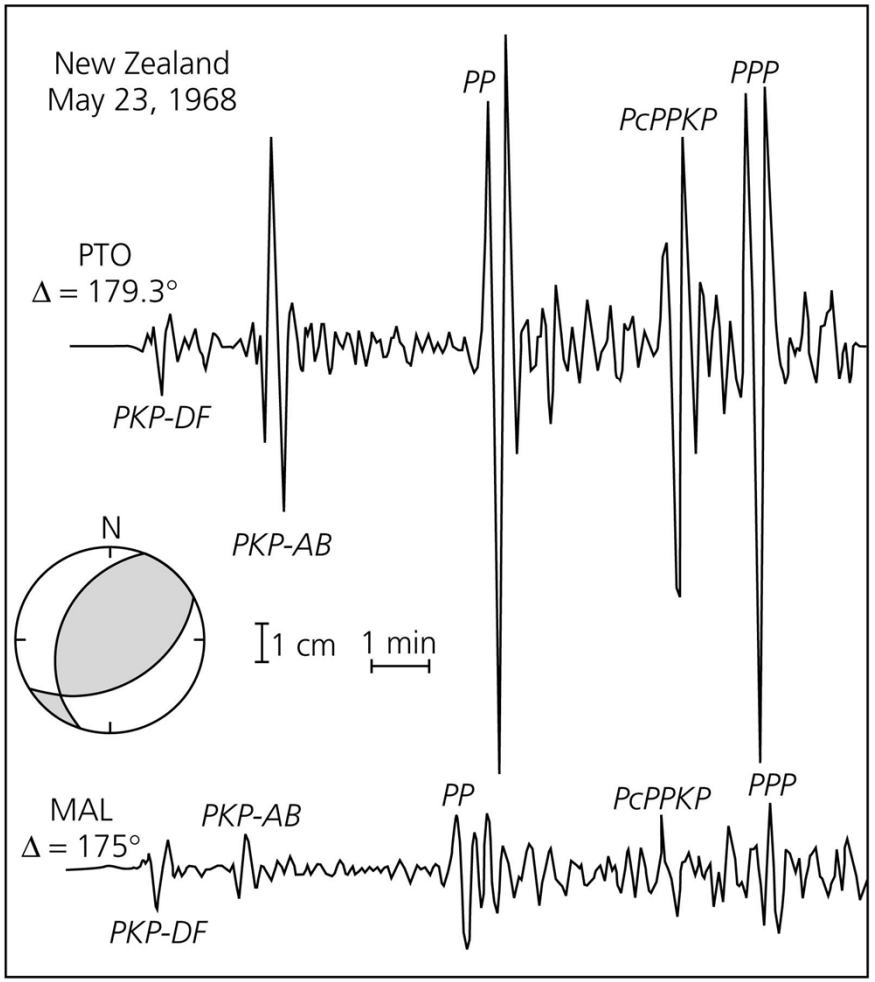
Boue et al., GJI, 2013





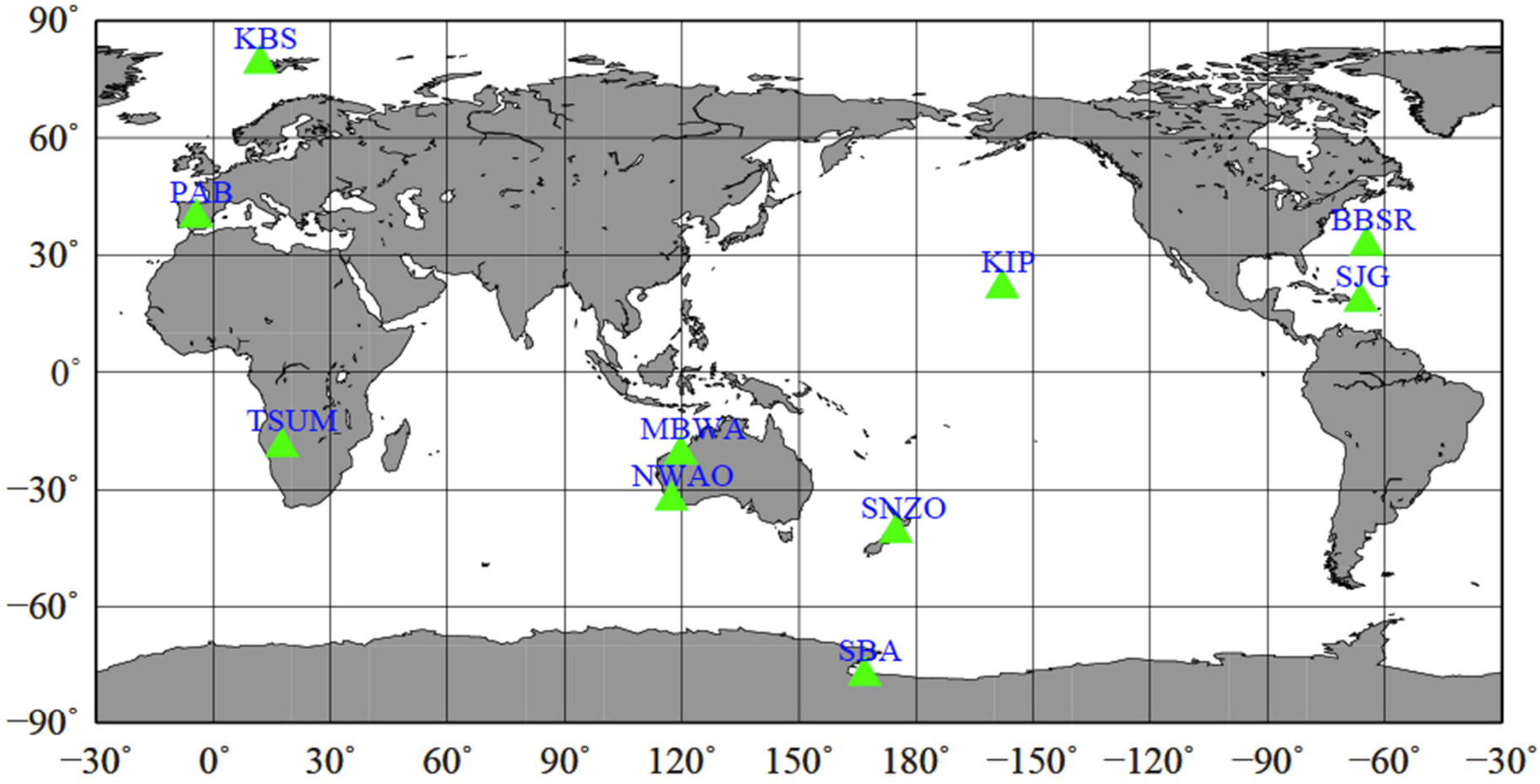
Focusing of P waves at the antipode



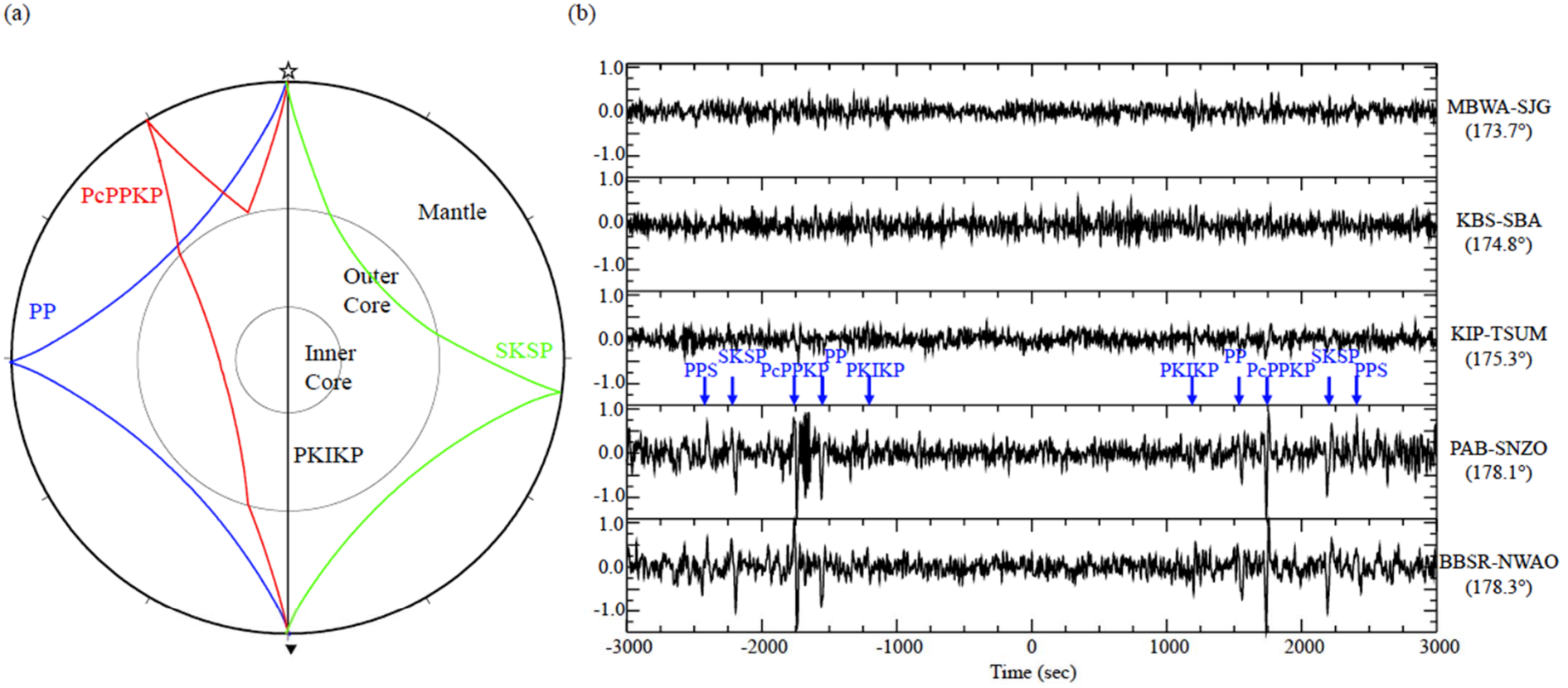


Rial & Cormier, 1980

Antipodal station pairs

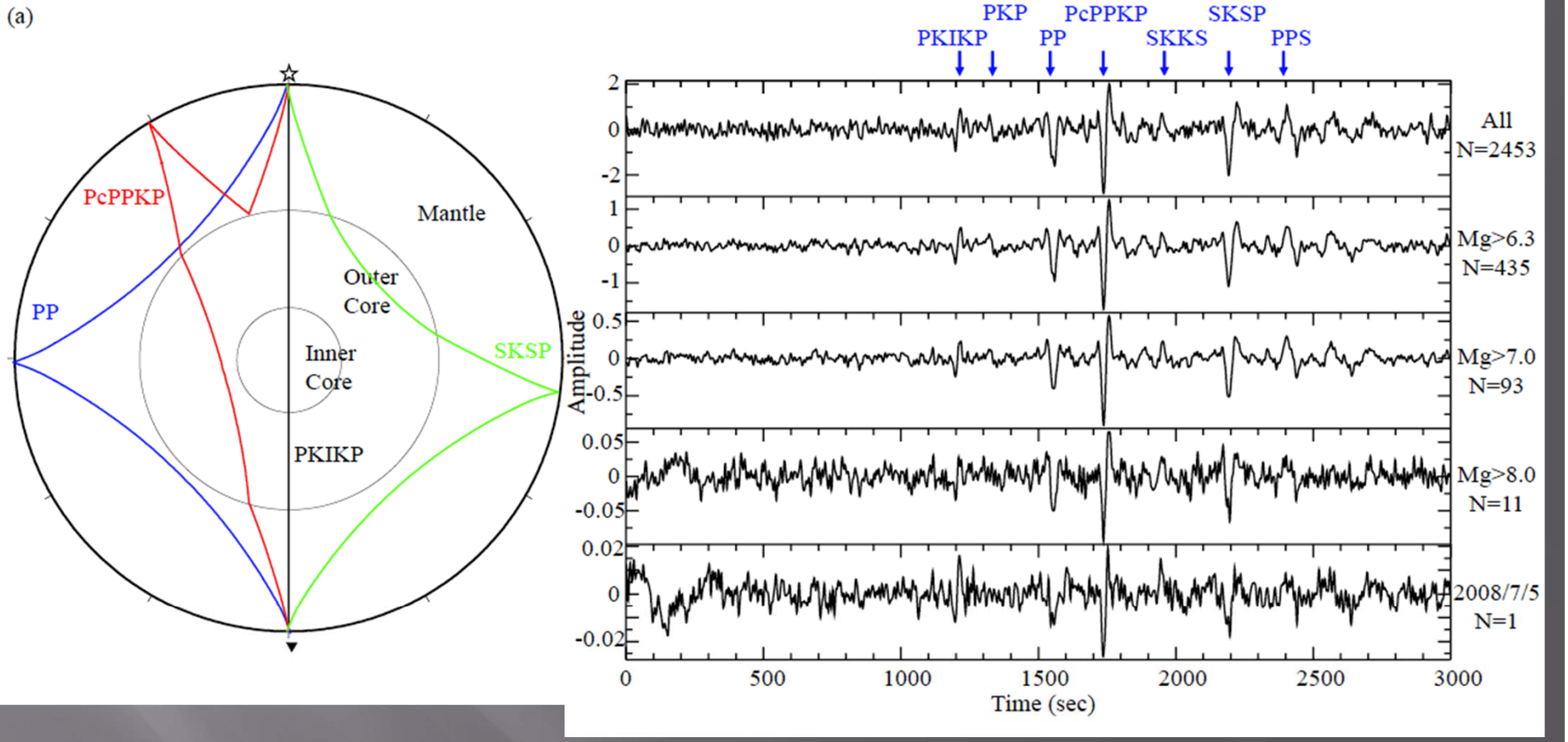


Ambient noise cross-correlations



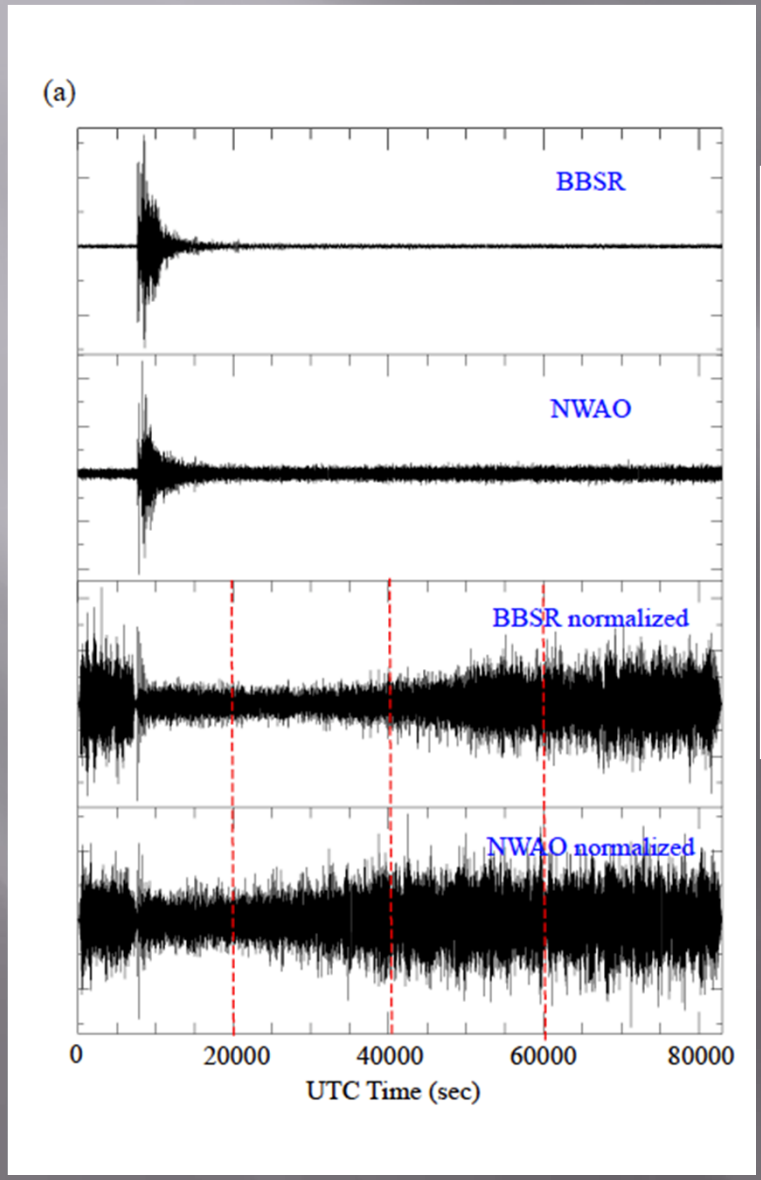
Lin et al., 2013

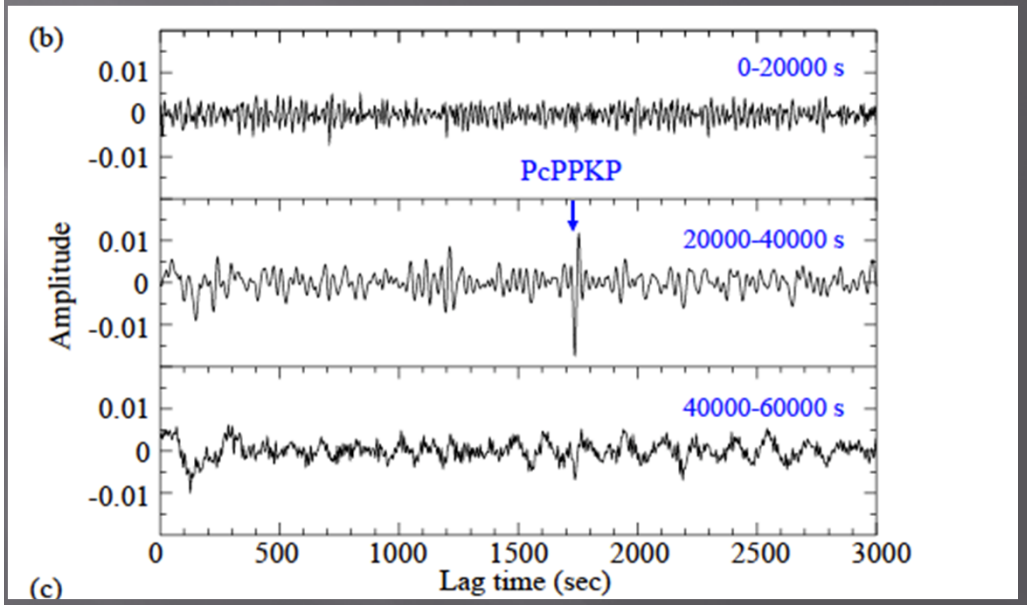
BBSR–NWAO cross-correlation



Lin et al., 2013

Single earthquake

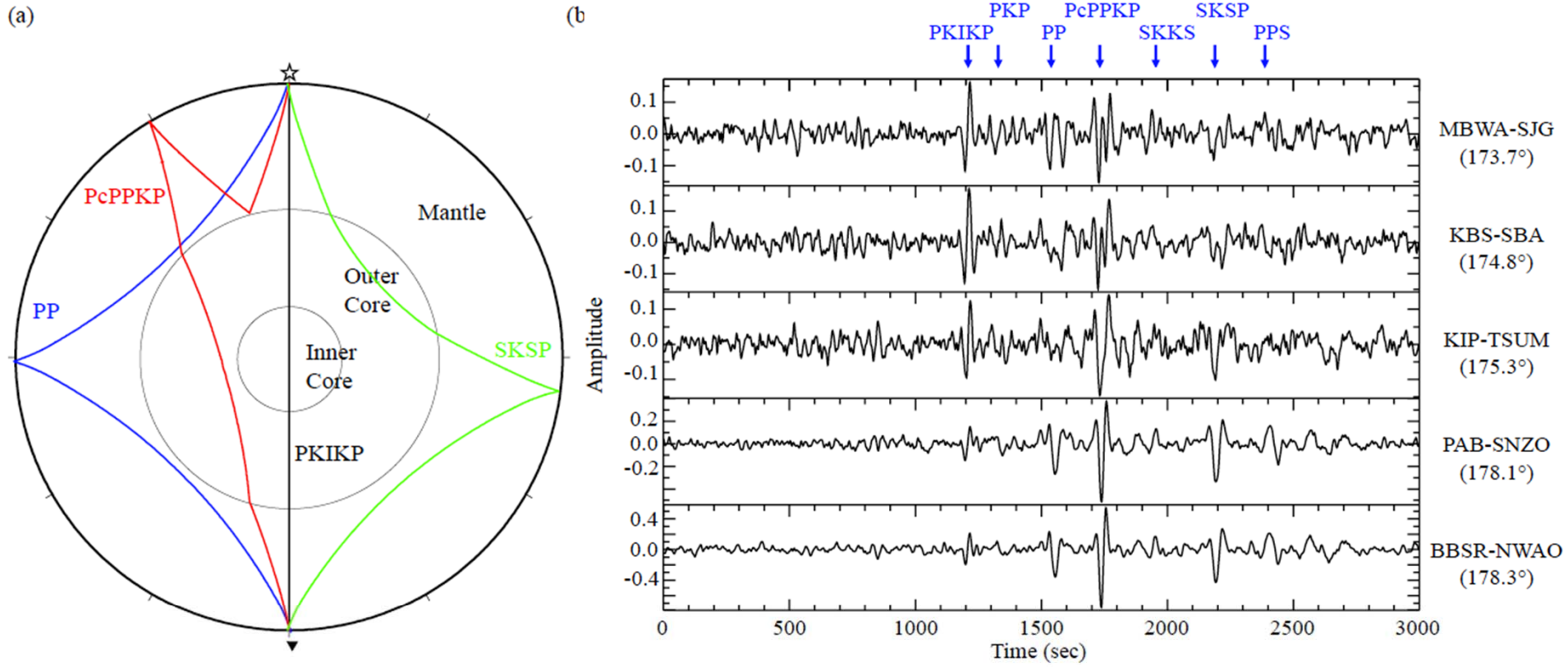




2008/7/5, Mg=7.7, Japan

Lin et al., 2013

Coda cross-correlations



Conclusions

- Seismic interferometry now can provide constraints to earth structure from shallow to deep.
- A high resolution 3D model of the upper crust can be constructed by combining Rayleigh wave phase velocity and ellipticity measurements.
- New applications based on deep propagating body waves extracted through coda interferometry are emerging.
- Collaboration, student, and postdoc opportunities are available at University of Utah!

Questions?

Salt Lake City, UT

The University of Utah

For more information about Utah, please contact Professor Chang. (張午龍教授 – room S209, ext 65615)

Utah