

**Determining the spatio-temporal patterns of intraplate earthquakes in the
Western Quebec Seismic Zone using clustering analysis**

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Appendix

Worked example of determining the significance of the *Approximate days between earthquakes* in the Spatio-temporal Analysis.

Example Cluster Scenario [15 000, 40], where [eps, minPts].

A. Spatial Analysis

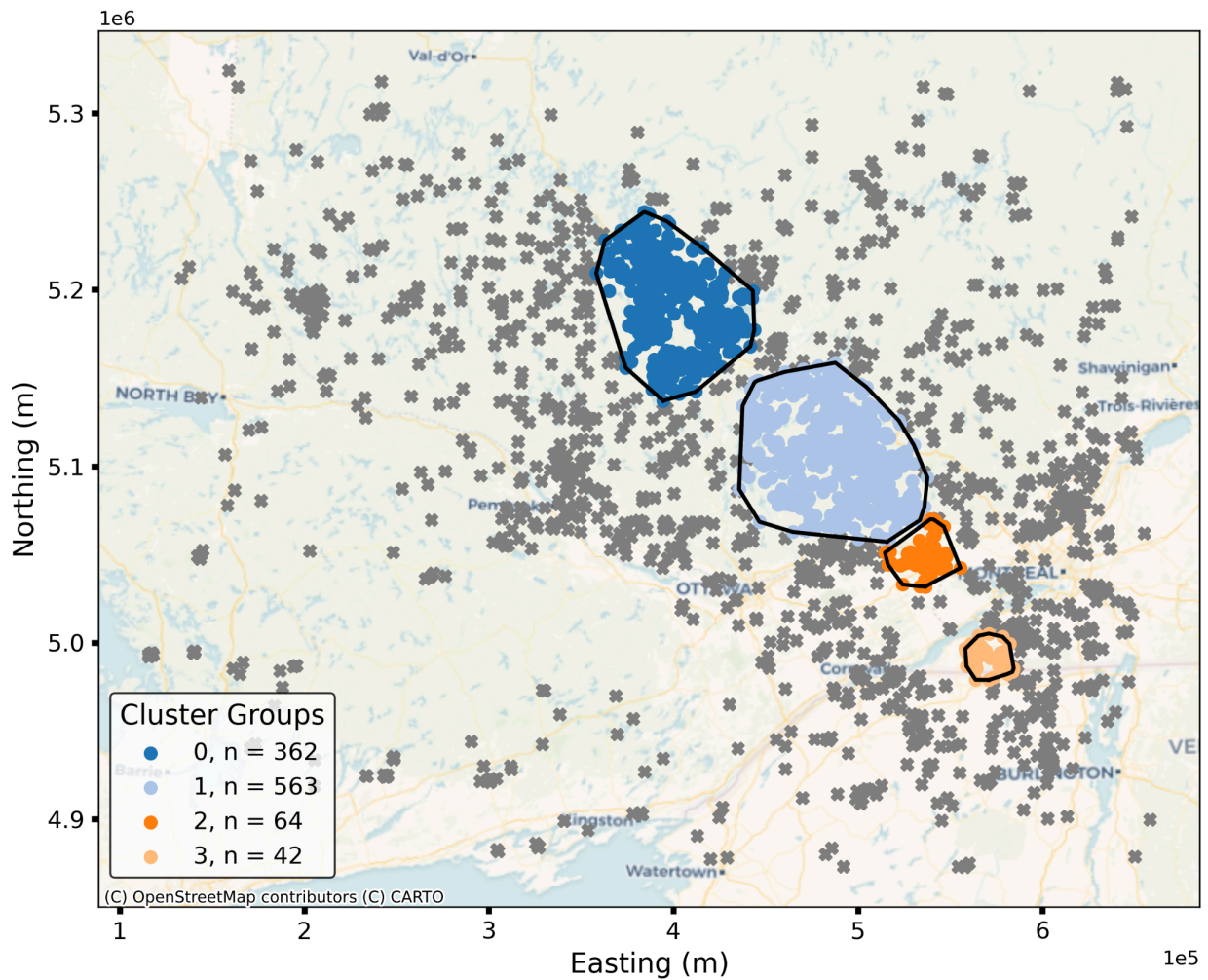


Figure 1. DBSCAN clustering result for [15 000, 40] which identified 4 different cluster groups.

B. Temporal Analysis

For each cluster group, the time interval between consecutive seismic events was calculated. These intervals were then used to construct a normalized cumulative frequency curve, which helps identify the maximum time gap between seismic events corresponding to a given proportion of events within the cluster. For example, in Figure 2A, a normalized cumulative frequency of 0.5 indicates that 50% of the earthquakes in Cluster 0 occur within a maximum interval of 26.4 days. This curve represents the cluster's "temporal signature."

To assess whether this temporal signature differs from a random pattern, it was compared to 1 000 simulated datasets generated under the assumption that seismic events occur randomly. Each simulation contained the same number of earthquakes as the observed cluster. Event times were assigned by sampling random values between 0 and 1, scaled to the study period (January 1, 1985 to December 31, 2024). A temporal signature was then computed for each simulation, allowing comparison with the observed cluster.

A cluster is considered to have a "unique temporal signature" if its value at the 0.5 cumulative frequency lies more than two standard deviations from the mean of the simulations (representing ~95% of the expected random outcomes). If it falls within this range, the temporal pattern observed in the cluster is considered random. In the case of Cluster 0 (Figure 2B), the temporal signature falls within this range, indicating a random temporal pattern.

These results were used to construct a spatio-temporal map that displays both the approximate time gap between seismic events for each cluster and whether this timing is statistically significant. Figure 6 presents this map for clustering scenario [15,000, 40] and Table 1 summarizes the results obtained from Figure 2-5.

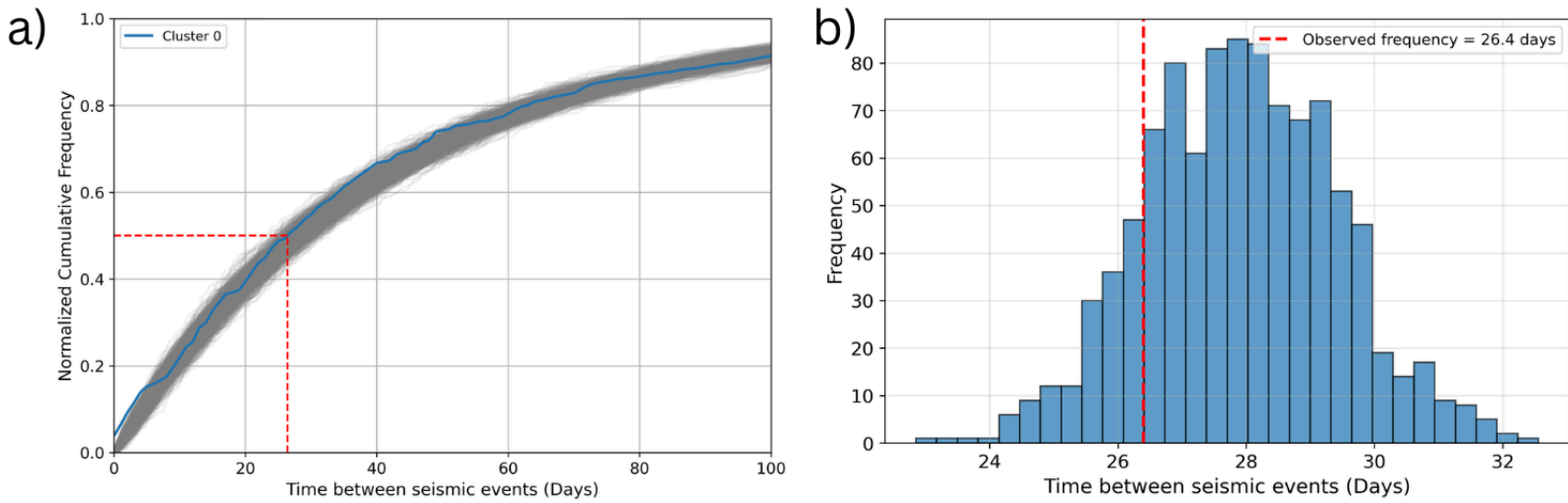


Figure 2. Statistical assessment of the time gap between earthquakes in Cluster 0 for clustering scenario [15,000, 40]. a) Normalized cumulative frequency curve for Cluster 0 compared with 1 000 simulations (each with $n = 362$ events). The red dashed lines indicate the maximum time interval corresponding to 50% of earthquakes within the cluster (26.4 days). b) Distribution of simulated time intervals at the 0.5 cumulative frequency. The observed value for Cluster 0 (26.4 days) falls within two standard deviations of the simulated mean ($\mu = 27.9$, $p = 0.3157$), indicating cluster 0 does not exhibit a unique temporal signature, and earthquake occurrences are consistent with a random temporal pattern.

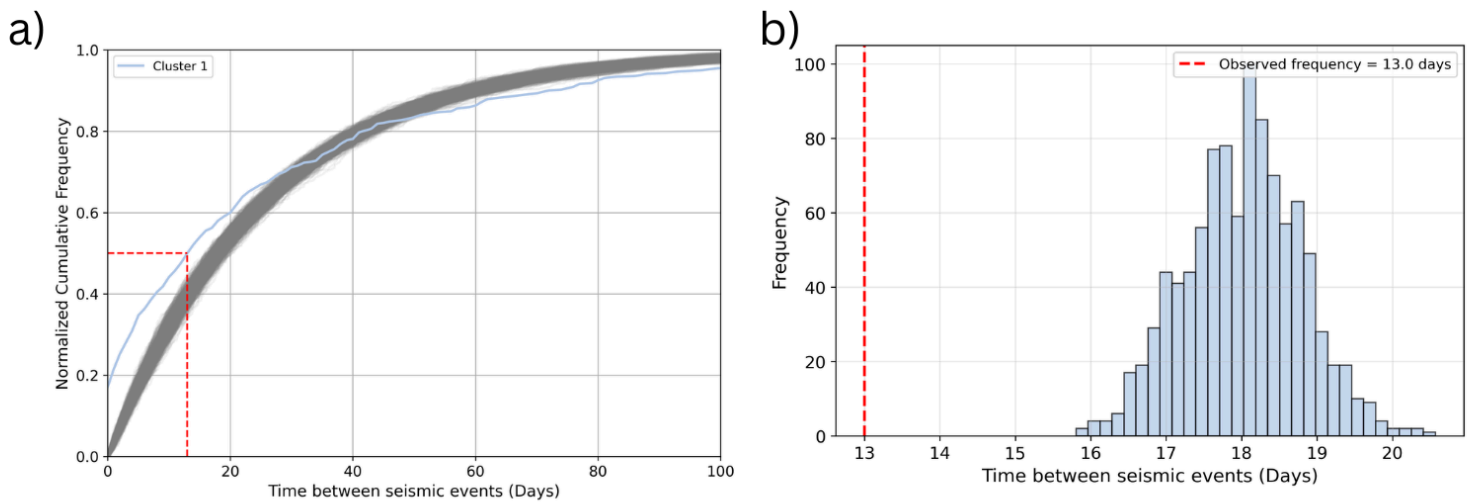


Figure 3. Statistical assessment of the time gap between earthquakes in Cluster 1 for clustering scenario [15,000, 40]. a) Normalized cumulative frequency curve for Cluster 1 compared with 1 000 simulations (each with $n = 563$ events). The red dashed lines indicate the maximum time interval corresponding to 50% of earthquakes within the cluster (13.0 days). b) Distribution of simulated time intervals at the 0.5

cumulative frequency. The observed value for Cluster 1 (13.0 days) falls within two standard deviations of the simulated mean ($\mu = 18.02$, $p = 7.66E-11$), indicating cluster 1 exhibits a unique temporal signature, and earthquake occurrences are not consistent with a random temporal pattern.

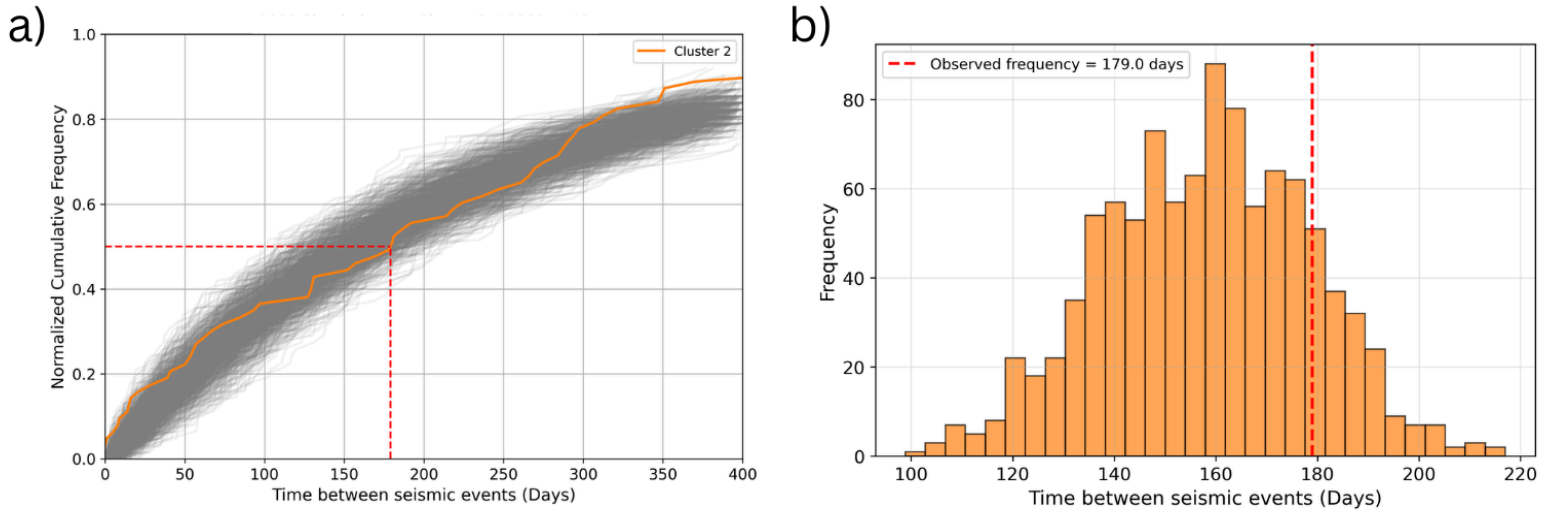


Figure 4. Statistical assessment of the time gap between earthquakes in Cluster 2 for clustering scenario [15,000, 40]. a) Normalized cumulative frequency curve for Cluster 2 compared with 1 000 simulations (each with $n = 64$ events). The red dashed lines indicate the maximum time interval corresponding to 50% of earthquakes within the cluster (179.0 days). b) Distribution of simulated time intervals at the 0.5 cumulative frequency. The observed value for Cluster 2 (179.0 days) falls within two standard deviations of the simulated mean ($\mu = 157.92$, $p = 0.2974$), indicating cluster 2 does not exhibit a unique temporal signature, and earthquake occurrences are consistent with a random temporal pattern.

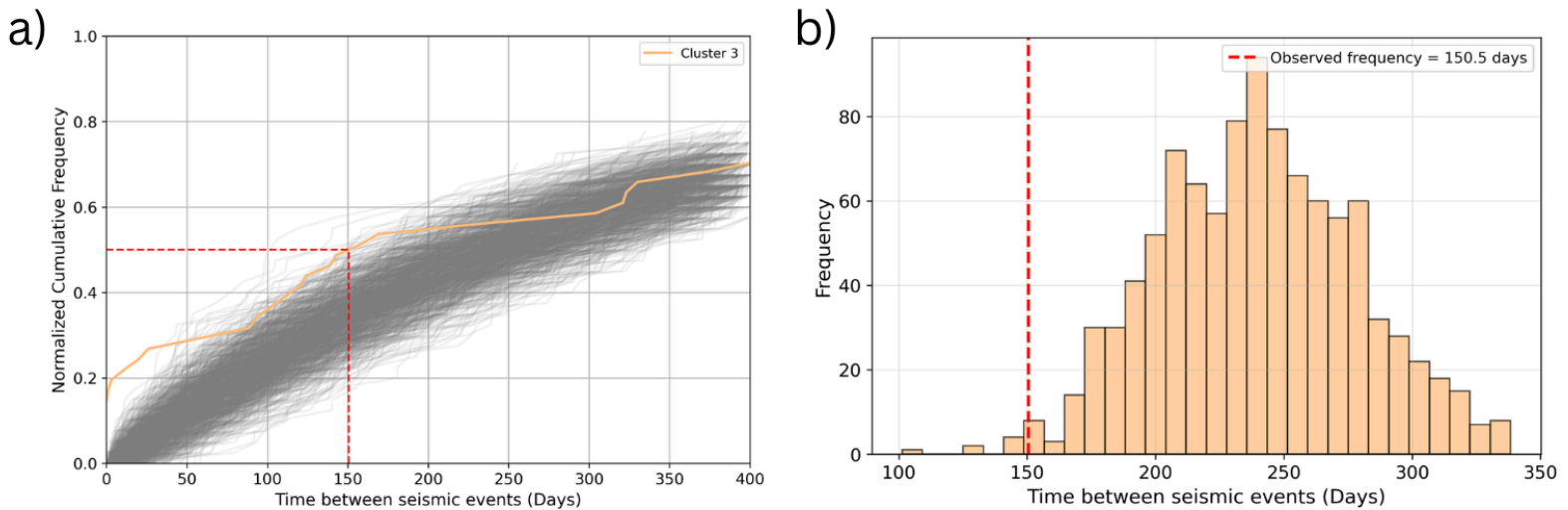


Figure 4. Statistical assessment of the time gap between earthquakes in Cluster 3 for clustering scenario [15,000, 40]. a) Normalized cumulative frequency curve for Cluster 3 compared with 1 000 simulations (each with $n = 42$ events). The red dashed lines indicate the maximum time interval corresponding to 50% of earthquakes within the cluster (150.5 days). b) Distribution of simulated time intervals at the 0.5 cumulative frequency. The observed value for Cluster 3 (150.5 days) falls within two standard deviations of the simulated mean ($\mu = 239.549$, $p = 0.021$), indicating cluster 3 exhibits a unique temporal signature, and earthquake occurrences are not consistent with a random temporal pattern.

Table 1: Summary of Statistical Analysis of the time gap between earthquakes in cluster groups within cluster scenario [15 000, 40].

Cluster Group	Observed Value at Normalized Cumulative Frequency = 0.5	Average Value of 1000 simulations at Normalized Cumulative Frequency = 0.5	P-Value
0	26.4	27.9	0.3157
1	13	18.02	7.66E-11
2	179	157.92	0.2974
3	150.5	239.549	0.021

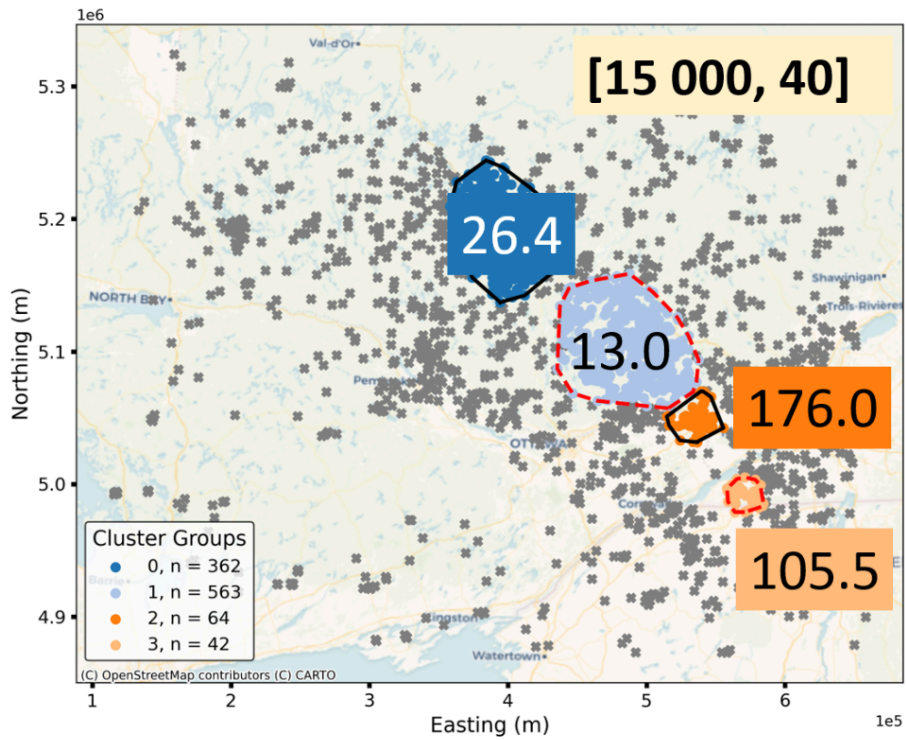


Figure 5. Spatio-temporal map for clustering scenario [15 000, 40], where values indicate the approximate time gap between seismic events in each cluster. Cluster groups outlined with a red dash indicate cluster groups experience a significant temporal signature, and the seismic occurrence within the cluster is not random.