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A Hilbert approach to investigate climate connectivity

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The Hilbert transform (HT) is a well-known method of time-series analysis that has been applied to a wide variety of oscillatory signals (physiological, neurological, geophysical, etc.). It provides, for each data point of a time-series, instantaneous amplitude, phase and frequency. In this work we investigate atmospheric data (ERA Interim reanalysis) at the global scale using the HT. We consider surface air temperature (SAT) with daily resolution, covering the period 1979-2017. We measure the statistical similarity of time series at different geographical regions by using the cross-correlation (CC) coefficient.

First, we analyse the connectivity of selected regions, by comparing CC maps computed from SAT anomaly time series and from Hilbert time series: instantaneous amplitude, frequency, phase and cos(phase). In the extra-tropics, we find that HT uncovers similar spatial patterns of connectivity as SAT anomalies (the analysis of the connectivity patterns as a function of time lag allows interpreting them as the effects of Rossby waves). In the tropics, Hilbert amplitude and SAT anomaly uncover similar connectivity maps, while in contrast Hilbert frequency analysis does not reveal any statistically significant connectivity.

We interpret these results as due to the fact that in extra-tropical regions, due to the annual cycle, SAT dynamics are similar to each other; while in tropical regions the annual cycle is weak and fast SAT variability (captured by large instantaneous frequency variations) is uncorrelated with the activity in the rest of the globe.

In a second step, we use the HT to quantify phase synchronisation: we calculate the well known Kuramoto parameter in three large-scale regions: northern extra-tropics, southern extra-tropics and the tropical belt. We find that the degree of synchronisation in the extra-tropics is high (being higher in the NH than in the SH, likely due to the presence of larger land masses), while the degree of synchronisation in the tropical region is very low.