Atmos. Chem. Phys. Discuss., 8, S8935–S8938, 2008
www.atmos-chem-phys-discuss.net/8/S8935/2008/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Parameterizing the competition between homogeneous and heterogeneous freezing in cirrus cloud formation – monodisperse ice nuclei" *by* D. Barahona and A. Nenes

D. Barahona and A. Nenes

Received and published: 11 November 2008

1. I support the statements made by reviewer 1. The K06 parameterization does resolve the competition between homogeneous freezing and an arbitrary number of heterogeneous modes. It has been the first of its kind without hard-wiring important IN information. It is argued that K06 resolve this competition through numerical integration. This step permits an accurate treatment of how IN affect the homogeneous freezing process by slowing the increase in supersaturation. The numerical treatment, when used in a GCM, is not prohibitive in terms of CPU time demand.

The manuscript did acknowledge this (page 15669, lines 9-15) but stressed that the

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

approach adopted by K06 was not analytical; we have shown that the same level of accuracy can be obtained without using numerical integration (as shown in Fig. 5 of the revised manuscript). We have rephrased the wording to clarify these points.

In terms of CPU requirements, numerical integration (for obtaining the sizes of the heterogeneously frozen crystals at the moment of homogeneous freezing) is more expensive than a simple analytical parameterization. Although the time difference between both approaches may not be very large for a single freezing threshold (but that still remains to be shown), numerical integration for a *distribution* of freezing thresholds may become quite taxing.

2. Reduction of the rate of supersaturation and subsequent freezing of fewer liquid particles is the first order effect IN exert. The authors claim that their parameterization "explicitly" (I presume "analytically" is meant) resolves this competition. I argue that their approach adds a second order accuracy in describing the competition, because the homogeneous freezing process is not sensitive to concomitant changes in the liquid aerosol size distribution.

The result speaks for itself. We reduced the original system of equations to a simple analytical expression that unravels the combined competition of homogeneous and heterogeneous freezing. The key to this success was to correctly scale the condensation problem about the point where homogeneous freezing is prohibited (from the IN effect), and *not* changes in the liquid aerosol distribution (which we agree is a second order effect).

3. I further argue that their explicit approach may be beneficial to refine predictions of total ice crystal concentrations only if the IN size distribution and chemical composition (and the resulting ice nucleation spectrum) are known. . . . The required information about atmospheric IN in cirrus levels is not easily available from measurements, so theoretical assumptions may not realistically describe the overall process and improve over K06.

ACPD

8, S8935–S8938, 2008

Interactive Comment

This is true for all physically-based parameterizations, including K06. We already stated that accurate knowledge of IN concentrations and freezing thresholds is required to account for aerosol indirect effects (page 15684 lines 5-10). However, we disagree that such knowledge is not easily available, as empirical parameterizations (e.g., Meyers et al., 1991; Phillips et al., 2008), theory (e.g., Khvorostyanov and Curry, 2004) or any combination thereof can be applied.

3. . . . However, the authors opt to study monodisperse and chemically uniform IN in this work, so an advantage over K06 is not readily apparent. . . ..

As we have stated throughout the text, the assumption of monodisperse IN was taken to present our approach in as simple terms as possible. The extension to polydisperse and chemically heterogeneous IN has already been done and will be presented in a follow up manuscript.

With that said, the two parameterizations do not differ as much in the description of IN characteristics. K06 adopt a single freezing threshold for the whole IN population, which can be well approximated by our assumption of chemically uniform and monodisperse IN. This is why our parameterization and K06 agree so well (shown in Figure 5 of the modified paper).

References

Khvorostyanov, V. I., and Curry, J. A.: The theory of ice nucleation by heterogeneous freezing of deliquescent mixed CCN. Part I: critical radius, energy and nucleation rate, J. Atmos. Sci., 61, 2676-2691, 2004.

Meyers, M. P., DeMott, P. J., and Cotton, R.: New primary ice-nucleation parameterization in an explicit cloud model, J. Appl. Meteorol., 31, 708-721, 1991.

Phillips, V. T. J., DeMott, P. J., and Andronache, C.: An empirical parameterization of heterogeneous ice nucleation for multiple chemical species of aerosol, J. Atmos. Sci., 65, 2757-2783, doi:2710.1175/2007JAS2546.2751, 2008.

ACPD

8, S8935–S8938, 2008

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 15665, 2008.

ACPD

8, S8935–S8938, 2008

Interactive Comment