How sensitive is the climate to added CO_2?

65 million years of Earth's history suggest we're in uncharted territory.

by **John Timmer** - Nov 28 2012, 11:40pm GMT

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JPL/NASA

As recent events have shown, even the World Bank is trying to understand the trajectory of future climate changes. Although there are a number of ways of doing this, many organizations rely on a measure called the climate sensitivity. It's a bit rough, but it's simple: it provides a value for the temperature increase we'd expect given a doubling of CO_2.

Currently, the Intergovernmental Panel on Climate Change places this value between 2 and 4.5°C, with a most likely value of about 3°C. But a variety of studies have come up with measurements spread around that range, and nailing down the likely upper limit has been a challenge. Now, a large group of researchers has gone through millions of years of data on the Earth's past, incorporating information from a number of past studies. In the end, the group decided that the IPCC estimates are more or less on target.

Adding more carbon dioxide to the atmosphere doesn't drive temperatures in a linear manner. You can think of this in terms of the infrared photons they absorb: each one can only be absorbed once, and the more CO_2 molecules you add, the more likely it is that an existing one would have absorbed that photon anyway. As a result, each doubling of carbon dioxide concentrations are expected to have roughly an equivalent impact.

What exactly is that impact? It's possible to calculate it from first principles. Put all the known forces and feedbacks into a climate model, double the CO_2, and see what it produces after it reaches an equilibrium. That has been the method of choice for the IPCC, but the different climate models it uses produce a range of values, which is why its estimate runs from 2.1 to 4.4 K.

The alternative approach is to try to measure the climate sensitivity displayed by the planet during periods of major climate change in the past. Unfortunately, these estimates don't always agree with the IPCC's; even more unfortunately, they don't always agree with each other. Those disagreements are what prompted a large collaboration of researchers called the PALAEOSENS project to try to figure out what was going on.

Part of the problem with historic reconstructions is simply that we don't have all the data we'd like. Ice

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cores cover the last 800,000 years or so very well, and the gas bubbles trapped within provide a reasonable estimate of global atmospheric content. But they only capture the local temperatures well. And once you get beyond the ice cores, you have to rely on proxies for most of the data you want. Right now, we simply don't good proxies for some things, such as levels of methane, a potent greenhouse gas.

Another problem is that the Earth is a dynamic system. Some responses to rising temperatures are fairly rapid, such as the loss of snow cover (which has a cooling effect by reflecting sunlight back to space). Others are far more gradual. Oceans, for example, act as a giant heat sink that can slow down any warming for centuries. That makes nailing down the long-term equilibrium response very difficult. As the authors put it, "the timescales to reach this [climate] equilibrium are long, so... the forcing normally changes before equilibrium is reached."

Confusing matters even further, different papers have used subtly different methods of defining the climate sensitivity.

So, the team went back and reanalyzed a variety of existing studies using a single definition of climate sensitivity and separating rapid climate responses to changes in greenhouse gasses from the longer-term response needed for the climate to reach an equilibrium. The authors estimate that rapid responses account for about two-thirds of the total change in temperature and typically occur within 100 years.

With the reanalysis, a couple of things become clear. One is that the climate sensitivity varies over time. This was already known to a certain extent, in that the configuration of the continents can influence the climate independently of atmospheric and orbital influences. in this new analysis, the variability was also apparent in the ice cores, which cover only the last 800,000 years during which the continents were in roughly their current configuration. The changes are small—within about a half-Kelvin—but they indicate that the climate sensitivity is itself sensitive to the initial conditions on the planet.

Extending the analysis out to 65 million years, the authors calculate that there's about a 70 percent probability the IPCC has it right. More specifically, their 68 percent confidence range ran from 2.2 to 4.8 K; the 95 percent confidence interval was a bit broader, but it encompassed the IPCC's range.

More disturbingly, however, they calculate that we can go back to roughly when the dinosaurs died off and not see another period like the present: "Present-day atmospheric GHG [greenhouse gas] concentrations and the radiative perturbation due to anthropogenic emissions increase much faster than observed for any natural process within the Cenozoic era." We really do seem to be into uncharted territory here.

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joshv | Ars Scholae Palatinae 14 days ago

"More specifically, their 68 percent confidence range ran from 2.2 to 4.8 K; the 95 percent confidence interval was a bit broader, but it encompassed the IPCC's range."

What was the range of the 95 percent confidence interval? Any reason you didn't quote it?

Also, why is a 68 percent confidence interval used? Is this a standard confidence range used in climate science?

(Edited for clarity as my questions were widely misunderstood).

Last edited by joshv on Wed Nov 28, 2012 6:55 pm

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