Review of "Upper tropospheric slightly ice-subsaturated regions: Frequency of occurrence and statistical evidence for the appearance of contrail cirrus" by Li et al. (2022)

Overview

This study is focused on the analysis of in-situ microphysical measurements of contrail cirrus and natural cirrus clouds based on the data collected during the ML-CIRRUS campaign. An important component of this work is the attempt to segregate contrail cirrus embedded in natural cirrus. One of the major outcomes of this study is the statistics of RH_{ice} which are suggestive of a bias in the average humidity in contrail and natural cirrus clouds towards undersaturaion, ranging, on average, from approximately 4% to 12%. The paper is well organized and undoubtedly deserves publication.

Recommendation: The paper should be published in ACP after addressing the comments indicated below.

Comments

1. Methodology: Identification of contrails embedded in cirrus and contrail cirrus clouds, within the P and T ranges, predetermined by CA, was based on the analysis of (a) the Schmidt-Appleman criterion (SAC) and (b) measurements of engine combustion products, aerosols and NO_y (aircraft plume detection). A potential caveat of this approach is that NO_y is a passive tracer, whereas cloud particles are an active cloud admixture in the atmosphere with a different response to the force of gravity and turbulent motions. As a result, at some point the contrail ice particles may become spatially separated from the plume and/or the plume may become spatially associated with particles formed in natural cirrus clouds. An explanation regarding this matter would clarify the limitations of the applied methodology. Specifically, what is the maximum age of contrail cirrus clouds when this method can be applied?

2. As indicated in Table 1, the plume detection was only applied to approximately 2% of the collected data set. This brings up a question about the statistical significance of this data subset compared to data set with the SAC only criterion applied. It also would be relevant to state upfront in section 2.3.3 that the plume detection was applied only to a small fraction of the collected data, rather than having the reader figure it out after analysis of the data statistics in Table 1, at the end of the paper.

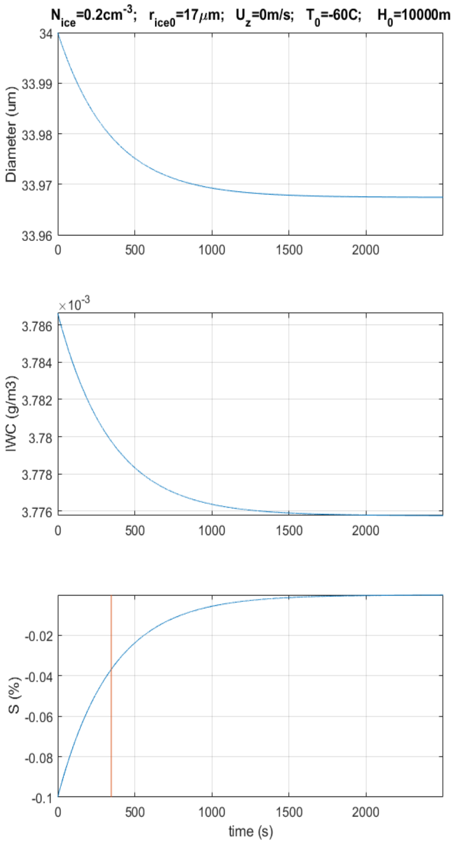
3. Airborne measurements of RH_{ice} at temperatures below -50C are known to be of great challenge. It appears that the accuracy of the RH_{ice} measurement required for the main outcomes of this paper should be of the order of 1%. Even though RH_{ice} is one of the key parameters in this study, there are no discussions of the accuracy of measurements, inflight checks of the performance of humidity probes, etc. A brief discussion of this topic would be highly relevant in this paper, and it facilitate its reading rather than surfing through references. In this regard, I am wondering if you attempted inflight calibrations of water vapor probes in liquid clouds based on the methodology proposed in Korolev and Isaac (2006, JAS, https://doi.org/10.1175/JAS3784.1)?

4. Section 4. I found the discussion around Figure 9 a bit misleading. The diagram in Figure 9 shows changes of T, R_{ice}, and S_{ice} in an adiabatically ascending and then ascending parcel. The supersaturation in the vertically moving parcel will set to its quasi-steady value $S_{qs} = \frac{a u_z}{N_{ice}\bar{r}_{ice}}$ at time $t > 3\tau_{ph}$, where τ_{ph} is the time of phase relaxation (see Korolev and Mazin, 2003, JAS, https://doi.org/10.1175/1520-0469(2003)060%3C2957:SOWVIC%3E2.0.CO;2). The two plateaus with S_{qs}>0 and S_{qs}<0 for the ascending and descending branches, respectively, are clearly visible in Fig.9. However, the authors consider only the descending branch, where the supersaturation is negative, and use it as an argument to explain the negative bias of RH_{ice} in cirrus clouds. However, in stratiform type clouds, vertical ascending and descending motions are approximately equally probable, and the distribution $F(u_z)$ is typically centered around 0. Keeping this in mind, and that $S_{qs}(u_z) = -S_{qs}(-u_z)$, the spatial averaging of humidity will yield $S \approx 0$.

   In addition to the above, it is worth mentioning that complete evaporation of particles in adiabatic parcel will occur at the same level Z_{ev}., which depend on initial IWC and the level Z_0. (To be strict, the level of complete sublimation depends on u_z. However, for the sake of argument, this effect of the condensational inertia can be neglected here.) Therefore, the lifetime of a descending cirrus parcel can be to a first approximation estimated as $t \sim (Z_0 - Z_{ev})/u_z$. Therefore, the estimated longevity of the subsaturated cirrus as 4h is a function of u_z and $IWC(Z_0)$.

   Having said the above, I would suggest reconsidering the argumentation in section 4 and the statement about 4h lifetime in the abstract.

5. I attempted a simulation of the response of cirrus at $u_z = 0$ to the subsaturated environment with $RH_{ice}(0) = 90\%$, and the same N_{ice} and R_{ice} as indicated in Section 4. The results are shown in three diagrams to the right. It turned out that the in-cloud air arrives to saturation within ~25min. The red vertical line indicated τ_{ph} for initial $N_{ice}(0)$ and $R_{ice}(0)$. τ_{ph} shows a typical time of reaching saturation (usually within $3\tau_{ph}$). In this regard, it would be highly beneficial to indicate in Table 1 the time of phase relaxation.



6. IAGOS-MOSAIC data: I believe that the autonomous instruments installed in the commercial passenger aircraft in the frame of IAGOS were not maintained and calibrated with the same depth and frequency as on the HALO research airplane. Even though there are several references in the paper about the IAGOS data quality, it would be helpful to see a few general statements about the accuracy of RH_{ice} measurements.

Minor comments

1. Lines 13, 101, 266: It is not clear what the spatial statistics of the sampled clouds is. It is worth indicating the total length of sampled clouds along with the total cloud sampling time 14.7h.

2. Line 141: In the equation for R_{ice} the notations, "$1.e^{4}$" and "$1.e^{-6}$" are confusing. It should be "10^{4}" and "10^{-6}".

3. Section 2.1, Figure 6 and associated text: It would serve to clarify the paper to use the same type of definition of particle size, rather than switching between radius and diameter. Also indicate the definition of D_p., i.e., max particle size, average projected size, equivalent volume size, etc.

4. Table 1. I found that IWC (mg/m^3) calculated from N_{ice} and R_{ice} based on Eq. on line 141 is systematically lower than those indicated in Table 1. Was IWC (mg/m^3) calculated from IWC (ppmv)? A brief explanation in a footnote would be relevant.

5. Figure 6b: The colors of PSDs for 'Contrail cirrus' and 'Contrail cirrus validated' appear to be the same (magenta and red). It is highly recommended to replace one of the colors by e.g., blue, violet, green, black for a better visualization of the curves.

6. Figure 7a: same as in #4.

7. Figure 8: This diagram uses the same type of lines (i.e., dashed and solid) to indicate different curves.

8. Line 651: "rather thin" => "rather optically thin".

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