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RESEARCH PAPER

# Prediction long term Surface Temperature Variation in Kurdistan Region using Meteonorm Weather Generator (MWG)

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**A B S T R A C T:**

The climate of Kurdistan Region was subjected to many changes that led to a noticeable rise in temperatures. The current study aims to assess the climate of Kurdistan Region- Iraq by using Weather Generator program (MWG). We have chosen two different regions which are Erbil and Duhok governorates. The global climate database (MWG) was run for the three climate scenarios B1, A1B and A2 for 2020, 2050 and 2100. The average temperature was calculated and analyzed for the period (2000-2009) for Erbil and Dohuk governorates. The results have shown that Scenario B1 predicted the lowest rise in temperature compared to Scenario A2 which expected the highest rise in temperature. The predicted temperature of Erbil is higher than Dohuk for the three selected years and scenarios.

KEY WORDS: Meteonorm, IPCC, Climate, Kurdistan, Temperature.
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## 1.INTRODUCTION :

Climate change of the earth is considered as one of the most important topics that need to be investigated. Climate change is a result of the change in earth's energy balance, how much of the energy from the sun that enters the earth (and its atmosphere) compared to energy released back into space (Park, Lee et al. 2022). It occurs at various timescales and in any meteorological parameter (temperature, rainfall, cloudiness, etc.), and gives how much change in the statistical distribution of weather patterns during an extended period of time (from decades to millions of years). From the perspective of large time periods, climate change is caused by a multitude of factors like variations in solar radiation (changing parameters of the earth's orbit, variations of the solar activity observed via sunspot number), drifting continents (see plate tectonics), and volcanic eruptions (producing large amounts of sulfate-based aerosols).

Some of atmospheric gases also play an important role in controlling the climate, which is called greenhouse gases. Greenhouse gases is almost useful within a considerable concentration. However, the variation of these concentration could lead to a remarkable change in global warming (Aizebeokhai 2009). During the last decades, human activities (in particular burning of fossil fuel and pollution as the main consequences of the growth of population and industrialization) have been identified as significant causes of recent global warming which in turn causes climate change. The Intergovernmental Panel on Climate Change (IPCC) is now 95 percent certain that humans are the main cause of current global warming (Haunschild, Bornmann et al. 2016). The climate change is posing a serious risk for both human societies and natural systems and global warming has become a worldwide public health concern. The main direct health effect of climate change is increasing risks for mortality and morbidity due to ambient temperature. Globally, 7.71% of total mortality was attributable to non-optimum temperature, most of which was

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caused by coal (7.29%) (Gasparrini, Guo et al. 2015). The Earth's temperature has increased by about (0.7 ◦C) in the twentieth century, and the rate of increase became greater during the past 50 years (de Lorenzo and Liaño 2017).
(Al-Jumur, Kareem et al. 2021) has built an intelligent temperature prediction model of Erbil city in Kurdistan region of Iraq based on a historical dataset from 1992 to 2016 in each year there are twelve months' average temperature readings from January to December while our research predicted the monthly temperature of both Erbil and Duhok governorates by using via some statistical models aimed to forecast the fluctuations that might have happened to atmospheric parameters such as temperature.

According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5), the globally averaged surface temperature showed a warming of 0.85℃ over the period from 1880 to 2012 and was predicted to increase by 2.6℃ to 4.8℃ at the end of the 21st century (2081–2100) relative to 1986–2005 under high-emission scenarios (IPCC, 2013). Climate change will potentially affect the regional and local activities such as construction, transport planning, infrastructure maintenance, engineering, and forestry. As the global climate changes, An increase of possibility to encounter extreme climate and weather events which often occur at regional scale (Xu 2019). As decision makers respond to these risks, the nation's scientific enterprise can contribute both by continuing to improve understanding of the causes and consequences of climate change, and by improving and expanding the options available to limit the magnitude of climate change and to adapt to its impacts. To do so, the nation needs a comprehensive, integrated, and flexible climate change research enterprise that is closely linked with action-oriented programs at all levels. A comprehensive climate observing system, improved climate models and other analytical tools, investments in human capital, and better linkages between research and decision are very necessary for improving climate research.
In recent years an increasing number of studies have addressed various aspects of some potential climate feedbacks, both from the point of view of modern processes and likely future climate. The subject received little attention in the most recent scientific assessments of the Intergovernmental Panel on Climate Change (IPCC, 2013) (Boscolo-Galazzo, Crichton et al. 2018). Seasonal and diurnal fluctuations of temperatures could impact the potential for outbreaks at increasing temperatures predicted due to climate change in future (Robert, Christofferson et al. 2019). Since temperature is considered as the most important factor of atmospheric circulation and climate change. In current research, suitability of Meteonorm Weather Generator (MWG) was investigated in Erbil region to predict the future long-term temperature. This study will be the first study that uses a forecast meteorological model in Kurdistan region.

## 2. Materials and methods

### 2.1 Study Area

The study area in this research is located at the, Kurdistan region-Iraq (Erbil, Duhok). Where Erbil is the city Kurdistan region and located east to Sulaymaniyah Governorate and it is only 350 km from Baghdad. The city is surrounded by Nineveh from west and Kirkuk city from south and Iran and Turkey from North. Dohuk governorate is located in north-west of Iraq and forms the western province in Iraqi Kurdistan region, and is encircled by mountains (TANRIVERDI and RAGAB) . The climate of Kurdistan region is characterized by extreme conditions, were thermal extremes difference between day and night and between winter and summer are noticed. In summer, the temperature range exceeds (30° C). During the day, the temperature reaches beyond (50°C) at the southern boundaries of the three Governorates, while in the northern edges it goes down well below (20°C). In winter the daily temperature ranges from about (-15°C) to about (15°C). Climate of Kurdistan region-Iraq is hot and dry in summer and cold and wet in winter , with short spring and autumn seasons compared to summer and winter (MUSTAFA, RASHID et al. 2018).
Erbil and Duhok location are described in the table (1) below:

Table (1): The location of two stations

| Station | Longitude $^{o}$ E | Latitude $^{o}$ N | Altitude Meters |
|---|---|---|---|
| Dohuk | 43.009 | 36.847 | 583 |
| Erbil | 44.039 | 36.195 | 420 |

**2.2 Metronome Weather Generator (MWG)**

The global climatological database Meteonorm (www.meteonorm.com) is frequently utilized in simulations of solar applications and structure. The Meteonorm 7.0 software program, which combines a stochastic weather generator, a spatial interpolation tool, and a climate database for any location(Mangan and Koçlar Oral 2020)
combines a stochastic weather generator, a spatial interpolation tool, and a climate database(Remund, Müller et al. 2010) .The temperature in this study was adjusted to account for temperature, precipitation, and radiation anomalies as well as the three scenarios B1, A1B, and A2. Meteorology is used in climate change studies. The interpolation algorithms and the stochastic generation typical years can be generated for any site, for many scenarios, and for any time period between 2010 and 2100 using Meteonorm's current database 1961-90.

**2.3 methodology**

As an input for the Meteonorm, we have chosen historical temperature data for the period 2010 for each of the three IPCC scenarios to obtain future temperature for periods of 2020, 2050, and 2100. Among the output, minimum ($T_{min}$), maximum ($T_{max}$), and daily ($T_{daily}$) temperatures were obtained. Two cities (Erbil, Duhok) were chosen to represent the northern of Iraq. Figure 1 shows the locations of the cities on the map of Iraq. The anomalies of the parameter's temperature, precipitation and global radiation and the three scenarios B1, A1B and A2 have been included. A2 depends on maximum temperature, B1 depends on the minimum temperature while A1B depends on the average temperature (Abd AlKareem 2016).

**3. Data and Results**

The data of Air Temperature (Average, Maximum, Minimum) for Erbil, and Dohuk regions were collected from the station of ministry of Agriculture in Erbil in Kurdistan region. The data is shown in the Table (2). Meteonorm Weather Generator (MWG) were used in this research to estimate and predict the variation of Temperature in Kurdistan region for the period up to 2020, 2050, and 2100. Latitude, and longitude data for both regions are required for running the model.

Table (2): The Monthly Air Temperature c$^{o}$ for Kurdistan region

| Month | Erbil | | | Dohuk | | |
|---|---|---|---|---|---|---|
| | $T_{daily}$ .°c | $T_{max}$ .°c | $T_{min}$ .°c | $T_{daily}$ .°c | $T_{max}$ .°c | $T_{min}$ .°c |
| Jan | 8.04 | 12.41 | 3.68 | 6.69 | 11.51 | 2.78 |
| Feb | 9.91 | 14.41 | 5.41 | 8.81 | 13.35 | 4.43 |
| Mar | 14.33 | 19.85 | 8.82 | 12.39 | 18.26 | 8.41 |
| Apr | 19.9 | 24.73 | 13.65 | 18.28 | 23.22 | 12.58 |
| May | 26.52 | 34.23 | 18.81 | 23.86 | 30.31 | 17.52 |
| Jun | 31.53 | 38.93 | 24.13 | 30.19 | 37.43 | 23.03 |
| Jul | 34.85 | 42.11 | 27.6 | 33.73 | 40.81 | 26.62 |
| Aug | 34.45 | 41.67 | 27.23 | 33.17 | 40.19 | 26.13 |
| Sep | 29.38 | 36.74 | 22.59 | 28.36 | 35.23 | 21.24 |
| Oct | 24.18 | 30.18 | 18.19 | 22.87 | 29.23 | 16.77 |
| Nov | 15.38 | 20.57 | 10.18 | 14.41 | 19.49 | 9.31 |
| Dec | 10.08 | 14.64 | 5.53 | 9.43 | 13.67 | 5.17 |

Climate change depends on changes that directly affect the temperature. As shown in Table (2), the temperature ($T_{daily}$,$T_{max}$, and $T_{min}$) for Erbil , and Duhok governorates in Kurdistan region of Iraq were recorded in station . The maximum value was in Jul (34.85 ℃, 42.11℃, 27.6℃) for Erbil and (33.73℃, 40.81℃, 26.62℃) for Duhok, while the minimum temperature was recorded in January for Erbil (8.04℃ ,12.41℃, 3.68℃) and Duhok (6.69 ℃, 11.51℃, 2.78℃).

Figure 1 shows the convergence of the values of monthly air temperature for 2010 taken from a meteorological station as well as the values recorded from Meteonorm Weather Generator (MWG) program to confirm that a program can be used to predict not only the temperature but also other factors that influence climate change, including Global radiation, Perception, and Sunshine duration. Depending on the correlation coefficient ($R^2$), the ratio is 0.99. The red color representas Erbil and the blue color is Duhok as shown below.

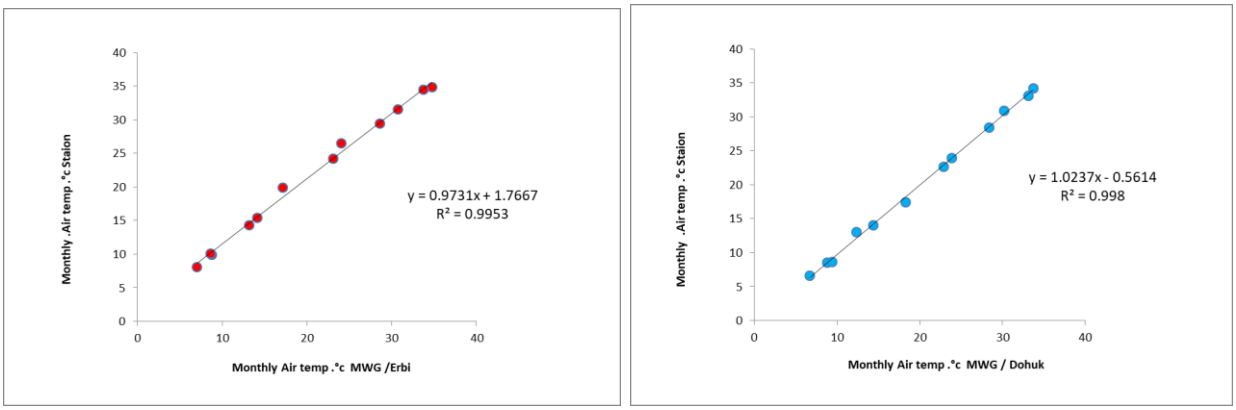



Fig 1: Correlation coefficient ($R^2$) of the monthly air Temperature between station and MWG c$^o$ for Kurdistan region cities for year 2010

The climate change forecasts (IPCC scenarios) used for the calculation of future time periods (2020, 2050, 2100), and three different scenarios B1 (low), A1B (mid) and A2 (high) for air temperature (daily, maximum, minimum). Figure 2 illustrates the scenarios that are used in Metronome Weather Generator (MWG) program which include climate changes depending on surface temperature changes for years 2020, 2050, and 2100 for two cities Erbil, and Duhok.
figure 2. shows an estimate of (ΔT) (Daily, Maximum, Minimum) for Erbil city for a scenario (B1). The figure shows extremism and changes in the temperature difference for years (2020,2050,2100). we note that the amount of extremism of temperature changes increases in October (2020, 2050), while in 2100, we observe an increase in April, and May. The amount of the increase was from 1 to 2 ℃ which is considered as a maximum difference value of temperature.
where this scenario represents the low estimate of temperature change.

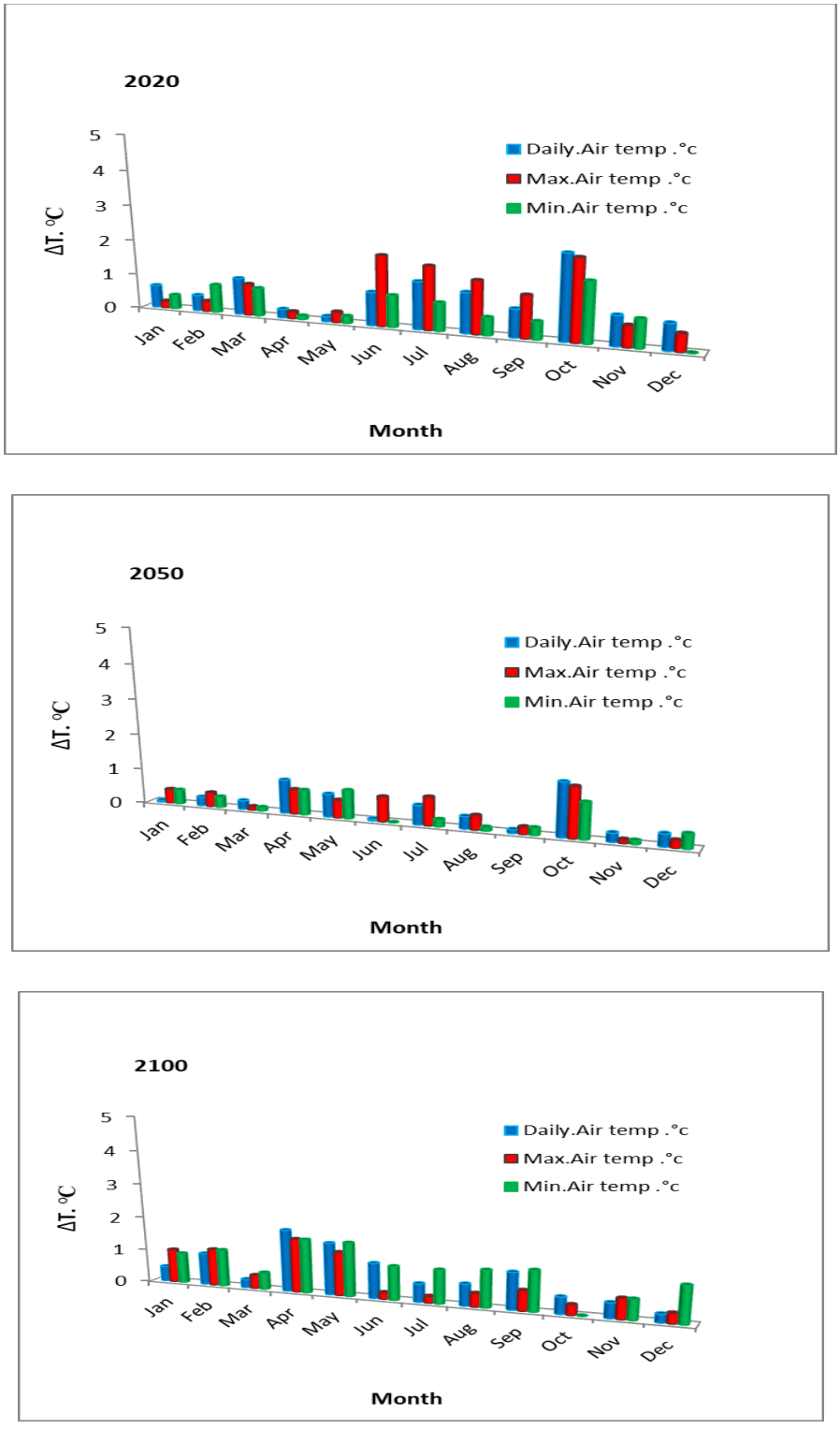



Fig (2): Temperature monthly anomalies for Erbil city by the end of 2020, 2050, and 2100 decades for scenario B1

figure 3 shows the average temperature (Daily, Maximum, Minimum) for Erbil city and show extremism changes in the temperature difference for years (2020,2050,2100). The estimation of ($\Delta T$) scenario (A1B) for estimating the amount of extremism(ΔT), the temperature changes increases in the month of (October) for year (2020), while for a year (2050, 2100) we observe an increasing in the (April, May), knowing that the amount of the increase ranges from1to 3 ℃ as a maximum difference value of temperature. However, this scenario represents the mid estimate of temperature change of Erbil city in Kurdistan region.

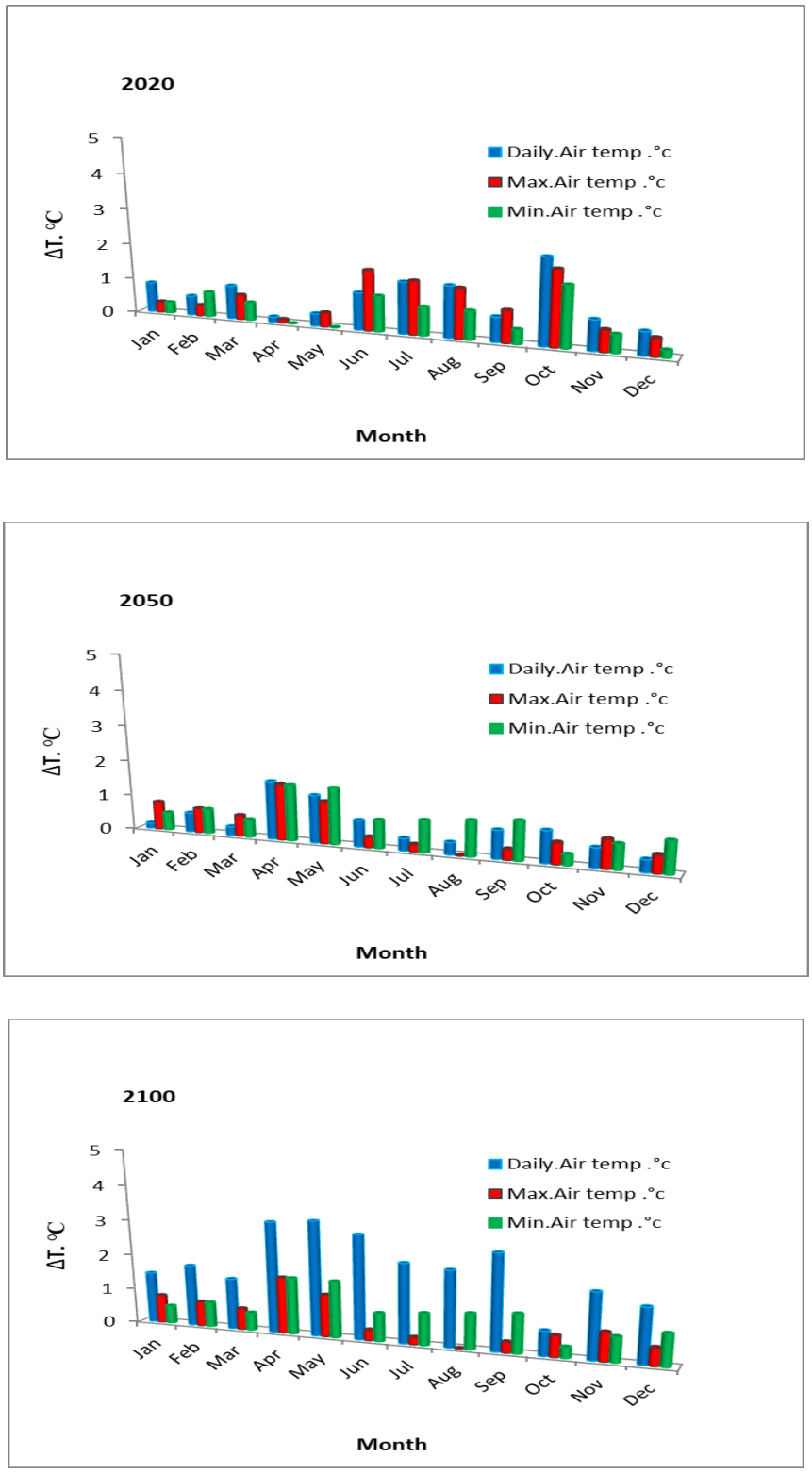
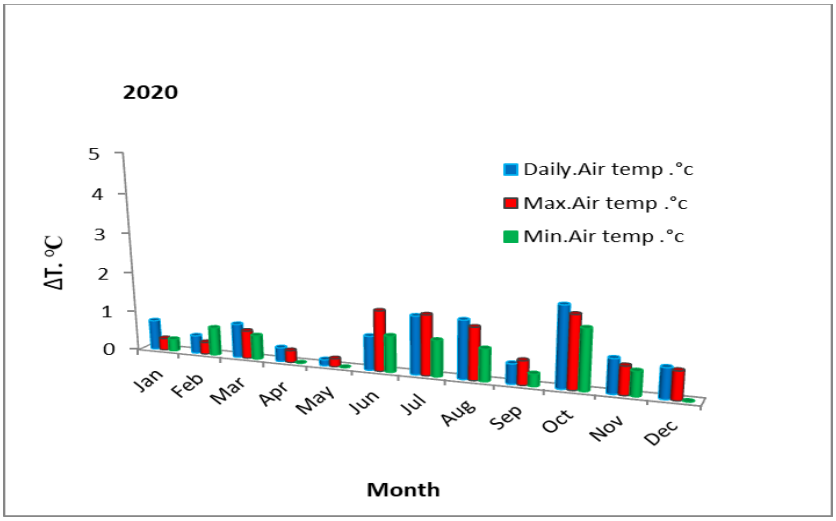
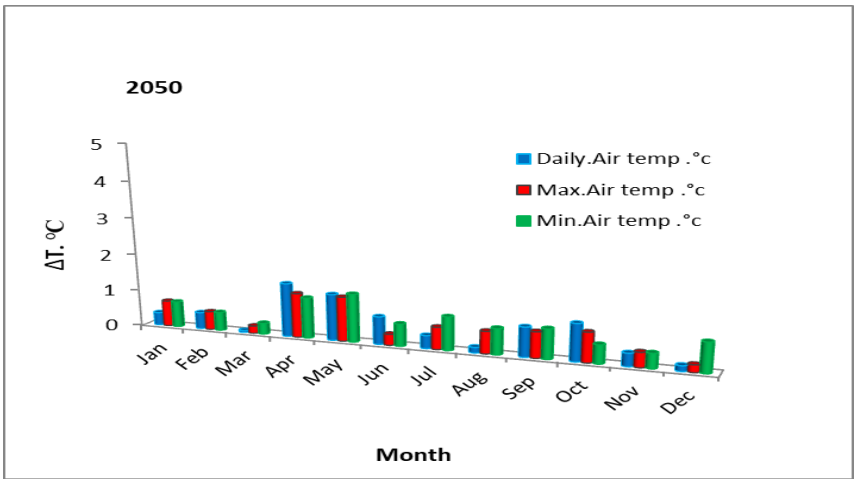



Fig (3): Temperature monthly anomalies for Erbil city by the end of 2020, 2050, and 2100 decades for scenario A1B

Figure 4 shows the average temperature (Daily, Maximum, Minimum) for the for the years (2020,2050,2100). The estimation of (ΔT) scenario ($A_2$) for estimating the amount of extremism(ΔT), and revel that the highest ΔT occurs in 2100 while lowest ΔT occurs in 2020 and 2050.



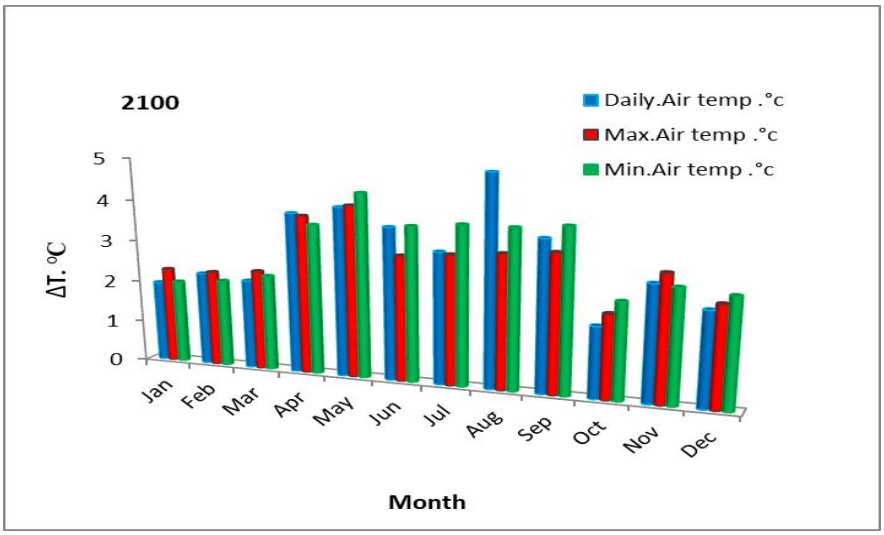




Fig (4): Temperature monthly anomalies for Erbil city by the end of 2020, 2050, and 2100 decades for scenario A2.

Figure (5) shows the forecasts of the monthly temperature changes anomalies (Daily, Max, Min) for Erbil city by the end of 2100 for scenarios B1, A1B, and $A_2$. The temperature difference ($\Delta T$) (Maximum, Minimum) was around 4 $^0$ C for $A_2$ scenario. while $\Delta T$ for $B_1$, and A1B scenarios were close to each other. However, daily temperature $\Delta T$ for the scenarios is a bit different. $B_1$ scenario shows less increase in temperature while $A_2$ shows higher increase in temperature which is in August.

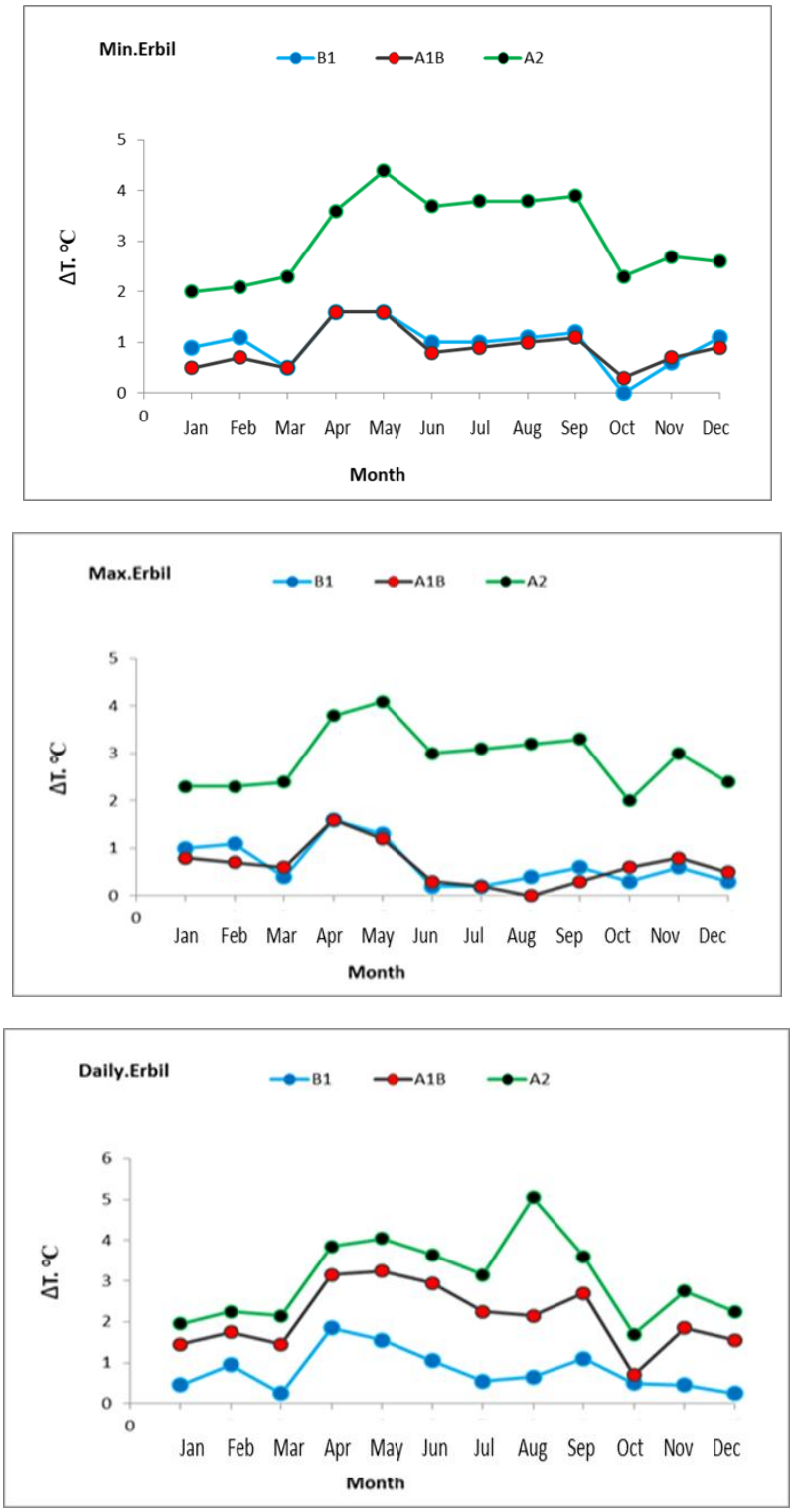



Fig (5): Forecasts of changes monthly temperature anomalies for (Erbil) city by the end of 2100 for scenarios B1, A1B, and A2.

Figure 6 represents a comparison between the predicted monthly temperature change anomalies by the end of 2100 between Erbil and Dohuk governorate. The temperature difference (ΔT) for the B1 scenario was close to each other for both governorates. The high difference temperature $\Delta T$ (daily, maximum, minimum) occurs in April, and May while the lower predicted temperature (ΔT) occurs in December.

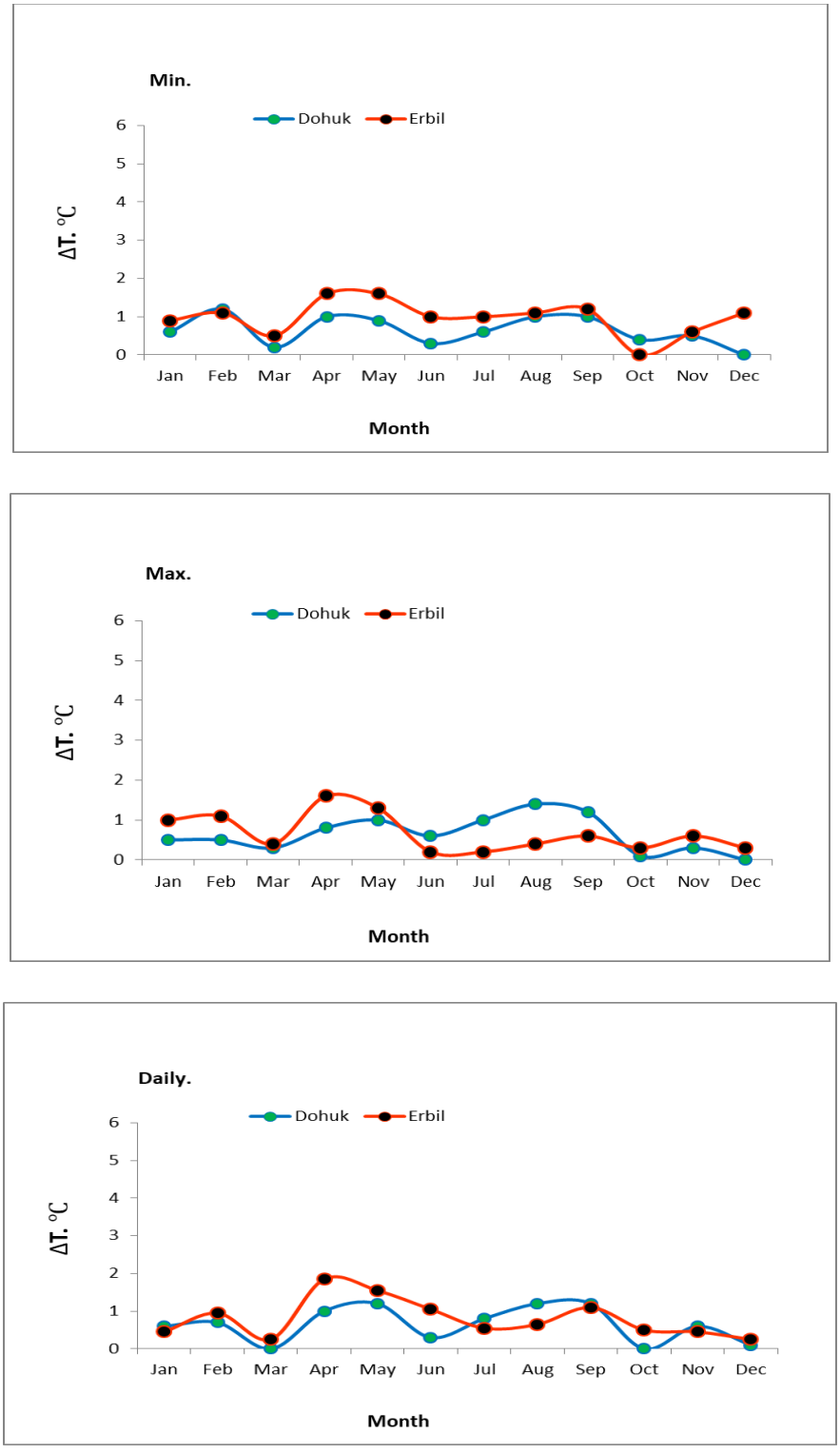



Fig (6): Compare forecasts of change monthly temperature anomalies by the end of 2100 for scenario B1 for (Erbil, Dohuk)

Figure (7) show the compare forecasts of change monthly temperature anomalies by the end of (2100 ) for scenario A1B between Erbil and Dohuk governorate, where the difference ($\Delta T$ ) are approximate for temperature (maximum, minimum) for Dohuk is higher than Erbil, where change was between (1-3℃) ,and for the daily temperature was close to each other , and the high difference temperature ($\Delta T$ ) was between (1-4℃) .

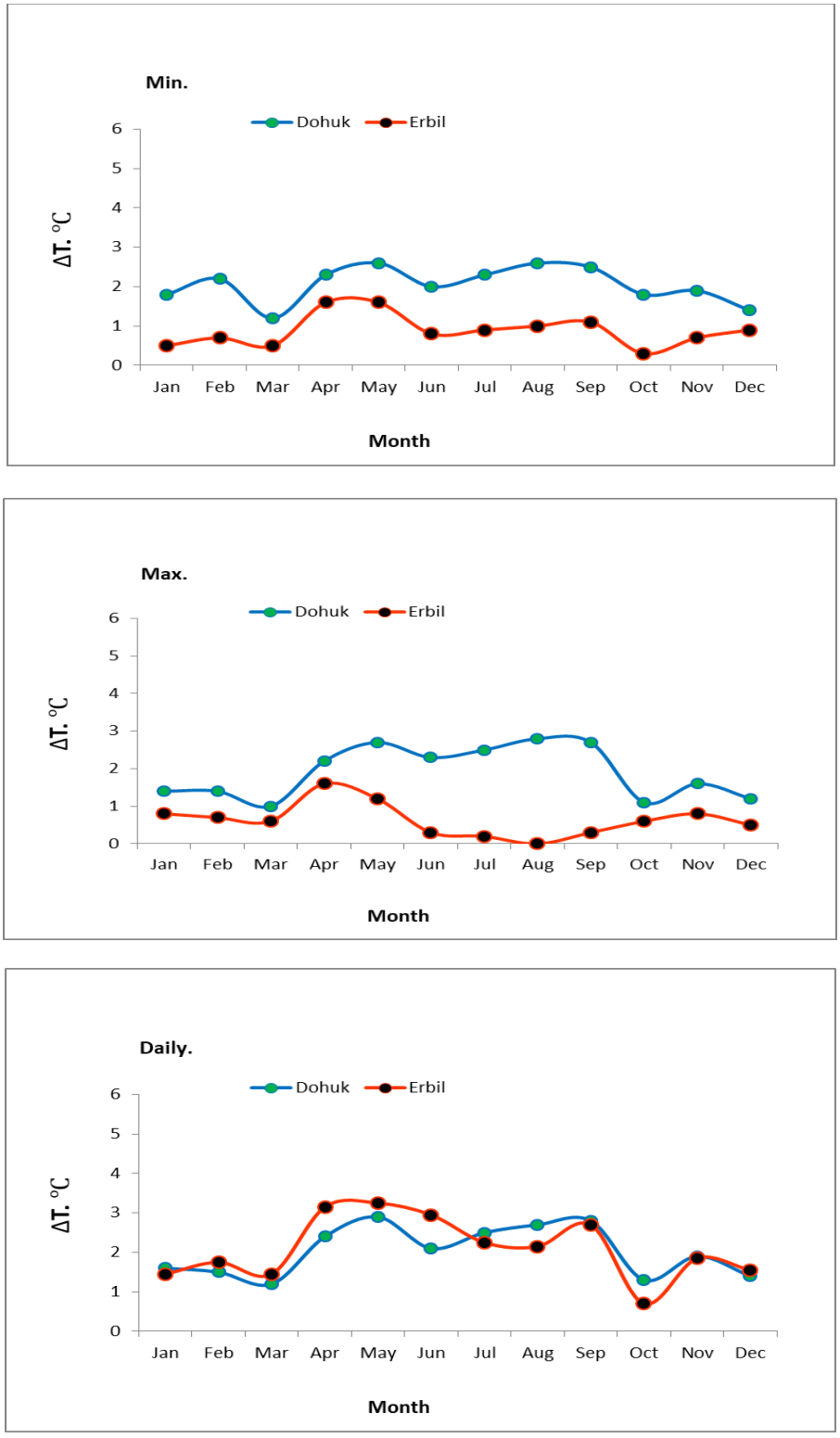
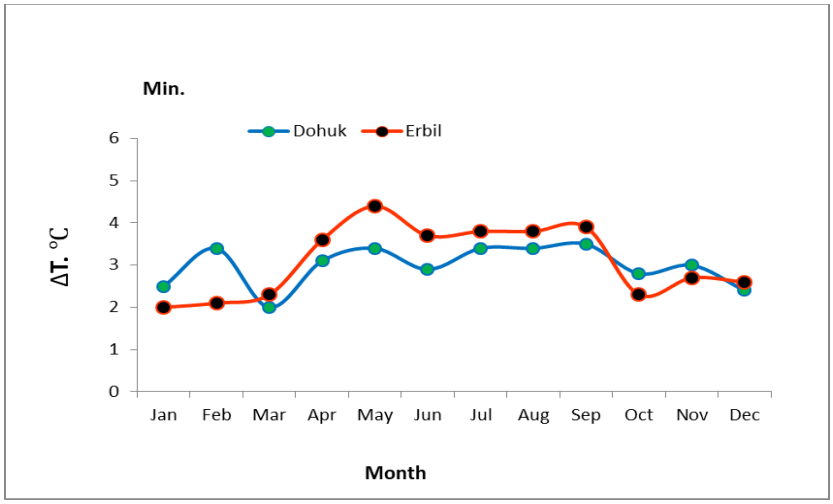
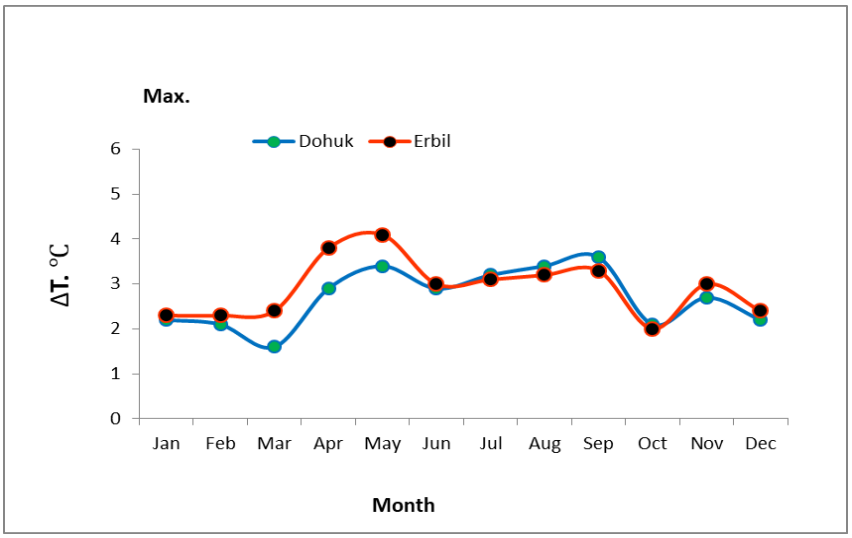



Fig (7): Compare forecasts of change monthly temperature anomalies by the end of 2100 for scenario A1B for (Erbil, Dohuk).

Figure (8) show the compare forecasts of change monthly temperature anomalies by the end of (2100) for scenario A2 between Erbil and Dohuk governorate, where the difference ($\Delta T$) are approximate for temperature (daily, maximum, minimum) for Erbil is higher than Dohuk, (2-5 ℃) this value changes as the month changes.



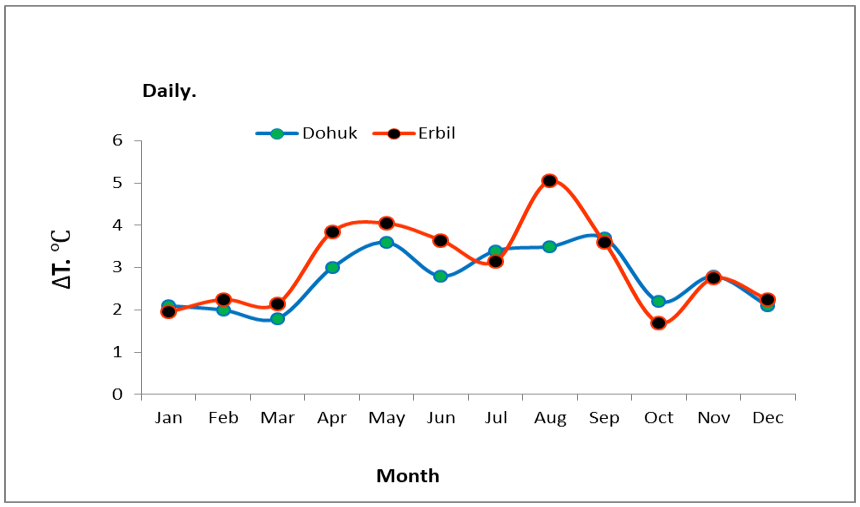
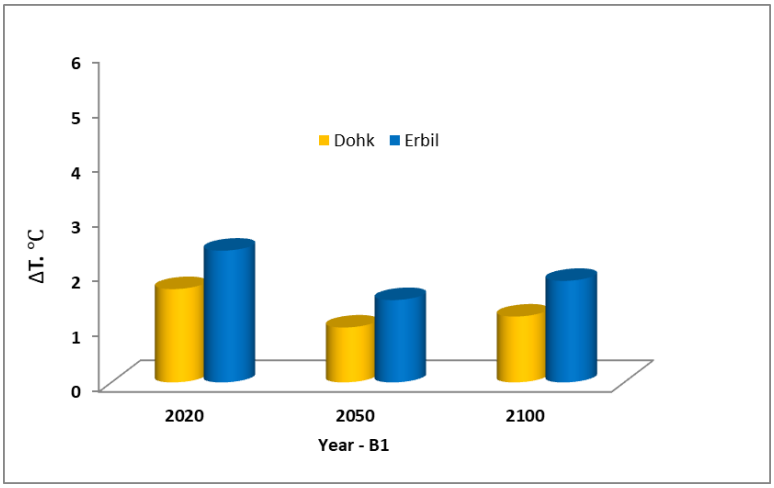
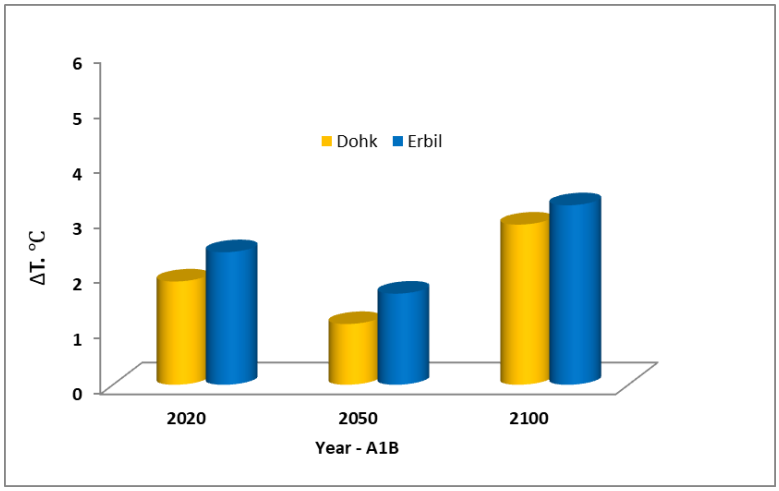




Fig (8): Compare forecasts of change monthly temperature anomalies by the end of 2100 for scenario A2 for (Erbil, Dohuk)

Figure (9) show the maximum rate of extreme maximum monthly temperature changes for scenario (B1,A1B,A2 ) for Erbil and Dohuk, the predicting value for three-years (2020,2050, 2100) shows extremes of temperature, where the changes in temperature for two cities was close to each other for scenarios ( A1 ,A1B ) for (2020, 2050, 2100) ,however the values of changes for the Erbil was higher in general, and the value of changes in temperatures (5℃) for the year (2100) and for Dohuk the value of changes in temperatures (4℃) for the year (2100) as shown in the figure for scenario A2 between Erbil and Dohuk governorate.



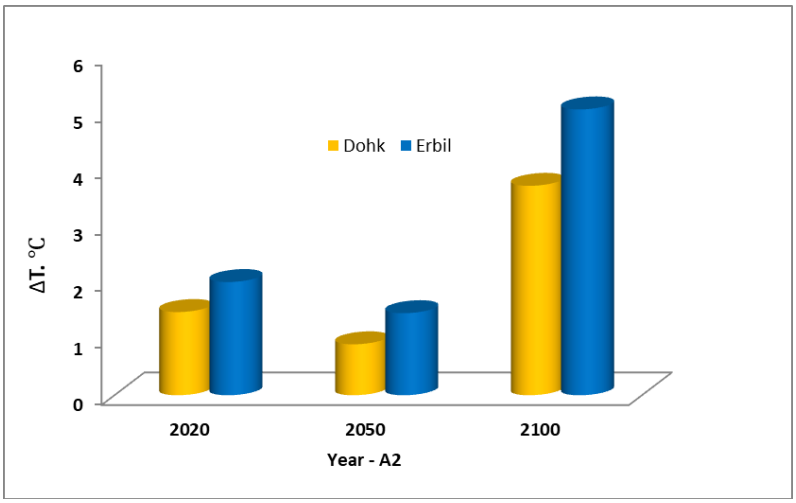




Figure (9): Maximum rate of extreme monthly temperature changes for scenario B1, A1B, A2 for (Erbil, Dohuk)

For the three IPCC scenarios B1, A1B, and A2, The results give an estimation that the predicted air temperature (ΔT) where the maximum value recorded in (A2) scenario and the minimum value of (ΔT) recorded in (B1) scenario, and by (2100) it will be a clear increase in daily temperatures and increase in summer periods of a year and thus will affect the global climate change.

## 4. Conclusion

In current research we conclude that the annual temperature extremes in value in Erbil are higher than in Dohuk of (1-2℃) for expected temperature ($\Delta T$) and this consequently affects daily temperatures for many reasons including a difference in the geographical nature as well as a geological nature, as for the governorate of Erbil it is a flat land and its climate is influenced by the climate of the regions in the center and south of Iraq because it is the closest, but in Dohuk it is mountainous and also the proportion of agricultural areas is more than a capital and is affected by the climate of Turkey and Syria ,were generated by the global climatological database.

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