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Data Set Description:

PI: Udo Friess, Heidelberg University, Germany
Instrument: UV-Vis MAX-DOAS
Site(s): Heidelberg, Germany, 49.42°N, 8.67°E, E 175m
Measurement Quantities: Ozone, NO₂
Data Version description: FRM4DOAS centralised processing system

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DOI: N/A

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Reference Articles:

U. Friess et al., "MAX-DOAS O₄ measurements: A new technique to derive information on atmospheric aerosols: 2. Modeling studies," *J. Geophys. Res.*, vol. 111, no. 14203, Art. no. 14203, 2006, doi: 10.1029/2005JD006618.

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Instrument Description:

The instrument operated at Heidelberg is an Airyx Skyspec 2D dual-channel 2D MAX-DOAS spectrometer. Azimuth and elevation motors allow collecting scattered sunlight from any point in the sky. A filter unit allows for direct sunlight measurements. The instrument is installed on the roof of our institute and is in continuous operation since February 2017.

Multi-Axis measurements are performed during daylight (SZA < 85°) pointing over the Rhine Valley towards the city of Mannheim. Zenith-sky only measurements are performed during twilight for SZA > 85°. Calibration measurements (offset, dark current, mercury emission lines) are recorded regularly each night. The elevation angle adjustment is performed in real-time using built-in inclination sensors with an accuracy of 0.2°. Direct sunlight and almucantar measurements are performed hourly.

Technical Data

Location:	Institute of Environmental Physics University of Heidelberg 49.41°N, 8.67°E 170 m a.s.l.
Instrument:	Airyx Skyspec D2 – see https://airyx.de/item/skyspec/
Operational since:	February 2017
Spectrometer:	Avantes, CCD with 2048 channels
Spectrometer temperature:	+20°C (thermoelectrically stabilised)
Telescope:	Motorised 2D-Telescope Rotatable prism for elevation scans Rotatable telescope housing for azimuth scans Grey filter for direct sunlight measurements Hg lamp for calibration measurements Field of view: ~0.3° Elevation accuracy: ~0.2°, inclination sensor controlled
Spectral range and resolution:	
UV:	295-460 nm, 0.6 nm FWHM, back-thinned detector
Vis:	440-585 nm, 0.6 nm FWHM

Measurement sequence:

Elevation angles:	1°, 2°, 3°, 4°, 5°, 6°, 8°, 15°, 30°, 90°
Azimuth angle:	324° (north-westerly direction over the Rhine valley towards the city of Mannheim)
Integration time:	1 minute during daytime, up to 3 minutes during twilight
Zenith-only measurements:	for $85^\circ < \text{SZA} < 95^\circ$
Direct sunlight:	Hourly measurements
Solar almucantar:	Hourly measurements at RAA of 5°, 6°, 10°, 15°, 30°, 50°, 70°, 90°, 120°, 150°, 180° with an integration time of 10 seconds each

Calibration measurements:

Frequency:	Each night
Measurements:	Offset, dark current, mercury line spectrum

Algorithm Description:

Spectra are analysed using the DOASIS software developed at the Institute of Environmental Physics of the University of Heidelberg using a non-linear least squares fitting routine based on the Levenberg-Marquardt algorithm.

Ozone slant column densities are retrieved in the wavelength range between 450 and 550 nm according to the recommendations for total ozone retrieval from NDACC zenith-sky UV-VIS spectrometers (v2) [Rozendael and Hendrick, 2009]. Slant column densities are converted to vertical column densities according to the NDACC recommendations using the NDACC AMF data base, with the reference SCD being determined using the Langley plot method.

The spectral retrieval of NO₂ dSCDs is performed in the wavelength region between 425 and 490 nm according to the recommendations for NO₂ column retrieval from NDACC zenith-sky UV-VIS spectrometers (v3) [Rozendael and Hendrick, 2012], and converted to VCDs using the NDACC AMF lookup table.

Expected Precision/Accuracy of Instrument:

Average random errors resulting from spectral noise amount to 6 DU for the ozone VCD and 6×10^{13} molec/cm² for the NO₂ VCD. In addition, the accuracy is affected by several systematic error sources. Inaccuracies in the spectral fit, caused by inaccurate cross sections, non-perfect removal of the effects caused by inelastic scattering (Ring effect), wavelength calibration and instrumental artefacts, is expected to lead to an additional uncertainty in the order of 2% for ozone and 5% for NO₂. Although considered in the NDACC AMF lookup tables, uncertainties in the vertical distribution of the trace gases lead to an uncertainty in the airmass factors, which can be estimated to contribute to the VCD error in the order of 4% for ozone and at most 10% for NO₂. Uncertainties in stratospheric photochemistry leads to additional uncertainties of the NO₂ AMF. Furthermore, the uncertainty in the residual trace gas amount of the reference spectrum determined by the Langley plot adds to the error budget with a small contribution of 1-2%. In addition, pollution in the troposphere can significantly affect the accuracy of the NO₂ VCD.