TPV35
Parkfield 2004 M6 Earthquake

November 29, 2016

This 3D benchmark is a spontaneous rupture model of the 2004 Parkfield, California M6 earthquake and nearby seismic stations. It is our first code validation benchmark.

Benchmark					
Benchmark	*Dimension*	*Rupture Type*	*Material Properties*	*Velocity Structure*	*Minimum V_S*
TPV35	3D	Strike-slip	Linear elastic	3D model	1100 m/s

Benchmark Summary

- The benchmark is based on a spontaneous rupture model from Ma, Custódio, Archuleta, and Liu (2008), Dynamic modeling of the 2004 Mw 6.0 Parkfield, California, earthquake, *J. Geophys. Res.*, 113, B02301, doi:10.1029/2007JB005216.

- For TPV35, we request that you use a resolution on the fault plane of 100 meters. You may optionally also submit results for a resolution of 50 meters.

- The geometry is a single, planar, vertical, right-lateral, strike-slip fault in a half-space. The fault is 40 km long and 15.5 km deep.

- Material properties are different on the two sides of the fault. There is a 1D velocity model on each side of the fault. The minimum V_S is 1100 m/s.

- Initial normal stress on the fault is constant. Initial shear stress and yield stress vary over the fault surface, in order to produce a rupture that resembles kinematic models of the 2004 Parkfield earthquake. The rupture stops spontaneously before reaching any border of the fault, and before it reaches the earth’s surface. There is no gravity in the model.

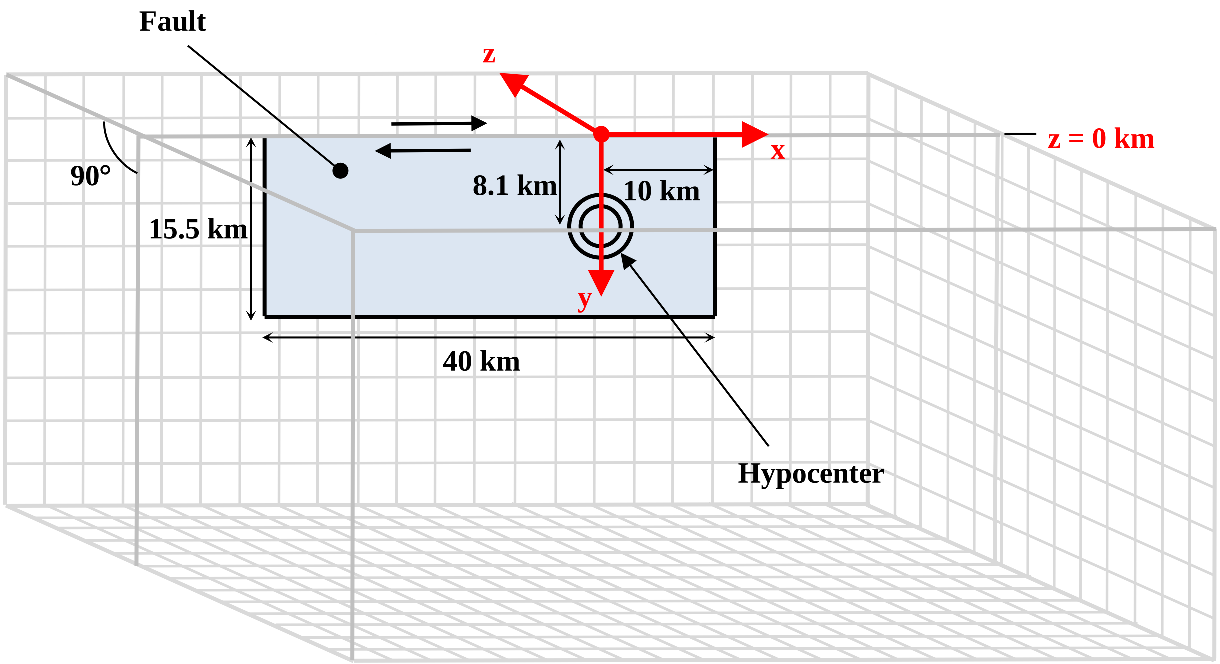
- The benchmark uses linear slip-weakening friction.

- The fault boundary condition is that slip goes to zero at the side and bottom borders of the fault. So, a node that lies precisely on the side or bottom border of the fault should *not* be permitted to slip. A node that lies precisely on the top border of the fault, at the earth’s surface, *is* permitted to slip.

- Nucleation is achieved by setting the yield stress to be slightly lower than the initial shear stress in a circular zone surrounding the hypocenter.

Contents

Part 1: Fault Geometry for TPV35



The model volume is a half-space.

The fault is a vertical plane measuring 40000 m along-strike and 15500 m deep. The fault is a strike-slip, right-lateral fault. The fault reaches the earth's surface.

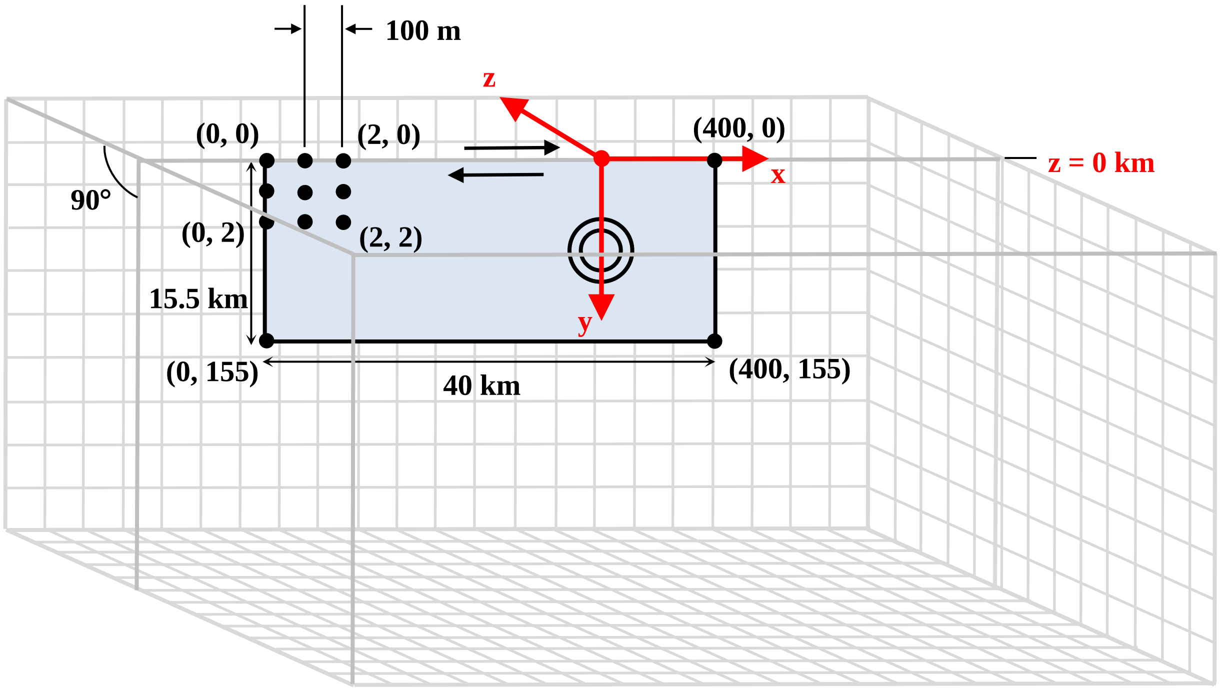
Introduce an (x, y, z) coordinate system, where x increases from left to right, y increases from top to bottom, and z increases from front to back. The origin of the coordinate system is on the earth's surface, 30000 m from the left edge of the fault. In this coordinate system, the fault is:

$$-30000 \text{ m} \leq x \leq 10000 \text{ m}$$
$$0 \text{ m} \leq y \leq 15500 \text{ m}$$
$$z = 0 \text{ m}$$

The hypocenter is located 30000 m from the left edge of the fault, and 8100 m deep, at coordinates $(x, y, z) = (0 \text{ m},\ 8100 \text{ m},\ 0 \text{ m})$.

Slip goes to zero at the side and bottom borders of the fault. So, a node that lies precisely on the side or bottom border of the fault should not be permitted to slip. A node that lies precisely on the top border of the fault, at the earth's surface, is permitted to slip. (A node that lies precisely at the upper-left or upper-right corner of the fault is not permitted to slip.)

Part 2: Input File Format for TPV35



The input file gives the static coefficient of friction and the initial shear stress at a set of grid points on the fault surface.

This section describes **`tpv35_input_data.txt`**, which is the input file. It can be found on our website.

The grid points are spaced 100 meters along-strike, and 100 meters along-dip. The fault surface has 401 grid points along-strike, and 156 grid points along-dip, making for a total of 62556 grid points.

Each grid point is labeled by a pair of integer coordinates (nx, ny). The coordinate nx is an integer ranging from 0 at the left edge of the fault to 400 at the right edge. The coordinate ny is an integer ranging from 0 at the top of the fault to 155 at the bottom. The grid point at the upper left corner of the fault has (nx, ny) coordinates $(0, 0)$.

The following excerpt shows the first six lines of the data file.

```
400  155  -30000.  10000.  0.  15500.
0  0  -30000.  0.  3.3000000e-01  1.6000000e+01
1  0  -29900.  0.  3.3000000e-01  1.6000000e+01
2  0  -29800.  0.  3.3000000e-01  1.6000000e+01
3  0  -29700.  0.  3.3000000e-01  1.6000000e+01
4  0  -29600.  0.  3.3000000e-01  1.6000000e+01
```

The first line is a header, and the remaining lines contain data. The header contains information about the gird points, but is not actually needed to run the simulation. In your code, you may wish to skip over the one-line header, and just read the data.

Line 1: Contains the total size of the fault surface. The six fields are:

- Number of grid cells along-strike (this is one less than the number of grid points along-strike). It is an integer. For TPV35, it is 400.

- Number of grid cells down-dip (this is one less than the number of grid points down-dip). It is an integer. For TPV35, it is 155.

- The x-coordinate of the left edge of the fault, in meters, as a floating-point number. For TPV35, it is -30000.

- The x-coordinate of the right edge of the fault, in meters, as a floating-point number. For TPV35, it is 10000.

- The y-coordinate of the top edge of the fault, in meters, as a floating-point number. For TPV35, it is 0.

- The y-coordinate of the bottom edge of the fault, in meters, as a floating-point number. For TPV35, it is 15500.

Remaining lines give the static coefficient of friction and initial shear stress for each grid point on the fault surface. For TPV35, there are 62556 of these lines. The six fields on each line are:

- Grid point location along-strike, measured in grid cells (counting from 0 at the left edge of the fault surface). This is coordinate nx. It is an integer.

- Grid point location down-dip, measured in grid cells (counting from 0 at the earth's surface). This is coordinate ny. It is an integer.

- Grid point location along-strike, in meters, measured from the origin. This is the x-coordinate, and it ranges from -30000 to 10000. It is a floating-point number.

- Grid point location down-dip, in meters, measured from the earth's surface. This is the y-coordinate, and it ranges from 0 to 15500. It is a floating-point number.

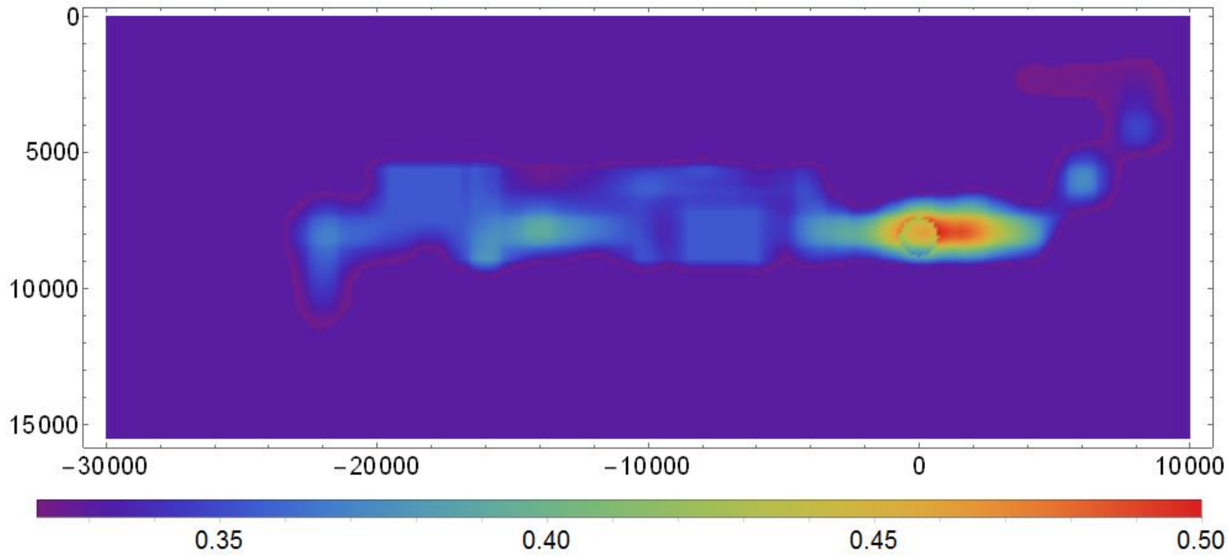
- The static coefficient of friction. It is a floating-point number.

- The initial shear stress, in MPa. The initial shear stress is pure right-lateral. It is a floating-point number.

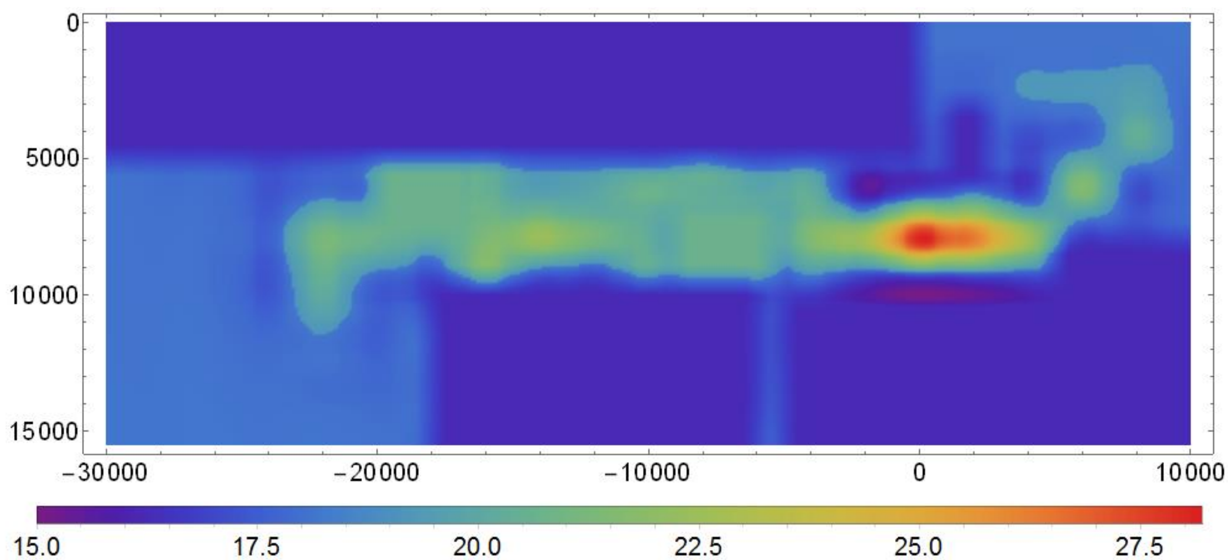
Grid points are listed in a specific order. The grid point in the upper left corner of the fault surface is listed first. Next come the remaining grid points at the earth's surface, listed left to right. Next come the grid points one cell (100 m) below the earth's surface, listed left to right. And so on. At the end of the file come the grid points at the bottom of the fault surface, listed left to right, with the grid point in the lower right corner of the fault surface appearing last.

If you need to know the static coefficient of friction or the initial shear stress at points on the fault other than the grid points in the file, then you should interpolate the values in the file.

The following figure shows the static coefficient of friction on the fault surface:



The following figure shows the initial shear stress, in MPa, on the fault surface:



Part 3: Description of the 3D Benchmark

Material Properties

In TPV35, there is a 1D velocity model on each side of the fault. The following tables show the layers in the 1D velocity models, starting at the earth's surface and proceeding downward. Within each layer, the material properties are uniform.

TPV35 Velocity Structure, on Near Side of Fault ($z < 0$)			
Layer Thickness (meters)	V_P *(meter/second)*	V_S *(meter/second)*	*Density=* ρ *(kg/m^3)*
1000	2000	1100	2000
1000	3500	2000	2300
1000	4500	2500	2300
500	5200	3000	2500
2300	5700	3200	2700
8300	6200	3600	2700
3000	6800	3600	2800
3300	6800	4300	2800
—	7300	4300	2800

TPV35 Velocity Structure, on Far Side of Fault ($z > 0$)			
Layer Thickness (meters)	V_P *(meter/second)*	V_S *(meter/second)*	*Density=* ρ *(kg/m^3)*
1000	2000	1100	2000
800	3500	2200	2300
300	4200	2800	2300
1300	4800	2700	2300
500	5200	2800	2300
4400	5300	3200	2700
4400	5700	3700	2800
4800	6500	3800	2800
2800	6700	4300	2800
—	7300	4300	2800

Initial Stresses

The initial normal stress is constant. Its value is:

$$\sigma_0(x, y) = 60 \text{ MPa}$$

The initial shear stress is pure right-lateral. The initial shear stress $\tau_0(x, y)$ for each point on the fault is given in the input data file provided on our website.

Nucleation is achieved by setting the yield stress to be slightly lower than the initial shear stress, in a circular region surrounding the hypocenter. The nucleation shear stress is built-in to the input data file, so you don't need to do anything special to nucleate the rupture.

Friction Parameters

We use a linear slip-weakening friction law, which has the following four parameters.

Friction Parameters		
Symbol	*Parameter*	*Unit*
μ_s	Static coefficient of friction.	Dimensionless
μ_d	Dynamic coefficient of friction.	Dimensionless
d_0	Slip-weakening critical distance.	Meter
C_0	Frictional cohesion.	Pascal

The operation of the slip-weakening friction law is described in detail later, in part 4.

The friction parameter values are as follows:

μ_s = Static coefficient of friction from the input data file.

$\mu_d = 0.30$

$d_0 = 0.15$ m

$C_0 = 0$ MPa

Running Time, Node Spacing, and Results

Run the model for times from **0.0 to 18.0 seconds after nucleation**.

The recommended resolution for TPV35 is **100 meters**. You may optionally also submit results for a resolution of 50 meters.

The requested output files are:

- **On-fault time-series files**, which give slips, slip rates, and stresses for each on-fault station at each time step. These files are described in part 5.

- **Off-fault time-series files**, which give displacements and velocities for each off-fault station at each time step. These files are described in part 6.

- **A contour-plot file** which, for each node on the fault, gives the time at which the slip rate first changes from 0 to greater than 0.001 m/s. This file is described in part 7.

Part 4: Linear Slip-Weakening Friction

Benchmark TPV35 uses linear slip-weakening friction. This friction law has the following parameters and variables:

Friction Parameters		
Symbol	*Parameter*	*Unit*
μ_s	Static coefficient of friction.	Dimensionless
μ_d	Dynamic coefficient of friction.	Dimensionless
d_0	Slip-weakening critical distance.	Meter
C_0	Frictional cohesion.	Pascal

Friction Variables		
Symbol	*Parameter*	*Unit*
σ_n	Total normal stress acting on the fault, taken to be positive in compression.	Pascal
τ	Shear stress acting on the fault.	Pascal

When the fault is sliding, the shear stress τ at a given point on the fault is given by:

$$\tau = C_0 + \mu \max(0,\ \sigma_n)$$

The time-varying coefficient of friction μ is given by the following formula, where D is the total distance the node has slipped:

$$\mu = \mu_s + (\mu_d - \mu_s) \min(D/d_0, 1)$$

The distance D that the node has slipped is path-integrated. For example, if the node slips 0.4 m in one direction and then 0.1 m in the opposite direction, the value of D is 0.5 m (and not 0.3 m).

Tension on the fault: If you encounter tension on the fault, you should **treat tension on the fault the same as if the normal stress equals zero**. This is shown in the above formulas by the expression $\max(0,\ \sigma_n)$. We do not expect tension on the fault to occur in TPV35.

You should **constrain the motion of the node so that the fault cannot open (that is, only permit sliding parallel to the fault), even when the fault is in tension**. During the time the fault is in tension, continue to accumulate the slip distance D as usual. Note however that we do not expect tension on the fault to occur in TPV35.

Part 5: On-Fault Stations, and Time-Series File Format

In addition to the Parkfield region's off-fault stations described later, the benchmark includes 7 hypothetical stations on the fault, which are listed below. A diagram of station locations is given following the table. You need to supply one time-series file for each station.

On-Fault Stations, for TPV35	
Station Name	**Location**
`faultst-250dp081`	On fault, −25.0 km along strike, 8.1 km down-dip.
`faultst-200dp081`	On fault, −20.0 km along strike, 8.1 km down-dip.
`faultst-150dp081`	On fault, −15.0 km along strike, 8.1 km down-dip.
`faultst-100dp081`	On fault, −10.0 km along strike, 8.1 km down-dip.
`faultst-050dp081`	On fault, −5.0 km along strike, 8.1 km down-dip.
`faultst000dp081`	On fault, 0 km along strike, 8.1 km down-dip (hypocenter).
`faultst050dp081`	On fault, 5.0 km along strike, 8.1 km down-dip.

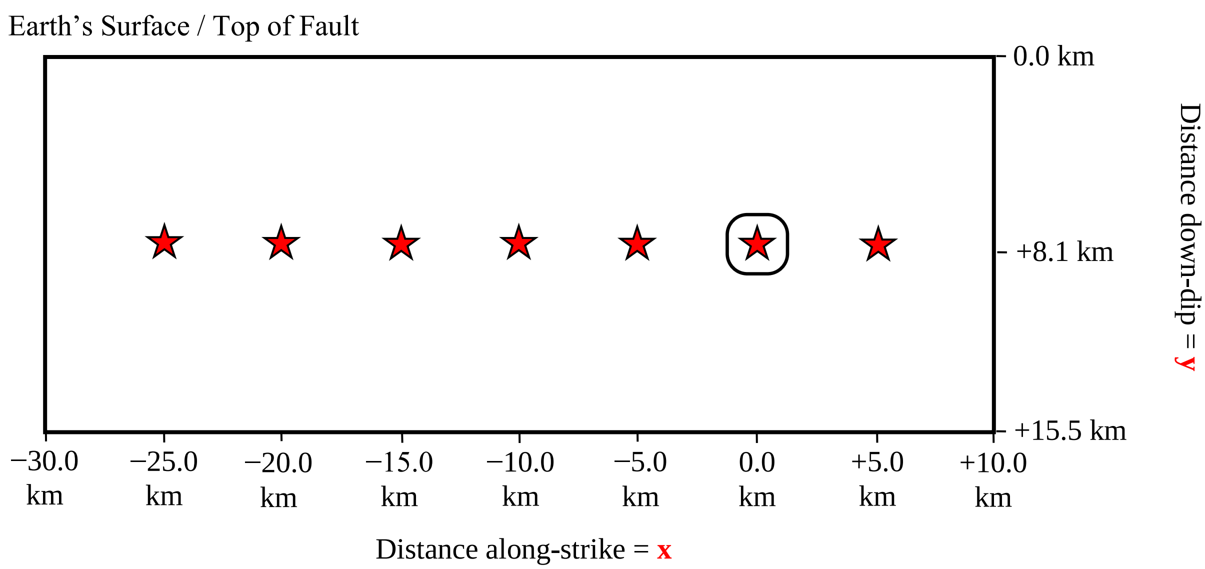
If you do not have a node at the location of a station, there are two options: (1) you can move the station to the nearest node, or (2) you can interpolate the data values from nodes near the station location.

Note: Location along-strike is measured relative to the origin of the (x, y, z) coordinate system Positive locations are to the right of the origin.

Note: The filenames and descriptions give the x and y coordinates of the station. For example, station `faultst-150dp081` is located at $(x, y, z) = (-15000 \text{ m},\ 8100 \text{ m},\ 0 \text{ m})$.

Remark: When you upload your files to the website, you don't have to upload them one-by-one. You can upload all your files in a single operation, using the Perl script available at: http://scecdata.usc.edu/cvws/downloads.html.
In order for the Perl script to work, your filenames must contain the station name as a substring. For example, the time series file for the first station listed in the above table must have a filename that contains "`faultst-250dp081`" as a substring, such as "`tpv35_faultst-250dp081.txt`".

On-Fault Station Locations



Each time series file is an ASCII file that contains 8 data fields, as follows.

On-Fault Time Series Data Fields for TPV35	
Field Name	**Description, Units, and Sign Convention**
`t`	Time (s).
`h-slip`	Horizontal slip along-strike (m). Sign convention: Positive means **right lateral** slip.
`h-slip-rate`	Horizontal slip rate along-strike (m/s). Sign convention: Positive means **right lateral** motion.
`h-shear-stress`	Horizontal shear stress along-strike (MPa). Sign convention: Positive means shear stress that tends to cause **right-lateral** slip.
`v-slip`	Vertical along-dip slip (m). Sign convention: Positive means **downward slip** (that is, the far side of the fault moving downward relative to the near side of the fault).
`v-slip-rate`	Vertical along-dip slip rate (m/s). Sign convention: Positive means **downward motion** (that is, the far side of the fault moving downward relative to the near side of the fault).
`v-shear-stress`	Vertical along-dip shear stress (MPa). Sign convention: Positive means shear stress that tends to cause **downward slip** (that is, the far side of the fault moving downward relative to the near side of the fault).
`n-stress`	Normal stress (MPa). Sign convention: Positive means **extension**.

The **near side** of the fault is in the front of the diagram (the $-z$ side of the fault).
The **far side** of the fault is in the back of the diagram (the $+z$ side of the fault).

The on-fault time series file consists of three sections, as follows.

On-Fault Time Series File Format for TPV35	
File Section	**Description**
File Header	A series of lines, each beginning with a # symbol, that gives the following information: • Benchmark problem (TPV35) • Author • Date • Code • Code version • Node spacing or element size • Time step • Number of time steps in file • Station location • Descriptions of data columns (7 lines) • Anything else you think is relevant
Field List	A **single line**, which lists the names of the 8 data fields, in column order, separated by spaces. It should be: `t h-slip h-slip-rate h-shear-stress v-slip v-slip-rate v-shear-stress n-stress` (all on one line). The server examines this line to check that your file contains the correct data fields.
Time History	A series of lines. Each line contains 8 numbers, which give the data values for a single time step. The lines must appear in order of increasing time. **C/C++ users:** For all data fields except the time, we recommend using 14.6E or 14.6e floating-point format. For the time field, we recommend using 20.12E or 20.12e format (but see the note on the next page). **Fortran users:** For all data fields except the time, we recommend using E15.7 or 1PE15.6 floating-point format. For the time field, we recommend using E21.13 or 1PE21.12 format (but see the note on the next page). The server accepts most common numeric formats. If the server cannot understand your file, you will see an error message when you attempt to upload the file.

Note: We recommend higher precision for the time field so the server can tell that your time steps are all equal. (If the server thinks your time steps are not all equal, it will refuse to apply digital filters to your data.) If you use a “simple” time step value like 0.01 seconds or 0.005 seconds, then there is no need for higher precision, and you can write the time using the same precision as all the other data fields. When you upload a file, the server will warn you if it thinks your time steps are not all equal.

Here is an example of an on-fault time-series file. This is an invented file, not real modeling data.

```
# Example on-fault time-series file.
#
# This is the file header:
# problem=TPV35
# author=A.Modeler
# date=2017/01/23
# code=MyCode
# code_version=3.7
# element_size=100.0 m
# time_step=0.01
# num_time_steps=1800
# location= on fault, -15.0 km along strike, 8.1 km down-dip
# Column #1 = Time (s)
# Column #2 = horizontal slip (m)
# Column #3 = horizontal slip rate (m/s)
# Column #4 = horizontal shear stress (MPa)
# Column #5 = vertical slip (m)
# Column #6 = vertical slip rate (m/s)
# Column #7 = vertical shear stress (MPa)
# Column #8 = normal stress (MPa)
#
# The line below lists the names of the data fields:
t h-slip h-slip-rate h-shear-stress v-slip v-slip-rate v-shear-stress n-stress
#
# Here is the time-series data.
# There should be 8 numbers on each line, but this page is not wide enough
#  to show 8 numbers on a line, so we only show the first five.
0.000000E+00   0.000000E+00   0.000000E+00   7.000000E+01   0.000000E+00  ...
5.000000E-03   0.000000E+00   0.000000E+00   7.104040E+01   0.000000E+00  ...
1.000000E-02   0.000000E+00   0.000000E+00   7.239080E+01   0.000000E+00  ...
1.500000E-02   0.000000E+00   0.000000E+00   7.349000E+01   0.000000E+00  ...
2.000000E-02   0.000000E+00   0.000000E+00   7.440870E+01   0.000000E+00  ...
2.500000E-02   0.000000E+00   0.000000E+00   7.598240E+01   0.000000E+00  ...
# ... and so on.
```

Part 6: Off-Fault Stations, and Time-Series File Format

The benchmark uses the 43 off-fault stations listed below. These stations are at the locations of actual seismic stations that recorded the 2004 Parkfield earthquake. There is a diagram of station locations following the table. You need to supply one time-series file for each station.

The table identifies the location of each station by its z and x coordinates. The z coordinate is perpendicular to the fault, and the x coordinate is along-strike. **All off-fault stations are on the earth's surface ($y = 0$).**

Station Name	Map Symbol	z (meters)	x (meters)
`4064_donna`	DFU	4875	-13363
`4065_eades`	EFU	1896	-9356
`4066_froel`	FFU	-1334	-14517
`4067_gold`	GFU	2712	164
`4069_jack`	KFU	4094	18744
`4070_joaqu`	JFU	4400	-13835
`4071_middl`	MFU	1285	-19045
`4072_redh`	RFU	-5703	23270
`4074_viney`	VFU	-3879	-18309
`4097_scn`	COAL	236	-30991
`4098_c01`	C1E	1240	11952
`4099_tm2`	C2E	2641	11826
`4100_c02`	C2W	-509	11930
`4101_tm3`	C3E	5098	11281
`4102_c03`	C3W	-1423	12177
`4103_c04`	C4W	-2686	12420
`4104_c4a`	C4AW	-4159	12630

Station Name	Map Symbol	*z* (meters)	*x* (meters)
4107_cow	FZ1	92	8823
4108_coh	FZ3	735	2857
4109_z04	FZ4	-440	-2900
4110_z06	FZ6	-528	-6301
4111_z07	FZ7	1431	-6391
4112_z08	FZ8	3518	-5651
4113_z09	FZ9	-829	-9447
4114_z11	FZ11	3626	-8164
4115_prk	FZ12	1496	-10531
4117_z15	FZ15	-319	-15096
4118_pg1	GH1W	165	-1235
4119_gh2	GH2E	3306	-769
4121_gh3	GH3E	6194	-2249
4122_pg3	GH3W	-4394	-435
4124_pg5	GH5W	-10807	-2063
4126_sc1	SC1E	3126	7029
4127_sc2	SC2E	5521	5857
4128_sc3	SC3E	7987	4599
4129_36510	TEMB	5883	21322
4131_vc1	VC1W	-495	-17125
4132_pgd	VC2E	4353	-18692
4133_vc2	VC2W	-1821	-17228
4134_vyc	VC3W	-3901	-18255

Station Name	Map Symbol	*z* (meters)	*x* (meters)
`4135_vc4`	VC4W	-6286	-17801
`4136_vc5`	VC5W	-8678	-16919
`8486_nphob`	PHOB	-4099	-10403

Note: A text file containing the station names and locations is available on the website.

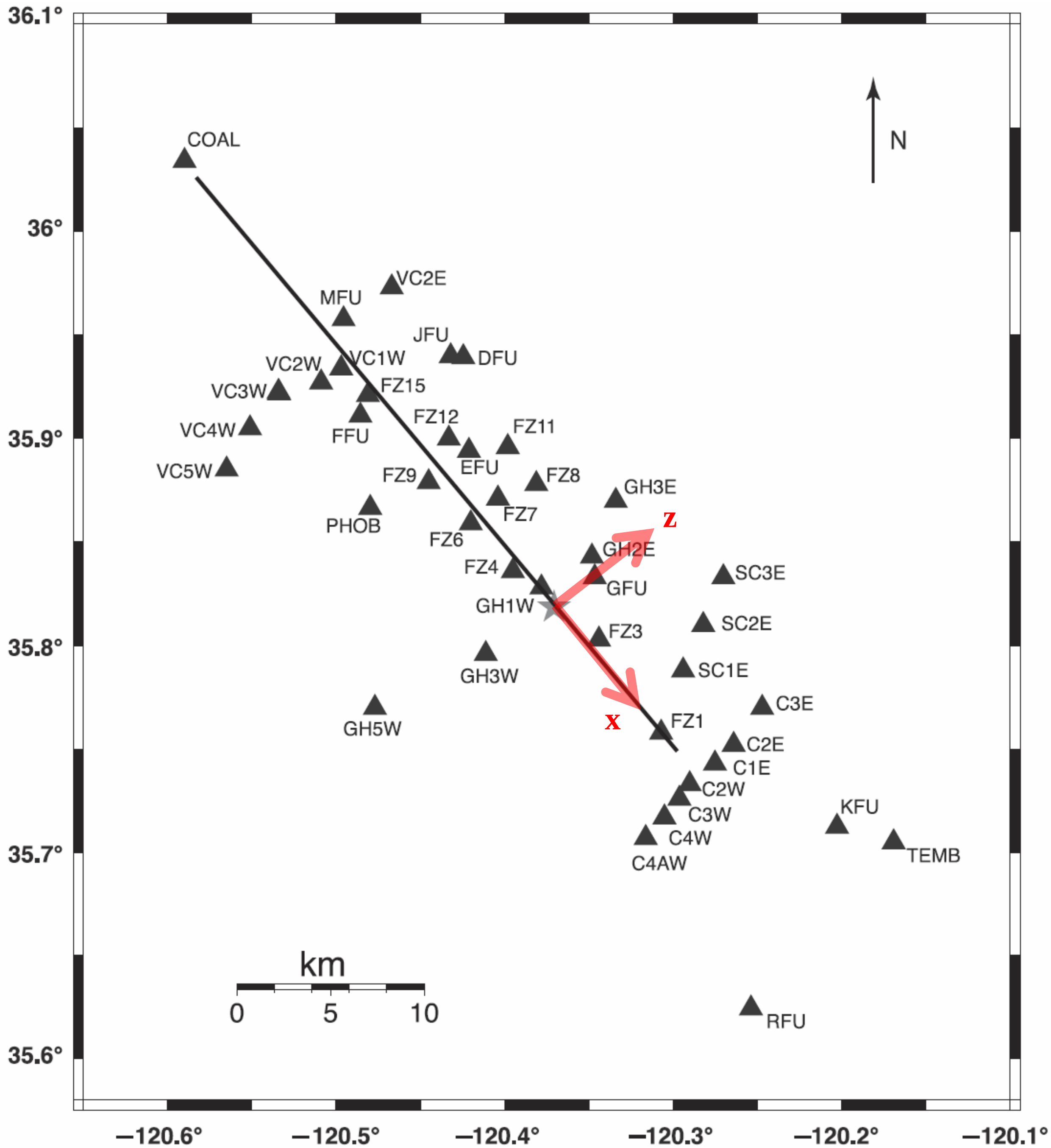
Note: The station names are derived from the NGA West 2 flatfile. The four-digit number is the NGA West 2 "record sequence number." The second part of the station name is from the NGA West 2 filename.

Note: The map symbol identifies where the station is located on the map below.

Note: If you do not have a node at the location of a station, there are two options: (1) you can move the station to the nearest node, or (2) you can interpolate the data values from nodes near the station location.

Remark: When you upload your files to the website, you don't have to upload them one-by-one. You can upload all your files in a single operation, using the Perl script available at:
http://scecdata.usc.edu/cvws/downloads.html.
In order for the Perl script to work, your filenames must contain the station name as a substring. For example, the time series file for the first station listed in the above table must have a filename that contains "`4064_donna`" as a substring, such as "`tpv35_4064_donna.txt`".

Off-Fault Station Locations



This map from Ma *et al.* 2008 shows the station locations relative to the fault. The epicenter is indicated by a gray star. The x and z axes are shown in red, with origin at the epicenter. The fault is a vertical plane 40 km long, with a strike angle of 140 degrees.

Each time series file is an ASCII file that contains 7 data fields, as follows.

Off-Fault Time Series Data Fields for TPV35	
Field Name	**Description, Units, and Sign Convention**
`t`	Time (s).
`h-disp`	Horizontal displacement, parallel to the fault strike (m). Sign convention: Positive means displacement **to the right** relative to the station's initial position (that is, in the $+x$ direction).
`h-vel`	Horizontal velocity, parallel to the fault strike (m/s). Sign convention: Positive means motion **to the right** (that is, in the $+x$ direction).
`v-disp`	Vertical displacement (m). Sign convention: Positive means displacement **downward** relative to the station's initial position (that is, in the $+y$ direction).
`v-vel`	Vertical velocity (m/s). Sign convention: Positive means motion **downward** (that is, in the $+y$ direction).
`n-disp`	Horizontal displacement, perpendicular to the fault strike (m). Sign convention: Positive means displacement **away from the viewer, into the paper** (that is, away from near side of the fault and toward the far side of the fault) relative to the station's initial position. In other words, displacement in the $+z$ direction.
`n-vel`	Horizontal velocity, perpendicular to the fault strike (m/s). Sign convention: Positive means motion **away from the viewer, into the paper** (that is, away from near side of the fault and toward the far side of the fault). In other words, motion in the $+z$ direction.

The **near side** of the fault is in the front of the diagram (the $-z$ side of the fault)..
The **far side** of the fault is in the back of the diagram (the $+z$ side of the fault).

The off-fault time series file consists of three sections, as follows.

<table>
<tr><th colspan="2">Off-Fault Time Series File Format for TPV35</th></tr>
<tr><th>File Section</th><th>Description</th></tr>
<tr><td>File Header</td><td>A series of lines, each beginning with a # symbol, that gives the following information:
Benchmark problem (TPV35)
Author
Date
Code
Code version
Node spacing or element size
Time step
Number of time steps in file
Station location
Descriptions of data columns (7 lines)
Anything else you think is relevant</td></tr>
<tr><td>Field List</td><td>A single line, which lists the names of the 7 data fields, in column order, separated by spaces. It should be:

<code>t h-disp h-vel v-disp v-vel n-disp n-vel</code>

(all on one line). The server examines this line to check that your file contains the correct data fields.</td></tr>
<tr><td>Time History</td><td>A series of lines. Each line contains 7 numbers, which give the data values for a single time step. The lines must appear in order of increasing time.

C/C++ users: For all data fields except the time, we recommend using 14.6E or 14.6e floating-point format. For the time field, we recommend using 20.12E or 20.12e format (but see the note on the next page).

Fortran users: For all data fields except the time, we recommend using E15.7 or 1PE15.6 floating-point format. For the time field, we recommend using E21.13 or 1PE21.12 format (but see the note on the next page).

The server accepts most common numeric formats. If the server cannot understand your file, you will see an error message when you attempt to upload the file.</td></tr>
</table>

Note: We recommend higher precision for the time field so the server can tell that your time steps are all equal. (If the server thinks your time steps are not all equal, it will refuse to apply digital filters to your data.) If you use a “simple” time step value like 0.01 seconds or 0.005 seconds, then there is no need for higher precision, and you can write the time using the same precision as all the other data fields. When you upload a file, the server will warn you if it thinks your time steps are not all equal.

Here is an example of an off-fault time-series file. This is an invented file, not real modeling data.

```
# Example off-fault time-series file.
#
# This is the file header:
# problem=TPV35
# author=A.Modeler
# date=2017/01/23
# code=MyCode
# code_version=3.7
# element_size=100.0 m
# time_step=0.01
# num_time_steps=9600
# location=(-13363, 0, 4875)
# Column #1 = Time (s)
# Column #2 = horizontal displacement (m)
# Column #3 = horizontal velocity (m/s)
# Column #4 = vertical displacement (m)
# Column #5 = vertical velocity (m/s)
# Column #6 = normal displacement (m)
# Column #7 = normal velocity (m/s)
#
# The line below lists the names of the data fields:
t  h-disp  h-vel  v-disp  v-vel  n-disp  n-vel
#
# Here is the time-series data.
# There should be 7 numbers on each line, but this page is not wide enough
#  to show 7 numbers on a line, so we only show the first five.
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00  ...
5.000000E-03  -2.077270E-85  -2.575055E-83  -2.922774E-86  -3.623018E-84  ...
1.000000E-02  -1.622118E-82  -2.005817E-80  -1.387778E-83  -1.713249E-81  ...
1.500000E-02  -9.020043E-80  -1.114231E-77  -4.402893E-81  -5.424313E-79  ...
2.000000E-02  -1.201684E-77  -1.467704E-75  -4.549845E-79  -5.533119E-77  ...
2.500000E-02  -1.528953E-75  -1.866265E-73  -4.126064E-77  -5.004886E-75  ...
# ... and so on.
```

Part 7: Contour-Plot File Format

There is one contour-plot file, as shown here:

Contour-plot file for TPV35	
File Name	**Description**
`cplot`	Rupture times for the fault.

The contour plot file lists the locations of all the nodes on the fault surface, and the time at which each node ruptures.

The contour plot file is an ASCII file that contains three data fields, as follows.

Contour Plot Data Fields for TPV35	
Field Name	**Description, Units, and Sign Convention**
`j`	Distance along strike (m). Sign convention: Positive means a location **to the right** of the origin. For TPV35, the value of `j` can range from −30000 to 10000.
`k`	Distance down-dip (m). Sign convention: Zero is the earth's surface, and positive means **underground**. For TPV35, the value of `k` can range from 0 to 15500.
`t`	Rupture time (s). This is the time at which fault slip-rate first changes from 0 to greater than 0.001 m/s. If this node never ruptures, use the value 1.0E+09.

A pair of numbers `(j,k)` denotes a point on the fault surface. It is equal to the (x, y) coordinates.

The contour plot file consists of three sections, as follows.

Contour Plot File Format for TPV35	
File Section	**Description**
File Header	A series of lines, each beginning with a # symbol, that gives the following information: • Benchmark problem (TPV35) • Author • Date • Code • Code version • Node spacing or element size • Descriptions of data columns (7 lines) • Anything else you think is relevant
Field List	A **single line**, which lists the names of the 3 data fields, in column order, separated by spaces. It should be: `j   k   t` (all on one line). The server examines this line to check that your file contains the correct data fields.
Rupture History	A series of lines. Each line contains three numbers, which give the `(j,k)` coordinates of a node on the fault surface, and the time `t` at which that node ruptures. **C/C++ users:** We recommend using 14.6E or 14.6e floating-point format. **Fortran users:** We recommend using E15.7 or 1PE15.6 floating-point format. If a node never ruptures, the time should be given as 1.0E+09. Nodes may be listed in any order.

Note: The nodes may appear in any order. The nodes do not have to form a rectangular grid, or any other regular pattern.

Note: When you upload a file, the server constructs the Delaunay triangulation of your nodes. Then, it uses the Delaunay triangulation to interpolate the rupture times over the entire fault surface. Finally, it uses the interpolated rupture times to draw a series of contour curves at intervals of 0.5 seconds.

Here is an example of a contour-plot file. This is an invented file, not real modeling data.

```
# Example contour-plot file.
#
# This is the file header:
# problem=TPV35
# author=A.Modeler
# date=2017/01/23
# code=MyCode
# code_version=3.7
# element_size=100.0 m
# Column #1 = horizontal coordinate, distance along strike (m)
# Column #2 = vertical coordinate, distance down-dip (m)
# Column #3 = rupture time (s)
#
# The line below lists the names of the data fields.
# It indicates that the first column contains the horizontal
#  coordinate (j), the second column contains the vertical
#  coordinate (k), and the third column contains the time (t).
j  k  t
#
# Here is the rupture history
-6.000000E+02   7.000000E+03   3.100000E-02
-6.000000E+02   7.100000E+03   4.900000E-02
-6.000000E+02   7.200000E+03   6.700000E-02
-7.000000E+02   7.000000E+03   1.230000E-01
-7.000000E+02   7.100000E+03   1.350000E-01
-7.000000E+02   7.200000E+03   1.470000E-01
# ... and so on.
```