

Extracting Core Phases with Array Interferometry

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Seismic Interferometry

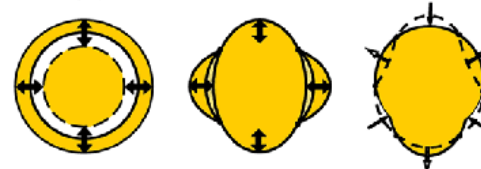
If

Noise


Equal
Excitation
of Normal
Modes



Toroidal modes ${}_0T_2$ (44.2 min), ${}_1T_2$ (12.6 min)
and ${}_0T_3$ (28.4 min)

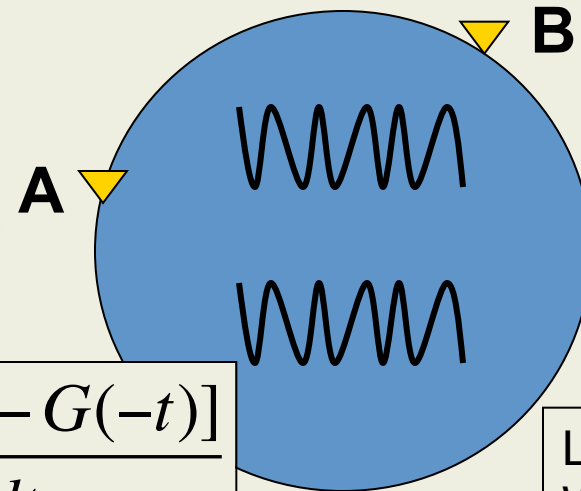
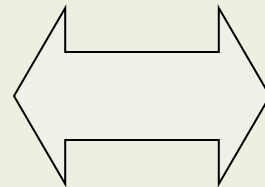
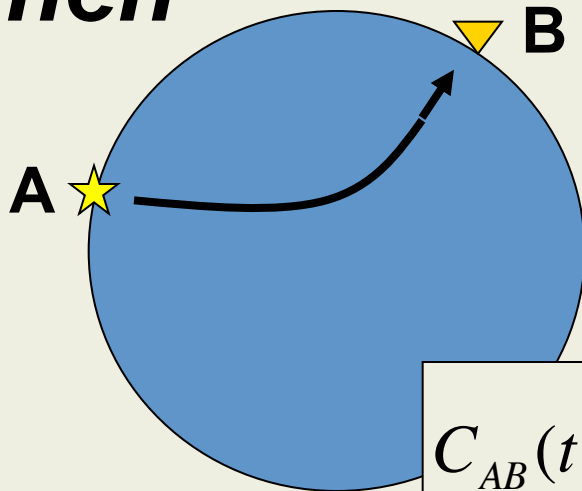


Spheroidal modes ${}_0S_0$ (20.5 min), ${}_0S_2$ (53.9 min)
and ${}_0S_3$ (25.7 min)

All
==

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Then



$$C_{AB}(t) = A \frac{d[G(t) - G(-t)]}{dt}$$

Lobkis and
Weaver 2001

Surface Waves Dominate Observations

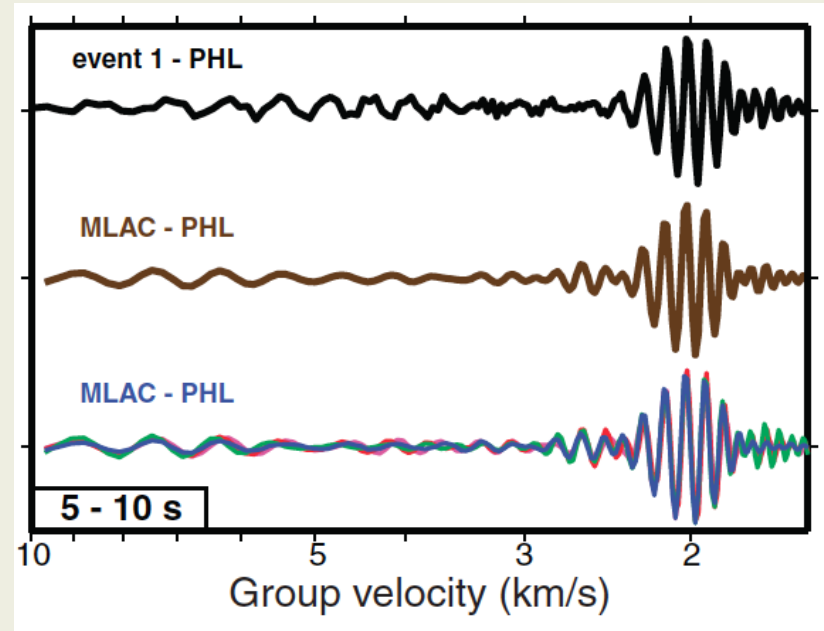
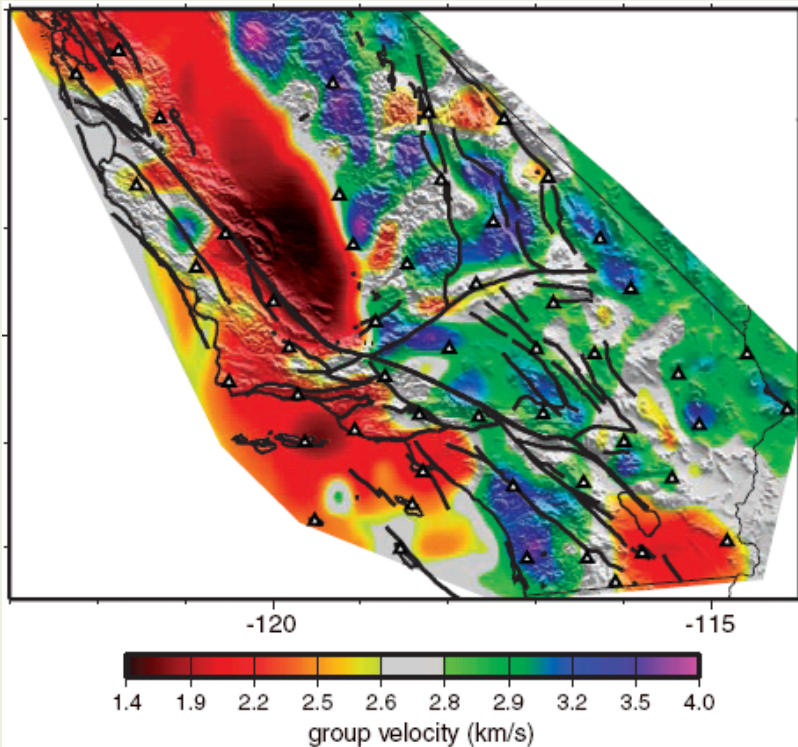
Shapiro et al.,
Science, 2005



waveforms
reasonable



tomography
reasonable



Question: What body-wave phases can we retrieve from ambient noise?

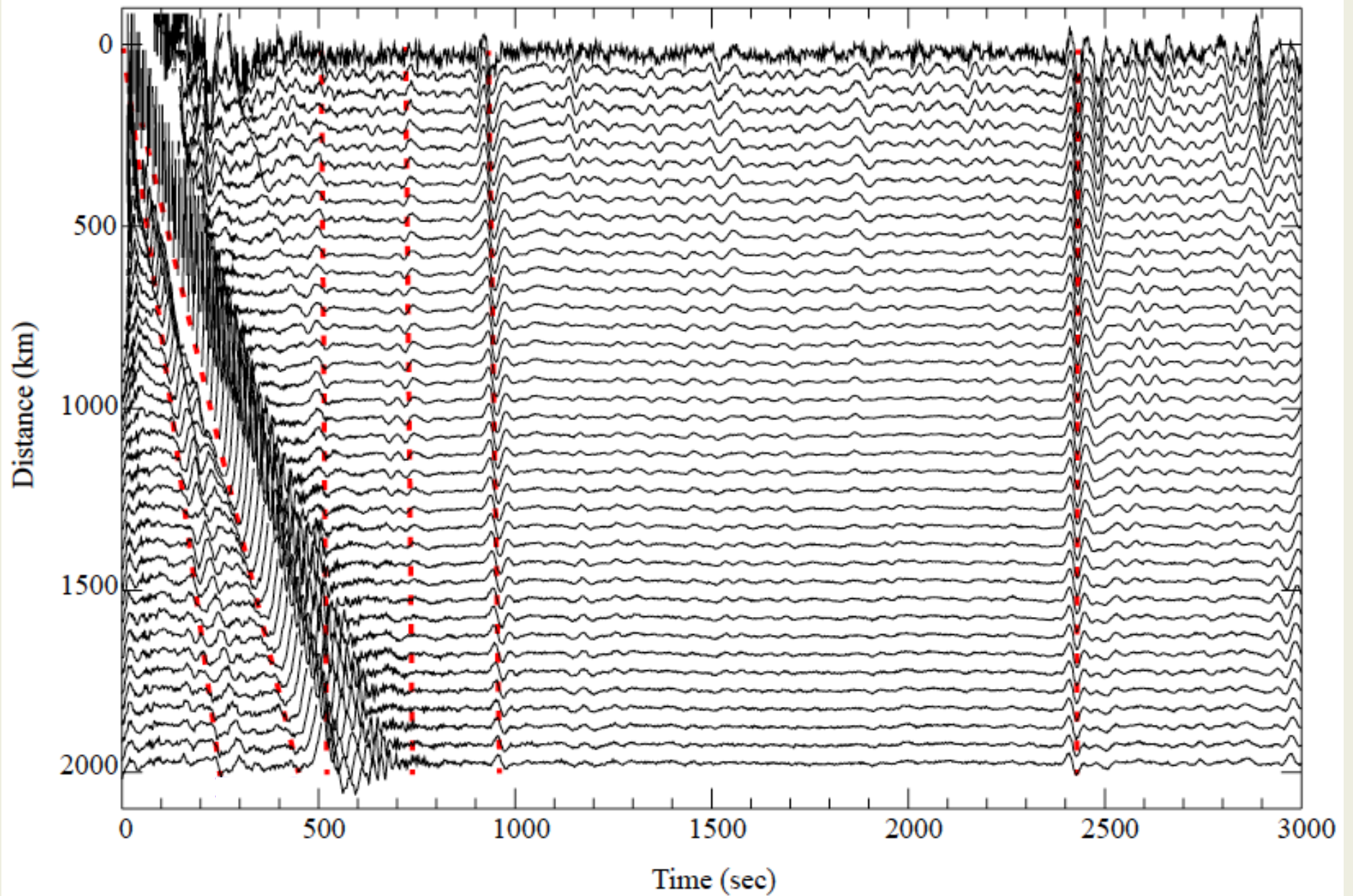
- Body waves from ambient noise is difficult, but successful in limited areas and scales
 - e.g., Zhan et al. 2010 (SmS), Poli et al. 2012 (P410P, P660P)
- Array-based techniques, with USArray
 - 1200 broadband stations → 400,000+ cross correlation pairs

Stacked USArray Cross Correlations

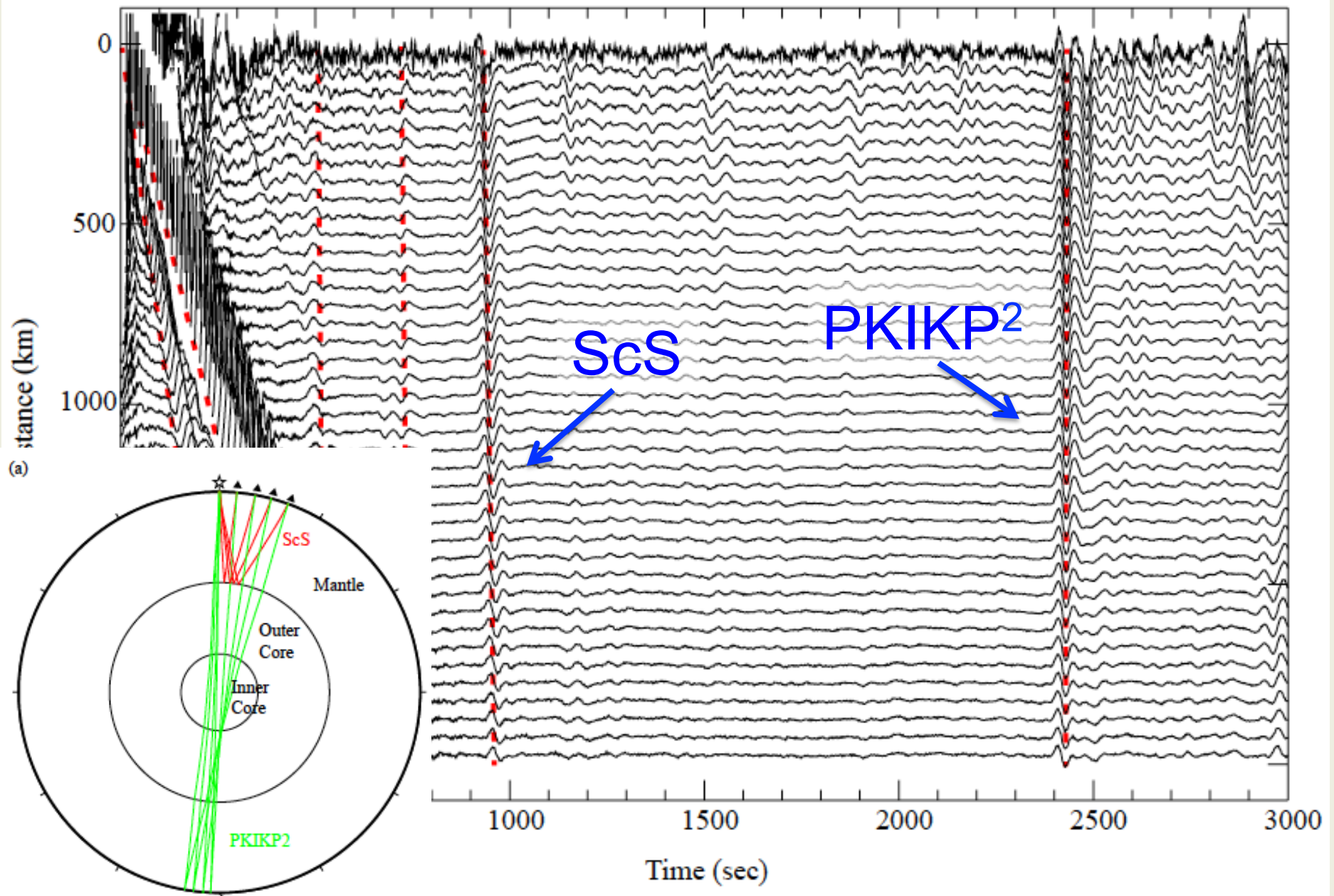
- Process all records from Jan 2007 to May 2011 with standard ambient noise processing (Bensen et al. 2007)
- ‘Noise’ includes all non-identified signals including low-amplitude scattered waves from earthquakes
- Stack all cross correlations into 50-km distance bins
 - 10,000 traces per stack



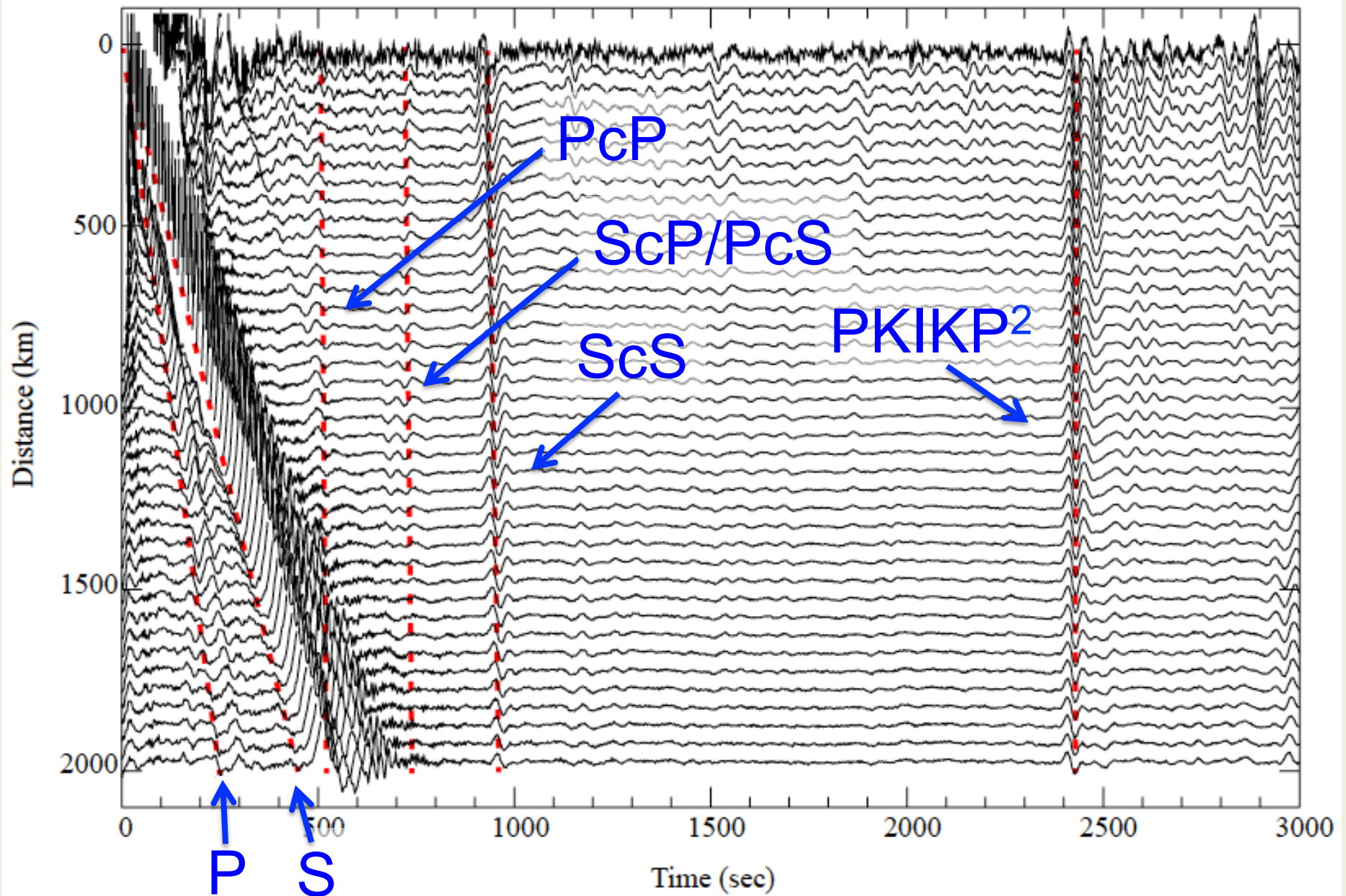
Stacked USArray Cross Correlations



Stacked USArray Cross Correlations

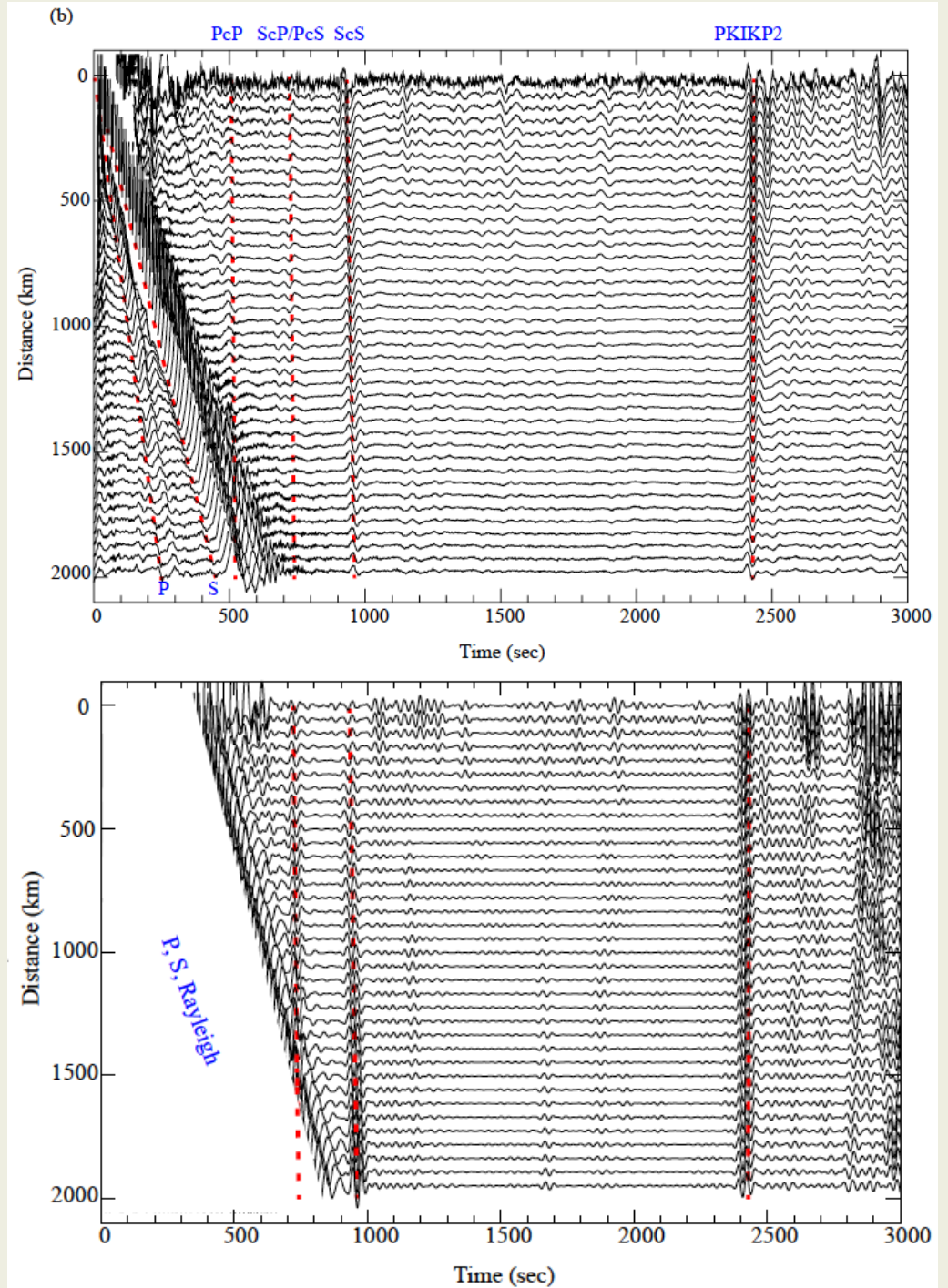


Stacked USArray Cross Correlations



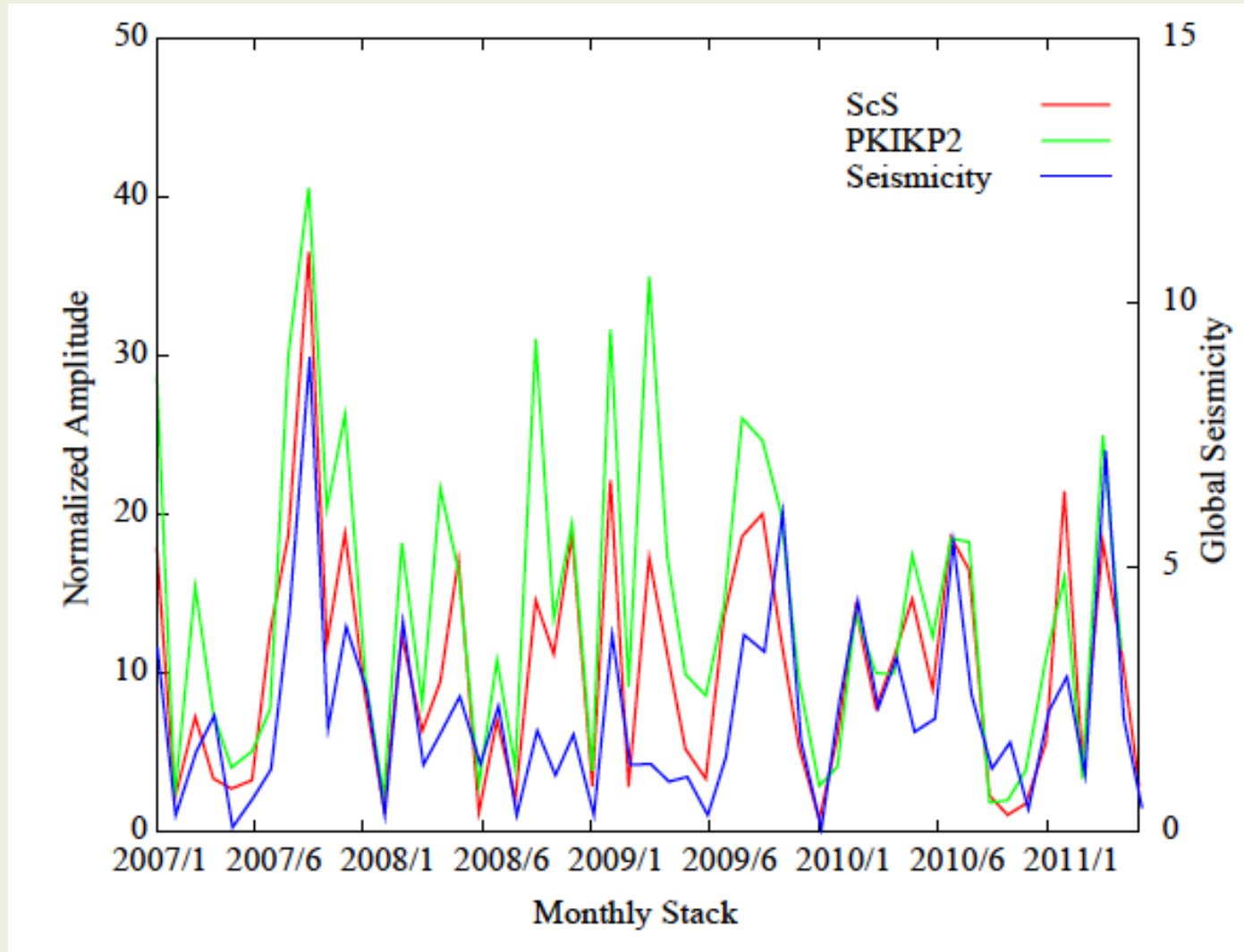
Comparison with Synthetic Green's Functions

- Data
- Normal-Mode Synthetic



Why does it work?

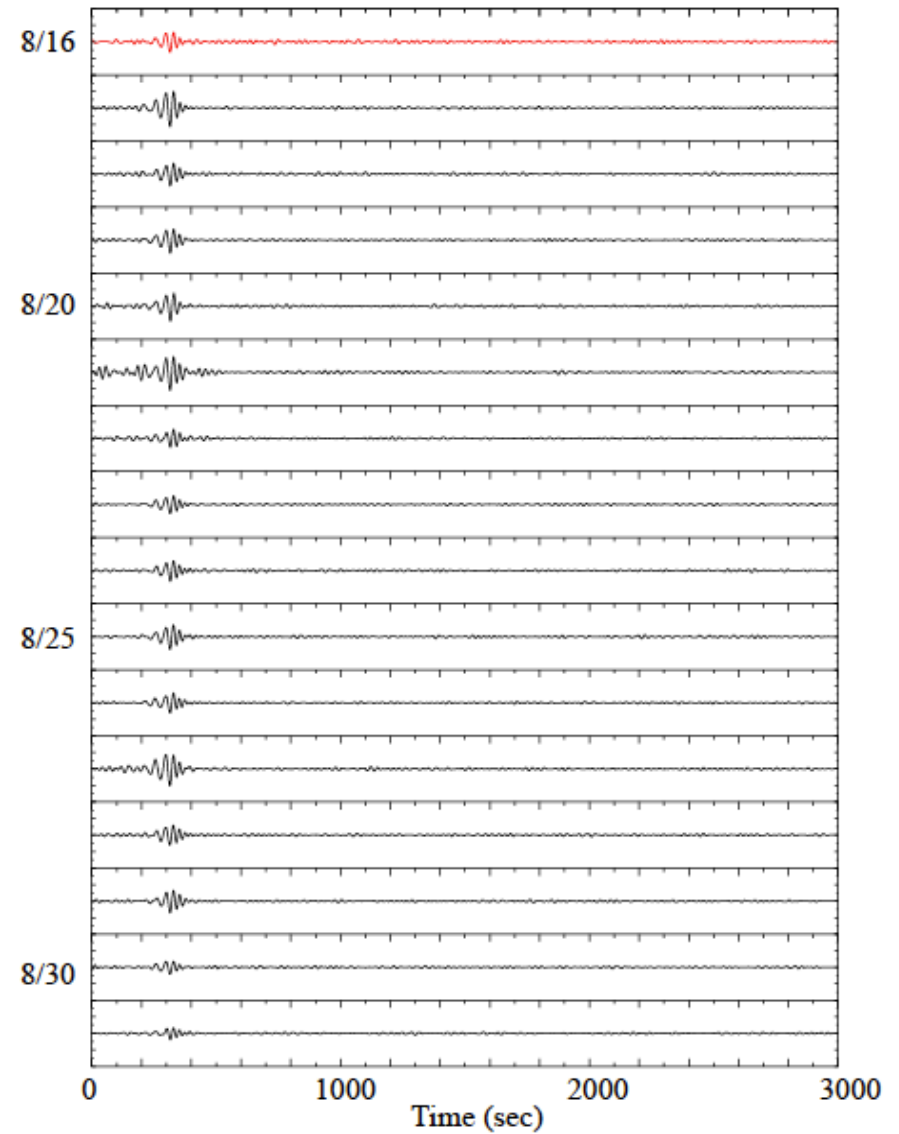
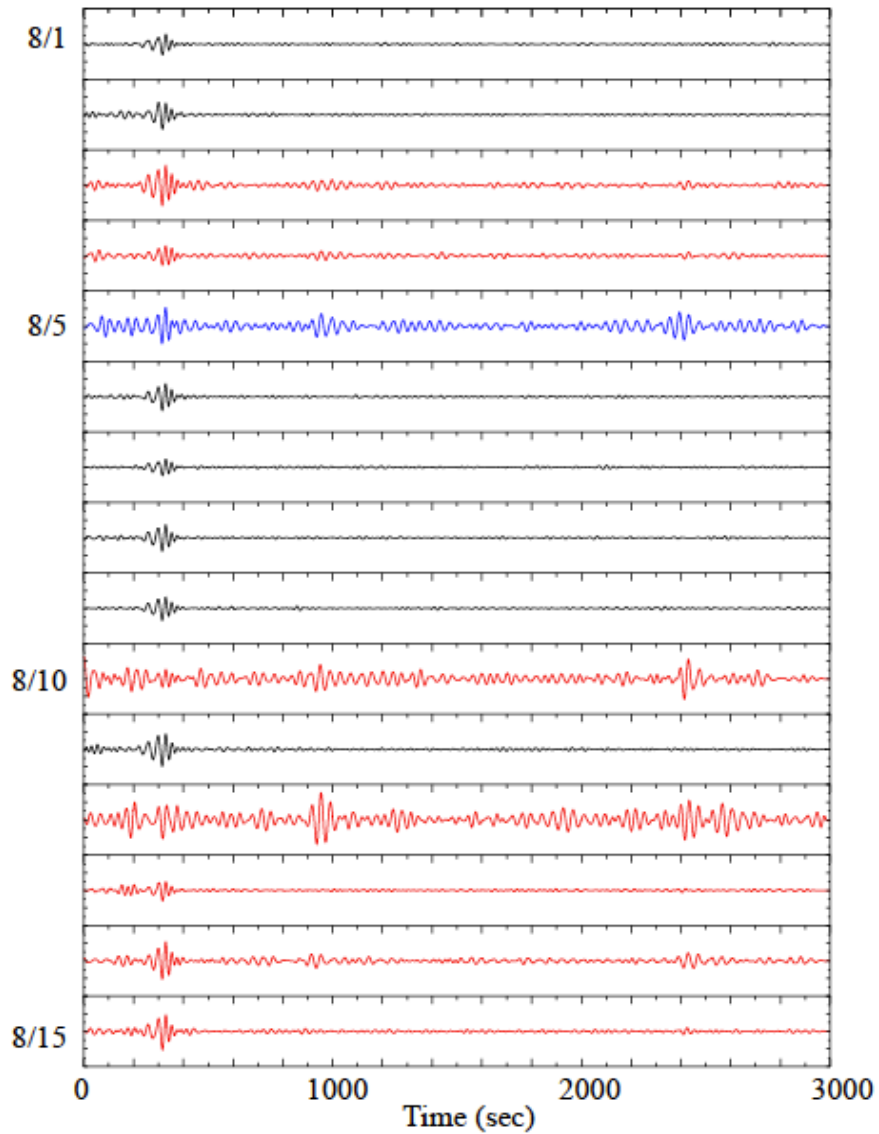
- Examine temporal variability



- Correlation with occurrence of $M_w > 6.3$ eqs.

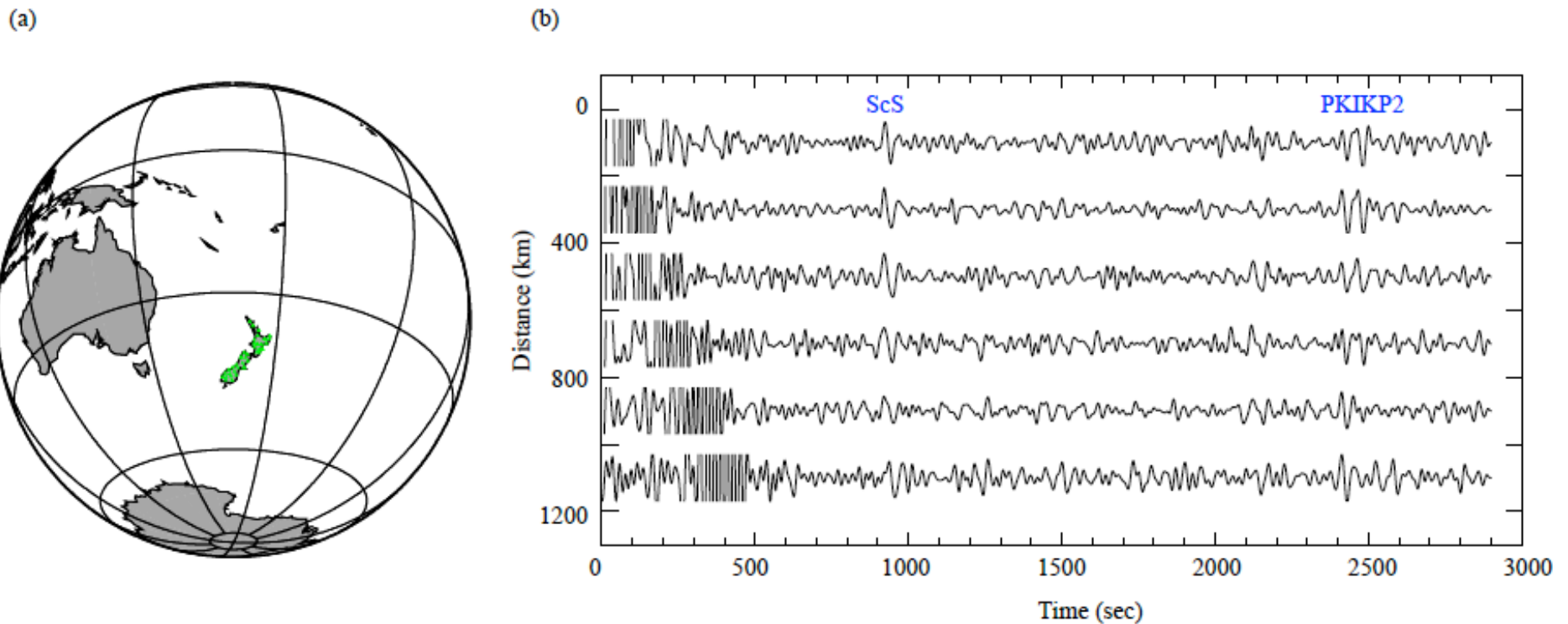
Confirmation from Daily Variability

$M_w > 6.3$ on that day



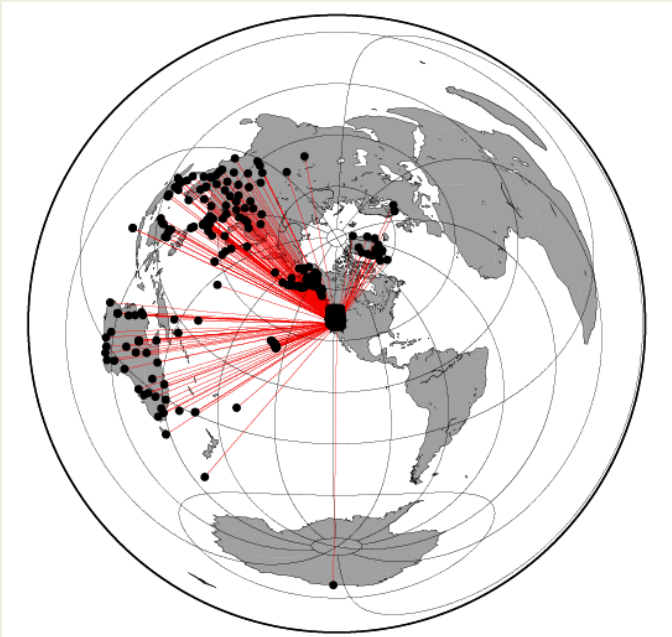
Does it work elsewhere?

- New Zealand national seismic network (42 stations)

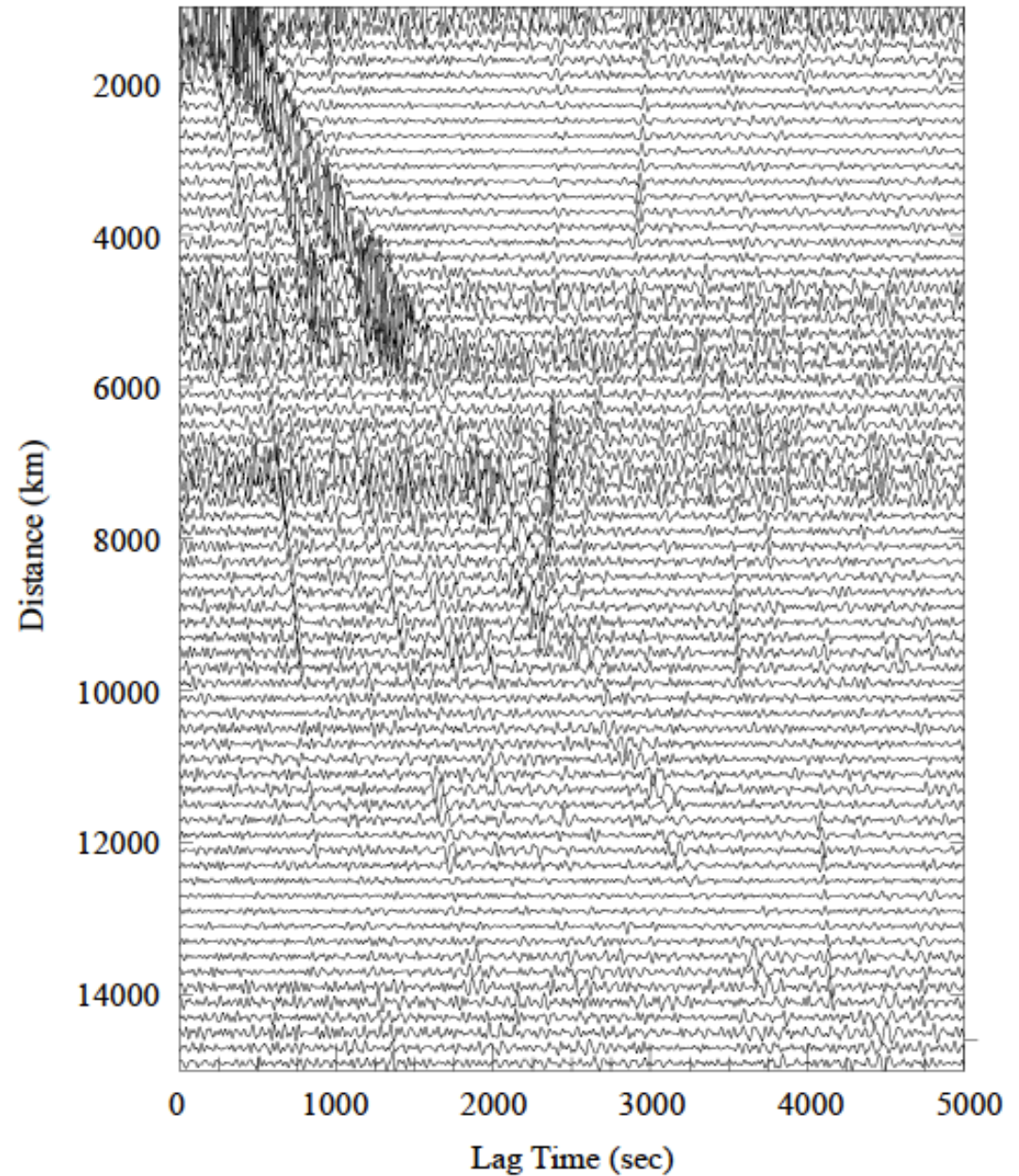


- Weaker, but still clear at short distances

Does it work for long distances?



c.f. Nishida (2013),
Boue et al. (2013)

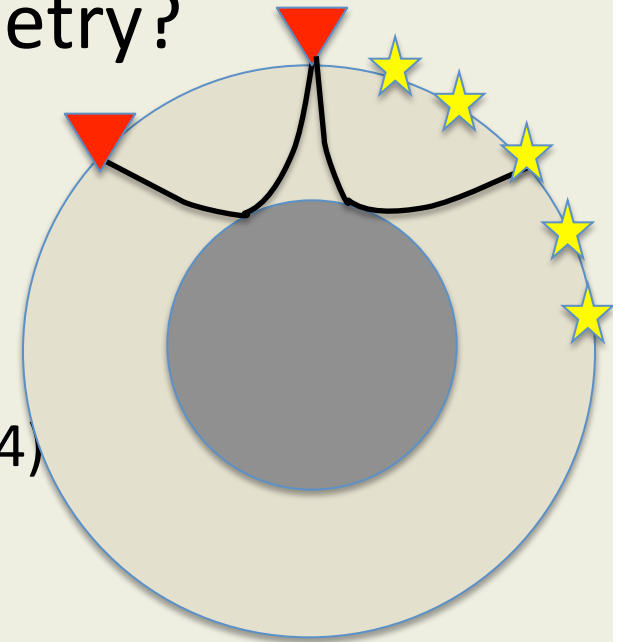


Why does it work? Revisited

- Traditional source-side interferometry?

- If *field is diffuse enough* to sample stationary phase points \rightarrow phase appears in cross correlations

- (e.g., Lobkis and Weaver, 2001; Snieder, 2004)



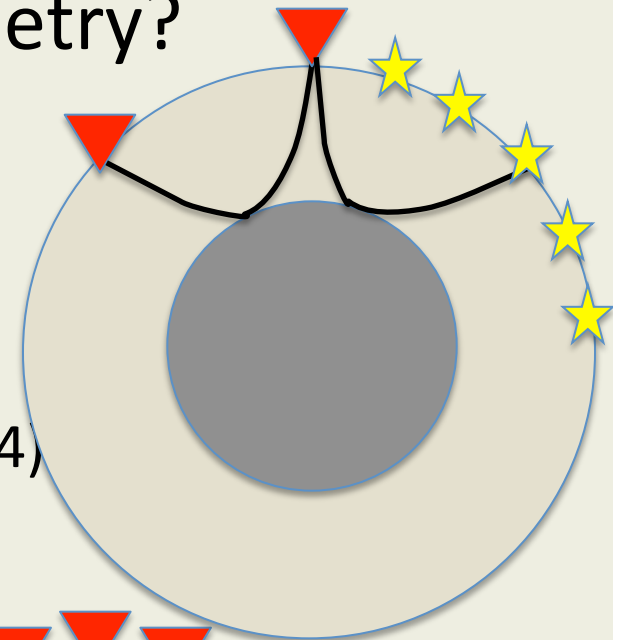
- Station-side interferometry?

Why does it work? Revisited

- Traditional source-side interferometry?

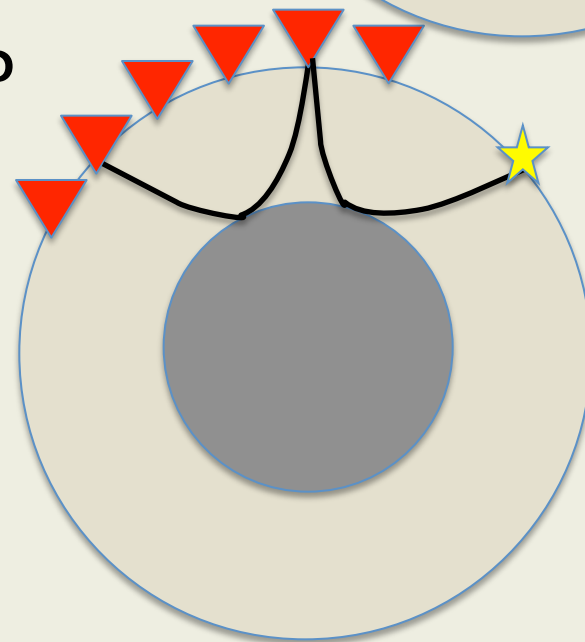
- If ***field is diffuse enough*** to sample stationary phase points \rightarrow phase appears in cross correlations

(e.g., Lobkis and Weaver, 2001; Snieder, 2004)



- Station-side interferometry?

- If ***stations are dense enough*** to sample stationary phase points \rightarrow phase appears in cross correlations



Summary of Findings

Lin, Tsai, Schmandt, Duputel, Zhan, *GRL* 2013.

- Array interferometry yields strong body-wave phases, especially ScS and PKIKP²
- Phases are excited primarily by scattered earthquake energy
- Preliminary theoretical understanding as due both to source-side & station-side interferometry

Implications/Future Work

- A number of possible applications
 - Inner core anisotropy
 - CMB topography
 - ...
- Important implications for Earth scattering
 - Length scale of heterogeneity
 - Effectiveness of interferometry in general

Thank You