AATSR DERIVED AEROSOL PROPERTIES OVER LAND

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ABSTRACT

The dual view of the Advanced Along Track Scanning Radiometer (AATSR) allows for the accurate retrieval of aerosol properties over land using an algorithm in which these two views are used to eliminate the influence of the land reflectance on the top of the atmosphere radiation. The algorithm uses the AATSR IR and visible wavebands for cloud detection and the visible wavebands for aerosol retrieval. The retrieval is based on minimizing the error function between modeled and measured TOA reflectances, using all available wavelengths. The TOA reflectances are modeled for a variety of aerosol mixes. Hence, both the aerosol optical depth at various wavelengths (and thus the Ångström coefficient) and the mixing ratio of the dominant aerosol types can be determined. The results are evaluated by comparison with independent data: sun photometers and, when available, aerosol composition. In this contribution, the AATSR results are evaluated, based on comparisons between AATSR and MODIS AOD, and AERONET data. Results are used for assimilation in a regional scale chemistry transport model. The goal is to use satellite data for the determination of PM2.5. Other applications at TNO are in the synergistic use with other satellites such as MSG-SEVIRI and OMI.

1. INTRODUCTION

Aerosol properties are retrieved from radiances observed at the top of the atmosphere (TOA) using various different instruments. The first retrievals were made over 25 years ago using a series of AVHRR instruments over the ocean and using TOMS for the absorbing aerosol index, a qualitative measure for the amount of absorbing aerosol particles. In the 1990’s other instruments were used to retrieve aerosol properties over the ocean. The first aerosol retrievals over land were made by Veefkind et al. (1998) over the USA East coast continuing over the North Atlantic, using TARFOX data for comparison. Veefkind et al. used the two views offered by the Along Track Scanning Radiometer ATSR-2 on board ERS-2, which allowed to account for land surface effects by using the ratio of the surface reflectance in the nadir and forward views, determined at 1.6 μm, assuming that the effect of aerosols in this wavelength band was small and that the ratio of the reflectances was independent of wavelength and could thus be used in the visible. Other publications on aerosol retrieval over land followed using, e.g., MODIS, POLDER-1 and 2, MISR, SeaWiffs, MERIS, AVHRR, as well as GOME, SCIAMACHY, OMI and recently also using geostationary satellites such as GOES and MSG-SEVIRI.

At TNO the use of ATSR-2 was pursued and various case studies showed the progress and applicability of this instrument. Aerosol properties that can be retrieved over land are the spectral aerosol optical depth (AOD) (0.555, 0.659 and 1.6 μm), the Ångström coefficient (which describes the wavelength dependence as a power law) and an indication for the most likely aerosol type. The algorithm has been applied over the East coast of the USA [1] and the North Atlantic [2], over Europe [3, 4], over S Asia and the Indian Ocean [5] and over Africa [6]. As an example, the AOD over Europe for July 2000 is shown in Fig. 1.

2. ATSR-2 AND AATSR

ATSR-2 on ERS-2 the Advanced Along Track Scanning Radiometer AATSR on ENVISAT are dual view imaging spectrometers with seven wavelength bands, four in the visible and NIR (0.555, 0.659, 0.865, and 1.6 μm) and three in TIR (3.7, 11, and 12 μm). The resolution of these instruments is 1 x 1 km² at nadir view and the swath width is 512 km, resulting in a return time of three days at mid-latitudes. The nadir view and the forward view at 55° incident angle to the surface allow for near-simultaneous observation of the same area on the Earth’s surface through two different
atmospheric columns within a time interval of approx. 2.5 minutes.

**Figure 1.** AOD over Europe for July 2000. The Fig. is a composite of all AOD data retrieved from ATSR-2 for that month.

**3. AEROSOL RETRIEVAL OVER LAND USING AATSR DATA**

The algorithm has also been applied using the Advanced Along track Scanning Radiometer (AATSR) to retrieve optical properties of aerosol over Europe for 2003 (Fig. 2), to assess the use of satellite data to determine PM2.5. Also MODIS data were used in this study and comparisons were made with MODIS, AATSR and AERONET (Fig. 3). The results show that AATSR usually compared favourably with AERONET sites, but spatial correlations were less good and also the spatial patterns were not as expected from earlier measurements and independent ground based and satellite observations. In view of earlier results with ATSR-2 this was a surprise and the results were rigorously screened which rendered a spatial pattern which was closer to expectation (Fig. 4), but only few data were left. Apparently the initial comparison with AERONET was already good because both data sets were screened for the presence of clouds, and only when both AATSR and AERONET observations were cloud free, the data were used. When only AATSR data were available, this second cloud check was not available and the screening may have been insufficient. In the remaining data set AATSR AOD scores were similar to MODIS data. Because MODIS has been shown to have a seasonal bias over Europe (cf. Fig. 3 as an example) and also elsewhere it’s performance over land could be better [7, 8], AATSR retrieval was further pursued. Fig. 3 further shows that AATSR performs quite well during the summer months, whereas during the fall and winter there are significant outliers. To further investigate this, the AATSR retrieval results were thoroughly checked for a small focus area to investigate whether objective methods can be applied to improve the data quality.

**Figure 2.** AOD over Europe for August 2003. The Fig. is a composite of all AOD data retrieved from AATSR for that month. Note that the spatial patterns are significantly different from those in Fig. 1.

**Figure 3.** Comparison of AATSR, MODIS and AERONET AOD measured over the AERONET site Avignon, for 2003.

**Figure 4.** As Fig. 3, but for August 2003 after application of a very rigorous screening in which, for instance, all results over potential problem areas were deleted, pixels with only few data were deleted, etc.
4. Data quality improvement

To improve the data quality, both views were used in the cloud screening process, as opposed to a single view. Further, all results were statistically analysed, i.e. all individual pixels of 1x1 km² were re-gridded into 10x10 km² pixels and in the distribution of AOD values both the highest and the lowest outliers were removed. This procedure is based on the assumption that no large gradients are expected in the aerosol concentrations on scales of 1 km, unless strong point sources are present. The latter has not been tested, nor has been tested whether gradual variations exist within a 10x10 km² pixel. This will be done in the future.

For the remaining pixels the standard deviation was calculated and when this exceeded a threshold the data were flagged as possibly cloud contaminated. In that case they can either be removed from the data set, or a value can be assigned based on interpolation between neighbouring pixels.

The procedure is illustrated in Figs. 5-7, with a frame over The Netherlands and Belgium, stretching into N. France and Germany.

5. Conclusions

Results presented in the past show that the ATSR-2 and AATSR aerosol retrieval algorithm works well, for all areas where it has been applied. The accuracy over water using ATSR-2 data is 0.04, based on comparison with independent ground-based measurements, usually AERONET sun photometer data. Coastal waters often cause a problem because of sub-surface reflectances by suspended matter and the retrieval is often less reliable when this occurs. Also the presence of algae blooms (Chlorophyll) may render less accurate results. This causes discontinuities in the AOD across land-sea boundaries. Land surfaces are usually brighter and often the contribution of the surface to the reflectance at the TOA is significant and needs to be accounted for to accurately determine the aerosol properties. The surface contribution to the TOA reflectance can be eliminated by using multiple viewing angles such as provided by (A)ATSR. (A)ATSR provides one viewing angle in nadir and one in the forward direction. This feature has been applied over land in various regions around the world and comparisons with AERONET data provide a means to evaluate the results, showing an excellent accuracy of 0.05-0.06 over most land surfaces.

Figure 5. Forward view showing an aerosol plume over the central part of the Netherlands, a thick cloud deck in the north and cloud patches in the SW.

Figure 6. Retrieved AOD. Comparison with the AERONET site in Hamburg [53.57N, 9.97E] shows excellent agreement (0.30 for AERONET vs 0.31 for AATSR). Other AERONET sites did not have data for the overpass.

Figure 7. Standard deviations within 10x10 km² pixels.
The scientific algorithms have been put together in a ‘quasi operational algorithm’ that was applied over Europe for 2000 using ATSR-2 data and for 2003 using AATSR data. As shown above, the latter poses some problems as regards spatial correlation, although in general the results compare favourably with AERONET. Likely this is due to insufficient cloud screening leaving sub-pixel clouds undetected. To overcome this, both the forward and nadir views are used and unless both indicate a cloud free pixel the pixel is flagged as cloudy. Furthermore statistics are applied to look at small scale variability that could be caused by clouds. As indicated, this needs to be further investigated to improve data quality.

The TNO aerosol retrieval algorithms have been transferred to Finland where they have been implemented at the University of Helsinki and the Finnish Meteorological Institute (FMI). In a cooperation between the three institutes they will be further improved and applied for scientific studies as well as to develop operational services. The latter will be demonstrated as part of the ESA project TEMIS for AOD over the Po Valley. In the framework of both scientific and applied projects the application needs to be extended to global scales. Studies are starting for application over China, India, Africa and the Amazon.

Furthermore, the synergy with other instruments will be explored, such as combining the AATSR accuracy with the high temporal resolution of MSG-SEVIRI.

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7. References