Project 13009: Rupture Dynamics Code Validation 2013 Workshop (convened March 14, 2014)

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The 2013 SCEC Dynamic Rupture Code Comparison Workshop was held March 14, 2014, at the U.S. Geological Survey in Menlo Park, California. Approximately 28 people participated, including approximately 10 remotely, and 18 in the meeting room. This year's workshop included at least five new people, among them two new students, two new postdocs, and one new university professor. Our workshop attendees, remote and in-person, this year included scientists from seven countries (China, Germany, Japan, Mexico New Zealand, Switzerland, U.S.A.). At least ten of our in-the-meeting-room participants were either students or postdocs. Many thanks to Tran Huynh for all of her dedicated work that helped make this workshop happen.

The workshop agenda and participant list are on the last page of this report.

Ruth Harris (USGS) introduced the SCEC workshop to the participants, who learned for the first time (or remembered, if they were code workshop veterans) what our group does to test our computer codes that simulate earthquakes as spontaneous ruptures, how we do it, and why. Harris then quickly summarized all of the spontaneous rupture code benchmarks performed to date by the group. She next showed where we currently are, and mentioned the group's goals for the rest of 2014.

The participants then learned from speaker Michael Barall (Invisible Software) about brand new quantitative metrics that he has developed for comparing code results. Before his new work, all of the code comparisons performed by the group over the past 10 years have been qualitative (visual) comparisons. Barall presented 'version 1' of his intensive work on formulating metrics for the many types of information that are produced by the codes, including synthetic time-series (seismograms), stressgrams, contours of rupture front progress, etc. This presentation showed for the first time a realistic path forward and achieved the first of the two goals of the 2013 SCEC group proposal – to construct quantitative metrics for comparing dynamic rupture code results. The proposed metrics were well received by the rest of the group in attendance (remotely or in-person). There were a few recommendations for additional aspects to examine, such as the color scale used for the metrics, and an aspect to evaluate, the resolution power of each code.

The group then learned about two new spontaneous rupture codes joining our group's efforts. USTC professor Xiaofei Chen who traveled (on mostly his own expense) all of the way from China to attend our workshop, presented his talk about his group's code, Curved Grids Finite-Difference Method. Professor Chen also showed the results of his code that completed the newest SCEC benchmarks, TPV26, TPV27, and TPV28. The group then took a break for lunch. Following lunch, Postdoctoral Associate Kenneth Duru (Stanford) presented his code FQWaveLab, that will soon be used to run benchmarks, as soon as fault-friction is implemented. His code is globally fourth order accurate, and uses co-located grids.

Next, Michael Barall (Invisible Software) returned to the 'podium'/presentation chair and presented a comprehensive talk explaining the details of the newest completed group

benchmarks, the case of the single vertical strike-slip fault set in an elastic halfspace (TPV26) or set in a viscoplastic halfspace (TPV27), along with case of the gently rough fault, TPV28. The construction of the benchmarks and completion by the modelers of benchmark results achieved the second of the two goals set forth in the 2013 SCEC group proposal. Please see our companion SCEC report for SCEC Project 13061 for information about these specific benchmark code comparisons, along with Barall's detailed workshop presentation available on our website, scecdata.usc.edu/cvws.

The matches among the modelers' benchmark simulation results were impressive, as quantified by the newly developed metrics that the group learned about earlier in the day. There was also some discussion about the similarities of and differences between the assumed benchmark parameters for the newest exercises and those adopted for our previous benchmark exercises.

Following a short break, workshop attendees then heard and participated in a talk by Katie Wooddell (PG&E). Wooddell presented information about the current state of kinematic ground motion modeling in seismic hazard projects such as the SWUS GMC (Southwestern U.S. Ground Motion Characterization) project that has examined the seismic hazard near two of the U.S.A.'s nuclear power plants. Wooddell showed examples where results from spontaneous rupture simulations could help constrain and sometimes correct some of the assumptions made for the kinematic-based ground motion estimates. This talk helped inform more members of the spontaneous rupture community about how we can assist the ground motion hazards community by providing physically plausible earthquake source scenarios.

Next, Brad Aagaard (USGS) presented his ideas about how depth-dependent material structure (e.g., velocity and density) can interact with assumptions about the state of fault-stress, and why it is important to consider both simultaneously, rather than as independent features whose interactions could lead to surprising ground motion and slip results.

Following a short break, SDSU scientists Zheqiang Shi and Kim Olsen presented their results of how complexity can affect both rupture propagation and the resulting ground motions. Shi showed detailed comprehensive simulations using the computer code SORD and a 3D rough fault for simulations of vertical strike-slip and normal/reverse dip-slip faulting. Olsen presented simulations that included heterogeneity in the rocks that surrounds the fault, particularly material velocities and attenuation. The differences between assuming homogeneous materials or not and a planar fault or not, were quite impressive. Future work by Olsen (and Shi) will likely combine the two effects, in a study of 3D fault zone and material heterogeneity. We look forward to seeing the results, and are motivated to continue with our benchmarking exercises that include more complexity of both fault geometry (i.e., rougher faults), and material heterogeneity.

For more information about our group, to download our group's collaborative papers, for descriptions of our group's benchmarks that we use to compare our codes' results, and to view many of our workshop presentations, please see our SCEC website: **scecdata.usc.edu/cvws**.

Thank you to SCEC for funding this workshop.

SCEC Rupture Dynamics Code Comparison Workshop

Conveners: *Ruth Harris and Ralph Archuleta*

Location: USGS Menlo Park (Building 3, Room 3-237)

SUMMARY: The purpose of the SCEC Rupture Dynamics Code Comparison Workshop is to discuss the results for our group's most recent benchmarks, TPV26, 27, 28, to discuss our next science steps for 2014-2015, and to learn about a new method of quantitative comparison metrics. For more information about our code comparison group and the benchmarks, please see the SCEC/USGS Spontaneous Rupture Code Verification Project website: http://scecdata.usc.edu/cvws.

FRIDAY, MARCH 14, 2014		Presenter
10:00	Introduction	Ruth Harris
10:20	Metrics, Version 1	Michael Barall
11:20	A New Participating Code	Xiaofei Chen
11:50	A New Participating Code	Kenneth Duru
12:20	*Lunch*	
13:20	Results from TPV26, TPV27, TPV28	Michael Barall
14:25	Break	
14:45	Implementation of source simulations for ground motion calculations	Katie Wooddell
15:15	Interactions between velocity structure and stress in source simulations	Brad Aagaard
15:30	*Break*	
15:45	3D simulations of rough faults and ground motions	Zheqiang Shi
16:15	Effects of velocity and attenuation on sources and ground motions	Kim Olsen
16:45	Additional Workshop Comments / Discussion	Ruth Harris / All
17:30	*Adjourn*	

27-28 PARTICIPANTS (9-10 of them Remote):

Brad Aagaard (USGS), Pablo Ampuero (Caltech), Ralph Archuleta (UCSB), Michael Barall (Invisible Software), Sam Bydlon (Stanford), Xiaofei Chen (USTC, China), Ben Duan (Texas A&M), Eric Dunham (Stanford), Kenneth Duru (Stanford), Alice Gabriel (LMU, Germany), Marcello Gori (Caltech), Ruth Harris (USGS), Yihe Huang (Caltech), Tran Huynh (USC), Yoshi Kaneko (GNS, New Zealand), Yuko Kase (GSJ, Japan), Jeremy Kozdon (NPS), Julian Lozos (USGS/Stanford), Bin Luo (Texas A&M), Shuo Ma (SDSU), David Oglesby (UCR), Kim Olsen (SDSU), Daniel Roten (ETHZ, Switzerland), Vito Rubino (Caltech), Jose David Sanabria Gomez (UNAM/UIS, Mexico), Zheqiang Shi (SDSU), Katie Wooddell (PG&E).