Aircraft imaging DOAS measurements of anthropogenic nitrogen dioxide


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1. Introduction

Objectives of aircraft imaging DOAS measurements:
- Retrieval of tropospheric trace gases, here nitrogen dioxide NO₂
- Applying Differential Optical Absorption Spectroscopy (DOAS) technique
- Mapping of NO₂ pollution sources, identification of source regions and strengths
- Satellite data validation, investigation of sub-pixel variability

Positive aspects of aircraft measurements and imaging DOAS:
- High spatial resolution -100 m (down to ~30 m at crucial emission sites)
- Several viewing directions across track are observed simultaneously
- No data gaps occur along track

The IODAS instrument in the Polar-5 aircraft

Aircraft Type: Basler BT-67 / DC3
Length/Height/Span: 21 m / 5.2 m / 29 m
Speed & Altitude: 50-105 m/s; 100-19000 ft
Owner & Operator: AWI, Germany;
Kern Borek Air Ltd. Canada
Photograph: (top) IODAS installed in Polar-5 aircraft (bottom) Polar-5 in the hangar at Bremen regional airport

2. Instrumental setup and viewing geometry

Technical information:
- Wide angle objective and fibre bundle (35 fibres) as entrance optics
- Acton 300i imaging spectrometer
- Grating 600/mm, blazed @500nm
- Spectral window 415 - 455nm
- Spectral resolution 0.7 - 1.0nm

Frame transfer (FT) CCD Detector, 512x512 pixels, 8.2x8.2 mm²

Gap-free measurements (due to FT CCD) and flexible positioning in aircraft (due to sorted fibre bundle)

Viewing geometry:
- 2 nadir ports: spectrometer 30cm area
- Geolocation: from GPS & gyrometer
- Viewing directions: max. 35 (typ. 9) lines of sight, (LOS), i.e. from 35 fibres
- Field of view: ~48° across track (ll)
- Swath width: ~30° along track/azimuth angle H
- Exposure time tₑ: typ. 0.5ms
- Spatial resolution: ~100 m and less

Computation of ground pixel location:
- Consideration of the aircraft angles (pitch, roll and yaw) is required in addition to GPS position for correct determination of the geolocation
- Displacements of the ground pixel due to aircraft motions can be significant

3. NO₂ vertical columns and emission flux calculations above a power plant

NO₂ retrieval above a power plant
- Black coal power plant (848 MW) at Ibbenbüren, Germany (52°-77°N, 7°45'E)
- Slant columns of NO₂ retrieved by Differential Optical Absorption Spectroscopy
- Large variability of NO₂ amounts across and along track is observed
- The NO₂ in the exhaust plume downward of the power plant is clearly visible
- Transsects through the plume are used for emission flux estimations

4. NO₂ above inhabited and rural areas

NO₂ above Hamburg and Northern Germany
- Urban NO₂ SC maxima lie around 1-10¹⁰ molecules/cm²
- Enhanced NO₂ above Hamburg and close to the airport
- Strong spatial variability of NO₂ is observed

5. Summary & Outlook

Summary
- Imaging DOAS instrument shows good imaging quality and good performance for NO₂ measurements
- Aircraft pitch, roll and yaw angles are fully taken into account for correct ground geolocation
- NO₂ column amounts have been retrieved, pollution sources are observed (power plant, cities, etc.)
- Further findings: Large spatial NO₂ variability, consistent NO₂ retrieval results for different LOS divisions, transported NO₂ within a cloud away from local sources, consistently low NO₂ above rural areas
- NO₂ emission fluxes are calculated for a power plant point source in agreement with emission reports

Activities for the future
- Air mass factor consideration will be refined in future analyses
- Further dedicated campaigns will be conducted with the imaging DOAS instrument above pollution sources

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References

see also: www.iup.uni-bremen.de/doas