AERO25 - PREPARATIONS FOR THE PRODUCTION OF A SATELLITE-BASED AEROSOL COMPONENT CLIMATOLOGY OVER 25 YEARS

Thomas Holzer-Popp, Marion Schroedter-Homscheidt, and Hanne Breitkreuz

Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR), Deutsches Fernerkundungsdatenzentrum (DFD), Oberpfaffenhofen, 82234 Wessling, Germany, Email: thomas.holzer-popp@dlr.de

ABSTRACT

It is the goal of this project to conduct a case study to prepare producing a 25 year satellite-based aerosol component climatology outside deserts ranging from mid-1995 to 2020 based on the lifetime of ERS-2, ENVISAT, and the MetOp system. In clean areas only the total aerosol optical depth and no composition will be retrieved. This paper will summarize the available results of the predecessor PI projects PAGODA (ERS-2 AO), SENECA (ENVISAT AO), and PROMOTE (GSE) as well as briefly summarize the work plan of AERO25.

1. INTRODUCTION

There is a strong need for accurate long-term information on aerosols, because they effect the Earth system in several ways and also are critical for other satellite retrievals: 1) The climate impact of aerosols (direct through altering solar radiation, indirect through acting as cloud condensation nuclei) is among the largest un certainties for climate prediction. 2) Aerosols near the surface have a detrimental impact on human health (particulate matter). 3) Aerosols in the lower atmosphere have the potential to change regional patterns of the hydrological cycle and thus to alter precipitation. 4) Aerosols influence solar radiation at the surface and also blur satellite observations of the Earth's surface. 5) Within trace gas retrievals from satellite aerosols work as a disturbing factor. In most of these aerosol impacts the detail of the aerosol composition matters. Therefore, long-term information on aerosol speciation, as it will be prepared by this project, is requested.

2. RETRIEVAL METHOD: OVERVIEW AND ITS VALIDATION STATUS

At the German Remote Sensing Data Center (DFD) the new aerosol retrieval method SYNAER (SYNergetic AErosol Retrieval) was developed ([1]) for the sensor combination of the radiometer ATSR (Along Track Scanning Radiometer) and GOME (Global Ozone Monitoring Experiment), both onboard ERS-2. It delivers boundary layer aerosol optical depth (AOD) and type over both land and ocean. The type is given as percentage contribution of representative components from the OPAC (Optical Parameters of Aerosols and Clouds, [2]) dataset to AOD in the boundary layer. The high spatial resolution of the AATSR instrument (Advanced Along Track Scanning Radiometer) permits accurate cloud detection, AOD calculation over automatically selected and characterized dark pixels and surface albedo correction for a set of 40 different pre-defined boundary layer aerosol mixtures. After spatial integration to the larger pixels of the spectrometer SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CartograpHY) these parameters are used to simulate SCIAMACHY spectra for the same set of different aerosol mixtures. A least square fit of these spectra to the measured spectrum delivers the correct AOD value and - if a uniqueness test is passed - the aerosol mixture. For humidity dependent components two models with 50% and 80% relative humidity have been included. Improvements in the definition of the aerosol model are described in [3]. SYNAER has been implemented for operational processing at the German Remote Sensing Data Center within the ESA GSE PROMOTE (Protocol Monitoring for the GMES Service Element; see also http://www.gse-promote.org) and delivers daily near-real time observations (within the same day) and an evolving archive of historic data.

Accurate cloud detection is an important prerequisite for each aerosol retrieval. The well established APOLLO (AVHRR Processing Scheme Over CLoud Land and Ocean; [4]) software was adapted to AATSR data. The capability of retrieving cloud cover in boxes of 1 km^2 means a significant strength of SYNAER because it reduces the erroneous aerosol detection due to the presence of sub pixel clouds significantly. It even allows the correction of partly cloudy SCIAMACHY pixels. However, a possible miss-interpretation of high AOD values in desert dust outbreaks over the ocean is still under investigation.

First inter-comparisons of SYNAER-ENVISAT results to ground based sun-photometer measurements of the spectral aerosol optical depth from NASA's Aerosol Robotic Network (AERONET) at 43 locations with dark surface albedo (below 0.15 at 670nm) show a good agreement with bias values of about 0.02 and standard deviations of 0.18 (0.15, 0.14) at 550 (440, 670) nm as shown in [5]. This indicates to a correct assessment of the amount and type (namely the spectral dependence of extinction) of aerosol. This ground-based validation comprised data from Europe and Africa in several climate zones distributed over 3 months in the summer season of 2005 (see also http://wdc.dlr.de/). A similar case study validation with 15 data pairs of AERONET and the predecessor satellite instruments ATSR-2/GOME onboard ERS-2 showed a similar agreement with an rms value better than 0.1 for these wavelengths ([6]). Furthermore, a comparison of monthly mean results from SYNAER and other satellite aerosol retrievals as well as AERONET stations over ocean ([7]) showed a satisfactory agreement with the other datasets for a number of cases.

3. DATASET AND EXAMPLES

A backup climatology based on GOME and ATSR-2, both onboard ERS-2 was produced as first application of the SYNAER method. Due to cloud coverage and method inherent limitations a one year dataset was obtained as first product for a 5 degree grid.

For this first application of the SYNAER method data products of the period July 1997 through August 98 covering Europe/Africa were received through the ESA AO project SENECA (AO ID-106). Unfortunately, GOME measures “small” pixels of 80x40 km^2 only for 3 days every month, and 320x40 km^2 pixels throughout the rest of the month. For producing the aerosol climatology only “small” pixels are meaningful in correspondence with horizontal variability scales of the aerosol loading and are thus exploited. With this small pixel mode GOME covers a swath width of 240 km with only 3 pixels in one scan line (SCIAMACHY delivers pixels of 60x30 km^2 for a swath of 960 km, i. e. 16 pixels in one line). Although this means a severe limitation to the available data base, it opens the opportunity to test the methodology with a one year dataset. Detailed handling of quality information from the retrieval process such as fit error, GOME-ATSR-2 cross-calibration deviation, spectral noise, surface elevation, solar elevation angle, etc. was optimized.

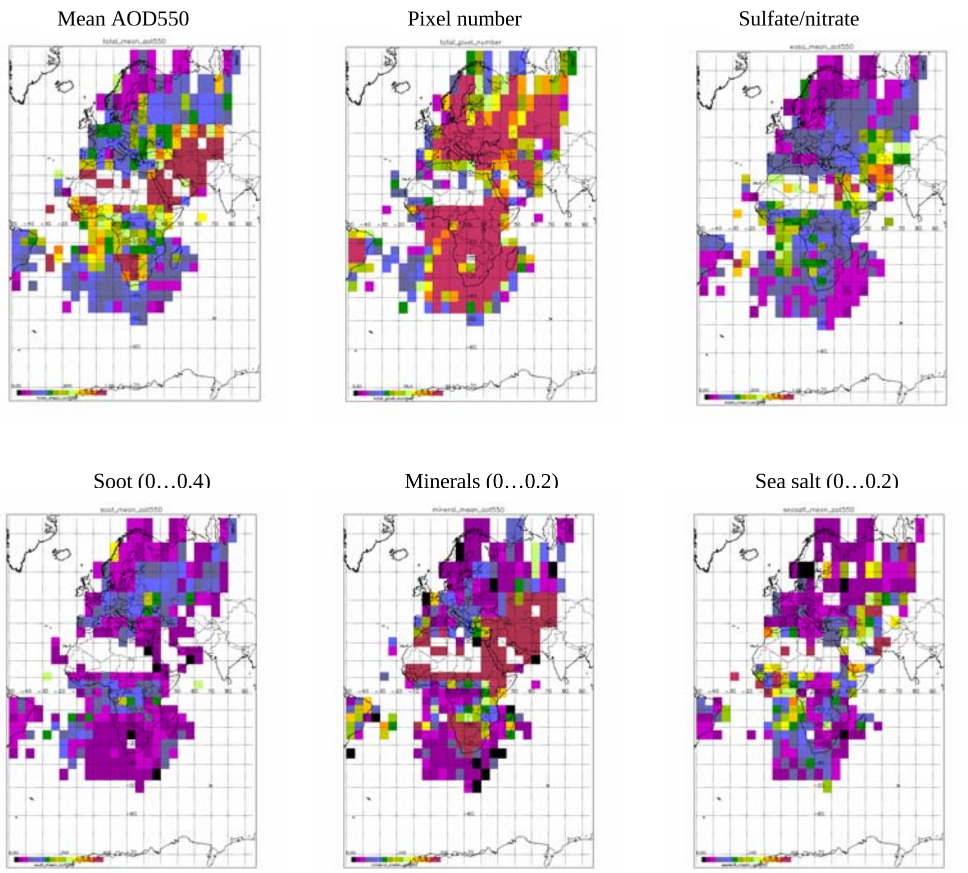

Fig. 1: climatology of aerosol components based on ERS-2 data of 7 / 1997 – 8 / 1998. From top left to bottom right: total aerosol optical depth, the pixel number and the optical depth contributions by components (water-soluble, soot, minerals, and sea salt).

Figure 1 shows the climatology dataset based on the 14 months of GOME/ATSR-2 data on a 5 degree grid using a total number of 18914 GOME pixels. The low number of observations in some boxes (particularly in the South-West Atlantic and at the edges of the dataset) leads to some unrealistic mean concentrations values which are determined by single episodes. However, despite of the small data base the aerosol distribution is rather smooth with a mean aerosol optical thickness of 0.26 and some interesting features can already be observed: Largest optical thickness values above 1 occur over / near the desert areas, whereas the Scandinavian area or oceanic zones far off from the continents show lowest values. Also biomass burning plumes from South America and Central Southern Africa are indicated over the Atlantic.

Figure 1 shows also the component-wise mean aerosol optical depth maps: Sulfate/nitrate aerosols which are included in all modelled aerosol types as background contribution show even clearer the unpolluted oceanic and Northern areas. Soot occurs most prominently over industrialized / densely populated areas in Central/Eastern Europe as well as over biomass burning source areas in Central/Southern Africa and in their plumes over the ocean. Dust is dominant in and around desertic areas (Sahara, Namib, Near East) and occurs with smaller amount in continental and oceanic aerosol. Sea salt occurs with low values also at inland locations which indicates to the limits of separating this component with low impact on the total optical depth, but it should be noted that its maximum occurs over the Southern Atlantic.

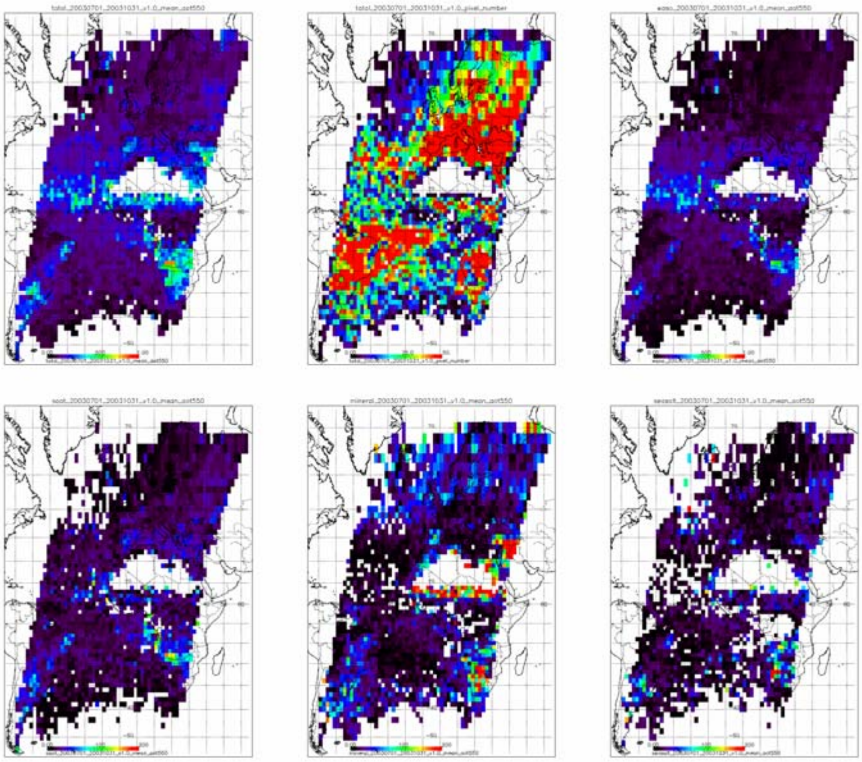

Fig. 2: examples of a 4-monthly average map based on SYNAER data of July – October 2003: upper line from left to right: total AOD at 550 nm, the number of contributing pixels per box, and component AOD at 550 nm of water-soluble aerosols; lower line from left to right: component AOD at 550 nm of soot, mineral, and sea salt aerosols. Note the different colour bars ranging from 0 – 50 for pixel number, from 0.0 to 1.0 for total and water-soluble AOD, and from 0.0 to 0.2 for components in the lower line.

Fig. 2 shows an example of the complete coverage of the currently available SYNAER ENVISAT dataset. Several well-known features can be clearly seen in the images. This dataset gives the 4-month average values for the period July – October 2003. In this time period a reasonable coverage in a 2x2 degree grid is achieved (as opposed to the earlier ERS-2 coverage [9], which needed one year of data for a similar pixel number on a 5x5 degree grid). Some values towards the edges of the covered region must be used with great caution, as there the exploited pixel numbers decrease significantly, so that a single episode can determine the “average” value. In the total aerosol optical depth distinct features are the tropical biomass burning regions in Africa and South America, the sub-tropical desertic regions (Sahara, Namib / Kalahari, Arabia, South America) and their plumes over the Atlantic. These are also to some extent visible in the water-soluble component, since this component contributes to all predefined aerosol types in SYNAER. However, AOD values in the regions with mineral and soot components are clearly reduced. The soot component has its peaks in the biomass burning regions, whereas mineral components concentrate around the desertic areas. No retrieval is possible inside the Sahara due to the bright surface. The sea salt component seems to be erroneous as the peaks occur inland. There seems to be a correlation with the mineral components. Thus, it must be concluded, that a separation of the different large particles (mineral, sea salt) is not successfully achieved so far. As a further indication of the value in the SYNAER ENVISAT dataset, the seasonal behaviour visible in the SYNAER data has been shown in [5] for the soot component.

4. PLANNED WORK IN AERO25

To prepare the production of a 25 year aerosol component climatology from 3 subsequent platforms, following specific objectives will be adressed:
1) evaluation of the accuracy of the SYNAER method for the 3 satellites.
2) evaluation of limitations due to different features of the 3 satellites (e.g. pixel size, intrinsic method limitations for low aerosol content, bright surface or high cloud fraction).
3) demonstration of the value of the a long-term dataset.
4) technical preparation / specification for the (re)processing of the entire dataset.

To achieve this aim 6 tasks will be conducted:
a) implementation of the synergetic aerosol retrieval methodology SYNAER for exploiting the METOP GOME-2 + AVHRR/3 sensor combinations.
b) extended validation of spectral aerosol optical depth results with AERONET ground-based observations with several case studies.
c) cross-comparison of synergetic aerosol retrieval results from ERS-2 GOME + ATSR-2, ENVISAT SCIAMACHY + AATSR and METOP GOME-2 + AVHHR/3 for selected cases.
d) development of methodology for combining these 3 datasets into one long-term dataset, including data assimilation techniques.
e) design of an operational system for (re)processing of the full 25 year radiometer + spectrometer dataset.
f) production of example datasets of the envisaged long-term data record.

5. SUMMARY AND CONCLUSION

This paper has clearly demonstrated the potential in the ERS-2 and ENVISAT SYNAER dataset to achieve long-term aerosol composition monitoring. With the transfer to GOME-2 / AVHRR onboard METOP the daily coverage will be improved significantly (which is also essential for near-real time data assimilation) and also the data record length can be extended to cover 25 years (1995 – 2020). Based on the SYNAER speciation information a systematic conversion of AOD into near-surface particle mass concentrations (PM values) has been demonstrated [8]. The promising perspective of these SYNAER derived pollution observations for air quality modelling and forecasting has been demonstrated by [9] and will be used within the ESA GMES Service Element PROMOTE to improve the treatment of episodic and gradually changing emission patterns in tropospheric chemistry transport models for air quality services.

6. ACKNOWLEDGEMENTS

The results presented in this paper were achieved within the ESA-ENVISAT-AO project SENECA (AO ID-106) through which the input data (SCIAMACHY and AATSR) were acquired as well as within the ESA GSE project PROMOTE, Stage I.

7. BIBLIOGRAPHIC REFERENCES

1. Holzer-Popp, T., M. Schroedter, and G., Gesell, *J. Geophys. Res.*, 107, D21, pp. AAC16-1 – AAC16-17, 2002
2. Hess, M., Köpke, P., Schult, I., *Bulletin of the Americal Meteorological Society*, 79, pp. 831-844, 1998
3. Holzer-Popp, T., Schroedter-Homscheidt, M., Proc. ERS/ENVISAT Symposium, Salzburg, 6.-10.9.2004, ESA, 2004
4. Kriebel K. T., Gesell G., Kästner M., Mannstein H., *Int. J. Rem. Sens.*, 24, 2389-2408, 2003
5. Holzer-Popp T. and Schroedter-Homscheidt M., Proc. of the ESA Atmospheric Science Conference, 8.-12. May, 2006, Frascati, ESRIN, 2006.
6. Holzer-Popp, T., M. Schroedter, and G., Gesell, *J. Geophys. Res.*, 107, D24, pp. AAC10-1 – AAC10-8, 2002
7. Myhre, G., Stordal, F., Johnsrud, M., Diner, D. J., Geogdzhayev, I. V., Haywood, J. M., Holben, B., Holzer-Popp, T., Ignatov, A., Kahn, R., Kaufman, Y. J., Loeb, N., Martonchik, J., Mishchenko, M. I., Nalli, N. R., Remer, L. A., Schroedter-Homscheidt, M., Tanre, D., Torres, O., Wang, *Atm. Chem. Phys*, 5, 1697-1719, 2005
8. Holzer-Popp, T., Schroedter-Homscheidt, M., in: C. A. Brebbia, (eds.), Air Pollution XIII, WIT Press, Southampton, 2004
9. Nieradzki L. and Elbern H., Proc. of the ESA Atmospheric Science Conference, 8.-12. May, 2006, Frascati, ESRIN, 2006