Intercomparison of model simulations of mixed-phase clouds observed during M-PACE. Part I: Single layer cloud

Steve Klein and Renata McCoy
Lawrence Livermore National Laboratory

Hugh Morrison
National Center for Atmospheric Research

Co-Authors
Andy Ackerman, Alex Avramov, Gijs de Boer, Mingxuan Chen, Jason Cole, Anthony Del Genio, Michael Falk, Michael Foster, Ann Fridlind, Chris Golaz, Tempei Hashino, Jerry Harrington, Corinna Hoose, Marat Khairoutdinov, Vince Larson, Xiaohong Liu, Yali Luo, Greg McFarquhar, Surabi Menon, Roel Neggers, Sungsu Park, Michael Poellot, Jerome Schmidt, Igor Sednev, Ben Shipway, Matthew Shupe, Douglas Spangenberg, Yogesh Sud, David Turner, Dana Veron, Knut von Salzen, Gregory Walker, Zhien Wang, Audrey Wolf, Shaocheng Xie, Kuan-Man Xu, Fanglin Yang, and Gong Zhang

Overview

This poster presents the results of an intercomparison of single-column and cloud-resolving models jointly sponsored by the Atmospheric Radiation Measurement (ARM) program's Cloud Modeling Working Group and the GEWEX Cloud System Study Polar Cloud Working Group.

Part I examines model simulations of a mixed-phase stratocumulus cloud observed during the ARM program's Mixed-Phase Arctic Cloud Experiment (M-PACE).

Participating Models

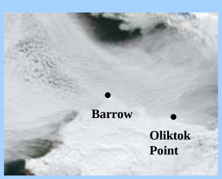
17 SCMs: ARCSCM, CCCMA, ECHAM, ECMWF, ECMWF-DUALM, GFDL, GISS, GISS-LBL, MCRAS, MCRASI, NCEP, SCAM3, SCAM3-LIU, SCAM3-MG, SCAM3-UW, SCRIPPS, UWM

9 CRMs: COAMPS®, DHARMA, METO, NMS-BULK, NMS-SHIPS, RAMS-CSU, SAM, UCLA-LARC, UCLA-LIN

Cold-Air Outbreak Stratocumulus

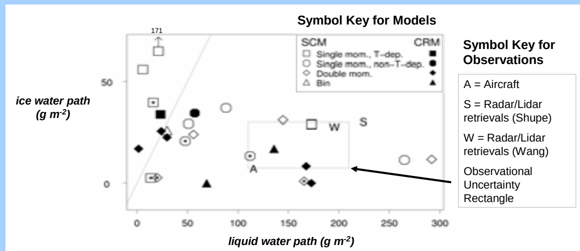
When cold air flowed over the Beaufort Sea from the northeast, ocean heat fluxes led to the formation of stratocumulus clouds. The clouds were observed by ARM aircraft and ground-based remote sensors at the Alaskan coast between Barrow and Oliktok Point.

The upper half of the well-mixed boundary layer contained a mixed-phase cloud with a cloud top temperature of –15°C. The observed liquid water path was about 160 g m^{-2} and the ice water path, which was computed as the mass of ice between the surface and cloud top, was around 15 g m^{-2}.



Satellite visible image of the North slope of Alaska and Beaufort Sea for October 9, 2004

Liquid Water Path Versus Ice Water Path



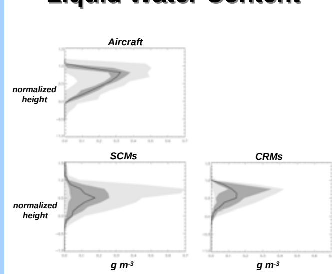
On average both SCMs and CRMs underestimate the amount of supercooled water by a factor of 3. Models simulations of ice water path are more consistent with observations.

Vertical Structure of Water Content

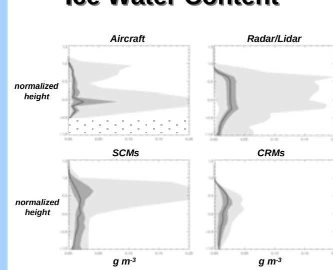
The observed liquid water content increased with height above cloud base at 2/3 of the adiabatic rate. The observed ice water content was more vertically uniform with values of about 0.02 g m^{-3} in the cloud and 0.01 g m^{-3} beneath.

On average both SCMs and CRMs underestimate the liquid water content while being able to reproduce the vertical structure of the ice water content.

Liquid Water Content



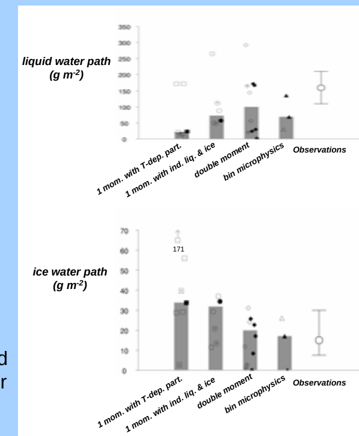
Ice Water Content



Normalized height is a vertical coordinate defined such that 0 is the liquid water cloud base, 1 is the cloud top, and -1 is the surface. The solid line indicates the median model value and the dark (light) shading indicates the inner (outer) 50% of model values.

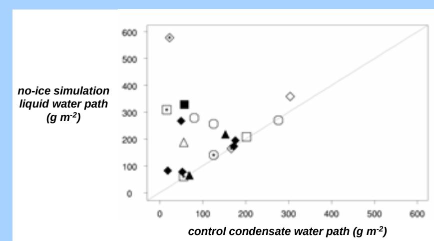
How Important Is Cloud Microphysics?

These plots stratify models by the type of cloud microphysics used: (a) single moment with temperature dependent partitioning, (b) single moment with independent liquid and ice, (c) double moment, and (d) bin. Median model results for each class of microphysics are indicated by the shaded bars.



Although the scatter is large, there is some evidence that models with more sophisticated microphysics simulate liquid and ice water paths that are in better agreement with the observed values.

What Is the Role of Ice Microphysics?



A sensitivity study was performed in which models removed their ice microphysics so that the simulated cloud would be purely liquid. For many of the models which underestimate the liquid water path in their control simulations, the liquid water path increases to levels equal to or greater than the observed liquid water path. This suggests that in this case many models too readily convert liquid to ice.

Reference

Klein, S. A., R. B. McCoy, H. Morrison, and 38 Co-authors, 2008: Intercomparison of model simulations of mixed-phase clouds observed during M-PACE. Part I: Single layer cloud. Quarterly Journal of the Royal Meteorological Society, submitted.

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