Atmospheric Chemistry and Physics
An Interactive Open Access Journal of the European Geosciences Union

Atmos. Chem. Phys., 9, 4747-4773, 2009
www.atmos-chem-phys.net/9/4747/2009/

Simulating mixed-phase Arctic stratus clouds: sensitivity to ice initiation mechanisms

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Abstract. The importance of Arctic mixed-phase clouds on radiation and the Arctic climate is well known. However, the development of mixed-phase cloud parameterization for use in large scale models is limited by lack of both related observations and numerical studies using multidimensional models with advanced microphysics that provide the basis for understanding the relative importance of different microphysical processes that take place in mixed-phase clouds. To improve the representation of mixed-phase cloud processes in the GISS GCM we use the GISS single-column model coupled to a bin resolved microphysics (BRM) scheme that was specially designed to simulate mixed-phase clouds and aerosol-cloud interactions. Using this model with the microphysical measurements obtained from the DOE ARM Mixed-Phase Arctic Cloud Experiment (MPACE) campaign in October 2004 at the North Slope of Alaska, we investigate the effect of ice initiation processes and Bergeron-Findeisen process (BFP) on glaciation time and longevity of single-layer stratiform mixed-phase clouds. We focus on observations taken during 9 – 10 October, which indicated the presence of a single-layer mixed-phase clouds. We performed several sets of 12-h simulations to examine model sensitivity to different ice initiation mechanisms and evaluate model output (hydrometeors' concentrations, contents, effective radii, precipitation fluxes, and radar reflectivity) against measurements from the MPACE Intensive Observing Period. Overall, the model qualitatively simulates ice crystal concentration and hydrometeors content, but it fails to predict quantitatively the effective radii of ice particles and their vertical profiles. In particular, the ice effective radii are overestimated by at least 50%. However, using the same definition as used for observations, the effective radii simulated and that observed were more comparable. We find that for the single-layer stratiform mixed-phase clouds simulated, process of ice phase initiation due to freezing of supercooled water in both saturated and subsaturated (w.r.t. water) environments is as important as primary ice crystal origination from water vapor. We also find that the BFP is a process mainly responsible for the rates of glaciation of simulated clouds. These glaciation rates cannot be adequately represented by a water-ice saturation adjustment scheme that only depends on temperature and liquid and solid hydrometeors' contents as is widely used in bulk microphysics schemes and are better represented by processes that also account for supersaturation changes as the hydrometeors grow.

Final Revised Paper (PDF, 5217 KB) Discussion Paper (ACPD)

Citation: Sednev, I., Menon, S., and McFarquhar, G.: Simulating mixed-phase Arctic stratus clouds: sensitivity to ice initiation mechanisms, Atmos. Chem. Phys., 9, 4747-4773, 2009. Bibtex EndNote Reference Manager