

Intercalibration and harmonization of MAX-DOAS measurements as part of the CINDI-2 and FRM₄DOAS projects



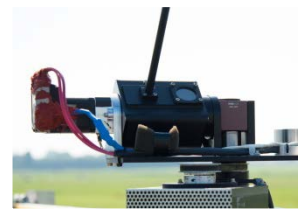
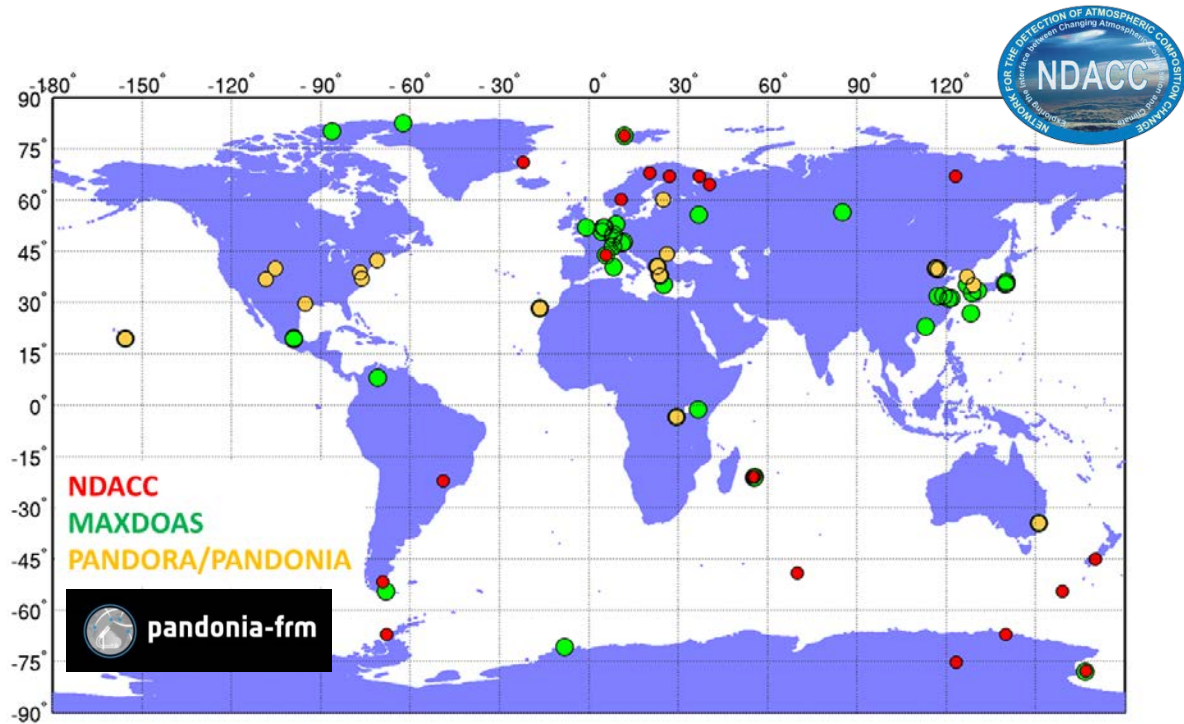
M. Van Roozendael, BIRA-IASB
and the CINDI-2/FRM₄DOAS teams

Global monitoring networks of DOAS systems

MOTIVATION:

Long, uninterrupted, well-maintained, homogeneously calibrated time-series of ground-based remote sensing atmospheric ozone measurements

Essential component of satellite validation for atmospheric trace gases



Outline

Can we make better use of existing local networks of (MAX-) DOAS instruments to serve satellite validation?

→ Summarize progress in 2 ongoing activities:

- Outcome of CINDI-2 intercalibration
- FRM₄DOAS intercomparison of MAX-DOAS algorithms



JUTWOOD BUNITE, AERONOMIC INSTITUTE DIABLOMIE SPA



CINDI-2

Cabauw, The Netherlands
12 -28 Sep 2016



M. Van Roozendael, GEMS ST Meeting #8, 25-27 Sep 2017, Seoul, Korea

Ancillary observations

In-situ

- NO₂
- O₃
- Aerosols
 - ACTRIS-2 campaigns:
 - Aerosol absorption
 - Aerosol flux



Vertical distribution

- NO₂ profile
- O₃ profile
- Aerosol profile

Horizontal distribution

- NO₂ column



Royal Netherlands
Meteorological Institute
Ministry of Infrastructure and the
Environment

- Raman lidar
- Wind lidar
- Ceilometer
- NO₂ lidar
- Sun photometer
- Clouds and radiation
- Ozone sondes
- NO₂ sondes
- In-situ ozone monitor
- Meteorological parameters



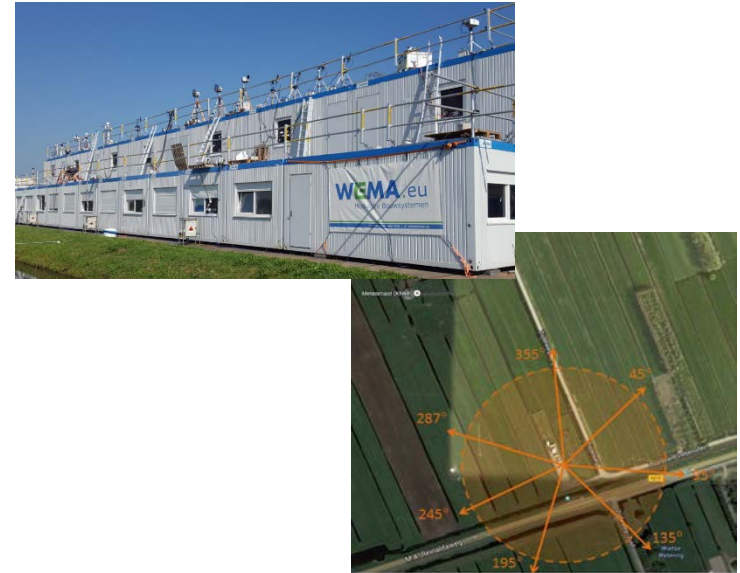
Modelling support

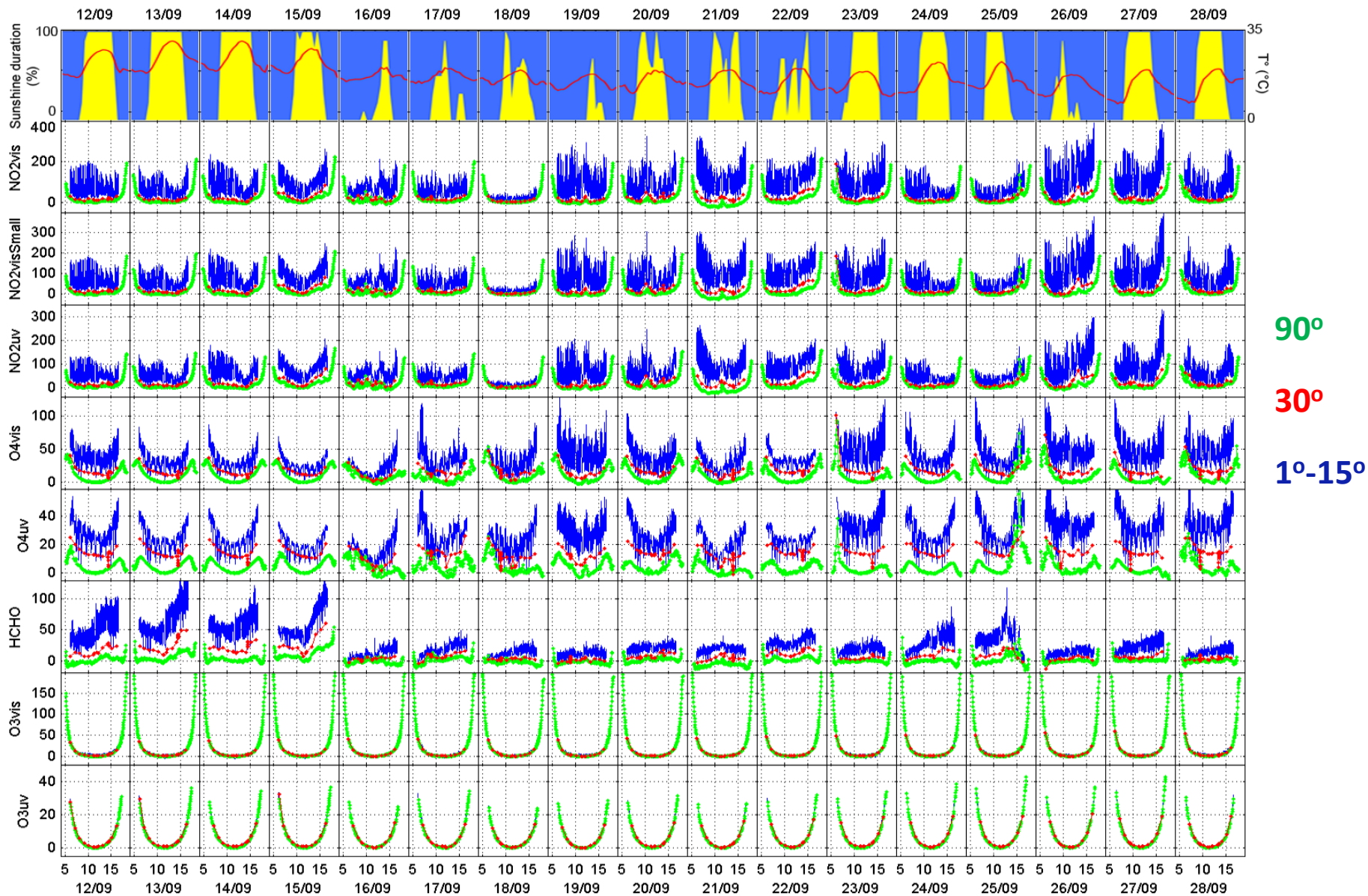
- AQ forecast (CAMS)
- Weather forecast



Semi-blind intercomparison of slant column measurements (12-28 Sep 2017)

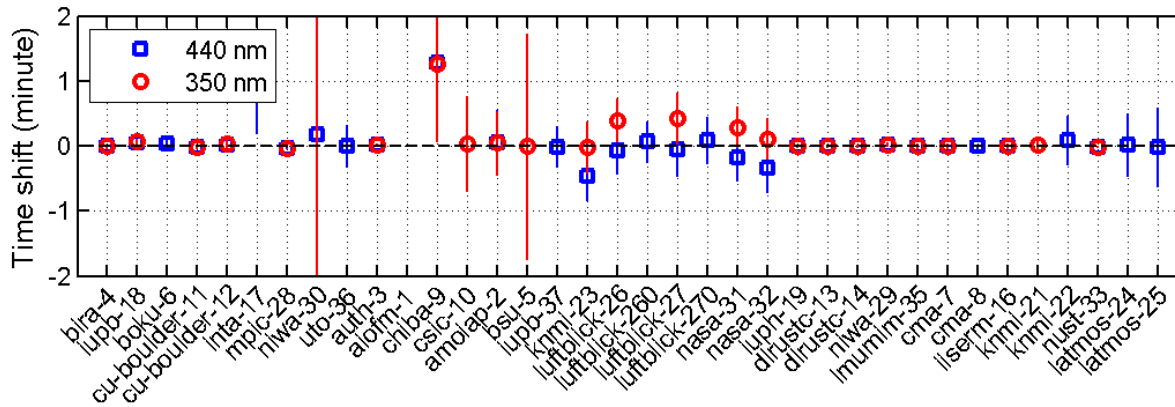
- 36 instruments, 24 teams
 - 2D, 1D MAX-DOAS & zenith-sky only
- 8 data products:
 - NO₂ vis, NO₂ visSmall, NO₂ uv
 - O₄ vis, O₄ uv, HCHO
 - O₃ vis, O₃ uv
- Comparison protocol:
 - Strict acquisition protocol to ensure optimal time and spatial collocation (clearly prescribed viewing geometries and synchronization of measurements).
 - Systematic monitoring of MAX-DOAS scanning accuracy, by means of active light source measurements and horizon scans.
 - Daily data submission and report back in meetings, procedures were following the semi-blind comparison protocol.
 - Thorough statistical analysis of comparison results.
 - Instrument certification for operation within NDACC.



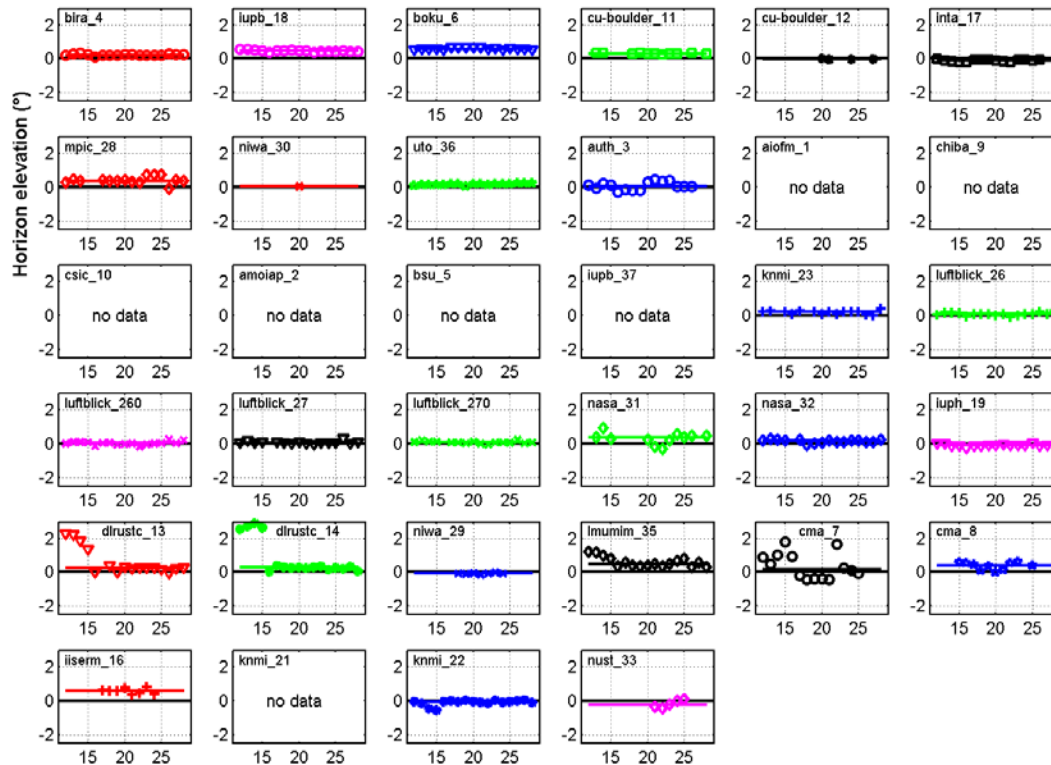


Overview of meteorological conditions and 8 data sets measured during the semi-blind MAX-DOAS intercomparison exercise (12 – 28 September 2017). Slant column data were measured by IUP Bremen as an example for one instrument, incl. all elevation angles, all viewing directions.

Mean and standard deviation of the time deviations with respect to the measurement schedule defined for the campaign



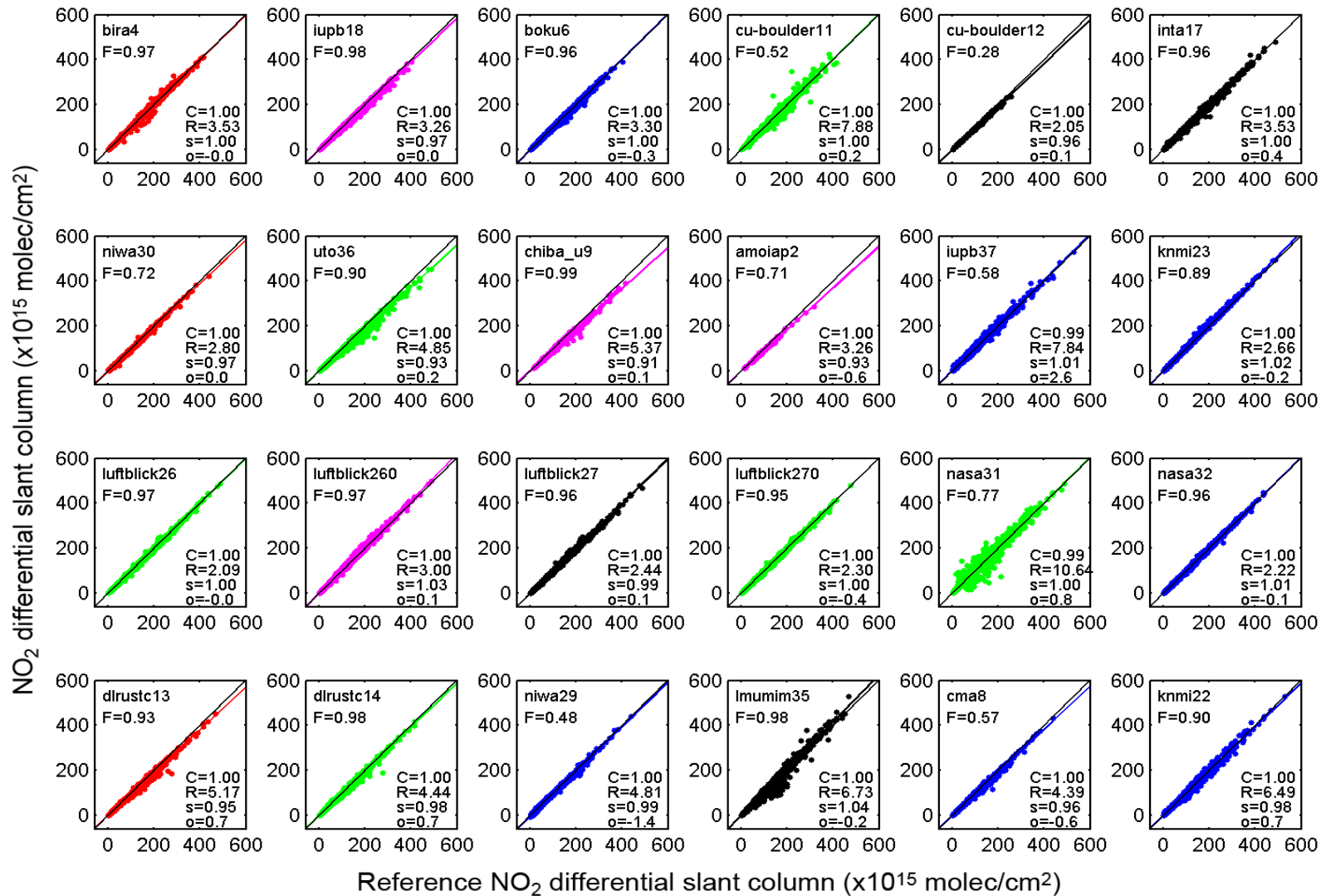
Instruments are identified using their affiliation and ID number.



Accuracy and stability of elevation pointing verified on a daily basis for most participating instruments using **horizon scans**.

Results used to correct elevation readings from instruments having experienced pointing problems during the campaign.



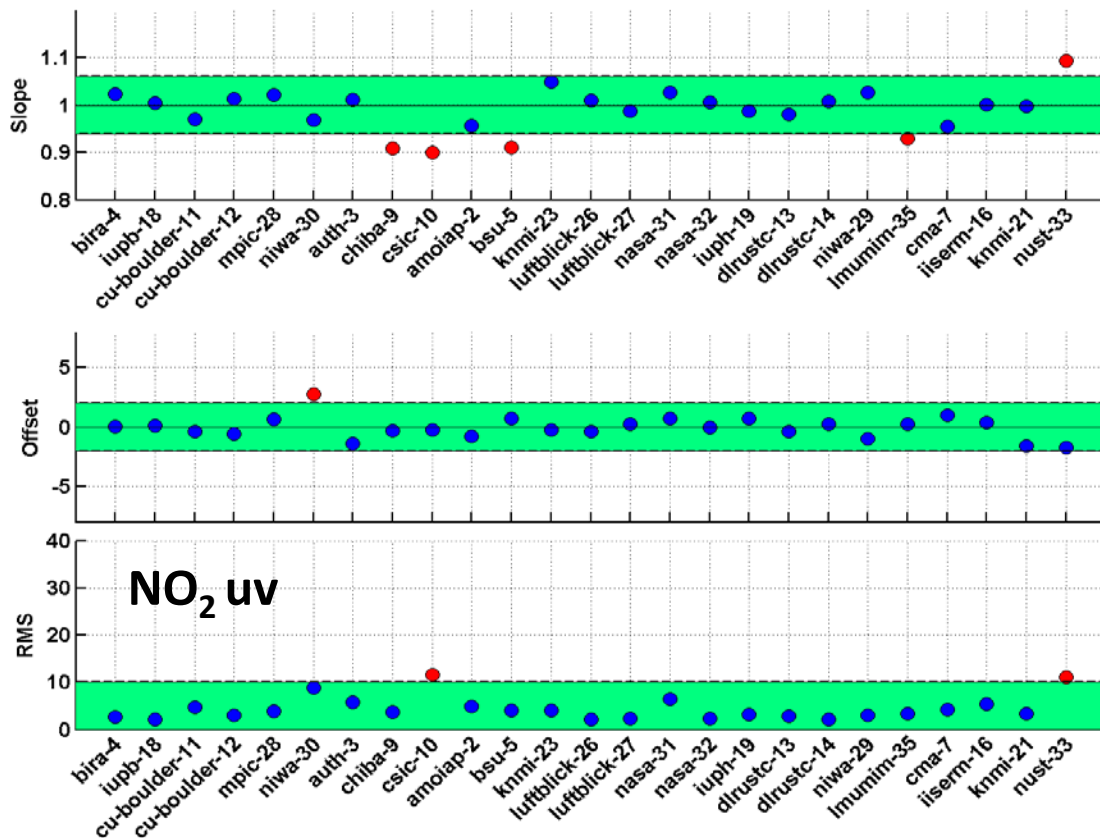


Regression analysis for NO₂ dSCDs (in the visible) plotted against median values for the whole semi-blind phase & for all viewing and all azimuth angles.

Instruments are identified with their affiliation and instrument ID number.



Performance assessment



Blue dots:
within limits

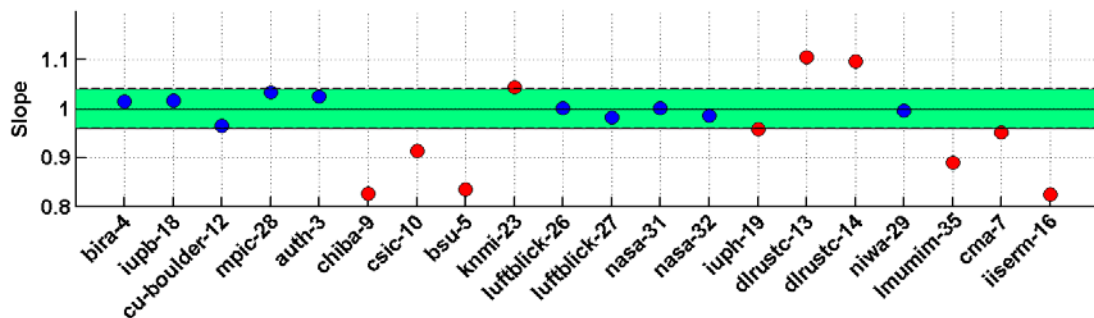
Red dots:
outside limits

Performance limits

Product	Bias (%)	Offset (molec/c m ²)	RMS (molec/cm ²)
NO ₂ vis*	5	1.5 E15	8.0 E15
NO ₂ visSm all	5	1.5 E15	8.0 E15
NO ₂ uv	6	2.0 E15	1.0 E16
O ₄ vis	5	0.7 E42	3.0 E42
O ₄ uv	6	0.8 E42	3.0 E42
HCHO	10	5.0 E15	1.5 E16
O ₃ uv	4	0.2 E18	1.0 E18
O ₃ vis*	4	1.0 E18	4.0 E18

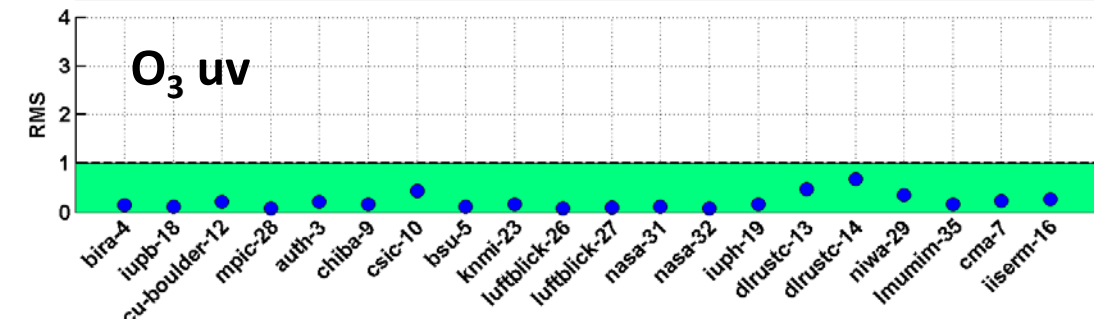
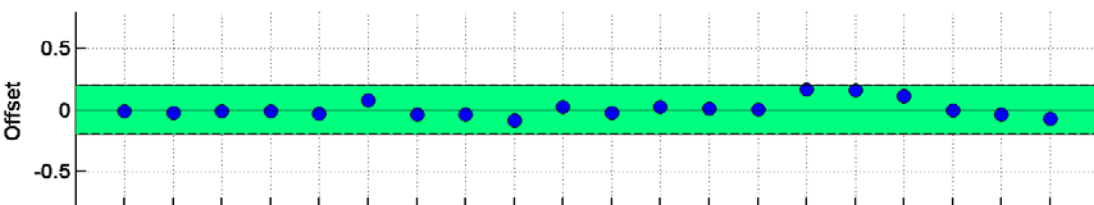
Summary of the three regression analysis parameters (slope, offset and RMS) with the performance assessment criteria applied as green shading.

Performance assessment



Blue dots:
within limits

Red dots:
outside limits



Performance limits

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O ₃ vis*	4	1.0 E18	4.0 E18

Summary of the three regression analysis parameters (**slope**, **offset** and **RMS**) with the performance assessment criteria applied as **green shading**.

Performance assessment matrix for all 36 instruments and 8 MAX-DOAS and 4 zenith-sky data products



	MAX-DOAS									ZENITH-SKY				
	NO2vis	NO2visSmall	NO2uv	O4vis	O4uv	HCHO	O3uv	O3vis		NO2vis	NO2visSmall	NO2uv	O3vis	
bira-4	4	3	1	4	1	1	2	6	Scientific grade	4	2	1	4	bira-4
iupb-18	1	1	5	1	5	4	3	3		2	1	2	2	iupb-18
boku-6	2			2				5		1			1	boku-6
cu-boulder-11	3	2	2	3	2	2		2		3	3	3	3	cu-boulder-11
cu-boulder-12	16	4	7	16	7		11			13	4	7		cu-boulder-12
inta-17	13			13				10		7			7	inta-17
mpic-28		13	3		3	3	4				11	6		mpic-28
niwa-30	15		12	15	12	10				11		8		niwa-30
uto-36	20	22		20				16		21	23		17	uto-36
auth-3		24	25		25	22	18				24	25		auth-3
aiofm-1														aiofm-1
chiba-9	18	18	10	18	10	11	20		Scientific grade	19	18	22		chiba-9
csic-10			24		24	20	15					23		csic-10
amoiap-2	22	23	23	22	23	21				17	17	13		amoiap-2
bsu-5			18		18	18	14					15		bsu-5
iupb-37	24			24					Pandora	24				iupb-37
knmi-23	10	8	14	10	14	12	10	11		12	12	14	13	knmi-23
luftblick-26	7	7	13	7	13	9	7	7		10	8	11	8	luftblick-26
luftblick-260	5	11		5				1		6	6		6	luftblick-260
luftblick-27	8	9	9	8	9	7	6	9		8	9	10	10	luftblick-27
luftblick-270	6	5		6				4		5	5		5	luftblick-270
nasa-31	11	12	21	11	21	17	12	12		14	14	19	11	nasa-31
nasa-32	9	10	11	9	11	8	8	8		9	10	12	9	nasa-32
iuph-19		6	4		4	6	5		Envimes		7	5		iuph-19
dlrustc-13	17	19	17	17	17	14	16	14		18	21	21	15	dlrustc-13
dlrustc-14	14	17	20	14	20	19	17	13		20	22	24	18	dlrustc-14
niwa-29	12	14	6	12	6	5	1	15		15	15	4	16	niwa-29
Imumim-35	21	15	8	21	8		19	19		22	13	9	19	Imumim-35
cma-7		16	19		19	15	13		miniDOAS		19	16		cma-7
cma-8	19			19				18		16			14	cma-8
iiserm-16		20	22		22	16	9				16	18		iiserm-16
knmi-21			15		15							20		knmi-21
knmi-22	23			23						23				knmi-22
nust-33		21	16		16	13					20	17		nust-33
latmos-24									SAOZ	25			20	latmos-24
latmos-25										26			21	latmos-25

Green: All 3 assessment criteria fulfilled

Yellow: 2

Orange: 1

Red: none of the criteria was fulfilled

White: No data available

Ranking: In each product category, groups are sorted by increasing values of the median DOAS fit RMS

(Pink: one criterion exceeded by more than a factor 4)

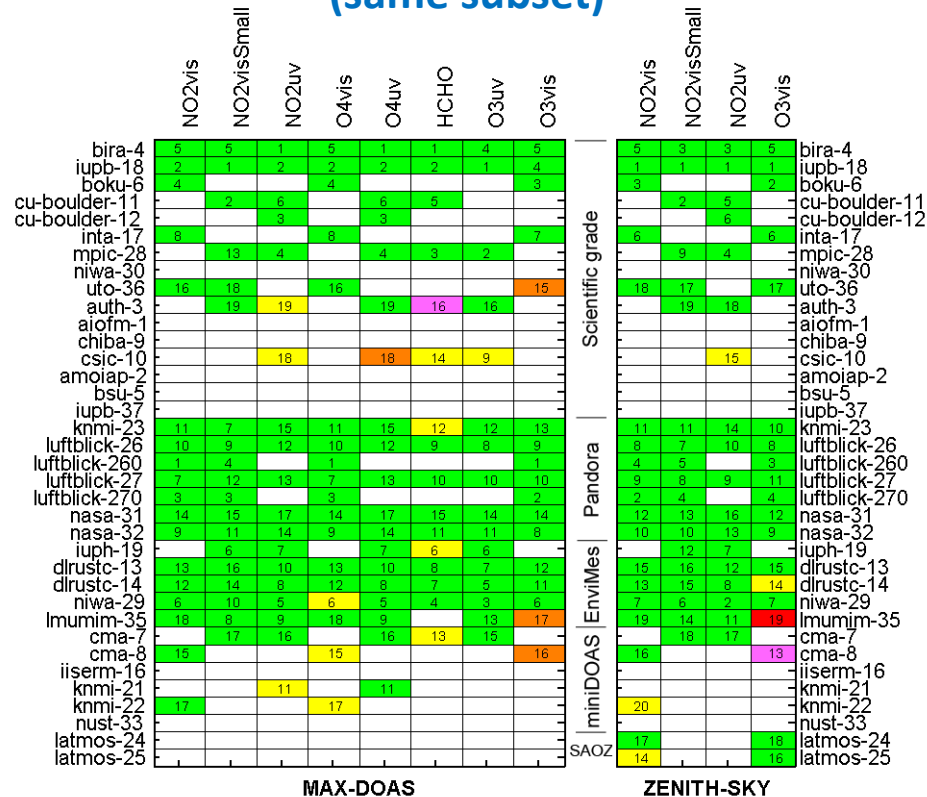
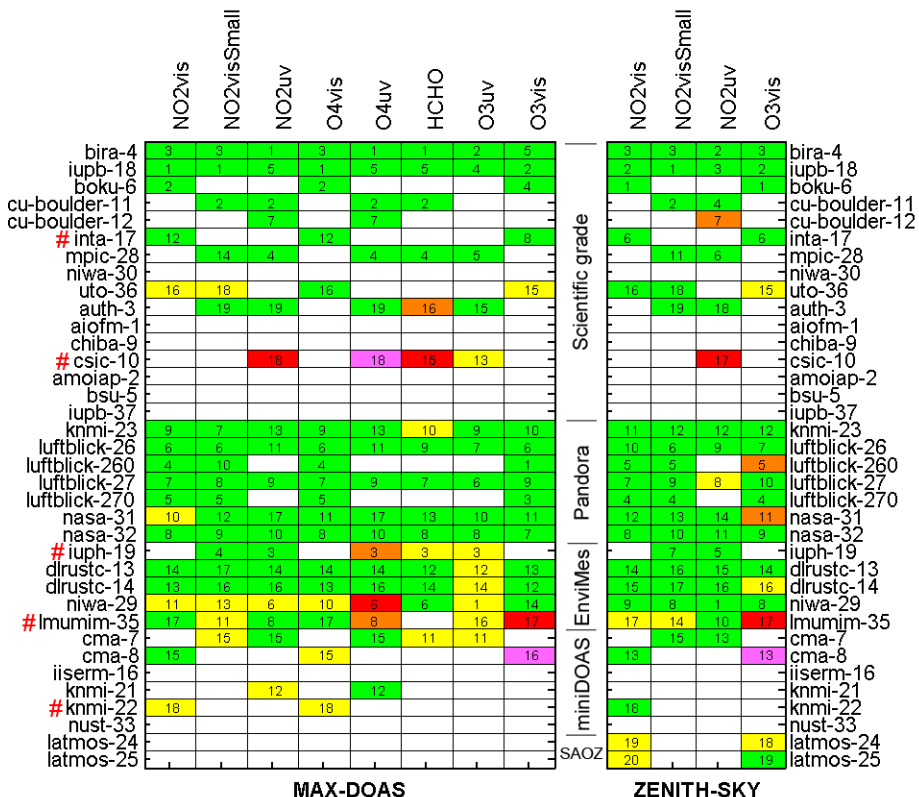
Centralised reprocessing of CINDI-2 spectra as part of FRM₄DOAS project



Ongoing work: spectra from all instruments centrally reprocessed at BIRA using QDOAS. Only partial data sets available so far → preliminary conclusions at this stage

Analysis of semi-blind data (subset)

Analysis of reprocessed data (same subset)



Only 1 day submitted

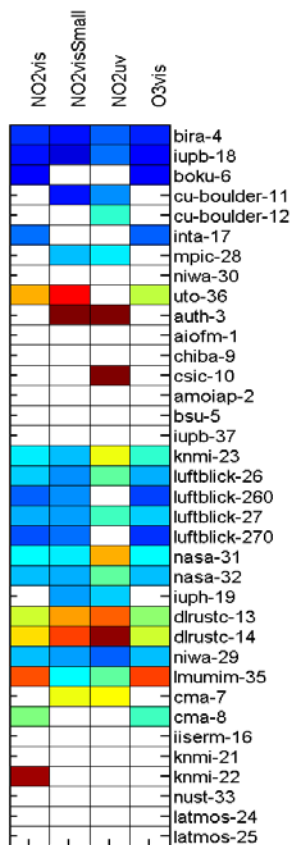
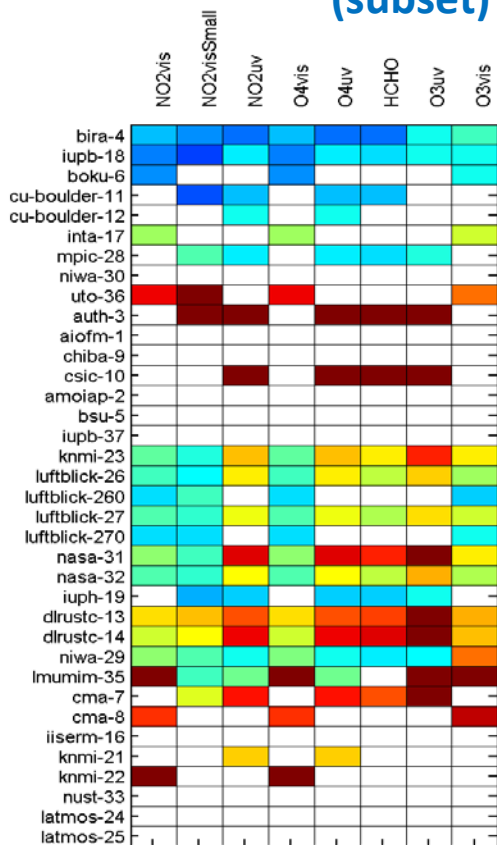
Reprocessed data (preliminary) show Improved homogeneity

Centralised reprocessing of CINDI-2 spectra as part of FRM₄DOAS project

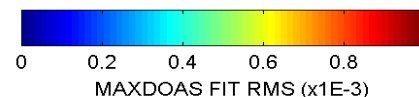
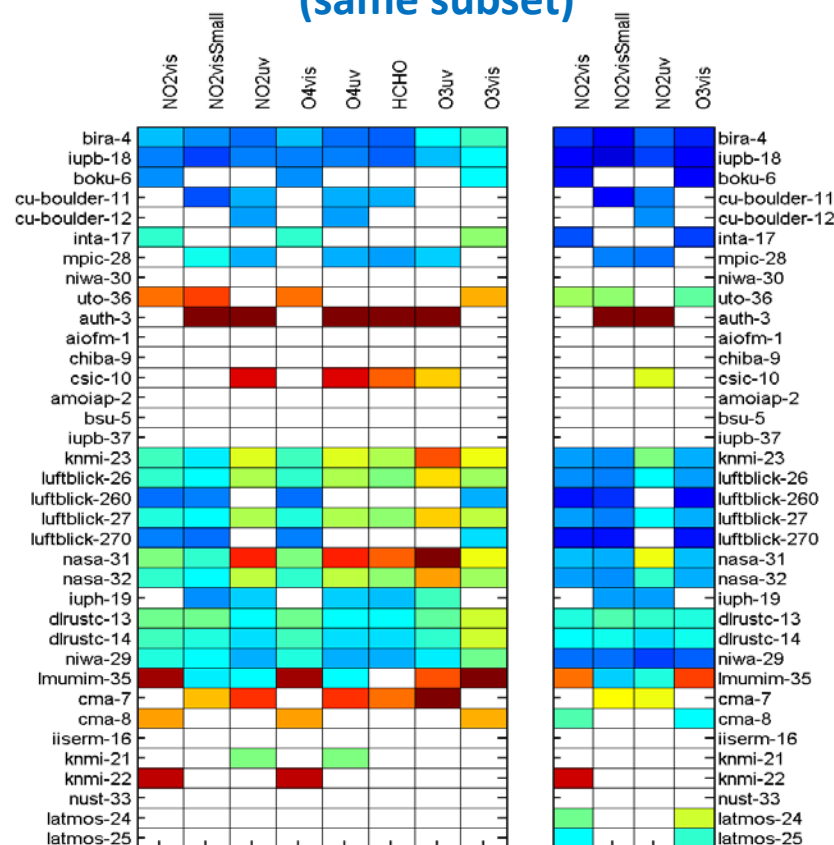


Ongoing work: spectra from all instruments centrally reprocessed at BIRA using QDOAS. Only partial data sets available so far → no firm conclusions can be drawn

DOAS fit RMS from semi-blind data (subset)



DOAS fit RMS from reprocessed data (same subset)

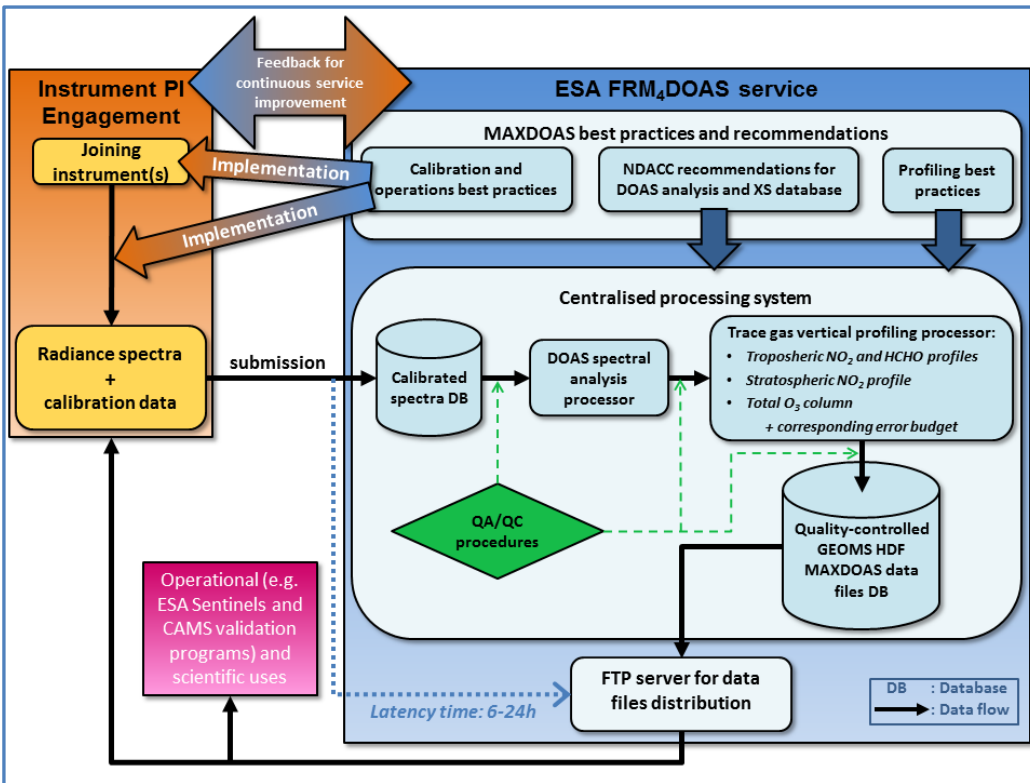
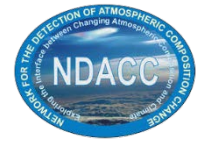


ESA FRM₄DOAS project



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2-years project, started in July 2016



- Consultation of user community (questionnaire)
- Round-robin of MAXDOAS algorithms
- Development of prototype centralised processing system
- Validation

<http://frm4doas.aeronomie.be>

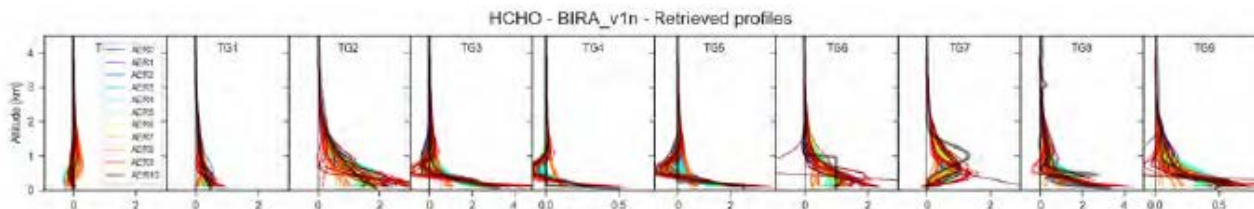


Round-Robin of MAX-DOAS algorithms

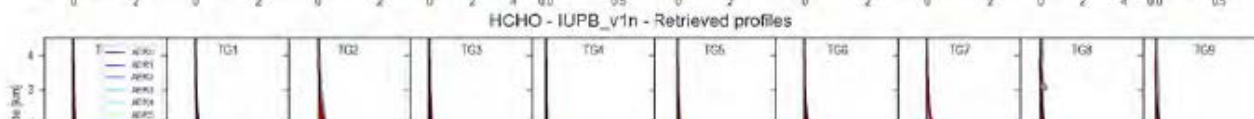
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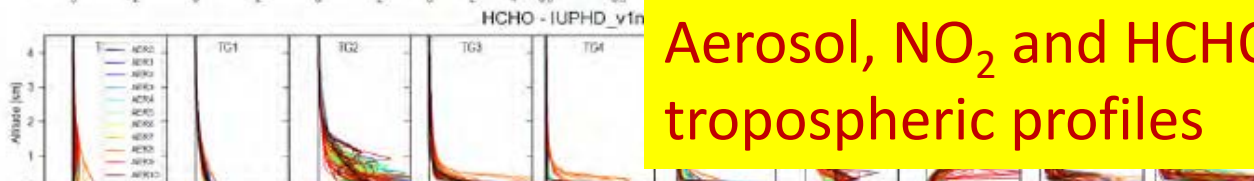
BIRA



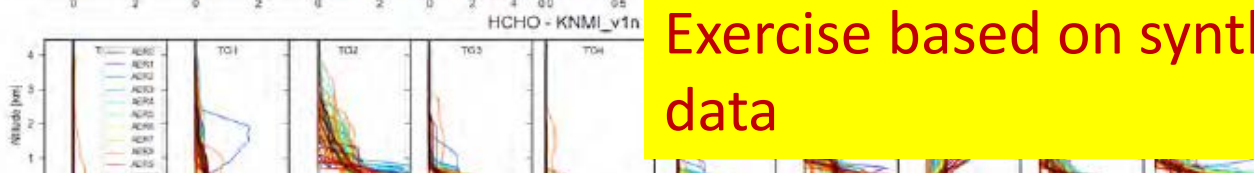
IUP-UB



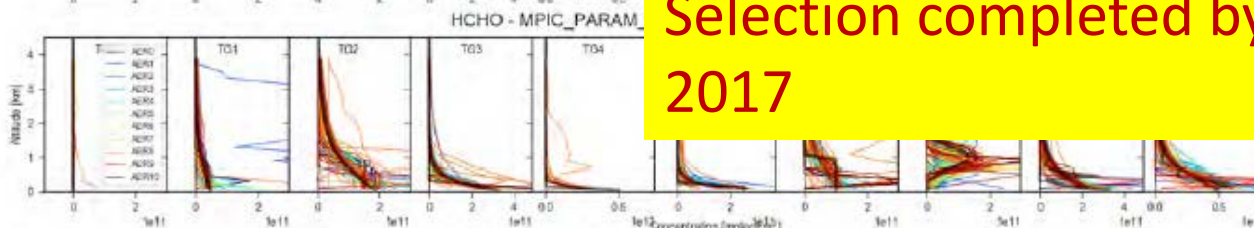
IUP-Heid



KNMI



MPIC



Focus:
Aerosol, NO₂ and HCHO tropospheric profiles

Exercise based on synthetic data

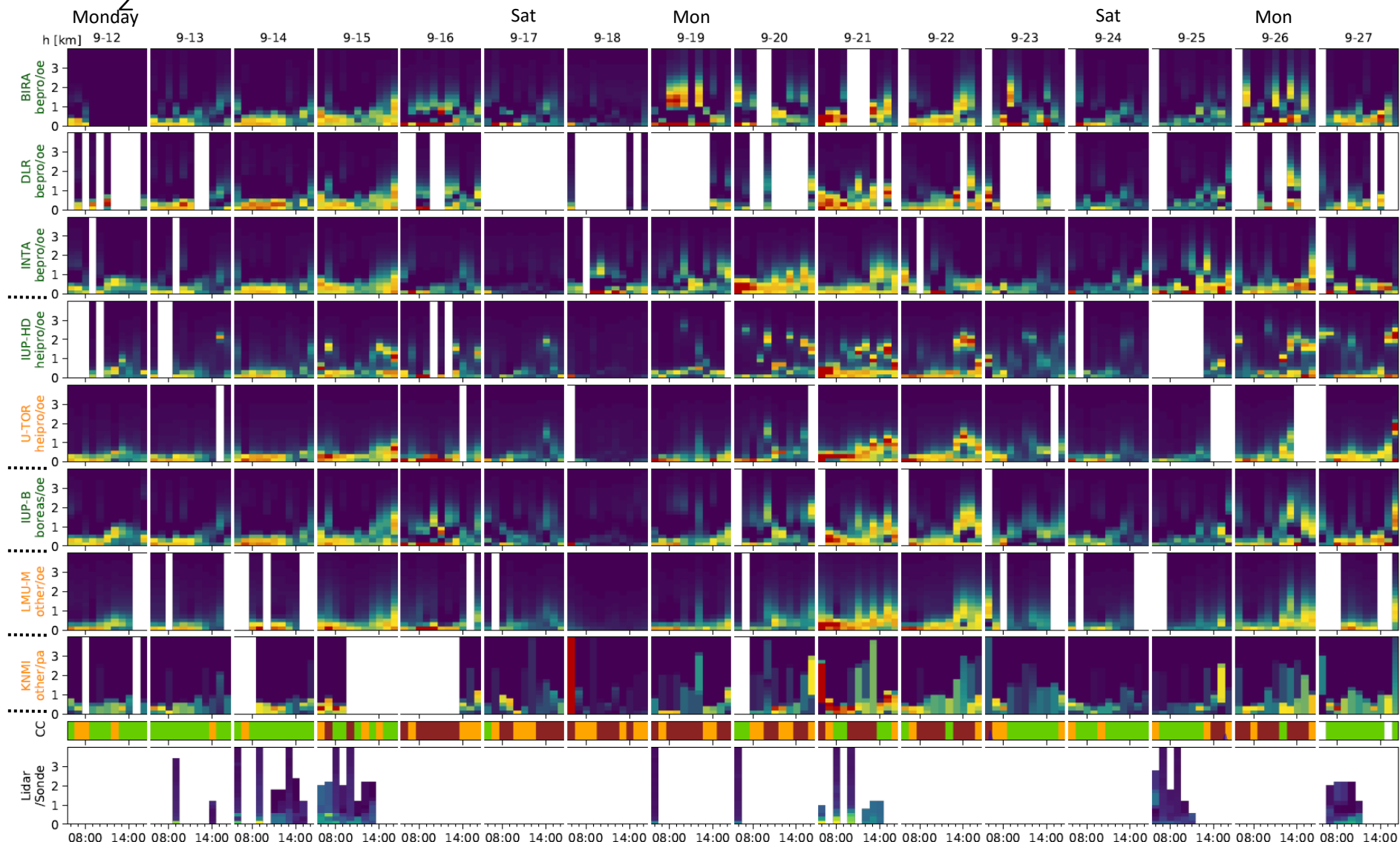
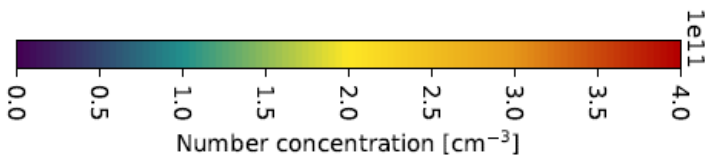
Selection completed by July 2017

U. Friess, U. Heidelberg

Overview

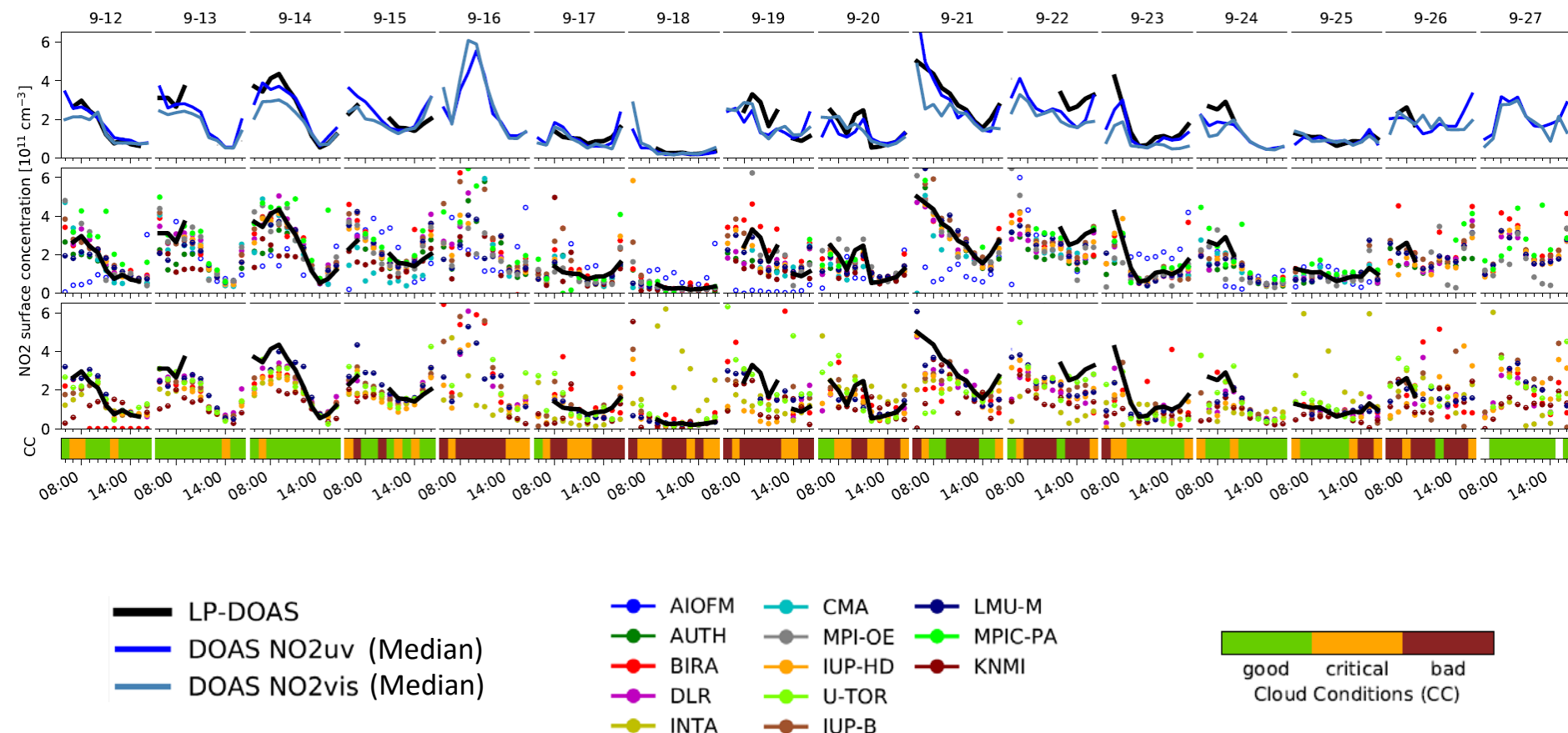


NO₂ - Vis



Surface Concentrations

NO₂: Comparison to LP-DOAS



J.-L. Tirpitz & U. Friess, IUP-Heidelberg

Conclusions and outlook

- CINDI-2 slant column intercomparison exercise is nearby completion (paper in preparation). Provides a quantitative photography of the status of the international DOAS community.
- Second CINDI-2 workshop planned in March 2018 (Mutters, Austria).
- FRM₄DOAS reprocessing of CINDI-2 slant columns data under way. Initial results show potential for improved homogeneity.
- FRM₄DOAS round-robin of MAX-DOAS algorithms completed in July 2017. MPIC parameterised algorithm selectionned.
- Will result in community algorithm (open source) to be implemented in FRM₄DOAS demonstration centralised processing system (beta version planned by early 2018).
- Strong links with Pandonia project.