A Minimalist Approach to Modeling Complex Arctic Clouds

Research Highlight

Mixed-phase stratiform clouds are common features in the Arctic environment. They contain a mix of ice and "supercooled" water that, despite the freezing temperatures, remains in liquid form. Scientists aren't sure why these clouds exist in the Arctic for long periods of time, even while steadily losing ice particles through precipitation.

To study these questions, researchers sponsored by DOE's Atmospheric System Research program developed a "minimalist" analytical model to closely examine ice in mixed-phase clouds. The model establishes the minimum number of physical assumptions necessary to reasonably explain the persistence of ice over long periods of time, while still providing a reasonable estimate of the ice crystal mass and precipitation rate.

The model, which assumes horizontally uniform and steady state conditions in which the cloud's ice crystal formation rate is balanced by precipitation rates, paints a picture of activity within a cloud. It gives a sense of how ice crystals form, grow (through vapor deposition) and settle, and their movement within and ultimately out of the cloud. These processes are influenced by factors such as the weight of the crystals and updrafts within the cloud.

For their study, researchers drew upon cloud property data obtained over Barrow, Alaska, during the Indirect and Semi-Direct Aerosol Campaign (ISDAC). The new model's predictions were evaluated against both ISDAC field observations and a large-eddy simulation (LES) cloud model.

The researchers determined that the minimalist model could successfully describe essential features of ice microphysical properties of mixed-phase clouds. Specifically, the model reveals a linkage between the number and mass of ice crystals falling from the cloud, with the linkage emerging as ice crystals grow while suspended in updrafts. The predicted linkage appears in LES and ISDAC results and suggests, remarkably, that the one-dimensional model can capture some statistical properties of three-dimensional clouds.

In the future, the model could be used to study the ice formation process, and similar models could help bridge laboratory investigations and complex field and cloud model observations. The new model also could be of value to larger-scale models in need of a physically based connection between cloud dynamics, ice nucleation and the cloud microphysical properties that impact precipitation, cloud lifetime and cloud optical properties.

Nordic winter landscape.

Reference(s)

Yang F, M Ovchinnikov, and RV Shaw. 2013. "Minimalist model of ice microphysics in mixed-phase stratiform clouds." Geophysical Research Letters, 40(14), doi:10.1002/grl.50700.

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Cloud Life Cycle