Statistical analysis of low-frequency earthquake catalogs

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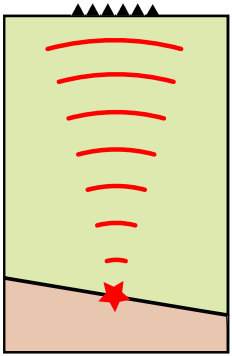
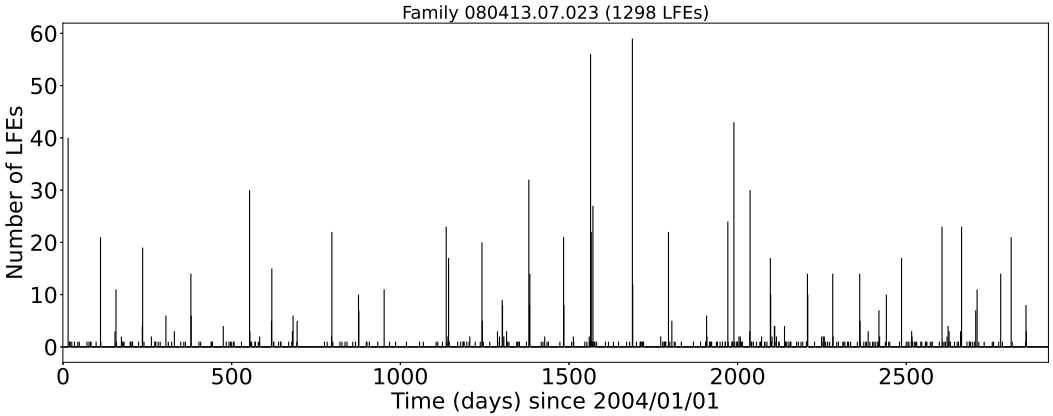
Low-frequency earthquakes (LFEs)



- Small magnitude earthquakes ($M \sim 0 - 2$).
- Reduced amplitudes at frequencies greater than 10 Hz.
- Earthquake source located close to the plate interface.
- Grouped into families: All LFEs from a given family originate from the same small patch.
- Dozens of LFEs within a few hours or days, followed by weeks or months of quiet.

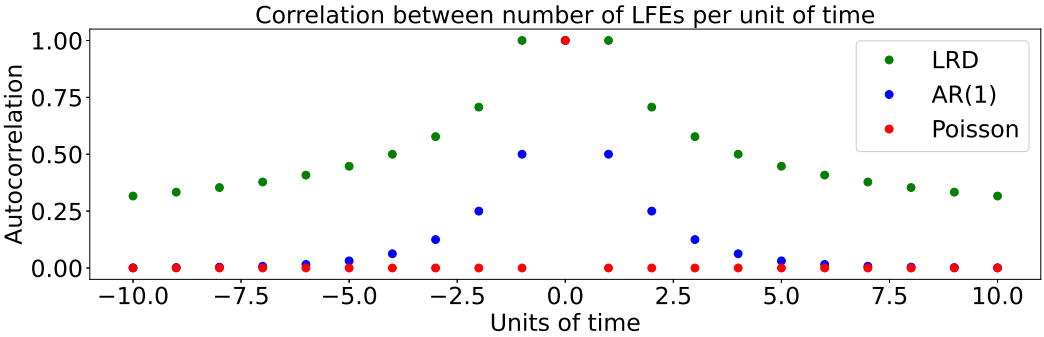
Example of an LFE family



Statistical analysis of LFE occurrence

1. We look at each LFE family independently from the others.
2. We translate the sequence of LFE occurrence times into a discrete time series defined by the number of LFEs per unit of time.

What is long-range dependence?



How to estimate long-range dependence: Variance of residuals method

Divide time series $X_i(t)$ into blocks of size m.

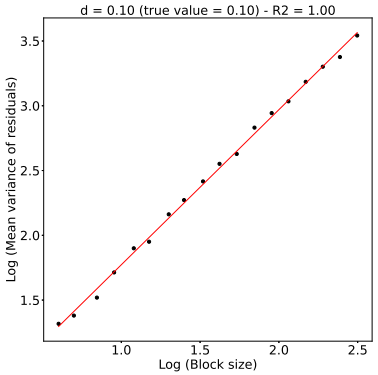
For each block k, compute the partial sums $Y_k(t) = \sum_{i=km+1}^{km+t} X_i$.

Fit a linear model over each block k and compute the sample variance of the residuals:

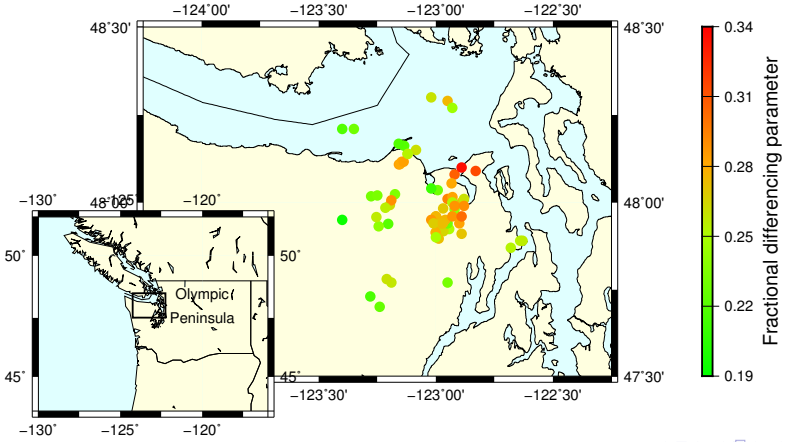
$$V_k = \frac{1}{m} \sum_{t=1}^{m} \left(Y_k(t) - a_k - b_k t \right)^2$$

Repeat for different values of the size m of the blocks.

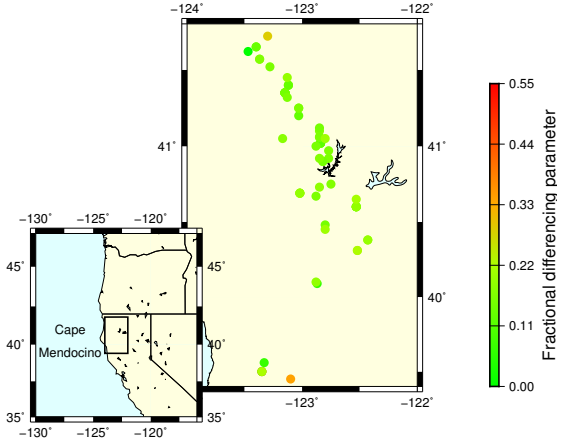
$\rightarrow$ The mean of the sample variance over all blocks behaves like m^{2d+1}.



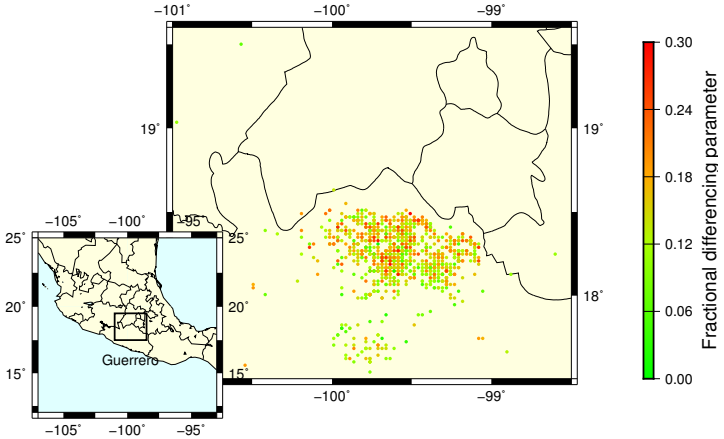
LFE catalog from the Olympic Peninsula (Chestler and Creager, 2017)



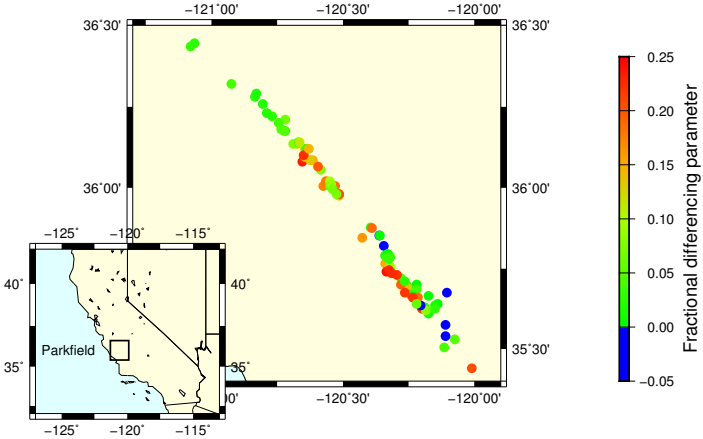
LFE catalogs from southern Cascadia (Ducellier and Creager, 2022)



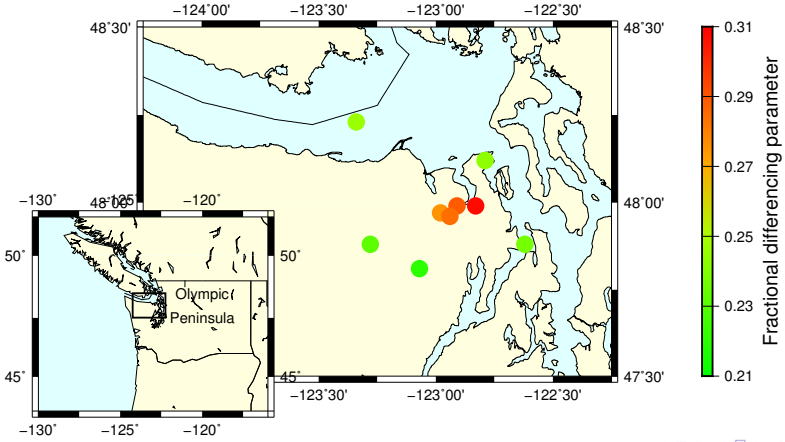
LFE catalogs from Mexico (Frank, 2014)



LFE catalogs from the San Andreas Fault (Shelly, 2017)



LFE catalogs from the Olympic Peninsula (Sweet *et al.*, 2019)



Future work

- Modeling the sequence of LFE occurrence times.
- Epidemic Type Aftershock Sequence (ETAS) model unsuccessful:
  - Model does not fit well the time sequence.
  - Model cannot reproduce the long-range dependence.
- Future work: Use more complex models based on neural networks.

Thank you

Thank you to the authors of the LFE catalogs: Shelley Chestler, William Frank, Alexandre Plourde, David Shelly, Justin Sweet

Questions?