Multi-scale event synchronization analysis for unravelling climate processes: a wavelet-based approach

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▼ What did the authors try to accomplish?

- Study of event synchronization at multiple scales to comprehend the dynamics of the investigated climate processes.

▼ What were the key elements of the approach?

1. Discrete Wavelet Transform
    - Haar wavelet used (Choice of wavelet does not affect the results to a great extent
2. Event Synchronization

works as follows: an event occurs in signals $x(t)$ and $y(t)$ at time t_l^x and t_m^y, where $l = 1, 2, 3, 4, \ldots S_x$, $m =$

$1, 2, 3, 4, \ldots S_y$, and S_x and S_y are the total number of events, respectively. In our study, we derive events from a more-or-less continuous time series by selecting all time steps with values above a threshold ($\alpha =$ 95th percentile). These events in $x(t)$ and $y(t)$ are considered synchronized when they occur within a time lag $\pm\tau_{lm}^{xy}$ which is defined as follows:

$$\tau_{lm}^{xy} = \min\left\{t_{l+1}^x - t_l^x, t_l^x - t_{l-1}^x, t_{m+1}^y - t_m^y, t_m^y - t_{m-1}^y\right\}/2. \quad (7)$$

This definition of the time lag helps to separate independent events, as it is the minimum time between two succeeding events. Then we count the number of times $C(x|y)$ an event occurs in $x(t)$ after it appears in $y(t)$ and vice versa $(C(y|x))$:

$$C(x|y) = \sum_{l=1}^{S_x} \sum_{m=1}^{S_y J_{xy}} \tag{8}$$

and

$$J_{xy} = \begin{cases} 1 & \text{if} \quad 0 < t_l^x - t_m^y < \tau_{lm}^{xy} \\ \frac{1}{2} & \text{if} \quad t_l^x = t_m^y \\ 0 & \text{else.} \end{cases} \tag{9}$$

$C(y|x)$ is calculated analogously but with exchanged x and y. From these quantities we obtain the symmetric measure:

$$Q_{xy} = \frac{C(x|y) + C(y|x)}{\sqrt{(S_x - 2)(S_y - 2)}}. \tag{10}$$

Q_{xy} is a measure of the strength of event synchronization between signals $x(t)$ and $y(t)$. It is normalized to $0 \leq Q_{xy} \leq 1$, with $Q_{xy} = 1$ for perfect synchronization (coincidence of extreme events) between signals $x(t)$ and $y(t)$.

▼ What can you use yourself?

- Multi-Scale Event Synchronization

▼ What other references do you want to follow?

- Event Synchronization: Quiroga, R. Q., Arnhold, J., and Grassberger, P.: Learning driverresponse relationships from synchronization patterns, Phys. Rev. E, 61, 5142, https://doi.org/10.1103/PhysRevE.61.5142, 2000