Spatial and Temporal Temperature trends on Iraq during 1980-2015

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Abstract. Monthly Mean surface air temperature at 23 stations in Iraq were analyzed for temporal trends and spatial variation during 1980-2015. Seasonal and annual temperature was analyzed using Mann-Kendall test to detect the significant trend. The results of temporal analysis showed that during winter, spring, summer and Autumn have a positive trend in all the parts of Iraq. A tendency has also been observed towards warmer years, with significantly warmer summer and spring periods and slightly warmer autumn and winter, the highest increase is (3.5)°C in Basrah during the summer. The results of spatial analyze using the ArcGIS showed that the seasonal temperature can be divided into two or three distinct areas with high temperature in the south and decreasing towards north, where the trend of spatial temperature were decreasing from south to the north in all the four seasons.

Keywords: Trend, temperature, Mann-Kendall, ArcGIS, Iraq.

1. Introduction
Temperature is one of the most influential elements of Meteorological and Climatological Components. Cause its directly affected in our lives. The global average surface temperature has increased in the 20th century by about (0.6°C). Recent studies reveal a significant worldwide warming and a general increase in frequencies and persistence of high temperatures, one of the major concerns with that potential change in climate is the increase in extreme events will occur. Generally the global surface temperature has been increasing over the past 100 years by presumably due to the greenhouse effect, as a result of increasing concentrations of carbon dioxide and other greenhouse gases into the atmosphere. This warming trend has exhibited considerable temporal and spatial variability [1]. Global mean air surface temperature has risen in the Twentieth century, and it’s expected to rise by (1.8-4.0)°C in the twenty first century [2]. Because global and regional effects of global warming become apparent that cause the studies on monitoring global and regional temperature change have sharply increased in the last few decades. Global average surface air temperature has increase by (0.13°C) to (0.03°C) per decade over the last 50 years according to (IPCC) Intergovernmental Panel on Climate Change Which is one of the most important association providing data on the global warming changes and it’s established back in 1988 [3]. Many regional studies have also indicated a positive trend in temperature although the changes slightly vary from one region to another indicated, the annual mean temperature has
increased between (0.5°C) and (1.58°C) in the south parts of Canada over the 20th century. With an intense warming trend of (+0.08°C +0.03°C) per decade over Europe, Where Europe has the highest increase (0.43°C) over the last 30 Years [4]. The analysis of temperature all over the world has shown that the increase is not only in mean annual but also in seasonal, monthly, maximum and minimum temperature [5]. Worldwide analysis of air temperature changes And the studies shown that temperature has increased in both Hemispheres. But warming was more dominant in the northern hemisphere in the last 50 years [6]. Many regional studies have also indicates a positive trend in temperature although the changes slightly vary from one region to another [7]. Mediterranean is the most affected area in the world from global warming, these intensified increased in temperature may cause potential evaporation, water Deficit and forest fire risk [8]. This study aimed to examine the spatial and temporal temperature trends in annual and seasonal mean temperatures in Iraq for 35 years time period (1980-2015) by using Mann-Kendall non-parametric test and Sen’s method.

2. Experimental

2.1 Study Area and Data

The study area is represented by Iraq, where geographically Iraq is located in the semi-tropical latitude in the Northern Hemisphere between latitudes (29.5°-37.5°N) north the equator, and between longitudes (38.45°-48.45°E) east of Greenwich line. Also, Iraq lies in the south west of Asian continent in the northern part of the Arab homeland, the north border is with turkey, Syria, Jordan from the west, Kuwait and Kingdom Saudi Arabia from south and Iran from the east. And this location determines the closeness or the distance of Iraq from water bodies which have clear impact in the climate and thermal properties of Iraq, where the Mediterranean Sea and the Arabian Gulf are the most influential water bodies in Iraq [9].

In this study a historical records of monthly mean temperature were acquired from the Iraqi Meteorological Organization and Seismology (IMOS) for thirty five years of the period (1980-2015). The long term data were collected from 23 ground weather stations located at different regions of the country. As shown in Table 1 and ‘Figure 1’.

Table (1): Meteorological stations that used in the study

| Station | Station Number | Longitude | Latitude | Elevation |
|---------|----------------|-----------|----------|-----------|
| Amara   | 680            | 47.17     | 31.83    | 9.5       |
| Baghdad | 650            | 44.4      | 33.3     | 31.7      |
| Biji    | 631            | 43.53     | 34.9     | 115.5     |
| Basrah  | 689            | 47.78     | 30.52    | 2         |
| Diwaniya| 672            | 44.95     | 31.95    | 20        |
| Haditha | 634            | 42.35     | 34.13    | 108       |
| Hella   | 657            | 44.45     | 32.45    | 27        |
| Kerbel  | 626            | 44.05     | 32.57    | 29        |
| Khanqin | 637            | 45.38     | 34.35    | 202       |
| Kirkuk  | 621            | 44.35     | 35.47    | 331       |
| Kut     | 665            | 45.75     | 32.49    | 17        |
| Mosul   | 608            | 43.15     | 36.31    | 223       |
| Najaf   | 670            | 44.32     | 31.95    | 53        |
| Nasiriya| 676            | 46.23     | 31.02    | 5         |
| Rabiah  | 602            | 42.1      | 36.37    | 382       |
| Ramadi  | 645            | 43.32     | 33.83    | 48        |
| Rutba   | 642            | 40.28     | 33.03    | 630.1     |
| Samawa  | 674            | 45.27     | 31.27    | 11.4      |
| Sinjar  | 604            | 41.83     | 36.32    | 583       |
2.2 Mann-Kendall Test (MK)
Simple linear regression analysis could give us a primary indication of existence of trend in times series data, whereas another method, such as the non-parametric Mann-Kendall (MK) test, which usually used in hydrologic data analysis, can used to detect trends that are monotonic but not necessarily linear. The MK test does need the assumption of normality, and only indicates the direction but not the magnitude of significant trends [10]. This test is usable in the situations where values $x_i$ of a time series may subjected to

$$x_i = f(t_i) + e_i$$  \hspace{1cm} (1)

The $f(t_i)$ is continuous monotonic growing or diminishing function with time, while $e_i$ presumed to came from same division with zero mean. Thus we can assume that the difference in the division is constant with time.
For testing the null hypothesis when there is no trend for example the monitoring \( x_i \) are randomly arrange with time, with the substitution hypothesis whereas a rising or declining monotonic trend. For computation of this statistical test MAKESENS which is a brief to Mann-Kendall test and Sen's method exploits both, so the S statistics and the normal approximation Z statistics in Gilbert are called \([11]\). For time series with less than 10 data points the S test is used, and for time series with 10 or more data points the normal approximation is used.

Trends were detected in the time series by means of Mann-Kendall test. The Mann-Kendall method has been suggested by the world meteorological organization to assess the trend in environment data time series.

The Mann-Kendall test statistic S is given by:

\[
S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{sgn}(x_j - x_k),
\]

(2)

where \( x_j \) and \( x_k \) represents the annual values in years \( j \) and \( k, j>k \), respectively, and

\[
\text{sgn}(x_j - x_k) = \begin{cases} 
1 & \text{if } x_j - x_k > 0 \\
0 & \text{if } x_j - x_k = 0 \\
-1 & \text{if } x_j - x_k < 0 
\end{cases}
\]

(3)

When \( n \) is 9 or lower, the absolute value of S is match straight to the theoretical distribution of S obtained by Mann-Kendall \([11]\).

The Z statistics used When the number of Values ten or further. When \( n \) is at minimum 10 thereafter normal approximation test is applied. Although whether there are various tied values for example a similar values in the time series, this may decrease veracity of the normal distribution when the number of values near ten. The contrast of S calculated by equation (4) with consideration that ties would be display as:

\[
VAR(S) = \frac{1}{18} \left[ n(n-1)(2n+5) - \sum_{p=1}^{q} t_p (t_p - 1)(2t_p + 5) \right]
\]

(4)

Where

- \( q \) the number of tied groups.
- \( t_p \) the number of data values on the \( p^{th} \) group.

The values of \( S \) and \( VAR(S) \) are applied for calculating the Z test as falls

\[
Z = \begin{cases} 
\frac{S - 1}{\sqrt{VAR(S)}} & \text{if } S > 0 \\
0 & \text{if } S = 0 \\
\frac{S + 1}{\sqrt{VAR(S)}} & \text{if } S < 0 
\end{cases}
\]

(5)

The existence of a statistically significant trend is estimated by using the Z value. A positive (negative) value of Z indicates an upward (downward) trend \([11]\).
3. Results & Discussion

3.1 Temporal Analysis

The statically significant levels, high (0.01), medium (0.05) and low (0.1) were used in this study. The estimate for magnitude of slope (Q) was computed for significant trends in (°C/Year). Mann–Kendall test was used to identify the pattern for the analysis of seasonal and annual mean temperature. Figures (2-5) shows the trends of temperature in four standard stations. It can be seen that there is a slight increase during winter season. In spring season the results reveal an increase in all the trends. While in summer, the trends of mean temperature shows the most increasing trends between the seasons. Autumn season is characterized by increasing trends in mean temperature with a slight increase or almost the same as in spring season.

![Seasonal and Annual Temperature Trends](image)

**Figure (2):** (a) Seasonally and (b) annually mean temperature at Baghdad Station
Figure (3): (a) Seasonally and (b) annually mean temperature at Basrah Station

Figure (4): (a) Seasonally and (b) annually mean temperature at Mosul Station
From the table (2) The results of annual analysis shows the highest increase in $Q(\degree C/\text{Year})$ was (0.07) noticed in Basrah station. And the lowest increase was (0.05) noticed in Mosul station. Seasonally the highest increase in $Q(\degree C/\text{Year})$ (0.10) noticed in Summer season at Basrah station. And the lowest was (0.04) Noticed in Autumn Season at both Baghdad and Mosul stations and in Spring season at Mosul and Rutba.

### Table 2: Seasonally & annually of Mann-Kendall Results For $T_{\text{mean}}$

|          | Baghdad | Basrah | Mosul  | Rutba  |
|----------|---------|--------|--------|--------|
| Seasonally        |         |        |        |        |
| Winter   | Z       | Q(°C/Year) | Z       | Q(°C/Year) | Z       | Q(°C/Year) | Z       | Q(°C/Year) |
|          | 2.77    | 0.05   | 2.48   | 0.05   | 2.97   | 0.05   | 2.77   | 0.06   |
| Spring   | 4.54    | 0.06   | 4.43   | 0.07   | 3.85   | 0.06   | 4.54   | 0.06   |
| Summer   | 5.16    | 0.07   | 5.71   | 0.10   | 2.80   | 0.04   | 5.16   | 0.04   |
| Autumn   | 3.09    | 0.04   | 5.13   | 0.07   | 2.95   | 0.04   | 3.09   | 0.05   |
| Annually |         |        |        |        | 5.59   | 0.06   | 4.91   | 0.07   | 4.24   | 0.05   | 5.59   | 0.06   |

#### 3.2 Spatial Analysis
Seasonal mean temperature over Iraq during the period 1980-2015 is displayed in figure (6). The results reveal that the mean temperature in the south part of Iraq was higher than the other parts of the country. In winter season, the temperature distribution over Iraq is can be divided into two distinct areas, the north and the west regions are below 10°C Which covers about 38% of the country, while the center and the southern parts that covers the other 62% of the studied area are 10-15°C as shown in Figure (6a) and table (3). The lowest Mean temperature $T_{\text{Mean}}$ in winter season was 5.6°C and the highest value 13.9°C. In summer, temperatures increased in the whole country, and the temperature distribution over Iraq can be divided into three distinct areas, The lowest temperature observed in the northern parts of the country was below 30°C, the center up to the north and the western regions experiments temperature between 30-35°C which is covers about 58% of the study area, and the southern regions was more than 35°C Which covers about 40% as shown in Figure 6b and table (3). The lowest Mean temperature $T_{\text{Mean}}$ in summer season was 29.2°C and the highest value 37.4°C. The study area during spring season divided into four regions, the highest mean temperature observed in the southern region of the country with temperature 25-30°C, the central regions which covers about 57% of country is between 20-25°C, and the north and west regions with temperatures between 15-20°C, with a small region in the northeast of Iraq with temperature below 15°C as shown in Figure (6c) and table (3). In autumn, the study area divided into three distinct areas, moderate temperature are observed all over the country with temperatures below 20°C in a small region in the northeast part of the country, the other northern region and center of the country to the east and west regions which cover more than 63% of the study area are with temperatures 20-
25°C, and the southern parts with temperatures more than 25°C as shown in Figure (6d) and table (3). The lowest Mean temperature \( T_{\text{Mean}} \) in autumn season was 19.2°C and the highest value 27.3°C.

From the figure 7 and table 4 annual mean temperature distribution over Iraq can be divided into three distinct areas the lowest mean averaged temperature is noticed in the northern region of the country which cover about 8% of the study area with temperatures between 15-20°C, the central region that occupy about 69% of the studied area are with temperatures between20-25°C, and the highest mean temperature noticed in the south part of the country above 25°C which cover about 23% of the country as shown in (Figure 7). The lowest Mean temperature \( T_{\text{Mean}} \) annually was 17.2°C and the highest value 26.3°C.
Figure 6. Spatial Distribution of Seasonal Mean Temperature ($T_{\text{mean}}$) in (°C) over Iraq for the period 1980-2015 By Kriging Technique in ArcGis

Table (3): Seasonal $T_{\text{mean}}$ over Iraq for the period 1980-2015

| Classes Color | Class Category | Count | Frequency Percent |
|---------------|----------------|-------|-------------------|
|               | 2              | 14464 | 37.94%            |
|               | 3              | 23653 | 62.06%            |
|               | Sum = 38117    |       | 100%              |

Lowest $T_{\text{Mean}}$ in Winter is 5.6 °C
Highest $T_{\text{Mean}}$ in Winter is 13.9 °C

| Classes Color | Class Category | Count | Frequency Percent |
|---------------|----------------|-------|-------------------|
|               | 6              | 669   | 1.76%             |
|               | 7              | 22230 | 58.32%            |
|               | 8              | 15218 | 39.92%            |
|               | Sum = 38117    |       | 100%              |

Lowest $T_{\text{Mean}}$ in Summer is 29.2 °C
Highest $T_{\text{Mean}}$ in Summer is 37.4 °C
### Spring Mean Temperature ($T_{\text{Mean}}$)

| Classes Color | Class Category | Count | Frequency Percent |
|---------------|----------------|-------|-------------------|
|               | 3              | 259   | 0.68%             |
|               | 4              | 8453  | 22.18%            |
|               | 5              | 21585 | 56.62%            |
|               | 6              | 7820  | 20.52%            |
|               | **Sum**       | **38117** | **100%**          |

Lowest $T_{\text{Mean}}$ in Spring is 14.7 °C  
Highest $T_{\text{Mean}}$ in Spring is 26.3 °C

### Autumn Mean Temperature ($T_{\text{Mean}}$)

| Classes Color | Class Category | Count | Frequency Percent |
|---------------|----------------|-------|-------------------|
|               | 4              | 830   | 2.18%             |
|               | 5              | 24090 | 63.20%            |
|               | 6              | 13197 | 34.62%            |
|               | **Sum**       | **38117** | **100%**          |

Lowest $T_{\text{Mean}}$ in Autumn is 19.2 °C  
Highest $T_{\text{Mean}}$ in Autumn is 27.3 °C
**Figure 7.** Spatial Distribution of Annual Mean temperature in (°C) over Iraq for the period 1980-2015 By Kriging Technique in ArcGis

**Table (4):** Annual ($T_{mean}$) over Iraq for the period 1980-2015

| Classes Color | Class Category | Count  | Frequency Percent |
|---------------|----------------|--------|-------------------|
|               | 2              | 2973   | 7.80%             |
|               | 3              | 26410  | 69.29%            |
|               | 4              | 8734   | 22.91%            |
| Sum = 38117   |                |        | 100%              |

Lowest $T_{mean}$ annually is 17.2 °C
Highest $T_{mean}$ annually is 26.3 °C
4. Conclusions
This study investigated the seasonal and annual variability on mean temperature in Iraq. The results show that trends of mean temperature for annual series, the trends in various regions are increased in northern and southern Iraq. The trend of increasing mean temperature was about (2.1°C/year). In winter season, the increasing trend of mean temperature was (1.75°C/year) in northern of Iraq and the same in the middle and southern region in Iraq. The increasing trend of autumn mean temperature was the same value in northern and middle parts of Iraq (1.4°C/year) and increase in the south to (2.45°C/year). In spring the rising trend of mean temperature was (2.1°C/year) in the northern and the middle region of the country and reach (2.45°C/year) in the south region. The highest value of increasing trend of mean temperature was in southern part of Iraq during the summer with value (3.5°C/year).

The results of the spatial analysis of mean temperature show that the mean temperature gradient is found to be from the south to the north of Iraq. Seasonally the study area can be divided into two or three distinct areas with high temperature in the south and decreasing toward north.

References
[1] Jones, P.D., Raper, S.C.B., Bradley, R.S., Diaz, H.F., Kelly, P. M., Wigley, T.M. L., 1986, "A northern hemisphere surface air temperature variations: 1851-1984.," American Meteorological Society, vol. 25, pp. 161-179, February 1986.
[2] Brohan P, Kennedy JJ, Harris I, Tett SFB, Jones PD, "Uncertainty estimates in regional and global observed temperature change: A new data set from 1850," journal of geophysical Research Atmospheres, vol. 111, no. D12106, DOI: 10.1029/2005JD006548., 2006 June 24.
[3] Solomon, S., D. Qin, M. Tignor and H.L. Miller, "Climate Change : The physical Science Basis," Cambridge University Press, Cambridge, United Kingdom, 2007.
[4] Luterbacher. J., D. Diertrich, E. Xoplaki, M. Grosjean and H. Wanne, " European seasonal and annual temperature variability, trends and extremes since 1500," Science, vol. 303, pp. 1499-1503, 2004 March 5.
[5] Pielke, R.A., C.A. Davey, D. Niyogi, S. Fall, J. Steinweg-Woods, K. Gallo, R. hale, R. Mahmood, S. Foster, R.T. McNider and P. Blanken, "Unresolved issues with assessment of multidecadal global and land surface temperature trends," Geophysical Research, vol. 112, no. D24S08, doi:10.1029/2006JD008229, 2007.
[6] Rabetez, M. and M. Reinhard, "Monthly air temperature trends in Switzerland 1901-2000 and 1975-2004," Theoretical and Applied Climatology, vol. 91, pp. 27-34, 2007 June 27.
[7] Stafford, J.M., G. Wendler and J.Curtis, " Temperature and precipitation of Alaska:50 year trend analysis," Theoretical and Applied Climatology, vol. 67, pp. 33-44, 2000 March 21.
[8] Miro, J.J., M.J. Esrela and M. Millan, "Summer temperature trends in a Mediterranean area (Valencia Region)," CONTRIBUTIONS to SCIENCE, vol. 3, p. 331–342, 2007.
[9] Al Quraishi, Dhiyaa AlDeen Abd Al Hussien Ewaeed,(2008)."thermal properties of the middle and south part of Sedimentary plain in Iraq".Msc Thesis,College of education Ibn Rushed,Baghdad University.
[10] Soman, M.R., Krishnakumar, K.,Singh, N., 1988.Decreasing trend in the rainfall of Kerala. Current science 57,7-12.
[11] Gilbert, R.O., 1987. "Statistical Methods for environmental pollution monitoring". Van Nostrand Reinhold, New York.