Future CyberShake

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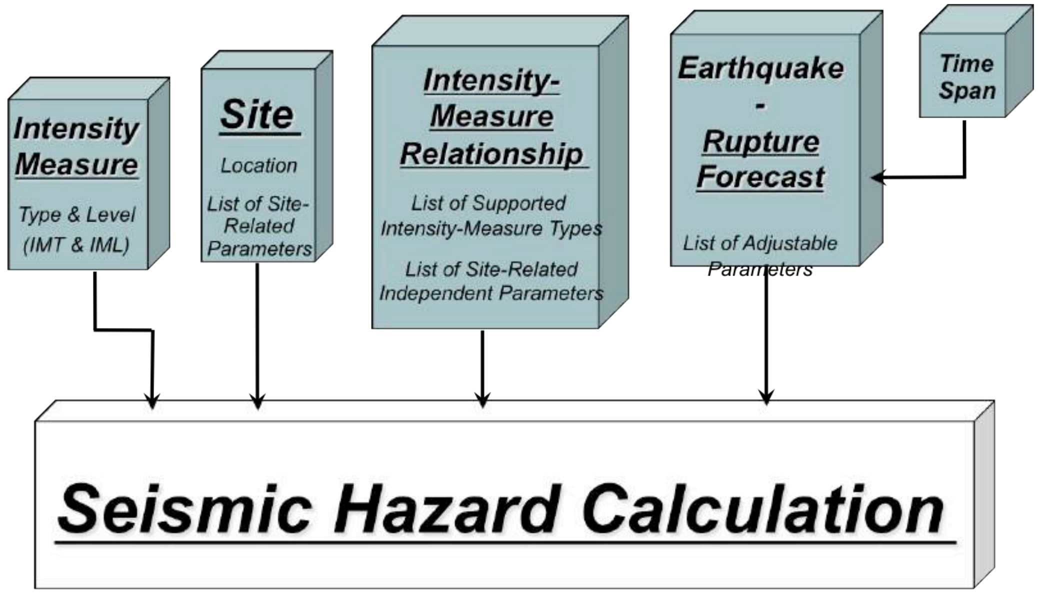
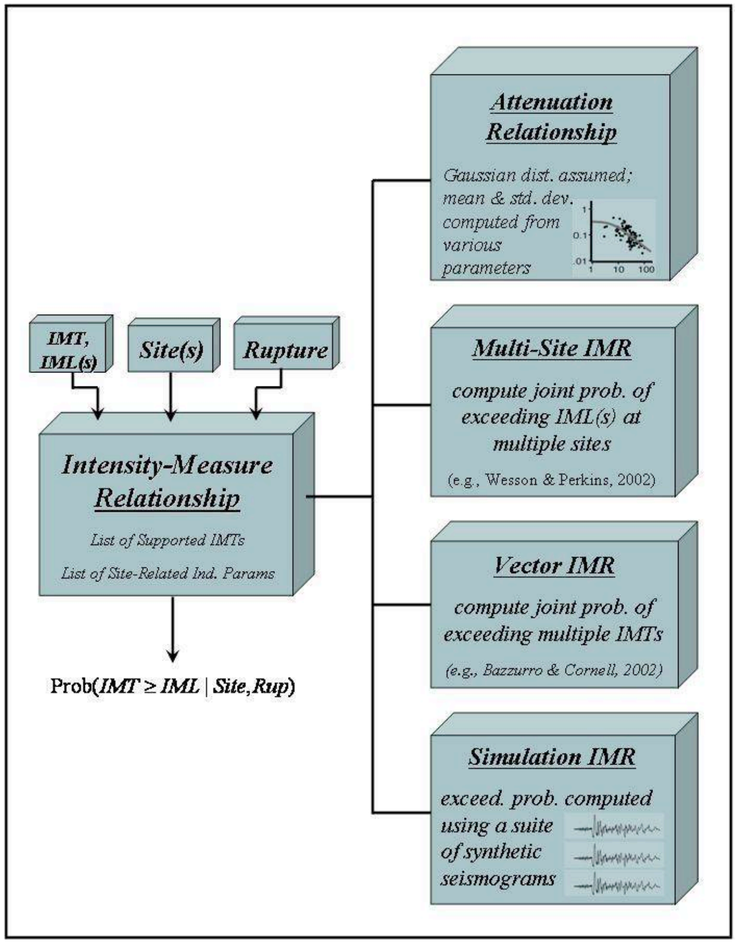
SCEC

Southern California Earthquake Center

Using Scientific Computing to Improve Probabilistic Seismic Hazard Analysis (PSHA)

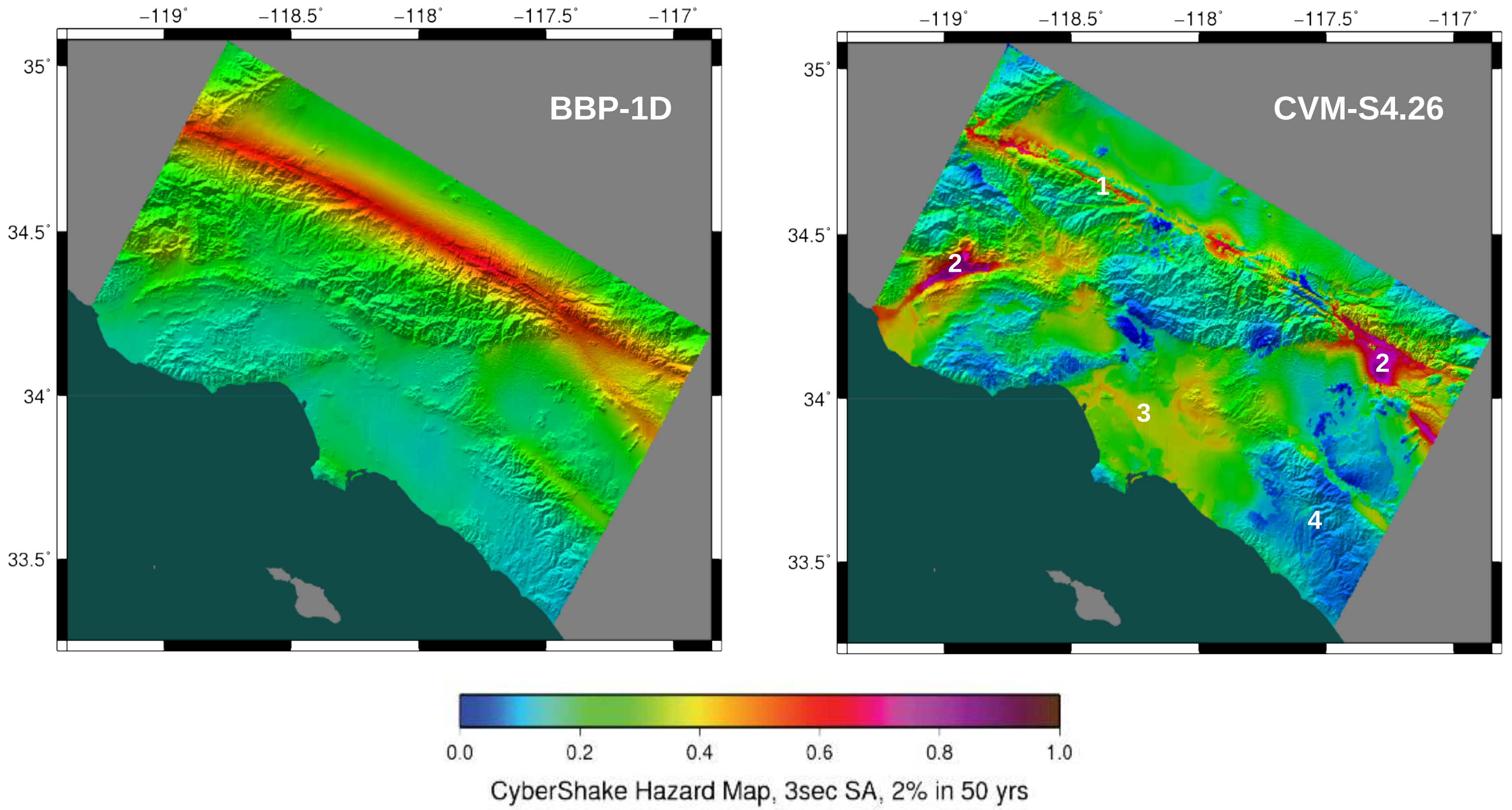




Types of Intensity Measure Relationships

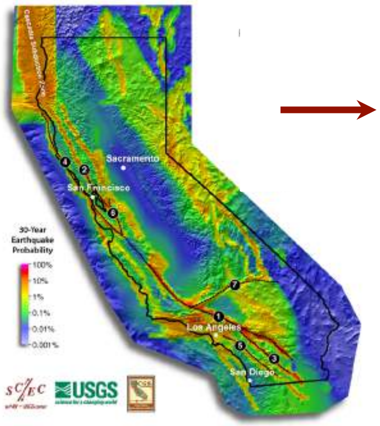
Southern California Earthquake Center

Comparison of 1D and 3D CyberShake Models for the Los Angeles Region



1. **lower near-fault intensities due to 3D scattering**
2. **much higher intensities in near-fault basins**
3. **higher intensities in the Los Angeles basins**
4. **lower intensities in hard-rock areas**

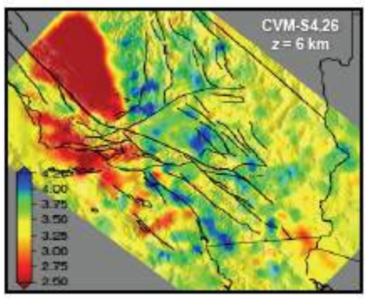
CyberShake Workflow



Uniform California Earthquake Rupture Forecast

→ **UCVM** → **AWP-ODC** → **SeisSynth** → *data transfer* → **Data Product Generation**

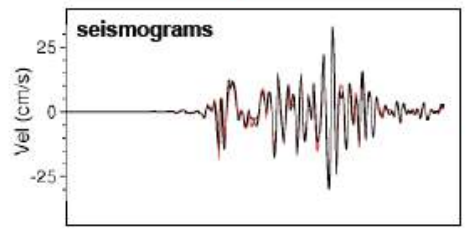
UCVM
Mesh generation
1 job per site
MPI, 320 cores



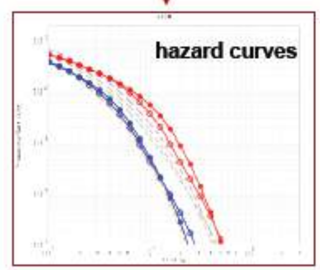
Full-3D tomographic model of S. California

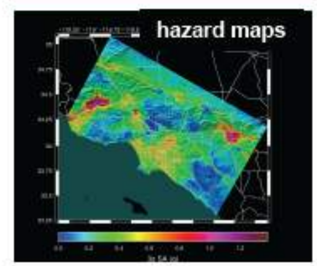
AWP-ODC
SGT computation
2 jobs per site
MPI, 10k CPUs or 100 GPUs

SeisSynth
Post-processing
415,000 jobs per site
serial



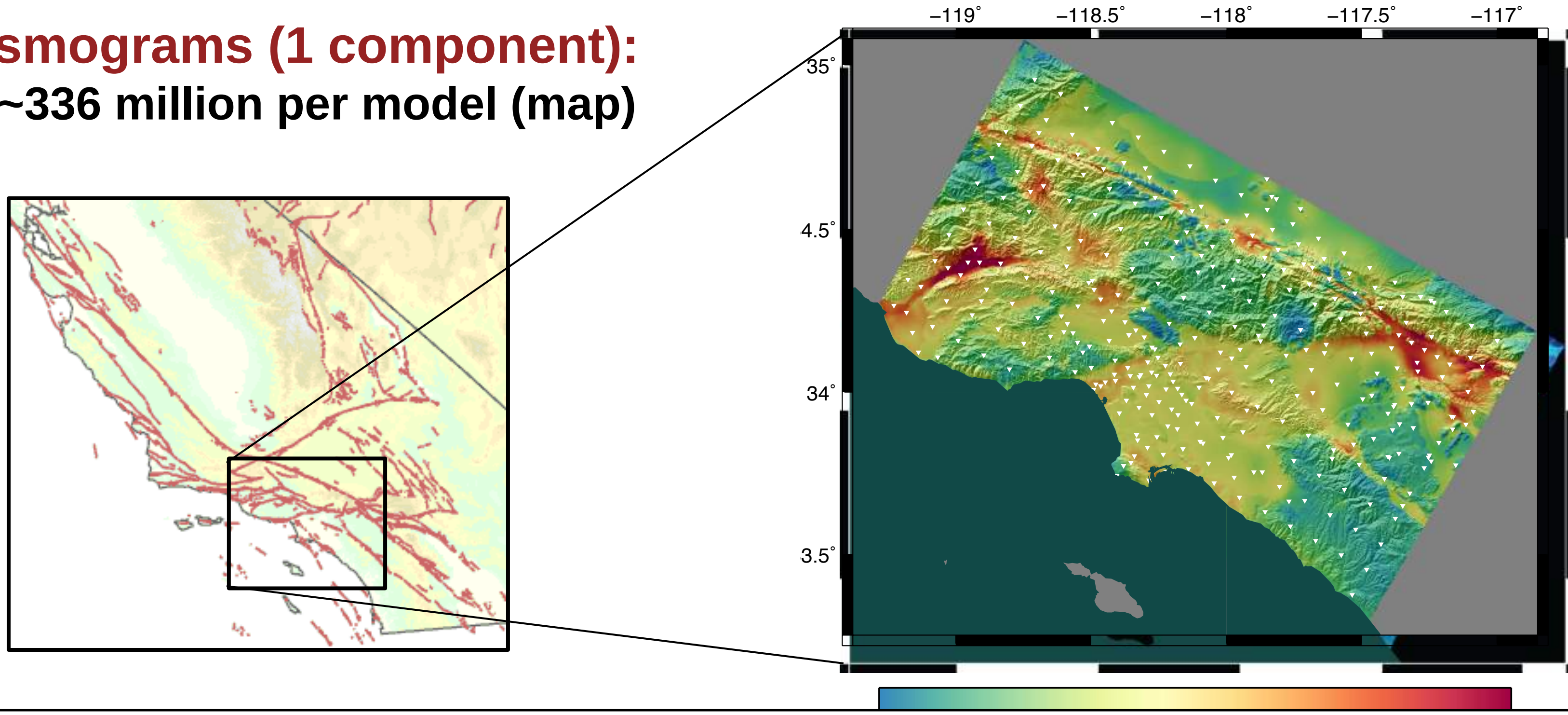
Data Product Generation
Populate DB, construct queries
4 jobs per site



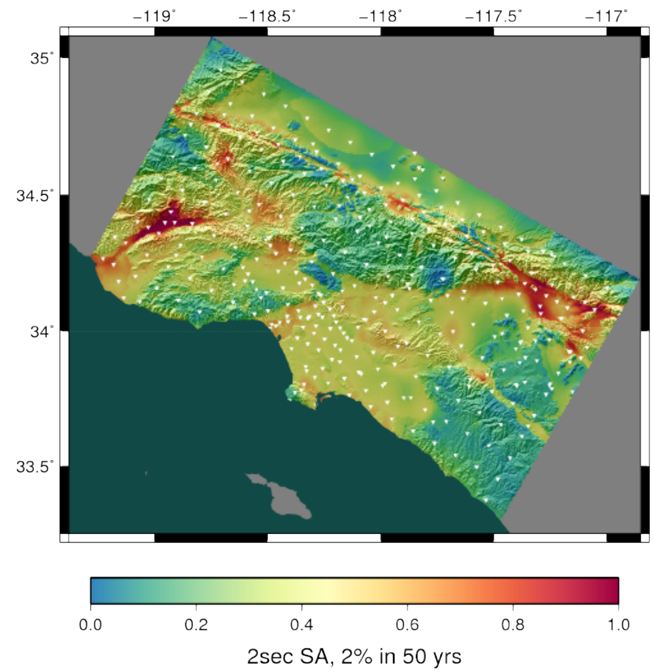


CyberShake 15.4 Hazard Model for the LA Region

- **3D crustal model:**
  - **CVM-S4.26**
- **Sites:**
  - **336 sites in the greater Los Angeles region**
- **Ruptures:**
  - **All UCERF2 ruptures within 200 km of site (~14,900)**
- **Rupture variations:**
  - **~500,000 per site using Graves-Pitarka pseudo-dynamic rupture model**
- **Seismograms (1 component):**
  - **~336 million per model (map)**



CyberShake Study 15.4 Results



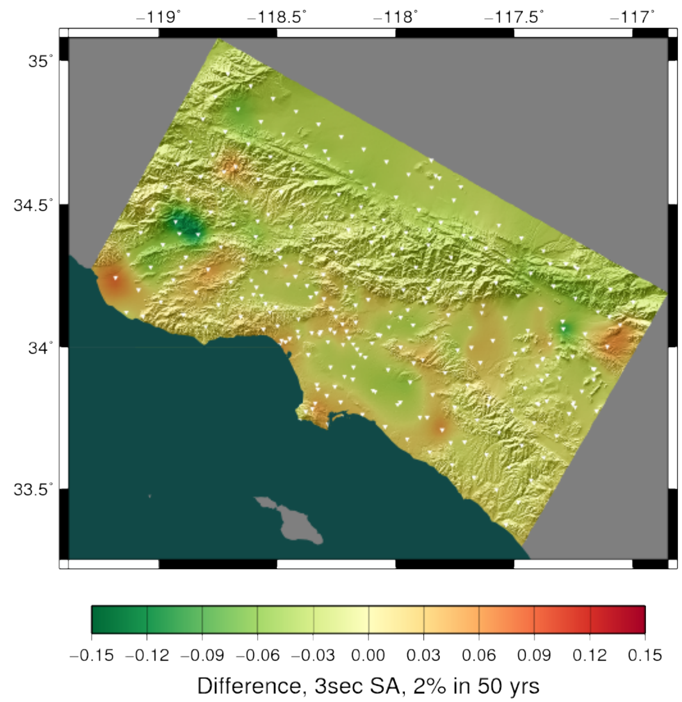


Fig1: CyberShake hazard model PSA2.0s 2% in 50 years

Fig2: Study 15.4 vs Study 14.2, 3 sec geometric mean, difference map. Warm colors are higher Study 15.4.

Advances in CyberShake Hazard Model 15.4

(1) Increased the frequency of simulation to 1.0 Hz

(2) Integrated a new rupture generator and introduced a regular distribution of hypocenters on faults

(3) RotD50 and RotD100 are calculated automatically, as part of the workflow

(4) Increased the frequency of the SGT source filter, to reduce rolloff at frequencies of interest

(5) Expanded the number of sites from 286 to 336.

Recent and Current CyberShake Activities

1. Completed 1Hz UCERF2 for Los Angeles as CyberShake Study 15.4
2. Verifying calculation of Risk-Targeted Maximum Considered Earthquake Response Spectra (MCER) using CyberShake seismograms.
3. Calculating 485K two-component BBP seismograms from UCERF2 rupture variations at 5 CyberShake sites by combining 1Hz LF 3D CyberShake seismograms with G&P HF seismograms
4. SEISM2 objective include running 3D CyberShake SGTs as 3D Low Frequency BBP Seismograms
5. Coupling CyberShake and UCERF to forecast time dependent ground motions
6. Running a 1.5Hz UCERF2 for LA within computational limitations

CyberShake Planning

Target:

- **CyberShake hazard model at 1.5Hz-2Hz based on UCERF3**

Development Approach:

- **Perform CyberShake hazard model calculation for Southern California with CVM-S4.26**
- **Next, perform Central California with Central California Area (CCA) CVM (under-development)**

CyberShake Scientific and Technical Challenges

(1) Standard verification process for CyberShake results before public release

(2) Near fault plastic yielding

(3) Non-linear site response

(4) UCERF3 Multi-fault ruptures

(5) UCERF3 low-probability very large ruptures

(6) Distribution of hazard model

(7) Distribution of computational system

Proposed Solutions: Challenges

(1) Standard verification process for CyberShake results before public release
  (1) Computational checks and ABF analysis prior to publishing
(2) Near fault plastic yielding
  (1) Equivalent Kinematic Source (EKS)
  (2) Forward CyberShake
(3) Non-linear site response
  (1) Post-process add site response
(4) UCERF3 Multi-fault ruptures
  (1) Assume sub-shear propagation time between faults
(5) UCERF3 low-probability very large ruptures
  (1) Largest amplitude ruptures are based on 1D BBP runs
(6) Distribution of hazard model
  (1) define interface to web-based amplitude db
  (2)Distribute portable DB with amplitudes
  (3)Seismogram self describing tar files
(7) Distribution of computational system
  (1)Create a virtual cluster

Thank you!

CyberShake Platform: Physics-Based PSHA

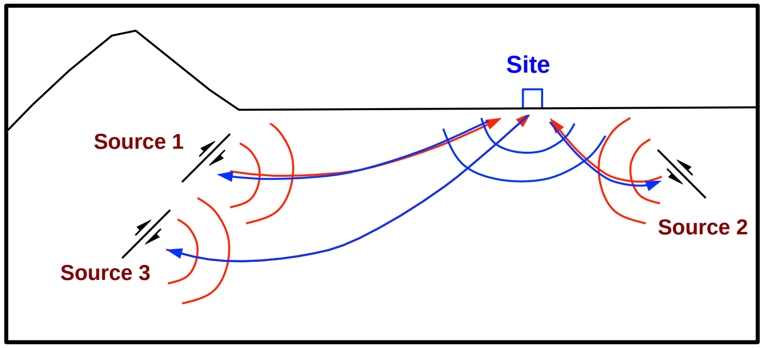
Essential ingredients

1. **Extended earthquake rupture forecast**
   - **probabilities of all fault ruptures (e.g., UCERF2)**
   - **conditional hypocenter distributions for rupture sets**
   - **conditional slip distributions from pseudo-dynamic models**
2. **Three-dimensional models of geologic structure**
   - **large-scale crustal heterogeneity**
   - **sedimentary basin structure**
   - **near-surface properties ("geotechnical layer")**

   } from SCEC CVMs
3. **Ability to compute large suites (> 10^8) of seismograms**
   - **efficient anelastic wave propagation (AWP) codes**
   - **reciprocity-based calculation of ground motions**

Rapid Simulation of Large Rupture Ensembles Using Seismic Reciprocity

- **To account for source variability requires very large sets of simulations**
  - **14,900 ruptures from UCERF2; 415,000 rupture variations**
- **Ground motions need only be calculated at much smaller number of surface sites to produce hazard map**
  - **283 in LA region, interpolated using empirical attenuation relations**
- ***Use of reciprocity reduces CPU time by a factor of ~1,000***



Strain Green Tensor (SGT)

***M* sources to *N* sites requires *M* simulations**

***M* sources to *N* sites requires 2*N* or 3*N* simulations**

Using the GP Rupture Generator to Create Multi-segment Kinematic Ruptures

Approach: Generate rupture for each individual segment separately and then combine into a single, multi-segment SRF file (SRF v2.0)

General Parameters:

- Location (lon, lat, depth of top center), dimensions (length & width), and orientations (strike & dip) of individual segments
- Primary hypocenter
- Magnitude (or seismic moment) of full rupture

Additional Parameters (expert judgment needed):

- Secondary hypocenters (locations of rupture initiation on 2^{nd}, 3^{rd}, … segments)
- Rupture delays for 2^{nd}, 3^{rd}, … segments
- Seismic moment (or average slip) for each individual segment; sum of individual moments must equal moment of full rupture

Using the GP Rupture Generator to Create Multi-segment Kinematic Ruptures

- Factors governing specification of additional parameters are poorly constrained/understood.
- Some guidance on this comes from rupture dynamics; however, the current state of knowledge is not mature enough to do this in a fully reliable manner.

- Possible solution, 2-stage approach:
  - Stage 1) crude/simple (pseudo?) dynamic calculation is done to estimate the "additional parameters"
  - Stage 2) uses these estimates in the full kinematic rupture generation