2005 ANNUAL REPORT

SCEC Broadband Ground Motion Simulation Workshop

Robert W. Graves, URS Group, Inc.

Workshop Objectives

One of the primary areas of research within SCEC is to develop and refine methodologies to estimate the ground motions that will be experienced during future earthquakes in Southern California. As stated in the 2005 SCEC RFP, the long term research goal for the ground motion problem area is *"to understand seismic ground motion in urbanized Southern California well enough to predict the ground motions from specified sources at frequencies up to at least 1 Hz, and to formulate useful, consistent, stochastic models of ground motions up to at least 10 Hz."* Currently, there are several large-scale efforts within SCEC that will rely on the capability of producing realistic broadband time histories, including, among others, the NSF Project on Implementation Interface (NGA-H, Structural Simulations) and the Pathway II components of CME. The main objectives of this workshop are:

1) Document the methodologies that are currently (or will soon be) available to SCEC scientists for use in simulating broadband ground motion time histories for earthquakes in Southern California.
2) Provide and document validation of the capabilities of the simulation methods using data from past earthquakes.
3) Develop format standards for the specification of model parameters to facilitate accurate and reliable exchange of information within the research community.
4) Identify goals that need to be addressed in the short term (end of SCEC2) and the longer term (during SCEC3) within the broadband modeling community.

Workshop Recommendations

The primary recommendations from the workshop are as follows:

1) Rupture model characterization and standardization is a critical issue that needs to be addressed as we proceed with current and planned simulation exercises. This requires specification of standardized file formats and conventions, as well as increased interaction between the Ground Motion Focus Group and the Earthquake Source Physics Group. It is clear that simulation of large magnitude events (Mw > 7.5) will need to be guided, in part, by physics based rupture models (i.e., rupture dynamics).

2) Formation of a formal Broadband Simulation Group. This will facilitate participation in projects such as NGA-H and the NSF Implementation Interface studies. In order for the simulation methodologies to become more accepted, we must demonstrate that the approaches produce reliable and consistent results. And furthermore, the methodologies must be transparent and useable by outside groups. This is particularly true for the NGA-H program.

3) Establishing a set of reference validation earthquakes against which the simulation methodologies can be assessed. The Northridge Simulation Exercise is a prototype of this type of activity. Other California events could include Landers, Hector Mine, Whittier-Narrows, Parkfield, and Loma Prieta.

Agenda and Participants

Listed below is the agenda of the workshop. The morning session was focused on the Northridge Simulation Exercise (summarized below), and the afternoon was focused on current projects and identification of needs and issues (summarized below). Table 1 lists the participants of the workshop.

10:00 AM **1. Workshop Introduction** (*Paul Somerville 15 min*)

10:15 **2. Northridge Exercise**

- Introduction (*Graves 15 minutes*)
- Modeler Descriptions (*Bielak, Dreger, Graves, Liu, Olsen, Tromp, Zeng;* ***no more than 10 minutes each***)
- Analysis and Discussion of Submitted Results (*Graves 30-45 minutes*)
- Goodness of Fit Issues (*John Anderson 15 minutes*)

12:30 **LUNCH** (*box lunch provided*)

13:15 **3. Current and Planned Activities**

- NGA-H (*Norm Abrahamson 20 minutes*)
- NSF Implementation Project (*Paul Somerville 20 minutes*)
- Puente Hills Scenario (*Graves 20 minutes*)
- Community Modeling Environment (*Phil Maechlin 20 minutes*)

14:35 **BREAK**

14:50 **4. Identification of Needs and Issues** (*moderated by Somerville*)

- Source Characterization
- Path / Velocity Structure
- Site Response
- Computational Resources
- Other (formal BB project group?)

16:00 **5. Summary and Adjournment**

Table 1: Participant list (01/28/05)

Name	email
Brad Aagaard	baagaard@usgs.gov
Norm Abrahamson	naa2@pge.com
John Anderson	jga@seismo.unr.edu
Jacobo Bielak	jbielak@andrew.cmu.edu
Ji Chen	jichen@gps.caltech.edu
Paul Davis	pdavis@ess.ucla.edu
Doug Dreger	dreger@seismo.berkeley.edu
Robert Graves	robert_graves@urscorp.com
Tom Heaton	heatont@institute.caltech.edu
Swami Krishnan	krishnan@gps.caltech.edu
Peng-Cheng Liu	pcliu@quake.crustal.ucsb.edu
Phil Maechling	maechlin@usc.edu
Lalliana Mualchin	lalliana_mualchin@dot.ca.gov

Anna Olsen	annao@caltech.edu
Kim Olsen	kbolsen@sciences.sdsu.edu
Arben Pitarka	arben_pitarka@urscorp.com
Paul Somerville	paul_somerville@urscorp.com
Jeroen Tromp	jtromp@gps.caltech.edu
Yuehua Zeng	zeng@seismo.unr.edu

Northridge Simulation Exercise

The exercise consists of simulating the broadband ground motion time histories at 30 selected sites for the 1994 Northridge earthquake. The target bandwidth is 0.1 to 10 Hz. Modelers were free to use any simulation methodologies, or combinations thereof, they desire. Additionally, the choices of rupture model, velocity structure (1D, 2D, or 3D) and site response were also left up to the individual modelers. The primary requirements are those listed below:

1) Simulated ground acceleration time histories for the selected sites must be submitted in the format described below.
2) The simulation methodology and model parameterization must be applied uniformly and consistently to the entire exercise (e.g., applying a point source model for some stations and a finite-fault rupture model for others is not allowed).
3) The simulation methodology must be fully described and documented; existing published papers are acceptable.
4) The rupture model parameterization must be fully described and documented in the format specified below.

Simulation results were submitted by six modeler groups:

Modeler Group	Methodology	Bandwidth
Beresnev	stochastic	f > 1 Hz
Dreger	Deterministic, 1D	0 – 10 Hz
Graves & Pitarka	Hybrid, 3D/1D	0 – 10 Hz
Olsen & Mai	Hybrid, 3D/1D	0 – 10 Hz
Tromp, Krishnan & Ji	Deterministic, 3D	0 – 0.5 Hz
Zeng	Deterministic/composite, 1D	0 – 10 Hz

Validation Results

Rob Graves analyzed the simulation results both in terms of how well they can reproduce the observed motions from the Northridge earthquake and how they may be applied to predict motions for future earthquakes. Figure 1 summarizes the spectral acceleration goodness-of-fit for these six sets of results. Figure 2 summarizes the predicted match to the observed PGA and PGV for the four fully-broadband results.

The comparisons indicate that most of the simulation methodologies do reasonably well at the longer periods (T > 2 sec). At shorter periods, the more mature simulation approaches (Graves, Zeng) do reasonably well, while the other methods require more refinement. This is the subject of current work.

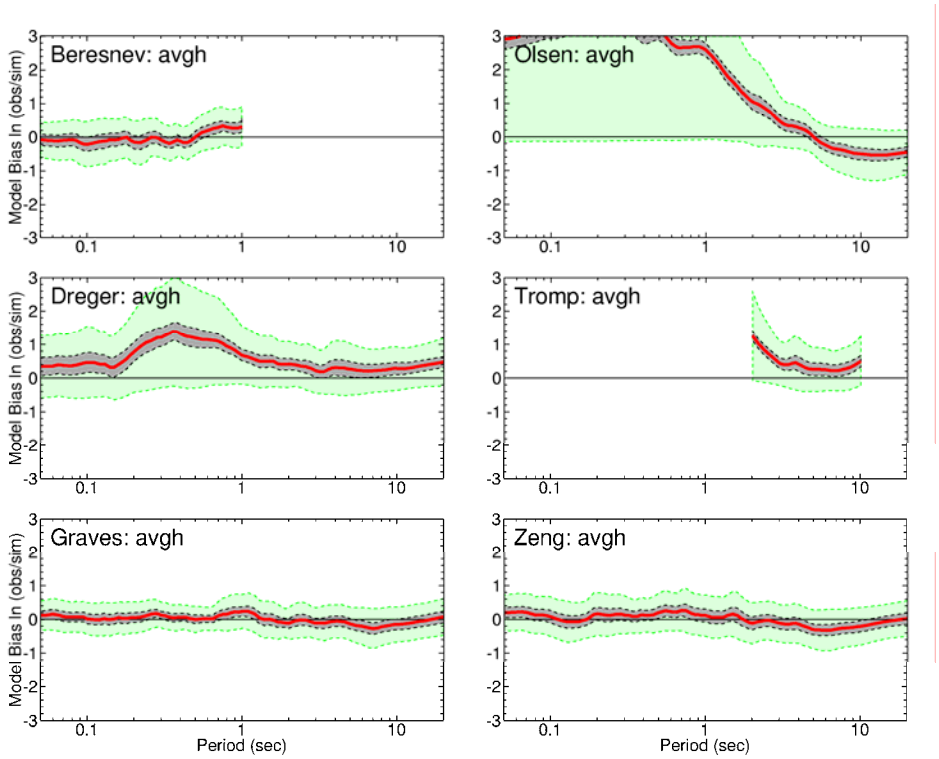

Figure 1: Spectral acceleration goodness-of-fit averaged over 30 sites.

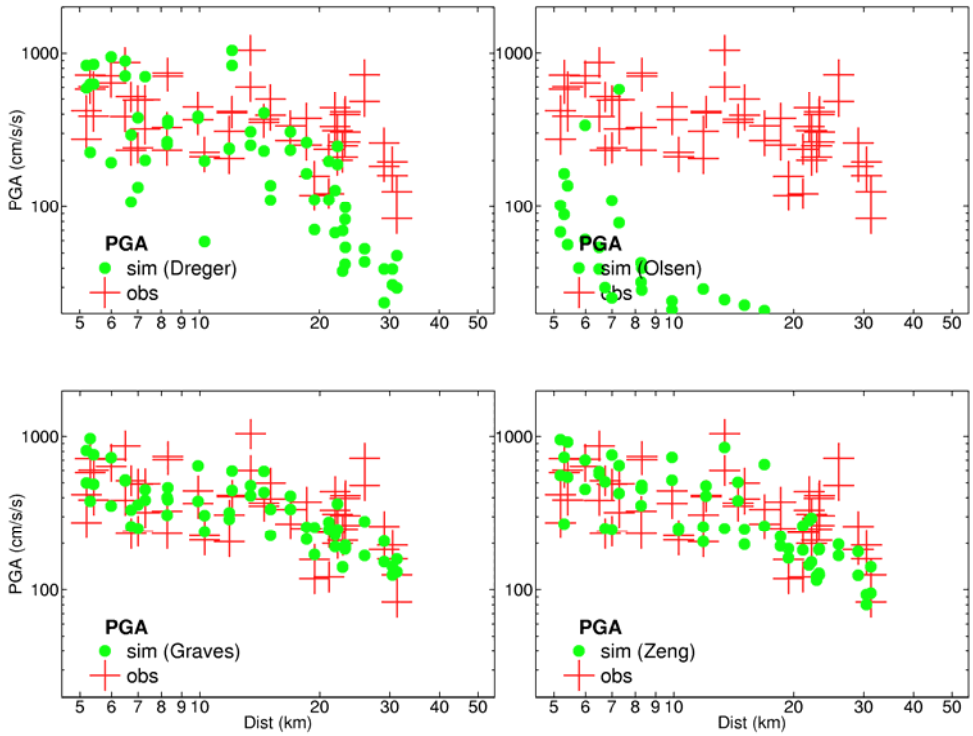

Figure 2a: Simulated and predicted PGA measured from time histories.

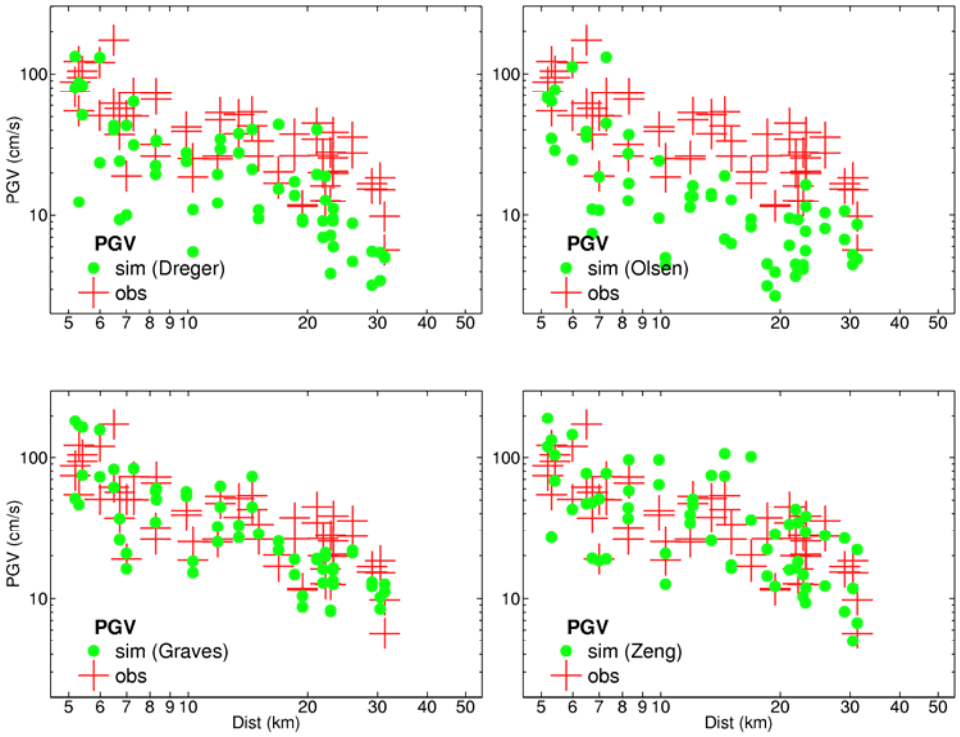

Figure 2b: Simulated and predicted PGV measured from time histories.