Evaluation of SAM Sensitivity to Ice Nuclei Concentrations

James M. Carpenter[1], P. J. DeMott[1], M. D. Branson[1], S. M. Kreidenweis[1], M. Wolde[2]

[1]Department of Atmospheric Science, Colorado State University, Fort Collins, CO (jmcarp@atmos.colostate.edu)
[2]Institute for Aerospace Research, National Research Council Canada, Ottawa, ON

Overview

The System for Atmospheric Modeling (SAM v 6.8.2) is used to model a cloud encountered over the North Slope of Alaska on April 26, 2008 during Flight 31 of the Indirect and Semi-Direct Aerosol Campaign (ISDAC). A base case run used aerosol observations to drive a new aerosol-linked ice nuclei parameterization (DeMott et al. 2010), followed by two additional runs in which ice nuclei concentrations are increased and decreased by a factor of 10. Simulated cloud and precipitation characteristics display strong sensitivity to changes in ice nuclei concentrations, with the base case results showing the most reasonable consistency with cloud and precipitation observations.

DeMott Parameterization

$$n_{in} = a\left(273.16 - T_k\right)^b \left(n_{aer,0.5}\right)^{(c(273.16-T_k)+d)}$$

Where:

a = 0.0000594, b = 3.33, c = 0.0264, d = 0.0033

T_k is cloud temperature in degrees Kelvin

$n_{aer,0.5}$ is the number concentration (scm^{-3}) of aerosol particles with diameters larger than 0.5 um

n_{IN} is ice nuclei number concentration (std L^{-1}) at T_k

(n_{IN} is multiplied by a factor (1, 10, or 0.1) in the microphysics source code to furnish the following results)

IN Data Comparison

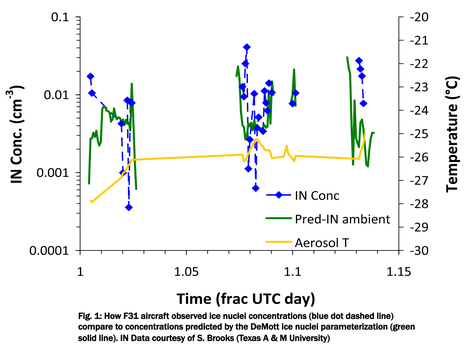


Fig. 1: How F31 aircraft observed ice nuclei concentrations (blue dot dashed line) compare to concentrations predicted by the DeMott ice nuclei parameterization (green solid line). IN Data courtesy of S. Brooks (Texas A & M University)

Aircraft Observations

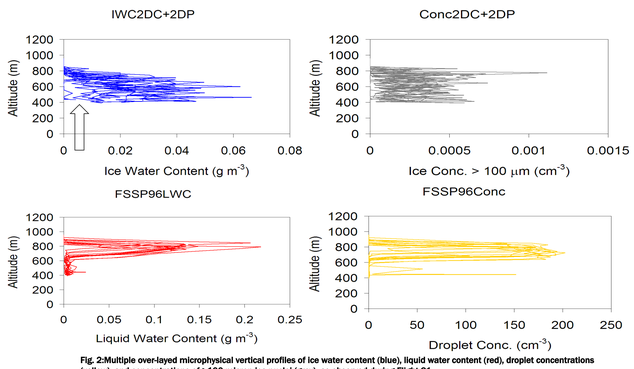


Fig. 2:Multiple over-layed microphysical vertical profiles of ice water content (blue), liquid water content (red), droplet concentrations (yellow), and concentrations of >100 micron ice nuclei (grey), as observed during Flight 31.

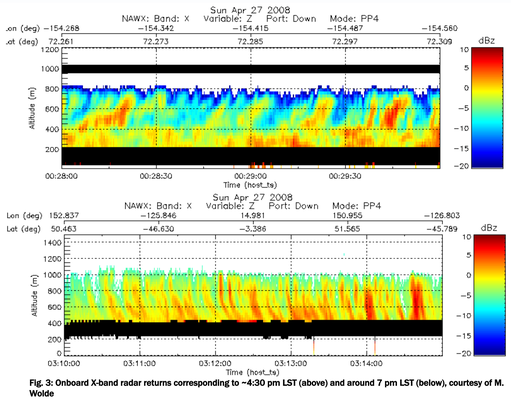


Fig. 3: Onboard X-band radar returns corresponding to ~4:30 pm LST (above) and around 7 pm LST (below), courtesy of M. Wolde

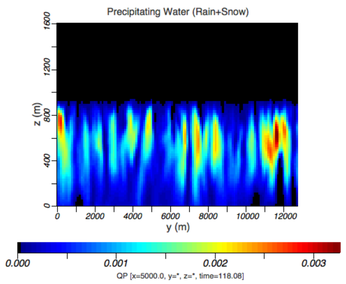
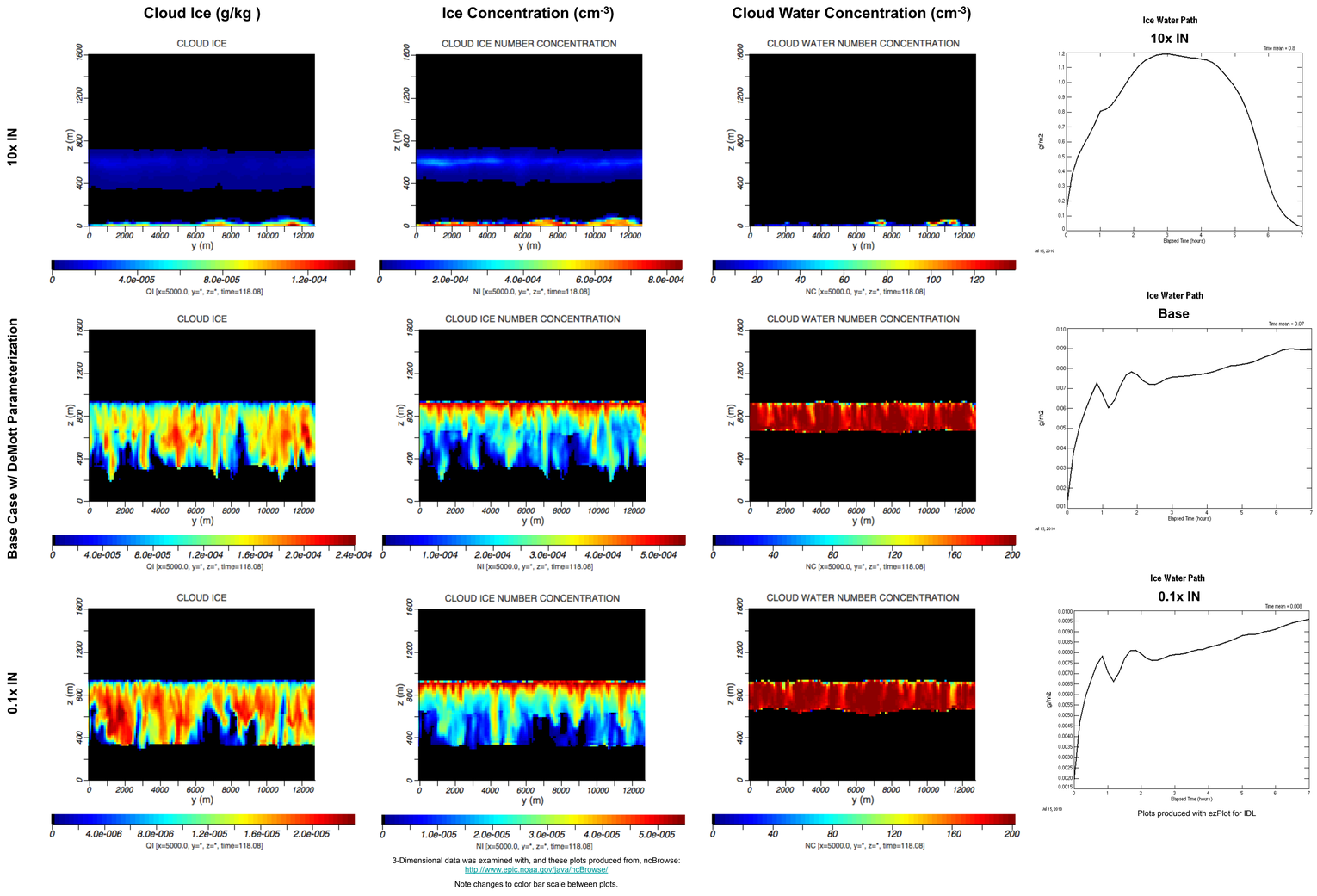


Fig. 4: Precipitating water output (g/kg) produced by 12-hour SAM run using DeMott parameterization. Intended as proxy to compare radar profile of cloud structure prior to integrating radar simulation package (upcoming step).

Simulation Results After 12 Hours (~4 PM LST)



3-Dimensional data was examined with, and these plots produced from, ncBrowse: http://www.epic.noaa.gov/java/ncBrowse/

Note changes to color bar scale between plots.

Plots produced with ezPlot for IDL

Summary

The end of the model run corresponds to the approximate time airborne data was collected during Flight 31 (near 4 pm local time). The cloud simulation with 10x the initial ice nuclei as the base case exhibits markedly different behavior in a 12-hour model run than the base and lower ice nuclei runs. In the simulation with ten times the initial ice nuclei, surface precipitation is observed as early as 20 minutes into the run, with complete cloud dissipation occurring before the end of the simulation (between 10 and 10.5 hours). The simulated cloud with 10% of the initial ice nuclei of the base case exhibited similar behaviors as the base model run, but on lower magnitudes, and without any surface precipitation observed throughout the course of the 12-hour run. Both simulations with altered ice nuclei concentrations fail to reach order of magnitude proximity to observed water and ice number concentrations and observed precipitation. The base case simulation, using the new IN parameterization, predicted cloud water and ice concentrations most similar to aircraft observational data. Discrepancies between observed and calculated total cloud ice mass remain, and differ by a factor of 10.

Next Steps

Evaluate continuing discrepancies between observed and model-predicted total cloud ice mass. Expand model simulations past the 12-hour mark, and for different seasons. Compare model output with observational data from additional sources. (CloudSat...) Use radar simulation package with model output for additional comparison to observations.

References:

DeMott et al., 2010, Proc. Natnl. Acad. Sci. 107: 11217-11222
Fan et al., 2009, J. Geophys. Res. 114
Morrison et al. 2008, J. Climate 21: 3642-3659.
Morrison et al. 2009, Q. J. R. Meteorol. Soc. 135: 1003–1019.
Prenni et al. 2007, B. Am. Meteorol. Soc. 88: 541-550.

Acknowledgments:

National Science Foundation Science and Technology Center for Multi-Scale Modeling of Atmospheric Processes, managed by Colorado State University under cooperative agreement No. ATM-0425247. DOE-ARM (Grant No. DE-FG02-09ER64772)