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Spatial and Temporal Analysis of Maximum Temperature over Iraq

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Abstract

Monthly Maximum 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 (3.9)oC in Basrah during the summer. The results of spatial analysis 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.

الخلاصة

تم تحليل درجةحرارة الهواء السطحية العظمى شهريا لل 23 محطة منتشرة في العراق لكل من المتجهات زمانيا وللتغاير المكاني للفترة 1980-2015. درجة الحرارة موسميا وسنويا تم تحليلها بواسطة ماان كيندل (MK) لتحديد المتجهات المهمة. نتائج التحليل الزماني اظهرت ان هنالك متجهات موجبة خلال فصل الشتاء والربيع والصيف والخريف لكل انحاء العراق. كما وجد ان هنالك ميل باتجاه السنين الاكثر دفئا مع ملاحظة وجود صيف دافئ وفترات دافئة في فصل الربيع ودفئ اكثر بقليل خلال كل من فصلي الخريف والشتاء. اعلى زيادة هي (3.9) ^{o}C خلال فصل الصيف في محطة البصرة. نتائج التحليل المكاني باستخدام برنامج ال (ArcGIS) اظهرت ان درجة الحرارة الموسمية يمكن ان تقسم الى منطقتين او الى ثلاث مناطق مميزة مع درجات حرارة عالية في المناطق الجنوبية وتقل باتجاه الشمال, حيث المتجه المكاني للحرارة يقل من الجنوب نحو الشمال خلال المواسم الاربعة.

Introduction

Temperature is one of the most influential elements of Meteorological and Climatological Components, because it's directly affected in our lives. The global average surface temperature has increased in the 20th century by about (0.6^{o}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. The global mean air surface temperature has risen in the Twentieth century, and it's expected to rise by (1.8-4.0^{o}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^{o}C) to (0.03^{o}C) per decade over the last 50 years according to Intergovernmental Panel on Climate Change (IPCC) 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^{o}C) and (1.58^{o}C) in the south parts of Canada over the 20th century. With an intense warming trend of (+0.08^{o}C +0.03^{o}C) per decade over Europe, Where Europe has the highest increase (0.43^{o}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.

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^{o}-37.5^{o}N) north the equator, and between longitudes (38.45^{o}-48.45^{o}E) east of Greenwich line. Also, Iraq lies in the south west of Asian continent in the northern part of the Arab homeland. 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 maximum 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	No.	Longitude	Latitude	Elevation
Amara	680	47.17^{o}	31.83^{o}	9.5m
Baghdad	650	44.4^{o}	33.3^{o}	31.7m
Biji	631	43.53^{o}	34.9^{o}	115.5m
Basrah	689	47.78^{o}	30.52^{o}	2m
Diwaniya	672	44.95^{o}	31.95^{o}	20m
Haditha	634	42.35^{o}	34.13^{o}	108m
Hella	657	44.45^{o}	32.45^{o}	27m
Kerbela	626	44.05^{o}	32.57^{o}	29m
Khanqin	637	45.38^{o}	34.35^{o}	202m
Kirkuk	621	44.35^{o}	35.47^{o}	331m
Kut	665	45.75^{o}	32.49^{o}	17m
Mosul	608	43.15^{o}	36.31^{o}	223m
Najaf	670	44.32^{o}	31.95 ^{o}	53m
Nasiriya	676	46.23^{o}	31.02^{o}	5m
Rabiah	602	42.1^{o}	36.37^{o}	382m
Ramadi	645	43.32^{o}	33.83^{o}	48m
Rutba	642	40.28^{o}	33.03^{o}	630.1m
Samawa	674	45.27^{o}	31.27^{o}	11.4m
Sinjar	604	41.83^{o}	36.32^{o}	583m
Sulaymaniya	623	45.45^{o}	35.53^{o}	843m
Teleafer	603	42.48^{o}	36.37^{o}	373m
Arbil	616	44^{o}	36.15^{o}	420m
Salahaddin	611	44.2^{o}	36.38^{o}	1075m

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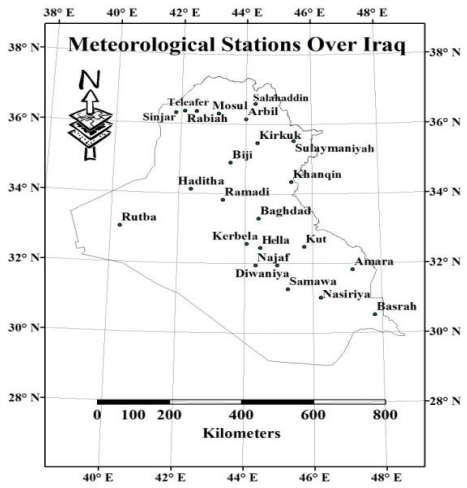


Figure 1: Meteorological stations in Iraq

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 xi of a time series may subjected to
whereas a rising or declining monotonic trend. For computation of this statistical test MAKESENS exploits both, so we called S statistics and the normal approximation Z statistics in GILBERT [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:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k), \qquad (2)$$

x_j and x_k represents the annual values in years j and k, $j>k$, respectively, and

$$sgn(x_j - x_k) = \begin{cases} 1 & if\, x_j - x_k > 0 \\ 0 & if\, x_j - x_k = 0 \\ -1 & if\, x_j - x_k < 0 \end{cases} \qquad (3)$$

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 the next equation with consideration that ties would be display as:

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5)\right] \qquad (4)$$

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 fallows

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{VAR(S)}} & if\, S > 0 \\ 0 & if\, S = 0 \\ \dfrac{S+1}{\sqrt{VAR(S)}} & if\, S < 0 \end{cases} \qquad (5)$$

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].

Results and Discussion

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 (^{o}C/Year). Mann–Kendall test was used to identify the pattern for the analysis of seasonal and annual mean maximum temperature. Figures 2-5 shows the trends of temperature in the 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 maximum temperature show the most increasing trends between the seasons. Autumn season is characterized by increasing trends in maximum temperature or sometimes almost constant as shown in Baghdad station with a slight increase the same as in spring season.

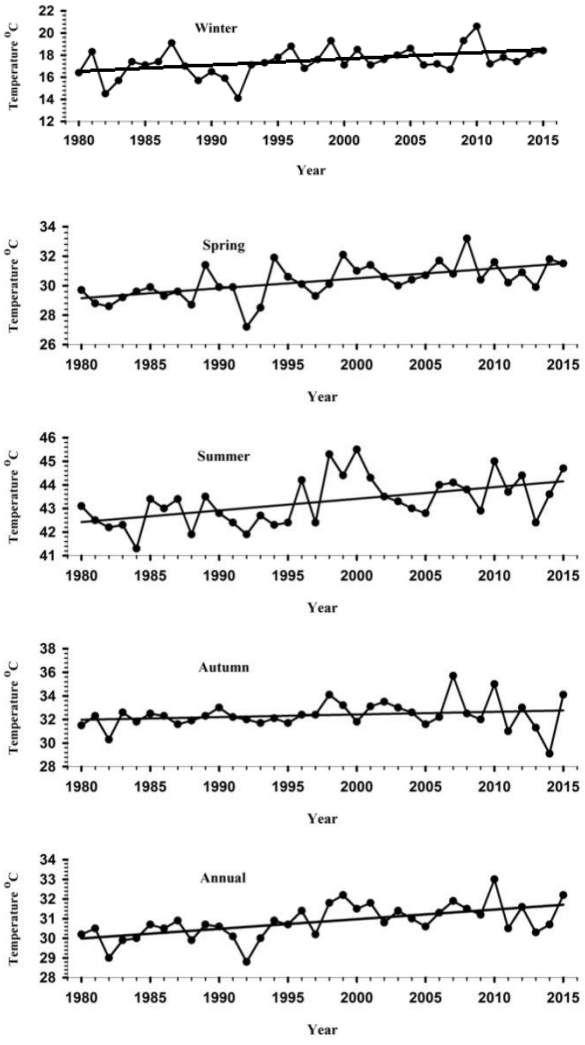


Figure 2: Seasonally and annually Maximum Temperature at Baghdad Station.

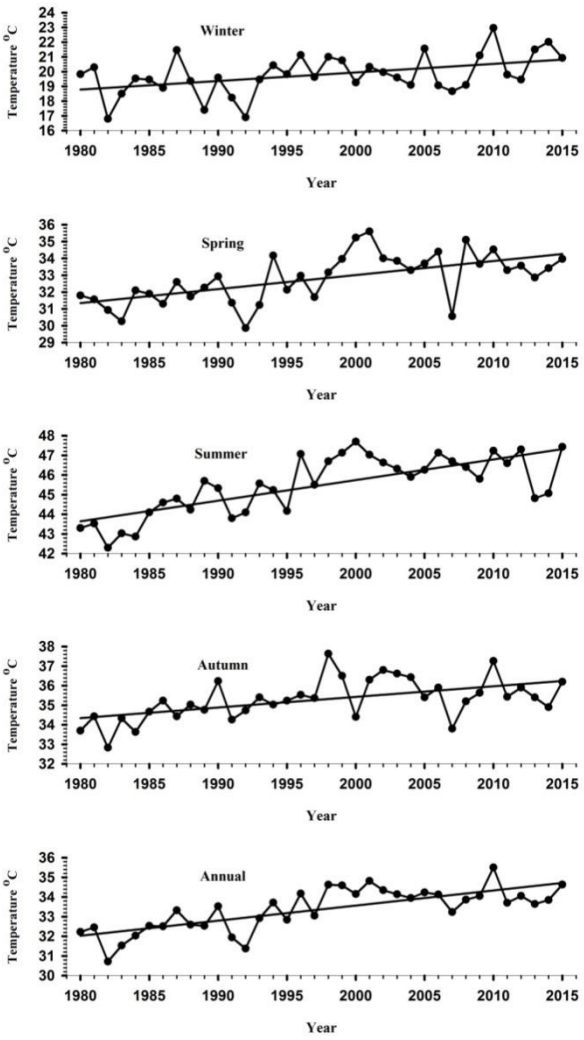
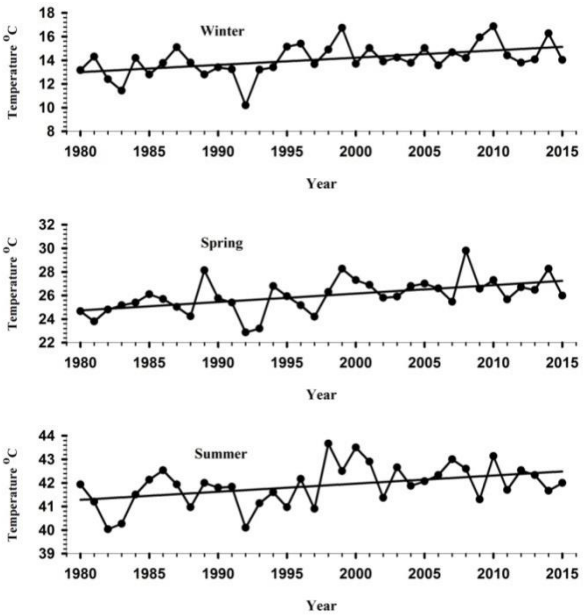


Figure 3: Seasonally and annually Maximum Temperature at Basrah Station.



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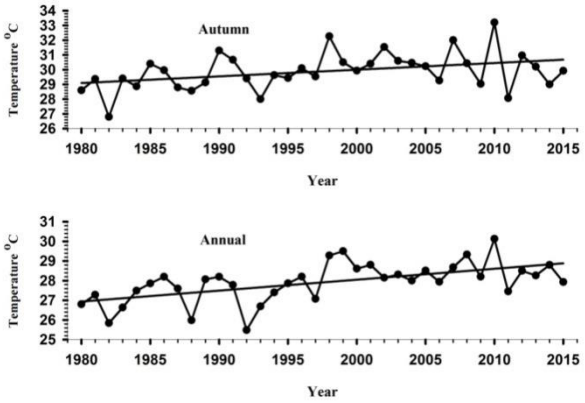

Figure 4: Seasonally and annually Maximum Temperature at Mosul Station.

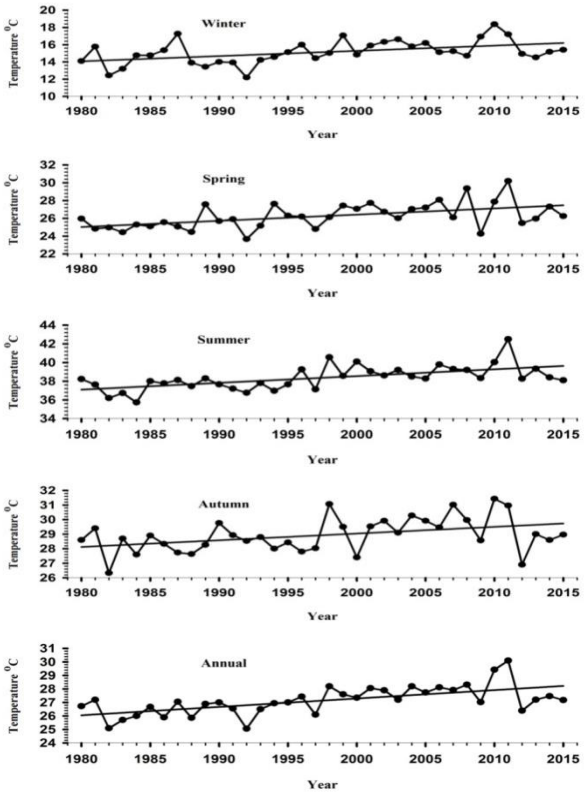

Figure 5: Seasonally and annually Maximum Temperature at Rutba Station.

From the table 2, The results of annual analysis shows the highest increase in Q(^{o}C/Year) is (0.07) noticed in Basrah station.

Table 2: Mann-Kendall Results annually and seasonally For T_{max}

	Baghdad		Basrah	
Season	**Z**	**Q(^{o}C/Year)**	**Z**	**Q(^{o}C/Year)**
Winter	2.84	0.05	2.17	0.05
Spring	3.89	0.06	3.49	0.09
Summer	2.97	0.05	4.57	0.11
Autumn	1.26	0.02	3.55	0.05
Annual	3.71	0.05	4.22	0.07
	Mosul		**Rutba**	
Season	**Z**	**Q(^{o}C/Year)**	**Z**	**Q(^{o}C/Year)**
Winter	3.11	0.06	2.79	0.06
Spring	3.27	0.07	3.26	0.08
Summer	2.21	0.03	3.86	0.06
Autumn	2.13	0.04	2.66	0.05
Annual	3.87	0.05	3.93	0.06

And the lowest increase was (0.05) noticed in Mosul and Baghdad stations. Seasonally the highest increase in Q(^{o}C/Year) (0.11) noticed In Summer season at Basrah station, and the lowest was (0.02) Noticed in Autumn Season at Baghdad station.

Spatial Analysis

Seasonal maximum temperature (T_{max}) averaged over Iraq during the period 1980-2015 is displayed in Figure 6. The results reveal that the mean maximum temperature in the south part of Iraq is higher than the other parts of the country.

In winter season, the temperature distribution over Iraq is can be divided into three distinct areas, A small part in the northeast region is below 10^{o}C which consist about only 2%, the other northern region to the west are between 10-15^{o}C which occupy about 22% of the country, and the southern parts and the most of central region to the east are 15-20^{o}C which occupies an area more than 76% of the country as shown in Figure 6a and Table 3.

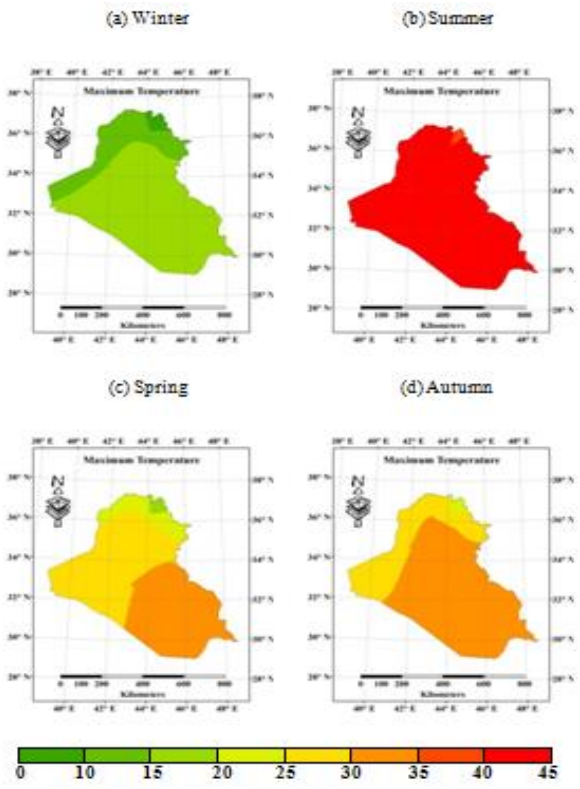

Figure 6: Spatial distribution of seasonal maximum temperature in (^{o}C) over Iraq for the period 1980-2015

The lowest maximum temperature T_{Max} in winter season is 8.8^{o}C and the highest value is (19.8)^{o}C. While in the summer season, generally the temperatures increased all over the country, the lowest temperature observed in a small part the northeastern region of the country which is occupies area less than 1% with temperatures between (35-40)^{o}C, While the other regions that almost 99% of the country are with temperatures more than (40)^{o}C as shown in Figure 6b and table 3. The lowest maximum temperature T_{Max} in summer season is (35.9)^{o}C and the highest Value is (45.5)^{o}C. In spring the study area divided into four distinct areas with the highest maximum temperature observed in the southern region of the country with temperature (30-35)^{o}C which covers about 42% of the country, The western region and rest parts of the central region are (25-30)^{o}C which occupies 47% of the study area, and the north region with temperature between (20-25)^{o}C, with a small part in the northeast with temperature below (20)^{o}C as shown in Figure 6c and table 3. The lowest maximum temperature T_{Max} in spring season is (19.1)^{o}C and the highest value (32.8)^{o}C. During autumn, maximum temperatures are below (25)^{o}C in a small part in the northeastern region of the country, the north and the west regions that consist about 27% of the covered area are with temperatures between (25-30)^{o}C, While the biggest part of the country that occupy about 71% of the study area in the south parts of Iraq up to the central and eastern regions are with temperatures (30-35)^{o}C Figure 6d and table 3. The lowest maximum temperature T_{Max} in autumn season is (23.9)^{o}C and the highest value (35.3)^{o}C.

From Figure7 and table 4 the annual maximum temperature increased all over the country where the temperature distribution over Iraq can be divided into three distinct areas. It can be noticed that the lowest maximum temperature are in the north and the northeast regions with temperatures between (20-25)^{o}C which covers about 5% of the country, the western region and the center up to the rest of the north region of the country with temperatures (25-30)^{o}C which occupies about 46%, and the other 49% of the studied area in the southern region up to the central and east part of the country are with temperatures above (30)^{o}C. The lowest maximum temperature annually is (21.7)^{o}C and the highest value is (33.4)^{o}C.

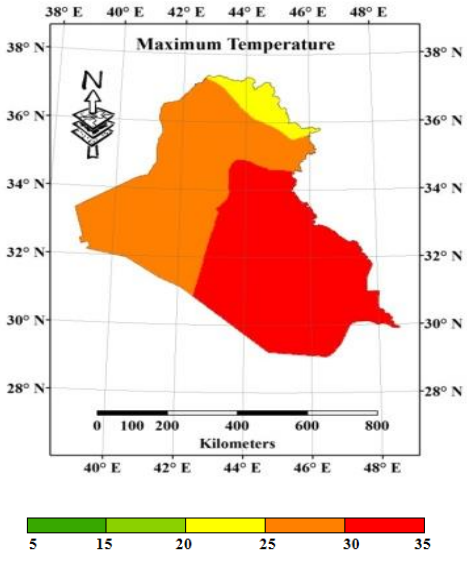

Figure 7: Spatial distribution of annual maximum temperature in (^{o}C) over Iraq for the period 1980-2015

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Table 3: Seasonal T_{max} over Iraq for the period 1980-2015

Winter Maximum Temperature (T_{Max})			
Class Color	Class Number	Area of Class	Class Percent
	1	8,982 Km^2	2.06%
	2	97,450 Km^2	22.40%
	3	328,620 Km^2	75.54%
		Sum = 435,052 Km^2	100%
Summer Maximum Temperature (T_{Max})			
Class Color	Class Number	Area of Class	Class Percent
	7	3,390 Km^2	0.78%
	8	431,662 Km^2	99.22%
		Sum = 435,052 Km^2	100%
Spring Maximum Temperature (T_{Max})			
Class Color	Class Number	Area of Class	Class Percent
	3	6,529 Km^2	1.5%
	4	41,545 Km^2	9.55%
	5	205,159 Km^2	47.16%
	6	181,819 Km^2	41.79%
		Sum = 435,052 Km^2	100%
Autumn Maximum Temperature (T_{Max})			
Class Color	Class Number	Area of Class	Class Percent
	4	7,955 Km^2	1.82%
	5	118,884 Km^2	27.33%
	6	308,213 Km^2	70.85%
		Sum = 435,052 Km^2	100%

Class Color								
Class Number	1	2	3	4	5	6	7	8
Temperature in ^oC	0-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45

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

Annual Maximum Temperature (T_{Max})			
Class Color	Class Number	Area of Class	Class Percent
	3	22,485 Km^2	5.17%
	4	198,231 Km^2	45.56%
	5	214,336 Km^2	49.27%
		Sum = 435,052 Km^2	100%

Class Color					
Class Number	1	2	3	4	5
Temperature In ^oC	5-15	15-20	20-25	25-30	30-35

Conclusions

This study investigated the seasonal and annual variability on maximum temperature in Iraq. The results show that trends of maximum temperature for annual series, the trends in various regions are increased in northern and southern Iraq. The trend of increasing maximum temperature was about (1.75^{o}C/year). In winter season, the increasing trend of maximum temperature was (2.1^{o}C/year) in northern of Iraq while it was about (1.75^{o}C/year) in southern Iraq. The increasing trend of autumn maximum temperature was the same value in northern and southern parts of Iraq. In spring the rising trend of maximum temperature was concentrated in the southern (3.15^{o}C/year). The highest value of increasing trend of maximum temperature was in southern region of Iraq during the summer with value (3.9^{o}C/year).The results of the spatial analysis of maximum temperature show that the maximum 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.

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