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Discussions

Interactive comment on "What controls the low ice number concentration in the upper troposphere?" *by* C. Zhou et al.

Anonymous Referee #1

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General Comments:

This paper was well prepared and written, and organized quite well. The content of new science is also considerable and represents an important advancement in our understanding of cirrus clouds. There is little that I could find to improve upon. Therefore I recommend that this paper be accepted in ACP with minor revisions.

This ACPD paper demonstrates the sensitivity of the relative roles of homo- and heterogeneous ice nucleation (henceforth hom and het) in a GCM to the treatment of cirrus updrafts, the presence of pre-existing ice, ice nuclei (IN; including SOA) and/or the accommodation coefficient. The article implies that by representing the cirrus updraft parameterization as a function of temperature or height, the contributions of het and hom to the cirrus microphysics (in the presence of pre-existing ice) can be modified

substantially. Similar changes can be affected through the accommodation coefficient α. By using different updraft parameterizations with lower updrafts at colder T, a key finding in this paper is that predicted ice crystal number concentrations (Ni) are more in conformity with in situ Ni measurements.

The lead author is a co-author on the 2015 GRL paper titled "Can cirrus cloud seeding be used for geoengineering?". In that paper as well as this one, pre-existing ice can dramatically affect the relative roles of hom and het since pre-existing ice will limit the in-cloud RHi whenever ice saturation is exceeded (RHi > 100%), and it often prevents the RHi from reaching the RHi hom threshold. Since the ice surface area from pre-existing ice is often much greater than that produced by freshly nucleated crystals via het, these factors make pre-existing ice a more powerful limiter for RHi. The main question I would like to pose here is this: assuming pre-existing ice and competition between het and hom (with reasonable IN concentrations), is it possible that some combination of physically plausible updraft schemes and a plausible value for α could change the results in Penner et al. (2015) such that a net radiative cooling is produced by seeding the cirrus clouds?

Another question concerns the accommodation coefficient α. As noted in the paper, one laboratory study estimated that α for ice was around 0.006 (Magee et al., 2006). As shown in Lamb and Verlinde (2011, Physics & Chemistry of Clouds, Cambridge Univ. Press, p.339) and Fukuta and Walter (1970, JAS) for liquid water droplets, changing α from 1.0 to 0.1 has a very modest impact on diffusional mass growth rates, but changing α from 0.1 to 0.01 will have a relatively huge impact. The same physics applies to ice crystal growth. Please comment on how assuming an α of 0.01 would impact the results shown here. A new figure would be helpful in this regard.

Last but not least, the recent work of Minghui Diao and colleagues uses in situ observations of RHi and Ni to understand the Lagrangian evolution of cirrus clouds (e.g. Diao et al. 2013, GRL; Diao et al. 2014, GRL; Diao et al. 2015, JGR). The horizontal extent of ice supersaturated regions (ISSRs) and ice crystal regions (ICRs) were measured by aircraft. During the ice nucleation phase of cirrus cloud growth (when cirrus are not produced through deep convection), the ICR/ISSR ratio is relatively small ($< \sim 0.5$) and the probability of this phase being sampled (a measure of temporal duration) is relatively small (3 to 4%). The ice nucleation zone is generally near cloud top (Diao et al., 2015). These findings suggest that ice nucleation is a short-lived transient event that occurs in an ISSR in the absence of pre-existing ice. Thus pre-existing ice is not likely to accompany ice nucleation events as assumed in many of the simulations in this paper. This point needs to be made in the paper along with the above references to the work of Diao et al.

Minor comments:

1. Page 35909, line 6: Suggest modifying sentence to read: Cirrus clouds (T < 235 K) cover about 30% . . .. 2. Page 35910, line 11: RHi is used for the first time here; please define it. 3. Page 35915, line 14: Please indicate what SOA01 refers to, or indicate the section where it is explained. 4. Page 35917, line 23: sizes => values? 5. Page 35919, line 21: concentrations is misspelled

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Interactive comment on Atmos. Chem. Phys. Discuss., 15, 35907, 2015.