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The complexity of carbon flux time series in Europe

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Observed geophysical time series usually exhibit pronounced variability, part of which is process-related and deterministic ("signal"), another part is due to random fluctuations ("noise"). To discern these two sources for fluctuations is notoriously difficult using conventional analysis methods, unless sophisticated model assumptions are made.

Here, we present an almost parameter-free innovative approach with the potential to draw a distinction between deterministic processes and structured noise, based on ordinal pattern statistics. The method determines one measure for the information content of time series (Shannon entropy) and two complexity measures, one based on global properties of the order pattern distribution (Jensen-Shannon complexity) and one based on local (derivative) properties (Fisher information or complexity). Each time series gets classified via its location in an entropy-complexity plane; using this representation, the method draws a qualitative distinction between different types of natural processes.

As a case study, we investigate Gross Primary Productivity (GPP) and respiration which are key variables in terrestrial ecosystems quantifying carbon allocation and biomass growth of vegetation. Changes in GPP and ecosystem respiration can be induced by land use change, environmental disasters or extreme events, and changing climate. Numerous attempts to quantify these variables on larger spatial scales exist. Here, we investigate gridded time series at monthly resolution for the European continent either based on upscaled measurements ("observations") or modelled with two different process-based terrestrial ecosystem models ("simulations").

The complexity analysis is either visualized as maps of Europe showing "hotspots" of complexity for GPP and respiration, or used to provide a detailed observations-simulations and model-model comparison. Values found for information and complexity will be compared to known artificial reference processes, either stochastic (long-range correlated noise) or deterministic ones (chaotic maps). The spatial patterns emerging can be used for a classification of European ecosystems according to their complexity; finally, this classification may be compared to existing landscape classifications based on other properties of the terrestrial biota or on climate.