

A scientific consensus on climate change

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Luis Nakano programs watch faces for cell phones and tablets, including designs showing times of sunrise and sunset by location and date going back centuries. He fine-tunes for fluctuations in the Earth's axis of rotation and orbit, even deviations caused by volcanoes.

I asked him whether changes in the tilt of the Earth's axis of rotation or in its orbit account for a large share of global warming. No, he said, those changes are too tiny to match the effect of rising atmospheric carbon. He found my question strange. I explained that I was trying to take a fresh start at understanding what has caused global climate change, and my first step was to compare fluxes in insolation to trends in carbon dioxide.

Besides changes in the earth's orbit and the tilt of its axis, there are irregular sunspot cycles. When sunspot activity is high, insolation rises as well. But sunspots also turn out to be inconsequential compared to rising atmospheric carbon. Look at how temperatures have changed at different heights above the earth. Solar radiation heats both the low troposphere and the higher stratosphere. Carbon dioxide, in contrast, absorbs and scatters radiation from the surface of the earth. As a result, it heats the troposphere but cools the stratosphere by absorbing infrared radiation from the Earth before it reaches stratospheric levels.

Temperature measurements, along with experiments on radiative absorption by carbon dioxide, settle the debate in favor of carbon. The troposphere has become hotter while the stratosphere has cooled. That's hard to explain with increased solar radiation.

As a second step in my quest for a fresh look at global warming, I read the 2016 edition of "Global Physical Climatology" by Dennis Hartmann, reasoning that a technically advanced textbook would be constrained in what it could say. Before studying climatology at the graduate level, students learn chemistry, physics and math. Thus the author of an advanced text must match later chapters on climate change to the basic science of earlier chapters on the global energy balance, radiative transfer and the components of the atmosphere. Whatever authors write about climate change must be coherent with the science of their foundation sections.

After 12 earlier chapters, Hartmann opens his chapter "Anthropogenic Climate Change" with a statement that "human activities are leading to a global climate change that may produce a mean surface temperature on Earth as warm as any for more than a million years." In a lengthy chapter full of chemistry, physics, equations and data, he shows that humans have been by far the major cause of warming from 1750 to today.

As my third step I asked, what do climatologists in general think? Here I wanted the views of people who are thoroughly grounded in the science of climate and not, for example, weather forecasters. For this I turned to a report in *Environmental Research Letters* by John Cook and Dana Nuccitelli. Counting thousands of abstracts in refereed journals, they report that “there is a 97 percent consensus in the peer-reviewed climate science literature that humans are causing global warming.” Since it is remotely imaginable that such a consensus could arise from a quest for research funding or shared political views, instead of data-driven analysis, I mention that economists of skill and integrity, such as William Nordhaus and Martin Weitzman, also think humans are the chief cause of recent warming.

Reports by the National Academy of Sciences merit confidence. In a joint statement with the British Royal Society, the Academy says, “It is now more certain than ever, based on many lines of evidence, that humans are changing Earth’s climate.” The International Panel on Climate Change, whose previous forecasts when not willfully misinterpreted have been on target, says that it is “extremely likely” that the majority of climate change in the past century has been caused by human activities. I feel free to ignore, in contrast, statements by Al Gore, the Union of Concerned Scientists, the Cato Institute and Scott Pruitt, the new head of the Environmental Protection Agency.

Some features of climate change that remain poorly understood just might — might — prove to be our salvation. Those include the slightly growing Antarctic ice cap and the long-run dynamics of heat transfer to the deep ocean. But as Fox News (yes, Fox News) asked Pruitt regarding massive proposed cuts to the EPA budget and his skepticism about carbon dioxide, “What if you’re wrong?” What if the rest of the world is right?