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Atmospheric
Chemistry
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Discussions

Interactive comment on "In-situ observations of young contrails – overview and selected results from the CONCERT campaign" *by* C. Voigt et al.

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We thank the reviewer for his/her valuable comments.

Anonymous Referee #1

Major Comments

1. The discussion of microphysics instrumentation and measurements is not as clear or complete as it should be. The only description of the 2DC is line 3 on page 12723. More information should be provided. From Figure 9, it is apparent that the authors decided not to present 2DC data in channels smaller than 100 mum. This choice is reasonable given the large uncertainty in sample volume for the smaller channels; however, some discussion of this issue should be provided. The lack of information about ice crystals

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in the 17-100 mum size range is unfortunate since it seems clear from Figure 9 that crystals larger than 17 mum likely exist even in young contrails and can contribute to area and mass. The CPI and CIP are described in Section 2, but the only data shown from these instruments is the comparison shown in Fig. 13 and discussed in section 9.1. Since data from these instruments is otherwise not used in the paper, I suggest that section 9.1 and the discussion of the instruments should be removed. A number of recent papers have suggested that ice crystal shattering on instrument inlets and probe tips can results in artifacts that overwhelm the natural concentration of small crystals in the observations [e.g., McFarquhar et al., 2007; Jensen et al., 2009]. This issue is apparently what is being referred to on lines 15-17 of page 12733. The authors state that Fig. 9 shows that "inlet effects from the FSSP do not significantly disturb the cirrus and contrail measurements." I would agree that Fig. 9 indicates that the small-crystal concentration in the contrail is not strongly affected by shattering, but there's every possibility that the small crystals indicated by FSSP in the cirrus are strongly affected by shattering artifacts.

Answer:

We extended the paragraph in the instrumental section describing the 2D-C in detail and we comment on the lack in the particle size distribution between 17 and 100 μm as follows.

The 2D-C probe provides information on crystal size and shape for the size range 100 to 800 mum. The method of data processing used in this study has been described in detail by [Febvre2009]. The 'reconstructed' method using partial images, has been considered for the calculations and the sampling surfaces have been derived according to Heymsfield [1978]. In order to improve the statistical significance of low particle concentrations, a 5-second running mean was applied. Irregular ice particles were the most predominant crystals sampled during the CONCERT experiment. Therefore, the bulk parameters were calculated assuming the surface-equivalent diameter relationships [Heymsfield1972, Locatelli1974]. As the sensitivity of the probe to small particles decreases with airspeed [Lawson2006], particles smaller than about 100 mum may not be detectable with the 2D-C at a Falcon airspeed of 200m/s.

Further we removed section 9.1 and Fig. 13. We kept the instrumental description from all particle instruments as the Falcon instrumentation should be complete in the overview paper.

In addition we now address the issue of ice particle shattering as follows: It has been questioned whether high ice crystal concentrations often observed with the FSSP are real or were caused by shattering of large ice crystals on protruding probe inlets [McFarquhar2007, Jensen2009]. Techniques have been proposed [Field2003, 2006] to correct the particle size distributions based on information of the particles interarrival times (Fast-FSSP or 2D-C) and new particle image probes with high pixel resolution (including CIP and 2D-S) may be used to quantify shattering artefacts. In our cirrus case, the particle concentration may be affected by particle shattering as large ice crystals were detected by the 2D-C and CPI instruments. In contrast, the contrail FSSP-300 measurements are not strongly affected by ice-crystal shattering since the cirrus contribution to the contrail ice crystal surface or volume distribution for particles smaller than17.7 mum is less than 1% (see Fig.10), ruling out that the contrail particle size distribution is significantly influenced by shattering. In the contrail measurements, the small particle mode with d<17.7 mum is clearly dominated by contrail ice crystals.

2. I believe that the authors should include comparisons with previous measurements of young contrails. In particular, the 1996 SUCCESS experiment included extensive young contrail measurements.

Answer:

We extended discussion of previous measurements of young contrails in the introduction and include a comparison to previous measurements of young contrails in the discussion of the CRJ-2 contrail data (see new references). We want to mention that measurements in young contrails with ages less than 5 minutes are sparse while some

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observations of aged and persistent contrails exist.

Minor Comments:

1. Page 12716, lines 25-26:

Has been changed to "...ice crystals can grow by condensation of entrained water vapor."

2. What is the particle size cutoff for the rear-facing NOy inlet?

The particle cut of size of d50 = 0.3 mum has been included in the description of the NOy instrument.

3. Fig. 3 shows that the mean RHI in contrails and cirrus is ’80-90%, whereas one would expect it to be very near 100% (particularly in young contrails with numerous ice crystals). This suggests to me that there may be a low bias in the water vapor measurement (or a high bias in the temperature measurement). Perhaps some discussion of this issue could be included. Related to this issue, on page 12727, lines 1-2, the authors state that the cloud-top sampling strategy may explain why the maximum in the RHI distribution is found to be below 100%. I don’t understand why this is the case.

Answer:

Fig. 3 is Fig. 4 in the revised manuscript. We extended Fig. 4 and the discussion about the RHI measurements as suggested: The contrails were probed at altitudes between 8.5 to 11.6 km and at temperatures between 213 and 229 K (Fig. 4, top panel). Here contrails were identified from a simultaneous increase in the extinction > 0 km-1 and the NO mixing ratio above 0.2 nmol/mol representing the upper limit for the upper tropospheric NO levels. Further the threshold temperature T < 240 K was used to exclude lower tropospheric cloud observations. 1.7 hours of contrail measurements were achieved. The contrails were sampled at RHI between 122 and 55%, with 80% of the observations concentrating at 105 to 70% RHI. Hence ice particles were detected in air that was near ice saturation or slightly sub-saturated with respect to ice. Fig.

4 (bottom panel) shows that the clear sky RHI is also mostly below 100% with the most frequent observations between 70% and 100%. Since air from the environment is continuously entrained into the contrails, the slightly sub-saturated conditions in the contrails might portray the clear sky conditions.

However, to ensure that there is no bias in the RHI measurements, we performed extensive calibrations after the campaign in addition to the frequent calibrations of the FISH instrument (see section 2.3). A similar RHI data analysis for 15.9 h measurements inside cirrus during 28 flights under a broad range of meteorological conditions showed a clear grouping of RHI around 100% (Krämer et al., 2009), confirming the high precision of the FISH measurements.

The sampling strategy in the top region or above optically visible cirrus clouds might introduce a bias towards lower RHI as we exclude measurements of contrails in cirrus clouds where the RHI distribution might be centered around 100%.

4. The gray bars on Figs. 4 and 5 are very difficult to see.

We improved the coloring in the Figures.

5. Addition of an RHI scale on Figs. 4, 5, and 8 would be very helpful.

We now additionally show the water vapor mixing ratios in the Figures.

6. Would it be possible to include a statistical comparison between CoCIP results and the observations for the entire campaign? This would provide a much clearer indication of the performance of the model.

We could perform further simulations but do not expect major additional insight. The purpose of this model is not to explain all details of the very complex contrail physics, it is rather to describe the order of magnitude of the bulk properties of contrails. This is what is shown in the figures and we do not intend to overstress our conclusions. The model is kept simple to allow for regional simulations of contrails from a number of aircraft or even for global simulations of the contrail impact from the global aircraft

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fleet.

7. I'm puzzled by the units on Figs. 9 and 13. Are these distributions normalized by bin width, or perhaps by log(bin width)? What is dm3 If it is (bin width)3 then apparently the distributions are not normalized by bin width. Some clarification would be helpful.

The size distribution is not normalized by bin width. It is the surface area (volume) within the individual bin. By summing up over each bin, we can directly calculate the total ice surface area and volume that is why we choose this representation. This representation is most indicative of the optical particle properties such as extinction and optical depth. We give an explanation in the text now.

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Interactive comment on Atmos. Chem. Phys. Discuss., 10, 12713, 2010.

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