INTERCOMPARISON OF TROPOSPHERIC NO_2 RETRIEVALS FROM THE GOME-2 AND OMI SENSORS

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0. Introduction

Satellite-borne UV-Vis spectrometers have been widely used for the retrieval of atmospheric trace gas concentrations (like O_3, NO_2, HCHO, SO_2, CHOCHO) on a global scale. In particular, the retrieval of tropospheric NO_2 column density has been demonstrated in several papers, and these measurements have been used in many studies on NO_2 burdens, emissions and their change over time, in the past decade.

The main approach of the current tropospheric NO_2 retrievals developed for the satellite sensors is the well known DOAS technique, composed of: a spectral fit to determine the slant column density (SCD), and the application of an air mass factor (AMF) to convert the tropospheric slant column into a vertical column. However, these retrievals use different settings (such as spectral fitting, stratospheric correction and a priori information in AMF calculations), which may lead to significantly different results in some situations.

In this study, we present intercomparison results for several available tropospheric NO_2 products (GOME-2: TEMIS TM4NO2A and DLR operational products; OMI: TEMIS DOMINO and NASA standard products) and a reference product generated at BIRA-IASB using common settings for both sensors. Both end-to-end and step-by-step comparisons are presented, with a special emphasis on the calculation of air mass factor, which is the key factor for NO_2 retrieval, in particular under polluted conditions. Effects of parameters (such as a priori profile shape, cloud treatment and surface albedo datasets) on the AMF calculation are discussed.

1. NO_2 Retrieval

$$VCD_{trop.} = (SCD - SCD_{strat.})/AMF_{trop.}$$

Tropospheric airmass factor: $AMF_{trop} = AMF_{clear} \cdot (1 - CRF) + AMF_{cloud} \cdot CRF$

Cloud radiance fraction: $CRF = I_{cloud} \cdot CF / (I_{cloud} \cdot CF + I_{clear} \cdot CF)$

$AMF_{clear} = \sum_{l=surface\ pressure}^{tropopause} m_l \cdot x_l$ and $AMF_{cloud} = \sum_{l=cloudtoppressure}^{tropopause} m_l' \cdot x_l$

Here, I_{clear} and I_{cloud} are the fit window averaged radiances for 100% clear and cloudy scenes respectively. CF are cloud fraction.

x_l is NO_2 profile from CTM, m_l and m_l' are the altitude-dependent air mass factor, calculated with surface albedo + surface pressure/ cloud top albedo + cloud pressure.

Table 1: Summary of retrieval settings

Instrument	GOME-2			OMI		
Products	**TM4NO2A v2.3**	**BIRA**	**GDP 4.8**	**DOMINO v2.0**	**BIRA**	**SP v5.1**
Abbreviation	**G2A/TEMIS**	**G2A/BIRA**	**G2A/DLR**	**OMI/TEMIS**	**OMI/BIRA**	**OMI/NASA**
Slant column	DOAS 425-450nm 240K NO_2 cross section		DOAS 425-450nm 240K NO_2 xs	DOAS 405-465nm 220K NO_2 cross section		DOAS 405-465nm 220K NO_2 xs
Stratospheric correction	Assimilated NO_2 stratospheric SCD with TM4 CTM		Spatial filtering and masking of the polluted field using MOZART-2 model	Assimilated NO_2 stratospheric SCD with TM4 CTM		Local analysis of stratospheric field in tropospheric pollution regions
AMF						
A-priori profile	Daily TM4	Daily IMAGES	Monthly MOZART-2	Daily TM4	Daily IMAGES	Monthly GSFC GMI CTM
Cloud	FRESCO+ (760nm)	O_2-O_2 CF(only screening ,no correction)	OCRA/ROCINN	O_2-O_2 (477nm)	O_2-O_2 CF(only screening ,no correction)	Improved O_2-O_2
Albedo	MERIS BSA	MODIS BSA	GOME/TOMS LER	OMI LER	MODIS BSA	OMI LER

2. End-to-end comparison

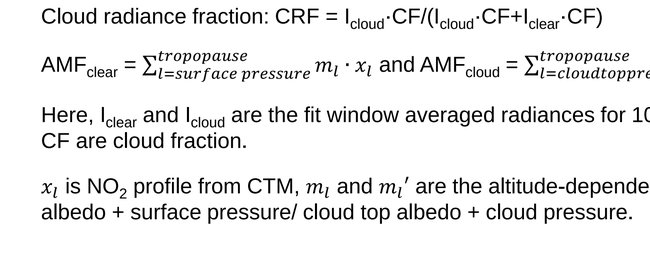
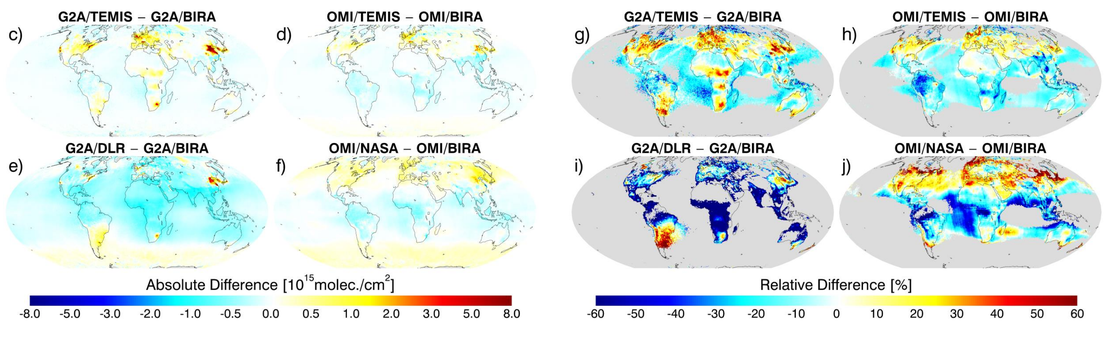


Figure 1: Comparison of annual mean (2007.2-2008.1) of tropospheric NO_2 products. (a) G2A/BIRA product; (b) OMI/BIRA product; (c)-(f) absolute differences compared with BIRA products; (g)-(j) relative differences. Satellite observations are gridded on a 0.5° ×0.5° resolution, and the measurements with cloud radiance fractions above 0.5 and surface albedo larger than 0.3 have been excluded. The pixels with the averaged NO_2 from either of retrievals less than 0.3×10^{15} molec./cm^2 are excluded in analysis of relative difference



- On a global scale, the comparison shows generally good agreement among products, except G2A/DLR, the retrieved NO_2 columns are systematic lower than the other retrievals for most of regions.
- Absolute differences are higher over the several polluted areas, but the corresponding relative differences are smaller than the background regions.

4. Summary and conclusions

We compare tropospheric NO_2 column densities from various retrievals for OMI and GOME-2 instruments based on one year of observations. Both the end-to-end comparison and the impact of each individual step on the algorithms are investigated.

- On a global scale, the comparisons show a good qualitative agreement for all retrievals, with differences in the range of -23%–12%, dominated by slant column retrieval and stratospheric correction.
- Profile shape is the most important parameter in the AMF calculation. Modelled NO_2 profiles tend to exhibit a large difference in the free troposphere over tropical regions yielding a significant bias in the AMF. A large bias is also found over polluted areas in winter, which is mainly related to processes of atmospheric horizontal and vertical transportation in the different CTMs.
- All cloud products well discriminate cloud free pixels among satellite observations, and application of cloud correction in NO_2 retrieval changes the retrieved NO_2 columns within 20% on average.
- The effect of surface albedo is also mostly of the order of 20%. The largest difference is found in winter over high latitudes, mainly due to snow contamination in surface albedo datasets. MODIS snow-free albedo dataset discriminate efficiently cloud/snow-free pixels among satellite measurements, minimizing the influence of cloud contamination, in particular over tropical ITCZ regions.
- The NO_2 retrievals based on BRDF and Lambertian approaches show results with up to 20% difference for individual pixels, while monthly averaged effect at the same location can be ignored.

3. Step-by-step differences

3.1 SCD_{trop}

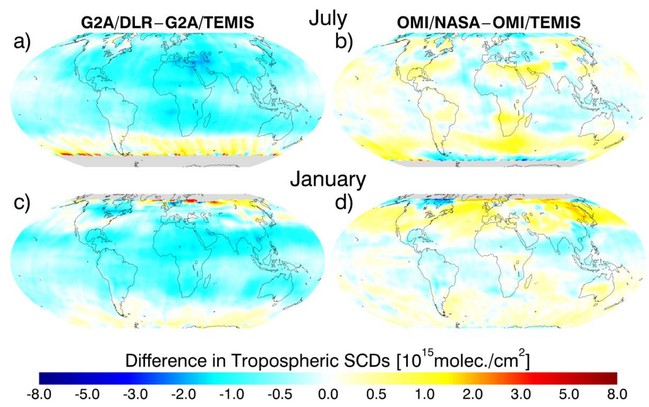


Figure 2: Monthly mean differences in residual tropospheric slant columns for July 2007 and January 2008. The residual tropospheric slant columns is defined as:

$$SCD_{trop} = SCD - SCD_{strat.}$$

- Since differences in NO_2 total slant columns appear on large scales, and as the biases are mostly transferred into the stratospheric correction, the remaining differences in tropospheric slant columns depend mainly on the stratosphere-troposphere separation (STS) approach.
- Systematic bias exist between G2A/DLR and G2A/TEMIS, which is similar with the difference in final NO_2 vertical column between G2A/DLR and the other two GOME-2 products.
- Good agreement between OMI/NASA and OMI/TEMIS, except middle and high latitudes, where OMI/NASA is ~1×10^{15}molec./cm^2 higher than OMI/TEMIS.

3.2 AMF

Tropospheric AMF is a key parameter for NO_2 retrieval over polluted regions. The uncertainty of the AMF depends on several factors, such as the surface albedo, the cloud fraction and pressure, as well as the a priori NO_2 profile shape. The effect of each individual parameter on the final NO_2 tropospheric column is discussed in this section.

Profile

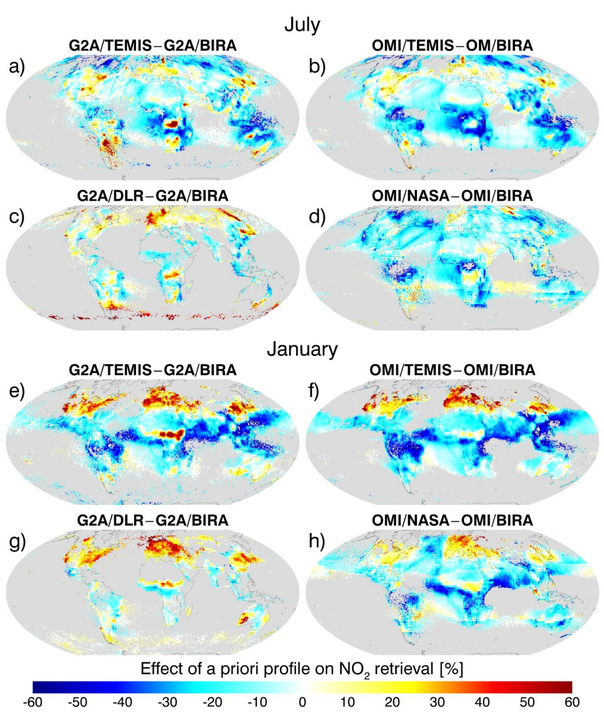


Figure 3.1: Comparison of NO_2 retrieval using IMAGES profiles with retrieval using the profiles from the other CTMs, for July 2007 and January 2008.

Cloud-free sampling

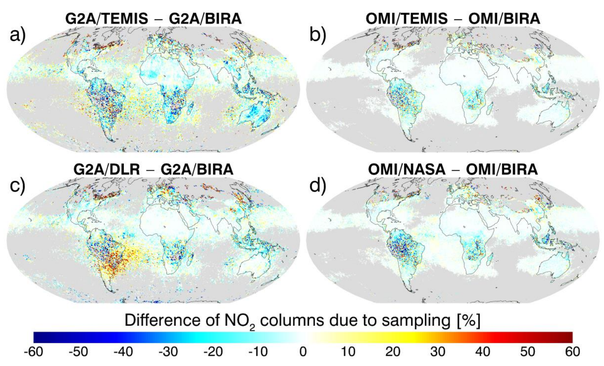


Figure 3.2: NO_2 difference due to the criteria of cloud-free data selection for January 2007. NO_2 columns are taken from BIRA products, only pixels with CRF below 0.5 are used in average, and CRF are taken from the various cloud products.

Cloud correction

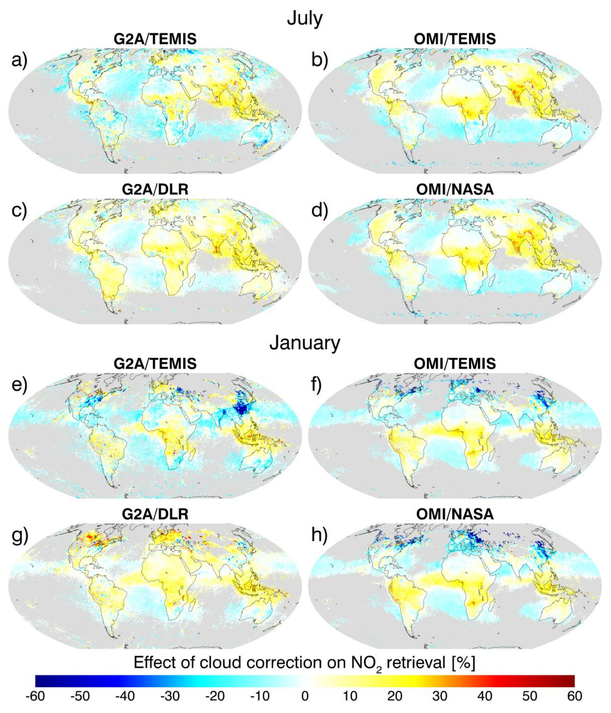


Figure 3.3: Differences of monthly NO_2 VCDs between the retrieval using SCD_{trop}/AMF_{trop} and SCD_{trop}/AMF_{clear}

Surface albedo database

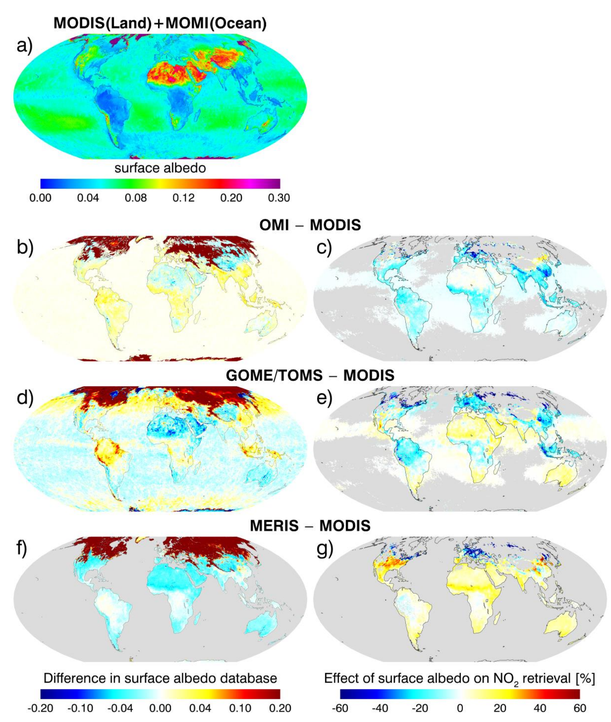


Figure 3.4: MODIS BSA (over land) is shown in (a), and albedo values over ocean are filled with OMI minimum LER. Differences of surface albedo database compared to MODIS albedo are displayed in (b), (d), (f), and the corresponding differences in NO_2 columns are shown in (c), (e), (g), respectively.

Effect of surface anisotropy

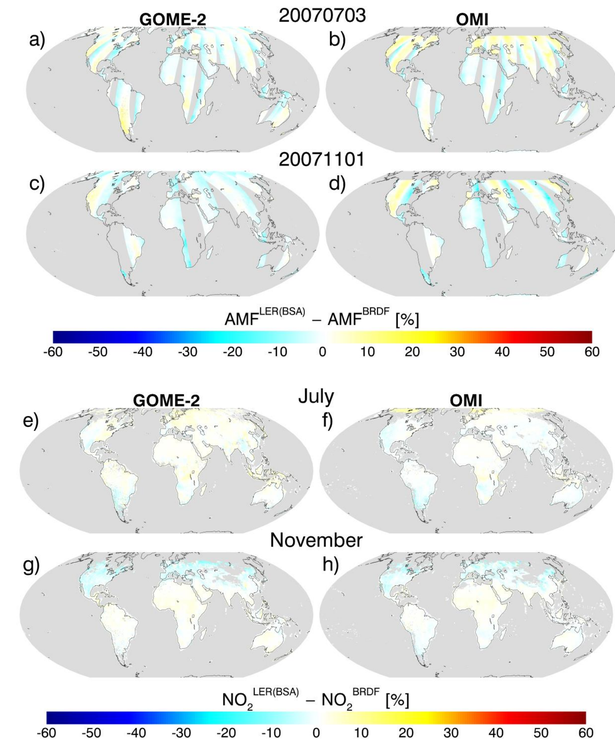


Figure 3.5: Comparison of tropospheric AMFs using the full BRDF treatment with the values obtained with the Lambertian surface assumption for one day of GOME-2 and OMI observations in July and November are shown in (a)-(d). (e)-(h) are monthly mean differences of NO_2 columns retrieved with different surface treatments.

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