Temperature variability as an indicator of climatic change in Erbil Province / Iraqi Kurdistan Region

Zahir A. Amin
College of Agriculture / University of Salahaddin / Erbil

Abstract

Climatic change is dedicated to the totality of the problem of climatic variability and change – its descriptions, causes, implications and interactions among these. Water resources, agricultural production and natural ecosystems are highly influenced by climatic changes, the current study was conducted to achieve this goal, trend analysis of monthly air temperature was performed. The data were obtained from 8 meteorological stations distributed over Erbil province for the period of 2002 -2011. Mann-Kandell and Sen's slope estimators were used to detect trends in monthly air temperature. The results indicated that temperature trends were mainly positive and most of them were insignificant at 95% level of significance. The number of months with decreasing trends tended to increase with an increase in altitude. Significant trends occurred at a few months. Among the winter and summer months, December and June offered more rapid trends respectively.

Key Words: Air temperature trends, Non-parametric tests, climate change, Erbil Province

Introduction

Air temperature is one of the principal parameters affecting evapotranspiration (Allen et al., 1998). Zhou et al., (2010) reported that climate change affects not only water resources but water demand for irrigation. Concurrence of scientific evidence shows that climate change has begun to manifest itself, globally, in the form of increased downpours and storms, rising temperature and sea level, retreating glaciers, etc (Mishra et al., 2013). Nowadays, study of long-term temperature variability has been a topic of particular attention for climate researchers as temperature affects straightway human activities in all domains (Safari, 2012). Increase in anthropogenic greenhouse gases concentrations in the atomsphere mainly due to human activities such as deforestation and burning fossil fuel and the conversion of the earth's land to urban uses driven largely by the rapid growth of the earth's human population are one of the main causes of warming of the climate system and of the process of climate change in several regions of the planet (Parker and Alexander, 2002). Temperature, one of the most important components of climatic parameter, has been widely measured as a starting point towards the apprehension of climate changes courses (Mishra et al., 2013). Duhan et al. (2012) pointed out that temperature is the second most important meteorological variable after precipitation because it can be related to solar radiation and thus with both evaporation and transpiration processes which constitute an important phase of the hydrologic cycle. The global mean air temperature has risen 0.74 ^{o}C over hundred years 1906 – 2005, the linear gradient in the 50 years is 0.13 /10

Date of research received 25/1/2015 and accepted 28/4/2015

a (IPCC, 2007). Some other studies have been done on regional scale and have indicated that significant trends in observed temperatures have occurred during the second half of the 20th century and the increasing has persisted, among others in Europe, in North America, in Arab countries, in Africa (Safari, 2012). It was also found that minimum temperature increased at higher rates (0.42 ^{o}C) followed by the mean (0.36 ^{o}C) and the maximum (0.32 ^{o}C) at Madhya Pradesh (MP) in central India. Changes in maximum and minimum temperatures provide more information than the mean alone (Braganza et al., 2004). This is because trends in mean surface temperature can be due to either maximum or minimum temperature or relative changes in both. The rise in global temperatures is attributed partly due to daily minimum temperature increasing at a faster rate than the daily maximum for many parts of the world. But the changes in the temperature patterns are different for different regions with the maximum and minimum temperatures have increased at similar rates in alpine regions of Europe (Thomas, et al., 2013). Maximum temperature remaining constant and the minimum temperatures increasing at a faster rate in U.S, whereas Kundzewicz et al., (2007) revealed that temperature fluctuation and its variability play a major role in management and planning of the environment, climate prediction and drought and flood management. On the other hand, Reza et al., (20ll) disclosed that studies related to rainfall and temperature are necessary for local and regional programming of water resources sections and help governors for selecting optimum strategies related to water management. Ghahreman (2006) used T-test method for trend detection of mean annual temperature in 34 stations of Iran and found that 50% of the stations showed positive trend, while 41% of the stations had negative trend. Chen et al., (2010) have measured climate change in terms of annual mean air temperature changes using methods linear regression analysis, multinomial fitting, empirical orthogonal function, rotated empirical orthogonal function, Mann-Kendall, Glide T- Examination, wavelet analysis and power spectrum analysis. Their results showed that the warming rate of the annual mean temperature in China northwest arid and semi-arid area was 0.35 ^{o}C /10 a during the 1961-2006 study period. It is apparent from the cited literatures that air temperature is a key factor for developing water resources programming. Accordingly the current study was conducted.

2. METHODOLGY

2.1. Data Collection

The database for the current study encompassed the time series of daily near surface daily maximum and minimum air temperatures for a period ranging from 1990 to 2011. They were obtained from 8 synoptic stations over Erbil Province (Table 1). Although daily temperature data are available before the indicated date, there are many unreliable and missing data before 1990 in most of the stations. Thus, this study focused on the 10-year period 2002-2011. The region is located between 35.77 and 36.65 North Latitude and 43.58 and 44.62 East Longitude with an area of 86.000 km^2.

Table (1): Some Selective information of the metereological stations included in the current study

stations		Geographical Coordinates			Length of recorded period (yrs)
ID	Name	Latitude (Degree)	Longitude (Degree)	Altitude (m)	
1	Erbil	36.2	44.03	420	10
2	Ankawa	36.22	44.02	434	10
3	Salahaddin	36.38	44.22	1087	10
4	Shaqlawa	36.4	44.32	975	10
5	Koya	36.08	44.62	610	10
6	Soran	36.65	44.53	680	11
7	Khabat	36.27	43.65	252	11
8	Makhmur	35.77	43.58	270	9

It is bordered on the north by Turkey and Iran, on the east by Iran, on the west by Syria and on the south by Central Iraq. It is characterized by having semiarid climate and the annual rainfall ranges from a minimum of about 250 mm at the southern parts to more than 1000 mm near the Iraqi Iranian and Iraqi Turkish borders. It is cold and rainy in winter, but hot and dry in summer. Fig.1 shows the geographical locations of the existing station over the region under study.

2.2. Data Processing

The obtained data were processed and reduced to monthly values for further analysis. The data were analyzed for temporal trends and spatial variations during the period 2002–2011. The indicated period was considered as a reference, because the data on air temperature were concurrently available at the stations. The data were considered homogeneous with a few missing data. Interpolation procedure was followed for adjusting missing data, short-cut Barlett test was applied to examine the data homogeneity. Mann-Kendall test as a non parametric method and Sen's slope estimator were used to detect trends in monthly air temperature.

3. Results and Discussion

Fig.2. displays the time series of monthly air temperature from 2002 to 2011 for the investigated stations over the study regions. It can be observed that the air temperature cycle repeats itself over the study period with minor changes. The months of January and July offered the lowest and highest air temperatures respectively. The minimum monthly air temperature hardly drops below 6 ^{o}C at Erbil, Koya, Khabat, Ankawa and Makhmur. On the other hand this parameter drops below 4^{o}C at Salahaddin, Shaqlawa and Soran over most of the recorded periods. Apart from this, the maximum air temperature may exceed 34 ^{o}C at the stations over the southern part of the region. In contrast, the maximum air temperature does not exceed 34 ^{o}C at the stations within the mountainous area, particularly, at Salahaddin, Shaqlawa and Soran. This implies that monthly air temperature at a given month tends to decrease with an increase in altitude or there is a decreasing trend in air temperature as one moves from the southern part in northward direction. Additionally, the minimum and maximum monthly air temperature showed an upward tendency, particularly at the stations of Erbil, Koya,

Khabat, Ankawa and Makhmur. Some stations such as Salahaddin, Shaqlawa and Soran exhibited no obvious trends.

Based on the station wise air temperature time series, it was concluded that the coldest and hottest zones of study region in the period 2002 to 2011 were Salahaddin and Ankawa respectively.

To test trends, twelve time series were analyzed with Mann-Kendall test at each station and the results are summarized in Table 2. It is noteworthy to mention that initially, the autocorrelation was performed to all time series data for checking randomness ascertained by computing autocorrelations for data values at varying time-lags. As all the lag-1 serial correlation coefficients were statistically not significant, there was no need to prewhite that data and the statistical test described above was applied to the original time series.

As can be seen from Table 2 that air temperature has a mixture of increasing and decreasing trends. The majority of the months in most of the stations exhibited positive Z-statistic. This increase in temperature is associated with greenhouse gases emitted due to increased human activities (Tett et al., 1999). But the trend test revealed that most of the series were statistically insignificant at 5% level of significance. A positive value of Z indicates an upward trend, while a negative value of Z indicates a downward trend. The number of time series (months) with down trend tends to increase with an increase in altitude, i.e., with an increase in distance from the south to the north. For instance at Erbil, only October has a down trend and Ankawa exhibited no down trend. Similarly, the results of regression analysis as a parametric test revealed that the increase in air temperature is more profound over the lower part of the Greater Zab River catchment compared to its middle and lower parts (Anwar, 2013). Unlike Erbil and Ankawa stations, most of the remaining stations offered both up and down trends. Contrarily, at each of Shaqlawa and Soran 5 and 6 months showed down trends respectively.

Among the winter months, only December offered a significantly increasing trend (95% level of significance) at Erbil, Salahaddin, Shaqlawa and Koya. Meanwhile, the increasing trend for this month was significant at about 90% level of significance at Ankawa and Soran. The results also indicated that among the summer months only June offered a significantly increasing trend at Erbil, Ankawa, Koya and Khabat. In contrast, the time series of this month is characterized by having a down trend at Soran station. Furthermore, it can be noticed from Table 2 that all the summer months offered significantly increasing trends at Ankawa and Koya stations. However, as mentioned earlier the overall result indicates that most of the parts of the area under study experienced an increase in monthly air temperature during the study time span. Likewise, Rahemzada et al., (2003) studied the climate change in Iran using mean air temperature of some selected synoptic stations and revealed that the climate of almost all the studied station had increased.

Sen's estimator of slope was also employed to figure out the change per unit time of the temperature series (Fig.3). It is clear from Fig. 3 that the change in monthly air temperature per year ranges from as low as -0.22 $^{o}C\ yr^{-1}$ in May at

Makhmoor station to as high as 0.44 $^{o}C\ yr^{-1}$ in December at Koya station and the warming or cooling rates for the remaining months in the study stations fell between these two extremes. With two exceptions, it was also elucidated that the warming rate in December was superior to those in the remaining months in most of the study stations.

Eventually, it can be inferred from the above results that among the stations, Makhmur and Ankawa experienced the lowest and highest rate of temperature change respectively over the period from 2002 to 2012.

Conclusions

It can be concluded from the above study that most of stations offered a mixture of up and down trends. The number of months with decreasing trends tended to increase with an increase in altitude. Among the months of the year, December exhibited the highest trend magnitude.

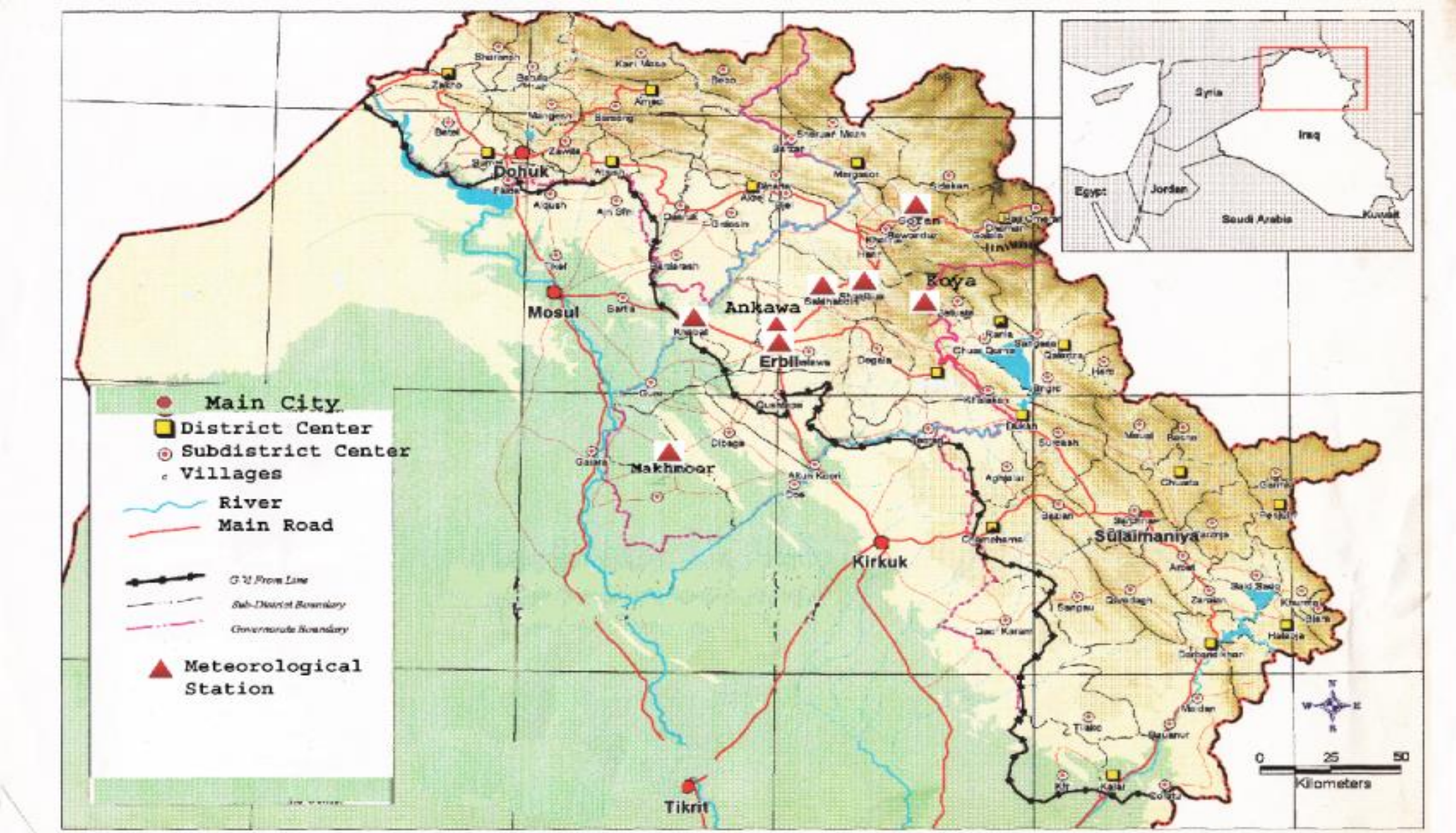


Fig.1. Location map showing the distribution of the meteorological stations over Erbil Province

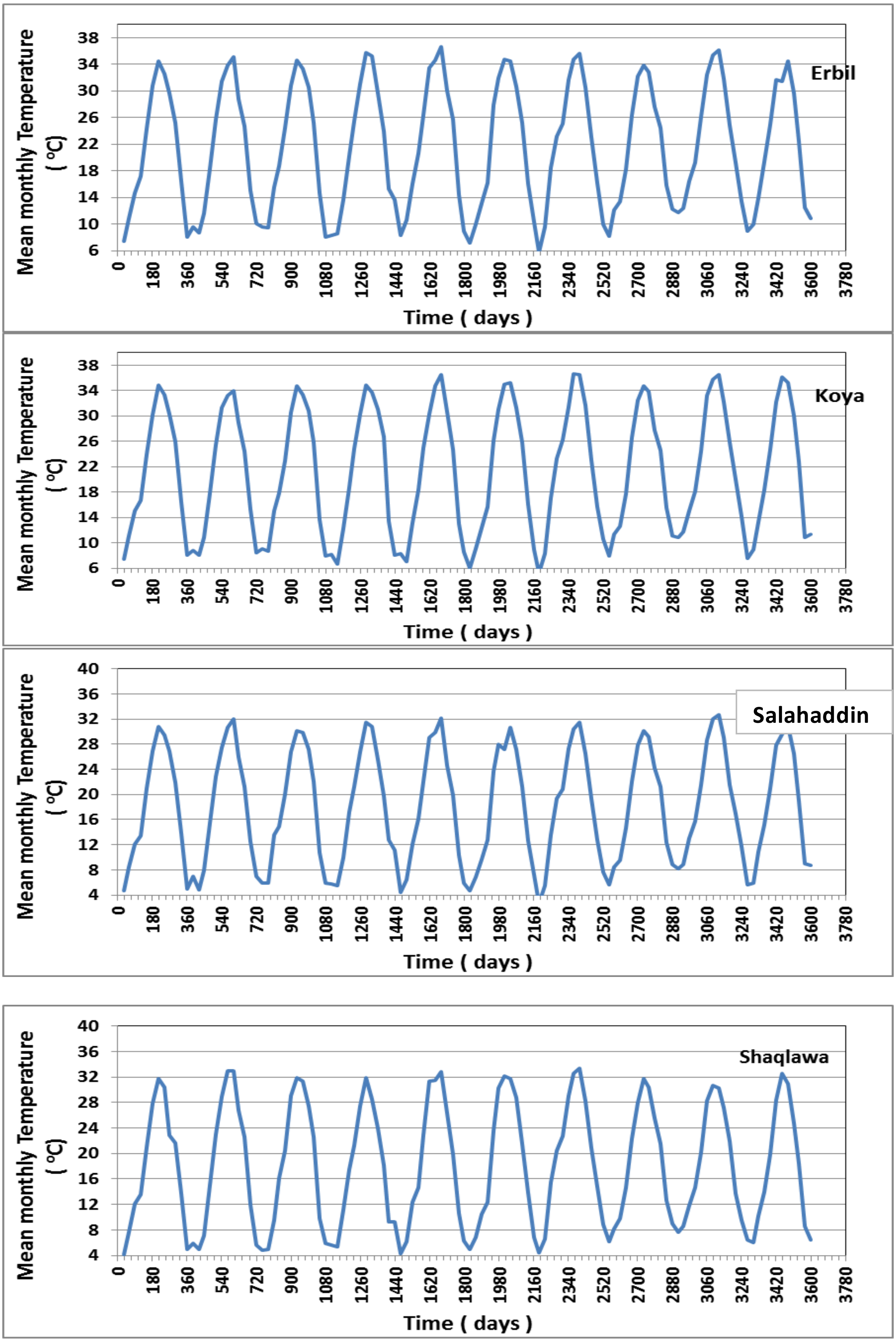


Fig. 2. Time series of mean monthly air temperature recorded at the existing stations over the period form 2002 to 2011.

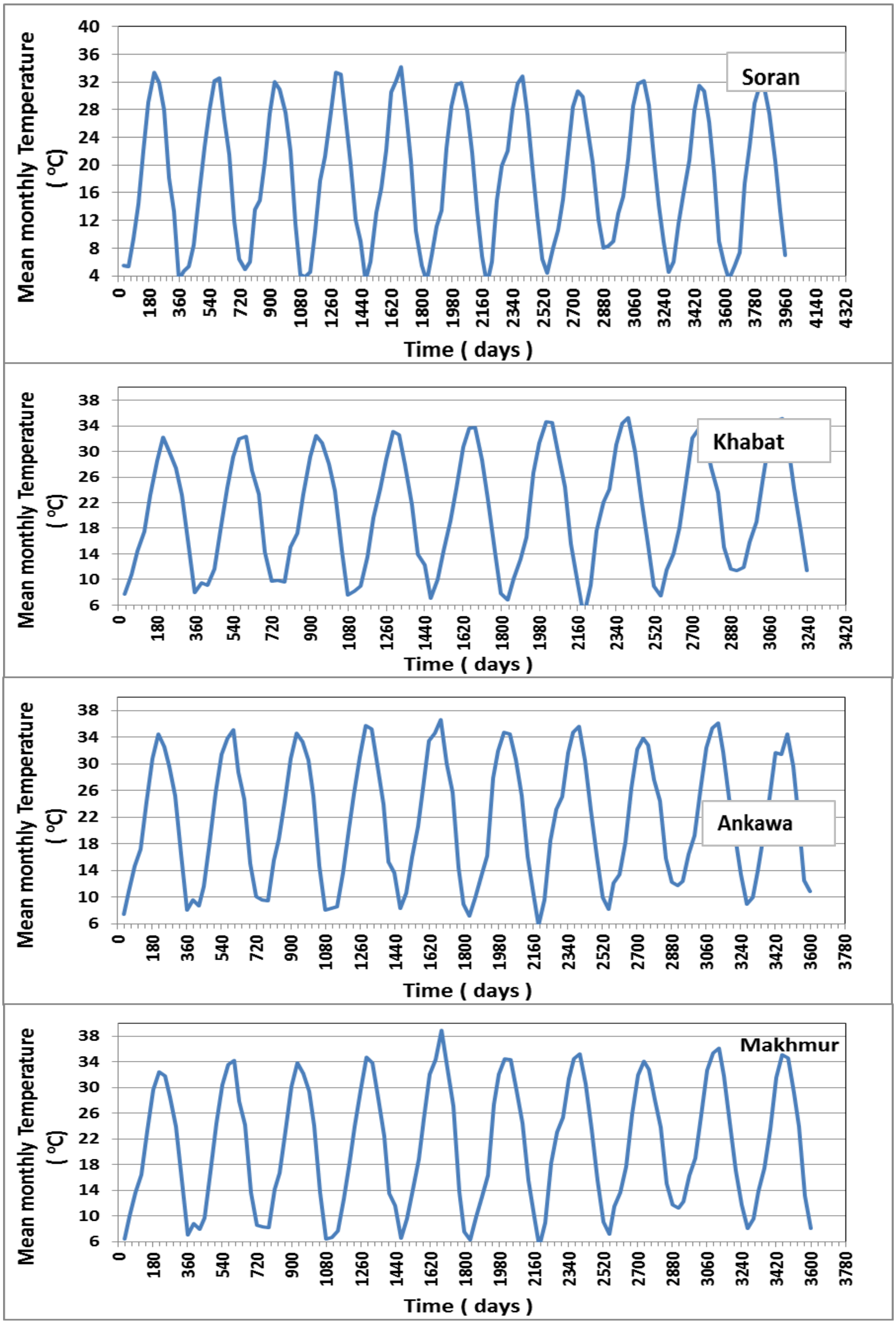


Fig.2. Continued

Table (2): Monthly temperature trend in Iraqi Kurdistan Region Using Mann_Kendall test

Station	Geographical Coordinates			Month	Length of recorded period(yr)	Z- value	Probabilty	Trend at 95% level of significancy
	Latitude (N)	Longitude (E)	Altitude (m)					
Erbil	36º 12 ´	44º 02 ´	420	Jan.	10	0.000	0.499	No trend
				Feb.		1.163	0.122	No trend
				Mar.		0.716	0.237	No trend
				Apr.		1.073	0.142	No trend
				May.		0.805	0.210	No trend
				Jun.		1.789	0.037	Increasing
				Jul.		0.000	0.499	No trend
				Aug.		0.805	0.210	No trend
				Sep.		0.805	0.210	No trend
				Oct.		-1.342	0.090	No trend
				Nov.		0.000	0.499	No trend
				Dec.		1.610	0.054	No trend
Ankawa	36º 13′	44º 01	434	Jan.	10	0.000	0.499	No trend
				Feb.		1.342	0.09	No trend
				Mar.		1.252	0.105	No trend
				Apr.		1.252	0.105	No trend
				May.		1.521	0.064	No trend
				Jun.		1.699	0.045	Increasing
				Jul.		2.415	0.008	Increasing
				Aug.		1.610	0.054	No trend
				Sep.		0.894	0.186	No trend
				Oct.		0.000	0.499	No trend
				Nov.		0.447	0.327	No trend
				Dec.		1.521	0.064	No trend
Salahaddin	36º 23	44º 13	1087	Jan.	10	-0.268	0.394	No trend
				Feb.		0.984	0.163	No trend
				Mar.		0.000	0.499	No trend
				Apr.		0.358	0.36	No trend
				May.		0.000	0.499	No trend
				Jun.		1.252	0.105	No trend
				Jul.		-0.805	0.21	No trend
				Aug.		0.716	0.237	No trend
				Sep.		-0.089	0.464	No trend
				Oct.		-1.163	0.122	No trend
				Nov.		-0.447	0.327	No trend
				Dec.		2.236	0.013	Increasing

Table 2 Continued

Station	Geographical Coordinates			Month	Length of recorded period(yr)	Z- value	Probabilty	Trend at 95% level of significancy
	Latitude (N)	Longitude (E)	Altitude (m)					
Shaqlawa	36º 24	44º 19	975	Jan.	10	1.789	0.037	Increasing
				Feb.		1.610	0.054	No trend
				Mar.		0.358	0.360	No trend
				Apr.		-0.447	0.327	No trend
				May.		-0.894	0.186	No trend
				Jun.		0.179	0.429	No trend
				Jul.		-0.089	0.464	No trend
				Aug.		-0.268	0.394	No trend
				Sep.		0.358	0.360	No trend
				Oct.		-0.716	0.237	No trend
				Nov.		0.000	0.499	No trend
				Dec.		2.326	0.010	Increasing
Koya	36º 05	44º 37	610	Jan.	10	-0.358	0.36	No trend
				Feb.		1.073	0.142	No trend
				Mar.		0.447	0.327	No trend
				Apr.		0.716	0.237	No trend
				May.		1.073	0.142	No trend
				Jun.		2.415	0.008	Increasing
				Jul.		1.789	0.037	Increasing
				Aug.		1.699	0.045	Increasing
				Sep.		0.894	0.186	No trend
				Oct.		-1.521	0.064	No trend
				Nov.		-0.358	0.36	No trend
				Dec.		3.220	0.001	Increasing
Soran	36º 39	44º 32	680	Jan.	11	-0.779	0.218	No trend
				Feb.		1.323	0.093	No trend
				Mar.		0.156	0.438	No trend
				Apr.		0.934	0.175	No trend
				May.		-0.234	0.407	No trend
				Jun.		0.389	0.349	No trend
				Jul.		-2.803	0.003	Decreasing
				Aug.		-0.856	0.196	No trend
				Sep.		-0.389	0.349	No trend
				Oct.		-0.234	0.407	No trend
				Nov.		0.311	0.378	No trend
				Dec.		1.479	0.069	No trend

Table 2 Continued

Station	Geographical Coordinates			Month	Length of recorded period(yr)	Z- value	Probabilty	Trend at 95% level of significancy
	Latitude (N)	Longitude (E)	Altitude (m)					
Khabat	36º 16	43º 39	252	Jan.	11	-0.623	0.267	No trend
				Feb.		0.000	0.499	No trend
				Mar.		-0.467	0.320	No trend
				Apr.		1.246	0.106	No trend
				May.		1.557	0.059	No trend
				Jun.		2.413	0.008	Increasing
				Jul.		2.569	0.005	Increasing
				Aug.		2.024	0.021	Increasing
				Sep.		2.336	0.009	Increasing
				Oct.		-0.628	0.265	No trend
				Nov.		1.090	0.138	No trend
				Dec.		0.779	0.218	No trend
Makhmur	35º 46́	43º 35	270	Jan.	9	0.313	0.377	No trend
				Feb.		1.147	0.126	No trend
				Mar.		0.730	0.233	No trend
				Apr.		0.000	0.499	No trend
				May.		-1.043	0.148	No trend
				Jun.		0.000	0.499	No trend
				Jul.		0.521	0.301	No trend
				Aug.		-0.313	0.377	No trend
				Sep.		0.417	0.338	No trend
				Oct.		-0.938	0.174	No trend
				Nov.		0.834	0.202	No trend
				Dec.		0.417	0.338	No trend

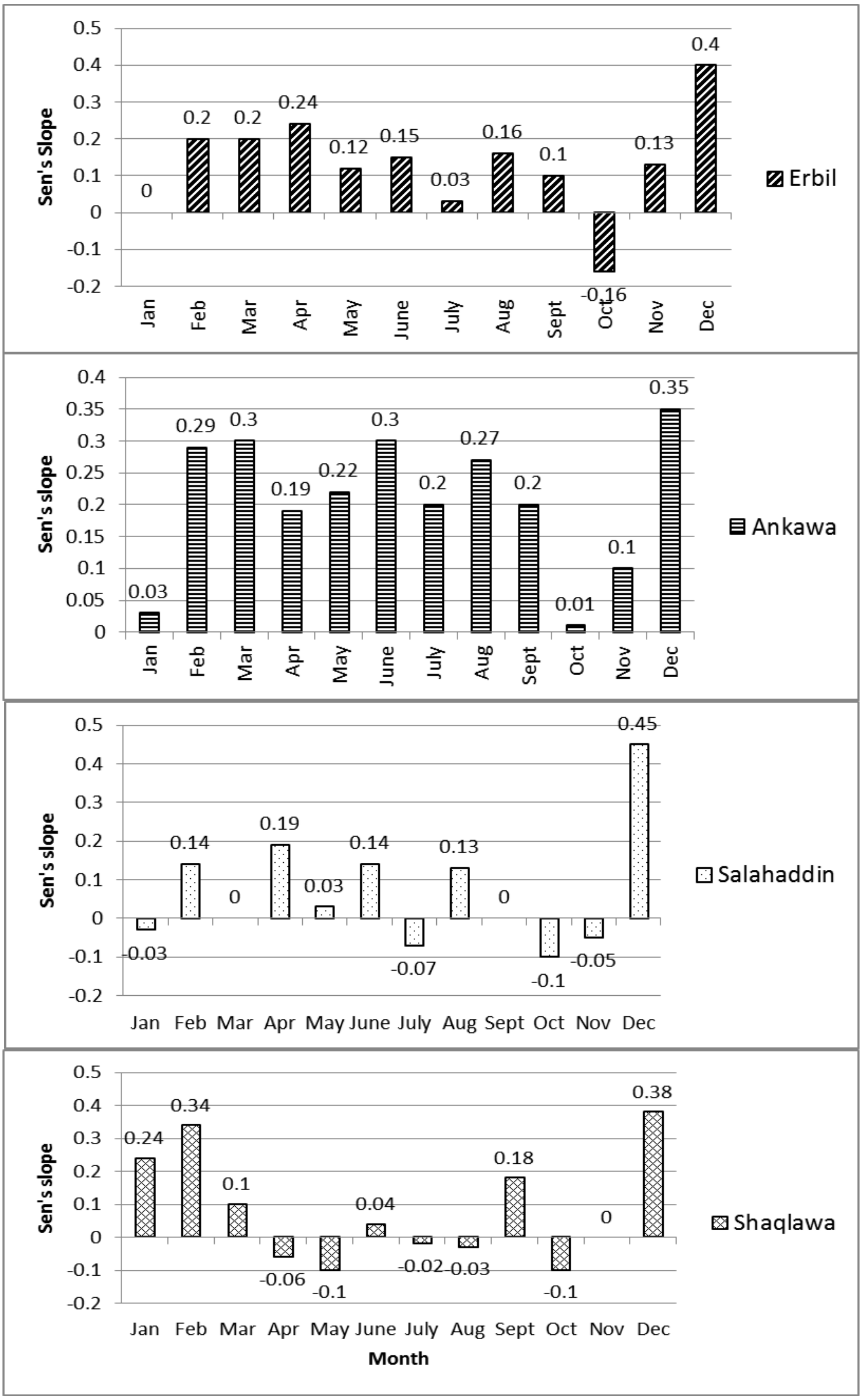
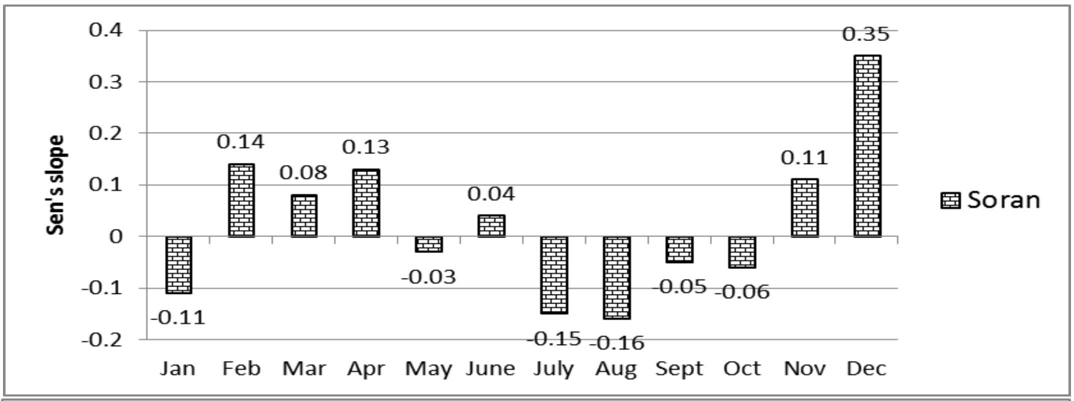
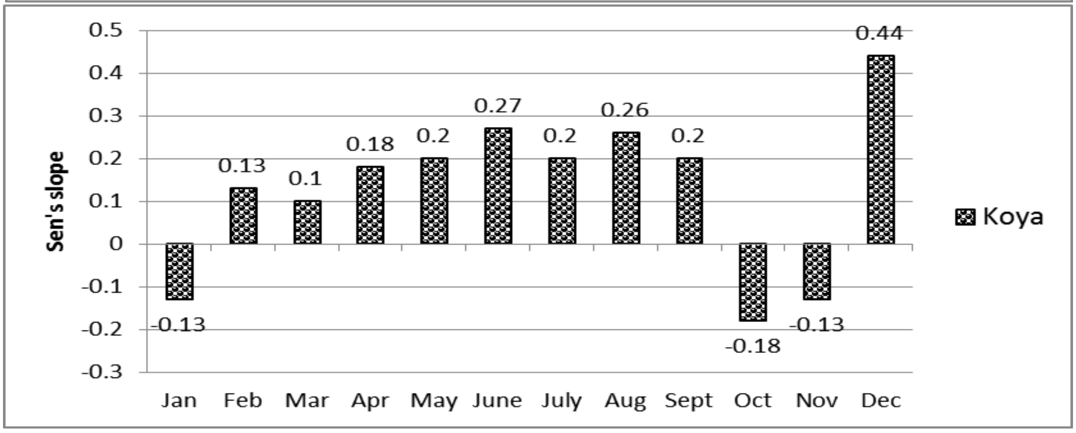
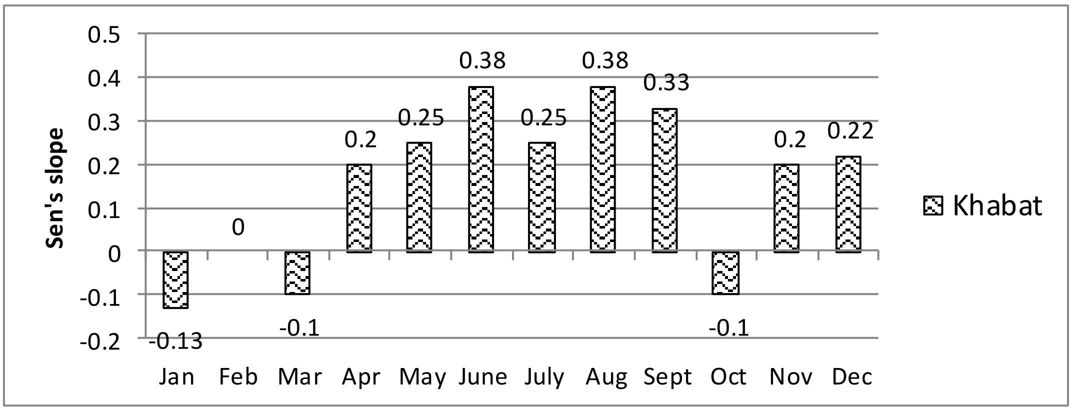
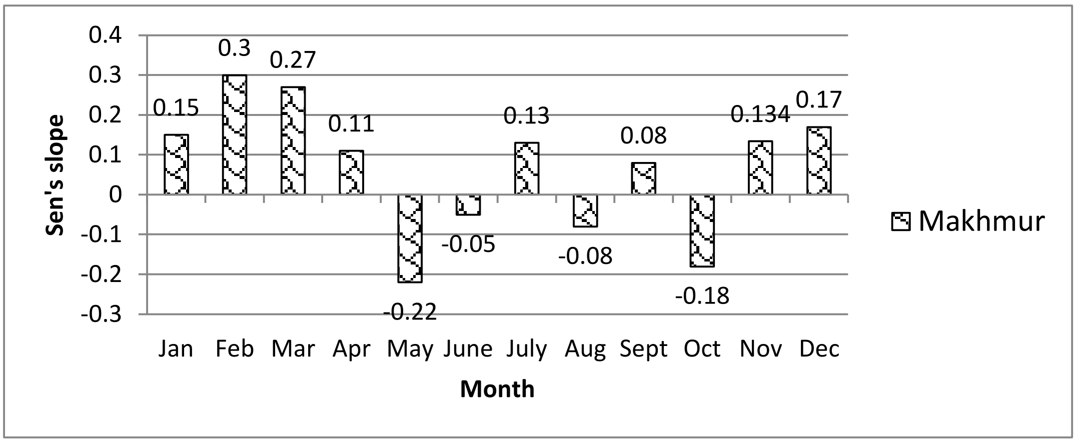


Fig. 3 . Mean monthly temperature trends in Iraqi Kurdistan Region over the10-year period using the Sen’s slope method


Sen's slope
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.11
0.14
0.08
0.13
-0.03
0.04
-0.15
-0.16
-0.05
-0.06
0.11
0.35
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
Soran


Sen's slope
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.13
0.13
0.1
0.18
0.2
0.27
0.2
0.26
0.2
-0.18
-0.13
0.44
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
Koya


Sen's slope
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.13
0
-0.1
0.2
0.25
0.38
0.25
0.38
0.33
-0.1
0.2
0.22
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
Khabat


Sen's slope
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
0.15
0.3
0.27
0.11
-0.22
-0.05
0.13
-0.08
0.08
-0.18
0.134
0.17
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
Month
Makhmur

Reference

1- Allen, R. G., L. S. Pereira, D. Raes and M. Smith. (1998). Crop evapo-transpiration. Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper No. 56, FAO, Rome, Italy, 300pp.

2- Anwar, G.M. (2013). Intensity and impact of drought and a strategic plan for its mitigation in Erbil Province. M.Sc. thesis submitted to the Faculty of Engineering and Applied Sciences, School of Planning, University of Duhok.

3- Braganza, K., D. Karoly and J.M. Arblaster. (2004). Diurnal temperature range as an index of global climate change during the twentieth century. Geophysical Research Letters Vol.31, L13217, doi. 1029/ 2004GL09998.

4- Chen, S., Y Shi, Y Guo and Y.Zheng. (2010). Temporal and spatial variation of annual mean air temperature in arid and semiarid region in northwest China over a recent 46 year period. Journal of Arid Land, Vol. 2, 2: 87 – 97.

5- Duhan, D., Pandey, Ashish, Gahalaut, K.P.S. and R.P. Pandey.2012. Spatial and temporal variability in maximum and minimum and mean air temperatures at Madhey Pradesh in central India. Academie des Science. Published by Elsevier Masson SAS.

6- Ghahreman, B. (2006). Time trend in the mean temperature of Iran. Turk J. Agric. For., 30: 439 -448.

7- IPCC. (2007). Climate change: climate change impacts, adaptation and vulnerability. Working group II contribution to the intergovernmental panel on climate change. Fourth Assessment Report. Summary for policy makers, 23pp.

8- Kundzewicz, z.w., c. Giannakopoulos, M. Schwab, I. Stjernquist, M. Szwed and J. Palutikof. (2007). Impacts of climate extremes on activity sectors-Stakeholder's perspective. Theoretical and Applied Climatology, 93(1-2): 117 – 132.

9- Mishra, N, D.Khare, R. Shukla and L. Singh. (2013). A study of temperature variation in upper Ganga canal command India. Advances in Water Resources, Volume 1, Issue 3: 45-51.

10- Parker, D. E. and L. V. Alexander. (2002). Global and Regional Climate in (2001). Weather, Vol. 57, No. 9, , pp. 328-340.

11- Rahimzada, F.A., A. Nohi and K.K. Asgari. (2003). An Approach to difference between maximum and minimum temperature and the reduction of their change in Iran. The 3rd Regional Conference.

12- Reza, Y. M. K.D. Javad, M. Mohammad and S. Asish. (2010). Trend detection of rainfall and air temperature data in the zayandehrud basin. Journal of Applied Sciences, 11:2125 – 2134.

13- Safari, B. (2012). Trend analysis of the mean annual temperature in Rwanda during the last fifty two years. Journal of Environmental Protection, 3: 538 – 551.

14- Tett, S.F.B., P.A. Scott, M.R. Allen, W.J. Ingram and J.F.B. Mitchell. (1999). Causes of twentieth century temperature change near earth's surface. Nature, 399: 569 :572.

15- Thomas, T. K., P. Sudhee, N.C. Ghosh and S.S. Gunte. (2013). Spatio-temporal variation of temperature characteristics over Narmada basin- is the consistent warming trend and possible climate change signal. 20th International Congress on Modeling and Simulation, Adelaide, Australia, 1- 6 December 2013.

16- Zhou , Y. W. François , Y. Wang and Y. Li. (2010). Impact of climate change on irrigation requirements in terms of groundwater resources. Hydro-geology Journal. 18(7): 1571-1582.

تباين درجات الحرارة كمؤشر للتغيرات المناخية في محافظة اربيل / اقليم كردستان / العراق

ظاهر علي امين
كلية الزراعة / جامعة صلاح الدين

الخلاصة

يكرس تغير المناخ المجموع الكلي لمشاكل التباين المناخي والتغير – اوصافها ، اسبابها، توريطها والتداخل بينها. نظرا للاهمية البالغة لتأثير التغيرات المناخية على الثروات المائية والانتاج الزراعي والانظمة البيئية، اجريتمثل هذه الدراسة، وتم من خلالها التحليل الاتجاهي للمعدلات الشهرية لدرجات الحرارة، ولتحقيق هذا الهدف جمعت البيانات اللازمة من ثمان محطات انواء الجوية موزعة ضمن محافظة اربيل للفترة تراوحت ما بين 2002-2011م. استخدم اختباري Mann-Kandell وميل Sen لتحديد الاتجاهات الحادثة في درجات الحرارة، واشارت النتائج الى كون الاتجاهات موجبة ومعظمها غير معنوية على مستوى 95%. وكذلك بينت النتائج بان عدد الاشهر التي اظهرت اتجاهات سالبة مال الى الازدياد مع ازدياد الارتفاع عن مستوى سطح البحر. ومن بين اشهر الشتاء والصيف، اظهرت شهري كانون الاول وحزيران تغيرات سريعة في درجات الحرارة على التوالي.