Challenges in Broad-Band Ground Motion Simulations

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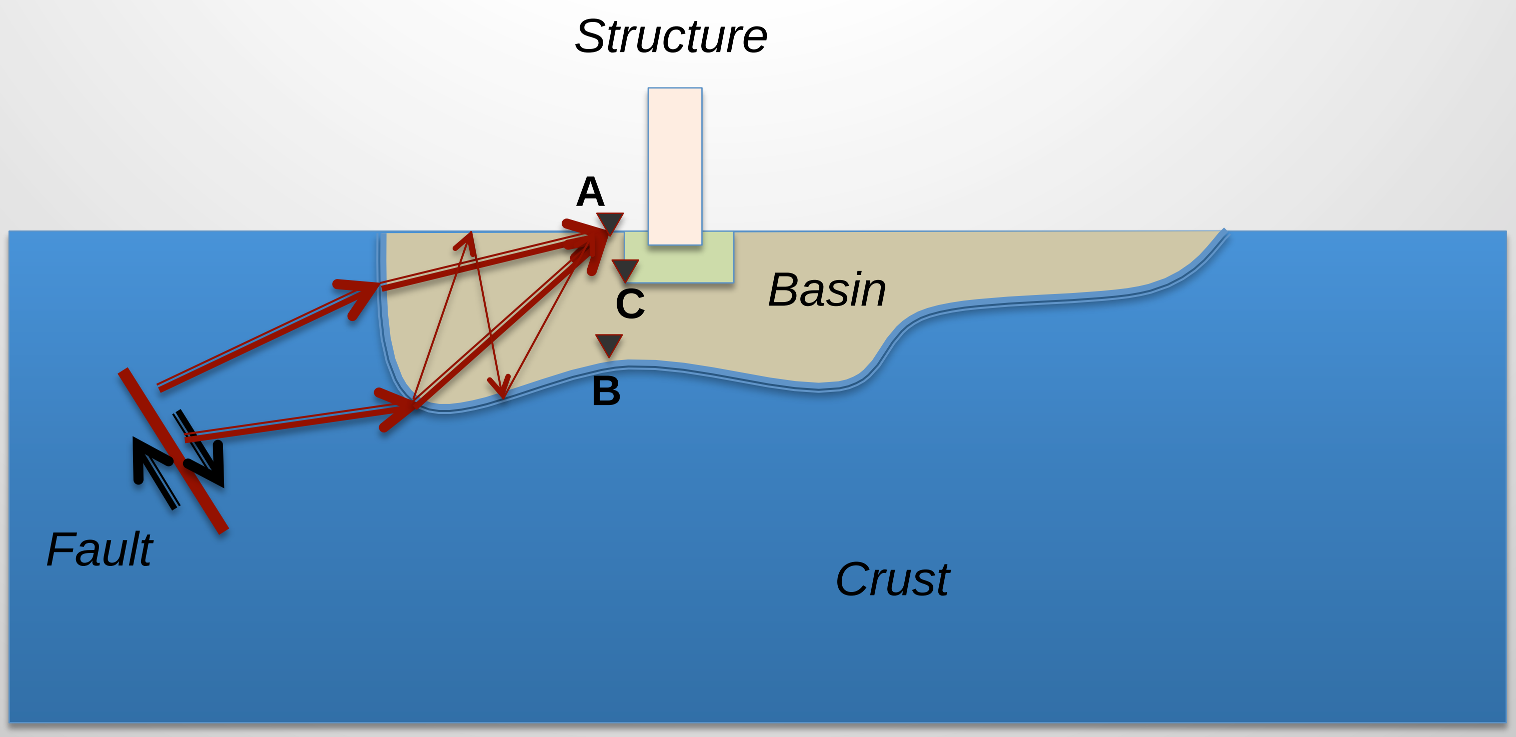
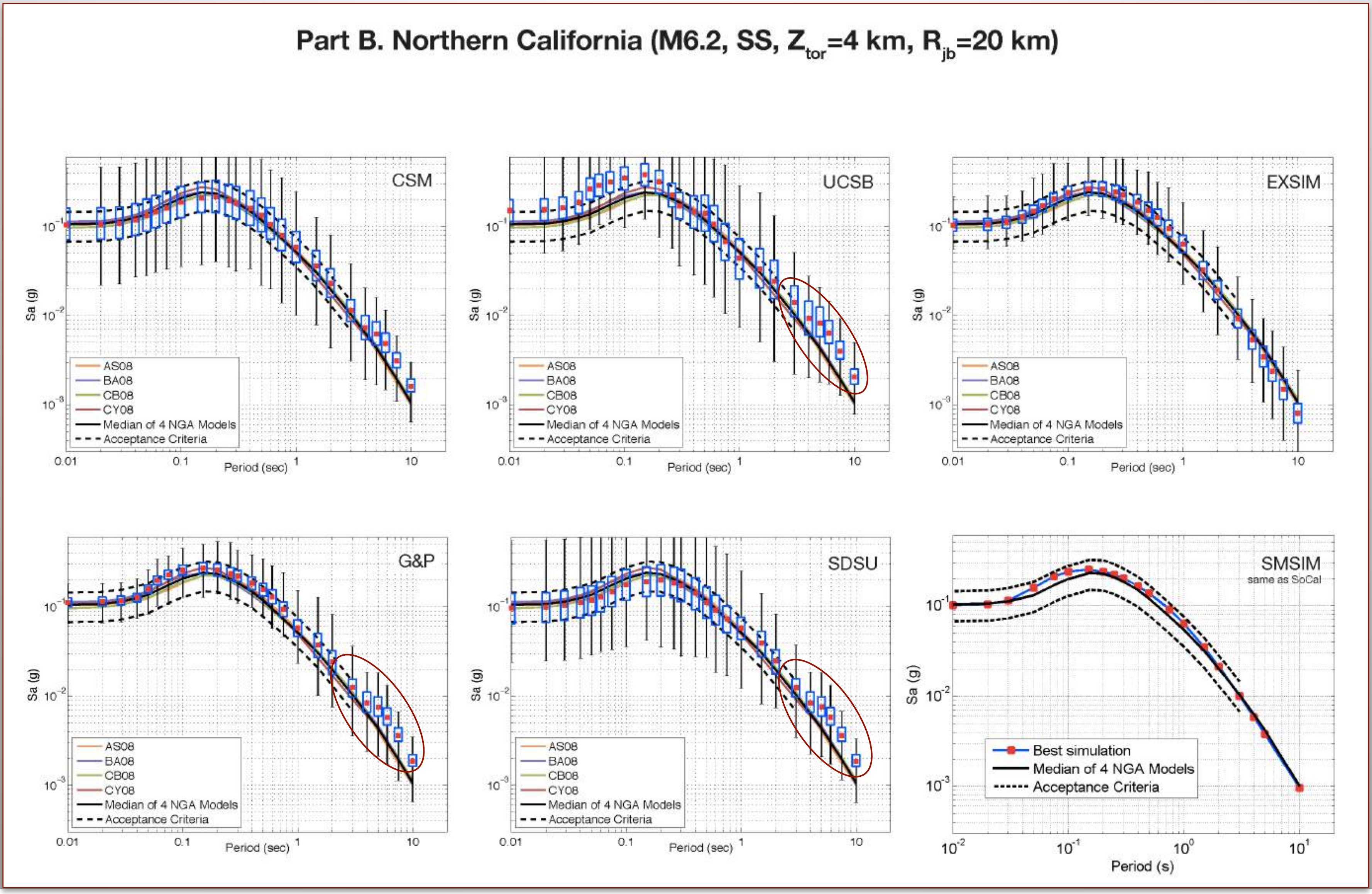


- Earthquake Rupture
- Elastic/Elasto-plastic modeling
- 3D/1D velocity models, inclusion of structural heterogeneity
- Topography
- 3D Q models in GMPEs used in validations of BB simulations
- Suggestions. Site response module in the SCEC BB platform

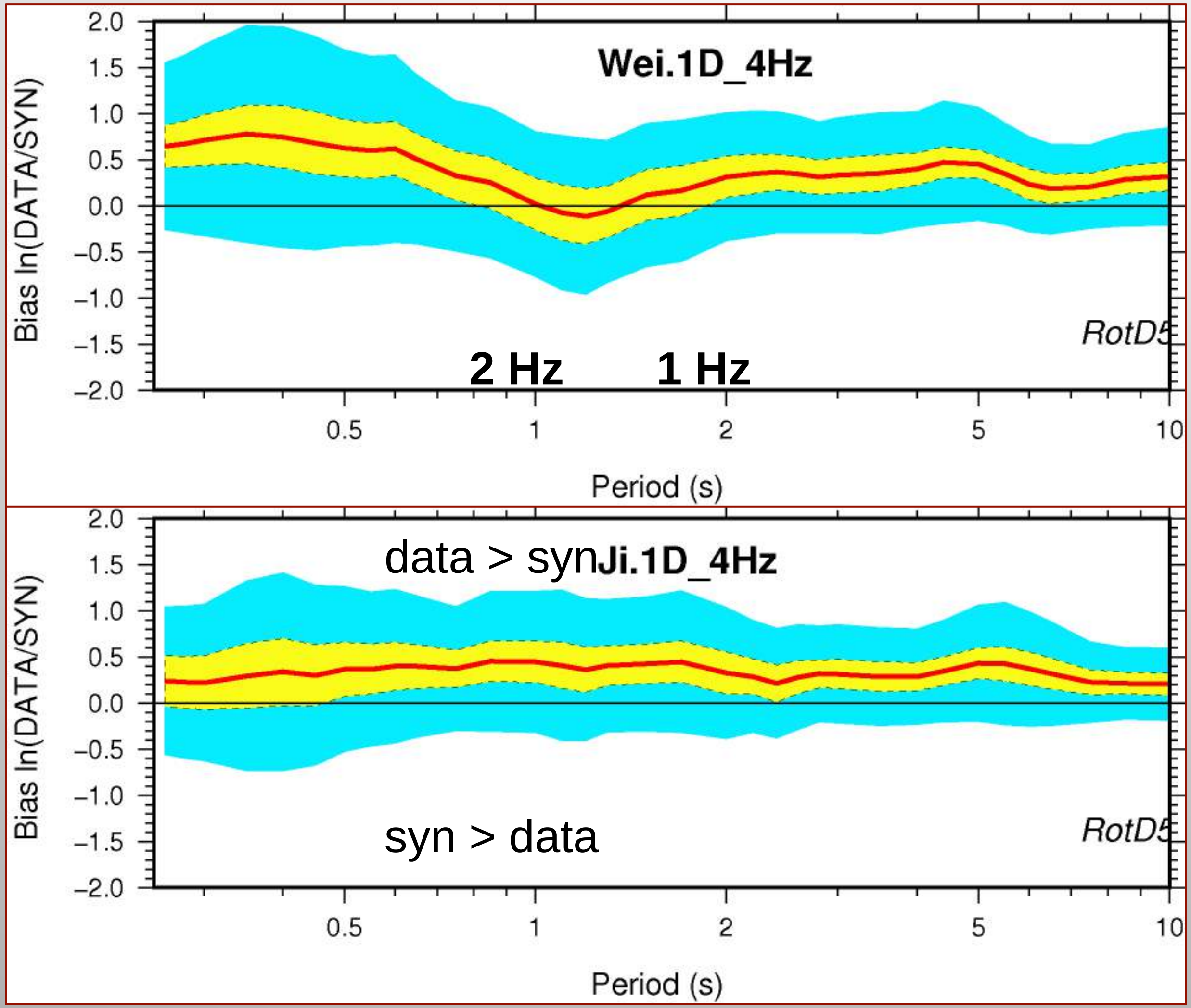
Validations Using GMPEs Using Planar Faults and 1D Velocity Models



Deterministic High Frequency Modeling

Napa earthquake 1D GIL7 model and two source models, <u>0.1 – 4 Hz</u>

Rodgers et al., 2015



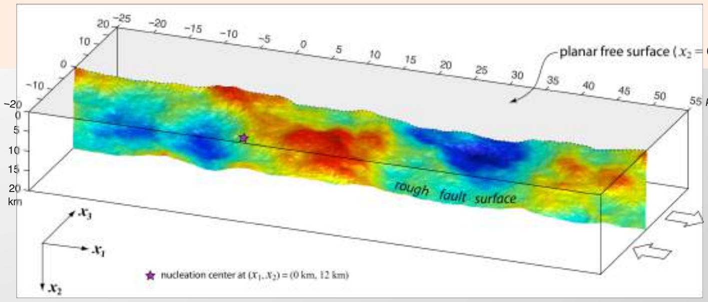
Underprediction when using 1D models

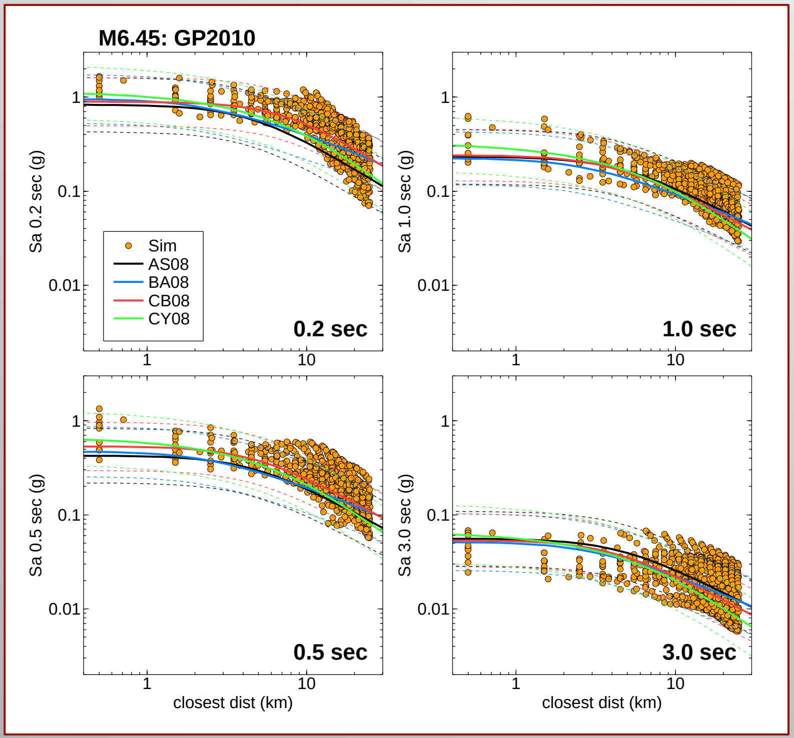
1. Geometrical Fault Complexities

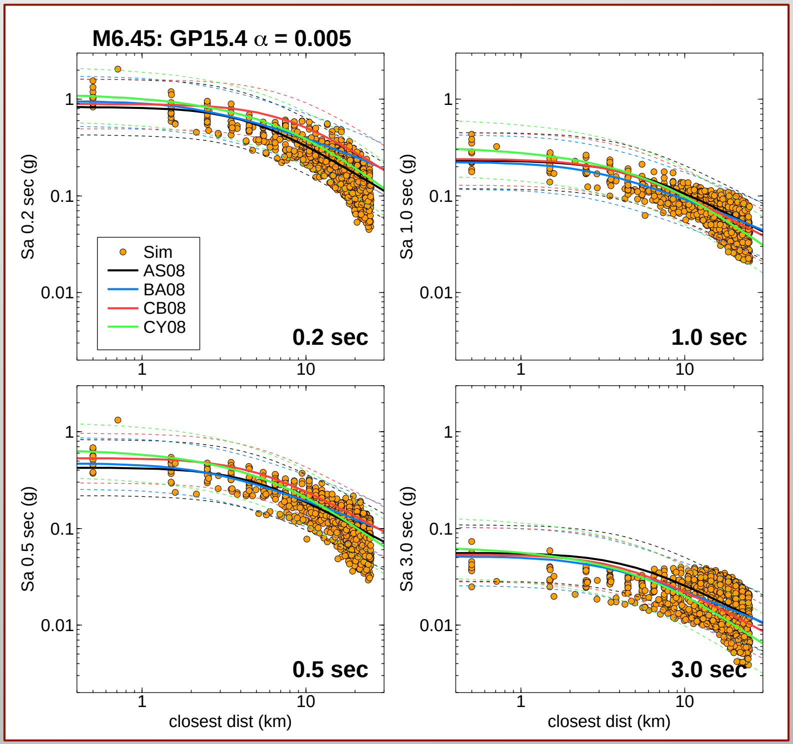
- Multi-segment faults
- Faults with rough surface

Simulations Using Rough Faults

(Graves and Pitarka, 2015)



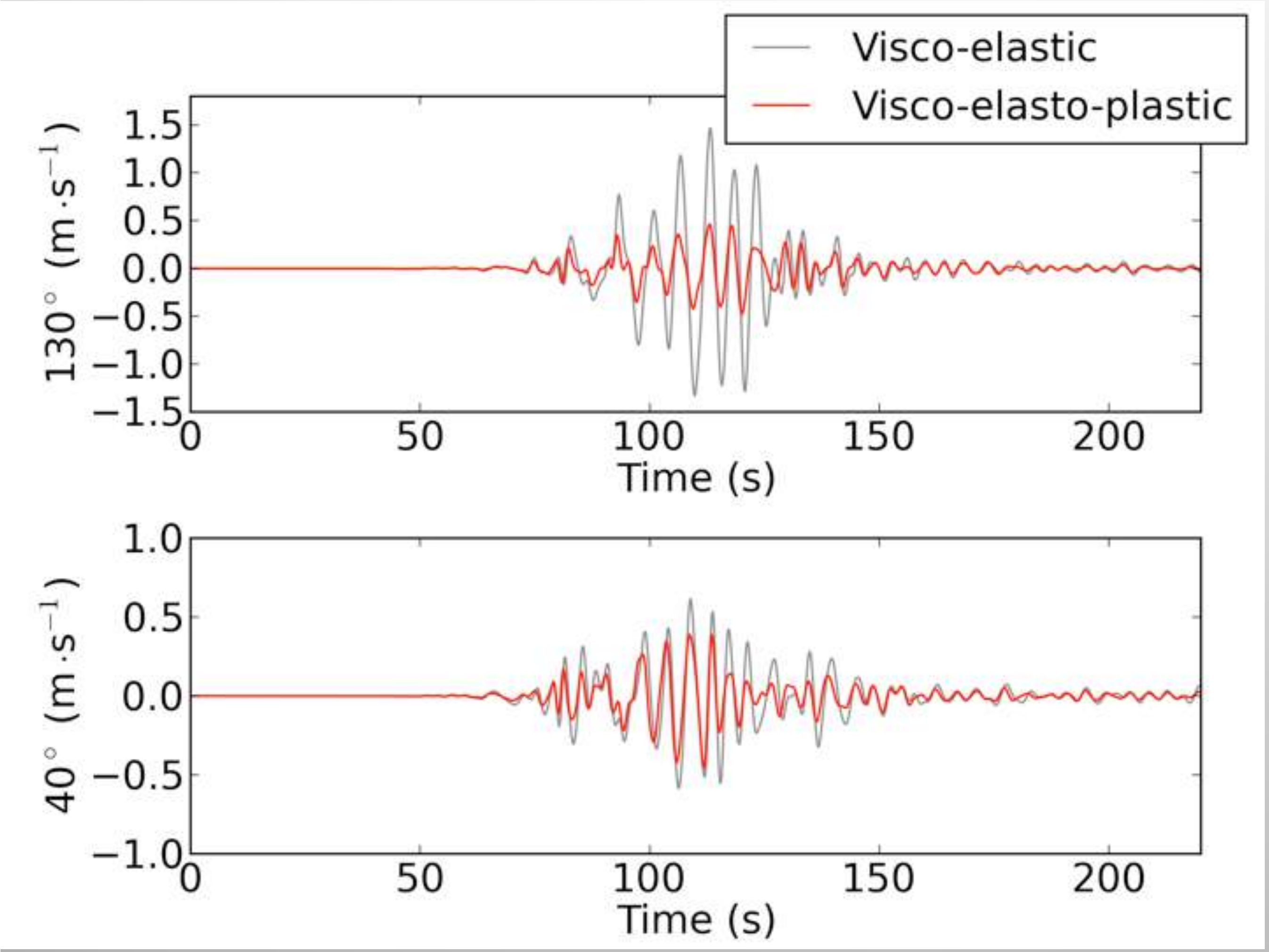




Shi and Day (2013) and Trugman and Dunham (2014)

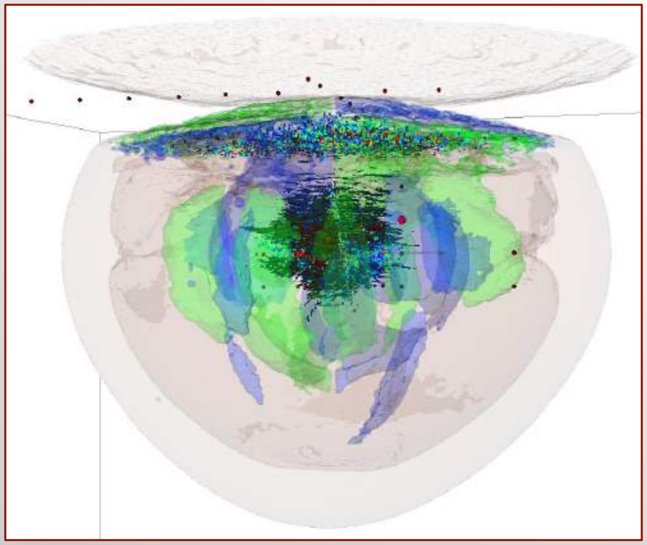
2. Off-Fault Plasticity Effects

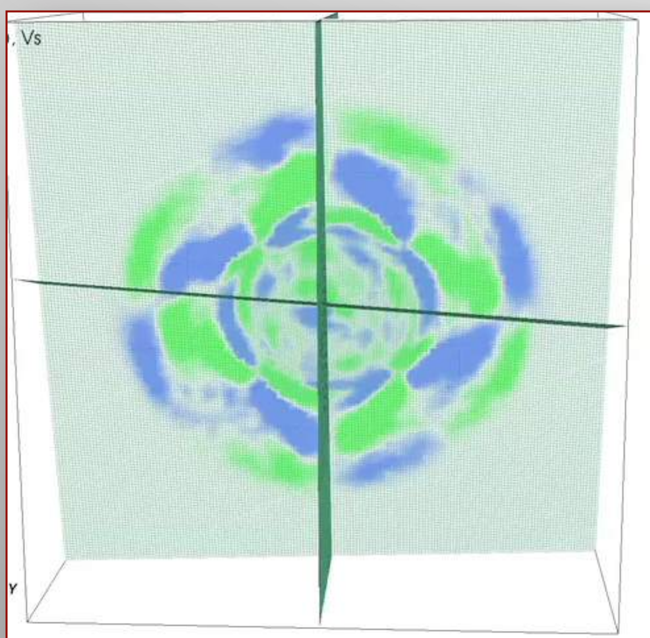
(Roten et al., 2013)



Large reduction of ground motion. Basin attenuation models need to be revised.

3. Joint Motion in Fractured Media



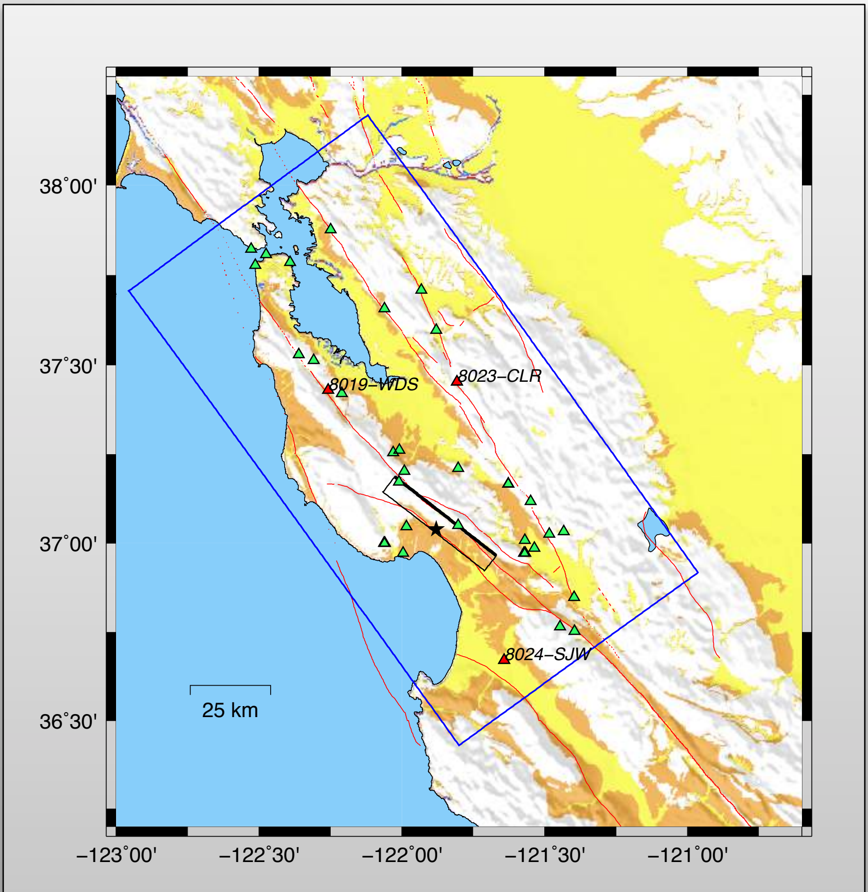


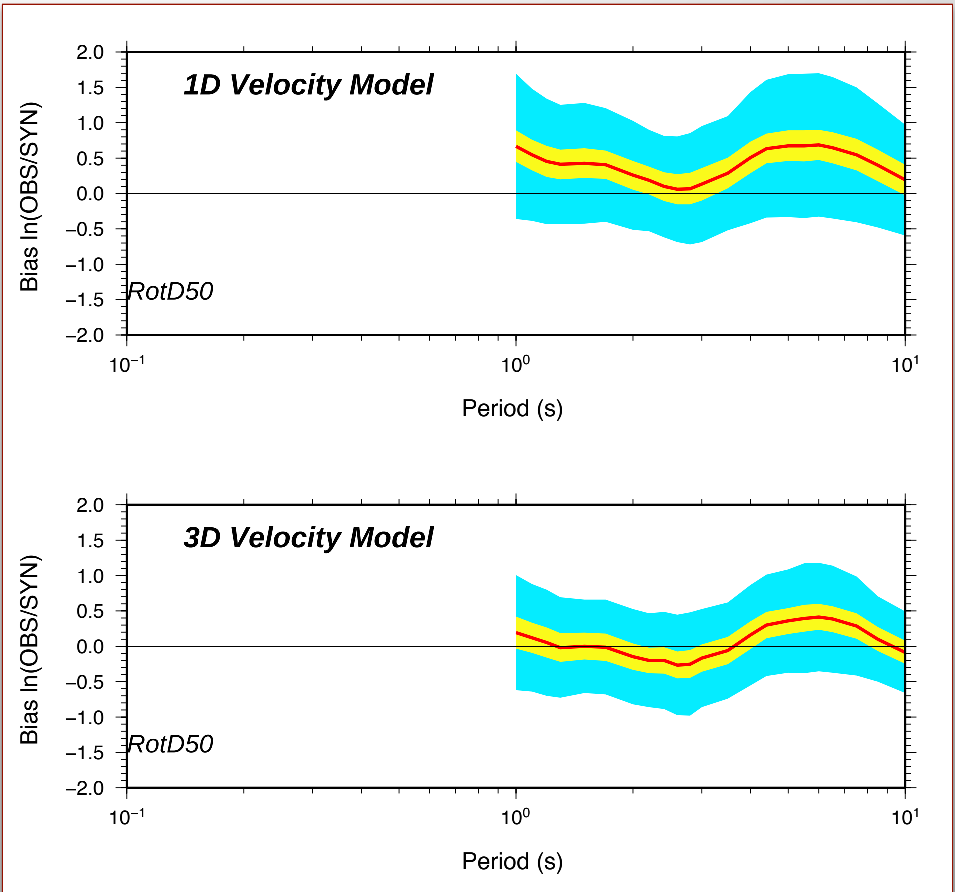
Substantial shear energy is generated due to joint motion for a shallow explosion source

Monte Carlo simulations of wave propagation in the jointed rock. Several realizations of stochastic discrete fracture network (SDFN) were generated and embedded into the hydrodynamic code to model chemical explosion sources. Joints are treated as penny-shape inclusions in the granite host rock.

Wave Propagation Effects

- 1D/3D models for short and long distances



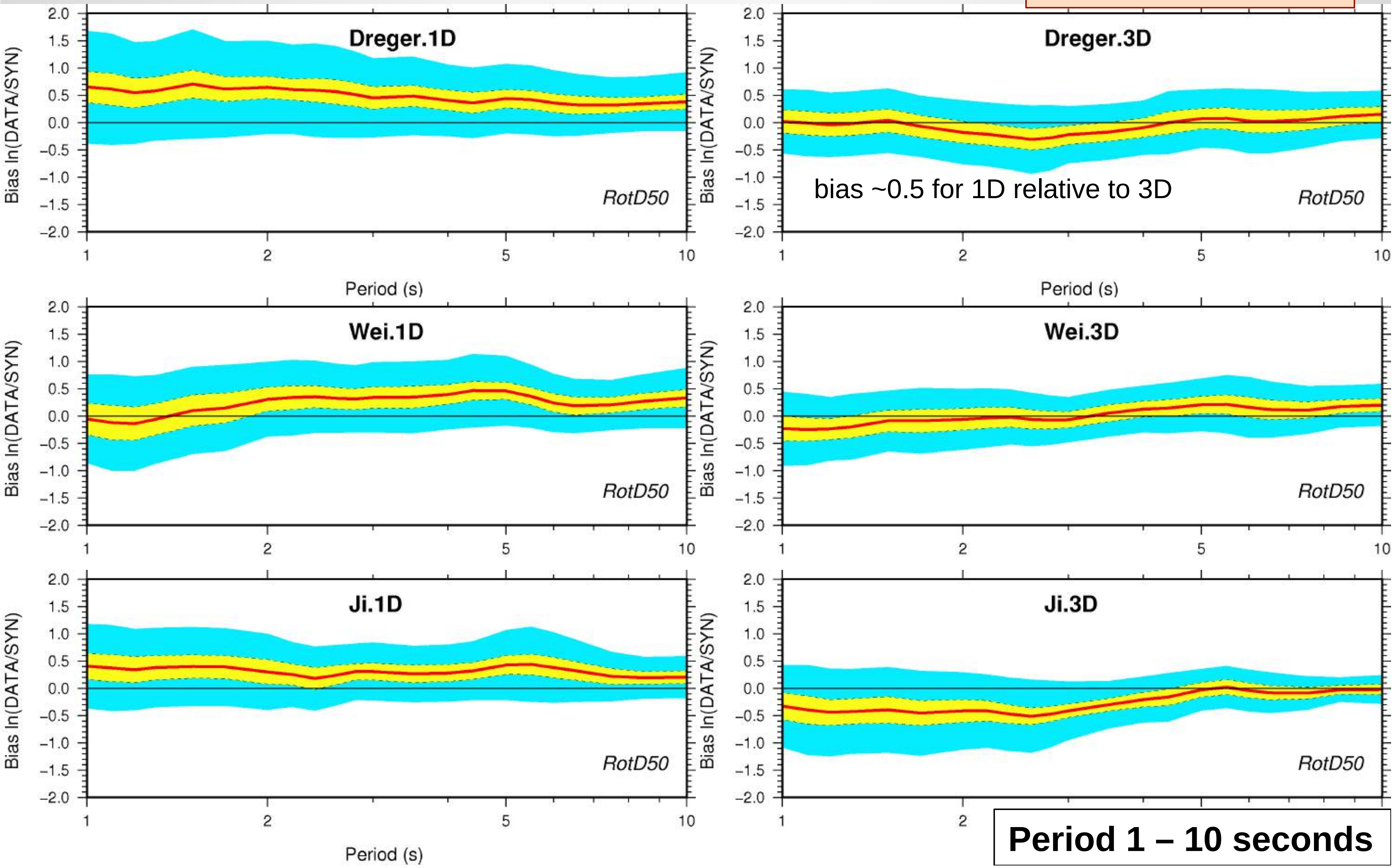


3D velocity model does a better job

Napa Earthquake, Dreger, Ji & Wei Sources

Rodgers et al., 2015)

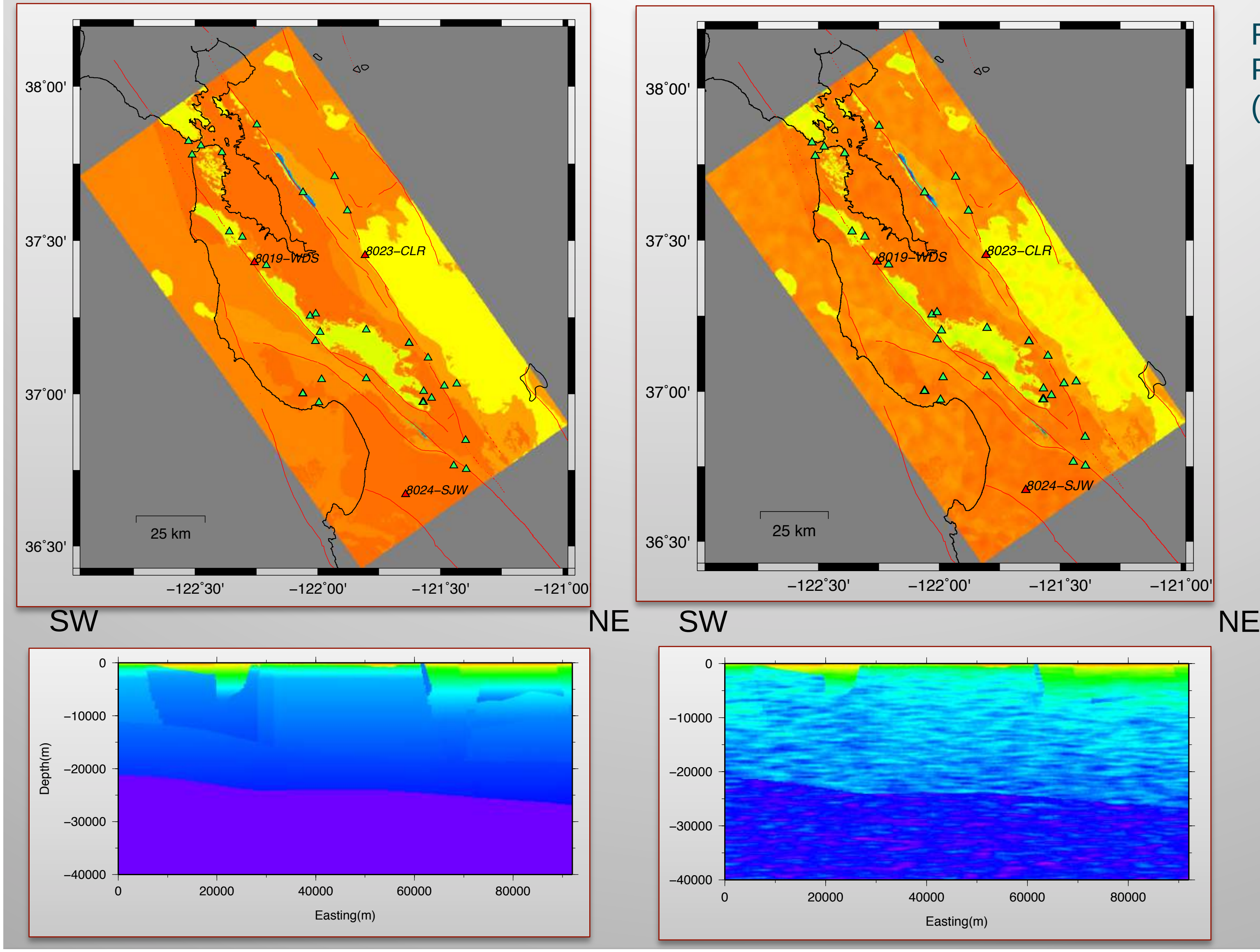
3D models are less biased across band



Period 1 – 10 seconds

Model heterogeneity in deterministic elastic wave propagation modeling

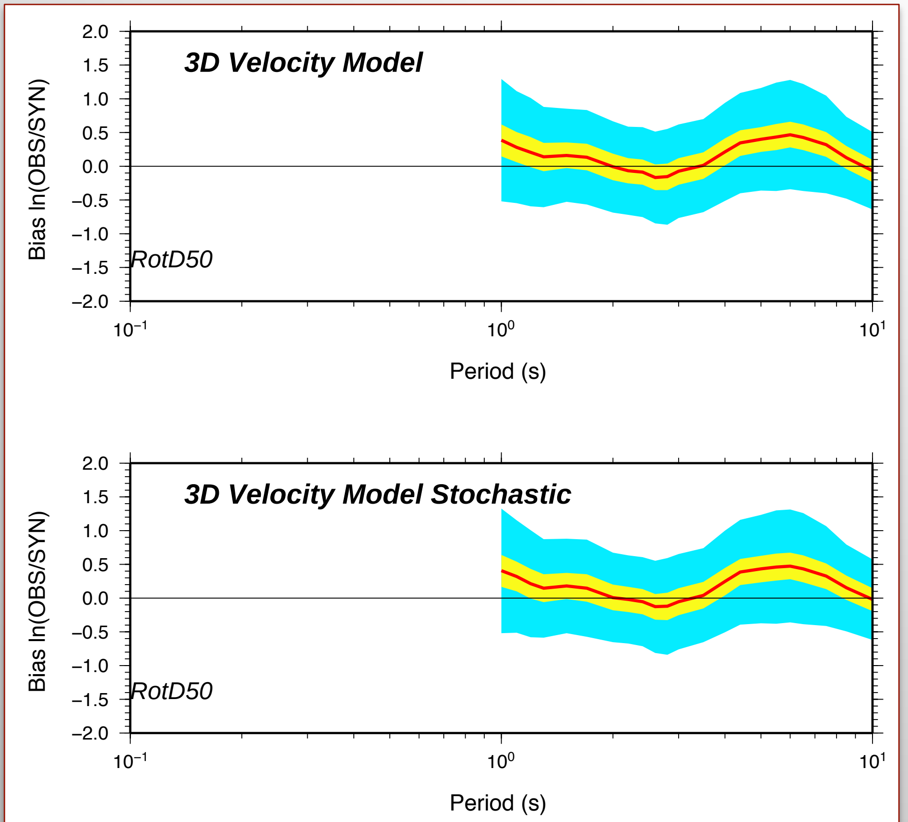
3D USGS Velocity Model Version 8.3.0 with Random Perturbations



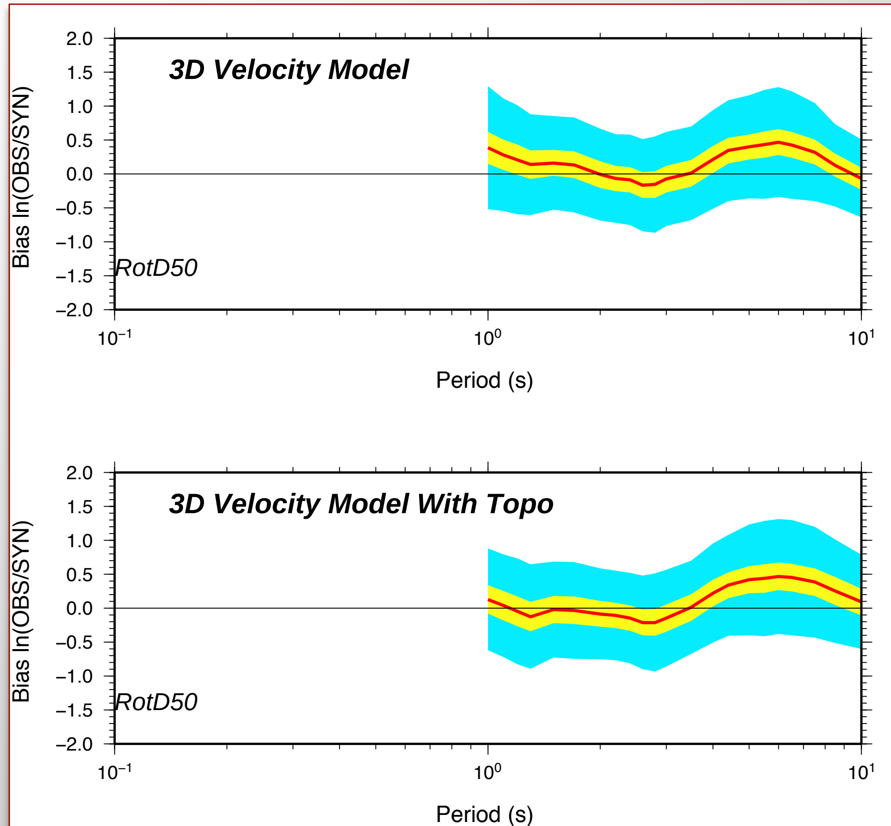
Random Velocity Perturbations (Pitarka et. al., 2009)

L_h=2000m
L_z=200m
Perturb=30%
V_{smin}=400m/s

Effects of Stochastic Velocity Variations



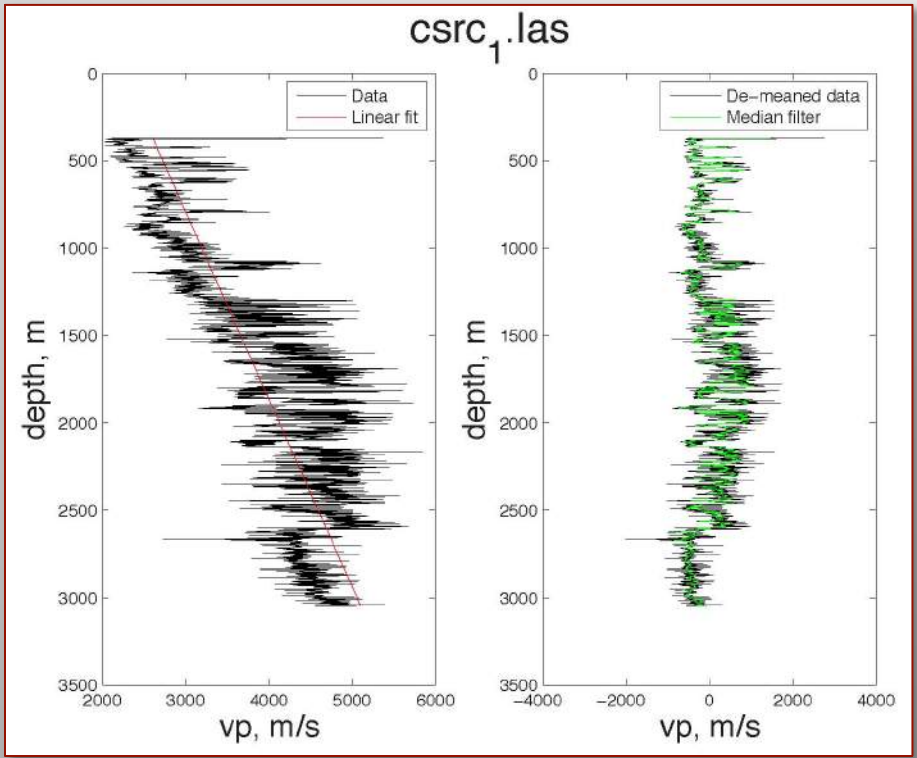
Effects of Surface Topography



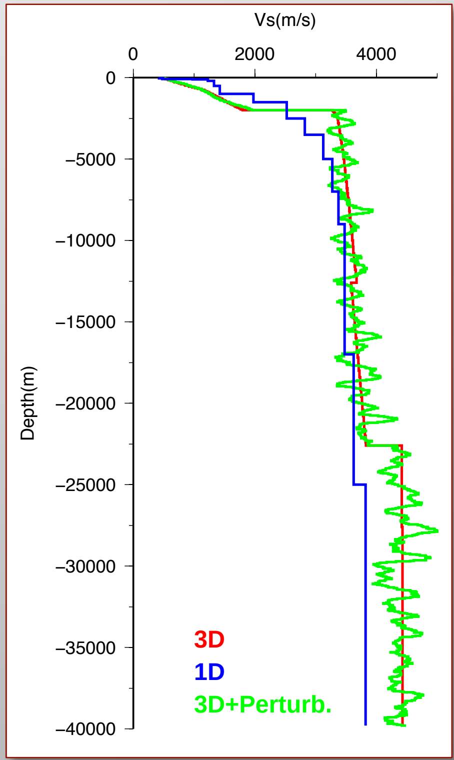
Wave Propagation Effects

- **Strategy for developing realistic 3D velocity models with random variability**
- Multiple-scale spatial variability (stochastic approach)
- Correlation length as a function of depth.
- Self-Similar/Gaussian, scattering mean free path (Obermann et al., 2012)
- Revision of Q models

Variograms using borehole data
Olsen et al. (2013; Withers et al, 2013)

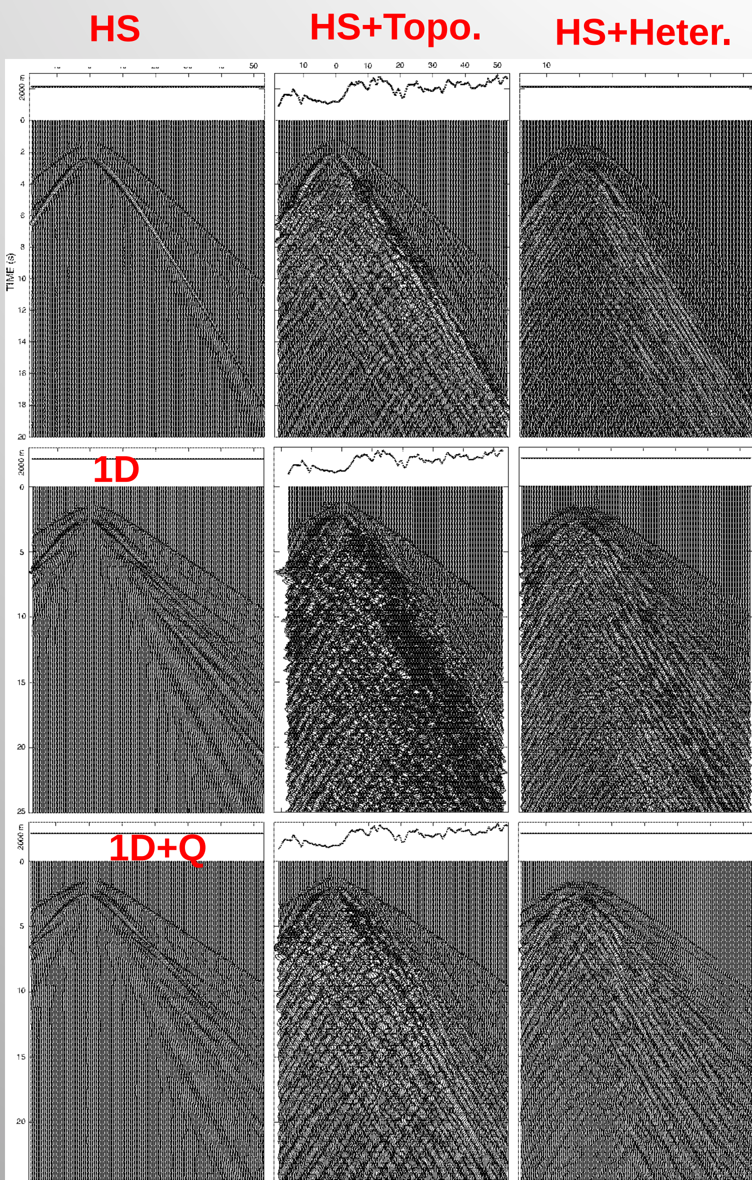


Pitarka 2013



Surface Topography Effects

(Imperatori and Mai, 2015)



Should topographic effects be considered as site response ?

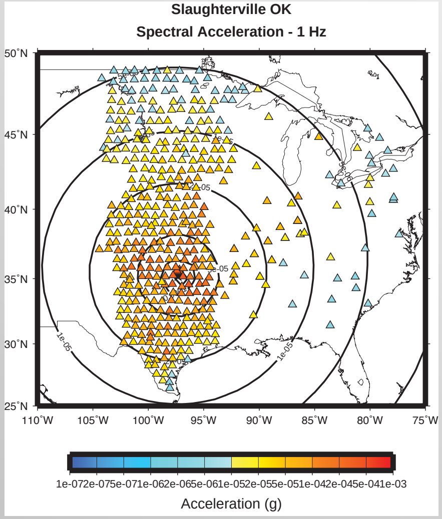
- Topographic effects increase significantly in the presence of soft surface layers due to mode generation and trapping.
- The effect is directional and incident wave type dependent

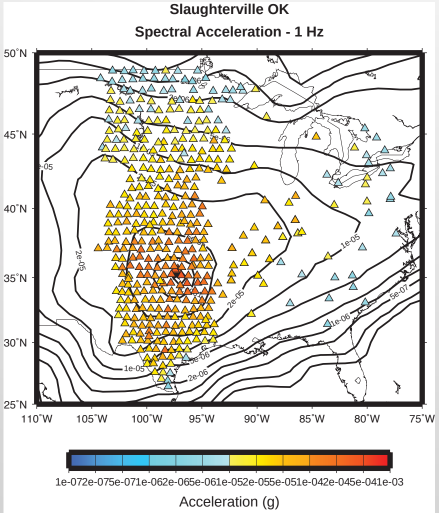
- Simulation results indicate that random velocity perturbations generate larger ground motion variability than random topography.
- Both random heterogeneity and random surface topography generate ground motion variability with similar standard deviation at close distance from.

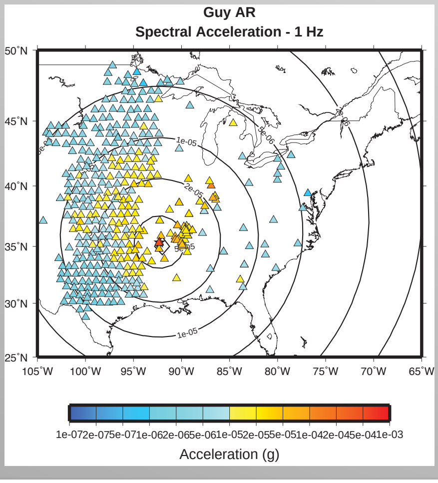
In contrast, at distances larger than 30km the standard deviation doubles.

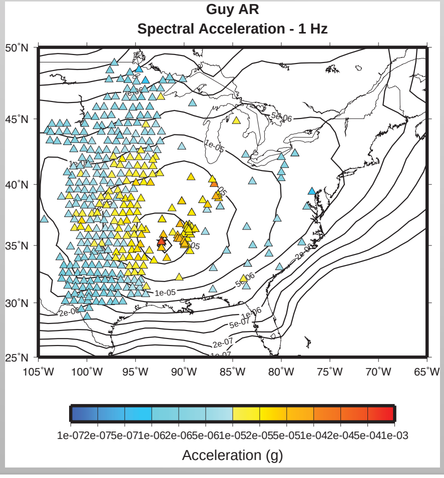
Broad-Band Ground Motion Validation

- SA / FA in comparison with recorded ground motion
- Use GMPEs that incorporate 3D attenuation (Pasyanos, 2015)





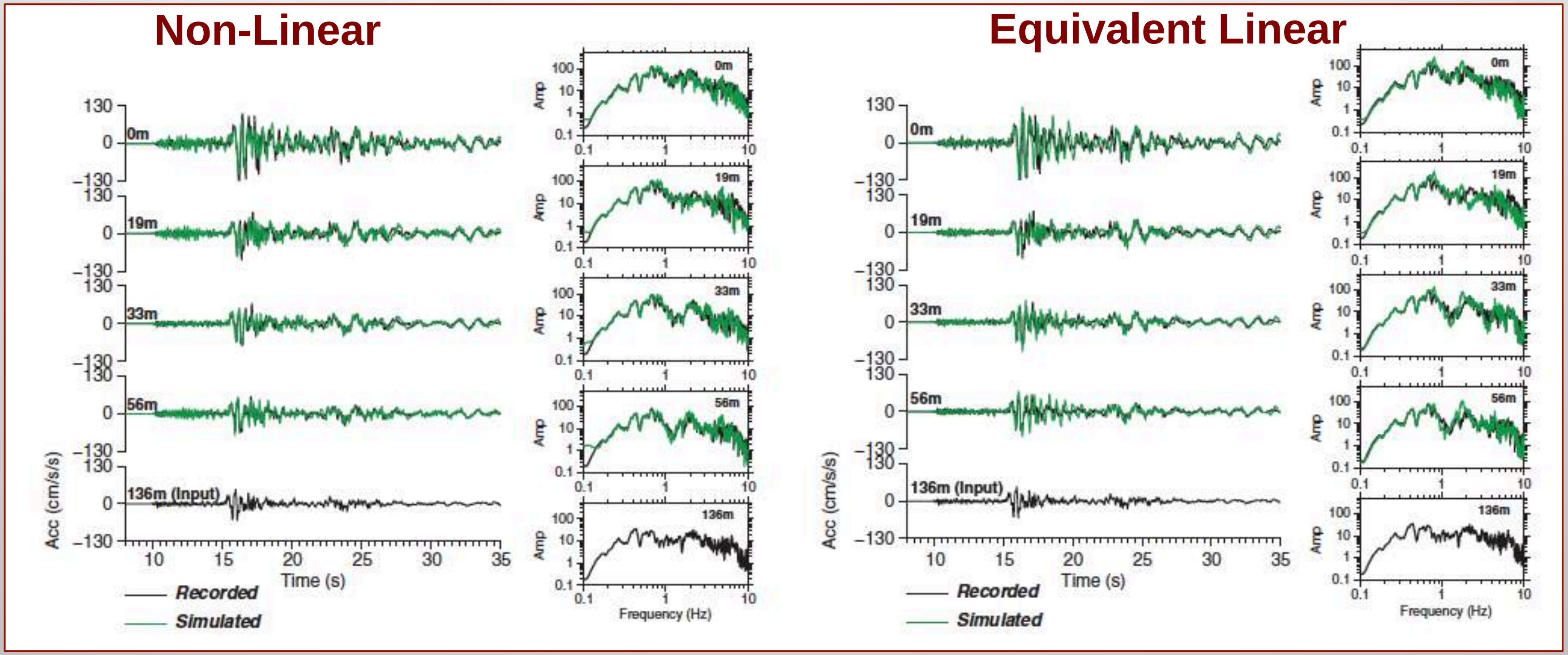




GMPEs might be improved by including 3D Q models in areas with strong 3D attenuation variations.

Equivalent Linear / Nonlinear 1D Site Response
Weak / Strong Input Motion

Pitarka et al., (2013)



NOAH_IWAN code (Bonilla, 2012, personal comm.)

Suggestions

- Strategy for improving parameterization of small-scale heterogeneity into 3D velocity models (correlation length and amplitude variations with depth)
- Sensitivity analysis for non-linear/linear 3D wave propagation modeling, including plasticity and crack modeling should be validated against recorded waveforms.
- Strategy for developing characterization of topographic effects as a function of distance to the fault
- Is it reasonable to include non-linear site response in the BB platform?
- If yes, site response modules can directly operate on time series, as opposed to frequency domain
- Strategy for developing site characterization parameters for large scale regions, i.e., across SoCal region covered by CVM.
- How to characterize a site category, use Vs30, topography ?

Acknowledgments:

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Thank You !