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Downscaling of Extreme Precipitation: Proposing a New Statistical Approach and Investigating a Taken-for-Granted Assumption

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In spite of the ability of General Circulation Models (GCMs) to predict and generate atmospheric variables under pre-identified climate change scenarios, their coarse horizontal scale is an obstacle for impact studies. Therefore, downscaling of variables (e.g., precipitation) from coarse spatial and temporal scales to finer ones is inevitable. Downscaling methods are classified into various types ranging from applications related to short term numerical weather prediction to multidecadal global climate prediction. For engineering applications of impact assessment of climate change on infrastructure, the multidecadal global climate projection, is the most widely used type. One of the important engineering applications of climate change impact assessment is the development and reconstruction of intensity-duration-frequency (IDF) curves under possible climate change. IDF curves are widely used for design and management of urban hydrosystems. Their construction requires accurate information about intense short duration rainfall, including sub-hourly, extremes. Previous attempts were made to construct IDF curves in various places under climate change using dynamical and statistical downscaling. The deficiency of GCMs, and even RCMs, in representing local surface conditions, especially extreme weather and convective precipitation in many areas, necessitates the use of statistical downscaling for IDF-related applications. In statistical downscaling methods, and in particular regression-based methods, the search is always for the optimum set of inputs at a coarser scale that act as predictors for the desired surface weather variable (predictand) at the local finer scale. The grid box nearest to the local site may not provide the optimum predictor-predictand relationship. In fact, even the set of predictors varies from one region to another.

In this study, a novel approach using genetic programming (GP) for specific application of downscaling annual maximum precipitation (AMPs) is presented. For constructing IDF-curves, only AMPs of different durations are needed. Strong correlation between the AMPs at the coarse-grid scale as output from GCMs and AMPs at the local finer scale is observed in many locations worldwide even though such a correlation may not exist between the corresponding time series of continuous precipitation records. The use of the GP technique, in particular its genetic symbolic regression variant, for downscaling the annual maximum precipitation is further expanded in two ways. First, the exploration and feature extraction capabilities of GP are utilized to develop both GCM-variant and GCM-invariant downscaling models/mathematical expressions. Second, the developed models as well as clustering methods and statistical tests are used to investigate a fundamental assumption of all statistical downscaling methods; that is the validity of the downscaling relationship developed based on a historical time period (e.g., 1960-1990) for the same task during future periods (e.g., up to year 2100). The proposed approach is applied to the case of constructing IDF curves for the City of Saskatoon, Canada. This study reveals that developing a downscaling relationship that is generic and GCM-invariant might lead to more reliable downscaling of future projections, even though the higher reliability comes at the cost of accuracy.