VDI Guideline passive DOAS (VDI 4212:2017-05)

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•Overview

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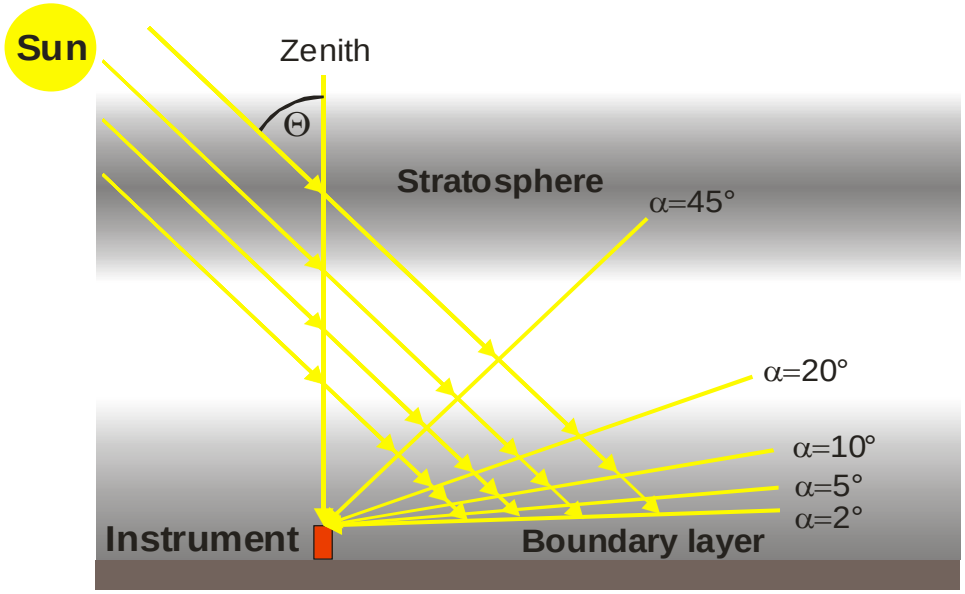


What is the VDI?

- Verein deutscher Ingenieure (Association of German Engineers) founded 1856
- German institute to develope „unified standards“
- Part of CEN (Comité Européen de Normalisation) and ISO (International Organization for Standardization)
- More than 2000 reviewed standards exist in order to define current ‚state-of-the-art‘ for engineering and scientific purposes
  - Active DOAS: DIN EN / ISO Guideline
- Standards are developed and reviewed in working groups including experts from science, industry and administration (reviewed every few years)
- **Unified standards define e.g. the measurement routines for public authorities and official institutions**

Goal of VDI ‚passive DOAS' Guideline

The ‚passive DOAS' guideline defines:

- Minimum hardware requirements
- Setup of instruments
- Operation of instruments and measurements
- Calibration
- Basics of data analysis

Goal:

- **Make passive DOAS measurements applicable for authorities for different kinds of trace gas measurements** (e.g. direct Sun, Zenith DOAS, MAX-DOAS, Plume measurements, Car-DOAS, ToTaL-DOAS)
- Guarantee **reliable passive DOAS observations**
- Unify different instrumentations to make observations compareable
- Define minimum standards for manufacturer
- Provide operation guidelines to technicians, public authorities and institutions to guarantee reliable data

https://www.vdi.de/technik/fachthemen/reinhaltung-der-luft/artikel/fernmessverfahren-messen-in-der-atmosphaere-nach-dem-passiv-doas-prinzip-messen-von-emissionen-un-1/

Hardware requirements

Parameter	Value	Comment
FOV	< 1° (MAX-DOAS)	
Elevation Accuracy	< 1° (MAX-DOAS)	
Telescope	Quartz glas	
Spectral coverage	Within 300-800nm	
Spectral resolution	< 1nm	(typically)
Spectral sampling	≥ 5 pixel	
Stray light	< 1 %	
Total Noise (RMS)	< 10^{-3}	Optimal: ~10^{-4}
Temperature Stability	< 0.1°C	
Fibre	suggested	UV/VIS suitable multimode type
No polarization dep. components		

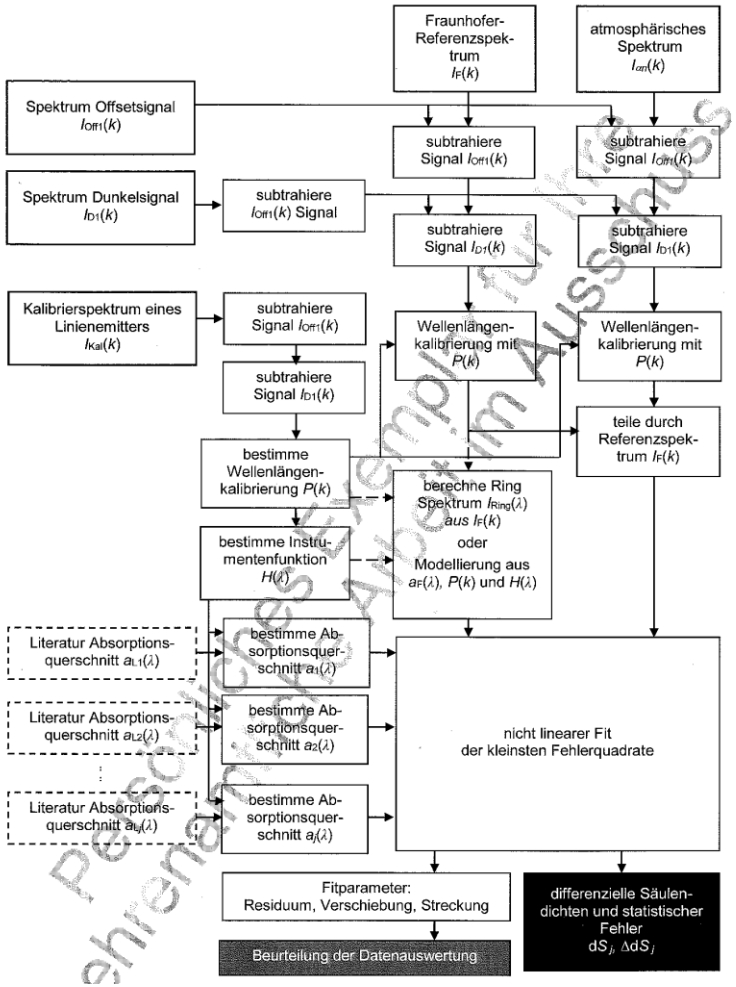
Measurements (MAX-DOAS)

- Instrument setup:
  - MAX-DOAS: Ideally at least horizon to zenith (0-90°) measurements of scattered sunlight
- Data Acquisition
  - Regular calibration measurements (offset, dark current, spectral calibration)
  - Scattered light spectra at different elevation angles

Everything formulated rather flexible to allow for different applications. Minimum requirements are listed, depending on observation type.

Spectral data analysis

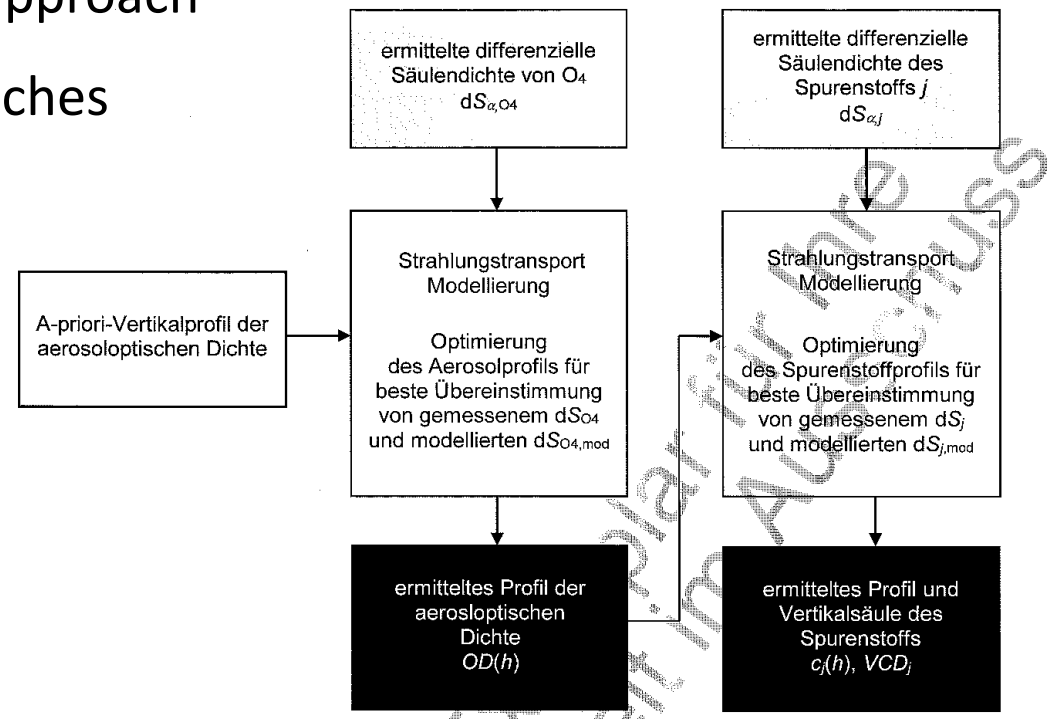
- Principle of data evaluation
  1. Application of Offs, DC, Hg
  2. Choice of reference
  3. Application of ILF
  4. Least square fit
- No fixed standard defined for data evaluation settings
  - Include strong absorptions
  - Avoid inferences
  - Interval size



- Future version might include guidelines for spectral evaluation settings, like e.g. from NDACC or CINDI (II), some literature is already cited

Data analysis – Profile inversion

- Conversion to vertical columns, surface concentrations or concentration profiles is outlined, but details remain outside the scope of the guideline
  - Geometric approximations for VCD
  - Optimal estimation approach
  - Parametrized approaches



Application to CINDI 2 instrument list

- Categories in CINDI II instrument list:
  (Kreher et al, Overview manuscript CINDI II)
  - Instrument type, ID
  - Instrument name
  - Azimuth Scanning
  - Direct Sun Functionality
  - Spectral range, spectral Res.
  - FOV (°)
  - Light Coupling
  - Detector type, temperature
- Missing categories?
  - Spectral sampling

Conclusion

- VDI guideline defines minimum for hardware requirements for passive DOAS observations
- Most CINDI II instruments comply with criteria
- Some basic information could be added to CINDI II overview table:
  - Spectral sampling
  - FOV?
  - …
- Guideline outlines conversion to mixing ratios, to be extended
- Passive DOAS guideline is currently translated to English
- VDI guidelines can be updated to represent current developments and improved „state of the art“ e.g. from CINDI II

VDI guideline hopefully helps to make passive (ground based) DOAS used by a broader (also non-scientific) community.

Thank you for your attention!

Application to CINDI 2 instrument list

Instrument-type	Instrument ID	Instrument name	Country	ASc	DS	Spectral range	Spectral (nm)	Res.	FOV (°)	Light Coupl.	Detector type	Detector-T (°)
Scientific grade MAX-DOAS	bira-4	2D MAX-DOAS	BE	y	y	303-389/ 407-542	0.37/ 0.58		0.5/ 1.0	F	CCD	-50/ -50
	iupb-18	2D MAX-DOAS	DE	y	n	305-390/ 406-579	0.45/ 0.83		0.5/ 0.85	F	CCD	-35/ -30
	boku-6	2D MAX-DOAS	AT	n	n	406-579	0.71		1.0	F	CCD	-30
	cu-boulder-11	2D MAX-DOAS	US	y	y	327-470/ 432-678	0.7/ 1.2		0.7	F	CCD	-30
	cu-boulder-12	1D MAX-DOAS	US	n	n	300-466/ 379-493	0.8/ 0.5		0.7	F	CCD	-30/ 0
	inta-17	RASAS-III	ES	y	n	325-445 or 400-550	0.55		1.0	F	CCD	17 if room T is 22-23
	mpic-28	Tube-DOAS	DE	n	n	315-475	0.72		1.0	F	CCD	10
	niwa-30	ACTON275 MAX-DOAS	NZ	n	n	290-363/ 400-460	0.54		0.5	F	CCD	-20
	uto-36	2D MAX-DOAS	CA	y	y	300-500	0.75		0.62	F	CCD	-70
	auth-3	PHAETON	GR	y	y	297-452	0.4		1.0	F	CCD	5
	aiofm-1	2D MAX-DOAS	CH	y	n	290-380	0.4		0.2	F	CCD	-30
	chiba_u-9	CHIBA-U MAX-DOAS	JP	n	n	310-515	0.4		<1	F	CCD	room T
	csic-10	1D MAX-DOAS	ES	n	n	300-500	0.5		1.0	F	CCD	room T
	amoiap-2	2-port DOAS	RU	n	n	420-490	0.5		0.3	F	CCD	-40
	bsu-5	MARSB	BL	n	n	300-500	0.4		0.2-1.0	D	CCD	-40
	iupb-37	Imaging-DOAS	DE	y	n	400-580	0.5		1.2	F	CCD	-30
PANDORA	knmi-23	Pandora	NL	y	y	285-530	0.6		1.5	F	CCD	20
	luftblick-26	Pandora-2S	AT	y	y	280-540	0.6		1.5	F	CCD	20
	luftblick-260	Pandora-2S	AT	y	y	400-900	1.3		1.5	F	CCD	20
	luftblick-27	Pandora-2S	AT	y	y	280-540	0.6		1.5	F	CCD	20
	luftblick-270	Pandora-2S	AT	y	y	400-900	1.1		1.5	F	CCD	20
	nasa-31	Pandora	US	y	y	285-530	0.6		1.5	F	CCD	20
	nasa-32	Pandora	US	y	y	285-530	0.6		1.5	F	CCD	20
EnviMes	iuph-19	2D EnviMes	DE	y	y	296-459/ 439-583	0.6/ 0.5		<0.5	F	CCD	room T
	dlrustc-13	1D EnviMes	DE	n	n	300-460/ 450-600	0.6/ 0.6		0.4	F	CCD	20
	dlrustc-14	1D EnviMes	DE	n	n	300-460/ 450-600	0.6/ 0.6		0.4	F	CCD	20
	niwa-29	1D EnviMes	NZ	n	n	305-457/ 410-550	0.6		<0.5	F	CCD	20
	lmumim-35	2D EnviMes	DE	y	n	300-460/ 450-600	0.6/ 0.9		0.4	F	CCD	20
Mini-DOAS Hoffmann GmbH	cma-7	Mini-DOAS-UV	CN	n	n	292-447	0.7		0.8	F	LinArr	room T
	cma-8	Mini-DOAS-Vis	CN	n	n	399-712	1.6		0.8	F	LinArr	room T
	iiserm-16	Mini-DOAS-UV	IN	n	n	317-466	1.0		0.7	F	CCD	<0 if room T is 20
	knmi-21	Mini-DOAS-UV	NL	n	n	290-433	0.7		0.45	F	LinArr	room T
	knmi-22	Mini-DOAS-Vis	NL	n	n	400-600	0.9		0.4	F	LinArr	room T
	nust-33	Mini-DOAS-UV	PA	n	n	320-465	0.7		1.2	F	CCD	room T

Kreher et al

- Noise: Einheit?