Manuscript Review

Aircraft type influence on contrail properties

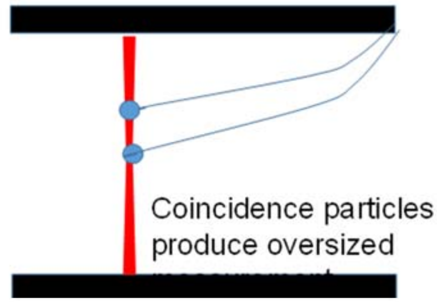
This paper evaluates the impact of aircraft type, e.g. size and emission factors, on the microphysical properties and spatial extent of contrails formed in their exhausts. A numerical model is used to analyze these difference after comparisons are made between the observations and model results of contrail effective diameter, total number concentration and extinction derived from the measured and modeled size distributions.

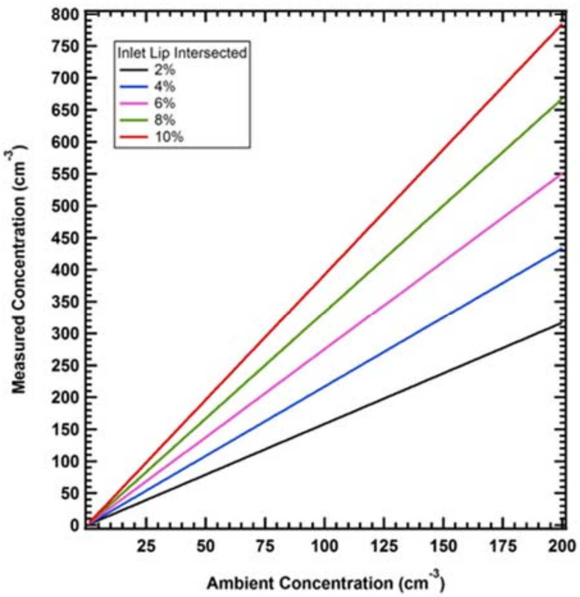
Given that I have no experience in the development and use of models such as the one that is implemented in this study, I will only direct my comments to the observations where I do have some experience.

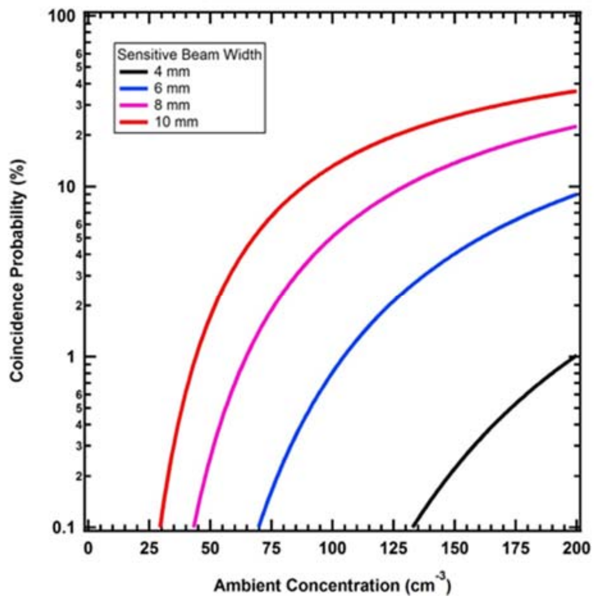
The paper is very well written and the authors have tried to address all the obvious problems with comparing models with measurements in contrails where the exact location of the measurement with respect to the contrail horizontal and vertical structure is difficult, if not impossible, to ascertain in order to do direct comparisons with the model. The approach they have taken for averaging the data is sensible and they have established reasonable uncertainties that are associated with the measurements.

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.

In the figure I show the inlet of the FSSP300 that has an outer diameter of 5.1 cm and an inner diameter of 3.8 cm. This presents a lip surface of approximately 9 cm^2 for particles to collide with. If they don't break then they will bounce. At an aircraft velocity of 200 m s^{-1}, 180000 cm^3 of volume are swept out each second so that even at a low concentration of 1 cm^{-3}, 1.8×10^5 particles collide with the rim. We can estimate how many of those will pass through the 0.188 mm^2 sample area of the FSSP by assuming that the trajectories of the particles that bounce into the airflow through the probe are random but uniform so that a bouncing crystal has equal probability of passing anywhere through the inlet cross section. The number of particles per unit that are in the airstream through the probe is calculated by dividing the number of colliding particles per second by the area of the inlet. To determine the number that will pass through the sensitive sample area we multiply by the area 0.00188 cm^2. Of course, only some small fraction of the colliding particles will bounce into the airflow rather than outside so we can calculate the number of measured particles assuming different fractions. In the figure I have used 2,4,6,8 and 10%. We see that using even a very conservative number like 6%, the bouncing increases the measured concentration by about a factor of three. We could of course make many other assumptions that could make this multiplication much larger or even negligible. 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.







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.

Minor comments:

The collection angles of the FSSP-300 are similar to the 100, $4\text{-}12^0$, not $6\text{-}15^o$

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.

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

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?

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.