AN ANALYSIS OF DIURNAL AIR TEMPERATURE RANGE CHANGE AND ITS COMPONENTS IN SHAHEED BENAZIR ABAD SINDH

Nadeem ul karim Bhatti[1], Saleem Raza Samo[2], Manthar Ali Keerio[3], Ahsan Ali[4], Abdul Aziz Ansari[5]*

1. *Department of Civil Engineering, Quaid-e-Awam University College of Engineering, Science and Technology, Larkana, Sindh, Pakistan Email: knadeem_b@quest.edu.pk*
2. *Energy and Environment Engineering Department, Quaid-e-Awam University of Engineering, Science and Technology Nawabshah, Sindh, Pakistan. Email: sfaizsamo@yahoo.com*
3. *Department of Civil Engineering, Quaid-e-Awam University College of Engineering, Science and Technology, Larkana, Sindh, Pakistan Email: mantharali99@quest.edu.pk*
4. *Department of Civil Engineering, Quaid-e-Awam University College of Engineering, Science and Technology, Larkana, Sindh, Pakistan Email: ahsanone@gmail.com*
5. *Department of Civil Engineering, MUET, Shaheed Zulifquar Ali Bhutto Campus Khairpur, Sindh, Pakistan Email: dransari@quest.edu.pk*

ABSTRACT

A study has been carried out to analyse the temporal and seasonal patterns in the trends of diurnal air temperature range (DTR) and its components in Shaheed Benazir Abad for the time period 1996–2014.The magnitude, the slope and the significance of trends were investigated by using the linear regression method, the trend magnitude, the Mann-Kendall test and the Sen's estimator of slope. The Mann-Kendall test and Sen's estimator of slope were calculated by using Addinsoft's XLSTAT 2015 software. The hypothesis of Mann-Kendall test was investigated at 95% confidence level for all variables. The result shows that minimum temperature of Shaheed Benazir Abad has increased at the rate of 0.063°C per year during study period while the maximum temperature for all months exhibits no change. This increase of minimum temperature contributed to the decreasing trend of diurnal temperature range. The DTR decreased at the rate of 0.057°C /year in Shaheed Benazir Abad. The investigation of seasonal DTR trends revealed that Summer and Spring seasons also witnessed a decreasing trends at the rate of 0.26 °C/year and 0.047°C/year respectively. Winter and aseasons, on the other hand, have experienced the increasing trends of DTR at the rate of 0.136 °C/year and 0.115 °C/year respectively. It is found by MK test that Tmax (winter), Tmax (Spring) and Tmin (Spring) exhibited the significant positive trends at the rate of 0.21°C/year, 0.368 °C/year and 0.421°C/year respectively. The increasing trends of Tmax of winter and spring indicate that winter and spring are warmer now.

KEYWORDS

Diurnal temperature range, Climate change, Mann-Kendall test, the Sen's slope, Shaheed Benazir Abad

INTRODUCTION

It is important to investigate the regional climate variations in order to understand the exertion of complex influence of climate on natural system. This needs the quantitative and descriptive analysis of regional climate variations. The DTR is a suitable measure of climate variations [1]. For central Sindh, no quantitative work has been carried out on diurnal basis. Diurnal temperature range (DTR) change has far reaching effects on natural ecosystem and socio-economic system because it is suitable sign of climatic change along with mean temperature changes [2]. Various researchers have conducted studies on diurnal temperature range and its components which show the variation of DTR in different regions of the world [3-6]. DTR demonstration on regional basis assumes special importance in context of global warming because its pattern is not uniform across the globe [7]. It has been observed that the warming of land surface is due to the relatively larger increase in daily minimum temperatures than in maximum temperatures [6, 8-9]. Various studies have indicated that the trend of DTR is decreasing globally since the mid of twenty century. The data of five stations (Islamabad, Lahore, Jhelum, Faisalabad and Multan) of Pakistan also display the decreasing trend of DTR [1, 10-11]. Dai et al. have studied the impacts of winds, soil moisture, cloud cover and precipitation on DTR [12]. They found that these hydrological variables have damping effects on DTR. Beside these variables, land cover and land use, deforestation, irrigation and urbanization of the region are identified as responsible factors for variation of DTR trend [13-15].Therefore the variation of DTR in different regions has a peculiar characteristics which is the outcome of complicated interaction of anthropogenic factors and local climatic conditions [1, 9-10].

The primary objective of this study is to examine the historical (1996–2014) variability in DTR and its components (Tmax and Tmin) over Shaheed Benazir Abad, Sind, Pakistan. Monthly and seasonal trends of DTR and its component are examined for whole period. Generally in Shaheed Benazir Abad, twelve months of year are divided in four seasons. So this study has considered four seasons, namely; winter (December- February), spring (March- April), summer (May -September), autumn (October- November).

DATA AND METHODOLOGY

Study Area Description

Geographically, Shaheed Benazir Abad is at the center of Sindh province of Pakistan. It is located between 25° 59' to 27° 15' North latitude and 67° 52' to 68° 54' East longitude .The Indus river flows at west border of district which is about 90 km long in the district. The net area of district is 451 thousand hectares out of which 189 thousand hectares are cropped areas. The study area is in tropical climate which is hotter environment. The total projected population of the city was 1676000 in 2014.The average rainfall in the district is 18.39 cm.

The surface air temperature data of Pakistan Meteorological Department (PMD) station at the airport of Nawabshah (OPNH-417490) was used for this study [16].

Methods

Surface air temperature Data on minimum maximum, monthly as well as annual have been compiled for the years 1996 – 2014. Diurnal Temperature Range (DTR) was calculated. Graphs were plotted for the maximum temperature, minimum temperature and DTR against the 12 months for each year. The monthly graphs were subsequently merged in a spreadsheet with the minimum, maximum and DTR against the 228 months and season-wise and also trend lines for each variable were plotted.

The many statistical procedures and techniques are used to detect and estimate of trends in different parameters of climate because the detecting and estimating the temporal and spatial trends are very important for various studies and monitoring program related to the environment.

The following four statistical methods were used to detect and estimate the trends of temperature.

The linear regression method

The behaviour of all parameters were computed and analysed with following linear trend model by using linear regression method [17-18].

$$y = \alpha x + \beta \qquad 3.1$$
$$\alpha = (\sum y_j \; \sum x_j^2 - \sum x_j \; \sum x_j y_j) \,/\, n \sum x_j^2 - (\sum x_j)^2 \qquad 3.2$$
$$\beta = n\sum y_j \, x_j - \sum x_j \, y_j \,/\, n \sum x_j^2 - (\sum x_j)^2 \qquad 3.3$$

Where x_j represents "years" and y_j represents “Parameters”

This method is frequently used to determine the trend. If the sign of α is positive then the trend is increasing and if the sign of α is negative then the trend is decreasing when the value of α is equal to zero then there is no trend in time series.

The trend magnitude

The second method was trend magnitude which was used to find out the magnitude of trend. The magnitude of trend was calculated by using the following equation.

$$\Delta y = y(\text{initial time}) - y(\text{terminate time}) \qquad 3.4$$

Where Δy indicates the total trend magnitude while y (initial time) and y (terminate time) represent the beginning and the end point of the trend equation respectively. However the positive and negative sign of Δy show the decreasing and increasing trend respectively.

The Mann-Kendall Test

This is the third statistical method which was used to analyse the significance of trends of all-time series. It is non-parametric test which is usually used in hydrological and climatological time series [19]. This test has been suggested by the World Meteorological Organization (WMO) for assessing the temporal trends in the time series of environmental data [20].This method is used to detect the statistically significant trends of long term data. There are two hypotheses to be tested in the Mann-Kendall test. One hypothesis is null hypothesis H_0 which means that the concerned time series has no trend while other one is alternative hypothesis Ha. This alternative hypothesis assumes that the concern time series possesses the significant trend.

The computation of the M-Kendall statistic is the main procedure for the application of MK test. The Mann-Kendall Statistic (S) is computed as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} Sign(Tj - Ti) \qquad 3.5$$

Where

$$\text{Sign(Tj - Ti)} = \begin{Bmatrix} 1 \; if \; (Tj - Ti) > 0 \\ 1 \; if \, (Tj - Ti) \; = 0 \\ -1 \; \; if \, (Tj - Ti) < 0 \end{Bmatrix} \qquad 3.6$$

Here Tj and Ti represent the data points at the time i and j respectively where j > i and *n* is the last period in the time series. If *n* > 10 then the Statistic *S* approximately normally distributed with the mean of *S* is zero and the variance statistic Var (*S*) is computed as:

$$V(S) = 1/18 \; n(n-1) \; (2n+5) \qquad 3.7$$

Kendall's tau (τ) is another statistic which is obtained by applying Mann-Kendall test. It represents the correlation between two variables which means the value of tau describes the relationship between two variables [21]. Mann-Kendall Tau is given by:

$$\tau = S / n (n-1) / 2 \qquad 3.8$$

Here,

S represents the Mann-Kendall statistic and

n shows the number of data pairs

The probability p is determined to know the confidence level in the hypothesis of Mann-Kendall test and it is computed as follows:

$$p = [1-f(Z)] \cdot 100 \qquad 3.9$$

Z is standard normal test statistics which is computed by using following equation:

$$Z = \begin{Bmatrix} \frac{S-1}{\sigma} \; if\ S > 0 \\ 0 \quad if\ S = 0 \\ \frac{S+1}{\sigma} \; if\ S < 0 \end{Bmatrix} \qquad 3.10$$

In the equation 3.9, f(Z) is a function of probability density and it is calculated by following equation:

$$f(Z) = 1/\sqrt{2\pi}\ exp\ (-z^2/2) \qquad 3.11$$

The value of p is very important for accepting and rejecting the hypothesis of Mann-Kendall test. The level of chosen significance is represented by Alpha (α = 0.05). If the calculated value of p is greater than the value of Alpha then H_o cannot be rejected.

If the value of p is less than the value of Alpha then Ha should be accepted [22].

The Sen's estimator of slope

This method is used to calculate the magnitude of linear trends which exist in the time series data. The slope (m) of all pairs of data is computed by following equation.

$$mi = xj-xk / j-k \quad i = 1,.....,N \qquad 3.12$$

In the above equation, x_j and x_k are used to represent data values at the time j and k respectively where j is greater than k. The Sen's estimator of slope is the median of these N values of m_i and computed by following equation.

$$Q_{med} = \begin{cases} \frac{1}{2}\left(m_{N/2} + m_{\frac{N+2}{2}}\right) \text{if N is even} \\ m_{(N+1/2)} \text{ if N is odd} \end{cases} \qquad 3.13$$

The sign of Q_{med} indicates the reflection of trend of time series data. The positive sign of Q_{med} represents the increasing trend while negative sign shows the decreasing trend [23]. Addinsoft's XLSTAT 2015 is the software which was used for Mann-Kendall test and Sen's estimator of slope. The hypothesis was tested at 95% confidence level for all variables.

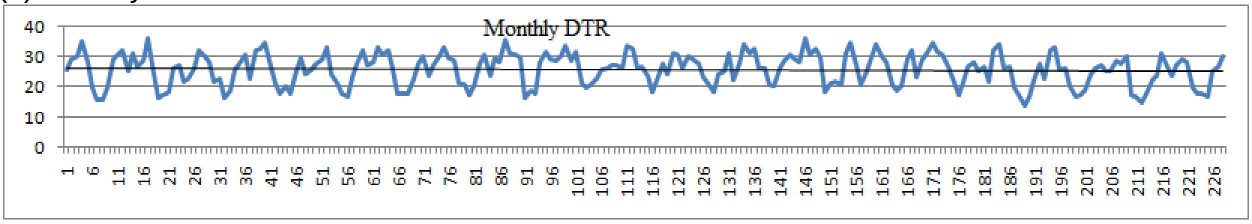
DOI 10.14311/CEJ.2019.02.0015

RESULTS AND ANALYSIS

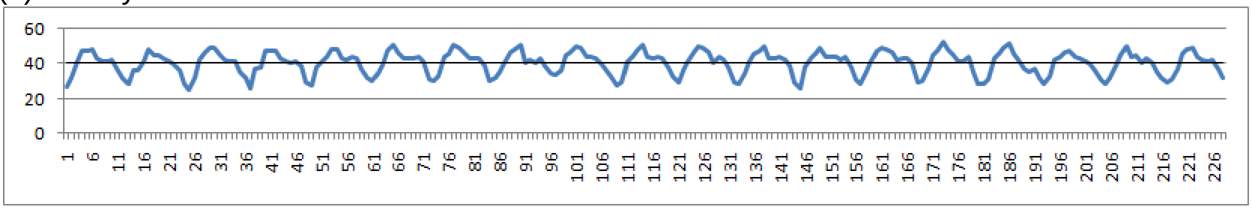
Trend analysis by linear regression and trend magnitude

The trends of monthly diurnal air temperature range, maximum air temperature, and minimum air temperature of the Shaheed Benazir Abad have been illustrated in Figure 1 from years 1996–2014. A steadily decreasing trend of DTR can be identified statistically, with the decreasing rate of 0.057°C /year during study period despite the fluctuations from year to year because of various climatic factors.

(a) Monthly DTR



(b)MonthlyTmax



(c)MonthlyTmin

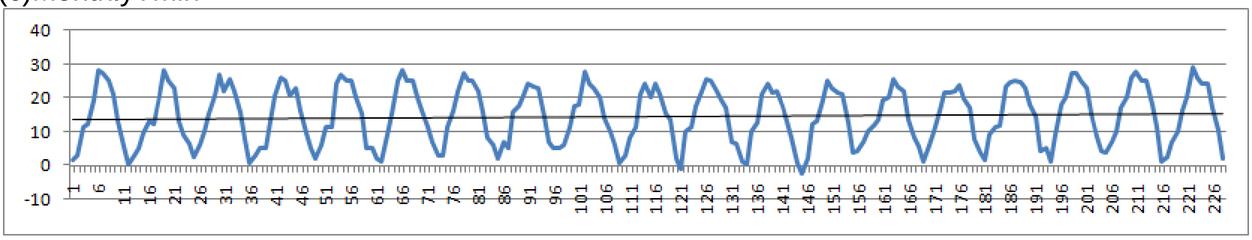


Fig.1- All month temperature variations in Shaheed Benazir Abad (a) monthly diurnal air temperature (b) maximum air temperature (c) minimum air temperature.

The rate of change of the monthly maximum air temperature is almost zero during study period but the monthly minimum air temperature is rising at the rate of 0.063158°C per year as demonstrated in Figure 1. So, the significantly increasing trend of minimum temperature contributes to the decrease of DTR trend. This decrease in DTR may have profound effect on human comfort and as well as on the agricultural ecosystem of this region. The increase in minimum temperature prevents the nocturnal cooling which is very essential to neutralize the maximum temperature of hot day especially during the summer season.

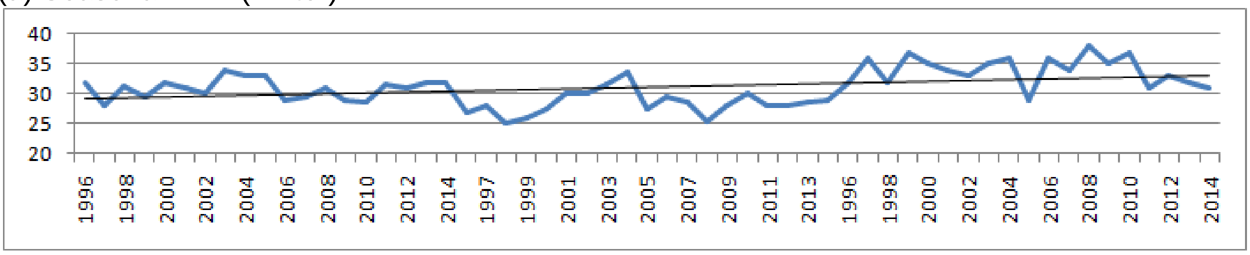
The special report of an IPCC also notes that the economies of agrarian countries are under threat due to global warming of 1.5°C above pre-industrial levels [24]. This change has reaching effects for the strength and timing of precipitation patterns of this region. The energy and agriculture sectors of this region are also adversely affected by climate change which are exclusively depend on water [25].

As temperate change has seasonal patterns, time series of seasonal DTR, Tmax, and Tmin of the SBA were analysed to investigate the seasonal characteristics of DTR change, as illustrated in Figures. 2–5.Trends of seasonal DTR, Tmax and Tmin were summarized in Table1. Obviously, from Figures. 2–5 and Table1, Tmax and Tmin have different seasonal behaviours, and DTR change demonstrates seasonal patterns. DTR has decreasing trend in spring and summer seasons, with the highest decrease rate in summer. While it shows the increasing trend in winter and autumn season, with the highest increasing rate in winter. In summer, Tmax has a highest decreasing rate but Tmin shows the lowest increasing rate among the four seasons, so DTR demonstrates the most significantly decreasing trend, at the rate of 0.263158 °C/year in this season. In winter season, the ascending slopes of trend lines of all parameters, DTR, Tmax and Tmin acknowledge the increase of temperature in this region. However Tmax demonstrates the highest increasing rate among all parameters in this season. Tmax increases with the rate of 0.210526 °C/year in winter season which indicates that winter in SBA is getting warmer. The DTR has shown the decreasing trend with the rate of 0.047368 °C/year but Tmax and Tmin have increasing trends during spring season. The winter season has also become hotter like winter. Tmax and Tmin demonstrate the decreasing trends during Autumn but DTR shows the increasing trend due to more rate of decreasing trend of Tmin than the decreasing rate of Tmax .

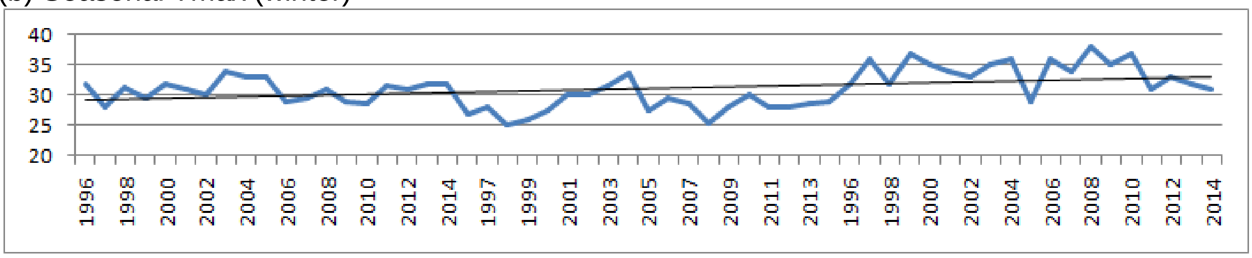
Tab. 1 - Trends of seasonal monthly maximum temperature(Tmax), minimum temperature(Tmin), and diurnal air temperature range(DTR) (unit: ^{o}C/yr) of the SBA.

	Winter	Spring	Summer	Autumn
Tmax	0.210526	0.368421	- 0.473684	-0.368421
Tmin	0.084211	0.421053	0.023684	- 0.421053
DTR	0.136842	- 0.047368	- 0.263158	0.115789

(a) Seasonal DTR (winter)



(b) Seasonal Tmax (winter)



(c) Seasonal Tmin (winter)

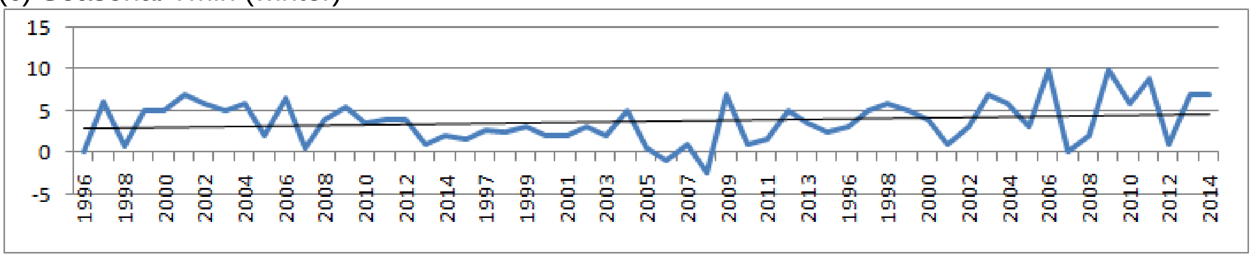
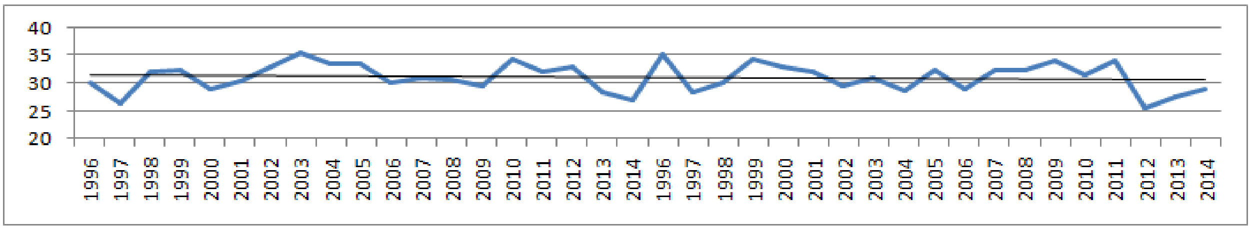


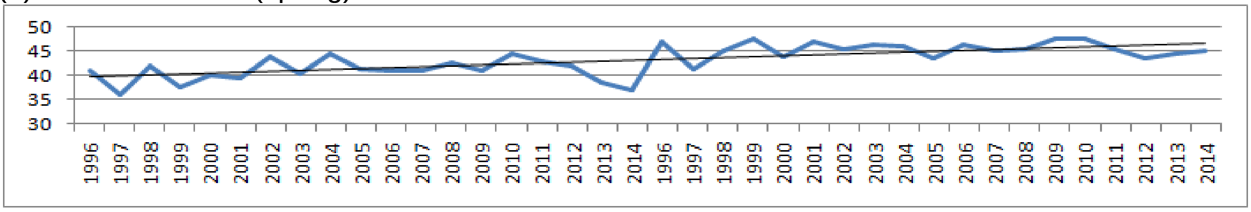
Fig. 2 - Air temperature variation of winter season in SBA (a) diurnal air temperature range (DTR) (b) maximum air temperature (Tmax) (c) minimum air temperature(Tmin)

DOI 10.14311/CEJ.2019.02.0015

(a) Seasonal DTR (spring)



(b) Seasonal Tmax (spring)



(c) Seasonal Tmin (spring)

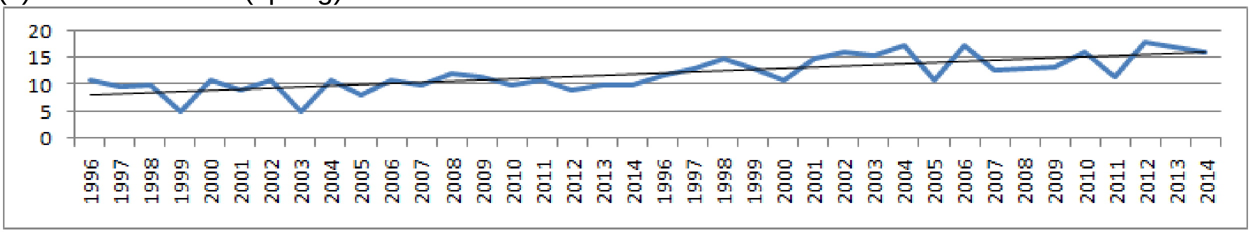
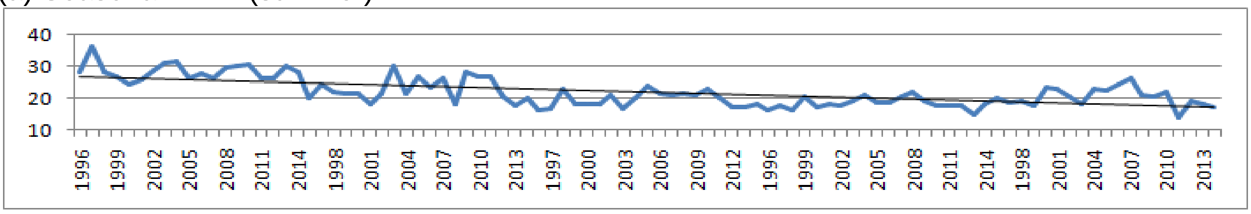
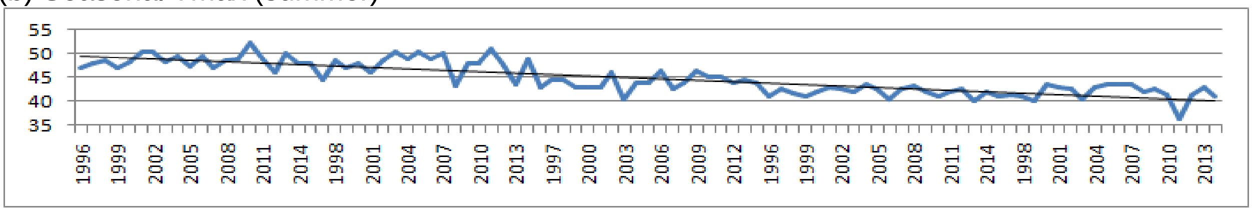


Fig. 3 - Air temperature variation of Spring season in SBA (a) diurnal air temperature range (DTR) (b) maximum air temperature (Tmax) (c) minimum air temperature(Tmin)

(a) Seasonal DTR (summer)



(b) Seasonal Tmax (summer)



(c) Seasonal Tmin (summer)

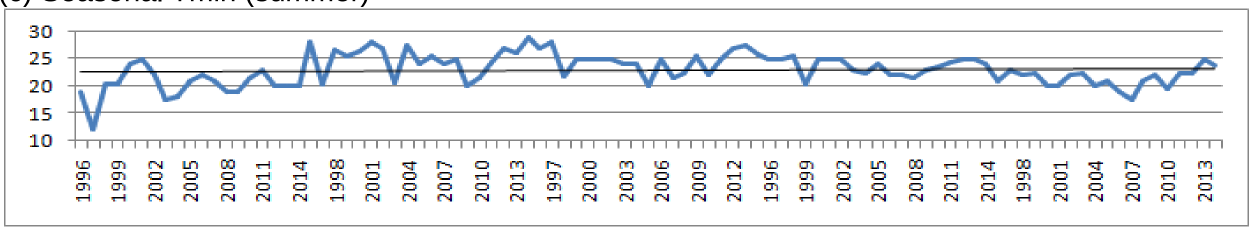


Fig. 4 - Air temperature variation of Summer season in SBA (a) diurnal air temperature range (DTR) (b) maximum air temperature (Tmax) (c) minimum air temperature(Tmin)

(a) Seasonal DTR (autumn)

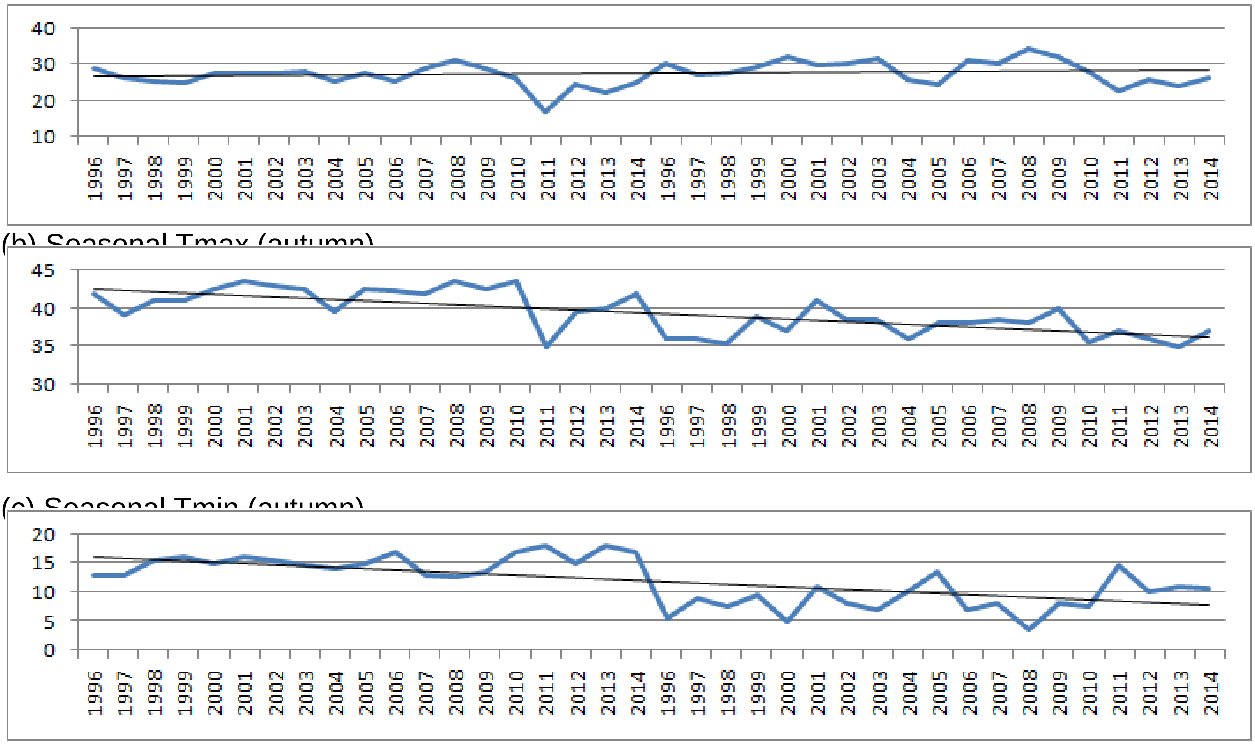


Fig. 5 - Air temperature variation of Autumn season in SBA (a) diurnal air temperature range (DTR) (b) maximum air temperature (Tmax) (c) minimum air temperature(Tmin)

Trend analysis by Mann-Kendall test and Sen's estimator

The Mann-Kendall test was performed on the all parameters in order to find out the statistics regarding the trends of temperature in Shaheed Benazir Abad. The results were summarized in the Table 2 and Table3 which were obtained by using Mann-Kendall test on the all parameters of temperature. The significance level was taken same (α = 5%) for all parameters of temperature.

Tab. 2 - Statistics by Mann-Kendall test of Temperature

Parameters	Mann-Kendall Statistic(S)	Kendall's Tau	P-value	Alpha	Test Interpretation
Tmax	-96.00	-0.004	0.533	0.05	Accept H_0
Tmin	571	0.022	0.309	0.05	Accept H_0
DTR	-1186	-0.047	0.850	0.05	Accept H_0
Tmax(winter)	355	0.228	0.007	0.05	Reject H_0
Tmin(winter)	129	0.083	0.188	0.05	Accept H_0
DTR(winter)	201	0.134	0.075	0.05	Accept H_0
Tmax(Spring)	339	0.491	0.0001	0.05	Reject H_0
Tmin(Spring)	401	0.591	0.0001	0.05	Reject H_0
DTR(Spring)	-38	-0.055	0.679	0.05	Accept H_0
Tmax(Summer)	-2610	-0.596	1	0.05	Accept H_0
Tmin(Summer)	-115	-0.026	0.643	0.05	Accept H_0
DTR(Summer)	-1751	-0.397	1	0.05	Accept H_0
Tmax(Autumn)	-326	-0.474	1	0.05	Accept H_0
Tmin(Autumn)	-253	-0.365	0.999	0.05	Accept H_0
DTR(Autumn)	87	0.125	0.139	0.05	Accept H_0

Tab. 3 - Nature of trends and their magnitudes

Parameters	Mann-Kendall Test Nature	Trend Significance	Sen's slope	Magnitude of Trend (°C/year)
Tmax	No change	No	0.00	0.00052
Tmin	Positive	No	0.003	0.06315
DTR	Negative	No	-0.006	0.05789
Tmax(winter)	Positive	Yes	0.067	0.21052
Tmin(winter)	Positive	No	0.018	0.084211
DTR(winter)	Positive	No	0.044	0.136842
Tmax(Spring)	Positive	Yes	0.182	0.36842
Tmin(Spring)	Positive	Yes	0.214	0.42105
DTR(Spring)	Negative	No	-0.025	- 0.04736
Tmax(Summer)	Negative	No	-0.094	- 0.473684
Tmin(Summer)	No change	No	0.00	0.023684
DTR(Summer)	Negative	No	-0.10	- 0.263158
Tmax(Autumn)	Negative	No	-0.168	-0.368421
Tmin(Autumn)	Negative	No	-0.206	-0.421053
DTR(Autumn)	Positive	No	0.056	0.115789

The results revealed that seven parameters have positive trends and six parameters have negative trends while two parameter show no change in trends which are indicated in Table 3. The P-values of twelve parameters are greater than Alpha value (significance level) as indicated in Table 2 which means that one cannot reject the hypothesis H_o. These values show that twelve parameters have insignificant trends. While the P-value of three parameters of time series of temperature are less than the value of Alpha which are interpreted that the hypothesis H_o should be rejected. It means that the significant positive trends were detected for Tmax(winter), Tmax(spring) and Tmin(spring) in Shaheed Benazir Abad during study period. The warming trend of winter season was also confirmed by MK test. The Sen's estimator of slope was used to find out the magnitude of slopes of trends of temperature in the study area. The result shows that Tmin(spring) exhibits significant increasing trend with slope of 0.214 and Tmin (Autumn) indicates the decreasing trend with slope of 0.206.

CONCLUSIONS

The all months and seasonal variation of Diurnal temperature range was investigated in Shaheed Benazir Abad from 1996 to 2014 by using the linear regression method, the trend magnitude, the Mann-Kendall test and the Sen’s estimator of slope. The result reveals that there is decreasing trend in all months DTR which means that the variation range of temperature is reducing in the past 19 years, as demonstrated in this paper. A steadily decreasing trend of DTR over the SBA was identified statistically. The minimum temperature increased by 0.0631°C/year across SBA in the past 19 years, whereas the DTR decreased by 0.05°C/year which was mainly due to the increasing rate of minimum temperature. The trends of DTR, maximum air temperature and minimum air temperature have significant seasonal differences. The summer season demonstrate higher DTR decreasing rate than the spring season while, in winter and autumn, the DTR shows increasing trend. The significant positive trends were detected by MK test for Tmax(winter), Tmax(spring) and Tmin(spring) in Shaheed Benazir Abad during study period which means that the winter and spring are warmer now than in the previous years.

REFERENCES

[1] Shen, X., Liu, B., Li, G., Wu, Z., Jin, Y., Yu, P. and Zhou, D., 2014. Spatiotemporal change of diurnal temperature range and its relationship with sunshine duration and precipitation in China. Journal of Geophysical Research: Atmospheres, 119(23)..DOI: 10.1002/2014JD022326

[2] Lewis, S.C. and Karoly, D.J., 2013. Evaluation of historical diurnal temperature range trends in CMIP5 models. Journal of Climate, 26(22), pp.9077-9089..https://doi.org/10.1175/JCLI-D-13-00032.1

[3] Qu, M., Wan, J. and Hao, X., 2014. Analysis of diurnal air temperature range change in the continental United States. Weather and Climate Extremes, 4, pp.86-95. https:// doi.org/10.1016/ j.wace. 2014 .05.002

[4]. Vose, R.S., Easterling, D.R. and Gleason, B., 2005. Maximum and minimum temperature trends for the globe: An update through 2004”. Geophysical Research Letters, 32(23)..DOI: 10.1029/2005GL024379

[5] Roy, S.S. and Balling, R.C., 2005. Analysis of trends in maximum and minimum temperature, diurnal temperature range, and cloud cover over India. Geophysical Research Letters, 32(12). DOI: 10.1029/2004GL022201

[6] Folland, C.K., Karl, T.R. and Vinnikov, K.Y., 1990. Observed climate variations and change. Climate change: the IPCC scientific assessment, 195, p.238.

[7] Rai, A., Joshi, M.K. and Pandey, A.C., 2012. Variations in diurnal temperature range over India: under global warming scenario. Journal of Geophysical Research: Atmospheres , 117(D2). DOI: 10.1029/2011JD016697

[8] Braganza, K., Karoly, D.J. and Arblaster, J.M., “Diurnal temperature range as an index of global climate change during the twentieth century”. Geophysical Research Letters ,31 (13) .2004. DOI: 10.1029/2004 GL019998

[9]. Easterling, D.R., Horton, B., Jones, P.D., Peterson, T.C., Karl, T.R., Parker, D.E., Salinger, M.J., Razuvayev, V., Plummer, N., Jamason, P. and Folland, C.K., 1997. Maximum and minimum temperature trends for the globe. Science, 277(5324), pp.364-367..DOI: jstor.org/stable/2892861

[10] Chaudhry, Q.U.Z., Mahmood, A., Rasul, G. and Afzaal, M., 2009. Climate change indicators of Pakistan. Technical Report No. PMD-22/2009, pp 1-43.

[11] Rebetez, M. and Beniston, M., 1998. Changes in sunshine duration are correlated with changes in daily temperature range this century: An analysis of Swiss climatological data. Geophysical Research Letters, 25(19), pp.3611-3613.

[12] Dai, A., Trenberth, K.E. and Karl, T.R.,. 1999. Effects of clouds, soil moisture, precipitation, and water vapor on diurnal temperature range. Journal of Climate, 12(8), pp.2451-2473. https ://doi.org /10.1175/ 1520-0442

[13] Englehart, P.J. and Douglas, A.V.,Changing behavior in the diurnal range of surface air temperatures over Mexico”. Geophysical Research Letters, 200532(1). DOI: 10.1029/2004GL021139

[14] Wang, K., Ye, H., Chen, F., Xiong, Y. and Wang, C., 2012. Urbanization effect on the diurnal temperature range: different roles under solar dimming and brightening. Journal of Climate, 25(3), pp.1022-1027. D.O.I.org/10.1175/JCLI-D-10-05030.1

[15] Lobell, D.B. and Bonfils, C., 2008. The effect of irrigation on regional temperatures: a spatial and temporal analysis of trends in California, 1934–2002. Journal of Climate, 21(10), pp.2063-2071. https://doi.org/10.1175/2007JCLI1755.1

[16]. TuTiempo. Average annual climate values 1996-2014.Available from: http://www.tutiempo.net/en/Climate

[17] Ahmad, I., Zhaobo, S., Weitao, D. and Ambreen, R., 2010. Trend analysis of January temperature in Pakistan over the period of 1961-2006: Geographical Perspective. Pakistan Journal of Meteorology, 7(13), pp.11-22.

[18] Sadiq, N. and Qureshi, M.S., 2010. Climatic variability and linear trend models for the five major cities of Pakistan. Journal of Geography and Geology, 2(1), p.83.

[19] Martinez, C.J., Maleski, J.J. and Miller, M.F., 2012. Trends in precipitation and temperature in Florida, USA . Journal of Hydrology, 452, pp.259-281.

[20] Shi, P., Ma, X., Chen, X., Qu, S. and Zhang, Z., 2013. Analysis of variation trends in precipitation in an upstream catchment of Huai River. Mathematical Problemsin Engineering, DOI. org/10. 1155/2013/ 929383.

[21] Yadav, G. and Mishra, D.N., 2015. Air Pollution Trend Analysis Using Sen Estimator Method. International Journal of Advanced Research in Computer Science and Software Engineering, 5(7), pp.1073-1080.

[22] Gavrilov, M.B., Marković, S.B., Jarad, A. and Korać, V.M., 2015. The analysis of temperature trends in Vojvodina (Serbia) from 1949 to 2006. Thermal Science, 19 (suppl. 2), pp.339-350. D.O.I. 10.2298/TSCI150207062G

[23] Tabari, H. and Talaee, P.H. 2011. Analysis of trends in temperature data in arid and semi-arid regions of Iran. Global and Planetary Change, 79(1), pp.1-10.

[24] O. Hoegh-Guldberg,D. Jacob, M. Taylor, M. Bindi, S. Brown, I. Camilloni, A. Diedhiou, R. Djalante, K. Ebi, F. Engelbrecht, J. Guiot, Y. Hijioka, S. Mehrotra, A. Payne, S. I. Seneviratne, A. Thomas, R. Warren, G. Zhou, 2018, Impacts of 1.5°C global warming on natural and human systems. In: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S.

Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. In Press.
[25] Y. Hijioka et al. 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability-Asia. Cambridge, United Kingdom, and New York, USA: Cambridge University Press. p. 1350.