Kinematic Rupture Generator

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- Graves and Pitarka (2004, *13WCEE*)
- Graves and Pitarka (2010, *BSSA*)
- Available on SCEC Broadband Simulation Platform
  http://scec.usc.edu/scecpedia/Broadband_Platform

- **Required Inputs**
  - Seismic moment (magnitude)
  - Location and dimensions (length, width, depth, segmentation)
  - Geometry (strike, dip, rake)
  - Hypocenter
- **Additional (region specific)**
  - Local seismic velocity structure
  - Magnitude-Area scaling
  - Corner frequency

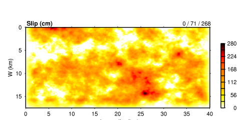
Kinematic Rupture Description

Given a specified fault and hypocenter, a complete kinematic rupture description gives the slip vector as a function of time for all points on the fault surface: **slip**(*x,y,z,t*)

Generation process guided by rupture model inversions of past EQs and dynamic rupture simulations of hypothetical EQs

Scaling relations
and Correlations

Final Slip: D(x,y,z)



Rupture Propagation Time

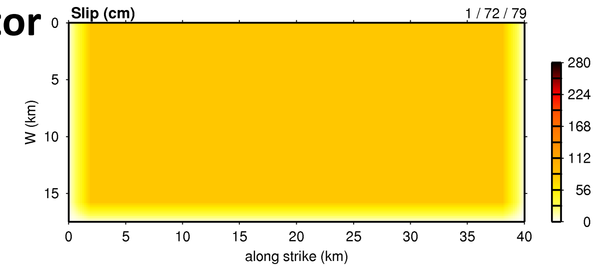
Slip Rate Function

Slip Orientation (rake)

Kinematic Rupture Generator

Scenario Earthquake

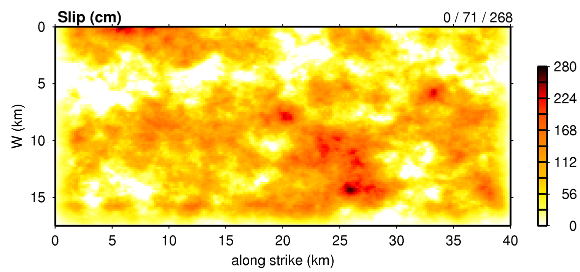
- Begin with uniform slip having mild taper at edges.

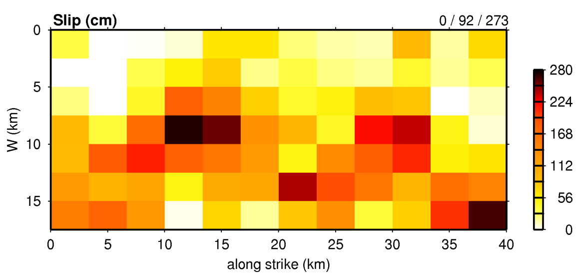


- Use Mai and Beroza (2002) spatial correlation functions (M_w dependent, K^{-2} falloff) with random phasing to specify entire wavenumber spectrum.

  Standard deviation of slip set to 85% of mean value:

  $\sigma_s = 0.85 \cdot D_{avg}$

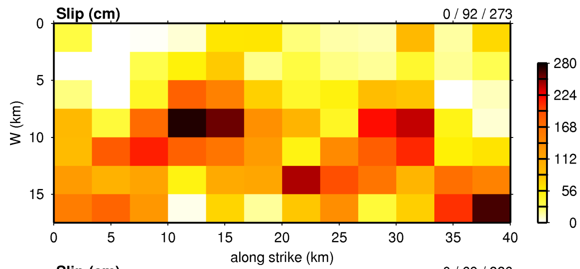




Validation Earthquake

- Validation events begin with coarse representation from slip inversion.

e.g., Loma Prieta, Wald et al (1991)



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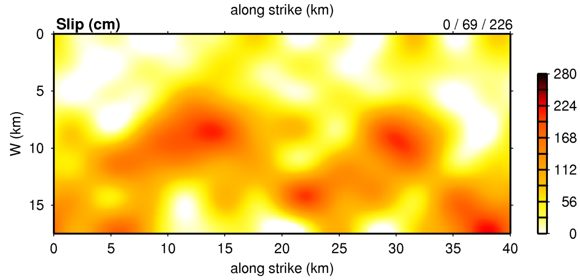
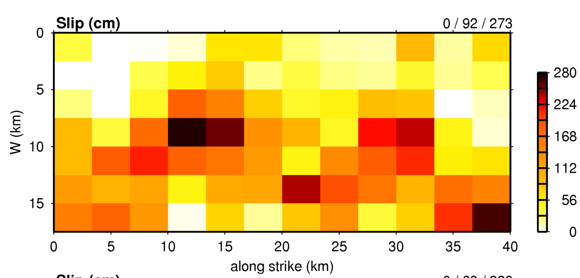


- Low-pass filter to retain only long wavelength features. Preserves gross asperity locations.



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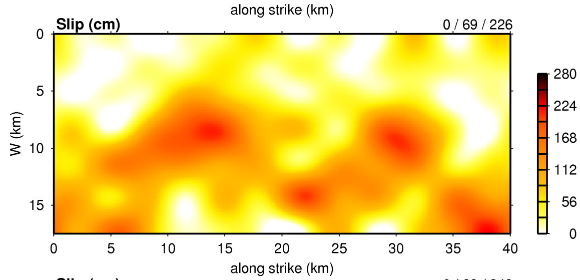

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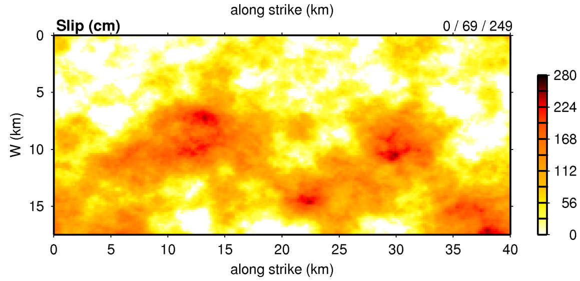


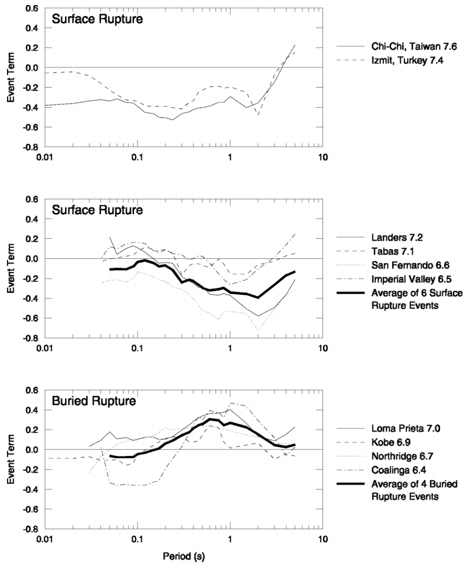
- Extend to fine grid using Mai and Beroza (2002) spatial correlation functions with random phasing for shorter wavelengths.

  And $\sigma_s = 0.85 \cdot D_{avg}$

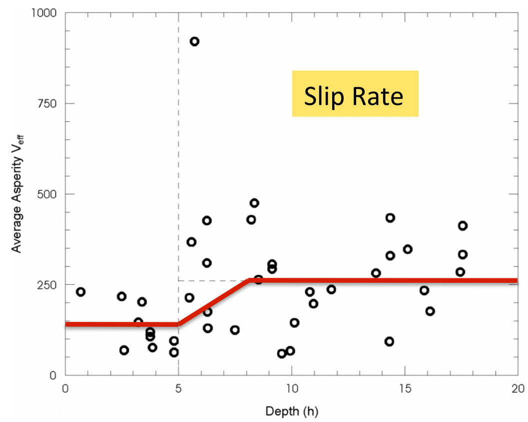
Differences in Shallow and Deep Rupture

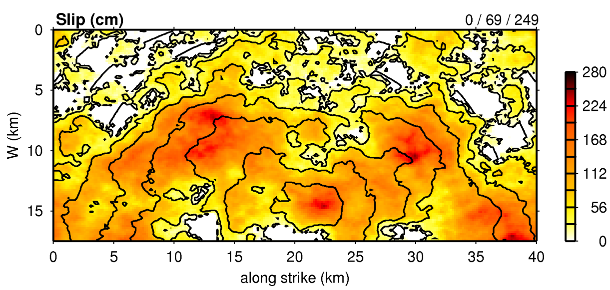
Kagawa et al. (2004)

Active Regions



- Ground Motions for shallow rupture less than deep rupture (on average)
- Rupture speed and slip rate decreased in upper 5 km
- Dynamically modeled with weak shallow portion of fault





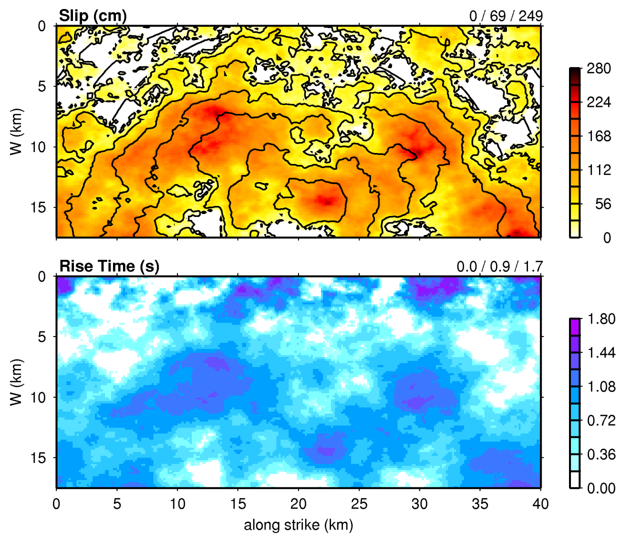
Rupture Initiation Time

$T_i \; = r / V_r - \delta t(D)$

V_r = 80% local V_s depth > 8 km
= 56% local V_s depth < 5 km
linear transition between 5-8 km

δt scales with local slip (D) to accelerate or decelerate rupture

$\delta t(D_{avg}) = 0$



Rise Time

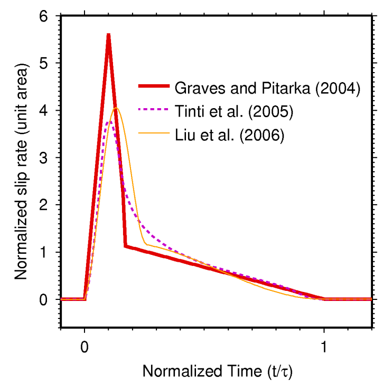
$\tau = k \cdot D^{1/2}$ depth > 8 km

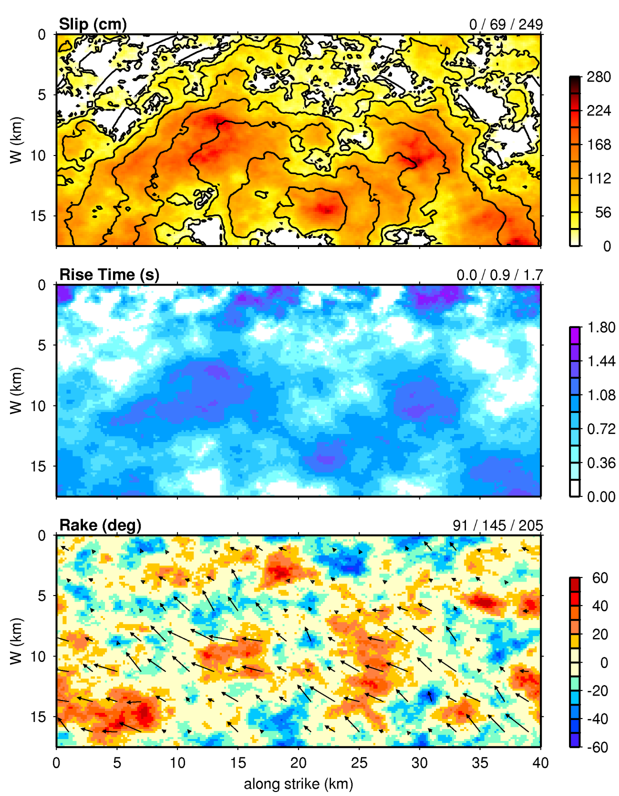
$= 2 \cdot k \cdot D^{1/2}$ depth < 5 km

linear transition between 5-8 km

Scales with square root of local slip (D) with constant (k) set so average rise time is given by the Somerville et al (1999) relation:

$\tau_A = 1.6e\text{-}09 \cdot M_o^{1/3}$





Rake

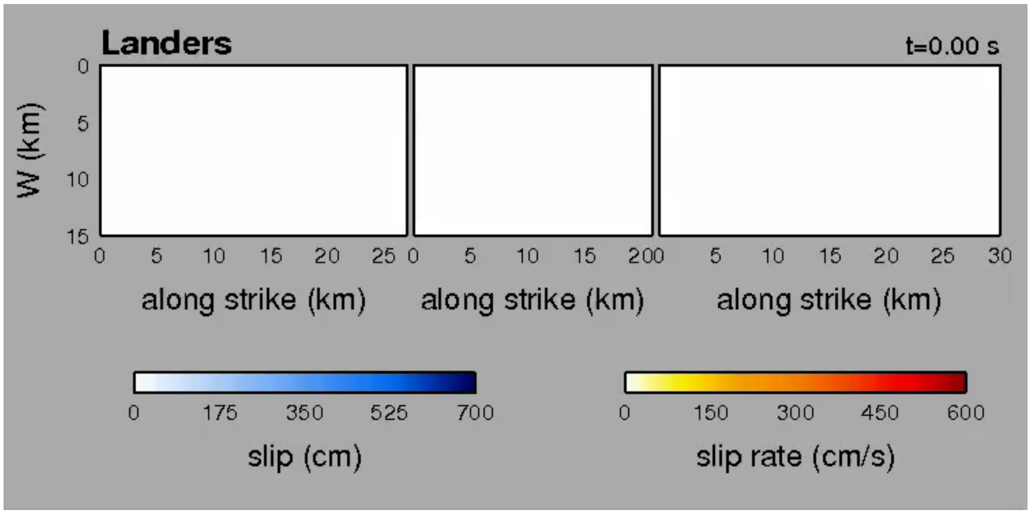
$\lambda = \lambda_o + \varepsilon \qquad \sigma_\varepsilon = 15^o$

$-60^o < \varepsilon < 60^o$

Random perturbations of rake follow spatial distribution given by K^{-2} falloff.

1992 Landers EQ:

- **Multi-segment jumps (rupture delay)**
- **Shallow rupture effects**

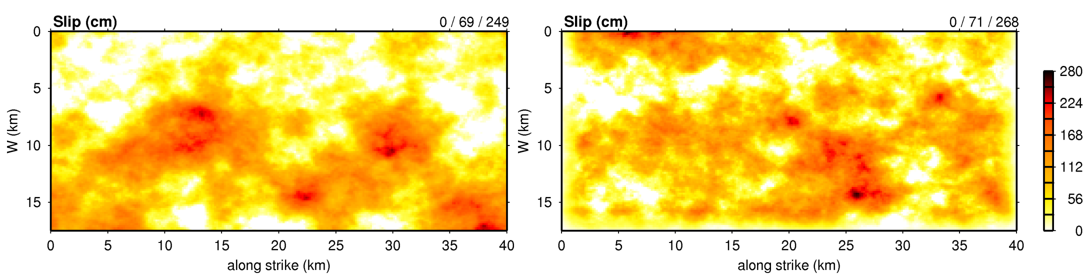


Limitations

- Not guaranteed to satisfy underlying physical constraints.
- Most experience and testing (validation) of kinematic rupture generators has been with EQs from Active Tectonic Regions.

  Stress Parameter SCR/TCR: 2.6 Rise Time SCR/TCR: 0.54
- The generators are designed/calibrated to produce “median” values, particularly with respect to rupture velocity and rise time. For example, in a given realization rupture velocity averaged over the fault is 0.8 Vs, but how often does a rupture with an average of 0.9 Vs occur?
- Current implementation has direct (1:1) correlation of rupture speed perturbations with slip and rise time perturbations with square root of slip (better to sample PDFs).

Validation Earthquake   Scenario Earthquake



- Rupture generator produces "realistic" slip distributions: Mai and Beroza (2002) correlation functions are derived from slip inversions of past earthquakes.
- Can also be applied to synthetic rupture models: Pseudo-dynamic approach (e.g., Guatteri et al., 2004).

Some Recently Proposed Methods:

- Bykovtsev and Kramarovskii (1987 in Russian, 1988)
- Frankel (1991), Frankel (2009)
- Zeng, Anderson and Yu (1994)
- Guatteri, Mai and Beroza (2004)
- Graves and Pitarka (2004), Graves and Pitarka (2010)
- Liu, Archuleta and Hartzell (2006), Schmedes, Archuleta and Lavallee (2010)
- Song and Somerville (2010)
- Aagaard, Graves, Schwartz, Ponce and Graymer (2010)

Kinematic Rupture Generator

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- **Kinematic Rupture Description**
  - Parameters
  - Inputs
- **Review of (some) Methods**
- **Assessment of Methods**
  - Sufficiently validated
  - Adequate for CEUS
  - Availability