

RC2: '[Comment on egusphere-2025-2052](#)', Eleni Marinou, 26 Aug 2025 [reply](#)

*Thank you to Eleni for her careful review and for the comments and suggestions on this manuscript. In the following, **the Referee's questions and comments are repeated in black and our responses follow in blue.***

This article by Li and Gross presents an analysis on statistics of cirrus cloud properties at Mid and high latitudes, and discusses the different findings per season, altitude, temperature, and aerosol abundance. The results are new, and the study is relevant to the objectives of the journal. The work is complete, scientifically accurate, and significant, and the manuscript is well-written and well-structured. Overall, the study is suitable for publication. Certain sections could benefit from some additional clarifications, as described herein.

General comments:

Smoke layers from Canadian fires were frequently detected from CALIPSO during the years of the study. It would be interesting to include a discussion about the possible effect of the elevated smoke layers in the stratosphere on the ice in these altitudes in the 2 domains.

➔ Thank you for the general comments. Indeed, smoke layers from Canadian wildfires were frequently detected with CALIPSO and with ground-based lidars in Europe. It has become a hot topic in the relevant research of aerosol-cloud interaction since the larger amount of smoke aerosols lifted into the UTLS regions can act as INPs to trigger cirrus formation and modify cloud optical and microphysical properties. In general, smoke provides surfaces for heterogeneous ice nucleation, suppressing homogeneous nucleation, which leads to the formation of fewer, larger and more irregular (non-spherical) ice crystals. In addition, smoke aerosols acting as INPs can trigger ice nucleation at higher temperatures and lower supersaturation leading column-like and bullet-rosette crystal formation. Consequently, this increases PLDR and tends to reduce extinction efficiency (and optical depth). However, due to different backgrounds in the 2 domains of high- and midlatitudes, the influence (or the contribution of the influence) of biomass burning smoke on cirrus clouds can be very different. Smoke transported into the very cold and stable UTLS regions at high latitudes (and Arctic) can suspend very long, providing a persistent INP reservoir for cirrus formation. Smoke at midlatitudes is normally episodic and mixed often with other aerosols and airmasses. The competition with other local aerosols, like dust, marine aerosols, and anthropogenic pollution aerosols, can dilute the smoke contribution to ACI.

Consider including in the abstract the information that the cloud statistics of this work focus on temperatures $< -38^{\circ}\text{C}$, excluding ice observations above these temperatures.

➔ The information is added.

In section 4.3, it is not clear what the contribution of this study is to this discussion. I suggest revising the text to make your results clearer in relation to or in addition to the past studies in this summary. The way it is written now could be part of the introduction of this paper.

- Section 4.3 is a very important part to interpret the observed difference of cirrus cloud properties in the high- and midlatitude regions, although no simultaneous measurement of embedded aerosols is available for the current study. For our argument, the statistical distributions of aerosol particles, theoretically and observationally, from literatures are sufficient for the scope of the current study.

Specific comments:

Page 1, line 9: “The distributions of PLDR in each 5-degree latitude bin show a general decrease with increasing latitude”: Suggestion to add the physical meaning of increased PLDR.

- The physical meaning of increased PLDR is added.

Page 4, line 124: “level 2 5-km cloud profile products”: It is useful to include the version of the product.

- “The Version 4” is included.

Page 4, line 125: “all the atmospheric entities”: With this phrase, one may be confused whether the product also includes information on the aerosols. Consider revising.

- In the next sentences, we clarified that we distinguish cirrus clouds from other features including aerosol by using VFM as well as a temperature threshold ($<-38^{\circ}\text{C}$).

Page 5, line 128: “..VFM..”: It is useful to include the version of the product.

- “The Version 4” is included.

Page 5, line 138: “mid-latitudes (35–60°N; 30°W–30°E) and high-latitudes (60–80°N; 30°W–30°E)”: suggestion to include a figure with the map and the 2 domains (maybe in the appendix).

- A map of the research area is added in the supplementary material.

Page 5, line 142: “in 5 years of 2014 and 2018–2021 are analyzed”: Please include a short explanation why you exclude the other good CALIPSO years (2007–2017).

- It is clarified that “the choosing of 2014 is due to the potential cross comparison study between satellite and airborne measurements during the ML-CIRRUS field campaign ...”. The years of 2018–2021 are chosen for covering 2 non-COVID years, a heavily COVID-influenced year of 2020, and 2021, a year with relatively mild COVID-19 impacts.

Page 5, lines 156-158, and Table 1: I suggest considering excluding the 2nd digit after the decimal point (statistically not significant).

→ They are revised accordingly.

Page 6, line 6: “variations in the altitudes with the maximum ORs along the latitudes are discernable, showing the largest values in summer”: suggestion to change as “showing the largest altitude values in summer”.

→ They are revised accordingly.

Page 6, line 192: “which is related to the larger variabilities in humidity at HL than at ML and is consistent with a recent model study showing larger INP effects on cirrus at higher latitude”: Isn’t the largest variability of temperature also a significant contribution for HL ORs also?

→ Temperatures play a crucial role in cirrus formation. Is the temperature variability larger at HL? I did not find any reference to back up that.

Page 7, line 202: “show that the thickest cirrus clouds formed in winter and the thinnest ones in summer”: I am not sure I see this in the plot, as overall Winter has the highest CR for thin clouds also. Can you rephrase this part to make it clearer?

→ From Figure 3, we can clearly see that the probability of occurrence with the geometrical depth larger than 0.1 km (or 0.3, 1.0, and 2.0 km) is the largest in winter and smallest in summer.

Page 7, line 210: “presumed to be smaller at HL than ML”: Is this correct? It seems higher at HL.

→ Thank you to point it out. Aviation density is much lower at HL, which means the contribution of aviation impact on cirrus at HL is lower. So the influence due to aviation reduction during COVID is presumed to be smaller at HL.

Page 7-8, section 3.2. Consider including a sentence on why you concentrate in Spring among all the seasons, if there is a reason of interest to the reader.

→ It’s mentioned that the datasets we analyzed in this study cover pre-COVID years, a strongly COVID-influenced year, and a moderate COVID-influenced year. The differences in cirrus properties under COVID-impact at HL and ML are the most pronounced in Spring. Nevertheless, the distribution of extinction in other seasons are also shown in the supplementary material. The descriptive texts are added.

Page 8, line 234: “indicating smaller and fewer ice crystals at higher altitudes”: suggestion to rephrase to and/or, and it could be one or the other also.

→ Thank you. Revised.

Page 8, line 237: “This is closely linked to the dominant formation processes of ice crystals depending on temperature and relative humidity over ice (RHi). “ This is also closely linked with the most frequent abundance of INP in these altitudes at ML. Consider revising this part to avoid confusion.

→ The discussions are revised.

Page 13, line 400: “more irregular”: more in comparison to what? Please enhance this sentence for clarity.

→ The sentence is revised.

Page 15, line 452: “we compare aerosol concentrations at different latitudes”: Where is this comparison shown? Consider adding a plot of the aerosol concentrations or revising the sentence by e.g., “we compare ice crystal concentrations in regions of different aerosol concentrations as reported in previous studies”.

→ The comparison of aerosol concentrations at different latitudes is widely recognized in terms of statistics and can be found easily in literature. The sentence is revised accordingly.

Figure 1: If possible, add a scale indicating the magnitude of the OR[%] in these plots.

→ The span between the two adjacent dashed lines indicates 3% of OR. The information can be seen in the caption of Figure 1.

Figure 3: Based on these occurrences, ML has more clouds than HL in spring and summer. This is surprising. Can you include a comment in the manuscript on this, maybe backing up the findings with past studies on cloud abundance, or is this a new finding? Also, it would be useful to include a description or equation on how these occurrences are calculated.

→ Cirrus cloud occurrence is generally higher at midlatitudes on an annual mean basis. But, it can become comparable to or higher at high latitudes compared to midlatitudes in autumn and winter due to enhanced moisture transport from lower latitudes and convective activity. From the CALIPSO measurements of cirrus clouds, there are more clouds at ML than HL in spring and summer (e.g. Sassen et al., 2008; Nazaryan et al., 2008; Stubenrauch et al., 2013; Gasparini et al., 2018). So, it is not a new finding but consistent with previous studies.

→ We calculate the frequency of occurrence with cloud thickness larger than a threshold following *Li and Groß* (2021). The full description of the calculation is added.

Typos:

Page 5, line 138: midlatitudes: mid-latitudes

Page 6, line 160: discernable: discernible

Page 11, line 342: exam: examin

Figure 1: 2014 (2018): 2014 and 2018

→ Thank you. They are revised.

Figure 3: occurrence frequency: occurrence rates?

→ The term ‘occurrence rate’ in this manuscript is defined as the ratio of number of lidar profiles where cirrus is detected at altitude z to total number of valid lidar profiles at that altitude. The term “occurrence frequency” is used to describe the probability of the occurrence according to the definition with cloud thickness larger than some threshold. To avoid misunderstanding, it is changed to “frequency of occurrence”.

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