

# Earthquake interactions: Georesource scale user guide



Anthropogenic seismicity rate and magnitude are analyzed using superposed epoch to extract mean field patterns that are more robust than a single series. This application analyses aftershock sequences in the 1-3L near field distances from the "reservoir". L is a proxy for geo-resource dimension, being mine gallery width, reservoir length, etc. Input data are time series from the seismic catalog. This application is important to quantify the mean field pattern of several aftershocks that should be compared with regional tectonic patterns. Outputs as aftershock rate over time may be compared to outputs of application "Earthquake interactions - mainshock scale".



REFERENCES [Document Repository](#)

**CATEGORY** Earthquake Interactions

**KEYWORDS** Geo-resource production impact, Statistical properties of seismicity, Mainshock, Aftershock

**CITATION** Please acknowledge use of this application in your work: IS-EPOS. (2019). *Earthquake interactions - georesource scale* [Web application]. Retrieved from <https://tcs.ah-epos.eu/>

## Scientific Background

There is no consensus on the a-priori distance-time-size pattern to be selected to relate a given earthquake to a given geo-resource-reservoir exploitation (e.g. Gupta, 2002, Klose 2013, NRC, 2013). On the one hand, some authors suggest (on observational bases) a 30-50 km distance and 10-20 years time range observation of a reservoir to relate an earthquake to a given geo-resource « reservoir » (e.g. for a review Gupta, 2002, Klose 2013). These a-priori space-time windows question any of the physics processes that may drive a constant triggering distance to an extended loading source (i.e. not a point source such as a lake surface or hydrocarbon reservoir).

On the other hand, there are evidences that the use of the absolute distance captures earthquake-earthquake triggering patterns (as aftershock-mainshock pair) that hide the key properties of the event interactions (e.g. Bak et al., 2002; Parsons and Velasco, 2009, Tahir et al., 2012, Tahir and Grasso, 2015, de Arcangelis et al., 2016). For tectonic earthquake interactions, the size of the triggering zone is mapped by static stress perturbation. This later is estimated to be in the 1-3 L range for aftershocks triggering (Parsons and Velasco 2009; Tahir et al., 2012; Tahir and Grasso, 2015). For the tectonic earthquake analysis "L" is the mainshock fault length derived from magnitude scale (e.g. Wells and Coppersmith, 1994). In order to mimic the earthquake interaction analysis, we choose ( $L_r$ ) the reservoir length (i.e. "geo-resource length" in the application inputs) as the equivalent of the mainshock fault length. It reflects the characteristic dimension that drives the stress change pattern induced by geo-resource productions (e.g. Gupta and Rastogi 1976, Bell and Nur, 1978, Roeloffs, 1988; Segall et al. 1994, Deng et al., 2010, Grasso et al., 2018).  $L_r$  is the characteristic dimension the user defines from the geometry of the geo-resource production the user work with.

Therefore, we propose to analyze the triggering patterns around geo-resource production using 1-3-10 $L_r$  normalized distances to the geo-resource "reservoir", respectively. Furthermore, the aftershocks rate, however defined, provides information on event proportions directly driven by the geo-resource production and the one triggered by other earthquakes (Helmstetter et al., 2002, Traversa et Grasso 2008, De Arcangelis et al., 2016).

### References:

- Tahir, M., J.-R. Grasso, and D. Amorese (2012): The largest aftershock: How strong, how far away, how delayed? *Geophys. Res. Lett.*, 39, L04301, doi:10.1029/2011GL050604.
- Tahir, M., and J-R Grasso, (2015): "Faulting style controls for the space-time aftershock patterns." *Bulletin of the Seismological Society of America* 105.5 2480-2497.
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- Zaliapin, I., and BenZion, Y. (2016): Discriminating characteristics of tectonic and humaninduced seismicity, *Bulletin of the Seismological Society of America*, 106(3), 846-859.
- Grasso, J. R., Karimov, A., Amorese, D., Sue, C., & Voisin, C. (2018): Patterns of ReservoirTriggered Seismicity in a LowSeismicity Region of France, *Bulletin of the Seismological Society of America*, 108(5B), 2967-2982.

## Step by step

### Note:

This service analyses aftershock patterns around mainshock events within normalized distance to the trigger shock targets ( $L^* = L_{real}/(L_f(M))$ ). For example: If mainshocks are selected as M2 events,  $L_f(M2)$  is close to 100 m, then the 1-3  $L^*$  distances to select aftershocks will correspond to  $L_{real} = 1-3L_f(M2)$  (i.e.  $L^* = 1 \times 100 = 100$  m, and  $3 \times 100 = 300$  m, respectively). Accordingly, the user, when using 1-3 $L^*$  distance to analyze near field triggering, will actually select earthquakes within 100-300 m range. Application inputs are Mm, and (ii) Maft range for triggering and triggered shocks, respectively. To increase the signal-to-noise ratio, we use superposed epoch analysis. It corresponds to the restriction of each time series after a given event to a common  $t_0$ . Outputs as aftershock rate over time may be compared to outputs of application "Earthquake interactions - georesource scale". We recommend to run the latter mentioned application with the same selection criteria on tectonic seismicity.

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

result

Site name

Latitude range [deg]

Min

Max

Longitude range [deg]

Min

Max

Depth range [km]

Min

Max

Time range

Start

End

Location of georesource centre

Latitude

Longitude

Depth

Georesource length [km] (min. 0)

10

Relative distance (min. 0)

1

Mainshock magnitude range

Min

Max

Aftershock magnitude range

Min

Max

Bin size [h] (min. 0)

6

Window duration [day] (min. 0)

10

Operated well locations

ADD

Application waits for inputs: Catalog

RUN

Status CREATED

Figure 1. Input window of the "Earthquake interactions: Georesource Scale" 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 choose among different magnitude scales (e.g.  $M_L$ ,  $M_W$ ), 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 event latitudes used for reshuffling analysis.
- *Longitude range* – Range of event longitudes used for reshuffling analysis.
- *Depth range* – Range of event depths used for reshuffled analysis.
- *Time range* - Range of event times used for reshuffled analysis. Here, the user can select a time range by clicking boxes.
- *Location of georesource centre* – The location of georesource zone centre.
- *Georesource length* – Length of the georesource zone.
- *Relative distance* – Relative distance to georesource zone:  $n \times$  (georesource length).
- *Mainshock magnitude range* – Range of mainshock magnitudes used for superposed epoch analysis.
- *Aftershock magnitude range* – Range of aftershock magnitudes used for superposed epoch analysis.
- *Bin size* – Bin sizes for a given time period.
- *Window duration* – Number of days before/after the time that is used for superposed epoch analysis.
- *Operated well location* – The User may enter as many coordinates of different wells as possible (e.g. injection, extraction, waste water). Optional parameter.

### INPUTS

**Catalog**  
Required 1 file  
Lacq\_Catalog\_3L.mat

CHANGE... CLEAR

Chosen magnitude column: Mw

Output file name prefix: Lacq georesource sc: ⓘ

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 ⓘ

Location of georesource centre: 43.44 -0.59 3 ⓘ

Georesource length [km] (min. 0): 10 ⓘ

Relative distance (min. 0): 3 ⓘ

Mainshock magnitude range: 3 9 ⓘ

Aftershock magnitude range: 2.2 9 ⓘ

Bin size [h] (min. 0): 6 ⓘ

Window duration [day] (min. 0): 10 ⓘ

Operated well locations: (43.3800, -00.6100, 3.000) ✕  
(43.4500, -00.6400, 4.000) ✕ ADD ⓘ

SAVE RUN Status CREATED

**Figure 2. Default values used 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', 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 from #3 to #6 describe the outputs of the LACQ field aftershocks patterns. It corresponds to seismicity rate in 6h window bins, 10 days before and after N=28 M3-3.7 events. Mean seismicity rate values before and after are shown as red and blue lines, respectively.

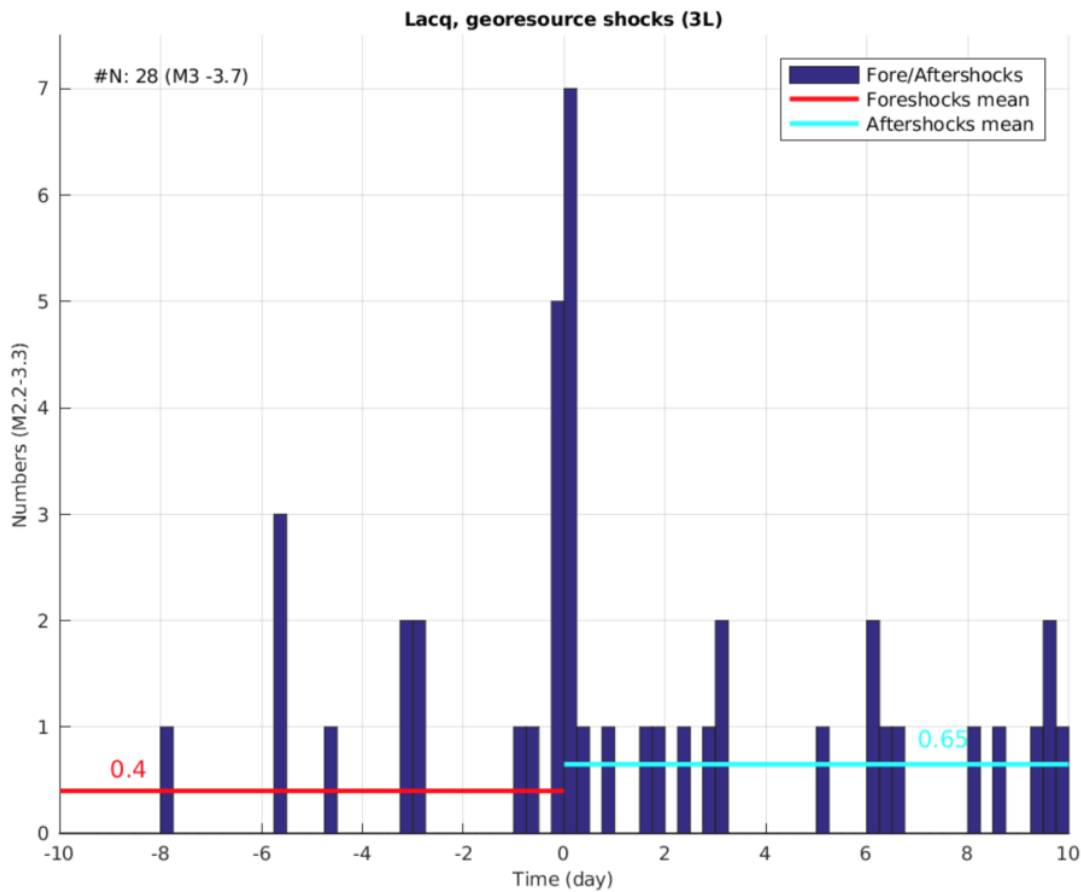


Figure 3. Output histogram "Output file name prefix\_gs\_length\_histograms.png".

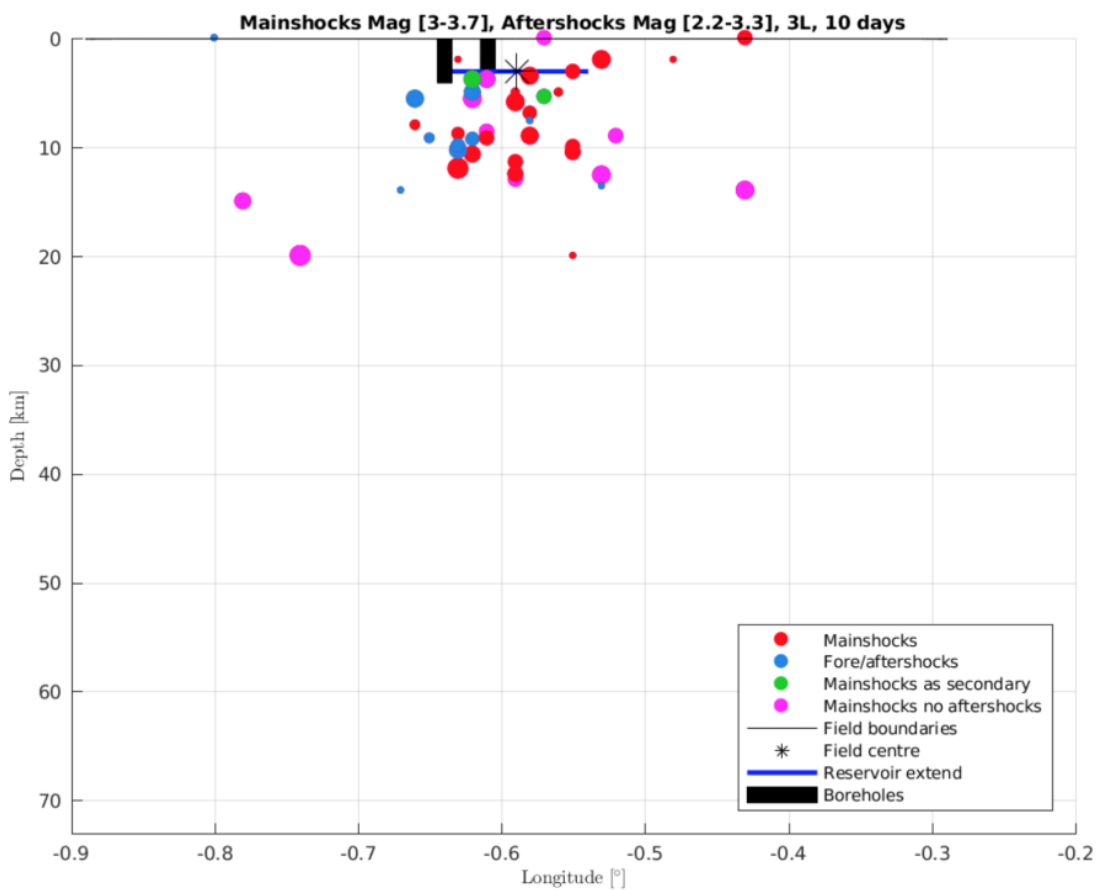


Figure 4. "Output file name prefix\_gs\_length\_lon\_vs\_depth.png".

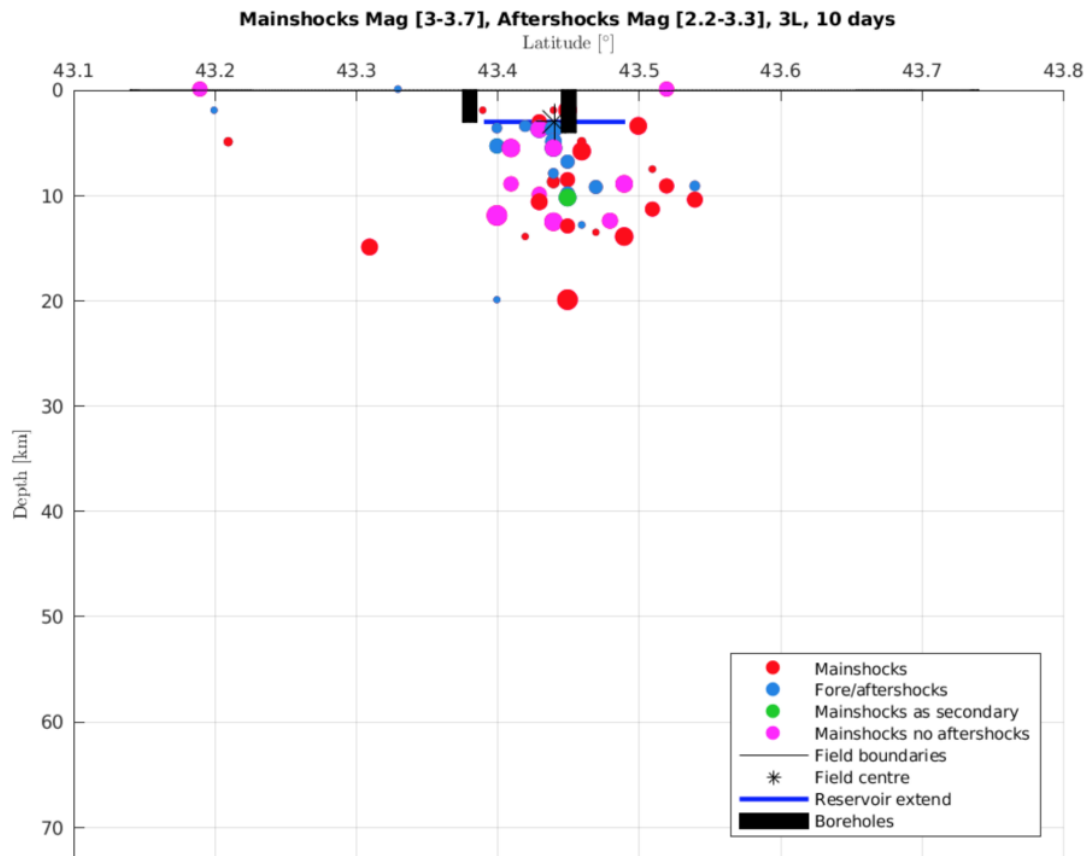


Figure 5. "Output file name prefix\_gs\_length\_lat\_vs\_depth.png".

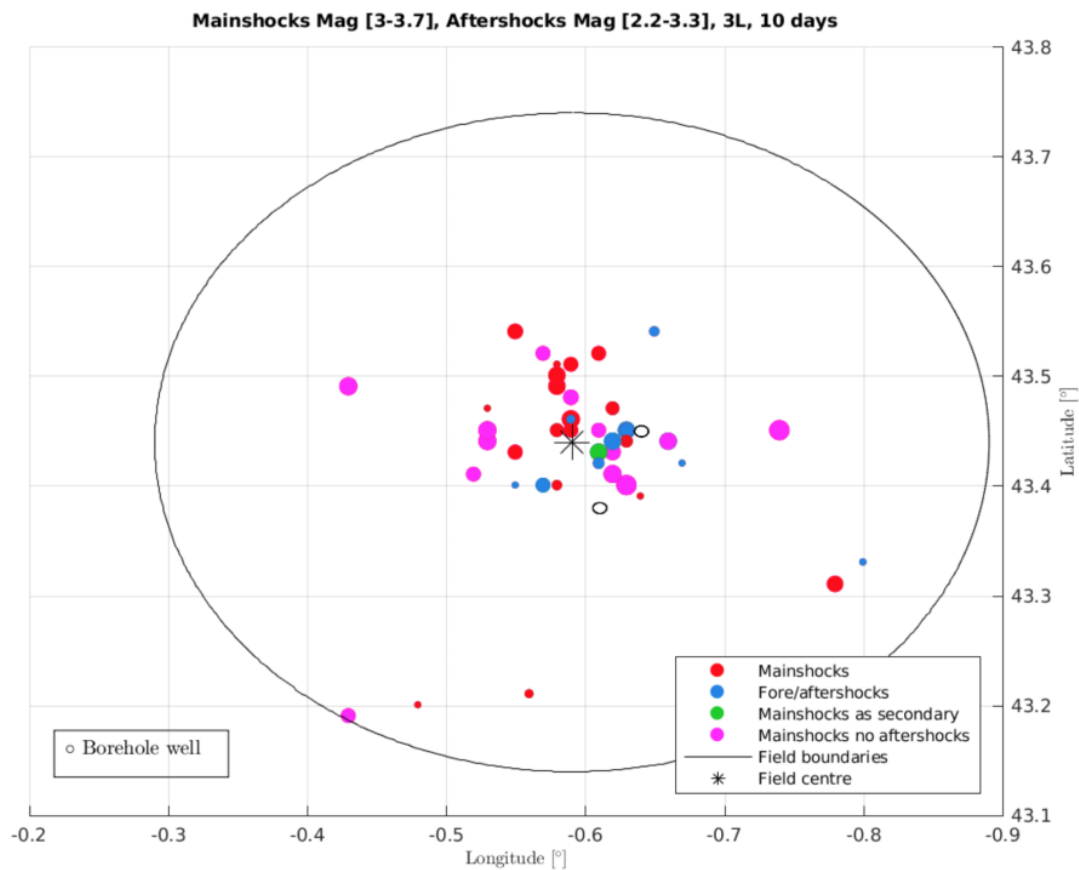


Figure 6. "Output file name prefix\_gs\_length\_lat\_vs\_lon.png".

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## Related Documents

- [Earthquake interactions: Georesource scale user guide](#)
- [Earthquake interactions: Mainshock scale user guide](#)
- [Earthquake swarm \(reshuffling analysis\) user guide](#)
- [Time correlated earthquakes \(Seasonal trends\) user guide](#)

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