Answer to referee 1 comments for "In-flight emission measurements with an autonomous payload behind a turboprop aircraft"

We would like to thank the reviewer for the suggestions, which will improve the manuscript substantially. We will address the comments point by point below in italic font.

General Comments

Summary: The impact is well-motivated, showing the importance of studying short range flights with turboprop aircraft. Significance of the impact, difficulty of the measurement, and lack of comparable datasets highly motivate the scientific significance. The method is sound and calibrations and subsequent analyses are thorough, including variance and error propagation. Some explanation as to why the aerosol instruments need to be pressurized would be preferable, since I was confused by the explanation of sampling stability. I am suspicious of the particle sizing and concentration accuracy at the small sizes ~10nm, due to the cut size of the particle counters (exacerbated by diffusion losses) leading to large correction factors, thus the mode size may be slightly overestimated; however, results compare well to previous airborne measurements with similar instrumentation from Moore et al., 2017. The author did a very good job characterizing instrument response to sample and environmental factors, and uncertainty. There are a couple of typos.

We thank the reviewer for this positive assessment and will address the specific comments below.

Specific Comments

L15-17: Are the size distributions presented from the total or nonvolatile aerosol? If total, suggest removing "soot" and generalizing as jet engine emissions, since the soot implies non-volatile particulates.
Agreed, the size distribution of the total aerosol is now explicitly specified. The observation that the discovered mode falls within the range of previously measured jet engine soot suggests that soot is the primary contributor to this distribution.

L25-26: Incomplete sentence. Suggest combining with previous sentence.
Thank you, we have clarified this sentence.

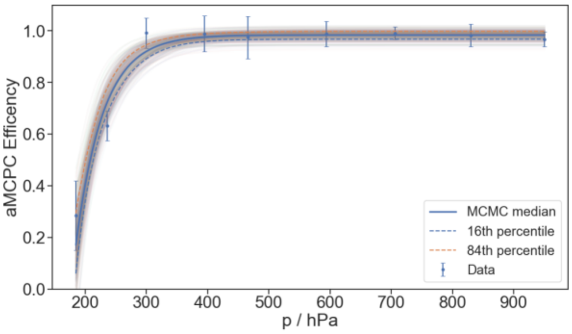
L97: L228 is the first time bringing up isokinetic, but it would be helpful to mention at the introduction of the aerosol inlet.
Agreed, we added this.

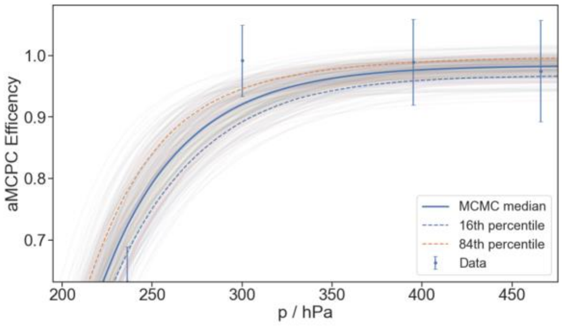
L122-123: Can you expand on what "ensuring stable sampling conditions" means? Why would the instruments need to be in a pressurized vessel? It introduces a higher deltaP and increases the potential for dilution/leak into the sample.
One key reason is that the Licor instrument for CO_2 measurements needs to be operated at cabin pressures. Additionally, the MCPCs, SEMS, and their associated computer systems were not originally designed for operation at such high altitudes and low pressures. The ceiling altitude of the measurements was unclear at the time of system design. To avoid the risk of electrical issues such as arcing, we chose not to operate them under these conditions. We discussed the possibility of testing the instruments in a cloud chamber. However, based on many hours of laboratory testing, where we operated with low pressure in the sample line,

we chose to run the instruments in a pressurized environment to enhance the stability of the measurements during the flights. You are correct that, in general, a higher deltaP increases the potential for leaks. For this reason, we repeatedly tested the system for leaks under high deltaP conditions during the campaign (by reducing the inlet pressure and sampling from a filter). For the tubing within the instruments, which were mostly Tygon tubing, we expected a higher impermeability.

L206-208 & F5b: The curve fit deviates from the measured counting efficiency right around your critical operating environment. The operating environment is barely captured in your data points. Higher resolution in the region that you measure (more points between 375-250 hPa) would result in more precise correction.

Thank you for this comment. We agree that additional measurement points between 250 and 350 hPa would have better constrained the fit in this range. We also acknowledge that the model may not capture the MCPC behavior perfectly in this range, however, considering all data points, the fit converges well. The figures below show the subset of the Markov Chain Monte Carlo (MCMC) results with the model median and the 1 σ credible interval. While the model median lies outside the 1 σ range of the experimental data at 300 hPa, it remains within the credible interval from the MCMC posterior. More measurements would probably not alter the median fit curve but rather constrain the 16^{th} and 86^{th} percentile. We therefore retained the model together with its associated uncertainty, which is propagated in our error analysis to account for this local deviation.





L223: Is the 90-degree tube bend sufficiently large enough radius to be negligible for inertial impaction of large particles? Valuable to mention if negligible here when describing other loss mechanisms.

Following the theoretical particle loss approach described by Baron & Willeke (2001), we used P. Baron's particle loss calculator to estimate losses of larger particles due to inertial effects. The calculation included all sample lines, including their diameters and curvatures, as well as the flow rates of sample air going through the sampling lines. Results indicate that particle losses become significant for diameters exceeding 1 µm. Although the OPC's size range includes such particles, we intentionally excluded them from our analysis because OPC concentrations drop to near zero for particles of D > 400 nm.

L259: Typo. soot soot.

Thank you, we fixed that.

L267: Why the range in sheath flow? Is the range from intentional changes, e.g., compensating for pressure to achieve the same size range in a scan, or fluctuation due to environment? What is the corresponding sample flow?

The range given here refers solely to the instrument's capability. The transfer function (the probability that an aerosol particle entering the SEMS will exit through the detector outlet) depends on the sheath flow, and a higher sheath flow narrows the classification window, thereby improving resolution. To achieve high resolution in short time intervals, we selected a sheath flow of 3 L min^{-1} for our measurements. This flow is maintained by an internal pump and was verified to be constant in the recorded data, although those data are not shown here. The sample flow was approximately 0.36 L min^{-1}.

L270: Typo on mSEMS. "Is able to operate at 5 s scan time", does that mean you did operate a 5 s scan? What was the lag time from the sample out of the DMA to the aMCPC? For a 5-second scan, the smearing may be significant. You don't mention operation scan times until L509, and it's worth mentioning how it was operated in section 2.1.8. 17s scan while in a highly variable plume seems too slow for samples shown in F7 without a large lag chamber. Were scans averaged to suppress the noise, and if so, how many scans are used for averaging?

- Thank you, the typo is fixed. 5s refers to the instrument's shortest possible scan time, although this setting was not used during these flights.

-The delay time between the SEMS and MCPC is 0.9 s; both up- and down-scans were evaluated under laboratory conditions to determine this delay time.

- As noted in the comment, we could only use scans clearly identified as in-plume, resulting in a total effective measurement time of just over 1 min. The conditions were sufficiently stable during these scans with clear CO_2 enhancements above the background. We acknowledge that this represents extremely sparse data. These data are from the first flight, in which the turboprop chase was the shorter of two planned experiments. For this initial run, we planned longer SEMS scan times to account for the variable background conditions. We acknowledge that a shorter scan time would have been advantageous in this case and had planned to adjust the settings accordingly for subsequent flights.

Unfortunately, we only had a shorter chase sequence during the first flight, and during the main chase flight, the SEMS failed to start due to a power issue.

L289-290: Is it supposed to read "sizing" instead of "size"? Why are instrument sizing and flow calibration major sources of uncertainty? Are you talking about the physical size due to unknown refractive indices?

Thank you! Yes, it should read "sizing". We have changed the wording.

The OPC flow is controlled with a critical orifice, which fixes the volume flow. It is not a major source of uncertainty, and we change that. We included the reference to Walser et al. (2017), who further describe the uncertainties in the optical sizing method. We don't examine the OPC data with the same detail as for other instruments, as its importance is secondary to our evaluation.

F9, F5c, F5d: The combined effects of the aMCPC size cut, counting efficiency with pressure, and diffusion losses, hurts the confidence in the size distributions below 20 nm. I expect the entire left-side falling edge of the curve in Figure 9 in plume would have increasing error bars associated with it, which may provide context/caution in interpreting the mode size from the fit in F9b. The aMCPC may not be the best choice for engine emission characterization since its cut size is near to the exhaust particle size range. There may be a significant number of sub-10 nm particles missing from the tPM when calculating the EI. Perhaps the EI should be specified as the EI_tPM>10nm at the top of the document. This may be less of a concern for this generation of engine, but consider ultra fine CPCs when testing future generation engines that combust more efficiently that they may have a smaller mode size where the aMCPC will completely misinform/bias the peak.

We agree to specify the measurements as >10 nm, since it falls slightly below the D50 cutoff under our sampling conditions. Thank you for this comment. We have now included the efficiency losses for small sizes in Figure 9. We also included the efficiency calibration of the SEMS + MCPC setup into the instrument analysis in Fig. 5e and section 2.1.8. This illustrates the combined effect of SEMS and MCPC on the particle cut-off. The calibration uncertainties propagate into the corrected data and show now a realistic estimation for the error at <10 nm particle diameters. While the correction did not change the general appearance of the distribution, it did shift the mode from Dg = 34.7 ± 1.9 nm to Dg = 27.5 ± 2.0 nm.