المجلد 26 (العدد 1) عام 2013

Ibn Al-Haitham Jour. for Pure & Appl. Sci.

مجلة إبن الهيثم للعلوم الصرفة و التطبيقية

Vol. 26 (1) 2013

The Mann-Kendall Test for Temperature Trends in Some Selected Stations in Iraq

Amani I. Al-Tmimi

Department of Atmospheric Science / College of Science / University of Al-Mustansiriyah

Abstract

In this paper, Mann-Kendall test was used to investigate the existence of possible deterministic and stochastic climatic trends in (Baghdad,Basrah,Mosul,Al-Qaim) stations. The statistical test was applied to annual monthly mean of temperatures for the period (1993-2009). The values of S-statistic were (62, 44, 52, 64) by comparing these values with the table of null probability values for S we get a probability of (0.002, 0.026, 0.010, 0.002) this result is less than α for the 95% confidence level ($\alpha = 0.05$) indicating a significant result at this level of confidence. Concluded that an increasing trend in concentration is present at the 95% confidence level and the variance of the S-statistic is calculated and it is compared to the table of null probability values for Z and our conclusion reject the null, there is an increasing of trend.

Keywords : Mann-Kendall test, mean monthly temperatures, Iraq

المجلد 26 (العدد 1) عام 2013

مجلة إبن الهيثم للعلوم الصرفة و التطبيقية

Ibn Al-Haitham Jour. for Pure & Appl. Sci.

Vol. 26 (1) 2013

Introduction

There is a growing concern about global warming and the impact it will have on people and the ecosystems on which they depend. Temperatures have already risen (1.4°F)since the start of the 20th century with much of this warming occurring in just the last 30 years and temperatures will likely rise at least another (2°F), and possibly more than11°F, over the next 100 years. Global warming refers to an average increase in the earth's temperature, which in turn causes changes in climate. The term "climate change" is often used interchangeably with "global warming." However, given the wide range of impacts beyond temperature variations, the former is generally the preferred in the scientific community because it helps convey that there are other changes in addition to rising temperatures .Climate change refers to the variation in the earth's global climate or in regional climates over time. It describes changes in the variability or average state of the atmosphere over time scales ranging from decades to millions of years. These changes can be caused by processes internal to the Earth, external forces (e.g. variations in sunlight intensity) or, more recently, human activities .In recent usage, especially in the context of environmental policy, the term "climate change" often refers only to changes in modern climate, including the rise in average surface temperature known as global warming. [1]

Various studies have been done in different parts of the world for detecting possible climate trends and changes. Some of these have shown significant trends (Karl et al., 1993) [2]. Studies in climate elements in the Middle East countries are rare. For example, Kadiolgu, 1997 in Turkey
 [3], El-Azraq, 1999 in Egypt [4], though there are serious problems in water resources, agriculture and environment in these countries. This study aims to study the trends in annual series of temperature in Iraq.

Theory

In the following section, the Mann-Kendall rank tests is given and will be applied for detecting possible stochastic and deterministic trends for temperature at (Baghdad,Basrah,Mosul,Al-Qaim)stations .This test is the result of the development of the nonparametric trend test first proposed by Mann (1945). This test was further studied by Kendall (1975) and improved by Hirsch et al (1982, 1984) who allowed taking into account seasonality. The Mann-Kendall test is a non-parametric test for identifying trends in time series data. The test compares the relative magnitudes of sample data rather than the data values themselves (Gilbert, 1987). One benefit of this test is that the data need not conform to any particular distribution. Moreover, data reported as non-detects can be included by assigning them a common value that is smaller than the smallest measured value in the data set. The procedure that will be described in the subsequent paragraphs assumes that there exists only one data value per time period. When multiple data points exist for a single time period, the median value is used. The data values are evaluated as an ordered time series. Each data value is compared to all subsequent data values. The initial value of the Mann-Kendall statistic, *S*, is assumed to be 0(*e.g.*, no trend). If a data value from a later time period is higher than a data value from an earlier time period, *S* is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, *S* is decremented by 1. The net result of all such increments and decrements yields the final value of *S*.[5]

Let x_1 , x_2 , … x_n represent n data points where x_j represents the data Point at time j. Then the Mann-Kendall statistic (*S*) is given by-

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k) \ldots \ldots (1)$$

where

$$sign(x_j - x_k) = 1 \; if \; x_j - x_k > 0$$
$$= 0 \; if \; x_j - x_k = 0 \quad \left.\right\} \; \ldots \ldots (2)$$
$$= -1 \; if \; x_j - x_k < 0$$

A very high positive value of S is an indicator of an increasing trend (upward trend), and a very low negative value indicates a decreasing trend (down ward trend). However, it is necessary to compute the probability associated with S and the sample size n, to statistically quantify the significance of the trend [6] .The test statistic S which has mean zero and variance of S; computed by-

$$Var(S) = \frac{n(n-1)(2n+5)}{18} \ldots \ldots (3)$$

For the cases that n is larger than 10, the standard normal variance of S is computed by using the following equation [7], [8]-

$$Z = \frac{S-1}{\{VAR(S)\}^{\frac{1}{2}}} \; If \; S > o$$
$$Z = 0 \qquad If \; S = 0 \qquad \left.\right\} \ldots \ldots (4)$$
$$Z = \frac{S+1}{\{VAR(S)\}^{\frac{1}{2}}} \; If \; S < o$$

Result and Discussion

   Time series of annual mean temperature at (Baghdad,Basrah,Mosul, Al-Qaim) stations for the period 1993-2009, data were obtained from the Iraqi Meteorological Organization and Seismology [9], The time series plots of annual mean temperature is shown in Fig.(1)for each station. Mann-Kendall nonparametric test results for these data was given in tables (1, 2, 3, 4). S-statistic are (62, 44, 52, 64) for the studied stations respectively and n (16) then compared those values by the table of null probability values for S we get a probability of (0.002, 0.026, 0.010, 0.002) [5]

   If the probability value for the calculated S-statistic and the number of data points (n) is less than the specified significance level for the test (α for one-sided; α/2 for two-sided), the

result is significant at the 1-α confidence level and a trend is present [5] , this result is less than α for the 95% confidence level (α = 0.05) indicating a significant result at this level of confidence. Concluded that an increasing trend in concentration is present at the 95% confidence level. Additional to that the positive values of the test *S*-statistic indicates that there is an increasing trend [10]. By using equations (3) we get-

$$Var(S) = \frac{16(15)(2*16+5)}{18} = 493.3$$

And by using equation (4) to calculate the variance of the *S*-statistic for each station we get-

$$Z = \frac{61}{22.20} = 2.74$$

$$Z = \frac{44}{22.20} = 2.29$$

$$Z = \frac{51}{22.20} = 1.93$$

$$Z = \frac{64}{22.20} = 2.88$$

And it is compared to the table of null probability values for *Z*, then our conclusion reject the null, which means there is a significant trend.

Reference

1. Olofintoye, O. O. and Sule ,B. F. (2010), Impact of Global Warming on the Rainfall and Temperature in the Niger Delta of Nigeria, Journal of Research Information in Civil Engineering, 7(2):33-43.
2. Karl, T. R. and Jones, P. D. and et al, (1993), Asymmetric Trends of Daily Maximum and Minimum Temperature, Bulletin of the American Meteorological Society ,74(6): 1007-1023.
3. Hogan, A. and M. Ferrick, 1997, Winter Morning Air Temperature, Journal of Applied Meteorology, 36(6): 53-68.
4. El- Azraq, M. (1999), Climate Change Over Egypt and its Relevance to Global Change, The Egyptian Meteorological Authority ,1-.7.
5. Wiedemeier, T. H. and etal., (2004),Multiple Lines of Evidence Used to Evaluate Natural Attenuation and Enhanced Remediation of Chlorinated Solvents,1,95

www.thwa.com

6. Khambhammettu, P.(2005), Annual Groundwater Monitoring Report, Appendix Mann-Kendall Analysis for the Fort Ord Site, Rep., California, 1-7.
7. Kahya, E. and Kalayc Serdar, 2004, Trend analysis of stream flow in Turkey, Journal of Hydrology, 289, (1):128-144.
8. Baggelaar ,P. K. and Ir.Eit,.C.J.Van der Meulen, (2007), Trendanalist User Guide, 1-28.
9. Iraqi Meteorological Organization and Seismology, Baghdad. (Unpublished data)

10. Hamdi ,M. R. and et al.(2009), Climate Change in Jordan, American, Journal of Environmental Sciences, 5,(1):58-68.
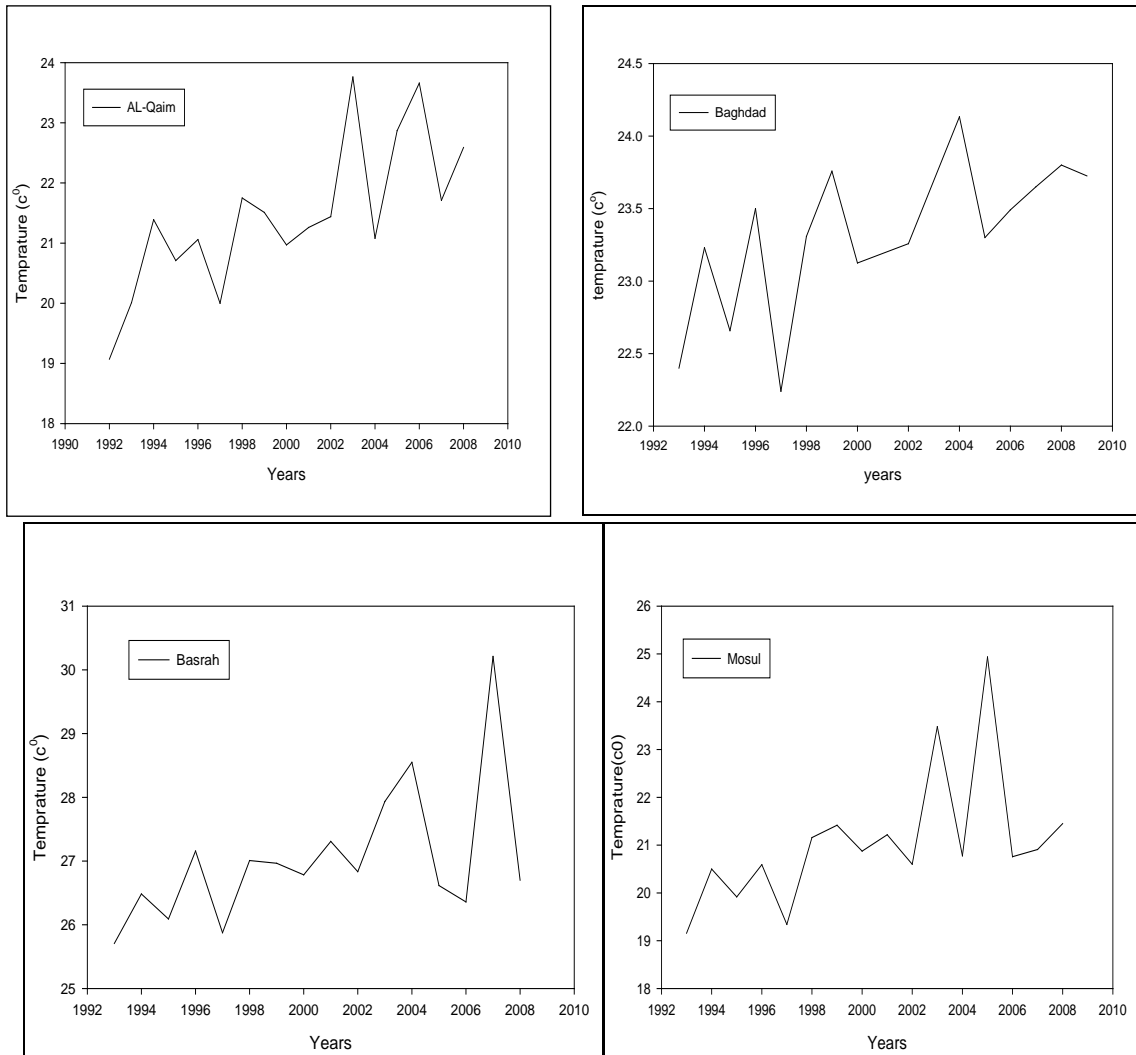
Fig. (1) :Plot of annual mean temperature for (Baghdad, Basrah, Mosul ,AL-Qaim,) stations

Table (1): The Mann–Kendall Statistic for annual mean temperature (1993-2009) Baghdad station

Event1 Temp. 22.40	Event2 Temp. 23.23	Event3 Temp. 22.65	Event4 Temp. 23.50	Event5 Temp. 22.24	Event6 Temp. 23.30	Event7 Temp. 23.75	Event8 Temp. 23.12	Event9 Temp. 23.25	Event10 Temp. 23.13	Event11 Temp. 23.30	Event12 Temp. 23.49	Event13 Temp. 23.49	Event14 Temp. 23.65	Event15 Temp. 23.80	Event16 Temp. 23.72	Sum rows
	+1	+1	+1	-1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	13
		-1	+1	-1	-1	+1	-1	+1	-1	+1	+1	+1	+1	+1	+1	4
			+1	-1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	11
				-1	-1	+1	-1	-1	-1	-1	-1	-1	+1	+1	+1	-4
					+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	11
						+1	-1	-1	-1	0	+1	+1	+1	+1	+1	3
							-1	-1	-1	-1	-1	-1	-1	+1	-1	-7
								+1	+1	+1	+1	+1	+1	+1	+1	8
									-1	+1	+1	+1	+1	+1	+1	5
										+1	+1	+1	+1	+1	+1	6
											+1	+1	+1	+1	+1	5
												0	+1	+1	+1	3
													+1	+1	+1	3
														+1	+1	2
															-1	-1
												Mann-	Kendall	statistic	(total)	62

مجلة إبن الهيثم للعلوم الصرفة و التطبيقية | المجلد 26 (العدد 1) عام 2013

Ibn Al-Haitham Jour. for Pure & Appl. Sci. | Vol. 26 (1) 2013

Table (2) The Mann–Kendall Statistic for annual mean temperature (1993-2009) Basrah statio

Event1 Temp.	Event2 Temp.	Event3 Temp.	Event4 Temp.	Event5 Temp.	Event6 Temp.	Event7 Temp.	Event8 Temp.	Event9 Temp.	Event10 Temp.	Event11 Temp.	Event12 Temp.	Event13 Temp.	Event14 Temp.	Event15 Temp.	Event16 Temp.	Sum rows
25.70	26.48	26.09	27.15	25.87	27.00	26.96	26.78	27.30	26.83	27.53	28.55	26.61	26.35	30.21	26.70	
	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	15
		-1	+1	-1	+1	+1	+1	+1	+1	+1	+1	+1	-1	+1	+1	8
			+1	-1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	11
				-1	-1	-1	-1	+1	-1	+1	+1	-1	-1	+1	-1	-4
					+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	11
						-1	-1	+1	-1	-1	+1	-1	+1	+1	+1	0
							-1	+1	-1	+1	+1	-1	-1	+1	-1	-1
								+1	+1	+1	+1	-1	-1	+1	-1	2
									-1	+1	+1	-1	+1	+1	+1	3
										+1	+1	-1	-1	+1	-1	0
											+1	-1	-1	+1	-1	-1
												-1	-1	+1	-1	-2
													-1	+1	+1	1
														+1	+1	2
		-													-1	-1
												Mann-	Kendall	statistic	(total)	44

Table (3): The Mann–Kendall Statistic for annual mean temperature (1993-2009) Mosul station

Event1 Temp.	Event2 Temp.	Event3 Temp.	Event4 Temp.	Event5 Temp.	Event6 Temp.	Event7 Temp.	Event8 Temp.	Event9 Temp.	Event10 Temp.	Event11 Temp.	Event12 Temp.	Event13 Temp.	Event14 Temp.	Event15 Temp.	Event16 Temp.	Sum rows
19.15	20.50	19.91	20. 59	19.34	21.15	21.41	20.87	21.21	20.60	23.47	20.77	24.93	20.75	20.90	21.45	
	+1	+1	+1	+1	+1	+1	-1	+1	+1	+1	+1	+1	+1	+1	+1	13
		-1	+1	-1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	10
			+1	-1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	11
				-1	+1	+1	+1	+1	-1	+1	+1	-1	+1	+1	+1	6
					+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	11
						+1	-1	-1	-1	+1	-1	+1	-1	-1	+1	-2
							-1	-1	-1	+1	-1	+1	-1	-1	+1	-3
								-1	-1	+1	-1	+1	-1	+1	+1	0
									-1	+1	-1	+1	+1	-1	+1	1
										+1	+1	+1	+1	+1	+1	6
											-1	+1	-1	-1	-1	-3
												+1	-1	+1	+1	2
													-1	-1	-1	-3
														+1	+1	2
															+1	1
												Mann-	Kendall	statistic	(total)	52

Table (4): The Mann–Kendall Statistic for annual mean temperature (1993-2009) Al-Qaim station

Event1 Temp.	Event2 Temp.	Event3 Temp.	Event4 Temp.	Event5 Temp.	Event6 Temp.	Event7 Temp.	Event8 Temp.	Event9 Temp.	Event10 Temp.	Event11 Temp.	Event12 Temp.	Event13 Temp.	Event14 Temp.	Event15 Temp.	Event16 Temp.	Sum rows
19.07	20.01	21.39	20.71	21.06	20.20	21.75	21.51	20.97	21.26	21.44	23.76	21.08	22.87	23.66	21.71	
	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	15
		+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	14
			-1	-1	-1	+1	+1	-1	-1	+1	+1	-1	+1	+1	+1	1
				1+	-1	+1	+1	+1	+1	-1	+1	+1	+1	+1	1+	8
					1-	+1	+1	-1	+1	+1	+1	+1	+1	+1	+1	7
						+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	10
							-1	-1	-1	-1	+1	-1	+1	+1	-1	-3
								-1	-1	-1	+1	-1	+1	+1	+1	0
									+1	+1	+1	+1	+1	+1	+1	7
										+1	+1	-1	+1	+1	+1	4
											+1	-1	+1	+1	+1	3
												-1	-1	-1	-1	-4
													+1	+1	+1	3
														+1	-1	0
															-1	-1
												Mann-	Kendall	statistic	(total)	46

121 | Physics

اختبارمان- كندل لاتجاه درجة الحرارة لبعض المحطات المختارة في العراق

اماني ابراهيم محمد

قسم علوم الجو / كلية العلوم / الجامعة المستنصرية

الخلاصة

تناولت هذه الدراسة اختبار اتجاه المتوسط السنوي الشهري للحرارة في بعض المحطات المختارة في العراق بالاعتماد على البيانات المناخية لاربعة محطات (بغداد،بصرة،موصل ،القائم) بهدف الكشف عن وجود اتجاهات تغايرية في متوسط الحرارة وللفترة الزمنية (1993-2009) عن طريق استخدام اختبار مان ــ كندال حيث كانت نتائج الاختبارللمحطات اعلاه   (62, 44, 52,64)وعلى التوالي وعند مقارنتها بقيم الاحتمالية نحصل على (0.002, 0.026, 0.010,0.002) وهذه النتائج هي اقل من مستوى الثقة %95 وهذا يشير الى وجود اتجاه تزايدي في متوسطات الحرارة.

الكلمات المفتاحية : اختبار- مان كندل،معدل شهري لدرجات الحرارة ،العراق.