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RESEARCH ARTICLE

Temperature trend in Bharuch district of Gujarat

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ABSTRACT : Temperature and rainfall are the most variable climatic parameters directly affecting to the agriculture and hydrologic cycle on the earth. Due to changing climate how to cope with the our agricultural produce to survive of human being, it is necessary to determine the effect of changing effect of temperature. So the present study was undertaken with objective of estimating the trend of temperature base on past meteorological data. The results obtained from the data analysis shows that there is significant increase in mean and minimum temperature of winter and summer, the season of summer is slightly shifting to winter as the higher temperature days in increasing in winter season, so in future time it will be necessary grow cold temperature loving plants in very precisely and short duration variety.

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Key Words :
Temperature trend, Rainfall, Climatic parameters directly affecting

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Temperature and its changes impact a number of hydrological processes including rainfall and these processes, in turn, also impact temperature (e.g., cooling due to rain/snow). Agricultural and related sectors, food security, and energy security of India are crucially dependent on the timely availability of adequate amount of water and a conducive climate.

The surface temperatures over a given region vary seasonally and annually depending upon latitude, altitude and location with respect to geographical features such as a water body (river, lake or sea), mountains, etc. Probably one of the most widely quoted aspects of climatic change and the one that will have important ramifications on a range of sectors, including water is the significant increase in the global mean air temperature during the past century. Since the hydrologic cycle is a thermally driven system, rise in global temperature is likely to accelerate this cycle. Identification of the temperature trends and their projection has been the subject matter of a large number of studies. India faced the rise of the annual mean temperature, the annual mean maximum temperature and the annual mean minimum temperature by 0.42°C, 0.92°C and 0.09°C, respectively over last century (Arora, 2005).

Several studies (Balling and Idso, 1989; Karl *et al.*,1988 and Goodrich, 1992) published in the last 15 years have attempted to assess the effects of urbanization on local and regional climate. A study by Jones *et al.* (1990) on urbanization and related temperature variation indicates that the impact of urbanization on the mean surface temperature would be no more than 0.05-1^0 C per 100 years. This value appears to be too small when compared with the other studies (Fujibe, 1995 and Hingane, 1996) using a similar technique.

According to the study for Japan by Fujibe (1995) a rising trend of 2–5 ^{0}C per 100 years in minimum temperature has been observed at several large cities in Japan. While another study (Hingane, 1996) estimates rising trends of 0.84 and 1.39. Numerous climatologist Jones *et al.* (1999); Parker and Horton (1999) and intergovernmental panel on climate change (IPCC) IPCC (2001) and Jones and Moberg (2003) and Vinnikov and Grody (2003) agree that there has been large scale warming of the earth's surface over the last hundred years or so. This warming up of the earth during the 20^{th} century brought with it a decrease in the area of the world affected by the exceptionally cool temperatures. Some analysis of long time series of temperatures on a hemispheric and global scale has indicated a warming rate of 0.3-0.6 ^{0}C since the mid 19^{th} century due to either anthropogenic causes or astronomic causes. Third assessment report projection for the present century is that average temperature rises by 2100 would be in the range of 1.4-5.8 ^{0}C. The global temperature averaged worldwide over the land and sea area rose 0.6 ± 0.2 ^{0}C during the 20^{th} century. From the studies it was concluded that the earth's surface air temperature increased by about 0.6 ^{0}C during the 20^{th} century that most of the warming during the latter half of the century is attributable to human emission of green house gases and that temperature increases were greatest during the 1990s.

EXPERIMENTAL METHODOLOGY

Study area :

Bharuch district is located in the Sourthern part of Gujarat, near the Gulf of Khambhat in Arabian Sea. The newly formed Bharuch district has 5253.30 Sq.km. area and situated between 21.30' to 22.00' North Latitude and 72.45' to 73.15' East Longitude. Bharuch district is bounded by Baroda and Anand district on the North, Narmada district on the East, Surat district is on the South and on its west lies the gulf of Cambay. The Eastern strip of the district is a hilly and forest area. The district enjoys moderate climate with greater humidity on its coastal side. The summer begins in early March and lasts till June. April and May are the hottest months, the average maximum temperature being 40 °C. Monsoon begins in late June and the city receives about 800 millimetres (31 in) of rain by the end of September, with the average maximum being 32 °C (90 °F) during those months. October and November see the retreat of the monsoon and a return of high temperatures till late November. Winter starts in December and ends in late February, with average temperatures of around 23°C.

Temperature data analysis :

Monthly maximum and minimum temperature data during the period 1982–2013 (32 years) were obtained from Meteorological station, Navsari Agricultural University, Navsari, Gujarat. From the basic temperature data, mean maximum (T_{max}), mean minimum (T_{min}) and mean temperature, along with their standard deviation (SD) and co-efficient of variation have been computed for each month and three seasons, *viz.*, summer, monsoon and winter, that are depicted in Table A. December, January and February are considered for the analysis of

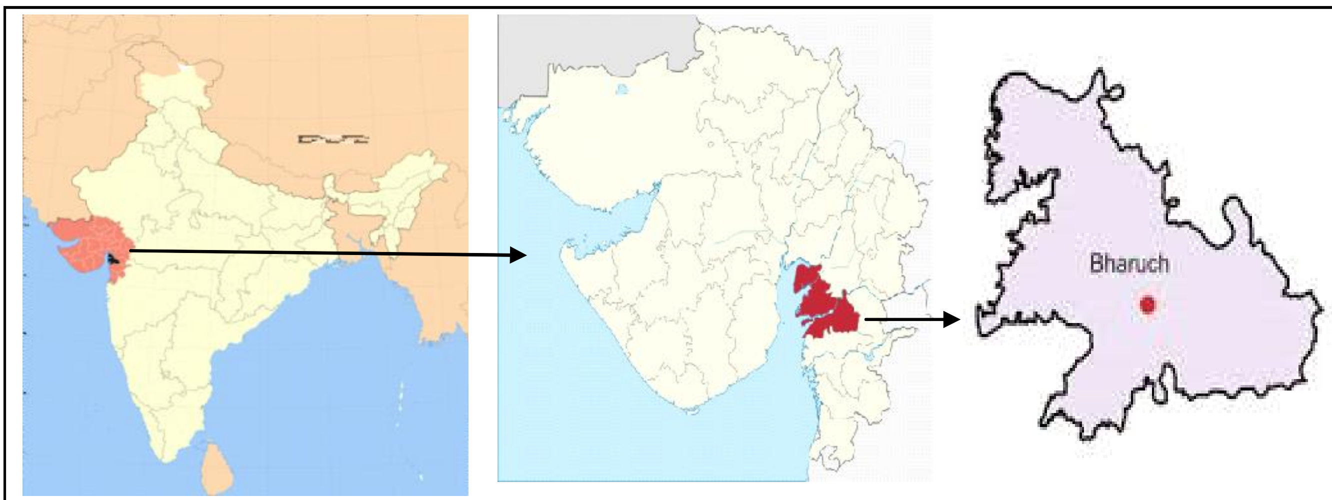


Fig. A : Location of study area

Table A : Monthly and seasonal temperature means

Months	T_{max}	T_{min}	T_{mean}	Standard deviation	Variance
January	31.22	14.51	22.87	1.20	1.44
February	33.27	15.61	24.44	1.19	1.41
March	37.85	18.67	28.26	1.05	1.09
April	40.64	22.11	31.37	0.89	0.78
May	41.12	25.96	33.54	0.67	0.45
June	36.52	26.81	31.66	1.00	0.99
July	30.2	24.9	27.5	0.81	0.65
August	28.5	24.0	26.2	0.73	0.54
September	30.8	23.1	26.9	0.91	0.82
October	33.8	20.7	27.3	1.05	1.09
November	33.3	18.4	25.8	0.95	0.90
December	31.4	15.9	23.7	0.82	0.67
Winter	32.28	16.12	24.20	0.50	0.25
Summer	39.03	23.39	31.21	1.54	2.37
Monsoon	30.84	23.15	26.99	2.19	4.79
Annual	34.05	20.89	27.47	0.56	0.31

winter temperature as these 3 months record lower temperatures (Table A). While computing the mean for winter season December of the previous year is included. March, April and May are months with highest mean maximum temperatures and, therefore, represent the summer season. June to September months constitute monsoon season. These data were then subjected to a 11-year running mean to find the trends. A linear trend line was added to the series to simplify the trend. Temporal changes in the annual and seasonal values were also analysed by Mann–Kendall rank statistics (t) to confirm the significance of the observed trend.

To investigate the changes in Temperature for daily temperature data were used. Daily temperature data converted to monthly, seasonal and annual, a year was divided into three seasons: winter (November – February), summer (March-June), monsoon (July – October). Temperature analysis was carried out for all the seasons as well as the whole year separately. For the trend analysis, daily min-max temperature series were used to form seasonal and annual series of these variables. Basic statistics, such as minimum, maximum, mean and co-efficient of variation (CV) of annual temperature of different data sets are given in Tables A and B. Fig. A shows the temporal variation of annual temperature for the Bharuch district.

Mann Kendall test :

Mann Kendall test is a statistical test widely used for the analysis of trend in climatologic Mavromattes and Stathis (2011) and in hydrologic time series (Yue and Wang, 2004; Mann, 1945 and Kendall, 1975). The MK test has been employed by a number of researchers (Yu *et al.*, 1993; Douglas *et al.*, 2000; Yue *et al.*, 2003; Burn *et al.*, 2004 and Singh *et al.*, 2008a and b) to ascertain the presence of statistically significant trend in hydrological climatic variables, such as temperature, precipitation and stream flow, with reference to climate change. There are two advantages of using this test. First, it is a non parametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series (Tabari *et al.*, 2011). Any data reported as non-detects are included by assigning them a common value that is smaller than the smallest measured value in the data set (Blackwell Publishing Kendall Tau, 2012). According to this test, the null hypothesis H_0 assumes that there is no trend (the data is independent and randomly ordered) and this is tested against the alternative hypothesis H_1, which assumes that there is trend. The computational procedure for the Mann Kendall test considers the time series of n data points and T_i and T_j as two subsets of data where i = 1,2,3,…, n-1 and j = i+1, i+2, i+3, …, n.

The data values are evaluated as an ordered time series. Each data value is compared with all subsequent data values. If a data value from a later time period is higher than a data value from an earlier time period, the

Table B : Results of Mann Kendall test

Months	T_{max}	T_{min}	T_{mean}
January	0	0	0
February	2.90**	2.22*	3.03**
March	2.29*	1.99*	2.38*
April	2.58**	2.42*	3.03**
May	-0.18	3.32**	3.03**
June	-1.61	0.86	-1.02
July	2.81**	0.11	-2.32
August	-0.34	1.67+	0.34
September	-1.18	1.86+	-0.92
October	-0.44	1.41	0.47
November	0.37	2.09*	1.70+
December	1.44	1.70+	2.35*
Winter	1.31	2.32*	2.87**
Summer	0.76	3.49***	2.03*
Monsoon	-1.35	1.83+	-0.66
Annual	0.24	3.29*	2.29*

*, ** and *** indicate significance of values at P=0.05, 0.01 and 0.10, respectively

Table C : Linear equations with their significance tested by t test

Months	Linear equation	Calculated t
Annual mean temperature	y = 0.013x + 27.18	3.048477***
Annual T_{min}	y = 0.000x + 33.96	3.462091***
Annual T_{max}	y = 0.001x + 34.01	1.521978
Winter mean temperature	y = 0.029x + 23.70	3.576827***
Winter T_{min}	y = 0.036x + 15.52	2.329815*
Winter T_{max}	y = 0.024x + 31.87	2.991053***
Summer mean temperature	y = 0.024x + 30.80	2.348849*
Summer T_{min}	y = 0.016x + 38.75	3.587223***
Summer T_{max}	y = 0.032x + 22.85	1.174608*
Monsoon mean temperature	y = -0.010x + 27.16	0.518492
Monsoon T_{max}	y = -0.035x + 31.42	1.750085*
Monsoon T_{min}	y = 0.014x + 22.90	0.018018

*, ** and *** indicate significance of values at P=0.05, 0.01 and 0.10, respectively

statistic S is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, S is decremented by 1. The net result of all such increments and decrements yields the final value of S (Drapela and Drapelova, 2011). The Mann-Kendall S Statistic is computed as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sign}(T_j - T_i)$$

$$\text{sign}(T_j - T_i) = \begin{cases} 1 \text{ if } & T_j - T_i > 0 \\ 0 \text{ if } & T_j - T_i = 0 \\ -1 \text{ if } & T_j - T_i < 0 \end{cases}$$

where T_j and T_i are the annual values in years j and i, j > i, respectively (Motiee and McBean, 2009).

Apart from this, the linear trend fitted to the data was also tested with t-test to verify results obtained by the Mann– Kendall test.

Experimental Findings and Discussion

The findings of the present study as well as relevant discussion have been presented under following heads :

Annual temperature trends :

The annual moving average graph of Mean,

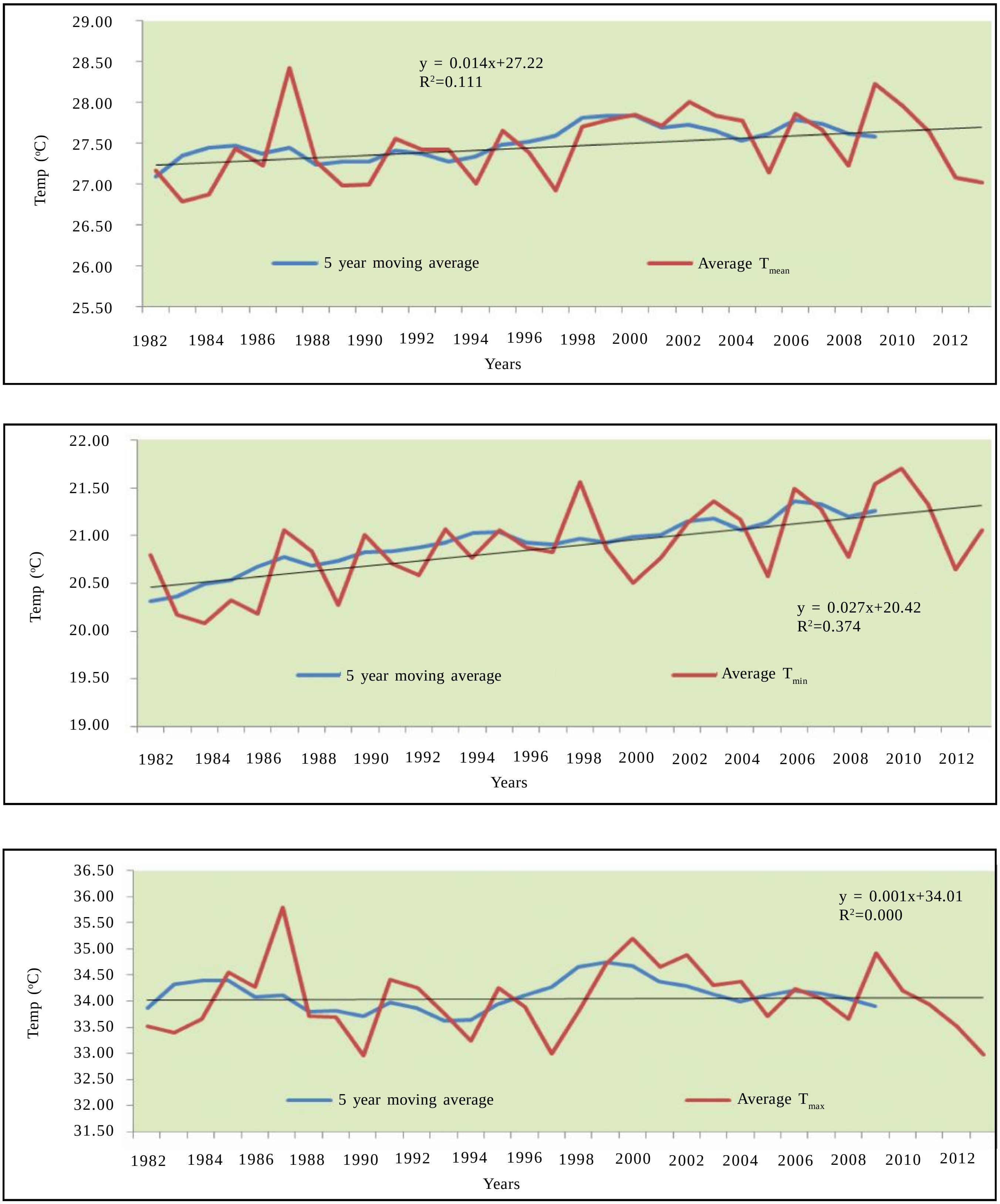
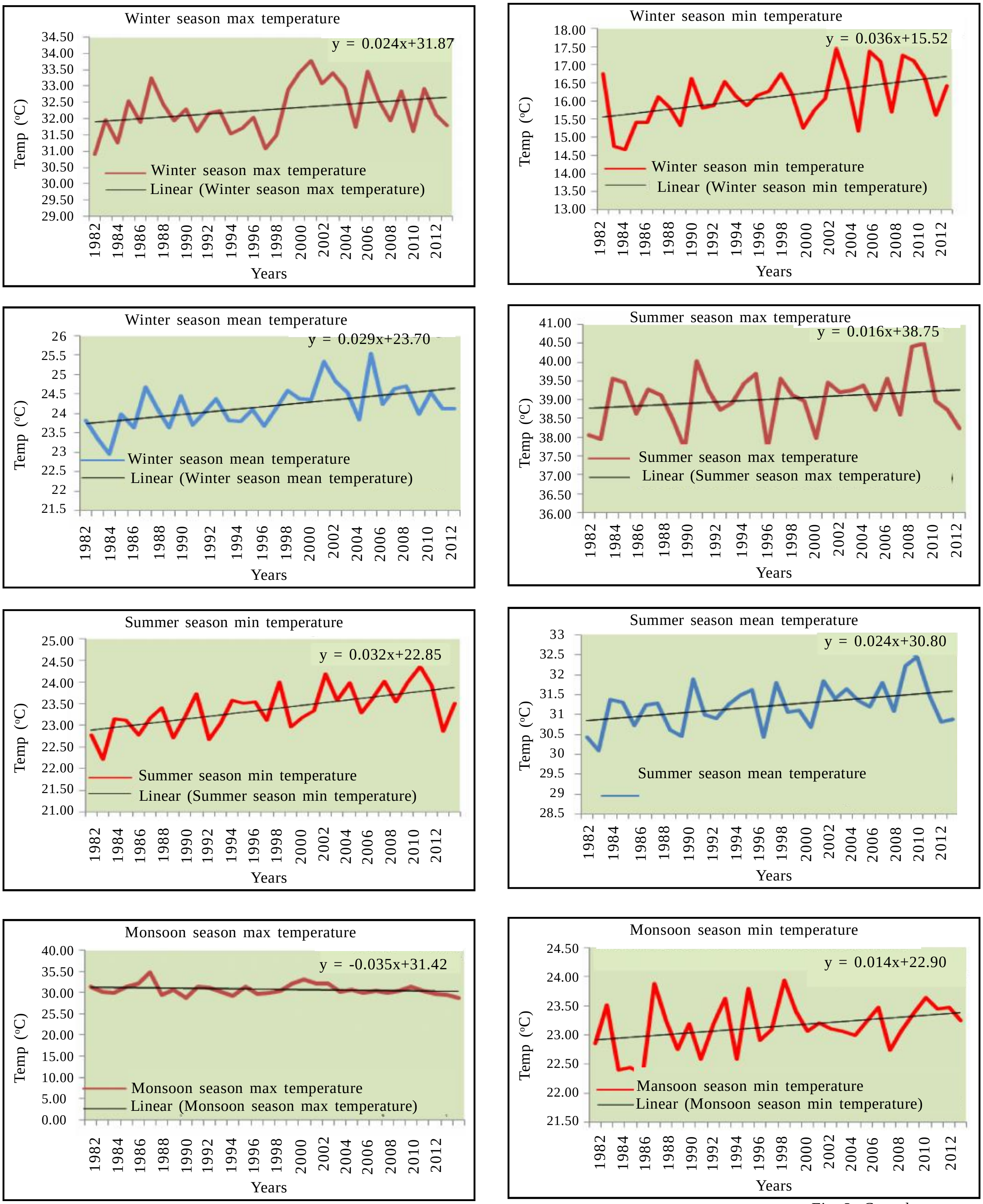


Fig. 1: Annual temperature and 5 year moving means


Winter season max temperature
y = 0.024x+31.87
Winter season max temperature
Linear (Winter season max temperature)
Temp (ºC)
Years
Winter season min temperature
y = 0.036x+15.52
Winter season min temperature
Linear (Winter season min temperature)
Temp (ºC)
Years
Winter season mean temperature
y = 0.029x+23.70
Winter season mean temperature
Linear (Winter season mean temperature)
Temp (ºC)
Years
Summer season max temperature
y = 0.016x+38.75
Summer season max temperature
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Temp (ºC)
Years
Summer season min temperature
y = 0.032x+22.85
Summer season min temperature
Linear (Summer season min temperature)
Temp (ºC)
Years
Summer season mean temperature
y = 0.024x+30.80
Summer season mean temperature
Temp (ºC)
Years
Monsoon season max temperature
y = -0.035x+31.42
Monsoon season max temperature
Linear (Monsoon season max temperature)
Temp (ºC)
Years
Monsoon season min temperature
y = 0.014x+22.90
Mansoon season min temperature
Linear (Monsoon season min temperature)
Temp (ºC)
Years

Fig. 2: Conted.................

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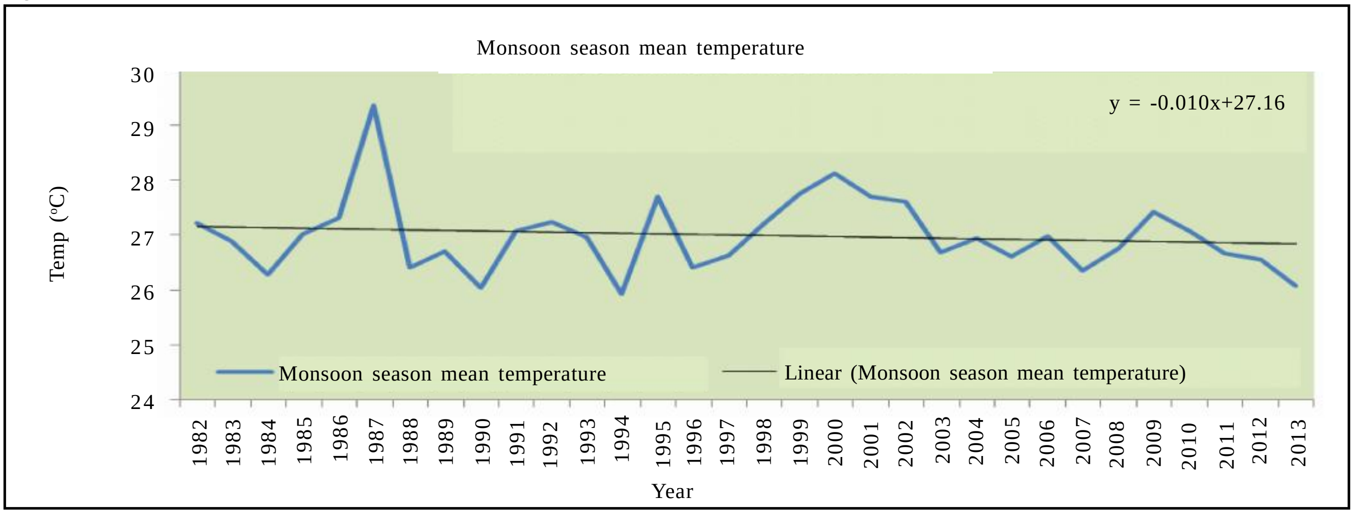

Fig. 2: Seasonal mean, min and max temperature

Maximum and minimum temperature are shown in Fig. 1. From the graph of annual mean temperature, it can be seen that the temperature trend is increasing with correlation co-efficient of 0.111 the similar results obtained by Rathore and Jasrai (2013). The annual mean temperature trend after year of 1994 is increasing. Similarly in the minimum temperature, increasing trend found with correlation co-efficient of 0.374. However, no significant trend was found in annual maximum temperature.

Seasonal temperature trends :

The mean temperature and the T_{max} and T_{min} for summer, winter and monsoon seasons during the period of 1982-2013 (32 years) are presented in Fig. 2.

Winter season :

From the data analysis, it was found that in the winter season, trend of T_{min} and T_{mean} is increasing significantly while T_{max} is not significantly increasing. From the 5 year moving mean more precisely it could be observed that, sudden increase in T_{max} in the period of 1995-2001 then after decreasing. In T_{min} and T_{mean} the trend is following increasing trend which is supported by Dhorde *et al.* (2009). The similar results obtained by Agarwal (2001) for winter and post monsoon season and greater temperature change in winter then in summer by Gates (1990).

Summer season :

In summer season T_{min} and T_{max} shows significant increasing trends while T_{max} is not increasing significantly, from the moving means it is clear that the T_{max} have poor increasing trend with correlation co-efficient of 0.048. From the Mann Kendall test it is clear that the T_{min} and T_{mean} have significantly higher trend while T_{max} have no trend.

Monsoon season :

In monsoon season from the analysis it could be seen that the only significant increasing trend was observed in T_{min} while T_{max} and T_{mean} does not showing any significant. From the 5 year moving means it is clear that T_{min} is significantly increasing while T_{max} and T_{mean} is decreasing. Now from the Mann Kendall trend test, positive trend observed in Tmin and no trend was observed in T_{mean} and T_{max}.

Monthly temperature trends :

Behaviour of T_{min}, T_{max} and T_{mean} has been studied individually for each months by subjecting them to Mann Kendall test and also presented in Table B. From the time series analysis of T_{min}, T_{max} and T_{mean}, it is very interesting that T_{min} shows significant trend in more over the month than T_{max} and T_{mean}. From December to April there is significant trend was observed at 0.5 level then after in May there is highly significantly increasing in minimum temperature and then after in monsoon season there is no significant trend observed in T_{min}. T_{mean} shows statistically significant trend in February – April and then December month at level of 0.5, while T_{max} does not show significant trend in months excluding February, March, April and July.

Conclusion :

The aim of the present study was to analysis temperature time series of 1982-2013, detecting potential trends and assessing their significance over a wide area of Bharuch district, Gujarat, India. By knowing the trend of temperature it is easy to understand the other hydro climatic events like evaporation, transpiration etc. This will helpful for the water management in the farms. The important aspect of the study is there is cooling or not significantly increasing trends of maximum temperature were found by observing the past temperature data. The minimum temperature is significantly increasing in over months, while mean and maximum temperature is not showing that much significant increasing trends. The results of the study supported by the results obtained by Kumar and Hingane (1988) for the and Ram *et al.* (2015) for the Junagadh region of Gujarat. From the study it is clear that summer days are shifting to winter season. The minimum temperature is increasing and those minimum and maximum temperature days are more, as higher temperature days starts from the winter to the early parts of summer.

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