Referee comments on "Three-dimensional distribution of fine particulate matter concentrations and synchronous meteorological data measured by an unmanned aerial vehicle (UAV) in Yangtze River Delta, China" by S.-J. Lu et al.

General comments

The manuscript describes measurements of fine particulate matter and meteorological parameters with an unmanned aerial vehicle. The aim of these measurements is to characterize the 3D distribution of PM2.5 and meteorological factors, which could be important to clarify the formation mechanisms of haze pollution and to help the forecast of atmospheric pollution. As such, the manuscript represents a substantial contribution to scientific progress within the scope of this journal, since it uses a new, though not completely original, methodology. In fact, some previous works about the application of UAV to the characterization of vertical profiles of atmospheric parameters, but also of particles as measured by optical particle counters (e.g., Brady et al., 2016; Renard et al., 2016) have been already published. These papers should be at least referenced in the work. The scientific approach and applied methods seem generally valid, although some appropriate references are missing. Finally, the number of the figures seems adequate, although the figures of the original version are not of enough quality. Apart from my specific comments below, it is very difficult to follow the presentation of scientific results due to the inappropriate use of English language: apart from some specific comments below, I strongly suggest that the English language of the manuscript is improved through the help of a native English-level speaker, since the language is not fluent and precise. The paper represents a sort of first study of the feasibility of the application of this kind of measurements, and as far as I understood more measurements are planned in the future. As such, conclusions reached are not substantial, and are also related to the main drawbacks of the adopted methodology (e.g., endurance of the batteries and limited payload of the UAVs). The description of experiments and calculations is sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results). Overall, I believe that a correct rewording of the language of the manuscript, including also the homogenization of tenses, is necessary prior it can be considered for publication on this journal.

Specific comments

Abstract

Page 1, line 9: Since this sentence is rather general and not restricted to your specific work, you should remove $PM_{2.5}$, since fine particulate matter could be also PM_1.

Page 1, lines 21-22: Probably it would be better to rephrase: "These findings are crucial for correct PM2.5 pollution forecast and environmental management."

Introduction

Page 1, line 25: Is only fine particulate matter responsible for climate change and visibility degradation? Are there any other important references for aerosols effect on climate?

Page 1, line 27: Dissipation is not the correct term here.

Page 1, lines 27-28, page 2, lines 1-4: It would be necessary to clarify the state of the art of these researches and why studies of vertical profiles are necessary for proceeding in our basic understanding of some mechanisms.

Page 2, lines 5-23: These lines are of key importance for the Introduction and for understanding how fine particulate matter measurements with UAV could help bridging the gap of our present understanding. It is therefore necessary here to correctly understand the pros and cons of each technique capable of retrieving vertical profiles (i.e., meteorological tower, LIDARs, manned aerial vehicles, unmanned aerial vehicles). After that, it is necessary here that the present state of the art about 3D distribution of fine particulate matter is correctly conveyed. I suggest therefore to dive this paragraph in two ones, the first one dealing with drawbacks and advantages of the techniques capable of retrieving vertical profiles of meteorological and atmospheric parameters, and the second one conveying the state of the art on the subject. In this respect, in the revision please mind that generally, it is more convenient to write sentences in this manner: example --   Ozone is an important greenhouse gas, especially in the upper troposphere [reference 1; reference 2].   This is much better than: Reference 1 studied … and found that ozone is an important greenhouse gas in the UT. Reference 2 examined …. and concluded that ozone in the UT has a significant greenhouse effect.

Page 2, lines 24-34, page 3, lines 1-3: Similar to my previous comment, please modify the way you refer to literature. This paragraph should explain the advantages, but also drawbacks, of the application of UAV with respect to other techniques. After that, previous findings obtained through the use of UAV should be summarized. Are there differences between UAVs, UAVM and UAMP? If not, please use one term only.

Page 2, line 30: How can UAMP provide partially dried size distributions? This sentence is not clear enough.

Page 3, line 3: Again, dissipation is not the correct term here.

Page 3, lines 4-10: This paragraph comprehends lots of information which should be provided in the Experimental section. You should provide the objective of this work and the structure of the article here.

Page 3, lines 6-7: Do you mean that your objective was to investigate spatial and temporal variations of the 3D distribution of PM concentrations? How can five days cover half a year? Temporal is a quite general term, and 5 days are not sufficient to achieve a correct and exhaustive characterization.

Page 3, lines 13-14: It is rather uncommon to find coordinates expressed in this order (i.e., E/W and S/N before numbers, and longitude before latitude.

Page 3, lines 15-16: Please quantify the term "some" and the kind of manufacture, this could be important for the characterization of particulate matter.

Page 3, lines 16-17: Please quantify what relative low density mean.

Page 3, lines 13-18: This paragraph could benefit from the addition of climatological information about the experimental site or at least for Lin'an, to better characterize it. Moreover, references for the information should also be provided.

Page 4, lines 1-7: It would be necessary to provide more technical details about the UAV (weight, maximum payload, …).

Page 4, line 6: It would be necessary to provide the speed in m/s, so that it could be really straightforward to understand how long the UAV stood in each layer. Please indicate here also the spatial interval between each vertical layer.

Page 4, line 6: Without knowing the time resolution of the measurements it is not possible to understand if 45 minutes are really enough. It would be better to cite the table where the time resolution of your measurements is provided here.

Page 4, line 14: Black carbon is not used in this work so it is quite confusing that you put it here. However, it would be interesting to know how black carbon is related to the other measurements. The authors should provide the sensor used by the aethalometer to provide pressure measurements.

Page 4, lines 11-16 and Table 1: From Table 1, it is apparent that the instruments onboard the UAV have different time resolutions. How did you make your data homogenous? Moreover, in case of such high time resolution, some sensors such as the aethalometer can be affected by noise problems. How did you make sure that noise did not affect your measurements? Finally, further problems may also arise due to vibrations, turbulence, electrical interferences: more technical details should be provided here.

Page 5, line 4: The correlation coefficient alone is not enough to take for granted the consistence between particle mass concentration instruments and TEOM mass measurements: the intercept should be also provided here.

Page 5, lines 7-8: "assigned" is not the correct term here.

Page 5, line 8: The information for the duration of the flight is different from the one reported on Page 4, line 7. Please be consistent.

Page 6, line 5: It is not clear what "checked to zero" means in this context. Please provide a better explanation.

Page 6, lines 6-8: This information should be provided before when describing the instruments onboard the UAV.

Page 6, lines 9-11: Explain a little bit the characteristics of the meteorological station (e.g., location, altitude, …)

Page 6, lines 11-14: You should retrieve and discuss the planetary boundary layer height, a parameter which could be very important for your investigations. More importantly, how can you relate measurements taken onboard the UAV with a 1-2 s time resolution taken at different hours of the day with sounding measurements taken every day at the same hour?

Page 6, lines 21 and 22: "self-monitoring" is not the correct term here.

Page 7, lines 1-2: As far as I understood, the TSI SIDEPACK AEROSOL is not an OPC as you report here, but it is rather an impactor, so it is not based on the light scattering principle.

Page 7, lines 7-8: It would be more convenient to use a coarser time resolution due to problems of noise for some instruments, and equal for all instruments onboard.

Page 7, lines 11-13, and Page 8, Figure 3: In the Experimental section (Page 7, lines 7-8), it seemed that an average for each height layer was retrieved losing the latitude-longitude variation, which is not the case as discussed in the sentences and as shown in the Figure 3. Please explain better that the average vertical variability was also retrieved, but also 10 s averages were separately analysed in order to examine the latitude-longitude-height (therefore 3D as reported from the Title) distribution. After that, since the vertical variation is more pronounced than the horizontal variability, it is correct to average each vertical layer to better examine the vertical $PM_{2.5}$ profiles.

Page 9, lines 7-20: These results could be discussed much better if you retrieved also the PBL height as I previously suggested. The English language should be greatly improved here.

Page 9, line 8: Probably you mean that the low PBL height limits the vertical distribution of $PM_{2.5}$, but this sentence is not so clear.

Page 9, lines 13-14: A range such that you report cannot be preceded by about.

Page 9, line 17-20: Please check the number of significant digits.

Page 9, lines 16-20: Rephrase, these sentences are not clear enough.

Page 10, Table 3: Check the units for the vertical gradient.

Page 10, Figure 5: You should briefly remind here that wind speed and direction measurements were taken

Page 11, lines 4-17, page 12, lines 1-2 and 6-13, page 13, lines 4-10: These sentences need substantial rewording. How can you relate sounding measurements take once a day with your vertical measurements averaged to 10 s?

Page 11, line 17: Check number of significant digits.

Page 12, lines 12-13: Increasing wind speed with increasing altitude could have some basic explanations, which you could try to provide here.

Page 13, lines 12-16: These sentences need substantial rewording. It is not clear how the consistency between sounding and UAV data indicates the feasibility and utility of UAV measurements.

Page 15, lines 2-4: Pearson's correlation coefficient is probably not appropriate here, since strictly speaking Pearson's correlation can be applied only in the case of normal distributions, which probably is not the case here (however, if it is the case you can just briefly discuss that).

Page 16, line 2: The only positive correlation which is apparent from the table is the one of PM2.5 with dew point. The correlations with pressure and temperature are instead observed only in some situations, and are therefore probably not conclusive.

Page 16, lines 2-6: The correlation of PM2.5 with relative humidity can be explained by some physical mechanisms. Please try to explain.

Page 16, lines 8-22: Conclusions should be greatly revised both for the language as well as after the appropriate revisions concerning other sections have been undertaken.

Technical comments

Page 1, line 13: Delete "for". Change "in one" with "a".

Page 1, line 14: Delete "the".

Page 1, line 16: Change "during the data collection" with "along the flight".

Page 1, line 18: Change "bigger" with "larger".

Page 1, line 21: Change "in" with "on", delete "on".

Page 1, line 28: Change "of significance" to "significant".

Page 1, line 29: Change the second "on" to "at".

Page 2, line 1: Delete "The only". Change "were" to "are". Change "further research" to "a correct understanding".

Page 2, line 3: Change "model" to "models".

Page 2, line 5: Delete "the". Change "concentrations" with "profiles".

Page 2, line 8: Change "continual" with "continuous".

Page 2, line 9: Change "to monitoring" to "in terms".

Page 2, line 18: Change "efficiency" to "efficient".

Page 2, line 21: "responsible" is not the correct term here.

Page 2, line 30: Change "Is of good quantitative performance" with "has a good performance".

Page 3, line 4: Change "a" with "the".

Page 3, lines 6-7: Rephrase: "A total of 20 monitoring flights over half a year were carried out over the suburban area of Lin.an in YRD."

Page 3, lines 8-9: Rephrase: "The diurnal variation of PM2.5 as well as its accumulation and dissipation in the atmosphere were captured and are discussed in the present article."

Page 3, line 10: Delete the second "the".

Page 3, line 13: Change "were" to "was".

Page 3, line 13: Change "were" to "was".

Page 3, line 14: Add "distant" before "from".

Page 3, line 16: Change "near around" to "close".

Page 4, line 5: Change "its" to "a" and "lands" to "landed".

Page 4, line 6: Add a space before "300".

Page 4, line 6: Add "of about" before "120" and delete ~.

Page 5, line 5: Change "on a total" with "for".

Page 5, line 6: Delete "including 16 flights". Rephrase the second sentence: "Four flights …, for a total of 16 flights (Table 2)."

Page 6, line 2: Move "such as remaining battery and storage space" before "were".

Page 6, lines 2-3: Rephrase: "… and a visual inspection was conducted to determine the eventual compression of inlet tubing at curve."

Page 6, line 4: Delete "allowed to" and change the tense of "warm up".

Page 6, line 11: Rephrase: "…), maintained by the Meteorological Bureau of Lin'an."

Page 6, lines 11-16: Rephrase: "Sounding meteorological data (air temperature, dew point temperature, relative humidity, wind speed and wind direction) from the sounding station located in Hangzhou, China, located about 40 km away far away from the experimental site which operates soundings at 12:00 UTC every day were downloaded from the University of Wyoming (…)."

Page 6, line 22: Change "when the UAV was taking off" to "during take-off".

Page 8, Figure 3: The Figure has a bad resolution. Moreover, scale units for the legend should be provided.

Page 9, line 2: "fligh-3" should be "flight-3". Delete the second comma. Add "as" before "afternoon".

Page 9, line 3: Move "increasing" before "altitude".

Page 9, line 4: Change "depicts" to "correspond to". Unify the two sentences as: "…, 2013) consistently with results from tower observations (…)".

Page 9, line 7: Delete "in the".

Page 9, line 13: Change "more" to "higher".

Page 9, line 16: Change "Ding (Ding et al., 2005)" to "Ding et al. (2005)".

Page 13, line 4: Change "particle" to "particulate".

References

Brady J.M., Stokes M.D., Bonnardel J., Bertram T.H., 2016. Characterization of a quadrotor unmanned aircraft system for aerosol-particle-concentration measurements. Environmental Science and Technology 50, 1376-1383, doi:10.1021/acs.est.5b05320

Renard J.-B., Dulac F., Berthet G., Lurton T., Vignelles D., et al., 2016. LOAC: a small aerosol optical counter/sizer for ground-based and balloon measurements of the size distribution and nature of atmospheric particles – Part 2: First results from balloon and unmanned aerial vehicle flights. Atmospheric Measurement Techniques Discussion 8, 1261-1299.