

Time correlated earthquakes (Seasonal trends) user guide



Test of of Number, space, and Magnitude pattern against reshuffled distribution in time e.g daily patterns for mine induced seismicity or monthly pattern for reservoir induced seismicity. The test aims to quantify how "seasonal" patterns remain uniform over time and to accept or to reject the uniform pattern under a given confidence level. Allows to capture anthropogenic trends in time pattern that correspond to georesource production type. It allows to extract time relationship to production patterns and departure from uniform tectonic seismicity background.



REFERENCES [Document Repository](#)

CATEGORY Earthquake Interactions

KEYWORDS Geo-resource production impact, Statistical properties of seismicity, Seasonal trend

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About the Service

The service use superposed epoch analysis to extract seasonal patterns in seismicity time series and it tests the result robustness against reshuffled series. One key time patterns of anthropogenic activity relatively to tectonic events is temporal driven by production history. When seasonal patterns for geo-energy production are known, we test in the application how these patterns impact the time series of anthropogenic seismicity. The users choose to test the time pattern of seismicity on a window that corresponds to the rhythm of georesource production (e.g. the hourly or daily basis for mining or fluid injection fracking); or monthly patterns for reservoir water level (e.g. Mekkawi et al. 2004), oil and gas production). The service further tests if the time patterns that are observed are significant as tested against reshuffled series. The reshuffled series are imposed to have the same number of events, in the same range of value (e.g. Lemarchand and Grasso, 2007, Tahir et al. 2012). It allows to accept or to reject the observed seasonal trend at a given (e.g. 95%) confidence level. It corresponds to Monte Carlo techniques (e.g. Lemarchand and Grasso, 2007, Tahir et al. 2012, Grasso et al. 2018), involving 1000 random sets of key events. This is assessed by random sampling 1000 sets of "synthetic event catalogues" (including bootstrap procedure). The 1000 sets of synthetic catalogues are then analysed in the same manner as the real seismicity catalogue to assess confidence levels for the observed episode distribution.

Reference:

- 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>
- Lemarchand, N., and J.-R. Grasso (2007), Interactions between earthquakes and volcano activity, *Geophys. Res. Lett.*, 34, L24303, doi:10.1029/2007GL031438.
- Mekkawi, M. J-R Grasso, and P Schnegg, 2004. A long lasting seismic relaxation at Lake Aswan, Egypt, 1982_2001, *Bull. Seis. Soc. Am.* 94, 2, 479-492.
- Tahir, M., J.-R. Grasso, and D. Amorèse, (2012) The largest aftershock: How strong, how far away, how delayed? *Geophys. Res. Lett.*, 39, L04301, doi:10.1029/2011GL050604

Step by step

After the User adds the application to his/her personal workspace, the following window appears on the screen (Figure 1):

INPUTS

Catalog
Required 1 file

SELECT FILES

Chosen magnitude column

Output file name prefix ⓘ

Site name ⓘ

Chosen depth or elevation ⬆

Latitude range [deg] ⓘ

Longitude range [deg] ⓘ

Depth range [km] ⓘ

Elevation range [km] ⓘ

Time range ⓘ

Magnitude Range ⓘ

Number of samples (min. 100) ⓘ

Size of bins ⓘ

⚠ Missing or invalid input files for: Catalog

SAVE **RUN** **Status CREATED**

Figure 1. Input window of the "Time correlated earthquakes (Seasonal Trends)" 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.
- *Magnitude range* – Range of the magnitude of events to be used for reshuffled analysis.

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- *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".

INPUTS

Catalog
Required 1 file
Lacq_Catalog_3L.mat

CHANGE...CLEAR

Chosen magnitude column

Mw

Output file name prefix

Lacq seasonal trends

Site name

Lacq

Latitude range [deg]

43.1900

43.7200

Longitude range [deg]

-00.8500

-00.3200

Depth range [km]

0.000

27.100

Time range

1967 Aug 14

2009 Dec 12

Magnitude Range

3

5.2

Number of samples (min. 100)

1000

Size of bins

Monthly

SAVERUNStatus CREATED

Figure 2. Default values for the 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', than 'Running' and finally 'Finished'. The output is created and plotted in the main window just below 'RUN' but ton. Also the output result appears on the left corner of the platform.

Figure 3 describes the outputs of the LACQ field seasonal trend. Original data and monthly earthquake stack are displayed as green bars, while the average value of green bars are shown as a red line. A synthetic dataset is used to see how sufficient (strong) original monthly earthquakes are.

Boxplot is used for synthetic dataset results. Thick and thin vertical blue bars are one and two sigma fluctuations estimated from the variability of the N synthetic series. It allows to estimate the 66% and 95% confidence level, respectively, when real series overpass these thresholds.

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 blue line" is (QR), as (QR= Q3- Q1).

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

Thin blue lines are the whiskers, defined as $Q3+1.5(IQR)$ and $Q1-1.5(IQR)$.

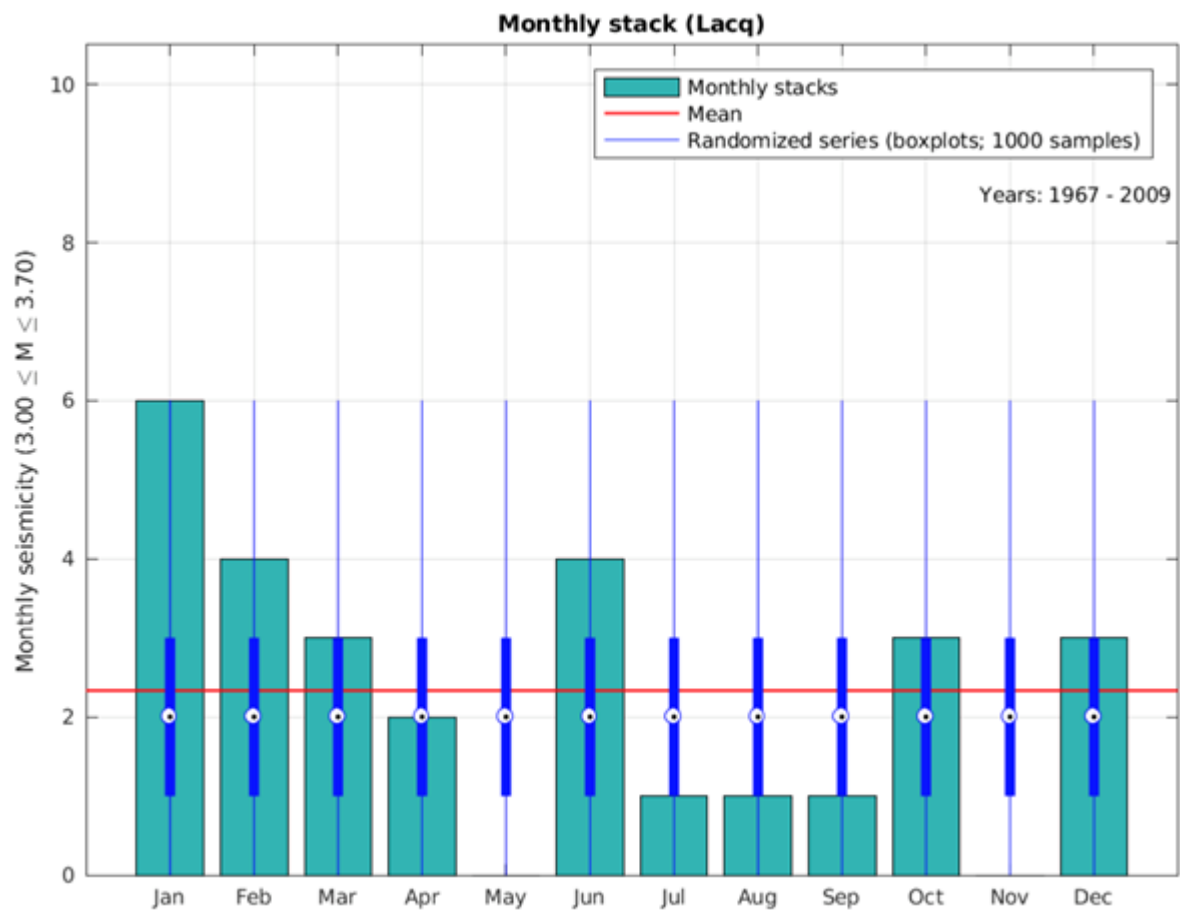


Figure 3. The LACQ field seasonal trends.

In this example, the January rate value is accepted at a 95% confidence level. January, February and June rates are accepted values above the uniform distribution at a 66% confidence level.

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