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Trend of surface temperature in the Konkan region of Maharashtra

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Abstract - *Change in climate have significant impact on Agriculture and water resources which affect the livelihood of millions of peoples especially along the coastal line such as Konkan region of Maharashtra state. Despite of study area having coastal line throughout the Konkan region surface temperature has varied from place to place even within the region. Assessment of temperature trend in the region is key component for water resource planning and management point of view. Konkan region of Maharashtra state extent from $15^0$6' N to $20^0$22' N latitude and $72^0$39' E to $73^0$48' E longitudes. In the present study, surface temperature data for selected study stations have been analyzed to detect trend. Study focus on the spatio-temporal trends of monthly minimum and maximum temperature in the Konkan region. Trend analysis has been exercised by using non-parametric Mann-Kendall test to assess nature of trend and magnitude of trend was estimated by using Sen's slope test. Results of the analysis was also tested for 90, 95 and 99 per cent confidence level. Results revealed that monthly minimum and maximum temperature exhibited significant trends at more number of stations in the month of August and February, respectively. Minimum and maximum temperature in the region were affected significantly, which increased diurnal temperature range. Results also indicate that climatic suitability for mango and cashew crop is reducing in the region day by day due to significant variation in the minimum and maximum surface temperature.*

***Key Words*: Mann Kendall, Sen's slope, Spatio-temporal, Trend, Temperature**

1.INTRODUCTION

Climate change is the shifting of climatic and meteorological parameters, while global warming or cooling, which refers the change of surface temperature at regional or national level. A number of studies were concentrated on impact assessment of climate change and variability on different components of hydrologic cycle. In the most recent studies, it is observed that significant warming in the second half of the 20th century resulted in a drastic change in the hydrology of an agricultural based country like India (IPCC, 2007). In India magnitude and trend of warming is matching with the global condition during the last century. Spatial and temporal pattern and variability of temperature over the region plays a vital role in modelling miscellaneous processes in hydrology, climatology, agriculture, environmental engineering, and forestry both at local and global levels (Anandhi et al., 2009; Tabari et al., 2011; Padmakumari et al., 2013). Among the various dominant atmospheric variables, temperature has a significant and direct effect on almost all hydrologic variables (Sonali and Kumar, 2013). The change in temperature more badly affects the rainfed agriculture and major part of Indian agriculture is comes under rainfed category. Rainfed agriculture dominates the food grain production chain of Konkan region during rainy season. Any abrupt change in surface temperature patterns poses a serious threat to food and environmental security of the entire region. Increase in the surface temperature results in increase in crop water requirement and decrease in its supply (Sonali and Kumar, 2013; Milly and Dunne, 2001). Increase in global surface temperature leads to drastic variation in hydrologic parameters such as evaporation and precipitation resulting in cumulative effect on river flow at basin, regional and country level (Zhang et al., 2001; Burn and Hag, 2002; Xiong and Shenglian, 2004; Padmakumari, et al., 2013). The effects of climate change specifically increase in minimum and maximum surface temperature of the region showed a significant impact on the production, productivity and quality of the mango (Alphanso), cashew and some dominant vegetable in the region (Datta, 2013). Water management practices may be less effective due to global warming and climate change, which widening gap between supply and demand. This indicates proper planning and management of water resource is crucial parameter (Jhajharia et al., 2015). Increasing surface temperature may have adverse effect on the human health also (Jhajharia and Singh, 2011). Crop stages changes from month to month and annual as well as seasonal assessment is not clear incites to know actual crop stage-wise situation. Therefore, in the present study monthly trends of surface minimum and maximum temperature was assessed.

1.1 Features of study area

The Konkan region is coastal part of Maharashtra covering total geographical area of 3.09 Mha. The Konkan region lies between 1506' N to 20022' N latitude and 72039' E to 73048' E longitudes, falls under heavy rainfall and hilly region. The annual precipitation in the region ranges from 2500 mm to 4500 mm (Mandale et al., 2016). The ambient temperature varies between 13.50C and 38.50C and relative humidity varies from 55 per cent to 99 per cent in the region (Gaikwad, 2013). Geographical location, data availability and source of data for all study stations are presented in Table 1 and shown in the Figure 1.

Table1: Details of station location, period of data for analysis and source of data acquisition

Sr. No.	Name of station	Latitude	Longitude	Period	Source
1	Suksale	19°55′	73°57′	1982 – 2014	WRDHP Nasik
2	Bhatsanagar	19°26′	73°48′	1996 – 2014	WRDHP Nasik
3	Karjat	18°91′	73°33′	1990 – 2016	DBSKKV Dapoli
4	Pali	18°32′	73°16′	1991 – 2011	WRDHP Nasik
5	Sudkoli	18°30′	72°59′	1981 – 2012	WRDHP Nasik
6	Harnai	17°48′	73°50′	1975 – 2008	DBSKKV Dapoli
7	Dapoli	17°54′	73°18′	1981 – 2016	DBSKKV Dapoli
8	Wakawali	17°45′	73°17′	1980 – 2016	DBSKKV Dapoli
9	Karak	16°65′	73°52′	1984 – 2014	WRDHP Nasik
10	Mulde	16°38′	73°70′	1991 – 2016	DBSKKV Dapoli
11	Awalegaon	16°26′	73°82′	1982 – 2014	WRDHP Nasik
12	Vengurla	15°43′	73°42′	1981 – 2016	DBSKKV Dapoli

WRDHP- Water Resource Department, Hydrological Project
DBSKKV- Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth

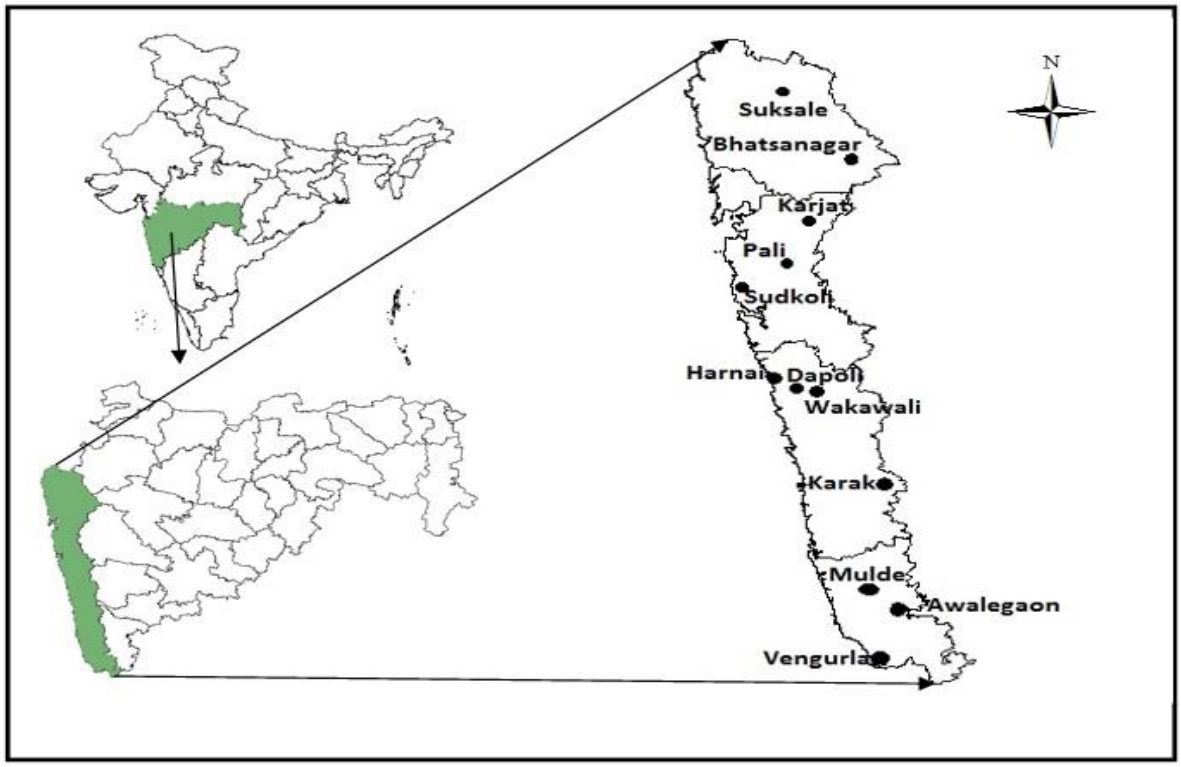

Fig. 1. Map locating the study stations in Konkan region

2. MATERIAL AND METHODS

2.1 Data Collection

The daily minimum and maximum temperature data of all study stations was procured from Department of Agronomy, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli and Water Resource Department, Hydrological Project, government of Maharashtra, Nasik.

2.2 Trend analysis of surface temperature

In the last few decades, considerable literatures concerning the trend detection techniques are available in environmental and hydrologic fields. Mann-Kendall is one of the most commonly used non-parametric test for detecting trends of climatic variables in time series (Mann, 1945; Kendall, 1955), which is able to suggest nature of trend in hydrologic and climatological time-series data (Modarres and Silva, 2007). Sen's slope test (Sen, 1968) is commonly used

for estimation of magnitude of the trend of time-series meteorological and hydrologic data (Choudhury et al., 2012; Mandal et al., 2013; Sonali and Kumar, 2013). MAKESENS excel template was developed by Salmi et al., 2002, which is used to detect trends of time series monthly temperature data. Trend analysis (increase or decrease) of minimum and maximum temperatures was statistically examined in two phases. Initially, using the non-parametric Mann-Kendall test, the presence of a monotonic increasing or decreasing trend was tested based on normalized test statistics (Z). In the second phase, the rate of increasing or decreasing trend was estimated by using non-parametric Sen's slope test (Choudhury et al., 2012, Drapela and Drapelova, 2011, Helsel and Hirsch, 2002). The trend analysis to detect the presence of rising or falling trends in monthly minimum and maximum temperatures was performed as follows.

Mann-Kendall Test (M-K)

The data values were evaluated as ordered time series. Each data value was compared with all subsequent data values. Let x1, x2, …, xn represent n data points where xj represents the data point at time j and xk represent the data point at time k. Then the Mann-Kendall statistic (S) is given by the following formula:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign\,(x_j - x_k) \quad \ldots (1)$$

$$Sign\,(x_j - x_k) = \begin{cases} 1 & if \quad x_j - x_k > 0 \\ 0 & if \quad x_j - x_k = 0 \\ -1 & if \quad x_j - x_k < 0 \end{cases} \quad \ldots (2)$$

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5)\right] \quad \ldots (3)$$

Where,

q = Number of tied groups,
tp = Number of data values in the pth group.
The standard test statistic Z computed as follows

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR\,(S)}} & if \quad S > 0 \\ 0 & if \quad S = 0 \\ \frac{S+1}{\sqrt{VAR\,(S)}} & if \quad S < 0 \end{cases} \quad \ldots (4)$$

The presence of a statistically significant trend was evaluated using two way statistical table of the Z values. A positive/negative value of Z indicates an increasing/decreasing trend. In the present study, 90, 95 and 99 per cent confidence level was determined by the test statistic. At the 90 per cent confidence level the null hypothesis of no trend is rejected if |Z| ≥ 1.64; at the 95 per cent confidence level, the null hypothesis of no trend is rejected if |Z| ≥ 1.96 and at the 99 per cent confidence level, the null hypothesis of no trend is rejected if |Z| ≥ 2.57.

Sen´s slope test

To estimate the true slope of an existing trend (as change per year) the Sen's slope test was used. The Sen's slope test can be used in cases where the trend can be assumed to be linear. In case of a linear trend available in a time series, then the true slope (change per unit time) was estimated by using a simple non-parametric procedure developed by Sen (1968). This means that linear model f (t) can be described as

$$f(t) = Qt + B \quad \ldots (5)$$

Where,
Qt = Slope
B = Constant.

To derive an estimate of the slope Qt, the slopes of all data pairs were calculated

$$Q_t = \frac{x_j - x_k}{j-k}, i = 1,2,3 \ldots N, j > k \quad \ldots (6)$$

If there is n number of sample values xj in the time series we get as many as N = n(n-1)/2 slope estimates of Qt. The N number slope values of Qt were ranked from the smallest to the largest and the Sen's estimator is the median of these N values of Qt.

$$Qt = \begin{cases} Q_{\frac{N+1}{2}} & if\ N\ is\ odd \\ \frac{1}{2}\left(Q_{\frac{N}{2}} + Q_{\frac{N+2}{2}}\right) & if\ N\ is\ even \end{cases} \quad \ldots (7)$$

3. RESULTS AND DISCUSSION

3.1 Monthly variation and trend statistic of minimum temperature

Monthly variation of minimum temperature and its trend statistic is presented in Table 2 and Table 3, respectively. Average minimum temperature was lowest in the month of January at most of the stations, while it was highest in the month of April. Mean monthly minimum temperature was varied in the region from 12.2°C at Dapoli in the month of January to 26.9 °C at Vengurla in the month of April. Variation of mean monthly minimum temperature was more in the month of December followed by November and January, while all month except January, November and December showed less than 10 per cent temporal variation. Average monthly minimum temperature was lowest in the middle-central part of the region, while it was highest in the middle-west part of the region along the sea shore.

Pali, Harnai and Mulde station did not exhibit significant trend throughout the year, whereas Wakawali and Karak evinced significant decreasing trend during most of the month. Minimum temperature showed significant increasing trend at Bhatsanagar (August, September and October), Karjat (February, May, August, September and December),

Dapoli (February, March, April, August, September, October, November, December) and Awalegaon (August). Effect of climatic variability on the minimum temperature in the south part of the Konkan region was more significant as compared to the north part of the region. This changing minimum temperature in the region may cause serious threats for the quality production of horticulture as well as rice crop. About fifty per cent of study stations reducing minimum temperature during January and February month which increase chances of causing deformed and fused ovaries and embryo abortion of mango (Rajan and Salvi 2011).

3.2 Monthly variation and trend statistic of maximum temperature

Mean monthly maximum temperature variation in the Konkan region and its trend statistic is presented in Table 4 and Table 5, respectively. Average monthly maximum temperature in the Konkan region varied between 27.7 ± 0.6 °C in the month of August at Dapoli to 39.5 ± 1°C in the month of April at Karjat. Average monthly maximum temperature in the Konkan region showed less than 10 per cent temporal variation at almost all the stations during almost all months. Maximum temperature was lower along the western side of the Konkan region during January to June and October to December, whereas it was shifted in the centre of the region during monsoon month viz. July, August and September.

The monthly maximum temperature was highest in the south part of the Konkan during January, February, March, August, November and December months, while it was maximum in the north part of the region during April, May, June, July and October. Maximum temperature during January to June and October to December was above 30 °C and below 40 °C in the Konkan region, whereas it was between 25 to 35 °C during July to September. This range of monthly maximum temperature was suitable for the quality production of most of the vegetables, which has utmost demand in the region. Trend statistic of maximum temperature was revealed that, Pali station exhibited significant decreasing trend during all months, on the contrary Karjat did not exhibit significant trend during any of the month. Monthly maximum temperature in the middle part of the Konkan region was varied significantly during most of the months as compared to north and south part of the region. Average monthly maximum temperature along the Arabian sea coast was increasing significantly. Maximum temperature in most of the month showed significant decreasing trend in the north part of the region, while it was increasing in the south part of the Konkan region. Average maximum temperature during August month was significantly changed at most of the study stations, whereas it was less affected in the month of September.

Table 2. Statistical parameters of monthly minimum temperature in Konkan region

Month		Suksale	Bhatsanagar	Karjat	Pali	Sudkoli	Harnai	Dapoli	Wakawali	Karak	Mulde	Awalegaon	Vengurla
January	Mean	13.5	16.9	13.6	13.7	14.6	21.4	12.2	13.6	18.5	16.7	15.7	18.9
	SD	1.6	1.7	1.6	1.7	1.5	1.1	1.3	1.5	3.0	1.8	1.2	2.6
	CV	11.6	10.4	12	12.3	10.1	5.0	10.3	11.4	16.4	10.6	7.3	13.8
February	Mean	14.9	18.1	14.6	14.7	15.3	21.6	12.5	14.7	19.3	17.2	16.4	19.8
	SD	2.3	1.3	2.0	1.8	1.4	1.1	1.5	1.5	3.4	1.5	1.0	2.5
	CV	15.7	7.1	13.5	12.0	8.9	5.1	12.2	10.1	17.8	8.7	6.0	12.7
March	Mean	18.7	21.1	18.1	18.1	18.6	23.2	15.7	17.7	22.7	20.5	20	22.9
	SD	2.0	1.0	1.6	1.8	1.6	1.4	1.3	1.5	3.2	1.3	1.0	2.8
	CV	10.7	4.8	9.1	9.8	8.5	5.8	8.2	8.7	14.3	6.3	5.2	12.2
April	Mean	22.9	23.5	22.5	22.4	22.5	25.1	19.6	20.8	26.1	23.7	23.7	26.9
	SD	1.5	1.2	2.2	1.6	0.8	1.1	1.3	1.4	2.6	1.4	0.9	2.2
	CV	6.5	5.2	9.7	7.0	3.7	4.2	6.6	6.6	9.9	5.8	3.6	8.2
May	Mean	26.5	24.8	24.8	25.5	24.4	26.6	22.8	22.7	27.6	25.2	25.6	28.3
	SD	1.1	1.4	1.6	1.8	1.2	0.9	0.8	1.6	2.2	0.9	0.7	1.7
	CV	4.3	5.6	6.3	6.9	5.0	3.5	3.5	7.3	8.0	3.7	2.6	5.9
June	Mean	25.1	24.9	25.8	25.2	25.3	25.6	23.8	23.3	26.2	24.6	24.7	26.4
	SD	5.7	1.3	3.2	1.5	0.8	0.8	0.8	1.9	1.6	0.7	0.6	1.6
	CV	22.5	5.0	12.3	6.1	3.0	3.3	3.4	8.3	6.1	2.9	2.3	6.1
July	Mean	25.3	23.8	24.3	24.4	25	24.7	23.3	23	24.7	23.9	24	25.8
	SD	0.5	1.05	1.2	1.4	1.0	0.7	0.8	1.1	1.5	0.8	0.3	1.7
	CV	2.1	4.4	5.1	5.8	4.2	3.0	3.5	4.7	5.9	3.4	1.4	6.8
August	Mean	24.9	23.3	24.6	24	24.8	24.3	23	22.7	24.7	23.9	24	25.5
	SD	0.6	1.1	2.2	1.4	0.8	0.7	0.8	1.1	0.9	0.6	0.4	0.4
	CV	2.4	4.8	8.8	5.8	3.1	2.9	3.6	4.7	3.6	2.4	1.5	1.5
September	Mean	24.3	23	23.2	23.5	24	24.3	22.4	22.2	24.6	23.7	23.7	25.1
	SD	0.7	0.8	1.3	1.4	0.8	0.7	0.8	1.0	1.3	0.9	0.4	0.6
	CV	3.0	3.3	5.4	5.9	3.4	2.7	3.6	4.5	5.3	3.7	1.7	2.6
October	Mean	21.6	22.4	21.6	21.9	22.3	24.7	20.5	20.8	24.1	23.3	22.9	25

	SD	1.2	0.7	1.8	1.6	0.9	0.8	1.3	1.1	1.9	0.9	0.5	1.5
	CV	5.8	3.2	8.2	7.4	4.1	3.1	6.3	5.2	7.8	3.8	2.2	5.9
	Mean	17.6	20.8	17.8	18.2	19.3	24.2	16.7	17.4	21.7	20.7	20.1	23.3
November	SD	1.9	1.1	2.4	1.9	1.2	0.9	1.9	1.7	2.9	1.5	1.3	1.5
	CV	10.8	5.2	13.4	10.5	6.4	3.6	11.3	9.8	13.4	7.2	6.6	6.5
	Mean	14.2	18.6	14.7	14.8	16.5	22.6	13.3	14.4	19.3	17.2	16.4	21
December	SD	1.3	0.9	2.3	2.1	1.2	1.0	1.3	1.2	3.4	1.8	1.2	3
	CV	9.3	4.6	15.9	14.3	7.3	4.3	9.7	8.4	17.3	10.5	7.4	14.3

Table 3. Trend statistics of monthly minimum surface temperature

Month		Suksale	Bhatsanagar	Karjat	Pali	Sudkoli	Harnai	Dapoli	Wakawali	Karak	Mulde	Awalegaon	Vengurla
January	Z	-2.96***	0.16	0.67	0.33	-1.25	1.13	1.22	-2.75***	-2.68***	0.07	-3.60 ***	-0.3
	Q	-0.14	0.08	0.04	0.02	-0.38	0.02	0.01	-0.07	-0.16	0.01	-0.09	-0.01
February	Z	-1.69*	0.00	2.06**	-0.11	-2.33**	0.7	2.45**	-2.64***	-2.05**	0.01	-3.54***	0.00
	Q	-0.11	-0.02	0.09	-0.01	-0.33	0.02	0.07	-0.06	-0.14	0.06	-0.1	0.00
March	Z	-2.96***	0.16	0.79	-0.05	-1.09	0.24	1.67*	-2.81***	-2.09**	-0.82	-2.48**	-1.39
	Q	-0.16	0.05	0.04	0.03	-0.28	0.01	0.05	-0.07	-0.12	-0.02	-0.09	-0.03
April	Z	-1.37	0.00	0.2	0.71	-1.4	0.21	2.74***	-3.03***	-2.23**	0.15	-1.94*	-1.37
	Q	-0.05	0.00	0.02	0.02	-0.13	0.00	0.08	-0.07	-0.1	0.01	-0.07	-0.04
May	Z	-1.85*	-0.47	1.71*	-0.87	-2.18**	0.03	0.89	-3.37***	-1.68*	-0.72	-1.53	-1.02
	Q	-0.06	-0.14	0.06	-0.04	-0.23	0	0.02	-0.08	-0.07	-0.01	-0.05	-0.02
June	Z	-2.14**	1.10	1.36	-0.9	-1.07	0.36	0.5	-4.23***	-2.25**	-1.0	-0.24	-1.24
	Q	-0.05	0.09	0.06	-0.04	-0.13	0.02	0.01	-0.07	-0.06	-0.03	-0.01	-0.02
July	Z	-3.83***	1.44	0.37	0.4	-1.25	1.36	1.17	-3.74***	-2.32**	-1.4	-0.07	0.42
	Q	-0.06	0.07	0.01	0.02	-0.15	0.02	0.01	-0.05	-0.05	-0.03	0.06	0.01
August	Z	-2.93***	1.92*	2.41**	0.26	-1.56	-0.09	2.14**	-3.63***	-1.20	-1.11	0.25	2.03**
	Q	-0.06	0.1	0.04	0.01	-0.1	0	0.03	-0.04	-0.03	-0.01	0.06	0.02
September	Z	-1.78*	1.71*	1.80*	0.06	-0.18	-0.5	2.22**	-3.63***	-1.36	0.12	-1.84*	0.56
	Q	-0.05	0.09	0.04	0.00	-0.08	-0.01	0.03	-0.05	-0.05	0.02	-0.03	0.00
October	Z	-1.41	3.50***	0.77	0.15	-0.18	-0.27	1.77*	-3.43***	-1.73*	0.82	-1.0	0.12
	Q	-0.08	0.16	0.02	0.01	-0.06	0	0.04	-0.04	-0.06	0.02	-0.01	0.0
November	Z	-0.75	0.75	0.33	-0.49	-8***	0.86	3.26***	-0.02	-1.70*	-0.07	-1.39	-1.12
	Q	-0.05	0.1	0.01	-0.04	-0.15	0.01	0.1	0.0	-0.12	-0.01	-0.04	-0.05
December	Z	0.03	-0.07	1.96**	0.53	4***	1.19	2.97***	-1.42	-2.03**	0.62	-2.91***	0.28
	Q	0.01	0.00	0.11	0.08	0.11	0.02	0.07	-0.03	-0.18	0.03	-0.1	0.01

*Significant at 90 per cent confidence level, **significant 95 per cent confidence level, ***Significant at 99 per cent confidence level

Table 4. Statistical parameters of monthly maximum temperature in Konkan region

Month		Suksale	Bhatsanagar	Karjat	Pali	Sudkoli	Harnai	Dapoli	Wakawali	Karak	Mulde	Awalegaon	Vengurla
	Mean	32.6	32.8	32.5	32.0	32.7	28.6	30.6	32.1	32.5	33.7	35.7	31.9
January	SD	2.4	1.2	3.9	1.7	1.8	0.9	0.8	1.4	2.5	0.8	1.1	3.3
	CV	7.3	3.6	11.9	5.4	5.4	3.1	2.6	4.2	7.8	2.3	3.1	10.5
	Mean	35.1	34.7	34.8	33.4	33.7	28.3	31.2	33.4	34.5	34.6	37.1	31.5
February	SD	1.7	1.5	1.2	1.9	2.0	1.0	0.9	1.6	2.7	1.0	1.5	2.8
	CV	4.8	4.2	3.5	5.7	6.0	3.7	3.0	4.7	7.9	2.8	4.1	8.8
	Mean	38.7	38.1	38.8	36.3	36.4	29.2	32.3	35.2	37.0	35.4	38.9	31.6
March	SD	3.5	1.3	2.4	2.1	1.6	1.0	0.8	1.7	2.5	0.8	1.1	2.4
	CV	9.0	3.5	6.2	5.7	4.5	3.3	2.4	4.9	6.8	2.2	2.9	7.6
	Mean	39.3	39.3	39.5	37.0	36.4	30.3	32.3	35.6	38.1	35.9	39.4	32.8
April	SD	2.0	1.4	1.0	2.0	2.0	0.8	0.5	1.5	2.4	0.7	0.9	0.6
	CV	5.2	3.7	2.6	5.4	5.6	2.5	1.6	4.3	6.4	2.0	2.4	1.7
	Mean	38.2	37.8	38.4	36.1	35.3	31.1	32.8	34.6	37.2	35.4	38.2	33.4
May	SD	2.1	1.1	0.8	1.7	1.9	0.5	0.4	1.2	2.0	0.9	1.4	0.9
	CV	5.6	3.0	2.1	4.6	5.5	1.7	1.3	3.4	5.4	2.6	3.7	2.6
June	Mean	33.4	32.2	34.6	31.6	30.9	30.5	30.4	30.7	31.5	31.8	32.0	30.9

	SD	2.2	1.8	6.3	1.8	2.0	0.5	0.7	1.2	2.0	2.5	1.4	0.7
	CV	6.7	5.5	18.1	5.8	6.4	1.6	2.4	4.0	6.2	7.8	4.3	2.2
	Mean	29.4	27.8	29.9	28.3	29.0	29.2	27.9	28.2	28.2	29.1	29.3	29.5
July	SD	1.5	1.0	2.1	1.1	0.5	0.3	0.4	0.8	1.2	0.8	0.9	0.5
	CV	5.2	3.4	7.2	3.8	1.8	1.1	1.3	2.8	4.2	2.7	3.1	1.6
	Mean	29.0	27.8	28.7	27.9	28.8	28.6	27.7	28.0	28.0	29.2	29.3	29.3
August	SD	1.5	0.9	0.9	1.3	1.0	0.4	0.6	0.7	1.2	0.4	0.7	0.6
	CV	5.0	3.4	3.0	4.5	3.4	1.4	2.0	2.4	4.2	1.5	2.4	1.9
	Mean	30.6	29.5	30.9	29.0	29.5	29.1	28.6	29.3	29.8	30.3	30.9	30.1
September	SD	1.7	1.7	2.3	1.5	1.2	0.4	0.5	1.0	1.9	0.5	1.0	0.5
	CV	5.4	5.7	7.5	5.3	4.2	1.4	1.7	3.5	6.4	1.7	3.3	1.7
	Mean	34.3	33.4	33.9	32.0	32.9	31.0	31.4	32.3	32.3	32.9	33.7	31.9
October	SD	1.8	0.8	1.1	2.0	1.0	0.9	0.7	1.4	2.2	0.9	1.0	0.7
	CV	5.4	2.5	3.4	6.2	3.1	2.9	2.1	4.4	6.8	2.6	2.9	2.3
	Mean	34.5	34.2	34.4	32.8	34.1	32.0	32.4	33.0	33.2	34.2	34.9	33.5
November	SD	2.1	0.9	0.9	2.2	1.6	0.8	0.7	1.7	2.4	0.7	0.9	1.9
	CV	6.0	2.7	2.6	6.7	4.6	2.5	2.2	5.3	7.1	2.0	2.6	5.7
	Mean	33.4	33.0	33.9	32.1	33.3	30.6	31.6	32.1	32.4	33.8	34.8	33.3
December	SD	2.2	0.8	2.0	2.0	2.1	0.9	0.8	2.0	2.5	0.8	1.1	2.4
	CV	6.7	2.4	5.9	6.2	6.2	2.9	2.4	6.1	7.8	2.3	3.1	7.3

Table 5. Trend statistics of monthly maximum surface temperature

Month		Suksale	Bhatsanagar	Karjat	Pali	Sudkoli	Harnai	Dapoli	Wakawali	Karak	Mulde	Awalegaon	Vengurla
January	Z	-1.30	-0.39	-1.31	-3.89***	1.44	1.39	-2.55***	-0.37	2.85 ***	2.21 **	-0.73	1.12
	Q	-0.11	-0.1	-0.06	-0.24	0.22	0.02	-0.03	-0.01	0.17	0.06	-0.04	0.02
February	Z	-1.35	-0.93	1.41	-3.16***	-0.21	0.83	2.65***	0.31	2.43 **	1.96 **	-1.12	0.65
	Q	-0.1	-0.21	0.04	-0.21	-0.04	0.02	0.03	0.01	0.18	0.06	-0.04	0.01
March	Z	-1.13	-0.55	0.47	-3.21***	0.21	1.30	2.52**	-0.28	2.25**	3.05 ***	-1.54	1.56
	Q	-0.12	-0.1	0.02	-0.23	0.09	0.02	0.02	-0.01	0.15	0.07	-0.05	0.03
April	Z	-1.69	-0.78	0.4	-2.96***	0.75	1.63	-2.69***	-1.22	1.70*	3.35 ***	-1.37	1.80 *
	Q	-0.09	-0.16	0.01	-0.21	0.16	0.03	-0.03	-0.02	0.1	0.07	-0.03	0.02
May	Z	-3.61***	-1.87*	-1.31	-3.67***	0.34	2.61***	2.99***	-0.74	0.18	3.05 ***	-1.34	0.82
	Q	-0.23	-0.23	-0.02	-0.21	0.19	0.02	0.02	-0.01	0.02	0.07	-0.05	0.01
June	Z	-2.37**	-0.34	-0.42	-2.93***	-0.23	2.15**	2.82***	-1.90*	-0.21	0.21	0.09	1.63
	Q	-0.21	-0.11	-0.03	-0.19	-0.09	0.02	0.03	-0.04	-0.01	0.01	0.00	0.02
July	Z	-3.38***	-1.71*	0.84	-3.7***	0.63	2.40**	2.35**	-0.68	-1.07	0.00	0.05	2.38**
	Q	-0.19	-0.16	0.02	-0.15	0.05	0.02	0.01	-0.01	-0.03	0.00	0.04	0.02
August	Z	-2.51**	0.62	1.52	-2.71***	1.61	1.84*	3.13***	1.65*	0.09	1.95 *	2.45**	3.81***
	Q	-0.13	0.05	0.03	-0.15	0.24	0.01	0.04	0.01	0.00	0.02	0.05	0.04
September	Z	-1.48	0.39	-0.21	-2.99***	0.81	2.74***	1.12	-0.71	-0.14	-0.12	-1.07	2.24**
	Q	-0.1	0.05	-0.02	-0.14	0.19	0.02	0.01	-0.01	-0.01	-0.01	-0.03	0.02
October	Z	-1.12	-0.75	0.58	-3.96***	0.36	2.64***	1.94*	-0.43	1.32	1.81*	0.09	1.73 *
	Q	-0.05	-0.09	0.03	-0.26	0.1	0.04	0.03	-0.01	0.09	0.06	0.03	0.03
November	Z	-0.21	0.21	0.61	-3.41***	6.00***	3.02***	1.16	-1.02	2.03**	1.61	-1.26	0.37
	Q	-0.02	0.04	0.01	-0.27	0.11	0.04	0.01	-0.02	0.14	0.03	-0.04	0.01
December	Z	-0.27	0.14	0.96	-2.92***	12***	1.87*	1.77*	-0.38	2.19 **	3.10 ***	-1.03	-1.36
	Q	-0.03	0.01	0.03	-0.22	0.29	0.04	0.03	-0.01	0.16	0.07	-0.01	-0.02

3. CONCLUSIONS

Impact of climatic variability on monthly minimum and maximum temperature was erratic in the Konkan region. Monthly minimum temperature in the north and middle part of the Konkan region was changed significantly. Mean monthly maximum temperature was affected more significantly in the middle part of the region as compared to north and south part of the Konkan region. Minimum and maximum surface temperature exhibited inverse trend at Pali, Harnai, Dapoli, Wakawali and Karak in the most of the month which increase diurnal range of temperature in the region. Maximum temperature along the Arabian sea coast was increasing significantly in the region.

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