Comparison between AATSR and MODIS AOD and assimilation in a regional chemistry transport model

A contribution to ACCENT-TROPOSAT-2 Task Group 1

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Summary

An intercomparison study shows a large bias in MODIS total AOD in summer as compared to the AERONET data. Inclusion of MODIS AOD_fine appears to largely solve this bias problem for the assimilation study.

Assimilation studies show that the system is able to assimilate AOD. Innovations are significant, mostly due to the underestimation of AOD by the model. Improvements are seen especially in timing and spatial patterns. Assimilation not effective near domain edge. PM2.5 levels are increased by about 2-3 µg in central Europe.

Introduction

Satellite remote sensing can be a cost-effective method to monitor the highly variable aerosol fields on regional scales (e.g. Robles-Gonzalez et al., 2003). Retrieved aerosol optical depth fields consist of data that are irregularly distributed in space and time. Data assimilation allows the calculation of continuous fields in space and time from observations that are irregularly distributed. The objective of our studies is to demonstrate that we can use the assimilation of aerosol optical depth (AOD) to obtain more knowledge on the PM2.5 distribution over Europe.

Scientific activities

Data assimilation defines a new atmospheric state by combining the observed and modelled state in an intelligent and statistically sound way. In this study we used an ensemble Kalman filter to assimilate MODIS AOD retrievals for the year 2003, within the LOTOS-EUROS chemistry transport model (Schaap et al., 2004). We have used random noise to the emissions of NOx, SOx, VOC, NH3 and particles to define the ensemble and therewith the model uncertainty.
To study the quality and suitability of the MODIS and AATSR AOD measurements for assimilation in the LOTOS-EUROS model, we have compared datasets from both satellite instruments for the year 2003 with ground-based measurements from the AERONET network.

Scientific results and highlights

The intercomparison between MODIS, AATSR and AERONET AOD values reveals a seasonal bias between MODIS and AERONET (Figure 1).

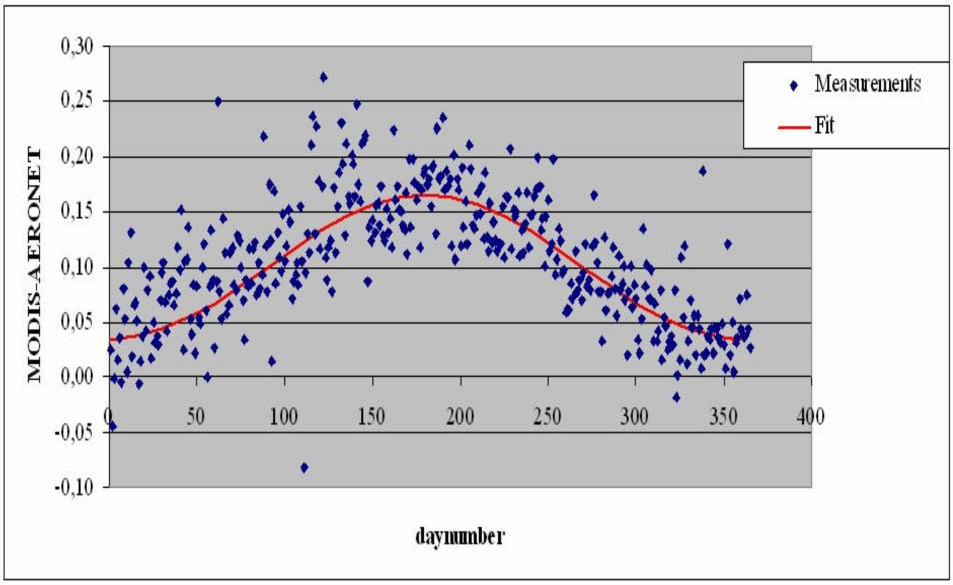

Figure 1. Difference between retrieved AOD from MODIS and colocated AERONET measurements as function of day in the year 2003.

This seasonality in the bias is not visible when comparing the MODIS fine fraction of AOD with AERONET. MODIS_fine shows a rather constant bias with AERONET of ~10 %.
AATSR on average slightly underestimates the AERONET values but shows some suspected high values over scandinavia and Ireland.
The correlation between the satellite datasets and AERONET is 0.65-0.72.

Previous study has shown that the data assimilation technique can be successfully applied to assimilate aerosol optical depth fields over Europe. However, from a scientific point of view a successful application is still hampered by a number of unresolved issues.
Comparison of modelled AOD to satellite and AERONET AOD data reveals that the model (without assimilation) underestimates AOD systematically. Verification of SO_4, NO_3 and NH_4 concentrations does not reveal large systematic deviations from observed concentrations and are probably not the cause for the underestimation of AOD.
The systematic underestimation of the retrieved AOD data by the model can be explained by a number of factors. Reliable parameterizations for emissions of fugitive dust and SOA formation do not exist and are therefore not incorporated in the model. Furthermore, primary emissions are uncertain and a previous study indicated that the concentrations of EC and OC are underestimated by a factor 2 (Schaap et al., 2004). The AOD calculation from the separate aerosol components was also identified to be a major source of uncertainties. The assumptions on optical properties, water uptake and (BC) mixing state have a large influence on the AOD calculations. Lastly, the retrieved AOD values may be biased due to undetected glint and cloud contamination.

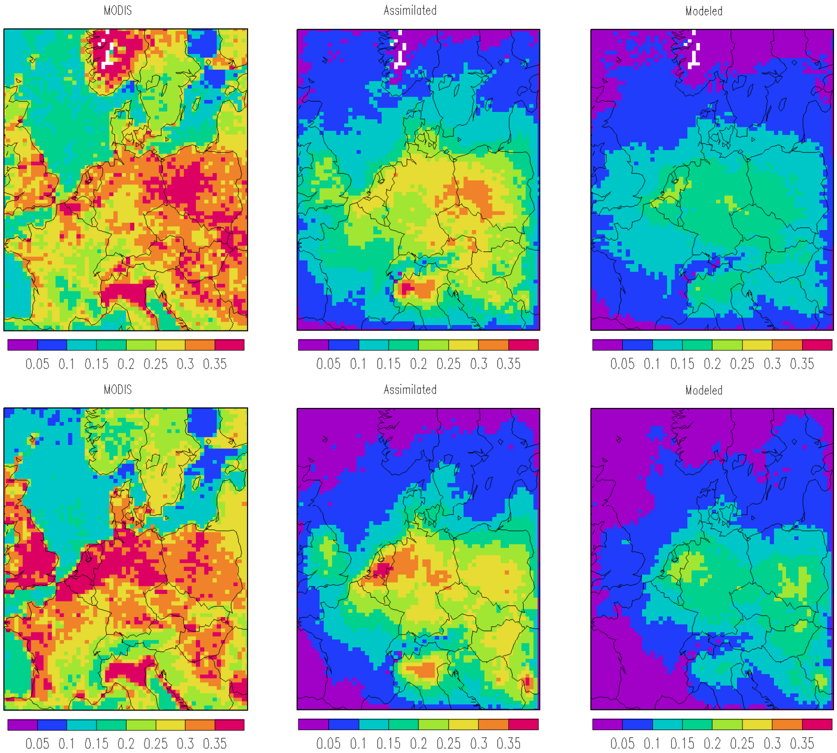

Figure 2. Seasonal averaged AOD fields from MODIS fine fraction (left side), the free running model (right side) and in the simulation where AOD from MODIS was assimilated (middle). Upper row corresponds to the seasonal averages for March, April and May, lower row to June, July and August.

Figure 2 shows the seasonal averaged results of the assimilation of MODIS AOD fine * 0.9 in the LOTOS-EUROS model. The systematic underestimation of the retrieved AOD by the model can clearly be seen. Using assimilation the gap between modelled and measured AOD is decreased considerably. At the boundaries of the model domain the assimilation is not effective due to the fixed boundary conditions in the model.
In addition to the absolute value of the AOD, especially the timing is improved. The correlation between modelled AOD and AERONET at almost all stations increases considerably when assimilating the MODIS data.

Through the assimilation the monthly mean PM2.5 levels are increased by about 2-3 µg (up to 50%) in central Europe (see Figure 3).

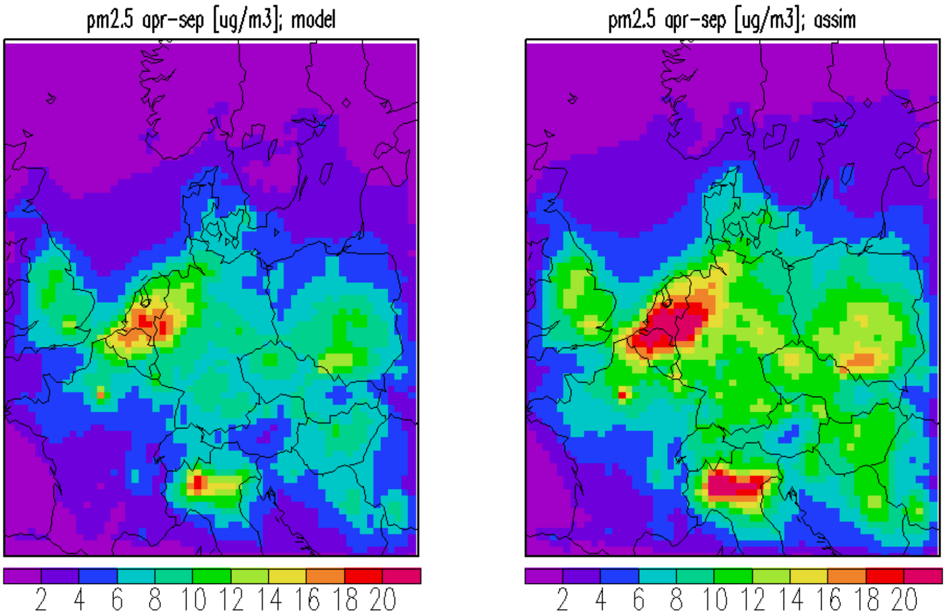

Figure 3 PM2.5 fields before and after assimilation of MODIS AOD fine values.

Future outlook

In the next year the results of the assimilation of 1 year of MODIS data will be carefully analysed and validated with both satellite and groundbased measurements.

Detailed evaluation of measurements before assimilation is very important. The AATSR AOD data will be further analysed and checked before assimilation in the LOTOS-EUROS model.

Also in the assimilation a combination of both satellite and groundbased measurements will be carried out.

References

Robles Gonzalez, C., Veefkind, J.P., de Leeuw, G. (2000), Aerosol optical depth over Europe in August 1997 derived from ATSR-2 data, GRL, 27, 955-958

Schaap, M., Denier Van Der Gon, H.A.C, Dentener, F.J. , Visschedijk, A.J.H., Van Loon, M., Ten Brink, H.M., Putaud, J-P, Guillaume, B., Liousse, C. and Builtjes, P.J.H. (2004), Anthropogenic Black Carbon and Fine Aerosol Distribution over Europe, J. Geophys. Res., 109, D18201, doi: 10.1029/2003JD004330