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SWUS GMC SSHAC Workshop #1

The SCEC/USGS
Rupture Dynamics
Code Comparison Exercise

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What our Group Does: We Test Computer Codes Used to Simulate Earthquakes

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

what we’re testing

Geologic Structure
(Fault Geometry & Material Properties)

Failure Criterion

Computer Codes
that Simulate Earthquakes as Spontaneous Ruptures

Initial Fault Stresses

Ground Shaking
(Seismograms), Fault Slip, etc.

Please see our website  http://scecdata.usc.edu/cvws

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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

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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

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Code Comparison Benchmarks – Incrementally add complexity

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

Slip-weakening friction

Rate-state friction using an ageing law

Thermal pressurization, rate-state friction, slip-law, strong rate-weakening

Slip-weakening friction

Slip-weakening friction

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Code Comparison Strategy
Incrementally adding complexity: stress, fault geometry

Rupture on a vertical strike-slip fault set in a homogeneous material elastic halfspace, **Heterogeneous initial Stresses**, Slip-weakening friction

Rupture on a **Branching** strike-slip fault set in homogeneous (material) **Plastic yielding**, Slip-weakening friction

TPV16, 17

TPV18, 19, 20, 21
elastic, plastic, elastic, plastic

2012 BENCHMARKS
TPV16 (Heterogeneous Initial Stress, SW Friction, Elastic, Vertical Strike-Slip Fault)

Assumptions

Results

2012 Benchmark Success

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TPV18 (SW Friction, Elastic, Branched Vertical Strike-Slip Fault)

Schematic

Results

Main Fault          Branch

2012 Benchmark Challenge

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2012-2013 Benchmarks: Two-Fault Stepovers
TPV22 and 23 (SW Friction, Elastic, Stepover in Vertical Strike-Slip Faults)

2012-2013 Benchmarks: Revisiting the Fault Branch
TPV24 and 25 (SW Friction, Elastic, Branched Vertical Strike-Slip Fault)
Results for Benchmarks TPV22 and TPV23 (rupture-front contour plots)

TPV22
Dilational stepover

Fault 1

Fault 2

TPV23
Compressional stepover

Fault 1

Fault 2

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Results for Benchmarks TPV22 and TPV23 (horizontal slip-rate vs. time)

TPV22
Dilational stepover

TPV23
Compressional stepover

3 m/s

15 seconds

3 hz low-pass Butterworth filter applied

On-Fault Station Location
(5 km along strike at the earth’s surface, on fault 2)

Fault #2

3 m/s

15 seconds

3 hz low-pass Butterworth filter applied

TPV22

TPV23

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Older Branch Benchmark: TPV18 (SW Friction, Elastic, Vertical Strike-Slip Faults)

Schematic

Results

Main Fault

Branch

2012 Benchmark Challenge

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Changes in Branch Fault Benchmarks from 2012 to 2013
Branch intersection definition changed, allowing for code-optimized implementations

2013: slip on the branch goes to zero at the intersection
2012: the branch ends one element away from the main fault

Nucleation method changed
2013: smoother nucleation with fewer unwanted oscillations.

Regional stress field changed
2013: neutral
2012: strongly extensional

Difference between static & dynamic friction coefficients reduced, producing an easier to resolve cohesive zone
2013: $\mu_s=0.18$ and $\mu_d=0.12$
2012: $\mu_s=0.60$ and $\mu_d=0.12$

Slip-weakening critical distance reduced
2013: 0.30 m
2012: 0.40 m

2013: Convergence of each benchmark was tested by running 50 m and 100 m cases

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New Branch Fault Benchmarks: TPV24 and TPV25

**TPV24**
Releasing Branch

**TPV25**
Restraining Branch
Results for Benchmarks TPV24 and TPV25 (rupture-front contour plots)

TPV24
Releasing Branch

TPV25
Restraining Branch

Main Fault
Branch Fault

TPV24

Main Fault
Branch Fault

TPV25

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Results for Benchmarks TPV24 and TPV25 (horizontal velocity vs. time)

TPV24
Releasing Branch

TPV25
Restraining Branch

Off-Fault Station Location
at the earth’s surface
between main fault & branch

3 hz low-pass Butterworth filter applied

TPV24
Releasing Branch

TPV25
Restraining Branch

3 hz low-pass Butterworth filter applied

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Results for Benchmarks TPV24 and TPV25 (final fault slip)

TPV24
- Releasing Branch

TPV25
- Restraining Branch

Main Fault          Branch Fault

TPV24 Releasing Branch

TPV25 Restraining Branch

Final slip
0.0   0.5   1.0   1.5   2.0   2.5 m
For More Information about our group’s work, Please see our website  http://scecdata.usc.edu/cvws

Our 2011 SRL article

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