Stochastic Weather Generation at High Spatial Resolution Informed by Convection-Permitting Modeling

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In a warming climate a projected increase in precipitation extremes is expected, and it has already been observed in many regions. Anyway, its translation into hydrological impacts, such as changes in flood frequency and magnitude, remains uncertain because runoff generation is modulated by the interplay of precipitation, snow processes, soil moisture, and catchment characteristics. Hydrological applications need long record to assess the hydrological response of catchments to climate change, but current tools used for the simulation of precipitation face limitations. Convective-permitting models (CPMs) provide physically realistic sub-daily precipitation but are computationally expensive and usually limited to about 10 years of simulations. Stochastic weather generators offer statistical realism and can produce long synthetic time-series, but they lack explicit climate-change integration. We aim to bridge these gaps by re-parameterizing the two-dimensional weather generator AWE-GEN-2d for a future, warmer climate, using CPM-derived factors of change. The framework is applied to three alpine catchments in South Tyrol (Italy), characterized by high elevations and strong elevation gradients. The study domain is equipped with a dense hydro-meteorological monitoring network including streamflow, rainfall, and temperature stations. A semi-distributed conceptual hydrological model, ICHYMOD, is used to simulate runoff generation and streamflow, and the TOPMELT snowpack model estimates spatially distributed snow accumulation and melt. Evaluation of weather generator outputs shows good agreement with observed precipitation and temperature statistics, with realistic storm occurrence and extreme precipitation behavior. Hydrological simulations forced by the generated data reproduce observed runoff patterns with minor seasonal deviations, supporting their applicability for exploring catchment-scale hydrological responses to climate change. This integrated framework demonstrates the potential of combining CPM climate projections with stochastic weather generators as input for hydrological modelling to better simulate the changes in climate dynamics and their hydrological responses. It provides a robust tool for assessing runoff patterns, extreme flows, and snow-driven contributions under current and future climate scenarios, supporting improved understanding of hydrological processes in high-elevation catchments.

Keywords: Hydrology, AWEGEN, Convection, Permitting Model

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