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Analysis of heat wave and mean maximum temperature for the months of march to June over Vidarbha during last 50 years

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सार – विदर्भ में मार्च से जून के दौरान लू और अधिकतम तापमान की प्रवृत्ति का विश्लेषण करने के लिए एक अध्ययन किया गया है। मध्य भारत, मुख्य रूप से महाराष्ट्र राज्य का विदर्भ क्षेत्र, मार्च से जून के महीनों के दौरान अत्यधिक तापमान होताहै। ऐसे विशेष मामलों की पहचान की गई है जहां इनमें से अधिकांश स्टेशनों ने अधिकतम तापमान ≥ 45 °C दर्ज किया है और इसका कारण निर्धारित करने का भी प्रयास किया गया है। भारतीय क्षेत्र में लू की प्रवृत्ति और विभिन्न क्षेत्रों पर इसके प्रभाव की जांच के लिए विभिन्न अध्ययन किए गए हैं। यह अध्ययन लू के सांख्यिकीय और मौसम संबंधी पहलुओं पर केंद्रित है। यह पाया गया कि सात में से चार स्टेशनों ने लू के दिनों की संख्या में सकारात्मक रुझान दर्शाएऔर छह में से तीन स्टेशनों ने प्रचंड लू में सकारात्मक रुझान दर्शाए। यह देखा गया कि औसत अधिकतम तापमान के लिए, केवल बुलढाणा स्टेशन ने सकारात्मक रुझान दर्शाए और अमरावती स्टेशन ने अप्रैल और जून महीनों के मान कैंडल परीक्षण आंकड़ों के फलस्वरूप सभी चार महीनों के लिए नकारात्मक रुझान दर्शाए

ABSTRACT. A study has been carried out to analyze the trend of heat wave and maximum temperature during March to June over Vidarbha. Central India, mainly the Vidarbha region of Maharashtra State, experience extreme temperatures during the month of March to June. Special cases have been identified where most of these stations have reported maximum temperature ≥ 45 °C and an attempt has also been made to determine its cause. Various studies have been taken up for examining the trend in heat waves over Indian region and its impact on various sectors. This study focuses on the statistical and meteorological aspects of heat wave. It was found that four out of seven stations displayed a positive trend in the number of heat wave days and three out of six stations displayed positive trend in severe heat wave days. It was observed that for the average maximum temperature, only Buldhana station showed positive trend for all four months and Amravati station showed negative trend for April and June months following Mann Kendall test statistics.

Key words– Heat wave, Severe heat wave, Trend, Extreme temperature, Mann-Kendall test.

1. Introduction

The Vidarbha region is situated in the Central Indian region and south of the Satpura Range in Madhya Pradesh, which comprises of 11 districts. It is the eastern part of Maharashtra State known for its high temperatures during summer season. Over this region, incident of heat waves usually commences in the last week of March and occur sporadically till the onset of the southwest monsoon over the region. The recent decade has shown an increase in the number of such events.

As per the assessment of Working Group I (WGI) for sixth assessment report of the Intergovernmental Panel on Climate Change (IPCC), there is an increase in global surface temperature by 1.09 °C [0.95 °C to 1.20 °C] in 2011-2020 above 1850-1900. As per the IPCC’ sixth assessment report and IPCC special report on Global Warming of 1.5 °C (2018), it is estimated that even for the very low greenhouse gas emissions scenario, there is more than 50% likelihood that global warming will reach or exceed 1.5 °C in the near-term. Various authors have carried out studies on the cases of the heat wave over Indian region.

During the month of April, the frequency where maximum temperature exceeded 42 °C over parts of Vidarbha is more than 6 days per year and during the month of May it is more than 16 days per year (Naveena *et al*., 2021). As per their findings, the intensity and duration of heat wave is more in succeeding El-Nino years in comparison with El-Nino and preceding El-Nino years.

The composite anomaly in mean maximum temperature is also higher than normal during succeeding El-Nino years. Similar study by Pai *et al*. (2013) revealed that, during El-Nino+1 year, the all India heat wave and severe heat wave days are higher than normal, on the other hand, during La-Nina+1 year, it is lower than normal. It was also found that during the period 1961-2010, the average number of days with heat wave is ≥8 days over many parts of Central India. Various meteorological factors were responsible for positive anomaly in heat waves over Telangana and Andhra Pradesh during May 2015, which includes incursion of northwesterly winds at 850 hPa over the region, presence of anticyclone over northeast Arabian Sea at 700 hPa, presence of ridge at 500 hPa running along latitude 20° N over Indian region, location of Sub-tropical Westerly Jetstream at 25° N (Singh *et al*., 2018). Ratnam *et al*. (2016) studied that positive values of composite Outgoing Longwave Radiation anomalies, significant anticyclone over India in 200 hPa eddy stream function anomalies and indication of sinking motion in vertical velocity at 500 hPa over Indian landmass results in heatwave condition over the region.

Over Indian region, the hottest days have the highest magnitude over central and western Indian regions (Rehana *et al*., 2022). The hottest days, warmest nights and all warm temperature indices, namely SU25, TR20, TXx, TNx, TX90p, WSDI has a positive trend for most parts of the country. An increasing trend of 0.1 days/ decade was observed over core heat wave zone which covers states of Punjab, Himachal Pradesh, Uttarakhand, Delhi, Haryana, Rajasthan, Uttar Pradesh, Gujrat, Madhya Pradesh, Chhattisgarh, Bihar, Jharkhand, West Bengal, Orissa, Telangana, meteorological Subdivisions Marathwada, Vidarbha, Madhya Maharashtra, Coastal Andhra Pradesh (Pai, *et al*., 2022). The duration of heat wave over these regions have shown an increase of 0.44 days/decade. An increasing trend of 1.5 °C/ 100 year to 2 °C/ 100 year in maximum temperature was observed over central India by Naveena *et al*. (2021), which is in agreement with the IPCC report. On the other hand, Yavatmal station in Vidarbha subdivision showed a significant decreasing trend in mean maximum temperature following Mann Kendall Test (Deshmukh *et al*., 2013). Since the beginning of 21st century, the hot days and heat wave duration has followed a rising pattern over Indian region (Panda *et al*., 2022). There has been 60% rise in the frequency of hot days during 2001 to 2016 and the maximum temperature anomaly has also shown 0.28 °C rise per 10 years. The mean duration of hot days and heat wave over Indian region is 2 days and 3 days respectively (Arulalan *et al*., 2023). The decadal trend shows a decreasing trend in the number of hot days and an increasing trend in heat wave days over most part of Indian region.

A large inter-annual variability with an increasing trend in the anomaly of mean maximum temperature was observed over four climatic zones of India namely, montane, arid and semi-arid, humid subtropical and tropical wet and dry (Bhattacharya *et al*., 2023). The frequency of heat wave events has an increasing trend over arid and semi-arid and tropical wet and dry zones. According to the study, the tropical wet and dry region has experienced an increase in heat wave events from 0.82 HW events per decade during 1970-1979 to 1.07 heat wave events during 2010-2019. As per the study carried by Goyal *et al*., 2023, the mean frequency of heat wave events under SSP245 and 585 will increase by 35.85% and 62.17% respectively, in hilly and northeast zones of India, for coastal region the increase is 37.87% and 49.48%, for interior Peninsular region it is 79.09% and 107.21% and for northcentral region it is 30.59% and 40.82% respectively.

The amplitude of hottest day, number of events of heat wave, frequency and duration of heat wave has shown an increasing trend for Queensland (Australia) since 1965 to 2020, which is also in agreement with the general trend in global warming. An overall global trend in maximum temperature based on analysis of data from 1961 to 1985 was observed to be +0.88 °C per 100 years (Easterling *et al*., 1997). The same analysis was done by eliminating large urban areas and the result was found to be +0.82 °C per 100 years. Global observations have also shown that the largest warning is observed during the months of March to May (Alexander *et al*., 2006). Based on the data from the period 1950 to 2012, it was found that most stations in Nigeria shows significant upward trend in maximum temperature at 0.01 and 0.05 significance level, also the Coefficient of Variation in maximum and minimum temperatures over Nigeria (9.08° N, 8.67° E) is latitude dependent, decreasing from higher to lower latitudes (Amadi *et al*., 2014).

In the review study on heat waves done by Perkins (2015), various physical drivers for heat waves *e.g*. synoptic systems, land surface and soil moisture, climate variability and large-scale teleconnections have been discussed. The most common synoptic feature is the blocking high or high-pressure system which persists for a longer period over the same region. With a decrease in soil moisture, the possibility of extreme temperatures is more likely. Heat wave early warning systems (HEWS) have been introduced by many countries over the globe. Diana Lowe *et al*. (2011) have discussed the HEWS implemented by 12 European countries with their corresponding trigger indicator, threshold trigger and lead time, *etc*. Timely and accurate heat wave warnings, recommendations on adaption and heat avoidance to the vulnerable and general population are the most important

Fig. 1. Vidarbha district map

features of HEWS. An attempt has been made to project the impact of heat wave on human health in UK (Arbuthnott *et al*. 2017). The estimated heat related mortality per year in 2050 is expected to be 257% more than the deaths reported during the 2000s. In the year 2080, this percentage is expected to increase by 535%. The health impact of heat wave has been discussed in brief by Yadav *et al*., 2003. Heart attack, cardiac disorders, respiratory illness are some of the health issues faced by the vulnerable population due to the uncomfortable hot weather. Yadav *et al*. (2023) concluded in their study that an improvement in the urban and regional planning is the need of the hour since the heat wave events have significant effect on the mortality rate and urban heat island. Necessary measure needs to be taken by the government to reduce the effect of heat wave and its occurrence.

The correlation between absorbing aerosol index (AAI) and maximum and minimum temperature shows that the absorbing aerosol exacerbate the heat wave conditions over northwest India (Dave *et al*., 2020). The heat hazard analysis over Indian regions shows that the effect of weight scores due to minimum temperature on the impact of heat wave are significant over Vidarbha and adjoining Marathwada, Rayalaseema, Telangana, interior Odisha, parts of Madhya Pradesh and at some pockets over Rajasthan and Uttar Pradesh with maximum impact seen to be shifted in the month of May over entire central India and adjoining Peninsular India (Srivastava *et al*., 2022). The effect of wind speed in aggravating the impact of heat wave is also observed over Sub-Himalayan West Bengal, Gangetic West Bengal and adjoining regions of East India, Vidarbha and adjoining Marathwada, few parts of Konkan and south Tamilnadu. Similarly, the weighted scores of heat wave spell also have significant contribution on the impact of Heat Wave particularly over west Rajasthan, Odisha, Vidarbha, Telangana and coastal Andhra Pradesh. To reduce the impact of heat wave on the vulnerable population, heat action plan has been executed in Ahmedabad, Gujarat, which has shown effective results in reducing the death toll over the region (Dutta, 2019).

2. Data and methodology

The daily maximum temperature data of 7 stations Akola, Amravati, Buldhana, Chandrapur, Nagpur, Wardha and Yavatmal for March to June months from 1970 to 2021 was used for the study. The data has been obtained from the National Data Centre, India Meteorological Department, Pune and Climate Section, Regional Meteorological Centre, Nagpur.

For classifying days with heat waves and severe heat wave, the following criteria defined by the India Meteorological Department (IMD)are used:

(*i*) When maximum temperature of a station is more than or equal to 40 °C for plains and 30 °C for hilly regions

Heat Wave: Departure from normal is 4.5 °C to 6.4 °C

Severe Heat Wave: Departure from normal is more than 6.4 °C.

(*ii*) *Heat Wave based on the actual maximum temperature*: When the actual maximum temperature of a station is 45 °C or more.

(*iii*) *Severe heat wave based on actual maximum temperature*: When actual maximum temperature of a station is 47 °C or more.

(*iv*) *For coastal station*: When the maximum temperature is 37 °C or more and departure from normal is 4.5 °C or more.

Following the above criteria for heat wave, the daily temperature anomaly was computed for 52 years over 7 stations and the number of heat waves and severe heat waves were calculated. For computing the departures, pentad normal of 1981-2010 were used. The number of days with heat waves and severe heat waves for each year was computed separately for each station using the above criteria and its variation over a 52 years was analyzed. The variation of mean maximum temperatures over a 52-year period was also examined. For trend analysis the Mann-Kendall test was applied on the maximum temperature data series.

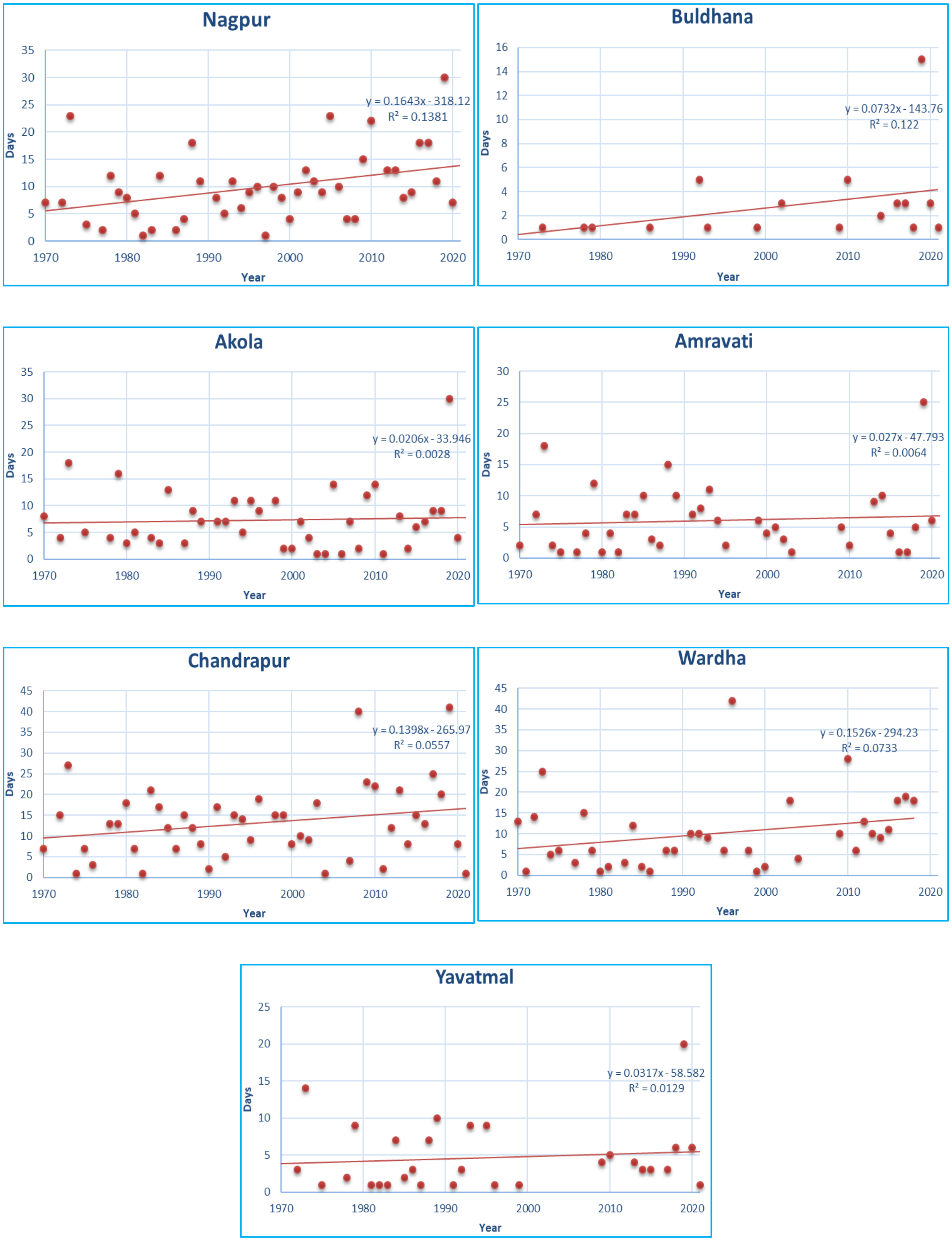


Fig. 2. Total number of heat wave days during March, April, May and June months for the period 1970-2021 (52 years)

Mann Kendall test

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{sgn}(x_j - x_k)$$

x_j and x_k represents the time series of observations and n is the length of a sample.

$$\text{sgn}(x_j - x_k) = \begin{cases} +1, & if (x_j - x_k) > 0 \\ 0, & if (x_j - x_k) = 0 \\ -1, & if (x_j - x_k) < 0 \end{cases}$$

where,

n = sample size

$x_k = 1, 2, \ldots, n\text{-}1$

$x_j = k+1, \ldots, n$

The variance of S is

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

q is the number of tied groups, t_p is the number of observations in the p^{th} group.

For meteorological analysis of heat wave conditions over Vidarbha, the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis data daily average wind fields of 850 hPa, 700 hPa and 500 hPa and 500 hPa geo-potential height (Z500), has been used. For plotting the maximum temperature of Vidarbha, CPC 0.5×0.5 Global Daily Gridded temperature data been obtained from NOAA PSL, Boulder, Colorado, USA, from https://downloads.psl.noaa.gov/Datasets/cpc_global_temp/ . Plotting of data has been done with the use of GrADS software.

3. Results and discussion

The number of days with heat wave has been computed for the four months from March to June. The graphs presented in Fig. 2 shows variation of the total number of days with heat wave with each year. A positive trend in heat wave days is observed for Nagpur (0.16 days/year), Buldhana (0.07 days/year), Wardha (0.15 days/year) and Chandrapur (0.14 days/year). A very weak but positive trend is implied for Akola (0.02 days/year), Amravati (0.03 days/year) and Yavatmal (0.03 days/year).

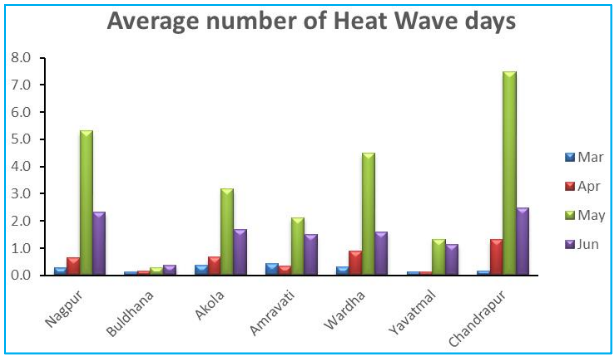


Fig. 3. Average number of days with heat wave over Vidarbha

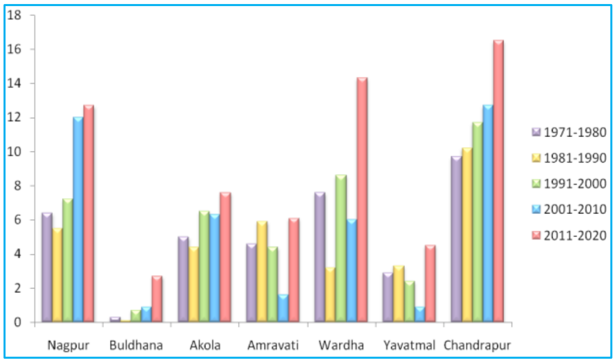


Fig. 4. Decadal variation of number of heat wave days

The average number of heat wave days was highest during the month of May and lowest during March for most stations (Fig. 3), which is also in agreement with the study carried out by Srivastava *et al.* (2023).

To further examine the above results, an analysis of decadal variation of heat wave, *i.e.*, average number of heat wave days per year in each decade, was studied for all seven stations for the five decades from 1970-2020. The same results have been shown in Fig. 4. There is a marked rise in the number of heat wave days over Nagpur in recent two decades, *i.e.*, 2001-2010 and 2011-2020. The heat wave day over Nagpur in the first three decades under study was a single digit number which has increased to a double digit value in recent two decades. For Buldhana station, the number of heat wave days in the first two decades was nil which has increased to an average value of 3 days in 2011-2020. However, Wardha has experienced a significant rise in the number of heat wave days per year only in the recent decade. Among all seven stations under study, Chandrapur has experienced highest number of heat wave days per year in all five decades. Also, a significant increase in the number of heat wave days has been observed in the recent decade over Chandrapur. Akola and Yavatmal has also received

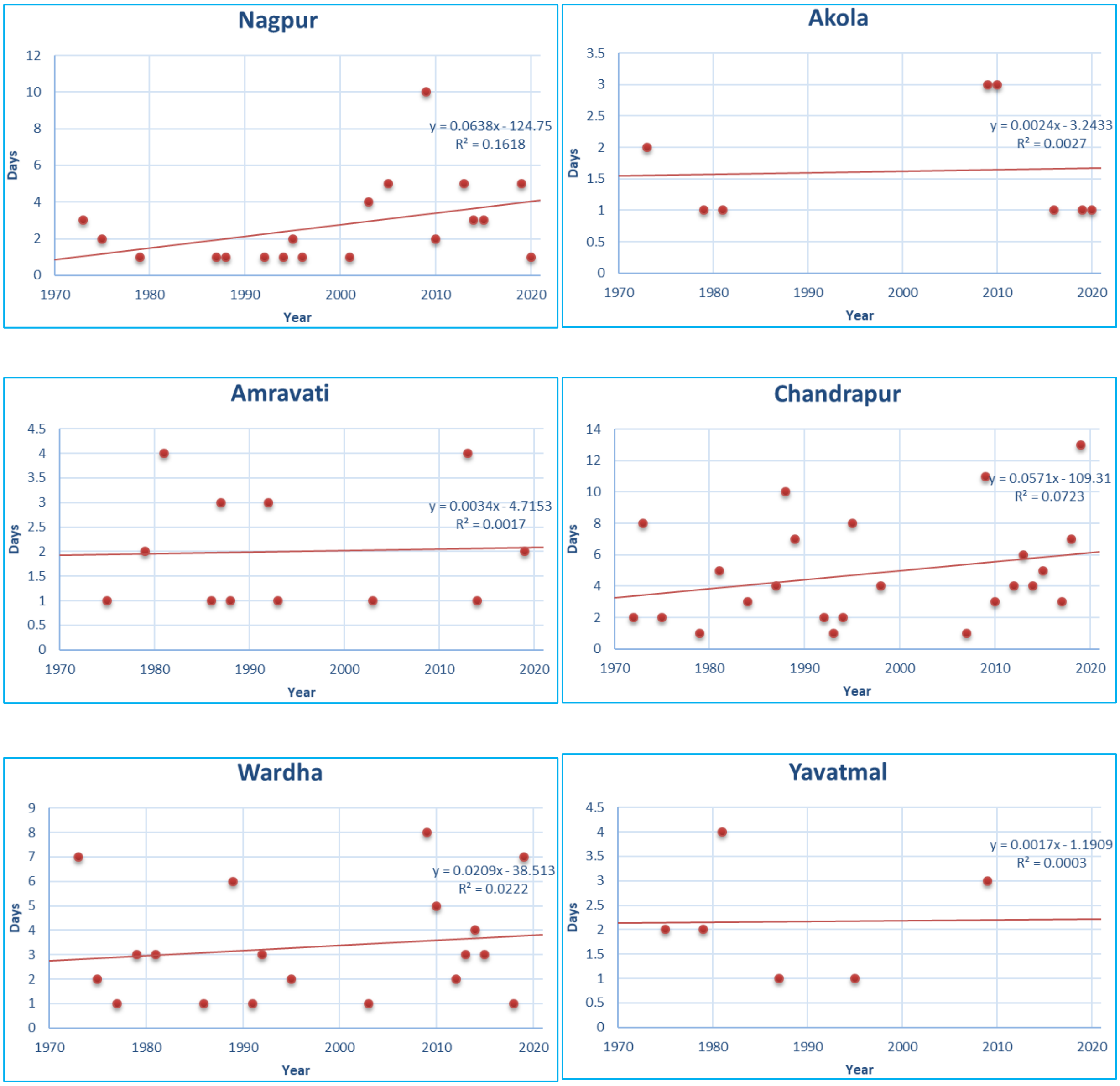


Fig. 5. Total number of severe heat wave days during March, April, May and June months for the period 1970-2021 (52 years)

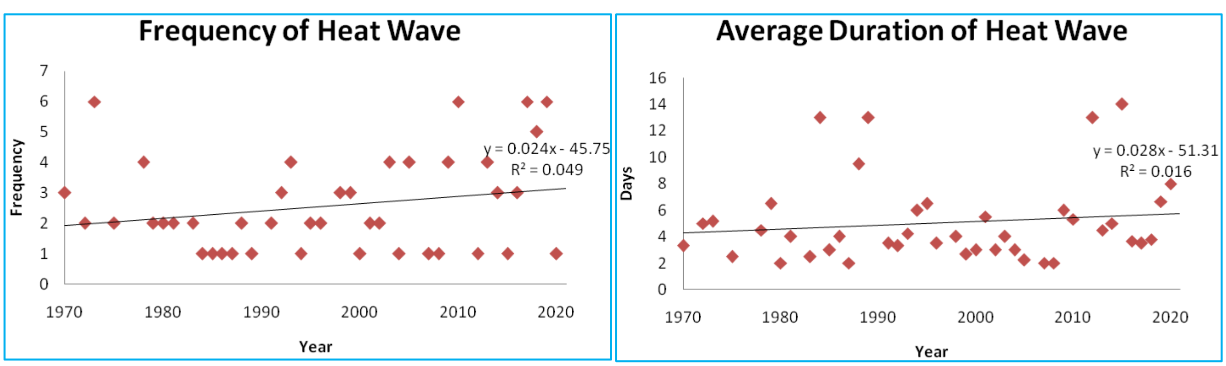
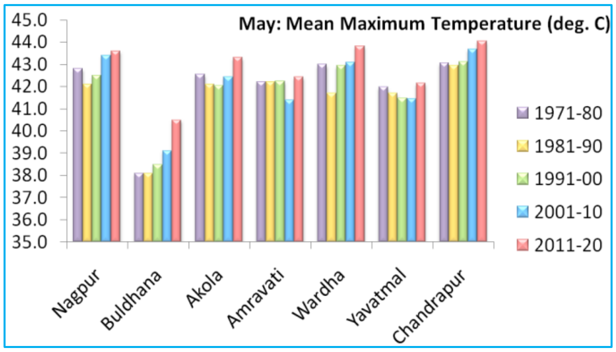


Fig. 6. Frequency and average duration of Heat Wave (in days) over Vidarbha



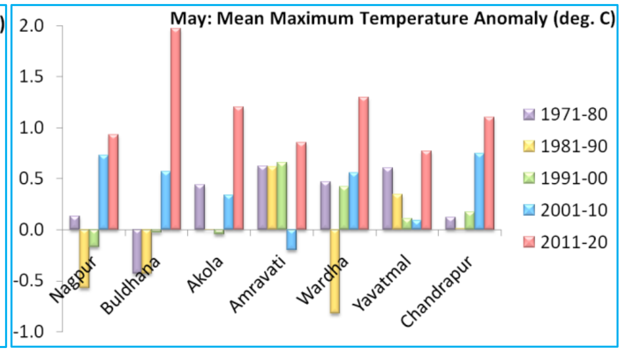


Fig. 7. Mean maximum temperature and anomaly (°C) during May month

TABLE 1

Mann-Kendall trend test results

Station	March			April			May			June		
	z-value	p-value	slope (°C/Year)	z-value	p-value	slope (°C/Year)	z-value	p-value	slope (°C/Year)	z-value	p-value	slope (°C/Year)
Akola	0.57	0.5687	0.0085	0.81	0.4179	0.0082	1.59	0.1118	0.0134	0.34	0.7339	0.0088
Amravati	-1.02	0.3077	-0.0140	-1.78	0.0751	-0.0180	-1.18	0.2380	-0.0134	-1.71	0.0873	-0.0374
Buldhana	2.34	0.0193	0.0369	3.29	0.0010	0.0497	4.22	0.0000	0.0511	2.18	0.0293	0.0377
Chandrapur	0.14	0.8887	0.0025	0.72	0.4715	0.0107	1.37	0.1707	0.0196	0.4	0.6892	0.0082
Nagpur	0.35	0.7263	0.0061	1.2	0.2301	0.0138	1.72	0.0854	0.0244	0.54	0.5892	0.0129
Wardha	0.1	0.9203	0.0024	0.81	0.4179	0.0083	1.41	0.1585	0.0210	1.25	0.2113	0.0256
Yavatmal	-0.71	0.4777	-0.0100	-0.56	0.5755	-0.0060	-0.1	0.9203	-0.0014	-0.71	0.4777	-0.0096

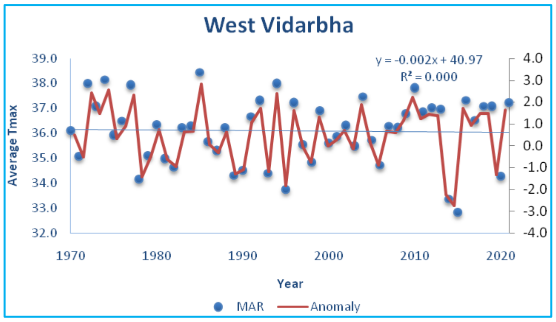
highest number of heat wave days during 2011-2020, but the increase is not as significant as in case of other stations. Amravati has not shown any significant change in heat wave days. These results are in consensus with Panda *et al*., 2022.

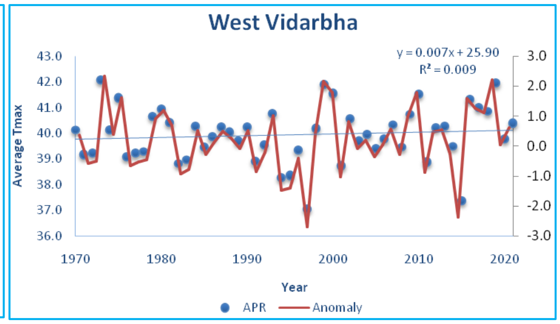
The number of days with severe heat wave is nil in case of Buldhana. For other six stations the computation of number of days with severe heat wave was done for all four months from March to June, the results are presented in Fig. 5. The severe heat wave days have a weak but positive trend for Nagpur (0.06 days/year), Chandrapur (0.06 days/year) and Wardha (0.02 days/year). Akola, Amravati and Yavatmal didn't indicate much variation in the severe heat wave days.

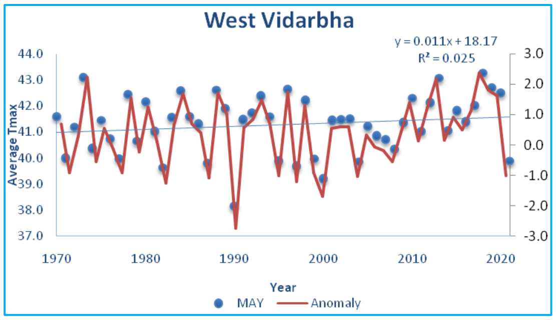
The frequency and average duration of heat wave over Vidarbha subdivision, considering the data of seven stations under study was examined. The frequency of heat wave over Vidarbha sub-division varies from one to six events per year. The results also show that there has been an increase in the frequency of heat wave in recent years (Fig. 6). The average duration of heat wave varies from two to fourteen days. A slight but positive trend (0.03 days/year) in the duration of heat wave has also been observed.

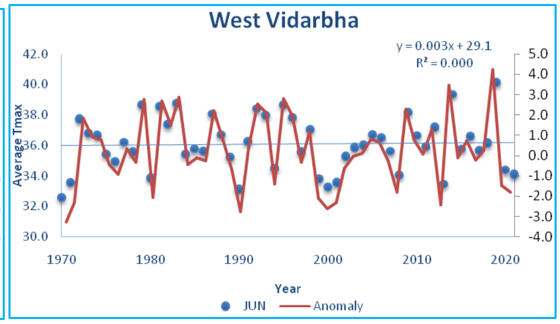
To study the behavior of mean maximum temperature over seven stations of Vidarbha subdivision for four months over 52 years, the data was subjected to the Mann Kendall test. The results are presented in Table 1. Among all seven stations of Vidarbha subdivision, only Buldhana showed positive trend in mean maximum temperature for all four months. An increasing trend in mean maximum temperature for the months of April and May was observed over Buldhana, which is statistically significant at $P<0.01$. For the month of March and June the positive trend was statistically significant at $P<0.05$. For all other cases, no statistically significant trend at $P<0.01$ and $P<0.05$ was indicated by the Mann Kendall test.

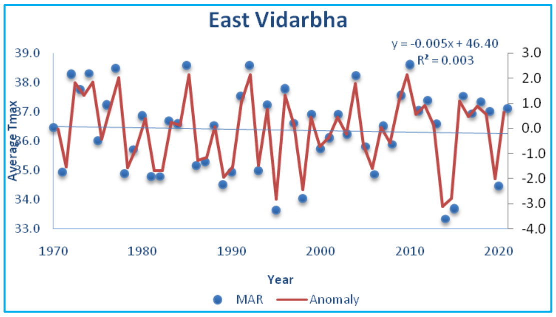
Linear trend analysis of the mean maximum temperature and maximum temperature anomaly for West

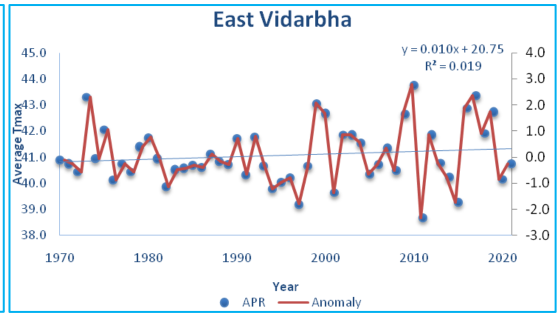

West Vidarbha
y = -0.002x + 40.97
R² = 0.000
Average Tmax
Year
MAR
Anomaly

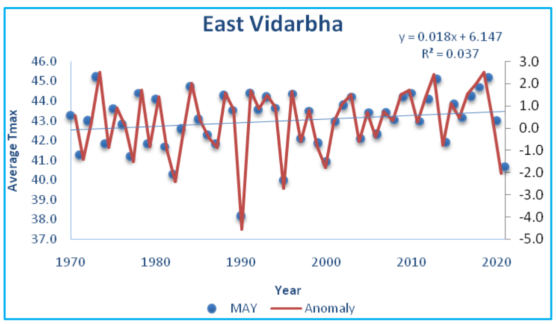

West Vidarbha
y = 0.007x + 25.90
R² = 0.009
Average Tmax
Year
APR
Anomaly

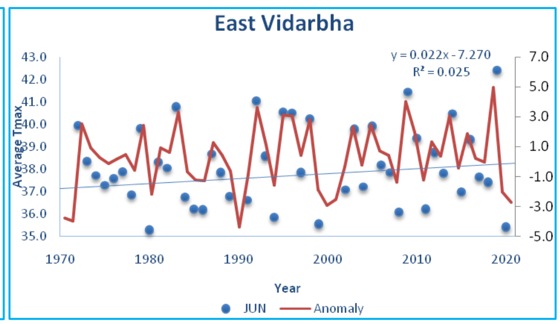

West Vidarbha
y = 0.011x + 18.17
R² = 0.025
Average Tmax
Year
MAY
Anomaly

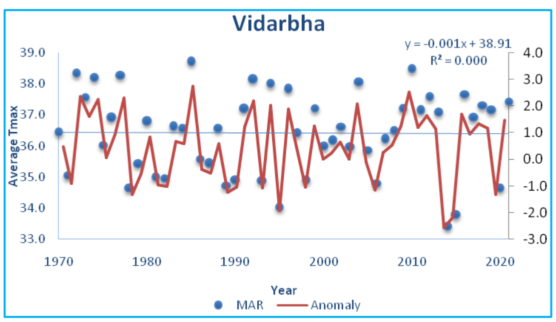

West Vidarbha
y = 0.003x + 29.1
R² = 0.000
Average Tmax
Year
JUN
Anomaly

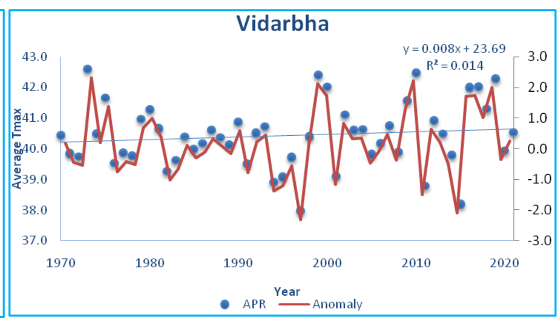

East Vidarbha
y = -0.005x + 46.40
R² = 0.003
Average Tmax
Year
MAR
Anomaly


East Vidarbha
y = 0.010x + 20.75
R² = 0.019
Average Tmax
Year
APR
Anomaly


East Vidarbha
y = 0.018x + 6.147
R² = 0.037
Average Tmax
Year
MAY
Anomaly


East Vidarbha
y = 0.022x - 7.270
R² = 0.025
Average Tmax
Year
JUN
Anomaly


Vidarbha
y = -0.001x + 38.91
R² = 0.000
Average Tmax
Year
MAR
Anomaly


Vidarbha
y = 0.008x + 23.69
R² = 0.014
Average Tmax
Year
APR
Anomaly

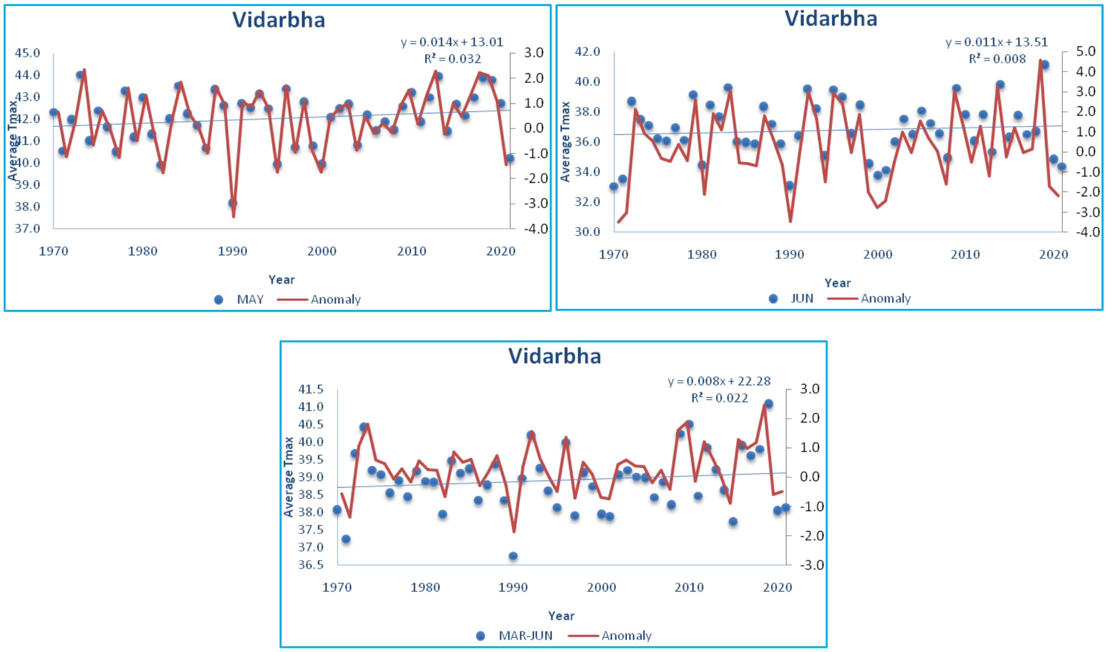


Fig. 8. Average maximum temperature and its anomaly (in °C) for West Vidarbha, East Vidarbha and Vidarbha Subdivision for the period 1970 to 2021

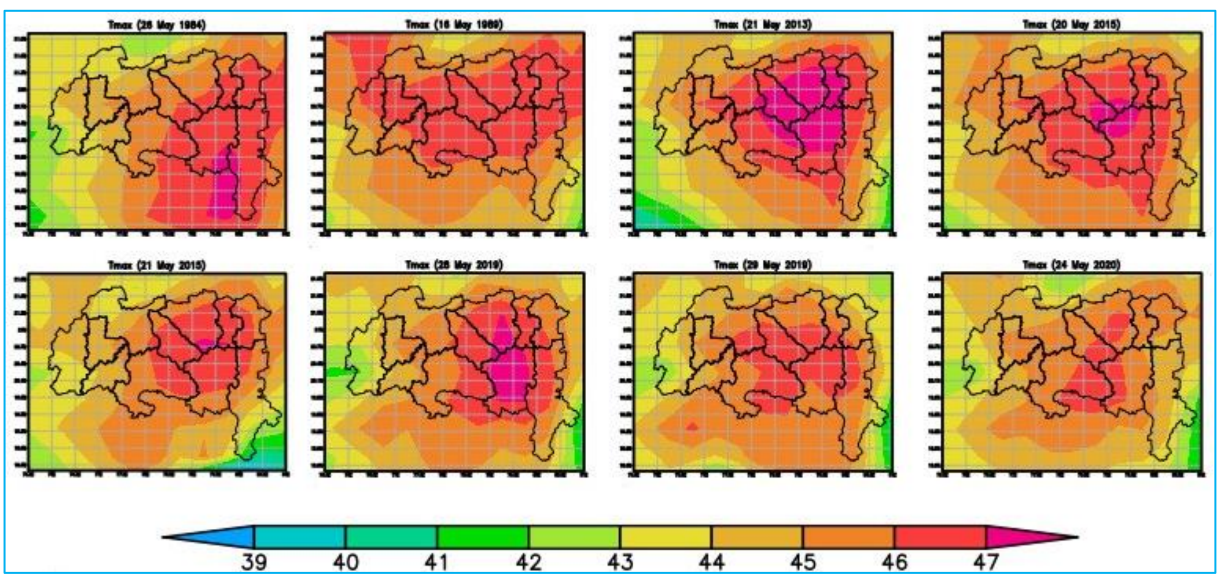
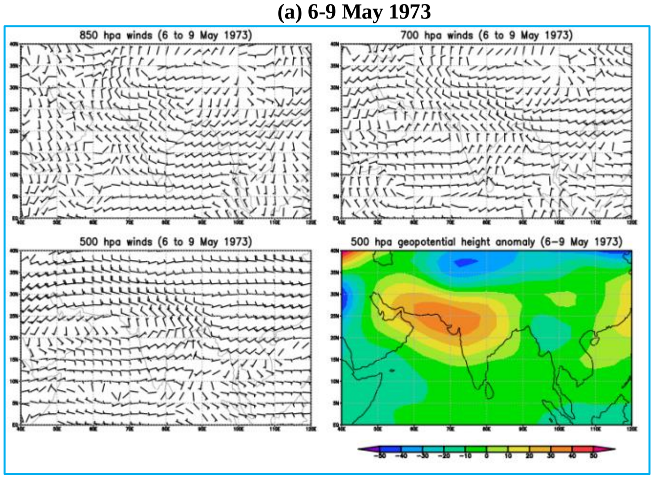


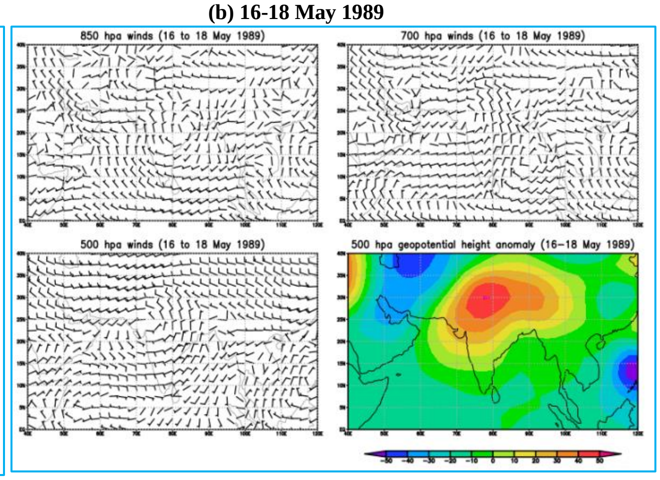
Fig. 9. Spatial distribution of maximum temperature (°C) over Vidarbha during heat wave days

Vidarbha, East Vidarbha and the entire Vidarbha sub-division is shown in Fig. 8. It is found that there is a weak but increasing trend for April (0.007 °C/year) and May (0.011 °C/year) months over West Vidarbha and not much significant trend exists for March and June months. For East Vidarbha there is an increasing trend for April (0.010 °C/year), May (0.018 °C/year) and June (0.022 °C/year) months and not very significant but slightly decreasing trends exist for March (0.005 °C/year) month. For the entire Vidarbha subdivision, April (0.0084 °C/year), May (0.0145 °C/year) and June (0.0117 °C/year) months have shown an increasing trend while no trend was observed

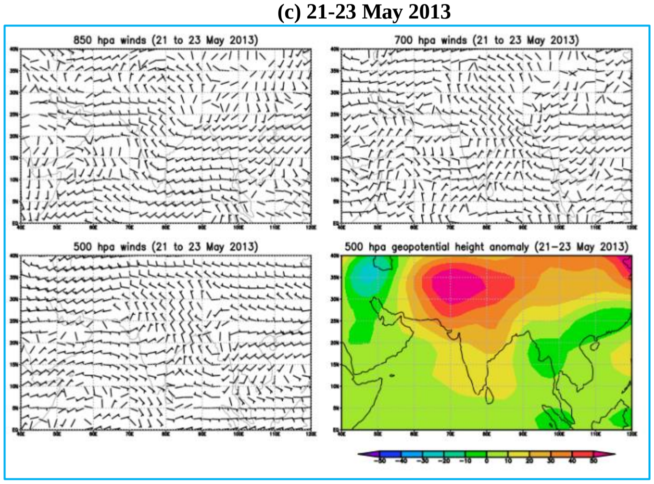
(a) 6-9 May 1973



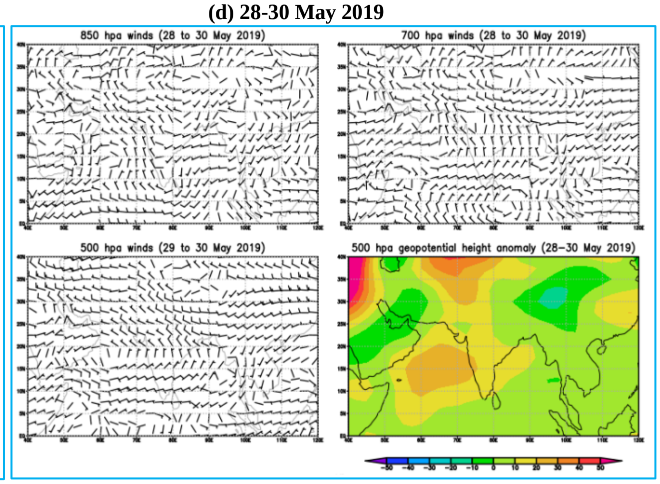
(b) 16-18 May 1989



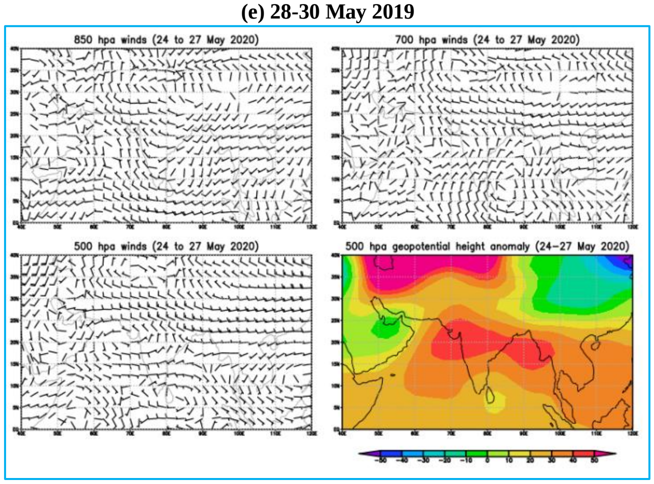
(c) 21-23 May 2013



(d) 28-30 May 2019



(e) 28-30 May 2019



Figs. 10(a-e). 850, 700, 500 hPa winds and geopotential height anomalies

for the March month. Also, for the overall period of March to June, there is an increasing tendency in mean maximum temperature over the subdivision.

As the average number of heat wave days during the month of May is highest for most station (Fig. 3), so an analysis was carried out on the decadal variation of mean maximum temperature during the month of May. It was found that among the five decades the month of May was warmest during 2011-2020 for all the seven stations which is also in agreement with Srivastava *et al*., 2022.

3.1. *Meteorological analysis of heat wave*

For meteorological analysis of heat waves over the Vidarbha subdivision, six major heat wave cases have been chosen where at least six out of seven stations of the Vidarbha subdivision under study have reported maximum temperature of ≥45 °C for consecutive 3 to 4 days. The spatial spread of maximum temperature for some of these cases is shown in Fig. 9. Most of the stations in the region are observed to have temperatures above 45 °C, few stations have also reported temperatures of 47 °C and above. Among all the stations, Chandrapur has reported the highest number of days with a maximum temperature ≥47 °C. For the period 2011-20, the average number of days when the maximum temperature is ≥47 °C is 2.5, which is the highest among all five decades from 1971 to 2020. There were two consecutive occasions in May 2013 where four stations reported maximum temperature ≥47 °C.

The synoptic analysis of the special cases shows that there is an anti-cyclonic flow over the Arabian Sea at 850 hPa and the wind flow over central India is westerly to north-westerly which bring warm dry air towards the region (Fig. 10). A ridge line is extending towards central India at 700 hPa and 500 hPa levels. Since the upper level ridge causes sinking motion, the air sinks and warms adiabatically as it moves towards the surface, leading to high temperatures. In addition, the presence of positive anomaly in geopotential height at 500 hPa level is seen over central India in all cases under study. A positive anomaly of geopotential height implies that there is warm air advection over the region and the layer of atmosphere is warmer than normal. This indicates the presence of anticyclonic flow which causes sinking motion and warm and dry conditions over the surface (Rohini *et al*. 2016). The above meteorological factors have contributed to the occurrence of heat wave at few to many places over the subdivision.

In addition, Urban Heat Island also plays an important role in amplifying the effect of heat wave, which may be reduced by proper urban planning, use of high albedo roofing materials, increased number of water bodies, green roofs *etc*. (Nuruzzaman, 2015).

4. Conclusion

The following conclusion can be drawn from the trend analysis of heat wave over Vidarbha:

(*i*) The number of days with heat wave has a positive trend for Nagpur, Buldhana, Wardha and Chandrapur. A very weak but positive trend exists for Akola, Amravati and Yavatmal.

(*ii*) The decadal variation of heat wave indicated a significant increasing trend for Nagpur, Buldhana, Wardha and Chandrapur.

(*iii*) The number of severe heat wave days shows a positive trend for Nagpur, Wardha and Chandrapur.

(*iv*) Mann Kendall test results show that, only Buldhana has an increasing trend that is statistically significant at 1% and 5% level, *i.e*. $P<0.01$ and $P<0.05$.

(*v*) The decadal variation of mean maximum temperature for four months implied that May month was the warmest during the last decade, 2011-2020, for all seven stations.

A meteorological analysis of special cases of heat wave events indicated mainly the presence of anticyclonic winds over Central India at 850 hpa levels, presence of a ridge line at 700 hpa and 500 hpa levels which lead to the warming over the surface. The positive geopotential height anomaly upto 500 hpa also substantiates the same.

Disclaimer: The contents and views expressed in this study are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

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