

Thanks for all the helpful comments from the reviewers. We have revised our manuscript addressing each of the suggestions. Detailed responses are listed below after each comment.

Atmospheric Measurement Techniques Title: Retrieval of aerosol optical depth over land surfaces from AVHRR data Authors: L. Mei, Y. Xue, A. A. Kokhanovsky, W. von Hoyningen-Huene, G. de Leeuw, and J. P. Burrows  
General Comments: This paper describes an initial effort to construct an aerosol retrieval algorithm using Advanced Very High Resolution Radiometer (AVHRR) data over land. The approach is essentially the MODIS “dark target” algorithm using an estimated surface reflectance at 0.64  $\mu\text{m}$  based on regressions from the 3.75  $\mu\text{m}$  (AVHRR) band, the 2.1  $\mu\text{m}$  (MODIS) band, and the 0.64  $\mu\text{m}$  (AVHRR) band. After including a Rayleigh correction, a retrieval is performed using a look up table (LUT) adopted from the Bremen AErosol Retrieval (BAER) algorithm developed for MERIS. This approach is tested for a limited set of cases over northeastern China, including the Beijing, Xinlong, and Xianghe Aerosol Robotic Network (AERONET) sites.

In my opinion, publication of this paper is premature. Important parts of the algorithm are poorly explained, and there is extremely little validation presented here. As the authors themselves state, “due to the limited number of reference points available for this study area, we cannot properly evaluate the retrieval algorithm over this region.” The primary innovation of using the AVHRR 3.75  $\mu\text{m}$  band with empirical relationships derived from MODIS itself has issues, only some of which are addressed by the authors. Without including more extensive validation and testing, I cannot recommend this paper for publication in Atmospheric Measurement Techniques.

Response: In the revised version, we include 142 validation points and follow the latest MODIS validation map (Fig 11 in Levy et al 2013), which shows that 71.8% points located in the  $\pm(0.1+15\%)$  tolerance line showed as follows.

Levy, R. C., Mattoo, S., Munchak, L. A., Remer, L. A., Sayer, A. M., Patadia, F., and Hsu, N. C.: The Collection 6 MODIS aerosol products over land and ocean, Atmos. Meas. Tech., 6, 2989-3034, doi:10.5194/amt-6-2989-2013, 2013.

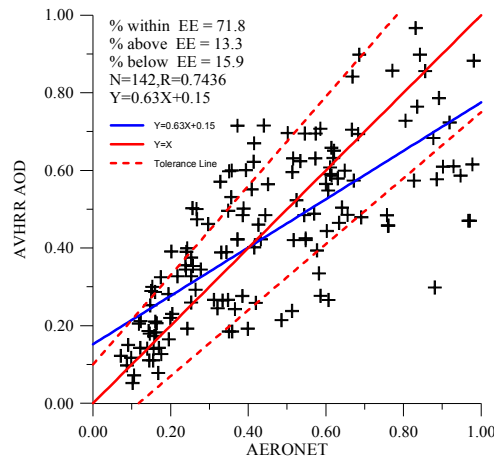


Fig 1 Scatterplots between the satellite-retrieved AOD and AERONET data with tolerance line of  $\pm(0.1+15\%)$ .

### Specific Comments

Below I have provided specific overall comments that may be helpful to the authors. Page and line numbers have been included where appropriate.

Page 2228, Line 3: The “consistency” of the AVHRR data record is somewhat limited by calibration drift, which the authors note later in the paper, as well as intercalibration issues.

Response: Calibration is a problem for AVHRR aerosol retrieval, especially for a long-term study. One researcher in our group has developed a cross-calibration method using SeaWiFS data for AVHRR data calibration, which has been submitted to Remote Sensing of Environment. We are going to use re-calibrated AVHRR data in our future study. In this paper, we only focus on the aerosol retrieval algorithm development for selected regions.

Page 2228, Line 18: The correlation coefficient does not in itself provide enough evidence for adequate performance. Note that the  $R^2$  value is 0.61, which suggests that a linear relationship between the two metrics explains 61% of the variability of the test variable. The other 39% is unexplained by this relationship.

Response: We improved the single statistic scattering map with only one correlation coefficient to a time series of three main statistic parameters; they are correlation coefficient, slope and intercept between estimated surface reflectance and MODIS reflectance product shown in Fig. 2. The correlation coefficient is  $85\% \pm 10\%$ , the slope is  $1 \pm 20\%$  and the intercept is  $0 \pm 0.15$ , which shows good correlation.

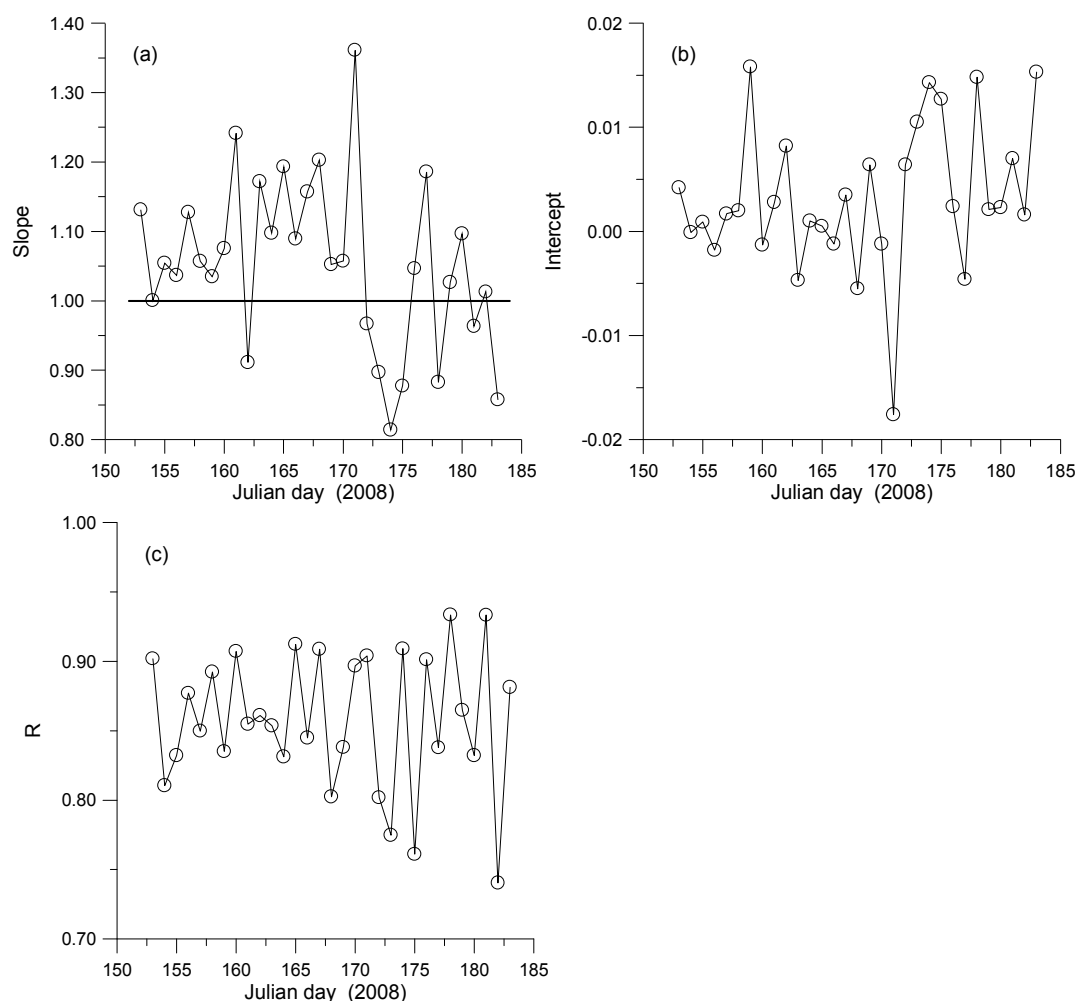


Fig. 2: Statistic parameters between estimated MODIS 0.66 $\mu$ m surface reflectance and MODIS 0.66 $\mu$ m surface reflectance product for June 2008 over East China: (a) Slope; (b) Intercept ;( c) Correlation (R)

Page 2228, Lines 23–24: Again, the correlation coefficient is insufficient. The authors do not describe the relative magnitude of the RMSE. Is 0.17 acceptable or not for an aerosol retrieval over land?

Response: We have revised the validation figures following the method presented in the latest paper from MODIS Team: regression equation, RMSE, error tolerance line and 1:1 line in the new version. According to the recent publication from the Aerosol-CCI project, RMSE for all Aerosol-CCI products from different algorithm for MERIS, AATSR are around 0.2 (see Fig. A5) in Holzer-Popp et al. (2013). The best algorithm chosen by Aerosol-CCI is SU-algorithm and the RMSE=0.121.

Holzer-Popp, T., de Leeuw, G., Griesfeller, J., Martynenko, D., Klüser, L., Bevan, S., Davies, W., Ducos, F., Deuzé, J. L., Grainger, R. G., Heckel, A., von Hoyningen-Hüne, W., Kolmonen, P., Litvinov, P., North, P., Poulsen, C. A., Ramon, D., Siddans, R., Sogacheva, L., Tanre, D., Thomas, G. E., Vountas, M., Descloitres, J., Griesfeller, J., Kinne, S., Schulz, M., and

Pinnock, S.: Aerosol retrieval experiments in the ESA Aerosol\_cci project, *Atmos. Meas. Tech.*, 6, 1919-1957, doi:10.5194/amt-6-1919-2013, 2013.

Page 2229, Line 5: I do not understand the meaning of the sentence beginning: “The results further depend...” Does this refer to the number of results, the quality of the results, or something else?

Response: Here we mean the quality of the result. Because we can obtain more constraints for the retrieval algorithm if we have high temporal observation, we have to consider the BRDF effect more carefully for high spatial resolution. For the large swath instrument, we have to deal with the different effect of view angles.

Page 2229, Line 25: The “popularity” of the MODIS “dark target” approach is mentioned before any reason is given for the need to determine the empirical relationships between radiances observed at different wavelengths. The key idea of the dark target approach is not described in this section. Put simply, it is that you can infer the “clear” reflectance of the surface at a short wavelength, where aerosols are significant, by using the top of atmosphere (TOA) reflectance of the same scene at a much longer wavelength, where the impact of aerosols is assumed to be insignificant. Essentially subtracting the inferred surface reflectance at the short wavelength from the TOA reflectance yields the path radiance, assumed to be due to aerosol alone.

Response: Thanks for the suggestion; we add more explanation of DDV algorithm according to (Kaufman et al, 1997; Remer et al., 2005; Levy et al., 2013, Remer et al., 2013) before the empirical relationship.

Kaufman, Y. J., Tanre, D., Remer, L. A., Vermote, E. F., Chu, A., and Holben, B. N.: Operational remote sensing of tropospheric aerosol over land from EOS moderate resolution imaging spectroradiometer, *J. Geophys. Res.*, 102, 17051–17067, doi:10.1029/96JD03988, 1997

Remer, L. A., et al, 2005: The MODIS Aerosol Algorithm, Products, and Validation. *J. Atmos. Sci.*, 62, 947–973. doi: <http://dx.doi.org/10.1175/JAS3385.1>

Levy, R. C., Mattoo, S., Munchak, L. A., Remer, L. A., Sayer, A. M., and Hsu, N. C.: The Collection 6 MODIS aerosol products over land and ocean, *Atmos. Meas. Tech. Discuss.*, 6, 159-259, doi:10.5194/amtd-6-159-2013, 2013.

Remer, L. A., Mattoo, S., Levy, R. C., and Munchak, L.: MODIS 3 km aerosol product: algorithm and global perspective, *Atmos. Meas. Tech. Discuss.*, 6, 69-112, doi:10.5194/amtd-6-69-2013, 2013.

Page 2230, Line 10: The “band-setting limitation,” introduced without description or reference here is, I believe, the central obstacle the authors are trying to overcome with their approach. This needs to be stated more clearly earlier in the paper.

Response: Band-setting limitation means limited visible bands without 1.6 $\mu\text{m}$  or 2.1 $\mu\text{m}$ , which brings lots of problem for aerosol estimation.

Page 2230, Line 22: This entire paragraph is devoted to specific attempts by previous investigators to derive aerosol optical depth (AOD) over land from AVHRR data. The final sentence of the paper, however, states, “the developed algorithm is the first promising steps towards the retrieval of AOD from AVHRR over land.” This assertion is directly contradicted by this paragraph.

Response: Here “the first promising steps” means the first step of our research; we have revised this sentence to make it clear.

Page 2330, Line 26: The word “data” appears twice in this sentence.

Response: We have revised this error.

Page 2230, Line 28: About their own retrieval authors write, “The approach assumes that surface reflectance of 0.64  $\mu\text{m}$  can be obtained using an empirical relationship between the reflectances at that wavelength and at 3.75  $\mu\text{m}$ , using the MODIS dark surface approach.” Just nine lines before, they criticize previous work on the basis that “the surface emissivity is variable, due to changing surface temperatures, which may cause an uncertainty in the relationship between the reflectance at 3.75 and 0.64  $\mu\text{m}$ .” It is never explained how this problem is overcome through the application of the MODIS dark target approach, or through the use of the intermediary 2.1  $\mu\text{m}$  channel.

Response: The emissivity is a great challenge for the reflectance extraction in 3.75 $\mu\text{m}$ . We tried to solve this problem by following the idea of Roger and Vermote (1998), the emissivity can be estimated by NDVI as follows:

$$\varepsilon = 1.009 + 0.047 \ln(\text{NDVI})$$

After obtaining the emissivity, we can estimate the temperature in channel 3 in AVHRR using emissivity, brightness temperature in channels 4 and 5 as well as NDVI.

Roger, J.C. and Vermote, E.F., A Method to Retrieve the Reflectivity Signature at 3.75  $\mu\text{m}$  from AVHRR Data, Remote Sensing of Environment, 1998, 64(1), 103-114.

A potentially critical issue that appears to be overlooked is the different spectral responses of the AVHRR and MODIS bands. Starting from the shortest wavelength, the nominal width of the AVHRR 0.64  $\mu\text{m}$  band is 0.58 – 0.68  $\mu\text{m}$ , while the nominal width of the MODIS 0.66  $\mu\text{m}$  band is 0.62 – 0.67  $\mu\text{m}$ . This means that the AVHRR band is twice as broad as the MODIS band (0.10  $\mu\text{m}$  vs. 0.05  $\mu\text{m}$ ). The 3.75  $\mu\text{m}$  AVHRR band has a nominal width from 3.55 – 3.93  $\mu\text{m}$ , while the MODIS band is nominally 3.66 – 3.84  $\mu\text{m}$  (0.38  $\mu\text{m}$

vs. 0.18  $\mu\text{m}$ ). Empirical relationships derived using the MODIS observations, and implicitly the MODIS bandwidths, may not be appropriate when applied to AVHRR data.

Response: We agree with the reviewer, spectral responses difference of AVHRR and MODIS is a problem when we are trying to use these two instruments. The highly-correlated relationship between reflective properties of 0.64 $\mu\text{m}$  and 3.75 $\mu\text{m}$  is due to the simultaneous occurrence of processes that darken the surface (Kaufman and Remer, 1994) by vegetation and soil components, which are the main contributor to remote sensing observation (von Hoyningen-Huene et al., 2011)

Different spectral responses may have different effect mainly due to the atmospheric gas effect and surface properties in the spectral range. There is no sudden change of spectral behavior of vegetation, soil and so on for both AVHRR and MODIS spectral range According to previous studies like Wu et al (2008), Pedelty et al (2007), there is very highly correlated between AVHRR channel1, which is used in the manuscript and MODIS channel 1 due to the minimally affected by atmospheric gaseous absorption. However, the case is completely different for channel2 due to the strong atmospheric absorption. As to 3.75 $\mu\text{m}$ , Lacovazzi et al (<ftp://ftp.orbit.nesdis.noaa.gov/pub/smcd/spb/lzhou/AMS86/PREPRINTS/PDF/S/100824.pdf>) shows that for northern hemisphere, the brightness temperature of 3.75 $\mu\text{m}$  from MODIS and AVHRR agree with each other quite well. Of course the atmospheric absorption is very important, especially for the emission part; however, we only use the reflective part of 3.75, which makes the difference between MODIS and AVHRR even smaller.

We can also follow the idea provided, for instance, by Romano et al. (2013) to convert the wavelength from MODIS to AVHRR in our further study.

Kaufman, Y.J, Remer, L.A (1994). Detection of forests using mid-ir reflectance - an application for aerosol studies. IEEE transactions on geoscience and remote sensing, 32(3), 672-683.

Wu, A., Xiong, X. and Cao, C, 2008, Terra and Aqua MODIS inter - comparison of three reflective solar bands using AVHRR onboard the NOAA - KLM satellites, International Journal of Remote Sensing

Pedelty, J.; Devadiga, S.; Masuoka, E.; Brown, M.; Pinzon, J.; Tucker, C.; Roy, D.; Junchang Ju; Vermote, E.; Prince, S.; Nagol, J.; Justice, C.; Schaaf, C.; Jicheng Liu; Privette, J.; Pinheiro, A., "Generating a long-term land data record from the AVHRR and MODIS Instruments," Geoscience and Remote Sensing Symposium, 2007. IGARSS 2007. IEEE International , vol., no., pp.1021,1025, 23-28 July 2007,doi: 10.1109/IGARSS.2007.4422974

Romano, F.; Ricciardelli, E.; Cimini, D.; Di Paola, F.; Viggiano, M. Dust Detection and Optical Depth Retrieval Using MSG-SEVIRI

Data. Atmosphere 2013, 4, 35-47.

von Hoyningen-Huene, W., Yoon, J., Vountas, M., Istomina, L. G., Rohen, G., Dinter, T., Kokhanovsky, A. A., and Burrows, J. P.: Retrieval of spectral aerosol optical thickness over land using ocean color sensors MERIS and SeaWiFS, Atmos. Meas. Tech., 4, 151-171, doi:10.5194/amt-4-151-2011, 2011.

Page 2231, Line 22: It was never clearly explained how the Raman-Pinty-Verstraete (RPV) bidirectional reflectance distribution model was employed in the algorithm. According to Fig. 3, only the visible reflectance is used, but perhaps I missed something. The RPV model should be used to estimate the surface albedo in Eq. (2) from the observed radiance, but it requires some additional assumptions.

Response: Yes, RPV is used for the estimation of surface albedo in Eq (2). More parameters are required, like  $k$ , which describes the surface anisotropy and  $\phi$ , which describe the forward-backward scattering of the surfaces, here we follow the idea from BAER algorithm, the RPV parameters in our paper came out from ground-based measurements, they have been derived from minimization of AOD for a lot of over flights over Germany. For the preliminary values,  $k=0.65$  and  $\phi=-0.06$  (von Hoyningen-Huene et al., 2011).

Page 2232, Line 19: The sentence beginning “Because we assume that TOA reflectance is equal to surface reflectance...” is key to the approach taken here, but I fail to grasp why the surface reflectance at  $0.64\ \mu\text{m}$  is not inferred directly from the  $3.75\ \mu\text{m}$  data. The sentence states, “to avoid using [an] additional reflectance product,” but why is this a problem? The majority of the next portion of the paper is devoted to this issue, so the authors should explain why this is critical to their approach.

Response: We can also use the products (like MODIS products) for the statistic analysis. MODIS AQUA surface reflectance products (MYD09CMG) are used and the statistic result as follows. NDVI greater than 0.55,  $R_{0.66}$  (MODIS surface product) less than 0.15, Clear land pixel with high aerosol quantity (classified by MOD09 QA state dataset), and we improved the constant part in Eq (12) to a similar function of scattering angle according to Holzer-Popp et al (2009) with the form  $0.1(\cos \Phi - \cos 150)$ . The results show as figure 2.

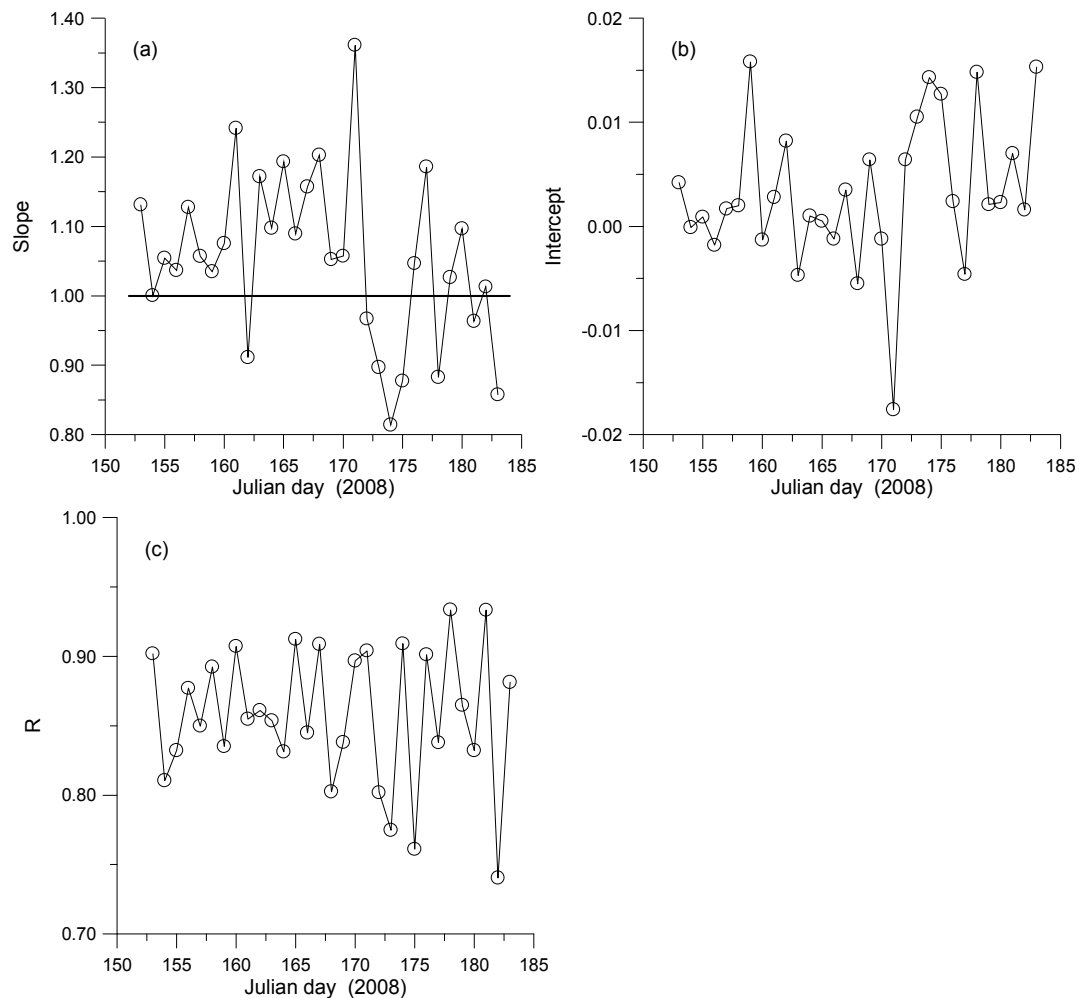


Fig. 2: Statistic parameters between estimated MODIS 0.66 $\mu$ m surface reflectance and MODIS 0.66 $\mu$ m surface reflectance product for June 2008 over East China: (a) Slope; (b) Intercept ;( c) Correlation (R)

Holzer-Popp T., Schroedter-Homscheidt M., Breitkreuz, H., Martynenko, D. and Kluser, L., Benefits and limitations of the synergistic aerosol retrieval SYNAER in “Satellite Aerosol Remote Sensing Over Land”, Kokhanovsky, A.A., and de Leeuw G. (Editors). Springer-Praxis (Berlin). ISBN 978-3-540-69396-3, 388 pp, 2009.

Page 2233, Line 5: The linear relationship is not given, it is assumed.

Response: We have revised the sentence.

Page 2233, Line 20: It is not clear to me what a “good linear relationship” is. It should be assessed quantitatively. What’s the maximum error introduced by assuming a linear relationship, for example?

Response: It is really difficult to evaluate the quality quantitatively, which is related to the surface and atmospheric properties. For the surface properties,



the reflectance of 0.64 $\mu$ m and 3.75 $\mu$ m is high-correlated as showed by Kaufman and Remer (1994). However, the linear relationship (without consider any other parameter like NDVI) is not stable for different region and different time. Boyd and Duane (2001) pointed out the temporal variation in MIR reflectance may due to the difference in canopy water content and canopy shadowing associated with the changing climatic condition and a positive relationship between NDVI and canopy water content has been observed (Roberts et al., 1997). So we tried to put NDVI in the statistical analysis, and only focused on the limited region, which recued unstable relationship between 0.64 $\mu$ m and 3.75 $\mu$ m. This is just the first attempt and according to figure 1 showed above, we can see that an error of  $\pm 20\%$  of surface estimation. For the case with surface reflectance 0.1, the error of surface estimation using statistic equation is 0.1.

Kaufman, Y. J., and Remer, L. A., 1994, Detection of forests using MID-IR reflectance: an application for aerosol studies. IEEE Transactions of Geoscience and Remote Sensing, 32, 672–683.

D. S. Boyd & W. J. Duane (2001) Exploring spatial and temporal variation in middle infrared reflectance (at 3.75  $\mu$ m) measured from the tropical forests of west Africa, International Journal of Remote Sensing, 22:10, 1861-1878, DOI: 10.1080/01431160116823 .

Roberts, D. A., Green, R. O., and Adams, J. B., 1997, Temporal and spatial patterns in vegetation and atmospheric properties from AVIRIS. Remote Sensing of Environment, 62, 223–240.

Page 2233, Equation (12): I am left to assume a linear least squares fit was applied to the data to “obtain” this result. What is the quality of this fit?

Response: Please refer to the explanation for the question above. The linear fit works for the selected region and time. However, this “fit” is not a general fit like MODIS DDV relationship because the relationship between visible and MIR reflectance may vary due to lots of factors.

Page 2234, Line 8: The line should read, “...fast economic development...”

Response: We have revised the sentence.

Page 2234, Line 21: The fact that the NOAA platforms observe the same Earth location twice a day is not relevant because one of these views is at night when aerosol retrievals using visible spectral bands cannot be performed.

Response: We have revised the sentence and explain that only daytime observation is used for the aerosol retrieval.

Page 2235, Line 7: What does “quite similar” mean? I also do not understand why the authors compare their results to the MOD09 (8-day) reflectances and not to the estimated 0.66  $\mu\text{m}$  MODIS reflectances determined using their own approach.

Response: Here “quite similar” means the spatial distribution. We have changed the compare to MODIS daily reflectance. We compare our AVHRR estimation to MODIS surface daily product as well as the MODIS surface reflectance determined using our own approach following the suggestion by the reviewer.

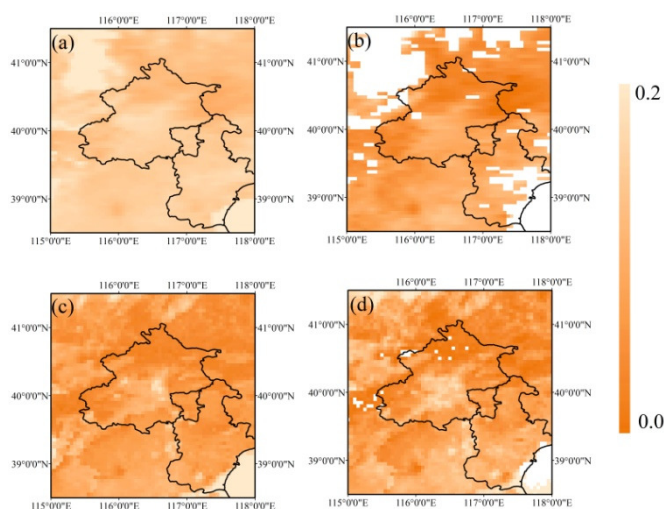


Fig. 3 An example of TOA and surface reflectances for AVHRR and MODIS (The most bright surface is due to cloud mask or negative estimated value). (a) AVHRR TOA reflectance; (b) Estimated AVHRR surface reflectance; (c) MODIS daily surface reflectance product (MOD09); (d) Estimated MODIS surface reflectance

Page 2235, Line 9: As described above, the correlation coefficient does not tell the whole story. I see a great deal of spread in the data plotted in Fig. 5.

Response: We improved the single statistic scattering map with only one correlation coefficient to a time serial of three main statistic parameters. They are correlation coefficient, slope and intercept between estimated surface reflectance and MODIS reflectance product shown in Fig. 2. The correlation coefficient is  $85\% \pm 10\%$ , the slope is  $1 \pm 20\%$  and the intercept is  $0 \pm 0.15$ , which shows good correlation for aerosol retrieval.

Page 2235, Line 13: What does “in good agreement” mean? The authors should be much more quantitative.

Response: We have revised the sentence and add the regression equation,

RMSE and the EE envelope in the new validation figure, and we found that 71.8% points located in the  $\pm(0.1+15\%)$  tolerance line, which shows the retrieval algorithm provides a potential approach for AVHRR retrieval.

Page 2235, Line 15: Looking carefully at Figs. 4 and 6, I notice what looks like an anticorrelation between the AVHRR derived surface reflectance and the retrieved AOD. It would be interesting and informative to make a regression plot of these two quantities.

Response: There is no anticorrelation between AVHRR derived surface reflectance and AOD, in the original paper, there is some problem for the cloud masking, which leads some very strange scenes in the AOD, in the revised version, we improved the cloud masking as well as the prior information for iteration. In the original version, only a fixed value was used as the first guess, which may cause problem during the iteration, in the revised version, MODIS monthly average AOD was used as the first guess, which is more reasonable.

Page 2235, Line 18: I do not feel that Fig. 7 contributes significantly to the discussion. The authors already state in the text the content of the figure.

Response: We deleted Fig.7, but we keep the discussion about the humidity and wind effect to the particle grow and transportation of aerosol in this region, which can explain why the AOD in the southern part are larger than northern part of Beijing.

Page 2236, Line 1: It seems to me that a calibration error would affect the overall image (and overall retrieval), not a particular region. One could imagine complicated non-linear calibration effects that depend on the observed reflectance, but to first order the calibration should be linear.

Response: Yes, the calibration problem can be introduced to the retrieval procedure.

Page 2236, Line 9: Given that the BAER LUT is known to perform so poorly in this region, why was it used at all? Alternatively, why was the analysis performed in this region instead of a location where the BAER LUT performs well?

Response: BAER LUT may cause some error for very strong absorption aerosol type and we are trying to solve this problem by considering the single scattering albedo. But for weak absorption aerosol, BAER LUT works well. During summer time, the single scattering albedo for Beijing is 0.93 (JJA) while 0.88 (DJF), 0.87 (MAM) and 0.88 (SON) (Lee et al 2007), and the study period is June and July (summer). And BAER LUT works well for AOT less than 1.0 (von Hoyningen-Huene et al., 2011), which represents almost all cases during

this time (No strong haze or dust events).

Lee, K. H., Z. Li, M. S. Wong, J. Xin, Y. Wang, W.-M. Hao, and F. Zhao (2007), Aerosol single scattering albedo estimated across China from a combination of ground and satellite measurements, *J. Geophys. Res.*, 112, D22S15, doi:10.1029/2007JD009077.

Page 2236, Line 13: This is the first (and last) mention of cloud screening in the entire paper. Since it is apparently important, it should be discussed.

Response: Cloud mask problem is discussed in the retrieval produce.

Page 2236, Line 24: I do not understand the meaning of the phrase “...we reduce the number of LUT in term of the polynomial by consideration of the single scattering approximation...” The use of the single scattering approximation in the retrieval algorithm is important and should have been discussed earlier.

Response: The simplified LUT is not a general LUT calculated by radiative transfer model, it has been parameterized as polynomials of second degree as follows:

$$R_{aero}(\lambda, \mu_0, \mu, \phi) = c_0 + c_1\tau + c_2\tau^2$$

Where  $c_0, c_1$  and  $c_2$  are constant. And the aerosol reflectance is a air mass corrected aerosol reflectance (von Hoyningen-Huene et al, 2011).

Page 2238, Line 3: The statement “... for such a small area the surface properties are expected to be relatively constant” should be supported with a reference.

Response: A reference has been added.

Jin, Menglin, Shunlin Liang, 2006: An Improved Land Surface Emissivity Parameter for Land Surface Models Using Global Remote Sensing Observations. *J. Climate*, 19, 2867–2881. doi: <http://dx.doi.org/10.1175/JCLI3720.1>

Page 2243, Figure 1: Does it make sense to have negative values on the y-axis? This plot should also include an error envelope and a mention of the number of points used in the regression.

Response: We have revised Figure 1.

Page 2246, Figure 4: The caption mentions that both the TOA reflectances

and the surface reflectances are shown on the right. The TOA reflectances are on the left. Why are the AVHRR surface reflectances in the upper right panel “blurry” compared to the MODIS reflectances?

Response: This is due to the instrument characteristics. The data type for MODIS is 16 bit while for AVHRR is 10 bit.

Page 2247, Figure 5: What is the number of points appearing in this figure. A one-to-one line and the regression line should also be included, at a minimum.

Response: We have revised Figure 5.

Page 2248, Figure 6: It is possible to use the MODIS data to determine the AOD at 0.66  $\mu\text{m}$  using the Angstrom coefficient for the MODIS aerosol model, which should be a more accurate comparison than assuming the Angstrom coefficient is 1.

Response: We revised the MODIS AOD product and using 660nm

Page 2249, Figure 7: This figure conveys very little information, and I would suggest eliminating it.

Response: We deleted Fig.7, but we keep the discussion about the humidity and wind effect to the particle grow and transportation of aerosol in this region, which can explain why the AOD in the southern part are larger than northern part of Beijing.

Page 2250, Figure 8: A one-to-one line should be included at least, since it is very hard to see the underestimation described in the text. It might also be interesting to color

Response: We have revised Figure 8.