Global satellite data shows clouds will amplify global heating

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A new approach to analyze satellite measurements of Earth's cloud cover reveals that clouds are very likely to enhance global heating.

The research, by scientists at Imperial College London and the University of East Anglia, is the strongest evidence yet that clouds will amplify global heating over the long term, further exacerbating climate

change.

The results, published today in *Proceedings of the National Academy of Sciences*, also suggest that at double atmospheric carbon dioxide (CO_2) concentrations above pre-industrial levels, the climate is unlikely to warm below 2°C, and is more likely on average to warm more than 3°C.

Pre-industrial CO_2 levels were around 280 ppm (parts per million), but current levels are approaching 420 ppm, and could approach double the pre-industrial amount by mid-century if significant emissions cuts are not made. The amount of climate warming predicted from a doubling of pre-industrial CO_2 levels is known as the 'climate sensitivity' - a measure of how strongly our climate will react to such a change.

The largest uncertainty in climate sensitivity predictions is the influence of clouds, and how they may change in the future. This is because clouds, depending on properties such as their density and height in the atmosphere, can either enhance or dampen warming.

Co-author Dr. Paulo Ceppi, from the Grantham Institute—Climate Change and the Environment at Imperial, said: "The value of the climate sensitivity is highly uncertain, and this translates into uncertainty in future global warming projections and in the remaining 'carbon budget' - how much we can emit before we reach common targets of 1.5°C or 2°C of global warming.

"There is therefore a critical need to more accurately quantify how clouds will affect future global warming. Our results will mean we are more confident in climate projections and we can get a clearer picture of the severity of future climate change. This should help us know our limits—and take action to stay within them."

Low clouds tend to have a cooling effect, as they block the sun from

reaching the ground. High clouds, however, have a warming effect, as while they let solar energy reach the ground, the energy emitted back from the Earth is different. This energy can be trapped by the clouds, enhancing the greenhouse effect. Therefore, the type and amount of cloud a warming world will produce impacts further warming potential.

Inspired by ideas from the artificial intelligence community, the researchers developed a new method to quantify relationships between state-of-the-art global satellite observations of clouds, and the associated temperature, humidity and wind conditions. From these observed relationships, they were then able to better constrain how clouds will change as the Earth warms.

They found it was very likely (more than 97.5% probability) that clouds will amplify global heating, by both reflecting less solar radiation and enhancing the greenhouse effect. These results also suggest that a doubling of CO_2 concentrations will lead to around 3.2°C of warming. This is the highest confidence of any study so far, and is based on data from global observations, rather than local regions or specific cloud types.

Co-author Dr. Peer Nowack, from the School of Environmental Sciences and Climatic Research Unit at the University of East Anglia and Imperial's Grantham Institute and Data Science Institute, said: "Over the last few years, there's been a growing amount of evidence that clouds probably have an amplifying effect on global warming. However, our new approach allowed us for the first time to derive a global value for this feedback effect using only the highest quality satellite data as our preferred line of evidence.

"Our paper makes a major step towards narrowing the most important uncertainty factor in climate sensitivity projections. As such, our work also highlights a new pathway in which machine learning methods can

help us constrain the key remaining uncertainty factors in climate science."

More information: Paulo Ceppi el al., "Observational evidence that cloud feedback amplifies global warming," *PNAS* (2021). www.pnas.org/cgi/doi/10.1073/pnas.2026290118

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