*Kali L. Allison*

*last updated: 1/26/2018*

Scycle Manual

1. Introduction 3

1.1. Basic input parameters 4

1.2. Linear Elastic 7

1.3. Power-Law Viscoelastic 8

1.4. Heat Equation 10

1.5. Pressure Diffusion Equation 11

# Introduction

Scycle (pronounced like *cycle*) is a code for simulating single earthquakes and sequences of earthquakes, called earthquake cycles. It only supports the antiplane geometry in 2D, as shown in Figure Figure 1.1.

Figure . Diagram showing geometry of domain. Only the block to the right of the fault is included in the domain. The coordinate system’s origin is at the upper left corner of the domain.

y

z

fault

T

L

B

R

0

Scycle requires an input text file, provided as the first command line argument after the name of the executable. For example, if the code has been compiled into an executable named “main”, and the input file is “in/ex1.in” then use this command to run the code from the command line on a single processor:

./main in/ex1.in

Or, to run using (for example) 4 processors, use:

mpirun –np 4 main in/ex1.in

Several example input files are provided:

**ex1.in**: This will run a 1D earthquake cycle simulation with linear elastic off-fault material, using the quasi-dynamic approximation. The material properties are constant, and symmetric around the fault. This is 1D, meaning that the fault is a single point and the domain extends in the y-direction but not the z-direction.

**ex2.in**: This will run a 2D earthquake cycle simulation with linear elastic off-fault material, using the quasi-dynamic approximation. The material properties are constant, and symmetric around the fault.

**ex3.in**: This will run a 2D ice stream simulation with linear elastic ice, using the quasi-dynamic approximation. The material properties are constant, and it is assumed that the material to the left of the fault is perfectly rigid.

**ex4.in**: This will run a 2D thermomechanical earthquake cycle simulation with power-law viscoelastic off-fault material, using a fixed-point iteration method to estimate steady state conditions. It includes the steady state heat equation.

A summary of parameters accepted by the input file is provided in the tables below. The bold parameters are required. Those which are not bold have default values. Input parameters are formatted as:

parameterName = value # optional comment

where the use of white space is important. Each parameter must be placed on its own line, and may not have any white space or characters before its name. The separation between a parameter and its value must be <space><equals sign><space>, with no extra spaces or characters. In the examples, # is used as the default comment symbol, but in actuality any input which does not perfectly match the format will be interpreted as a comment (i.e. misspelled parameters will be ignored, any text that follows the value will be ignored), so any symbol may effectively be used as a comment symbol.

**A word of caution: the input parameters are NOT in base SI units.**

## Basic input parameters

Input parameters to select what type of problem to run:

|  |  |  |
| --- | --- | --- |
| Input Parameter | Meaning | Allowed Values |
| problemType | which problem type to run | strikeSlip, iceStream  default: strikeSlip |
| bulkDeformationType | which constitutive law to use | linearElastic, powerLaw  default: linearElastic |
| momentumBalanceType | how to treat inertial term in momentum balance equation, also whether to use fixed point iteration or not | quasidynamic, dynamic, quasidynamic\_and\_dynamic, steadyStateIts  default: quasidynamic |
| guessSteadyStateICs | whether or not to try to converge to steady state initial conditions, assuming  on the fault is known | 0 = no, 1 = yes  default: 0 |
|  |  |  |

Basic input parameters for every simulation

|  |  |  |
| --- | --- | --- |
| Input Parameter | Meaning | Allowed Values |
| order | order of accuracy for spatial derivatives | 2, 4, default: 4 |
| Ny | # of points in y-direction | must be large enough to resolve physics |
| Nz | # of points in z-direction | must be large enough to resolve physics |
| Ly | (km) domain size in y-direction | >0 |
| Lz | (km) domain size in z-direction | >0 |
| sbpType | type of SBP operators used | mc = matrix-based, compatible  mfc = matrix-based, fully compatible  mfc\_coordTrans = matrix-based, fully compatible, allows curvilinear coordinate transformation |
| bCoordTrans | if sbpType is mfc\_coordTrans, then this argument tunes how extreme the grid space change in y is | any floating point number, recommended between 1 and 10 |
| outputDir | full path to output, possibly including prefixes  may be the relative path, if running Scycle from the command line | string  default: data/  example:  /data/dunham/kallison/data/ test\_ |

## Rate-and-State Friction

Input arguments for rate-and-state friction parameters

|  |  |  |
| --- | --- | --- |
| Input Parameter | Meaning | Allowed Values |
| rootTol | relative tolerance for root-finding algorithm | default: 1e-9 |
| stateLaw | evolution law for state variable | agingLaw, slipLaw  default: agingLaw |
| f0 | rate-and-state factor | 0.6 |
| v0 | (m/s) rate-and-state scaling factor | 1e-6 |
| impedanceVals, impedanceDepths | radiation damping coefficient | required, no default |
| cohesionVals, cohesionDepths | (MPa) cohesion | not required, defaults to 0 |
| DcVals, DcDepths | (m) state evolution distance, sometimes called L in the literature | required, no default |
| aVals, aDepths | direct effect parameter | required, no default |
| bVals, bDepths | state evolution effect parameter | required, no default |
| sigmaNVals, sigmaNDepths | (MPa) effective normal stress | required, no default |
| sigmaN\_floor | (MPa) floor for effective normal stress (overrides sigmaNVals, sigmaNDepths) | example: 5.5  optional, no default |
| sigmaN\_cap | (MPa) ceiling for effective normal stress (overrides sigmaNVals, sigmaNDepths) | example: 50  optional, no default |

## Time stepping algorithms

Input parameters to control the time integration algorithm

|  |  |  |
| --- | --- | --- |
| Input Parameter | Meaning | Allowed Values |
| timeIntegrator | time integration algorithm | FEuler, RK32, RK43, RK32\_WBE, RK43\_WBE  default: RK32 |
| timeControlType | control type for time step selection | options: P, PI, PID  default: PID |
| stride1D, stride2D | how frequently to write output for 1D and 2D files, in number of time steps | default: 1, 1 |
| maxStepCount | maximum number of time steps to take before terminating the simulation | default: 1e8 |
| initTime | (s) initial time | default: 0 |
| maxTime | (s) final time | default: 1e15 |
| initDeltaT | (s) size of first time step | default: 1e-3 |
| minDeltaT | (s) minimum allowed time step | default: 1e-3 |
| maxDeltaT | (s) maximum allowed time step (can be overridden if the user provides functions to compute this as the simulation runs) | default: 1e10 |
| atol | absolute tolerance for selection of time step | default: 1e-9 |
| timeIntInds | names of explicitly integrated variables to be used to control time step size | no default values  example: [psi slip] |
|  |  |  |
|  |  |  |
|  |  |  |

## Linear Elastic

For simulations with linear elastic off-fault material.

|  |  |  |
| --- | --- | --- |
| Input Parameter | Meaning | Allowed Values |
| momBal\_computeSxz | determines whether or not to compute stress sxz | 0 = no, 1 = yes  default: 0 |
| momBal\_computeSdev | determines whether or not to compute the deviatoric stress (also involves calculating sxz) | 0 = no, 1 = yes  default: 0 |
| momBal\_bcR\_qd, momBal\_bcT\_qd,  momBal\_bcL\_qd,  momBal\_bcB\_qd | type of (right, left, top, or bottom) boundary condition for the momentum balance equation | symm\_fault, rigid\_fault, remoteLoading, freeSurface, tau, outGoingCharacteristics |
|  |  |  |
|  |  |  |
|  |  |  |

## Power-Law Viscoelastic

For simulations with power-law nonlinear viscoelastic simulations. Some of these parameters are for earthquake cycle simulations, and some are for the fixed point iteration algorithm to find steady state initial conditions.

|  |  |  |
| --- | --- | --- |
| Input Parameter | Meaning | Allowed Values |
| momBal\_bcR\_qd, momBal\_bcT\_qd,  momBal\_bcL\_qd,  momBal\_bcB\_qd | type of (right, left, top, or bottom) boundary condition for the momentum balance equation | symm\_fault, rigid\_fault, remoteLoading, freeSurface, tau, outGoingCharacteristics |
| fss\_T | damping parameter for steady state temperature | 0 -1, default: 0.1 |
| fss\_EffVisc | damping parameter for steady state effective viscosity | 0 – 1, default: 0.25 |
| ssEffViscScale | scaling factor to reduce floating point errors for steady state convergence routine | any value, default: 1e-15 |
| maxEffVisc | (GPa s) ceiling value for effective viscosity | default: 1e30 |
| gss\_t | guess viscous strain rate | default: 1e-8 |
| maxSSIts\_effVisc | maximum allowed number of iterations to converge to steady state effective viscosity | default: 50 |
| maxSSIts\_tau | maximum allowed number of iterations to converge to steady state shear stress on fault | default: 50 |
| maxSSIts\_timesteps | maximum allowed number of time steps for portion of steady state iteration involving explicit time integration | default: 2e4 |
| atolSS\_effVisc | absolute error for determining if effective viscosity has converged | 1e-3 |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

|  |  |  |
| --- | --- | --- |
| Input Parameter | Meaning | Allowed Values |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

|  |  |  |
| --- | --- | --- |
| Input Parameter | Meaning | Allowed Values |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

|  |  |  |
| --- | --- | --- |
| Input Parameter | Meaning | Allowed Values |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

## Heat Equation

This is the paragraph about how to add the heat equation to any simulation.

## Pressure Diffusion Equation

This is the paragraph about how to add the fluid-diffusion equation to any simulation.

Options for linear elastic simulations

|  |  |
| --- | --- |
| input parameter | value |
| momBal\_computeSxz | 0 = no, 1 = yes |
| momBal\_computeSdev | 0 = no, 1 = yes |
| momBal\_bcR\_qd |  |
| momBal\_bcT\_qd |  |
| momBal\_bcL\_qd |  |
| momBal\_bcB\_qd |  |
|  |  |

Simulations including the pressure diffusion equation along the fault

Input arguments:

|  |  |
| --- | --- |
| Input file variable | Possible Values |
| hydraulicCoupling | no, uncoupled, coupled |
| hydraulicTimeIntType | explicit, implicit |
| linSolver\_p | AMG, MUMPSCHOLESKY, MUMPSLU |
| kspTol\_p | any floating point value |
| n\_pVals, n\_pDepths |  |
| beta\_pVals, beta\_pDepths |  |
| k\_pVals, k\_pDepths |  |
| eta\_pVals, eta\_pDepths |  |
| g | any floating point value |
| rho\_fVals, rho\_fDepths |  |