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TEMPERATURE AND PRECIPITATIONS TRENDS FOR HILLA CITY USING NOAA/ESRL GRIDDED HIGH-RESOLUTION DATA

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Abstract

Global climate change and its consequences on the ecosystems have been of big concern by the majority of the world countries. Iraq as part of the Middle East is vulnerable to the effects of climate change. Most of climate change researches in Iraq focused on major cities such as Baghdad, Mosul, and Basra. This work aimed at determining the trends of temperature and precipitation for the city of Hilla during the past 10 decades. To accomplish this purpose, high-resolution gridded data obtained from the University of Delaware were analysed. The results showed that temperature trend was increasing and most warming period happened during the past 20 years, especially during summer when monthly mean of daily temperature exceeds 35 ºC . Results of Mann-Kendall test no trend exist for the months of January, February, October, November, and December. Analysis of precipitation time series indicated that highest precipitation over Hilla city occurred during the early decades of 1910s and 1920s, that mount gradually declined, and the lowest precipitation occurred during the last 20 years when precipitation rate was always below the 115 years mean value. Applying Mann-Kendall test on the annual precipitation time series showed that there is a statistically significant decreasing trend. The significance of study is to provide detailed information on the effect of global warming on the local climate of Hilla city.

Keywords: Global climate change, Hilla City, NOAA/ESRL, Precipitations.

1. Introduction

The Earth planet faces, nowadays, serious environmental problems, such surface water pollution [1-8], high wastewater generation rate [9-15], high solid waste generation rate [16-21], air and soil pollution [19, 20], and global warming [22-26]. The scientists tried to provide solutions for each one of these problems, such treatment methods, sensing technologies, recycling techniques, and implementation of strict standards and regulations [27-35]. However, these environmental problems still the main threat for the existence of humankind. For example, there has been major concern about global warming and its impacts on the environment and human activities [2].

Climate change can lead to a rise in sea level due melting of polar ice, more unusual and severe weather events, shortage of precipitation [36]. Warmer temperature and less precipitation ultimately cause aridity [36]. In 2007, the International Panel for Climate Change (IPCC) has reported that the global air temperature has been risen by 0.7 ^{o}C in during the period 1906-2005 [37]. Folland, et al. [38] indicated that the 1990s decade was likely the warmest one over past 100 decades over the entire Northern Hemisphere. The Middle East is considered as one of the most water-stressed areas in the world [39]. There have been numerous research works on the Middle East climate change. It has been concluded that increase in temperature and decrease in rainfall in this region may lead to more aridity [39].

Iraq is among most Middle East countries vulnerable to climate change, in recent years Iraq is facing changes in weather patterns, increasing heat waves, frequent dust and sand storms [18]. All these phenomena are consequence of climate change [18, 19]. Recently, there has been an increasing trend in research activities concerning climate change in Iraq. Bilal, et al. [40] reported on the changes in air temperature for the city of Baghdad during the period 1941-2000. They found that air temperature tends to increase in summer season during late 1990s. Their statistics suggested that the mean air temperature significantly increases during the month of August, and decreases during the month of November.

Zakaria, et al. [41] compared and studied historical records (1900-2009) and future (2020-2099) of temperature and precipitation. Results indicted some evidences of climate change in Iraq. Azooz and Talal [42] applied a nonlinear regression on mean monthly temperatures, and precipitations for four main cities in Iraq, They concluded that a significant climate changes occurred in these cities, for example Robaa and Al-Barazanji [43] reported on surface air temperatures and rainfall in Iraq and found that temperature was increasing and precipitation was decreasing. Shubbar, et al. [44] investigated ten meteorological indices at selected weather stations covering the entire country of Iraq for a period of 30 years. They found that rainfall is relatively high in the northern region and lower values in the central and southern region. Their results the capitol city of Baghdad and the southern region also showed that temperature was characterized by very high temperature during summer season.

Abd AlKareem [45] assessed climate change on Iraq using climate scenarios for three decades of 2020, 2050, and 2100 generated from the global climatological database Meteonorm for scenarios B1, A1B, and A2. Anomalies of mean monthly air. Salman, et al. [46], investigated the long-term trends in daily temperature extremes in Iraq in recent years (1965–2015) using both ordinary Mann-Kendal (MK) test; and the modified Mann-Kendall (m-MK) test. They concluded that

temperature in Iraq is increasing 2 to 7 times faster than global temperature rise. Al-Timimi and Al-Khudhairy [47] investigated the spatial and temporal temperature trends on Iraq during 1980-2015. Their results indicted the presence of a positive tendency for temperature increase.

The aim of this work is to analyse the University of Delaware's database, provided by the National Oceanic and Atmospheric Administration Earth System Research Laboratory (NOAA/ESRL), of air temperature and precipitation for 115 years (1900-2014) to determine the trends of these two meteorological parameters and how they are affected by climate change in the city of Hilla in Iraq. The selection of this particular city was based on the fact that the majority of research works about temperature and precipitation trends in Iraq focused on the three largest cities in Iraq (Baghdad, Mosul, and Basra) and the desert town of Rutba. In addition, the city of Hilla has been facing more heat waves, drought, and dust storms.

2. Materials and Methodology

Hilla city is the capital of the Babil (Babylon) Governorate in central Iraq. Babil is characterized by a typical dry; desert climate with temperatures may approach more than 40°C in summer. The rainy season extends from October to May. Rainfall from mesoscale convective system usually occur during December and January while local thunderstorms are most active during spring season (March to May). Figure 1 shows the location of the Hilla city on Iraq map. The geographic coordinates of the city are 32.48 ^{o}N and 44.43 ^{o}E and elevation above sea level is 32 m [48].

Fig. 1. Map of Iraq showing the location of Hilla city [48].

Version V4.01 database of temperature and precipitation provided by the University of Delaware consists data from 1900 to 2014 with a spatial resolution of 0.5^{o}. The data are stored in NetCDF files (NC files) and were accessed from NOAA/ESRL site. The NC files were converted to ASCII text files using the Panoply software provided by National Aeronautics and Space Administration (NASA).

The non-parametric Mann-Kendall test which is commonly employed to detect monotonic trends in time series of climate data was used to detect the trends in the monthly time series of temperature and precipitation. The statistics of this test is calculated as follows [49]:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(X_j - X_k) \quad (1)$$

With

$$sgn(x) = \begin{cases} 1 & if\ x > 0 \\ 0 & if\ x = 0 \\ -1 & if\ x < 0 \end{cases} \quad (2)$$

The mean of S is $E|S| = 0$ and the variance σ^2 is [50]:

$$e^2 = \frac{\left\{n(n-1)(2n+5) - \sum_{j=1}^{p} t_j(t_{j-1}-1)(2t_j+5)\right\}}{18} \quad (3)$$

where p = the number of tied groups in the data set, t_j =The number of data points in the j^{th} tied group. The statistics S is approximately normal distribution provided that the following Z-transformation is used:

$$Z = \begin{cases} \frac{S-1}{\sigma} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sigma} & if\ S < 0 \end{cases} \quad (4)$$

The statistic S is closely related to Kendall's as given by [49]:

$$\tau = \frac{S}{D} \quad (5)$$

where

$$D = \left[\frac{1}{2}n(n-1) - \frac{1}{2}\sum_{j=2}^{p} t_j(t_j 1)\right]^{1/2} \left[\frac{1}{2}n(n-1)\right]^{1/2} \quad (6)$$

3. Results and Discussion

Figure 2 shows the long monthly means of air temperature and precipitation for Hilla city during the 115 years period (1900-2014). It is seen that the warmest months of the year are July and August. The temperature may reach 35 °C. It has been observed that maximum temperature can exceed 50 °C on daily basis particularly during mid-July to mid-August. The temperature during winter is mild and ranges between 5 and 10 °C. The results also illustrate that the rainy season in Hilla, as the case for the entire country extends from October to May and most precipitation activities occur during December and January and rainfall may reach 20 mm/month. Figure 3 gives the monthly variations of temperature during the 115-year period. It is clear that during the last 20 years (1995-2014) a usual warming occurred, and temperature reached more than 35 °C.

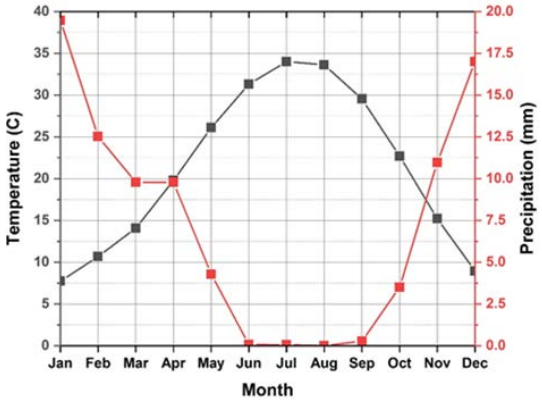

Fig. 2. Monthly means of temperature and precipitation for Hilla city during the period of 1900-2014.

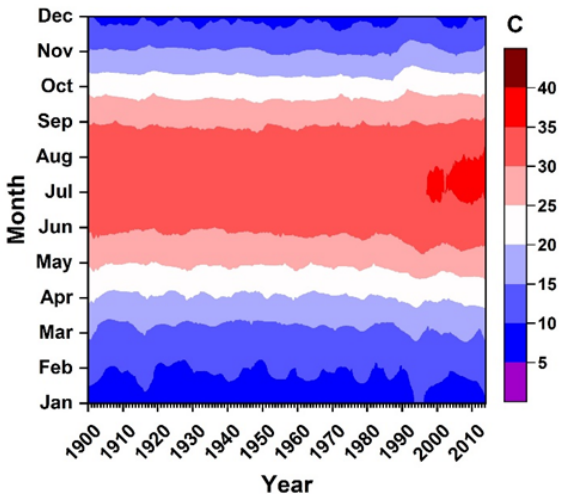

Fig. 3. Monthly variations of temperature during 1900-2014 for Hilla city.

Figure 4 shows the seasonal variations of temperature during the period under study. The results indicate that the autumn season is warmer than spring and summer and these two seasons exhibits relatively slower increase in temperature than summer. Figure 5 gives the results of anomalies calculations for monthly temperature during the period 1900-2014. The anomaly was calculated by subtracting the 115 years mean of a specific month from the mean of that month for a given year. It is obvious that the summer months have higher linear regression slopes.

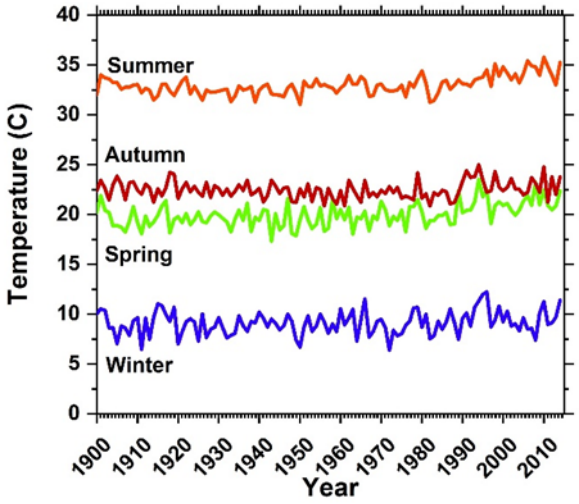

Fig. 4. Seasonal variations of temperature during 1900-2014 for Hilla city.

The non-parametric test of Mann-Kendall was applied on these time series of temperature anomalies and the results are summarized in Table 1. These results indicate that no trend was detected for the months of January, February, October,

November, and December, and most significant trend was observed in June followed by May and July. Figure 6 presents the monthly variations of precipitation during the period under study. It is observed that the during last 20 years the Hilla city received relatively lower rain than during older periods and during the past 10 years the rainfall did not exceed 10 mm/month. Figure 7 shows the time series of annual precipitation during the 115 years period. The results reflect the nature of precipitation variations. Precipitation is quite variable and can dramatically change from one year to another. The results clearly show that Hilla received the highest precipitation during the early decades of 1910s and 1920s, the mount gradually declined, and the worst case occurred during the last 20 years when precipitation was always below the mean. Applying Mann-Kendall test on the annual precipitation time series gave S=-1810, Z=4.3726, and p=1.2277E-05 which indicate that there is a statistically significant decreasing trend.

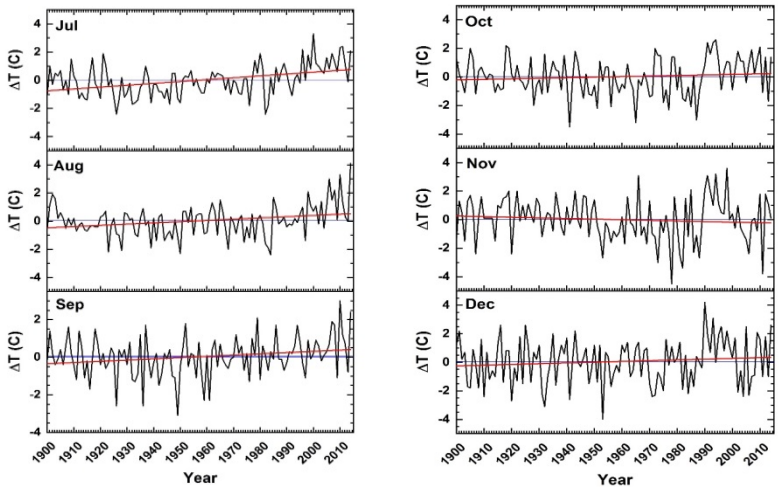

Fig. 5. Anomalies of Jul-Dec monthly temperature during the period 1900-2014 for Hilla city.

Table 1. Mann-Kendall test for monthly mean temperature time series (1900-2014) for Hilla city.

Month	S	Z	P	Trend
Jan	496	1.197	0.2313	No
Feb	513	1.238	0.2157	No
Mar	1153	2.786	0.0053	Increasing
Apr	1403	3.390	0.0007	Increasing
May	1900	4.593	4.374E-06	Increasing
Jun	2424	5.561	4.615E-09	Increasing
Jul	1787	4.321	1.557E-05	Increasing
Aug	976	2.359	0.0183	Increasing
Sep	871	2.106	0.0352	Increasing
Oct	371	0.895	0.3708	No
Nov	-552	1.333	0.1826	No
Dec	448	1.081	0.2797	No

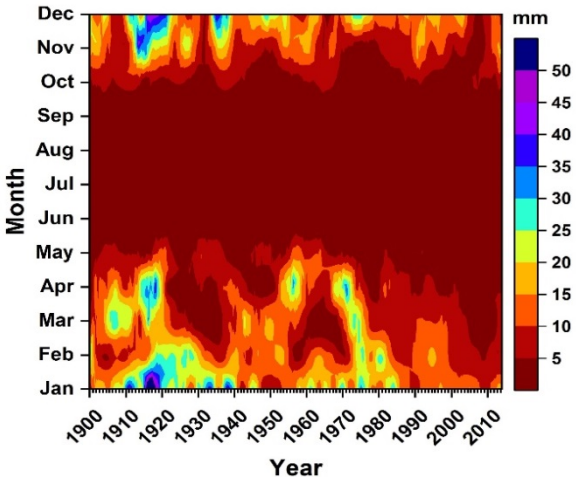

Fig.6. Monthly variations of precipitation during 1900-2014 for Hilla city.

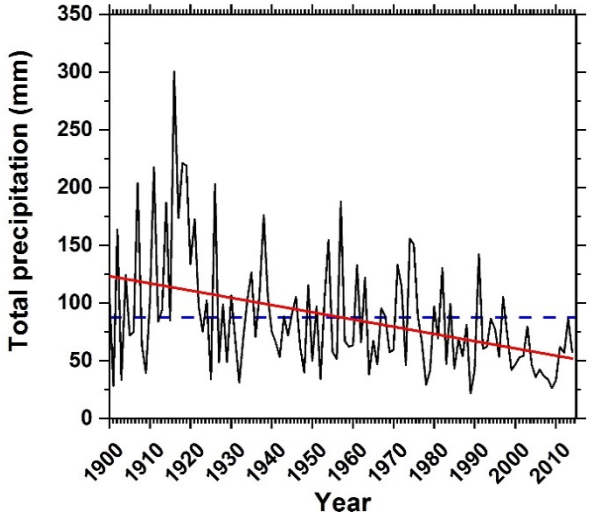

Fig.7. Seasonal variations of precipitation during 1900-2014 for Hilla city.

4. Conclusions

In this work the University of Delaware gridded high-resolution data of air temperature and precipitation for 115 years (1900-2014) were analysed for Hilla city, Iraq to determine the trends of these two meteorological parameters and assets how the city is affected by climate change. Some conclusions from the investigation are given below.

- Due to the impact of the global warming, the average temperature in Hilla city is increasing, especially during summer months while the average of precipitation is decreasing.
- Unusual warming has been noticed during the past 20 years, the monthly average temperature was always above 35 ^{o}C during summer months.
- The non-parametric test of temperature anomalies indicated that no trend was detected for the months of January, February, October, November, and December, and most significant trend was observed in June followed by May and July.
- The precipitation was always below the mean during the 20 years period.
- The continuous increase in temperature and decrease in precipitation could lead to drought, desertification and many other environmental issues.

Nomenclatures

p	The number of tied groups in the data set
t_j	The number of data points in the jth tied group

Greek Symbols

σ^2	Variance

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