Retrieval of tropospheric NO_2 vertical column densities from multiple MAX-DOAS measurements in Vienna and comparison with satellite data

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Motivation

- Ground-based MAX-DOAS spectra can be used for the retrieval of tropospheric NO_2 vertical column densities and thus, are important data for satellite validation.
- Within the VINDOBONA project, three new 2-D MAX-DOAS instruments have been installed at three different locations in Vienna.
- Recent validation studies have found a systematic underestimation of satellite measurements of tropospheric NO_2 VCDs. Two possible reasons were highlighted: **(1)** Satellite observations do not fully resolve the horizontal gradients and **(2)** profile heights of NO_2 and aerosols in satellite retrievals are not accurate enough
- In this study, **(1)** is evaluated by including and converting NO_2 surface concentrations from air quality monitoring stations. Moreover, ancillary measurements that could be used to correct **(2)** are presented.

Tropomi vs. MAX-DOAS NO_2 VCDs

Fig. 3. Tropomi NO_2 VCDs vs. BOKU MAX-DOAS NO_2 VCDs

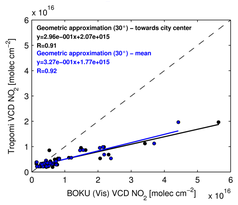


Fig. 4. Tropomi NO_2 VCDs vs. Arsenalturm MAX-DOAS NO_2 VCDs

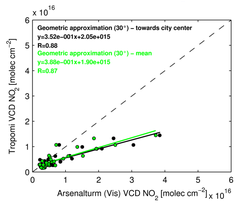
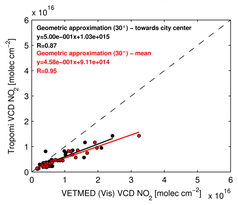


Fig. 5. Tropomi NO_2 VCDs vs. VETMEDMAX-DOAS NO_2 VCDs



Tropomi vs. ground-based NO_2 VCDs

Fig. 14. Tropomi NO_2 VCDs of pixels closest to BOKU (upper), Arsenalturm (middle) and VETMED (lower) MAX-DOAS sites vs. averaged ground-based NO_2 VCDs from MAX-DOAS measurements and in situ stations within the same pixels. NO_2 concentrations have been converted by using the linear relationship of BOKU vs Hohe Warte (left) and VETMED vs Floridsdorf (right)

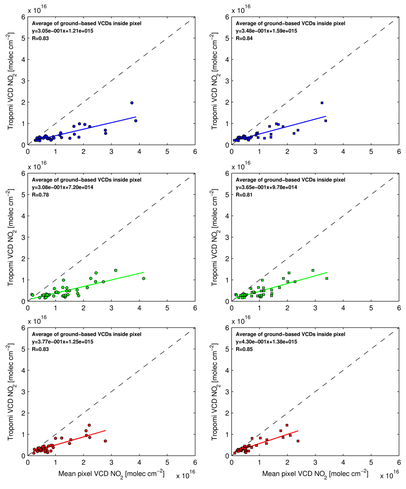
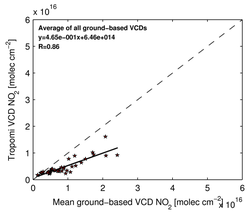


Fig. 15. Averages of NO_2 VCDs from three Tropomi pixels closest to MAX-DOAS sites vs. averages of all ground-based NO_2 VCDs from MAX-DOAS measurements and in situ stations used in this study

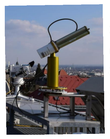


- The inclusion of converted NO_2 surface concentrations from air quality monitoring stations does not really change the slope of the linear regression lines.
- Overall, higher correlation is found when the linear relationship bewteen VETMED MAX-DOAS NO_2 VCDs and NO_2 concentrations from Floridsdorf is applied for the conversion of surface concentrations into NO_2 VCDs.
- Lowest systematic underestimation of satellite measurements is found when NO_2 VCDs from all selected stations are included.

Three MAX-DOAS instruments in Vienna

BOKU site (B)
Universität für Bodenkultur
Peter-Jordan Straße 82
1190 Wien, Österreich
Altitude: 267 m asl
Start of measurements: May 2017

VETMED site (V)
Veterinärmedizinische Universität
Veterinärplatz 1
1210 Wien, Österreich
Altitude: 171 m asl
Start of measurements: Dezember 2016



Cimel photometer
@ BOKU site
as part of AERONET
Start of measurements: May 2016

Arsenal site (A)
Objekt
Arsenal 24
1030 Wien, Österreich
Altitude: 333 m asl
Start of measurements: August 2018

Spatiotemporal variability of NO_2 and aerosols

Fig. 6. In situ NO_2 concentrations, interpolated to match the S5P overpass time and averaged over the 27 selected days

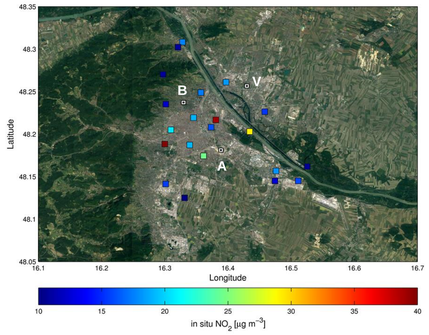


Fig. 7. Mixing-height, interpolated to match the S5P overpass time of the 27 selected days (39 overpasses)

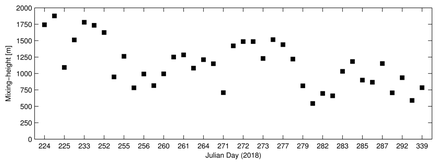


Fig. 8. NO_2 and PM10 concentrations from closest stations to MAX-DOAS sites, interpolated to match the S5P overpass time of the 27 selected days (39 overpasses)

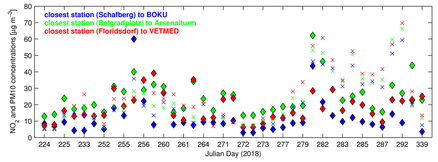


Fig. 9. Exemplary Car DOAS zenith-sky measurements of NO_2 DSCDs between the BOKU and VETMED sites

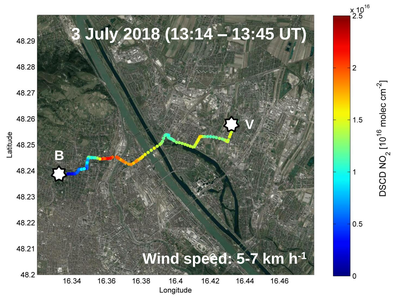


Fig. 10. AOD from BOREAS retrieval and AERONET measurements, interpolated to match the S5P overpass time of the 27 selected days (39 overpasses)

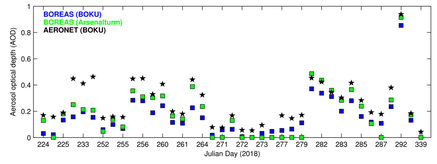
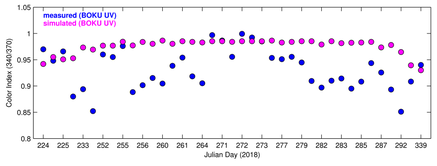


Fig. 11. Measured and simulated CI from BOKU UV measurements, interpolated to match the S5P overpass time of the 27 selected days (39 overpasses)



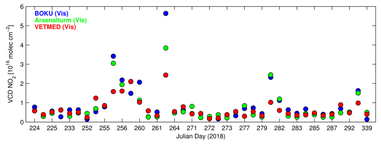
- Ancillary data are used to evaluate the spatial and temporal variability of NO_2 and aerosols in Vienna on the selected days and during the time of satellite overpasses.
- Interestingly, PM10 concentrations are obviously higher than NO_2 concentrations on a few days in October –> transport?! –> elevated aerosol layers?

Retrieval of NO_2 VCDs

MAX-DOAS measurements of NO_2 VCDs via

1) Geometrical approximation
   $VCD_{trop} = DSCD_{trop}(\alpha)/((1/\sin(\alpha))-1)$
2) BOREAS – MAX-DOAS profile retrieval algorithm

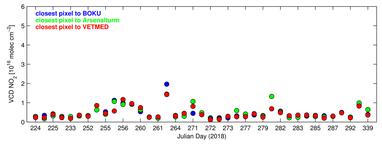
Fig. 1. Tropospheric NO_2 VCDs retrieved from MAX-DOAS measurements of the three instruments and interpolated to match the S5P overpass time



TROPOMI measurements of NO_2 VCDs

- Data from August to December 2018 were downloaded from the ESA Copernicus Open Access Hub.
- For this study, 27 days (39 overpasses) during cloudless situations are analyzed.

Fig. 2. Tropospheric NO_2 VCDs retrieved from Tropomi data



Conversion of concentrations into VCDs

Fig. 12. VCD NO_2 from BOKU vs NO_2 concentrations from Hohe Warte (left) and VCD NO_2 from VETMED vs NO_2 concentrations from Floridsdorf (right)

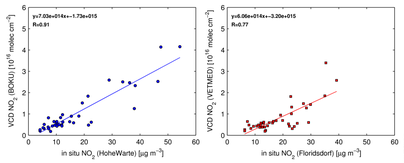
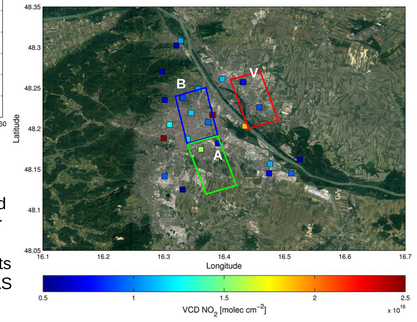


Fig. 13. VCD NO_2 from MAX-DOAS and in situ stations. The latter have been converted by applying the linear relationship of Fig. 12 (left). The three rectangles show exemplary (closest) Tropomi pixels



- To investigate the effect of horizontal gradients, NO_2 concentrations from air quality monitoring stations falling within Tropomi pixels are converted into tropospheric NO_2 VCDs and then included for comparison.
- Linear relationship with high correlation coefficients is found between BOKU and VETMED MAX-DOAS and closest in situ measurements.

Summary & Outlook

- Tropospheric NO_2 VCDs from three MAX-DOAS instruments in Vienna, Austria, are used for satellite validation.
- As highlighted in recent validations studies, a systematic underestimation of satellite observations is found.
- The inclusion of converted surface NO_2 concentrations from 21 air quality monitoring stations for comparison with satellite data does not really change the result.
- Other factors than horizontal gradients, e.g. aerosol and NO_2 layer height used for the computation of airmass factors might have a larger effect.
- Future efforts are directed towards development of correction factors for AMFs by using ancillary data.

Acknowledgements

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- Copernicus Sentinel-5P level 2 NO2 data for the year 2018 were used in this study (http://www.tropomi.eu/data-products/nitrogen-dioxide).
- Mixing-height from ceilometer measurements were provided by Martin Piringer and Christoph Lotteraner from „Zentralanstalt für Meteorologie und Geodynamik" (ZAMG).
- We thank the PIs of the AERONET site used in this study for maintaining their instruments and providing their data to the community.

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http://www.doas-vindobona.at/

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