Recurrence analysis of spatially extended high-dimensional dynamics

Recurrence plots and their quantification are modern and powerful tools for nonlinear time series analysis – however, can this approach be applied to high-dimensional systems?

$$R_{ij} = \Theta(t - \|x_i - x_j\|)$$

Phase space representation and corresponding recurrence plot.

Prototypical Example: Lorenz96

$$\frac{dx_k}{dt} = (x_{k+1} - x_k)x_{k-1} - x_{k-1} + f$$

shows different types of spatio-temporal dynamics (chaotic, periodic), high-dimensional ($x_k$ = state at node $k$, $f$ = external force)

Recurrence plots of (a) periodic (N=47) and (b) chaotic dynamics (N=47).

Real World Application: Satellite Time Series (EVI)

investigate the difference in the spatio-temporal vegetation dynamics in a subhumid (Spain) and a semiarid (Brazil) climate

Spatial-time representation of (a) periodic (N=47) and (b) chaotic dynamics (N=47).

EVI time series of all pixels in the subareas of (a) NE Spain and (b) NE Brazil.

Geographical location and MODIS covered geographic indices (EVI) within the 5 × 5 km² subareas used for the analysis for the regions (a) NE Spain and (b) NE Brazil.

Clear difference in the spatio-temporal vegetation dynamics where Spain shows a more regular pattern, whereas Brazil is characterized by a more irregular and less predictable behavior.