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Comparison of the SDSM and LARS-WG weather generators in Modeling of Climate Change in Golestan Province of Iran

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Abstract

The impact of climate change on hydrologic design and management of hydro systems could be one of the important challenges faced by future practicing hydrologists and water resources managers. Because of the increasing demand for water, studying the potential climate change and its impacts on water resources is necessary. The purpose of this paper is to predict the climate change based on the General Circulation Models (GCM), by applying two weather generators, namely SDSM and LARS-WG, at the Golestan province of Iran, in the period of 2011-2040 and compare their Result for a variety of different weather characteristics of the observed and synthetic weather data such as, the lengths of wet and dry series, the distribution of precipitation and Temperature. After modeling different Result obtained from SDSM and LARS-WG Models, will be compare to select the best climate change model for the case study.

Keywords: Weather generators, Model comparison, Climatic change, LARS-WG, SDSM

1. INTRODUCTION

A rising trend of the Earth's temperature and changes in the associated weather conditions across the globe are referred to as climate change. In the absence of suitable mitigation and adaptation measures, climate change is likely to affect major sectors of the world, such as agriculture, water resources, and tourism. Global Climate Models (GCMs), which are presently considered to be the most reliable source providing the climate change information, have spatial resolutions too coarse for hydrologic impact models. To provide hydrologists with the desired information in terms of hydro-meteorological variables at a very fine spatial resolution (in the order of a few kilometers) or station scale, downscaling is usually employed. The existing downscaling techniques have two broad classes: statistical and dynamical. Extensive details about the theories behind these classes as well as their advantages and disadvantages can be found in [1 to 4]. Among the statistical downscaling techniques used by hydrologists to obtain station-scale climatic information, multiple regression models and stochastic weather generators have far more applications than the others [5], as they are computationally less demanding, simple to apply, and efficient [6 to 9]. Regression-based downscaling methods involve developing empirical relationships between large-scale GCM data or observed data as ‘‘predictor’’ variables and local- or small-scale climate variables as ‘‘predictand’’ variables (e.g. temperature, precipitation) using traditional linear and nonlinear regression methods [10,11]. Examples of traditional regressionbased downscaling methods include linear regression, canonical correlation analysis (CCA), and principal component analysis (PCA) [12].

Weather generators are traditionally used to stochastically generate long synthetic series of data, fill in missing data, and produce different realizations of the same data [13]. They employ random numbers and take the observed time series of a station/site as input. Stochastic weather simulation is not new, and has a long history starting from the 1950s, as reported by Racsko [14]. Among the researchers who contributed to its evolution are Bruhn [15], Bruhn et al. [16], Nicks and Harp [17], Richardson [18], Richardson and Wright [19], and Schoof et al. [20]. Wilby presented a comprehensive review of its theory and evolution over time

[13]. Weather generators have also been employed to simulate long time series of hydrometeorologic variables that can be used by crop growth models for forecasting gricultural production [21,22], multi-site data generation [23], and assessment of risk associated with climate variability [24]. Further details on the use of weather generators in crop productionstudies can be found in Semenov [25].

Statistical downscaling methods are usually considered to be not very effective for simulation of extreme events of precipitation [13]. On the other hand, the frequency and intensity of extreme precipitation events are very likely to come under impact of envisaged climate change in most parts of the world (IPCC) [26], thus posing the risk of increased floods and droughts. In this situation, hydrologists should only rely on those statistical downscaling tools that are equally efficient for simulating means

as well as extreme precipitation events. Thus, there is indeed a need for testing the available statistical downscaling tools for their ability to simulate extreme climatic events, especially precipitation (which is highly complex in nature and difficult to model) at the watershed scale. There have been some studies on this topic, but they have mainly used nonparametric methods based on extreme climatic indices [27]. Fowler et al. [4] have commended the study by Goodess et al. [28]as the most comprehensive study comparing skills of many different downscaling methods for simulating climatic extremes in terms of 10 extreme indices. They have also argued over the applicability of such indices-based studies for hydrologic

impact assessment, as these studies deal only with moderate extremes while frequency of rare events is more desirable to hydrologists. Semenov [29] has pioneered the evaluation of a weather generator in terms of simulating rare precipitation events through the use of parametric distributions. The present study focuses on the evaluation and comparison of two very popular statistical downscaling models in terms of their ability to simulate extreme precipitation frequency using a parametric distribution at a watershed scale. The first model is the SDSM, which is a multiple regression model [13], and the second model is the Long Ashton Research Station Weather Generator (LARS-WG), which was specially designed for climate change studies [30].

The rest of the paper is organized as follows. First, a brief description of the study watershed and data sources is given. Next, details of methods and analysis are provided, which include application of the two downscaling models and climate parameters analysis. This is followed by presentation of results and their discussion. Finally, conclusions of the study are given.

2. Area under study and Data

Gorganroud basin is the sixth basin of first grade Basin of Caspian Sea which is located in the southeastern part of this sea. This basin has been located in elevation of 132, Longitude range of 54-00 to 56-29' Eastern and latitude 36-36' to 37-47' Northern and it is bounded to Atrak river basin in North and East and to basin of salt desert in South and to Neka river basin in Southwest [31].

Average annual rainfall in the basin is varied about from 300 mm in the northern and southern sides of the basin to 1000 mm in the central part of it and the annual rainfall variation procedure is the Mediterranean-like. The annual mean temperature is variable from about 17 degrees Celsius in the area of low-altitude to 7.5 ° C in the southern highlands [31].

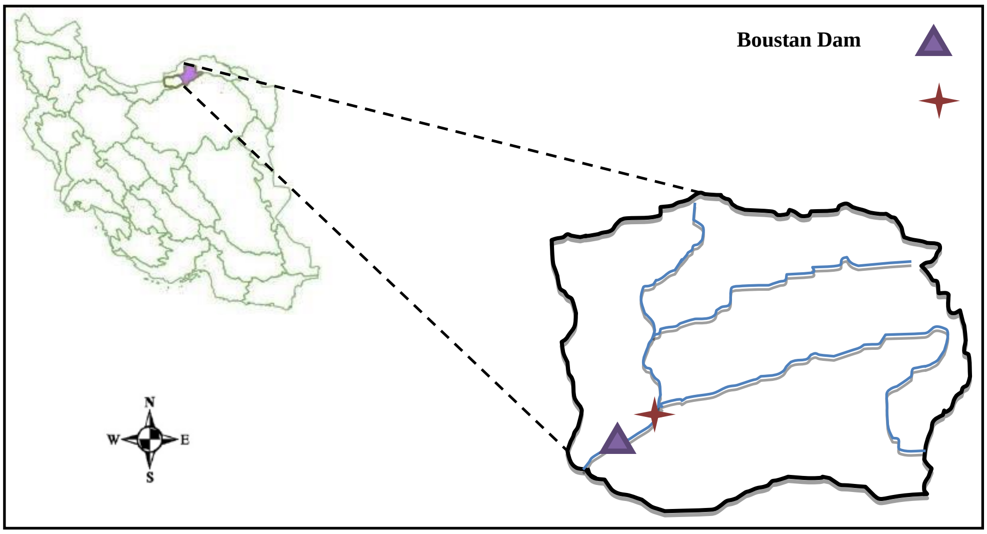

Fig. 1. Location of the study area

In this study, data will be used from Tamer meteorological stations located in the upstream of Boustan dam in Gorganroud basin of Golestan Province at the base of a 30-year period (1981 to 2010) [31]. It is worth mentioning that the choice of this period is such that firstly, the station has enough data and secondly, wet, dry and normal periods have been occurred during this period. Checking the accuracy and precision of the collected data has been studied at the beginning by objective examinations and comparison of numbers among nearby stations and suspicious and unaccepted numbers and digits have been omitted from the calculations.

3. Methodology

The statistical downscaling model (SDSM) is a multiple regression-based tool for generating future scenarios to assess the impact of climate change. It has the ability to capture the inter-annual variability better than other statistical downscaling approaches, e.g. weather generators, weather typing [13]. The model is a combination of a stochastic weather generator approach and a transfer function model [13] needing two types of daily data. The first type corresponds to local predictands of interest (e.g. temperature, precipitation) and the second type corresponds to the data of large-scale predictors (NCEP and GCM) of a grid box closest to the study area. Correlation and partial correlation analysis are performed in SDSM between the predictand of interest and predictors to select a set of predictors most relevant for the site in question [13]. Initially, the precipitation data of Tamer station in the study watershed are used in SDSM.

The Long Ashton Research Station Weather Generator (LARS-WG) can be used to synthesize daily data and fill in missing values of a recorded climatic time series. It can also generate data of an ungaged site for the daily climatic parameters, such as precipitation, temperature, and solar radiation (using observed data properties of a neighboring gaged site). It takes as input the long-term daily information of the climatic parameter of interest for a site. It can also generate the scenarios of changed climate for a site by perturbing the parameters derived from the observed data to generate synthetic data, representing future climate change.

Frequency analysis of precipitation is used in this study mainly to evaluate SDSM and LARS-WG in terms of simulating extreme precipitation events of present climate and downscaling future extreme events. This analysis is based on the data obtained from three time series: Observed, SDSM, and LARS-WG. In SDSM, the data series is obtained from the 30-year long daily precipitation time series generated using the calibrated and validated model and the NCEP predictors' set for the period of 1981–2010. The LARS-WG is used after calibration to produce a 30-year daily precipitation time series without any perturbations to the precipitation properties and, based on derived RCFs, a 30-year precipitation time series representing a future time. From these two sets of synthetic time series, the values are obtained for further analysis.

4. Results and discussion

Figure 2 shows comparisons of the observed and the SDSM-estimated month precipitation. Examination of Fig. 2 shows that the model reproduces the monthly precipitation values quite well. It slightly underestimates the precipitation for the months of Jan, May, Jun, Jul, Aug and Sep and almost equally overestimates it in the months of, Feb, Mar, Apr, Oct, Nov, and Dec. As Wilby et al. point out, downscaling models are often regarded as less able to model the standard deviation (or variance) of the observed precipitation with great accuracy [13]. Figure 3 shows the results obtained using LARS-WG. As can be seen, the precipitation for each month are very well modeled by LARS-WG, except for the Jan, May and Dec months where it underestimates the mean precipitation in the other months precipitation equally overestimates.

These two contrasting pictures of the future are a result of the difference in the basic concept behind the two downscaling models. The SDSM makes use of the changes in atmospheric circulation patterns in terms of the large-scale predictors, as suggested by a GCM which can be considered more reliable. On the other hand, LARS-WG uses the RCFs derived from the direct precipitation output of a GCM. As the current GCMs are still very coarse in spatial resolution, their direct precipitation output is unreliable.

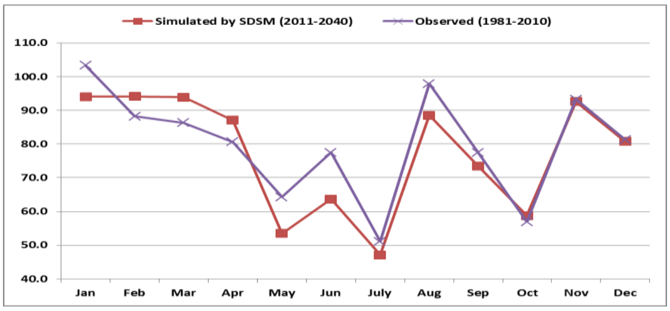

Fig. 2. comparisons of the observed and the SDSM estimated month precipitation

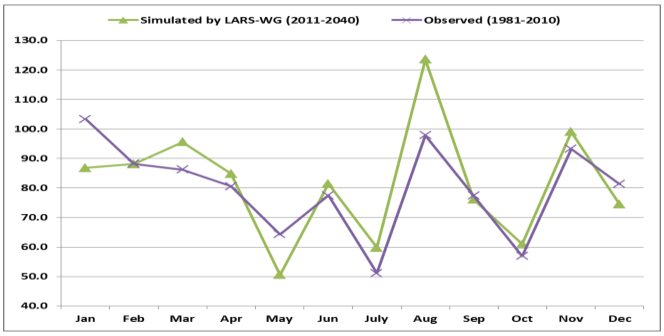

Fig. 3. comparisons of the observed and the LARS-WG estimated month precipitation

5. CONCLUSIONS

The performances of a multiple regression model, called SDSM, and a weather generator, called LARS-WG, were evaluated in terms of their ability to simulate present and downscale future frequency of precipitation. Daily areal average precipitation data from the Gorganroud watershed in North Iran, were used for the analysis. Three sets of data series were obtained: observed (1981–2010), the SDSM downscaled (2011–2040), the LARS-WG downscaled (2011–2040). The estimates of precipitation amounts for three return periods (10, 20, 30 year) were obtained. Comparing the two models in terms of precipitation values reveals that it is difficult to conclude in favor of either of them. On the whole, both the models (i.e. SDSM and LARS-WG) show similar results for simulating present-day extreme events of precipitation. Future precipitation frequency analysis, based on the downscaled data of both the models, presents two different pictures. The contrasting implication of the two models about the future is a result of the difference in their downscaling strategy and their basic concepts. These results further reinforce multimodel strategies for conducting climate change studies. On the basis of the results obtained in this study, both SDSM and LARS-WG models can be adopted with reasonable confidence as downscaling tools to undertake climate change impact assessment studies for the future.

6. ACKNOWLEDGMENT

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