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Atmospheric Measurement Techniques Discussions

Interactive comment on "A low-cost $PM_{2.5}$ monitor for wildland fire smoke" *by* Scott Kelleher et al.

Scott Kelleher et al.

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We thank the reviewer for their insightful comments, which have allowed us to produce a stronger manuscript. Our responses to the general and specific comments are given below. Please note that line number references pertain to the "tracked changes" version of the revised manuscript.

Reviewer 1 general comments: In general, the paper present new findings on use of lower cost technologies deployed during a fire event. The authors need to better present the results of the OAS sampler and expand on the discussion of the failed Sharp sensor as described in detailed comments below.

Response: Please find our responses to the comments and clarifications detailed below, and details of the corresponding changes in the revised manuscript.

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Discussion paper

Reviewer 1 specific comments

1. Comment: The authors need to expand on the characteristics known to impact sensor performance (e.g. type of wood burned, humidity, inversion vs. non inversion days, temperature, and wind direction) in the discussion and results section.

Response: We agree that factors such as particle size distribution and refractive index, as manifested through changes in ambient humidity, or the type of wood burned, and/or atmospheric aerosol processing, would affect sensor response. We also agree that ambient temperature and humidity could affect sensor performance (at high humidity the optics can become obscured due to condensation). While inversions and wind direction may influence ambient aerosol concentrations, we do not see how these factors would affect sensor performance, per se.

We have revised lines 285-295 of the manuscript to: "Factors that may affect sensor performance include but are not limited to changes in aerosol size and refractive index, ambient humidity, and ambient temperature. Biomass burning aerosols are known to span a range of particle sizes and refractive indices; these properties can also change over time due to aerosol processing in the atmosphere (Vakkari et al., 2014). Increases in humidity may lead to overestimation of (dry) aerosol mass concentration due to water uptake by hygroscopic particles. An ambient relative humidity of 60% is considered a lower threshold for water uptake to begin affecting nephelometer response (Chakrabarti et al., 2004); this level was exceeded for 38% of the sampling time during the Pargin fire. However, relative humidity rarely exceeded 70% during this period (7% of the time). Published growth factors for biomass burning aerosol are relatively low at 70% humidity (Rissler et al., 2006), indicating that water uptake from particle hygroscopicity (and, thus, sensor response) was probably not substantial during the Pargin fire. The effect of temperature on sensor response can be manifested by influencing particle size via gas-particle partitioning and by affecting the sensitivity/response of the photodiode and photodetectors inside the sensor itself. The latter effect is shown in Figure S4."

2. Comment: Specifically, the discussion on OAS results over 200 is confusing. Where were these located, how many out of the 61 sensors were affected by this issue, and further describe what you mean by extrapolating over 24-hours?

Response: We apologize for the confusion here. Some of our monitors did not sample for the full 24hrs because of premature power failure (i.e., the battery ran out of charge). Most of these power failures were due to overloading of the air sampling filter under extremely high PM levels. We wanted to include these high PM events in Figure 7, so we decided to extrapolate any measurements that lasted at least 10 hours up to a 24hr average. We recognize that extrapolating a 10hr measurement to a 24hr average is very conservative (this assumption essentially combines a 10hr measurement with an additional 14hrs of zero values). However, most of these averages are still above 200 μg/m3 – which means the OAS was measuring an extremely high PM concentration!

Lines 261-271 of the revised manuscript have been updated to: "Approximately half of these failures (Fig. S6, n=7) were due to premature power failure, defined as depletion of the battery before the conclusion of a 24-hr sampling period. Analysis of filter pressure drop data (collected on board each OAS) and filter mass accumulation revealed that these failures occurred in sampling locations where PM2.5 concentrations were extremely high, often exceeding a 24-hr average level of 200 μg/m3. Power consumed by the OAS is strongly dependent on filter loading, which is a function of the sampled aerosol mass concentration. High filter loadings create greater than normal pressure drops across the OAS filter, forcing the pumps to work harder (and thus consuming more battery power) to maintain a flow rate of 2 L/min. In these situations, if the OAS sampled for at least 10hrs, the measured mass concentrations were extrapolated out to a 24-hr average for reporting purposes (i.e., a 10hr mass concentration was multiplied by 10/24 to extrapolate the measurement to a 24hr average). This method of extrapolation is highly conservative but serves to maintain a standard metric for comparison across all sampling locations and days; further, in all cases the extrapolated PM2.5 concentrations still exceeded 100 μg/m3 - indicating the presence of extremely

high PM levels."

We recognize the value of identifying the locations of OAS failures on each sampling day. Therefore, we have revised Figure S6 to show monitor failures modes (and completed measurements) as a function of sampler location (as defined in Figure 3). We have also added these data (including run-times) to our supplementary data file.

3. Comment: Figure 8 clearly shows an outlier near 1000 (which needs discussion) and other values above 200.

Response: The extremely high concentration on Sept 10th captured by one of OAS is due to black lining operations taking place upslope and in the vicinity of the sampler. Lines 308-312 have been revised: "On 9/10/2017, a sampler recorded a 24-hr average PM2.5 concentration of 915 μg/m3 – the highest reported value during the study. This measurement occurred during black-lining operations along the perimeter of the Pargin burn area and pertains to location 8 on Figure 3, which is the point nearest to the fire boundary. Measured PM2.5 concentrations at this location were consistently high due to its close proximity to fire operations and also to meteorological conditions that favoured transport of emissions downwind and downslope."

4. Comment: Figure 8 shows the reference value reading near the high point of âĹij500 on the 17th. Can you create a similar figure that identifies each monitor? Was the highest recorded value during the inversion the monitor closest to the reference?

Response: Shown in Figure 7 and S3 are individual sampler locations and measured concentration data for each sampling day. A few data points shown in Figures 7 and S3 have been extrapolated due to premature power failure (see response to comment 2 above) – these results are not reported in Figure 8, where only data for samplers that completed at least 75% of sampling period are compared with data from the reference monitors.

In regard to the last question, (Was the highest recorded value during the inversion

the monitor closest to the reference?) the answer is 'no'. The E-sampler reference instrument was positioned at location 9 (see Figure 3). Referring to Figure S3.B, the OAS at location 9 recorded a 24 hour concentration of 287 μg/m3 on 17 September 2016. The OAS adjacent to this monitor at location 8 recorded the highest value on that day.

5. Comment: Besides collocation of OAS monitors at sites 1 & 9, describe the evaluation of precision & accuracy amongst the sensors before, during, and after the study.

Response: We did conduct additional evaluation of OAS units following the Pargin fire deployment. These tests were conducted to verify that the OAS units were performing as expected. We now describe these tests in the Methods/Results sections:

Added to Methods (lines 174-184):

"Following the Pargin fire deployment, we verified the accuracy and precision of the OAS with respect to time-integrated PM2.5 measurements. In the laboratory, ten OAS units were arrayed with three PM2.5 impactor samplers (PEM PM2.5 2 L/min, SKC Inc) in a 0.75m3 aerosol chamber to verify OAS accuracy and precision relative to a commercially-available PM2.5 sampler operating at similar flow rate. Sodium chloride was used as the test aerosol following the protocol described in Volckens et al. (2017). Additionally, we evaluated OAS precision through a series of outdoor deployments whereby two OAS devices were co-located outdoors to sample ambient air concentrations for 48hr in Fort Collins, CO (n=23 paired deployments). From these tests, instrument precision was estimated from the coefficient of variation among co-located instruments and also as a mean absolute difference in measured concentration (μg/m3) between paired instruments; OAS accuracy was estimated by calculating the average percent difference in measured concentration between the OAS and PEM samplers."

Added to Results and Discussion (lines 348-355):

"For the post-fire validation experiments, the OAS and PEM samplers reported good

agreement for sodium chloride aerosol measured in chamber tests (532+/-32 vs. 522+/-46 μg/m3, respectively); the average mass concentrations reported between instruments differed by only 2%. These results confirmed previous data reported by Volckens et al. (2017) that co-located the UPAS (the predecessor to the OAS) in a chamber with both PEM and FEM samplers. The coefficients of variation among co-located instruments were also similar: 8.9% for the PEMs and 7.9% for the OAS. For the outdoor deployments, the coefficient of variation among co-located OAS was 13%, which translated to an average difference in measured concentration of 1.4 μg/m3 at typical ambient PM2.5 concentrations ($\sim$8 μg/m3) in Fort Collins, CO. A tabular summary of these performance tests is provided in the online supplement."

6. Comment: Starting at line 279 - there is only brief discussion on temperature and drift, describe other met conditions affecting the Sharp sensor.

Response: Please see our response to Reviewer #2, Comment 8, where we further describe the types of drift observed when using the Sharp sensor outdoors. A discussion of these phenomena (and an accompanying figure) has been added to the online supplement provided with the manuscript.

The performance of the Sharp sensor regarding its sensitivity to limit of detection, dependence on compositions, sensitivity to particle size, relative humidity influence, and temperature influence have been previously reported by Wang et al.:

Wang, Y., et al., Laboratory Evaluation and Calibration of Three Low-Cost Particle Sensors for Particulate Matter Measurement. Aerosol Science and Technology, 2015. 49(11): p. 1063-1077.

7. Comment: Future work could involve mobile monitoring with reference instruments to co-locate sensors in the highest concentration environments. Also discuss whether a different low cost, real-time sensor with greater concentration ranges or known size ranges should be used.

Response: We agree that selection of an improved real-time aerosol sensor with improved performance should be the result of future work.

We note on lines 379-380:

“Low cost PM2.5 optical sensing technology is an active area of research and development; future iterations of the OAS technology should seek to improve this capability.”

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2017-358/amt-2017-358-AC1-supplement.pdf

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