END-TO-END VALIDATION OF TOTAL AND TROPOSPHERIC NO_2 FROM ATMOSPHERIC COMPOSITION SATELLITE SENSORS

G. Pinardi*[1], H. Yu[1,2], F. Hendrick[1], F. Tack[1], J. Granville[1], J.C. Lambert[1], M. Van Roozendael[1]
(1) BIRA-IASB, Belgium, (2) IAP, China
*gaia.pinardi@aeronomie.be

aeronomie.be

Introduction

Total and tropospheric NO_2 column data have been measured from space by remote sensing in the UV-Vis spectral range for more than 15 years, by the GOME, SCIAMACHY, OMI and GOME-2 sensors. These measurements will be continued and further extended in the future with GOME-2 sensors on two additional MetOp platforms, and further with the GMES atmospheric Sentinels 4 and 5 and, already in 2015, by the Sentinel-5 Precursor mission. The validation and inter-calibration of these different datasets is essential to ensure the consistency of the time series.

An **end-to-end validation strategy** has been developed in the framework of ESA Multi-TASTE and EUMETSAT O3MSAF to validate the operational NO_2 data products. It is applied here to the GOME-2 GDP tropospheric NO_2 product. This validation approach is based on the verification and validation of **each individual component** of the **level-1-to-2 retrieval chain**. This includes the evaluation of **slant column density**, the **air-mass factor** needed to convert slant into vertical columns, **cloud correction**, and the **stratospheric NO_2 background** to be subtracted from total columns to derive tropospheric columns.

$$V_t = \frac{S - M_s V_s}{M_t}$$

S: slant column density (DOAS fit);
V_s: stratospheric component;
M_s: stratospheric air mass factor;
M_t: tropospheric air mass factor

Our approach is based on the exploitation of a set of complementary correlative observations from **ground-based instruments**, complemented by data from **multiple satellite sensors**, and supported by modelling results. Zenith-sky twilight measurements from the NDACC network are used to assess the stratospheric contribution on the global scale, while MAXDOAS instruments are used to validate tropospheric NO_2 columns. We focus on regions where correlative ground-based measurements are currently available, with a particular emphasis on the MAXDOAS stations operated by BIRA at **Observatoire de Haute Provence** (44°N, 5.7°E) in South of France, **Beijing/Xianghe** (40°N, 116.3°E) **in China**, and **Uccle** (50.8°N, 4.35°E) in Belgium.

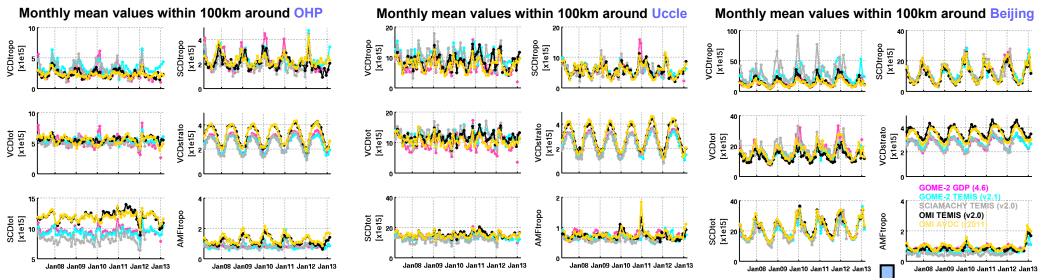
1. End-to-end comparison of satellite NO_2 products

■ Comparison of each component of the L1 to L2 retrieval chain (here focus above BIRA-IASB stations in order to compare to MAXDOAS columns afterwards):

Main retrieval settings of the 5 data products intercompared:

	GOME-2 (GDP 4.6)	GOME-2 (TEMIS v2.1)	SCIAMACHY (TEMIS v2.0)	OMI (TEMIS v2.0)	OMI (AVDC release 2011)
Reference	Valks et al. 2011	Boersma et al. 2004 + v2 upgrade (TEMIS website)		Boersma et al. 2011	OMI readme (nov. 2011) Bucsela et al., 2013
Slant column retrieval	DOAS retrieval (425-450nm)	DOAS retrieval (425-450nm)	DOAS retrieval (426.5-451.5nm)	DOAS retrieval (405-465 nm)	DOAS retrieval (405-465 nm)
Stratospheric correction	Spatial filtering and masking of the polluted field using MOZART-2 model	Assimilated NO_2 stratospheric SCD with the TM4 chemistry-transport model		Assimilated NO_2 stratospheric SCD with the TM4 chemistry-transport model	Local analysis of stratospheric field in tropopsheric pollution regions.
AMF calculation					
NO_2 a-priori profile	Monthly mean profiles (MOZART-2)	Daily profiles (TM4)		Daily profiles (TM4)	Monthly mean profile shapes from GSFC GMI CTM (2005-2007) simulations
Cloud treatment	OCRA/ ROCCIN cloud retrieval scheme	FRESCO+ (v6) cloud retrieval scheme		O_2-O_2 cloud retrieval scheme	
Aerosols	Implicitly corrected by cloud treatment				
Albedo	GOME/TOMS database	MERIS black sky albedo (land, Popp et al., 2011) /GOME		OMI based monthly climatology (Kleipool et al., 2008)	

Selection of **cloud free pixels** (CF<20%) within **100km** of the stations



Mean difference in **VCDtropo** for cloud free pixels, over the stations (2007-2012) wrt GOME-2 GDP

Difference wrt GOME-2 GDP	OHP Within 100km		Beijing Within 100km		Beijing Within 50km		Uccle Within 100km	
Absolute and relative values	10^{15} molec /cm²	%	10^{15} molec /cm²	%	10^{15} molec /cm²	%	10^{15} molec /cm²	%
GOME-2 (TEMIS)	0.75	**42**	11	**77**	13	**73**	3	52
SCIAMACHY (TEMIS)	0.25	15	17	**>100**	25	**>100**	2.6	42
OMI (TEMIS)	-0.28	-1.1	0.86	3.9	3.4	15	1.4	31
OMI (AVDC)	-0.35	-1.4	-1.4	-8.5	-1.1	-5.3	0.44	15

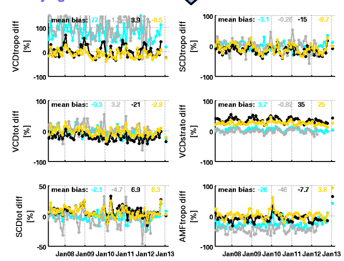
Good consistency of GOME-2 GDP, OMI TEMIS and OMI AVDC **tropospheric columns** at every stations.

VCDtropo: depending on the pollution levels, large differences between the products, with general **larger columns of the TEMIS SCIAMACHY and GOME-2 columns**, especially over (very) polluted regions.

VCDstrato: offset of **~1x10[15]** molec/cm² of OMI data, which is too high to be explained only by the morning VS afternoon overpass time difference in photochemistry (~0.5x10[15]). This issue is currently under investigation at KNMI by the OMI team (impact of the different DOAS window...).

AMFtropo: oscillations in OMI AMFs need to be further investigated.

Beijing: differences wrt to GOME-2 GDP

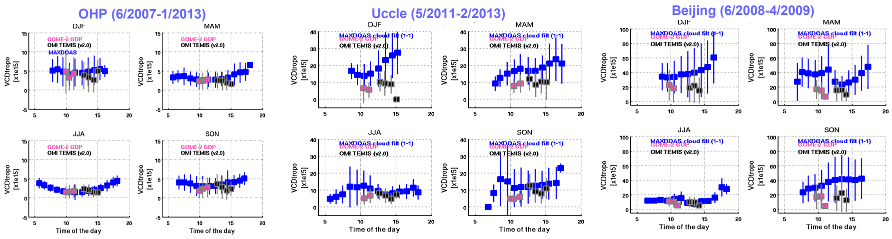


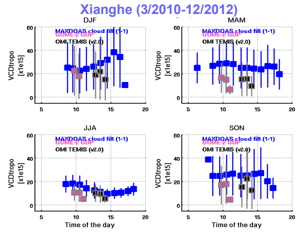
2. Comparison with correlative ground-based data

■ Comparison of tropospheric columns with MAXDOAS mean data at the BIRA-IASB stations:

OHP: clean/remote NDACC station alternating between clean air and pollution episodes, MAXDOAS measurements used to set up the method for the validation of GOME-2 GDP tropospheric NO_2 (Valks et al., 2011). Beijing: MAXDOAS measurements from June 2008 to April 2009 in the city centre and since March 2010 in its neighbourhood Xianghe (~60km south-east of the city), heavily polluted region. Since May 2011, MAXDOAS continuous measurements in Uccle with intermediary pollution levels.

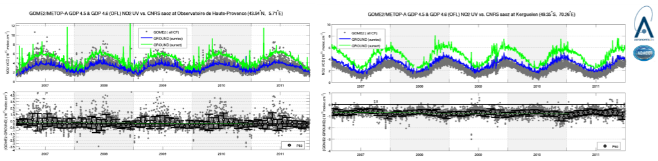
Comparison of **diurnal variation** from MAXDOAS and satellites instruments

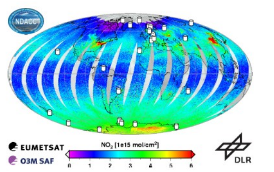




- OMI and GOME-2 consistent in terms of diurnal variation.
- Good agreement with MAXDOAS for background and low pollution conditions and in the summer season.
- Systematic underestimation in urban conditions.
- More work needed to interpret these differences.

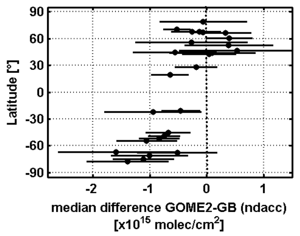
■ Comparisons with total/stratospheric columns from the NDACC network. Example at OHP and Kerguelen for **GOME-2 GDP data**:





Good agreement in the **Northern Hemisphere**.
Systematically smaller NO_2 column values than NDACC/UV-Visible network measurements in the **Southern Hemisphere.**

Median difference GOME-2 GDP and GB NDACC stations (2007-2012)



■ Direct comparison of daily coincident points and monthly means (time-series + correlation plots): see Pinardi et al. 2012.

Future work

- Apply Averaging Kernels in the MAXDOAS to satellite comparisons and use the MAXDOAS profile information (NO_2 and aerosols) to verify the assumptions made for satellite's AMF calculations.
- Extend database of MAXDOAS (more sites for the comparisons).
- Extend validation to GOME-2 on Metop-B.

Selected References

Valks et al., 2011: AMT 4, 1491-1514.
Pinardi et al. 2012: EUMETSAT conference proceedings.
TEMIS data: www.temis.nl
Boersma et al., 2011: AMT 4, 1905-1928.
Bucsela et al., 2013: AMTD 6, 1361-1407 (OMI AVDC readme file (11/2011).

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O3M SAF