Source Inversion Validation

Problem inv3: Large hypothetical earthquake in Southern California

In this test we consider a very large (M_W 7.8) hypothetical strike-slip earthquake in Southern California, occurring on the southern San Andreas Fault. The synthetic rupture model includes variations in slip, rupture time, rise time and slip direction, while the fault geometry is mildly non-planar (i.e. some geometrical complexity of the San Andreas Fault is included in the forward simulations).
In the first stage, synthetic teleseismic data (P- and SH waves) are disseminated for a set of globally distributed seismic stations, chosen as a subset of existing IRIS stations. The assumed velocity model is based on the radially isotropic Earth model AK135, applied at the source with the shallow structure given below, and with local modifications at the stations (see related data files).
In the next stage, we will also distribute synthetic near-field data in order to examine how the different datasets are able to constrain the rupture process of this scenario of a large strike-slip event.

Coordinate system:
Right-handed Cartesian coordinate system, with positive X pointing East, positive Y pointing North, and positive Z upward.

Material properties at the source:
Layered isotropic velocity-density structure; Q_S and Q_P are assumed to be infinite everywhere.

Depth [km]	V_P [km/s]	V_S [km/s]	Density [g/cm^3]
0.0	2.50	1.20	2.10
-1.0	2.50	1.20	2.10
-1.0	4.40	2.50	2.50
-1.5	4.40	2.50	2.50
-1.5	6.10	3.50	2.75
-10.5	6.10	3.50	2.75
-10.5	6.30	3.60	2.80
-19.0	6.30	3.60	2.80
-19.0	6.60	3.60	2.90
-27.5	6.60	3.60	2.90
-27.5	8.00	4.60	3.00

Material properties at receivers:

Station-dependent crustal velocity structures were acquired from Crust2.0 model (see website: http://igppweb.ucsd.edu/~gabi/crust2.html). The corresponding nearest grid point was picked for each of the stations. Eventually existing water layers (e.g., for seismic stations located on Pacific/Atlantic islands) were removed.

General source information (**label: inv3**)

- Predominantly strike-slip rupture, with varying fault strike
- Magnitude: **M_W 7.8**
- Epicentral location: **Longitude: -115.708°; Latitude: 33.346°**
- Hypocenter depth: **Z = - 7.3 km;**
- Slip, slip-rate, and slip-direction are heterogeneous over the fault plane.
- Rupture times imply some variations in rupture speed over the fault

Receivers (surface receivers only, Z = 0):

For the teleseismic dataset, the receiver configuration consists of 52 stations, globally distributed. Precise locations and station names are specified in the file **`inv3_tele-stations.dat`**. At each of these sites, both P- and SH-wave synthetics are computed. Synthetics are contained in the file **`inv3_tele-data.zip`**, in the format given below.

Format of synthetic seismograms

Seismic waveform data for P- and SH-waves are provided as single-column ascii-files, named using the station code and the corresponding phase. Sampling interval is dt = 0.1 sec, and each record has a duration of 300 sec (total time-series length: 3000 points). The lead-time before each phase arrival is 10 sec. The displacement records are given in units of micrometers.

Additional information:

- Provided synthetic seismogram have a nominal maximum resolved frequency of ~1 Hz for the P-waves, and ~0.4 Hz for the SH-waves
- If the inversion is carried out with filtered ground-motions, please specify the chosen frequency range as well as the type of filter (i.e. 'butterworth') and filter order.
- Specify the method/code with which the seismic waves are computed (e.g. Kikuchi & Kanamori; finite-difference, SEM-code etc …), and the inversion approach (i.e. multi time-window linearized inversion; non-linear inversion with genetic algorithm, etc …)

Output instructions:

Predicted waveforms

Submit clearly and unambiguously named ascii-files in the following format, containing displacement time histories in micrometers. The file-format for submitting waveform data is as follows:

filename for waveform data:

label_modeler_station#.syn

e.g. inv3_myname_12.syn for station #12 used in the inversion

header in waveform files:

label	modeler	date
station#	rec_lon	rec_lat
npts	dt	fmax

time-series data for waveform data (formatted as 15.6e, see example below):

P-syn (or SH-syn)

where:

- label — inv3 in this case
- modeler — name/identifier of modeler or modeling group; for several proposed solutions by one group, use myname1, myname2 etc …
- station # — station number
- date — date when calculations were performed (format dd.mm.yyyy)
- rec_lon, rec_lat — receiver coordinates
- npts — number of points in time series
- dt — sampling interval (in sec)
- fmax — maximum resolved frequency in these calculations (in Hz)

Example time-series output file: inv3_kermit1_1.syn

inv_3	kermit1	15.10.2014
1	-61.650	12.130
2500	0.1	1.0
1.000659e-08		
1.068342e-05		
2.708477e-03		
2.953652e-01		

Important note: For the SIV-online submission, all modeled waveforms need to be arranged/grouped into a single .synar-file, which is then read by the online processing software. The station ordering matters as well as their correct formatting. See http://equake-rc.info/sivdb/utilities/ for further information.

Rupture model output

Submit clearly and unambiguously labeled ascii-files in the following format, containing the estimated macroscopic source parameters in the header as well as information on the source-inversion parameters. We accept two different formats, specified below, depending on whether a single time window or several time windows are used in the inversion. The following parameters are reported in the header section:

- label — inv3 in this case
- modeler — name/identifier of modeler or modeling group; for several proposed solutions by one group, use myname1, myname2 etc …
- date — date when calculations were performed (format dd.mm.yyyy)
- inversion method — specify the inversion approach used
- forward-code — specify the numerical code for seismic-wavefield computation
- SourcePar1 — moment magnitude and seismic moment (in Nm)
- SourcePar2 — estimated length and width of fault plane (in km)
- Hypocenter — hypocenter coordinates on the fault plane (in km)
- Depth2Top — estimated depth to top of fault plane (in km)
- NumPoints — number of points in along-strike (Nx) and down-dip (Nz) direction of the rupture model
- NumTimeWn — number of time windows (Nt) and their spacing (Dt, in sec)
- ElemSTF — string to indicate elementary source-time function used

For each point on the fault, indicated by its X, Y, and Z position, several rupture quantities are then listed in subsequent columns, i.e. each row of the output table contains the source parameters at a given point on the fault plane. Thus, the rupture-model output looks as follows:

If the inversion is carried out using a single time window:

```
# ------------------------------------------------------------------------
#  SIV Inversion Exercise :  inv3_kermit1
#  Date                   :  15.10.2014
#  Modeler                :  Kermit
#  Inversion Method       :  non-linear single time-window
#  Ground-motion code     :  Axitra
#  SourcePar1  Mw-Mo [Nm] :  6.113, 1.658e+18
#  SourcePar2  L-W [km]   :  25.0, 14.00
#  Hypocenter  X-Y-Z [km] :  3.00, 0.00, -12.50
#  Depth2Top   Z2top [km] :  -3.000
#  NumPoints   Nx-Nz      :  13, 12
#  NumTimeWn   Nt-Dt      :  1, 0.0
#  ElemSTF                :  iso-tri
# ------------------------------------------------------------------------
#  X           Y           Z      TotalSlip    Rake      RupTime    RiseTime
# km          km          km         m         deg         s          s
# ------------------------------------------------------------------------
 -4.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     5.0000
 -3.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     5.0000
 -2.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     5.0000
```

```
 -1.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     5.0000
  0.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     5.0000
  1.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     5.0000
  2.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     5.0000
  3.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     5.0000
  4.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     5.0000
```

If the inversion is carried out using several time windows:

```
# ------------------------------------------------------------------------------------
#  SIV Inversion Exercise :  inv3_kermit1
#  Date                   :  15.10.2014
#  Modeler                :  kermit
#  Inversion Method       :  linearized multi time-window
#  Ground-motion code     :  own 3D-FD code
#  SourcePar1  Mw-Mo [Nm] :  6.113, 1.658e+18
#  SourcePar2  L-W [km]   :  25.0, 14.00
#  Hypocenter  X-Y-Z [km] :  3.00, 0.00, -12.50
#  Depth2Top   Z2top [km] :  -3.000
#  NumPoints   Nx-Nz      :  13, 12
#  NumTimeWn   Nt-Dt      :  4, 0.5
#  ElemSTF                :  iso-tri
# ------------------------------------------------------------------------------------
#  X           Y           Z      TotalSlip    Rake      RupTime    SlipTW1   SlipTW2 ...
# km          km          km         m         deg         s          m         m
# ------------------------------------------------------------------------------------
 -4.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     1.0000    0.5555
 -3.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     1.0000    0.5555
 -2.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     1.0000    0.3333
 -1.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     1.0000    0.6666
  0.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     1.0000    0.1111
  1.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     1.0000    0.2345
  2.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     1.0000    0.4444
  3.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     1.0000    0.1111
  4.0000    -0.0000    -6.0000     0.0000     0.0000     3.0000     1.0000    077777
```