

Interactive comment on “Simulating mixed-phase Arctic stratus clouds: sensitivity to ice initiation mechanisms” by I. Sednev et al.

I. Sednev et al.

Received and published: 11 September 2008

Response to Reviewer #1

We thank the reviewer for the comments/suggestions made. We have addressed the questions and concerns of the reviewer and will modify the paper accordingly. Our response to the questions raised are as follows:

"This study evaluates the relative importance of CCN characteristics, coalescence, ice nucleation mechanisms and supersaturation wrt to water and ice on the microphysical properties of mixed-phase Arctic stratus cloud. The principal conclusion appears to be that the dominating factor, whether in water only processes or in the production of ice crystals is the shape of the initial CCN spectrum."

The shape of CCN spectra determines the relative importance of the second ice initia-

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



tion mechanism for the MPACE single-layer mixed-phase clouds.

"The authors go to great length in explaining the various details of their bin resolved model, including a set of appendices that are almost as long as the main text. It is not clear to this reviewer how important these appendices are with respect to the principal conclusions given that there is virtually nothing that is discussed in the appendices that helps the reader understand how the CCN spectra were originally selected or how they are modified in order to obtain scenarios W3 and W4 in contrast to W1 and W2. Equations A1 and A2 show the functional relationship but, unless I have missed something in the discussion of the various scenarios, I was unable to locate information about: 1) the reference source from which the initial CCN spectrum was derived, i.e. why ammonium sulfate and why the relatively high concentrations of particles larger than 1 μm and 2) what is the scheme for changing spectrum shape, i.e. what is being changed - total concentration, modes in the distribution, length of the large particle tail...?"

The initial CCN spectra was proposed by the ARM Cloud Parameterization and Modeling Working Group (CPMWG) for MPACE period B simulation (Klein et al., 2008). Some discussion regarding how this spectra was obtained as well as CCN chemical composition can be found in http://science.arm.gov/wg/cpm/scm/scmic5/docs/Document_ic5_v3.2.1.pdf. In the BRM scheme the parameterization of the activation of aerosol particles to form cloud droplets depends on the assumed aerosol composition and supersaturation w.r.t. water. In our runs aerosol particles of a certain size are activated when the supersaturation calculated exceeds the critical value determined by the Koehler equation assuming an ammonium sulfate composition as defined by ARM CPMWG. Koehler theory is used to determine so called critical supersaturation and critical and equilibrium radii. In the case the AP distribution contains aerosols with dry radius greater than critical radius at a given point, these APs can be activated and transformed into droplets (Kogan, 1991; Khain and Sednev, 1996). Because this approach for droplet nucleation

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



and its modifications (Yin et al., QJRMS, 2004) is now routinely used in different BRM schemes, we decided not to focus on it. At the same time we decided to outline in our Appendix an approach to numerical implementation of liquid/ice phases growth due to water vapor transformation in liquid, icy, and mixed-phase clouds for different types of environmental conditions (condensational growth of liquid phase and depositional growth of ice phase; evaporation of liquid phase and sublimation of ice phase; and evaporation of liquid phase and depositional growth of ice phase). It should be noted that this approach is applicable in any cloud model that resolves supersaturation. It can be used in bin-resolved and bulk microphysical schemes. In the latter case it can be significantly simplified using prescribed a priori liquid/solid phase size distributions. The approach outlined in the Appendix can be used for the numerical modeling of cloud processes using cloud resolving models and developing parameterization of processes of vapor/liquid/solid phase transformations for use in large-scale models.

"There have been a couple of recent papers on mixed-phase clouds and the importance of the Wegener-Bergeron-Findeisen process. Both of these papers use fundamental, analytical solutions for deriving the relationship of water and ice growth, supersaturation with respect to water and ice, and vertical velocity in mixed-phase clouds. Korolev and Field (2007, JAS) show that the necessary and sufficient conditions for activation of water in ice clouds is that 1) the vertical velocity of an ice cloud parcel must exceed a threshold velocity to activate liquid water and 2) the activation of liquid water within an ice cloud parcel, below water saturation, requires a vertical ascent above some threshold altitude to bring the vapor pressure of the parcel to water saturation. Korolev (2008, QJRMS) shows that there are four scenarios of mixed phase equilibrium but only two lead to WBF. Maximum efficiency of the WBF process occurs at $w=0$ for all mixed phase clouds and it does not depend either on the integral radius of water or of ice."

Conclusions in papers mentioned above are based on Korolev and Mazin (2003, JAS) (KM2003) who solved analytically the supersaturation w.r.t. water equation derived in

[Full Screen / Esc](#)[Printer-friendly Version](#)[Interactive Discussion](#)[Discussion Paper](#)

a manner similar to Cheng (1994, JAS) and Khain and Sednev (1996). In KM2003 expression (11) is considered as a solution for the supersaturation equation (9) if both liquid and ice phase size distributions are mono-disperse and do not depend on time. Whereas the assumption regarding constant concentration is valid for the condensational process, the assumption about unchanged mean liquid/ice phase mean radius is only valid for very limited time periods, and having mean radius constant during hundreds and thousands of seconds is problematic. For constant concentration mean radius must increase even for mono-disperse distribution. Otherwise, there is no condensation/deposition process. It is not within our scope to review KM2003, but we suggest that coefficient "a" in expressions (19), (22), and (23) among others be modified (Li should be used instead of L_w). For example, Korolev and Field (2008, JAS) (KF2008) use this correct "a" coefficient in expression (13), whose definition is given in their Appendix A. We state the above points to help the reviewer recognize the fact that we completely understand how supersaturation equations can be derived and solved. KF2008 listed nine assumptions that must be satisfied in order for their conclusions to be valid. They also highlighted their understanding that their results "will not be directly applicable to real cloud systems". Thus it appears that KF2008 do not consider their conclusions as "fundamental". Moreover, there is nothing "fundamental" in solving supersaturation equations. This approach was novel about two decades ago, but nowadays it is only the approach that is routinely used in BRM and BLK models (Chen, 1994; Khain and Sednev, 1996; Resin et. al, 1996; Morrison et. al, 2005 among others). At the same time we agree with many conclusions made by KF2008 keeping in mind all limitations of "half"-dimensional (parcel model) approach and applicability of assumptions made. Based on the above discussion, we will modify our text to include suggested references and the main conclusions as outlined by the reviewer.

"Given that these papers precede the manuscript under review, and that they concern the WBF and mixed phase processes, it would seem that their conclusions are very relevant to the conclusions of the current paper. Would the authors care to comment? In particular, in the current manuscript, very little is said about the sensitivity of vertical

S6940

ACPD

8, S6937–S6942, 2008

Interactive
Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



velocity other than it is controlled by large-scale lifting, yet the sensitivity of the liquid phase processes to supersaturation with respect to water, shouldn't vertical velocity have been one of the independent parameters that is evaluated?"

As discussed above, these papers use a parcel model with BLK microphysics (prescribed a priori mono-disperse hydrometeor distributions) and some analytical formulae. In our simulations we use an SCM model with bin resolved microphysics to evaluate the relative importance of different ice initiation mechanisms in low-level mixed-phase Arctic clouds observed during MPACE period B. Although we agree that it would be interesting to study changes in vertical velocity on liquid-phase processes, evaluation of the relative importance of vertical velocity as proposed by reviewer is outside the scope of our study which was focused on ice initiation. We will include this additional point in our paper.

Minor points:

"The use of content instead of water content throughout the manuscript and in the figures is awkward."

Definition of content is given in the Appendix by expression (A4). It should be noted that "content" is not necessary "water". It might be "ice content", "total content" or "dendrite content", for example. Such words as hydrometeor concentration (A3), content, reflectivity, and precipitation flux (A5) are widely used by cloud modelers.

"I think Wegener-Bergeron-Findeisen process (WBFP) should be used instead of Bergeron-Findeisen process (BFP) in recognition of Wegener's contribution to our understanding of mixed-phase processes."

We are aware about these differences in terminology. Recently it was discussed by Korolev (2007, JAS). Since either terms are commonly used, we prefer to keep the term "Bergeron-Findeisen process (BFP)" in our manuscript.

References:

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



Chen, J.-P.: Prediction of saturation ration for cloud microphysical models. J. Atmos. Sci., 51, 1332-1338, 1994.

Korolev, A. V. and Mazin I. P.: Supersaturation of water vapor in clouds. J. Atmos. Sci., 60, 2957-2974, 2003.

Korolev, A. V.: Limitation of the Wegener-Bergeron-Findeisen mechanism in the evolution of mixed-phase clouds. J. Atmos. Sci., 64, 3372-3375, 2007.

Korolev, A. V. and Field I. P.: The effect of dynamics on mixed-phase clouds: Theoretical considerations. J. Atmos. Sci., 65, 66-86, 2008.

Yin, Y., K.S. Carslaw, and G. Feingold: Vertical transport and processing of aerosols in a mixed-phase convective cloud and the feedback on cloud development. Q. J. R. Meteorol. Soc., 131, 221-245, doi: 10.1256/qj.03.186, 2005.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 11755, 2008.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

