

Interactive comment on “Rare temperature histories and cirrus ice number density in a parcel and one-dimensional model” by D. M. Murphy

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Reviewer 2:

Main points 1) It is well known that sedimentation is of major importance for shaping cirrus clouds in the vertical. . . . Thus, the qualitative results about the role of sedimentation in comparison with the observations seem not really new. . . . Since all events were tracked, I would like to see a quantitative statistical analysis about the frequency of occurrence of such events. . . . For the stratiform cirrus clouds in the model study, the vertical extensions of nucleation zone and sedimentation dominated vertical layer could be estimated and used for a more quantitative comparison with observations.

Reply: I do not claim to have found the importance of sedimentation, and I think this is
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stated in the discussion. The new result is the interaction of the variability of temperature histories with sedimentation to add importance to those histories that only produce a few crystals. The frequency of occurrence of the events is shown in Figure 1 for the parcel. The 1D model uses the same microphysical code and temperature histories. Comparing the vertical extent of the sedimentation dominated vertical layer to observations would be interesting but can't be done because the initial humidity vertical profile is an assumption in the 1D model.

2) Lack of model description and setup.

Reply: More detail has been added to the model description; see also response to reviewer 1. The reviewer is incorrect in thinking that the model was developed for polar stratospheric clouds; the parcel model was developed for cubic ice over a range of temperatures and the one-dimensional model was developed for cirrus.

Minor points: 1) Description and realism of temperature fluctuations.

Reply: The temperature fluctuations are now explained more in the text. The reviewer is correct that temperature fluctuations “are not just noise but they stem from dynamic features.” Unfortunately, a one-dimensional model or parcel model cannot resolve those dynamics and must therefore use imposed fluctuations. The fractal fluctuations are quite realistic in terms of reproducing the spectrum and autocorrelations found in the atmosphere.

2) Ice nucleation: better reference the well-known effect of modification and/or suppression of homogeneous nucleation events due to previous heterogeneous nucleation events.

Reply: Most of the suggested references have been added; two didn't quite fit. For example, one of the papers modeled measurements now known to be affected by shatter.

3. Accommodation coefficient: There is a recent review including new measurements

on the role of the accommodation coefficient for phase transitions vapour-ice (Skrotzki et al., 2013). They report values in order of 0.5 to unity for the accommodation coefficient.

Reply: This paper is now referenced. Based on it I have rerun the simulations (and changed all figures) with slightly higher values of the accommodation coefficients (0.2 and 0.4 for I_c and I_h , respectively). I'm not quite willing to go up near unity on the basis of this study when studies such as Magee et al. (2006) still support much lower values. It makes me wonder if some of the discrepancy in the literature is due to some experiments measuring the accommodation coefficient on disordered ice and some on hexagonal ice.

4. Interpretation of low ice crystal number concentrations: It is not correct that low ice crystal number concentrations are hard to obtain at low temperatures. Spichtinger and Krämer (2013) have shown that under certain conditions this work quite well. In addition, former studies by Lin et al. (1998) showed that for wavy structures phase shifts might lead to low number concentrations, even in a high velocity regime.

Reply: Both papers are already cited as showing that it is possible to create low ice crystal number concentrations at low temperatures from homogeneous freezing. This paper goes beyond that to show (Figure 1) that the vast majority of temperature histories produce high numbers. Yet the few that produce low numbers are still important.

5. Mixing of different scenarios in the discussion: In the discussion, different scenarios were mixed in a confusing way. For instance, the comparison with cold stratospheric conditions including NAT particles is misleading. ... The comparison to liquid clouds is also not really meaningful, since the conditions for pure ice clouds are quite different.

Reply: The comparison to stratospheric NAT clouds is there because the Fueglistaler et al. paper identified a mechanism of sedimentation that also applies to cirrus. I've added a sentence to try to clarify the mechanisms. I agree that conditions for ice clouds are different – the point of mentioning liquid clouds is to say that they are very different.

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6. Cirrus clouds in a supersaturated environment: This issue is strongly related to the former point. Ice formation requires high supersaturation (in contrast to droplet formation), thus from theory it is very clear that ice clouds are embedded into a supersaturated environment. This was shown in many former measurements, thus some articles of the relevant literature should be cited.

Reply: I've moved the citation of Diao et al. to a separate sentence where I also cite several of the observational studies suggested by the reviewer.

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