Aerosol effects on the OMI tropospheric NO_2 retrievals over industrialized regions: how good is the aerosol correction of cloud-free scenes *via* a simple cloud model?

J. Chimot[1], T. Vlemmix[1], J.P. Veefkind[1,2], P.F. Levelt[1,2]

[1] Department of Geoscience and Remote Sensing, Civil Engineering & Geosciences – TU Delft, The Netherlands

[2] Royal Netherlands, Meteorological Institute, KNMI, De Bilt, The Netherlands

1: Introduction

The retrieval of tropospheric NO_2 Vertical Column Density (VCD) from OMI observations is done by dividing the tropospheric Slant Column Density (SCD) by the tropospheric NO_2 Air Mass Factor (AMF). **Current representative OMI tropospheric NO_2 products DOMINO v2** [Boersma *et al.*, 2011] **use a Lambertian opaque cloud model to determine the AMF in case of cloudy scenes. The same model is employed in presence of aerosols.**

Then, **the OMI cloud algorithm retrieves effective cloud parameters.** This means that the retrieved cloud fractions and cloud pressures are affected by aerosols.

The motivation of this work is to understand and evaluate the aerosol correction based on this cloud model. This study used the DISAMAR software, developed by KNMI and the associated results are detailed in [Chimot *et al.*, 2015, manuscript under submission to AMT]

2: Explicit aerosol effects on AMFs - Simulations

The net effects of aerosols / clouds on the tropospheric NO_2 AMF depends on the vertical distribution of NO_2 and particles in the low troposphere. They can be separated into 2 groups:

- Enhancement (albedo) effect: increased sensitivity within and above the particles layer;
- Shielding effect: decreased sensitivity within and below the particles layers.

Change in the AMF is directly associated with a change in the altitude-resolved AMF.

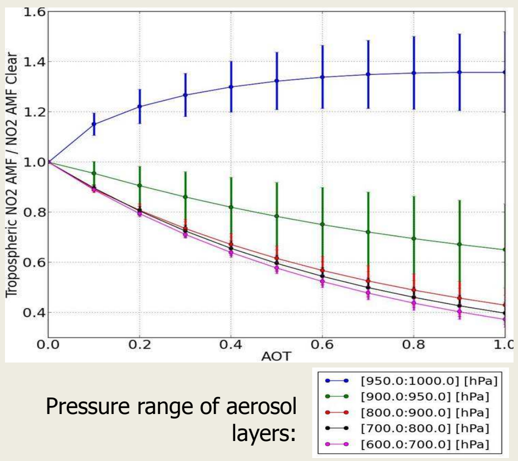


Fig. 1: Simulated tropospheric NO_2 AMF, based on TM5 NO_2 profiles of January 2006 over East China. Aerosol SSA = 0.95 and Angström coefficient = 1.5.

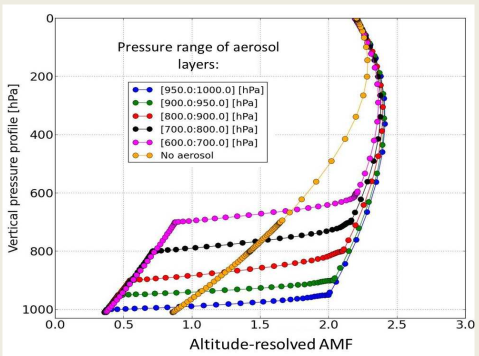


Fig. 2: Altitude-resolved AMF with and without scattering aerosols (AOT = 1).

3: Implicit *vs.* explicit aerosol corrections

The tropospheric NO_2 AMF is computed with a radiative transfer model F:

AMF = F{Geometry, temperature, surface, pressure, gases vertical profiles, particles}

Implicit aerosol corrections	Explicit aerosol corrections
No aerosol	Aerosols: size, altitude, aerosol optical thickness (AOT), single scattering albedo (SSA)
Effective cloud parameters: fraction, pressure	Cloud parameters: fraction, pressure

4: Implicit aerosol effects on AMFs – Observations

Collocated OMI DOMINO and MODIS Aqua aerosol products over East China show:

- Decreasing AMF with increasing AOT in summer.
- No modification of AMF in average with increasing AOT in winter.

This is a consequence of responses of effective cloud fractions and pressures to aerosols (in particular AOT and altitude).

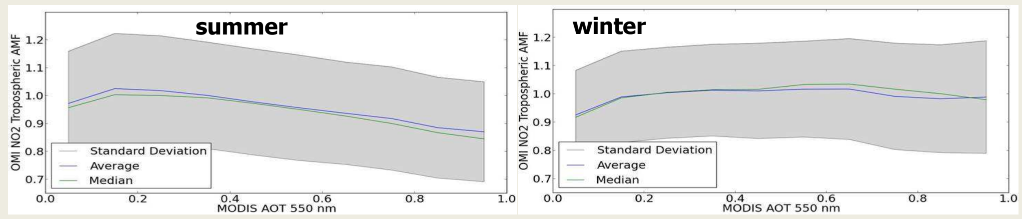


Fig. 3: OMI tropospheric NO_2 AMF against MODIS Aqua AOT over 2005-2007 and East China.

5: Response of the OMI O_2-O_2 cloud algorithm to aerosols

The OMI cloud algorithm [Acarreta *et al.*, 2004] exploits the O_2-O_2 spectral range through the DOAS approach, assuming an opaque Lambertian reflector. A Look-Up-Table (LUT) is then used to convert the retrieved O_2-O_2 SCD and the continuum reflectance into cloud fraction and pressure. In this study, the OMI cloud retrieval (as achieved in the operational chain) has been reproduced on simulations in order to understand the aerosol effects:

- ✓ Effective cloud fraction increases with increasing AOT, representing the excess of the top of the atmosphere reflectance caused by the additional scattering of aerosols and the impact of the surface reflectance.
- ✓ Effective cloud pressure generally decreases with increasing AOT due to the shielding of the O_2-O_2 column: *i.e.* the absorption of the photons by optically thicker aerosol layers shortening the length of the average light path.
- ✓ For low AOT, the aerosol altitude has no effect on the cloud pressures as low continuum reflectance has little impact on the O_2-O_2 SCD [Acarreta *et al.*, 2004]. Only for high AOT, cloud pressures are close to the mean aerosol layer height.

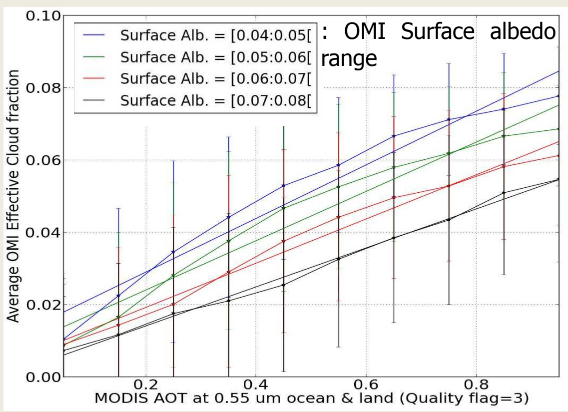
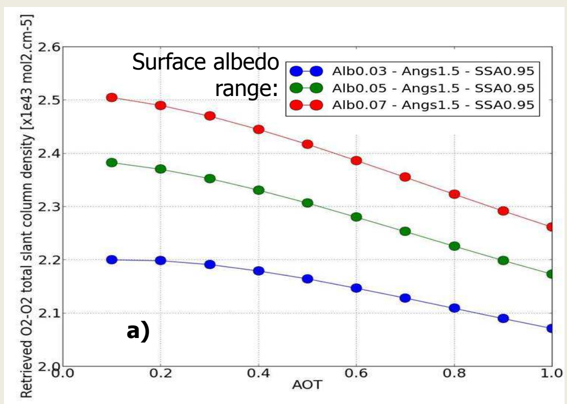
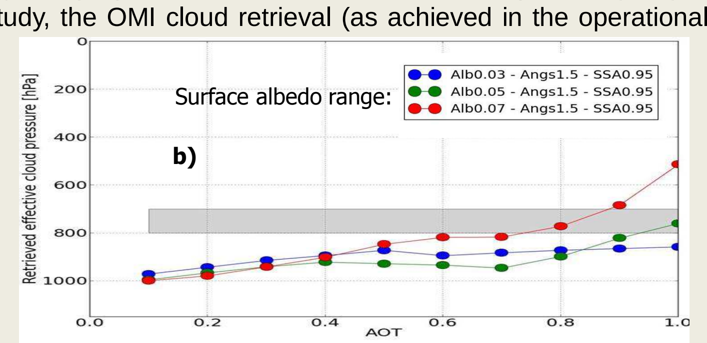


Fig. 5: OMI effective cloud fractions against MODIS Aqua AOT over 2005-2007 and East China in summer





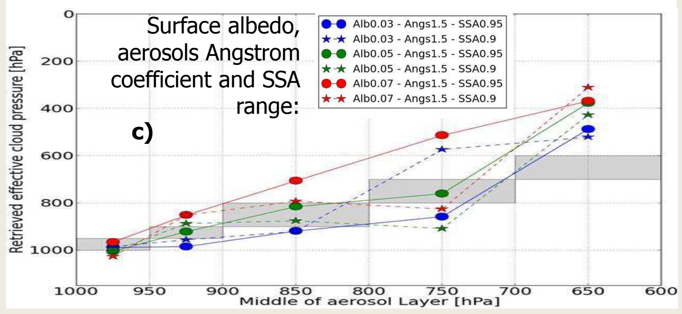


Fig. 6: Simulated OMI cloud retrievals on aerosol scenes, without clouds: **a)** O_2-O_2 SCD against AOT (aerosols between 700 and 800 hPa); **b)** Effective cloud pressure against AOT (aerosols between 700 and 800 hPa); **c)** Effective cloud pressure against middle of aerosol layer for AOT = 1.

6: Accuracy of the implicit aerosol correction

- The implicit aerosol correction leads to an overestimation of AMFs between **20%** and **40%** for **AOT > 0.6**.
- No aerosol correction would cause larger biases, from **-20%** to **60%** (and even more for larger angles).
- AOT and aerosol altitudes (relative to the tropospheric NO_2 bulk) are the key drivers of these biases. Aerosol microphysical properties are of secondary importance.
- As a result of complex relation between AOT and the combination of effective cloud fraction and pressure, the relative biases of implicit correction shows an irregular behavior. This is probably caused by the coarse sampling of the designed cloud LUT.

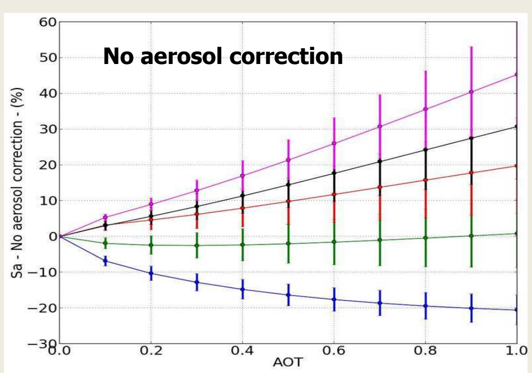
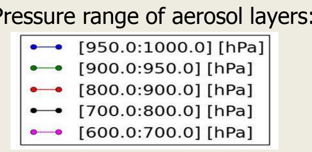
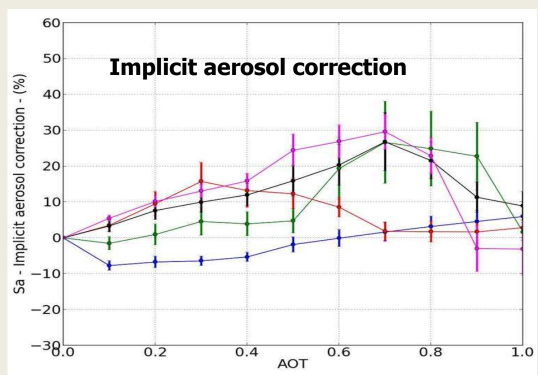


Fig. 7: Relative tropospheric NO_2 AMF biases (Sa) against AOT, based on TM5 NO_2 profiles of July. SZA = 25° and VZA = 25°. Aerosol SSA = 0.95 and Angstrom coefficient = 1.5.

Pressure range of aerosol layers:





Conclusion

The response of the OMI cloud retrievals to aerosols is a combination of the cloud model properties and the LUT sampling used for the interpolation. The biases of the implicit aerosol correction are caused by an insufficient shielding effect applied by the current OMI cloud algorithm on the tropospheric NO_2 AMF. They explain most of the underestimation of the OMI tropospheric NO_2 columns found in various ground-based comparison studies over industrialized area. These analyses highlight the necessity to implement and evaluate improved operational aerosol correction.

References

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Corresponding author: J.J.Chimotl@tudelft.nl

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