

Manuscript "Speeding up the AOT retrieval procedure using RTT analytical solutions: FAR code" by Katsev et al. MS No: amt-2010-33

### **Answer to Reviewer 1**

We appreciate the detailed and useful comments of our reviewers. Below, please, find our answers. All needed additions and corrections have been made in the revised version of the manuscript.

### **General comment**

“The main purpose of aerosol retrieval algorithms is the derivation of an accurate measure of the atmospheric aerosol load with the purpose of adequately accounting for the role of the atmospheric aerosol load in the radiative balance of the atmosphere and its potential climate effect. Thus, the fundamental goal is accuracy and not processing speed.” “The accuracy achievable by the proposed code is inferior to that of radiative transfer codes currently used in the generation of the LUT’s used by operational AOT algorithms.”

We agree with this statement. Nevertheless, along with the above problem, there exist some very important problems where just the satellite data processing time rather than high accuracy of the AOT retrieval is crucial and the accuracy of the AOT retrieval about 10-20% is acceptable. The good example is monitoring the trans-boundary transfer of impurities, particularly in the cases of the emergencies as volcano eruptions, various industrial disasters.

By the way the error of the AOT retrieval by standard MODIS technique is  $\Delta\tau = \pm 0.05 \pm 0.15\tau$  (Remer et al.: The MODIS Aerosol Algorithm, Products, and Validation, J. Atm. Sci., 62, 947-973, 2005). It means that for example at AOT  $\tau \leq 0.3$   $\Delta\tau > 30\%$ . The accuracy of well known techniques is illustrated also by the Fig.1 taken from (Kokhanovsky et al., 2007).

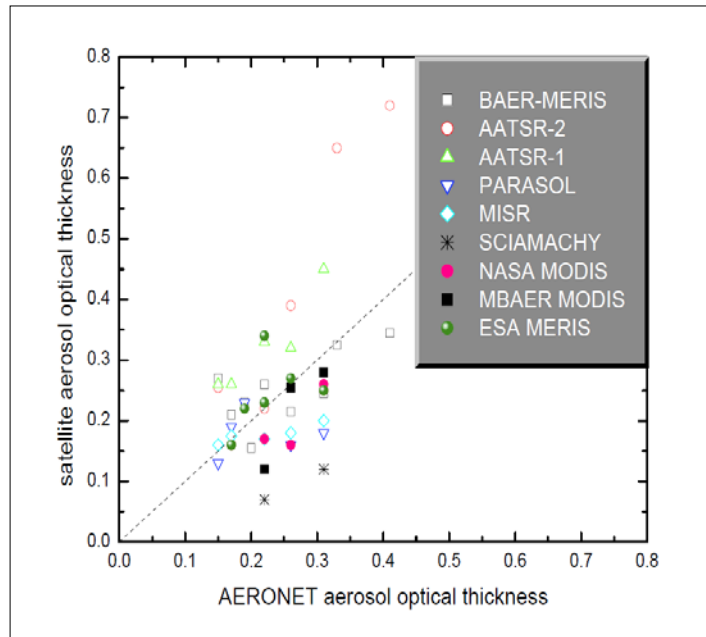


Fig.1. The comparison of satellite and ground measurements of the aerosol optical thickness at the wavelength 0.55  $\mu\text{m}$ . Data from AERONET stations located in the central Europe has been used in the analysis

**Specific comments:**

1. Page 3: “What does ‘our codes’ mean. Refer to the institution or research center:”

The corrected sentence is:

“The RAY code becomes a core of codes for the AOT retrieval developed in the B.I. Stepanov Institute of Physics of National Academy of Sciences of Belarus (see, for instance in Katsev et al., 2009)”.

2. Page 3: “ Substitute ‘services’ with features... “

Done

3. Page 3: “Slightly exceed errors’, be more quantitative... ‘Stay much less... ‘, it is not clear what is mean

The corrected version is:

“As it will be shown in Sec. 3, the errors of the AOT retrieval with the FAR only slightly (about 15-20%) exceed errors providing by the ART retrieval and stay less than

inaccuracy due to other factors including a priory choice of optical models of aerosol and surface.”

4. Page 5: “The authors introduce the parameter  $H$  as the vertical extent of Layer 1 but never addressed how it is determined.”

As a rule, the value of  $H$  is about 2-3 km. This remark is included in the manuscript.

5. Page 5: “Substitute ‘ignorance’ with neglecting (or ignoring)”

Done.

6. Page 6: “How is  $w_{aer}$  determined?”

The single scattering albedo of aerosol  $w_{aer}$  is completely determined by the chosen aerosol model.

7. Page 7: “Use...Because neither algorithm  
How about NO<sub>2</sub> absorption at 442.5?”

The optical thickness due to absorption of NO<sub>2</sub> at 442.5 nm is less than 0.003 and can be neglected (see Fig. 2, that presents computed values of the atmosphere transmittance due to NO<sub>2</sub> and O<sub>3</sub> absorption (the cross section values are taken from SCIATRAN data base, the altitude profiles are taken from LOWTRAN)).

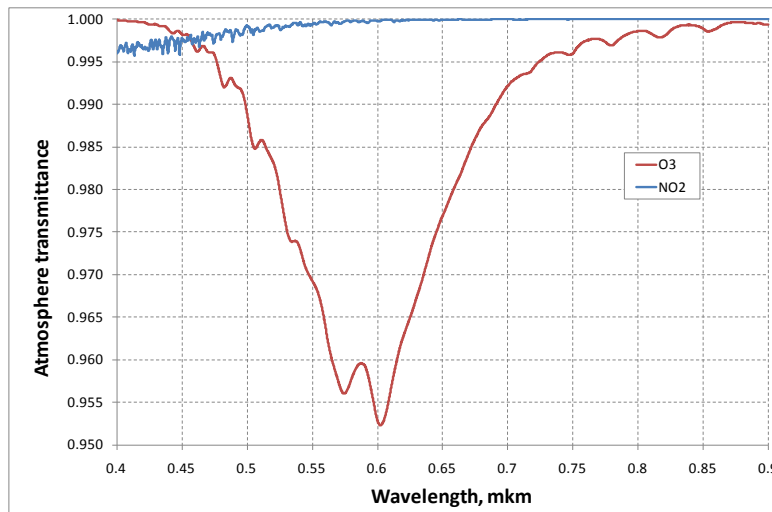


Fig.2. Spectral dependence of the atmosphere transmittance due to absorption by NO<sub>2</sub> and O<sub>3</sub>

8. Page 10: “Give proper reference for the ‘well known equation’ ...[Chandrasekhar, 1960] .

Done

9. Page 10: “The use of this equation to get  $r_s$  at large visible wavelengths is questionable as the Lambertian approximation breaks down. Needs to provide accuracy estimates.”

In the FAR retrieval the Lambertian underlying surface is assumed (as in majority of the retrieval codes (Kokhanovsky A. A. and de Leeuw G. (Eds.): Satellite Aerosol Remote Sensing over Land, Springer-Praxis, Berlin, 2009). As known, in the case we have the rigorous equation:

$$R_{TOA}(\mu, \mu_0, \varphi) = R_a(\mu, \mu_0, \varphi) + \frac{t_a(\mu)t_a(\mu_0)r_s}{1 - r_s r_{sa}^*}. \quad (1)$$

Nevertheless, one can say that BRDF effect is partially regarded in the FAR code. Here are some arguments to prove this assertion.

If the surface is not Lambertian, the following approximation for  $R_{TOA}$  can be used:

$$R_{TOA}(\mu, \mu_0, \varphi) = R_a(\mu, \mu_0, \varphi) + \frac{t_a(\mu)t_a(\mu_0)r_s^{ef}(\mu, \mu_0, \varphi)}{1 - r_s r_{sa}^*}. \quad (1a)$$

As in Eq. (1), the spherical albedo  $r_s$  stays in the denominator of Eq. (1a) because of at the multiple re-reflections between the surface and atmosphere the surface is illuminated by the diffuse light. Beside the value  $r_s r_{sa}^* \ll 1$  and error in the value of  $r_s$  has a little effect on the accuracy of calculation  $R_{TOA}(\mu, \mu_0, \varphi)$ . In the numerator of Eq. (1a) instead of the albedo  $r_s$  there is some effective reflection coefficient  $r_s^{ef}(\mu, \mu_0, \varphi)$ , which depends on the incidence and observation angles and on the ratio of diffuse to direct components of the solar light after propagating through the atmosphere. This means that the value  $r_s^{ef}(\mu, \mu_0, \varphi)$  also depends on the atmosphere parameters, which determine this ratio. In fact, just Eq. (1a) is used in the FAR algorithm. Indeed an effective surface reflection coefficient  $r_s^{ef}(\mu, \mu_0, \varphi)$  for the particular observation geometry that correspondent to the

pixel is calculated by the iteration process. Thus, there is an approximate regard to the real surface BRDF in the FAR algorithm.

This note is included in the manuscript.

10. Page 13: “What does ‘correctly enough’ means? If the expression is an approximation, say it, describe the approximation, and state to what accuracy the suggested expression is supposed to work.”

We are sorry. Here the procedure from the very first FAR version is described.

In the current (described in the paper) version of FAR the interaction between layers is included accurately using the layer adding method ((Lenoble, 1985). The reflection and transmission functions of the layer «2» are computed accurately with the RAY code taking into account the atmosphere stratification and light polarization effects, the reflectance  $R_1(\mu, \mu_0, \varphi)$  from the layer “1” is determined within the MSA by Eqs.(16)-(20) without accounting for polarization. As it was shown in (Katsev et al., 2009), the errors due to neglecting polarization effects for the layer “1” in the most typical situations do not exceed 1%.

Correspondent changes are included in the revised version of the manuscript.

11. Page 18: “MISR JPL and MODIS NASA are ambiguous ways to refer to these sensors. JPL is part of NASA.”

We regarded this comment in the revised version of the manuscript.

12. Fig 8: “Retrieval comparisons to AERONET are far from satisfactory, especially 440 and 550. Need to provide statistical parameters of the comparison: correlation coefficient, intercepts. How does this accuracy compare to the accuracy needed for climate analysis?”

We have included much more representative comparison FAR with AERONET at 440 nm and provided statistical parameters of this comparison in the revised version of the manuscript (see Fig.3). About accuracy, see our answer to general comment.

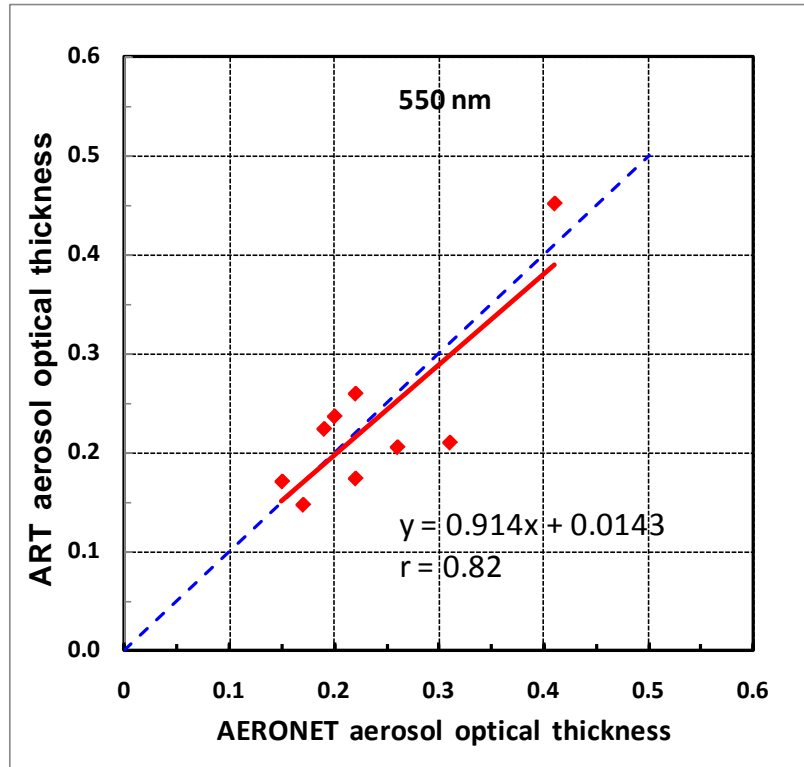


Fig.3. The AOT retrieved with the ART code versus AERONET AOT at  $\lambda = 440 \text{ nm}$

13. Page 15 (Should be Page 19): “15-20% error is too large a price to pay for reducing retrieval speed which is a non problem.”

As we have already noted the choice of accuracy vs time depends on the problem considered. As for 15-20% error, see our answer to general comment.

14. Figure 15: “This figure depicts a comparison to AERONET 412 nm AOD. Aeronet does not measure AOT at that channel.”

AERONET AOT data at 412 nm were obtained by extrapolation of AOT spectral dependence. Now Figure 15 is changed: the data at 440 nm with more representative statistic (two years measurements) are given in the revised version of the manuscript (see Fig.4).

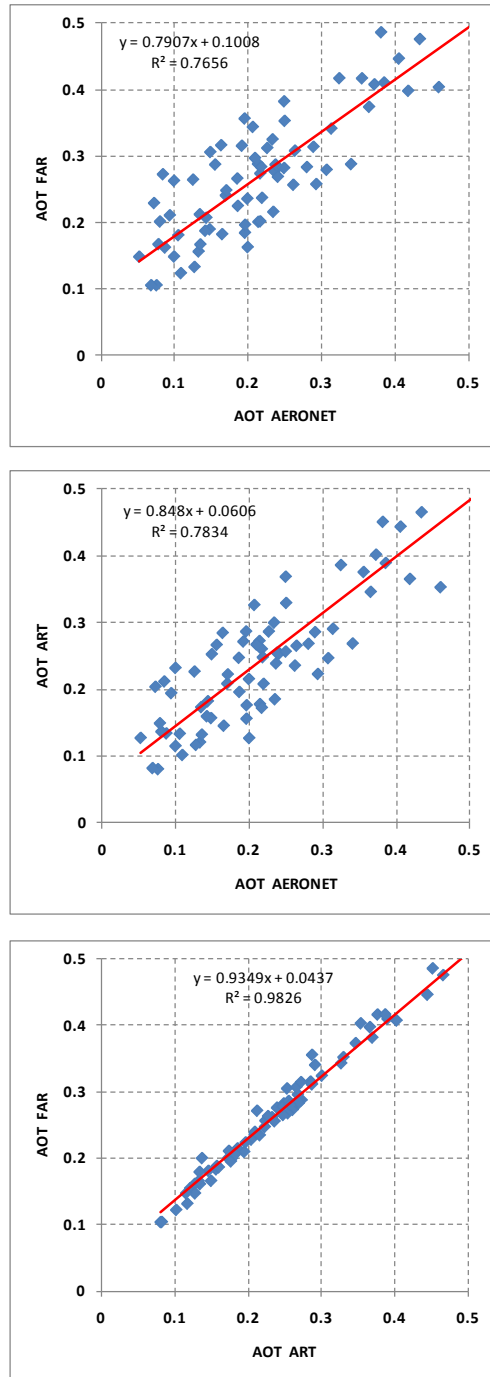


Fig.4. AOT retrieval at 440 nm with codes FAR (top) and ART (center) in comparison with the measurements of AERONET stations in Zvenigorod (Russia, near Moscow) and Belsk (Poland) for periods from March to September in 2008 and 2009 and correlation of values of AOT retrieved with ART and FAR technique (bottom)