Aerosol Effects on Satellite Observations of NO_2 Pollution

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The background…

Several instruments flying on satellites (e.g., GOME, GOME-2, SCIAMACHY and OMI) allow for the observation of atmospheric pollution from space. Trace gas columns (such as ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2)) can be inferred from the measured backscattered solar radiation.

The retrieval of tropospheric columns of NO_2 from satellite measurements is based on several *a priori* assumptions used in the computation of an airmass factor (AMF). The improvement of those is essential to obtain more accurate tropospheric NO_2 values.

Here, results are presented for a sensitivity study performed with the goal of identifying key parameters in the radiative transfer calculations. In addition, the outcome of a case-study is shown, with focus on the Eyjafjallajökull volcanic eruption in the Spring of 2010. The impact of ash on the satellite observations is analysed. These studies were performed by changing in the radiative transfer model (RTM) Sciatran (Rozanov et al., 2005) the vertical distribution of aerosol extinction coefficients and single scattering albedo. Furthermore, also the trace gas distribution was altered.

In this poster, we show the latest results obtained for the analysis performed

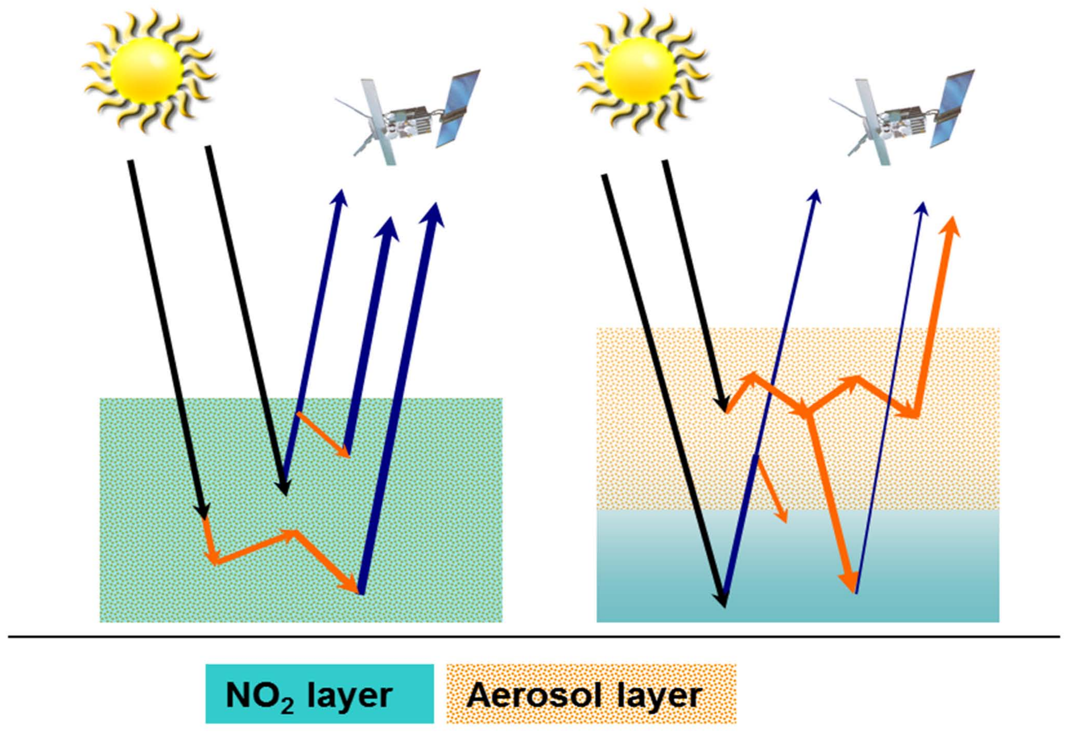
Why is this study important?

The aerosols present in the atmosphere will interfere with the satellite measurements of tropospheric NO_2. The signal can be :

- enhanced because of multiple scattering within aerosol layer;
- or shielded by an aerosol layer standing, for example, above the trace gas.

The effect of aerosol scattering is quite complex and depends both on its profile (vertical distribution and optical depth), as well as its properties (e.g., size distribution and refractive index).

Currently in IUP-Bremen, the NO_2 retrieval method uses data taken from climatological assumptions (Richter et al., 2005). Several alternatives exist, including the use of simultaneous measurements of trace gas and aerosol, or dynamic application of CTM data to define atmospheric conditions at the time of satellite observations.



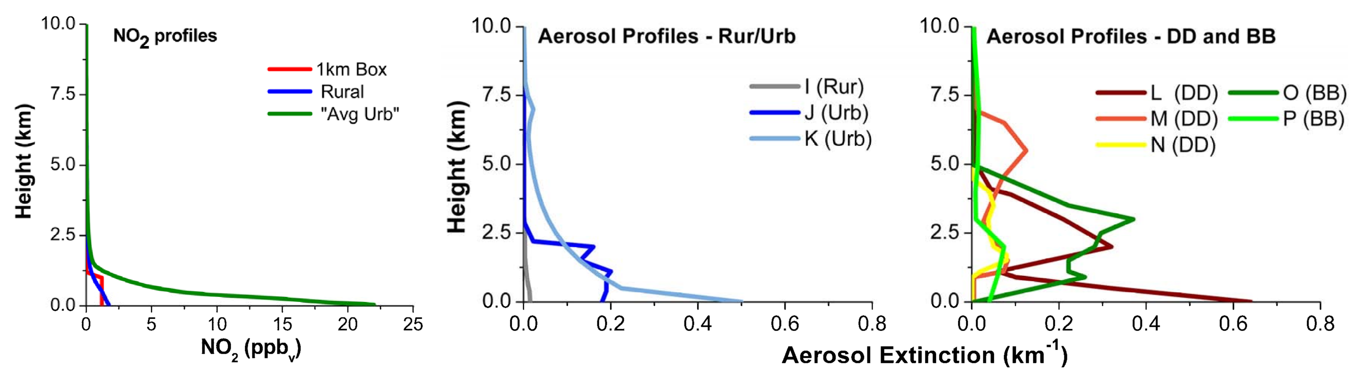
The settings for the sensitivity study

Radiative transfer calculations

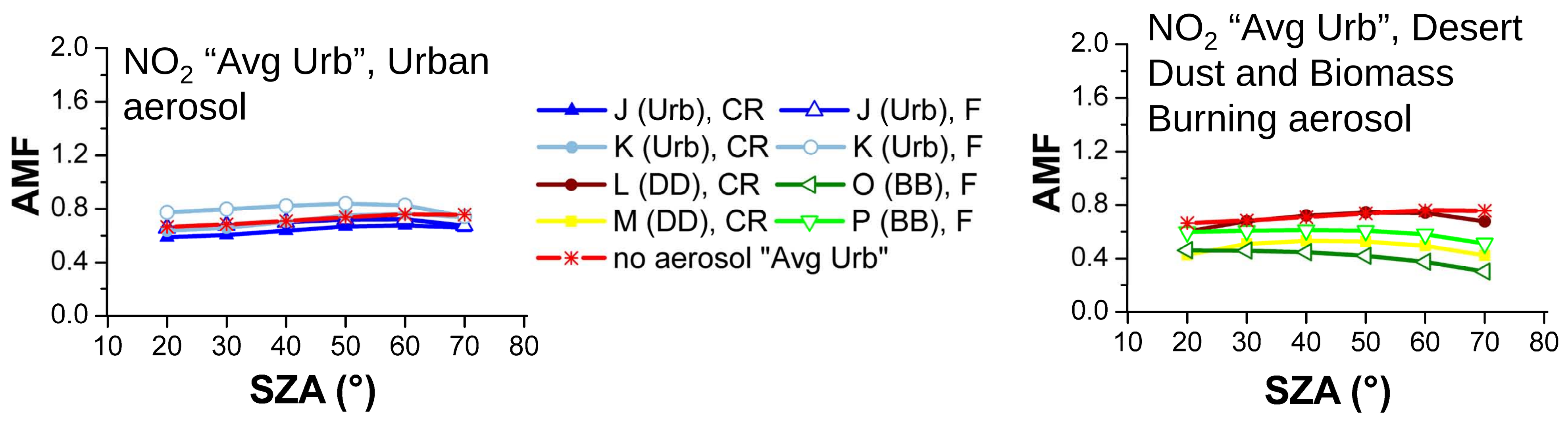
- RTM: Sciatran 2.2
- Surface albedo = 0.03
- Wavelengths: 425, 437.5, 440, 450nm
- SZA: 20° to 70° (every 10°)
- NO_2 Profiles: "box" 1.0 km height; Rural and "Avg Urban" profile from CHIMERE model, for Paris downtown and surroundings.

Aerosol settings (440nm):

- Refractive indices and size distribution of AERONET data (Dubovik et al. (2002)).
- Phase function calculated with a FORTRAN program developed by Michael Mishchenko (de Rooij et al., 1984; Mishchenko et al., 1999).
- Legendre expansion coefficients – fine (F) and coarse particles (CR).
- Extinction coefficient profiles from lidar observations at several locations: **Rur**al, **Urb**an, **D**esert **D**ust and **B**iomass **B**urning.



Results – illustrative examples

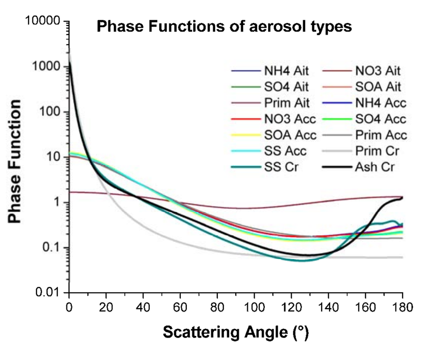


- **Aerosol mixed with the trace gas** (in the same layer or lower than it) will enhance the measured signal by means of multiple scattering.
- A discrete **aerosol layer above the trace gas** will act as a shield and the AMF values decrease. This is often the case observed for long-range transport of biomass burning smoke and/or desert dust.
- Changes in **NO_2 profile** (not shown) also influence the AMF values, and the higher values are obtained for the box profile of 1km height, rather than with the modelled NO_2.
- **More aerosol** in the atmosphere will result in the intensification of either the shielding effect or multiple scattering. In addition, NO_2 AMF are usually more enhanced by **fine particles**.

The settings for the case-study

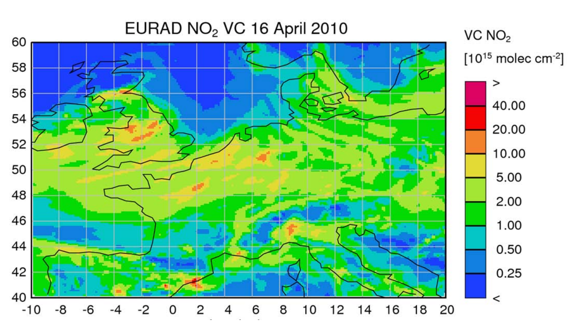
Radiative transfer calculations

- RTM: Sciatran 3.1
- Surface albedo = 0.05
- Wavelengths: 437.5, 461nm
- SZA: 20° to 70° (every 10°)
- Period: 16th to 18th of April 2010
- Domain: central Europe

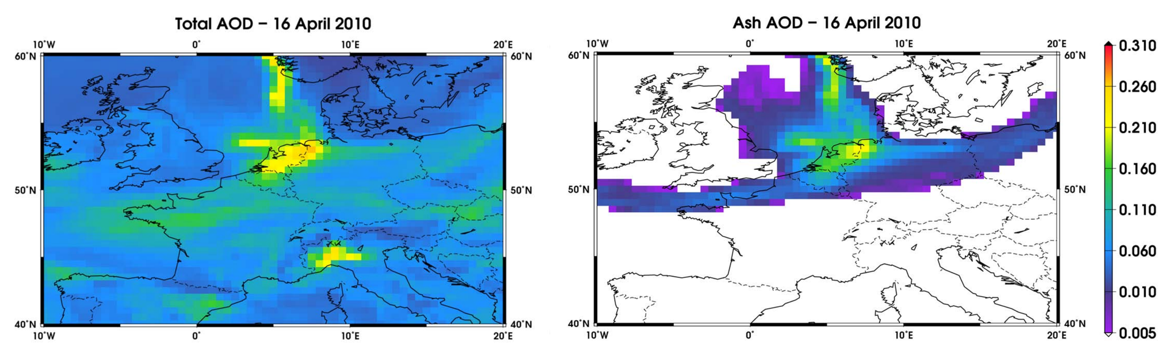


NO_2 and Aerosol settings derived from EURAD model data

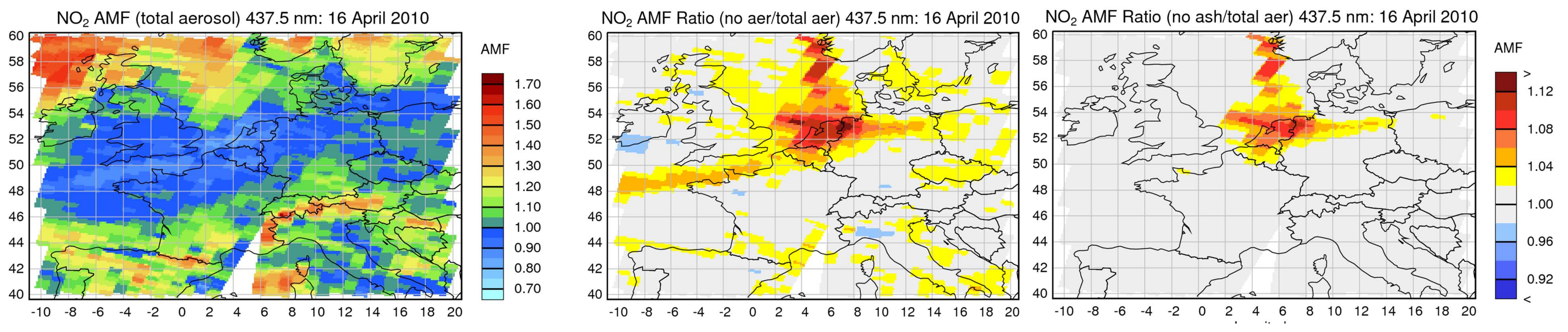
- Model NO_2 taken for troposphere.



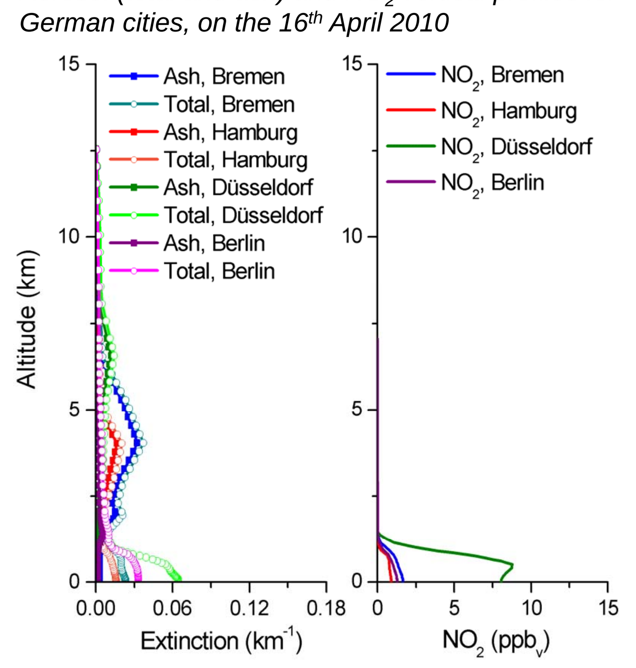
- Aerosol size distribution from initial conditions of the CTM.
- Refractive indices from Pére et al. (2010).
- Aerosol mass concentrations converted to extinction and scattering coefficients assuming internal mixture.



Results – 16th of April, central Europe



Aerosol (total and ash) and NO_2 vertical profiles for German cities, on the 16th April 2010



Location	AOD		SSA		AMF		
	Total	Ash	Total	No Ash	No Aerosol	Total	No Ash
Bremen	0.15	0.11	0.83	0.82	1.021	0.953	1.001
Hamburg	0.07	0.03	0.82	0.82	1.019	0.979	1.000
Berlin	0.07	0.01	0.73	0.72	1.016	0.993	1.004
Düsseldorf	0.12	0.04	0.86	0.87	0.951	0.924	0.936

- Vertical profiles show that ash plume is found mostly at high altitudes, but also close to surface mixed with the NO_2. Yet, the main effect verified was a **reduction of measurement sensitivity**.
- Clear distinction of **AMF reduction by volcanic ash** compared to total aerosol mixture in the regions with high ash AOD.
- Overall, little effect of volcanic ash in the satellite observations - **changes in NO_2 AMF are small,** with a max. of 13%.

Acknowledgements

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What have we learned…

- AMFs depend on many factors, and the correct definition of **particle optical properties, and the aerosol vertical profile** (together with the trace gas, NO_2 here) is important for the accuracy of the retrieved tropospheric vertical columns.
- Distinction between **fine and coarse aerosol** is significant to determine the magnitude of the aerosol influence.
- Measurement sensitivity changes of **up to +/- 50%** can be obtained. However, for more **realistic urban profiles** of both NO_2 and aerosol, the impact is much smaller.
- The analysis of conditions during a volcanic eruption show that **ash also affects** the satellite observations of tropospheric NO_2, although this effect can be minor.

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