# Point-by-point reply to the comments

Ref. No.: amt-2011-105

Title: Aerosol optical depth and fine-mode fraction retrieval over East Asia using multi-angular total and polarized remote sensing

**We are grateful to the anonymous referee for useful comments! According with your advice, we amended the relevant part in manuscript. The point-by-point report on how I addressed each of the comments is below:**

**Anonymous Referee #4:**

The authors present a retrieval algorithm that provides an alternative to the POLDER global algorithm that appears to be relatively simple, uses aerosol microphysical models that are specific to East Asia and allow not just fine mode optical depth, but also total optical depth to be estimated. The comparisons to AERONET are encouraging and suggest that the algorithm performs quite well.

The main issues I have with this paper are 1) a lack clarity and comprehensiveness in the discussion of the algorithm and 2) an absence of error estimates associated with the forward model and the measurements that would allow the residual terms to be appropriately weighted.

1) With regard the first item the authors state that "The retrieval algorithm employs the least mean squares fitting method in the form of a series of umberical iteration procedures to search for the computed total and polarization reflectance that best match the measured total and polarized reflectance, " However Figure 1 does not indicate that there is any interation and I am guessing that what they mean is that the algorithm outlined in Figure 1 is applied to each of the 36 possible mixtures. If so they should say so. It is also totally unclear how the initial Total AOD is weighted in the determination of Total AOD and FMF from the polarized reflectance which are presumably dominated by the FMF*AOD. Without a complete description of the functioning of the algorithm it is not possible to reproduce these results and they cannot therefore be regarded as scientifically sound.

**Answer:**

Thanks for these constructive suggestions which would make the manuscript more consistent. The detailed information of the regional algorithm has been added in the revised manuscript.

In order to test the ability of the inversion algorithm, to discuss why this particular design of the algorithm was chosen, what are limitations and accuracy, and what are the alternatives and perspectives, we added a section “sensitivity study”:

“In order to test the ability of the inversion algorithm, we have studied the relationship between the polarized reflectance at 0.675μm, 0.870μm, based on the numerical simulation (LUT) as a function of aerosol optical depth and FMF (Fig. 2). The solar zenith angle is 50°; the satellite viewing angle is 30°; and the azimuth relative angle is 180°. The solid lines represent constant FMF (from 0.0 to 1.0) while the symbols on the solid lines represent different AOD (from 0.0 to 2.0).

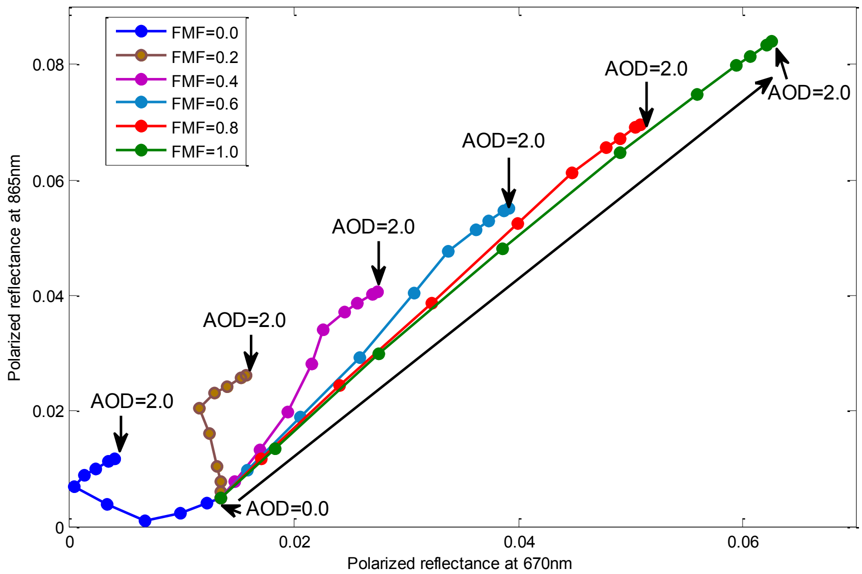


Fig.. Two-dimensional polarized reflectance correlation diagram in terms of the FMF (0.0, 0.2, 0.4, 0.6, 0.8, 1.0) and AOD (0.0, 0.1, 0.2, 0.3, 0.5, 0.8, 1.0, 1.2, 1.5, 2.0) for two wavelengths of 0.675μm, 0.870μm in the calculation for a solar zenith angle is 50°, a satellite viewing angle is 30°, and the azimuth relative angle is 180° .

From the 2-dimensional diagram, for a given geometry, it is noted that there is a strong sensitivity of the combination of polarized reflectance at 0.675μm, 0.870μm to FMF when the AOD is confirmed. The sensitivity to FMF decrease with the AOD decrease, and the accuracy of retrieved FMF is very low when the AOD is smaller than 0.1 at 0.870μm. There is also a strong sensitivity of the combination of polarized reflectance at 0.675μm, 0.870μm to AOD when the FMF is confirmed, especially for higher FMF (fine aerosol mode), and the sensitivity to AOD decrease with the AOD increase which means it's very hard to accurately detect the AOD with AOD lager than 1.5 at 0.870μm. The sensitivity to FMF is larger than that of AOD, so the FMF can be retrieved using the initial total AOD from radiance measurements, and then the adjusted Total AOD can be retrieved using the FMF. The accuracy of the FMF can be accepted when the AOD is larger than 0.1 at 0.870μm, and the AOD cannot be detected when the AOD lager than 1.5 at 0.870μm."

2) In terms of my second concern, there are potentially substantial errors associated with the use of the von Hoyningen et al and nadal and Breon models that are parameterized on NDVI that will depend on the aerosol loading and the surface type (cf. the cited references to Waquet et al. 2009 and Litvinov 2010 for example). There are also errors in mixing approximations that are smaller for polarized reflectance that for total reflectance, but which should be quantified (see Wang and Gordon papers references by Referee #1 and Abdou, W.A., Martonchik, J.V., Kahn, R.A., West, R.A., and Diner, D.J.,' A modified linear-mixing method for calculating atmospheric path radiances of aerosol mixtures', J. Geophys. Res., 102(D14), 16, 883-16,888(1997). If estimates of these errors were derived it would be possible to also provide estimates for the retrieval errors on the Total AOD and FMF and also to appropriately weight the total and polarized measurements that are being used. Without error bars retrieval of this kind have little value, since it is impossible to evaluate them against other sources of information.

**Answer:**

1) **Surface reflectance mode**

We agree with the reviewer that a precise estimate of the radiation (including polarization of radiation) reflected by the surface is crucial for remote sensing of aerosol properties over land. In this paper, the TOA reflectance was only used to retrieve the initial total AOD, and the adjusted Total AOD and FMF were retrieved using TOA polarized reflectance at 0.675μm, 0.870μm.

In order to retrieve the initial total AOD accurately, the effects of directionality of land surface reflectance are accounted for by a liner mixing model of vegetation and bare soil spectra (von Hoyningen et al., 2003) using NDVI to weight the categories. It should be noted, however, that the von Hoyningen et al. (2003) formulations, chosen as primary models for BRDF in the present algorithm, have limited accuracy (e.g. see Litvinov et al., 2010, 2011). In order to improve the accuracy of the von Hoyningen et al. (2003) method, the NDVI were derived from the PARASOl measurements on the clear-sky conditions in this paper. And the von Hoyningen et al. (2003) method has already been successfully used for simulating the surface reflectance over East Asia land by K. H. Lee and Y. J. Kim, 2010 (K. H. Lee and Y. J. Kim: A case study of clean, polluted, and Asian dust storm days, Atmos. Meas. Tech., 3, 1771–1784, 2010).

**2) Aerosol mode**

We agree with the reviewer that the method of Wang and Gordon (1994) have limited accuracy. Wang and Gordon (1994) described the method by which the aerosol component of the radiance at TOA can be synthesized from the radiances generated by individual components of the aerosol size-refractive-index distribution. The method is exact in the single-scattering approximation and usually reproduces the aerosol contribution with an error < 2-3% (and only rarely >3-4%) for aerosol optical thickness as large as 0.5 at 865nm. Only when the aerosol is strongly absorbing, the method can fail.

From the AERONET observations at Beijing and Xianghe from September to December in 2010, we found that the aerosol optical depth over Beijing and Xianghe are smaller than 0.8 at 870nm, so we believed that the method used in this paper will not introduce much quite significant error. This method has already been successfully used for interpretation of MODIS and POLDER aerosol retrieval over ocean. So the Wang and Gordon (1994) method has been used in this paper.

**3) Evaluate the algorithm**

In order to evaluate the present regional algorithm using the other sources of information, the products from regional algorithm with the products (fine mode AOD) from operational algorithm of PARASOL (the fine mode AOD of regional algorithm were retrieved from Total AOD and FMF). Fig.7 shows the spatial distributions of the Fine AOD from regional algorithm (left-hand side column) and operational algorithm (right-hand side column) for the three aerosol cases (clean, polluted, and dusty cases), respectively. Fig.8 and Fig.9 show the comparison of Fine AOD retrieved regional algorithm with those of operational algorithm at Beijing and Xianghe AERONET station.