Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2020-136-AC2, 2020

Atmospheric Measurement Techniques Discussions

Interactive comment on "Combining low-cost, surface-based aerosol monitors with size-resolved satellite data for air quality applications" *by* Priyanka deSouza et al.

Priyanka deSouza et al.

desouzap@mit.edu

Received and published: 30 July 2020

Response to Reviews

We are grateful for the constructive reviews we received for our paper. We have modified the manuscript to address the reviewers' comments, and herein resubmit the updated paper and detailed responses to the reviewers. "

Reviewer

This work deals with the combination of low-cost sensors combined with satellite data to obtain PM2.5 near surface. The novelty of this technique has no doubt and the impli-

cations in the aerosol science community are huge. Authors include the shortcomings and other issues related to the technique. Methodology is well described too.

Thank you

However, I have concerns before recommending the final publications. As the other referee suggests and even the authors admit, the technique needs evaluation versus other instrumentation that provide accurate PM2.5 measurements.

Authors must provide at least an intercomparisons of low-cost sensors with reference instrumentation and provide a plan for future evaluations of the methodology in places with more advanced instrumentation.

Thank you for this comment. We cite in the paper previous inter-comparisons of the OPC-N2 we used with reference equipment elsewhere. Specifically, we note:

"Sousan et al. (2016) discuss the accuracy of these [OPC] count measurements in detail and note that they agree well with reference instrument measurements for coarser particles (> 0.78 μm in diameter), but underestimate the particle counts for finer particles."

As Nairobi did not have a reference monitor at the time of the OPC deployment, it is impossible for us to do such an inter-comparison within the current study.

Specifically, we say:

"Co-locating the OPC with a reference monitor to obtain high-quality PM data would be required to calibrate the raw OPC measurements and distinguish the signal from noise directly. However, this would be costly and possibly time-consuming (Castell et al., 2017; Rai et al., 2017). Due to limited resources, and lack of access to a reference monitor, we were unable to co-locate our low-cost sensors with a reference monitor in Nairobi at the time of the experiment. As such, we rely primarily upon the more robust raw particle counts per size bin reported by the monitors, rather than the reported PM2.5."

We agree that this is a limitation, and we make this clear in the paper. As also stated in the paper, we need to repeat this experiment under more ideal conditions; we enumerate the key improvements required in the Discussion section of our paper.

I have also other concerns: With the hypothesis related to MISR retrievals and aerosol vertical distribution, why not doing intercomparisons directly with MERRA-2 data? What are the peculiarities of Alphasense OPC versus other low-cost sensors?

The MISR data have been extensively validated, and the Research Algorithm results for particle properties, in particular, are among the best available. Comparing the MISR results directly with MERRA-2 in a meaningful way for the current application would require assuming the mass-extinction efficiency (MEE) of the particles, which is uncertain to factors of three or more.

It is difficult to follow the methodology section. At least a Flow chart is needed.

Thank you. We have included the flow-chart below at the beginning of the Methods section. Also included as a supplemental figure in this reply

Also, I get confused in the intercomparisons because you make mention to number concentration in MISR and mass concentration with the sensors. That must be clarified. The results section is not clear. Much information from the supplement must be included in the paper as supplement seems an independent paper.

The optical measurements from MISR allow us to derive column AODs and particle size distributions. Given the vertical aerosol distribution constraints from reanalysis, we can deduce particle number concentrations.

The PM2.5 criteria pollutant is technically the mass of near-surface particles with diameter <2.5 μm. The OPC-N2 also makes optical measurements. The proprietary software from the company assumes particle density, in order to convert the number concentration of aerosols each size bin to a mass concentration. Thus, we assume particle density as well, to compare the MISR result with the OPCs.

Regarding the Supplement, based on other reviewer comments, we make a clear distinction between the presentation of the Method, appropriate for the AMT journal and given in the main paper, and the Nairobi experiment, which represents a loose demonstration of the method, but not a validation. Given the limitations of the Nairobi data for validating the method formally, we include that analysis in the Supplement. This keeps the work available to interested readers, but avoids leaving any impression that the Nairobi experiment in itself should be considered an adequate test of the method.

Minor concerns: Line 46: Latest development in technology has reduced the cost of accurate instrumentation. Please, be careful

Thank you. We have changed this sentence to read:

“This is because air quality monitoring equipment tends to be costly to purchase (capital costs are in the range of several thousand of US dollars) and maintenance, and data processing and analysis requires additional expertise and resources (deSouza, 2017; Kumar et al., 2015; Mead et al., 2013).“

Line 73: Be aware that new satellites are improving the spatial resolution

Thank you for this note

Line 110: Please, add references.

Thank you. We have included a reference

Line 212: What uncertainties are you referring to?

The uncertainties in MISR-retrieved aerosol particle properties are assessed based on the range of particle size, SSA, and fraction non-spherical values among the aerosol mixtures from the algorithm climatology that pass the acceptance criteria (Kahn and Gaitley, 2015). There is additional uncertainty due to any limitations in the range of particle types in the assumed climatology, though the MISR Research Algorithm has an especially rich climatology (Limbacher and Kahn, 2014).

We have added this information to line 212.

Please check Lines 244-245: Why do you need gases from GEOS-Chem? Please avoid unnecessary information because paper is already too long.

Thank you we have deleted this information

Lines 353-354: AOD is by definition over the vertical, so your definition is not correct. Are you referring to aerosol optical thickness? Please correct.

We have modified the text in the paper to read:

By definition, AOD558 is proportional to [the number concentration of aerosols] x [the extinction area of each particle at 558 nm wavelength] x [the path over which AOD is assessed (which for MISR is the entire column. Here, we scale the AOD to provide the near-surface component residing in the lowest layer of the GEOS-Chem model, which is 130 meters vertically)].

Lines 442-448: Here is what I do not understand about particle density. Why do you need that?

Particle density is required to relate the particle volume, which is constrained optically from MISR, with particle mass, which is measured by the OPCs. (See our previous answer to this question)

Results: I do not understand what do you mean about Analysis 1, 2, 3, 4 y 5 Tables 1 and Tables 2 need further explanations.

Table 1 provides the successful co-incident MISR retrievals corresponding to each surface site for the duration of the experiment. MISR retrievals where the total AOD >=0.15 (indicating a favorable retrieval where MISR is able to distinguish between 3-5 bins in column-effective particle size) are highlighted.

In the text we add:

“Table 1 shows the near-surface AOD for the Nairobi data obtained from the vertically scaled MISR Research Algorithm results for aerosol components 1,3,6,19 and 21, as well as that for the aerosol group comprised of components 2,8 and 14, using the standard universe of 74 mixtures. Near-surface values were obtained by scaling total-column AOD based on GEOS-Chem simulated aerosol vertical distributions. The 10 highlighted rows correspond to observations that have a MISR total AOD (sum of the AOD of the eight MISR aerosol components) > 0.15. The corresponding surface PM2.5 from the ground-based OPC for the 10 favorable MISR retrievals is also presented."

And then later:
"We have performed multiple analyses making different assumptions, to explore the range of impacts these choices have on the results. The different analyses are summarized here:

- Analysis 1: We only consider observations from MISR, for all MISR aerosol components except for component 21
- Analysis 2: We only consider observations from MISR, for all components except for components 1 and 21
- Analysis 3: We consider the scaled MAIAC AODs for all MISR components except 21
- Analysis 4: We considered scaled MAIAC AODs for all components except 1 and 21
- Analysis 5: We considered scaled MAIAC AODs where the total MAIAC AOD >= 0.15, for all components except 1 and 21”

  In order to make this clearer, we have reorganized the section 4.1 to read as follows:

“**4.1.1 Only MISR retrievals considered (Analyses 1 and 2)**

For all regression analyses we excluded MISR component 21 as the AOD retrieved for this component is 0.

In Regression Analysis 1, we included the remaining MISR components. Not all of the coefficients in the regression are significant, and some are negative. Each coefficient in the regression represents the total number concentration of the respective aerosol group, which physically cannot be negative. However, it is possible for a statistical weight to be negative, as the regression approach aims to formally match the retrieved values with available observations, and there can be aerosol components and mixtures missing from the MISR algorithm climatology (Kahn et al., 2010). As such, leveraging from the better-fitting components can skew the coefficients for other particles negative. Provided the negative weights are small compared to the dominant retrieved components, the negative values represent noise in the results. This can apply to components 1 and 8 that are often retrieved in relatively small quantities, as well as to component 19, a dust optical analog, that very likely does not match actual dust in the region. Moreover, MISR component 1, with re=0.06 μm, is well below the OPC lowest size sensitivity limit.

Regression Analysis 2 was thus run without component 1 and 19.

The results of regression Analyses 1 and 2 are given in Table 2. Figure 2 shows the particle size distributions (dN/dlnD) from the air quality monitors obtained for all relevant ground-based observations, superimposed on the size distributions derived from the regression analysis results of Analysis 2. The derived size distributions from each instrument are quite well matched in nearly all cases, despite the assumptions involved. The Nairobi aerosol has a size distribution that is sampled by MISR. The large-end tail is sampled by the OPCs, and our method uses the region of size-overlap to perform the particle-size scaling, The results in Figure 2 indicate that the two instruments are in fact sampling parts of the same particle size distribution. For Analysis 2, the adjusted R squared is 0.82.

4.1.2 Using scaled-MAIAC retrievals (Analyses 3, 4, and 5)

To increase satellite sampling, we repeated the regression analysis by scaling MAIAC AODs using the monthly effective MISR aerosol component AOD fractions (Steps 2e and 2f). We have 1712 MAIAC AOD retrievals that fall within a radial distance of 1.6 km of a ground-station. However, there are only 10 favorable MISR particle property retrievals, on three unique days. Using the MISR component AOD values to parse the MAIAC total-AOD, even on a monthly basis, leaves 304 MAIAC retrievals on 20 unique days (Figure S6 in Supplementary Information). Yet this provides about 30 times as much data as the MISR data alone.

Like Analysis 1, Analysis 3 includes all MISR aerosol components, but was run using the scaled MAIAC dataset. We also ran Analyses 4 and 5 with the MAIAC data, this time excluding MISR components 1 and 19. For Analysis 5, we further restricted the MAIAC retrievals to those with the total AOD $\geq$ 0.15 (85 MAIAC AODs), to ensure that near-surface aerosols dominate in this analysis. The adjusted R squared for Analysis 5 is 0.76. When we used MAIAC AODs at a radial distance of 1 km and 0.5 km from each site (instead of 1.6 km), repeating Analysis 5, yielded adjusted R squared values of 0.77 in both cases. This suggests that our results are robust to the radius considered.

The results for the five analyses are given in Table 2. All the coefficients for the remaining aerosol groups included in Analyses 2, 4 and 5 are positive and statistically significant (p-value almost equal to, or less than 0.05)”

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2020-136, 2020.

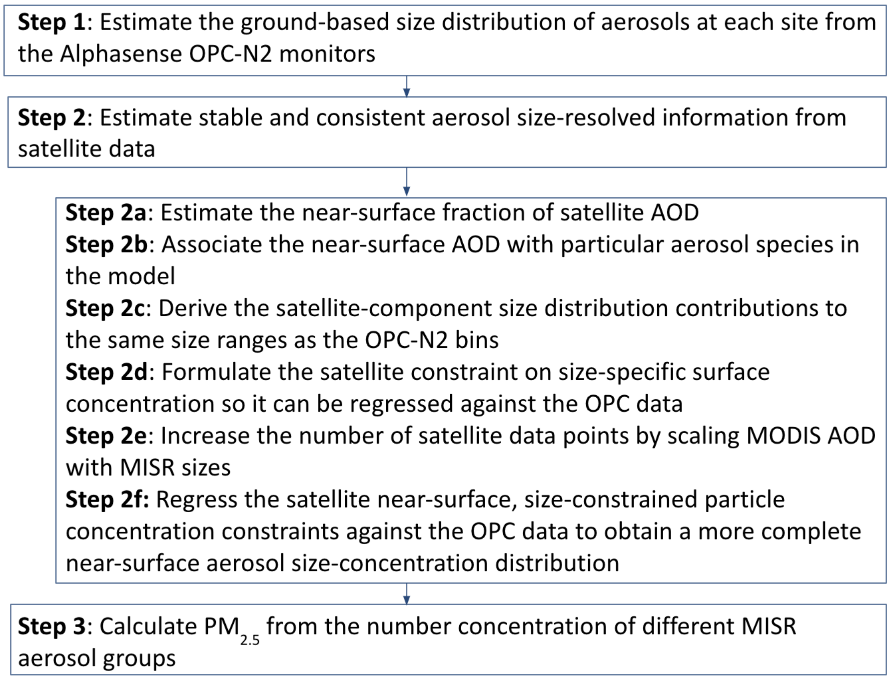

Fig. 1. Flowchart