Fiducial Reference Measurements for Ground-Based DOAS Air-Quality Observations

FRM$_4$DOAS

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Table of contents

1. Introduction

This document gives an inventory of the MAXDOAS and SAOZ/Zenith-sky DOAS instruments that have been identified as potential candidates for future integration in the FRM_4DOAS centralised processing system. Based on the outcome of a consultation with the community, the Technology Readiness Level (TRL) of each candidate instrument is evaluated and described as part of a network assessment review presented in section 3 of this document. This D3 deliverable is meant to remain a living document that will be regularly updated in the future, based on further input received from operators of existing and new candidate instruments.

2. Existing DOAS-type instruments overview

A large number of UV-Vis DOAS (Differential Optical Absorption Spectroscopy) instruments is currently operated worldwide for the regular monitoring of NO_2, O_3, HCHO, and several other species. While the overall measurement principle of DOAS is the same for all instruments, there are many different approaches to instrument design and operation. These differences are driven by the various scientific applications for which the instruments are developed (stratospheric research, air pollution monitoring, monitoring of volcanic emissions, power plant emission monitoring, process studies, …), but also by cost and ease of deployment which are important factors for the establishment of networks. As many of the instruments were designed and built by individual research groups, there is a wide diversity of instruments in operation today, and comparability of measurement results is an issue that needs to be addressed for integration of data from all these instruments into a centralised processing system. This is in contrast to other measurement systems such as the FTIR networks, where both instruments and data analysis software is much more homogeneous.

There are different ways of categorizing DOAS instruments, possible options being viewing modes, target quantities, size and quality of spectrometers and detectors used, or their participation in networks. Here a mixed approach is taken, separating the instruments by their viewing options (MAXDOAS, zenith-sky and direct sun) but also by existing or developing networks (MAXDOAS, Pandonia, SAOZ). It is based on information collected as part of the activities of the NDACC (Network for the Detection of Atmospheric Composition Change) UV-vis Working Group (see http://ndacc-uvvis-wg.aeronomie.be/) and the EUMETSAT Atmospheric Composition (AC) SAF, and the NIDFORVal S5P validation project coordinated by BIRA-IASB.

2.1. MAXDOAS instruments

All instruments classified as MAXDOAS systems are capable of performing observations at several elevations, either by scanning or by imaging onto 2D detectors. There is however a large diversity of designs when considering the specificities of each system. Some instruments are designed to also allow for zenith-sky twilight observations (needed for NDACC stratospheric monitoring), others are directed simultaneously to different azimuth directions or allow for azimuthal scans in addition to elevation scans. The latter are usually referred to as 2D MAXDOAS systems and provide information on the horizontal distribution of tropospheric species in addition to their vertical profile. Finally some systems are designed to alternate between elevation scans and direct-sun measurements through a diffusor plate and a sun-

tracking system. This enables accurate determination of tropospheric columns and yields additional information on aerosol optical depth.

Although their detailed design can differ considerably, most MAXDOAS systems consist of three basic components: the entrance optics, the spectrometer, and the detector, as illustrated in Figure 1. The entrance optics includes a telescope that defines the Field of View (FOV) of the instrument which must be of about 1° or less preferably, at least for the low elevation angles. It is often mounted on a motorized mechanical tracker. The telescope is usually connected to the spectrometer by means of depolarizing quartz fibre bundles for ease of operation and in order to reduce the sensitivity of the instruments to the polarisation of sky light. The spectrometer subsequently separates the incoming light by wavelength, and projects it on the detector. The spectrometer and detector are often housed in the same unit.

One generally distinguishes between high-performance sensitive "research grade systems" which have high throughput, low-noise cooled CCD detectors and efficient temperature stabilization, and smaller/cheaper "mini-MAXDOAS" systems which have reduced performance for minor absorbers.

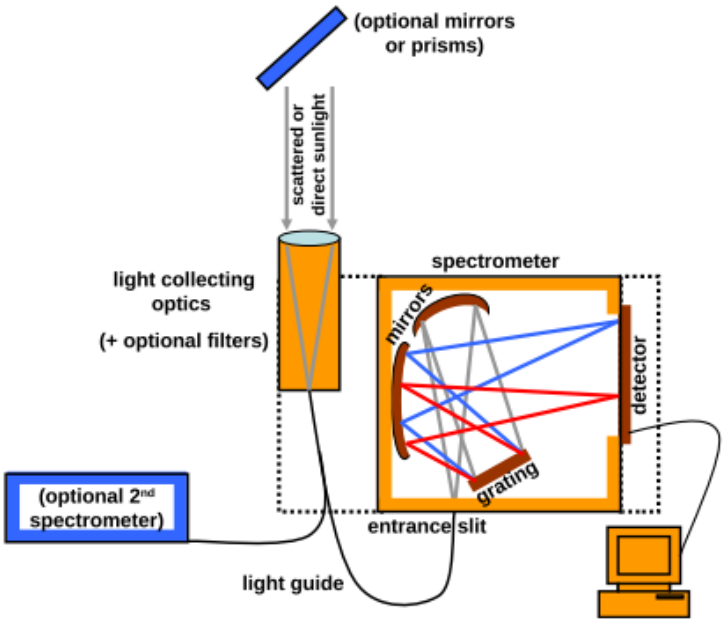

Figure 1: Typical MAXDOAS instrument layout. The dashed box indicates that the three components (optics, spectrometer, detector) can be separate units or included in the same housing (adapted from Piters et al., 2012).

An incomplete list of MAXDOAS instruments currently in operation is shown in Table 1.

Table 1: List of MAXDOAS sites

Station	Country	Latitude	Longitude	Instrument owner
Alert	Canada	82.45	-62.51	IUP Heidelberg
Eureka	Canada	80.10	-86.40	University Toronto
Ny Alesund	Norway	78.90	11.90	IUP Bremen
Tomsk	Russia	56.48	85.05	JAMSTEC
Zvenigorod	Russia	55.70	36.78	JAMSTEC - IAP/RAS

Bremen	Germany	53.00	9.00	IUP Bremen
De Bilt	The Netherlands	52.10	5.18	KNMI
Leicester	UK	52.00	-1.00	University Leicester
Cabauw	The Netherlands	52.00	4.90	KNMI
Uccle	Belgium	50.80	4.35	BIRA
Mainz	Germany	50.00	8.30	MPIC
Heidelberg	Germany	49.00	8.00	IUP Heidelberg
Vienna (2 stations)	Austria	48.20	16.30	IUP Bremen and Boku
Hohenpeissenberg	Germany	47.80	11.67	DWD/IUP Heidelberg
Zugspitze	Germany	47.42	10.98	IUP Heidelberg
Schneefernerhaus	Germany	47.40	11.00	DWD/DLR
Jungfraujoch	Switzerland	46.55	7.98	BIRA-IASB
OHP	French Alps	43.94	5.71	BIRA-IASB
Thessaloniki	Greece	40.63	22.96	AUTH
Madrid	Spain	40.30	8.30	INTA
Beijing	China	39.98	116.38	BIRA-IASB
Xianghe	China	39.75	116.96	BIRA-IASB
Athens	Greece	38.05	23.86	IUP Bremen
Tsukuba	Japan	36.06	140.13	Chiba University
Chiba	Japan	35.63	140.10	Chiba University
Yokosuka	Japan	35.32	139.65	JAMSTEC
Gwangju	South Korea	35.23	126.84	JAMSTEC - GIST
Kasuga	Japan	33.52	130.48	Chiba University
Fukue	Japan	32.75	128.68	JAMSTEC
Nanjing	China	32.12	118.95	DLR
Hefei	China	31.91	117.16	JAMSTEC
Shanghai	China	31.30	121.50	DLR
Wujiang	China	31.14	120.64	DLR
Mohali	India	30.80	76.70	MPIC/ISER Mohali
Basra	Iraq	30.30	47.50	MPIC/University of Basra
Izana	Spain	28.31	-16.50	INTA
Greater Noida	India	28.30	77.30	MPIC/Sharda University
CapeHedo	Japan	26.87	128.25	JAMSTEC
Ghuangzhu	China	23.00	113.00	AUTH
Cuautitlan	Mexico	19.70	-99.20	UNAM
Mauna Loa	USA (Hawaii)	19.50	204.40	CU Boulder
Acatlan	Mexico	19.50	-99.20	UNAM
Vallejo	Mexico	19.50	-99.10	UNAM
UNAM	Mexico	19.30	-99.20	UNAM
Bujumbura	Burundi	-3.38	29.38	BIRA-IASB
St Denis	Reunion Island, France	-20.90	55.50	BIRA-IASB

Wollongong	Australia	-34.40	150.90	University Wollongong
Ushuaia	Argentina	-54.50	-68.20	INTA
Neumayer	Antarctica	-70.62	-8.27	IUP Heidelberg
Arrival Heights	Antarctica	-77.83	166.65	IUP Heidelberg

2.2. Pandora/Pandonia instruments

Pandora systems have initially been developed at NASA using small Avantes spectrometers. They are based on a head sensor mounted on a tracker capable of pointing at any position in the sky up to a zenith angle of 110°. Light is transmitted to the Avantes spectrometer using a depolarizing fibre. These systems use non-cooled Hamamatsu detectors (CCD or CMOS technology). Under the impulse of ESA, some of the Pandora instruments are currently being organized in a coordinated network for Fiducial Reference Measurements called Pandonia (see http://pandonia.net/). Within this project, new instrumental developments have been recently performed at the LuftBlick company (see http://luftblick.at/) leading to an improved Pandora 2S system which includes an additional channel covering the red and NIR spectral region for aerosol characterization, as well as an improved optical head. An incomplete list of instruments currently available in the Pandonia network is provided in Table 2.

Table 2: List of Pandora/Pandonia sites.

Station	Country	Latitude	Longitude	Instrument owner
Helsinki	Finland	60.20	25.00	NASA/FMI
Cabauw	The Netherlands	52.00	4.90	KNMI
Bucharest	Romania	44.20	26.10	INOE
Harvard	USA	42.38	-71.10	NASA
Boulder	USA	40.00	-105.26	NASA
NASAHQ	USA	39.00	-76.84	NASA
GSFC	USA	39.00	-76.80	NASA
Athens	Greece	38.00	23.70	IERSD-NOA
Seoul	South Korea	37.56	126.93	NASA
Langley	USA	37.10	-76.39	NASA
Four Corners NM	USA	36.80	-108.48	NASA
Busan	South Korea	35.24	129.08	NASA
UHMT	USA	29.72	-95.34	NASA
Izana	Spain	28.30	-16.50	AEMET
MaunaLoa	USA	19.48	-155.60	NASA
Wollongong	Australia	-34.40	150.90	University Wollongong

2.3. SAOZ and zenith-sky DOAS instrument

Zenith-sky DOAS instruments have been largely deployed in the nineties in support of ozone layer monitoring as part of the NDACC. These systems are similar in concept to MAXDOAS, but measurements

are usually performed only in zenith direction and they are optimized for low signal during twilight conditions. Zenith-sky twilight measurements are ideal for stratospheric NO_2, BrO, OClO and O_3 monitoring, since owing to the particular geometry of the sun and atmospheric scattering (Hendrick et al., 2011), large sensitivity is obtained for stratospheric species. The main advantages of this method are simplicity of operation, possibility to measure under all weather conditions, and weak sensitivity to clouds and tropospheric absorbers. A large number of the zenith-sky DOAS instruments operated within NDACC is of the SAOZ design (Pommereau and Goutail, 1988). Developed in the early days of NDACC (formerly NDSC), SAOZ systems are based on small spectrometers from Jobin-Yvon (CP200) directly oriented to the zenith without any further entrance optics. The spectrometer is housed in a water-proof container with a quartz window to enable measurements of light from the zenith sky. Recently a new improved mini-SAOZ design has been introduced by LATMOS based on small Avantes spectrometers similar to those used in the Pandora system and fibre optics to direct the light from zenith to the spectrometer. An overview of the SAOZ/Zenith-sky DOAS instruments currently in operation is given in Table 3.

Table 3: List of SAOZ/Zenith-sky DOAS sites

Station	Country	Latitude	Longitude	Instrument owner
NyAlesund	Norway	78.90	11.90	NILU
ScoresbySund	Groenland	71.00	-22.00	LATMOS
Kiruna	Sweden	67.84	20.41	MPIC
Zhigansk	Russia	67.00	123.00	LATMOS
Sodankyla	Finland	67.00	27.00	LATMOS
Salekhard	Russia	67.00	37.00	LATMOS
Arkhangelsk	Russia	64.60	40.50	CAO
Harestua	Norway	60.22	10.75	BIRA
OHP	France	43.94	5.71	LATMOS
StDenis	Reunion Island, France	-20.90	55.50	LATMOS
Reunion	ReunionIsland	-21.00	55.00	LATMOS
Bauru	Brezil	-22.00	-49.00	LATMOS
Lauder	New Zealand	-45.00	170.00	NIWA/LATMOS
Kerguelen	Antartic	-49.00	70.00	LATMOS
Rio-Gallegos	Argentina	-51.60	-69.32	LATMOS
Macquarie Island	MacquarieIsland	-54.50	158.90	NIWA
Rothera	Antartica	-67.00	-68.00	BAS/LATMOS
DumontDUrville	TerreAdelie	-67.00	140.00	LATMOS
Concordia	Antartica	-75.10	123.31	LATMOS
Arrival Heights	Antarctica	-77.80	166.70	NIWA

The geographical distribution of currently operational SAOZ/Zenith-sky DOAS instruments, as well as MAXDOAS and Pandora systems, is provided in Figure 2.

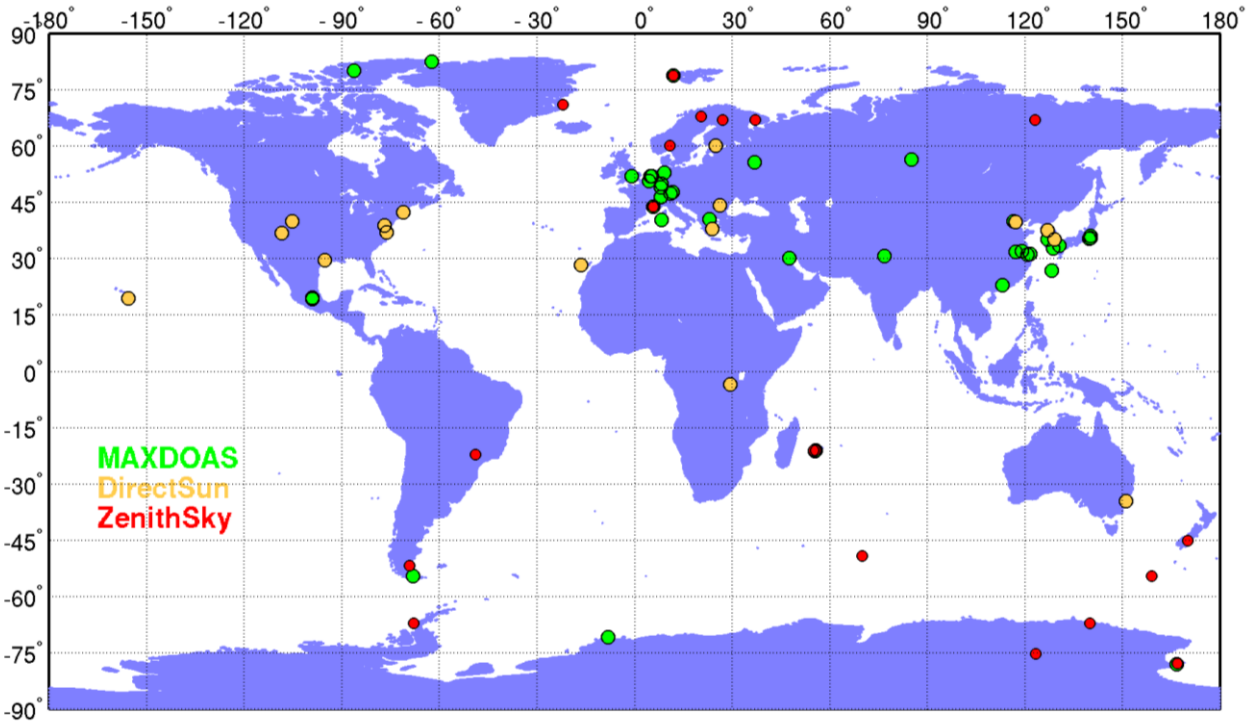

Figure 2: Geographical distribution of MAXDOAS, Pandora/Pandonia and SAOZ/Zenith-sky DOAS monitoring sites currently in operation globally.

3. The FRM$_4$DOAS network

3.1. Evaluation of Technical Readiness Level

A crucial step when considering an instrument for inclusion in the FRM$_4$DOAS network is the evaluation of its Technical Readiness Level (TRL). This is important to a) understand the type and status of the instrument, b) evaluate the usefulness of the instrument for the network and c) provide feedback to the instrument owners with respect to possible development needs. Within FRM$_4$DOAS, it has been decided to collect information (instrument technical characteristics and calibration/operation procedures) for the TRL evaluation through a dedicated questionnaire which is available on the FRM$_4$DOAS website at http://frm4doas.aeronomie.be/index.php/frm4doas-questionnaire. This questionnaire is also included in Appendix A. In addition to instrument type, location, corresponding principle investigator, and institution contact details, it includes questions about:

- Instrument details (spectral resolution and coverage, fields of view, pointing abilities and speed, type of spectrometer and detector, cooling of detector, temperature stabilisation of instrument, …)
- Calibration and characterisation of instrument (slit function, straylight, FOV, pointing accuracy, …)
- Instrument operation procedure (automatic operation and calibration, QA/QC tests, operation documentation,…)

- Procedures for data transfer from the station to the institution
- Procedures for spectra calibration
- Questions about the willingness to be part of the FRM_4DOAS network and possible constraints
- List of publications and projects where corresponding data are used

The technical specifications collected for the CINDI-2 campaign (see Appendix B) will be also used as additional source of information in the evaluation. It is important to point out that depending on the intended application of a DOAS instrument, very different approaches can be taken for the set-up and operation of the instrument. Also, again depending on the field of application, different levels and means of instrument characterisation are needed. Here, the focus is on the use of data from DOAS instruments for a centralised processing in view of satellite data validation. Therefore, the technical readiness for the FRM_4DOAS network should not be confused with a quality judgement, let alone an assessment of the scientific quality of measurements performed with the instrument.

As a first step, the TRL self-evaluation of the MAX-DOAS systems operated by the FRM_4DOAS partners at the stations selected for the project (see Table 4) is presented in Table 5 below.

Table 4: List of FRM_4DOAS demonstration stations.

Location	Lat (°N)	Long (°E)	Alt (m) a.s.l	Owner	NDACC-affiliated	Instrument-type
Ny-Alesund, Norway	79	12	15	IUPUB	yes	Research grade
Bremen, Germany	53	9	50	IUPUB	yes	Research grade
Cabauw, The Netherlands	52	4.9	0	KNMI	candidate	Hoffmann mini-DOAS UV
De Bilt, The Netherlands	52.1	5.2	0	KNMI	candidate	Hoffmann mini-DOAS VIS
Uccle, Belgium	51	4	104	BIRA	yes	Research grade
Mainz, Germany	50	8	150	MPIC	no	Research grade
Heidelberg, Germany	49	8	115	UHEID	no	EnviMes
Xianghe, China	40	116	178	BIRA/IAP-CAS	yes	Research grade
Athens, Greece	38	24	300	IUPUB	no	Research grade
Bujumbura, Burundi	-3	29	820	BIRA	yes	Research grade
Lauder, New-Zealand	-45	170	370	NIWA	yes	Research grade
Neumayer	-71	-8	50	UHEID	yes	Research grade

Table 5: Criteria for the identification of MAX-DOAS TRLs for entering in a centralized processing system and self-evaluation for the FRM$_4$DOAS demonstration stations. For each station, relevant specifications are marked with a cross.

Criteria	Xianghe, Bujumbura, Uccle (from 01/2017) (BIRA)	Ny-Alesund, Bremen, Athens (IUPUB)	Mainz (MPIC)	Heidelberg, Neumayer (UHEID)	Lauder (NIWA)	Cabauw (KNMI)	De Bilt (KNMI)
1) Instrument specifications							
UV spectral range (300-400nm)	X	X (335-500 nm for Athens)	X	X	X	X	
Visible spectral range (400-550nm)	X	X (335-500 nm for Athens)		X	X		X
Depolarizing fibre(s)	X	X	X	X	X	X	X
Fibre light mixing				X			
Detector(s) cooling	X	X	X	X	X	X	X
Instrument thermal stabilization	X	X	X	X	X	X	X
Elevation scan capability	X	X	X	X	X	X	X

Azimuthal scan capability	X	X	4 fixed azimuth directions	X (Heidelberg only)			
Direct-sun pointing capability	X			X (Heidelberg only)			
2) Instrument characterization and calibration in laboratory							
Slit function (ISRF)	X	X	X	X	X	X	X
Wavelength registration	X	X	X	X	X	X	X
Dark signal	X	X	X	X	X	X	X
Spectral stray-light	X		X	X	X		
Detector non-linearity		X		X	X		
Detector interpixel variability		X		X	X	X	X
Field of view	X	X	X	X	X	X	X
Elevation angle	X	X	X	X	X	X	X
Radiometric calibration							
3) Instrument operation							
Automatic operation	X	X	X	X	X	X	X

Automatic calibration		X		X	X		
Automatic QA/QC of instrument parameters	X	X	X		X		
Documentation (e.g. data acquisition protocol, calibration report, etc)	X	X	X	X	X		
4) Station->institute data transfer							
Manual							
Automatic with a latency >24h				X (Neumayer)		X	X
Automatic with a latency <24h	X	X	X	X (Heidelberg)	X		
5) Calibrated radiance spectra ready for DOAS processing							
Manual			X	X	X	X	X
Automatic with a latency >24h							
Automatic with a latency <24h	X	X					
Final QA/QC check on calibrated radiance spectra implemented							

Table 5 shows that the relevant criteria for instrument specifications, characterization and calibration, and operation are met to a large extent by all FRM_4DOAS demonstration instruments. However, this table also points out to the criteria that need to be improved for being part of a NRT centralised processing system: e.g., although the station-to-institute data transfer is generally done automatically with a latency time smaller than 24h, the generation of calibrated radiance spectra ready for DOAS processing is still done manually for half of the demonstration stations.

3.2. Potential extension of the FRM_4DOAS network

In a second step, the potential for extending the FRM_4DOAS network to additional stations has been evaluated by circulating the questionnaire to the whole DOAS Community via e-mail (an official questionnaire release e-mail was sent by ESA on 04/05/2017) but also through dedicated presentations at major conferences/workshops (e.g. EGU2017, 8th International DOAS Workshop). So far, 21 groups (including the 6 FRM_4DOAS partners) representing a total of 61 (MAX)DOAS instruments operated worldwide expressed their interest in being part of the FRM_4DOAS network and provided their self-assessment to BIRA-IASB. The list of potential FRM_4DOAS stations together with instrument type are summarized in Table 6 and the corresponding geographical distribution is presented in Figure 3.

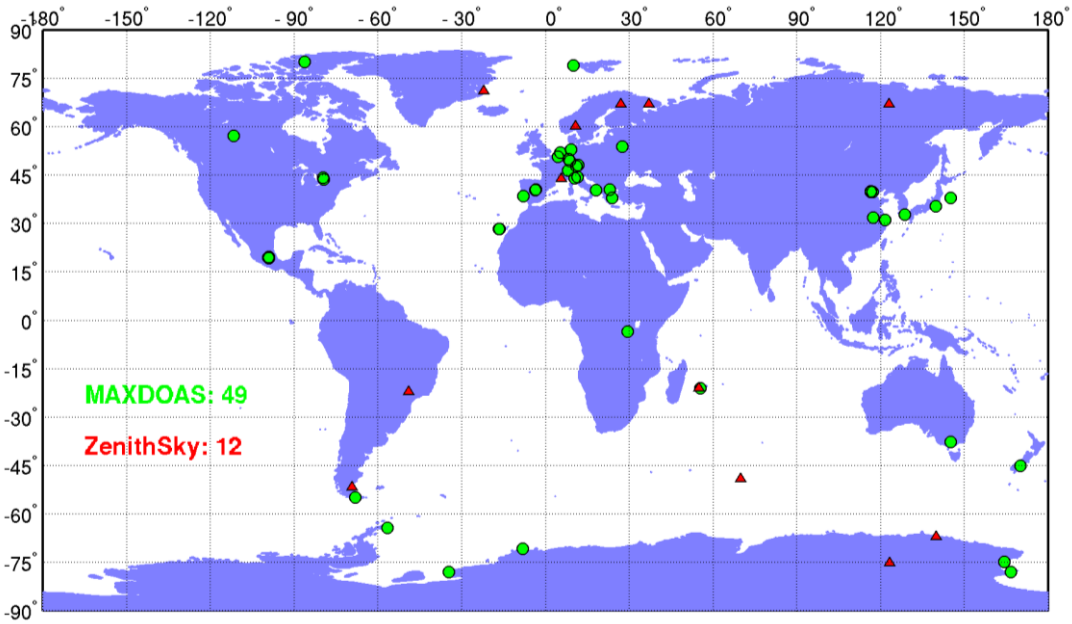

Figure 3: Potential FRM_4DOAS network as on 21/11/2017.

All groups listed in Table 6 expressed their willingness to provide their radiance spectra to the FRM_4DOAS centralised processing system and to be involved in future community efforts for improving (MAX)DOAS standards. The inventory of the received questionnaires shows that most instruments meet the technical specifications for being included in FRM_4DOAS but efforts should be put on (1) the characterization and calibration of the instruments, and (2) the automation of the processes producing calibrated radiance spectra ready for DOAS analysis. In that sense, calibration activities carried out during the CINDI-2 campaign should contribute to improve point (1) since most of those groups have participated in CINDI-2. Finally, it is also important to note that almost all of them expressed difficulty for financially supporting their (MAX)DOAS measurements in a long-term perspective.

Both Table 6 and Figure 3 will be continuously updated during the framework of the project, based on further input received from new candidate instruments.

Table 6: Potential FRM$_4$DOAS network as on 21/11/2017. RG: Research grade/MB: Manufacturer-built/CB: Custom-built. Convention for lat, long: + for N and E; - for S and W.

Group	Station	#	Country	Lat (°)	Long (°)	Geometry	Type	Channel		NDACC-affiliated
								UV	VIS	
AIOFM (Hefei, China)	Hefei	1	China	31.9	117.17	MAXDOAS	RG-MB	X		no
	Shanghai	2	China	31.19	121.45	MAXDOAS	RG-MB	X		no
KNMI (De Bilt, The netherlands)	DeBilt	3	The Netherlands	52.10	5.18	MAXDOAS	MiniDOAS Hoffmann	X	X	no
AUTH (Thessaloniki, Greece)	Thessaloniki Campus	4	Greece	40.63	22.96	MAXDOAS	MiniDOAS-CB	X	X	no
	Thessaloniki CIRI	5	Greece	40.56	23.00	MAXDOAS	MiniDOAS-CB	X	X	no
BOM (Melbourne, Australia)	Broadmeadows	6	Australia	-37.69	144.95	MAXDOAS	EnviMes	X	X	no
BSU (Minsk, Belarus)	Minsk	7	Belarus	53.84	27.48	MAXDOAS	RG-CB	X		no
BIRA (Brussels, Belgium)	Xianghe	8	China	39.75	116.96	MAXDOAS	RG-CB	X	X	yes
	Uccle	9	Belgium	50.8	4.35	MAXDOAS	RG-CB	X	X	no
	Jungfraujoch	10	Swiss	46.55	7.98	MAXDOAS	RG-CB	X	X	yes
	Le Port	11	Reunion Island (Fr)	-20.93	55.28	MAXDOAS	RG-CB	X	X	no
	Bujumbura	12	Burundi	-3.38	29.38	MAXDOAS	RG-CB	X	X	yes
	Harestua	13	Norway	60.22	10.75	ZenithSky	RG-CB	X	X	yes
CMA (Beijing, China)	Beijing CMA	14	China	39.95	116.32	MAXDOAS	MiniDOAS Hoffmann	X		no
	Beijing Nanjiao	15	China	39.85	116.49	MAXDOAS	MiniDOAS Hoffmann	X		no
CSIC (Madrid, Spain)	Madrid	16	Spain	40.3	-3.7	MAXDOAS	RG-CB	X	X	no
INTA (Madrid, Spain)	Izaña	17	Spain	28.31	-16.50	MAXDOAS	RG-CB		X	yes
	Torrejón de Ardoz	18	Spain	40.48	-3.47	MAXDOAS	RG-CB	X		no
	El Arenosillo	19	Spain	28.3	-16.78	MAXDOAS	RG-CB		X	no
	Ushuaia	20	Argentina	-54.8	-68.28	MAXDOAS	RG-CB		X	yes
	Marambio	21	Antarctica	-64.27	-56.7	MAXDOAS	RG-CB	X	X	yes
	Belgrano	22	Antarctica	-77.87	-34.62	MAXDOAS	RG-CB	X	X	yes
IUPB (Bremen, Germany)	Bremen	23	Germany	53.0	9.0	MAXDOAS	RG-CB	X	X	yes
	Ny-Alesund	24	Svalbard	79.0	10.0	MAXDOAS	RG-CB	X	X	yes
	Athens	25	Greece	38.05	23.86	MAXDOAS	RG-CB	X	X	no
IUPH (Heidelberg, Germany)	Arrival Heights	26	Antartica	-77.83	166.65	MAXDOAS	RG-CB	X	X	no
	Neumayer	27	Antartica	-70.69	-8.27	MAXDOAS	RG-CB	X	X	yes

	Hohenpeissenberg	28	Germany	47.80	11.01	MAXDOAS	RG-CB	X	X	no
	Heidelberg	29	Germany	49.42	8.67	MAXDOAS	EnviMes	X	X	no
JAMSTEC (Yokohama, Japan)	Yokosuka	30	Japan	35.32	139.65	MAXDOAS	MiniDOAS-CB	X	X	no
	Fukue	31	Japan	32.75	128.68	MAXDOAS	MiniDOAS-CB	X	X	no
LATMOS (Guyancourt, France)	ScoresbySund	32	Groenland	71.0	-22.0	ZenithSky	SAOZ		X	yes
	Sodankyla	33	Finland	67.0	27.0	ZenithSky	SAOZ		X	yes
	Zhigansk	34	Russia	67.0	123.0	ZenithSky	SAOZ		X	yes
	Salekhard	35	Russia	67.0	37.0	ZenithSky	SAOZ		X	yes
	OHP	36	France	43.9	5.7	ZenithSky	SAOZ		X	yes
	Bauru	37	Brezil	-22.0	-49.0	ZenithSky	SAOZ		X	yes
	Reunion	38	Reunion Island (Fr)	-21.0	55.0	ZenithSky	SAOZ		X	yes
	Kerguelen	39	Antartic	-49.0	70.0	ZenithSky	SAOZ		X	yes
	Rio Gallegos	40	Argentina	-51.6	-69.3	ZenithSky	SAOZ		X	yes
	Dumont D'Urville	41	Antarctica	-67.0	140.0	ZenithSky	SAOZ		X	yes
	Concordia	42	Antarctica	-75.1	123.3	ZenithSky	SAOZ		X	yes
LMU (Munich, Germany)	Munich LMU	43	Germany	48.15	11.57	MAXDOAS	EnviMes	X		no
MPIC (Mainz, Germany)	Mainz	44	Germany	50	8.27	MAXDOAS	RG-CB	X	X	no
NIWA (Lauder, new Zealand)	Lauder	45	New Zealand	-45	170	MAXDOAS	RG-CB	X	X	yes
	Lauder	46	New Zealand	-45	170	MAXDOAS	RG-CB	X	X	yes
UEVORA/ISAC-CNR (Evora, Portugal/ Bologna, Italy)	Evora	47	Portugal	38.56	-7.91	MAXDOAS	RG-CB	X	X	no
	Monte Cimone	48	Italy	44.11	10.42	MAXDOAS	RG-CB	X	X	no
	Lecce	49	Italy	40.33	18.12	MAXDOAS	RG-CB	X	X	no
	Mario Zucchelli Station	50	Antarctica	-74.69	164.12	MAXDOAS	RG-CB	X	X	no
	Bologna	51	Italy	44.52	11.42	MAXDOAS	RG-CB	X	X	no
UNAM (Mexico City, Mexico)	UNAM	52	Mexico	19.33	-99.18	MAXDOAS	RG-CB	X	X	no
	Acatlán	53	Mexico	19.48	-99.24	MAXDOAS	RG-CB	X	X	no
	Vallejo	54	Mexico	19.48	-99.15	MAXDOAS	RG-CB	X	X	no
	Cuautitlãn	55	Mexico	19.71	-99.20	MAXDOAS	RG-CB	X	X	no
University of Melbourne (Melbourne, Australia)	Melbourne	56	Canada	40.0	145.0	MAXDOAS	EnviMes	X	X	no
UTORONTO (Toronto, Canada)	Eureka - PEARL	57	Canada	80.05	-86.42	MAXDOAS	RG-CB	X		yes

	Eureka - UT	58	Canada	80.05	-86.42	MAXDOAS	RG-CB		X	yes
Environment Canada (Toronto, Canada)	Toronto	59	Canada	43.78	-79.47	MAXDOAS	EnviMes	X	X	no
	Egbert	60	Canada	44.23	-79.78	MAXDOAS	EnviMes	X	X	no
	Fort McKay	61	Canada	57.18	-111.64	MAXDOAS	EnviMes	X	X	no

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Appendix A: Questionnaire for evaluating potential candidate instruments for inclusion in the FRM_4DOAS network.

Fiducial Reference Measurements for Ground-Based DOAS Air-Quality Observations

ESA Contract No. 4000118181/16/I-EF

Questionnaire for MAX-DOAS network assessment in view of joining the FRM_4DOAS centralised processing system

Date: 13/04/2017

Version: 1.0

Contributing authors:

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1. Introduction

Fiducial Reference Measurements (FRM) are a suite of independent, fully characterized, and traceable ground measurements that follow the guidelines outlined by the GEO/CEOS Quality Assurance framework for Earth Observation (see http://qa4eo.org). These FRM provide the required confidence in data products, in the form of independent validation results and satellite measurement uncertainty estimation, over the entire end-to-end duration of a satellite mission (for more information, see https://earth.esa.int/web/sppa/activities).

The Fiducial Reference Measurements for Ground-Based DOAS Air-Quality Observations (FRM4DOAS) is a 2-year ESA project which started in July 2016. It aims at further harmonization of MAXDOAS systems and data sets, through the

- specification of best practices for instrument operation
- demonstration of a centralised NRT (near-real-time/6-24h latency) processing system for MAXDOAS instruments operated within the international Network for the Detection of Atmospheric Composition Change (NDACC)
- establishment of links with other UV-Visible instrument networks, e.g. Pandonia

The target species for the first phase of the project are tropospheric and stratospheric NO_2 vertical profiles, total O_3 columns, and tropospheric HCHO profiles. The aim is to produce homogenous ground-based reference datasets from instruments being operated at long-term monitoring sites (e.g. NDACC) or during field campaigns. Such reference data sets will play a crucial role in the validation of future atmospheric composition satellite missions, in particular the ESA Copernicus Sentinel missions S-5P, S-4, and S-5. More detailed information about the project can be found on the FRM_4DOAS website (http://frm4doas.aeronomie.be).

A general overview of the FRM_4DOAS service is given in Figure 1. Although the NRT MAX-DOAS centralized processing system will be demonstrated on a limited number of stations from project partners (11 sites in total; see Table 1), it will be designed to allow efficient ingestion and processing of radiance spectra (Level 1 data) from a large number of instruments and sites not part of the initial project. The system will also allow for extension to additional species such as SO_2, CHOCHO, HONO and H_2O.

Participants joining the FRM_4DOAS Service as data providers will benefit from the following advantages:

- ✓ Free-of-charge systematic Level 1 (radiance spectra) to Level 2 (vertical columns and profiles) NRT processing service
- ✓ Only 6-24h latency between the submission of the spectra and the availability of final products data files
- ✓ Continuous quality monitoring for both Level 1 and 2 data with automated feedback to instrument PI in case of anomaly
- ✓ Increased data visibility as part of an international network (NDACC)
- ✓ Collaboration to international operational validation projects, e.g. in the frame of Copernicus
- ✓ Processed level-2 data for scientific use by instrument PIs but also by the overall scientific community

In return of the processing service, instrument PIs will commit to follow the FRM_4DOAS guidelines and standards in terms of best practices, data acquisition protocol, and QA/QC for instrument calibration and operation. The protocol for participation to the FRM_4DOAS Service will be described in living documents to

be made available on the FRM$_4$DOAS website (see http://frm4doas.aeronomie.be/ProjectDir/Deliverables/FRM4DOAS_D4_MAXDOAS_Best_Practices_20170328_preliminary.pdf). To protect the Intellectual Property Rights of the instrument PIs and avoid any misuse of the generated data sets, a strict data policy will be applied.

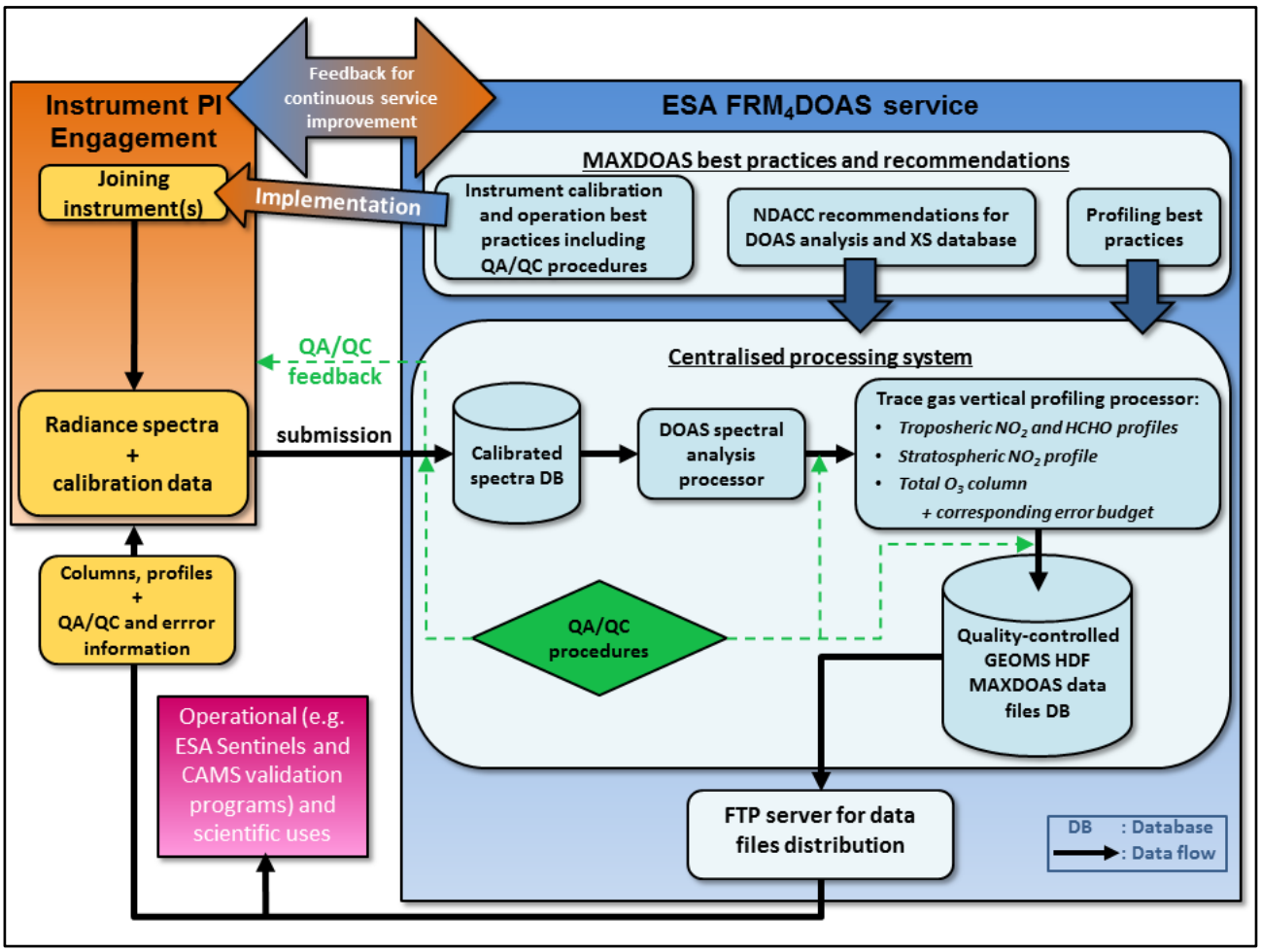


Figure 1: Detailed flow-chart of the FRM$_4$DOAS service.

Table 1: MAXDOAS sites planned for integration in the FRM$_4$DOAS demonstration processing system

Location	Lat (°N)	Long (°E)	Alt (m) a.s.l	Owner
Ny-Alesund, Norway	79	12	15	IUPUB
Bremen, Germany	53	9	50	IUPUB
Cabauw, The Netherlands	52	5	0	KNMI
Uccle, Belgium	51	4	104	BIRA
Mainz, Germany	50	8	150	MPIC
Heidelberg, Germany	49	8	115	UHEID
Xianghe, China	40	116	178	BIRA/IAP-CAS
Athens, Greece	38	24	300	IUPUB
Bujumbura, Burundi	-3	29	820	BIRA
Lauder, New-Zealand	-45	170	370	NIWA
Neumayer	-71	-8	50	UHEID

The FRM$_4$DOAS project aims to develop and set up the basis for a sustainable operational system providing Fiducial Reference Measurements that in the long term shall contribute to the regular stream of satellite

validation data. Starting with the Sentinel-5 Precursor planned to be launched in August 2017, continued by the low-earth Sentinel-5 and the geostationary Sentinel-4 series in the early 2020s, there is a multi-decadal requirement for air-quality FRMs. In this context the resulting FRM_4DOAS data set is a main source to verify the quality of these and other future atmospheric composition satellite programmes. Beyond the on-going initiating two-year project, ESA plans to financially support the operations and developments for FRM_4DOAS, as well as a contribution to the operational MAX-DOAS activities, to ensure the long-term availability of a harmonised atmospheric composition data set.

The NDACC UV-VIS Working Group (http://ndacc-uvvis-wg.aeronomie.be) is part of the established Network for the Detection of Atmospheric Composition Change, where UV-Visible instruments contribute since more than two decades to the regular monitoring of stratospheric trace gases, in particular O_3, NO_2, BrO and OClO, total column amounts. NDACC instruments are formally evaluated and quality assessed through participation to regular intercomparison exercises. Protocols and procedures have also been established to ensure network consistency and long-term stability of the generated data records.

FRM_4DOAS aims to bring new capabilities to the NDACC by operationally generating the tropospheric data products needed to support the validation of current and future atmospheric composition satellite missions such GOME-2/METOP, AURA/OMI, Sentinel 4, 5 and 5P, TEMPO, GEMS, etc.

The purpose of the present document is to identify the potential candidate instruments for future inclusion in the FRM_4DOAS processing system. To this aim, we kindly ask you to fill the questionnaire below indicating your interest for eventual participation.

2. Questionnaire

Personal details:

Name :……

Position :……

Institute + address :……

:……

:……

:……

:……

E-mail :……

Q1/ Are you interested in providing radiance spectra (Level 1 data) from your MAXDOAS instrument(s) to a centralised processing system making use of common community algorithms? If yes, go to Q2; if not, please explain the reason(s) why you are not interested:

y/n

……..

Q2/ What are the locations (site name + coordinates) of the MAXDOAS instruments from your Institute that could provide Level 1 data to the FRM$_4$DOAS processing system? For each site/instrument, please indicate whether it is already part of NDACC, provide a general classification of the instrument type (e.g. "research grade system" , "mini-DOAS", "EnviMes" etc + pointing/imaging CCD/PDA; outdoor/indoor instrument; manufacturer/custom-built; see example below), and provide instrument specifications according to the Table below:

Site 1: site_name, country (lat, long); NDACC-affiliated site ? ; instrument type

Site 2: site_name, country (lat, long); NDACC-affiliated site ? ; instrument type

Site 3: site_name, country (lat, long); NDACC-affiliated site ? ; instrument type

Site 4: site_name, country (lat, long); NDACC-affiliated site ? ; instrument type

……

Example:

Site 1: Bremen, Germany (53°N, 9°E), NDACC-Yes, research grade, pointing, CCD, indoor, custom-built

Instrument specifications (mark relevant specification with a cross):

	Site 1	Site 2	Site 3	Site 4
UV spectral range (300-400nm)*	*x (310-390)*			
Visible spectral range (400-550nm)*				
Depolarizing fiber(s)				
Fiber light mixing				
Detector(s) cooling				
Instrument thermal stabilization				
Elevation scan capability				
Azimuthal scan capability				
Direct-sun pointing capability				

*Please also mention the spectral range in nm (see example in *italic*).

Comments (optional):

……..

Q3/ What are your usual procedures for instrument characterization/calibration ?

Instrument characterization and calibration (mark relevant specification with a cross):

	Site 1	Site 2	Site 3	Site 4
Slit function (ISRF)				
Wavelength registration				
Dark signal				
Spectral stray-light				
Detector non-linearity				
Detector interpixel variability				
Field of view				
Elevation angle				
Radiometric calibration				

Comments (optional):

……..

Q4/ How do you operate your instrument(s) ?

Instrument operation (mark relevant specification with a cross):

	Site 1	Site 2	Site 3	Site 4
Automatic operation				
Automatic calibration				
Automatic QA/QC of instrument parameters				
Documentation (e.g. data acquisition protocol, calibration report, etc)				

Comments (optional):

……..

Q5/ What are the procedure in place for data transfer ?

Station->institute data transfer (mark relevant specification with a cross):

	Site 1	Site 2	Site 3	Site 4
Manual				
Automatic with a latency >24h				
Automatic with a latency <24h				

Comments (optional):

……..

Q6/ What is the current latency for spectral data accessibility ?

Calibrated radiance spectra ready for DOAS processing (mark relevant specification with a cross):

	Site 1	Site 2	Site 3	Site 4
Manual				
Automatic with a latency >24h				
Automatic with a latency <24h				
Final QA/QC check on calibrated radiance spectra implemented				

Comments (optional):

……..

Q7/ Please list below your relevant publications (i.e. where your instrument(s) and data are described and/or used):

……

Q8/ Please list below your relevant past and current international research projects (i.e. projects in relation to your MAXDOAS measurements):

……

Q9/ In case you would join the FRM$_4$DOAS centralized processing system, would you be willing to be involved in future community efforts for improving standards ?

y/n

Q10/ If not yet the case, would you be willing to affiliate to NDACC ? If not, could you explain why ?

y/n

……

Q11/ General comments and constraints

Comments/remarks/questions are welcome, e.g. about your financial and manpower constraints/efforts to reach FRM$_4$DOAS standards.

……..

Please return to:

Dr François Hendrick, BIRA-IASB (francois.hendrick@aeronomie.be)

Appendix B: Technical characteristics of MAX-DOAS and zenith-DOAS instruments having participated to the CINDI-2 campaign

Colour code: 1D-MAXDOAS; 2D-MAXDOAS; ZS-DOAS

Institute: Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences (AIOFM), Hefei, China **Responsible person(s):** Ang Li, Pinhua Xie **Contact details:** angli@aiofm.ac.cn, mobile phone: + 86-13855196384; phxie@aiofm.ac.cn, mobile phone: + 86-13856904878		
Instrument type: 2D-MAXDOAS	**Nr:** CINDI-2.01	
Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** Princeton Instrument 150i **Detector type:** Princeton Instrument PIXIS-2K BUV **Optical fibers:** quartz optical fiber, length: 10 m **Filters:** ZWB3(=UG5) **Mirrors: no** **Temperature control of spectrometer/detector:** 35°C /-30°C	
Instrument performance	**Spectral range/resolution:** 290-380 (adjustable)/0.35 nm **Azimuthal scan/direct-sun capabilities:** yes/no **Elevation angle capability:** fully configurable **Field of view:** 0.2° **Typical integration time:** 10-60s **Typical scan duration:** 15 minutes	
Calibration/characterization procedures	**Elevation angles:** inclinometer **Field of view:** scanning over a light source in the laboratory **Straylight:** **Dark signal:** by using the shutter **Line shape:** Hg lamp in the laboratory **Polarization: -** **Detector nonlinearity:** halogen lamp/dark background **Pixel-to-pixel variability**: halogen lamp/dark background	
Spectral analysis software	QDOAS / WinDOAS	
Supporting measurements	Video camera, inclinometer, GPS, electronic compass	
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 300 W **Internet:** data volume: 200 MB, 2 IP addresses, ftp **Outdoor space requirements:** 1 m(H) x 0.5 m x 0.5 m; 20 kg **Indoor space requirements:** 0.3 (H) m x 0.5 m x 0.5 m; 50 kg **Maximum distance between telescope and spectrometer:** <10 m **Indoor facility:** air conditioning **Local support:** mobile elevator	

Institute: A.M.Obukhov Institute of Atmospheric Physics (AMOIAP), Russian Academy of Sciences, Moscow, Russia **Responsible person(s):** Alexander Borovski, Oleg V.Postylyakov **Contact details:** alexander.n.borovski@gmail.com (+7 915 390 56 45) oleg.postylyakov@gmail.com (+7 905 5512 27 35)	
Instrument type: 2-port DOAS	**Nr:** CINDI-2.02

Overall design of the instrument	**Optical head including telescope:** separated; 2 telescope units (one for zenith + one for off-axis) **Spectrometer type:** Shamrock303i spectrograph with filter wheel **Detector type:** Newton CCD (DU940N-BU2, 2048×512 pxls) **Optical fibers:** standard fiber cable with two inputs and one output, length: 15 m **Filters:** unknown yet **Mirrors:** no **Temperature control of spectrometer/detector:** 35°C/-40°C
Instrument performance	**Spectral range/resolution:** 420-490 / 0.5 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** two fixed elevation angles (one zenith and one off-axis) **Field of view:** 0.3° **Typical integration time:** 1 – 10 s **Typical scan duration:** 1 – 10 s
Calibration/characterization procedures	**Elevation angles:** adjusted manually using bubble level **Field of view:** measured in the lab **Straylight:** unknown **Dark signal:** unknown **Line shape:** Gaussian **Polarization:** unknown **Detector nonlinearity:** unknown **Pixel-to-pixel variability**: unknown
Spectral analysis software	Andor Solis/own-developed software
Supporting measurements	Cloud stereo photo-cameras. We will be in need in place of 2 ethernet cables to connect notebook with cameras.
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 1.2kW (max) **Internet:** 3 IP addresses, no big data volume to be transferred, remote desktop (TeamViewer) **Outdoor space requirements:** flat surface (about 1 m^2) to mount telescope holder (tripod; height:0.5m). Weight of outside part: 14kg. **Indoor space requirements:** 1.6 m (width) × 0.5 m (depth) × 0.8 m (height) for instrument and notebook(s). Weight indoor part: ~80kg **Maximum distance between telescope and spectrometer:** up to 12 m **Indoor facility:** air-conditioned room (18-25°C), 9 sockets 220VAC **Local support:** one extra people needed for installation, mobile elevator

Institute: Physics Department, Section of Applied and Environmental Physics, Laboratory of Atmospheric Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece **Responsible person(s):** Theano Drosoglou, Alkis Bais **Contact details:** tdroso@auth.gr,mobile phone: + 306977483092	
Instrument type: Phaethon mini MAXDOAS	**Nr:** CINDI-2.03

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** AvaSpec-ULS2048LTEC (Avantes) **Detector type:** SONY2048L (CCD linear array) **Optical fibers:** standard fiber cable with metal silicone jacketing, 800 µm fiber core diameter and overall length of 8 meters **Filters:** filter wheel: neutral density filter + ground quartz diffuser plate for direct-sun, clear aperture for sky-radiance, opaque for dark signal **Mirrors:** no mirrors, plano-convex lens **Temperature control of spectrometer/detector:** 5°C/5°C
Instrument performance	**Spectral range/resolution:** 297-452/0.3-0.4 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable, 0.125° resolution **Field of view:** 1° **Typical integration time:** 200-3000 ms (scattered light) **Typical scan duration:** 10-20 minutes for a sequence of elevation angles
Calibration/characterization procedures	**Elevation angles:** Sighting using the solar disk **Field of view:** white reflecting stripe measurements in laboratory **Straylight:** tunable-laser measurements **Dark signal:** after each scan sequence for all integration times used **Line shape:** laser lines and spectral discharge lamp measurements **Polarization:** zenith radiance measurements at different azimuth angles **Detector nonlinearity:** tunable-laser measurements with varying output **Pixel-to-pixel variability**: tungsten halogen lamp measurements
Spectral analysis software	QDOAS (currently version 2.109.3)
Supporting measurements	None during the campaign
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 200 W **Internet:** data volume: 300MB, 2 IP addresses, remote desktop (TeamViewer) + ftp **Outdoor space requirements:** 1.5 x 1.5 m^2 (tripod), height: 1-1.6m, 30kg **Indoor space requirements:** 1m^2 on a bench or desk **Maximum distance between telescope and spectrometer:** 6 m **Indoor facility:** air conditioning (ambient temperature <30°C) **Local support:** no extra people needed

Institute: Royal Belgian Institute for space Aeronomy (BIRA-IASB), Brussels, Belgium **Responsible person(s):** Christian Hermans and Michel Van Roozendael **Contact details:** christh@aeronomie.be, tel: +3223730375 michelv@oma.be, tel: +32472352580	
Instrument type: 2D MAXDOAS	**Nr:** CINDI-2.04

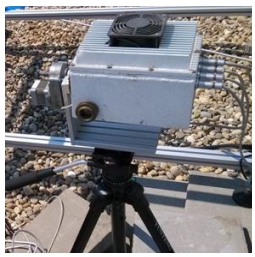
Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable; active sun tracking system **Spectrometer type UV:** Newport, model: 74086 **Spectrometer type vis:** Horiba, model: Micro HR **Detector type UV:** CCD Back-illuminated Princeton Instrument Pixis 2K **Detector type vis:** CCD Back-illuminated Princeton Instrument Pixis 100 **Optical fibers:** quartz UV chanel**:** monofiber (l:6m,diam:1000µm)+ bundle(length:2m, 51 fibers 100µm) Vis chanel**:** monofiber (l:6m,diam:800µm)+ bundle(length:2m, 37 fibers 100µm) **Filters:** UV chanel : Filter band U-340 Hoya **Mirrors:** no (for telescope we use lens in quartz) **Temperature control of spectrometer and detector UV:** 30°C/-50°C **Temperature control of spectrometer and detector vis:** 30°C/-50°C
Instrument performance	**Spectral range/resolution UV:** 300–390/0.4 nm **Spectral range/resolution vis:** 405–540/0.7 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable; resolution: <0.1° **Field of view: <**1° **Typical integration time:** total measurement t:60 sec (t min: vis 0.03s, UV 0.1s) **Typical scan duration:** 20 minutes
Calibration/characterization procedures	**Elevation angles:** digital inclinometer in telescope **Field of view:** white light source in lab **Straylight:** double monochromator fed by white light source **Dark signal:** measured as night every day **Line shape:** HgCd lamp in the lab, further adjusted using QDOAS **Polarization:** n/a (use of long depolarising fiber bundle) **Detector nonlinearity:** white light source in the lab **Pixel-to-pixel variability**: white light source in the lab
Spectral analysis software	QDOAS
Supporting measurements	Video camera
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ <1000 W on average **Internet:** data volume: 600MB, 4 IP addresses, VNC, Logmein, ftp **Outdoor space requirements:** 1 m^2; height: 1.6m, weight: 30kg **Indoor space requirements:** 2.5x1.5m **Maximum distance between telescope and spectrometers:** 6 m **Indoor facility:** air conditioning temperature between 20 and 25 ° **Local support:** no extra people needed; a mobile elevator could be useful

Institute: Belarusian State University, Minsk, Belarus **Responsible person(s):** Ilya Bruchkovsky **Contact details:** bruchkovsky2010@yandex.by, mobile phone: +375293279807	
Instrument type: MAXDOAS one azimuth, catadioptric telescope / MARS-B	**Nr:** CINDI-2.05

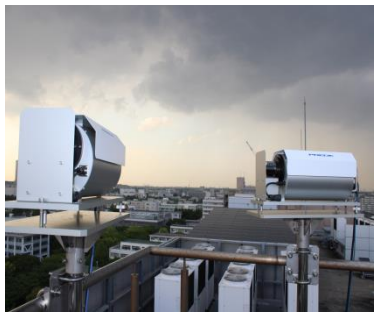
Overall design of the instrument	**Optical head including telescope:** integrated **Spectrometer type:** Oriel MS257 imaging spectrograph (1:4) **Detector type:** Andor DV420-OE 256*1024 pixels CCD **Optical fibers:** n/a **Filters:** red **Mirrors:** yes **Temperature control of detector:** -40°C
Instrument performance	**Spectral range/resolution:** 409-492/0.4 nm + possibly also UV **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** 0.2° (azimuth); 1° (elevation) **Typical integration time:** 1-3s **Typical scan duration:** 1.5 minutes (12 elevation angles)
Calibration/characterization procedures	**Elevation angles:** Udo Friess method (laser level, narrow mercury lamp) **Field of view:** measured in the lab **Straylight:** N/A **Dark signal:** 485 ±6 counts **Line shape:** Gaussian **Polarization:** N/A **Detector nonlinearity:** above 25000 counts **Pixel-to-pixel variability**: ±6 counts
Spectral analysis software	Self-made + Windoas
Supporting measurements	Video camera (possibly)
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 300 W **Internet:** Only WIFI for e-mails **Outdoor space requirements:** distance between telescope and basement is about 1 m, therefore there should be no obscurances along line of sight and above 1 m; two boxes: 1x0.7x0.3 m^3 (60kg); 1x0.8x0.7 m^3 (81kg) **Indoor space requirements:** need space for computer, LCD monitor, keyboard **Maximum distance between instrument and computer:** 3 m **Indoor facility:** I have no special requirements

Institute: Institut für Meteorologie (BOKU-Met), Universität für Bodenkultur Wien, Wien, Austria **Responsible person(s):** Stefan Schreier **Contact details:** Stefan.Schreier@boku.ac.at, mobile phone: +43 69915091095	
Instrument type: 1 channel scientific grade elevation and azimuth scanning MAXDOAS	**Nr:** CINDI-2.06

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** Acton Standard Series SP-2356 Imaging Spectrograph **Detector type:** PIX100B-SF-Q-F-A **Optical fibers:** Y-type quartz bundle, diameter: 150µm, length: 25m **Filters:** no **Mirrors:** no **Temperature control of spectrometer and detector:** 35°C/-30°C
Instrument performance	**Spectral range/resolution:** 406–579/0.85 nm **Azimuthal scan/direct-sun capabilities:** yes/no **Elevation angle capability:** fully configurable **Field of view:** 1° **Typical integration time:** 60s; 120s for zenith **Typical scan duration:** 15 minutes for 11 elevation angles
Calibration/characterization procedures	**Elevation angles:** geometric alignment of telescope, horizon scan **Field of view:** white light source in lab **Straylight:** not yet characterized **Dark signal:** nightly measurements **Line shape:** HgCd lamp in telescope **Polarization:** - **Detector nonlinearity:** white light source in lab, characterization only **Pixel-to-pixel variability**: white light source in lab, characterization only
Spectral analysis software	NLIN
Supporting measurements	Video camera, HgCd lamp
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 500 W on average; 1000 W peak **Internet:** data volume: 200MB, 2 IP addresses, remote desktop + ftp **Outdoor space requirements:** 1.5 x 1.5 m^2 for telescope tripod **Indoor space requirements:** 2.5 x 1 m^2 rack, 150 kg, no more than 25°C **Maximum distance between telescope and spectrometer:** 20 m **Indoor facility:** air conditioning (<25°C) **Local support:** mobile elevator

Institute: Chinese Academy of Meteorology Science, China Meteorological Administration, Beijing, China **Responsible person(s):** Junli Jin, Jianzhong Ma **Contact details:** jinjunli@camscma.cn, mobile phone: +86 13426397058		
Instrument type: mini-DOAS Hoffmann UV (#1)	**Nr:** CINDI-2.07	
Overall design of the instrument	**Optical head including telescope:** integrated **Spectrometer type:** Ocean Optics usb 2000 **Detector type:** Sony ILX511 CCD (2048 pixels) **Optical fibers:** n/a **Temperature control of spectrometer/detector:** n/a	
Instrument performance	**Spectral range/resolution:** 292-447/0.6-0.8 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** 0.8° **Typical integration time:** 1-2 minutes **Typical scan duration:** 15-30 minutes	
Calibration/characterization procedures	**Elevation angles:** horizontal scan calibration **Field of view:** not yet characterized **Straylight:** not characterized **Dark signal:** measurement in night or measured with telescope covered, then substracted before spectra analysis **Line shape:** not yet characterized **Polarization:** not yet characterized **Detector nonlinearity:** not yet characterized **Pixel-to-pixel variability**: not yet characterized	
Spectral analysis software	WinDOAS	
Supporting measurements	none	
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 200 W **Internet:** data volume: 300 MB, 2 IP addresses, remote desktop, VNC, and ftp **Outdoor space requirements:** 0.5*0.5*0.5 m^3, height: 1m; weight not a problem **Indoor space requirements:** 1*1m^2 desk(for laptop and electric power converter) **Maximum distance between telescope and instruments:** n/a **Indoor facility:** air conditioning **Local support:** medal framework or stand to support the instrument ; sticky tape to fix the accessories/wires; extended power cord (electricity line) if the instrument is far away from power supply; one external people	

Institute: Chinese Academy of Meteorology Science, China Meteorological Administration, Beijing, China **Responsible person(s):** Junli Jin, Jianzhong Ma **Contact details:** jinjunli@camscma.cn, mobile phone: +86 13426397058		
Instrument type: mini-DOAS Hoffmann VIS (#1)	**Nr:** CINDI-2.08	
Overall design of the instrument	**Optical head including telescope:** integrated **Spectrometer type:** Ocean Optics usb 2000 **Detector type:** DET2B-vis (2048 pixels) **Optical fibers:** n/a **Filters:** n/a **Mirrors:** n/a **Temperature control of spectrometer/detector:** n/a	
Instrument performance	**Spectral range/resolution:** 399-712/0.6-0.8 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** 0.8° **Typical integration time:** 1-2 minutes **Typical scan duration:** 15-30 minutes	
Calibration/characterization procedures	**Elevation angles:** horizontal scan calibration **Field of view:** not characterized **Dark signal:** measurement in night or measured with telescope covered, then substracted before spectra analysis **Line shape:** not yet characterized **Polarization:** not yet characterized **Detector nonlinearity:** not yet characterized **Pixel-to-pixel variability**: not yet characterized	
Spectral analysis software	WinDOAS	
Supporting measurements	none	
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 200 W **Internet:** data volume: 300 MB, 2 IP addresses, remote desktop, VNC, and ftp **Outdoor space requirements:** 0.5x0.5x0.5 m^3, height: 1m; weight not a problem **Indoor space requirements:** 1x1m^2 desk(for laptop and electric power converter) **Maximum distance between telescope and instruments:** n/a **Indoor facility:** air conditioning **Local support:** medal framework or stand to support the instrument ; sticky tape to fix the accessories/wires; extended power cord (electricity line) if the instrument is far away from power supply; one external people	

Institute: Center for Environmental Remote Sensing (CEReS), Chiba University, Chiba, Japan **Responsible person(s):** Hitoshi Irie **Contact details:** hitoshi.irie@chiba-u.jp, mobile phone:+81 9015492635		
Instrument type: 1 channel scientific grade elevation and azimuth scanning MAXDOAS	**Nr:** CINDI-2.09	
Overall design of the instrument	**Optical head including telescope:** separated **Spectrometer type:** Ocean Optics Maya2000Pro **Detector type:** Back-thinned, 2D FFT-CCD **Optical fibers:** premium-grade UV/VIS Optical fibre, length - 10 m **Filters:** no **Mirrors:** quartz mirror **Temperature control of spectrometer and detector:** 40°C/40°C	
Instrument performance	**Spectral range/resolution:** 310–515/0.4 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** set of 6 elevation angles, values can be adjusted but not the number of angles **Field of view:** <1° **Typical integration time:** 4 minutes **Typical scan duration:** 30 minutes	
Calibration/characterization procedures	**Elevation angles:** Two horizontal levels embedded in the base plate and in a plate holding the reflecting mirror are used to adjust the zero angle of the reflecting mirror. A stepping motor with an angle step of 0.038) is used for controlling the mirror angle. **Field of view:** Characterized by Prede **Stray light:** Subtracted as an offset component in DOAS analysis **Dark signal:** nightly measurements **Line shape:** An asymmetry Gaussian shape is determined during the wavelength calibration. **Polarization:** - **Detector nonlinearity:** characterized by Ocean Optics **Pixel-to-pixel variability**: nightly measurements	
Spectral analysis software	JM2 (Japanese MAXDOAS profile retrieval algorithm, version 2)	
Supporting measurements	none	
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ <500 W **Internet:** data volume: 15 MB**,** 2 IP addresses, SSH+ftp **Outdoor space requirements:** 0.6m x 0.2m x 1.5m (H); weight: 10 kg; space for 1-m high rack on which the outside unit is placed may be required too. **Indoor space requirements:** 0.5m x 0.5 m **Maximum distance between telescope and spectrometer:** 10 m **Local support:** no	

Institute: Department of Atmospheric Chemistry and Climate (AC2), Spanish National Research Council (CSIC), Madrid, Spain **Responsible person(s):** David García, Nuria Benavent, Shanshan Wang **Contact details:** dgarcia@iqfr.csic.es, mobile phone: +34 666467907		
Instrument type: MAXDOAS	**Nr:** CINDI-2.10	
Overall design of the instrument	**Optical head including telescope:** separated; elevation angles fully configurable **Spectrometer type:** Princeton Acton SP2500 **Detector type:** Pixis 2D CCD Camera, 1340x400 pixels **Optical fibers:** Multifiber UV-VIS, 10 m length **Temperature control of spectrometer and detector:** 20-25°C/20-25°C	
Instrument performance	**Spectral range/resolution:** 300–500/0.5 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** 1° **Typical integration time:** 0.01-1s **Typical scan duration:** 5 minutes	
Calibration/characterization procedures	**Elevation angles:** 45 ^{o} **Field of view:** lamp in telescope **Straylight:** - **Dark signal:** by using the shutter **Line shape:** Hg/Ne **Polarization:** - **Detector nonlinearity:** laboratory **Pixel-to-pixel variability**: laboratory	
Spectral analysis software	QDOAS	
Supporting measurements	Video camera	
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 550 W **Internet:** data volume: 500MB; 1 IP address; VNC + SFTP **Outdoor space requirements:** Telescope and tracker are inside a box of about 60*60*40 cm^3; <20-30kg **Indoor space requirements:** Working space of about 1.5 m (for the spectrometer, computer, filter wheel, temperature control…) **Maximum distance between telescope and spectrometer:** 10 m **Indoor facility:** air conditioning (steady temperature for the spectrometer) **Local support:** no extra people needed ?	

Institute: University of Colorado, Boulder, Colorado **Responsible person(s):** Rainer Volkamer, Henning Finkenzeller **Contact details:** Rainer.Volkamer@colorado.edu, Henning.Finkenzeller@colorado.edu	
Instrument type: 3D-MAXDOAS	**Nr:** CINDI-2.11
Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable; integrating sphere for direct sun measurements **Spectrometer type:** 2 x Acton SP2150 **Detector type:** 2 x PIXIS 400 back-illuminated CCD **Optical fibers:** Monofiber, diameter: 1.25mm, length: 25m connects to Y-type bundle, diameter: 0.145mm, length: 1m **Filters:** BG3/BG38, GG395 **Mirrors:** quartz prisms **Temperature control of spectrometer and detector:** 34°C/-30°C
Instrument performance	**Spectral range/resolution:** 327-470/0.7 & 432–678/1.2 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable **Field of view:** 0.7 degrees (full angle) **Typical integration time:** ~20s **Typical scan duration:** ~8min (12 EA & 12 Az)
Calibration/characterization procedures	**Elevation angles:** geometric alignment, solar aureole/horizon scan **Field of view:** laser pointer backwards **Straylight:** dark areas on CCD **Dark signal:** characterized at night, and by dark areas on CCD **Line shape:** Hg/Kr lamps (external) & QDOAS for wavelength dependency **Polarization:** - **Detector nonlinearity:** Fraunhofer OD at different saturation levels of CCD **Pixel-to-pixel variability**: monitored
Spectral analysis software	QDOAS
Supporting measurements	Webcam, Hg & Kr lamp
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 380 W average / 785 W peak **Internet:** data volume: 1 GB, 2 IP addresses, remote desktop + SSH **Outdoor space requirements:** railing mount, 1.5 x 1.5 m^2 (access & rotat.); 15kg **Indoor space requirements:** 1 standard rack: 1.1 x 0.9 x 1.2 m^3 (L x W x H) **Maximum distance between telescope and spectrometer:** 12 m **Indoor facility:** air conditioned, ethernet plug accessible

Institute: University of Colorado, Boulder, Colorado **Responsible person(s):** Rainer Volkamer **Contact details:** Rainer.Volkamer@colorado.edu		
Instrument type: ZS & MAXDOAS (1D)	**Nr:** CINDI-2.12	
Overall design of the instrument	**Optical head including telescope:** rotating prism, elevation angles fully configurable horizon-to-horizon across zenith **Spectrometer type:** Acton SP2356i & QE65000 **Detector type:** PIXIS 400 back-illuminated CCD & Sony CCD **Optical fibers:** Monofiber, diameter: 1.5mm, length: 10m connects to Y-type bundle, diameter: 0.145mm, length: 1m **Filters:** BG3/BG38 **Mirrors:** quartz prism **Temperature control of spectrometer/detector:** 34°C/-30°C	
Instrument performance	**Spectral range/resolution:** 300-466/0.8 & 379–493/0.5 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** 0.4 degrees (full angle) **Typical integration time:** ~30s **Typical scan duration:** ~8min	
Calibration/characterization procedures	**Elevation angles:** geometric alignment, horizon scan **Field of view:** laser pointer backwards **Straylight:** dark areas on CCD **Dark signal:** characterized at night, and by dark areas on CCD **Line shape:** Hg/Kr lamps (external) & QDOAS for wavelength dependency **Polarization:** - **Detector nonlinearity:** Fraunhofer line distortion at different sat levels **Pixel-to-pixel variability**: monitored	
Spectral analysis software	QDOAS	
Supporting measurements	Webcam, Hg & Kr lamp	
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 400 W average / 800 W peak **Internet:** data volume: 1 GB, 2 IP addresses, remote desktop + SSH **Outdoor space requirements:** railing mount, 1.5 x 1.5 m^2; 15kg **Indoor space requirements:** shares indoor rack (with #13 2D-MAXDOAS); 120kg **Maximum distance between telescope and spectrometer:** 10m **Indoor facility:** air conditioned, ethernet plug accessible	

Institute 1: Institut fuer Methodik der Fernerkundung (IMF), Deutsches Zentrum fuer Luft- und Raumfahrt e.V. (DLR), Wessling, Germany **Institute 2:** School of Earth and Space Sciences, University of Science and Technology of China (USTC), Hefei, Anhui, China **Responsible person(s):** Nan Hao (DLR) and Cheng Liu (USTC) **Contact details:** nan.hao@dlr.de, Chliu81@ustc.edu.cn		
Instrument type: 1D MAXDOAS EnviMeS (#1)	**Nr:** CINDI-2.13/2.14	
Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type UV and Vis:** Avantes AvaBench-75 **Detector type UV:** Backthinned Hamamatsu CCD (2048 pixel) **Detector type vis:** Backthinned Hamamatsu CCD (2048 pixel) **Optical fibers:** Multifibre (UV), single fibre (VIS), length: 10m **Filters:** UV bandpass filters (BG3) **Mirrors:** none (rotatable prism for elevation angle selection) **Temperature control of spectrometer and detector UV:** 20°C/20°C **Temperature control of spectrometer and detector vis:** 20°C/20°C	
Instrument performance	**Spectral range/resolution UV:** 296–460/0.56 nm **Spectral range/resolution vis:** 440–583/0.54 nm **Azimuthal scan/direct-sun capabilities:** yes/no **Elevation angle capability:** fully configurable; step: 0.1° or less **Field of view:** <0.5° **Typical integration time:** 2.5ms -60s **Typical scan duration:** 5 minutes	
Calibration/characterization procedures	**Elevation angles:** Point-like light source and laser level **Field of view:** Point-like light source and laser level **Straylight:** Optical filters **Dark signal:** Measurement during the night **Line shape:** Atomic emission lines (Hg/Ne) **Polarization:** n/a (depolarizing fibre) **Detector nonlinearity:** Measurement of artificial light source with varying integration times **Pixel-to-pixel variability**: Halogen lamp	
Spectral analysis software	DOASIS	
Supporting measurements	Webcam, tilt sensor, GPS	
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/20-120 W on average **Internet:** data volume: 10 GB, VNC, 2 IP addresses **Outdoor space requirements:** about 50 cm x 50 space, preferably mounted on a metal frame **Indoor space requirements:** 1 m^2 tablespace **Maximum distance between telescope and instruments:** 10 m **Indoor facility:** PC and spectrometer	

Institute: Meteorological Observatory, Hohenpeissenberg, Germany **Responsible person(s):** Robert Holla **Contact details:** robert.holla@dwd.de, mobile phone: +4917656219264		
Instrument type: MAXDOAS EUSAAR-Type	**Nr:** CINDI-2.15	

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type UV:** OMT ctf-60 Spec-1275 **Spectrometer type vis:** OMT ctf-60 Spec-1310 **Detector type UV:** Backthinned Hamamatsu CCD (1024 pixel) **Detector type vis:** Backthinned Hamamatsu CCD (2048 pixel) **Optical fibers:** Multifibre (UV),Multifibre (VIS), length: 10 m **Filters:** UV bandpass filters (BG3+BG40), UV-Spec only **Mirrors:** spherical object mirror **Temperature control of spectrometer and detector UV:** 20°C/-7°C **Temperature control of spectrometer and detector vis:** 20°C/-7°C
Instrument performance	**Spectral range/resolution UV:** 307–436/0.6 nm **Spectral range/resolution vis:** 415–637/0.7 nm **Azimuthal scan/direct-sun capabilities:** yes/no **Elevation angle capability:** fully configurable; step: 0.1° or less **Field of view:** <1° **Typical integration time:** 3 min per elevation **Typical scan duration:** 20 min
Calibration/characterization procedures	**Elevation angles:** Udo Friess method (laser level, narrow mercury lamp)+ scanning horizon **Field of view:** Udo Friess method (laser level, narrow mercury lamp) **Straylight:** not yet characterized **Dark signal:** determined during night, telescope facing down **Line shape:** N/A **Polarization:** N/A **Detector nonlinearity:** Laboratory measurement using halogen lamp **Pixel-to-pixel variability**: N/A
Spectral analysis software	Windoas, DOASIS
Supporting measurements	Webcam
Special needs/requests regarding logistics	**Power supply/consumption:** 150 W Instrument, ~300 W measurement PC **Internet:** data volume: 50 MB, 1 IP address, remote desktop **Outdoor space requirements:** 0.5x0.5x1.2 m³ (length x width x height) **Indoor space requirements:** 0.6x0.6x0.5 m³ (length x width x height) **Maximum distance between telescope and instruments:** 10 m **Indoor facility:** air conditioning

Institute: Indian Institute of Science Education and Research Mohali Department of Earth and Environmental Sciences, Indian Institute of Science Education and Research Mohali, Punjab, India **Responsible person(s):** Abhishek Kumar Mishra and Vinod Kumar **Contact details:** abhishekkumar.mishra21@gmail.com, vinodmagic@hotmail.com		
Instrument type: mini-MAX DOAS Hoffmann UV (#2)	**Nr:** CINDI-2.16	
Overall design of the instrument	**Optical head including telescope:** integrated **Spectrometer type UV:** Ocean Optics usb 2000+ **Spectrometer type :** CCD (2048 pixels) **Filters:** no **Mirrors: -** **Temperature control of spectrometer and detector :** n/a	
Instrument performance	**Spectral range/resolution :** 316–466/1 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable; step: 0.1° or less **Field of view:** 0.7° **Typical integration time:** 60ms **Typical scan duration:** ~5 minutes for one full elevation sequence	
Calibration/characterization procedures	**Elevation angles:** - **Field of view:** - **Straylight:** - **Dark signal:** - **Line shape:** - **Polarization:** - **Detector nonlinearity:** - **Pixel-to-pixel variability**: -	
Spectral analysis software	WinDOAS and DOASIS	
Supporting measurements	None	
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/<100 W on average **Internet:** 2 IP addresses (500 MB/IP), remote desktop and ftp, **Outdoor space requirements:** 30cm(L)*20cm(W)*20cm(H); 3 kg **Indoor space requirements:** - **Maximum distance between telescope and instruments:** 10 m **Indoor facility:** Three power sockets, bench for placing laptops, battery and battery charger **Local support:** no extra people needed	

Institute: National Institute of Aerospatial Technology (INTA), Madrid, Spain **Responsible person(s):** Olga Puentedura Rodriguez **Contact details:** puentero@inta.es		
Instrument type: 2D-MAXDOAS RASAS III	**Nr:** CINDI-2.17	

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** Andor Shamrock SR-163i **Detector type:** IDUS Andor **Optical fibers:** Bundle 100 µm, length: 8 m **Filters:** No **Mirrors:** No **Temperature control of spectrometer/detector:** 17°C/-30ºC
Instrument performance	**Spectral range/resolution:** 325-445 or 400-550/0.55 nm **Azimuthal scan/direct-sun capabilities:** yes/no **Elevation angle capability:** fully configurable **Field of view:** 1° **Typical integration time:** ~1 minute/pointing direction **Typical scan duration:** ~1 minute x number of pointing directions
Calibration/characterization procedures	**Elevation angles:** inclinometer during operation **Field of view:** Geometrical **Straylight:** HgCd lamp **Dark signal:** measured at constant temperature and subtracted during analysis **Line shape:** HgCd lamp **Polarization:** Optical fiber depolarizes the signal **Detector nonlinearity:** HgCd lamp **Pixel-to-pixel variability**: HgCd lamp
Spectral analysis software	LANA software
Supporting measurements	Video camera, inclinometer, and GPS
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 2350 W; peak at 3450 W **Internet:** data volume: 20MB, VNC, SSH, and FTP, 4 IP addresses **Outdoor space requirements**: 1.5x1.5x1.2 m^3, 20kg **Indoor space requirements:** 2x1m. 80kg. Room temperature lower than 25ºC. **Maximum distance between telescope and spectrometer:** <8 m **Indoor facility:** air conditioning + a room for the air zero generator which uses a compressor that makes some noise. **Local support:** one people for installing the instrument

Institute: Institute for Environmental Physics (IUP), University of Bremen, Bremen, Germany **Responsible person(s):** Andreas Richter **Contact details:** richter@iup.physik.uni-bremen.de, mobile phone: +49 160 911 345 33	
Instrument type: 2 channel scientific grade elevation and azimuth scanning MAXDOAS	**Nr:** CINDI-2.18

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type UV:** Acton ARC500 **Spectrometer type vis:** Acton ARC500 **Detector type UV:** Princeton NTE/CCD-1340/400-EMB **Detector type vis:** Princeton NTE/CCD-1340/400-EMB **Optical fibers:** Y-type quartz bundle, diameter: 150µm, length: 22m **Filters:** UG5 (UV only) **Mirrors:** no **Temperature control of spectrometer and detector UV:** 35°C/-35°C **Temperature control of spectrometer and detector vis:** 35°C/-30°C
Instrument performance	**Spectral range/resolution UV:** 305–390/0.5 nm **Spectral range/resolution vis:** 406–579/0.85 nm **Azimuthal scan/direct-sun capabilities:** yes/no **Elevation angle capability:** fully configurable **Field of view:** 1° **Typical integration time:** 60s; 120s for zenith **Typical scan duration:** 15 minutes for 11 elevation angles
Calibration/characterization procedures	**Elevation angles:** geometric alignment of telescope, horizon scan **Field of view:** white light source in lab **Straylight:** not yet characterized **Dark signal:** nightly measurements **Line shape:** HgCd lamp in telescope **Polarization:** - **Detector nonlinearity:** white light source in lab, characterization only **Pixel-to-pixel variability**: white light source in lab, characterization only
Spectral analysis software	NLIN
Supporting measurements	Video camera, HgCd lamp
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 500 W on average; 1000 W peak **Internet*:** data volume: 200 MB, 10 IP addresses, remote desktop + ftp, **Outdoor space requirements:** 1.5 x 1.5 m^2 for telescope tripod **Indoor space requirements:** 2.5 x 1 m^2 desk, 150kg, no more than 25°C **Maximum distance between telescope and instruments:** 10 m

Institute: Institute of Environmental Physics, University of Heidelberg, Heidelberg, Germany **Responsible person(s):** Udo Friess **Contact details:** udo.friess@iup.uni-heidelberg.de, Mobile phone: +49-151-22278453	
Instrument type: 2D MAXDOAS EnviMeS (#3)	**Nr:** CINDI-2.19

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type UV and Vis:** Avantes AvaBench-75 **Detector type UV:** Backthinned Hamamatsu CCD (2048 pixel) **Detector type vis:** Backthinned Hamamatsu CCD (2048 pixel) **Optical fibers:** Multifibre (UV), single fibre (VIS), length: 10m **Filters:** UV bandpass filters (BG3) **Mirrors:** none (rotatable prism for elevation angle selection) **Temperature control of spectrometer and detector UV:** 20°C/20°C **Temperature control of spectrometer and detector vis:** 20°C/20°C
Instrument performance	**Spectral range/resolution UV:** 296–460/0.56 nm **Spectral range/resolution vis:** 440–583/0.54 nm **Azimuthal scan/direct-sun capabilities:** yes/no **Elevation angle capability:** fully configurable; step: 0.1° or less **Field of view:** <0.5° **Typical integration time:** 2.5ms -60s **Typical scan duration:** 5 minutes
Calibration/characterization procedures	**Elevation angles:** Point-like light source and laser level **Field of view:** Point-like light source and laser level **Straylight:** Optical filters **Dark signal:** Measurement during the night **Line shape:** Atomic emission lines (Hg/Ne) **Polarization:** n/a (depolarizing fibre) **Detector nonlinearity:** Measurement of artificial light source with varying integration times **Pixel-to-pixel variability**: Halogen lamp
Spectral analysis software	DOASIS
Supporting measurements	Webcam, tilt sensor, GPS
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/20-120 W on average **Internet:** yes **Outdoor space requirements:** about 50 cm x 50 space, preferably mounted on a metal frame **Indoor space requirements:** 1 m^2 tablespace **Maximum distance between telescope and instruments:** 10 m **Indoor facility:** PC and spectrometer

Institute: Institute of Environmental Physics, University of Heidelberg, Heidelberg, Germany **Responsible person(s):** Udo Friess **Contact details:** udo.friess@iup.uni-heidelberg.de, Mobile phone: +49-151-22278453		
Instrument type: Compact MAXDOAS	**Nr:** CINDI-2.20	
Overall design of the instrument	**Optical head including telescope:** integrated; elevation fully configurable **Spectrometer/detector type UV:** Hamamatsu TM (2048 pixels) **Spectrometer/detector type vis:** Sony TM 2048L **Optical fibers:** n/a (compact system) **Filters:** Schott TM BG3 (UV) **Mirrors:** none (rotatable prism for elevation angle selection) **Temperature control of spectrometer and detector UV:** 10-20°C **Temperature control of spectrometer and detector vis:** 10-20°C	
Instrument performance	**Spectral range/resolution UV:** 295–430/0.53 nm **Spectral range/resolution vis:** 430–565/0.74 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** 0.27° (UV) and 0.32° (vis) **Typical integration time:** 1 minute **Typical scan duration:** 5 minutes	
Calibration/characterization procedures	**Elevation angles:** Point-like light source and laser level **Field of view:** Point-like light source and laser level **Straylight:** Optical filters **Dark signal:** Measurement during the night **Line shape:** Atomic emission lines (Hg/Ne) **Polarization:** n/a (depolarizing fibre) **Detector nonlinearity:** Measurement of artificial light source with varying integration times **Pixel-to-pixel variability**: Halogen lamp	
Spectral analysis software	Windoas	
Supporting measurements	Inclinometer	
Special needs/requests regarding logistics	**Power supply/consumption:** 12 V/30 W **Internet:** data volume: 50 MB, 10 IP addresses for all Heidelberg instruments, VNC and remote desktop **Outdoor space requirements:** will be mounted on the railing of the tower **Indoor space requirements:** none (only small power supply) **Maximum distance between telescope and spectrometers:** n/a **Indoor facility:** power supply	

Institute: Royal Netherlands Meteorological Institute (KNMI), De Bilt, The Netherlands **Responsible person(s):** Ankie Piters **Contact details:** ankie.piters@knmi.nl, mobile phone: +31-30-2206433		
Instrument type: mini-DOAS Hoffmann UV (#3)	**Nr:** CINDI-2.21	
Overall design of the instrument	**Optical head including telescope:** integrated **Spectrometer type:** Ocean Optics usb 2000 **Detector type:** Sony ILX511 CCD (2048 pixels) **Optical fibers:** n/a	
Instrument performance	**Spectral range/resolution:** 290-443/0.6 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** 0.45° **Typical integration time:** 1-2 minutes **Typical scan duration:** 15-30 minutes	
Calibration/characterization procedures	**Elevation angles:** calibration of horizon (+/-0.5 degree) via quick horizon-scan (-3 to +3, very short integration time) **Field of view:** scanning over a light source in the laboratory **Straylight**: not yet characterized **Dark signal:** characterized in the dark room as a function of detector temperature **Line shape:** determined from lamp lines (function of temperature and wavelength) **Polarization:** not yet characterized **Detector nonlinearity:** not yet characterized **Pixel-to-pixel variability**: characterized in the dark room as a function of detector temperature	
Spectral analysis software	Own software (Python-based)	
Supporting measurements	none	
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 5-50 W **Internet:** yes **Outdoor space requirements:** already mounted at 20m platform of Cabauw tower **Indoor space requirements:** no **Maximum distance between telescope and instruments:** n/a **Indoor facility:** table to put laptop on (or, when on tower: n/a)	

Institute: Royal Netherlands Meteorological Institute (KNMI), De Bilt, The Netherlands **Responsible person(s):** Ankie Piters **Contact details:** ankie.piters@knmi.nl, mobile phone: +31-30-2206433	
Instrument type: mini-DOAS Hoffmann VIS (#3)	**Nr:** CINDI-2.22

Overall design of the instrument	**Optical head including telescope:** integrated **Spectrometer type:** Ocean Optics usb 2000+ **Detector type:** Sony ILX511 CCD (2048 pixels)
Instrument performance	**Spectral range/resolution:** 400-600/0.5 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** 0.4° **Typical integration time:** 1-2 minutes **Typical scan duration:** 15-30 minutes
Calibration/characterization procedures	**Elevation angles:** calibration of horizon (+/-0.5 degree) via quick horizon-scan (-3 to +3, very short integration time) **Field of view:** scanning over a light source in the laboratory **Straylight**: not yet characterized **Dark signal:** characterized in the dark room as a function of detector temperature **Line shape:** determined from lamp lines (function of temperature and wavelength) **Polarization:** not yet characterized **Detector nonlinearity:** not yet characterized **Pixel-to-pixel variability**: characterized in the dark room as a function of detector temperature
Spectral analysis software	Own software (Python-based)
Supporting measurements	none
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 5 W **Internet:** yes **Outdoor space requirements:** 30x30x30cm (can be mounted on tripod or a horizontal bar, e.g. next to other KNMI MAXDOAS on tower); 10kg **Indoor space requirements:** 50x50x50cm (laptop) **Maximum distance between telescope and instruments:** n/a **Indoor facility:** table to put laptop on (or, when on tower: n/a)

Institute: Royal Netherlands Meteorological Institute (KNMI), De Bilt, The Netherlands **Responsible person(s):** Ankie Piters **Contact details:** ankie.piters@knmi.nl, mobile phone: +31-302206433	
Instrument type: PANDORA (#1)	**Nr:** CINDI-2.23
Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** AvaSpec-ULS2048x64 **Detector type :** 2046 x 64 pixel backthinned non-cooled Hamamatsu CCD **Optical fibers:** single strand 400um core diameter high OH fused silica fiber, 10m long **Filters:** spectral filters (U340 and BP300 to remove visible light) **Mirrors:** no **Temperature control of spectrometer and detector:** 20°C/20°C
Instrument performance	**Spectral range/resolution UV:** 290-530/0.6 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable **Field of view:** circular, 1.5° (sky mode); 2.0° (sun mode) **Typical integration time:** 2.4ms-300ms (sun), 20ms to 1000ms (sky) **Typical scan duration:** 20-40s per pointing position
Calibration/characterization procedures	**Elevation angles:** based on astronomical calculations and 'sun searches' **Field of view:** determined in the laboratory **Stray light:** not determined **Dark signal:** determined in laboratory **Line shape:** determined in the laboratory with a mercury lamp **Polarization:** no residual polarization measured after 10m fiber **Detector nonlinearity:** determined in laboratory **Pixel-to-pixel variability**: determined in laboratory
Spectral analysis software	Own software (Python-based) and participating in PANDONIA
Supporting measurements	none
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 125 W **Internet*:** data volume: 40 MB, 3 IP addresses, rdp and ftp **Outdoor space requirements:** 1x1x1.5m^3 **Indoor space requirements:** 100x100x100cm (box) **Maximum distance between telescope and instruments:** 10 m

***In total for KNMI MAXDOAS instruments**

Institute: Laboratoire Atmosphère, Milieux, Observations Spatiales (LATMOS), Guyancourt, France **Responsible person(s):** Andrea Pazmino **Contact details:** andrea.pazmino@latmos.ipsl.fr, Manuel.pinharanda@latmos.ipsl.fr, +33 (0)6 64 13 86 43	
Instrument type: Système d'Analyse par Observations Zénithales (SAOZ)	**Nr:** CINDI-2.24

Overall design of the instrument	**Optical head including telescope:** n/a **Spectrometer type:** Jobin-Yvon CP200 flat field **Detector type:** 1024 NMOS diode array from Hamamatsu **Optical fibers:** n/a **Filters:** no **Mirrors:** Yes **Temperature control of spectrometer and detector:** n/a
Instrument performance	**Spectral range/resolution:** 270–640/1.3 nm **Azimuthal scan/direct-sun capabilities:** n/a **Elevation angle capability:** n/a **Field of view:** 10° **Exposure time:** 0.19 s - 5 x measurement cycle (adjusted automatically) **Measurement cycle:** 60 s (programmable)
Calibration/characterization procedures	**Elevation angles:** n/a **Field of view:** n/a **Straylight:** n/a **Dark signal:** shutter **Line shape:** wavelength calibration based on reference spectrum **Polarization:** Est-West fixed direction of the entrance slit **Detector nonlinearity:** exposure time calibrated to 12000 counts in elementary spectrum **Pixel-to-pixel variability**: dark background
Spectral analysis software	SAM version 5.9
Supporting measurements	GPS
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 500 W **Internet:** data volume: 5 MB, 2 IP addresses, ftp + remote desktop (TeamViewer10) **Outdoor space requirements:** 0.7 x 0.4 m^2; 30 kg **Indoor space requirements:** interface box + computer; cable length between interface box and computer < 2 m **Maximum distance between SAOZ and interface box:** 20 m **Indoor facility:** - **Local support:** one extra people

Institute: Laboratoire Atmosphère, Milieux, Observations Spatiales (LATMOS), Guyancourt, France **Responsible person(s):** Andrea Pazmino **Contact details:** andrea.pazmino@latmos.ipsl.fr, Manuel.pinharanda@latmos.ipsl.fr, +33 (0)6 64 13 86 43	
Instrument type: Mini Système d'Analyse par Observations Zénithales (mini-SAOZ)	**Nr:** CINDI-2.25

Overall design of the instrument	**Optical head:** separated **Spectrometer type:** Cerny-Turner, grating 600 grooves/mm **Detector type:** 2048x16 CCD back-thinned from Hamamatsu **Optical fibers:** HGC950; diameter: 950 µm; length:10 m **Temperature control of spectrometer and detector:** n/a
Instrument performance	**Spectral range/resolution:** 270–820/0.7 nm **Azimuthal scan/direct-sun capabilities:** n/a **Elevation angle capability:** n/a **Field of view:** 8° **Exposure time:** 0.037 s - 5 x measurement cycle (adjusted automatically) **Measurement cycle:** 60 s (programmable)
Calibration/characterization procedures	**Elevation angles:** n/a **Field of view:** n/a **Straylight:** n/a **Dark signal:** shutter **Line shape:** wavelength calibration based on reference spectrum **Polarization:** n/a **Detector nonlinearity:** exposure time calibrated to 12000 counts in elementary spectrum **Pixel-to-pixel variability**: dark background
Spectral analysis software	SAOZ.gui Version 1.25-50f870
Supporting measurements	GPS
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 300 W **Internet:** data volume: 5 MB, 2 IP addresses, ftp + remote desktop (TeamViewer10) **Outdoor space requirements:** 0.4 m x 0.25 m x 0.15 m; 5kg; support for optical header; optical header placed horizontally **Indoor space requirements:** interface box + computer; cable length between interface box and computer < 2 m **Maximum distance between mini-SAOZ and optical header:** <10 m; GPS antenna cable <5 m **Indoor facility:** Air conditioned room (18°- 20° C) **Local support:** one extra people

Institute: LuftBlick, Mutters, Austria **Responsible person(s):** Alexander Cede **Contact details:** alexander.cede@luftblick.at, mobile phone: +43 681 84448717		
Instrument type: PANDORA-2S (#2)	**Nr:** CINDI-2.26/2.27	
Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** AvaSpec-ULS2048x64 (one for UV and one for vis) **Detector type :** 2046 x 64 pixel backthinned non-cooled Hamamatsu CCD (one for UV and one for vis) **Optical fibers:** single strand 400um core diameter high OH fused silica fiber, 10m long **Filters:** spectral filters (U340 and BP300 to remove visible light) **Mirrors:** no **Temperature control of spectrometer and detector UV:** 20°C/20°C **Temperature control of spectrometer and detector vis:** 20°C/20°C	
Instrument performance	**Spectral range/resolution UV:** 280-540/0.6 nm **Spectral range/resolution vis:** 400–900/1.1 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable **Field of view:** circular, 1.5° (sky mode); 2.8° (sun mode) **Typical integration time:** 2.4ms-300ms (sun), 20ms to 1000ms (sky) **Typical scan duration:** 20-40s per pointing position	
Calibration/characterization procedures	**Elevation angles:** based on astronomical calculations and 'sun searches' **Field of view:** 1.5deg FWHM (sky view), 2.8deg FWHM (sun view) **Stray light:** Correction **Dark signal:** Correction **Line shape:** Modified Guassian **Polarization:** no residual polarization measured after 10m fiber **Detector nonlinearity:** Correction **Pixel-to-pixel variability**: Corrected	
Spectral analysis software	Blick Software Suite (Python-based)	
Supporting measurements	None	
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 220 W **Internet:** data volume: 2x70 MB, 2 IP addresses, SSH (putty SCP) **Outdoor space requirements:** 1mx1mx1.5m; 9kg **Indoor space requirements:** Box L 70cm, W 55cm, H 40cm; 30 kg **Maximum distance between telescope and instruments:** 8m **Local support:** to check on the instrument or clean the entrance window from time to time (PI not present during the whole campaign)	

Institute: Max-Planck Institute for Chemistry (MPIC), Mainz, Germany **Responsible person(s):** Thomas Wagner, Sebastian Donner **Contact details:** thomas.wagner@mpic.de (mobile phone: +491629228450) Sebastian.donnner@mpic.de		
Instrument type: TubeMAXDOAS	**Nr:** CINDI-2.28	
Overall design of the instrument	**Optical head including telescope:** separated; elevation angles fully configurable **Spectrometer type:** Avantes **Detector type:** CCD **Optical fibers:** quartz fibre bundle, length: 5 m **Filters:** BG3 (UV) **Mirrors:** no **Temperature control of spectrometer and detector:** 10°C/10°C	
Instrument performance	**Spectral range/resolution:** 316–474/0.6 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** 1° **Typical integration time:** 30s **Typical scan duration:** 30 minutes	
Calibration/characterization procedures	**Elevation angles:** performed at the campaign using laser device or water level **Field of view:** performed at the campaign using laser device or water level **Straylight:** has to be quantified **Dark signal:** will be measured on site **Line shape:** almost symmetric Gaussian-like, almost not dependent on wavelength **Polarization:** - **Detector nonlinearity:** characterised in the laboratory **Pixel-to-pixel variability**: -	
Spectral analysis software	Windoas	
Supporting measurements	Video camera	
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 100 W **Internet:** Data volume: 150 MB**,** 1 IP address, remote desktop via VPN **Outdoor space requirements:** 25x25x35 cm^3, weight: 3kg **Indoor space requirements:** 2.5 x 1 m^2 desk **Maximum distance between telescope and spectrometer:** 4 m **Indoor facility:** air conditioning (<25°C) **Local support:** not needed	

Institute: National Institute of Water and Atmospheric Research (NIWA), Lauder, New Zealand **Responsible person(s):** Richard Querel, Paul Johnston **Contact details:** richard.querel@niwa.co.nz; +64 21 0722540		
Instrument type: EnviMeS 1D MAXDOAS (#3)	**Nr:** CINDI-2.29	
Overall design of the instrument	**Optical head including telescope:** elevation angle configurable **Spectrometer type UV:** Avantes AvaBench-75 **Spectrometer type vis:** Avantes AvaBench-75 **Detector type UV:** Backthinned Hamamatsu CCD (2048 x 64 pixels) **Detector type vis:** Backthinned Hamamatsu CCD (2048 x 64 pixels) **Optical fibers:** Multifibre (6 x UV), single fibre (1 x VIS), length: 10m **Filters:** UV bandpass filter (BG3), VIS bandpass filter (BG40) **Mirrors:** Rotating glass quartz prism as entrance optic **Temperature control of spectrometer and detector UV:** 20 °C / 20 °C **Temperature control of spectrometer and detector vis:** 20 °C / 20 °C	
Instrument performance	**Spectral range/resolution UV:** 305–457 nm / 0.7 nm **Spectral range/resolution vis:** 410–550 nm / 0.7 nm **Azimuthal scan/direct-sun capabilities:** no **Elevation angle capability:** fully configurable; step: 0.1° or less **Field of view:** <0.5° **Typical integration time:** 2.5ms -60s **Typical scan duration:** 60 s	
Calibration/characterization procedures	**Elevation angles:** Calibrated tilt meter and level **Field of view:** ? **Straylight:** <1e-3 ? **Dark signal:** shutter blocks light path in scanning head **Line shape:** taken from Hg lamp spectra **Polarization:** 10 m fibre effectively depolarizes incoming light **Detector nonlinearity:** observations of a temperature stabilized LED with several different exposure times, assuming LED to be constant intensity. **Pixel-to-pixel variability**: Not tested	
Spectral analysis software	DOASIS, STRATO	
Supporting measurements	Tilt sensor (for elevation angle), PTU	
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/120 W on average **Internet:** 1 IP address, VNC and remote desktop, data volume: 25 MB **Outdoor space requirements:** 36 x 13 x 20 cm³ (width x depth x height); weight: 2 kg **Indoor space requirements:** 40 x 30 x 13 cm³ (width x depth x height) **Maximum distance between telescope and instruments:** 10 m **Indoor facility:** air conditioning (< 28 C)	

Institute: National Institute of Water and Atmospheric Research (NIWA), Lauder, New Zealand **Responsible person(s):** Richard Querel, Paul Johnston **Contact details:** richard.querel@niwa.co.nz; +64 21 0722540		 
Instrument type: Lauder Acton275 MAXDOAS	**Nr:** CINDI-2.30	
Overall design of the instrument	**Optical head including telescope:** elevation angle configurable **Spectrometer type UV/Vis:** Acton 275 with grating control **Detector type UV/Vis:** Backthinned Hamamatsu CCD (1044 x 128pixels x 24um) **Optical fibers:** Multifibre with 100um fibres, input end circular 1mm diam, length: 12m **Filters:** **Mirrors:** Front silvered rotating mirror and quartz lens optic. **Temperature control of detector:** -20 °C	
Instrument performance	**Spectral range/resolution: multi band configurable; typical two bands are: alternating** 290–363 nm and 400-460; 0.6 nm **Azimuthal scan/direct-sun capabilities:** no **Elevation angle capability:** fully configurable; step: < 0.1° **Field of view:** about 0.5° **Typical integration time:** 16ms -20s **Typical scan duration:** 60 s (but flexible)	
Calibration/characterization procedures	**Elevation angles:** Bubble level on mirror and external laser level **Field of view:** ? **Straylight:** <1e-2 ? **Dark signal:** night spectra or manual scan **Line shape:** taken from Hg and other line lamp spectra **Polarization:** 12 m fibre effectively depolarizes incoming light **Detector nonlinearity:** quantified by comparing observations of a clear sky with and without neutral density filter. **Pixel-to-pixel variability**: Measured with white lamp.	
Spectral analysis software	STRATO (Lauder, NIWA)	
Supporting measurements	GPS time, Camera possible.	
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/100 W on average **Internet:** 1 IP address, VNC and remote desktop, data volume: 25 MB **Outdoor space requirements:** 60x40cm flat surface; 35 cm high; weight: 15kg **Indoor space requirements:** 80 x 130 cm table (1m^2**)** **Maximum distance between telescope and instruments:** 10 m **Indoor facility:** air conditioning (< 28 C)	

Institute: NASA-Goddard (Greenbelt, Maryland) **Responsible person(s):** Jay Herman **Contact details:** jay.r.herman@nasa.gov, **mobile phone**: 443-994-3560 **On-Site Person**: Elena Spinei (elena.spinei@nasa.gov) **Mobile phone: +**509-432-4674		
Instrument type: PANDORA-1S (#3)	**Nr:** CINDI-2.31 CINDI-2.32	
Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** AvaSpec-ULS2048x64 (one for 285 – 530 nm) **Detector type :** 2046 x 64 pixel backthinned non-cooled Hamamatsu CCD **Optical fibers:** single strand 400um core diameter high OH fused silica fiber, 10m long **Filters:** spectral filters (U340 and BP300 to remove visible light) **Mirrors:** no **Temperature control of spectrometer and detector UV:** 20°C/20°C **Temperature control of spectrometer and detector vis:** 20°C/20°C	
Instrument performance	**Spectral range/resolution UV:** 280-540/0.6 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable **Field of view:** circular, 1.6° (sky mode); 2.8° (sun mode) **Typical integration time:** 2.4ms-300ms (sun), 20ms to 1000ms (sky) **Typical scan duration:** 20-40s per pointing position	
Calibration/characterization procedures	**Elevation angles:** based on astronomical calculations and 'sun searches' **Field of view:** 1.5^{O} FWHM (sky view), 2.8^{O} FWHM (sun view) **Stray light:** Correction **Dark signal:** Correction **Line shape:** Modified Guassian **Polarization:** no residual polarization measured after 10m fiber **Detector nonlinearity:** Correction **Pixel-to-pixel variability**: Corrected	
Spectral analysis software	**Blick Software Suite** (Python-based)	
Supporting measurements	**Laboratory Calibration and Field Calibration**	
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 220 W **Internet:** data volume: 100 MB/instrument (200 MB in total), 4 IP addresses, Logmein remote desktop + SSH **Outdoor space requirements:** circle of 70cm radius space; weight: 20 kg **Indoor space requirements:** 2 m^2 **Maximum distance between telescope and instruments:** 8m **Local support:** 2 people for 3 hours + one ladder; people to check on the instrument or clean the entrance window from time to time (PI not present during the whole campaign)	

Institute: National University of Sciences and Technology (NUST), Islamabad, Pakistan **Responsible person(s):** Muhammad Fahim Khokhar and Junaid Khayyam Butt **Contact details:** fahim.khokhar@iese.nust.edu.pk (mobile phone: +92-341-8422377), jkb2ravian@gmail.com (mobile phone: +92-310-4320293)	
Instrument type: Mini MAXDOAS	**Nr:** CINDI-2.33

Overall design of the instrument	**Optical head including telescope:** integrated **Spectrometer type:** Czerny-Turner spectrometer **Detector type:** 1 dimensional CCD (Sony ILX511, 2048 individual pixels) **Optical fibers:** n/a **Filters:** n/a **Mirrors:** n/a **Temperature control of spectrometer and detector:** n/a
Instrument performance	**Spectral range/resolution:** 320–465/0.7 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable; 1 degree resolution **Field of view:** ~1.2^{o} **Typical integration time:** 10-60s **Typical scan duration:** 20 minutes
Calibration/characterization procedures	**Elevation angles:** water/sprit level **Field of view:** n/a **Straylight:** n/a **Dark signal:** manual procedure **Line shape:** n/a **Polarization:** n/a **Detector nonlinearity:** n/a **Pixel-to-pixel variability**: n/a
Spectral analysis software	QDOAS (version:2.111) / WinDOAS
Supporting measurements	GPS but not integrated
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 200 W (4 sockets needed) **Internet:** 2 IP addresses, **Outdoor space requirements:** 1.5 x 1.5 m^2; 5kg **Indoor space requirements:** 2.5 x 1 m^2 desk **Maximum distance between telescope and instruments:** n/a **Laboratory facility:** no **Local support:** mounting Pipes/stands and accessories to fix the instrument

Institute: Delft University of Technology (TU-Delft), Delft, The Netherlands **Responsible person(s):** Tim Vlemmix **Contact details:** t.vlemmix@tudelft.nl, mobile phone: +31 6 167 900 98	
Instrument type: mini-DOAS Hoffmann uv/vis (#4)	**Nr:** CINDI-2.34
Overall design of the instrument	**Optical head including telescope:** integrated **Spectrometer type:** Ocean Optics usb 2000+ **Detector type:** Sony ILX511 CCD (2048 pixels) **Optical fibers:** n/a **Filters:** n/a **Mirrors:** n/a **Temperature control of spectrometer/detector:** n/a
Instrument performance	**Spectral range/resolution:** 300-515 / 0.67nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** 0.4° **Typical integration time:** 1-2 minutes **Typical scan duration:** 15-30 minutes
Calibration/characterization procedures	**Elevation angles:** calibration of horizon (+/-0.5 degree) via quick horizon-scan (-3 to +3, very short integration time) **Field of view: values taken from similar KNIM instrument:** scanning over a light source in the laboratory **Straylight**: not yet characterized **Dark signal:** characterized in the dark room as a function of detector temperature **Line shape:** TBD **Polarization:** not yet characterized **Detector nonlinearity:** characterized in the dark room as a function of detector temperature **Pixel-to-pixel variability**: characterized in the dark room as a function of detector temperature
Spectral analysis software	Own software (Matlab-based)
Supporting measurements	none
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/ 5 W **Internet:** data volume: <50 MB, 1 IP addresses + 2 more if WIFI not available, remote desktop **Outdoor space requirements:** 75x75x50cm (can be mounted on tripod or a horizontal bar, e.g. next to other KNMI MAXDOAS on tower); weight: 5kg **Indoor space requirements:** 50x50x50cm (laptop) **Maximum distance between telescope and instruments:** n/a **Indoor facility:** table to put laptop on (or, when on tower: n/a) **Local support:** no

Institute: Meteorologisches Institut, Ludwig-Maximilians-Universität München, Munich, Germany **Responsible person(s):** Mark Wenig **Contact details:** mark.wenig@physik.uni-muenchen.de, lok.chan@ physik.uni-muenchen.de, mobile phone: +49 089 2180 4386	
Instrument type: 2D MAXDOAS EnviMeS (#4)	**Nr:** CINDI-2.35

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type UV:** Avantes AvaBench-75 **Spectrometer type vis:** Avantes AvaBench-75 **Detector type UV:** Backthinned Hamamatsu CCD (2048 pixel) **Detector type vis:** Backthinned Hamamatsu CCD (2048 pixel) **Optical fibers:** Multifibre (UV), single fibre (VIS), length: 10m **Filters:** UV bandpass filters (BG3) **Mirrors:** N/A **Temperature control of spectrometer and detector UV:** 20°C/20°C **Temperature control of spectrometer and detector vis:** 20°C/20°C
Instrument performance	**Spectral range/resolution UV:** 305–460/0.56 nm **Spectral range/resolution vis:** 430–650/0.54 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable **Field of view:** <0.5° **Typical integration time:** 2.5ms -60s **Typical scan duration:** 15 min
Calibration/characterization procedures	**Elevation angles:** tilt sensor **Field of view:** not yet characterized **Straylight:** not yet characterized **Dark signal:** not yet characterized **Line shape:** not yet characterized **Polarization:** not yet characterized **Detector nonlinearity:** not yet characterized **Pixel-to-pixel variability**: not yet characterized
Spectral analysis software	DOASIS
Supporting measurements	Two video cameras, inclinometer
Special needs/requests regarding logistics	**Power supply/consumption:** 220 V/20-120 W on average **Internet:** data volume: 10 GB, 2 IP addresses, remote desktop, VNC, and SSH **Outdoor space requirements:** telescope 80cm(W)x80cm(L)x50cm(H) **Indoor space requirements:** spectrometer and controller 80cm(W)x50cm(L)x30cm(H) ~1mx2m desk space for the PC and work **Maximum distance between telescope and instruments:** 10 m **Indoor facility:** electricity, internet, air conditioning (<25°C) **Local support:** one extra people, ladder

Institute: Department of Physics, University of Toronto, Toronto, Canada **Responsible person(s):** Xiaoyi Zhao, Kristof Bognar, Kimberly Strong **Contact details:** xizhao@atmosp.physics.utoronto.ca, kbognar@physics.utoronto.ca, strong@atmosp.physics.utoronto.ca Kristof Bognar: 1-416-566-6763 (Toronto) or 06-30-494-8464 (preferred) Xiaoyi Zhao: 1-647-283-9629	 Note: This is a photo of the spectrometer and CCD detector. At Cabauw, it will be deployed outdoors in a box (details below).
Instrument type: PEARL-GBS instrument (MAXDOAS, ZSL-DOAS, and DS) — **Nr:** CINDI-2.36	
Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** Jobin Yvon Triax-180 grating spectrometern **Detector type:** back-illuminated cooled CCD with 2048 x 512 pixels **Optical fibers: fibre** bundle (37 HOH mapped fibres, spot-to-slit), spot end diameter: ~0.8 mm, length: 6 m **Filters:** Filter wheel containing one empty spot, 4 metallic neutral density filters (31.6%, 1%, 0.1%, 0.01% transmittance) and a UV diffuser **Mirrors:** UV-enhanced aluminum (suntracker) **Temperature control of spectrometer and detector:** 25°C/-70°C
Instrument performance	**Spectral range/resolution:** 300–550/0.4 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable **Field of view:** 0.6^{o} **Typical integration time:** 50-140s **Typical scan duration:** 12-23 minutes for 9 elevation angles
Calibration/characterization procedures	**Elevation angles:** calibrated by levelling the suntracker **Field of view:** calculated analytically **Straylight:** determined using a red filter and a halogen lamp **Dark signal:** determined from a series of closed shutter measurements **Line shape:** assumed to be Gaussian **Polarization:** determined using a polarizer and a halogen lamp; fiber bundle mostly depolarizes incoming light **Detector nonlinearity:** <0.4% as given by the CCD manufacturer **Pixel-to-pixel variability**: not characterized
Spectral analysis software	Raw data is processed using in-house MATLAB code and analysis is performed using the QDOAS software
Supporting measurements	Webcam
Special needs/requests regarding logistics	**Power supply/consumption:** 120 V/ 2200 W (10 sockets needed) **Internet:** no daily data transfer, 6 IP addresses, VNC and SSH **Outdoor space requirements:** spectrometer will be installed outdoors, inside a box of dimensions 1.1 x 0.9 x 1.2 m^3 (length x width x height), which should be located close (<10 m) to indoor space for laptop computers, weight: 120 kg **Indoor space requirements:** table space for 3 laptop computers **Maximum distance between telescope and spectrometer:** 0 m (suntracker is mounted on top of the box containing the spectrometer) **Local support:** no extra people needed, heavy duty cart would be useful