# 2009 SCEC REPORT

## Source Inversion Validation (SIV) Workshop


**Investigators**

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**Source Inversion Validation Workshop: SCEC 2009 Annual Meeting**

Detailed knowledge about the kinematics of the earthquake source process is critical for inferring rupture dynamics, for building source models for ground-motion simulation, and for studying earthquake mechanics in general. However, source-inversion results for past events exhibit large intra-event variability for models developed by different research teams for the same earthquake. Also, the reliability, resolution, and robustness of the inversion strategies and the obtained rupture models have not received their due attention.

This workshop is a follow-up on two workshops in the past year during which the Source Inversion Validation (SIV) project for earthquake rupture imaging was discussed. We thus particularly invite researchers working in earthquake source inversion and statistical analysts interested in developing a "testing platform" for the SIV-project. The first part of this workshop will be dedicated to invited lectures. This will be followed by presentations and discussions on the first "testing models", and in particular results from initial Green's function testing. The second part of the workshop will feature presentations and discussions on the infrastructure and implementation of the testing center. Future funding for participating groups will also be discussed. We hope for many dedicated scientists who will devote time & energy into the SIV-project, but we also invite users of source-rupture models and those genuinely interested in earthquake source inversion.

## SCEC: Source Inversion Validation (SIV) Workshop

## Sunday, Sept. 13, 2009; 8:00 AM – 5:30 PM

**P. Martin Mai, Morgan Page, Danijel Schorlemmer**

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### PART A : METHODS

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| **8:00 – 8:15** | **Martin Mai/Morgan Page** | **Introduction and review of SIV activities** |
| **8:15 – 8:45** | **Ralph Archuleta** | **Uncertainty assessment in source inversions** |
| **8:45 – 9:15** | **Damiano Monelli** | **Bayesian inference of kinematic rupture parameters** |
| **9:15 – 9:45** | **Ozgun Konca** | **Kinematic inversion of physically plausible earthquake source models obtained from Dynamic Rupture Simulations** |
| **9:45 – 10:15** | **Coffee break** | |
| **10:45 – 11:15** | **Takahiko Uchide** | **Resolution of source inversion problems and the use of inhomogeneous and multi-scale source models** |

**11:15 – 11:45 Guangfu Shao What do we learn from the exercise of the SIV BlindTest I ?**

**11:45 – 12:15 OPEN DISCUSSION ON METHODS SECTION**

**12:15 – 14:00 LUNCH**

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## PART B : SIV Implementation

**14:00 – 14:15 Danijel Schorlemmer CSEP: experience with a scientific testing center**

**14:15 – 14:45 Masha Liukis / D.Schorlemmer Implementational aspects of CSEP**

**14:45 – 15:30 OPEN DISCUSSION ON IMPLEMENTATION OF SIV**

**15:30 – 16:00 Coffee break**

**16:00 – 17:00 OPEN SESSION: Planning the next steps**

- **Expectations for the forward-modeling problems**
  - **Point-source Green's function**
  - **Finite-fault with known (and simple) inhomogeneous rupture**
- **Expectations for inverting for a simple, but inhomogeneous rupture**
- **Workshop in March 2010:**
  - **Date, location & duration**
  - **Source of future funding**
  - **Commitment to participation of the modeling groups**

### Summary of the workshop discussions

Below is a summary of the workshop discussions, based on the notes taken during the workshop:

- **Dynamic models for Problem 2**: We work with Luis Dalguer to generate simple, one-patch dynamic models and corresponding ground motions. We can then create a comparable kinematic model, using perhaps even the same final slip distribution, for computing an additional set of synthetic seismograms

- **Resolvable deep slip** and **Crack versus pulse-like models**: Generate models and synthetics that allow us to study of deep slip can be resolved, or distinguish between crack-like and puls-like models.

- **Real earthquakes**: Examine the possibility to use real earthquake data to construct test exercises

- **Errors**: Generating different Green's function by using randomized velocity models to address "epistemic uncertainty" which the modelers could, in principle, solve by finding the optimal velocity structure themselves. Similarly, we can perturb the geometry of the fault w/o telling the modelers; however, we may also want to include true "random noise" or "aleatory variability" (random noise)

- **Multiple solutions**: how to accommodate various types of solutions
  - for a non-linear code, producing a suite of models, the modeler should submit his/her "preferred" (personally biased) model, as done commonly in published papers, along with a suite of "successful" models that also well explain the data
  - for classic linearized codes, we have to press modelers to submit alternative solutions, for instance by choosing slight different fault geometry (variation of 5° in dip or strike; different gridding; different rupture-speed and/or rise-time assumptions), so that we also get a suite of 10-20 models
  - Similarly, we can allow for subsequent solutions of the same team for the same problem, by time-stamping each submitted solution as a means for version control; at some point solutions should be submitted electronically, and it should be easy to do this

- **Solution metrics**: Establish a variety of metrics, considering also potential correlations; note that we need to consider also the max. slip values etc, which are "lost" in the correlation analysis that only accounts for the spatial pattern

- **Data format**: concerning the waveforms, the simple proposed format should be sufficient, but we can expand to a (modified) version of Rob Graves' rupture-model format – for each point on the fault, its location (lat/lon and/or x,y,z in some reference frame), followed by the number of points and time-step representing the arbitrarily complex slip-velocity function.

- **KAUST workshop**: Please ask all potential attendees from the USGS to check what is needed for the foreign travel approval; my discussions with KAUST admin people in the past few weeks very extremely positive, and I think we can pull this off in March! We should be able to supply funding as well (maybe the whole costs of the trip but a significant chunk). I also believe that we should restrict the attendance to the 20-30 key people, and use the time not only for talks and comparisons, but also for model generation and code installation

- **CSEP-style testing**: Fund a person to work on this for us. Ideally, the person should spend some time at KAUST, or perhaps be even based at KAUST.

**Proposed Rupture Model Format (adapted from a description by Rob Graves, 2005)**

Source variability can be the largest single contributor to uncertainty in predicting ground motions for future earthquakes This variability includes fault location, magnitude, style of faulting, depth of faulting, slip distribution, hypocenter location, rupture velocity, and slip time function (rise time). Likewise, rupture model variability is an expression of the underlying

earthquake source dynamics, and hence we need to accurately and comprehensively document the details of any inverted rupture model. A simple matrix-like representation of slip, rise time, or rupture onset time at fault-point locations may therefore insufficient. Instead, we need to specify the complete temporal rupture evolution on each point of the fault, along with macroscopic earthquake source parameters.

The following format was proposed by Rob Graves as the "standard format" for the specification of kinematic rupture models, and is used in the SCEC Broadband Ground-Motion Simulation Platform. Thus, it may also serve well within the SIV-project, and has the advantage that we could "inject" correspondingly formatted SIV-rupture-models into SCEC ground-motion computation tools.

The use of a standard rupture model format is necessary for both this exercise and for future SCEC related activities. The reasons for this include:

1) It allows for the direct comparison of rupture parameterizations used by different modelers.
2) It provides an efficient, consistent and reliable mechanism to exchange rupture model specifications among source modeling groups, using both kinematic and dynamic rupture specifications.
3) Ground motion simulations for future scenario earthquakes within SCEC (e.g. Pathway II, CME) will require standardized data formats.
4) It facilitates reproducibility of results by independent researchers.

Note that this rupture-model description could be further generalized to allow for time-dependent rake, even fault opening, by specifying three separate slip-velocity functions at each point on the fault (in fact that is what Graves proposed). Also, the HEADERBLOCK could be repeated for different planar fault segments, if present. I think, however, that for now we could restrict ourselves to the simplified format – or should we adopt the most general rupture-model specification? That would be advantageous for any long-term planning.