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Unprecedented hot weather diagnosis in India during March-April 2022

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सार – भारत के लिए दीर्घ अवधि के रिकॉर्ड तोड़ने वाले उच्च तापमान के मामले में मार्च और अप्रैल 2022 के महीने विशेष थे। यह अध्ययन उन विभिन्न मौसम संबंधी कारकों को समझाने का प्रयास करता है जिनके कारण 2022 के मार्च और अप्रैल के महीनों के दौरान अभूतपूर्व गर्म मौसम रहा। विश्लेषण में यह देखना दिलचस्प रहा कि उत्तरी ध्रुव में मार्च के महीने में उच्च सतह तापमान असंगति उन महत्वपूर्ण कारकों में से एक थी जिसने भारत के ऊपर उपोष्णकटिबंधीय पश्चिमी जेट प्रवाह की दक्षिण की ओर प्रगति में बाधा उत्पन्न की और भारतीय क्षेत्र से कम संख्या में पश्चिमी विक्षोभों का कारण बना। इसके अलावा, मध्य-क्षोभमंडल स्तर पर प्रतिचक्रवात परिसंचरण के कारण मध्य पाकिस्तान और आसपास के क्षेत्रों में गर्मी बढ़ गई, जिससे उत्तर-पश्चिमी पवनओं द्वारा तापमान संवहन के कारण भारतीय क्षेत्रों में तापमान अधिक बढ़ गया।

ABSTRACT. March and April 2022 months were peculiar with respect to the high temperatures breaking long-period records for India. This study attempts to explain the different causative meteorological factors that led to unprecedented hot weather during the March and April months of 2022. It is interestingly seen in the analysis that the high surface temperature anomaly for the month of March over the North Pole was one of the important factors that hindered the southward progression of the sub-tropical westerly jet stream over India and caused a lesser number of western disturbances to cross over the Indian region. Also, the anticyclonic circulation in the mid-tropospheric levels caused warming over central Pakistan and adjoining regions which caused the high temperatures over Indian regions due to temperature advection by northwesterly winds.

Key words – Hot weather, North pole warming, Western disturbances, Heat wave.

1. Introduction

Heat Waves (HW) are one ofthe major extreme weather events faced by humanity in the 21st century owing to climate change, global warming, and anthropogenic alterations of the environment. India being a highly populous country is at risk of greater impacts from these high-temperature events. The March 2022 maximum temperatures were the highest and minimum temperatures were the third highest in the last 122 years since 1901 (https://internal.imd.gov.in/press_release/20220402pr1551.pdf, https://mausam.imd.gov.in/Forecast/marqueedata/Statement_climate_of_india_2022_final.pdf, 10. Qin *et al*., 2003). For the month of April 2022, maximum temperatures were the third highest while minimum temperatures were the second highest in the last 122 years since 1901 (https://internal.imd.gov.in/press_release/20220519_pr_1634.pdf, Qin *et al*., 2003). March and April recorded all India mean temperature anomalies of +1.61 °C and +1.36 °C, which were 2nd highest since 1901(https://mausam.imd.gov.in/Forecast/marquee_data/Statement_climate_of_india_2022_final.pdf).

There have been various studies to document the causes and occurrences of HW events. However, the HW doesn't fail to surprise weather and climate enthusiasts with its novel characteristics and new extremes of its spatial and temporal extents year after year. The Indian hot weather season of 2022 was no exception with the starting two months (March-April) presenting the challenges of increased intensity and duration of heat waves impacting majorly northwest and central India. The March and April months of 2022 saw major HW events, particularly during the 11th - 21st March, 2022, 26th - 31st March, 2022, and 25th - 30th April, 2022. In this study, an attempt has been made to compare the characteristics of the current observed HW events with climatologically recorded HW events along with the causes and factors leading to this year's events.

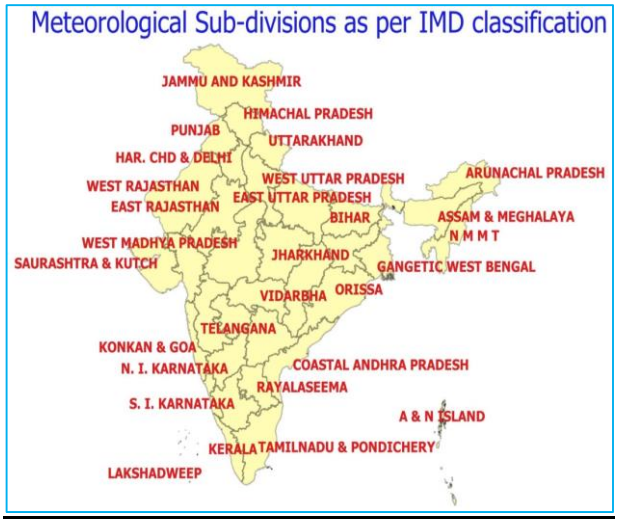

Fig. 1. Meteorological Sub-divisions classification as per IMD

2. Heat waves March-April 2022

In this study the HW days considered are defined based on the definition used by India Meteorological Department (IMD) in HWweather forecasting and is given below:-

"Heat wave is considered if maximum temperature of a station reaches at least 40 °C or more for Plains, at least 37 °C for Coastal region and at least 30 °C or more for Hilly regions. The heat Wave are defined as follows:

Based on Departure from Normal

(*i*) *Heat Wave* : Departure from normal is 4.5 °C to 6.4 °C

(*ii*) *Severe Heat Wave* : Departure from normal is >6.4 °C

Based on Actual Maximum Temperature

(*i*) *Heat Wave* : When actual maximum temperature ≥ 45 °C

(*ii*) *Severe Heat Wave* : When actual maximum temperature ≥47 °C

If above criteria met at least in 2 stations in a Meteorological sub-division for at least two consecutive days and it declared on the second day" (Bedekar *et al*., 1974; IMD, 2002).

The Indian region is divided into different meteorological subdivisions by India Meteorological Department for issuing the weather forecasts. The details of meteorological subdivisions are presented in Fig. 1. The number of observed HW days in the months of March and April 2022 in different subdivisions are shown in Figs. 2(a&b).

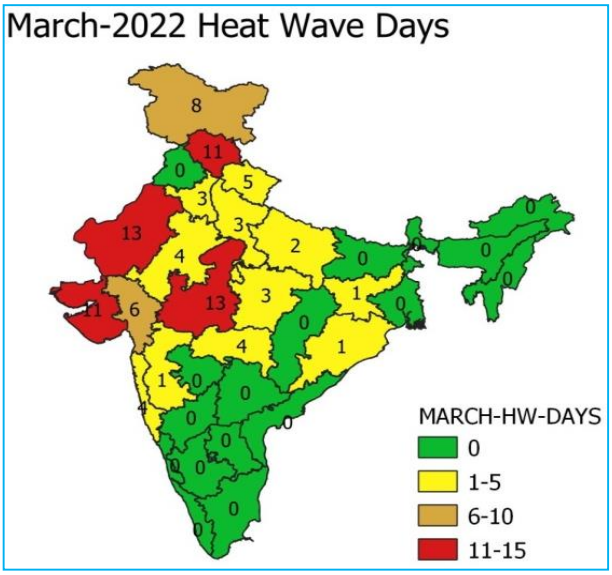

Fig. 2(a). Number of HW days observed in March 2022 as per IMD criteria

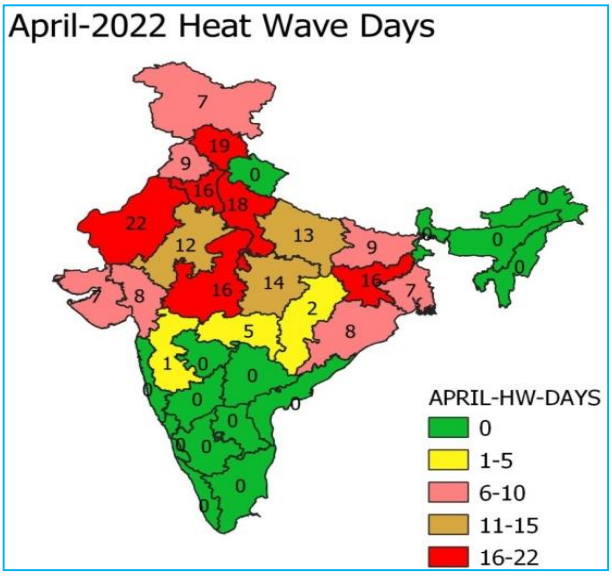

Fig. 2 (b). Number of HW days observed in April 2022 as per IMD criteria

March and April are typically characterized by a lower number of HW days compared to the other months in the hot weather season of India, which includes March, April, Mayand June.May and June months have the highest spatial coverage and average HW frequency (Pai *et al*., 2013). May is known to have the highest number of HW days across the country due to the sun's location in its

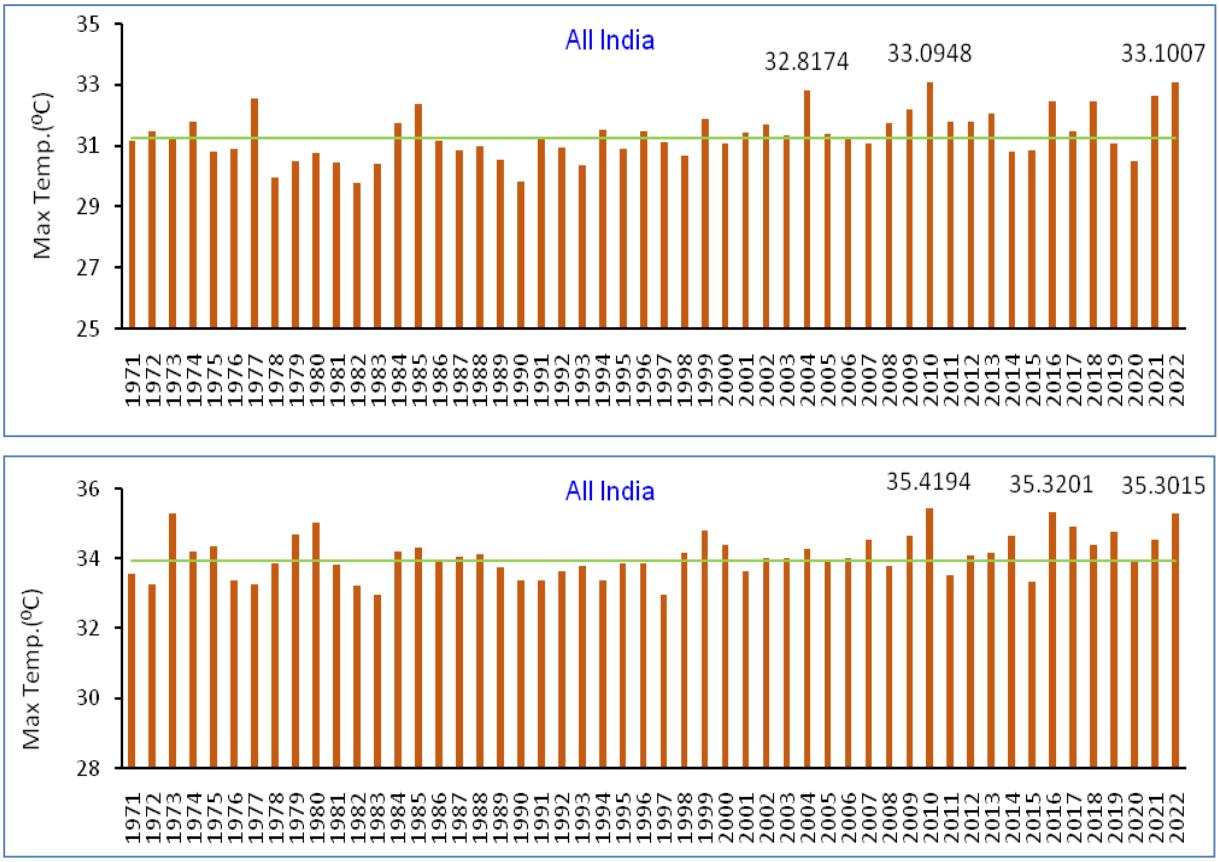

Fig. 3. Average Maximum Temperatures of March (Upper Panel) and April (Lower Panel) during past 122 years (reproduced from IMD Monthly reports (https://internal.imd.gov.in/pressrelease/20220402pr1551.pdf, https://internal.imd.gov.in/pressrelease/ 20220519pr1634.pdf)

northernmost latitudinal position, combined with clear skies and dry weather conditions (Pai *et al*., 2013). March and April months are typically associated with isolated HW events across the country because of the sun's annual northward movement (Pai *et al*., 2013). In March, heat waves were observed for 10-15 days in West Rajasthan, West Madhya Pradesh, Saurashtra and Kutch, and Himachal Pradesh, while 1 to 5 heat wave days were observed in the remaining parts of northwest and central India. This is higher than the normal range of 1 to 3 days for these regions. In the month of April, the number of heat wave days observed over major parts of northwest and central India was 10 to 20 days against the normal of 1 to 5 days. By the end of the April month about 70% of the country was affected by Heat Waves (https://mausam.imd.gov.in/Forecast/marqueedata/Statement climateofindia2022final.pdf).

Temperature-wise the present year stands at the top of the list when ranked with respect to the maximum temperatures across northwest India and central India. However, the temperatures as well as the heat wave spells were comparatively lesser over the south peninsular part of the country. Maximum temperatures were 40 °C to 45 °C over major parts of the plains of northwest India and central India in March and April 2022 (https://internal.imd.gov.in/press_release/20220402_pr_1551.pdf, https://internal.imd.gov.in/press_release/ 20220519pr1634.pdf). These temperatures were above normal by 5 °C - 7 °C over northwest and some parts of central India in March and some parts of northwest India in April. March recordedthe highest average maximum temperature in the last 122 years (1901-2022) while April recorded the third highest average maximum temperature in the last 122 years (https://internal.imd.gov.in/press_release/20220402pr1551.pdf, https://internal.imd.gov.in/pressrelease/ 20220519pr1634.pdf).

3. Causes & reasons for this heat wave and high temperatures events

There are many underlying mechanisms that contribute to the development of a heat wave. The main

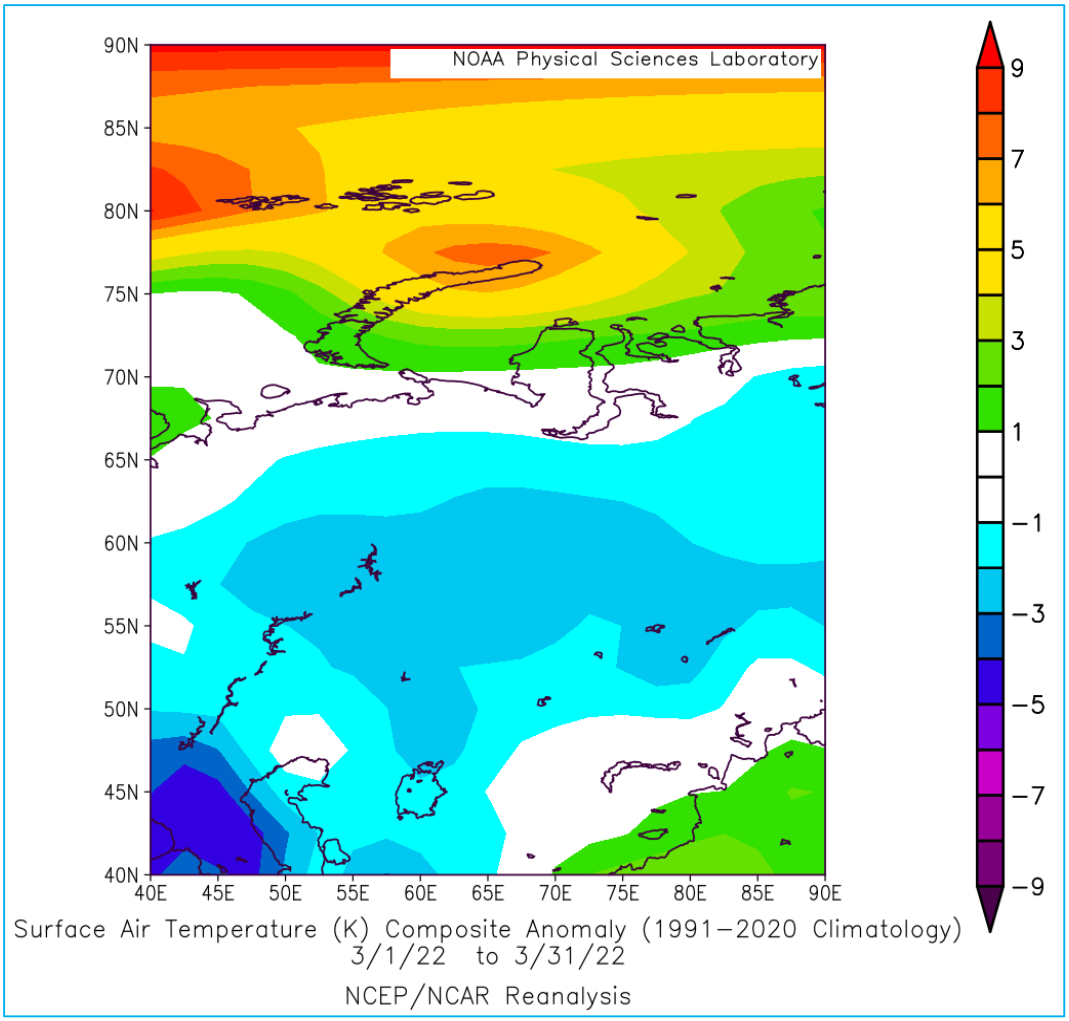

Fig. 4. Surface temperature composite Anomaly for March 2022 based on 1991-2020

meteorological factors which modulate the heat waves over the Indian subcontinent are the intensity and frequency of Western Disturbances impacting India, Anticyclone's persistence and intensity over northwest India along with the arctic waves generated due to temperature gradient between the poles (https://internal.imd.gov.in/section/nhac/dynamic/FAQheatwave.pdf). When a warm high-pressure system stalls in a region, it also leads to Heatwave events. The associated anti-cyclonic flow causes a sinking motion which leads to increased surface temperatures due to adiabatic compression thereby contributing increase in the temperatures. The associated outward anti-cyclonic flow also makes it difficult for other systems to enter the area and disturbs the process of increasing temperatures. Variations in the jet stream and the flow of air that steers movement of high and low-pressure areas which transports hot dry air into a region are also favorable conditions for the development of heat waves. These factors were evaluated for the current high-temperature events of March and April 2022.

Western Disturbances are in general the upper-level synoptic-scale systems, generally originating around the Mediterranean and Caspian Sea, embedded in the subtropical westerly jet stream (STWJ), propagates eastwards and are often associated with extreme rainfall events in north India and Pakistan. In the hot weather season, they are found to suppress the heat wave conditions in the northern parts of the country by bringing rainfall (non-monsoonal rainfall). The previous studies on statistical relationship between the Sub-tropical westerly jet position and Western Disturbances on inter-annual time-scales has shown that Western Disturbance frequency in north India is highly sensitive to the jet location over Eurasia (Hunt*et al*., 2018). The shift of Sub-

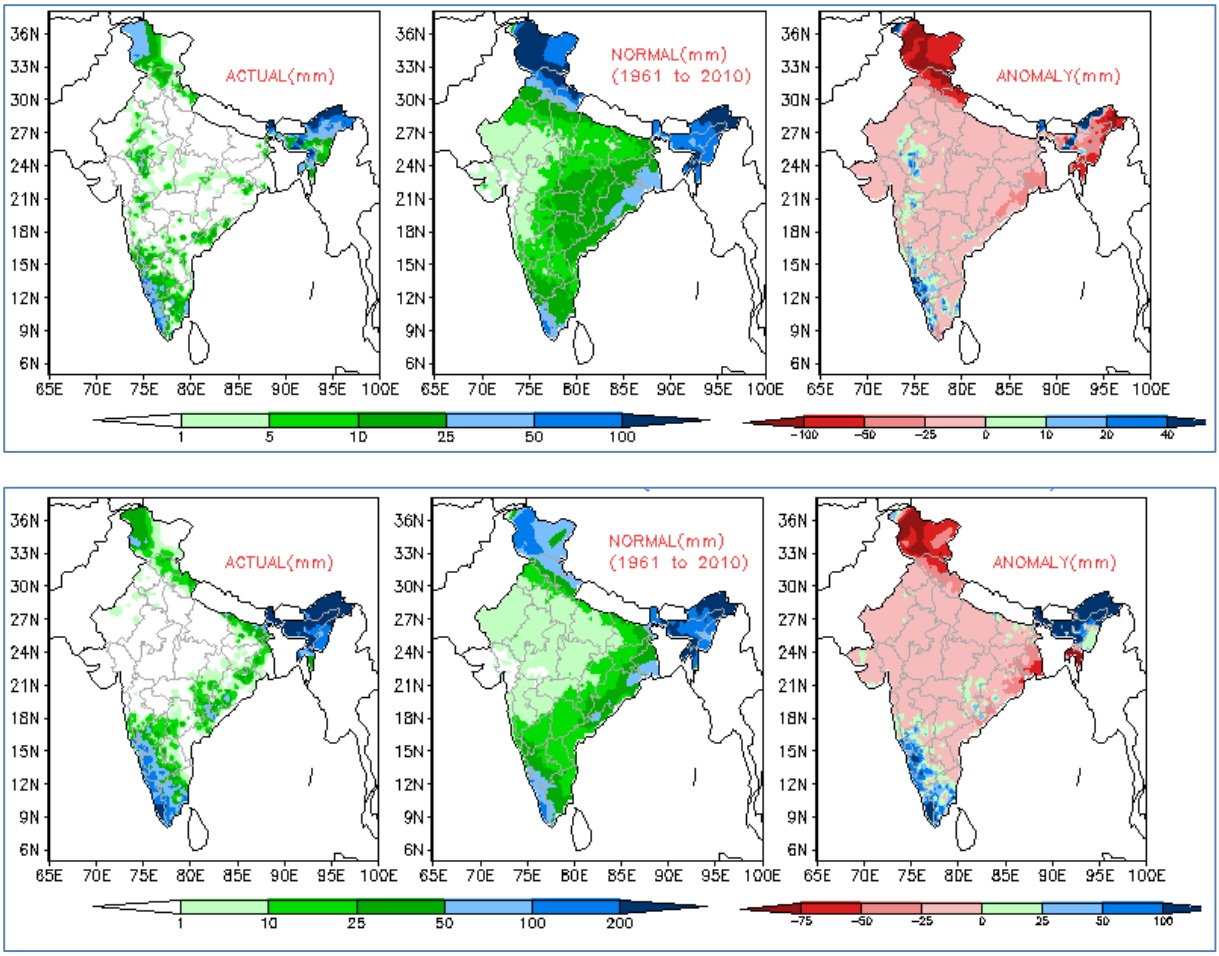

Fig. 5. Monthly Realized Rainfall Map for (a) March 2022 (Upper Panel) and (b) April 2022 (Lower Panel) [reproduced from IMD monthly reports (https://internal.imd.gov.in/press_release/20220402pr1551.pdf, https://internal.imd.gov.in/pressrelease /20220519 pr1634.pdf)]

tropical westerly jet is coherently seen towards south with the greater number of western disturbances (Hunt *et al.*, 2018).

This particular year 2022 saw very less rainfall realizing over northern parts of the country associated with the western disturbances. During March month, 5 feeble Western Disturbances and during April month 6 feeble Western Disturbances affected Indian regions (https://internal.imd.gov.in/pressrelease/20220402pr1551. pdf, https://internal.imd.gov.in/pressrelease/20220519pr 1634.pdf). The peculiar smaller number of feeble western disturbances can be attributed to the position of the Sub-tropical westerly jet which was mostly situated towards the north in the month of March 2022. This was largely due to the abnormal warming seen at the north pole during the month of March as shown in Fig. 4. The surface temperatures displayed 6-8 °C positive anomaly over northern most latitudes which hindered southward movement of Subtropical westerly jet streams and subsequently lead to less number of western disturbances over northern parts of India.

These feeble and lesser number of western disturbancesin general were dry and caused light rainfall/snowfall over Western Himalayan Region only and moved across higher ridges of Himalayas. Nearly there was no rainfall/thunderstorm over plains of northwest India and over central India in the month of March and gusty and Dust rising winds along with dry thunderstorm in some places of northwest India in April 2022. The observed rainfall was 88% below normal over Jammu & Kashmir, 95% below normal over Himachal Pradesh and 96% below normal over Uttarakhand in month of March 2022; whereas rainfall over Northwest India as a whole was 3rd lowest since 1901 in month of April 2022 (as shown in Fig. 5) (https://internal.imd.gov.in/pressrelease/20220402pr1551.

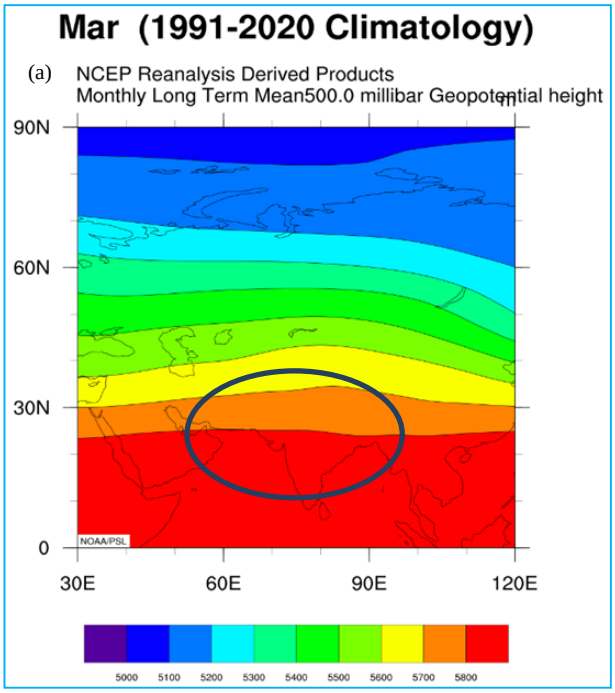

Fig. 6(a)

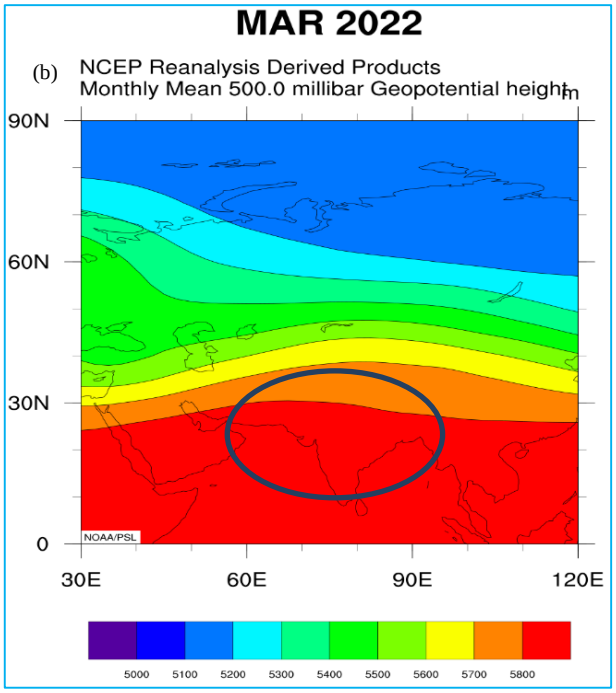

Fig. 6(b)

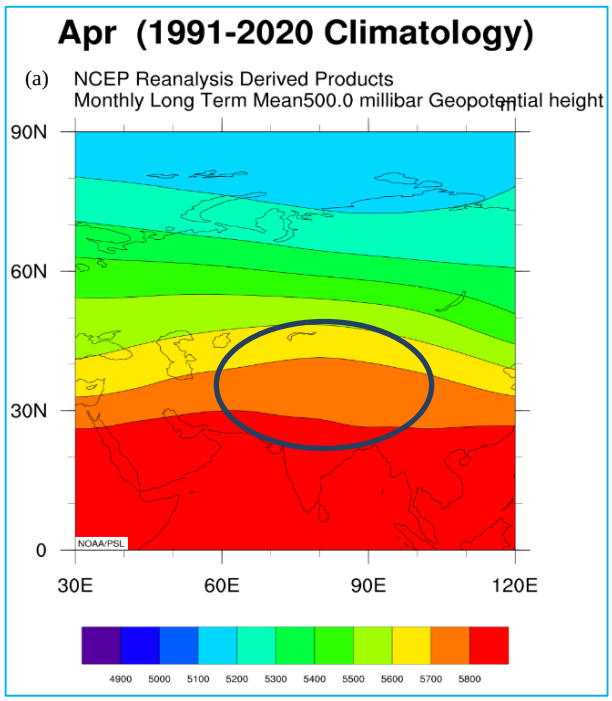

Fig. 7(a)

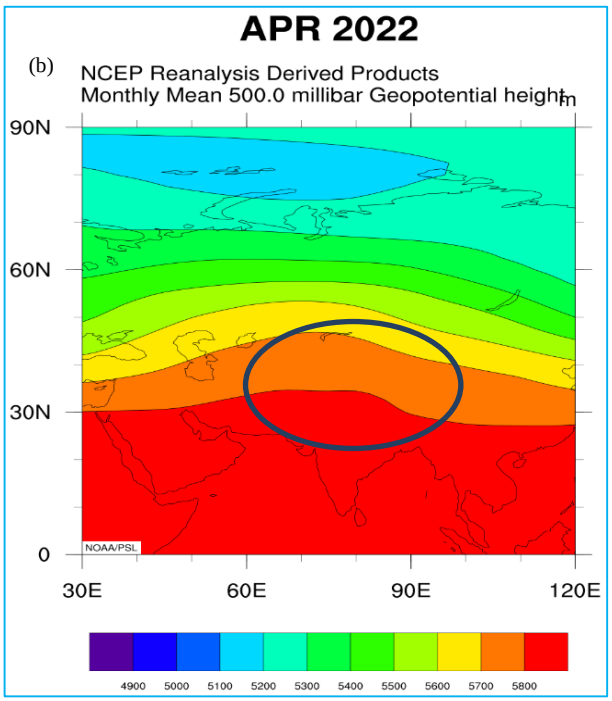

Fig. 7(b)

pdf, https://internal.imd.gov.in/pressrelease/20220519pr1634.pdf). Hence, there was no moisture in the upper atmosphere and region was practically cloudless allowing maximum insolation over northwest and adjoining areas, which created favorable environment for heat wave over the region.

Apart from the western disturbances not producing good rainfall over India there was other factor related to large amplitude anti-cyclonic flow over central Pakistan and adjoining region at middle tropospheric levels. The Figs. 6 (a&b) and 7(a&b) shows the 500 hPa Geopotential heights imageprovided by the NOAA/ESRL Physical Sciences Laboratory, Boulder Colorado from their Web site at http://psl.noaa.gov/ (Kalnay *et al*., 1996). These figures show the climatology of 500 hPa geopotential height based on 1991-2020 for months of March and April along with the monthly mean 500 hPa geopotential height for the months of March 2022 and April 2022. The Geopotential height is important for identifying location of troughs and ridges. The troughs and ridges are respectively associated with the relatively lower and higher geopotential heights. The geopotential heights also signify the average temperature of air below it. The density of air changes with temperature therefore, as air warms (cools) it becomes less (more) dense and thus becomes less (more) compact. This in turn leads to more (less) geopotential heights which relates to the ridge positions in the atmosphere. Therefore, ridges are regions with relatively higher geopotential heights and are associated with sinking air & warm air mass bringing drier weather.

The March and April months of 2022 were peculiar with respect to the ridge/anticyclone as seen when monthly mean 500 hPa geopotential height is compared with its long-term climatology. The Fig. 6(a) and Fig. 7(a) shows the climatology of monthly mean Geopotential height at 500 hPa for months of March and April respectively whereas, Fig. 6(b) and Fig. 7(b) shows corresponding monthly mean 500 hPa Geopotential heights from March and April months of 2022. It can be seen from the circled region in these figures that the mean Geopotential heights were relatively more over northwest parts of the country during 2022 as compared to climatology which related to sinking motion leading to warmer air temperatures during March and April months of 2022 as compared to their climatology. There was large amplitude anti-cyclonic flow over central Pakistan and adjoining regions at middle tropospheric levels.The temperature over central and south Pakistan was in the range of 43-45 °C and high temperature westerly/northwesterly winds outflow from this region towards northwest and adjoining India again produced the favorable factor for rising temperatures over northwest and adjoining parts of the country.

4. Conclusion

March and April 2022 were peculiar events in the recorded history with respect to temperatures and heat waves over India. Different meteorological factors coordinated the unprecedented high temperatures over the country. The major factor that propelled high temperatures over Indian region was due to lesser number and intensity of western disturbances as a result of high surface temperature anomaly over north pole region. This also shown how important is the polar region for weather in the topical/subtropical belts. Large amplitude anti-cyclonic flow over the central Pakistan & adjoining region at middle tropospheric levels and westerly/northwesterly winds comes from this region to northwest India & adjoining areas was another favourable factor for rising temperatures over northwest India and adjoining areas leading to the heat wave conditions during march and April 2022.

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

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