Detection Of Extreme Events In Palaeo-climate Proxy Data Using Recurrence Plots

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Recurrence Plots

Recurrence is a fundamental property of dynamical systems. Recent developments in nonlinear data analysis have focused on recurrences in order to successfully analyse and understand processes in different scientific fields (physiology, economy, astrophysics etc.).

An appropriate tool for a recurrence analysis is the recurrence plot,

$$\mathbf{R}_{i,j} = \Theta\left(\varepsilon - \left\|\vec{x}_i - \vec{x}_j\right\|\right), \quad i,j = 1,\dots, N$$

which visualises such times, when a state of the system (at a certain time) recurs.

Recurrence plots exhibit typical large- and small-scale structures, which can be interpreted and quantitatively analysed (cf. Marwan et al., 2007). The density of points in a recurrence plot corresponds to the probability that the system recurs.

Here we propose the recurrence point density as a measure for the extremeness of a state at a certain time *i*.

$$RR_i = \sum_j \mathbf{R}_{i,j}$$

The more rare the state the smaller this value. Furthermore, we apply a normalisation ensuring that this measure of extremeness ranges between the values 0 and 1.

$$E_i = \frac{\sum RR_i - RR_i}{\sum_i RR_i} \quad \text{for} \quad \left(\sum RR_i - RR_i\right) > 0$$

The more this measure tends towards 1, the more rare the state at time *i* is.

References

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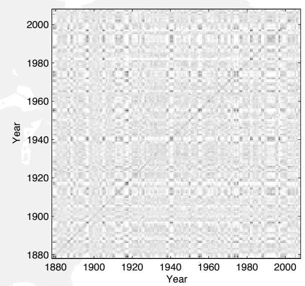
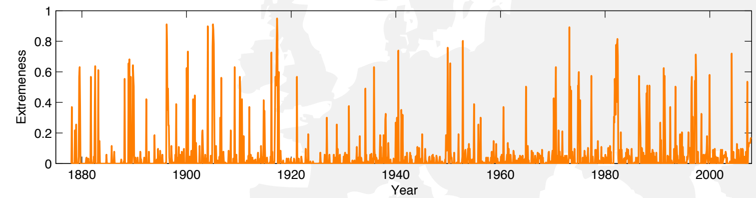
N. Marwan, M. H. Trauth, M. Vuille, J. Kurths: Comparing modern and Pleistocene ENSO-like influences in NW Argentina using nonlinear time series analysis methods, Climate Dynamics, 21(3–4), 317–326 (2003)

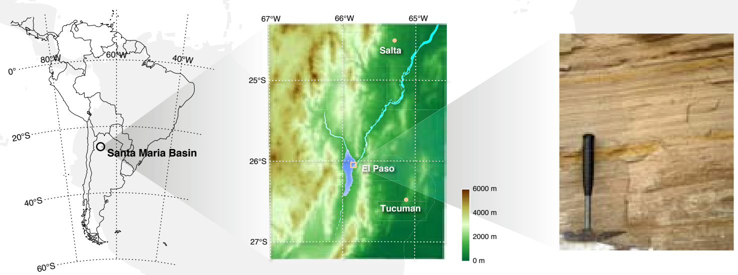
Southern Oscillation Index

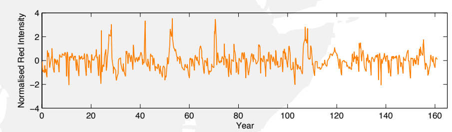




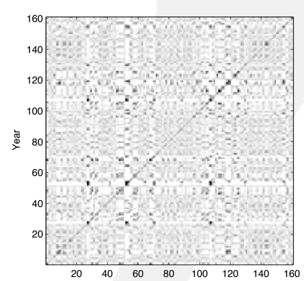
Recurrence plot (RP) and Extremeness for the Southern Oscillation Index (SOI). Bright regions in the RP correspond to rare events (which do not have to be El Niño or La Nina events!) and to high values of Extremeness *E*. The mean recurrence time between rare events (E > 0.9) is 44 years and for less "extreme" events (E > 0.7) is 9.5 years.

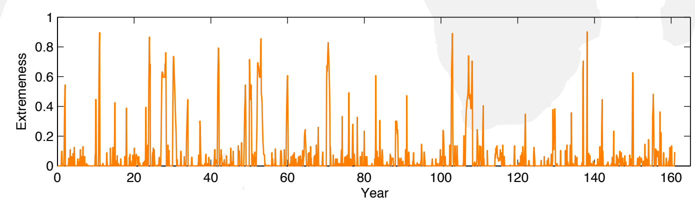
Palaeo-rainfall in NW Argentina





Warved lake sediments deposited in a palaeo-lake at the Santa Maria basin (NW Argentina) 35 kyr ago provide an archive of rainfall variation during this epoch (colour variation).





Recurrence plot (RP) and Extremeness fo a palaeo-rainfall proxy derived from lake sediments from NW Argentina (35 kyr). The mean recurrence time between "extreme" events (E > 0.9) is 54 years and for intermediate "extreme" events (E > 0.7) is 11.5 years.

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