SCIENCE

A New Solution to Climate Science's Biggest Mystery

For the first time in 41 years, researchers have provided a new answer to one of the thorniest—and most fundamental—questions in Earth science.

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The project began, in one telling, five years ago, in a castle that overlooks the Bavarian Alps, where three dozen of the world's most successful and rivalrous earth scientists came together for a week of cloistered meetings.

They gathered, in part, out of embarrassment. For the past four decades, their field—the study of Earth's natural phenomena, including its land, ocean, and climate—had boomed. Generations of young researchers who once would have become nuclear physicists or oil geologists instead pursued careers in glaciology and paleoclimatology. Governments, hoping to understand the dangers of global warming, had poured hundreds of millions of dollars into climate science. And the work was good. It gave humans a new way of seeing Earth: We learned to map the flow of the oceans, to chart the growth of continent-spanning glaciers, and to read the evidence left behind in lake mud and caves by ancient rainstorms, droughts, and hurricanes.

Which is, you know, nice. It's fun to play weatherman for people who lived 1,000 years ago. Yet for all the immeasurable wonder and glory, and for all those millions of National Science Foundation dollars spent, there was one fundamental question on which climate scientists had not really made progress. It is among the field's oldest and most purely scientific questions—it was first investigated in 1896 by Svante Arrhenius, a Nobel laureate—yet central to understanding modern, human-caused climate change. But for all that importance, climate scientists would have answered the question the same way five years ago as they would have in 1979. It is this trouble that brought the empiricists to Bavaria. They wanted a better answer to the question, which is: If you greatly increase the amount of carbon dioxide in the atmosphere, how hot will the planet get?

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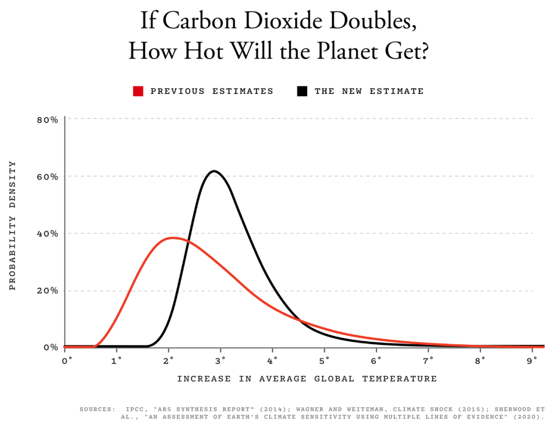
This week, a team of 25 researchers—drawn from across the earth sciences and descended from the Bavaria effort—published the first new answer in 41 years. Their estimate of this value, called "climate sensitivity," significantly reduces the amount of uncertainty involved in forecasting climate change. "It helps us answer this fundamental question, which is: How warm is it gonna get?" Kate Marvel, a climate scientist at

NASA and an author of the paper, told me.

Since Arrhenius first tried to calculate climate sensitivity, scientists have talked about it by estimating how much temperatures would rise if CO_2 doubled. The new paper finds that doubling carbon dioxide will likely increase Earth's average temperature by 2.6 to 3.9 degrees Celsius (about 5 to 7 degrees Fahrenheit). That's much narrower than the old estimate, which said that a doubling of CO_2 would raise temperatures by 1.5 to 4.5 degrees Celsius (about 3 to 8 degrees Fahrenheit).



The biggest change in the new study is on the lower end: It zeroes out any chance that Earth isn't sensitive to carbon emissions.

There's no way to double the planet's carbon-dioxide content and avoid fewer than 2.3 degrees Celsius (4 degrees Fahrenheit) of warming, the authors found. But they have also reduced their estimate of the chance of a major overshoot, with a doubling of CO_2 leading to 6 degrees Celsius (about 10 degrees Fahrenheit) or more of global warming. "We've ruled out 'We'll be fine,' and we don't think 'doom' is very likely," Marvel said.

[Read: This is your life on climate change]

The paper is considered a landmark by other researchers. "It's a really important study," Bjorn Stevens, an atmospheric scientist at the Max Planck Institute for Meteorology, told me. In a 2015 paper, he laid out a method for how climate-sensitivity might be refined, and he helped organize the gathering at the castle, but he is not an author of the new study. "It tells us we understand the Earth system better than we thought we did."

"This study probably shouldn't do much to affect our baseline view of climate change," Joseph Majkut, a climate scientist and the director of climate policy at the Niskanen Center, a nonpartisan think tank, told me by email. "Despite the controversy about the possible bounds of warming, the central estimates for climate sensitivity have been pretty consistent (around 3 [degrees Celsius] for doubling CO2). This study doesn't find different, but shows that basically any way you cut the evidence, expected warming is pretty similar."

One group that the refined result does not bode well for is "self-styled lukewarmers," Majkut said, "who claim that global warming is real but not too much of a problem." The paper undercuts their claims, he said, by showing that "when you carefully calibrate your estimate and confront it with other pieces of evidence in a rigorous way, very low climate sensitivity appears really unlikely."

After Arrhenius first mused about climate sensitivity in 1896, the concept was revisited a few times. For most of the early 20th century, scientists did not put much stock into the warming effects of carbon dioxide, because water vapor was seen as a more potent greenhouse gas. It wasn't until Guy Callendar, a British chemist, revisited the concept in the late 1940s that it was revived. In 1964, Charles Keeling, an American climatologist, showed that carbon dioxide was already warming the planet in a manner predicted by Callendar's and Arrhenius's work.

[Read: Are we living through climate change's worst-case scenario?]

Fifteen more years passed before Jule Charney, an American meteorologist, produced the first modern estimate of climate sensitivity with a team of climate modelers and experts. Charney's paper found that climate sensitivity was in a range of 1.5 to 4.5 degrees Celsius. "The really frustrating thing about this number is that the first time they did this exercise, they got a range of 1.5 C to 4.5 C. The next time they did it, with more sophisticated models, they got a range 1.5 C to 4.5 C," Marvel said.

The range proved stubborn. About a decade after Charney and his colleagues first reached their estimate, the Intergovernmental Panel on Climate Change—a global panel of scientists led by the United Nations—considered the planet's climate sensitivity anew. In 1991, in its first synthesis report on the evidence for and dangers of climate change, the IPCC said that climate sensitivity was somewhere from 1.5 to 4.5 degrees Celsius. In 1995, in its second report, it reached the same conclusion. It found the same range again in 2001, in its third report; in 2007, in its fourth; and in 2014, in its fifth and most recent assessment. "People say, 'What the hell, climate scientists? You had one job,'" Marvel said.

Climate sensitivity is something of a technical idea, meant to answer a scientific question that doesn't fully capture the planet in all its specificity. Sensitivity is meant to describe the relationship between atmospheric CO_2 and the planet's temperature—and nothing else. The new paper—which, at more than 150 pages long, is unusually lengthy for a scientific paper—looks at computer models, but also the climate record left behind in earlier eras and evidence from the past century and a half of global weather observation. The authors wanted to know what would happen, in essence, if the amount of CO_2 in Earth's atmosphere doubled instantaneously. (Spoiler: The stratosphere would heat up in a few seconds, while the deepest oceans would take centuries to warm.)

This scenario differs from the real world in at least two important ways. First, the amount of atmospheric CO_2 hasn't skyrocketed overnight, but has slowly risen over the course of a century and a half. Second, climate change could launch unpleasant feedback loops, causing more carbon dioxide to enter the atmosphere. For instance, if runaway wildfires were to torch millions of square miles of forest, then the carbon once stored in those trees would enter the atmosphere. But climate sensitivity isn't meant to measure that feedback.

The new work may represent the end of the era for this vein of climate science, Stevens said. At this point, policy makers have all the information about climate sensitivity they should need to act, he said. While it's not always clear what a change in the global mean temperature means for local climates, it is clear now that—with virtually no uncertainty—any doubling of atmospheric CO_2 would be a significant event. "I think science has done a good job of putting its foot forward on the global mean," Stevens said. "This could be the end."

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