Anonymous Referee #2

Review of Atmospheric aerosol, gases and meteorological parameters measured during the LAPSE-RATE campaign, D. Brus et al.

We thank reviewer #2 for constructive comments, we really appreciate their time spent reading our manuscript.

This manuscript presents an overview of the data acquired from copter UAVs that conducted vertical profiles of aerosols, gases and meteorological parameters during the LAPSE-RATE campaign in the summer of 2018. Members from the Finnish Meteorological Institute (FMI) and Kansas State University (KSU) conducted measurements over a period of five days in the San Luis Valley, CO. The FMI copter measurements include vertical profiles up to nearly 900 m AGL of aerosol number concentrations and size distributions, CO2, and meteorological parameters (pressure, temperature, relative humidity), while KSU copter measurements conducted vertical profiles (up to 150 m AGL) of aerosol size and number distributions. In addition, FMI and KSU conducted ground-based measurements of aerosol and meteorological parameters to compare with the airborne copter measurements. The data from these flights is readily available from the websites provided in the manuscript. It is understood that ESSD is dedicated to the publication of datasets; however, key features of the dataset as well as its limits are needed to highlight the utility of the data in future publications. Several issues are described below that the authors should address before publication.

General comments:

RC1) The authors allude to a number of regional / local sources and meteorological patterns that impact diurnal cycles, changes in aerosol properties, generation of new particle formation events. However, few specific examples were highlighted in the text (farm vehicles), and summary (new particle formation). A few sentences on the defining characteristics of this dataset (for example, temporally with respect to meteorological patterns and vertically with respect to atmospheric structure) would be useful.

AR1) In general, there was/is very little known about the background aerosol concentrations within the SLV from the literature. The aerosol and generally any air quality measurements are very sparse in Colorado and are mostly concentrated around larger cities. The analysis of the data collected by FMI and KSU, however limited, with narrative is provided in our ACP publication Brus et al. 2021. We will provide several sentences to reflect reviewer's comment.

RC3) Airborne aerosol measurements are a challenge – especially for measurements of particles larger than several micrometers in diameter in a non-isokinetic flow. A description of the KSU inlet has been provided; however, the orientation with respect to the wind and propeller wash is not clear. The stated largest diameter for the N2 and POPS are 17 and 33 um, respectively. The authors need to provide an assessment of sampling biases related to super-micron aerosol particles. I also suggest that authors compare ground-based and airborne measurements for the OPC-N2 and POPS at a range of sizes between 0.3 and 30 um diameter.

AR3) The inlet orientation of POPS was clarified in revised manuscript. There was a terrible mistake in decimal point on line 186 concerning the mid bin diameters of POPS, however in many other places it is clearly stated that the lowest and largest diameter measurable by POPS are 0.13 and 3.65 microns. OPC-

N2 and POPS overlap in the range between 0.46 to 3.5 microns. Discussion on sampling losses and comparison of airborne and ground measurements was also added.

The following was added to line 63:" Each of the CPCs used a 30 cm inlet made of conductive tubing, led from the sides upwards to the center of the rotorcraft, where both lines were merged to an additional 10 cm piece of conductive inlet tubing, also facing upwards. Penetration for such an inlet was estimated to be between 90% and 99% or particles between 7 and 100 nm and 99 % for particles between 100 nm and 1um."

To line 84:"Both OPCs N2, in the particle and ground module, were used with no additional inlet, as those OPCs were not meant to be used with any kind of inlet due to the use of a fan for aerosol intake."

To line 96:" … a horizontally oriented naked inlet approximately 9 cm (3.5 in.) long with an inner diameter of 1.7 mm (0.069 in.)."

To line 100: "… it was located approximately 1.8 m AGL and used a vertically oriented tube inlet of approximately 45cm (18 in.) long with an inner diameter of 3.175 mm (0.125 in.). The penetration through the inlet was estimated to be ∼92% for 3 um particles and better for smaller ones."

RC4) Along the same line, when comparing the OPC-N2 between the copter and the ground based measurements (Figures 2D,E and Figures 3C,D), it appears that the N2 concentrations on the copter are systematically at least a factor of two larger than the ground based measurements. Was there any additional flow control or flow measurements for the OPC-N2? The off-the-shelf version does not provide precise measurement of the air volume for determining the number concentration.

AR5) No, we did not make any additional flow measurements or additional flow control of OPC-N2, it was used as it was purchased. The nominal flow through OPC-N2 is ~220 ccm/min and is calculated with a time-of-flight method. Transit times of particles are recorded to eventually correct the flow speed. The comparison between surface and airborne measurements please see AR6 below.

RC5) The authors state that hysteresis between ascent and descent profiles was significant. This difference is expected given the high ascent rates (up to 8 m. s-1) and considerably slower descent rates (as low as 2 m.s-1). The authors then suggest using the ascents for the best representation of the vertical profiles with no justification. Given that the ascent rates were faster, the impact of hysteresis on the vertical profile should also be greater. Are there other factors that need to be considered? What is the bias related to the hysteresis? I also suggest showing a figure to illustrate the impact of hysteresis on the vertical profiles.

AR5) The authors state the hysteresis was noticeable. The ascent data are recommended for use since they copy the temperature profile better when compared to sounding data from Leech airport located about 15 km from the FMI and the KSU teams sampling location. As an example, please see attached FIG. 1 and FIG. 2 for comparison profiles of temperature and RH at matching times between multicopter and sounding. The BME280 sensor descending profiles are flatter compared to ascend profiles, ascend data copy the sounding slope better in our opinion. It seems the sensor cools faster than it warms up, since the observed hysteresis. In our experience, when the sensor was flown against reference 300 m tower and the ascend and descent rates are close to 1 m/s the hysteresis disappears. But during LAPSE-RATE such slow ascend and descent rates were in contrary to our preference to sample aerosol properties in whole permitted vertical column 3000 feet, i.e. climb very fast in a limited time given by multicopter battery capacity.

The profiles are plotted separately in our ACP manuscript Brus et al. (2021) with detailed discussion, here we would like to provide solely data sets.

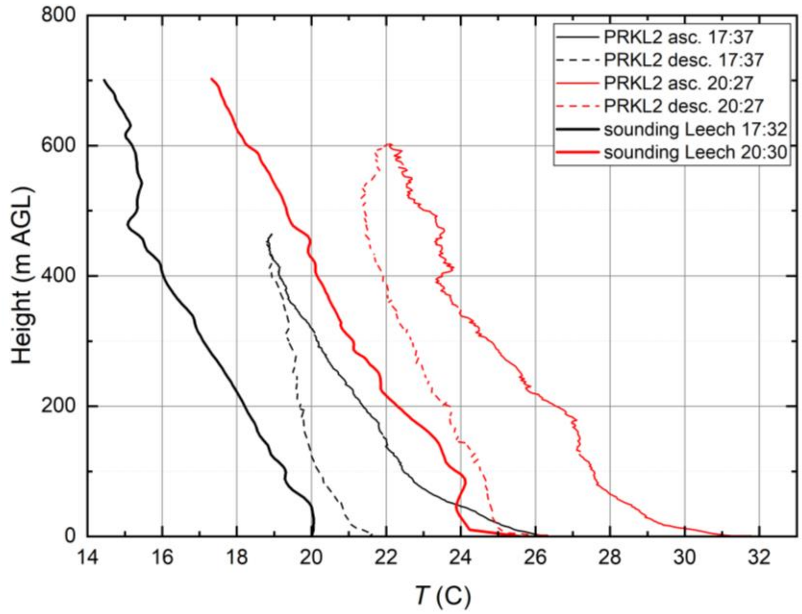

Figure 1. Comparison of temperature profiles between BME280 on multicopter and sounding made at Leech airport.

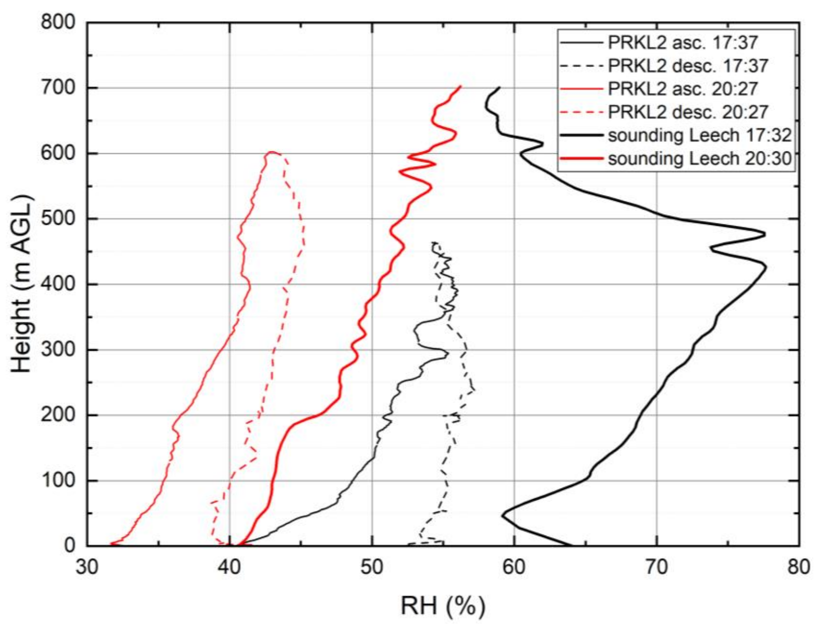

Figure 2. Comparison of RH profiles between BME280 on multicopter and sounding made at Leech airport.

RC6) The figures show time series of averaged values and variability for each flight. However, there are no examples of vertical profiles and no specific comparisons / validations between airborne and ground-based data. Yet, there are some differences between the airborne and ground-based averages that cannot be reconciled in the figures that have been shown. For example, ground-based temperature and relative humidity show no consistent relationship with the airborne observations. I would have expected to see the ground-based temperature similar to the warmest airborne temperature in a wellmixed boundary layer. As mentioned above, the ground-based number concentrations reported by the OPC N2 are consistently less than the airborne values by more than a factor of two. Otherwise, ground-based and airborne measurements of pressure, CPC, and POPS show expected relationships (at least what can be seen from the figures).

A very similar comment was raised during the review of our manuscript in ACP Brus et al. (2021) the following analysis was provided, and it can be accessed via Supplementary materials of the above mentioned manuscript.

We performed a short comparison (about 5 minutes) before each flight among the particle counters to check their performance, mostly visually from the laptop screen, if the number concentrations roughly correspond to each other. The rotorcraft with particle module was not in the same location as surface module, neither the particle counters were using the same inlet. The rotorcraft was standing on the camping table approximately one third of the height of surface module which was placed on the car roof. Since the provided comparison is rather semi quantitative.

The comparison of rotorcraft particle module to surface module for CPC could be seen in attached FIG. 3, we must point out that each CPC was calibrated to different D50 cut-off, the most pronounced disagreement could be seen on Jul 16th when a weak NPF took place also at the surface (the red circles).

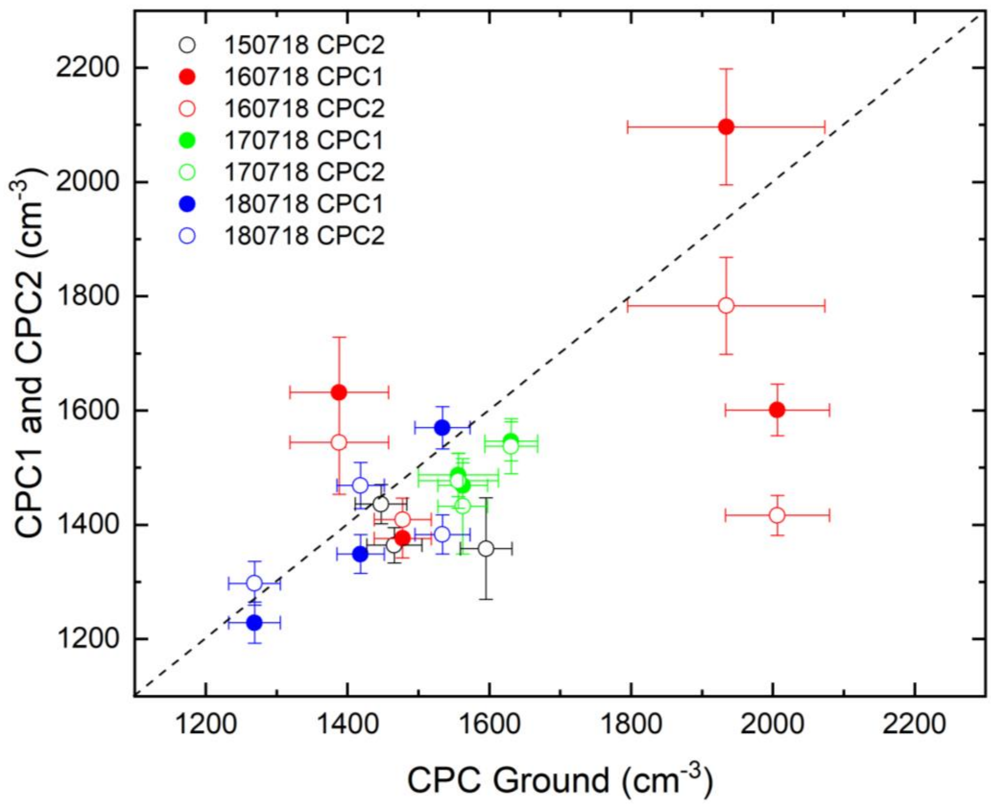

Figure. 3 Inter-comparison of CPCs mounted on rotorcraft particle module (CPC1 and CPC2) and surface module (CPC Ground).

The comparison of OPCs in particle and surface module is shown in attached FIG. 4. In some cases, the OPC on particle module shows higher concentrations than the OPC on surface module. This might due to rotorcraft proximity to dusty surface during comparison. Similarly, when we compare normalized concentration per bin, the OPC on particle module slightly overcounts in all bins, see FIG. 5.

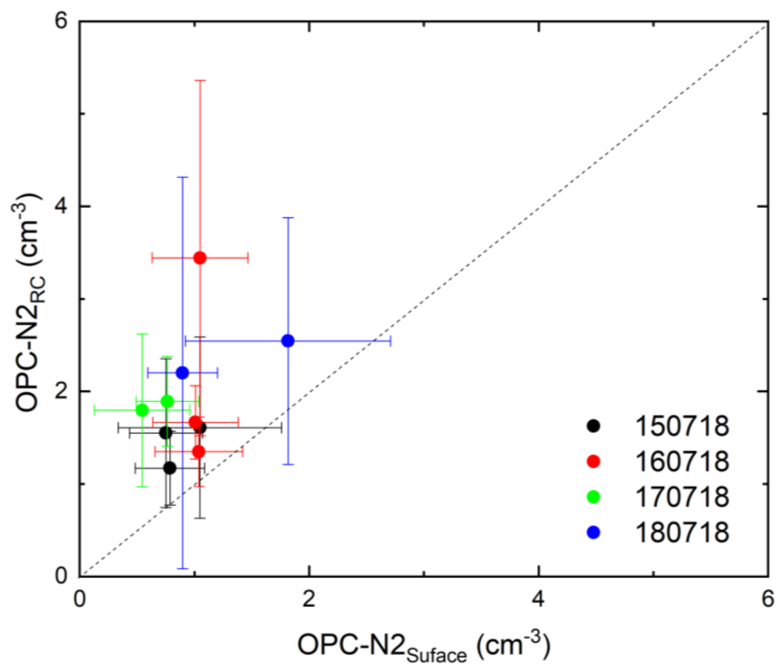

Figure 4. Daily comparison of total number concentration of OPCs mounted on rotorcraft particle module (OPC-N2_RC) and surface module (OPC-N2_Surface).

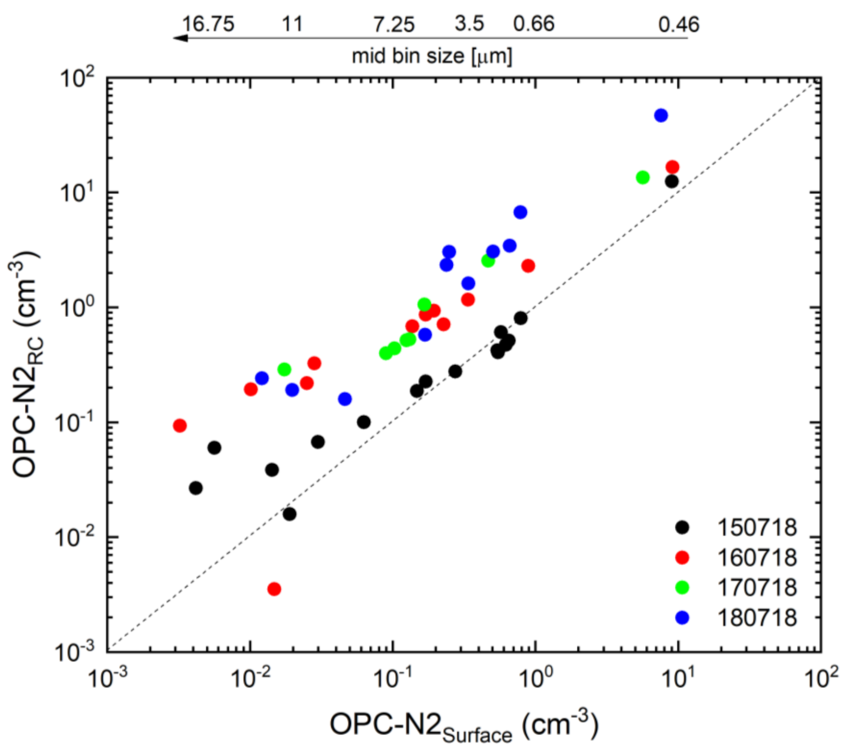

Figure 5. Daily comparison of normalized concentration per bin of the OPCs mounted on rotorcraft particle module (OPC-N2_RC) and surface module (OPC-N2_Surface).

There was no intentional comparison made for the pair of POPS counters, however we made a comparison of total particle number concentration using the air unit data just before the flight, when the KSU rotorcraft was ready for take-off, e.g. height was zero or close to zero, see Fig 6. The particle concertation data are slightly biased toward higher counts of air unit, on average about 10%.

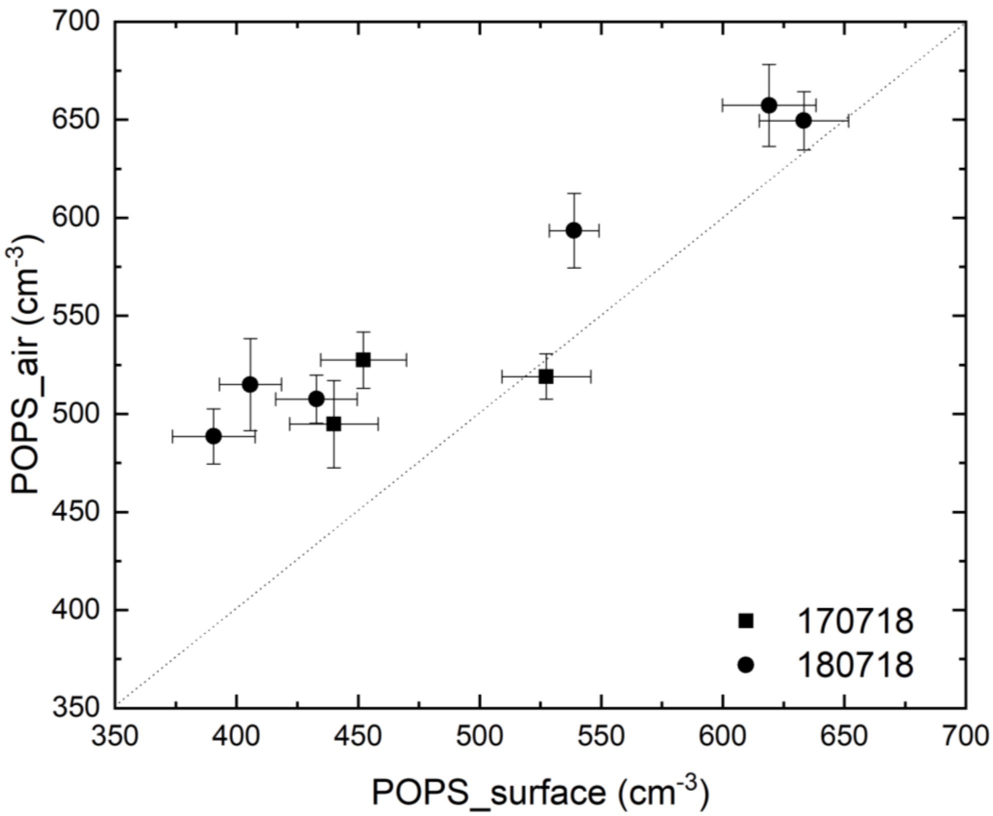

Figure 6. Comparison of POPS air and surface unit particle number concentration.

We will add following to manuscript, line 209: "Also, a short inter-comparison (~5 minutes) was performed before each flight among the surface and airborne particle counters to check their performance. Based on data postprocessing, the CPCs of particle and surface modules compared well within the manuscript stated uncertainty of 10%, except for July 16th when NPF at the surface level took place. This is due to different calibrated cut-off diameter of each CPC. The OPCs compared within factor of 2, however it has to be considered that very low particle concentrations were measured, about 2 cm^{-3} in the OPCs size range. There were no inter-comparison measurements made for POPS instruments. For more details please see Supplementary materials of Brus et al. (2021), where the detailed analysis was provided."

RC7) In the summary, it would be useful to state the size of the dataset, the format (netCDF), quality-control level, and other important issues (e.g., measurement biases) that users need to take into account when using this data set.

AR7) The following was added to Summary section: The dataset was divided into two parts: FMI dataset containing 60 files (21 MB) and KSU dataset containing 31 files (11.3 MB), all files are available in netCDF format. The QC and measurement biases are discussed in details in appropriate sections of the manuscript.

Specific comments:

RC8) It would be helpful to diameter throughout the text when referring to the size of the aerosol particles.

AR8) Corrected accordingly.

RC9) Line 67: when introducing the other trace gas measurements CO, NO2, SO2, O2 the authors need to immediately state these measurements are not included as their concentrations were below the detection limit. I suggest moving lines 73 to 75 to line 67.

AR9) Corrected according reviewer's suggestion.

RC10) Line 72, Was the Gelman filter was added to avoid contamination of aerosol particles in the optical path? Specify the type of Gelman filter.

AR10) Yes, the filter is included to protect the optical path from contamination. Producer (Li-cor) recommended and provided Gelman 1 Micron Filter Assembly was used. The manuscript was updated accordingly.

RC11) Line 133: Specify 'These variables' Lines 127-133 and Lines 144-149 are nearly identical – I suggest combining and stated that these parameters are the same for both PRKL1 and PRKL2 copters.

AR11) Changed according to reviewer suggestion.

RC12) Line 155: change 'Further' to 'Furthermore'

AR12) Changed accordingly.

RC13) Line 160: Was the GMP343 data corrected based on the intercomparison to the PICARRO? A few lines later, the authors state that GMP343 suffered from inaccurate pressure compensation. Consequently, the authors recommend the use of the Licor 840A data for CO2 measurements. If this is the case, then why publish the GMP343 dataset?

AR13) No, the data were not corrected for the bias after measurements against Picarro. The correction to our dataset cannot be done since the comparison to Picarro was done at sea level and our dataset from GMP343 is obtained in vertical column i.e. changing pressure. Our point is that the Vaisala proprietary compensation algorithm does not work well for such application, the device (GMP343) is simply not meant for UAV vertical profiling. On the other hand, the GMP343 when compared to Li-840A has very nice shape factor that makes it suitable for use in for example a small fixed wing UAV and sampling plumes, however lower precision of the GMP343 has to be kept in mind.

The GMP343 data set is published for the case there would be someone interested in developing better compensation algorithm for this probe, all data necessary to do it are included in our dataset.

RC14) Line 185: The POPS recorded 16000 cm-3 during passages of farm vehicles, which is well above the maximum concentration limit stated in Table 1. Can the POPS and N2 number concentrations be corrected for high particle concentrations?

AR14) Such data were cleaned off from the data sets, our interest was only in characterizing background aerosol concentrations in SLV and not an exhaust emission of passing cars. The coincidence counts are in place in case of POPS, in Mei et al. (2020) they claim that the coincidence error is less than 25% when the concentration is less than 4000/ccm when compared to Ultra-High Sensitivity Aerosol Spectrometer (UHSAS). The car exhaust particles are smaller than the range of OPC-N2, thus OPC-N2 was not suffering from the coincidence counts. When measuring aerosols in plumes or exhausts the dilution of sampling flow is preferable over coincidence count corrections, as mentioned above this was not our intention during this campaign.

RC15) Line 197: The authors write 'preliminary quality control' – are future updates / data products expected? The datasets published to ESSD should be better than 'preliminary'.

AR15) The word "preliminary" was omitted from the sentence. It was not meant as it was understood, our apology for confusion, all data sets were quality checked. We published our limited analyses of the data sets already in Brus et al. (2021) and the authors currently have no other planes on creating further products out of those data sets.

RC16) Line 212: change 'anc' to 'and'

AR16) Corrected accordingly.

RC17) Line 218: change 'written' to 'wrote'

AR18) Corrected accordingly.

RC18) Figure 2F shows systematic biases in the CO2 measurements (as mentioned in a comment above). Why not correct the copter CO2 measurements to the reference Picarro instrument for the final data set?

AR18) Answered in a comment above.

RC19) Figure 3: The times corresponding to the ground-based averages are centered at 0:00, which does not correspond to an average of the times reported in Table 5.

AR19) The mistake was corrected.

RC20) To facilitate comparison of the aerosol measurements in Figures 2 and 3, I suggest combining measurements of the CPCs, OPC-N2 and POPS on a single semi-log plot.

AR20) Combining all three instruments into a single plot completely flattens the data and hides the daily variations, even though it is not very pronounced. The three orders of magnitude between CPC+POPS and OPC-N2 is too huge. We would like to keep separate figures as they are.

RC21) Table 1 needs to specify the instruments used for the ground-based measurements. 'Diameter' needs to be added to the size range.

AR21) Changed accordingly.

References:

Brus, D., Gustafsson, J., Vakkari, V., Kemppinen, O., de Boer, G., and Hirsikko, A.: Measurement report: Properties of aerosol and gases in the vertical profile during the LAPSE-RATE campaign, Atmos. Chem. Phys., 21, 517–533, https://doi.org/10.5194/acp-21-517-2021, 2021.

Mei F, McMeeking G, Pekour M, Gao R-S, Kulkarni G, China S, Telg H, Dexheimer D, Tomlinson J, Schmid B. Performance Assessment of Portable Optical Particle Spectrometer (POPS). Sensors. 2020; 20(21):6294. https://doi.org/10.3390/s20216294