J. Sc. & Tech. Univ. Peshawar, 2010, 34 (1) 59-72.

TEMPERATURE TRENDS IN DIFFERENT CLIMATIC ZONES OF PAKISTAN

SALMA[1], S. SHAFIQUR REHMAN[1], MUSHTAQ ALI SHAH[2] & SAREER BADSHAH[3]

[1]*Department of Environmental Sciences, University of Peshawar*
[2]*Regional Meteorological Centre, Peshawar*
[3]*Department of Statistics, Islamia College University, Peshawar*

Abstract: In this study, variability and the trend of mean minimum and mean maximum temperatures in different climatic zones of Pakistan have been analyzed. For the determination of trend in temperature 30 years data (1976-2005) from 30 meteorological observatories from different parts of the country have been selected by using the Kööpen climate classification. The analysis has shown a mixture of trends. The climate zone covering in high mountains in North, North West and West of the country show no trends whereas most of the plain and coastal areas show a positive trend because of big cities and towns with huge population, congested traffic, lack of developed infrastructure, mega industries and environmental degradation. However for the whole country a positive trend of 0.11°C/decade in the mean temperature, 0.1°C/decade in minimum temperature and 0.12°C/decade in maximum temperature were found during the entire period of analysis. This calculated temperature trend in Pakistan (0.11°C per decade) is less than the global temperature trend, but it has significant impacts on the society as observed during the recent years. The human induced activities responsible for increasing temperatures in Pakistan, if not minimized, the situation may further worsen in the near future and may have great negative impacts on agriculture, water supply and quality, health, socio-economic and environmental conditions.

Introduction

Most of the world's scientists accept the fact, that climate of the globe is going towards a warmer trend. This can be observed from the air, surface and ocean temperatures (IPCC, 2007). Climate change, as one of the most important global challenges facing humanity, could cause far-reaching environmental effects. Rising of sea levels around the world, frequent and uneven rainfall distribution, flash floods, droughts, glacial melting (Alam, 2009), tropical cyclones and hurricanes, severe dust storms, prolonged dry and cold spells etc, are all adverse consequences of that change (Karl and Trenberth, 2006). The observed increase in temperature has great implications on food productions, natural eco-systems, loss of biodiversity, altered fresh water supply and quality and increase health risks (Dai et al., 1999; Przybylak, 2000; Braganza et al., 2004; Alam, 2009). Mozaharul et al (2007), in their report, notify that increase in the intensities and frequencies of these extreme events will further lead to hunger, susceptibility to diseases, economic losses, human survival and well being of current as well as future generations.

The observed increase in temperature is mainly due to combustion of fossil fuels (oil, natural gas, and petrol) for industry and transport, industrialization, fast growing population and deforestation for agriculture and unplanned urban developments. According to IPCC (2001) report, it is evident that due to the human activities, the earth's green house effect has been intensifying since the later part of the 19th century and global climate will remain warm over the next decades of the 21st century (Karl and Trenberth, 2006). The increased use of fossil fuels has raised the level of carbon dioxide (CO_2) in the atmosphere, and the destruction of natural vegetation has prevented the environment from restoring the balance. Level of other GHG including methane (CH_4) nitrous oxide (NO_2) and ozone (O_3) has also been rising and the net result has been a gradual global warming (Goreau, 1992). According to the IPCC report (IPCC, 2001) emission of GHG are increasing and not remaining stable due to increased energy consumption as a result of population growth, industrialization and less robust human health, social security and basic infrastructure, especially in the developing countries.

Since the late 19th century, average global surface temperature has been recorded with an increase of approximately 0.6°C, with 95% confidence intervals of 0.4 and 0.8°C and future change is expected in the order of 1.4 °C – 5.8 °C over the 21st century (Folland et al, 2000). This increase has been noted in two periods, from 1910-1945 and 1976 to 2011 (Jones et al., 2001). The warming rate since 1976, 0.17°C/decade, has been slightly larger than the rate of warming during the 1910-1945 (IPCC, 2007). However, changes in climate are already being observed—the last 60 years were the warmest in the last 1000 years (Wassmann and Dobermann, 2007). The most recent warming period is faster over land as compared to the oceans warming (Christy et al, 2000). In addition, the 1990 was the warmest decade (Palutikof, 2001) whereas 2005 was the warmest year followed by 2006 and 2007 (IPCC 2007), since the start of the global mean temperature record from 1856 (Jones and Moberg, 2003).

The studies of Mann and Jones (2003) have shown that the mean surface temperature over the past two millennia detecting that late 20th century warmth is unprecedented and attributed to the anthropogenic forcing of climate (Thorne et al, 2003). Global temperature data covering the meteorological year from December 2004 through November 2005 show 2005 tied with 1998 as the hottest year on record (Hansen et al, 2005, and WMO, 2005). Similarly, recent researches from NOAA and NASA showed that 2010 equal to 2005 as the earth's warmest year on record over the lat 131 years (instrumented monitoring stations date back to 1880).

According to US global change research, warmer temperatures are likely to increase evaporation from land surface and cause severe rains. In the mid/high latitudes of the Northern Hemisphere, an increase of 0.51 percent per decade of precipitation has been recorded over the course of the twentieth century (IPCC, 2001). Analysis of the frequency of heavy rainfall events indicates a probability of over 90 percent that a 2-4 percent increase in frequency has occurred during the past 50 years (IPCC, 2001).

Besides, many studies (WMO, 2010; Cavallo and Ilan Noy, 2010; Peduzzi, 2005; Munich, 2002; International Federation of the Red Cross and Red Crescent Societies, 1999; Erbach and Gaudet, 1998) have been conducted on the occurrence and intensities of extreme weather events. According to these reports, temperature rising and frequent rainfall are the main factors of economic damage in the world. According to Munich report (2002) extreme climatic events took heaviest toll on human life and high damage costs, resulting in more than 725,000 lives and economic costs of US$ 700 billion worldwide during the second half of the 20th century. The same has been mentioned by Mirza (2003) in his report about the economic damage occurring in the developing countries due to extreme weather events. Around US$ 35 billion have been spent annually during the past decade. Many scientists from different parts of the world have consensus that extreme weather events are due to global warming and it is assumed that the frequency of occurrence of extreme events will increase in future with increase in the global temperature as in IPCC report (Shah, 2008).

Like other developing countries, Pakistan is also facing extreme weather events. According to recently published data by Pakistan Meteorological Department, in 1998 to 2001 severe droughts occurred in the southern and central parts of the country (Awan, 2002). Heavy rainfall of 1300 mm, far above the normal figure of 900 mm was recorded in Balakot in the monsoon of 2006. Last decade, in 1992, worst flood in Jhelum River. Severe cyclonic storm in 1999, hit the coastal areas of Pakistan and India. Similarly temperature up to 43° C has been recorded for more than a week in Chitral and other cities of northern areas in June 2005. While minimum temperature dropped as low as -12°C in Parachinar, Kalam, Malamjaba and Dir for consecutive ten days in the 1st week of Jan 2007 whereas their normal is -1°C to -2°C. Pakistan has faced super flood in July 2010, after heavy monsoon rainfall which hit the Khyber Pakhtunkhwa, Sindh, Punjab and many parts of Balochistan in over eighty years period. In this worst flood, an estimated 2000 people wer[illegible] and over 700,000 homes has been destroyed (Encyclopedia, 2011).

After reviewing the adverse consequences of rapidly changing climate, it is necessary to determine the existence of any significant trends in the minimum, maximum and mean temperature of Pakistan. Determination of recent trends over the last three decades, after comparing with the global temperature trends, indicate that the consequences of climate change have already been noted in Pakistan.

Study area

Pakistan experiences diversified climate due to its large latitudinal extent from north to south and also due to large variations in the topography. Pakistan is geographically situated approximately between 24-37° N latitudes and 62-75° E longitudes in the western zone of south Asia. The country is bordered by Iran on the west, India in the east, Afghanistan in the northwest, China in the north and the Arabian Sea in the south. The plains of Pakistan, drained by the river Indus and its tributaries, are surrounded by many mountain ranges in the north, northwest and the west (Rodo, 2003). High mountain ranges comprise of Himalaya and Karakoram with a small part of the Hindukush located in the north of the country. Pakistan is the only country where these three great mountain ranges meet. Besides the northern mountains, there are western highlands separated by Kabul river from the mountainous north and consist of series of dry and lower hills. Some parts of Balochistan and Sindh provinces constitute deserts. The country occupies a total geographical area of 803943 km^2 (Pant and Rupa Kumar, 1997). List of Meteorological stations along with their location and climate are shown in Table 1.

Table 1. List of Meteorological stations along with their location and climate.

	Station	WMO Ref	Altitude (m)	Latitude	Longitude	Zone and Climate
1	Astor	41520	2168	35°20'N	74° 54'E	**Zone 1,** Cold climate and high mountains
2	Chilas	41519	1250	35° 25'N	74° 06'E	
3	Chitral	41506	1499	35°51'N	71° 50'E	
4	Dir	41508	1375	35° 12'N	71° 51'E	
5	Gilgit	43516	1459	35° 55'N	74° 20'E	
6	Kakul	41535	1308	34° 11'N	73° 15'E	
7	Muzafarabad	43532	701	34° 22'N	73° 29'E	
8	Parachinar	41560	1725	33° 52'N	70° 05'E	
9	Said-u- Sharif	41523	961	34° 44'N	72° 21'E	
10	Skardu	43517	2209	35° 18'N	75° 41'E	
11	Cherat	41565	1372	33° 49'N	71° 33'E	**Zone 2,** Mild cold climate and sub-mountains
12	D .I. Khan	41624	173	31° 49'N	70° 55'E	
13	Islamabad	41571	507	33° 37'N	73° 06'E	
14	Lahore	41640	213	31° 33'N	74° 20'E	
15	Peshawar	41530	359	34°01'N	71° 35'E	
16	Sialkot	41600	255	32°31'N	74°32'E	
17	Kalat	41696	2015	29° 02' N	66° 35' E	**Zone 3a,** Cold climate in winter and hot in summer
18	Khuzdar	41744	1231	27° 50'N	66° 38'E	
19	Quetta	41660	1719	30° 15' N	66° 53' E	
20	Zhob	41620	1405	31° 21'N	69° 28' E	
21	Bahawalpur	41700	110	29°20'N	71°47'E	**Zone 3b,** Hottest and dry zone, where highest max temp are recorded
22	Jacobabad	41715	55	28° 18'N	68° 28'E	
23	Khanpur	41718	87	28° 39'N	70° 41'E	
24	Multan	41675	122	30° 12'N	71° 26'E	
25	Rohri	41725	66	27° 40'N	68° 54'E	
26	Sibbi	41697	133	29° 33'N	67° 53'E	
27	Hyderabad	41764	28	25° 23'N	68° 25'E	**Zone 4,** Warm humid sub-tropical climate mostly coastal cities
28	Jiwani	41756	56	25° 04'N	61° 48'E	
29	Karachi	41780	21	24° 54'N	67° 08'E	
30	Nawabshah	41749	37	26° 15'N	68° 22'E	

Climate variability in Pakistan

Pakistan is a country with diversified topography and extremely variable climate. Most of the areas in the central and southern Pakistan are arid, while the northern part of the country is humid except the extreme northern mountains where it is dry. During the summer months (April to September), the mountainous north is pleasant and temperate, but the Indus Valley has mean temperatures in the range of 40° C or more whereas, in late summer the southern region experiences monsoon weather systems, particularly along the coastal belt. In the winter season, the low-lying areas cool down appreciably and the average temperatures remain in the range of 10-25° C, while the northern mountains are covered with snow with the air well below freezing (Rodo, 2003). The dominant component of climate variations was spatial shifts in the rainfall patterns, associated with fluctuations in the general circulation of the atmosphere, in the Indian-sub continent (Rodo, 2003), like the monsoon winds that bring rainfall in summer. The Western Depression originating from the Mediterranean region and entering Pakistan from the west brings rainfall in winter. These extra-tropical weather systems cover a long overland journey before reaching Pakistan and its moistures are robbed mostly by the time they reach Pakistan. Similarly other climate controlling factors are the sub-tropical location of the country that leads to keep the temperature high, particularly in summer and the oceanic influence of the Arabian Sea that keeps down the temperature along the coast. In the west and north higher altitudes keep the temperature down throughout the year. During the summer in the south, a temperature inversion layer is created which does not allow the moisture-laden air to rise and condensation to take place.

Climate zones

The temperature is greatly affected by altitude, location in relation to the coast, desert, mountainous area and other such geographical features. Therefore, for analysis, it is difficult to consider the whole country as one region because different stations have different topography and microclimates. For this purpose the study area has been divided into five zones, considering their climatic conditions as defined by Kööpen for classification of different microclimates. These zones were named zone 1, 2, 3a, 3b and 4 as shown in the Fig. 1, along with their latitudinal extent.

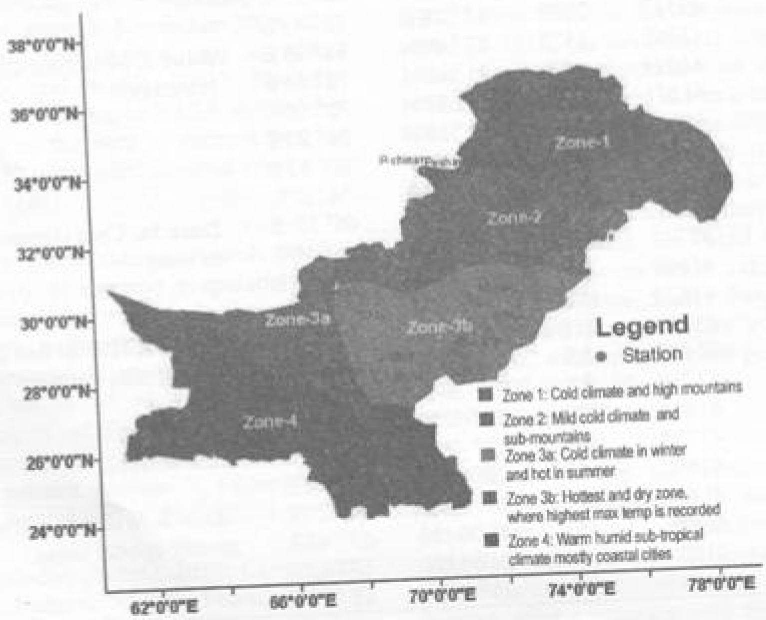

Fig. 1. Map showing the climatic zones of the study area.

Zone 1

Zone one comprises those stations having cold climate and high mountains, situated in the north of Pakistan. These stations are Chitral, Gilgit, Muzaffarabad, Said-u-Sharif, Skardu, Astor, Dir, Chilas Parachinar and Kakul. These are mostly hill stations located between 34°N to 38°N in the Himalaya, Hindukash and Koh-e-Sufaid mountain ranges.

Zone 2

This zone has mild cold climate and Sub Mountains, located between 31°N to 34°N. The stations are Sialkot, D.I.Khan, Islamabad, Peshawar, Cherat and Lahore.

Zone 3(a)

Climate is cold in winters and hot in summers. Most of them are mountainous stations with high elevations from mean sea level and cover an area between 27°N to 32°N and 64°E to 70°E. Stations included in this zone are Quetta, Zhob, Kalat and Khuzdar.

Zone 3(b)

This is the hottest and dry zone of the country where highest maximum temperatures are recorded in stations of Sibbi and Jacobabad. The area is almost plain with some area included in Thar Desert. Stations included are Sibbi, Jacobabad, Bahawalpure, Khanpur, Multan and Rohri.

Zone 4

This zone comprises the warm humid sub tropical climate mostly coastal cities, near the Arabian sea. Hyderabad, Karachi, Jewani and Nawabshah stations are listed in the zone.

Data and Method

Long term data set of annual mean minimum and mean maximum temperatures from 1976-2005 of 30 meteorological stations of the whole country has been used in this study. The data was collected from climate data processing centre (CDPC) of Pakistan Meteorological Department. The stations were selected by keeping into account their length, completeness and reliability of the data, so that most of the country was covered by the corresponding data. Also in this study , the data set of those stations has been used which were not changed/ displaced for the last 30 years, because some of the meteorological stations were re-established and the change of site may give difference in the data value.

For comparison of trends, average values were compiled carefully for the entire period 1976-2005, for fifteen and five year periods for each zone and for the whole country as well. The reliability of data and homogeneity of means were statistically tested by applying student t-test, using SPSS version 17. Student t-test is designed for the situations in which the researcher has already obtained a significant value and difference among the means of two groups by assuming equal variances or normal distribution of the data. Mostly for the detection of the temperature trend analysis student t-test is used like Easterling et al (1997) and Russel et al (2004) have applied student t-test for the global temperature anomalies. In this sense, the application of statistical test makes it easy to compare the means of different periods and to assess the significance of the changes for each zone and country. Further, for the visualization of the data, ArcGIS software is applied which is used for all mapping and editing tasks as well as for map-based query and analysis.

Results and Discussion

The annual mean of minimum and maximum temperatures, trimmed mean, 95% confidence interval of the mean, medians, standard deviations and standard errors and percentile were carried out by using descriptive statistics of minimum and maximum temperatures for different climate zones of Pakistan as shown in Table 2. The number of valid cases indicates the length of the data i.e., from 1976-2005. By comparing the mean values for the study area it has been found that zone 1 shows the lowest value of mean (9.26°C) and (22.89°C) for both minimum and maximum temperatures respectively. Furthermore, zone 4 shows the highest value of mean (20.35°C) for minimum temperature whereas in case of maximum temperature zone 3b shows the higher value (33.69 °C).

Similarly, the highest and lowest values of standard deviation for minimum and maximum temperatures were observed. It has been observed that the highest value of standard deviation in case of minimum temperature for zone 3a was 3.85°C whereas the lowest value was 1.25°C for zone 3b. Moreover, the highest value in case of maximum temperature for zone 2 was 4.36°C and the lowest value for zone 3b is 1.06° C.

Analysis of 30 stations from all Pakistan for 30 years data revealed a positive trend.

Table 2. Descriptive statistics of climate zones.

Minimum Temperature

		Zone 1	Zone 2	Zone 3a	Zone 3b	Zone 4
Stations		10	6	4	6	4
30 Years	Valid/Missing cases	293/7	180/0	120/0	180/0	120/0
Mean	All value used	9.26	15.83	10.27	18.92	20.35
	5%trimmed Mean	9.32	15.84	10.26	18.96	20.37
Median		8.84	15.94	9.66	19.08	20.86
Std. Dev		3.47	1.96	3.85	1.25	1.68
Std. Error		0.20	0.15	0.35	0.09	0.15
95%CI	Lower Bound	8.86	15.54	9.58	18.74	20.05
	Upper Bound	9.66	16.11	10.97	19.11	20.65
Minimum		-0.21	11.20	3.57	15.65	14.88
Maximum		15.53	20.30	18.29	21.26	24.21
Percentile	25	7.07	14.37	7.54	17.93	18.72
	50	8.84	15.94	9.66	19.08	20.86
	75	12.29	17.17	13.70	20.02	21.37

Maximum Temperature

		Zone 1	Zone 2	Zone 3a	Zone 3b	Zone 4
Stations		10	6	4	6	4
30 Years	Valid/Missing cases	300/0	180/0	120/0	120/0	120/0
Mean	All value used	22.89	29.21	25.51	33.69	33.02
	5%trimmed	23.04	29.36	25.49	33.69	33.04
Median		23.31	29.78	25.57	33.65	33.24
Std. Dev		3.49	4.36	2.62	1.06	2.20
Std. Error		0.20	0.32	0.24	0.08	0.20
95%CI	Lower Bound	22.49	28.57	25.04	33.53	32.62
	Upper Bound	23.29	29.85	25.98	33.84	33.42
Minimum		13.19	18.52	20.55	31.35	27.23
Maximum		29.24	36.63	31.62	35.97	37.05
Percentile	25	21.10	28.51	23.31	32.92	31.11
	50	23.31	29.78	25.57	33.65	33.24
	75	25.65	31.69	27.69	34.45	34.84

Trend Analysis

5 Years analysis

To get a better understanding of the observed trends, the annual mean of minimum and maximum temperatures of each zone and that for the whole country were computed into 5 years moving averages. Each zone shows great variation in temperature trend but they have a regular increase after 1996-2000 to 2001-2005. In Fig.2 (b, d and e), the anomalies of time series data of minimum temperature shows the most significant increase than any other time period. The annual average of maximum temperature in Fig.2 (c and e) shows increasing trend in the last two time periods. In zone 1(a), from 1976 to 1990, the temperature remained constant with some increase but there is a regular swift downfall in temperature after 1991-2000 and then further a gradual increase has been noted.

The overall observed variation in temperature was found positive for the country as a whole which has clear increasing trends in mean minimum and mean maximum temperatures as shown in the Fig.2 (f).

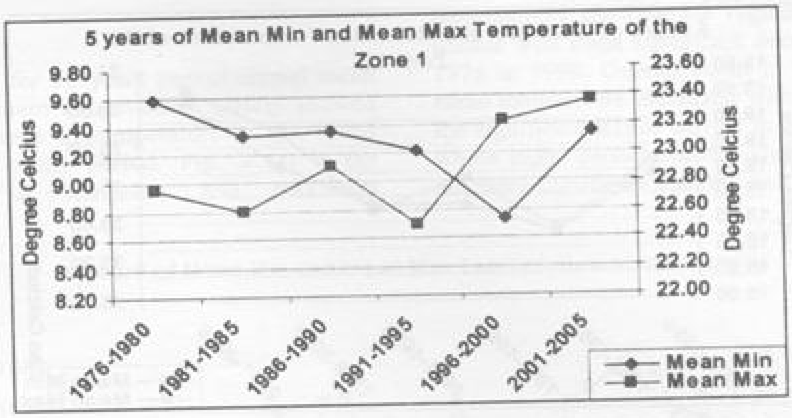

Fig. 2. (a) 5 years mean minimum and mean maximum temperature trend for zone 1 from 1976-2005;

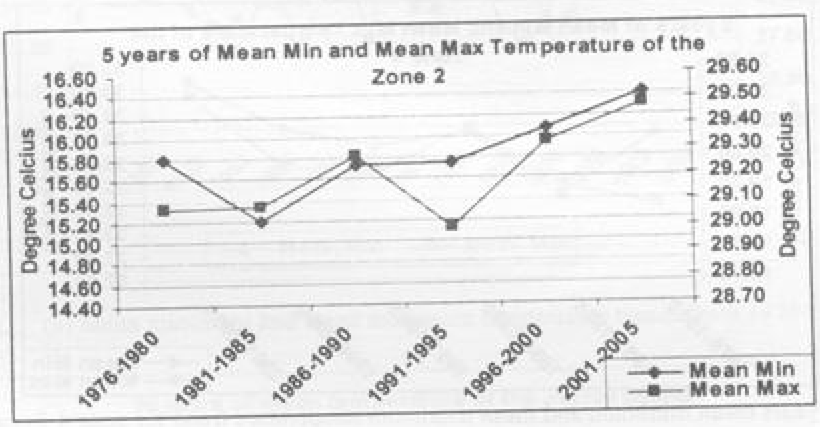

Fig. 2. (b) 5 years mean minimum and mean maximum temperature trend for zone 2 from 1976-2005;

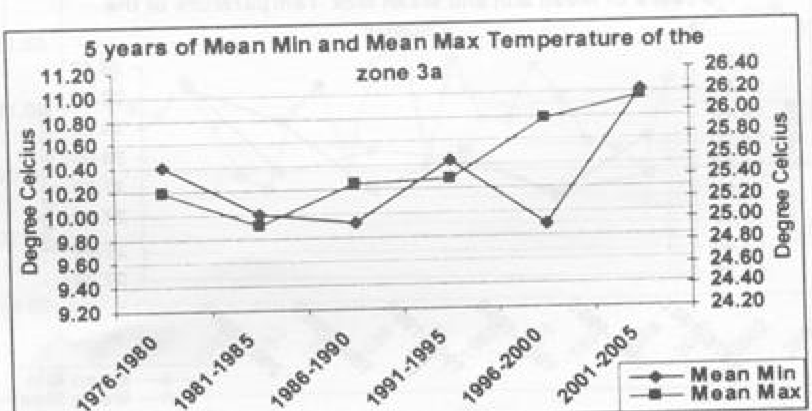

Fig. 2. (c) 5 years mean minimum and mean maximum temperature trend for zone 3a from 1976-2005;

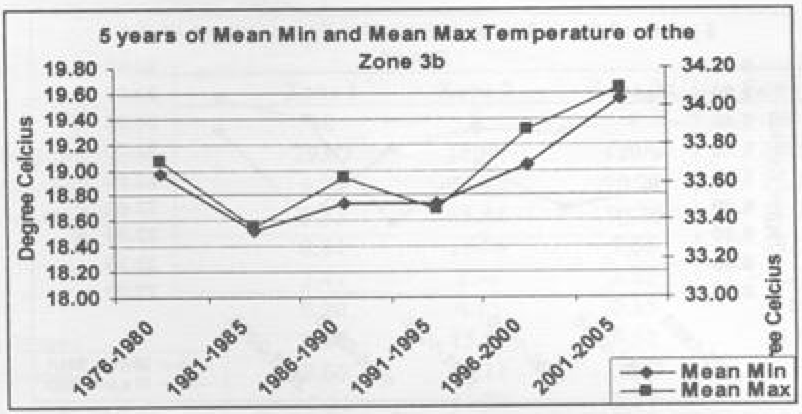

Fig. 2. (d) 5 years mean minimum and mean maximum temperature trend for zone 3b from 1976-2005;

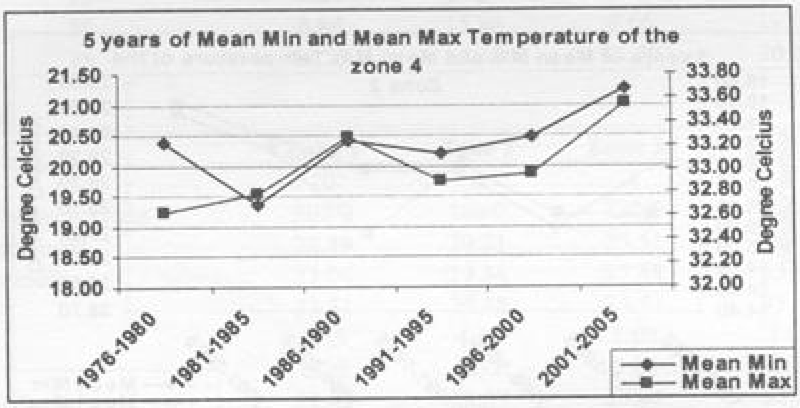

Fig. 2. (e) 5 years mean minimum and mean maximum temperature trend for zone 4 from 1976-2005;

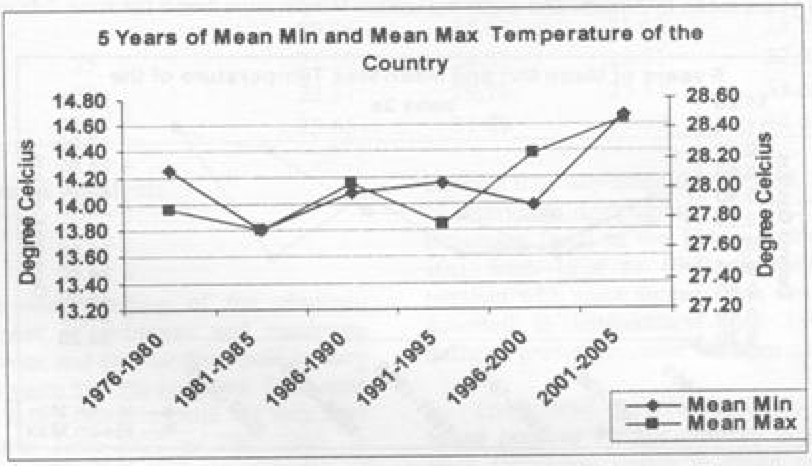

Fig. 2. (f) 5 years mean minimum and mean maximum temperature trend for overall country from 1976-2005).

30 Years analysis

The time series for 30 years period annual mean minimum and maximum temperatures clearly showed that the overall change in temperature is not found uniform during the study period. Fig. 3 (a) is the combined result of minimum and maximum temperatures showing the regular increase in the last decade with some significant decreasing fluctuations in 1976 to 1990. Overall result in Fig. 3 (b) shows that mean temperature increased with fluctuations but have the significant trends of rise in temperature during the whole study period but this change in two decade is not more significant than the last decade.

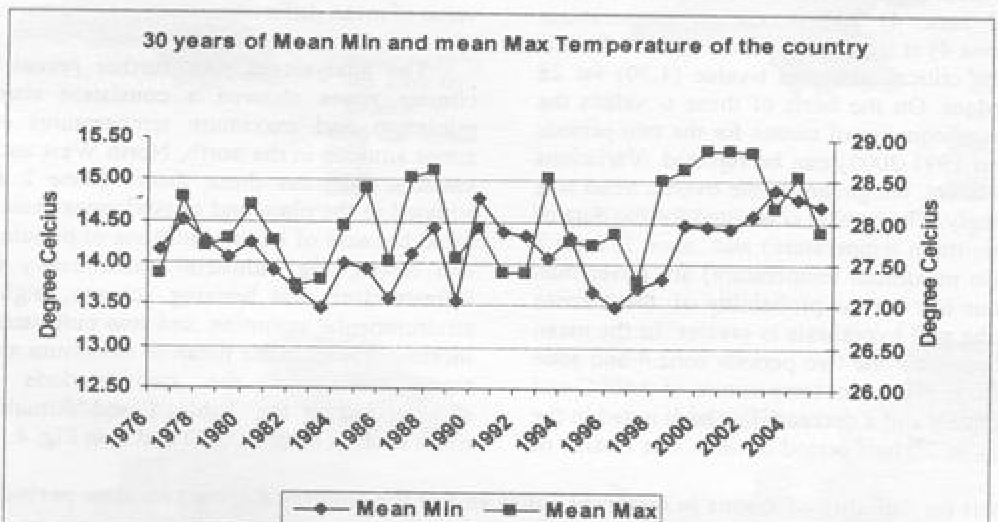

Fig. 3. (a) Mean minimum and mean maximum temperature trends from 1976-2005;

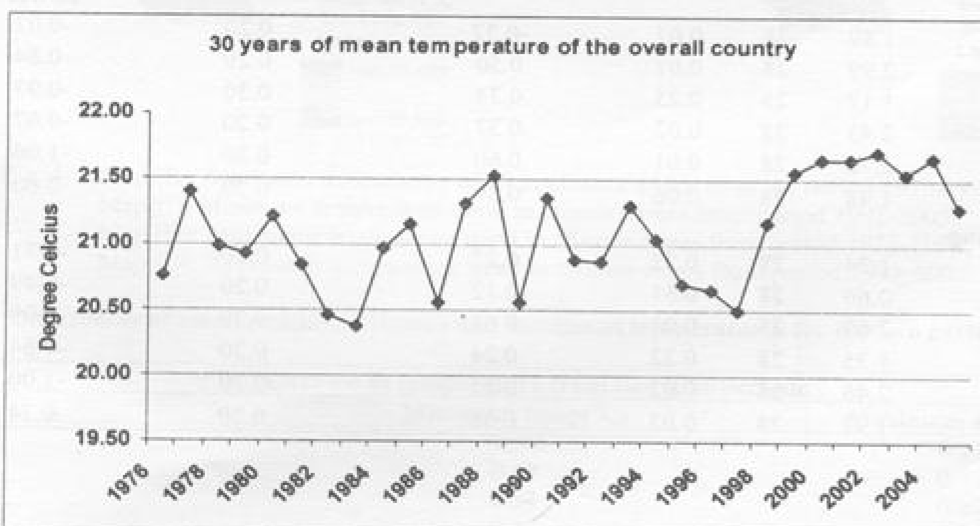

Fig. 3. (b) Mean temperature trend of the overall country from 1976-2005.

Statistical test

The value of student t-test was calculated to check the significance of variances of means for all zones and for the country as well.

In the Table 3, the student t-test was found to be significant for both minimum (i.e. for zone 1, zone 2, zone 3b, and zone 4) and maximum temperatures (zone3a and zone 4) at significance level of 0.1 which is greater than the critical tabulated t-value (1.70) for 28 degree of freedom. On the basis of these t- values the null hypothesis of equality of means for the two periods (1976-1990 and 1991-2005) can be rejected. Variations were found different, but generally the overall trend was found increasingly. The t-value computed for the data of zone 3a (in minimum temperature) and zone 1, zone 2 and zone 3b (in maximum temperature) are lower than the critical value of t but the probability of these zones for rejecting the null hypothesis is greater. In the mean difference column , for the two periods zone 4 and zone 2 show increase in minimum temperature of 0.60° C and 0.50° C respectively and a decrease has been noted in the mean of zone 1 in 2nd half period of time. The t value of the country (1.98) for minimum temperature is found greater than the tabulated critical value at the significance of 0.1 levels. The mean difference of temperature for the two periods is 0.30° C and Standard Error is 0.2° C. Similarly, for maximum temperature, t value of the country (1.92) is observed significantly greater with 0.36° C increase in temperature while zone 3a (0.62° C) and zone 4 (0.55° C) are showing the highest value of mean difference.

The analysis of data further reveal that all the climate zones showed a consistent rising trend in minimum and maximum temperatures except those zones situated in the north, North West and west of the country. Whereas those Zones (zone 2 and zone 4) situated in the plain and coastal areas show great rising trend because of having millions of population in cities and towns, big industrial units, heavy traffic, poor infrastructure and housing scheme, high amount of environmental pollution and less cultivated areas. The increase trends in the mean of minimum and maximum temperatures for the two periods have been summarized in the Table 4 and virtualized through maps such as map B, C, D and E in Fig. 4.

Table 3. T-test for equality of means in different zones and of the country during two time periods.

Minimum Temp	t-value	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Conf. Interval	
						Lower	Upper
zone1	1.89	28	0.07	-0.32	0.20	-0.03	0.67
zone2	2.99	28	0.01	0.50	0.20	-0.84	-0.16
zone3a	1.17	28	0.25	0.34	0.30	-0.93	0.25
zone3b	2.43	28	0.02	0.37	0.20	-0.67	-0.06
zone4	2.72	28	0.01	0.60	0.20	-1.06	-0.15
country	1.98	28	0.06	0.30	0.20	-0.60	0.01
Maximum Temp							
zone1	1.24	28	0.23	0.27	0.20	-0.71	0.17
zone2	0.66	28	0.51	0.12	0.20	-0.49	0.25
zone3a	2.69	28	0.01	0.62	0.20	-1.09	-0.15
zone3b	1.25	28	0.22	0.24	0.20	-0.64	0.15
zone4	2.46	28	0.02	0.55	0.20	-1.00	-0.09
country	1.92	28	0.07	0.36	0.20	-0.74	0.02

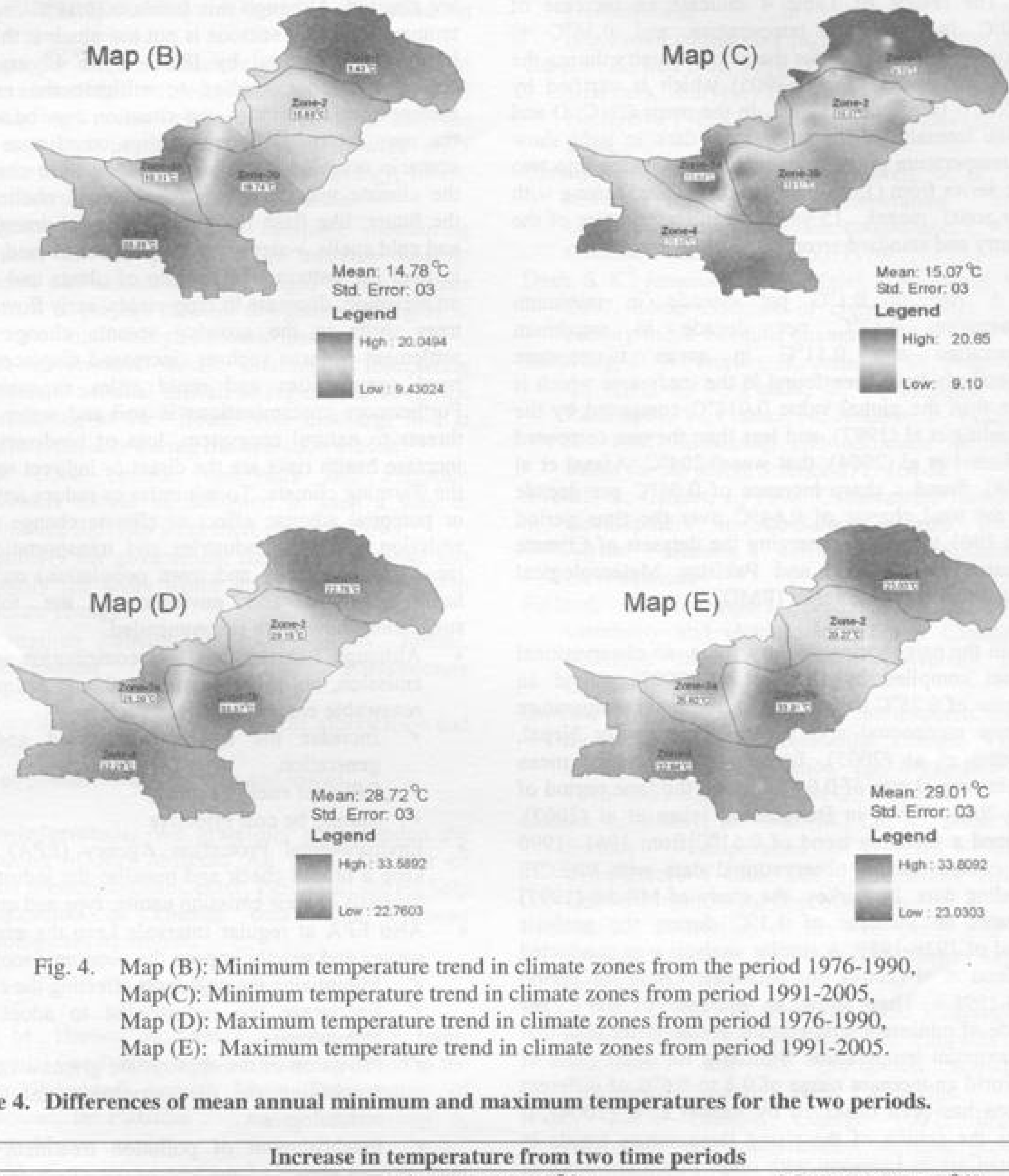

Fig. 4. Map (B): Minimum temperature trend in climate zones from the period 1976-1990, Map(C): Minimum temperature trend in climate zones from period 1991-2005, Map (D): Maximum temperature trend in climate zones from period 1976-1990, Map (E): Maximum temperature trend in climate zones from period 1991-2005.

Table 4. Differences of mean annual minimum and maximum temperatures for the two periods.

	Increase in temperature from two time periods	
S. No	Minimum temp(°C)	Maximum temp(°C)
Zone 1	-0.32	0.27
Zone 2	0.49	0.12
Zone 3a	0.34	0.62
Zone 3b	0.37	0.24
Zone 4	0.60	0.55
Mean	0.30	0.36
St. Error	0.3	0.3

The results of Table 4 indicate an increase of 0.30°C in minimum temperature and 0.36°C in maximum temperature for the whole country during the period of analysis (1976-2005) which is verified by student t- test in the Table 3. In the maps (B, C, D and E) the intensity of the color from dark to light show the temperature range from high to low value into two time series from (1976- 1990 to 1991-2005) along with their zonal means, 15 years mean temperature of the country and standard error.

A rise of 0.1°C per decade in minimum temperature, 0.12°C per decade in maximum temperature and 0.11°C in mean temperature respectively have been found in the study area which is more than the global value 0.018°C computed by the Easterling et al (1997), and less than the one computed by Russel et al (2004), that was 0.204°C. Afzaal et al (2009), found a sharp increase of 0.06°C per decade and the total change of 0.64°C over the time period from 1901 to 2007 by merging the datasets of Climate Research Unit (CRU) and Pakistan Meteorological Department real time series (PMD).

In the neighboring country India, an observational dataset compiled by Dash et al (2007), found an increase of 0.25°C per decade in minimum temperature of post monsoonal and winter seasons. For Nepal, Shrestha et al (2005), found an increase of mean temperature at rate of 0.04°C during the time period of 1975-2005. While in Bangladesh Islam et al (2007), obtained a variation trend of 0.61°C from 1961 -1990 with comparison of observational data with PRECIS modeling data. In Turkey, the study of Mikdat (1997) indicates an increase of 1.1°C during the analysis period of 1939-1989. A similar analysis was conducted by Zhou et al (2004), for southeast China for period 1979-1998. They show an increase of 0.6°C per decade of minimum temperature, a rate faster than that of maximum temperature. Similarly for other parts of the world an increase range of 0.3 to 0.6°C of different seasons has been observed by Russel et al (2004). It means the results of the rising temperature trends in Pakistan are in harmony with other published work in south Asian countries as well as in the globe.

Conclusions

From the above discussion it is concluded that the dataset of Pakistan is showing a significant increase, especially in those zones where big cities of country are situated. Although this increase (0.11°C/decade) in temperature of all seasons is not too much at this stage, but if steps advised by IPCC in its 4th assessment report, were not applied to mitigate the excessive anthropogenic activities, the situation may be worse in the near future. Different studies on climate change scenario revealed that short and long term changes in the climate may lead to environmental challenges in the future; like flash flooding, prolonged droughts, hot and cold spells, water shortage, dryness of land, change in land use pattern like shifting of plants and animals on elevation, decrease in crop yields, early flowering of trees shifts in the growing season, change in the settlement patterns such as increased displacement of rural communities and rapid cities expansion etc. Furthermore contaminations in soil and water bodies, threats to natural ecosystem, loss of biodiversity and increase health risks are the direct or indirect results of the warming climate. To minimize or reduce any actual or potential adverse effect of climate change (due to emission of GHG, industries and transportation, and rapid growth of city and town population) on human health, welfare and environment, the following suggestions have been recommended.

- Although Pakistan has less contribution in GHG emission, but the government should promote the renewable energy resources such as:
  - ✓ Increase the hydropower, wind and solar generation
  - ✓ Efficient energy supply
  - ✓ Should be cost effective
- Environmental Protection Agency (EPA) should keep a proper check and penalize the industries on the basis of their emission nature, type and quantity.
- Also EPA at regular intervals keep the economic survey and strictly impose the economic tools for:
  - ✓ Minimizing the pollutants effecting the climate
  - ✓ Encourage the industrialist to adopt green technologies
  - ✓ Provision of the appropriate grants/awards for purchasing the new environmental friendly technologies
  - ✓ Establishment of pollution treatment plants and enhanced the use of 3R (Reduce, Reuse and Recycling) processes.
- For transportation , pollution checking cells should be established all over the country for:
  - ✓ Proper monitoring of emissions from vehicle
  - ✓ Keep control on the number of vehicles, particularly diesel and petrol operated.
  - ✓ Issues pollution under control certificates

- ✓ Implement NEQs related to air pollution control
- A proper research structure should be established to assess the vulnerabilities in the form of analyzing recent climate variability, extreme events and impacts in integration with other sectors such as water, agriculture, energy, forest, biodiversity, livestock and costal areas.
- Country should have an adequate monitoring system for the prediction of extreme weather events and assessment of changes in the weather pattern to prepare disaster mitigation strategies in terms of minimizing economic losses.
- The government should established forecasting centers at national as well as regional level for the forecasting of the flood, river discharge and at dams especially during the monsoon season
- For flood control, reservoirs and irrigation channels should be designed in such a way to minimize the risks from increase peak flows.
- Similarly the government should characterise and classify the areas which are most susceptible to climate change.
- Strengthen policies for food security, forests, management disasters and infrastructure development
- Control deforestation and promote aforestation and reforestation.
- Tree plantation in the cities and towns.

Acknowledgements: We gratefully acknowledge the contribution of Mr. Mushtaq Ali Shah, Director of Regional Meteorological Center, Peshawar, for his help in acquisition of climate data from Pakistan Meteorological Department.

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