KYUSHU UNIVERSITY

Public Relations Initiative, Kyushu University
744 Motooka Nishi-ku Fukuoka, 819-0395
TEL: +81-92-802-2443 FAX: +81-92-802-2139
E-MAIL: sysintlkh@jimu.kyushu-u.ac.jp
URL: https://www.kyushu-u.ac.jp

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Clouding the forecast: study reveals why so many climate models are wrong about the rate of Arctic warming

The key may lie in wintertime Arctic clouds, as climate models underestimate how much liquid they contain and how much heat they trap, leading to skewed warming predictions.

Fukuoka, Japan—The Arctic is one of the coldest places on Earth, but in recent decades, the region has been rapidly warming, at a rate three to four times faster than the global average. However, current climate models have been unable to account for this increased pace.

Now, two researchers from Kyushu University, graduate student Momoka Nakanishi, from the Interdisciplinary Graduate School of Engineering Sciences, along with her adviser, Associate Professor Takuro Michibata, from the Research Institute for Applied Mechanics, have reported in a study, published April 29 in *Ocean-Land-Atmosphere Research*, that clouds may be to blame.

The most common clouds found in the Arctic are mixed-phase clouds, which contain both ice crystals and supercooled liquid water droplets. In the Arctic summer, when the sun shines around the clock, these clouds act like a parasol, reflecting sunlight back into space and providing a cooling effect. But in the long, dark Arctic winter, when there's no sunlight to reflect, these clouds act more like a blanket, trapping heat that's radiated from the Earth's surface and sending it back down to the Arctic's surface.

"However, how well these mixed-phase clouds trap heat depends on their ratio of ice to liquid," explains Nakanishi. "The more liquid water the clouds contain, the better they are at trapping heat. But many climate models have a large bias in representing this ratio, causing incorrect predictions."

In this study, Nakanishi and Michibata analyzed 30 climate models and compared them to satellite observations of clouds in the Arctic during winter over the last decade. They found that 21 of the 30 models significantly overestimated the fraction of ice to liquid in wintertime Arctic clouds.

"These ice-dominant models are not properly accounting for the present-day warming potential of the clouds during the winter," says Nakanishi. "That's why they cannot account for the rapid warming we are currently seeing."

However, every cloud has a silver lining. While climate models are underestimating the rate of global warming in the present day, they are overestimating the rate of global warming in the future.

The errors in future projections are due to a process called "cloud emissivity feedback". In a nutshell, as the Arctic warms, clouds shift from containing mostly ice to more liquid, which increases their ability to trap heat, further warming the Arctic and creating a positive feedback

loop.

But importantly, this feedback loop has a time limit. Once clouds become so rich in liquid that they behave like blackbodies—fully absorbing and re-emitting heat—further warming has less effect.

However, because many climate models underestimate how much liquid is already present in today's clouds, they assume a larger shift still lies ahead. As a result, they overestimate how much extra heat-trapping will occur in the future, and predict the feedback effect will last longer than reality suggests.

Moving forward, the study's findings could be used to refine climate models so that they provide a more accurate representation of the ice-to-liquid ratio within clouds and better predictions of current and future rates of Arctic warming.

Since the Arctic's climate also plays a key role in shaping weather patterns further south, these findings could also lead to more accurate forecasts of extreme weather in mid-latitude regions.

"The biggest uncertainty in our forecasts is due to clouds," concludes Michibata. "Fixing these models is essential not just for the Arctic, but for understanding its impact on weather and climate change across the globe."

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For more information about this research, see "How Does Cloud Emissivity Feedback Affect Present and Future Arctic Warming?" Momoka Nakanishi and Takuro Michibata, *Ocean-Land-Atmosphere Research,* https://doi.org/10.34133/olar.0089

About Kyushu University

Founded in 1911, Kyushu University is one of Japan's leading research-oriented institutes of higher education, consistently ranking as one of the top ten Japanese universities in the Times Higher Education World University Rankings and the QS World Rankings. The university is one of the seven national universities in Japan, located in Fukuoka, on the island of Kyushu—the most southwestern of Japan's four main islands with a population and land size slightly larger than Belgium. Kyushu U's multiple campuses—home to around 19,000 students and 8000 faculty and staff—are located around Fukuoka City, a coastal metropolis that is frequently ranked among the world's most livable cities and historically known as Japan's gateway to Asia. Through its VISION 2030, Kyushu U will "drive social change with integrative knowledge." By fusing the spectrum of knowledge, from the humanities and arts to engineering and medical sciences, Kyushu U will strengthen its research in the key areas of decarbonization, medicine and health, and environment and food, to tackle society's most pressing issues.

Fig. 1. The Arctic is warming at a rate three to four times faster than the global average.
Credit: 2012 RUSALCA Expedition, RAS-NOAA | Kate Stafford

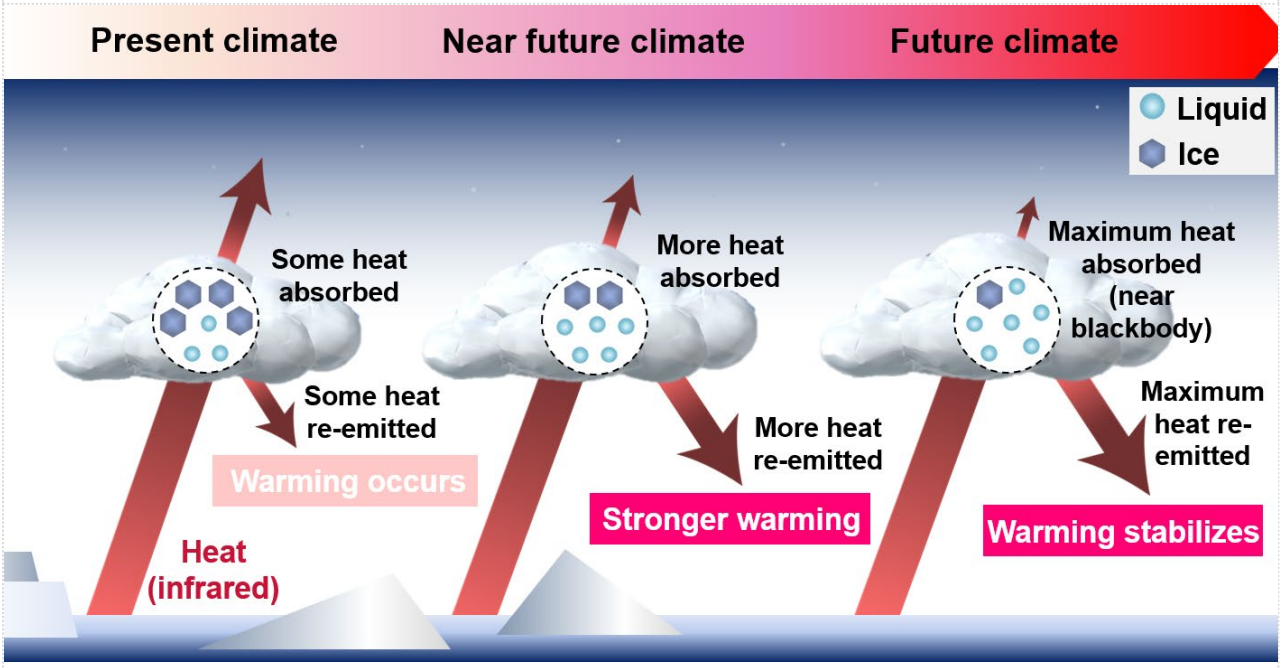

Fig. 2. In the present climate, mixed-phase clouds have a slightly larger ice-to-liquid ratio. As the climate warms, more ice shifts to liquid, increasing the amount of heat emitted from the clouds, leading to an increased warming effect. However, in the future, clouds will contain enough liquid that the heat emitted reaches a maximum, stabilizing the warming effect.
Credit: Takuro Michibata/Kyushu University

[Contact]
Takuro Michibata, Associate Professor
Research Institute for Applied Mechanics
Tel: +81-92-583-7680
E-mail: michibata@riam.kyushu-u.ac.jp