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 is fitted to optical depth
- DOAS equation (I and A are measured):
  \[ I = \epsilon \cdot A + \tau \]
- Result: Slant columns \( \tau \) integrated over path height
- 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° azimuth), large vertical FOV (ca. 50°)
- Trace gas (NO₂) 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
  (IT, 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 fibre bundle: 50 single fibres vertically aligned and mounted in the same order on both sides
  - Different elevations measured simultaneously (1D imaging)
- Mounted on Pan/Tilt-Head
- Apply other azimuths for 2D mapping

Measuring NO₂ measurements during CINDI-2

- 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
- NO₂ and O₃ DOAS fit: 425-490 nm (O₂, NO₂, NO, H₂O, 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 agreement
- Many (instantaneous) imaging-DOAS measurements in different elevations within one MAX-DOAS scan
  - IMPACT captures temporal evolution within one MAX-DOAS scan

Retrieval of aerosol information

- Measured O₃ slant columns:
  - Example day: 24.09.2016, sunny and cloud free viewing conditions
  - Position of sun clearly visible in intensity
  - Residual polynomial fit of light path
  - Attention: Elevations pointing partly towards the ground (red box) should not be considered
- Simulated O₃ slant columns:
  - Radiative transfer model SCIAMAN used
  - Rayleigh atmosphere not able to reproduce measured O₃
  - Inclusion of different aerosol scenarios tested
- O₃ pattern largely reproduced, aerosol information sensitive to aerosol assumptions
  - Retrieval of aerosol parameters (e.g. asymmetry parameter if profile is constant) seems feasible
  - Currently under investigation

Conclusion / Outlook

- Full hemispheric detection, i.e. vertical as well as azimuthal distribution, of tropospheric NO₂ and O₃ 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)

References


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