Atmospheric Measurement Techniques Discussions

Interactive comment on "Aerosol Optical Depth (AOD) retrieval using simultaneous GOES-East and GOES-West reflected radiances over the Western US" *by* H. Zhang et al.

Anonymous Referee #1

Received and published: 18 December 2012

The manuscript provides a new retrieval approach for aerosol optical depth using geostationary satellites. The overlap of GOES-East and Goes-West is used to apply a hybrid retrieval for pixel where both satellites give radiance measurements at different geometry. The most significant improvement is the increased number of valid retrieval pixel based on the fact that geometries unsensitive to AOD of one sensor are covered by the second sensor with different geometry. This method requires a precise estimation of surface BRDF and inter-calibration of both sensors. Both issues have been discussed in the manuscript. Results are compared to AERONET observations.

The approach of a hybrid AOD retrieval using two satellites is a very innovative idea potentially improving routine AOD retrievals and worth to be published. However, in my opinion the manuscript lacks of three issues which have to be reassessed in detail before publishing the manuscript. First the sensitivity of AOD retrieval to the geometry was misinterpreted. Second, a discussion on uncertainties in the retrieved AOD is missing. And the explanation of the retrieval algorithm has to be improved.

Below, I compiled a list of comments which have to be considered in a revised version of the paper. There might be some contradictory statements resulting from my misinterpretation of the text when first reading. I am sure the authors will know how to weight in such cases and how to improve the text to avoid misinterpretations by other readers.

1 Major comments

Sensitivitiy to AOD:

The whole argumentation why the retrieval is not sensitive to AOD for large scattering angles is wrong. The authors claim the anisotropic BRDF with higher reflectance in backscattering geometry (hot spot) causes the problems (e.g., p7957, 7 and p7952, 10 and p7964 24). This is only half the truth. As can be seen in Figure 7 surface reflectance does not change dramatically but the sensitivity does for scattering angles of about 90°. Lower scattering angles (forward scattering) gives higher sensitivity to AOD than high scattering angles (backscatter geometry). This is not due to surface BRDF. This is due to the shape of the scattering phase function of aerosol particles. You may use a Mie-tool and calculate the scattering phase function for your given aerosol size distribution. It comes out that the scattering phase function increases significantly for scattering angles below 90°. Especially for the fine fraction which is assumed to have twice the volume concentration than the coarse fraction and thus by far the strongest radiative impact. This sharp threshold of 90° perfectly fits to your

calculation of Figure 7.

Due to the argumentation of the authors, the focus of the retrieval is to correctly estimate surface BRDF. Sure this is quite important, but scattering properties of aerosol are very important as well. Please revise the manuscript with regard to the significance of aerosol scattering. First a plot of the scattering phase function would help. Second it might be worth to check how sensitive the retrieval is to aerosol optical properties. Is a Henyey-Greenstein approximation used or Mie-calculations? What if the aerosol type is changed in the calculation of LUTs? Especially dust particles are mostly non-spherical and will show enhanced backscattering.

Uncertainties:

A detailed discussion of retrieval uncertainties is missing. The only validation is the comparison with AERONET data. But still this does not tell much about the uncertainties as the AERONET data may have uncertainties as well. Additionally this comparison is not presented well and summarized with "...results compare well to the AERONET AOD with correlation coefficients of 0.67–0.81 and the RMSEs of 0.06–0.07." This is all relative. Correlation coefficients do not tell anything about an agreement only on correlation. Also an overestimation of factor 2 or 100 may have a correlation of 1.0. The RMSE is more meaningful. But here you have to consider the mean AOD values. RMSE of 0.06 for mean AOD of about 0.1 is a difference of more than 50%. This is not quite well in my opinion. In this regard, the discussion of Figure 8 and the regressions is not sufficient. As stated in one of the minor comments below, there seem to be systematic offsets,... which have to be discussed.

Further, there are a lot of filters and screws in the algorithm which may affect the retrieved AOD. E.g. mean AOD in section 4.1, sensitivity quantity in 4.4. and several filters in 4.2. How does the choice of these thresholds affect the AOD? There might be some systematic biases due to the filters.

I know aerosol retrievals are difficult and I encourage your work. But this also means

uncertainties have to be shown clearly even if they are high. In my point, it would be sufficient to estimate an uncertainty with respect to uncertainties in surface reflectance, aerosol scattering properties and radiance calibration of the sensors.

Inter-calibration:

Similar to above, I appreciate the inter-calibration work but think it has to be discussed better as a wrong calibration will bias your AOD significantly.

First, only one single point, Boulder, is used for the inter-calibration. How other locations behave?

Second, what does mean Boulder is located almost midway? The deviation from perfect midway may be the reason for the 5% difference.

Third, why GOES-East is the reference sensor? GOES-West might measure the truth. Who is right West or East?

And finally, at **P7951, 9:** a precision of 1% of the sensors is mentioned. This does not fit to the factor of 0.95 obtained in the inter-calibration. This has to be discussed.

Due to this high uncertainty of 5% I suggest to investigate how this will bias the retrieved AOD.

Description of retrieval algorithm:

It is quite hard to understand the retrieval algorithm when first time reading. This can be improved by little restructuring. Here are some suggestion which came into my mind when reading. First I suggest to add a brief road map before starting to describe the algorithm in detail. Here you can motivate why the single steps 4.1, 4.2,.. have to be taken.

One example is section 4.1 the part explaining the sensitivity study (p 7956, 8- 24). It was not introduced or motivated why now AERONET data is analyzed and a clear day AOD threshold is justified. This does not fit into the reading fluency as I expected a

complete description of the algorithm first. Such a sensitivity study may be conducted after the description of the whole algorithm or in advance by defining clear sky conditions. Also section 4.4. come without introduction of the problem.

A road map in advance and a short introduction, motivation of each step of the algorithm description would help a lot.

Some comments resulting from my misunderstanding of the algorithm may follow in the minor comments. Please consider these comments to improve the description of the algorithm.

Reflectance or reflectivity, surface or TOA:

The use of reflectivity properties is not consistent throughout the manuscript. Mostly reflectance is used but not at P7956, where surface reflectivity is discussed. Please stick to one, reflectivity or reflectance, unless there is a physical difference in between. Then exactly define what is meant with both quantities.

Further, sometimes "surface" or "TOA" is used together with reflectance but again not consistently. At some occasions "surface" or "TOA" is missing and it is not clear if the authors refer to the surface or TOA reflectance. This makes an understanding of the algorithm unnecessary difficult. Please add "surface" or "TOA" always even if it is repeated again and again.

Figures

The labelling of most figures (4, 8, 9, 10, 11) is to small and has to be enlarged.

2 Minor comments

P7946, 17: What UCSP stands for?

P7946, 21: "coincidences with AERONET" is to specific for the abstract and coincidence is not the right word implying, that AOD also matches. Better write: "For single observation areas the number of valid AOD data increases..."

P7947, 22: SEVIRI provides also a rapid scan service with 5 min temporal resolution for a smaller area of Europe.

P7948, Fig. 1: There is no need to show both morning and afternoon. Only one sketch is sufficient. The definition of the geometry does not change at noon. The sensitivity to surface reflectance is illustrated in Fig. 7.

Instead of two sketches better show the scattering angle for both satellites and selected spots at the surface (image center, mid and high latitudes, in and outside the overlap region) over an entire day. Similar to Fig. 7c. This plot can be used to discussed the threshold of extreme viewing geometries of the mentioned prior work better.

Further, symbols are to small. One single sketch can be printed larger. This would help to identify the symbols as well. For (a): the two arcs for Φ_w and Φ_e look like one. I first thought Φ_w is the entire arc. Please separate.

P7949, 3: Are there any references discussing and quantifying the rapid change of surface reflectance. It would be helpful to read the numbers here again and get a feeling for this issue.

P7949, 4: Do not forget to mention snow.

P7950, 1-8: The part starting with "It is found... the BRDF shape." should be removed from the introduction. It already summarizes findings which will be shown later. At this point the statements are not convincing as the sensitivities have not been shown jet. This part can easily be converted into a road map of the retrieval algorithm.

P7950, 22: "be" change to "are"

P7951, 9: 1% precision does not fit to the factor of 0.95 obtained in the inter-calibration.

This has to be discussed.

P7951, 5: Are both pairs of satellites used in this study? If yes, change "should" to "are". Otherwise it should be mentioned, that this study only uses 11 and 12.

P7951, 9: I do not understand what is meant with an exponential change of calibration over time and how this can be allowed. Please specify this argument.

P7952, 1: Explain where this reference image comes from? Is it also from GOES or from a different sensor?

P7953, 24: add "... BRDF kernels f_{iso}, f_{vol}, f_{geo}, respectively." This would help to understand what is done here.

P7953, 26: remove "of"

P7954, 12: Why BRDF is now assumed to be lambertain? Didn't you just convince the reader, that BRDF is very important for aerosol retrieval? I don't understand. Do you have two retrieval steps? First retrieving BRDF with RT simulations considering BRDF and a second step for the AOD implementing the retrieved BRDF as lambertain value into the simulations?

If so, then clearly explain this: "The reflectance in the viewing geometry is used and assumed to be the lambertain value for the AOD LUT." That's right?

P7955, 8: Instead of "view geometries away from the backscattering direction" use "low scattering angles". This is easier to understand and the reader has not to transform the geometry into scattering angle in mind.

P7955, 17: "clear day". What do you mean with clear day? Usually it is called clear pixel as the entire scene of GOES will never be completely clear sky. After further reading I understood, that a single pixel has to be clear sky for the whole day so that BRDF can be obtained for different scattering angles. You should add the word "pixel" somewhere in your explanation. Further one might ask, why an AOD retrieval is used

C3310

to screen for clear sky? You already applied a cloud mask.

P7955, 21: What the 80 km horizontal scale stands for? Probable, aerosol variability? Please justify.

P7955, 23: Wording. Simplify: "This step requires a sensitivity of retrieved AOD to the assumed surface reflectance."

P7956, 1: Figure 4 is discussed twice in the text. During the first occasion it is not clear where the dashed lines come from and how the sensitivity threshold is defined?

P7956, 2: Is TOA reflectance measured or simulated. In the figure caption it is written that TOA reflectance was simulated.

P7956, 10: Space is missing after "Here, "

P7956, 20: Justify the value of 0.05. Standard deviation?

P7956, 23, Fig. 6: You did plot only $AOD^{\text{av}} < 0.3$. So you can not judge if this threshold is appropriate. What about AOD=0.4. Do the differences increase for higher AOD? To show this, Fig. 6 has to be expanded and to be discussed why 0.3 is the threshold.

In Fig. 6 only overestimations of AOD are assumed. What about underestimations? Do they show the same differences?

Further, Fig. 6 applies a single fixed surface reflectivity of 0.1. What if the reference surface reflectivity is changed from 0.1 to 0.2? How your criterion will change? Or is it robust enough to account for all possible surface reflectivities?

P7957, 3-10: These geometry related issues should be discussed earlier, because you already talked a lot about that before.

P7957, 13: The sensitivity parameter is later (P7959, 25) defined different.

P7957, 21: remove "also"

P7957, 25: change "one-three" to "one to three"

C3311

P7957, 25: change to " are required to ... of the entire image."

P7959, 4 and 8: add equation numbers

P7959, 4: It is a bit unfortunate that a is defined here and not earlier when Fig. 4 is discussed the first time.

P7959, 8: Here again the road map is missing. I thought after obtaining the new BRDF you are fine and do not have to think about BRDF again. Why not simply the new updated BRDF is used not caring about the change from the last day. Or do you want to account for short changes in surface BRDF/reflectance again?

P7961, 4: Is there any explanation for the improvement at Boulder and not for the other sites? Check potential differences, geometry, surface BRDF,...

P7973, Fig. 4: This figure is hard to understand from the description in the text and my comments might be wrong. Take this as a motivation to improve your explanation.

First, isn't it better to switch a and AOD, abscissa and ordinate? Later you define the slope like that and the quantity searched for is AOD. The quantity causing differences is a.

Second, what are the dashed lines? Where do they come from? How did you define the sensitivity threshold?

Third, when I do understand right, for $a = 1.0$ the correct AOD is retrieved because surface reflectance did not change. For GOES EAST this would be something like 0.15. Why for GOES-West a never has a value of 1?

Further in the text **P7959, 16:** I would have thought it its vice versa and 4a is the problem. In 4b both sensors yield the same a and τ. This is OK. But in 4a both sensors give different a and τ. There should be only one real solution, one pair of a and τ. But in 4a GOES-East and -West give different pairs.

P7973, Fig. 4 caption line 2: Line 2 "where a represents" Here "a" is the quantity a.

Use italic letters for symbols. Otherwise it is hard to distinguish from text. Especially "a".

P7976, Fig 7: For the upper panels add labels "GOES-west" and "GOES-east".

P7976, Fig 7: I suggest to rearrange the panels to facilitate an easy comparison of what is interesting. e.g. scattering angle vs. TOA reflectance and scattering angle vs. surface reflectance. (a) and (b) are fine. (c) and (d) scattering angle and surface reflectance should be merged with one panel for GOES-west and one panel for GOES-east. The GOES-west plot should be positioned below the west TOA reflectance. Same holds for GOES-east. This will help a lot to interpret the figure.

P7977, Fig 8: A description of the regression lines is missing in the caption.

P7977, Fig 8: How the linear regressions were calculated. By eye I would assume completely different slopes. E.g., panel (h) most data is in a box between 0-0.1 AOD(AERONET) and 0-0.2 AOD(GOES). The slope should be much steeper. Here and also in other panels, AOD(AERONET) seem to have a lower threshold at about 0.05. This does not come out in the regression equations. Why? This differences should be discussed in the text.

P7978, Fig 9: This plot does not tell much. You may add some more information to interpret potential relations. E.g., mean AOD, scattering angle,...

P7979, Fig 10: Labels use GOES-11 and 12 here. Better use GOES-East and -West as before in the manuscript.