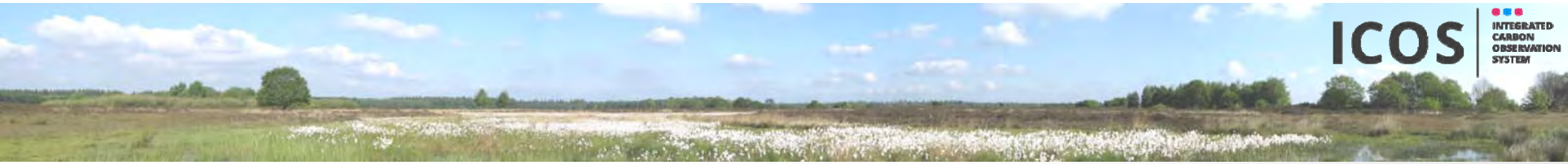


EcoTech FTIR instrument modifications and testing for tall tower deployment

Alex Vermeulen, Arjan Hensen, Pim van den Bulk,
Chris Edwards, Marie Laborde, David Griffith

ECN

GHG Observations: demands

Instrumentation needs to be:

- Robust
- Very high precision
- High time resolution
- Continuous measurement
- Lifetime >10 years
- Low maintenance
- Low consumables
- Easy to operate
- Completely automated
- Easy to integrate
- Low power+gas consumption
- Commercially available
- Supplier support

Tall tower applications

- Vertical gradients along tower
  - Switching levels
  - Buffer volumes
- Remote locations
- Limited space/accessibility
- Climatic conditions sub-optimal
- Standalone operation > 1 month
- Multiple gases

Winderlich et al, 2010. doi:10.5194/amt-3-1113-2010, 2010

Instrument development: Ecotech Spectronus in-situ FTIR

Upper section
Computer and temperature control

Perspex Shipping covers
(must be removed before operation)

Middle section
Optical system – temperature controlled.

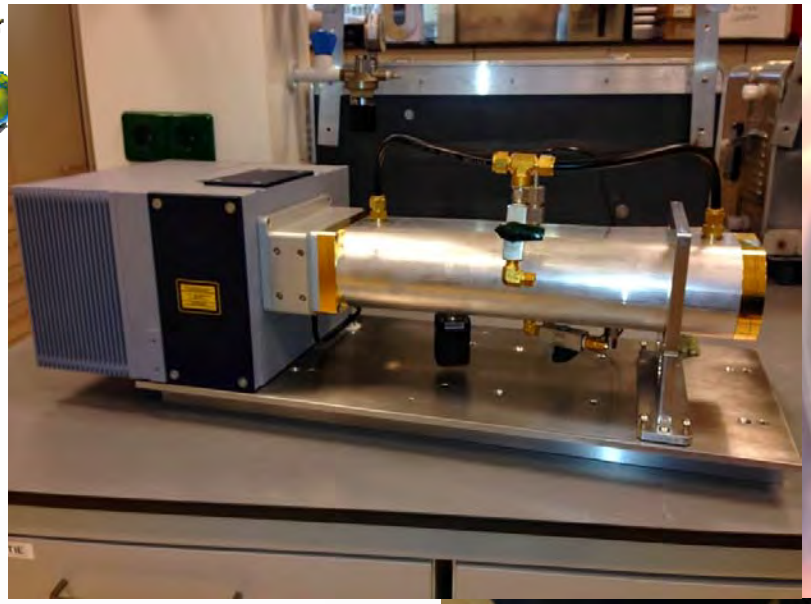
Lower section
Gas handling system

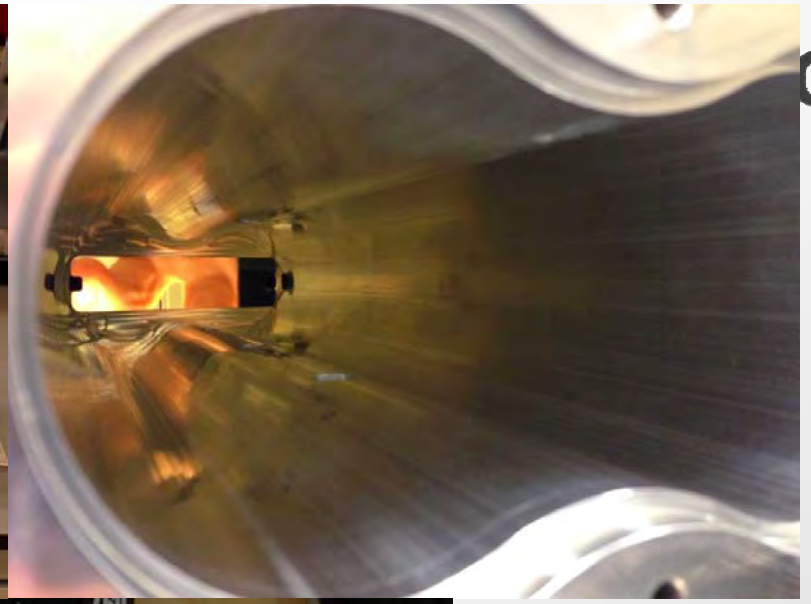
Gases	Precision (5 min average)
CO_2 /ppmv	0.04
CH_4 /ppbv	0.2
N_2O/ppbv	< 0.06
CO/ppbv	0.2
$\delta^{13}C$-CO_2/‰	< 0.08*
δD in H_2O vapour/‰	< 1

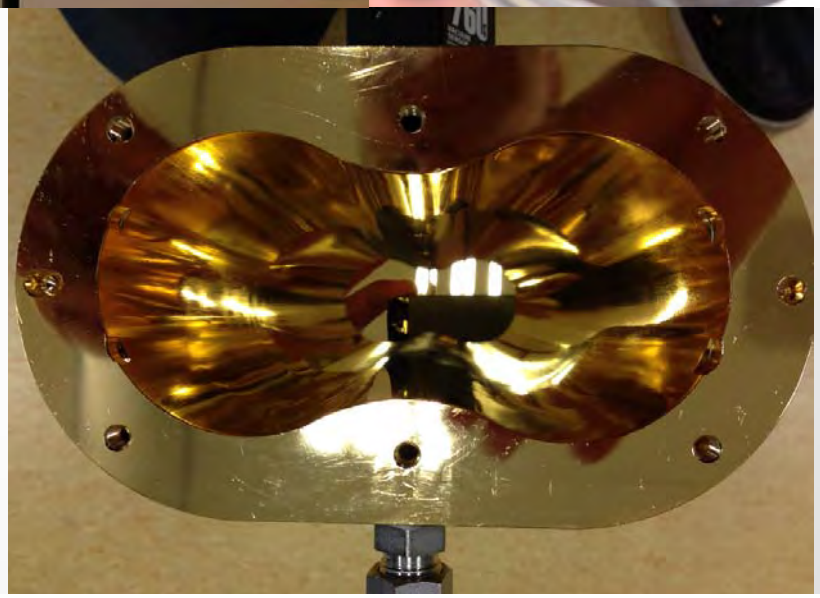
120 kg
pump 17 kg
1160x486x885 mm
200 W
Pump 310 W
24 m multipass cell
3.5 liter **glass** cell
0.5-1.5 $l.min^{-1}$ or static
MCT detector
2000-7800 cm^{-1}
Spectral res 1.0 cm^{-1}
15 s-60 min averaging
10-40 ^oC oper. temp
Built-in sample drying

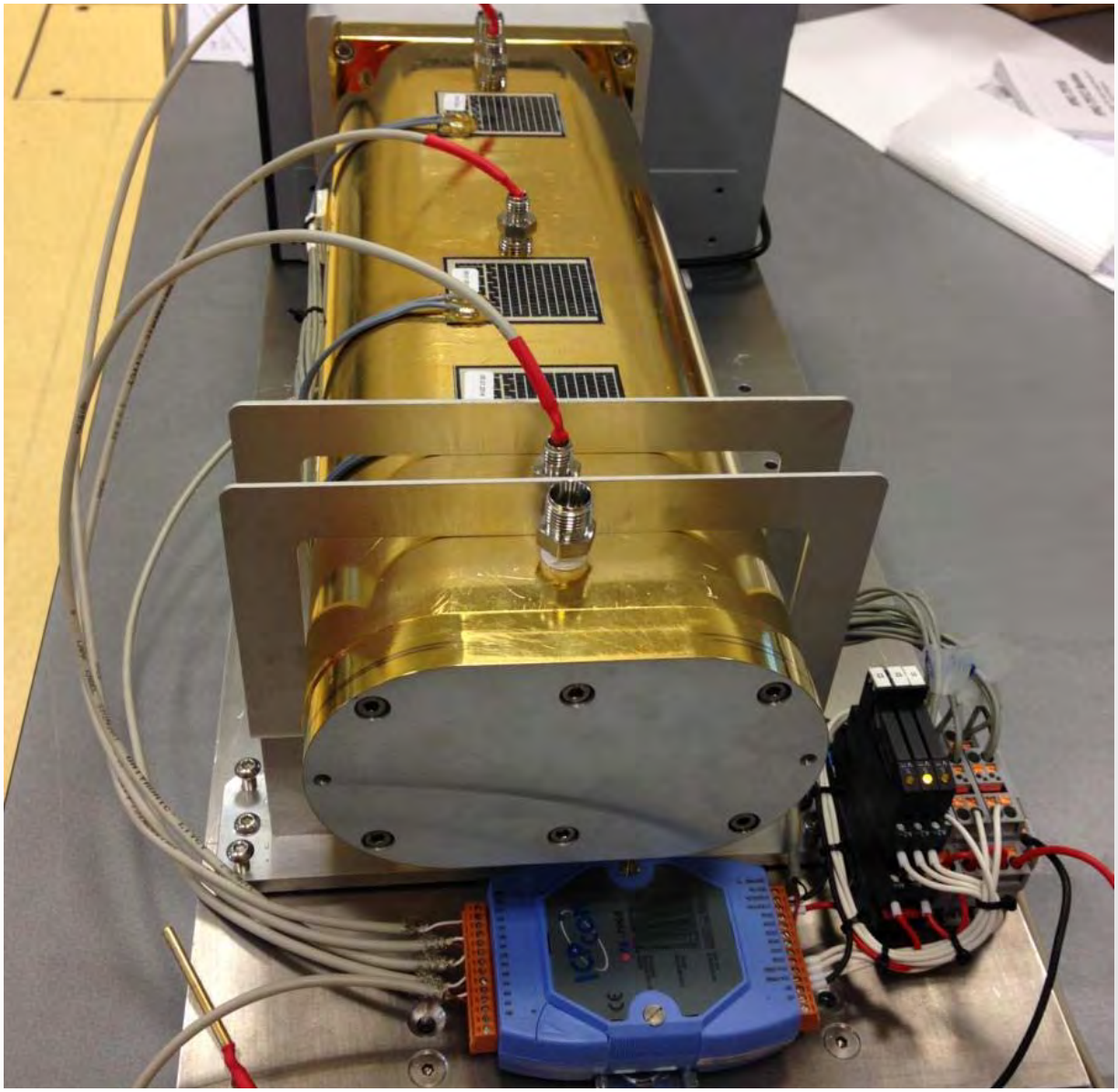
Improvements tested at ECN

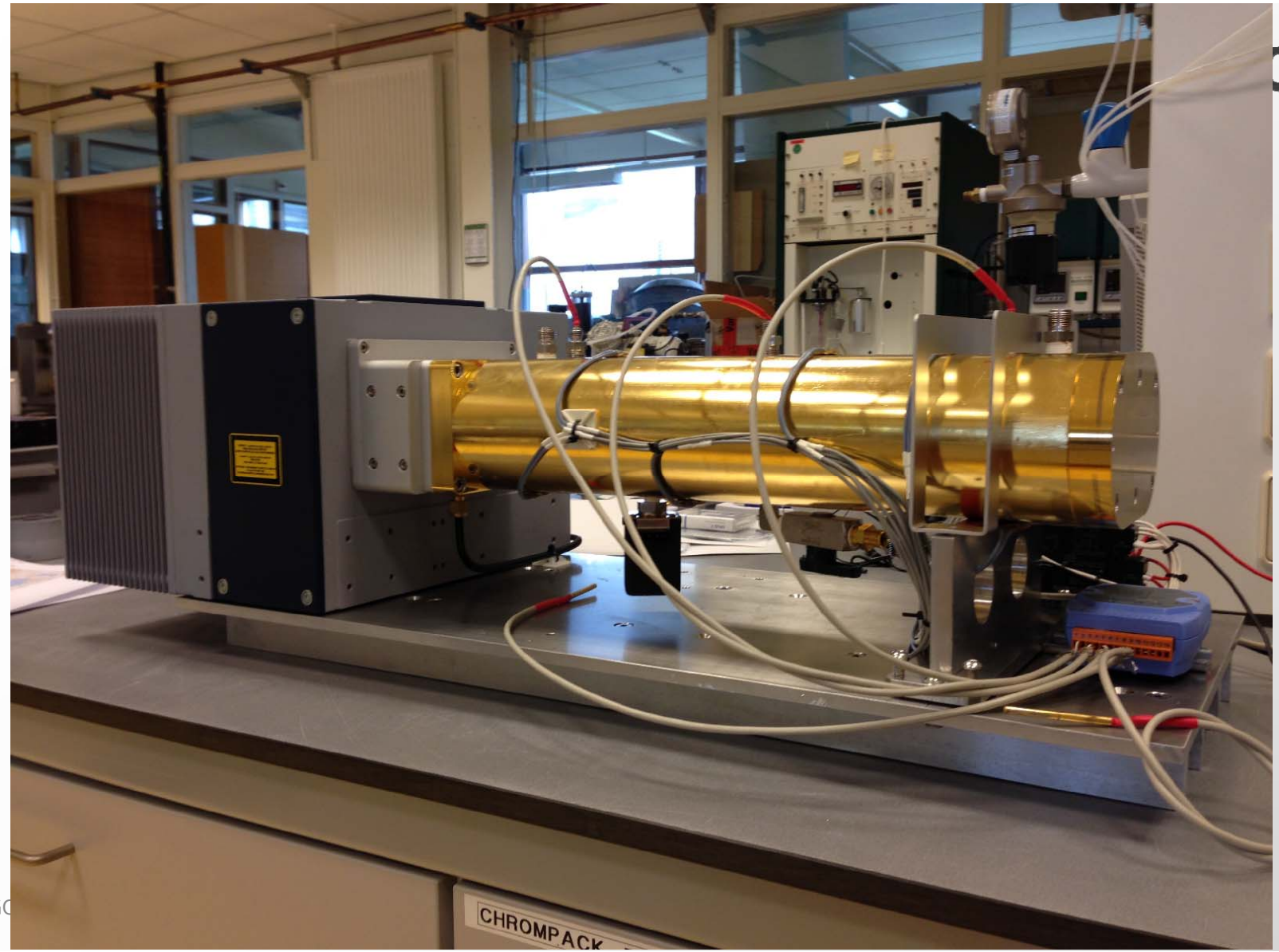
- Aluminium Cell (Bruker)
  - Smaller cell volume 2.5 liter
  - Improved thermal properties
- Cell temperature control
  - Heating at 6 locations, 3 individually controlled zones
  - Increase accuracy of temp meas. with thermistors (0.1->0.001 K)
  - Temperature control of cell within 10 mK in 60 sec
  - Enhanced air circulation in measurement compartment
- Polishing for reduced air-cell active surface area
- Surface gold plating to reduce wall interactions
- Additional material costs less than € 1000

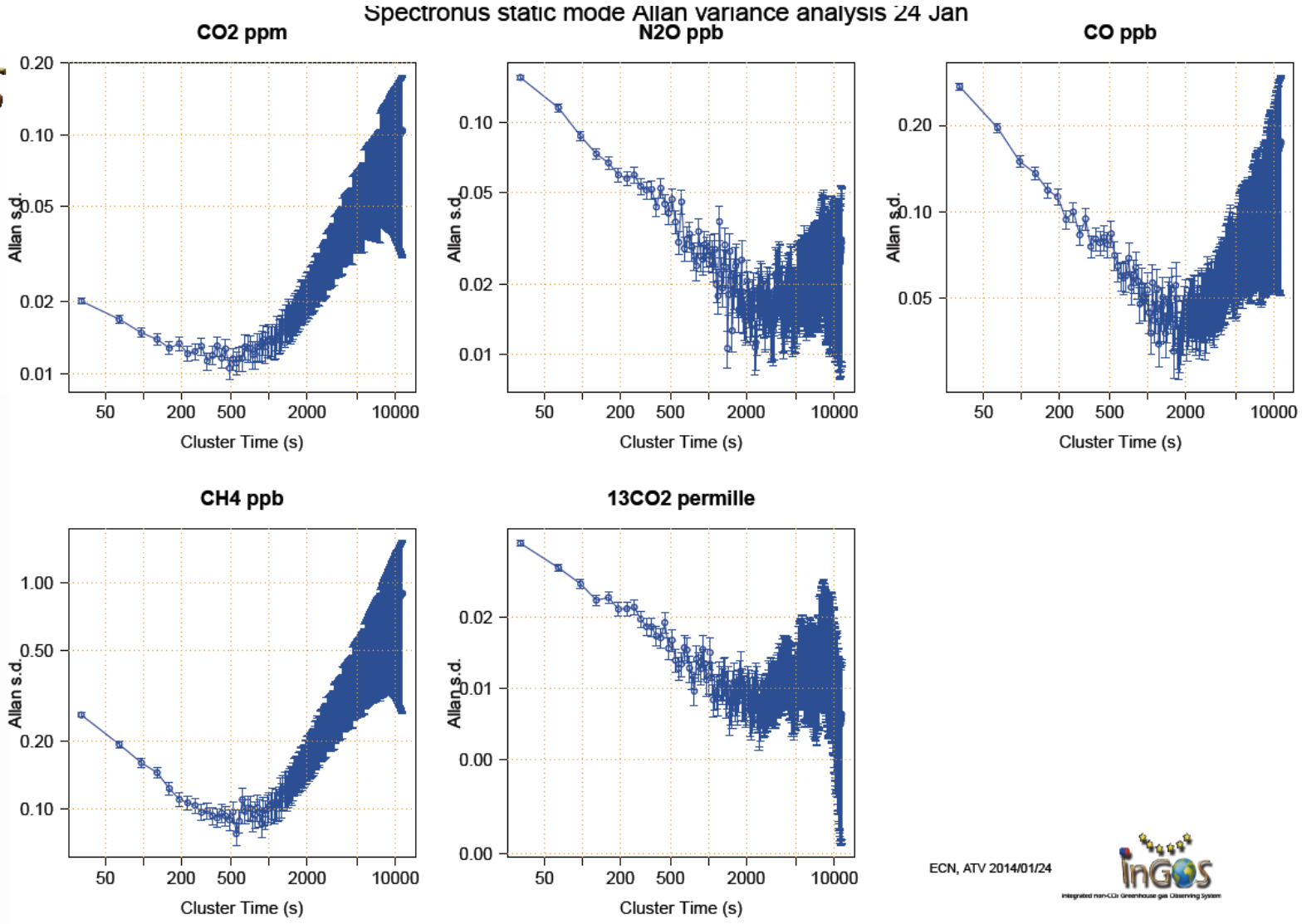


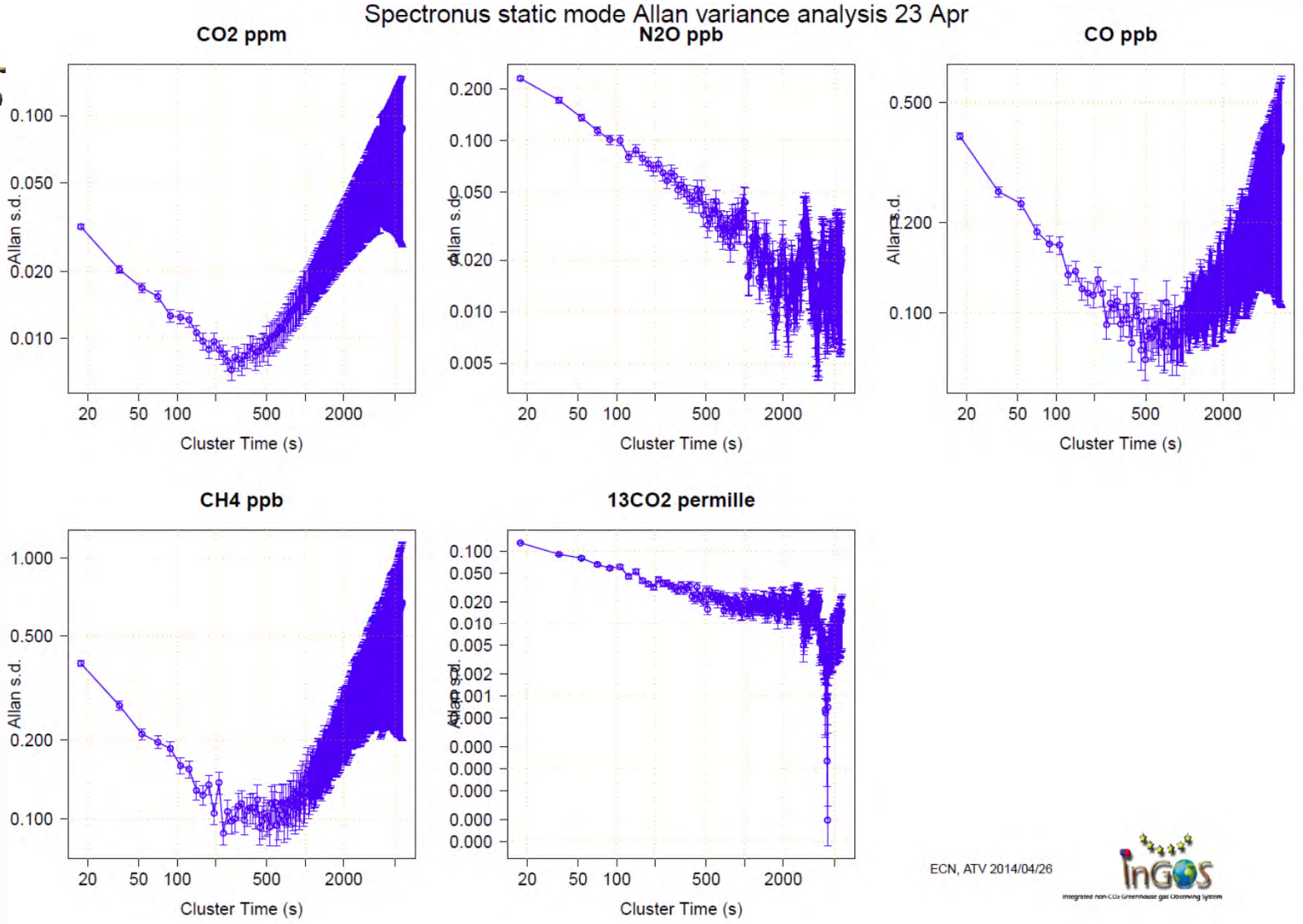


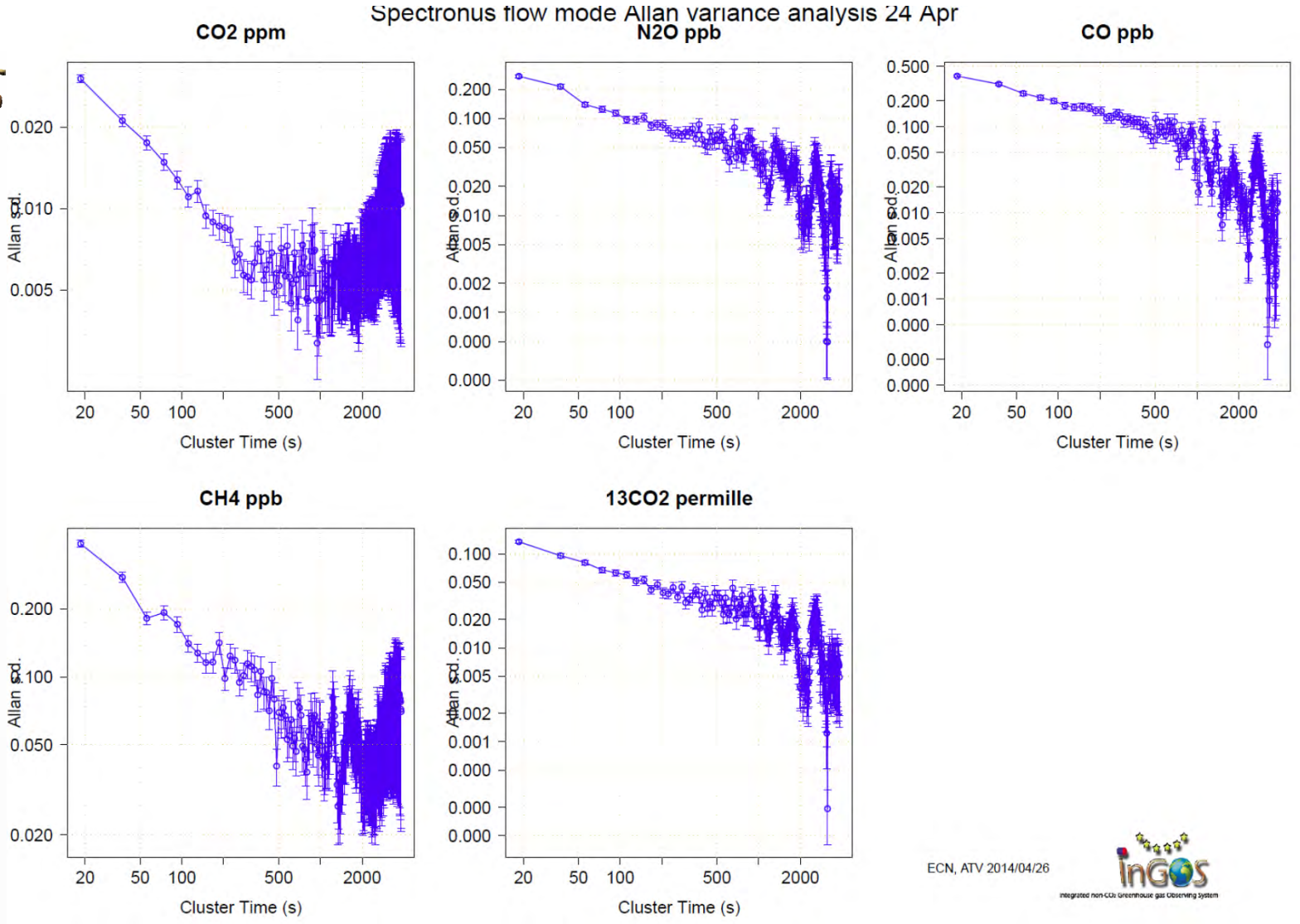





CHROMPACK


Spectronus static mode Allan variance analysis 24 Jan
CO2 ppm
N2O ppb
CO ppb
CH4 ppb
13CO2 permille
Allan s.d.
Cluster Time (s)
50
200
500
2000
10000
ECN, ATV 2014/01/24

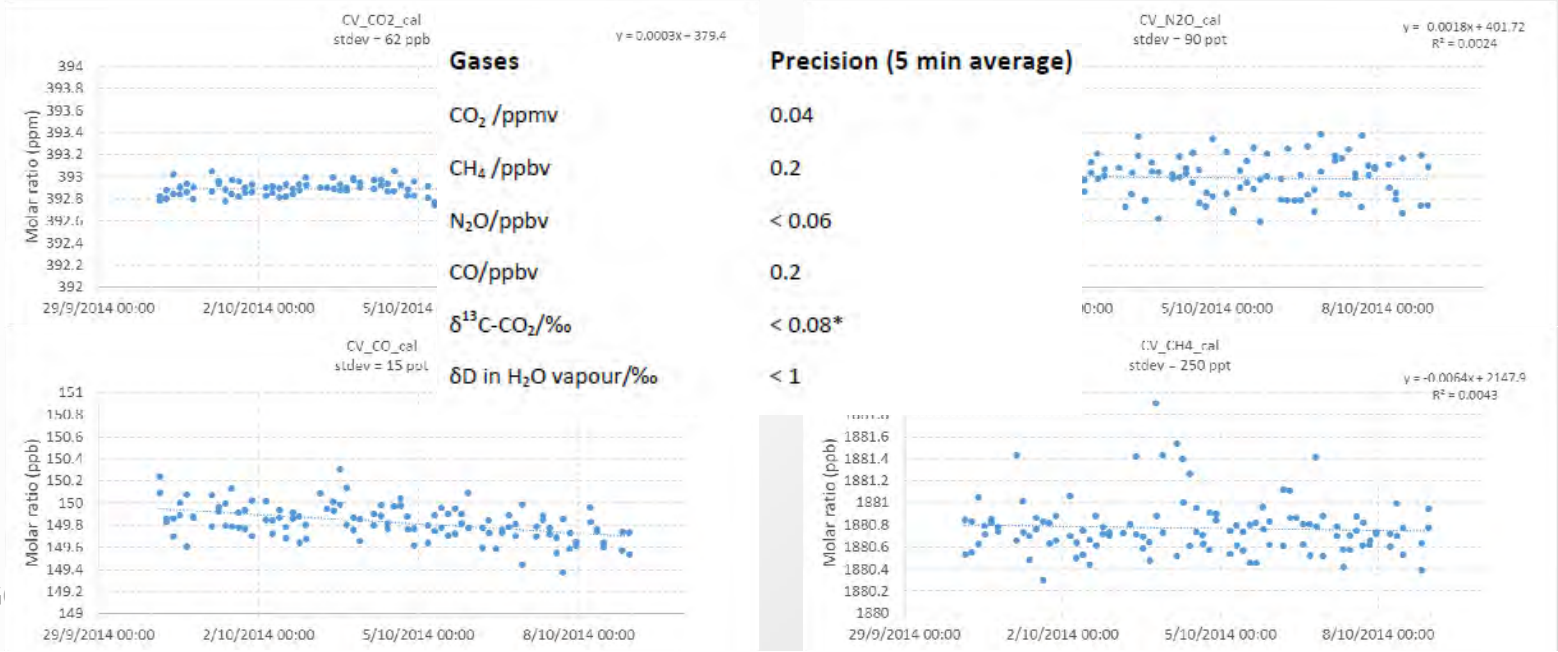

Spectronus static mode Allan variance analysis 23 Apr
CO2 ppm
N2O ppb
CO ppb
CH4 ppb
13CO2 permille
Allan s.d.
Cluster Time (s)
20
50
100
500
2000
ECN, ATV 2014/04/26


Spectronus flow mode Allan variance analysis 24 Apr
CO2 ppm
N2O ppb
CO ppb
CH4 ppb
13CO2 permille
Allan sd.
Cluster Time (s)
20
50
100
500
2000
ECN, ATV 2014/04/26

FTIR performance posterior

Spectronus metal cell, increased temp control

Species	Allan Var				Precision	Drift	Unit
	flow 1 min	flow 5 min	static 1 min	static 5 min	stdev 3 days	per day	
CO2	0.018	0.007	0.018	0.014	0.031	0.021	**ppm**
13CO2	0.08	0.04	0.03	0.02	0.07	0.03	**permille**
CH4	0.18	0.10	0.20	0.10	0.18	0.11	**ppb**
N2O	0.15	0.07	0.12	0.05	0.08	0.009	**ppb**
CO	0.25	0.12	0.20	0.07	0.14	0.04	**ppb**



Real life deployment

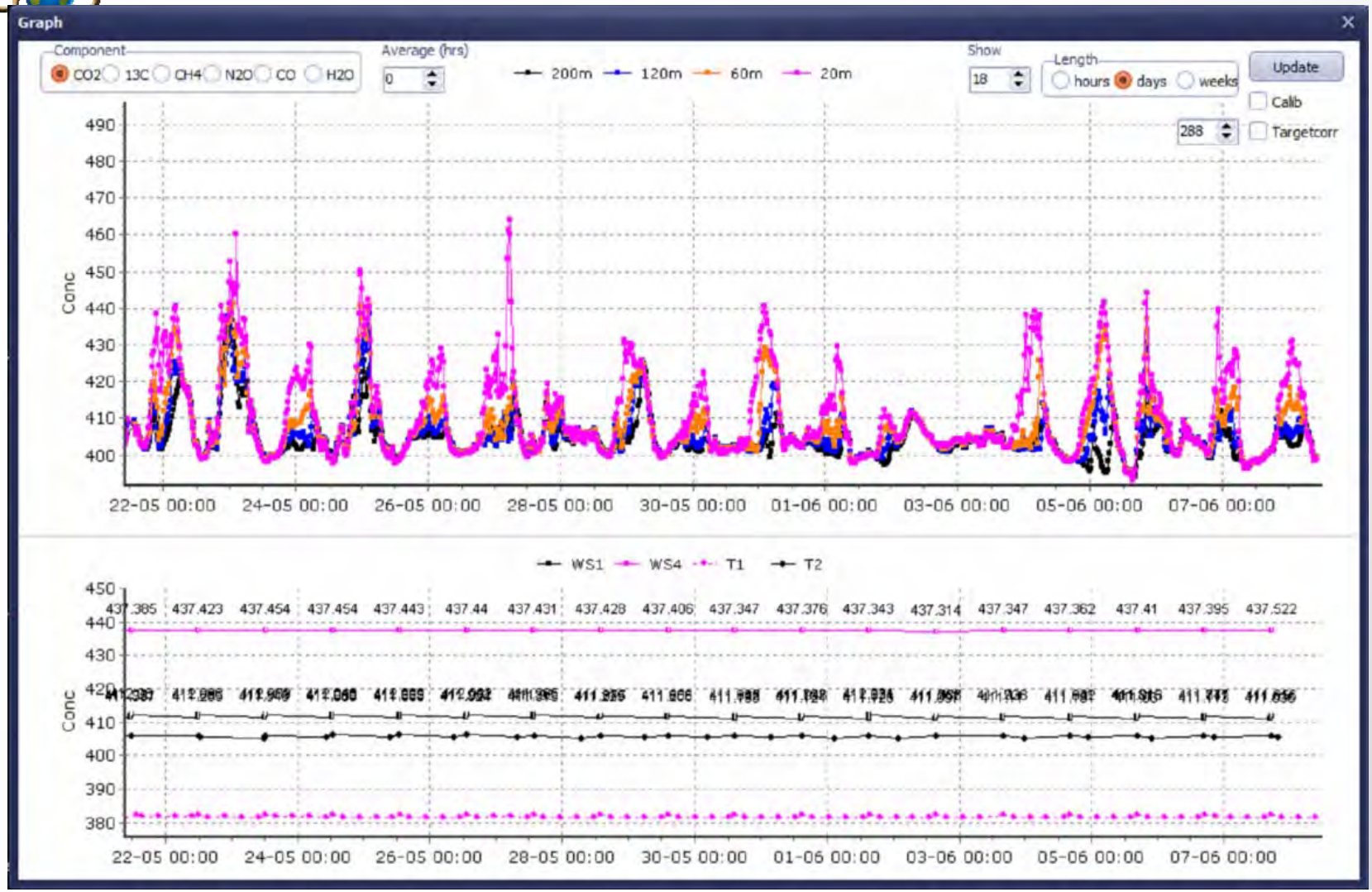
Buffer volumes

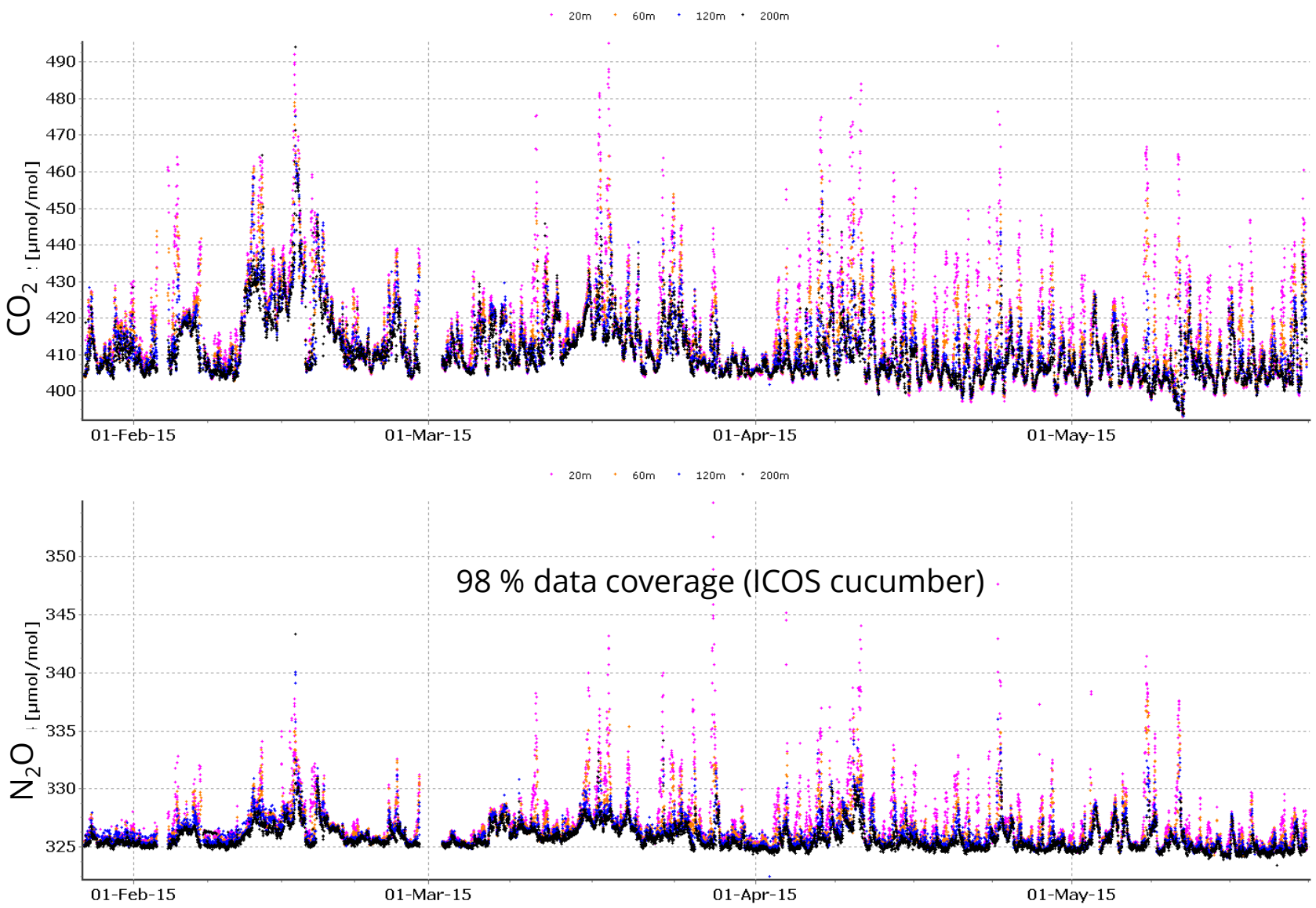
Two controlling programs

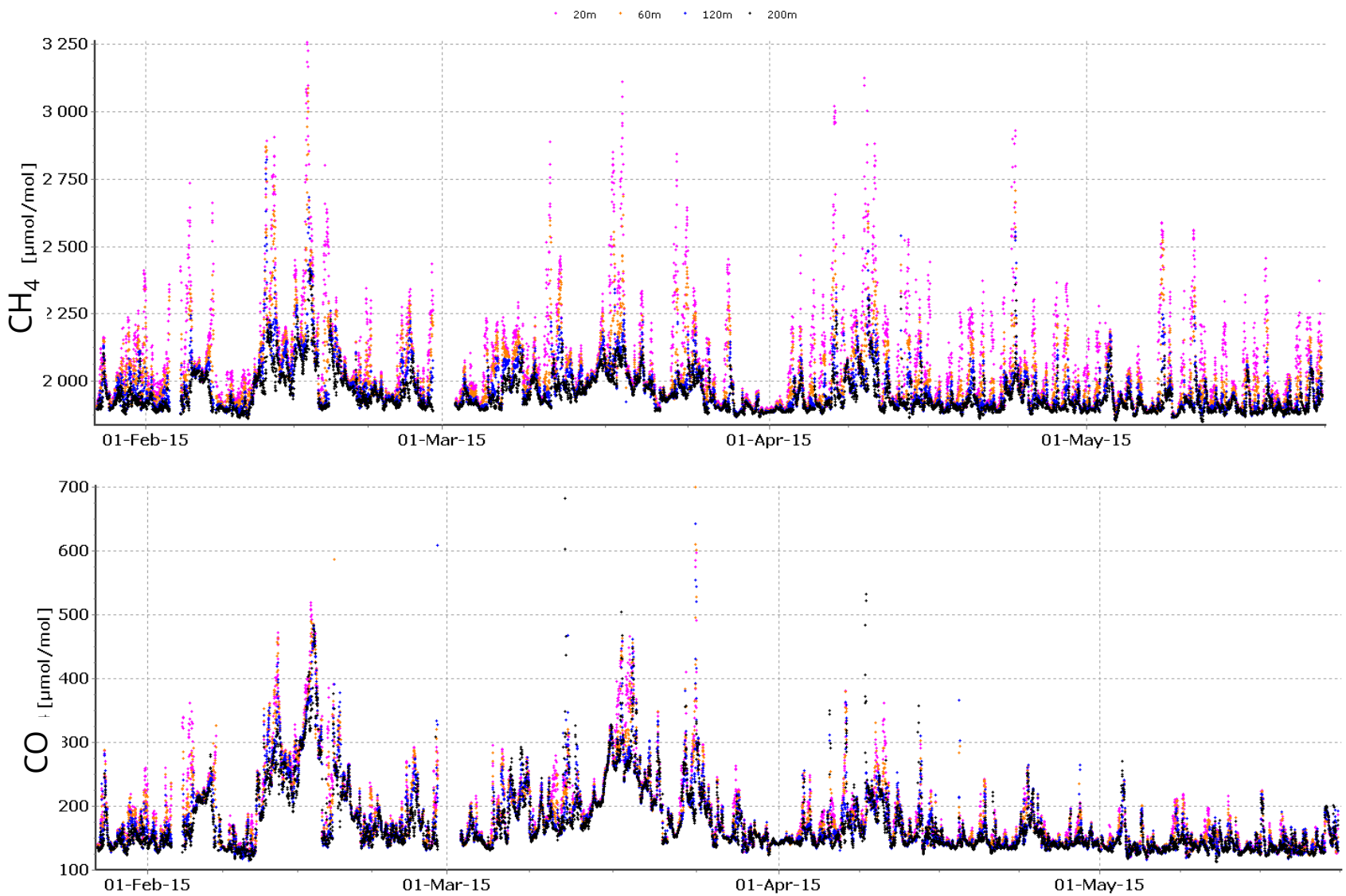
- Temperature control program, three zones, 10 mK accuracy
  - Controls ICP DAS 7005 unit
  - Reads thermistors
  - Switches heating pads (3 W)
  - Feedbacks average cell temperature to Analog Input of Spectronus
- Cycle steering program
  - Switches Valco 12 multiport valve at serial port
  - Triggers Spectronus cycle by pulse of 2V+port number*0.2 V
  - Retrieves molar ratios from Spectronus database
  - Performs at NRT target correction and smoothed calibration
  - Planned: reads Picarro data and sets valve id

- 5 minute cycle
  - Evacuate
  - Flush cell to 500 mbar
  - Evacuate
  - Fill cell to 1100 mbar
  - Collect spectra for 1.5 minute
- 3 full gradients at 4 heights per hour! (4 or 6 at 3 resp. 2 heights)
- Gas use per cycle: 4 liter
- 2000 calibrations/target measurements per 50l tank
- Lifetimes tanks
  - Hi freq target (12h): 2-3 years
  - Lo freq target (1/week): 20-40 years
  - Calibration (2/week): 10 years
- Virtual air sample archive with full IR spectra

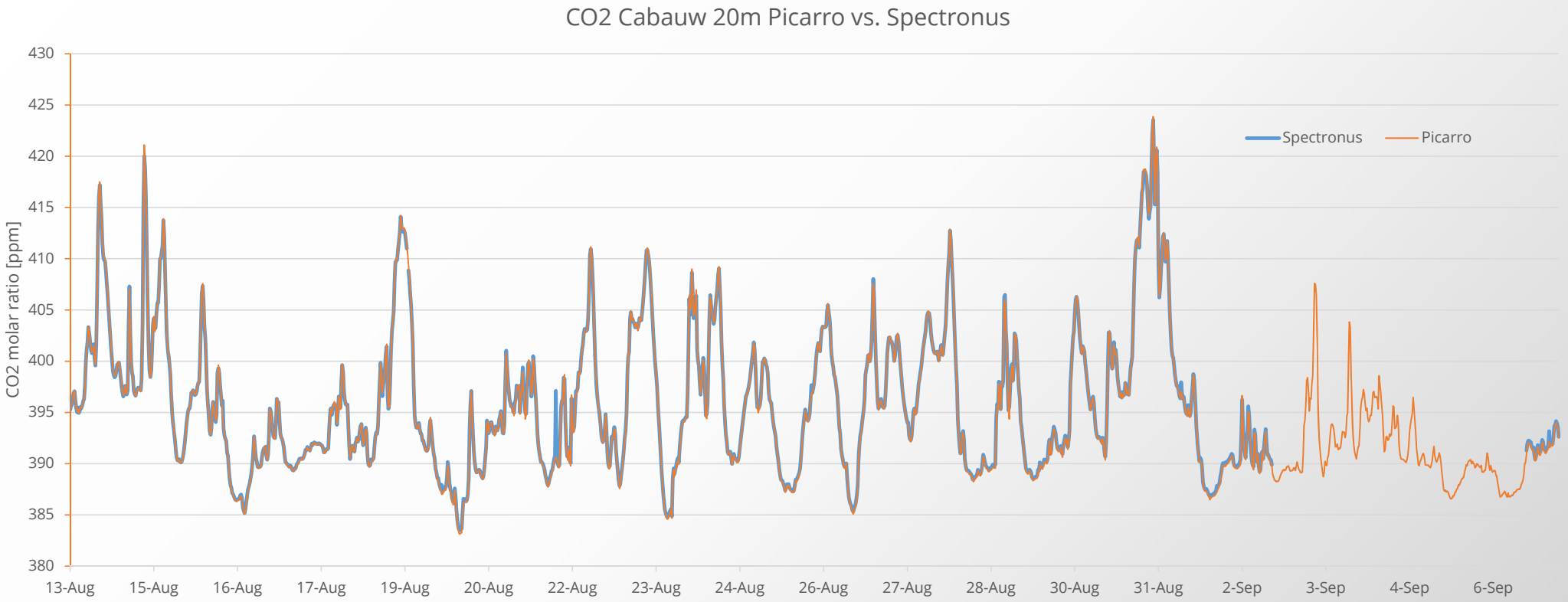
Buffer volume
19.5 l
Stainless steel
€ 170,= piece
Max 6 bar


Graph
Component
CO2 13C CH4 N2O CO H2O
Average (hrs)
0
200m 120m 60m 20m
Show
18
Length
hours days weeks
Update
Calib
Targetcorr
288
Conc
490 480 470 460 450 440 430 420 410 400
22-05 00:00 24-05 00:00 26-05 00:00 28-05 00:00 30-05 00:00 01-06 00:00 03-06 00:00 05-06 00:00 07-06 00:00
WS1 WS4 T1 T2
450 440 430 420 410 400 390 380
437.385 437.423 437.454 437.454 437.443 437.44 437.431 437.428 437.406 437.347 437.376 437.343 437.314 437.347 437.362 437.41 437.395 437.522
Conc
22-05 00:00 24-05 00:00 26-05 00:00 28-05 00:00 30-05 00:00 01-06 00:00 03-06 00:00 05-06 00:00 07-06 00:00

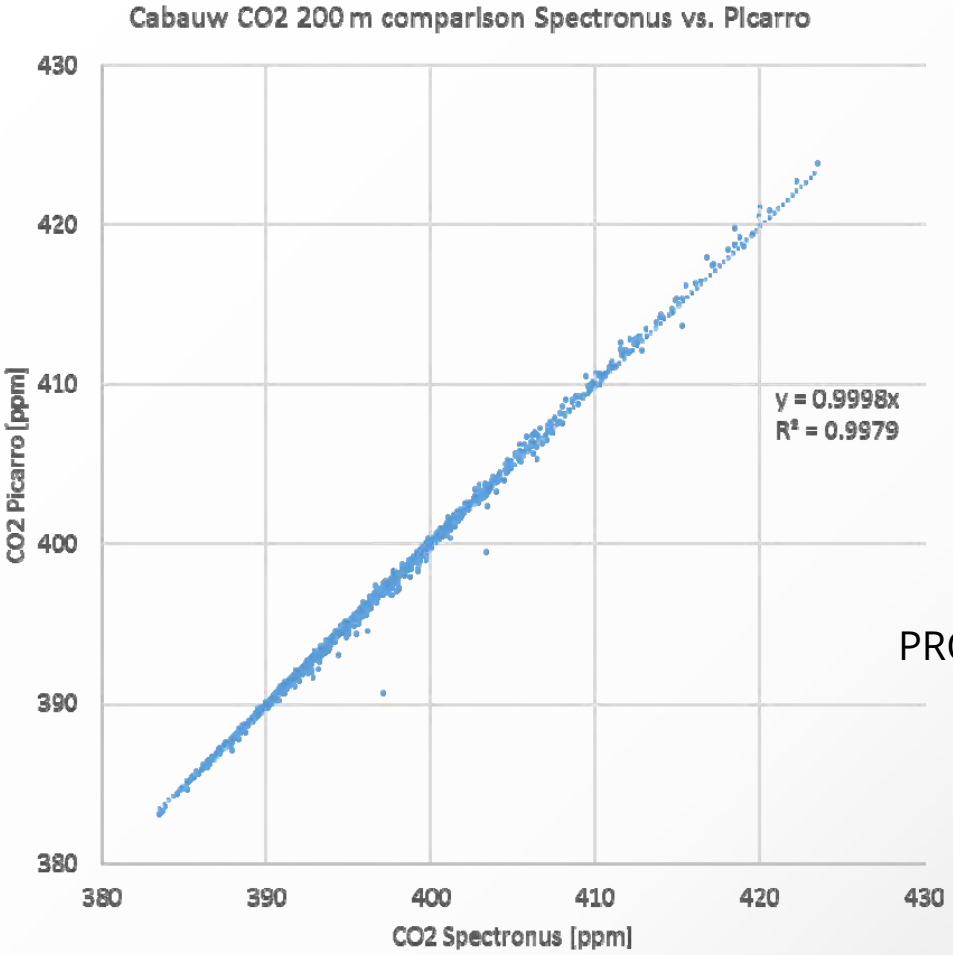

20m
60m
120m
200m
490
480
470
460
450
440
430
420
410
400
[µmol/mol]
01-Feb-15
01-Mar-15
01-Apr-15
01-May-15
20m
60m
120m
200m
350
345
340
335
330
325
[µmol/mol]
98 % data coverage (ICOS cucumber)
01-Feb-15
01-Mar-15
01-Apr-15
01-May-15

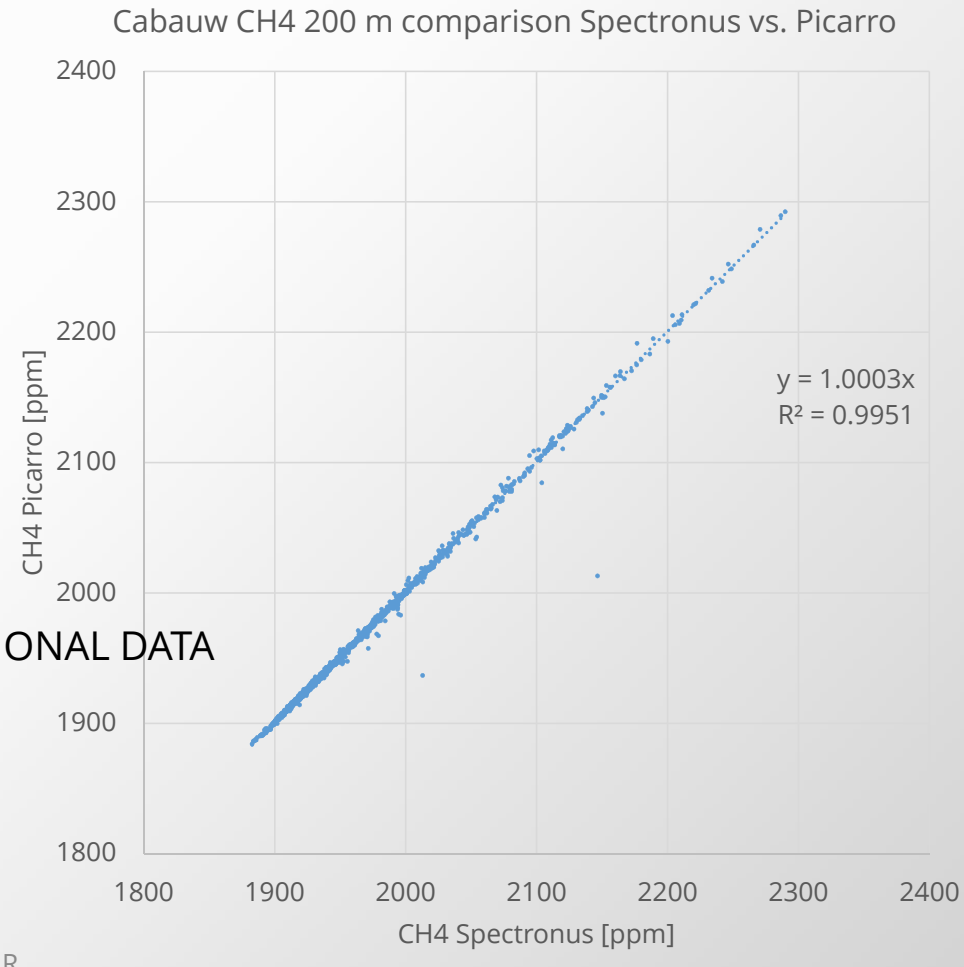

20m
60m
120m
200m
3 250
3 000
2 750
2 500
2 250
2 000
CH4 [µmol/mol]
01-Feb-15
01-Mar-15
01-Apr-15
01-May-15
700
600
500
400
300
200
100
CO [µmol/mol]
01-Feb-15
01-Mar-15
01-Apr-15
01-May-15

Picarro G2301 vs Spectronus, CBW 200 m



PROVISIONAL DATA





PROVISIONAL DATA

Summary

- Performance improved considerably
- WMO compatibility targets achieved
- Robust deployment at tall tower
- Low maintenance (once per month)
- Very low gas consumption
- Manufacturer will adopt changes (upgrade possible)
- Virtual air archive!