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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Aircraft type influence on contrail properties" *by* P. Jeßberger et al.

P. Jeßberger et al.

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We thank Darrel Baumgardner for his valuable comments and the careful calculations of probe inlet effects. We first answer the comments on the effects of particle bouncing in particle probe inlets enumerated by Reviewer Comment (RC) 1 to 3.

RC 1

The one uncertainty that I think has been glossed over is that of artifacts caused by the inlet of the FSSP-300. Shattering is mentioned as probably insignificant, and although it has not been actually shown that small ice crystals won't shatter, I am willing to concede that shattering is unlikely to affect the measurements. A number of publications, particularly the most recent one by Korolev et al (2013) in JTECH note that bouncing of ice crystals can be just as important as shattering. I have included the figure below

to illustrate why measurements of ice particles that bounce from the lip of the FSSP-300 should not be ignored; however, that being said, I don't think that the conclusions drawn in this paper will change at all. I just do not want to have this paper perpetuate the idea that there can't be sampling artifacts in clouds with small ice.

The point is that it is not unreasonable to assume that bouncing is contributing some non-negligible number of particles to the observations and could account for some part of the discrepancy between the observations and simulations.

Answer to RC 1:

We agree with the reviewer that sampling artifacts caused by particle probe inlets are important in certain conditions and have to be assessed. In this paper and even more extensively in a previous one (Gayet et al., ACP, 2012), we discuss why effects of particle shattering on the protruding inlet tips are small in young contrails and can be neglected in contrails which form in clear sky or thin cirrus conditions. We now additionally discuss the effects of particle bouncing.

A thorough analysis and comparison of FSSP-300 and Polar Nephelometer (PN) data collected during the CONCERT campaign is given by Gayet et al., 2012. A good agreement between the extinction derived from FSSP-300 and PN data is shown in their Fig. A1. As pointed out be the reviewer, the two particle probes (FSSP-300 and PN) have very different inlet designs, see Figure 1 from Shcherbakov et al., 2010, below.

Because of the very sharp edge of the PN lip compared to the rounded and rather thick of the FSSP lip the hypothesis that the bouncing of ice crystals affects the FSSP-300 and PN measurements in the same way, or with a same efficiency, appears unlikely. Still the extinctions calculated from two different measurement techniques are very consistent over a large range of particles concentration (from a few cm-3 to 350 cm-3, Gayet et al., 2012). Hence, this would appear unlikely if artefacts dominated the measurements.

We may conclude that the relative importance of the effects of the bouncing of ice crystals on contrail observations performed during CONCERT with old version of instruments (not equipped with Korolev's tips) is within the variability of the data points in Fig. A1 (Gayet et al., 2012).

In addition, we have included this possible error source in the text in chapter 2.1.

2.1 The Forward Scattering Spectrometer Probe FSSP-300

"Effects of particle bouncing off the inlet walls of particle probes have been discussed in detail by Korolev et al., 2013. This effect may lead to an overestimation of the particle number densities and a broadening of the particle size distribution. The extinction data from the polar nephelometer and the FSSP-300 with different inlet geometries are consistent (Gayet et al., 2012) and hence suggests that inlet artifacts are small also at high particle number concentrations. Still, we cannot completely exclude that particle bouncing may occur."

Korolev, A., Emery, E., and Creelman, K.: Modification and Tests of Particle Probe Tips to Mitigate Effects of Ice Shattering, J Atmos Ocean Tech, 30, 690-708, 2013.

Gayet, J.-F., Shcherbakov, V., Voigt, C., Schumann, U., Schäuble, D., Jessberger, P., Petzold, A., Minikin, A., Schlager, H., Dubovik, O., and Lapyonok, T.: The evolution of microphysical and optical properties of an A380 contrail in the vortex phase, Atmos. Chem. Phys., 12, 6629-6643, doi:10.5194/acpd-11-26867-2011, 2012.

Shcherbakov, V., Gayet, J.-F., Febvre, G., Heymsfield, A. J., and Mioche, G.: Probabilistic model of shattering effect on in-cloud measurements, Atmos. Chem. Phys. Discuss., 10, 11009-11045, doi:10.5194/acpd-10-11009-2010, 2010.

RC 2

The second effect of these bouncing particles is that of coincidence that causes the FSSP to measure two or more particles as one and hence oversize the particle. One of the discrepancies between model and observations was found to be in the larger

particle tail of the particle size distributions (PSD). Cooper (1988) estimated the effect for the FSSP-100 when in cloud droplets, showing that the ambient size distribution was broadened as a result of coincidence. The FSSP-300 is different than the FSSP-100 in how particles are qualified as in or out of the DOF. In the case of the FSSP-300, depending on the relative sizes of two coincident particles, one in and the other outside the DOF, in one case the particle in the DOF will be rejected but in other cases, the particle in the DOF will be qualified but oversized due to the contribution of the light scattered from the particle out of the depth of field. A full analysis of this effect is outside the scope of this review but a quick analysis can be made to see the probability of more than a single particle within a section of the laser beam where they will both be detected. Assuming Poisson statistics, the probability of more than a single particle in the sensitive beam volume is $P(x) = \exp(-Vp/Vb)$ where Vp is the volume per particle that is approximately equal to the inverse of the number concentration and Vb is the sensitive beam volume. In the graph on the right the different curves assume that the length of the beam sensitive to the out of the DOF particles is between 4 and 10 mm. The actual sensitive length is a function of particle size but this example serves to illustrate that the probabilities are not insignificant and could lead to some broadening of the size distribution, and artificially increase the derived optical depth, as a result of the additional particles produced by bouncing.

Obviously I don't expect the authors to include an analysis similar to the one presented here, but I feel that it is important that this source of measurement artifact not be totally excluded.

Answer to RC 2

We thank the reviewer for pointing out this effect. It may help to explain differences between the observations and the models in the number densities of large particles. Still is does not modify the conclusions of our paper as pointed out by the reviewer. We now included this additional uncertainty in chapters 2.1 and 5.1.3 of the manuscript.

2.1 The Forward Scattering Spectrometer Probe FSSP-300

“Coincidence effects eventually caused by particle bouncing may result in a broadening of the particle size distribution (Cooper, 1988).”

5.1.3 Calculation of the evolution of the A319 and A380 contrail under identical meteorological conditions

“A possible overestimation of the number of large particles in the observations due to coincidence effects leading to a broadening of the size distribution may also contribute to the difference.”

Cooper, W. A.: Effects of Coincidence on Measurements with a Forward Scattering Spectrometer Probe, Journ. Atm. Ocean. Tech., 5, 823-832, doi:10.1175/1520-0426(1988)005<0823:eocomw>2.0.co;2, 1988.

Minor Comments:

MC 1

The collection angles of the FSSP-300 are similar to the 100, 4-12, not 6-15

Answer to MC 1

The collection angles for our instrument FSSP-300 were investigated during the PhD work by M. Fiebig (2001) in comparison to other instruments with the best agreement being found for assumed collection angles 6°-15°, which have been used from that point on.

Fiebig, M. (2001) Das troposphärische Aerosol in mittleren Breiten - Mikrophysik, Optik und Klimaantrieb am Beispiel der Feldstudie LACE 98,Dissertation, DLR-Forschungsbericht, 259 p., 2001-23p.

MC 2

The PN is even more sensitive to shattering/bouncing than the FSSP-300 since it has

a larger inlet and its sensitive sample area is much larger than the FSSP. This needs to be acknowledged and the potential impact on the phase functions discussed.

Answer to MC 2

We agree that the PN is likely to be more sensitive to shattering/bouncing than the FSSP-300. We may argue analogue to RC 1 that according to the comparison between FSSP-300 data and PN data in Gayet et al., 2012, we can assume that these effects do not pose a major uncertainty in our measurements. As the instrument PN is not the central instrument in our study, we do not analyze measurements uncertainties in detail in this study.

MC 3

Figure 2 should be separated into three larger panels. I had to amplify by a factor of three to see any detail.

Answer to MC 3

We agree and enlarge the figure in the final paper.

MC 4

How is effective diameter defined/calculated? Given the uncertainties in the sizing with the FSSP-300, if the effective diameter is derived from the PSD, then what is the uncertainty and isn’t it large enough so that reporting the effective diameter to one significant figure is irrelevant?

Answer to MC 4

We have added our definition of the effective diameter to the manuscript in chapter 4.1, which is analogue to Foot (1988) and Schumann et al. (2011):

Deff = (3/2)(V/A) (1)

with the total ice particle volume V and the total projected particle cross-sectional area

A.

We agree that the differences between the effective diameters derived from the PSD for the different contrails are smaller than the uncertainties. That is why we point out that effective diameters are similar. We explicitly write “similar effective diameters Deff (5.2 - 5.9 μm)” in the abstract and conclusion. However, we still think the effective diameter is an important parameter to report.

Foot, J. S.: Some observations of the optical properties of clouds. II: Cirrus, Q. J. R. Meteorol. Soc., 114, 145-164, 1988.

Schumann, U., Mayer, B., Gierens, K., Unterstrasser, S., Jessberger, P., Petzold, A., Voigt, C., and Gayet, J. F.: Effective Radius of Ice Particles in Cirrus and Contrails, Journ. Atm. Sci., 68, 300-321, doi:10.1175/2010JAS3562.1, 2011.

MC 5

I strongly urge the authors to show the size distributions of number and area with linear scales on the Y axis. Using a log scale masks important differences and doesn’t make physical sense since particles at sizes where their concentration is three orders of magnitude lower than particles at smaller sizes have little impact on mass or extinction. On the other hand, since extinction is important to this study, and extinction is proportional to the cross sectional area, it makes sense to show area on a linear scale to highlight which optical diameters are important.

Answer to MC 5

Thank you for this suggestion. By displaying the particle size distribution in linear scale on the Y axis, we cannot show the particle size distribution of the surrounding cirrus clouds in the same graph.

We agree that it makes sense to show the cross sectional area on a linear scale and additionally include it in Figure 3c.

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 13915, 2013.

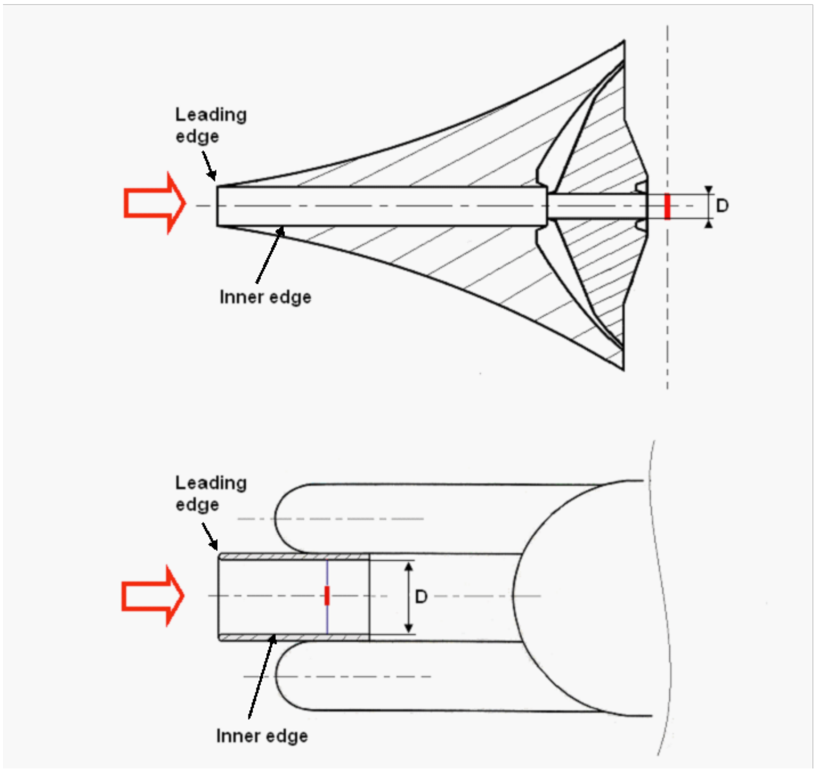

Fig. 1. Inlet designs of the Polar Nephelometer (upper panel) and FSSP probe (lower panel). Red lines represent the sampling volume. D is the inlet diameter. Figure 1 from Shcherbakov et al., 2010.