Estimating the Ice Crystal Enhancement Factor in the Tropics

Research Highlight

Recent studies reveal that ice nuclei (IN), a class of aerosol particles, can significantly affect clouds via ice crystal concentration (ICC), which in turn impacts radiation and further global warming. To quantify the effect of IN variability on global warming, it is imperative to know other dominant factors of ICC besides IN.

ICC can exceed IN concentration significantly via natural ice crystal enhancement processes. Since the ice crystal enhancement (IE) factor, defined as the ratio of ICC to the concentration of active IN in an air parcel, varies greatly from one cloud to another, how to obtain its climatological characteristics (e.g., ensemble average, geographic distribution) is of great interest. In this study, the IE factor is inferred by comparing long-term cloud-resolving model (CRM) simulations with field campaign remote sensing observations in the tropics and middle latitudes.

Cloud ensembles and radiation are sensitive to the IE factor. If a cloud simulation with an assumed IE factor can be made to match the associated observations, then the IE factor should be a better inference of the in situ one. This approach is applied to estimate the IE factor over various geographic regions, using observations from field campaigns such as the Tropical Warm Pool – International Cloud Experiment (TWP-ICE) and observations gathered at the Atmospheric Radiation Measurement Climate Research Facility Southern Great Plains site (ARM-SGP).

Figures 1 and 2 display the vertical profiles of retrieved and modeled ice water contents (IWCs) for ARM-SGP and TWP-ICE cases, respectively. Since the upper-tropospheric IWCs from the observations are reliable (in terms of the retrieval algorithm and observational sampling), they are compared with model results to infer in situ ICC or IE factor. The comparison of the two figures indicates that the IE factor (or ICC) in tropical clouds (e.g., TWP-ICE) is about 10^3 times larger than that in midlatitudinal ones (e.g., ARM-SGP).

This significant decrease in the IE factor with increasing latitude makes physical sense. Fine cloud dynamic structures (e.g., convective downdrafts) can affect the IE factor greatly by bringing new ice particles originated from heterogeneous (or even homogeneous) ice nucleation at colder temperatures down to warmer temperatures. As a result, the frequent downdrafts or strong vertical mixing in the tropics bring about the large IE factor there.

In summary, the present study revealed that the IE factor in tropical clouds is about 10^3 times larger than that in midlatitudinal ones, which suggests that climate models should represent not only IN but also the IE factor in modeling the effect of IN variability on global warming.

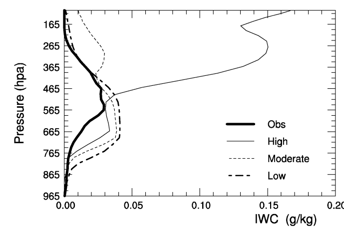

Figure 1. Twenty-day mean vertical profiles of IWC from the ARM-SGP observations and the three simulations using low, moderate, and high ice crystal concentrations, respectively.

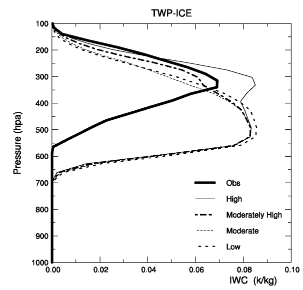

Figure 2. Eight-day mean vertical profiles of IWC from the TWP-ICE observations and the four simulations using low, moderate, moderately high, and high ice crystal concentrations, respectively.

Reference(s)

Zeng X, W Tao, T Matsui, S Xie, S Lang, M Zhang, DO Starr, and X Li. 2011. "Estimating the ice crystal enhancement factor in the tropics." Journal of the Atmospheric Sciences, 68(7), doi:10.1175/2011JAS3550.1.

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Cloud Life Cycle, Cloud-Aerosol-Precipitation Interactions