

# SATELLITE VALIDATION OF TROPOSPHERIC TRACE GASES WITH MAX-DOAS MEASUREMENTS DURING THE DANDELIONS FIELD CAMPAIGN

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## Introduction

This study presents time series for tropospheric amounts of nitrogen dioxide (NO<sub>2</sub>), formaldehyde (HCHO) and glyoxal (CHOCHO) retrieved from MAX-DOAS measurements at the DANDELIONS (Dutch Aerosol and Nitrogen Dioxide Experiments for validation of OMI and SCIAMACHY) field campaign that took place at Cabauw (Netherlands) from May 9 to July 17, 2005. These results are compared to independent ground-based and SCIAMACHY satellite data. It is shown that the multi-axis-DOAS technique in combination with an automated profile retrieval is a powerful tool in establishing long-term observations of tropospheric trace gases and facilitating the validation of tropospheric column amounts from satellite instruments.

## Measurements at Cabauw

As part of the DANDELIONS project, MAX-DOAS measurements of different trace gases have been carried out in Cabauw (52°N, 5°E), Netherlands from May 9 to July 17, 2005. The objective of this experiment is the validation of OMI, SCIAMACHY and AATSR measurements of aerosols and NO<sub>2</sub> over the Netherlands. Additionally, the quality of ground-based MAX-DOAS observations will be investigated by the intercomparison of different set-ups and by comparison to an NO<sub>2</sub> LIDAR experiment as well as to an *in situ* monitor (see table 1). Cabauw is located in a rural environment but close to the cities of Utrecht and Rotterdam. The Cabauw experimental site is operated by the Royal Netherlands Meteorological Institute (KNMI). The following Table 1 shows some of the participating instruments, partly used in this study for the interpretation of the MAX-DOAS data.



Figure 1: Measurement site at Cabauw

Table 1: Selection of instruments that participated in DANDELIONS

Instrument	Group	Products
MAX-DOAS	IUP Bremen	NO <sub>2</sub> (HCHO, CHOCHO)
MAX-DOAS	IUP Heidelberg	NO <sub>2</sub>
MAX-DOAS	IASB/BIRA Brussels	NO <sub>2</sub>
NO <sub>2</sub> -LIDAR	KNMI	NO <sub>2</sub>
<i>in situ</i> monitor	KNMI	NO <sub>2</sub> near to the surface
SCIAMACHY		NO <sub>2</sub> (CHOCHO, HCHO), absorbing aerosol index
OMI		NO <sub>2</sub> , aerosol optical depth
Boundary layer LIDAR	KNMI	aerosol extinction
ozone and radio sondes	KNMI	T, p, relative humidity, ozone

## Experimental Setup: Telescope

The MAX-DOAS-telescope is shown in figure 2. This set-up is able to switch between zenith and any elevation angle between 0° and 30°. Here, a scan in 1°-steps from 1° to 18° elevation in addition to a 30°-measurement and zenith measurement was chosen. The temporal resolution is then given as 20 minutes for a complete measurement cycle.

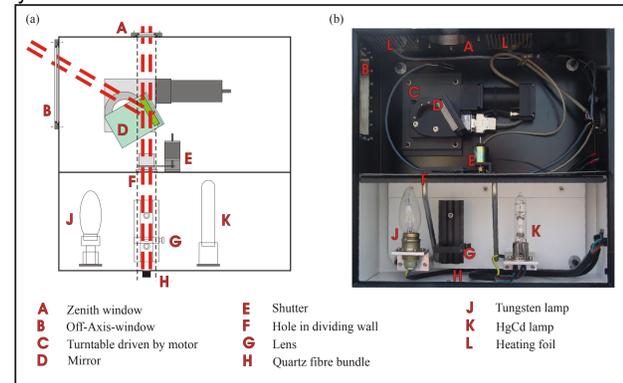


Figure 2: Schematic of the telescope. Left panel: mirror position for zenith measurements. Right panel: off-axis mirror position.

## MAX-DOAS Data Analysis

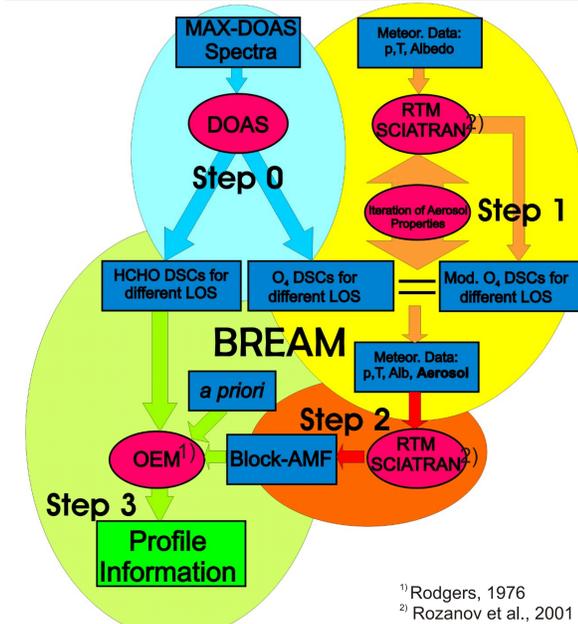


Figure 3: Flowchart for the retrieval steps applied to the measured differential slant columns (DSC) in order to obtain profile information (here illustrated for formaldehyde). The DSCs of O<sub>2</sub> are used to retrieve aerosol properties like the extinction profile of the atmosphere.

## Nitrogen Dioxide NO<sub>2</sub>

The figure 4 shows ground-based DOAS measurements compared to satellite data and to *in situ* measurements respectively. Excellent agreement is found for both tropospheric columns and NO<sub>2</sub> concentrations demonstrating the ability of the MAX-DOAS to work as a link between *in situ* and satellite observations.

The correlation of 0.72 between the ground-based measurements and SCIAMACHY tropospheric NO<sub>2</sub> columns (IUP Bremen data product) was found (see figure 5). For the ground-based data, days with clouds are included. For the satellite data, pixels with less than 30 percent cloud cover. The closest pixel on each day was used, subject to a maximum distance of 50km.

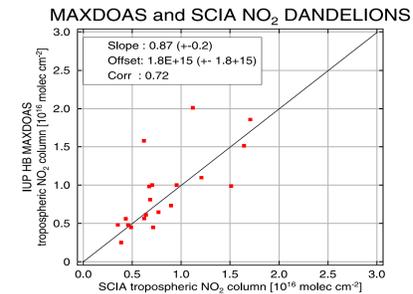


Figure 5: Correlation plot for the data shown in figure 4, upper panel.

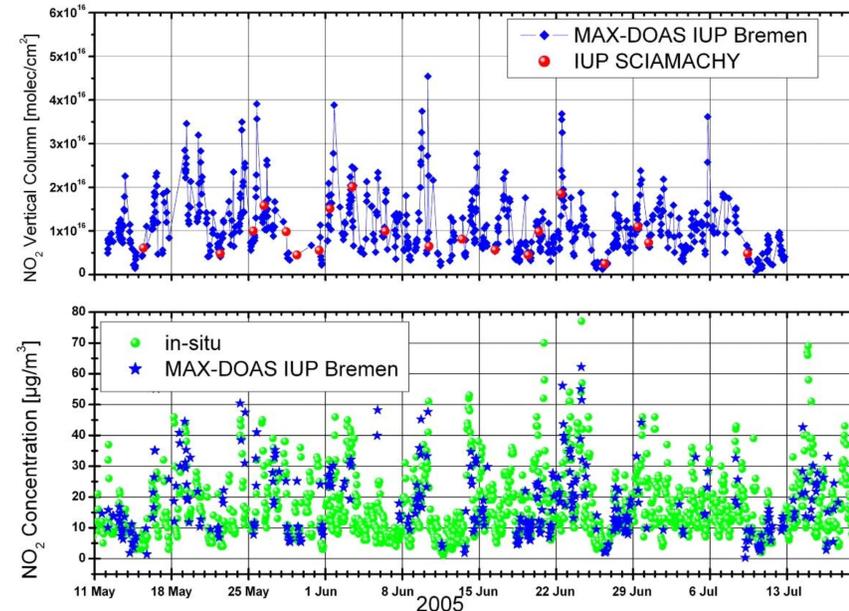


Figure 4: Upper panel: Comparison of tropospheric NO<sub>2</sub> columns from the MAX-DOAS and SCIAMACHY. Lower panel: Intercomparison plot showing data of an *in situ* NO<sub>2</sub> monitor (KNMI) and the NO<sub>2</sub> concentration derived from a ground layer of 50 m thickness.

## Formaldehyde HCHO & Glyoxal CHOCHO

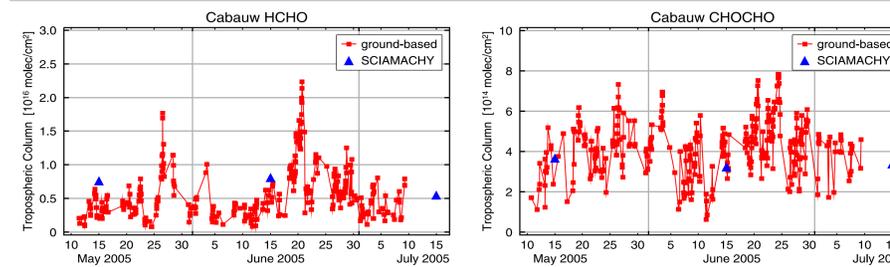


Figure 6: Validation of formaldehyde and glyoxal above Cabauw. For SCIAMACHY, monthly means were calculated. The tropospheric columns of formaldehyde are more variable than for those of glyoxal probably due to direct emissions from anthropogenic sources in the heavily polluted area. However, similarities can be observed: Enhanced HCHO is always associated with an increase in CHOCHO, e.g. 25/26 May or around 20 June.

## Summary & Outlook

- It was shown that MAX-DOAS data can be used for the validation of tropospheric column amounts from satellites like SCIAMACHY: Excellent agreement for NO<sub>2</sub> and on average for CHOCHO and HCHO was found.
- Excellent agreement between the *in situ* NO<sub>2</sub> from KNMI and the Bremen MAX-DOAS data.
- The 'new' species glyoxal (Volkamer et al., 2005) can be detected from ground and from the satellite.
- Future work:
  - Comparison of the NO<sub>2</sub> profiles with the LIDAR measurements and with model calculations.
  - Comparison of the MAX-DOAS aerosol extinction profile with independent measurements.

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## Acknowledgements

- This project has been funded in parts by:
- the German Federal Ministry of Education and Research (BMBF), [50EE0005]
  - the German Research Council (DFG)
  - the State of Bremen and the University of Bremen
  - This work is part of and facilitated by IGBP-IGAG and EU-ACCENT network of excellence.

Also the help of the Cabauw crew was very much appreciated.

Please also visit the DANDELIONS webpage: <http://www.knmi.nl/omi/research/validation/dandelions/>