SEAS Benchmark Problems BP6-QD-A/S/C

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Benchmark problems BP6-QD (-A: aging law; -S: slip law; -C: constant friction) are a set of quasi-dynamic two-dimensional (2D) problems in a whole-space with a 1D fault governed by either velocity-strengthening rate-and-state friction or constant friction subjected to perturbations in effective normal stress due to fluid injection and along-fault pore fluid diffusion.

1 2D Problem Setup

The medium is assumed to be a homogeneous, isotropic whole-space defined by:

$$(x, y, z) \in (-\infty, \infty) \times (-\infty, \infty) \times (-\infty, \infty).$$

A planar fault is embedded at $x = 0$, see Figure 1. We use the notation "+" and "−" to refer to the side of the fault with x positive, and x negative, respectively. The medium deforms in antiplane shear with respect to a prestressed reference configuration at time $t = 0$; displacements and strains are measured with respect to this reference configuration. The prestress tensor is $\boldsymbol{\sigma}^0$, which satisfies the equilibrium equation.

Let $u = u(x, z, t)$ denote the displacement in the y-direction. Motion is governed by the equilibrium equation:

$$0 = \frac{\partial \sigma_{xy}}{\partial x} + \frac{\partial \sigma_{yz}}{\partial z}. \tag{1}$$

The stresses are given by $\sigma_{ij} = \sigma_{ij}^0 + \Delta\sigma_{ij}$, the sum of the prestress and stress changes caused by slip. Deformation with respect to the reference configuration is assumed to be linear elastic. Hooke's law relates stresses to strains by:

$$\sigma_{xy} = \sigma_{xy}^0 + \mu \frac{\partial u}{\partial x}; \quad \sigma_{yz} = \sigma_{yz}^0 + \mu \frac{\partial u}{\partial z}, \tag{2}$$

for shear modulus μ. Displacements u vanish at infinity, with no rigid body translation.

2 Boundary and Interface Conditions

We supplement equations (1)–(2) with the following interface conditions on the fault at $x = 0$. We define slip as the jump in displacement across the fault:

$$\delta(z, t) = u(0^+, z, t) - u(0^-, z, t), \tag{3}$$

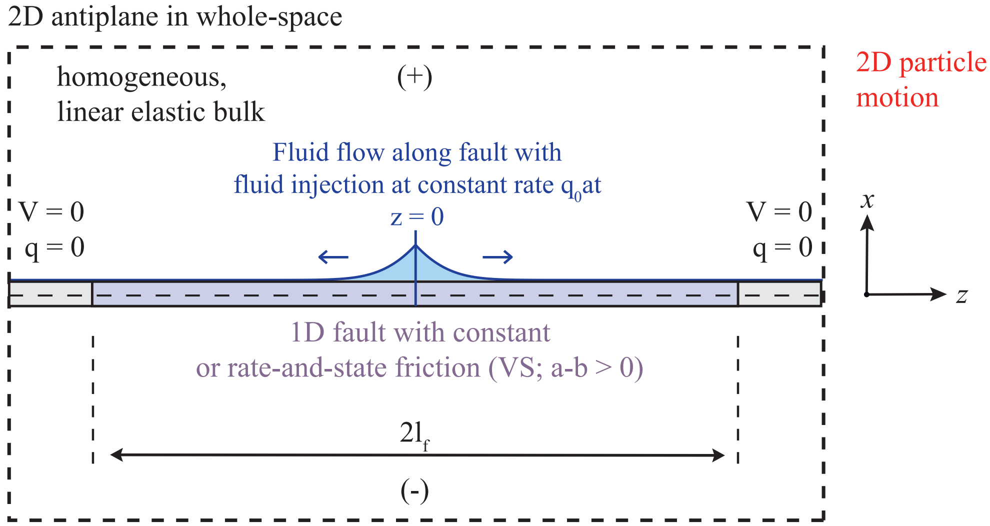

Figure 1: This benchmark considers a 2D antiplane problem for a planar fault embedded in a homogeneous whole-space that responds in a linear elastic manner to slip. The fault ($|z| \leq l_\mathrm{f}$, blue)is governed by either constant (BP6-C) or velocity-strengthening rate-and-state (BP6-A/S) friction. Fault slip is induced by pore pressure perturbations due to the injection of fluid in the middle of the fault ($z = 0$) and the along-fault diffusion of pore fluids.

and slip velocity as $V(z,t) = \partial\delta/\partial t$.

We require that components of the traction vector be equal and opposite across the fault, which yields the conditions:

$$\sigma_{xx}(0^+, z, t) = \sigma_{xx}(0^-, z, t), \tag{4}$$
$$\sigma_{xy}(0^+, z, t) = \sigma_{xy}(0^-, z, t). \tag{5}$$

The total normal stress on the fault is provided by the prestress and does not change in time. We denote this as $\sigma = -\sigma^0_{xx}$, which is positive in compression and spatially uniform. The background pore pressure, p_o, is also spatially uniform. The background effective normal stress is therefore $\bar{\sigma}_0 = \sigma - p_o$. Letting $p(z,t)$ denote the pressure change in response to fluid injection, we have effective normal stress

$$\bar{\sigma}(z,t) = \bar{\sigma}_0 - p(z,t). \tag{6}$$

The fault shear stress is the sum of the initial shear traction $\tau^0 = \sigma^0_{xy}$, which is spatially uniform, the shear stress change due to quasi-static elastic deformation $\Delta\tau$, and the stress change from the radiation damping approximation to inertia:

$$\tau(z,t) = \tau^0 + \Delta\tau(z,t) - \eta V = \sigma_{xy}(0, z, t) - \eta V, \tag{7}$$

where $\eta = \mu/2c_s$ is half the shear-wave impedance for shear wave speed $c_s = \sqrt{\mu/\rho}$ and density ρ.

For $z \in \Omega_f = (-l_f, l_f)$, we solve for the evolution of fault slip and shear stress that is consistent with the elastic material response and the fault friction law. The fault shear resistance F is assumed to be frictional:

$$F = (\bar{\sigma}_0 - p)f, \tag{8}$$

where f is the friction coefficient.

We impose no-slip interface conditions outside of the frictional domain Ω_f (i.e. $|z| > l_{\mathrm{f}}$):

$$V(z,t) = 0. \tag{9}$$

2.1 BP6-A/S: Rate-and-state friction

For **BP6-A/S**, the fault is governed by rate-and-state friction, for which shear traction on the fault is always equal to fault shear resistance F, which depends on slip rate V, state variable θ, and change in pore pressure p, namely:

$$\tau = F(V,\theta,p). \tag{10}$$

Specifically, the friction coefficient f is given by a regularized formulation:

$$f(V,\theta) = a \sinh^{-1}\left[\frac{V}{2V_*}\exp\left(\frac{f_* + b\ln(V_*\theta/D_{\mathrm{RS}})}{a}\right)\right], \tag{11}$$

with the reference friction coefficient f_* at a reference slip rate V_*, and rate-and-state direct effect and evolution parameters a and b, respectively. For **BP6-A**, θ evolves according to the aging law:

$$\frac{d\theta}{dt} = 1 - \frac{V\theta}{D_{\mathrm{RS}}}, \tag{12}$$

where D_{RS} is the characteristic slip distance. For **BP6-S**, θ evolves according to the slip law:

$$\frac{d\theta}{dt} = -\frac{V\theta}{D_{\mathrm{RS}}}\ln\left[\frac{V\theta}{D_{\mathrm{RS}}}\right]. \tag{13}$$

2.2 BP6-C: Constant friction

For **BP6-C**, the the coefficient of friction f is constant and the shear resistance $F(p)$ depends only on the change in pore fluid pressure p. With constant friction, we distinguish between locked and slipping states of the interface. When the shear stress is lower than the shear resistance, the fault is locked and the shear stress is given by the sum of the reference shear traction and the shear stress change due to quasi-static deformation:

$$\tau = \tau^0 + \Delta\tau, \quad \tau < F(p), \quad V = 0. \tag{14}$$

When the fault is sliding, the shear stress is equal to the shear resistance:

$$\tau = \tau^0 + \Delta\tau - \eta V, \quad \tau = F(p), \quad V > 0. \tag{15}$$

These conditions are often written as

$$V \geq 0, \quad F - \tau \geq 0, \quad (F-\tau)V = 0. \tag{16}$$

2.3 Fluid flow

Fault slip is induced due to perturbations in pore fluid pressure via fluid injection at the center of the fault $z = 0$. Fluid flow is confined to the fault: $x = 0$, $z \in \Omega_f$; fault-normal flow is neglected. The continuity of fluid mass is thus:

$$\frac{\partial m}{\partial t} + \frac{\partial(\rho_f q)}{\partial z} = \rho_f q_{\mathrm{inj}}(t)\delta_D(z) \tag{17}$$

where $m(z,t)$ is the fluid mass per unit volume of rock, ρ_f is the fluid density, $q(z,t)$ is the Darcy velocity (volume flux through x-y plane per unit surface area of porous solid). The right-hand-side represents the fluid source term with $q_{\text{inj}}(t)$ being the fluid injection rate (volume per time, per unit area in the x-y plane) and $\delta_D(z)$ is the Dirac delta function.

Assuming only elastic changes in rock porosity ϕ and a compressible fluid, then the change in fluid mass is given by:

$$\frac{\partial m}{\partial t} = \rho_f \phi \beta \frac{\partial p}{\partial t}, \tag{18}$$

where β is the sum of the fluid and pore compressibilities. In the linearized model used in this benchmark, both ϕ and β in (18) are regarded as constants. The Darcy velocity is given by:

$$q = -\frac{k}{\eta}\frac{\partial p}{\partial z}, \tag{19}$$

where k is the permeability, η is the fluid viscosity, and the effects of gravity are neglected.

Given (18) and (19) and assuming constant permeability, fluid viscosity, porosity, and compressibility, fluid mass conservation can be rewritten to express the evolution of pore fluid pressure along Ω_f as the 1D pressure diffusion equation:

$$\frac{\partial p}{\partial t} = \frac{k}{\phi\beta\eta}\frac{\partial^2 p}{\partial z^2} + \frac{q_{\text{inj}}(t)}{\beta\phi}\delta_D(z). \tag{20}$$

The hydraulic diffusivity for this diffusion problem is given by $\alpha = k/(\phi\beta\eta)$.

We impose the following boundary condition for fluid flow:

$$q(\pm l_f, t) = 0, \tag{21}$$

indicative of zero fluid flux outside of the frictional domain Ω_f.

3 Initial Conditions and Simulation Time

Initial conditions are required for slip, pore pressure, and (for BP6-A/S) state. By definition, slip is initially zero,

$$\delta(z,0) = 0, \tag{22}$$

which together with the requirement that displacements vanish at infinity, implies that displacements everywhere are initially zero: $u(x,z,0) = 0$.

For **BP6-A/S**, τ^0 is chosen as:

$$\tau^0 = \tau_{\text{init}} + \eta V_{\text{init}}, \tag{23}$$

such that the initial ($t = 0^+$) shear stress and slip rate are τ_{ini} and V_{init}, respectively, which are spatially uniform. The initial state θ^0 is also uniform:

$$\theta^0 = \frac{D_{\text{RS}}}{V_*}\exp\left\{\frac{a}{b}\ln\left[\frac{2V_*}{V_{\text{init}}}\sinh\left(\frac{\tau_{\text{init}}}{a\bar{\sigma}_0}\right)\right] - \frac{f_*}{b}\right\}. \tag{24}$$

For **BP6-C**, the fault is initially locked ($V_{\text{init}} = 0$) with uniform initial shear stress $\tau^0 = \tau_{\text{init}}$. Note that while τ_{init} is the same for all benchmark versions, τ^0 is not.

By definition, the initial pore pressure change is zero: $p(z,0) = 0$. Fluids is injected at a constant injection rate q_0 for time $0 \leq t < t_{\text{off}}$, after which fluid injection is turned off:

$$q_{\text{inj}}(t) = \begin{cases} q_0, & 0 \leq t < t_{\text{off}} \\ 0, & \text{otherwise.} \end{cases} \tag{25}$$

For timescales sufficiently shorter than the diffusion time across l_f (i.e. $t \ll l_f^2/(4\alpha) \approx$ 31.7 years), the evolution of pore pressure approximately follows the analytic solution for injection into an infinite fault:

$$p(z,t) = \frac{q_o}{\beta\phi\sqrt{\alpha}} \left[G(z,t,\alpha)H(t) - G(z,t-t_{\text{off}},\alpha)H(t-t_{\text{off}}) \right], \tag{26}$$

where

$$G(z,t,\alpha) = \sqrt{t} \left[\frac{\exp\left(-\frac{z^2}{4\alpha t}\right)}{\sqrt{\pi}} - \frac{|z|}{\sqrt{4\alpha t}} \text{erfc}\left(\frac{|z|}{\sqrt{4\alpha t}} \right) \right], \tag{27}$$

and $H(t)$ is the heaviside function.

The problem stated above is solved over the time period $0 \leq t \leq t_{\text{f}}$, where t_{f} is a specified final simulation time. All necessary parameter values for this benchmark problem are given in Table 1.

Table 1: Parameter values used in this benchmark problem.

Parameter	Definition	Value, Units
μ	shear modulus	32.04 GPa
ρ	density	2670 kg/m^3
c_s	shear wave speed	3.464 km/s
$\bar{\sigma}_0$	initial effective normal stress	50 MPa
τ_init	initial shear stress	29.2 MPa
q_0	fluid injection rate	1.25×10^{-6} m/s
β	pore and fluid compressibility	10^{-8} Pa^{-1}
ϕ	porosity	0.1
k	permeability	10^{-13} m^2
η	fluid viscosity	10^{-3} Pa·s
α	hydraulic diffusivity	0.1 m^2/s
l_f	half-length of rate-and-state fault	20 km
Δz	suggested cell size	10 m
t_off	injection turn-off time	100 days
t_f	final simulation time	2 years
	Parameters for BP6-A/S	
a	rate-and-state direct effect parameter	0.007
b	rate-and-state evolution effect parameter	0.005
D_RS	state evolution distance	4 mm
V_*	reference slip rate	10^{-6} m/s
f_*	reference friction coefficient	0.6
V_init	initial slip rate	10^{-12} m/s
	Parameters for BP6-C	
f	coefficient of friction	0.6
V_init	initial slip rate	0 m/s

4 Benchmark Output

We request three types of data output, if available, for this benchmark:

(1) On-fault time series (section 4.1)

(2) Source parameter time series (section 4.2)

(3) Slip, pore pressure, Darcy velocity, and stress evolution profiles (section 4.3)

Data files for (1) and (2) are uploaded to the SCEC code verification web server (section 5). Information on how to share output (3) is detailed in section 4.3.

4.1 On-fault Time Series Output

You need to upload on-fault ($x = 0$) time series files, which give slip δ, base 10 log of the slip rate V, base 10 log of the state variable (i.e. $\log_{10}(\theta)$; for BP6-C set to zero), shear stress τ, pore pressure change p, and Darcy velocity q for each on-fault station at representative time steps. When outputting modeling results, consider time intervals of 1-hour increments. More variable time steps are OK. Please keep the total number of time steps in the data file on the order of 10^4–10^5.

Time series data is supplied as ASCII files, one file for each station. There are 9 observational points on the fault, as follows:

1. `fltst_strk-15`: $z = -1.5$ km;
2. `fltst_strk+00`: $z = 0$ km;
3. `fltst_strk+05`: $z = 0.5$ km;
4. `fltst_strk+10`: $z = 1$ km;
5. `fltst_strk+15`: $z = 1.5$ km;
6. `fltst_strk+25`: $z = 2.5$ km;
7. `fltst_strk+35`: $z = 3.5$ km;
8. `fltst_strk+50`: $z = 5$ km;
9. `fltst_strk+75`: $z = 7.5$ km;

Each time series has 7 data fields, as follows.

Field Name	Description, Units and Sign Convention
`t`	Time (s)
`slip`	Slip (m). Positive for right-lateral motion.
`slip_rate`	$\log_{10}$ of the amplitude of the slip-rate ($\log_{10}$ m/s), which is positive for right-lateral motion.
`shear_stress`	Shear stress (MPa), which is positive for shear stress that tends to cause right-lateral motion.
`pore_pressure`	Pore fluid pressure change (MPa).
`darcy_vel`	Darcy velocity (m/s)
`state`	$\log_{10}$ of state variable ($\log_{10}$ s).

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

File Section	Description
File Header	A series of lines, each beginning with a # symbol, that give the following information: • Benchmark problem (e.g. BP6-A) • Code name • Code version (optional) • Modeler • Date • Node spacing or element size • Station location • Minimum time step (optional) • Maximum time step (optional) • Number of time steps in file (optional) • Anything else you think is relevant (optional) • Descriptions of data columns (7 lines) • Anything else you think is relevant
Field List	A single line, which lists the names of the 7 data fields, in column order, separated by spaces. It should be: `t slip slip_rate shear_stress pore_pressure darcy_vel state` (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 7 numbers, which give the data values for a single time step. The lines must appear in order of increasing time. **Make sure to use double-precision when saving all fields.** **C/C++ users:** We recommend using 21.13E or 21.13e floating-point format for the time field and 14.6E or 14.6e format for all other data fields. **Fortran users:** We recommend using E22.14 or 1PE22.13 floating-point format for the time field and E15.7 or 1PE15.6 format for other data fields. 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.

Here is an example of an on-fault time-series file, with invented data.

```
# This is the file header:
# problem=SEAS Benchmark BP6-A
# code=MYcode
# version=1.0
# modeler=A.Modeler
# date=2021/08/10
# element_size=10 m
# location= on fault, z = 0 km
# minimum_time_step=9.622E-04
# maximum_time_step=5.000E+02
# num_time_steps=42356
# Column #1 = Time (s)
# Column #2 = Slip (m)
# Column #3 = Slip_rate (m)
# Column #4 = Shear_stress (MPa
# Column #5 = Pore_pressure (MPa)
# Column #6 = Darcy_velocity (m/s)
```

```
# Column #7 = State (log10 s)
# The line below lists the names of the data fields
t slip slip_rate shear_stress pore_pressure darcy_vel state
# Here is the time-series data.
0.00000000E+00 0.0000000E+00 -1.2000000E+01 2.9200000E+01  0.0000000E+00 ...
6.73595073E-03 6.7359534E-15 -1.1999999E+01 2.9200000E+01 -8.4199100E-07 ...
6.06235565E-02 6.0623808E-14 -1.1999995E+01 2.9200000E+01 -7.5776430E-06 ...
4.91724403E-01 4.9174118E-13 -1.1999955E+01 2.9200000E+01 -6.1445444E-05 ...
# ...  and so on.
```

4.2 Source Parameter Time Series Output

You need to upload a file named `global.dat`, which includes time series of two global source variables, maximum amplitude of slip rates

$$V_{\max} = \max_{z \in \Omega_{\mathrm{f}}} V(z)$$

and moment density rates

$$M_t = \int_{\Omega_{\mathrm{f}}} \mu V(z) dz$$

for the frictional domain Ω_{f}, i.e. $(|z| \leq l_{\mathrm{f}})$. Upload data corresponding to the same time steps you used for section 4.1.

Here is an example of a source parameter time-series file, with invented data.

```
# This is the file header:
# problem=SEAS Benchmark BP6-A
# code=MYcode
# version=1.0
# modeler=A.Modeler
# date=2021/08/10
# element_size=10 m
# location= frictional domain
# minimum_time_step=9.622E-04
# maximum_time_step=5.000E+02
# num_time_steps=42356
# Column #1 = Time (s)
# Column #2 = Max_slip_rate (log10 m/s)
# Column #3 = Moment_density_rate (N/s)
# The line below lists the names of the data fields
t max_slip_rate moment_rate
# Here is the time-series data.
0.00000000E+00 -1.2000000E+01 1.2000000E+03
6.73595073E-03 -1.2000000E+01 1.2177690E+03
6.06235565E-02 -1.1999997E+01 1.2177690E+03
```

```
4.91724403E-01 -1.1999978E+01 1.2177690E+03
# ...  and so on.
```

4.3 Slip, Effective Normal Stress, Darcy Velocity and Shear Stress Evolution Output

The slip and stress evolution output files with the names

```
slip.dat
shear_stress.dat
normal_stress.dat
darcy_vel.dat
```

are 4 ASCII files that record the spatial distribution of slip, shear and effective normal stress, and Darcy velocity on a subset of fault nodes at representative time steps throughout the simulation. Data can be saved using representative time intervals 3 hours or with variable time steps. Either way, data will be interpolated to plot slip every 3 hours.

The data should include nodes with a spacing of $\sim$ 100 m along the fault (-10 km $\leq z \leq 10$ km). The files should also contain the time series of maximum slip rate amplitude (taken over the entire fault).

NOTE: Please upload this data to a Dropbox folder that will be shared with you (or send a request to valerelambert@ucsc.edu).

Each data file has 4 data fields, as follows:

Field Name	Description, Units and Sign Convention
`z`	Position along fault (m) at $\sim$ 100 m increments from -10 km to 10 km
`t`	Time (s). Nonuniform time steps.
`max_slip_rate`	The $\log_{10}$ of maximum amplitude of slip-rate (taken over the entire fault) ($\log_{10}$ m/s).
`slip` OR `shear_stress` OR `normal_stress` OR `darcy_vel`	Slip (m) OR shear stress in (MPa) OR effective normal stress (in MPa) OR Darcy velocity (in m/s).

The data output consists of three sections, as follows:

File Section	Description
File Header	A series of lines, each beginning with a # symbol, that give the following information: • Benchmark problem (e.g. BP6-A) • Modeler • Date • Code • Code version (if desired) • Node spacing or element size • Descriptions of data fields (4 lines) • Anything else you think is relevant (e.g. computational domain size)

Field List	Four lines. The first line lists position z. The next two lines lists the time steps and max slip rate (respectively). The last line lists slip, stress, pore pressure or darcy velocity. It should be:
	`z`
	`t`
	`max_slip_rate`
	`slip` OR `stress` OR `pore_pressure` OR `darcy_vel`

Slip History	A series of lines that form a 2-dimensional array of rows and columns. The first row/line lists the numbers 0, 0 (to maintain a consistent array size), followed by the spatial nodes with increasing distance along the fault as you go across the row. Starting from the second row/line, each row/line contains time, maximum slip rate, and the variable of interest (e.g. slip OR stress) at all nodes at the time. These lines appear in order of increasing time (from top to bottom) and the selected variable (e.g. slip OR stress) is recorded with increasing distance along fault (from left to right). **Make sure to use double-precision when saving all fields**. **C/C++ users:** We recommend using 21.13E or 21.13e floating-point format for the time field and 14.6E or 14.6e format for all other data fields. **Fortran users:** We recommend using E22.14 or 1PE22.13 floating-point format for the time field and E15.7 or 1PE15.6 format for other data fields.

Note that z should appear in the first row, preceded by two zero numbers, for nodes with a spacing of ~100 m. Time and maximum slip rate should appear as two single columns that start on the second row, with time increasing as you go down. The variable of interest (e.g. Slip or stress history) is represented by a two-dimensional array (the remaining block) with time increasing as you go down the rows/lines, and z increasing as you go across the columns (~$201 + 2 = 203$ columns total). For example, the output in `slip.dat` is a two-dimensional matrix of the form:

$$\begin{bmatrix} 0 & 0 & z \\ T & \max(V) & \text{slip} \end{bmatrix}$$

The matrix should be of size $(N_\text{t} + 1, \sim 203)$, where N_t is the total number of time steps. This means that you output slip at selected nodes at one time step and move on to the next time step. (To keep the file on the order of 10s of MB, N_t should be on the order of 10,000).

Here is an example of a slip-evolution file for `slip.dat`, with invented data.

```
# This is the file header:
# problem=SEAS Benchmark BP6-A
```

```
# author=A.Modeler
# date=2021/08/10
# code=MyCode
# code_version=1.0
# element_size=10 m
# Row #1 = Along-fault (m) with two zeros first
# Column #1 = Time (s)
# Column #2 = Max slip rate (log10 m/s)
# Columns #3-203 = Slip along fault (m)
# Computational domain size:  -25 km < z < 25 km
# The line below lists the names of the data fields
z
t
max_slip_rate
slip
# Here are the data
0.000000E+00  0.0000000E+00 -1.0000000E+04 -9.9000000E+03 ...  1.0000000E+04
0.000000E+00 -1.2000000E+01  0.0000000E+00  0.0000000E+00 ...  0.0000000E+00
1.100451E+04 -1.1829690E+01  1.1004520E-08  1.1004520E-08 ...  1.1004520E-08
2.200451E+04 -1.1758690E+01  2.2004550E-08  2.2004550E-08 ...  2.2004550E-08
3.250451E+04 -1.1706290E+01  3.2504600E-08  3.2504600E-08 ...  3.2504600E-08
...
6.307239E+07 -8.5039670E+00  7.4924930E-05  7.5614600E-05 ...  7.4924930E-05
```

5 Using the Web Server

The web server lets you upload your modeling results (section 4). Once uploaded, you and other modelers can view the data in various ways.

5.1 Logging in and Selecting a Problem

To log in, start your web browser and go to the home page at:

`https://strike.scec.org/cvws/cgi-bin/seas.cgi`

Click on "Upload Files," and then log in using your user name and password. Remember that passwords are case-sensitive. You are then presented with a list of code validation problems. Find the problem you want, and click the "Select" button. You will then see a list of files for the problem.

5.2 Navigating the Site

You navigate through the site by clicking buttons on the web pages. Avoid using your browser's Back or Forward buttons. If you use the Back or Forward buttons, you may get error messages from your browser.

5.3 Uploading Files

To upload a file, do the following steps:

- Find the file you want to upload, and click “Select.” The server displays a page for you to upload the file.
- Select the data file on your computer. The exact method for file selection varies depending on operating system and web browser.
- Click on “Click Once to Upload.” The file you selected is uploaded to the server.

When you upload a file, the web server immediately checks for correct formatting. There are three possible results:

- If the file is correctly formatted, the server displays a page noting the successful upload.
- If the file contains errors, the server displays an error log. The error log lists the errors that were detected in the file, each identified as specifically as possible.
- If the file is correctly formatted, but is questionable in some way (for example, a missing time step), then the server displays a warning log, which describes the problem.

When uploading time series files, the website may issue a warning that the time series cannot be filtered. Modelers should ignore this warning. After uploading a file, the file list shows the date and time that you uploaded the file. Remember that any file you upload will be visible to anyone who has access to the web site.

Additional help is available by clicking the “Help” link in the upper right corner of the webpage. Modelers who want to upload multiple versions of the benchmark (for example, using different element sizes), can do so using the “Change Version” feature of the website, which is described in the help screens. Direct further questions to Michael Barall.

5.4 Graphing, Viewing, and Deleting Files

After uploading a file, additional functions become available. These functions let you graph, view, or delete the uploaded file.

Graphing: To graph a file, find the file you want and click “Graph.” For a time-series file, the server displays graphs of all the data fields in the file. At the bottom of each graph page, there is a box you can use to adjust graphing preferences. Graphing a file is a good way to check that the server is interpreting your data as you intended.

Viewing: To view the text of a file, find the file you want and click “View.”

Deleting: To delete a file from the server, find the file you want and click “Delete.” The server displays a page asking you to confirm the deletion.

6 Benchmark Tips

Numerical boundary conditions (to truncate the whole-space in x and z directions when defining the computational domain) will most likely change results at least quantitatively, or even qualitatively. We suggest extending these boundaries until you see results appear independent of the computational domain size. We prefer participants to use the cell size suggested in Table 1 and welcome results for different spatial resolutions. Each person can submit (at most) results from two different spatial resolutions and two different computational domain sizes.

The inequality constraints for BP6-C are often enforced using the following algorithm: First, assume $V = 0$. If $\tau^0 + \Delta\tau < F(p)$, this locked state is accepted; set $V = 0$ and $\tau = \tau^0 + \Delta\tau$. However, if $\tau^0 + \Delta\tau > F(p)$, then the fault is slipping. Solve $\tau^0 + \Delta\tau - \eta V = F(p)$ for $V > 0$ and set $\tau = \tau^0 + \Delta\tau - \eta V$.