

Earthquake swarm (reshuffling analysis) user guide



Anthropogenic seismicity rate and magnitude are tested against non correlated series with the same number of data. It is achieved by "reshuffling" the data. It is a robust way to check how significant is the variability over time of anthropogenic seismicity. Input data are time series from seismicity catalogue. This application is important to quantify the robustness of observed seismicity pattern against random fluctuations of the same size system. Outputs are observed and reshuffled time series.



REFERENCES Document Repository

CATEGORY Earthquake Interactions

KEYWORDS Geo-resource production impact, Statistical properties of seismicity, Earthquake swarm

CITATION Please acknowledge use of this application in your work:
IS-EPOS. (2017). *Earthquake swarm: reshuffling analysis* [Web application]. Retrieved from <https://tcs.ah-epos.eu/>

About the Service

Every Anthropogenic episode may highlight changes in either rate or magnitude that possibly correlate in time with change in production (or geo-resource operations) patterns. The service primarily tests if the seismicity changes we observed is significant as tested against reshuffled series with the same number of events, in the same range of value (e.g. Lemarchand and Grasso, 2007, Tahir et al. 2012, De Arcangelis et al. 2016). It allows to accept or to reject the change at a given (e.g. 95%) confidence level. It corresponds to Monte Carlo techniques (e.g. Kelly and Sear, 1984; Lemarchand and Grasso, 2007, Tahir et al. 2012, De Arcangelis et al. 2016, Grasso et al. 2018), involving 1000 random sets of key events. This is assessed by random sampling, (including bootstrap procedure), 1000 sets of "synthetic event catalogues". The 1000 sets of synthetic catalogues are then analyzed in the same manner as the real seismicity catalogue to assess the confidence levels for the observed episode distribution. This application is important to quantify the robustness of observed seismicity pattern against random fluctuations in the same size system.

References:

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- Grasso, J-R, A. Karimov, D. Amorese, C. Sue, C. Voisin, (2018) Patterns of Reservoir Triggered Seismicity in a Low Seismicity Region of France. *Bulletin of the Seismological Society of America* doi: <https://doi.org/10.1785/0120180172>
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Step by step

After the User adds the Application into his/her personal workspace, the following window appear on the screen (Figure 1):

Earthquake swarm: reshuffling analysis

File EqkeSwarmShufflingAnalysis
Description Anthropogenic seismicity rate and magnitude are tested against non correl... [EXPAND](#)

INPUTS

Catalog
Required 1 file
SELECT FILES

Chosen magnitude column
Output file name prefix result ⓘ
Site name ⓘ
Latitude range [deg] Min Max ⓘ
Longitude range [deg] Min Max ⓘ
Depth range [km] Min Max ⓘ
Time range Start End ⓘ
Magnitude range Min Max ⓘ
Threshold magnitude range Min Max ⓘ
Number of samples (min. 100) 1000 ⓘ
Size of bins Yearly ⓘ ⓘ
Duration of the period [years] (0, 10) 1

⚠ Application waits for inputs: Catalog


RUN Status CREATED

Figure 1. Input window of the "Earthquake swarm (reshuffling analysis)" application.

The User shall click on 'SELECT FILES' button in order to use seismic catalog data among the ones that are already uploaded in his/her personal workspace.

The User is then requested to fill in the fields shown below:

- *Chosen Magnitude Column* - The user may chose among different magnitude scales (e.g ML, MW), in the Episodes where these scales are available.
- *Output file name prefix* – File name for the output plot.
- *Site name* – Name of the site for which the episode is uploaded.
- *Latitude range* – Range of the latitudes of events to be used for reshuffling analysis.
- *Longitude range* –Range of the longitude of events to be used for reshuffling analysis.
- *Depth range* – Range of the depth of events to be used for reshuffled analysis.
- *Elevation range* - Range of the elevation of events to be used for reshuffled analysis.
- *Time range* - Range of the time of events to be used for reshuffled analysis. The user can here select a time range to be analysed by clicking boxes.
- *Magnitudinal range* – Range of the magnitude of events to be used for reshuffled analysis.
- *Threshold magnitude range* - Range of the magnitude of events to be counted for reshuffled analysis
- *Number of samples* – Number of reshuffled catalogues to be stacked as superposed epoch reference; number of synthetic datasets. The User inserts the number of synthetic datasets in the empty box as an integer.
- *Size of bins* – Bin sizes for a given time period. The user can choose "yearly", "monthly", "weekly", "daily", "hourly" and "minutely".
- *Duration of the period* – The period of the size of bins.

 **Earthquake swarm: reshuffling analysis**

File EqkeSwarmShufflingAnalysis **Description** Anthropogenic seismicity rate and magnitude are tested against non correl... [EXPAND](#)

INPUTS

Catalog
Required 1 file

Lacq_Catalog_3L.mat

CHANGE... CLEAR

Chosen magnitude column

Mw

Output file name prefix

Lacq swarm

i

Site name

Lacq

i

Latitude range [deg]

43.1900

43.7200

i

Longitude range [deg]

-00.8500

-00.3200

i

Depth range [km]

0.000

27.100

i

Time range

1967 Aug 14

2009 Dec 12

i

Magnitude range

1.2

5.2

i

Threshold magnitude range

2.2

5.2

i

Number of samples (min. 100)

1000

i

Size of bins

Yearly

i

Duration of the period [years] (0, 10)

1

RUN

Status CREATED

Figure 2. Default values for Lacq hydrocarbon field.

After defining the aforementioned parameters, the user shall click on the 'RUN' button and the calculations are performed. The Status changes from 'Submitting' through 'Queued', then 'Running' and finally 'Finished'. The output is created and plotted in the main window just below 'RUN' button. Also the output result appears on the left corner of the platform.

Figures #3 and #4 describe the outputs of the LACQ field swarm analysis. Blue curve is the seismicity rate over time, for given magnitude range. We observe an increase in the 1980-1990 period relatively to period after and before. We compare the LACQ field swarm pattern to reshuffled time series (brown line). Shaded area are 2 sigma values for observations and reshuffled series. Only the 1990 peak value is above the 95% confidence level deduced reshuffled synthetic data. It allows to estimates, at a 95% confidence level when real series overpass the shaded area thresholds.

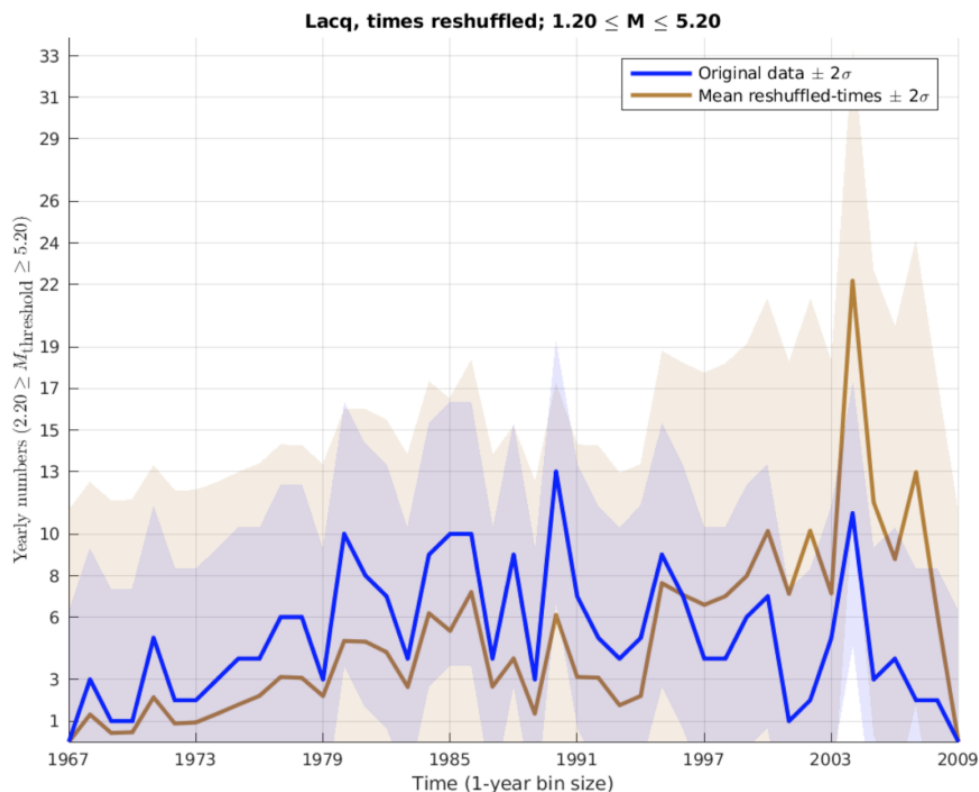


Figure 3. The LACQ field swarm analysis.

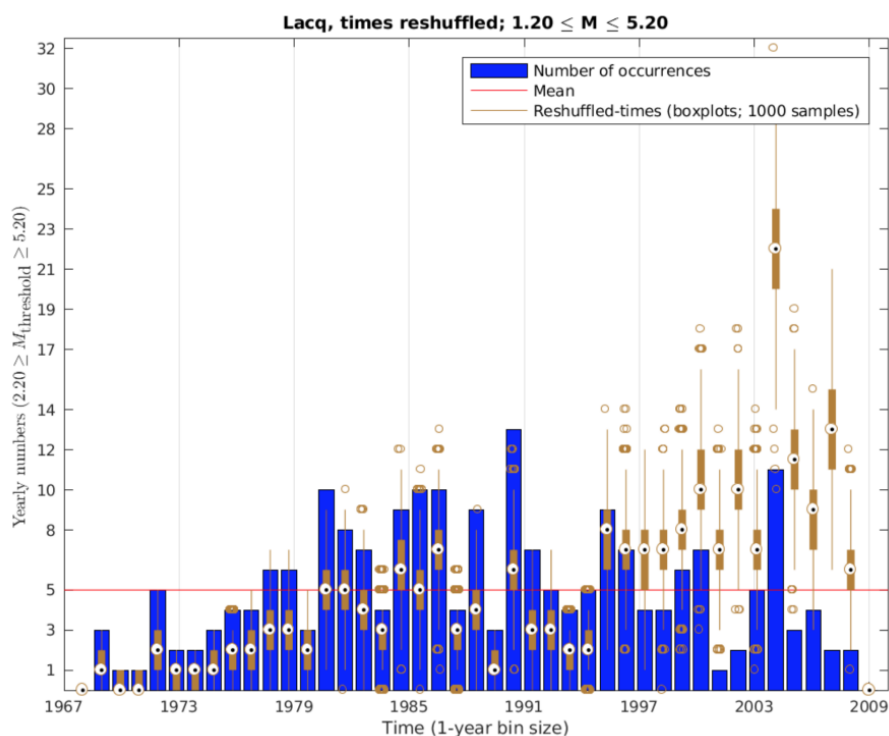


Figure 4. The LACQ field swarm time reshuffled histograms.

Figure 4. describes the outputs time reshuffled histograms for the LACQ field swarm. Boxplots is used for synthetic dataset results.

Boxplot definition:

The first quartile (Q1) is defined as the middle number between the smallest number and the median of the data set.

The second quartile (Q2) is the median of the data.

The third quartile (Q3) is the middle value between the median and the highest value of the data set.

The "thick brown line" is IQR, so from Q1 to Q3.

The "white dot" inside the thick brown line (in compact view) is the median value.

The thin brown line are the whiskers; they are defined as $Q3 + 1.5(IQR)$ and $Q1 - 1.5(IQR)$.

Anything outside the whiskers is "outlier", and is represented as isolated dots.

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Related Documents

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- [Earthquake interactions: Mainshock scale user guide](#)
- [Earthquake swarm \(reshuffling analysis\) user guide](#)
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