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Principal Component Analysis to Explore Climate variability of Pakistan

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ABSTRACT

Various studies have reported that global warming causes unstable climate and many serious impact to physical environment and public health. The climatic or environmental structure data was processed by coding, editing, tabulating, recoding, restructuring in terms of re-tabulating was carried out.Applying different statistical methods, techniques and procedures for the evaluation.To study the global warming effects on overall environmental conditions of Pakistan. Annual data of maximum and minimum temperature of four provincial capitals have been taken from 1947 to 2012. The data isconsideredas representative environmental components, use for further analysis. Time series plot shows difference of behaviors in maximum and minimum temperatures of Karachi and Lahore while bend of Quetta indicates increasing trend and Peshawar shows flat and smooth. The fit of trend line, maximum temperature of Karachi, has significant regression coefficient b = 0.0504 with p-value 0.000 and R^2equal to 70.2%. The minimum temperature has decreasing trend but it is insignificant. The data of Lahore shows decreasing and increasing trends for maximum and minimum temperatures respectively shows the differences reducing with the passage of time and expected to have cooler weather than the past. Quetta and Peshawar temperatures fit of trend lines and graphs, revealed that both cities getting warmer with the passage of time.Principal component analysis is performed for the purpose of finding if there is/are any general environmental factor/structure which could be considered as Pakistani climate.

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The PC1 is constructed by six manifest variables and represent the environmental factor called as "Index of Pakistan weather". Explain 42.74% of the total variation. The time series plot of this index seems to have increasing trend. The PC2 represents the temperature of Karachi, Quetta and Lahore. PC3 is the contrast between of minimum and maximum temperature. PC4 represents complex contrast between maximum and minimum temperature explain 9.0% of total variation of temperature. PC5 represent contrast between Karachi and Peshawar weather and its contribution to the total or overall variation of Pakistani weather is only 3.5%.

Key Words—   Global warming, Environmental condition, Fit of trend, Principal component analysis.

I.   Introduction

The human activity on environmental structure of earth especially has become the priority matter. Change in climate causes transmission and spread of viral diseases which become a health burden to the developing countries like Pakistan[1][2].

Climate is a composite term and this refers to environmental conditions over a period of time. Climate is a general condition of temperature, humidity, atmospheric pressure, wind speed and rainfall of a place[3]. These elements act as climatic factors. Climate is an important subject of scientific enquiry, particularly as it has such an impact on vegetation, soil and health etc. Its importance increases manifold because of its influence on human life. Extreme temperatures, whether hot or cold affect human beings, crops, animals and mosquitoes lifecycle. In short, there are many ways in which climate affects on our daily lives.

Pakistan is mainly a dry region with great extremes of elevation, topography and temperature, where climate varies from region to region, temperatures far below freezing point to equatorial heat. The coastal south has arid conditions, monsoon season with adequate rainfall, and a dry season with less rainfall.

Since last six decades the environmental structure of Pakistan has been bifurcated in to pre and post industrial era. After the industrial revolutions amount of green house gas in the atmosphere like carbon dioxide (30%), methane (145%)and nitrous oxide (15%) has significantly increased.The growing rate of fossil fuel combustion in major cities of Pakistan like, Karachi, Lahore, Peshawar and Quetta increases the temperature [4].

I. Data and Methodology

To study overall environment of Pakistan especially urban Pakistan, we have selected four provincial capitals, i.e. Karachi, Quetta, Lahore and Peshawar as representatives of Pakistan. Their location and elevation from sea are given in Table 1. We have taken the annual data of minimum and maximum temperature from 1947 to 2012 provided by Pakistan metrological department, as representative environmental components use for further analysis.

Time series analysis is used to see the differences in behavior of temperatures.Principal component analysis (PCA) is performed for the purpose of finding if there is/are any general environmental factor/ structure which could be considered as Pakistani climate.

Table 1: Geographical and temperatures records of Four Major Cities of Pakistan.

	Karachi	Quetta	Peshawar	Lahore
Latitude	24° 48'	30° 11' 13"	34° 00' 30"	31° 15'
Longitude	N(24.8)	N(30.1872200)	N(34.0083)	N(31.0.25)
Elevation	66° 59 E	67° 00' 45"	71° 34' 48"	71° 01'
	(66.983)	E(67.0125)	E(71.58)	E(71.0167)
	8m=	1671m=5482ft	306m=1003ft	217m=712ft
	26.4ft			
Summer (Temperatures)	23.4°C– 36.4°C	9.5°C– 37.9°C	20.5°C–42.7°C	22.2°C-41.8°C
Winter (Temperatures)	8.4°C– 33.7°C	-6.2°C– 25.5°C	2.2°C–26.8°C	4.8°C–31.3°C

Source: Data provided by Metrological department of Pakistan.

III. Results and Discussion

A. Time series Analysis

We have used time series analysis to plot minimum and maximum against time from 1947 to 2012. Figure 1a, Figure 1b, Figure 1c and Figure 1d are plots for Karachi, Quetta, Peshawar and Lahore data respectively. Looking at these figures one can notice that in case of Karachi the bend between maximum and minimum temperature is getting wider as time (year) passes, but in case of Lahore this bend getting thinner with the passage of time. Figure 1bshows the plot of Quetta minimum temperature indicates an increasing trend, from 1971 to onwards the bend become flat and it takes the value closer to the values of 1950s and 1960s. Where thebend of Peshawar is smooth and flat.

Table 2: Fitting trend lines of maximum temperature and minimum temperature

Station	Climatic variable	Model Equation	R^2	Adj- R^2
Karachi	Max-temp	$Y_t = 38.10 + 0.05 MaxtempK$ (0.000) (0.000)	0.701~70.1%	0.69
	Min-temp	$Y_t = 20.35 - 0.006 MintempK$ (0.000) (0.357)	0.013 ~ 0.13%	-0.0021
Quetta	Max-temp	$Y_t = 141.35 + 0.042 MaxtempQ$ (0.000) (0.000)	0.466~46.6%	0.457
	Min-temp	$Y_t = 76.24 + 0.0248 MintempQ$ (0.0073) (0.0161)	0.087~8.7%	0.0728
Peshawar	Max-temp	$Y_t = 61.933 + 0.0118 MaxtempP$ (0.000) (0.000)	0.118~11.8%	0.104
	Min-temp	$Y_t = 53.103 + 0.0135 MintempP$ (0.000) (0.0015)	0.1462~14.6%	0.1329
Lahore	Max-temp	$Y_t = -41.70 - 0.015 MaxtempL$ (0.0428) (0.0006)	0.168 ~ 16.8%	0.155
	Min-temp	$Y_t = 213.39 + 0.0417 MintempL$ (0.000) (0.000)	0.645 ~ 64.5%	0.640

Max-Temp: Maximum Temperature, Min-Temp: Minimum Temperature
MaxtempK : Karachi Maximum Temperature, MintempK : Karachi Minimum Temperature
MaxtempQ : Quetta Maximum Temperature, MintempQ : Quetta Minimum Temperature
MaxtempP: Peshawar Maximum Temperature, MintempP : Peshawar Minimum Temperature
MaxtempL : Lahore Maximum Temperature, MintempL: : Lahore Minimum Temperature

Table 2 shows the results of fitting linear time series trend on maximum (maxtempK) temperature and minimum (mintempK) temperatures of Karachi from (1947 to 2012) and graphs are shown in Figure 2a and Figure 2b. The fit of trend line, maximum temperature of Karachi, has significant regression coefficient b = 0.0504 with p-value 0.000 the model is also very good representative of data with R^2 equal to 70.1%. From the result one can say that, on average after every 10 years maximum temperature increases by 0.5 °C.

The minimum temperature (mintempK) has decreasing trend but it is insignificant. It means Karachi is becoming warmer by the passage of time; the reason may be that the Karachi is a metropolitan city having large numbers of vehicles plying on the road and having large industrial area while other station does not show increasing temperature. Figure 1b of Quetta shows sudden increase in maximum and sudden decrease in minimum temperature in 1970. The fit of trend line of maximum temperature of Quetta, has significant regression co-efficient 0.042 with p-value 0.000 suggest that model is significant and good representative of data with R^2 equal to 0.466. The model revealed that, on average after every 10 years maximum temperature of Quetta increases by 0.42% which is 1% less than maximum temperature of Karachi shows that temperature of Quetta is cooler as compare to Karachi. The minimum temperature of Quetta also shows increasing trend, but its R^2 is very small indicate that model is not good representative of data.

Figure 3a of Peshawar maximum temperature shows increasing trend, it is interesting to note that in early period the maximum temperature of Peshawar was below 30 °C, however with the passage of time a systematic increase in its maximum temperature from 2°C to 3°C. This rise in temperature indicates warmer climatic condition of Peshawar, this rise may be due to global warming; however we can not over rule other factors which foster the maximum temperature of Peshawar. Figure 3b of Peshawar minimum temperature also supports our finding about rise in temperature of Peshawar. Figure 3b clearly indicates increasing trend in minimum temperature. Interestingly in last two decades minimum temperature of Peshawar has increased by 3°C. Both maximum temperature and minimum temperature graph of Peshawar reveals that as the time passes climate of Peshawar become warmer, this indicate alarming situation for the concern health authorities and decision makers. The fit of trend line of maximum temperature of Peshawar having significant co-efficient b= 0.0118 and minimum temperature has also significant coefficient b = 0.0135, their regression coefficients shows that minimum temperature of Peshawar increasing rapidly as compared to maximum temperature, however small value of R^2 shows that model is not good representative of data.

Table 2 give result fitting trend lines of maximum temperature and minimum temperature respectively of Lahore. Their graphs are given in Figure 5a and Figure 5b. It can be seen from this table and the two graphs that the maximum temperature of Lahore has a decreasing trend and minimum temperature show an increasing trend. This indicates that the difference between maximum and minimum is reducing by the passage of time, therefore one may conclude that Lahore is expected have cooler weather than in the past.

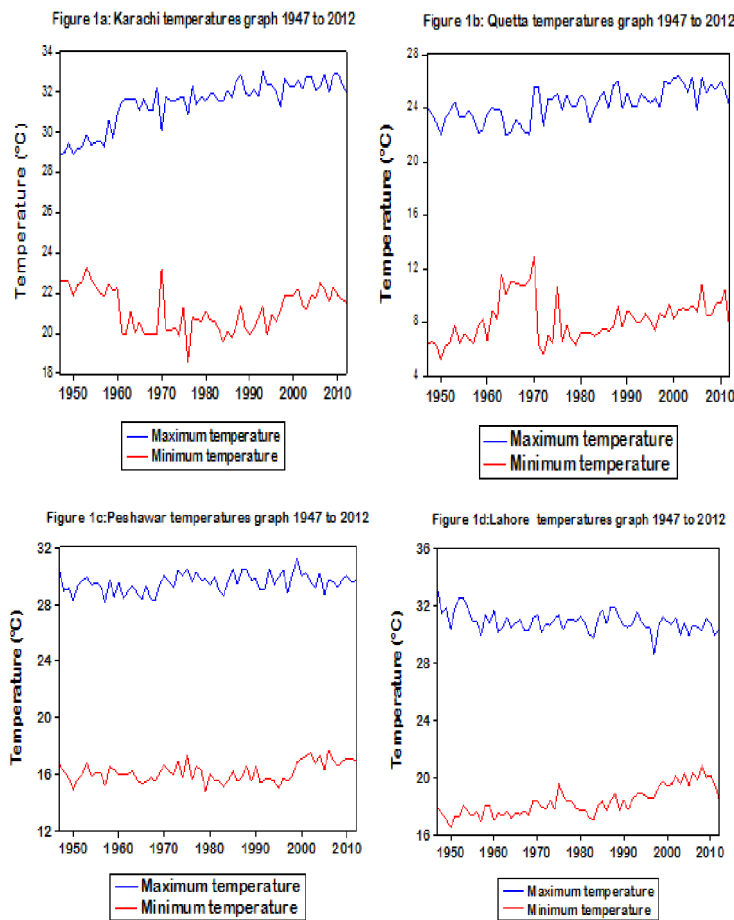Figure (1a to 1d) Yearly maximum and minimum temperatures graphs 1947 to 2012

Figure 1a: Karachi temperatures graph 1947 to 2012

Figure 1b: Quetta temperatures graph 1947 to 2012

Figure 1c: Peshawar temperatures graph 1947 to 2012

Figure 1d: Lahore temperatures graph 1947 to 2012

Figure (2a & 2b): Fitted trend graphs of Karachi maximum and
minimum temperatures 1947 to 2012

Figure 2a: Fitted trend graph of Karachi Max-temp 1947 to 2012   Figure 2b: Fitted trend graph of Karachi Min-temp 1947 to 2012
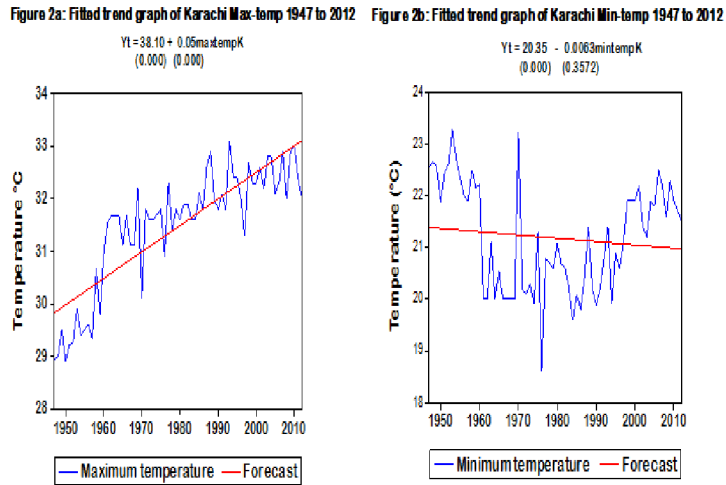

Figure (3a & 3b): Fitted trend graphs of Quetta maximum and
minimum temperatures 1947 to 2012

Figure (4a & 4b): Fitted trend graphs of Peshawar maximum and
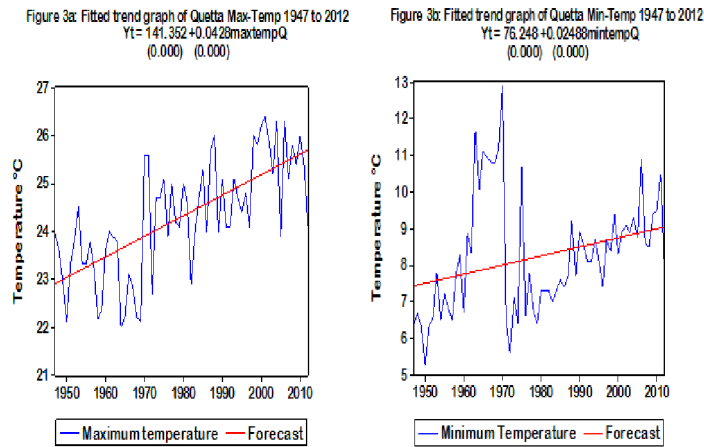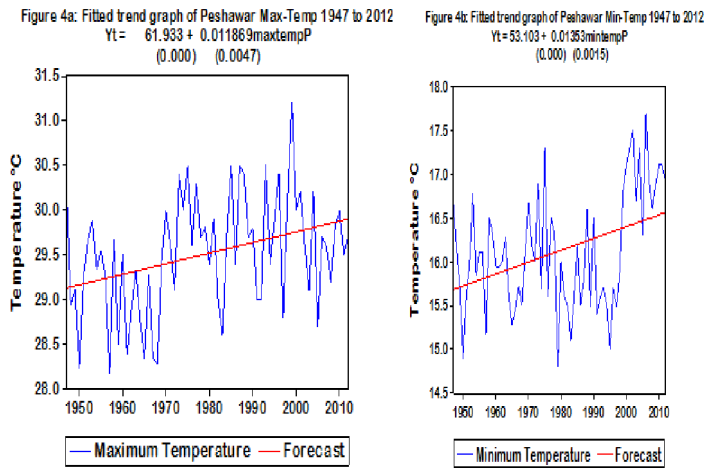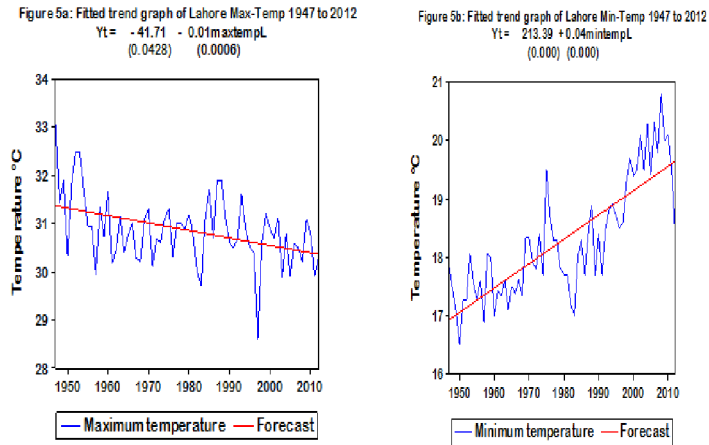minimum temperatures 1947 to 2012

Figure 4a: Fitted trend graph of Peshawar Max-Temp 1947 to 2012
Yt= 61.933 + 0.011869maxtempP
(0.000)   (0.0047)

Figure 4b: Fitted trend graph of Peshawar Min-Temp 1947 to 2012
Yt = 53.103 + 0.01353mintempP
(0.000) (0.0015)

Figure (5a & 5b): Fitted trend graphs of Lahore maximum and
minimum temperatures 1947 to 2012

Figure 5a: Fitted trend graph of Lahore Max-Temp 1947 to 2012
Yt= - 41.71 - 0.01maxtempL
(0.0428)   (0.0006)

Figure 5b: Fitted trend graph of Lahore Min-Temp 1947 to 2012
Yt= 213.39 + 0.04mintempL
(0.000) (0.000)

B. Exploration of Environmental Components byPrincipal component analysis

Principal component analysis is performed for the purpose of finding if there is/are any general environmental factor/structure which could be considered as Pakistani climate. We considered the maximum temperature and minimum temperature of four stations as manifest variables for "Pakistan climatic factors". PC method is appliedbecause assumption of distribution is not required. This method finds uncorrelated linear combinations with maximize variances {V (PC1)> V (PC2) > . . . V(PCK)} [4],[5]. The correlation matrix for eigen analysis to remove the effect of size of the data values [6], [7].We are going to interpret and comment on first five PCs only.Since PC1 is constructed bythe six manifest variables [(maxtempK +mintempQ) + (maxL+ minL) + (maxP + minP)]this components has representation of all the station. Therefore this environmental factor may be called as "Index of Pakistan weather" which explains 42.74% of the total variation. The time series plot of this index seems to have increasing trend.

Table 3: Principal component analysis of four major cities (1947-2012)

PCs	1947-2012		
	Linear combination	*Label*	*%*
PC1	0.9(MxQ+MxL)+	**IPW**	42.74
PC2	0.8MnP+0.7MxP	**CKQLTs**	24.20
PC3	0.8MxQ+ 0.7MnK – 0.6MxK-	**CMxMnTs**	14.14
PC4	0.4MnL	**CxCMxMnTs**	9.00
PC5	0.59 (MnL +MnK) -0.5MnP	**CKPW**	3.5
	0.6MnL+ 0.5MnQ		

IPW: Index of Pakistani weather,**CKQLTs**: Combination of Karachi, Quetta and Lahore temperatures
CMxMnTs: Contrast between minimum and maximum temperatures ,
CxCMxMnTs: Complex contrast between
minimum and maximum temperatures, **CKPW**: Contrast between Karachi and Peshawar weather

The PC2 [(maxQ+mink)- (maxk+minL)], represents the temperature of Karachi, Quetta and Lahore.PC3 is very interesting that the sign of all factors loadings of maximum temperature is negative, while all factors loadings for minimum temperature is positive and the percentage of variation explains by this component is 14.14%, this variation in Pakistan occurs due to contrast between minimum and maximum temperature.

PC4 represents complex contrast between maximum and minimum temperature and explain 9.0% of total variation of temperature.

PC5 represents contrast between Karachi and Peshawar weather and its contribution to the total or overall variation of Pakistani weather is only 3.5%. From the above analysis, we come to the conclusion that two important factor which can be considered as indices of Pakistan temperatures are PC1 and PC3. The graph of PC2, PC3, PC4 and PC5 are indicative of some sort of cyclic variation needs further depth study.

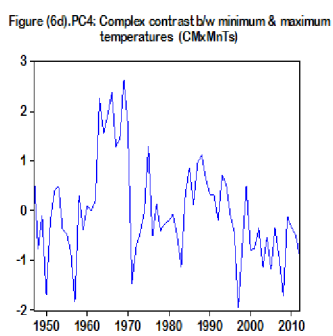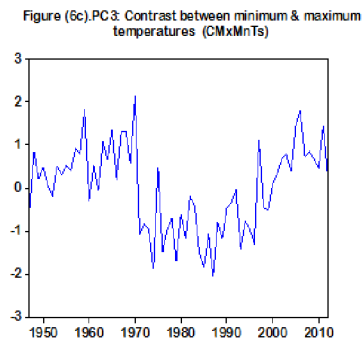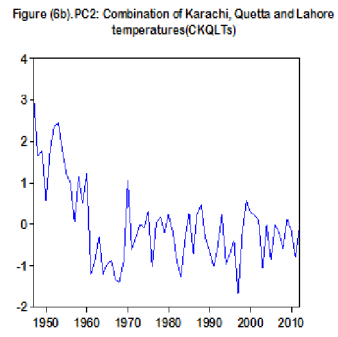Figure (6a to 6e): PCs graph of maximum and minimum
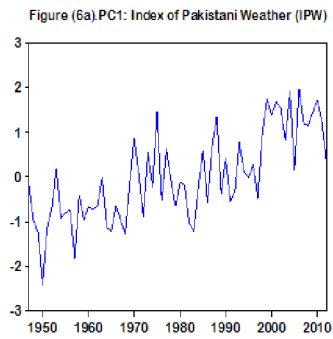temperatures 1947 to 2012

Figure (6a).PC1: Index of Pakistani Weather (IPW)

Figure (6b).PC2: Combination of Karachi, Quetta and Lahore temperatures(CKQLTs)

Figure (6c).PC3: Contrast between minimum & maximum temperatures (CMxMnTs)

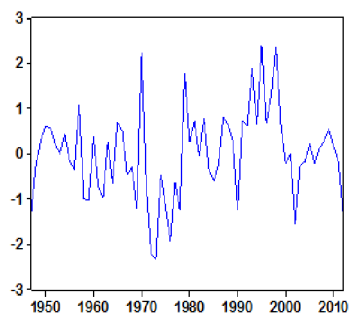Figure (6d).PC4: Complex contrast b/w minimum & maximum temperatures (CMxMnTs)

Figure (6e).PC5: Contrast b/w Karachi &Peshawar weather(CKPW)

IV. Conclusion and Recommendations

Time series analysis revealed that on average after every 10 years maximum temperature of Karachi increases by 0.5 °C. The minimum temperature has decreasing trend but it is insignificant. It means Karachi is becoming warmer by the passage of time. For the Quetta on average after every 10 years maximum temperature of Quetta increases by 0.42% which is 1% less than maximum temperature of Karachi, shows that temperature of Quetta is cooler as compare to Karachi. The regression coefficient of minimum temperature of Peshawar shows it increasing rapidly as compare to maximum temperature. The graph of Lahore indicates that the difference between maximum and minimum is reducing by the passage of time. We may conclude that due to effect of global warming overall temperature of Karachi and Peshawar is increasing with the passage of time, while Lahore and Quetta is expected to have cooler weather than in the past.

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