Atmos. Chem. Phys. Discuss., 12, C9561–C9567, 2012
www.atmos-chem-phys-discuss.net/12/C9561/2012/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Assessment of the Level-3 MODIS daily aerosol optical depth in the context of surface solar radiation and numerical weather modeling" *by* J. A. Ruiz-Arias et al.

J. A. Ruiz-Arias et al.

jararias@ujaen.es

Received and published: 20 November 2012

This paper attempts to validate daily "Level 3" (gridded, aggregated) MODIS aerosol retrieval products against daily averages of AERONET sunphotometer data. Whether or not the errors of Level 3 can be quantified has relevance to such applications as numerical weather prediction and solar energy forecasting. The results suggest that when the Level 3 product indicates AOD $<$0.5, that the uncertainty for Direct Normal Irradiance (DNI) is $<$15% and for Global Hemispheric irradiance (GHI) is $<$5%. These uncertainties are small enough that the L3 AOD is of sufficient quality to produce "good enough" GHI (but not DNI).

Overall, I think this paper is interesting and useful, but could use some clarifications. I would also like to comment the authors on their figure presentations. I think they are dense with information, yet readable. However, I would like more figure caption information for Fig 6. Having the benefit of also reading comments from other reviewers, I am generally happy with the authors' responses.

Response: We propose the next caption for Fig. 6: Joint histograms of the L3 AOD residuals (L3 AOD minus AERONET AOD). (a) AERONET AOD in the X-axis and pixel counts in the Y-axis. Colors of the joint-histogram bins indicate the mean residual of the collocations within that bin. (b) Cloud fraction in the X-axis and pixel counts in the Y-axis. Colors of the joint-histogram bins indicate the mean residual of the collocations within that bin. In both panels, the top plot contains the mean residual for all points forming each column bin (green line) and the fraction of points in that column bin (grey bars). The plot to the right of each histogram contains the mean residual for all the points forming each row bin (green line) and the fraction of points in that row bin (grey bars).

Major comments

1. As indicated clearly by another reviewer, there are aspects of ill-posed problems here. It is hard to justify comparing rather large spatial boxes ($1^\circ \times 1^\circ$) with single point AERONET measurements, even if these AERONET measurements were averaged over an entire day. Aerosol may be spatially homogenous on the 40-100 km scales, but only if there are no clouds (almost never). More likely there are heterogeneous cloud fields, surfaces, etc, in 1° that would make this assumption generally false. So "apparent error" or just plain "difference" is a better term, and the relationship between this "difference" and cloudiness (or un-retrievable pixels) should be more quantified. There is enough information

ACPD

12, C9561–C9567, 2012

in the MODIS Level 3 dataset (histograms, pixel counts, etc) that some of these questions could be explored more fully.

Response: We agree that the use of the term "error" in this evaluation effort is not appropriate without, at least, some cautionary explanation to make its meaning clear within the context of this work. In response to a comment along the same line by the anonymous referee #2 (available in the interactive discussions on-line) we proposed to add a new paragraph to address this issue, and we further commented on the reasoning to use a point-wise ground observations network to assess the Level-3 MODIS AOD product. We kindly refer this referee to this response for a clarification.

Regarding the role of clouds: in this work, as in former studies, it has been shown that high AOD values retrieved with MODIS have a higher uncertainty than lower values. This is directly linked to cloud-contaminated retrievals. Figure 6a (for easier discussion we include the figure in this response) shows that for small pixel-count values (small values in the y-axis of the joint histogram), when the cloudy situations occur, there is an evident overestimation of the MODIS AOD (see the green line in the right plot of Fig. 6a). Particularly, it can be seen that for small AERONET AOD values (small values in the x-axis of the joint histogram) the residual of the satellite is high, reaching up to about 0.15 (see the orange to dark-red colors in the lower-left corner of the joint histogram). This results in satellite estimates of more than 0.3 while the ground truth remains below 0.2. This is a typical situation for low pixel-count values as can be seen, again, in the right plot of Fig. 6a: the gray bars represent the amount of points in each pixel-count bin. Around 70% of the Level-3 AODs are calculated using less than 30 Level-2 AOD values.

Additionally, Figure 6b shows that, for low pixel-count values (small values in the y-axis) most of the points cluster around low values of cloud fraction (see gray bars on the left side of the upper plot in Fig. 6b). Specifically, about 40% of the satellite retrievals were done with less than 10% of cloud fraction. That is, when pixel-count is

ACPD

12, C9561–C9567, 2012

low, many MODIS observations are made under clear skies. But note that as the pixel cloud fraction increases the residual also increases. This, again, indicates and makes evident that MODIS overestimates when clouds are nearby.

Therefore, this issue is probably important enough to deserve a separate study. We agree with the reviewer that further analyses should be undertaken. In particular, we think that the increasing interest in aerosol observations from densely-populated small-scale grids, as discussed below, could be of great help to reach a deeper understanding of this issue. However, our main interest in this work was to conduct a global and general evaluation of the Level-3 MODIS AOD product with the aim of quantifying its potential usability for surface solar radiation assessment. Therefore, the issue raised by the reviewer is beyond the goal of this paper.

2. I am a little confused by the title. It is clear to me how estimation of GHI and DNI can help with applications such as solar energy forecasting. I am a little less clear how any of this information pertains to numerical weather modeling. Unless, I see that link explictely, I would recommend, dropping the "and numerical weather modeling" from the title.

Response: The "numerical weather modeling" stands because one of the motivations of the study was to evaluate whether the Level-3 AOD is worthy for weather models. Currently, if one wants to include the effect of aerosols on solar radiation in one of these models only one of two things can be done: i) use a climatology (monthly, typically), or ii) use a chemical transport model. In forecast applications, the use of a chemical model is likely the natural choice. But in hind-cast applications, for instance for local solar resource evaluation in feasibility studies of solar power plants, a better choice might be the use of direct AOD observations (from, e.g., MODIS) instead of climatologies or modeled data. The latter applications heavily use NWP models. But, obviously, the applicability of MODIS L3 data in that process is something that needs to be confirmed, and this is precisely what we try to do here. Moreover, and very importantly,

ACPD

12, C9561–C9567, 2012

a reliable gridded AOD database could also be used to improve the current aerosol parameterizations in weather models.

3. Which Level 3 products are actually being compared with AERONET? The separately retrieved data over land and ocean (e.g. "Corrected_Optical_Depth_Land_Mean" and "Effecitve_Optical_Depth_Ocean_Mean") or the already joined "Optical_Depth_Land_And_Ocean"? Presumably the already joined data includes only data with higher quality, but the other two parameters have no filtering for quality. Also, it is hard to tell whether any Deep Blue measurements are compared in this exercise (it is mentioned in section 1.1 that there is Deep Blue data, but I don't see what happens to them).

Response: We are using the already combined product (as mentioned in Sect. 2.1), with retrievals only with the Dark-Target algorithm. In the documentation it is stated that this product is only derived from data flagged QA=3 (highest quality). However, another reviewer noted that there is an error in the documentation so that, actually, they also include data flagged QA=1 and 2 over land, and QA=0, 1 and 2 over oceans. We'll indicate this in the Sect. 2.1 in the revised version of the manuscript.

4. One more assessment of Level 3 variability (and bias) might be to compare Terra against Aqua daily data? or Terra compared to MISR, or some other satellite dataset with spatial sampling? It turns out there may be calibration and aggregation issues that may make absolute differences hard to interpret, but one could compare L3-daily from two separate datasets.

Response: Some existing studies have focused on this: *Remer et al. (2005, doi: 10.1175/JAS3385.1), Levy et al. (2010, doi: 10.5194/acp-10-10399-2010), Mischenko*

ACPD

12, C9561–C9567, 2012

et al. (2008, doi: 10.1016/j.jqsrt.2009.11.003). We preferred to focus on the validation of the Level-3 AOD from MODIS aboard Terra because this should be enough to answer the question whether this product is usable or not for surface solar radiation. Former studies have shown that the differences between the Terra and Aqua sensors should be, or actually were, small. Moreover, although differences between MISR and MODIS have been documented, it is expected that these differences are not significant enough to discard the use of MISR for surface solar irradiance. We plan to expand our study towards MISR or other satellite sensors in the future.

Other comments

1. I want to point out that there is a recent focus for AERONET group to collect data in high resolution "grids". For example, there was the DISOCVER-AQ experiment performed in 2011, where 44 AERONET sites were deployed in an area about $1^\circ \times 1^\circ$ (see AERONET web site). Other similar experiments have been and will be held in other parts of the world. One upshot is that 40-100 "homogeneity" (e.g. Anderson et al, 2003) is definitely not a universal truth (especially in the vicinity of clouds and frontal systems).

Response: Such campaigns (as well as ground or airborne lidar observations) will indeed be essential in the near future to achieve a better understanding of the small-scale spatial variability of aerosols. We think that clouds play a major role in this variability, but also the surrounding mesoscale conditions and the chemical structure of the aerosol (composition, size distribution...), for instance. We think that our study might provide insights about this small-scale spatial variability and its causes if it is taken as a reference frame in future validations using dense networks of observation. It might provide details on how the small-scale variability evolves when it is averaged to synoptic scales as could be the one of the Level 3 products.

ACPD
12, C9561–C9567, 2012

2. Page 23224, lines 16-27. I understand what is being said here, but maybe a figure would help?

Response: These figures can be found in Hubanks et al. (2008) (http://modis-atmos.gsfc.nasa.gov/_docs/L3_ATBD_2008_12_04.pdf). We added this information to the text.

3. Page 23226: line 1. I think "annual" should be removed.

Response: From the abstract of Kaufman et al. (2000): "...AERONET demonstrates that Terra and Aqua aerosol measurements can represent the *annual* average value within 2% error. This excellent Terra representation of the daily average optical thickness is independent of..." They conducted their study on a yearly basis, and that is why they talk about annual averages of daily-averaged optical thickness.

ACPD

12, C9561–C9567, 2012