IDENTIFICATION AND PHYSICAL RETRIEVAL OF DUST STORM FROM MSG GEOSTATIONARY OBSERVATION

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ABSTRACT: Aerosols influence significantly the radiation balance of the atmosphere and their role is crucial for a projection of the future climate scenario. The main difficulty of aerosol detection is the separation of the contributions to the measured signal that are due to atmospheric scattering and surface reflectance. An innovative method is presented to estimate the vertical column of aerosol optical depth (AOD) of the troposphere over the continents on daily basis. 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 retrieve AOD simultaneously with surface bi-directional reflectance. As a result, tracking rapid variations of surface properties or sudden aerosol episode is then made possible.

The application to observations that are offered by the Spinning Enhanced Visible and Infra Red Imager (SEVIRI) instrument onboard the geostationary satellite Meteosat Second Generation (MSG) was first carried on from June 2005 to August 2007 for mid-latitude regions in Europe and from March 2006 to August 2006 over Africa. The method appears competitive not only to track the anthropogenic aerosol emissions in the troposphere but also to estimate dust events over bright targets.

The present 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, e.g. by merging MSG and MetOp observations which is already planned for albedo retrieval in the framework of the SAF-Land project.

The low computation cost of the algorithm would make it possible to achieve a very high generation frequency, i.e. full disk coverage every 15 minutes corresponding to the repeat cycle of the MSG/SEVIRI instrument. This present algorithm is planned to be implemented in the EUMETSAT operational ground segment.

INTRODUCTION

Aerosols influence significantly the radiation balance of the atmosphere and their role is crucial for a projection of the future climate scenario. Because atmospheric particles have a direct link with energy use, economic activities and societal impacts of climate change, then the topic entails political issues in the context of the Intergovernmental Panel on Climate Change (IPCC, 2001). Indeed, a determination of the aerosol load in the low troposphere is at the core of many applications in a vast number of domains like epidemiologic risk, food security, air quality, health, natural hazards management, weather forecasting, climate change detection and hydrological cycle.

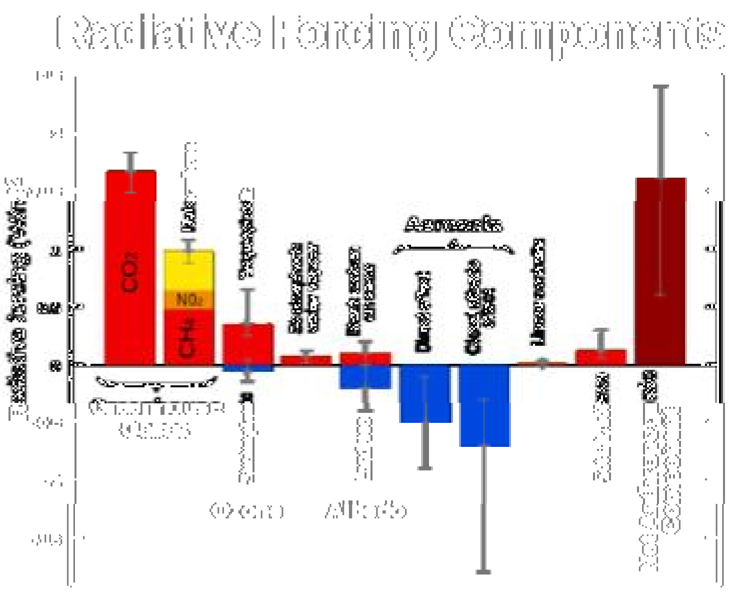

Figure 1: Estimation between 1750 and 2005 from GIEC

The main difficulty of aerosol detection (especially over bright surfaces) is the separation of the contributions to the measured signal that are 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.

Also over brightening surfaces, recent studies have been carried out to identify based on TIR window channels the dust-storm outbreak and the spatial extent. 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, and combines VIS and TIR channels for dust detection. The present method operates a simultaneous retrieval of the aerosol and surface Bidirectional Reflectance Distribution Function (BRDF).

METHODOLOGY

An innovative method [1] is presented to estimate the vertical column of aerosol optical depth (AOD) of the troposphere over the continents on daily basis. 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 retrieve AOD simultaneously with surface bi-directional reflectance.

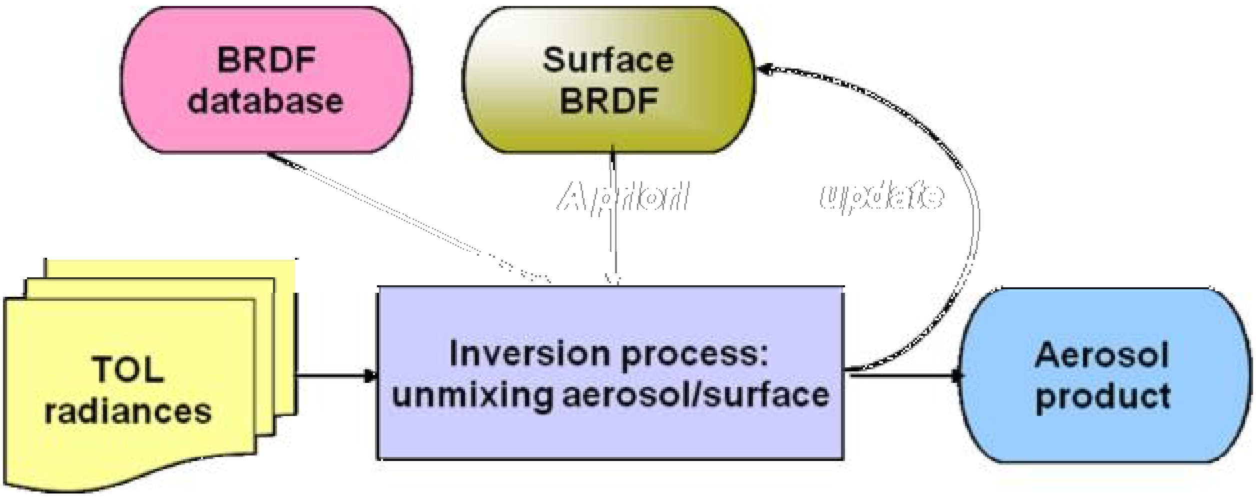

Figure 2: Method scheme

As the method operates a discrimination between the directional signatures of the surface and the ones for aerosols in using a kernel-driven BRDF model. The phase function of the aerosols according to Mie theory are fitted with an optimum double function Henyey-Greenstein, which plays the role of the aerosol kernel in the BRDF model. Aerosol types considered are dust, black carbon, and sea salt for different modes.

The method performs betters with data sets for high values of the solar angle because the forward scattering of light due to aerosol load is enhanced. As a result, tracking rapid variations of surface properties or sudden aerosol episode is then made possible. Surface and aerosol directional signatures are materialized by a suitable extended semi-empirical BRDF model of surface+atmosphere system This latter is combined with the use of Kalman filter which uses different temporal scales to characterize atmosphere and land surface properties. This serves a better discrimination of the surface and aerosol contributions to the directional signature of the whole signal. This is sustained by the fact that atmosphere and land surface properties evolve on different temporal scales. Based on numerical experiments using 6S atmospheric code, validity of the semi-empirical BRDF model is demonstrated.

Also, the presence of dust aerosols impacts the longwave outgoing radiation, allowing the aerosols over desert targets to be detected in the thermal infrared (TIR) wavelengths (De Paepe et al., 2008). For SEVIRI, the information from TIR channels is investigated in combination with the 3 VIS channels (0.6µm, 0.8µm,1.6µm)..

Figure 3: Aerosol optical depth retrieved in the 3 "visible" SEVIRI channels on March 9th, 2006. Clouds are flagged in white in the image.

EVALUATION OF THE METHOD

The application to observations that are offered by the Spinning Enhanced Visible and Infra Red Imager (SEVIRI) instrument onboard the geostationary satellite Meteosat Second Generation (MSG) is carried on from June 2005 to August 2007 for mid-latitude regions in Europe and from March 2006 to August 2006 over Africa.

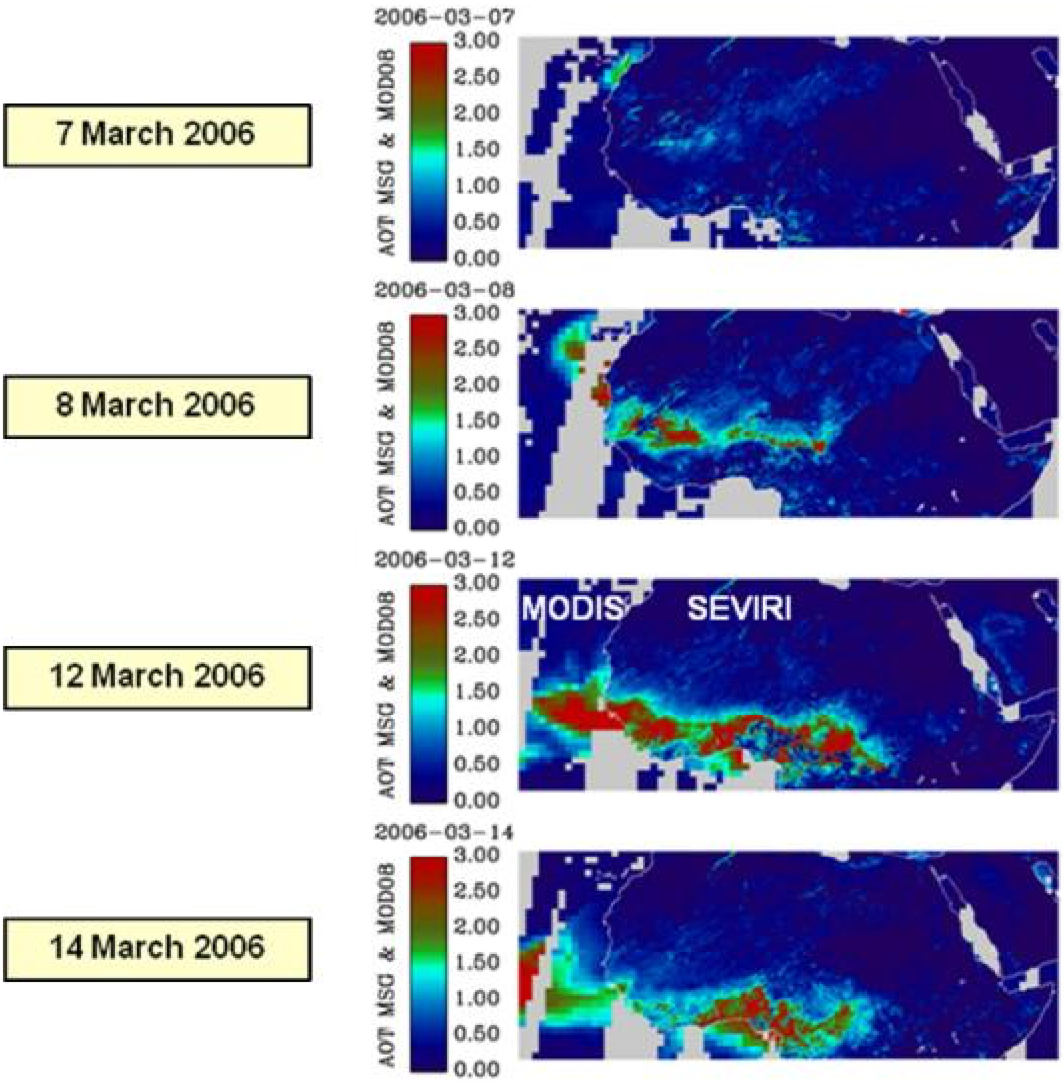

Figure 4: AOD550 retrieved by satellite. Our method was appllied over land while the MODIS product is ploted over ocean to show the consistency between the two products.

First, it was important to train the algorithm in order to improve the cloud detection in the case of intense episodes in aerosol and remove possible ambiguity with residual cloud coverage. However, cirrus may still be present at this stage. After a few days necessary to yield a numerical stability of the inversion algorithm, an analysis of the BRDF from SEVIRI over selected AERONET stations indicates a very good reactivity from day to day in the case of the aerosol event of 8 March 2006 seen at Dakar (Senegal) and Banizoumbou (Niger).

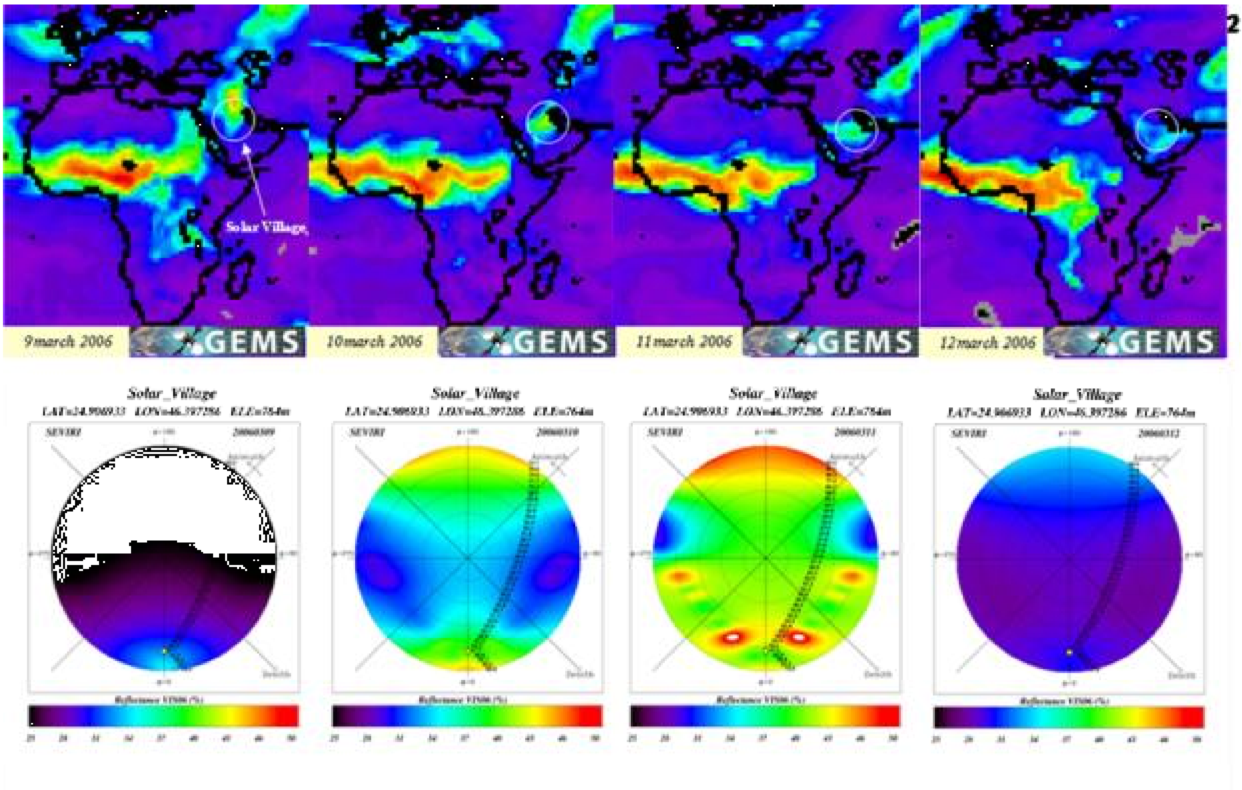

Figure 5: Tracking the change of the BRDF over Solar Village during an aerosol event. The forecast aerosol map is provided by the GEMS MACC project.

The forward peak of aerosol is evidenced here. The estimates of the satellite-derived AOD compare favorably with AERONET measurements for a number of contrasted stations and also similar MODIS (Moderate Resolution Imaging Spectro-radiometer) products, typically within 20% of accuracy. The method appears competitive not only to track the anthropogenic aerosol emissions in the troposphere but also to estimate dust events over bright targets. Particularly, different AOD values are obtained for each SEVIRI channel, which reveals the presence of particles of different sizes. For instance, large mode (coated particles) over ocean are evidenced by 1.6µm. Over desert, fine and medium dust modes are mixed from the information given by 0.6µm and 0.8µm. Furthermore, an aerosol class comes out that it is not sensitive particularly to any wavelength. This latter rather reports on the occurrence of fine cirrus. The additional information given by TIR channels is exploited to identify the dust storm occurrence and spatial extent. A dust event on March 2006 in Africa is investigated with VIS and IR bands.

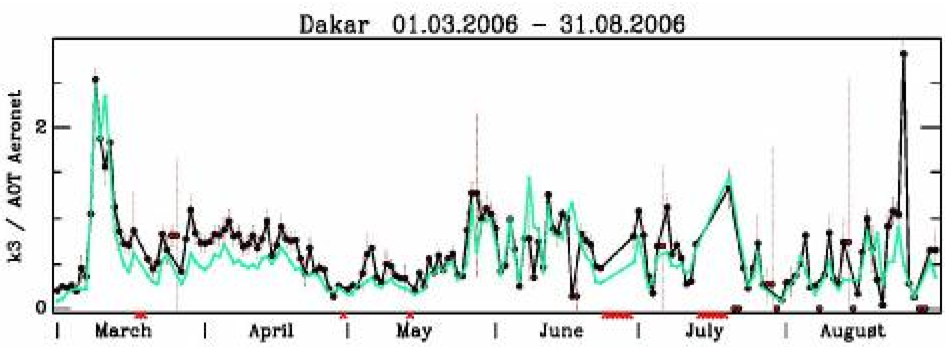

Figure 6: Validation of the AOD retrieved and the ground based aerosol data from the AERONET network. Aeronet data are shown in green while SEVIRI retrieval are shown in black.

PERSPECTIVES

An innovative method to retrieve daily AOD over land has been presented. 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. Also tests of combination of VIS and TIR channels are achieved for dust detection over brightening surfaces.

The present 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, e.g. by merging MSG and MetOp observations which is already planned for albedo retrieval in the framework of the SAF-Land project [2][3]. Including data from different instruments does not require further methodological developments.

The low computation cost of the algorithm would make it possible to achieve a very high generation frequency, i.e. full disk coverage every 15 minutes corresponding to the repeat cycle of the MSG/SEVIRI instrument. With regard to the growing size and frequency of remote sensing datasets, approached and computationally fast radiative transfer models are becoming increasing relevant [4]. In combination with the quantitative uncertainty estimate, this would be particularly useful for data assimilation purposes in the field of numerical weather prediction.

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