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Theoretical framework for the stochastic synthesis of the variability of global-scale key hydrological-cycle processes and estimation of their predictability limits under long-range dependence.

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Uncertainty and change in geophysical processes can be robustly quantified by analyzing the observed variability. A challenging task in engineering studies is to introduce a framework that can simulate this observed variability while preserving only important stochastic attributes. An innovative methodology for genuine simulation of stochastic processes is presented based on the recent work by Koutsoyiannis and Dimitriadis (2021). The proposed algorithm includes the demanding task of simulating any second-order dependence structure of a process (with a focus on long-range dependence behaviour) and any marginal distribution (with focus on heavy tails) through the explicit preservation of its autocovariance function and its cumulants. The long-range dependence behaviour (i.e., power-law drop of variance vs. scale) and heavy-tails are known to be highly associated with the variability magnitude of a process, through which the range of its predictability-window can be also quantified. To estimate this range, an extensive global-scale network of stations of key hydrological-cycle processes (i.e., near-surface hourly temperature, dew point, relative humidity, sea level pressure, atmospheric wind speed, streamflow, and precipitation; for details see Dimitriadis et al., 2021) is analyzed using ensemble techniques and the proposed stochastic simulation algorithm. The limitations of existing methodologies for the stochastic simulation and estimation of the predictability-window, and how can they be tackled through the proposed approach, are discussed over applications in flood risk management.

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