Intercomparison of NO_2 satellite retrievals and spectral fitting

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Introduction

This work has been performed as part of the Quality Assurance for Essential Climate Variables project (QA4ECV, http://www.qa4ecv.eu). The project's objectives are to develop a Quality Assurance (QA) system for observational data products concentrating on six Essential Climate Variables (ECVs) and to generate multi-decadal satellite-derived global ECV records for which harmonized retrievals will be developed based on the community's best practice.

As part of this project, the agreement of NO_2 slant columns resulting from different DOAS retrieval codes is evaluated. Participating institutes and their DOAS retrieval codes are:

- Institute of Environmental Physics, University of Bremen (IUPB) [1]
- Belgian Institute for Space Aeronomy (BIRA-IASB) [2]
- Max-Planck-Institute for Chemistry, Mainz (MPIC) [3]

} Linear fit on optical depth (OD)

- Royal Netherlands Meteorological Institute (KNMI) [4] } Non-linear intensity fit

NO_2 slant columns from the GOME, SCIAMACHY, GOME-2, and OMI satellite instruments are planned to be intercompared. The intercomparison consists of
a) Harmonized DOAS fit settings (agreed on in advance)
b) Preferred DOAS fit settings (different for each group)

For each sensor, 4 days of data are compared (different season, early/late in lifetime of the sensor). Here, first results from the OMI intercomparison is presented (**Tab. 1**).

Sensor	February	August	February	August
OMI	02 Feb 2005	16 Aug 2005	04 Feb 2013	04 Aug 2013

Tab. 1: Days included in the OMI intercomparison

OMI data (harmonized settings)

Fit mode	Optical density (IUPB, BIRA, MPIC) Intensity (KNMI)
Fit window	405-465 nm [4]
DOAS polynomial	4th order (5 coefficients)
Cross-sections	O_3 (223 K), NO_2 (220 K), O_4, H_2O, Ring
Intensity offset correction	Yes (IUPB, BIRA, MPIC) No (KNMI)
Reference	Average solar spectrum

Tab. 2: Harmonized fit settings for OMI intercomparison

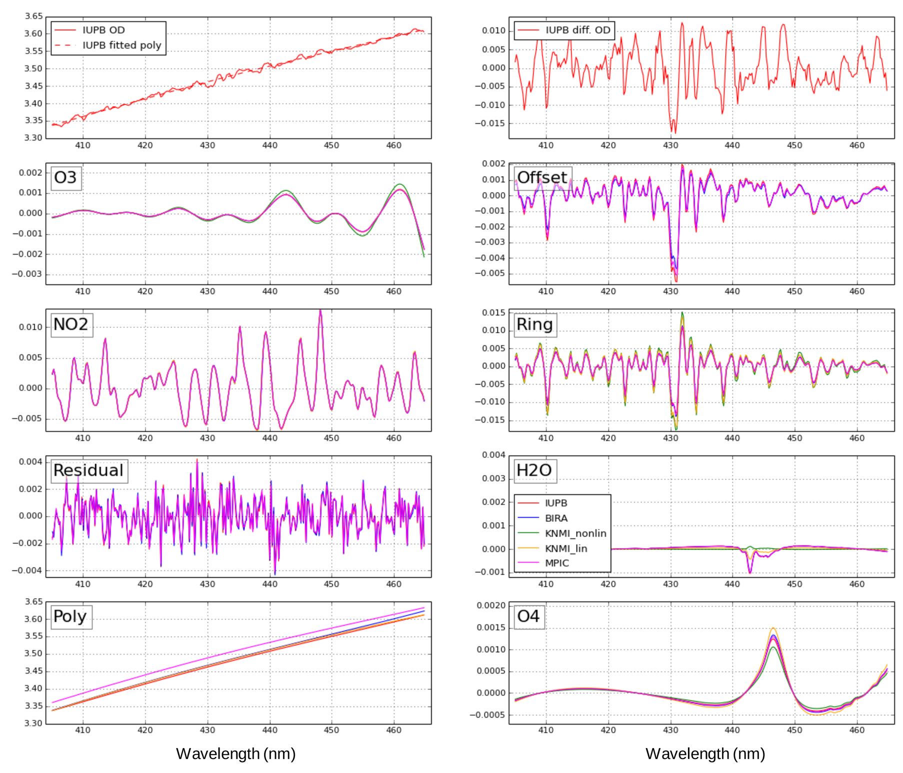

Fig. 1: Detailed intercomparison of a single OMI pixel (over Korea, IUPB-BIRA NO_2: $3x10^{14}$ molec/cm², medium agreement).

- The agreement of IUPB, BIRA, MPIC, and KNMI NO_2 retrievals was tested for harmonized DOAS settings (**Tab. 2**).
- Typical NO_2 slant column differences (**Fig. 1-3**) are in the range of 10^{14} molec/cm² for OD fitting groups and 10^{15} molec/cm² between OD and intensity fits.
- Excellent correlation of > 99.6% (**Fig. 2**) except over the SAA in August is obtained. The correlation is slightly decreasing with the lifetime of the sensor.
- Spatial distribution of NO_2 differences (**Fig. 3**): Most homogeneous between IUPB and KNMI as the intensity offset correction is almost the same. Cloud pattern and clear water surfaces (due to VRS) are visible in IUPB-BIRA and IUPB-KNMI for the same reason. Differences in IUPB-KNMI are one order of magnitude larger (intensity fit instead of OD fit) and stripes are visible (see also **Fig. 4**).

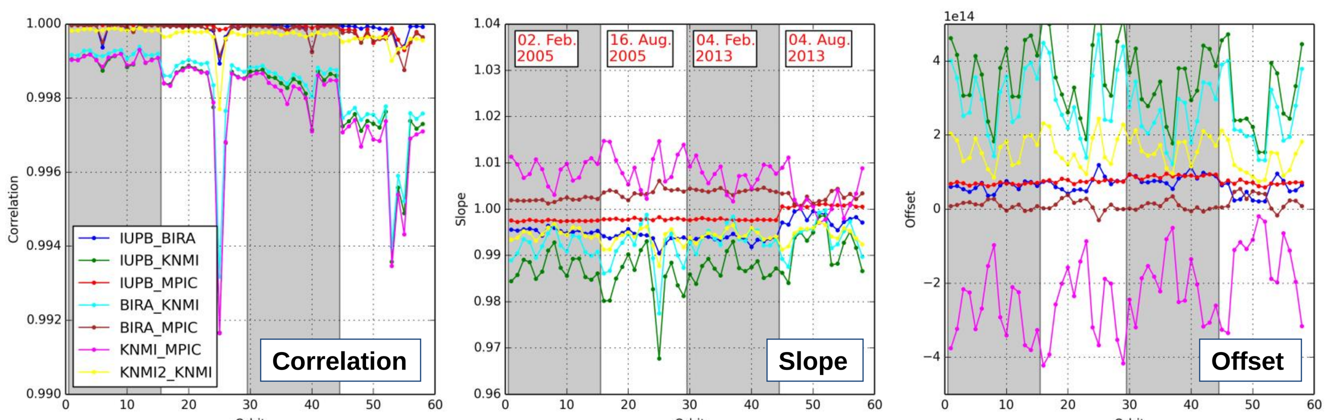

Fig. 2: Correlation coefficients, slope and offset from a linear regression analysis of NO_2 slant columns retrieved from different institutes (for all 4 days in Tab. 1). KNMI2 is an experimental fit mode based on OD (i.e. linear).

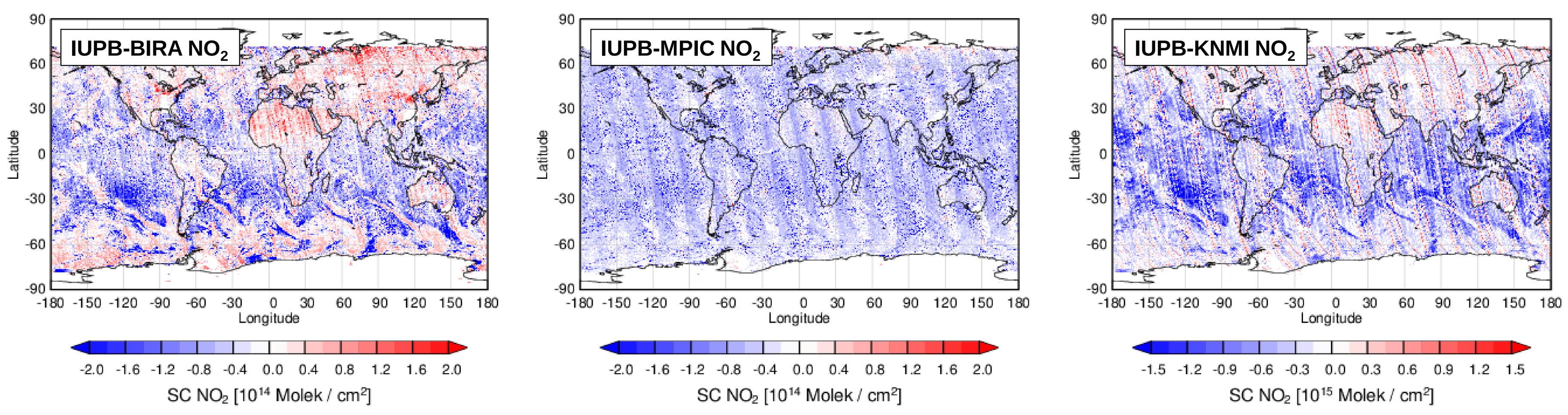

Fig. 3: Spatial distribution of NO_2 slant column differences (data from 02 Feb 2005).

Systematic differences

- The NO_2 difference shows strong similarities to the intensity offset fit factor (**Fig. 4**)
- The intensity offset is implemented in different retrieval codes in a different way (IUPB and MPIC fit $1/I_{sun}$, BIRA fits 1/I, KNMI omits the offset)
- A linear relation is found between offset fit factor and NO_2 difference if the offset correction is omitted (as KNMI does, **Fig. 5**).

→ Which one is more correct? Does offset prevent or introduce misfit, i.e. does it compensate a real signal?

- Over clear water surfaces, the offset partially compensates liquid water Vibrational Raman Scattering (VRS)
- But: enhanced offsets coinciding with NO_2 disagreement also found over land (**Fig. 4, bottom**)

→ Still under investigation (coincides with small intensities and low cloud cover, often surrounded by clouds)

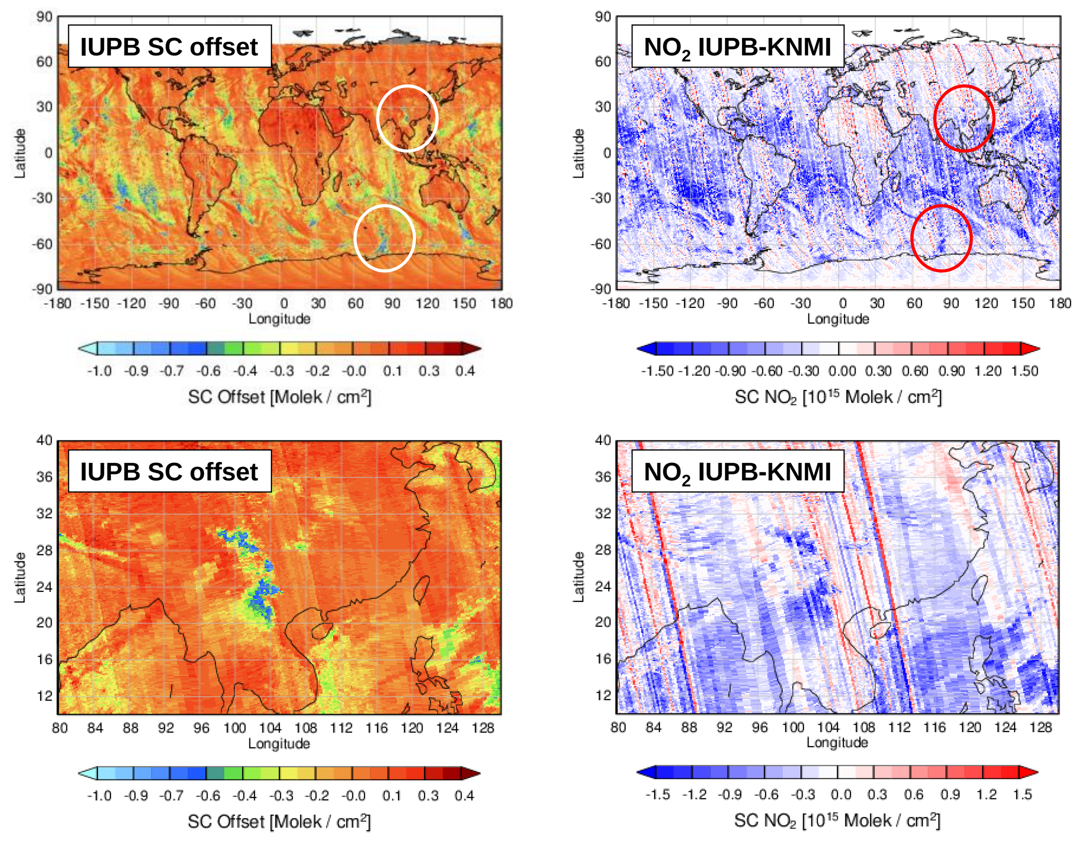

Fig. 4: Left: Fit factor of intensity offset correction in IUPB retrieval (circles indicate enhanced intensity offset not caused by VRS). Right: NO_2 slant column difference between IUPB and KNMI. Global maps (top) and zoom-in over China (bottom). Data from 02 Feb 2005.

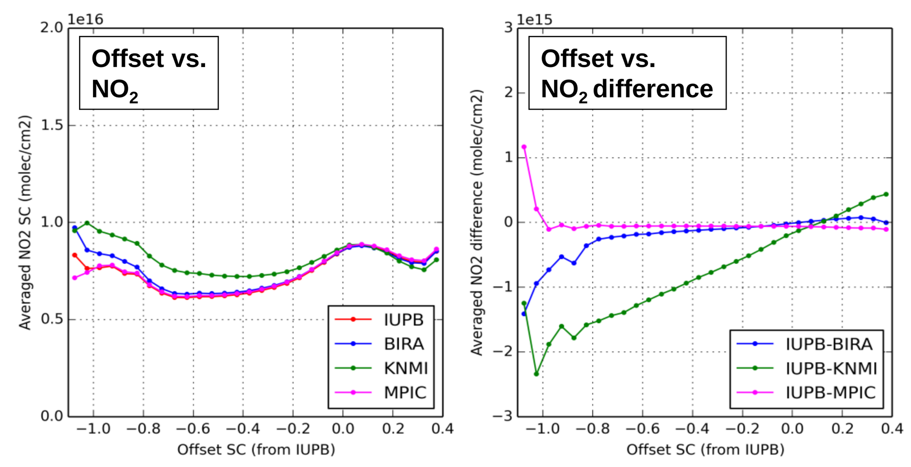

Fig. 5: Left: Offset intensity fit factor from IUPB retrieval (x-axis) vs. NO_2 slant columns, color-coded for different groups (y-axis). Right: IUPB offset (x-axis) vs. NO_2 slant column differences. A linear trend of the NO_2 difference (between IUPB and KNMI) with the IUPB offset fit factor is found.

Preferred settings and sensitivity studies

- NO_2 slant columns resulting from preferred fit settings have been intercompared in analogy to harmonized settings (**Fig. 6**)
- Correlation > 99% except over SAA (as expected, slightly worse than for harmonized settings)

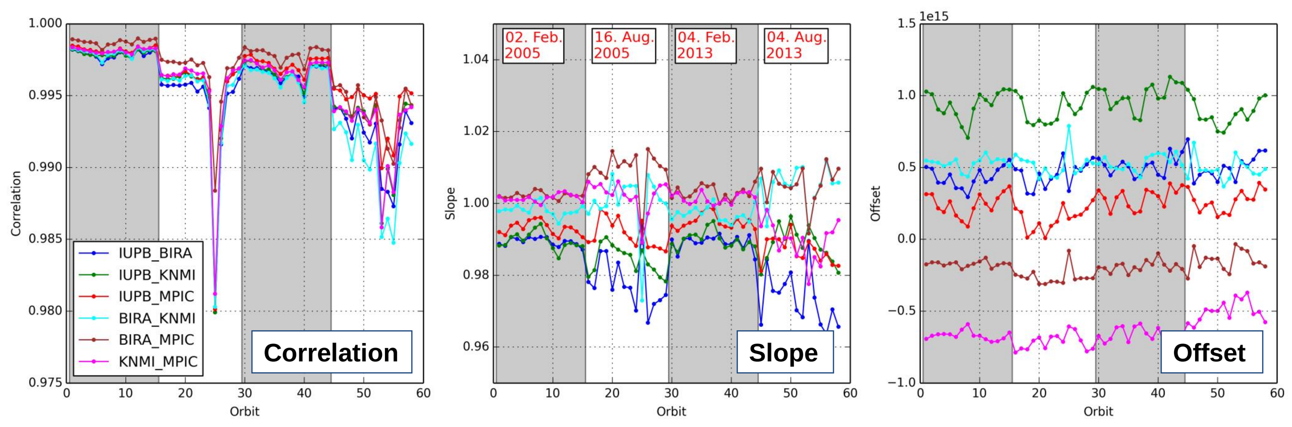

Fig. 6: Statistics (linear regression) for the NO_2 intercomparison using preferred settings (same as Fig. 2 but for preferred instead of harmonized settings).

- Correlation slightly decreasing with lifetime of the sensor (as already seen for harmonized settings)
- In addition, sensitivity tests based on the harmonized settings (**Tab. 2**) have been performed and summarized in **Tab. 3**

Test performed	Difference observed
Convolution per row vs fixed	Up to **2E13** (< 1%)
Intensity offset (1/I vs $1/I_{sun}$)	**2E14**
Including first order intensity offset	**2E14**
Including liquid water	Up to **1E15** larger NO_2 over oceans Recommendation: Include liquid water

Tab. 3: Sensitivity tests performed on OMI data.

Summary and conclusions

- For OMI data, NO_2 slant columns from different DOAS retrieval codes by IUPB, BIRA, MPIC, and KNMI show excellent agreement if harmonized fit settings are applied (correlation coefficient > 99,6%).
- Largest differences of $1.5x10^{15}$ molec/cm² for individual pixels were found between intensity fitting (KNMI) and OD fitting groups (IUPB, BIRA, KNMI). Between OD fitting groups, largest differences for individual pixels are $2\text{-}3x10^{14}$ molec/cm².
- Systematic NO_2 differences originate from different treatment of the intensity offset correction. Over water, the intensity offset correction probably interferes with VRS. Over land, enhanced offset fit factors coinciding with NO_2 disagreements are still under investigation.
- Comparing preferred fit settings, the correlation is smaller than for harmonized settings but still > 99%.
- Sensitivity studies suggest a typical sensitivity of $2x10^{14}$ molec/cm² on the retrieved NO_2 slant columns if fit settings are slightly modified (treatment of offset correction etc.). Inclusion of liquid water has a larger impact of up to $1x10^{15}$ molec/cm² selectively over clear water surfaces. It is recommended to include the liquid water cross section in the 405-465 nm window.

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Selected References

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