CLIMATE VARIABILITY OVER GUJARAT, INDIA

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ABSTRACT:

Climate variability and occurrence of extreme weather events are the major concerns linked to global warming. In this paper past 40 years data of all IMD observatories in Gujarat state of India has been analyzed. Moving averages of Maximum Temperature during summer season and minimum temperature during winter season have been analysed and a significant increasing trend has been observed. Similarly for rainfall, some significant results have been obtained. There was a significant trend in case of various extreme weather events like cold wave conditions, heat wave conditions and heavy rainfall instances. In addition to above IMD's gridded data for Gujarat state for Maximum, Minimum and Mean temperature showed a significant steady increasing trend in the past 40 years.

1. INTRODUCTION

Meteorological data compiled over the past century suggests that the earth is warming, but there are significant differences at regional level (Rupa Kumar, 2003). Most of the studies during the last four decades have clearly pointed out that the monsoon rainfall is trend less, particularly on an all India Scale (Parthasarthy, 1984), but Rupa Kumar et al (1992) have shown regional monsoon rainfall trends in the past century. Rupa Kumar et al. (1994) also showed that there was an asymmetry in the temperature trends in terms of daytime and night time temperatures over India. The observed warming was predominantly due to an increase in maximum temperature, while the minimum temperature remained practically constant during the past century. In this study the results obtained for Gujarat State showed a significant increase in minimum temperature during winter season as compared to day temperatures in summer. The increase in night temperatures was found to be significant enough to have lowered the cold wave conditions during winters for most of the districts. Dhorde et al (2009) also found out that some of the metropolitan cities in India recorded significant increase in minimum temperature during winter. Hingane et al. (1895) had prepared an all-India mean series of seasonal and annual surface air temperature for a long term trend studies, using data for 1901-82. The analysis indicates a significant warming of 0.4°C per hundred years in mean annual temperatures of the country as a whole. There are large areas showing significant warming trends along the west coast and adjoining areas. Another study by Srivastava et al. (1992) on decadal trends of temperature over India also confirms the increasing temperature trends in India. They have shown that 1901-1940 was the cooler regime whereas there was a warmer regime from the end of 5th decade (1940-1950) to (1980—1990).In this paper ,attempt has been made to study the variability in various temperature parameters for various observatories of Gujarat and compare the results with the gridded temperature prepared by IMD fro 1965 to 2005. Seasonal rainfall data has also been analyzed during the above period for various observatories. Extreme weather conditions like heat wave conditions, cold wave conditions and heavy rainfall instances in the past 40 years have also been studied decade wise.

2. DATA AND METHODOLOGY

2.1 Study Area

Gujarat is in the extreme West of India (Figure 1). It has tropical climate, namely sub humid, arid and semi arid spread over different region of the state. North Gujarat region comprising of Kutch, part of Banaskantha, Mehsana and North Western part of Saurashtra have arid climate while the South Gujarat sub humid climate and in the rest of the state, semi arid climate. Temperature varies from 6 to 45^{0}Celsius.Annual rainfall varies from 250 mm in the North West and to more than1500 mm in South Gujarat. Out of 225 talukas, 56 talukas are drought prone.

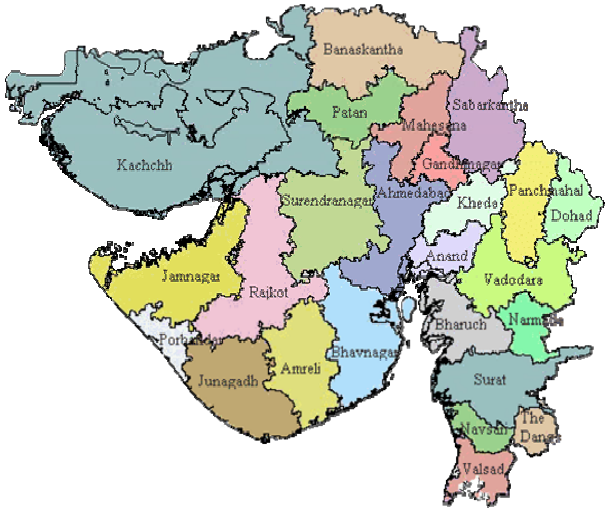

Figure 1. Map of Gujarat State of India

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2.2 Data Used

Daily Maximum temperature, daily minimum temperature and rainfall data for 18 full time and part time IMD observatories of Gujarat state of India, for the period 1965-2008 has been utilized for the analysis. Gridded data for Gujarat state, prepared by IMD for the period 1965-2005 has also been utilized.

2.3 Analysis

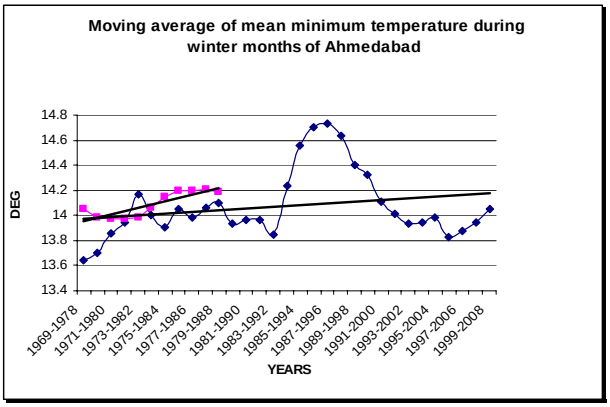
Thirty years and ten years moving normals at one-year gap have been calculated for all parameters in order obtain the climatological rise in the past forty years. Extreme Weather conditions have been computed season wise using the following definitions.

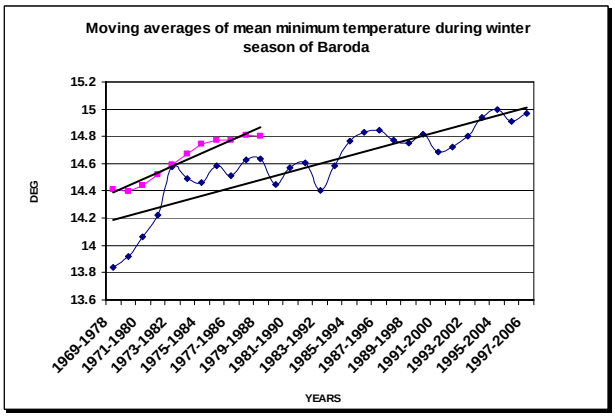
- Heat wave in summer: Monthly Average of Maximum Temperature (40 years) +5ºC
- Cold wave in winter: Monthly Average of Minimum Temperature (40 Years) -5ºC
- Heavy Rainfall: >70 mm

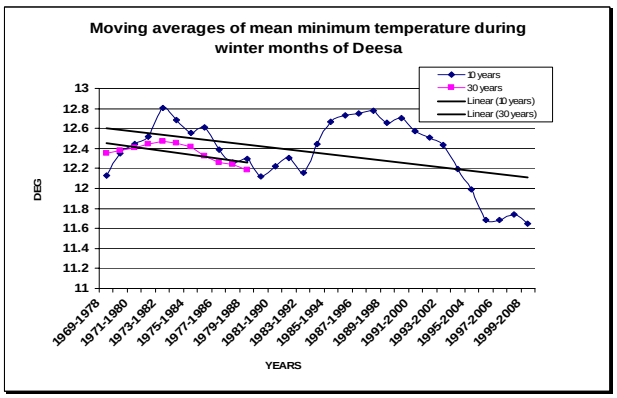
3. RESULT AND DISCUSSIONS

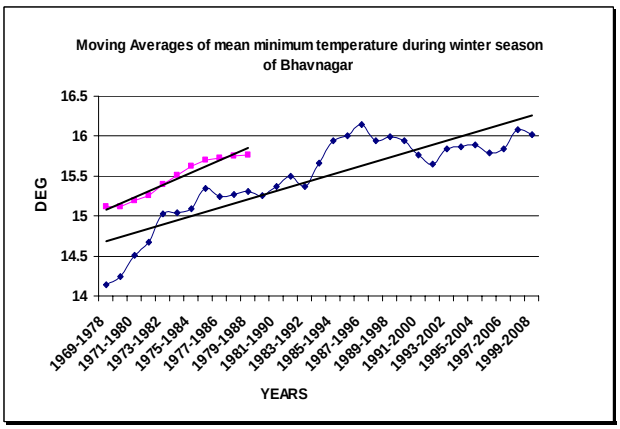
3.1 Minimum Temperature

30 years moving averages of mean minimum temperature during winter season (November, December, January, February) have been prepared for the various IMD observatories of Gujarat state. Most of the observatories showed a steady increasing trend in mean minimum temperature during winter season.. The normals were seen to increase by 1.2°C in Bhuj, followed by 0.7°C in Veraval and Bhavnagar, 0.6 °C in Naliya and 0.5°C in Rajkot (Fig 2). The rise of temperature normals was steady and highly linear.The averages were more or less stable in, Okha and Ahmedabad and decrease of 0.3 °C was noticed in Deesa. The instances of cold wave were seen to be highest in Bhuj in the past 40 years (412) i.e. on an average 10 per year (Table 1). The maximum number of cold waves was recorded in the month of February for all places and -0.2°C was the lowest temperature in the state recorded in Bhuj on 28th Jan 1977. The decadal instances of cold wave conditions in Bhuj showed a considerable decrease of cold wave conditions in the decade 1999-2008. As compared to earlier decades having more than 100 cold waves conditions, only 10 cold waves were recorded in the last decade. Similarly the cold wave instances over Veraval have decreased to less then 10 in the decade 1999-2008 as compared to earlier decades, similarly for Bhavnagar, Naliya, Rajkot and Baroda. In general, except for Ahmedabad, Surat and Deesa, the cold wave conditions have decreased considerably in various districts of Gujarat, thus indicating an increase in night temperatures during winters over the state. The IMD gridded data of minimum temperature over Gujarat with 1x1 grid intervals have also been analyzed for the period 1969-2005 and the results showed an increasing trend in the past 40 Years (Fig 3). The normals had increased by 0.107ºC. The trend again showed a steady increase over the years. In case of moving averages of 10 years the increase was 0.25 ºC. Analysis was performed for north and South Gujarat region separately but not much difference was obtained in case of gridded data. In general the temperature rise was found to be highest in Saurashtra and Kutch as compared to North and central Gujarat region.









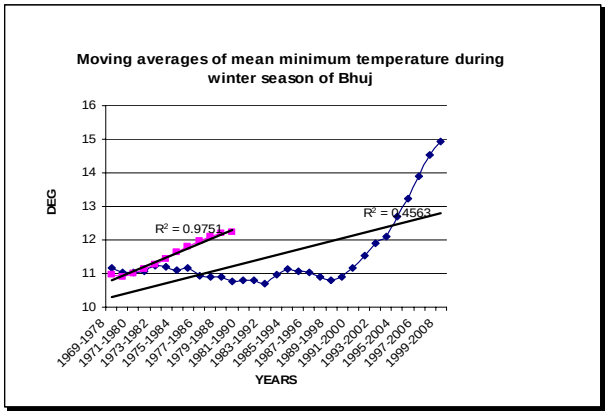


Figure 2. Station Wise Moving Averages of 10 and 30-year Period for Mean Minimum Temperature During Winter Months

Station\Period	1969-1978	1979-1988	1989-1998	1999-2008
Ahmedabad	52	72	35	46
Baroda	67	47	22	6
Deesa	60	32	15	47
Bhuj	146	111	144	10
Rajkot	95	33	10	21
Veraval	54	43	21	4
Naliya	107	33	19	27
Okha	4	3	4	2
Surat	48	25	0	62
Bhavnagar	116	50	8	5

Table 1: Decadal Frequency of Cold Wave Conditions in Selected Stations

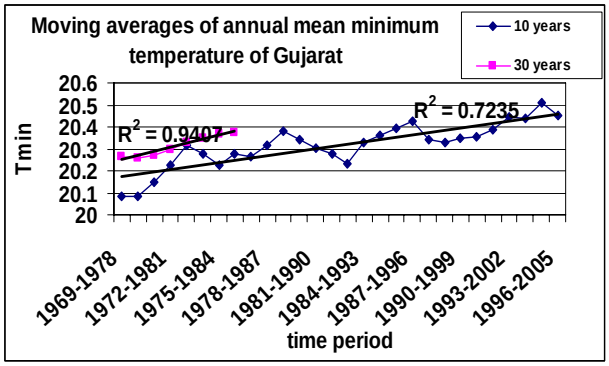
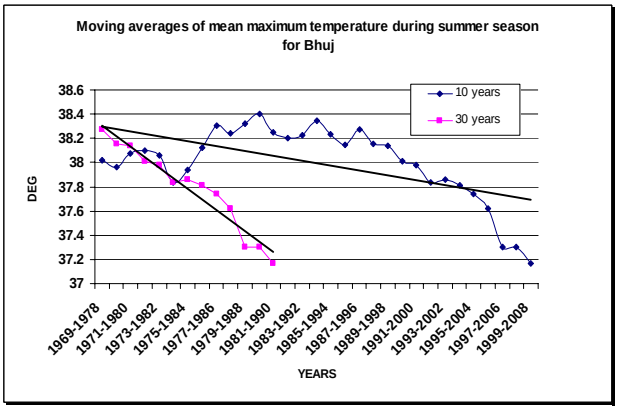
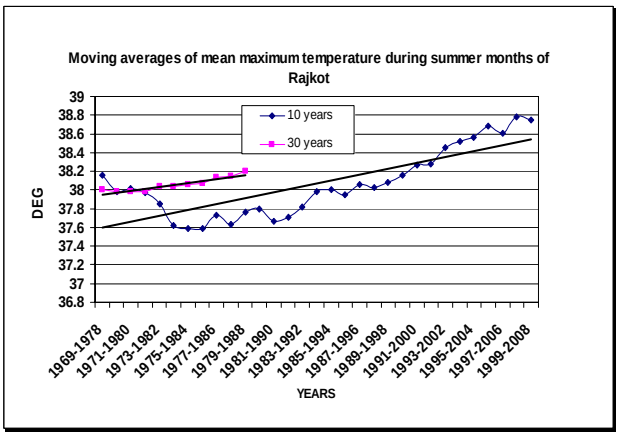


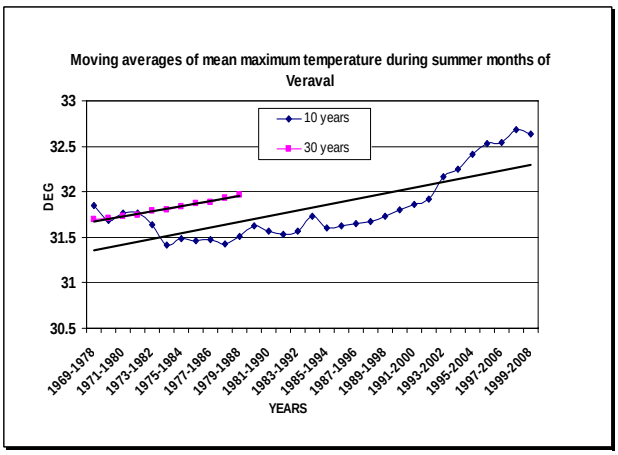
Figure 3. Variation of Annual Mean Minimum Temperature Over Gujarat State Using IMD grid Data

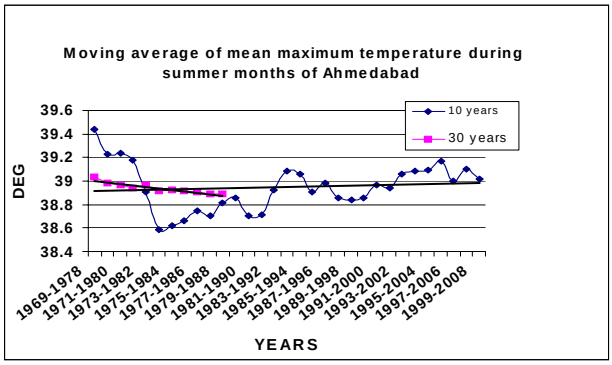
3.2 Maximum Temperature

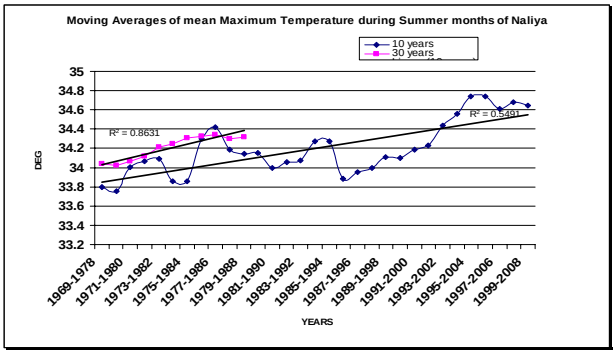
30 years moving averages of mean maximum temperature during summer season (March, April, and May) were prepared for various observatories placed in Gujarat. The mean maximum temperature in summer was found to have increased over Naliya, Okha, Veraval and Rajkot and decreased by 1°C over Bhuj (Fig 4). The mean maximum temperatures have remained more or less stable in Deesa, Baroda, Ahmedabad and Surat in the past 40 years. The rise in temperature ranges from 0.2 to 0.4 °C for Saurashtra, where as for Gujarat region they were more or less stable. The heat wave conditions have increased in the last decade over most of the districts as shown in the Table 2, except for, Ahmedabad, Bhuj and Okha. The number of heat waves recorded along the coastal districts of the state was highest in the last decade as compared to earlier three decades. Veraval recorded 72 cold waves in the last decade, amounting to an average of 7 cold wave conditions each year. Similarly Naliya recorded 52 heat wave conditions in the last decade with an average of 5 heat waves each year.









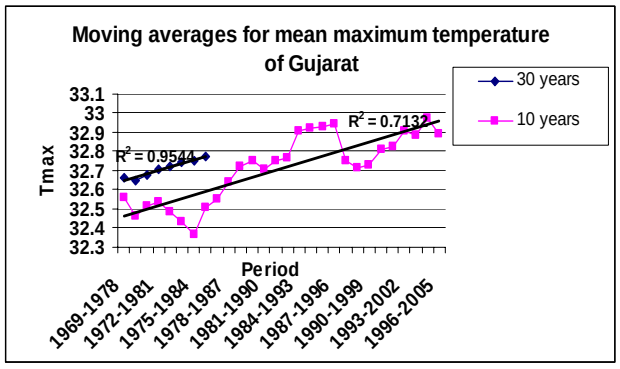


Figures 4. Station Wise Moving Averages of 10 and 30-year Period for Mean Maximum Temperature During Summer Months

The heat waves and cold waves had decreased considerably over Bhuj in the last decade indicating a general rise in night temperatures and fall in day temperatures. The IMD gridded data of maximum temperature over Gujarat with 1x1 grid intervals have also been analyzed for the period 1969-2005 and the results showed an increasing trend in the past 40 Years (Fig 5). The annual mean maximum temperature normal were found to have increased by 0.11°C.The rise was again very steady and highly linear. The 10 years moving averages showed an increase of 0.5°C in the past 40 years. The increase has been stable and significant for both maximum and minimum temperature. The analysis was carried out for North Gujarat and South Gujarat region separately and same trend was observed, with higher increase in Saurashtra and South Gujarat region as compared to the other regions. The rise in normals of annual mean temperatures over Gujarat state was 0.07ºC and 10 years averages showed a rise of 0.3ºC(fig 5).

Station\Period	1969-1978	1979-1988	1989-1998	1999-2008
Ahmedabad	20	4	17	13
Baroda	16	12	9	28
Deesa	20	5	10	29
Bhuj	31	27	42	16
Rajkot	9	1	14	22
Veraval	53	52	34	72
Naliya	17	35	30	52
Okha	5	1	2	1
Surat	54	43	25	32

Table 2: Decadal Frequency of Heat Wave Conditions in Selected Stations



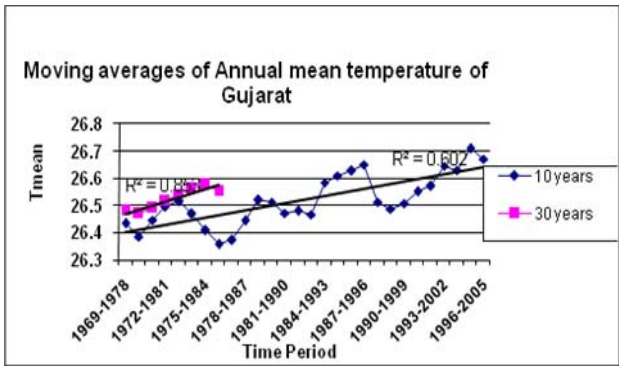
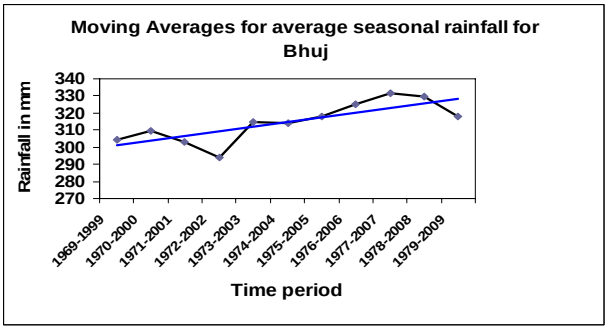
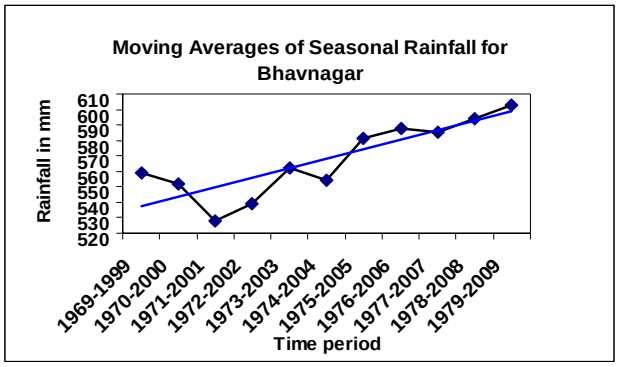


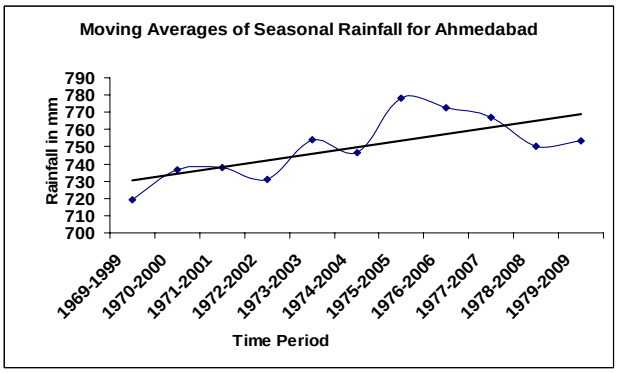
Figure 5. Variation of Annual Mean Maximum and Mean Temperature over Gujarat State Using IMD Gridded Data

3.3 Rainfall

Seasonal rainfall for all observatories for the 40 years period (1969-2008) was analyzed. 30 years moving averages of seasonal rainfall indicate an increase in rainfall normals for all the stations. Maximum rise of seasonal rainfall normals was found to be in Saurashtra (Bhavnagar,60mm) and South Gujarat region (Surat ,100mm) (Fig 6). Year to year variation was found to be highly variable for all stations and standard deviations of seasonal rainfall over the past 40 years ranged from 250mm to 500mm. Therefore the analysis was done for 30 years moving averages only .The seasonal rainfall normals varied from 300mm in Bhuj to 1100 mm in Surat,.Inspite of high year to year variation and high interstate variation the seasonal rainfall normals showed a increasing trend. The heavy rainfall events (>70mm) were found to have increased in all stations in the last decade as compared to earlier decades (Table 3). Surat recoded 106 heavy rainfall days in the past decade. In Bhuj , Ahmedabad and Naliya the events had remained more or less same.







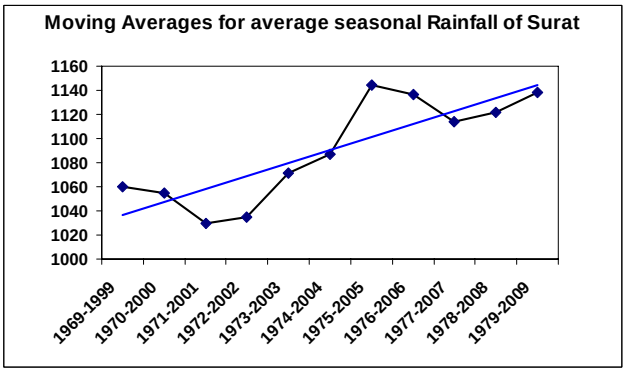


Figure 6. Station Wise Moving Averages of 30 Year Period for Seasonal Monsoon Rainfall

Station\Period	1969-1978	1979-1988	1989-1998	1999-2008
Ahmedabad	42	39	50	50
Baroda	21	14	17	34
Deesa	13	7	21	25
Bhuj	5	10	12	10
Rajkot	13	18	15	21
Veraval	21	27	26	33
Naliya	10	13	10	11
Porbandar	16	25	19	22
Surat	92	88	39	101
Bhavnagar	13	10	13	17

Table 3: Decadal Frequency of Heavy Rainfall Events in Selected Stations

CONCLUSION

- The gridded 30 years moving averages of mean maximum temperature over Gujarat state indicate an increase by 0.11°C in past 40 years (1969-2005). The station wise analysis (1969-2008) further indicates that the increase is more over Saurashtra region as compared to that of the remaining parts.

- 30 years of moving averages of the gridded mean minimum temperature over Gujarat state indicate an increasing trend with a increase of 0.107ºC in the past 40 years (1969-2005). The station wise analysis further indicates higher increase in night temperature over Saurashtra and Kutch as compared to other parts of the state.

- The gridded 30 years moving averages of mean temperature over Gujarat state indicate an increase by 0.07°C in past 40 years (1969-2005). The station wise analysis (1969-2008) further indicates that the increase is more over Coastal Saurashtra region as compared to that of the remaining parts.

- Cold wave conditions have decreased considerably over the past decade indicating an increase in night temperature. As compared to an average of 103 cold wave conditions in Saurashtra and Kutch region in the decade 1969-1978 ,the average cold wave conditions recorded in the past decade (1999-2008) were only 13. The rise in normal mean minimum temperature during winter season was found to 0.3ºC as compared to the annual mean minimum rise of 0.107ºC. The maximum rise in minimum temperature was found to be in winter months in comparison to other months of the year.

- Heat wave conditions have increased in southern part of the Gujarat, while they have decreased in northern parts.Rise was appreciable along Coastal stations of Saurashtra.

- Mean seasonal rainfall has increased over Saurashtra and south Gujarat region (along west coast) and has remained more or less same over north Gujarat region and adjoining Kutch.

- Rainfall extremes have also increased in the past decade for south Gujarat region and Saurashtra. The difference is not much in the past 4 decades for north Gujarat and Kutch.

From the above result it is clear that majority of the trends, both seasonal as well as annual showed increasing tendency in temperature and rainfall during past 40 years. The annual mean temperature of Gujarat as a whole has also increased. The rise in minimum temperature during winter season was found to be higher than the rise in maximum temperature in summer season.

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REFERENCES

Dhorde, Amit, Dhorde, Anargha, Gadgil. A.S. 2009. .Long-term temperature trends at four largest cities of india during the twentieth Century.J.Ind.Geophys.Union,13(2),85-97.

Henjane, C.S., Rupa Kumar, K. and Ramana Murthy, Bh. V., 1985, Long term trends of surface air temperature in India. International Journal of Climatology, 5, 521–528.

Partha Sarthy, B., 1984, Interannual and long term variability of Indian summer monsoon rainfall. The proceedings of the Indian Academy of Sciences. Earth and Planetary Sciences, 93, 371-385.

Rupa Kumar, K., Krishna Kumar, K.,Prasanna, V., Kamala, K., Despand N.R., Parmardhan, S.K., Pant, G.B., 2003, Future climate Scenarios, In Climate change of India. Vulnerability Assessment and Adaptation. (Ed: Shukla, P.R., Sharma, Subodh, K. et al.)

Rupa Kumar, K., Pant, G.B., Parth Sarthy, B., and Sontakke, N.A., 1992. Spatial and sub seasonal patterns of the long term trends of Indian summer monsoon rainfall. International Journal of Climatology, 12, 257–268.

Rupa Kumar, K., Krishna Kumar, K., Pant, G.B., 1994, Diurnal asymmetry of surface temperature trends over India, Geophysical Research letter, 21, 677-680.

Srivastava, H.N., Denian, B.N., DIkshit, S.K., Rao, G.S.P., Singh, S.S. and Rao, K.R., 1992, Decadal trends in climate over India. Mausam, 43, 7–20.