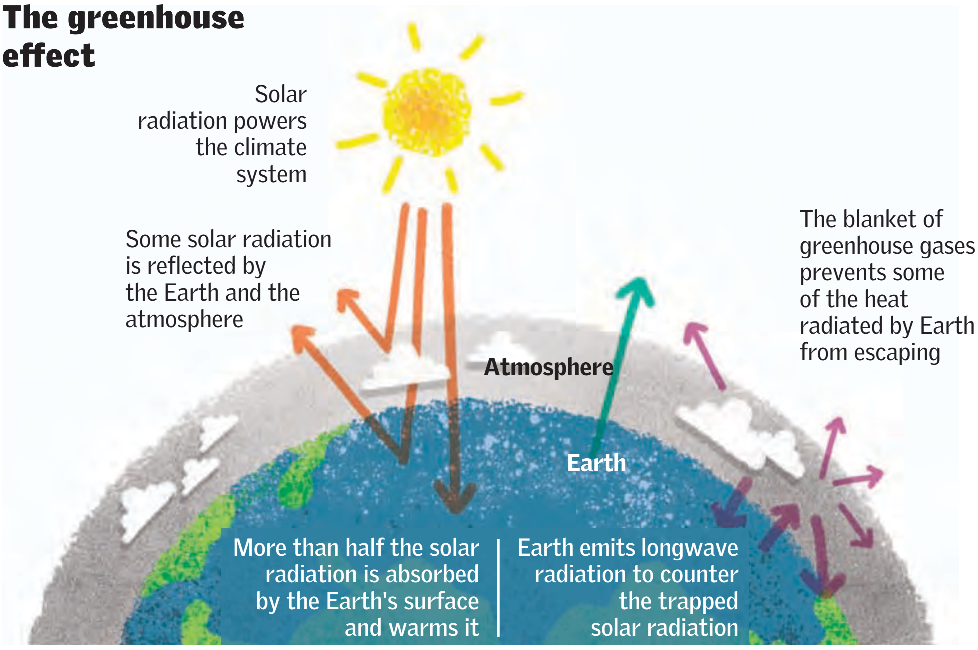
WHAT IS CLIMATE CHANGE?

Climate change has emerged as the biggest developmental challenge today. Climate deniers have had to eat humble pie in the face of mounting scientific evidence. In the last 100 years, the Earth has become hotter by 1°C. A warming world has played havoc with global climate systems causing unprecedented extreme weather events —droughts, floods, cyclones, dust storms, crop loss and triggering new diseases. Significantly, people living in poor and developing countries are the worst affected as they do not have the capacities to grapple or cope with the changes.

There are many definitions of climate change. According to the United Nations Framework Convention on Climate Change (UNFCCC), an international treaty adopted in 1992: "Climate change is a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The Intergovernmental Panel on Climate Change (IPCC), a body of scientists set up by the World Meteorological Organization and the United Nations Environment Programme (UNEP), defines climate change as "a change in the state of the climate that can be identified (for example, by using statistical tests) by changes in the mean and/or variability of its properties, and that persists for an extended period, typically decades or longer".

The greenhouse effect



Source: Le Treut et al 2007, 'Historical overview of climate change', Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, p 115

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In its Fourth Assessment Report in 2007, IPCC says, "Climate change may be due to internal processes and/or external forcings. Some external influences, such as changes in solar radiation and volcanism, occur naturally and contribute to the total natural variability of the climate system. Other external changes, such as the change in composition of the atmosphere that began with the industrial revolution, are the result of human activity."

Though the Earth has been warming, or cooling through the ages, scientific evidence suggests that the present heating is due to human activities—the burning of fossil fuels and deforestation among others. Scientists have documented three warming periods, the Holocene thermal maximum, which occurred 5,000 to 9,000 years ago; the last interglacial, which occurred 116,000 to 129,000 years ago; and, the mid-Pliocene warm period, which occurred 3 to 3.3 million years ago (see '*Lecture #1*', *p*16).

In the case of the first two periods, the climate changes were caused by changes in the Earth's orbit. The mid-Pliocene event was the result of atmospheric carbon dioxide (CO_2) concentrations that were at similar levels to what they are today. But in each period, the planet had warmed at a much slower rate than it is warming today, as a result of rising greenhouse gas (GHG) emissions caused by humans.

Consider these tipping points: CO_2 levels in the air are at their highest in 650,000 years—409.33 parts per million (ppm) as of October 2018, says the US National Oceanic and Atmospheric Administration (NOAA) (see graph '*Rise in CO_2 level*', *p*12); 17 of the 18 warmest years in recorded history have occurred since 2001; in 2012, Arctic summer sea ice shrunk to its lowest on record; satellite data show that the Earth's polar ice sheets are losing mass; and, global average sea level has risen nearly 10-25 cm over the past 100 years, says the Second Assessment Report of the IPCC.

CLIMATE SYSTEM

The Earth's climate system is a complex, interactive system consisting of the atmosphere, land surface, snow and ice, oceans and other bodies of water, and living things (see '*The Greenhouse Effect*' on *p*10). The atmospheric component of the climate system most obviously characterises climate; hence climate is generally defined as "average weather".

As such, climate change and weather are intertwined. Observations can show there have been changes in weather, and it is the statistics of changes in weather over time that identify climate change. The climate system evolves in time under the influence of its own internal dynamics. It can also evolve due to changes in external factors that affect climate—these factors are called "forcings". External forcing includes natural phenomena, such as volcanic eruptions and solar variations, as well as human-induced changes in the chemical composition of the atmosphere.

So how does the Earth balance these energy fluctuations in the atmosphere? Radiative energy from the Sun powers the climate system. About 30 per cent of the sunlight that reaches the top of the atmosphere is reflected back to space. Roughly two-thirds of this reflection are due to clouds and small particles in the atmosphere known as “aerosols”. Light-coloured areas of the Earth’s surface—mainly snow, ice and deserts—reflect the remaining sunlight.

The energy not reflected back to space is absorbed by the Earth’s surface and atmosphere, and amounts to approximately 240 Watts per square metre (W/sq m). To balance the incoming energy, the Earth itself must radiate, on average, the same amount of energy back to space. The Earth does this by emitting outgoing long wave radiation. Everything on Earth emits long wave radiation continuously. The warmer an object, the more heat energy it radiates.

To emit 240 W/sq m, a surface would have to have a temperature of –19°C. This is much colder than actual conditions at the Earth’s surface. The requisite –19°C is found about 5 km above the surface. This is where the greenhouse effect comes into play.

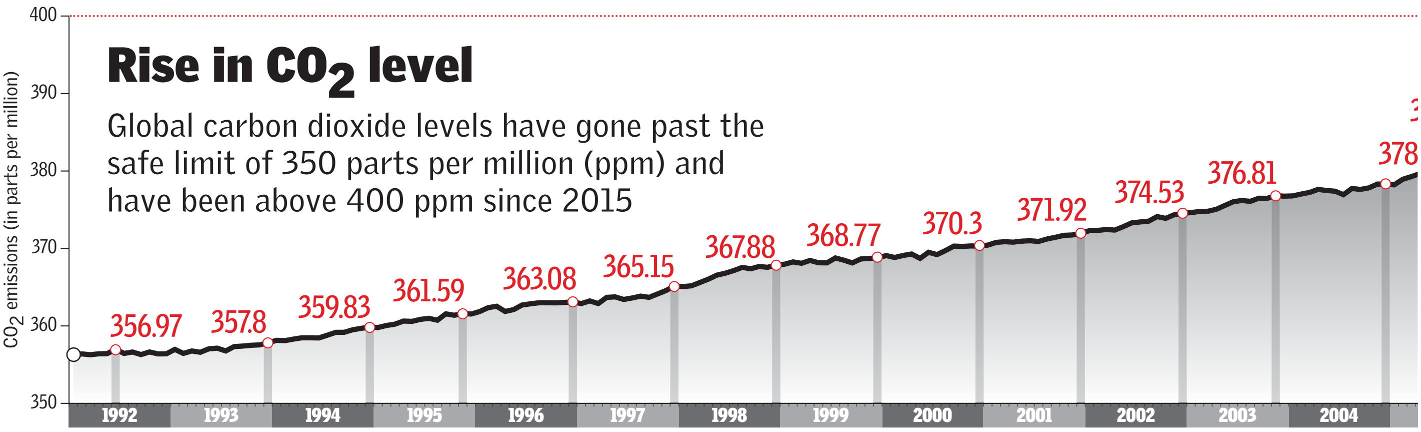
The global mean surface temperature of Earth is about 14°C. This is due to the presence of gases, known as greenhouse gases (GHG), which act as a partial blanket for the long wave radiation coming from the surface. This blanketing is known as the natural greenhouse effect.

The glass walls in a garden greenhouse reduce airflow and increase the temperature of the air inside. Analogously, but through a different physical process, the Earth’s greenhouse effect warms the surface of the planet. Without the natural greenhouse effect, the average temperature at Earth’s surface would be below the freezing point of water. Thus, Earth’s natural greenhouse effect makes life as we know it possible.

The natural GHG effect exists only in theory. While many factors continue to influence climate, scientists are now quite clear that human activities have become the dominant force, and are responsible for most of the warming observed over the past 50 years.

Human activities contribute to climate change by causing changes in Earth’s atmosphere in the amounts of GHGs, aerosols (small particles), and cloudiness. The largest known contribution to the enhanced GHG effect comes from the burning of fossil fuels, which releases CO_2 gas to the atmosphere.

There are about 61 gases, most of them human-invented, which can alter the balance of the atmosphere. The concentration of 19 such gases is controlled by



Rise in CO_2 level

Global carbon dioxide levels have gone past the safe limit of 350 parts per million (ppm) and have been above 400 ppm since 2015

Source: EM-DAT, CRED; NASA; UNFCCC

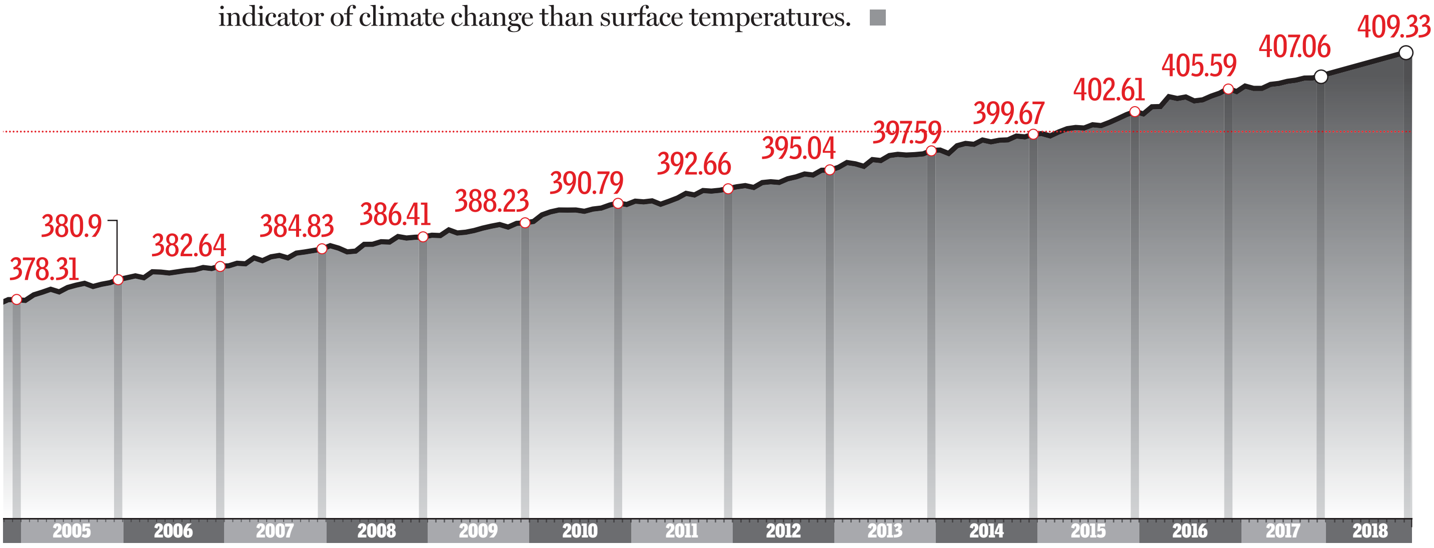
the Montreal Protocol, a global treaty to ban substances that deplete the ozone layer that the world adopted in 1987. Many other gases have so far escaped regulation because their abundance, or lifetime, in the atmosphere is too miniscule, or little.

The 1997 Kyoto Protocol of UNFCCC focuses on GHG not regulated under the Montreal Protocol. Among them are CO_2, methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCS), perfluorocarbons (PFCS) and sulphur hexafluoride (SF_6).

The most abundant and important GHG in the atmosphere is water vapour (H_2O). Theoretically, human activities have only a small direct influence on the amount of atmospheric water vapour. But such activities—say, burning fossil fuels—have huge potential to indirectly affect water vapour concentrations, by changing the concentration and abundance of the principal GHGs.

A warmer atmosphere contains more water vapour, creating conditions for further warming. GHGs accumulate in the atmosphere, causing concentrations to increase with time (see '*The greenhouse effect*', *p*10). Global Warming Potential or GWP is a metric, or a standard of measurement, used to put a quantifiable figure to the impact of a GHG on climate change. It is not a stand-alone measure (say, parts per million or gigatonne). Implicit to this metric is a comparison with other gases with respect to their (relative) impact on climate forcing (see '*Lecture #1*', *p*16).

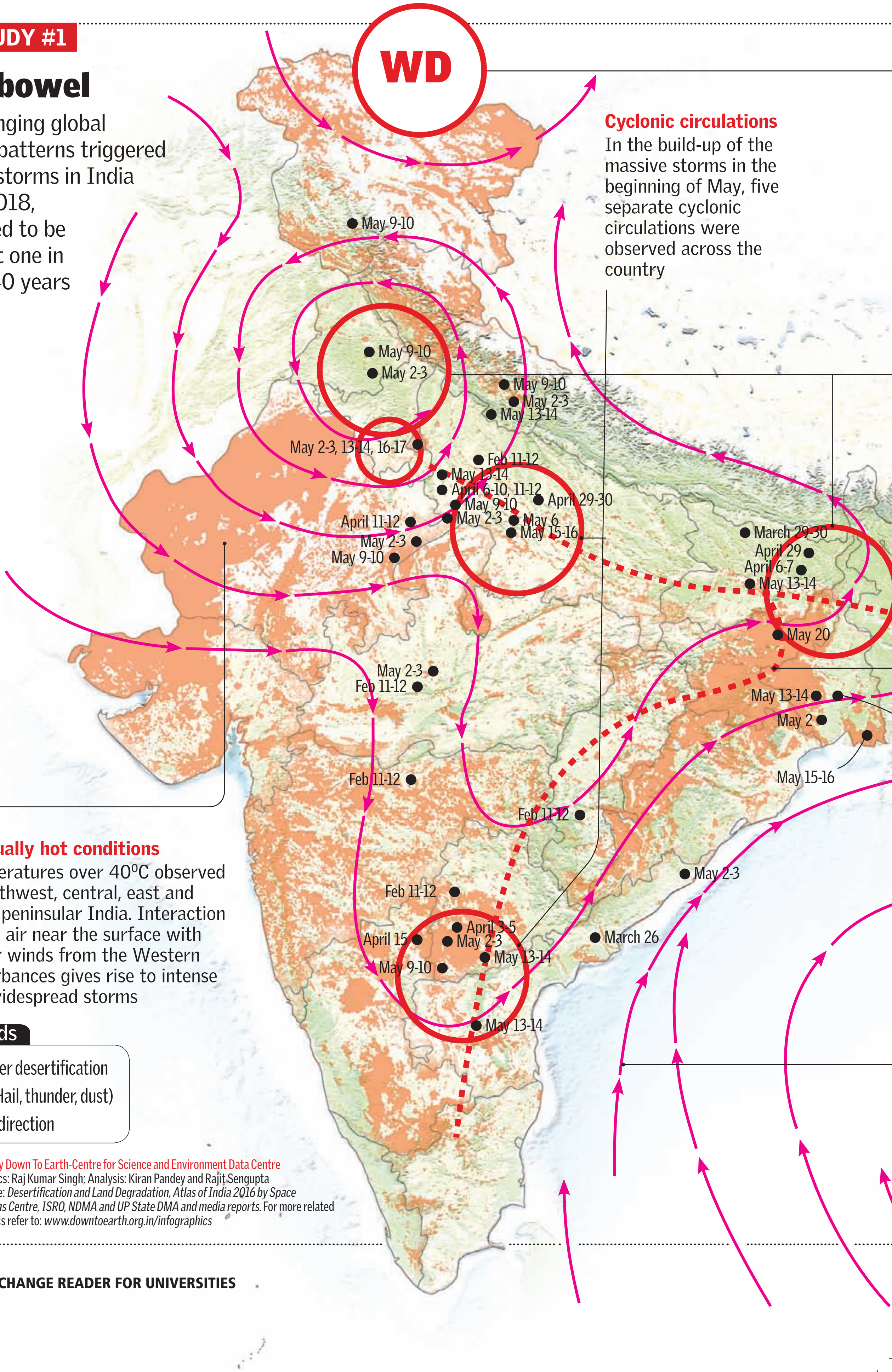
In fact, the 20 warmest years on record have occurred in the last 22 years. This trend also sits in perfectly with the emission rates of greenhouse gases (GHGS) which were at a record high in 2018, according to the World Meteorological Organisation (WMO). Another major indicator of the warming trend due to climate change is ocean heat content (OHC). The year 2018 recorded a new high in terms of OHC since observations began in 1940. There is more heat stored in the Earth's oceans today than at any time in the last 78 years. When GHGS trap heat in the atmosphere some of it gets converted into surface temperature but 90 per cent of it gets assimilated into the oceans. Therefore OHC is a much better indicator of climate change than surface temperatures. ■



CASE STUDY #1

Dust bowel

How changing global weather patterns triggered the dust storms in India in May 2018, considered to be the worst one in the last 40 years



Cyclonic circulations

In the build-up of the massive storms in the beginning of May, five separate cyclonic circulations were observed across the country

Unusually hot conditions

Temperatures over 40^{0}C observed in northwest, central, east and north peninsular India. Interaction of hot air near the surface with colder winds from the Western Disturbances gives rise to intense and widespread storms

Prepared by Down To Earth-Centre for Science and Environment Data Centre
Infographics: Raj Kumar Singh; Analysis: Kiran Pandey and Rajit Sengupta
Data source: *Desertification and Land Degradation, Atlas of India 2016 by Space Applications Centre, ISRO, NDMA and UP State DMA and media reports.* For more related infographics refer to: *www.downtoearth.org.in/infographics*

Western Disturbances

While Western Disturbances (WDs) normally peak between December and February, a greater number of active WDs have been observed in spring and summer months. Instead of the normal 2-3 active WDs seen during the months of April and May, over the past month and a half, at least 10 separate active WDs have been observed. WDs carry high velocity winds that agitate the atmosphere and aggravate storm conditions

Trough

A trough is an extended area of low pressure developed along the East-West axis. This where moisture-laden winds from the Bay of Bengal met hot and dry air from central and western India. These winds also came in contact with the cold front that develops due to active WDs. The confluence of these different winds culminated in intense and widespread storms across the Indo-Gangetic plain. Similarly a North-South trough was formed from Bihar to northern Tamil Nadu, along which stormy weather was observed in Telangana, Andhra Pradesh and some parts of Karnataka

Easterly winds

Winds from the Bay of Bengal carry moisture and are associated with pre-monsoon thunder storms in the eastern coast. Moving towards the troughs, these winds provided the moisture that further intensified the convective storms

Between February and May in 2018, India witnessed an unprecedented storm season—more than 44 storms in 16 states. This brings out the linkages of geographically distant events related to climate change. "Climatologically, these storms were anything but typical. Initial analyses have revealed several reasons for the stormy weather, including the activity of the Western Disturbances (WDs), the low pressure over the Indo-Gangetic plains and the intense heating in west and northwest India," said M Mohapatra of the India Meteorological Department (IMD), New Delhi.

As the Arctic warms, the difference in temperature between the Arctic and the equator has reduced, particularly during recent winters which have seen highly anomalous heating around the North Pole. A warmer Arctic has been correlated to the extended winters punctuated with blasts of frigid weather in the northern hemisphere. The weakening temperature gradient is, in fact, causing the jet streams to meander rather than take a straight course which, in turn, affects the seasonality and movement of the WDs. Additionally, steep increases in temperatures in the Western Himalayan region and the Tibetan Plateau have been linked to a further destabilisation of climatic patterns in the region. Western Himalayas and the Tibetan Plateau are considered to play a crucial role in maintaining the hydrological and weather cycles over the Indian subcontinent. Rapid warming, which has caused temperatures to increase by up to 3.5°C since 1951, have been linked with increased variability in the distribution and direction of WDs and associated precipitation.

There are clear indications of how the general trend of warming is exacerbating stormy weather during the pre-monsoon season. The general physics behind storms unequivocally points at a higher incidence and intensity. A review of the EM-DAT Disaster Database that compiles information regarding disasters the world over reveals a worrying trend. One has to go back 40 years to see the last time convective storms during this season caused comparative loss of life. In 1978, storms in March and April across North and East India caused the deaths of over 600 people. But large-scale convective storms in the pre-monsoon season were few and far between. Between 1980 and 2003, just nine deadly convective storms were recorded in India in the March-May period. However, a steep increase has been observed in the last 15 years. Between 2003 and 2017, 22 such storms were observed over the Indian region accounting for nearly 700 fatalities compared to 640 fatalities in the preceding 22-year period. In 2018, 423 people have died owing to extreme weather systems. ■