The VINDOBONA MAX-DOAS instruments: Characterization and first comparison results

EGU 2018
AS3.14
X5.181

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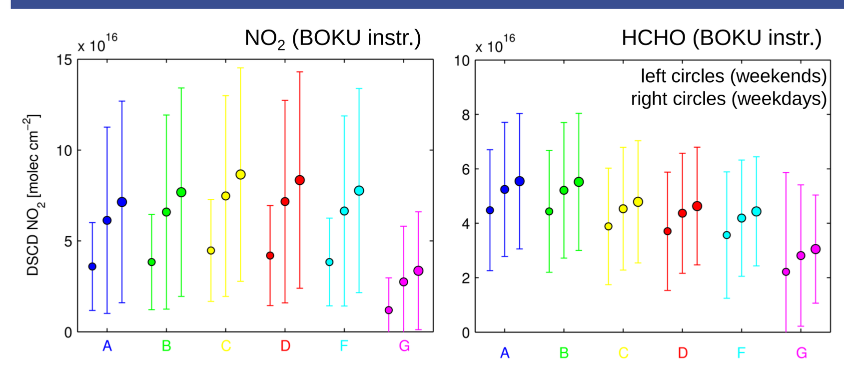
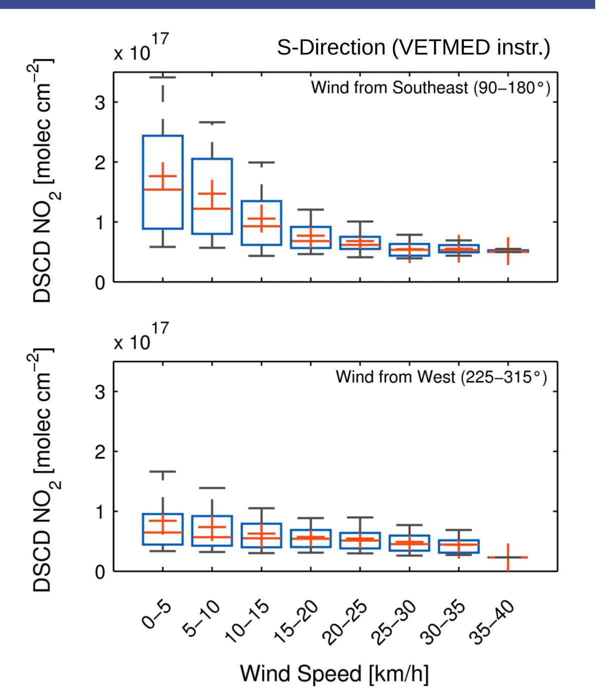
Motivation

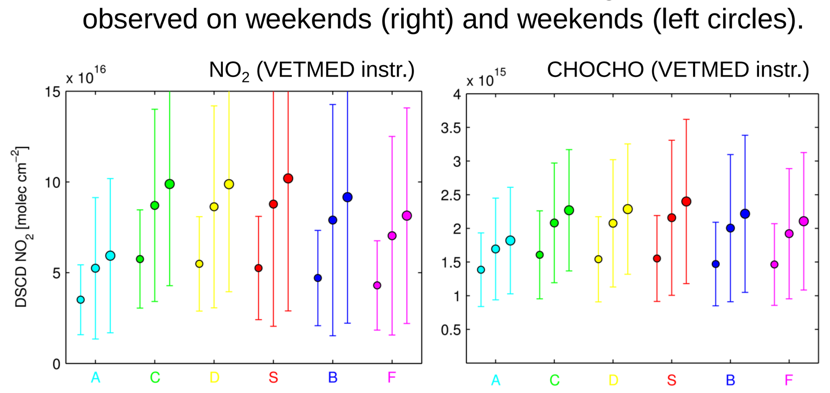
- The overall goal of the **VINDOBONA** (**VI**enna horizontal a**N**d vertical **D**istribution **OB**servations **O**f **N**itrogen dioxide and **A**erosols) project is to improve our current knowledge of air pollution in large agglomerations caused by mankind.
- The investigation of nitrogen dioxide (NO_2), glyoxal (CHOCHO), formaldehyde (HCHO), and aerosol is based on spectral measurements performed with two **M**ulti **AX**is **D**ifferential **O**ptical **A**bsorption **S**pectroscopy (**MAX-DOAS**) instruments located at two different sites in Vienna.
- The MAX-DOAS instrument allows for measurements at different viewing directions and thus, it can be used for obtaining both the horizontal and vertical variations of trace gases and aerosols in the troposphere – useful measurements for quantifying air pollution.
- The proposed long-term measurements (more than two years) will in addition provide a valuable data set for analyzing the temporal variability of air pollutants over Vienna.

Average DSCDs during summer months



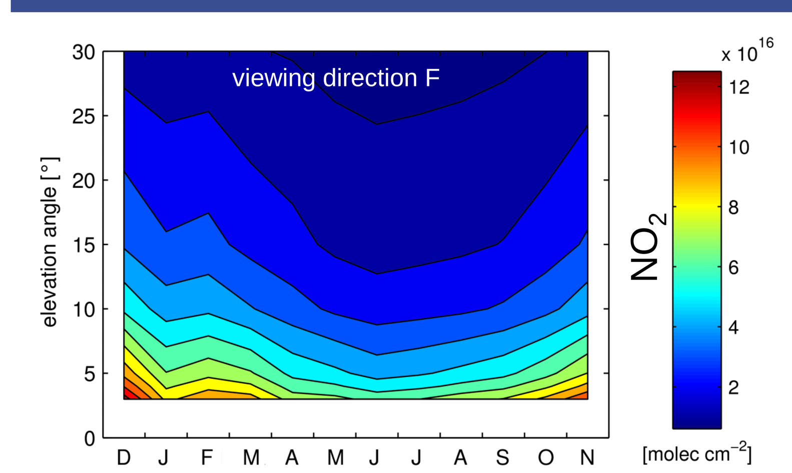
- Average NO_2 and HCHO as well as NO_2 and CHOCHO DSCDs observed at different azimuth angles during summer (J,J,A) are shown in the upper and lower panels, respectively (error bars indicate the std).
- There is a clear difference between trace gas amounts observed on weekends (right) and weekends (left circles).



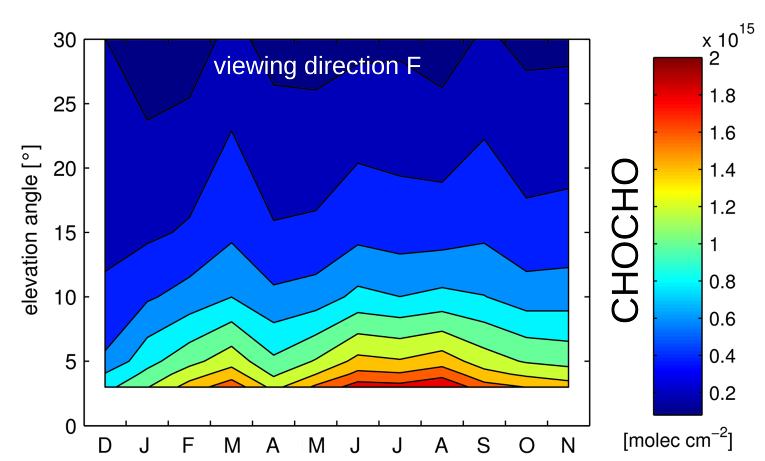


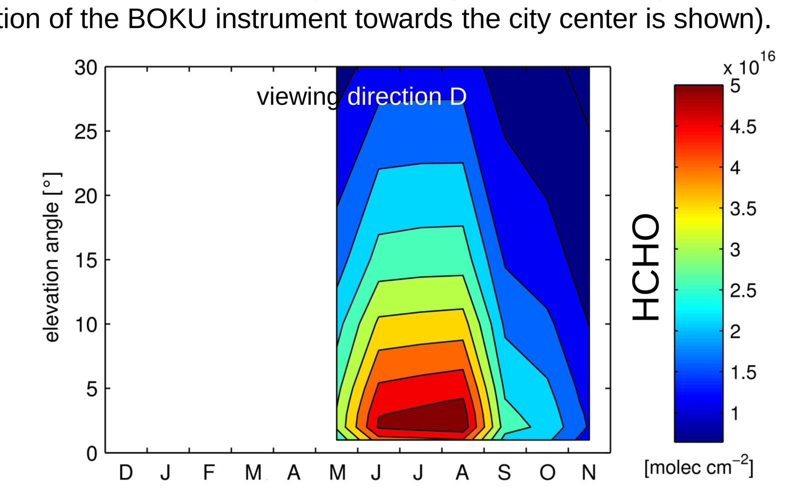
- Tropospheric NO_2 amounts over the city center of Vienna largely depend on wind direction (see figures above).
- Highest NO_2 levels are observed when wind is blowing from southeastern directions.
- When wind is blowing from the West, tropospheric NO_2 amounts are clearly smaller and the influence of wind speed is less strong than for the other case.

Seasonal variability of trace gas amounts



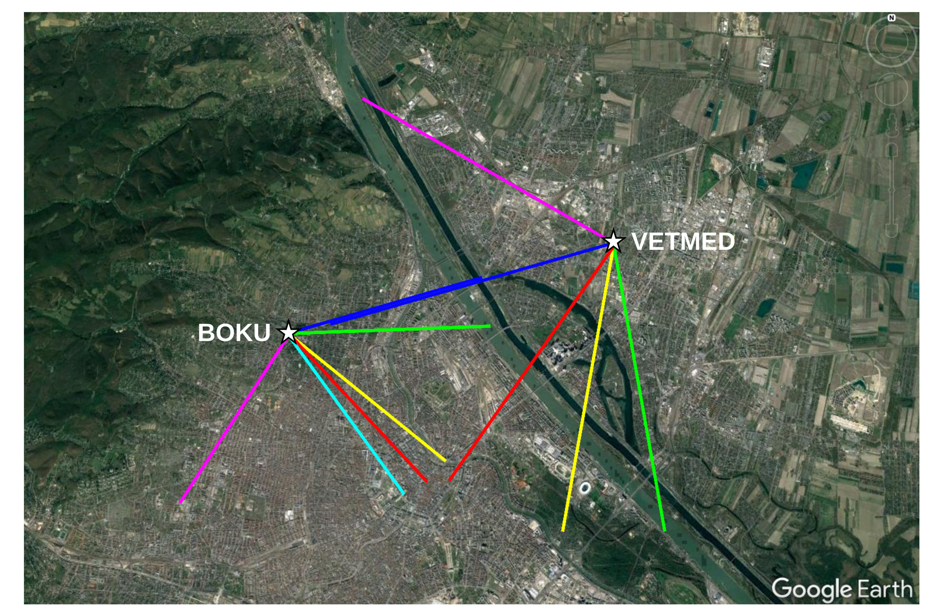
- Seasonal cycles of NO_2 and CHOCHO are shown for the VETMED instrument for all elevation angles and for the viewing direction pointing towards Klosterneuburg (Azimuth = 300°).
- Highest NO_2 amounts are observed for the lowest elevation angles (higher NO_2 concentrations close to the ground) and during winter months (because of the longer lifetime of NO_2 and shallower boundary layer in winter).
- CHOCHO amounts are also highest at the lowest elevation angles, but rather during summer than winter (because of increased photooxidation).
- The largest seasonal variability is found for HCHO, although only seven months of data are analyzed here (here, the viewing direction of the BOKU instrument towards the city center is shown).

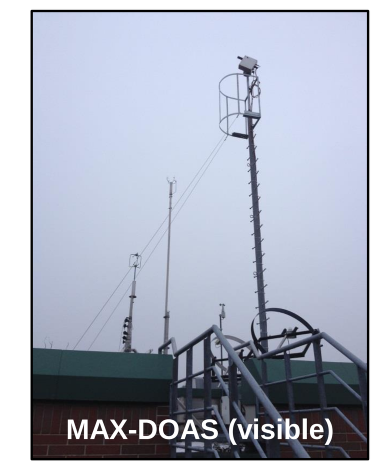




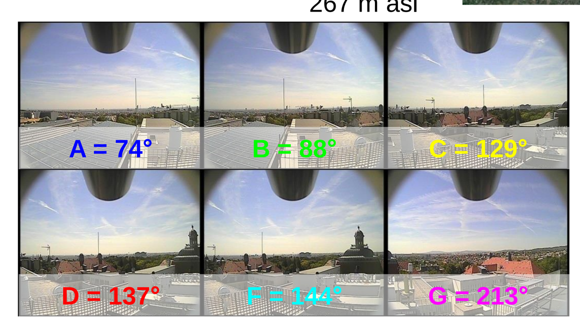
Two MAX-DOAS instruments in Vienna

BOKU Site
Universität für **BO**den**KU**ltur
48° 14' 16.45" N
16° 19' 54" E
267 m asl



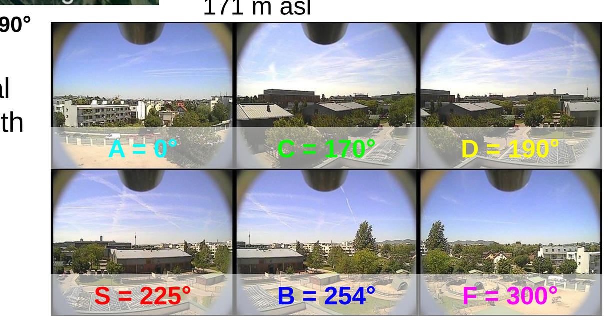


VETMED Site
VETerinär**MED**izinische Universität
48° 15' 26.45" N
16° 25' 54.4" E
171 m asl



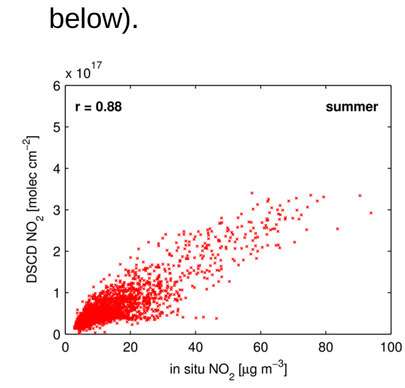
Elevation Sequence: α = 1°, 2°, 3°, 4°, 5°, 10°, 15°, 30°, and 90°

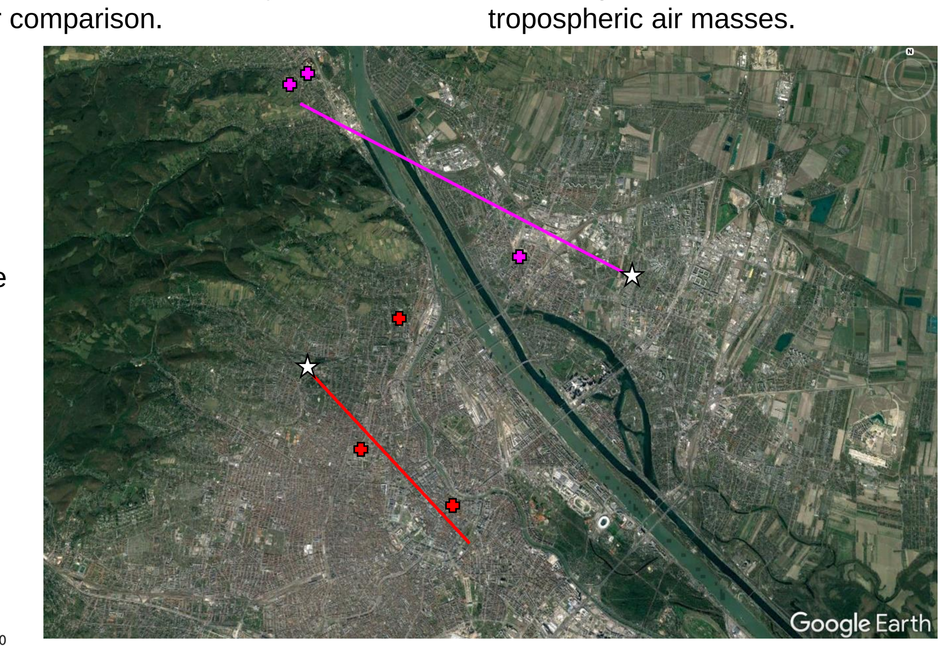
- Since December 2016 and May 2017, spectral measurements are continuously performed with the VETMED and BOKU MAX-DOAS visible and UV spectrometers, respectively.
- The measurement geometry of both instruments consists of six different azimuth angles with one uniform elevation sequence.

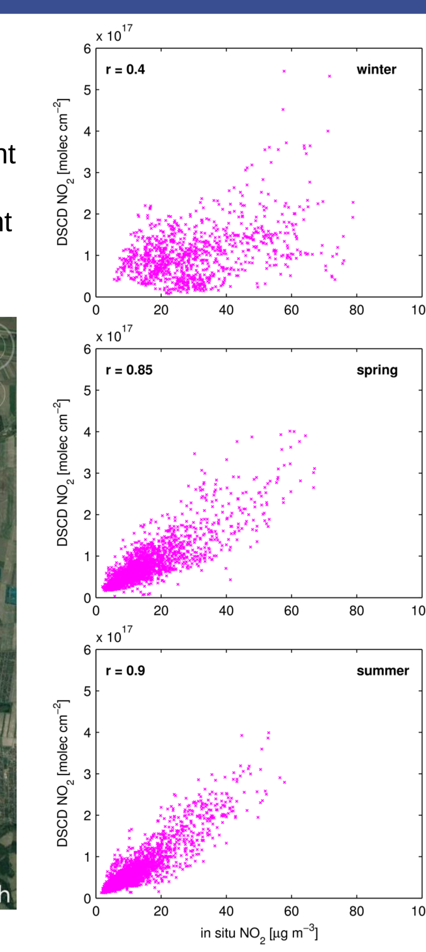


Comparison with in-situ NO_2

- For a first comparison of the MAX-DOAS retrieved NO_2 DSCDs with NO_2 surface concentrations from in-situ monitoring stations, the viewing directions F at α = 3° (VETMED instrument) and D at α = 1° (BOKU instrument) have been selected.
- Within each of the two light paths, half-hour values from three in-situ stations (displayed as crosses on the Google Earth map below) can be used for comparison.
- For the VETMED instrument, best (worst) agreement is found for the summer (winter) period.
- The reason for the lower agreement in winter might be the shallow boundary layer –> MAX-DOAS light paths might include 'cleaner' free-tropospheric air masses.
- The correlation between mean values from the three in-situ sensors and NO_2 DSCDs from the BOKU instrument shows good agreement for the summer period (R = 0.88) (see figure below).







Summary & Outlook

- Two MAX-DOAS instruments have been installed at two different locations in Vienna.
- First analyses of the one-year data indicate overall good agreement for NO_2 DSCDs measured by the two instruments.
- Seasonal and diurnal cycles of tropospheric NO_2, HCHO and CHOCHO amounts are derived.
- Measurements of in-situ NO_2 concentrations from different stations are used for the comparison with MAX-DOAS.
- The BOKU MAX-DOAS instrument will be extended by a visible spectrometer soon.
- (More) Car DOAS and Tower DOAS measurements are planned in the near future.

Acknowledgements

- Financial support was provided by the Austrian Science Fund (FWF): I 2296-N29 and the German Science Foundation (DFG): Ri 1800/6-1.
- We like to thank "Amt der Niederösterreichischen Landesregierung" and "Amt der Wiener Landesregierung" for making the air quality data freely available.

DOAS data analysis

VETMED

Fit parameter		Selection/Source
Spectral range		425-490 nm (NO_2, O_4) 433-458 nm (CHOCHO)
Polynomial degree		6 (NO_2, O_4) and 5 (CHOCHO)
Wavelength calibration		Solar atlas (Kurucz et al., 1984)
Reference		Sequential zenith spectrum
Cross section	**Temperature**	**Data source**
O_3	223 K	Serdyuchenko et al. (2014)
NO_2	298 K	Vandaele et al. (1996)
	220 K	Vandaele et al. (1996)
O_4	293 K	Thalman and Volkamer (2013)
CHOCHO	296 K	Volkamer et al. (2005)
H_2O	296 K	Rothmann et al. (2010)
Ring	-	QDOAS

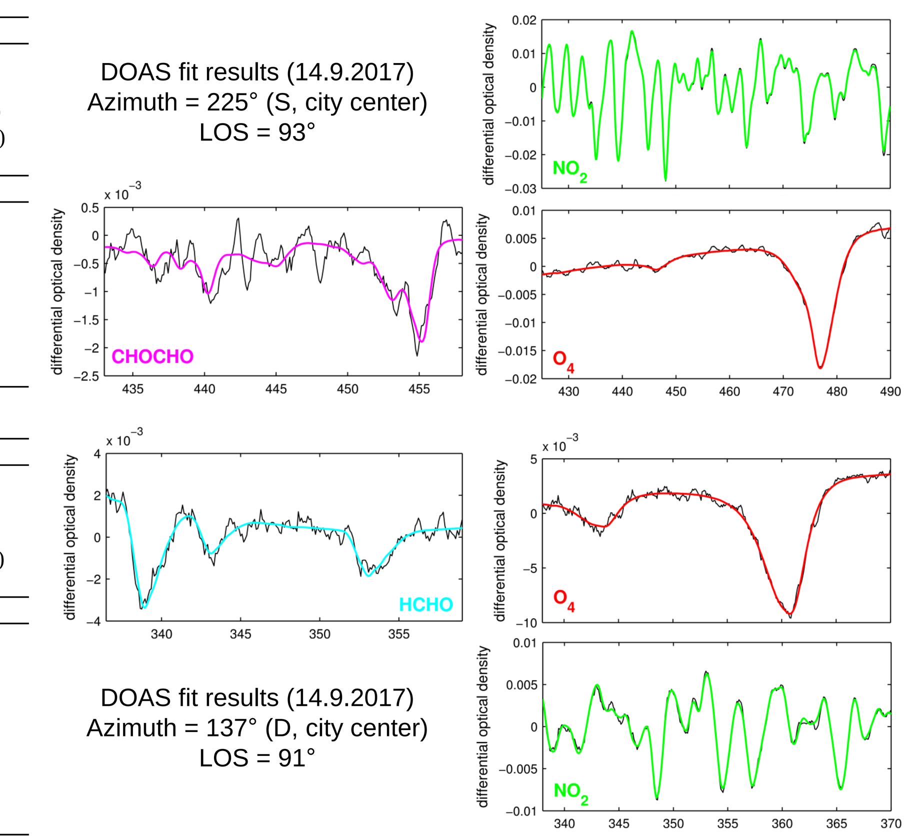
(following the retrieval settings of CINDI-2)

BOKU

Fit parameter		Selection/Source
Spectral range		338-370 nm (NO_2, O_4) 336.5-359 nm (HCHO)
Polynomial degree		6
Wavelength calibration		Solar atlas (Kurucz et al., 1984)
Reference		Sequential zenith spectrum
Cross section	**Temperature**	**Data source**
O_3	223 K	Serdyuchenko et al. (2014)
	243 K	Serdyuchenko et al. (2014)
NO_2	298 K	Vandaele et al. (1996)
	220 K	Vandaele et al. (1996)
O_4	293 K	Thalman and Volkamer (2013)
HCHO	293 K	Meller and Moortgat. (2000)
BrO	223 K	Fleischmann et al. (2004)
Ring	-	QDOAS

DOAS fit results (14.9.2017)
Azimuth = 225° (S, city center)
LOS = 93°

DOAS fit results (14.9.2017)
Azimuth = 137° (D, city center)
LOS = 91°



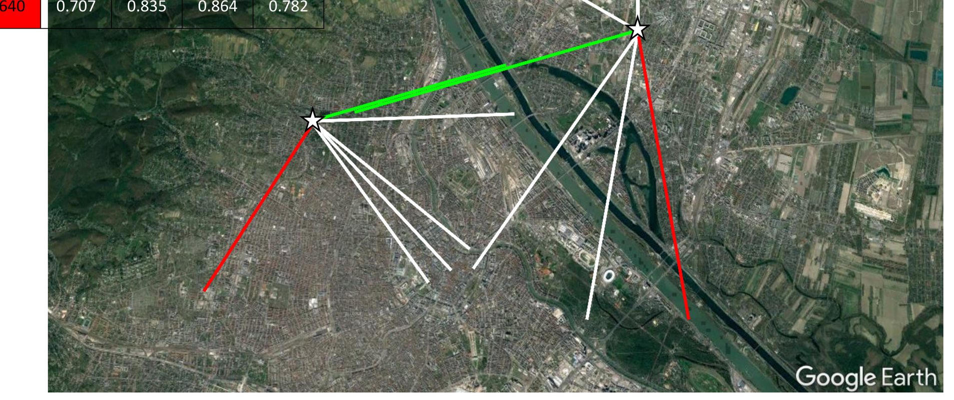
Correlation matrix of NO_2 DSCDs

- A comparison of NO_2 DSCDs as observed at different azimuth angles was performed for the summer period.
- The measurements at different azimuthal viewing directions and at α = 3° (VETMED instrument) and α = 1° (BOKU instrument) elevation angles are correlated with each other.
- While the best agreement (R = 0.947) is observed between the two azimuthal directions pointing into the direction of the other instrument (VETMED azimuthal viewing direction F vs. BOKU azimuthal viewing direction A), worst agreement (R = 0.640) is found between VETMED azimuthal viewing direction C and BOKU azimuthal direction G.
- Although the two azimuthal viewing directions pointing into the direction of the other instrument do not capture exactly the same air masses, correlation is extremely high –> good quality of NO_2 data products.

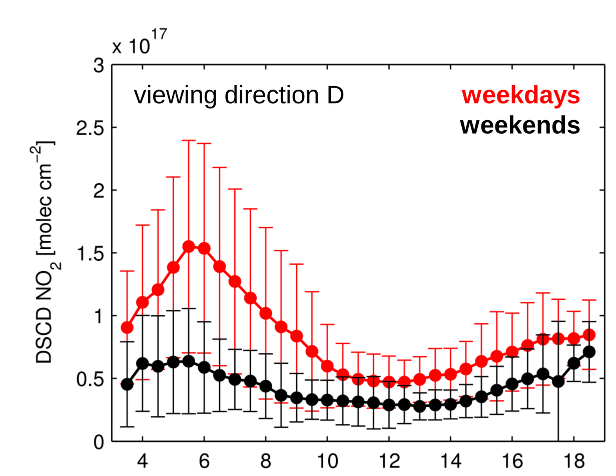
VETMED vis instrument (LOS = 93°)

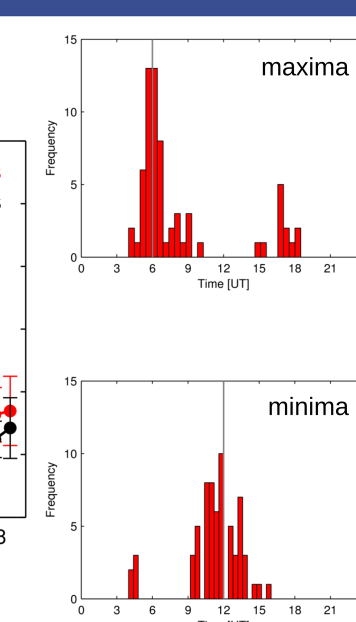
BOKU UV instrument (LOS = 91°)	A	C	D	S	B	F
A	0.879	0.848	0.880	0.932	0.947	0.910
B	0.867	0.865	0.893	0.934	0.937	0.892
C	0.764	0.857	0.888	0.914	0.878	0.795
D	0.770	0.851	0.891	0.919	0.879	0.793
F	0.765	0.839	0.883	0.922	0.882	0.789
G	0.699	0.640	0.707	0.835	0.864	0.782

summer
(June/July/August)



Average diurnal cycle of NO_2 DSCDs





- The average diurnal cycle of NO_2 during summer (June, July, and August) is shown for the BOKU instrument pointing towards the city center at 1° elevation angle.
- While highest NO_2 amounts as a result of rush-hour traffic are observed around 6:00 UT in the morning, minima are found in the early afternoon (~12:00 UT), when the maximum vertical extension of the boundary layer is reached.
- An obvious difference between weekdays and weekends is found, especially in the morning.
- The distribution plots show that maxima of NO_2 amounts can also be observed in the late afternoon/early evening.
- Minima NO_2 amounts are centered around 12:00 UT. This might also be a consequence of NO_2 depletion, before traffic density and NOx emissions start to increase again.

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University of Natural Resources and Applied Life Sciences, Vienna

Universität Bremen

Deutsche Forschungsgemeinschaft

vetmeduni vienna

FWF Der Wissenschaftsfonds.

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