Atmos. Chem. Phys. Discuss., 12, C4211–C4214, 2012
www.atmos-chem-phys-discuss.net/12/C4211/2012/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Sensitivity studies of dust ice nuclei effect on cirrus clouds with the Community Atmosphere Model CAM5" *by* X. Liu et al.

Anonymous Referee #2

Received and published: 1 July 2012

General Comments:

This paper presents important results showing the potential impact of mineral dust on cirrus clouds using two ice nucleation schemes in CAM5. Suggestions are made for presenting the climate impact results more clearly. The paper is well written and organized with figures of high quality. It is definitely worthy of being published in ACP.

It is always helpful to relate model results to observations. The observational study by Haag et al. (2003, ACP) and perhaps other INCA papers are relevant to the results presented in Figs. 2-4. Using RHi distributions, Haag et al. showed that NH mid-latitude cirrus likely resulted from a combination of homo- and heterogeneous nu-

cleation processes, whereas SH mid-latitude cirrus were dominated by homogeneous nucleation. These INCA results appear to support the LP parameterization more than the BN scheme, and this should be mentioned.

Since differences between the LP and BN schemes result primarily from differences in the way ice nuclei are predicted from the aerosol size distributions (note dust concentrations are roughly equal for both LP and BN simulations), some discussion regarding the differences between the CNT method and PDA08 method appears warranted.

As discussed in Section 2.3, first paragraph, the subgrid variability of the updraft velocity (w) in CAM5 used for driving the LP05 parameterization has an upper threshold limit of 20 cm s-1. This was done to decrease ice particle number concentrations Ni, which in turn increased ice particle effective size De, bringing De into closer agreement with measurements during the development of CAM5. This improved the realism of ice cloud-radiation interactions in CAM5. However, it did not change the over-prediction of w by the Bretherton-Park moist turbulence-convection scheme. Thus, w tends to be near 20 cm s-1 much of the time in CAM5, and its mean value is likely high relative to observations. This in turn may produce anomalously high supersaturations with respect to ice (RHi), and this high RHi bias may induce a homogeneous nucleation bias. That is, it may take relatively high concentrations of ice nuclei (IN) to prevent RHi in cirrus cloud updrafts from reaching threshold RHi values at which homogeneous nucleation occurs. These points should be mentioned in the paper.

This study shows that the LP scheme produces results that agree with observations better than those predicted by the BN scheme. However, could this be an artifact of the treatment of w in CAM5 as described above? If there is a high RHi bias and this bias were removed, might the BN scheme show more sensitivity to IN? Reducing w would make it easier for IN to prevent RHi from reaching threshold values for homogeneous nucleation initiation. Would the PDA08 IN spectra then have a greater influence on Ni, producing greater differences between BNhom and BN results? If so, might this bring the BN results into greater agreement with observations?

The results shown in Fig. 8 and Fig. 9 in Section 5 are very interesting. Regarding Fig. 8, it might strengthen the findings to cite other studies having similar results. Regarding Fig. 9, the details are interesting but cannot be clearly seen in this format. It is suggested to break this into two figures; Fig. 9a and 9b, with larger panels to clearly show the details. In addition, what many are interested in is the net cloud radiative forcing (SWCF + LWCF) or net CRF for each simulation as a function of latitude, as well as the net CRF differences between simulations (e.g. net CRFLP – net CRFLPhom, net CRFLPhet – net CRFLP). This, for example, would show the potential cooling effect that heterogeneous nucleation may have on our present and future climate, and issues like these are driving climate research. The net CRF plots could constitute Fig. 10.

The Lohmann et al. (2008, ERL) study also addresses “simple” competition effects between heterogeneous nucleation from dust aerosol and homogeneous nucleation using the ECHAM5 GCM. They find much stronger net CRF cooling effects than in this study (-2.0 W m-2 vs. -0.3 W m-2 found here). This should definitely be mentioned, and if possible reasons given for the differing results.

Specific Comments:

1. Page 13134, line 28: Suggest changing 170% to 180% based on results in Fig. 6. 2. In Fig. 7, the LP histogram is more correlated with the observations than the BN histogram, LP is better matched with LPhet than LPhom, and BN is better matched with BNhom than BNhet. Does this imply that heterogeneous nucleation was the dominant nucleation mode during SPARTICUS? 3. SWCF in Fig. 9: Why are all of the simulations excepting BNhet exceeding the observed SWCF in the tropics? Is this a cirrus cloud coverage issue or more likely a problem with the treatment of low and mid-level clouds? 4. Effective radius in Fig. 9: Why is Re evaluated only at the tops of cirrus clouds rather than a vertically integrated average? 5. Page 13139, lines 26-28: This contradicts the points raised in comment 2 above, which may indicate that heterogeneous nucleation dominated during SPARTICUS. 6. Page 13140, lines 11-14: While the net global cooling is -0.3 W m-2 for the LP simulations, the latitudinal dependence

on this net cooling is also worth mentioning. Please indicate what this net cooling is for the tropics and the extra-tropics, separately for each hemisphere in the extra-tropics. This information could also be in a table.

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 13119, 2012.