Models, observations not so far apart on planet's response to greenhouse gas emissions

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Credit: public domain

How hot our planet will become for a given amount of greenhouse gases is a key number in climate change. As the calculation of how much warming is locked in by a given amount of emissions, it is crucial for

global policies to curb global warming.

It is also one of the most hotly debated numbers in climate science. Observations in the past decade seem to suggest a value that is lower than predicted by models. But a University of Washington study shows that two leading methods for calculating how hot the planet will get are not as far apart as they have appeared.

In climate science, the climate sensitivity is how much the surface air temperature will increase if you double carbon dioxide from pre-Industrial levels and then wait a very long time for the Earth's temperature to fully adjust. Recent observations predicted that the climate sensitivity might be less than that suggested by models.

The new study, published April 17 in *Nature Climate Change*, focuses on the lag time in Earth's response. According to most models of climate change, during the early stages of global warming the sensitivity to greenhouse gas emissions is relatively small. As the ocean catches up and feedbacks kick in, however, the sensitivity increases and the warming rate speeds up. The new study shows that when this difference is factored in, the observations and climate models are in agreement, with recent observations supporting a previously accepted long-term climate sensitivity of about 2.9 degrees Celsius.

"The key is that you have to compare the models to the observations in a consistent way," said author Kyle Armour, a UW assistant professor of oceanography and atmospheric sciences. "This apples-to-apples approach—where you factor in how long the planet has been adjusting to a change in its atmosphere—shows that climate sensitivity in the models is actually in line with what has been seen in the recent observations."

The planet's temperature takes thousands of years to fully adjust to a shift in the makeup of its atmosphere—the warming Earth has

experienced to date is just a taste of what is in store. Early climate studies suggested that if the amount of carbon dioxide in the atmosphere doubled from pre-Industrial levels (we're now about 1.4 times) the planet would eventually warm by about 3 degrees C, with possible values as high as 5 or 6 degrees C.

But recent observations of warming so far and emissions to date have suggested that climate sensitivity may be just under 2 degrees Celsius, with a maximum possible value of 4 degrees C.

"If true, this really would be a shift in our understanding of the long-term climate sensitivity," Armour said. For the new study, Armour looked at 21 leading global climate models run with increasing carbon dioxide. He focused on the warming rate compared to carbon dioxide levels, or climate sensitivity, in the early stages compared with in the late stages. The late-stage sensitivity across all the models was an average of 26 percent higher than the early-stage values. When factoring in that today's observations are for the early stages of warming, the recent observations support a climate sensitivity of 2.9 degrees Celsius.

"There have been a lot of other papers that looked at the reasons for the changes in climate sensitivity over time," Armour said. "This paper was the first attempt to quantify the effect across all the comprehensive models we use for climate prediction."

The situation can be likened to pressing the gas pedal on a car, but the mass of the vehicle takes a while to get rolling. If the driver floors the gas pedal, it can be tricky to calculate the car's final speed based on its initial reaction.

In the Earth system, the ocean temperatures around Antarctica and in the eastern Pacific Ocean have not risen in recent decades. Armour's previous research showed that deep, slow currents mean seawater

touched by climate change will take centuries to reach the surface of the Southern Ocean. Similar but less extreme, currents reaching the eastern tropical Pacific from below the surface have also not seen daylight for decades.

Eventually, water touched by a warmer atmosphere will reach the eastern tropical Pacific and later the Southern Ocean. Warming in these regions will then activate feedbacks that will kick the planet's warming into a higher gear."Currently we don't have any evidence that the models are too sensitive compared to the observations," Armour said. "The models appear to be in line with the observed range of warming."

The various climate models show a wide range of values between the early-stage and late-stage sensitivities. Armour and students are exploring why these differences between the models exist, in order to improve them and better model how climate sensitivity shifts over time.

More information: Energy budget constraints on climate sensitivity in light of inconstant climate feedbacks, *Nature Climate Change* (2017). nature.com/articles/doi:10.1038/nclimate3278

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