Response to the Reviewers
Format: The reviewers' comments are quoted in italic
Section number in the response refers to the revised manuscript with tracked changes
Quotation in red stands for revised/added text in the revised manuscript

Overall comment:
We thank the reviewers for their detailed comments. We provided more discussions regarding the possible influence of ice shattering on the generation of large aerosols as requested by Reviewer #1, provided more time series figures with information of small ice crystals (Ni_1-3μm), added a new supplemental Figure S7, and added references as suggested by both reviewers. We also discussed the drawbacks (i.e., significantly fewer samples, missing real variability) of using the clear-sky Na data calculated for a coarser scale (100 seconds) and explained why we kept using the 1-Hz Na data in the main text and included the clear-sky Na in the supplemental figures. Our main conclusions remain the same, for example, a near-linear relationship between $\mathrm{dlog_{10}IWC}$ and $\mathrm{dlog_{10}Na_{500}}$ is seen, regardless of lower or higher IWC.

Below are our individual responses to the reviewers' comments and the corresponding changes.

Response to Reviewer 1's comments:

Overall, the authors have put extensive work towards addressing my comments; and I thank the authors for doing so. However, some of my concerns still stand, particularly related to biases associated with aerosol measurements in-cloud. I recommend the authors address the concerns below. I respond to my previous three major concerns in the prior review below:

Addressing Major Concern #1:

The authors go through great lengths to argue large aerosol measurements (Naer500) are not biased by ice crystals, which is much appreciated. But I am not convinced by their arguments. They note that most in-cloud samples have Naer500=0. However, the frequencies of Na500=0 and >0 may correspond with low and high IWC, respectively. I had requested in Major Comment #2 that they should provide sensitivity tests for what I would argue to be more realistic in-cloud thresholds. These larger thresholds would most likely be associated with greater frequencies of Naer500>0 due to the greater likelihood of shattering. They also mention small ice particles having comparable sizes to large aerosol have very low lifespans. This does not account for the possibility of ice shattering, where studies show relatively larger ice particles are more likely to shatter (references within Section 3 of McFarquhar et al. (2017)). Comments related to those associated with their respective supplementary figures are provided below:

We thank the reviewer for these detailed comments. Regarding the question of whether the positive correlations between IWC and $\mathrm{Na_{500}}$ is mainly caused by shattering, we would like to point out that the positive correlations of $\mathrm{dlog_{10}(IWC)}$, $\mathrm{dlog_{10}(Ni)}$, $\mathrm{dlog_{10}(Di)}$ with respect to $\mathrm{dlog_{10}(Na_{500})}$ are nearly linear, and these positive correlations follow very similar slopes either for $\mathrm{dlog_{10}(IWC)} <= 0$ or $\mathrm{dlog_{10}(IWC)} > 0$. This means that even for lower IWC values, they follow nearly the same positive correlations with $\mathrm{Na_{500}}$ compared with higher IWC values. If shattering events were the main reason to cause such positive relationship, we would expect to see this positive correlation varies between lower and higher IWC values, which is not the case. Below we copied Figure 6 from the manuscript, which shows the linear regressions.

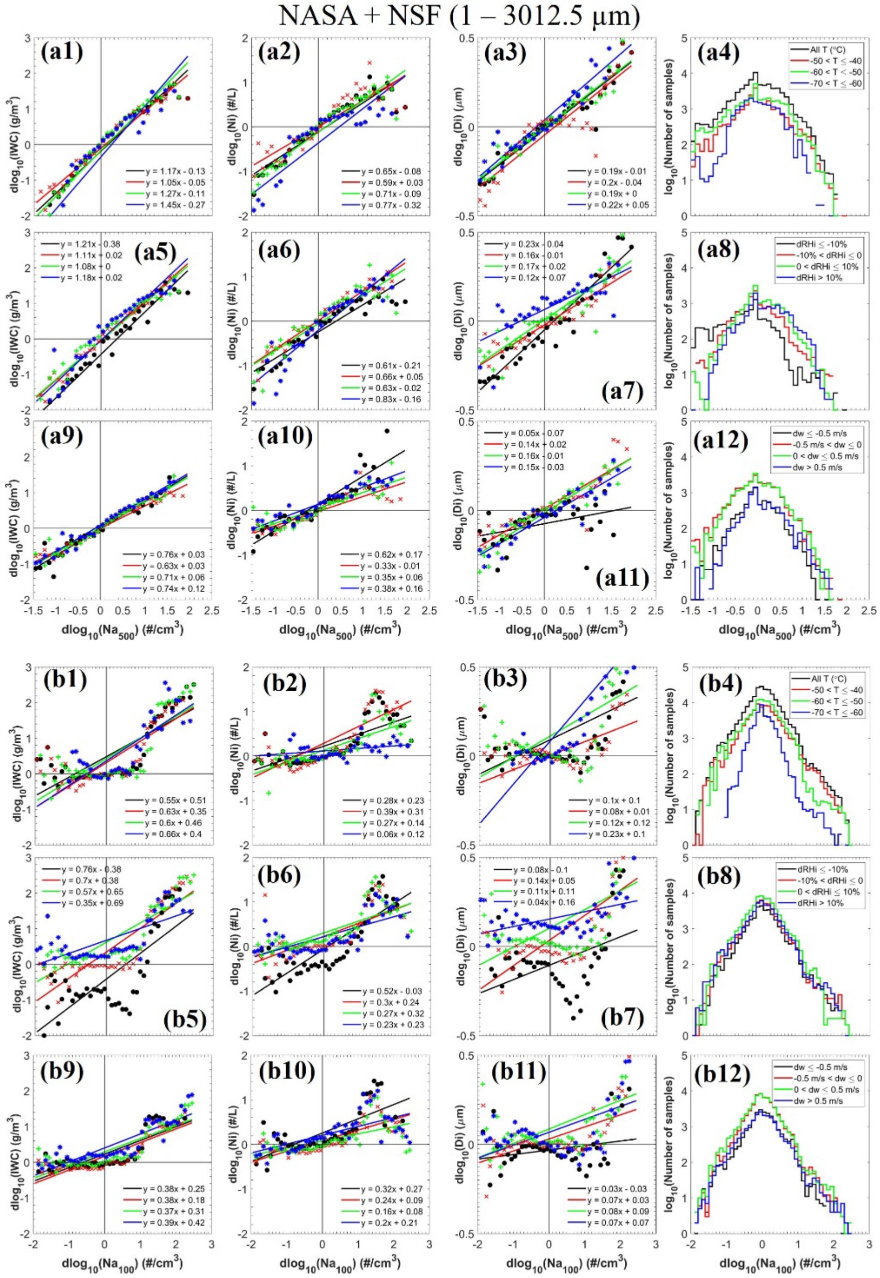


Figure 6. Linear regressions quantifying the correlations of dlog$_{10}$IWC, dlog$_{10}$Ni, and dlog$_{10}$Di with respect to dlog$_{10}$(Na$_{500}$) in top 3 rows and dlog$_{10}$(Na$_{500}$) in bottom 3 rows. The analyses in Figures 6 – 10 use the combined NASA+NSF datasets (1 – 3012.5 µm). ACI is examined for various ranges of temperature (in rows 1 and 4), dRHi (in rows 2 and 5), and d*w* (in rows 3 and 6). Colored dots represent geometric means of ice microphysical properties in each Na bin. Slope and intercept values are shown in the legend. The last column represents the distributions of the number of samples.

Addressing figure R1: I initially recommended they provide multiple case studies showing Naer500 within and in the vicinity of the cloud. They provide one time series and state: "the fluctuations of both Na100 and Na500 are independent of those of IWC." However, there is a clear increase in the frequency of Na500>0 where IWC peaks (~25:52:00). They then argue that Naer500 should be greatest where Di is smallest and

Ni is relatively high at 26:00:00, but no aerosols are observed at this time, thus supporting their claim of no bias. Not only does this not account for the possibility of ice shattering, but aerosol measurements here appear to be missing data, since all aerosol measurements immediately vanish. I had hoped to confirm this, but the UTC times extend beyond those of the research flight they are showing, which appear should end around ~23 UTC. I urge the authors to revisit this figure and their arguments.

Perhaps I could have been clearer initially in requesting case studies. I had hoped the authors could show cases of level flight legs which have relatively similar aerosol concentrations within and right outside of the cloud – ideally where the cloud boundaries are observed at RHi>=~100. In fact, aerosol concentrations would likely be slightly lower than outside of the cloud due to the activated INP. I am open to arguments of why such cases are not found and/or why this is not a plausible verification method.

We thank the reviewer for diligently checking the time series. After diagnosing the problem that the reviewer pointed out, we noticed that the RF number was mistakenly labelled due to a small error in our original code that automatically plotted every hourly segment for individual flights in each campaign. Because that code automatically grabbed the file number in a folder to be the RF number and some file sequence was shuffled during the editing, the sub-title RF number was wrong for the original figure. The time series we previously showed in the original Figure R1 were actually from RF08 in NASA DC3 campaign (instead of RF03). We corrected that error by using the exact date of each time series in the figure sub-title to avoid future problems. Below is the corrected figure, labelled as the new **Figure R1**. Regarding the reviewer's comment about the higher Na_{500} at ~ UTC 25:52, we saw other spikes of Na_{500} at similar magnitude when IWC was much lower (by 1 order of magnitude) around UTC 25:38 or UTC 25:55 compared with the highest IWC at UTC 25:52. Thus, it is not only the higher IWC that has higher Na_{500} values but lower IWC values can also have higher Na_{500} values.

Previously, Reviewer #2 gave us a very good suggestion, which was to examine the relationship between Na_{500} and Ni of small ice crystals (1-3μm), here after named as Ni_1-3μm. The logic is that if ice shattering events were to happen frequently, they would generate small ice particles such as 1-3 μm. We added the Ni_1-3μm variable in these time series. In addition, we added another variable called sigma_Di (i.e., the standard deviation of size distribution) in the bottom row of these figures, because shattering events tend to create a bimodal distribution of particle size distribution (PSD), that is, some small ice would be created due to shattering while the large ice peak still exists. In **Figure R1**, no small ice was detected for this cirrus segment, i.e., Ni_1-3μm = 0.

We chose another time series from NSF DC3 (**Figure R2**, below) to illustrate a relatively constant value of Na_{100} inside and outside of clouds as requested by the reviewer. The Na_{500} is also relatively constant for the cirrus cloud segment between UTC 19:40 and 20:10, although it is more sporadic since not many large aerosols exist at those lower temperatures. When examining the ratios between Na_{500} / Ni_1-3μm, we found that this ratio is quite high. For example, for the cirrus segment, the Na_{500} is around $10^{0.3} = 2$ cm^{-3} (i.e., 2000 L^{-1}) while Ni_1-3μm is zero. Or if we compare it with the Ni_1-3 μm values at higher temperatures at UTC 19:20 to 19:30, their values are $10^{1.5} = 31.6$ L^{-1}. Thus, in this example, the Na_{500} values are 63 times the Ni_1-3μm values.

In **Figure R3** below, we showed the previous example that we showed in our response to reviewer #2 in the last round of revision (the original Figure R3). Reviewer #2 responded back to us in the second round of review that this is evidence that Na_{500} is less likely affected by Ni: "*Fig. R3 shows that Na_500 is generally > 28 times higher than small ice or Ni(1-3 um), showing that it is unlikely that Ni affects Na_500 significantly*." To be exact, the Na500 values are around 1778 to 31623 L^{-1}, while Ni_1-3μm is 31.6 to 3162 L^{-1}.

We also calculated the average Na_{500} / Ni_1-3µm ratios for each campaign and SEAC4RS shows relatively lower ratios compared with other campaigns, possibly due to higher influences of convective activity in that campaign that generated more small ice crystals. This indicates that other campaigns are even less likely to have artifacts for in-cloud Na_{500} measurements: "Nevertheless, when calculating the ratios between Na_{500} and small ice concentrations (Ni_1-3µm) when both large aerosols and small ice were detected, the average ratios for each campaign are 24 for NASA SEAC^{4}RS, 81 for NSF CONTRAST, 96 for NSF-DC3, 108 for HIPPO, 242 for ORCAS, 68 for PREDICT, and 716 for TORERO, indicating that it is unlikely that the sublimation or shattering of ice crystals contributes to the existence of large aerosols (i.e., $Na_{500} > 0$). Note that this ratio can only be calculated for campaigns with both aerosol and small ice measurement (by CDP, FCDP, or Hawkeye-CDP)."

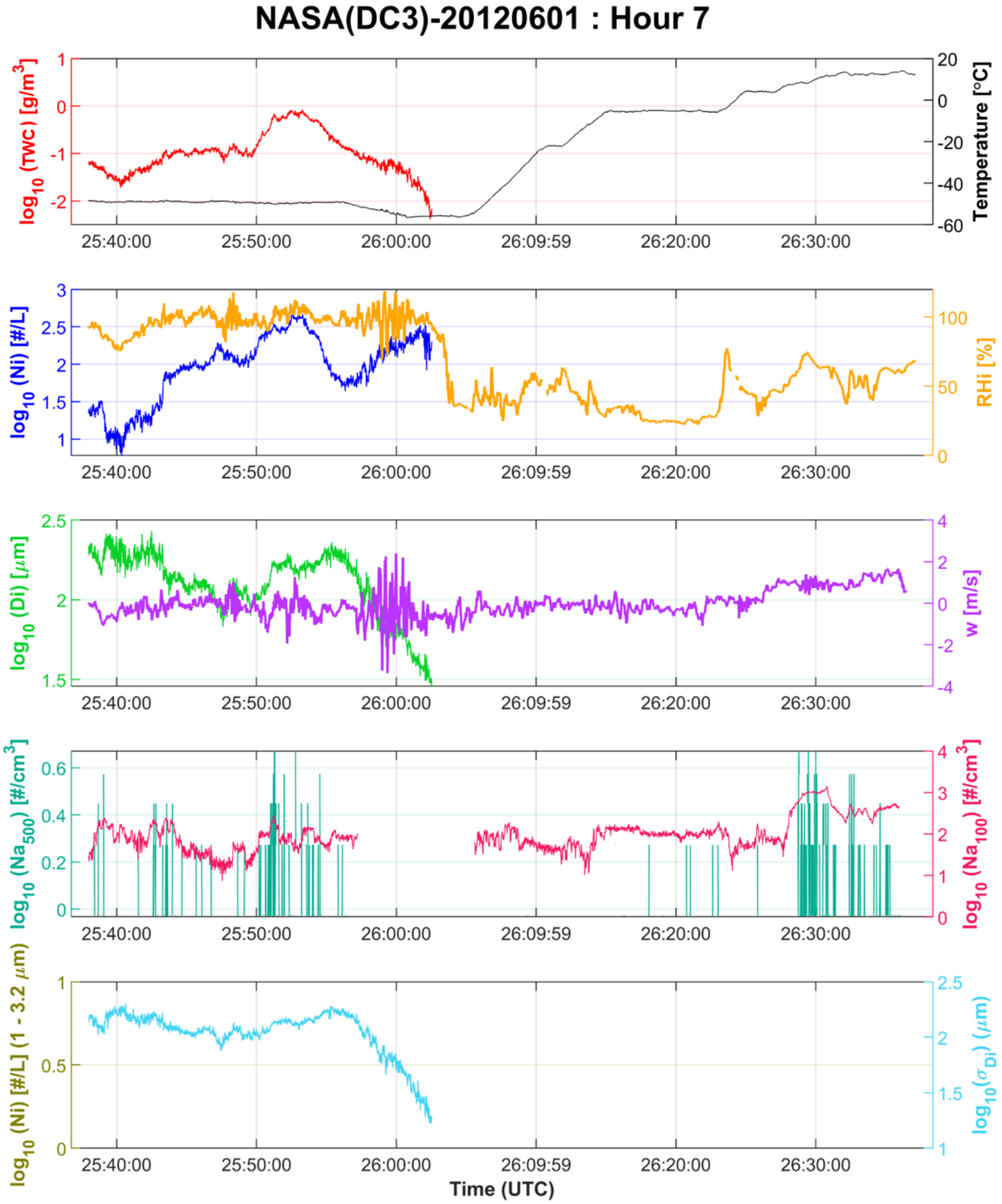


Figure R1. Time series of NASA DC3 campaign RF08 on June 1, 2012, which was the original Figure R1 used in our last response to reviewers in January 2025. No small ice was detected for this cirrus segment, i.e., Ni_1-3µm = 0.

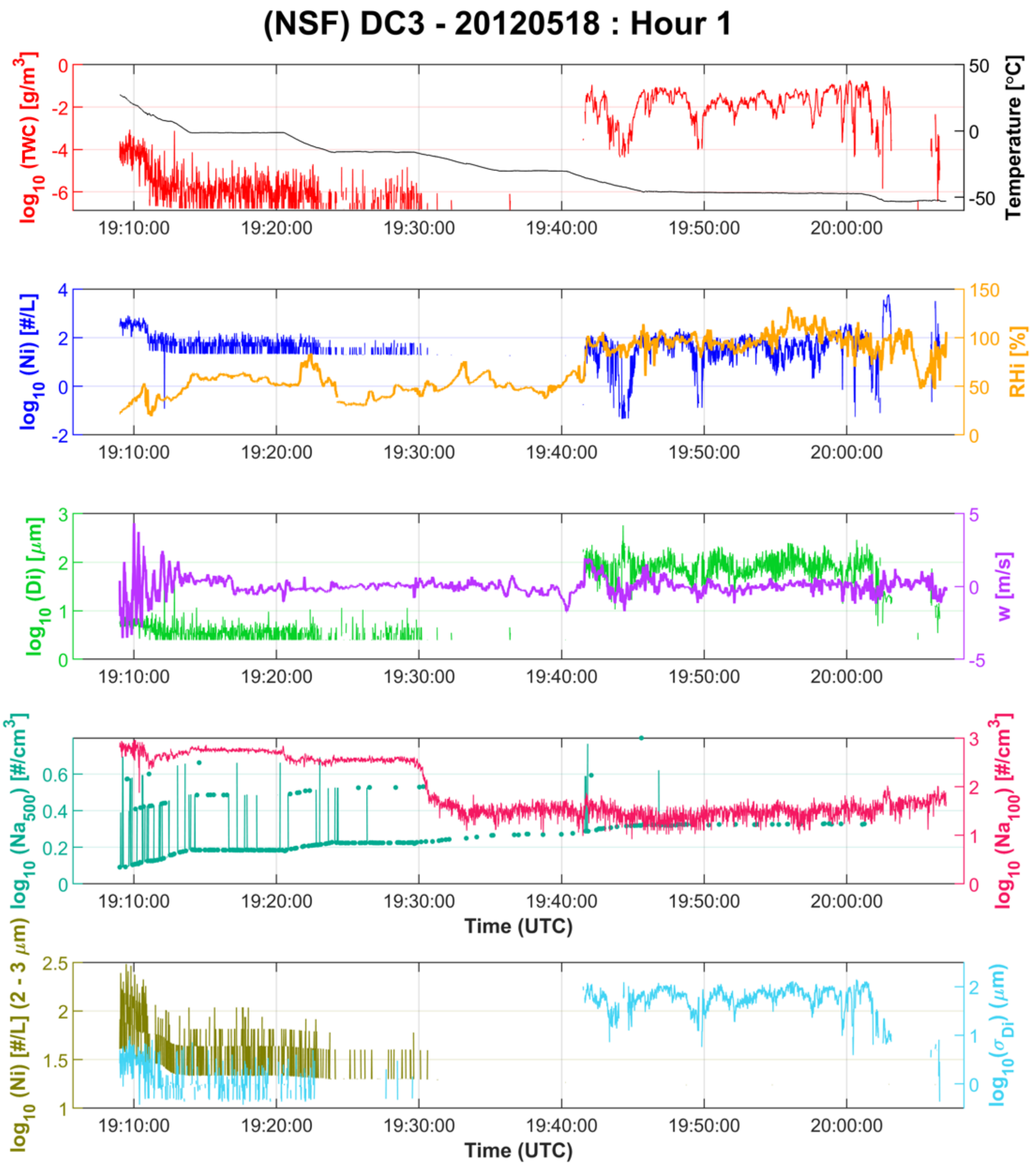


Figure R2. Time series examples from NSF DC3 campaign RF01 on May 18, 2012. Please note that some parts of the time series segment cover a wide temperature range, not only restricted to T <= -40C. At temperatures higher than -40C, the particles can be either liquid, ice or both. The label of Ni or Di of the Y axes does not mean that these particles are all ice. We kept using these labels of Y axes for consistency with our text description.

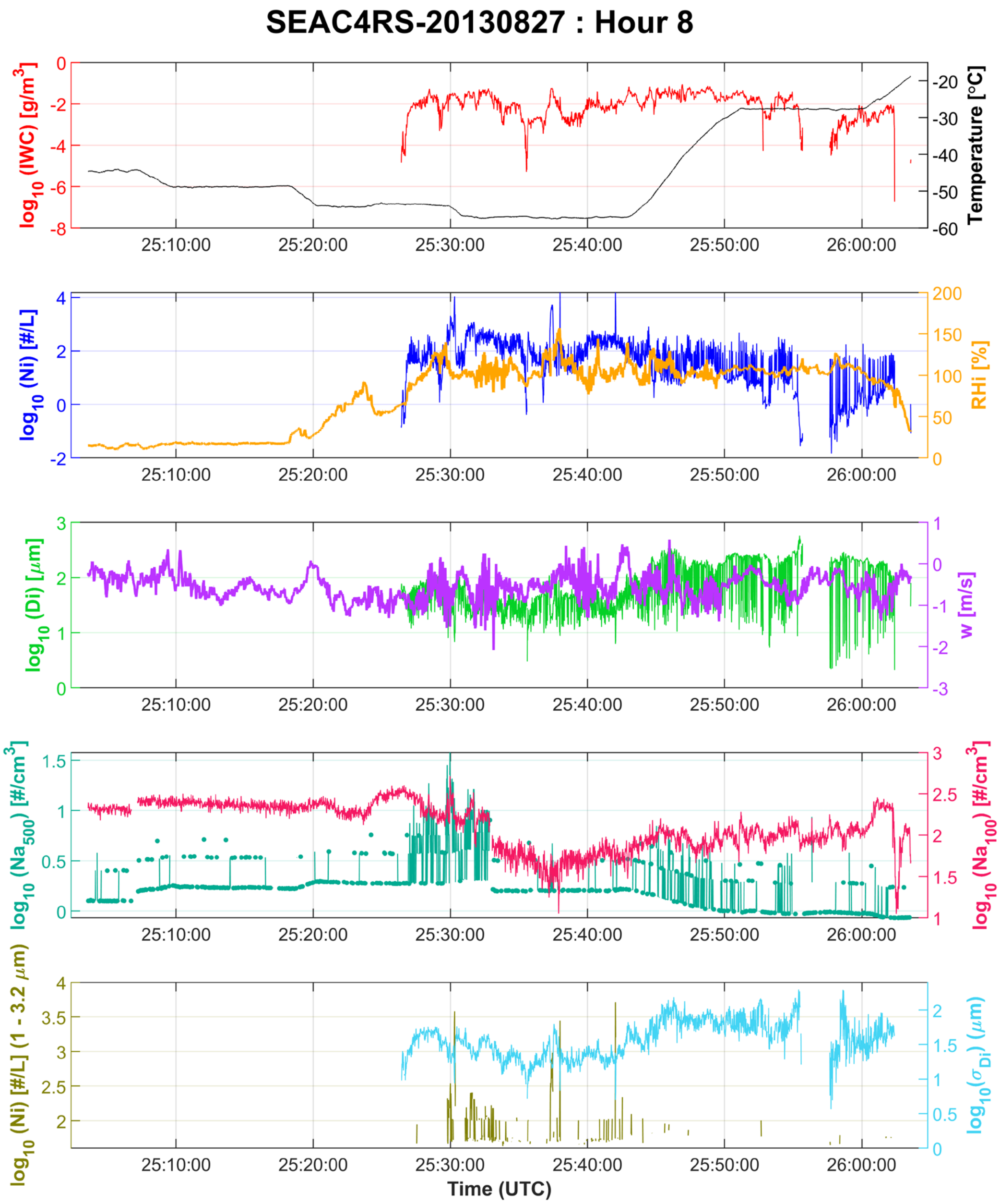


Figure R3. Time series of NASA SEAC^{4}RS campaign RF10 on August 27, 2013. This is the same segment as our original Figure R3 in our last response to Reviewer #2.

Addressing figure r2:

The authors show a scatter plot of Ni vs Di and argue that since there are multiple modes of Naer500>0 within different ranges of the variables, that "This result indicates that there is no evidence showing that sublimation of small ice or shattering of large ice could be the main cause of large aerosol occurrences measured." I do not understand why. There are indeed likely ranges where a particular bias may be more likely observed, but without showing actual occurrence frequencies of data at given Ni and Di it cannot be determined. The overlap of datapoints makes it impossible to determine whether Naer500>0 occur at greater frequencies at large Di relative to small Di. In fact, the mode of Naer500>0 at 1.5<log10(Ni)<4 *and 1.3<log10(Di)<2.3 could be argued to be associated with relatively larger IWC, where such biases are suspected to result from shattering.*

To further illustrate the occurrence frequencies of small Ni_1-3µm and sigma_Di values, we showed a series of figures for NASA SEAC^{4}RS campaign in new supplemental **Figure S7**. The panel (a) is similar to what we showed previously in our last response, however, our previous response showed the entire temperature range of Ni vs Di without applying the temperature restrictions to cirrus regime only. This time we added this restriction (T<=-40C) to all panels, since we mainly focus on the possible influences of ice shattering on Na_{500} for cirrus here. We also showed the number of samples in panel (b) per the reviewer's request, since the scatterplot has dots overlapping each other. Panel (c) shows that number of samples of Ni_1-3µm > 0 (regardless of having Na_{500} or not). Panel (d) shows the ratio between two conditions: Number of samples of (Ni>0 & Na500 > 0 & T<=-40C & Ni_1-3µm > 0 & sigmaDi > 50µm) / number of samples of (Ni>0 & Na500 > 0 & T<=-40C). Basically, this ratio shows how likely shattering may happen (i.e., indicated by small ice particles and larger standard deviation of PSD) relative to all the samples where Na_{500} are seen in cirrus. The results show that the conditions to support shattering events are a small fraction of the total samples, which indicates that it is less likely shattering happened frequently when Na_{500} was observed.

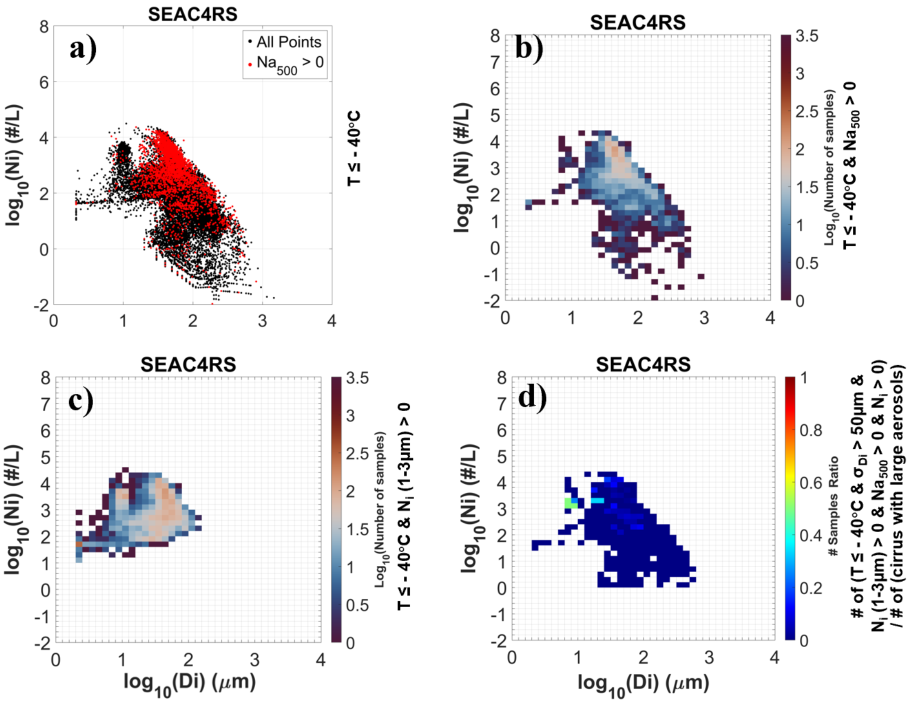


Figure S7. Distributions of samples for the NASA SEAC^{4}RS campaign. All panels are restricted to temperature ≤ -40°C. (a) Scatter plots of all cirrus samples in black as well as those with $Na_{500} > 0$ in red. (b) Number of samples for cirrus clouds with $Na_{500} > 0$. (c) Number of samples for cirrus clouds with small ice, i.e., Ni_1-3µm > 0, regardless of aerosol existence. (d) Ratio of number of samples of two conditions, i.e., samples with possible shattering indicators versus total cirrus samples with large aerosols.

Addressing Table r3:

The authors show that 33% of in-cloud samples have Naer500>0, and state "the existence of ice particles does not always directly cause the occurrences of large aerosols." It could possibly be argued that biases are minimal if most samples do not detect Naer500. I mentioned above I wish they had applied more *"physically relevant" in-cloud thresholds as requested, which would likely increase the frequency of Naer500>0 in clouds.*

We addressed this comment above, since the correlations between delta values of cirrus microphysical properties and $d\log_{10}Na_{500}$ are almost following straight lines (Figure 6), regardless lower or higher IWC.

Addressing Table r4:

The authors show that the ratio of in-cloud+Naer500>0 / clear-sky+Naer500>0 is much greater when restricted to supersaturated conditions than when using all samples regardless of RHi. They state "If ice sublimation or ice shattering is the main cause of large aerosols, one would not expect to see large aerosols occur more frequently when ISS is available." I'm unsure of this, simply because we should expect the presence of cloud to be more likely at ISS. Therefore, we would expect the ratio at ISS to be greater for this reason. Perhaps I'm misunderstanding this point.

We can see that our previous discussion regarding ice supersaturation was misleading. After thinking about this argument more carefully, it is quite hard to prove a definitive causal relationship among the three variables, i.e., ISS, ice crystals (Ni > 0) and $Na_{500} > 0$, since there are several possible relationships among them. We revised the main text to remove the comment about this part.

We revised the discussion in Section 3.3: "~~To further examine the role of aerosols in the ACI relationship, the number of samples of in-cloud and clear-sky conditions associated with large and small aerosols are analyzed. The results show that for large aerosol samples (i.e., $Na_{500} > 0$), 30 % of them are in-cloud while the rest are in clear-sky conditions. For small aerosol samples (i.e., $Na_{100} > 0$), 18 % of them are in-cloud. When restricted to ice supersaturated conditions only, a significant increase is seen for large aerosol samples associated with in-cloud conditions (75 %) while the rest are clear-sky conditions. Similarly, a significant increase is seen for small aerosol samples at in-cloud conditions (79 %) when ice supersaturation is available. In addition, when~~ When examining the distributions of Na_{500} at in-cloud conditions, the occurrences of large aerosols are seen at various Ni and Di ranges (Figure S7 a and b), suggesting that large aerosols are not solely observed when large or small ice crystals are available. ~~These results suggest that it is more likely that the coexistence of aerosols and ice supersaturation leads to the formation of ice crystals instead of the other way around (i.e., occurrences of ice crystals affecting aerosol measurements).~~ In the Ni – Di relationship shown for the NASA SEAC^{4}RS campaign (Figure S7 a), a group of samples was observed at relatively lower Di (~10 μm) and higher Ni (100 – 10^4 L^{-1}), which indicates possible influences of homogeneous freezing on the formation of these particles. A similar feature of high Ni and low Di values was also reported by a remote sensing study (Mitchell and Garnier, 2024). To further examine the likelihood of ice shattering affecting Na_{500} values, number concentrations of small ice particles (i.e., Ni_1-3μm) and standard deviations of particle size distributions (σ_{Di}) are used to indicate the possible occurrences of ice shattering. Figure S7 c shows the number of samples of Ni_1-3μm>0 regardless of the existence of aerosols, and Figure S7 d shows the ratio between the number of samples for incidents with possible shattering and the total samples with large aerosols. The results show that a small fraction (<10%) of the in-cloud Na_{500} samples have indicators of shattering (not definitive proof that shattering actually occurred). When comparing Na_{500} against Ni_1-3μm values along time series (not shown), their ratios are generally larger than 30, indicating relatively small effects on Na_{500} even if shattering occurred."

We also deleted a similar comment in the discussion section about the coexistence of ice supersaturation and large aerosols and replaced it by a new comment: "The fact that a near-linear correlations are seen with respect to Na_{500} at both higher and lower IWC values suggests that the ice shattering is less likely a main cause of the higher Na_{500} at in-cloud conditions, since higher IWC values are more likely to induce ice shattering based on previous in-situ observations (McFarquhar et al., 2017)."

Addressing Figure S6&7:

While I've been especially skeptical of the aerosol measurements and the authors' arguments in favor of them to this point, I like the clear-sky aerosol diagnosis methodology. Seeing as this method addresses the in-cloud biases, I recommend the authors use this clear-sky methodology throughout the manuscript—although I am open to continued debate on biases if the authors wish to provide additional evidence.

This also seems to improve the output in the Figures. Particularly for Figure 4, panels g-i show a sharp change in occurrence frequency trends from – to + Naer500. This feature nearly vanishes in Figure S6.

Please give credit to D'Alessandro et al. (2023) who used a nearly identical methodology, especially considering there is overlap in authorship of both papers.

We looked into the reasons behind the sharp changes in Figure 5 as pointed out by the reviewer, regarding the X axis values, which are delta values – $d\log_{10}(Na_{500})$ and $d\log_{10}(Na_{100})$. We found that this sharp change is caused by real variabilities, and it is mainly visible in field campaigns that measured more convective activity, such as NASA-DC3, NSF-DC3, and NASA SEAC^{4}RS campaigns. This sharp transition in the delta values of Na_{500} and Na_{100} represents the significant increase of Na values when convection transported aerosols from lower altitudes to higher altitudes, therefore causing a significant bump in the delta Na values of a certain second compared with the mean Na values calculated for every 1-degree temperature bin. The reason that the clear-sky Na values show no obvious sharp transition is actually caused by the smoothing effect of the moving average. That is, when we calculated clear-sky Na, we had to use a 100-second segment surrounding each second, and average just the clear-sky section of those 100 seconds. This smoothing effect indeed blurred the real variabilities of Na values in the atmosphere, which is one of the reasons that we decided to keep the Na analysis in the main manuscript by using the 1-Hz in-cloud Na values, instead of switching to the 100-second averaged clear-sky Na values.

Another reason that we decided to keep using the 1-Hz in-cloud Na values is that when we applied the smoothing average to clear-sky Na, we had to apply a series of restrictions, including only calculating the clear-sky Na if (1) more than 10 seconds out of the 100 seconds are in clear-sky conditions, and (2) all of the 100 seconds are at temperatures <= -40C. This means that clear-sky Na would not be calculated (i.e., labelled as NaN) if a cirrus segment is very long or if the aircraft flew into higher temperatures within 100 seconds. In fact, we checked the number of samples after applying the restrictions and only 50% of the original in-cloud samples would still have clear-sky Na surrounding them calculated. This is a significant reduction in the number of samples. Thus, considering that we found no clear evidence that ice shattering is causing a significant bias for the IWC – Na relationship, and the calculation of clear-sky Na itself also has drawbacks by smoothing out the real variability and reducing number of samples, we decided to keep using the in-cloud Na in main text and kept the clear-sky Na as supplemental figures.

We added the reference of D'Alessandro et al. (2023) in the revised manuscript. Please note that we previously did not include that reference because of different temperature ranges between the two studies, since this current work focuses on lower temperatures for cirrus clouds (<= -40C) while the paper by D'Alessandro et al. (2023) focused on mixed-phase clouds. We also added the reference of McFarquhar et al. (2017) when discussing the higher likelihood of shattering by larger particles with higher IWC values.

Major Concern 2:

The authors have addressed this concern by providing sensitivity tests of two figures, showing major trends are still observed. Assuming sensitivity tests applied to other analyses in the study reveal consistent results (e.g., the ML method, using the clear-sky aerosol method if the authors choose to do so), this point was adequately addressed.

We would like to point out that the clear-sky Na calculation basically is similar to a moving average calculation, except for just calculating the clear-sky segments. The ML test for Table 3 (Test B) actually shows that even if averaging the variables at various scales (1-s, 50-s, 250-s, and 500-s averaged), the key results are consistent between 1-s and 250-s scales, such as the dominant effect of RHi variables, and the added values when aerosol information is provided.

Major Concern 3:

By updating the dataset, the authors show RHi as a single predictor variable is much more successful than Naer500, whereas previously both predictors had approximately similar predictor scores. The authors now also discuss including T into the predictions as a method of testing how the variables' predictor scores change when introducing a form of noise into the calculation. I find this unnecessary and do not necessarily agree with the logic, since there is no way to see how the noise is amplified in each case. I would avoid this latter point altogether.

We revised that sentence to avoid using the term "noise amplification": "Using Na_{500} as a single predictor also shows high accuracy of 84 % for all cirrus, but the accuracy decreases to 72 % when using T+ Na_{500}. This is likely because when using only Na_{500}, the ML model focuses on a small number of samples with non-zero values of Na_{500} for predicting in-cloud conditions, while after adding T predictor ~~can lead to noise amplification as~~ the ML model would need to predict cirrus occurrences using many T samples without Na_{500} information (i.e., $Na_{500} = 0$)."

The authors have adequately addressed my other concerns in this section.

Bibliography

D'Alessandro, J. J., G. M. Mcfarquhar, J. L. Stith, J. B. Jensen, Minghui. Diao, P. J. DeMott, and K. J. Sanchez, 2023: An evaluation of phase, aerosol-cloud interactions and microphysical properties of single- and multi-layer clouds over the Southern Ocean using in situ observations from SOCRATES. Journal of Geophysical Research: Atmospheres, https://doi.org/10.1029/2023JD038610.

McFarquhar, G. M., and Coauthors, 2017: Processing of Ice Cloud In Situ Data Collected by Bulk Water, Scattering, and Imaging Probes: Fundamentals, Uncertainties, and Efforts toward Consistency. Meteorological Monographs, 58, 11.1-11.33, https://doi.org/10.1175/amsmonographs-d-16-0007.1.

Both references were added to the revised manuscript.

Response to Reviewer 2's comments:

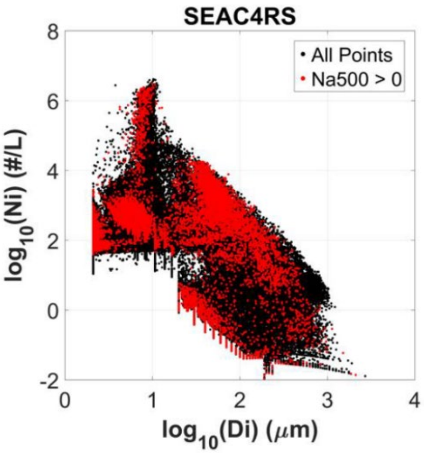
Second review of Ngo, Diao, et al., 2025, ACP
egusphere-2024-2122
Title: Aerosol-Cloud Interactions in Cirrus Clouds Based on Global-Scale Airborne Observations and Machine Learning Models
Author(s): Derek Ngo et al.
MS type: Research article
Iteration: Revised submission
General Comments:

This reviewer thanks the authors for a diligent job in responding to the review comments. They have demonstrated that it is unlikely that small ice crystals comprise a significant fraction of the aerosol particle concentration having sizes > 500 nm (Na_500). For example, Fig. R3 shows that Na_500 is generally > 28 times higher than small ice or Ni(1-3 um), showing that it is unlikely that Ni affects Na_500 significantly. However, this extended analysis has revealed some interesting relationships, one of which is worth including in the article or Supplement as described below.

We thank the reviewer for the helpful comments. Below we provided response to individual comments.

Specific Comments:

1. Figure R2 (pasted below) plots the log10 of Ni against the log10 of Di (the mean maximum dimension of the ice particle size distribution, or PSD) for all samples obtained during the SEAC4RS field campaign (black dots) and for only Na_500 samples (red dots). Homogeneous ice nucleation (hom) tends to produce higher Ni than heterogeneous ice nucleation (het), and when hom strongly dominates over het, Di tends to be smaller as well. This is shown in the EGUsphere preprint by Mitchell and Garnier (a remote sensing study of cirrus clouds): https://doi.org/10.5194/egusphere-2024-3814. For example, see their Figures 16 and 17 where Ni is relatively high when Di is relatively low. This same relationship is expressed in Fig. R2, albeit from in situ measurements. The "spike" in Fig. R2 corresponding to the highest Ni with relatively small Di (Di < 12 μm) may be from cirrus clouds where hom is most active relative to het, where vapor competition effects keep Di relatively small. This is the clearest in situ evidence that I am aware of that arguably shows the influence of hom on cirrus cloud microphysics, and it would be worth including in either the article or Supplement so that future studies could relate their findings to this result.



We thank the reviewer for pointing out this interesting feature. We added a new supplemental **Figure S7** for NASA SEAC^{4}RS campaign so that readers can refer to this figure. The panel (a) is similar to what we showed previously in our last response, however, our previous response showed the entire temperature range of Ni vs Di without applying the temperature restrictions to cirrus regime only, and this time we added this temperature restriction since we mainly focus on the possible influences of shattering on Na$_{500}$ for cirrus here. We also showed the number of samples in panel (b) per Reviewer #1's request, since the scatterplot has dots overlapping each other. Panel (c) shows that number of samples of Ni_1-3μm > 0 (regardless of having Na$_{500}$ or not). Panel (d) shows the ratio between two conditions: Number of samples of (Ni>0 & Na500 > 0 & T<=-40C & Ni_1-3μm > 0 & sigmaDi > 50μm) / number of samples of (Ni>0 & Na500 > 0 & T<=-40C). Basically, this ratio shows how likely shattering may happen (i.e., indicated by small ice particles and larger standard deviation of PSD) relative to all the samples where Na_{500} are seen in cirrus. The results show that the conditions to support shattering events are a small fraction of the total samples, which indicates that it is less likely shattering happened frequently when Na_{500} was observed. As for the spike of lower Di associated with higher Ni values, this spike is still there after applying the temperature restriction (even though the spike is smaller than the previous figure).

We added discussion on this new Figure S7 in the main text about the evidence for relatively small effects from shattering on large aerosols, as well as for evidence of possible homogeneous freezing around Di = 10 micron and Ni between 100 to 10^4 L^{-1}. We also cited Mitchell and Garnier (2024) in the text: "In addition, when examining the distributions of Na_{500} at in-cloud conditions, the occurrences of large aerosols are seen at various Ni and Di ranges (Figure S7 a and b), suggesting that large aerosols are not solely observed when large or small ice crystals are available. In the Ni – Di relationship shown for the NASA SEAC^{4}RS campaign (Figure S7 a), a group of samples was observed at relatively lower Di (~10 μm) and higher Ni (100 – 10^4 L^{-1}), with very few occurrences of large aerosols. This feature indicates possible influences of homogeneous freezing on the formation of these particles. A similar feature of high Ni and low Di values was also reported by a remote sensing study (Mitchell and Garnier, 2024). To further examine the likelihood of ice shattering affecting Na_{500} values, number concentrations of small ice particles (i.e., Ni_1-3μm) and standard deviations of particle size distributions (σ_{Di}) are used to indicate the possible occurrences of ice shattering. Figure S7 c shows the number of samples of Ni_1-3μm>0 regardless of the existence of aerosols, and Figure S7 d shows the ratio between the number of samples for incidents with possible shattering and the total samples with large aerosols. The results show that a small fraction (<10%) of the in-cloud Na_{500} samples have indicators of shattering (not definitive proof that shattering actually happened). When comparing Na_{500} against Ni_1-3μm values along time series (not shown), their ratios are generally larger than 30, indicating relatively small effects on Na_{500} even if shattering happened."

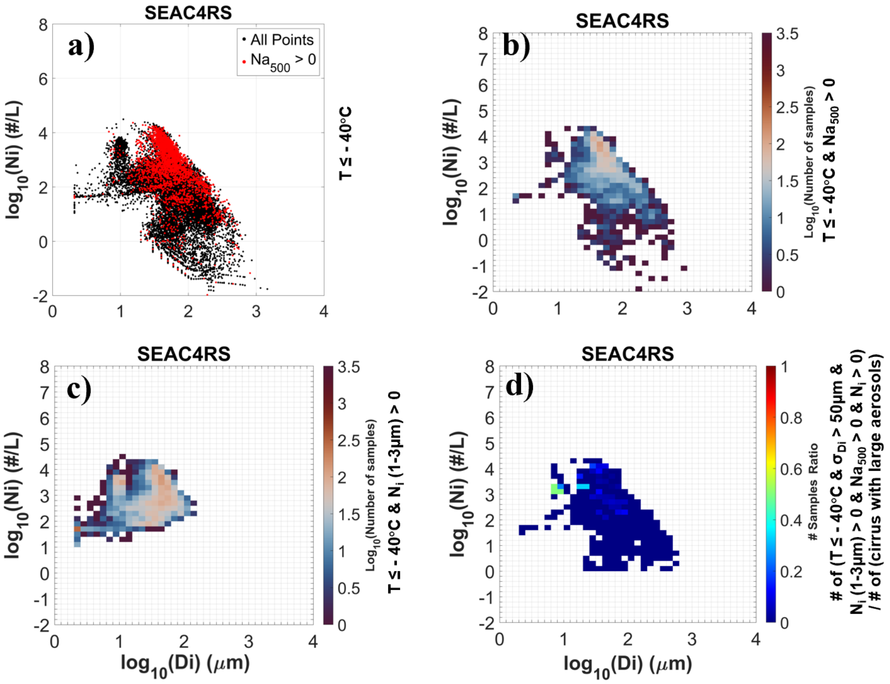
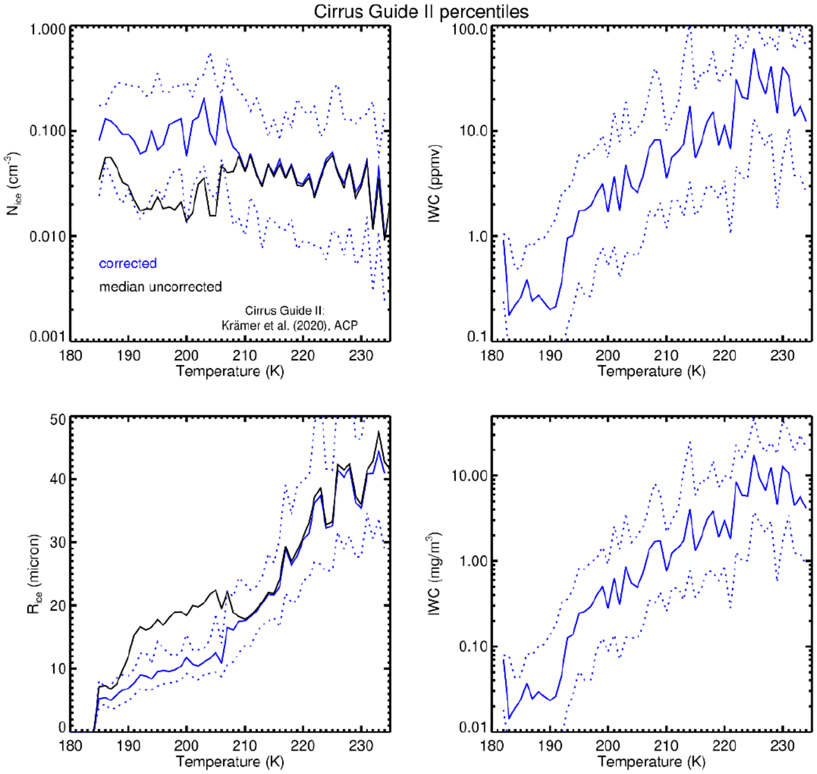


Figure S7. Distributions of samples for the NASA SEAC^{4}RS campaign. All panels are restricted to temperature ≤ -40°C. (a) Scatter plots of all cirrus samples in black as well as those with $Na_{500} > 0$ in red. (b) Number of samples for cirrus clouds with $Na_{500} > 0$. (c) Number of samples for cirrus clouds with small ice, i.e., Ni_1-3μm > 0, regardless of aerosol existence. (d) Ratio of number of samples of two conditions, i.e., samples with possible shattering indicators versus total cirrus samples with large aerosols.

2. Thank you for relating the cirrus dataset in this paper to the cirrus climatology of Krämer et al. (2020). It might be worth mentioning that the Krämer et al. climatology was recently corrected; see Krämer, M., Rolf, C., and Spelten, N.: The Cirrus Guide II In-situ Aircraft Data Set, B2SHARE-EUDAT, https://doi.org/10.34730/70b8b58472c9444d9a54e1bafc2b09cf, 2025.

Last December I was informed by Dr. Krämer that there was a bug in the code that processed the ATTREX and POSIDON PSD data. This affected values of Ni and R_ice for temperatures < 210 K, as shown below. IWC was not affected.



We thank the reviewer for providing us the latest information about the climatology data from Dr. Krämer's 2020 paper. We revised the main text to not only refer to the original Krämer et al. (2020) paper, but also pointing out that updated dataset can be found from the Krämer et al. (2025) data archive webpage that the reviewer mentioned. This way, readers can follow the latest updates on the dataset website and also have a journal article to reference to if needed.

3. Figure S3 in the Supplement provides a nice description of cirrus cloud properties related to altitude and latitude for this NSF – NASA dataset. I think members of the cloud modeling and remote sensing community would be interested to know how this compares with the cirrus cloud climatology of Krämer et al. (2020). Please consider plotting the 25, 50 and 75 percentiles of IWC, Ni, and Di as functions of temperature for direct comparison with corresponding corrected results from Kramer et al. (2020). Although Di may not be directly proportional to the mean volume radius Rv (used in Krämer et al. and referred to as Rice), temperature trends may still be meaningful.

As mentioned in (2) above, the Krämer et al. (2020) values have changed for Ni and Rv for T < 210 K, and the corrected dataset referenced in (2) should be used. It would be interesting if the 25, 50, and 75 percentiles for corrected Krämer et al. Ni and Rv, along with IWC, could also be plotted (perhaps using *another color) for comparison. This is only a suggestion, but it would be useful information, especially since parts of the published Krämer et al. (2020) climatology are no longer valid.*

We thank the reviewer for sharing with us the update of the distributions for IWC, Ni, and Di as a function of temperature based on the Krämer et al. (2025) dataset. In Figure 4 top 2 rows, we provided the median values and the standard deviations of IWC, Ni, and Di as a function of temperature. In the original text, we mainly referred to the increasing IWC with increasing temperature seen in both our data and Krämer et al. (2020) paper, and this IWC-T relationship remains the same. We also referred to the similar median Ni values in Krämer et al. (2020) compared with our NSF dataset in the temperature range of -70C to -40C. Since the Ni values at this temperature range are relatively similar between Krämer et al. (2020) and Krämer et al. (2025), we kept our original text as it is. But we added the reference of Krämer et al. (2025) so that readers are aware of ongoing update to the Krämer et al. (2020) dataset.

Here is the text from our Section 3.2: "For both NASA and NSF campaigns, an increasing trend of average IWC with increasing temperatures is seen, which is consistent with previous observational studies of the IWC – T relationship (e.g., Diao et al., 2014a; Woods et al., 2018; Krämer et al., 2020; Patnaude and Diao, 2020). Both NASA and NSF datasets show a nonlinear trend of Ni with increasing temperatures. The NSF dataset exhibits median Ni values near $10^{1.5}$ L^{-1}, or 32 L^{-1}, which is similar to the median Ni in Krämer et al. (2020). Note that the compiled aircraft in-situ observation dataset used in Krämer et al. (2020) has been recently updated in Krämer et al. (2025) with slight changes to Ni values below -65°C. Readers are recommended to refer to that data archive webpage for the latest version of that dataset."