Review of

Statistical Analysis of Contrail to Cirrus Evolution during the Contrail and Cirrus Experiments (CONCERT)

by Chauvigné et al.

The manuscript presents a new form of statistical analysis, the Principal Component Analysis (PCA), to investigate contrail to cirrus evolution based on two field campaigns. The observed ice clouds are divided in six clusters representative of different development stages of the contrails (primary wake, young contrail, contrail-cirrus and natural cirrus). Optical, chemical and microphysical properties of the clusters are then characterized to describe the ice-cloud properties during contrail to cirrus evolution .

Overall, the paper is very interesting and the topic is timely and suitable for ACP. Especially, the new approach to distiguish contrail and cirrus clouds seems to be promising. The manuscript is well structured and fluently to read. I found a number of minor points that I think needs claryfication before publishing the manuscript, they are listed below. Nevertheles, my overall rating is major revisions because of two points emphasized here:

– I strongly recommend to include the RHi measurements of flight 19b during CONERT 1. They are published in Gayet et al. (2012), so the data are available – see comment 8).

– Some numbers in Table 2 needs to be checked,
the mean and median IWC and, especially,
the mean and median of Ntotal for CC are too high for natural cirrus – see comment 20).

Comments:

1) Introduction: I like the very detailed introduction, but recommend to introduce more subsections (maybe even with titles), since now there are quite long paragraphs and the structure is not clearly visible.

2) Page 5, Line 194-195: ‚*Particle size distributions and corresponding microphysical and optical integrated properties (IWC, Deff, N, and extinction) were derived from FSSP-300 measurements (Baumgardner et al., 1992).*‘

FSSP measurements does not include the larger ice particle and is thus know to be not suitable for calculations of at least IWC and Deff. The 2DC was also flown during the field campaign, so why not combining the two probes for the calculations ? The missing size range between the two probes could be interpolated.

3) Shattering of large ice crystals is negligible in contrails since the maximum size of the crystals is not large enough to cause this effect. I would mention that somewhere in the manuscript.

4) Page 5, lines 220-221: ‚*The bulk parameters were calculated assuming the surface-equivalent diameter relationships of Heymsfield (1972) and Locatelli and Hobbs, (1974).*‘

Which bulk parameters do you mean ?

5) Page 6, line 234 - 238 : Calculation of $IWC_{non\text{-}spherical}$:

Is the validity of Equ. (6) ever checked by comparison to bulk IWC measurements?

6) Page 6, lines 254-256: ‚*In addition, hygrometers using the Lyman-alpha technique (FISH, Zöger et al., 1999; Meyer et al., 2015), and frost point hygrometers (CR-2, Heller et al., 2017) were implemented on the Falcon during CONCERT-1 and 2.*'
Please add the names of the hygrometers as indicated in blue.

7) Figure 1:

a) Caption: ‚*Time series at 1 s resolution for flights a) 19b (CONCERT 1) and b) 16b (CONCERT 2).*'
Please add the names of the campaigns as indicated in blue.

b) Plot of gPN: it would be helpful if a line at 0.85 woul be drawn in the figure to better see if the particles are spherical or aspherical.

c) Plot of NO: a log scale might be better here, especially for Flight 19b from CONCERT 1.

8) Flight 19b from CONCERT 1: Why are the RHi measurements of that flight not included here? They are published in Gayet et al. (2012), so the data are available.

I strongly recommend to include this data. It can be seen later in the paper that the number of RHi data from only flight 16 b fom CONCERT 2 is too low to apply the PCA analysis, see Figure 3, bottom right. Further, on page 8, lines 304-305 you write for flight 16 b: '*However, no accurate ambient RHI data can retrieved for measurements in natural cirrus due to instrumental calibration problems*.' but there are natural cirrus data available for 19b , CONCERT 1, yes ?

In addition, on page 6, line 252 you state the importance of RHI to characterize contrail ice crystals and on page 8, 3rd paragraph, you describe how RHI influences the sphericity of ice crystals. So I think it is of importantance not to leave out available RHI measurements!

9) Page 8, lines 294-297: ‚*In a supersaturated environment of contrails, crystals grow by water vapor deposition and become increasingly aspherical with time. This is why spherical ice crystals prevail in very young contrails with an asymmetry coefficient around 0.85 with RHI above 100%.*'

These sentences are a bit confusing. The reason that the ice crystals in young contrails are spherical under supersaturated conditions is that the time was too short to become aspherical, yes ? Maybe better: ‚*In very young contrails, not enough time has passed so that despite RHI is above 100% spherical ice crystals with an asymmetry coefficient around 0.85 prevail.*'

10) Page 8, lines 305-309: ‚*A good example of the evolution of gPN is the CRJ-2 contrail observed between 11:40 and 11:45 during flight 19b. The sequence illustrates the potential of the gPN measurement to characterize the evolution of contrail properties, with decreasing crystal sphericity documented by the decreasing asymmetry parameter from 0.88 to 0.79 (uncertainties around 0.04) after only 5 min and down to 0.77 after 20 min.*'

Again, it would be very good to see the corresponding RHI measuremenst here.

11) Page 8/9, last/first paragraph: Correlations between parameters are hard to recognize from Figure 1. Scatterplots for the main correlating parameters (gPN, RHI - from both flights, NO, extPN) would greatly improve the visualization of the discussed relations.

12) Page 12, last paragraph: For a better understanding of this paragraph, I recommend
→ to make a table of the of the cluster numbers and the corresponding definitions (now listed at page 13, lines 453 – 458) and refer to the table at the beginning of the paragraph. In the present form, it is hard to follow the text without knowing the meaning of the numbers.
→ Further, it would be good to note the abbrevations of the numbers (0: PW, 1: YC1, 2: ...) in one panel of Figure 3, e.g. in 3a.

13) Page 12, line 420-421:
‚*Figure 3a suggests an increase of Cj2 and a decrease of Cj1 with increasing aircraft size.*‘

In Fig. 3a Cj2 vs. Cj3 is plotted, in the text you refer Cj2 vs. Cj1 – please correct.

14) Definition of Clusters 3 (AC: Aged contrail) and 4 (ACC: aged contrail clean):
What is the difference between the two clusters ? Does ‚clean‘ means low NO ?
Please explain.

15) Figure 4: It would be helpful if you would include the circles from Figure 3 (a) in this plot.

16) Page 14, line 479: attribuate → attribute

17) Figure 5: I found it difficult to recognize the message of the panels of Figure 5. Here are some recommendation how this important figure can be improved:

a) in panel (a), a vertical line at gpN=0.85 would be helpful to distinguish between spherical and aspherical.
b) in panel (c), when using a logarithmic scale for the frequency the effects you discuss in the text will become better visible.
c) in panel (d), a logarithmic scale for NO and also the frequency would help to better see the the differences between the clusters.
d) in panel (e), a vertical line at RHI=100% would be good.
Further, in the text it is mentioned that the most frequent value of RHI is 95%. Shouldn‘t that be 100% ? And, the histogram is divided into small RHI intervals (2% ?), but the accuracy of the measurements is not better than 10-20%, I guess. I recommend to divide RHI in intervals corresponding to the accuracy and center them around 100%.
e) How many data points does each cluster contain ? This can be indicated in the legend.
f) The legend could be included in each panel – this would make it easier for the reader to assign the colors to the clusters when zooming the Figure on the screen.
Another idea could be to use more intuitive colors and sort the legend somehow into the stages of development, here a suggestion:
PW YC1 YC2 AC ACC CC

18) Page 18, line 592:
‚*Figure 6 shows mean volume particle size distributions (PSD) for all six clusters.*‘

I see mean number PSDs – dN/dlogD

19) Figure 6: The maximum sizes of PW and YC1 are already close to 200 µm, the maximum size of YC2 is close to that of ACC and CC. I would have expected smaller maximum sizes in the PW and YC categories, because ice crystals needs time to grow to larger sizes?
Further, the maximum size of CC is quite small – Voigt et al. (2017) show maximum sizes of natural cirrus PSDs up to 1000 µm or more ? See also comment 19 (b).

20) Table 2: (a) I suggest to sort the clusters like recommended under Point 16 f).
A further suggestion is to sort Ntotal in two size intervals, namely <~30um and >~30um, since the grouping of the clusters cange with size.

(b) The mean and median values of IWC does not fit to each other.
For example, for PW / CC the means are 15.46/28.69 mg/m3, but the medians are 6.26/0.96 mg/m3, i.e. the mean of CC is almost twice the mean of PW, but the median of CC is much lower than that of PW ?
Please check all numbers.

(c) Mean/median of Ntotal for CC are 6.06/3.75 cm^{-3} .
This is too high for natural cirrus – from Voigt et al. (2017), I would expect something around 0.1 cm^{-3} or even lower.
Is that an arithmetical error , shattering or could it be that contrails are accidentally attributed to CC ? Please clarify!

21) One last comment: could you discuss the possibility to use other/more parameters for the PCA? For example, could Ntotal be included in the PCA ? Or in case no Polar Nephelometer is on board, but PSD, IWC and NO is available, do you think the analysis would be possible ?