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Assessing of Climate Chang on Iraq using Meteonorm Weather Generator

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Abstract: *Iraq is considered one of the most Middle East countries vulnerable to climate change, Iraq faces a unique set of environmental challenges. In recent years, changing weather patterns, increasing heat waves, frequent dust and sand storms are all evidence of climate change. This research aims on assessing climate change on Iraq. Future climate scenarios for three decades of 2020, 2050, and 21000 were generated from the global climatological database Meteonorm for scenarios B1, A1B, and A2. Anomalies of mean monthly air temperature by the end of these decades, relative to the mean temperatures for the period 2000-2009 were calculated and analyzed for three cities; Mosul, Bagdad, and Basra, which represent the northern, middle, southern parts of Iraq. The showed air temperature is expected to increase gradually from one decade to another and the increase in minimum and maximum temperatures is comparable. The results also illustrated that effects of climate change during the months of February, March, and October will be less than that during other months. It was evident that scenario B1 resulted in the lowest increase in temperature and scenario A2 predicted the highest increase in temperature. The results indicated that Northern city of Mosul is expected to be relatively less affected by climate change than the other two cities.*

Keywords: *Climate, Iraq, IPCC, Meteonorm, Temperature*

I. Introduction

Emissions of greenhouse gasses have been increased since the industrial revolution in the early 19th century due to increasing in fossil fuel burning and developments in human economic and social lifestyles. The greenhouse effect makes life on Earth possible. As solar radiation warms the Earth's surface, a portion of the Earth's atmosphere acts like a greenhouse and retains heat that would otherwise be lost back to space. While the greenhouse effect is natural and necessary for human life, the fundamental problems are that human activities have created an excess of greenhouse gases in the atmosphere, and that the enhanced greenhouse effect has brought about global warming at a rapid and accelerating rate [1]. Research works by world's scientific community concluded that over the next fifty to a hundred years, global change has to be the greatest economic and environmental threat facing the planet. For example, many of the world's coastal cities will be in trouble because of sea level rise caused by melting ice sheets and the warming ocean, and millions of people will be environmental refugees, displaced from the deltas of the world's major rivers [2]. Climate numerical models predict that the air temperature will increase by 1 to 3.5 oC by the year 2100. This amount of increase is more than changes in temperature during the past 10,000 years [3].

A large number of publications in the literature deal with climate change in the Middle East countries. However, fewer publications have focused on climate change impacts on Iraq. Zakaria et al., (2013) used the climatic model CGCM3.1 (T47)2 to explain the changes in average temperatures and the rainfall on the Middle East and North Africa region with special emphases on Iraq. Their results suggested that fluctuation in the average monthly temperature gives a clear impression that the future portends a higher temperature. Azooz and Talal (2015) applied a nonlinear regression to compiled historical data related to mean monthly temperatures, and precipitations for four main cities in Iraq. They concluded that air temperature is increasing while precipitation is declining. Al-Jobori et al., (2015) used EdGCM to evaluate the global warming over Iraq. Their results indicated that that during the decade of 2050's the northern part of Iraq is less affected by global warming while during the decade of 2090's, the entire country will be affected by global warming. The increase in the annual temperature is expected to be within 4 oC. De Pauw et al., (2015) employed GIS for mapping climate change in Iraq and Jordan. Results indicate that in both Iraq and Jordan the climate should become drier, with reduced growing periods, shifts in climatic zones, and higher temperatures and water requirements than currently.

II. Materials and methods

1. *Study Area*

Iraq lies between 29°5ˉ to 37°15ˉ N latitudes and 38°45ˉ to 48° 45ˉ E longitude. Iraq is a country in Western Asia spanning most of the northwestern end of the Zagros mountain range, the eastern part of the Syrian Desert and the northern part of the Arabian Desert. The desert is in the southwest and central provinces

along the borders with Saudi Arabia and Jordan and geographically belongs with the Arabian Peninsula. The climate of Iraq is characterized by sub-tropical, continental, arid to semi arid with dry hot summers and cooler winters. The average annual temperature is varies from 8.5ºC to 49°C. The summer temperature range is between 16ºC –49ºC while the winter temperature range is between 8.5ºC - 14ºC [8].

2. *Meteonorm Weather Generator*

The global climatological database Meteonorm (www.meteonorm.com) is widely used as meteorological input for simulation of solar applications and buildings. It's a combination of a climate database, a spatial interpolation tool and a stochastic weather generator. Meteonorm can also be used for climate change studies. Instead of climate values, the results of IPCC AR4 results are used as input. From all 18 public models an average has been made at a resolution of 1o. The anomalies of the parameters temperature, precipitation and global radiation and the three scenarios B1, A1B and A2 have been included. With the combination of Meteonorm's current database 1961-90, the interpolation algorithms and the stochastic generation typical years can be calculated for any site, for different scenarios and for any period between 2010 and 2100 [9].

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 selected for Baghdad city (33.33 oN, 44.4 oE). For each of the three IPCC scenarios future periods of 2020, 2050, and 20100 were selected. Among the output only minimum (Tmin), maximum (Tmax), and daily (Tdaily) temperatures were chosen. Anomalies of these three temperatures, relative to the period 2000-2009, were calculated for the periods 2020, 2050, and 2100. Three cities (Mosul, Baghdad, and Basra) were chosen to represent northern, central, and southern regions of Iraq. Table 1 gives the geographical longitude, latitude, and height above sea level for the three cities. Figure 2 shows the locations of the three cities on map of Iraq.

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

City	Longitude	Latitude	Height above sea level
Mosul	43.16° E	36.36° N	228 m
Baghdad	44.36° E	33.31° N	34 m
Basra	47.78° E	30.51° N	3 m

III. Results and discussion

Table 2 shows the monthly mean of Tmin, Tmax, and Tdaily temperature for the cities of Mosul, Baghdad, and Basra. It is seen that for Mosul, Tdaily ranges from 6.9 oC in January to more than 33 oC in July. For Baghdad, Tdaily ranges from 7 oC in January to more than 33 oC in July for Basra, Tdaily ranges from 10.9 oC in January to more than 38 oC in July.

Table 2: Mean monthly temperatures for Mosul, Baghdad, and Basra

Month	Mosul			Baghdad			Basra		
	$T_{Min.}$	$T_{Max.}$	T_{Daily}	$T_{Min.}$	$T_{Max.}$	T_{Daily}	$T_{Min.}$	$T_{Max.}$	T_{Daily}
Jan	3.2	11.6	6.9	2.6	12.5	7.0	6.7	15.9	10.9
Feb	4.6	13.6	8.9	5.0	16.2	10.3	9.8	19.9	14.6
Mar	8.5	18.7	13.4	8.8	21.6	14.9	14.8	26.8	20.5
Apr	12.4	22.9	17.8	13.2	25.7	19.6	20.5	32.4	26.6
May	18.2	30.2	24.2	18.2	32.5	25.3	26.6	40.4	33.4
Jun	24.2	37.2	31.2	22.5	38.4	30.9	28.7	44.1	36.9
Jul	25.1	40.8	33.5	25.9	41.4	33.6	30.5	45.8	38.1
Aug	27.0	40.0	33.4	25.7	40.7	33.0	29.8	45.2	37.3
Sep	21.9	35.1	28.7	20.0	36.4	28.2	24.5	40.6	32.6
Oct	17.3	29.2	22.9	15.9	30.5	22.8	20.5	35.0	27.3
Nov	9.3	19.5	14.3	8.0	20.1	13.9	12.7	24.6	18.5
Dec	5.0	13.4	8.9	4.3	14.4	8.9	8.3	18.0	12.8

To illustrate how temperature is affected by climate change for 2020, 2050, and 2100 decades. Temperate anomalies, for Baghdad are displayed in Figures 2 through 4 for the three scenarios B1, A1B, and A2. It is seen that is progressively increases with decades and the values of are comparable for most months of the year except the months February, March, and October. For scenario B1, is expected to reach more 1, 3, and 3 oC by the end of 2020, 2050, and 2100 decades respectively. For scenario A1B, is expected to reach more 1.5, 3, and 4 oC and for scenario A2, will increase to 1.5, 3, and 5 oC. This indicates that the amount of increase in during by the end of 2050 decade is close to that expected by the end of 2050 decade for the three scenarios. By the end of 2100 decade, the effects of the scenarios on the increase of air temperature is notable since the amount of is expected to be 3, 4 and 5 oC. The results also show that Tmin, Tmax, and Tdaily are affected by

the same amount for most months expect for the month of February and August. In these two months the minimum temperature is less affected that the maximum temperature. Figure 5 shows a comparisons of values by the end of 2100 decade for the three scenarios for Baghdad. It is clear that among the three scenarios, scenario B1 results in lowest values of and scenario A2 results in highest values of. Again is seen that values during the months of February, March, and October will be less that the other months. Figures 6 through 8 give a comparison between expected values of the three cities by the end of 2100 decade for each scenario. It is seen that for Basra is expected to be higher than those expected for Baghdad and Mosul for all three scenarios. The results reflect that Mosul city will be relatively less affected by global warming. It is noted that the values of for Mosul is clearly lower that of the two other cities during the months of October through December and they are almost close to those of Baghdad during the months of April and May.

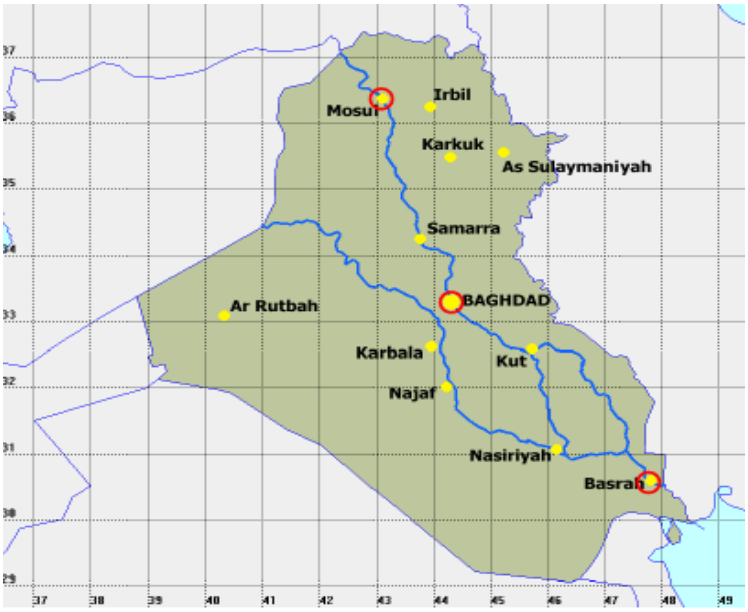

Figure 1: Map of Iraq showing the location of Mosul, Baghdad, and Basra.

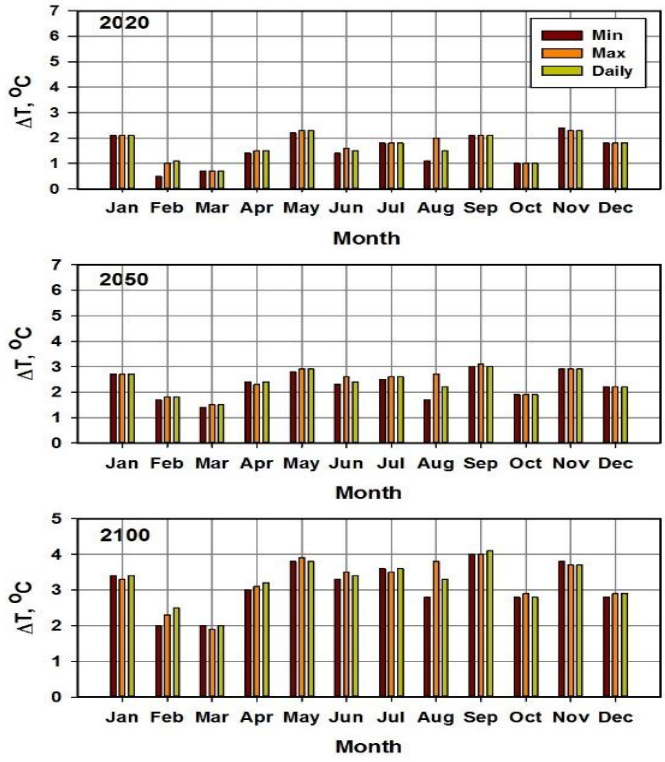

Figure 2: Temperature monthly anomalies for Baghdad city by the end of 2020, 2050, and 2100 decades for scenario B1.

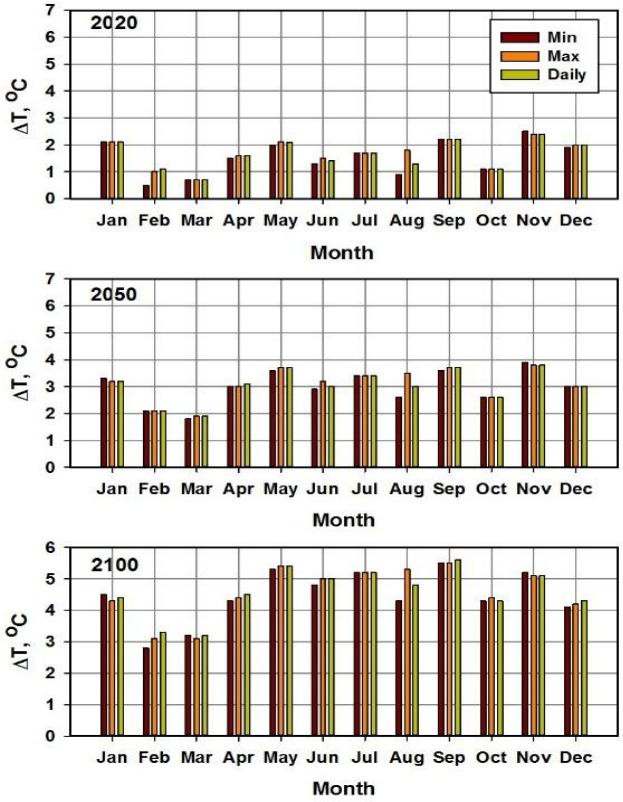

Figure 3: Temperature monthly anomalies for Baghdad city by the end of 2020, 2050, and 2100 decades for scenario A1B.

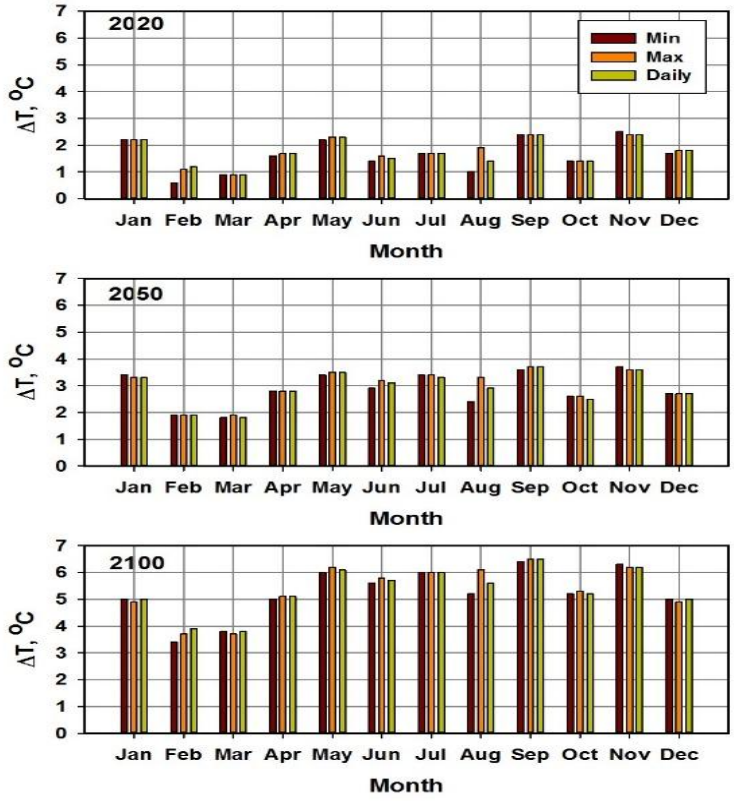

Figure 4: Temperature monthly anomalies for Baghdad city by the end of 2020, 2050, and 2100 decades for scenario A2.

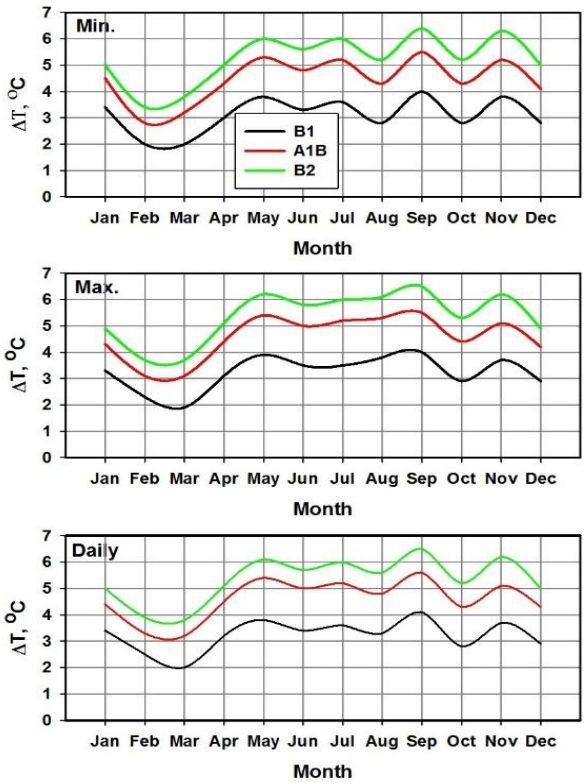

Figure 5: Comparisons of monthly temperature anomalies for Baghdad city by the end of 2100 for scenarios B1,A1B, and A2.

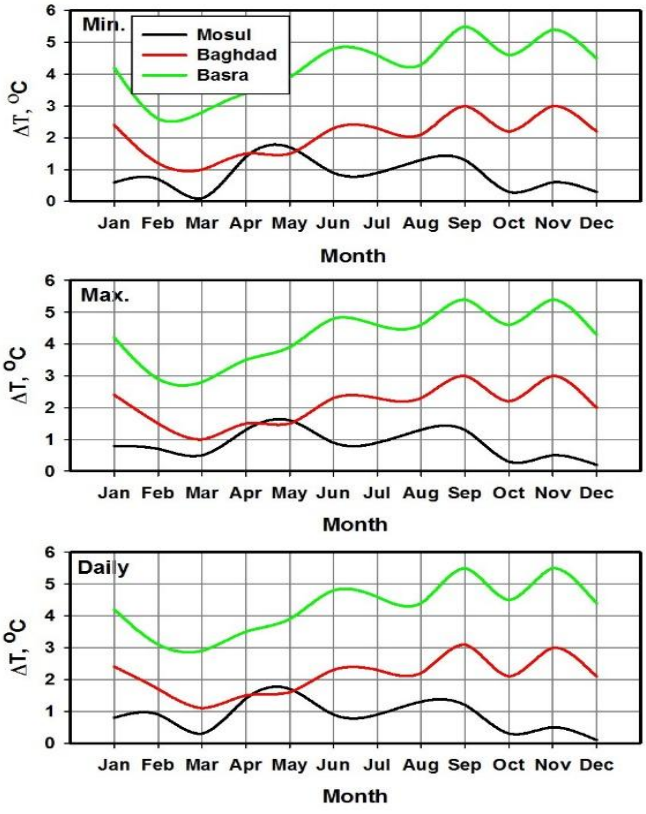

Figure 6: Comparisons of monthly temperature anomalies by the end of 2100 for scenario B1 for Mosul, Baghdad, and Basra

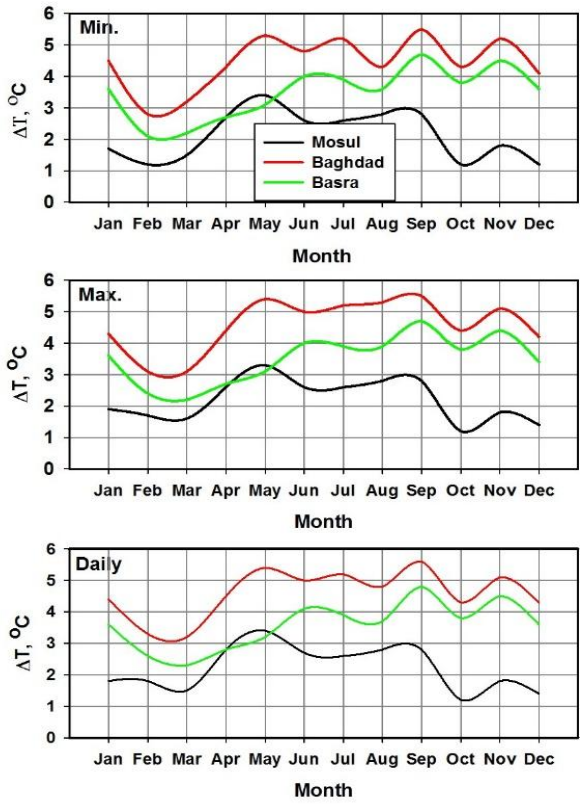

Figure 7: Comparisons of monthly temperature anomalies by the end of 2100 for scenario A1B for Mosul, Baghdad, and Basra

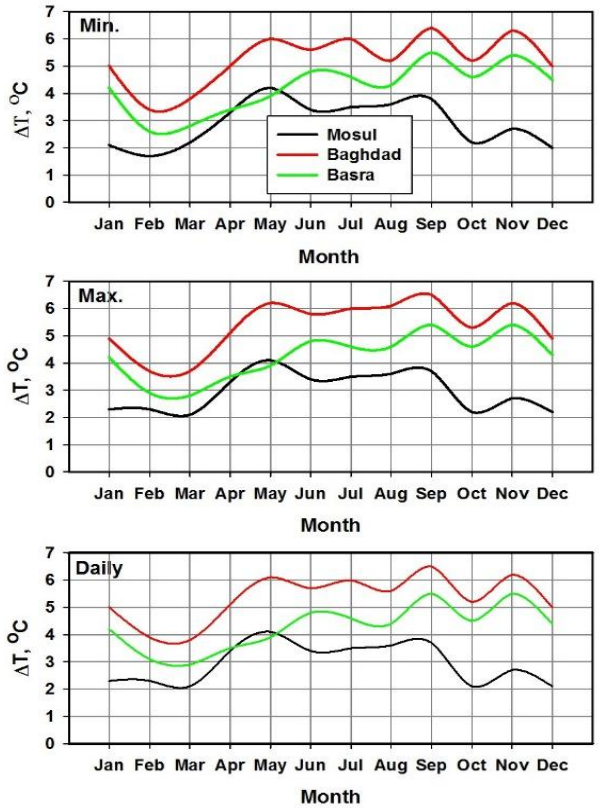

Figure 8: Comparisons of monthly temperature anomalies by the end of 2100 for scenario A2 for Mosul, Baghdad, and Basra

IV. Conclusion

In this research future minimum, maximum, and daily air temperature for three cities in Iraq, representing northern, central, and southern part of the country, were generated by the global climatological database, *Meteonorm*, for the three IPCC scenarios B1, A1B, and A2. The results give an estimation that the air temperature will gradually increase from one to century to another and scenario A2 will give highest estimate and scenario B1 will produce the less estimate. It was found that minimum and maximum temperatures, and consequently daily temperature, will be affected by almost in same manner. The analysis showed that the warming is expected to be relatively higher during warmer months, April to September. Also the effect of global warming on the southern part of the country will higher compared with that on the northern part.

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