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Dynamical Systems Theory Sheds New Light on Compound Climate Extremes in Europe and Eastern North America

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We propose a novel approach to the study of compound extremes, grounded in dynamical systems theory. Specifically, we present the co-recurrence ratio (α), which elucidates the dependence structure between maps by quantifying their joint recurrences. This approach is applied to daily climate extremes, derived from the ERA-Interim reanalysis over the 1979-2018 period. The analysis focuses on concurrent (i.e. same-day) wet (total precipitation) and windy (10m wind gusts) extremes in Europe and concurrent cold (2m temperature) extremes in Eastern North America and wet extremes in Europe. Results for wet and windy extremes in Europe, which we use as a test-bed for our methodology, show that α peaks during boreal winter. High αvalues correspond to wet and windy extremes in north-western Europe, and to large-scale conditions resembling the positive phase of the North Atlantic Oscillation (NAO). This confirms earlier findings which link the positive NAO to a heightened frequency of extra-tropical cyclones impacting north-western Europe, resulting in frequent wet and windy extremes. For the Eastern North America-Europe case, α extremes once again reflect concurrent climate extremes -- in this case cold extremes over North America and wet extremes over Europe. Our analysis provides detailed spatial information on regional hotspots for these compound extreme occurrences, and encapsulates information on their spatial footprint which is typically not included in a conventional co-occurrence analysis. We conclude that α successfully characterises compound extremes by reflecting the evolution of the associated meteorological maps. This approach is entirely general, and may be applied to different types of compound extremes and geographical regions.