Climate change occurring 10 times faster than at any time in past 65 million years

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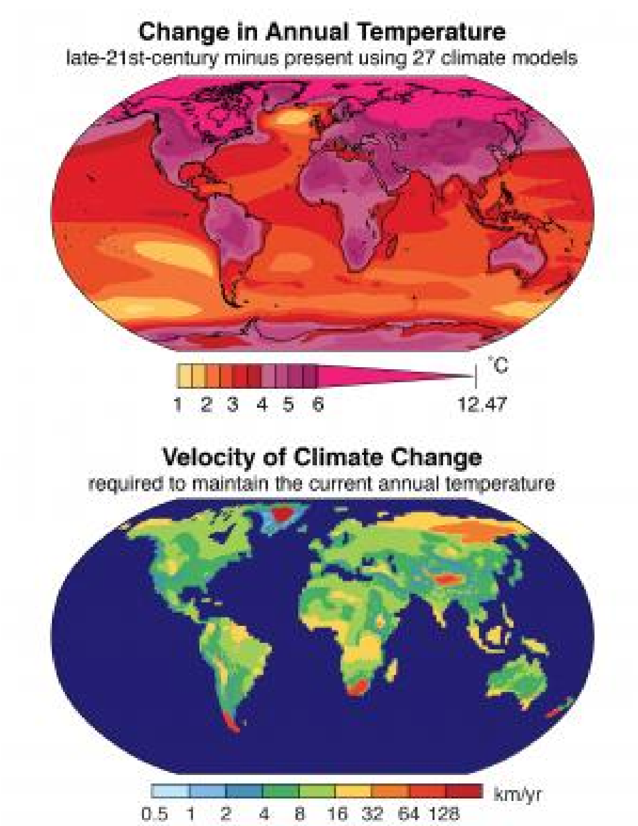

Top: The change in annual temperature projected for the late 21st century using simulations from 27 global climate models. The change is calculated as the 2081-2100 mean minus the 1986-2005 mean. Bottom: The velocity of climate change required to maintain the current annual temperature should the late-21st-century climate change occur. The velocity is calculated for each location by identifying the closest location in the future climate that has the same annual temperature as the starting location has in the present climate. Credit: Noah Diffenbaugh

The planet is undergoing one of the largest changes in climate since the dinosaurs went extinct. But what might be even more troubling for humans, plants and animals is the speed of the change. Stanford climate scientists warn that the likely rate of change over the next century will be at least 10 times quicker than any climate shift in the past 65 million years.

If the trend continues at its current rapid pace, it will place significant stress on terrestrial ecosystems around the world, and many species will need to make behavioral, evolutionary or geographic adaptations to survive.

Although some of the changes the planet will experience in the next few decades are already "baked into the system," how different the climate looks at the end of the 21st century will depend largely on how humans respond.

The findings come from a review of climate research by Noah Diffenbaugh, an associate professor of environmental Earth system science, and Chris Field, a professor of biology and of environmental Earth system science and the director of the Department of Global Ecology at the Carnegie Institution. The work is part of a special report on climate change in the current issue of *Science*.

Diffenbaugh and Field, both senior fellows at the Stanford Woods Institute for the Environment, conducted the targeted but broad review of scientific literature on aspects of climate change that can affect ecosystems, and investigated how recent observations and projections for the next century compare to past events in Earth's history.

For instance, the planet experienced a 5 degree Celsius hike in temperature 20,000 years ago, as Earth emerged from the last ice age. This is a change comparable to the high-end of the projections for warming over the 20th and 21st centuries.

The geologic record shows that, 20,000 years ago, as the ice sheet that covered much of North America receded northward, plants and animals recolonized areas that had been under ice. As the climate continued to warm, those plants and animals moved northward, to cooler climes.

"We know from past changes that ecosystems have responded to a few degrees of global temperature change over thousands of years," said Diffenbaugh. "But the unprecedented trajectory that we're on now is forcing that change to occur over decades. That's orders of magnitude faster, and we're already seeing that some species are challenged by that rate of change."

Some of the strongest evidence for how the global climate system responds to high levels of carbon dioxide comes from paleoclimate studies. Fifty-five million years ago, carbon dioxide in the atmosphere was elevated to a level comparable to today. The Arctic Ocean did not have ice in the summer, and nearby land was warm enough to support alligators and palm trees.

"There are two key differences for ecosystems in the coming decades compared with the geologic past," Diffenbaugh said. "One is the rapid pace of modern climate change. The other is that today there are multiple human stressors that were not present 55 million years ago, such as urbanization and air and water pollution."

Record-setting heat

Diffenbaugh and Field also reviewed results from two-dozen climate models to describe possible climate outcomes from present day to the end of the century. In general, extreme weather events, such as heat waves and heavy rainfall, are expected to become more severe and more frequent.

For example, the researchers note that, with continued emissions of greenhouse gases at the high end of the scenarios, annual temperatures over North America, Europe and East Asia will increase 2-4 degrees C by 2046-2065. With that amount of warming, the hottest summer of the last 20 years is expected to occur every other year, or even more frequently.

By the end of the century, should the current emissions of greenhouse gases remain unchecked, temperatures over the northern hemisphere will tip 5-6 degrees C warmer than today's averages. In this case, the hottest summer of the last 20 years becomes the new annual norm.

"It's not easy to intuit the exact impact from annual temperatures warming by 6 C," Diffenbaugh said. "But this would present a novel climate for most land areas. Given the impacts those kinds of seasons currently have on terrestrial forests, agriculture and human health, we'll likely see substantial stress from severely hot conditions."

The scientists also projected the velocity of climate change, defined as the distance per year that species of plants and animals would need to migrate to live in annual temperatures similar to current conditions. Around the world, including much of the United States, species face needing to move toward the poles or higher in the mountains by at least one kilometer per year. Many parts of the world face much larger changes.

The human element

Some climate changes will be unavoidable, because humans have already emitted greenhouse gases into the atmosphere, and the atmosphere and oceans have already been heated.

"There is already some inertia in place," Diffenbaugh said. "If every new power plant or factory in the world produced zero emissions, we'd still see impact from the existing infrastructure, and from gases already released."

The more dramatic changes that could occur by the end of the century, however, are not written in stone. There are many human variables at play that could slow the pace and magnitude of change – or accelerate it.

Consider the 2.5 billion people who lack access to modern energy resources. This energy poverty means they lack fundamental benefits for illumination, cooking and transportation, and they're more susceptible to extreme weather disasters. Increased energy access will improve their quality of life – and in some cases their chances of survival – but will increase global energy consumption and possibly hasten warming.

Diffenbaugh said that the range of climate projections offered in the report can inform decision-makers about the risks that different levels of climate change pose for ecosystems.

"There's no question that a climate in which every summer is hotter than the hottest of the last 20 years poses real risks for ecosystems across the globe," Diffenbaugh said. "However, there are opportunities to decrease those risks, while also ensuring access to the benefits of energy consumption."

More information: "Changes in Ecologically Critical Terrestrial Climate Conditions," by N.S. Diffenbaugh et al *Science*, 2013.

Provided by Stanford University