Stanford scientists test links between extreme weather and climate change

A new four-step “framework” aims to test the contribution of climate change to record-setting extreme weather events.

After an unusually intense heat wave, downpour or drought, Noah Diffenbaugh and his research group inevitably receive phone calls and emails asking whether human-caused climate change played a role.

“The question is being asked by the general public and by people trying to make decisions about how to manage the risks of a changing climate,” said Diffenbaugh, a professor of Earth system science at Stanford’s School of Earth, Energy & Environmental Sciences. “Getting an accurate answer is important for everything from farming to insurance premiums, to international supply chains, to infrastructure planning.”

In the past, scientists typically avoided linking individual weather events to climate change, citing the challenges of teasing apart human influence from the natural variability of the weather. But that is changing.

“Over the past decade, there’s been an explosion of research, to the point that we are seeing results released within a few weeks of a major event,” said Diffenbaugh, who is also the Kimmelman Family Senior Fellow at the Stanford Woods Institute for the Environment.

In a new study, published in this week’s issue of Proceedings of the National Academy of Sciences, Diffenbaugh and a group of current and former Stanford colleagues outline a four-step “framework” for testing whether global warming has contributed to record-setting weather events. The new paper is the latest in a burgeoning field of climate science called “extreme event attribution,” which combines statistical analyses of climate observations with increasingly powerful computer models to study the influence of climate change on individual extreme weather events.

Climate change fingerprints
In order to avoid inappropriately attributing an event to climate change, the authors began with the assumption that global warming had played no role, and then used statistical analyses to test whether that assumption was valid. “Our approach is very conservative,” Diffenbaugh said. “It’s like the presumption of innocence in our legal system: The default is that the weather event was just bad luck, and a really high burden of proof is required to assign blame to global warming.”

The authors applied their framework to the hottest, wettest and driest events that have occurred in different areas of the world. They found that global warming from human emissions of greenhouse gases has increased the odds of the hottest events across more than 80 percent of the surface area of the globe for which observations were available. “Our results suggest that the world isn’t quite at the point where every record hot event has a detectable human fingerprint, but we are getting close,” Diffenbaugh said.

For the driest and wettest events, the authors found that human influence on the atmosphere has increased the odds across approximately half of the area that has reliable observations. “Precipitation is inherently noisier than temperature, so we expect the signal to be less clear,” Diffenbaugh said. “One of the clearest signals that we do see is an increase in the odds of extreme dry events in the tropics. This is also where we see the biggest increase in the odds of protracted hot events – a combination that poses real risks for vulnerable communities and ecosystems.”

The Stanford research team, which includes a number of former students and postdocs who have moved on to positions at other universities, has been developing the extreme event framework in recent years, focusing on individual events such as the 2012-2017 California drought and the catastrophic flooding in northern India in June 2013. In the new study, a major goal was to test the ability of the framework to evaluate events in multiple regions of the world, and to extend beyond extreme temperature and precipitation, which have been the emphasis of most event attribution studies.

Test cases

One high-profile test case was Arctic sea ice, which has declined by around 40 percent during the summer season over the past three decades. When the team members applied their framework to the record-low Arctic sea ice cover observed in September 2012, they found overwhelming statistical evidence that global warming contributed to the severity and probability of the 2012 sea ice measurements. “The trend in the Arctic has been really steep, and our results show that it would have been extremely unlikely to achieve the record-low sea ice extent without global warming,” Diffenbaugh said.

Another strength of a multi-pronged approach, the team said, is that it can be used to study not only the weather conditions at the surface, but also the meteorological “ingredients” that contribute to rare events. “For example, we found that the atmospheric pressure pattern that occurred over Russia during the 2010 heat wave has become more likely in recent decades, and that global warming has contributed to those odds,” said co-author Daniel Horton, an assistant professor at Northwestern University in Evanston, Illinois, and a former postdoc in Diffenbaugh’s lab who has led research on the influence of atmospheric pressure patterns on surface temperature extremes. “If the odds of an individual ingredient are changing – like the pressure patterns that lead to heat waves – that puts a thumb on the scales for the extreme event.”

Diffenbaugh sees the demand for rigorous, quantitative event attribution growing in the coming years. “When you look at the historical data, there’s no question that global warming is happening and that extremes are increasing in many areas of the world,” he said. “People make a lot of decisions – short term and long term – that depend on the weather, so it makes sense that they want to know whether global warming is making record-breaking events more likely. As scientists, we want to make sure that they have accurate, objective, transparent information to work with when they make those decisions."

Other authors on the study, titled "Quantifying the influence of global warming on unprecedented extreme climate events," include Danielle Touma, Allison Charland, Yunjie Liu and Bala Rajaratnam of Stanford University, and Stanford alumni Deepti Singh and Justin Mankin (now at the Lamont-Doherty Earth Observatory of Columbia University); Daniel Swain and Michael Tsiang (now at the University of California, Los Angeles); and Matz Haugen (now at the University of Chicago). *Funding was provided by the U.S. National Science Foundation, the Department of Energy, the National Institutes of Health and Stanford University.*

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