On the use of the MAXDOAS technique for the validation of tropospheric NO_2 column measurements from satellite

G. Pinardi[1]*, Y. Huan[2],K. Clémer[1], J.-C. Lambert[1], C. Fayt[1], F. Hendrick[1], C. Hermans[1], M. Van Roozendael[1],
(1) BIRA-IASB, Belgium, (2) IAP, China
*gaia.pinardi@aeronomie.be

aeronomie.be

Introduction

The MultiAxis approach of Differential Optical Absorption Spectroscopy (MAXDOAS) technique has been recently developed as a new remote sensing method for the monitoring of tropospheric pollutants. Complementary to the zenith-sky DOAS approach commonly used over the last two decades e.g. within the framework of the NDACC network for stratospheric monitoring and satellite validation, the MAXDOAS approach enhances the sensitivity towards atmospheric absorbers present close to the surface. MAXDOAS systems are designed to observe the scattered sun light in a range of different line-of-sight (LOS) directions from the horizon to the zenith. Through adequate retrieval process, the near-surface concentration of atmospheric pollutants like NO_2 can be derived, as well as their integrated tropospheric and stratospheric column abundances. Owing to these capabilities, MAXDOAS technique provides reference measurements suitable for the ground-based validation of tropospheric NO_2 column measurements from satellite nadir instruments such as SCIAMACHY, OMI, GOME-2 and the future GMES Sentinels. In this work, we summarize the experience acquired at BIRA-IASB with tropospheric NO_2 validation, with particular emphasis on the OMI and GOME-2 instruments. Results are based on measurements performed at the semi-rural NDACC station of the Observatoire de Haute Provence (OHP, Southern France, since 2005) as well as in the highly polluted Beijing area (P.R. China, since June 2008).

E.g.: end-to-end validation of GOME-2 GDP 4.4 NO_2 retrieval

■ GOME-2 NO_2 tropospheric columns: a residual approach

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

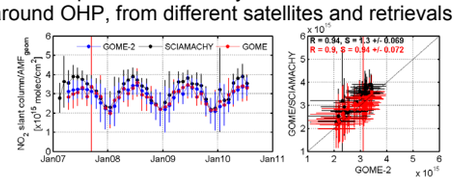
S: slant column density (DOAS fit)
V_s: stratospheric component (spatial filtering method)
M_s: stratospheric air mass factor (used for the calculation of the initial total column V)
M_t: tropospheric air mass factor

■ Verification and validation of each components of the retrieval chain.
S: test the operational algorithm on GOME and GOME2 datasets, and compares it to state-of-the-art scientific algorithms
V_s: compare with the NDACC network columns (unpolluted and polluted conditions)
[M: assessment of accurary with independent processors]
V_t: direct comparison with other satellite data and with MAXDOAS columns

Illustration for OHP station

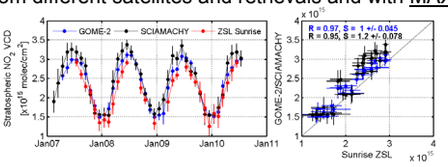
■ OHP: 44°N, 5.7°E; NDACC station alternating between clean air and pollution episodes; BIRA-IASB performs MAXDOAS measurements since 2005; data since June 2007 have been used to test and set up a method for the validation of GOME-2 tropospheric NO_2 (Valks et al., 2011).

1. S: comparison of monthly mean normalized slant columns within 300km around OHP, from different satellites and retrievals



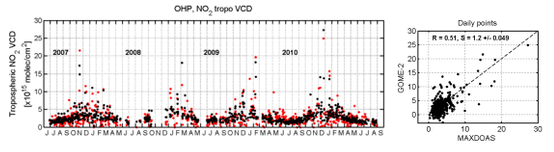
GDP4.4: good agreement, considering the instrumental differences

2. V_s: comparison of monthly mean stratospheric columns within 300km around OHP, from different satellites and retrievals and with MAXDOAS twilight columns

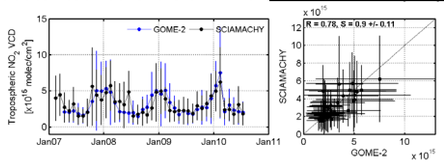


GDP4.4: good comparisons, with values between ZSL and SCIAMACHY data (differences < 1.9×10^{14} molec/cm²). Difference in the separation approach: spatial masking/smoothing of the polluted NO_2 field VS assimilated stratospheric SCD with TM4 chemistry-transport model)

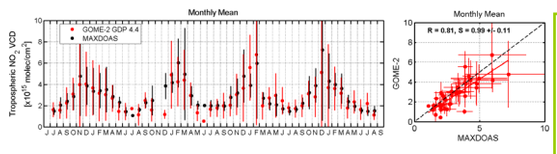
3. V_t: comparison of (monthly mean) columns within 100km around OHP, from different satellites retrievals and with MAXDOAS tropospheric columns



GDP4.4: very good agreement with MAXDOAS columns (interpolated at the satellite overpass time)



GDP4.4: good agreement of the monthly means with other satellite data



Direct comparison with other algorithms:

GOME-2 TEMIS v2.00 — **Results of application to other satellite retrievals:** — **OMI TEMIS v1.02**

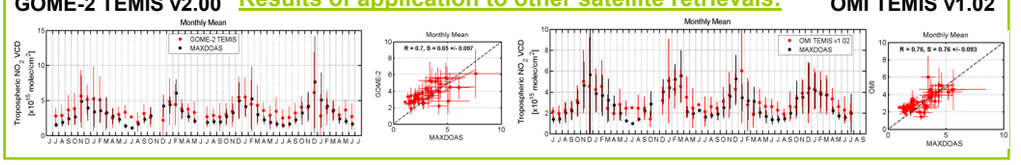
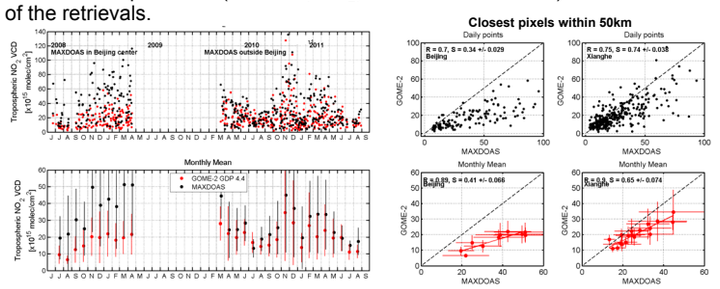


Illustration for Beijing station

■ Beijing: 40°N, 116.3°E; BIRA-IASB MAXDOAS measurements from June 2008 to April 2009 in the city centre and since April 2010 outside the city (Xianghe); extension of the validation method to this much polluted station is on-going. With this instrument, profile retrievals are possibles (aerosols, NO_2, …Clémer et al. 2010) and the MAXDOAS data can then be used to test the AMF input values of the retrievals.



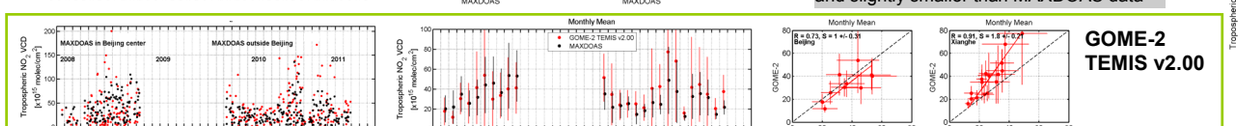
Closest pixels within 50km

Part of the difference is related to the different sensitivity of each technique to the local emissions, BUT also importance of satellite retrieval choices for the AMF_{tropo} calculation: cloud treatment and a-priori profiles, particularly.

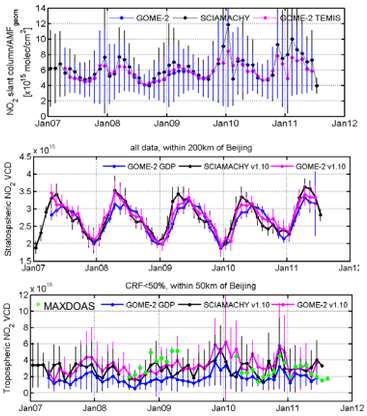
Clouds: OCRA/ROCCIN vs FRESCO
A-priori: monthly MOZART-2 profiles vs daily TM4 profiles for GDP4.4 and for TEMIS respectively.

E.g., mean AMF_{tropo} GOME-2 in 2008 are of ~0.85 (GDP) and ~0.45 (TEMIS) (wrt ~0.80 and ~0.60 at OHP)

GDP4.4: smaller than other satellite data and slightly smaller than MAXDOAS data



GOME-2 TEMIS v2.00



Conclusions and future work

- MAXDOAS measurements are well suited for end-to-end validation approach, allowing for verification and validation of different parts of the retrieval scheme: stratospheric and tropospheric content. Although not illustrated here, additional aerosols and profile information are useful to verify the assumptions made for AMF calculation.
- The end-to-end validation of GOME-2 NO_2 GDP 4.4 at the OHP station shows very good results. The extension to more polluted regions (as Beijing) or mountain regions (as Jungfraujoch, Switzerland, ~3600m) is on-going and more challenging.
- Large differences between different satellite retrieval algorithms are found, and are under investigation.

Selected References

Valks et al., 2011: AMT 4, 1491-1514.
Clémer et al. 2010: AMT 3, 863-578.
TEMIS data: www.temis.nl

Acknowledgements: Part of this work is funded by EUMETSAT through the O3M-SAF Continuous Development and Operation Project (CDOP), and by ProDEx and the Belgian Science Policy via SECPEA.

O3M SAF