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

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1 Introduction

In 2009, about thirty in-situ and remote sensing instruments were intercompared as part of the Cabauw Intercomparison campaign for Nitrogen Dioxide measuring Instruments (CINDI) which took place at KNMI's Cabauw Experimental Site for Atmospheric Research (CESAR) in the Netherlands. The main objectives of this field experiment were to determine the accuracy of ground-based remote sensing measurement techniques for the detection of atmospheric nitrogen dioxide, and to investigate their usability in satellite data validation. As a result, a large dataset of NO_2, aerosols and other air pollution components were observed and documented in a number of peer-reviewed articles (Piters et al, 2012; Roscoe et al., 2010; Friess et al., 2016; Pinardi et al., 2013; Zieger et al., 2011; Irie et al., 2011), providing an assessment of the performance of ground-based remote sensing instruments for the measurement of NO_2 and aerosol vertical profiles and tropospheric/total columns. Recommendations were issued regarding the operation and calibration of such instruments, retrieval settings, and observation strategies for the use in ground-based networks for air quality monitoring and satellite data validation.

In the preparation of the Sentinel-5 Precursor validation, and seven years after the first CINDI campaign, a CINDI-2 campaign will be organized at the CESAR site between 25 August and 7 October 2016, with the target to intercompare an expanded new generation of ground-based remote-sensing and in-situ air quality instruments. The activity aims at characterising the differences between the measurement approaches and systems used within the overall DOAS community and to progress towards harmonisation of settings and methods for data acquisition and retrieval from similar but not identical systems of MAXDOAS type. Such an activity is essential to enable harmonised global validation of satellite missions focusing on air quality, such as the ESA Sentinel 4, 5 and 5P, and the future TEMPO and GEMS missions planned in the US and Korea respectively.

CINDI-2 is a broad international activity supported by ESA and by the Dutch National Agency NSO, with part in-kind support from KNMI. It builds on the experience gained during and after the first CINDI campaign as well as on several ongoing projects (e.g. ESA FRM_4DOAS) aiming to improve the exploitation of MAXDOAS network data for satellite validation. CINDI-2 is also organised under the auspices of the Network for the Detection of Atmospheric Composition Change (NDACC). A successful participation in such formal instrument intercomparison campaign ensures the NDACC certification of new instruments and associated teams.

The major science objectives of CINDI-2 can be summarised as follows:

Objective 1:
To assess the consistency of slant column measurements of several key target species (NO_2, O_3, O4 and HCHO) of relevance for the validation of S5P and the future ESA atmospheric Sentinels, through coordinated operation of a large number of DOAS and MAXDOAS instruments from all over the world.

This objective will be met by organizing a two-week semi-blind intercomparison exercises involving 34 MAXDOAS and 2 zenith-sky DOAS instruments. All participating groups will apply common data acquisition schemes (e.g. common pointing direction, same number and values of elevation angles, synchronised data acquisition) and spectral analysis settings. Both will be based on the experience gained during the previous CINDI-1 and MADCAT campaigns and on MAXDOAS harmonisation efforts carried out within the framework of the EC FP7 projects NORS and QA4ECV. Trace gas slant column densities will be collected and intercompared on a daily basis under the coordination of an independent campaign referee. The interpretation of the comparison results will benefit from additional observations and ancillary data collected during the campaign, in particular aerosol lidar, ceilometer, O_3 and NO_2 sondes, in-situ monitors, long-path DOAS as well as co-located satellite and air quality model data.

Objective 2

To study the relationship between remote-sensing column- and profile-measurements of NO_2, HCHO and O_3 and reference in-situ concentration measurements of the same species.

This objective will be addressed by comparing trace gas profiles derived from MAXDOAS slant column observations using various approaches (see e.g. Clémer et al., 2010; Friess et al., 2006; Ortega et al. (2015); Peters et al., 2012; Vlemmix et al., 2011; Wagner et al., 2011) to correlative profile measurements from sondes (NO_2, O_3), lidar (NO_2) and LP-DOAS system (NO_2, HCHO) as well as to near-surface concentrations from in-situ monitors operated in parallel at the CESAR site. The agreement between the different techniques will be assessed considering the known horizontal extent of the MAXDOAS observations, the characteristics of the emission sources around Cabauw and relevant meteorological parameters such as wind speed and direction. The established relationship between retrieved vertical profiles and surface concentration measurements will also be investigated in the context of the needs for satellite validation in support of air quality studies.

For tropospheric O_3, exploratory work on retrieval methodologies will be performed in order to better evaluate the information content of MAXDOAS as a new technique for routinely monitoring this species.

Objective 3

To investigate the horizontal representativeness of MAXDOAS measuring systems in view of their use for the validation of satellite tropospheric measurements featuring ground pixel sizes in the range of 25-50 km^2.

In order to meet this objective, 17 2D-MAXDOAS instruments with azimuthal scan capability will be operated during the campaign. O_4 measurements will be used to determine the azimuth-dependent horizontal extent of the MAXDOAS observations. In addition, the horizontal distribution of the trace gas column and concentrations will be assessed through comparison with mobile-DOAS and bicycle-based NO_2-sonde measurements regularly performed around Cabauw during the most intensive parts of the campaign. High resolution air quality model data will also be used in support of this study.

2 Description of the CESAR site

The Cabauw Experimental Site for Atmospheric Research (CESAR; 51.971°N, 4.927° E; 0.7m below sea level) is located in an extended and flat polder landscape in the direct proximity (<40 km) from the 4 largest cities of the Netherlands (see Figure 1).

Figure 1: Location of the Cabauw/CESAR site on a map of The Netherlands. Cabauw is a background site surrounded by 4 main Dutch cities: Utrecht, Amsterdam, The Hague and Rotterdam.

This site, which has been used for the CINDI-1 campaign (see Piters et al., 2012), is chosen because of its unobstructed view close to the horizon, its large day-to-day variability in tropospheric nitrogen dioxide and aerosols enabling the sampling of a wide range of pollution conditions, the absence of local pollution sources, the 213 m research tower as depicted in Figure 4, from which the planetary boundary layer can be sampled at various altitudes, and the excellent local support. Although being a rural site, with only a few pollution sources nearby, the wider vicinity of Cabauw is densely populated, with the city of Utrecht and a dense highway grid within 25 km, so that the site experiences recurring pollution events such as from the daily morning and afternoon rush hours.

In addition, Cabauw is influenced by the transport of air pollution from emission sources further away. The mean NO_2 surface concentration in the Netherlands, as estimated from land use models, are represented in Figure 2. Northerly winds generally carry relatively clean air from the sea, but winds from any other direction are likely to result in the sampling of polluted air. For winds from the west to south-west, Cabauw is downwind of Rotterdam (40 km), Europe's largest harbour and location of petrochemical plants, and of the UK. Inflow from the south to south-east carries pollution from the southern parts of the Netherlands, Belgium, and the industrialized and densely populated German Ruhr area (140 to 190 km).

For more information, visit the CESAR Observatory website: www.cesar-observatory.nl. The website includes an overview of active instrumentation:
http://www.cesar-observatory.nl/index.php?pageID=2000
and access to (near real time) quicklooks of data:
http://www.cesar-observatory.nl/index.php?pageID=9000.

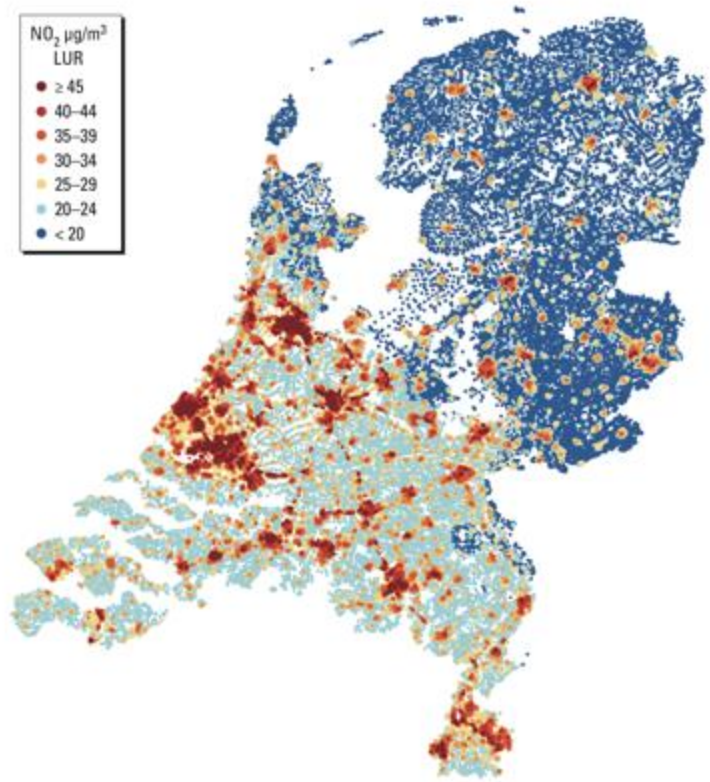

Figure 2: Distribution of the estimated mean NO_2 concentrations in the Netherlands for the year 2001, based on land use regression models (Fischer et al., 2015).

3 Participating Instruments

3.1 Static MAXDOAS and zenith-sky DOAS

Static MAXDOAS and zenith-sky DOAS (ZS-DOAS) systems will be intercompared as part of the semi-blind intercomparison exercise (see section 5.2.3). Table 1 presents an overview of the different systems which will all be installed on the Remote Sensing Site (RSS). The complete technical specifications of each instrument can be found in Appendix A of the present document.

Table 1: **List of MAXDOAS (1D and 2D) and ZS-DOAS spectrometers participating in the semi-blind intercomparison exercise. Columns denote: Institute, instrument type, instrument number, azimuthal scan/direct-sun capability, field of view, spectral range and resolution, coupling between telescope and spectrometer (F: multimode fibre, D: direct coupling), type of detector, detector temperature, power consumption. Instruments have been assigned a number for the campaign (third column).**

Institute	Instrument	Nr	Az./DS Cap.	FOV (°)	Spectral Range (nm)	Resol. (nm)	Light Coupl.	Det. type	T (°C)	Power (W)
AIOFM	2D-MAXDOAS	CINDI-2.01	y/n	0.2	290-380	0.35	F (10 m)	CCD	-30	300 (220 V)

AMOIAP/IAPh	2-port DOAS	CINDI-2.02	n/n	0.3	420-490	0.5	F	CCD	-40	1000
AUTH	PHAETHON	CINDI-2.03	y/y	1	297-452	0.34-0.42	F (10 m)	CCD	5	50 (100-240V)
BIRA-IASB	2D-MAXDOAS	CINDI-2.04	y/y	<1	300-400	0.6	F (10m)	CCD	-50	<1000 (220 V)
					400-560	1.0		CCD	-50	
BLS	Catadioptric telescope-MARSB	CINDI-2.05	n/n	0.2-1	300-500 (80 nm width)	0.4	D	CCD	-40	300 (220 V)
BOKU	2D-MAXDOAS	CINDI-2.06	y/n	1	Approx. 406-579	0.85	F (25 m)	CCD	-30	500-1000 (220 V)
CAMS	Mini-DOAS Hoffmann UV+Vis	CINDI-2.07	n/n	0.8	292-447	0.6-0.8	D	LinArr		200 (220 V)
		CINDI-2.08	n/n	0.8	399-712	0.6-0.8	D	LinArr		200 (220 V)
CHIBA-U	CHIBA-U/MAX-DOAS	CINDI-2.09	n/n	<1	310-515	0.4	F (10 m)	CCD	40	<500 (220 V)
CSIC	MAXDOAS	CINDI-2.10	n/n	1	300-500	0.5	F (10 m)	CCD	20-25	550 (220 V)
CU-Boulder	2D-MAXDOAS	CINDI-2.11	y/y	0.7	327-470	0.7	F (25 m)	CCD	-30	380-785 (220 V)
					432-678	1.2		CCD	-30	
	1D-MAXDOAS	CINDI-2.12	n/n	0.7	300-466	0.77	F (25 m)	CCD	-30	400-800 (220 V)
					379-493	0.5		CCD	0	
DLR+USTC	2D-EnviMeS (X2)	CINDI-2.13	y/n	0.4	300-460	0.6	F (10 m)	CCD	20	<120 (220 V)
		CINDI-2.14			450-600	0.6		CCD	20	
~~**DWD**~~	~~MAXDOAS~~	~~CINDI-2.15~~	~~y/n~~	~~<1~~	~~307-436~~	~~0.6/0.7~~	~~F~~	~~CCD~~	~~-7~~	~~450 (220 V)~~
IISER	Mini-DOAS Hoffmann UV	CINDI-2.16	n/n	0.7	317-466	1.0	D	CCD	<0 (if room t is ~20)	<100 (220V)
INTA	RASAS-III MAXDOAS	CINDI-2.17	y/n	1	325-445 or 400-550	0.55	F (8 m)	CCD	~17 if room t° is 22-23	2350-3450 (220 V)
IUP-Bremen	2D-MAXDOAS	CINDI-2.18	y/n	1	305-390	0.5	F (22m)	CCD	-35	500-1000 (220 V)
					406-579	0.85		CCD	-30	
IUP-Heidelberg	2D-EnviMeS	CINDI-2.19	y/y	<0.5	296-459	0.6	F (10 m)	CCD	0-40	20-120 (220 V)
					439-583	0.5		CCD	0-40	
	~~1D compact MAXDOAS~~	~~CINDI-2.20~~	~~n/n~~	~~0.3~~	~~295-450~~	~~0.53~~	~~D~~	~~CCD~~	~~10-20~~	~~30 (12 V)~~
					~~430-565~~	~~0.74~~		~~CCD~~	~~10-20~~	
KNMI	Mini-DOAS Hoffmann	CINDI-2.21	n/n	0.45	290-433	0.6	n/a	LinArr		5 (220 V)

	UV+Vis	CESAR-2.22	n/n	0.4	400-600	0.5	n/a	LinArr		5 (220 V)
	PANDORA	CINDI-2.23	y/y	1.5-2	290-530	0.6	F (10 m)	CCD	+20	220 (220 V)
LATMOS	SAOZ	CINDI-2.24	n/n	10	270-640	1.3	D	LinArr	n/a	500 (220 V)
	Mini-SAOZ	CINDI-2.25	n/n	8	270-820	0.7	F (10m)	CCD	18-20 AirCo room	300 (220 V)
LuftBlick	PANDORA-2S (x2)	CINDI-2.26	y/y	1.5 (sky) 2.8 (sun)	280-540	0.6	F (10m)	CCD	15	220 (220 V)
		CINDI-2.27			400-900	1.1		CCD		
MPIC	TubeMAXDOAS	CINDI-2.28	n/n	1	316-474	0.6	F (5m)	CCD	10	100 (220 V)
NIWA	EnviMeS	CINDI-2.29	n/n	<0.5	305-457	0.7	F (10m)	CCD	20	120 (220 V)
					410-550	0.7		CCD	20	
	ACTON275 MAXDOAS	CINDI-2.30	n/n	0.5	290-363	0.6	F (12m)	CCD	-20	100 (220 V)
					400-460	0.6		CCD	-20	
NASA	PANDORA (x2)	CINDI-2.31	y/y	1.5	285-530	0.6	F (10 m)	CCD	+20	220 (220 V)
		CINDI-2.32								
NUST	Mini-DOAS	CINDI-2.33	n/n	1.2	320-465	0.7	D	CCD		400 (220V)
~~**TU-Delft**~~	~~Mini-DOAS Hoffmann~~	~~CINDI-2.34~~	~~n/n~~	~~0.4~~	~~300-515~~	~~0.67~~	~~n/a~~	~~LinArr~~		~~5 (220 V)~~
U. Munich	EnviMeS	CINDI-2.35	y/n	0.4	300-460	0.6	F (10m)	CCD	20	<120 (220 V)
					450-600	0.6		CCD	20	
U. Toronto	PEARL-GBS	CINDI-2.36	y/y	0.62	300-500	0.4-0.5	F (6 m)	CCD	-70	2200 (120V)

── **A strikethrough line indicates groups/instruments cancelled at a late stage in the campaign planning.**

3.2 Static Imaging-DOAS

Table 2 presents an overview of the Imaging-DOAS systems which will be installed on the Remote Sensing Site (RSS). The complete technical specifications of each instrument can be found in Appendix B of the present document.

Table 2: **List of participating Imaging-DOAS spectrometers. Columns denote: Institute, instrument name, azimuthal scan/direct-sun capability, field of view, spectral range and resolution, coupling between telescope and spectrometer (F: multimode fibre, D: direct coupling), type of detector, detector temperature, power consumption.**

Institute	Instrument	Nr	Az./DS Cap.	FOV (°)	Spectral Range (nm)	Resol. (nm)	Light Coupl.	Det. type	T (°C)	Power (W)

IUP-Bremen	Imaging-DOAS	CINDI-2.37	y/n	50 (vert.) 1.2 (hori.)	To be decided	~0.5	F (15 m)	CCD	-30	350-700 (220 V)
~~**VTT-FMI**~~	~~Imaging spectrometer~~	~~CINDI-2.38~~	~~y/y~~	~~7~~	~~UV, Vis, Nir~~	~~TBD~~	~~D~~	~~CCD, CMOS, InGaAs~~	~~n/a~~	~~100 W 230 V~~

—— A strikethrough line indicates groups/instruments cancelled at a late stage in the campaign planning.

3.3 Long-Path DOAS (LP-DOAS)

[Instrument number CINDI-2.39]

A LP-DOAS instrument will be operated by the University of Heidelberg during the campaign. The main purpose of these measurements is to provide 'true' surface concentrations of the CINDI-2 target trace gases averaged over a representative light path. The instrument will be located at ~3.8 km South-East of the tower and will point towards four retro-reflectors installed at different altitude levels on the CESAR tower (see **Figure 3** and Figure 4). This configuration will allow to derive average concentrations at several altitudes between the surface and the top of the tower (213 m).

Figure 3: Location of the LP-DOAS system (Cabauwsekade 95, 3411EG Lopik) and view from LP-DOAS position to the tower.

The wavelength ranges used by the LP-DOAS system is: 290-370 nm, 390-470 nm, and 600-680 nm. In these spectral windows, the following trace gases can in principle be monitored: NO_2, HCHO, HONO, SO_2, O_3, NO_3, H_2O, BrO, IO, CHOCHO and O_4.

The technical requirements for installing the instrument are the following:

- 200 m of power cable (220 V);
- Power should be stable, UPS is optional
- Power meter for electricity bill

- Mobile internet
- Air-conditioned container for instrument housing

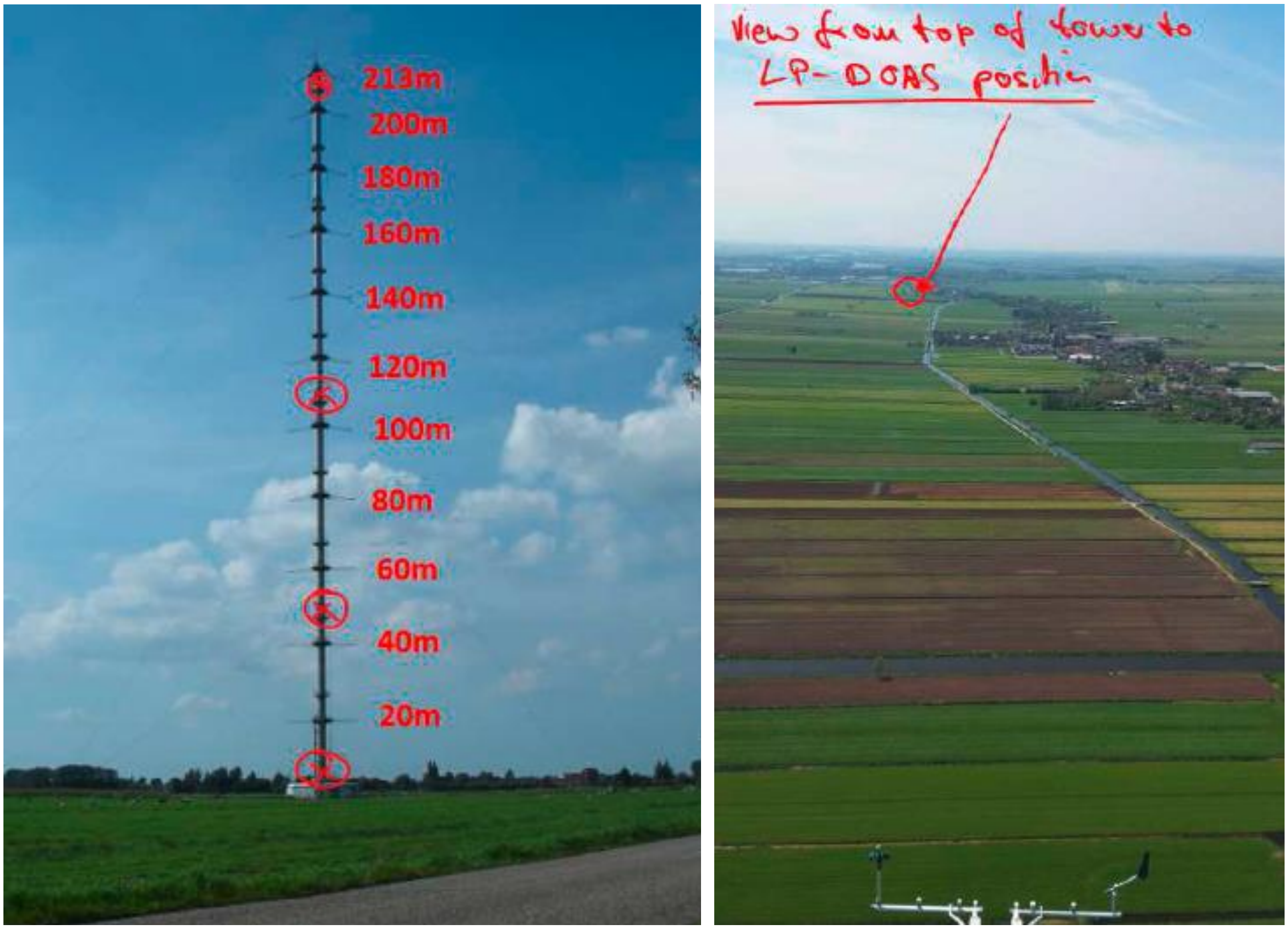

Figure 4: Position of the retro-reflectors on the tower (left) and view from top of the tower to LP-DOAS position (right).

3.4 Cavity-Enhanced DOAS (CE-DOAS)

[Instrument number CINDI-2.40]

The ICAD (Iterative Cavity-DOAS)-instrument is operated by IUP HD in the basement of the meteorological tower. It based on the CE-DOAS technique described in (Platt et al., 2009). It uses the wavelength resolved NO_2 absorption along a light path of about 1.5km within an optical resonator cell in order to determine the NO_2 absorption. The specific absorption features in the blue wavelength range allow for an interference-free detection of NO_2 and detection limits of less than 100ppt at 1 minute time resolution. The setup has an overall size of approximately 20x30x70cm^3 and weights less than 10kg. The power consumption of typically less than 20W and insensitivity to vibrations allow also mobile applications. It will operate from the sample line with inlet at 27m altitude, i.e. the one also used by the CAPS and NO_2 analysers (see Sect. 3.5.1 and 3.5.2, respectively).

3.5 In-situ analysers

3.5.1 Cavity Attenuated Phase Shift NO_2 monitor (CAPS)

[Instrument number CINDI-2.41]

Two AS32M analyzers will be operated by BIRA-IASB at the tower, at 27 and 200m altitude. AS32M is a commercial instrument from Environnement SA which measures the volume mixing ratio of NO_2 based on its absorption properties at 450 nm, following the Cavity Attenuated Phase Shift Spectroscopy (CAPS) technique (Kebabian et al., 2005). The measurement range is 0-1 ppm with a detection limit (2s) of 0.1 ppb. The system fits in a 3 unit 19 inch rack (591 mm x 483 mm x 133 mm) and weights 12.5 kg. The power consumption reaches 225 W at boot-up.

3.5.2 NO_2 analysers

[Instrument number CINDI-2.42]

NO_2 is sampled three times per hour during 5 minutes from the sample line with inlets at 27, 60, 120 and 200 m altitude at the tower (also measuring CO_2, CH_4, N_2O, CO). Ozone is also measured using this configuration. NO, NO_2 are measured with a Teledyne API, model M200E with Photolytic converter and simultaneously with a molybdenium system. Ozone is measured with a Thermo 49i. The NO_2 observations are a collaboration between ECN (Energy research Centre of the Netherlands) and RIVM (Dutch National Institute for Public Health and the Environment).

3.5.3 NO_2 sonde

[Instrument number CINDI-2.43]

NO_2 sondes are experimental devices developed at KNMI. The measurement is based on the chemiluminescent reaction of NO_2 in an aqueous luminol solution, which is optimised to be specific to NO_2 (Sluis et al., 2010). The sonde is attached to a small meteorological balloon. It has a vertical resolution of 5m and a measurement range between 1 and 100 ppbv. The instrument weighs 0.7 kg.

During the CINDI-2 campaign, one launch per day during the semi-blind intercomparison period is planned. Launch times are to be decided.

3.5.4 O_3 sonde

[Instrument number CESAR.01]

ECC ozone sondes are routinely launched from De Bilt (about 20 km distance from Cabauw) once per week. Additional soundings are possible on request. The ECC ozone sensor (Komhyr, 1969; Komhyr and Harris, 1971) is an electrochemical cell consisting of two half cells, made of Teflon, which serve as cathode and anode chamber, respectively. Both half cells contain a platinum mesh serving as electrodes. They are immersed in KI solution of different concentrations. The two chambers are linked together by an ion bridge in order to provide an ion pathway and to prevent mixing of the cathode and anode electrolytes. The ECC does not require an external electrical potential. The ECC gets its driving electromotive force from the difference in the concentration of the KI solution in the cathode and anode chamber. The electrical current is directly related to the uptake rate of ozone. The sonde is flown in a polystyrene protective box (source: Harris et al., 1998).

3.5.5 In-situ O_3 monitor

[Instrument number CESAR.02]

An in-situ ozone analyser is sampling from the same 4 altitudes as the NO_2 analysers (see Sec. 3.5.2). In addition, an ozone analyser from the Dutch air quality monitoring network is operational (http://www.lml.rivm.nl/histo/index.php?stat=NL10644). The instrument is a Thermo 49i.

3.5.6 Nephelometer

[Instrument number CESAR.03]

TNO continuously performs aerosol observations in the basement of the tower where air is sampled via a common inlet at 60 m.

The inlet system consists of four parts: (a) PM10 size selective inlets (4 PM10 heads), (b) a Nafion drying system that dries aerosol to or below 40% RH, (c) a 60-m stainless steel pipe, and (d) a manifold that splits the flow to the suite of instruments. The manifold and the in-situ instruments are all located at the basement of the tower. The instruments sample their flow from the manifold using separate pumps to adjust the required flow for proper operation of the instruments.

The total flow sustained in the 60-m inlet pipe is 60 lpm, for optimal operation of the PM10 inlets. Whenever an instrument is added or removed, the flows to the other instruments need to be checked and adjusted when needed. See also (Zieger, ACP, 2011).

An integrating nephelometer (DryNeph, TSI Inc., Model 3563) is used for the (back-) scattering coefficient.

To increase comparability between observations in (global) aerosol networks (WMO/GAW guidelines, 2003) prescribe that sampled aerosol is dried to relative humidities below 40%.

Note that aerosol optical properties, most notably the scattering coefficient, strongly increase with increasing relative humidity; thus drying frustrates comparison to aerosol optical properties measured at ambient conditions, e.g. re- motely sensed aerosol properties.

3.5.7 MAAP

[Instrument number CESAR.04]

TNO continuously performs aerosol observations in the basement of the tower where air is sampled via a common inlet at 60 m. A multi-angle absorption photometer (MAAP, Thermo Scientific Inc., Model 5012) is used to quantify the aerosol absorption coefficient. See also remarks under Sec.3.5.6.

3.5.8 SMPS

[Instrument number CESAR.05]

TNO continuously performs aerosol observations in the basement of the tower where air is sampled via a common inlet at 60 m. See also remarks under Sec.3.5.6.

The SMPS (a modified TSI Inc., Model 3034) consists of a bipolar particle charger, a differential mobility analyzer (DMA) and a condensation particle counter (CPC). Particles are charged before they are classified in the DMA according to their electrical mobility diameter and are counted by the CPC. A correction for multiple charged particles is applied. Number size distributions in the diameter range between approximately 10 and 520 nm are recorded with a time resolution of 5 min.

3.6 Mobile measurement systems

Mobile measurements will be used to characterise the spatial variability of the measured trace gases around the CESAR site. These measurements will be performed using compact DOAS systems operated in cars, as well as using NO_2 sondes installed on board of bicycles operated by KNMI. Figure 5 shows the routes that can be accessed in the neighbourhood of the site. A full circle around Cabauw starting from Vianen and going through Gouda, Rotterdam, Dordrecht and back to Vianen corresponds to approximately 120 km in length.

Table 3 presents an overview of the mobile-DOAS systems which will be deployed during CINDI-2. The complete technical specifications of these instruments can be found in Appendix C of the present document.

Figure 5: Map of highways and local roads surrounding Cabauw.

Table 3: List of participating Mobile-DOAS spectrometers. Columns denote: Institute, instrument name, field of view, spectral range and resolution, coupling between telescope and spectrometer (F: multimode fibre, D: direct coupling), type of detector, detector temperature, power consumption.

Institute	instrument	Nr	FOV (°)	Spectral range (nm)	Resol. (nm)	Light coupl.	Det. type	T (°C)	Power
BIRA-IASB	Aeromobil	CINDI-2.45	2.5	270-500	1.15	F	LinArr	Ambient	

MPIC	Car-DOAS	CINDI-2.46	1.2	299-454	0.6 - 0.9	F	CCD	+5	200 W
Uni. Galati	Car-DOAS	CINDI-2.47	1.2	280-550	0.7	F	CCD	Ambient	
IUP-Bremen*	IUP-Truck DOAS*	CINDI-2.48	1	286-419	0.55	F	CCD	-35	10kVA, 32 A (truck)
				413-524	0.65		CCD	-35	

***Will be used as a moveable static instrument**

3.7 Sun-photometer, all-sky imager and aerosol Lidar systems

3.7.1 Sun photometer

[Instrument number CESAR.06]

At Cabauw a Cimel sunphotometer is installed that is part of AERONET:

http://aeronet.gsfc.nasa.gov/new_web/photo_db/Cabauw.html

and following the AERONET protocols the data is automatically uploaded to the data center: http://aeronet.gsfc.nasa.gov/cgi-bin/type_one_station_opera_v2_new?site=Cabauw&nachal=0&year=24&aero_water=0&level=1.

3.7.2 All-sky imager

[Instrument number CESAR.07]

The Total Sky Imager (TSI) operated by KNMI takes an image every minute of the sky in daytime projected on a hemispherical shaped mirror. The fractions of 'thin' and 'opaque' clouds are calculated by the TSI-processing based on the red-blue ratio of the pixels. TSI images are available at http://projects.knmi.nl/cloudnet/realtime/rt_img_tsi.html.

Additional cloud cover information is obtained from a Nubiscope. Near real time information is available from http://projects.knmi.nl/cloudnet/realtime/rt_img_nubi.html.

3.7.3 Raman LIDAR CAELI

[Instrument number CESAR.08]

The CESAR Water Vapor, Aerosol and Cloud Lidar (CAELI, Apituley et al., 2009) is a high-performance, multi-wavelength Raman lidar, capable of providing round-the-clock measurements. The instrument is part of the European Aerosol Research Lidar Network (EARLINET), and provides 24 profiles of volume backscatter and extinction coefficients of aerosol particles, the depolarization ratio, and water-vapour-to-dry-air mixing ratio. A high-power Nd:YAG laser transmits pulses at 355, 532, and 1064 nm. Because a large telescope is essentially blind for lidar signals from close to the instrument, a second, small telescope is needed to cover the near range, in particular for measurements in the planetary boundary layer.

Quicklooks of the observations are made available in near-real time:

http://projects.knmi.nl/earlinet/quicklookpages/lidar/Cabauw/images/?year=2016

3.7.4 Ceilometer

[Instrument number CESAR.09]

Diurnal profiling of aerosol layers and cloud layers is obtained from a Lufft CHM15k Nimbus ceilometer. Data is not yet provided on-line, but is planned to have that established before CINDI-2. An automated detection algorithm is implemented for boundary layer height detection.

3.7.5 RIVM mobile NO_2 LIDAR

[Instrument number CINDI-2.49]

The RIVM mobile lidar will take part in CINDI-2 configured to measure nitrogen dioxide with elevation scanning and operating from a mobile truck provided vertical profiles of nitrogen dioxide at moderate resolution (Volten et al., 2009) The lidar will not be located at the remote sensing site, but at the parking lot at the main entrance to the Cabauw site, or close to the tower. The lidar will be deployed at Cabauw during a selected number of days during the semi-blind intercomparison period.

4 Meteorological data

A complete set of meteorological parameters are routinely measured at the Cabauw tower at 7 altitude levels (2, 10, 20, 40, 80, 140, and 200m). This includes:

- Surface temperature and pressure,
- wind speed and direction,
- relative humidity,
- cloud cover.

Real time quicklooks of meteorological parameters obtained at various levels in the tower are available: http://www.cesar-observatory.nl/index.php?pageID=9000.

In addition weather forecast information will be available on a daily basis or at higher frequency. Tailored meteorological model output will be provided through a password protected website, e.g. http://projects.knmi.nl/imau/ISPEX/, login: HIRLAM, pwd: H@rmoni3. This website will be updated.

ECMWF will also provide through the ESA/EVDC database 24/48h forecast of T, U, V, RH on 100 and 850 hPa isobar/pressure levels, PV on 300 and 475 K isentrop level, and BLH.

5 CAMS chemical forecast

Low resolution global analysis and forecast of the atmospheric chemical composition are available from the Copernicus Atmospheric Monitoring Service (CAMS). CAMS output will be provided for CINDI-2 by H. Eskes (KNMI). Dedicated scripts will be written to make the data for Cabauw (and surroundings) available. The delivered CAMS data fields also include LOTOS-EUROS simulations. These simulations will be made available at http://www.tropomi.eu/science/cams-air-quality-forecasts-over-cabauw.

6 Regional air quality modelling

Output fields from regional and/or local air quality models might be available from Dutch colleagues. Further information still need to be collected.

In addition, IUP-Bremen (LAMOS group) is evaluating the possibility to perform spatially high resolved air quality simulations, using the WRF-Chem model together with TNO-MACC3 (7 km resolution) and RIVM ("emissieregistratie.nl", 1km resolution) emissions.

7 Satellite data

Daily overpass NO_2 and HCHO measurements from the OMI and GOME-2 B instruments will be made available for comparison and further analysis of the campaign results. The NASA LaRC Satellite Overpass predictor tool available at http://cloudsgate2.larc.nasa.gov/cgi-bin/predict/predict.cgi will be used to generate overpass table of the nadir position of many satellites including Aura (OMI), NPP (VIIRS), Metop-A and -B (GOME-2). Instructions on how to use this tool will be provided by KNMI at http://www.tropomi.eu/science/forecast-information.

8 Logistics

8.1 Site Layout

Several areas can be distinguished on the Cabauw site:

- The main facility is the tower with the main building.
- The Remote sensing site
- The Wind profiler site
- The energy balance field
- The North side of the station with air quality observations
- Parking lot near the main gate

Many instruments are installed permanently. The CINDI-2 instruments will be distributed over the site.

Almost all MAXDOAS systems will be placed on the remote sensing site. To accommodate this, temporary containers or units will be rented. The layout of the remote sensing site is shown in Fig.6a and 6b.

No parking is allowed at the Remote Sensing Site, other than for delivery and pick up of equipment and supplies. Parking will be provided near the main gate, either on the permanent parking lot, and/or a temporary parking.

More information about local logistics can be found on the cindi-2 website : http://projects.knmi.nl/cindi-2

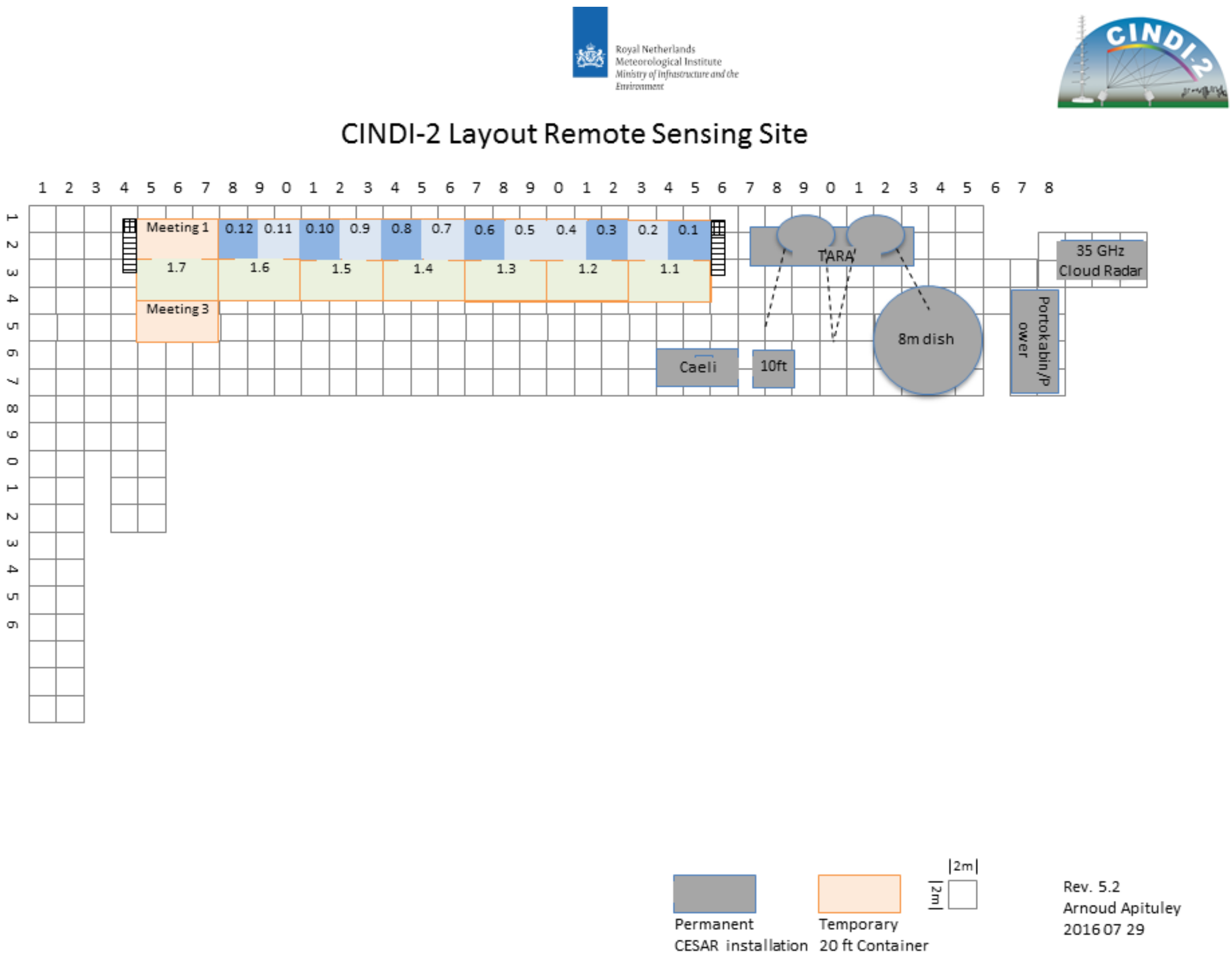

Figure 6a: **Site layout of the Remote Sensing Site. Squares are 2x2 m^2. The general viewing direction of the non-scanning instruments will be to the top of the figure.**

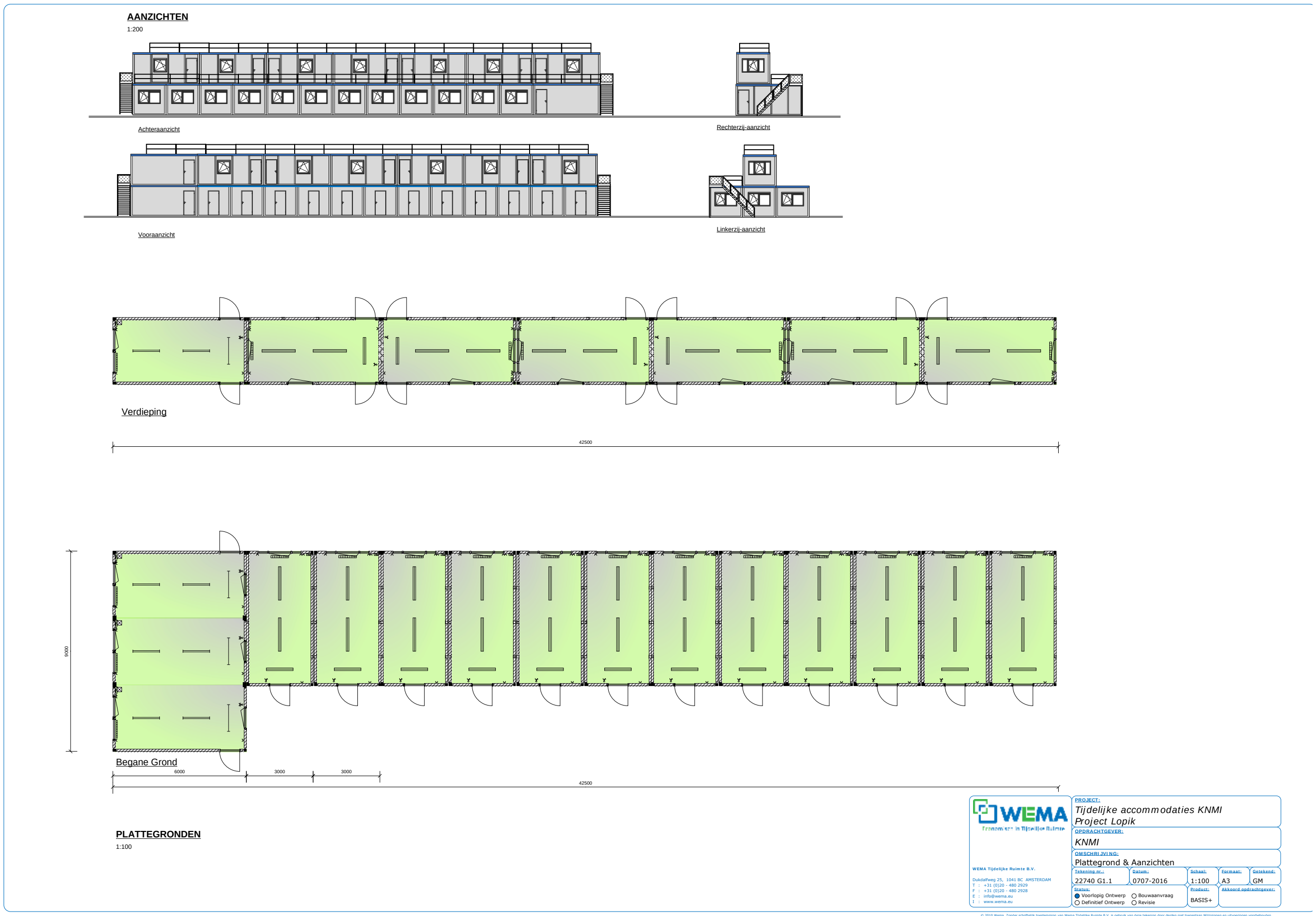

Figure 6b: **Container layout on the Remote Sensing Site.**

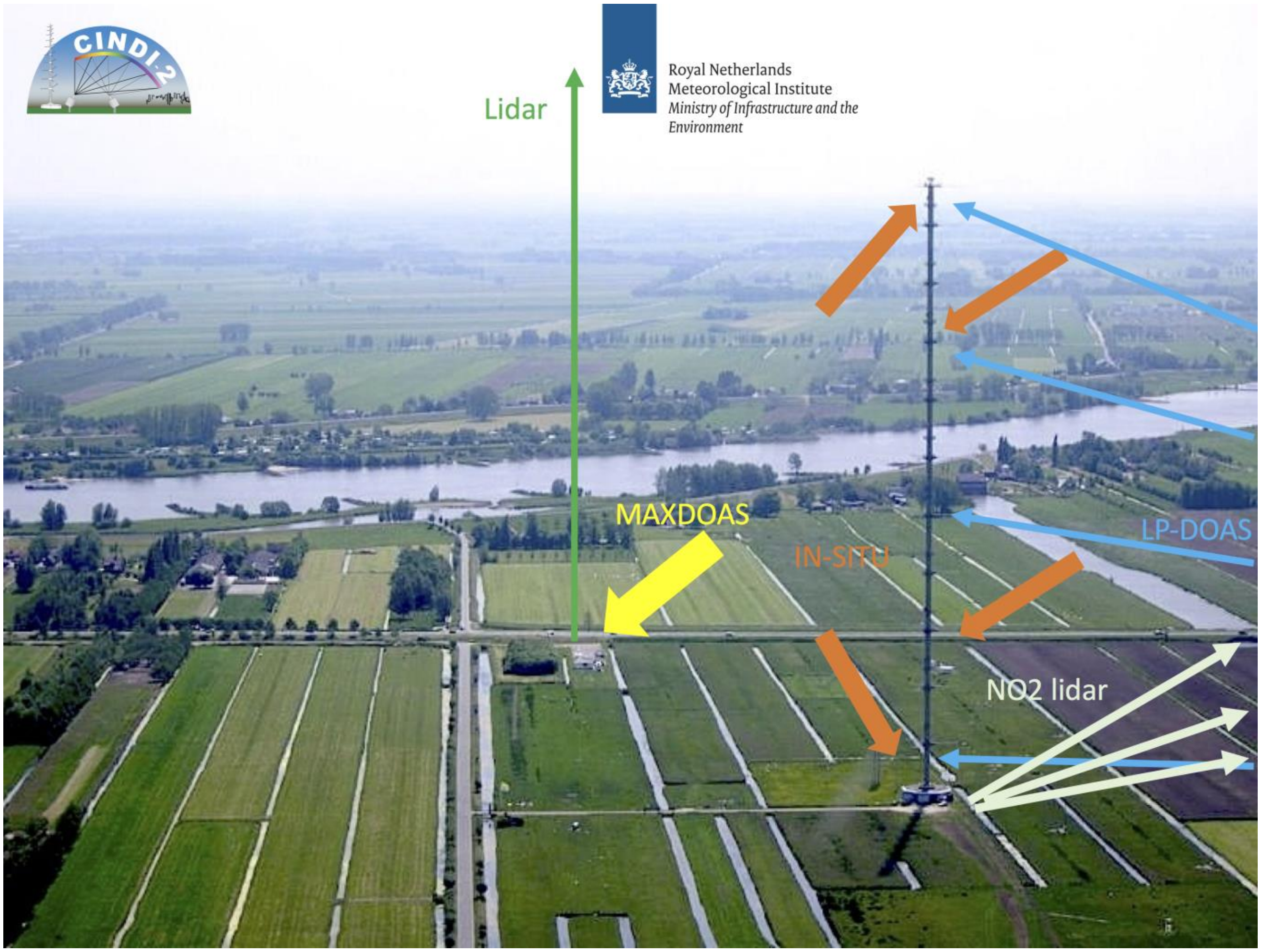

Figure 6c: General placement of CINDI-2 instrumentation at the CESAR site

Ground floor

For CINDI-2 a series of 12 containers (3m x 6m each) will be placed side by side on the remote sensing site as indicated in Fig.6a. Adjacent to those, three more units (3m x 6m each) will be linked together to form a meeting room.

Access to the roof of the ground level units is via fixed staircases on either side of the row. A railing will be put around the roof for safety (required). The railing is about 1 m high and consists of 6 cm diameter aluminium tubes. The railing will be kept in place by concrete slabs.

The roofs of the units consist of corrugated material that will be partially covered by board material to walk on. Instruments will be placed directly on the roof.

All units housing instruments will be air-conditioned. And two tables and four chairs are provided for each unit (also if no instruments are placed).

For each unit used for instruments, instrument cables and fibers will be fed though the window facing the observation direction. A wooden panel will replace a window. For most units, a second window will provide daylight.

Units on the ground floor that are not used for instruments will not be air-conditioned and can be used for storage and/or office space.

Top level

On top of the units on the ground floor, 7 units (3m x 6m each) will be placed over the length of the bottom layer.

Access to the roof of the top level units is first via a fixed staircase on either side of the row on the ground floor and next via a ladder to the top level (one ladder for each unit). A railing will be put around the roof for safety (required). The railing is about 1 m high and consists of 6 cm diameter aluminium tubes. The railing will be kept in place by concrete slabs.

The roof will be partially covered by plate material to walk on. Instruments will be placed directly on the roof.

All units housing instruments will be air-conditioned. And two tables and four chairs are provided for each unit.

For each unit on the top level, instrument cables and fibers will be fed though the window facing the observation direction. A wooden panel will replace the window. For most units, a second window will provide daylight.

Instrument placement

The instruments with fixed azimuth will be placed on the roof and (if needed) in front of the units on the ground floor. The azimuthal scanning instruments and imaging instruments will be placed on the roof of the top level units.

During installation and break-up, lifting material will made available if needed.

8.2 Instrument location assignment

The instrument location assignment is given in the tables below. Note that the units are numbered right to left, according to the drawings in Fig.6.

RS-site ground level	Unit#	Institute	Instr.Number	Instrument
	0.1			Office/storage use
1	0.2	AMOIAP/IA Ph	CINDI-2.02	2-port DOAS
2		BLS	CINDI-2.05	Catadioptric telescope-MARSB
				Airco
	0.3			Office/storage use
3	0.4	CAMS	CINDI-2.07	Mini-DOAS Hoffmann UV+Vis (#1)
4		CAMS	CINDI-2.08	Mini-DOAS Hoffmann UV+Vis (#1)
5		CHIBA-U	CINDI-2.09	CHIBA-U/MAX-DOAS
				Airco
6	0.5	KNMI	CINDI-2.21	Mini-DOAS n/n Hoffmann-UV+Vis (#3)
7		KNMI	CESAR-22	Mini-DOAS n/n Hoffmann-UV+Vis (#3)
				Airco
	0.6			Office/storage use
8	0.7	CSIC	CINDI-2.10	MAXDOAS
9		CU-Boulder	CINDI-2.12	1D-MAXDOAS
10		NUST	CINDI-2.33	Mini-DOAS
				Airco

	0.8			Office/storage use
11	0.9	LATMOS	CINDI-2.24	SAOZ
12		LATMOS	CINDI-2.25	Mini-SAOZ
13		MPIC	CINDI-2.28	TubeMAXDOAS
				Airco
	0.10			Office/storage use
14	0.11	NIWA	CINDI-2.29	EnviMeS (#3)
15		NIWA	CINDI-2.30	ACTON275 MAXDOAS
16		IISER	CINDI-2.16	Mini-DOAS Hoffmann-UV (#2)
				Airco
	0.12			Office/storage use

RS-site top level	**Unit#**	**Institute**	**Instr.Number**	**Instrument**
1	1.1	AIOFM	CINDI-2.01	2D-MAXDOAS
2		AUTH	CINDI-2.03	PHAETHON
3		INTA	CINDI-2.17	RASAS-III MAXDOAS
				Airco
4	1.2	BIRA-IASB	CINDI-2.04	2D-MAXDOAS
5		IUP-Heidelberg	CINDI-2.19	2D-EnviMeS (#2)
				Airco
6	1.3	DLR+USTC	CINDI-2.13	2D-EnviMeS (#1)
7		DLR+USTC	CINDI-2.14	2D-EnviMeS (#2)
8		U. Munich	CINDI-2.35	2D-EnviMeS (#4)
9		KNMI	CESAR.23	PANDORA (#1)
				Airco
10	1.4	CU-Boulder	CINDI-2.11	2D-MAXDOAS
~~11~~	-	~~DWD~~	~~CINDI-2.15~~	~~MAXDOAS~~
				Airco
12	1.5	IUP-Bremen	CINDI-2.18	2D-MAXDOAS
13		IUP-Bremen	CINDI-2.37	Imaging DOAS
14		BOKU	CINDI-2.06	2D-MAXDOAS
				Airco
15	1.6	Luftblick	CINDI-2.26	PANDORA-2S (#2)
16		Luftblick	CINDI-2.27	PANDORA-2S (#2)
17		NASA	CINDI-2.31	PANDORA (#3)
18		NASA	CINDI-2.32	PANDORA (#3)
				Airco
19		U. Toronto	CINDI-2.36	PEARL-GBS
~~19~~	-	~~VTT-FMI~~	~~CINDI-2.38~~	~~Imaging Spectrometer~~
				Airco

Tower	Unit#	Institute	Instr.Number	Instrument
1	ground floor	RIVM	CINDI-2.49	Mobile DIAL
2	ground floor	IUP-Bremen	CINDI-2.48	IUP-Truck DOAS
3	~10 m	IUP-Heidelberg	CINDI-2.39.2	retroreflector
4	~50 m	IUP-Heidelberg	CINDI-2.39.3	retroreflector
5	~110 m	IUP-Heidelberg	CINDI-2.39.4	retroreflector
6	~213 m	IUP-Heidelberg	CINDI-2.43	NO_2 sonde preparation and ground station
7	workshop/lab	KNMI	CINDI-2.40	CE-DOAS
8	unk	BIRA-IASB	CINDI-2.41	CAPS
9	27, 60, 120, 200m	RIVM/ECN	CINDI-2.42	NO_2 analysers
10	basement	RIVM/ECN	ACTRIS-JRA1.1	CAPS
11	workshop/lab	TNO - PSI	ACTRIS-JRA1.2	SP2
12	workshop/lab	TNO - SP2	ACTRIS-JRA1.3	MAAP (CESAR.04)
13	workshop/lab	TNO	ACTRIS-JRA1.4	MAAP (CESAR.04)
14	workshop/lab	TNO	ACTRIS-JRA1.5	Aethalometer Dual Spot
15	workshop/lab	TNO	ACTRIS-JRA1.6	Aethalometer AE31
16	workshop/lab	TNO	ACTRIS-JRA1.7	EC/OC samplers
17	basement	TNO	ACTRIS-JRA2.1	Windlidar
18	outside	ECN	CINDI-2.49	Mobile DIAL
19	27, 60, 120, 200m	RIVM/ECN	CESAR.02	O_3 anlyser
20	Basement/60m	TNO	CESAR.03	Nephelometer
21	Basement	TNO	CESAR.05	SMPS
22	outside	TNO	CESAR.06	Sun photometer (AERONET)
23	outside	KNMI	CESAR.07	All-sky imager
24	outside	TNO	CESAR.09	Ceilometer

— **A strikethrough line indicates groups/instruments cancelled at a late stage in the campaign planning.**

Main parking lot	Institute	PI name	Instr.Number	
1	BIRA-IASB		CINDI-2.45	Aeromobil
2	MPIC		CINDI-2.46	Car-DOAS
3	Uni. Galati		CINDI-2.47	Car-DOAS
4	KNMI		CESAR.08	Raman LIDAR CAELI

Cabauwsekade 95, Lopik	Institute	PI name	Instr.Number	
1	IUP-Heidelberg		CINDI-2.39	LP-DOAS

8.3 Internet

A dedicated microwave link operating at 5 GHz will be installed at the remote sensing site to provide internet access at 50 Mbit/sec.

Wired network with fixed ip-addresses will be provided for computers controlling instruments. Wifi (dynamic adresses) will be made available for general use, e.g. email, browsing etc.

8.4 FTP Server

An FTP server will be available for upload and exchange of campaign data.

A directory will be assigned to each participant (group), with read and write access for that participant only. Participants will not have read or write access to directories from other groups.

A cindi-2 directory will be assigned to the referee, with write access for all participants, but without read access for the participants. In this way the (daily) campaign results can be submitted to the referee, while only the referee is able to see all the results.

Furthermore, a cindi-2-share directory will be available for exchange of commonly accessible material. Access to this common directory is possible using the following:

```
sftp guest@bbc.knmi.nl
pwd: Gu3st
directory: ./share/
```

8.5 Security

During the nighttime hours, between 21:00 and 07:00, a guard will be on-site for security.

9 Additional ACTRIS-2 activities

During the CINDI-2 campaign two additional activities from ACTRIS-2 (www.actris.eu) will take place. These are experiments for aerosol absorption measurements (ACTRIS-2 JRA1) and aerosol flux measurements (ACTRIS-2 JRA2). Additional instruments will be installed, mainly in the tower and will therefore not interfere with activities at the remote sensing site. The benefit from the additional aerosol measurements for CINDI-2 is that more background information is collected about aerosol optical properties, in particular aerosol optical absorption in the boundary layer (in-situ). For the aerosol flux measurements, detailed observations will be made for the vertical distribution and the dynamics of the aerosol (vertical) distribution.

10 Campaign planning

10.1 Schedule

The overall schedule of the main campaign activities is represented in Figure 7. The site will be open for installation of the instruments on 25 August 2016, i.e. one week before the formal start of the campaign which is planned for 1st September 2016. From this time on, instruments should be ready for data acquisition. We plan for one full week of warm-up during which hardware and software adjustments as well as various calibrations will be performed.

At the occasion of a Press Event planned to take place on 12 September, the semi-blind intercomparison exercise will be kicked off for 2 weeks of intensive coordinated measurements (see details in section 10.2). Upon necessity (e.g. due to persisting bad weather conditions during weeks 37 and 38) an optional 1-week extension of the semi-blind exercise is planned in week 39 (26 Sep – 2 Oct). After that period the Cabauw site will remain open for one additional week during which interested groups might conduct specific experiments not performed during the semi-blind exercise.

August 2016

Mo	Tu	We	Th	Fr	Sa	Su	*Wk*
15	**16**	**17**	**18**	**19**	**20**	**21**	*33*
22	**23**	**24**	**25** Site opening	**26** Installation Phase	**27**	**28**	*34*

September 2016

Mo	Tu	We	Th	Fr	Sa	Su	*Wk*
29 Installation Phase	**30**	**31**	**1** Start	**2** Warm-up Phase	**3**	**4**	*35*
5 Warm-up Phase	**6**	**7**	**8**	**9**	**10**	**11**	*36*
12 Press event	**13** Semi-blind intercomparison (Intensive phase)	**14**	**15**	**16**	**17**	**18**	*37*
19 Semi-blind intercomparison (Intensive phase)	**20**	**21**	**22**	**23**	**24**	**25**	*38*
26 Backup semi-blind/ extra measurements	**27**	**28**	**29**	**30**	**1**	**2**	*39*

October 2016

Mo	Tu	We	Th	Fr	Sa	Su	*Wk*
3 Extra measurements	**4**	**5**	**6**	**7**	**8**	**9**	*40*
10	**11**	**12**	**13**	**14**	**15**	**16**	*41*

Figure 7: Schedule of the CINDI-2 campaign.

10.2 Main campaign phases

As already indicated, the campaign will include 4 main successive phases: installation, warm-up, semi-blind intercomparison and extra measurements.

10.2.1 Installation

The installation of the instruments is planned to take place between 25 August and 1st September 2016. During this period, no coordinated activity will take place. Each measurement team will bring and install their instrumentation on-site, perform all necessary adjustments and tests and interact with the local organisation team to fix possible issues and be ready to start the campaign in optimal conditions. Upon feasibility, some of the on-site calibration activities requested from the teams participating in the semi-blind intercomparison might already be started (see details in the CINDI-2 measurement protocol document).

10.2.2 Warm-up phase

In the first 11 days of the formal campaign, starting on 1st September 2016, it is anticipated that most measurement systems will be operational. This period will be used for intercomparison protocol rehearsal (including adjustments if necessary) and continued calibration activities.

Additional activities will also take place such as intercomparison of the various in-situ NO_2 and HCHO analysers, test flights of the NO_2 sonde, set-up of mobile systems and test of most adequate roads circuits, set-up of long-path and cavity-enhanced systems, preparation of all ancillary data, etc.

10.2.3 Semi-blind intercomparison

The semi-blind intercomparison of the MAXDOAS instruments will take place during two weeks from 12 to 25 September 2016. Details on the organisation of this exercise are given in the next section and in a separate Semi-blind Intercomparison Protocol document.

10.2.4 Backup week/extra measurements

An additional (backup) week is reserved for a possible extension of the semi-blind intercomparison in case of major instrumental issues or persisting bad weather conditions during the formal 2-weeks period. If the original schedule is maintained, this extra-week and the following one (first week of October) will be used to explore more specifically additional science topics such as, e.g.

- Focused measurements of other gases (e.g. CHOCHO, HONO)
- Setup of specific experiments that could contribute to better interpretation of the remote-sensing measurements in combination with other measurement system available on site, etc.

11 The semi-blind intercomparison exercise

11.1 Aim and purpose

Passive UV-visible spectrometry using scattered sunlight as a source provides one of the simplest methods for routine remote sensing of atmospheric trace gases from the ground. While zenith-sky measurements have been used for decades to monitor stratospheric gases such NO_2, O_3, BrO and OClO, observations of the sky at several elevations between horizon and zenith using the so-called Multiple Axis or MAXDOAS method allow to derive vertically resolved information on tropospheric species and aerosols (e.g. Hönninger and Platt, 2002; Wagner et al., 2004; Friess et al., 2006). The number of MAXDOAS-type instruments deployed world-wide has grown considerably in recent years. This increasing use of MAXDOAS instruments for tropospheric observations, together with the diversity of their designs and operation protocols, has created the need for formal intercomparisons including as many different instruments as possible. The first CINDI intercomparison campaign was organised in 2009 under the auspices of ESA, NDACC and the EU GEOMON project to provide an assessment of the status of the capabilities for NO_2 monitoring. This resulted in the first successful large scale intercomparison of both MAXDOAS and zenith-sky ground-based remote sensors of NO_2 (Roscoe et al., 2010).

Seven years following CINDI, the CINDI-2 campaign has the target to intercompare a new and extended generation of ground-based remote-sensing and in-situ air quality instruments. The interest of ESA for such Intercalibration activities is stimulated by the ongoing development of several UV-Visible space missions targeting air quality monitoring such as the Copernicus Sentinel 5 Precursor instrument to be launched in late 2016 and the future ESA Copernicus Sentinel 4 and 5 at the horizon 2020. The validation of measurements from such space missions is essential and requires appropriate dedicated ground-truth measurement systems. Because tropospheric measurements from space-borne nadir UV-visible sensors show little or no vertical discrimination and inherently provide measurements of the total tropospheric amount, surface in-situ measurements are generally unsuitable for validation. Instead, validation demands a technique that can deliver column-integrated information on the key tropospheric species measured by satellite instruments such as NO_2, HCHO, O_3 and SO_2 with a horizontal representativeness compatible with the resolution of space measurements (typically 8x8 km^2 for the Sentinels).

The aim of the CINDI-2 semi-blind intercomparison is to characterise the differences between a large number of measurement systems and approaches and to contribute to a harmonisation of the measurement settings and retrieval methods for similar systems of the MAXDOAS type. Following the precedent set by Roscoe et al. (1999), Vandaele et al. (2005) and Roscoe et al. (2010), the adopted intercomparison protocol is semi-blind, i.e.:

a) Measurement and analysis results from the previous day have to be provided to the campaign referee in early morning. At a daily meeting in the early afternoon, slant columns measured during the previous day are displayed without assignment to the different instruments.
b) The referee notifies instrument representatives if there is an obvious error so that this can be corrected for the rest of the campaign.

c) At the end of the formal campaign, plots have instrument names attached, and plots of mean differences from one selected reference instrument or an average of several selected reference instruments are discussed.
d) After the end of the formal campaign time, revisions are only accepted where full details of the reasons for changes are supplied.

More details on the data policy and intercomparison protocol are given in the FRM_4DOAS Deliverable D14 (Campaign Data Protocol).

11.2 Participating instruments and intercomparison setup

The groups and instruments which have been registered for participation in the semi-blind intercomparison exercise are listed in Table 1. In total 36 instruments from 26 different organisations and 17 countries will be accommodated on the site. Among these instruments, 19 will be two-dimensional MAXDOAS systems allowing for scans in both elevation and azimuth, 15 will be one-dimensional MAXDOAS systems performing elevation scans in one fixed azimuthal direction, and the last 2 instruments will be simple zenith-sky DOAS systems.

11.3 Intercomparison setup

Because the tropospheric species under focus for this intercomparison (in particular NO_2, but also aerosols and HCHO) can feature fast changing concentrations in both space and time, it is essential to setup the measurement systems in such a way that they all sample the same air masses at the same time. For this reason, all the instruments participating in the intercomparison will be installed on the CESAR remote-sensing platform (see Figure 8) making use of containers which will be organised in the most compact way. Considering the large number of systems that need to be accommodated, we plan to deploy two rows of containers. The first row will be similar to the one deployed during CINDI-1 (see Figure 8) and will be used to host the 1D-MAXDOAS and the zenith-sky systems. The second row will be deployed on the other side of the platform and will consist of stacked double-containers high enough to exceed the height of the grove of trees visible on the left side of Figure 8. The 2D-MAXDOAS systems will be installed on the top of these containers allowing for more flexibility on the azimuth scan settings and avoiding any risk of interference with the 1D systems.

All the 1D-MAXDOAS instruments will use the same azimuth viewing direction of 287° (i.e. WNW, N=0), which was already used during CINDI-1. This direction will also be one of the azimuth directions used by the 2D MAXDOAS systems. More details on the synchronisation of the instruments are given below in section 11.6.)

Figure 8: Aerial picture of the CESAR remote-sensing site, as configured during the CINDI-1 campaign in 2009. DOAS and MAXDOAS systems were installed on the roof or in front of the 5 white containers.

11.4 Intercomparison campaign referee

The formal intercomparison exercise will be coordinated by Karin Kreher (BK Scientific GmbH) assisted by Ermioni Dimitropoulou (BIRA-IASB/AUTH). Karin Kreher has more than 20 years of research experience working with UV-Visible remote-sensing of the atmospheric composition. She has been acting as co-chair of the NDACC UV-Vis working group for about 10 years and was involved as participant in all the recent NDACC Intercomparison exercises. In particular she was part of the CINDI-1 campaign in 2009. Therefore she has the adequate experience and knowledge to coordinate the CINDI-2 semi-blind intercomparison.

Her role as referee will be to interface with the different participating groups, to organise the daily data collection, to manage and chair the daily intercomparison campaign workshops with the support of her assistant for assembling and plotting the measurement data, to provide daily summaries of the campaign progress and, after the campaign, to coordinate the writing of a peer-review publication on the intercomparison results.

11.5 Instrument characterisation

Before starting the formal intercomparison campaign, all the participating teams will be asked to perform specific tests and to provide complete information on the specifications of their instrument(s). Most of the required calibrations and instrument tests will be possible on site during the installation and warm-up phases. This information will be collected by the campaign referee and used in support of the interpretation of the measurement results. The calibration procedures described below are based on the 'DOAS Best Practice for Instrument Characterization and Operation' document edited by A. Richter (IUP-Bremen) as part of the EC FP7 QA4ECV project.

11.5.1 Time reference

All computer clocks will be synchronised on the universal UTC reference time. To this aim, a common time server will be used by all groups. Guidelines on this will be provided by the referee and the local organisation.

11.5.2 Solar angles calculation

For consistency checks, all groups will be asked to provide the campaign referee with a set of solar zenith and azimuth angles calculated using the software routines implemented in their acquisition or data processing code.

11.5.3 Spectral stray-light test

The best way to characterize spectral stray-light in a grating spectrometer is to use a tunable laser or other monochromatic light source (e.g. double monochromator fed by white light source) to measure spectral response functions on a series of wavelengths. This approach can of course only be applied in the lab. Its main limitation is that it only accounts for stray-light being generated in the spectral interval covered by the instrument. The possible contribution from out-of-band stray-light has to be estimated in a different way.

For on-site characterization, we propose to use a combination of band-pass filters having different cut-off wavelengths (e.g. every 50 nm). This approach has been successfully applied in previous intercomparison campaigns and provides a qualitative estimate of the stray-light level in working conditions (see e.g. Vandaele et al., 2005).

11.5.4 Polarisation sensitivity test

Most of the MAXDOAS instruments involved in the campaign are using 5-20m long quartz optical fibers, which are strongly depolarizing. As result, residual polarisation should not be an issue for these instruments.

Since the campaign involves a large number of instruments of varying designs, we propose to systematically test the polarisation sensitivity of each of them on-site by using a halogen lamp and placing a polariser in front of the telescope or fiber. Spectra will be measured for different polarizer orientations allowing to identify possible spectral features in the presence of residual polarization.

11.5.5 Instrumental slit function characterization

Instrumental slit functions (also known as Instrumental Spectral Response Function – ISRF) are generally characterized in the lab using a spectral line lamp (e.g. HgCd). Temporal changes of the slit function should be monitored during the campaign when the instrument is stabilized by taking regular measurements with such a lamp placed in front of the telescope or fibers. For a good representation of the slit function, a full and homogenous illumination of the instrument needs to be ensured (e.g. by using a diffusor).

To minimize spectrometer non-linearity effects on the ISRF spectra, the emission peaks which shall be used later for the analysis should be recorded at a similar saturation as the MAX-DOAS measurement spectra itself. This is especially important for weaker emissions like at 334nm.

11.5.6 Signal-to-noise ratio (SNR) determination

We propose to measure the signal-to-noise ratio of the different systems following the simple approach adopted for the QA4ECV intercomparison. The average S/N ratio in a given fitting interval can be estimated from the inverse of the DOAS fit RMS, for a zenith spectrum analyzed with respect to another zenith spectrum close in time on a clear-sky day. We recommend to select zenith spectra close in time to the noon reference. A common accumulation time should be used to allow for S/N comparison on a fair ground. We propose to adopt a common accumulation time of 1 min.

11.5.7 Detector linearity test

Detector linearity should be determined in the lab by taking measurements of a broadband light source using a range of exposure times resulting in coverage of the full dynamic range. After dark signal correction, ratios of measurements taken at different exposure time should equal the ratio of the exposure times. Deviations from this value indicate non-linearities. As light sources might be changing in intensity over time, care must be taken to keep the time between measurements short. In principle, a different linearity curve can be derived for each detector pixel. However, in many cases it is sufficient to determine a mean dependency for all pixels.

For the campaign, we propose to test the linearity of the different systems in a simple way by performing successive measurements with different integration times using a stabilized halogen lamp as light source. The option of using sky measurements on a clear-sky day under stable illumination conditions will be also investigated.

11.5.8 Dark signal and offset

Dark signal measurements can be performed automatically either by using a shutter if the instrument is such equipped or alternatively at night and pointing the instrument to a dark surface. In the second case, caution should be taken regarding possible contamination by residual light (e.g. street light reflected by low clouds). Each group will provide estimates of the dark signal level at prescribed integration times.

11.5.9 Calibration of elevation viewing angle

The accuracy of the elevation viewing angle is one amongst the most critical parameters for MAXDOAS measurements. Experience from past campaigns in particular CINDI-1 and the more recent MADCAT campaign in Mainz (Wagner et al., 2015) has shown that pointing inaccuracies are often the source of systematic biases between instruments. Therefore, this parameter will receive particular attention.

We plan to use one or several among the 4 different approaches described below to verify the accuracy and stability in time of the zero-elevation angle reference of each instrument.

Approach 1: laser level and fluorescent lamp

This approach has been developed by the University of Heidelberg (U. Friess) during the MADCAT campaign.

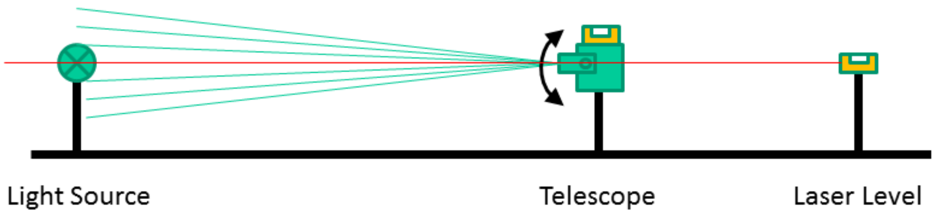

Figure 9: Sketch describing Approach 1 for elevation angle calibration (© U. Friess/IUP-Heidelberg)

It consists in four steps (see Figure 9):

1. Make sure the telescope is at the same height as the light source using a laser level.
2. Level out the telescope housing.
3. Measure intensity as a function of elevation angle.
4. Determine elevation angle offset (= angle between motor end-switch and horizon) by fitting a Gaussian to the observed intensity distribution (see Figure 10).

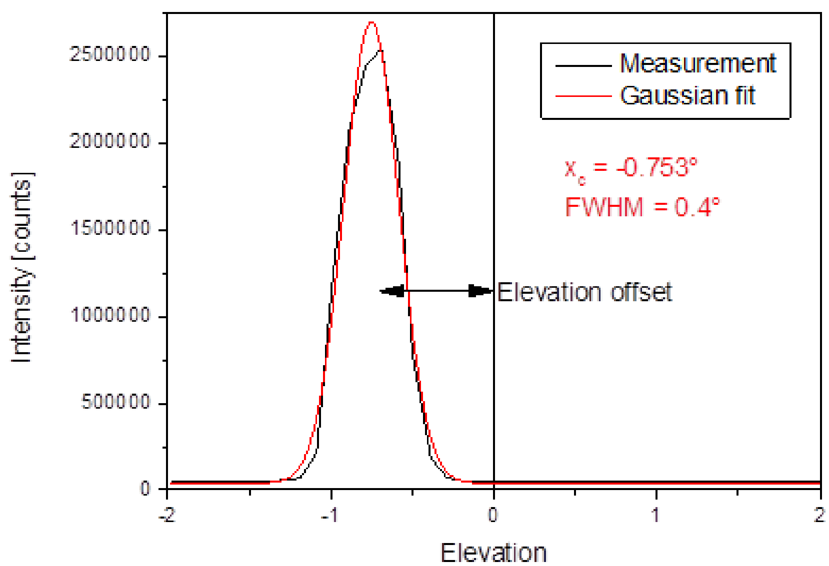

Figure 11: Illustration of the determination of the elevation angle offset using Approach 1.

Approach 2: White stripe on black target

The main drawback of Approach 1 is that such measurements must be performed at night. A variant of this approach which can be applied during daytime is to replace the light source by a black target with a white stripe as proposed by MPIC-Mainz (T. Wagner) also during MADCAT (see Figure 12).

Figure 12: Black target with a white stripe prepared for elevation calibration during the CINDI-2 campaign (© M. Gu and T. Wagner/MPIC-Mainz).

<u>Approach 3: common light source at long distance</u>

An artificial light source (array of LEDs) will be installed at some distance from the remote-sensing site in the pointing direction of the 1D-MAXDOAS systems. This light source will be scanned by all the instruments once a day at night, providing a way to verify the accuracy of the MAXDOAS scanner alignment in both azimuth and elevation axes.

<u>Approach 4: camera image correlation</u>

Jonas Kuhn (University of Heidelberg) will set up a system to measure the MAXDOAS scanner FOV using camera images to invert the actual FOV of the instrument according to an approach introduced by Holger Sihler (MPIC), currently in preparation for submission to AMTD. Proof-of-concepts experiments using digital reflex camera have been recently realised by Johannes Lampel (see https://vimeo.com/162520417).

11.5.10 Calibration of azimuth viewing angle

The accuracy of the azimuth viewing angle is by far less critical than the elevation angle, however it might be useful to optimise this parameter as well for the purpose of optimising the colocation of the sampled air masses. The approach 2 used for elevation angle calibration, which makes use of a light source installed at a reference azimuth and elevation point can be used to this purpose.

11.5.11 Field of view characterization

The field of view of each MAXDOAS instrument should be characterised at least along the elevation axis. We encourage the participants to perform such calibrations before the campaign. Additional estimates of the instrument field of view will be possible on-site based on the results of the elevation angle measurements.

11.6 MAXDOAS and zenith-DOAS data acquisition scheme

The settings recommended for MAXDOAS and zenith-sky DOAS data acquisition are described below. The baseline for all MAXDOAS instruments is to point towards a fixed azimuth direction (287°, i.e. west-north-westerly) throughout the day. In addition, 2D-MAXDOAS instruments will perform azimuthal scans at regular time interval. The convention for the azimuth angle is 0° for North, 90° for East, etc. The scheme described below is designed in order to ensure the maximum of synchronicity between the same type of instruments (e.g. azimuthal scans by 2D-MAXDOAS) but also between the different types of instruments (1D-, 2D-MAXDOAS and zenith-DOAS).

We distinguish between twilight (morning and evening) and daytime conditions, for which separate data acquisition protocols are prescribed. According to the geometry of the solar position during the campaign (see Figure 13), the daytime period is set between 6:00 UTC and 17:00 UTC.

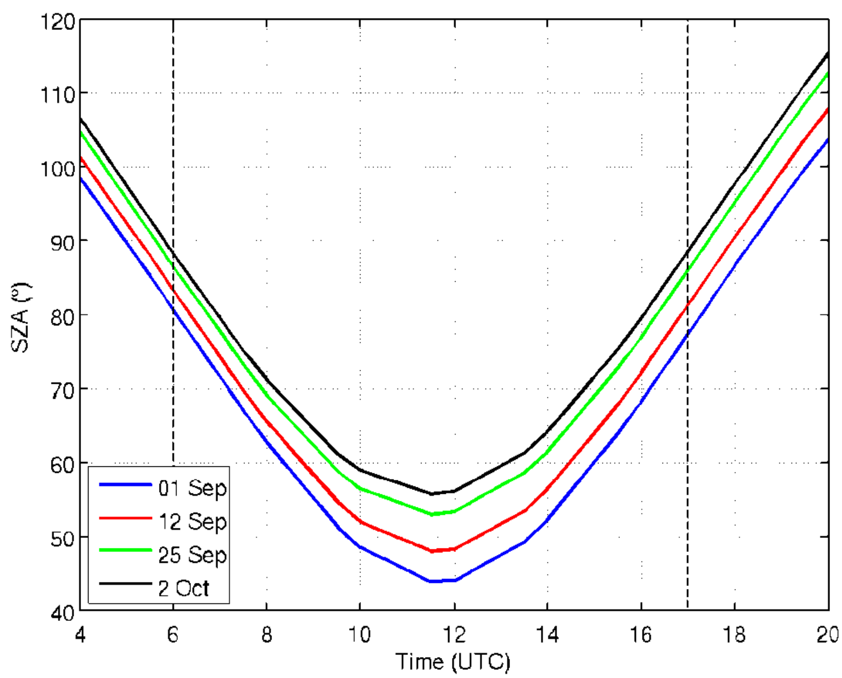

Figure 13: SZA diurnal variation at Cabauw during the CINDI-2 period. The black dashed lines denote the limits between the twilight and daytime observations.

11.6.1 Twilight zenith observations

This protocol holds for all instruments willing to contribute to the zenith-sky NDACC-type intercomparison of stratospheric measurements at twilight.

For measurements at sunrise, the following acquisition scheme shall be followed:

- 39 measurements with a duration of 180s (integration time: 170s; overhead: 10s) starting at 04:00:00 UTC and ending at 05:57:00 UTC
- This sequence is then followed by a 180s (3 min) interval allowing for a transition to the MAXDOAS mode of which the first scans starts 06:00:00 UTC (see below).

For measurements at sunset, 40 acquisitions shall be recorded with a duration of 180s each (integration time: 170s; overhead: 10s) starting at 16:45:00 UTC and ending at 18:45:00 UTC.

11.6.2 MAXDOAS and zenith-sky observations during daytime

For daytime observations the following baseline shall be followed:

- 4 sequences of 15 minutes starting at 06:00:00 UTC
- Duration of each single acquisition: 1 minute total integration
- For 1D-MAXDOAS systems (pointing azimuth direction: 287°):
  - 1 scan per 15' sequence (→ 4 scans/hour) at the following elevation angles: 1,2,3,4,5,6,8,15,30,90°

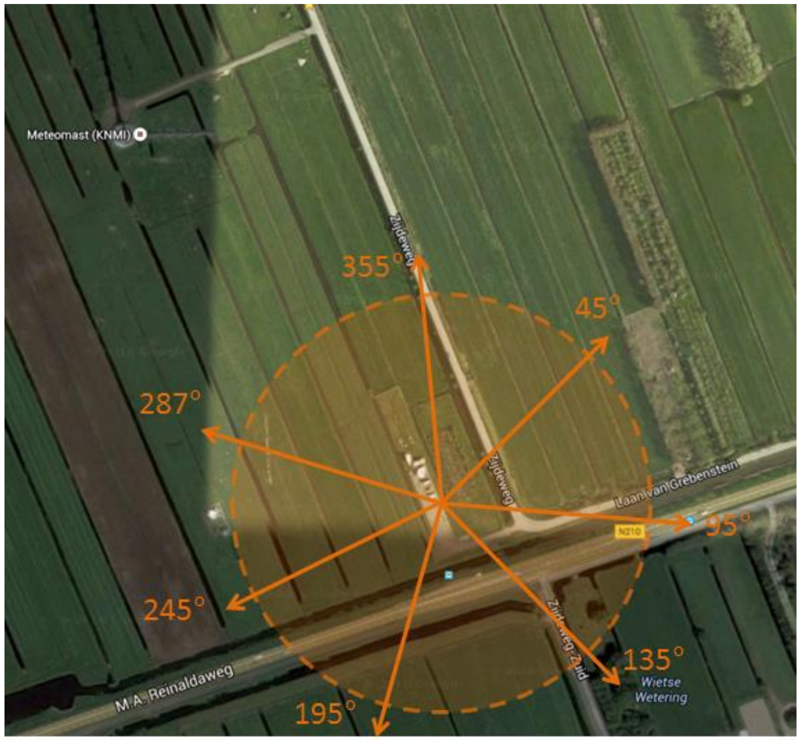

Figure 14: Azimuthal directions for the 2D-MAXDOAS instruments (North is 0°).

- For 2D-MAXDOAS systems:
  - 1 full azimuthal scan per hour at the following azimuth angles (see Figure 14): 355, 45, 95, 135, 195, 245, 287°
  - For each azimuth, 4 elevation angles (1, 3, 5, 15°) will be scanned except for the reference azimuth of 287° where the same elevations as prescribed for the 1D-MAXDOAS systems will be used.
  - 1 zenith reference spectrum shall recorded per 15' sequence
  - For instruments having the appropriate technical capabilities, direct-sun measurements or 1 almucantar scan shall performed between the 10^{th} and 15^{th} minutes of the sequence
- For Zenith-DOAS systems:
  - Zenith measurements of one minute total integration shall be performed during the whole day from 06:00.00 UTC to 16:44:00 UTC

These data acquisition schemes are described in tabular form in Table 4 and Table 5. The corresponding variation of the viewing elevation and relative azimuth angles around noon are represented for the 2D-MAXDOAS and 1D-MAXDOAS systems in Figure 15 and Figure 16, respectively.

Table 4: **Data acquisition scheme for daytime conditions at the following UTC times (hh in the Table): 06, 07, 08, 09, 10, 12, 13, 14, 15, 16h.**

TIME (UTC)	2D-MAXDOAS		1D-MAXDOAS	Zenith
	Azimuth(°) 0° : north ; 90° : east 180° : south ; 270° : west	Elevation (°)	Pointing direction : 287°	
hh:00:00	287	1	1	x
	287	2	2	x
	287	3	3	x
	287	4	4	x
	287	5	5	x
hh:05:00	287	6	6	x
	287	8	8	x
	287	15	15	x
	287	30	30	x
	287	90	90	x
hh:10:00	Direct-sun acquisition, or continued zenith-sky		90	x
			90	x
			90	x
			90	x
			90	x
hh:15:00	355	1	1	x
	355	3	2	x
	355	5	3	x
	355	15	4	x
	move	move	5	x

hh:20:00	45	1	6	x
	45	3	8	x
	45	5	15	x
	45	15	30	x
	45	90	90	x
hh:25:00	Almucantar scan: 15 measurements with a 10s integration time + 5s overhead at solar elevation for the following relative azimuth angles*: -15, -10, -6, -5, 5, 6, 10, 15, 30, 50, 70, 90, 120, 150, and 180°. Or continued zenith-sky.		90	x
			90	x
			90	x
			90	x
			90	x
hh:30:00	95	1	1	x
	95	3	2	x
	95	5	3	x
	95	15	4	x
	move	move	5	x
hh:35:00	135	1	6	x
	135	3	8	x
	135	5	15	x
	135	15	30	x
	135	90	90	x
hh:40:00	Direct-sun acquisition, or continued zenith-sky		90	x
			90	x

			90	x
			90	x
			90	x
hh:45:00	195	1	1	x
	195	3	2	x
	195	5	3	x
	195	15	4	x
	move	move	5	x
hh:50:00	245	1	6	x
	245	3	8	x
	245	5	15	x
	245	15	30	x
	245	90	90	x
hh:55:00	Almucantar scan: 15 measurements with a 10s integration time + 5s overhead at solar elevation for the following relative azimuth angles*: -15, -10, -6, -5, 5, 6, 10, 15, 30, 50, 70, 90, 120, 150, and 180°. Or continued zenith-sky.		90	x
			90	x
			90	x
			90	x
			90	x

***For instruments which need an overhead time longer than 5s, the number of relative azimuth angles (RAA) should be reduced in such a way that the total time of 225s for this Almucantar sequence is kept. The measurements at the selected RAA should also be synchronized with those from the faster instruments. RAA values are given with respect the current position of the sun and not its position at the start of the Almucantar sequence. The sign convention for the relative azimuth angle is + for the hemisphere which is clockwise with respect to the instrument-sun direction and – for the other hemisphere.**

Table 5: Data acquisition scheme for noon conditions between 11:00:00 UTC and 11:59:00 UTC. It includes a zenith-only acquisition sequence between 11:30:00 and 11:41:00 UTC and a horizon scan between 11:41:00 and 11:44:00 UTC.

TIME (UTC)	2D-MAXDOAS		1D-MAXDOAS	Zenith
	Azimuth(°) 0° : north ; 90° : east 180° : south ; 270° : west	Elevation (°)	Pointing direction : 287°	
hh:00:00	287	1	1	x
	287	2	2	x
	287	3	3	x
	287	4	4	x
	287	5	5	x
hh:05:00	287	6	6	x
	287	8	8	x
	287	15	15	x
	287	30	30	x
	287	90	90	x
hh:10:00	Direct-sun acquisition, or continued zenith-sky		90	x
			90	x
			90	x
			90	x
			90	x
hh:15:00	287	1	1	x
	287	2	2	x
	287	3	3	x
	287	4	4	x
	287	5	5	x

hh:20:00	287	6	6	x
	287	8	8	x
	287	15	15	x
	287	30	30	x
	287	90	90	x
hh:25:00	Almucantar scan: 15 measurements with a 10s integration time + 5s overhead at solar elevation for the following relative azimuth angles*: -15, -10, -6, -5, 5, 6, 10, 15, 30, 50, 70, 90, 120, 150, and 180°. Or continued zenith-sky.		90	x
			90	x
			90	x
			90	x
			90	x
hh:30:00	287	90	90	x
	287	90	90	x
	287	90	90	x
	287	90	90	x
	287	90	90	x
hh:35:00	287	90	90	x
	287	90	90	x
	287	90	90	x
	287	90	90	x
	287	90	90	x
hh:40:00	287	90	90	x
	287	Horizon scan between -5° and +5° above the horizon with a step of 0.2° between -2 and +2° and a step of 1° outside this		x
	287			x

	287	range. 5s integration time + 5s overhead per elevation		x
	287			x
hh:45:00	287	1	1	x
	287	2	2	x
	287	3	3	x
	287	4	4	x
	287	5	5	x
hh:50:00	287	6	6	x
	287	8	8	x
	287	15	15	x
	287	30	30	x
	287	90	90	x
hh:55:00	Direct-sun acquisition, or continued zenith-sky		90	x
			90	x
			90	x
			90	x
			90	x

***For instruments which need an overhead time longer than 5s, the number of relative azimuth angles (RAA) should be reduced in such a way that the total time of 225s for this Almucantar sequence is kept. The measurements at the selected RAA should also be synchronized with those from the faster instruments. RAA values are given with respect the current position of the sun and not its position at the start of the Almucantar sequence. The sign convention for the relative azimuth angle is + for the hemisphere which is clockwise with respect to the instrument-sun direction and – for the other hemisphere.**

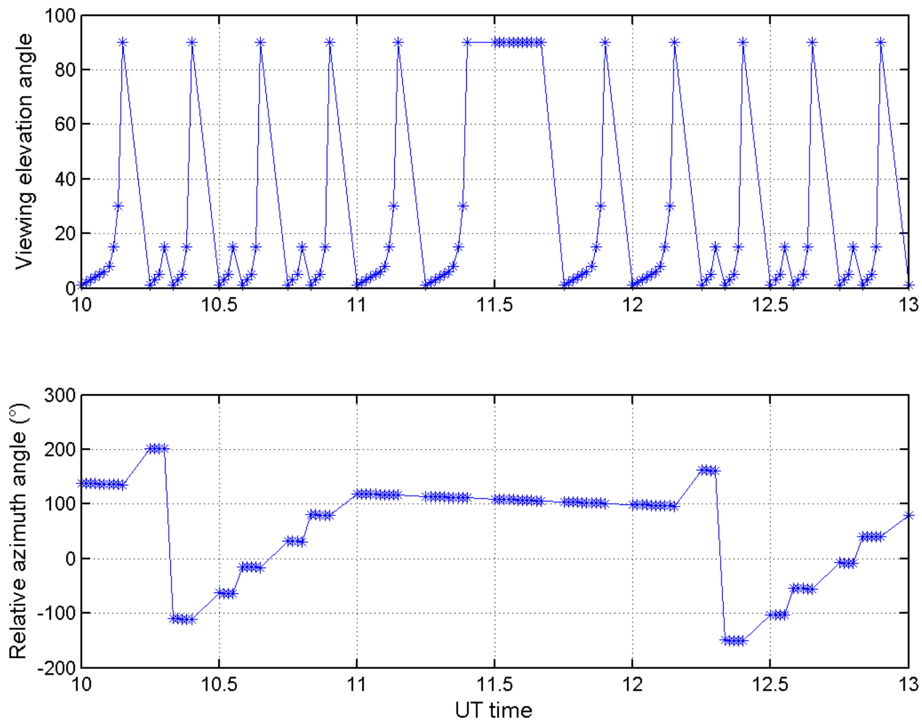

Figure 15: Variation of the viewing elevation and relative azimuth angles around noon for 2D-MAXDOAS systems (calculated for the conditions of 12/09/2016, in Cabauw).

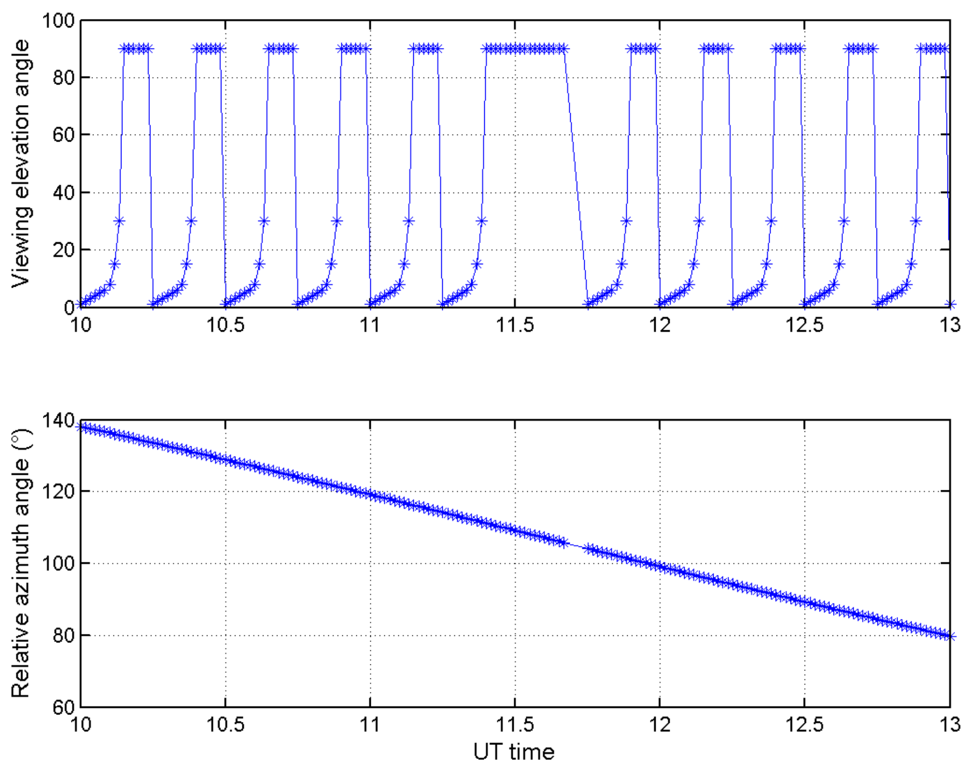

Figure 16: Variation of the viewing elevation and relative azimuth angles around noon for 1D-MAXDOAS systems (calculated for the conditions of 12/09/2016, in Cabauw).

11.7 Target species and retrieval settings

The semi-blind intercomparison exercise will focus on a limited number of key data products of direct relevance for satellite validation and NDACC operation continuity. These products are list in Table 6. Note that it is not mandatory to provide results for all data products. Depending on the specific characteristics of their instrumentation, participants are free to contribute only a subset of the data products. This will be communicated to the campaign referee ahead of the comparison exercise.

Table 6: Data products included in the semi-blind intercomparison exercise.

Data product	**Typical wavelengths**
NO_2 (VIS range)	425 – 490 nm
NO_2 (UV range)	338 – 370 nm
O_4 (VIS range)	425 – 490 nm
O_4 (UV range)	338 – 370 nm
HCHO	336.5 – 359 nm
O_3 (Chappuis bands)	450 – 520 nm
O_3 (Huggins bands)	320 – 340 nm
Relative intensity	340, 380, 440, 500 nm
Colour Index	To be defined

For each data product, a set of retrieval settings and parameters is prescribed. The use of these settings will be mandatory for participation in the semi-blind exercise. A preliminary version of the CINDI-2 prescribed settings is given in the Tables below. These settings are based on the experience and results from the recent MADCAT (http://joseba.mpch-mainz.mpg.de/mad_analysis.htm) and QA4ECV intercomparison exercises. The corresponding spectral data (absorption cross sections and solar spectra) will be made available for the campaign on the CINDI-2 ftp server. A final baseline will be defined during the warm-up period in the first week of the campaign, and frozen upon consensus for the semi-blind intercomparison period.

Note that the reported intensities should be calculated without normalisation with respect to the noon spectrum, i.e. using the formula: *I=total_counts/total_integration_time* (or equivalent according to individual acquisition schemes). They should be provided in the trace gas data files, if possible at similar wavelengths as AERONET: 340, 380, 440, 500, 675, 870, and 1020 nm.

Colour indices CI should be defined as the ratio of the intensity of the lowest over the highest wavelength:

$I_{\lambda,low}/I_{\lambda,high}$.

Table 7: DOAS settings for NO_2 and O_4 (VIS range)

Wavelength range	425-490 nm
Fraunhofer reference	Noon zenith spectra averaged between 11:30:00 and 11:40:00 UT

spectra	
Cross-sections:	
NO_2 (298 K)	Vandaele et al. (1998) with I_0 correction (SCD of 10^{17} molecules/cm^2) File: no2_298K_vanDaele.xs
NO_2 (220 K)	Pre-orthogonalized Vandaele et al. (1998) with I_0 correction (SCD of 10^{17} molecules/cm^2) File: no2a_220p298K_vanDaele_425-490nm.xs
O_3 (223 K)	Serdyuchenko et al. (2014) with I_0 correction (SCD of 10^{20} molecules/cm^2) File: o3_223K_SDY_air.xs
O_4 (293 K)	Thalman and Volkamer (2013) File: o4_thalman_volkamer_293K_inAir.xs
H_2O	HITEMP (Rothman et al., 2010) File: H2O_HITEMP_2010_390-700_296K_1013mbar_air.xs
Ring	RING_QDOAS_SAO2010 File: Ring_QDOAScalc_HighResSAO2010_Norm.xs
Polynomial degree	Order 5 (6 coefficients)
Intensity off-set	Constant

Table 8: DOAS settings for NO_2 and O_4 (alternative VIS range)

Wavelength range	411-445 nm
Fraunhofer reference spectra	Noon zenith spectra averaged between 11:30:00 and 11:40:00 UT
Cross-sections:	
NO_2 (298 K)	Vandaele et al. (1998) with I_0 correction (SCD of 10^{17} molecules/cm^2) File: no2_298K_vanDaele.xs
NO_2 (220 K)	Pre-orthogonalized Vandaele et al. (1998) with I_0 correction (SCD of 10^{17} molecules/cm^2) File: no2a_220p298K_vanDaele_425-490nm
O_3 (223 K)	Serdyuchenko et al. (2014) with I_0 correction (SCD of 10^{20} molecules/cm^2) File: o3_223K_SDY_air.xs
O_4 (293 K)	Thalman and Volkamer (2013) File: o4_thalman_volkamer_293K_inAir.xs
H_2O	HITEMP (Rothman et al., 2010) File: H2O_HITEMP_2010_390-700_296K_1013mbar_air.xs
Ring	RING_QDOAS_SAO2010 File: Ring_QDOAScalc_HighResSAO2010_Norm.xs
Polynomial degree	Order 4 (5 coefficients)
Intensity off-set	Constant

Table 9: DOAS settings for NO_2 and O_4 (UV range)

Wavelength range	338-370 nm
Fraunhofer reference spectra	Noon zenith spectra averaged between 11:30:00 and 11:40:00
Cross-sections:	
NO_2 (298 K)	Vandaele et al. (1998) with I_0 correction (SCD of 10^{17} molecules/cm^2) File: no2_298K_vanDaele.xs
NO_2 (220 K)	Pre-orthogonalized Vandaele et al. (1998) with I_0 correction (SCD of 10^{17} molecules/cm^2) File: no2a_220p298K_vanDaele_338-370nm.xs
O_3 (223 K)	Serdyuchenko et al. (2014) with I_0 correction (SCD of 10^{20} molecules/cm^2) File: o3_223K_SDY_air.xs
O_3 (243 K)	Pre-orthogonalized Serdyuchenko et al. (2014) with I_0 correction (SCD of 10^{20}

	molecules/cm^2) File: o3a_243p223K_SDY_338-370nm.xs
O_4 (293 K)	Thalman and Volkamer (2013) File: o4_thalman_volkamer_293K_inAir.xs
HCHO (297 K)	Meller and Moortgat (2000) File: hcho_297K_Meller.xs
BrO (223 K)	Fleischmann et al. (2004) File: bro_223K_Fleischmann.xs
Ring	RING_QDOAS_SAO2010 File: Ring_QDOAScalc_HighResSAO2010_Norm.xs
Polynomial degree	Order 5 (6 coefficients)
Intensity off-set	Constant

Table 10: DOAS settings for HCHO

Wavelength range	336.5-359 nm
Fraunhofer reference spectra	Noon zenith spectra averaged between 11:30:00 and 11:40:00 UT
Cross-sections:	
HCHO (297 K)	Meller and Moortgat (2000) File: hcho_297K_Meller.xs
NO_2 (298 K)	Vandaele et al. (1998) with I_0 correction (SCD of 10^{17} molecules/cm^2) File: no2_298K_vanDaele.xs
O_3 (223 K)	Serdyuchenko et al. (2014) with I_0 correction (SCD of 10^{20} molecules/cm^2) File: o3_223K_SDY_air.xs
O_3 (243 K)	Pre-orthogonalized Serdyuchenko et al. (2014) with I_0 correction (SCD of 10^{20} molecules/cm^2) File: o3a_243p223K_SDY_324-359nm.xs
O_4 (293 K)	Thalman and Volkamer (2013) File: o4_thalman_volkamer_293K_inAir.xs
BrO (223 K)	Fleischmann et al. (2004) File: bro_223K_Fleischmann.xs
Ring	RING_QDOAS_SAO2010 File: Ring_QDOAScalc_HighResSAO2010_Norm.xs
Polynomial degree	Order 5 (6 coefficients)
Intensity off-set	Order 1

Table 11: DOAS settings ozone in the Chappuis band

Wavelength range	450-520 nm
Fraunhofer reference spectra	Noon zenith spectra averaged between 11:30:00 and 11:40:00 UT
Cross-sections:	
O_3 (223 K)	Serdyuchenko et al. (2014) with I_0 correction (SCD of 10^{20} molecules/cm^2) File: o3_223K_SDY_air.xs
O_3 (293 K)	Pre-orthogonalized Serdyuchenko et al. (2014) with I_0 correction (SCD of 10^{20} molecules/cm^2) File: o3a_293p223K_SDY_450-550nm.xs
NO_2 (298 K)	Vandaele et al. (1998) with I_0 correction (SCD of 10^{17} molecules/cm^2) File: no2_298K_vanDaele.xs
NO_2 (220 K)	Pre-orthogonalized Vandaele et al. (1998) with I_0 correction (SCD of 10^{17} molecules/cm^2) File: no2a_220p298K_vanDaele_450-550nm.xs

O_4 (296 K)	Thalman and Volkamer (2013) File: o4_thalman_volkamer_293K_inAir.xs
H_2O	HITEMP (Rothman et al., 2010) File: H2O_HITEMP_2010_390-700_296K_1013mbar_air.xs
Ring	RING_QDOAS_SAO2010 File: Ring_QDOAScalc_HighResSAO2010_Norm.xs
Polynomial degree	Order 5 (6 coefficients)
Intensity off-set	Order 1

Table 12: DOAS settings ozone in the Huggins band

Wavelength range	320-340 nm
Fraunhofer reference spectra	Noon zenith spectra averaged between 11:30:00 and 11:40:00 UT
Cross-sections:	
O_3 (223 K)	Serdyuchenko et al. (2014) with I_0 correction (SCD of 10^{20} molecules/cm^2) File: o3_223K_SDY_air.xs
O_3 (293 K)	Pre-orthogonalized Serdyuchenko et al. (2014) with I_0 correction (SCD of 10^{20} molecules/cm^2) File: o3a_293p223K_SDY_320-340nm.xs
O_3	Non-linear correction terms (Puķīte et al., 2010) Files: o3_SDY_Pukite1_320-340nm.xs and o3_SDY_Pukite2_320-340nm.xs
NO_2 (298 K)	Vandaele et al. (1998) with I_0 correction (SCD of 10^{17} molecules/cm^2) File: no2_298K_vanDaele.xs
HCHO (297 K)	Meller and Moortgat (2000) File: hcho_297K_Meller.xs
Ring	RING_QDOAS_SAO2010 File: Ring_QDOAScalc_HighResSAO2010_Norm.xs
Polynomial degree	Order 3 (4 coefficients)
Intensity off-set	Order 1

11.8 Data reporting

The output data file format used for the semi-blind intercomparison will be based on the ascii format adopted for the MADCAT campaign. Example files for all target species and wavelength domains can be found on the ftp server of the campaign. File headers include all necessary information on instrument and data provider, column content, and DOAS settings (see examples in Appendix D of the present document).

For the file naming, we propose the following convention (one file per day and per species/wavelength domain):

Institute_MAXDOAS_ InstrumentNr _species+wavelengthdomain_CINDI2_yyyymmdd_vx.asc

where *Institute* is the Institute acronym, *Nr* is the campaign number of the instrument (see Table 1), *species* is NO2/HCHO/O3, *wavelengthdomain* is the wavelength range (uv, vis, visSmall), *yyyymmdd* is the date, and *x* is the version of the file.

11.9 Daily Briefings

For the whole duration of the semi-blind intercomparison, daily briefings will be organised in a dedicated cabin at around 16:00 local time. WebEx access for these meetings will be organized for participants who are not on-site. The aim of these daily workshops will be to present an overview on the status of the intercomparison and discuss various scientific, organisational or logistical points.

In order to be included in the daily overview plots, data shall be turned in for analysis on the dedicated FTP-site before 10:00 LT (i.e. 8:00 UTC). In case data cannot be submitted in time for a given day, this data set will not be part of the comparison for that day. Later the complete data sets will of course be intercompared.

11.10 Intercomparison protocols

The data policy and intercomparison protocols can be found In FRM_4DOAS Deliverable D14 (Campaign Data Protocol).

12 List of participants

Table 13: List of participants (a live version of the participant list will be maintained as a Google Docs document accessible to all participants).

	Name + First name	Affiliation	E-mail address	Mobile phone number	Period(s) of on-site presence + arrival of the instruments
1	Ang, Li	AIOFM	angli@aiofm.ac.cn	+ 86-13855196384	
2	Anguas, Mónica	CSIC	manguas@iqfr.csic.es		
3	Apituley, Arnoud	KNMI	apituley@knmi.nl	+31655457540	26 Aug. – 10. Sept.
4	Bais, Alkis	AUTH	abais@auth.gr	+30 6977558850	8-14 Sep
5	Benavent, Nuria	CSIC	nbenavent@iqfr.csic.es	+34 633473877	3-28 Sep
6	Bognar, Kristof	U. Toronto	kbognar@physics.utoronto.ca	+ 06-30-494-8464 (or + 1-416-566-6763)	31 Aug-30 Sep
7	Alexander Borovski	A.M. Obukhov Institute of Atmospheric Physics	alexander.n.borovski@gmail.com	+7 915 390 56 45	(01-05) – (25-30) Sep 2016
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10	Chan, Ka Lok	LMU	lok.chan@physik.uni-muenchen.de	+49 089 2180 4386	
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	Manuel				
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14 References

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Appendix A: Technical characteristics of static MAXDOAS systems

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

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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

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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

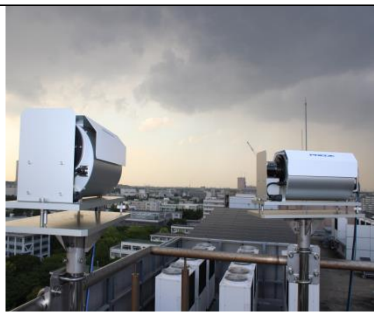
Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** Acton Standard Series SP-2356 Imaging Spectrograph **Detector type:** PIX100B-SF-Q-F-A **Optical fibers:** Y-type quartz bundle, diameter: 150µm, length: 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^{o} **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

<table>
<tr><td colspan="2"><u>Institute:</u> Chinese Academy of Meteorology Science, China Meteorological Administration, Beijing, China
<u>Responsible person(s):</u> Junli Jin, Jianzhong Ma
<u>Contact details:</u> jinjunli@camscma.cn, mobile phone: +86 13426397058</td><td rowspan="2"></td></tr>
<tr><td><u>Instrument type:</u> mini-DOAS Hoffmann UV (#1)</td><td><u>Nr:</u>
CINDI-2.07</td></tr>
</table>

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^{o} **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

<u>Institute:</u> University of Colorado, Boulder, Colorado

<u>Responsible person(s):</u> Rainer Volkamer

<u>Contact details:</u> Rainer.Volkamer@colorado.edu

<u>Instrument type:</u> ZS & MAXDOAS (1D)

<u>Nr:</u> 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

<table>
<tr><td colspan="2"><u>Institute 1:</u> Institut fuer Methodik der Fernerkundung (IMF), Deutsches Zentrum fuer Luft- und Raumfahrt e.V. (DLR), Wessling, Germany
<u>Institute 2:</u> School of Earth and Space Sciences, University of Science and Technology of China (USTC), Hefei, Anhui, China
<u>Responsible person(s):</u> Nan Hao (DLR) and Cheng Liu (USTC)
<u>Contact details:</u> nan.hao@dlr.de, Chliu81@ustc.edu.cn</td><td rowspan="2"></td></tr>
<tr><td><u>Instrument type:</u> 1D MAXDOAS EnviMeS (#1)</td><td><u>Nr:</u>
CINDI-2.13
CINDI-2.14</td></tr>
</table>

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 m^3 (length x width x height) **Indoor space requirements:** 0.6x0.6x0.5 m^3 (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

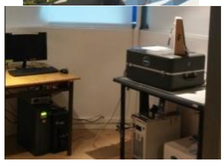
Responsible person(s): Abhishek Kumar Mishra and Vinod Kumar

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^{o} **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 CINDI-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

Contact details: thomas.wagner@mpic.de (mobile phone: +491629228450)

Instrument type: TubeMAXDOAS

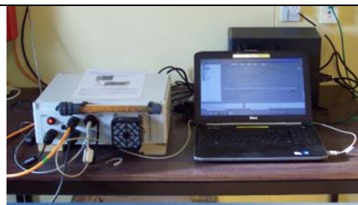
Nr: CINDI-2.28

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° **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

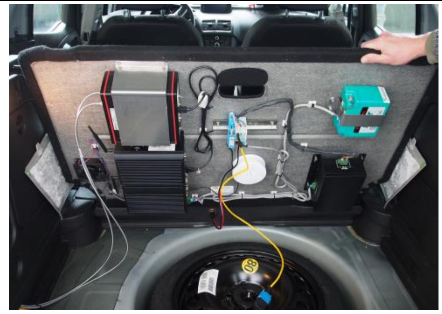
Appendix B: Technical characteristics of the static Imaging-DOAS systems

<table>
<tr><td colspan="2"><u>Institute:</u> Institute for Environmental Physics (IUP), University of Bremen, Bremen, Germany
<u>Responsible person(s):</u> Enno Peters
<u>Contact details:</u> Enno.Peters@iup.physik.uni-bremen.de, mobile phone: +49 171 6761981</td><td rowspan="2">Instrument picture</td></tr>
<tr><td><u>Instrument type:</u> single channel scientific grade imaging-DOAS, telescope mounted on pan-tilt-head for azimuthal scans and zenith (reference) pointing, indoor parts equipped in a 19'' rack</td><td><u>Nr:</u>
CINDI-2.37</td></tr>
</table>

<table>
<tr><td>Overall design of the instrument</td><td>Optical head including telescope: separated; elevation and azimuth angles fully configurable
Spectrometer type: Andor Shamrock 303i
Detector type: Andor Newton DU940P-BU, 2048x512 pixel (only inner pixels for imaging)
Optical fibers: Fibre bundle with 69 sorted single fibres, diameter: 100µm, length: 15m
Filters: BG39
Mirrors: no
Temperature control of spectrometer and detector: 35°C/-30°C</td></tr>
<tr><td>Instrument performance</td><td>Spectral range/resolution: To be decided/~0.50 nm
Azimuthal scan/direct-sun capabilities: yes/n/a
Elevation angle capability: fully configurable
Field of view: to be decided, vertically approx. 50°, horizontally 1.2°
Typical integration time: 10s
Typical scan duration: 10 min for complete horizon scan (10° azimuthal steps 0-360° followed by zenith reference)</td></tr>
<tr><td>Calibration/characterization procedures</td><td>Elevation angles: to be decided; probably between -5 and +30 + regular zenith-sky
Field of view: white light source in lab
Straylight: not yet characterized
Dark signal: manually
Line shape: HgCd lamp (manually)
Polarization: -
Detector nonlinearity: white light source in lab, characterization only
Pixel-to-pixel variability: white light source in lab, characterization only</td></tr>
<tr><td>Spectral analysis software</td><td>NLIN</td></tr>
<tr><td>Supporting measurements</td><td>Video camera</td></tr>
<tr><td>Special needs/requests regarding logistics</td><td>Power supply/consumption: 220 V/ 350 W on average; 700 W peak
Internet: remote desktop + ftp
Outdoor space requirements: 1.5 x 1.5 m^2 space for telescope tripod outdoors, free view of horizon
Indoor space requirements: 1 x 1 m^2 space indoors for rack, 80kg, no more than 25°C
Maximum distance between telescope and spectrometer: 8 m</td></tr>
</table>

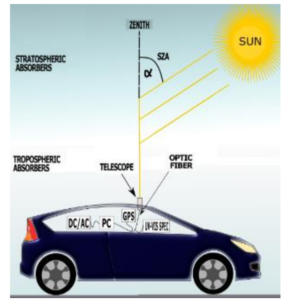
Institute: Technical Research Centre of Finland VTT and Finnish Meteorological Institute (FMI) **Responsible person(s):** Heikki Saari (VTT), Harri Ojanen (VTT) and Johanna Tamminen (FMI), Jukka Kujanpää (FMI) **Contact details:** Heikki.saari@vtt.fi, harri.ojanen@vtt.fi, Johanna.tamminen@fmi.fi, jukka.kujanpaa@fmi.fi	
Instrument type: Imaging spectrometers	**Nr:** CINDI-2.38
Overall design of the instrument	**Optical head including telescope:** elevation and azimuth angles fully configurable **Spectrometer type:** Fabry-Pérot interferometer based hyperspectral imagers for different wavelength ranges in a single telescope mount **Detector type:** UV enhanced CCD, CMOS (Vis), InGaAs (Nir) **Optical fibers:** n/a **Filters:** Interchangeable band pass filters for wavelength range selection and ND filters **Mirrors:** n/a **Temperature control of spectrometer and detector:** uncooled
Instrument performance	**Spectral range/resolution:** UV instrument uses a tunable transmission comb for matching with trace gas absorbance **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable **Field of view:** 7^{o} full frame **Typical integration time:** 0.1ms – 100ms **Total time for a measurement cycle:** 1s - 10s
Calibration/characterization procedures	**Elevation angles:** TBD **Field of view:** TBD **Straylight:** TBD **Dark signal:** TBD **Line shape:** TBD **Polarization:** TBD **Detector nonlinearity:** TBD **Pixel-to-pixel variability**: TBD
Spectral analysis software	In house software
Supporting measurements	Ocean Optics HR4000 and NirQuest in the same mount
Special needs/requests regarding logistics	**Power supply/consumption:** 230V /100 W **Internet:** yes (preferably wired) **Outdoor space requirements:** 1m x 1m for instrument + working area for scientists **Indoor space requirements:** 1m x 1m x 1m (for overnight storage), desk area for scientists **Maximum distance between telescope and spectrometer:** n/a **Indoor facility: -**

Appendix C: Technical characteristics of the mobile-DOAS systems

Institute: Royal Belgian Institute for space Aeronomy (BIRA-IASB), Brussels, Belgium **Responsible person(s):** Alexis Merlaud, Frederik Tack **Contact details:** alexis.merlaud@aeronomie.be, mobile phone: +32 486 963 937	
Instrument type: Car-DOAS	**Nr:** CINDI-2.45

Overall design of the instrument	**Optical head including telescope:** separated; Two telescopes (one for zenith and one for 30° elevation) **Spectrometer type zenith:** Avantes-2048, Grating UB, 50 um slit, 75 mm bench, coating DUV-800 and OSC-UB **Spectrometer type 30° elevation:** Avantes-2048, same characteristics **Detector type:** Sony CCD 2048 linear array **Optical fibers:** 2 chrome plated brass mono fibers, diameter: 400 µm, length: 2.5 m **Temperature control of UV and vis spectrometers and detector:** no
Instrument performance	**Spectral range/resolution:** 270–500/1.15 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** zenith and 30° elevation **Field of view:** 2.5° **Typical integration time:** 30s **Typical scan duration:** n/a
Calibration/characterization procedures	**Elevation angles:** with a light source before the campaign **Field of view:** with a lamp in the lab before the campaign **Straylight:** estimated from UV signal during measurements **Dark signal:** nightly measurements **Line shape:** Hg-Cd lamp before the campaign **Polarization:** With a polarizer in the lab before the campaign **Detector nonlinearity:** with a lamp before the campaign **Pixel-to-pixel variability**: Avantes spec
Spectral analysis software	QDOAS
Supporting measurements	GPS antenna
Special needs/requests regarding logistics	**Power supply/consumption:** car battery **Internet:** n/a **Outdoor space requirements:** n/a **Indoor space requirements:** n/a **Maximum distance between telescope and instruments:** n/a **Indoor facility:** n/a

<table>
<tr><td colspan="2"><u>Institute:</u> MPI for Chemistry, Mainz, Germany
<u>Responsible person(s):</u> Thomas Wagner
<u>Contact details:</u> thomas.wagner@mpic.de; +49 6131 3054700; mobile +49 162 9228450</td><td rowspan="2"></td></tr>
<tr><td><u>Instrument type:</u> Car-MAX-DOAS</td><td><u>Nr:</u>
CINDI-2.46</td></tr>
<tr><td>Overall design of the instrument</td><td colspan="2">Optical head including telescope: integrated in instrument
Spectrometer type: Ocean optics USB2000, integrated in instrument
Detector type: 1D- CCD, integrated in instrument
Optical fibers: monofibre, ca. 1.5m, diameter: 400 µm
Filters: yes
Mirrors: only inside spectrometer
Temperature control of spectrometer and detector: yes</td></tr>
<tr><td>Instrument performance</td><td colspan="2">Spectral range/resolution: 299 – 451 nm/0.6 – 0.9 nm
Azimuthal scan/direct-sun capabilities: no/no
Elevation angle capability: yes
Field of view: 1.2°
Typical integration time: 30 or 60 sec
Total time for a measurement cycle: 30 to 60 sec</td></tr>
<tr><td>Calibration/characterization procedures</td><td colspan="2">Elevation angles: water level
Field of view: elevation scan
Straylight: n/a
Dark signal: measurements with telescope covered
Line shape: mercury lamp
Polarization: n/a
Detector nonlinearity: n/a
Pixel-to-pixel variability: n/a</td></tr>
<tr><td>Spectral analysis software</td><td colspan="2">WINDOAS, MDOAS</td></tr>
<tr><td>Supporting measurements</td><td colspan="2">Video camera, GPS</td></tr>
<tr><td>Special needs/requests regarding logistics</td><td colspan="2">Power supply/consumption: car battery, external battery
Internet: n/a
Outdoor space requirements: n/a
Indoor space requirements: n/a
Maximum distance between telescope and instruments: n/a
Indoor facility: n/a</td></tr>
</table>

Institute: University of Galati, Galati, Roumania **Responsible person(s):** Daniel Constantin **Contact details:** Daniel.Constantin@ugal.ro, mobile phone: +40726320942		
Instrument type: Car-DOAS	**Nr:** CINDI-2.47	

Overall design of the instrument	**Optical head including telescope:** separated; zenith geometry only **Spectrometer type:** UV-Vis Avantes-AvaSpec-ULS2048XL **Detector type:** Back-thinned CCD image sensor 2048 pixels **Optical fibers:** one chrome plated brass mono fibers, diameter: 400 µm, length: 3 m **Filters:** n/a **Mirrors:** n/a **Temperature control of spectrometer and detector:** n/a
Instrument performance	**Spectral range/resolution:** 280–550/0.7 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** zenith only **Field of view:** 1.2^{o} **Typical integration time:** 30-200ms **Total time for a measurement cycle:** 10s
Calibration/characterization procedures	**Elevation angles:** n/a **Field of view:** 1.2^{o} **Straylight:** $< 0.3\%$ **Dark signal:** nightly measurements **Line shape:** n/a **Polarization:** by optical fiber **Detector nonlinearity:** n/a **Pixel-to-pixel variability**: n/a
Spectral analysis software	QDOAS
Supporting measurements	Video camera, GPS and G-Sensor with 3 axes
Special needs/requests regarding logistics	**Power supply/consumption:** car battery **Internet:** WLAN, ftp **Outdoor space requirements:** n/a **Indoor space requirements:** n/a **Maximum distance between telescope and instruments:** n/a **Indoor facility:** n/a

Institute: Institute for Environmental Physics (IUP), University of Bremen, Bremen, Germany **Responsible person(s):** Folkard Wittrock **Contact details:** folkard@iup.physik.uni-bremen.de, mobile phone: +49 175244350		
Instrument type: mobile 2 channel scientific grade elevation and azimuth scanning MAXDOAS	**Nr:** CINDI-2.48	

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type UV:** Isoplane SCT-320 Imaging Spectrograph **Spectrometer type vis:** Acton SP2156 **Detector type UV:** Princeton PIXIS:2KBUV **Detector type vis:** Princeton PIXIS:100B **Optical fibers:** Y-type quartz bundle, diameter: 150µm, length: 20m **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/-35°C
Instrument performance	**Spectral range/resolution UV:** 286–419/0.55 nm **Spectral range/resolution vis:** 413–524/0.65 nm **Azimuthal scan/direct-sun capabilities:** yes/no **Elevation angle capability:** fully configurable **Field of view:** 1^o **Typical integration time:** 5s; 15s for zenith **Typical scan duration:** 3 minutes
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:** 10 kVA, 32 A for whole truck **Internet:** yes, remote desktop **Outdoor space requirements:** 8x3 m for whole truck, height of telescope 3.8 m agl **Indoor space requirements:** n/a **Maximum distance between telescope and instruments:** n/a

Appendix D: Output file format description

We provide 6 examples of output format for HCHO, NO_2 in the UV range, NO_2 in the visible range, NO_2 in the specific mini-DOAS interval, and O_3 in the visible Chappuis and UV Huggins Bands.

The corresponding output files will use the following naming convention:

Institute_MAXDOAS_InstrumentNr_species+wavelengthdomain_CINDI2_yyyymmdd_vx.asc

Example: assuming data produced with the BIRA instrument, the following files will be generated:

- BIRA_MAXDOAS_5_HCHO_CINDI2_20160901_v1.asc (HCHO in the 336.5-359 nm range)
- BIRA_MAXDOAS_5_NO2uv_CINDI2_20160901_v1.asc (NO_2 in the 338-370 nm range)
- BIRA_MAXDOAS_5_NO2vis_CINDI2_20160901_v1.asc (NO_2 in the 425-490 nm range)
- BIRA_MAXDOAS_5_NO2visSmall_CINDI2_20160901_v1.asc (NO_2 in the 411-445 nm range)
- BIRA_MAXDOAS_5_O3vis_CINDI2_20160901_v1.asc (O_3 in the 450-550 nm range)
- BIRA_MAXDOAS_5_O3uv_CINDI2_20160901_v1.asc (O_3 in the 320-340 nm range)

```
* NofHeaderlines: 48
* NofColumns: 27 (if any info missing, put -999, even if it's the whole column)
* Instrument identifier: BIRA_MAXDOAS
* Retrieval code: QDOAS (v2.110, June 2015)
* Created by: Gaia Pinardi
* Version: HCHO_v1
*  X-Axis (Col  1) = Day of year (DOY) 2016   (please start with 0.0 for January 1st, 0:00 UTC)
* Y1-Axis (Col  2) = Time of day in hours (UTC)
* Y2-Axis (Col  3) = Total Integration Time(s)
* Y3-Axis (Col  4) = Solar Zenith Angle (°)
* Y4-Axis (Col  5) = Solar Azimuth Angle (°) North=0, East=90
* Y5-Axis (Col  6) = Elevation Angle (°)
* Y6-Axis (Col  7) = Viewing Angle (°) North=0, East=90
* Y7-Axis (Col  8) = HCHO_DSCD (1*10^15 molec/cm2)
* Y8-Axis (Col  9) = HCHO_DSCD_Error (1*10^15 molec/cm2)
* Y9-Axis (Col 10) = O4_DSCD (1*10^40 molec2/cm5)
* Y10-Axis (Col 11) = O4_DSCD_Error (1*10^40 molec2/cm5)
* Y11-Axis (Col 12) = NO2_DSCD_298  (1*10^15 molec/cm2)
* Y12-Axis (Col 13) = NO2_DSCD_298_Error  (1*10^15 molec/cm2)
* Y13-Axis (Col 14) = O3_DSCD_223 (1*10^20 molecules/cm2)
* Y14-Axis (Col 15) = O3_DSCD_223_Error (1*10^20 molecules/cm2)
* Y15-Axis (Col 16) = O3a_DSCD_243 (1*10^20 molecules/cm2)
* Y16-Axis (Col 17) = O3a_DSCD_243_Error (1*10^20 molecules/cm2)
* Y17-Axis (Col 18) = BrO_DSCD (1*10^15 molec/cm2)
* Y18-Axis (Col 19) = BrO_DSCD_Error (1*10^15 molec/cm2)
* Y19-Axis (Col 20) = Ring
* Y20-Axis (Col 21) = Ring_Error
* Y21-Axis (Col 22) = Fit RMS (in OD)
* Y22-Axis (Col 23) = Spectrum shift (nm, against FRS reference)
* Y23-Axis (Col 24) = Relative Intensity (counts/integration time @ 340nm)
* Y24-Axis (Col 25) = Colour index: (340 nm / 359 nm)
* Y25-Axis (Col 26) = intensity offset with normalisation by I, I is the mean intensity in the
spectral analysis windows, constant term
* Y26-Axis (Col 27) = intensity offset, linear term
* Fit settings: 1
* Fitting Window: 336.5-359 nm
* Polynomial: 5 (6 coefficients)
* Offset: 1st order
*  Calibration:  Based  on  reference  SAO  solar  spectra  (Chance  and  Kurucz,  2010)  -->
sao2010_solref_air.dat
* Wavelength adjustment: all spectra shifted and stretched against reference spectrum
* Reference: noon zenith spectra averaged between 11:30:00 and 11:40:00
*    HCHO  : Meller and Moortgat (2000), 297 K --> file: hcho_297K_Meller.xs
*     O4   : Thalman_volkamer, 293 K  --> file: o4_thalman_volkamer_293K_inAir.xs
*     NO2   : Vandaele et al. (1998), 298 K with I0 correction (1*10^17 molecules/cm2) --> file:
no2_298K_vanDaele.xs
*      O3   : Serdyuchenko  et al., (2014), 223 K with I0 correction (1*10^20 molecules/cm2) -->
file: o3_223K_SDY_air.xs
*     O3a   : Serdyuchenko  et al., (2014), 243 K with I0 correction (1*10^20 molecules/cm2) pre-
orthogonalized --> file: o3a_243p223K_SDY_324-359nm.xs
*    BrO   : Fleischmann et al. (2004), 223 K --> file: bro_223K_Fleischmann.xs
*    RING    : High Resolution calculation with QDOAS according to Chance and Spurr (1997) and
normalized as in Wagner et al. (2009) --> file: Ring_QDOAScalc_HighResSAO2010_Norm.xs
*DOY    UTC     Tint    SZA     SAA     Elev    Viewing_angle  HCHO_DSCD      HCHO_DSCD_error
        O4_DSCD O4_DSCD_error  NO2_DSCD_298   NO2_DSCD_298_Error    O3_DSCD_223
        O3_DSCD_223_Error      O3a_DSCD_243   O3a_DSCD_243_Error    BrO_DSCD       BrO_DSCD_Error
        Ring    Ring_Error     RMS     Spectrum_shift Intens(340)    CI(340/359)    offset_cst
        offset_lin
```

Frame 1: Header of the file for reporting HCHO analysed in the 336.5-359 nm wavelength range. Each line starts with a *. Lines not starting with * are due to a carriage return for presentation purpose here.

```
* NofHeaderlines: 50
* NofColumns: 28 (if any info missing, put -999, even if it's the whole column)
* Instrument identifier: BIRA_MAXDOAS
* Retrieval code: QDOAS (v2.110, June 2015)
* Created by: Gaia Pinardi
* Version: NO2uv_v1
*  X-Axis (Col  1) = Day of year (DOY) 2016   (please start with 0.0 for January 1st, 0:00 UTC)
* Y1-Axis (Col  2) = Time of day in hours (UTC)
* Y2-Axis (Col  3) = Total Integration Time(s)
* Y3-Axis (Col  4) = Solar Zenith Angle (°)
* Y4-Axis (Col  5) = Solar Azimuth Angle (°) North=0, East=90
* Y5-Axis (Col  6) = Elevation Angle (°)
* Y6-Axis (Col  7) = Viewing Angle (°) North=0, East=90
* Y7-Axis (Col  8) = NO2_DSCD_298 (1*10^15 molec/cm2)
* Y8-Axis (Col  9) = NO2_DSCD_298_Error (1*10^15 molec/cm2)
* Y9-Axis (Col 10) = O4_DSCD (1*10^40 molec2/cm5)
* Y10-Axis (Col 11) = O4_DSCD_Error (1*10^40 molec2/cm5)
* Y11-Axis (Col 12) = NO2a_DSCD_220  (1*10^15 molec/cm2)  (Fit results for the "cold NO2 residue")
* Y12-Axis (Col 13) = NO2a_DSCD_220_Error  (1*10^15 molec/cm2)
* Y13-Axis (Col 14) = O3_DSCD_223 (1*10^20 molecules/cm2)
* Y14-Axis (Col 15) = O3_DSCD_223_Error (1*10^20 molecules/cm2)
* Y15-Axis (Col 16) = O3a_DSCD (1*10^20 molecules/cm2)
* Y16-Axis (Col 17) = O3a_DSCD_Error (1*10^20 molecules/cm2)
* Y17-Axis (Col 18) = BrO_DSCD (1*10^15 molec/cm2)
* Y18-Axis (Col 19) = BrO_DSCD_Error (1*10^15 molec/cm2)
* Y19-Axis (Col 20) = HCHO_DSCD (1*10^15 molec/cm2)
* Y20-Axis (Col 21) = HCHO_DSCD_Error (1*10^15 molec/cm2)
* Y21-Axis (Col 22) = Ring
* Y22-Axis (Col 23) = Ring_Error
* Y23-Axis (Col 24) = Fit RMS (in OD)
* Y24-Axis (Col 25) = Spectrum shift (nm, against FRS reference)
* Y25-Axis (Col 26) = Relative Intensity (counts/integration time @ 340nm)
* Y26-Axis (Col 27) = Colour index: (340 / 370 nm)
* Y27-Axis (Col 28) = intensity offset with normalisation by I, I is the mean intensity in the
spectral analysis windows, constant term
* Fit settings: 1
* Fitting Window: 338-370 nm
* Polynomial: 5 (6 coefficients)
* Offset: 1st order
* Calibration: Based on reference SAO solar spectra (Chance and Kurucz, 2010) -->
sao2010_solref_air.dat
* Wavelength adjustment: all spectra shifted and stretched against reference spectrum
* Reference: noon zenith spectra averaged between 11:30:00 and 11:40:00
* NO2_298  : Vandaele et al. (1998), 298 K with I0 correction (1*10^17 molecules/cm2)  --> file:
no2_298K_vanDaele.xs
* NO2a_220  : Vandaele et al. (1998), 220 K with I0 correction (1*10^17 molecules/cm2) pre-
orthogonalized --> file: no2a_220p298K_vanDaele_338-370nm.xs
*   O3     : Serdyuchenko  et al., (2014), 223 K with I0 correction (1*10^20 molecules/cm2) -->
file: o3_223K_SDY_air.xs
*   O3a    : Serdyuchenko  et al., (2014), 243 K with I0 correction (1*10^20 molecules/cm2) pre-
orthogonalized --> file: o3a_243p223K_SDY_338-370nm.xs
*   O4     : Thalman and Volkamer 2013, 293 K  --> file: o4_thalman_volkamer_293K_inAir.xs
*   HCHO   : Meller and Moortgat (2000), 297 K --> file: hcho_297K_Meller.xs
*   BrO    : Fleischmann et al. (2004), 223 K  --> file: bro_223K_Fleischmann.xs
*    RING    : High Resolution calculation with QDOAS according to Chance and Spurr (1997) and
normalized as in Wagner et al. (2009) --> file: Ring_QDOAScalc_HighResSAO2010_Norm.xs
*DOY    UTC            Tint    SZA            SAA            Elev    Viewing_angle  NO2_DSCD_298
       NO2_DSCD_298_error     O4_DSCD O4_DSCD_error  NO2a_DSCD_220  NO2a_DSCD_220_Error
       O3_DSCD_223    O3_DSCD_223_Error      O3a_DSCD       O3a_DSCD_Error BrO_DSCD
       BrO_DSCD_Error HCHO_DSCD      HCHO_DSCD_Error        Ring    Ring_Error     RMS
       Spectrum_shift Intens(340)    CI(340/370)    offset_cst     offset_lin
```

Frame 2: Header of the file for reporting NO_2 and O_4 analysed in the 338-370 nm wavelength range. Each line starts with a *. Lines not starting with * are due to a carriage return for presentation purpose here.

```
* NofHeaderlines: 44
* NofColumns: 24 (if any info missing, put -999, even if it's the whole column)
* Instrument identifier: BIRA_MAXDOAS
* Retrieval code: QDOAS (v2.110, June 2015)
* Created by: Gaia Pinardi
* Version: NO2vis_v1
*  X-Axis (Col  1) = Day of year (DOY) 2016   (please start with 0.0 for January 1st, 0:00 UTC)
* Y1-Axis (Col  2) = Time of day in hours (UTC)
* Y2-Axis (Col  3) = Total Integration Time(s)
* Y3-Axis (Col  4) = Solar Zenith Angle (°)
* Y4-Axis (Col  5) = Solar Azimuth Angle (°) North=0, East=90
* Y5-Axis (Col  6) = Elevation Angle (°)
* Y6-Axis (Col  7) = Viewing Angle (°) North=0, East=90
* Y7-Axis (Col  8) = NO2_DSCD_298 (1*10^15 molec/cm2)
* Y8-Axis (Col  9) = NO2_DSCD_298_Error (1*10^15 molec/cm2)
* Y9-Axis (Col 10) = O4_DSCD (1*10^40 molec2/cm5)
* Y10-Axis (Col 11) = O4_DSCD_Error (1*10^40 molec2/cm5)
* Y11-Axis (Col 12) = NO2a_DSCD_220  (1*10^15 molec/cm2)
* Y12-Axis (Col 13) = NO2a_DSCD_220_Error  (1*10^15 molec/cm2)
* Y13-Axis (Col 14) = O3_DSCD_223 (1*10^20 molecules/cm2)
* Y14-Axis (Col 15) = O3_DSCD_223_Error (1*10^20 molecules/cm2)
* Y15-Axis (Col 16) = H2O_DSCD (1*10^23 molec/cm2)
* Y16-Axis (Col 17) = H2O_DSCD_Error (1*10^23 molec/cm2)
* Y17-Axis (Col 18) = Ring
* Y18-Axis (Col 19) = Ring_Error
* Y19-Axis (Col 20) = Fit RMS (in OD)
* Y20-Axis (Col 21) = Spectrum shift (nm, against FRS reference)
* Y21-Axis (Col 22) = Relative Intensity (counts/integration time @ 440nm)
* Y22-Axis (Col 23) = Colour index: (425 / 440 nm)
* Y23-Axis (Col 24) = intensity offset with normalisation by I, I is the mean intensity in the
spectral analysis windows, constant term
* Fit settings: 1
* Fitting Window: 425-490 nm
* Polynomial: 5 (6 coefficients)
* Offset:  zeroth order
* Calibration: Based on reference SAO solar spectra (Chance and Kurucz, 2010) -->
sao2010_solref_air.dat
* Wavelength adjustment: all spectra shifted and stretched against reference spectrum
* Reference: noon zenith spectra averaged between 11:30:00 and 11:40:00
* NO2_298  : Vandaele et al. (1998), 298 K with I0 correction (1*10^17 molecules/cm2) --> file:
no2_298K_vanDaele.xs
* NO2a_220 : Vandaele et al. (1998), 220 K with I0 correction (1*10^17 molecules/cm2) pre-
orthogonalized --> file: no2a_220p298K_vanDaele_425-490nm
*   O3     : Serdyuchenko  et al., (2014), 223 K with I0 correction (1*10^20 molecules/cm2) -->
file: o3_223K_SDY_air.xs
*   O4     : Thalman and Volkamer 2013, 293 K  --> file: o4_thalman_volkamer_293K_inAir.xs
*   H2O    : HITEMP, Rothman et al., 2010 --> file: H2O_HITEMP_2010_390-700_296K_1013mbar_air.xs
*    RING    : High Resolution calculation with QDOAS according to Chance and Spurr (1997) and
normalized as in Wagner et al. (2009) --> file: Ring_QDOAScalc_HighResSAO2010_Norm.xs
*DOY   UTC           Tint    SZA            SAA            Elev    Viewing_angle  NO2_DSCD_298
       NO2_DSCD_298_error    O4_DSCD O4_DSCD_error  NO2a_DSCD_220  NO2a_DSCD_220_Error
       O3_DSCD_223    O3_DSCD_223_Error     H2O_DSCD       H2O_DSCD_Error Ring   Ring_Error
       RMS    Spectrum_shift Intens(440)    CI(425/440)    offset_cst
```

Frame 3: Header of the file for reporting NO_2 and O_4 analysed in the 425-490 nm wavelength range. Each line starts with a *. Lines not starting with * are due to a carriage return for presentation purpose here.

```
* NofHeaderlines: 44
* NofColumns: 24 (if any info missing, put -999, even if it's the whole column)
* Instrument identifier: BIRA_MAXDOAS
* Retrieval code: QDOAS (v2.110, June 2015)
* Created by: Gaia Pinardi
* Version: NO2visSmall_v1
*  X-Axis (Col  1) = Day of year (DOY) 2016   (please start with 0.0 for January 1st, 0:00 UTC)
* Y1-Axis (Col  2) = Time of day in hours (UTC)
* Y2-Axis (Col  3) = Total Integration Time(s)
* Y3-Axis (Col  4) = Solar Zenith Angle (°)
* Y4-Axis (Col  5) = Solar Azimuth Angle (°) North=0, East=90
* Y5-Axis (Col  6) = Elevation Angle (°)
* Y6-Axis (Col  7) = Viewing Angle (°) North=0, East=90
* Y7-Axis (Col  8) = NO2_DSCD_298 (1*10^15 molec/cm2)
* Y8-Axis (Col  9) = NO2_DSCD_298_Error (1*10^15 molec/cm2)
* Y9-Axis (Col 10) = O4_DSCD (1*10^40 molec2/cm5)
* Y10-Axis (Col 11) = O4_DSCD_Error (1*10^40 molec2/cm5)
* Y11-Axis (Col 12) = NO2a_DSCD_220  (1*10^15 molec/cm2)  (Fit results for the "cold NO2 residue")
* Y12-Axis (Col 13) = NO2a_DSCD_220_Error  (1*10^15 molec/cm2)
* Y13-Axis (Col 14) = O3_DSCD_223 (1*10^20 molecules/cm2)
* Y14-Axis (Col 15) = O3_DSCD_223_Error (1*10^20 molecules/cm2)
* Y15-Axis (Col 16) = H2O_DSCD (1*10^23 molec/cm2)
* Y16-Axis (Col 17) = H2O_DSCD_Error (1*10^23 molec/cm2)
* Y17-Axis (Col 18) = Ring
* Y18-Axis (Col 19) = Ring_Error
* Y19-Axis (Col 20) = Fit RMS (in OD)
* Y20-Axis (Col 21) = Spectrum shift (nm, against FRS reference)
* Y21-Axis (Col 22) = Relative Intensity (counts/integration time @ 440nm)
* Y22-Axis (Col 23) = Colour index: (412 / 440 nm)
* Y23-Axis (Col 24) = intensity offset with normalisation by I, I is the mean intensity in the
spectral analysis windows, constant term
* Fit settings: 1
* Fitting Window: 411-445 nm
* Polynomial: 4 (5 coefficients)
* Offset:  Zeroth order (constant)
* Calibration: Based on reference SAO solar spectra (Chance and Kurucz, 2010) -->
sao2010_solref_air.dat
* Wavelength adjustment: all spectra shifted and stretched against reference spectrum
* Reference: noon zenith spectra averaged between 11:30:00 and 11:40:00
* NO2_298   : Vandaele et al. (1998), 298 K with I0 correction (1*10^17 molecules/cm2) --> file:
no2_298K_vanDaele.xs
* NO2a_220  : Vandaele et al. (1998), 220 K with I0 correction (1*10^17 molecules/cm2) pre-
orthogonalized --> file: no2a_220p298K_vanDaele_411-445nm.xs
*   O3      : Serdyuchenko  et al., (2014), 223 K with I0 correction (1*10^20 molecules/cm2) -->
file: o3_223K_SDY_air.xs
*   O4     : Thalman and Volkamer 2013, 293 K  --> file: o4_thalman_volkamer_293K_inAir.xs
*   H2O    : HITEMP, Rothman et al., 2010 --> file: H2O_HITEMP_2010_390-700_296K_1013mbar_air.xs
*    RING    : High Resolution calculation with QDOAS according to Chance and Spurr (1997) and
normalized as in Wagner et al. (2009) --> file: Ring_QDOAScalc_HighResSAO2010_Norm.xs
*DOY   UTC            Tint    SZA            SAA            Elev    Viewing_angle  NO2_DSCD_298
       NO2_DSCD_298_error     O4_DSCD O4_DSCD_error  NO2a_DSCD_220  NO2a_DSCD_220_Error
       O3_DSCD_223    O3_DSCD_223_Error      H2O_DSCD       H2O_DSCD_Error Ring    Ring_Error
       RMS     Spectrum_shift Intens(440)    CI(412/440)    offset_cst
```

Frame 4: Header of the file for reporting NO_2 analysed in the 411-445 nm wavelength range. Each line starts with a *. Lines not starting with * are due to a carriage return for presentation purpose here.

```
* NofHeaderlines: 48
* NofColumns: 27 (if any info missing, put -999, even if it's the whole column)
* Instrument identifier: BIRA_MAXDOAS
* Retrieval code: QDOAS (v2.110, June 2015)
* Created by: Gaia Pinardi
* Version: O3vis_v1
*  X-Axis (Col  1) = Day of year (DOY) 2016   (please start with 0.0 for January 1st, 0:00 UTC)
* Y1-Axis (Col  2) = Time of day in hours (UTC)
* Y2-Axis (Col  3) = Total Integration Time(s)
* Y3-Axis (Col  4) = Solar Zenith Angle (°)
* Y4-Axis (Col  5) = Solar Azimuth Angle (°) North=0, East=90
* Y5-Axis (Col  6) = Elevation Angle (°)
* Y6-Axis (Col  7) = Viewing Angle (°) North=0, East=90
* Y7-Axis (Col  8) = O3_DSCD_223 (1*10^20 molecules/cm2)
* Y8-Axis (Col  9) = O3_DSCD_223_Error (1*10^20 molecules/cm2)
* Y9-Axis (Col  10) = O3a_DSCD_293 (1*10^20 molecules/cm2)
* Y10-Axis (Col 11) = O3a_DSCD_293_Error (1*10^20 molecules/cm2)
* Y11-Axis (Col 12) = O4_DSCD (1*10^40 molec2/cm5)
* Y12-Axis (Col 13) = O4_DSCD_Error (1*10^40 molec2/cm5)
* Y13-Axis (Col 14) = NO2_DSCD_298 (1*10^15 molec/cm2)
* Y14-Axis (Col 15) = NO2_DSCD_298_Error (1*10^15 molec/cm2)
* Y15-Axis (Col 16) = NO2a_DSCD_220  (1*10^15 molec/cm2)
* Y16-Axis (Col 17) = NO2a_DSCD_220_Error  (1*10^15 molec/cm2)
* Y17-Axis (Col 18) = H2O_DSCD (1*10^23 molec/cm2)
* Y18-Axis (Col 19) = H2O_DSCD_Error (1*10^23 molec/cm2)
* Y19-Axis (Col 20) = Ring
* Y20-Axis (Col 21) = Ring_Error
* Y21-Axis (Col 22) = Fit RMS (in OD)
* Y22-Axis (Col 23) = Spectrum shift (nm, against FRS reference)
* Y23-Axis (Col 24) = Relative Intensity (counts/integration time @ 500nm)
* Y24-Axis (Col 25) = Colour index: (440 / 500 nm)
* Y25-Axis (Col 26) = intensity offset with normalisation by I, I is the mean intensity in the
spectral analysis windows, constant term
* Y26-Axis (Col 27) = intensity offset, linear term
* Fit settings: 1
* Fitting Window: 450-520 nm
* Polynomial: 3 (4 coefficients)
* Offset:  1st order
*  Calibration:  Based  on  reference  SAO  solar  spectra  (Chance  and  Kurucz,  2010)  -->
sao2010_solref_air.dat
* Wavelength adjustment: all spectra shifted and stretched against reference spectrum
* Reference: noon zenith spectra averaged between 11:30:00 and 11:40:00
* O3_223    : Serdyuchenko  et al., (2014), 223 K with I0 correction (1*10^20 molecules/cm2) -->
file: o3_223K_SDY_air.xs
* O3a_293   : Serdyuchenko  et al., (2014), 293 K with I0 correction (1*10^20 molecules/cm2) Pre-
orthogonalized --> file: o3a_293p223K_SDY_450-550nm
* NO2_298   : Vandaele et al. (1998), 298 K with I0 correction (1*10^17 molecules/cm2) --> file:
no2_298K_vanDaele.xs
*  NO2a_220  :  Vandaele  et  al.  (1998),  220  K  with  I0  correction  (1*10^17  molecules/cm2)  Pre-
orthogonalized --> file: no2a_220p298K_vanDaele_450-550nm
* O4       : Thalman and Volkamer 2013, 293 K  --> file: o4_thalman_volkamer_293K_inAir.xs
* H2O      : HITEMP, Rothman et al. (2010) --> file: H2O_HITEMP_2010_390-700_296K_1013mbar_air.xs
*  RING       :  High  Resolution  calculation  with  QDOAS  according  to  Chance  and  Spurr  (1997)  and
normalized as in Wagner et al. (2009) --> file: Ring_QDOAScalc_HighResSAO2010_Norm.xs
*DOY    UTC            Tint    SZA            SAA            Elev    Viewing_angle  O3_DSCD_223
       O3_DSCD_223_Error      O3a_DSCD_293   O3a_DSCD_293_Error     O4_DSCD O4_DSCD_error
       NO2_DSCD_298   NO2_DSCD_298_error     NO2a_DSCD_220  NO2a_DSCD_220_Error    H2O_DSCD
       H2O_DSCD_Error Ring    Ring_Error     RMS     Spectrum_shift Intens(500)    CI(440/500)
       offset_cst     offset_lin
```

Frame 5: Header of the file for reporting O_3 analysed in the Chappuis bands (450-520 nm wavelength range). Each line starts with a *. Lines not starting with * are due to a carriage return for presentation purpose here.

```
* NofHeaderlines: 43
* NofColumns: 21 (if any info missing, put -999, even if it's the whole column)
* Instrument identifier: BIRA_MAXDOAS
* Retrieval code: QDOAS (v2.110, June 2015)
* Created by: Gaia Pinardi
* Version: O3uv_v1
*  X-Axis (Col  1) = Day of year (DOY) 2016   (please start with 0.0 for January 1st, 0:00 UTC)
* Y1-Axis (Col  2) = Time of day in hours (UTC)
* Y2-Axis (Col  3) = Total Integration Time(s)
* Y3-Axis (Col  4) = Solar Zenith Angle (°)
* Y4-Axis (Col  5) = Solar Azimuth Angle (°) North=0, East=90
* Y5-Axis (Col  6) = Elevation Angle (°)
* Y6-Axis (Col  7) = Viewing Angle (°) North=0, East=90
* Y7-Axis (Col  8) = O3_DSCD_223 (1*10^20 molecules/cm2)
* Y8-Axis (Col  9) = O3_DSCD_223_Error (1*10^20 molecules/cm2)
* Y9-Axis (Col  10) = O3a_DSCD_293 (1*10^20 molecules/cm2)
* Y10-Axis (Col 11) = O3a_DSCD_293_Error (1*10^20 molecules/cm2)
* Y11-Axis (Col 12) = NO2_DSCD_298  (1*10^15 molec/cm2)
* Y12-Axis (Col 13) = NO2_DSCD_298_Error  (1*10^15 molec/cm2)
* Y13-Axis (Col 14) = HCHO_DSCD (1*10^15 molec/cm2)
* Y14-Axis (Col 15) = HCHO_DSCD_Error (1*10^15 molec/cm2)
* Y15-Axis (Col 16) = Ring
* Y16-Axis (Col 17) = Ring_Error
* Y17-Axis (Col 18) = Fit RMS (in OD)
* Y18-Axis (Col 19) = Spectrum shift (nm, against FRS reference)
* Y19-Axis (Col 20) = Relative Intensity (counts*n_scans/integration time @ 340nm)
* Y20-Axis (Col 21) = Colour index: (320 / 340 nm)
* Y21-Axis (Col 22) = intensity offset with normalisation by I, I is the mean intensity in the
spectral analysis windows, constant term
* Y22-Axis (Col 23) = intensity offset, linear term
* Fit settings: 1
* Fitting Window: 320-340 nm
* Polynomial: 3 (4 coefficients)
* Offset:  1st order
* Calibration: Based on reference SAO solar spectra (Chance and Kurucz, 2010) -->
sao2010_solref_air.dat
* Wavelength adjustment: all spectra shifted and stretched against reference spectrum
* Reference: noon zenith spectra averaged between 11:30:00 and 11:40:00
* O3_223    : Serdyuchenko  et al., (2014), 223 K with I0 correction (1*10^20 molecules/cm2) -->
file: o3_223K_SDY_air.xs
* O3a_293   : Serdyuchenko  et al., (2014), 293 K with I0 correction (1*10^20 molecules/cm2) pre-
orthogonalized --> file: o3a_293p223K_SDY_320-340nm.xs
* O3 non-linear correction terms (Pukite et al., 2010) at 223K --> files: o3_SDY_Pukite1_320-
340nm.xs and o3_SDY_Pukite2_320-340nm.xs
* NO2_298   : Vandaele et al. (1998), 298 K with I0 correction (1*10^17 molecules/cm2) --> file:
no2_298K_vanDaele.xs
* HCHO     : Meller and Moortgat (2000), 297 K --> file: hcho_297K_Meller.xs
* RING      : High Resolution calculation with QDOAS according to Chance and Spurr (1997) and
normalized as in Wagner et al. (2009) --> file: Ring_QDOAScalc_HighResSAO2010_Norm.xs
*DOY   UTC           Tint    SZA            SAA            Elev    Viewing_angle  O3_DSCD_223
       O3_DSCD_223_Error      O3a_DSCD_293   O3a_DSCD_293_Error     NO2_DSCD_298
       NO2_DSCD_298_Error     HCHO_DSCD      HCHO_DSCD_error        Ring    Ring_Error     RMS
       Spectrum_shift Intens(340)    CI(320/340)    offset_cst     offset_lin
```

Frame 6: Header of the file for reporting O_3 analysed in the Huggins bands (320-340 nm wavelength range). Each line starts with a *. Lines not starting with * are due to a carriage return for presentation purpose here.