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Rainfall Downscaling Conditional on Upper-air Atmospheric Predictors: Improved Assessment of Rainfall Statistics in a Changing Climate

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To improve the level skill of Global Climate Models (GCMs) and Regional Climate Models (RCMs) in reproducing the statistics of rainfall at a basin level and at hydrologically relevant temporal scales (e.g. daily), two types of statistical approaches have been suggested. One is the statistical correction of climate model rainfall outputs using historical series of precipitation. The other is the use of stochastic models of rainfall to conditionally simulate precipitation series, based on large-scale atmospheric predictors produced by climate models (e.g. geopotential height, relative vorticity, divergence, mean sea level pressure). The latter approach, usually referred to as statistical rainfall downscaling, aims at reproducing the statistical character of rainfall, while accounting for the effects of large-scale atmospheric circulation (and, therefore, climate forcing) on rainfall statistics.

While promising, statistical rainfall downscaling has not attracted much attention in recent years, since the suggested approaches involved complex (i.e. subjective or computationally intense) identification procedures of the local weather, in addition to demonstrating limited success in reproducing several statistical features of rainfall, such as seasonal variations, the distributions of dry and wet spell lengths, the distribution of the mean rainfall intensity inside wet periods, and the distribution of rainfall extremes. In an effort to remedy those shortcomings, Langousis and Kaleris (2014) developed a statistical framework for simulation of daily rainfall intensities conditional on upper air variables, which accurately reproduces the statistical character of rainfall at multiple time-scales.

Here, we study the relative performance of: a) quantile-quantile (Q-Q) correction of climate model rainfall products, and b) the statistical downscaling scheme of Langousis and Kaleris (2014), in reproducing the statistical structure of rainfall, as well as rainfall extremes, at a regional level. This is done for an intermediate-sized catchment in Italy, i.e. the Flumendosa catchment, using climate model rainfall and atmospheric data from the ENSEMBLES project (http://ensembleseu.metoffice.com). In doing so, we split the historical rainfall record of mean areal precipitation (MAP) in 15-year calibration and 45-year validation periods, and compare the historical rainfall statistics to those obtained from: a) Q-Q corrected climate model rainfall products, and b) synthetic rainfall series generated by the suggested downscaling scheme. To our knowledge, this is the first time that climate model rainfall and statistically downscaled precipitation are compared to catchment-averaged MAP at a daily resolution.

The obtained results are promising, since the proposed downscaling scheme is more accurate and robust in reproducing a number of historical rainfall statistics, independent of the climate model used and the length of the calibration period. This is particularly the case for the yearly rainfall maxima, where direct statistical correction of climate model rainfall outputs shows increased sensitivity to the length of the calibration period and the climate model used. The robustness of the suggested downscaling scheme in modeling rainfall extremes at a daily resolution, is a notable feature that can effectively be used to assess hydrologic risk at a regional level under changing climatic conditions.

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