Answer to the author's reply of May 8:

It would be really a pity if this nice study would suffer from ice particle measurements contaminated by shattering. And I'm not convinced whether the high ice concentrations in natural cirrus are caused by shattered ice fragments. First, the observed ice particles are not large enough to cause shattering (see Fig. 10 of Voigt et al., 2010, ACP). Their maximum sizes are below 500 µm diameter, while shattering starts to occur in the presence of larger ice particles. Second, in cases of shattering the concentrations are mostly much higher than those shown here.

The second argument presented by the authors to explain the enhanced ice concentrations are uncertainties due to the interpolation of the PSD in size range of 17 µm – 50 µm. To my opinion, this is also unlikely since the concentrations in this size range are not high enough.

I propose another idea where the higher concentrations could come from: from a closer look into Voigt et al. (2010) I got the impression that the ice particle concentrations are derived by integration over the total FSSP size interval of 0.45 µm to 17.7 µm instead of considering only the cloud particles > 3 µm (see Voigt et al., 2017). That would mean that aerosol particles are added to the ice concentrations, which would explain the bias in the data.

This could be easily checked and if it is the case, non-contaminated data could be presented in the paper, which would make it scientifically more sound.

To publish data including shattering seems problematic to me, though I understand the point that the applicability of the PCA method can be demonstrated on the basis of the current data set.

We thank the reviewer for taking in charge the review of the present paper and allowing minor revisions for the publication. The manuscript has been further improved as a consequence of the suggestions of the reviewer, both on the cluster definition and the calculation of microphysical properties.

First, in order to be clear about ice cloud definitions from CONCERT's measurements, the cloud event which we called "natural cirrus" before is now called "unidentified ice cloud". Indeed, we have no ATC information to classify this event as contrail, but extinction and asymmetric coefficients show that these measurements occurred in a significantly thick ice cloud. Due to pollution by intense air traffic in this region, the cluster defining this part of the measurements is then called "polluted-cirrus" (cluster PC).

Modifications:

The term "natural-cirrus" has been replaced by "unidentified ice cloud" in the all relevant text parts and related tables/figures, and the term "polluted cirrus" or "PC" is used for cluster 5.

l. 267: "*When no ATC information is available, the cloud segment is called "unidentified ice cloud".*"

l. 279: "*The last cloud event ("unidentified ice cloud") during flight 16b is not a contrail because it is measured at temperatures significantly above the Schmidt Appleman temperature (-38°C, Schumann 1996). This is an ice cloud with high extinction (> 0.5 km^{-1}) and low asymmetry values (<0.75), characteristic for ice particles (Jourdan et al., 2003b, Febvre et al., 2009). Relative humidity and NO mixing ratio data are not available for this cloud.*"

l. 435: “*9 of the original clusters are merged into 2 clusters (clusters 3 and 5) presenting similar NO concentrations and optical properties.*”

l. 449: “According to *ATC information, these clusters both contain parts of the measurements in the B767, A343, A346 and CRJ-2 contrails. In addition, the unidentified ice cloud event from flight 16b is fully included in cluster 5. Unpolluted natural cirrus was rarely observed during the CONCERT campaigns (Voigt et al., 2010). Since we have no objective way of discriminating natural cirrus from contrail cirrus region, these clouds are referred to polluted cirrus or PC, and cluster 3 to aged contrails.*”

L. 699: “*The optical and microphysical properties of the aged contrails are often similar to those found in ambient cirrus which may be polluted cirrus.*”

Secondly, the number concentrations were calculated from the full diameter range of the FSSP and the 2DC. It means that the range from 0.5 to 800 µm was considered.

In Voigt et al. (2010) particle size distributions were derived from FSSP and 2DC considering the full size range. It was discussed that cirrus cases may have been affected by particle shattering because large ice crystals were detected by the 2DC. The contrail FSSP-300 measurements seemed not to be strongly affected by ice shattering since the cirrus contribution to contrail ice crystal surface or volume distribution for particles smaller than 17.7 µm was less than 1% (figure 10 Voigt et al., 2010).

Voigt et al. (2017) chose to select particle diameters higher than 3 µm to retrieve the number concentration of cirrus ice particles. In addition, we know that contrail cirrus occurs at ambient temperatures below -38°C.

Hence, the extinction coefficients, the Ice Water Content, and the number concentration for aged contrail clusters and the polluted cirrus cluster have been calculated for temperatures lower than -38°C. In addition, for the same clusters, optical and microphysical properties have been calculated for diameters higher than 3 µm. Results are in better agreement with previous results including those shown by Voigt et a. (2017) and in other studies of natural cirrus. We choose to present both concentrations (for the complete size range and for diameters larger than 3 µm) for comparison purposes.

Modifications:

Figure 7: Particle size distributions of aged contrails and polluted cirrus clusters have been modified according the temperature threshold of -38°C.

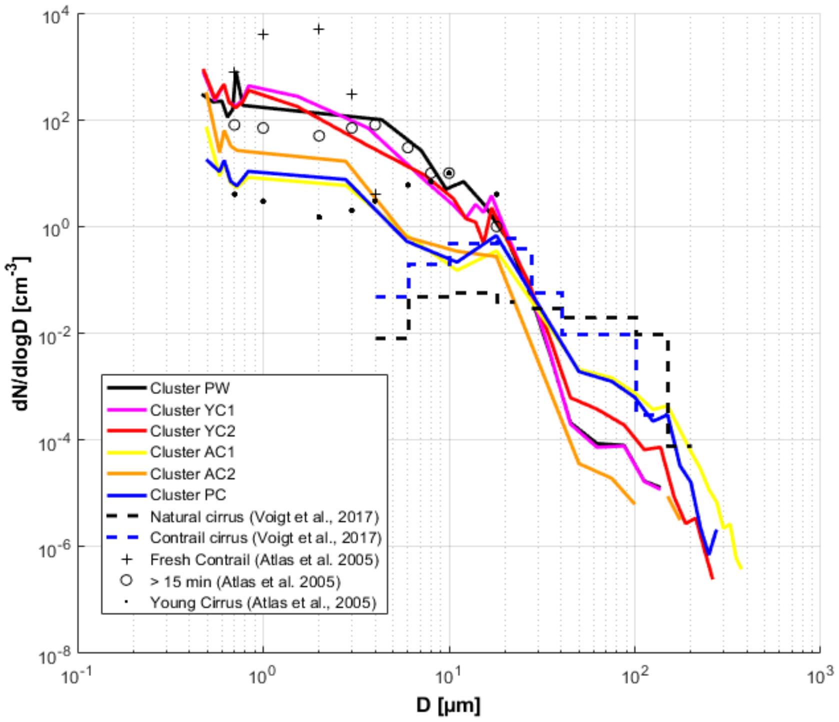

Figure 7: Number particle size distribution for each cluster including all data points of all flights. FSSP-300 measurements from 0.5 to 17 µm and 2DC measurements from 50 µm to 800 µm. The data are linearly interpolated in logarithm space in the gap between 17 µm and 50 µm.

l. 610: “*Higher concentrations of ice crystals with diameters larger than 100 µm are observed for polluted cirrus (cluster PC) and for well-developed contrails (cluster AC1). The average PSD of AC1 cluster shows much larger ice concentrations (around 10 times) compared to YC1 cluster within the 2DC size range.*”

l. 614: “*It is important to note that shattering effects can significantly influence the PSD measurements especially when particles with diameters higher than 100 µm are present. Polluted cirrus or aged contrail measurements could be subject to such artefacts even though the concentrations of large ice particles were low in the aged contrails and in the polluted cirrus cases during these two campaigns. Shattering effects are likely to be small for the measurements in young contrails.*”

Table 3: Values for ambient temperatures higher than -38°C have been included in the table, and values for particles with diameters higher than 3 µm have been added to the table for aged contrails and the polluted cirrus clusters (AC1, AC2 and PC). The values for the limited size range are given in parenthesis.

Extinction (km^{-1})		mean	std	Median	prctile 25	prctile 75
cluster	PW	4.230	3.820	3.308	1.104	6.485
	YC1	0.720	0.410	0.680	0.351	1.026
	YC2	2.070	2.655	1.017	0.271	2.836
	AC1	0.212 (0.204)	0.465 (0.456)	0.037 (0.033)	0.008 (0.005)	0.152 (0.138)
	AC2	0.114 (0.090)	0.163 (0.149)	0.060 (0.038)	0.007 (0.003)	0.135 (0.094)
	PC	0.207 (0.197)	0.363 (0.360)	0.072 (0.062)	0.032 (0.026)	0.178 (0.160)

IWC (mg m^{-3})		mean	std	Median	prctile 25	prctile 75
cluster	PW	8.173	10.586	5.573	1.665	11.363
	YC1	0.191	0.107	0.168	0.111	0.281
	YC2	4.860	8.918	1.235	0.218	6.604
	AC1	5.707 (5.705)	25.120 (25.120)	0.124 (0.122)	0.007 (0.004)	1.126 (1.123)
	AC2	0.310 (0.304)	1.103 (1.103)	0.112 (0.093)	0.005 (0.002)	0.290 (0.285)
	PC	3.024 (3.022)	8.845 (8.845)	0.218 (0.214)	0.080 (0.079)	0.641 (0.639)

NTOTAL (cm^{-3})		mean	std	Median	prctile 25	prctile 75
cluster	PW	172.965	114.497	152.398	95.564	223.374
	YC1	409.726	205.625	405.127	230.907	603.187
	YC2	188.139	199.736	125.344	52.584	236.100
	AC1	8.148 (0.372)	24.646 (2.103)	1.688 (0.086)	0.027 (0.027)	3.311 (0.179)
	AC2	29.517 (0.427)	44.723 (1.005)	8.021 (0.128)	0.0120 (0.020)	46.762 (0.290)
	PC	6.646 (0.360)	7.237 (0.864)	4.602 (0.213)	0.110 (0.110)	8.354 (0.394)

Table 3: Optical and microphysical properties for each cluster according interpolated particle size distributions from FSSP-300 and 2DC measurements. Values in parenthesis correspond to number concentrations for sizes larger than 3 µm.

l. 622: "*The aged contrail clusters (AC1 and AC2) and the polluted cirrus cluster (PC), include some data points at temperatures higher than -38°C. These values cannot be contrails and are excluded from this analysis. Ice particles with diameters higher than 3 µm are considered for aged contrails and polluted cirrus to exclude possible contributions from large aerosol particles, as in the earlier studies of Krämer et al. (2009) and Voigt et al. (2017), and these values are shown in parenthesis. These results again show that each cluster can be related to a specific contrail phase, and their properties can be compared to previous studies.*"

l. 640: "*Indeed, the averaged extinction and number concentration values of aged contrails do not exceed 0.4 km^{-1} and 30 cm^{-3} (0.5 cm^{-3} for diameters higher than 3 µm), respectively.*"

l. 645: "*For aged contrail, concentrations of ice particles with sizes greater than 3 µm are below 0.5 cm^{-3}, which is in agreement with concentrations presented in other contrail studies. Also IWC values and extinction coefficients of aged contrails agree with previous studies and their values are only weakly sensitive to the cut-off size used (below or above 3 µm).*"

l. 653: "*The polluted cirrus IWC is significantly higher (3.02 mg m^{-3}) than observed in previous studies for clean natural cirrus. The same holds for ice number concentration and extinction coefficient with values of 6.66 cm^{-3} and 0.21 km^{-1}.*"

l. 659: "*When limiting the analysis to ice particles larger than 3 µm, the ice number concentrations for the polluted cirrus have mean values of 0.36 cm^{-3}, which is in better agreement with previous cirrus studies. However, IWC and extinction coefficients values (3.02 mg m^{-3} and 0.20 km^{-1}, respectively) are still significantly higher than for clean cirrus cases observed in previous studies (0.001 mg m^{-3} and 0.023 km^{-1}, respectively). Their optical and microphysical properties are closer to aged contrail* *properties. This is consistent with our interpretation that high air traffic emissions in the measurement region may have influenced the cirrus collected in cluster PC.*"

l. 700: "*For polluted cirrus, the agreement with previous cirrus data is better when considering only ice particles with diameter higher than 3 µm.*"

Finally, some editorial improvements have been made to improve English language and clarity of the paper.