Work Plan for Scenario Earthquake Simulations (SEQ.1)

Robert W. Graves

prepared for the SCEC 3D Modeling Group

July 1, 2003

Introduction

This documentation describes the work plan for the simulation of scenario earthquakes in Southern California using the SCEC 3D Velocity Model. The results of these simulations will be used for a variety of applications, including the estimation of ground motions for future earthquakes and to provide guidance in developing engineering ground motion models that explicitly account for basin response. Along with this documentation, I have included a Unix tarfile that contains additional information (files). The tarfile is named 'scenarios.tar'.

Faults

We will use the 10 faults listed in Table 1 for the scenario calculations. The surface projections of these faults are also shown in Figure 1. The lon. and lat. coordinates in this table refer to the geographic location of the top center of the fault, that is, the point on the surface that is directly above the midpoint of the top edge of the fault. Strike, dip and rake follow Aki and Richards' convention. Length, width and depth are all given in km. The "depth" refers to the depth below the surface of the top edge of the fault (0 means surface outcrop).

TABLE 1: Scenario Faults.

Fault	Lon (TC)	Lat (TC)	M_w	Length	Width	Strike	Dip	Rake	Depth
1) smad	-118.1776	34.2415	7.0	61	18	288	53	90	0
2) smon1	-118.4785	34.0385	6.3	14	14	261	36	45	1
3) hwood	-118.3427	34.0993	6.4	14	19	256	69	70	0
4) raym2	-118.1281	34.1388	6.6	26	17	258	69	70	0
5) ph2e	-118.0037	33.9042	6.8	25	27	268	27	90	3
6) phla	-118.2293	34.0026	6.7	21	26	293	28	90	3
7) phall	-118.1020	33.9670	7.1	46	27	289	27	90	2
8) comp	-118.3440	33.8428	6.9	63	14	306	22	90	5
9) nin	-118.2020	33.8676	6.9	51	16	319	90	180	0
10) whitn	-117.8762	33.9330	6.7	35	15	297	73	160	0

Model Region

The "minimum" area that should be covered by the 3D model is the 100 km $\times$ 100 km region outlined by the green box in Figure 1. The corners of this region are given by the geographic coordinates:

$$c1 = -118.70000, 33.58000$$
$$c2 = -118.70000, 34.47746$$
$$c3 = -117.61823, 34.47746$$
$$c4 = -117.61823, 33.58000$$

The origin of this model region is at the lower left (southwest) corner:

$$Lon = -118.7000$$
$$Lat = 33.5800$$

By "minimum" area, I mean that we should put the boundaries of our computational model (i.e. absorbing boundaries) to lie at or outside of this area. The model should extend to a depth of at least 30 km. For the uniform grid FD modelers (with 4th order spatial operators), a maximum grid spacing of 200 m should be used. This gives a model grid of at least 500 $\times$ 500 $\times$ 150 points.

Material Properties

We will use the same velocity model specification as was used in NOR.1. This means that the minimum shear wave velocity will be set at 500 m/s and our target bandwidth is T > 2 s. All grid spacing parameterizations should be made to ensure adequate resolution for this bandwidth.

For attenuation, we will use the same parameterization that was used for NOR.1. That is,

$$Q_s = 0.02 * V_s \qquad \text{for} \quad (V_s < 1500\ m/s),$$
$$Q_s = 0.1 * V_s \qquad \text{for} \quad (V_s > 1500\ m/s),$$
$$Q_p = 1.5 * Q_s.$$

Duration

The total duration of the runs should cover 80 seconds at a minimum. Since some of these faults are rather long (eg., Sierra Madre), we need to make sure we simulate a long enough time window to capture the major arrivals. Extending the simulations to longer duration is certainly acceptable, and this decision will be left up to the individual modelers.

Output

The output (i.e. 3 component time histories) should be saved on a 2 km × 2 km grid covering the inner 80 km × 80 km of the minimum model area. This means that there will be a minimum 10 km buffer zone between the station output grid and the nearest computational boundary. No filtering (other than the source time function) should be applied to the output.

The above parameterization will give us 1600 sites for each realization. The locations of these 1600 points are indicated by the red dots in Figure 2.

The following naming convention will be used for the points in the output grid. Taking the origin as the lower left (SW) corner of the minimum model area (green box in Figure 2), the grid stations will be named in the form **gNNEE**, where **NN** and **EE** are, respectively, the distance north and east of the model origin (to the nearest km). The first station will be at **NN**=11 km and **EE**=11 km and will have a name of **g1111**. The next station to the east will be **NN**=11 km, **EE**=13 km and **g1113**. And so on so that the last station (NE corner) will be **NN**=89 km, **EE**=89 km and **g8989**. Mathematically, the northing and easting of these stations is given by:

$$
\begin{aligned}
&for(j = 0; j < 40; j++) \quad \{ \\
&\qquad for(i = 0; i < 40; i++) \quad \{ \\
&\qquad\qquad EE[i + j * 40] = 11.0 + i * 2.0; \\
&\qquad\qquad NN[i + j * 40] = 11.0 + j * 2.0; \}\}
\end{aligned}
$$

In addition, we will use a subset of 16 stations from this grid to do the cross-checking of the runs. These stations are indicated by the black triangles in Figure 2 (along with their names using the above convention).

For the cross-checks, the responses for the 16 stations can be put into an ASCII file following the MATLAB format that we have been using for other runs. This way, we can easily exchange and compare these responses to make sure we are all on the same page.

The file name convention for the MATLAB file should follow the format:

group.slip_hypo.SEQ.1

where group is the modeling group, slip is the name of the fault and slipmodel, and hypo is the hypocenter number. For example, the ouput calculated by **URS 2** for slipmodel number **02** of fault **phall** with hypocenter number **h1** would have a file named:

urs2.phall_02_h1.SEQ.1

Within the MATLAB file, please use the following order for the cross-check stations:

1)	-118.40730	33.82280	g2727
2)	-118.23390	33.82280	g2743
3)	-118.06050	33.82280	g2759
4)	-117.88700	33.82280	g2775
5)	-118.40730	33.96670	g4327
6)	-118.23390	33.96670	g4343
7)	-118.06050	33.96670	g4359
8)	-117.88700	33.96670	g4375
9)	-118.40730	34.11060	g5927
10)	-118.23390	34.11060	g5943
11)	-118.06050	34.11060	g5959
12)	-117.88700	34.11060	g5975
13)	-118.40730	34.25440	g7527
14)	-118.23390	34.25440	g7543
15)	-118.06050	34.25440	g7559
16)	-117.88700	34.25440	g7575

Listings of the Lon. and Lat. coordinates for the output grid stations and cross-check stations are also given in the files

StatInfo/fd1600.lonlat
StatInfo/fdcheck.lonlat

which are contained in the tarfile 'scenarios.tar'.

I am going to defer a final decision on the formatting and exchange of output for the large grid of stations until we get into the simulations a little further. For the time being, I would like to have each modeler save the results for each run as three component time histories at each of the 1600 grid stations. This will be a minimum requirement, if you would like to save the results at more locations (e.g. time-slices), please do so. Also, if possible, please save the responses at the time sampling rate used in the calculation. We can always subsample the data (in time and/or space) later; however, at this point I am not prepared to specify any particular mechanism for doing this. I suspect that after we have started on the simulations and have had a chance to look at the results from the cross-checks, then we will have a better idea on exactly how to proceed with the final data formatting and exchange.

Rupture Models

For each fault, we will run 2 hypocenter locations and 3 slipmodels. The format of the rupture model description will be similar to that used for NOR.1. That is, each fault is divided into a number of rectangular subfaults each having a different slip amount. Over each individual subfault, the slip amount will be constant. The subfault dimensions are the same for all faults and are set at 1 km $\times$ 1 km.

We will use a single constant rake value for all subfaults on the entire fault. The rake values for each fault are listed in Table 1.

Slip Distributions

For each of the fault geometries, I have generated random slip distributions for use in the simulations. The slip distributions are generated following some empirical rules for the size and distribution of asperities as given by Somerville et al. (1999). I originally generated 10 slip distributions for each fault, and from this set I selected 3 slip models that appear to be reasonably "different" from one another. Plots of the selected slip models are shown in Figures 3a-j.

Individual files containing these slipmodels are included on the tarfile, 'scenarios.tar'. On the tarfile, the slipmodels are in the directory:

SlipModels/GenSlip/Scec

For each fault, there are three files corresponding to the 3 slip distributions. The file naming convention is of the form:

<name>_<SS>, e.g., smad_03, hwood_06, ph2e_09, ...

The name is the fault name and the suffix SS is an integer code which refers to the number of that particular slipmodel (out of the original set of 10). Theoretically the value of SS can be 01, 02, 03, ..., 10, but obviously, only three files are provided for each fault.

These ASCII files have the following format:

Line 1:	name lon lat strike dip rake Mw
Line 2:	NS ND length width depth
Line 3:	comment_line
Line 4:	data
.	
.	
.	
Line ND+3:	data

Here NS and ND are the number of subfault elements along strike and down-dip, respectively. The data are absolute slip values given in cm. The ordering of the subfaults is by rows, starting from the top end of the fault opposite the strike direction.

Hypocenter Locations

The two hypocenter locations are defined as follows for each fault: Hypocenter 1 is located at an along strike (AS_1) distance of 0.25 of the fault length and at a down-dip (DD_1) distance of 0.7 of the fault width (measured within the fault plane from the top edge of the fault, *not* the ground surface). Hypocenter 2 is located at an along strike (AS_2) distance of 0.75 of the fault length and at a down-dip (DD_2) distance of 0.7 of the fault width. Table 2 lists the hypocenter locations (in km) for each of the specific faults. In addition, the two hypocenter locations are plotted on the slipmodel contours shown in Figures 3a-j.

Slip Velocity Function

The slip velocity function for all runs will be an isosceles triangle with a base of duration T_r. The explicit form of this function is the same as given in the NOR.1 documentation. The value of T_r is magnitude dependent and given by the empirically derived expression (Somerville et al., 1999):

$$\log_{10}(T_r) = 0.5 * (M_w + 10.7) + \log_{10}(2.0 \times 10^{-9})$$

where $\log_{10}$ is base 10 logarithm and M_w is moment magnitude. Table 2 lists the values of T_r for each event.

TABLE 2: Hypocenters and Rise Times.

		Hypocenter 1		Hypocenter 2		
Fault	M_w	AS_1(km)	DD_1(km)	AS_2(km)	DD_2(km)	T_r(s)
1) smad	7.0	15.25	12.6	45.75	12.6	1.4
2) smon1	6.3	3.5	9.8	10.5	9.8	0.63
3) hwood	6.4	3.5	13.3	10.5	13.3	0.71
4) raym2	6.6	6.5	11.9	19.5	11.9	0.89
5) ph2e	6.8	6.25	18.9	18.75	18.9	1.1
6) phla	6.7	5.25	18.2	15.75	18.2	1.0
7) phall	7.1	11.5	18.9	34.5	18.9	1.6
8) comp	6.9	15.75	9.8	47.25	9.8	1.3
9) nin	6.9	12.75	11.2	38.25	11.2	1.3
10) whitn	6.7	8.75	10.5	26.25	10.5	1.0

Rupture Velocity

Rupture velocity will be constant for all faults and all slipmodels. This value is set at 2.8 km/s. The rupture starts at the hypocenter and spreads radially outward from this point at the specified velocity.

Division of Labor

The distribution of runs is set up to try to evenly balance the manpower demands in terms of model set-up, while still taking advantage of the CPU power where it is most readily available. Table 3 outlines the proposed distribution of runs:

TABLE 3: Distribution of Simulation Runs.

	Modeling Groups				
Fault	UCB-LLNL	UCSB	CMU	URS 1	URS 2
1) smad	f		c		
2) smon1	f		c		
3) hwood	f			c	
4) raym2	f			c	
5) ph2e		f		c	
6) phla		f		c	
7) phall		f			c
8) comp		f			c
9) nin			f		c
10) whitn			f		c

where

f = run full set of 6 realizations for particular fault
c = run 1 check realization for particular fault

Under this plan, each modeler will have to set up runs for 4 faults (thus, equalizing the manpower load, more-or-less). However, the number of runs will be different from modeler to modeler (thus, taking advantage of the CPU resources where they are available).

This means that UCB-LLNL and UCSB will run 24 simulations each, CMU will run 14 simulations, and URS1 and URS2 will run 4 simulations each.

For each of the cross-check runs (i.e., the "c" runs above), the modeler will use Hypocenter 1 and the lowest number slipmodel available for that particular fault. For example, to do the cross-check run for fault **smon1** (fault 2), the CMU group would use Hypocenter 1 (AS_1 and DD_1 in Table 2) and the slipmodel in the file **smon1_03**. We should start with these runs so we can do the cross-checks first and hopefully prevent any major set backs. This means that the groups doing the full set of realizations (i.e., "f" runs) should also start with Hypocenter 1 and the lowest number slipmodel available for that particular fault.

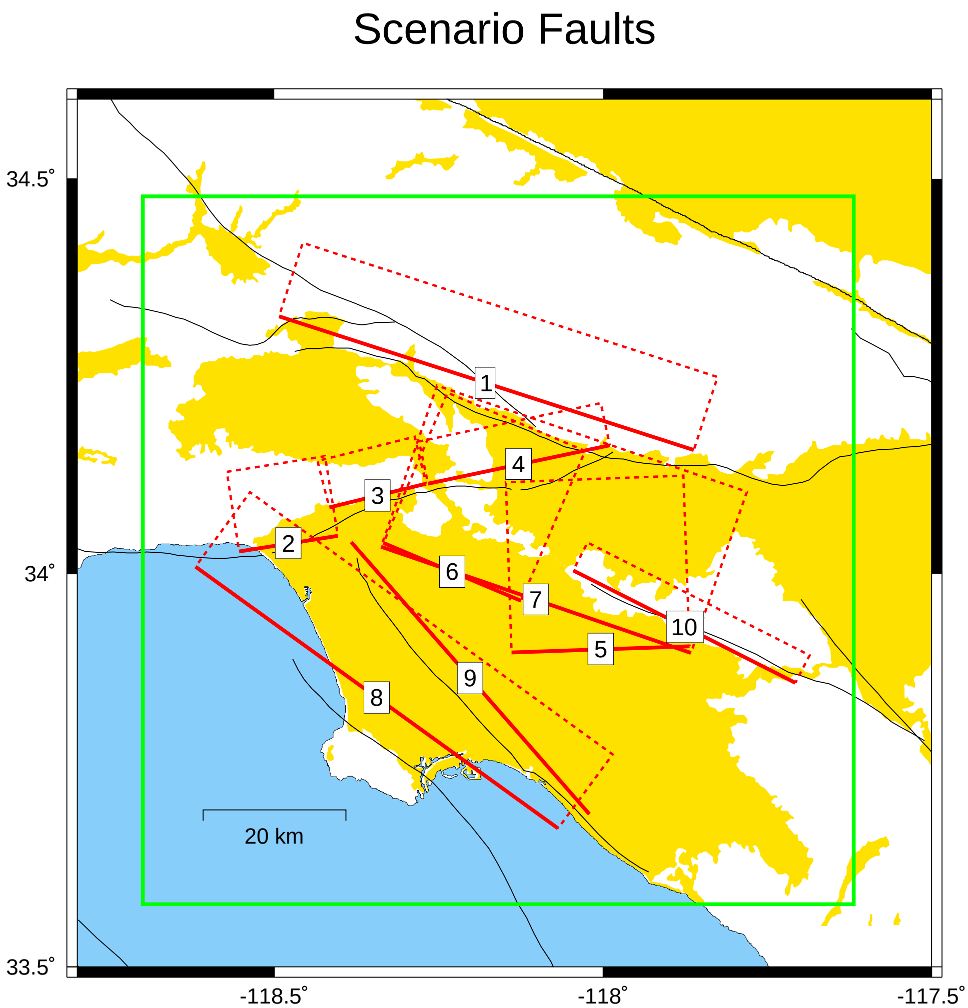
Schedule

We have at least two main deadlines on the horizon. The first is the SCEC Annual Meeting (Sep. 7-10) and the second is when we need to provide input for the NGA program (tentatively October). Obviously, we all have other demands on our time (and CPU resources), so we need to get started quickly if we intend to meet these deadlines.

Below is a rough outline of the proposed work schedule for the next few months:

Early July:	review plan, begin model set-up
Mid July:	start simulations (cross-checks first!)
End July:	compare initial cross-checks, continue full simulations
Mid August:	complete cross-checks, continue simulations, begin data analysis (basin response metrics)
End August:	complete at least 1/2 set of full simulations, continue data analysis
Early Sept.:	prepare and present results at SCEC Mtg
October:	provide results to NGA (PEER-LL)

The above plan represents a "target", and realistically, it may be rather optimistic. At the very least, I think we should all try to accomplish as much as we can in the next two months (July and August), so we can make a substantive presentation at the SCEC Meeting.



1) smad: Mw 7.0 Sierra_Madre
2) smon1: Mw 6.3 Santa_Monica_south_west
3) hwood: Mw 6.4 Hollywood
4) raym2: Mw 6.6 Raymond_connectors
5) ph2e: Mw 6.8 Puente_Hills_Santa_Fe_Coyote_Hills
6) phla: Mw 6.7 Puente_Hills_Los_Angeles
7) phall: Mw 7.1 Puente_Hills_all
8) comp: Mw 6.9 Compton
9) nin: Mw 6.9 Newport_Inglewood_north
10) whitn: Mw 6.7 Whittier_north

Figure 1: Map of scenario events and model region.

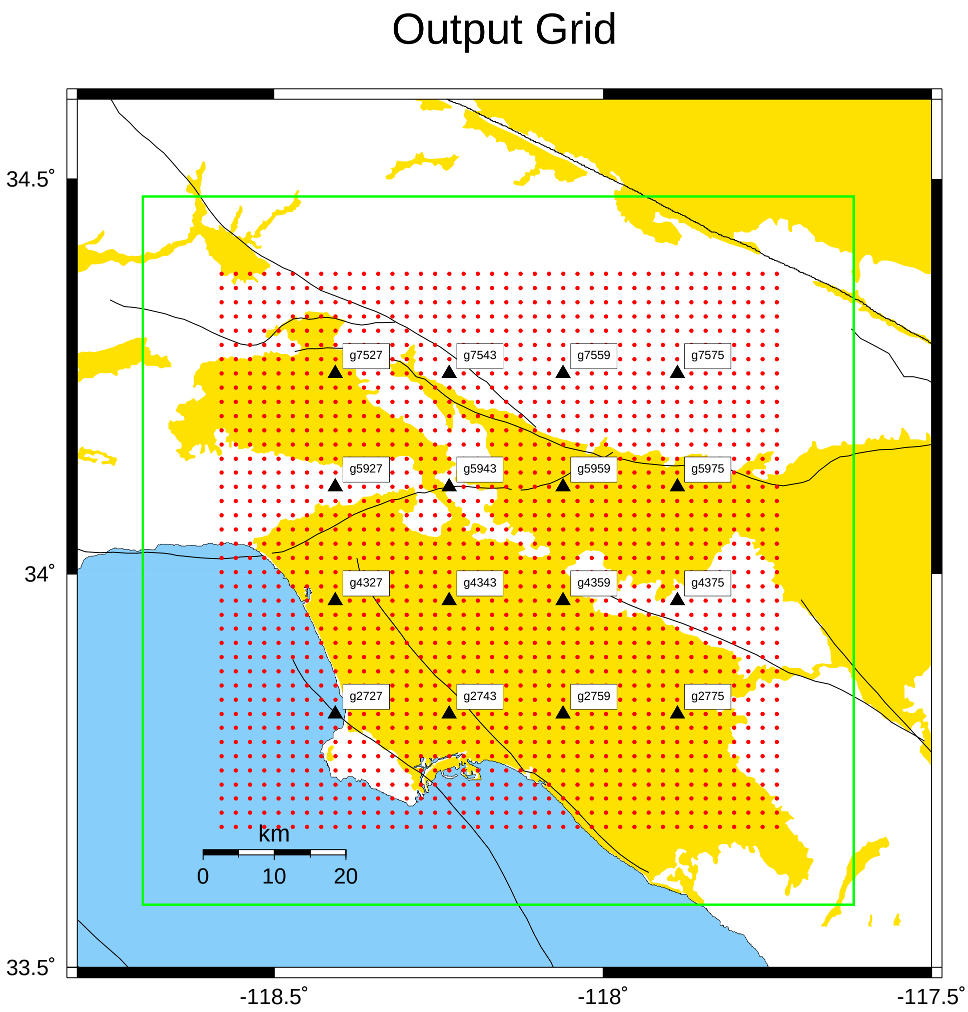


Figure 2: Map of output grid and cross-check stations.

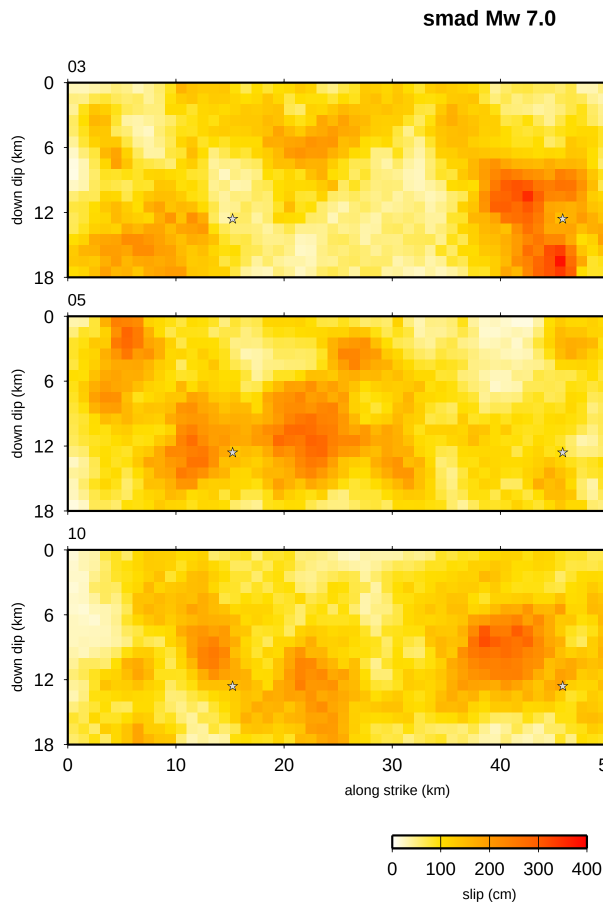


Figure 3a: Slip distributions for the Sierra Madre fault. Number of slipmodel file is given at top left of each contour plot. Average slip and maximum slip (in the form AVG/MAX, where both are in cm) are given at top right of each contour plot. The two hypocenter locations are shown by the open stars.

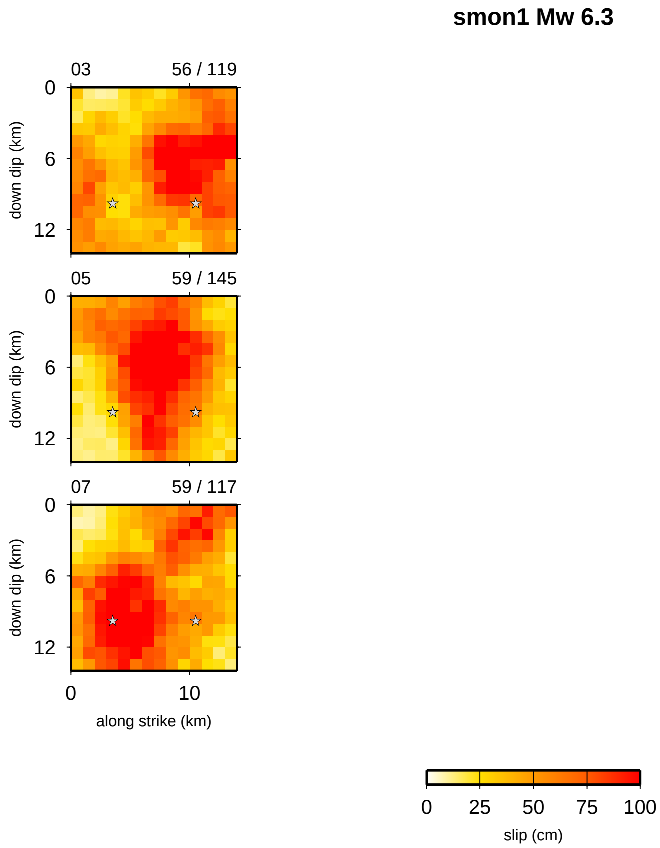


Figure 3b: Slip distributions for the Santa Monica fault.

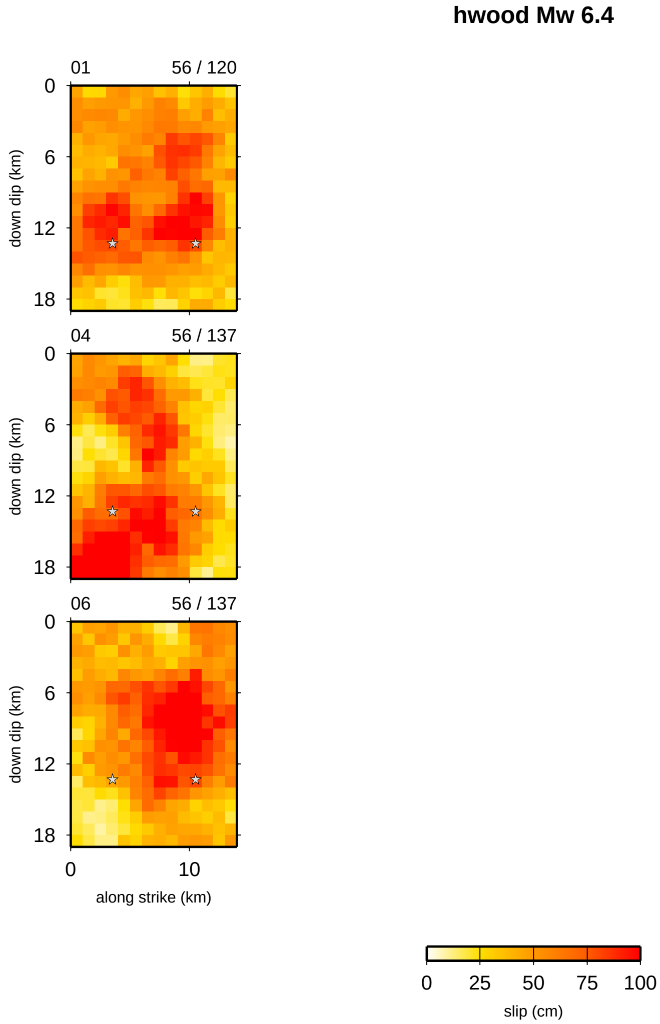


Figure 3c: Slip distributions for the Hollywood fault.

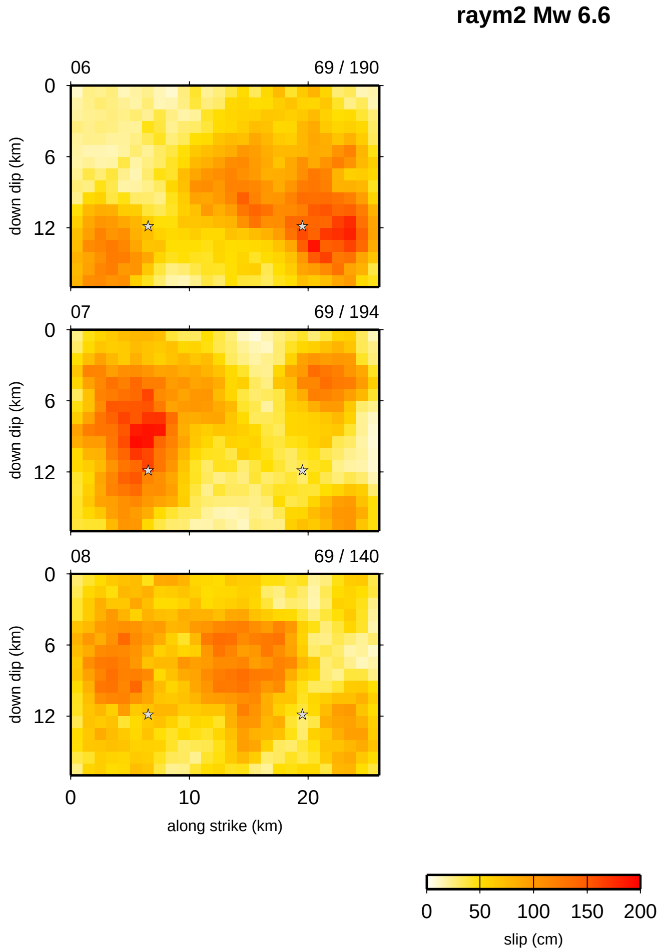


Figure 3d: Slip distributions for the Raymond fault.

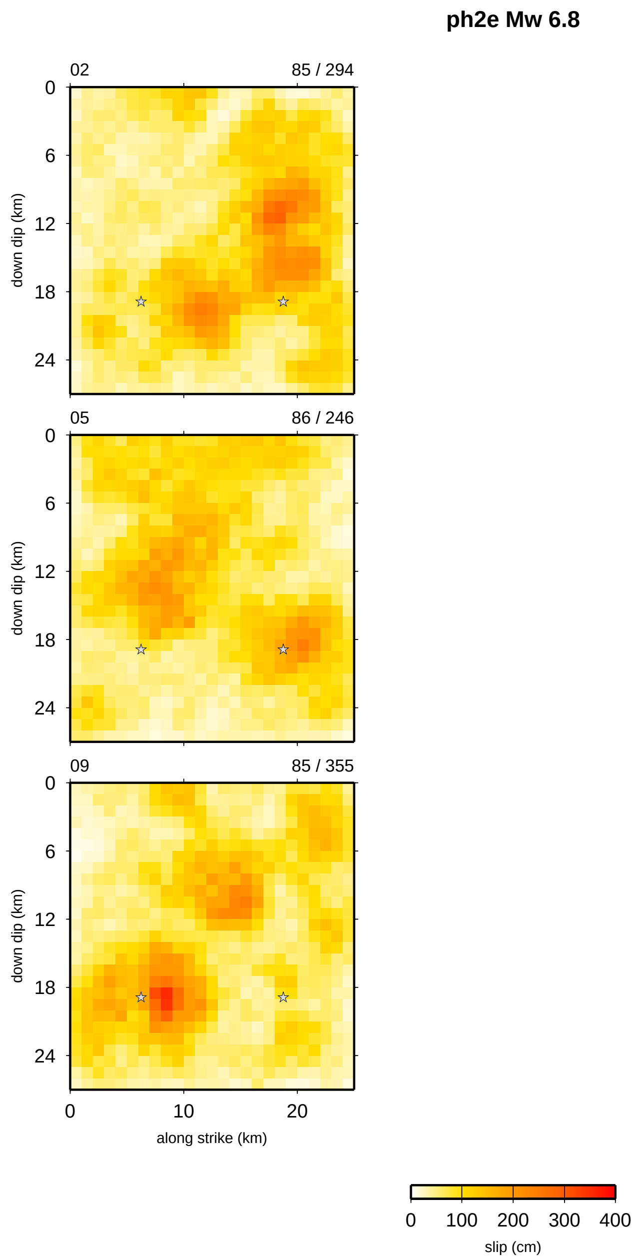


Figure 3e: Slip distributions for the Puente Hills (Santa Fe Springs and Coyote hills segments) fault.

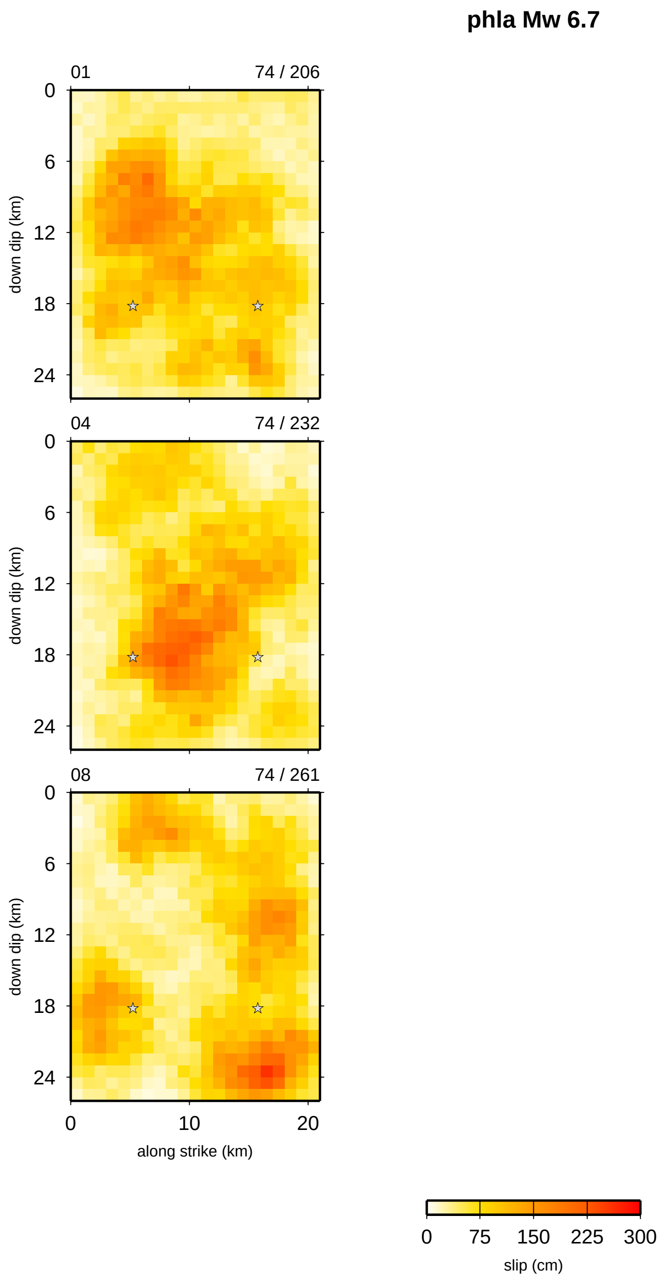


Figure 3f: Slip distributions for the Puente Hills (Los Angeles segment) fault.

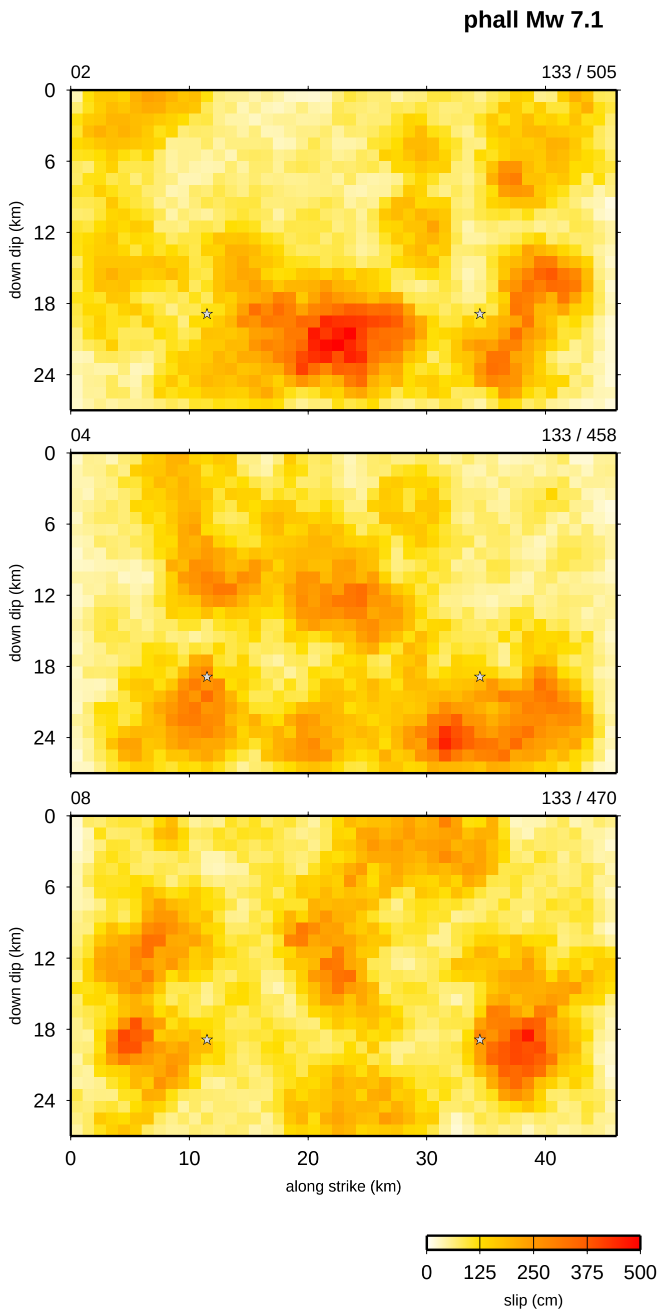


Figure 3g: Slip distributions for the Puente Hills fault.

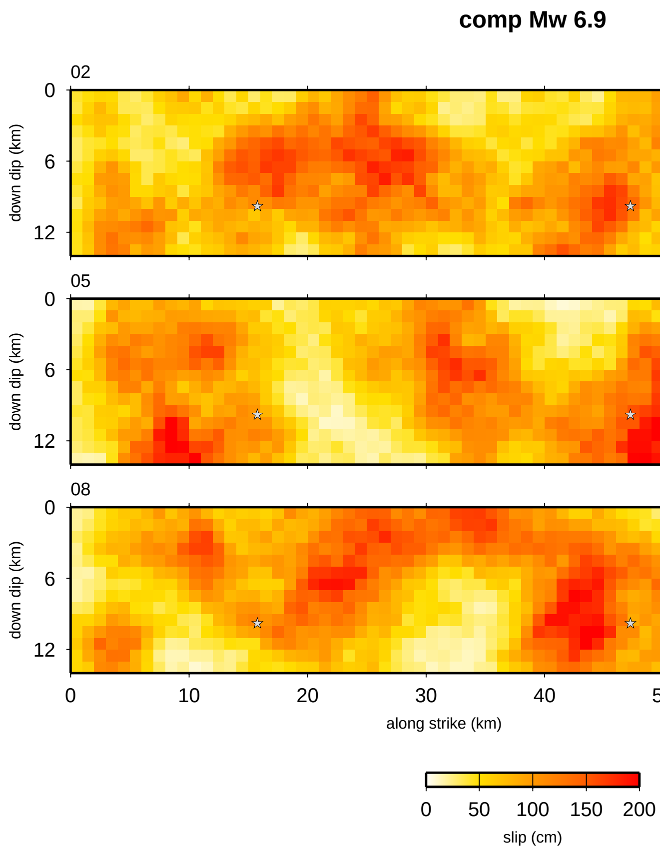


Figure 3h: Slip distributions for the Compton fault.

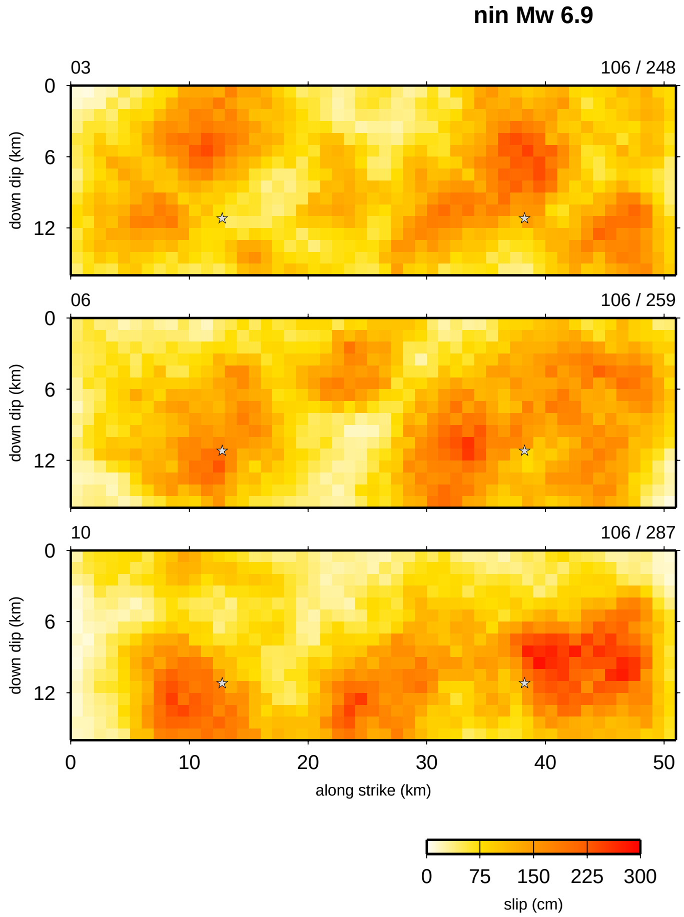


Figure 3i: Slip distributions for the Newport Inglewood fault.

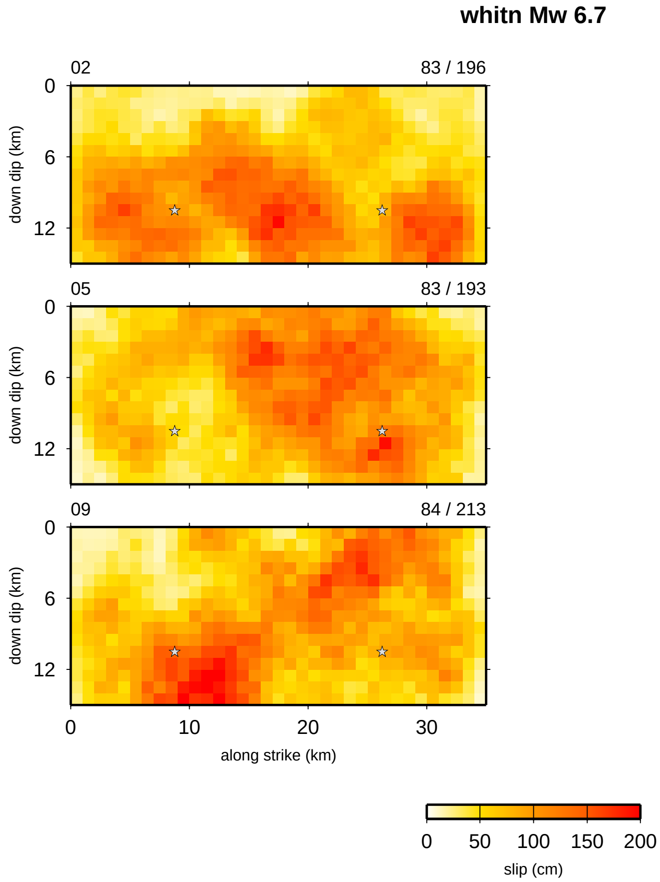


Figure 3j: Slip distributions for the Whittier fault.