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Mechanism of Phase Inversion in Arctic Stratiform Clouds

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Arctic stratiform clouds (ASC) often exhibit phase inversion structure (i.e., liquid top and mixed- or ice-phase below) and can persist for a very long time. According to past studies, the phase inversion structure is the result of persistent liquid cloud generation aloft and gravitational ice precipitation; however, observation reveals that the largest cloud reflectivity appears in the middle of the cloud, implying that the gravitational ice precipitation cannot fully explain the mechanism of phase inversion structure. Also, the role of ice nucleation in ASC is not fully addressed before. Ice nucleation processes are affected by temperature, ice nuclei (IN) species and number concentration. As the result, strong inversion or strong vertical gradient of IN number concentration may favor ice nucleation to occur in the lower levels and result in phase inversion.

This study aims to find out the mechanism of phase inversion and the dominant ice nucleation processes in ASC. Weather Research and Forecasting (WRF) model with detailed ice nucleation mechanisms is applied. The ice nucleation scheme used in the model takes different ice nucleation processes and IN species into account. Dust and soot, taken from MERRA-2, are the two main IN considered in this study and are fitted into lognormal distributions for providing the initial and boundary conditions. The 2008 Mar 04-05 case, chosen from the Atmospheric Radiation Measurement (ARM) program, is simulated. From observation, ASC and the phase inversion structure persisted for half a day. Temperature decreases with height in cloud, indicating that temperature inversion is not the mechanism of phase inversion in this case. More dust in the lower levels is seen from the model simulation results. In this case, strong vertical gradient of IN number concentration serves as the main mechanism of phase inversion, suggesting that ice nucleation process plays an important role in ASC. The role of soot particles will also be addressed.