Know what climate change has done to heatwave in India: An explainer

India has been battling probably the worst heatwave in its history, with scorching day temperatures baking almost 15 states of the country during the past week. Series of heat waves in India and neighbouring Pakistan have made headlines globally for unprecedented temperatures. March has been recorded as the hottest in 122 years from 1901-2022. April was not far behind, with Northwest and Central India being the hottest in the same time period. Overall, it was the fourth hottest April the country has witnessed.

March recorded three days of heatwave against the normal of one day. Meanwhile, April registered 10 days of heatwave against the average of three days. It is not only the intensity of the heatwave but also its prolonged duration this season, which has tested the limits of human survivability and our preparedness. Several places recorded maximum day time temperatures in the range of 44-46°C for several consecutive days, while a few places even touched the 47°C mark.

Experts have already established the fact that both March and April are warming much faster [LB1] than core summer months of May and June. The long persistence of heatwave has highlighted global warming's cascading effect on the temperature profile across the country. Both the frequency and intensity have increased sharply over the last few decades.

Climate change is not only raising temperatures and making India's heatwaves hotter, but is also changing weather patterns that further drive dangerous heat extremes. Among the effects are that the cooling Western Disturbance is being disrupted, making anticyclones more dominant, Arctic heatwave and weird persistence of ENSO phases.

Western Disturbance (WD): These can be defined as storms that originate in the Caspian or Mediterranean Sea, bringing non-monsoonal rainfall to Northwest India and adjoining areas of Central India. In simpler words, **WDs drive the weather and govern the wind pattern over the region that includes both mountains and plains. In fact, they are very crucial in the summer season as they are known to suppress heat wave conditions in the Indo-Gangetic plains[LB2] .** WD infuses moisture laden winds over the landlocked northwest region. This further interacts with the humid easterly winds from Arabian Sea, triggering the formation of weather systems such as cyclonic circulations and trough, resulting in rain and thundershower activities.

However, **climate change has led to dynamic changes in the pattern of WDs. Although the frequency of Western Disturbances has increased, those have not translated to the precipitation associated with them**. According to **A P Dimri, Director, Indian Institute of Geomagnetism, Mumbai,** *"Global warming can be held responsible up to an extent. WDs are getting lighter by virtue of increasing heat, as it decreases the moisture content. Subsequently, these Western Disturbances are now moving across higher elevation due to heat and are reaching up to Karakoram range. Climate change has made some dynamic changes in the pattern of WD."*

In the last two months, the country witnessed only four WDs travelling through Western Himalayas between March and April. They were feeble in nature and thus, restricted their effect to mountains only. Northern plains recorded very light activity in terms of some passing showers and dust storms around the fag end of April that did not make any impact over the temperature profile.

Meanwhile, this prolonged dry spell paved the way for the continuous flow of hot north-westerly winds from arid regions in association with anticyclones. These hot winds blow unchecked across Northwest India and parts of Central India and also reach the eastern parts as well. These winds were already blowing from the much hotter region of Pakistan and adjoining Rajasthan, which led to record high temperatures.

Anticyclone: This weather phenomenon can be defined as large-scale circulation of winds around a central region of high atmospheric pressure. While a cyclone attracts the winds around it, anticyclone throws the winds in all directions as it rotates clockwise.

Formation of anticyclones was nothing abnormal as they usually develop over Northwest India during summers. However, **it is the longer persistence of these anticyclones that exaggerated the heatwave conditions in India. This is another indirect impact of changing climatic conditions.** This season, we saw anticyclones with their centre hovering around Rajasthan and adjoining Pakistan. Normally, these anticyclones move forward or dissipate with the arrival of Western Disturbance in the Western Himalayas that changes the wind pattern. But since, WDs were travelling in the upper latitudes, anticyclone extended their stays over the region spreading hot winds across Northwest and Central India.

"The anticyclone sent warm winds from north-west to central and western India for longer duration, causing as well as intensifying the heat waves. In absence of rains, the desert region was already witnessing high temperatures. Not to forget, that winds have been warmer than earlier on account of global warming, hence heat waves are more intense now. This makes Western Disturbances even of more importance for Northwest India, as only they can force anticyclone to dissipate or move further," [LB3] **said Mahesh Palawat, VP- Meteorology and Climate Change, Skymet Weather.**

Climate Change triggered Arctic Heatwave Impact on Heatwave in India:

Arctic heat waves have been breaking records this season, with the annually averaged Arctic near-surface air temperature increasing by 3.1°C from 1971–2019, which is three times faster than the global average. Recent findings include fresh increases in the frequency and/or intensity of rapid sea-ice loss events, melt events on the Greenland Ice Sheet, and wildfires. There has been an increase in extreme high temperatures and a decline in extreme cold events. Cold spells lasting more than 15 days have almost completely disappeared from the Arctic since 2000.

"Above normal temperatures across the Arctic region are a major cause of concern as it directly impacts the circulations affecting the Asia region. Warming in the Arctic region pushes air upwards leading to formation of low-pressure area, which attracts the circulations in the sub-polar region. This has been the case this season. The intensifying Arctic heatwave pulled up the weather systems including Western Disturbances northwards, making them travel in higher latitudes and thus, it did not affect the weather over India," ***added Palawat.***

Going by the rule book, WDs increase both in terms of intensity and frequency from October onwards. By this time, they also start travelling in lower latitudes, marking the onset of winter season. However, by March, their intensity starts declining gradually. By May, the frequency also drops and they start travelling in upper latitudes, limiting their major impact to higher regions of

Western Himalayas.[LB4] Thus, as reiterated above, WDs are very important for Northwest India, to suppress heatwaves during summer months. According to scientists and meteorologists, if the Arctic heatwave continues, we might see a greater number of hotter days quite early in the season, with their potential impact on WDs.

According to a report, "Arctic Climate Change Update 2021: Key Trends and Impacts', Arctic snow cover extent during the months of May through June declined by 21% from 1971 to 2019, with a larger decrease (25%) over Eurasia compared with North America (17%). Annual mean surface air temperatures in the Arctic will rise to 3.3–10°C above the 1985–2014 average by 2100, depending on the course of future emissions. Under most emission scenarios, the vast majority of weather models project the first instance of a largely sea-ice-free Arctic in September occurring before 2050. The probability of an ice-free Arctic summer is 10 times greater under a 2°C global warming scenario compared with a 1.5°C scenario.

La Niña: Last but not the least, the relation between ENSO (El Nino Southern Oscillation) and the heatwave cannot be ignored[LB5] . The IPCC WGI Report 'Climate Change 2021: The Physical Science Basis' had already warned that in the warming atmospheric conditions, the associated ENSO precipitation variability on regional scales is likely to intensify.

During a La Niña winter, a north-south pressure pattern sets up over India. The persistence of the La Niña pressure pattern into spring has been driving the unprecedented dust storm and heatwaves far south into the western coast of India**. The associated low pressure anomaly over the Indian subcontinent has been inviting westerly winds and the blast of hot air from the Middle East into Pakistan and India. The La Niña pressure pattern has been splitting the hot air over the Arabian Sea south into western India and north into Pakistan and northern India.**

The La Niña is usually associated with intense winters and wet Monsoon in India. During La Niña, sea surface temperatures become cooler than average across the Tropical Pacific. This sea surface temperature anomaly alters the trade winds flowing over the ocean surface through change in wind stress, leading to strange summer weather around the world.

While La Niña was earlier predicted to crash by the spring of 2022, but it is far away from this. Sea Surface temperatures continue to be well below normal in the Tropical Pacific. This has aided La Nina to survive through the spring season and rather extend far into 2022 till Monsoon arrival. The ongoing episode of La Nina had begun with Monsoon 2020 and is still holding the fort. According to latest predictions, a mild drop in the temperatures is expected during July-August 2022. According to meteorologists, La Nina has defied its crash as cold-water layers seem to be more stable than before, therefore delaying the expected warming of the ocean.

"The north-south pressure pattern has been persisting over India, with La Nina extending its stay over the Pacific. This has definitely impacted the weather over India, which has been seen even during 1998-2000 when La Nina had persisted for three years. We did see some strange weather activities this year as well which include dust storm over Mumbai, early deep depressions out of which one even became feeble cyclone and the heatwaves are all part of this weird and extended persistence of La Nina," said **Raghu Murtugudde, Professor, department of atmospheric and oceanic science, University of Maryland.**

According to the Ministry of Earth Sciences report, 'Assessment of Climate Change over the Indian Region', all India averaged frequency of summer heatwaves will increase to about 2.5 events per season by the mid-21st century (2040–2069), with a further slight rise to about 3.0 events by the end-21st century (2070–2099) under the medium (RCP4.5) emission scenario. The average total duration of summer heatwaves is projected to increase to about 15 and 18 days per season during the mid- and end-twenty-first century respectively under this future scenario.

Representative Concentration Pathway (RCP) 4.5 is a scenario of long-term, global emissions of greenhouse gases, short-lived species, and land-use-land cover which stabilises radiative forcing at 4.5 Watts per meter squared (W m2, approximately 650 ppm CO2-equivalent) in the year 2100 without ever exceeding that value.

Worse is in store for southern India, which is currently not influenced by heatwaves, and is expected to be severely affected by the end of the twenty-first century. In near future more frequent and long-lasting heatwave events are projected to affect the Indian sub-continent in response to the warming of the tropical Indian Ocean and the increasing frequency of extreme El Nino events.

With all these parameters interlinked, as the recently released IPCC WG2 Report 'Climate Change 2022: Impacts, Adaptation and Vulnerability' warned, we are moving to tougher times ahead as heat waves will continue to become more frequent, harsher and prolonged.