

Heat Trends for Holi

Climate change increases risks of hot weather for Holi, 2024

INTRODUCTION

In 2024, Holi occurs on March 25. Here we consider how warming trends in India increase the chances of uncomfortably and possibly dangerously hot conditions.

RESULTS

1. March and April are warming across India

Every region considered had net warming during both March and April (Figure 1). During March, the northern and western regions have the fastest warming, with the largest change since 1970 in March occurring in Jammu and Kashmir (2.8°C). Warming is more uniform in April and Mizoram has the largest change since 1970 (1.9°C).

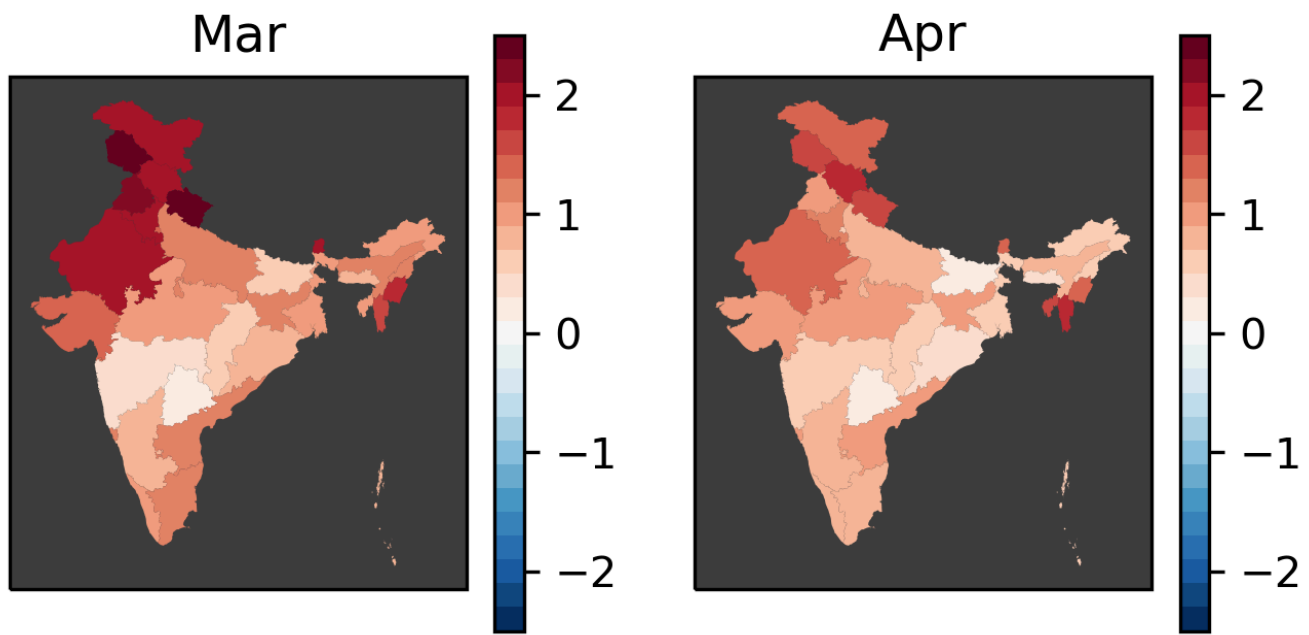


Figure 1. March and April warming trends. The warming rate is expressed as the change in temperature since 1970.

2. India has increased risk of extreme heat during Holi

Hot temperatures are an increasing health concern in India and around the world. For this analysis, we focused on the chance that people celebrating Holi would encounter temperatures above 40°C (detailed methods below). In the climate of the early 1970s, it would be exceedingly rare to encounter temperatures in late March above 40°C. Maharashtra, Chhattisgarh, and Bihar were the only states in that period with more than a 5% chance of reaching these temperatures.

In contrast, in this year's climate, the chance of reaching 40°C expands to nine states in total: the three original states plus Rajasthan, Gujarat, Telangana, Madhya Pradesh, Odisha, Andhra Pradesh. The highest probability is now in Maharashtra (14%).

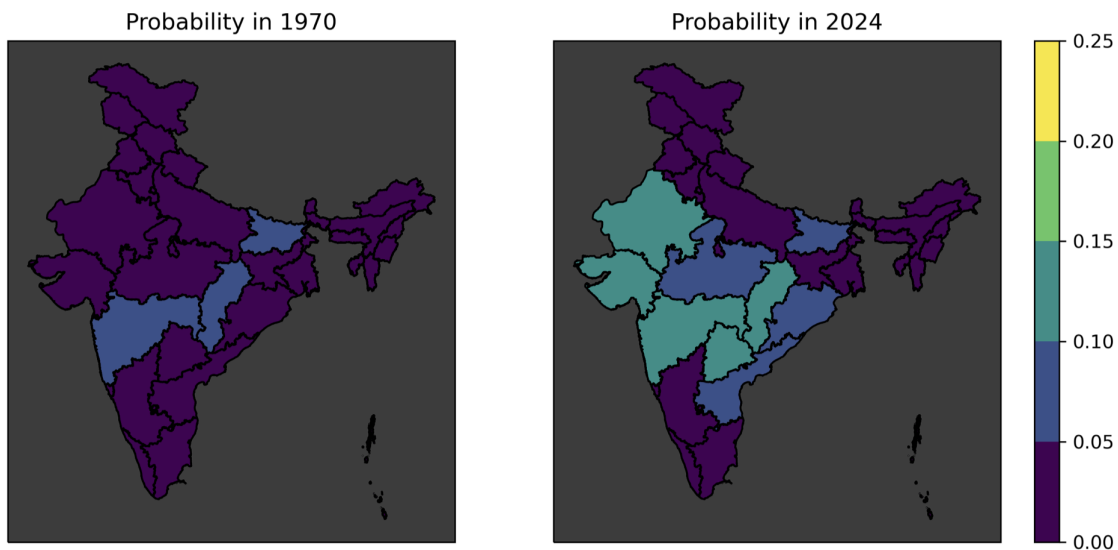


Figure 2. Probability that a day in late March/early April is above 40°C

Averaging over the states smooths out differences in risk between locations. We considered the change in probability in 51 large cities across the country. A total of 37 cities now have at least a 1% chance of experiencing 40°C or warmer temperatures, and 11 have a 10% or greater probability.

With the exception of Madurai, the 15 cities with the highest risk of a day in late March being above 40° occur in the center of the country (Table 1). Bilaspur now has the highest risk (31%), and the city's chance is now 2.5 times higher than in the 1970s. The largest change in risk between the two periods occurs in Indore. While the risk is relatively low (8%), it is 8.1 times higher than in the past. Madurai and Bhopal also have very large changes (7.1 and 5.5 times higher, respectively) and relatively high overall risk (19% and 12%).

City	past (~1970)	current (~2024)	Probability Ratio
Bilaspur	12%	31%	2.5
Nagpur	13%	27%	2.1
Bhilai	10%	20%	2.0
Kota	5%	20%	3.6
Raipur	11%	20%	1.8
Madurai	3%	19%	7.1
Jodhpur	3%	14%	4.5
Jabalpur	3%	14%	4.2
Bhopal	2%	12%	5.5
Vadodara	10%	12%	1.2
Varanasi	12%	10%	0.9
Gwalior	5%	10%	1.8
Mirzapur	11%	10%	0.9
Prayagraj	8%	10%	1.1
Indore	1%	8%	8.1

Table 1. Probability of a late March day being above 40°C in the climate of the early 1970s and the current climate. The probability ratio is the current probability divided by the past probability.

Methods

Calculating Monthly Average Temperatures

We extracted daily average temperatures from [ERA5](#) from January 1, 1970 to December 31, 2023. ERA5 uses sophisticated computer models to blend meteorological observations from weather stations, balloons, and satellites. For each 0.25°-by-0.25° grid cell, we computed the mean over each month. The monthly data was then averaged across 34 states and union territories. Chandigarh and Lakshadweep were excluded from the analysis due to their small size.

Calculating Monthly Trends

For each region we used linear regression to fit a trend line for each month. The trend lines describe how the climate is changing. They are the best estimate of the most likely temperature in a given year. The actual observed temperature is then a combination of the long-term trend and variability from weather in that year.

The trend line captures the rate of warming (°C per year). These rates were multiplied by 53 to get the change in temperature since 1970. Note that this is not the difference in temperature between starting and ending years. This is the change in the long-term average conditions captured by the linear regression.

Estimating Probability of Temperatures above 40°C

The Climate Shift Index, Climate Central's system for calculating the influence of climate change on daily air temperatures, has assembled an array of information for exploring changes in temperature.

We used the system's estimates of the frequency of different temperatures during a 31 day period centered on April 1. This covers the period of Holi in 2024.

We used the Climate Shift Index estimates of the frequency of daily temperatures in reference climate (1991-2020) for the period of interest for each ERA5 cell. This period has an average global mean temperature of 0.88°C above pre industrial levels. The Climate Shift Index system also has an estimate for how local temperatures shift in response to a 1°C change in global temperatures. This estimate is based on the trends over the period 1950-2020.

We then use the local climate sensitivity to shift the reference frequency distribution to the current climate (1.3°C global mean temperature) and to the past climate (0.24°C global mean temperature circa 1970). We then use these two distributions to calculate the probability of encountering a daily temperature above 40°C. The probabilities were averaged across the states and union territories. We also extracted the values for 51 cities.

About Climate Central

[Climate Central](#) is an independent group of scientists and communicators who research and report the facts about our changing climate and how it affects people's lives. They collaborate widely with TV meteorologists, journalists, and other respected voices to reach audiences across diverse geographies and beliefs. Their work addresses climate science, sea level rise, extreme weather, energy, and related topics. Climate Central is a policy-neutral 501(c)(3) nonprofit.

Climate Central's [Climate Shift Index](#) (CSI) system, grounded in the latest [peer-reviewed attribution science](#), quantifies the influence of climate change on daily temperatures around the world. CSI levels indicate how much human-caused climate change has altered the frequency of daily temperatures at a particular location.

Major funding for this work provided by the Bezos Earth Fund and The Schmidt Family Foundation.

Quotes

Dr. Andrew Pershing, VP for Science, Climate Central, said:

"There has been an abrupt transition in the temperatures from cool winter-like temperatures to much warmer conditions now. After the strong warming trend observed in February, March is also likely to follow the same pattern. These warming trends in India are a clear sign of the impacts of human-led climate change."

Additional Quotes

Mahesh Palawat, Vice President- Meteorology and Climate Change, Skymet Weather

"There is no denying the fact that climate change is behind the soaring mercury levels. In fact, we can say that there is a gradual shift in temperature patterns. Heatwaves in March were rare but with the

increasing global warming, the probability of heatwaves or high temperatures have also increased. We will witness similar weather conditions this year as well. This trend will continue in the coming days and we must prepare for an intense summer season ahead.”

Dr. Akshay Deoras, Research Scientist, National Centre for Atmospheric Science, University of Reading, UK

“Global warming is favouring an early arrival of the hot weather season in India. The concentration of greenhouse gasses, which is responsible for global warming, is much larger at present compared to what it was in the 1970s. This is turning the planet into a furnace, and Indian hilly states are facing the brunt of it in particular. Given that Holi is an outdoor festival, the early onset of hot weather increases the vulnerability to heat related illness.”