Anonymous Referee #1

We thank reviewer #1 for constructive comments, we really appreciate their time spent reading our manuscript.

General comments: This paper demonstrates the unique aerosol and gas measurements via UASs and provides a promising data example for environmental research.

The authors presented a very useful payload for the atmospheric study and shared the exciting datasets from July 14 – July 18, 2018. However, analysis of the measurements is limited, and lack of a meaningful uncertainty estimation, which is critical for many data applications, such as the modeling evaluation.

RC1) *Specific comments: P3, section 2.1: What is the typical flight operation? "The maximum endurance of these rotorcraft was about 15 minutes." (in line 61) Does that suggest the measurements with this platform only last for 15 mins? If so, it is too short for any study. Maybe the authors can explain how to operate this platform to provide meaningful vertical datasets?*

AR1) For the LAPSE-RATE campaign we purchased a brand-new set of LiPo batteries, since it was the only way how to secure our operation. There was not enough time to make enough of charge-discharge cycles to rich the full batteries capacity. We put a lot of emphasis on safety during our operation, when battery voltage reached 23 V (6S 1600 mAh) during the rotorcraft ascend we started the descend to safely land. The progress in achieved maximum altitude is clearly visible from FIG 9 in the manuscript. If well cycled battery is used, the flight times are about 20 minutes, depended on environment (wind and temperature), our maximum achieved height ever with this rotorcraft was 1000 m AGL when flying in stabilized mode and conditions were perfect. Usually the combination of legal flight limits and the rotorcraft capabilities dictate the flight strategy. For example, we can choose, when measuring aerosols, do we want to characterize whole vertical column within the legal limits (3000 feet) but with poor statistics or rather have better statistics and give up on full height of the column. We made our choice and were able to observe high altitude NPF event.

We will elaborate this issue in revised manuscript.

RC2) *P4, section 2.2, line 89, is this "basic meteorological sensor" the Arduino Bosh BME280 sensor?*

AR2) Yes, we meant Arduino Bosh BME280 to be basic meteorological sensor. It will be clarified in revised version of the manuscript.

RC3) *P4, section 2.2, There is no uncertainty or accuracy information about the CPCs and OPC. The BME280 sensor accuracy mentioned in this section (in line 100) are all based on manufacturer statements, and very different from the comparison difference discussed in line 106-107. Does the field environment affect those manufacturer's accuracy? Were other sensors compared with high precision "siblings" in the laboratory, like CO2 sensors? If so, that information should be included here too. Does the KSU Matrice 600 Pro contain any other met sensors? POPS was not shielded from direct sunlight during the flights. Does that cause any overheating? What is the optical chamber temperature during the flights?*

AR3) The uncertainty and accuracy information on CPCc, OPC and BME280 will be elaborated in revised manuscript.

In Barbieri et al. 2019 it was discussed that placement of the sensor (shielded/not-shielded, aspirated/not-aspirated) plays dominant role rather than its own accuracy and uncertainty, that was also valid in our case, sensors shielded but not forcefully aspirated. When BME280 sensors are calibrated in environmental chamber – well controlled conditions, against national standard at FMI, their response is very satisfactory, please see FIG 1 attached.

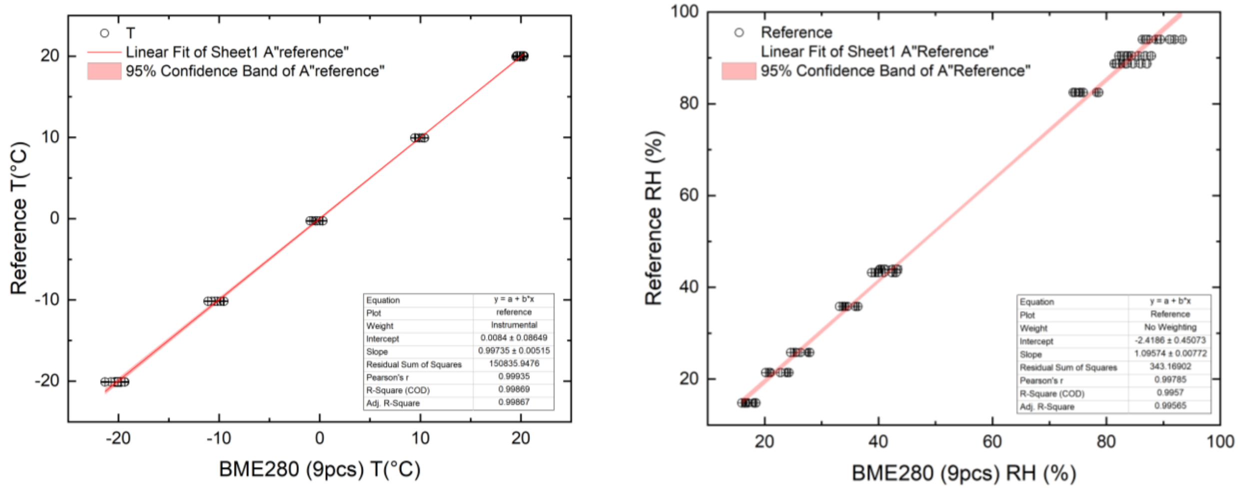

Figure 1. T and RH calibration for 9 pcs of BME280 sensors against FMI national standard.

The KSU Matrice 600 Pro did contain Meteorological sensor (iMetXQ2, International Met Systems, Grand Rapids, MI, USA) borrowed from Oklahoma State University. However, the sensor data were found corrupted, and we were not able to recover the files for this manuscript.

The flight POPS was in direct sunshine only for a limited time due to the flights being short and was being cooled by an airflow during the flights. As a consequence, the highest optical chamber temperature recorded was 33C. The ground POPS was exposed to longer durations of direct sunshine and less airflow. As a result, the highest optical chamber temperature recorded was 53C. The manufacturer does not give a specific recommendation for the optical chamber temperature, but after reviewing the data raised no concerns about the overheating. As such, we believe that the temperatures are within acceptable ranges, especially for the flight unit.

RC4) P6, section 3.1.1, the ground meteorological comparison is meaningless because two sites are 15 km apart. Maybe change the Fig 4 (Surface vs. MURC) to diurnal variation plot (time vs. T, RH, P).

AR4) In general, during LAPSE-RATE campaign there was a lack of reference measurements. We will change the Fig. 4. To diurnal plot as suggested by reviewer, but we would like to keep the MURC data too even though they were measured at different height and 15 km distance.

RC5) P7, section 3.1.2, if I understand the section 2.2 correctly, a duplicate CPC, OPC, and POPS were operated on the ground. Do you compare them with the flying version on the ground?

AR5) Yes, 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. 2, 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).

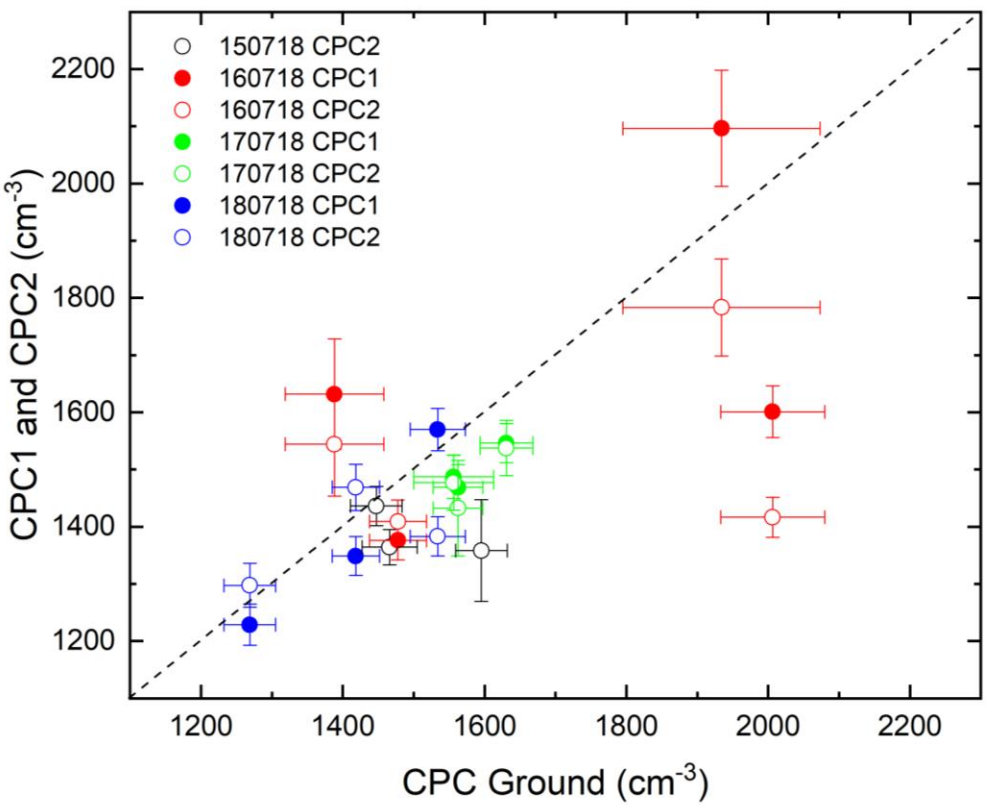

Figure. 2 Inter-comparison of CPCs mounted on rotorcraft particle module (CPC1 and CPC2) and surface module (CPC Ground).

The comparison of OPCs in particle and surface module is shown in attached FIG. 3. 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. 4.

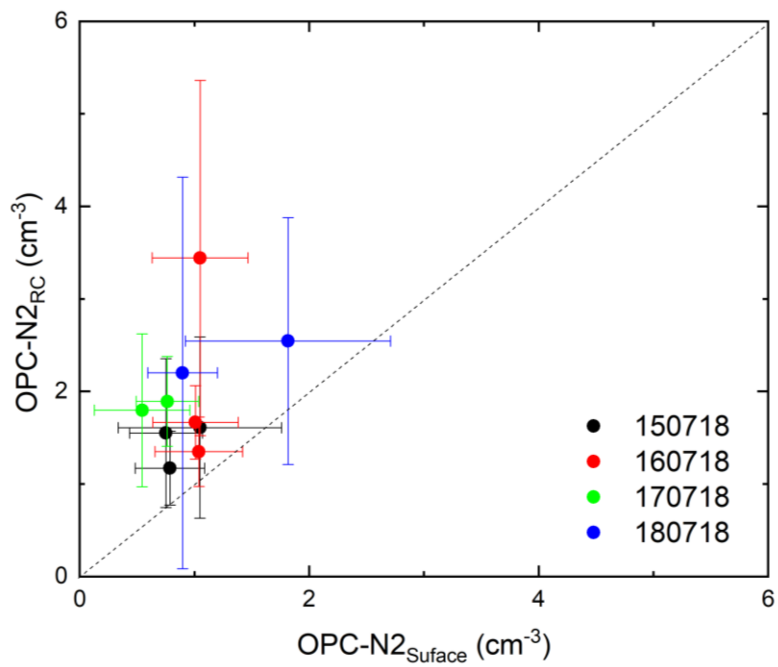

Figure 3. Daily comparison of total number concentration of OPCs mounted on rotorcraft particle module (OPC-N2_RC) and surface module (OPC-N2_Surface).

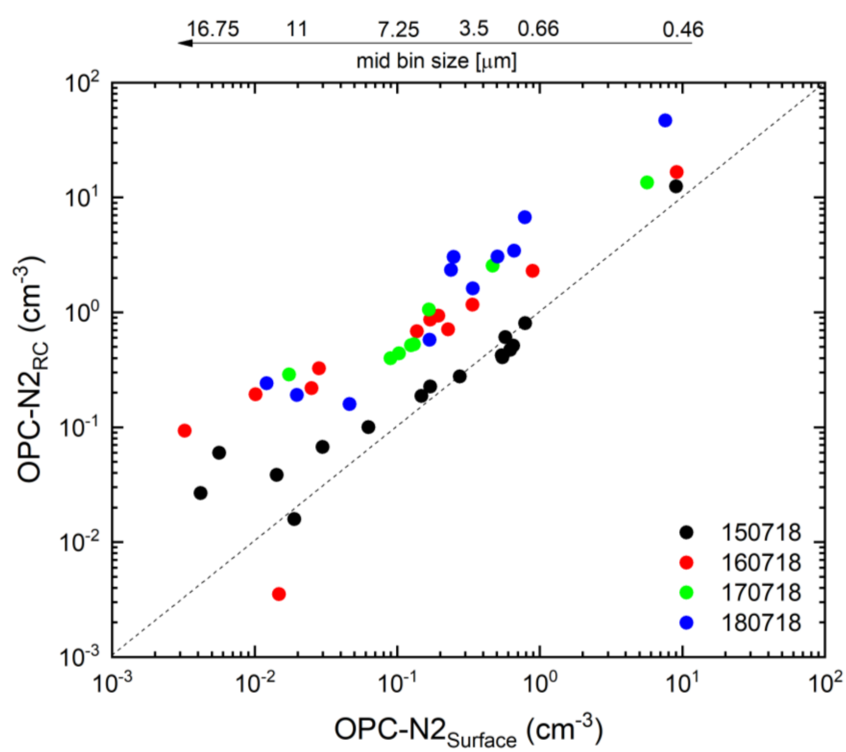

Figure 4. Daily comparison of normalized concentration per bin of the OPCs mounted on rotorcraft particle module (OPC-N2_RC) and surface module (OPC-N2_Surface).

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 5. The particle concertation data are slightly biased toward higher counts of air unit, on average about 10%.

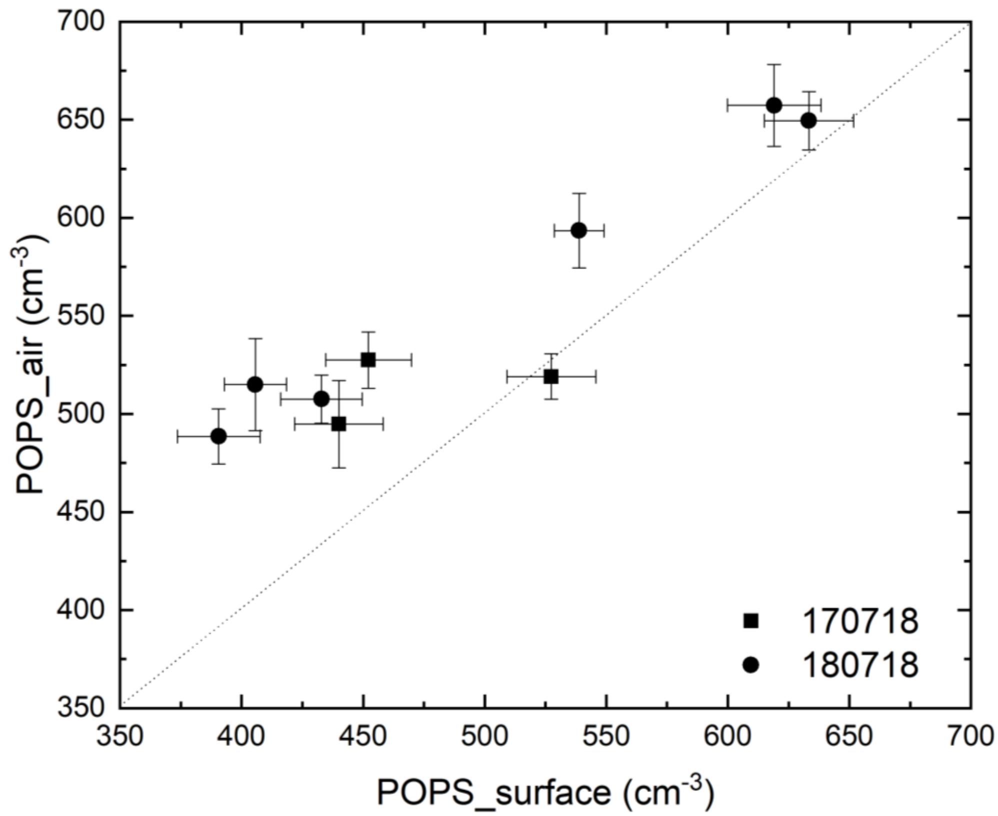

Figure 5. Comparison of POPS air and surface unit particle number concentration.

We will add following to manuscript: “A short comparison (about 5 minutes) was performed before each flight among the particle counters to check their performance, mostly visually from the laptop screen 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}. There were no inter-comparison measurements made for POPS instruments. For more details please see the manuscript discussion.”

RC6) *Figure 8, “POPS and OPC-N2 overlap well over eight size bins” may overstate the comparison. The figure is in log scale, and POPS seemed to be a factor of 2 of the OPC-N2.*

AR6) True, it is on average about factor of 2, the expression will be softened in revised version of manuscript.

RC7) *P8, section 3.2.1, The BME280 sensor has a +2 C difference comparing to the MURC. Will this difference constant for the hysteresis temperature profile? Will the observed T and RH data scientifically useful?*

AR7) The temperature difference of 2 C of BME280 when compered to MURC, was the same as factory calibrated Vaisala AQT400 sensor mounted on the same rotorcraft. Many other sensors participated in the comparison showed deviation of same magnitude and direction, for details see Barbieri et al. (2019). The observed difference is very difficult to extrapolate to vertical profile, and most probably it will not be constant in whole column. In general, any comparisons to standards (P, T, RH, winds, particle counts) are of high value. The best way to do it is a comparison with in-situ measurements at different heights on the high towers or against tethered balloon system. During LAPSE-RATE the best we had was MURC with measurements at one height, 18 m AGL.

RC8) P9, section 3.2.2, it is great to see the new particle formation detection capability developed here. It will be beneficial to correct the over-counting behavior of CPC2 before calculating the delta(CPC). Line 266, if the descending rotorcraft would push aerosol particles downwards. Would the ascending flight push aerosol particles upwards? What is the ascending and descending rate of this flight?

AR8) The overcounting of CPC2 is given mostly by fluctuations in flow which is not recorded. Both CPCs are intentionally calibrated to different cut-off diameter 7 and 14 nm and if no particles smaller then 14 nm are measured, e.g. monodisperse aerosol is used in lab, the uncertainty in count will be still 10 % only due to flow instability. All CPC data are already corrected since their flow rate deviates from nominal 0.7 lpm. The TSI 3007 is a good instrument, but it was not meant for UAV measurements.

The overall movement of the airmass will be down in any case, 11 kg UAV needs to push 11 kg of air down to keep hovering.

Line 231: "Our ascent rates were approximately 5-8 and 3-5 $m.s^{-1}$ and descent rates were about 2-5 and 2-3 $m.s^{-1}$ for flights with particle module (FMI-PRKL1) and gas module (FMI-PRKL2), respectively.

RC9) Line 273, the site is about 700 m AGL. Will the 1000 AGL Flexpart dispersion model represent the 700 m AGL condition?

AR9) Here, our focus is on the air mass origin of the elevated layer of nucleation-mode particles discussed in the previous paragraph. We chose 1000 m AGL to make sure that the Flexpart simulation represents air mass movements for the elevated layer and not the surface layer below 700 m AGL.

In case of such layered structure of the atmosphere as seen on July 18th it is uncertain how accurately the underlying meteorological data can represent the vertical structure of the wind profile. Therefore, running the simulation close to the lower edge of the layer (700 m AGL) would increase the risk of simulating the surface layer instead of the elevated layer.

We have modified line 273 as: "We used the Flexpart dispersion model to investigate the air mass history of the elevated layer of nucleation-mode particles observed on July 18th."

RC10) P10, section 3.2.3, It sounds that the platform motion has an impact on the POPS data. Please quantify the impactor. Does the author characterize the inlet loss for all the aerosol instruments – CPC, POPS, and OPC? It is critical to know the inlet loss for OPC during the descending and ascending because *the concentration is very low – 5 cm^-3.*

AR10) Impact on POPS data had only fast movement during horizontal transects with inlet placed horizontally and facing the direction of the movement. There were very few such flights, but we have noticed the bias. This will be clarified in revised manuscript.
The POPS on rotorcraft had horizontally orientated naked inlet facing out front of the rotorcraft. The surface POPS used 45 cm long vertically orientated inlet made of conductive tubing, the penetration through the inlet was estimated ~92% for 3 um particles and better for smaller ones.
Both OPCs, surface and particle module, were used with no additional inlet, those OPCs are not meant to be used with any kind of inlet due to use of fan for aerosol intake. On the rotorcraft the OPC was mounted from the bottom and middle of the carbon plate of the module, thus shielded from airmass movement and propeller eddies.
Each of the CPCs used 30 cm inlet made of conductive tubing, led upwards to the center of the rotorcraft where both lines were merged to additional 10 cm piece of conductive inlet tubing, also facing upwards. Penetration for such inlet is ~90 to 99% for particle between 7-100 nm and ~99 % for 100 nm -1 um.