2019 Crustal Deformation Modeling Workshop Report

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WORKSHOP OVERVIEW

The 2019 Crustal Deformation Modeling Workshop was held June 10–14 at Colorado School of Mines. This continued a series of workshops that Mark Simons and Brad Hager began in 2002; the most recent prior workshop was held in June, 2017. The workshop organizers included Brad Aagaard (USGS), Sylvain Barbot (USC), Elizabeth Hearn (Capstone Geophysics), Eric Hetland (Univ. of Michigan), Matthew Knepley (Univ. of Buffalo), and Charles Williams (GNS Science). The Computational Infrastructure for Geodynamics at UC Davis provided the majority of the funding for this workshop with additional funding from the Southern California Earthquake Center to cover travel costs for about one-third of the participants. Registration was first-come, first-served with a cap of 60 participants needing lodging and open to anyone in the community with an interest in crustal deformation modeling. We sent email announcements to CIG, SCEC, UNAVCO, and EarthScope email lists. The 54 participants included 23 graduate students, 13 postdocs, 5 faculty, 9 researchers, and 4 others. Our combination of tutorials and science discussions continues to draw very strong participation from graduate students and postdocs, with two thirds of the participants fitting those categories this year. As in several other vibrant SCEC sub-disciplines, we see faculty, who participated as graduate students or postdocs in earlier workshops in this series, sending their own students and postdocs to this workshop. Two thirds of the participants had not participated in a previous Crustal Deformation Modeling workshop or PyLith tutorial.

The complete agenda is available on the CIG website. We are still collecting PDF files of the slides from the presentations, and improving the slides and videos for the tutorials.

The consensus of the workshop wrap-up discussion and post-workshop survey (with a response rate of 50%) was to continue this series of workshops, preferably on a biannual basis. The graduate students and postdocs showed strong interest in numerical modeling with several wanting to contribute to the development of community software, such as PyLith. Participants expressed overwhelming support for the 5-day duration and format of the workshop, with 2-3 days dedicated to tutorials and 2-3 days dedicated to science talks and discussions. A majority of the survey would like to add incite-style talks in future workshops. On a scale of 1 to 5 with 5 indicating the workshop exceeded expectations, over 80% of the post-workshop survey respondents gave a score of 4 or 5. For the tutorial portion, more than 80% of the post-workshop survey respondents also gave a score of 4 or 5. The participants expressed strong support for continued use of online tutorials to supplement the training provided during in-person workshops. The respondents to the post-workshop survey were evenly split between favoring a first-come, first-served approach or using an application process. We will continue to assess whether an application process is needed; this year we did not have a wait list, whereas in the past we have sometimes had a short wait list.

TUTORIALS

The first two days of the workshop were dedicated to tutorials related to the use of PyLith, an open-source code for 2-D and 3-D simulations of quasi-static and dynamic crustal deformation associated with earthquake faulting. A pre-workshop online help session attended by about 10 users facilitated answering initial questions about PyLith features and how to overcome some common installation issues. Most participants made use of the extensive written documentation and on-demand videos from the 2011, 2013, 2015, 2016, and 2017 tutorials to get started.

The tutorials at the workshop focused on introducing users to the changes and new features present in the upcoming v3.0 release of PyLith. The tutorials were divided into 6 sessions intermixed with dedicated time for running examples and getting one-on-one help. The sessions discussed generating finite-element meshes in 2-D and 3-D, how to specify material properties and assign boundary conditions and prescribed earthquake ruptures, include gravitational body forces in the context of compressible and incompressible elasticity, and troubleshoot running simulations. Many of the participants applied the skills they learned in the tutorials to begin working on research problems in a variety of tectonic settings using either the current v2.2.1 release or a beta release of v3.0.

SCIENCE TALKS AND DISCUSSIONS

The final two and one half days of the workshop focused on science talks and discussions, lightning talks, and informal poster sessions. The talks spanned a range of topics under the themes of the mechanics of fault slip in subduction zones and crustal faults, constraining geodetic-based slip rates, crustal deformation associated with volcanic eruptions, viscoelastic and elastoplastic processes throughout the earthquake cycle, and advancing numerical modeling techniques. Eric Hetland gave an overview of InSAR data repositories and resources to help facilitate use of InSAR data in crustal deformation modeling. Elizabeth Hearn described the SCEC Community Rheology Model and its relation to the other SCEC community models. Her presentation was followed by a breakout discussion (discussed in the next section) to help assess the priority of features to be included in the Community Rheology Model.

Community Rheology Model Breakout Discussion

The four groups were asked to focus on the following topics:

- What is the simplest Community Rheology Model that would be useful, i.e., what is a good target for an initial release that would be useful to the community?
  - How might you make use of a community rheology model? Describe the application.
  - What structural features should a community rheology model include?
  - What is the minimum about of information you need from a community rheology model?
  - What is the simplest way you would access the information?
- What are the priorities for adding more complexity beyond an initial release of the model?
  - What information would you like to have from a community rheology model? What are the key features?
  - What are potential milestones between a minimum model and a more complete model?
  - What changes to the user interface might be useful as the model becomes more complex?
- A query tool is also being developed to make the SCEC Community Fault Model (CFM) easier to use. What file formats do deformation modelers prefer for fault surfaces? Any requests for future updates to this tool?
  - How would use of a community fault model?
  - What resolution would you need?
  - How should the geometry be provided? What file formats do you prefer?

Here we summarize the key points from the discussions. The priorities for an initial release of a community rheology model include:

- Collocated temperature, mineralogy, and effective viscosity with cross references to model components (i.e., which thermal model provided the temperature);
- Background strain-rate or stresses (community stress model) for nonlinear rheologies; and
- Provide multiple (or user-specified) model resolutions suitable for different applications.

The priorities for adding more complexity to a community rheology model include:

- Ability to include/exclude fault/shear zones;
- Rheology of faults (e.g., rate-state parameters);
- Define lithological/rheological horizons as independent surfaces, such as the brittle ductile transition, similar to LITHO2.0;
- Additional constitutive related information, such as pore fluid pressure;

- Uncertainty estimates and metrics for data quality; and
- Interface to customize the model (e.g., specify region of interest, select thermal models and rheology parameters) and plot cross sections.

Some requests for improvements to delivery of the SCEC Community Fault Model include:

- Ability to download/export the surface of a fault or fault segment at a user-specified resolution;
- Distribution or export in standard CAD formats (e.g., STEP) for better integration with solid modeling tools;
- Provide files that can be read directly into common visualization tools, such as Google Earth and GeoMapApp;
- Classify faults by maturity and importance; and
- Video-based tutorials and a public forum for questions/discussion.