Review of ACP MS No.: acp-2022-717
Title: Characteristics of supersaturation in mid-latitude cirrus clouds and their adjacent cloud-free air
Author(s): Georgios Dekoutsidis, Silke Groß, Martin Wirth, Martina Krämer, and Christian Rolf
MS type: Research article
Iteration: Correction

General Comments:

A longstanding question in cloud physics is whether homogeneous ice nucleation (henceforth hom) is a relevant process in the atmosphere. Recent satellite remote sensing studies (Sourdeval et al., 2018, ACP; Gryspeerdt et al., 2018, ACP; Mitchell et al., 2018, ACP) have provided evidence that hom can strongly affect the microphysics of cirrus clouds as inferred through changes in the relative concentration of ice particles, but direct in situ airborne measurements have not yet provided compelling evidence for this. This study by Dekoutsidis et al. appears to be the first measurement-based study that provides mechanistic evidence that hom is an important process affecting cirrus cloud properties. That is, by profiling the atmosphere during the ML-Cirrus campaign with the WALES lidar system to obtain the relative humidity over ice (RHi) inside and outside of cirrus clouds, this study reveals the cloud levels relative to cloud top where hom is likely to dominate, and cloud levels where heterogeneous ice nucleation (i.e., het) or sublimation is likely to be the dominant process. While previous work has shown that RHi in cirrus is highest near cloud top (Diao et al., 2016, JGR), no earlier study has shown that RHi conducive to hom is typically found near cirrus cloud top. This study thus provides a mechanistic foundation helpful for interpretating other cirrus cloud studies, including anvil cirrus as shown in Fig. 7 of this manuscript.

Figure 10 in Mitchell et al. (2018, ACP) shows CALIPSO retrieved N_i for cirrus cloud layers at various temperature levels in terms of their layer thickness, where layer thickness is characterized by the difference $T_c - T_{top}$ with T_c = median cloud radiative temperature and T_{top} = cloud top temperature. The cirrus clouds sampled were relatively thick optically, having optical depths (OD) ranging from ~ 0.3 to 3.0. A key finding was that the relatively thin cirrus cloud layers had a much higher N_i than the other cirrus cloud layers. This begs the question "What is causing the high N_i in the thin cirrus layers?" Would it be possible for the authors to organize their RHi data in terms of cirrus cloud layer geometrical thickness (for a similar OD range) in order to address this science question? This is similar to what has already been done, but in this case RHi is not being profiled within a given cloud, but rather a single median RHi characterizes each cloud layer. The working hypothesis to be tested might be that relatively thin cirrus have RHi closer to the hom RHi threshold than for thicker cirrus clouds. Theory supporting this hypothesis may be found in Spichtinger and Geirens (2009, ACP).

I found little to criticize in this manuscript, which is well written and organized with high quality figures. A few comments are given below for possible improvements. This manuscript is definitely worthy of publication in ACP.

Major Comments:

1. Lines 204-205: Do you think this may be due to entrainment?

2. Lines 242-250: The probability density at cloud top for RHi > 140% is ~ 0.012 in Fig. 3 (for all clouds sampled) but is much lower at cloud top for both in situ and liquid origin cirrus clouds in Fig. 5. Perhaps this is an artefact of different binning procedures, but some explanation seems warranted.

3. Lines 329-330: This conclusion also appears consistent with the findings in Diao et al. (2015, JGR) that use RHi and ice crystal concentration measurements to define 5 stages of cirrus cloud evolution (Diao et al., 2013, GRL), with the ice nucleation stage in the uppermost portion of cirrus clouds. Please cite these papers if appropriate.

4. Lines 352-354: From Fig. 4, these two maxima (corresponding to liquid origin and in situ cirrus) appear to occur at 223 K and 217 K, respectively. Please check this and revise the maxima temperatures if this is correct.

5. Lines 394-395: What was the flight ceiling for HALO during ML Cirrus? Please report this in the paper.

6. Lines 419-422: The global cirrus cloud retrievals of N_i and D_e reported in Mitchell et al. (2018, ACP; Figs. 9 & 11) also show considerable differences between tropical, mid- and high latitude cirrus cloud properties as a function of season. Sourdeval et al. (2018, ACP) shows the same for N_i. Please cite these studies if appropriate.

Technical Comments:

1. Line 109: where => were?

2. Line 127: No comma is needed in this sentence.