Comparison of 3D and 1D Wave Propagation Effects in the San Francisco Bay Area on Simulated Long Period Ground Motion From the 1989 Loma Prieta Earthquake

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San Francisco Bay Area Seismic Velocity Models for Seismic Hazard Assessment
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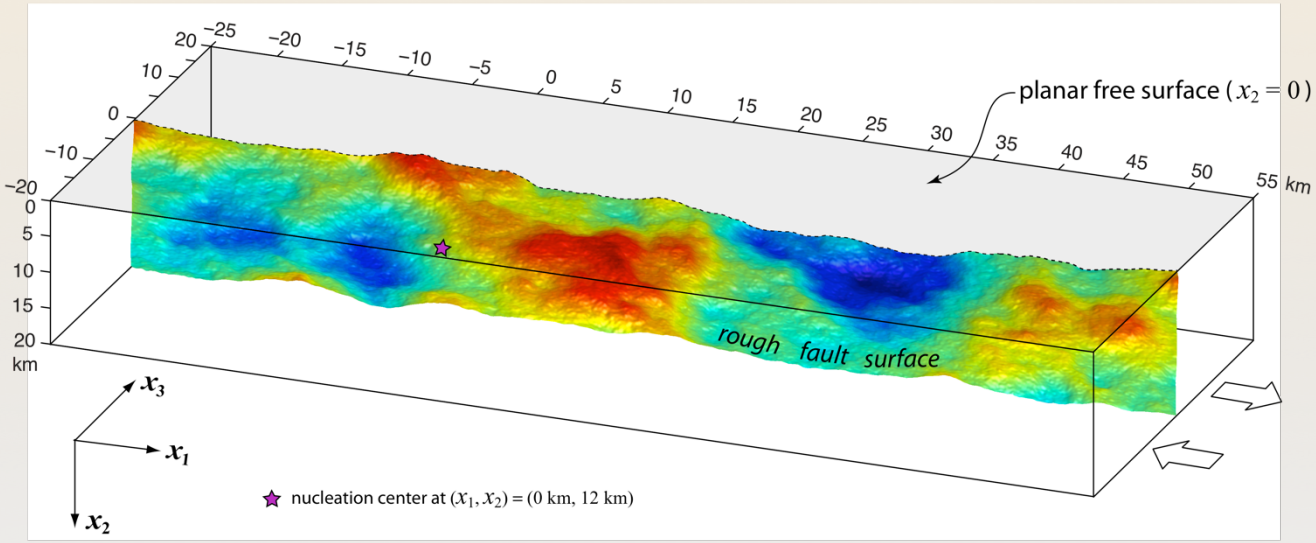
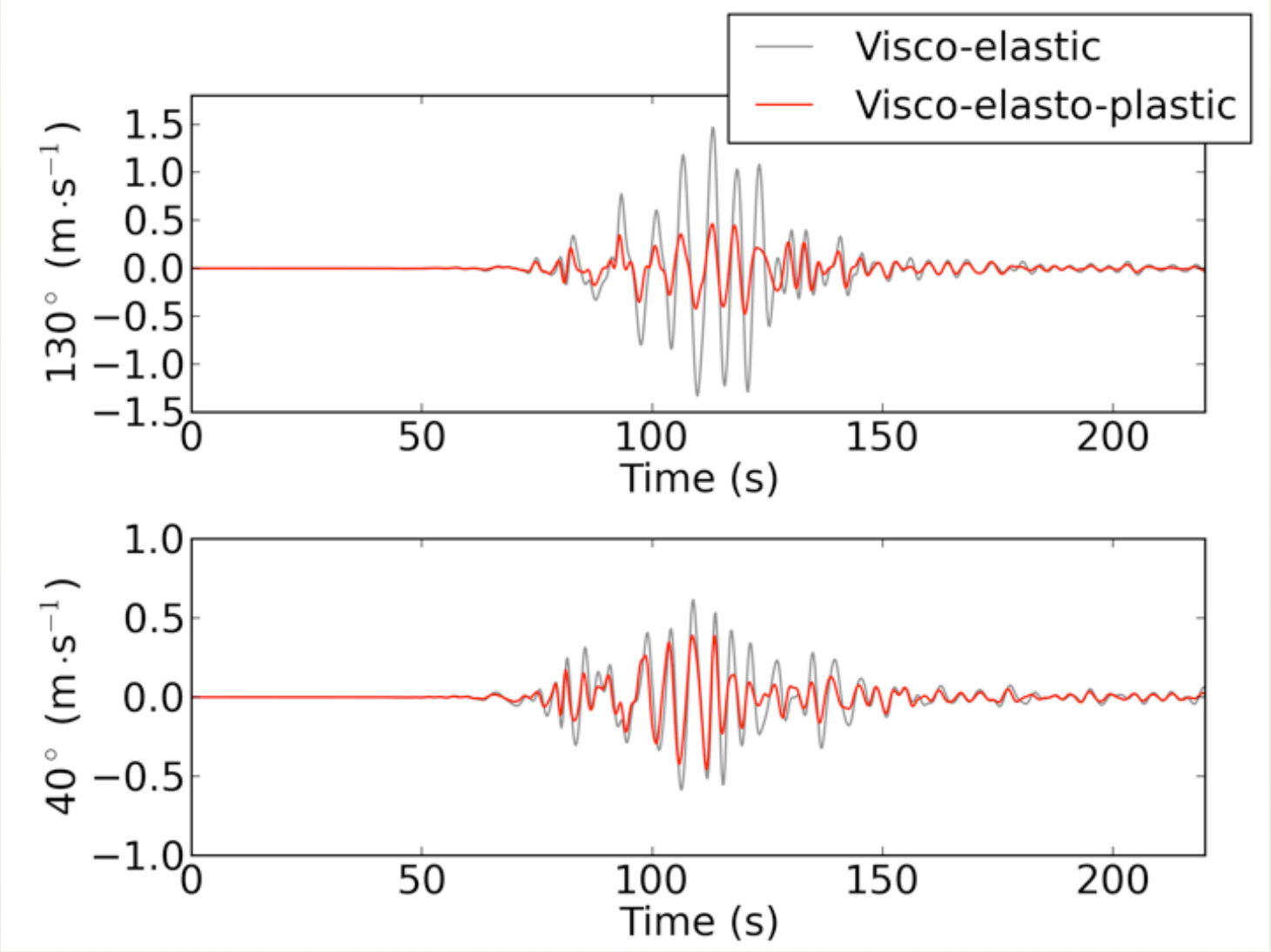
1. Geometrical Fault Complexities

- Multi-segment faults
- Faults with complex geometry (Rodgers et al. 2019)
- Faults with rough surface (Graves and Pitarka,2015; Shi and Day,2013; Trugman and Dunham, 2014)

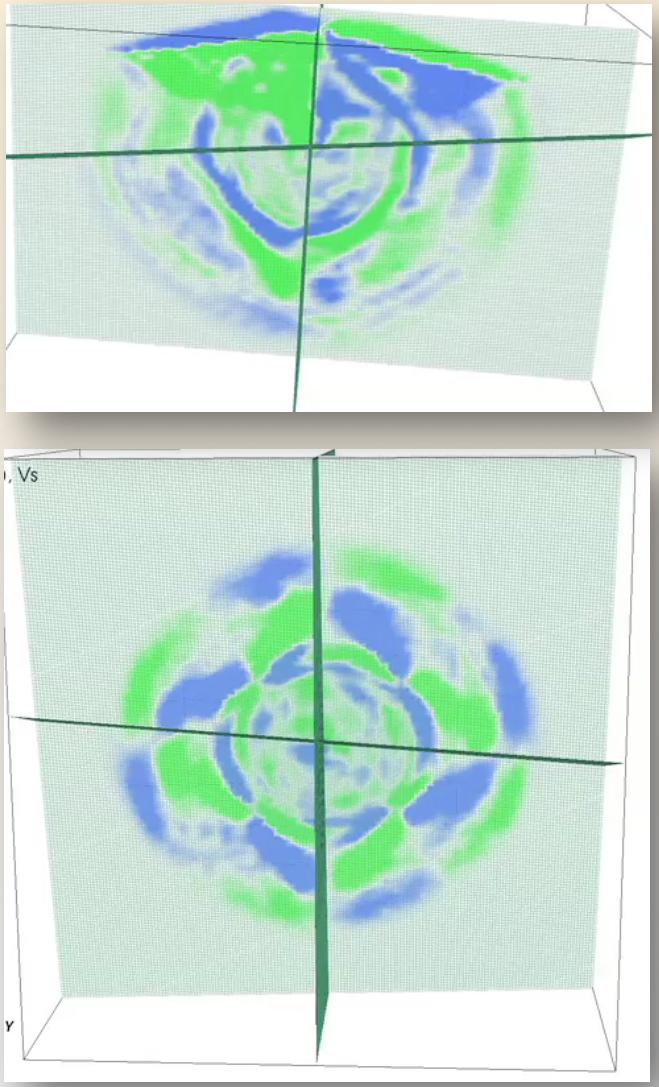


2. Off-Fault Plasticity Effects



(Roten et al., 2013)

3. Joint Motion in Fractured Media

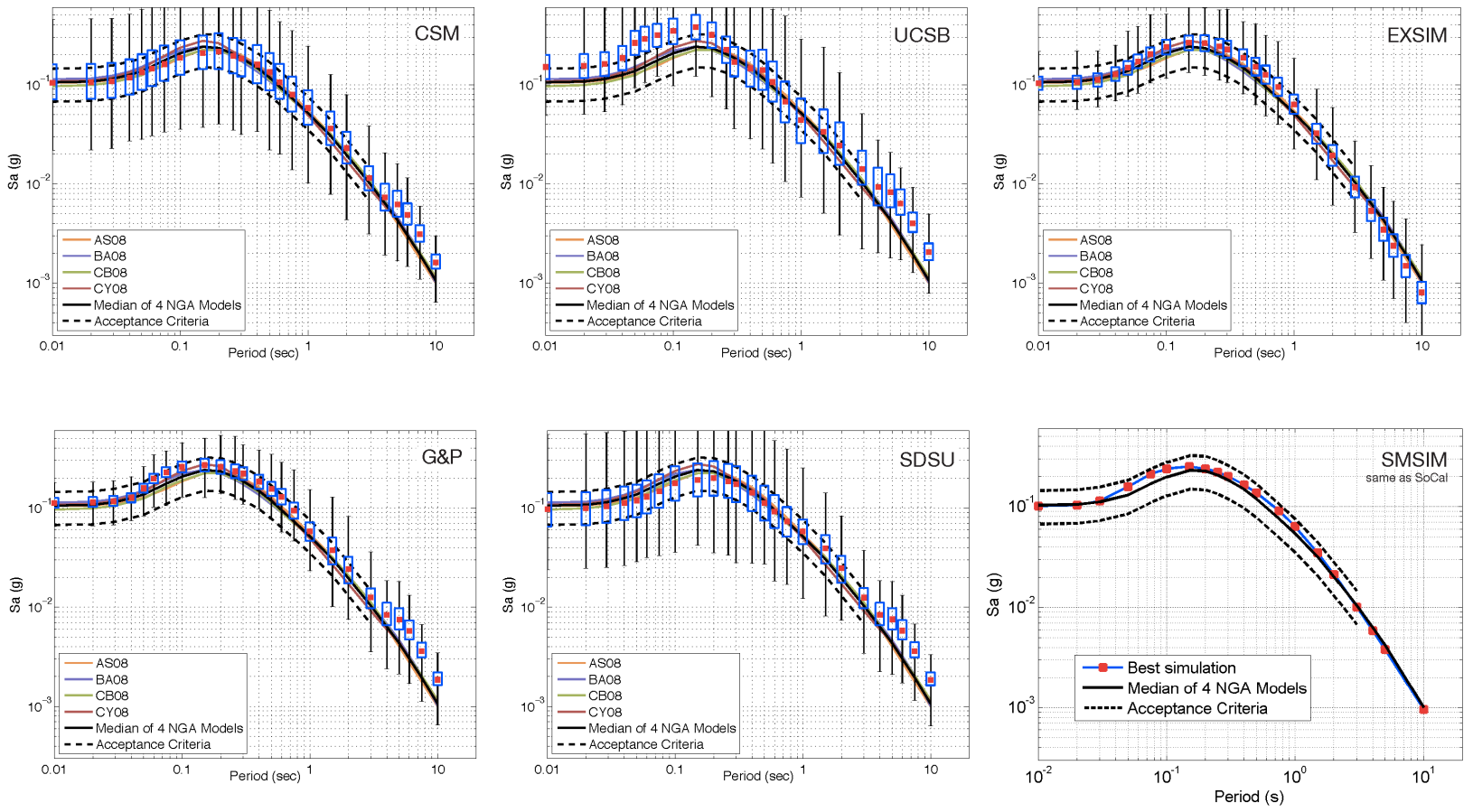


Modeling of joints motion in fractured rock indicates alteration of local source radiation pattern

4. Wave Propagation Effects

- 3D/1D models

SCEC BBP



Ground Motion Simulation for the Loma Prieta Earthquake

- Simulate ground motion from Loma Prieta earthquake in the Bay Area in the long **period range 0.6-10 s**
- Use kinematic rupture scenarios generated on the SCEC BB Platform
- Analyze performance of 1D and 3D velocity models :

  - large-scale structural complexities (3D-USGS Model)

  - small-scale velocity variations (random correlated perturb.)

  - surface topography

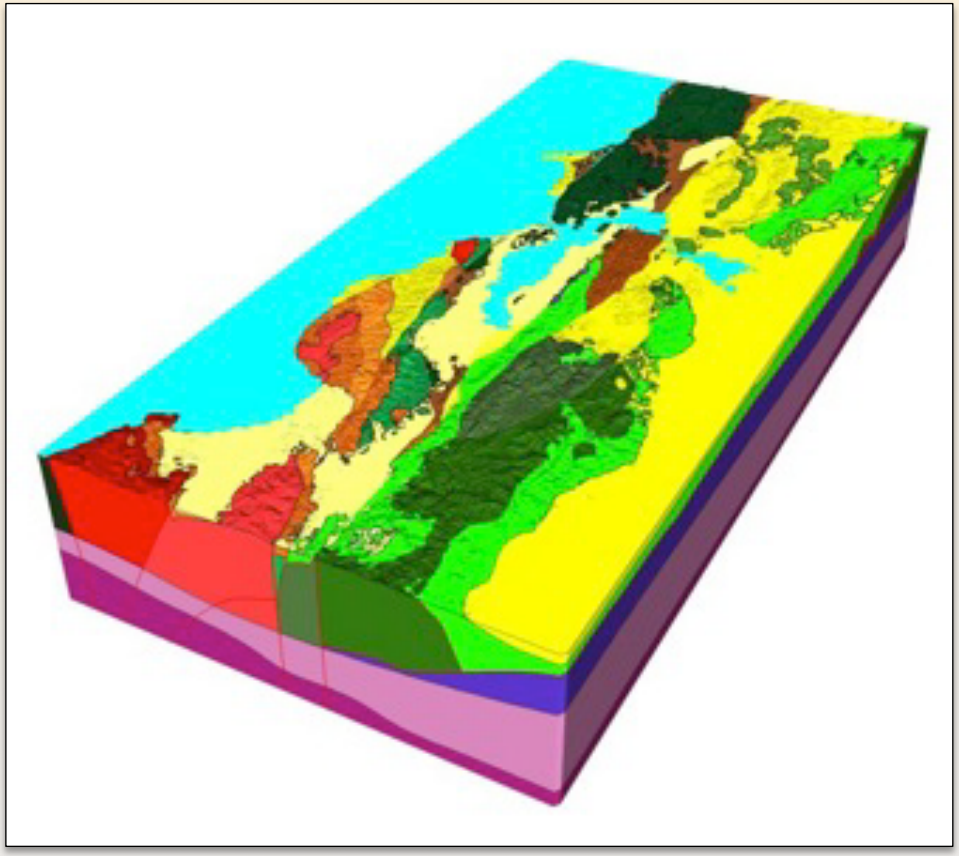
Computer Program:

SW4-3DFDM (Sjogreen and Petersson, 2009)

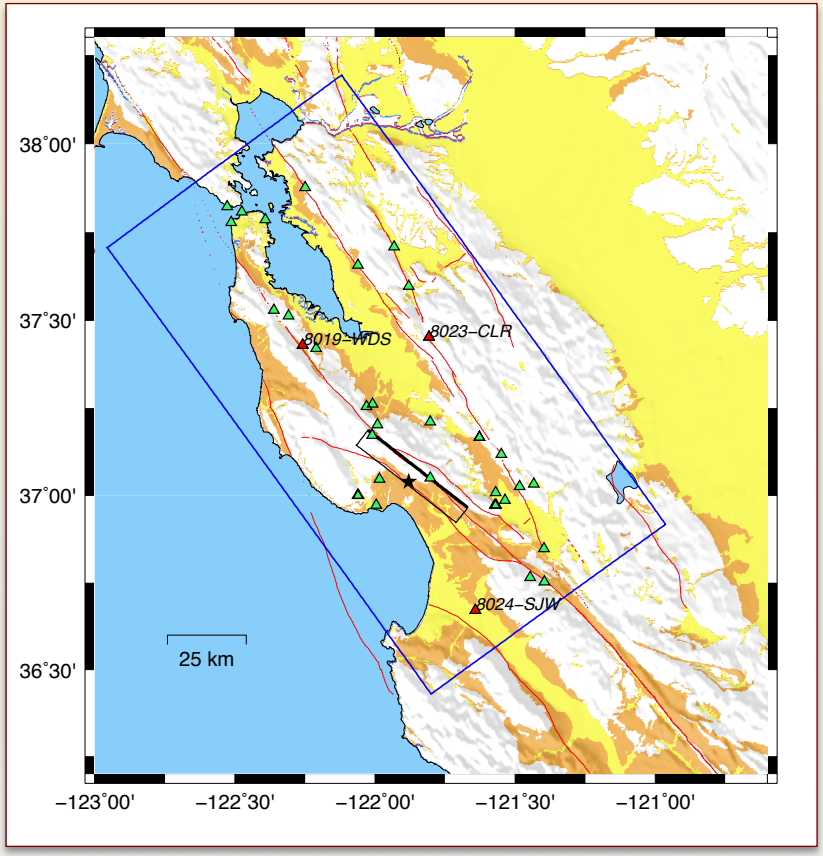
40m grid spacing, 3000 cores, $\mathbf{f_{max}=1.5hz}$

High-Performance Computing

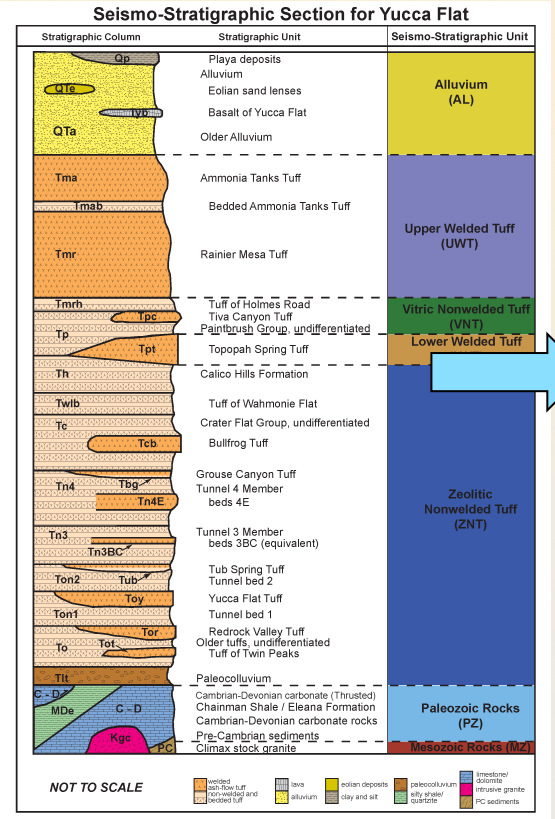
USGS 3D Velocity Model

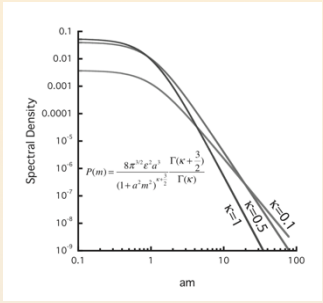


Study Area



Von Karman Distribution of Velocity Perturbations in Random Media





Recommended von Karman Parameters

L_h: 400-2000m

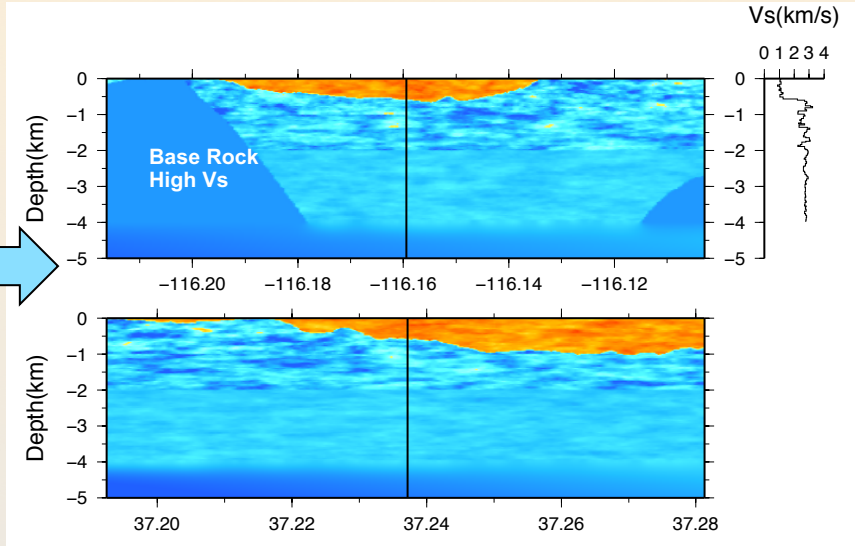
L_z: L_h/4-5

H: 0-0.7

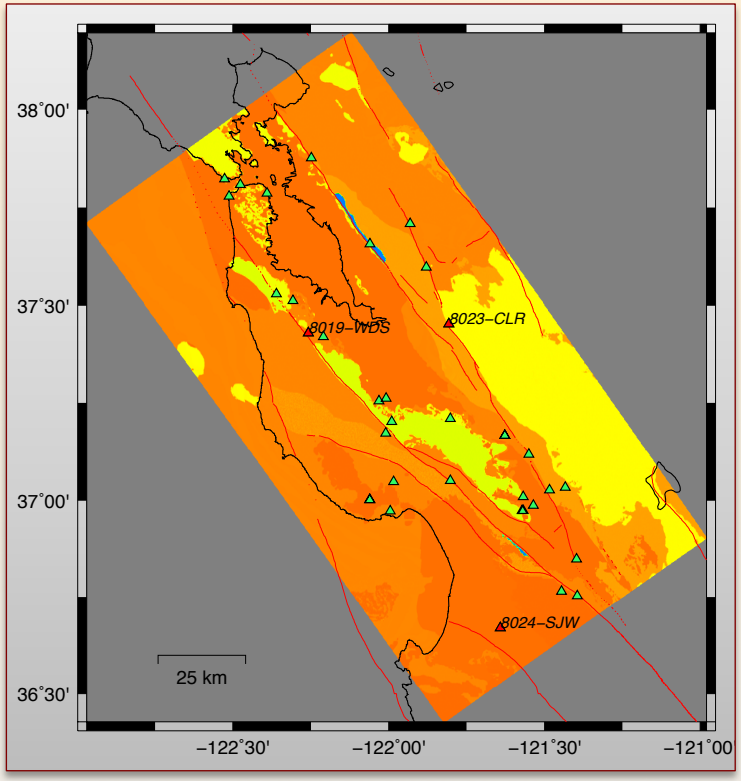
s: 5-15%

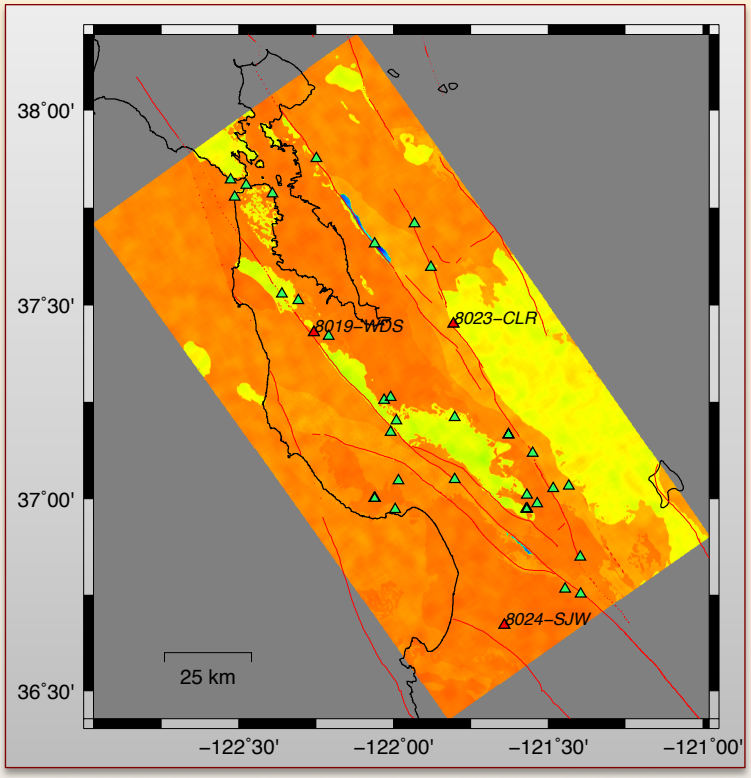
$$C_K \frac{1}{(1 + a^2 k_r^2)^{d/2+H}}.$$

Laterally Discontinuous Random Perturbations



3D USGS Velocity Model Version 8.3.0

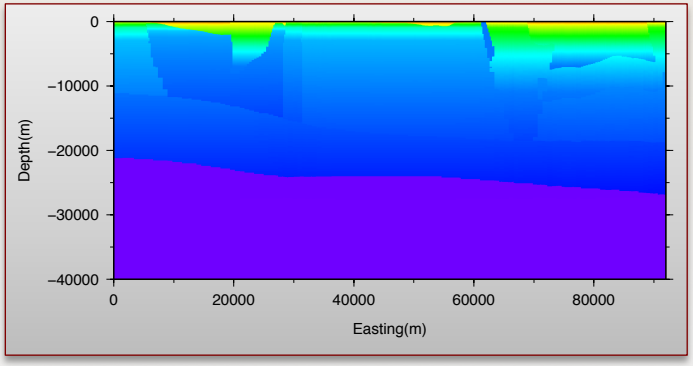




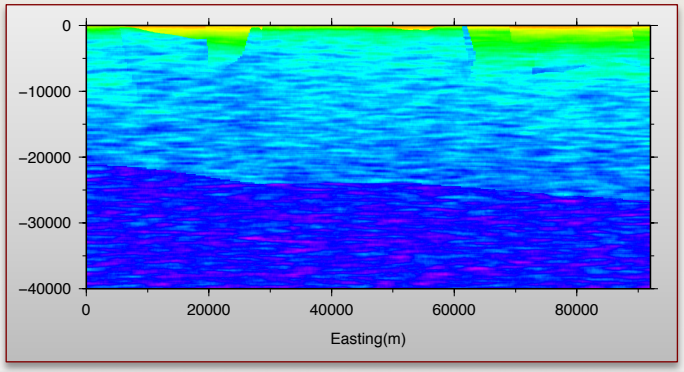
Random Velocity Perturbations

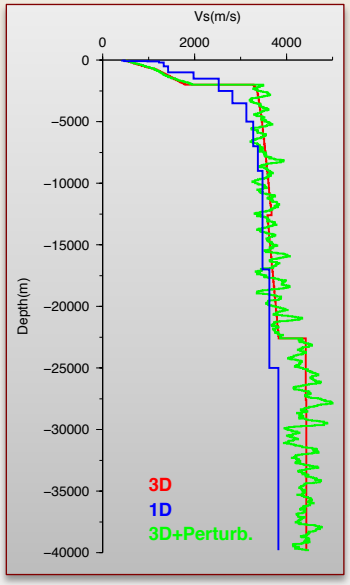
$L_{h(max)}$= 2000m
$L_{z(max)}$= 200m
MaxPerturb=20%
V_{smin}= 400m/s

SW NE



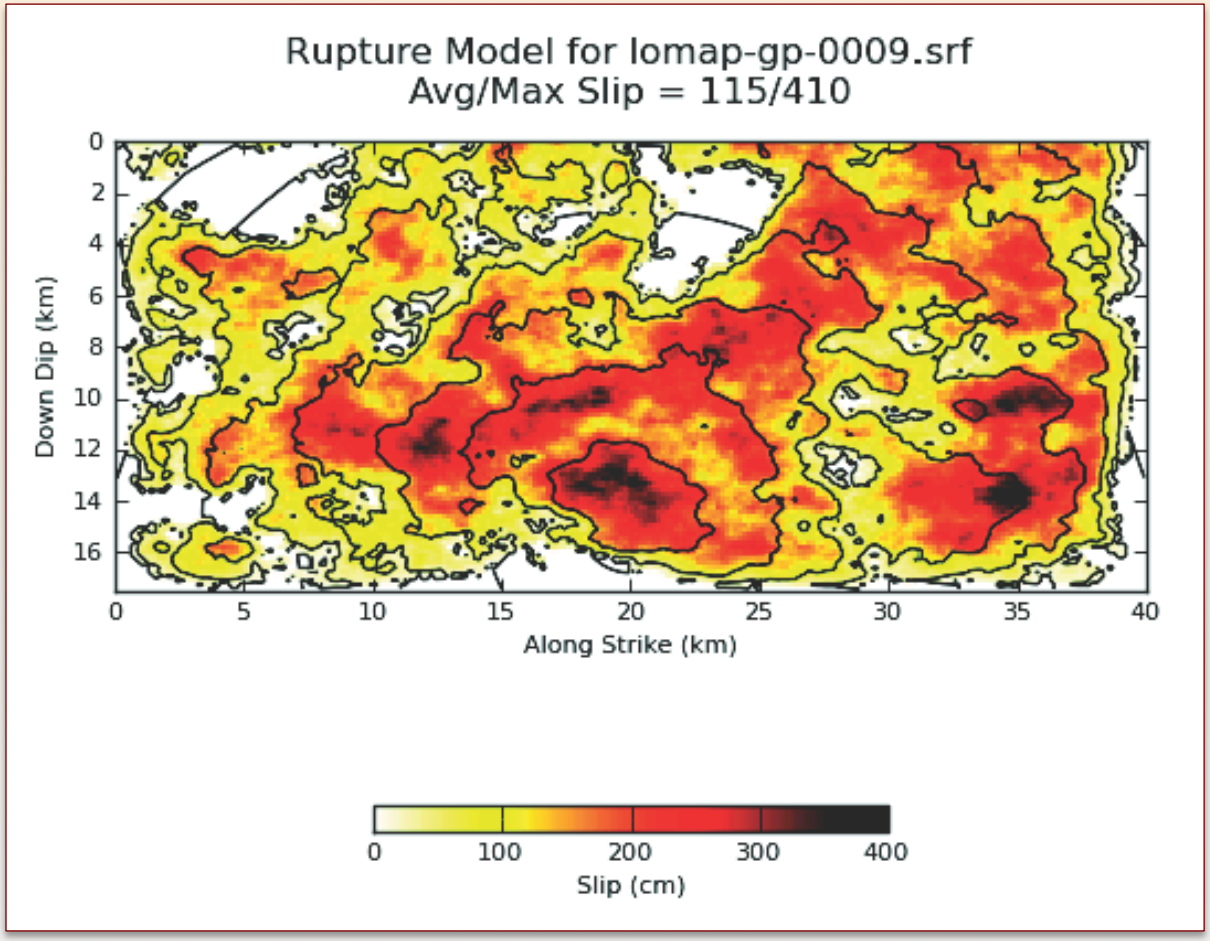
SW NE





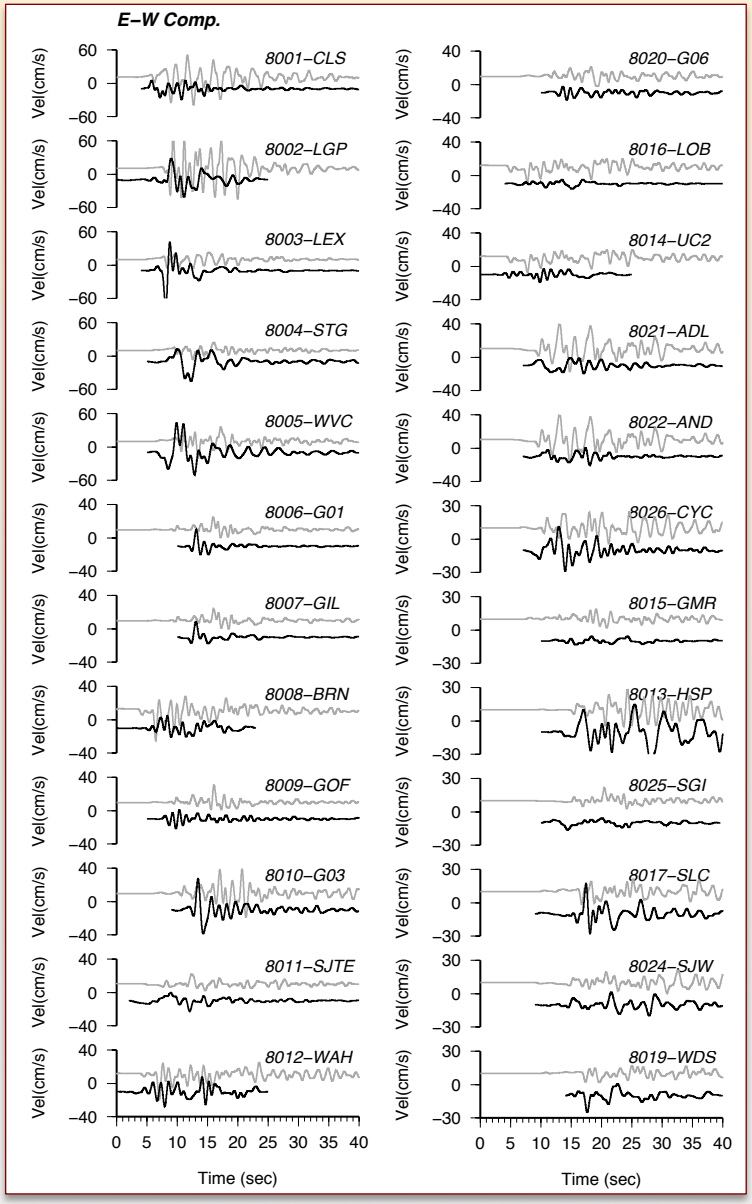
Kinematic Rupture Model Using SCEC BB Platform

Graves&Pitarka (2010) Method

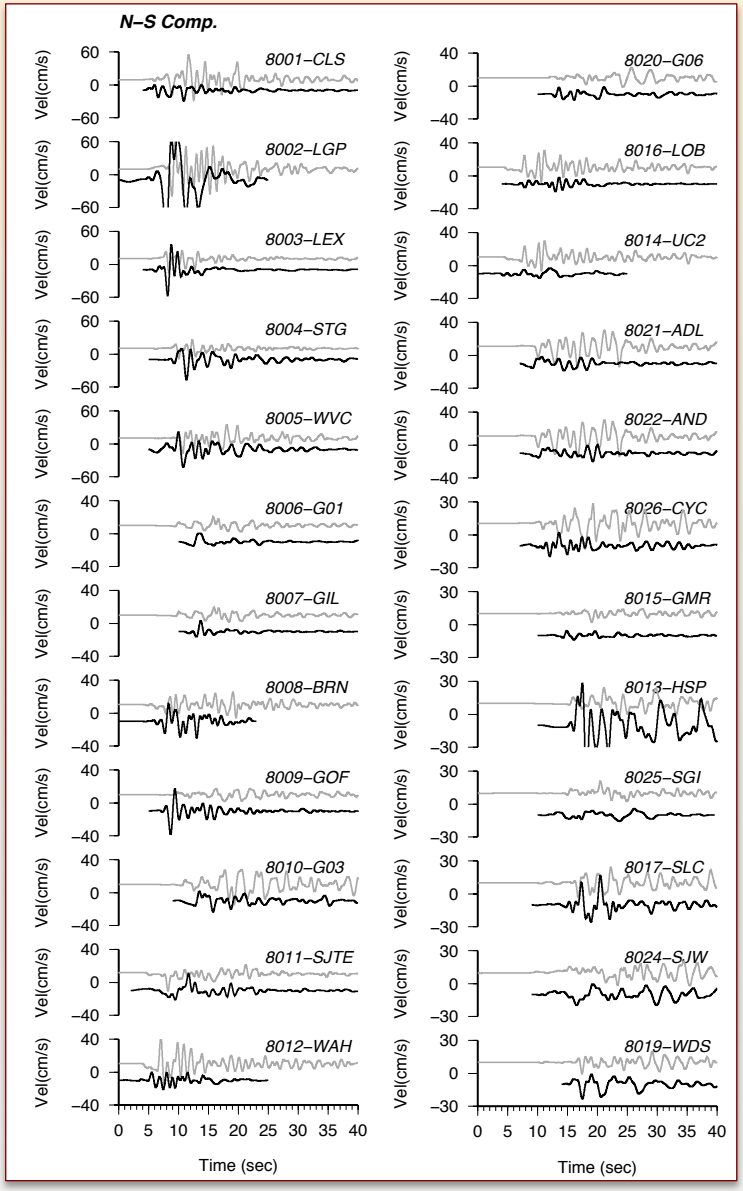


Recorded and Simulated Ground Motion Velocity

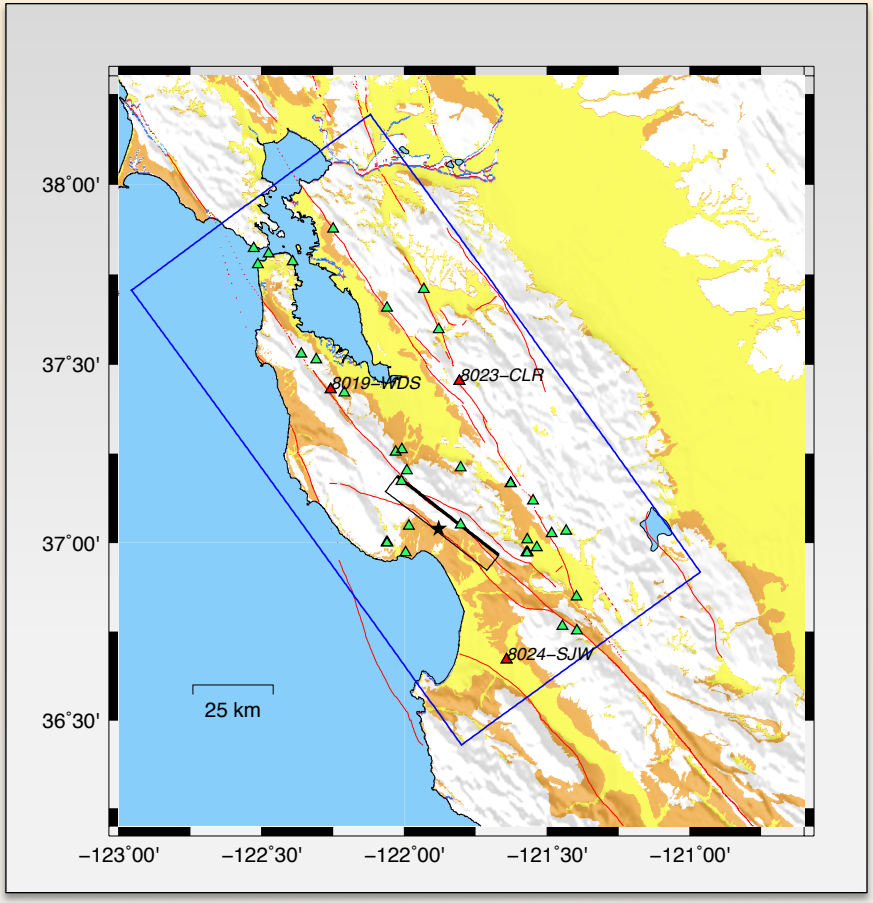
E-W

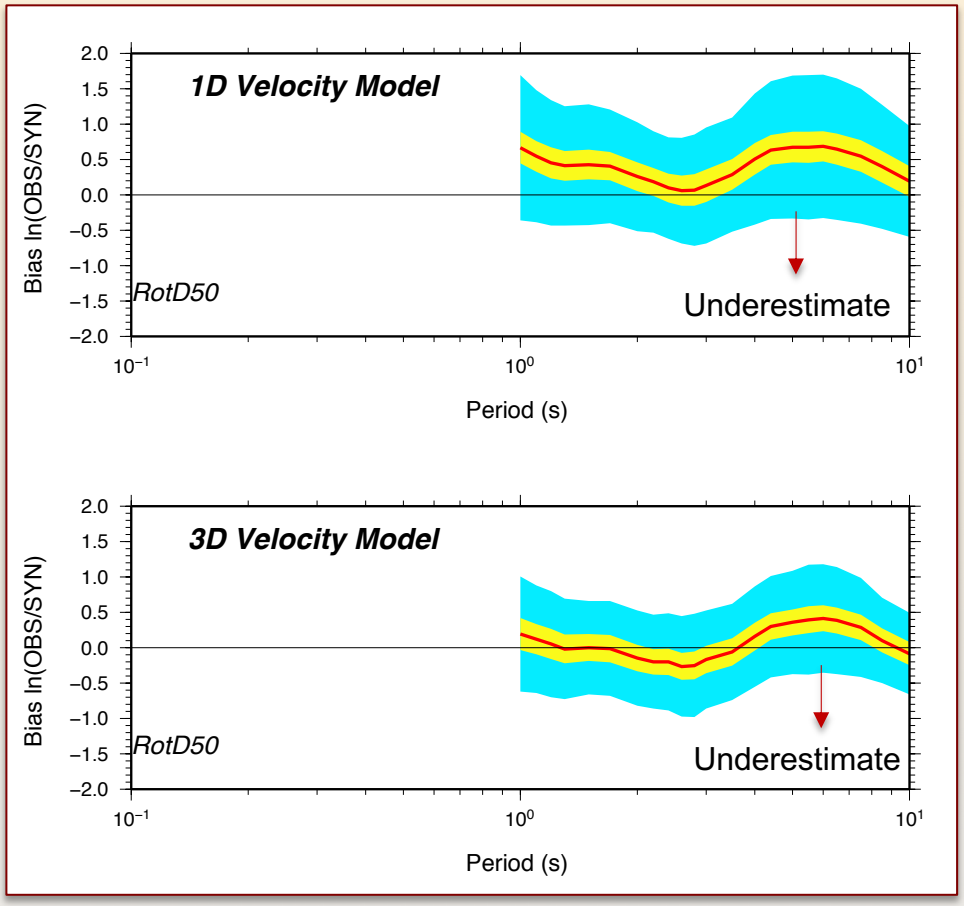


N-S



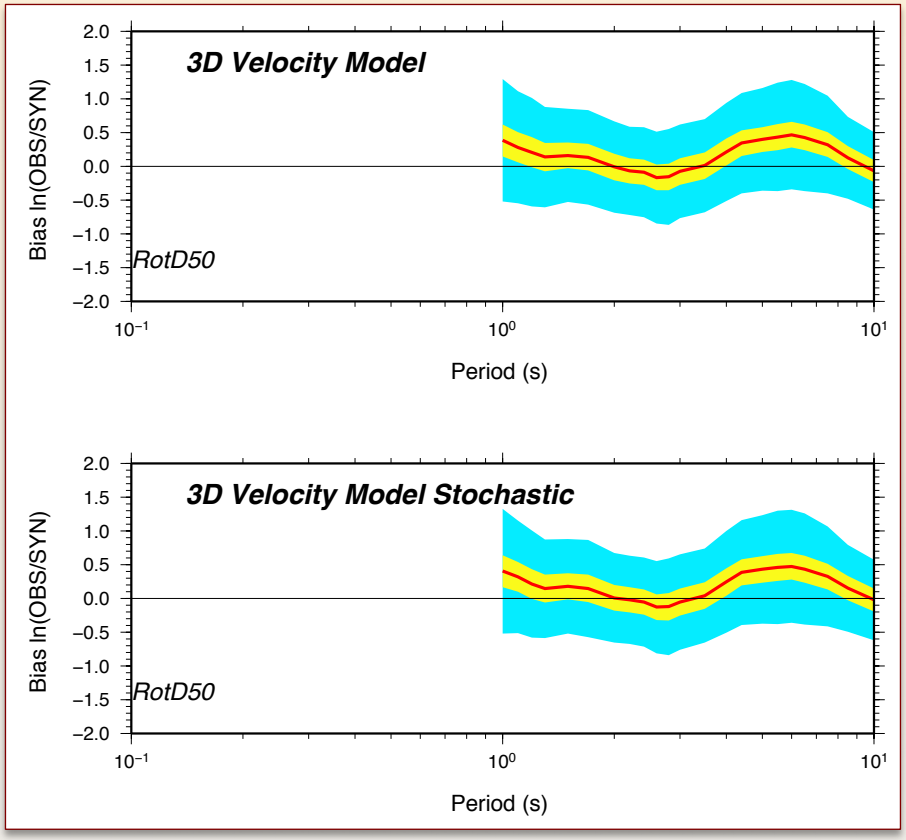
Goodness of Fit
Observed/Synthetic Ground Motion



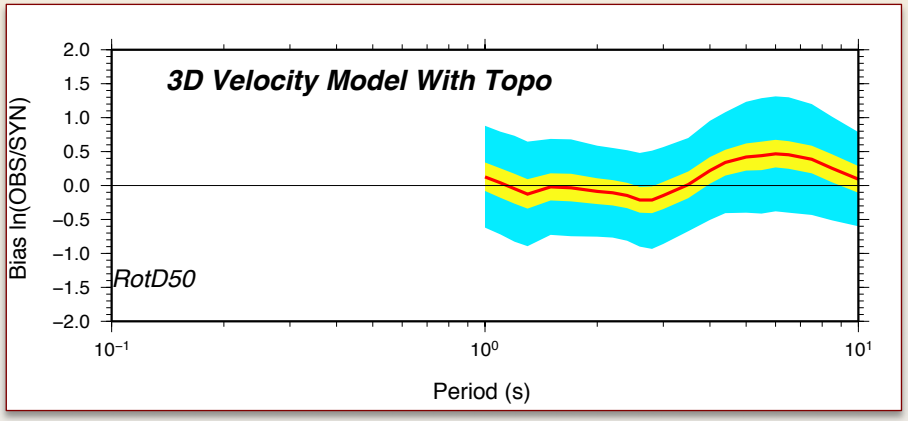


- 3D modeling reduces the bias.
- Both 3D and 1D simulated motions are systematically lower than the recorded motion at periods > 3s. (3D attenuation?)

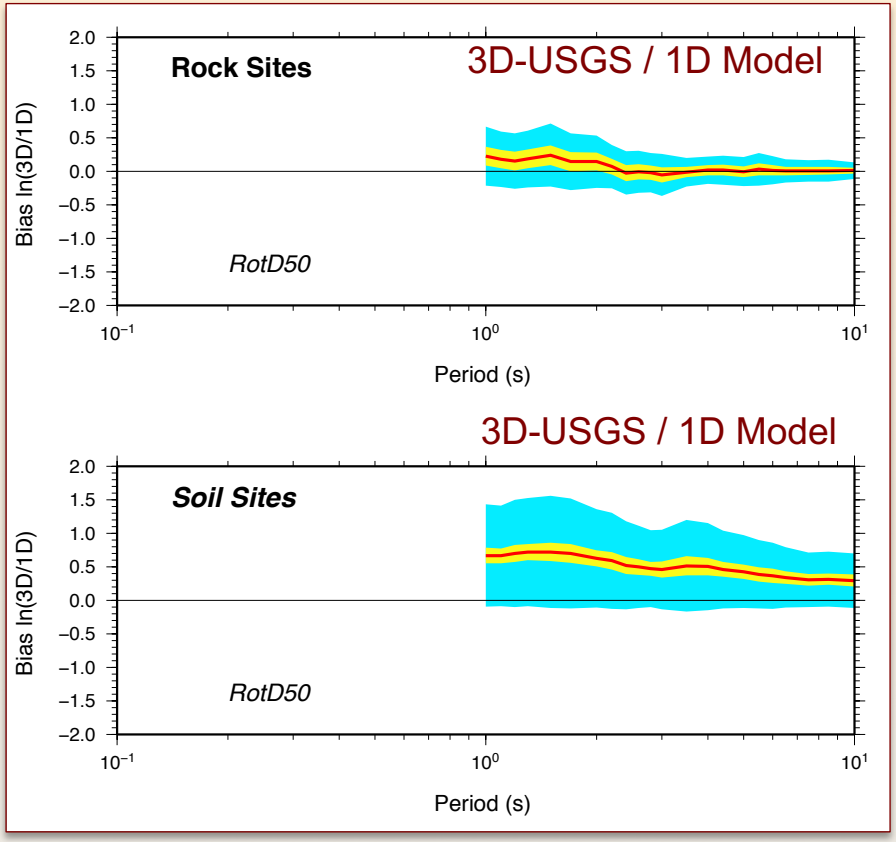
Effects of Stochastic Velocity Variations

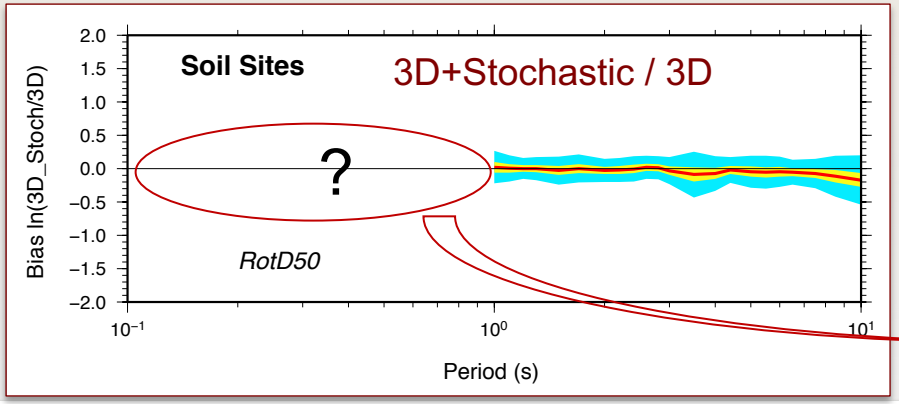


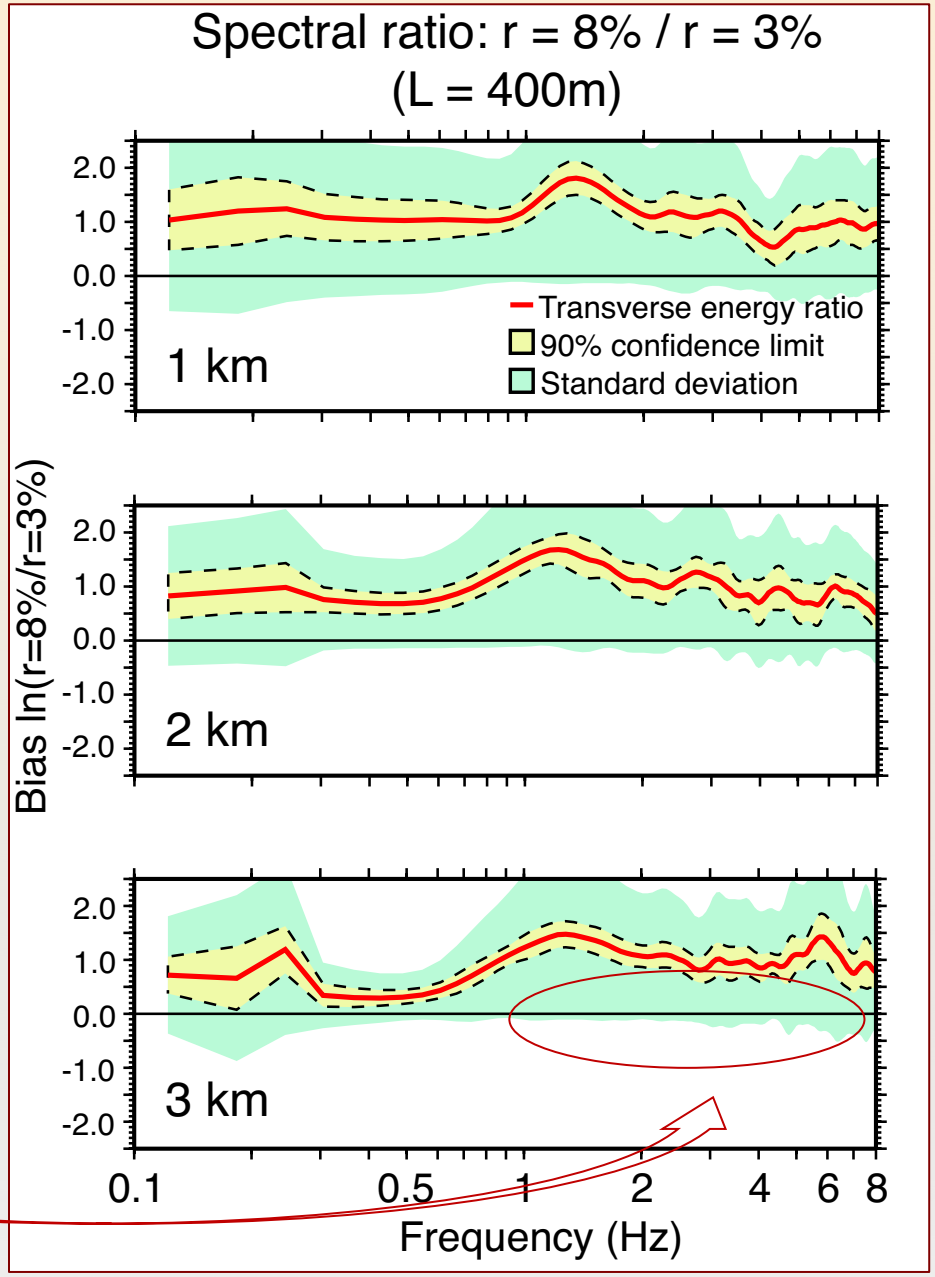
Effects of Surface Topography



Hirakawa et al.,2016)







Conclusions:

1. The 3D model in the San Francisco Bay area performs better than 1D model for T > 2s.

2. There are larger differences between 3D and 1D simulations for basin sites, but relatively small differences for rock sites.

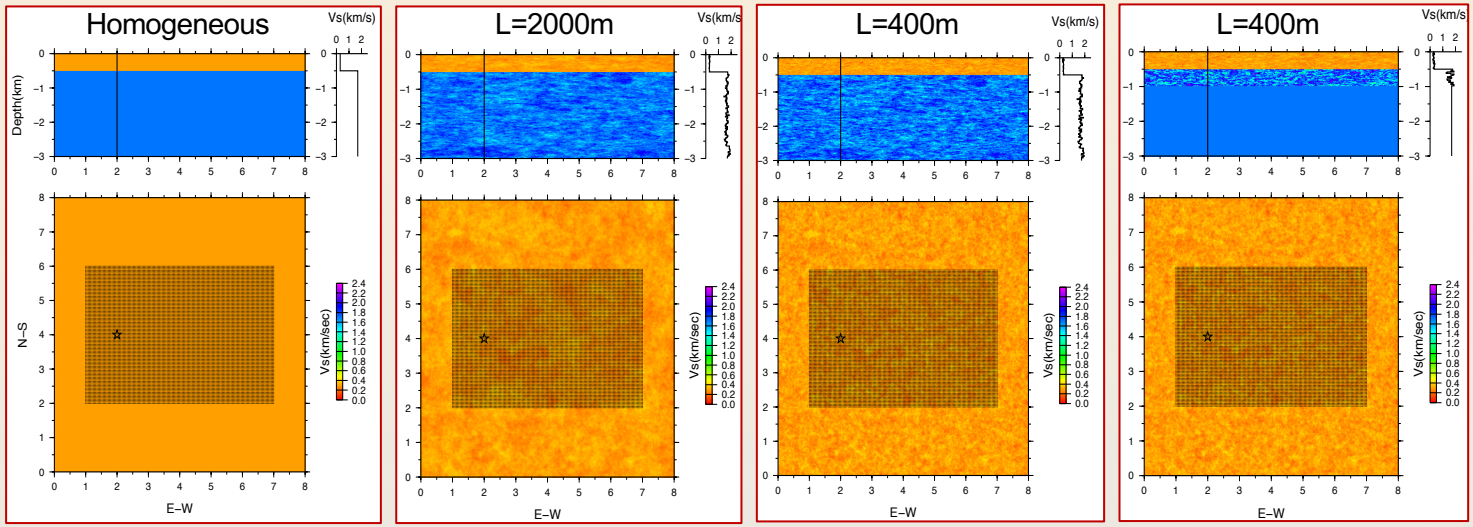
3. The inclusion of surface topography improves the goodness-of-fit for T = 1-5 s

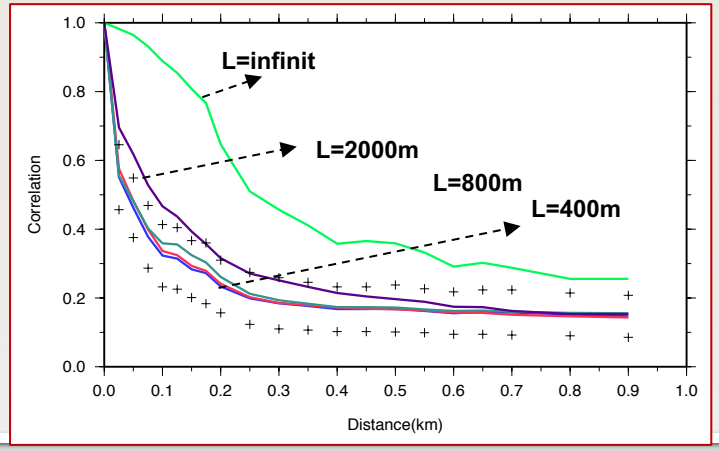
4. Effects of small scale random velocity perturbations on ground motion are small for T > 2 s.

Work in Progress:

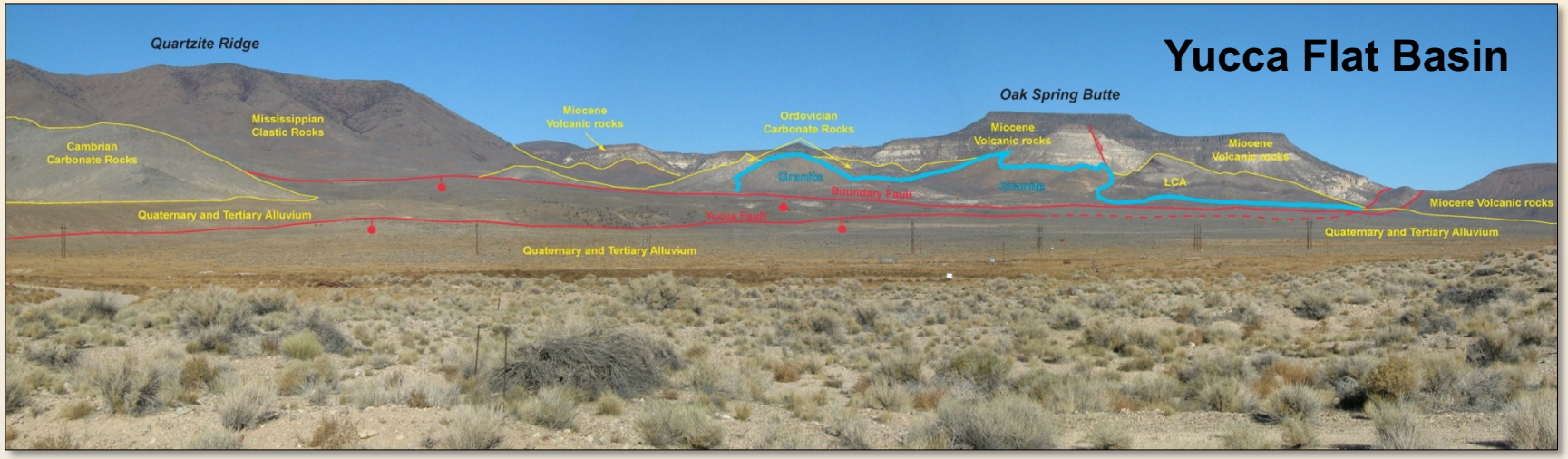
- Assess the quality of the 3D USGS model by modeling recorded earthquakes (Rodgers et al, 2018;2019)
- Increase modeling frequency range to 5Hz (Rodgers et al., 2019)
- **Characterize stochastic model perturbations for high frequency simulations** (Hirakawa et al., 2016; Pitarka et al.,2019)

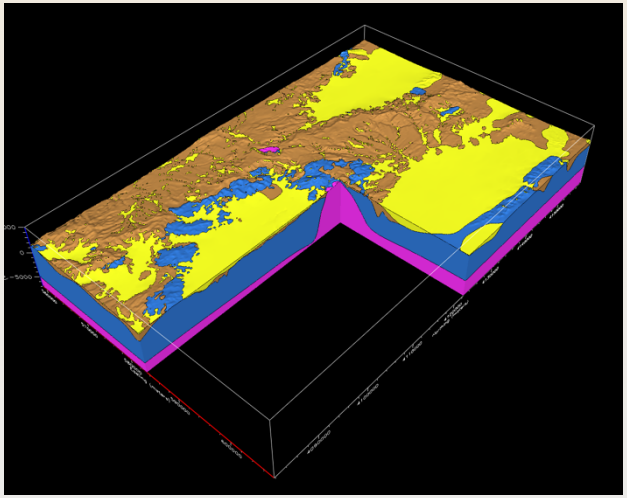
Waveforms Correlation as Function of Between Stations Distance

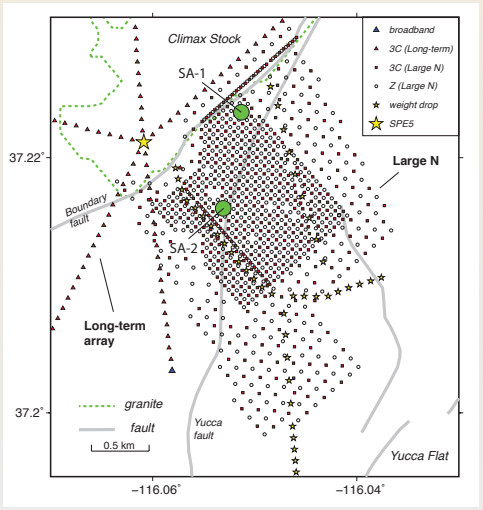


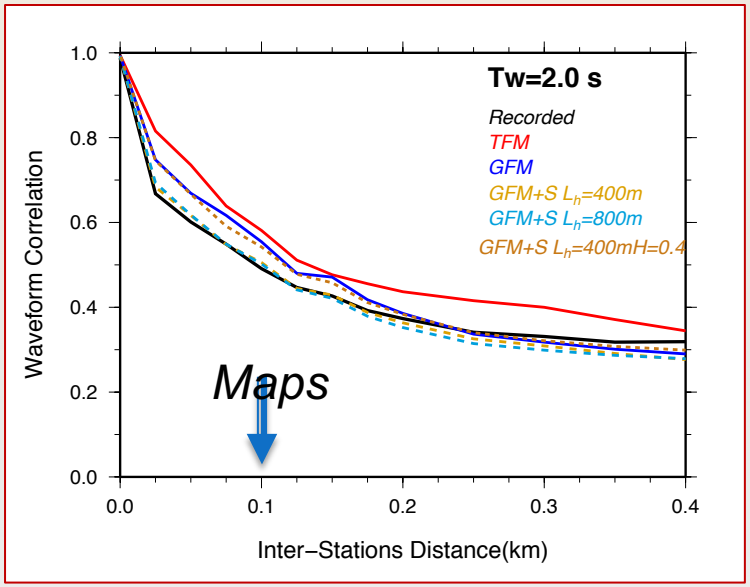


Characterization of Stochastic Models Using Large Array Observations (LargeN Array at NNSS)

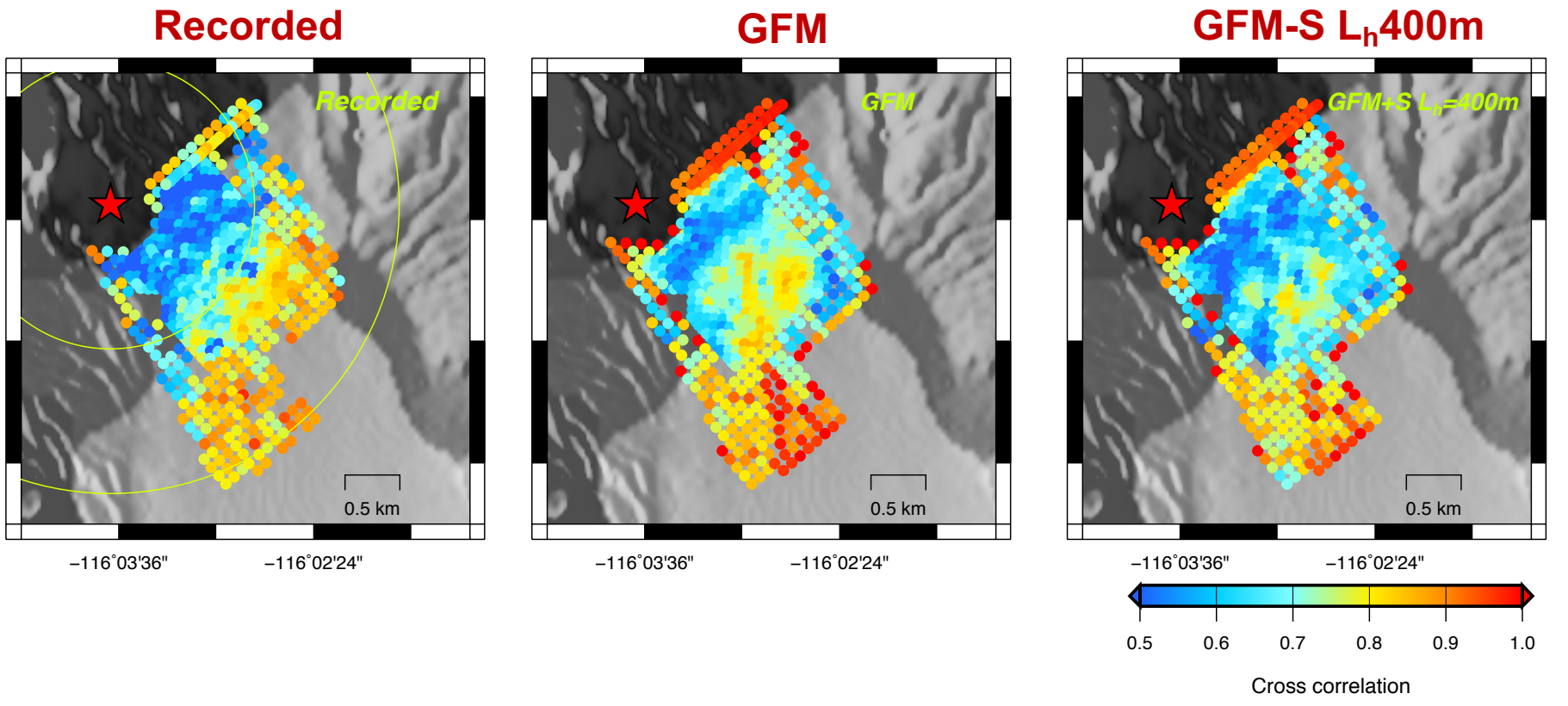








SPATIAL VARIATION OF CROSS-CORRELATION FOR STATIONS SPACING D= 100M



Acknowledgments:

We thank Christine Goulet at SCEC for helpful discussions, and for providing the recorded ground motion data for the Loma Prieta Earthquake, Brad Aagaard for providing the Hayward fault rupture scenarios, and Rob Graves and Artie Rodgers for helpful discussions

Thank You !