Journal of River Engineering
Volume 1, Issue 1, 2013
http://www.scijour.com
SCIJOUR

Utilization of LARS-WG Model for Modelling of Meteorological Parameters 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 resource managers. Issues such as risk, reliability and robustness of water resources systems under different climate change scenarios were addressed in the past. Also Changes in temperature and precipitation patterns have serious impacts on the quantity and quality of water supply. Because of the increasing demand for water, studying the potential climate change and its impacts on water resources is necessary. To predict the climate change based on the General Circulation Models (GCM), the successful downscaling tool of LARS-WG is applied. This stochastic weather generator downscaled the climate change of Hashemabd synoptic station in the Golestan province of Iran by using the HADCM3 model and emission scenarios in the period of 2011-2040. A real-life case study example is presented to illustrate the applicability of a LARS-WG Model for generating these parameters and direction of climate change. The results show increase in solar radiation and decrease in precipitation almost in all of the months, also not changing in minimum and maximum temperatures. The results show that, in general, LARS-WG model performance in meteorological variables modeling is appropriate and could advise the decision makers to take suitable actions in securing the water supply and it can be used to recover data station or to extend the data to the future period. Also it can be used in the assessment of future climate of province in a local scale.

KEYWORD

Lars-WG, Downscaling, Meteorological Parameters, GCM.

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INTRODUCTION

In general, water resources management includes two crucial basics: estimating water demand and predicting the flow. Estimating water demand is possible to be calculated by taking resource consumption, but what makes the problem difficult is to predict river flow in the coming months. At the beginning, rainfall should be anticipated for the months ahead for predicting the flow. Climate models are a new issue that is not more than 30 years old. Every climate model tries to simulate the processes that affect the climate and according to it, climate will be forecasted for the coming years. Since predicting the future climate is not definitively possible based on climate change effects, there is an alternative solution for specifying different possibilities which are called climate change scenarios. Currently, the most reliable tool for generating scenarios is a General Circulation Model (GCM). These models are based on physical laws which are solved in a three-dimensional grid on the Earth's surface by the mathematical equations. Some of these models are USCLIAMTE WGEN, GEM, LARS-WG CLIMGEN, SDSM and etc.

Some of these models provide useful information about atmosphere response to increasing concentration of greenhouse gases. Considering the low spatial resolution of the atmospheric General Circulation Model and the need for powerful hardware and time-consuming downscaling and statistical models to manufacturer the weather were developed. These models convert the general circulation data in large scale to small by using GCM output models and utilizing specific scenarios of climate data production model (Semenov & Barrow, 1998). The most important advantages of these models are low cost, high speed and the possibility of using without supercomputers.

The models WG-LARS, AXE-JEN and WG-PCA are also Stochastic Models that are also benefiting from the results of General Circulation Models. LARS- WG is one of the most popular models of Stochastic weather generator data in the series approach that is used To produce large amounts of precipitation, solar radiation, maximum and minimum daily temperatures in a Station under baseline and future climate changes. A preliminary version of this model was to develop as part of the project a risk assessment of agriculture in Hungary in Budapest during 1990. The Markov chain model is used to model the rainfall event. LARS- WG model in the new version uses an empirical probability distribution function instead of the normal distribution to estimate the temperature. Also, in this version, the range of values has been increased close to zero probability and one for better estimation of extreme values. Applying the results of 15 general circulation models of the LARS-WG is a possibility that other small-scale models don't have it.

Semenov and Barow investigated performance of LARS-WG and WGEN models in 18 stations in the U.S., Europe and Asia and concluded LARS-WG model gives better results than WGEN model (Semenov & Barrow, 1998). Bazrafshan et al. compared performance of LARS-WG and ClimGen models in the simulation of meteorological variables in Iran. They concluded that Lars model performs better in simulating rainfall and sunshine hours .But in case of temperature the verse is true and ClimeGen will perform better in temperature simulation.(Bazrafshan et al, 2009). Also Babaeian and Najafi Nick (2006), analyzed the ability of the LARS-WG model to simulate meteorological variables in a Khorasan province from 1961 to 2003 and concluded that the LARS model has simulated rainfall variables, minimum and maximum temperature lower than actual values in three stations Mashhad, Sabzevar and Birjand . So maximum bias of precipitation stations in Torbate Heydariyeh and Mashhad was -0.4 mm. The maximum bias of minimum temperature in Sabzevar station was -0.7°C and the maximum temperature in Sabzevar and Birjand was calculated as -1.9°C .Generally the results of model are acceptable.

Harmsen and et al. have studied to assess precipitation, evaporation - aspiration and crop yields under climate change by using LARS-WG model under different scenarios and concluded that rainy season is getting more humid and humid and dry season is getting drier and drier because of the effect of climate change. Their results also showed that evaporation - aspiration and transpiration rates will be increased due to the reduction in rainfall and increasing in temperature in the dry months.(Harmsen, E.W., et al.,2009)

MATERIALS AND METHODS

In this study, data will be used from Hashem Abad meteorological stations located in the basin of Gorganroud in Golestan province in a 25-year period (1986 to 2010). The data used includes temperature, rainfall and sundial. And future meteorological data are simulated by using of LARS- WG model.

In Lars model, simulation precipitation modeling and its probability is used by quasi-experimental distribution method and the Markov chain .Radiation modeling is done based on semi experimental distribution model and the Temperature modeling is performed using Fourier series (Semenov & Barrow, 2002).To producing the data for LARS model, at first some characteristics of each station to model include the name of the station, location and altitude, daily meteorological data in observation period must be given, and then these data will be analyzed by the Lars model. The results of this is a summarize text file containing statistical properties of observed data including monthly averages and quarterly averages for the entire period under. Considering the existing trend in observation data time series the model starts to reproduce the station data in the same period . At the end by using statistical analysis and charting, the simulated monthly average are compared with observed data to evaluate the ability of meteorological data simulation in these stations. After assessing the model ability in each station, to generate data for the future periods, it is necessary to prepared and define climate change scenario file for the case study, considering the atmosphere general circulation model output (Semenov & Barrow,2002).

For producing data, at first, the profile of each station with daily meteorological data during observation period should enter into the model as input as input to the model is the observation period, then these data is analyzed by the model and the model is evaluated. Then it is necessary to be done small scale exponential in order to generate data for future periods, due to the mismatch of probability distribution functions of the model output and observed data by using statistical methods.

The process of the synthetic data generation is simulated by the model in three steps which are: calibration phase, evaluation phase and simulation phase of the meteorological data in coming decades. In the calibration phase, The basic need of model is the file that defines the behavior of climate during last period and the file was prepared by using daily rainfall, minimum and maximum temperatures and sunshine hours of weather station under study by considering a 25-year period as the base period and the model was performed based on it. In the next phase, the data produced by the model and the actual data (observed) in the base period was evaluated by using Coefficient of Determination (R2), Root Mean Square Error (RMSE), Mean Bias Error (MAE) and Mean Absolute Error (MAE) which are Equations 1 to 4. The results of this phase are shown in Table 2.

Tab.1. Profile of station under Study

Station Name	Type of Station	Longitude	Latitude	Height
Hashem Abad Gorgan	Synoptic	54.16	36.51	13.3

$$R^2 = \frac{\left[\sum_{i=1}^{n}(X_i-\bar{X})(Y_i-\bar{Y})\right]^2}{\sum_{i=1}^{n}(X_i-\bar{X})^2\sum_{i=1}^{n}(Y_i-\bar{Y})^2} \tag{1}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_i-Y_i)^2}{n}} \tag{2}$$

$$MBE = \frac{\sum_{i=1}^{n}(X_i-Y)}{n} \tag{3}$$

$$MAE = \frac{\sum_{i=1}^{n}|X_i - Y_i|}{n} \quad (4)$$

In the above equations, X_i and Y_i are i^{th} of observed data and simulated data from the model, respectively, $\bar{X}$ and $\bar{Y}$ are mean of observed data and simulated data and n is the total number of data. After verifying the evaluation results and the feasibility and reliability of the WG5-LARS model simulate rainfall climate data, minimum temperature , maximum temperature and sundial, implementation of the third phase or climate simulation data in the period 2011-2030 has been started. WG5-LARS was implemented by using AIB pessimistic climate change scenario which was confirmed by the IPCC. This scenario depicts a world of rapid economic growth and population so that maximum growth of population has been occurred in the half-century and then the increase in population would be reduced. Also, the rapid development of new technologies and effective on the scenario basis will occur in future periods. At the end, the monthly mean of weather data was calculated and the results were plotted as graphs which are shown in Figures 1 to 4.

RESULTS AND DISCUSSION

After re-producing and analyzing the data by Lars model, to evaluate the model's ability to simulate meteorological data in observed period, T-Student statistics test and charts were used and the results were analyzed.

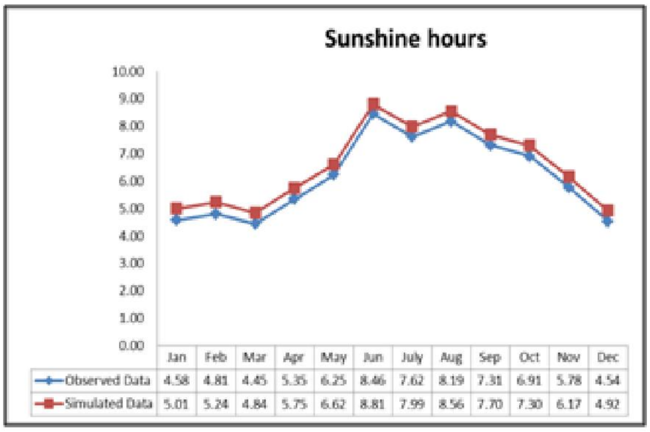

Fig.1. Monthly average changes of observed data and simulated data of sunshine hours sundial

According to Figure 1, simulated sunshine hours is more than the observed amount in almost every month. The maximum difference in the sunshine hours is in February, January and April and it is 0.44 and 0.42 and 0.4 hour more than the observed average, respectively.

According to Figure 2, simulated data of rainfall is less than the observed amount in almost every month. The greatest difference in the amount of rain falling occurs during January which is Equal to 7.3 mm more than the average observations.

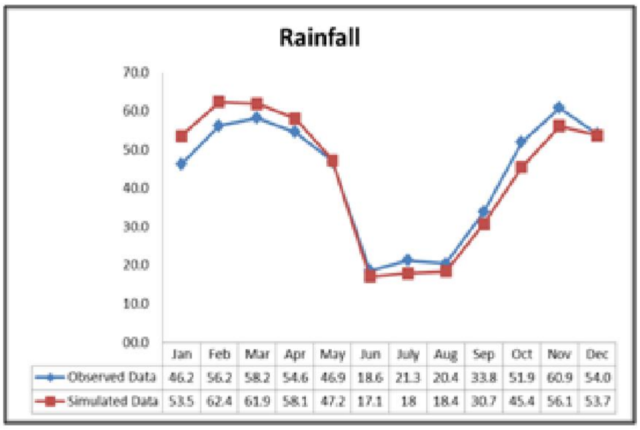

Fig .2.Total monthly rainfall changes of observed data and the simulated data

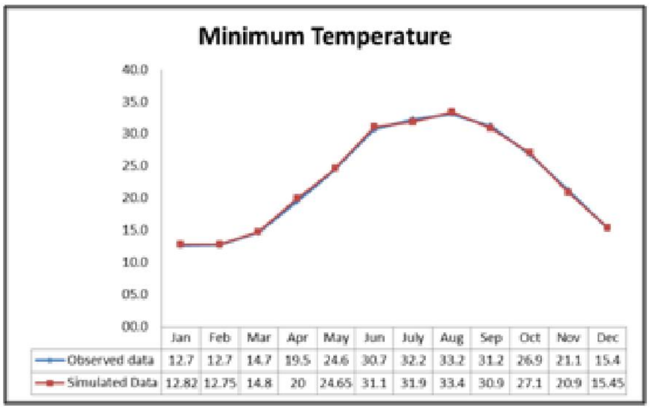

Fig.3. Monthly average changes of observed data and the simulated data of the minimum temperature

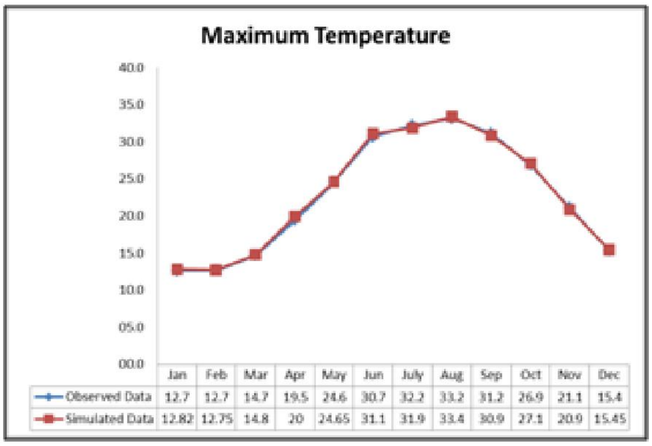

Fig. 4. Monthly average changes of observed data and the simulated data of maximum temperature

According to Figure 3 and 4, the simulated values of maximum and minimum temperatures are not much different than the values observed, but the greatest change in minimum temperature has been observed in August and the highest difference in maximum temperature was observed in April.

CONCLUSION

In this paper, four meteorological parameters -minimum temperature and maximum temperature, rainfall and sunshine hours have been simulated by using the LARS-WG5 model in Golestan province. The results showed that these variables are modelled with good accuracy. As a general conclusion it can be said LARS model can be used with high confidence to reproduce the daily meteorological data and to study the climate change in future periods.

Using a weather data builder to complete missing data and also data extending (for the future periods) due to study on the return period of extreme weather events such as rain, flash flood and drought is very useful. But the ability of these models to simulate meteorological variables will have direct effects on the results.

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