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RESEARCH ARTICLE - ATMOSPHERE

Climate data generation employing meteonorm model over selected stations in Iraq

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Abstract

Climate is the average weather conditions for a region for a long time, it is also assuming as a relation between weather phenomena and environment whether its natural or human made. The aim of this work is to generate climatological normal for selected cities in Iraq using the software package meteonorm weather and climate generator. The results showed that the temperature during summer in Mosul and Baghdad may reach more than (42^{o}C) while in Rutba and Basra temperature may reach above (38^{o}C) and (48^{o}C) respectively, while the temperature during winter can reach values close to freezing level in Mosul, Baghdad and Rutba while Basra temperature dose not reach such level. The difference in the highest value of diffuse and global radiation (low diffuse - high global) in Rutba city is attributed to the fact that this city is rural which means that it has relatively low pollution particles. The highest maximum sunshine occurs in the Mosul because it is located relatively on high latitude while highest minimum sunshine occurs in the Basra because of low cloud cover during the year also The results showed that the optimal data generation of meteonorm in Mosul station with statistical metric evaluation criteria (R=0.96, RMSE=3.87, MAE=2.91) for maximum air temperature, (R=0.88, RMSE=3.45 , MAE=2.44) in Baghdad station for minimum air temperature and finally (R=0.91, RMSE=0.97, MAE=0.77) for maximum air temperature in Mosul station.

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Keywords: Climate, Air Temperature, Solar Radiation, Meteonorm model, Iraq.

Introduction

Climatology is one of the basic branches of applied sciences that deals with the atmosphere, and interest in this branch of applied sciences has become increasingly due to its direct impact on humans, animals and plants on planet Earth.[1]. Climate can be described as the atmospheric condition of certain elements such as temperature and self-rainfall, which constitute the basic elements of this science for a period exceeding 30 years and for a specific geographical area [2], Climate refers to the rates and variability of weather and the climatic elements mentioned above during a period extending to many decades [3]. In general, climate can be described as the general and prevailing condition during a specific period of time and geographical area. [4, 5]. There are several researcher investigated on change in different world countries such as [6], [7, 8] whereas there are several authors such as [9-15] analyzed the climate patterns of Iraq using data for air temperature and precipitation for 50 years' period. She found that the lowest temperatures occur during January and highest temperatures occur during July and August, and the result showed that the highest precipitation rate in the northern region occurs during February while the lowest precipitation rate occurs during October and in the middle and southern regions, the highest precipitation rate occurs during December and the lowest precipitation rate for these regions occurred during May and October.[16] studied the analysis between some indices such as North Atlantic Oscillation NAO, Pacific North American Oscillation PNA, Oscillation Southern Index SOI and NINO3.4 and climate variable using Pearson's method. The results showed that SOI is the most important SSTA. (7) Evaluated the Impact of Global Climate Change on Air Temperature in Iraq using Climate Models. They found that the increase in diffusivity causes an increase in the heat flux towards the poles causing the temperature to increase in the Polar Regions and sub–Polar Regions and to decrease in the tropics and subtropics regions. The aim of this research is to generate climatological normal for selected cities in Iraq using the software package meteonorm weather and climate generator.

Materials and Methods

Study Area

Iraq is located in southwest Asia. It is characterized by a diverse and different topography from one region to another, as the northern region of Iraq is characterized by the presence of a mountain range such as the Zagros Mountains. To the west, it has borders with Syria, and these borders have a desert character. To the south, Iraq borders Kuwait and the Arabian Gulf, which forms a coast on the Arabian Gulf of about 58 km. To the east, it borders with Iran, which reaches 1,200 km. The climate of Iraq is semi-arid and sometimes dry in many areas of the country, with hot and dry summers and cold and sometimes moderate winters.

Temperature rates vary from 8 degrees Celsius to 49 degrees Celsius during summer and winter respectively [17]. Figure (1) shows the map of Iraq and its location within the Middle East region [18]

Fig. 1. Map of Iraq [18]

Meteonorm Weather Generator

The global climatological database Meteonorm (www.meteonorm.com) is commonly utilized as meteorological input for the simulation of solar applications and buildings [20 ,19]. It consists of a climate database, a spatial interpolation tool, and a stochastic weather generator. Meteonorms can also be utilized in climate change research. Instead of climatic values, the IPCC AR4 findings are used as input. An average of 1^{o} resolution was calculated from all 18 public models. The anomalies in the temperature and global radiation parameters, as well as the three scenarios B1, A1B, and A2, have been included. With the combination of Meteonorm's current database 1961-1990, the interpolation techniques and the stochastic generation average years can be generated for every site, scenario, and time between 2010 and 2100. In this work, Meteonorm was only used to generate meteorological monthly means for four cities in Iraq, namely Mosul, Baghdad, Rutba, and Basra. The geographical coordinates of these cities are given in Table 1.

Table 1. Longitude, latitude, and height above sea level for the selected cities.

City	Longitude ^oE	Latitude ^oN	Elevation (m)
Mosul	43.16	36.36	228
Baghdad	44.36	33.31	34
Rutba	40.29	33.04	630
Basra	47.78	30.51	3

Methodology

As an input for the Meteonorm, historical temperature data for the period 2000-2009 and historical radiation data for the period 1991-2010 were used. Climate daily and monthly means for basic meteorological and radiation parameters were generated for the selected four cities. All generated values were based on the Meteonorm database.

Statistical Evaluation of meteonorm model

The accuracy performance of meteonorm model was evaluated based on statistical indicators, which included the following, Correlation coefficient (R), Root Mean Square Error (RMSE), Mean Absolute Error (MAE). The coefficient of determination shows the percentage that the model can explain the variance in the values of the estimated elements. As for RMSE, MAE, they measure the residual errors, and the closer it is to zero, the more it indicates the efficiency and accuracy of estimations of meteonorm model.

$$R = \frac{\sum(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum(x_i - \overline{x})^2 \sum(y_i - \overline{y})^2}} \qquad (1)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y})^2} \qquad (2)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}| \qquad (3)$$

Where:

y_i *actual value*, $\overline{y}$ *mean value*, $\hat{y}$ *predicted value*

Results and Discussion

Fig (2) shows the meteorological parameters for the city of Mosul. It’s seen that the highest maximum temperature occurred in approximately in mid-July while the highest minimum temperature occurred during mid-July. It’s clear that the daily range between maximum and minimum temperatures is higher during summer than during winter.

Part (b) gives the box plot for the monthly temperature. It’s seen that the highest maximum monthly temperature occurred in July (42^{o}C) and the lowest minimum monthly temperature happened in January (4^{o}C). The ends of the thin lines in the plot represent the highest and lowest daily temperature reached during the period of 2000-2009. It’s clear that in the city of Mosul daily temperature may reach (47^{o}C) during the month of July and (-3^{o}C) during the month of January. In addition, the range between the maximum and minimum temperatures is larger during months of June, July, August and September and the smaller during January and December.

The daily global radiation on horizontal surface given in part (c). The results suggest that the global radiation may reach its peak value during the period from mid-May to mid-July. The maximum of global radiation is 8.1 kWh/m^2 which occurred in mid-July and the lowest global radiation is 0.9 kWh/m^2 reached during the first week of February.

The histogram is part (d) of the figure shows the monthly total of diffuse and global radiation. It's clear that the highest value of the diffuse and global radiation occurred during the month of June with a peak value of 219 kWh/m^2.
The actual and astronomical sunshine duration are given in part (e). It's obvious that the astronomical sunshine duration reach's 14 hours during the months of May, June and July while the actual sunshine duration reach's 12.2 hours during the month of July.
Fig (3) gives the meteorological parameters for the city of Baghdad. The results reflect that the highest maximum and highest minimum temperatures occurred in mid-July. Also, it's seen that the daily range between maximum and minimum temperatures is higher during summer than during winter.
The monthly temperature shown in part (b) of the box plot. It's clear that the highest maximum monthly temperature occurred in July (42^oC) and the lowest minimum monthly temperature happened in January (3^oC). The ends of the thin lines in the plot represent the highest and lowest daily temperature reached during the period of 2000-2009. It's seen that in the city of Baghdad daily temperature may reach (47^oC) during the month of July and (-5^oC) during the month of January. In addition, the range between the maximum and minimum temperatures is larger during months of June, July, August and September and the smaller during January and December.

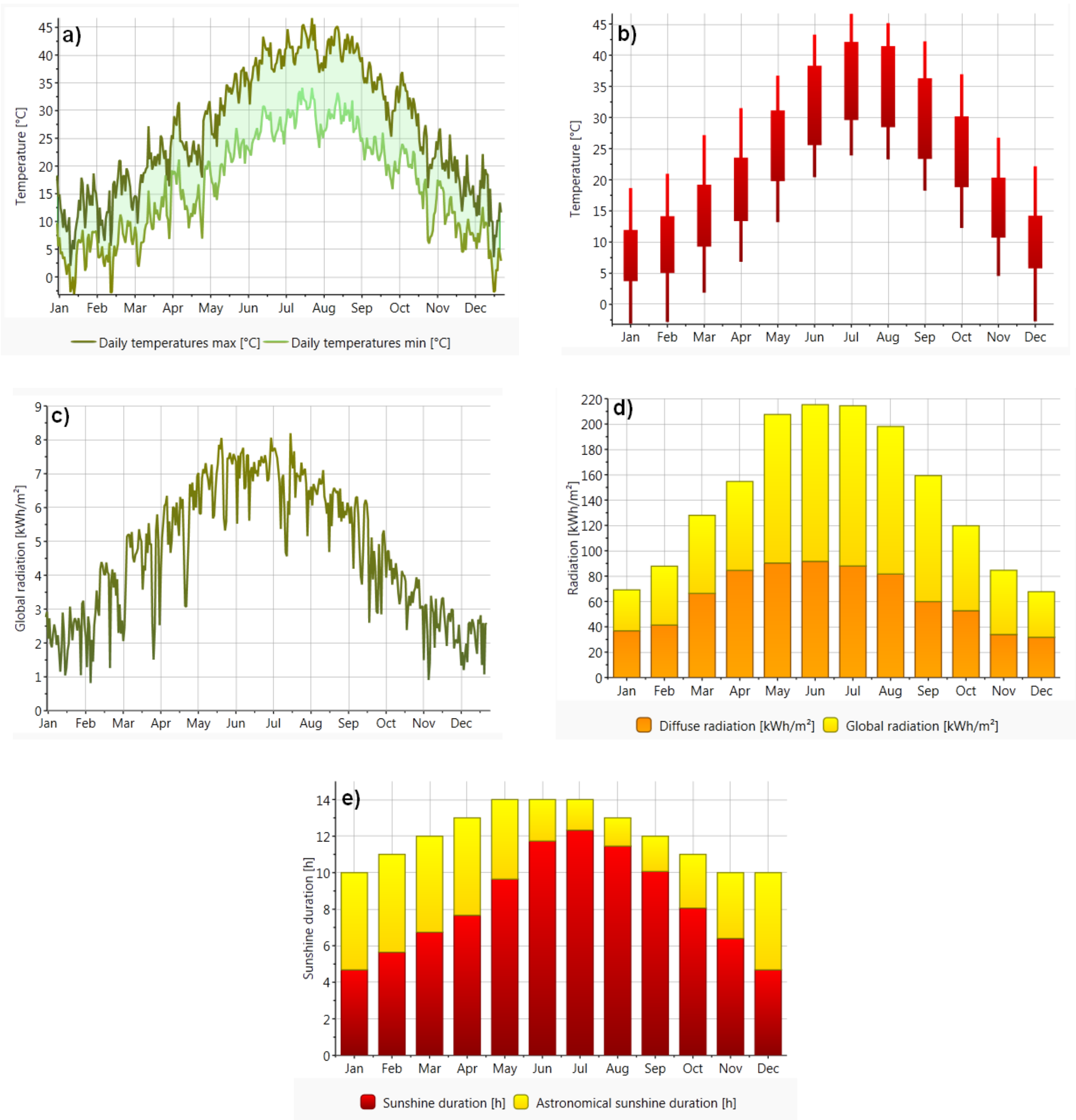


Fig. 2. Meteorological parameters for the city of Mosul. a) daily temperature, b) monthly temperature, c) daily radiation, d) monthly radiation, e) sunshine duration.

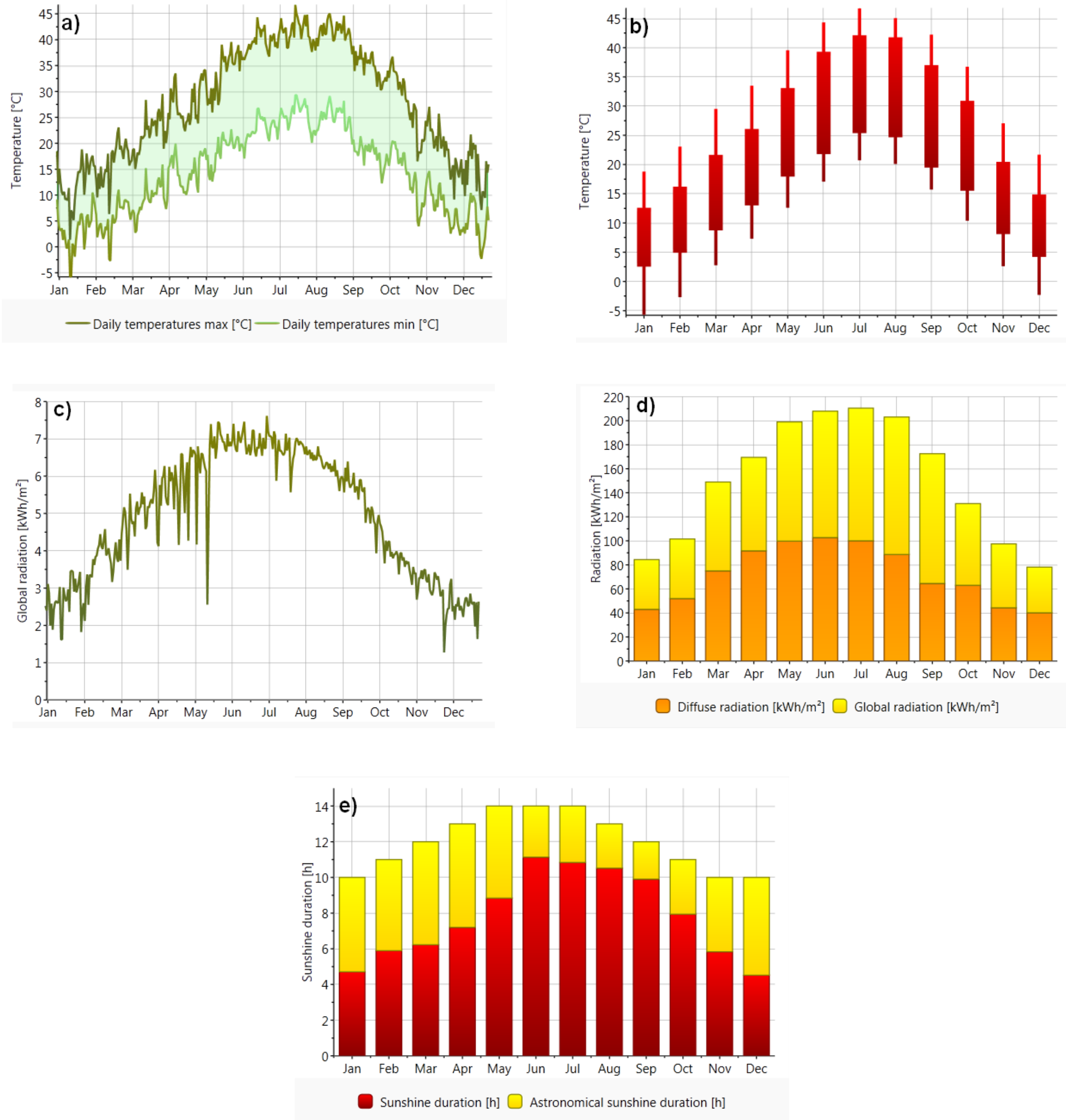


Fig. 3. Meteorological parameters for the city of Baghdad. a) daily temperature, b) monthly temperature, c) daily radiation, d) monthly radiation, e) sunshine duration.

Part (c) gives the daily global radiation on horizontal surface. It's seen that the global radiation may reach its peak value during the period from mid-May to July. The maximum of global radiation is 7.5 kWh/m^2 which occurred in July and the lowest global radiation is 1.3 kWh/m^2 reached during the last week of November.

The histogram is part (d) of the figure gives the monthly total of diffuse and global radiation. It's obvious that the highest value of the diffuse occurred during the month of June with a peak value of 105 kWh/m^2 and the highest value of the global radiation occurred during the month of July with a peak value of 210 kWh/m^2.

Part (e) reflects the actual and astronomical sunshine duration. The results indicate that the astronomical sunshine duration reach's 14 hours during the months of May, June and July while the actual sunshine duration reach's 11 hours during the month of June.

Fig (4) shows the meteorological parameters for the city of Rutba. It's clear that the highest maximum and highest minimum temperatures occurred in approximately in mid-July. It's seen that the daily range between maximum and minimum temperatures is higher during summer than during winter.

Part (b) shows the box plot for the monthly temperature. The results reflected that the highest maximum monthly temperature occurred in July (38^{o}C) and the lowest minimum monthly temperature happened in January (3^{o}C). The ends of the thin lines in the plot represent the highest and lowest daily temperature reached during the period of 2000-2009. It's clear that in the city of Rutba daily temperature may reach (43^{o}C) during the month of July and (-2.5^{o}C) during the month of January. In addition, the range between the maximum and minimum temperatures is larger during months of June, July, August and September and the smaller during January and December.

The results in part (c) represent the daily global radiation on horizontal surface. It's obvious that the global radiation may reach its peak value during the month of July. The maximum of global radiation is 8.7 kWh/m^2 which occurred in July and the lowest global radiation is 1.1 kWh/m^2 reached during the first week of December.

The monthly total of diffuse and global radiation given in part (d). That the highest value of the diffuse occurred during the month of May with a peak value of 78 kWh/m^2 and the highest value of the global radiation occurred during the month of July with a peak value of 250 kWh/m^2.

The histogram is part (e) of the figure shown the actual and astronomical sunshine duration. The results suggest that the astronomical sunshine duration reach's 14 hours during the months of May, June and July while the actual sunshine duration reach's 12 hours during the months of June and July.

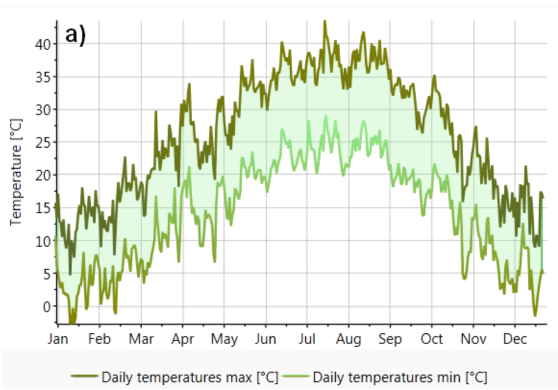
Fig (5) gives the meteorological parameters for the city of Basra. That the highest maximum and highest minimum temperatures occurred in mid-July. That the daily range between maximum and minimum temperatures is higher during summer than during winter.

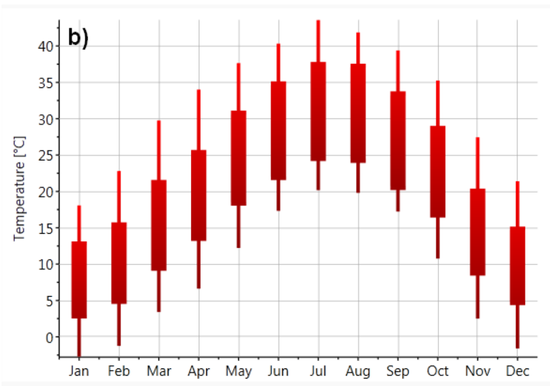
Part (b) reflect the box plot for the monthly temperature. It's seen that the highest maximum monthly temperature occurred in July (48^{o}C) and the lowest minimum monthly temperature happened in January (5.5^{o}C). The ends of the thin lines in the plot represent the highest and lowest daily temperature reached during the period of 2000-2009. It's obvious that in the city of Basra daily temperature may reach (52^{o}C) during the month of July and (1^{o}C) during the month of January. In addition, the range between the maximum and minimum temperatures is larger during months of June, July, August and September and the smaller during January and December.

The daily global radiation on horizontal surface given in part (c). The results show that the global radiation may reach its peak value during the period from mid-May to approximately mid-June. The maximum of global radiation is 7.4 kWh/m^2 which occurred approximately in mid-June and the lowest global radiation is 1.5 kWh/m^2 reached during the approximately mid-December.

Part (d) gives the monthly total of diffuse and global radiation. That the highest value of the diffuse occurred during the months of May and June with a peak value of 110 kWh/m^2 and the highest value of the global radiation occurred during the month of July with a peak value of 220 kWh/m^2.

The actual and astronomical sunshine duration given in part (e). It's clear that the astronomical sunshine duration reach's 14 hours during the months of May, June and July while the actual sunshine duration reach's 9.9 hours during the month of July.





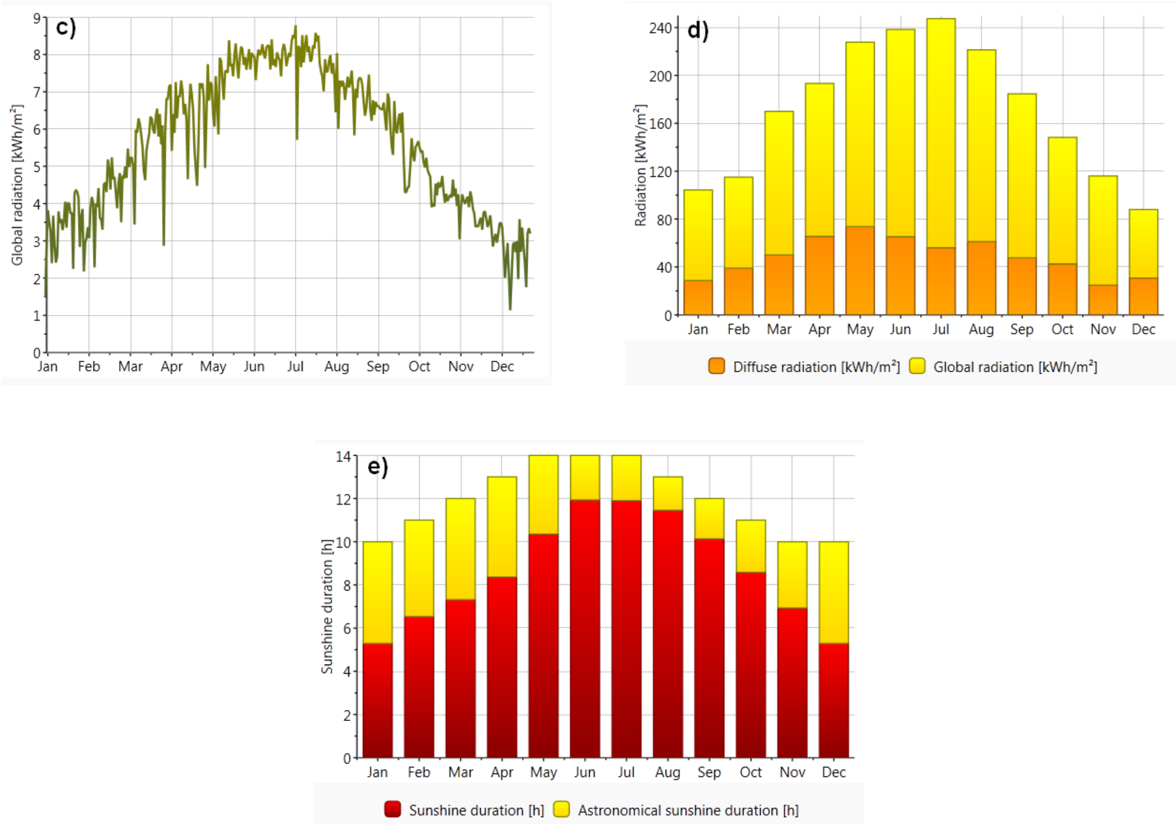
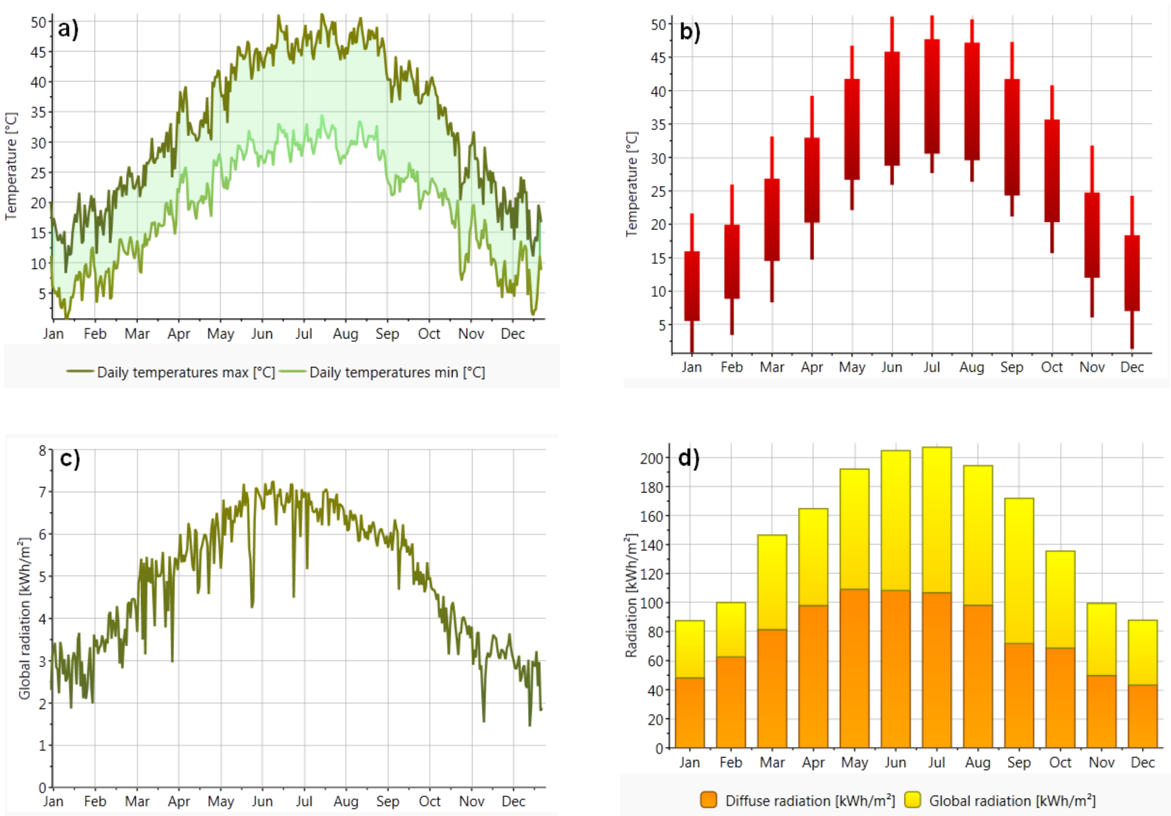


Fig. 4. Meteorological parameters for the city of Rutba. a) daily temperature, b) monthly temperature, c) daily radiation, d) monthly radiation, e) sunshine duration.



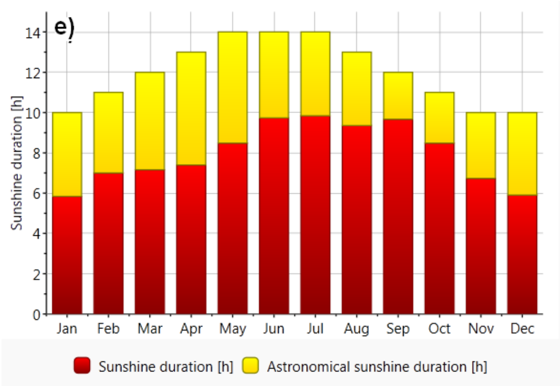


Fig. 5. Meteorological Parameters for the city of Basra. a) daily temperature, b) monthly temperature, c) daily radiation, d) monthly radiation, e) sunshine duration.

In this part of the study, data retrieved from the proposed program, including maximum and minimum temperatures, automated radiation, and total radiation measured by the automatic stations of the Climate Data Center of the Iraqi Ministry of Agriculture, are compared. The comparison included all stations included in this study (Mosul, Baghdad, Rutba, and Basra) as shown in figures (6,7 and 8).

The statistical criteria were employed; the correlation coefficient (R), Root Mean Square Error (RMSE)and Mean Absolute Error (MAE) as tabulate in Table (2) for maximum and minimum temperatures and total radiation values. The program's performance was generally acceptable, based on the previously mentioned statistical criteria.

The Mosul station demonstrated excellent performance in estimating maximum temperatures, with the program's outputs being the best at the Mosul station. This was due to the correlation coefficient between the estimated and measured data, with the maximum temperature around 0.96, the lowest RMSE being around 3.37, and the lowest MAE being around 2.91, Therefore, the Mosul results are the best if compared to the results of other stations.

As for the minimum temperatures, Baghdad station achieved the optimal result, although the correlation coefficient between the estimated and measured minimum temperature values was only on the RMSE and MAE criteria, which were the lowest at 45.3 and 2.44 respectively. Thus, the program’s give the best performance at Baghdad station was based on the RMSE and MAE values, while the other stations (Mosul, Rutba and Basra) achieved similar values of MAE and RMSE values, as shown in the table (2).

Finally the Global radiation prediction by program's, the performance at the Mosul station was the most accurate and optimal, with a correlation coefficient higher than at other stations, at around 0.91and The RMSE and MAE were the lowest, at 0.97 and 0.77 respectively. Therefore, the program's estimation of global radiation values was better than at other considered stations.

Table 2. Statistical evaluation of meteonorm model accuracy of (Max temperature, Min temperature and Global Radiation) through the year 2024

Max temperature				
Statistical Criteria	Mosul	Baghdad	Rutba	Basra
R	**0.96**	0.95	0.94	0.93
RMSE	**3.87**	4.35	9.35	11.33
MAE	**2.91**	3.15	8.11	10.45
Min temperature				
Statistical Criteria	Mosul	Baghdad	Rutba	Basra
R	0.95	**0.88**	0.91	0.88
RMSE	5.55	**3.45**	6.21	6.56
MAE	4.89	**2.44**	7.08	4.75
Global Radiation				

Statistical Criteria	Mosul	Baghdad	Rutba	Basra
R	**0.91**	0.78	0.89	0.78
RMSE	**0.97**	1.33	1.67	4.97
MAE	**0.77**	0.92	1.36	1.28

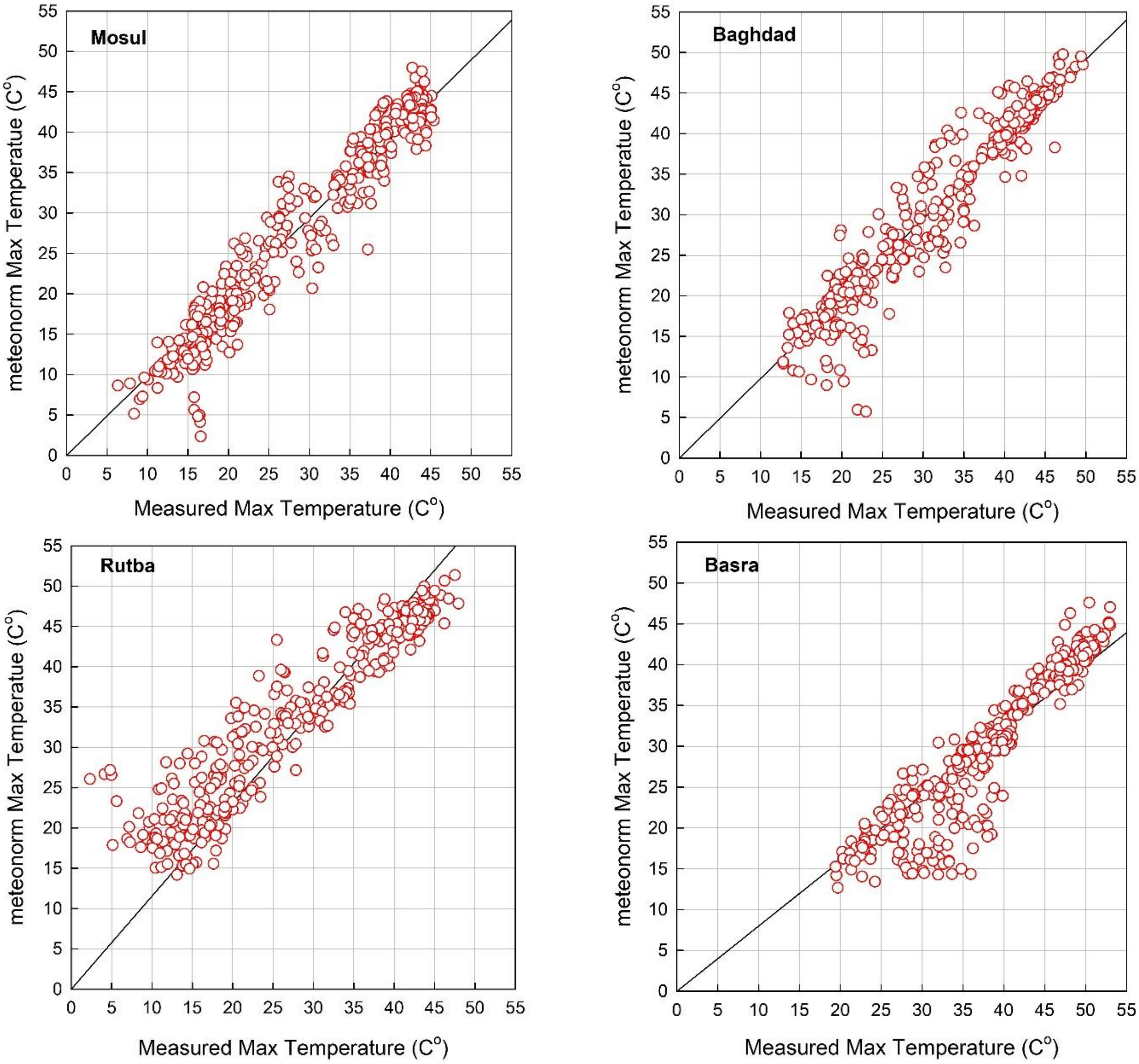


Figure 6. Scatter plots measured against meteonorm model estimated Maximum Temperature (C°) for all considered stations respectively

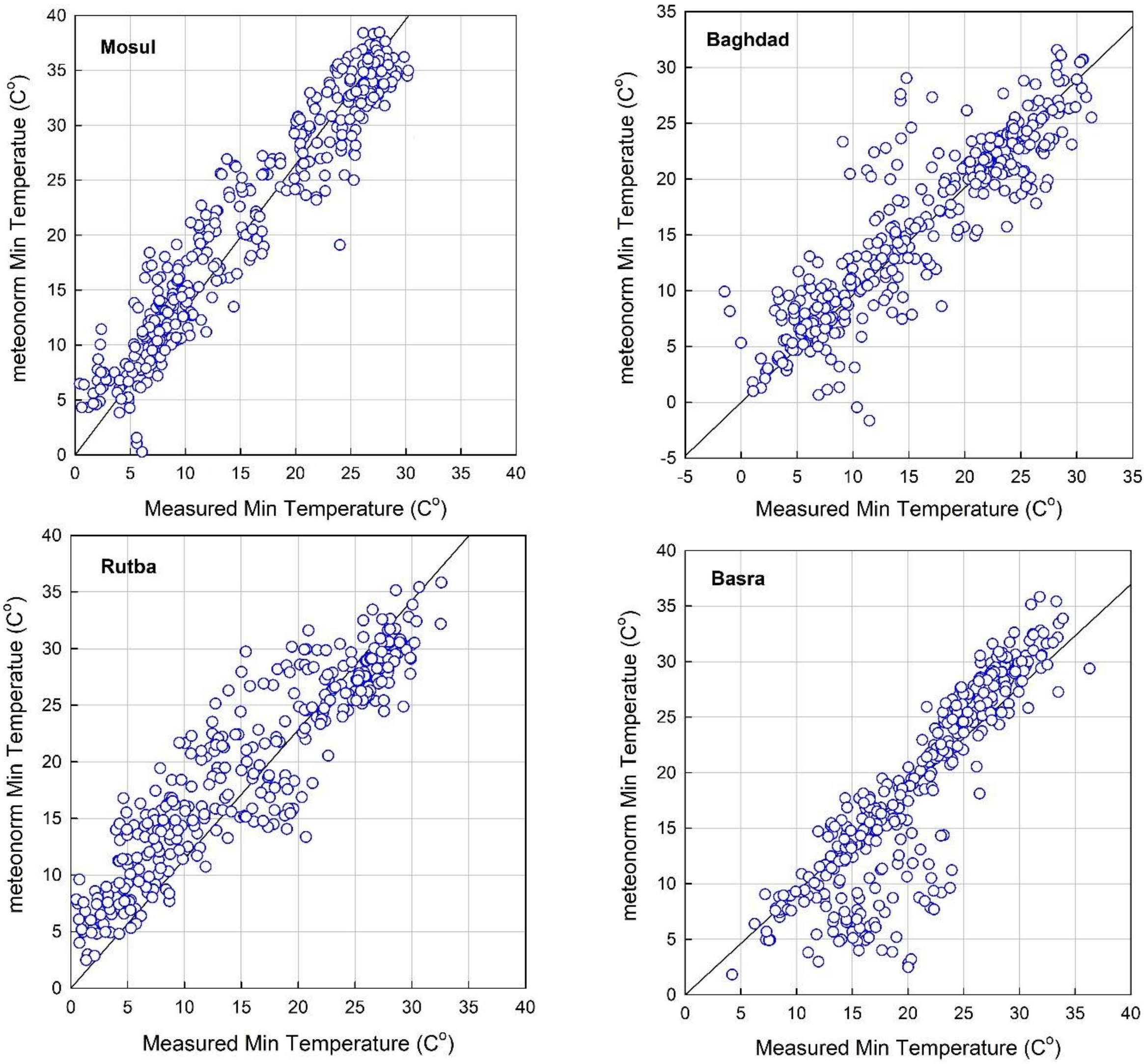
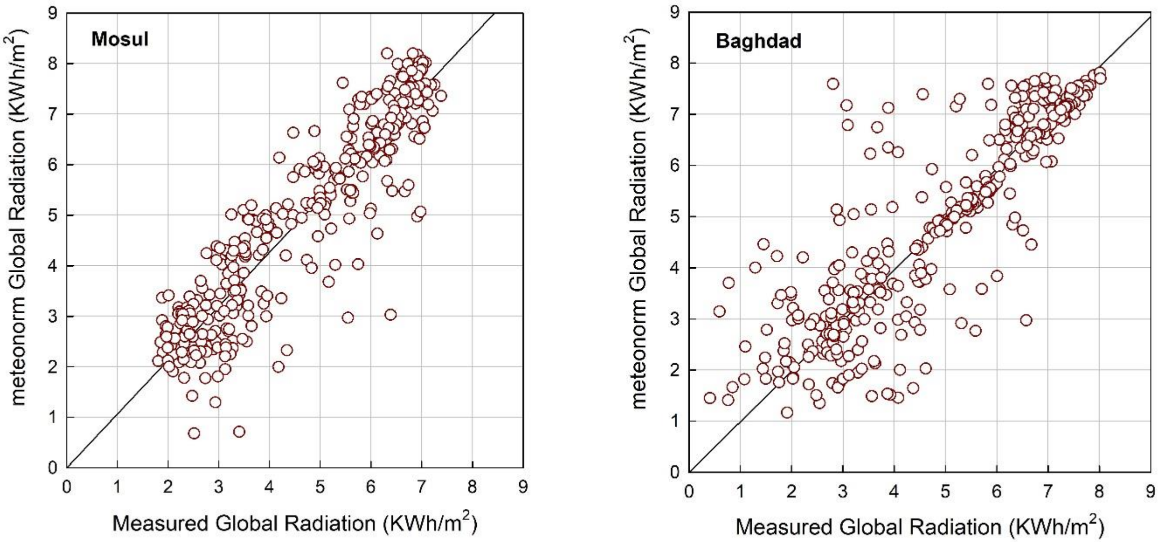
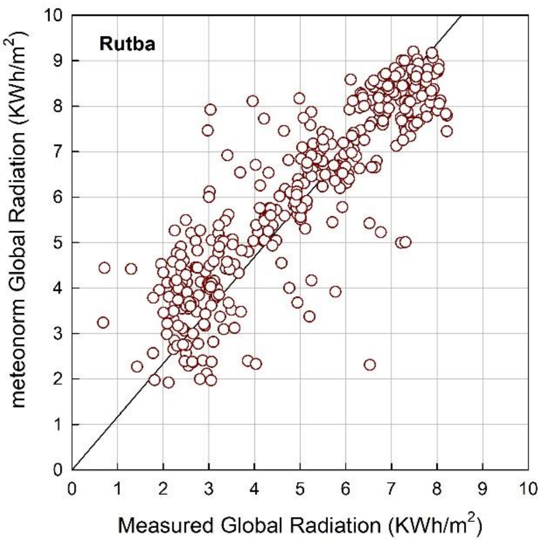


Figure 7. Scatter plots measured against meteonorm model estimated Manimum Temperature (C^o) for all considered stations respectively





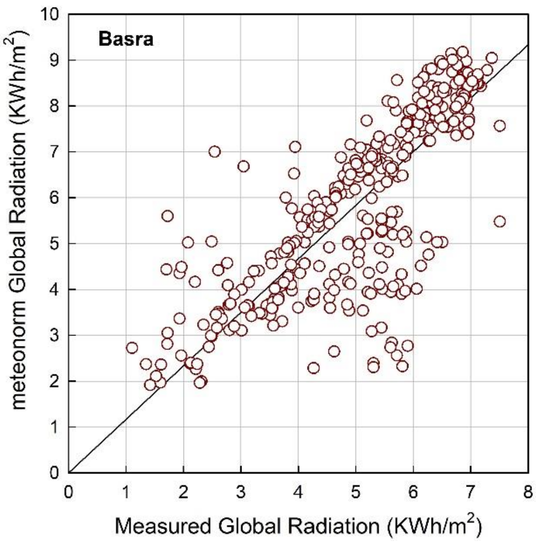


Figure 8. Scatter plots measured against meteonorm model estimated Global Radiation (Kw .h m $^{-2}$ /day) for all considered stations respectively

4. Conclusions

In this work the software package meteonorm weather and climate generator was used to generate the meteorological monthly means for four cities in Iraq, namely Mosul, Baghdad, Rutba, and Basra. The mean concluding remarking obtained from this work are the monthly and daily temperature of Mosul and Baghdad are comparable. Rutba is characterized by relatively low temperature while Basra is characterized by high temperature. The temperature during summer in Mosul and Baghdad may reach more than (42^{o}C) while in Rutba and Basra temperature may reach above (38^{o}C) and (48^{o}C) respectively. While during winter the temperature can reach values close to freezing level in Mosul, Baghdad and Rutba while Basra temperature dose not reach such level. The highest value of maximum diffuse radiation occurs in Basra (110 kWh/m^2) and the lowest value of maximum diffuse radiation occurs in Rutba (78 kWh/m^2), while the highest value of minimum diffuse radiation also occurs in Basra (45 kWh/m^2) and the lowest value of maximum diffuse radiation occurs in Rutba (26 kWh/m^2). The highest value of maximum global radiation occurs in Rutba (250 kWh/m^2) and the lowest value of maximum global radiation occurs in Baghdad (210 kWh/m^2), while the highest value of minimum global radiation also occurs in Basra (70 kWh/m^2) and the lowest value of minimum global radiation occurs in Mosul (69 kWh/m^2). The difference in the highest value of diffuse and global radiation (low diffuse - high global) in Rutba city is attributed to the fact that this city is rural which means that it has relatively low pollution particles. The highest maximum sunshine occurs in the Mosul because it is located relatively on high latitude while highest minimum sunshine occurs in the Basra because of low cloud cover during the year. Finally the proposed model has been evaluated by comparing with measured meteorological data and the evaluation results showed an acceptable ranges of data generation and the proposed model have a capability to employed in other regions of Iraq.

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