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ASSESSMENT OF CLIMATE CHANGE IN ANAND OF CENTRAL GUJARAT WITH REFERENCE TO TEMPERATURE FLUCTUATION : A CASE STUDY

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ABSTRACT : The rainfall and temperature is the most fundamental physical parameter among the climate as it determines the environmental factors of the particular region which affect the agricultural productivity. Global warming/climate change is one of the most important worldwide issue talked among the scientists and researchers. Attempts have been made to study the temporal variations and trends in monthly, seasonal and annual temperature over Anand (middle Gujarat). Analysis has been carried for four temperature indices, namely - minimum temperature (T_{min}), maximum temperature (T_{max}), mean temperature (T_{mean}) and diurnal temperature range (DTR). Non-parametric Mann-Kendall (MK) test was used to detect the trends and the magnitude of the trends were determined with Sen's estimator of slope.The present study is the warming trends in T_{min}, T_{max} and T_{mean} temperatures and decreasing trends in DTR over City of Anand. At the site, the total numbers of statistically significant values in three temperature indices - T_{min}, T_{max} and T_{mean} are more than total numbers of non-significant values on annual, seasonal and monthly timescale.All the trend in T_{min} variable are increasing at the station on annual, seasonal and monthly scale. These increasing trends in T_{min} are significant at annual, seasonal and monthly scales over January, July August and December over Anand, it is significant at annual, seasonal (winter, monsoon, post-monsoon). In general, the magnitudes of rate of change in Tmin are higher as compared to other variables on all time scale at the station.The increasing trends in T_{max} at Anand are significant on annual scale, monsoon season as well as in February, March, May,June, August, October to December at Anand Similar to the trends observed in T_{min} and T_{max}, T_{mean} shows significant increasing trends on annual, seasonal (monsoon and post-monsoon) and monthly (except January) scale over Anand timescale.DTR shows significant decreasing trends on annual scale, winter season, post-monsoon season and in April month at Anand.

Keywords : *Global warming, meteorological data, linear trend, Mann-Kendall trend test, Sen's slope.*

The rainfall and temperature is the most fundamental physical parameter among the climate as it determines the environmental factors of the particular region which affect the agricultural productivity. Global warming/climate change is one of the most important worldwide issue talked among the scientifics and researchers. This problem worries the scientific community, as it could have a major impact on natural and social systems at local, regional and national scales. Numerous climatologists; Intergovernmental Panel on Climate Change (IPCC), agree that there has been a large-scale warming of the Earth's surface over the last hundred years or so. This warming up of the Earth during the 20th century brought with it a decrease in the area of the world affected by exceptionally cool temperatures, and, to a lesser extent, an increase in the area affected by exceptionally warm temperatures. Some analyses of long time-series of temperatures on a hemispheric and global scale have indicated a warming rate of 0.3-0.6°C since the mid-19th century, due to either anthropogenic causes or astronomic causes. The Third Assessment Report projections for the present century are that average temperature rises by 2100 would be in the range of 1.4-5.8°C. Records show that global temperatures, averaged world-wide over the land and sea, rose 0.6 ± 0.2°C during the 20th century. A number of recent studies have been devoted to global, hemispherical, or regional long-term temperature variations. On a global scale, climatologically studies indicate an increase of 0.3-0.6°C of the surface air temperature 0.5-0.7°C for the Northern Hemisphere) since 1860, while the eighth warmest years ever recorded were observed after. A broad consensus of scientists has concluded that the earth's surface air temperature increased by about 0.6°C during the 20th century, that most of the warming during the latter half of the century is attributable to human emissions of

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greenhouse gases, and that temperature increases were greatest during the 1990s. Numerous other factors such as variations in solar radiation and pollutant aerosols also contribute to climate change.The IPCC panel further concluded that global temperature increases are likely to persist in the 21st century and will probably be accompanied by changes in precipitation and runoff amounts. Future climate change is more difficult to predict with great certainty at the regional scale due to spatial resolution limitations of current climate models and to the likely influence of unaccounted for factors such as regional land use change.

The dominating climatic feature in the region is the summer Southwest Asian Monsoon, which influences the climatology of the nations within the sub-region to varying degrees and in diverse ways. Climate trends and variability in Asia are generally characterized by increasing surface air temperature which is more pronounced during winter than in summer. The observed increases in some parts of Asia during recent decades ranged between less than 1°C to 3°C per century. Increases in surface temperature are most pronounced in North Asia; Climate Change in Russia. The Third Assessment Report predicted that the area-averaged annual mean warming would be about 3°C in the decade of the 2050s and about 5°C in the decade of the 2080s over the land regions of Asia as a result of future increases in atmospheric concentration of greenhouse gases.

Many researchers across the world have studied the affect of rising temperatures on the environment on global scale. Karl *et al.* (12) have used monthly T_{max} and T_{min} data over the global landmass and found that the rise in T_{min} is three times faster than the T_{max} during the period 1951-1990 (0.84 °C verses 0.28 °C). Analysis of the global surface temperature data for the past five centuries by Mann *et al.* (16) clearly indicates that the 20th century temperatures are warmer than any other century. Jones et al. (7) observed a decrease of 0.8°C per decade in DTR due to much greater increase in T_{min} than T_{max} for the period 1950-1993.

Several researchers have also investigated the spatial and temporal variability in surface temperature over Northeast India (Jain and Vijay Kumar, 8; Jain *et al.,* 9; Jhajharia and Singh, 10; Laskar *et al.,* 14). Jain and Vijay Kumar (8) has observed that some stations in North and Northeast India showed falling trends in annual T_{mean} data. Jain *et al.* (9) analyzed the temperature trends in Northeast India and found that all the four temperature variables (T_{max}, T_{min}, T_{mean} and DTR) showed rising trend. Jhajharia and Singh (10) noticed decreasing as well as increasing trends in DTR over Northeast India. They have observed decreasing trends at four stations on yearly, seasonal (pre-monsoon and monsoon) and monthly (September) scale and increasing trends at other three stations on seasonal (monsoon and post-monsoon season) and monthly (June, October and December) scale.

The annual mean temperature of India as a whole has risen to 0.51°C over the period during 1901-2005. A number of scientific research studies shown that the surface air temperature increased about 0.2 till 0.6°C during the last century (Abaurrea and Cerian, 1).This rate of increase may vary in different geographical regions (Colin *et. al.,* 4). Weather observations indicated that global average surface temperature has increased by 0.6°C since 19th century (Chahal, 2). Studies indicate that if no corrective measures are taken, the atmospheric temperatures may increase by 1.4° to 5.8°C by the year 2100 (IPCC,6).

The investigations of long-term variations and trends in temperature data are not getting enough attention even though this area is suffering from

Fig. 1 and 2 : Map showing study area and location of the station Anand.

Table 1 : Monthly, seasonal and annual means of Temperature (°C) for Anand (middle Gujarat).

Month/season	T_{min} (°C)	T_{max} (°C)	T_{mean} (°C)	DTR (°C)
January	10.9	27.7	19.3	16.7
February	12.4	30.1	21.2	17.8
March	16.6	34.8	25.7	18.2
April	21.0	38.0	29.5	17.0
May	24.7	39.0	31.9	14.2
June	26.6	36.6	31.6	10.0
July	25.7	32.5	29.1	6.8
August	24.9	31.2	28.0	6.3
September	24.2	32.6	28.4	8.5
October	20.7	34.9	27.8	14.3
November	15.9	32.3	24.1	16.5
December	12.4	29.0	20.7	16.6
Annual	**19.7**	**33.2**	**26.4**	**13.6**
Pre-monsoon	20.8	37.3	29.0	16.5
monsoon	25.4	33.2	29.3	7.9
Post-monsoon	16.3	32.1	24.2	15.8
Winter	11.7	28.9	20.3	17.3

serious environmental, agricultural and water resources problems. In this study an attempt has been made to analyze the variability and trends of temperatures over Anand consolidated form meterological experts. (Chinchorkar *et.al.,* 3).The daily surface temperature data of Anand has been utilized for the analysis. The work is focused to investigate the trends in T_{min}, T_{max}, T_{mean} and DTR at annual, seasonal and monthly timescale.

MATERIALS AND METHODS

Study Area

The present study area is located in the Anand of middle Gujarat state of India (Fig.1). Geographically, it is located at Anand (Lat - 22°.35' N and Long- 72° 58'E) station is located in Middle Gujarat Ago-climatic zone-3. It has an average elevation of 39 metres form the mean sea level. The Annual Rainfall at Anand is ranged between 286.9 to 1693 mm. The Data used in this paper are the monthly, seasonally and annual means of temperatures (Max and Min) and DTR during 1958-2016 (*i.e.,* 58 years). The monthly, seasonally and Annual averages calculated form the monthly readings which is provided by the Department of Agricultural Meteorology BACA, AAU ,Anand. Daily T_{mean} are obtained by averaging daily T_{max} and daily T_{min} data and daily DTR data are calculated by subtracting the daily Tmin from daily T_{max}. The Monthly, seasonal and annual temperature data are calculated by averaging the daily temperature data for the month, season and annual respectively.

Mann Kandall (MK) statistic (Mann, 15; Kendall, 11) and Sen's estimator slop (Sen, 20) were used to detect the trends and magnitude of the trends in the time-series of all temperature indices. In the present study the null hypothesis was tested at 95% significance level.

RESULTS AND DISCUSSION

Temperature characteristics

The four seasons in India as defined by IMD are: winter season (January - February), pre-monsoon season (March to May), monsoon season (June to September) and post-monsoon season (October to December) based on the climatology of the region. The characteristics of monthly, seasonal and annual average temperatures are reported in Table 1. The annual average T_{max} is around 33.2 °C. The annual T_{min} min are 19.7 °C, T_{mean} are 26.4 °C and DTR are 13.6 for Anand, respectively.

The seasonal T_{max} is highest (37.3 °C) during the pre-monsoon season and lowest (28.9 °C) during the winter season. The seasonal Tmin is lowest (11.7 °C) during the winter season and highest (25.4 °C) during the monsoon season. The seasonal average T_{mean} temperature varies from 20.3°C to 29.3°C and the highest (29.3°C) is experienced during the monsoon season. The seasonal mean DTR are also found highest 17.3 °C during the winter season and lowest 7.9 ºC during the monsoon season.

The highest values (28-29 ºC) of monthly T_{mean} are observed during pre-monsoon season and monsoon season. The monthly T_{mean} is maximum during May-September period and June-September period respectively.

The monthly T_{max} is highest in May and lowest in January. The highest monthly T_{max} observed in May are 39.0 ºC at Anand respectively. During pre-monsoon season and monsoon season, *i.e.,* from March to September months the maximum temperature varies from 32.5 ºC to 38.0 ºC over Anand. January is the coldest month for Anand station with monthly minimum temperature at around 10.9 ºC. The monthly T_{min} are highest (24.0 ºC to 26.0 ºC) during June-to-September months (monsoon season) over Anand.

The DTR values are highest during January-February months (winter season) and lowest during June-September months (monsoon season). At Anand, DTR is highest in January (16.7 ºC) followed by February (17.8 ºC).During June-September months (monsoon season) DTR varies from 6.3 ºC to 10.0 ºC.

Trend analysis of annual temperature

The yearly T_{min}, T_{max}, T_{mean} and DTR time-series are presented in Fig.2 for Anand respectively. The linear trend lines, linear regression equations and value of R_2 are also depicted in these figures to indicate the linear tends in annual temperature indices. MK test statistics and Sen's slop for the annual temperatures indices namely; T_{min}, T_{max}, T_{mean} and DTR are provided in Table 2.

The three indices, viz., annual T_{min}, T_{max}, and T_{mean} show an increasing trend but DTR shows decreasing trends. The increasing trends in T_{min}, T_{max} and T_{mean} indices are statistically significant at Anand whereas the decreasing trend in DTR is significant for Anand. Among the four temperature variables, the T_{min} observed the highest rate of change at Anand. Sen's estimator of slop indicates increase during the period of study over Anand (0.02650ºC/year), respectively (Table 2). The annual increase in T_{max} indices is slowest at the rate of 0.02469 ºC/year over Anand respectively. The magnitude of increase in annual Tmean is 0.02661ºC/year over Anand respectively. The comparatively higher increase in T_{min} as compared to T_{max} leads to significant fall of 0.01555

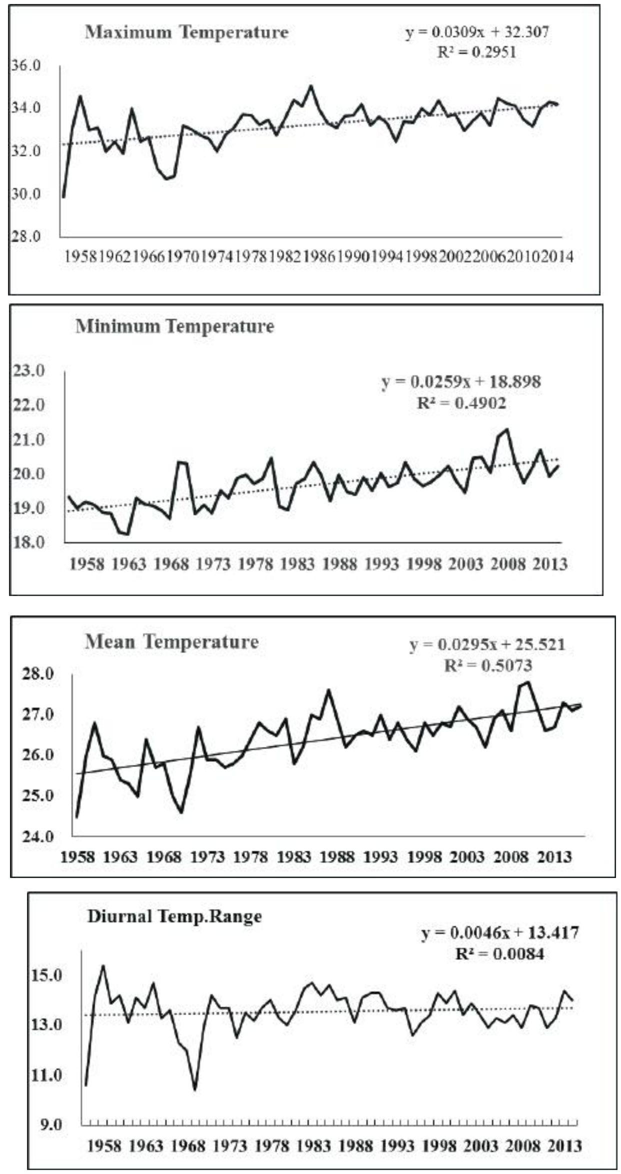

Fig. 3 : Annual maximum, minimum, mean temperature and DTR plots for Anand.

ºC/year but the trends are found non-significant as per MK test.

The above results are in contrast to the finding of Srivastava *et al.* (19), Rupa Kumar *et al.* (17) and Jain *et al.* (9) but are consistent with the trends observed by other scientists over India (Kothawale and Rupa Kumar, 13; Dash *et al.,* 15; Jhajharia and Singh, 10) and over the globe (Karl *et al.,* 12; Jones *et al.,* 7) too.

Positive and negative values show increasing and decreasing trends respectively. Bold values indicate statistical significance at 95% confidence level as per the MK test.

Table 2 : Sen's slop (°C/year) for monthly, seasonal and annual temperature at Anand.

Month/season	T_{min}	T_{max}	T_{mean}	DTR
January	0.01658	0.00047	0.01089	-0.01883
February	**0.02612**	**0.02586**	0.02563	-0.01728
March	**0.02887**	0.02288	0.02777	-0.01013
April	**0.04071**	0.01407	**0.02571**	-0.02291
May	**0.03933**	0.02204	0.02696	-0.01360
June	**0.02047**	**0.02765**	0.02283	0.00476
July	0.00977	0.01441	0.01198	0.00728
August	0.00956	**0.02266**	0.01528	0.01263
September	**0.02577**	0.01548	0.01807	-0.01020
October	**0.02872**	0.02825	0.03042	-0.00442
November	**0.02935**	0.03607	0.02857	0.00403
December	0.01528	**0.03612**	0.02505	0.01280
Annual	**0.02650**	0.02469	0.02661	-0.00267
Pre-monsoon	**0.03635**	0.01659	**0.02894**	-0.01555
monsoon	0.01598	0.01938	**0.02740**	0.00127
Post-monsoon	**0.02473**	0.03517	**0.02775**	0.01254
Winter	**0.02088**	0.01279	0.01634	-0.01555

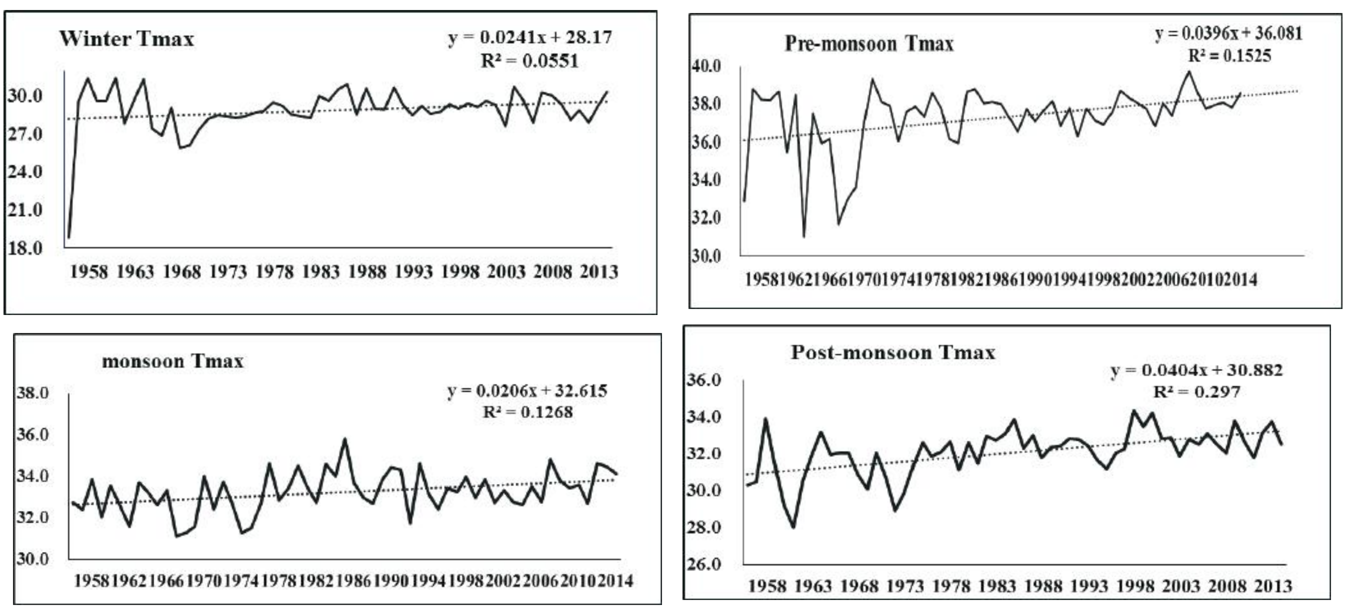

Fig. 4. (a) :Linear trends and times-series of maximum temperature (T_{max}) for four seasons (winter, Pre-monsoon, Monsoon and Post-monsoon) at Anand (Middle Gujarat).

Trend analysis of seasonal temperature

Figs. 4(a-d) show the time series and linear trend in T_{min}, T_{max}, T_{mean} and DTR variables for the four seasons- winter, pre-monsoon, monsoon and post-monsoon season over Anand respectively. During four seasons, the trends in T_{min}, T_{max} and T_{mean} are increasing over station in T_{max} over Anand during the post monsoon season (Table 2). The analysis indicates that the increasing trends in three temperature variable namely- T_{min}, T_{max} and T_{mean} are significant during the monsoon season over the station. At Anand, the largest increase in T_{min} (1.8 ºC) and T_{mean} (1.1 ºC) are seen in post-monsoon season whereas the largest increase in T_{max} (0.5 ºC) are observed during the monsoon season. So, analysis clearly indicates higher rate of change in T_{min} than T_{max} on seasonal scale over site. The highest significant increase of 1.8 ºC and 1.1 ºC during the period 1958-2016 in T_{min} are

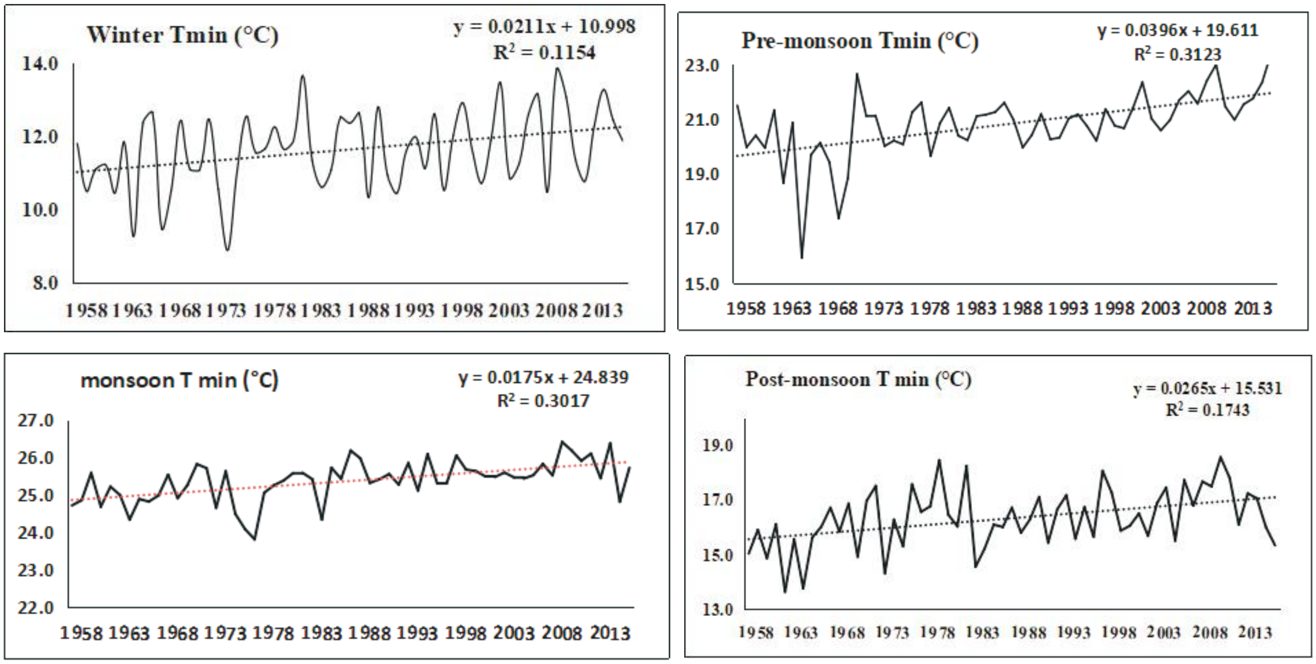

Fig. 4. (b) : Linear trends and times-series of minimum temperature (T_{min}) for four seasons (Winter, Pre-monsoon, Monsoon and Post-monsoon) at Anand (Middle Gujarat).

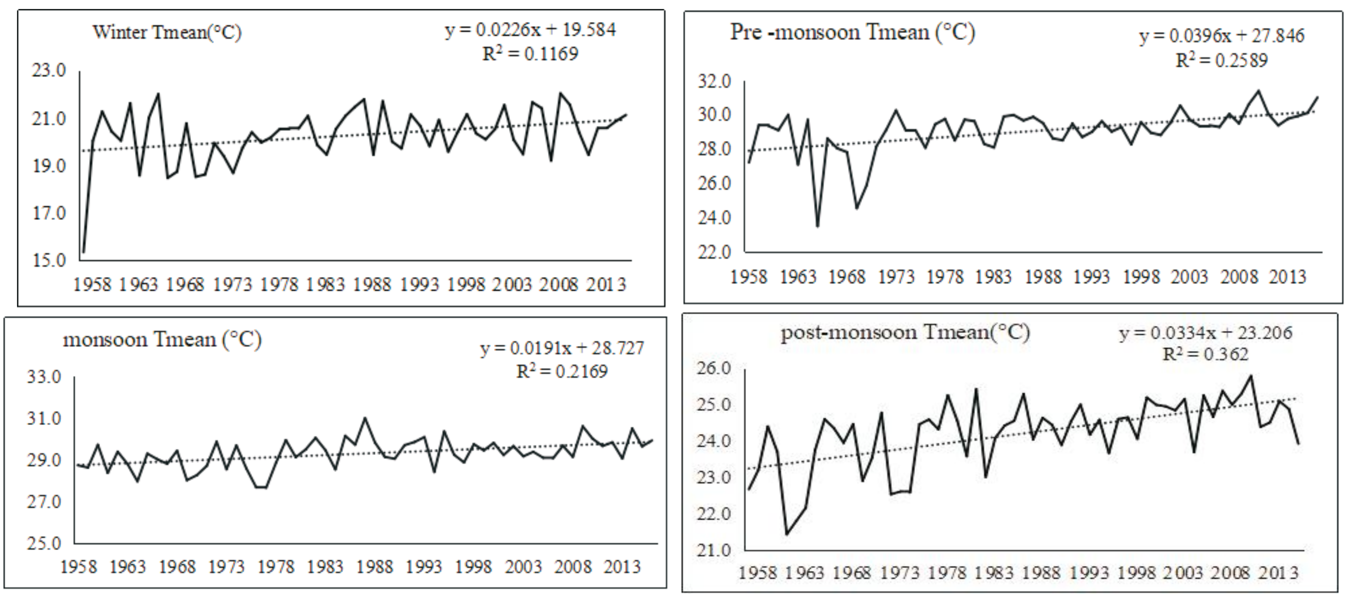

Fig. 4. (c) : Linear trends and times-series of mean temperature (T_{mean}) for four seasons (winter, Pre-monsoon, Monsoon and Post-monsoon) at Anand (Middle Gujarat).

observed in the post monsoon season at Anand respectively.

The comparatively higher rate of increase in T_{min} leads to fall in DTR values at site for all four seasons except during the monsoon season over Anand, where, rising trend in T_{max} is slightly higher than T_{min} (Table 2). The significant decreasing trends in DTR values are seen only over Anand during the winter and post-monsoon season. During the period of study the DTR trends at Anand in winter season and post-monsoon season indicates decrease of –1.5ºC and –1.2ºC, respectively.

Trend analysis of monthly temperature

The trend in T_{min} data indicates increase in temperature for all the months over Anand. Quantitatively, the highest magnitudes in trend values are also observed in Tmin as compared to magnitude of trend in other three temperature indices (T_{max}, T_{mean} and DTR) over site. At the station, the rate of increase

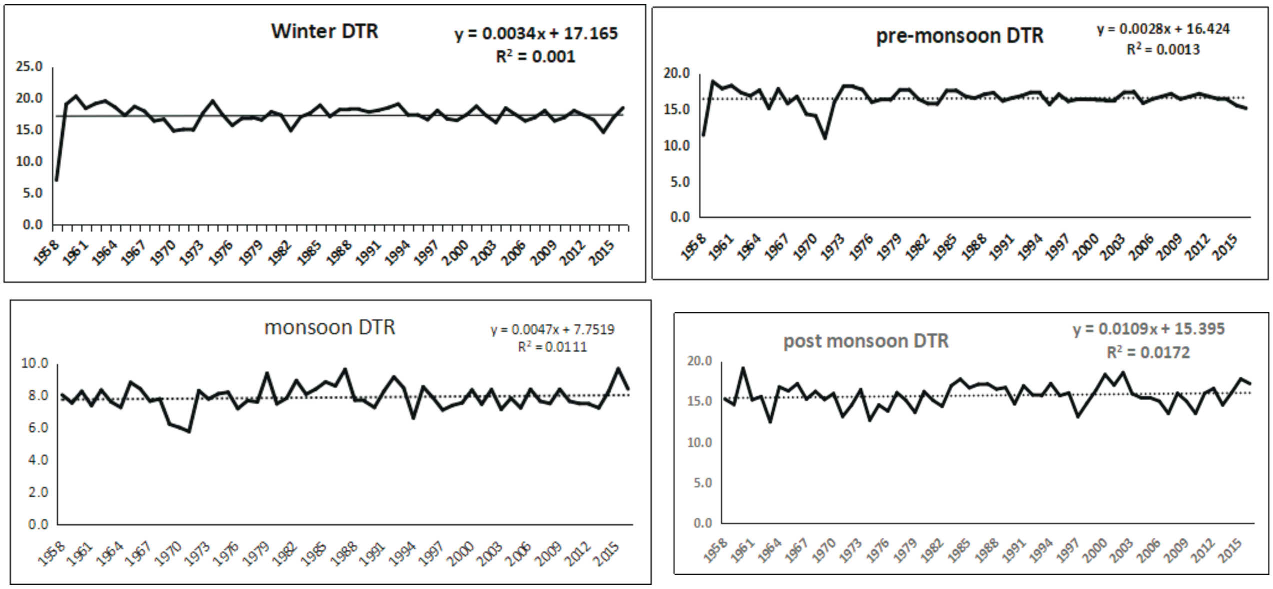

Fig. 4. (d) : Linear trends and times-series of DTR for four seasons (winter, Pre-monsoon, Monsoon and Post-monsoon) at Anand (Middle Gujarat).

in T_{min} is highest during April followed by May. The warming trends in T_{min} trend over Anand are significant for eight months.

The positive trend in T_{max} also indicates increase in temperature over Anand. The statistically significant highest rates of increase in T_{max} temperature are found in the month of December (0.03612 °C/year) and November (0.03607°C/year) at Anand, respectively.

All the T_{mean} values also show increasing trends at the station except a significant. The increasing trends in T_{mean} are statistically significant from February to June and October to December at Anand . Similar to T_{min} index, the trends in T_{mean} are also largest in April at the station. The increase of 1.2 °C in Tmean has been detected during the period of study at Anand, respectively.

At station, the statistically significant fall in DTR are observed in the April. During the period of study, Anand witnessed a fall of 2.0 °C in DTR values in the month of April respectively. Therefore, at both the stations the magnitudes of increase in T_{min} are higher than the magnitudes of increase in T_{max} on all timescale. These findings are consistent with the result obtained by other meteorologist (Roy and Balling, 18; Jhajharia and Singh, 10). According to Roy and Balling (18) the significant increase in clouds causes the rise in minimum temperature and hence fall in DTR over the most parts of India for winter and summer season. Correlation analysis performed by Jhajharia and Singh (10) revealed that the different meteorological parameters (sunshine duration, pan evaporation, temperature, rainfall and humidity) influence DTR in different seasons over different sites in Northeast India. They have also observed significant decreasing trends in the sunshine duration at annual, seasonal (winter and pre-monsoon) and monthly (January, February and March) scales and suggested that the decrease in sunshine duration may be one of the potential cause for decreased DTR values over Northeast India.

CONCLUSION

The present study is the warming trends in T_{min}, T_{max} and T_{mean} temperatures and decreasing trends in DTR over City of Anand. At the site, the total numbers of statistically significant values in three temperature indices - T_{min}, T_{max} and T_{mean} are more than total numbers of non-significant values on annual, seasonal and monthly timescale. All the trend in T_{min} variable are increasing at the station on annual, seasonal and monthly scale. These increasing trends in T_{min} are significant at annual, seasonal and monthly scales over January, July, August and December over Anand, it is significant at annual, seasonal (winter, monsoon, post-monsoon) . In general, the magnitudes of rate of change in T_{min} are higher as compared to other variables on all time scale at the station.The increasing trends in T_{max} at Anand are significant on annual scale, monsoon season as well as in February, March, May, June, August, October to December at Anand. Similar to the trends observed in T_{min} and T_{max}, Tmean shows significant increasing trends on annual, seasonal (monsoon and post-monsoon) and monthly (except January) scale over Anand timescale.DTR shows significant decreasing trends on annual scale, winter season, post-monsoon season and in April month at Anand.

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