Assessment and ground-based correction of the Level-3 MODIS daily AOD implications in the context of surface solar radiation and numerical weather modeling

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INTRODUCTION AND OBJECTIVES

WHAT: Aerosol optical depth (AOD) is a semi-parametrical index for surface solar radiation assessment, in particular, for those applications involving direct irradiance. The Level-3 MODIS (L3M) daily AOD product is a global daily spatial aggregation of the Level-2 MODIS AOD (10 km spatial resolution) into a regular grid with a resolution of 1°x1°. It has interesting characteristics for surface solar radiation and numerical weather modeling applications. Remarkably, the Level 5.1 dataset extends more than a decade, and provides daily values of AOD over a global regular grid of 1°x1° spatial resolution.

HOWEVER: Most of the validation efforts so far have been focused on Level-2 products and only rarely on L3M products.

ASSESSMENT OF THE LEVEL-3 MODIS DAILY AOD PRODUCT

For some applications, the uncertainty associated with the AOD is needed. We found that both the mean error and the standard deviation of the apparent error can be fairly well approximated as a function of the L3M AOD value only. The figure to the left shows the error of the L3M AOD as compared against AERONET sites for all the globe (blue dots) as a function of the L3M AOD value. The blue-shaded area is the region encompassing the mean apparent error plus/minus one standard deviation. The solid and dashed lines are fitted curves to the experimental data using the following model:

\[
\Delta_{\text{L3}} = a_{\text{L3}} + b_{\text{L3}} \cdot \text{L3 aerosol optical depth}
\]

where \(a_{\text{L3}}\) and the coefficients \(b_{\text{L3}}\) were fitted for the mean apparent error and the standard deviation separately. The model can also be fitted for regional areas. From the figure it is clear that the mean error and its spread increase as the predicted L3M AOD value increases. Furthermore, for AOD values above 0.1 the increase is linear. For smaller AODs, the L3M AOD underestimates, in average.

A sensitivity study was conducted with the help of the REST2 broadband solar radiation model (Guemard, 2008). Our aim was to investigate how the Level-3 AOD uncertainty propagates into the calculated direct and global irradiances. The figure to the left shows the expected relative uncertainty in DNI assessment due only to the uncertainty in the L3M AOD, as resultant from our study. We assumed a standard atmosphere and a solar zenith angle of 30°. For average AOD values, the uncertainty keeps below 20% everywhere, but in West North America, where it is way off the rest of the regions. The same analysis for GHI reveals that the uncertainty keeps always smaller than 5%, with a maximum in all the regions around 0.1. Figures below show also the relative uncertainty expected in DNI (left) and GHI (right) due only to the uncertainty in the L3M AOD, but calculated for the mean AOD value observed at each AERONET station. From the figures, it is clear that the highest uncertainties in DNI assessment using L3M AOD values occur in Asia and northern and southern Africa, coinciding with the highest measured AODs. The highest uncertainties in GHI occur in west North America, as a consequence of the very low mean measured AOD. Note the different color scales in both panels.

An extended presentation of these and other results can be found in Ruiz-Arias et al. (2012), which also includes an update of the Level-2 MODIS AOD expected error to the L3M AOD, and discussions on the role of the pixel counts, the clouds and the spatial representativeness in the L3M AOD product.

LEVEL-3 MODIS DAILY AOD ANALYSES

The analysis of the L3M AOD product pursues to remove the existing data gaps and regional biases. The result is a daily regularly-gridded AOD dataset. The procedure entails three major steps: i) empirical bias reduction, ii) filling missing values, and iii) optimal interpolation of point-wise ground observations. The panel (a) of the figure to the left shows the available L3M AOD estimates from the satellite for June, 17th, 2009 in the study region. The data were previously bias corrected using Eq (1). The panels (b) and (c) show two gridded AOD versions after the data removal procedure using kriging. In the panel (b) the satellite retrievals error was weighted.

In the panel (c) the standard error of the L3M AOD values were included in the interpolation. As a result, the more uncertain pixels were filtered out. Usually these pixels correspond with measurements gathered in cloudy regions. In all the panels the available ground observations are shown as circles colored with the same color-scheme as the map. Panel (d) shows the result of the optimal interpolation stage. Note that the main biases of the map are removed.

The figure to the left shows in the top row the mean bias error of the initial L3M AOD dataset (left) and the error after the correction method (right). The bottom row shows the standard deviation of the error. The figure up to the right shows an independent validation in two SURFRAD stations not included in the assimilation. All these comparisons against ground data were approached using an iterative cross-validation.

CONCLUSIONS

The L3M AOD dataset is prone to data gaps and regional biases. Overall, the induced uncertainty in DNI is smaller than about 15% for AOD values below 0.3 (90% of the global AOD dataset). In GHI, the relative uncertainty keeps below 5%. Therefore, at regional scale, the L3M AOD is of overall quality to produce good-enough GHI estimates but, conversely, this is not generally the case for DNI.

The L3M AOD dataset can be corrected based on ground observations as those from the AERONET network. The data gaps can be removed and the biases corrected. With the correction methodology here proposed the DNI can be calculated within 5% of error (only due to AOD) for AOD values below 0.2, which are the 90% of the cases according to ground observations.

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REFERENCES