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PCI

Absolute Tunable-Diode-Laser-Hygrometers for AIDA

for Simultaneous Gas Phase and Total Water Measurements

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1st Annual VI-ACI Meeting, 5/6.05.2008, Frankfurt

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Goals: Next generation AIDA-TDL-Hygrometer

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- Simultaneous gas phase and total water detection
- Suitability for mixed phase clouds (mid temp, high H_2O, stronger scattering)
- Very high dynamic range (sub ppm to 20000 ppm) with high accuracy
- Calibration-free, absolute accuracy, high precision, rigid validation
- Use of AIDA TDL for active feedback controlled humidity in AIDA

Fully fiber-coupled, multi-path, dual laser instrument

⇨ Simultaneous weak line/short absorption path + strong line / long absorption path

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Ro-Vibrational Spectrum of Water Vapour

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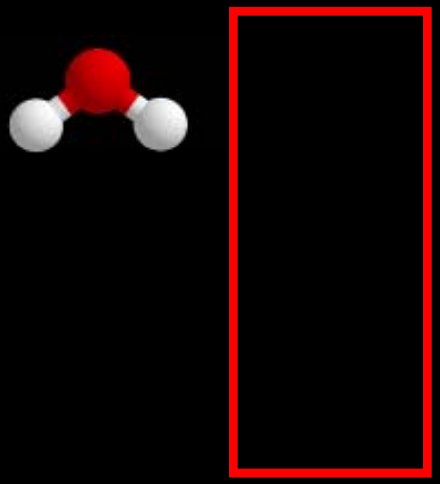

Gas phase water (inside AIDA chamber):

A) fiber-coupled open path White cell (100m / λ= 1.4µm)
$\Rightarrow \Delta H_2O \approx$ 10ppb ; max $H_2O \approx$ 100ppm

B) fiber-coupled open single-path (4m / λ= 1.3µm)
$\Rightarrow \Delta H_2O \approx$ 20ppm ; max $H_2O \approx$ 20.000ppm

Total water (extractive measurement):

C) fiber-coupled closed Herriott cell (30m / λ= 1.4µm)
$\Rightarrow \Delta H_2O \approx$ 30ppb ; max $H_2O \approx$ 300ppm

D) fiber-coupled closed single-path cell (0.1m / λ= 1.4µm)
$\Rightarrow \Delta H_2O \approx$ 10ppm ; max $H_2O \approx$ 30.000ppm

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High Sensitivity ➡Long Path Optics

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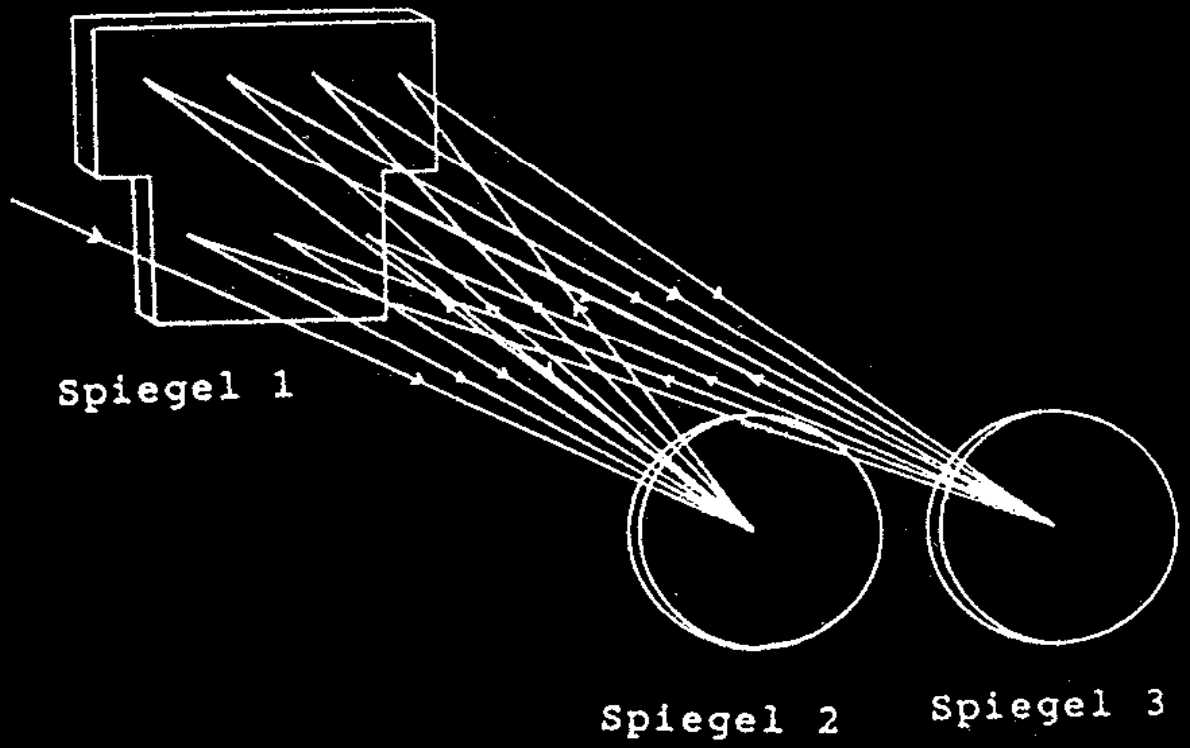
Multi-Path-Cell: White-Type



- 3-Mirror concept
- Constant base length
- Mirror tilt
  - ⇨Modifies Abs.-path
  - ⇨(4n+2)·base length
- Spatially separated entrance and exit spots

AIDA-Cell

- Permanent setup
- Motorized alingment
- base length 3.74m
- L : 15-254m (22 round trips, 82.28 m)

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Top View into the AIDA Chamber

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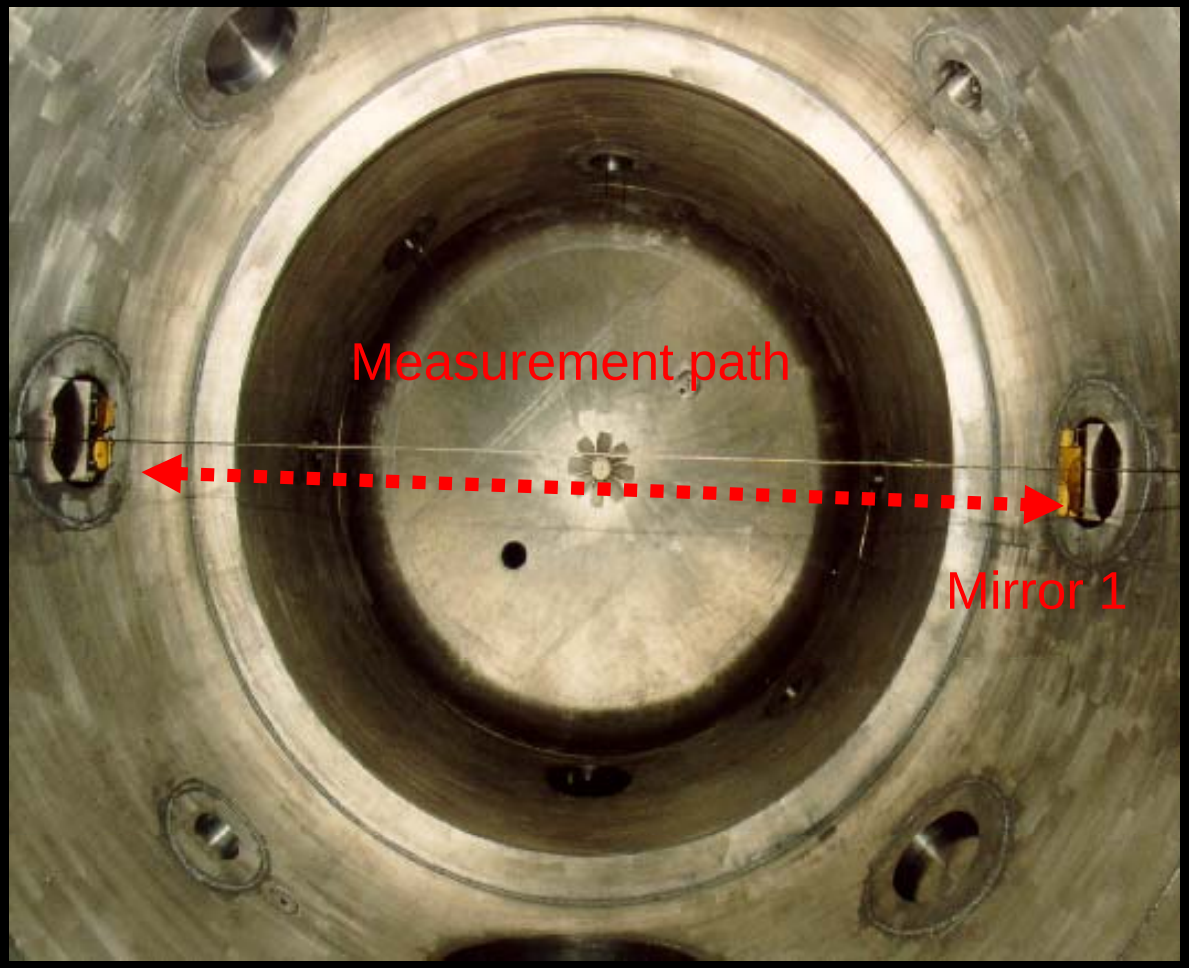

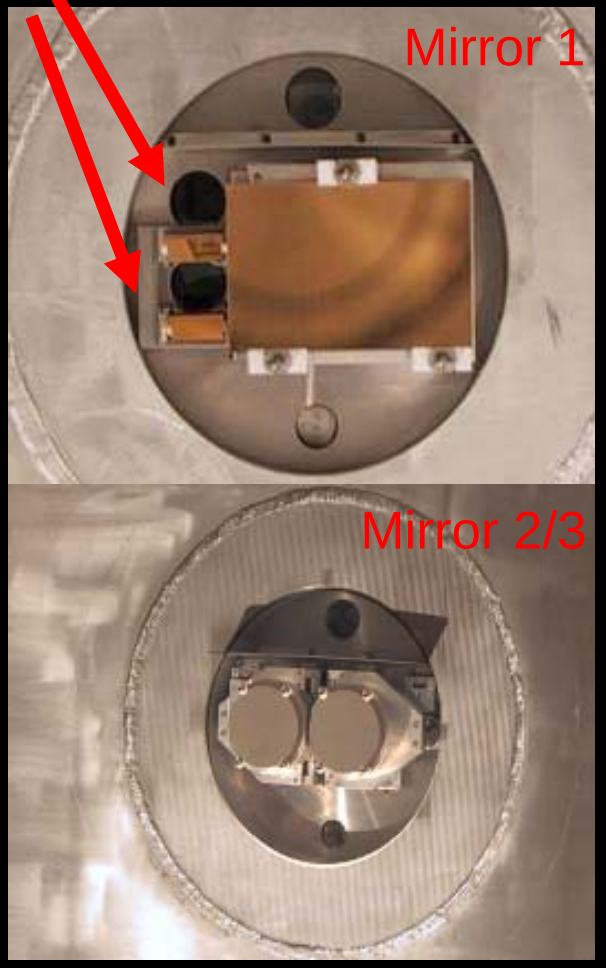

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Optical Coupling ➡ Glass Fibers

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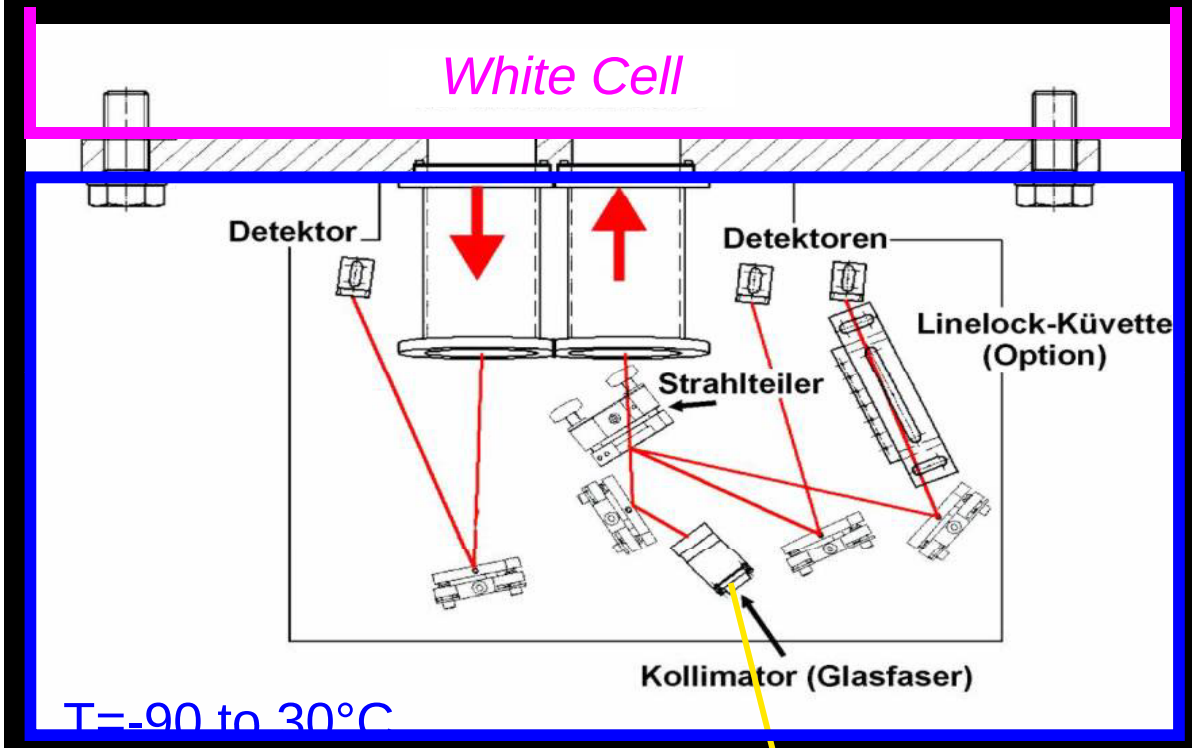
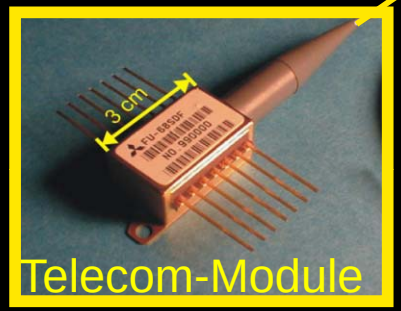
AIDA-Chamber



Transfer optics

Laser +
electronics



Inner AIDA - White Cell:

T = 190 – 271 K

P = 1 – 1000mbar

P_{H2O}= 10^{-3} – 5 mbar (sat.)

Intermediate AIDA-T.Optics:

T = 190 – 271 K

P = atmospheric

P_{H2O}= 10^{-3} – 5 mbar (sat.)

Outer part = Laser module:

P, T = 1 bar / 300K /

≈ 15 mbar H_2O

⇒ Suppress "Outside" H_2O
⇒ Avoid pressure gradients

Setup: Dual Phase - TDLAS

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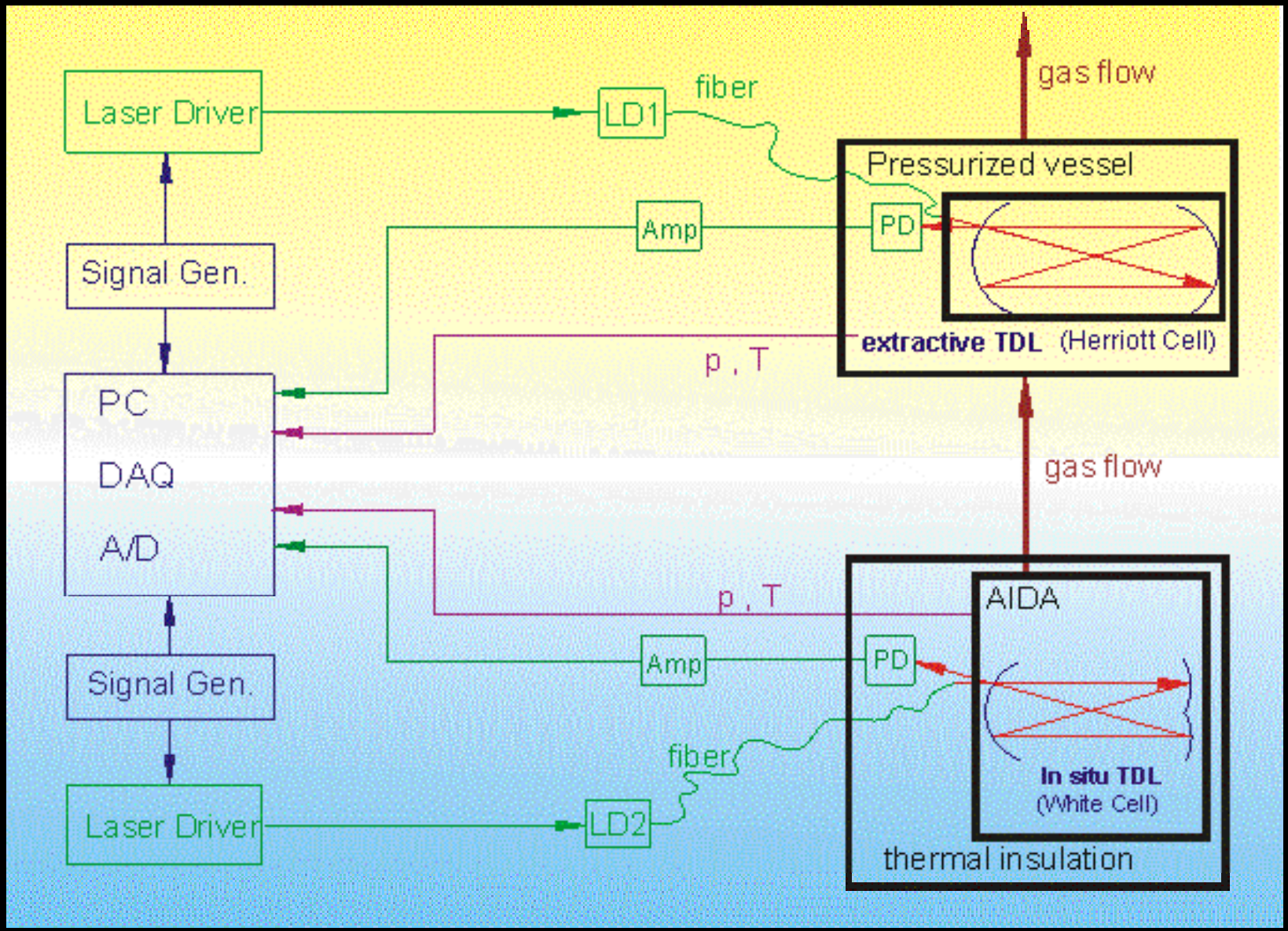
Extractive TDLAS ⇒ Total Water



Insitu TDLAS ⇒ Gas Phase Water – In-cloud

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Extractive TDL Setup I

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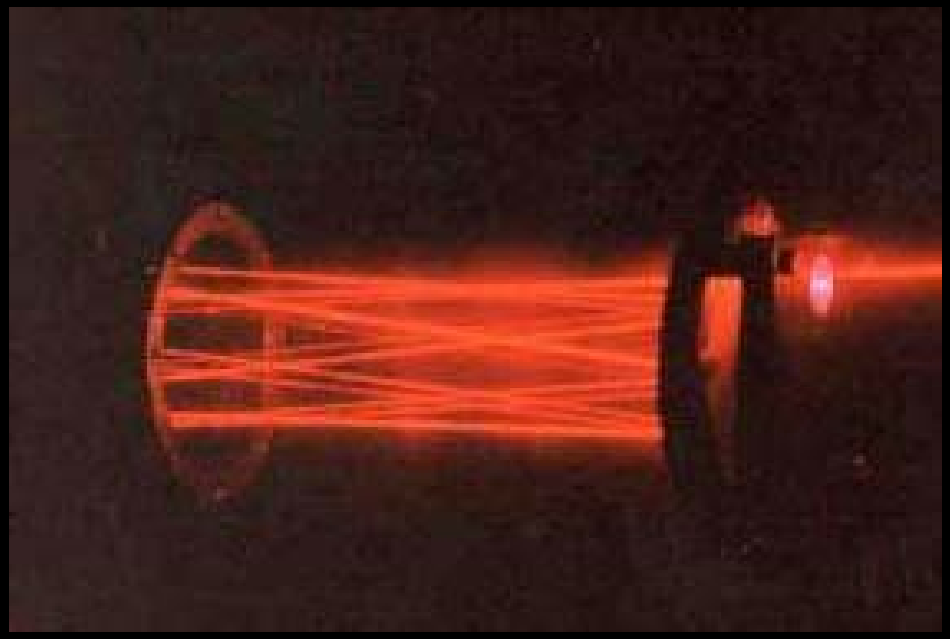

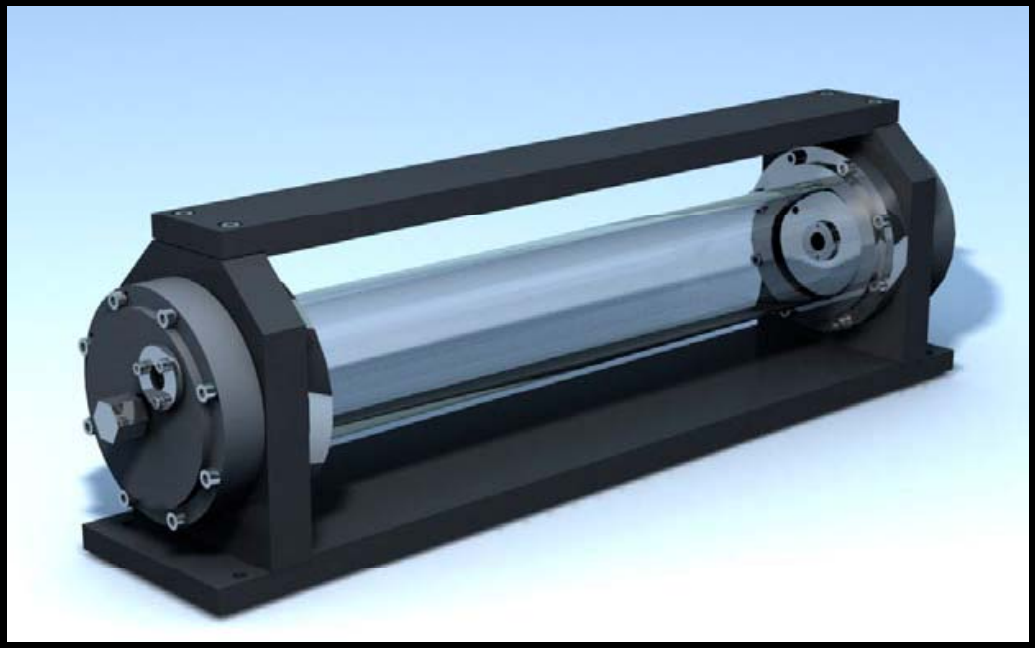

- 2 mirror concept (Herriott cell)
- Base length 0.5 m
- Path length 30 m

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Extractive TDL Setup II

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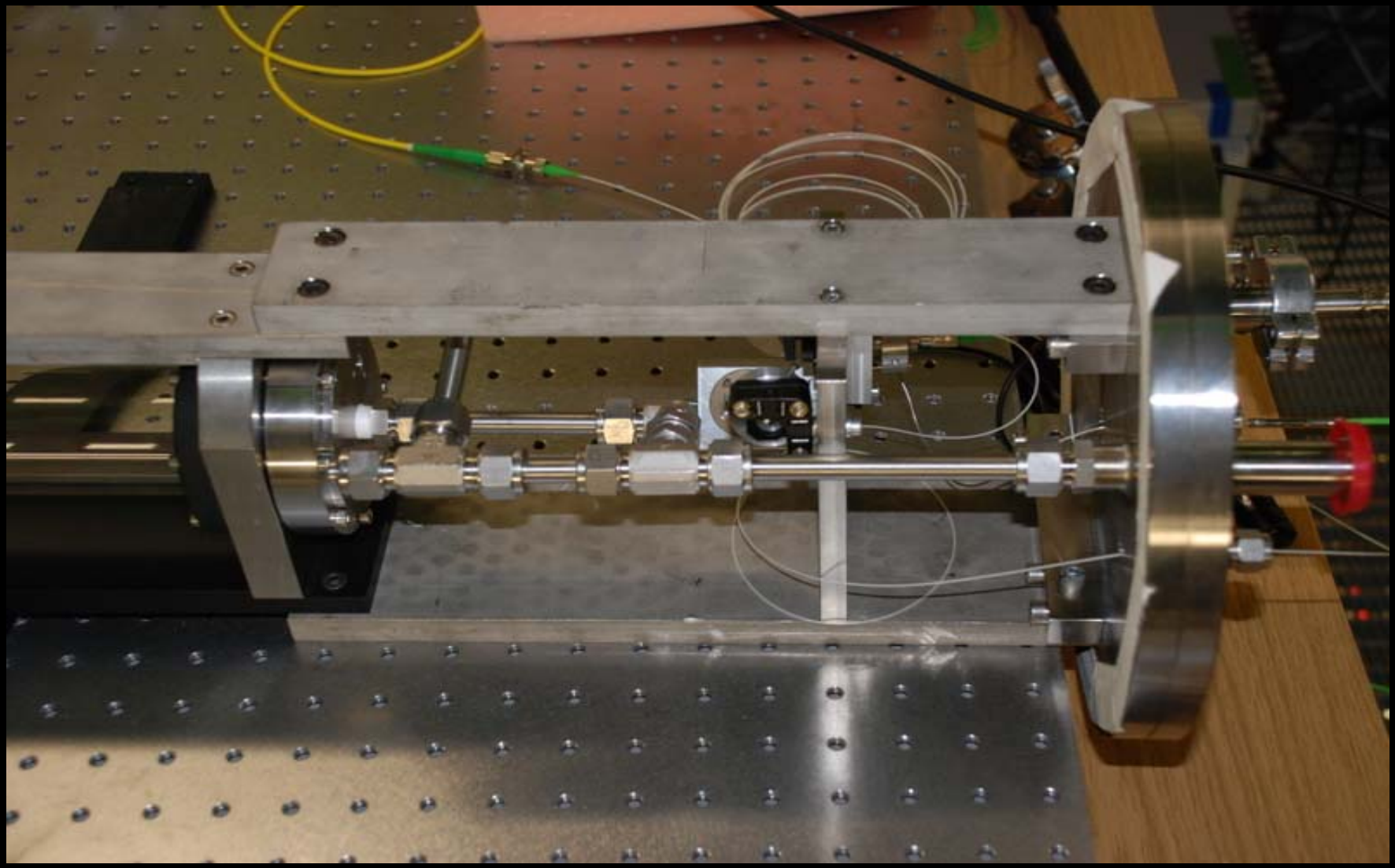
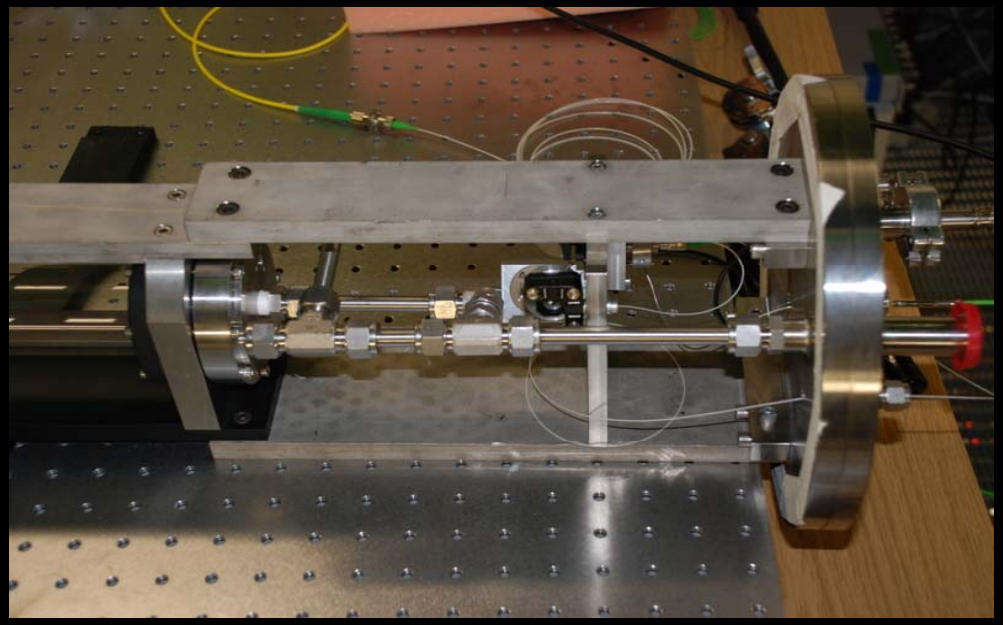


- Fiber coupled, purged transfer optics
  - *Minimize parasitic absorption*

Extractive TDL Setup II



- Fiber coupled, purged transfer optics
  - *Minimize parasitic absorption*
- Herriott cell with glass body
- Inner Cell volume 0.9 l,
- Recipient volume 35 l
  - *Total flow 1-2 SLM at 100 mbar*

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Typical Signals: In situ TDL

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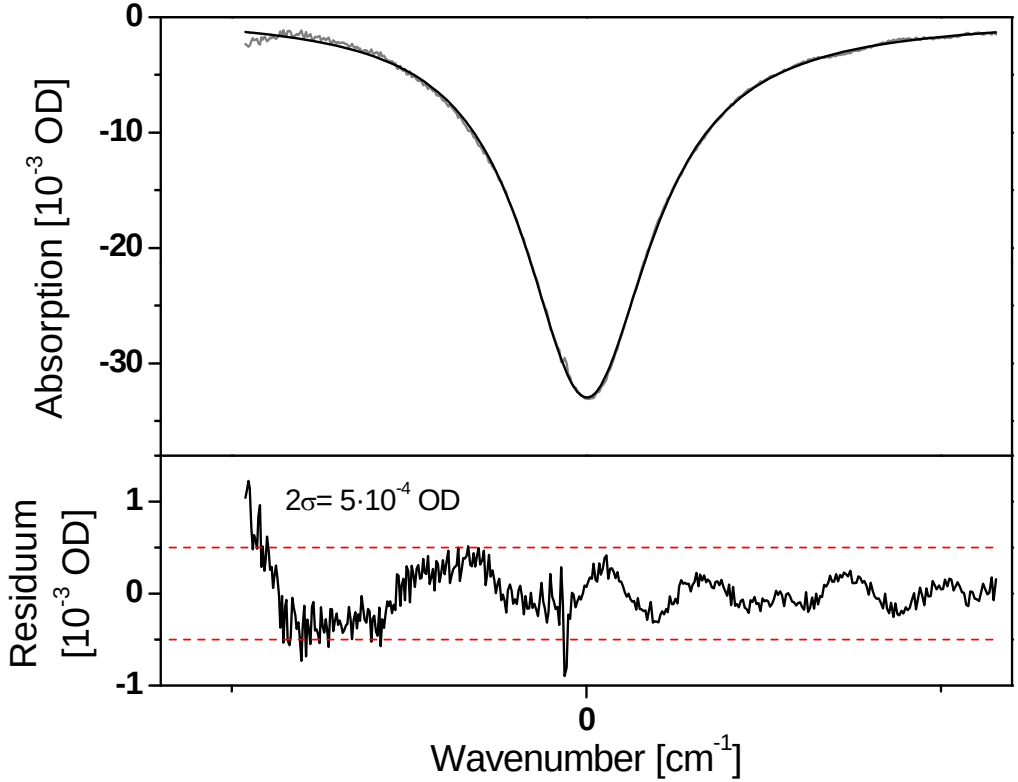

Open path TDL = Gas phase H2O

- 1000 hPa, 203 K, 82m
- 3 % Absorption
- 18 Line - Voigt Fit
- no calibration !

Resolution

- $2 \cdot 10^{-4}$ OD (1σ)
- **12ppb H2O**
- 124:1 S/N

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Typical Signals: Extractive TDL

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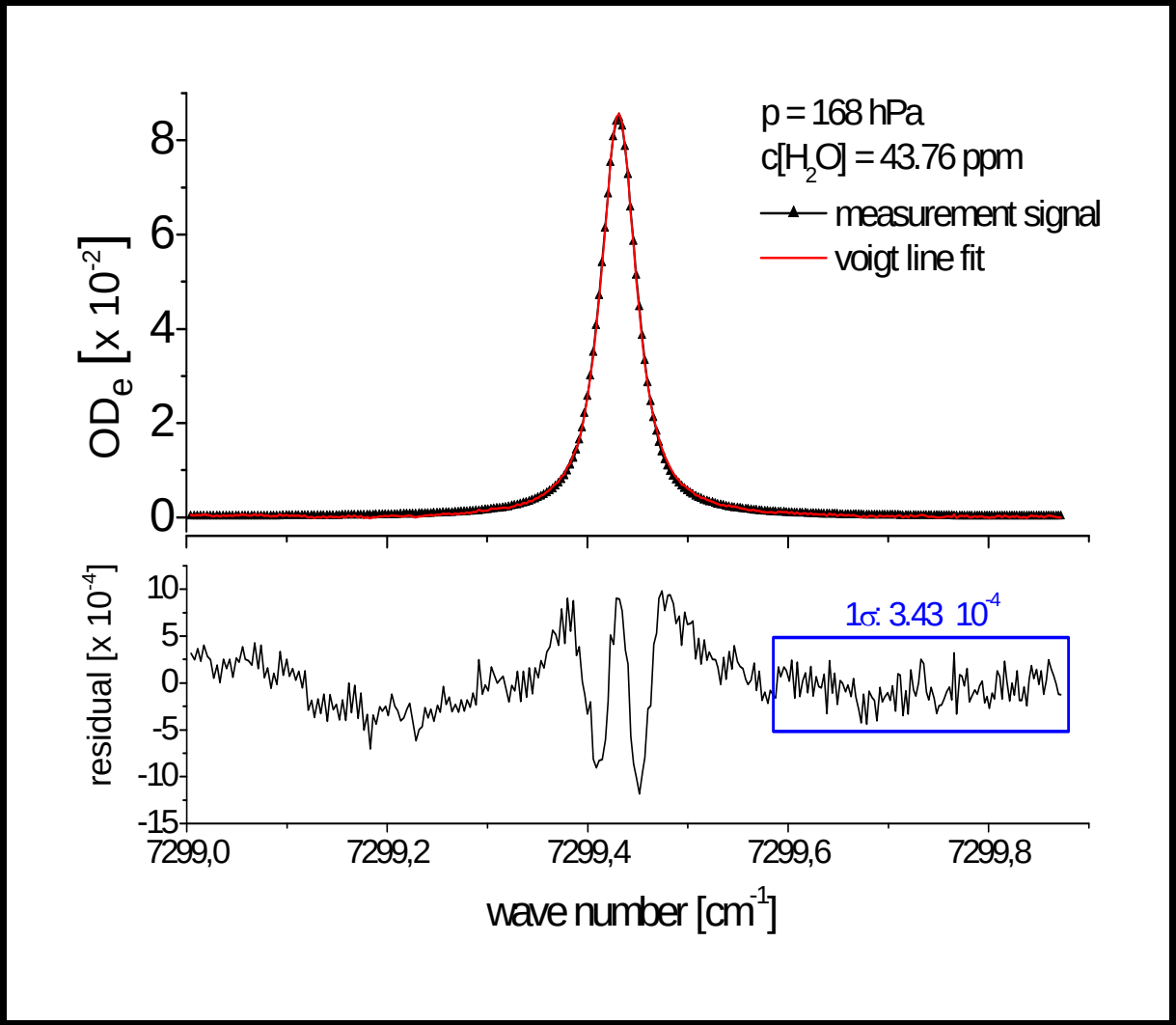

Extractive TDL = Total H2O

- 168 hPa, 300 K, 30m
- 8 % Absorption
- Voigt, Fit w/o calibration !

Resolution

- $3 \cdot 10^{-4}$ OD (1σ)
- 280 ppb H2O (opt. 90 ppb)
- 154:1 S/N

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AQUAVIT- Intercomparison

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- H_2O (Aqua) Validation and Instrument Tests
  - ⇨22 Instruments , 17 Groups , 7 Countries
- Organisers:

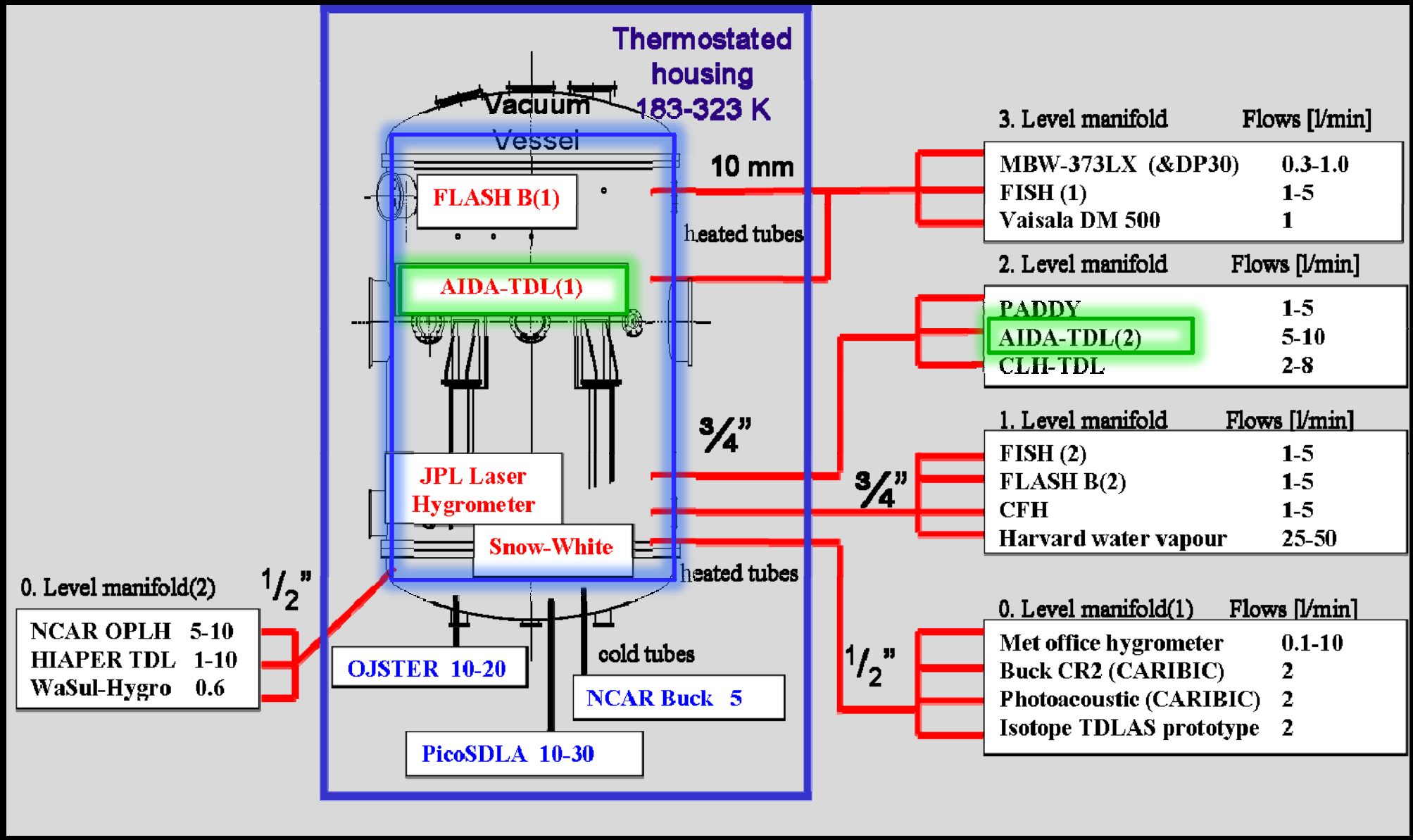
  H Saathoff (FZK) C Schiller (FZJ) V Ebert (U-HD)
- Referees:

  DW Fahey + R Gao (NOAA, Boulder) O Möhler (FZK)
- More Info:
  - ⇨http://imk-aida.fzk.de/campaigns/RH01/Water-Intercomparison-www.htm
- 1st AQUAVIT-Workshop:

  May 28-30, 2008

  ETH Zürich, Inst. for Atmospheric and Climate Science

Aquavit – Instrument Overview



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Aquavit – Measurement Program

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	Exp. No.	Experiment type	T (K)	P (hPa)	H_2O (ppm)	
Week 1	3	Constant p,T	243	50-500-50	30 - 300	In-situ TDL
	4, 5	Constant p,T	223	100-500-50	3 - 20	
	6	Constant p,T	213	100-300-50	3 - 20	
	7	Constant p,T	196	80-300-50	3 - 17	
	8	Constant p,T	185	80-500-50	0.5 - 3	
Week 2	9	Dynamic p,T	243	200 - 140	1800 - 3800	In-situ TDL + Extractive TDL
	10	Dynamic p,T	223	200 - 140	190 - 400	
	11	Dynamic p,T	213	300 - 50	35 - 210	
	12	Dynamic p,T	200	300 - 50	5 - 30	
	13	Dynamic p,T	185	300 - 50	0.5 - 3	

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Extr.-TDL vs FP-Hygrometer

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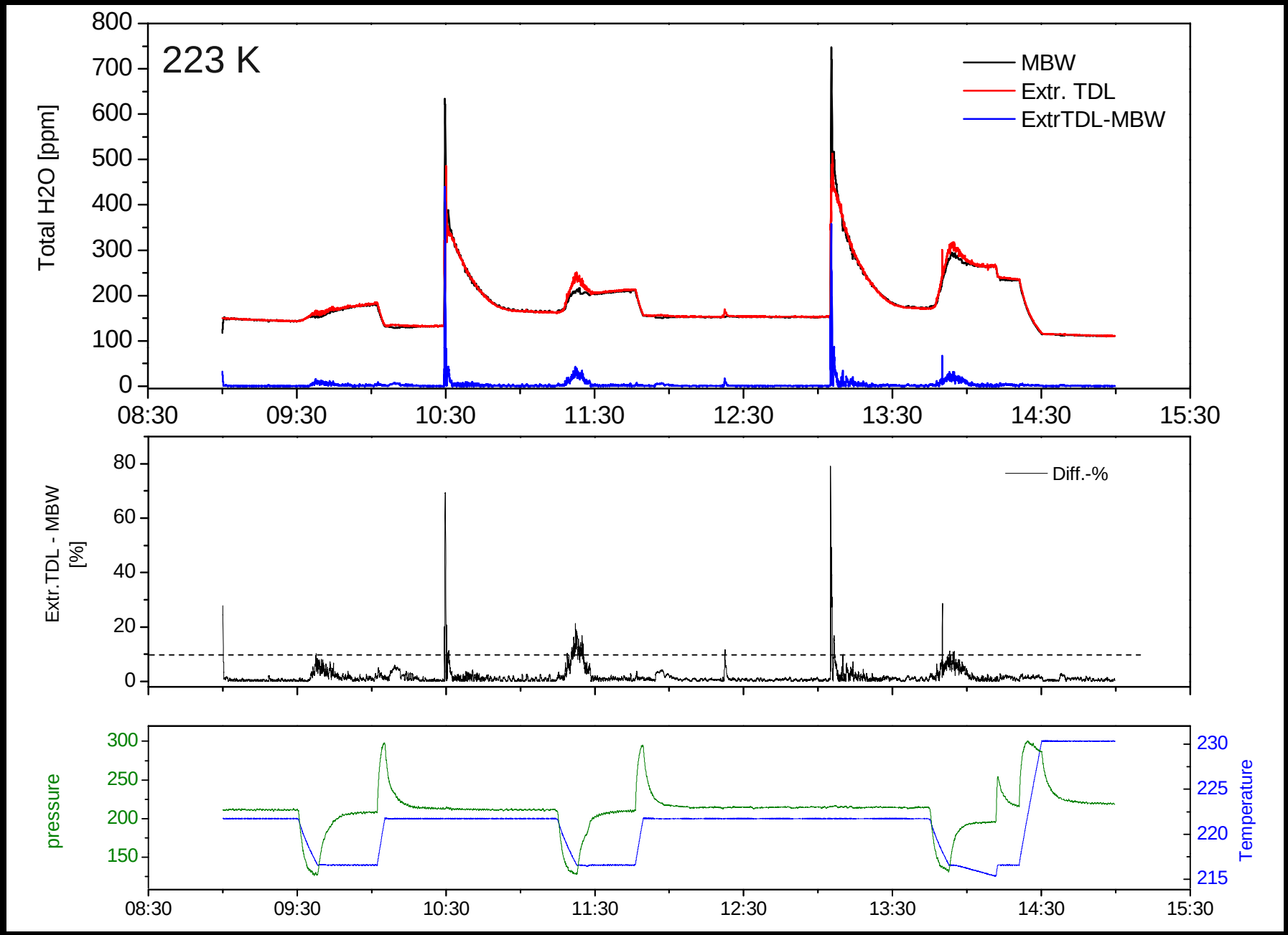

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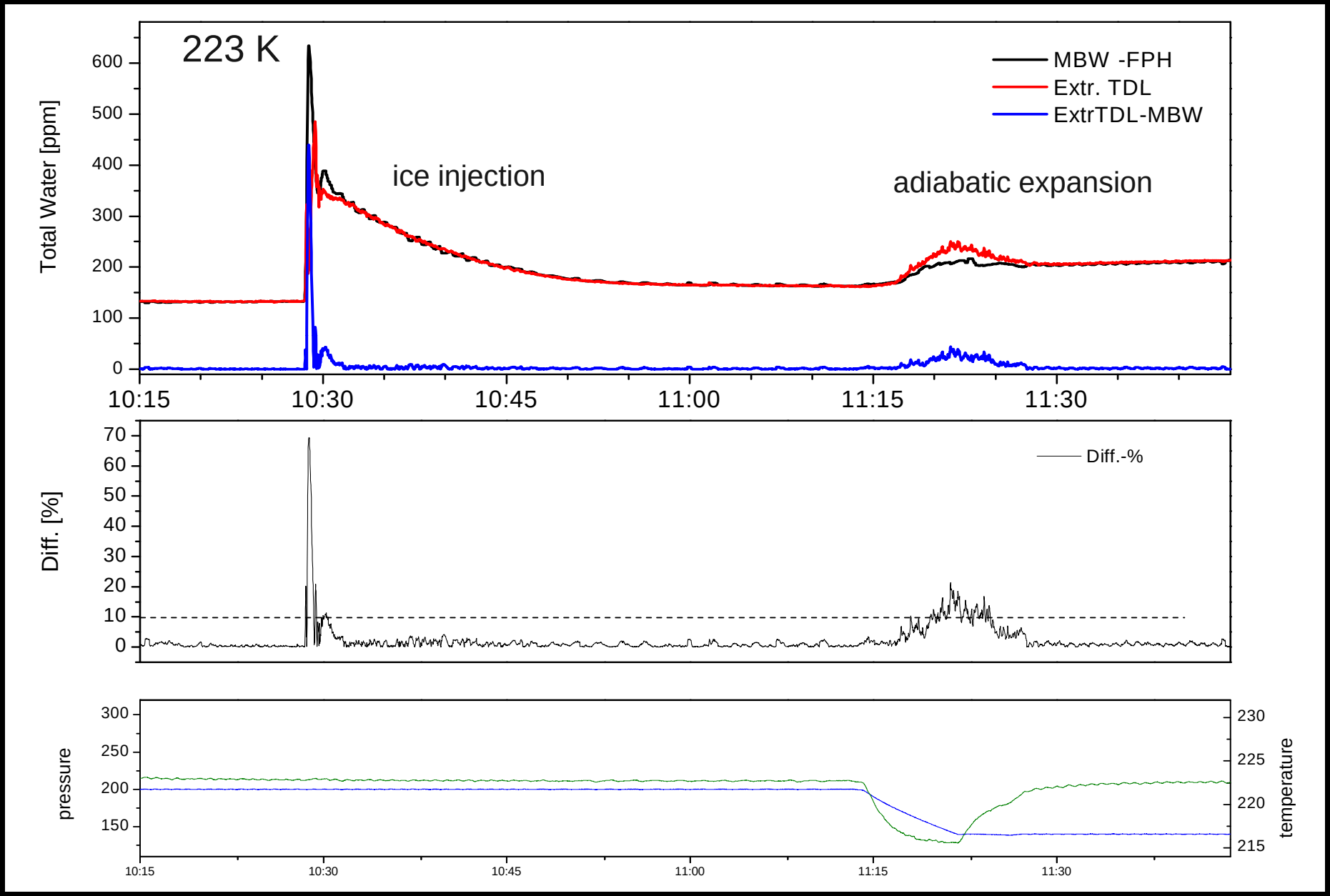
Extr.-TDL vs FP-Hygrometer II

PCI



Dual TDL Measurement

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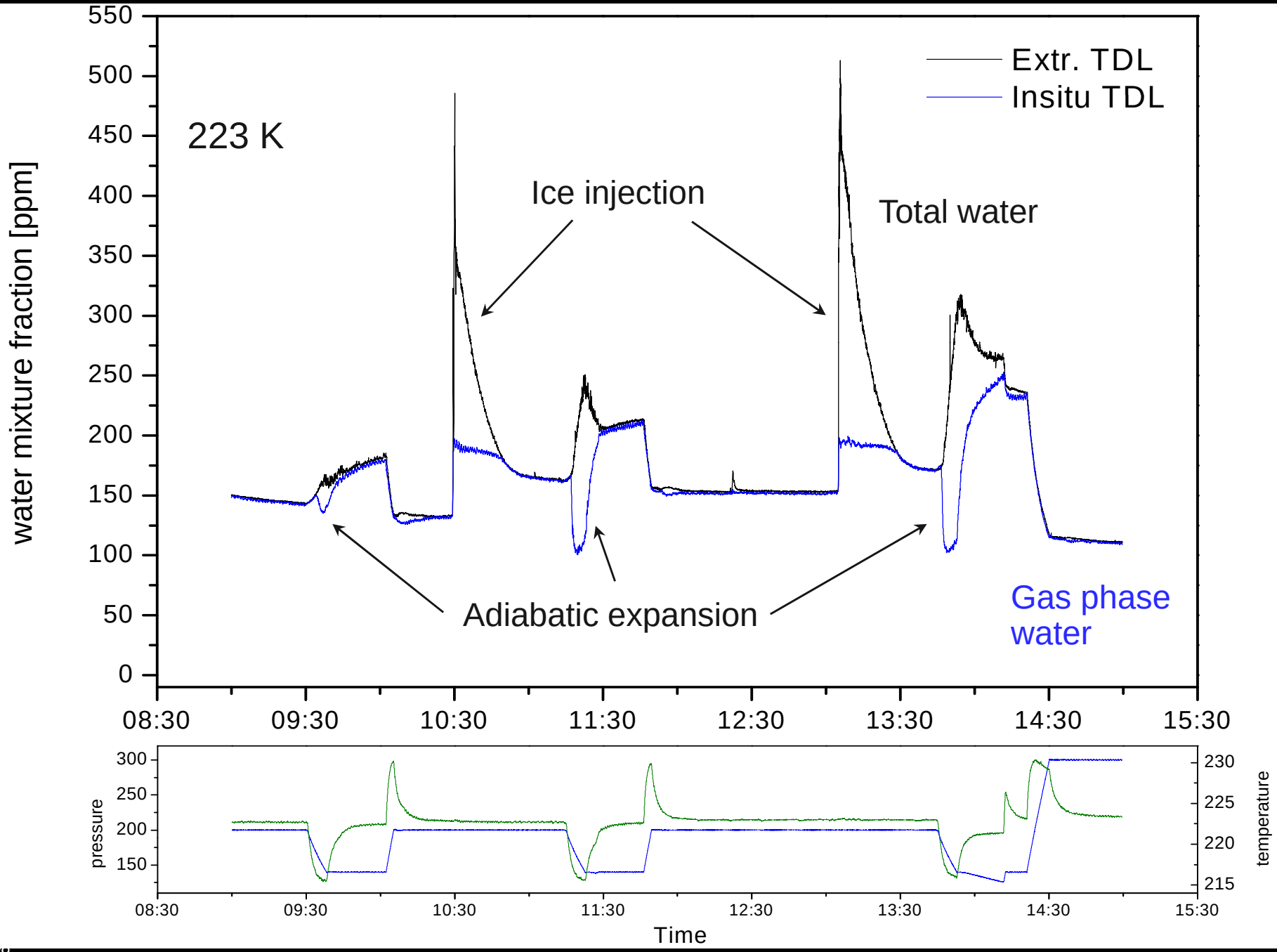
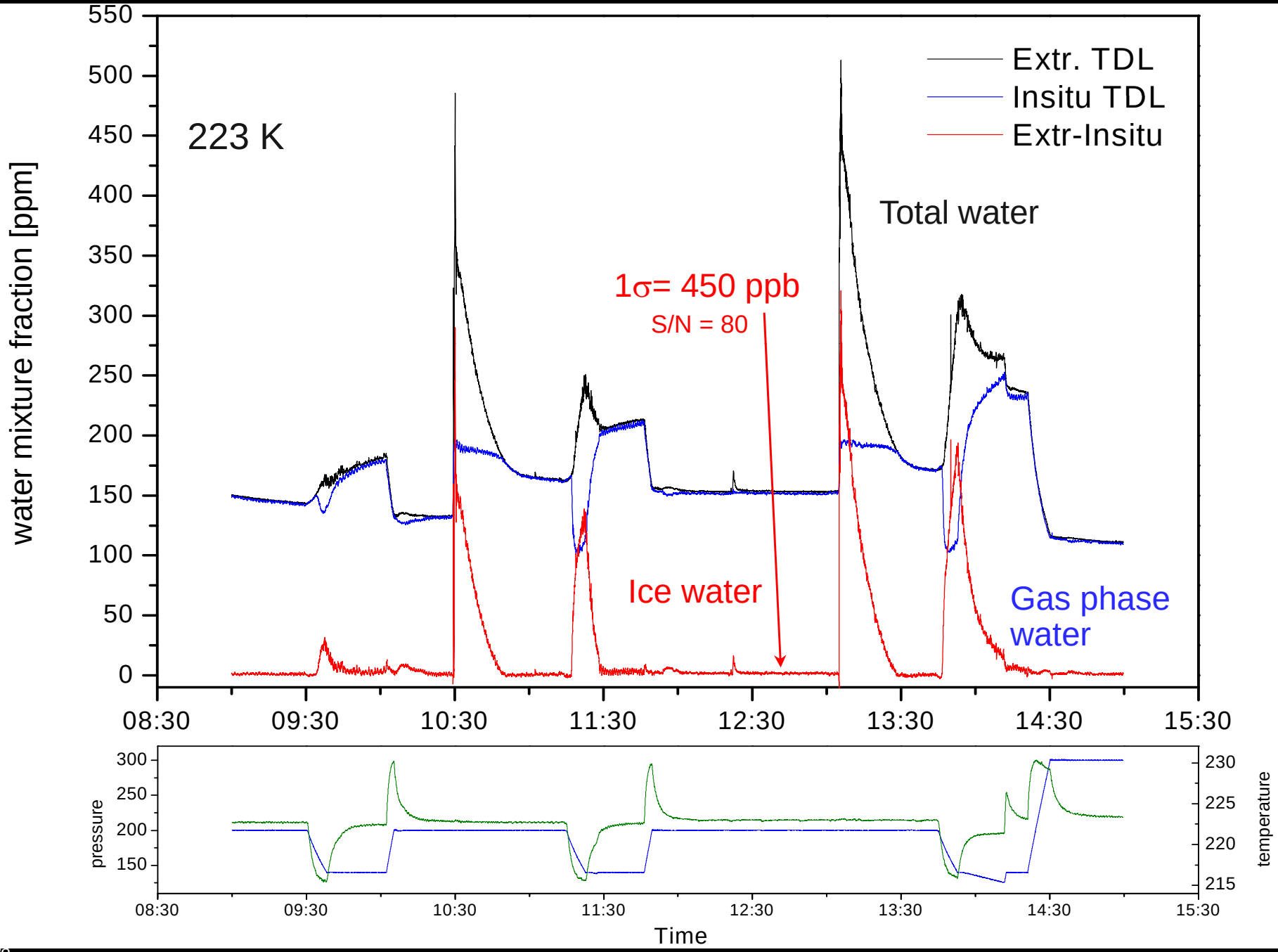
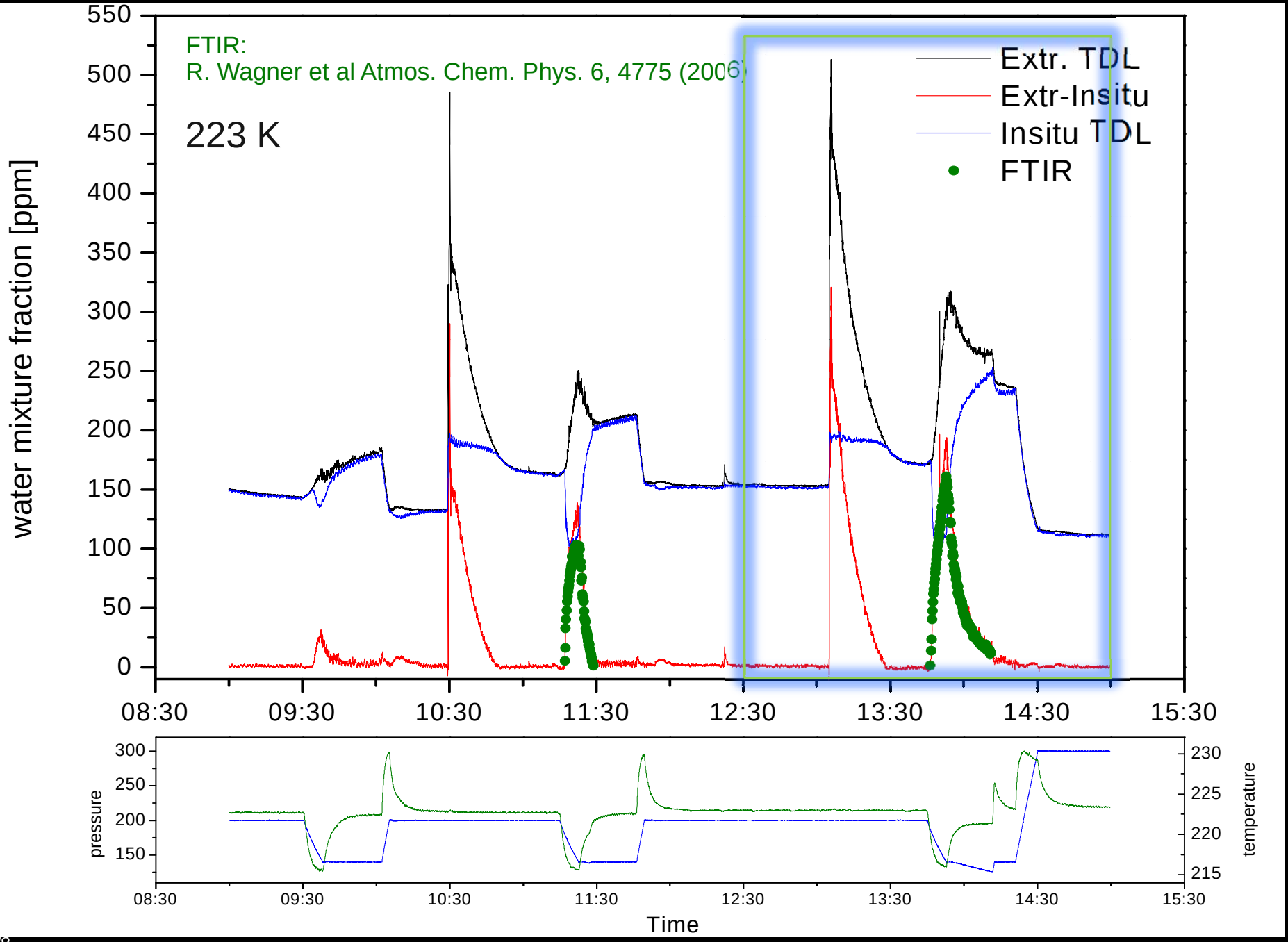


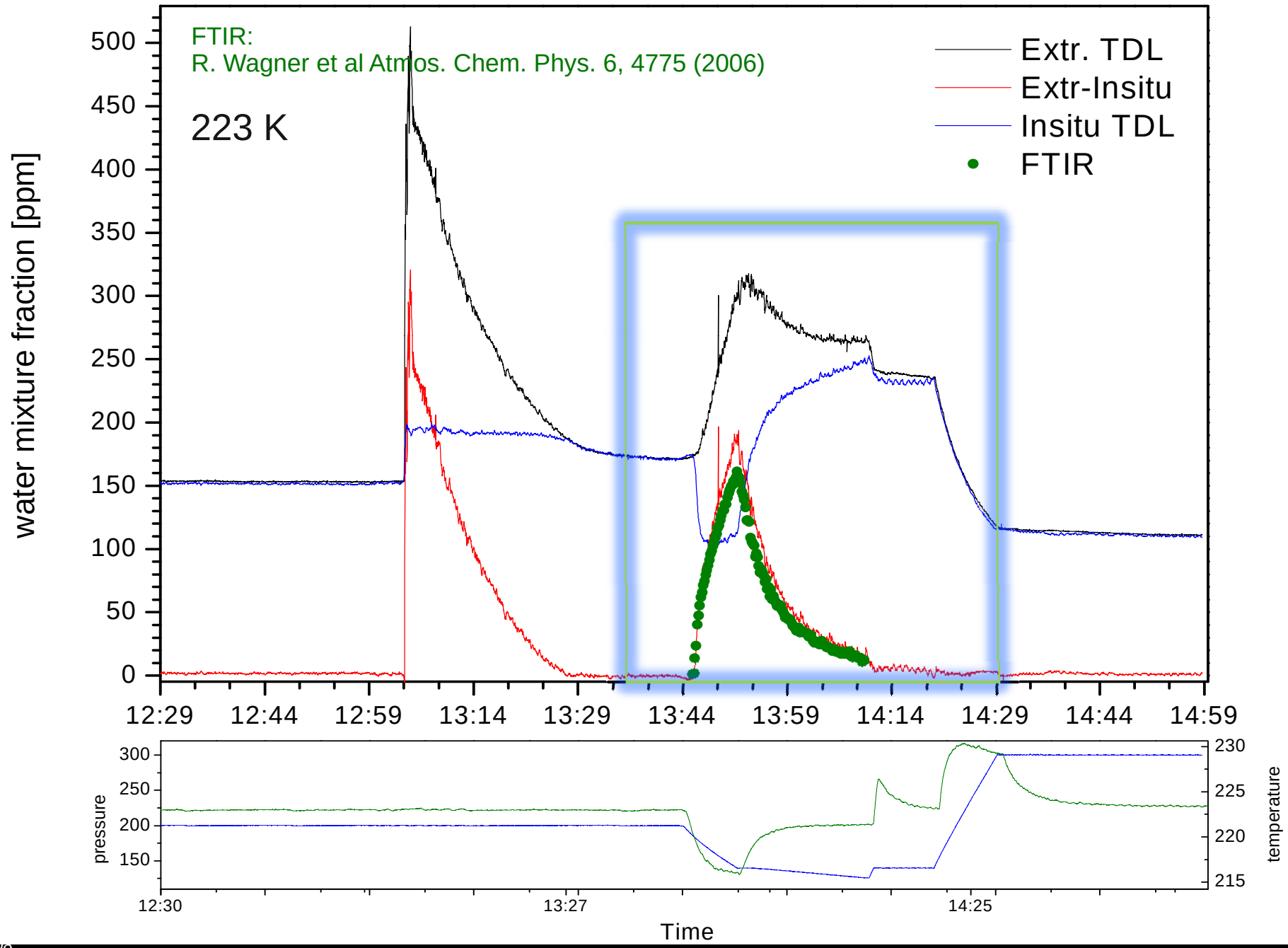
Ice Water


223 K
Extr. TDL
Insitu TDL
Extr-Insitu
Total water
1σ= 450 ppb
S/N = 80
Ice water
Gas phase water
water mixture fraction [ppm]
550
500
450
400
350
300
250
200
150
100
50
0
08:30
09:30
10:30
11:30
12:30
13:30
14:30
15:30
pressure
300
250
200
150
temperature
230
225
220
215
Time

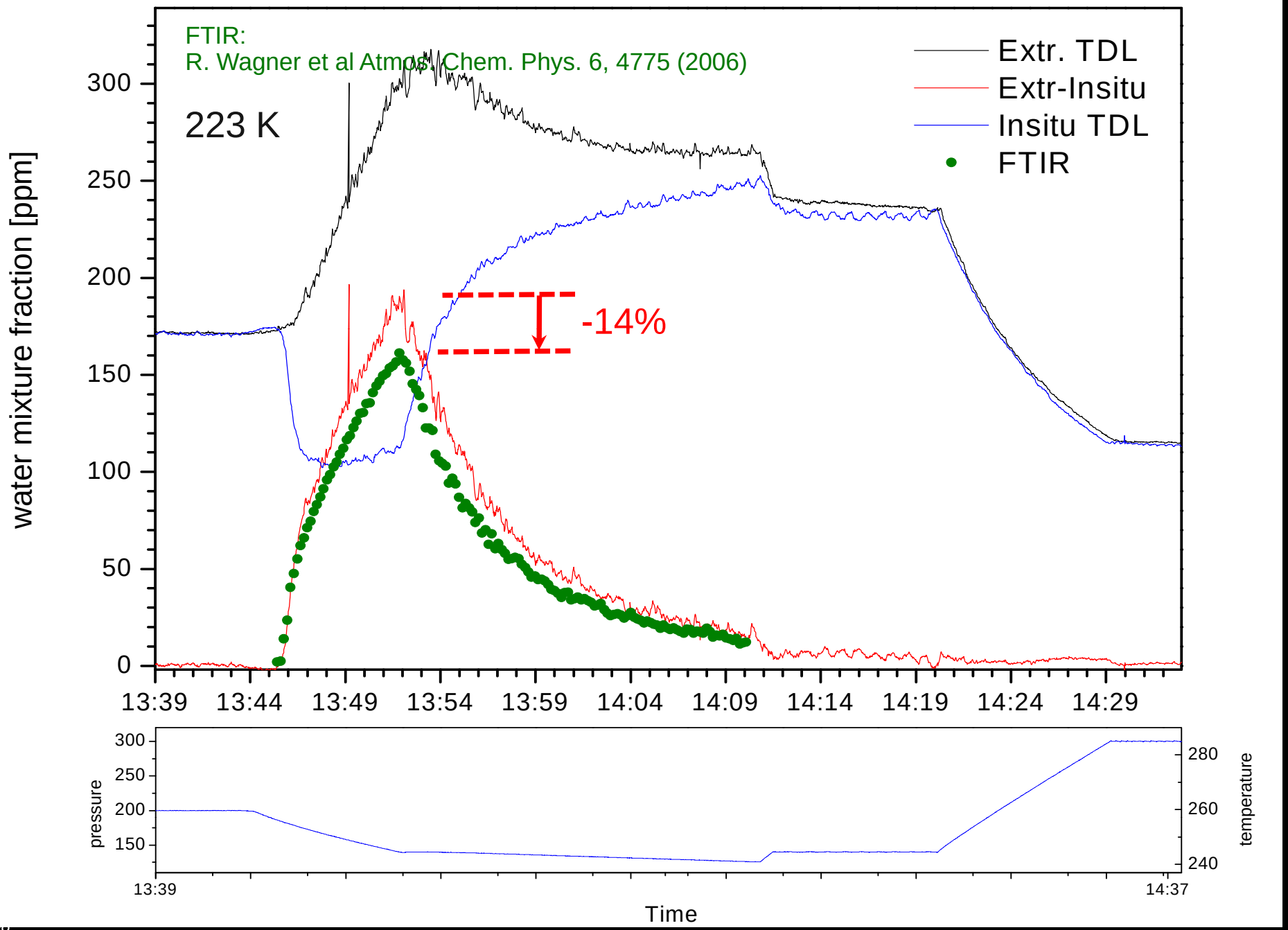
Ice Water Validation

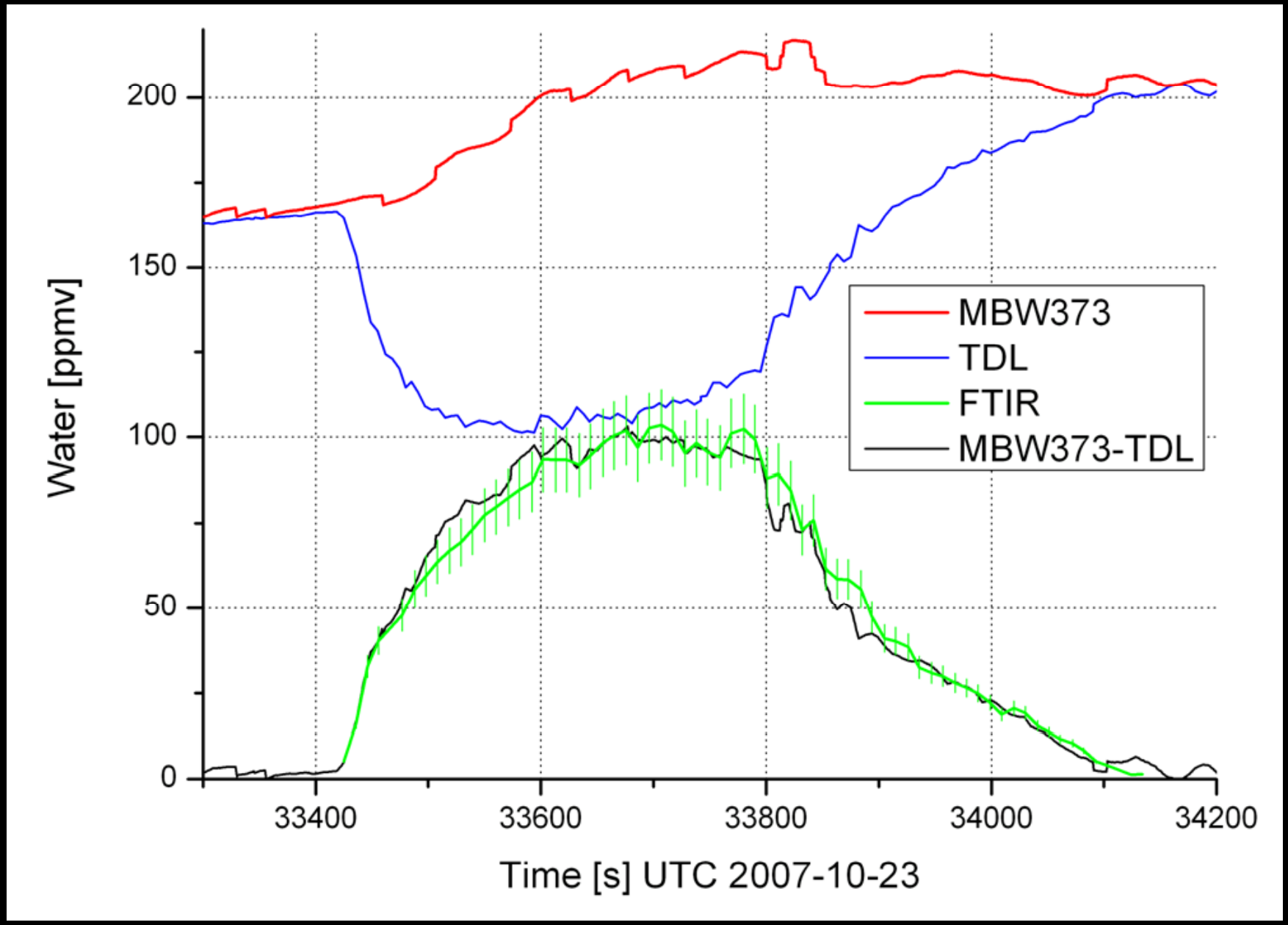


Ice Water Validation

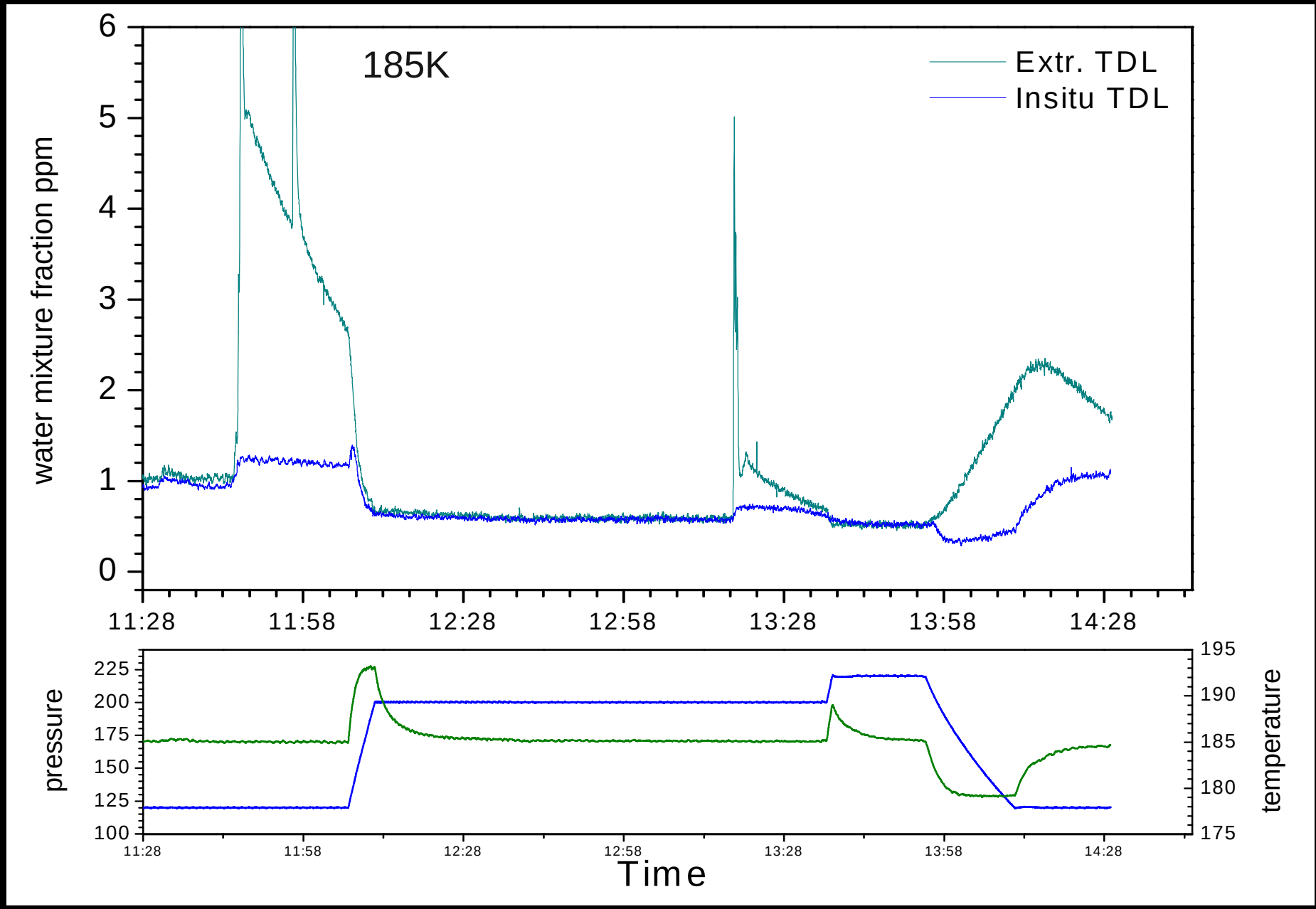


Ice Water Validation




Water [ppmv]
200
150
100
50
0
33400
33600
33800
34000
34200
Time [s] UTC 2007-10-23
MBW373
TDL
FTIR
MBW373-TDL

Low Humidity Results



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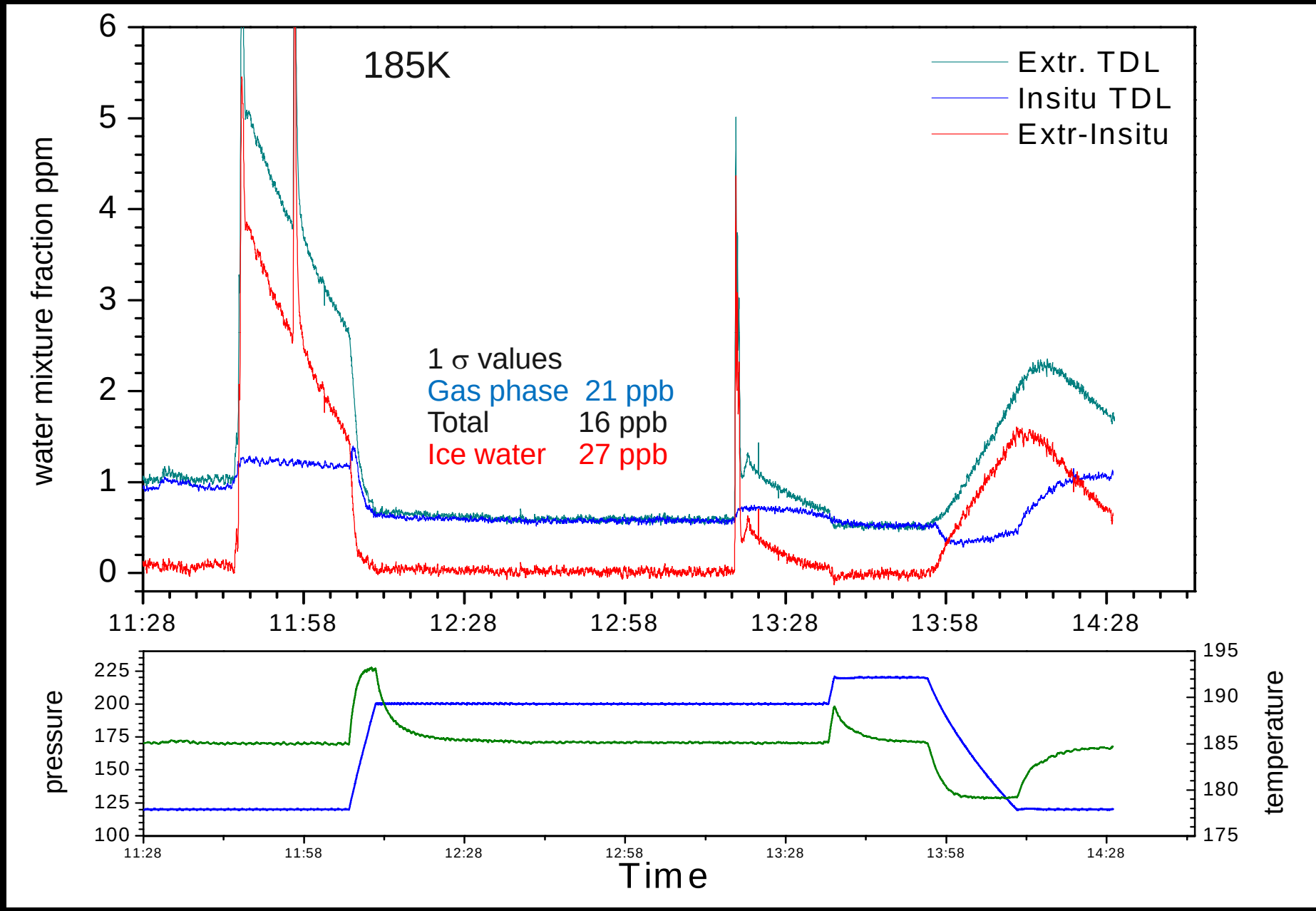
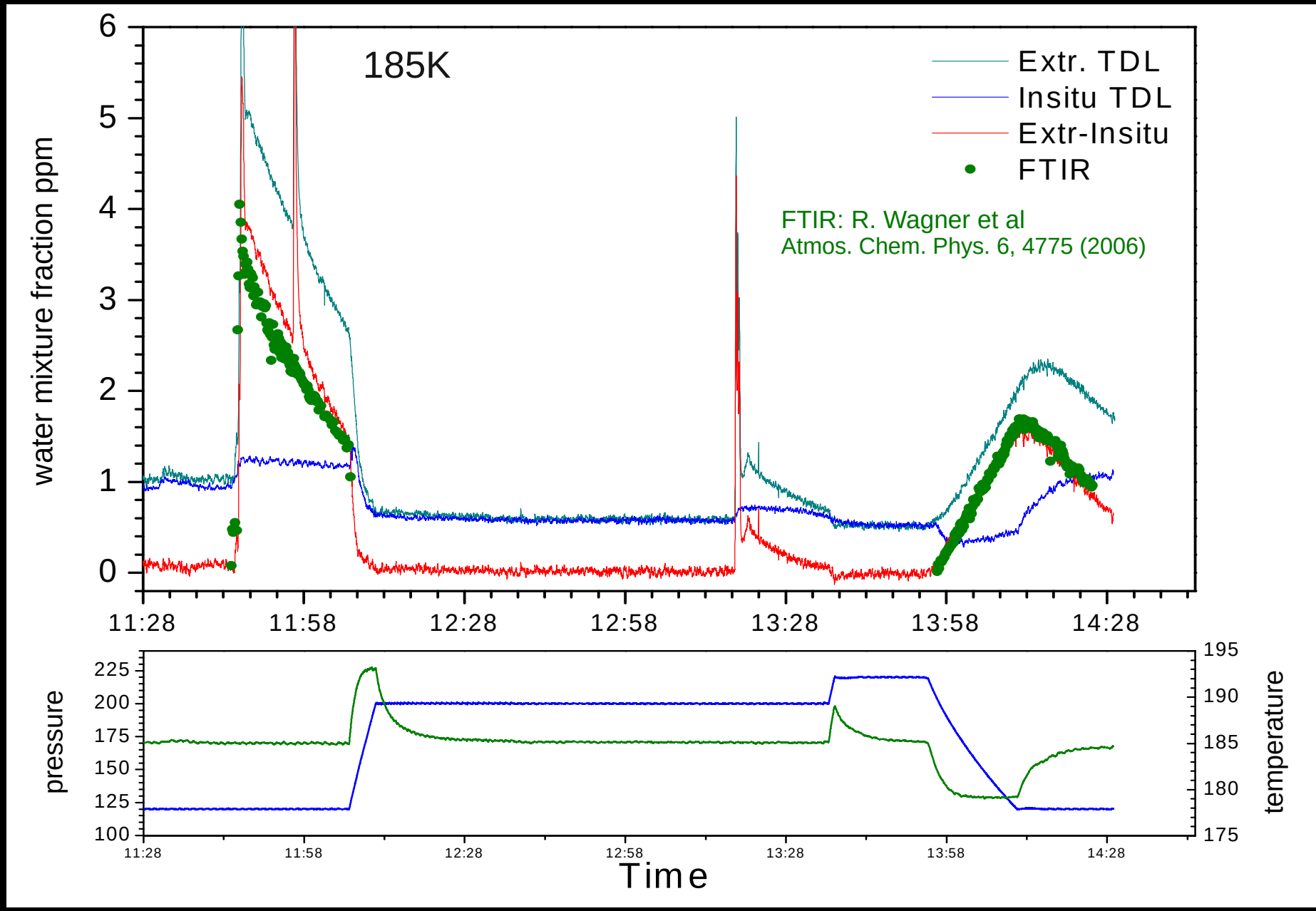
Low Humidity Results

PCI



Low Humidity Results



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Extr.-TDL vs MBW

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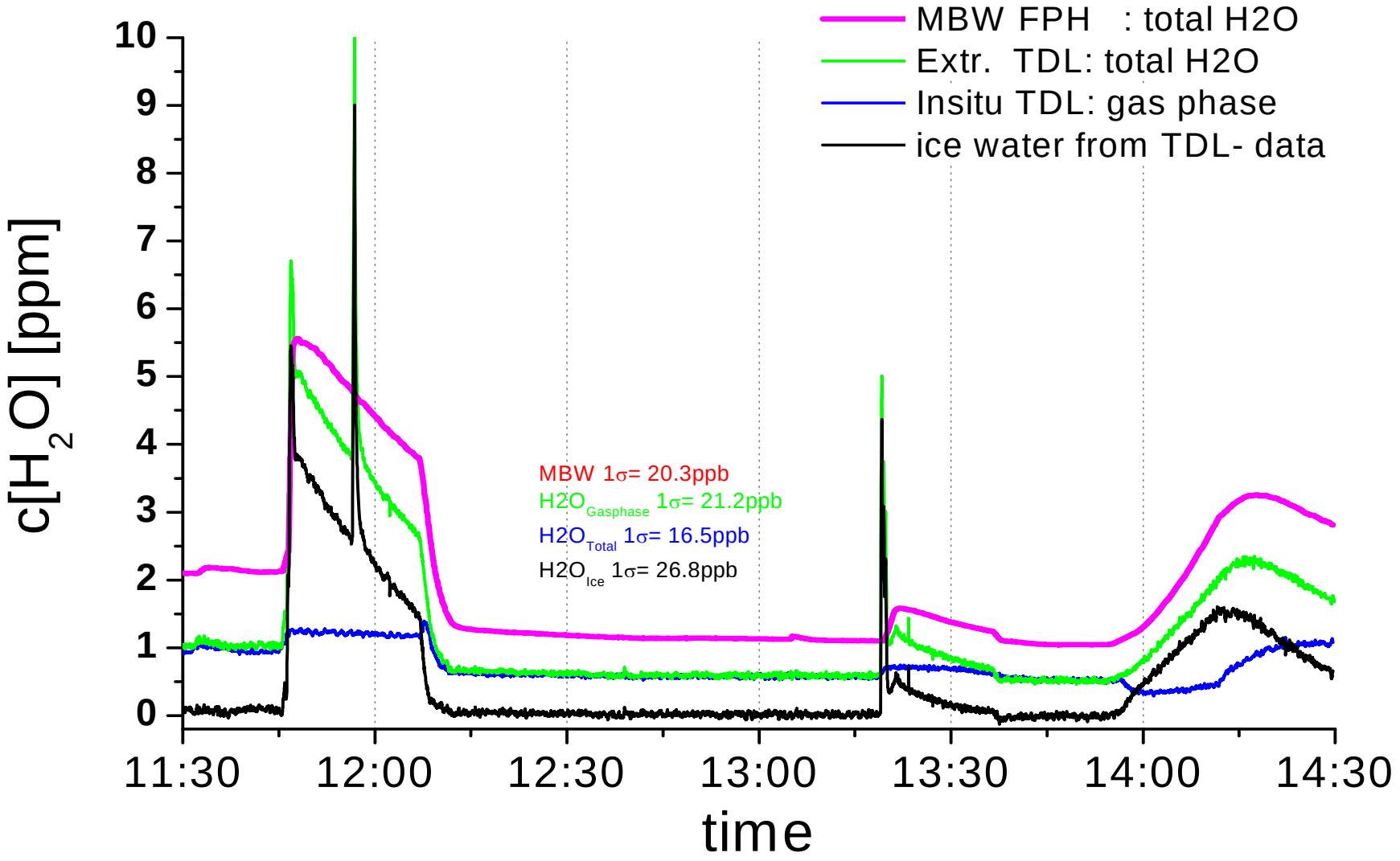

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Conclusion

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- Gas phase water (inside AIDA chamber):
  - ⇨ A) fiber-coupled open path White cell (100m / λ= 1.4µm)
    ⇒ Δ H_2O ≈ 10ppb ; max H_2O ≈ 100ppm
  - ⇨ B) fiber-coupled open single-path (4m / λ= 1.3µm)
    ⇒ Δ H_2O ≈ 20ppm ; max H_2O ≈ 20.000ppm
- Total water (extractive measurement):
  - ⇨ C) fiber-coupled closed Herriott cell (30m / λ= 1.4µm)
    ⇒ Δ H_2O ≈ 90 ppb (-> 30ppb); max H_2O ≈ 300ppm
  - ⇨ D) fiber-coupled closed single-path cell (0.1m / λ= 1.4µm)
    ⇒ Δ H_2O ≈ 10ppm ; max H_2O ≈ 30.000ppm

- Simultaneous absolute detection of *gas phase and total water (0.1 -500ppm)*
- TDLAS based, absolute *ice water detection (0.1 -500ppm)*
- Ice water validiation by FTIR (10% level)
- Rigid tests during international intercomparison (AQUAVIT)