Analysis of some extreme temperature indices over Iraq

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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
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 analyze 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 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° × 0.5° (latitude × 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:

\[ TXxkj = \max (Txkj) \] (1)

where, Txkj is the daily maximum temperature in month (year) k, period j.

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

\[ TNxkj = \max (TnkJ) \] (2)

where, TnkJ is the daily minimum temperature in month (year) k, period j.

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

\[ TX nkj = \min (Txkj) \] (3)

Fig. 2. Five indices of extreme temperature for Baghdad station
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|
| salahaddini  | 0.04 | 0.015| 0.059| 0.007| -0.008|
| Sulaymaniyyah| 0.03 | 0    | 0.045| -0.005| -0.016|
| Sinjar        | 0.045| -0.018| 0.044| -0.003| 0.003|
| Duhok         | 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|
| Samarraa      | 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|
| Countrry      | 0.038| -0.024| 0.041| -0.012| -0.0043|

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         | 84.6     |
| TXx       | Increase   | 100.0    | 0         | 0        |
| TXn       | Decrease   | 15.8     | 5.3       | 78.9     |
| TNx       | Increase   | 100.0    | 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 (TNn) is given by:

$$TN_{n} = \min (T_{nkj})$$

where, $T_{nkj}$ T 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 TXn 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 linear trend of extreme temperature indices for Baghdad station. It can be seen that there is a significant
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.
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 Sulaymaniyyah 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. 5. Extreme temperature index DTR in Iraq during the period 1981-2017

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 DTR index has a decreasing trend at 32 stations and an increase in six stations in the west region of Iraq 0.0043 °C/years. This trend corresponds to a decrease of 0.15 °C for DTR index.

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References

Abbasnia, M., Tavousi, T. and Khostravi, M., 2016, “Assessment of future changes in the maximum temperature at selected stations in Iran based on HADCM3 and CGCM3 models”, Asia-Pacific, Journal of Atmospheric Sciences, 52, 4, 371-377, DOI:10.1007/s13143-016-0606-z.

Alexander, L., Zhang, X., Peterson, T. C., Caesar J., Gleason, B., Klein, A. M. G., Haylock, M., Stephenson, D., Burn Aguilar, J. E., Brunet, M., Taylor, M., New, M., Zhai, P., Rastcucicu, M. and Azquez-Aguirre, J. L., 2006, “Global Observed Changes in Daily Climate Extremes of Temperature and Precipitation”, Journal of Geophysical Research, 111, D05109. DOI:10.1029/2005JD006290.

Al-Timimi, Y. K. and Al-Jiboori M. H., 2013, “Assessment of spatial and temporal drought in Iraq during the period 1980-2010”, Journal of Energy and Environment, 4, 2, 219-302.

Al-Timimi, Y. K. and Al-Khudhairy, A., 2017, “Analysis of Minimum temperature spatially and temporally over Iraq During the period 1980-2015”, Journal of Applied and Advanced Research, 2, 5, 309-316. DOI:10.21839/jaar.2017.v2i5.109.

Al-Khudhairy, A. and Al-Timimi, Y. K., 2017, “Spatial and Temporal Analysis of Maximum Temperature over Iraq”, Al-Mustansiriyyah Journal of Science, 29, 1, 1-8, DOI: http://doi.org/10.23851/jms.v29i1.257.

Al-Timimi, Y. K. and Al-Khudhairy, A., 2018, “Spatial and Temporal Temperature trends on Iraq during 1980-2015”, Journal of Physics: Conference Series, Ibn Al-haitham first international scientific conference 13-14 December, 2017, Baghdad, Iraq, , 1003,1-12. Doi :10.1088/1742-6596/1003/1/012091.

Brunetti, M., Maugeri, M., Monti, F. and Nanni, T., 2006, “Temperature and precipitation variability in Italy in the last two centuries from homogenized instrumental time series”, International Journal of Climatology, 26, 345-381. Doi:10.1002/joc.1251.

Easterling, D. R., Evans, J. L., Groisman, P. Y., Karl, T. R., Kunkel, K. E. and Ambenje, P., 2000, “Observed variability and trends in extreme climate events”, Bulletin of American Meteorological Society, 81, 417-425.

Frich, P., Alexander, L., Della-Marta, P., Gleason, B. Haylock, M., Klein Tank, A. M. G. and Peterson, T. C., 2002, “Observed Coherent Changes in Climatic Extremes during the Second Half of the Twentieth Century”, Climate Research, 19, 193-212.

Haylock, R., M. R. and Peterson, T. C., 2006, “Trends in total and extreme South American rainfall 1960-2000 and links with sea surface temperature”, Journal of Climate, 19, 490-1512.

IPCC (Intergovernmental Panel on Climate Change), 2013, “Climate Change: The Physical Science Basis. The contribution of Work Group I to the Fifth Assessment” Report of the Iner-governmental panel on Climate Change. Cambridge university press, p1550.
IPCC (Intergovernmental Panel on Climate Change), 2001, “Climate Change Impacts, Adaptation and Vulnerability”, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press 2001.

IPCC (Intergovernmental Panel on Climate Change), 2007, “The Physical Science Basis”, Edited by: Solomon, S., Qin, D., Manning M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. and Miller H. L. UK: Cambridge University Press.

Jones, P. D. and Moberg, A., 2003, “Hemispheric and large-scale surface air temperature variations: An extensive revision and an update to 2001”; *Journal of Climate*, 16, 2, 206-223. doi.org/10.1175/1520-0442 (2003) 016%3C0206 : HALSSA%3E2.0.CO;2.

Mohammad, R., Nooshin, M., Ameneh, R. and Kirien, W., 2018, “Trends in Indices of Extreme Temperature and Precipitation in Iran over the Period 1960-2014”, *Open Journal of Ecology*, 8, 396-415. DOI: 10.4236/oje.2018.87024.

Toreti, A. and Desiao, F., 2008, “Changes in temperature extremes over Italy in the last 44 years”, *International Journal of Climatology*, 28, 733-745, DOI: 10.1002/joc.1576.

Zhang, X. and Yang, F., 2009, World Wide Web “RClimDex (1.0) User Manual”, http://etccdi.pacificclimate.org/RClimDex/RClimDexUserManual.doc.