Documentation for installation and running FQSHA software

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Abstract

This documentation provides a comprehensive guide to the installation process and a step-by-step example demonstrating the capabilities and workflows available in the FQSHA software. The guide is intended to help users efficiently set up the software and run a sample to showcase its functionality.

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1. Installation

To install the FQSHA software, follow the steps outlined below. Start by downloading the package from the official GitHub repository: https://github.com/GeoSignalAnalysis/FQSHA (Fig. 1). The installation process is explained in detail in the README.md file, which can be found within the repository. The main steps for installation are as follows:

- Download the package and extract the contents of the Zip file.
- Open a terminal window in the directory where the Zip file was extracted, and run the following commands:

  ```
  conda env create -f environment.yml
  conda activate FQSHA
  ```

  This will create a new conda environment named "FQSHA" and install the required packages.
- Once the environment is set up, execute the following commands to complete the installation:

  ```
  conda activate FQSHA
  chmod +x post_install.sh
  ./post_install.sh
  ```

- After running the post-installation script, FQSHA is fully installed and ready for use!

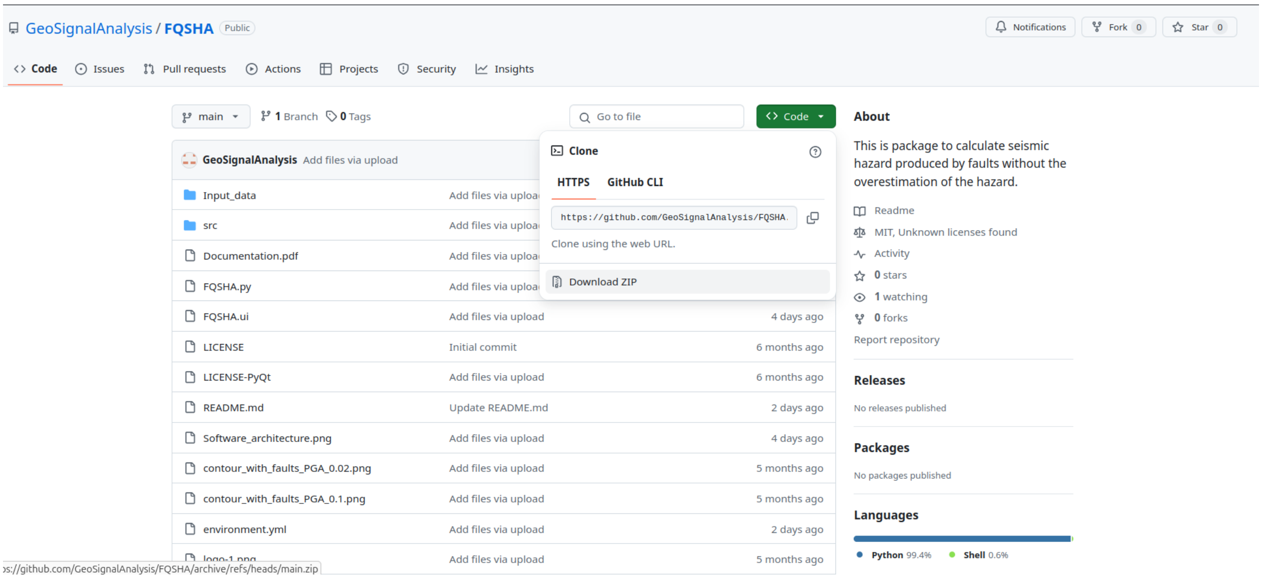


Figure 1: FQSHA GitHub page. The software is publicly available in this page.

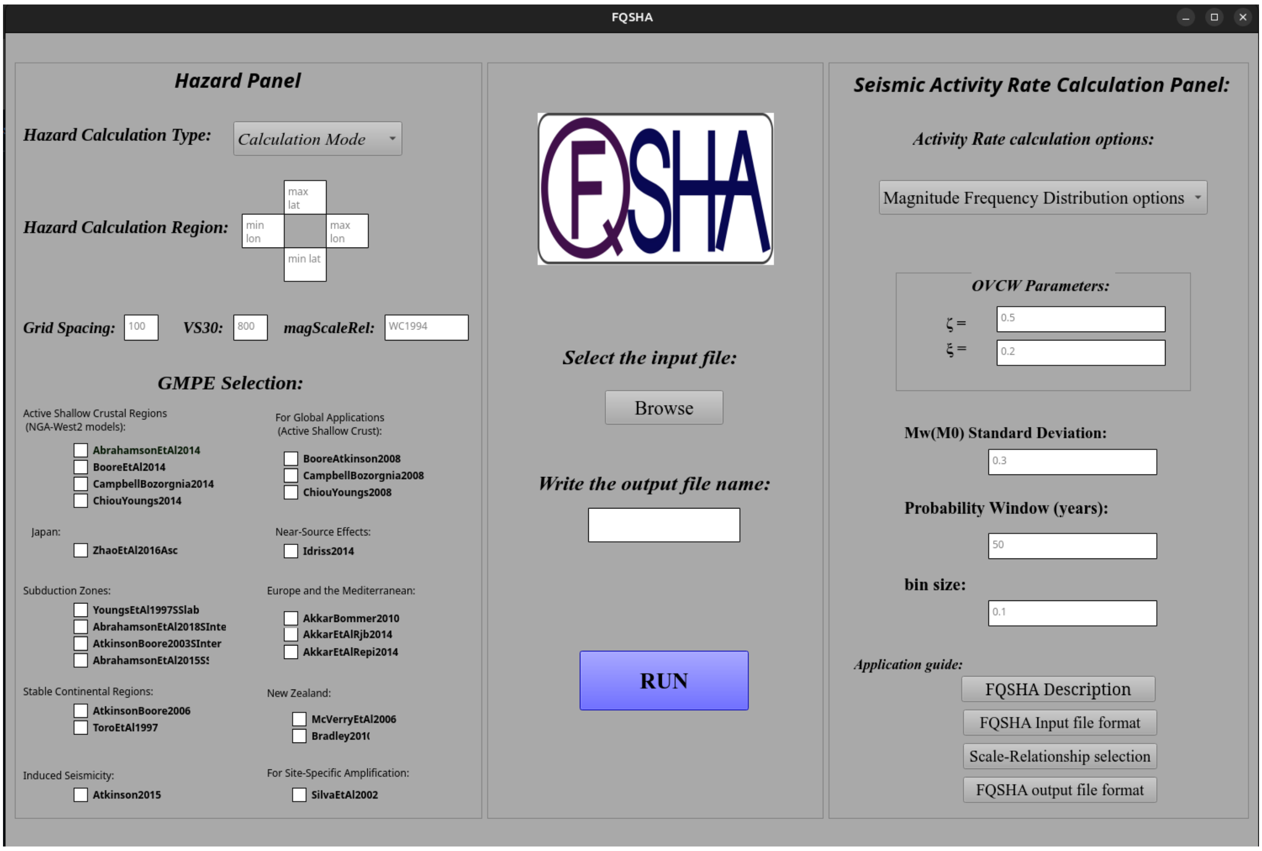


Figure 2: FQSHA GitHub page. The software is publicly available on this page.

2. **Running with the sample input file:**

You can use any Integrated Development Environment (IDE) to run this package, or you can run it directly from the terminal by executing the following command:

```
python ./FQSHA.py
```

The GUI window will appear (Fig. 2). The left panel is for entering the parameters of Seismic Activity Rates (SAR) calculation for the input faults based on the theory introduced by [1]. The default inputs are pre-filled, and if any adaptations are needed, they can be made through the GUI. The right panel is for entering the hazard calculation parameters.
As a sample running case, the steps to run the case study from the paper are presented here. First, use the browse button (Fig. 3) to select the *input_data* folder and insert the file *Zagros_faults.json*. Then, from the opened window, the input data can be selected. A name for the output file can also be modified. However, if a name is not defined, the software will automatically create an output directory to save the results.

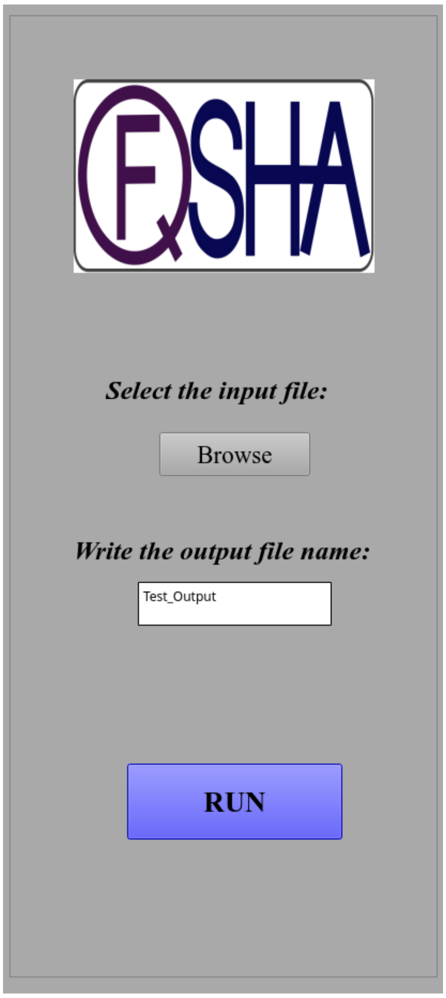


Figure 3: Left panel.

In the left panel (Fig. 4a), the hazard calculation options are available. The hazard calculation type (classical or event-based) can be selected. Based on the selection, the `job.ini` file will be created. Additionally, the hazard calculation region, which covers the input faults, is defined to apply the gridding and hazard calculation. If not defined in the GUI, the software will automatically calculate the hazard calculation region from the extent of the fault traces

in the input data. The grid spacing defines the distance in each axis of the map for gridding and hazard computation.
The shear wave velocity and magnitude scale relationship for hazard calculation must be inserted. Default parameters for these three values are pre-defined, and if the user does not provide them, the defaults will be used. The available magnitude scale relationship options are those applicable by OpenQuake [2], including:

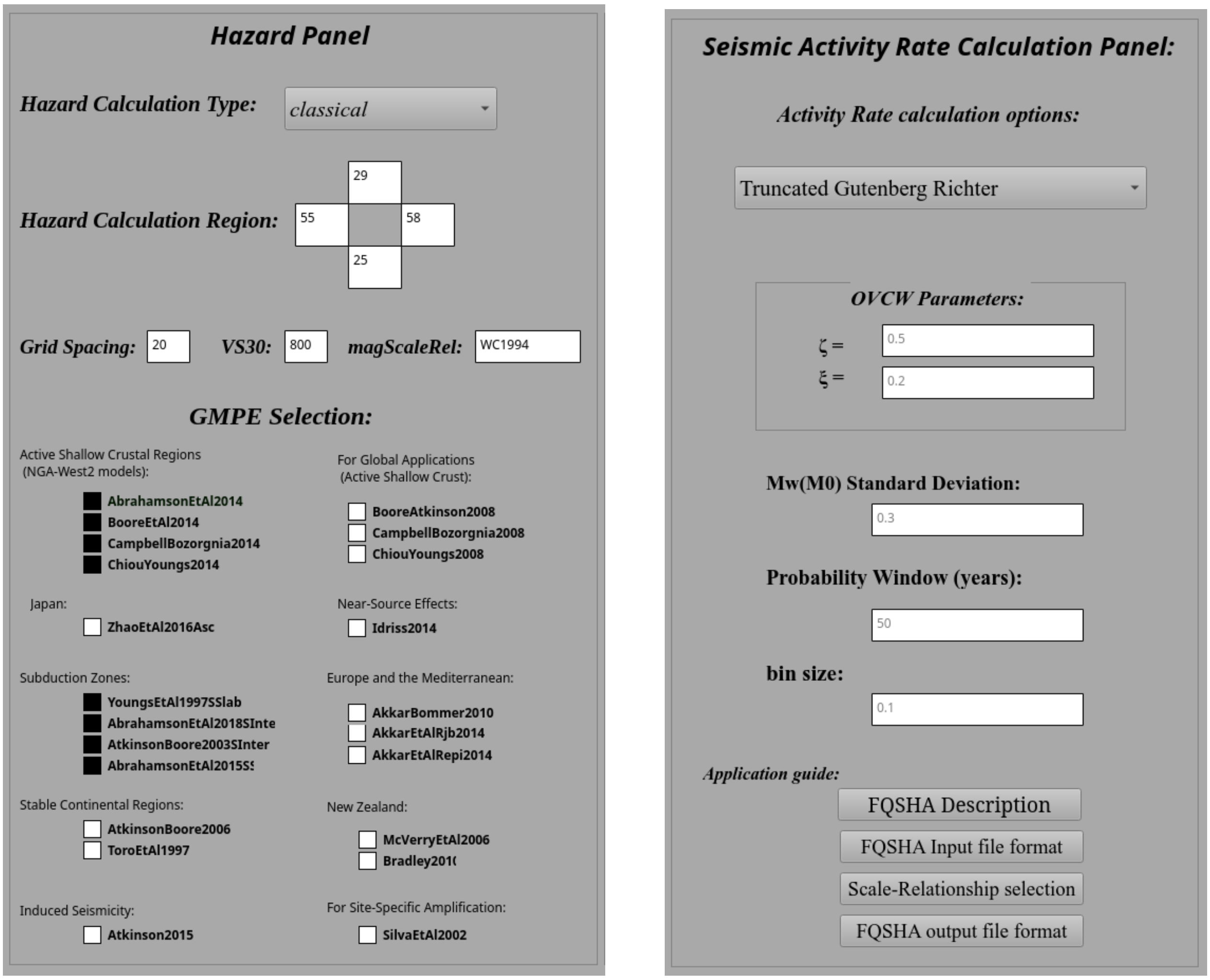
- `magScaleRel = "WC1994"`
- `magScaleRel = "PW1994"`
- `magScaleRel = "HanksBakun2002"`
- `magScaleRel = "CoxKuehni1987"`
- `magScaleRel = "Frankel1996"`
- `magScaleRel = "Scholz2002"`
- `magScaleRel = "SteinBarrientos1985"`
- `magScaleRel = "Geller1996"`
- `magScaleRel = "SavySanchez2001"`

The Ground Motion Prediction Equations (GMPE) options are also available in the GUI. These options are mandatory to select in order to prepare the `gmpe_logic_tree.xml` file.
In the right panel (Fig. 4b), the Magnitude-Frequency Distribution (MFD) options can be selected, and here the Truncated Gutenberg-Richter is chosen. The Optimal Value Computation Workflow (OVCW) parameters are optional variables for applying the Conflation of Probabilities (CoP) methodology in computing M_{max}. According to the methodology, the default parameters are defined, and for this example, we may not need to change them.
M_w represents the moment magnitude, and M_0 represents the Scalar Seismic Moment. The Standard Deviation (SD) (σ) of $M_w(M_0)$ is set to 0.3, which may be adjusted if necessary. The probability window and bin size are parameters for balancing the calculated moment rate over the calculated mean recurrence time by the algorithm. The default values are 50 and 0.1, respectively, and we will not change them for this example.
The `source_model_logic_tree.xml` is created during the SAR calculation process and is saved in the $./FQSHA\_output$ directory to be included in the hazard calculation process.

3. Results and Outputs

After inserting the necessary inputs and running the software, the interim outputs are generated, including:

- Faults' `.XML` files are located in: `./FQSHA/FQSHA_output/Sources`
- `source_model_logic_tree.xml`
- `gmpe_logic_tree.xml`
- `job.ini`



(a) The hazard calculation parameter panel.

(b) The SAR calculation panel.

Figure 4: The panels of FQSHA.

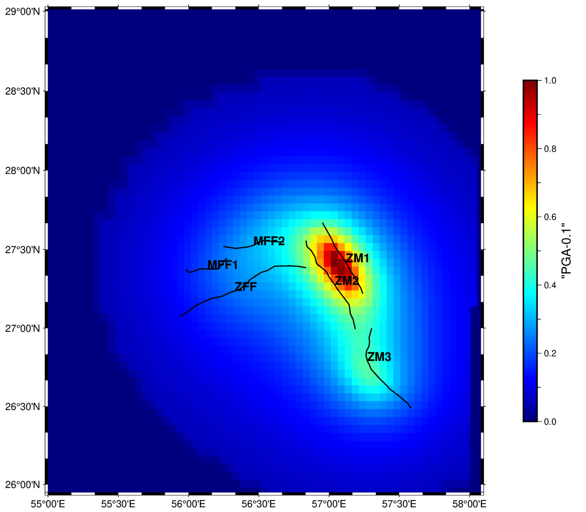
The hazard calculation results in maps with different Probabilities of Exceedance (PoE)s. In this software, we plot two main outputs, including the 10% (Fig. 5a) and 2% PoEs (Fig. 5b). The grid spacing plays a major role in the resultant hazard and affects the resolution. The maps plotted here use a 10-degree grid spacing.

In OpenQuake, the grid spacing parameter defines the distance between calculation points used in the seismic hazard analysis. This parameter, referred to as `region_grid_spacing`, is specified in **degrees** of latitude and longitude.

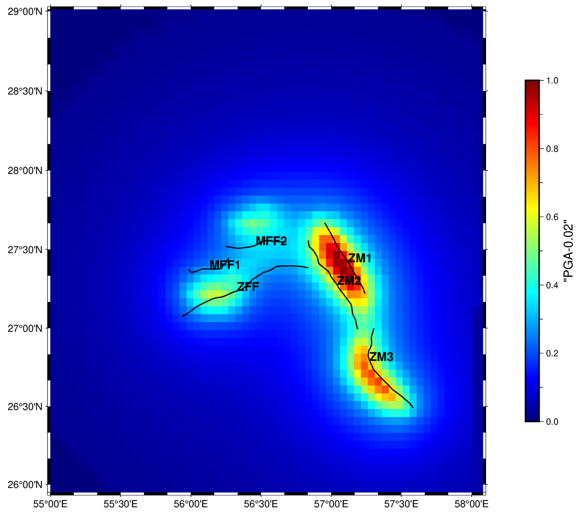
For example, when setting `region_grid_spacing = 10`, this means the grid points are spaced **10 degrees apart**, which corresponds to a distance of approximately **1110 km** (since 1 degree of latitude is roughly 111 km).

However, since the region for the hazard analysis in this study is relatively small (approximately 3° by 2°), a grid spacing of 10 degrees produces only a few points within the region, resulting in a coarse, lower-resolution hazard map. While this larger spacing still provides a valid result, a finer grid spacing (e.g., 0.1 degrees or 0.05 degrees) would provide a more detailed map with higher resolution, particularly useful for local studies where more precise hazard information is needed.

The choice of grid spacing depends on the scale of the study area and the level of detail required in the hazard maps. For smaller regions, finer grid spacings are recommended to ensure a more accurate representation of seismic hazard.



(a) Output hazard map for sample faults with a 10% Probability of Exceedance.



(b) Output hazard map for sample faults with a 2% Probability of Exceedance.

Figure 5: Generated Hazard map by FQSHA.

References

[1] N. Tavakolizadeh, H. Mohammadigheymasi, F. Visini, and N. Pombo, "Faultquake: An open-source python tool for estimating seismic activity rates in faults," *Computers & Geosciences*, vol. 191, p. 105659, 2024.

[2] M. Pagani, D. Monelli, G. Weatherill, L. Danciu, H. Crowley, V. Silva, P. Henshaw, L. Butler, M. Nastasi, L. Panzeri, M. Simionato, and D. Vigano, "The openquake engine: An open hazard (and risk) software for the global earthquake model," *Seismological Research Letters*, vol. 85, no. 3, pp. 692–702, 2014.