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The Study of Climate Change, Using Statistical Analysis Case Study Temperature Variation in Basra

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Abstract : *The impact of climate change on air temperature have different effects within and between countries which has received a great deal of attention by scholars worldwide. Extreme climate events are widely reported in local media. Record of temperature highs in recent years show that five Arab countries including Iraq (Basra, 52.0 °C) were affected and the temperature is expected to reach a new highs. This study aims to assess the impacts of climate change on air temperature and can serve as a resource for researchers to begin to assess climate risks in present and future on the region particularly Basra province.*

A retrospective study was carried out to identify trends in temperature and humidity time series of Hay Al-Hussien weather stations covering a period of 72 years 1941-2013 in province of Basra. Three variables related to temperature, viz. (mean, mean maximum and mean minimum) and humidity variable were considered for analysis on both a monthly and an annual basis. The percentages of significant trends and Regression equations obtained for each parameter over 12 months and were presented annually. Temperature and humidity anomalies are plotted and it is observed that, monthly and annually, temperature have increased. While humidity trends have decreased. Also, strong relationship was determined between temperature and humidity, which was measured by Pearson's Correlation coefficients. The annual mean temperature in Basra Province is expected to increase to (7.6 °C) by 2100.

Keywords: *anomalies, climate change, greenhouse, trend, time series*

1- Introduction

There is no question that increased levels of greenhouse gases must cause the Earth to warm in response. Human activities have increased the atmospheric concentration of greenhouse gases, changing the Earth's climate on both global and regional scales. There is evidence that the recent climate is the result of both natural and anthropogenic forcing. In recent years the potential impacts of climatic change and variability have received a lot of attention from researchers. A comprehensive review of the potential impacts of climatic change is provided in IPCC (1998, 2001). According to IPCC (2001), increases in greenhouse gas concentrations increased the annual mean global temperature by 0.6 ± 0.2°C since the late 19th century. (M. Arora et al,2005). Over the past 100 years, the global average temperature has increased by approximately 0.74 ± 0.18°C (Mean ± s.e.) and is projected to continue to rise at a rapid rate (IPCC 2007). The global mean surface air temperature has risen about 0.5°C during the 20th century

(1). Analysis has shown that this has resulted in part from daily minimum temperature increasing at faster rate or decreasing at a slower rate than maximum, resulting in a decrease in the diurnal temperature range for many parts of the world (*2, 3*) (David R. Esterling. et al, 1997). Climate models are fairly consistent in projecting the continuation of this trend through the 21st century. According to the (IPCC), temperatures are likely to increase by 2°F to 11.5°F, with a best estimate of 3.2°F to 7.2°F, by 2100, relative to 1980–1990 temperatures. (J. A. Welbergen et al, 2008) also modeling results show that average annual temperatures will increase in the future with average annual temperatures projected to reach a high of about 28.7°C in Kuwait during the 2010-2035 period. This represents about a 1.6°C increase over the average annual temperature of the past decades (Kuwait's Initial National).

Increases in temperature is projected to continue to causing changes in the hydrological cycle and impact water resource managers in a variety of ways, including a decrease in water supplies due to increased evapotranspiration, decreased runoff, an increase in urban and agricultural demand. The range of impacts associated with warmer temperatures will alter seasonal water supplies. Warmer freshwater temperatures will also reduce dissolved oxygen levels, promote algal blooms, increase bacteria and fungi content, concentrate pollutants, and cause other adverse impacts on both water quality and habitat viability for fish and other aquatic species. Additionally, Higher temperatures are also likely to lead to a global increase in drought conditions, as less summer rainfall and increased evaporation combine to reduce surface water availability. Analysis of long-term climatic datasets is currently of unprecedented interest to the scientific community.

This study aims to assess the impacts of climate change on air temperature, extreme climate events are widely reported in local media. Record of temperature highs in recent years show that five Arab countries were affected (Kuwait 52.6 °C, south of Iraq Basra 52°C, Saudi Arabia 52°C and Qatar 50°C and Sudan 49.7°C (Report N° 64635 – MNA,2011)) and the temperature is expected to reach a new highs. This is a serious challenge for the government to act appropriately to address climate change issues and take steps to reduce climate change impacts. The study can also serve as a resource for researchers to begin to assess climate risks in present and future on the region particularly Basra province.

2- Study Area:

Basra Province (Fig. a), is located in the southern part of Iraq, on Shatt al-Arab river, between Kuwait and Iran, northwest of Arabian Gulf, lies within longitude (46^{o} 60′ to 48^{o} 60′ E) and from latitude (29^{o} 13′ to 31^{o} 29′ N) with a total area of 19,070 km^{2} and current population (February,2014) around 2 million. The city is situated in a desert-type environmental zone with a monsoon climate; summers are very hot, especially July and August, with a mean temperature of 37.4 °C and a max. temperature of 45 °C. The average potential evapotranspiration exceeds 2,450 mm/year, while average annual rainfall is less than 100 mm/year (Jabbar and Zhou 2011).

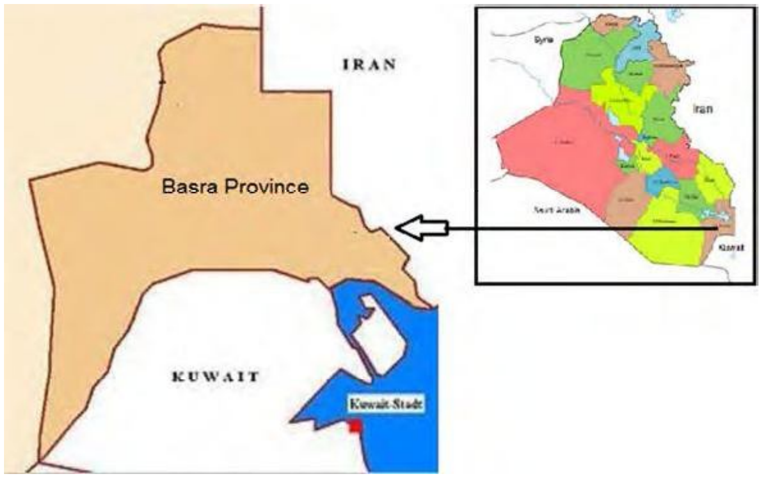

Fig.(a) study aria

3- Methodology and data

3-1 Data Sources

Time series of monthly mean temperature, annual mean (Maximum and Minimum) temperature and annual mean humidity from Hay Al-Hussien weather stations which located on (30^0.28 N – 47^0.47 E) covering a period of 72 years (1941–2013) were analyzed for this study. This data was provided by the Iraqi meteorological Organization and Seismology (IMOS) and NOAA Central Library. The temperature data was in degrees Celsius and humidity as a percentage.

3-2 Missing data correction

The existence of missing data in climate time series can be solved with temporal interpolation, using data of the same time series before and after the data gap, or with spatial interpolation, using data from nearby weather stations (*WMO*, 2011) and adopted a procedure to fill the gaps on monthly mean temperature and humidity.

3-3 Time series and Roughness coefficient

Time series is a set of time views taken in accordance with the natural order. Smoothing is usually done to help us better see patterns in a time series. This generally smooths out the irregular roughness to see a clearer signal. Smoothing doesn't provide us with a model, but it can be a good first step in describing various components of the series. Before we do so, we examine the time series roughness scale by computing the Roughness coefficient RC

$$RC = \frac{\sum_{t=2}^{n}(x_t - x_{t-1})^2}{\sum_{t=2}^{n}(x_t - \bar{x})^2} \ldots\ldots\ldots\ldots (1)$$

x_1 , $x_2, \dots \dots, x_n$ are the views of this series, $\bar{x}$ is the average of time series elements, and n is the number of time series elements.

The lesser the coefficient, the more smooth the data is. If not, we smooth the time series by using a moving average.

3.3- Ordinary least squares

Ordinary least squares is a statistical technique that uses sample data to estimate the true population relationship between two variables.

The following approach has been adopted to perform the analysis,

$$\hat{x}_i = a + bt_i \ (i = 1,2,3 \dots . n)$$

The above equation establishes linear regression between, the time series t_i, and climate variable $\hat{x}_i$ (temperature or humidity) for the specified study time period.

Considering t_i as independent and $\hat{x}_i$ dependent variable, regression coefficient 'b' and the regression constant 'a' of least-squares estimation have been calculated respectively by using the following relations. (Iftikhar Ahmad1, et al)

$$b = \frac{\sum_{i=1}^{n} x_i t_i - \frac{1}{n}(\sum_{i=1}^{n} x_i)(\sum_{i=1}^{n} t_i)}{\sum_{i=1}^{n} t_i^2 - \frac{1}{n}(\sum_{i=1}^{n} t_i)^2} + \cdots$$

$$a = \frac{1}{n}\sum_{i=1}^{n} x_i - \frac{b}{n}\sum_{i=1}^{n} t_i$$

3.4 Determination of anomalies

For better understanding of the observed trends, the temperature and humidity anomalies were computed.

3-5 Pearson's moment correlation coefficient

There are several types of correlation coefficient: Pearson's correlation is a correlation coefficient commonly used in linear regression.

$$r = \frac{n(\sum x_i y_i) - (\sum x_i)(\sum y_i)}{\sqrt{n(\sum x_i^2) - (\sum x_i)^2}\sqrt{n(\sum y_i^2) - (\sum y_i)^2}} \cdots (2)$$

Where i = 1,2,3……n element of the time series, x is annual mean temperature and y is annual mean humidity.

3-6 Coefficient of Determination (R^2)

In statistics, the coefficient of determination, denoted R^2, indicates how well data points fit a line or curve.

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4- Results : First, we examined the time series whether it was rough or smooth, Roughness coefficients were computed by using equation (1). Table (1) shows the results, all values in the table are small so that the time series is smooth and it is not necessary to smooth it.

Table (1) Roughness coefficient for monthly and annual mean for temperature, max. temperature, min. temperature and humidity time series

Roughness coefficient for period 1941 to 2013															
January	February	March	April	May	June	July	August	September	October	November	December	Men annual temperature	Mean annual humidity	Mean annual max.	Mean annual min.
1.8	1.7	2.1	1.0	0.5	0.3	0.3	0.4	0.6	1.1	2.1	2.3	0.4	0.1 4	0.5	0.7

4.1. Temperature

Annual mean temperature for each month of the year, annual mean (max. and min.) temperature and annual mean humidity time series have been plotted by using MS Excel, and the linear trends observed were represented graphically for Hay Al-Hussien stations with respect to their mean of 72 years (1941–2013). Figures (1-6) have been selected from 12, which represent annual change of the mean temperature for the months (January1941-2013, March 1941-2013, May 1941-2013, July1941-2013, September1941-2013, November 1941-2013) and Figures (7,8,9) represent annual mean temperature, annual mean maximum and mean minimum temperature, and annual mean humidity respectively for the period 1941-2013. The regression equations and the coefficient of determination (R^2) which have been determined by ordinary least squares method have been placed in Table (2).

Annual change of the mean temperature for the month of (January, March, May, July, September, November) time series (1941-2013) in blue color and linear trend in black color for each month

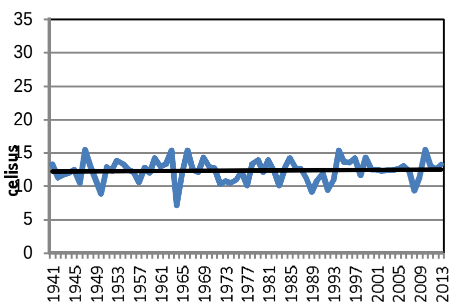


Fig. (1) January

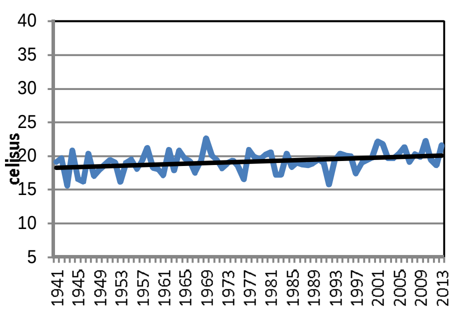


Fig. (2) March

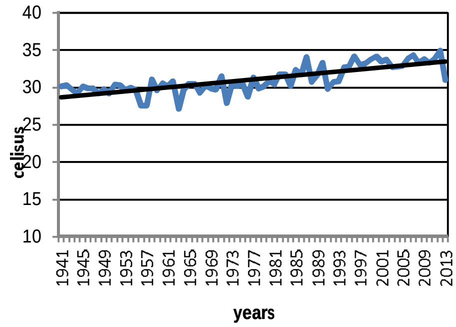


Fig. (3) May

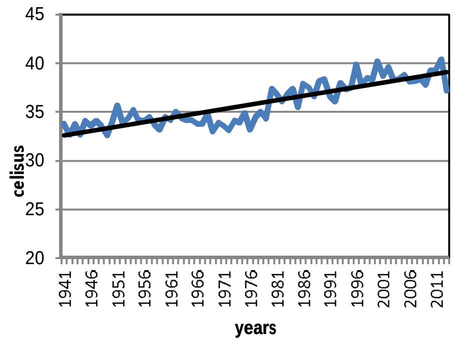


Fig. (4) July

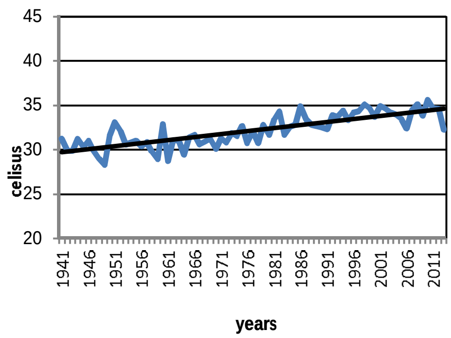


Fig. (5) September

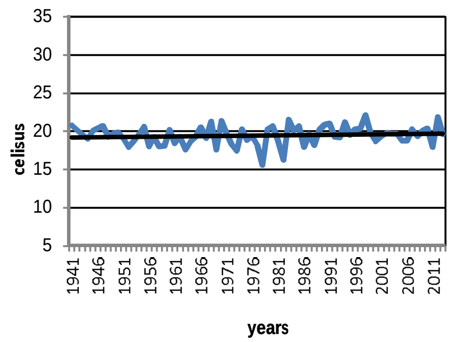


Fig. (6) November

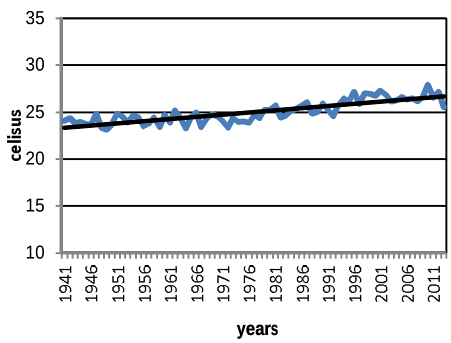


Fig. (7) Annual mean temperature time series in blue color and linear trend in black color for the period (1941-2013)

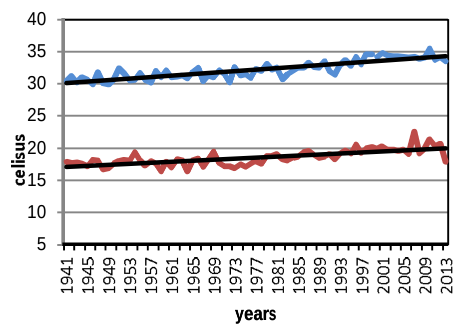
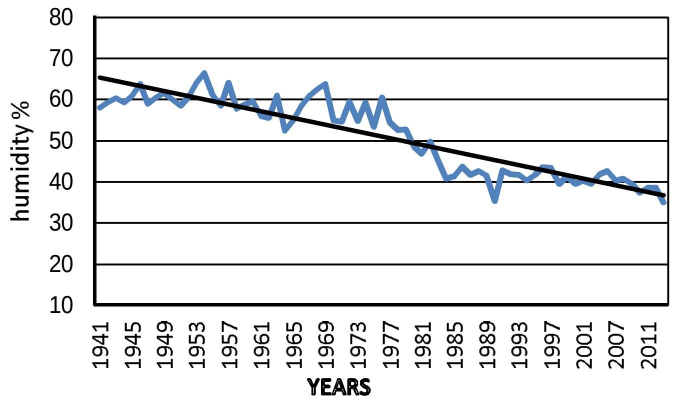


Fig. (8) Annual mean max. temperature in blue color, annual mean min. temperature in red color and linear trend in black color for the period (1941-2013)



Fig(9) Annual mean humidity time series in blue color and linear trend in black color for the period (1941-213).

Table(2) show the regression equation and coefficient of determination

Months and annual	Formula number	formula	Coefficient of determination
January	1	y = 0.0044x + 12.199	R^2 = 0.0033
February	2	y = 0.0148x + 14.223	R^2 = 0.0367
March	3	y = 0.0255x + 18.247	R^2 = 0.1269
April	4	y = 0.0474x + 23.391	R^2 = 0.4349
May	5	y = 0.0668x + 28.628	R^2 = 0.6058
June	6	y = 0.0819x + 31.377	R^2 = 0.7413
July	7	y = 0.0905x + 32.508	R^2 = 0.7602
August	8	y = 0.0883x + 32.145	R^2 = 0.6704
September	9	y = 0.0685x + 29.655	R^2 = 0.6503
October	10	y = 0.0471x + 25.108	R^2 = 0.3687
November	11	y = 0.007x + 19.228	R^2 = 0.0146
December	12	y = 0.0149x + 13.232	R^2 = 0.0395
annual mean temperature	13	y = 0.0478x + 23.293	R^2 = 0.7033
annual mean max. temperature	14	y = 0.0576x + 30.091	R^2 = 0.7222
annual mean min. temperature	15	y = 0.0412x + 17.009	R^2 = 0.5296
Annual mean humidity	16	y = -0.4091x + 65.755	R^2 = 0.8232

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4.2 Temperature anomalies

Using anomalies, the departure from an "average," allows more accurate descriptions than actual temperatures and provides a frame of reference that allows easier analysis. Figures (10-19) show temperature and humidity anomalies were plotted against time and the linear trends observed were represented graphically for Hay Al-Hussien stations with respect to their mean of 72 years (1941–2013). Figures (10-15) have been selected from 12, which represent anomalies in annual change of the mean temperature for the months (January1941-2013, March1941-2013, may1941-2013, July1941-2013, September1941-2013, November 1941-2013) and Figures (16,17,18,19) represent anomalies in annual mean temperature, annual mean maximum temperature, annual mean minimum temperature and annual mean humidity respectively.

4.3 Pearson's moment correlation coefficient

In order to measure the strength of association between annual mean temperature and annual mean humidity, Pearson product-moment correlation coefficient have been computed and its value (-0.804) which indicates opposite and strong relationship.

Anomalies in annual change of the mean temperature for the month of (January, March, May, July, September, November) time series (1941-2013) in blue color and linear trend in red color for each month

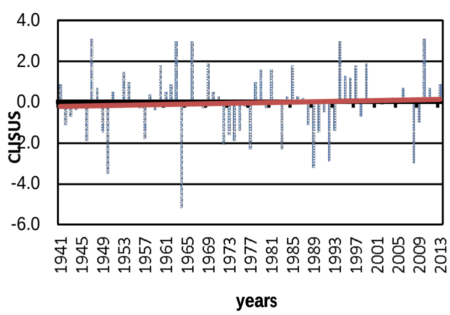


Fig.(10) January

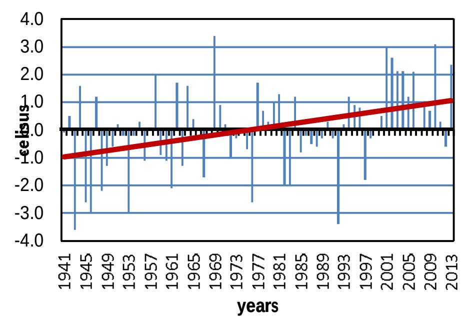


Fig.(11) March

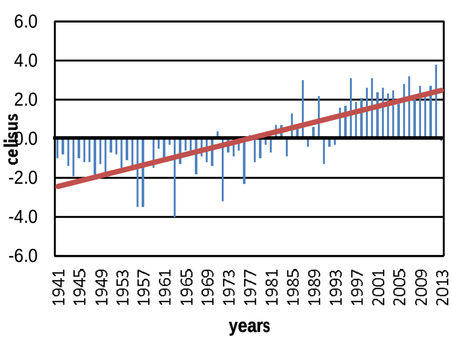


Fig.(12) May

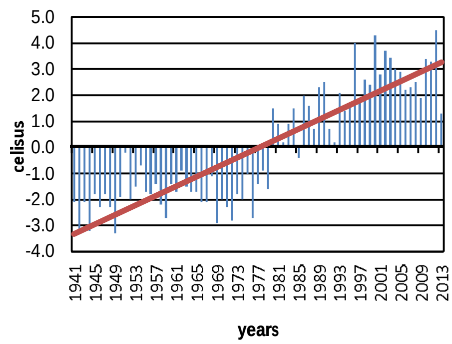


Fig.(13) July

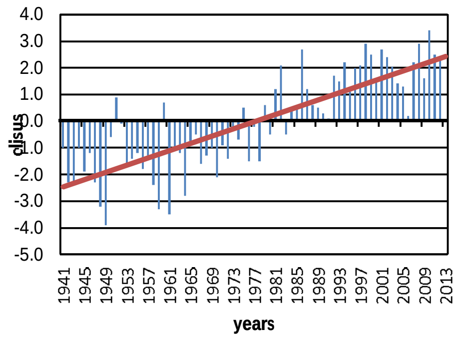


Fig.(14) September

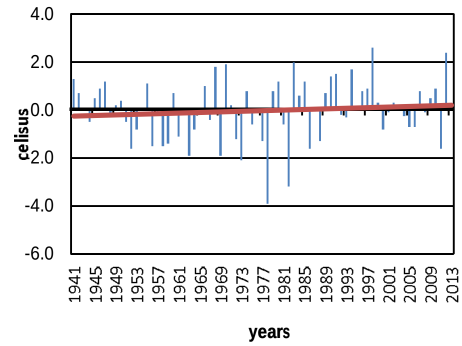
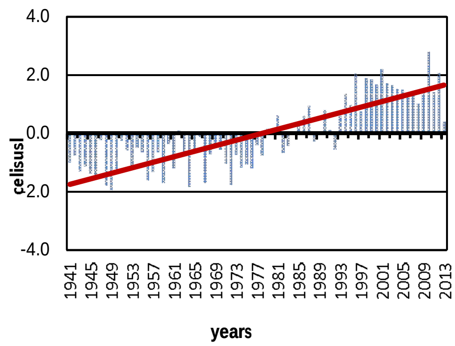
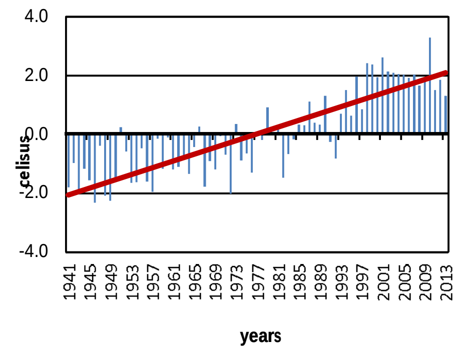


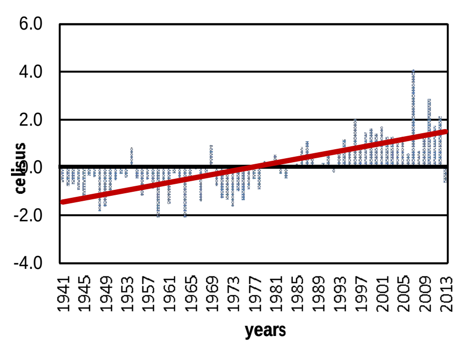
fig.(15) November



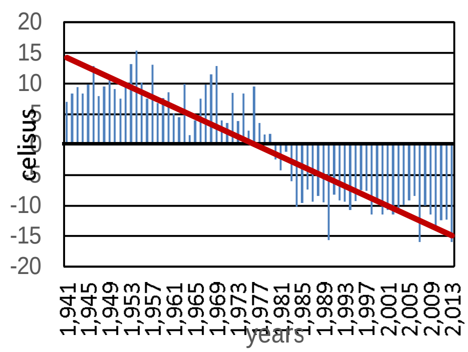
Fig(16) Anomalies in annual mean temperature blue color and liner trend in red color for the period (1941-2013)



Fig(17) Anomalies in annual mean Max. temperature in blue color and liner trend in red color for the period (1941-2013)



Fig(18) Anomalies in annual mean Min. Temperature in blue color and liner trend in red color for the period (1941-2013)



Fig(19) Anomalies in annual mean humidity in blue color and liner trend in red color for the period (1941-2013)

4.4 Temperature and Humidity Projected in the Future

Regression equations in table (2) have been applied to project monthly mean temperature, annual mean temperature, annual mean max. temperature, annual mean min. temperature, and annual mean Humidity by using equation No. (1 to 12), (No. 13), (No. 14), (No. 15), (No.16) respectively for Basra Province for the period (2014 to 2020). The results are shown in table (3), and By using equation (No. 13), the annual mean temperature in Basra Province is expected to increase to (7.6 °C) by 2100. This expectation is close to that of IPCC, 2001 (the amount of the global average surface temperature has increased by 0.6 ± 0.2°C over the last century and it is expected that, by 2100, the increase in temperature could be 1.4–5.8°C. Temperature changes have not been uniform globally, but have varied over regions and different parts of the lower atmosphere, M. Arora. et al, 2005).

Table(3) show prediction of monthly and annually temperature in (^{0}C) and humidity in (%)

Years / Months and annual	2014	2015	2016	2017	2018	2019	2020
January	12.52	12.53	12.53	12.53	12.54	12.54	12.55
February	15.30	15.32	15.33	15.35	15.36	15.38	15.39
March	20.11	20.13	20.16	20.19	20.21	20.24	20.26
April	26.86	26.90	26.95	26.99	27.04	27.09	27.14
May	33.50	33.57	33.64	33.71	33.77	33.84	33.92
Jun	37.36	37.44	37.52	37.60	37.68	37.76	37.85
July	39.12	39.21	39.30	39.39	39.48	39.57	39.66
August	38.60	38.68	38.77	38.86	38.94	39.03	39.12
September	34.67	34.72	34.79	34.86	34.93	35	35.07
October	28.55	28.59	28.64	28.69	28.74	28.78	28.83
November	19.74	19.75	19.75	19.76	19.77	19.77	19.78
December	14.32	14.34	14.35	14.36	14.38	14.39	14.41
Annual mean temperature	26.78	26.83	26.89	26.93	26.97	27.02	27.07
Annual mean max. temperature	34.30	34.35	34.41	34.47	34.53	34.58	34.64
Annual mean min. temperature	20.24	20.29	20.33	20.38	20.42	20.46	20.26
Annual mean humidity	35.89	35.48	35.07	34.66	34.25	33.85	33.44

5- Discussion: All data records show peaks and valleys in sync with each other. All show rapid warming in the past few decades, with the last decade being the warmest. The resultant indicates how strong the trend in temperature or humidity is, and whether it is increasing or decreasing as shown in Figures (1-9). Fig(1) represents variations of annual change of the mean temperature for the month of January, it is clear that the trend is increased from year to year by a rate of (0.0044 ^{0}C) which is regarded as the minimum value compared with other months, and the magnitude of temperature increase is 0.32 °C for the period (1941 to 2013), this value is less than that presented by the IPCC, 2007 (Over the past 100 years, the global average temperature has increased by approximately 0.74 ± 0.18°C (Mean ± s.e.)). Fig.(2) represents the month of March, this figure shows that the regression line is increased by a rate of (0.0255 ^{0}C) and the magnitude of temperature increase is (1.84 ^{0}C) which is higher than that of January, and so on for fig(3) which express the month of May, the regression line is increased by a rate of (0.0668) with temperature increase (4.81 ^{0}C). Fig (4) represents the month of July, the regression line is increased by a rate of (0.0905) and temperature increase (6.52 ^{0}C) which is the largest value. Thus, it can be seen in the remaining figures, the rate of regression line and the magnitude of temperature decreases gradually where the minimum value was (0.007 ^{0}C) for the month of November fig.(6). Fig.(7) represents annual mean temperature, the regression line is increased by a rate of (0.0478 ^{0}C) and in fig.(8) which express the annual mean max. and min. temperature, the regression line is increased by a rate of (0.0576 ^{0}C) and (0.0412 ^{0}C). Fig.(9) which represents annual mean humidity, shows that the regression line decreased by a rate of (-0.4091%). It is observed from Table (4) that the magnitude of the increase in the three annual temperature parameters, viz. annual mean, annual mean max. and annual mean min. were (3.44 ^{0}C), (4.15 ^{0}C), (2.97 ^{0}C) respectively, where the magnitude of annual mean Humidity decreased (29.46%). These values of temperature increases and humidity decreases tend to speed up drought conditions.

Table (4) the values of temperature increase and humidity decrease for the period 1941 to 2013

Months and annual	*Temperature increased and Humidity decrease for period 1941 to 2013*
January	0.32 ^{0}C
February	1.07 ^{0}C
March	1.84 ^{0}C
April	3.41 ^{0}C
May	4.81 ^{0}C
June	5.90 ^{0}C
July	6.52 ^{0}C
August	6.36 ^{0}C
September	4.93 ^{0}C
October	3.39 ^{0}C
November	0.50 ^{0}C
December	1.07 ^{0}C
annual mean temperature	3.44 ^{0}C
annual mean max. temperature	4.15 ^{0}C
annual mean min. temperature	2.97 ^{0}C
Annual mean humidity	-29.46 %

The temperatures we experience locally and in short periods can fluctuate significantly due to predictable cyclical events (night and day, summer and winter). But the global temperature mainly depends on how much energy the planet receives from the Sun and how much it radiates back into space-quantities that change very little. The amount of energy radiated by the Earth depends significantly on the chemical composition of the atmosphere, particularly the amount of heat-trapping greenhouse gases.

Temperature anomalies

In figures (10 to 19) the linear trend value, represented by the slope of a regression line with time as the independent variable, gives the magnitude of rise or fall in temperature and humidity.

It is noted that the slop of regression line was increasing from January to July and decreased to the smallest value in November.

Of the most important results that we draw from these figures is that the linear regression line divided the temperature and humidity time series into two parts, the first part begins from the first year of the series in 1941 until 1977 with a negative value, while the second part takes positive value from 1977 until the end of the series in 2013. This means that the first part is cold and the second is warm relative to the mean value. While the situation in Fig.(31) is the opposite, the first part of the humidity time series is positive and second part is negative, this means that humidity begins to decrease and from 1977 its value decreased below the average.

6- Conclusion

In this study, the trends of the annual mean temperature for each month of the year, annually mean air temperature, annually mean max. and min. temperature, and Humidity time series were examined in province of Basra for a period of 72 years (1941 to 2013).

The time series had been examined and found to be smooth. The time series of temperature and humidity have been plotted. The slope of the regression line was increasing gradually. In January, the trend line has a small value (0.0044), in February the trend increased more than before (0.0148) and so on, but in July the trend increased up to maximum value (0.0905), after that the trend values in August, September and October decreased gradually, the minimum value was (0.007) for November, where for humidity, the trend decreased by a value (-0.4091). It is observed that the maximum magnitude of monthly mean temperature was (6.52 °C) in July and the minimum magnitude was (0.32 °C) in January. The magnitude of annual mean temperature increased (3.44 °C), the magnitude of the annual mean max. and min. temperature (4.15 °C), and (2.97 °C), while the magnitude of annual mean humidity decreased (29.46%). The regression equations and the coefficient of determination (R^2) for temperature and humidity have been Determined. Regarding anomalies in temperature and humidity, the linear regression line divided the temperature and humidity time series into two parts, the first part has negative values while the second part takes positive values, this means that the first part is cold and the second is warm relative to the mean value while the situation in humidity is the opposite. The value of Pearson correlation coefficient (-0.804) indicates opposite strong relationship between temperature and humidity. By using regression equations, temperature and humidity for Basra Province were projected for the period (2014 to 2020). Annual mean temperature in Basra Province expected by 2100 increase to (7.6 °C).

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