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Causal signatures in rainfall cascade: a wavelet approach

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A central topic in rainfall research is to determine whether rainfall variability at a given space-time scale is caused by dynamics acting at some other scales. Random multiplicative cascades (RMCs) are standard approaches for describing rainfall variability across a wide range of time scales. Their popularity stems from their ability to reproduce rainfall self-similarity and long-range correlations as well as intermittency buildup at finer scales. However, standard RMCs only predict instantaneous flow of variance (energy or activity) from large to fine scales and cannot account for scale-wise causal relationships. Such relationships reveal themselves through non-instantaneous cascade mechanisms – namely large scale events influencing finer scale events at later times (i.e. forward causal cascade) or conversely (inverse causal cascade). The presence of causal cascade signatures within the rainfall process is explored here using both continuous wavelet decomposition (CWT) and scale-by-scale causality measures such as cross-scale correlation and linearized transfer entropy. The causality hypothesis is further tested against results from toy models, surrogate data, and a scalar turbulence time series (water vapor) to ensure that rainfall causality is not an artifact of the estimation method or resulting from the redundancy in CWT. The analysis demonstrates the presence of causal cascades (mainly forward) in rainfall series when sampled at fine temporal resolutions (seconds). These causal relationships tend to vanish when rainfall is aggregated at coarser time scales (hours and longer).