Integrated non-CO_2 Greenhouse gas Observing System

Performance test of an improved FTIR analyzer for simultaneous high precision observation of ambient concentrations of greenhouse gases

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ECN

Introduction

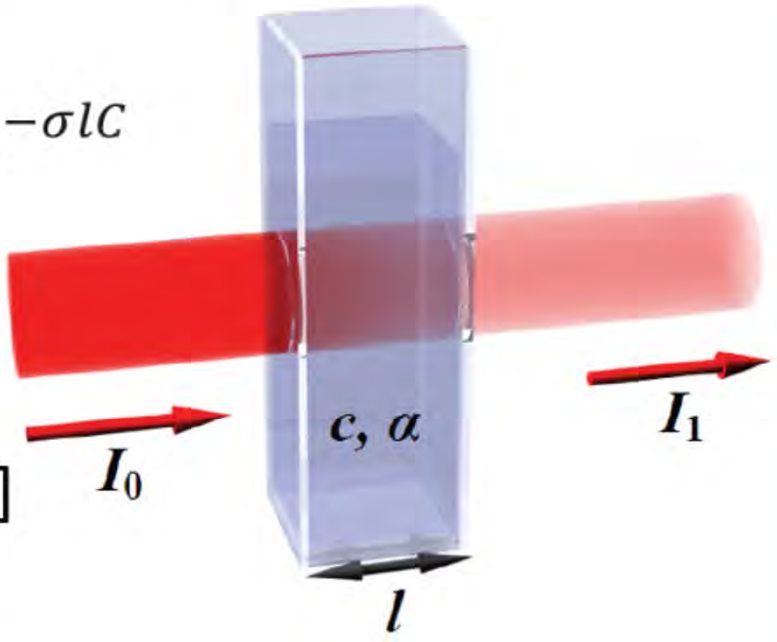
- Measurement principles
- What is FTIR
- Advantages
- Test
- Improvements
- Analysis
- Outlook

How to measure is why we measure

- Greenhouse Gases (GHGs): IR absorption
- Beer-Lambert Law:

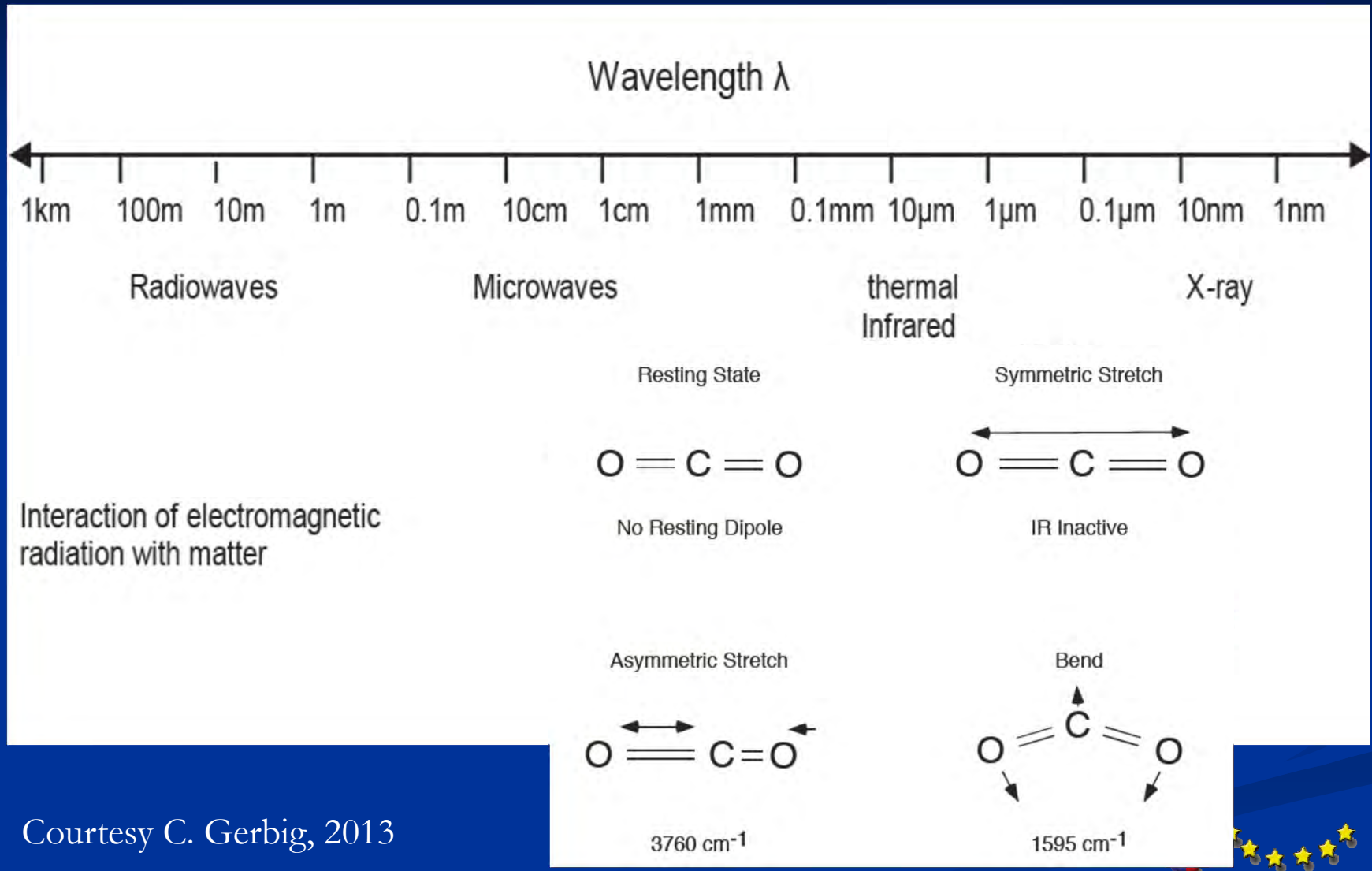
$$T = \frac{I}{I_0} = e^{-\sigma l C}$$

T: Transmission
I_0: intensity of incident light
I: intensity of transmitted light
σ: absorption cross section [cm^{-1}]
l: absorption path length
C: concentration [mole fraction]



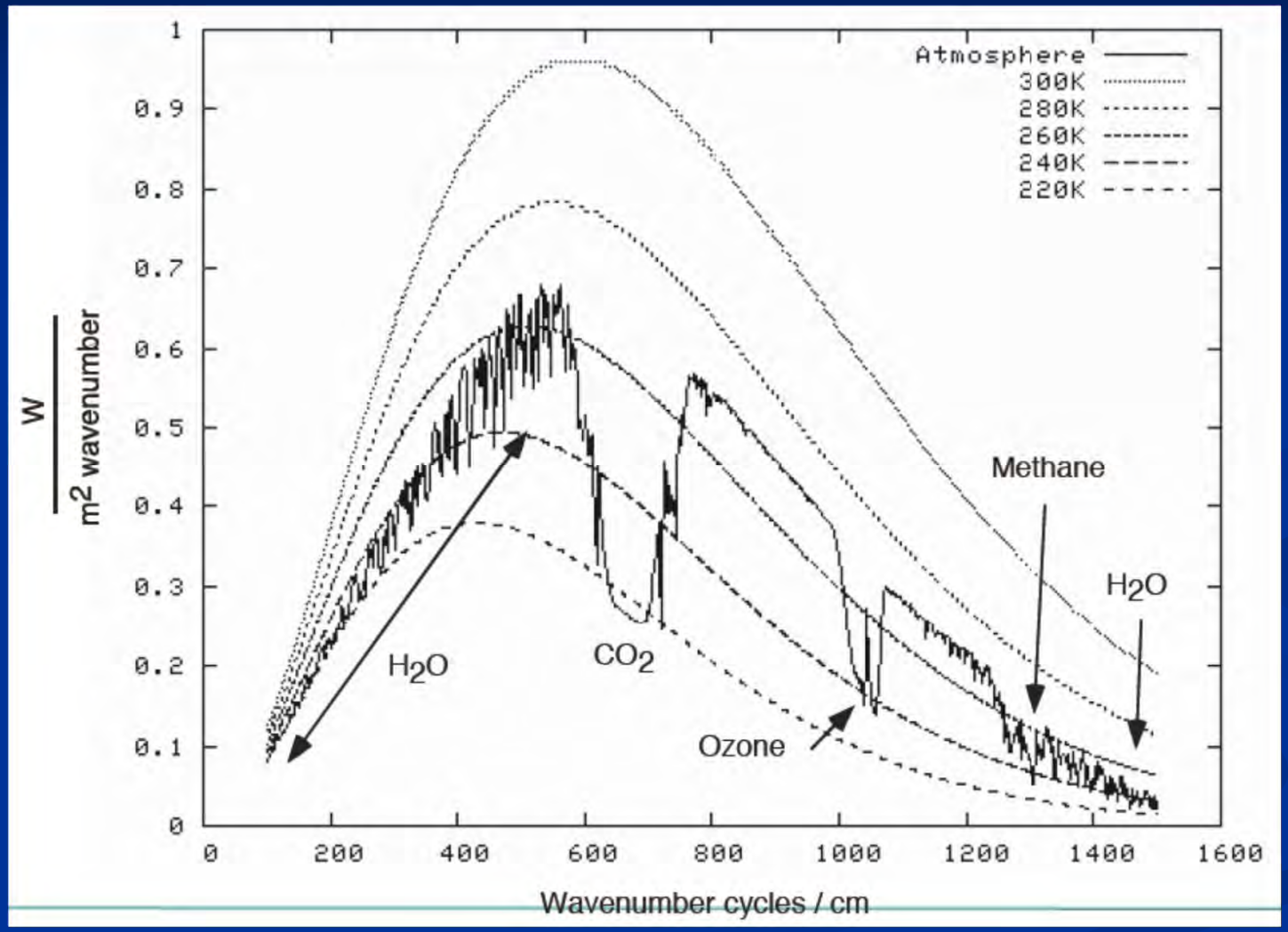
Courtesy C. Gerbig, 2013

IR absorption of Greenhouse Gases



Interaction of electromagnetic radiation with matter

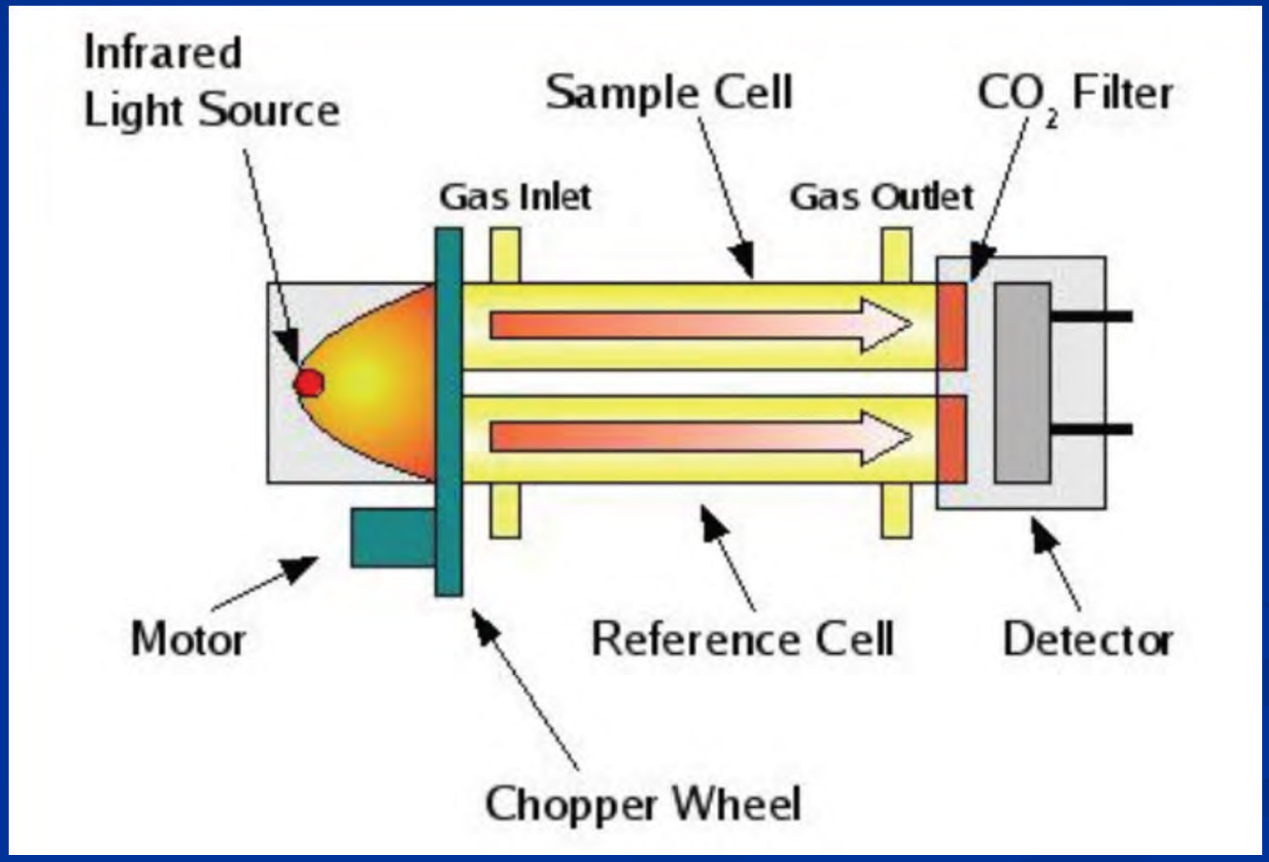
Courtesy C. Gerbig, 2013



Courtesy C. Gerbig, 2013

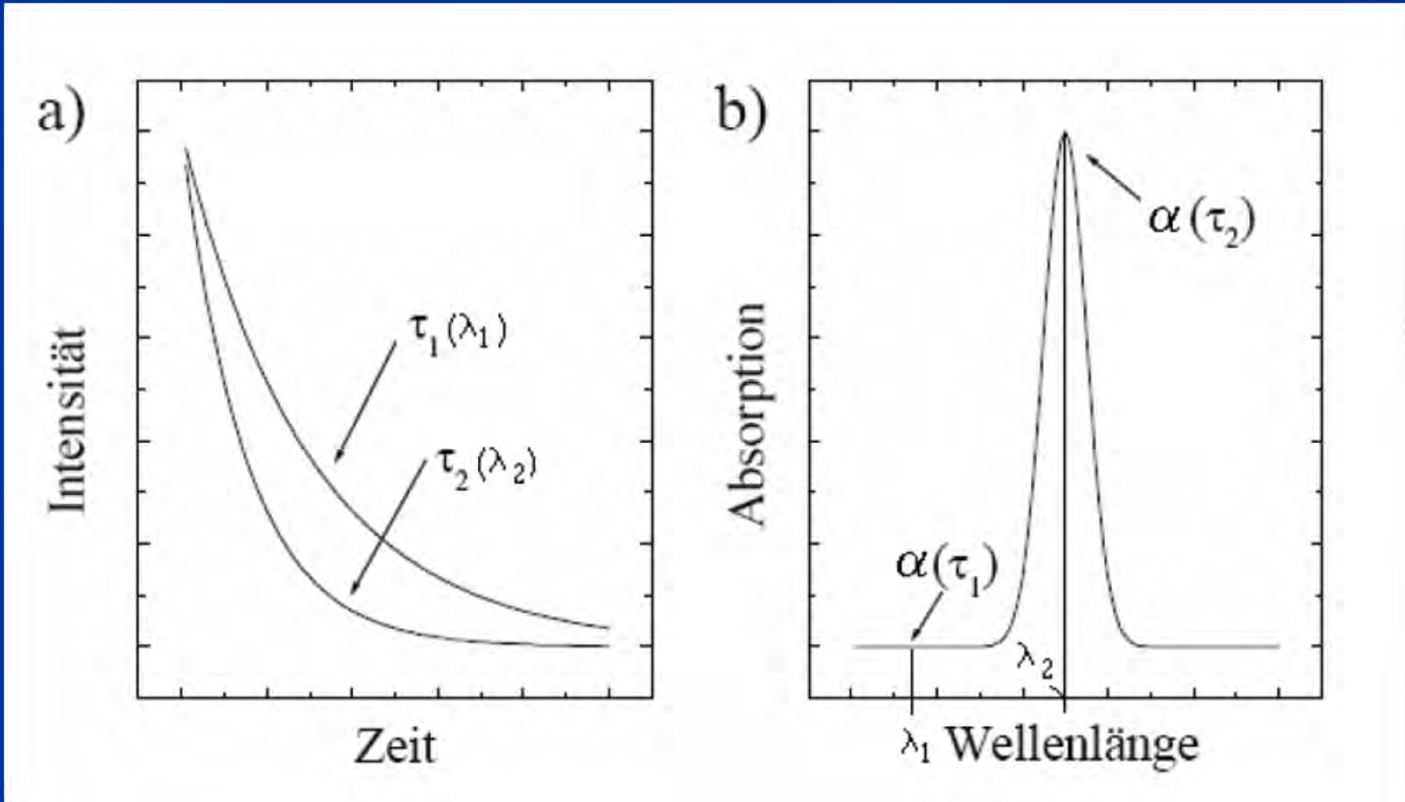
Detection methods

- NDIR- non dispersive infrared
- direct absorption measurement in cell



Detection methods

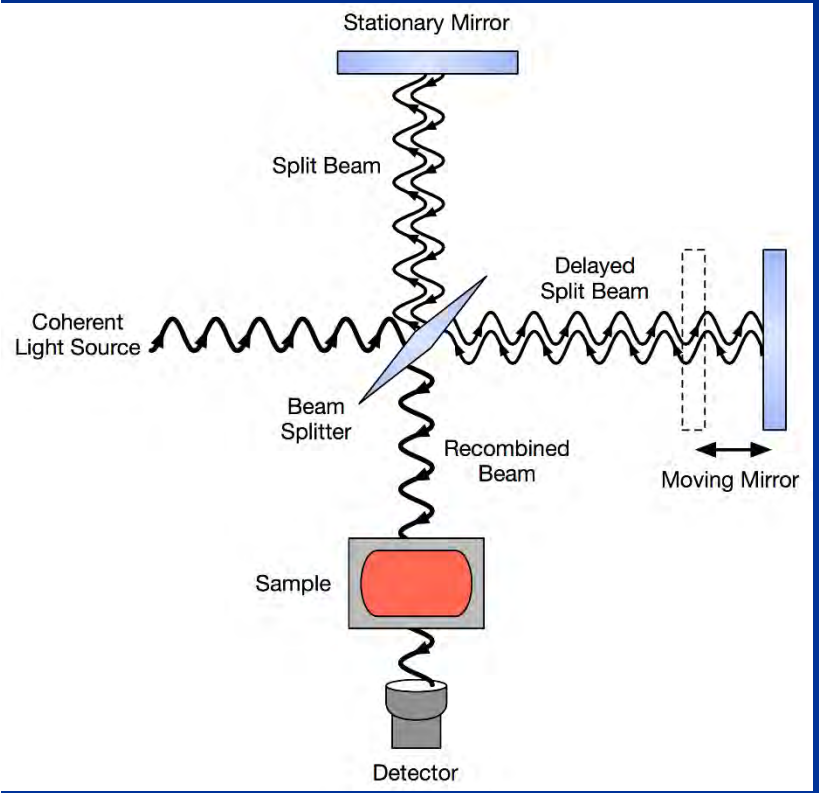
- Laser based spectroscopy:
- TDLAS, QCLAS, OA-ICOS, CRDS, Photo-acoustic

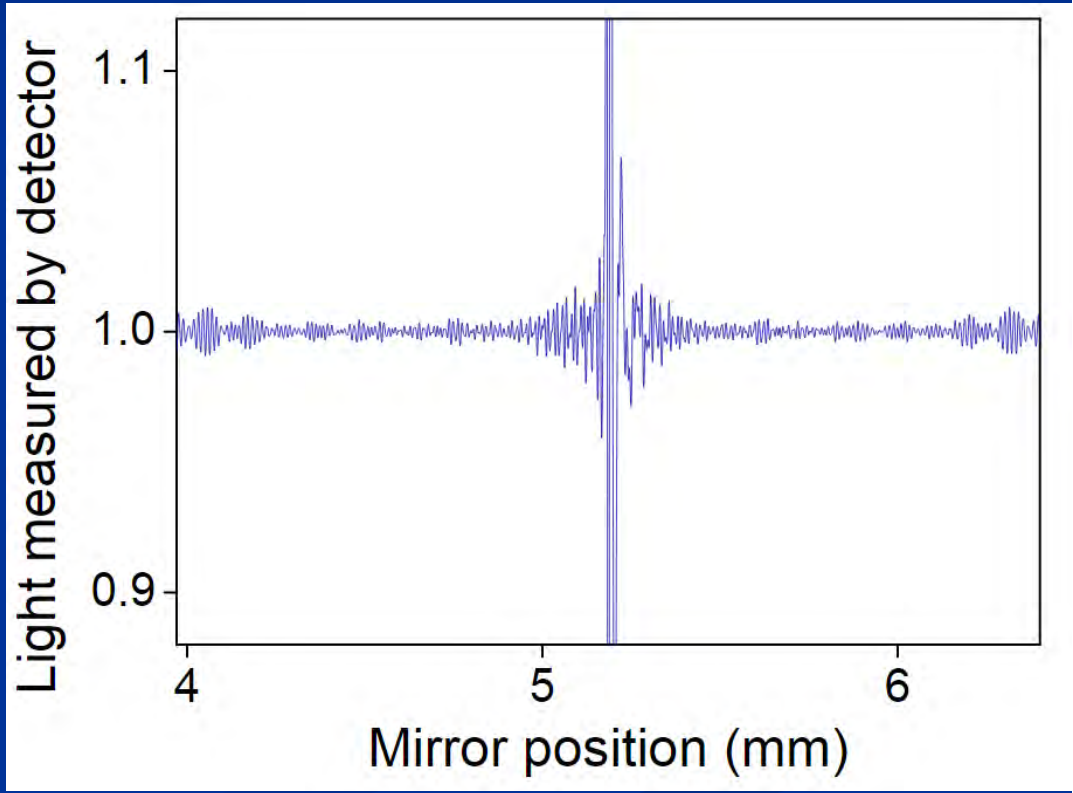


sson, 2004

Fourier transform IR spectrometry

- Full IR spectrum in 1 second, multiple components with one lightsource





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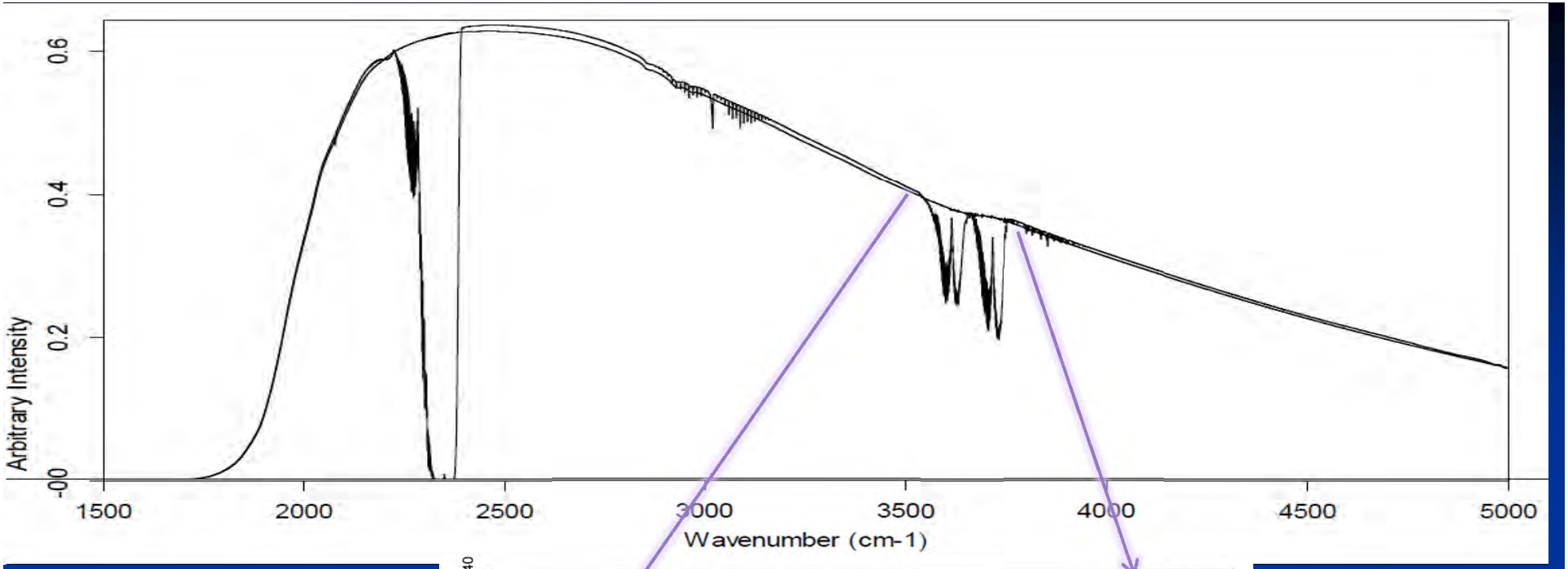
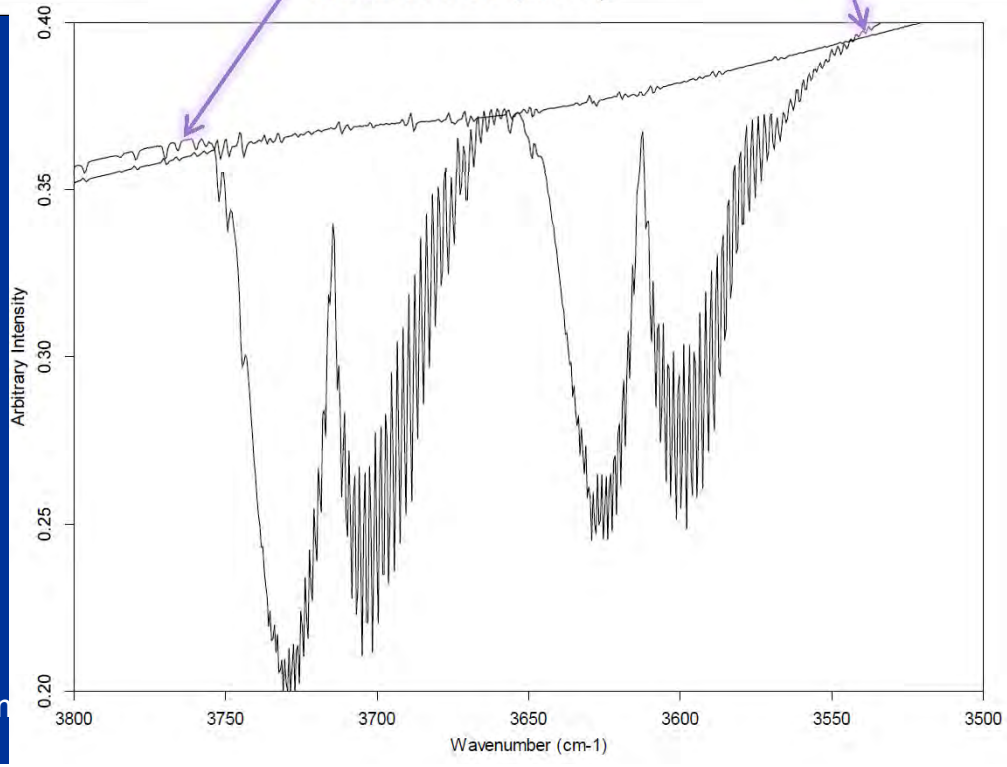




InGOS
CO2 Greenhouse gas Observing System

Instrument development: Ecotech in-situ FTIR

Upper section
Computer and temperature control

Perspex Shipping covers
(must be removed before operation)

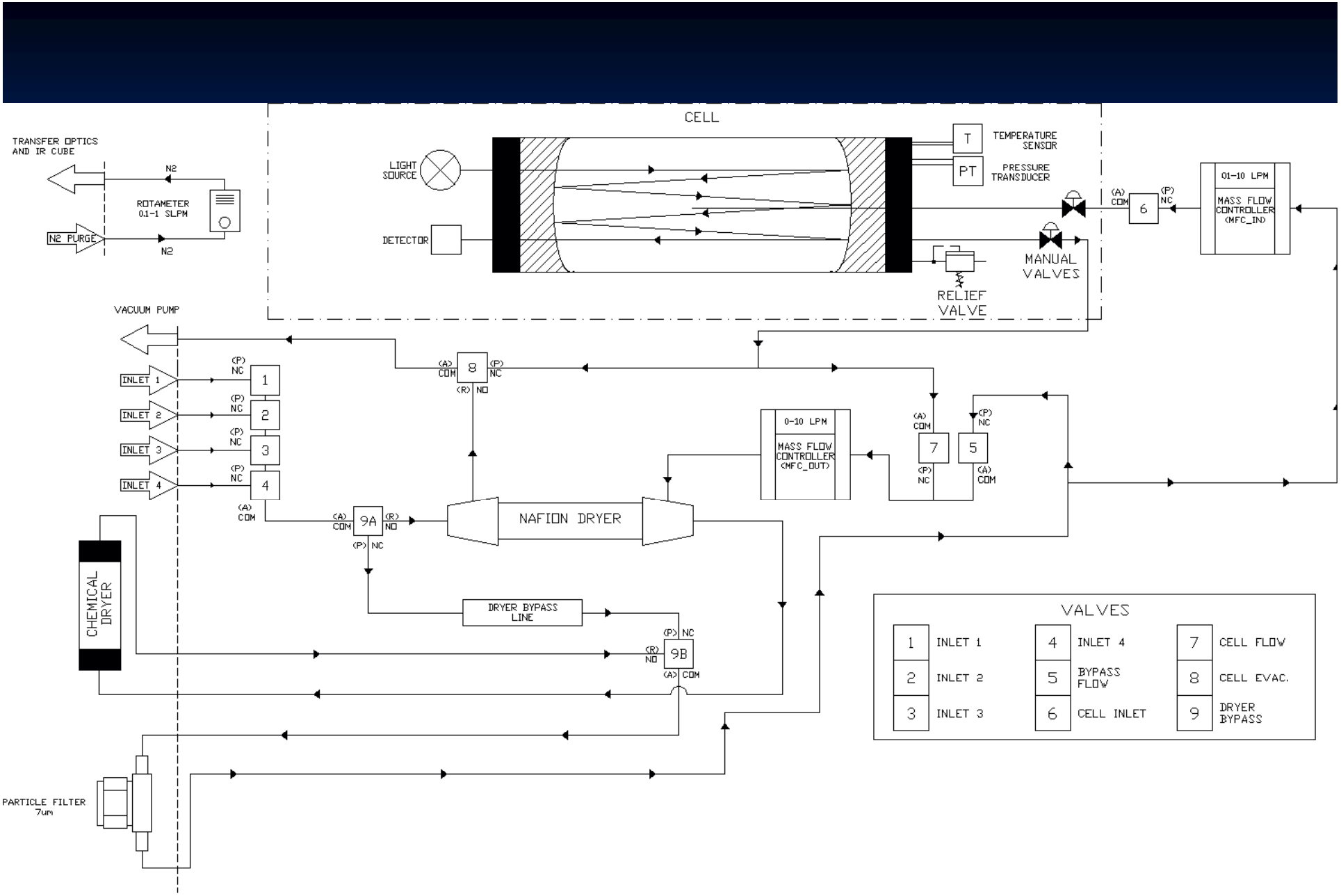
Middle section
Optical system – temperature controlled.

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

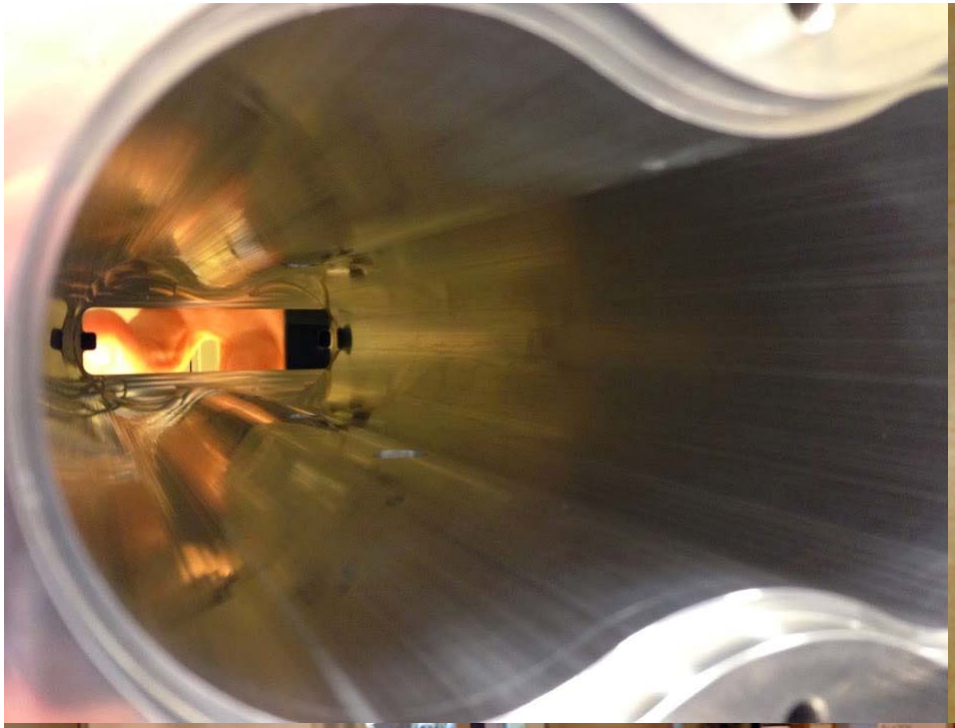
120 kg
pump 17 kg
1160x486x885 mm
200 W
Pump 310 W
24 m multipass cell
3.5 liter **glass** cell
0.5-1.5 $l.min^{-1}$ or static
MCT detector
2000-7800 cm^{-1}
Spectral res 1.0 cm^{-1}
15 s-60 min averaging
10-40 ^oC oper. temp
Built-in sample drying

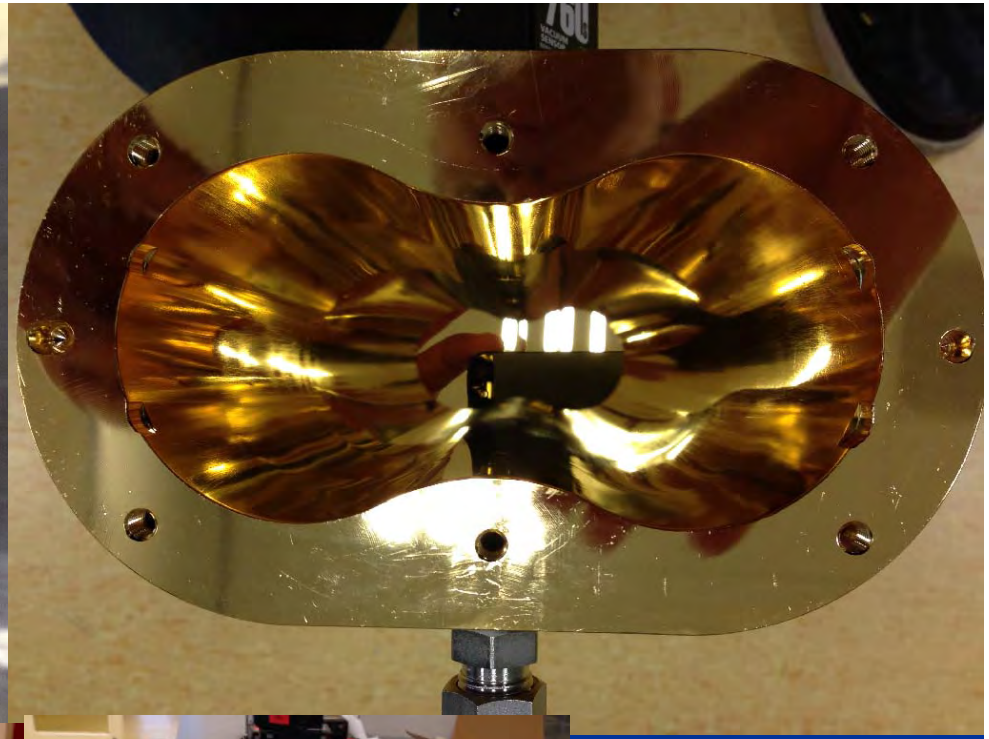
InGOS
Integrated non-CO_2 Greenhouse gas Observing System

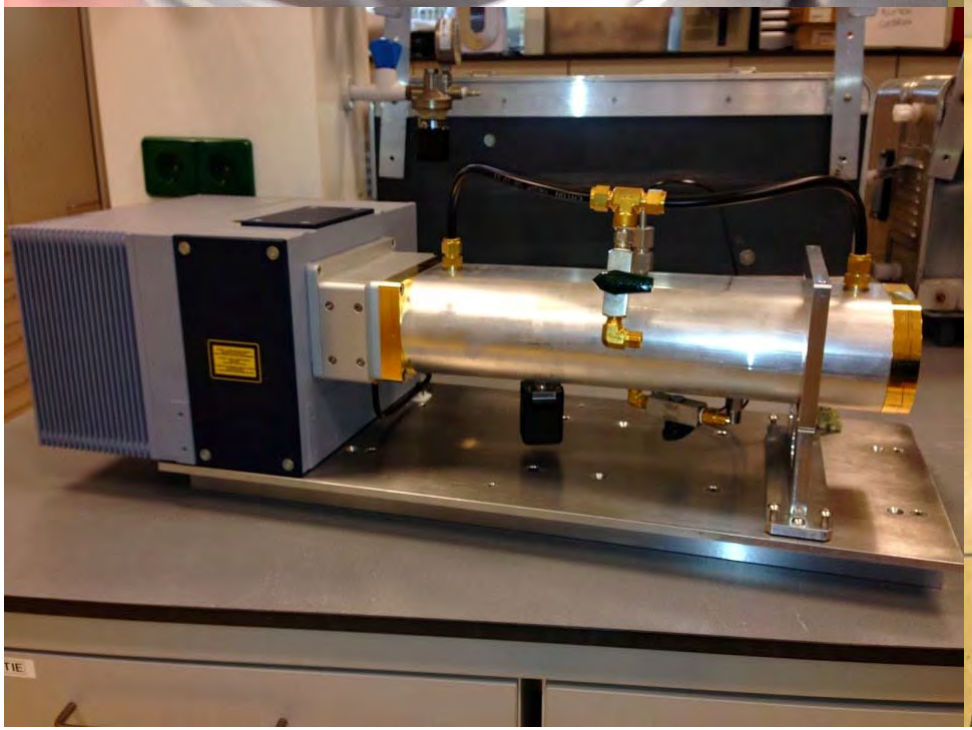

CELL
TRANSFER OPTICS AND IR CUBE
N2
ROTAMETER 0.1-1 SLPM
N2 PURGE
N2
LIGHT SOURCE
DETECTOR
T
TEMPERATURE SENSOR
PT
PRESSURE TRANSDUCER
MANUAL VALVES
RELIEF VALVE
(A) COM
6
(P) NC
0-10 LPM
MASS FLOW CONTROLLER (MFC_IN)
VACUUM PUMP
INLET 1
INLET 2
INLET 3
INLET 4
(P) NC
1
2
3
4
(A) COM
8
(R) NO
0-10 LPM
MASS FLOW CONTROLLER (MFC_OUT)
7
5
9A
NAFION DRYER
CHEMICAL DRYER
DRYER BYPASS LINE
9B
PARTICLE FILTER 7um
VALVES
1 INLET 1
2 INLET 2
3 INLET 3
4 INLET 4
5 BYPASS FLOW
6 CELL INLET
7 CELL FLOW
8 CELL EVAC.
9 DRYER BYPASS

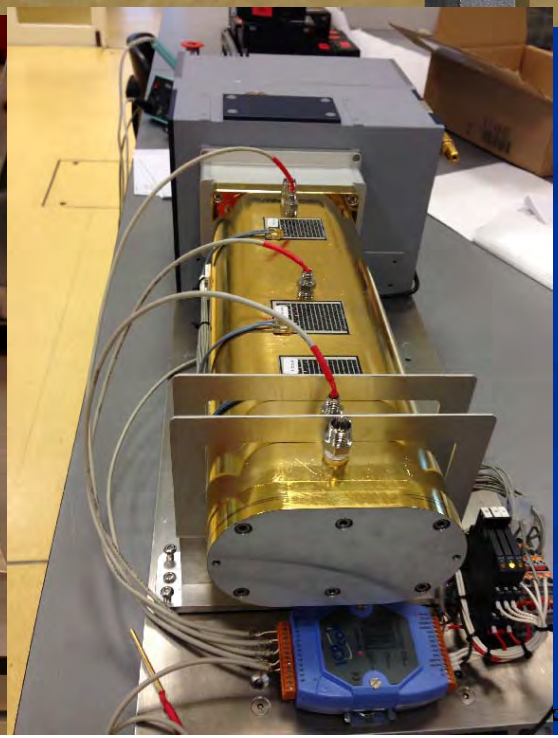
Improvements tested at ECN

- 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





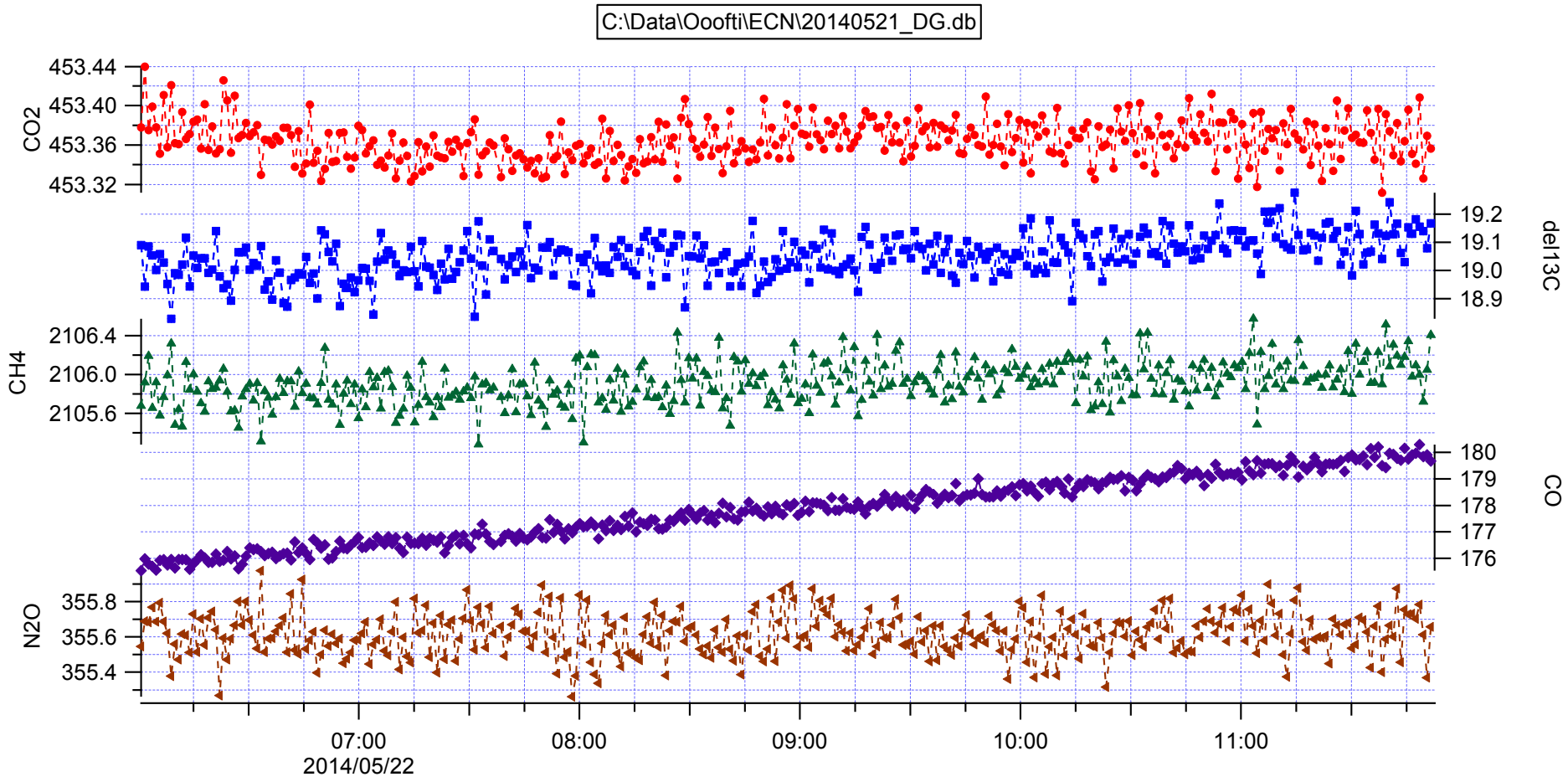




InGOS

In-situ CO2 Greenhouse gas Observing System

Performance



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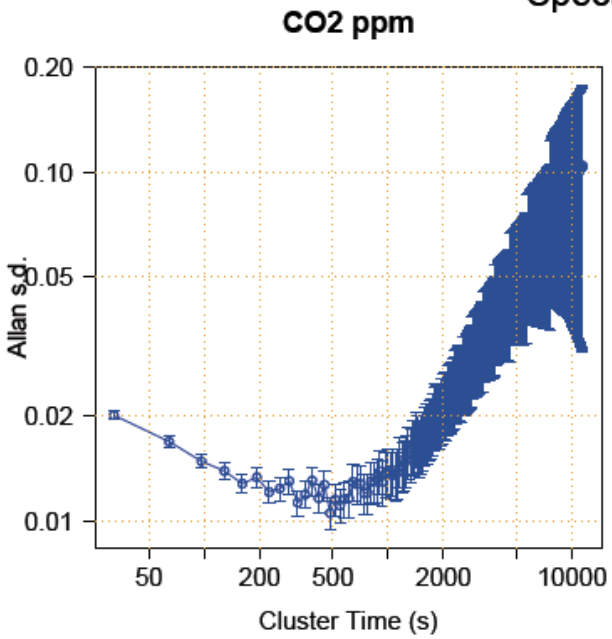
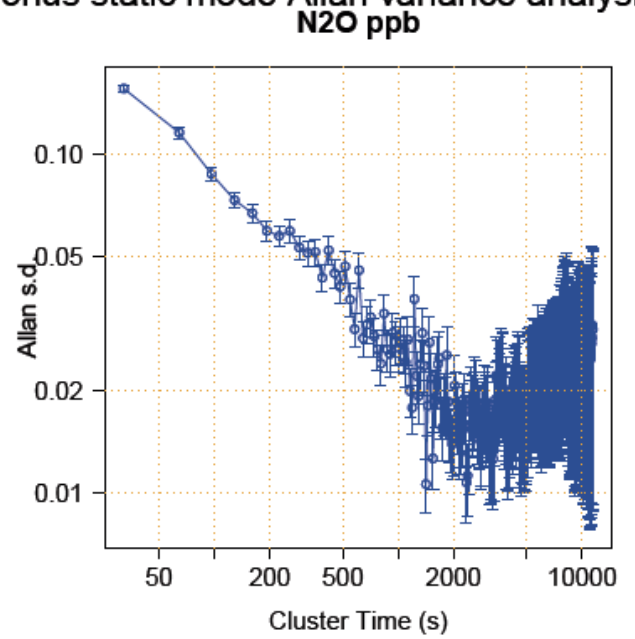
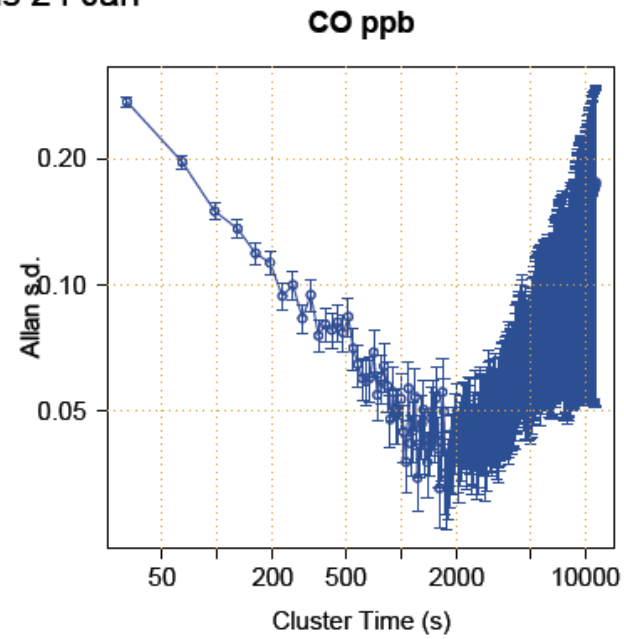
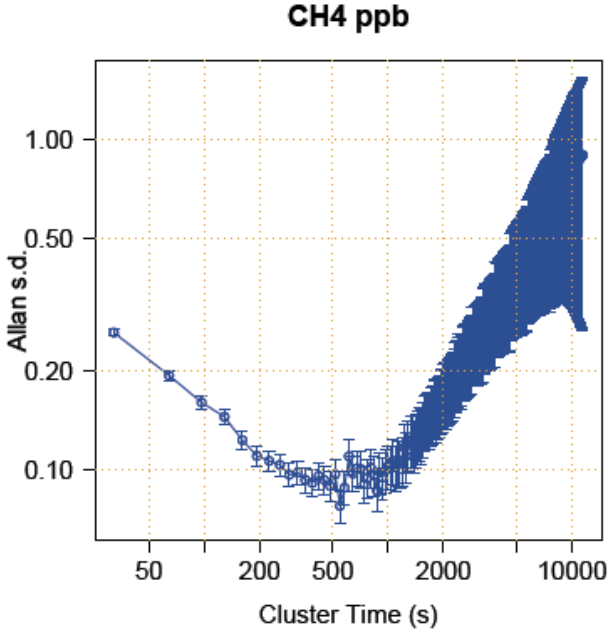
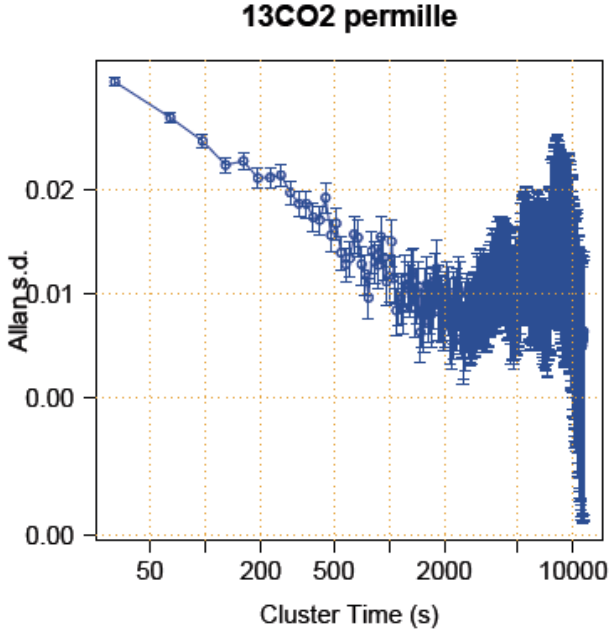
Spectronus static mode Allan variance analysis 24 Jan











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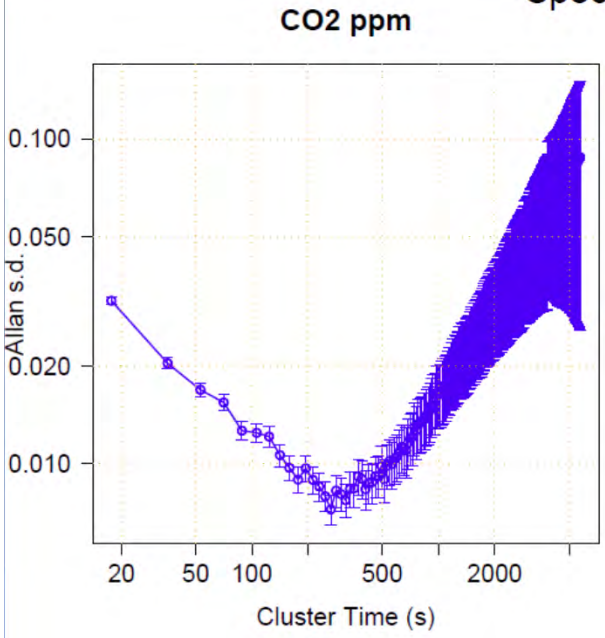
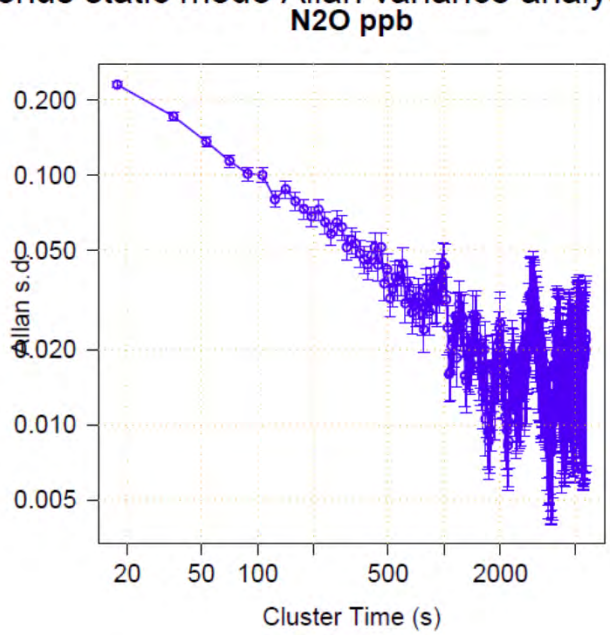
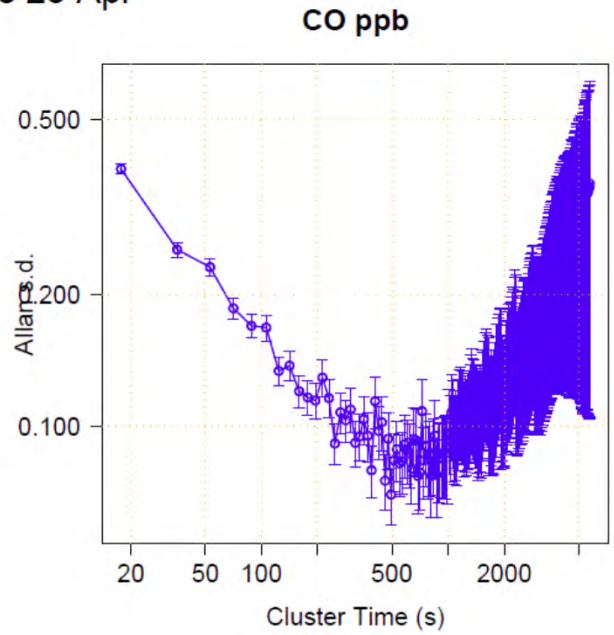
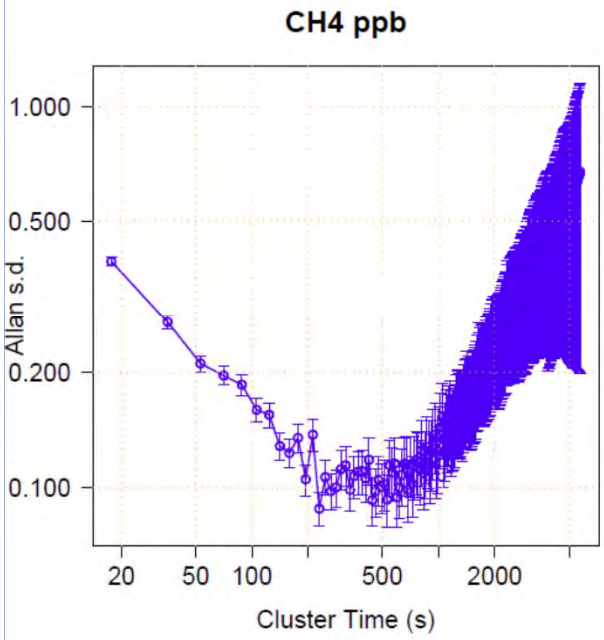
Integrated non-CO2 Greenhouse gas Observing System

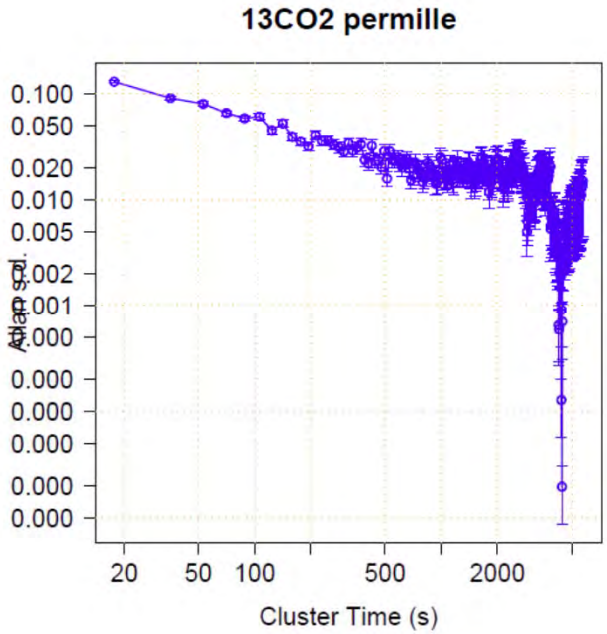
Spectronus static mode Allan variance analysis 23 Apr











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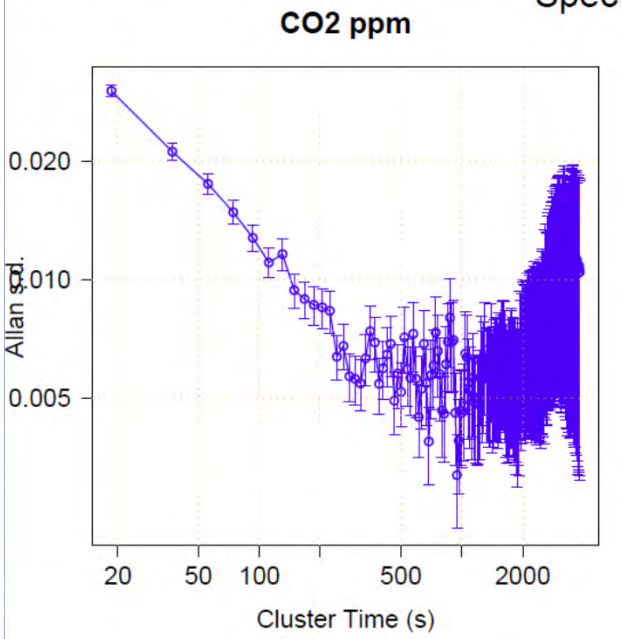
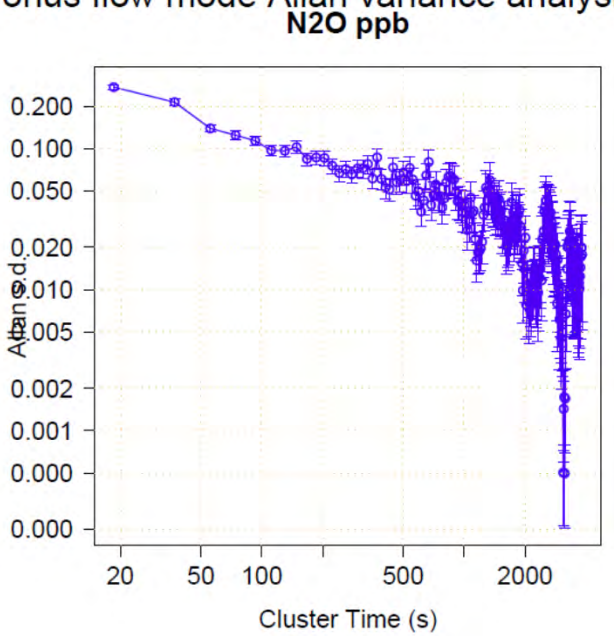
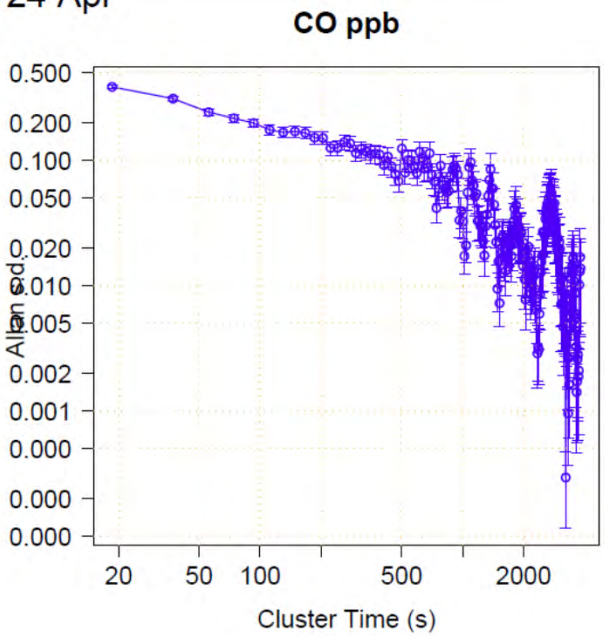
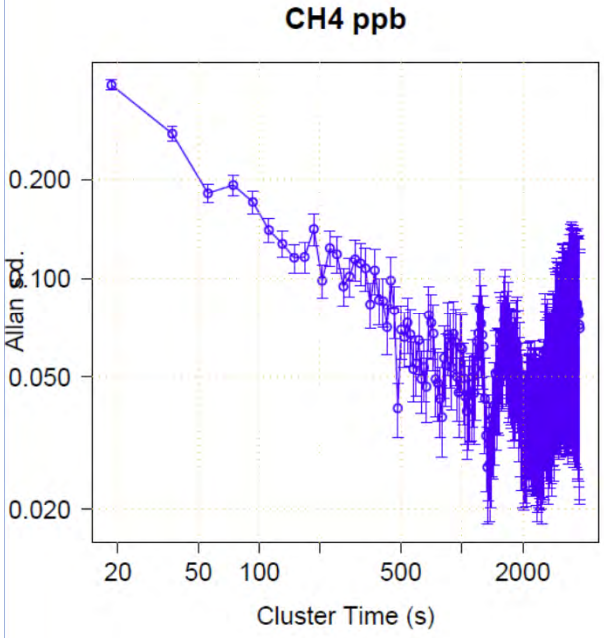
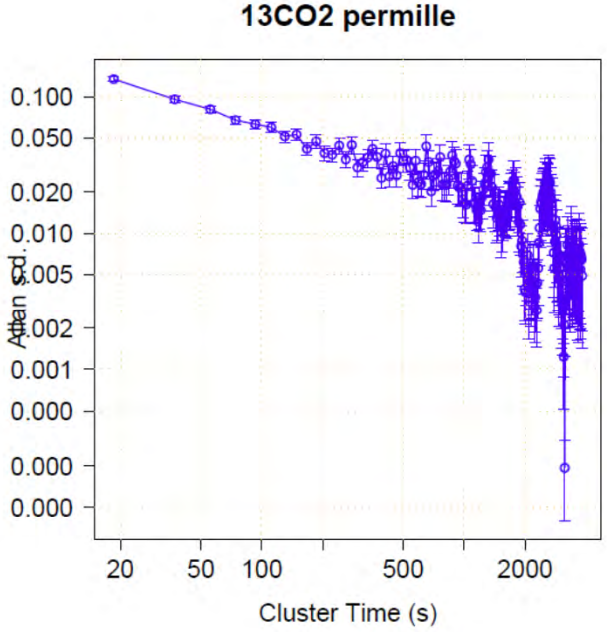
Spectronus flow mode Allan variance analysis 24 Apr











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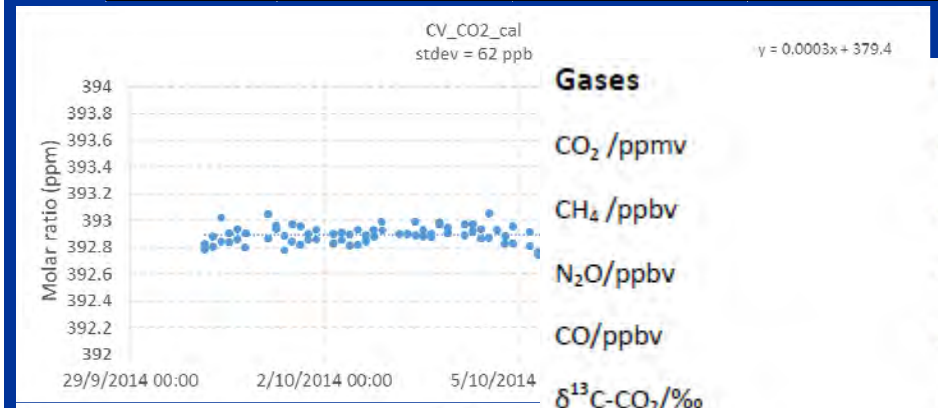
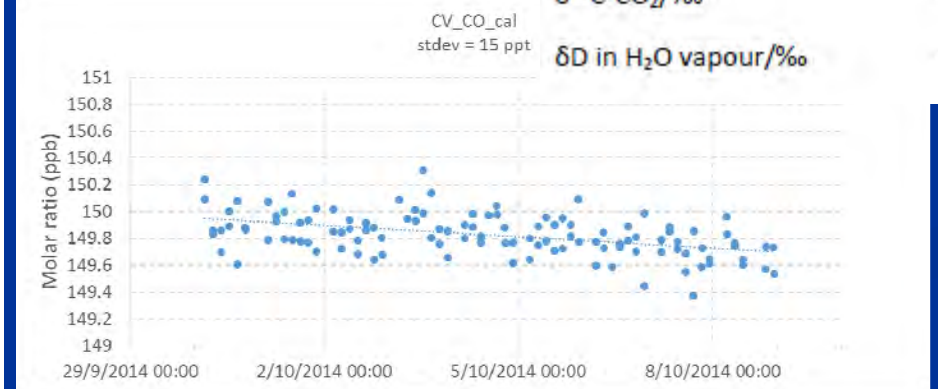
FTIR performance analysis

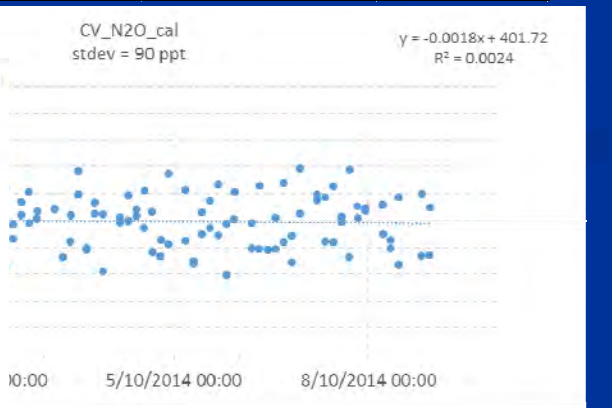
Spectronus metal cell, increased temp control

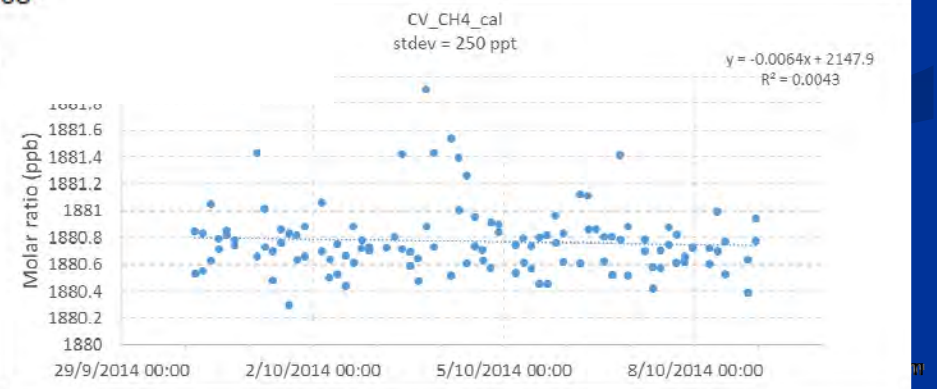
Species	Allan Var				Precision	Drift	Unit
	flow 1 min	flow 5 min	static 1 min	static 5 min	stdev 3 days	per day	
CO2	0.018	0.007	0.018	0.014	0.031	0.021	**ppm**
13CO2	0.08	0.04	0.03	0.02	0.07	0.03	**permille**
CH4	0.18	0.10	0.20	0.10	0.18	0.11	**ppb**
N2O	0.15	0.07	0.12	0.05	0.08	0.009	**ppb**
CO	0.25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



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



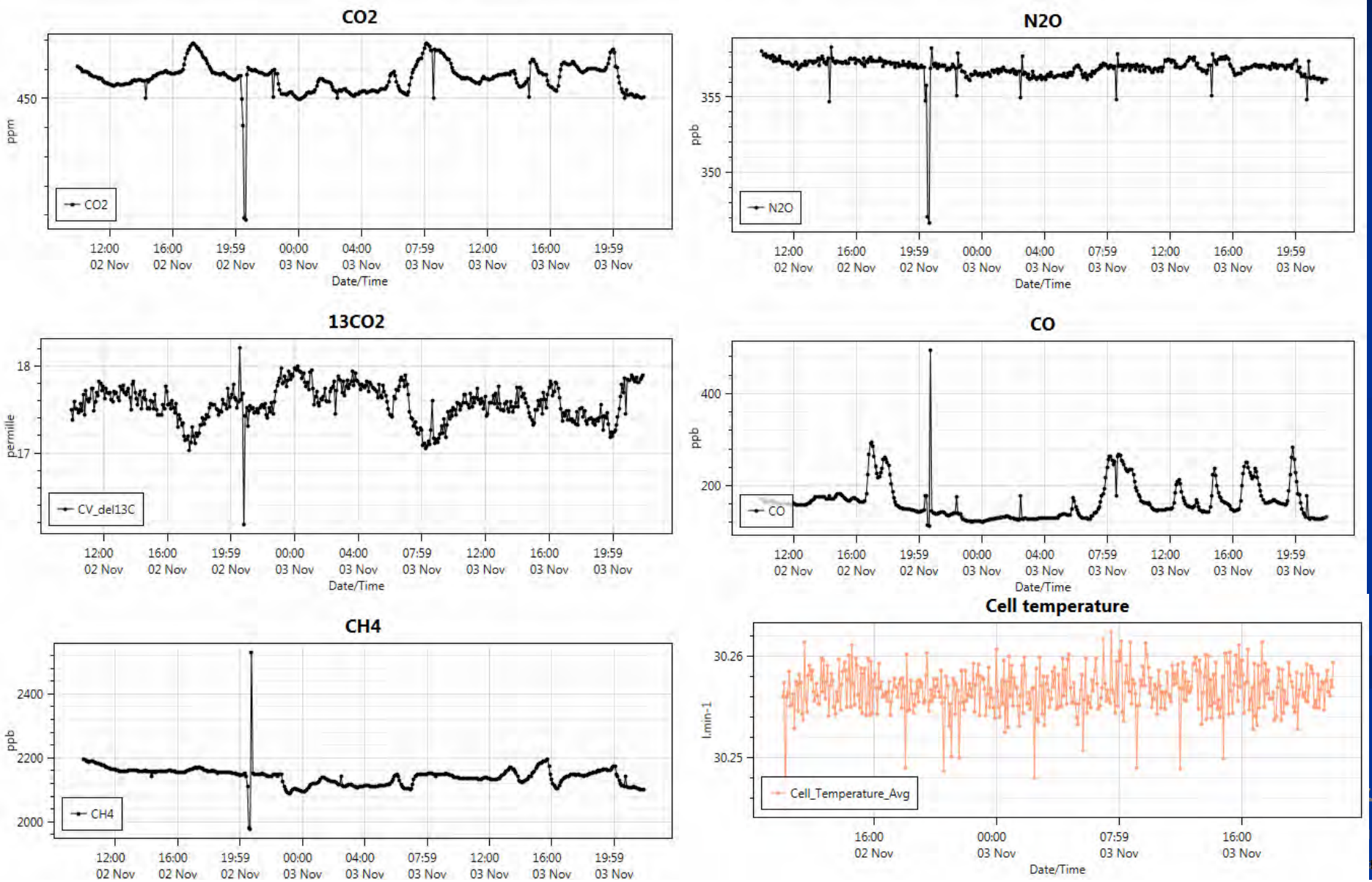




Conclusions

- Considerably less use of (calibration/target) gas
- Accuracy improved through the 3 temperature sensors
- Precision slightly improved, WMO targets achieved
- Instrument much faster ready for operation
  - Stabilisation time after turning on drastically reduced to less than 30 min (N_2 flushing on)
  - Static measurement can be completed in less than 5 min
  - Static mode gas use ~4 l per sample
- Considerably less wall effects and associated drift
- Dryer cartridge exchange every 1-2 months for undried ambient air in static mode (fridge trap; >3 months)

Spectronus FTIR ambient 5 min refill (static mode), 15 sec spectra 3 hourly target, daily calibration/target



FTIR what's next

- Extended precision and performance tests
- Installation at Cabauw tall tower (Nov '14)
- Further improvements on Spectronus software stability and usability
- Integrate improved temperature control in Spectronus software

THANK YOU!

The InGOS project receives funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 284274

Integrated non-CO_2 Greenhouse gas Observing System

Modular sampling unit for (tall) towers

For each height:

- Continuous flow
- Glass (fridge) Trap
- Integration volume SS 19.5 l
- Sample flow 1-2 l/min MFC
- 1600 hPa back pressure reg.
- KNF membrane pump N86AT18
- Atmospheric outlet for GC, Picarro

- Valco valve for selection of sample height or standard/target (12 or 16-way)
- 5 minute meas cycle in static mode
  - Evacuate/fill 500 mbar (flush)
  - Evacuate/fill 1200 mbar
  - Analyse (2 minutes)