How satellite retrievals of NO_2 vertical columns can be improved using aerosol measurements

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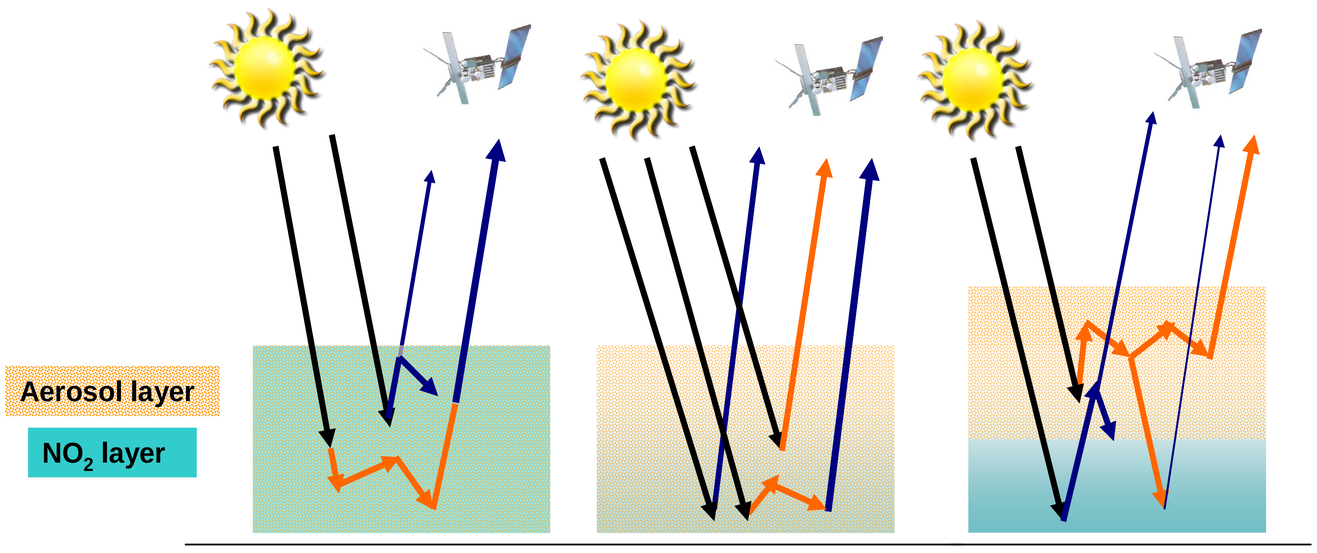
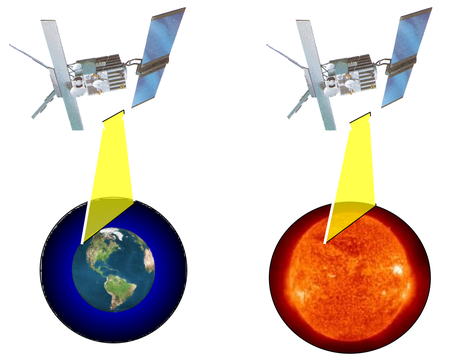
The background…

The several instruments flying on satellite (e.g., GOME, GOME-2, SCIAMACHY and OMI) allow for the observation of atmospheric pollution from space measuring concentrations of trace gases (such as ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2)).

The retrieval of NO2 slatn columns is done with the DOAS method. The vertical tropospheric columns of NO2 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.

This sensitivity study was performed by changing several aerosol settings in the radiative transfer model (RTM) Sciatran (Rozanov et al., 2005): AOD, SSA, phase function, vertical distribution. In addition, impact of surface albedo and NO2 profile were also analised. Like this we uncertainty key factors are identified and the current retrieval can be improved.





DOAS method and Lambert-Beer law

$$\ln\left(\frac{\text{Measurement}}{\text{Reference}}\right)$$

Radiative transfer model (SCIATRAN)
→Air Mass Factors (AMF)

NO_2 Vertical Column

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 in 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 their profile (like vertical distribution and optical depth) as well as their optical properties (e.g., size distribution and refractive index).

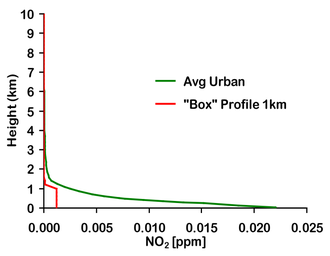
Currently in IUP-Bremen, the NO_2 retrieval method uses data taken from climatological assumptions (Richter et al., 2005). A synergistic approach is ideal to account with the full spatial and time variability of aerosols and its characteristics: using data of aerosol optical properties and/or vertical profiles measured either at ground (e.g. AERONET, EARLINET) of from space (e.g. MODIS, MISR, MERIS, CALIPSO).

The settings for the sensitivity study

Radiative transfer calculations

- RTM: Sciatran 2.2
- Surface albedo = 0.03
- Wavelengths: 440nm
- SZA: 20° to 70° (every 10°)
- AOD: 0.1, 0.5, 0.9

NO_2 Profiles



"Avg Urban" profile from CHIMERE model for Paris downtown.

Aerosol Settings (440nm):

Optical properties and size distribution mostly from Dubovik et al. (2002) – 12 AERONET stations – and some from the literature consulted for profiles.

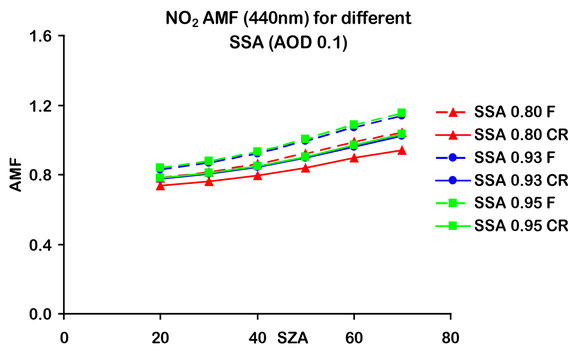
Phase function calculated with a FORTRAN program developed by Michael Mishchenko (de Rooij et al., 1984; Mishchenko et al., 1999).

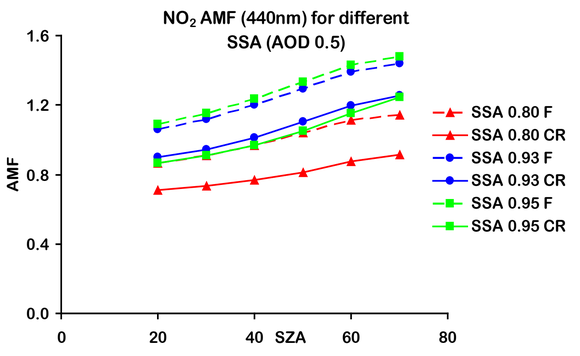
Legendre expansion coefficients - fine and coarse particles.

Single Scattering Albedo (SSA) was taken from the correspondent measurements (average from AERONET was 0.93)

Effects for change of SSA

For this study the aerosol (fine (F) and coarse (CR) particles) and NO_2 are assumed to be homogenously mixed in the boundary layer of 1km (**NO_2 „Box" Profile** & **AL1km**).

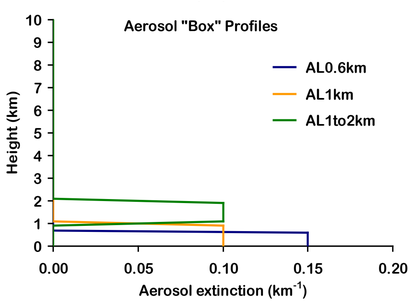




- The sensitivity of the NO_2 measurements is improved by less absorbing aerosol **(higher SSA)** – AMF values are higher.
- This effect is intensified with the **increase of the aerosol load**.

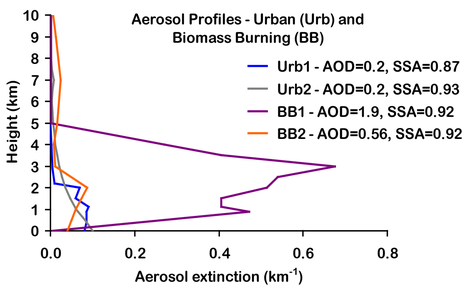
Effects for change in vertical profiles

These profiles correspond to the AOD of 0.1. For the scenarios with AOD=0.5 and AOD=0.9 the shape was kept but extinction increased in proportion.

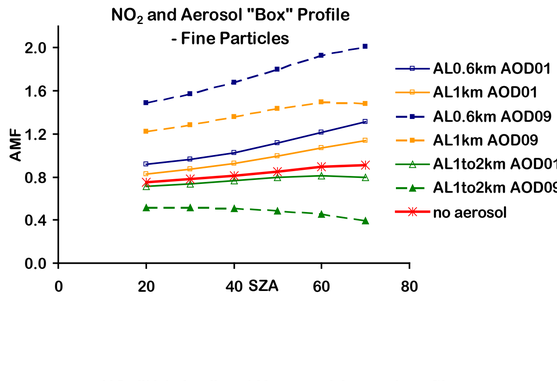


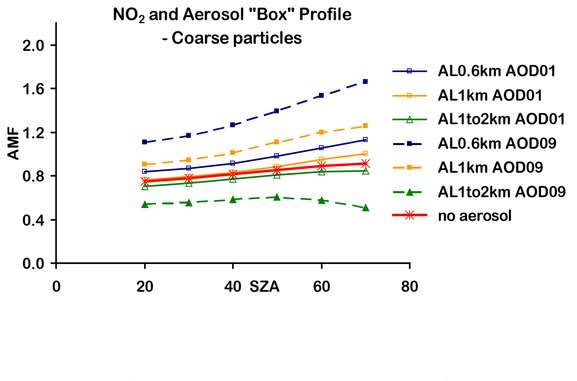
NO_2 "Box" profile

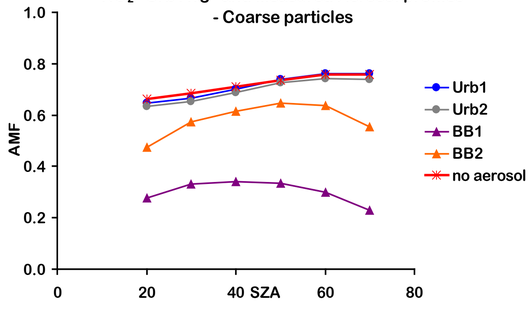
Aerosol profiles: "Urb1" from Chazette et al. *(2005); "Urb2" adapted from "Amiridis* et al *(2009); "BB1" from Balis* et al. *(2003) and "BB2" from Müller* et al. *(2005).*

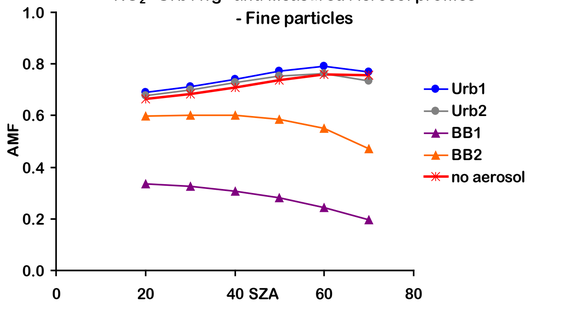


NO_2 "Avg Urban" profile









- **Aerosol mixed with the trace gas** (equal 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 decreases.
- NO_2 AMF are usually more enhanced by **fine particles** (differences are more evident for the box profiles).
- **More aerosol** in the atmosphere will result in the intensification of either the shielding effect or multiple scattering.

Acknowledgements

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What have we learned…

- The AMF are dependent on many factors and the correct definition of both aerosol and trace gas (NO_2 here) **vertical profiles** is important for the accuracy of the retrieved tropospheric columns.
- Depending on the **relative vertical distribution of NO_2 and aerosol**, sensitivity changes of up to **+/- 50%** can be obtained.
- Distinction between **fine and coarse aerosol** is significant to determine the magnitude of the aerosol influence. In addition, it is also recommended to consider the **particles' optical properties and the load of aerosol**.
- For more **realistic urban profiles** of both NO_2 and aerosols, the effect of aerosol is much smaller.