Source Inversion Validation

Inversion Exercise 1

Inverting noise-free synthetic seismograms, computed on a dense receiver grid, for a simple crack-like spontaneous dynamic rupture model

In this test we consider a crack-like spontaneous dynamic rupture, embedded in a layered isotropic velocity-density structure, to test how well source-inversion techniques can retrieve the macroscopic source properties as well as the spatio-temporal evolution of the rupture process. The material parameters are identical to the ones used in the Green's function tests. Synthetic data at 40 receiver locations are provided, **all of which have to be used in the inversion**. Additionally, forward predictions at 16 locations are required; these synthetics are not furnished to the modelers, but are used as an independent validation.

IMPORTANT: Submission of inversion results (waveforms and rupture model) has to be done in a specific format and online, via http://eqsource.webfactional.com/db/sivtools/list_benchmarks/. The use of this site requires an account, which can be obtained by sending an email to martin.mai@kaust.edu.sa

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

Material properties:
Layered isotropic velocity-density structure; Q_S and Q_P are assumed to be infinite everywhere (Fig. 1).

Depth [km]	V_P [km/s]	V_S [km/s]	Density [g/cm^3]
0.0	4.8	2.6	2.3
-2.0	4.8	2.6	2.3
-2.0	5.5	3.1	2.5
-4.8	5.5	3.1	2.5
-4.8	6.2	3.6	2.7
-18.0	6.2	3.6	2.7
-18.0	6.8	3.8	2.8
-24.0	6.8	3.8	2.8
-24.0	8.0	4.62	3.2
-45.0	8.0	4.62	3.2

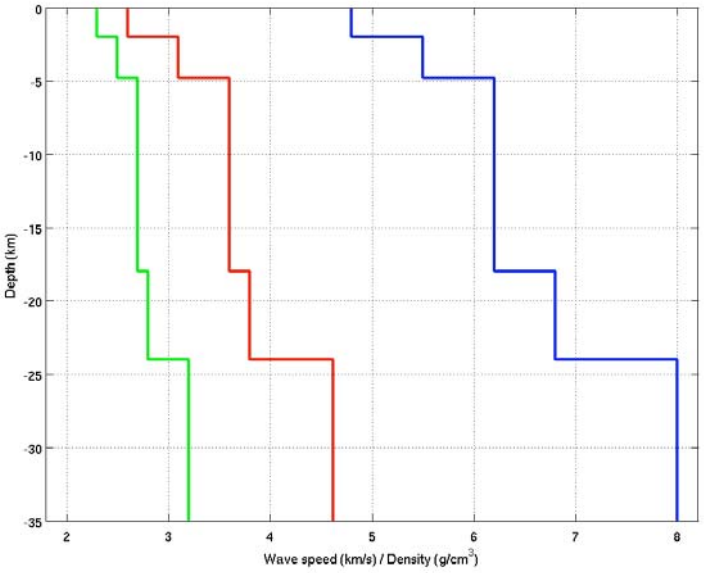

Figure 1: Velocity-density model for inversion exercise; see 'vmodel.dat' for details.

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

- Strike-slip fault: **fault dip = 80°**; fault strike = 90°
- The rupture remains buried and does not reach the surface
- Fault dimensions: **approximately 30-35 km in length, 15-20 km in down-dip extent**
- Seismic moment: $M_0 \approx 1.06 \times 10^{19}$ Nm (M_W 6.62)
- Hypocenter Location: X = 9.2 km; Y = -1.6 km; Z = 14.0 km;
- Slip and slip-rate are heterogeneous over the fault plane, as a result of the dynamic rupture simulation with heterogeneous initial stress on the fault.
- Rupture times imply some variations in rupture speed over the fault
- The source-time function may vary over the rupture plane

Receivers (surface receivers only, Z = 0):

The receiver configuration consists of 40 receivers for the inversion itself and 16 receivers for the forward prediction, sampled from a regular "race-track" pattern of ~80 sites around the surface-projection of the fault (Fig.2). The locations of the receivers at which synthetic ground-motions are computed are given in the file **`StationList.dat`**; locations named as 'Ixx' are to be used in the inversion, sites named 'Pxx' have to be used for forward-predicting the waveforms for validation purposes utilizing the inferred rupture model. It is intended to keep this station configuration (or a somewhat modified one) for all upcoming inversion exercises.
Synthetic seismograms are contained in the zip-file **`inv1_dyn.zip`**, in the format given below.

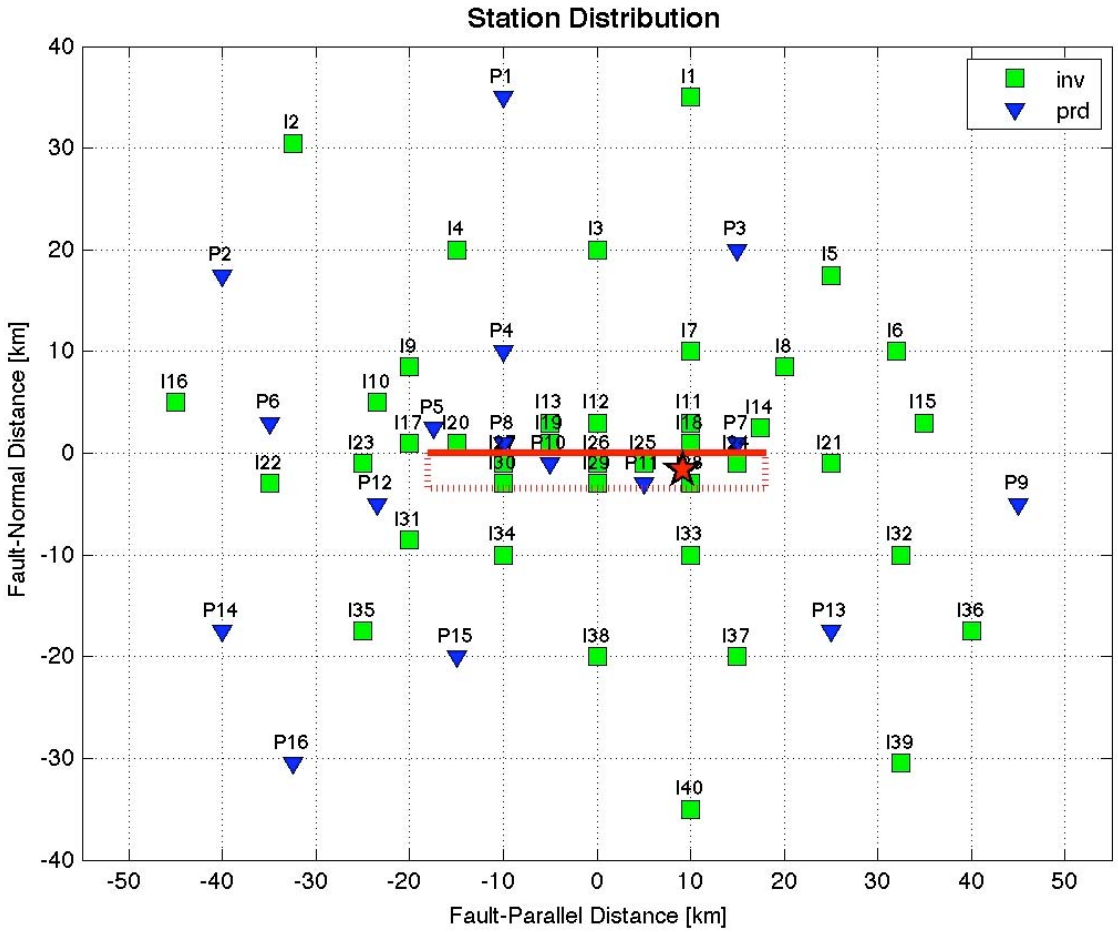

Figure 2: Receiver geometry for inversion exercise on 80° dipping strike-slip fault with an M 6.6 rupture. We use a right-handed coordinate system with positive X pointing "East", positive Y pointing "North", and positive Z pointing "Up". The red line indicates the surface projection of the up-dip edge of the fault plane at depth, the dotted rectangle indicates the fault-surface projection, the star marks the epicenter. Green squares mark the stations (named "Ixx") that have to be used in the inversion, the blue inverted triangles denote the stations at which waveforms have to be forward predicted.

Other information:

- Provided synthetic seismogram have a nominal maximum resolved frequency of ~2.5 Hz
- 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 ground-motion computation tool used (i.e. CompSyn, Axitra, 3D-finite-difference code), and the inversion approach (i.e. multi time-window linearized inversion; non-linear inversion using an genetic algorithm)

Output instructions:

Predicted ground motions

Submit clearly and unambiguously labeled ascii-files in the following format, containing velocity time histories in m/s (Vx positive East, Vy positive North, Vz positive up)

- "label" is the above (in red) noted source-model indicator
- "modeler": name/identifier of modeler or modeling group
- date: date when calculations were performed (format dd.mm.yy)
- rec#: receiver number (see above tables)
- rec_crd_X, rec_crd_Y: receiver coordinates (see above tables, in km)
- npts: number of points in time series
- dt: sampling interval (in sec)
- fmax: maximum resolved frequency in these calculations (in Hz)

filename:

label_modeler_receiver#.inv or label_modeler_receiver#.fwd

e.g. ss_inv1_mai_12.inv for a site used in the inversion

ss_inv1_mai_12.fwd if motions are computed using the inferred rupture model

header:

label	modeler	date
rec#	rec_crd_X	rec_crd_Y
npts	dt	fmax

time-series data

x-comp	y-comp	z-comp

Example time-series output file: ss_inv1_MaiMartin_3.inv

ss_inv_1	MaiMartin	15.10.2010
3	10.0	1.0
1666	0.006	2.5
2.708477e-01	2.854577e-01	2.933980e-01
2.953652e-01	2.918521e-01	2.831548e-01
2.694041e-01	2.505884e-01	2.266108e-01
1.973462e-01	1.627026e-01	1.226894e-01
7.748341e-02	2.749405e-02	-2.658398e-02

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" is the above (in red) noted source-model indicator
- "modeler": name/identifier of modeler or modeling group
- date: date when calculations were performed (format dd.mm.yy)
- "inversion method": specify the inversion approach used
- "Ground-motion code": specify the numerical code for ground-motion computation
- SourcePar1: moment magnitude and seismic moment (in Nm)
- SourcePar2: estimated length and width of fault plane (in km)
- Hypocenter: estimated hypocenter coordinates in X, Y, Z (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 :  ss_inv1_frog
#  Date                   :  23.10.10
#  Modeler                :  Kermit „The Frog“
#  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
```