Tropospheric NO₂ and HCHO derived from dual-scan MAX-DOAS measurements in Uccle (Belgium) and application to SSP/TROPOMI validation

E. Dimitropoulou 1, 2, F. Hendrick 1, M. M. Friedrich 1, G. Pinardi 1, F. Tack 1, A. Merlaud 1, C. Fayt 1, C. Hermans 1, F. Fierens 2 and M. Van Roozendael 1

1 Royal Belgian Institute for Space Aeronomy (BIRA-IASB), Brussels, Belgium; 2 IRCEL-CELINE, Brussels, Belgium

Contact: ermioni.dimitropoulou@aeronomie.be

Motivation
Study of tropospheric nitrogen dioxide (NO₂):
• Mainly emitted by anthropogenic activities
• Participation in tropospheric ozone formation and formaldehyde (HCHO)
• Intermediate product in the oxidation of most volatile organic compounds (VOCs)
• Trace of VOCs

Focusing on Brussels area:
• NO₂ concentrations among the highest in Europe as observed by in-situ stations and satellite instruments
• HCHO concentrations have never been presented for such a big time period (March 2018 – December 2020)

Instrumentation
A. Multi-Axis Differential Optical Absorption Spectroscopy (MAX-DOAS) instrument
• Measures continuously in both UV and VIS wavelength ranges in dual-scan configuration
• Dual-scan configuration (Fig. 1): One vertical scanning towards the blue azimuthal direction (the so-called main azimuthal direction in 9 elevation angles) and 9 azimuthal measurements at one elevation angle (2 degrees)
• Capable of determining the vertical and horizontal distribution of trace gases

Fig.1: The dual-scan experimental set-up of the BIRA-IASB MAX-DOAS instrument. The colored dots show the locations of the in-situ stations in Brussels.

B. TROPMI instrument
• UV-Vis-NIR-SWIR spectrometer
• Atmospheric composition measurements with high spatio-temporal resolution (ground pixel of 3.5 x 7 km² and 3.5 x 5.5 km² since 6 August 2019) related to air quality, climate forcing, ozone and UV radiation
• Daily global coverage
• Data continuity between Envisat Satellite and NASA’s Aura mission and the launch of BIRA-IRCEL DOAS instrument.

Fig.3: Tropospheric NO₂ columns derived from the TROPMI and the MAX-DOAS instrument on 06 June 2018 near the measurement site in Uccle (overlaid on OSM Standard layer).

Fig.4: Box and whisker plots representing the seasonal horizontal sensitivity as derived from all the azimuthal viewing directions for the Vis and UV spectral ranges.

Fig.5: Monthly NO₂ (left panel) VCD and (right panel) VMR means covering two years of MAX-DOAS measurements.

Fig.6: Monthly HCHO (left panel) VCD and (right panel) VMR means covering two years of MAX-DOAS measurements.

Fig.7: Seasonal NO₂ (left panel) VCD and (right panel) VMR mean values during weekdays and weekends.

Fig.8: Seasonal HCHO (left panel) VCD and (right panel) VMR mean values during weekdays and weekends.

Fig.9: Scatter plots between the tropospheric HCHO columns derived from the dual-scan MAX-DOAS observations and the TROPOMI collected pixels.

Fig.10: Scatter plots between the tropospheric NO₂ columns derived from the dual-scan MAX-DOAS observations and the TROPOMI collected pixels.

Fig.11: Scatter plots between the tropospheric NO₂ columns derived from the dual-scan MAX-DOAS observations and the re-calculated TROPOMI tropospheric columns.

Seasonal variation of NO₂ and HCHO
• NO₂ and HCHO near-surface VMRs and VCDs as retrieved in the main azimuthal direction
• Clear seasonal cycle for both trace gases
• Maximum concentrations: NO₂ during cold months and HCHO during warm months, as expected

Fig.12: Scatter plot between the tropospheric NO₂ columns derived from the dual-scan MAX-DOAS observations and the re-calculated TROPOMI columns.

Impact of systematic uncertainties in the satellite retrieval
• A-priori profile shape
• Recalculation of the TROPOMI/SSP VCDs using vertical profiles from MAX-DOAS measurements
• Change of the a-priori profile significantly improves the agreement between TROPOMI and MAX-DOAS data sets for both NO₂ and HCHO.

Fig.13: Scatter plots between the tropospheric HCHO columns derived from the dual-scan MAX-DOAS observations and the re-calculated TROPOMI columns.

Take-home message
• Two years of dual-scan MAX-DOAS NO₂ and HCHO near-surface VMRs and VCDs in Uccle are presented here
• The dual-scan MAX-DOAS measurements conducted in an urban area, like Brussels can:
  • better characterize the spatial variability of important pollutants, such as NO₂ and HCHO
  • improve our knowledge about the longitudinal and the horizontal NO₂ and HCHO in Brussels
  • improve validation results of satellite air quality measurements with high spatial resolution, such as TROPOMI/SSP

References

Fig.2: The MAX-DOAS Instrument in Brussels.

Fig.8: Seasonal NO₂ (left panel) VCD and (right panel) VMR mean values during weekdays and weekends.