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Evaluation of the RadEst and ClimGen Stochastic Weather Generators for Low-Medium Rainfall Regions

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Abstract: The aim of present study is to generate the daily weather values for maximum and minimum air temperatures and solar radiation. Two well known weather generators are evaluated here. Data from the five Iranian synoptic stations having long-term weather records and dry climates have been used to compare the actual data sets with generated one. The accuracy of the different weather generators models was evaluated by means of three widely used statistics: Correlation coefficient (R), Root Mean Square Error (RMSE) and Mean Bias Error (MBE). For maximum and minimum temperatures, Bushehr's data show the lowest RMSE and Esfahan's data show the highest RMSE. For radiation data, RMSEs of all of the stations are very high, except for Esfahan station. In general, the computed values of temperature are in good agreement with the data derived by the observation, but the computed values for radiation do not indicate a good agreement with the measured data.

Key words: Weather generator, ClimGen, RadEst, solar radiation, air temperature

INTRODUCTION

A Stochastic Weather Generator (SWG) is a numerical model which produces synthetic daily time series of a suite of climate variables, such as precipitation, temperature and solar radiation, with certain statistical properties (Racsko *et al*., 1991; Richardson, 1981; Richardson and Wright, 1984). A SWG produces synthetic time series of weather data having unlimited length for a location based on the statistical characteristics of observed weather at that location (Anonymous, 2005; Meinke *et al*., 1995).

Stochastic daily weather generators which used in conjunction with crop and other simulation models have found a range of applications in agricultural research. Applications usually involve the cases where either gap in the historic record should be filled, the period of record is insufficiently long for the intended analyses, or realistic daily data must be derived in the absence of historic data (Allen *et al*., 1998). Weather generators are sometimes used to provide an adequate sample of weather realizations for risk studies, where the probable distribution of simulated outcomes (e.g., crop yields) is important for understanding or decision making (Mavromatis and Hansen, 2001; Meza and Varas, 2000; Thornton *et al*., 2000). An increasingly-important application of stochastic weather generators is in the construction of climate change scenarios for impact assessment studies.

Weather generators are now widely used by researchers from many different backgrounds in conjunction with their impact models. They are becoming a standard component of decision support systems in agriculture, hydrology and environmental management (USDA Agriculture Research Service). There is a danger, however, that generators will be used as supplied i.e., without sufficient validation is being carried out for the sites at which they are applied. Most weather generators have been tested intensively, but usually only for one country or one region (Semenov *et al*., 1998). The objective of this study is to evaluate two well known weather generators, RadEst, developed in Europe and ClimGen, developed in USA, for a diverse range of climates in Iran.

MATERIALS AND METHODS

Description of weather generators: The two weather generators described here, ClimGen and RadEst are used by many researchers all over the world. In this study, the

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first generator, ClimGen, is used to generate daily maximum and minimum air temperatures and the second one is used for producing daily global solar radiation. The observed weather data as input are used to determine the parameters of the probability distributions and the correlation coefficients between the variables. The parameters for each distribution are varied either on a monthly or a daily basis to express the seasonal component of each weather variable.

Temperature estimation ClimGen: This program is used to estimate maximum and minimum air temperatures. The technique used in ClimGen for generating maximum and minimum air temperatures is similar to that in WGEN, a well-known weather generator and is based on the assumption that temperature is a weakly stationary process (Stöckle *et al.*, 2001). Generating weather data in ClimGen consists of the following steps:

- Describing the location.
- Preparing the location parameters either with statistical analysis of real weather data, or providing known monthly statistics.
- Generating the data.
- Exporting the data to available file formats used by other applications.

The ClimGen Wizard provides a step by step procedure presenting input fields for entering parameters. The available data options and the actual data provided will determine what additional data will need to be provided or what additional data might be estimated to produce the optimal set of parameters for data generation (Stöckle and Nelson, 2001).

Radiation estimation RadEst: The RadEst program allows evaluating daily global solar radiation values for a location of given latitude and it also allows estimating daily values. Four models are available to estimate daily radiation from air temperature data; they are all derived from the model proposed by Bristow and Campbell (1984). All of the models estimate atmospheric transmissivity of global solar radiation based on the difference between maximum and minimum air temperatures. The estimate value of radiation is calculated as the product of the estimated transmissivity times the value of potential radiation outside the earth atmosphere (Donatelli *et al.*, 2003; Donatelli and Bellocchi, 2001).

For each model, parameters can be estimated using iterative procedures either minimizing the amount or the pattern of residuals. One year or more (at most five) of daily data can be used to estimate one parameter for each model. The models are as: (i) Bristow and Campbell (1984) (BRC); (ii) Donatelli and Campbell (1998) (DC); (iii) Donatelli and Bellocchi (2000) (DB); (iv) Modular DCBB (DCBB) (Donatelli *et al.*, 2003).

Table 1: Geographic location of the sites and their yearly climatic averages for maximum (T_{max}) and minimum (T_{min}) temperatures, solar radiation (Rad) and rainfall

Stations	WMO No.	Latitude (°N) Deg.	Min.	Longitude (°E) Deg.	Min.	Elevation (m)	T_{max} (°C)	T_{min} (°C)	Rainfall (mm)
Hamedan	40768	34	15	48	32	1749.0	19.1	3.3	316.6
Karaj	40752	35	55	50	54	1312.5	21.1	8.7	239.5
Kerman-shah	40766	34	17	47	07	1322.0	22.6	5.8	447.2
Shiraz	40848	29	36	52	32	1488.0	25.6	9.8	341.1
Yazd	40821	31	54	54	24	1230.2	11.7	26.5	61.5

Weather data: Five Iranian synoptic stations with long-term measured data are selected. The stations are purposely chosen to cover a wide geographical area and several climatic zones in Iran (Table 1). The geographical spread ensures weather data can be used confidently across these climatic zones. Data were recorded between the years 1985 and 1995.

RESULTS

The accuracy of the different models is evaluated by means of three widely used statistics: Correlation coefficient (R), Root Mean Square Error (RMSE) and Mean Bias Error (MBE).

Observed vs. estimated temperatures: Correlation coefficient, RMSE and MBE all indicate that the observed and estimated data are in a good agreement for all of the cases but one. This exception involved the daily values of minimum temperature at Esfahan station. A good linear fit is obtained yielding a slope between 0.75 at Bushehr station and 0.90 at Tehran station and intercept values between -0.52 at Mashad station and 5.4 at Bushehr station. A student t-test at the 0.05 level of significance indicates that the slope does not differ from unity and that the intercept does not differ significantly from zero in all of the cases but one, T_{min} at Esfahan station. The minimum RMSEs were observed in Bushehr with 4.76°C for T_{min} and 5.55°C for T_{max} and the maximum RMSEs were occurred in Esfahan with 7.27°C for T_{min} and 7.77°C for T_{max} (Table 2).

Observed vs. estimated radiations: Correlation coefficient, RMSE and MBE all indicate that the observed and estimated data, except for Esfahan station, are not in a good agreement.

Table 2: Linear regression (Y = a+bX) and correlation coefficient (R), RMSE and MBE between the estimated and observed daily minimum and maximum air temperatures

Parameters	Station	Slope (b)	Intercept (a)	Correlation coef.	RMSE	MBE
T_{min}	Bushehr	0.87	3.85	0.82	4.76	1.48
	Esfahan	0.02	8.40	0.10	6.12	-1.33
	Mashad	0.81	-0.52	0.72	7.27	-2.31
	Tabriz	0.87	0.23	0.79	6.58	-0.74
	Tehran	0.88	0.30	0.78	6.93	-1.28
T_{max}	Bushehr	0.75	5.40	0.79	5.55	-2.17
	Esfahan	0.86	3.27	0.82	6.36	0.05
	Mashad	0.79	4.10	0.77	7.77	-0.42
	Tabriz	0.89	1.85	0.85	6.82	-0.03
	Tehran	0.90	2.30	0.78	6.80	0.05

Table 3: Linear regression (Y = a + bX) and correlation coefficients (R), RMSE and MBE between estimated and observed daily global solar radiations

Stations	Model	Slope (b)	Intercept (a)	Correlation coef.	RMSE	MBE
Bushehr	BRC	0.55	10.00	0.33	5.60	0.11
	CD	0.50	7.80	0.23	6.44	-0.17
	DB	0.46	9.00	0.30	5.36	0.19
	DCBB	*	*	*	*	*
Esfahan	BRC	1.14	-4.30	0.71	1.93	0.40
	CD	1.11	-2.10	0.73	4.51	0.54
	DB	0.85	2.40	0.72	3.73	0.69
	DCBB	1.07	-1.40	0.74	4.28	0.59
Mashhad	BRC	0.43	13.60	0.36	9.83	0.24
	CD	0.49	11.20	0.35	9.82	0.24
	DB	0.35	14.90	0.32	9.93	0.23
	DCBB	*	*	*	*	*
Tabriz	BRC	0.21	22.80	0.10	13.63	-1.14
	CD	0.03	18.00	0.01	12.92	-0.92
	DB	0.02	18.70	0.01	11.71	-0.58
	DCBB	17.20	0.20	0.14	15.20	-0.23
Tehran	BRC	0.25	10.20	0.23	12.50	0.15
	CD	0.34	12.30	0.15	10.20	0.16
	DB	0.21	8.60	0.01	18.00	-0.17
	DCBB	0.01	9.60	0.10	17.40	-0.12

*: The parameter could not be computed

A student t-test evaluated at the 0.05 level of significance indicates that the slope differs from unity and that the intercept differs significantly from zero in all of the cases but one, total solar radiation at Esfahan station (Table 3).

DISCUSSION

An evaluation of the well known stochastic weather generators including ClimGen, for simulating temperature and RadEst, for estimating radiation, based on measured data has been carried out for Iranian data.

Statistics between the observed and estimated minimum and maximum air temperatures show that the measured and modeled data are in good agreement for all cases, except for the daily values of minimum temperature at Esfahan station. The minimum and maximum RMSEs for both maximum and minimum temperatures were observed in Bushehr and Esfahan, respectively. Results for temperature indicate that the observed and simulated (estimated) temperature data are in a good agreement and the methods could be simply used for generating long-term daily temperature data or estimating missing data, particularly for low-medium rainfall regions.

It has been observed that relatively high MBE and RMSE values are found for the radiation data estimated by RadEst. The minimum RMSE was observed in Esfahan for the Bristow and Campbell (1984) and maximum was occurred in Tabriz for the Donatelli and Bellocchi (2000). In general, the estimated radiations in Esfahan are in agreement with the measured data but for the other stations, the measured and modeled data show significant differences. The main reason of the significant difference between the measured and estimated radiations is the quality of the data. In most stations, the pyranometers devices which are used for measuring total solar radiation are old and the calibration coefficients which are used for converting the device output from voltage to a standard unit of radiation such as w.m^{-2} are not precise. It is recommended that the Meteorological Organization of Iran could replace the too old pyranometers with the new ones and could calibrate the other pyranometers each 1.5-2 years to improve the accuracy of measured data.

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