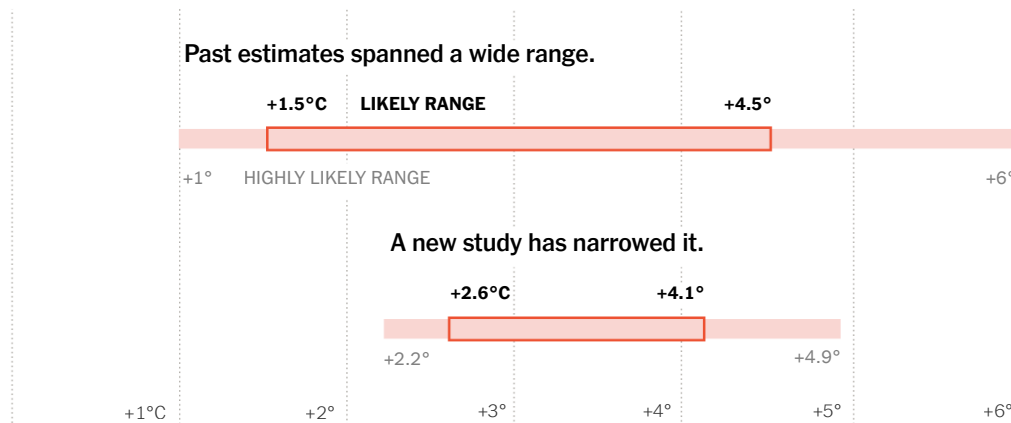


How Much Will the Planet Warm if Carbon Dioxide Levels Double?



Sources: Sherwood et al. in Reviews of Geophysics, IPCC • By The New York Times



By John Schwartz

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How much, exactly, will greenhouse gases heat the planet?

For more than 40 years, scientists have expressed the answer as a range of possible temperature increases, between 1.5 and 4.5 degrees Celsius, that will result from carbon dioxide levels doubling from preindustrial times. Now, a team of researchers has sharply narrowed the range of temperatures, tightening it to between 2.6 and 4.1 degrees Celsius.

Steven Sherwood, a climate scientist at the University of New South Wales in Sydney, Australia, and an author of the new report said that the group's research suggested that these temperature shifts, which are referred to as "climate sensitivity" because they reflect how sensitive the planet is to rising carbon dioxide levels, are now unlikely below the low end of the range. The research also suggests that the "alarmingly high sensitivities" of 5 degrees Celsius or higher are less likely, though they are "not impossible," Dr. Sherwood said.

What remains, however, is still an array of effects that mean worldwide disaster if emissions are not sharply reduced in coming years.

Masahiro Watanabe, a professor in the atmosphere and ocean research institute at the University of Tokyo and an author of the report, said that determining an accurate range of temperatures was critically important for international efforts to address global warming, like the Paris climate agreement, and for mitigating the effects of climate change.

“Narrowing the uncertainty is relevant not only for climate science but also for society that is responsible for solid decision making,” he said.

The new paper, published on Wednesday in the journal *Reviews of Geophysics*, narrowed the range of temperatures considerably and shifted it toward warmer outcomes. The researchers determined that there was less than a 5 percent chance of a temperature shift below two degrees, but a 6 to 18 percent chance of a higher temperature change than 4.5 degrees Celsius, or 8.1 degrees Fahrenheit.

If the effects of carbon dioxide are at the low end of the range or even below it, then climate change will be affected less by emissions and the planet will warm more slowly. If the Earth’s climate is more highly sensitive to carbon dioxide levels, then the expected results are not only more imminent, but also more catastrophic.

The scientists noted that the Earth’s temperature is already about 1.2 degrees Celsius above preindustrial levels, and that, if current emissions trends continue, the doubling of atmospheric carbon dioxide could happen well before the end of this century.

Andrew Dessler, a climate scientist at Texas A&M University, who was not an author of the report but who was one of its earlier outside reviewers, called the paper “a real tour de force,” adding that “this is probably the most important paper I’ve read in years.”



Dead livestock in Ethiopia in 2016. “Narrowing the uncertainty” about temperature

change is crucial for solid decision making, one of the report's authors said. Tiksa Negeri/Reuters

For many years, those who wished to underplay the threat of climate change have tried to say that the sensitivity is low, and so rising greenhouse gases would have little effect. And some recent climate models have suggested warming could be frighteningly worse.

The value of the paper, Dr. Dessler said, lies in the way that it narrows the probable range of temperatures the world can expect. "There were a number of people who were arguing the climate sensitivity was much lower, and a smaller number claiming it was much higher," he said, "and I think the case for either of those positions is a lot weaker now that this paper has been published."

That means that those who undercut the seriousness of climate change and the need for action have a much harder case to make now, Dr. Dessler said. "It would be great if the skeptics were right," he said. "But it's pretty clear that the data don't support that contention."

The paper, produced under an international science organization, the World Climate Research Program, brought together three broad fields of climate evidence: temperature records since the industrial revolution, records of prehistoric temperatures preserved in things like sediment samples and tree rings, as well as satellite observations and computer models of the climate system. None alone could determine the range, but the researchers found ways mathematically to reconcile the three disciplines to reach their conclusions.

"This paper is really the first to try and include all of those disparate sources of observational evidence in a coherent package that actually makes sense," said Gavin A. Schmidt, director of the NASA Goddard Institute for Space Studies and an author of the paper.

Another author on the paper, Gabriele Hegerl, a professor of climate system science at the University of Edinburgh, said that the way the threads of research came together was surprising: "We don't expect these three lines of evidence to agree completely," she said, but hoped they would "overlap." And they did, she said, so "our research is more robust than I initially expected."

Not everyone is prepared to accept the new results. Nicholas Lewis, an independent scientist who has been critical of aspects of mainstream climate research and who has found flaws in the work of others that led to the retraction last year of a major study on ocean warming, questioned the new paper's reliance on computer models to interpret the lines of evidence, as well as the group's definition of climate sensitivity itself. He also suggested that the paper ignored some possible complications from changes in clouds and convection.

Dr. Schmidt said that the new paper made all of the data and methodology available. "This is a real challenge to people who think the experts are wrong to go in, change the assumptions, run the code and show us their results," he said.

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Some degree of uncertainty about planetary warming is inevitable, said Zeke Hausfather, a scientist with The Breakthrough Institute and an author of the paper. But the current range is “not a good amount of warming at all,” he said, noting that eliminating the extremes still leaves a middle range that means climate disaster. “You don’t need five degrees of warming to justify climate action,” he said. “Three degrees is plenty bad.”

William Collins, a climate scientist at Lawrence Berkeley National Laboratory who was not involved with the study, praised the effort to tie together so much research into a single paper, but said that further advances in computing and data gathering would continue to drive the quest for answers. He compared climate sensitivity research to climbing Mount Everest and said: “This is an extremely important base camp. We are not at the pinnacle yet.”

John Schwartz is a reporter on the climate desk. In nearly two decades at The Times, he has also covered science, law and technology. [@jswatz](#) • [Facebook](#)