The effects of climate change on Intensity-Duration-Frequency curves: past and future trends based on multifractal scaling arguments

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Intensity-Duration-Frequency (IDF) curves are fundamental tools for engineering design, as they encompass information on extreme rainfall over a wide range of characteristic temporal scales and exceedance probability levels. Since natural systems are argued to evolve in ways that current protection standards may be systematically overwhelmed in the upcoming years, several non-stationary IDF estimation approaches have been proposed, allowing for distribution parameter estimates to vary (in most cases linearly) with time. Yet, the introduction of additional model parameters increases the estimation variance of rainfall intensity quantiles, especially when interest is in low probability events. To remedy the foregoing complication, Emmanouil et al. (2022) proposed an elaborate parametric approach founded on multifractal (MF) scaling arguments (see Langousis et al., 2009), which assumes that the statistical structure of rainfall at interannual scales can be approximated by sequential realizations of a stationary multifractal process with parameters that vary slowly across (not within) realizations. The MF framework has been proven particularly robust when describing the intensity and frequency of extreme rain rates from small precipitation samples (i.e., down to 2 years; see Emmanouil et al., 2020) and, therefore, it can be effectively applied to adequately short sequential segments of data, allowing for climatic variations to be revealed. In this study, we evaluate the effects of future climate pathways on IDF curves under a wide spectrum of topographical and climatological conditions, by extending the analysis of Emmanouil et al. (2022) to statistically downscaled estimates of multiple climate model outputs (e.g., Mearns et al., 2017) that cover a 120-year period (i.e., from 1979 to 2099) over the Contiguous United States (CONUS). The results show that, on average, the IDF curves display similar shifts and trends over the study domain, for both historical data and climate model hindcasts. However, it is revealed that the dependence structure and variability of extreme rain rates vary significantly across data sources, and should be meticulously characterized when assessing how existing infrastructure and future design considerations could actually be affected. Finally, we argue that based on the rate of changes in future IDF estimates, strategically planned future infrastructure could encapsulate all possible outcomes for the remainder of the century.

References

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