Climate-change ‘fingerprint’ is identified in the upper atmosphere

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It's colder up there: a new study confirms an important fingerprint of anthropomorphic climate change. (Courtesy: iStock/magann)

A new study has confirmed that the predictions of climate-change models agree with observations of the atmosphere made at altitudes up to 50 km above Earth’s surface. The research focusses on an important “fingerprint” of human-driven climate change, whereby the lower part of the atmosphere gets hotter as carbon dioxide levels rise, whereas the upper part gets colder. The findings do not surprise experts in the field, but they provide further confirmation that climate change is caused by humans, as well as detailed information that can be used to refine future models.

Earth could not support life if atmospheric gases such as carbon dioxide and water vapour did not raise its black-body temperature by trapping infrared radiation, behaving much like greenhouse glass. The first concerns that fossil fuel-derived carbon dioxide might enhance this greenhouse effect came in 1896 from Svante Arrhenius (who would later win the 1903 Nobel Prize for Chemistry for unrelated work), but these were largely speculative.

In 1967, however, Syukuro Manabe at the Geophysical Fluid Dynamics Laboratory in Washington DC – who shared the 2021 Nobel Prize in Physics for his work on modelling global warming – used an early computer model to make concrete predictions about the

effect of rising carbon dioxide levels.

Famous paper

“In a famous paper that was specifically called out by the Nobel Prize committee, he raised carbon dioxide levels from 150 to 300 to 600 parts per million, and he saw this very curious phenomenon in which the lower atmosphere – the troposphere – warmed, whereas the upper atmosphere – the stratosphere – cooled,” explains Benjamin Santer of Woods Hole Oceanographic Institution and University of California, Los Angeles. This is principally because most of the carbon dioxide remains in the troposphere and – wrapped in a thicker blanket – Earth radiates less heat into the stratosphere.

Data from weather balloons and, more recently, satellites showed warming in the troposphere and limited cooling in the lower stratosphere (above around 16 km). Most weather balloons burst above 25 km, however, and early satellite datasets diverged markedly. This made it difficult to compare models and observations above 25 km, where Manabe had predicted that cooling would be strongest. Now, however, agreement is better.

In the new work, Santer and colleagues around the world compared satellite observations from three groups made between 1986 and 2022 with state-of-the-art computational climate models, before using a “vertical fingerprinting” technique developed by Klaus Hasselmann – the founding director of the Max Planck Institute for Meteorology in Germany and one of Manabe’s co-recipients of the 2021 Physics Nobel Prize – to determine whether the data showed clear evidence of anthropogenic carbon dioxide emissions or whether they were consistent with other explanations.

Stronger signal

The higher-altitude data assisted the researchers not just because the signal is stronger at higher altitudes, but also because the noise from other sources such as sulfate emissions from coal burning and the dramatic effect of the eruption of Mount Pinatubo in 1991 becomes weaker. Moreover, ozone is a greenhouse gas, which has been drastically depleted in the lower stratosphere by CFCs. These were phased out by the Montreal protocol in 1987 and the ozone layer is now recovering. This can confound measurements in the lower stratosphere. “Above 25 km, though, you’re looking predominantly at human-caused carbon dioxide changes,” says Santer.

Including the higher-altitude data increased the signal-to-noise ratio by a factor of around five relative to previous studies, providing incontrovertible evidence of anthropogenic climate change. The effects appear smaller than current computer models predict, but even if the average warming trend was subtracted, a statistically significant signal could be detected from the difference between the temperatures of the two atmospheric layers. The research is described in *Proceedings of the National Academy of Sciences*.

“It’s a very nice paper, but I wasn’t surprised by the results,” says Keith Shine of the University of Reading in the UK; “If you go back 15 or 20 years you could separate models into those that simulated the troposphere well and those that simulated the stratosphere well. More recently models – particularly the ones used in this study – are more unified. It just reinforces what was already in the literature.” He suggests that future work could focus on separating out the contributions of different greenhouse gases, which are not treated separately in all the models available to the researchers.

Consilience of evidence

“In theory, someone could have done this detection and attribution study for at least the past decade, but this is the first study that’s really tried to look at it,” agrees Peter Thorne of Maynooth University in Ireland. “The more pieces of evidence you bring in, the more and more damning the evidence becomes. There have been detection and attribution studies on deep ocean heat content, on humidity, on a whole host of variables. So it’s really the consilience of evidence of who the perpetrator of the crime is. This is just one more indelible fingerprint that leaves you in no doubt whatsoever that humans are responsible.”