New Developments in Ambient Noise Imaging

Victor C. Tsai

Seismological Laboratory

California Institute of Technology

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IRIS Workshop

Sunriver, Oregon

Caltech

Outline

Previous studies…

- Ambient noise surface waves
- Temporal variability in velocity structure

New work (in the last ~2 years):

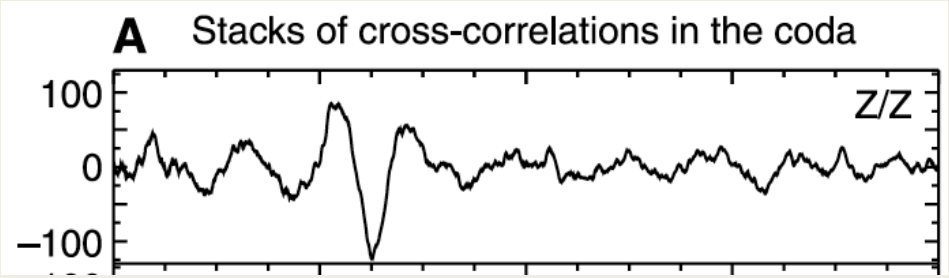
- Body wave imaging
- Monitoring of time variations
- Improvement in theory/understanding
- Multi-component correlations
- Amplitudes
- Imaging physical processes through 'noise'

Previous Noise Correlation Applications

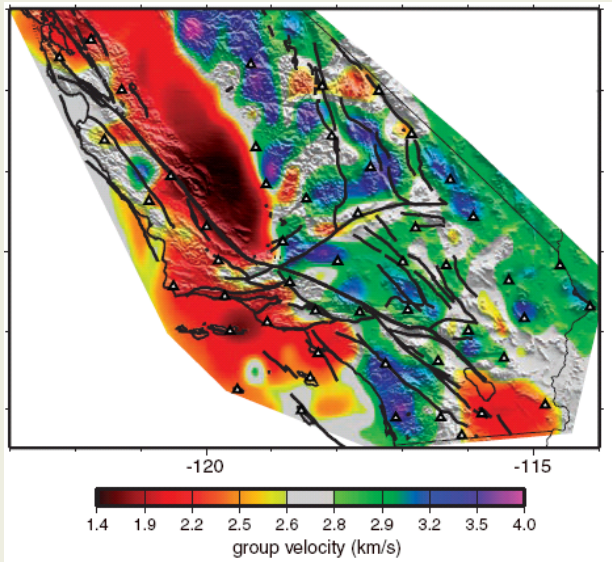
- Eckart, *JASA* (1953):
  - Noise correlation matches Green's function

$$\psi(r,\tau) = (1/2\pi)\int_0^\infty S(\omega)\, j_0(\omega r/c)\, \cos(\omega\tau)\, d\omega,$$

- Campillo & Paul, *Science* (2003):
  - Coda correlation similar, waveforms reasonable

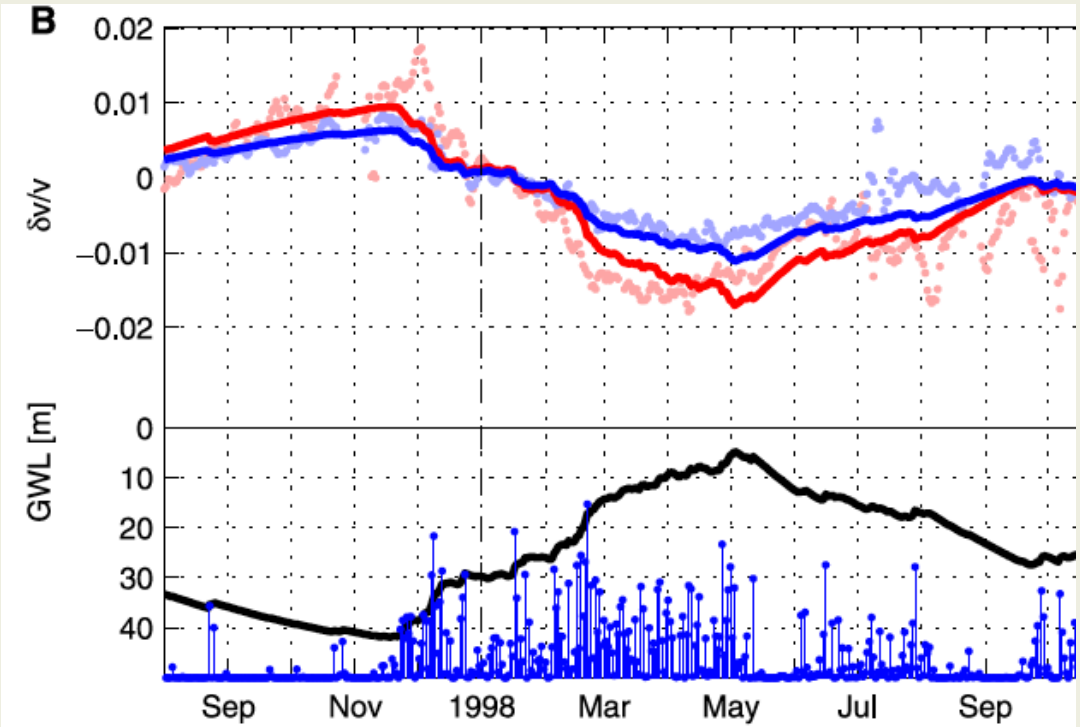


- Shapiro et al., *Science* (2005)
  - Tomography reasonable

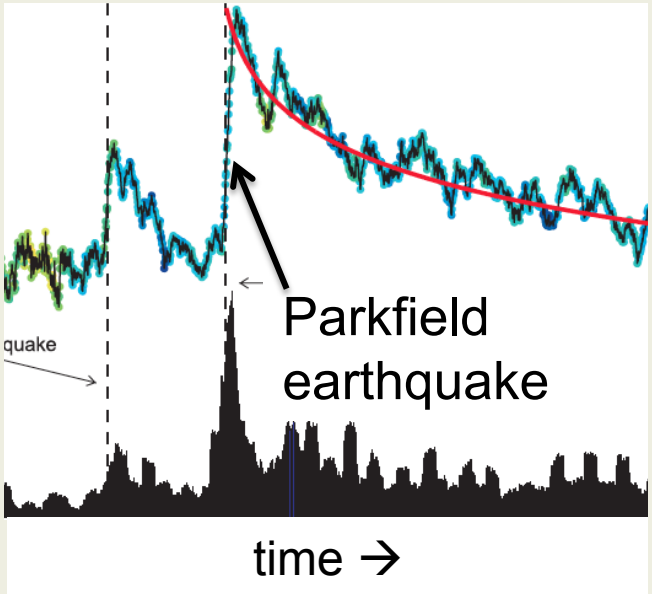


Time-dependent velocities

- Sens-Schönfelder & Wegler, GRL 2006:
  - Hydrology at volcano



- Brenguier et al., *Science* (2008):
  - Similar study shows variability with volcano deformation



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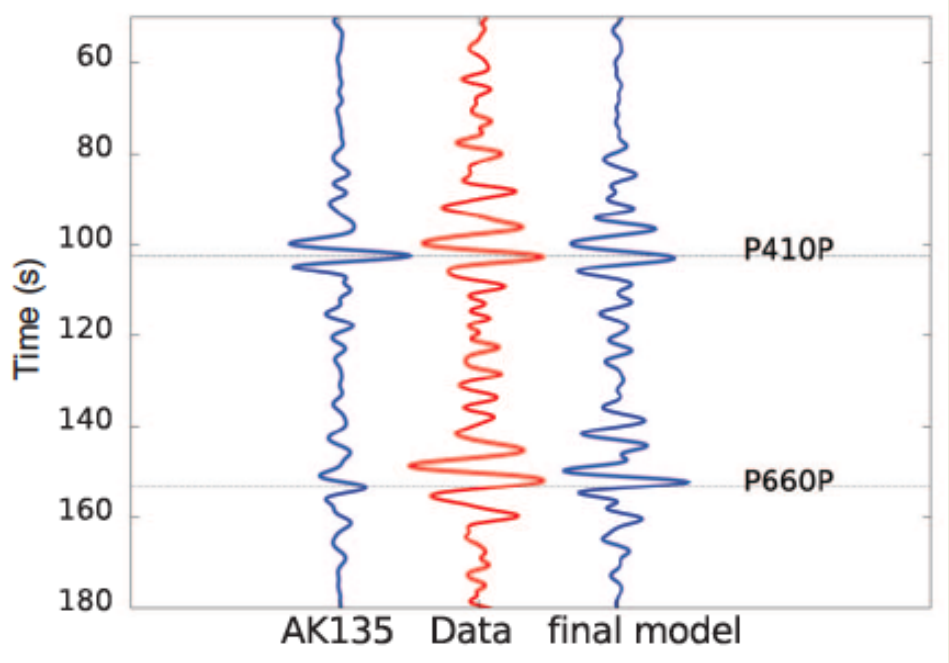
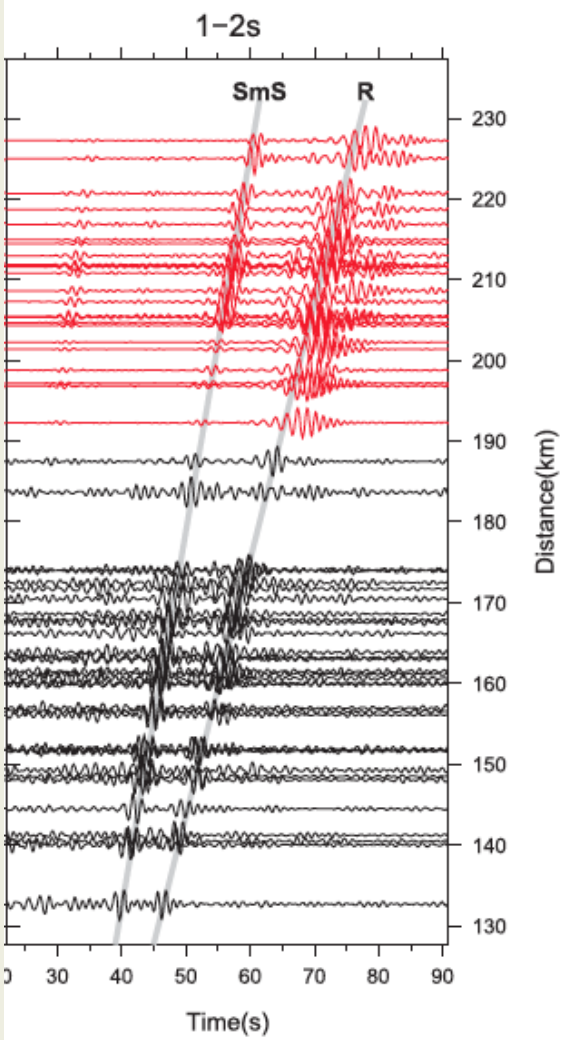
Body Wave Imaging

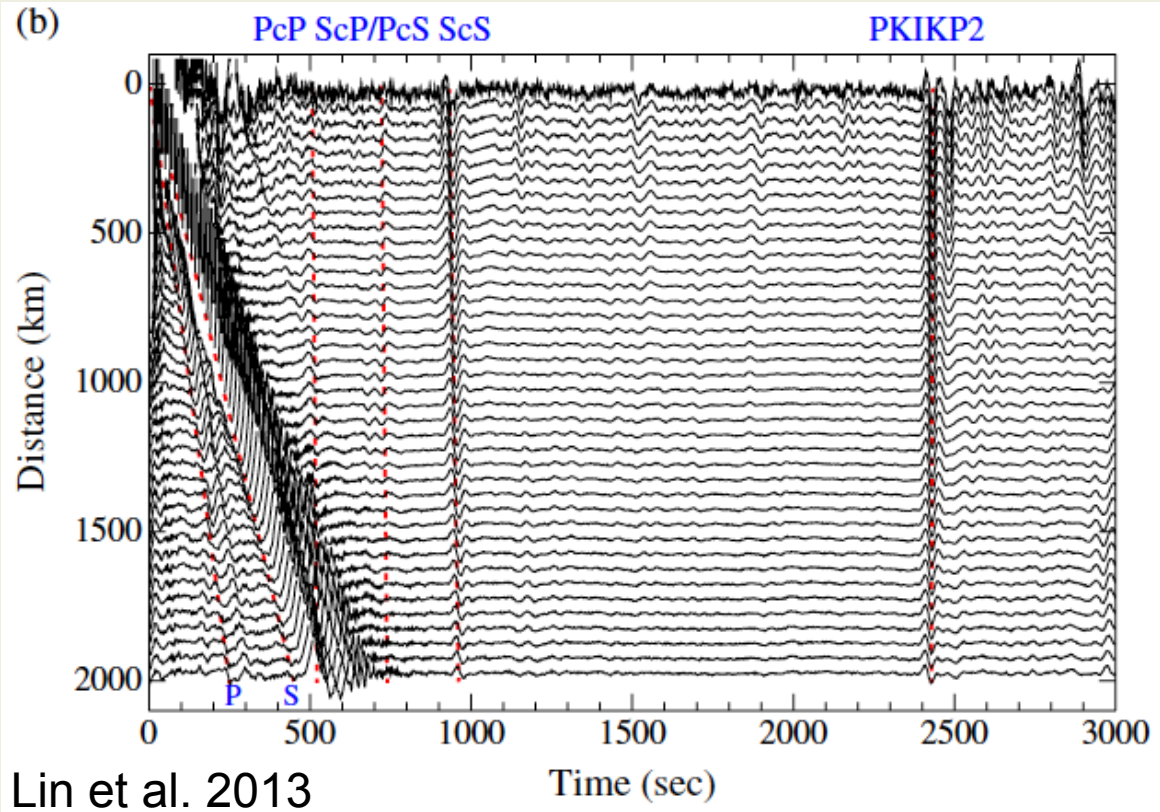
- Most noise at surface → surface waves dominate
- Does 'noise'-based body-wave imaging work?
- Simple regions: flat & cratonic
  - SmS: Zhan et al. 2010
  - P410P, P660P: Poli et al. 2012





Body Wave Imaging

- Core phases (from eq. coda): ScS, $PKIKP_2$
- Global correlations
- Antipodal phases, targeted time window (no stacking)



Lin et al. 2013

Array interferometry using all of USArray

Body Wave Imaging

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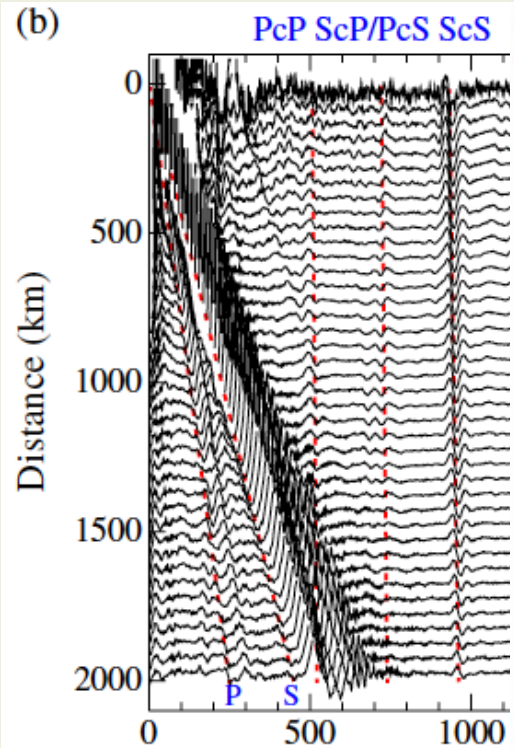

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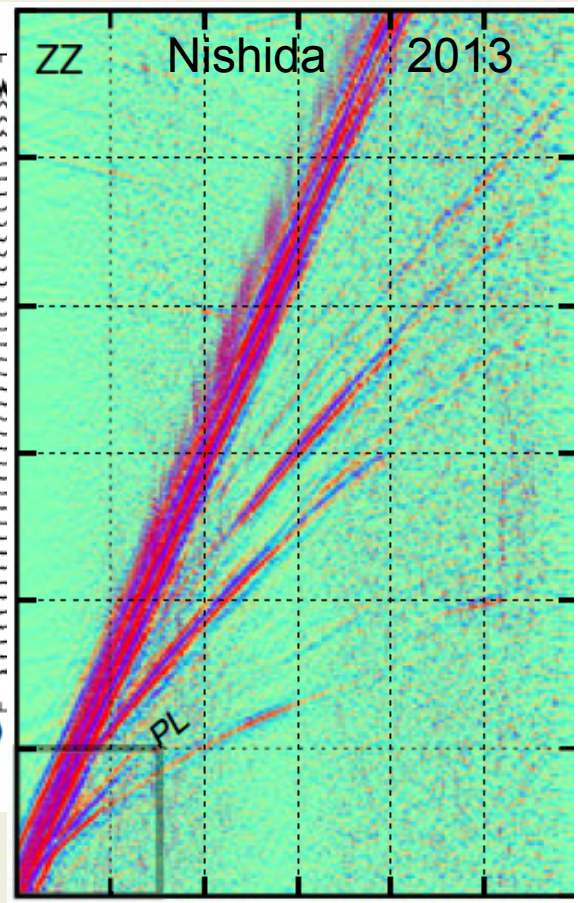

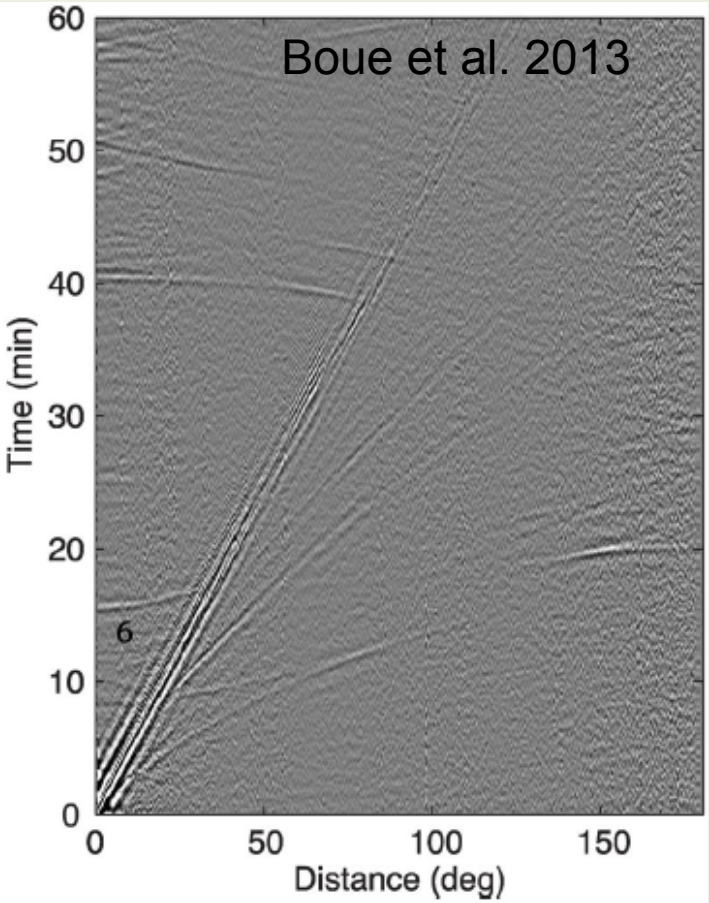

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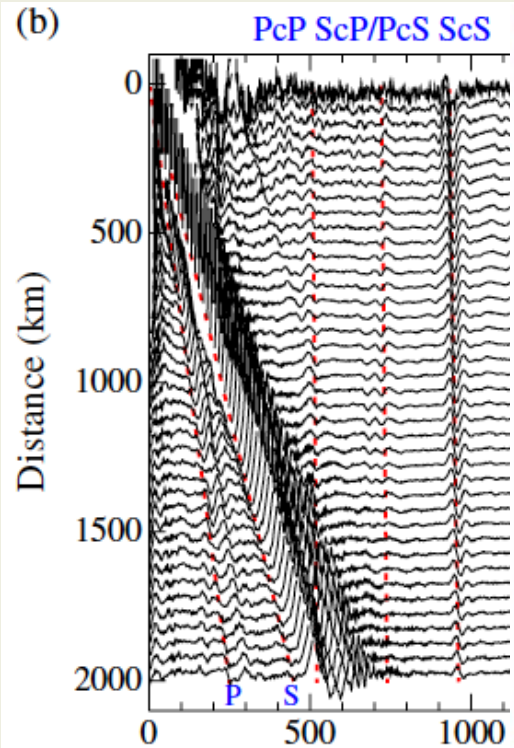

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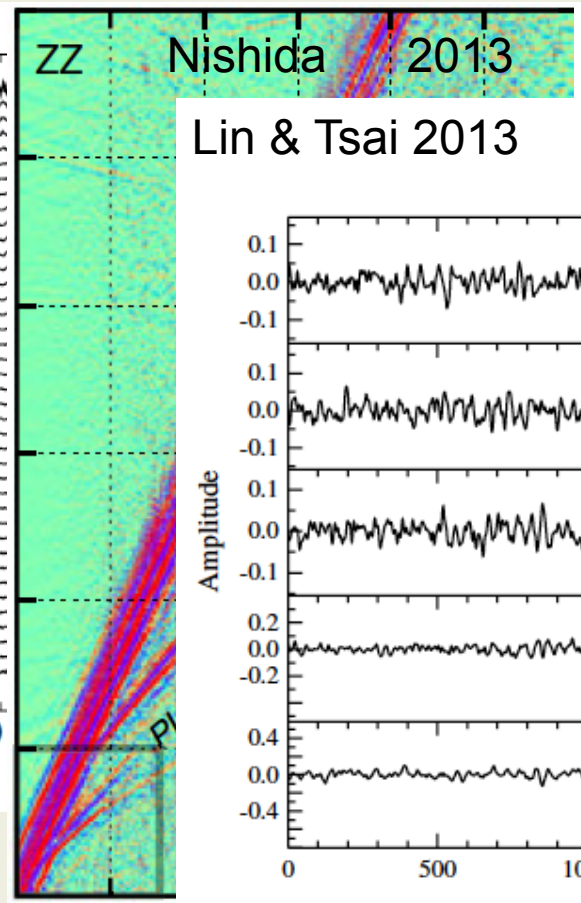
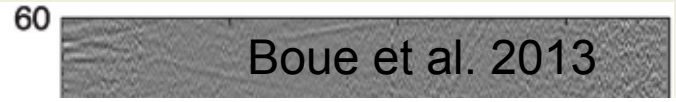
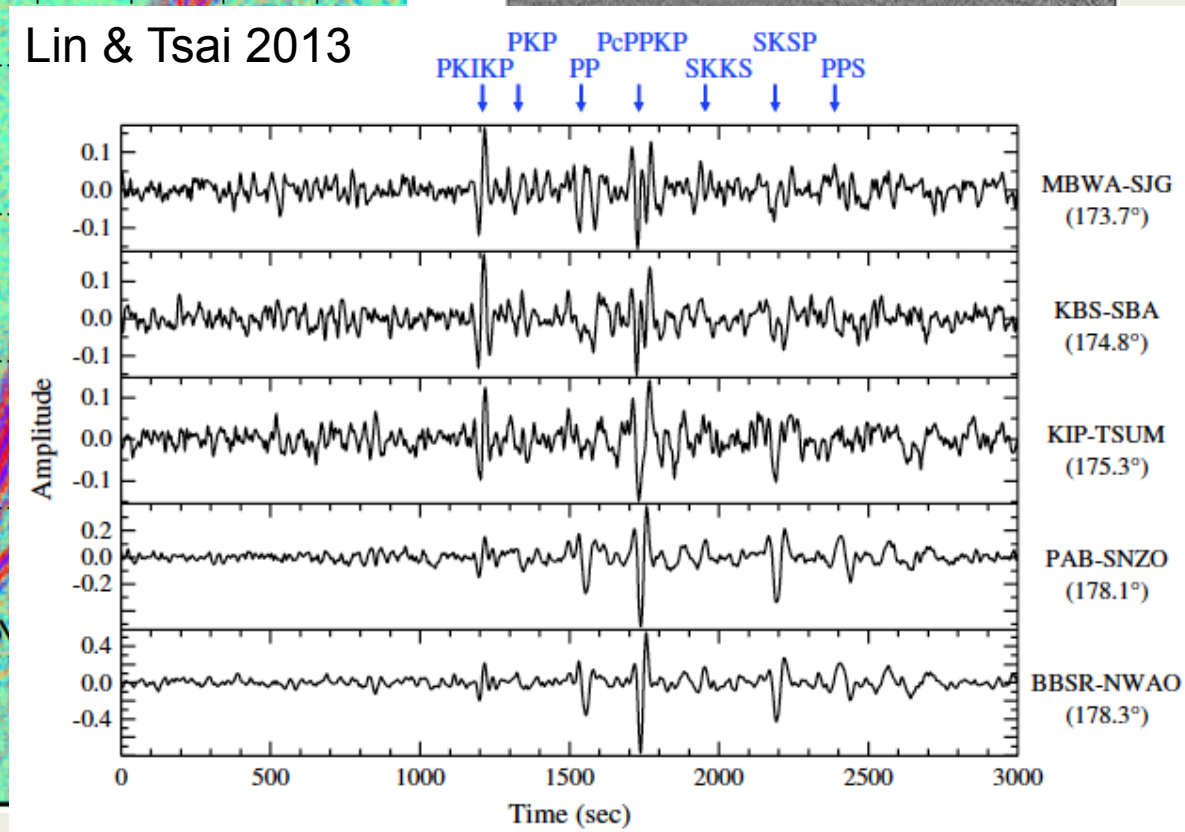


Nishida 2013



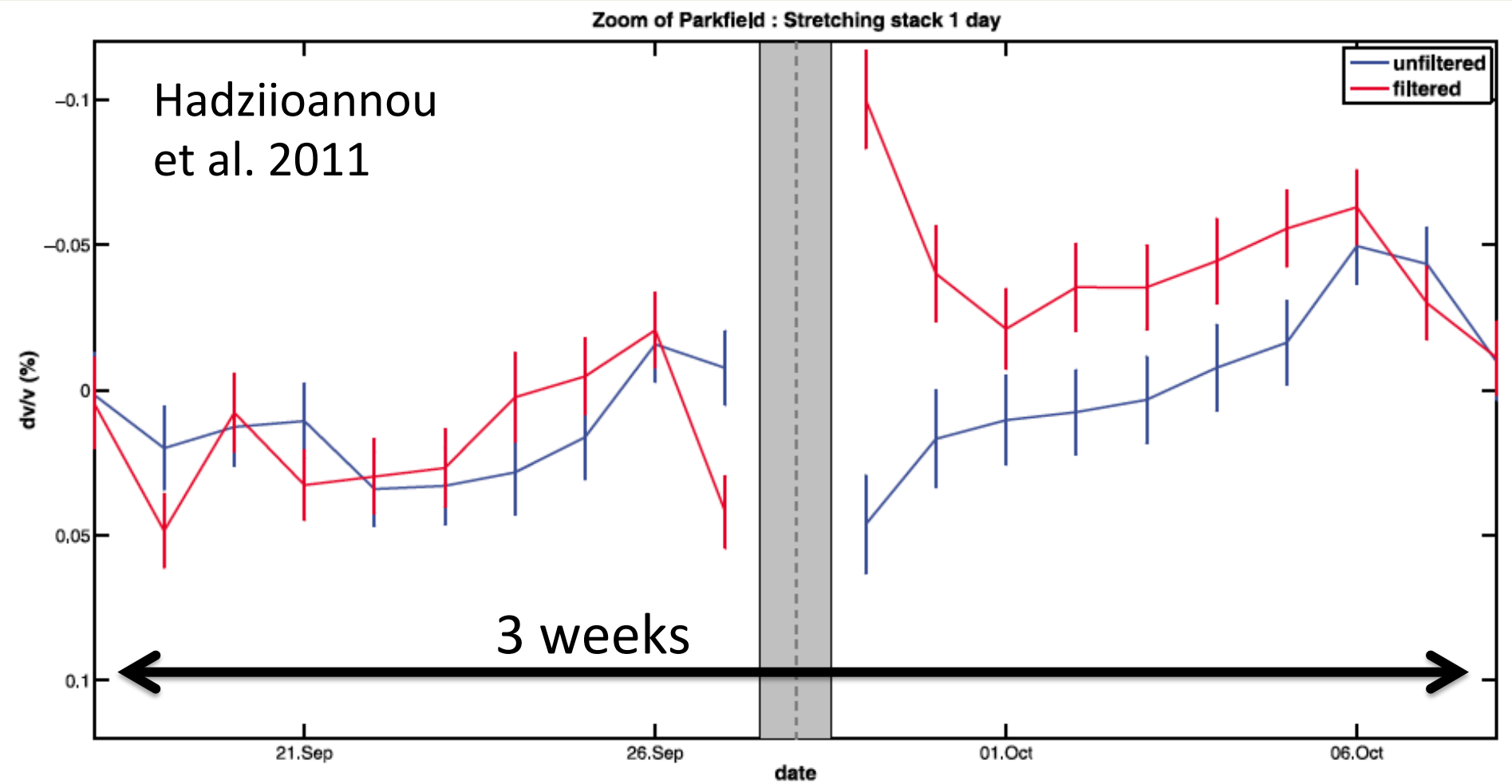
Boue et al. 2013

Lin & Tsai 2013



Monitoring of Time Variations

- Short timescale variability
- Shallow & deep, different timescales for Tohoku
- Induced seismicity, injection rate



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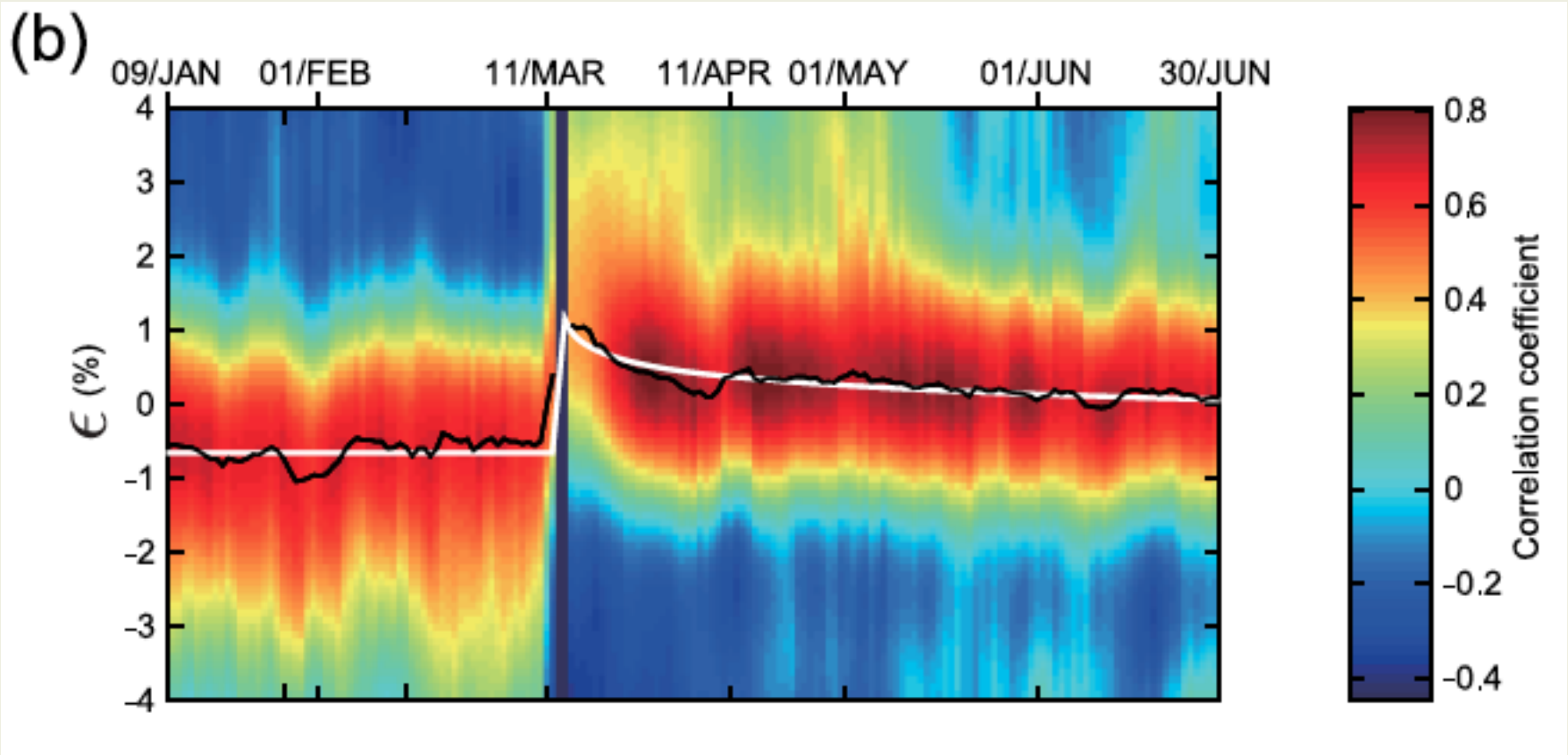

Minato et al. 2012

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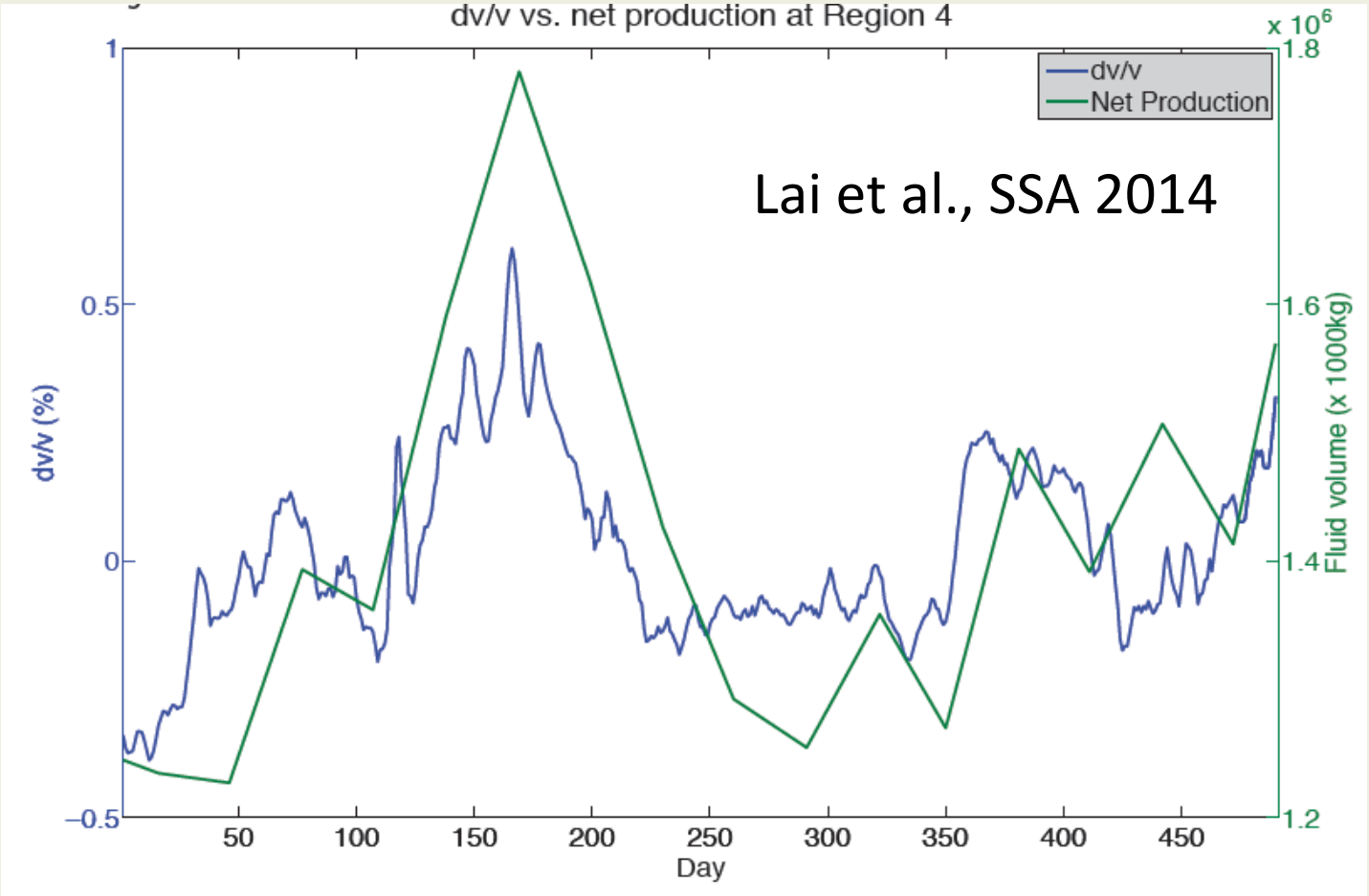


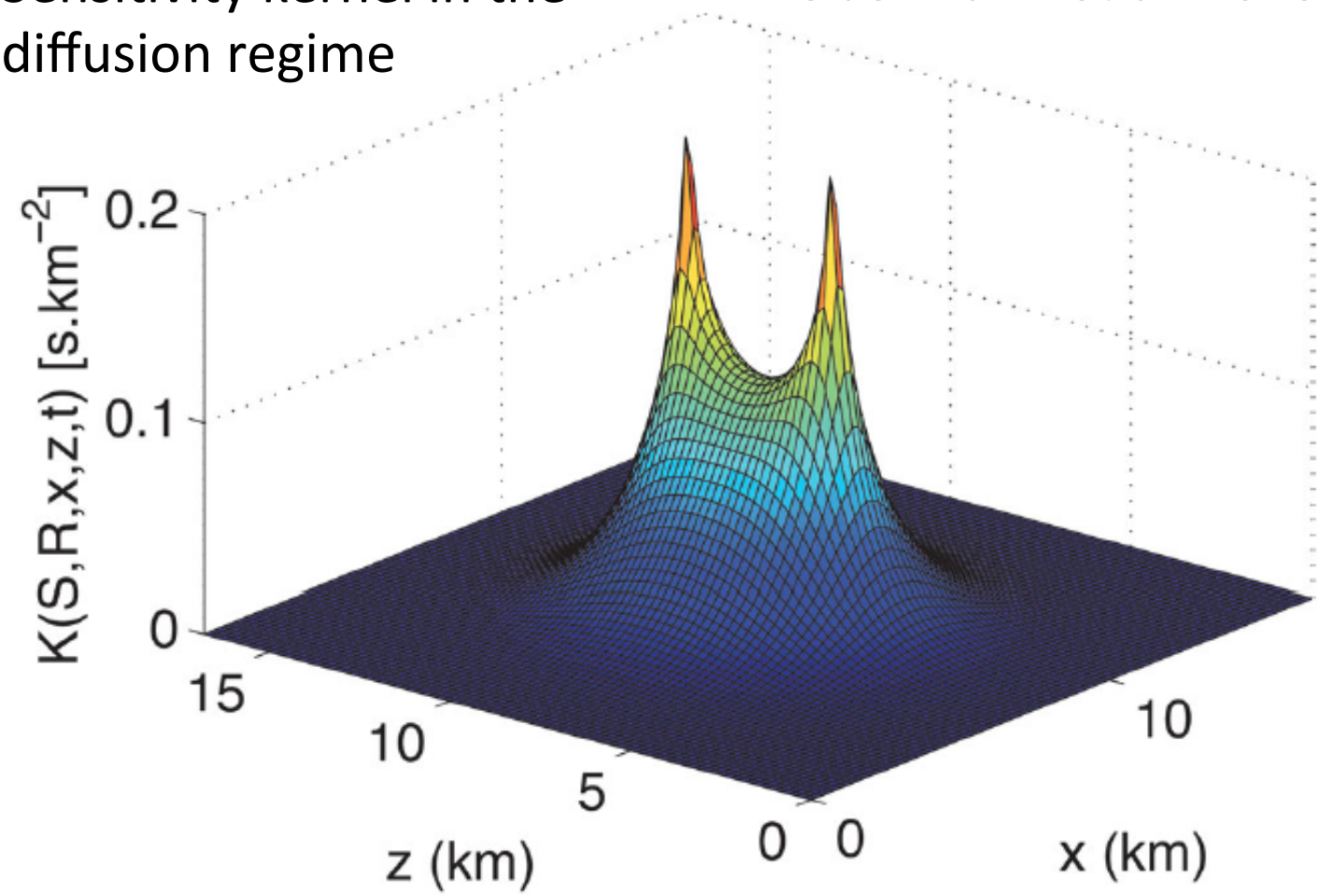
Monitoring of Time Variations

- But one needs to be careful in interpretation…

  which theory is getting better at characterizing

Sensitivity kernel in the diffusion regime

Obermann et al. 2013



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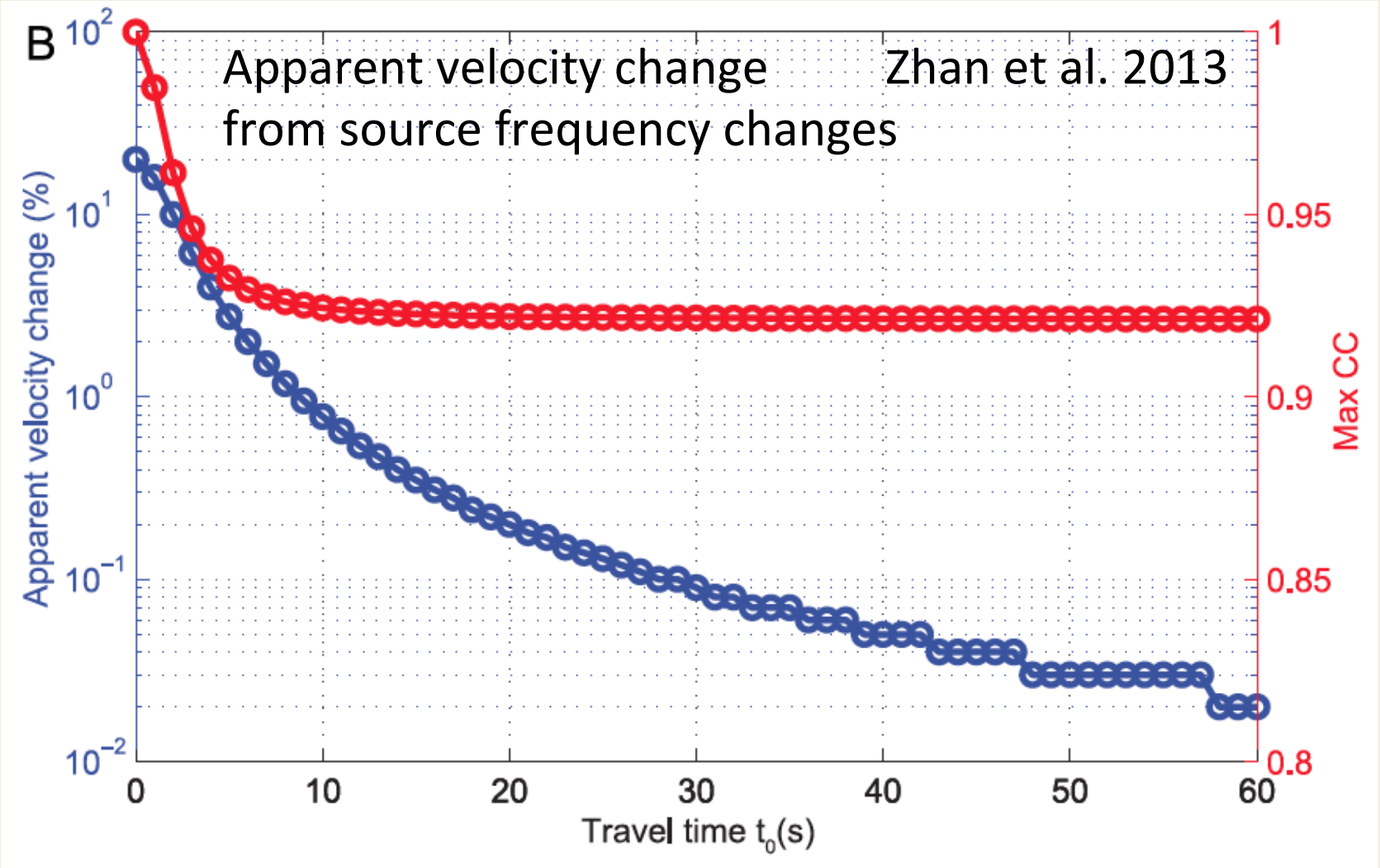
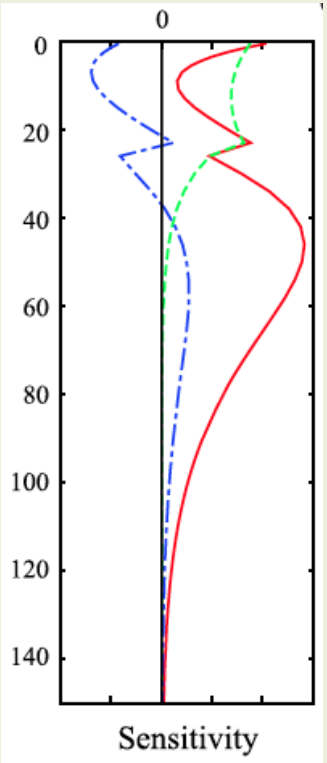


Multi-Component Correlations

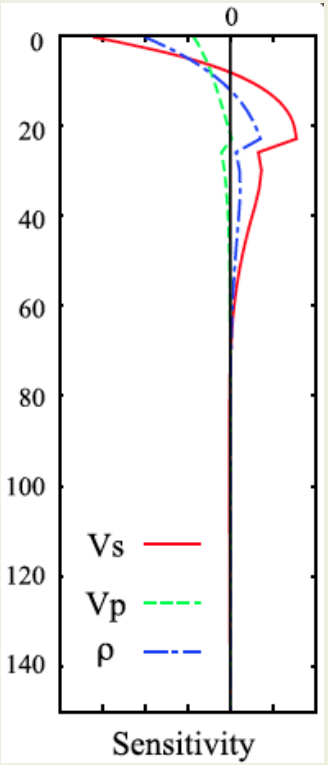
- Can R-Z corr. be useful beyond added travel time?
- R-Z SPAC (Haney et al. 2012), OBS R-Z (Zha et al. 2013)
- H/V amplitude ratios of NCFs: Lin et al. 2014

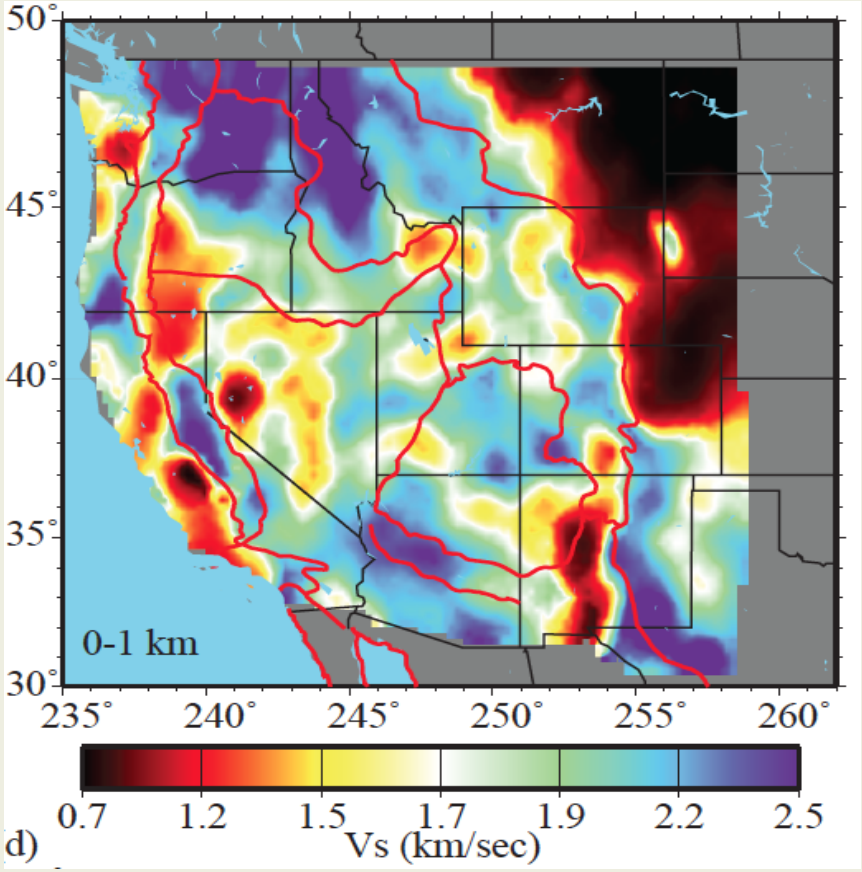
At 30s:

Phase velocity



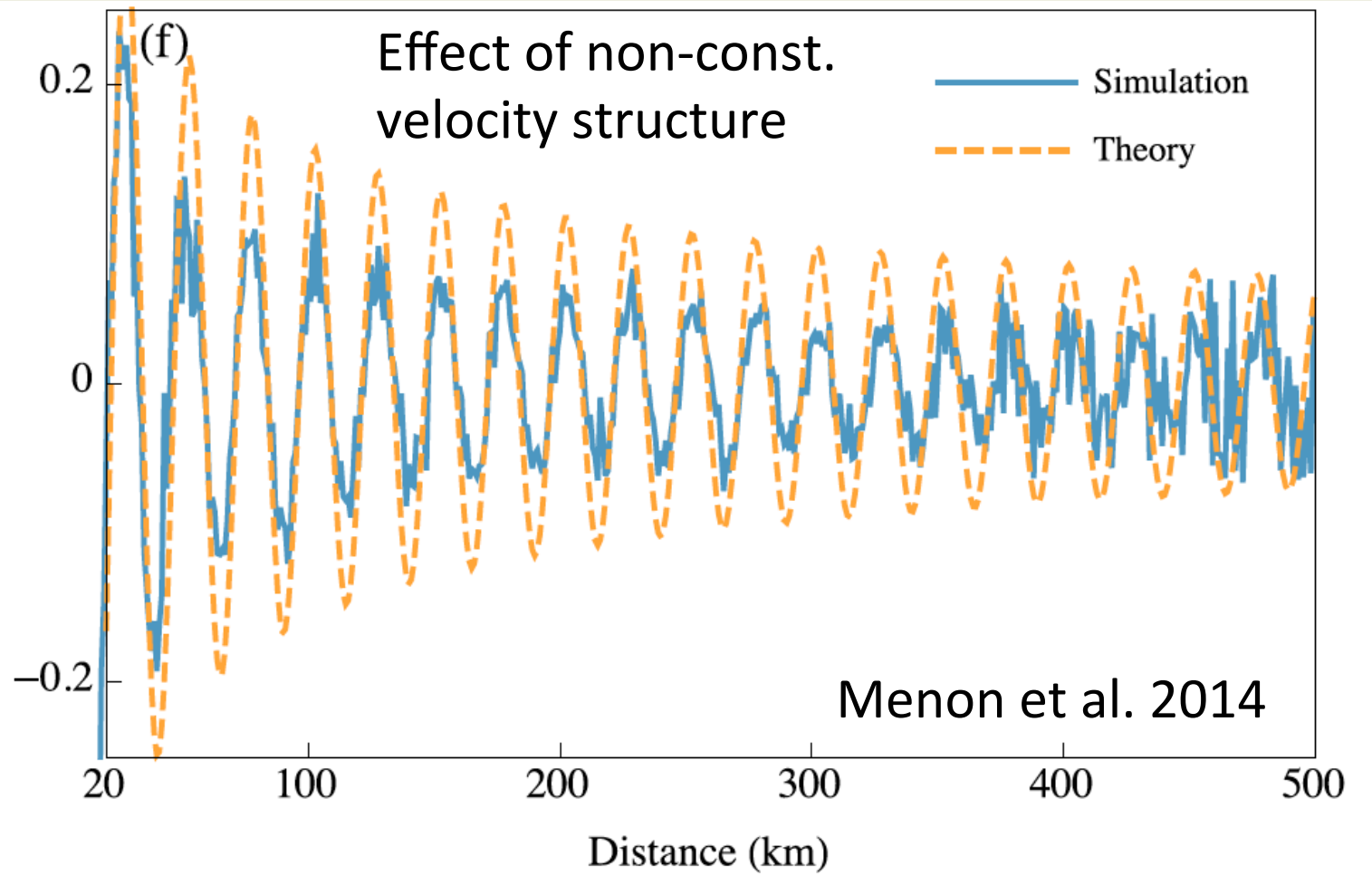
H/V





Amplitudes

- Better theory for correlations
- High density arrays



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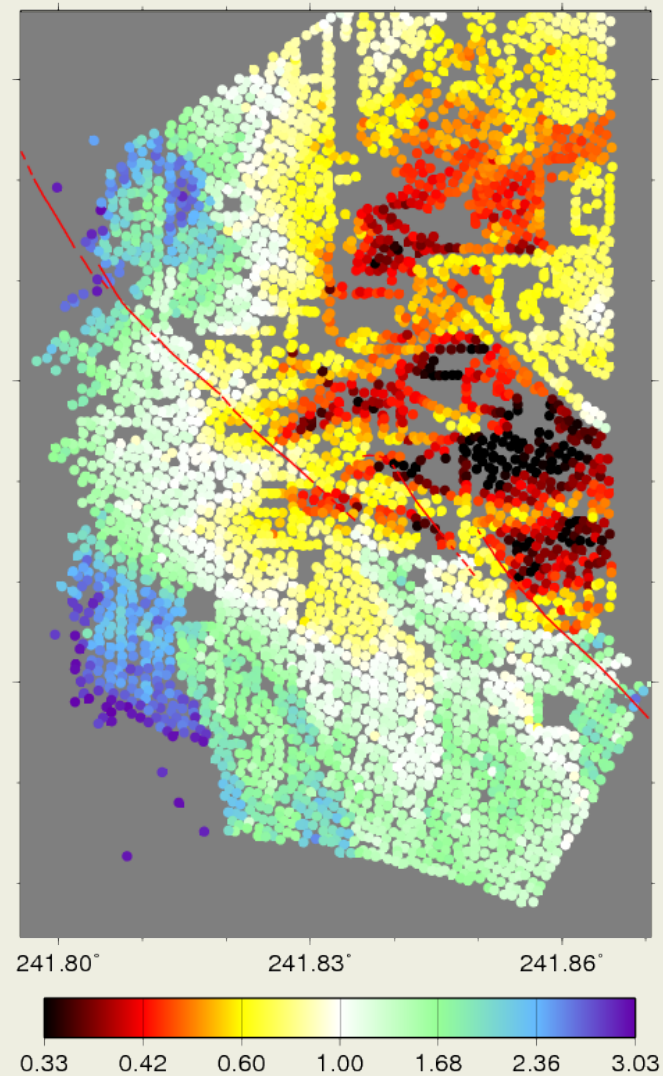
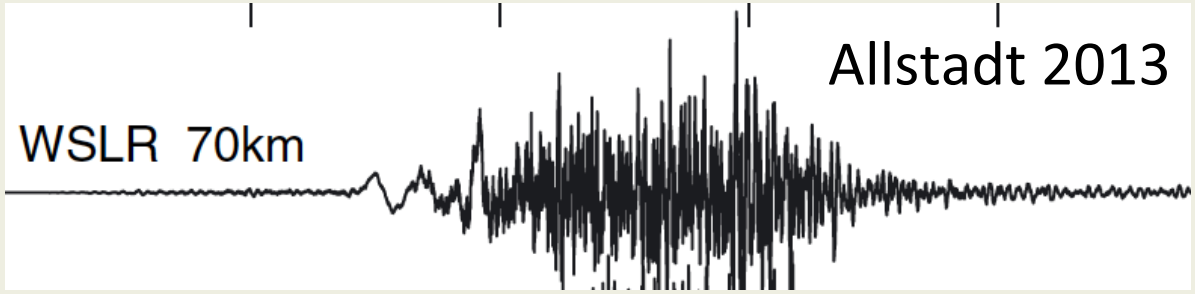
  - from Daniel Bowden (in prep.)

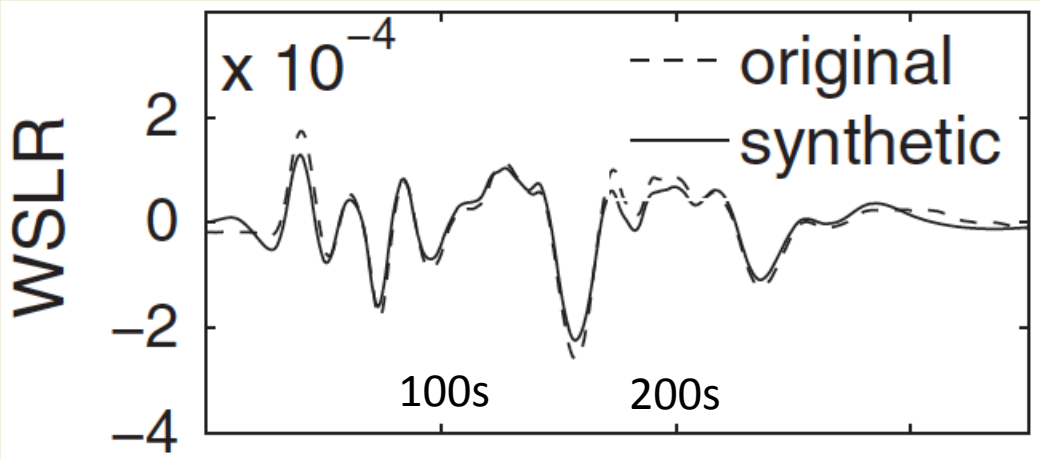
Amplification 2Hz



Imaging Physical Processes

- Landslides
- Debris Flows
- Rivers
  - Sediment transport
  - Turbulent stress
- Hurricanes
- Sea Ice





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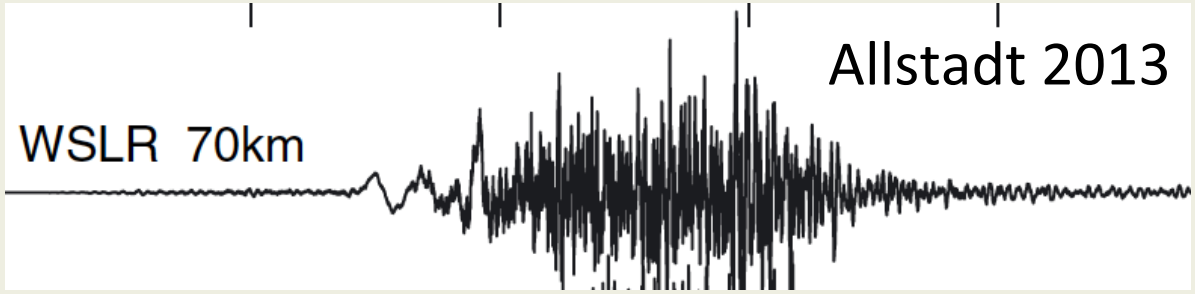

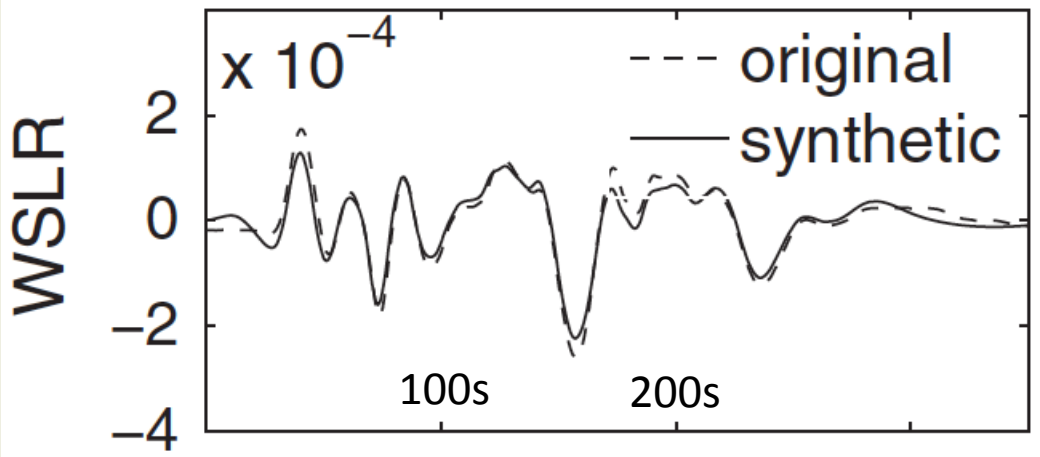

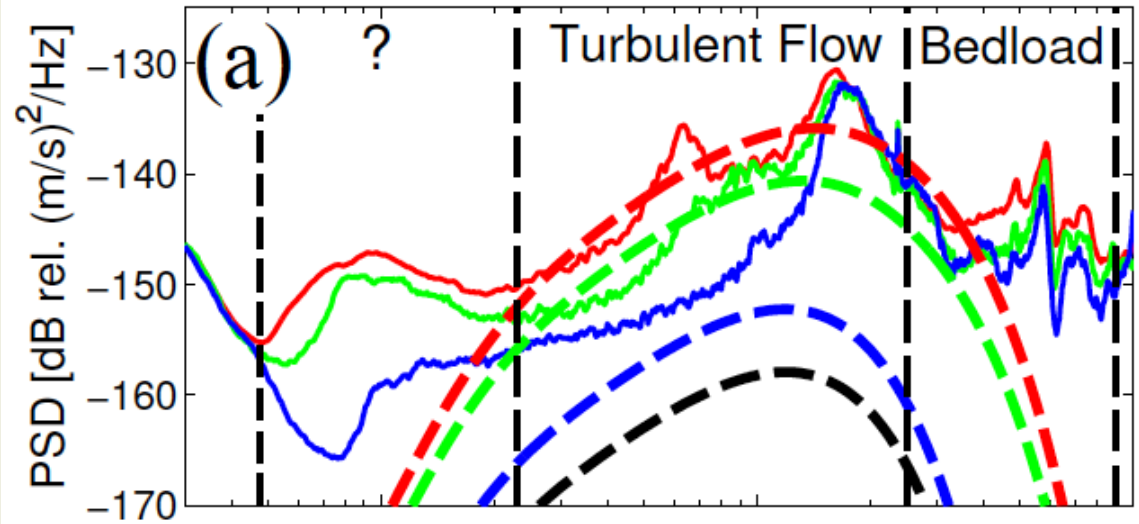

Gimbert, Tsai, Lamb, submitted 2014

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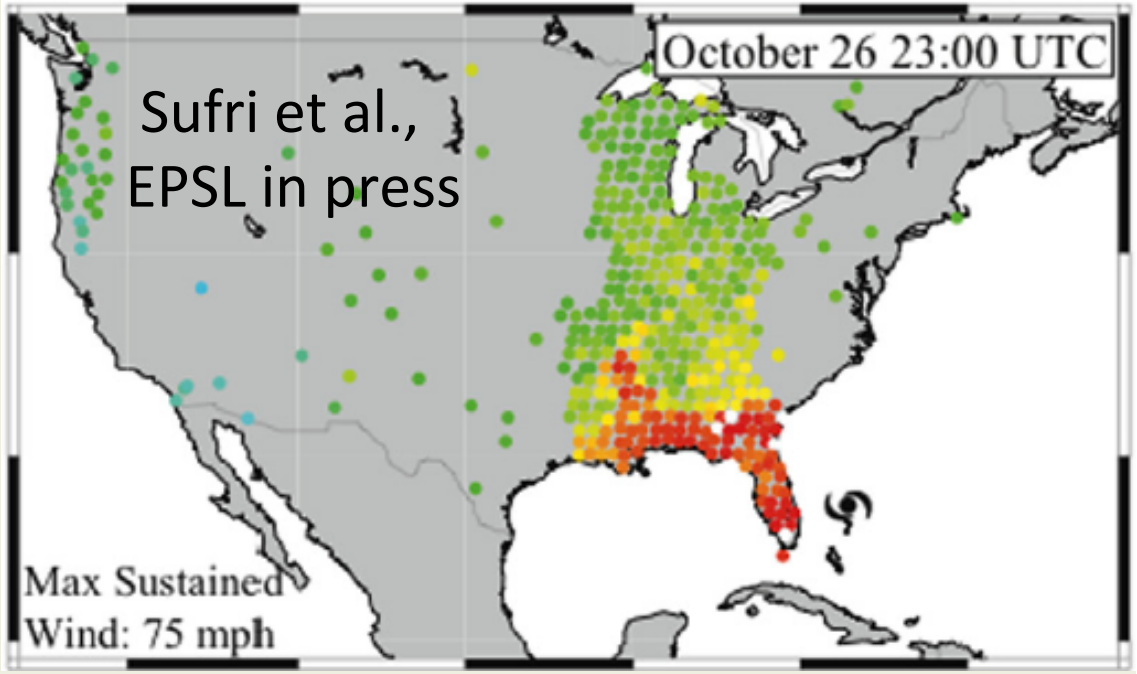

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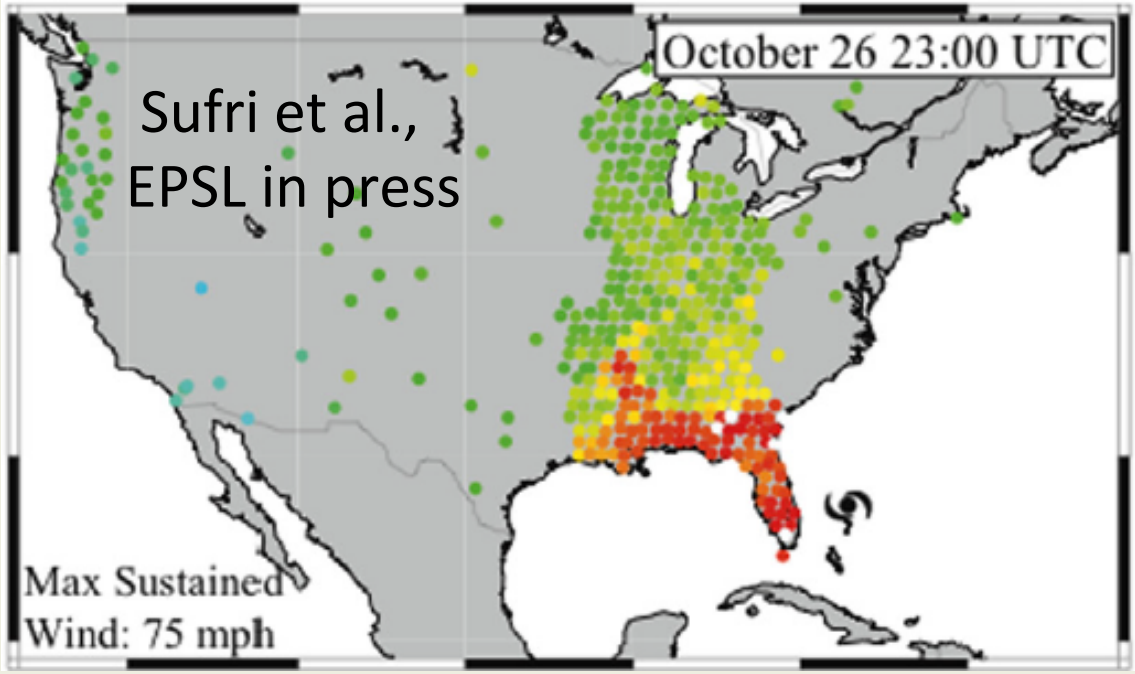
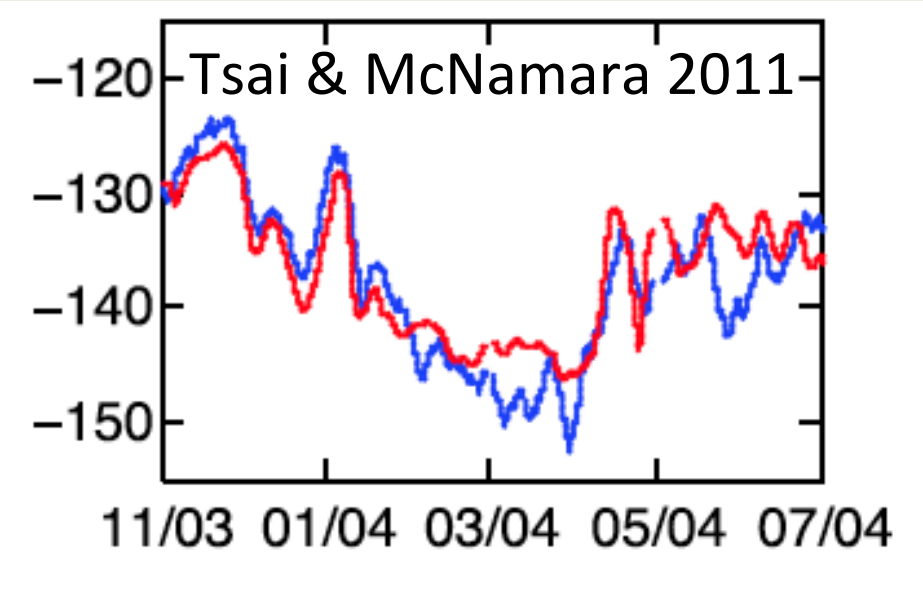


0.6-2.0s Spectral Power (dB)



Lots of new **and unexpected** results in ambient noise imaging!