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Comment on acp-2022-632

Minghui Diao (Referee)

Referee comment on "Upper-tropospheric slightly ice-subsaturated regions: frequency of occurrence and statistical evidence for the appearance of contrail cirrus" by Yun Li et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-632-RC1, 2022

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

This manuscript examines the thermodynamic conditions (particularly relative humidity) of contrail cirrus in the upper troposphere. Two aircraft campaign data were used in the analysis, ML-CIRRUS campaign and IAGOS-MOZAIC campaign. There are several main results of this work. First, the authors used the IAGOS-MOZAIC campaign to propose a new criterion for identifying contrail cirrus based on frequently observed flight pressure levels (cruising altitude). The second main contribution is the finding on contrail cirrus located in subsaturated air, about 10% lower than ice saturation. Third, a box model (MAID) was used to quantify the lifetime of cirrus in sub-saturated conditions. The results show that cirrus can last 4 hours even when RHice is below 100%, until RHi further reduces to 80%.

The study compared cirrus microphysical properties of several different types – all cirrus sampled in ML-cirrus, natural cirrus with liquid origin or in-situ origin, contrail cirrus satisfying both Schmidt-Appleman criterion (SAC) threshold and Cruising Altitude (CA) threshold. In addition, a few methods to categorize contrail cirrus are compared, including using both SAC and CA methods, using just SAC threshold without CA restriction, and using SAC plus plume detection method.

Overall, the manuscript is well written. The structure is easy to follow, and the logic is clear. The reviewer only has a few main comments/concerns for the authors to address.

Comment 1:

In Figure 7, the occurrence frequency of RHice in natural cirrus peaks at 95%. But the authors described this figure as the RHice centers at 100%: (line 460) "In comparison to Fig. 4e, where the frequencies of RHice in the natural cirrus (SAC–) centre around 100% at temperatures above 225 K (also reported in a global RHice climatology by Krämer et al. (2020), …" The reviewer wonders if this suggests that the water vapor measurements or the combination of water vapor and temperature measurements in ML-CIRRUS has a low bias by 5%? The distributions of all in-cloud RHice for in-situ and remote sensing observations also suggest there may be a low bias for in-situ observations. If this is the case, then the subsaturated conditions for contrail cirrus would be more around 95% instead of 90%.

Previously, several studies on US NSF-funded field campaigns analyzed in-situ measurements of RHice for cirrus clouds. They all showed a peak position at 100% for RHi distribution, such as:

Figure 12b in Patnaude, R., M. Diao, X. Liu, S. Chu. Effects of Thermodynamics, Dynamics and Aerosols on Cirrus Clouds Based on In Situ Observations and NCAR CAM6 Model. Atmospheric Physics and Chemistry, 21, 1835–1859, https://doi.org/10.5194/acp-21-1835-2021, 2021

Figure 5 in Diao, M., G.H. Bryan, H. Morrison, and J.B. Jensen, Ice nucleation parameterization and relative humidity distribution in idealized squall line simulations, Journal of the Atmospheric Sciences, 74, 2761–2787, https://doi.org/10.1175/JAS-D-16-0356.1, 2017.

Figure 4 in Diao, M., M.A. Zondlo, A.J. Heymsfield, L.M. Avallone, M.E. Paige, S.P. Beaton, T. Campos and D.C. Rogers. “Cloud-scale ice supersaturated regions spatially correlate with high water vapor heterogeneities”, Atmospheric Chemistry and Physics, 14, 2639-2656, 2014.

Can the author look more closely into the time series of the flights, and see if there was possible bias in RHi measurements? One possible method is to look at RHliq for warm clouds and they should be very close to 100% liquid saturation. Although this method may not work well if the bias from the instrument is temperature dependent (which you should be able to tell from lab calibrations). Did the SHARC instrument participate in any water vapor intercomparison experiment, or lab comparisons with commercial chilled mirror hygrometer such as RHS system (accuracy +/-1 0.1degC)? Another possible method is to examine typical cirrus clouds sampled in ML-CIRRUS, and especially the ones mixed with ice supersaturated segments. When the ice crystal regions and clear-sky ice supersaturated regions are intermittently observed, it is often that the ice crystal regions show ice saturation or slight ice supersaturation instead of ice subsaturation. If these segments frequently show ice subsaturation when they are surrounded by clear-sky ice supersaturation, it would be an indicator of possible low bias in RHice.

The uncertainty of water vapor instrument, temperature probe, and the combined RHice uncertainty from water vapor and temperature should be added in the description around line 125.

Comment 2:

The reviewer suggests adding an analysis on the distribution of RHi for inside contrail cirrus with respect to the cruising altitude. If the author calculate delta_z or delta_p for each second of flight data with respect to cruising altitude, and plot RHi only for inside contrail cirrus (CA + SAC methods), will the RHi distribution show more ice supersaturation on the higher levels and more subsaturation in the lower levels? This can help verify if these contrails in the sub-saturated conditions happen due to ice crystals sedimenting into lower altitudes with subsaturated conditions, or the contrail ice crystals stay at similar altitudes, but their environmental condition gradually becomes subsaturated.

Comment 3:

In Figure 3, can the authors add a third row, for Nice versus Rice and RHice versus temperature (similar to Figure 3 c and d), but categorize the samples into two groups, (1) fulfilling the plume detection criterion or (2) not fulfilling that criterion? It is unclear where the samples fulfilling that plume detection criterion would be distributed, and how they are related to the SAC and CA criteria.

Figure 5 would also benefit from an additional row, illustrating Cirrus: fulfilling SAC, inside CA, and also with restriction to plume detection. The reviewer wonders if applying a third restriction of plume detection criterion to the combined SAC+CA criteria would make a big difference.

Comment 4:

Line 74, CONCERT 2018 campaign, should this be 2008?