Mixed-phase Arctic Clouds Simulated by a Cloud-resolving Model:

Comparison with Aircraft Observations and Sensitivity to Microphysics Parameterization

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Objectives

§ To evaluate the ability of a cloud-resolving model (CRM) to simulate mixed-phase stratiform (MPS) Arctic clouds;

§ To explore the sensitivity of the CRM simulated MPS to microphysics parameterization.

Case and Evaluation Data

§ Case Description:

In the period 9-14 October, 2004, there was east-northeast flow, which brought cold near-surface air from the sea-ice located about 500 km north over the warm open ocean that was adjacent to the northern coast of Alaska. The large ocean sensible and latent heat fluxes combined with large-scale subsidence promoted a well-mixed Single layer mixed-phase clouds were formed under these conditions. These clouds were then advected to the Alaskan coast where they were observed at the ARM NSA sites: Barrow and Oliktok Point (Fig. 1).

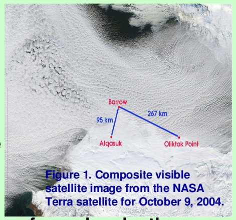


Figure 1. Composite visible satellite image from the NASA Terra satellite for October 9, 2004.

§ Evaluation Data

The evaluation data used are the bulk properties of the MPS clouds that McFarquhar et al. (2007) derived from observations measured by instruments on the University of North Dakota Citation aircraft.

CRM Simulations

§ Model Description:

- Anelastic dynamic framework
- Either a one- or a two-moment bulk microphysics scheme
- A state-of-the-art δ-4 radiative transfer scheme
- Third-order turbulence closure

§ Initial Conditions and Forcing:

- Initialized with an adiabatic profile of liquid water
- Large-scale subsidence
- Large-scale horizontal advection of temperature and moisture
- Surface sensible and latent heat fluxes
- Observed aerosol properties and ice nuclei (IN) concentration

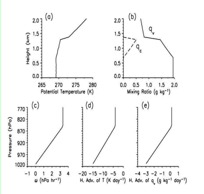


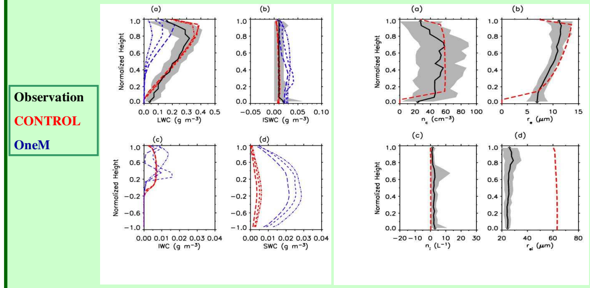
Figure 2. Profiles of the initial conditions and large-scale forcings.

§ Sensitivity Tests:

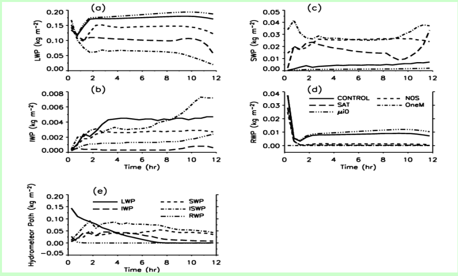
CONTROL	Two-moment microphysics scheme of Morrison et al. (M05)
OneM	One-moment microphysics scheme of Lin et al. (L83) combined with the water-ice saturation adjustment scheme of Lord et al. (L84)
SAT	M05 combined with L84
N0S	Same as CONTROL except for using the constant intercept parameter of snow spectra as in L83
μi0	Same as CONTROL except for specifying the spectra shape parameter of cloud ice as zero rather than 5
IN20	Same as CONTROL except for increasing the IN concentration by 20 times (i.e. from 0.16 L^{-1} to 3.2 L^{-1})

Results

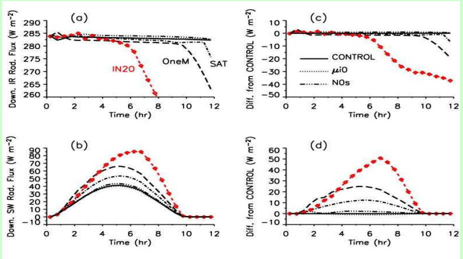
§ Vertical Profiles of Microphysical Properties



§ Vertically Integrated Water Contents



§ Surface Downward Radiative Fluxes



Summary

§ With the M05 two-moment microphysics scheme and the observed ice nuclei concentration (CONTROL), the CRM reproduced the magnitudes and vertical structures of cloud liquid water content, total ice water content, number concentration and effective radius of cloud droplets as suggested by the aircraft observations, but underestimated/overestimated the number concentration/size of ice crystals, respectively.

§ Using the L83 one-moment microphysics scheme (OneM) resulted in too little liquid water path (LWP) and too much ice plus snow water path.

§ A sensitivity test that used the same ice-water saturation adjustment scheme as in OneM produced cloud properties that were more similar to the OneM than the CONTROL.

§ Increasing the ice nuclei concentration to an unrealistic large value (factor of 20) forced the MPS clouds to become glaciated and dissipate, but the simulated ice number concentration agreed initially with the observations better.

§ The CONTROL predicted spatially varying values of the intercept parameter of snow size spectra (N_{0s}) that were one order of magnitude smaller than the prescribed N_{0s} used in L83. A sensitivity test that prescribed the larger L83 N_{0s} resulted in 20% less LWP and 5 times larger snow water path (SWP) than the CONTROL.

Selected References

1. Luo, Y., K.-M. Xu, H. Morrison, and G. McFarquhar, 2007: Mixed-phase Arctic clouds simulated by a cloud-resolving model: Comparison with ARM observations and sensitivity to microphysics parameterization. Submitted to *J. Atmos. Sci.*
2. McFarquhar, G. M., G. Zhang, M. Poellot, J. Verlinde, G. Kok, R. McCoy, T. Tooman, and A. J. Heymsfield, 2007: Vertical variability of the phases, shapes, and sized of hydrometeors in single layer mixed-phase Arctic stratus clouds. Submitted to *J. Atmos. Sci.*
3. Morrison, H., J. A. Curry, V. I. Khvorostyanov, 2005: A new double-moment microphysics parameterization for application in cloud and climate models. Part I: Description. *J. Atmos. Sci.*, 62, 1665-1677.

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