Journal of Hydrology 510 (2014) 182–196

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Nonparametric statistical temporal downscaling of daily precipitation to hourly precipitation and implications for climate change scenarios

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ARTICLE INFO

Article history:
Received 23 April 2013
Received in revised form 9 September 2013
Accepted 15 December 2013
Available online 21 December 2013
This manuscript was handled by Andras Bardossy, Editor-in-Chief, with the assistance of Uwe Haberlandt, Associate Editor

Keywords:
Climate change
Daily precipitation
Extreme events
Hourly precipitation
RCP
Temporal downscaling

SUMMARY

Hydro-meteorological time series on finer temporal scales, such as hourly, are essential for assessing the hydrological effects of land use or climate change on medium and small watersheds. However, these time series are, in general, available at no finer than daily time intervals. An alternative method of obtaining finer time series is temporal downscaling of daily time series to hourly time series. In the current study, a temporal downscaling model that combines a nonparametric stochastic simulation approach with a genetic algorithm is proposed. The proposed model was applied to Jinju station in South Korea for a historical time period to validate the model performance. The results revealed that the proposed model preserves the key statistics (i.e., the mean, standard deviation, skewness, lag-1 correlation, and maximum) of the historical hourly precipitation data. In addition, the occurrence and transition probabilities are well preserved in the downscaled hourly precipitation data. Furthermore, the RCP 4.5 and RCP 8.5 climate scenarios for the Jinju station were also analyzed, revealing that the mean and the wet-hour probability (P1) significantly increased and the standard deviation and maximum slightly increased in these scenarios. The magnitude of the increase was greater in RCP 8.5 than RCP 4.5. Extreme events of different durations were also tested. The downscaled hourly precipitation adequately reproduced the statistical behavior of the extremes of the historical hourly precipitation data for all durations considered. However, the inter-daily relation between the 1st hour of the present day and the last hour of the previous day was not preserved. Overall, the results demonstrated that the proposed temporal downscaling model is a good alternative method for downscaling simulated daily precipitation data from weather generators or RCM outputs.

1. Introduction

General climate models (GCMs) and their spatially downscaled versions, regional climate models (RCMs), provide superb areal coverage (Orlowsky et al., 2008; Kendon et al., 2010). Hydrologists employ the outputs of these models to characterize the interaction between the land surface and the atmosphere and to assess the hydrological effects of climate change (Prudhomme and Nick Reynard, 2002). While time series data are essential for assessing the hydrological effects of climate change on medium- or small-sized watersheds, time series of hydro-meteorological variables of interest such as precipitation (or rainfall) are not always available at the desired time interval (Alfieri et al., 2012). Therefore, hydro-meteorological data with time scales on the order of 1 h or less are urgently required (Krajewski et al., 1991).

Weather generators, one of the popular statistical downscaling methods, can provide daily outputs. In the literature, weather generators for statistical downscaling are used to simulate the time series of daily hydro-meteorological variables (Soltani and Hoogenboom, 2003; Mason, 2004; Boe et al., 2007; Lee et al., 2012). However, physical rainfall-runoff simulations with daily rainfall underestimate the magnitude of runoff by averaging out the characteristics of short and intense rainfall (Eagleson, 1978). To obtain precipitation time series with finer temporal resolution, the creation of hourly time series from daily time series using disaggregation rules such as preserving the diurnal cycle and the additive condition is recommended (Jones and Harpham, 2009).

Several approaches for statistical temporal downscaling of precipitation time series have been suggested in the literature, including methods based on a point-process model (Rodriquez-Iturbe et al., 1988; Glasbey et al., 1995; Koutsoyiannis and Onof, 2001; Marani and Zanetti, 2007). Koutsoyiannis and Onof (2001) used the Bartlett-Lewis model to simulate rainfall time series by

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http://dx.doi.org/10.1016/j.jhydrol.2013.12.027

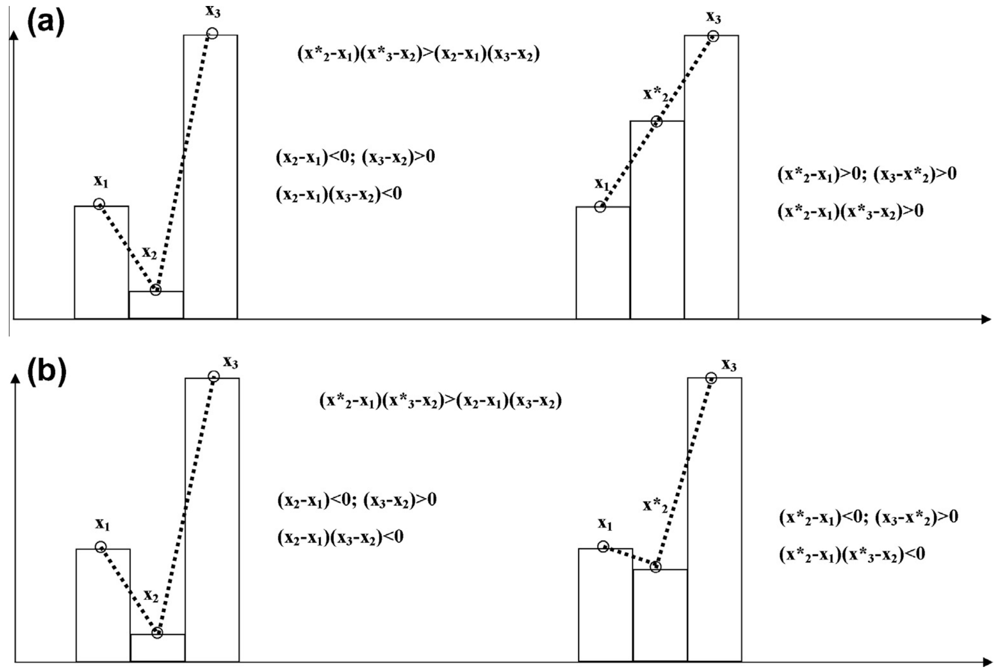

Fig. 1. Selection of crossover element with respect to the rule of gradual variation in a precipitation event. Note that for both (a and b) cases, it is supposed to substitute x_2 into x_2^* since x_2^* more likely follows the rule of precipitation gradual variation.

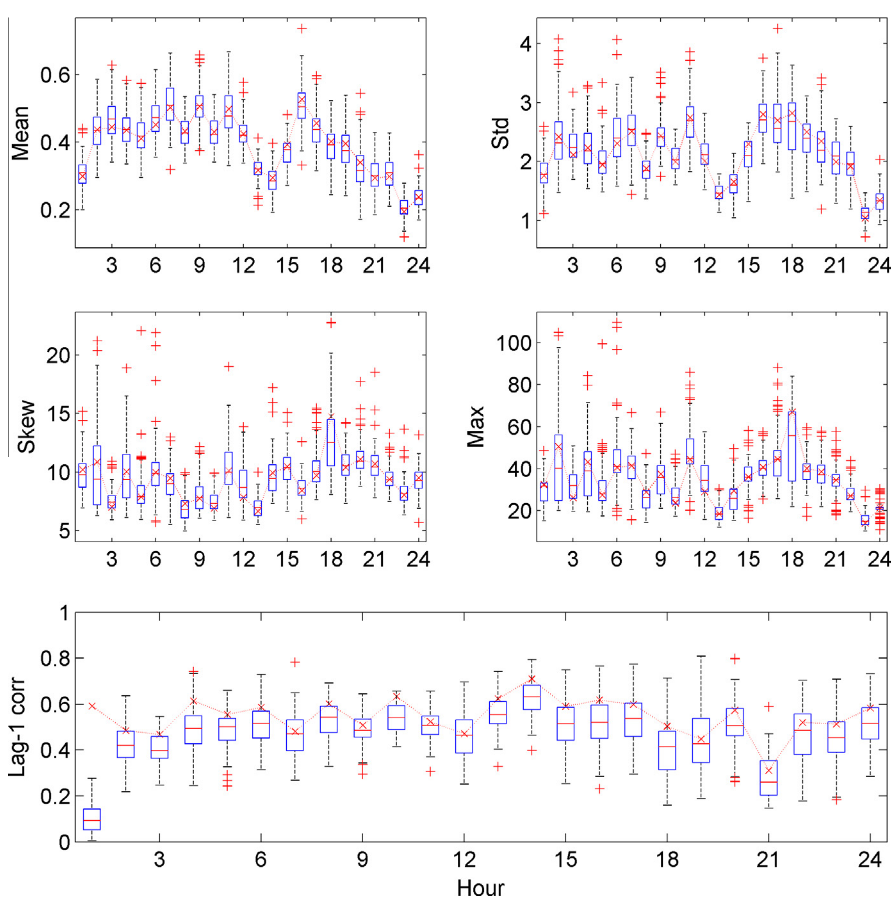

Fig. 2. Key statistics of the historical data (–×–) and downscaled data (boxplots) with the proposed model without considering the inter-daily connection for month 8 of Jinju station. The employed values of the GA mixture parameters, P_c and P_m are 0.3 and 0.1, respectively.