



Firefighters battle blazes in southwestern France on 17 July that were spurred by an extreme heatwave.

EXTREME HEATWAVES: SURPRISING LESSONS FROM THE RECORD WARMTH

Unprecedented temperatures are coming faster and more furiously than researchers expected, raising questions about what to anticipate in the future. **By Alexandra Witze**

From London to Shanghai, unprecedented heatwaves have scorched many parts of the world in recent weeks. In June, Tokyo baked through nine consecutive days above 35 °C, its most severe heatwave since official tallies began in the 1870s.

In mid-July, the United Kingdom shattered records as temperatures soared above 40 °C for the first time since measurements started. Meanwhile, heat-fuelled wildfires ravaged parts of France, Spain, Greece

and Germany. And China has faced multiple widespread heatwaves, including one that hit more than 400 cities last month.

Climate scientists have long warned that heatwaves will strike more frequently and with higher temperatures as the world warms. But the future has arrived faster than researchers had feared, particularly in Western Europe, which is a hotspot for heatwaves, according to research published last month¹. These aren't just more and more-powerful heatwaves – they are record-shattering heatwaves

that have defied expectations derived from climate models.

Researchers are now scrambling to dissect the details of this year's heatwaves, to better understand how extreme heat will affect society going forwards.

"The science community has obviously been thinking about the possibility of these events," says Eunice Lo, a climate scientist at the University of Bristol, UK, who has studied the UK heatwave. But "it was still quite surreal that it actually happened".

Extreme heat is one of the more deadly consequences of global warming. It kills people directly, such as those working outdoors. And it overloads energy grids, disrupting electricity supplies at times when people most need air conditioning or fans to survive in overheated homes. A heatwave in Europe in 2003 is estimated to have killed more than 70,000 people. And heatwaves can also exacerbate other disasters, such as wildfires, and exact a high toll on mental health.

Although heatwaves have been getting worse in the past few years, studies of the most extreme examples leapt forward after a June 2021 heatwave in the Pacific Northwest region of North America.

That heatwave was so far off the charts that it essentially reset the field of research on extreme heat, says Vikki Thompson, a climate scientist at Bristol. In a study published in May, she and her colleagues showed² that only five heatwaves recorded anywhere in the world since 1960 had been more extreme, as measured by departure from the climate of the previous decade. Just looking at temperature records across the Pacific Northwest from the years before the event, it seemed “completely implausible” that such a record-breaking heatwave could occur, she says. And yet it did – driven mainly by a high-pressure atmospheric system that funnelled in hot air, combined with drier-than-normal soil conditions across much of the region.

Defying expectations

This July's heatwave in the United Kingdom was not quite so severe, but it might still go down in history as the event that shook a nation into awareness of the dangers of extreme heat. On 18 and 19 July, a broad swathe of the country set new temperature records, in many cases a full 3 or 4 °C higher than the previous one. Forty-six weather stations broke the nation's previous record high temperature of 38.7 °C, which was set just three years ago. Hundreds of people are estimated to have died.

Scientists had foreseen this to some extent. A climate-modelling study published two years ago found that it was possible, although not likely, that the United Kingdom would pass 40 °C in the coming decades³. And yet it happened this year, with a new national high of 40.3 °C.

The fact that temperatures topped the threshold so much more quickly than expected might stem from the reality that climate models don't capture everything that influences heatwaves, and thus don't project future heat extremes completely accurately⁴. Changes in factors including land use and irrigation affect heatwaves in ways that models don't entirely account for yet. That means that model projections can sometimes misjudge the true impact of climate change.

A 28 July analysis by the international World

Weather Attribution research group found that human-induced climate change made this year's UK heatwave at least ten times more likely⁵. The study also concluded that the heatwave would have been 2–4 °C cooler in the absence of global warming.

“It is more evidence that there are some things we're probably not catching with the models,” says Peter Stott, a climate scientist at the Met Office, the UK national weather service in Exeter, who was a co-author of the 2020 study about the United Kingdom³. “There is a research question there.”

Like the Pacific Northwest heatwave of 2021, the UK heatwave of 2022 might become a catalyst for understanding what causes heatwaves

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to become even more extreme than expected, says Erich Fischer, a climate scientist at the Swiss Federal Institute of Technology in Zurich. In a modelling study published last year⁶, Fischer and his colleagues projected that, in the coming decades, climate extremes will break previous records by wide margins. “This is exactly what we've been seeing,” he says.

Studying the extent to which extremes shatter records, and not just whether they pass the mark, can help local officials to plan for the types of extreme they might expect in the near future, Fischer argues.

Dynamic change

Beyond the United Kingdom, much of Europe has already experienced several heatwaves this year. In fact, the continent has seen record heat several times over the past five years, says Kai Kornhuber, a climate scientist at Columbia University in New York City. He was part of the team that identified Western Europe as particularly prone to heatwaves¹. Over the past four decades, extreme heat has been increasing at rates three to four times faster there than in other mid-latitude regions in the Northern Hemisphere.

That could be because the atmospheric jet stream that flows east across the North Atlantic Ocean often breaks into two separate strands as it approaches Europe. When that happens, the strands can funnel storms away from Europe and allow heatwaves to develop and persist. It isn't yet clear whether climate change is leading to more of these ‘double jets’, but that pattern set up this July's heatwave in Western Europe and is responsible for many of the other recent heat events there.

Similar patterns of atmospheric dynamics might turn out to be important in revealing

the factors that make heat events even more extreme than expected, says Kornhuber.

Another striking feature of the past few months is that extreme heat has occurred simultaneously in several parts of the world. China and western North America were both roasting in hotter-than-normal temperatures in late July, at the same time as Europe. Such concurrent heatwaves became six times more common in the Northern Hemisphere between 1979 and 2019, a study published in February found⁷.

One reason might be atmospheric patterns called Rossby waves that settle into a snaking shape around the entire planet, setting up stagnant patterns of weather in certain locations, which then become prone to extreme heat⁸. Those might or might not be becoming more common under global warming. But the sheer chance of having simultaneous heatwaves, unrelated to atmospheric patterns, does go up as the climate warms, says Deepti Singh, a climate scientist at Washington State University in Vancouver. “The entire world is warming, and just the likelihood of having extreme heat regions is increasing,” she says.

Heatwaves are also coming earlier in the year in some places, such as India and Pakistan, which experienced baking temperatures from March to May. Parts of India passed 44 °C at the end of March, well before the usual hottest part of the year. At least 90 people died. The heatwave was made 30 times more likely by climate change, the World Weather Attribution group found⁹.

As global temperatures continue to rise, climate scientists are reiterating the importance of both cutting carbon emissions and increasing people's ability to adapt to extreme temperatures. The UK heatwave was a major wake-up call about the nation's vulnerability to extreme heat, says Stott. After decades working on climate projections for the future, what startled him most was to see wildfires raging in London's urban area, fuelled by the extreme heat. “It was very sobering, really, and shocking that this was happening.”

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