Extreme weather events linked to climate change impact on the jet stream

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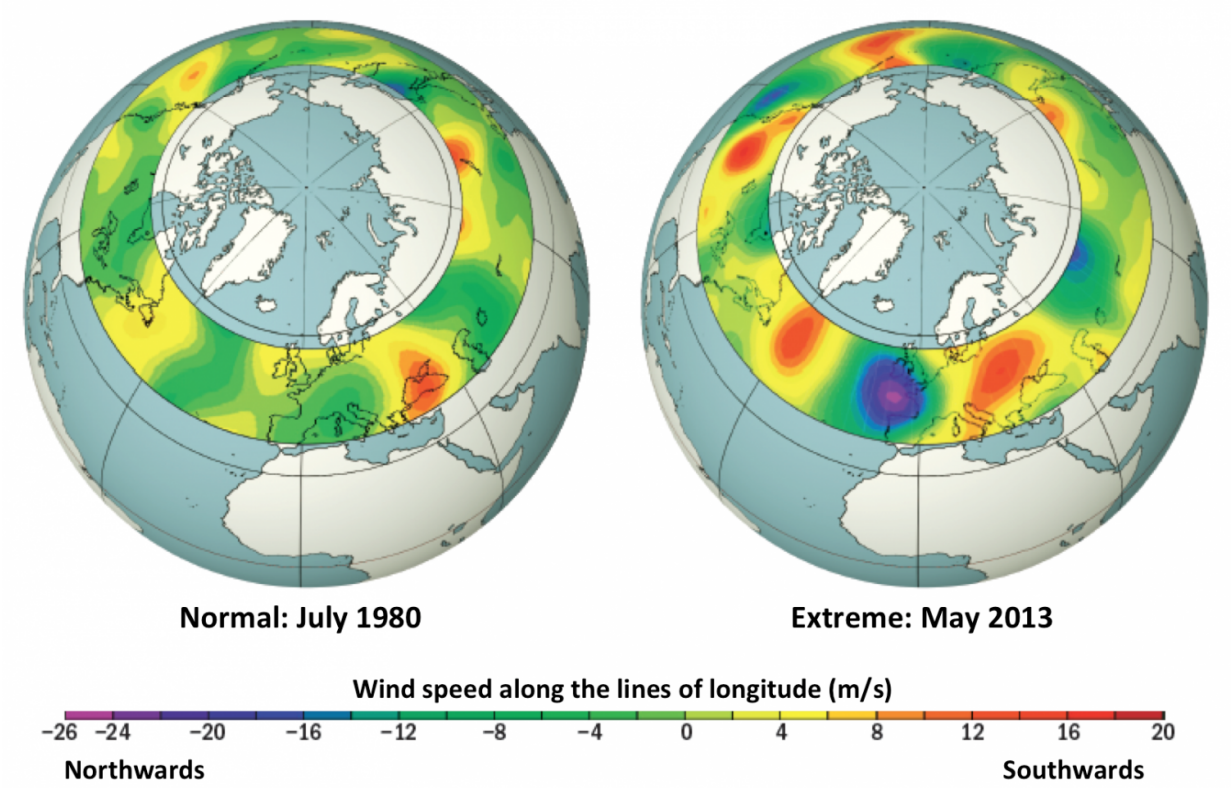

On the is an image of the global circulation pattern on a normal day. On the right is the image of the global circulation pattern when extreme weather occurs. The pattern on the right shows extreme patterns of wind speeds going north and south, while the normal pattern on the left shows moderate speed winds in both the north and south directions. Credit: Michael Mann, Penn State

Unprecedented summer warmth and flooding, forest fires, drought and torrential rain—extreme weather events are occurring more and more often, but now an international team of climate scientists has found a connection between many extreme weather events and the impact climate change is having on the jet stream.

"We came as close as one can to demonstrating a direct link between climate change and a large family of extreme recent weather events," said Michael Mann, distinguished professor of atmospheric science and director, Earth System Science Center, Penn State. "Short of actually identifying the events in the climate models."

The unusual weather events that piqued the researchers' interest are things such as the 2003 European heat wave, the 2010 Pakistan flood and Russian heatwave, the 2011 Texas and Oklahoma heat wave and drought and the 2015 California wildfires.

The researchers looked at a combination of roughly 50 climate models from around the world that are part of the Coupled Model Intercomparison Project Phase 5 (CMIP5), which is part of the World Climate Research Programme. These models are run using specific scenarios and producing simulated data that can be evaluated across the different models. However, while the models are useful for examining large-scale climate patterns and how they are likely to evolve over time, they cannot be relied on for an accurate depiction of extreme weather events. That is where actual observations prove critical.

The researchers looked at the historical atmospheric observations to document the conditions under which extreme weather patterns form and persist. These conditions occur when the jet stream, a global atmospheric wave of air that encompasses the Earth, becomes stationary and the peaks and troughs remain locked in place.

"Most stationary jet stream disturbances, however, will dissipate over time," said Mann. "Under certain circumstances the wave disturbance is effectively constrained by an atmospheric wave guide, something similar to the way a coaxial cable guides a television signal. Disturbances then cannot easily dissipate, and very large amplitude swings in the jet stream north and south can remain in place as it rounds the globe."

This constrained configuration of the jet stream is like a rollercoaster with high peaks and valleys, but only forms when there are six, seven or eight pairs of peaks and valleys surrounding the globe. The jet stream can then behave as if there is a waveguide—uncrossable barriers in the north and south—and a wave with large peaks and valleys can occur.

"If the same weather persists for weeks on end in one region, then sunny days can turn into a serious heat wave and drought, and lasting rains can lead to flooding," said Stefan Rahmstorf, Potsdam Institute for Climate Impact Research (PIK), Germany.

The structure of the jet stream relates to its latitude and the temperature gradient from north to south.

Temperatures typically have the steepest gradients in mid-latitudes and a strong circumpolar jet stream arises. However, when these temperature gradients decrease in just the right way, a weakened "double peak" jet stream arises with the strongest jet stream winds located to the north and south of the mid-latitudes.

"The warming of the Arctic, the polar amplification of warming, plays a key role here," said Mann. "The surface and lower atmosphere are warming more in the Arctic than anywhere else on the globe. That pattern projects onto the very temperature gradient profile that we identify as supporting atmospheric waveguide conditions."

Theoretically, standing jet stream waves with large amplitude north/south undulations should cause unusual weather events.

"We don't trust climate models yet to predict specific episodes of extreme weather because the models are too coarse," said study co-author Dim Coumou of PIK. "However, the models do faithfully reproduce large scale patterns of temperature change," added co-author Kai Kornhuber of PIK.

The researchers looked at real-world observations and confirmed that this temperature pattern does correspond with the double-peaked jet stream and waveguide patter associated with persistent extreme weather events in the late spring and summer such as droughts, floods and heat waves. They found the pattern has become more prominent in both observations and climate model simulations.

"Using the simulations, we demonstrate that rising greenhouse gases are responsible for the increase," said Mann. The researchers noted in today's (Mar. 27) issue of *Scientific Reports* that "Both the models and observations suggest this signal has only recently emerged from the background noise of natural variability."

"We are now able to connect the dots when it comes to human-caused global warming and an array of extreme recent weather events," said Mann.

While the models do not reliably track individual extreme weather events, they do reproduce the jet stream patterns and temperature scenarios that in the real world lead to torrential rain for days, weeks of broiling sun and absence of precipitation.

"Currently we have only looked at historical simulations," said Mann. "What's up next is to examine the model projections of the future and

see what they imply about what might be in store as far as further increases in extreme weather are concerned."

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