User's manual of the AutoCoulomb program

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The program is termed 'AutoCoulomb', which is used for the automatic computation of Coulomb stress changes caused by earthquake faulting in a batch processing way. This manual provides basic usages of command lines and associated explanations on how to use the program. The basic philosophy for the program is to repeatedly apply the Coulomb failure model for computing Coulomb stress changes. Coulomb stress changes can be resolved on horizontal planes with given depth, sliced profiles with various orientation, optimally oriented failure planes and major faults.

1. Preparation work:

1.1 Install GMT (recommended) and MATLAB (required).
1.2 Set environment variables for GMT and MATLAB (note here GMT 4 is used).
1.3 Install Fortran compiler (gfortran).

2. Example

Assuming that AutoCoulomb be in the directory: /home/AutoCoulomb

2.1 Coulomb stress changes at grids of a horizontal plane

(1) Run MATLAB and change its current directory using the following command: *cd /home/AutoCoulomb/preproc*

(2) In the command window enter the following commands:
preproc_sampling_grids
the minimum longitude (deg): 100
the maximum longitude (deg): 106
the minimum latitude (deg): 28
the maximum latitude (deg): 36
the longitude interval (deg): 0.01
the latitude interval (deg): 0.01
the depth at which CFS is computed (km): 10

preproc_sampling_grids.m: The sampling file was save in the following directory:
/home/AutoCoulomb/grid/sampling_grids.in
total sampling points: 481401

dlon=   1.1 km dlat=   1.1 km

(3) In a linux terminal enter the following commands:

cd /home/AutoCoulomb/grid/

./all.sh -T synthetic_1slipmodel.in -P sampling_grids.in -M 104 -C 1 -S 0 -D 90 -R 0 -F 0.4 -B 0

(4) Result

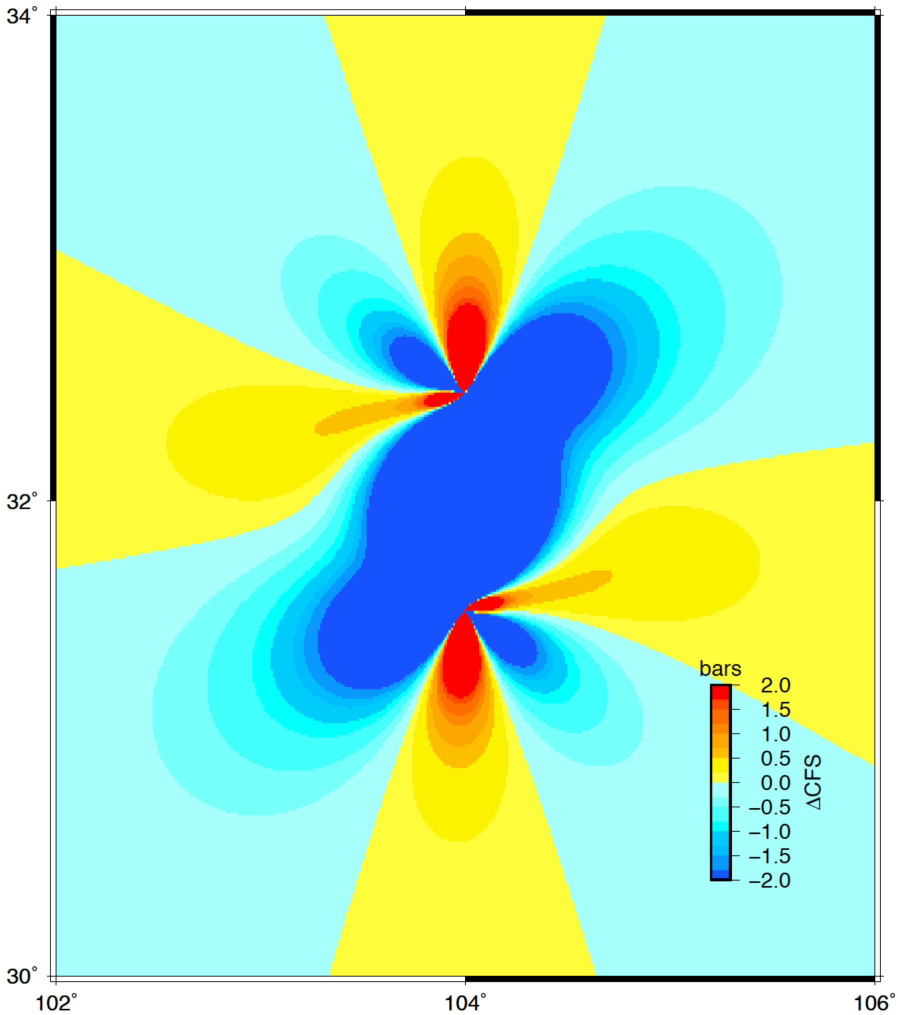

Figure 1. Coseismic Coulomb stress changes aroused by the synthetic source fault at a depth of 10 km. The NS vertical left-lateral strike-slip source fault has 100 km in length, 20 km in width and slip of 4 m. Strike angle, dip angle and rake angle of the receiver fault are 0°, 90° and 0°, respectively.

The resulted Coulomb stress changes are saved in the directory './CFS_result/coulomb.out'.

(5) Explanation of the command line:

./all.sh -T synthetic_1slipmodel.in -P sampling_grids.in -M 104 -C 1 -S 0 -D 90 -R 0 -F 0.4 -B 0

- 'synthetic_1slipmodel.in' is the synthetic source fault. The file of the source fault should be prepared in a given directory (here in the current directory) before running the command line.

- ‘sampling_grids.in’ is the sampling points. The file of the sampling points should be prepared in a given directory (here in the current directory) before running the command line. At step (2) this file is generated and saved in the current directory.
- ‘104’ in ‘-M 104’ is the meridian of the gridded plane. This parameter is used for the Gaussian projection. The unit of meridian is in degree.
- ‘1’ in ‘-C 1’ is the value of a switch variable. If it is ‘-C 1’, it means to recompute the stress tensors induced by the synthetic source fault. If it is ‘-C 0’, it means not to recompute the stress tensors. Note that at least the command line is run with the option ‘-C 1’ once before doing so for a case when to set ‘-C 0’, because the stress tensors imparted by the source fault should be generated first and then the stress tensors can be used repeatedly.
- ‘0’ in ‘-S 0’ is the strike angle of the receiver fault.
- ‘90’ in ‘-D 90’ is the dip angle of the receiver fault.
- ‘0’ in ‘-R 0’ is the rake angle of the receiver fault.
- ‘0.4’ in ‘-F 0.4’ is the friction coefficient (it’s an empirical value).
- ‘0’ in ‘-B 0’ is Skempton’s coefficient.

(6) Explanation of the file of the source fault ‘synthetic_1slipmodel.in’:

This file consists of two lines: the first line is the number of subpatches of the source fault; the second line has the following format (note that more such lines as the second one can be succeeded only if the number of subpatches is equal to that of such lines):

latitude longitude depth length width AL1 AL2 AW1 AW2 strike dip s1 s2 s3 0 0 0

‘latitude longitude depth’ is the reference point in the source fault.

‘length width’ are the length and width of the source fault.

AL1 and AL2 are the distances from left and right edges of the rectangular source fault, respectively; AL1<=0 and AL2 >=0. AW1 and AW2 are the distance from bottom and top edges of the rectangular source fault, respectively; AW1<=0 and AW2>=0.

‘strike dip rake’ are strike angle, dip angle and rake angle of the source fault, respectively.

‘s1 s2 s3’ are strike slip, dip slip and tensile slip of the source fault, respectively. The strike slip, dip slip and tensile slip are positive in strike direction, updip direction and normal to source fault.

‘0 0 0’ are dummy values.

The units of the latitude, longitude, strike, dip and rake are in degree. The units of s1, s2 and s3 are in meter. The units of the others in the second line of the file of the source fault are in kilometer.

(7) Explanation of the file of the sampling points ‘sampling_grids.in’:

The first line of this file is the number of sampling points. Each of the following line has the format:

latitude(deg) longitude (deg) depth(km)

‘latitude longitude depth’ are the position of a grid point at which the stress tensor induced by the source fault is computed. The receiver fault at each grid point is the fault plane onto which the stress tensor is projected.

2.2 Coulomb stress changes on a major fault

The computation of Coulomb stress changes on a major fault is similar to that in the gridded plane as shown in section 2.1. The following presents how to compute Coulomb stress changes induced by the synthetic source fault (see section 2.1) on a major fault. The command line is as follows:

./all.sh -T synthetic_1slipmodel.in -M 104 -R sampling_faulttrace.in

(1) Explanation of the above command line:

- 'synthetic_1slipmodel.in' is the synthetic source fault. The file of the source fault should be prepared in a given directory (here in the current directory) before running the command line.
- '104' in '-M 104' is the meridian of the horizontal gridded plane with a given depth. This parameter is used for the Gaussian projection.
- '*sampling_faulttrace.in*' is the sampling file of a fault trace. Here the fault trace is referred to as the intersection line between a targeted major fault surface and the horizontal plane at a given depth. The file of the sampling points along the major fault should be prepared in a given directory (here in the current directory) before running the command line. When digitalizing the major fault, at each sampling point one should prescribe the strike angle, dip angle and rake angle respectively associated with the segment of the major fault at the sampling point as well as the friction and Skempton's coefficients. Digitalizing the major fault can be fulfilled using the MATLAB functions of 'imread', 'imshow' and 'ginput'.

(2) Explanation of the sampling file:

The first line of the sampling file 'sampling_faultrrace.in' is the number of sampling points for the fault trace. Then each of subsequent line has the format as follows:

latitude longitude depth strike dip rake friction skempton

'latitude longitude depth' are the latitude, longitude and depth for each grid point, respectively.

'strike dip rake' are the strike angle, dip angle and rake angle of the receiver fault, respectively.

'friction' is the friction coefficient.

'skempton' is Skempton's coefficient.

The units of latitude, longitude, strike, dip and rake are in degree. The unit of depth is in kilometer.

(3) Result

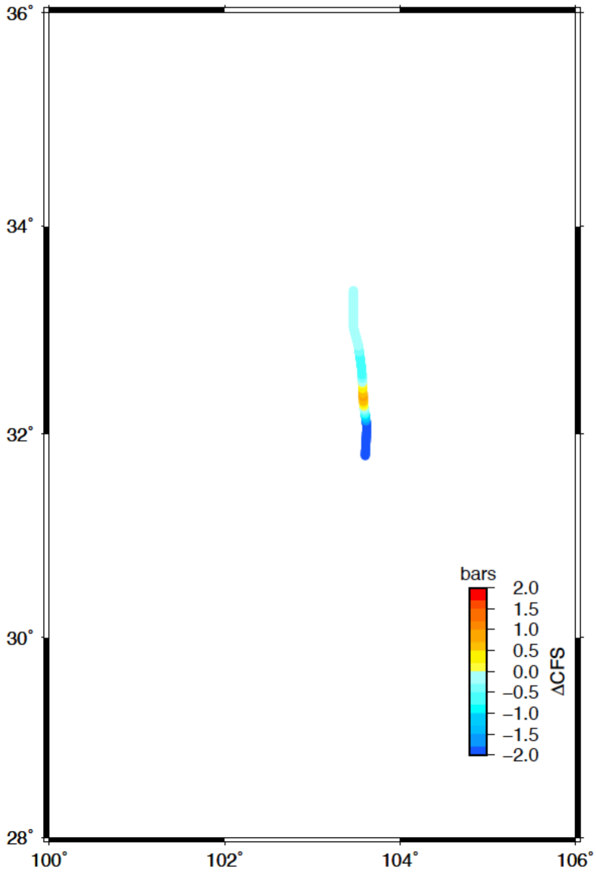

Figure 2. Coseismic Coulomb stress changes induced by the synthetic source fault as used in Figure 1 and imparted on the major fault at a depth of 10 km.

The resulted Coulomb stress changes are saved in the directory './CFS_result/coulomb.out'.

2.3 Coulomb stress changes on profiles

(1) Run MATLAB and change its current directory using the following command: *cd /home/AutoCoulomb/preproc*

(2) In the command window enter the following commands:
preproc_sampling_profile
profile plane with the same format as a single source fault: ../profile/profile.in

(3) In a linux terminal enter the following commands:
cd /home/AutoCoulomb/profile/
./all.sh -T synthetic_1slipmodel.in -P profile_along_fault_plane1.txt -M 104 -C 1 -S 0 -D 90 -R 0 -F 0.4 -B 0

(4) Result

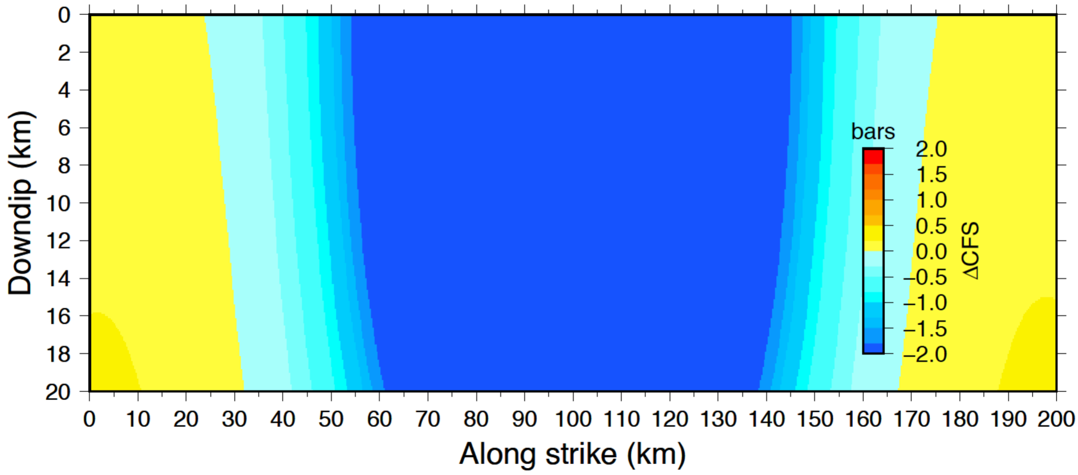

Figure 3. Coseismic Coulomb stress changes induced by the synthetic source fault and imparted on a profile. The synthetic source fault is that used in Figure 1. The profile is 200 km in length and 20 km in width; The middle point of the upper edge of the profile is (104°E, 32°N, 0 km); The strike angle and dip angle of the profile are 90° and 90°, respectively. The profile is in fact a vertical slice along the latitude of 32° and its upper edge is centered at (104°, 32°) for Figure 1. The strike angle, dip angle and rake angle of the receiver fault are 0°, 90° and 0°, respectively.

The resulted Coulomb stress changes are saved in the directory './CFS_result/coulomb.out'.

(5) Explanation of the command line:

./all.sh -T synthetic_1slipmodel.in -P profile_along_fault_plane1.txt -M 104 -C 1 -S 0 -D 90 -R 0 -F 0.4 -B 0

- 'synthetic_1slipmodel.in' is the synthetic source fault. The file of the source fault should be prepared in a given directory (here in the current directory) before running the command line.
- 'profile_along_fault_plane1.txt' is the sampling points. The file of the sampling points should be prepared in a given directory (here in the current directory) before running the command line. At step (2) this file is generated and saved in the current directory.
- '104' in '-M 104' is the meridian. This parameter is used for the Guassian projection. The unit of meridian is in degree.
- '1' in '-C 1' is the value of a switch variable. If it is '-C 1', it means to recompute the stress tensors induced by the synthetic source fault. If it is '-C 0', it means not to recompute the stress tensors.
- '0' in '-S 0' is the strike angle of the receiver fault.
- '90' in '-D 90' is the dip angle of the receiver fault.
- '0' in '-R 0' is the rake angle of the receiver fault.
- '0.4' in '-F 0.4' is the friction coefficient.
- '0' in '-B 0' is Skempton's coefficient.

(6) Explanation of the file profile.in:

The file profile.in has the same format as a single source fault (say the synthetic_1slipmodel.in). If the dip angle in the file profile.in is not 90°, the corresponding profile is nonvertical. The basic idea for the computation of the Coulomb stress changes on the profile is that: obtaining the geographic coordinate of each grid point (latitude, longitude, depth) in the profile and calculating the Coulomb stress change at the grid point. The second step is quite similar to that in section (2.1). The following are the lines of profile.in:

1

32 104 0 200 20 -100 100 -20 0 90 90 4 0 0 0 0 0

The above first line ‘1’ is the number of profiles that is always fixed to be 1 (a dummy value).

At the second line, ’32 104 0’ are the latitude, longitude and depth of a reference point in the profile; ‘200 20’ are the length and width of the profile; ‘-100 100 -20 0’ means ‘AL1 AL2 AW1 AW2’ (AL1 and AL2 are the distances from left and right edges of the rectangular profile, respectively; AL1<=0 and AL2 >=0. AW1 and AW2 are the distances from bottom and top edges of the rectangular profile, respectively; AW1<=0 and AW2>=0); ’90 90’ are the strike angle and dip angle of the profile, respectively; ‘4 0 0 0 0 0’ are the dummy values. The units of the latitude, longitude, strike, dip and rake are in degree. The units of the length, width, depth, AL1, AL2, AW1 and AW2 are in kilometer.

2.4 Coulomb stress changes on optimally oriented failure planes (OOPs)

(i) Vertical strike-slip OOP case

(1) Run MATLAB and change its current directory using the following command: *cd /home/AutoCoulomb/preproc*

(2) In the command window enter the following command and inputs:

preproc_sampling_OOP

-----the boundary and grid size of sampling points-----

minimum longitude (deg): 102

maximum longitude (deg): 106

minimum latitude (deg): 30

maximum latitude (deg): 34

step of longitude (deg): 0.01

step of latitude (deg): 0.01

depth (km): 10

-----the principal tectonic stress-----

the maximum principal stress s1 (magnitdue(bar), plunge(deg),trend(deg)):

s1: [-100 0 7]

the intermediate principal stress s2 (magnitdue(bar), plunge(deg),trend(deg)):

s2: [0 90 0]

the minimum principal stress s3 (magnitdue(bar), plunge(deg),trend(deg)):

s3: [0 0 97]

(3) In a linux terminal enter the following commands:

cd /home/AutoCoulomb/OOP/
./all.sh -T synthetic_1slipmodel.in -P sampling_grids.in -M 104 -C 1 -F 0.4 -B 0 -S tectonic_stress.in -N 1

(4) Result

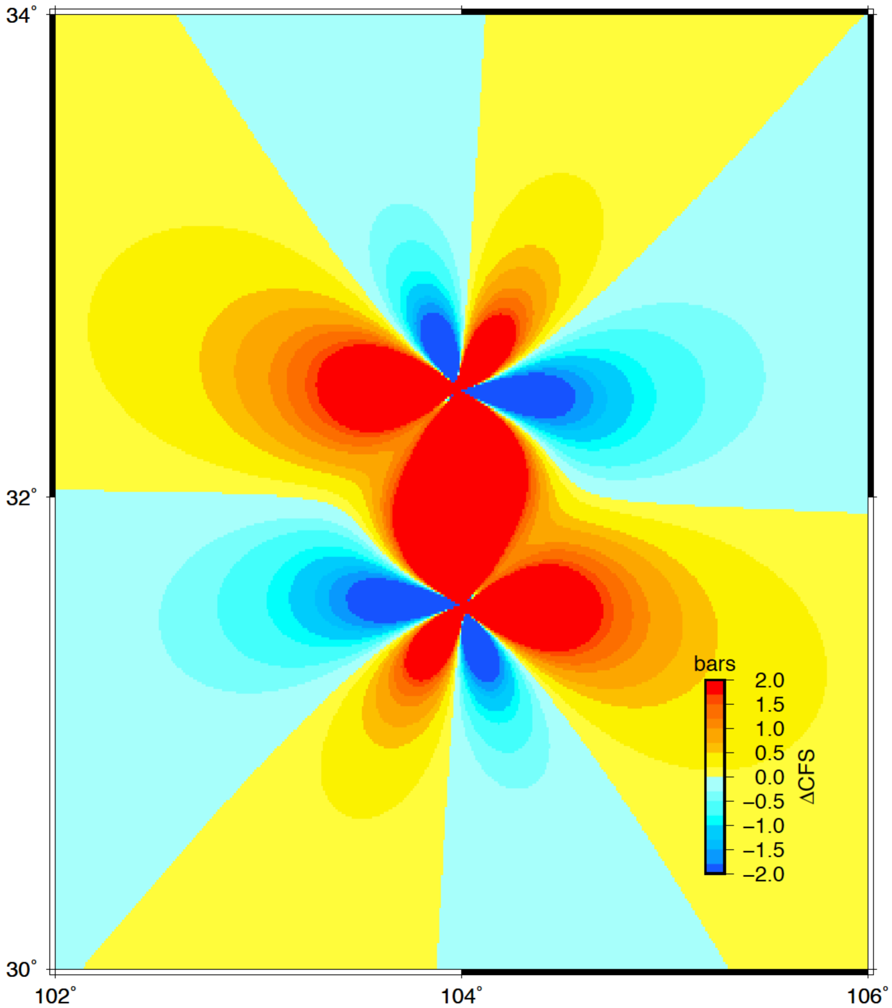

Figure 4. Coseismic Coulomb stress changes induced by the synthetic source fault as used in Figures 1 to 3 and resolved on the vertical strike-slip OOPs at a depth of 10 km. The maximum principal stress component of the tectonic background stress tensor is prescribed to -100 bar (positive in extension) and its azimuth is NE7°; the magnitudes of intermediate and minimum principal stresses are predefined to zeros.

The following are the first two lines in the file /CFS_result/coulomb.out:

lon(deg) lat(deg) opt_str1 opt_dip1 opt_rake1 opt_str2 opt_dip2 opt_rake2 shear stress(bar) normal stress(bar) coulomb stress(bar)
102.000000 30.000000 41.1264 90.0000 0.0000 152.9278 90.0000 180.0000 3.4916547234533649e-02 -9.9418572714139550e-02 -4.8508818511221741e-03

'lon (deg) lat(deg)': The longitude and latitude of a gird point, respectively.

'opt_str1 opt_dip1 opt_rake1': the strike angle, dip angle and rake angle of one OOP (the left-lateral).

'opt_str2 opt_dip2 opt_rake2': the strike angle, dip angle and rake angle of the other

OOP (the right-lateral).

'shear stress(bar) normal stress(bar) coulomb stress(bar)': shear stress, normal stress and Coulomb stress changes resolved on the 1D OOP. Note that the Coulomb stress changes on both 1D OOPs are equal to each other.

The unit of angles is in degree. The unit of stresses is in bar (1 bar = 0.1 MPa).

(5) Explanation of the command line:

./all.sh -T synthetic_1slipmodel.in -P sampling_grids.in -M 104 -C 1 -F 0.4 -B 0 -S tectonic_stress.in -N 1

- 'synthetic_1slipmodel.in' is the synthetic source fault.
- 'sampling_grids.in' is the sampling points.
- '104' in '-M 104' is the meridian of the gridded plane. This parameter is used for the Guassian projection. The unit of meridian is in degree.
- '1' in '-C 1' is the value of a switch variable. If it is '-C 1', it means to recompute the stress tensors induced by the synthetic source fault. If it is '-C 0', it means not to recompute the stress tensors.
- '0.4' in '-F 0.4' is the friction coefficient.
- '0' in '-B 0' is Skempton's coefficient.
- 'tectonic_stress.in' is the tectonic background stress field that is generated in the above step (4). Each line of this file is comprised of six independent stress components as follows:

  e11 e12 e13 e22 e23 e33

  the unit of eij is in bar and they belong to a local topographic Cartesian coordinate whose x, y and z axes are due east, due north and upward, respectively.

  The tectonic background stress field can also be produced using the following command line:

  ./generate_tectonic_stress.sh -s1 "-100 0 7" -s2 "0 90 0" -s3 "0 0 97" -o tectonic_stress.in -n 160801

  The values "-100 0 7" of the option '-s1' are the maximum principal stress, plunge and azimuth for the maximum principal axis, respectively.

  The values "0 90 0" of the option '-s2' are the intermediate principal stress, plunge and azimuth for the intermediate principal axis, respectively.

  The values "0 0 97" of the option '-s3' are the minimum principal stress, plunge and azimuth for the minimum principal axis, respectively.

  'tectonic_stress.in' is the output filename of the tectonic background stress field.

  '160801' is the number of repeated lines for the output file 'tectonic_stress.in'. This number should be equal to the number of the sampling points in the file 'sampling_grids.in'. The unit of principal stresses is in bar. The units of plunge and azimuth are in degree.
- '1' in '-N 1' is the value of a switch variable. If the option is '-N 1', it means to compute the Coulomb stress changes on the vertical left-lateral/ right-lateral OOPs.

  If the option is '-N 2', it means to compute the Coulomb stress changes on the optimal thrust OOPs; the dip angle and rake angle of these type of OOP are set to

$1/2\tan^{-1}1/\mu'$ and 90°, respectively; the letter μ' is the apparent friction coefficient.

If the option is '-N 3', it means to compute the Coulomb stress changes on optimal normal OOPs; the dip angle and rake angle of these type of OOP are set to $\pi/2-1/2\tan^{-1}1/\mu'$ and -90°, respectively; the letter μ' is the apparent friction coefficient.

If the option is '-N 4', it means to compute the Coulomb stress changes on 3D OOPs, each of which strike angle, dip angle and rake angle belonging to the complete parameter space are resolved using a set of analytical formulae. The complete parameter space is referred to [0, 360°] × [0, 90°] × [0, 360°] for possible strike angles, dip angles and rake angles, respectively.

If the option is '-N 5', it means to compute the Coulomb stress changes on constrained OOPs of which the strike angle, dip angle and rake angle are determined using grid search in an incomplete parameter space. In such a case, it is a bit time-consuming to resolve constrained OOPs if the number of equal fractions of the range of strike angle is set to be too large. On the other hand, if the number is prescribed to be too small, the computed Coulomb stress changes would not be precise enough. Therefore, there is a trade-off between computing speed and precision of Coulomb stress changes.

(ii) The thrust OOP case

The thrust OOP is referred to as the receiver fault whose strike angle is determined from the parameter interval of strike angles [0, 360°] but the dip angle and rake angle are fixed to $1/2\tan^{-1}1/\mu'$ and 90°, respectively. The letter μ' is the apparent friction coefficient and in the following case it is set to 0.4.

After repeating the steps in case (i) but merely modifying the value in '-N 1' to '-N 2', that is, running the following command line:

./all.sh -T synthetic_1slipmodel.in -P sampling_grids.in -M 104 -C 1 -F 0.4 -B 0 -S tectonic_stress.in -N 2

Then the following Coulomb stress map resolved on the thrust OOPs is generated.

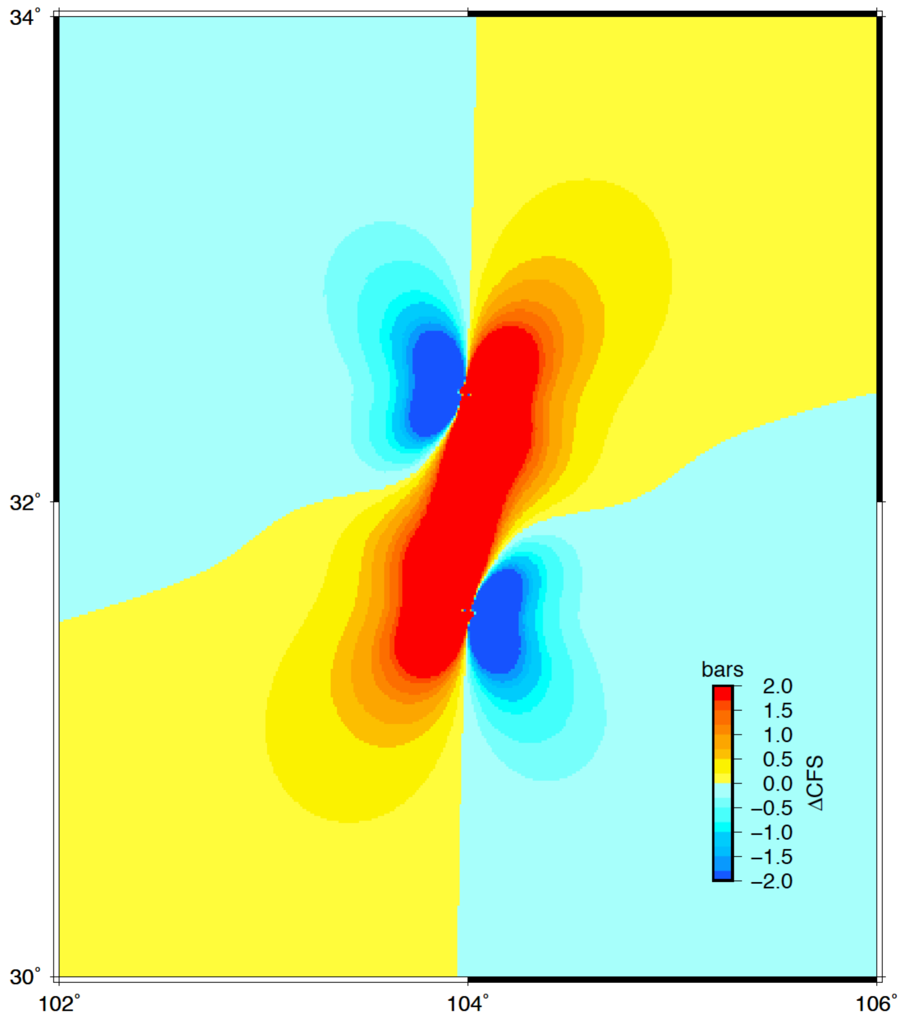

Figure 5. Coseismic Coulomb stress changes induced by the synthetic source fault as used in Figure 4 and resolved on the thrust OOPs at a depth of 10 km. The maximum principal stress component of the tectonic background stress tensor is prescribed to -100 bar (positive in extension) and its azimuth is NE7°; the magnitudes of intermediate and minimum principal stresses are predefined to zeros.

The following is the first two lines in the file ./CFS_result/coulomb.out:

lon(deg) lat(deg) opt_str1 opt_dip1 opt_rake1 opt_str2 opt_dip2 opt_rake2 shear stress(bar) normal stress(bar) coulomb stress(bar)

102.000000 30.000000 97.0000 34.0993 90.0000 97.0000 34.0993 90.0000 3.5362670361501071e-02 -2.0418363704668974e-02 2.7195324879633481e-02

'lon (deg) lat(deg)': The longitude and latitude of a gird point, respectively.

'opt_str1 opt_dip1 opt_rake1': the strike angle, dip angle and rake angle of one OOP.

'opt_str2 opt_dip2 opt_rake2': the strike angle, dip angle and rake angle of the other OOP (which are set to be the same as the above line in the program when using a grid-search scheme because only one OOP can be resolved using grid search).

'shear stress(bar) normal stress(bar) coulomb stress(bar)': shear stress, normal stress and Coulomb stress changes resolved on the thrust OOP.

(iii) The normal OOP case

The normal OOP is referred to as the receiver fault whose strike angle is determined from the parameter interval of strike angles [0, 360°] but the dip angle and rake angle are fixed to $\pi/2 - 1/2\tan^{-1}1/\mu'$ and -90°, respectively. The letter μ' is the apparent friction coefficient and in the following case it is set to 0.4. After repeating the steps in case (i) but merely modifying the value in '-N 1' to be '-N 3', that is, running the following command line:

./all.sh -T synthetic_1slipmodel.in -P sampling_grids.in -M 104 -C 1 -F 0.4 -B 0 -S tectonic_stress.in -N 3

Then the following Coulomb stress map resolved on the normal OOPs is generated.

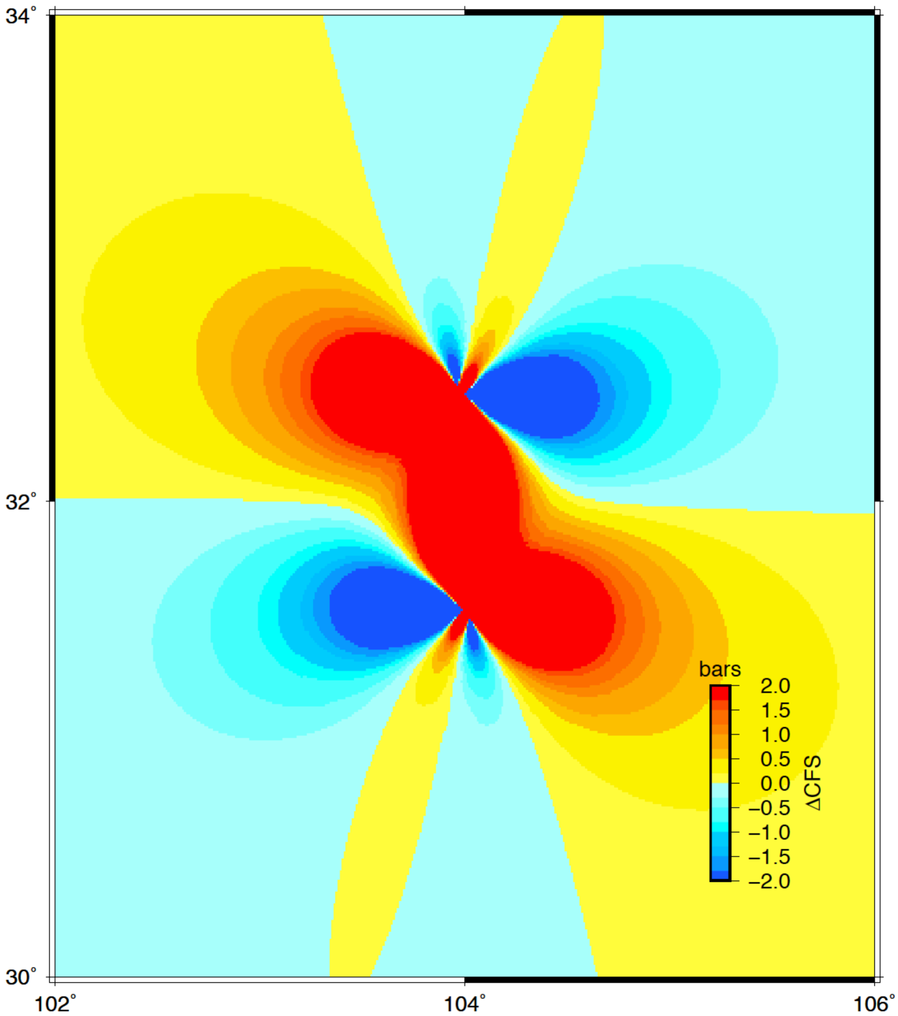

Figure 6. Coseismic Coulomb stress changes induced by the synthetic source fault as

used in Figure 4 and resolved on the normal OOPs at a depth of 10 km. The maximum principal stress component of the tectonic background stress tensor is prescribed to -100 bar (positive in extension) and its azimuth is NE7°; the magnitudes of intermediate and minimum principal stresses are predefined to zeros.
The following are the first two lines in the file ./CFS_result/coulomb.out:
lon(deg) lat(deg) opt_str1 opt_dip1 opt_rake1 opt_str2 opt_dip2 opt_rake2 shear stress(bar) normal stress(bar) coulomb stress(bar)
102.000000 30.000000 7.0000 55.9007 -90.0000 7.0000 55.9007 -90.0000 -1.8737510285851192e-02 -3.3687622080674051e-02 -3.2212559118120813e-02
'lon (deg) lat(deg)': The longitude and latitude of a gird point, respectively.
'opt_str1 opt_dip1 opt_rake1': the strike angle, dip angle and rake angle of one OOP.
'opt_str2 opt_dip2 opt_rake2': the strike angle, dip angle and rake angle of the other OOP (which are set to be the same as the above line when using a grid-search scheme because only one OOP can be resolved using grid search).
'shear stress(bar) normal stress(bar) coulomb stress(bar)': shear stress, normal stress and Coulomb stress changes resolved on the normal OOP.

(iv) The 3D OOP case

The 3D OOP is referred to as the optimal receiver fault whose strike angle, dip angle and rake angle are determined from the complete parameter space of [0, 360°] × [0, 90°] × [0, 360°] under the condition that the Coulomb stress change resolved on the receiver fault is at the maximum. After repeating the steps in case (i) but merely modifying the value in '-N 1' to be '-N 4', that is, running the following command line:

./all.sh -T synthetic_1slipmodel.in -P sampling_grids.in -M 104 -C 1 -F 0.4 -B 0 -S tectonic_stress.in -N 4

Then the following Coulomb stress map resolved on the complete 3D OOPs is generated.

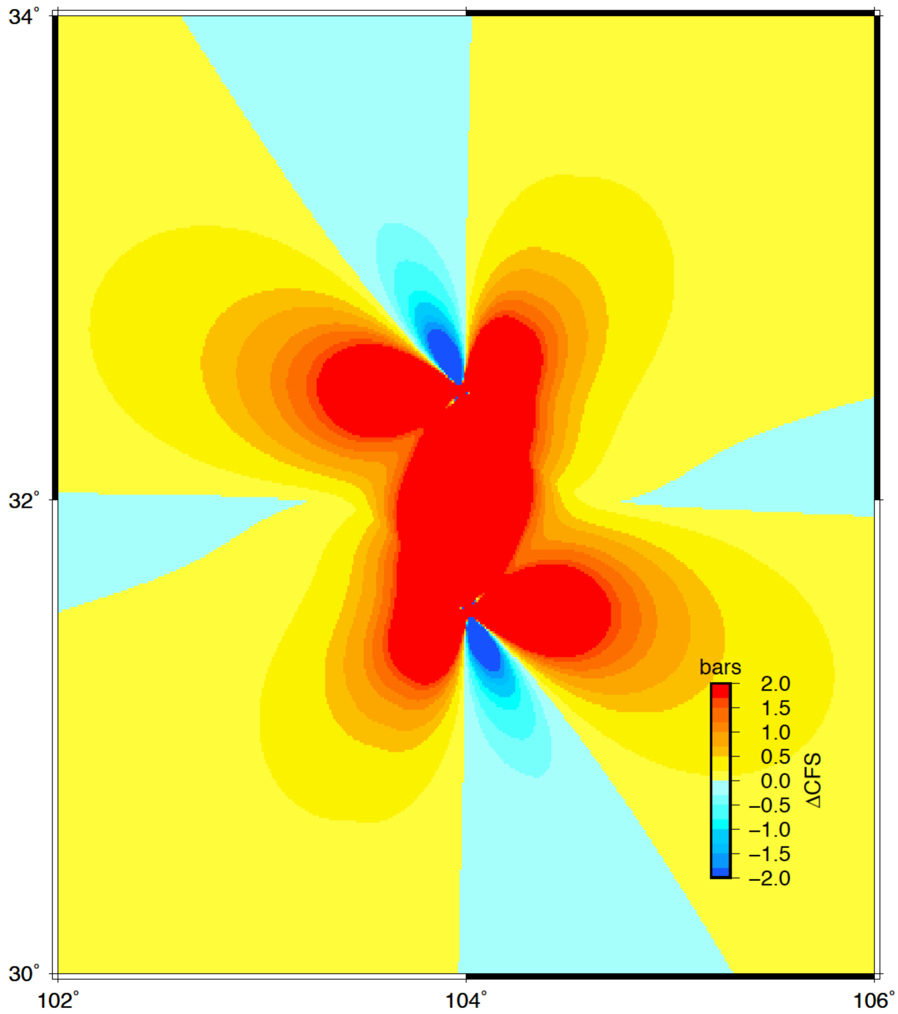

Figure 7. Coseismic Coulomb stress changes induced by the synthetic source fault as used in Figure 4 and resolved on complete 3D OOPs at a depth of 10 km. The maximum principal stress component of the tectonic background stress tensor is prescribed to -100 bar (positive in extension) and its azimuth is NE7°; the magnitudes of intermediate and minimum principal stresses are predefined to zeros.

The following is the first two lines in the file ./CFS_result/coulomb.out:

lon(deg) lat(deg) opt_str1 opt_dip1 opt_rake1 opt_str2 opt_dip2 opt_rake2 shear stress(bar) normal stress(bar) coulomb stress(bar)

102.000000 30.000000 269.6206 34.4231 81.0441 104.4325 34.4295 98.9545 3.7099924024657192e-02 -2.4091463106967199e-02 2.7463338781870312e-02

'lon (deg) lat(deg)': The longitude and latitude of a gird point, respectively.

'opt_str1 opt_dip1 opt_rake1': the strike angle, dip angle and rake angle of one OOP.

'opt_str2 opt_dip2 opt_rake2': the strike angle, dip angle and rake angle of the other OOP.

'shear stress(bar) normal stress(bar) coulomb stress(bar)': shear stress, normal stress and Coulomb stress changes resolved on 3D OOPs.

(v) A constrained OOP case: the 2D thrust OOPs

The constrained 2D thrust OOP is referred to as the receiver fault whose strike angle and dip angle are resolved using grid search in the parameter space [0, 360°] × [0, 90°] but its rake angle is fixed to 90°. After repeating the steps in case (i) but modifying the value in '-N 1' to '-N 5' and adding the ranges of receiver faults as well as the number of dividing the range of strike angles [0, 360], that is, running the command line:

./all.sh -T synthetic_1slipmodel.in -P sampling_grids.in -M 104 -C 1 -F 0.4 -B 0 -S tectonic_stress.in -N 5 0 360 0 90 90 90 36

(Note that the number of equal fractions for the range of strike angles (here it is the number 36) should not be too large. Otherwise, it is much more burdensome to search the (inaccurate) optimal angles of the receiver faults).

Then the following Coulomb stress map resolved on the constrained 2D OOPs is generated.

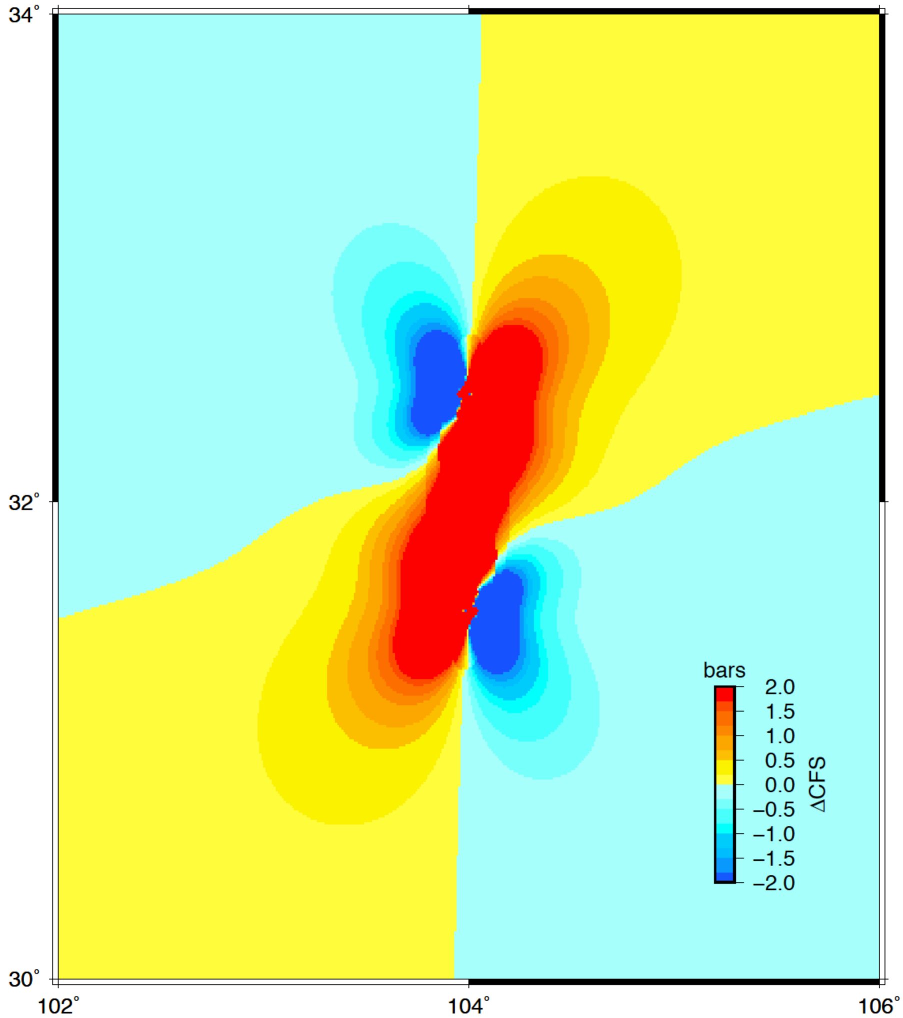

Figure 8. Coseismic Coulomb stress changes induced by the synthetic source fault as used in Figures 4 and resolved on constrained 2D thrust OOPs at a depth of 10 km. The maximum principal stress component of the tectonic background stress tensor is prescribed to -100 bar (positive in extension) and its azimuth is NE7°; the magnitudes of the intermediate and minimum principal stresses are predefined to zeros.

The following is the first two lines in the file ./CFS_result/coulomb.out:

lon(deg) lat(deg) opt_str1 opt_dip1 opt_rake1 shear stress(bar) normal stress(bar) coulomb stress(bar)

102.000000 30.000000 100.000000 35.000000 90.000000 0.381935E-01 -0.229530E-01 0.290124E-01

'lon (deg) lat(deg)': The longitude and latitude of a gird point, respectively.

'opt_str1 opt_dip1 opt_rake1': the strike angle, dip angle and rake angle of constrained 2D thrust OOP (only one OOP can be resolved using grid search).

'shear stress(bar) normal stress(bar) coulomb stress(bar)': shear stress, normal stress and Coulomb stress changes resolved on constrained 2D thrust OOPs.

(vi) A constrained OOP case: the 2D normal OOPs

The 2D normal OOP is referred to as optimal receiver faults whose strike angle and dip angle are resolved using grid search in the parameter space [0, 360°] × [0, 90°] but their rake angles are fixed to -90°. After repeating the steps in case (i) but modifying the value in '-N 1' to be '-N 5' and the ranges of receiver faults, that is, after running the following command line:

./all.sh -T synthetic_1slipmodel.in -P sampling_grids.in -M 104 -C 1 -F 0.4 -B 0 -S tectonic_stress.in -N 5 0 360 10 90 -90 -90 36

Then the following Coulomb stress map resolved on the constrained 2D normal OOPs is generated.

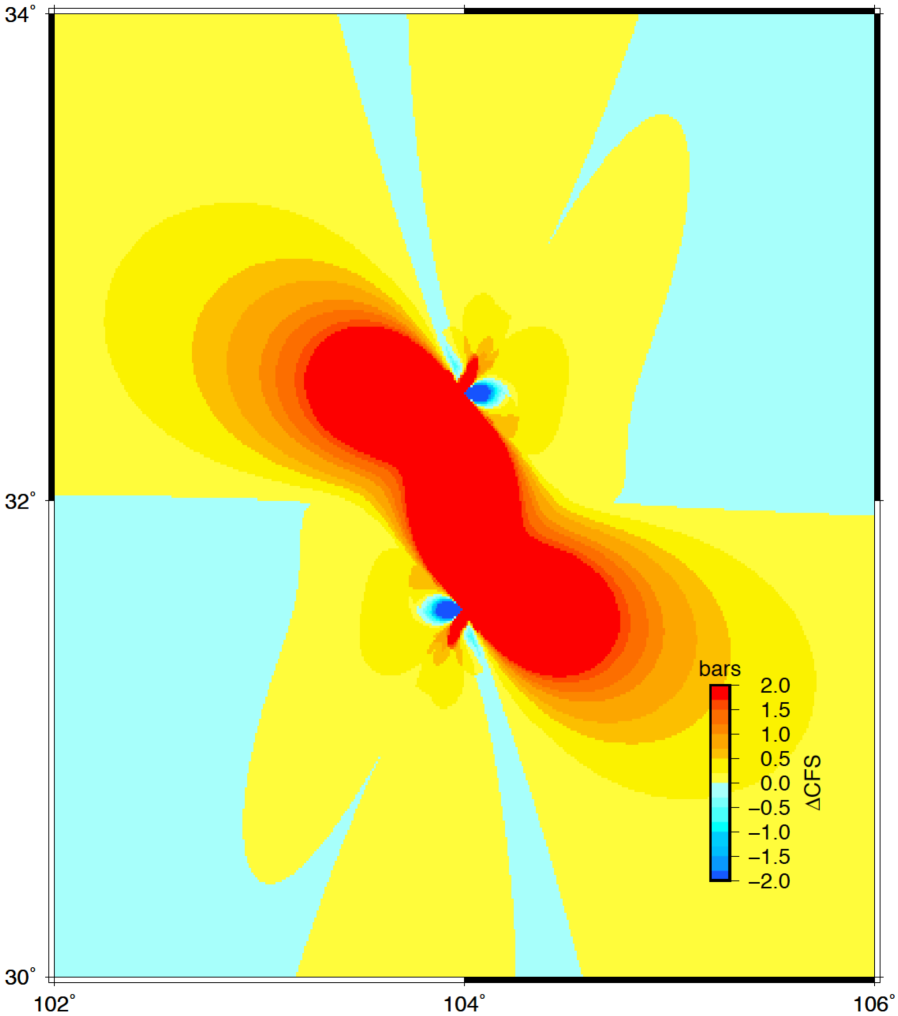

Figure 9. Coseismic Coulomb stress changes induced by the synthetic source fault as used in Figures 4 and resolved on constrained 2D normal OOPs at a depth of 10 km. The maximum principal stress component of the tectonic background stress tensor is prescribed to -100 bar (positive in extension) and its azimuth is NE7°; the magnitudes of the intermediate and minimum principal stresses are predefined to zeros.

The following is the first two lines in the file ./CFS_result/coulomb.out:

lon(deg) lat(deg) opt_str1 opt_dip1 opt_rake1 shear stress(bar) normal stress(bar) coulomb stress(bar)

102.000000 30.000000 190.000000 10.000000 -90.000000 -0.3247543577806214E-02 -0.2381956436683797E-03 -0.3342821835273566E-02

'lon (deg) lat(deg)': The longitude and latitude of a gird point, respectively.

'opt_str1 opt_dip1 opt_rake1': the strike angle, dip angle and rake angle of constrained 2D normal OOP (only one OOP can be resolved using grid search).

'shear stress(bar) normal stress(bar) coulomb stress(bar)': shear stress, normal stress and Coulomb stress changes resolved on constrained 2D normal OOPs.