Method fills gaps in monsoon understanding

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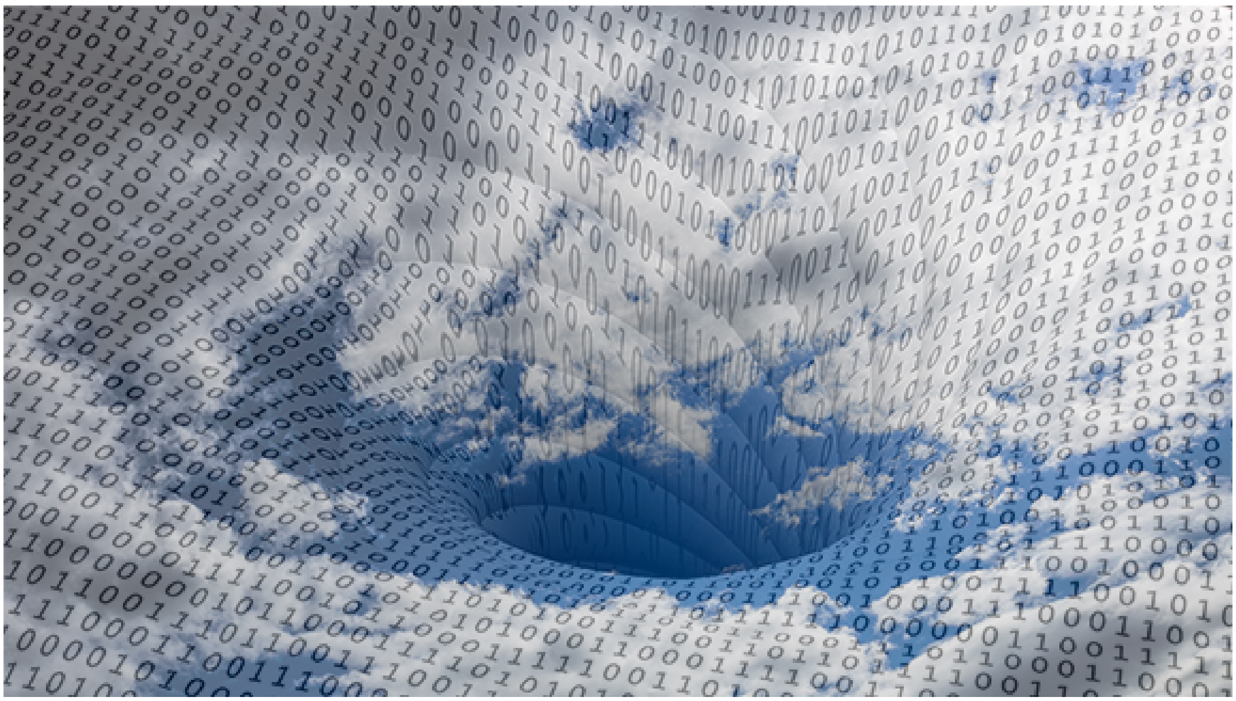

Scientists quantified the gaps in climate modeling to better understand complex cloud and aerosol particle interactions. By using a computational technique called uncertainty quantification, they are able to do just that.

Dwindling monsoon rain is a big deal for millions in East Asia who rely on the storms for their yearly water supply. Scientists at Pacific Northwest National Laboratory uncovered some culprits most likely to have the largest impact on the monsoon changes. And they did so using a modeling technique—called "uncertainty quantification," or UQ for short—to zero in on the data. Using this technique, they found that sulfur-containing compounds from fossil fuel use, soot, and dust particles have very different impacts on the monsoon climate, and not always in a linear way.

"Our team used a UQ technique that systematically gathers and analyzes the model's reactions to the most uncertain factors around clouds, aerosol particles, and how they interact," said Dr. Yun Qian, atmospheric scientist and climate modeler at PNNL. "By filling in the gaps in data, our approach enabled us to identify the particles with the most significant impact on the East Asian monsoon."

Anyone who has endured a dust storm, or an "air quality alert," can describe the tangible effects. The day seems cooler than normal, the air seems harder to breathe and the overall effect feels confining and stuffy. These can be seen and felt by humans. But what happens above us in the sky? How do these incidents affect weather and climate? Are there long-term effects?

In East Asia, especially China, there are severe dust storms and heavy pollution days from different sources. The air gets loaded with tiny particles of sulfuric acid and other sulfates, mineral dust, and soot particles that clog lungs and air filters alike. They also "clog" clouds. These particles change how much of the sun's energy reaches the surface and how much is absorbed or bounced around the atmosphere. They also change cloud conditions, transforming the type of cloud or how the cloud reacts to water vapor, and they can modify how well clouds can produce rain or snow. Climate modelers want to quantify these changes to understand which effects are more severe or variable. But the problem is complex because they are trying to "count" something that is extremely variable.

Imagine gathering data on an alphabetic scale. When modeling the atmosphere, very often the complexity of the model and variability of the atmospheric parts only allows answers 'A' and 'Z'. This may cause an unrealistic picture. Scientists in this study used advanced computational techniques to fill in-between, with 'B' through 'Y' data points in the wide range of possibilities. Using this UQ technique to quantify those gaps resulting from the introduction of the particles themselves and the interactions between the particles and clouds means they can better understand where the widest range of gaps exist. By quantifying the "gaps" they can determine where the greatest "fill in" must occur to understand these complex systems.

The research team led by scientists at PNNL used a UQ framework that integrated a sampling approach and a surrogate model to analyze the sensitivity of the aerosol effects on the East Asian climate. They ran 256 ensemble simulations in the Community Atmosphere Model v5, and analyzed them for insights into the responses of uncertainty ranges of those parameters that deal with cloud microphysics and the strength of aerosol particle emissions, and the interactions between those aerosol particles and clouds. They focused on the effects of sulfate particles, soot (black carbon), and mineral dust, the three most prevailing and important aerosol types over East Asia.

This study simulated the so-called "fast" response of aerosol particle effects, and used prescribed information for sea surface temperature. The full range of aerosol particle effects must be calculated in models that couple both atmosphere and ocean. But in today's models, those calculations may be too computationally expensive to run for studies that require a large number of simulations. And this study only tackled one type of cloud, called stratus, which are low-level, fog-like clouds. Storm-forming clouds called "convective" will be included in future studies.

More information: Huiping Yan et al. A new approach to modeling aerosol effects on East Asian climate: Parametric uncertainties

associated with emissions, cloud microphysics, and their interactions, *Journal of Geophysical Research: Atmospheres* (2015). DOI: 10.1002/2015JD023442

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