GMP Research Goals for SCEC 5

How can the hazard from simulated earthquakes effectively reduce risk in the real world?

4. Ground Motion Simulations - Olsen/Graves

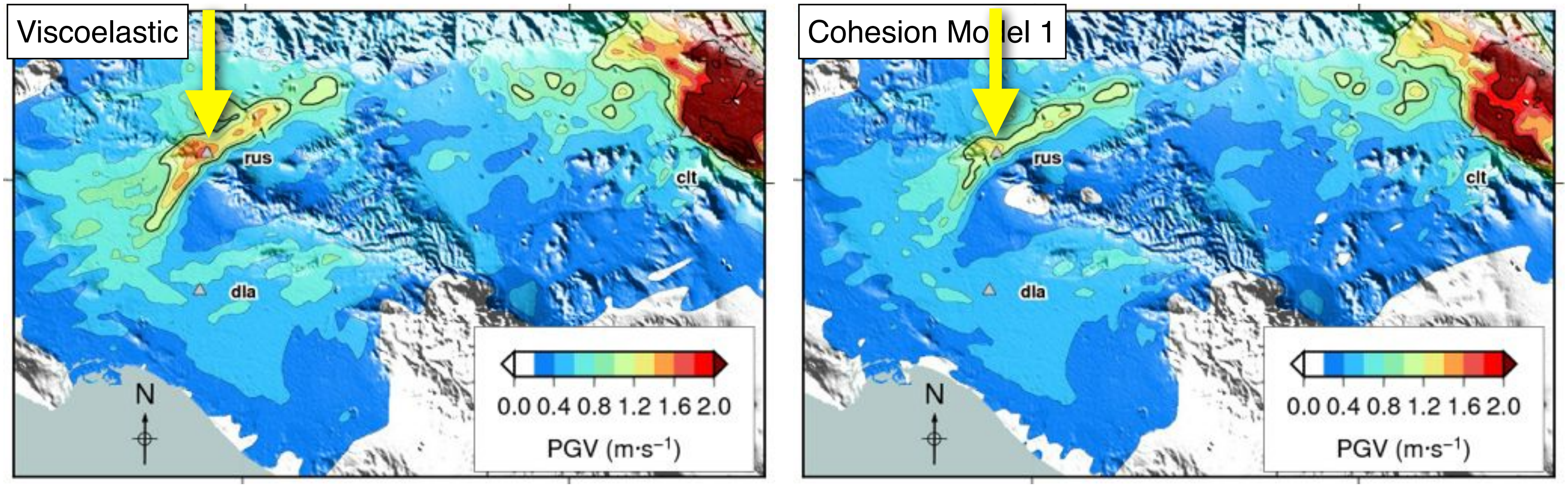
5. Infrastructure System Risk - Baker

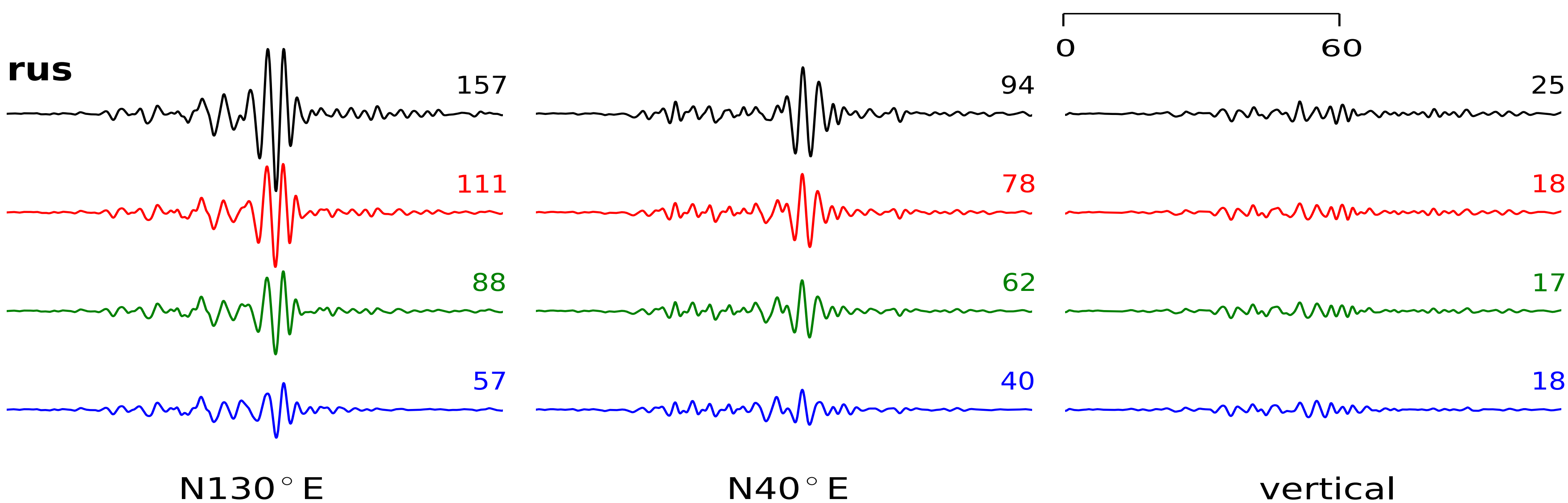
Reduce uncertainty in PSHA

- This can, in part, be done by turning aleatory uncertainty into epistemic uncertainty via improvements in our physical understanding and knowledge base
- Improve physics-based modeling techniques, and use techniques to get better constraints on and understanding of parameters

Nonlinear/Plastic Effects in GMP

Roten et al. (2014)

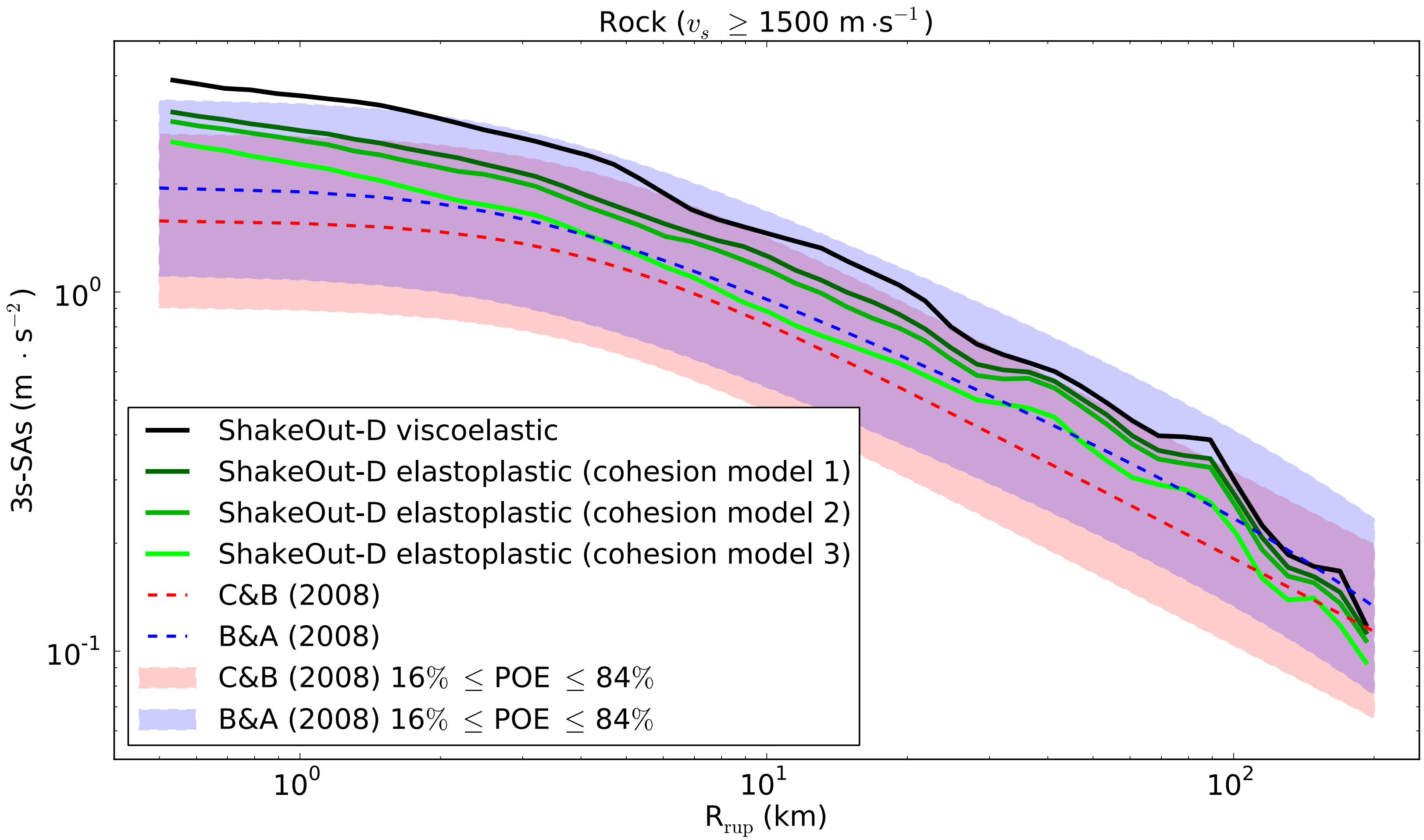




Nonlinear/Plastic Effects in GMP

g3d7 (rock sites, $v_{s0} \geq 1500$ m·s⁻¹)

Roten et al. (2014)



Nonlinear/Plastic Effects in GMP

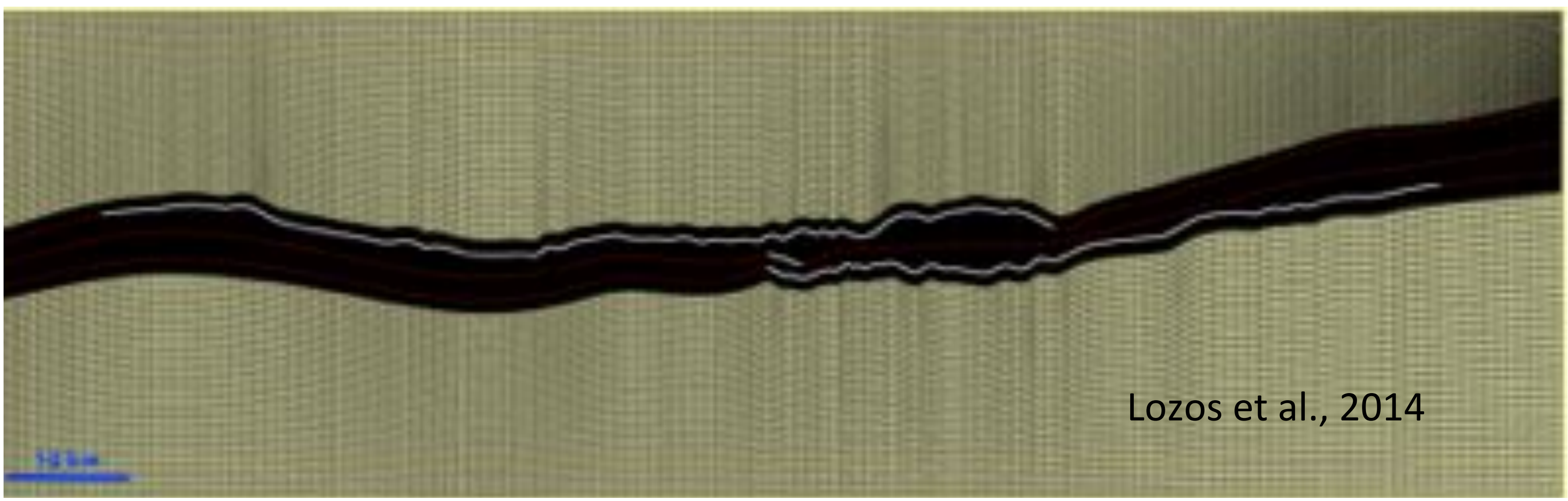
- Map and validate nonlinear/plastic effects for both long-period and short-period ground motions, realistic (dynamic) rupture conditions, magnitude, depth of burial, damage zones, and distance from fault
- Develop/consolidate community models for nonlinear rock/dynamic soil/stress properties. Use multi-cycle simulations to obtain realistic initial conditions

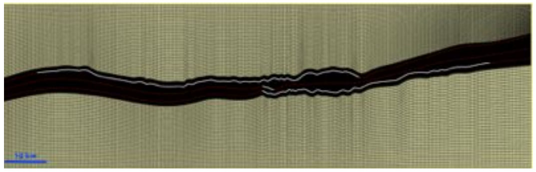
Ground Motion Effects of Complex Fault Rupture

Lozos et al., 2014

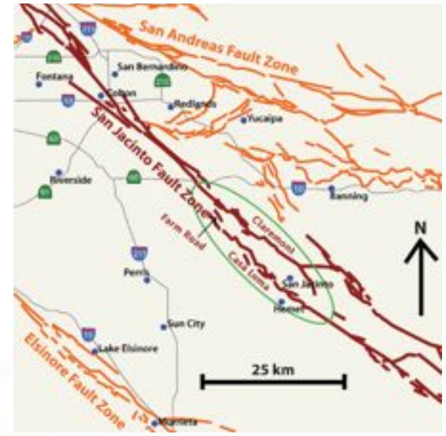
Ground Motion Effects of Complex Fault Rupture

- Unstructured Meshes
- Small dx near fault, surface, larger further away
- Accurate long-range wave propagation
- Efficient

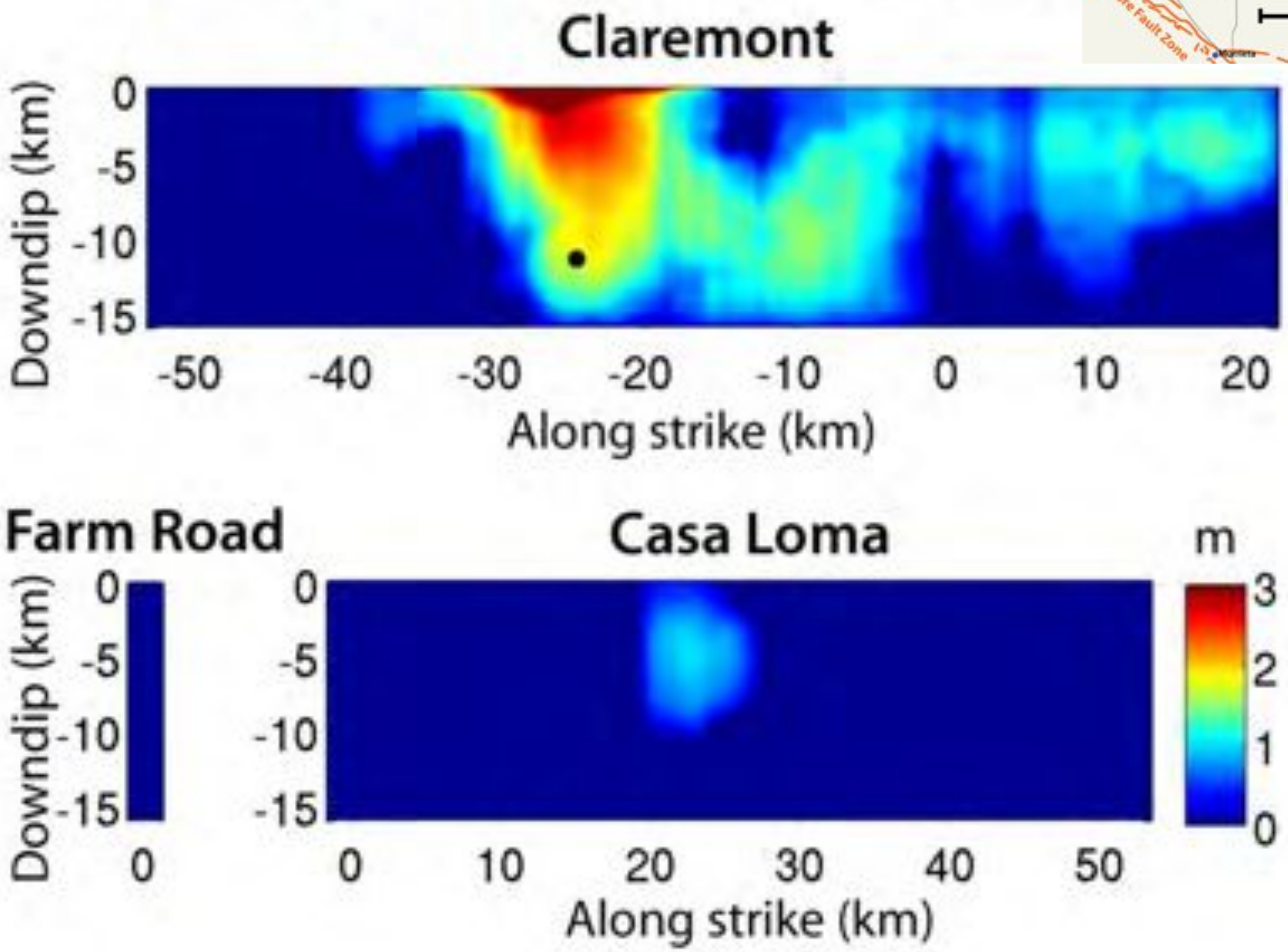




Stepovers



San Andreas Fault Zone
San Bernardino
Fontana
Colton
Redlands
Yucaipa
San Jacinto Fault Zone
Riverside
Banning
Farm Road
Claremont
Casa Loma
Perris
San Jacinto
Hemet
Sun City
Lake Elsinore
Elsinore Fault Zone
N
25 km

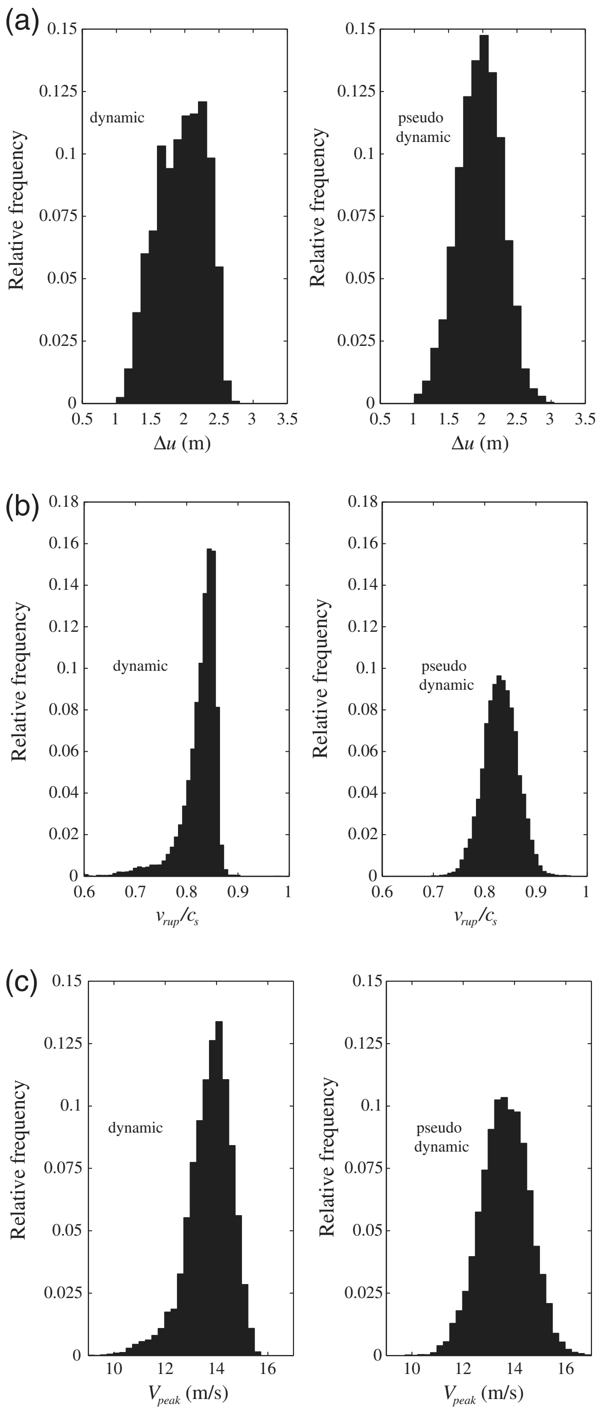


Claremont
Downdip (km)
0
-5
-10
-15
-50
-40
-30
-20
-10
0
10
20
Along strike (km)
Farm Road
Casa Loma
m
3
2
1
0
Downdip (km)
0
-5
-10
-15
0
0
10
20
30
40
50
Along strike (km)

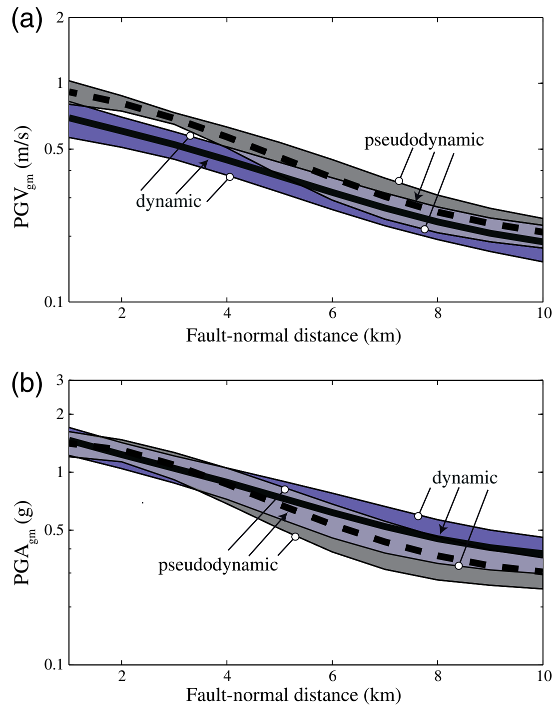
Efficient GM Modeling of Complex Fault Rupture and Wave Propagation

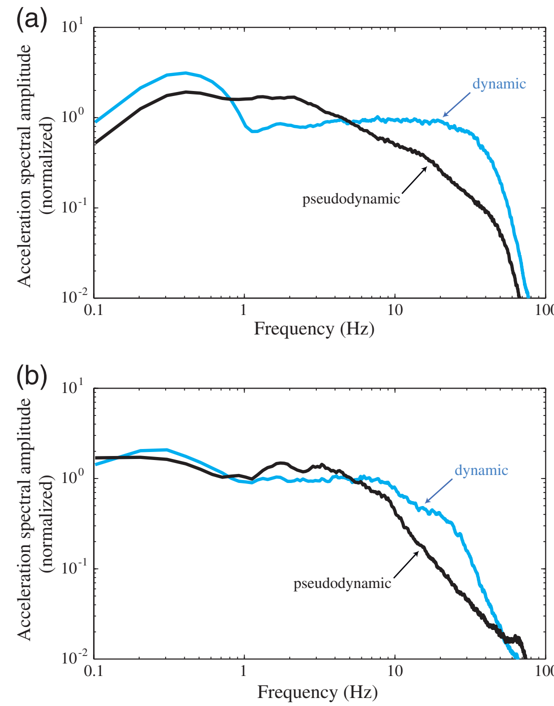
- Dynamic simulations of geometrically complex rough fault rupture propagation show promise for realistic modeling of acceleration spectra to higher frequencies (10Hz+)
- Mapping the ground motion effects of fault stepovers, rupture jumps, rupture from a main rupture plane to secondary (splay) faults in 3D. How much moment goes with each segment, time delay at segment interfaces, etc
- Develop efficient numerical method(s) that propagate waves to long distances with minimal dispersion errors and meshing techniques handling complex geometries
- Use multi-cycle simulations to obtain realistic initial conditions

Next-generation pseudo-dynamic rupture generators

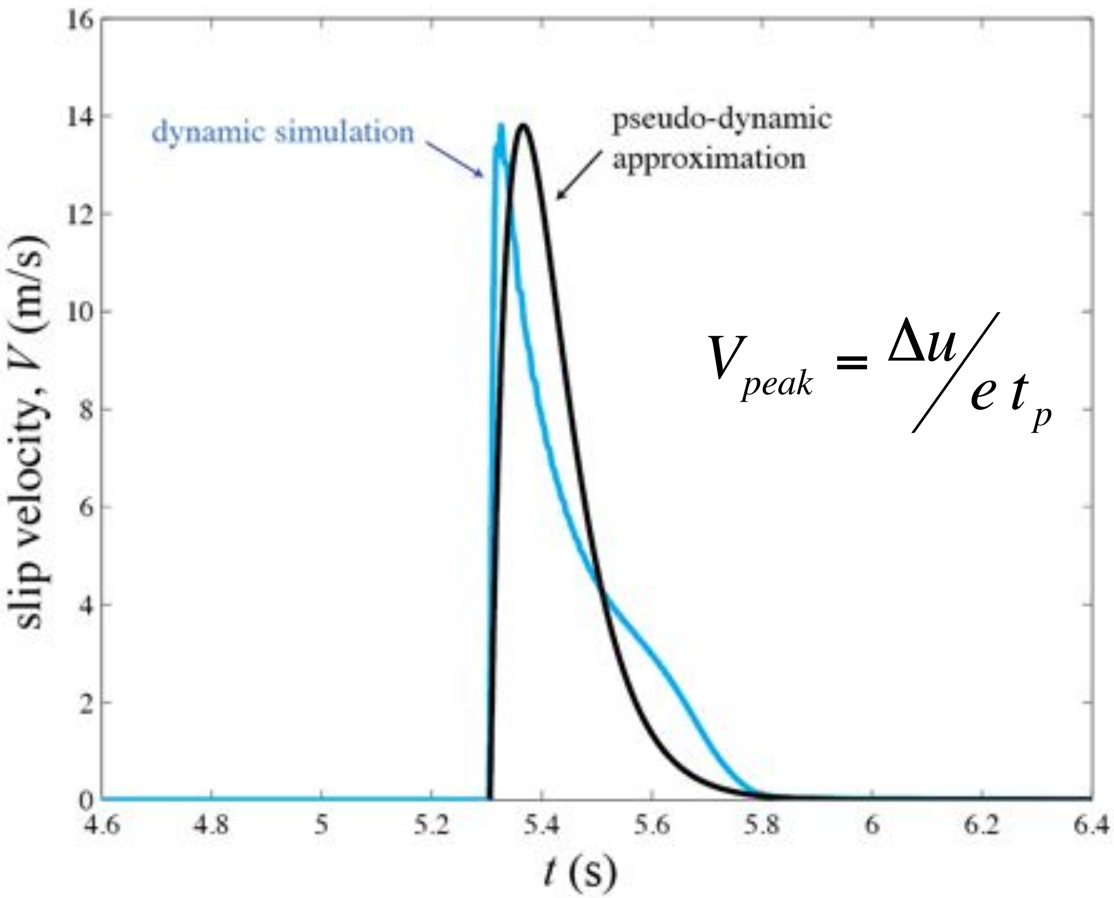


Trugman and Dunham (2014)





Next-generation pseudo-dynamic rupture generators

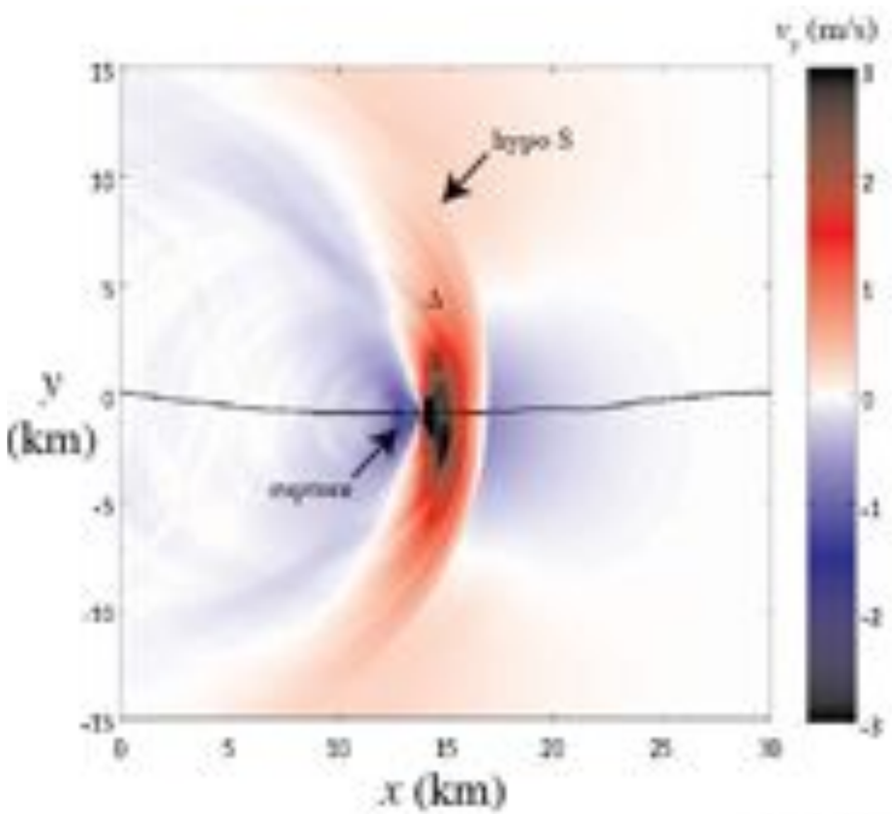


$$V_{peak} = \Delta u / e\, t_p$$

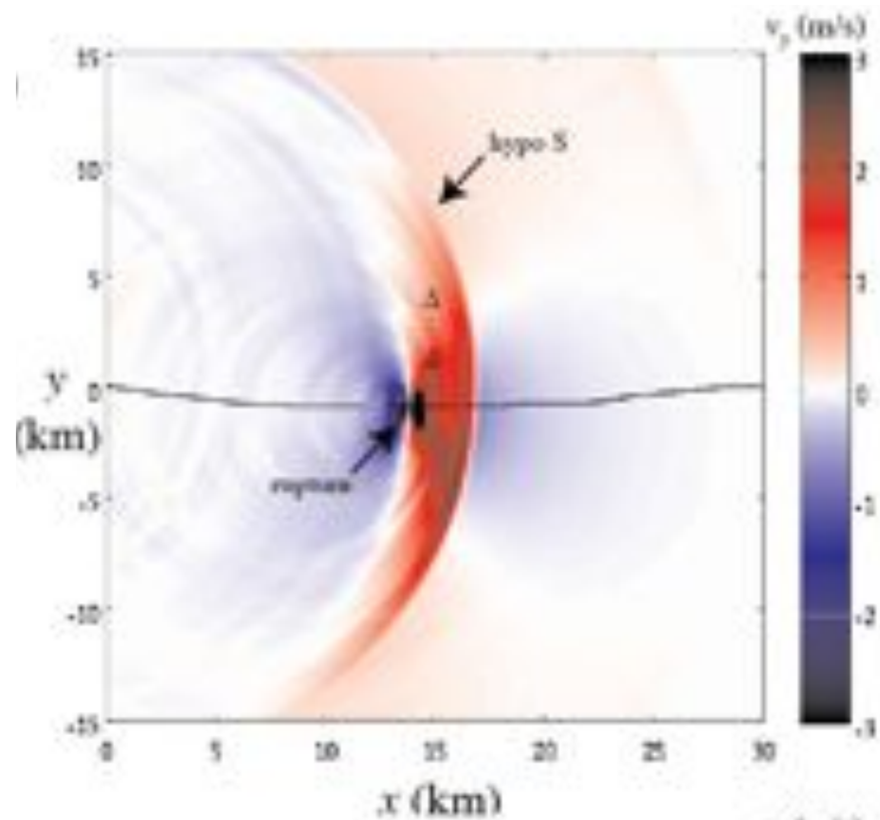
$$V(t) = \frac{\Delta u}{t_p}\left(t/t_p\right)\exp\left(-t/t_p\right)$$

Trugman and Dunham (2014)

Next-generation pseudo-dynamic rupture generators



dynamic simulation



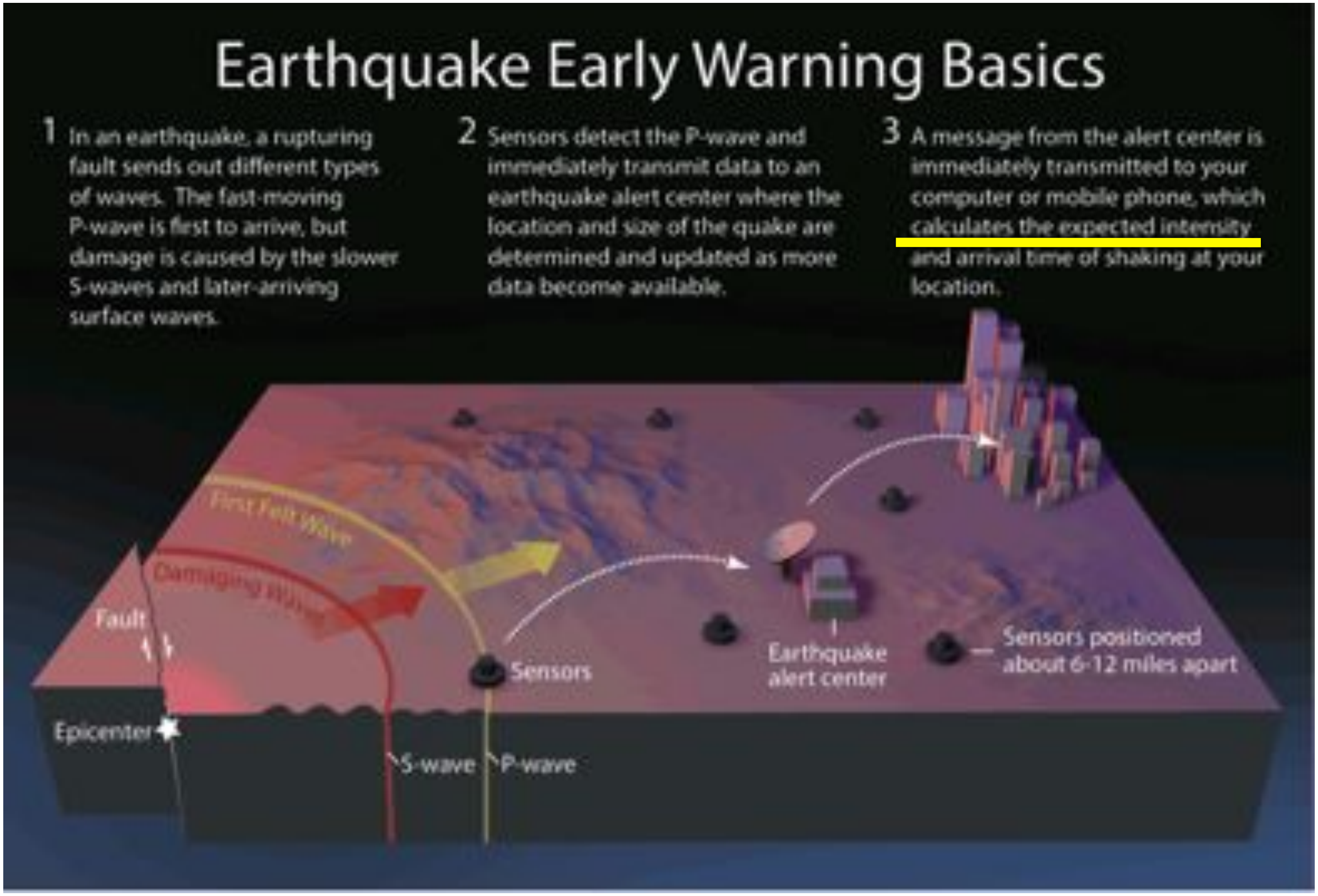
pseudo-dynamic simulation

Trugman and Dunham (2014)

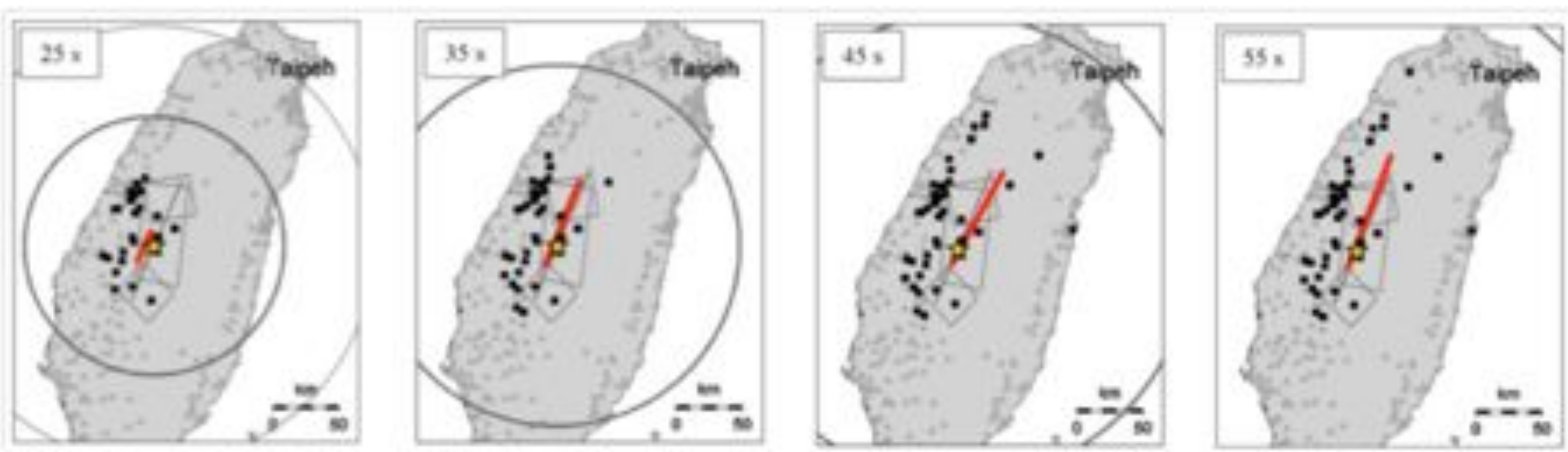
Develop next-generation pseudo-dynamic rupture generators

- Capture the nonlinear and complex fault rupture effects in a form that can be used on SCEC platforms such as CyberShake and BBP. Develop equivalent kinematic implementations that capture first-order effects of these features
- This ensures that engineers are kept in the loop, including easy access to building performance assessment, in line with the current SCEC Utilization of Ground Motion Simulation Committee

EEW


Earthquake Early Warning Basics
1 In an earthquake, a rupturing fault sends out different types of waves. The fast-moving P-wave is first to arrive, but damage is caused by the slower S-waves and later-arriving surface waves.
2 Sensors detect the P-wave and immediately transmit data to an earthquake alert center where the location and size of the quake are determined and updated as more data become available.
3 A message from the alert center is immediately transmitted to your computer or mobile phone, which calculates the expected intensity and arrival time of shaking at your location.
First Felt Wave
Damaging Wave
Fault
Sensors
Earthquake alert center
Sensors positioned about 6-12 miles apart
Epicenter
S-wave
P-wave

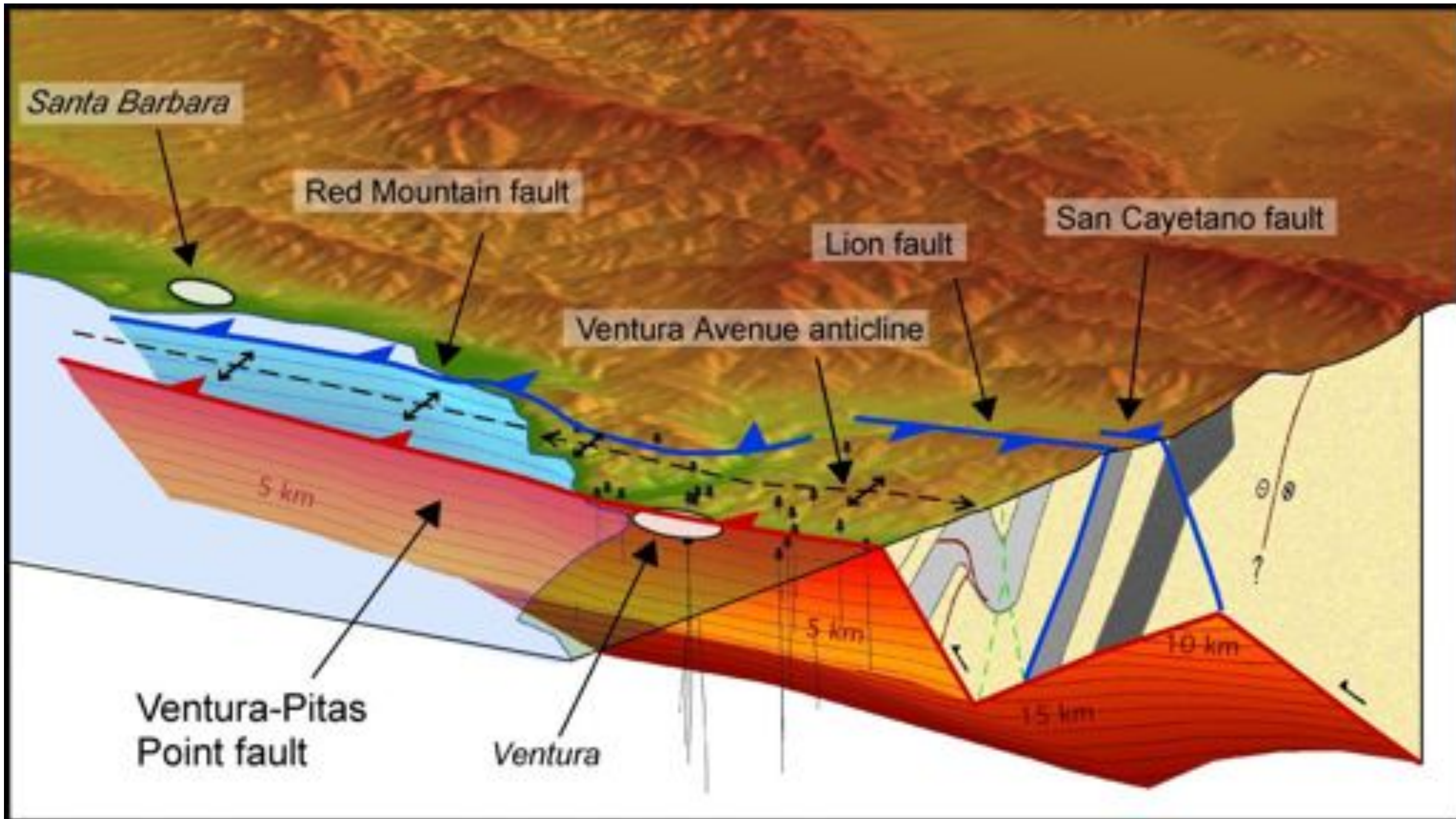
Finite Fault Effects

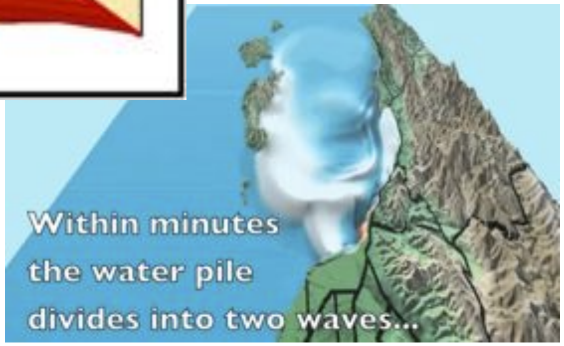


Earthquake Early Warning

- EEW consists of both alert and ground motion prediction for specific locations. The ground motion prediction is currently limited in accuracy from the methodologies available (point sources, GMPEs)
- SCEC has the capabilities for reducing the uncertainty in the ground motion calculation and providing better ways of predicting ground motions for EEW

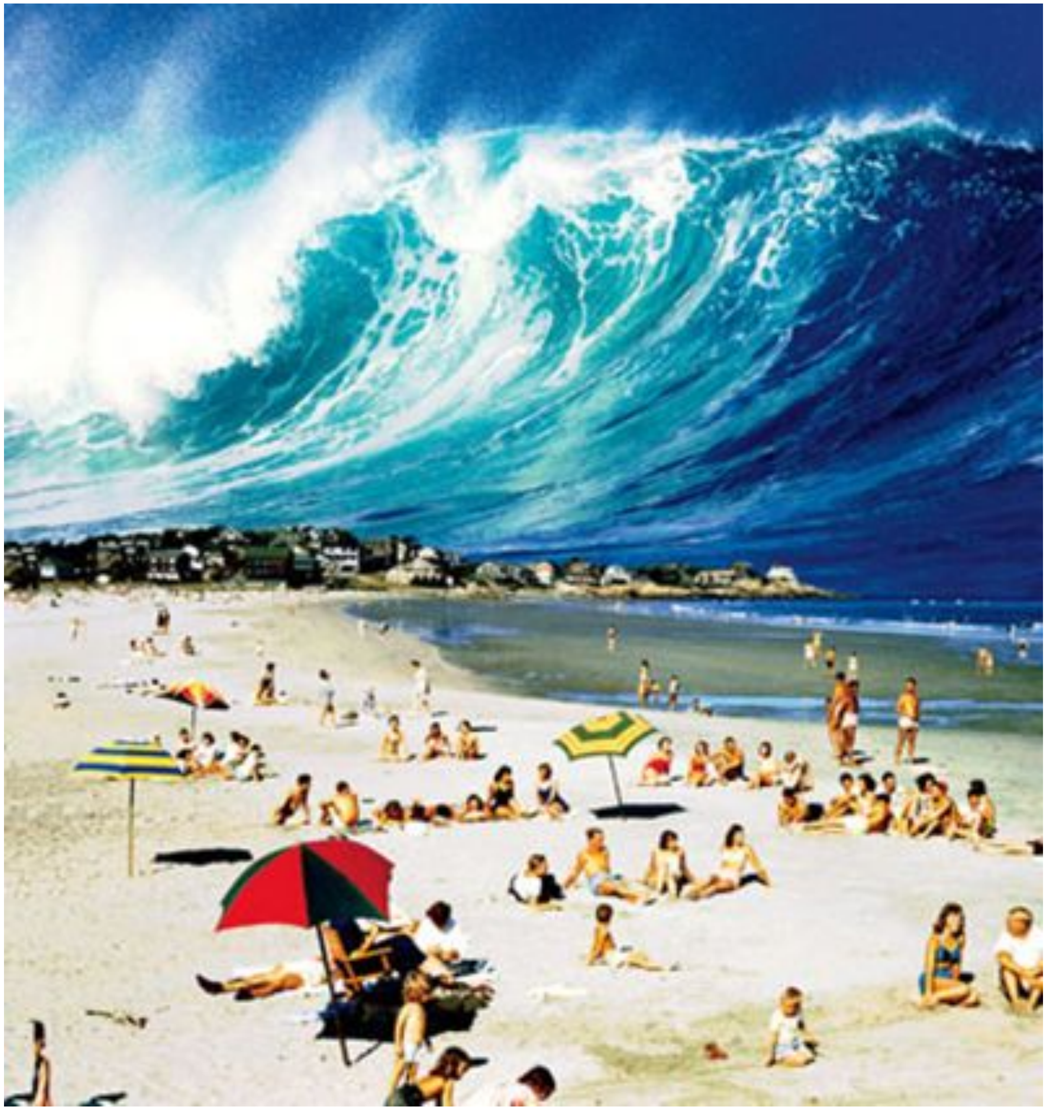
Tsunami Modeling





- Need to generate state-of-the-art tsunami code in SCEC
- Ventura SFSA

Tsunami Modeling



- Add gravity elasto-dynamic modeling codes
- Inundation
- Realistic initial conditions

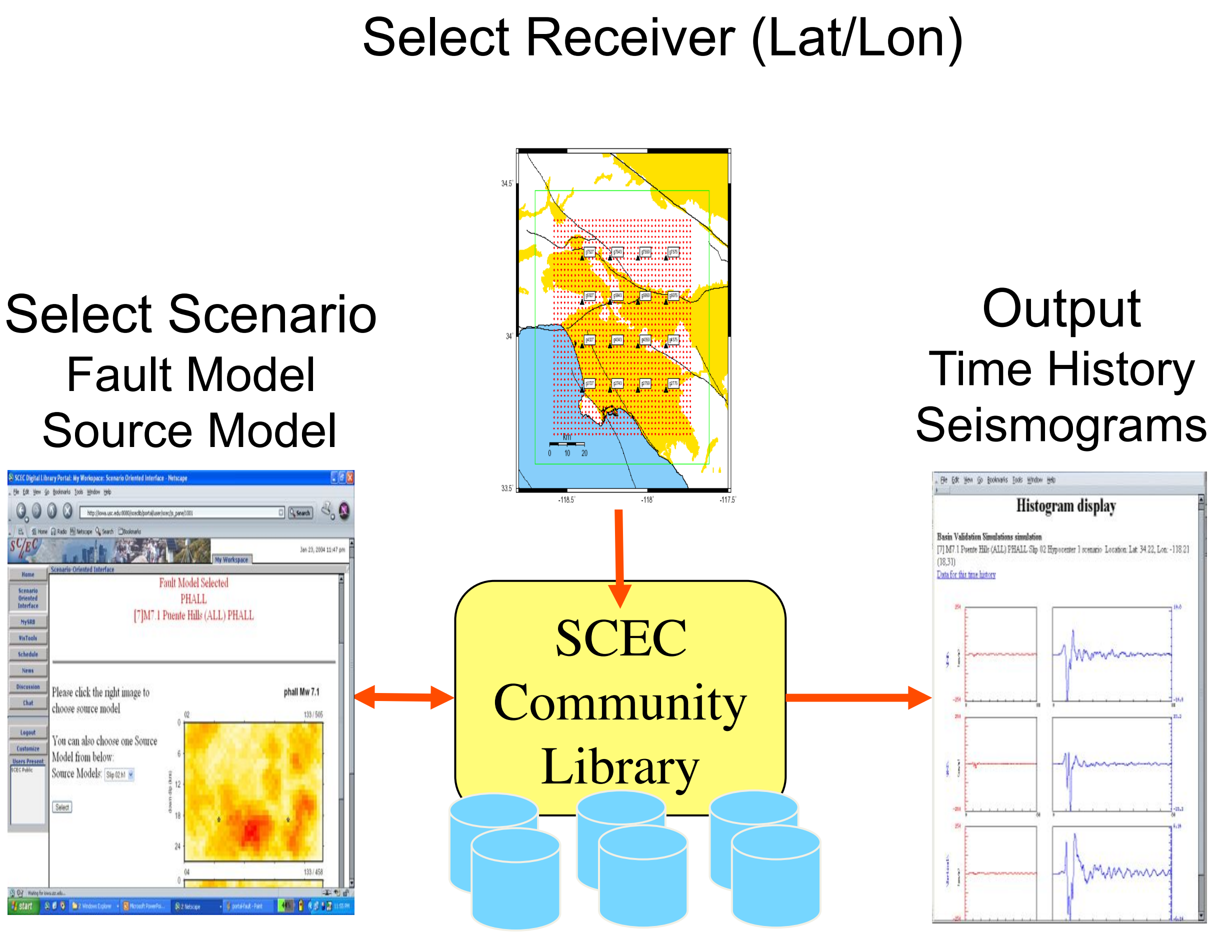
Tsunami Modeling

- Develop software to model tsunamis
- Inundation
- Handle more realistic initial conditions

Summary and Additional Topics

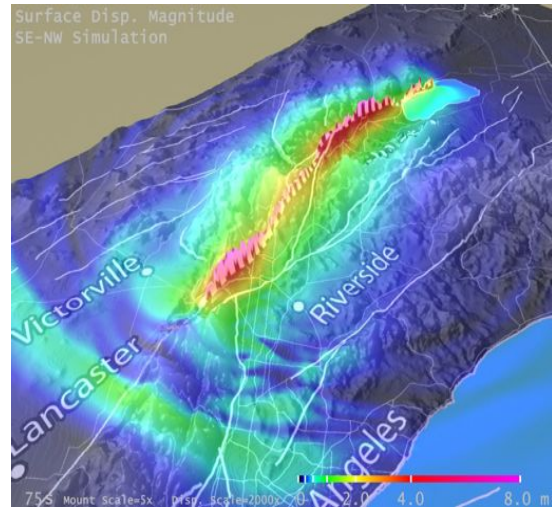
- Nonlinear/plastic Effects on GMP
- Efficient GM Modeling of Complex Fault Rupture and Wave Propagation
- Pseudo-dynamic source generator
- Tsunami modeling code
- Earthquake Early Warning
- Urban Seismic Hazard Maps, i.e., hazard maps such as CyberShake products on a smaller, refined scale (e.g,. Los Angeles downtown, dx~10^2 m)
- Induced seismicity and its relation to ground motion hazards in southern California (and beyond). Induced seismicity relation to stress transfer in the crust? How is PSHA affected by induced seismicity?
- ShakeMap. SCEC has the capabilities for improving these calculations tremendously by 3D physics-based (or deterministic-stochastic hybrid) calculation of the ground motion intensities
- Determine upper limit for simulating deterministic high-frequency wave propagation. What are the best metrics to check the simulations against data? Using those metrics, above which frequency will the stochastic nature of faulting and surrounding media prevent acceptable fits?
- Data management. What is the best way to store and preserve simulation output (time series, snapshots, movies), that otherwise gets lost with time
- Generate and demonstrate the use of standards for updating and validating the 3D SCEC CVMs contained in UCVM

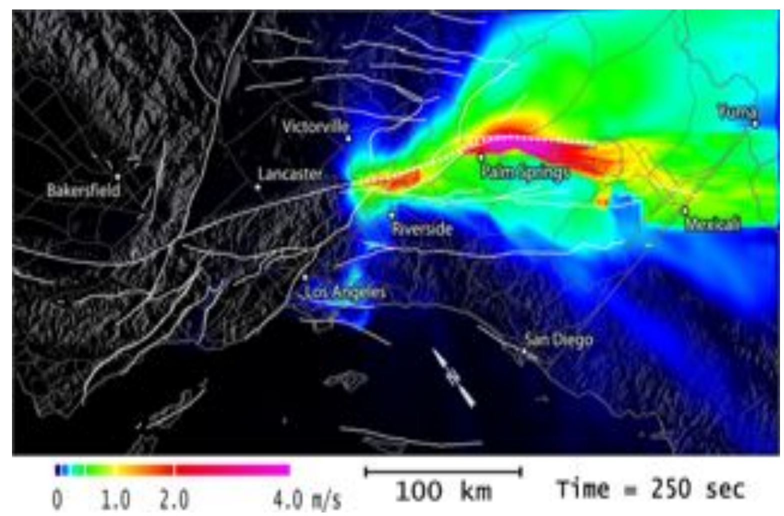
SCEC Digital Library



Terashake Data Handling

- Simulate 7.7 magnitude earthquake on San Andreas fault
  - 50 Terabytes in a simulation
  - Move 10 Terabytes per day
- Post-Processing of wave field
  - Movies of seismic wave propagation
  - Seismogram formatting for interactive on-line analysis
  - Velocity magnitude
  - Displacement vector field
  - Cumulative peak maps
  - Statistics used in visualizations
  - Register derived data products into SCEC digital library





EEW – GMP Improvement