SSA workshop: Earthquake Source Inversion

- Scope of this mini workshop
- Review of an initial blindtest
- Open discussion

Martin Mai

Morgan Page

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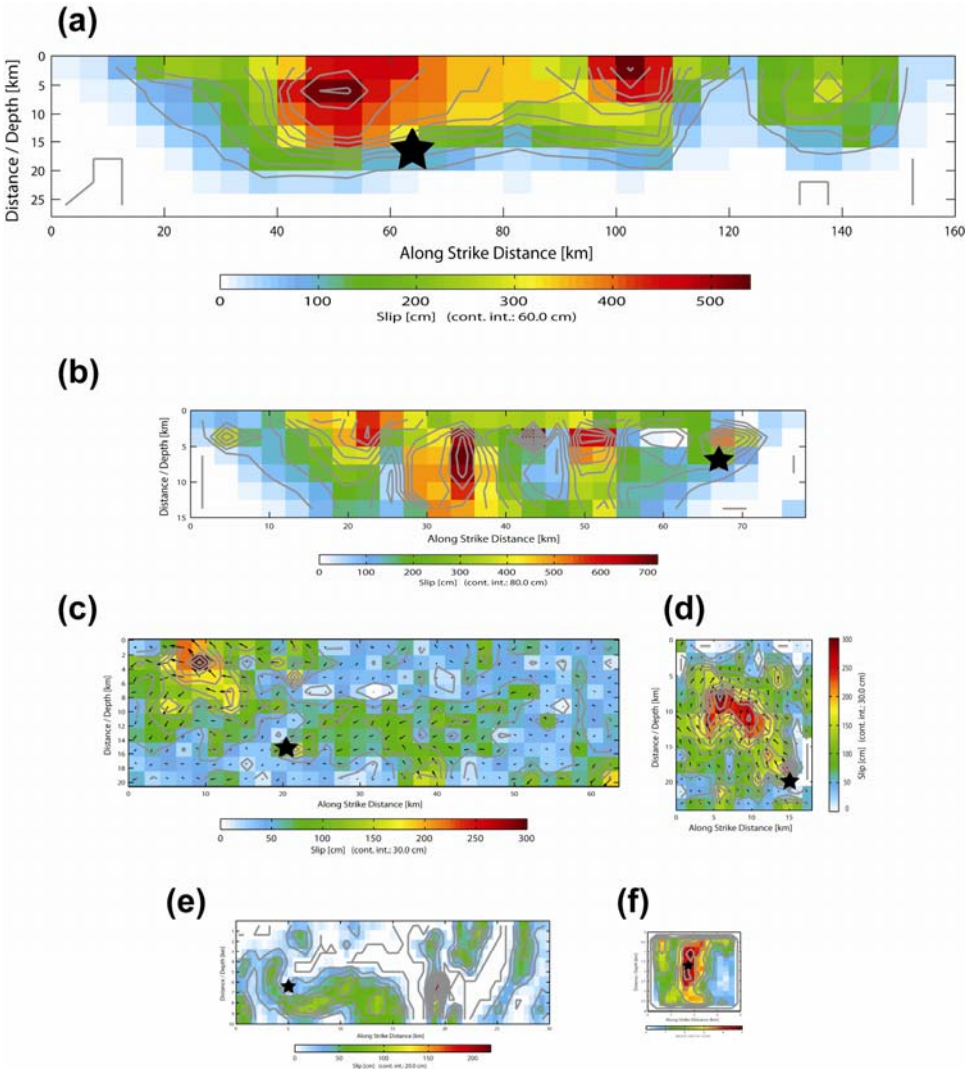
Schedule

7:30 – 7:45	**Martin Mai**	**Introduction to workshop; brief review of past activities**
7:45 – 8:00	**all participants**	**Step 0 – Green's function validation: review & discuss proposed computational and modeling set up**
8:00 – 8:30	**all participants**	**Discussion on data formats: dissemination of synthetics, submission of predicted waveforms; source-model formatting**
8:30 – 9:00	**all participants**	**Definition of time lines; future activities & workshops (2009, 2010 and beyond)**

Earthquake Rupture Models

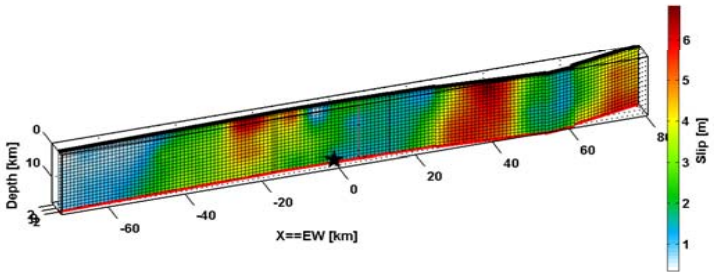
- Finite-source inversion are done almost routinely today, using a variety of inversion / modeling approaches, different data sets and processing steps
- We use the slip models to infer rupture dynamics, to devise source-characterization methods for ground-motion simulations, to perform Coulomb stress modeling, to ….
- But: how "good", i.e. reliable and robust, are these rupture models ?

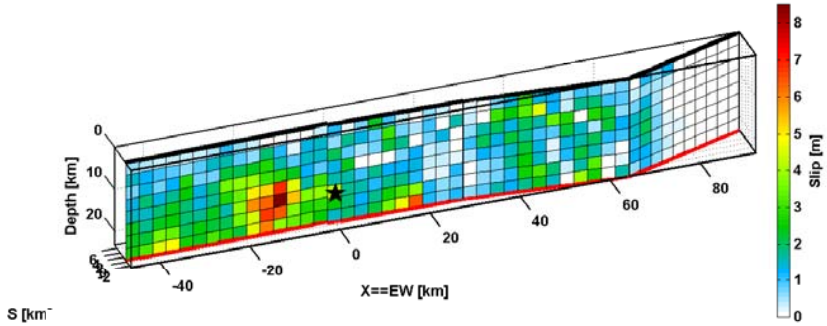


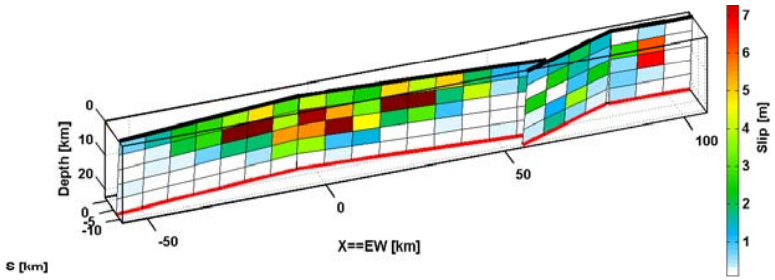
Intra-event variability

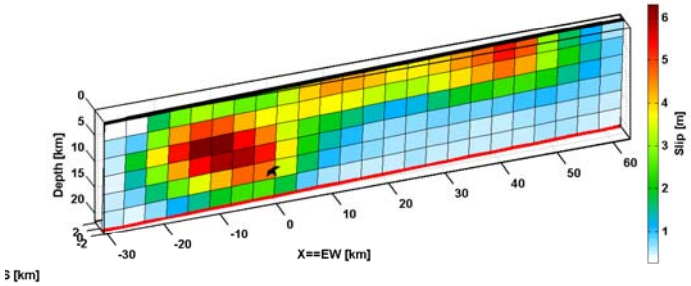
- **In cases where multiple slip-inversion solutions exist for a single earthquake we often find striking differences in the slip maps**

A suite of models for the 1999 Izmit (M 7.5) earthquake



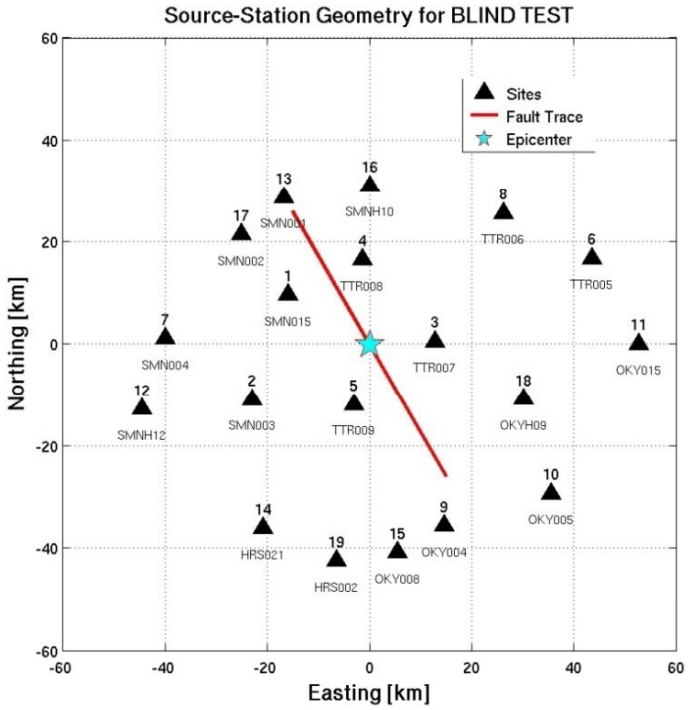


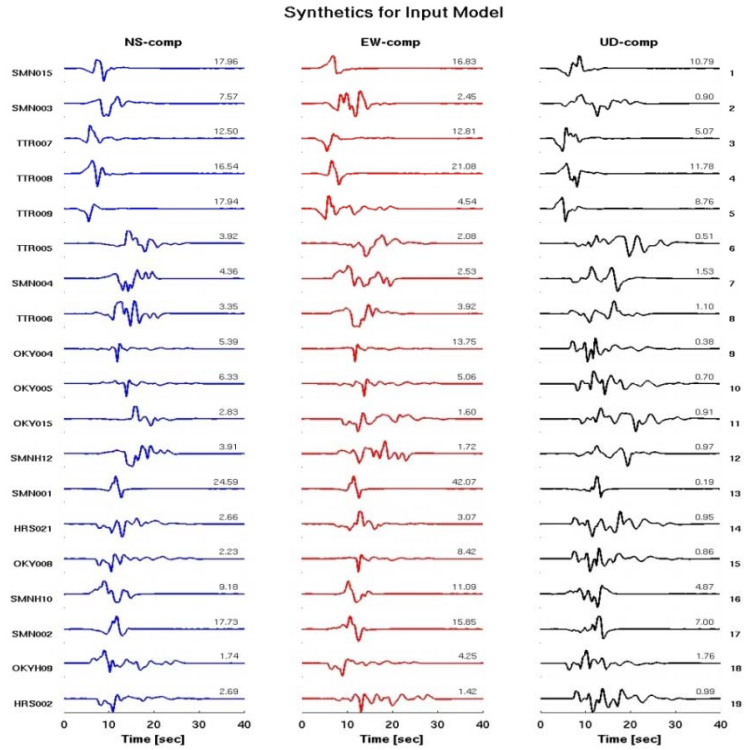




SPICE source-inversion blindtest

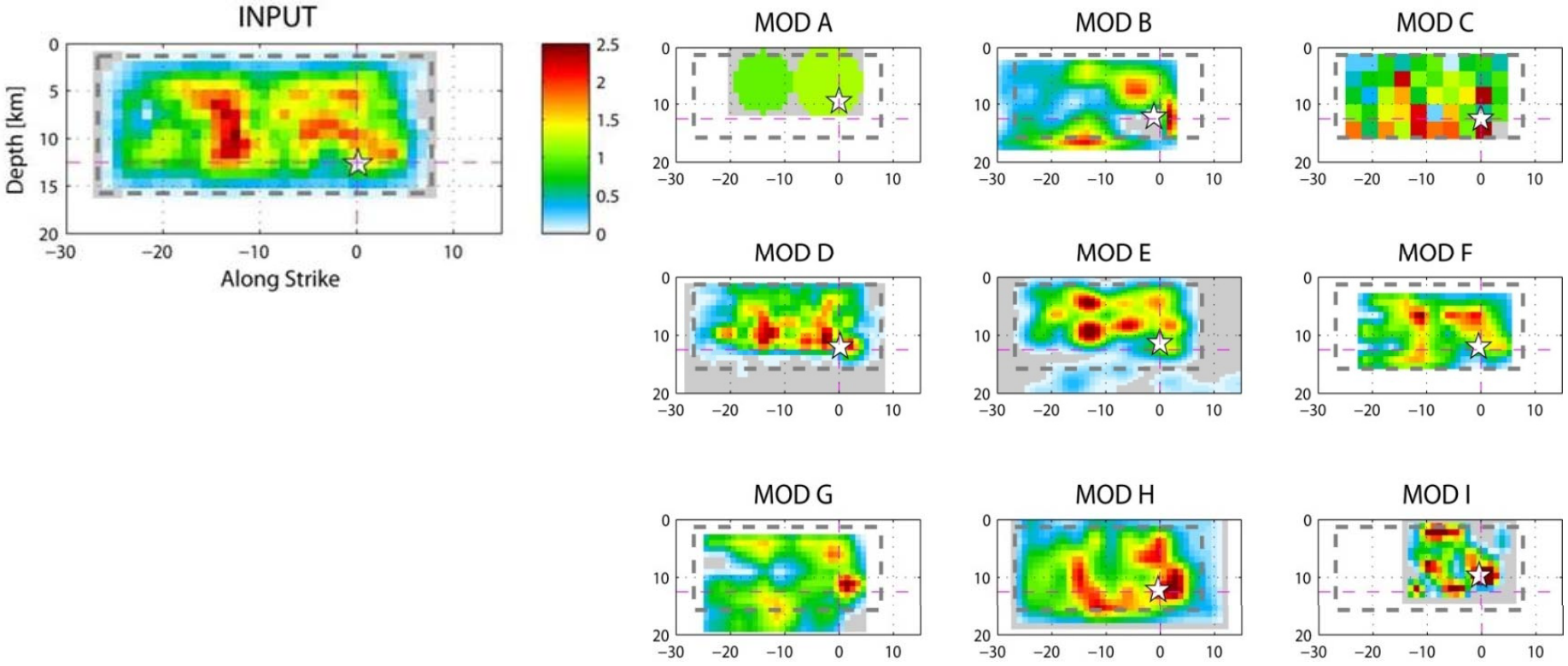
- Source geometry and station distribution similar to the 2000 Tottori earthquake
- Synthetic seismograms for 19 near-fault sites (COMPSYN, f_{max} ~ 3 Hz)
- Known: seismic moment: 1.43 × 10^{19} Nm, geometry (strike, dip, rake: 150°, 90°, 180°), hypocentral location and depth (Z= 12.5 km), velocity-density structure
- Unknown: slip on fault plane, rupture velocity & rise time (both constant)





SPICE source-inversion blindtest

- 9 groups; the slip models from 5 groups are “visually” similar to the input model
- variability in inferred rise time and rupture velocity (assumed constant) up to 20%
- waveform fits in all cases implied visually a “very good fit” ….



An initial summary

The first results of the blind test were unexpected

- Despite the "simplicity" of the input model, inversions could not resolve slip very well; uncertainties in rupture velocity and rise time up to 20%
- Despite differences among all inversion solutions, predicted waveforms are remarkably similar (f < 1 Hz), resulting in low misfit values (generally L_2-norm)
- 4 out of 9 inversion results are, statistically speaking, NOT better than a random model with somehow correlated slip!

- **Efforts toward source-inversion validation need to be continued & expanded to improve our current approaches to earthquake source inversion**

Past Activities

- **SPICE source inversion blindtest**
  - Initiated March 2005, started August 2005
  - 9 participating groups submitted their results, but in variable formats
  - Special AGU session (Dec 2007) with invited speakers, presentations on the blindtest methods, and a summary of the key finding of the blindtest

- **SCEC workshop on earthquake source inversion (Sept. 2008)**
  - ~50 participants, 6 invited speakers, and ~3 hrs intense discussions
  - General consensus that **SIV** (**S**ource **I**nversion **V**alidation) has to continue
  - Collection of general ideas on how to setup the problems and how to organize ourselves … but no formal decisions or "constitution of a core group"

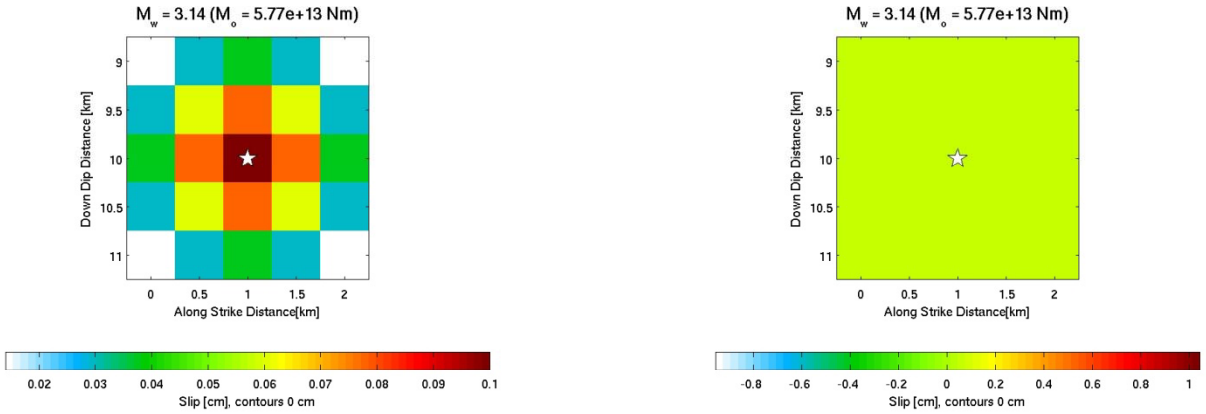
Past Activities, cont'd

- **Proposal to SCEC for financial support to continue the SIV-project**
  - Proposal submitted to SCEC (Nov 2008; Mai, Page, Schorlemmer)
  - Funding will come, but not clear yet at what level
  - To ensure long-term (3-5 year) support, we may need to think about additional funding sources

- **Dedicated webpage launched (March 2009)** **http://siv.usc.edu**
  - Online platform to distribute the inversion problems and all relevant meta-data
  - General communication & exchange platform for everyone interested in SIV
  - Planned: tools for uploading and comparing inverse solutions and corresponding data predictions

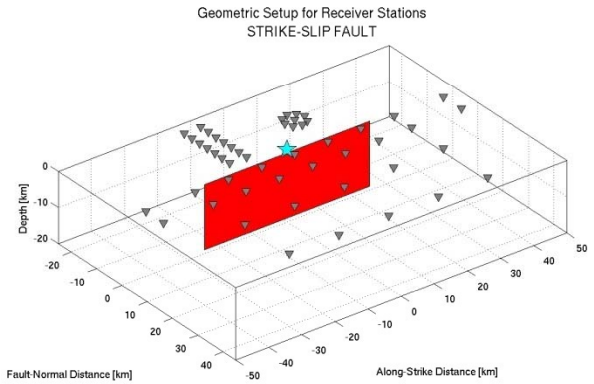
Step 0: Green's Function Validation

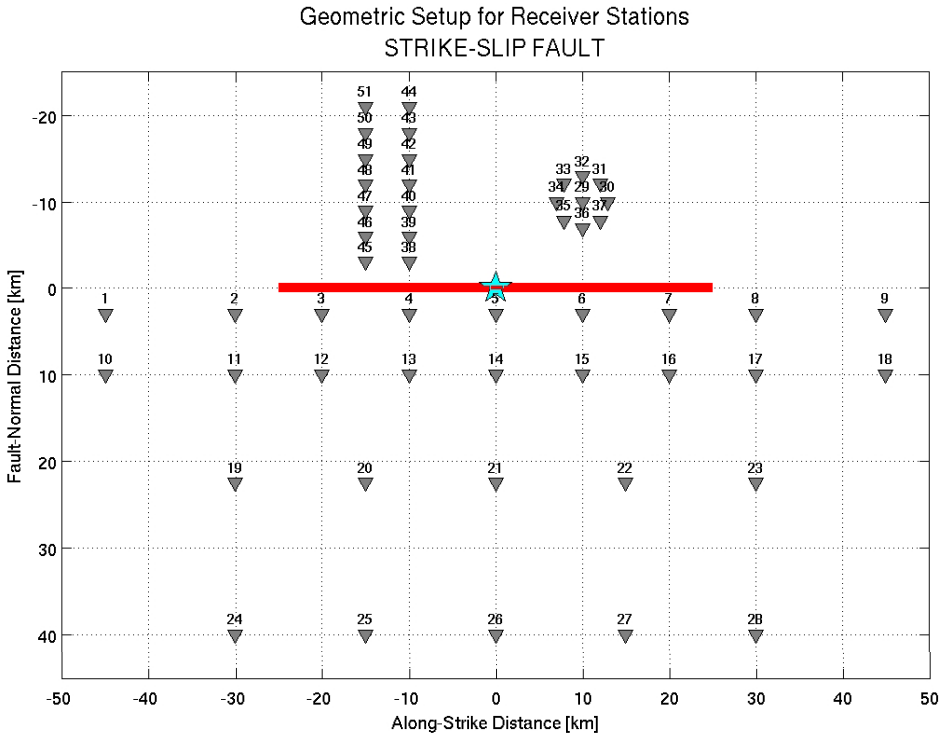
- **During the 2008 SCEC workshop, it was questioned if all groups participating in the blind test calculated the Green's functions correctly**
- **The SIV-project thus start with a zero-order test to verify GF-computations:**
  - "point-source" at 10 km depth, parameterized as a 2 x 2 km^2 slip patch
  - purely left-lateral strike-slip rupture on a vertical fault, M_w 3.14, M_0 = 5.77 x 10^{13}
  - Delta-pulse like slip-velocity function: 0.05-sec boxcar



Step 0: Green's Function Validation

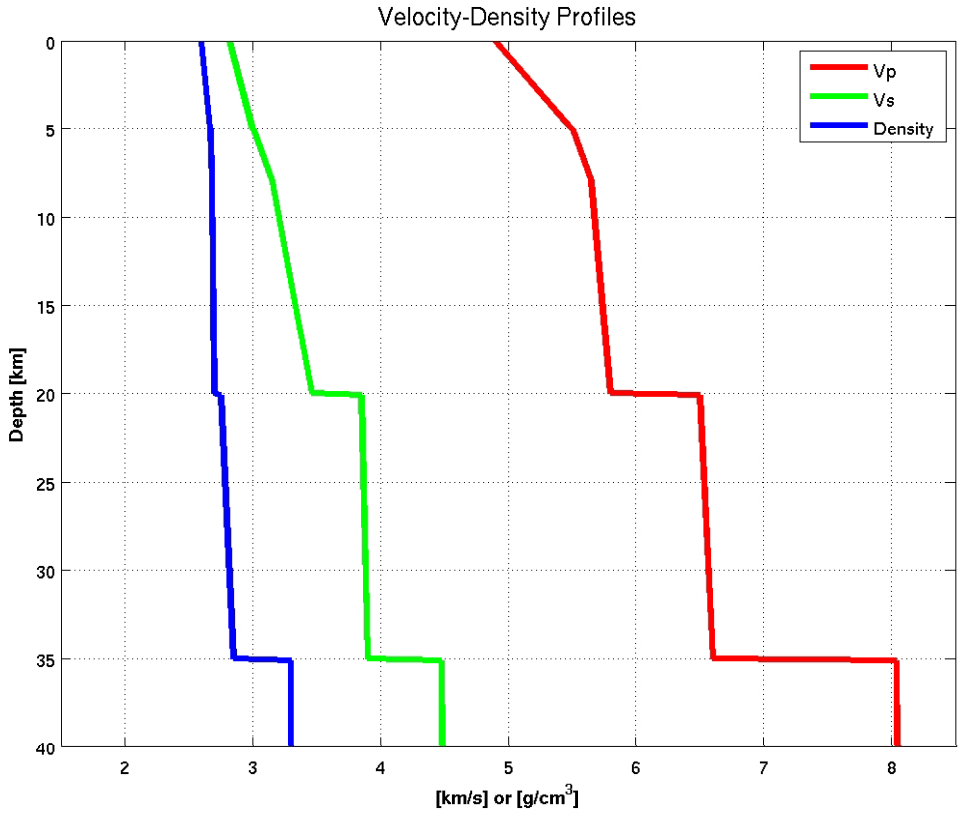
- **Proposed receiver geometry, consisting of several arrays:**
  - "regular" grid at various fault-normal distances
  - small-scale circular array
  - two fault-perpendicular line arrays





Step 0: Green's Function Validation

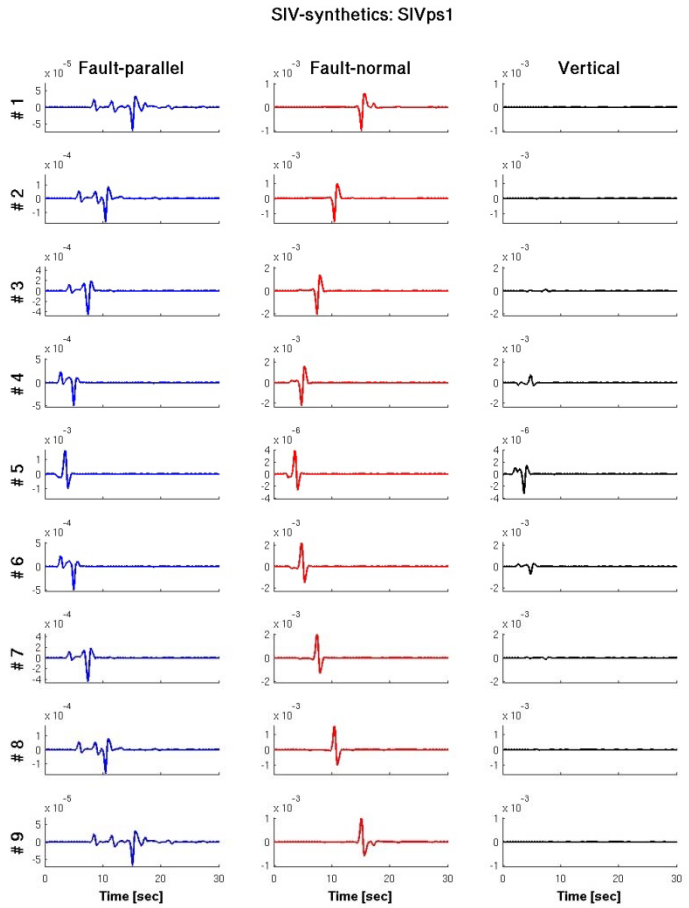
- **A first set of Green's function synthetics (0 – 2 Hz)**
  - Velocity-density structure modified from ak135-crust

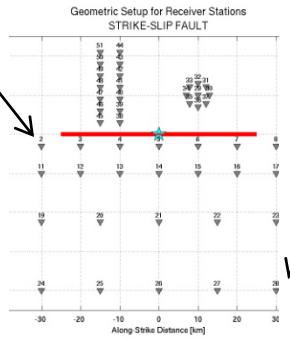


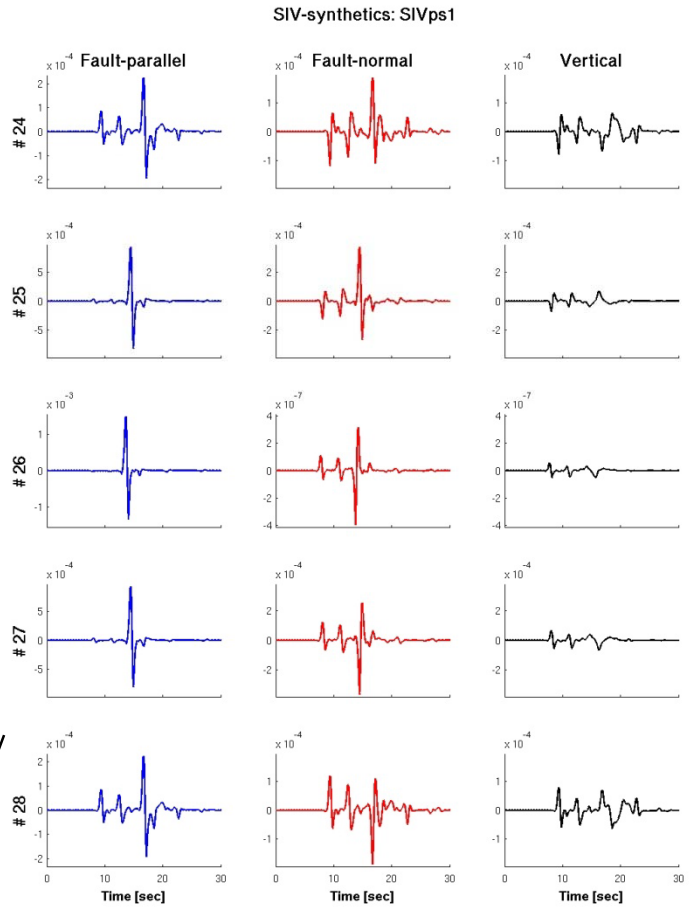
Z [km]	Vp [km/s]	Vs [km/s]	Rho [g/cm³]
0.0	4.90	2.82	2.60
5.0	5.50	3.00	2.67
8.0	5.65	3.15	2.68
20.0	5.80	3.46	2.70
20.1	6.50	3.85	2.75
35.0	6.60	3.90	2.85
35.1	8.04	4.48	3.30
80.0	8.05	4.49	3.30

Step 0: Green's Function Validation

- A first set of Green's function synthetics (CompSyn, 0 – 2 Hz)







Step 0: Green's Function Validation

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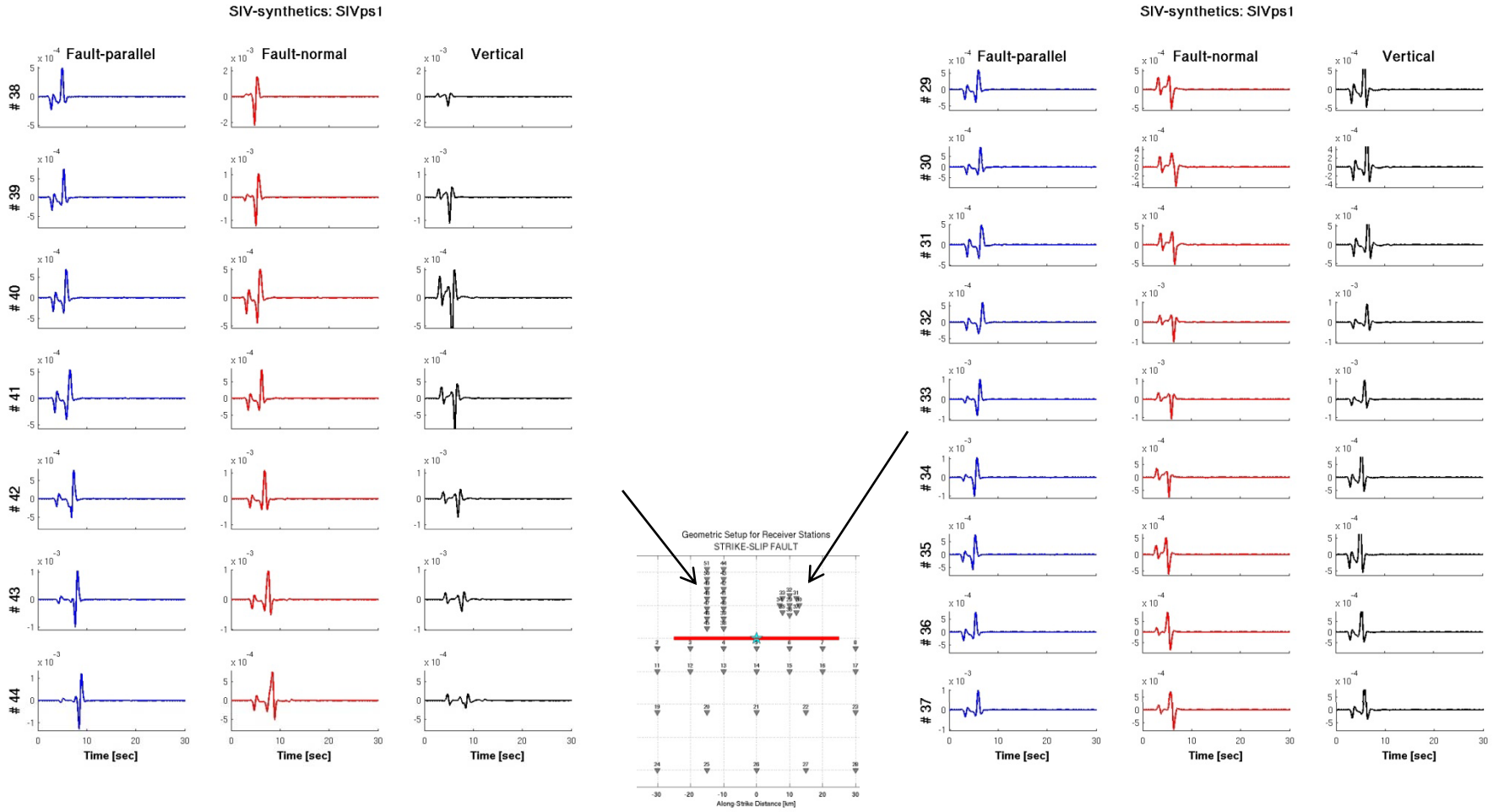

Schedule / Discussion

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8:30 – 9:00	**all participants**	**Definition of time lines; future activities & workshops (2009, 2010 and beyond)**

Discussion on modeling setup / Green's function

- **Comments & suggestions**
  - Blablabla
  - More blabla

Discussion on data & data formats

- **Proposed formats: plain ascii files, following exactly specified requirements**
  - Source model files →
  - Seismogram files ↳

```
Synthetic Seismograms for model SIVps1
Observer #  8, Station s25
XPOS =  -15.0000, YPOS = 40.0000
NPTS =  4096, DT = 0.0200
Velocity seismograms in cm/sec
    X (EW)     Y(NS) comp     U-D comp
    -0.00000     -0.00000     -0.00000
    -0.00000     -0.00000     -0.00000
    -0.00000     -0.00000     -0.00000
    -0.00000     -0.00000     -0.00000
    -0.00000     -0.00000     -0.00000
    -0.00000     -0.00000     -0.00000
    -0.00000     -0.00000     -0.00000
    -0.00000     -0.00000     -0.00000
    -0.00000     -0.00000     -0.00000
    -0.00000     -0.00000     -0.00000
    -0.00000     -0.00000     -0.00000
    -0.00000     -0.00000     -0.00000
    -0.00000     -0.00000     -0.00000
    -0.00000      0.00000      0.00000
     0.00000      0.00000      0.00000
     0.00000      0.00000      0.00000
     0.00000      0.00000      0.00000
```

```
% ------------------------------------------------------------
% POINT-SOURCE MODEL 1
% used as input for Source Inversion Validation (SIV)
%
% XPOS     ZPOS     ZABS     YPOS     TON       RISE     SS-AMP    DS-AMP
%  km       km       km       km      sec        sec      cm        cm
% ------------------------------------------------------------
  -1.00,    9.00,  9.0000,  0.0000,  0.4714,   0.100,   0.0140,   0.0000
  -0.50,    9.00,  9.0000,  0.0000,  0.3727,   0.100,   0.0290,   0.0000
   0.00,    9.00,  9.0000,  0.0000,  0.3333,   0.100,   0.0370,   0.0000
   0.50,    9.00,  9.0000,  0.0000,  0.3727,   0.100,   0.0290,   0.0000
   1.00,    9.00,  9.0000,  0.0000,  0.4714,   0.100,   0.0140,   0.0000
  -1.00,    9.50,  9.5000,  0.0000,  0.3727,   0.100,   0.0290,   0.0000
  -0.50,    9.50,  9.5000,  0.0000,  0.2357,   0.100,   0.0610,   0.0000
   0.00,    9.50,  9.5000,  0.0000,  0.1667,   0.100,   0.0780,   0.0000
   0.50,    9.50,  9.5000,  0.0000,  0.2357,   0.100,   0.0610,   0.0000
   1.00,    9.50,  9.5000,  0.0000,  0.3727,   0.100,   0.0290,   0.0000
  -1.00,   10.00, 10.0000,  0.0000,  0.3333,   0.100,   0.0370,   0.0000
  -0.50,   10.00, 10.0000,  0.0000,  0.1667,   0.100,   0.0780,   0.0000
   0.00,   10.00, 10.0000,  0.0000,  0.0001,   0.100,   0.1000,   0.0000
   0.50,   10.00, 10.0000,  0.0000,  0.1667,   0.100,   0.0780,   0.0000
   1.00,   10.00, 10.0000,  0.0000,  0.3333,   0.100,   0.0370,   0.0000
  -1.00,   10.50, 10.5000,  0.0000,  0.3727,   0.100,   0.0290,   0.0000
  -0.50,   10.50, 10.5000,  0.0000,  0.2357,   0.100,   0.0610,   0.0000
   0.00,   10.50, 10.5000,  0.0000,  0.1667,   0.100,   0.0780,   0.0000
   0.50,   10.50, 10.5000,  0.0000,  0.2357,   0.100,   0.0610,   0.0000
   1.00,   10.50, 10.5000,  0.0000,  0.3727,   0.100,   0.0290,   0.0000
  -1.00,   11.00, 11.0000,  0.0000,  0.4714,   0.100,   0.0140,   0.0000
  -0.50,   11.00, 11.0000,  0.0000,  0.3727,   0.100,   0.0290,   0.0000
   0.00,   11.00, 11.0000,  0.0000,  0.3333,   0.100,   0.0370,   0.0000
   0.50,   11.00, 11.0000,  0.0000,  0.3727,   0.100,   0.0290,   0.0000
   1.00,   11.00, 11.0000,  0.0000,  0.4714,   0.100,   0.0140,   0.0000
```

Discussion on data & data formats

- **Which other data are requested ?**
  - Statics (GPS)
  - Teleseismic

- **Comments & Suggestions**
  - blablabla
  - More blablabla

Who does what ?

- Defining the problems and source-model generation ?
- Near-field synthetics & static displacements?
- Far-field synthetics ?
- Defining and testing misfit norm for seismograms and source models ?
- Programming of online submission & comparison tools ?
- General website maintenance ?

http://siv.usc.edu