

Generative AI for Climate-Informed Precipitation Synthesis: Implications for Flood Modeling and Uncertainty Propagation

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ABSTRACT

This study investigates the potential of generative artificial intelligence (AI) to produce climate-informed synthetic precipitation fields, addressing key limitations of conventional stochastic and statistical rainfall generators, particularly in data-scarce regions. The proposed framework is applied to the Tetouan Martil region (northern Morocco), where observational records are sparse and flood risk is significant. We develop an integrated modeling chain that links AI-based precipitation generation to hydrological transformation and subsequent hydrodynamic simulation. This end-to-end framework enables the propagation of multiple synthetic precipitation realizations through the system, allowing for probabilistic flood hazard assessment and improved flood risk mapping. However, the cascading structure of the modeling chain introduces compounded uncertainties originating from model structure, parameterization, and input variability. In this work, we focus on systematically quantifying these uncertainties, with particular emphasis on those associated with the generative precipitation models. We assess how uncertainty propagates across the hydrological–hydrodynamic continuum and evaluate its impact on flood extent and intensity estimates. The results provide critical insights into the reliability and robustness of AI-driven hydroclimatic modeling frameworks, supporting their application in risk assessment and decision-making in data-limited environments.

Keywords: Artificial Intelligence; Rainfall generator; Data-scarce region; Flood risk mapping.