A Hilbert approach to investigate climate connectivity

Dario A. Zappalà[1], Marcelo Barreiro[2], and Cristina Masoller[1]
[1]Universitat Politècnica de Catalunya, Departament de Física, 08222 Terrassa, Barcelona, Spain
[2]Universidad de la República, Instituto de Física, Facultad de Ciencias, Iguá 4225, Montevideo, Uruguay

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.). We have already used it to get, from temperature time series, instantaneous amplitude, phase and frequency [1]. Recently, we used it to find patterns of change in temperature dynamics that arised during the last decades [2]. In the present work we investigate atmospheric data (ERA-Interim reanalysis) at the global scale using the HT. We consider surface air temperature with daily resolution, covering the period 1979–2017.

Firstly, we use the HT to quantify phase synchronisation: we calculate the well-known Kuramoto parameter in three large-scale regions: northern extratropics, southern extratropics and the tropical belt. The result is shown in Fig. 1. We find that the degree of synchronisation in the extra-tropics is high (being higher in the NET than in the SET, likely due to the presence of larger land masses), while the degree of synchronisation in the tropical region is very low.

In a second step, we measure the statistical similarity of time series at different geographical sites by means of cross-correlation coefficient. We use this information to build a climate network and analyse the connectivity of selected regions. In particular, we compare connections computed from temperature anomaly with the ones computed from Hilbert time series (instantaneous amplitude, phase and frequency).

In the extra-tropics, we find that the HT uncovers similar spatial patterns of connectivity as temperature anomalies (the analysis of the connectivity patterns as a function of time lag allows us to interpret them as the effects of Rossby waves). In the tropics, Hilbert amplitude and temperature 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 the extratropics, temperature dynamics are similar due to the strong annual cycle; while in tropical regions the annual cycle is weak and fast temperature variability (captured by large instantaneous frequency variations) is uncorrelated with the activity in the rest of the globe.

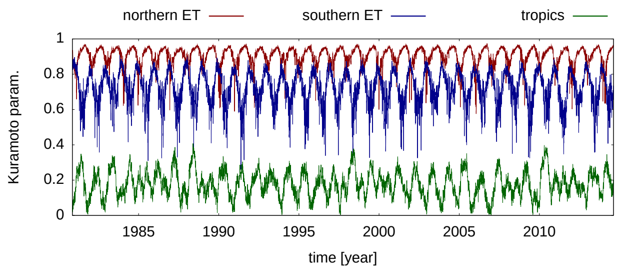

Fig. 1. Evolution of the Kuramoto parameter, calculated separately for three geographical regions: northern extratropics (lat > 30), southern extratropics (lat < -30) and tropics ($-30 \leq$ lat ≤ 30).

[1] D. A. Zappalà, M. Barreiro, and C. Masoller, Global atmospheric dynamics investigated by using Hilbert frequency analysis, Entropy **18**, 408 (2016).

[2] D. A. Zappalà, M. Barreiro, and C. Masoller, Quantifying changes in spatial patterns of surface air temperature dynamics over several decades, Earth Syst. Dynam. **9**, 383-391 (2018).