

## ***Interactive comment on “Aerosol optical depth retrieval in the Arctic region using MODIS based on prior knowledge” by L. Mei et al.***

**Anonymous Referee #2**

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### General comments

Model simulations suggest that the Arctic climate is very sensitive to changes in aerosol abundance. The related aerosol radiative forcing contributes through the snow/ice feedback and other processes to the recently observed Arctic warming. It is therefore of utmost importance to supplement drastically undersampled in-situ aerosol observations in high latitudes. Unfortunately, standard aerosol remote sensing retrievals discard most Arctic regions because of the strong sensitivity to errors over bright surfaces and large zenith angles. More research is needed to address and overcome these difficulties and to provide spatial continuous AOD retrievals over bright surfaces. The topic of this paper is therefore very relevant and well within the scope of AMT.

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The paper shows AOD results using MODIS data on AQUA and TERRA around the North pole. It describes a semi-empirical approximative relationship between the reflectance at top-of-atmosphere and surface. Although, the corresponding equations are used instead of a forward radiative transfer model, the actual AOD retrieval method or inversion is not described at all. An almost identical concept was already published by Tang et al. (2005) and more recently by Wang et al. (2012). It is therefore questionable if 'The new aerosol optical depth retrieval method proposed in this paper' is really new. It may contain a new tuning for the empirical parameter 'b', but I can not recognize any substantial new concept, ideas, methods, or data as required by AMT. Furthermore, the list of symbols is a copy from Tang et al. (2005) and was not even adapted of the current manuscript. Beside that, I acknowledge that the authors provide reasonable credit to their sources.

The paper touches many aspects, from methods to AOD results to a comparison against AERONET. Unfortunately, it does not strive for a sufficient completeness in any of these aspects. The paper would significantly improve in scientific quality if it would focus on one of these aspects thoroughly, i.e. the AOD results over the Arctic.

The traceability of the method and the results needs to be improved. It is not clear if Eq. 16 was used for  $\theta=60$  or  $\theta>60$ . And why is the parameter 'b' intruded from Kondratyev (1969) for large  $\theta$ , but 'b' is not used in the corresponding Eq. 16? Why does Fig. 1 provide results from Eq. 13 if Eq. 16 is used for the AOD results? If Eq. 16 is an original contribution to this paper, a comparison to an independent accurate radiative transfer calculation would be required for various solar zenith angles to show its accuracy. Further, the paper should clearly state the data used as prior inputs and the data used for quality control or comparison. This applies to MODIS, AERONET, surface and meteorological data. Finally, the conclusions should not contain information and results, which were not previously introduced in the main body to the manuscript. Please see the specific comments for more details.

In my opinion, the paper does not provide a substantial contribution to the scientific

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community of AMT and requires significant improvements in most formal aspects. For the above reasons, I recommend to reject this paper without further review and discussion.

In case the authors prefer to submit an improved manuscript to another journal, I provide my specific comments and technical corrections below.

#### Specific comments

Page 7599, line 14: Please state the prior knowledge explicitly.

Page 7602, lines 9-12: Please correct this sentence. The surface albedo itself is not a function of the solar zenith angle, irradiance, cloud cover, etc. The may have thought in terms of the retrieval of surface albedo.

Page 7602, lines 9-15: Please state which prior knowledge or information.

Page 7602, lines 16-19: Please mention the context in which the work of Holzer-Popp et al. (2002) is relevant to the described method.

Page 7604-7605, Eq. 13,15,16: It is not clear where the solar and sensor (or relative) azimuth is used. The text and Fig. 1 mention the relative azimuth with a constant 35deg.

Page 7605, Eq. 16:  $\Theta'$  in  $1/\cos(\Theta')$  is not defined.

Page 7606, line 3: Use other subscripts than 1,2 to avoid confusions with Eq. (2) to Eq. (12).

Page 7606, lines 8-9: A percent error is a relative error. An absolute error would be given in reflectance units. Explain k-approximation and Lambertian error.

Page 7606, lines 18, 23, 26: Use another word than 'threshold', such as 'critical reflectance' or 'critical surface albedo'.

Page 7606, line 19: Mention in what respect these parameters are 'most important'.

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Page 7606, lines 22-24: I can not verify this statement in Fig. 1. Either improve the figure or explain the conclusion from Fig. 1 more clearly.

Page 7606, lines 26-27: Fig. 1 does not show a sensitivity study per se. One would expect partial derivatives of the TOA reflectance with respect to surface reflectance, AOD or other parameters to study sensitivities.

Page 7606, lines 26-27 to page 7607, line 1: I can not follow the conclusions from Fig. 1 on the separation of the aerosol and surface from the total signal. There is a low sensitivity in the TOA reflectance to AOD at large zenith angles and bright surfaces and the determination of AOD is therefore not reliable. Please explain your conclusions from Fig. 1 more clearly or provide a new Figure to support it.

Page 7607, lines 24-27 / page 7616 and 7618: Provide either Tab. 1 or Fig. 2. to avoid redundancy.

Page 7608, lines 7-8: Meteorological data are mentioned here but not specified. Please correct.

Page 7608, lines 9-13: Its confusing if the 'MODIS-retrieved' AOD values are taken from the MODIS standard product or derived with the proposed algorithm.

Page 7609, line 8-9: Second part of this sentence is unclear. Were only  $AOD < 0.2$  values used for the comparison between AERONET and retrieved AOD? Why?

Page 7609, line 18: Which MODIS retrieval is mentioned here? The retrieval using MODIS L1 data or the MODIS standard product?

Page 7609, line 29 & page 2610, lines 1-2: Remove this sentence or explain in more details.

Page 7610, lines 22-24: A plot of back trajectories from reanalysis would be helpful to support this statement. See e.g. <http://croc.gsfc.nasa.gov/aeronet/>

Page 7611, line 5: Replace 'relatively high level of accuracy' with a quantitative state-

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ment.

Page 7611, line 8: Water vapor is not mentioned in the paper before the conclusions. Further, water vapor absorption is not relevant for the used wavelengths and should have therefore no influence on the AOD retrieval accuracy.

Page 7611, line 10: Directional effects of the surface are not mentioned in the text before the conclusions. BRDF corrections should be mentioned and explained in the method section.

Page 7611, line 12: This paper does not provide a validation study and the word 'comparisons' should be used instead of 'validation'.

Page 7611, line 12: Spectral differences are not presented in this paper. Maybe the authors refer to the errors introduced by the rigid assumption on an invariant Angstrom parameter. Please make this sentence more clear and discuss potential errors together with the comparison in Fig. 4.

Page 7616 and 7618: See above.

Page 7617: I would suggest to remove two or three sub-figures because the TOA reflectance as function of surface reflection is changing linearly with respect to the zenith angle. This would allow to increase the size of the individual plots to enhance their readability.

Page 7617: Why are there no values at  $R=1$ ?

Page 7617: It is strongly suggested to mention the equation, aerosol properties, wavelength and vertical distribution used for the calculation of this results. E.g. aerosol absorption has a strong influence and should be mentioned therefore explicitly. Also, the authors should mention in the text and in the caption that Rayleigh scattering is not included in this plots. Why is that the case? Does the algorithm remove the Rayleigh scattering from the MODIS data? Please provide some details on that in Sect. 2.

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Page 7617: One legend is sufficient.

Page 7617: Use descriptive axis titles, such as TOA reflectance and Surface reflectance.

Page 7619: Please increase the figure size.

Page 7620 & page 7621: The last data points (Date 11) in Subfig. 5e shows an A value (blue) of  $AOD=0.2$ . At the same time Fig. 5 does not contain a data point with  $AOD=0.2$ . Any suggestion?

Page 7621: Please increase the figure size.

Technical corrections

Page 7599, line 15: Add 'results' between 'model' and 'demonstrates'.

Page 7600, lines 26-29: Please rephrase both sentences.

Page 7602, lines 19-21: Replace 'we' with Tang at al. (2005) and remove (Tang at al. 2005) at the end of this sentence.

Page 7602, lines 21-25: Please rephrase to be more concise and clear. Further, use 'caused' instead of 'causing', 'platforms' with s and 'temporal and spatial co-registration'.

Page 7606, line 25: 'regions' instead of 'region'.

Page 7607, lines 4-18: Check tense and rewrite to improve language and remove repetitions.

Page 7607, line 6: Add 'which' after comma.

Page 7607, line 19: Add 'in situ' or 'point' between 'distributed' and 'observations'.

Page 7608, line 19: 'AOD retrieval resolution' instead of 'resolution of retrieval AOD'.

Page 7608, line 28: Why are the AOD values averaged over time? Please explain.

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Page 7609, line 13: Add 'AOD' between 'AERONET' and 'values'.

Page 7609, line 27: Remove 'ship'.

Page 7610, line 4: 'and multitemporal' could be added between 'area' and 'coverage'.

Page 7610, line 5: Replace 'that' by 'of'.

Page 7610, lines 5-6: Replace 'to Arctic atmospheric environment' by 'AOD in the Arctic'.

Page 7610, lines 6-7: Remove 'Regarding this topic,'.

Page 7610, line 8: Add 'AOD' between 'background' and 'outside'.

Page 7610, line 20: Remove line brake and rewrite this sentence.

Pages 7611-7612, List of symbols: Please make sure the symbols correspond to the text. E.g. A and A' are used as R and R' in the text. In addition, many symbols in this list are not used in the given equations. E.g. S and S<sub>0</sub>, P and R and rho. I am concerned that the majority of the list of symbols was copied from Tang et al. (2005).

#### References

T. Holzer-Popp, M. Schroedter, and G. Gesell. Retrieving aerosol optical depth and type in the boundary layer over land and ocean from simultaneous GOME spectrometer and ATSR-2 radiometer measurements, 1. method description. *Journal of Geophysical Research*, 107, doi:10.1029/2001JD002013, 2002. <http://www.agu.org/pubs/crossref/2002/2001JD002013.shtml>

K. Y. Kondratyev. *Radiation in the atmosphere*. Academic Press, New York, NY; London, 1969.

J. Tang, Y. Xue, T. Yu, and Y. Guan. Aerosol optical thickness determination by exploiting the synergy of TERRA and AQUA MODIS. *Remote Sensing of Environment*, 94(3):327-334, doi:10.1016/j.rse.2004.09.013, 2005.

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Y. Wang, Y. Xue, Y. Li, J. Guang, L. Mei, H. Xu, and J. Ai. Prior knowledge-supported aerosol optical depth retrieval over land surfaces at 500 m spatial resolution with MODIS data. *International Journal of Remote Sensing*, 33(3):674-691, doi:10.1080/01431161.2011.577832, 2012. <http://www.tandfonline.com/doi/abs/10.1080/01431161.2011.577832>

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Interactive comment on *Atmos. Meas. Tech. Discuss.*, 4, 7597, 2011.

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