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CLIMATE CHANGE AND RELATIONSHIP BETWEEN METEOROLOGICAL PARAMETERS: A CASE STUDY OF JACOBABAD (SINDH), PAKISTAN

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ABSTRACT

This paper aims to establish a relationship between selective meteorological variables such as wind speed, relative humidity, precipitation, maximum temperature and minimum temperature that contribute in the climate change of Jacobabad, a small district of Sindh province of Pakistan. Mean monthly time series data of meteorological variables were obtained for 10 years from Jan 2001 to Dec-2010. Regression analysis, Co-integration technique and Granger Causality test were applied to model wind speed as a function of meteorological conditions. The results reveal that a stable long run relationship exists between factors of climate change. Bi-directional causality was found between wind speed (V) and independent variables such as humidity (H), maximum temperature (T max) and minimum temperature (T min).

Keywords: Relative humidity, Precipitation, Granger causality test, Unit root test.
JEL Classification: O44, Q5, Q54

1. INTRODUCTION

Analysis of past depicts changes in the global climate. The steady rate of transformation and the nature of the impacts of change will vary over time and across regions and countries, affecting every aspect of life on the planet. Concurrent efforts are required to reduce greenhouse gas emissions as well as take various necessary steps to adapt to the impacts of changing climate, (O'Connor *et al.*, 2005). In its fourth assessment report, AR4 2007, the Intergovernmental Panel on Climate Change has reported an increase of 0.6 degrees Celsius during last century. It also predicts an increase of 2 to 4 degrees Celsius in the present century. The expected increase in the global temperature is despite necessary measures being adopted to counter its effects all over the world. Climate change refers to general shifts in climate, including temperature, precipitation, winds, and

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other factors where as global warming (as well as global cooling) refers specifically to any change in the global average surface temperature, (Back and Bretherton, 2004). Global warming can be termed as sub-set of the climate change which is a critical issue attributed to building up of greenhouse gases because of numerous industrial activities during the past two centuries, (Akpinar *et al.*, 2007). However, the issue of climate change has created hype and controversy. To develop an understanding, the meaning of climate change, for a country like Pakistan, is only one step in that process. Some people doubt the potential negative impacts of man induced global warming and ward off threat posed by climate change as an unnecessary fear, (Xie, 2009).This group of people do not subscribe to the increase in the global temperature as an unnatural phenomenon induced by human intervention. They believe that the melting of polar ice and glaciers is happening as per nature's plan. Melting of Himalayan glaciers may take decades to complete, but it is a matter of grave concern and distress for South Asian regional countries such as Pakistan, Maldives, Nepal and Bhutan,(Giri *et al.*, 2008).

Pakistan is faced with the challenge of interpretation of the phenomenon of climate change. Here we need to figure out how the human induced climate change impacts, for which the developed world is mainly responsible for, affecting us, (Farooqi *et al.*, 2005). Sub-continent is densely populated with just 5 per cent of the area covered with trees and jungles. It comprises extensive area that has very high average temperatures. Earth surface heat radiation index stays high because of designs of housing structures. Large water bodies like Arabian Sea, the Bay of Bengal and the Indian Ocean surround the vast area. Even a small increase in average temperature means large amounts of heat content available can cause abnormal weather conditions leading to flash floods, (O'Connor *et al.*, 2005). Thus an anomalous rise in temperature would raise the severity level in the area every few years with an increased frequency of occurrence, (Shukla and Misra, 1976). The World Bank[1] has reported an estimated loss of around $3.57 billion due to negative impacts of climate change on Pakistan in the South Asian region, over the past 18 years. The report alarms Pakistan of the existence of five major risks related to climate change/global warming and potentially risking half of the country's population.

The report, warns of disasters in five main areas: rise in sea level, glacial retreat, floods, higher average temperatures, and high frequency of droughts. Since higher temperatures are being recorded every year, this has created an emergency. Besides other unusual events, Pakistan has suffered from extremely damaging and unprecedented floods during July/August 2010. The extent of vulnerability to the destruction from potential disasters is around 23% of the country's land and nearly 50% of the entire population. There is an urgent need to check steady increase in harmful carbon emissions that contribute to climatic disasters. It is imperative for Pakistan and other South Asian countries to formulate and implement clean technology policies and turn to environment-friendly energy resources, (Rasul, 2010).

[1] http://data.worldbank.org/country/Pakistan

2. Pakistan-Country Profile

Official name:	**Islamic Republic of Pakistan**
Capital:	Islamabad
Area:	total: 803,940 sq km land: 778,720 sq km water: 25,220 sq km
Climate:	mostly hot, dry desert; temperate in northwest; arctic in north
Location:	Southern Asia, bordering the Arabian Sea, between India on the east and Iran and Afghanistan on the west and China in the north
Geographic coordinates:	30 00 N, 70 00 E
Comparative Area:	slightly less than twice the size of California
Land boundaries:	total: 6,774 km border countries: Afghanistan 2,430 km, China 523 km, India 2,912 km, Iran 909 km
Coastline:	1,046 km
Terrain:	Flat Indus plain in east; mountains in north and northwest; Baluchistan plateau in west
Elevation extremes:	lowest point: Indian Ocean 0 m highest point: K2 (Mt. Godwin-Austen) 8,611 m

The geographical situation of Pakistan is such that it lies in the temperate zone. The climate is characterized by hot summers, cold winters and generally arid with wide variations between extremes of temperature at given locations. Generally, Pakistan does not experience heavy rainfall as it is mostly limited. However, his does not imply in under-estimating the distinct differences that exist among particular locations. For instance, the southern part of the country which is the coastal area along the Arabian Sea is mostly warm, whereas the northern areas comprised of frozen snow-covered ridges of the Karakoram Range and of other mountains where temperature remains below freezing point, mostly round the year. It's only in the month of May and June when mountain climbers are able to have access to these cold mountains.

Pakistan has four seasons: cool, dry winter from December through February; hot, dry spring from March through May; the summer rainy season, or southwest monsoon period, from June through September; and the retreating monsoon period of October and November. Different locations vary in terms of onset and duration of these seasons. Pakistan is comprised of arid and semi-arid areas where climatic parameters exhibit significant spatial and temporal variability.

The annual rainfall is 59% due to monsoon rains; a dominant hydro-meteorological resource for Pakistan. Greater Himalayan region above 35°N receives winter precipitation mostly in the form of snow and ice. The rivers remain perennial due to melting of snow, throughout the year. The coastal climate is confined to a narrow strip along the coast in the south and southeast. The north is dominated by the mountain climate ranging from humid to arid.

2.1. Changes in Weather

- *Expected increase in temperatures*: Geographical location already places the country in heat surplus zone of earth.

- *Expected changes in precipitation patterns*: One most imminent threat from climate change is altered monsoon intensity in the Indo-Pakistan sub continent. Erratic and intensive rains, late monsoons, dry winters, and prolonged dry spells are expected.
- *Potential impacts on natural resources*: The increases in temperature and late / intensive monsoon rains will:

  – Further enhance the ongoing process of land degradation

  – Cause increasing glacier out-falls and enhances land slides

  – Further increase siltation loads down stream

  – Bring changes in species patterns (fast growing species are expected to take over and will affect the native biodiversity)

  – Cause shift in special boundaries (shifts of conifers and alpine species towards higher altitude are expected)

2.2. Jacobabad

Jacobabad is situated on the border area between Sindh and Baluchistan provinces. It is a small place which was founded near the village of Khangarh in 1847. Jacobabad is said to be one of the hottest cities in Pakistan, (Khoso, 2008).The city is famous for its consistently high temperatures and holds the record for the highest temperature recorded in Pakistan, 126° F (52° C) in the shade.

2.2.1. Climatic Statistics

- Jacobabad, Sindh, Pakistan latitude & longitude; 28°17'N 68°29'E.
- Altitude; 62 m (203 ft).
- The average temperature in Jacobabad, Sindh, Pakistan is 27.2 °C (81 °F).
- The range of average monthly temperatures is 22 °C.
- The warmest average max/ high temperature is 45 °C (113 °F) in June.
- The coolest average min/ low temperature is 7 °C (45 °F) in January & December.
- Jacobabad, Sindh receives on average 83 mm (3.3 in) of precipitation annually or 7 mm (0.3 in) each month.
- On balance there are 13 days annually on which greater than 0.1 mm (0.004 in) of precipitation (rain, sleet, snow or hail) occurs or 1 day on an average month.
- The month with the driest weather is June & October when on balance 0.5 mm (0.0 in) of rainfall (precipitation) occurs.
- The month with the wettest weather is July when on balance 24 mm (0.9 in) of rain, sleet, hail or snow falls across 2 days.
- Mean relative humidity for an average year is recorded as 34.2% and on a monthly basis it ranges from 27% in May to 49% in August.
- There is an average range of hours of sunshine in Jacobabad, Sindh of between 8.1 hours per day in January & December and 10.0 hours per day in May.
- On balance there are 3303 sunshine hours annually and approximately 9.0 sunlight hours for each day.

In this paper, we investigate the relationship between meteorological parameters by taking an example of Jacobabad, a small district of Sindh, Pakistan, undertaking co-integration analysis and determining the causal relationships by using Granger causality test. We examine the climate change that can be caused by variation in wind speed, precipitation, relative humidity, maximum temperature and minimum temperature.

3. DATA AND METHODOLOGY

The data set from Pakistan Meteorological Department is being used for this study. It covers a period of 10 years from 2001 to 2010 and means monthly data is used to fully ascertain the impact of variables. We use Johansen's test for co-integration and proceed to Granger Causality tests to establish causal links between variables. Possible relationships between these variables were examined statistically using the multiple linear regression model which is appropriate to relate wind speed to climate variables, has the formulation given as follows:

$V = \alpha + \beta_1 H + \beta_2 PP + \beta_3 Tmax + \beta_4 Tmin + \mu \ldots\ldots\ldots 1$

Relationships (-) (+) (-) (+)

where β's are the statistical parameters.

Variables:

- Tmin**:** Minimum Temperature
- Tmax**:** Maximum Temperature
- PP **:** Precipitation
- H **:** Humidity
- V **:** Wind speed

4. ESTIMATION AND RESULTS

Analysis of the meteorological parameters includes relative humidity, maximum temperature, minimum temperature, precipitation and wind speed. Regression analysis was performed to determine the effect of independent variables on dependent variable and to find out the expected relationships between them. The result of regression equation is listed below in **Table 1:**

Table-1. Regression Results

Dependent Variable - V				
Variable	Coefficient	Std. Error	t-Statistic	Probability
C	9.228688	2.519139	3.663429	0.0004
PP	0.00662	0.004558	1.452269	0.1491
TMAX	-0.178758	0.091074	-1.96277	0.0521
TMIN	0.300514	0.075966	3.955916	0.0001
H	-0.097896	0.01904	-5.14171	0.0000
R-squared	0.606536	F-statistic		44.31899
Adjusted R-squared	0.592851	Prob (F-statistic)		0.0000
Durbin-Watson stat	1.233334			

Precipitation (PP)

It is positively related to wind speed because as precipitation rises, evaporation may increase which leads to increase in wind speed. No significant relationship was found as it has not much significant impact on dependent variable. The correlation coefficient between precipitation and wind speed is 0.086550.

Humidity (H)

Humidity and wind speed are negatively related with a strong and significant relationship was found between them. Therefore, the higher the relative humidity, the lower will be the wind speed. Humidity also correlates negatively to wind speed i.e., -0.446641.

Maximum Temperature (TMAX)

It is negatively related to the dependent variable. A significant relationship was found between wind speed and maximum temperature. As maximum temperature rises, wind speed may decrease because of lower evaporation. The correlation coefficient between maximum temperature and wind speed shows positive correlation of 0.715966 and it is not according to the expected theoretical relationship.

Minimum Temperature (TMIN)

It is one of the contributing factors of climate change and it is positively related to wind speed. The resulting t-value was strong 3.955916 and statistically significant at 0.05 level of significance. Therefore wind speed may increase as minimum temperature rises. The correlation coefficient is 0.667672 between minimum temperature and wind speed that yields reasonable positive relationship.

These four climate change factors were combined to produce simple regression equation. The result is outlined in Table 1 in terms of parameter coefficient, overall significance of variables and coefficient of determination (R^2). The four variables account for 60 percent (0.606536) of the variability in the wind speed. Regression analysis is used to interpret the relationship between wind speed, humidity, precipitation, maximum temperature and minimum temperature. Now we proceed to co-integration analysis to investigate the long run relationship between these variables.

4.1 Co- integration Technique

Co-integration analysis has been done using following three-step procedure.

i. Test Unit Roots for individual series.
ii. Test co-integration if individual series are I(1).
iii. Estimate Error Correction Model (ECM) using lagged residual from Co-integration regression.

The first step involve in applying co-integration is to determine the order of integration of each variable/series (temperature both maximum and minimum, precipitation, humidity and wind speed). That is why, we performed the, Phillips Perron (PP) Unit root Test and Correlogram Test to test the null hypothesis of unit root against the alternative of stationary both at level and first differences of all the series. The results are presented below in Table 2:

Table-2. Stationary Test Results

Variables	Phillips Perron (PP) Unit Root Test Statistics								Correlogram Test	
	I(0)				I(1)					
	C		C & T		C		C & T		Non Stationary At	Stationary At
	t-values	Prob	t-values	Prob	t-values	Prob	t-values	Prob		
H	-3.5774	0.0076	-3.6113	0.0330	-17.334	0	-17.251	0	I(0)	I(1)
PP	-9.1476	0	-9.2788	0	-45.574	1E-04	-40.050	1E-04	I(0)	I(1)
V	-4.6356	2E-04	-4.6754	0.0013	-11.265	0	-11.218	0	I(0)	I(1)
Tmin	-4.5630	3E-04	-4.0352	0.0101	-4.557	3E-04	-4.573	0	I(0)	I(1)
Tmax	-3.2485	0.0196	-3.2465	0.0806	-4.2895	0	-4.3068	0	I(0)	I(1)

The results in Table 2 show that the null hypothesis of a unit root test is not rejected in all cases for the levels series. On the other hand, by differencing from these variables, they will be stationary. The Phillips Perron Unit root Test is indicating that all the variables are integrated at order I(1). As per the above table all series were non-stationary at level while stationary at first difference.

The OLS regression results were reported as soon as the functional form was finalized. Hence in the following Table 3, the results of regressing Wind speed (V) on its determining factors humidity (H), precipitation (PP), maximum temperature (T max) and minimum temperature (T min) as given as per the model.

Table-3. Regression Results – OLS estimation

Dependent Variable: V				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	10.87379	2.552517	4.260028	0.0000
PP	-0.000769	0.004113	-0.187064	0.8519
H	-0.098349	0.019941	-4.931999	0.0000
Tmin	0.387099	0.079487	4.869965	0.0000
Tmax	-0.275986	0.091971	-3.000801	0.0033
AR(1)	0.452923	0.090401	5.010180	0.0000
R-squared	0.678595	F-statistic		47.71637
Adjusted R-squared	0.664374	Prob(F-statistic)		0.000000
Durbin-Watson stat	2.087332			

Speed and maximum and minimum temperature, precipitation and humidity through co-integration analysis in case of Jacobabad. The results are presented below in Table 4:

Table-4. Unrestricted Co-integration Rank Test (Trance)

Hypothesized		**Trace**	**0.05**	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.552064	186.6818	88.80380	0.0000
At most 1 *	0.305980	94.32466	63.87610	0.0000
At most 2	0.237856	52.32043	42.91525	0.0045
At most 3	0.119027	21.08420	25.87211	0.1759
At most 4	0.055040	6.510458	12.51798	0.3984

Trace test indicates 2 co-integrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

The results of the above table confirmed the existence of a long term equilibrium relationship, as supported by the Johansen test. The null hypothesis of no co-integration among the variables is rejected; the trace statistics exceeds the critical value at 0.05 level of significance. It is possible to reject the null hypothesis in favor of alternative hypothesis of co-integration among variables.

$$\Delta V = \alpha_0 + \alpha_1 \Delta H + \alpha_2 \Delta PP + \alpha_3 \Delta Tmax + \alpha_4 \Delta Tmin + \alpha_5 \mu t_{-1} + \mu t \ldots\ldots 2$$

Therefore, we conclude that there are 2 co-integrating equations/relationships involving wind speed, humidity, and precipitation, minimum and maximum temperature.

The analysis concludes that a long run co-integrating relationship exists between all these variables. Since the existence of a long run relationship has been established between these variables, the short run dynamics of the model or the short run adjustment behavior of the variables can be established within an error correction model and help these variables to co-integrate in the long run. This is the third step, to estimate the Error Correction Model (ECM), lagged residual from co-integrated regression has been used. The regression equation for ECM is as follows:

$$\Delta V = \alpha_0 + \alpha_1 \Delta H + \alpha_2 \Delta PP + \alpha_3 \Delta Tmax + \alpha_4 \Delta Tmin + \alpha_5 \mu t_{-1} + \mu t \ldots\ldots 3$$

Where Δ is difference operator, α's are parameters, α_5= error correction term or speed of adjustment term and μ is the error term. The results of ECM are presented in Table 5.

$\Delta V = \alpha_0 + \alpha_1 \Delta H + \alpha_2 \Delta PP + \alpha_3 \Delta Tmax + \alpha_4 \Delta Tmin + \alpha_5 \mu t_{-1} + \mu t \ldots\ldots 4$

Where Δ is difference operator, α's are parameters, α_5= error correction term or speed of adjustment term and μ is the error term. The results of ECM are presented in Table 5.

All the variables have the correct theoretical signs except precipitation. It was found to be negative and insignificant in the given set of data. (See, Table C: Descriptive Statistics and Table D: Correlation Matrix in the appendices).

In second step after analyzing the individual properties of various series, we applied the Co-integration test by using Johansen multivariate co-integration Test. Since all the variables are integrated to the same order, we can test whether a long run relationship exists between wind

Table-5. Error Correction Mechanism

Dependent Variable: D(CPI)				
Variable	Coefficient	Std. Error	t-statistic	Prob.
C	-0.030565	0.127975	-0.238840	0.8117
D(H)	-0.092891	0.016697	-5.563450	0.0000
D(PP)	0.000567	0.003068	0.184956	0.8536

D(Tmax)	-0.361133	0.074465	-4.849707	0.0000
D(Tmin)	0.493307	0.070486	6.998604	0.0000
RES(-1)	-0.799795	0.184605	-4.332458	0.0000
AR(1)	0.155504	0.193008	0.805687	0.4222

Since the lagged residuals coefficient(α_5) from the co-integrating regression was found to be negative as per expectations & significant for the period under consideration suggesting that the short run discrepancies will convergence towards long run equilibrium after taking 79 percent adjustment to return to their equilibrium level & short run equilibrium would be attained in the same time period.

Granger Causality Test

Pair wise causality analysis has been carried out to explore the causal relationship between meteorological parameters. Table 6 presents the Pair wise Granger Causality Test (results with lags 2):

Table-6. Pair Wise Granger Causality Tests Results

H_O :	**No Causality**				
Cause	V	H	PP	Tmin	Tmax
V	-	0.05574	0.00244	0.00047	3.2E-07
H	4.4E-06	-	0.02260	0.05667	0.18826
PP	0.72064	0.75765	-	0.23742	0.02682
Tmin	1.1E-13	2.5E-11	0.13364	-	4.4E-12
Tmax	1.1E-08	2.3E-12	0.03529	0.04779	-

The table above provides information that Wind Speed is significantly affected by all the independent variables. Bi-directional causality is found between wind speed (V) and independent variables such as humidity (H), maximum temperature (T max) and minimum temperature (T min). The analysis also has been traced out unidirectional relationship between Wind speed and Precipitation. (See Table B, given in the appendices).

5. CONCLUSION AND POLICY IMPLICATIONS

The core objective of this study is to determine a long run stable relationship between wind speed, humidity, precipitation, maximum temperature and minimum temperature in Jacobabad, district of Sindh, Pakistan. We had a unique data set which consists of 10 years of mean monthly observed values of the required variables. In our empirical analysis, wind speed is being significantly affected by factors of climate change for the period under consideration from Janu-2001 to Dec-2010. The results of the analysis reveal that minimum temperature is positively related to wind speed whereas maximum temperature, humidity and precipitation contribute negatively to wind speed. In the short run, the coefficient of error correction term is -0.79 suggesting 79 percent short run adjustment towards long run equilibrium. The co-integration analysis and ECM (Error Correction Mechanism) tests suggests the existence of a stable long run relationship between wind speed and all climate change factors.

Incremental adaptation strategies and policies are needed to be implemented in a developing country like Pakistan, where impacts of climate change are potentially damaging because of scarcity of resources and infrastructure constraints. It must also be emphasized that climate change should become the integral issue in planning, designing and implementing development activities. It is more imperative for less developed areas like Jacobabad in Sindh.

Various aspects of climatic variations are needed to be under continuous focus in order to harmonize with correlated adaptability. The promotion of adaptation to climate change warrants establishment of new institutions and modification of existing ones. It would also involve modifying climate-sensitive infrastructures already planned or implemented or other long-term decisions that are sensitive to climate. The priority should be given to continued monitoring and analysis of variability and trends in key climatic elements which is the need of hour. New techniques for confident projection of regional climate change and its variability, including extreme events must be applied.

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Appendices

Tables

Table-A. Mean month wise data of variables

Month	Tmin	Tmax	PP	H	V
2001-01	6.6	23.4	0	60.3	2.9
2001-02	9.8	27.5	2.3	43.5	5.2
2001-03	15.7	33.1	1.2	39.7	5.9
2001-04	22.3	38.8	7.8	39.8	6.1
2001-05	29.1	45.2	0	42.7	7
2001-06	30	43.6	6	52.3	8.7
2001-07	29.6	39.4	3	64	6.1
2001-08	28.6	38.1	0	66	5.4
2001-09	26	37.3	0	60.7	3.8
2001-10	20	36.7	0	57.4	1.4
2001-11	14.2	31.3	0	56	1.5
2001-12	10.8	26.6	0	64.3	1.2
2002-01	7.7	23.9	1.2	54.7	3.3
2002-02	9.9	25.7	5	51.3	3.6
2002-03	17	33.3	5.6	44.7	3.9
2002-04	22.9	40.5	0	39.3	5.8
2002-05	28.8	46.6	0	27	10.6
2002-06	31	45.7	50	42.2	8.1
2002-07	29	41.3	0	56.9	7.2
2002-08	28.1	38	0	60.2	4.5
2002-09	26.6	36.3	0	63.9	4.9
2002-10	20.7	35.8	39.8	57.6	2.6
2002-11	15.1	30.4	20	55	1.3
2002-12	9.9	25.3	56.1	52.4	1.3
2003-01	8.5	24.2	0	55.9	1.7
2003-02	12.2	25.6	19.2	55.9	3.7
2003-03	17.1	31.4	2	47.8	8.6
2003-04	23.3	39.3	0	31.8	6.5
2003-05	27.2	43.6	0	28	9.2
2003-06	30.4	46	0	44.3	7
2003-07	29.3	38	134.8	67.8	6.1
2003-08	29	37.5	54	67.3	5.2
2003-09	26.8	36	0	71	5
2003-10	20.5	35.2	0	64.5	2.6
2003-11	13.1	29.7	0	53	1.8
2003-12	9.3	24.8	0	58.3	1.4
2004-01	9.6	22.5	13.4	58.8	3.6
2004-02	12.6	27.8	0	48.9	2.1

2004-03	18.2	36.3	0	26.2	5.5
2004-04	24.3	41.3	0	31.6	5.3
2004-05	28.1	44.5	0	30.4	4.9
2004-06	30.2	44.2	1.4	38.7	4.5
2004-07	29.5	39.9	5	56.8	3.3
2004-08	29.2	38.3	5	61.5	4.8
2004-09	26.1	36.4	0	63	3.8
2004-10	20.2	33	0.8	55.2	3.3
2004-11	14.4	30.9	0	53.5	1.3
2004-12	9.7	25.4	24	50.2	2
2005-01	8.3	21.3	6.1	55.6	1.9
2005-02	11.2	21.2	22.2	57.8	4.2
2005-03	18.3	30.4	5.1	56.7	3.4
2005-04	21.3	37.6	0	40.2	5.5
2005-05	26.9	42	6.3	35.8	5.3
2005-06	30.5	44.7	50.4	41.5	5.4
2005-07	30	39.8	15	57.7	4.8
2005-08	28.2	37.7	3.4	64.2	4.3
2005-09	27.4	36.7	10	63.5	5.2
2005-10	21.6	34.8	0	54	2.9
2005-11	15.4	30.3	0	58.3	1.8
2005-12	7.1	25.1	0	49.3	1.7
2006-01	6.6	22.5	0	45.3	2.9
2006-02	14.2	29.1	0	52.3	3.5
2006-03	16.8	31.1	8	48.2	4.9
2006-04	23.1	39.4	2	28.8	5.1
2006-05	29.5	46	0	33.5	6.5
2006-06	29.9	43.8	0	37.4	7.1
2006-07	30.8	41.5	2	56.8	6.3
2006-08	29.1	37.5	18.5	65.6	4.9
2006-09	27.6	36.7	24	65.2	3.4
2006-10	24.3	34.7	0	62.4	3.1
2006-11	16.9	29.5	0.7	59.9	4.4
2006-12	10.9	22.5	39	64.4	3
2007-01	8.2	23.1	0	54.2	2
2007-02	14	25.5	15.2	62.7	4.1
2007-03	17.4	29.8	53	54.1	3.3
2007-04	24.6	40.8	2	35.4	4.7
2007-05	28.3	43.9	0	32.6	6.4
2007-06	30.7	43	34	49.5	8.4
2007-07	30.2	39.1	59.8	60.2	4.7
2007-08	29.4	38.1	10	64	4.3
2007-09	28	37.3	8	63.9	3.9
2007-10	20.3	35.1	0	47.8	3.1
2007-11	15.5	31.5	39.8	59.3	1.1
2007-12	8.7	23.4	1.2	59.2	1.8
2008-01	6.9	20.1	3.6	50.1	3.4
2008-02	9	25.2	0.9	37.7	4.6
2008-03	18.4	35.1	0	40.1	3.8
2008-04	22.8	38.1	5.3	35.9	5.6
2008-05	28.3	44.1	10	29.6	5.7
2008-06	30.4	42.8	0	45.3	6.8
2008-07	29.9	40.2	0	55.5	5.4
2008-08	28.4	36.5	42	68.6	4.6
2008-09	27	36.1	1.2	66.6	3.9

2008-10	22.9	35.8	0	62.3	2.6
2008-11	14.3	30.9	0	43.9	2.9
2008-12	12	23.1	125.2	75.9	2.3
2009-01	11.1	21.3	5.2	70.2	3.2
2009-02	14	26.3	3	58.5	4.3
2009-03	18	31.6	28.4	54.6	4
2009-04	23	37.6	1.2	36.8	5.2
2009-05	29.5	45.3	0	25.5	5.5
2009-06	29.4	43.4	51.06	32.6	6.9
2009-07	30	41.7	32	52.7	5
2009-08	28.8	38.3	0	64.8	4.9
2009-09	26.6	37	50	63.2	4.3
2009-10	19.4	35	0	46.4	3.4
2009-11	13	29.1	0	47.6	1.4
2009-12	9.3	24.5	1.2	51.6	2
2010-01	7.9	23.1	0	62.6	1.7
2010-02	10.3	25.9	1.2	45.7	3.5
2010-03	18.1	35.7	0	38.9	4.3
2010-04	23.8	41.9	9.2	26	5.8
2010-05	27.9	45.4	4	22.7	6.9
2010-06	30.9	45.1	17	44.6	11.2
2010-07	29.9	40.1	193.8	62.7	6.4
2010-08	27.8	36.5	71	79.1	4.7
2010-09	25	35.1	0	65.6	3.4
2010-10	23.8	34.6	0	67.5	2.4
2010-11	15.2	29.5	0	63.4	0.8
2010-12	8.3	23.5	0	68.4	1.8

Source: Pakistan Meteorological Department

Table B: Granger Causality Test

Pairwise Granger Causality Tests

Date: 02/24/12   Time: 01:01

Sample: 2001M01 2010M12

Lags: 2

Null Hypothesis:	Obs	F-Statistic	Probability
PP does not Granger Cause H	118	0.27822	0.75765
H does not Granger Cause PP		3.91965	0.02260
TMAX does not Granger Cause H	118	34.2852	2.3E-12
H does not Granger Cause TMAX		1.69486	0.18826
TMIN does not Granger Cause H	118	30.5294	2.5E-11
H does not Granger Cause TMIN		2.94472	0.05667
V does not Granger Cause H	118	2.96206	0.05574
H does not Granger Cause V		13.7878	4.4E-06
TMAX does not Granger Cause PP	118	3.44507	0.03529
PP does not Granger Cause TMAX		3.73685	0.02682
TMIN does not Granger Cause PP	118	2.04887	0.13364
PP does not Granger Cause TMIN		1.45637	0.23742
V does not Granger Cause PP	118	6.34643	0.00244
PP does not Granger Cause V		0.32857	0.72064
TMIN does not Granger Cause TMAX	118	33.2435	4.4E-12
TMAX does not Granger Cause TMIN		3.12420	0.04779

V does not Granger Cause TMAX	118	17.1212	3.2E-07
TMAX does not Granger Cause V		21.6385	1.1E-08
V does not Granger Cause TMIN	118	8.21062	0.00047
TMIN does not Granger Cause V		39.3567	1.1E-13

Table-C. Descriptive Statistics

	H	PP	TMAX	TMIN	V
Mean	51.94000	12.91467	34.48000	20.83917	4.328333
Median	54.65000	1.200000	36.05000	22.85000	4.300000
Maximum	79.10000	193.8000	46.60000	31.00000	11.20000
Minimum	22.70000	0.000000	20.10000	6.600000	0.800000
Std. Dev.	12.50170	27.97268	7.255547	8.005128	2.044800
Skewness	-0.44901	3.788452	-0.26015	-0.32624	0.652779
Kurtosis	2.392716	20.59069	1.964142	1.629973	3.623802
Jarque-Bera	5.876094	1834.209	6.718608	11.51355	10.46806
Probability	0.052969	0.000000	0.034759	0.003161	0.005332
Sum	6232.800	1549.760	4137.600	2500.700	519.4000
Sum Sq. Dev.	18598.81	93114.06	6264.512	7625.766	497.5637
Observations	120	120	120	120	120

Table-D. Correlation Matrix

	H	PP	TMAX	TMIN	V
H	1.000000	0.275974	-0.413664	-0.115164	-0.446641
PP	0.275974	1.000000	0.044606	0.161041	0.086550
TMAX	-0.413664	0.044606	1.000000	0.933828	0.715966
TMIN	-0.115164	0.161041	0.933828	1.000000	0.667672
V	-0.446641	0.086550	0.715966	0.667672	1.000000

Figures

Figure-A. Variation in Climatic Condition of Pakistan over a year (month wise)

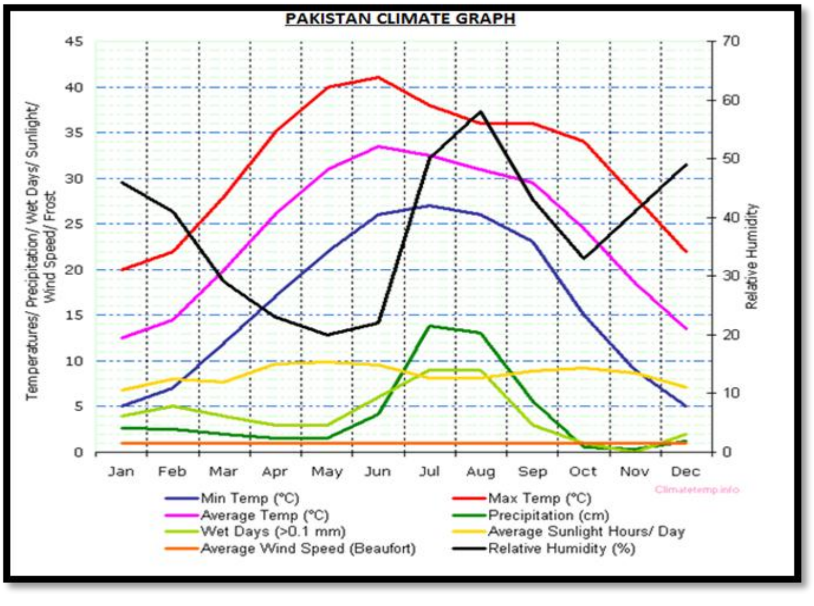

Figure-B. Variation in Climatic Condition of Pakistan over a year (month wise)

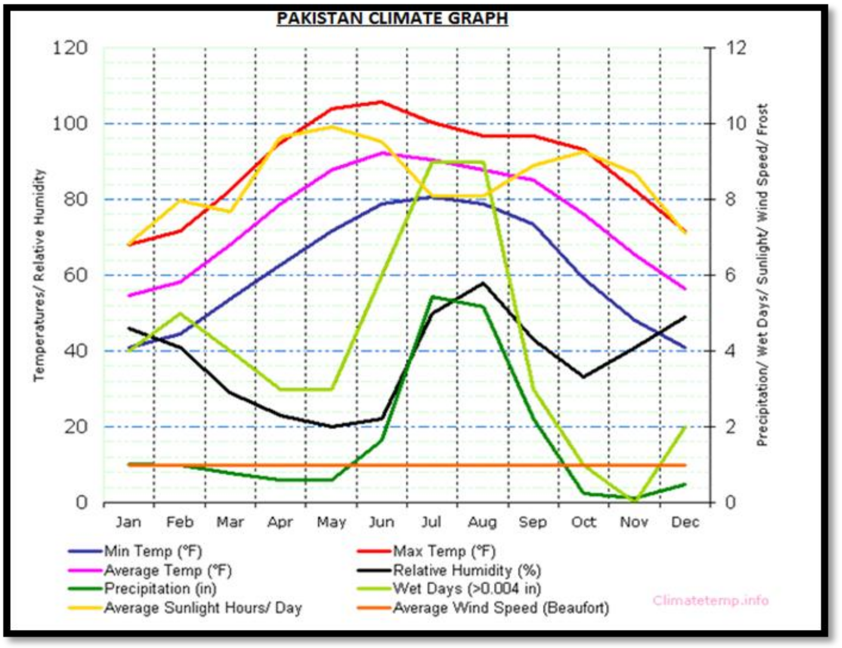

Figure-C. Variation in Climatic Condition of Jacobabad over a year (month wise)

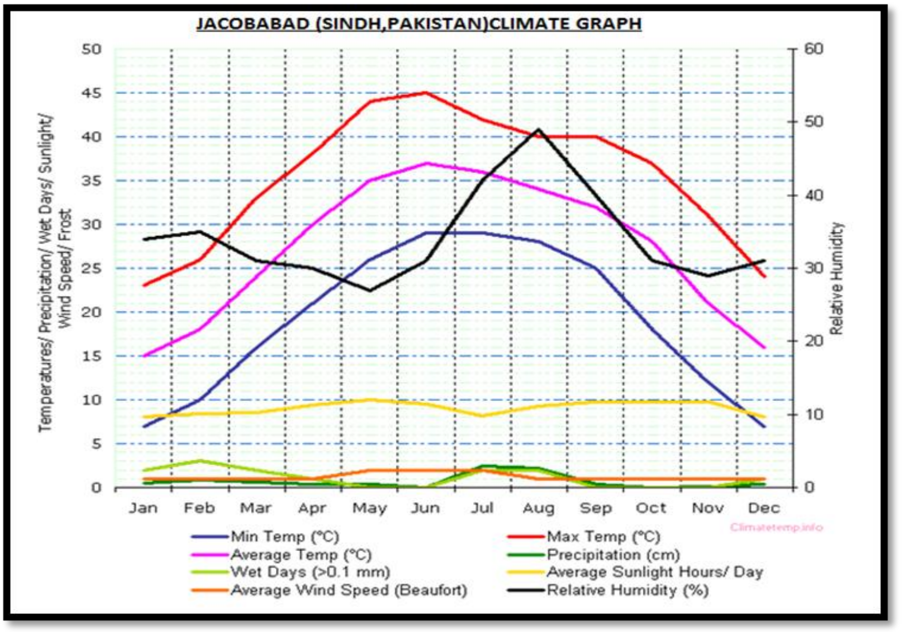

Figure-D. Variation in Climatic Condition of Jacobabad over a year (month wise)

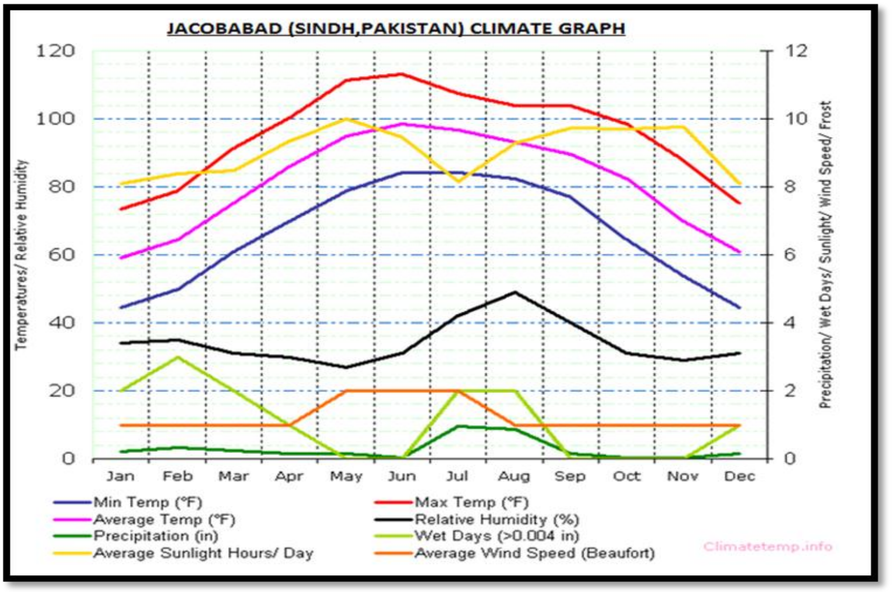

Figure-E. Average temperature of Jacobabad during a year (month wise)

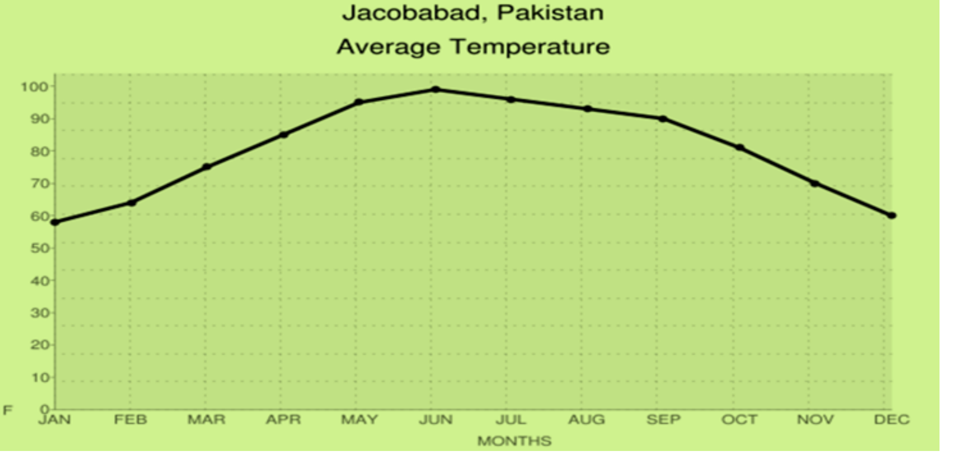

Figure-F. Average high temperature of Jacobabad during a year (month wise)

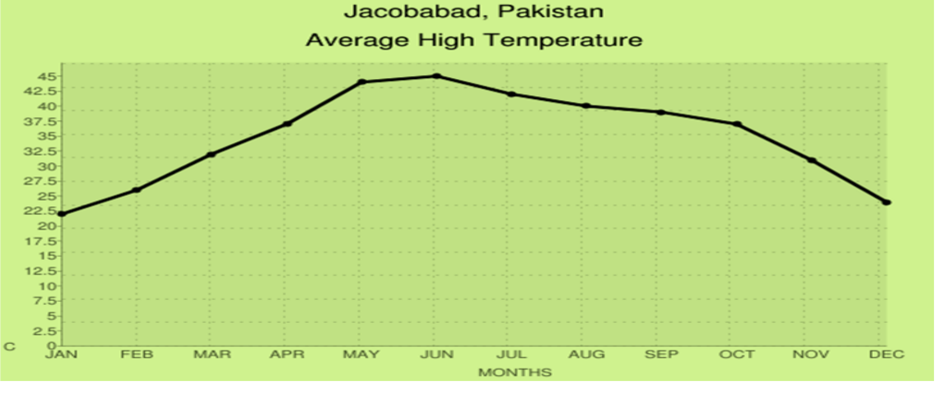

Figure-E. Average low temperature of Jacobabad during a year (month wise)

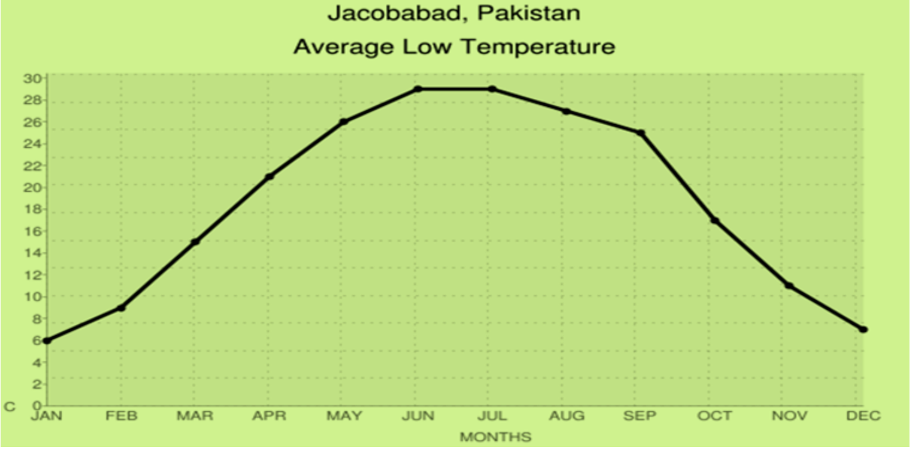

Figure-F. Average precipitation of Jacobabad during a year (month wise)

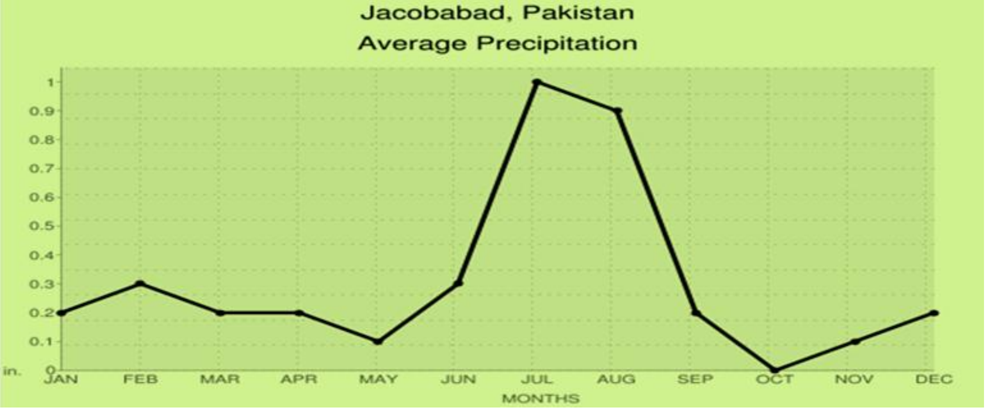

Figure-G. Average relative humidity of Jacobabad during a year (month wise)

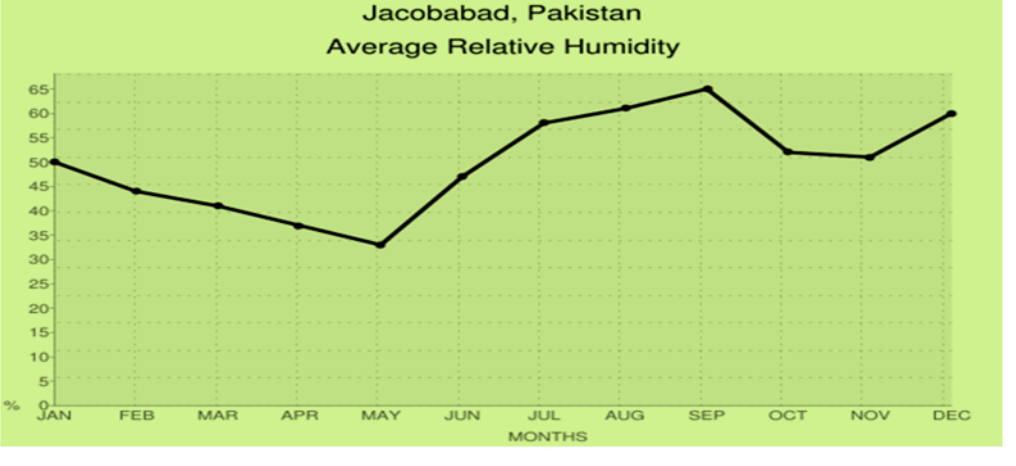

Figure-H. Graphs of Humidity, Precipitation, Wind Speed, Maximum & Minimum Temperature