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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A critical assessment of high resolution aerosol optical depth (AOD) retrievals for fine particulate matter (PM) predictions" *by* A. Chudnovsky et al.

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Authors: We would like to express our gratitude to the Anonymous Referee #2 for the focused and very constructive comments. Based on this input, the paper has been changed and improved. Here is a list of the referee's comments followed by our response.

Reviewer 2: A more complete literature review about AOD-PM estimation is needed; I would suggest a similar table like Hoff and Christopher (2009), containing the recent (after2007) progress about PM2.5 prediction; As to AOD retrieval, at least two more

papers about MODIS Collection 6.0 should be included, "Remer et al., 2013" and "Levy et al.,2013".

Authors: Agreed and implemented. We chose not to provide a new Table (Hoff and Christopher 2009) because the scope and goals of our papers are entirely different. However, we expanded the introduction considerably, and included many post-Hoff&Christopher references as well as the suggested MOD04 C6 references. One additional important reference (Munchak et al., 2013) to validation of the MOD04 3km product in urban environment was also added.

Reviewer 2: Page14587, Line 13, "These regions differ in topography and climate condition" need to be clarified. The effects of all these different situations to AOD retrieval, especially to the conversion from AOD to PM2.5 should be explained. The authors gave very simple explanation when some abnormal cases occurred, but this is not enough in such a comprehensive analysis paper.

Authors: Agreed. This paragraph has been re-written as follows (section 2.3):

"Although there are some variations among the three regions in topography and climate conditions, mostly via the usual north-south snow cover gradient in winter, the main difference appears at the level of urbanization and land use affecting surface brightness and thus the quality of the aerosol product. For instance, a validation analysis of the MODIS 3km product (Munchak et al., 2013, Fig. 9) showed a strong correlation between percent of retrievals with error above expected and percent of the urban land cover. A similar investigation is ongoing for MAIAC. Of the three regions, region 1 is the least urbanized with a high fraction of forest cover and region 2 is the most urbanized. Thus, by dividing the study area into regions we can evaluate the role of environmental conditions (e.g. snow coverage) and different land use settings on the AOD-PM2.5 relationship in the two algorithms."

Reviewer 2: For figure 2, if I understand right, the authors directly compared the single satellite pixel with 24-hour average PM2.5 concentration without considering the scale

problem. With the same wind speed, it takes different time for aerosol/PM to cross a pixel with different spatial resolution. How to overcome this problem?

Authors: Reviewer raises a very challenging point for future research. In fact, there are three issues we need to be aware about: 1) 24h hour PM-averages were used in AOD-PM2.5 correlations; 2) differences in scale/resolutions, 3) different time for aerosol/PM to cross a pixel with different spatial resolution.

Regarding the first issue, the PM2.5 National Air Quality Standard is based on 24 hours and majority of the EPA sites collect 24 hour samples rather than conduct continuous measurements. Also most of mortality and morbidity epidemiological studies use 24 hour exposures for estimating effects. Considering that a primary objective of our work is to provide estimates of human exposures to PM2.5, it is appropriate to evaluate the 24 hour average PM2.5 concentrations.

The second issue becomes particularly important in urban areas with close spacing of EPA monitors when the satellite AOD product footprint should at least resolve individual EPA sites. In our data set this is a case for Boston (4 EPA sites and the Harvard Supersite within a 10km area), New Haven (3-4 sites) and three other sites (2 sites correspond to a single 10km AOD footprint).

Finally, to estimate hourly concentrations of PM2.5with different spatial resolutions, different times for aerosol/PM crossing a given pixel might be critical. Kumar et al., 2008 showed that PM correlates positively with the 5 km AOD; a 1% change in the AOD explains 0.52% $\pm$ 0.20% and 0.39% $\pm$0.15% changes in PM2.5 within 45 and 150 min intervals (of AOD data) respectively. At a coarser spatial resolution the relationship between AOD and PM becomes weaker. On the other hand, this relationship becomes significantly stronger when monthly estimates are analyzed over a span of several years (2000 to 2005 in study of Kumar), especially for the winter months, which have relatively stable meteorological conditions. Since our main interest was in the 24 hour average values of PM, the differences in time that aerosol/PM crosses a pixel becomes

less critical. However, we recognize it as an important concern which requires further study.

Kumar N, Chu A, Foster A. Remote Sensing of Ambient Particles in Delhi and Its Environs: Estimation and Validation. Int. J. Rem. Sens. 2008; 29:3383–3405

Reviewer 2: Page 14588, Line 11, “but with room for improvement”, what does this sentence mean? Room for the improvement of AOD retrieval or PM prediction from AOD?

Authors: Corresponding sentence was modified to avoid ambiguities. In general, we improved the text throughout the paper making language more precise. Also, a brief discussion of algorithm retrieval errors was added in section "Concluding Remarks".

Reviewer 2: Page 14588, Line 24, why negative slope occurs in region 2(even the EPA sites location is near the road or lack of auxiliary information)? So that means the bias/intercept should be very large with a negative slope and this makes no sense for the regression.

Authors: This is a good observation. Yes, we can have negative slope for certain days mostly due to lack of auxiliary information. A good example is the pollution transport which occurred during 20-24th of June 2003. A forest fire in the Quebec province, Canada, brought smoke pollution into Massachusetts, NE. While the optical depth represents an entire vertical column, particle concentration is measured at the ground level. Thus, substantial contribution to AOD aloft may reduce the correlation with ground-level PM2.5 or make it negative. In the physical sense, this means that the main sources of AOD and PM are different, and such days should be excluded from the regression analysis. As we mention in the paper, this issue may be partly mitigated by the use of the chemical transport models in the analysis of the AOD-PM relationship.

Reviewer 2: Page 14589, Line 4, “The improvement can be related to the finer resolution of MAIAC”, this sentence should be clarified because the converting from AOD

toPM2.5 is affected by many other factors as described by the authors and these factors may/may not also be affected by the scale/resolution. The authors should avoid the effects of other factors before coming to the conclusion.

Authors: Agreed. The sentence was modified accordingly.

Reviewer 2: Page 14589, Line5, “and better performance over brighter urban areas”, any references or may be the author should provide some validation figures of MAIAC AOD for bright surface compared with MODIS product.

Authors: The validation results for MAIAC AOD were investigated in Lyapustin et al., 2011b for different AERONET sites for both dark and brighter urban surfaces in continental USA in comparison to MOD04 product. Also, see our reply to Reviewer 1 (Materials and Methods).

Lyapustin, A., Wang, Y., Laszlo, I., Kahn, R., Korkin, S., Remer, L.,Levy, R., and Reid, J. S.: Multi-Angle Implementation of Atmospheric Correction (MAIAC): Part 2. Aerosol Algorithm, J. Geophys. Res., 116, D03211, doi:10.1029/2010JD014986, 2011b.

Reviewer 2: Page 14592, Line 1. I got confused for Table 3 and Figure 9(b), both of them discussed about the situation when no match-ups between MYD04 and PM2.5, in Table3, most correlation are less than 0.4, why the correlation in Figure 9 (b) is 0.51? Do Table 3 and Figure 9 (b) use different dataset?

Authors: The same dataset was used to produce both Table 3 and Figure 9 (b). The only difference is that Figure 9 (b) includes all points (e.g. all seasons and all locations), while Table 3 makes differentiation based on season and region. We include this comment in our revised version, section 3.3.

Reviewer 2: Page 14592, Line 17. I would suggest the authors presenting one more figure about the relationship between AOD/PM2.5 after using the thresholds to avoid the noise.

Authors: The revised version includes discussion of uncertainties of the AOD retrieval

and PM2.5 measurements. In general, the proposed threshold filter excludes a rather insignificant number of MAIAC AOD retrievals. Below we present a Figure showing the raw AOD-PM2.5 correlation for the year 2003 and the same data screened for possible outliers. We used the following threshold criteria: 1) AOD greater than 1.7 were discarded; 2) pairs with low PM2.5 concentrations but high AOD values (e.g. PM2.5 concentration lower than 5 μg/m3 and AOD higher than 0.4); 3) pairs with high PM2.5 concentrations but low AOD values (e.g. PM2.5 concentration higher than 25 μg/m3 and AOD lower than 0.1)This figure, however, is not included in the final manuscript which we feel is already somewhat overloaded with graphic materials.

Specific points and suggestions:

(1)Page 14583, Line 15, Hoff and Christopher (2009) reviewed more than 30 papers, not all are about PM2.5, some of them are about PM10.

Authors: Agree. In our Introduction, we correct it to read as follows:

Hoff and Christopher (2009) reviewed more than 30 papers that investigated the relationships between total-column AOD and surface PM2.5/PM10 measurements.

Reviewer 2: Page 14583, Line 19, “et.al. 2010” should be “et al., 2010”

Authors: Done

Reviewer 2: Page 14583, Line 20, “et. al., 2007” should be “et al., 2007”

Authors: Done

Reviewer 2: Page 14590, Line 20, this sentence makes no sense because cloud screening of MODIS AOD are different from MYD35 cloud product.

Authors: The MOD04 product uses a part of the MODIS operational cloud mask MOD35 (specifically, the first three bits or tests). Then, it also uses an internal data selection/screening procedure. Since there are several components used to assure aerosol data quality, and cloud mask is only a part of it, we expanded the discussion

as follows:

"The increase in the number of MAIAC AOD retrievals can be linked to differences in both the cloud mask and the conservativeness of data filtering to assure aerosol data quality in MOD04 and MAIAC algorithms, as well as to the extended range of brighter surfaces in MAIAC aerosol retrievals. For example, a recent comparison (Hilker et al., 2012) between the MAIAC and the MODIS operational cloud mask (MOD35), part of which is used in the MOD04 algorithm, showed that over the tropical Amazon basin with very high average cloudiness (75–99%), MAIAC provides on average between 20-80% more cloud-free data."

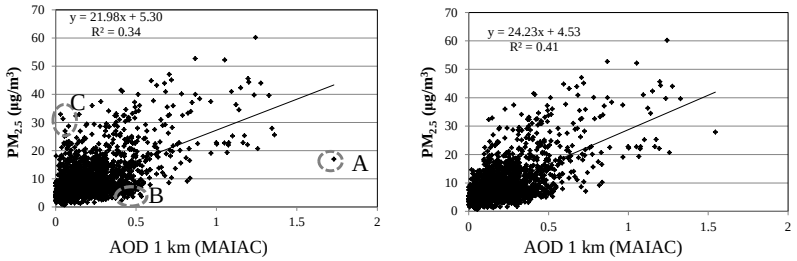
Reviewer 2: Page 14598, Line 20/24, should be arranged in alphabetical order.

Authors: Done.

Reviewer 2: Some similar sentences repeated several times, please try to avoid the redundancies

Authors: Done. The entire manuscript went through a comprehensive editing process and redundancies were removed.

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 14581, 2013.



Left: AOD vs $PM_{2.5}$ relationship. A, B and C correspond to the threshold criteria applied to filter possible noise and to improve the correlation. Specifically: 1) AOD greater than 1.7 (designated by A); 2) $PM_{2.5}$ concentrations lower than 5 µg/m^3 and AOD higher than 0.4 (designated by B); 3) $PM_{2.5}$ concentrations higher than 25 µg/m^3 and AOD lower than 0.1 (designated by C).
Right: Improved correlation after thresholds 1-3 were applied.

Fig. 1.