Impact of Small Ice Crystals on Ice Sedimentation Rates in Cirrus Clouds and GCM Simulations

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Research Highlight

Recent research shows that surface temperatures predicted by Global Climate Models (GCMs) depend mostly on two physical parameters; the efficiency by which clear air is mixed into thunderstorms (i.e., entrainment) and the fall speed of ice particles in cirrus clouds. Our research demonstrates the dependence of the representative ice fall speed on the concentration of relatively small ice crystals. These are difficult to measure and their concentrations are highly uncertain. But more importantly, it relates differences in small ice crystal concentration directly to GCM predictions of climate.

The Community Atmosphere Model version 3 (CAM3) was implemented with new parameterizations regarding ice cloud size distributions, sedimentation rates and optical properties, with all three of these developed under the ARM Program. The ice fall speed and optical property schemes will become part of CAM4. Two different temperature-dependent parameterizations of the ice particle size distribution producing different estimates for small ice crystal concentrations were used. Two 1-year CAM3 simulations (one size distribution scheme per simulation) were performed to examine the model's sensitivity to small ice crystal assumptions.

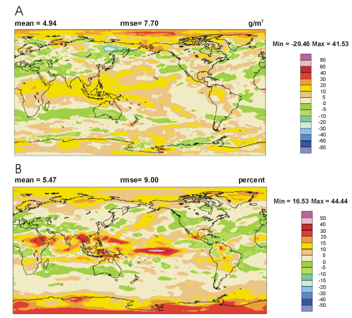
It was found that the higher assumed small ice crystal concentrations result in lower fall speeds, more cirrus cloud ice content and coverage (a 5.5% global increase), and warmer temperatures (over a 3° C increase) in the upper tropical troposphere. In the tropics these changes had an overall cooling effect, but elsewhere a warming effect. The long term effect is unknown since the GCM simulations were for only 1 year, and longer simulations are recommended.

This study underscores the need to reduce measurement uncertainties regarding the concentration of small ice crystals. In addition, it suggests that the direct effect of ice particle size on cirrus radiative properties may be secondary to its affect on ice fall speed and subsequent impacts on the global radiation budget. Since fall velocities depend on an ice particle's mass and area cross-section, these properties need to be well characterized in cirrus clouds. Currently ice particle mass is poorly characterized.

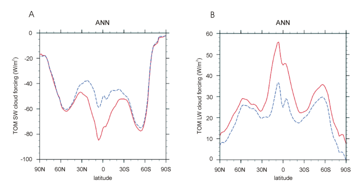
Reference(s)

Mitchell, David L., Philip Rasch, Dorothea Ivanova, Greg McFarquhar, and Timo Nousiainen, 2008: Impact of small ice crystal assumptions on ice sedimentation rates in cirrus clouds and GCM simulations. Geophysical Research Letters, VOL. 35, L09806, doi:10.1029/2008GL033552.

Working Group(s)
Cloud Properties



(a) The annual average in-cloud ice water path (IWP) for the PSD2 run (relatively high small ice crystal concentrations) minus that for the PSD1 run. Typical IWPs in the tropics were 30–40 g/m2 for the PSD1 run. (b) Annual average cirrus cloud coverage for the PSD2 simulation minus that for the PSD1 simulation, shown as percent difference.



Zonal mean (a) shortwave cloud forcing (SWCF) and (b) longwave cloud forcing (LWCF) for the PSD2 (red) and PSD1 (blue) CAM3 runs. Note that PSD2 is having higher concentrations of small ice crystals. Cloud forcing refers to the upwelling solar or terrestrial radiation flux at the top of the atmosphere with a cloudless atmosphere minus that with clouds included. TOM refers to "top of model," analogous to top of atmosphere.

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