

IMPACT OF SEVIRI 1.6 μm CHANNEL ON AEROSOL CHARACTERISATION: A POLAR AND GEOSTATIONARY DATA BASED METHOD

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ABSTRACT

MSG SEVIRI's twelve spectral channels set new spectral, temporal and spatial standards with respect to the present METEOSAT MVIRI's.

Costa et al. (1999, 2000) have shown that aerosol optical properties and thickness can be derived from blended GOME (Global Ozone Monitoring Experiment) and MVIRI data, improving over the MVIRI stand alone aerosol mapping capability over the ocean. A potential exists for deriving additional spectral information from the new SEVIRI channels that complement GOME high spectral resolution spectra. GOME measurements are in fact limited to the visible-ultraviolet (UV-VIS) spectral region (up to 790 nm) imposing constraints on the characterization of coarse particles.

Test cases of GOME-METEOSAT synergy are chosen to test the effect on the inversion algorithm of the introduction of the near IR (NIR) spectral channel centered at 1.6 μm . The addition of the new spectral information is shown to have positive impacts on the existing method.

1. INTRODUCTION

Aerosol particles play a major role in the atmospheric processes. These particles scatter and absorb solar radiation and enter cloud microphysical processes as cloud condensation nuclei, heavily affecting precipitation processes, as recently confirmed by Rosenfeld (1999 and 2000).

Since these effects can be extremely relevant, not only an accurate characterization of aerosol particles is essential, but also a monitoring of their evolution in terms of particle load (aerosol optical thickness) and type. This can be achieved using measurements from satellite sensors. However, an accurate monitoring of aerosols can be problematic if a single sensor strategy is adopted, since presently there is no single sensor with optimum spatial/temporal/spectral resolution and coverage.

Geostationary (GEO) satellites ensure the adequate spatial and, most important, temporal resolution for monitoring the aerosol optical thickness on the global scale (Griggs, 1979; Moulin et al., 1997). However, due to the lack of spectral resolution of present GEO sensors, which is needed to characterize the aerosol properties, aerosol retrieval techniques are constrained to make use of fixed aerosol classes based on climatology. This can introduce considerable errors on aerosol optical thickness retrievals since these classes refer to mean atmospheric conditions that not necessarily represent the actual state of the atmosphere. Note that sensors onboard polar low Earth orbit (LEO) satellites are not suited to monitor atmospheric aerosol concentrations due to their poor temporal resolution. Nevertheless, some of these sensors supply essential data for an accurate aerosol analysis and characterization. In particular the GOME spectrometer (Burrows et al., 1999) onboard the polar orbiting satellite ERS-2 (European Remote Sensing Satellite) has been successfully used to retrieve aerosol properties over the ocean (Torricella et al., 1999; Bartoloni et al., 2000). Despite of GOME's low spatial resolution the techniques take advantage of its high spectral resolution to avoid gas absorption as much as possible.

Costa et al. (1999, 2000) presented an algorithm that aims at overcoming the obvious limitations from GEO as well as from LEO measurements. The method extends the accurate aerosol characterization obtained from LEO high spectral resolution sensors to the GEO scale, which ensures adequate spatial and temporal resolution for monitoring purposes. The comparison of retrievals using independent measurements from the ground-based sun/sky-photometer network AERONET (AEROSOL ROBOTIC NETWORK) and POLDER results is to be found in the paper by Costa et al. (2001). The work demonstrates that the proposed method is a powerful tool for aerosol characterization and optical thickness monitoring over oceanic areas covered by GEO satellites, especially for substantial aerosol transport events.

The new Spinning Enhanced Visible and InfraRed Imager (SEVIRI) scheduled to fly onboard the METEOSAT Second Generation (MSG) is expected to further improve the quality of the retrievals. The better calibration and spectral response accuracy as well as the narrower VIS and the new NIR spectral bands will allow for more accurate aerosol characterization.

A test is conducted of the effects of adding SEVIRI spectral information to GOME's spectral coverage (0.240 – 0.793 μm) used in the algorithm up to the present. The extension of the spectral coverage to the NIR region (the channel centered at 1.6 μm) provides further information to distinguish between different aerosol types, when the VIS spectral information is not enough. The study is based on simulations of the spectral reflectance for several aerosol types and optical thickness values prior to MSG launch due in year 2002.

2. SPECTRAL REFLECTANCE SIMULATIONS

Simulations of the spectral reflectance in the VIS and NIR spectral regions are done using the radiative transfer model 6S (Second Simulation of the Satellite Signal in the Solar Spectrum) (Vermote et al., 1997). The ocean surface is considered as a lambertian reflector and a tropical atmospheric vertical profile is taken. The impact of such approximations has already been addressed (Costa et al., 2000). Geometry is taken into account and consequently the simulations represent typical GOME measurements.

First, the spectral reflectance is simulated considering aerosol classes available in the literature and varying only the aerosol optical thickness values. The aerosol classes considered are: 1) maritime

defined accordingly to Vermote et al. (1997), 2) desert described by Shettle (1984), and 3) biomass burning presented in Remer et al. (1996). For each one of these classes the spectral reflectance is simulated for six different values of the aerosol optical thickness (0.0, 0.2, 0.5, 1.0, 2.0 and 3.0). The analysis of the simulations is presented in the next section.

Secondly, simulations have been computed varying not only the aerosol optical thickness values (0.2, 0.8 and 1.5), but also the aerosol microphysical characterization. Aerosols are characterized with a bimodal lognormal size distribution with a fine and a coarse mode, and a common spectral complex refractive index for both modes. The imaginary part of the refractive index is varied in two spectral regions (0.35-0.5 and 0.7-1.6 μm). Table 1 summarizes the parameters considered in the simulations. When more than one value is indicated for the same parameter this indicates that simulations were done by using both values.

Mode	Modal radius (μm)	Standard Deviation of the modal radius (μm)	Relative number density of particles	Spectral Complex Refractive Index	
				Spectral regions (μm)	
				0.35 – 0.50	0.70 – 1.6
Fine	0.08, 0.5	0.301	0.999, 0.80	1.48 – (1E-6, 1E-2)i	1.48 – (1E-6, 1E-2)i
Coarse	1.0, 5.0	0.301	1-0.999, 1-0.80		

Table 1 - Aerosol microphysical parameters used for the spectral reflectance simulation.

The simulated spectral reflectance values are used as input to the inversion algorithm (Costa et al., 2001) to retrieve the microphysical parameters characterizing the aerosols, with and without the NIR additional reflectance. The test of the impact of the channel on the aerosol parameters' retrieval is thus made possible. Results of the retrievals are presented in section 3.2.

3. RESULTS

3.1 SIMULATIONS VARYING THE AEROSOL CLASS

The spectral reflectance simulations considering three different aerosol classes taken from the literature and the six aforementioned aerosol optical thickness values are analyzed in order to understand the influence that the 1.6 μm spectral channel might exert on the aerosol characterization.

The plots in Fig. 1 show the analysis of the simulated reflectance at different wavelengths. The available spectral information is used to discriminate between different aerosol types, since the particle spectral behavior changes according to their microphysical/optical properties. The example in Fig. 1 corresponds to simulations for the nadir GOME ground pixels (see Burrows et al., 1999), for a solar zenith angle of 30°. The scatter plot in Fig. 1a makes use of simulations in the VIS spectral region strictly within GOME spectral coverage as a first attempt to discriminate the aerosol classes. The plot in Fig. 1b includes the additional simulated reflectance at 1.6 μm , which tries to quantify the contribution from SEVIRI.

Note that in the first scatter plot different aerosol classes can hardly be distinguished in some instances. In these cases the maritime and desert classes are very close to each other and consequently no clear discrimination is attainable. In the second plot when the NIR reflectance is considered the separation of the previously superimposed data points is evident. Moreover, when the aerosol optical thickness increases it becomes easier to distinguish between the various classes

since the dissimilar spectral behavior of the different aerosol types is magnified. The use of additional NIR spectral information is thus important for the discrimination of the aerosol type.

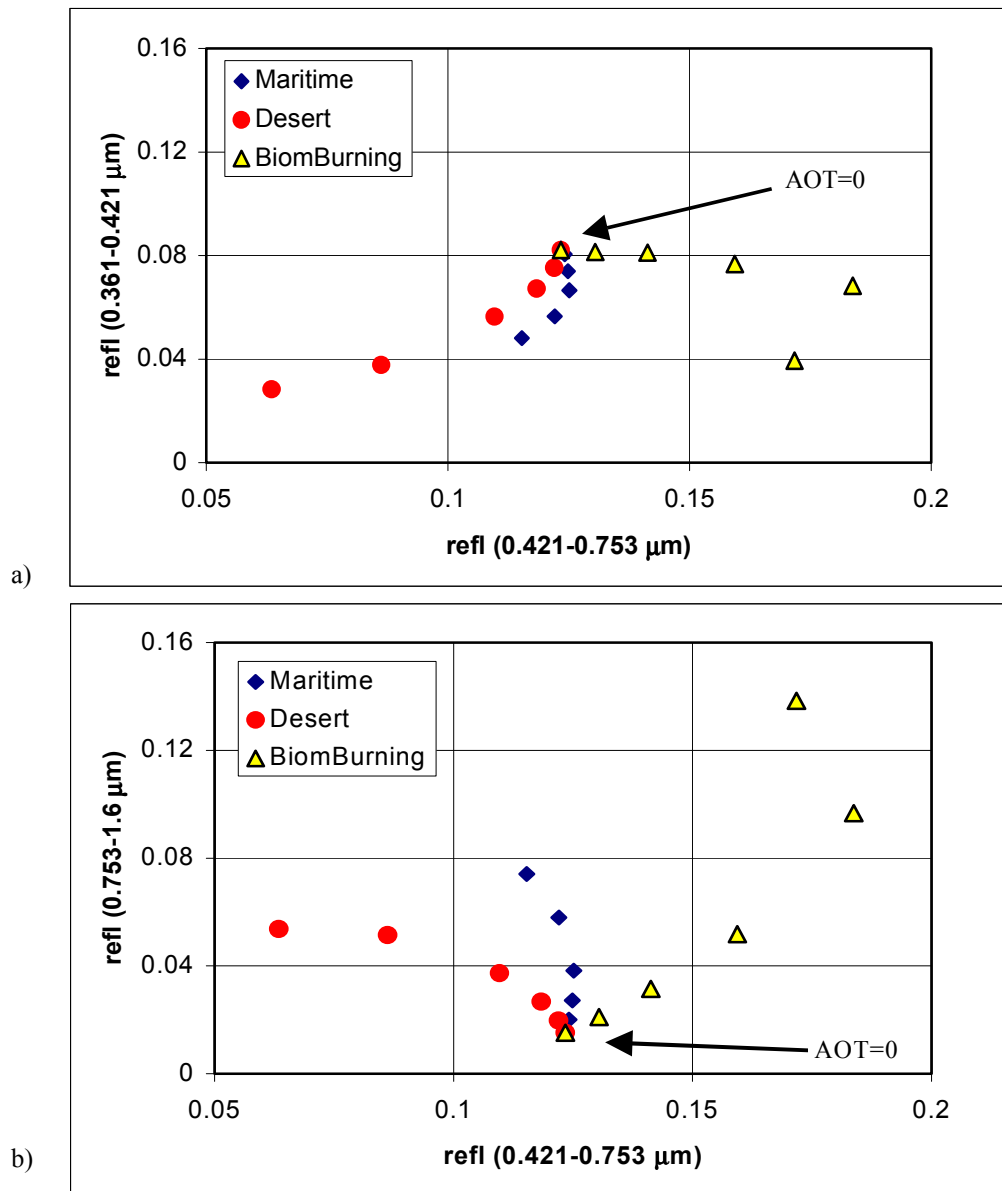


Figure 1 - Scatter plot of the simulated spectral reflectance difference (0.361 - 0.421 μm) (a) and (0.753 - 1.6 μm) (b) versus the simulated spectral reflectance difference (0.421 - 0.753 μm) for three aerosol classes taken from literature (maritime, desert and biomass burning) and six aerosol optical thickness (AOT) values (0.0, 0.2, 0.5, 1.0, 2.0 and 3.0).

3.2 SIMULATIONS VARYING THE AEROSOL MICROPHYSICAL PARAMETERS

The same analysis is applied to the simulations conducted varying the microphysical parameters characterizing the aerosols that are summarized in Table 1. Fig. 2 illustrates a few examples of spectral reflectance differences for a nadir GOME ground pixel when the solar zenith angle is 30°; the varying parameters are indicated in the legend.

The scatter plots show again that the addition of the 1.6 μm reflectance to the GOME simulated measurements (note that in Fig. 2 they are simulated data) allows for a better distinction of the

aerosol type. In fact, data points are superimposed only in the case of null aerosol optical thickness values since the simulations differ only for the aerosol characterization. When the optical thickness increases the discrimination between different aerosol particles becomes easier with the 1.6 μm channel as clearly demonstrated by aerosol types A and E.

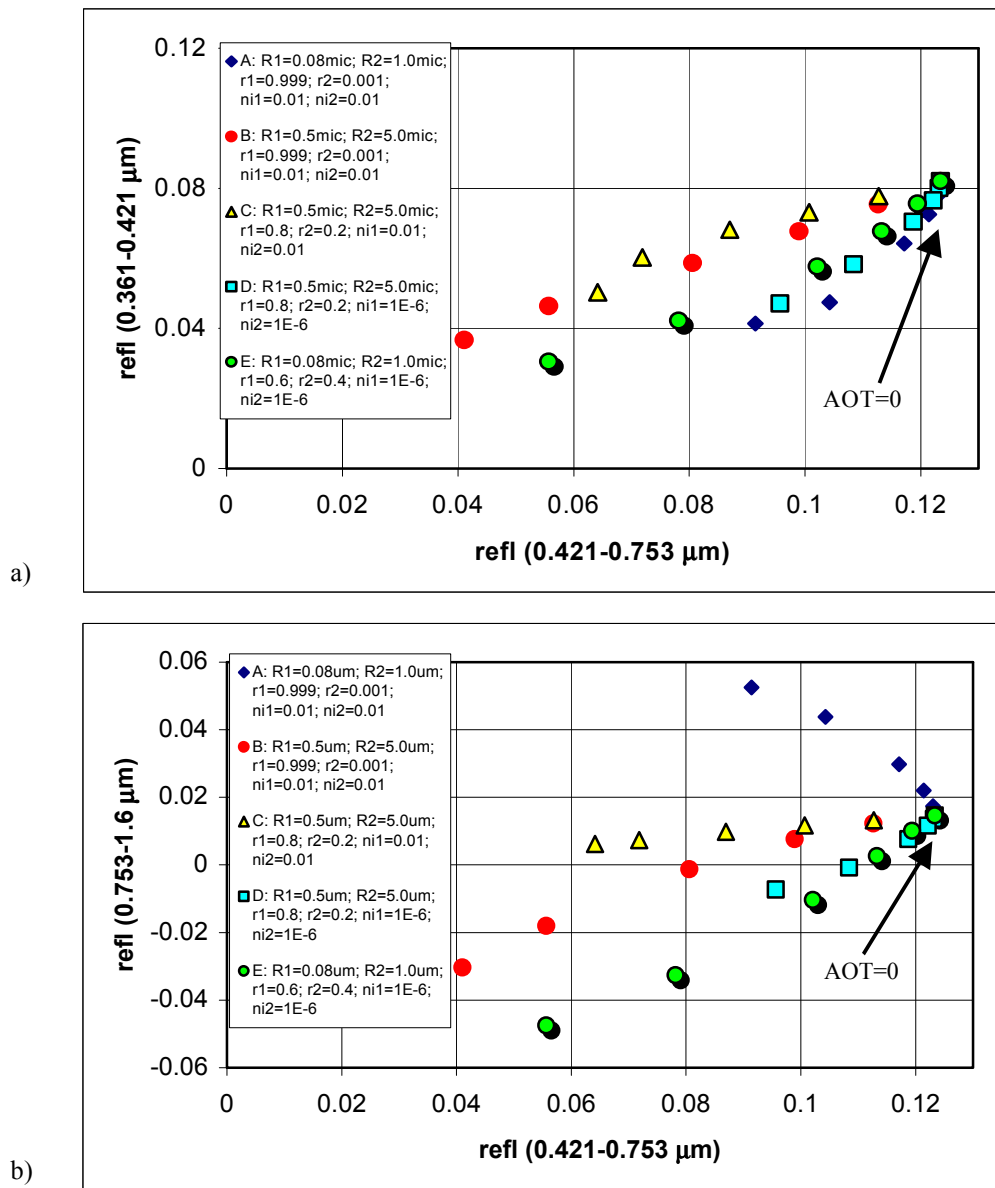


Figure 2 – Same as in Fig. 1 for several aerosol microphysical parameters' combination and six aerosol optical thickness (AOT) values (0.0, 0.2, 0.5, 1.0, 2.0 and 3.0). In the legend R1 and R2 represent the modal radii of the fine and coarse mode, respectively, r1 and r2 the relative number density of particles for the fine and coarse mode, and ni1 and ni2 the imaginary part of the refractive index for the two considered spectral regions (0.35-0.5 μm and 0.7-1.6 μm).

Simulations of the spectral reflectance are then pseudo-inverted in order to obtain the correspondent aerosol microphysical parameters (Costa et al., 2001). This inversion is performed twice, not considering and considering the 1.6 μm reflectance, aiming at verifying whether the additional spectral information plays an effective role in improving the aerosol characterization.

Table 2 displays the average results of the simulation for the aerosol optical thickness, coarse mode modal radius and relative particle number density. Results summarize the pseudo-inversion of 25 simulations.

Parameter	Simulated Value	Retrieval not considering 1.6 μm channel		Retrieval considering 1.6 μm channel	
		Average	Standard Deviation	Average	Standard Deviation
Aerosol Optical Thickness	0.8	0.8	0.08	0.8	0.04
	1.5	1.4	0.1	1.5	0.09
Modal radius - coarse mode (μm)	1.0	1.0	0.2	1.0	0.1
	5.0	4.9	0.6	5.0	0.4
Relative number density of particles (fine mode)	0.8	0.8	0.05	0.8	0.02
	0.999	0.978	0.017	0.986	0.015

Table 2 – Average parameters obtained from the pseudo-inversion of the simulated spectral reflectance values computed varying the set of parameters summarized in Table 1.

The average retrieved values of the aerosol optical thickness match the simulated ones. However, the standard deviation is higher when the 1.6 μm channel is not considered.

The retrieved coarse mode modal radius for the 1.0 μm case matches the simulated value in both cases, but once more a lower standard deviation is computed when the new channel is used. As for the 5.0 μm case, the disagreement disappears when using the 1.6 μm reflectance. This may be explained by the fact that these particles are too large to be detected from the scattered radiation measured by GOME, which is limited to the UV-VIS spectral range. When using also the NIR reflectance, the sensitivity to particles of comparable size increases.

The relative number density of particles retrieved for the fine mode is also presented in Table 2. The sum of this parameter for both modes equals 1.0, so the relative number density of particles for the coarse mode can be easily obtained. There is a greater dispersion of results for 0.8 case than for 0.999 (higher standard deviation values), which diminishes when the 1.6 μm reflectance is used. A possible explanation is the increase of the coarse particles' fraction, which increases the importance of using measurements that are sensitive to larger particles.

4. CONCLUSION

The analysis aims at verifying whether the use of the SEVIRI NIR spectral channel centered at 1.6 μm improves results of an aerosol characterization method based on GOME UV-VIS spectral measurements (Costa et al., 2001).

As expected, the new spectral channel is shown to be sensitive to optically quite different aerosol classes, as biomass burning and desert types. Furthermore, the analysis reveals that the distinction between aerosol classes characterized in terms of microphysical parameters instead of static literature classes, improves when the new channel is considered.

In particular, the use of the new channel seems to be more effective as the fraction of the coarse particle mode increases, resulting mainly in the reduction of uncertainties associated with other variable quantities that interfere in the retrievals.

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