Rising Heat and Shifting Western Disturbances Fuel Extreme Weather in Himalayas

Following heavy rains and thunderstorms, flash floods and landslides wreaked havoc in several parts of Jammu and Kashmir last week. Parts of Himachal Pradesh and Uttarakhand also recorded heavy rains, triggering flash flooding and landslides earlier in the month.

According to meteorologists, the passage of back-to-back Western Disturbances (WD) has led to heavy rainfall spells across the hilly states.On the other hand, the arrival of these systems at a regular interval has kept prolonged heat waves away from the northwestern plains so far.

"Heatwave has made on and off appearance over the northwestern plains as an increased frequency of western disturbances has been affecting the flow of dry and hot northwesterly winds. These warmer winds are replaced with easterly winds, which are comparatively cooler and thus bring temperatures down. Parts of Central and West India, too, have not seen prolonged heatwave spells in the season so far, " **said Mahesh Palawat, Vice President - Meteorology and Climate Change, Skymet Weather.**

A rise in the frequency of western disturbances has made the Himalayan states more vulnerable to extreme weather events, directly linked to climate change.

"After remaining insignificant till January, Western Disturbances picked up frequency from late January onwards and have been affecting Western Himalayas at regular intervals. The influence of Western Disturbances has been growing significantly over Jammu and Kashmir, Himachal Pradesh and Uttarakhand. They have been dumping more rainfall over the Himalayan region, which is directly related to climate change," said **Dr K J Ramesh, Former Director General of Meteorology, India Meteorological Department.**

Western disturbances are storms that predominantly affect North India and Pakistan during winters. These weather systems are embedded within the subtropical westerly jet that lies over the Indian region.

Western Disturbances travel across the year but in different latitudes. They travel in lower latitudes during Winters bringing significant amounts of rain and snow over North India. Meanwhile, in Summers, these weather systems tend to travel in higher latitudes, confining snow and rainfall activities to the higher reaches of the region.

He further explained how rising global temperatures are instrumental in amplifying the extreme weather events led by *Western Disturbances*.

"Global warming has led to rapid warming of the Arabian Sea, which then emits more moisture northwards. Now, when the amplitude of Western Disturbances extends up to the North Arabian Sea, more moisture is fed into the system, resulting in intense weather activity over the hills," Dr Ramesh said. "If we see, snow water equivalent anomaly, there is the presence of unusual snowfall. In a large sense, their weather patterns this year show a different trend."

Snow water equivalent is the depth of water that would cover the ground if the snow cover was in a liquid state. The following pictures show the accumulation of snow in blue patches over the Himalayan region in December (24-12-2024) and April (15-04-2025).

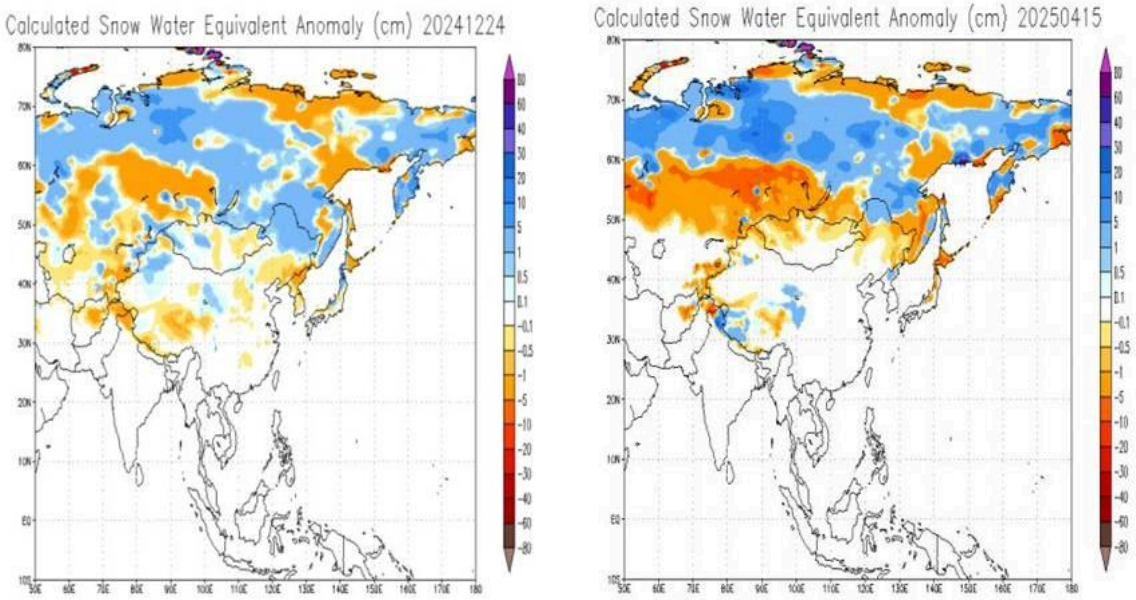


Image Courtesy: NOAA

Scientists have warned against an increasing erratic trend in Western Disturbances amid global warming. **Professor A P Dimri, Director, Indian Institute of Geomagnetism** said increasing heat stress has also altered characteristics of Western Disturbancess and continues to do so if the global temperatures continue to rise. *"Growing evidence shows that Western Disturbances are impacting weather outside the winter season, leading to extreme precipitation events. There is no doubt that increasing heat stress is the basis of everything, as it is generating more energy and at the same time pushing moisture upwards."*

Role of Climate Change in altering dynamics of Western Disturbances

Western Disturbances govern the weather patterns over Northwest India throughout the year, with prime significance during the winter and spring months. They account for 15% of annual precipitation. As the climate warms, we expect changes to Western Disturbance dynamics – as warming in the upper-tropospheric of the atmosphere modifies strong winds known as the subtropical jet in which these Western Disturbances are embedded. Also, warmer near-surface conditions modify atmospheric stability and increase moisture content, which in turn changes the behaviour of the western disturbances.

According to latest research, higher elevations are very likely to receive significantly more precipitation in a warmer climate, with insignificant drying in the foothills and increased rainfall over the northern Indian and Pakistani plains. There was also a shift in precipitation seasonality, with peak snowfall moving from the month of February to March by the end of the 21st century. These trends are attributed to changes in Western Disturbance frequency.

Based on increasing variability in the Western Disturbances, following are the three big changes identified by the climate scientists recently:

a) **The subtropical westerly jet (SWJ) has widened because of climate change**.
SWJ is a jet stream that prevails near the Himalayan and Tibetan highlands in the middle-latitudes in the upper levels of the atmosphere. Western Disturbances travel eastward embedded in the SWJ stream which exists over the Indian region in Northern Hemisphere Winters at 200 hPa (hectopascals) – a pressure level in the atmosphere which corresponds to the upper troposphere at an altitude of around 12 km (roughly 39,000 feet) . Broadening of SWJ provides a wider area to Western Disturbances and allows them to travel in different directions.

"Western Disturbances will now have more meridional oscillations, which means that they can now travel to the north boundary as well as to the south boundary of the jet. Earlier, there was not enough space for such oscillation in comparison to the present situation. They are also getting uplifted and are now reaching up to Karakoram range bringing more snowfall there," **said Professor Dimri.**

A research paper 'Western disturbances and climate variability: Review of recent developments' cited high confidence (robust evidence, medium agreement) that climate change will cause winter precipitation to increase over the western Himalaya but decrease in the foothills. There is very high confidence that climate change will cause the ratio of snowfall to rainfall across the region in winter to decrease. Snowfall will tend to decline at the expense of increasing rainfall across the foothills but will tend to increase over the Karakoram and Tibetan Plateau. Glaciated regions like much of the Karakoram are projected to witness increase in snowfall. True to this, same regions are experiencing anomalous glacier growth in the present climate.

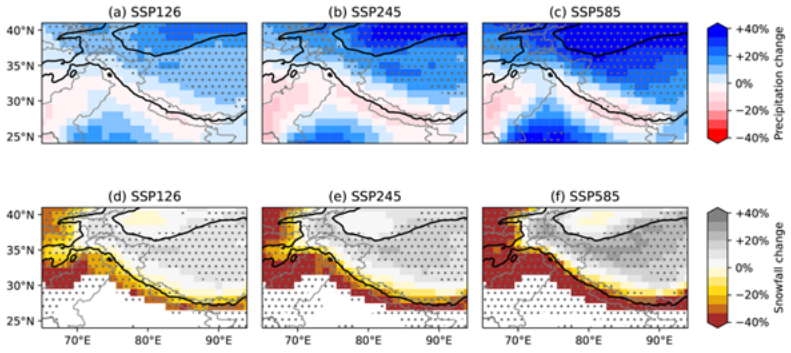
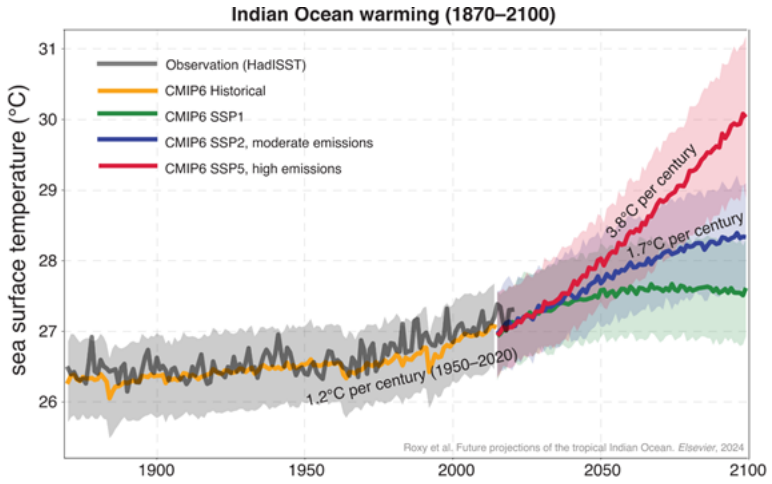


Figure 25. Projected change in winter (DJFM) precipitation **(a–c)** and snowfall **(d–f)** from the current climate (1960–2000) to the end of the century (2060–2100) as a function of emissions scenario. Computed using 37 CMIP6 models, each regridded to 1° × 1°. Stippling indicates where at least two-thirds of the models agree on the sign of change. The 2500 m surface-elevation contour is denoted with a thick black line.

b) **Split in the track of Western Disturbances:** With more space available for oscillation, Western Disturbances are now able to split their track. While Western Disturbances that are propagating northwards over high Asian mountains provide precipitation over North Jammu and Kashmir, Western Disturbances tracking south bring more rain and snow over the foothills of the Himalayas.

c) **All Western Disturbances do not precipitate, and rains are also recorded on the non-Western Disturbance days:** There has been an increasing trend in the variability of short-duration heavy rainfall events over northwest India, which is partially attributed to Western Disturbances. The overall increase in precipitation in the region can be attributed to the strengthening of subtropical jet and increased southerly moisture flux over the Arabian Sea. Once they reach over the Indian region, Western Disturbances draw their moisture feed from the Arabian Sea. Secondly, it has been seen that rains are also recorded during the non-Western Disturbance days. During this time, we see moisture incursion from the Bay of Bengal.

According to a recent study, while the Indian Ocean warmed at a rate of 1.2°C per century during 1950–2020, climate models predict accelerated warming, at a rate of 1.7°C–3.8°C per century during 2020–2100. Though the warming is basin-wide, maximum warming is in the northwestern Indian Ocean including the Arabian Sea.



"The traditional dynamics of Western Disturbances are undergoing a profound shift due to climate change. This year-round moisture feed is making the Himalayas increasingly vulnerable to extreme weather events like flash floods and heavy snowfall. What we're witnessing is the blurring of seasonal boundaries and a restructuring of atmospheric behavior. These aren't isolated anomalies — they're signals of a changing climate that is re-engineering India's weather systems. Policymakers, disaster authorities, and communities must adapt swiftly to this new normal," said **Prof Anjal Prakash, Clinical Associate Professor (Research) and Research Director, Bharti Institute of Public Policy.**

"With climate models being able to detect the track of Western Disturbances, it becomes very important for monitoring authorities to include these climate models in the forecast which will be able to predict the region that is likely to receive substantial rainfall. This can help us limit the damage and timely preparedness for the extreme weather event," **said Professor Dimri.**

According to the IPCC's (Intergovernmental Panel on Climate Change) 6th Assessment Cycle's Working Group 1 report, most of the Hindu Kush Himalayan region's snow cover has reduced since the early 21st century, and glaciers have retreated and lost mass since the 1970s. The Karakoram glaciers have remained either in a balanced state or slightly gained mass. During the 21st century, snow-covered areas and snow volumes will decrease in most of the Hindu Kush Himalayas and snow line elevations will rise as glacier volumes will decline (high confidence). A general wetting across the

whole Tibetan Plateau and the Himalayas is projected, with increases in heavy precipitation in the 21st century.

Western Disturbances play a critical role in winter precipitation, providing water and food security across the region**.** The snow they bring sustains reservoirs through spring melt, providing essential irrigation for rabi crops like barley and wheat—staples for food security in the subcontinent. This meltwater also helps bridge the dry pre-monsoon months of May and June. Additionally, late-season Western Disturbances can affect kharif crops such as rice and maize, influencing agricultural outcomes. Over longer timescales, they are essential for maintaining glacier mass balance in a region noted for its unusual glacial stability. Consequently, Western Disturbances have both direct and indirect economic impacts in India, as they are increasingly expected to affect agricultural output and aviation planning.

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