COMPARISON OF TWO METHODS FOR AEROSOL OPTICAL DEPTH RETRIEVAL OVER NORTH AFRICA FROM MSG/SEVIRI DATA

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ABSTRACT

A comparison between the algorithm for Land Aerosol property and Bidirectional reflectance Inversion by Time Series technique (LABITS) and a daily estimation of aerosol optical depth (AOD) algorithm (AERUS-GEO) over land surface using MSG/SEVIRI data over North Africa is presented. To obtain indications about the quantitative performance of two AOD retrieval methods mentioned above, daily SEVIRI AOD values is considered with respect to those measured from the global aerosol-monitoring Aerosol Robotic Network (AERONET) data. The correlation coefficient (R^2) between retrieved SEVIRI AOD at 650 nm from the AERUS-GEO algorithm and the AERONET Level 2.0 daily average AOD at 675 nm is 0.80 and root mean square error (RMSE) is 0.044, and R^2 between retrieved AOD from the LABITS algorithm and AERONET AOD is 0.80 and RMSE is 0.037.

Index Terms—Aerosol optical depth; LABITS; AERUS-GEO; MSG SEVIRI; North Africa

1. INTRODUCTION

Since atmospheric aerosols highly vary in their chemical and physical properties as well as in their spatiotemporal distribution, the description and quantification of their direct and indirect effects on the global radiation budget is still a challenging and complex task [1]. In spite of advances in aerosol remote sensing, most retrieval methods are limited by the nature of polar satellites, which does not allow accounting for the diurnal variations of atmospheric aerosol parameters. Up-to-date geostationary instruments like the Spinning Enhanced Visible and Infrared Imager (SEVIRI) on board the current and future satellites of the Meteosat Second Generation (MSG) offer considerable prospects to enhance the frequency of aerosol mapping.

The primary objective of the study described in this paper is to compare two AOD retrieval methods using MSG/SEVIRI data described in section 2.

2. METHODS

2.1. LABITS algorithm

Land Aerosol property and Bidirectional reflectance Inversion by Time Series technique (LABITS) algorithm was developed to jointly retrieve the surface reflectance and AOD based on two fundamental assumptions: (1) the surface reflective property changes little during the observation period; and (2) the aerosol optical properties change little over short distances. Therefore, if we use the Ross-Li BRF model, there are only three free parameters describing the surface reflectance during multiple observations, and if we define the elementary processing area as a block with the size of N, there are $N\times N$ pixels with the same AOD and other optical parameters for a single measurement. Except for AOD, the atmospheric parameters can be determined in advance based on prior knowledge (e.g., from ground-based measurements or satellite remote sensing products). Thus, during multiple observations, with the number K representing the block of $N\times N$ pixels and using one single optical channel for retrieval, there are KN^2 measurements and $K+3N^2$ unknowns. If $KN^2\geq K+3N^2$ then the number of measurements exceeds the number of unknowns, and we can jointly retrieve the surface BRF and AOD. Obviously, K=4 and N=2 can meet the requirements, and there are 16 measurements and 16 unknowns. The details of the atmospheric radiative transfer (RT) model and surface bidirectional reflectance distribution function model used to achieve this can be found in Li *et al.* [2, 3].

2.2. AERUS-GEO algorithm

An innovative method for joint retrieval of AOD and surface BRDF was presented in Carrer *et al*. [4]. The algorithm is computationally efficient for processing daily estimates over the full MSG disk, which ensures a geographic coverage of Europe, Africa and the eastern region of South America. The solution to the classical radiation transfer equation corresponding to a light beam traveling from the top of layer level downward to a land surface pixel and being bounced back upward to this level [5]. The solution is obtained through an unconstrained linear inversion procedure and perpetuated in time using a Kalman filter. More details can be found in Carrer *et al*. [4]. The method is called AERUS-GEO (Aerosol and surface albEdo Retrieval Using a directional Splitting method - application to GEO data). The collection 1 of AERUS-GEO will be disseminated in 2014 by the ICARE thematic centre based in France (http://www.icare.univ-lille1.fr).

3. EVALUATION OF THE METHOD

3.1. Implementation with SEVIRI observations

Since January 2004, SEVIRI sensor on the MSG satellite series is declared operational and performs quarter-hourly scans in the 650 nm visible band (560-710 nm). North Africa was chosen as the study area, and the range of latitude and longitude is around 22°W~55°E, 0°~39.5°N. Calibrated and geo-located SEVIRI scenes of level 1.5 data from 1 March 2006 to 15 March 2006 were selected. The two methods used the same top of atmosphere reflectance of the cloud-free MSG/SEVIRI data as input, of which the Rayleigh scattering and corrects for water vapor and ozone column absorption have been removed by using the Simplified Method for Atmospheric Correction (SMAC) [6]. Data preprocessing also includes a thorough cloud screening and the resulting pixels are flagged non-cloudy.

Figure 1 shows the retrieved AOD at 650 nm using SEVIRI data. Figure 1 (a) is the AOD map by the AERUS-GEO algorithm and Figure 1 (b) is the AOD map by the LABITS algorithm. In AERUS-GEO algorithm, all available observations of each day's SEVIRI scenes are used, so the retrieved AOD in Figure 1(a) represents the daily averaged AOD. In LABITS algorithm, AOD at 8:00, 9:00, 10:00, 11:00, 12:00, 13:00, 14:00, 15:00, 16:00 were derived each day. Figure 1(b) represents these 9 hours mean AOD. A strong belt of high AOD from west to east in the North Africa can be seen both in Figure 1(a) and Figure 1(b). This huge continental dust storm affecting the whole Sahara and West Africa in March 2006 was also well described by Tulet *et al.* [7].

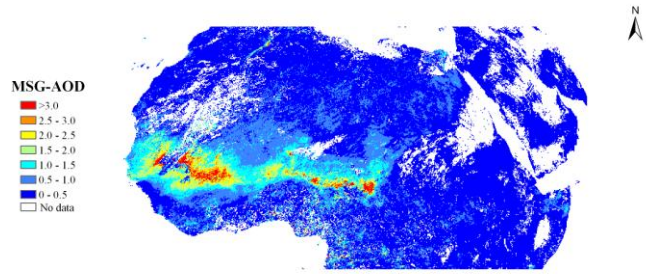

Figure 1(a). Spatial distribution of MSG AOD by the AERUS-GEO algorithm on 8 March 2006 over North Africa

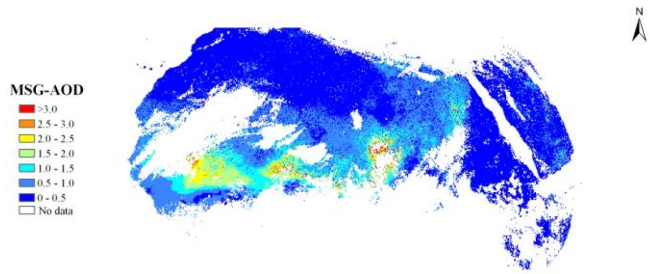

Figure 1(b). Spatial distribution of 9 hours' (8:00~16:00) means MSG AOD by LABITS algorithm on 8 March 2006 over North Africa

3.2. Comparison with AERONET data sets

To obtain some indication about the quantitative performance of two AOD retrieval method mentioned above, daily SEVIRI AOD values is considered with respect to those inverted from the global aerosol-monitoring Aerosol Robotic Network (AERONET, http://aeronet.gsfc.nasa.gov) data. 11 stations (Figure 2) are used to validate the retrieved AOD results.

Retrieved SEVIRI AOD at 650 nm and the AERONET Level 2.0 daily averaged AOD at 675 nm are compared. It is worth mentioning that the SEVIRI AOD values derived by the AERUS-GEO algorithm with relative uncertainty estimate larger than 75%, i.e., $\triangle\tau > 0.75\tau$, were discarded from the analysis in Figure 3. From Figure 3 and Figure 4, we noticed that the retrieved AOD is lower than the AERONET AOD when the AOD values greater than 1.0. It may be caused by the inaccuracy assumption of aerosol type. The asymmetric coefficient (g) is fixed as 0.6 in the AERUS-GEO algorithm, and g and single scattering albedo (w) is interpolated by very few AERONET sites in LABITS algorithm.

As AOD at multiple times can be derived by LABITS algorithm, we also compared the hourly AERONET AOD with retrieved MSG AOD as well as daily AODs in Figure 5. Due to space limitations, only lists the comparison of two AERONET sites.

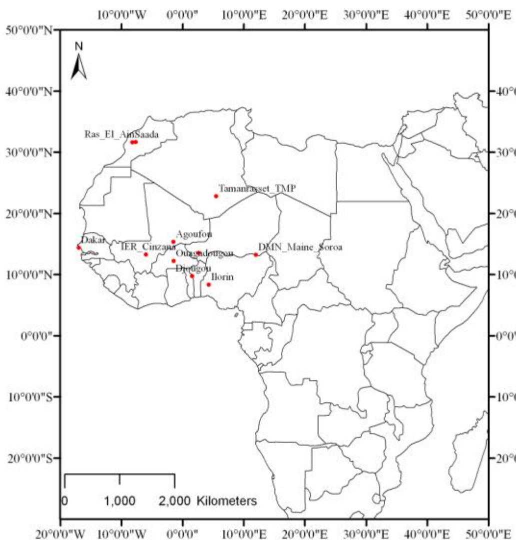

Figure 2. Location of the AERONET stations investigated in the present study

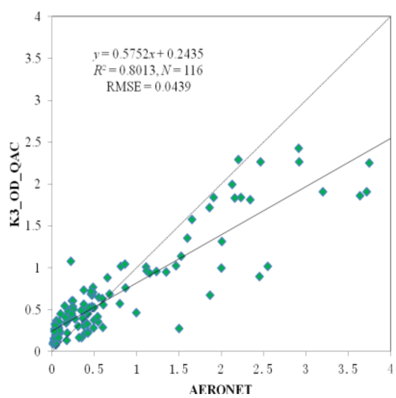

Figure 3. Scatterplots between daily average AERONET and MSG AOD estimates by the AERUS-GEO algorithm during 1 March 2006 to 15 March 2006.

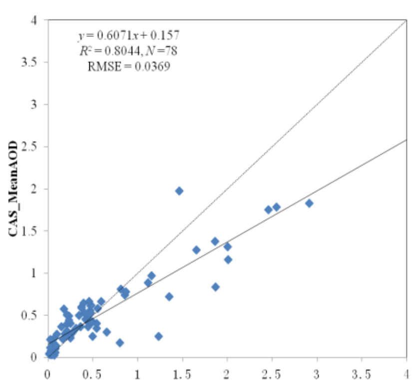

Figure 4. Scatterplots between daily average AERONET and Mean MSG AOD estimates by LABITS algorithm during 1 March 2006 to 15 March 2006.

4. CONCLUSIONS AND FUTURE WORK

The AERUS-GEO algorithm and the LABITS algorithm both can used for aerosol optical depth retrieval based on MSG by the time series technique. A comparison between these two algorithms for estimating AOD over land surface using MSG/SEVIRI data over North Africa is presented.

The reasons which caused these differences between two AOD retrieval methods as well as AERONET AOD should be analyzed by other ancillary data and ground surveys in future.

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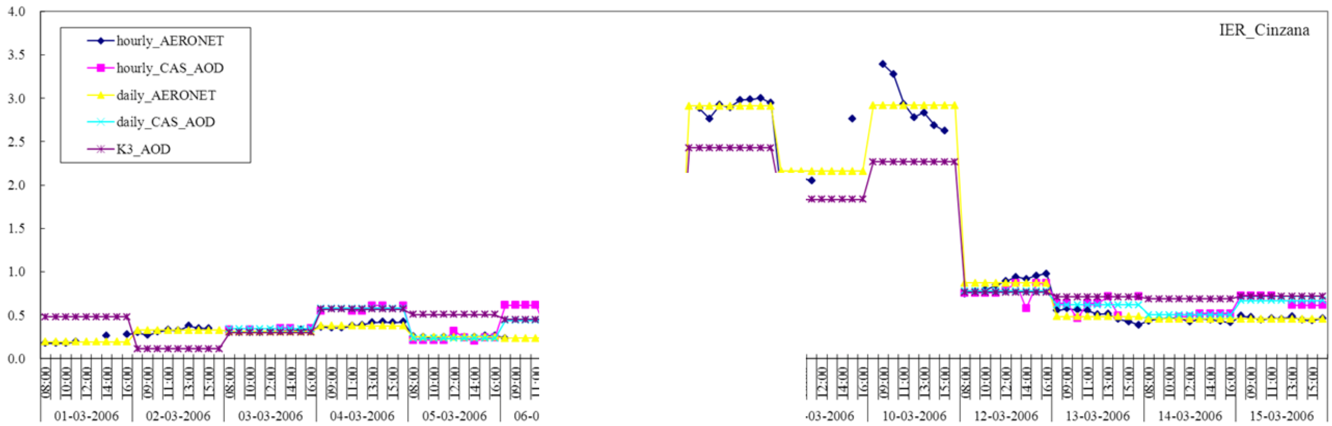

Figure 5(a). Comparison between AERONET and Retrieved AOD. "hourly_AERONET" means the AERONET Level 2.0 hourly averaged AOD at 675 nm, "hourly_CAS_AOD" means the AOD at 650 nm estimates by LABITS algorithm at 8:00, 9:00, 10:00, 11:00, 12:00, 13:00, 14:00, 15:00, 16:00 each day, "daily_CAS_AOD" means these 9 hours mean AOD estimates by LABITS algorithm, "daily_AERONET" means the daily averaged AERONET AOD and "K3_AOD" means the AOD at 650 nm estimates by AERUS-GEO algorithm. The X-axis represents the date and time, and the Y-axis represents AOD values. "IER_Cinzana" is the AERONET station name.

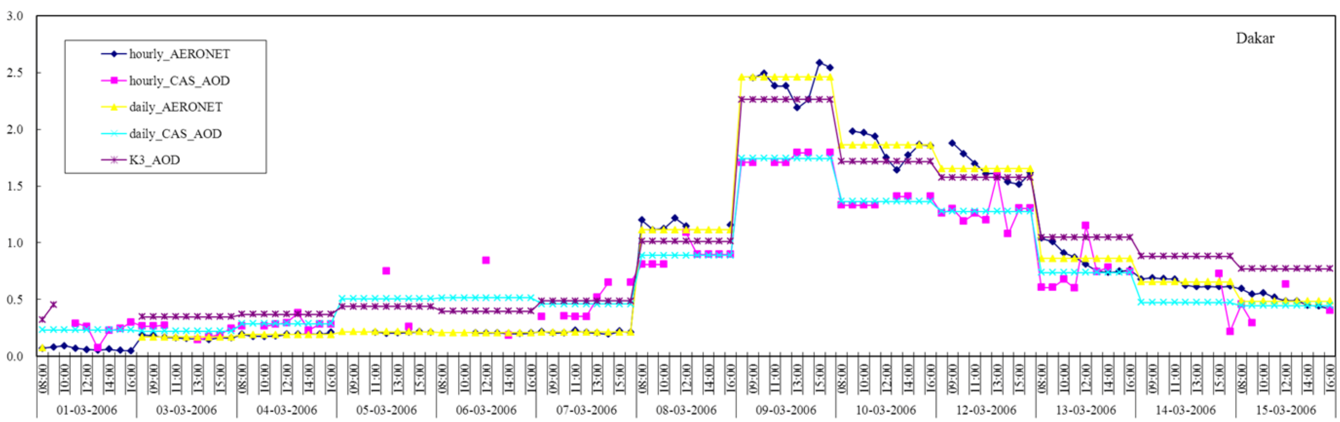

Figure 5(b). Some as Figure 5(c). "Dakar" is another AERONET station name.