Analysis of Relative Humidity in Iraq for the Period 1951-2010

Abdulwahab H. Alobaidi

Department of Electronics, Institute of Technology, Middle Technical University, Baghdad, Iraq

Abstract- The analysis of trends in temperature, precipitation, and relative humidity and evaluating their statistical significance have recently received a great concern for the assessment climate change effects. This research is to analyze a long time record of surface relative humidity for four cities, representing different climate zones, in Iraq using NCEP data. Parametric linear regression and nonparametric Mann–Kendall tests were applied for detecting monthly and annual trends in the relative humidity. The monthly time series showed that relative humidity is decreasing during winter, spring and autumn months. The decreasing trend during summer months is relatively weaker. This because summer in Iraq is hot and dry so changes in relative humidity is small. The annual relative humidity also exhibited a decreasing trend for the four cities. The results also illustrated that the deceasing trend in relative humidity is relatively stronger for Mosul because of it rather cooler climate and relatively smaller for the southern city of Basrah.

Index Terms- Relative humidity, Time series, Mann-Kendall, Iraq

I. Introduction

The climate system of the Earth is ever changing across all space and time scales. Evidence for past changes arises from “proxies” such as ice cores and geological records, and for more recent times from tree rings, coral growth, and historical documentary records. Only over the last two Centuries the atmosphere have been actively measured. Since the late 18th Century, measurements by thermometers and other surface instruments on land have been available along with measurements made by ships. After the Second World War, balloon-based sounding of the free atmosphere began and finally, since the 1970s satellites have also been employed to monitor the climate system. To date, climate data record construction efforts have principally considered temperature and to a lesser extent pressure and precipitation. However, even taken together these are an incomplete diagnostic of the climate system and do not adequately constrain our understanding. Humidity, both relative and absolute, is potentially a very insightful tool for climate research. In addition, humidity has important implications for Climate Impact studies including human heat stress [1].

Analyzing long-term trends in hydroclimatic parameters and assessing their statistical significance are fundamental tools in the detection of climate change [2]. Recently, many scientists with analyzing trends in hydroclimatic parameters attempted to clarify whether or not there is an obvious climate change [3][4][5][6][7]. Compared with the analysis of air temperature and precipitation records, a few studies have been carried out to examine the trends of relative humidity and dew point temperature searching for evidence of climate change. Gaffen and Ross (1999) [8] studied the trends of relative humidity and dew point temperature in the United States for the period 1951–1990. They found that relative humidity trends were weaker than specific humidity trends. van Wijngaarden and Vincent (2003) [9] assessed changes in relative humidity in Canada over the period 1953–2003 and found a substantial decrease in relative humidity throughout the country. Abu-Taleb et al. (2007) [10] examined recent changes in annual and seasonal relative humidity in Jordan. Their analysis showed an increasing trend in the relative humidity time series at different stations which were found to be statistically significant during summer and autumn seasons. Wright et al. (2010) [11] analyzed the zonal mean relative humidity changes in a warmer climate. They found that relative humidity changes near the extratropical tropopause and in the lower troposphere are largely dependent on changes in the distribution and gradients of temperature. Talee et al. (2012) [12] reported on observed changes in relative humidity and dew point temperature in coastal regions of Iran. Their results showed that annual relative humidity increased by 1.03 and 0.28% per decade while annual dew point temperature increased by 0.29 and 0.15°C per decade at the northern and southern regions, respectively. Frimpong et al. (2014) carried out an extensive analyses of trends in mean annual and mean seasonal minimum and maximum temperatures and relative humidity were examined for Bawku East, northern Ghana, for the period 1961 to 2012. They concluded that there declining trends in relative humidity were observed at 6 am and 3 pm at seasonal and annual levels at Binduri and Garu, while there was a rising trend in relative humidity at Manga. The aim of this work is to analyze long term records of relative humidity in Iraq. NCEP data for the period 1951-2010 were used for four stations located in the different climate zones of Iraq.

II. Materials and Method

In this research surface relative humidity data from the National Center for Environmental Prediction (NCEP) were used. Data are available for the period from 1951 to 2010. Relative humidity data for four cities representing different climate zones in Iraq were analyzed. Table I gives the geographical coordinates of these cities.

Table I: The geographical parameters for selected cities

Station	Longitude (^{o}E)	Latitude (^{o}N)	Elevation (m)
Mosul	43.15	36.32	223
Baghdad	33.23	44.23	34
Rutba	33.03	40.28	615
Basra	30.57	47.78	2

Statistical methods were used for trend detection in the relative humidity time series. Linear regression and non–parametric test of Mann–Kendall were employed for trend detection in the time scales of monthly and annual. Linear regression is a parametric test and it assumes that data has normal distribution and it evaluate existence of linear trend between time variable (X) and desire variable (Y). Slope of regression line is calculated by following equation [13]:

$$a = \overline{Y} - b\overline{X} \quad (1)$$

$$b = \frac{\sum_{i=1}^{n}(X_i - \overline{X}) - (Y_i - \overline{Y})}{\sum_{i=1}^{n}(X_i - \overline{X})^2} \quad (2)$$

A single variable statistics of Mann–Kendall is defined for a special time series ($Z_k K=1,2,\ldots,n$) by following relation:

$$T = \sum_{j<i} \operatorname{sgn}(Z_i - Z_j) \quad (3)$$

$$\operatorname{sgn}(x) = \begin{cases} 1, \ldots.\text{if} \ldots.x > 0 \\ 0, \ldots.\text{if} \ldots.x = 0 \\ -1, \ldots\text{if} \ldots x < 0 \end{cases} \quad (4)$$

If there is no any relationship between variables and the series has no trend, thus It would have [2]:

$$E(T) = 0 \quad (5)$$

and

$$Var(T) = n(n-1)(2n+5)/18 \quad (6)$$

Table II gives the degree of correlation and interpretation for the coefficients [14].

Table II: The degree of correlation and interpretation of the test coefficients

Coefficient	Correlation	Interpretation
Less than 0.2	Slight correlation	Almost no relationship
0.2 to 0.4	Low correlation	Small relationship
0.4 to 0.7	Moderate correlation	Substantial relationship
0.7 to 0.9	High correlation	Marked relationship
0.9 and above	Very high correlation	Solid relationship

III. RESULTS AND DISCUSSION

Figures 1 to 4 show the results of the linear regression analysis of the monthly mean surface relative humidity for Mosul, Baghdad, Rutba and Basra. It is seen that in general the relative humidity has a decreasing trends for the four cities during all months of the year. The results also indicate that during the summer months and the month of September trends are relatively small compared with those of the other months. This because summer the driest season in Iraq. Figure 5 illustrates the trend analysis of the annual mean of

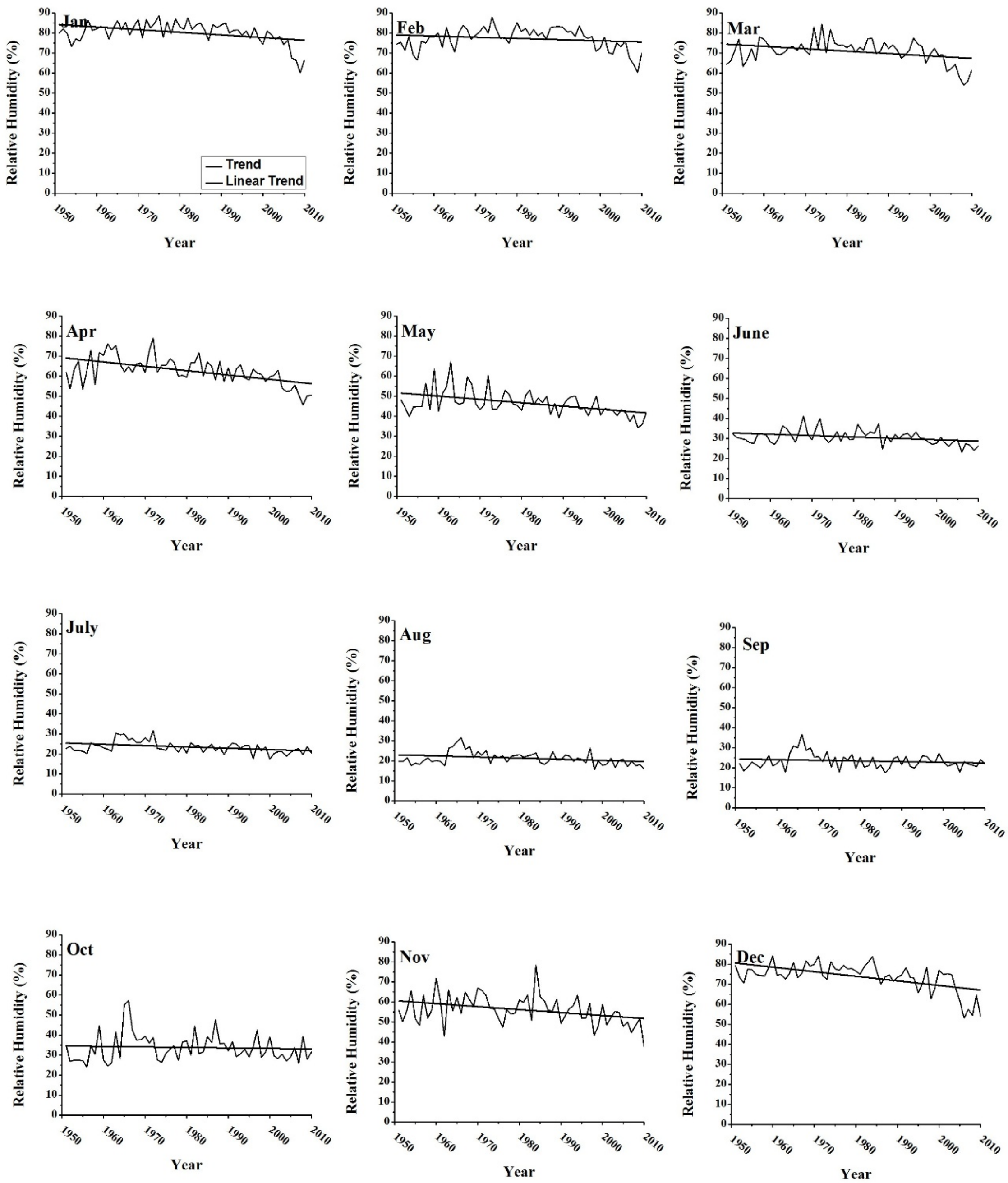

Figure 1: Time series of monthly relative humidity for Mosul city.

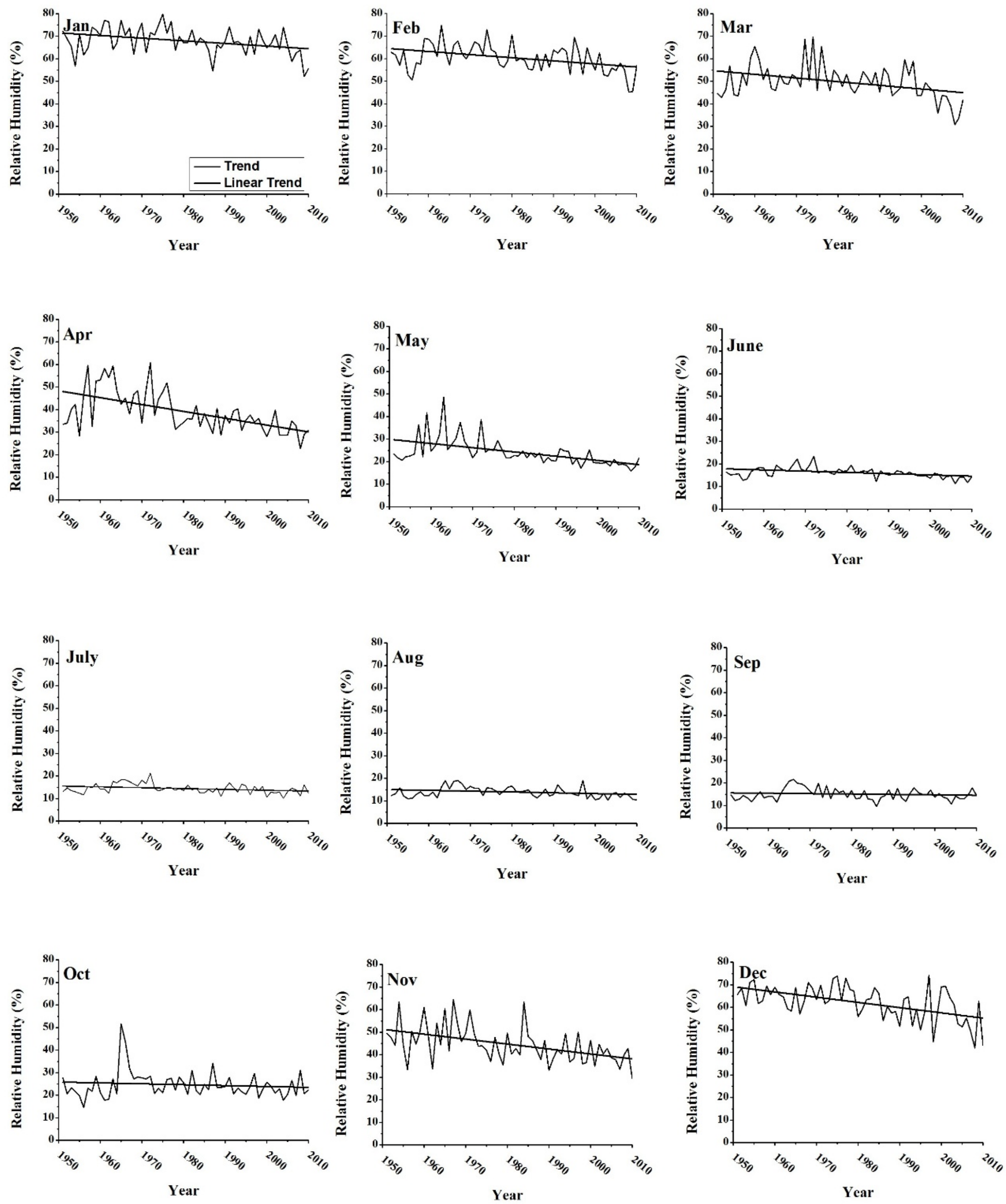

Figure 2: Time series of monthly relative humidity for Baghdad city.

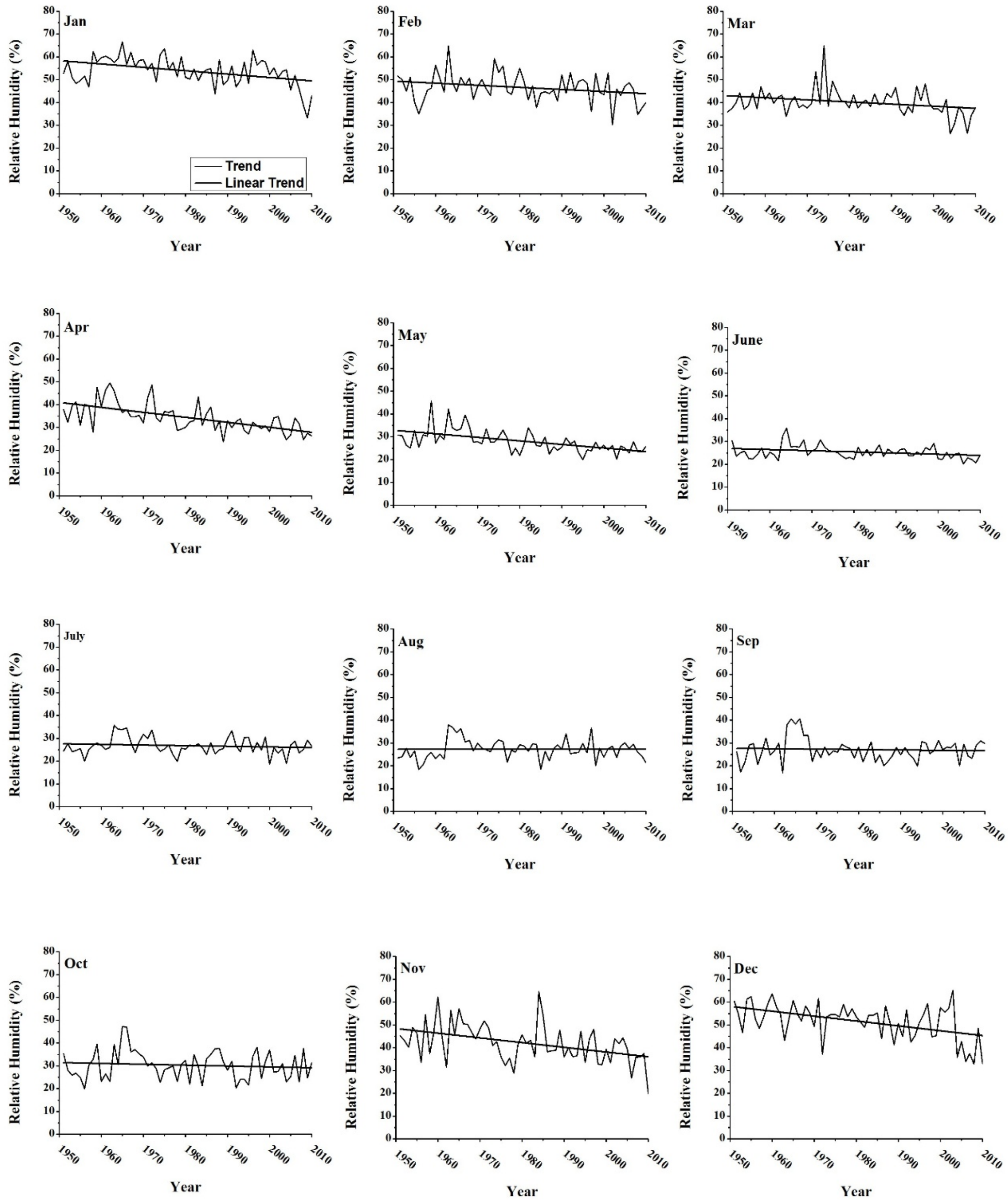

Figure 3: Time series of monthly relative humidity for Rutba city.

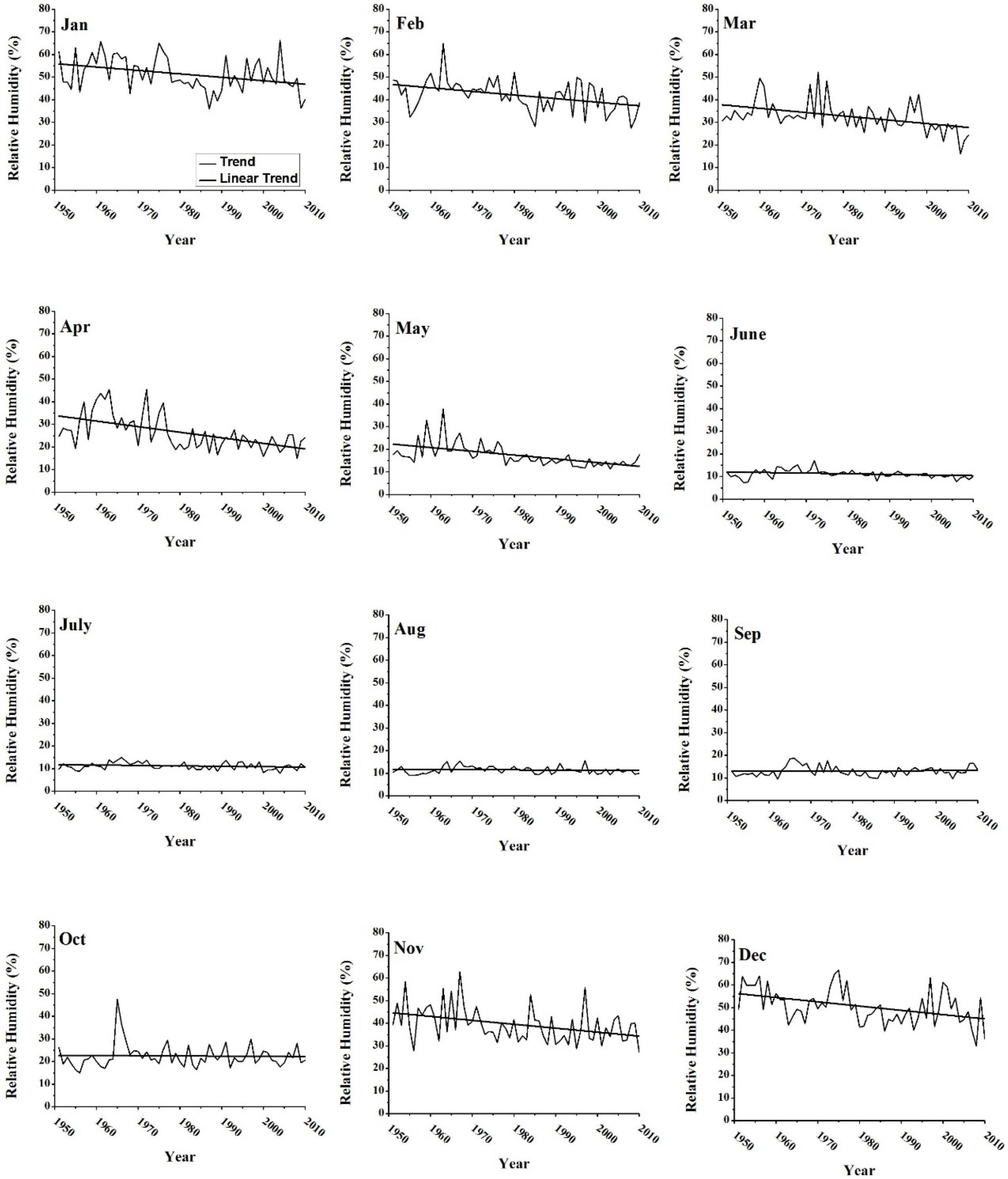

Figure 4: Time series of monthly relative humidity for Basra city.

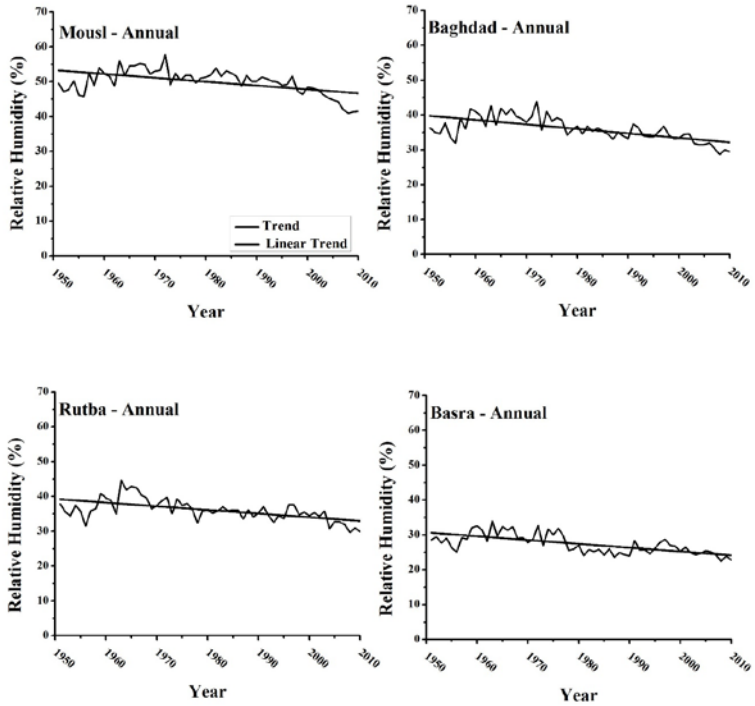

Figure 5: Annual time series of relative humidity for the four cities.

relative humidity for the four cities. It is clear that the annual relative humidity fluctuates around 50% for the northern city of Mosul and around 40% for central city of Baghdad and western city of Rutba, and around 30% for Basrah in the south. The most decreasing in annual relative humidity occurred in Mosul because of its relatively cooler climate. Table 3 summarizes the parameters of the linear regression equation for the four cities. It is seen that for Mosul and Baghdad the slope of the linear equation is negative for all months. For the Rutba, the linear trend is negative for all months except of August. Basra is characterize by negative linear trend for all months except of September and from the table its shown that the Annual linear trend is negative for all locations. Table 4 shows that the values of Mann–Kendall coefficient are comparable. It's evident that Mosul, and Baghdad stations are characterizes by negative trends for all months. Rutba station was characterize by negative trend for most of months except for the months of August and September, the coefficients are positive. Basra station was characterize by negative trend for most of months except for months of September and October, the trend was positive. The values of the correlation coefficients for Mosul, Baghdad and Basra stations are greater than 0.2 in most of months except for months of February, March, September and October for Mosul station, July, September and October for Baghdad station and July, August, September and October for Basra station the correlation coefficients are less than 0.2. This low correlation suggests that there is small significant change in the relative humidity pattern over these regions. The statistical test for Rutba stations shows that the values of the correlation coefficients are less than 0.2 in most of months except for months of April, May, November and December the correlation coefficients are slightly greater than 0.2. This slight correlation suggests that there is no significant change in the relative humidity pattern over this region. The values of the correlation coefficients of Annual for the four cities greater than 0.3. This correlation suggests that there is substantial significant change in the annual relative humidity pattern over these regions.

I. CONCLUSION

Time series of monthly relative humidity were analysed for four cities in Iraq. Results indicated that relative humidity showed a notable decreasing trends during the most months of the year except the summer months. The summer season in Iraq is hot and dry and consequently small change in relative humidity from one year to another is expected. The northern part of Iraq was found to be the most part by the change in relative humidity. It is believed this reduction in relative humidity may be attributed to the global warming.

Table III: Monthly linear equations for selected cities

Station Month	Mosul b	Mosul a	Baghdad b	Baghdad a	Rutba b	Rutba a	Basra b	Basra a
January	-0.13305	343.68887	-0.11734	300.23254	-0.14851	347.8971	-0.15164	351.60672
February	-0.05984	195.65467	-0.13799	333.60205	-0.09163	227.99238	-0.15972	358.26971
March	-0.12126	310.91115	-0.16265	371.82312	-0.09286	224.02851	-0.16955	368.4757
April	-0.21721	492.70174	-0.30415	641.35803	-0.21859	467.16068	-0.24667	514.847
May	-0.16777	378.75565	-0.18751	395.50322	-0.15577	336.56173	-0.16654	347.12104
June	-0.07003	169.29453	-0.05453	124.13693	-0.0511	126.5186	-0.02837	67.30762
July	-0.06642	154.99275	-0.03769	89.08258	-0.02781	81.79037	-0.01855	47.88465
August	-0.05703	134.25854	-0.03634	85.83149	0.00169	23.87473	-0.00946	30.16294
September	-0.03403	90.7669	-0.01792	50.48665	-0.0183	63.30938	0.00606	1.01263
October	-0.02545	84.19389	-0.03931	102.42528	-0.0377	104.88459	-0.00919	40.59931
November	-0.14921	351.60101	-0.21937	479.02634	-0.20689	451.81724	-0.17374	383.4941
December	-0.22912	527.61158	-0.23217	521.8132	-0.21412	475.62199	-0.18886	424.56431
Annual	-0.11087	269.53594	-0.12892	291.27679	-0.10513	244.28811	-0.10969	244.61214

Table IV: Results of Mann–Kendall test for selected cities

Station Month	Mosul	Baghdad	Rutba	Basra
January	-0.2528	-0.2432	-0.2713	-0.2588
February	-0.0696	-0.2645	-0.1675	-0.2812
March	-0.1911	-0.2488	-0.1901	-0.3249
April	-0.4057	-0.4206	-0.4659	-0.3828
May	-0.3359	-0.4724	-0.4109	-0.4848
June	-0.2444	-0.3779	-0.1998	-0.2761
July	-0.2627	-0.1993	-0.0493	-0.1317
August	-0.2073	-0.2045	0.0091	-0.0874
September	-0.0720	-0.0591	0.0040	0.0795
October	-0.0096	-0.0658	-0.0537	0.0357
November	-0.2598	-0.3540	-0.2975	-0.2620
December	-0.3327	-0.3425	-0.2935	-0.2964
Annual	-0.3962	-0.5130	-0.4439	-0.4775

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AUTHORS

First Author – Abdulwahab H. Alobaidi, Department of Electronics, Institute of Technology, Middle Technical University, Baghdad, Iraq

Correspondence Author – Abdulwahab H. Alobaidi, PhD (Atmospheric Sciences), awhalobaidi@gmail.com