Ambient Noise Surface-Wave Tomography of the San Francisco Bay Area, Northern California

Avinash Nayak[1*] and Taka'aki Taira[2+]

*anayak7@lbl.gov
+taira@berkeley.edu

1. *Earth and Environmental Science Area, Lawrence Berkeley National Laboratory, Berkeley, CA, USA*
2. *Berkeley Seismological Laboratory, Berkeley, CA, USA*

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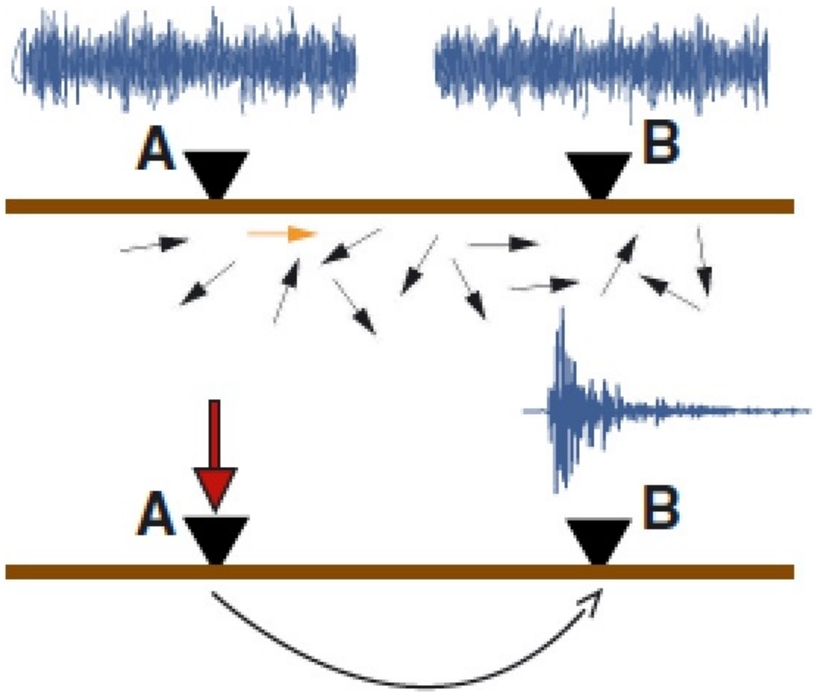
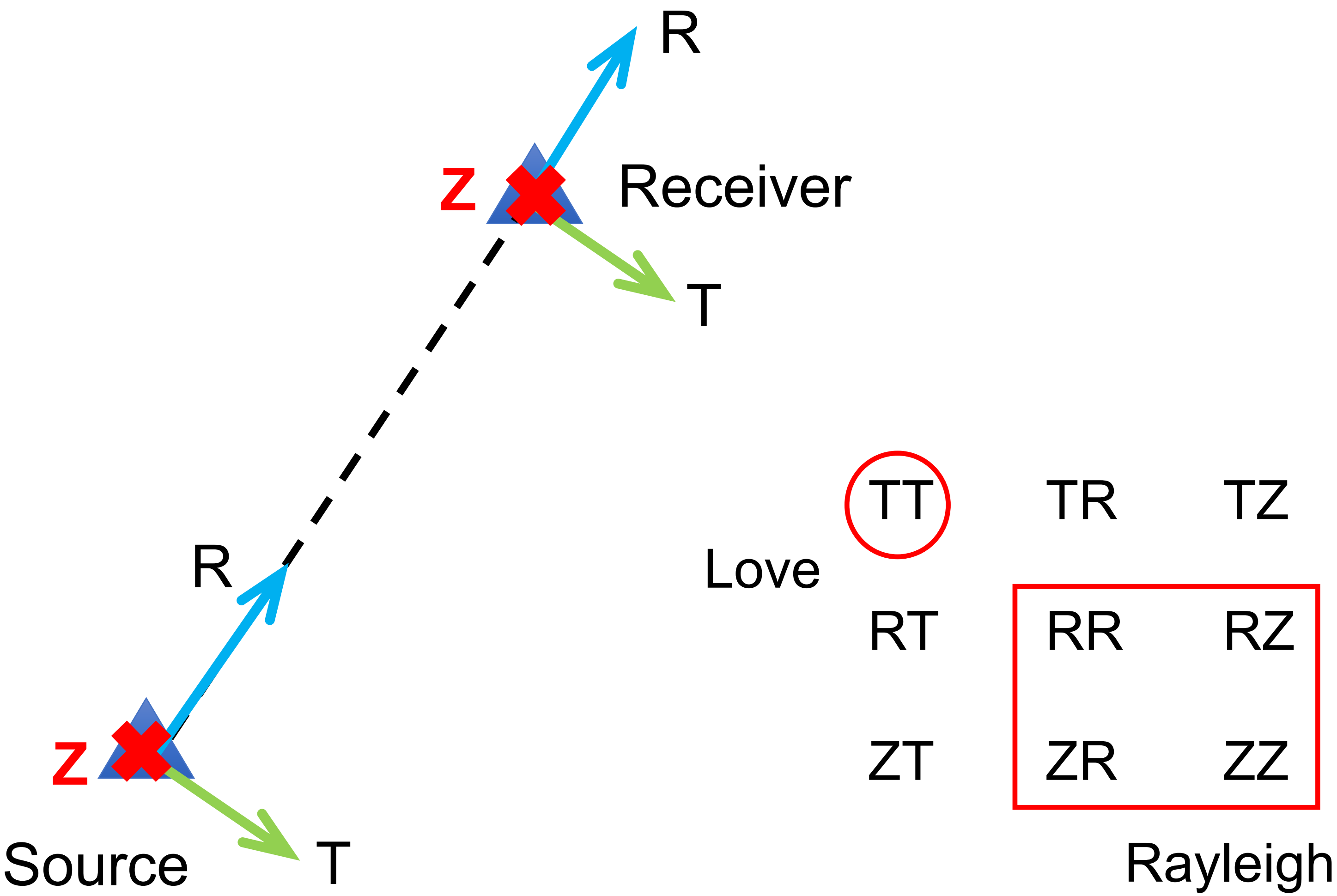
Surface-wave tomography with multicomponent seismic noise cross-correlations

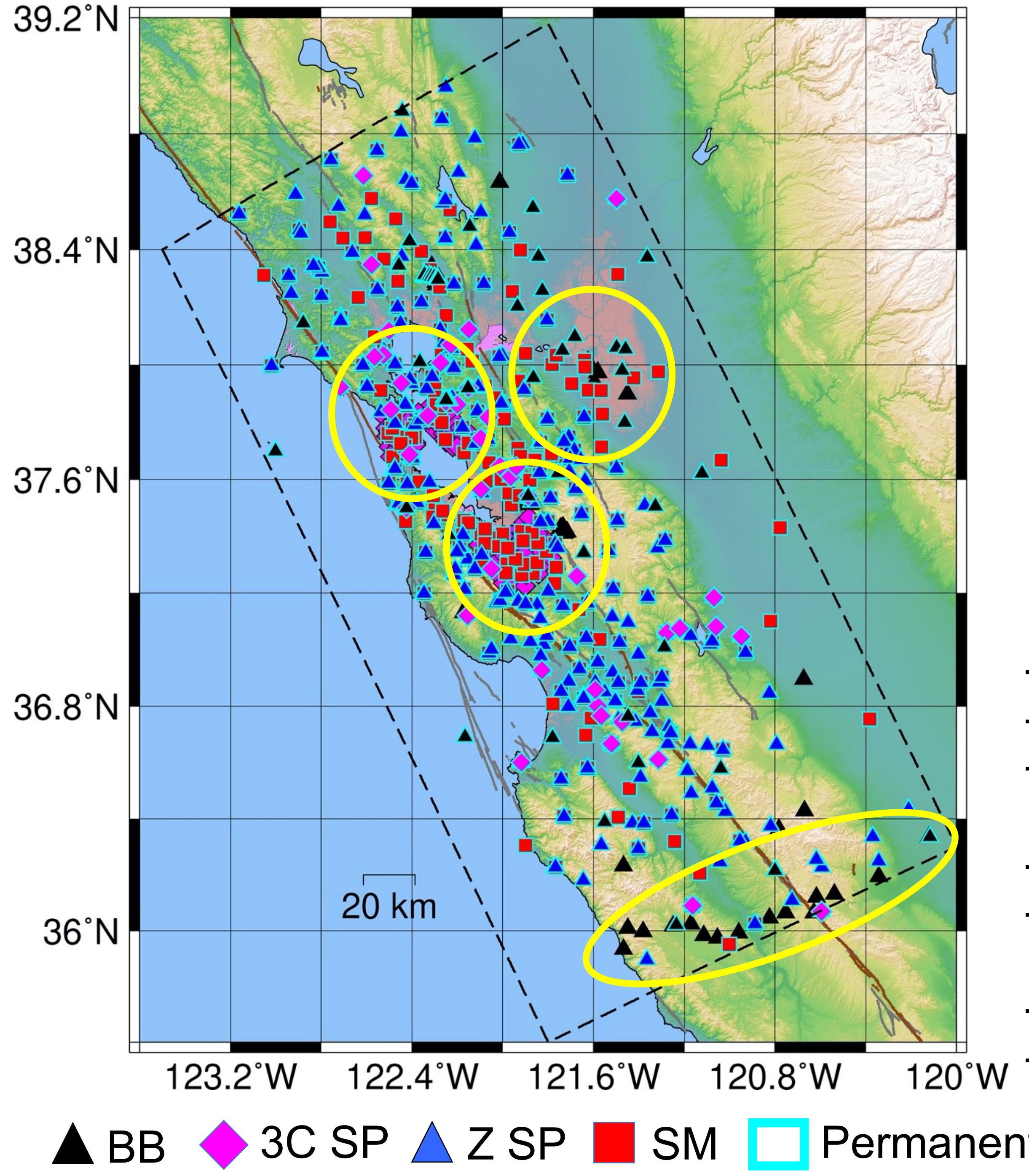
Cross-correlation of diffused wavefields (ambient noise/coda waves) recorded at 2 sensors converges to the empirical Green's Function between the receivers.

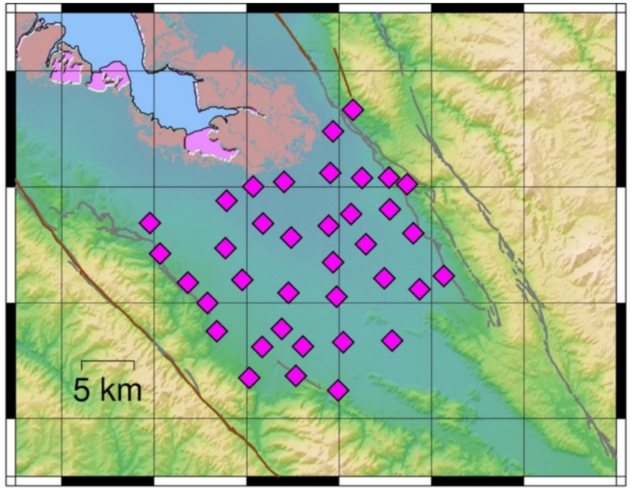


Denolle et al. (2013)

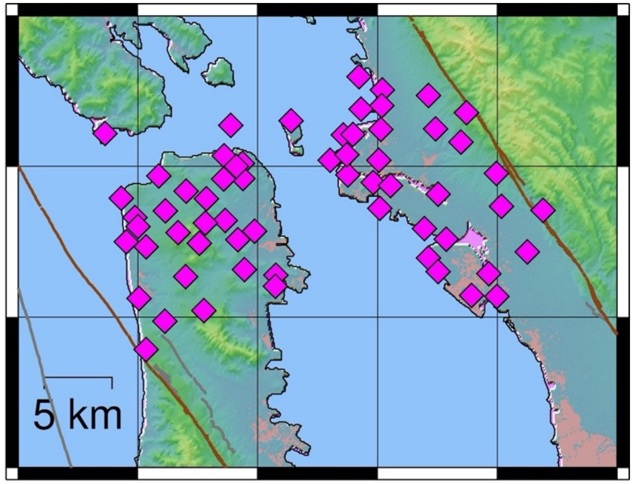


Data





Santa Clara Valley Fill Structure Array (1998)



Oak-SFO Array (2000)

- 2007- Sacramento Delta Array (Fletcher & Erdem 2017)
- 2006-07 TA stations
- 2011-12 Few USGS BB stations at Poverty Ridge and Mission peak (Hartzell et al. 2014, 2017)
- 2014 Napa aftershock deployment
- 2014-15 Central California Seismic Experiment (Jiang et al. 2018)
- Accelerometers
- New permanent BB + SP stations

Surface-wave tomography workflow

Rayleigh and Love waves from cross-correlations

AFTAN (Bensen et al. 2007) analysis to get group velocity dispersion measurements ~5-16 s

Invert group velocity measurements for 2D group velocity maps ~10 km spacing

Invert group velocity dispersion at each XY point to get V_S(depth)
Herrmann (2013)

Combine V_S-depth at all XY points to get 3D Vs model

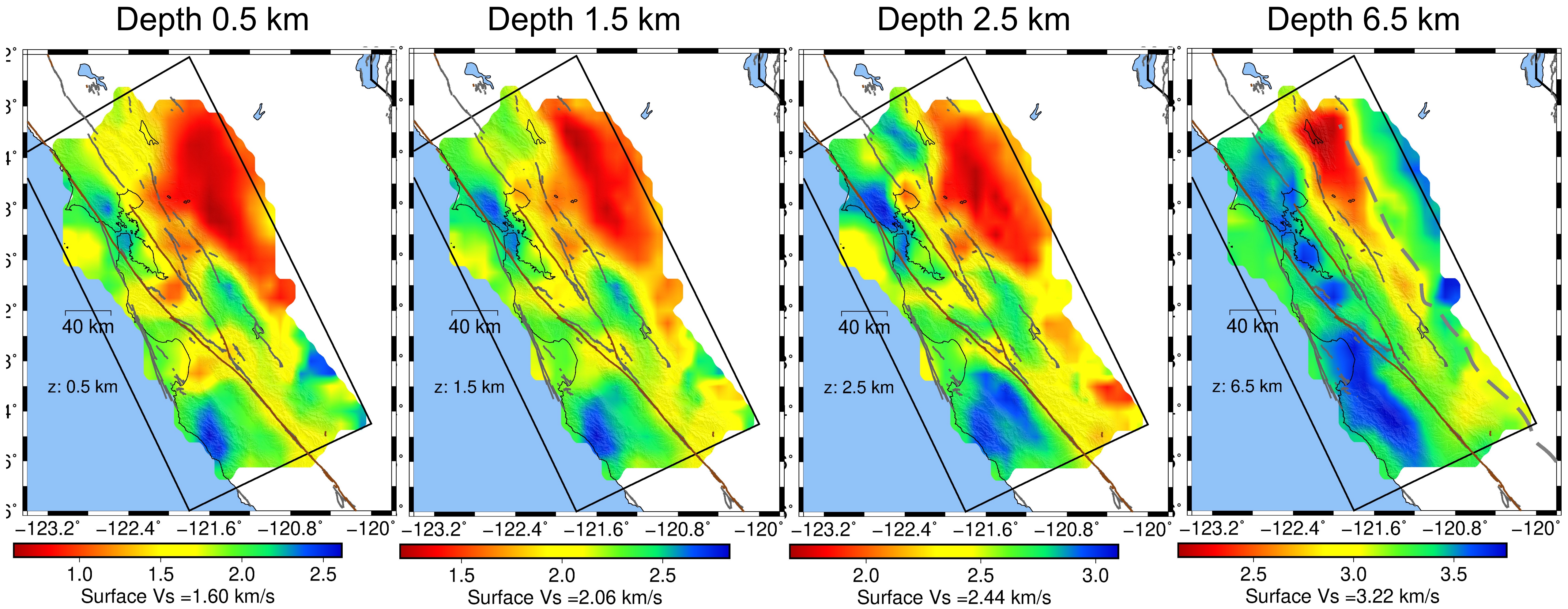
Use 3D Vs model to get reference phase velocity dispersion measurements ~3-16 s

Invert phase velocity measurements for 2D phase velocity maps at ~10 km spacing
2D Fast marching method
Rawlinson & Sambridge (2000)
Damping/smoothing

Invert phase velocity dispersion at each XY point to get V_S(depth)
Herrmann (2013)

Combine V_S-depth at all XY points to get 3D Vs model (~10 km spacing, ~20 layers, min thickness ~ 1 km)

This study



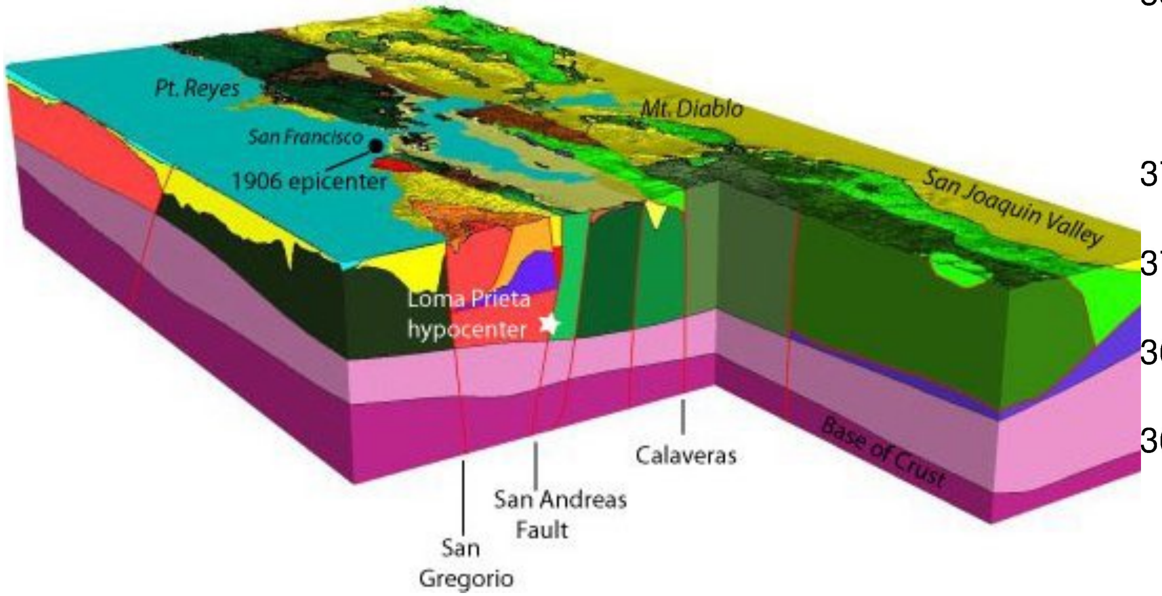
Sedimentary basins

Velocity contrast across faults

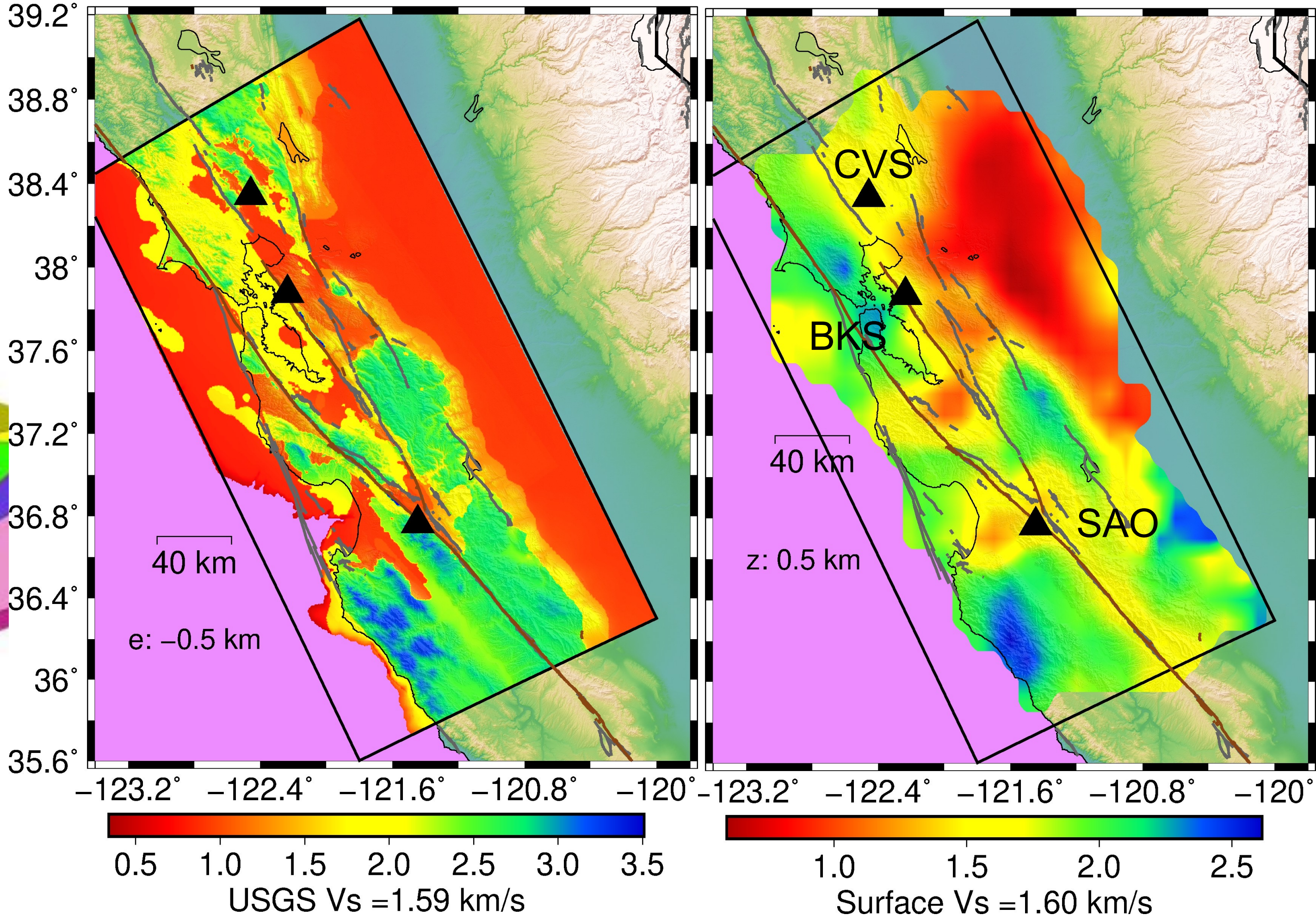
Crystalline basement contour from Wentworth et al. (1995)

Comparison of synthetic waveforms and empirical fundamental mode surface-wave Green's functions derived from ambient noise

USGS Bay Area Model 8.3.0
Geologic/seismic model



Jachens et al. (2006), Brocher (2005, 2008), Aagaard et al. (2008, 2010); updated following Rodgers et al. (2008), Thurber et al. (2009), Kim et al. (2010)



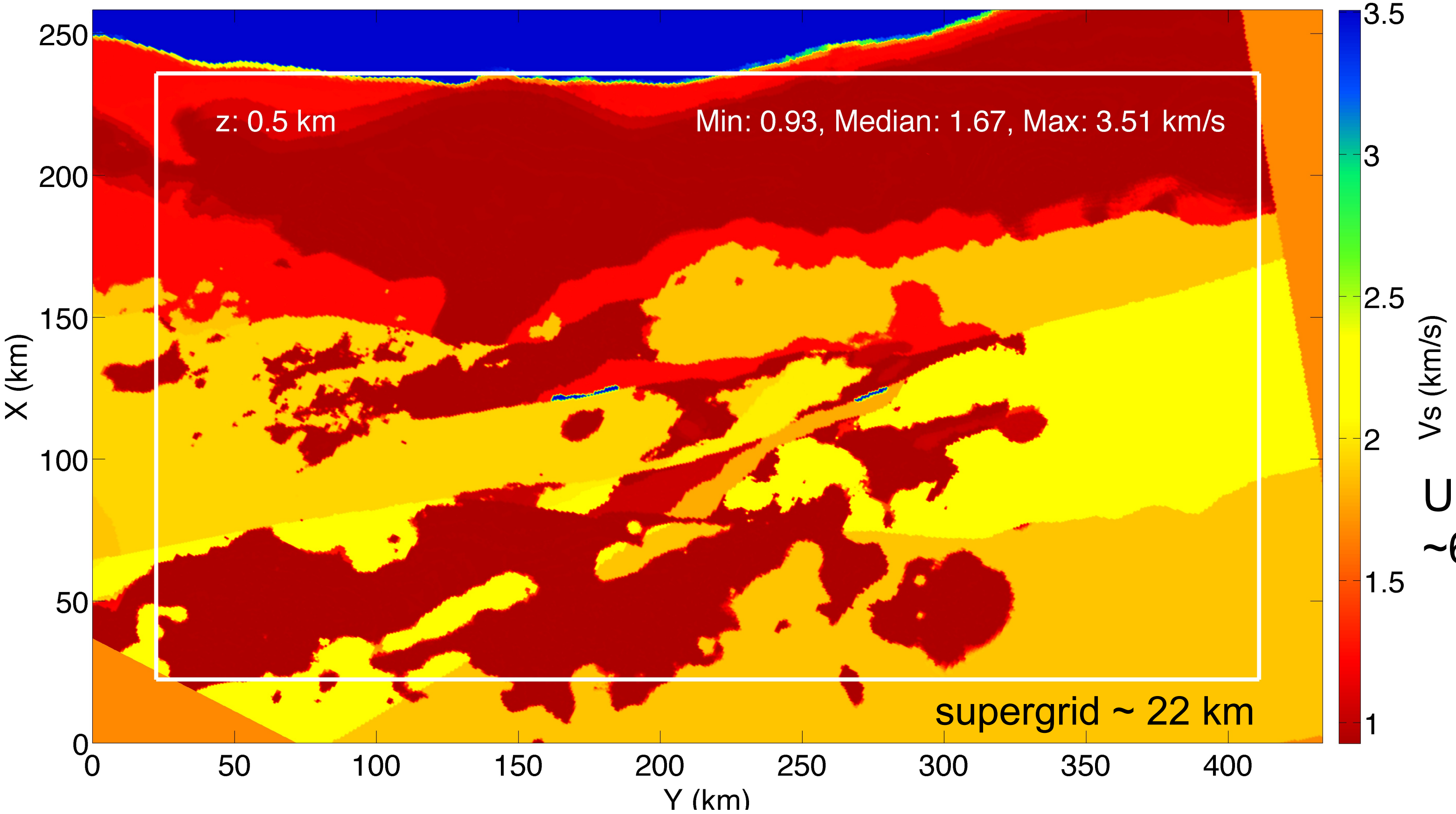
Topography pushed down,
Minimum Vs~0.5 km/s imposed
Model queried at dx~800 m

Comparison of synthetic waveforms and empirical fundamental mode surface-wave Green's functions derived from ambient noise

- Synthetics for the 2 3D models calculated using SW4 (Sjogreen & Petersson 2012; Petersson and Sjogreen, 2017); grid spacing ~87 m at surface to ~700 m at depth; ~6.8 grid points per minimum wavelength at ~1.2 s

- Synthetics for a local 1D model (GIL7, Stidham et al. 1999) calculated using FK integration (Herrmann 2013)

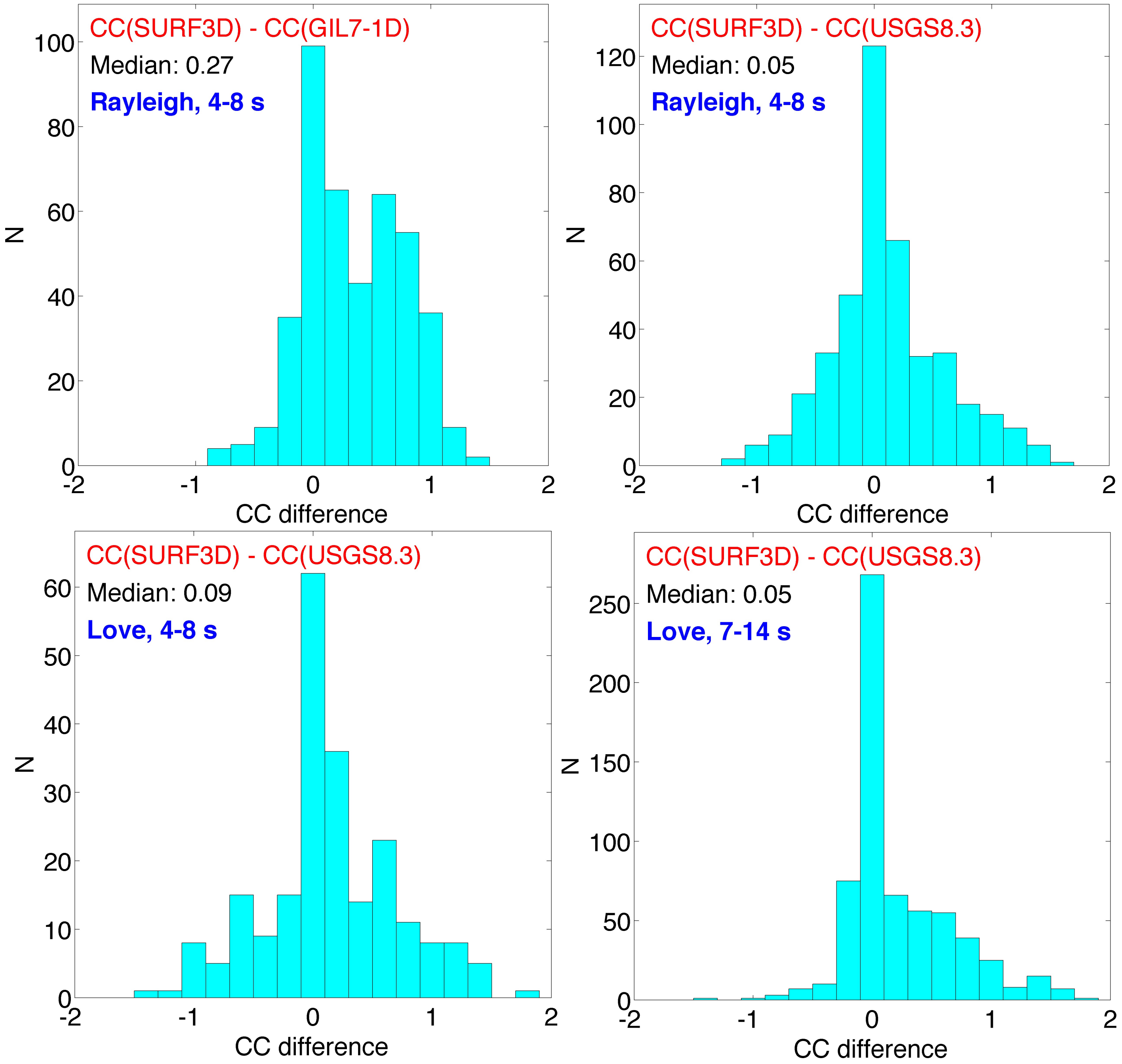
- Waveforms in 2 passbands for comparison: ~4-8 s and ~7-14 s; calculate zero-lag correlation between obs and syn waveforms; select station pairs for which CC exceeds ~0.6 for any one model.



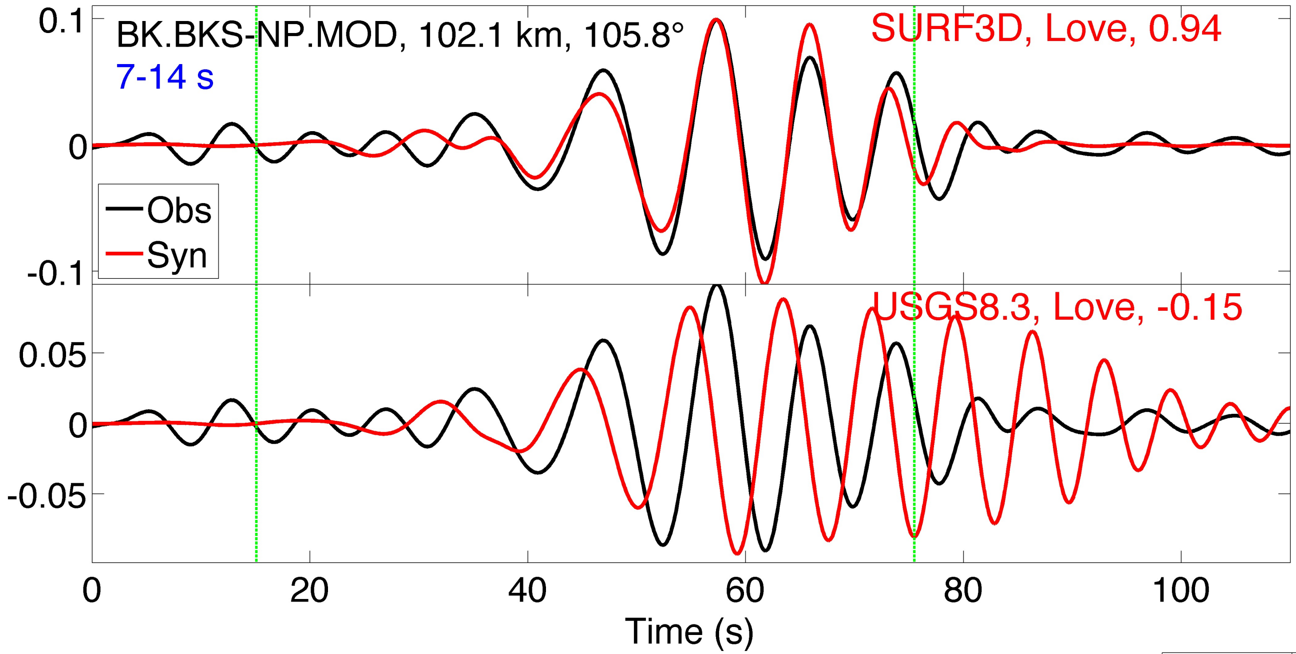
USGS model
~60 million grid pts

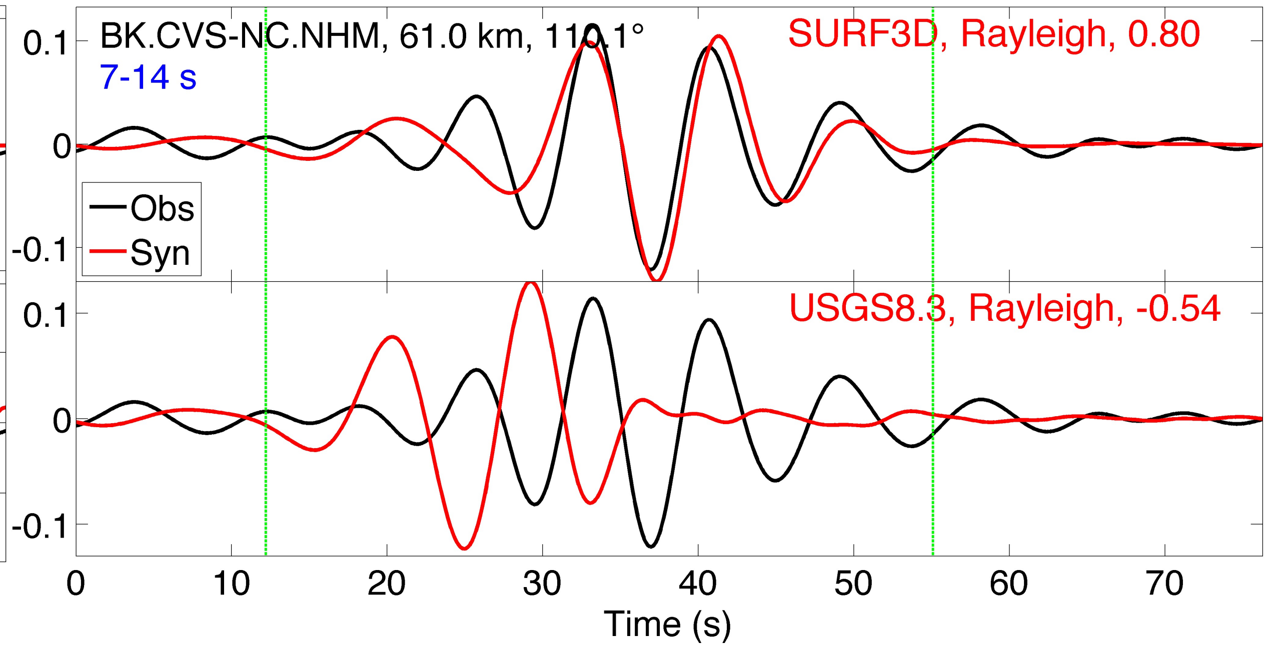
Comparison of synthetic waveforms and empirical fundamental mode surface-wave Green's functions derived from ambient noise

Our surface-wave model fits similar or slightly better than USGS model; largest difference for long-period Love waves

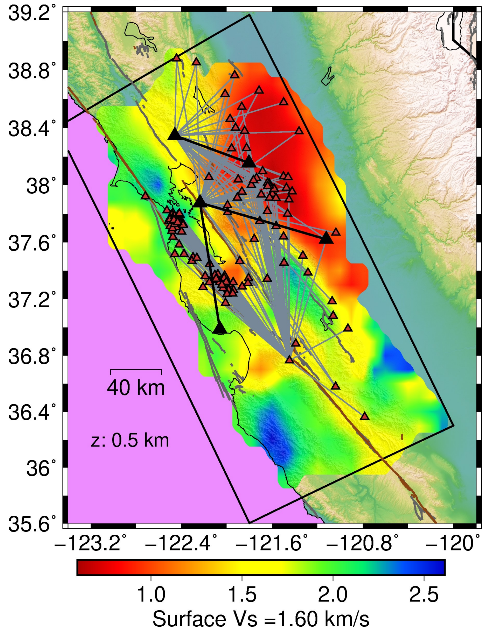


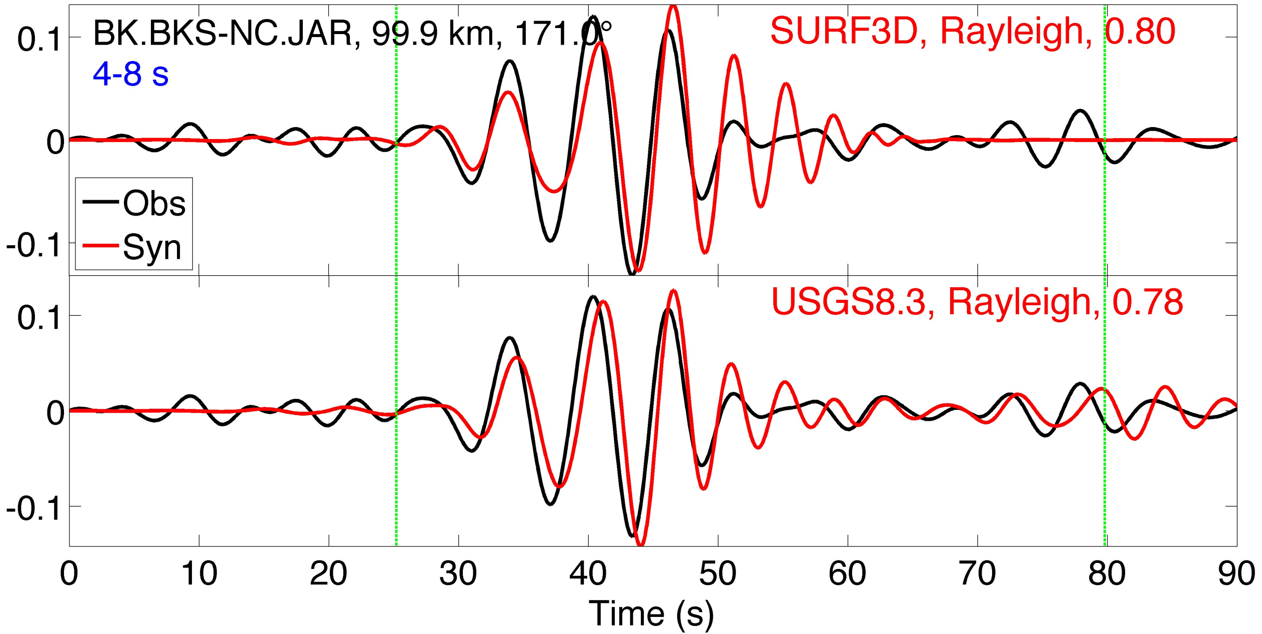
Comparison of synthetic waveforms and empirical fundamental mode surface-wave Green's functions derived from ambient noise





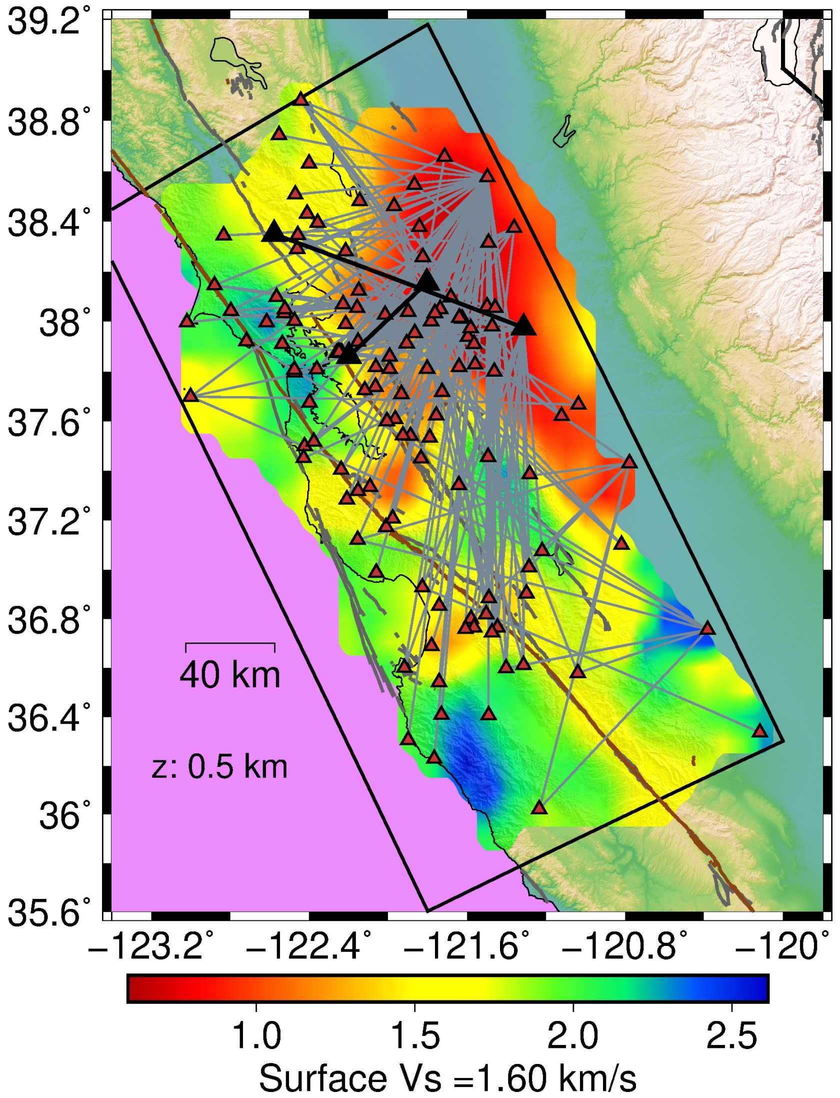
The paths with the largest differences are over sedimentary basins, particularly the Sacramento-San Joaquin delta





Identified paths with prograde elliptical particle motion in the radial-vertical components: 1st higher mode Rayleigh wave (~200 pairs)

Work in progress: direct and joint inversion of fundamental mode and first higher mode Rayleigh wave phase arrival times



Future Work/Possibilities/Limitations/Issues

- Surface-wave tomography at these periods using ambient noise only accounts for long-wavelength structure. How to incorporate long-wavelength structures from the inverted model into the current USGS model ? Alternatively, if the USGS model is used as an initial model in the inversion, how to best preserve short-wavelength structure in the inversion ?

- Surface-wave tomography software used in this study does not account for topography.

- Once we have the final model, we will compare synthetic waveforms and noise cross-correlations for more paths for the two models.

- Incorporate body-wave travel times from earthquakes and active source experiments in a joint inversion.

- Incorporate Rayleigh wave ellipticity and teleseismic receiver functions in the joint inversion for shallower and deeper structure respectively

- Compare earthquake waveforms and synthetics for the two models – need a set of reference earthquakes with reference locations and moment tensors (from Rodgers et al., Kim et al., recent events)