Extreme Rain Generation Modeling using Score-Based Generative Models

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Modeling extreme rainfall, and extreme events in general, remains a major challenge in stochastic weather generation due to their complex dependencies and heavy-tailed statistical nature. Traditional statistical and physical models often struggle to accurately represent heavy-tailed distributions, while classical machine learning approaches such as Normalizing Flows, GANs, and VAEs typically fail to capture fine distributional details or correctly reproduce tail behavior. Score-Based Generative Models (SGMs), also known as diffusion models, have recently demonstrated remarkable performance in both tabular and image data modeling, establishing themselves as state-of-the-art methods for learning complex probability distributions. From a diffusion-theoretic perspective, the success of SGMs crucially depends on the proper choice of the initial distribution, the denoising network, and the discretization schedule. By carefully tuning these components and leveraging sufficient data, SGMs provide a simple yet powerful framework for the detailed modeling of heavy-tailed distributions. In this work, we investigate the potential of SGMs for modeling heavy-tailed distributions, presenting preliminary results that highlight their ability to reproduce realistic samples and capture extreme tail behavior with high generation quality.

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