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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The roles of dynamical variability and aerosols in cirrus cloud formation" *by* B. Kärcher and J. Ström

B. Kärcher and J. Ström

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Specific Comments

(1) CVI measurements

We agree that the one example shown in Gayet et al. is not enough to convince oneself about the one-to-one relation between residual particle number density and crystal number density. For this reason, in Seifert et al. (2002), we extended the comparison to include the whole INCA data set (both campaigns). The result is a convincing relationship very close to a one-to-one relation extending over several orders of magnitude in crystal number density. At lower number densities the two instruments deviate because of the detection limit of the FSSP-300 (equivalent to one count during the sampling period). The much better agreement in Seifert at al. in comparison to the plot by Gayet et al. can be fully explained by the shorter time response of the FSSP-300.

In making a comparison as in Figure 1 of Seifert et al. it is important how one makes the averages. Binning the FSSP data according to CVI data or vice versa will provide different results simply because of the smoothing in the CVI data caused by the longer time response. The CVI used in INCA samples crystals in the aerodynamic size range between 5 and 60 μm. In terms of the total number density of crystals the upper cut off is not important.

(2) Wave structure

We do believe that the air parcels actually follow such small scale wave structures and think that should also be seen in 2- or 3 dimensional cirrus models provided they are driven with corresponding wave forcings.

At this point, without comprehensive cirrus models, we can only argue qualitatively. Starting from ice saturation, an air parcel will reach the relative humidity required for homogeneous freezing in about 30 min (parcel displacement 450 m) at an updraft speed of ~ 25 cm/s. That is the mean updraft speed observed during the campaigns.

Now it seems likely that the ice nucleation events preferentially occur in the fastest cooling cycles. That is what we typically observe in parcel model simulations. A typical mean wave period found to be roughly consistent with the measured wind speed distribution is ~ 1200 s. Nucleation occurs frequently in waves with lower periods (still well above the Brunt-Vaisala period). Consequently, the actual parcel displacements in nucleation events are likely much smaller than the above quoted 450 m.

To address this concern, we plan to include one additional figure early in Sect.4 showing that the vertical wind speed distributions are consistent with small scale adiabatic temperature fluctuations; the text will contain elements of the above reply.

(3) Low wind speeds

Note that we have already randomized the measured updraft speeds by ± 5 cm/s (p.1426); in the manuscript, we have called that noise. The differences between the

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distributions of n_i with and without noise as shown in Figs.3c and f provide the hint the reviewer asks for. The data points at low wind speeds are all taken into account in producing the distributions of n_i, so, we think that no additional sensitivity studies for the low velocity range are necessary.

We do not see why the scenario ”less waves” in Fig.7 should seem to lead to a better agreement with the observations, as suggested in the review. The figure should display the sensitivity of the n_i distribution related to possible changes in wave activity based on the model. Also, we do not understand the remark concerning Fig.8. We believe that neither the vertical motion measurements are wrong (to the degree described in Sect.2.1) nor the CVI data are incorrect (see above under 1).

We noted that we missed to show how the wind speed distributions (as shown in Fig.1, bottom panel) look like when noise and wave-driven variability are added. We will provide the resulting distribution along with the additional figure explained in (2) above, hoping that this figure helps to clarify the reviewer's concern.

(4) Heterogeneous ice nucleation

Heterogeneous nucleation was allowed with unlimited concentrations of ice nuclei freezing at 130% RHI to illustrate the pure effect of reducing the freezing threshold, keeping everything else unchanged. The effect turns out to be an increase of n_i (p.1435, l.26ff), as also detailed in Kärcher and Lohmann (2003).

It was pointed out (p.1430, l.22ff) that we think the pure heterogeneous case is not the realistic scenario. Evidence is presented elsewhere (Haag et al., 2003) that few efficient ice nuclei (freezing around 130% in the NH case) form ice crystals but do not prevent homogeneous freezing from occurring. This effect may decrease n_i (Kärcher and Lohmann, 2003). To model this scenario is outside the scope of the present paper, but this will most likely only affect the low concentration portion of the distribution of n_i (p1430, l.22ff).

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It is not required that a steady state supersaturation of 130% is sustained in the NH case; it is just that freezing sets in earlier in the NH case compared to the SH case. It is not straightforward to say whether cirrus should be more frequent when they form at lower supersaturations (because they occur more often than higher values). Cloud frequency of occurrence (or cloud cover) depends on other processes as well such as ice crystal size (modulating sedimentation rates) and details of the small-scale wave forcing.

(5) NS versus SH

We fully agree. We do not suggest that these results are typical for the entire hemispheres. In fact, we have stressed that the similarity in vertical wind speed and temperature distributions between NH and SH cases may be pure coincidental (p.1422, l.2ff). Nevertheless, we will add a sentence early in Sect.2 stating that NH ans SH are just labels to distinguish the campaigns and do not suggest general applicability of the findings to other locales or seasons.

Given the distinct differences in orography between both hemispheres, we may even expect marked interhemispheric differences in mesoscale temperature fluctuations caused by lee wave activity; this alone may bring about more cirrus at northern latitudes if other factors would show no interhemispheric differences. The lucky situation that the meteorology was similar in the Punta Arenas and Prestwick (both locations contain mountain ridges and winds mainly blowing perpendicular to them) helped to work out the relative importance of dynamical forcing and aerosols in cirrus formation.

Technical corrections

(1) Color coded plots will be checked. The captions of Figs.7 and 9 contain errors.

(2) Seifert et al. is published (see below). Will be corrected.

References

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