Development of EO Aerosol Products

A contribution to ACCENT-TROPOSAT-2, Task Group 1
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Summary

Aerosol retrieval work at TNO in the second year of ACCENT was aimed at the further application of AATSR data to extend the data base over Europe with 2003 data, including Mega cities, and its application for data assimilation on the LOTOS model, for the assessment of PM2.5 and radiative forcing. Evaluation of AATSR retrievals with campaign data was continued: bright surfaces (UAE^2 campaign), over Northern Italy (ADRIEX campaign), validation of OMI aerosol retrieval (DANDELIONS campaigns) and the application for the synergistic use of MSG-SEVIRI and AATSR.

Introduction

Satellites allow for the instantaneous observation of aerosol properties over large areas. However, as discussed in the first year report (De Leeuw et al., 2005), the retrieval of aerosol properties over land using satellites is hampered by the large contribution of the surface reflectance to the satellite observed radiance at the top of the atmosphere. This may be overcome by using multiple views of the same area. At TNO, we are using the dual view of the Advanced Along Track Scanning Radiometer (AATSR) to eliminate the surface reflectance. 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 the available visible and near infrared wavelengths. The TOA reflectances are modeled for a variety of aerosol mixtures. As a result, 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.

The TNO single and dual view algorithms have been merged into a quasi-operational algorithm that has been demonstrated to work well over Europe. Data over Europe for the year 2000 are available as a service through GSE PROMOTE (http://www.gse-promote.org/) and TEMIS (www.temis.nl). This data base has been extended for the year 2003. The results have been compared to MODIS AOD, using AERONET data as reference (Timmermans et al. 2006). Results are used for assimilation in a regional scale chemistry transport model to determine both PM2.5 and aerosol radiative forcing. Current studies focus on Europe for the year 2003, with a zoom on megacities. Furthermore, the synergistic use of AATSR and MSG-SEVIRI is explored to improve the temporal resolution which may be an advantage for restriction of the model results using data assimilation (Bennouna and De Leeuw, 2006). OMI data are used to provide global coverage of satellite-derived aerosol properties (Curier et al., 2006).

Scientific activities

1. Improvement of algorithms for the retrieval of aerosol properties such as AOD, Ångström parameter and speciation from ATSR-2 and AATSR data. *In situ* data from

monitoring sites (AERONET, but also aerosol chemical and physical observations) and field campaigns such as DANDELIONS and ADRIEX are used to further improve and test algorithms for a variety of different aerosol mixtures, and for validation of the results.

2. Improvement of the OMI algorithm and validation of the results with in situ data from sites such as Cabauw and application of OMI data for scientific studies.
3. Comparison of AATSR and OMI retrievals with other satellites
4. Exploration of the synergy of different sensors on the same or on different platforms for the retrieval of aerosol properties. In particular the synergy between geostationary and polar orbiting platforms (e.g., SEVIRI/AATSR) is promising to simultaneously achieve high spatial and high temporal resolution.
5. Assimilation of EO aerosol products in CTM and, vice versa, exploration of the use of CTM to improve the retrieval results.
6. Development of aerosol products such as maps of aerosol properties on local, regional and global scales with the appropriate spatial resolutions, time series and provision of NRT AATSR data. Applications to AQ studies (PM2.5) and radiative forcing. This activity will be undertaken in close interaction with the various user communities, including both scientific and institutional users.

Scientific results and highlights

AATSR. The use of the scientific single (SV) and dual view (DV) aerosol retrieval algorithms is very time consuming. Therefore, in the framework of the ESA DUP project TEMIS and EU FP5 project CREATE, they were used as the basis for the development of a quasi-operational ATSR-2/AATSR aerosol retrieval algorithm, as reported in the first annual report (De Leeuw et al., 2005). This algorithm has now been applied to provide the AOD over Europe for the whole year of 2003, with a resolution of 10x10 km^2, and over 4 Megacities with a resolution of 2x2 km^2. This was done in the framework of the Dutch National project HIRAM (coordinated by Dr Koelemeijer of the Netherlands Environmental Assessment Agency) to derive PM2.5 and radiative forcings, as well as the exploration of the use of satellite data for determination of the emissions of Megacities. To this end, the satellite data were assimilated in the TNO BSS transport model LOTOS. Furthermore, comparisons were made between AATSR and MODIS derived AOD (Timmermans et al. 2006).

As an example, Figure 1 shows the AOD maps for August 2003 over Europe retrieved from AATSR data. Retrieval is done over cloud-free scenes for the 1 x 1 km^2 sensor resolution and binned in pixels of 10x10 km^2 by means of an automated post-processing step. The final maps however cannot be considered as monthly averages; rather they are composites providing information on the spatial variation of aerosols, hot spots and other regions with high aerosol loading. The results are validated by comparison with collocated AERONET sun photometer AOD measurements [Holben *et al.*, 1998], within 30 minutes of the satellite overpass, as described in the first year report. However, over many areas quite high values were observed, such as over Norway, Ireland and parts of the UK. In these areas there are no sun photometers to compare with and other methods for evaluation were considered, such as effectiveness of cloud screening, the effects of bright surfaces at high elevation due to snow, the number of data points used in the average (Figure 1 b) and the standard deviation (figure 1c). Accounting for these factors resulted in Figure 1a.

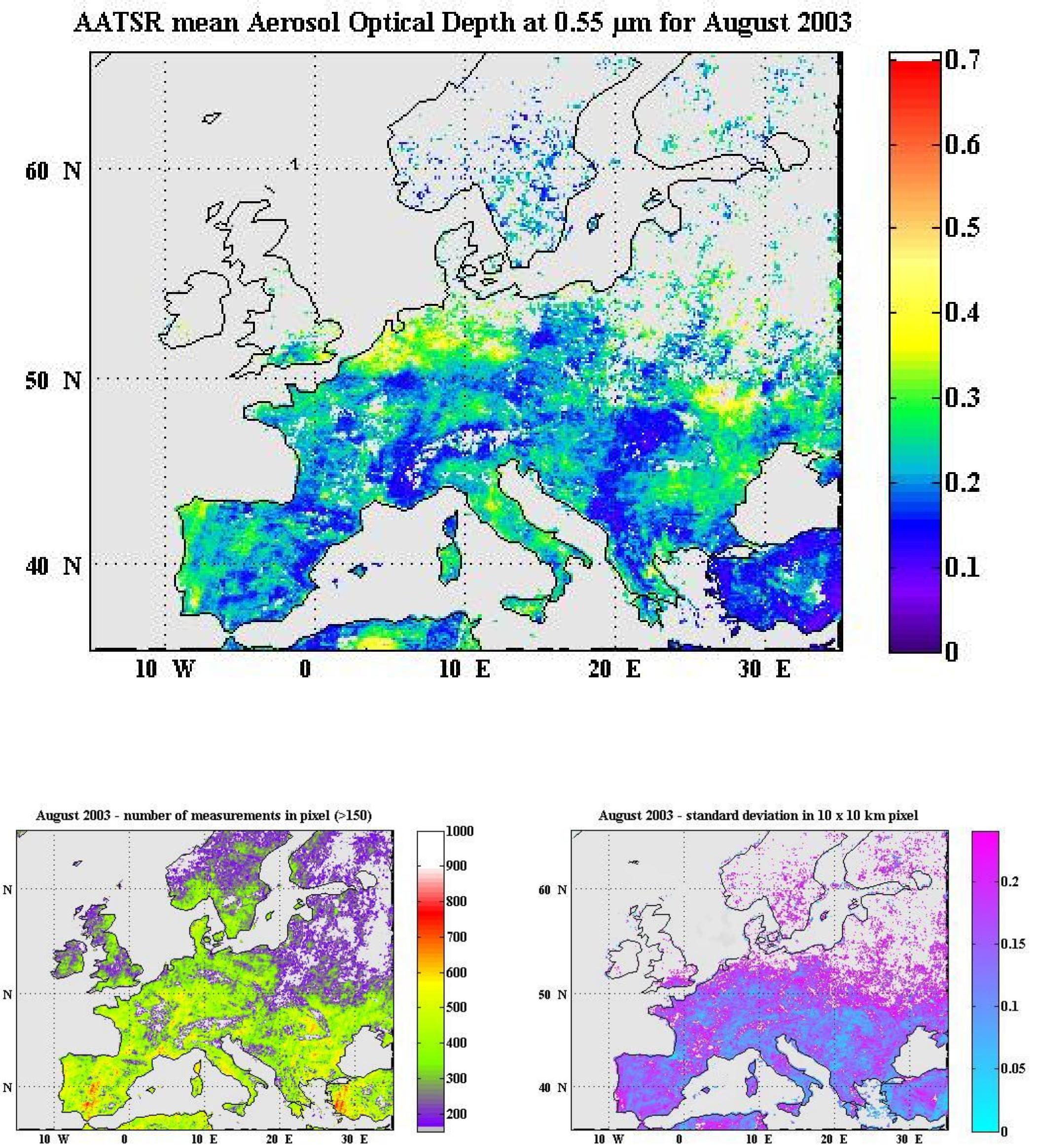

Figure 1. Composite showing the AATSR derived AOD at 0.55 µm over Europe for the month of August 2003 (top). The composite is made from all available AATSR observations for that month (bottom left). Standard deviations are presented in the figure at the bottom right. Strict cloud screening has been applied and uncertainties due to surface effects (e.g. over bright surfaces) have been removed.

Other efforts on AATSR retrieval were the evaluation of the results from comparison with field campaigns, in particular ADRIEX using aircraft aerosol chemical and physical sampling, comparison with sun photometers and intercomparison with AATSR single view retrieval and MSG SEVIRI. This work has been completed and three publications for a special issue were co-authored (Highwood et al., 2006; Barnaba et al., 2006; Thomas et al. 2003).

OMI. The validation of OMI aerosol retrieval results was undertaken using DANDELION field campaign data. To this end, the OMI algorithm had to be further developed. Contributions of TNO, in close cooperation with the KNMI team, were on the effect of the surface reflectance, cloud screening and the preparation of an aerosol data base. These have been implemented in the OMI reflectance algorithm and the first retrieval results are under evaluation by comparison with AERONET and with MODIS data, on both regional and global scales. Publications are in preparation.

MSG-SEVIRI. The retrieval of aerosol properties from MSG SEVIRI data, using a synergistic approach with AATSR and AERONET data, has been continued in the second year of ACCENT. The aim is to combine the high AATSR spatial resolution and the dual view feature to provide good aerosol data over land, with the high temporal resolution provided by MSG to obtain good AOD values with both high temporal and spatial resolution. To this end, a stand alone cloud detection algorithm had to be developed for the SEVIRI data and a method had to be developed to determine the surface reflectance for the SEVIRI geometry. The latter comes down to an atmospheric correction to determine the surface albedo, which was accomplished by using independent AOD data (AERONET, AATSR). Currently, the actual aerosol retrieval is developed for cloud free scenes. The idea behind this is to use the AATSR overpass as a 'calibration step' to determine the surface albedo, and use the subsequent SEVIRI data to determine the AOD evolution until the next AATSR clear sky overpass. AERONET data are sued to evaluate assumptions on the temporal evolution of the surface albedo as determined form SEVIRI.

Relevancy for policy development: The results are used in the 2006 EMEP report on the state of the environment in Europe [Fahre Vik *et al.*, 2006]. Other users are RIVM (Netherlands Environmental Assessment Agency European Air Quality and Sustainability) and TNO DSS.

Future outlook

The work described above will be continued in the third year of ACCENT. Algorithm development and validation will be continued based on participation in field campaigns such as DANDELIONS2 (September 2006) and likely other campaigns. These campaigns provide ground truth data for comparison whereas the retrieval results will be made available to the participants, providing a larger spatial view of the occurrence of aerosols. This way the applicability of the aerosol retrieval algorithms will be extended to other areas, where other aerosol types may occur than over Europe. Expectation is that the accuracy of the retrieval results will not only be established, but also improve as more knowledge becomes available.

The quasi-operational algorithm will be applied over the Po Valley to demonstrate a near real time service, in the framework of the ESA DUP TEMIS. There is a demand for such data from both scientific and policy users. Scientific use includes the assimilation in CTM [Robles Gonzalez *et al.*, 2003]. Policy users are interested in the state of the atmosphere over Europe and the identification of aerosol hot spots and emission sources. Studies on PM2.5 will be continued as part of a National Project. Satellite aerosol retrieval data will further be used in European projects such as EUCAARI, GEOMON and AMFIC.

The MSG-SEVIRI/AATSR synergy will be further developed. In addition, the application of satellite data to study aerosol cloud interaction will be explored.

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