Identifying Uncertainties in Climate Models

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A view of Hurricanes Jose, Irma, and Katia swirling across Earth's Northern Hemisphere in September 2017. Scientists are working to unravel just how the spatial patterns of climate change vary from the equator to the poles. Credit: NASA

The enduring consensus among scientists is that Earth's climate is warming because of human activity. But exactly how climate change will manifest at regional scales remains a topic of discussion; in particular, scientists are interested in unraveling how the spatial patterns of climate change vary from the equator to the poles. These "meridional" patterns (moving north–south) are important in understanding the future of our planet, but climate models often do not agree on the exact magnitude of warming at each latitude. Future warming in the Arctic and Antarctic, for instance, is particularly uncertain.

Bonan et al. aim to investigate out why climate models disagree on these warming patterns. To start, the researchers used a simplified model known as a moist energy balance model (MEBM) to simulate how energy is transported through the atmosphere from the warm tropics to the cold poles. In a scenario in which carbon dioxide (CO_2) was abruptly quadrupled relative to preindustrial levels, they found that this simple model could explain 90% of the variance in local surface warming seen in more complex global climate models.

Once satisfied that the MEBM could capture the uncertainty in warming predictions made by global climate models, the researchers began to identify the variables that contributed most to the spread in warming patterns. They focused on three variables that regulate the balance between energy absorbed from the Sun and energy reflected back into space: radiative feedbacks, ocean heat uptake, and top-of-the-atmosphere radiative forcing from CO_2. Their analysis showed that radiative feedbacks account for 70% of the total uncertainty in the meridional pattern of warming.

Next, the researchers broke down the feedbacks into individual components, specifically, how surface albedo, combined lapse rate and water vapor, and net cloud feedbacks influence warming uncertainty. They concluded that among these subcategories, cloud feedbacks are the main driving factor behind uncertainty in the pattern of warming. Because clouds are some of the hardest processes to represent in global climate models, each model has a completely different pattern of cloud feedbacks that can result in either positive or negative values at different latitudes.

Despite the challenges that cloud feedbacks present, the researchers assert that understanding these processes better is vital to understanding the pattern of climate change on Earth. Their work here shows that uncertainty surrounding how clouds change in the tropics leads to warming uncertainty at all latitudes through changes in poleward energy transport but that uncertainty in polar processes results in warming uncertainty that is confined to the poles. This fact, the researchers say, makes the polar regions of the planet, which are important determinants of global climate, particularly uncertain because they aggregate uncertainty from distant feedbacks in the tropics and from strong local feedbacks.

The team concludes that studies like this will become more important as global climate models continue to become increasingly complex and their sources of uncertainty become increasingly obfuscated. (*Geophysical Research Letters,* https://doi.org/10.1029/2018GL079429, 2018) **—David Shultz, Freelance Writer**