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Short Commentary

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Statistical Procedure for the Downscaling of Daily Rainfall Time Series at Ungauged Locations

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Implications for Science and technology development

The management and allocation of water resources have been considered as one of the most significant endeavors in human society due to water's vital role in all natural and environmental systems. However, in most practical applications, precipitation records at the location of interest are often either limited or unavailable due to the lack of adequate network of rainfall measurements. Moreover, the estimation and prediction of hydrological variables with climate change conditions for ungauged sites remains a crucial challenge for water resources applications. This study demonstrates a statistical procedure to downscale climate change model outputs at ungauged stations. The proposed model is consistent of three steps: i) regionalization approach using PCA/OFA for identifying homogeneous regions of daily precipitation series, ii) stochastic weather model for estimating daily precipitation series at ungauged locations, and iii) a statistical downscaling model (SDRain).

As the first step, a regionalization technique was proposed based on the similarities of both precipitation amount and occurrence at different locations using the combination of Principal Component Analysis (PCA) and Ordinal Factor Analysis (OFA) for describing the spatial properties of daily precipitation. The PCA/OFA allows to identify regions within which stations have similar statistical properties. Hence, station observations within the delineated homogeneous region can be used to estimate precipitation at other locations within the region [1].

The second step in the proposed method involves a Stochastic weather generator (SWG). In general, SWGs have been widely used to generate synthesized hydrometeorologic information in agricultural, hydrological, or climate change impacts studies [2,3]. The representation of precipitation amount and occurrence are two main components of them. For reproducing daily precipitation amount process, major uncertainty in SWGs results from the selection of an appropriate distribution and a parameterization method. Moreover, Markov Chain Models (MCMs) have been used with different order states to derive the random feature of wet/dry process. Although these MCMs provide synthesized information on daily time scales [2,4], there is no match between the daily observed and estimated occurrences. However, keeping the time property of the estimated daily series is one of major factors because the main purposes of this study are not only generating daily precipitation series but also estimating accurately daily streamflow rate from catchments. Therefore, Yeo et al. [5] proposed a new stochastic model to transfer daily precipitation information from a station to another based on actual observed daily data rather than the long-term observed data pool.

The third step in this study includes a statistical downscaling model that links atmospheric variables, which represent circulation features, to the daily hydrometeorological information synthesized the previous SWG for an ungauged location. Due to too coarse spatial resolutions, various downscaling methods have been hence proposed for associating GCM predictions of climate change with hydrologic processes at the desired space and time scales [4]. However, these downscaling methods are not suitable for dealing with cases where precipitation data at the location of interest are limited or not available because a sufficient record of observed data is required for establishing a linkage between GCMs' output and observed data. There is, therefore, a growing need to suggest a new downscaling method for assessing climate change impacts on ungauged locations.

The feasibility of the proposed approach is assessed using the available daily precipitation data for the period 1971–2000 from a network of 38 rain gauge stations in the Catskill Mountain region of New York State, United States and three climate change scenarios (RCP 2.6, RCP 4.5, and RCP 8.5) given by the second-generation Canadian Earth System Model (CanESM2). Because the Catskill Mountains provide most of the water supply for New York City and other regional municipalities, changes to the hydrological cycle over the system can be critical to over nine million residents of New York State [1]. Due to complex seasonal and spatial patterns of precipitations caused by the geographical features of the region, the information on the spatial distribution of precipitation at a sufficiently high resolution is essential to allow calculation of local values of hydrologic variables such as streamflow. This study encompassed five watersheds and the surrounding region of about 31,000 km2 in New York and Pennsylvania. Historical precipitation data over this region were obtained from the Northeast Regional Climate Center (NRCC) and National Climatic Data Center (NCDC) of National Oceanic and Atmospheric Administration (NOAA). Daily precipitation data from the 1950s at 38 rain gauge stations in this region were used to establish a model of spatial distribution of precipitation. After identifying the homogeneous regimes for daily precipitation series, comparison study was carried out using the observed and estimated time series in order to evaluate the modeling performance. From the comparison with the observed time series, it was concluded that the proposed generator could produces accurate daily precipitation series. As the last step, theconstructed daily time series was implemented to SDRain with three climate change scenarios given by CanESM2. The calibrated precipitation series for an ungauged location are used to projecting future weather condition from 2006 to 2100. Application results have indicated that the proposed SD procedure for an ungauged site could.Provide comparable results as those given by the downscaling method for a gauged location with the available real-observed precipitation data.

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