AQ-related Fiducial Reference Measurement projects

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CEOS AC-VC4 Meeting

NOAA NCWCP, College Park, MD, 2-4 May 2018

Fiducial Reference Measurements (FRM)

ESA development of FRM activities specifically for the Atmospheric Composition data sets during the last 2 years:

✓ **FRM$_4$DOAS** http://frm4doas.aeronomie.be
- Harmonization of retrievals from UV-Vis ground based spectrometers (e.g. MAXDOAS) and development of centralised processing system
- Adopt FRMs standards for: tropospheric & stratospheric NO_2 vertical profiles, total O_3, & tropospheric formaldehyde profiles.

✓ **Pandonia FRM** http://pandonia.net
- Ground-based remote sensing network using Pandora-2S and Pandora spectrometers
- Target products, total & tropospheric column: O_3, NO_2 ; additional possible products: SO_2, formaldehyde & H_2O,

✓ **FRM$_4$GHG** http://frm4ghg.aeronomie.be
- Inter-comparison of ground based transportable FTIR systems with reference to TCCON as standard system – goal to complement the TCCON network as GHG validation standard

esa

Fiducial Reference Measurements (FRM)

ESA S5P-FRM Longer Term Planning:

✓ **Pandonia FRM**
- ESA operational and development projects
  - implementation Q1 2018 (4 years duration)

✓ **FRM$_4$GHG and FRM$_4$DOAS**
- operational support to be implemented through Open Competition,
- KO planned Q1 2019 (4 years duration)

+ additional support from EUMETSAT for the validation of core EUM and Copernicus AC/AQ products (MetOp-SG & MTG)
- KO planned Q4 2018 (3 years duration)

The FRM$_4$DOAS Project

<u>F</u>iducial <u>R</u>eference <u>M</u>easurements <u>for</u> Ground-Based <u>DOAS</u> Air-Quality Observations

- 2-year ESA project started in July 2016

- **Coordination:** BIRA-IASB

- **Partners:** IUP-Bremen, IUP-Heidelberg, MPIC, KNMI, BKScientific

- **Objectives:**

  - ✓ Support to the planning of CINDI-2 intercalibration campaign

  - ✓ Operationalisation of MAX-DOAS systems in view of satellite validation:

    1. Specification of best practices for instrument operation

    2. Round-Robin selection of retrieval algorithms

    3. Prototype centralised processing system for MAX-DOAS measurements to be operated within NDACC

- Close link with **Pandonia FRM** project → both meant to enable the provision for mandatory FRMs (suite of independent, fully characterized, and traceable ground measurement) in support of Copernicus Sentinels 5P, S-4 and S-5 missions.
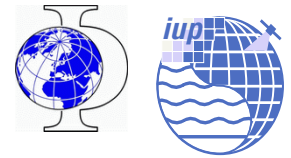
The FRM₄DOAS Project

Centralised Processing System
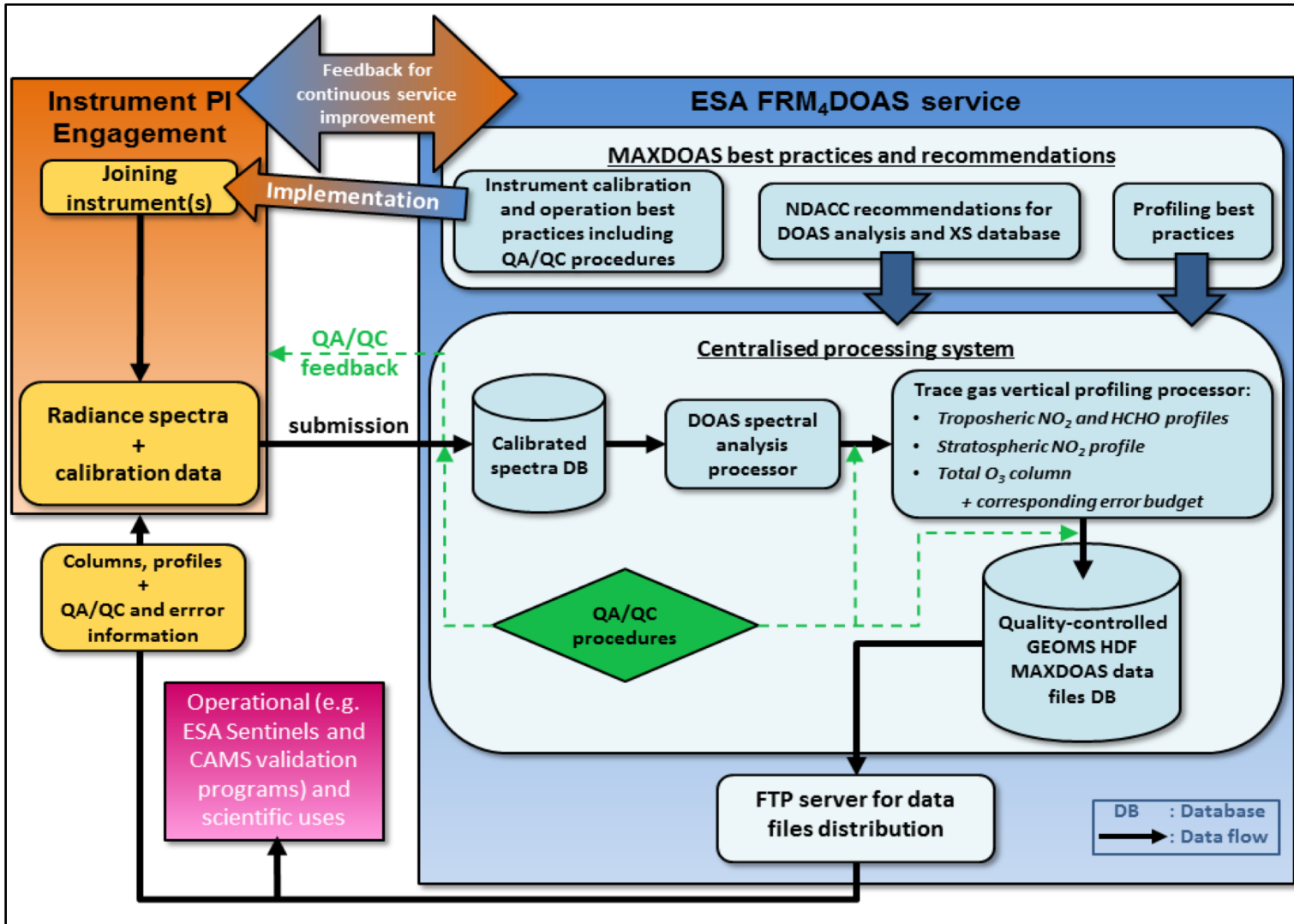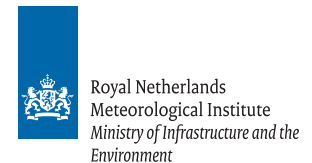
The FRM₄DOAS Project: Profile Retrieval Round Robin

Objectives:

Round-robin exercise with the aim to:

1. Review the strengths and weaknesses of the MAXDOAS profile retrieval algorithms available in the scientific community

2. Jointly define a community algorithm that will be implemented as baseline in the centralized processing system

Target species:
Aerosols @ 360 and 477 nm, HCHO, NO_2

- Creation of a synthetic dSCD reference dataset based on 5 different RTMs

- 9 trace gas profiles and 11 aerosol profiles

- 20 000+ simulated dSCDs for different scenarios and viewing geometries

- 3 960 retrieved profiles

Participating institutes/algorithms

Participant	Method	Algorithm	Forward Model
BIRA-IASB	OEM	BePro	LIDORT
BIRA-IASB	OEM	MMF	VLIDORT
IUPUB	OEM	Boreas	SCIATRAN
IUPHD	OEM	HEIPRO	SCIATRAN
KNMI	Parametrised	MARK	DAK
MPIC	Parametrised	MAPA	McArtim
MPIC	OEM	Priam	SCIATRAN
NASA	OEM	Quicklook	N/A

Retrieval strategy
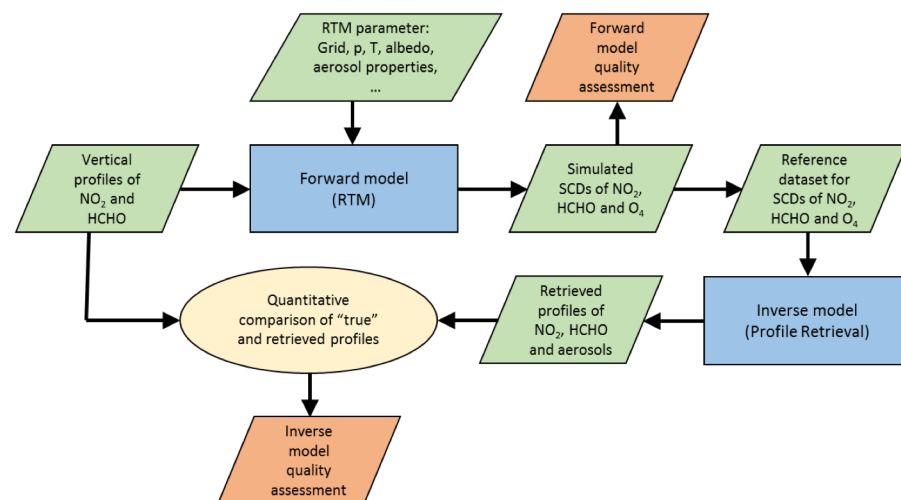
FRM$_4$DOAS Model Scenarios

#	Trace gas	Wavelength [nm]
1	NO$_2$	460
2	HCHO	343
3	O$_4$	360
4	O$_4$	477

Retrieval using simulated SCDs for any combination of:
- 10 Trace gas profiles
- 11 Aerosol profiles
- 10 Elevation angles
- 3 SZAs
- 3 RAAs

- ➢ 9900 trace gas simulations
- ➢ 990 O$_4$ simulations

Retrieval Results:
- Aerosol and trace gas vertical profiles
- Error components
- Simulated SCDs
- Averaging kernels (OEM only)
- Validity flag (using own criteria)

Retrieval settings:
- 200 m layers from 0-4 km resolution from 0-4 km
- Prescribed p, T profiles, surface albedo, aerosol optical properties
- Prescribed a priori profiles

Retrieval Versions:
v1:	Common settings
v2:	Own ("best") settings
_n:	5% random noise added to simulated measurements
_f:	Data flagged as invalid filtered out
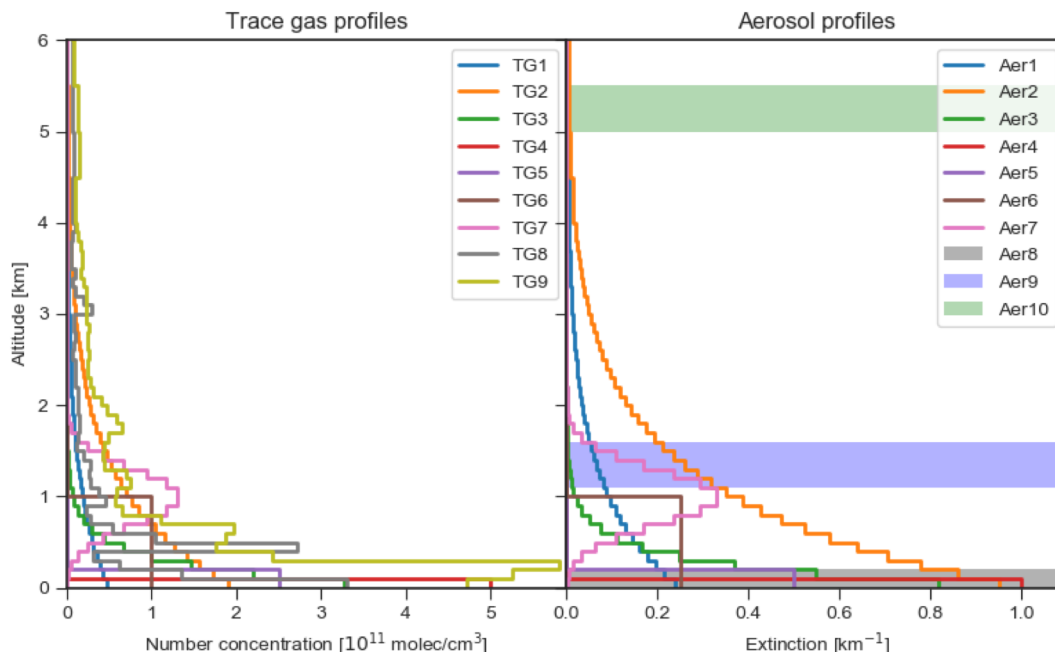
Profile Intercomparison

aer_360 - v1 - Retrieved profiles
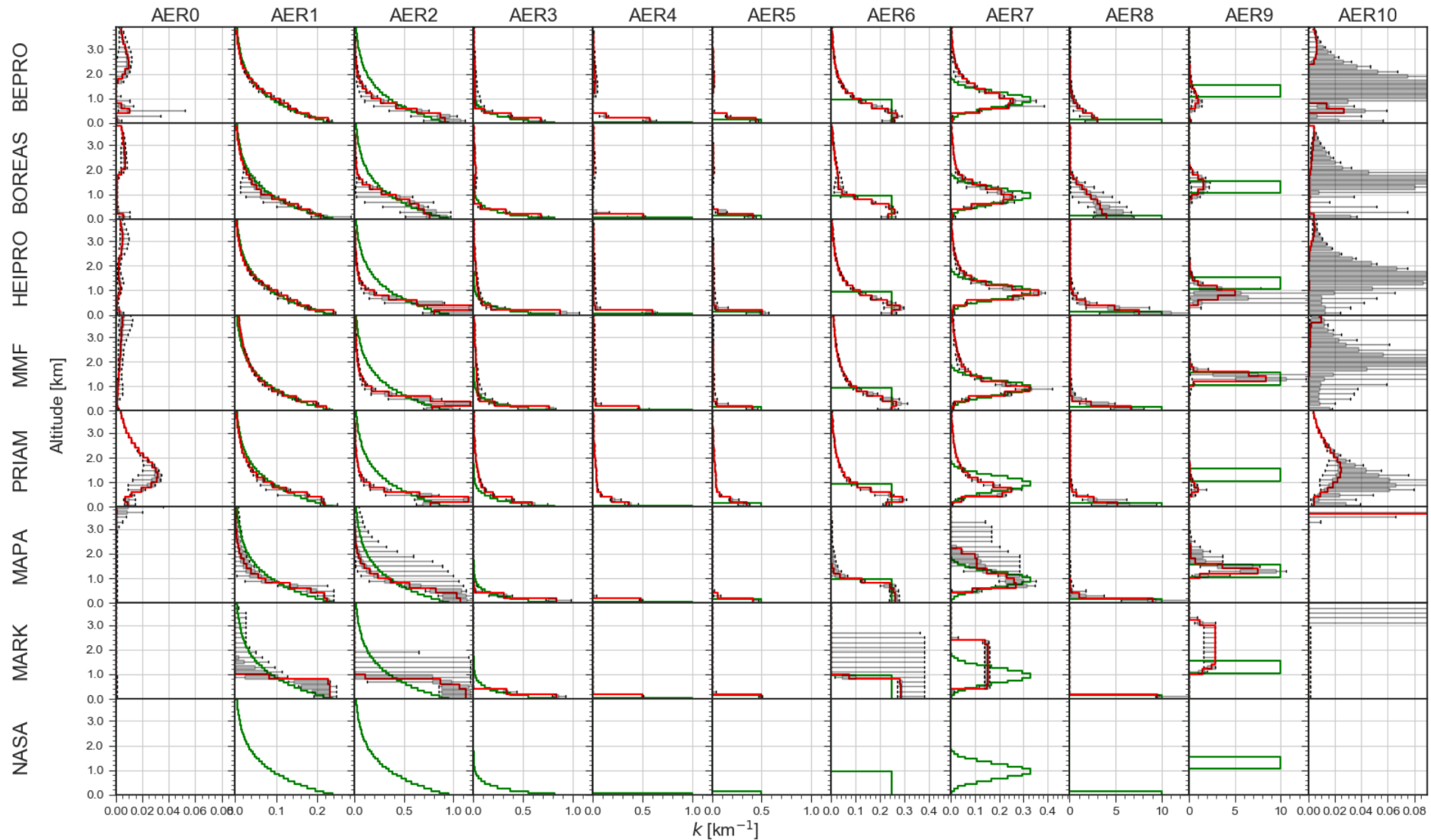
Profile Intercomparison

aer_360 - v1n - Retrieved profiles

Profile Intercomparison

NO2 - v1 - Retrieved profiles

Profile Intercomparison

NO2 - v1n - Retrieved profiles

FRM$_4$DOAS Intercomparison: Overall Algorithm Performance

Ranking based on RMS difference (retrieved – true)

v1

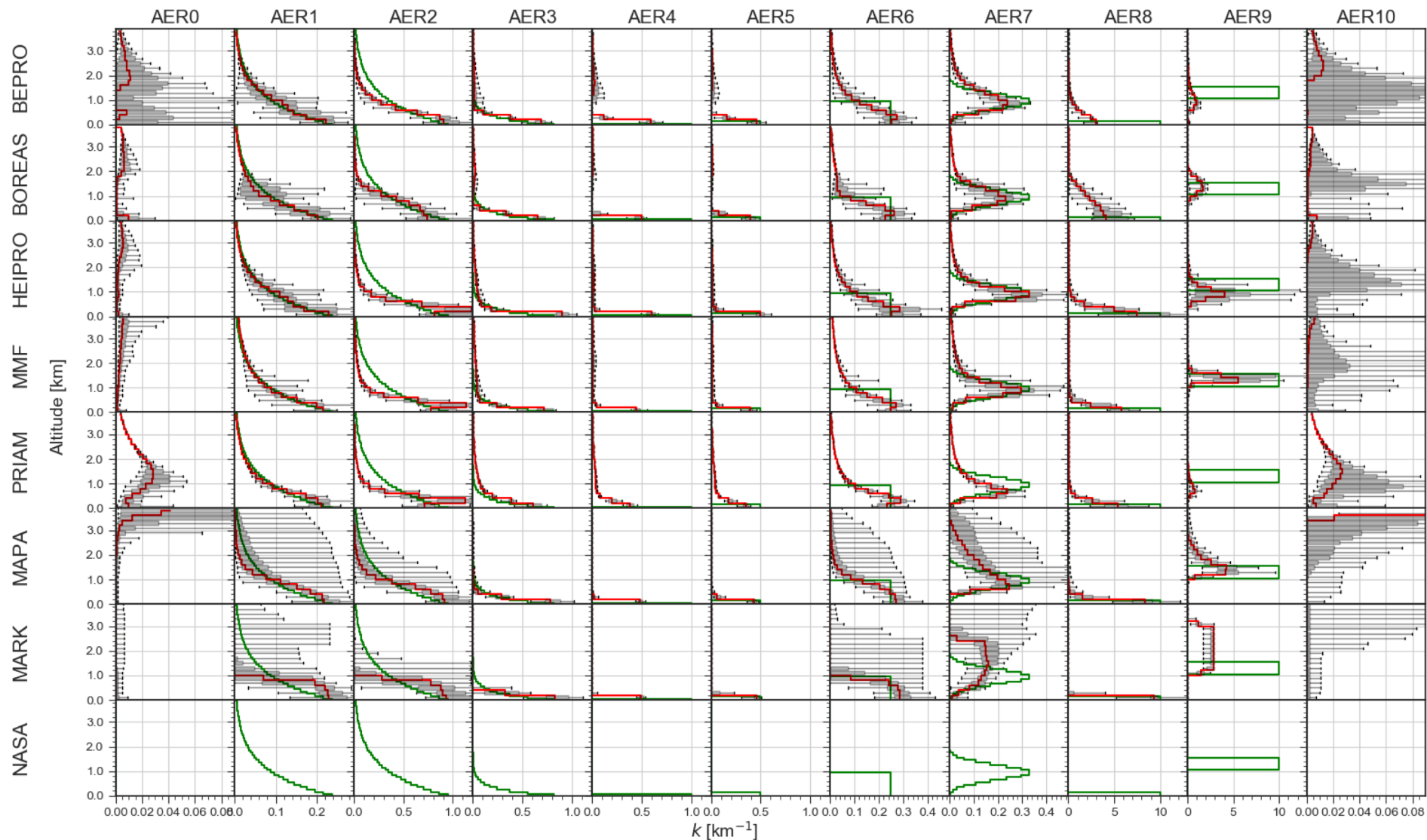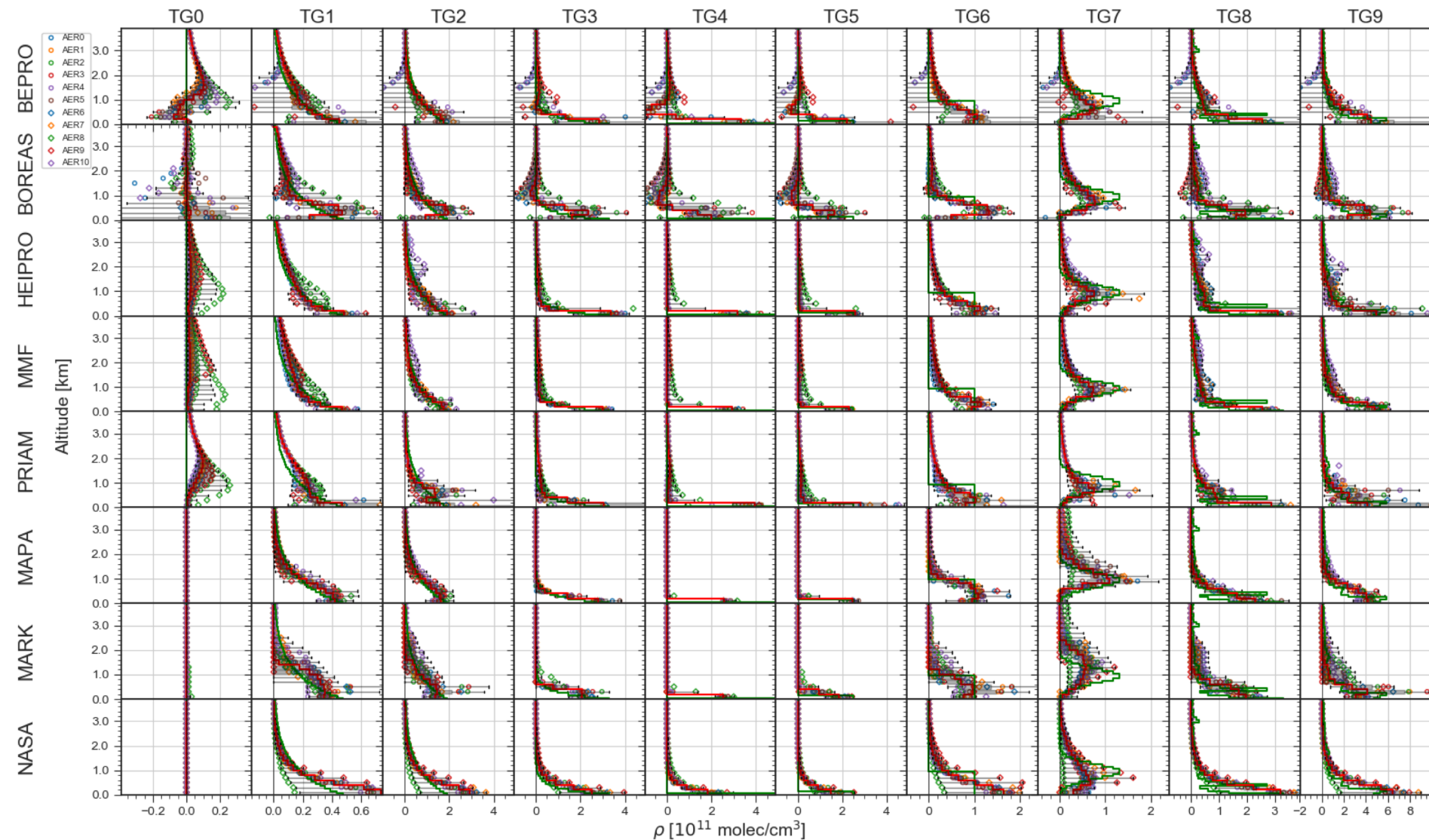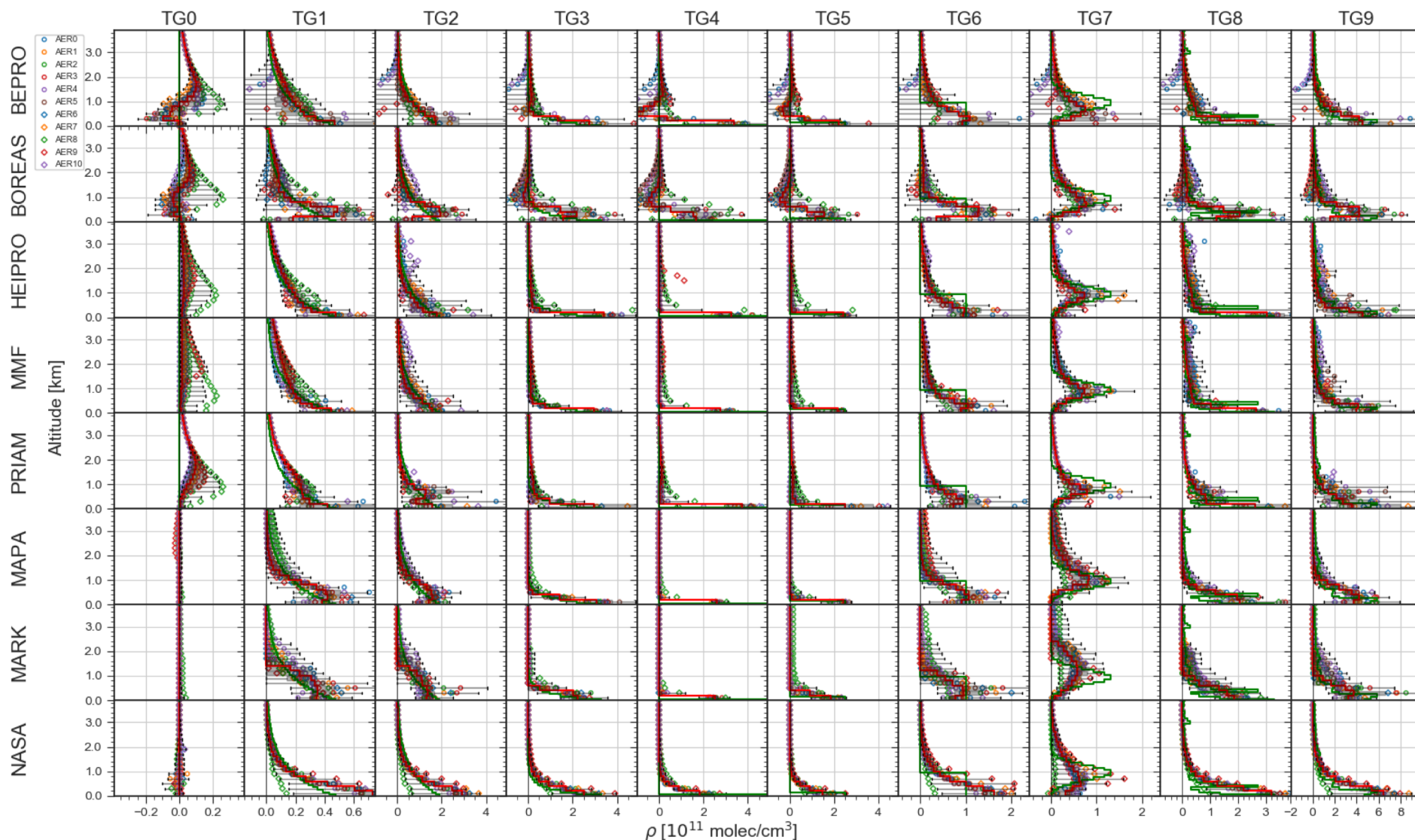			Aerosol - 360 nm						Aerosol - 477 nm						HCHO						NO$_2$					
		dSCD	Profile	Surface	Column	Speed	Valid	dSCD	Profile	Surface	Column	Speed	Valid	dSCD	Profile	Surface	Column	Speed	Valid	dSCD	Profile	Surface	Column	Speed	Valid
BEPRO	a	6	1	1	3	5	100%	7	8	8	8	5	85%	2	3	2	2	3	87%	7	8	8	8	3	77%
	f	6	2	1	4	5		7	2	2	4	5		2	3	3	2	3		5	4	3	1	3	
BOREAS	a	5	2	3	4	8	94%	5	2	1	3	8	93%	6	7	8	4	4	94%	6	7	7	7	4	85%
	f	5	1	3	2	8		5	1	3	2	8		6	7	8	4	4		6	8	8	6	4	
HEIPRO	a	4	5	7	1	7	100%	3	3	4	2	7	100%	4	4	5	5	7	100%	2	3	4	4	8	100%
	f	4	5	7	1	7		4	4	6	2	7		4	4	5	5	7		4	3	4	5	8	
MMF	a	2	3	2	2	4	100%	2	1	3	1	4	100%	3	1	3	3	6	100%	3	1	1	1	6	94%
	f	2	3	2	3	4		2	3	3	1	4		3	1	2	3	6		2	1	2	2	6	
PRIAM	a	7	6	6	5	6	97%	6	4	7	5	6	88%	5	6	6	6	5	97%	5	6	6	5	5	85%
	f	7	6	6	5	6		6	6	8	6	6		5	6	6	7	5		3	6	7	7	5	
MAPA	a	1	4	4	6	2	100%	4	7	2	6	2	92%	1	2	1	1	2	90%	1	2	2	2	2	90%
	f	1	4	4	7	2		3	5	4	7	2		1	2	1	1	2		1	2	3	3	2	
MARK	a	3	7	5	7	3	83%	2	6	5	4	3	90%	7	8	4	8	8	84%	2	5	3	3	7	89%
	f	3	7	5	6	3		2	8	5	5	3		7	8	4	6	8		5	7	5	4	7	
NASA	a							5	6	7	1		100%	5	7	7	1		100%		4	5	6	1	96%
	f							7	7	7	8			5	7	8	1				5	6	8	1	

v1n

		Aerosol - 360 nm						Aerosol - 477 nm						HCHO						NO$_2$					
		dSCD	Profile	Surface	Column	Speed	Valid	dSCD	Profile	Surface	Column	Speed	Valid	dSCD	Profile	Surface	Column	Speed	Valid	dSCD	Profile	Surface	Column	Speed	Valid
BEPRO	a	6	1	1	3	5	100%	7	8	8	8	5	79%	2	1	1	1	3	86%	7	8	8	8	3	78%
	f	7	1	1	4	5		5	3	2	1	5		2	2	1	3	3		7	4	6	2	3	
BOREAS	a	5	2	2	2	8	93%	5	1	1	3	8	90%	6	7	8	3	4	92%	3	7	7	2	4	82%
	f	5	2	2	3	8		7	1	1	4	8		6	7	8	4	4		4	8	8	6	4	
HEIPRO	a	3	4	6	1	7	100%	3	3	4	2	7	100%	4	3	5	4	7	100%	5	5	5	3	8	100%
	f	3	5	6	2	7		4	5	6	2	7		5	4	5	5	7		6	5	5	5	8	
MMF	a	2	5	3	5	4	96%	1	2	2	1	4	85%	3	2	2	2	6	100%	4	3	3	1	6	86%
	f	2	6	3	6	4		1	4	3	3	4		3	1	1	3	6		1	1	1	1	6	
PRIAM	a	7	3	4	4	6	94%	6	4	6	4	6	88%	5	6	6	6	5	92%	6	6	6	6	5	92%
	f	6	4	4	5	6		6	6	8	6	6		4	6	6	7	5		3	7	7	7	5	
MAPA	a	1	7	5	7	2	50%	4	7	3	7	2	43%	1	4	4	8	2	50%	1	2	2	4	2	74%
	f	1	3	4	1	2		2	5	4	2	2		1	5	6	2	2		2	3	3	3	2	
MARK	a	4	6	7	6	3	83%	2	6	7	5	3	88%	7	8	3	6	8	85%	2	4	1	5	7	89%
	f	4	7	7	7	3		2	8	5	7	3		7	8	3	7	8		5	6	2	4	7	
NASA	a							5	5	6	1		100%	5	7	7	1		95%	1	4	7	1		90%
	f							7	6	8	1			5	4	7	8			2	4	8	1		

Conclusions & Outlook

FRM$_4$DOAS Retrieval Round Robin Exercise

- Quantitative comparison of seven profile retrieval algorithms based on synthetic data

- Target species: Aerosols (360 & 477 nm), NO$_2$, HCHO

- Synthetic dataset enables quantitative assessment of the capabilities of the retrieval algorithms by comparison of 'true' and retrieved quantities

- Selected Algorithms for the FRM$_4$DOAS Central Processing System:

  1. **MPIC – MAPA (parametrised)**
  2. **BIRA – MMF (OEM)**

- Reference dataset of simulated O$_4$, NO$_2$ and HCHO dSCDs created within the FRM$_4$DOAS Retrieval Round Robin represents a basis for future retrieval algorithm benchmarks

Outlook

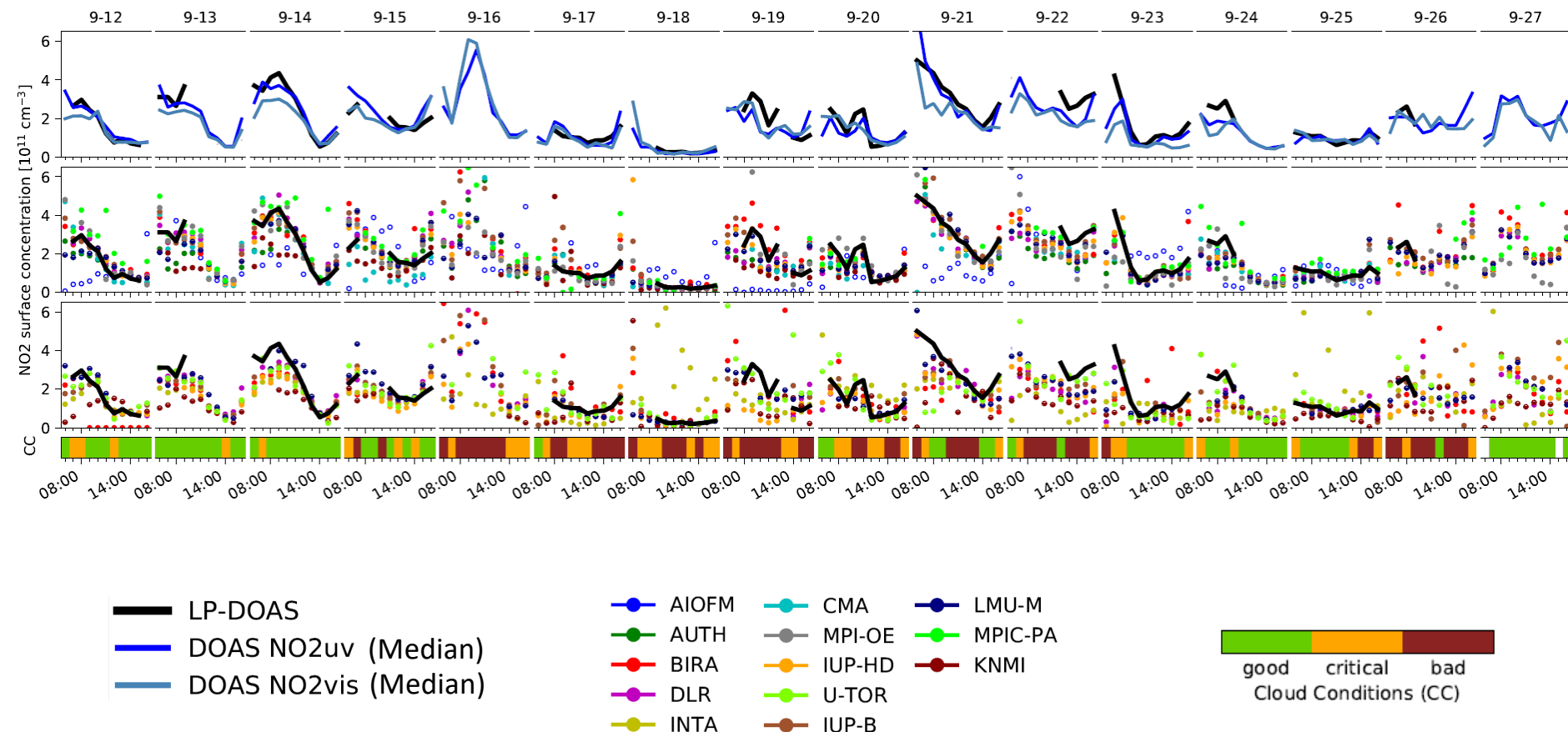- FRM$_4$DOAS Central Processing under development (first demonstration next week in Mainz)

- Test and validation planned this summer on CINDI-2 data sets and at project sites

- Final review scheduled in November 2018

- Operationalisation and extension to more data products planned in extension project (ESA ITT)

Surface Concentrations
NO$_2$: Comparison to LP-DOAS

J.-L. Tirpitz, U. Friess, Uni. Heid.

MAX-DOAS sites

FRM$_4$DOAS demonstration sites

Location	Country	Lat (°N)	Long (°E)	Owner
Ny-Alesund	Norway	79	12	IUPUB
Bremen	Germany	53	9	IUPUB
Cabauw	The Netherlands	52	5	KNMI
Uccle	Belgium	51	4	BIRA
Mainz	Germany	50	8	MPIC
Heidelberg	Germany	49	8	UHEID
Xianghe	China	40	116	BIRA/ IAP-CAS
Athens	Greece	38	24	IUPUB
Bujumbura	Burundi	-3	29	BIRA
Lauder	New-Zealand	-45	170	NIWA
Neumayer	Antarctica	-71	-8	UHEID

Potential addition

> 45 existing sites interested to join

Station	Country	Lat. N.	Long. E.	Owner
Eureka	Canada	80.10	-86.40	University Toronto
Ny Alesund	Norway	78.90	11.90	IUP Bremen
Fort McKay	Canada	57.20	-116.6	ECCC
Minsk	Belarus	53.8	27.5	BSU
Bremen	Germany	53.00	9.00	IUP Bremen
De Bilt	NL	52.10	5.18	KNMI
Cabauw	NL	52.00	4.90	KNMI
Uccle	Belgium	50.80	4.35	BIRA
Mainz	Germany	50.00	8.30	MPIC
Heidelberg	Germany	49.00	8.00	IUP Heidelberg
Munich	Germany	48.1	11.6	Munich Uni.
Hohenpeissenberg	Germany	47.80	11.67	DWD/IUP Heidelberg
Jungfraujoch	Switzerland	46.55	7.98	BIRA-IASB
Mt. Cimone	Italy	44.11	10.42	ISAC-CNR
OHP	French Alps	43.94	5.71	BIRA-IASB
Toronto	Canada	43.70	-79.5	ECCC
Thessaloniki	Greece	40.63	22.96	AUTH
Lecce	Italy	40.33	18.12	ISAC-CNR
Madrid	Spain	40.30	8.30	INTA
Beijing	China	40.0	116.0	CMA
Xianghe	China	39.75	116.96	BIRA
Evora	Portugal	38.56	-7.91	Evora Uni.
Palermo	Italy	38.12	13.35	ISAC-CNR
Athens	Greece	38.05	23.86	IUP Bremen
Yokosuka	Japan	35.32	139.65	JAMSTEC
Fukue	Japan	32.75	128.68	JAMSTEC
Hefei	China	31.91	117.16	AIOFM
Shanghai	China	31.30	121.50	AIOFM
Izana	Spain	28.31	-16.50	INTA
Huelva	Spain	28.3	-16.48	INTA
Cuautitlan	Mexico	19.70	-99.20	UNAM
Mauna Loa	USA	19.50	204.40	CU Boulder
Acatlan	Mexico	19.50	-99.20	UNAM
Vallejo	Mexico	19.50	-99.10	UNAM
Tor	Ghana	5.66	0.00	ISAC-CNR
Bujumbura	Burundi	-3.38	29.38	BIRA
Le Port	Reunion Island	-20.90	55.50	BIRA
Buenos Aires	Argentina	-34.5	-58.5	CITEDEF
Broadmeadows	Australia	-37.7	145	BOM, Melbourne
Ushuaia	Argentina	-54.50	-68.20	INTA
Marambio	Antarctica	-64.2	-56.6	INTA
Neumayer	Antarctica	-70.62	-8.27	IUP Heidelberg
PES	Antarctica	-72.0	23.0	BIRA
Belgrano	Antarctica	-77.8	-34.6	INTA
Arrival Heights	Antarctica	-77.83	166.65	IUP Heidelberg

FRM**4**DOAS