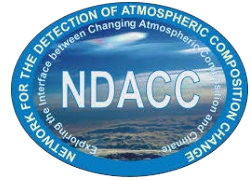




Royal Netherlands
Meteorological Institute
Ministry of Infrastructure and the
Environment



Status and future plans of the air-quality FRM projects

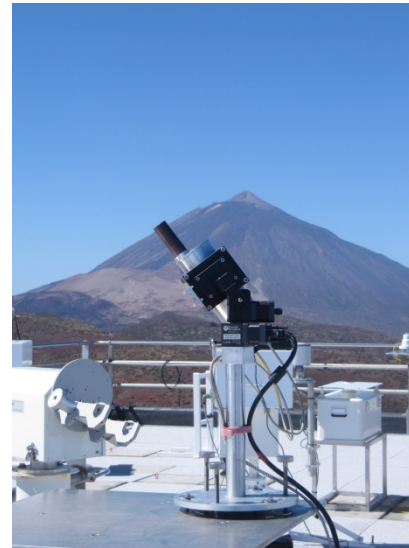


Fiducial Reference Measurements

Ground-based remote sensing network for air pollution monitoring and satellite validation

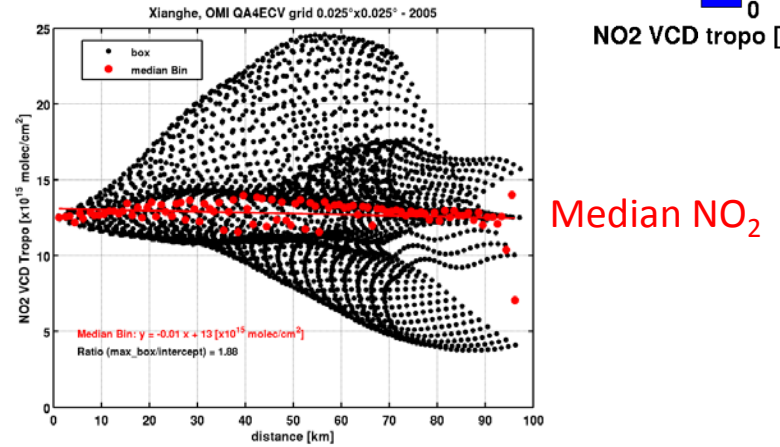
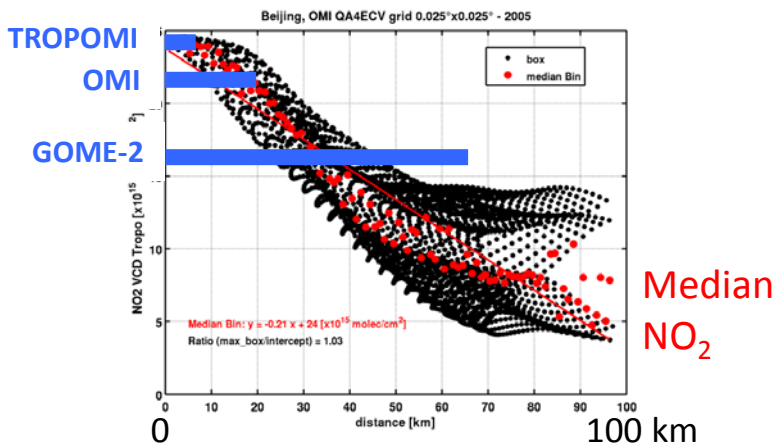
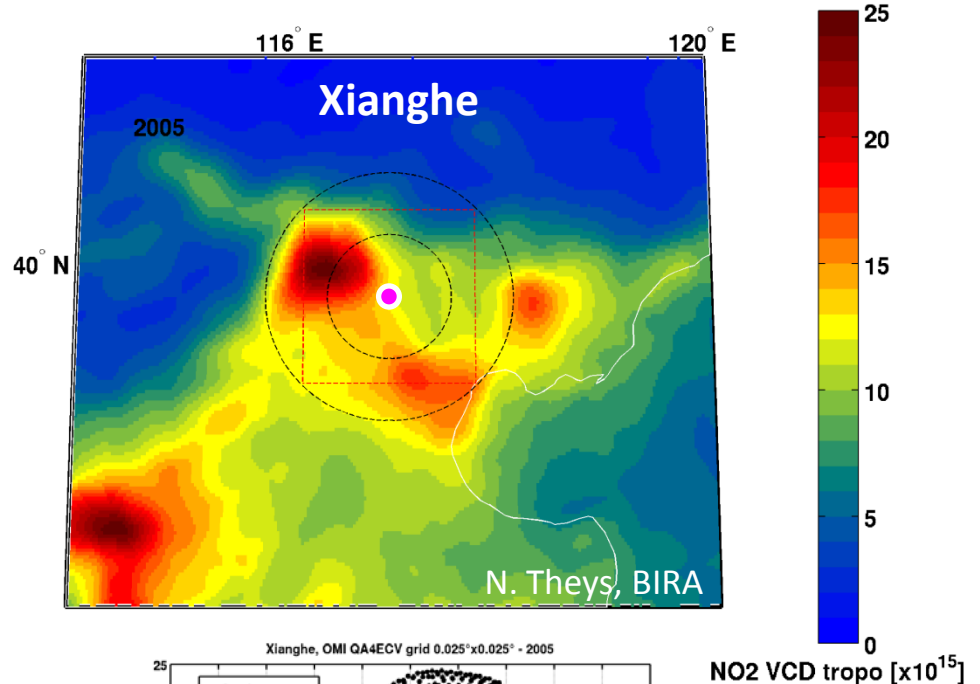
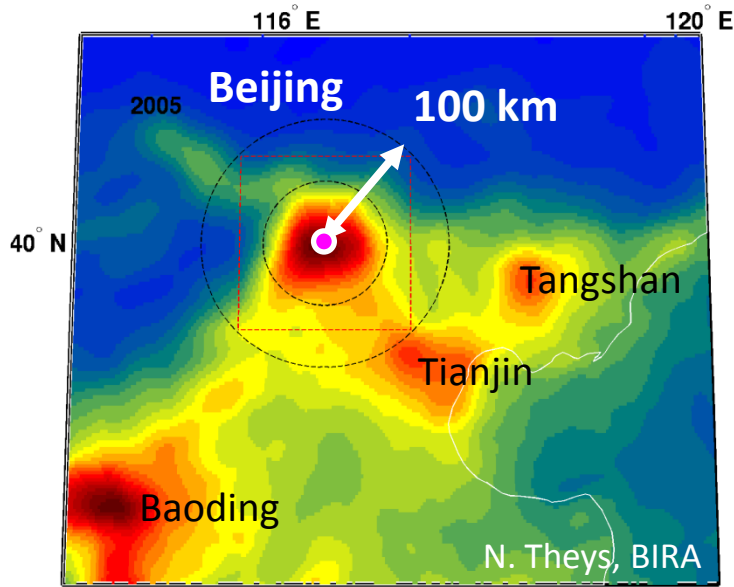
MOTIVATION:

Long, uninterrupted, well-maintained, homogeneously calibrated time-series of ground-based remote sensing atmospheric ozone measurements have been and still are the backbone for the validation of ozone columns measured from satellite (e.g. TOMS, OMI). There is no comparable network for other satellite-derived trace gas measurements (e.g. NO_2).



OMI NO₂ VCD gridded at 2.5x2.5 km²

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Outline

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- Introduction
- Status of Pandonia project
- CINDI-2 campaign outcome and ongoing data harvesting
- Status of FRM₄DOAS project
- Conclusions and outlook

Pandonia updates Oct 2016 to Jun 2017

Alexander Cede

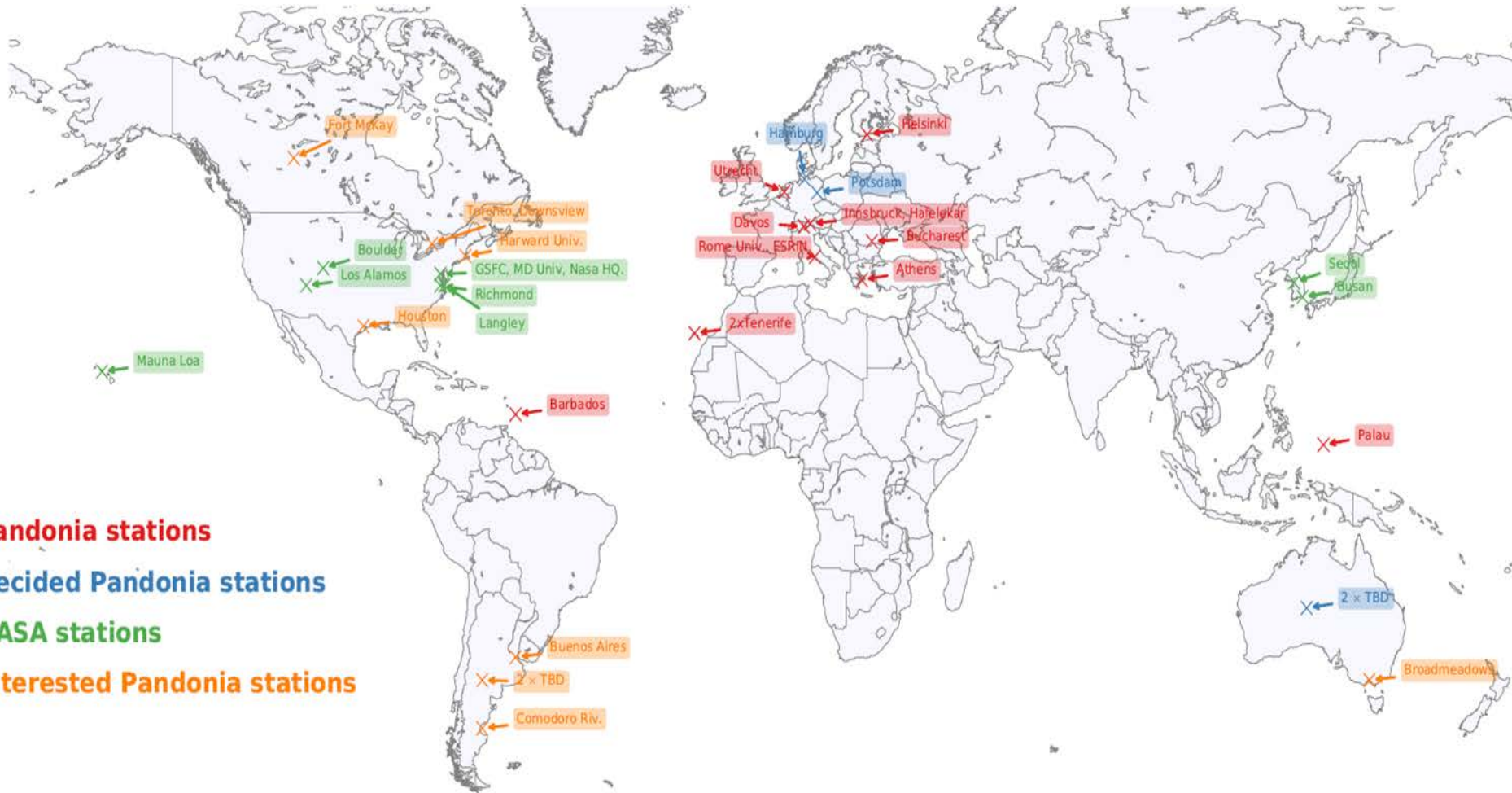
BELGISCH INSTITUUT VOOR RUIMTE-AERONOMIE INSTITUT D'AERONOMIE SPATIALE DE BELGIE BELGIAN INSTITUTE OF SPACE AERONOMY BELGISCH INSTITUUT VOOR RUIMTE-AERONOMIE INSTITUT D'AERONOMIE SPATIALE DE BELGIE BELGIAN INSTITUTE OF SPACE AERONOMY BELGISCH INSTITUUT VOOR RUIMTE-AERONOMIE INSTITUT D'AERONOMIE

- 3-year ESA Pandonia project ended in Jan 2017.
- A 10 months CCN is about to be starting in Jun 2017 to work on the new tracker, Aerosol retrievals and a Field Calibration Tool.
- Some more instruments have been distributed (see map on next page)
- NASA Pandora effort has new lead (Bob Swap) since Mar 2017
- A first version of a parametrized sky algorithm to retrieve trace gas surface concentrations and tropospheric columns from MAXDOAS type measurements at 5 elevation angles (1°, 2°, 15°, 30°, 90°) has been made operational.

- NASA LMOS campaign (Lake Michigan Ozone Study 2017, <https://www-air.larc.nasa.gov/missions/lmos/index.html>, May-June 2017) is being supported by Pandonia
- NASA SARP campaign (Student Airborne Research Program, [https://airbornescience.nasa.gov/nsrc/content/National Suborbital Research Center SARP 2017](https://airbornescience.nasa.gov/nsrc/content/National%20Suborbital%20Research%20Center%20SARP%202017), June-Aug 2017 around Los Angeles) is being supported by Pandonia
- NASA OWLETS (Ozone Water-Land Environmental Transition Study, <https://www-air.larc.nasa.gov/missions/owlets/index.html>, Jul-Aug 2017 Chesapeake Bay) will be supported by Pandonia

Current instrument distribution

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Pandonia stations

Decided Pandonia stations

NASA stations

Interested Pandonia stations

Developed, but not validated new data product

- Surface concentrations of O₃

Pandora versus in-situ at Smith Point, Texas, USA

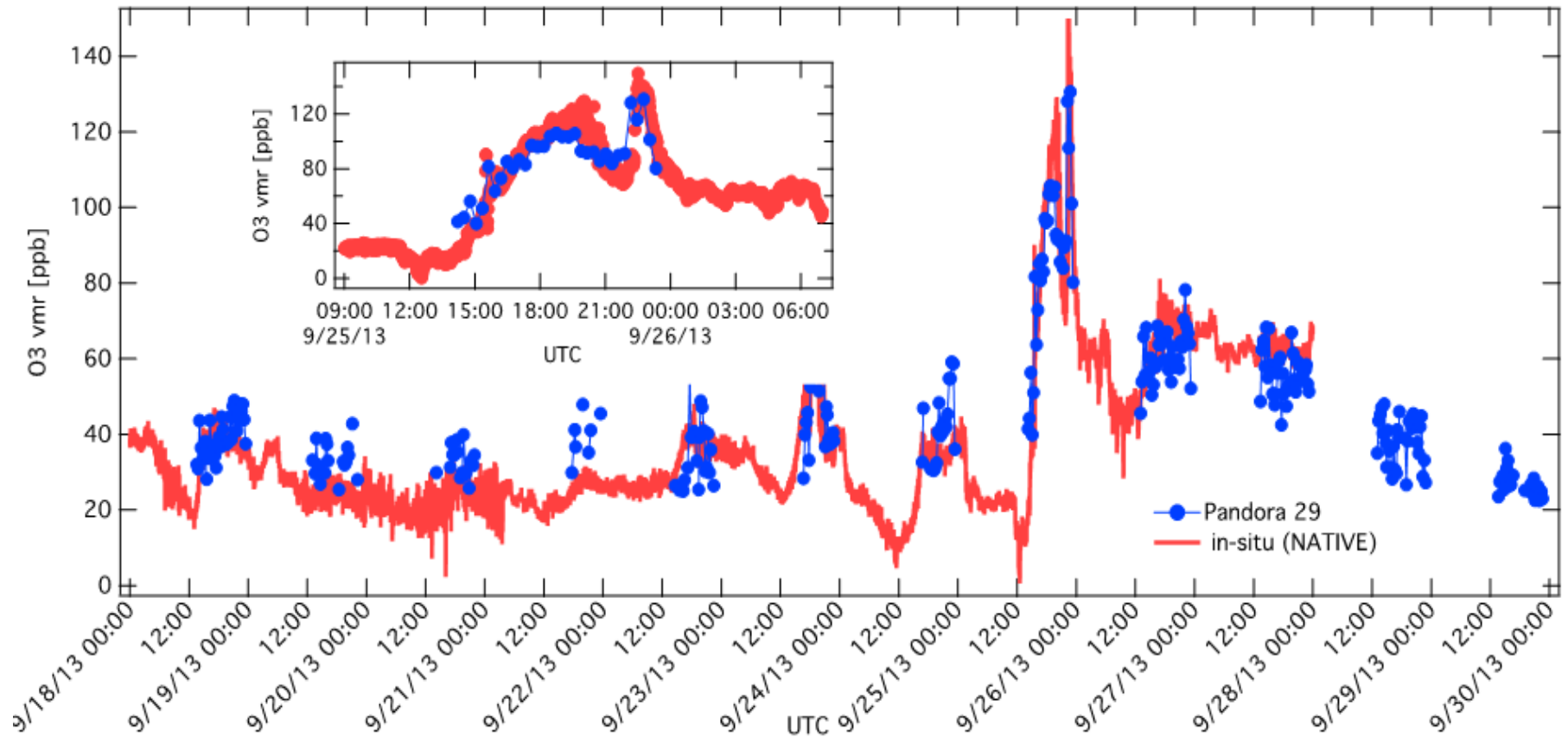


Figure from E. Spinei, NASA

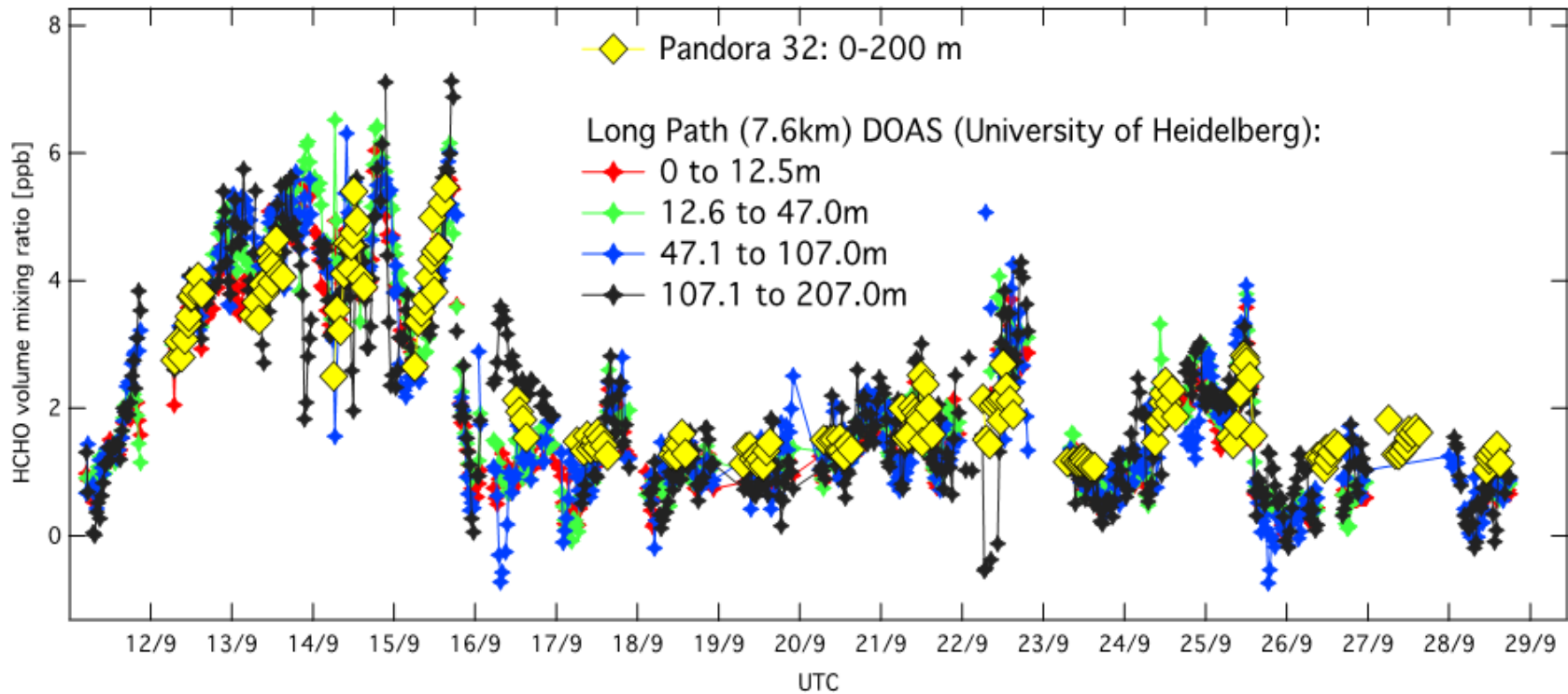
HCHO – surface concentrations



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HCHO: CINDI-2016

Figure from E. Spinei





Royal Netherlands
 Meteorological Institute
 Ministry of Infrastructure and the
 Environment

Netherlands
Space
 Office



Cabauw, NL
 1-28 Sep 2016

CESAR

Cabauw Experimental Site for Atmospheric Research
 M. Van Roozendael, CEOS AC-VC#13, 28-30 June 2017, Paris, France



Deployed DOAS systems

34 instruments

8 Scientific grade

3 Pandora-2S

2 Pandora

5 EnviMes

6 MiniDOAS

1 Phaeton

2 SAOZ

+ few others...

#	Instrument	ID	Type	Spectral range	Resolution	Detector type	T°
1	BIRA	4	MAXDOAS (2D)	300-390 nm/ 400-560 nm	0.4/ 0.6 nm	CCD	-50°
2	AUTH	3	PHAETON (2D)	300-450 nm	0.4 nm	CCD	5°
3	AIOFM	1	MAXDOAS (2D)	290-380 nm	0.4 nm	CCD	-30°
4	IUPH	19	EnviMes (2D)	300-460 nm/ 440-580 nm	0.6/ 0.5 nm	CCD	Room T°
5	IUPB	18	MAXDOAS (2D)	305-390 nm/ 405-580 nm	0.5/ 0.9 nm	CCD	-35°
6	IUPB	37	I-DOAS (2D)	400-580 nm	0.5 nm	CCD	-30°
7	BOKU	6	MAXDOAS (2D)	405-580 nm	0.9 nm	CCD	-30°
8	CMA	7	Hoffmann (1D)	300-450 nm	0.7 nm	PDA	Room T°
9	CMA	8	Hoffmann (1D)	400-710 nm	0.7 nm	PDA	Room T°
10	CHIBA-U	9	MAXDOAS (1D)	310-515 nm	0.4 nm	CCD	0-40°
11	CSIC	10	MAXDOAS (1D)	300-500 nm	0.5 nm	CCD	Room T°
12	CU-Boulder	11	MAXDOAS (2D)	325-470 nm/ 430-680 nm	0.7/ 1.2 nm	CCD	-30°
13	CU-Boulder	12	MAXDOAS (1D)	300-465 nm/ 380-490 nm	0.8/ 0.5 nm	CCD	-30°/ 0°
14	DLR-USTC	13	EnviMes (2D)	300-460 nm/ 450-600 nm	0.6/ 0.6 nm	CCD	Room T°
15	DLR-USTC	14	EnviMes (2D)	300-460 nm/ 450-600 nm	0.6/ 0.6 nm	CCD	Room T°
16	IISERM	16	Hoffmann (1D)	320-470 nm	1.0 nm	CCD	Room T°
17	INTA	17	MAXDOAS (2D)	400-550 nm	0.5 nm	CCD	-20°
18	KNMI	21	Hoffmann (1D)	290-430 nm	0.5 nm	PDA	Room T°
19	KNMI	22	Hoffmann (1D)	400-600 nm	0.6 nm	PDA	Room T°
20	KNMI	23	Pandora (2D)	285-530 nm	0.6 nm	CCD	20°
21	LUFTB	26	Pandora-2S (2D)	280-540 nm	0.6 nm	CCD	15°
22	LUFTB	260	Pandora-2S (2D)	400-900 nm	1.1 nm	CCD	15°
23	LUFTB	27	Pandora-2S (2D)	280-540 nm	0.6 nm	CCD	15°
24	LUFTB	270	Pandora-2S (2D)	400-900 nm	1.1 nm	CCD	15°
25	MPIC	28	Tube-DOAS (1D)	315-475 nm	0.6 nm	CCD	10°
26	NASA	31	Pandora (2D)	285-530 nm	0.6 nm	CCD	20°
27	NASA	32	Pandora (2D)	285-530 nm	0.6 nm	CCD	20°
28	NIWA	29	EnviMes (1D)	305-460 nm/ 410-550 nm	0.7 nm	CCD	20°
29	NIWA	30	MAXDOAS (1D)	290-365 nm/ 400-460 nm	0.6 nm	CCD	-20°
30	NUST	33	Hoffmann (1D)	320-465 nm	0.7 nm	CCD	Room T°
31	LMU-MIM	35	EnviMes 2D	300-460 nm/ 450-600 nm	0.6 nm	CCD	20°
32	U-Toronto	36	MAXDOAS (2D)	300-500 nm	0.5 nm	CCD	20°
33	AMOIAP	2	2-port DOAS (1D)	420-490 nm	0.5 nm	CCD	-40°
34	LATMOS	24	SAOZ (ZS)	270-640 nm	1.3 nm	PDA	Room T°
35	LATMOS	25	Mini-SAOZ (ZS)	270-820 nm	0.7 nm	CCD	Room T°
36	BSU	5	MARSB (1D)	300-500 nm	0.4 nm	CCD	-40°



Ancillary observations

In-situ

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



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

Vertical distribution

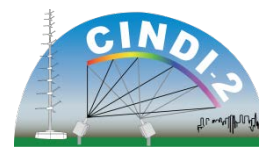
- NO₂ profile
- O₃ profile
- Aerosol profile

Horizontal distribution

- NO₂ column

• Modelling support

- AQ forecast (CAM5)
- Weather forecast



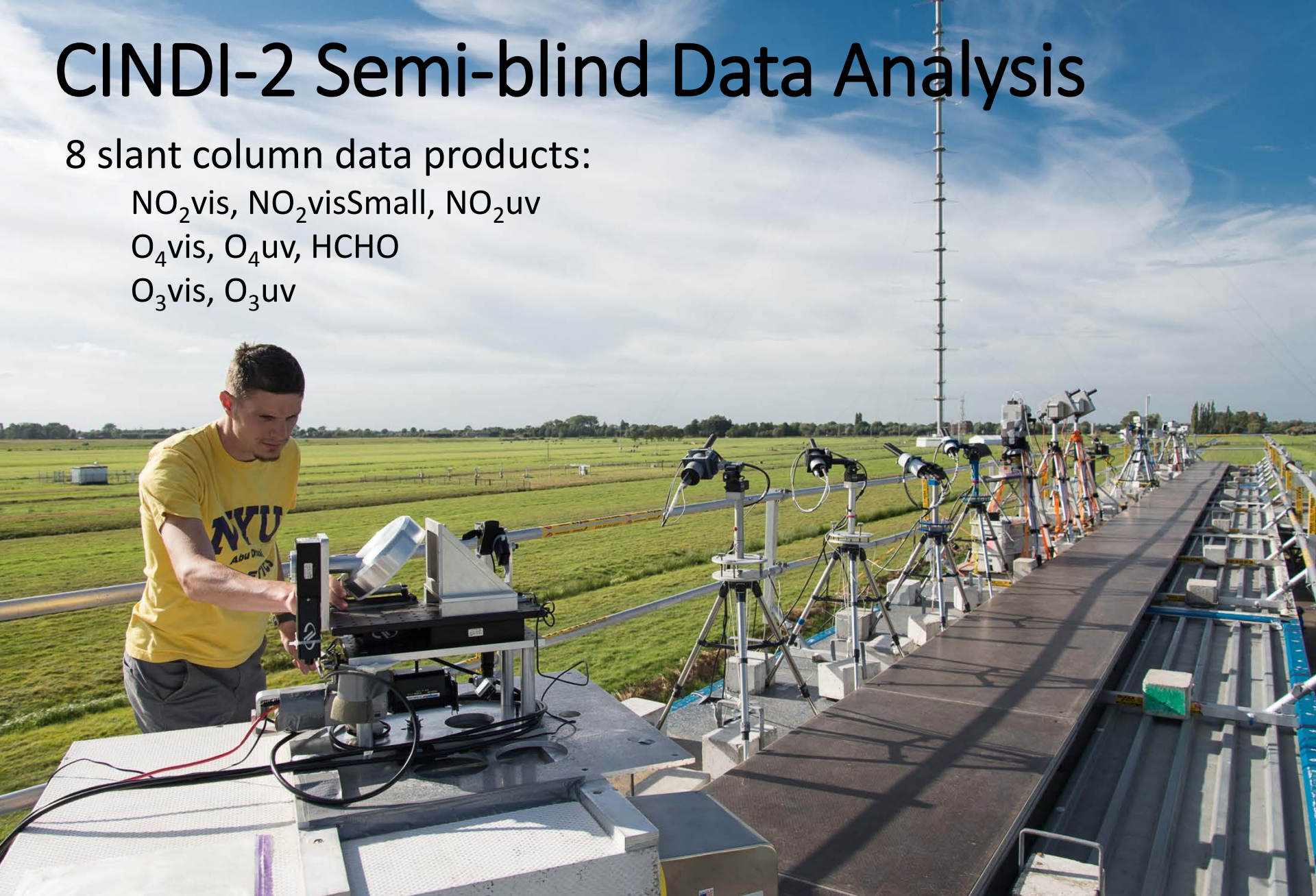
CINDI-2 Semi-blind Data Analysis

8 slant column data products:

NO_2 vis, NO_2 visSmall, NO_2 uv

O_4 vis, O_4 uv, HCHO

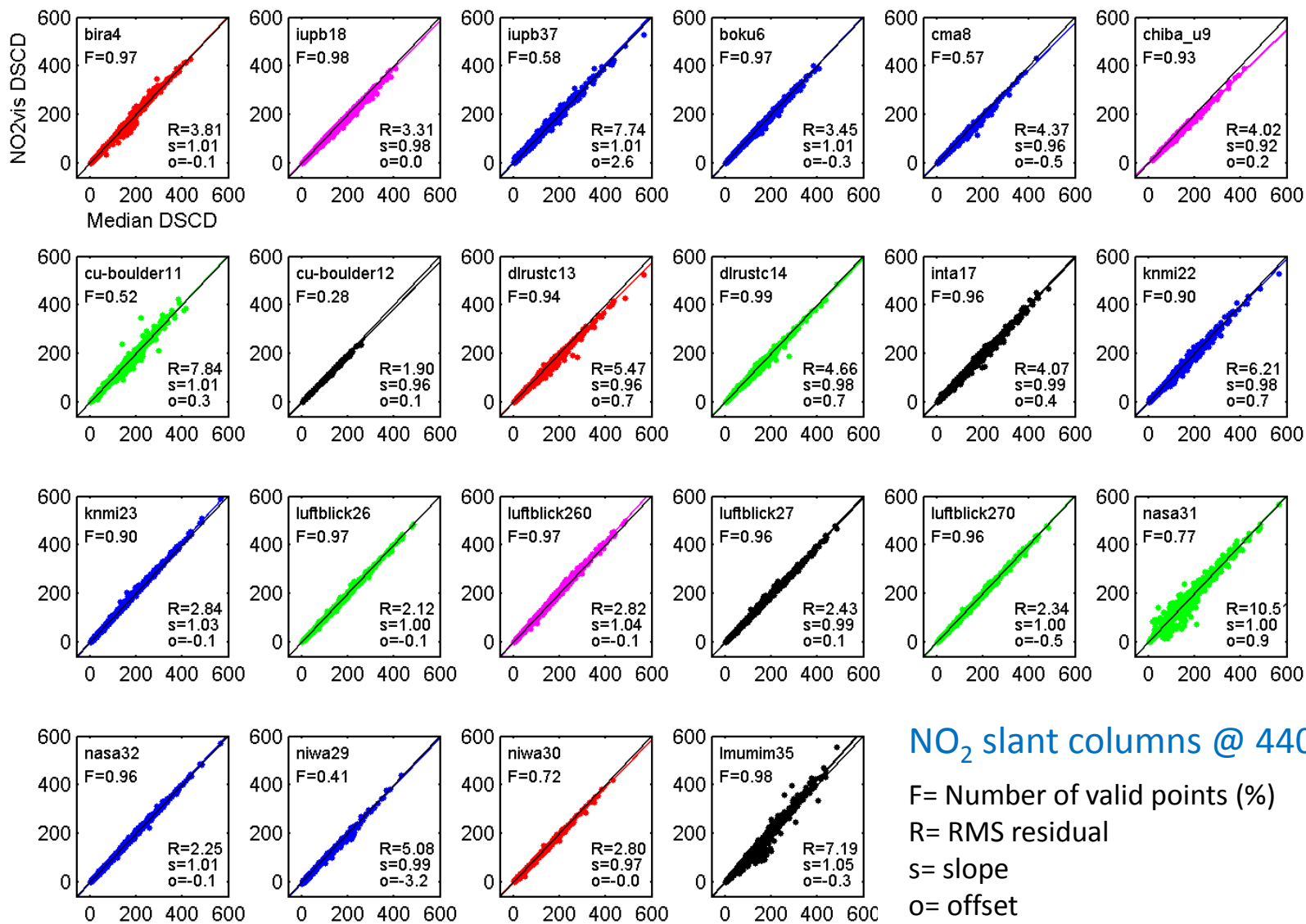
O_3 vis, O_3 uv



Regression analysis (NO₂vis)



Elevation angle corrected, regressions weighted by DSCD errors



NO₂ slant columns @ 440 nm

F= Number of valid points (%)

R= RMS residual

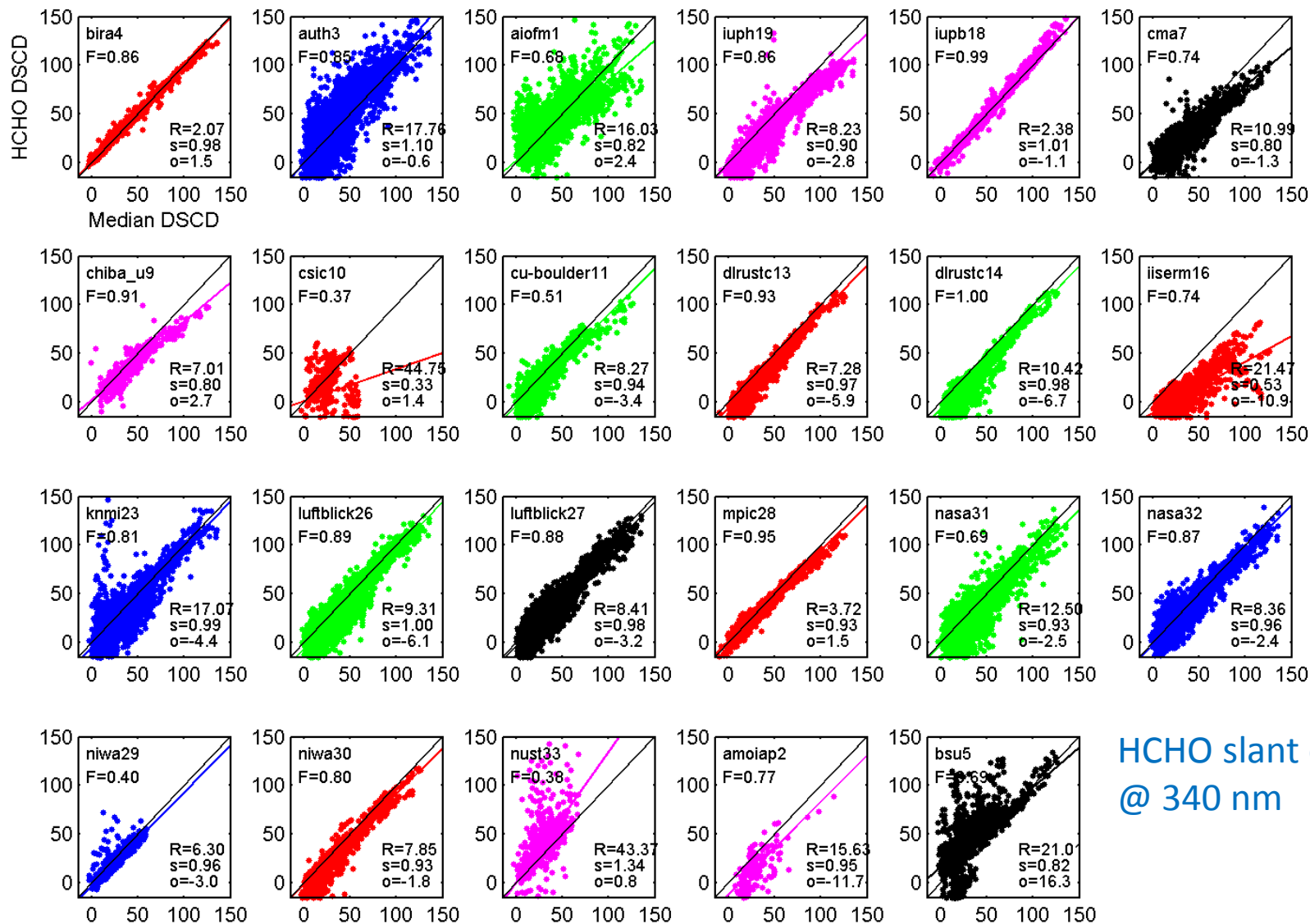
s= slope

o= offset

Regression analysis (HCHO)



Elevation angle corrected, regressions weighted by DSCD errors



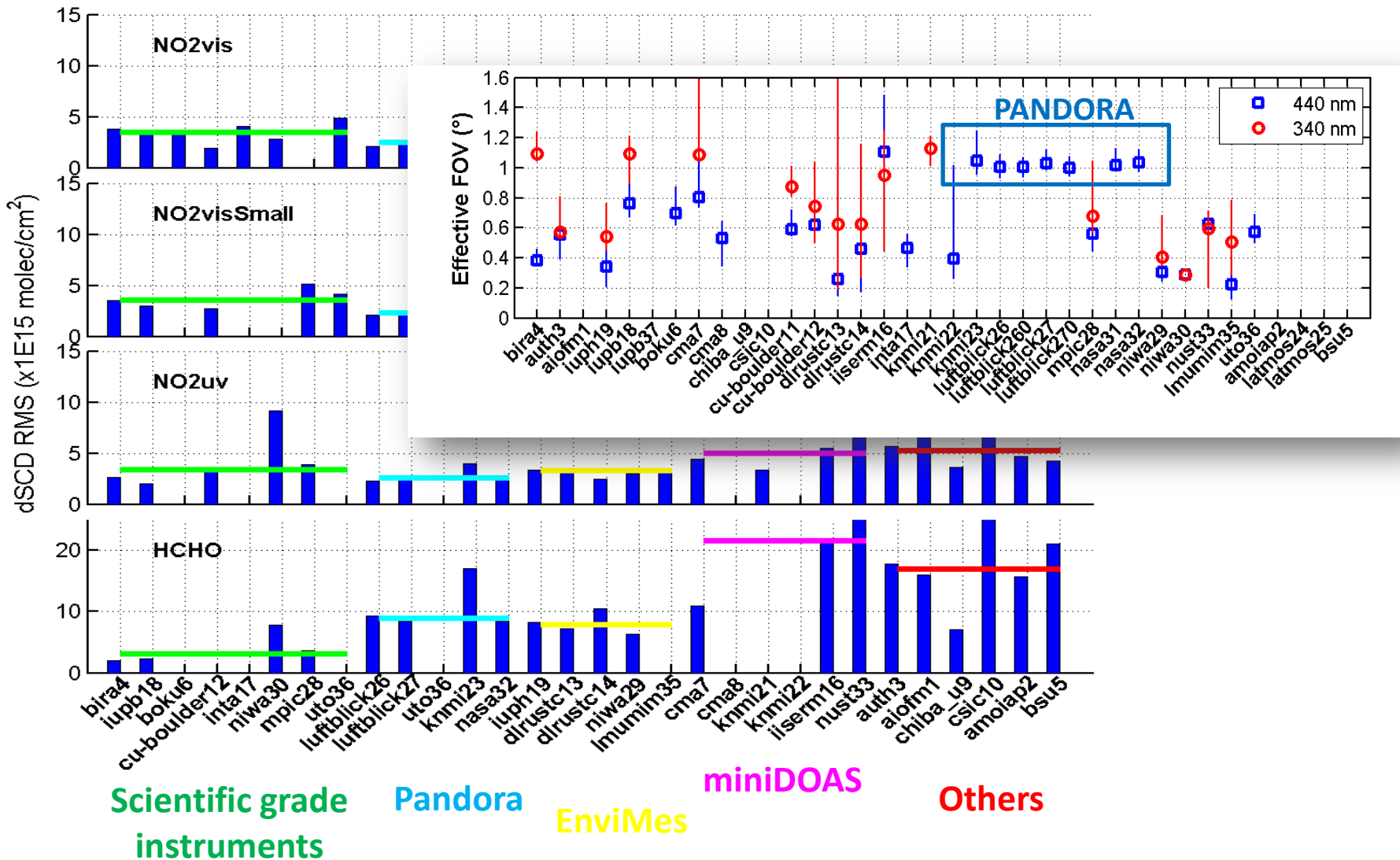
HCHO slant columns
@ 340 nm

Estimated precision of dSCDs

Based on RMS noise of regression analysis



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Performance assessment

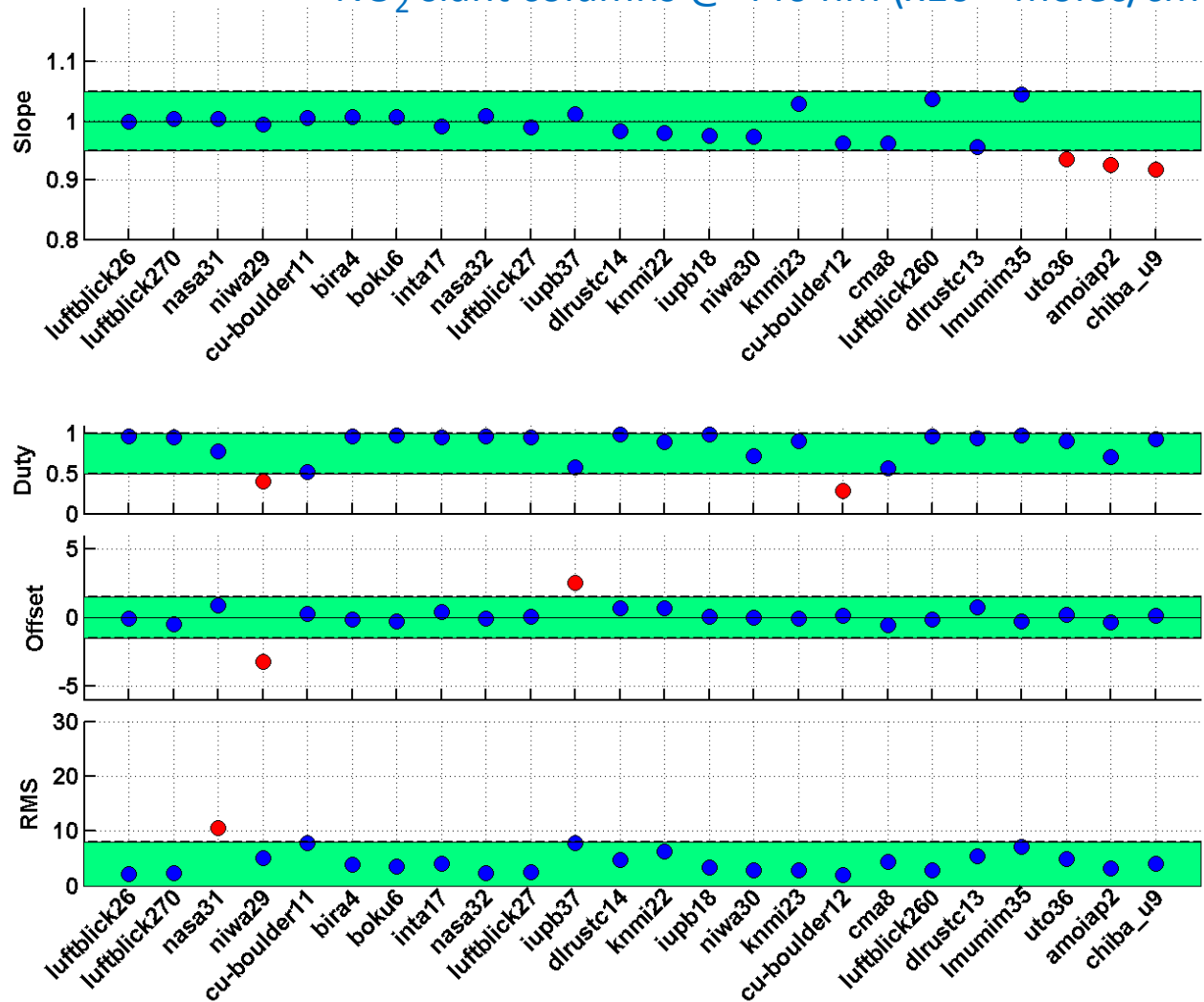


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NO₂ slant columns @ 440 nm (x10¹⁵ molec/cm²)

4 criteria for MAXDOAS performance assessment :

- Number of valid measurements (**Duty**)
- Regression:
 - **Slope**
 - **Offset**
 - **RMS**



Certification matrix



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Green label:

- All criteria fulfilled

Orange label:

- Majority of criteria fulfilled

Red label:

- Majority of criteria not fulfilled

Data product

← Instrument

	NO2vis	NO2visSmall	NO2uv	O4vis	O4uv	HCHO	O3uv	O3vis
bira4	4	3	1	4	1	1	1	6
auth3		17	17		24	19	8	
aiofm1			24		18	15	18	
iuph19		5	3		3	5	10	16
iupb18	1	1	5	1	5	4	2	3
iupb37	24			23				
boku6	2			2				5
cma7		13	12		14	17	13	
cma8	15			20				19
chiba_u9	21	21	21	24	20	16	21	
csic10			26		26	23	14	
cu-boulder11	3	2	2	3	2	2		2
cu-boulder12	20	18	19	18	19		12	
dlrustc13	14	15	11	19	12	11	15	14
dlrustc14	12	14	13	17	15	13	16	13
iiserm16		16	15		22	21	18	
inta17	11			11				10
knmi21			10		11			
knmi22	17			14				
knmi23	10	7	9	10	10	10	11	11
luftblick26	7	6	8	7	9	8	5	7
luftblick260	5	10		5				1
luftblick27	8	8	6	8	7	6	4	9
luftblick270	6	4		6				4
mpic28		11	4		4	3	3	
nasa31	18	19	14	15	16	12	7	12
nasa32	9	9	7	9	8	7	6	8
niwa29	19	20	18	16	17	14	9	17
niwa30	13		22	12	21	9		
nust33		24	25		25	20		
lmumim35	16	12	20	21	6		17	18
uto36	22	22		13				15
amoiap2	23	23	16	22	23	18		
latmos24								
latmos25								
bsu5			23		13	22	20	

MAXDOAS

	NO2vis	NO2visSmall	NO2uv	O3vis	
bira4	4	2	1	4	bira4
auth3		17	15		auth3
aiofm1			25		aiofm1
iuph19		6	4	9	iuph19
iupb18	2	1	2	2	iupb18
iupb37	23				iupb37
boku6	1			1	boku6
cma7		13	11		cma7
cma8	14			21	cma8
chiba_u9	26	24	21		chiba_u9
csic10			24		csic10
cu-boulder11	3	3	3	3	cu-boulder11
cu-boulder12	20	18	17		cu-boulder12
dlrustc13	16	14	13	10	dlrustc13
dlrustc14	17	16	14	15	dlrustc14
iiserm16		21	22		iiserm16
inta17	7			5	inta17
knmi21			23		knmi21
knmi22	19				knmi22
knmi23	13	11	9	13	knmi23
luftblick26	11	7	7	6	luftblick26
luftblick260	6	5		11	luftblick260
luftblick27	8	8	6	8	luftblick27
luftblick270	5	4		12	luftblick270
mpic28		10	5		mpic28
nasa31	12	12	12	20	nasa31
nasa32	9	9	8	7	nasa32
niwa29	21	20	16	16	niwa29
niwa30	10		18		niwa30
nust33		23	26		nust33
lmumim35	22	19	19	17	lmumim35
uto36	18	15		14	uto36
amoiap2	15	22	20		amoiap2
latmos24	24			18	latmos24
latmos25	25			19	latmos25
bsu5			10		bsu5

ZENITH-SKY

CINDI-2 working groups



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- **Aerosol & trace gas profiling** (U. Friess, IUPH and F. Hendrick, BIRA)
- **Pointing calibration** (S. Donner, MPIC)
- **Mobile-DOAS measurements** (A. Merlaud, BIRA)

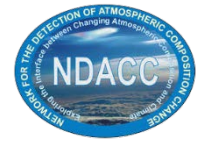
- **HONO retrieval** (Y. Wang, MPIC)
- **Glyoxal retrieval** (T. Koenig, CU Boulder)
- **Tropospheric ozone retrieval** (Y. Wang, MPIC)
- **Centralised reprocessing of CINDI-2 spectra** (FRM₄DOAS)
- ...

ESA FRM₄DOAS project

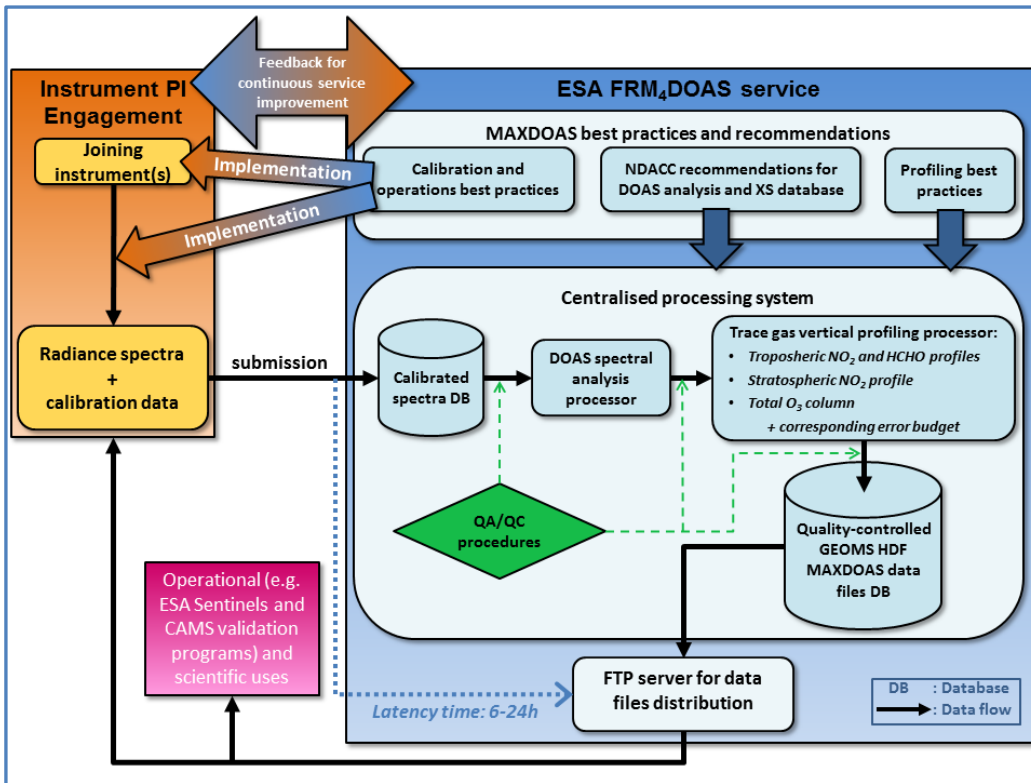


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2-years project, started in July 2016



- Round-robin of MAXDOAS profiling algorithms
- Selection of community algorithm
- Demonstration of centralised processing system for MAXDOAS



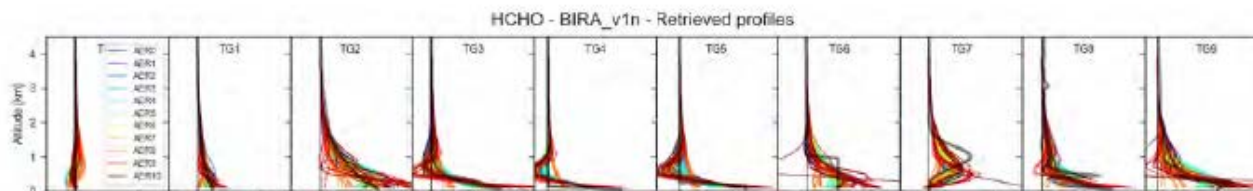
<http://frm4doas.aeronomie.be>



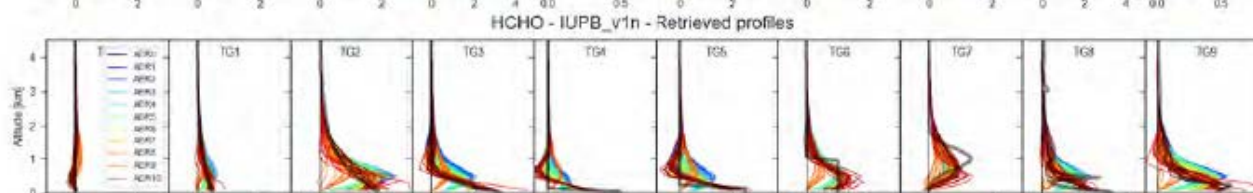
FRM₄DOAS round-robin

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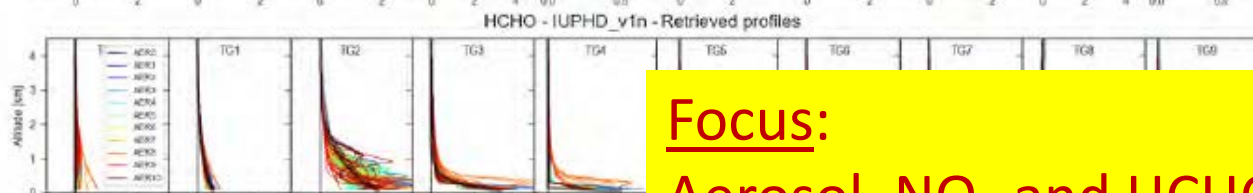
BIRA



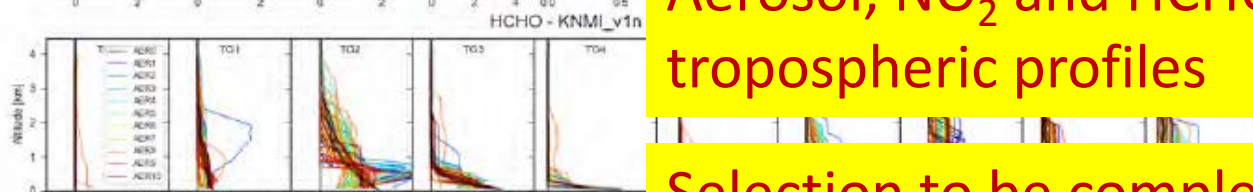
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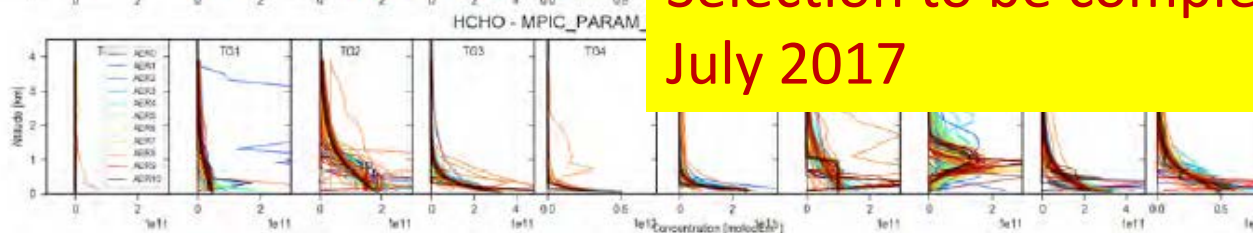
IUP-Heid



KNMI



MPIC

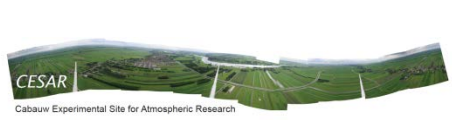
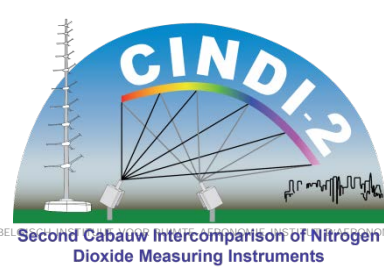


Focus:
Aerosol, NO₂ and HCHO
tropospheric profiles

Selection to be completed by
July 2017

Conclusions and outlook

- Pandonia network up and running, number of site is growing steadily. Developments ongoing to extend the number of products.
- Successful large scale intercalibration campaign in Cabauw, Sep. 2016 (CINDI-2). Provides a quantitative photography of the state-of-the-art in the international DOAS community.
- CINDI-2 data processing ongoing in various working groups. Status reviewed at CINDI-2 workshop (KNMI, 3-5 April 2017). Second workshop provisionally planned in early 2018 (Innsbruck, Austria).
- FRM₄DOAS round-robin of MAXDOAS algorithms under way. Selection to be completed soon. Will result in community algorithm (open source) to be implemented in FRM4DOAS demonstration centralised processing system (beta version planned by early 2018).
- FRM activities strongly linked to Sentinel-5 Precursor (and future Sentinel 4 & 5) validation programme.



Royal Netherlands Meteorological Institute
Ministry of Infrastructure and the Environment



Thank you for your attention!



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