

SERA Hazard Analysis Toolbox

Application: SHAPE_ver1 – Seismic Hazard Parameters Evaluation

Current Version: ver1.2, last updated 04/2020, compatible with Matlab version 2017b or later, with 'Statistics and Machine Learning' and 'Image Processing' Toolboxes, installed

Please cite any use of the Software as:

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SHAPE_ver1 DESCRIPTION

OVERVIEW:

“SHAPE_ver1” Application performs time-dependent Seismic Hazard Analysis (SHA), taking into account the activity rate and the magnitude distribution of seismicity for selected time windows (Kijko et al., 2001; Lasocki and Orlecka-Sikora, 2008; Lasocki, 2017; Leptokaropoulos et al., 2017). The hazard parameters estimated are:

- 1) The Mean Return Period (MRP) of a given magnitude, M , which is defined as the average elapsed time between the occurrence of consecutive events of M and
- 2) The Exceedance Probability (EPR) of a given magnitude, M , within a given time period of length, T , which is defined as the probability of an earthquake of magnitude greater than or equal to M to occur during T .

These hazard parameters are estimated for different time windows which are constructed upon User's particular specifications. 4 different magnitude distribution models can be chosen:

- **GRU**, for Unbounded Gutenberg-Richter law
- **GRT**, for Upper bounded (truncated) Gutenberg-Richter law
- **NPU**, for Unbounded non-parametric Kernel estimate
- **NPT**, for Upper bounded (truncated) non-parametric Kernel estimate

The input files must be in ASCII format (e.g. *.txt). Please see “Input Data Requirement Specification” section below for details on input Data format.

The application is a standalone version performed within a series of steps which allows a high interactivity level with the User. This version supports a GUI in order to allow the User interactively select the options and parameter values needed for the calculations.

PACKAGE:

The SHAPE_ver1 package includes the following material (Fig. 0):

- **3 Matlab Scripts**
 - **SHAPE_ver1**: This is the main application script that the User must launch to perform the analysis. All the other scripts and functions included into this and the other directories are auxiliary and run within SHAPE_ver1.
 - **Zplo**: This is an auxiliary script called by SHAPE_ver1 to create and save the output figure.
 - **Zsave_output**: This is an auxiliary script called by SHAPE_ver1 to create the and save the output results.

- **6 Directories**
 - **CATALOGS:** Seismic data directory (*see INPUT section below*).
 - **PRODUCTION_DATA:** Production data directory (*see INPUT section below*).
 - **TIME_WINDOWS:** Directory with files to define time windows (*see INPUT section below*).
 - **SSH:** Directory with source size distribution functions and function for calculating seismic hazard parameters, called by SHAPE_ver1.
 - **Filtering:** Directory with functions and scripts called by SHAPE_ver1 for data filtering.
 - **OUTPUTS_SHA:** Directory where the output data, figures and reports will be stored (this is automatically generated after running SHAPE_ver1).
- **1 pdf document** – READ_ME_SHAPE_ver1.pdf (user guide)

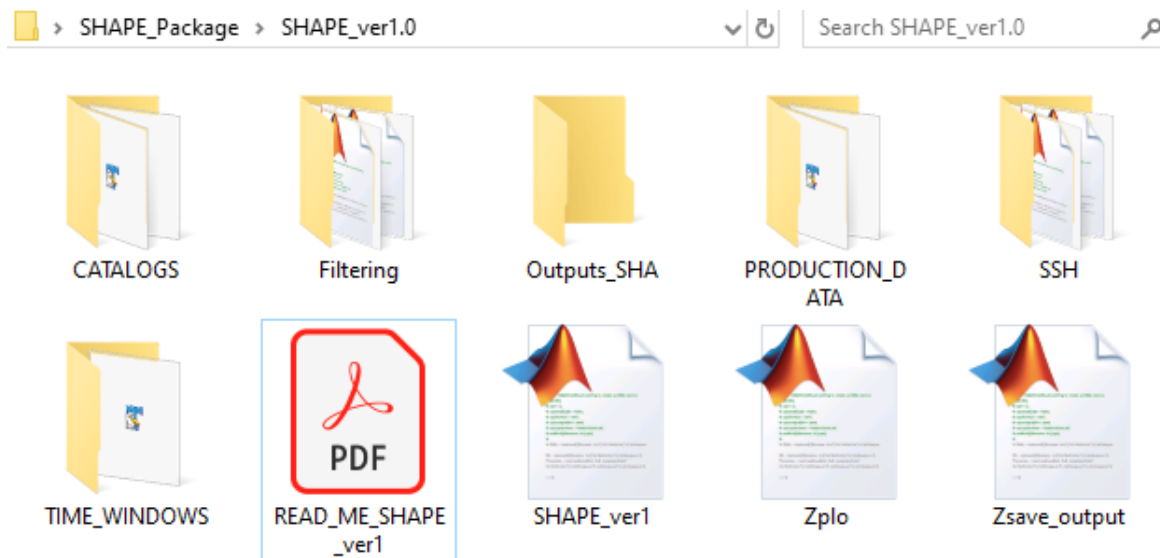


Fig. 0. Material included within SHAPE_ver1

INPUT:

The input files, options and parameter values are set by the User through a GUI in a step-by-step interactive implementation process.

For the application performance 3 Input Directories must be available (one mandatory, two optional). Sample data files must be located in these directories in appropriate format. An Output directory where the results are stored is created as well after running the ‘SHAPE_ver1’ Application:

- **INPUT DIRECTORY – “CATALOGS” [Mandatory]:** This directory must be named after “CATALOGS” and it must contain
 - Seismic catalogs in ASCII format (e.g. “ST2_SEIS_Data.txt”).
 - Files with the description of the Fields of the corresponding seismic catalog, also in ASCII format (e.g. “ST2_SEIS_Fields.txt”)
- **INPUT DIRECTORY – “PRODUCTION_DATA” [Optional]:** This directory must be named after “PRODUCTION_DATA” and must contain
 - Files with production data in ASCII format (e.g. “ST2_PROD_Data.txt”)

- Files with the description of the Fields of the corresponding production data, also in ASCII format (e.g. “ST2_PROD_Fields.txt”)
- INPUT DIRECTORY – “TIME_WINDOWS” [*Optional*]: This directory must be named after “TIME_WINDOWS” and must contain
 - Files with two columns, the first of which corresponds to the time windows starting time and the second column corresponds to the time windows’ ending time. Their format must be matlab time format (e.g. “ST2_test_timewindows.txt”).
- OUTPUT DIRECTORY – “Outputs_SHA”: This is the directory where the output data, figures and reports will be stored (Automatically generated by SHAPE).

INPUT DATA Requirements Specification: There is no difference in Catalog/Production Data format, therefore the DATA and FIELD generic formats are only specified here (See also Figures 1 and 2 below and refer to the sample data included in the package, within the corresponding directories):

✓ **SEISMIC CATALOG/PRODUCTION DATA File:** The **Data** files must be in ASCII format (e.g. ST2_SEIS_Data.txt). The data must be stored in columns, such that each column contains the values of a specified parameter. All records must be in numerical format, no strings are allowed (with the exception of ‘NaN’ values, which are acceptable). The minimum number of columns is 7 - 6 date/time columns plus one magnitude column for catalog data (or production parameter observation for production data). The first 6 columns must correspond to the occurrence time of the seismic events (or production data observation time), such that (see Fig. 1a and Fig. 2a):

Column 1: **Year** (*integer*)

Column 2: **Month** (*integer*)

Column 3: **Day** (*integer*)

Column 4: **Hour** (*integer*)

Column 5: **Minute** (*integer*)

Column 6: **Second** (*double*)

Note that SHAPE_ver1 provides the option of filtering data according to the origin time of the events. There is no upper limit on the number of columns. The rest of the columns may correspond to any other seismic parameter (e.g. depth, a moment tensor component, rms error, fault plane strike etc) – or equivalently, production parameter (e.g. water level, volume of extracted gas etc). Only magnitude and time columns are considered for the analysis. However, data filtering according to epicentral location (in either geographical or Cartesian coordinates) and depth distribution of the events is possible. The Production Data parameters are only used to facilitate visual inspection of input parameters and results and they do not take part in the calculations.

✓ **SEISMIC CATALOG/PRODUCTION FIELDS File:** The **Fields** files must be stored separately from the **Data**, in ASCII format as well (e.g. ST2_SEIS_Fields.txt). The specified Fields must be typed in a row, separated by space intervals (one or more spaces). Note that no commas, tabs or any other delimiters are allowed (see Fig. 1b and Fig. 2b). The first Field must be ‘Time’ (for Catalog) or ‘Date’ (for Production) and it corresponds to the 6 first columns of the Data file (see “*seismic catalog/production data file*” above). The remaining number of the specified fields must be equal to the number of the remaining columns in the Data file. For example, if the **Data** file has 10 columns (6 for time and 4 for other parameters, including at least

one magnitude), the *Fields* file must have 5 columns (the first to be ‘Time’ and the rest corresponding to each one of the 4 remaining parameters, respectively).

IMPORTANT NOTE: be aware that the last character of the string line in the text file CANNOT be space or line! Make sure that the file ends with a character (letter or number).

Magnitude Fields: The Application provides the option of filtering data for Completeness Magnitude. In doing so, one or more Magnitude fields must be identified. SHAPE_ver1 supports the following names for Magnitude Scales (case sensitive): ‘ML’, ‘Mw’, ‘Ms’, ‘mb’, ‘Md’ and ‘M’. If the User wishes to specify a different magnitude scale (other than the first 5 stated above), he/she may name it after ‘M’ (general case). Please make sure that the corresponding Magnitude column fields have one of the aforementioned names.

a TG_SEIS_Data.txt ×

2007	12	10	10	27	50.00	2.261	514922	4298613	2218	14	44	97	38.836193000000	122.828070000000	2.2
2007	12	14	2	13	55.00	2.270	514865	4298893	2546	223	37	44	38.838719000000	122.828722000000	2.5
2007	12	16	23	42	43.00	1.712	514874	4298841	2382	153	82	164	38.838247000000	122.828613000000	2.3
2007	12	19	12	17	16.00	2.414	514774	4298429	1703	218	53	56	38.834539000000	122.829776000000	1.7
2007	12	31	11	54	14.00	1.631	514800	4298819	2055	343	27	135	38.838054000000	122.829477000000	2.0
2008	1	1	11	19	40.00	1.901	514912	4298900	2249	353	35	61	38.838779000000	122.828174000000	2.2
2008	1	7	11	6	43.00	2.486	514831	4299037	2711	262	32	83	38.840011000000	122.829105000000	2.7
2008	1	20	21	23	2.00	1.568	514895	4298839	2373	115	82	177	38.838231000000	122.828377000000	2.3
2008	1	21	10	53	45.00	1.802	514883	4298898	2258	74	39	83	38.838759000000	122.828519000000	2.2
2008	2	2	8	47	2.00	1.937	514931	4298790	2625	289	51	124	38.837786000000	122.827964000000	2.6
2008	2	12	18	56	9.00	1.478	515115	4299119	2102	140	71	148	38.840750000000	122.825832000000	2.1
2008	2	12	19	6	14.00	2.162	515146	4299128	2125	86	42	111	38.840830000000	122.825484000000	2.1
2008	2	18	23	24	0.00	1.928	514852	4299100	2540	55	34	79	38.840585000000	122.828865000000	2.5
2008	2	22	6	14	24.00	1.568	514955	4299102	2057	173	47	83	38.840602000000	122.827682000000	2.0
2008	2	22	14	41	16.00	1.919	515154	4299101	2556	9	42	93	38.840590000000	122.825391000000	2.5
2008	3	3	23	12	28.00	2.261	514840	4298968	2511	354	28	144	38.839395000000	122.829003000000	2.5

b TG_SEIS_Fields.txt ×

Time	Mw	X	Y	Depth	StrikeA	DipA	RakeA	Lat	Long	Elevation	MO	R	delta	sigma
------	----	---	---	-------	---------	------	-------	-----	------	-----------	----	---	-------	-------

Fig. 1. Example of a seismic data file (a) and the corresponding seismic data fields file (b).

a ST2_PROD_Data.txt ×

2013	08	23	00	00	00	139.89
2013	08	24	00	00	00	140.04
2013	08	25	00	00	00	140.32
2013	08	26	00	00	00	140.44
2013	08	27	00	00	00	140.34
2013	08	28	00	00	00	140.29
2013	08	29	00	00	00	140.42
2013	08	30	00	00	00	140.34
2013	08	31	00	00	00	140.21
2013	09	01	00	00	00	140.2
2013	09	02	00	00	00	140.3
2013	09	03	00	00	00	140.22
2013	09	04	00	00	00	140.16

b ST2_PROD_Fields.txt ×

Date	Water_Level
------	-------------

Fig. 2. Example of a production data file (a) and the corresponding production data fields file (b).

Epicentral Coordinates Fields: SHAPE_ver1 also provides the option of filtering data according to the epicentral location of the events. The program supports both geographical as well as Cartesian coordinates (in any local system and unit). The corresponding Fields for Latitude and Longitude must be specified in the Field File as “Lat” and “Long”, respectively. Equivalently, the corresponding Fields for the horizontal components of the Cartesian coordinate system must be specified as “X” and “Y” (see Fig. 1).

Depth Field: SHAPE_ver1 also provides the option of filtering data according to the depth distribution of the events. For this reason, the corresponding Field in the Fields File must be specified as “Depth”.

TIME WINDOWS File: This file is optional and can only be used when “Windows Creation Mode”: ‘Files’ is selected (see next section). The **Time Windows** files must be in ASCII format (e.g. ST2_test_timewindows.txt). The data must be stored in 2 columns, such that each column contains the values of a specified parameter: 1st column – the starting time of each time window, 2nd column – the ending time of each time window. The file format must be matlab time (Fig. 2b).

Parameter	Variable	Input	Type	Format	Range	Default
Mode	Model	Type in Screen	Scalar	Integer	1 or 2	-

Fig. 2b. Example of a time windows file.

RUNNING THE PROGRAM:

After launching “SHAPE_ver1” the Application runs in the following sequence of steps:

STEP 1. MODE Selection: A message appears in the screen showing the 2 available modes and the corresponding numbers (codes of the modes). The mode is selected by the User after typing a number (numerical input) and pressing ‘enter’. The available modes are: “1” for Seismic Data only and “2” for both Seismic and Production Data.

Parameter	Variable	Input	Type	Format	Range	Default
Mode	Model	Type in Screen	Scalar	Integer	1 or 2	-

STEP 2. DATA Selection: Depending on the MODE selection (STEP 1), the User is requested here to select dataset(s) (Catalog and optionally Production data), field file(s) (Catalog fields file and optionally Production data fields file) and parameters from Production fields file (if selected), as follows for each MODE:

For MODE 1 and MODE 2

Parameter	Variable	Input	Type	Format	Comments
Seismic Catalog Data File		Select from pop-up window	ASCII file	Please see “ <i>Input Data Requirements Specification</i> ” section above	Only one can be selected
Seismic Catalog Fields File					Only one can be selected

Additional Input for MODE 2

Parameter	Variable	Input	Type	Format	Comments
Production Data File		Select from pop-up window	ASCII file	Please see “ <i>Input Data Requirements Specification</i> ” section above	Only one can be selected
Production Fields File					Only one can be selected
Fields from Production dataset			Vector(s)	variable	Only one can be selected

STEP 3. Magnitude Scale Selection: The User is requested to select one of the magnitude scales available in the uploaded catalog (See ‘Magnitude Fields’ in the “INPUT Data” section above).

Parameter	Variable	Input	Type	Format	Comments
Magnitude Scale	Mtype	Select from pop-up window	String	String	Only one can be selected

STEP 4. Data Filtering: Before proceed to Seismic Hazard Analysis the User is given the option to filter the data according to the following filters (See also Fig. 4). The filtering process is done interactively, in an iterative way, such that the same way of filtering can be performed many times, as long as the User selects ‘Yes’ in “Data Filtering” dialog box (Fig. 3):

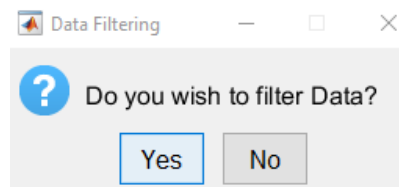


Fig. 3. Filtering data dialog box.

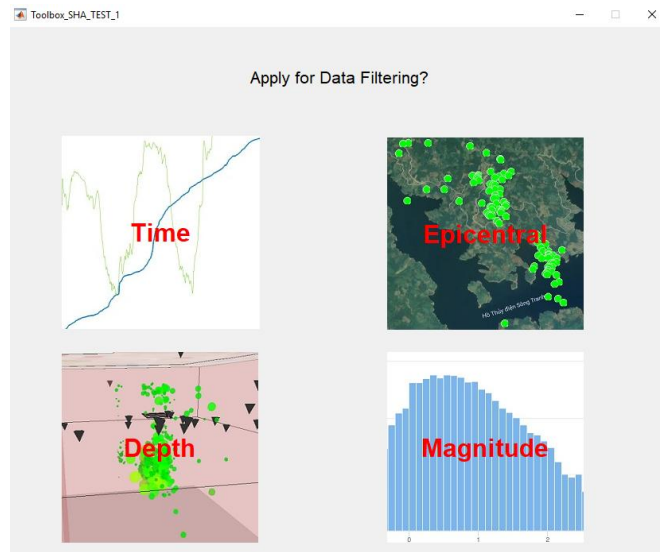


Fig. 4. Filtering options.

There are 4 different filters that can be applied (each one more than once), which the User can access by clicking on the corresponding buttons (Time, Epicentral, Depth and Magnitude) shown in Fig. 4:

- **Time Filtering:** The User is requested to select a starting and an ending time point from the seismic activity plot, to constrain the period of analysis between these two points. If production data have been uploaded (see Step 2) then the corresponding time-series of the production parameter is plotted as well (Fig. 5). After the filter has been applied, a message appears in the screen showing the remaining number of events after the filtering and SHAPE requests from the User for further data filtering (Fig. 3).

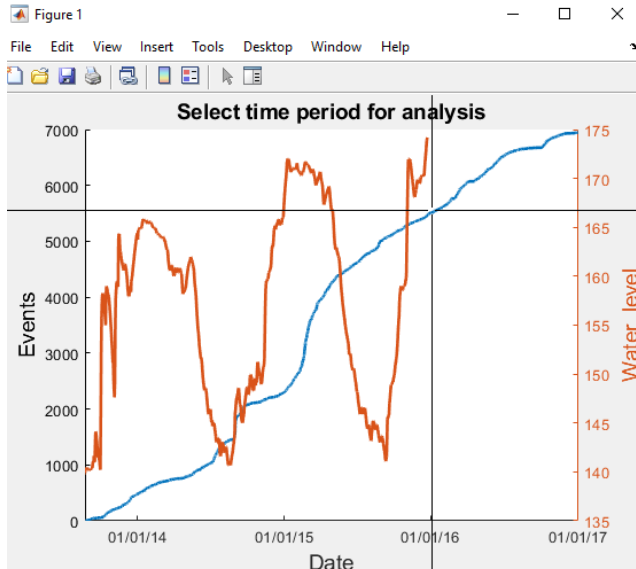


Fig. 5. Interactive time filtering.

- **Depth Filtering:** The User can inspect the vertical distribution of the events from a figure like the one shown in Fig. 6. In the left frame, the histogram of events for specified depth range is shown. The User can change the number of bins by typing a number in the box which lies on the right of the 'Enter number of bins' textbox. Then the User may click on the 'Update Histogram' button to update the figure. On the right frame the vertical distribution of the seismic events are shown. Once the User decides, he/she may click on the "Proceed" button in order to set the desirable depth values (Fig. 7). After the filter has been applied, a message appears in the screen showing the remaining number of events after the filtering and SHAPE requests from the User for further data filtering (Fig. 3).

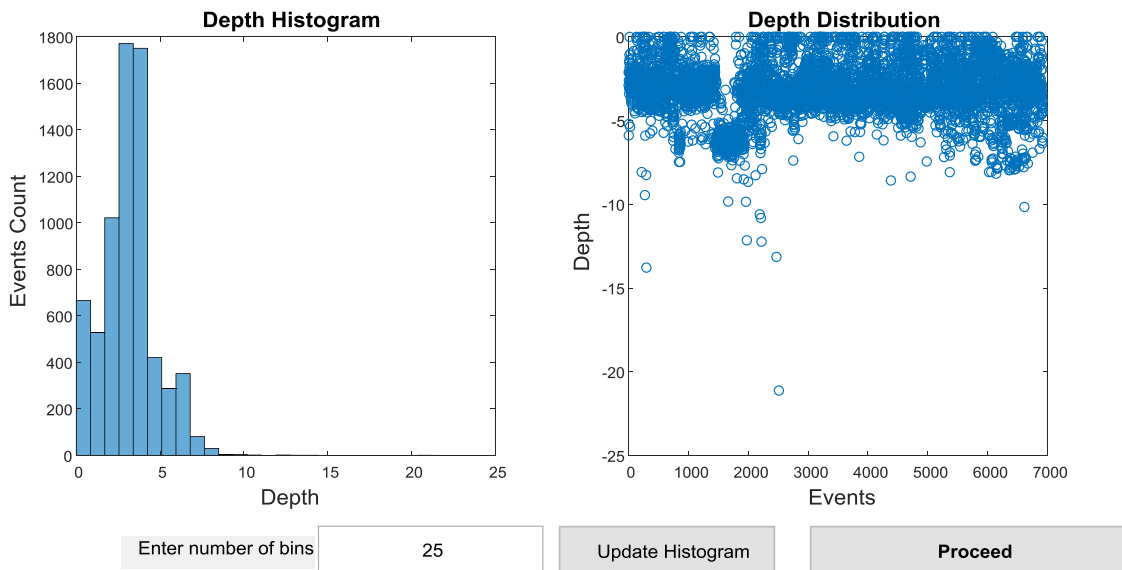


Fig. 6. Interactive depth filtering.

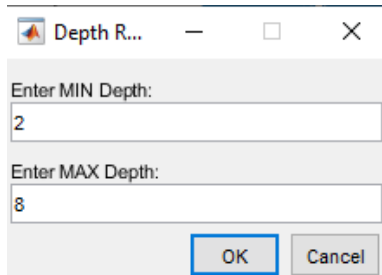


Fig. 7. Depth range selection.

- **Mc Filtering:** The User is here requested to graphically choose the minimum magnitude threshold, corresponding to the catalog completeness level, by clicking at a point on a plot similar to this shown in Fig. 8. After the filter has been applied, a message appears in the screen showing the selected M_c and the remaining number of events after the filtering and SHAPE requests from the User for further data filtering (Fig. 3).

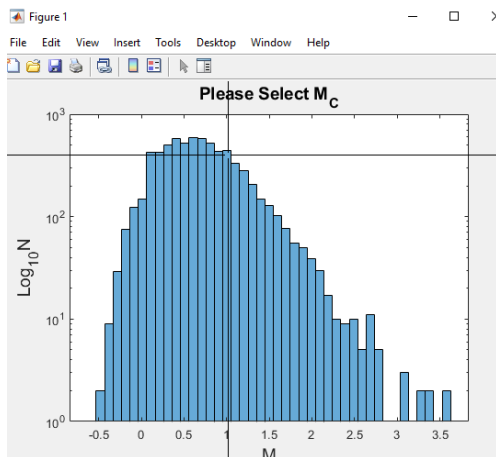


Fig. 8. Interactive magnitude filtering.

- **Epicentral Filtering:** Epicentral filtering can be applied in either geographical or Cartesian coordinates, if they are available in the data (Fig. 9). First the Users clicks on one of the two coordinate systems. Then, the User is provided two additional options, to constrain a either polygonal or a circular area (Fig. 10).

If the 'Polygon' is selected, the User subsequently clicks in the plot (Fig. 11) to define the edges of the polygon (Double-click to close the polygon). Next, the User can use the mouse to re-adjust the polygon position and the location of its edges. When the area has been decided, the User has to press 'enter' in order to proceed to data filtering.

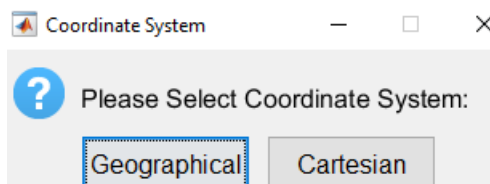


Fig. 9. Select coordinate system.

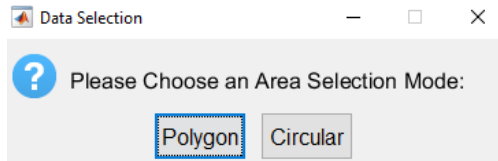


Fig. 10 Area selection mode.

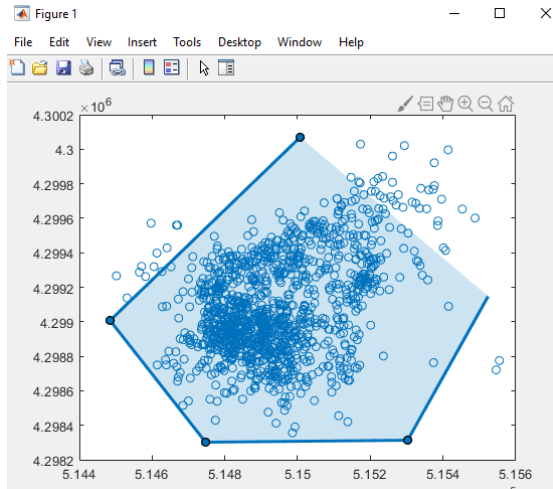


Fig 11. Polygonal area selection mode.

If the 'Circular' is selected, the User clicks on a point in the plot (Fig. 12) to define center of the circle, and drags the mouse to set the radius. Next, the User can use the mouse to re-adjust the circle's position and diameter. When the area has been decided, the User has to press 'enter' in order to proceed to data filtering.

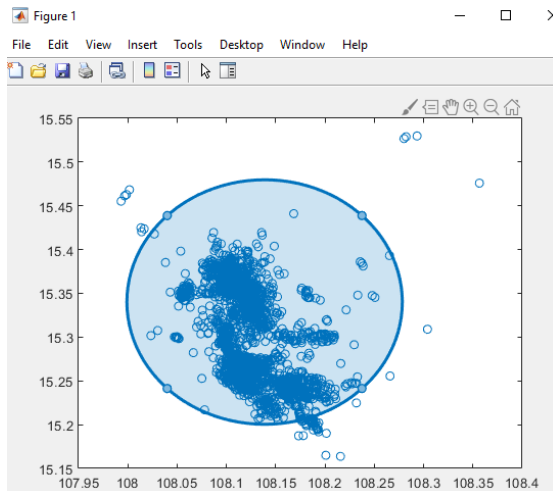


Fig. 12. Circular area selection mode.

Once the filter has been applied, a message appears in the screen showing the remaining number of events after the filtering and SHAPE requests from the User for further data filtering (Fig. 3). If the User clicks on 'No', then no further data filtering applied and SHAPE proceeds to Seismic Hazard Analysis.

STEP 5. Time Windows Generation: In this step the data is divided into time windows defined by the User, by means of 4 different modes: 'Time', 'Events', 'Graphical' and 'File' (Fig. 13). If 'Time' mode is selected the User has to define the window size (in days) and the window step (in days), by typing values in the corresponding fields in a pop-up window which appears in the screen (Fig. 14 left frame). If 'Events' mode is selected the User has to define the window size (in events) and the window step (in days), by typing values in the corresponding fields in a pop-up window which appears in the screen (Fig. 14 right frame). Alternatively, the User can select 'graphical', for graphical selection of subsequent points from a plot (Fig. 15). The first point corresponds to the starting point of the first period, the next point corresponds to the ending points of the first period and at the same time to the starting point of the next period etc. To define the ending point of the last period, the User has to press 'Enter'. Finally, if 'File' is selected, the User is requested to select a file containing the starting and ending points of time windows, which is located in the "TIME_WINDOWS" directory (Fig. 16).

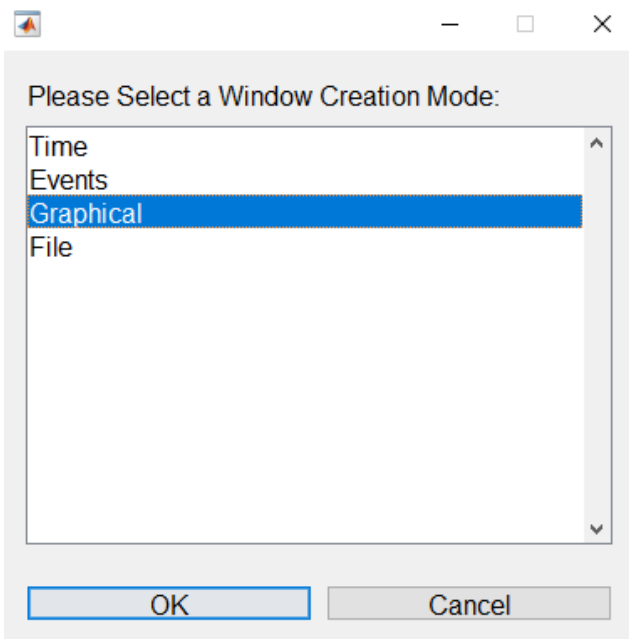


Fig. 13. Time windows generation mode selection.

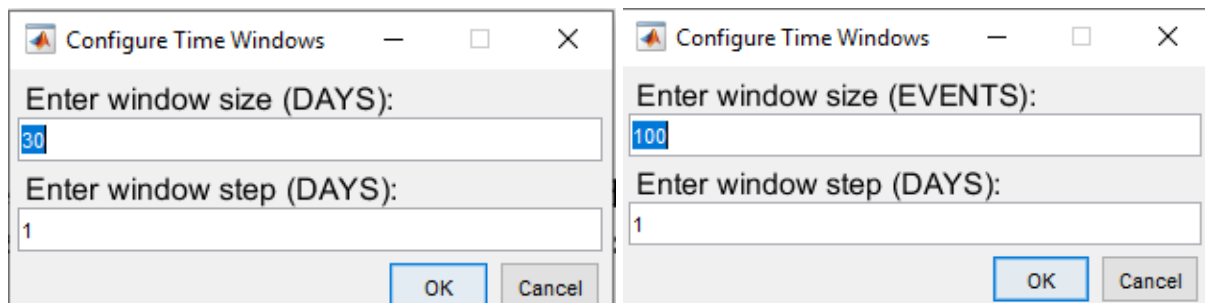


Fig. 14. Parameters set for time windows generation.

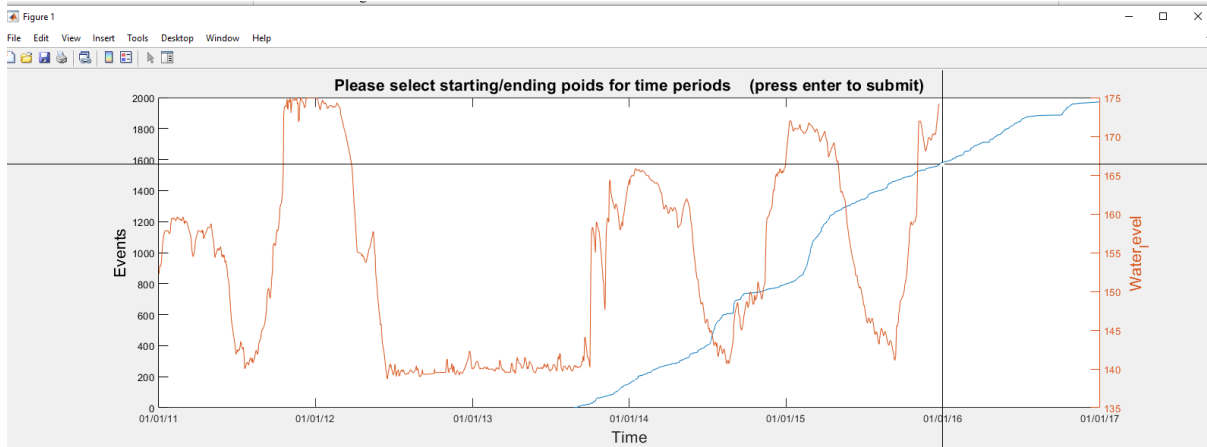


Fig. 15. Graphical selection of time windows.

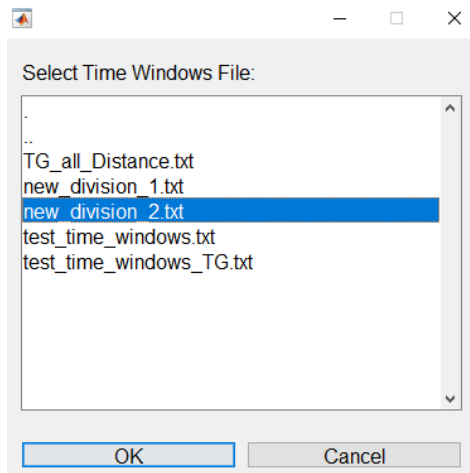


Fig. 16. Selection of time windows from a file.

STEP 6. SHA (Seismic Hazard Assessment) Parameters Selection: The User selects from subsequent pop-up windows the parameters required for data handling within SHAPE_ver1.

Parameter	Variable	Input	Type	Format	Possible Values	Default
Magnitude Distribution Model	Method	Select from pop-up window	String	String	'GRU', 'GRT', 'NPU', 'NPT'*	-
Time Unit	Tunit		String	String	'Day', 'Month', 'Year'	-
Target Magnitude	MaG		Scalar	Double	real	Equal to catalog maximum
Target Period	PLength		Scalar	Double	Positive	30
Maximum Magnitude ⁺	Mmax		Double (or string as default)		Greater or equal to the maximum magnitude in the catalog	'estimated'
Number of Synthetic samples for M_{max} Bias estimation	Nsynth		Scalar	Integer	Greater than 1	1000

*GRU: Gutenberg-Richter unbounded, GRT: Gutenberg-Richter truncated, NPU: non-parametric unbounded, NPT: non-parametric truncated

†For the special case of the truncated magnitude distributions (GRT and NPT), the maximum magnitude must also be set. This magnitude corresponds to the maximum possible magnitude given the dimensions of the area and/or seismicity history. The default value is ‘estimated’, meaning that the Mmax is estimated by the Kijko and Sellevoll (1989) formula, considering the entire available sample (all time windows) with $M \geq M_C$. The Mmax bias is also taken into account (Lasocki and Urban, 2011). Alternatively, the User may set a specific value of Mmax applied to the entire study area.

STEP 7. OUTPUTS: after the analysis is performed by the System, the following output results are produced and stored in the directory ”Outputs_SHA”.

Structure “SHA.mat” containing fields with outputs from ‘SHAPE_ver1.m’ script as well as the corresponding input values. The structure has as many cells as the number of time windows generated. These fields are the following:

Field	Type	Format	Parameter/comments
Time	Vector	Double	Origin times of the events included in each time window
M	Vector	Double	Magnitudes of the events included in each time window
Mmin	Scalar	Double	Minimum magnitude threshold
eps	Scalar	Double	Magnitude round-off interval
lambda	Scalar	Double	Mean activity rate
lambda_err	Logical	0, 1	Events number sufficiency: if lambda_err=0, all parameters are estimated, if lambda_err=1 all outputs are set as NaN.
unit	String	String	Time unit
method	String	String	Magnitude distribution model selected among ‘GRU’, ‘GRT’, ‘NPU’ and ‘NPT’
b ¹	Scalar	Double	b-value of the Gutenberg-Richter law
h ²	Scalar	Double	Kernel smoothing factor
xx ²	Vector	Double	Background sample for the non-parametric kernel estimators of magnitudes
ambd ²	Vector	Double	Weighting factors for the adaptive kernel
ierr ²	Scalar	0, 1, 2	h convergence indicator: ierr=0: process converged, ierr=1: multiple zeros found, ierr=2: no zeros found.
Mmax ³	Scalar	Double	Upper limit of the magnitude (truncated) distribution
err ³	Logical	0,1	Mmax convergence indicator: err=0: convergence, err=1: no convergence
PDF	Array	Double	Array with 2 columns: the first representing magnitudes and the second the Probability Density Function of those magnitudes, derived by the selected model (‘method’).
CDF	Array	Double	Array with 2 columns: the first representing magnitudes and the second the Cumulative Distribution Function of those magnitudes, derived by the selected model (‘method’).

¹ Applies only when “method” is set to “GRU” or “GRT”

² Applies only when “method” is set to “NPU” or “NPT”

³ Applies only when “method” is set to “GRT” or “NPT”

Note that the User is requested to change the default output filename of the structure (Fig. 17), after closing the output figures (see below).

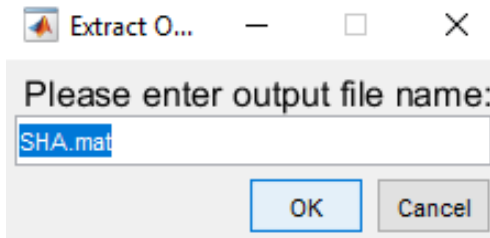


Fig. 17. Dialog box for setting output structure name

Report: 'REPORT_Hazard_Analysis.txt' is generated and stored (by the auxiliary script "Zsave_output.m", called by SHAPE_ver1), including a summary of the input parameters and data considered, as well as the results obtained from the analysis.

FIGURE SHA.mat/SHA.jpeg: An output figure is generated by the auxiliary script "Zplot.m" called by SHAPE_ver1 (see also Fig. 18 and Fig. 19 below). The output figure has three frames:

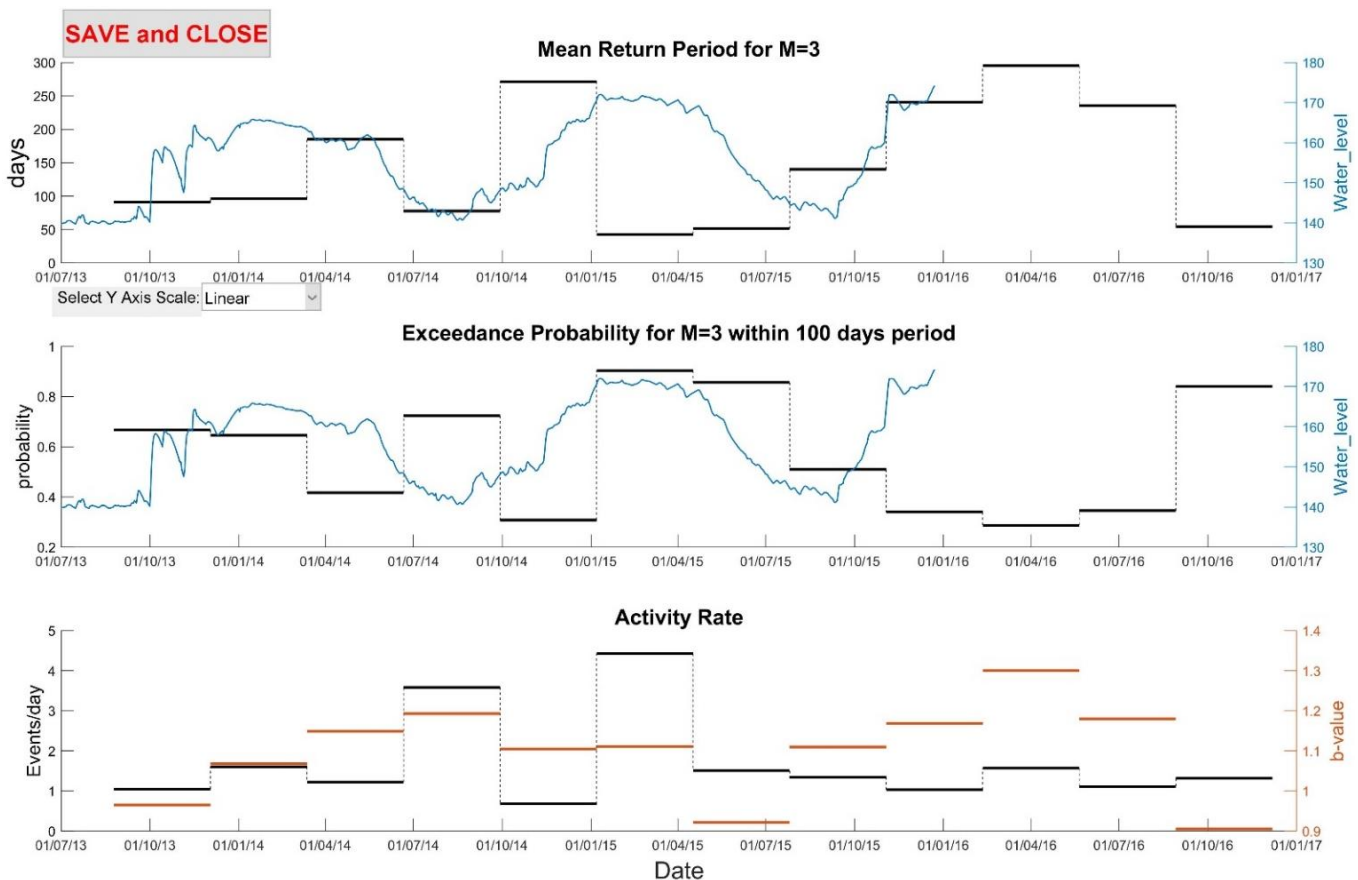


Fig. 18. Output figure for non-overlapping windows and Production Data plotted (GRU selected).

The upper frame demonstrates MRP for the selected target magnitude (Fig. 18 and Fig. 19). In the left axis the selected time unit is shown. Optionally, if Production Data are loaded, they are

plotted as well (right axis, Fig. 19). The left y-axis can be switched from linear to log scale and vice versa.

The middle frame demonstrates EPR for the selected target magnitude and period duration (Fig. 18 and Fig. 19). Optionally, if Production Data are loaded, they are plotted as well (right axis, Fig. 18).

The lower frame shows the mean activity rate in events/unit selected. In the right axis, the b-values are plotted if ‘GRU’ or ‘GRT’ method is selected (Fig. 18). Alternatively, the mean magnitude for each dataset is plotted (right axis) if method is set to ‘NPU’ or ‘NPT’ (Fig. 19).

In all three frames there are 2 plotting types. If the time windows are not overlapping, the resulted plot looks like Fig 18 (horizontal lines). Otherwise, if time windows overlap with each other, the resulting plot looks like Fig. 19 (Circular points). Click on the ‘SAVE and CLOSE’ button to save the figure in .mat and .jpeg formats.

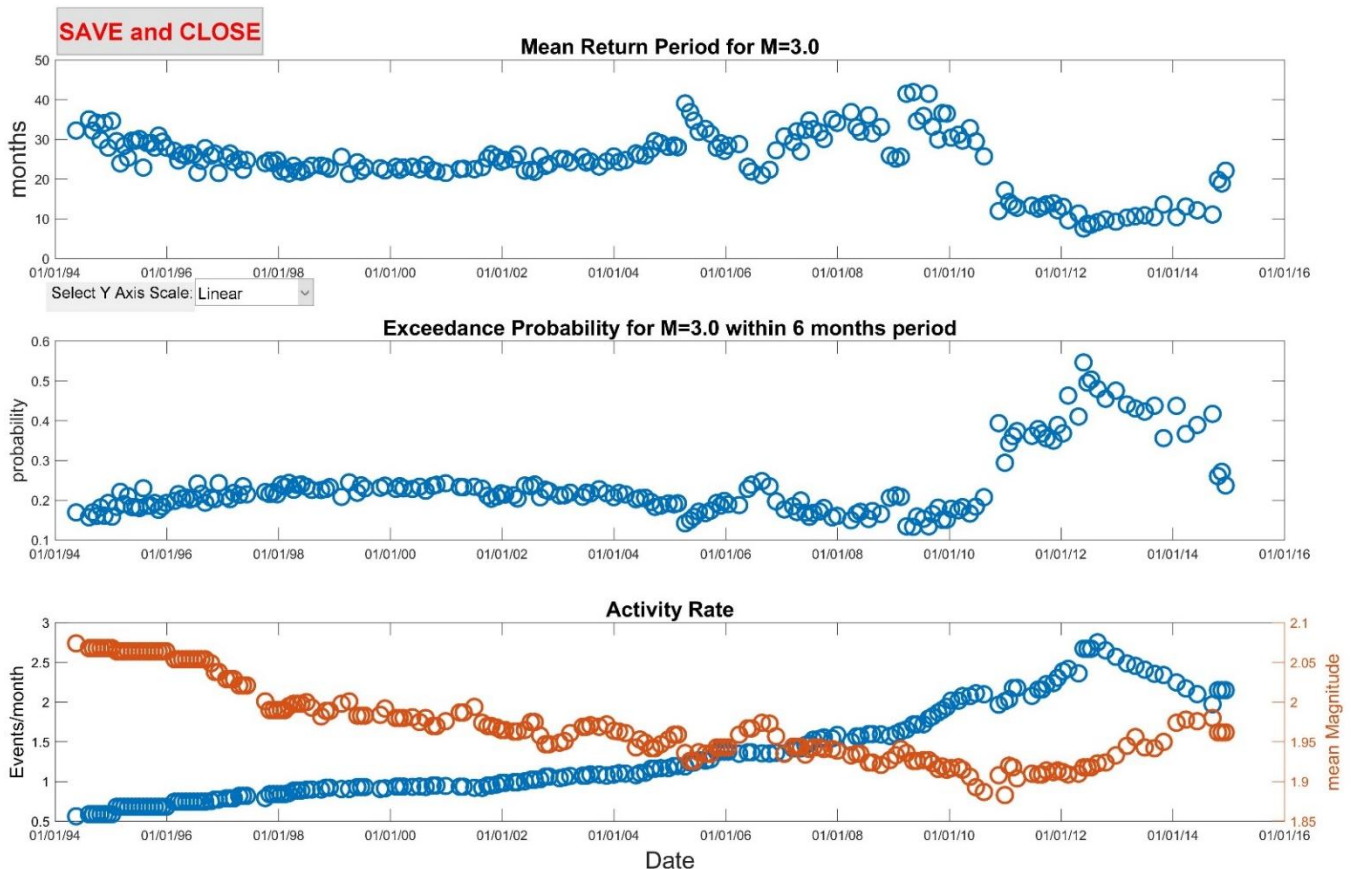


Fig. 19. Output figure for overlapping windows without Production Data plotted (NPU selected).

For a comprehensive description of the methodology applied in SHAPE, the User may read Leptokaropoulos and Lasocki (2020) and references therein.

The Users may also use the on-line versions in the IS-EPOS Platform of the Thematic Core Service Anthropogenic Hazards (TCS-AH) of EPOS (Leptokaropoulos et al., 2019; Orlecka-Sikora et al., 2020).

Appendix: Parameter Values Tutorial

Although this application can be evenly used tectonic seismicity case studies, it has been developed to mainly apply for anthropogenic seismicity episodes. Therefore, the default parameter values are adjusted rather to anthropogenic than to natural seismicity. By setting the appropriate parameter values and units, the application can be equivalently implemented for any seismic hazard analysis. The following table presents examples of typical (yet, not exclusive) values set for anthropogenic as well as for tectonic seismicity case studies.

Parameter	Anthropogenic SHA	Tectonic SHA
Magnitude Distribution Model	Non-parametric kernel	Gutenberg-Richter law
Time Unit	Days to months	Years
Maximum Magnitudes	Depending on technology, usually $M_{\max} < 4.0$	Depending on the seismic zone, can be as high as $M_{\max} \sim 9.5$
Target Magnitudes for EP and MRP	Depending on technology, $2 < M < 5$	Depending on the seismic zone, $M > 5.0$
Target time period for EP	1 day to 1 week	10-50 years

NOTE: This table does NOT show the observed range, it just provides some typical values for comparison between anthropogenic and tectonic seismicity. Please consult relevant references in order to adapt proper values for specific case studies.

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