

**TIMES  
EVOKE**

**THE REASON FOR SEASONS**

As 2021 draws down, it leaves a trail of climate disasters. From floods in Europe to heatwaves in Canada, hurricanes across the US, droughts in Africa and deluges in Asia, the climate has changed from being a stable friend to an entity none can recognise. Its devastation is huge — Swiss Re, the global reinsurance company, estimates that losses from extreme weather exceeded \$100 billion in 2021. The World Meteorological Organization estimates that in 2020, while India lost \$87 billion to extreme weather, China lost \$238 billion. From 1980 onwards, 285 climate disasters caused losses of over \$1.875 trillion for the US. These are only one side of the tale — changing climate is now causing the loss of five million precious lives each year, giving rise to the term 'mortality cost of carbon'.

These losses are due to human behaviour. As we've consumed, produced and wasted more and more, carbon emissions have risen, increasing temperature in the atmosphere. As Times Evoke's global experts explain, this has impacted the complex and intricately interwoven dynamics of the winds, oceans, glaciers and precipitation which create our climate — as these change, so will our seasons, impacting all life on Earth.

Such behaviour is driven by humanity trivialising its own self. In our pursuit of all that is plastic and tin, we are forgetting the grandeur of our lives. We are placed on a planet blessed to bear life due to its orbit around the sun which gives it just enough warmth to live. Further, our Earth stands at a tilt which means it receives differing sunlight at different times, causing the seasons and allowing it to radiate excess warmth back.

This incredible metaphysical dance — of distance and nearness, physics and astronomy — creates glowing summers and chilling winters, spring that rejuvenates, burnished autumn and rains that drench us with joy. As we intensify carbon emissions, thickening Earth's delicate greenhouse cover, we lose these seasons and their gifts. For sustainable lives, we must rediscover this wondrous science. Join Times Evoke on a journey of understanding our climates, why these are changing — and how to preserve them for they enable the miracle of our life.

# 'Humans have created an unknown climate — India's per capita GDP is 30% lower due to this'

Noah Diffenbaugh teaches earth system science at Stanford University. Speaking to Srijana Mitra Das at Times Evoke, Diffenbaugh explains the planetary factors that cause climates on Earth — and changes in these:

**What is the core of your research?**

I study climate change — I am particularly interested in understanding how the climate system impacts people and other life on Earth. I've worked on how historical global warming impacted economic growth in different countries and how climate shocks affect poverty and inequality. I also research extreme events like heatwaves, floods and droughts as much of the climate system's impacts is felt through these.



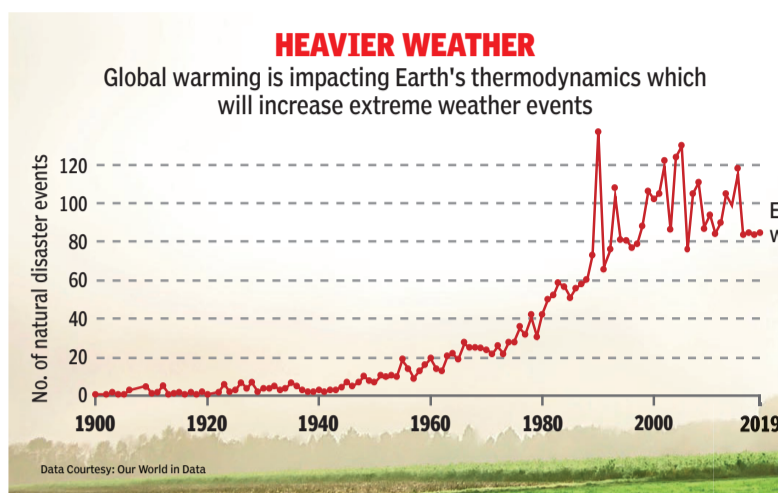
**What causes climate and weather?**

The answer is the sun — we are on a planet that orbits a star which emits a huge amount of energy. We have the seasons because Earth's rotation is tilted on an axis. As Earth orbits the sun, different parts of the planet get differing sunlight. An extreme example is the poles where during summer, there are 24 hours of sunlight and in winter, 24 hours of darkness. The seasons are a result of the tilt of Earth's axis that affects the solar input. This creates an imbalance in energy across the world — there's a net excess of energy in the tropics in terms of solar input and the outgoing radiation from the planet's surface. There is a net deficit of energy in the high latitudes. So, the weather and climate we experience is a result of that energy gradient across Earth.

**How is climate change reshaping these dynamics which make our weather?**

If we look at the inner planets, Venus is very hot, Mars is very cold and Earth is just right. The greenhouse effect makes all the difference — Venus has a very strong greenhouse effect which makes it so hot. Mars has a very weak greenhouse effect which causes its temperature to be well below the freezing point of water. Earth has a greenhouse effect which keeps our temperature above water's freezing point but not much above it.

The greenhouse effect is necessary for life on Earth — increasing the amount of greenhouse gases increases the amount of energy going into the climate system and thereby affects weather because that energy input drives these phenomena.



**Why do you say California has a new climate?**

California's water reservoir and management systems are all built around the natural reserves of snowpack in the western US. But that snowpack is becoming less reliable which means changes like a greater risk of flooding during the wet season and exacerbated water deficits during the dry season.

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**WHITHER THE WEATHER**

a new climate. Across the US, we're seeing more heatwaves and rainfall, storm surge flooding, wildfires and extreme drought risks. These events are impacting lives and livelihoods significantly. We've documented how a third of the financial losses from flooding in the US are due to changes in precipitation, intensifying extreme wet events. Similarly, 20% of insured crop losses over the last three decades have been due to rising temperatures. Climate change is already costing the US billions of dollars.

**What specifically links emissions from human activity to these changes in weather?**

The main pathway is called the thermodynamic effect — the warmer the atmosphere gets, the more water vapour it can hold. So, wind storms have more intensity of precipitation now because there is more water vapour in the atmosphere.

**What are the thermodynamic implications for India?**

Deepti Singh, who teaches at Washington

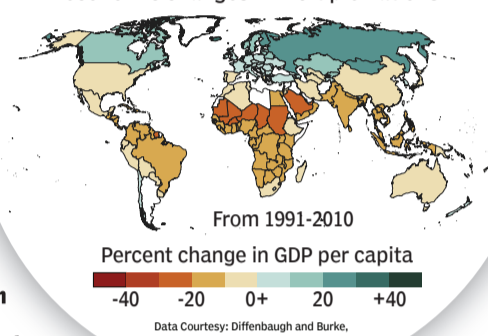
State University and is a former student of mine, analysed the wet and dry spells in India. She found that the wet spells have become more intense with greater risk of extreme precipitation — alongside, the dry spells have grown more protracted. So, during the monsoon in India, precipitation has become more extreme with flooding hazards. There will also be severe heat during the dry spells alongside the late onset of the monsoon becoming a growing risk.

**Is the hallmark of the Anthropocene how humans have made their own weather?**

Humans are clearly influencing the weather. Our actions are impacting Earth's climate system. These impacts are resulting in a new number and intensity of extreme weather events which impact us. Of course humans are adaptable — we manage to live everywhere from the Saharan desert to Antarctica and in-between. But we are now experiencing climate phenomena outside our historical experience. We can expect greater intensification of these extreme conditions since our activities will cause more warming before this lessens — that will drive more intensification of extreme weather. Our water systems and ecosystems, agriculture, infrastructure and economic growth are already being impacted by this. My research has found that tempera-

**ATMOSPHERE CALLING EARTH**

Human activity has impacted geophysical processes in the atmosphere — these are now causing economic changes in multiple nations



ture variability affects economic growth at a country-wide level. With my colleague Marshall Burke, I've analysed how the warming that's already happened impacted diverse countries. We've found that with warm countries tending to grow slightly less in terms of per capita GDP in warmer years than cooler years, aggregated over half a century, the cumulative effects of this warming are large — India's per capita GDP is about 30% lower today than it would have been without global warming. World over, global warming is driving up global economic inequality with changes in the weather producing a substantial drag on growth in warmer countries.

**CURBING OUR CARBON**

China (at over 29% of global carbon emissions), the US (at 14.02%) and India (at 7.02%) are the world's three largest carbon emitting nations. By calculating your own carbon footprint, you can help to reduce climate impacts — energy consumption causes 76% of greenhouse gas emissions globally. Switching to renewable energy in your home can reduce carbon by 1.5 tonnes per capita

Adopting a vegetarian diet saves half a tonne of carbon — vegetables cause 4.9% of global greenhouse emissions while poultry, seafood and eggs cause 14% and dairy products contribute 19% greenhouse gas emissions from food

For every 10% of waste reduction through recycling, reusing, buying local produce and not using plastic bags, you can reduce upto 1,200 pounds of CO2 added to the atmosphere

Housework matters — doing laundry in washers-dryers creates 8% of all residential-sector CO2 emissions in the US. The energy required to move, treat and use water for residential and commercial purposes produces 290 million metric tonnes of CO2 or 5% of the USA's overall carbon emissions

Keeping your kitchen tap running adds 157 kg of CO2 per year — using a bowl to wash up instead of running water can save emissions equal to a London-Oslo return flight

Research: UNEP, WRI, BBC, CNN



**THE SEASONS OF THEIR LIVES**

Birds and animals have environmental cues that tell them what season it is, the weather then shaping their lives — snails are called photoperiodic animals since they respond to changes in day length. Common garden snails thus start laying their eggs only when the days begin to get longer in spring

In autumn, as the days grow shorter, North American bears begin hyperphagia or eating and drinking as much as possible to gain weight for hibernation — scientists find grizzly bear genes are designed to reduce sensitivity to insulin during hibernation, so that their blood sugar stays normal and they can metabolise fat while they hibernate



The musical little bluethroat, a 14-cm-sized passerine bird, responds to changes in day lengths and temperature — as winter approaches, the bluethroat flies all the way from its home in birch woods and bushy swamps in Europe, the Palearctic and western Alaska to sing in the warmth of north Africa and India



## 'India must prepare for changes in the great Himalayan water tower'

Environmental historian Mahesh Rangarajan is Vice-Chancellor of Krea University. Speaking to Times Evoke, he explains why changes in the weather are particularly significant for India:

India encompasses around three million square kilometres with multiple agro-climatic regions. It has great diversity in climates, from arid areas in the north-west like the Thar desert to Ladakh's cold desert to areas with very high rainfall in north-east India and parts of the Western Ghats. Scholars of these climatic patterns are now pointing to two significant shifts.

One is the distribution of precipitation that falls upon an area in a year. Let's suppose an area receives three months of rain — we are now seeing either a majority of that rain fall in just one month or long periods of aridity. This is a major change — if an area which gets 100 centimetres of rain evenly spread gets a very large amount of rainfall now concentrated in a very small timeframe, that has major implications for lives and livelihoods.

**OUR SUBCONTINENT OF SEASONS**

The other change is the onset and duration of winter in areas which have a cold season — this appears to be ending faster. In much of northern India, if the cold season ends earlier and the hot season starts sooner, the entire pattern of sowing and harvesting crops will change. Earlier, the festival of Diwali was meant to approximately mark the beginning of the cold season while Basant Ritu and Holi marked the beginning of spring and the unfolding of summer. But these co-relations are less precise now than before.

With more intensified precipitation comes a longer and more concentrated dry spell and higher temperatures in the hot season. These weather changes affect two critical cycles — the first is the hydrological cycle or the availability of water. The other is the cycle of the variations of temperature. These have direct impacts on plant productivity which forms the basis of all life.

Of course climates have never been entirely stable through history — over the last 12,000 years and in studies on



**A PANORAMIC CHANGE:** The Himalayas are the bedrock of India's perennial rivers. Changes in glacial melt will impact water nation-wide

protohistory and prehistory, there have been instances of climatic disruptions. Scholars of the Harappan civilisation studied pollen grains from city sites in Rajasthan that show the nature of cropping changing, reflecting longer dry or wet spells. This is similar to

There are deeper challenges as well. Dry spells due to climate change will impact the dynamics of Earth's third water tower — the great mountain chain of Asia, the centre of which is the Himalayas. The ice and snow of the Himalayas are surpassed only by the north and south poles

— there are over 10,000 glaciers in the greater Himalayan mountain chain. These glaciers have been known through history as the source of the perennial rivers which flow across the northern part of South Asia. If these glaciers are impacted by changes in temperature, their melt rate will change. That will affect people living even thousands of miles downstream. Such changes introduce a level of uncertainty not known in living memory.

These are steps we should take to tackle such changes in time. One of them can help us stem the flooding we've seen recently in coastal cities like Chennai. If you examine the pattern of land utilisation in many sea-front cities over the last few decades, you will see low-lying areas have been subject to permanent structures which wasn't the practice before. But these areas are exactly where water accumulates when there is excess precipitation. Water needs spaces to flow away to and we are now considering amounts of water which are unprecedented in history — our urban development must take this profound change into account.

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## 'Studying the weather is critical now — the tropics could have fewer mild days'

Gabriel A. Vecchi teaches geosciences at Princeton University. He tells Times Evoke about how human actions are impacting Earth's oceans and winds — and its mild weather days:

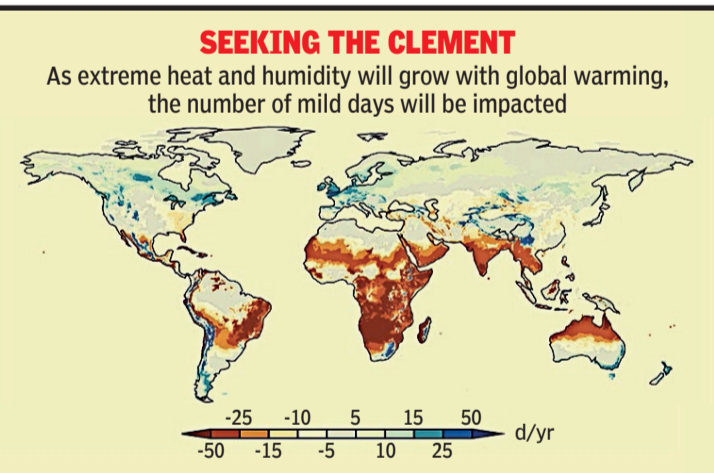
The core of my research is to understand how the oceans and atmosphere come together to give us our climate and weather that affects land, like tropical cyclones, the monsoons and phenomena like El Nino. The seasons we currently see are a specific type of climate change, the predictable changes that come from the fact that Earth's orbit is tilted relative to the sun. So, higher latitudes have a distinct cold and warm season with a transition.

Tropical places broadly have a rainy season and a dry season.

Attribution studies by scientists are now finding that global warming has changed the odds of certain climate events. For example, we've studied 2021's powerful heatwave in western USA and Canada. Using physics, temperature records and climate models, we've shown that such an event would have been almost impossible without global warming. Over the past 150 years, the amount of carbon dioxide, methane and other



**BLOWING IN THE WIND:** Warmer air means faster cyclonic winds and more moisture causing extreme weather



gases in the atmosphere have increased, largely due to the burning of fossil fuels. When these molecules are in the atmosphere, it makes it more difficult for our planet to cool — Earth's temperature rises. One of the places where the temperature really rises is the oceans — they take up a lot of heat and consequently they expand, leading to sea level rise. In addition, as the planet warms, ice on land also melts. That water, from ice caps, glaciers, etc., will run off into the oceans, causing further sea level rise. These are some of the clearest signals of the warming we as a global society have been driving on Earth.

Another way warming impacts climate is by increasing moisture in the atmosphere — a warmer atmosphere holds more water vapour. On a hot day, take a glass of cold water outside. You'll see droplets forming on the outside of the glass as moisture in the air turns into liquid water because the cold air near the glass can't hold

the water vapour — but the warmer air farther away from the glass can. In the same way, while we've been warming the atmosphere, the amount of moisture in the air has been rising — hence, we're getting extreme rain events increasing in intensity because there is just more rain to squeeze out of the atmosphere.

Now, in addition, we have observational evidence that the circulation of the winds in the tropics may be slowing down. These are average winds you'd expect over the course of seasons. Alongside, the speed of certain extreme winds, particularly tropical cyclones, are seemingly increasing, in large part due to the warming oceans and increased atmospheric moisture. Two main ingredients drive extreme rain — the amount of moisture in the air and how rapidly the winds bring that moisture together, which then fuels rain. Global warming is impacting both these factors and doing so particularly in the tropics.

There is yet another aspect to these climatic changes. We've studied mild days, defined as when the temperature is neither too hot, nor too cold, humidity isn't high and rain is slight or non-existent. These are the days when you might like to walk in the park or just sit outside. We've investigated how climate change will impact such days — we found globally, on average, the number of mild days, impacted by anthropogenic warming, will go down. There will be more extremely warm and humid days. In some places, global warming could produce more mild days — but these are higher latitude locations that tend to be colder, so when you raise the baseline temperature, you get fewer uncomfortably cold days. The effect of global warming reducing mild days will be more pronounced in the tropics.

For India, the temperature of the warmest days will continue to increase. The temperature at night will also continue to increase. There will still be weather — days that are colder and hotter — but with the general baseline moving up into higher temperatures. The seasons will still be present — tropical parts of India will have the rhythm of the monsoon dictating temperature and rainfall. However, a key factor will be El Nino, the phenomenon in the tropical Pacific which involves an intermittent warming of the East Pacific every few years and has the potential to impact the monsoon, even weakening it. Given the importance of the monsoon for millions of people, this needs extremely careful study.

The weather shows us how our understanding of the world is never static — it changes constantly. However, while facing the challenges of global warming, the more we learn, the better a relationship we can hope to develop with the elements that surround us and shape our lives.

**READERS WRITE**

Dear Times Evoke,  
The quality of TE's articles is top-notch every weekend! The article on Megan Herbert (11th December) was so inspiring for an IIT-educated professional like me. The media shapes perceptions around climate change, so kudos to TE's dedication!  
—Purvish Shah, Mumbai

Megan Herbert's wonderfully presented article made me feel elated! I want to do something positive for society by writing but I wasn't sure of the genre. I might now write for children! Thanks, Times Evoke, for this uplifting article!  
—Abhinaya Ramakrishnan, Surat

I am an avid reader of vibrant Times Evoke. Megan Herbert's art will help inculcate empathy in children towards climate refugees. Kudos to TOI for running the imaginative Times Evoke.  
—Ravi Mathur, Noida

Each Saturday, I wait eagerly to receive TOI for reading the beautiful Times Evoke! I have gained a lot of knowledge from this section. It has become a topic of discussion with my friends and family. All papers should have TOI's Times Evoke.  
—Riddhi Deb, Kolkata

Thank you, TE, for Megan Herbert's lovely drawings of the polar bear! Some children were seen hugging it and one kid gave the bear suffering from global warming an ice bath. I would love to see a polar bear myself. I want to thank TE for showing me this one in my home!  
—K Vernita Soimah, Class VI student, Bengaluru

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