February 2011
SCEC Rupture Dynamics Code Validation Workshop

Ruth A. Harris
(U.S. Geological Survey)
Plans for this workshop

*See a quick overview of our group’s activities to date

*Learn about related SCEC Technical Activity Groups

*Learn about a new code

*Examine the results from the latest benchmarks

*Learn about fault intersections

*Plan our next steps
<table>
<thead>
<tr>
<th>Time</th>
<th>Session Title</th>
<th>Speaker(s)</th>
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<tr>
<td>10:00</td>
<td>Introduction to Workshop</td>
<td>Ruth Harris</td>
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<td>17:00</td>
<td>Adjourn</td>
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What our Group Does – Computer Code Testing

- **Initial Fault Stresses**
- **Geologic Structure (Fault Geometry & Material Properties)**
- **Failure Criterion**
- **Computer Codes that Simulate Earthquakes as Spontaneous Ruptures**
- **Ground Shaking (Seismograms), Fault Slip, etc.**

**how we do the test:**
we compare these results among the codes

**what we’re testing**

Please see our website  [http://scecdata.usc.edu/cvws](http://scecdata.usc.edu/cvws)
Our SRL article

link available on our website

http://scecdata.usc.edu/cvws

Overall Goal of our Code Verification Group

Compare the computational methods currently being used by SCEC and USGS scientists to simulate (spontaneous) earthquake rupture dynamics

Some Specific Objectives

Understand if our methods are producing the same results when using the same assumptions about friction, crustal structure, fault geometry, etc.

Funding

This project has been funded by the Southern California Earthquake Center, the U.S. Geological Survey, the U.S. Dept. of Energy, and the PG&E Company
Code Comparison Strategy
Start simply

Spontaneous rupture on a vertical strike-slip fault set in a homogeneous (materials) elastic Fullspace

homogeneous initial stresses
slip-weakening friction

Some Results
Code Comparison Benchmarks – Incrementally add complexity

- Slip-weakening friction

- Rate-state friction using an ageing law

- Rate-state friction using a slip law with strong rate-weakening

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Code Comparison Strategy
Incrementally adding complexity: friction, fault geometry

Rupture on a Vertical strike-slip fault set in a homogeneous materials elastic halfspace, **Thermal pressurization** with rate-state friction, slip-law, strong rate-weakening

Rupture on a **Branching** strike-slip fault set in a Homogeneous (materials) elastic halfspace, homogeneous initial stresses, Slip-weakening friction

TPV105-2D

TPV14-15

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Recently Completed Work – ExGM project

New multi-author (TPV12-13 modelers) paper about to be submitted to SRL
Andrews et al., BSSA, 2007

Figure 7

**Extreme** Ground Motion
Produced by an **Extreme Event**

Benchmarks TPV12 and 13

TPV12 = elastic
TPV13 = plastic

*Figure 7.* Color orthophoto map of the Yucca Mountain area with surface fault traces from figure 2 of Whitney, Taylor, and Menges, 2004 shown in the smaller boxed area. Numbers show locations of observed maximum-slip values of 1.3 m on the Sollitario Canyon fault, 0.4 m on the Fatigue Wash fault, and 1.0 m on the Windy Wash fault at the time of the Lathrop Wells eruption. The footprint of the proposed repository is approximate.
elastic

Benchmark: tpv12 (The Problem, Version 12)

<table>
<thead>
<tr>
<th>Name</th>
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<tbody>
<tr>
<td>aagaard</td>
<td>Brad Aagaard - Finite Element - EqSim</td>
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<tr>
<td>barall</td>
<td>Michael Barall - Finite Element - FaultMod</td>
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<tr>
<td>duan</td>
<td>Benchun Duan - Finite Element - EQdyna</td>
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<td>kaneko</td>
<td>Yoshihiro Kaneko - Spectral Element - SPECFEM3D</td>
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<td>kase</td>
<td>Yuko Kase - Finite Difference</td>
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<td>ma2</td>
<td>Shuo Ma - MAFE</td>
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<td>oglesby</td>
<td>David Oglesby - Finite Element - DYNA3D</td>
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Benchmark: tpv13 (The Problem, Version 13)

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<td>Michael Barall - Finite Element - FaultMod</td>
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<tr>
<td>duan</td>
<td>Benchun Duan - Finite Element - EQdyna</td>
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Benchmark: tpv13-2d (2D Version of TPV13)

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<td>andrews</td>
<td>Joe Andrews - 100 m</td>
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<td>andrews.2</td>
<td>Joe Andrews - 50 m</td>
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<td>andrews.3</td>
<td>Joe Andrews - 25 m</td>
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<tr>
<td>barall</td>
<td>Michael Barall - FaultMod - 100 m</td>
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</tr>
<tr>
<td>barall.2</td>
<td>Michael Barall - FaultMod - 50 m</td>
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<td>duan2</td>
<td>Benchun Duan - 2D Finite Element - 100 m</td>
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<td>duan2.2</td>
<td>Benchun Duan - 2D Finite Element - 12.5 m</td>
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<td>dunham3</td>
<td>Eric Dunham - FDMAP (2D) 6.25 m</td>
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<td>dunham3.2</td>
<td>Eric Dunham - FDMAP (2D) 100 m</td>
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<td>dunham3.3</td>
<td>Eric Dunham - FDMAP (2D) 25 m</td>
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<td>gabriel</td>
<td>Alice Gabriel - 2D Spectral Element - SEM2DPACK - 100m</td>
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2D
Vertical Velocity at Station 1-km from fault, 0.3 km-depth, footwall side of the fault (3 Hz filter)
Horizontal (Fault-trace Perpendicular) Velocity at Station 1-km from fault, 0.3 km-depth, footwall side of the fault (3 Hz filter)
SCEC Rupture Dynamics Code Validation Workshop
Friday February 25, 2011
Kellogg West Conference Center, Cal Poly Pomona, Pomona, CA

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‘100 Runs’ Exercise

Regular ground motion produced by **regular M6.5’s**

used spontaneous rupture simulations
to produce ‘100’ **M6.5 sources**
Work done for ‘100 runs’ – Assigned 100 different ‘values’

- Initial Fault Stresses
- Geologic Structure (Fault Geometry & Material Properties)
- Computer Codes that Simulate Earthquakes as Spontaneous Ruptures
- Failure Criterion
- Ground Shaking (Seismograms), Fault Slip, etc.

‘100 runs’- generated this 100x, for 100 M6.5’s
Developed Hybrid Initial-Conditions Method and Received Committee Approval

Features:
* Gradual Forced Nucleation
* Slip-weakening failure criterion
* Rigid barriers at fault edges
* 24 km x 13.6 km fault plane with constant dip
* Initial normal stress distribution:
  depth dependent
* Initial shear stress distribution:
  1-point statistics = Levy distribution
  2-point statistics = von Karman power spectrum
* M6.5
* 1-D 3-layer shear-modulus (and velocity) model
* Elastic behavior
One Initial Stress-Conditions Realization from the ‘100 Runs’ Exercise

Distance along strike (km)

Distance down dip (km)

initial shear stress / initial normal stress
Rupture front contour plot and ground motion from this one realization

Unfiltered motion at YM station
Vertical-velocity (0.1 to -0.1 m/s) vs. time (0-15 secs)

Rupture-front contours (0.5 sec intervals) on the fault-plane

PGV=-0.1 m/s