The IUP-Bremen imaging DOAS Instrument IMPACT during CINDI-2

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Introduction

Measurement principle: Differential Optical Absorption Spectroscopy (DOAS)
- Based on Lambert-Beer's law
- High-frequency part of (known) absorption structures σ are fitted to optical depth τ
- DOAS equation (I and are I_0 are measured):

$$\tau_{meas} = \ln\left(\frac{I_0}{I}\right) = \sum_i \sigma_i(\lambda)\cdot SC_i + polynomial + residual$$

- Result: Slant columns $SC_i = \int \rho_i \cdot ds$ (absorber concentration ρ integrated over light path s)

- Current Multi-Axis (MAX)-DOAS instruments are able to point in any direction, but only one direction per time

→ Impossible to measure horizontal and vertical distribution at once (too slow)

Previous imaging DOAS observations (e.g., [1])
- Very high angular resolution (0.1° - 0.2°), but total FOV small (e.g., 13° vertically, 36° horizontally)
- Mostly focused on plume mapping (stacks/volcanoes)
- 1D imaging instantaneously, mirror system for 2nd dimension

Objectives of IMPACT instrument
- Full hemispheric scans (0°-360° azimuthal), large vertical FOV (ca. 50°)

→ Trace gas (NO_2) profiles around site

→ Aerosol information around site (to be tested)
- Use of fibre bundle (like MAX-DOAS)

→ Robustness/flexibility (separate in- and outdoor parts), overcoming polarization issues

Instrument

- Adaptation from an air-borne DOAS instrument [2,3,4]

- ANDOR Shamrock 303i imaging spectrometer (CT, astigmatism correction, temperature stabilized to 35°C, good spatial and spectral resolution in 425-490 nm window)

- Entrance optic (Camera objective, 50° total FOV) mounted on commercial ENEO VPT-501 pan-tilt-head)

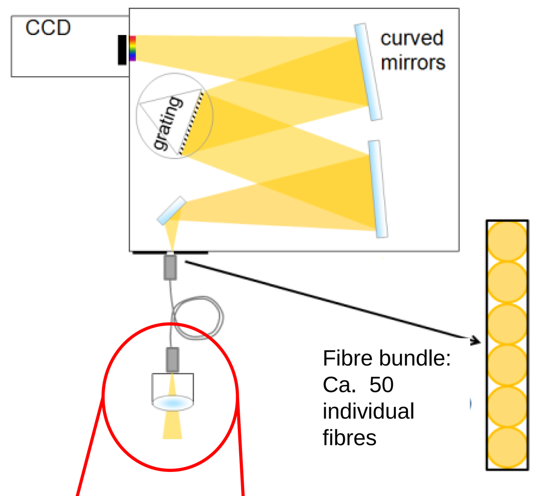
- Optical fiber bundle: 50 single fibers vertically aligned and sorted in the same order at both sides

→ Different elevations measured simultaneously (1D imaging)

- Mounted on Pan/Tilt-Head

→ Apply other azimuths for 2D mapping

Fig 1: Sketch of the instrument [3].



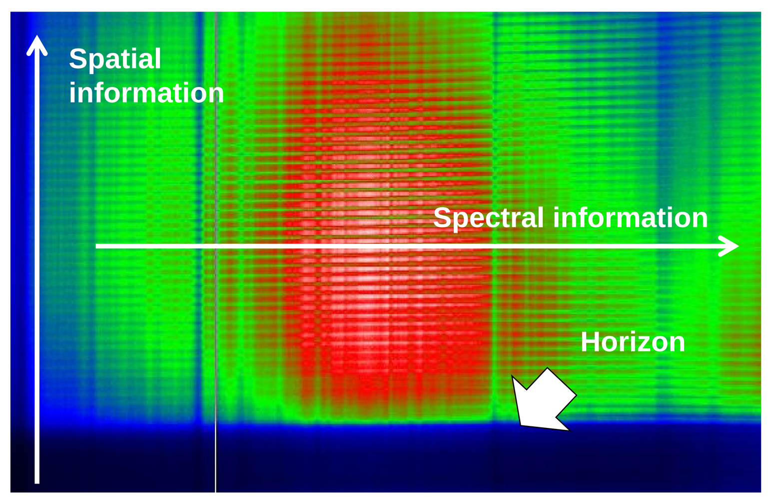


Fig 3: Image of the CCD. Single fibres (pointing in different elevations, 1D imaging) are clearly visible as well as the position of the horizon.

Fig 3: Telescope providing 50 elevations simultaneously, mounted on pan-tilt-head for azimuthal movement.

Imaging NO_2 measurements during CINDI-2

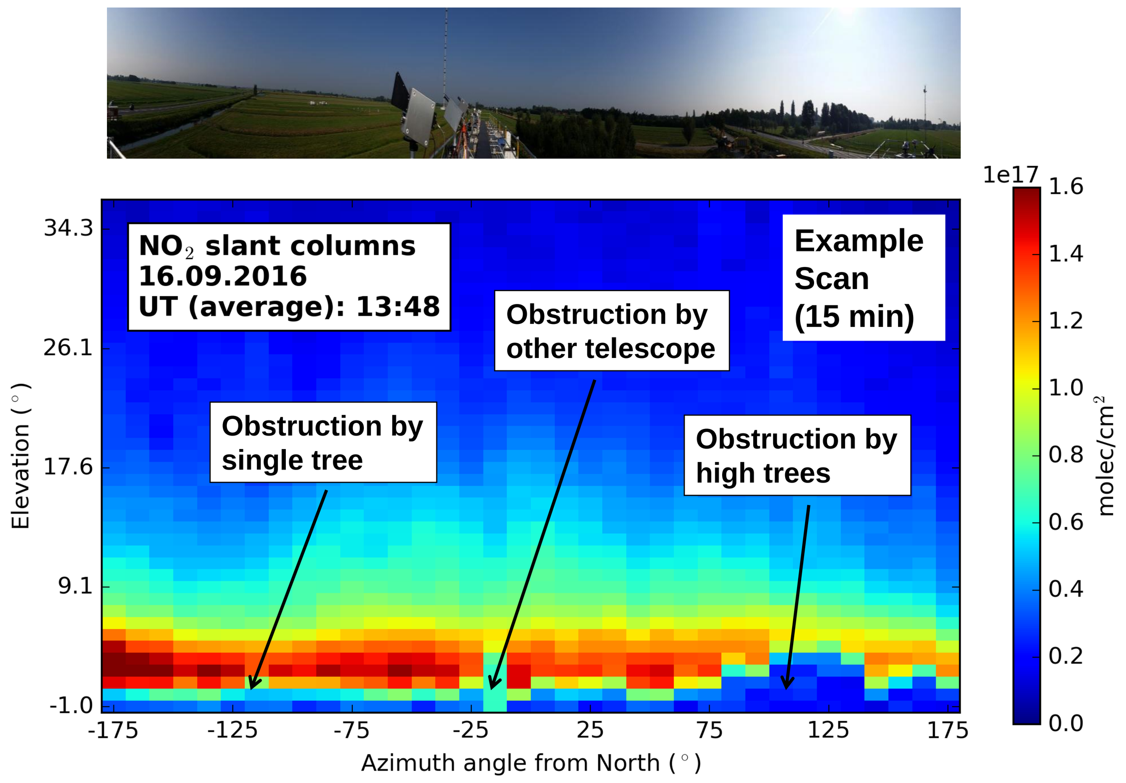


Fig 4: Top: Panorama view around measurement site. Bottom: NO_2 slant columns around measurement site on 16 Sept 2016 (example scan).

The CINDI-2 campaign
- **C**abauw **I**ntercomparison of **N**itrogen **D**ioxide measuring **I**nstruments **2**
- Follow-up of the CINDI campaign in 2009
- Cabauw, the Netherlands
- September 2016
- Semi-blind intercomparison
- > 30 groups, 40 instruments
- In addition, lidar, ceilometer, In situ etc…

Measurement scheme during CINDI-2
- Elevations measured simultaneously
- Azimuthal direction (motor): 10° steps from -175° to + 175° (36 directions, 15 s each)
- Zenith reference measurement
- Ca. 15 min for complete scan (incl. reference)

→ 2D image of the hemisphere around site, resolution 50 x 36 pixels
- NO_2 and O_4 DOAS fit: 425-490 nm (O_3, NO_2, O_4, H_2O, Ring, intensity offset)

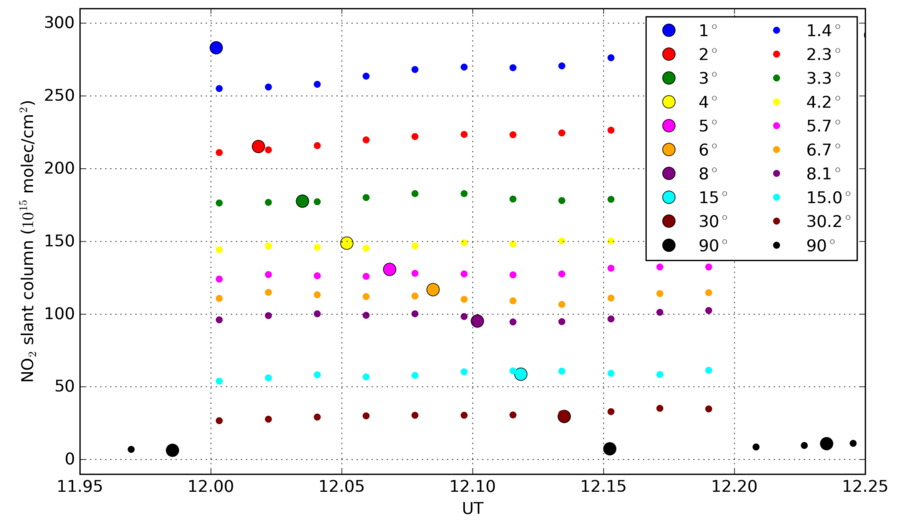
→ Allows insight in pollution conditions and variability/events

Comparison to MAX-DOAS measurements
- Measurements in the common azimuthal direction (in addition to hemispheric scans above)
- Attention: Elevation angles are not exactly the same (in particular 1° elevation)!
- Good general agreement
- Many (instantaneous) imaging-DOAS measurements in different elevations within one MAX-DOAS scan

→ IMPACT captures temporal evolution within one MAX-DOAS scan

Fig 5: CINDI-2 measurement site.

Fig 6: Comparison of MAX-DOAS (large circles) and Imaging-DOAS (small circles) NO_2 slant columns in different elevations (color-coded), exemplarily for one MAX-DOAS scanning sequence.



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Retrieval of aerosol information

Measured O_4 slant columns
- Example day: 24.09.2016, sunny and cloud-free viewing conditions
- Position of sun clearly visible in intensity
- O_4 slant columns (from NO_2 fit) are a measure of the light path (pressure-dependent profile), e.g., small O_4 slant columns around position of the sun due to strong aerosol forward scattering
- Attention: Elevations pointing partly towards the ground (red box) should not be compared!

Simulated O_4 slant columns:
- Radiative transfer model SCIATRAN used
- Rayleigh atmosphere not able to reproduce measured O_4
- Inclusion of different aerosol scenarios tested

→ O_4 pattern largely reproduced, azimuthal dependency sensitive to aerosol assumptions

→ Retrieval of aerosol parameters (e.g. asymmetry parameter if profile is constant) seems feasible

→ Currently under investigation

Fig 7: Top: Measured intensity and O_4 slant columns at 24.09.2017 during CINDI-2. Middle and bottom rows: Simulated O_4 slant columns (right) and differences (left) w.r.t. measurements.

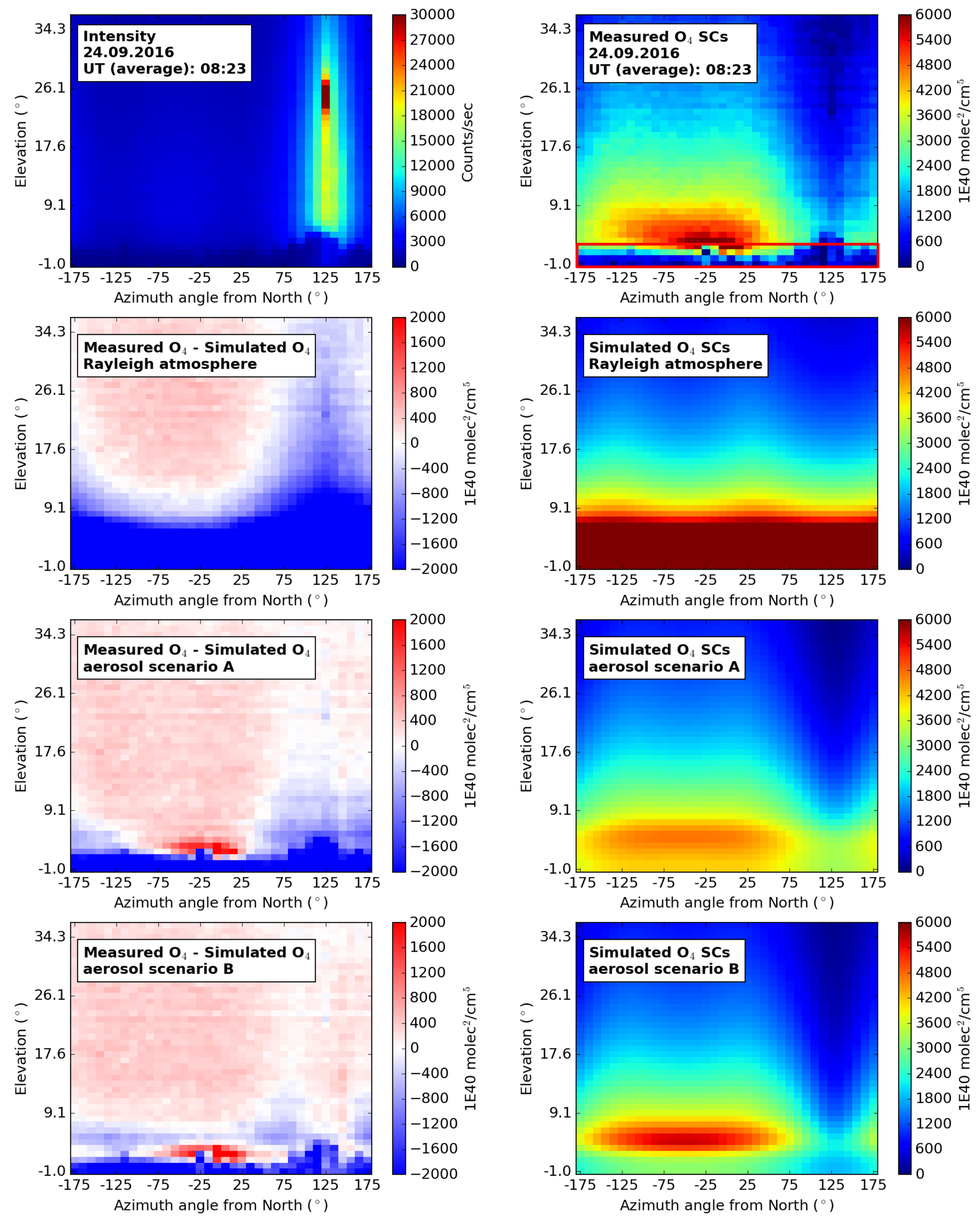


Fig 8: Aerosol profile used as input for scenario A.

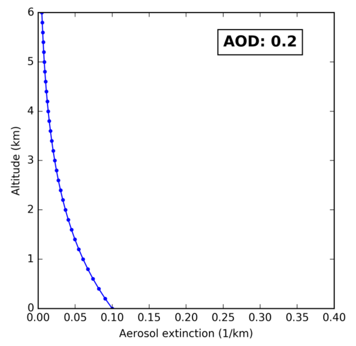
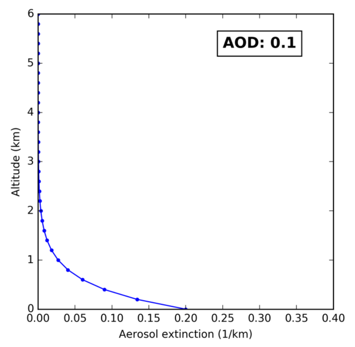


Fig 9: Aerosol profile used as input for scenario B.



Conclusion / Outlook

- Full hemispheric detection, i.e. vertical as well as azimuthal distribution, of tropospheric NO_2 and O_4 around the measurement site during CINDI-2
- „Refreshing rate" of hemispheric observations ca. 15 min
- Good agreement with close-by MAX-DOAS measurements, temporal evolution within one MAX-DOAS scan can be captured
- Profile retrieval to be implemented (2D images of profiles around measurement site)
- Retrieval of aerosol parameters seems feasible (work in progress)

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