Source Inversion Validation

Stage 1: Forward Problems

Green's function validation

In this first test we evaluate the different codes/methods that are used for computing the Green's functions for the earthquake source-inversion problem. This test is divided into two parts:

A) Point-source on a vertical strike-slip fault with purely right-lateral motion
B) Point-source on a dipping fault with purely thrust-faulting motion

The material parameters for the two cases are identical.

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

<u>Material properties:</u>
Layered isotropic velocity-density structure, simplified from the "generic" Californian rock-site velocity model of Boore & Joyner (1997). 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	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

<u>Part A: Strike-slip point-source (label: ssp0)</u>

<u>Source:</u>

- Fault dip = 90°
- Source depth = 10 km, i.e. with the epicenter at the origin, the source is at [0, 0, 10] km
- Point dislocation: 1.0 m right-lateral slip (± 0.5 m on each side, λ = 180°,) across an elementary fault plane of 1 x 1 km^2
- Seismic moment: M_0 = 3.4992 x 10^{16} Nm (M_W = 4.996)
- Source-time function: boxcar of width 0.2sec (rise time t_r = 0.2 sec)
- Equivalently, the corresponding moment-tensor component ($M_{xy} = M_{yx}$) can be specified with the moment-rate history of a boxcar of t_r = 0.2 sec and the above seismic moment

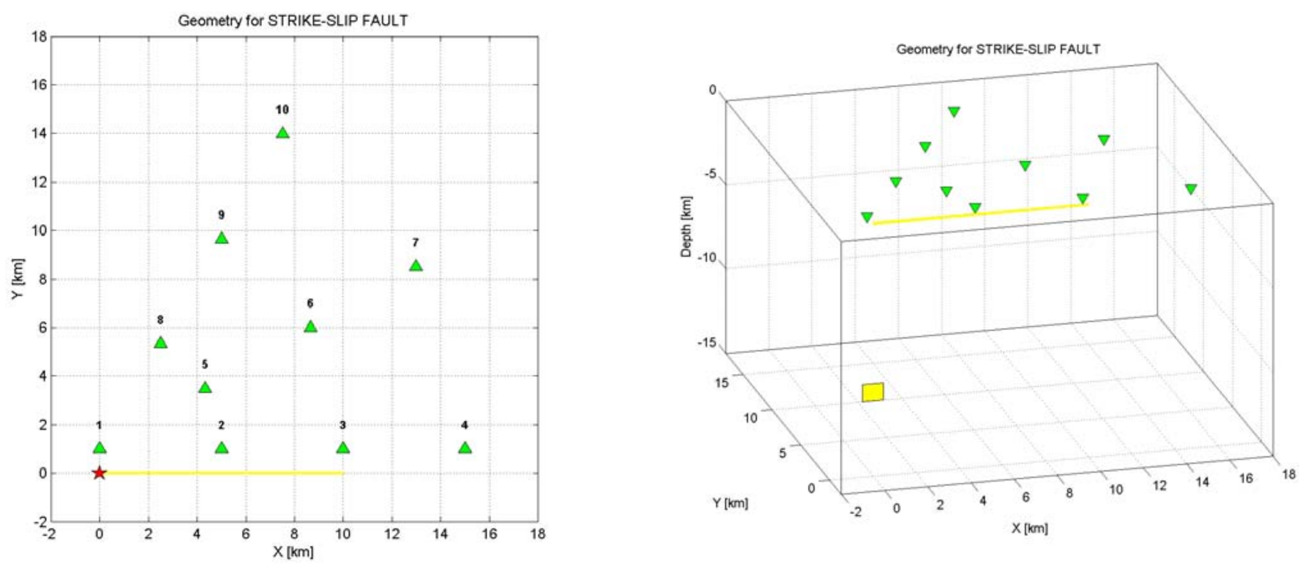

Figure 1: Source-receiver geometry for the strike-slip point-source in map view (left) and 3D-view (right). The red star shows the epicenter at X = 0, Y = 0 in the chosen right-handed coordinate system with positive X pointing East, positive Y pointing North, and positive Z pointing up. The yellow line indicates the vertical projection of the updip-edge of an extend fault plane at depth. The little yellow square (right) marks the uniform-slip point-source on a 1 x 1 km^2 fault patch.

Receivers (surface receivers only, Z = 0):

The receiver configuration consists of three linear arrays: one fault-parallel array at 1 km fault-normal distance from the surface projection of a vertical fault (at X = 0 km in the chosen coordinate system), and two inclined arrays at α = 30° and α = 60° from the fault-parallel array.

	X [km]	Y [km]
1	0.00	1.00
2	5.00	1.00
3	10.00	1.00
4	15.00	1.00
5	4.33	3.50
6	8.66	6.00
7	12.99	8.50
8	2.50	5.33
9	5.00	9.66
10	7.50	13.99

Part B: Dip-slip point-source (label: dsp0)

Source:

- Fault dip = 40°, such that the fault dips towards the North (Y^+-side, see figure below)
- Source depth = 10 km, i.e. with the epicenter as origin, the source is at [0, 0, 10] km
- Point dislocation: 1.0 m dip-slip motion ($\pm$ 0.5 m on each side, λ = 90°) across elementary fault plane of 1 x 1 km^2;
- Seismic moment: $M_0 = 3.4992 \times 10^{16}$ Nm (M_W = 4.996)
- Source-time function: boxcar of width 0.2sec (rise time t_r = 0.2 sec)
- Equivalently, the corresponding moment-tensor component (M_{xx} and M_{zz}) can be specified with the moment-rate history of a boxcar of t_r = 0.2 sec and the above seismic moment

Receivers (surface receivers only, Z = 0):

The receiver configuration consists of three linear arrays: one fault-parallel array at 1 km fault-normal distance from the surface projection of a vertical fault (at X = 0 km in the chosen coordinate system), and two inclined arrays at α = 30° and α = 60° from the fault-parallel array. These three arrays are then mirrored across the X = 0 surface-projection of the fault to capture both hanging-wall and foot-wall sites.

	X [km]	Y [km]
1	0.00	1.00
2	5.00	1.00
3	10.00	1.00
4	15.00	1.00
5	4.33	3.50
6	8.66	6.00
7	12.99	8.50
8	2.50	5.33
9	5.00	9.66
10	7.50	13.99
11	0.00	-1.00
12	5.00	-1.00
13	10.00	-1.00
14	15.00	-1.00
15	4.33	-3.50
16	8.66	-6.00
17	12.99	-8.50
18	2.50	-5.33
19	5.00	-9.66
20	7.50	-13.99

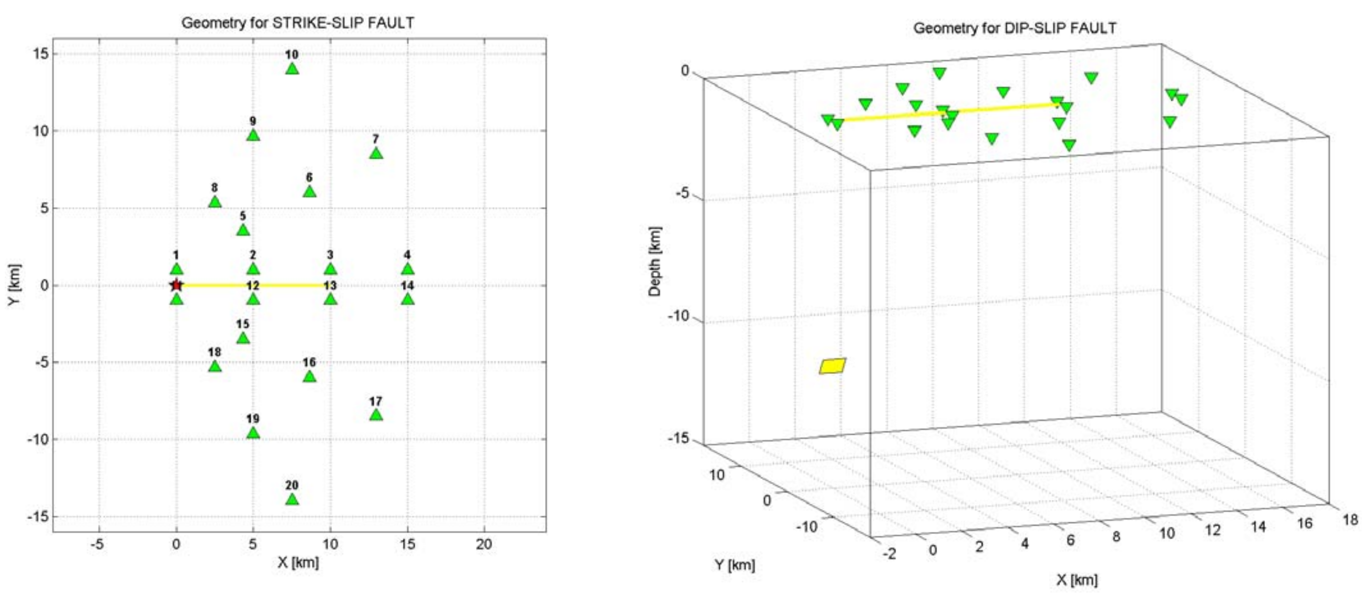

Figure 2: Source-receiver geometry for the dip-slip point-source in map view (left) and 3D-view (right). The red-star shows the epicenter at X = 0, Y = 0 in the chosen right-handed coordinate system with positive X pointing East, positive Y pointing North, and positive Z pointing up . The little yellow square (right) marks the uniform-slip point-source on a 1 x 1 km^2 fault patch, with downward dip toward in the positive Y direction.

Other information:

- Target frequency: 5 Hz
- No filtering of Green's function allowed (we may apply a common post-processing for clarity)
- If it's known that the Green's function code generates velocity time series that do not exactly go back to zero after the seismic waves have passed, the time series could be truncated. This needs to be stated in the output file (see below).
- Choose mesh-size to ensure adequate waveforms and minimal numerical oscillations
- Place domain boundaries at large-enough distances to avoid boundary reflections, or use absorbing boundary conditions

Output instructions:

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)
- trunc: 3-record line to state whether or not a time-series truncation has been applied to avoid non-zero velocity after the waves have passed.
  - o If yes, than enter [1 original length of time-series truncated time-series length]
  - o If not, than enter [0 0 0]

filename:

label_modeler_receiver#.syn (e.g. ssp0_mai_12.syn)

header:

label	modeler	date
rec#	rec_crd_X	rec_crd_Y
npts	dt	fmax
trunc1	trunc2	trunc3

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

x-comp	y-comp	z-comp

Example time-series output file: ssp0_MaiMartin_3.syn

```
ssp0            MaiMartin            10.08.2009
3               10.0                 1.0
1666            0.006                5.0
1               12.2880              9.9960
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
```