

Analysis of some extreme temperature indices over Iraq

YASEEN K. AL-TIMIMI, ALAA M. AL-LAMI, HASANAIN K. A. AL-SHAMARTI and
SAMIR K. AL-MAAMORY

Department of Atmospheric science, College of Science, Mustansiriyah University, IRAQ

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e mail : yaseen.altimimi.atmsc@uomustansiriyah.edu.iq

सार – जलवायु परिवर्तन का विभिन्न क्षेत्रों में नकारात्मक प्रभाव पड़ता है। सामान्यतः चरम घटनाओं के गुणों में आँकड़ों की महत्वपूर्ण भूमिका होती है। पिछले 36 वर्षों की अवधि में (1981-2017) महत्वपूर्ण प्रवृत्तियों और चरम तापमान संकेतों के परिमाण की प्रवृत्तियों का पता लगाने के लिए इराक में 36 मौसम स्टेशनों के दैनिक न्यूनतम और दैनिक अधिकतम तापमानों के आँकड़ों का विश्लेषण किया गया। संकेतों की गणना के लिए आर क्लिम डेक्स का उपयोग किया गया तथा प्रवृत्ति विश्लेषण के लिए सरल समाश्रयण विधि का उपयोग किया गया। परिणाम दर्शाते हैं कि सभी स्टेशनों पर अधिकतम तापमान (TXx) के अधिकतम मानों, वार्षिक औसत तथा न्यूनतम तापमान TNx के अधिकतम मानों के वार्षिक औसत में महत्वपूर्ण परिवर्तन दिखाई दिए। वार्षिक दैनिक तापमान के क्षेत्र में लगभग 81.6% स्टेशनों में कम होने की प्रवृत्ति रही जबकि 18.4% में वृद्धि की प्रवृत्ति रही। TXn सूचकांक सभी स्टेशनों के लिए 78.9% में कम होने की प्रवृत्ति दर्शाता है जबकि 5.3% में कोई परिवर्तन नहीं हुआ और 15.8% में वृद्धि की प्रवृत्ति रही। इसके विपरीत सभी स्टेशनों पर TNn सूचकांक 63.2% में कम होने की प्रवृत्ति और 31.6% में वृद्धि की प्रवृत्ति रही। चरम तापमान के विश्लेषण से अधिकांश स्टेशनों पर महत्वपूर्ण वृद्धि देखी गई जिससे यह भी पता चलता है कि देश में गर्मी की प्रवृत्ति देखी गई।

ABSTRACT. Climate change has negative impacts on different sectors. Generally, data display significant changes in the properties of extreme events. Daily minimum and maximum temperatures data for 36 meteorological stations of Iraq (1981-2017) were analysed to detect the significant trend and the magnitude trend extreme temperature indices over the 36-year period. RclimDex was used to compute indices and simple regression method was used for trend analysis. The results show that all stations displayed a significant increase in the annual average of maximum value of maximum temperature TXx and the annual average of maximum value of minimum temperature TNx. For the annual diurnal temperature range, about 81.6% of stations have a decreasing trend, while 18.4% have an increasing trend. The TXn index shows 78.9 has a decreasing trend for all stations except 5.3% have no change and 15.8% have an increasing trend. In contrast, the represent of TNn index demonstrate a decreasing trend for 63.2% of stations and 31.6% have an increasing trend fall all stations. Analysis of temperature extremes revealed a significant increase in most stations, which also shows that the country has seen a trend of warming.

Key words – Extreme temperature, RclimDex, Climate change, Iraq.

1. Introduction

Climate change it is a fact. Temperature is the most important factor in climate change and extreme temperatures affect our lives more than others. Many studies have revealed warming trends at temperature in the world, but the value of changes are not constant (Jones and Moberg, 2003; Abbasnia, *et al.*, 2016). Global mean of temperature has an increased 0.85 °C over the last century (IPCC, 2013). According to the Intergovernmental Panel on Climate Change (IPCC, 2007) climate change will affect agriculture, increase the risk of hunger; water scarcity and will lead to rapid melting of glaciers in future.

Recent studies of world climate have shown that important changes in temperature happened during the last

century. These studies denote that the minimum intensity of extreme temperature has decreased trend (IPCC, 2007). Also the value of maximum temperatures has increased trend (Mohammad *et al.*, 2018). The temperatures indices employed in various studies are arranged by the Commission for Climatology (CCL), World Meteorological Organization (WMO) and the Expert Team on Climate Change Detection and Indices (ETCCDI) who helped several workshops in the globe. Many studies have studied extreme temperatures and found significant trends in temperature indices (Frich *et al.*, 2002). Annual trends have increased for the maximum and minimum temperatures in Iraq and middle east. Over an increasing trend has been found in extreme temperature indicators over the last 100 years, with a stronger trend in the past three

decades (Alexander *et al.*, 2002). Over the past 100 years, the Earth's average temperature has increased by about 0.7 °C, with the warming rate accelerating in recent decades (IPCC, 2013). Eleven years of 12 years were the warmest since 1850 (the beginning of reliable weather records). Cold days, cold nights and frosts became less frequent, while heat waves became more common. Global ocean temperatures have risen, sea level has risen about 7 inches since 1900 and about 1 inch in the last decade (IPCC, 2007).

Based on intensive scientific research, there is very high confidence that anthropogenic increases in concentrations of greenhouse gases are responsible for most of the global warming observed over the past 50 years. In some areas, maximum temperatures and precipitation have already shown amplified responses to changes in mean values as shown in Report of the Intergovernmental Panel on Climate Change (IPCC, 2001). The impacts and volatility of climate change have been studied by many researchers around the world. The results of these studies have clearly demonstrated that there are climatic fluctuations as a result of human intervention in ecosystems. Extreme climatic events, such as heat waves, floods and drought, can have a strong impact on society and ecosystems and are therefore important for study (Toreti and Desiao, 2008). Studies aimed at studying changes in extreme climatic events are important because of the potential social, economic and environmental impact of these events. In the past, the limited availability of long records of daily climate data in some parts of the world has hampered efforts to analyse the effects of climate change and its volatility on the frequency and intensity of extreme weather events around the world. Thus, many studies on climate change and extremism have achieved various levels (Easterling *et al.*, 2000; Haylock *et al.*, 2006; Brunetti *et al.*, 2006). Multiple recent studies have been applied to getting a better understanding of mean, maximum and minimum temperature patterns and trends in Iraq. One study (Al-Timimi and Al-Khudhairy, 2018) reported that the trends of annual mean temperature are increased in northern and southern Iraq at an average rate 2.1 °C over the period 1980-2015. (Al-Khudhairy and Al-Timimi, 2017) showed that the trend of maximum temperature was increasing about 1.75 °C during the period of 1980-2015. In another study Al-Timimi and Al-Khudhairy 2017 showed that the minimum temperature increased by 0.7 °C in northern Iraq for the period 1980-2015. While it was about 1.75 °C in southern Iraq. The increasing trend of the minimum temperature drop was the same in the northern and southern parts of Iraq. In the spring, the upward trend of the minimum temperature 2.45 °C for the period 1980-2015 was in the northern and central region of the country. The highest value of the minimum temperature trend in

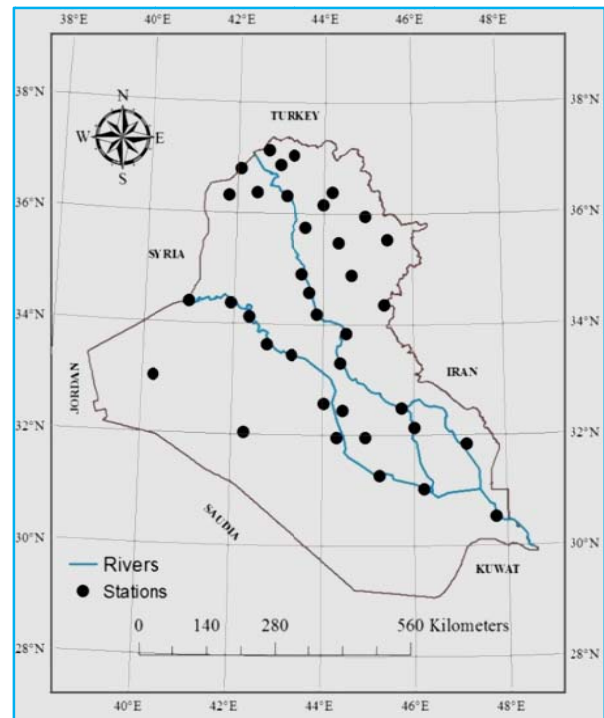


Fig. 1. Map of Iraq with the geographical locations of the stations

the central region of Iraq during the summer was 3.9 °C for the period 1980-2015. This study aimed to detect the significant trend and the magnitude trend extreme temperature indices over Iraq using the daily minimum and maximum temperatures data for 36 stations of Iraq (1981-2017).

2. Area of study and data

The Study area is represented *via* Iraq which located in Southwest of Asia, the total area (437072 km²), where the land area is (432162 km²) while the area of water bodies is 4910 km². Iraq is located in the northern hemisphere specifically in the northeastern. Iraq have a borders with Turkey from the north with a length of 367 km, Iran from the east with a length 1599 km, Kuwait to the southeast about 255 km, Saudi Arabia to the southeast about 814 km, Jordan from the west with a length 179 km and finally Syria northwest about 599 km. Iraqis of a great Mesopotamian alluvial plain of the two rivers Tigris and the Euphrates, they flow north-west to the southeast before integrating into the Shatt al-Arab. Iraq's climate is semi-dry. Average temperatures in Iraq range from (50 °C) in summer and in winter range (0 °C). Most of the rainfall occurs between December and April and the annual rainfall rate is "100-180 mm", the mountainous region in northern Iraq has a higher rainfall than the central and southern regions. Cyclones that move

across Iraq come from the West. The source of Cyclones is the Atlantic Ocean. The numbers of Cyclones vary depending on time it maybe seasons, months and Space that the Cyclones are going through (Al-Timimi and Al-Jiboori, 2013). They usually increase in the winter, decrease in autumn and disappear completely in the summer. The number of Cyclones moving over the south is greater than that which moves through the mountains and slopes However, the north and north-east of Iraq usually receive a higher amount of rainfall from the south (Al-Timimi and Al-Khudhairy, 2017). The data in this study, daily maximum and daily minimum were obtained from NASA Website data. The spatial resolution of gridded data was $0.5^\circ \times 0.5^\circ$ (latitude \times longitude), to procedure the analysis of extreme temperature indices. The long-term data of daily average of minimum and maximum temperatures for the time period 1980-2017 were collected at different regions of the country. Fig. 1 shows geographical locations of the stations.

3. Extreme temperature indices

Extreme temperature indices are the statistical indicators which describe how the temperature changes in the studied area. There are different classes of temperature indices supported by ETCCD. In this study, we used a set of five indices of extremes temperatures.

In this study, indicators were selected to assess many aspects of regional climate change, including changes in the intensity and high temperature events.

The formulas for calculating each of the indices are as follows (Zhang and Yang, 2009):

The monthly (annual) maximum value of maximum temperature (TXx) is given by:

$$TXx_{kj} = \max (Tx_{kj}) \tag{1}$$

where, Tx_{kj} is the daily maximum temperature in month (year) k, period j .

The monthly (annual) maximum value of minimum temperature (TNx) is given by:

$$TNx_{kj} = \max (Tn_{kj}) \tag{2}$$

where, Tn_{kj} is the daily minimum temperature in month (year) k, period j.

The monthly (annual) the maximum value of minimum temperature (TNx) is given by:

$$TX n_{kj} = \min (Tx_{kj}) \tag{3}$$

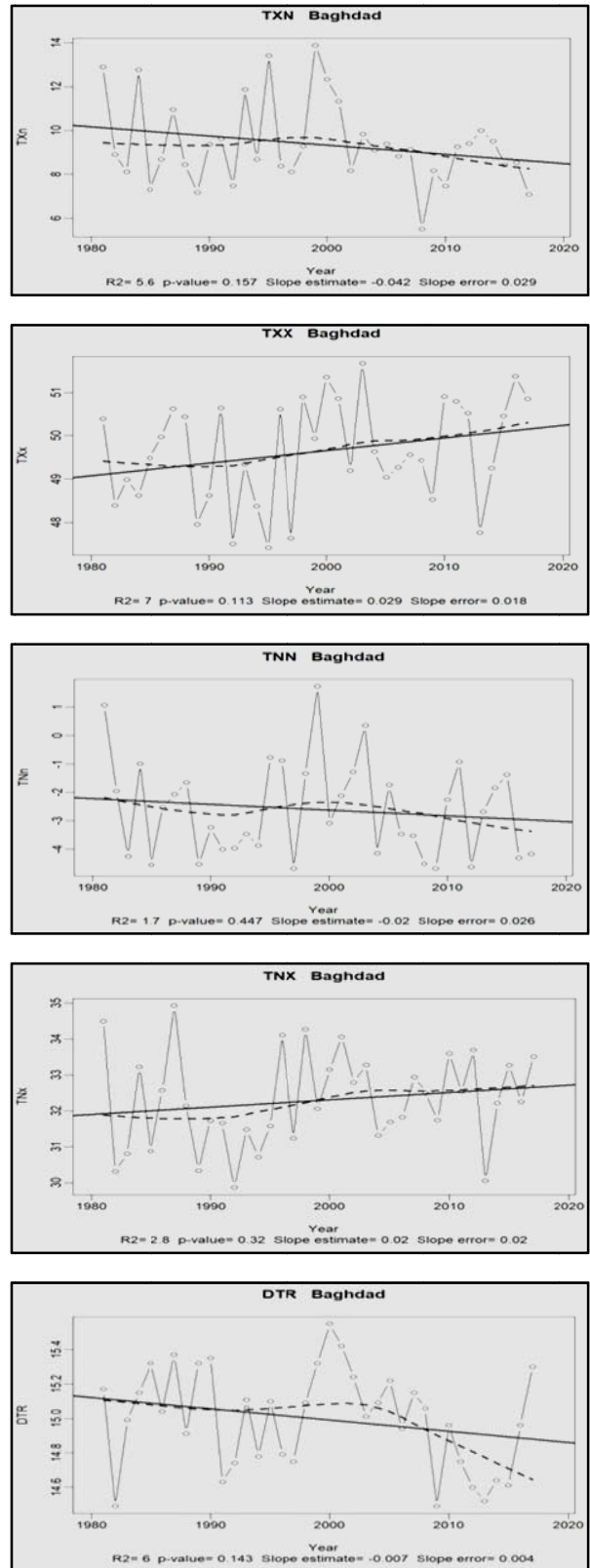


Fig. 2. Five indices of extreme temperature for Baghdad station

TABLE 1

Annual linear trends of the extreme temperature indices in Iraq during the period 1981-2017

Stations	TXx	TXn	TNx	TNn	DTR
Emadiyah	0.041	-0.004	0.053	0.01	-0.004
salahaddin	0.04	0.015	0.059	0.007	-0.008
Sulaymaniyah	0.03	0	0.045	-0.005	-0.016
Sinjar	0.045	-0.018	0.044	-0.003	0.003
Duhook	0.047	0.019	0.052	0.013	-0.004
Zakho	0.05	-0.006	0.05	-0.009	-0.004
Arbil	0.04	0.015	0.059	0.007	-0.008
Rabiah	0.051	-0.008	0.044	0	0.001
Teleafer	0.048	0	0.04	-0.001	0.002
Kirkuk	0.037	-0.007	0.04	0.011	-0.007
Nukheb	0.036	-0.001	0.043	0.017	-0.003
Dukan	0.034	0.016	0.053	0.009	-0.013
Mosul	0.052	0.02	0.046	0.016	-0.002
Tuz	0.033	-0.037	0.039	0.003	-0.011
Khanqin	0.033	-0.08	0.038	-0.023	-0.01
Qaim	0.06	-0.013	0.048	-0.015	0.005
Anah	0.05	-0.019	0.052	-0.008	0.004
Makhmoor	0.048	-0.002	0.047	0.017	-0.001
Biji	0.03	-0.031	0.031	-0.013	-0.004
Hadithah	0.036	0.002	0.038	0	-0.001
Tikrit	0.028	-0.018	0.033	0.004	-0.006
Samaraa	0.03	-0.031	0.031	-0.013	-0.004
Heet	0.044	-0.022	0.031	-0.009	-0.001
Ramadi	0.037	-0.035	0.023	-0.023	-0.003
Khahlis	0.032	-0.069	0.028	-0.018	-0.006
Baghdad	0.029	-0.042	0.02	-0.02	-0.007
Kut	0.028	-0.065	0.025	-0.034	-0.007
Hai	0.026	-0.065	0.036	-0.039	-0.008
Amara	0.028	-0.061	0.052	-0.042	-0.009
Basrah	0.03	-0.04	0.052	-0.04	-0.003
Rutba	0.067	-0.034	0.063	0.018	0.003
Najaf	0.033	-0.031	0.025	-0.025	-0.008
Kerbela	0.029	-0.048	0.025	-0.024	-0.007
Hella	0.031	-0.035	0.025	-0.025	-0.008
Diwaniya	0.037	-0.035	0.03	-0.03	-0.007
Samawa	0.04	-0.051	0.035	-0.035	-0.006
Nasiriya	0.033	-0.047	0.047	-0.04	-0.006
Fao	0.04	-0.036	0.058	-0.037	0.01
Country	0.038	-0.024	0.041	-0.012	-0.0043

TABLE 2

Percentage of annual trends of the extreme temperature indices in Iraq during the period 1981-2017

Index	Trend	Positive	No change	Negative
DTR	Decrease	15.4	0.0	84.6
TXx	Increase	100.0	0.0	0.0
TXn	Decrease	15.8	5.3	78.9
TNx	Increase	100.0	0.0	0.0
TNn	Decrease	31.6	5.2	63.2

where, T_{xkj} is the daily maximum temperature in month (year) k, period j.

The monthly (annual) the minimum value of minimum temperature (T_{Nn}) is given by:

$$T_{N nkj} = \min (T_{nkj}) \quad (4)$$

where, T_{nkj} is the daily minimum temperature in month (year) k, period j

Linear trends of each index at each weather station are computed using linear least square method. This method is a procedure to determine the best fit line to the data. In this study, linear trends with p-value less than 0.10 are considered statistically significant.

4. Results and discussion

RClimDex relies on the statistical computing environment (R) and provides an easy-to-use interface for calculating extreme climate indicators to monitor and detect climate change. ClimDex calculates all indicators recommended by CCI / CLIVAR. In this study, five temperature indicators were investigated: the maximum value of maximum temperature TXx , the minimum value of maximum temperature TXn , the maximum value of minimum temperature TNx and the minimum value of minimum temperature TNn and Diurnal temperature range DTR. The magnitude of slope have been used to analyze climate variability in Iraq for 38 years. This analysis revealed mainly positive trends in TXx and TNx indicators and negative trends in TNn , TXn and DTR indicators. The temporal distribution of the extreme temperature indices was studied for Iraq. Baghdad station has been chosen to represent the study area. Fig. 2 shows the annual liner trend of extreme temperature indices for Baghdad station. It can be seen that there is a significant

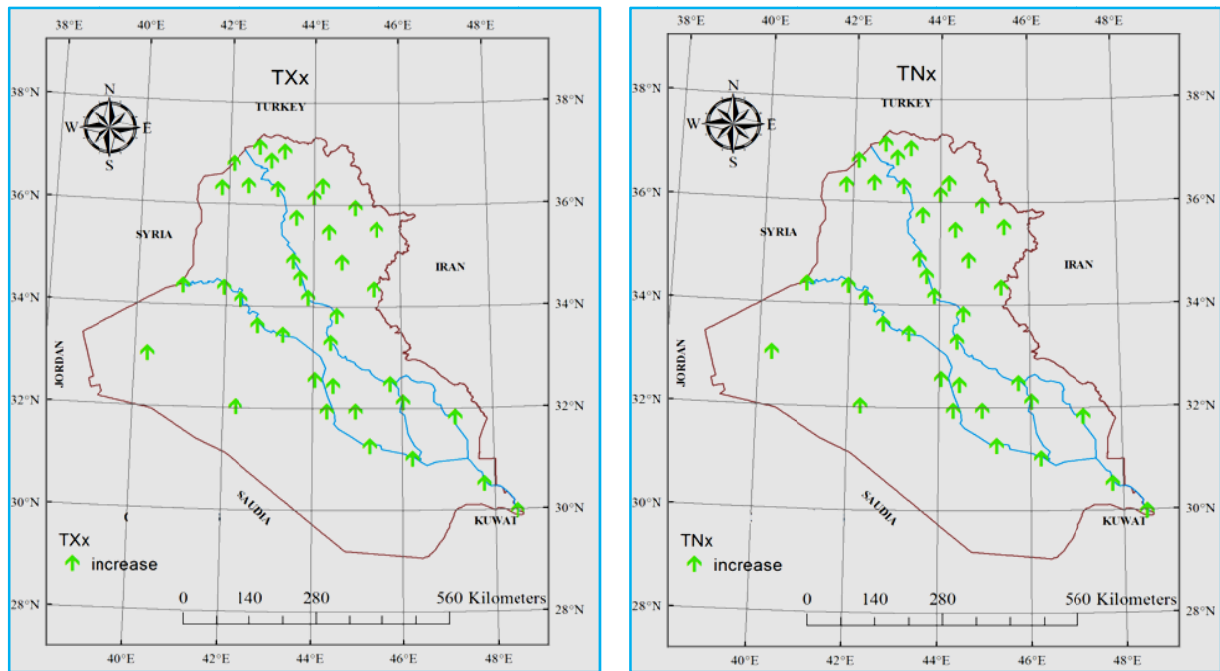


Fig. 3. Monthly extreme temperature indices TXx and TNx trends of in Iraq during the period 1981-2017

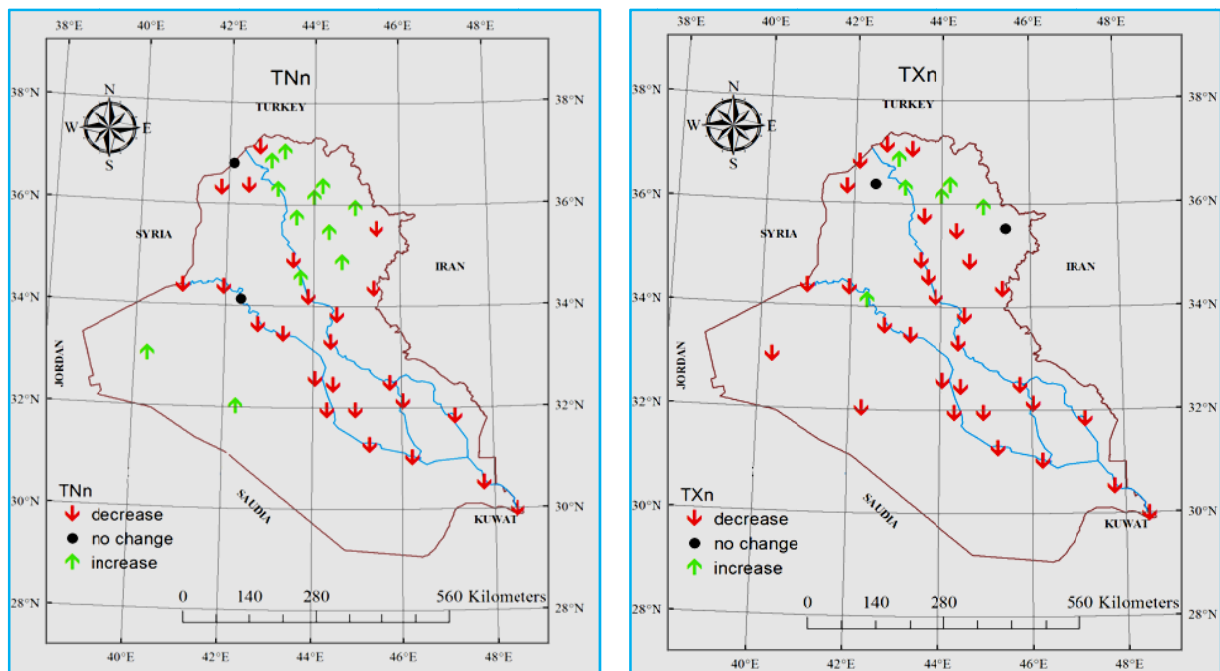


Fig. 4. Annual extreme temperature indices TXn and TNn trends of in Iraq during the period 1981-2017

positive trend of TXx and negative trend of TNn, TNx and DTR indices. during the period 1981-2017. Temperature indices in TNx indices, while there is a significant Baghdad station.

The Annual trends of the extreme temperature indices in Iraq during the period 1981-2017 for 38 stations over Iraq are presented in Table 1. The values in bold represent a positive trend.

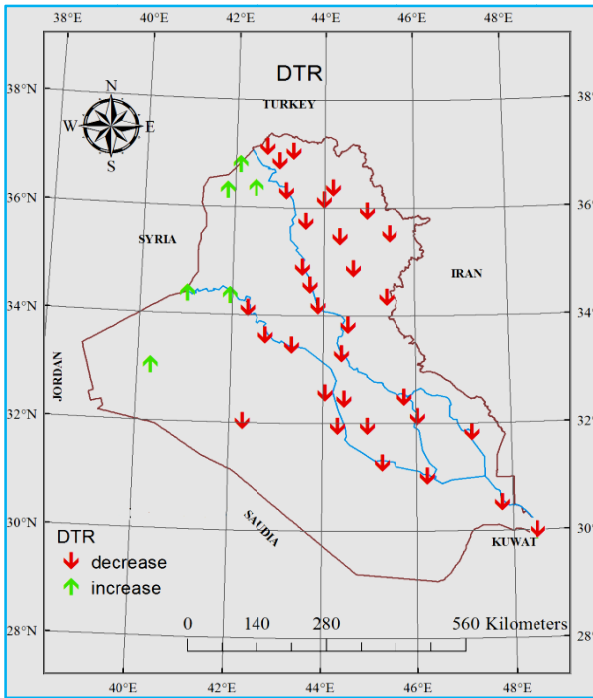


Fig. 5. Extreme temperature index DTR in Iraq during the period 1981-2017

The distribution of the trends of the selected indices: the maximum value of maximum temperature TXx, the minimum value of maximum temperature TXn, the maximum value of minimum temperature TNx and the minimum value of minimum temperature TNn and Diurnal temperature range DTR are presented in Figs. 3-5. The green arrow up symbol represents an increasing trend, the red arrow down symbol represents the decreasing trend and while the circle represents no change in trend.

From Fig. 3, the maximum monthly maximum temperature TXx index shows an increasing trend at 100% of stations. Similarly, the monthly maximum value of the lowest daily temperature TNx shows an increasing trend at 100% of stations. It is clear that all stations show positive trends for these two indicators. Fig. 4 shows the annual trend of TXn and TNn indices in Iraq. TXn has a decreasing trend at 30 stations and an increase in six stations in the northern region of Iraq east of the Tigris and a zero trend has been found for 2 stations they are Sulaymaniyah and Telfer. The TNn shows a similar pattern of trend TXn. There is a decreasing trend at 24 stations and a zero trend is found for two stations they are Rabiah and Hadithah. There are 12 stations with increased TNn in the northern region of Iraq east of the Tigris and southwest of Iraq.

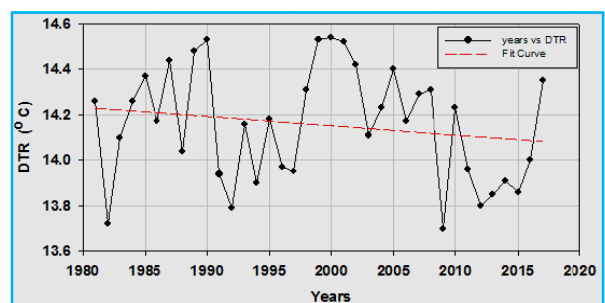
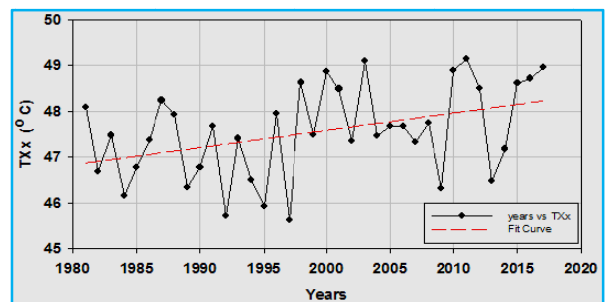
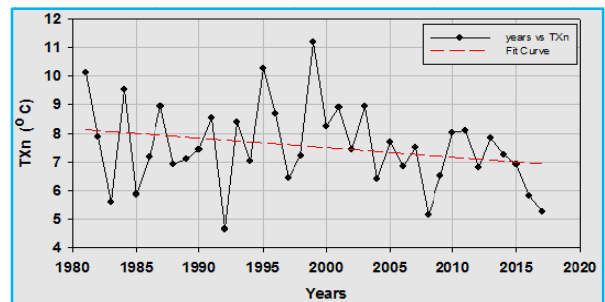
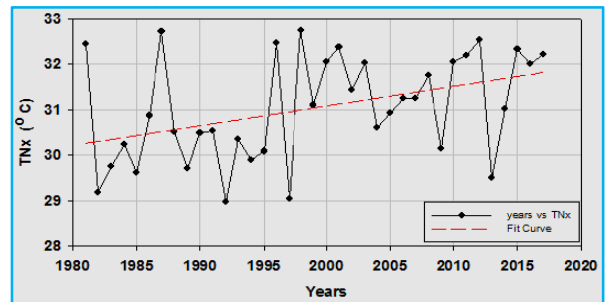
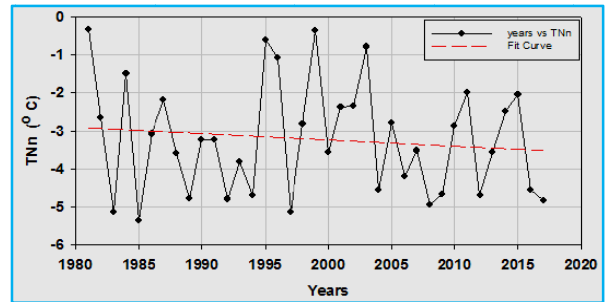


Fig. 6. Time series curves of annual indices over Iraq during 1981-2017

DTR has a decreasing trend at 32 stations and an increase in six stations in the west region of Iraq (Fig. 5).

The Percentage of annual trends of the extreme temperature indices over Iraq are presented in Table 2. The trends of TXN, TNN and DTR has a negative value (decreasing), while the trends of TXx and TNx has a positive value (increasing).

The warmest day (TXx), warmest night (TNx), diurnal temperature range (DTR), coldest night (TNN) and coldest day (TXn) all display trends consistent with warming.

Fig. 6 shows the inter-annual variability of the nationally averaged time series for TNN, TNx, TXx, TXn and DTR indices. The TNx and TXx indices have an increasing trend over Iraq for the period 1981-2017. The annual mean of TNx index trend is that of 0.0411 °C/36 years. This trend corresponds to an increase of 1.48 °C in the total period analyzed of mean TNN index. Annual mean TXx trend was a little less 0.0385 °C/36 years. The TXx increase corresponding to the total period was 1.38 °C of TXx index. In contrast, the annual mean of TNN and TXn indices have a decreasing trend in Iraq. The annual mean of TXn index trend is that of -0.0238 °C/36years. This trend corresponds to a decrease of 0.85 °C in the total period analyzed of mean TXn index. Annual mean TNN trend was a little less 0.0105 °C/36 years. The TNN increase corresponding to the total period was 0.38 °C of TNN index. Also, the difference between daily maximum and minimum temperature DTR in °C was analyzed, the annual mean DTR index has a declining trend in Iraq it was 0.0043 °C/36 years. This trend corresponds to a decrease of 0.15° in the total period analyzed (1981-2017) of DTR index.

5. Conclusions

The change of extremes temperature associated with climate change has been increasing at most of the stations during the study period (1981-2017). The nationally annual index of the maximum value of maximum temperature TXx and the maximum value of minimum temperature TNx revealed showed an increasing trend at 100% of the stations. For other three indices TXn, TNN and DTR decreasing trends have been detected in most area. The annual mean of TNx index trend was 0.0411 °C/years. This trend corresponds to an increase of 1.48 °C. Annual mean TXx trend was a little less 1.38 °C. The annual mean of TXn index trend is that of -0.0238 °C/years. This trend corresponds to a decrease of 0.85 °C in the total period analyzed of mean TXn index. Annual mean TNN trend was a little less 0.0105 °C/years.

The TNN increase corresponding to the total period was 0.38 °C of TNN index. Annual mean DTR index has a decreasing trend in Iraq 0.0043 °C/years. This trend corresponds to a decrease of 0.15 °C for DTR index.

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