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Atmospheric Measurement Techniques Discussions

Interactive comment on "Critical surface albedo and its implications to aerosol remote sensing" *by* F. C. Seidel and C. Popp

Anonymous Referee #3

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General comments:

This paper is a modelling study investigating the critical surface albedo (CSA), which is the surface albedo at which top-of-atmosphere (TOA) reflectance measured by satellites is insensitive to changes in aerosol optical depth (AOD). There have been several papers in recent years making use of the CSA from pairs of scenes of the same region to estimate aerosol absorption. The goal of this paper is to assess typical values of CSA, and how they depend on factors such as observation geometry and aerosol type.

The study is quite well-written (I have a small number of stylistic suggestions, below) and will be of use to the aerosol remote sensing community. In my view there are a few shortcomings which, if addressed, would make the manuscript even more useful (and

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should not take the authors too long to perform). These are discussed in my specific comments, below, and I would strongly urge the authors to make these changes. As the other reviewer noted, I would also have preferred if realistic bidirectional reflectance distribution function (BRDF) models were used rather than the Lambertian approximation, although acknowledge that this would have increased the complexity of the study. Still, as it stands, this is a nice study, and perhaps the authors can build upon it to model some typical BRDF situations in the future.

Based on the above, I favour acceptance of the article following minor revisions.

Specific comments:

Abstract: "CSA is defined as the surface albedo, where the reflectance at top-of atmosphere (TOA) does not depend on aerosol optical depth (AOD). ... We show that the CSA also depends on AOD" This appears to be a contradiction, and is a somewhat confusing pair of statements! It should be addressed. I suppose what you are really saying is that CSA is an idealised concept while in reality there is a range of surface albedo at which the sensitivity of TOA reflectance to AOD is minimal. Is that correct?

Page 7727, around line 25: You are missing the recent and relevant paper by Wells et al. (2012), which would fit well in this section.

Page 7730, line 10: As pointed out by the other reviewer, there is a contradiction between the text and table caption with respect to the dust model's origin.

Page 7731, lines 3-4: This relates to my point in the abstract. Is it not better to say rather that there is a range of conditions over which the retrieval solution will be degenerate? The lines not crossing at the same point really show that the CSA is an approximation which is not always valid, i.e. there does remain some sensitivity of TOA reflectance to changes in AOD, it is just very small. I suspect the range of albedo of crossing points of the lines in Figure 2 is smaller than the uncertainty of knowledge on surface albedo. Or do I not understand correctly what you are doing?

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Page 7732, lines 2-4: You might note here that marine AOD over 0.2 is unlikely (e.g. Smirnov et al., 2011), which then is good news for AOD retrieval over ocean, as it suggests there will be sensitivity to AOD for typical conditions.

Page 7733, section 3.1.3: This section would benefit from some cursory mention at least of BRDF effects. You note that the CSA is often higher for backward scattering geometries. Such geometries are also often where BRDF effects are strongest, e.g. the hotspot effect. So I would expect that the simulations might be less representative of reality for these conditions. Some comment on this in the paper would be helpful.

Page 7734, section 3.1.4: See previous comments about why it might be more meaningful to talk about an albedo range with minimal AOD sensitivity, rather than a distinct CSA.

Page 7734, section 3.2.1: How do you 'retrieve' AOD in this case? Manually run 6S for a set of AOD and figure out which one corresponds to the TOA reflectance simulated with the 'true' albedo?

Page 7737, lines 7-8: see my comments about section 3.1.3 above, which is also relevant to mention here.

Page 7737, line 16: It would be good to comment on deserts, also.

Page 7737, lines 22-27: This is a good point. Some retrieval algorithms such as the Oxford-RAL Aerosol and Clouds (ORAC) scheme take this approach, see e.g. Sayer et al. (2012). Surface reflectance is constrained based on the MODIS BRDF product, and the retrieval is performed as a simultaneous inversion from multiple wavelengths, so that channels are effectively weighted based on such partial derivatives (i.e. according to the actual information present in the channels). This methodology also directly produces the uncertainty estimates you mention. Another example of such a retrieval scheme is given by Govaerts et al. (2010). I would suggest these are worth mentioning in your conclusions, to show these ideas are possible in practice.

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Finally, there is one obvious extension of this work which should be simple to do and, in my view, would make the manuscript much more useful. You have already simulated CSA for a range of different geometric conditions and aerosol types. You can also freely download e.g. MODIS data, which can give you global maps of surface albedo, together with viewing geometry, and AOD. Together with some simple assumptions about aerosol types, you could make some first-order maps of when and where in the world we are likely to run into situations where we are near the CSA. Even with simple assumptions it would be a step forward which I don't believe we have now. Such a map would be useful for the aerosol remote sensing community. It would be interesting to see whether such regions correspond to those where different satellite datasets differ.

This should only really take the authors a day or two of work because they already have all of the complicated results from their simulations. I suggest creating seasonal maps of where conditions are such that satellites are within some threshold of the CSA. Maybe a colour scale which shows the absolute difference between surface albedo and CSA. Most satellite sensors are either in late morning or early afternoon orbits, so you could use the two MODIS sensors (Terra/Aqua) as representative examples. The wavelengths you have already calculated for would be good to show (although the MODIS albedo product does not have 412 nm, you could use the other two wavelengths). It may be that the pattern looks the same for different wavelengths and orbit times, in which case you'd only need to show one.

I don't know what the result would be, but it would be interesting and useful, and since the authors have already performed the more time-consuming part of the analysis, should be a very easy extension. Please consider this.

Technical corrections:

Page 7726, line 3: Remove comma after 'albedo'.

Page 7727, line 1: 'Many spaceborne sensors allow the retrieval of total vertical columnar...'

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Page 7727, line 6: Delete the word ‘factor’.

Page 7727, line 8: I suggest deleting ‘(or reflectance)’ for simplicity, as typically radiance is what is measured. I would also suggest replacing ‘a correct’ with ‘an accurate’.

Page 7727, lines 9-10: I suggest replacing ‘the reflecting Earth’s surface’ with ‘reflection from the Earth’s surface’.

Page 7727, line 25: replace ‘could improve’ with ‘improved’.

Page 7730, lines 23-25: ‘In general, TOA reflectance increases with increasing AOD for darker surfaces and decreases with increasing AOD for brighter surfaces.’

Page 7730, lines 26-29: ‘At this particular surface albedo, the increase in TOA reflectance from aerosol scattering is balanced by the decrease in TOA reflectance from aerosol absorption.’

Page 7731, line 14: replace ‘relation revealed’ with ‘relationship revealed,’.

Page 7731, line 17: ‘which fits the TOA reflectance well’

Page 7736, line 11: ‘to the studies mentioned above is’

Page 7736, line 12: ‘assume a linear relation’ or ‘assume a linear relationship’. Also, the word ‘reflectance’ is missing after ‘TOA’ here and on the next line.

Page 7737, line 5: delete comma after ‘although’

Page 7737, line 11: ‘the studies mentioned above’ or ‘the previously-mentioned studies’

Additional references used:

Govaerts, Y. M., S. Wagner, A. Lattanzio, and P. Watts (2010), Joint retrieval of surface reflectance and aerosol optical depth from MSG/SEVIRI observations with an optimal estimation approach: 1. Theory, J. Geophys. Res., 115, D02203, doi:10.1029/2009JD011779.

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Sayer, A. M., G. E. Thomas, R. G. Grainger, E. Carboni, C. Poulson, and R. Siddans (2012). Use of MODIS-derived surface reflectance data in the ORAC-AATSR aerosol retrieval algorithm: Impact of differences between sensor spectral response functions, Rem. Sens. Environ, 116, 177-188, doi:10.1016/j.rse.2011.02.029

Smirnov, A., Holben, B. N., Giles, D. M., Slutsker, I., O'Neill, N. T., Eck, T. F., Macke, A., Croot, P., Courcoux, Y., Sakerin, S. M., Smyth, T. J., Zielinski, T., Zibordi, G., Goes, J. I., Harvey, M. J., Quinn, P. K., Nelson, N. B., Radionov, V. F., Duarte, C. M., Losno, R., Sciare, J., Voss, K. J., Kinne, S., Nalli, N. R., Joseph, E., Krishna Moorthy, K., Covert, D. S., Gulev, S. K., Milinevsky, G., Larouche, P., Belanger, S., Horne, E., Chin, M., Remer, L. A., Kahn, R. A., Reid, J. S., Schulz, M., Heald, C. L., Zhang, J., Lapina, K., Kleidman, R. G., Griesfeller, J., Gaitley, B. J., Tan, Q., and Diehl, T. L.: Maritime aerosol network as a component of AERONET – first results and comparison with global aerosol models and satellite retrievals, Atmos. Meas. Tech., 4, 583-597, doi:10.5194/amt-4-583-2011, 2011.

Wells, K. C., J. V. Martins, L. A. Remer, S. M. Kreidenweis, and G. L. Stephens (2012), Critical reflectance derived from MODIS: Application for the retrieval of aerosol absorption over desert regions, J. Geophys. Res., 117, D03202, doi:10.1029/2011JD016891.

Interactive comment on Atmos. Meas. Tech. Discuss., 4, 7725, 2011.