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Using Hilbert transform to uncover hidden periodicities in SAT time series

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Hilbert transform is a well-known tool that has been applied to a variety of complex signals (physiological, neurological, geophysical, etc.). The main limitation for its general applicability is the narrow-band nature of the signal. To overcome such restriction, the signal is first decomposed into a number of intrinsic mode functions (IMFs) by using the empirical mode decomposition (EMD); then, the Hilbert transform is applied to each component. This approach has the drawback that the decomposition of the signal in IMFs increases the complexity of the algorithm and is computationally demanding.

In this work we propose an alternative approach which is based in first using a smoothing moving average, and then applying the Hilbert transform to the smoothed signal. The key is the analysis of how the results of Hilbert analysis depend on the length of the smoothing window. To demonstrate the effectiveness of the proposed approach we analyse surface air temperature (SAT) time series, taken from a reanalysis dataset with daily time resolution.

We find that with increasing smoothing length, as expected, geographical areas with fast dynamics (period < 1 year) are gradually washed out, while in central Pacific Ocean an area of slow dynamics (period > 1 year) gradually emerges. Then, to further illustrate the insights obtained with this methodology, we characterise several relevant geographical regions in terms of the relation between the Hilbert phase and the day of the year, as a function of the smoothing window. This procedure allows to uncover climatic differences and hidden periodicities in SAT dynamics. We conclude by discussing how this new approach yields physically meaningful results that can be interpreted in terms of underlying known climatic processes.