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ABSTRACT

The paper presents an innovative method to derive aerosol optical thickness (AOT) on a continental scale, using MSG observation. The approach consists in taking into account the high temporal resolution of the observing system, in order to discriminate between surface and aerosol effects. A suitably extended semi-empirical BRDF model is applied, combined with a recursive scheme. The method is not instrument-specific (can be adapted to instruments onboard polar satellites) and was tested with MSG/SEVIRI data over mid-latitude and African regions. The aerosol optical thickness estimates are compared to AERONET ground measurements and to the corresponding MODIS product over land. The method appears very promising for tracking anthropogenic emissions in the troposphere and also for estimating dust events over bright surfaces. The high spatial and temporal resolution of the estimate is appropriate to investigate the dependence of AOT on the density of urbanization and potentially on motor vehicle traffic. Finally, this study suggests that this approach is appropriate for multi-sensor data fusion, for the simultaneous retrieval of surface albedo and aerosol optical thickness, and to generate these products in near-real time with a very high generation frequency.

1. INTRODUCTION

Recent projects use remote sensing information to document the presence and typology of aerosols. Algorithms developed for aerosol optical thickness (AOT) retrieval use to exploit primarily the spectral and spatial dimension of the signal. An examination of the wavelength dependence provides information for an analysis of the aerosol mode (fine, medium, coarse), which can be completed by polarization measurements. Moreover, the algorithms were specifically designed to be applied on dark targets like the oceans, and their transposition to land is not straightforward, while most of aerosol emission sources are located over land.

The main difficulty of aerosol detection (especially over bright surfaces) is the separation of the contributions to the measured signal that is due to atmospheric scattering and surface reflectance. A better quantification of temporal (and spatial) variations of the surface albedo would lead to a higher accuracy of aerosol estimates. In practice, simultaneous retrieval of surface albedo and aerosol information is complicated by the non-linear dependence of the measured signal on the physical variables.

In contrast with the preferred spectral-based and space-based methods, the method presented here focuses on a directional and temporal inspection of the satellite signal. The present method operates a simultaneous retrieval of the aerosol and surface Bidirectional Reflectance Distribution Function (BRDF).

2. METHODOLOGY

The approach consists in taking into account the high frequency of geostationary observations and high temporal variability of aerosol, as opposed to relatively more static surface, to derive AOT simultaneously with surface bi-directional reflectance. To track between eventual real high temporal variation of surface properties and suddenly aerosol effects the method discriminate directional signatures of the surface and aerosols by isolating at high solar angles the higher sensitivity to atmospheric properties (aerosol scattering in forward direction). A suitable extended semi-empirical BRDF model of surface atmosphere system materializes surface and aerosol directional signatures. This latter is combined with the use of Kalman filter which uses different temporal scales to characterize atmosphere and land surface properties and better discriminate each surface and aerosol contribution to directional signature of the signal. This is sustained by the fact that atmosphere and land surface properties evolve on different temporal scales. Detail descriptions of theory, physical assumption, and model parameterization are given in [1].

3. METHOD EVALUATION

3.1. Implementation with MSG/SEVIRI observations

Since January 2004, the Spinning Enhanced Visible and Infra Red Imager (SEVIRI) sensor on the Meteosat Second Generation (MSG) satellite series is declared operational and performs quarter-hourly scans in the 650 nm visible band referred hereafter as VIS06. The observation geometry per SEVIRI pixel remains invariable but illumination geometry between the scans changes during the day.

The retrieval method for daily aerosol described above was tested with MSG/SEVIRI data processed within the scope of the Satellite Application Facility for Land Surface Analysis (Land-SAF) [http://landsaf.meteo.pt/]. The satellite and auxiliary input data required for the aerosol retrieval correspond to those of the albedo algorithm developed for the Land-SAF system [2]-[3]. The calculations were carried out for the European and North African regions. Each day, all image scenes available at quarter-hourly intervals are collected. Required input data are column water vapor and atmospheric pressure estimates provided by forecasts of the European Centre for Medium-Range Weather Forecasts (ECMWF), as well the ozone content, which is specified according to the TOMS (Total Ozone Mapping Spectrometer) climatology.

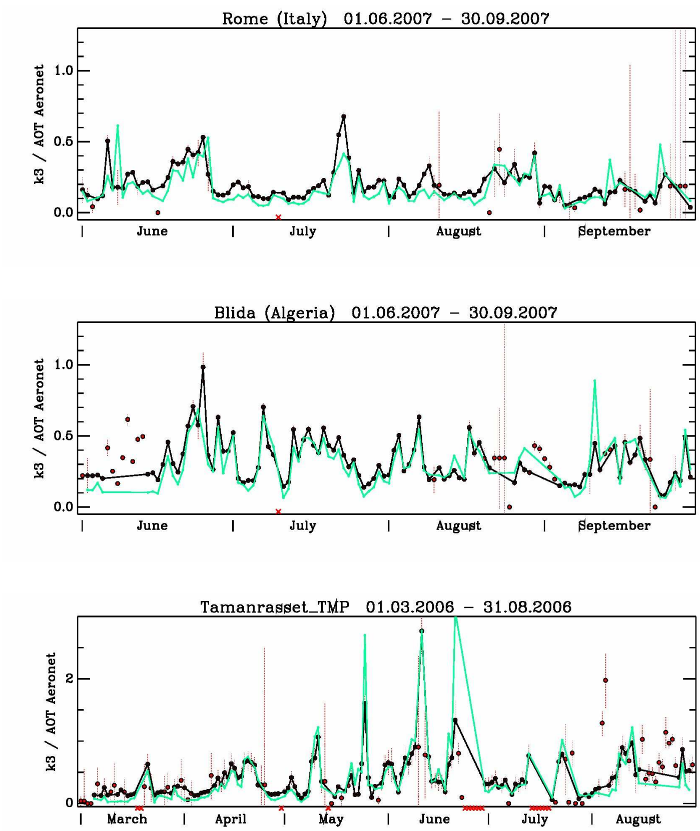

Figure 1: Time series of AOT values from SEVIRI (black) and AERONET (green) for 3 stations: Blida and Rome during the period June 1st 2007 to September 30th, 2007; Tamanrasset from March 1st 2006 to August 31th, 2006. Data points are connected provided the AERONET level 1.5 AOT is available and the corresponding SEVIRI estimate is better than 75% of its value. The vertical red bars represent the uncertainty. A red cross on the x-axis means no product available.

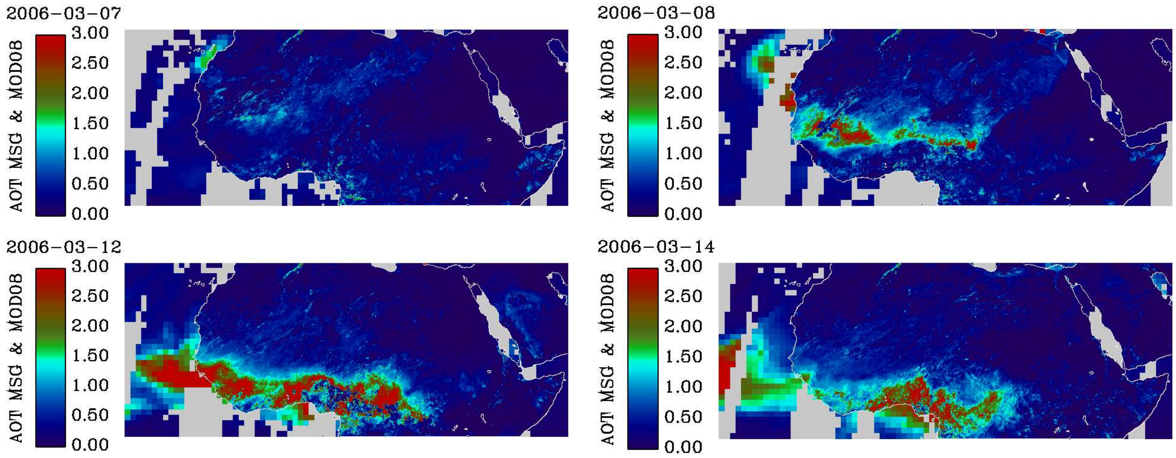

Figure 2: SEVIRI images of AOT at 650 nm on 7th, 8th, 12th, and 14th March 2006. MODIS AOT at 550 nm from Collection 5 is superimposed over ocean. The geographic projection is 0.1°x0.1° (over land for SEVIRI) and 1°x1° (over ocean for MODIS).

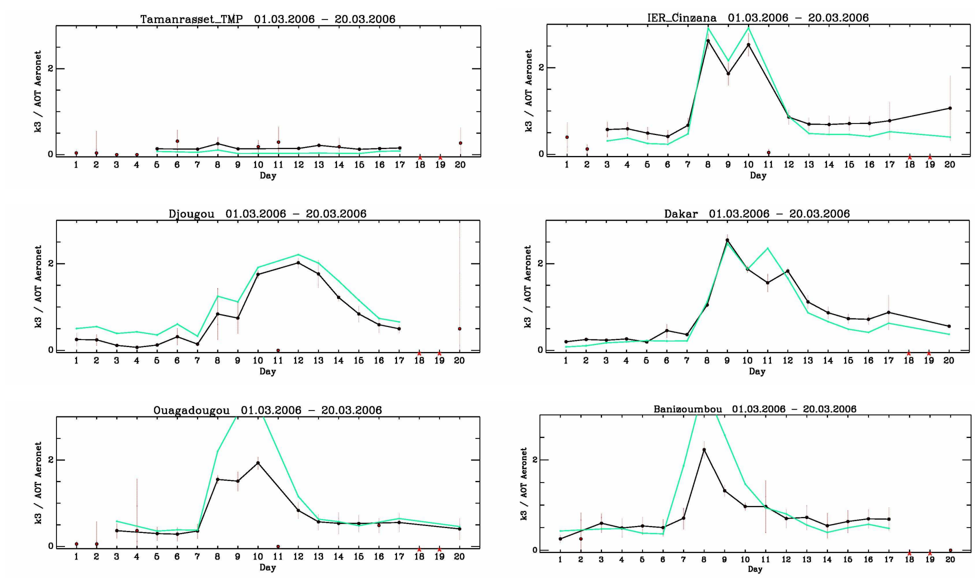

Figure 3: Time series of AERONET (green) and SEVIRI (black) AOT estimates during the period March 1st-20th, 2006, for 6 West African sites: Tamanrasset TMP (Algeria), Dakar (Senegal), IER Cinzana (Mali), Banizoumbou (Niger), Ouagadougou (Burkina Faso), and Djougou (Benin).

3.2. Comparison with AERONET data sets

To obtain some indications about the quantitative performance of the proposed algorithm, daily SEVIRI AOT values will now be considered with respect to those inverted from the global aerosol-monitoring Aerosol Robotic Network (AERONET, http://aeronet.gsfc.nasa.gov/), which encompasses ground-based sun-photometer measurements. We use the AERONET Level 1.5 representing cloud-cleared data without final calibration.

The estimates of the satellite-derived AOT compare favorably with AERONET measurements for a number of contrasted stations. Time series of daily SEVIRI pixel-based AOT at 650 nm are shown for the AERONET stations of Blida and Tamanrasset (Algeria), and Rome (Italy) (Figure 1). Over Blida, several strong aerosol episodes are observed with AOT values beyond 0.5. Such events are generally well reproduced both in timing and intensity by the satellite-based method and are likely due to dust occurrence. In Rome, the situation is complex because of the cumulative influence of maritime, desert and urban aerosols. A good correlation is observed. Over the desert site of Tamanrasset it is also the case even if some discrepancies are noticeable.

On March 8th 2006, an aerosol burden appeared suddenly along the inter-tropical front, probably from a source in the Bodele depression (lake Chad). During the following days, a pervasive aerosol plume stretched along the coastline of the Gulf of Guinea and intensified. Also observed were narrow thin dust plumes near the border between Mauritania and Senegal. Figure 2 depicts the chronology of well-pronounced aerosol episode stretching over several days in early March 2006. On March 7th, 2006, no aerosol concentration was yet noticeable. On March 8th 2006, an aerosol burden appeared suddenly along the inter-tropical front, probably from a source in the Bodele depression (lake Chad). During the following days, a pervasive aerosol plume stretched along the coastline of the Gulf of Guinea and intensified. Also observed were narrow thin dust plumes near the border between Mauritania and Senegal. Values of AOT up to 3 were not unusual. The phenomenon vanished totally on March 25th. The event is poorly evidenced with MODIS due to the difficulty of observing it over bright desert surfaces. It is worth emphasizing that we processed the SEVIRI pixels independently. Hence, the spatial coherence of the results reinforces the reliability of our method. Figure 3 illustrates the consistency between SEVIRI and AERONET AOT values for this event during the aerosol episode covered by six West African sites (Figure 3): Tamanrasset (Algeria), Dakar (Senegal), Cinzana (Mali), Banizoumbou (Niger), Ouagadougou (Burkina Faso), and Djougou (Benin).

4. CONCLUSION

An innovative method to retrieve daily aerosol optical thickness over land has been presented. The method is not instrument-specific and could also be applied to other kinds of satellite data. It would be interesting to test it on multi-sensor data. It consists in the application of a recursive scheme combined with a suitably extended semi-empirical BRDF model and also delivers an estimate of the retrieval quality. The approach was tested with data provided by the SEVIRI instrument onboard the MSG geostationary satellite.

Comparisons with AERONET AOT ground-measurements indicate the capability of the approach to react correctly to rapid aerosol fluctuations. This appears very promising for tracking anthropogenic emissions in the troposphere at mid-latitudes and also for estimating dust events over bright surfaces. Others comparisons are presented in [3]. Intercomparisons with instantaneous or monthly MODIS AOT show well-correlated products. Dependence of AOT on the density of urbanization and potentially on motor vehicle traffic was also investigated, and the consistency of the results supports the validity of the method.

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