Accounting for surface reflectance in the derivation of vertical column densities of NO₂ from airborne imaging DOAS

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1. AROMAT campaign
- The AROMAT (Airborne ROmanian Measurements of Aerosols and Trace Gases) campaign was held in September 2014
- Dedicated to comparison of multiple remote sensing and in-situ instruments for satellite data validation
- Many European research institutions involved
- Two target sites
  - City of Bucharest (urban emissions from traffic and industry)
  - Ju Valley (Two large power plants with high emissions and localized plumes)
- Shown here: solely measurements in the Bucharest area

2. Instrumental setup and method
- **Instrumental setup**: Scattered sunlight from below the aircraft is collected and fed into an imaging spectrometer via a fiber bundle (35 individual fibers), retaining the spatial information.
- **Photographs of AirMAP & Aircraft**:
  - Top left: Aircraft AirMAP was installed on (Cessna 207 Turbo); operated by FU Berlin.
  - Bottom left: Aircraft with port of entrance optics and video camera
  - Right: Instrument rack carrying spectrometer, PCs, UPS etc.
- **The AirMAP viewing geometry**: The swath of the push-broom imager depends on flight altitude, groundspeed of the aircraft and exposure time. For typical values during AROMAT this results in a resolution of 30 x 84 m².

3. Air Mass Factors
- **VCD = DSCD / AMF**: 
- **AMF computed with SCIPTRAN and compiled into a look-up table with the following dependences:**
  - NO₂, NO₃ profile: sun/sky reflectance 
  - Surface reflectance 
  - Relative air mass factor (AMF) 
  - Viewing zenith angle
  - Sea level pressure
  - Flight altitude
  - Downwelling solar radiation
  - Aerosol profile derived from AERONET measurements from FURIBIS

4. Surface reflectance
- **Importance of surface reflectance for the Air Mass Factor**
  - Strong dependency of the AMF on surface reflectance
  - Bright surfaces increase the contribution of light coming from the surface
  - Thereby increasing the fraction of light that has passed the trace gas layer (close to the ground)

5. Application of surface reflectance on VCD retrieval
- **Surface reflectance constant (0.05)**
- **Surface reflectance derived from measured intensities**: Comparison to mobile car DOAS measurements
- **Surface reflectance derived from measured intensities**
  - Generally good agreement between the mobile car DOAS and AirMAP
  - The slope of the linear orthogonal fit is mainly determined by assumptions on the aerosol and NO₂ profile
  - Depending on the viewing geometry (airborne / ground-based) aerosols above the NO₂ layer can shield the sunlight from passing through the layer (airborne) while they might enhance the NO₂ signal for the ground based system by multiple scattering processes.
  - Up to now the data was evaluated independently by the different research groups, without common assumptions in the AMF computation

6. Comparison to mobile car-DOAS measurements
- **University of Galati**
  - Elevation angle: zenith
- **Max-Plank-Institute for Chemistry Mainz**
  - Elevation angle: 22°
- **Selected references**

7. Summary & Outlook
- **We have developed a method to account for highly variable surface reflectance in an urban environment**
- Applying the derived surface reflectances in AMF computation success fully eliminates spatial patterns in the retrieved NO₂ VCD originating from varying surface reflectances
- Comparison to two independent co-located mobile car DOAS measurements yields good agreement
- Comparison between car and airborne measurements can be further improved by homogenized assumptions on the aerosol and NO₂ profile
- Further analysis of the dataset to better understand the influence of aerosols on the radiative transfer

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