Evaluating the performance of a Weather Generator WGEN Under Indian Condition for Agricultural Impact Studies
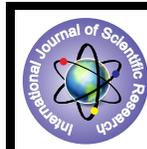
Science

C N Tripathi	Department of Environmental Engineering, Hindustan College of Science and Technology, Farah Mathura-281122
M K Mishra	Freelance Environmental Consultant & Modeler at Freelance/Consultancy New Delhi Area, India
K. K. Singh	Freelance Environmental Consultant & Modeler at Freelance/Consultancy New Delhi Area, India

ABSTRACT

A weather generator based on short methods of WGEN in which the weather parameters are estimated from the monthly weather summaries instead from daily values has been calibrated and evaluated in this study. The model parameters were calibrated using daily observed weather data from 40 locations in India for 20 years (15 years for some of the locations). These parameters are calculated in terms of monthly weather statistics of rainfall were directly used to generate the daily weather at selected locations of India. Result indicate that there is several deviations in summery of generated weather statistics as compared to observed statistics, but over all nature of generated rainfall is fairly good replications of observed rainfall. Generated rainfall can be helpful in rice crop planning in North India because of better agreement between generated and observed rainfall during monsoon months in which rice crop is grown in North India. However it can not be useful in winter months planning of wheat because of lesser agreement between generated and observed rainfall during winter months. In addition due to several deviations in generated temperature (both maximum and minimum temperature) the use of the generated weather in crop simulation and hydrological models will not yield realistic results. To use this for agricultural and hydrological impact studies it need to be calibrated for maximum and minimum temperature generation as well.

Introduction

A stochastic weather generator is a computer algorithm that uses existing meteorological records to produce a long series of synthetic daily weather data. An important application of weather generators involves them serving as computationally inexpensive tools to produce multiple-year climate change scenarios at the daily time scale, which are used to assess the impact of future climate change (Semenov and Barrow, 1997; Wilks, 1992, 1999; Pruski and Nearing, 2002; Zhang et al., 2004; Zhang, 2005; Zhang and Liu, 2005; Minville et al., 2008. Unlike historical weather records, which may have missing data, the weather generator output provides a complete record for any desired period of time, thus enhancing the use in hydrological and agricultural impact studies (Kevin et al., 2005). Moreover, it can be used to generate daily weather data for ungauged areas through spatial interpolation of model parameters from adjacent gauged sites (Baffault et al., 1996). In recent years, agricultural scientists have developed considerable interest in modeling and simulation of rainfall as new ways of analyzing rainfall data and assessing its impact on agriculture. Over the years, several weather generators have been developed, such as the Weather Generator (WGEN) (Richardson, 1981 , Richardson and Wright, 1984), USCLIMATE (Hanson et al.,1994), Climate Generator (CLIGEN) (Nicks et al., 1995), Climate Generator (ClimGen) (Stockle et al., 1999), Long Ashton Research Station-Weather Generator (LARS-WG) (Semenov and Barrow, 2002), etc.

Most common method of generating rainfall is a combination of Markov chain and gamma distribution function is recognized as a simple approach and is demonstrated to be effective in generating daily rainfall data for many environments. In the context of climate projections, the reliability of weather generators does not only depend on the weather generator it self but also on the ability of the forcing model to capture the observed climatology. In some cases it may be required to assess the impact of the changes in the climatic mean and variability separately or of the both simultaneously. Therefore the statistical properties of the generated data are expected to be similar to those of the actual data for a specified site Therefore it is important that weather generators do not only provide reliable estimates of the precipitation and temperature climatology, but also produce a realistic day to day variability. Unfortunately, weather generators described above require that many years of daily weather records be available for estimating the model parameters. Thus

the availability of the weather data limits the applicability of the simulation method. When these model parameters are evaluated over time and at different places, however, certain general characteristics are revealed. First, the transitional probability of a wet day followed by a wet day tends to be greater but parallel to the transitional probability of a dry day followed by a wet day. This phenomenon leads to a linear relationship of the transitional probabilities to the fraction of wet days per month. Second, the beta parameter in a gamma distribution function, which is used to describe the amount of rainfall, is closely related to the amount of rain per wet day owing to the positive skewness of the rainfall distribution. Based on these relationships, a simple method is introduced, by which model parameters can be estimated from monthly summaries instead of from daily values. In the present study this simple method is used (Geng et al., 1986) to calibrate and evaluate a weather generator WGEN in Indian conditions for agricultural and hydrological implications.

2. Methodology
2.1. The weather Generator WGEN

(WGEN) weather generator (Richardson and Wright (1984) provides daily-generated values of precipitation, maximum temperature, Minimum temperature and solar radiation for an n-years period at a given location. The precipitation component of WGEN is a first order two-state Markov chain gamma distribution model. The occurrence of wet or dry days is generated with a first order Markov chain model in which the probability of rain on a given day is conditioned whether the previous day was wet or dry. When a wet day is generated, the two-parameter gamma distribution is used to generate the precipitation amount. Maximum and minimum temperature and solar radiation are then generated depending on whether the generated day is wet or dry. For generating daily values of maximum and minimum temperature and solar radiation, the residual of the three variables are generated using a multivariate normal generation procedure that preserves the serial correlation and cross correlation of the variables. Final values of the three variables are determined by adding the seasonal means and standard deviation to the generated residual elements. For more details refer to Richardson (1981) and Richardson and Wright (1984).

In addition a weather generator, program W_GEN based on the "short method" version of the WGEN model of Richardson and Wright (1984) and re- written by Deena C. Mobbs (Institute of Terrestrial Ecology, Edinburg Research Stations, Bush Estate,

Penicuik, Midlothian EH26 0QB, Scotland) was modified and calibrated for use under Indian conditions. It is a short method version of WGEN in which the weather parameters are estimated from the monthly weather summaries instead from daily values. Transitional probability of a wet day followed by a wet day and the transitional probability of a dry day followed by a wet day is approximated in terms of fraction of wet days per month based on the linear relationship between them. The beta parameter in a gamma distribution function, which is used to describe the amount of rainfall, is closely related to the amount of rain per wet day. Similarly the temperature and solar radiation parameters are approximated in terms of corresponding monthly summary of the weather parameters. The method is also described in Geng et al., 1986.

2.2. Input Data and Setting the Weather Generator Run
Daily weather data on Rainfall, Maximum temperature, Minimum Temperature and sunshine hours were collected from India meteorological Department for 40 location of India scattered through out India as shown in figure 1. For most of the location daily data for 20 years were collected but for some of the locations 15 years data were available and used in the study. Daily solar radiation were calculated using daily sunshine hour.

Figure 1: Weather observation locations
In first stage all the rainfall parameters used by W_GEN (namely Monthly mean of probabilities of wet day followed by wet days, probabilities of dry day followed by wet days, alpha the gamma distribution shape parameter, and beta the gamma distribution scale parameters) were calculated from the daily observed weather data from 40 locations in India for 20 years (15 years for some of the locations). Then the monthly summary of the fraction of wet days and rain per wet days were also calculated from the daily observed weather data for all the selected location in India. Mean monthly statistics of fraction of wet days for all the locations combined were plotted against the mean monthly statistics of probabilities of dry days followed by wet days and equation of linear relationship between them were noted. Similarly the monthly statistics of the beta parameter of the gamma distribution for all the locations combined, were plotted against the rain per wet days and the equation of the linear relationship between them was noted. Other rainfall parameters were also approximated thereof from the interrelationships existing between them. Subsequently these equations in which parameters are calculated in terms of monthly statistics were directly used to generate the daily weather at selected locations of India.

Above program has been used to generate the daily weather for six selected locations for 20 years (15 years for some of the locations). Number of years of data generated depended on the number of the years of the observed data available for

comparison at different locations (Table 1). Mean values of simulated rainfall, maximum temperature and minimum temperature were calculated and has been compared to the corresponding observed values. The results are described in the following section.

3. Results and Discussion
Figure 2, shows the comparison of observed and generated rainfall for six selected location in India. Generated rainfall is replicating the trend in mean monthly rainfall in over with minor deviation from observed rainfall at all the selected location in India. At Ludhiana (North India) it is overestimated between January to June and underestimated during June-July. Again it is over estimated during November to December. However during monsoon months of August to October i.e. the periods when most rain happens generated rainfall is in very close proximity to observed rainfall. At Coimbatore (South India) very close match is obtained between observed and generated rainfall in all months. At Anand (West India) rainfall is underestimated between June to August where as it is better matched in other months. At Powerkheda (central India) generated rainfall is comparable to observed one in all months except for August where it is underestimated. At Pusa (East India) there is best match between generated and observed rainfall in all months except for monsoon months (July to September). At Jorhat (North east India) it is underestimated during January to March and Over estimated during July to September.

Figure 2: Comparison of Monthly Means of Observed and Generated Rainfall (mm) at Different Locations in India
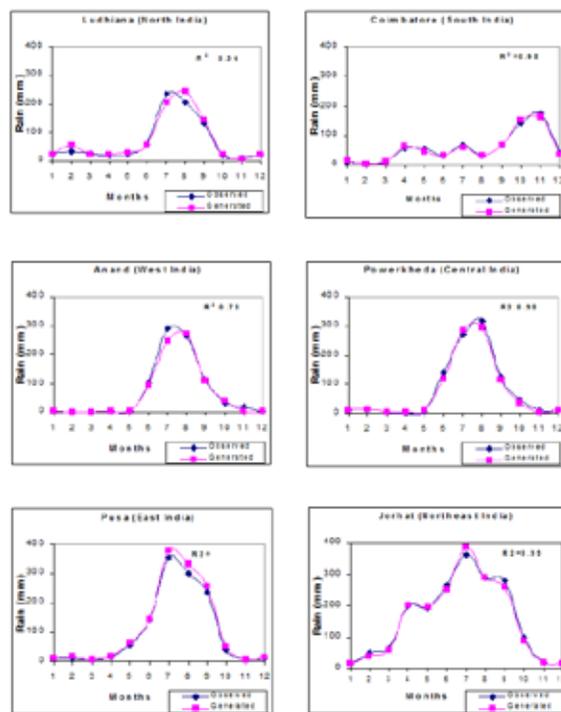

Figure 3 shows the comparison of observed and simulated maximum temperature for six selected location in India. It is observed that generated maximum temperature is not replicating the trend in monthly variation in maximum temperature except for Jorhat in NE India. At all other locations maximum temperature is overestimated from January to March and underestimated from April to June. Again it is overestimated between July to August and underestimated from

Figure 3. Comparison of Monthly Means of Observed and Generated Maximum Temperature at Different Locations in India
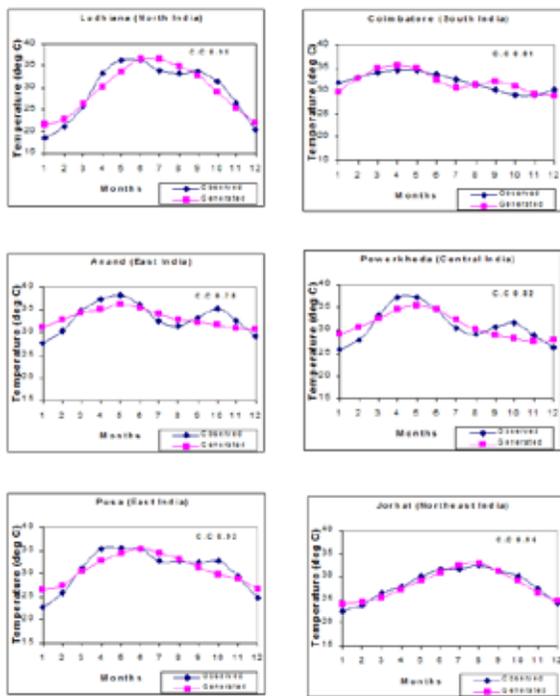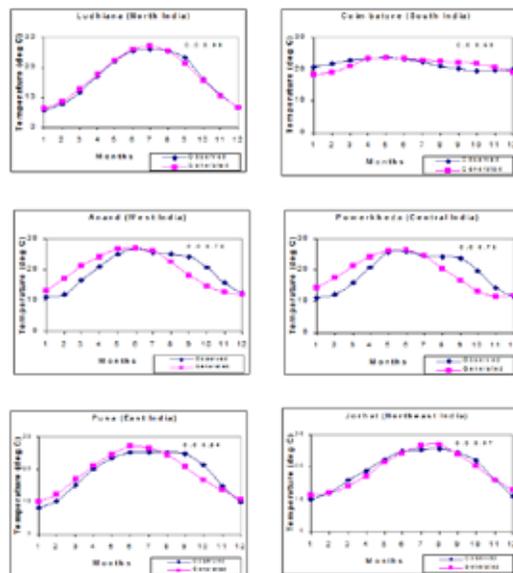
Research Paper

Figure 4. Comparison of Monthly Means of Observed and Generated Minimum Temperature at Different Locations in India

Between September to December.

Figure 4 shows the comparison of observed and simulated minimum temperature for six selected location in India. At most of the selected locations generated minimum temperature is also not replicating the trend in monthly variation in observed minimum temperature except for Ludhiana (North India). At Coimbatore(South India) and Powerkheda (Central India) is underestimated between January to April and it is overestimated between July to September. At Anand minimum temperature is overestimated between January to June and underestimated between August to December. At Pusa it is overestimated between January to August and then underestimated from September to December.

4. Conclusions

Though there is several deviations in summery of generated weather statistics as compared to observed statistics, but over all nature of generated rainfall is fairly good replications of observed rainfall. Generated rainfall can be helpful in rice crop planning in North India because of better agreement between generated and observed rainfall during monsoon months in which rice crop is grown in North India. However it can not be useful in winter months planning of wheat because of lesser agreement between generated and observed rainfall during winter months. However due to several deviation in generated temperature (both maximum and minimum temperature) the use of this generated weather in crop simulation and hydrological models will not yield realistic results. To use this for agricultural and hydrological impact studies it need to be calibrated for maximum and minimum temperature generation as well.

REFERENCE

Baffault, C., Nearing, M.A., Nicks, A.D., 1996. Impact of CLIGEN parameters on WEPP predicted average annual soil loss. Transactions of the ASAE 39 (2), 447–457. Geng, S., Penning de Vries, F.W.T., and Supit I. (1986) "A simple method for generating daily rainfall data." Agric. For. Meteorol., 36, 363 – 376 Hanson, C.L., Cumming, K.A., Woolhiser, D.A., Richardson, C.W., 1994. Microcomputer Program for Daily Weather Simulations in the Contiguous United States. USDA ARS Publ. ARS 114, Washington, DC Kevin, M., Ramesh, R., John, O., Imran, A., Bahram, G., 2005. Evaluation of weather generator ClimGen for southern Ontario. Canadian Water Resources Journal 30 (4), 315–330 Minville, M., Brissette, F, Leconte, R., 2008. Uncertainy of the impact of climate changeonthehydrologyofanordicwatershed.Journal of Hydrology358,70–83 Nicks, A.D., Lane, L.J., Gander, G.A., 1995. Weather generator. In: Flanagan, D.C., Nearing, M.A. (Eds.), USDA Water Erosion Prediction Project: Hillslope Profile and Watershed Model Documentation, NSERL Report No. 10. West Lafayette, Ind.: USDA ARS NSERL (Chapter 2). Pruski, F.F., Nearing, M.A., 2002. Climate-induced changes in erosion during the 21st century for eight US locations. Water Resources Research 38 (12), 341–3411. Richardson, C.W., 1981. Stochastic simulation of daily precipitation, temperature, and solar radiation. Water Resources Research 17, 182–190. Richardson, C.W., Wright, D.A., 1984. WGEN: A model for generating daily weather variables. US Dept. Agric., Agricultural Research Service. Publ. ARS-8. Semenov, M.A., Barrow, E.M., 1997. Use of a stochastic weather generator in the development of climate change scenarios. Climatic Change 35, 397–414. Semenov, M.A., Barrow, E.M., 2002. LARS-WG, A Stochastic Weather Generator for Use in Climate Impact Studies, User Manual. Stockle, C.O., Campbell, G.S., Nelson, R., 1999. ClimGen Manual. Biological Systems Engineering Department, Washington State University, Pullman, WA. Wilks, D.S., 1992. Adapting stochastic weather generation algorithms for climate change studies. Climatic Change 22, 67–84. Wilks, D.S., 1999. Interannual variability and extreme-value characteristics of several stochastic daily precipitation models. Agricultural and Forest Meteorology 93, 153–169. Zhang, X.C., Nearing, M.A., Garbrecht, J.D., Steiner, J.L., 2004. Downscaling monthly forecasts to simulate impacts of climate change on soil erosion and wheat production. Soil Science Society of America 68, 1376–1385 Zhang, X.C., 2005. Spatial downscaling of global climate model output for site-specific assessment of crop production and soil erosion. Agricultural and Forest Meteorology 135, 215–229. Zhang, X.C., Liu, W.Z., 2005. Simulating potential response of hydrology, soil erosion, and crop productivity to climate change in Changwu tableland region on the Loess Plateau of China. Agricultural and Forest Meteorology 131, 127–142.