Referee #1

Dear Referee 1,

we would like to thank you for your time and the valuable feedback. Your positive opening comments are a strong motivation. Your suggestion to group the RHi data depending on the geometrical depth of the layers has stirred discussions in the group and we find it a very interesting scientific question.

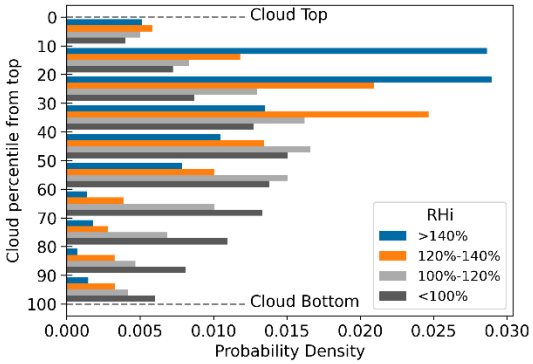
Regarding the reviews, please find in the following a detailed reply on your comments. We present your comments/questions in Bolt lettering followed by the reply. For changes in the text I present the original text in blue and the updated/added text in green color.

Major Comments

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

   Yes, entrainment could be a possible explanation for this finding. Unfortunately, entrainment is not something we can study with a lidar instrument. Another possibility is that this stems from measurements of clouds in their last stages of their life cycle. Since we perform a statistical analysis of all the data it is not possible to attribute this to certain clouds. Finally, another probable explanation would be that the cloud mask misidentifies some areas as in-cloud in regions where the cloud-top is not smooth, leading to some otherwise lower-RHi cloud-free points to be counted with the in-cloud points

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.**

   Thank you for pointing this out. This confusing characteristic is not due to binning, but rather a different handling of the data set when treated as a whole and in groups. When analyzing the whole dataset, in-situ and liquid-origin separation is not considered. In some cases, the uppermost part of a detected cloud is classified as in-situ while beneath is a liquid-origin part. For the analysis of all data points this was seen as one cloud. We have repeated the analysis for all clouds, separating already at that step the liquid-origin and in-situ part. We have recreated the plot and changed the text accordingly.

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.**

Thank you for bringing these publications to our attention. Diao et al., 2015 and 2013 also classify the ice nucleation, growth and sublimation stages based mainly on the values of Relative Humidity over ice. We cite the papers as follows:

…sediment at the cloud base. Diao et al., 2013 & 2015 also define the ice nucleation, growth and sublimation stages based on the measured ice super- and subsaturation. Model simulations…

Regarding the vertical structure, Diao et al., 2015 consider ice supersaturation with respect to distance from tropopause rather than cloud top. We believe this would be misleading for the reader as we define our vertical structure from cloud top. Despite that, Diao et al., 2013 classify evolutionary phases which largely agree with our conclusions on cirrus evolution. Based on this we cite these papers also at line 380 as follows:

…cycle as we do. The evolutionary stages we find are also confirmed by in-situ measurements (Diao et al., 2013 & 2015). Ovarlez et al. (2002), split their observed…

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

Thank you for noticing this in the plots. We have checked the histograms with the latest binning used in the paper and we find the maximum for liquid origin at 225 K 100% RHi and for in-situ at 218 K 79% RHi. The text has been updated accordingly at lines 17, 172, 228, 353.
Line 172:
…distribution is bimodal: One peak can be seen at a temperature of 225K and ice saturation, RHi 100%, and a second one at 218 K and below ice saturation at RHi around 79 %. An increase…

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

Unfortunately, there is no definite answer to this request as there was no fixed flight ceiling set. According to Krautstrunk and Giez 2012 the maximum cruise altitude for HALO is 15540m. After HALO was configured for the ML-CIRRUS campaign and the extra weight was added from the instrumentation and fuel this height was not achieved during the campaign. The flight planning was done in such a way that HALO would fly at least 1.5km over the cloud tops in order to warrant good measurements with the lidar. We have added the extra information at section 2.1 as follows:
Line 86:
…research flights over Central Europe and the NE Atlantic. One advantage of HALO is its high flight ceiling of 15 km (Krautstrunk and Giez, 2012). Due to its payload during the research flights this altitude was not reached, but the flight planning was done in such a way that HALO

would fly at least 1.5km over the cloud tops in order to warrant good measurements with the lidar. More details…

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.**

   The two studies are relevant to be cited and we thank you for your suggestion. The paragraph starting at line 419 has been rewritten as follows:

   Ice nucleating particles, water vapor and the ambient temperature are three factors that strongly affect the formation of cirrus clouds. Common among these three, is that they have a dependence on latitude (DeMott et al., 2010). The microphysical characteristics and thus the radiative effects of cirrus clouds strongly depend on their formation mechanism (Gensch et al., 2008). Based on this it is known that cirrus clouds in the mid- and high latitudes also have different characteristics (Hong and Liu, 2015; Gasparini et al., 2018; Mitchell et al., 2018; Sourdeval et al., 2018) and different effects on the climate (Hong and Liu, 2015; Mitchell et al., 2018; Krämer et al., 2020). Lidar measurements of cirrus clouds in high latitudes are scarce and necessary in order to compare their characteristics with mid-latitude cirrus clouds and investigate possible differences.

Technical Comments

1. Line 109: where => were?
2. Line 127: No comma is needed in this sentence.

Both technical comments have been corrected in the text.