Review on Dekoutsidis et al. paper

This is an excellent study, with a substantial contribution to scientific progress within the scope of ACP. It is based on airborne lidar observations from the PM-Cirrus experimental campaign in the broader Europe domain, and provides characteristics of supersaturation conditions in and around cirrus clouds. The authors classify their finding to clouds formed from in-situ or liquid-origin processes, and provide findings on the relative humidity conditions observed in different locations of the cloud and at different phases of a cloud evolution. The paper is well written and the overall presentation is well structured and clear. It is recommended for publication in ACP after a few revisions provided bellow.

General comment:

A general question popup in my mind while reading the manuscript, which would be nice to have as a reader: What are the cloud depths observed for the cloud categories "in-situ" and "liquid-cloud" in the dataset discussed here? If the authors can provide this information (e.g. median and standard deviation of the cloud depths in the 2 categories) it would be nice.

Specific comment:

Page 3, line 95: "…accurate and suitable for the study of ice clouds: Groß et al. (2014), used water vapor measurements from WALES and found a good agreement with in-situ measurements. Kiemle et al. (2008) …".

This sentence raise the question if these authors provide an indicative quantification of the good agreement from this study, and if yes what was the result. I suggest for the authors to revise this part in order to highlight the new information provided in Groß et al. (2014) on the accuracy of the measurements in ice clouds, in relation to the Kiemle et al. (2008) study discussed afterwords.

Page 4, line 117: "Groß et al. (2014) compared the model temperature with in-situ measurements and found that ECMWF temperature data induces an error of about 10 to 15 % in the calculated RHi. Despite that, they concluded that the ECMWF model temperature is suitable for the study of cirrus clouds at the mid-latitudes".

It would be nice to include a comment related to which extend this error is representative for the cirrus clouds of this study. Furthermore, do you find similar induced errors in the calculated RHi during the ML-Cirrus campaign (e.g. comparing the temperatures from the radiosondes and the ECMWF data)? Is the expected uncertainty constant for the different temperatures (i.e. for 230 K and 215 K), or higher uncertainties are expected for lower/higher temperatures?

Page 4, lines 105 – 108: It I not clear how the classification between the in-situ formed and the liquid origin clouds is done for this study. It would be nice if the authors can provide more specific information on how this classification was done for this work.

Page 5, line 130: "We consider the vicinity around cirrus clouds as a maximum horizontal distance of 250 km from the cloud edges and altitudes from 7 km to 12 km as we mostly detect cirrus clouds in this range".
Will the results of RHi in cloud-free areas change as the distance from the cloud shortens, i.e. in the cloud twilight zone? It would be interesting to use these data and investigate if/how the RHi changes in the clouds twilight zone. it would be nice if the authors can include a comment on that.

Page 5, lines 134 - 141: "Finally… abundant".
Please rephrase to make this part more clear on which are the thresholds used and what they represent. Specifically, in the first sentence is not clear on which parameters are the thresholds calculated. For the 3rd sentence on, is not clear which is the physical rationale that the specific temperature thresholds represent/imply.

Page 5, line 147: "In order to get a more detailed insight in the supersaturation we define three bins of RHi, 100 %–120 %, 120 %–140 % and > 140 %. RHi 120 % and 140 % can be considered approximate thresholds for HET and HOM respectively".
Similarly as for the previous comment, it would be good to rephrase this sentence to provide a clearer connection between the HET and HOM relevant temperature regions mentioned and the three defined bins.

Page 5, line 170 – Page 7, line 186: I think it would be nicer for the reader if you could combine the discussion of these 3 paragraphs, by mentioning the general statistics along with the qualitative discussion in the 2 last paragraphs.

Page 6, line 170: "The in-cloud data points reach temperatures down to 207 K and are most frequently detected close to ice saturation (RHi = 100 %) for the entire temperature range."
From figure 2 it seems like the majority of the in-cloud points at T > 230 K are between RHi = 75% to 100%, and well below 100%. Can you comment on this?

Page 6, line 170: "This feature is detected in many cases and is indicative of air masses with various temperatures and a constant water vapor mixing ratio around 1.5ppmv, which is the minimum value observed in the upper troposphere (Krämer et al., 2009) or data points measured in the stratosphere."
Please rephrase this part to make clearer for which ranges in troposphere and stratosphere this mixing ration is observed.

Page 7, line 202: "In summary, high supersaturations are detected at cloud top and lower supersaturations gradually become dominant towards the middle of the clouds. From around the mid-point of the clouds and until the cloud bottom most data points are subsaturated."

In which extend could the attenuation of the lidar signal through the cloud affect the RHi values closer to the cloud bottom? Could this contribute to the statistics presented in these altitudes? If possible it would be interested to comment on this in the manuscript.

Page 9, Line 204: "For around 20 % of the cases the uppermost layer has lower supersaturation than deeper layers or is even subsaturated (not shown)."
Can you comment if these clouds are observed with some characteristic that differentiate them from the majority? E.g. temperature or vertical extend or aerosol abundance..?

Section 3.2: Similar comment as earlier. I think it would be nicer for the reader if you could combine the discussion of these paragraphs, by mentioning the relevant general statistics of Table 2 along with the qualitative discussion of Figure 4.

Page 10, Line 252: "we choose two special cases".
If possible indicate how the 2 cases chosen are special in compared to the rest of the dataset.

Figure 6, 8: Please include legents in the plot's colorscales. And values (or mention in the legent if unitless).

Figure 7: "The number of layers differs depending on the depth of the cloud".
This is also depending on the lidar penetration in the cloud (especially for p2 phase). Consider revising this sentence accordingly.

Page 13, Line 308: "… Gensch et al. (2008), Kübbeler et al. (2011), Petzold et al. (2017), Kaufmann et al. (2018), and Krämer et al. (2009, 2020) also found an RHi mode close to or at ice saturation for mid-latitude cirrus clouds".
It would be nice to mention the type of dataset used for these studies, i.e. in-situ measurements, radiosondes, lidars?

Page 14, Line 342: "Voigt et al. (2010) also find the cloud-free RHi values to be mostly subsaturated, but higher than 70 % RHi".
Please improve the syntaxes of this sentence to make it clearer.

Page 14, Line 366: "Liquid-origin clouds are thus more frequently measured in environments with ever so slightly lower updrafts, than in-situ clouds".
One would expect that from the way the liquid-origin clouds were defined in section 2.3 they would be in environments with stronger vertical motions (updrafts and downdrafts in the cloud) than the in-situ clouds, while the sentence is arguing the opposite. If possible, it would be nice if the authors can enhance this discussion (e.g. by adding some other references supporting this statement) or provide a comment on why this may be observed.

Page 15, line 397: "The use of a lidar instrument is advantageous over in-situ measurements, as it provides a 2D curtain including the complete vertical structure of the measured clouds. This way one overflight is sufficient enough to measure a whole cloud or cloud system..".
The lidar signal gets often totally attenuated as it measures through a cloud (which is also evident in the 2 case studies of this work). It would be better if the authors rephrase this part to be more accurate to the real capabilities of a lidar instrument.

Page 16, Line 422: "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".
Lidar measurements of cirrus clouds in high latitudes are not scarce, considering the 15-year record of CALIPSO dataset. But the lidar water vapor measurements are. Consider rephrasing this part.

Technical corrections:
Page 1, line 16: "..ML-Cirrus data-set**,** there are two.."
Page 10, line 250: "..lower than **the ones in** the deeper.."
Page 11, line 273: "..**in** the young cells..."
Page 11, line 278: "**In** the third part.."
Page 14, line 369: "Young, newly formed**,** clouds.."