Spatial Permutation Entropy: a new tool for climate data analysis

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Abstract

Efficient and effective data analysis techniques are needed to manage the large outputs of Earth models and monitoring systems. Spatial permutation entropy (SPE), a generalization of Permutation Entropy [1], is a nonlinear analysis tool that has been used to characterize two-dimensional (2D) data, such as images and textures [2]. In this work we present SPE as a new and valuable technique to characterize spatio-temporal geophysical data, allowing detailed comparison of different data sets at different scales. Specifically, we show that SPE is able to uncover differences in two sea surface temperature (SST) products, in two relevant geographical regions: the equatorial Pacific (Niño3.4) and the Gulf Stream. SPE is calculated as the entropy of the probabilities of occurrences of symbols that are defined along two orientations, west-east (WE) or north-south (NS), and either in consecutive grid points, or in grid points that are separated by a lag, δ. We find substantial differences between the analyzed datasets, ERA5 and NOAA OI v2, for the WE orientation with $\delta = 1$, that gradually disappear as δ increases. We also identify two transitions that correspond to the year 2007 when ERA5 changed its sea–surface boundary condition to OSTIA and the second one in 2021 when NOAA SST changed satellite, from MeteOp–A to MeteOp–C. These transitions were not detected when using conventional data analysis tools, which demonstrates that SPE is a valuable tool for the analysis of 2D geophysical data.

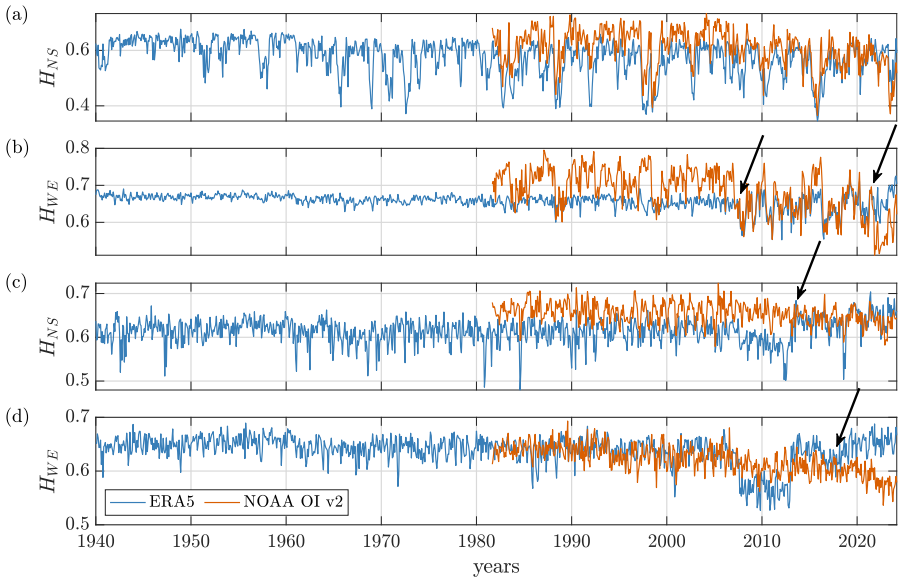

Figure 1: Spatial permutation entropy ($L = 4$ and $\delta = 1$) for the Niño3.4 region, panels (a) and (b), and for the Gulf Stream region, panels (c) and (d). Arrows indicate observed changes-transitions.

References

[1] Bandt, C., & Pompe, B. (2002). *Permutation entropy: a natural complexity measure for time series*. Physical review letters, 88(17), 174102.

[2] Ribeiro, H. V., Zunino, L., Lenzi, E. K., Santoro, P. A., & Mendes, R. S. (2012). *Complexity-entropy causality plane as a complexity measure for two-dimensional patterns*. PLoS One, 7, e40 689.