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TEMPORAL REGRESSION RELATIONS BETWEEN AIR TEMPERATURE, WIND VELOCITY, RAINFALL AND RELATIVE HUMIDITY IN RIVER NILE STATE, SUDAN

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ABSTRACT

This work was conducted in River Nile State to produce broad data base on regression relations between air temperatures and selected climatic elements, mean monthly climatic data for Atbara meteorological station were analyzed during the first (1978-1980) and the second period (2008-2010). Data were subjected to simple regression analysis, statistical analysis and computations were done by "Excel 2000". Regression analysis showed that air temperature in the two periods was significantly ($P \leq 0.001$) increased with decrease in wind speed (r=0.698) and (r=0.504), air temperature accounted for 48.7% and 24.8%, of the variability of the wind speed respectively. Air temperature versus relative humidity for first and second period gave significant negative correlation ($p \leq 0.05$, r=0.350) and ($p \leq 0.01$, r=0.473), respectively and air temperature accounted for 12.2% and 22.4% of the variability of the relative humidity respectively. In the two periods, air temperature versus rainfall relations indicated a significantly negative correlation ($p \leq 0.01$, r=0.417), ($p \leq 0.05$, r=0.304), and air temperature accounted for17.4% and 9.3%, of the variability of the rainfall respectively. Air temperatures in the two periods was qualitatively similar and with low variability (CV of 15.7% and 15.2%, respectively). The variability of wind speed in the second period has decreased from 27.9% to 19.0% (31.9%). However, the rainfall in the two periods gave a very high variability (215.1% and 244.0%, respectively). The relative humidity also showed low variability with minor increases in the second period (CV of 24.7% to 26.8% and an increase by 8.5%).

Key word: *Temporal, regression analysis, climatic elements and Sudan.*

INTRODUCTION

Climatic behavior prediction is one of the challenging tasks to meteorological society all over the world. All climatic variables like air temperature, humidity etc. are affected by each other (Givoni, 1976). High air temperature with below normal precipitation can cause moisture stress to agricultural crops, such as corn and soybeans, and negatively impact yields (Carlson, 1990). The air temperature variation brings change in water evaporation and air saturation, leading to the change in air humidity. Furthermore, the air temperature differences between different locations will also cause air pressure differences, which in turn would produce air movement, thereby leading to wind. This variation in humidity and wind speed and direction affects rainfall. Thus, all weather variables on the Earth are more

or less affected by each other and this fact is widely acknowledged (Madden & Williams, 1978; Carlson, 1990; Trenberth & Shea, 2005; Powell & Reinhold, 2009; and Valsson & Bharat, 2011).

Adam and Abdalla (2008), studied the climate of the drylands in Sudan; they found that deforestation affects the effective rainfall but not the actual rainfall. Climate change is a reality. Unless serious efforts are made to stop the increases in CO2, global temperature will continue to rise. Increase in temperature will lead to an increase in water vapour in the atmosphere, the estimated increase in energy as a result of an increase of 0.1 0C is about 7000 billion mega joules. This energy has to be dissipated in the form of more frequent and more intense storms leading to more floods and destructive winds (El gamri et al., 2009). Mohamed & Mohamed (2010), made classification of climates of Sudan using aridity indices and they cleared that Elddebba and Emberger aridity indices are more appropriate for classification of Sudan climates compared to other methods and that Sudan climate can be classified into hyper-arid, arid, semi-arid, sub-humid and humid zones. Mohamed (2012) made a simple thermal zonation of the Sudan, he found that Sudan can be divided into seven zones according to their mean annual temperatures, with Khartoum and Atbara depends on the highest means and El-fashir and Wadihalfa the lowest one. In spite of all works that mentioned, till now there is a little attention was given to climate studies.

The climate variability directly influences on many sectors such as our life especially in urban areas related to human comfort and health beside agriculture sector. So it is necessary to determine the relationship among the climatic variables and its influence on these sectors. Assessment of temporal variability of climate elements is essential for assess and monitor climate and climate change. The study aimed to produce broad database on regression relations between temperatures, wind velocity, rainfall and relative humidity in two periods (1978-1980) and (2008-2010). The study was undertaken to achieve the following objectives:

1. **To generate broad base quantitative data on regression relations between temperatures, wind velocity, rainfall and relative humidity in the study area.**
2. **To investigate temporal variability of climatic elements that may help in understanding the trend of climate in the study area.**
3. **To generate empirical relationships between temperature and other climate elements.**

MATERIALS AND METHODS

In Sudan, the hyper-arid, arid and semi-arid lands constitute 41.2, 33.4 and 25.2% of the total area of Sudan, respectively, (Mustafa, 2008). The River Nile State lies between latitudes 17o and 19o N and longitudes 32o and 34o E. It is dominated by hyper–arid and arid climatic zones with mainly two seasons, a hot summer from April to September and cold winter from October to March. The mean annual rainfall is less than 100 mm. and temperatures as high as 49o C is not uncommon in the period extending from April to June. In winter temperature as low as 1.5o C have been recorded. The vapor pressure is only 10.8 mb and the relative humidity is less than 20%. Clouds are generally rare. Short-wave solar radiation is as high as 659 calorie cm-2 in May. Winds prevail from the north with a mean maximum speed of 17.6 km/hr (Izzeldin & Ahmed, 2004).

Mean monthly climatic data dating back to (1978-1980 and 2008-2010), obtained from the Meteorological Authority, Ministry of Environment, Forestry and Physical Development, Sudan. Simple regression analysis (Little & Jackson, 1975) was made also statistical analysis and computation were done by "Excel 2000"

RESULTS

The relationship between temperature and climatic variables

First period (1978-1980)

Fig.1. Shows highly significant ($p<0.001$, R=0. 698) cubic, decrease in wind speed with increase in air temperature. Air temperature accounted about 48.7% of the variability of the wind speed.

Fig.2. Indicated a significant ($p<0.05$, R=0.350) cubic, decrease in relative humidity with increase in air temperature. Air temperature accounted about 12.2 % of the variability of the relative humidity.

Fig.3. Shows a significant ($p<0.01$, R=0.417) cubic, decrease in rainfall with increase in air temperature. Air temperature accounted about 17.4% of the variability of the rainfall.

Fig.1 Mean temperature versus mean wind speed

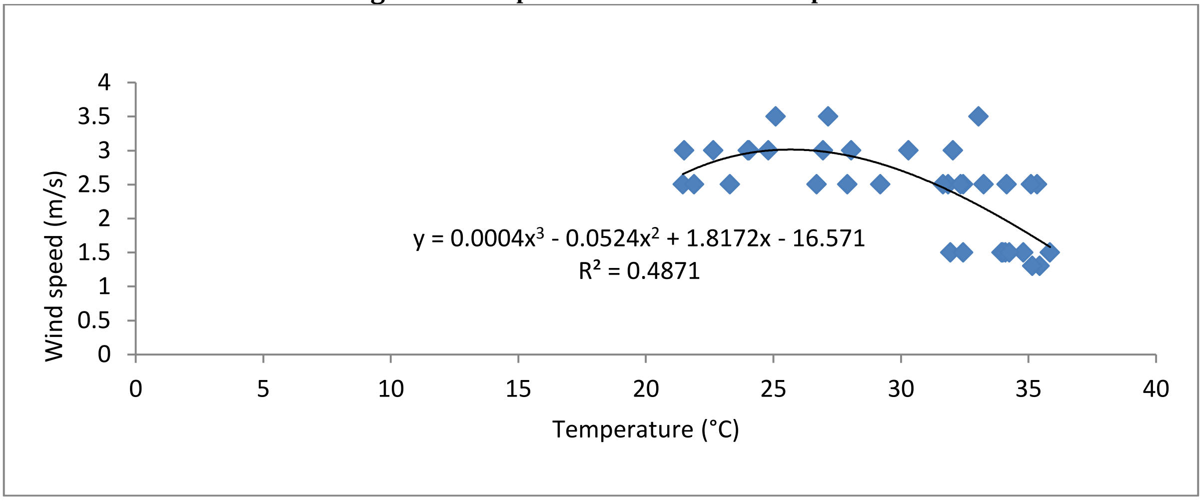


Fig.2 Mean temperature versus mean relative humidity

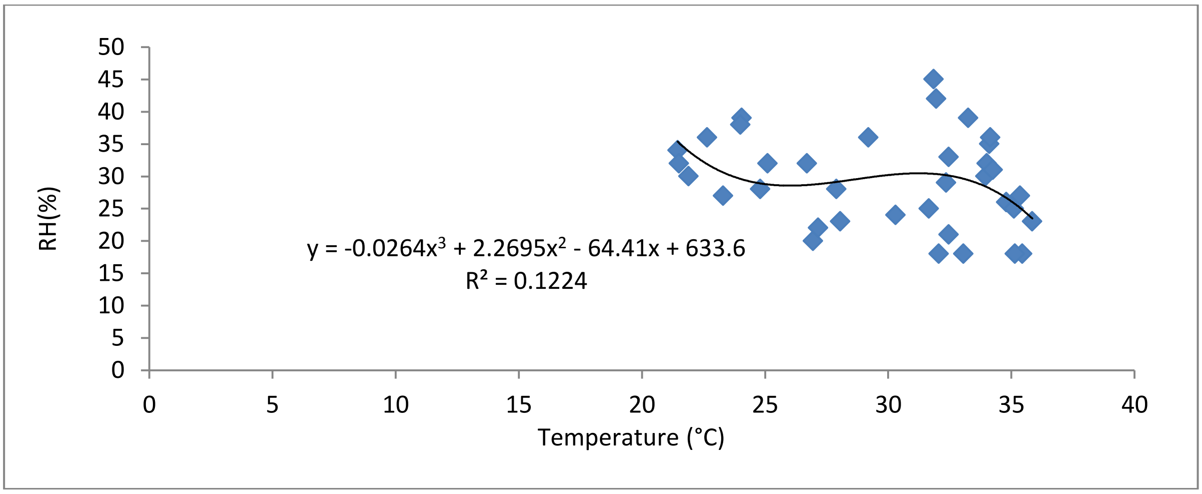
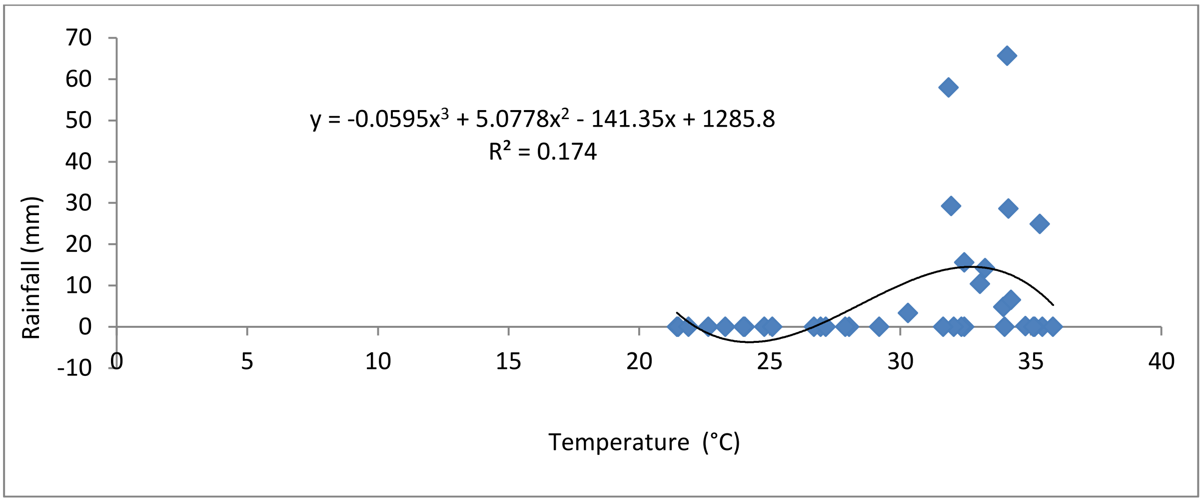


Fig.3 **Mean temperature versus mean rainfall**



The results showed that air temperatures ranged from 21.5 to 35.9 with a mean of 30, Celsius a standard deviation (STD) 4.7 and a coefficient of variation (CV) of 15.7%. Wind speed ranged from 1.3 to 3.5 with a mean of 2.4, m/s a STD of 0.67 and a CV of 27.9%.

The rainfall ranged from 0.0 to 65.6 with a mean of 7.3, mm a STD of 15.7 and gave very high variability a CV of 215.1%. The relative humidity ranged from 18% to 45% with a mean of 29.2%, a STD of 7.2 and a CV of 24.7%. Simple regression analysis (Little and Jackson, 1975) between air temperature and climatic variables presented in table 1

Table 1: **Equations of the trend lines showing the relationship between temperature and some climatic variables during first period**

Climatic variable	Type of equation	a	b	c	d	R	R^2
Wind speed	Cubic	0.0004	- 0.0524	1.8172	- 16.571	0.698	0.4871
Rainfall	Cubic	-0.0595	5.0778	- 141.35	1285.8	0.417	0.174
Relative humidity	Cubic	-0.0264	2.2695	- 64.41	633.6	0.350	0.1224

*** Cubic: Y=ax3+bx2+cx+d. R (0.05) =0.3296; R (0.01) =0.4243; R (0.001) =0.5259**

The relationship between temperature and climatic variables Second period (2008-2010)

Fig.4. Shows highly significant ($p<0.001$, R=0.504) cubic, decrease in wind speed with increase in air temperature. Air temperature accounted about 24.8% of the variability of the wind speed.

Fig.5. Indicated a significant ($p<0.01$, R=0.473) cubic, decrease in relative humidity with increase in air temperature. Air temperature accounted about 22.4 % of the variability of the relative humidity.

Fig.6. Shows a significant ($p<0.05$, R=0.304) cubic, increase in rainfall with increase in air temperature. Air temperature accounted about 9.3% of the variability of the rainfall

Fig.4 Mean temperature versus mean wind speed

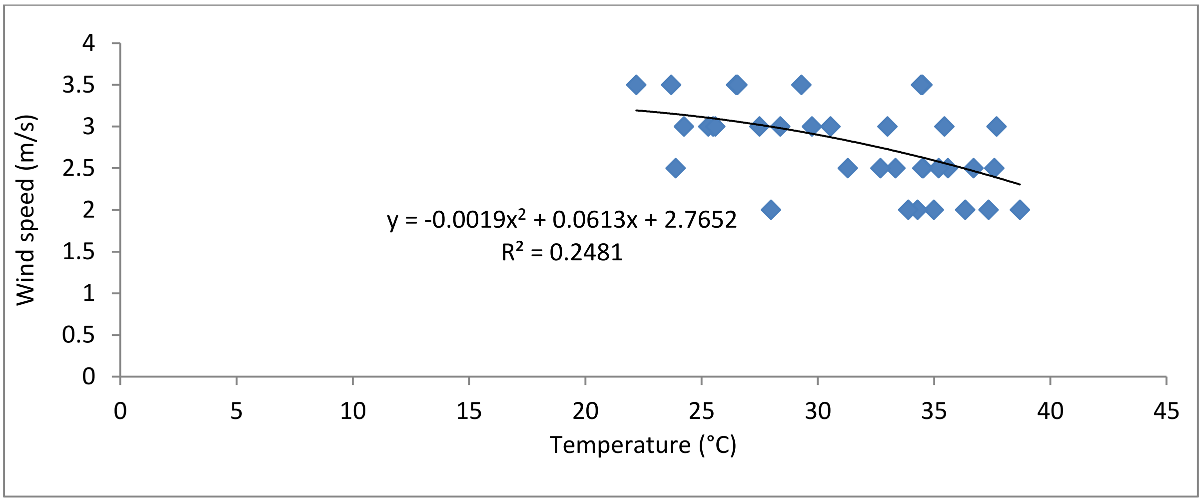


Fig.5 Mean temperature versus mean relative humidity

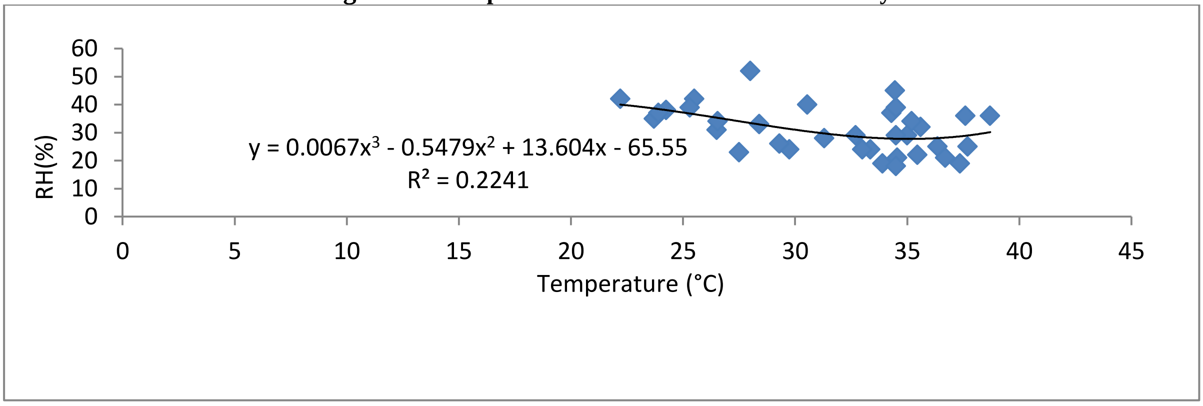
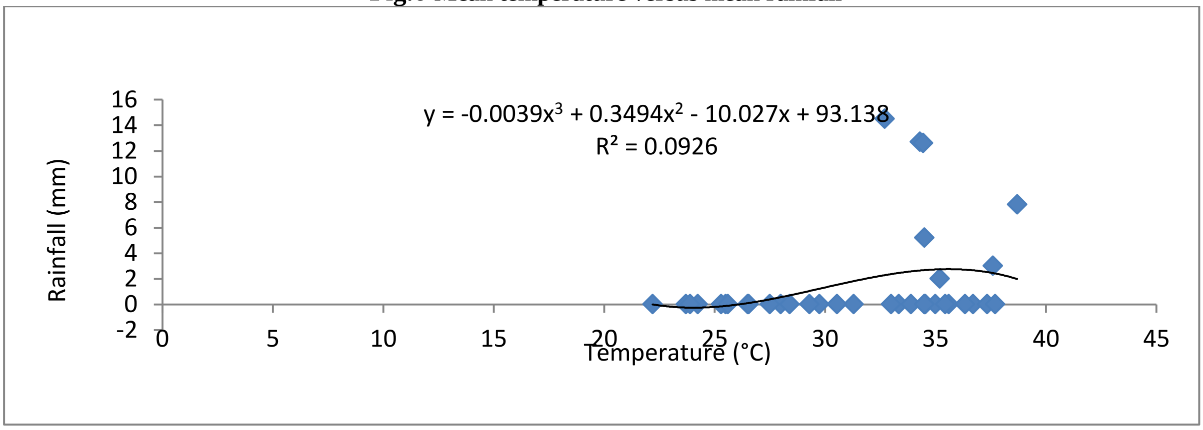


Fig.6 Mean temperature versus mean rainfall



The results cleared that air temperatures ranged from 22.2 to 38.7 with a mean of 31.5, Celsius a STD of 4.8 and a CV of 15.2%. Wind speed ranged from 2.0 to 3.5 with a mean of 2.8, m/s a STD of 0.53 and a CV of 19.0%. The rainfall ranged from 0.0 to 14.5 with a mean of 1.6, mm a STD of 3.9 and gave very high variability a CV of 244.0%. The relative humidity ranged from 18% to 52% with a mean of 31.4%, a STD of 8.4 and a CV of 26.8%. Simple regression analysis between air temperature and climatic variables presented in table 2

Table 2: **Equations of the trend lines showing the relationship between temperature and some climatic variables during second period**

Climatic variable	Type of equation	a	b	c	d	R	R^2
Wind speed	Cubic	-0.0004	0.0379	- 1.1426	14.734	0.504	0.2536
Rainfall	Cubic	-0.0039	0.3494	- 10.027	93.138	0.304	0.0926
Relative humidity	Cubic	0.0067	- 0.5479	13.604	- 65.55	0.473	0.2241

*** Cubic: Y=ax3+bx2+cx+d. R (0.05) =0.3296; R (0.01) =0.4243; R (0.001) =0.5259**

DISCUSSION

Temperature and pressure are directly proportional to each other. This means that as the temperature decreases, the pressure also decreases, and as the temperature increases, the pressure increases. A hot surface heats the air above it and the air expands, lowering the air pressure and its density. The resulting horizontal pressure gradient accelerates the air from high to low pressure, creating wind. The relationship between wind speed and pressure are co-dependent with temperature (Powell & Reinhold, 2009). Temperature and wind speed are directly proportional to each other and gave very high correlation in spite of the indirect relationship between pressures and wind speed. Regression analysis showed that air temperature in the two periods significantly (P <0.001) increased with decrease in wind speed (r = 0.698) and (r=0.504), air temperature accounted about 48.7% and 24.8% of the variability of the wind speed respectively.

Relative humidity depends on two factors the amount of moisture available and the temperature. In the two periods the relationship between air temperature and relative humidity gave a significant negative correlation (p <0.05, r=0.350) and (p <0.01, r=0.473) respectively. Regression analysis proved that the moisture holding capacity of air depends on the air's temperature. It increases with increase in temperature. As the moisture holding capacity increases the relative humidity decreases, provided no moisture is added to the air. So inversely relation between temperature and relative humidity is logical result. This finding agrees with previous findings (Valsson & Bharat, 2011). Air temperature accounted 12.2% and 22.4% of the variability of the relative humidity for the two periods; this difference may be attributed to the difference impact of temperature on relative humidity in first period low impact within other contributed elements.

An opposite result occurred in the latest period. The relative humidity gave low variability with meager increases in second period from a CV of 24.5% to 26.8%, increased by 9.4%. Madden and Williams, (1978) found that there are significant large-scale correlations between observed monthly mean temperature and precipitation. In the warm season over continents, higher temperatures accompany lower amount of precipitation and vice versa. Hence, over land, strong negative correlations dominate, as dry conditions favors more sunshine and less evaporative cooling, while wet summers are cool (Trenberth & Shea, 2005). In the two period air temperature versus rainfall relations indicated a significantly negative correlation (p <0.01, r=0.417), (p <0.05, r=0.304), and air temperature accounted 17.4% and 9.3% respectively. Rainfall in two periods gave very high variability, 217.0% and 244.2% of the variability of the rainfall respectively; very high variability was attributed to the location of state which lies in the hyper-arid and arid zone beside prevalent harsh climatic conditions including high temperature, low and erratic rainfalls.

CONCLUSION AND RECOMMENDATIONS

- **The regression between climate elements gave strong and well correlation ranged between (R <0.001 to R<0.05).**
- **In the two periods air temperature qualitatively similar with low variability with a CV of 15.7% and 15.2% respectively; decreased by 3.2%. The variability of wind speed decreased in second period from 27.9% to 19.0% by 31.9%. The relative humidity gave low variability with meager increases in second period from a CV of 24.5% to 26.8%, increased by 9.4%.**
- **The rainfall in the two periods gave very high variability, 217.0% and 244.2% respectively; this result was attributed to the location of state which lies in the hyper-arid and arid zone beside prevalent harsh climatic conditions including high temperature, low and erratic rainfalls.**
- **The results are cleared that regression technique can be used effectively for the explicit the relationship between climate variables Thus, it is recommended to carry out periodically.**

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علاقة الانحدار المؤقت بتن درجة حرارة الهواء، سرعة الرياح تساقط الأمطار والرطوبة النسبية في ولاية نهر النيل،السودان

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الملخص:

تم إجراء هذا العمل في ولاية نهر النيل لإنتاج قاعدة بيانات واسعة حول علاقات الانحدار بين درجات حرارة الهواء وعناصر مناخية مختارة ، وتم تحليل البيانات المناخية الشهرية لمحطة عطبرة الجوية خلال الفترة الأولى (١٩٧٨-١٩٨٠) والفترة الثانية (٢٠٠٨-٢٠١٠).). خضعت البيانات لتحليل الانحدار البسيط ، وتم إجراء التحليل الإحصائي والحسابات بواسطة "Excel 2000". أظهر تحليل الانحدار إرتفاع معنوي في درجة حرارة الهواء في الفترتين (P ≤ 0.001) مع انخفاض في سرعة الرياح (r = 0.698) و (r = 0.504) ، وشكلت درجة حرارة الهواء ٤٨.٧ ٪ و ٢٤.٨ ٪ ، من تقلبات سرعة الرياح على التوالي. أعطت درجة حرارة الهواء مقابل الرطوبة النسبية للفترة الأولى والثانية ارتباطا سلبيا معنويا (p ≤0.05، r = 0.350) و (p ≤0.01، r = 0.473) ، على التوالي ، وشكلت درجة حرارة الهواء ١٢.٢ ٪ و ٢٢.٤ ٪ من تقلبات الرطوبة النسبية على التوالي. في الفترتين، أشارت درجة حرارة الهواء مقابل علاقات تساقط الأمطار إلى ارتباط سلبي كبير (p ≤0.01، r = 0.417)، (p ≤0.05، r = 0.304) ، وشكلت درجة حرارة الهواء ١٧.٤٪ و ٩.٣٪ من تساقط الأمطار علي التوالي. كانت درجات حرارة الهواء في الفترتين متشابهة من حيث النوعية مع تقلبات منخفضة (١٥.٧٪ و ١٥.٢٪ على التوالي). تقلب سرعة الرياح في الفترة الثانية نتقص من ٢٧.٩٪ إلى ١٩٪ (٣١.٩٪)، أعطى سقوط الأمطار في الفترتين تقلبات عالية جدا (٢١٥.١ ٪ و ٢٤٤.٠ ٪ ، على التوالي). كما أظهرت الرطوبة النسبية تقلبات منخفضة مع زيادات طفيفة في الفترة الثانية (من ٢٤.٧ ٪ إلى ٢٦.٨ ٪ وزيادة بنسبة ٨.٥ ٪).