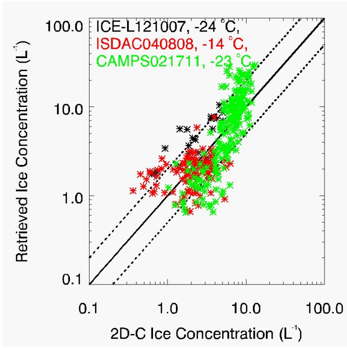
Ice Concentration Retrieval in Stratiform Mixed-Phase Clouds Using Cloud Radar Measurements

Research Highlight

The production of ice particles in clouds has significant impacts on their precipitation efficiency, lifetime, and radiative properties. Recent observations reveal that mixed-phase clouds, which contain both liquid droplets and ice particles, have a large global coverage and are the dominant cloud type over polar regions. The ice number concentrations (Ni) in these clouds are critical but are still not well parameterized in climate models and are poorly measured, especially at the global scale. Although in situ aircraft measurements of Ni are regarded as a reliable source, there are many potential errors due to the ice crystal shattering of in situ probes and limited temporal and spatial coverage. Thus, it is difficult to accumulate a large Ni database with aircraft measurements for the statistical study of Ni in clouds and to understand ice generation processes under various conditions, such as different dynamical environments and aerosol loadings.

Motivated by widely available ground-based and space-borne radar measurements, this study developed an approach to derive N_ice in stratiform mixed-phase clouds (SMCs) by combining cloud radar reflectivity (Ze) measurements and one-dimensional (1D) ice-growth model simulations. SMCs represent a relatively simple scenario for retrieving N_ice because of their less-complex dynamic environments and well-defined vertical thermodynamic structures. A 1D ice-growth model was developed to calculate ice growth along ice particle fallout trajectories in SMCs. The simulations are evaluated with four years of Atmospheric Radiation Measurement (ARM) Climate Research Facility, North Slope of Alaska ground-based radar reflectivity and Doppler velocity measurements. To evaluate the retrieved N_ice, we analyzed the integrated airborne radar and in situ measurements from several field campaigns and compared the retrieved N_ice in SMCs with in situ two-dimensional cloud (2D-C) measurements. The retrieved N_ice are also evaluated with three-dimensional cloud-resolving model simulations that include more complex microphysical processes. These comparisons statistically show that the retrieved ice number concentrations are within an uncertainty of a factor of two (see figure).

The results of the study have wide applications. First, the developed 1D ice-growth model could be implemented in cloud-resolving models to improve the simulations of SMCs. Second, the algorithm developed in this study could be applied to the large amount of ground-based and space-borne radar measurements to retrieve N_ice in SMCs. The long-term and global-coverage of the data sets enable us to study N_ice characteristics in SMCs globally and better understand their geographical variations and dependency on aerosols. Third, the retrieved N_ice could be used to evaluate model simulations of SMCs when radar measurements are available. Currently, the algorithm is being applied to ARM ground-based remote sensing measurements and the retrieved N_ice will be available to the community as a principal investigator data product.



This figure shows comparisons of the retrieved Ni with 2D-C measurements for the three SMC systems during the Ice in Clouds Experiment - Layer Clouds (ICE-L; black), Indirect and Semi-Direct Aerosol Campaign (ISDAC; red), and Colorado Airborne Multi-Phase Cloud Study (CAMPS) (green) field campaigns. The legend on the top left indicates the field campaign name, date, and mean cloud top temperature, respectively. The dashed lines are a factor of two lines.

Reference(s)

Zhang D, Z Wang, A Heymsfield, J Fan, and T Luo. 2014. "Ice concentration retrieval in stratiform mixed-phase clouds using cloud radar reflectivity measurements and 1-D ice-growth model simulations." Journal of the Atmospheric Sciences, , . ACCEPTED.

Contributors

Damao Zhang, *University of Wyoming*; Zhien Wang, *University of Wyoming*

Working Group(s)

Cloud Life Cycle