551.583 : 551.577.37 (540.51)

ANALYSIS OF CLIMATIC VARIABILITY AT HEAVY RAINFALL ZONE OF SOUTH GUJARAT

1. The present study was carried out by using the 32 years (1980-2011) daily meteorological data of Agro meteorological observatory, Navsari Agricultural University, Navsari, Gujarat (20° 57′ N latitude, 72° 54′ E longitude and 10 m AMSL) and 22 years (1990-2011) daily meteorological data of Agro meteorological observatory, Regional cotton research station Maktampur, Navsari Agricultural University, Bharuch, Gujarat (22° N latitude, 73° 5′ E longitude and 16.5 m AMSL). Navsari station comes under South Gujarat heavy rainfall zone while Bharuch station falls under South Gujarat zone. The daily weather data were utilized for preparing daily, weekly and monthly averages. The monthly averages of weather parameters were analyzed to determine climatic trend. The climatic study was analyzed by calculating the mean, standard deviation (SD), coefficient of variations (CV). The significant test (*t*) for all the weather parameters have also been carried out.

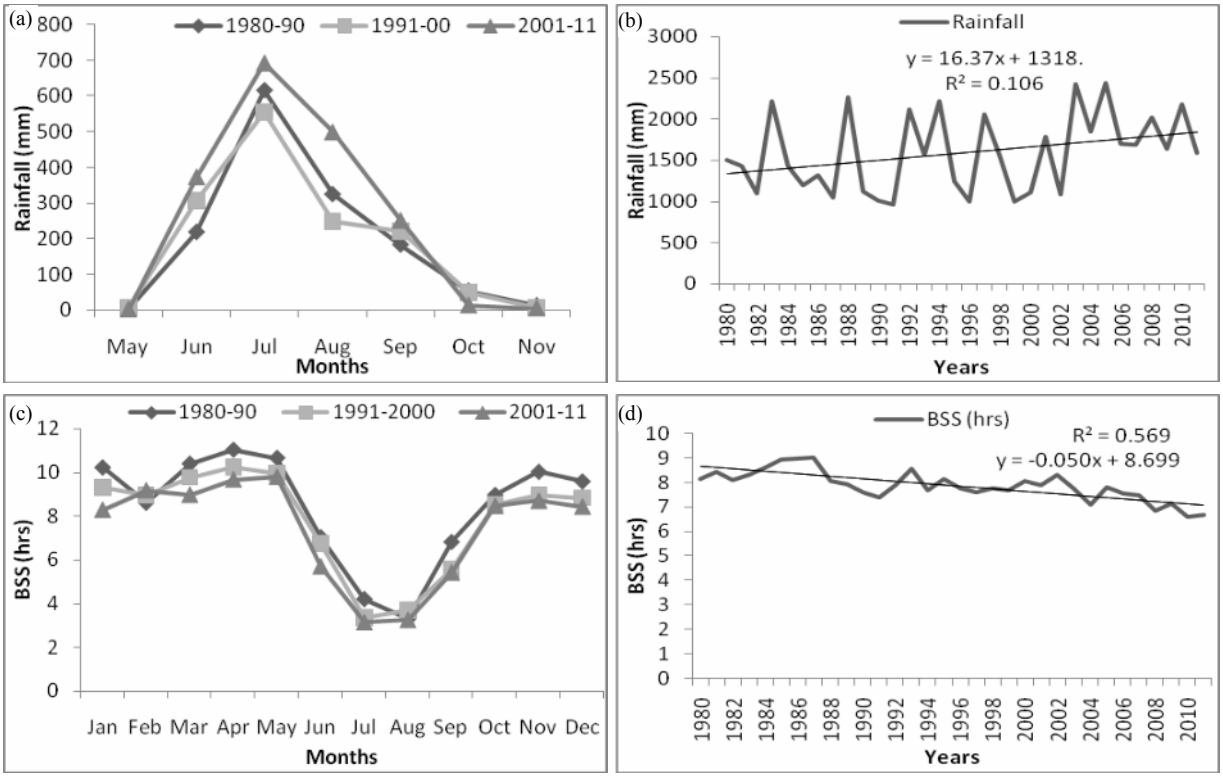
2. South Gujarat receives 97% rainfall from South west monsoon (24 to 32 standard weeks) during the months of June to September. Normal rainfall of Navsari district is about 1606 mm in 54 rainy days. The average rainfall during decades 1980-90, 1991-2000 and 2001-11 [Fig.1(a)] were 1418.8, 1404.4 and 1843.8 mm, respectively with 437.31 standard deviation and 29.87 CV% Table 1. The comparison of decadal and normal rainfall during 1980-90 and 1991-2000 shows deficiency by 11.66% and 12.55% respectively, while during 2001-11 the rainfall was 14.81% above the normal. The standard deviations and coefficients of variations were 442.08, 426.33, 424.57 and 31.16, 30.36, 23.03 % during decades 1980-90, 1991-00 and 2001-11, respectively (Table 2). During the decade 2001-11 the coefficient of variation was quite low, it shows low variability in annual rainfall, while during 1991-2000 and 1980-90 the CV% were higher due to high variability in annual rainfall. Overall annual rainfall variation shows significant (at 10% probability level) increase in rainfall during past 32 years with annual increase of 16.37 mm per year with R^2 0.10 ($y = 16.37x + 1318$) [Fig. 1(b)]. The decadal trend analysis shows dissimilarities in trend as compare with overall database.

Normal rainfall of Bharuch district is about 949 mm in 47 rainy days. The average rainfall during 1990-2000 and 2001-11 (4a) were 844.8 and 1062.9 mm, respectively with 312.97 standard deviation and 32.81 CV% (Table 1). The comparison of decadal and normal rainfall during 1990-2000 shows deficiency by 10.49%, while during 2001-11 the rainfall was 12.01% above the normal. During the decades 1990-00 and 2001-11 the standard deviation and coefficients of variations were 265.46, 307.81 and 32.52, 28.96%, respectively (Table 2). During both decades coefficient of variation was quite high, it shows higher variability in annual rainfall. Decadal variation shows non significant increase in rainfall during last two decades with annual increase of 9.93 mm per year with R^2 0.042 ($y = 9.930x + 839.6$) [Fig. 4(b)]. Above all annual rainfall analysis of south Gujarat shows an increasing trend and shifting pattern of rainfall distribution. Similar rainfall behavior was also reported by Mukharjee and Banergee (2009).

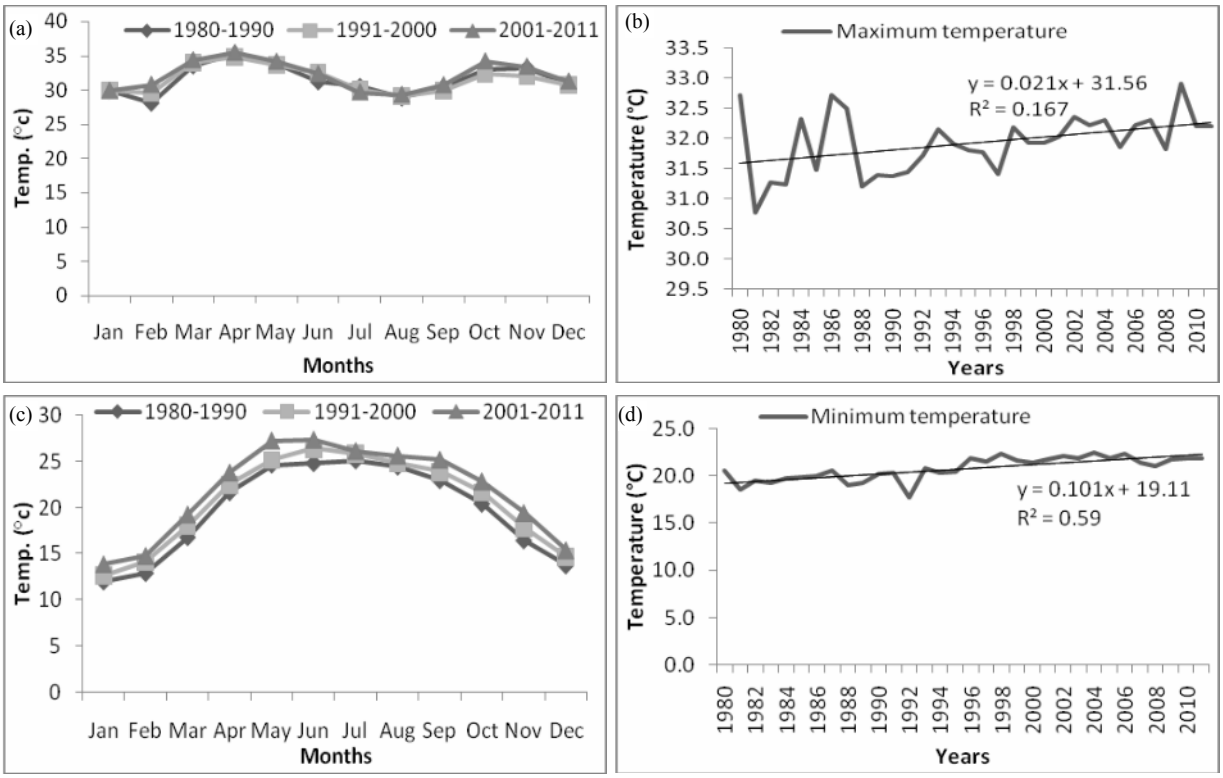
3. Annual bright sunshine hours (BSS) of Navsari region is oscillated between 0 hr in monsoon to 10.7 hrs in summer season. Annual average BSS during decades 1980-90, 1991-2000 and 2001-11 [Fig. 1(c)] were 9.56, 8.84 and 8.44 hours, respectively with 0.62 standard deviation and 7.94% CV (Table 1). The BSS at Navsari shows significantly decreasing trend with the annual rate 0.050 hours per year with R^2 0.56 ($y = -0.050x + 8.699$) Fig. 1(d).The standard deviations and coefficients of variations were 0.48, 0.33, 0.56 and 5.72, 4.19, 7.54% during 1980-90, 1991-00 and 2001-11, respectively (Table 2).

Annual Bright sunshine hours (BSS) of Bharuch region is vacillated between 0 hour in monsoon to 10.6 hours in summer season. Annual average BSS during decades 1990-2000 and 2001-11 [Fig. 4(c)] were 7.43 and 7.41 hours, respectively with 0.48 standard deviation and 6.46% CV (Table 1). The BSS at Bharuch shows non-significantly decreasing trend with the annual rate 0.044 hours per year with R^2 0.27 ($y = -0.044x + 7.637$) [Fig. 4(d)]. The standard deviations and coefficients of variations were 0.29, 0.67 and 3.93, 9.65 % during 1990-00 and 2001-11, respectively (Table 2). Overall decreasing tendency of BSS is in confirmative to enhancement of rainfall.

4. The annual maximum temperature of Navsari region is oscillated between 43.5 °C during summer and 7.2 °C in winter season. Temperature rises to its maximum level during the months of March-April and lowest in December-January. Annual average maximum temperature during decades 1980-90, 1991-2000 and 2001-11 [Fig. 2(a)] were 31.61, 31.55 and 32.20 °C, respectively with 0.50 standard deviation and 1.57% CV (Table 1). The past 32 years trend analysis shows the non significant increase in maximum temperature with the rate of 0.02 °C with R^2 0.16 ($y = 0.021x + 31.56$) [Fig. 2(b)], while their decade wise trend analysis shows decreasing trend during first two decades (1980-90 and 91-2000) and increasing trend for last decade (2001-11). During



Figs. 1(a-d). Rainfall and BSS pattern and trend at Navsari district during last three decades



Figs. 2 (a-d). Maximum and minimum temperature pattern and trend at Navsari district during last three decades

TABLE 1

Decadal variations in weather parameters at Navsari and Bharuch districts

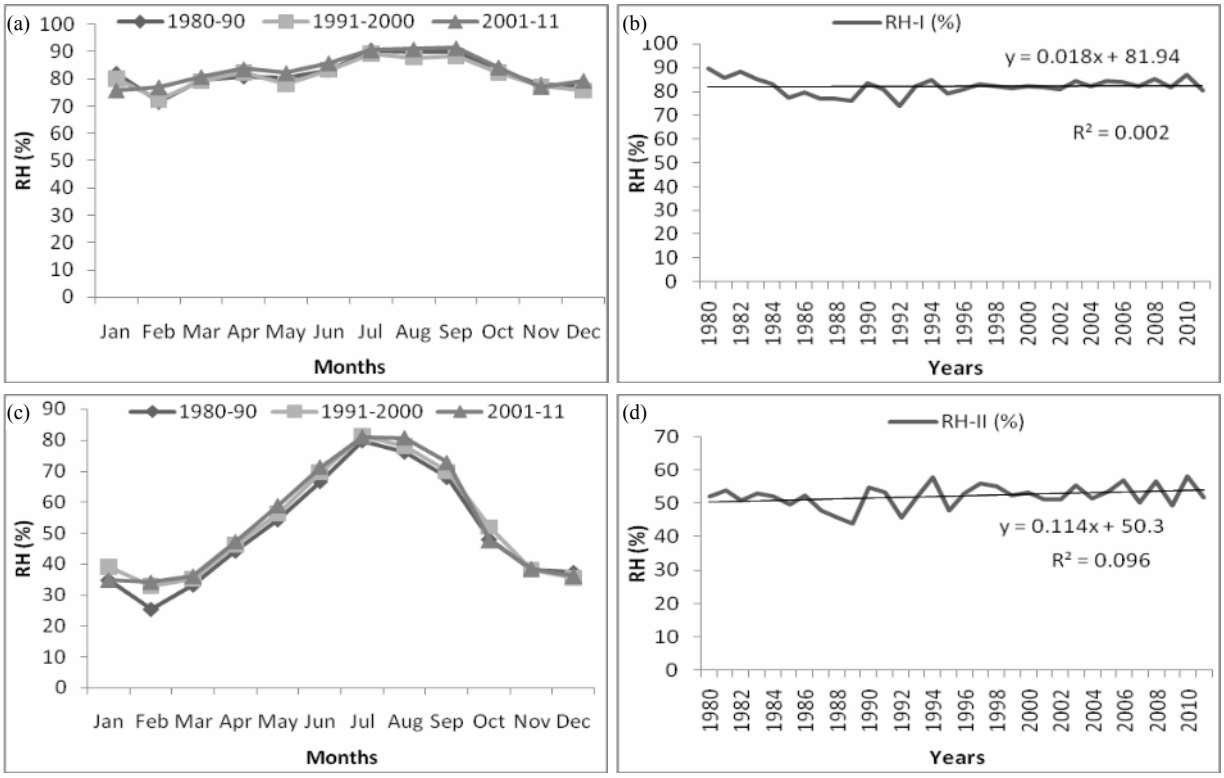
Weather parameters	Decades			Standard deviation	CV (%)
	1980-90	1991-00	2001-11		
Navsari					
Rainfall (mm)	1418.76	1404.41	1843.82	437.31	29.87
Bright Sunshine Hours (hrs)	9.56	8.84	8.44	0.62	7.94
Maximum temperature (°C)	31.61	31.55	32.20	0.50	1.57
Minimum temperature (°C)	19.67	20.71	21.73	1.24	5.97
Morning Relative Humidity (%)	82.17	81.44	83.21	3.51	4.27
Afternoon Relative Humidity (%)	50.49	52.84	53.34	3.47	6.66
Bharuch					
Rainfall (mm)	-	844.83	1062.95	312.97	32.81
Bright Sunshine Hours (hrs)		7.43	7.41	0.48	6.46
Maximum temperature (°C)	-	34.05	34.14	0.56	1.64
Minimum temperature (°C)	-	21.02	21.54	0.46	2.16
Morning Relative Humidity (%)	-	71.15	71.37	2.63	3.69
Afternoon Relative Humidity (%)	-	43.21	41.44	4.71	11.13

TABLE 2

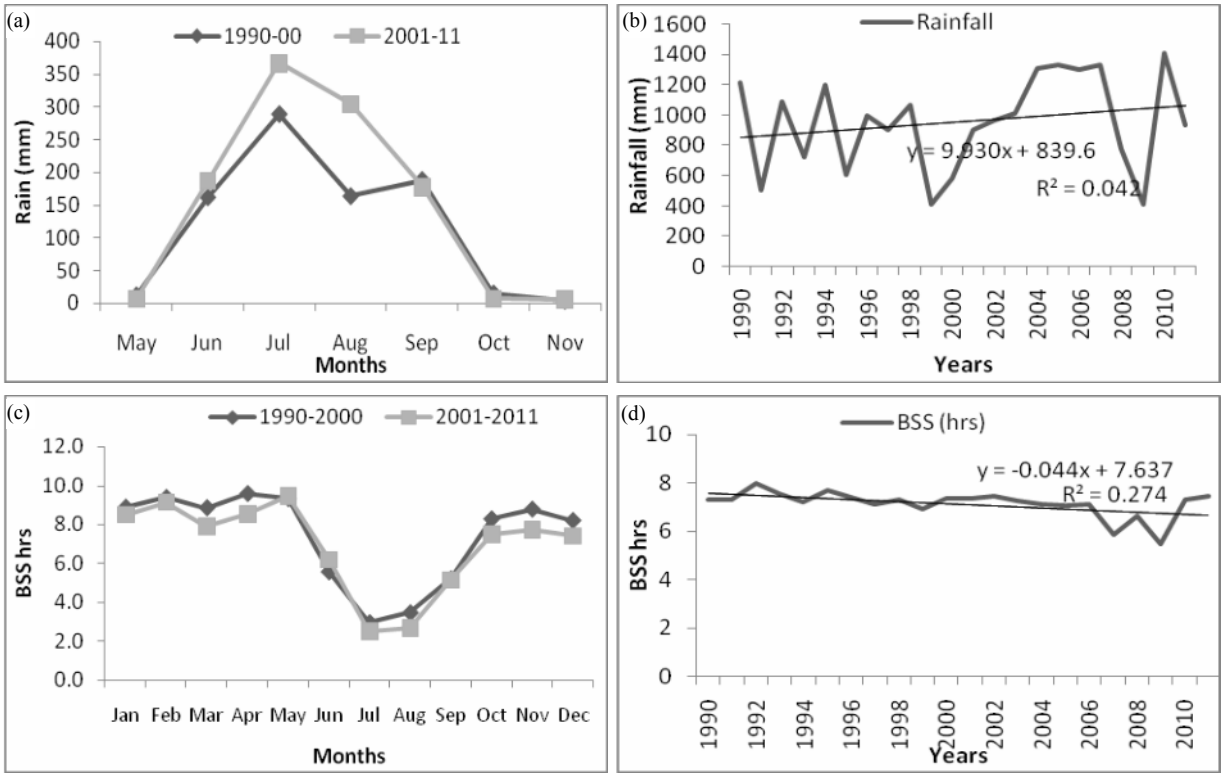
Decadal analysis of weather parameters at Navsari and Bharuch districts

Weather parameter	Decades (1980-90)		Decades (1991-00)		Decades (2001-11)	
	Sandard deviation	CV %	Sandard deviation	CV %	Sandard deviation	CV %
Navsari						
Rainfall (mm)	442.08	31.16	426.33	30.36	424.57	23.03
Bright Sunshine Hours (hrs)	0.48	5.72	0.33	4.19	0.56	7.54
Maximum temperature (°C)	0.82	2.59	0.85	2.68	0.30	0.93
Minimum temperature (°C)	0.65	3.32	1.30	6.25	0.40	1.83
Morning Relative Humidity (%)	4.92	5.99	2.81	3.45	2.04	2.45
Afternoon Relative Humidity (%)	3.45	6.81	3.50	6.65	3.11	5.80
Bharuch						
Rainfall (mm)	-	-	265.46	32.52	307.81	28.96
Bright Sunshine Hours (hrs)	-	-	0.29	3.93	0.67	9.65
Maximum temperature (°C)	-	-	0.46	1.34	0.66	1.94
Minimum temperature (°C)	-	-	0.32	1.51	0.37	1.73
Morning Relative Humidity (%)	-	-	2.36	3.35	2.21	3.06
Afternoon Relative Humidity (%)	-	-	3.35	7.84	6.55	15.97

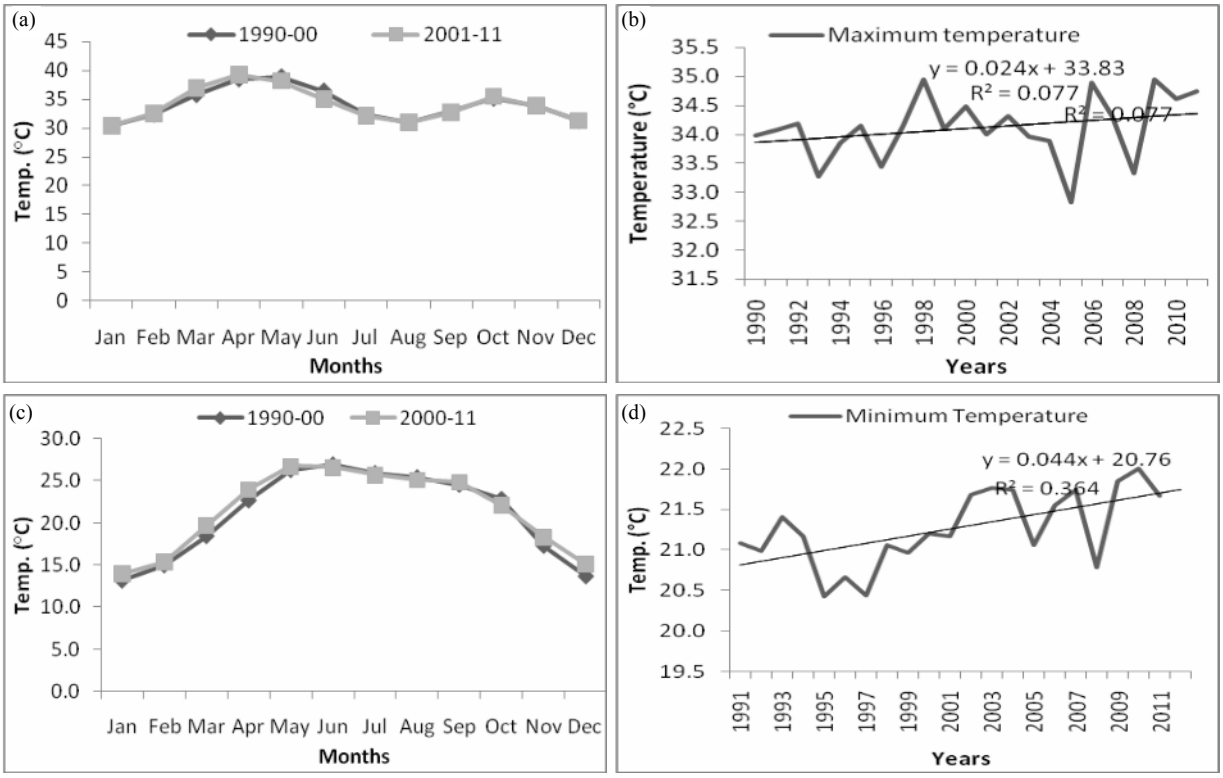
decades 1980-90, 1991-00 and 2001-11 the coefficients of variations were 2.59%, 2.68% and 0.93% with standard deviation 0.82, 0.85 and 0.30, respectively (Table 2).



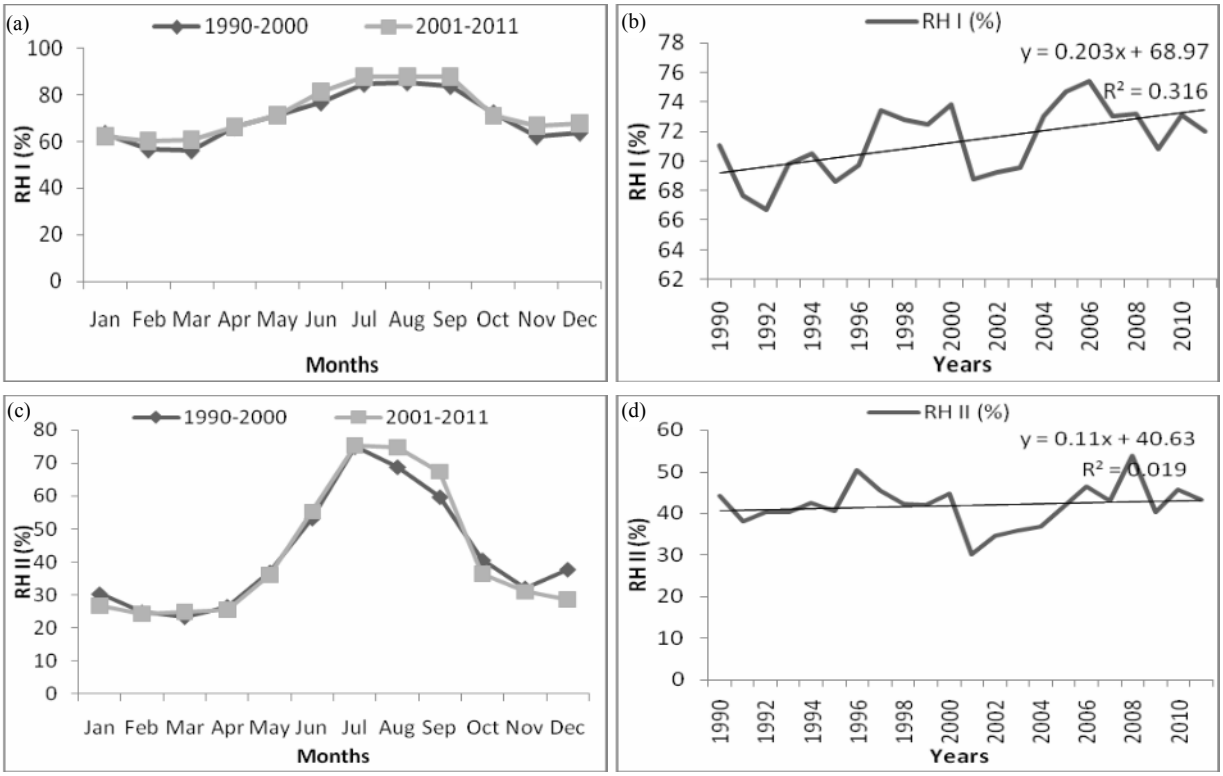
Figs. 3 (a-d). Morning and afternoon relative humidity pattern and trend at Navsari district during last three decades



Figs. 4 (a-d). Rainfall and BSS pattern and trend at Bharuch district during last two decades



Figs. 5 (a-d). Maximum and minimum temperature pattern and trend at Bharuch district during last two decades



Figs. 6 (a-d). Morning and afternoon relative humidity pattern and trend at Bharuch district during last two decades

variations were 2.59%, 2.68% and 0.93% with standard deviation 0.82, 0.85 and 0.30, respectively (Table 2).

The average annual minimum temperature during decades 1980-90, 1990-2000 and 2001-11 [Fig. 2(c)] were 19.67, 20.71 and 21.73 °C, respectively and having 1.24 standard deviation and 5.97% CV (Table 1). The 32 years trend analysis shows significantly increasing trend in minimum temperature at the rate of 0.10 °C per year with R^2 0.59 ($y = 0.101x + 19.11$) [Fig. 2(d)]. The coefficients of variations for annual minimum temperatures were 3.32%, 6.25% and 1.83% with standard deviation 0.65, 1.30 and 0.40 during decades 1980-90, 1991-00 and 2001-11, respectively (Table 2).

The annual maximum temperature of Bharuch district varies between 43.5 °C during summer to 8.4 °C in winter season. The maximum temperature reported to its maximum level during the months of April-May and lowest in December-January. Annual average maximum temperature during 1990-2000 and 2001-11 [Fig. 5(a)] were 34.05 and 34.14°C, respectively and having 1.64 CV% and 0.56 standard deviation Table 1. Trend analysis shows non significant increase in temperature with the rate of 0.02 °C with R^2 0.07 ($y = 0.024x + 33.83$) [Fig. 5(b)], while similar trend was also observed in their decade wise analysis. The coefficients of variations were 1.34% and 1.94% with standard deviation 0.46 and 0.66 during decades 1990-00 and 2001-11, respectively (Table 2).

The average annual minimum temperature during decades 1990-2000 and 2001-11 [Fig. 5(c)] were 20.97 and 21.55 °C, respectively with 0.46 deviation and 2.16% CV (Table 1) for Bharuch district. Past 22 years trend analysis shows significantly increasing trend in minimum temperature at the rate of 0.04 °C per year with R^2 0.36 ($y = 0.044x + 20.76$) [Fig. 5(d)], while their decade wise trend analysis shows decreasing trend during first decade and increasing trend during last decade. The coefficients of variations for annual minimum temperatures were 1.51 and 1.73% with standard deviation 0.32 and 0.37 during 1990-00 and 2001-11, respectively (Table 2). It has been observed that minimum temperature increased at higher rate at both stations as compare with maximum temperature. In global warming it has been shown that minimum temperature will rise more than maximum at a certain extent (Singh and Rai, 2011).

5. The annual relative humidity of Navsari region is oscillated between 21.0 to 96.0%. Morning relative humidity rises to its maximum level during the months of June to September and lowest in February-March. Annual average morning relative humidity during decades 1980-90, 1991-2000 and 2001-11 [Fig. 3(a)] were 82.17, 81.44 and 83.2%, respectively with 3.51 standard deviation and 4.27% CV (Table 1). The past 32 years trend analysis shows the non significantly increase in morning humidity with the rate of 0.018 with R^2 0.002 ($y = 0.018x + 81.94$) [Fig. 3(b)]. During decades 1980-90, 1991-00 and 2001-11 the coefficients of variations were 5.99%, 3.45% and 2.45 % with standard deviation 4.92, 2.81 and 2.04, respectively (Table 2).

The average annual afternoon relative humidity during decades 1980-90, 1991-2000 and 2001-11 [Fig. 3(c)] were 50.49, 52.84 and 53.34%, respectively with 3.47 standard deviation and 6.66% CV (Table 1). The 32 years trend analysis shows significantly increasing trend in afternoon relative humidity at the rate of 0.11% per year with R^2 0.096 ($y = 0.114x + 50.3$) [Fig. 3(d)]. The coefficients of variations for annual afternoon relative humidity were 6.81%, 6.65% and 5.80% with standard deviation 3.45, 3.50 and 3.11 during 1980-90, 1991-00 and 2001-11, respectively (Table 2).

The annual morning humidity of Bharuch district varies between 18.0 to 88.0%. Morning relative humidity rises to its maximum level during the months of June to September and lowest in February-March. Annual average morning relative humidity during decades 1990-2000 and 2001-11 [Fig. 6(a)] were 71.15 and 71.7%, respectively with 2.63 deviation and 3.69% CV (Table 1). The past 22 years trend analysis shows the non significantly increase in morning humidity with the rate of 0.20 with R^2 0.31 ($y = 0.203x + 68.97$) [Fig. 6(b)]. During decades 1990-00 and 2001-11 the coefficients of variations were 3.35% and 3.06 % with standard deviation 2.36 and 2.21, respectively (Table 2).

The average annual afternoon relative humidity during decades 1990-2000 and 2001-11 Fig. 6(c) were 43.21 and 41.44%, respectively having 4.71 standard deviation and 11.13% CV (Table 1). The 22 years trend analysis shows significantly increasing trend in afternoon relative humidity at the rate of 0.11% per year with R^2 0.019 ($y = 0.11x + 40.63$) [Fig. 6(d)]. The coefficients of variations for annual afternoon relative humidity were 7.84% and 15.97% with standard deviation 3.35 and 6.55 during decades 1990-00 and 2001-11, respectively (Table 2).

6. The average decadal rainfall for Navsari region during past three decades (1980-90, 1991-2000 and 2001-11) were 1418.8, 1404.4 and 1843.8 mm, respectively and for Bharuch region past two decades (1990-2000 and 2001-11) average rainfall were 844.8 and 1062.9 mm, respectively. The annual rainfall of Navsari and Bharuch

region shows increasing tendency and both stations reported higher rainfall in last decade 2001-2011. Similarly, past years BSS analysis affirmed the decreasing trend and relative humidity at increasing trend, which may in confirmation to increase in rainfall for both stations. Past years analysis for maximum temperature showed slightly increasing tendency, while minimum temperature revealed in significant increase. The average decadal minimum temperature for Navsari region during decades 1980-1990, 91-2000 and 2001-11 were 19.67, 20.84 and 21.73 °C, respectively, as well for Bharuch region average minimum temperature during past two decades were 20.97 and 21.55 °C, respectively. The likely cause for increase in minimum temperature is global warming.

The reasons for these observed trends will be investigated in further studies. The results of trends in weather parameters at stations Navsari and Bharuch have limited applicability due to unavailability of long period of data for this study.

References

Mukharjee, A. and Banergee, S., 2009, "Rainfall and temperature trend analysis in the red lateritic zone of West Bengal", *J. Agrometeorol.,* **11**, 2, 196-200.

Singh, K. A. and Rai, S. K., 2011, "Long term variability and trends of temperature over various time scales at Pusa, Bihar", *J. Agrometeorol.,* **13**, 1, 77-78.

NEERAJ KUMAR
R. R. PISAL
S. P. SHUKLA
S. S. PATEL

Agricultural Meteorological Cell,
N.M. College of Agriculture,
Navsari Agricultural University,
Navsari- 396 450 (*Gujarat*).
(*Received 28 May 2013, Modified 17 February 2015*)
e mail: aasnavsari@gmail.com