User Manual SHERIFS

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1 Introduction

The SHERIFS program is a code first developed in the framework of the PhD thesis of Thomas Chartier under the supervision of Oona Scotti (IRSN) and Hélène lyon-Caen (ENS). Since version 1.3, developments of the code have been realized at GEM. Seismic Hazard and Earthquake Rates In Fault Systems (SHERIFS) is a computer code written in python that allows computing earthquake rates on faults given a geometry of a fault system and of the background, a list of potential earthquake ruptures and specified rules to set the moment rate target for the fault system. The underlying approach used in the code is to first estimate the moment rate available for each fault and then to apply a set of rules that allow the slip rate of each fault to be consumed in either single or multi-fault rupture scenarios (FtF) allowed in the model depending on the picked magnitude until their slip-rate budget is exhausted.

Updates to this manual are available at: https://github.com/tomchartier/SHERIFS/

2 Previous versions

The first version of the code was distributed to the participants of the SHERIFS training (IRSN, Paris, France in December 2017). The present Version 1.1 of SHERIFS is published under a GNU Affero Global Public license together with a publication explaining the main features of SHERIFS (Chartier et al, submitted). The initial version of the code was used to model the fault system of the West Corinth rift published in NHESS special issue [1] (Chartier et al 2017). The code has evolved since. The following are the main aspects that have been implemented after the publication:

- The code now allows considering background seismicity. The user needs to define a zone surrounding the fault system.
- There is a new option in the code that allows correlating the sampling of the slip-rate on neighboring faults. In this way the slip rate budget of two faults that break together in many rupture scenarios will be sampled in the same way. If one of these faults is sampled in the upper part of the slip-rate distribution, it is admissible that the neighboring fault that breaks very often with this fault is similarly

in its upper part of the distribution. This option can be turned on or off.

- The code allows to define magnitude-frequency distribution MFD that deviate from the classical Gutenberg-Richter assumption (e.g. characteristic distribution, Youngs and Coppersmith 1985)
- A modified version of the Youngs and Coppersmith equation has been implemented.

New in version 1.1 (since 2019 article):

- More text files are generated during the Visualization to allow the users to generate more easily their own figures.
- For advanced users, in Sampling_analysis.py, comparison between the model and the data are automatically generated. See code for more details.

New in version 1.3 (2020 developments):

- Greatly improved computational speeds by saving intermediate results that are shared by different branches of the logic tree.
- SHERIFS now supports Geojson as input which allows for compatibility with the Global fault database and the output results coming from Oiler (GEM products).
- An automatic calculation of the possible rupture in a fault system according to the distance between faults.
- A general clean up and reorganisation of the libraries.
- The graphical user interface is no longer supported, running using Spyder is still possible but the command line is now preferred

3 Installing SHERIFS Version 1.3

for now, we suggest to download from Github. Basemap is not needed anymore a required library for the figures. In the future, SHERIFS will start using GMT instead. In the meanwhile, SHERIFS relies on the use of geojson files and QGIS.

The current version of SHERIFS needs to be run using python 3.6 or more

- if when running, python doesn't find a module, you can install it byt running in the command line: pip install name_of_the_module or conda install name_of_the_module (if you are a anaconda user)

- for any questions or bugs you cannot solve, please use the google group : `https://groups.google.com/forum/#!forum/sherifs` . If not already asked and answered, your question will be answered shortly.

4 Running SHERIFS Version 1.3

The SHERIFS code allows end-users to build the fault model with complex multifault ruptures. The files structure, the logic tree structure and the input files can be easily modified for a re-run if different parameters need to be tested. The code is written to build Openquake-compatible input files (OpenQuake V3.12). The user of SHERIFS should consult Openquake for further details about the hazard computation.

Flow chart

To run SHERIFS from the command line

Make sure you are in the folder containing SHERIFS.

Run :

To automatically cut the long faults into sections and generate the possible multifault ruptures:

python 0_build_ruptures.py path_to_sherifs_in.toml

To run calculate the earthquake rate on the faults :

python 1_SHERIFS.py path_to_sherifs_in.toml

4.1 The SHERIFS input parameter file

4.2 sherifs.in

This file is separated in several sections.

4.2.1 pre

File_Oiler = "data/Example/faults_data.geojson" File_out = "data/Example/sections.geojson"

If File_Oiler and File_out are used, the code will cut the faults in File_Oiler, create the section file File_out and generate the ruptures.

If you already have the faults cut into sections, instead of inputting File_Oiler and File_out, simply input the File_sections path.

File_sections = """data/Example/sections.geojson"""

This file is necessary to indicate the Mmax in each area of the model. File_Mmax_areas = "data/Example/zone_Mmax.geojson"

Indicate the model and set names. Model_name = "Example" Set_Name = "set_1"

Indicate the rupture meshing that you will use in openquake (not critical if you are not planning to run openquake) rupture_mesh_spacing = 2.0

Set the maximal jump distance between two faults jump_dist = 10.0

Apply a reduction of slip rate for all the faults in the model (between 0 and 1) apply_sr_reduction = 0.0

The File_Mu is only used if you which to create the sections from the faults and set the shear modulus value for some faults in some specific areas. File_Mu = "data/Example/zone_Mu.geojson"

4.2.2 main

Main input files for SHERIFS

Set the input type for the faults between geojson or txtsherifs. The geojson format is strongly recommended. For older models that need conversion, a tool for converting the old format in the new geojson one is available. fault_input_type = "geojson"

if using txt file a la SHERIFS (not supported for the new features) File_geom = "path/to/file" File_prop = "path/to/file"

if using geojson file (recommended) faults_file = "data/Example/sections.geojson"

The rupture file contains the list of the FtF ruptures in the model rupture_file = "input/Example/ruptures.txt"

Logic Tree file LT_file = ”input/Example/LT.toml”

Optional if you want to set specific b value for some area of the model. local_MFD_file = ”data/Example/mfd_area.geojson”

4.2.3 main.background

There are three options for the background seismicity : smooth, zone, and none smooth requires a smoothing seismicity model in the openquake format, zone will create an area source with uniform seismicity around the faults and none doesn't include any background seimicity.

option_bg = ”zone”

File_bg contains the geometry of the background, if zone is used, that's the geometry of the rea source, is smooth is used, the earthquake rates for the points included in this zone will be modified to fit the mfd of the background calculated by SHERIFS. File_bg = ”data/Example/bg.geojson”

file_prop_bg is only used when the zone option is chosen. It contains the parameters necessary for defining a area source in openquake. file_prop_bg = ”data/Example/Background_properties.txt”

With option zone, possibility to use a host model. In this case, the host model will be cut to fit the area source and the background in it. use_host_model = ”False” host_model_file = ”_.xml”

If smooth is used, you need to specify the smoothing model xml. smoothing_xml = ”input/Example/bg”

If include all faults is true, include faults even outside the background. This option can be useful to include small faults laying away from the main system. include_all_faults = ”True”

4.2.4 main.parameters

Contains a lot of parameters used in SHERIFS, only the main ones are described here. Please refer to the toml example file for the full description of all the parameters.

nb_sample explores random sampling on the slip-rate uncertainty and the uncertainty within the scalling law. sample 1 is always the mean parameters.

dsr if the slip rate increment size (mm/yr), we recommend using at least a thousandth of the slip-rate of the faults in the model. dsr = 0.0001

Mmin is the minimal magnitude to be considered. Mmin = 5.0

Random_seed is the seed for the random samplings.

SR_correl = "True" meeans that if the slip rate is sampled in the distribution of uncertainty, the faults that rupture together are correlated when sampled. (e.g. all high slip rate for one sample and all low sample for another)

Mmax_range sets strong boundaries for the acceptable models. if a model Mmax is not included in this range, the sampling of the scaling law parameters is redone. Mmax_range = [0.0, 10.0]

explo_time is the time frame for calculating the rate, we suggest to use 1 year and calculate the hazard of 1 year also. explo_time = 1

aspect_ratio sets the aspect ratio of the ruptures, we suggest to use 1. aspect_ratio = 1.0

4.2.5 figures

This section allows activating the plotting of figures. print = "True"

model_mfd gets the mfd for the whole model, the one for the faults only, and the one for the background only model_mfd = "True"

mfd_cat is the mfd calculated for the whole model area from the catalog it should be the cumulative MFD. In this case, it is a 2D list with the bins of magnitude and the rate in each bin. mfd_cat = "False" mfd_cat = [[4,5,6],[1.0,0.1,0.01]]

part_mfd gets the same things as model mfd but for parts of the model defined in the parts_gjson geojson file. If will extract the mfd from the model and compare it the catalog rate if it is included in the geojson file. part_mfd = "True" parts_gjson = "data/Example/mfd_area.geojson"

specific_section gets the participation rate (rate of all ruptures involvingthis section) for a set of predefined sections. This can be useful for comparing with paleoseismicity rates. sections is defined as a list of str. This is not tested yet. specific_section = "False" sections = ["1", "2"]

4.2.6 OQ

The parameters here are the same as the ones described in the openquake manual. They are not used in SHERIFS so we refer to the OQ engine manual for the description.

4.3 Fault information geojson file

The geometry is described in a LineString describing the trace at the surface. SHERIFS will describe a kite fault surface between the min and max seismogenic depth.

Description of the parameters:

si = name of the section, can be a string of an integer

model = name of the model the fault belongs to **fault name = name** of the fault (one fault name should not contain the name of another fault) **sr** = slip-rate in mm/yr in the direction of slip **e_sr** = error on the slip-rate in mm/yr in the direction of slip

dip = dip of the fault

oriented = orientation of the dip (important for the "right hand rule" of OpenQuake)

rake = value of the rake for this section

up_s_d = upper limit of the fault, (km) following the OpenQuake definition

lo_s_d = lower limit of the fault, (km) following the OpenQuake definition

Domain = seismotectonic model used as a key in OpenQuake to attribute to each seismogenic source the correct GMPE.

shear_modulus = Shear modulus applied to this fault (in GPa, typical value 30 GPa)

Two parameters nb_rup and max_rup_length are also included in the file by the reprocessing tools but optional and are not directly used within SHERIFS.

4.4 Background geojson file

A geojson with a MultiPolygon describes the background geometry. Several backgrounds can be included in this file, the ones chosen for a given model is identified by the property "model" of the feature. It is important that the model property correspond with the one used in the logic tree file and the fault property file.

4.5 Mmax geojson file - optional

This file is used in the precomputational phase to define the maximum magnitude or length that rupture can reach in different regions described by polygons.If you want to automatically generate the ruptures, you need to define this file. The file contains geometries of polygons and the maximum rupture length (inkm) and magnitude allowed in the area of the polygon. Any rupture with a larger magnitude or larger length than the one allowed will not be included in the model.

4.6 Shear modulus correction geojson file - optional

This file is used in the precomputational phase to modify the shear modulus of a large number of faults in specific regions.

4.7 Background_geometry.txt

```
Model_used  lon lat
Example_Model   21.77   38.450
Example_Model   22.018  38.400
Example_Model   22.330  38.300
Example_Model   22.330  38.163
Example_Model   22.018  38.210
Example_Model   21.77   38.311
```

This file contains the description of the geometry of the background zone.

```
Example_Model   upperSeismoDepth    0.
Example_Model   lowerSeismoDepth    8.
Example_Model   ruptAspectRatio 1.
Example_Model   nodalPlane  0.7 270.    60. -90.
Example_Model   nodalPlane  0.3 90. 60. -90.
Example_Model   hypoDepth   0.2 2.
Example_Model   hypoDepth   0.3 4.
Example_Model   hypoDepth   0.3 6.
Example_Model   hypoDepth   0.2 8.
```

4.8 Background_properties.txt

This file contains the description of the source parameters for the background region used in OpenQuake. The details of this parameters are explained in the OpenQuake manual. New lines can be added if more options need to be in the model.

4.9 LT.toml

This toml files contains a list of hypotheses for each node of the logic tree.

Models = alternative fault models that should be explored. this is useful for exploring uncertainties in the geometries of the faults, for example.

MFD_shape = Hypotheses on the target shape of the MFD. Each hypothesis contains the name of the MFD shape and the needed parameters to constrain it.

Background = List of the background hypotheses to explore. The name needs to correspond to the name in the bg_seismicity.txt file.

scenario_set = List of the scenario sets to explore. This list needs to correspond to the scenarii defined in the rupture.txt files.

Scaling_Laws = List of the scaling laws to use with associated parameters such as the rake dependency and the dimension to use (Area or Length).

4.9.1 bg_seismicity.txt

bg "name of the bg branch"

0.2 0.2 0.3 0.3 0.4 0.6 0.75 0.95 0.999

add new lines for new hypotheses.

This file contains the ratio of earthquakes on the faults for magnitude 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5 and 8.0.

4.10 rutpures.txt

first line	set name$_{o}f_{t}he_{r}upture_{s}et$
next lines, rupture scenarios	F1 F2
	F1 F2 F3
	F1 F2 F3 F5
	F2 F3
	F2 F3 F5
	F3 F5

The first line of this file is the name of the set; the following lines are the possible FtF ruptures in the model. This file can also be modified manually before re-running SHERIFS.py. Filling all the possible FtF rupture of a model with the graphical interface can be a drag, if your model has a lot of possible FtF ruptures, it is much easier to change it afterwards. But as always, be careful when editing manually the files.

Each fault name is separated by a space. No tab and no newline at the end.

4.11 Running SHERIFS

In order to run SHERIFS with the command line, move to the SHERIFS repo and run the following line:

python 1_SHERIFS.py path_to_sherifs_in.txt

... The python code creates OpenQuake input files and many different log files for each branch of the logic tree (including the random sampling of the slip-rates, the Mmax and the b value)....

Console 3/A

```
invalid value encountered in true_divide
  shape_mfd_i = (moment_rate_in_bin)/sum(moment_rate_in_bin)
25%
50%
- target set -
75%
90%
ratio between the target and the shape of the model : 0.99
ratio of NMS : 32
Example2/Example_Model/bg_BG_1/WC1994_A_m/sc_Set_1/bmin_0.9_bmax_1.1/MFD_GR sample : 2
7.736812675802851 21.149464617802565 18.031804789257524
number of dsr to spend : 3253.0
1%
25%
50%
- target set -
75%
90%
ratio between the target and the shape of the model : 0.99
ratio of NMS : 26
Example2/Example_Model/bg_BG_1/WC1994_A_m/sc_Set_1/bmin_0.9_bmax_1.1/MFD_GR sample : 3
7.736812675802851 21.149464617802565 18.031804789257524
number of dsr to spend : 3370.0
1%
25%
50%
- target set -
75%
90%
ratio between the target and the shape of the model : 0.99
ratio of NMS : 22
Example2/Example_Model/bg_BG_1/WC1994_A_m/sc_Set_1/bmin_0.9_bmax_1.1/MFD_GR sample : 4
7.736812675802851 21.149464617802565 18.031804789257524
number of dsr to spend : 3154.0
1%
25%
50%
- target set -
75%
90%
ratio between the target and the shape of the model : 0.99
ratio of NMS : 32
Example2/Example_Model/bg_BG_1/WC1994_A_m/sc_Set_1/bmin_0.9_bmax_1.1/MFD_GR sample : 5
7.736812675802851 21.149464617802565 18.031804789257524
number of dsr to spend : 3287.0
1%
25%
50%
- target set -
-target filled-
75%
90%
ratio between the target and the shape of the model : 0.99
ratio of NMS : 33
```

For each model, the name of the branch and the sample number are written. The number of dsr (slip-rate increment) to spend is displayed. The user can follow the advancement of the calculations since the code displays when 1%,25%,50%,73% and 90% of the slip-rate budget is spent. When the rate of the three largest bins of magnitude is limited, the target is set and the code writes 'target set'. At the end of the calculation for one branch, the code writes the ratio between the target shape and the actual shape. 1.0 is a perfect score. If the ratio is not good enough given the error accepted (indicated by the user in the 1_SHERIFS.py file), the model is ran another time with a smaller dsr.

References

[1] T. Chartier, O. Scotti, H. Lyon-Caen, and A. Boiselet. Methodology for earthquake rupture rate estimates of fault networks: example for the western corinth rift, greece. *Natural Hazards and Earth System Sciences*, 17(10):1857–1869, 2017.