Atmos. Chem. Phys. Discuss., 10, C6546–C6554, 2010
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Atmospheric
Chemistry
and Physics
Discussions

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

C. Voigt et al.

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Received and published: 17 August 2010

We thank the reviewer for his/her valuable comments.

Anonymous Referee #2

1. The paper needs to be very carefully proofread. There are several places where there is a mismatch between singular nouns and plural verbs (or vice versa), or where the tense is incorrect.

Answer:

We proofread the manuscript.

2. Both the abstract and especially the conclusions need to be rewritten to highlight what are the major scientific findings of this study....

Answer:

The aim of the paper is to give an overview of the CONCERT campaign. We show the major results of the campaign and highlight some case studies. It is beyond the scope of the paper, to give a detailed discussion of the individual results and their scientific implications, as these issues will be discussed in several follow up papers, which are in preparation right now. Still, we modified the abstract to more specifically show the results and scientific findings. The conclusion lists future research plans and ongoing data evaluations. We further extended the introduction and the comparison to previous contrail measurements (see new reference list) particular in sight of recent discussions of particle probe issues.

3. Right now there is some material that should not be included in the paper because it does not contribute to the scientific findings of the study. For example, section 9 is particularly lacking and needs to be much better developed, or preferably can be expanded into a separate manuscript on its own. Detection of cirrus clouds on its own is not an important scientific finding. However, if data collected in cirrus can be used to tell us a new conclusion about cirrus properties or formation mechanisms, then this should be included. Right now that is not the case with Section 9 (and a few other sections in the manuscript).

Answer:

We removed section 9 from the manuscript and moved the water vapor intercomparison to the instrumental section.

4. The microphysical observations in cirrus need to be much better described. In particular, what are the uncertainties associated with the derived concentrations, ice water contents and size distributions. Do these uncertainties allow the authors to make the conclusions that they do in the manuscript? For example, the authors claim in

section 9.1 that the CIP and CPI show reasonable agreement in Figure 13. What is reasonable agreement? To me, it appears that the size distributions differ by almost an order of magnitude! How well do the size distributions and other quantities need to be known in order to evaluate the model? What is the definition of a similar result or how well do the modeled observed quantities need to be in agreement for the model results to be considered validated, and the conclusion that there are no indications of additional ice formation beyond soot induced ice particles to be verified. Right now, the comparisons are far too hand wavy to justify these conclusions, especially given the incredible amount of scatter in Figure 7.

Answer:

As described above, we removed Sec.9.1 and Fig.13.

Concerning the model intercomparison, the CoCiP model does not simulate size distributions but just the ice water content and the number if ice particles per unit volume. In addition, the number of soot particles per volume is computed.

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 fleet.

Of course, the results cannot be used to conclude that there is no ice formation beyond soot induced ice particles. But at present we do not see obvious reasons to include additional ice formation at present and we do not see that contrail formation by other processes is of primary importance.

5. Related to point 4, is the potential impact of shattering of large ice crystals on the inlets of microphysical probes in artificially amplifying the concentrations of small

ice crystals. This is a very important issue, especially considering that observed concentrations down to 1 micrometer are being compared against model concentrations. This issue and how the microphysical probe data are analyzed needs to be described. Further, what is the justification for using the CPI to derive concentrations, especially given the poor agreement with the CIP that is shown in Figure 13. The CPI does not have a well defined sample volume so it would seem that there is large uncertainty in concentration, even if the size distributions are integrated over large time periods to compensate for the poor sampling statistics. Is the CPI concentrations affected by shattering? Similarly, work by Alexei Korolev has shown that the CIP concentrations may be affected by shattering for particles as large as 400 micrometers. How are these issues dealt with?

Answer:

We removed Fig 13 according to the reviewers suggestions. Further 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.

Additional comments:

FSSP300 description: How significant was the shattering problem on this probe? Was there a shroud used on this instrument? Given past studies showing the magnitude of the problem of shattering artificially amplifying small crystal concentrations, can this probe be trusted?

The answer is included in the previous comment.

2DC, PN and CPI: description: More description of the data processing is needed, especially given that the derived products are being used to evaluate the performance of a model. Also, past studies have shown that the 2DC has a poorly defined depth of field for particles smaller than 125 micrometers, making concentrations of particles in these size ranges highly uncertain. In addition, as stated above, there may be shattering problems associated with the 2DC. Also, how are the CPI data processed given the poorly defined sample volume?

Answer:

We included a paragraph describing the particle instruments in more detail in the instrumentation section.

The 2D-C Probe, the Polar Nephelometer (PN) and the Cloud Particle Imager (CPI)

The particle size distribution of large particles (100 mum to 1 mum) was measured with a 2D-C probe, the particle shape (2.3 mum pixel size) with a cloud particle imager (CPI) and the scattering phase function of cloud particles (3 mum to 1 mm) with a Polar Nephelometer (PN). The method of data processing, the reliability of the instruments and the uncertainties of the derived microphysical and optical parameters have been described in detail by Gayet [2009].

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 Febvre [2009]. 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.

The CPI records very high resolution (2.3 mum) digital images of cloud particles as they pass through the sample tube of the instrument. It casts an image of the particle on a solid-state CCD camera by freezing the motion of the particle using a 25 ns pulsed, high-power laser diode. Upstream lasers precisely define the depth-of-field so that at least one particle in the image is almost always in the focus. This eliminates out-of-focus sizing errors that have plagued the conventional 2D imaging probes. The method of data processing leads to derive the particle size distribution, shape and extinction coefficient.

The PN is designed to measure the optical and microphysical parameters of clouds containing either water droplets or ice crystals or a mixture of both over a size range from a few micrometers to about 800 microns diameter. The probe measures the scattering phase function of an ensemble of cloud particles which intersect a collimated laser beam near the focal point of a paraboloidal mirror. The light scattered from polar angles from +/-3.49 to +/-169° is reflected onto a circular array of 54 photodiodes. The signal processing electronics and computer storage can provide one measurement of the scattering phase function every 10 ms. The optical properties (extinction coefficient, asymmetry factor, backscattering coefficient) are derived from the measured scattering phase functions. The particle size spectra and subsequent derived quantities such bulk and size parameters are retrieved using an inversion technique. The particle phase discrimination (water droplet/ice particles) can be derived from the shape of the scattering phase function.

CIP: See above comment about uncertainties in depth of field for particles smaller than 125 micrometers, and also, how is shattering compensated for?

Answer:

The correction for particle shattering is given in DeReus[2009] and we removed Fig. 13 according to the reviewers suggestions. Further we modified the description of the CIP as follows: During the last flight the 2D-C has been exchanged with a Cloud Imaging Probe (CIP), which is a new version of the 2D-C. The CIP measures the size and shape of particles passing through its collimated laser beam, from 125 mum to 1600 mum with a resolution of 25 mum. It is capable to detect particle concentrations up to 100 cm-3 at airspeeds up to 200 m/s. It uses a fast 64-element photodiode array to generate 2-dimensional images of the particles. The uncertainty in the CIP particle number concentration is mainly determined by the uncertainty in the sample volume of 20%. At low particle concentrations also counting statistics have to be taken into account. The uncertainty in the particle size decreases with particle size and is +/-25 mum for particles >125mum in diameter [DeReus2009].

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