ICOS | Atmosphere Thematic Centre

Document reference: ATC-ML-TW-RP-18

ICOS ATC Metrology Laboratory Evaluation report for the LICOR LI-7810 instrument

Tests by L. Lienhardt
Approved by O. Laurent
Date: 2020-06-10

Document history

Version	Date	Actions
1.0	2020-06-10	Creation

Diffusion

☐ ATC internal

☐ ICOS community

☒ Public

Repository

☐ Alfresco in Library/Documents/Common/ICOS-RI/ATC/MetrologyLab/Reports

☐ ICOS ATC website: https://icos-atc.lsce.ipsl.fr/docs

Disclaimer

Contents

1 Instrument references

Owner	Reception Date	Departure date
LICOR	2019-09-23	2019-12-10

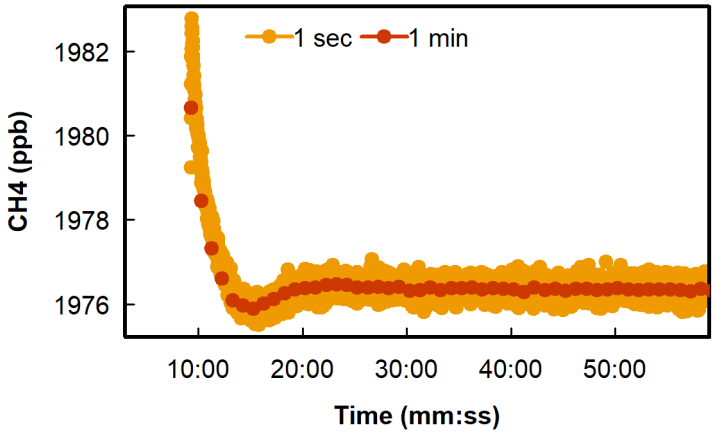
Brand	Model	S/N	Software release version
LICOR	LI-7810	TG10-01102	

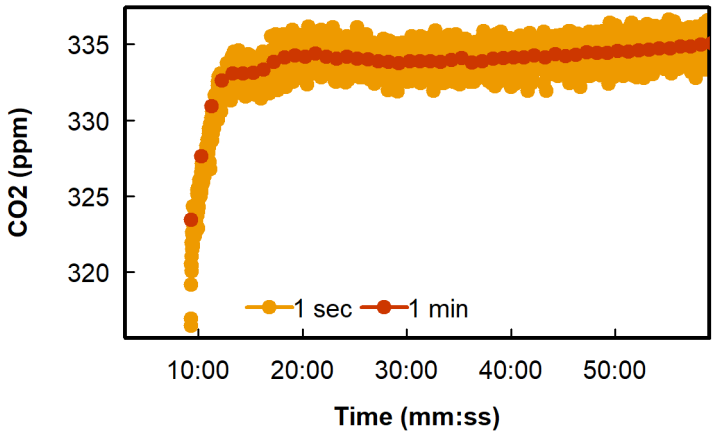
ID	Associated documents	Reference	Date
AD1	Procedure of initial tests	ATC-ML-IT-PR-02-2.0	2016-10-14
AD2	ICOS atmospheric station specifications	ATC-GN-GN-SP-1.3	2017-11
AD3	Incoming control sheet	ATC-ML-IT-IC-04	
AD4	Follow-up sheet	ATC-ML-IT-FS-09	2019-12-02

In the following pages, we present the results of the tests performed at the ATC MLab. For more details about these tests, please refer to the procedure of initial tests [AD1]. For each test, we either show the results not corrected for the water vapor (w, e.g. CO_2w) or corrected for the water vapor using the factory correction or the ATC correction (d, e.g. CO_2d). Except for the temperature test, the laboratory temperature is regulated at 22°C ± 2.

2 Initialization Time

Methodology: Measure continuously a tank filled with dry natural air after 1 hour of shutdown. No calibration applied. No rejected data. Target gas measured right after turning the instrument on.



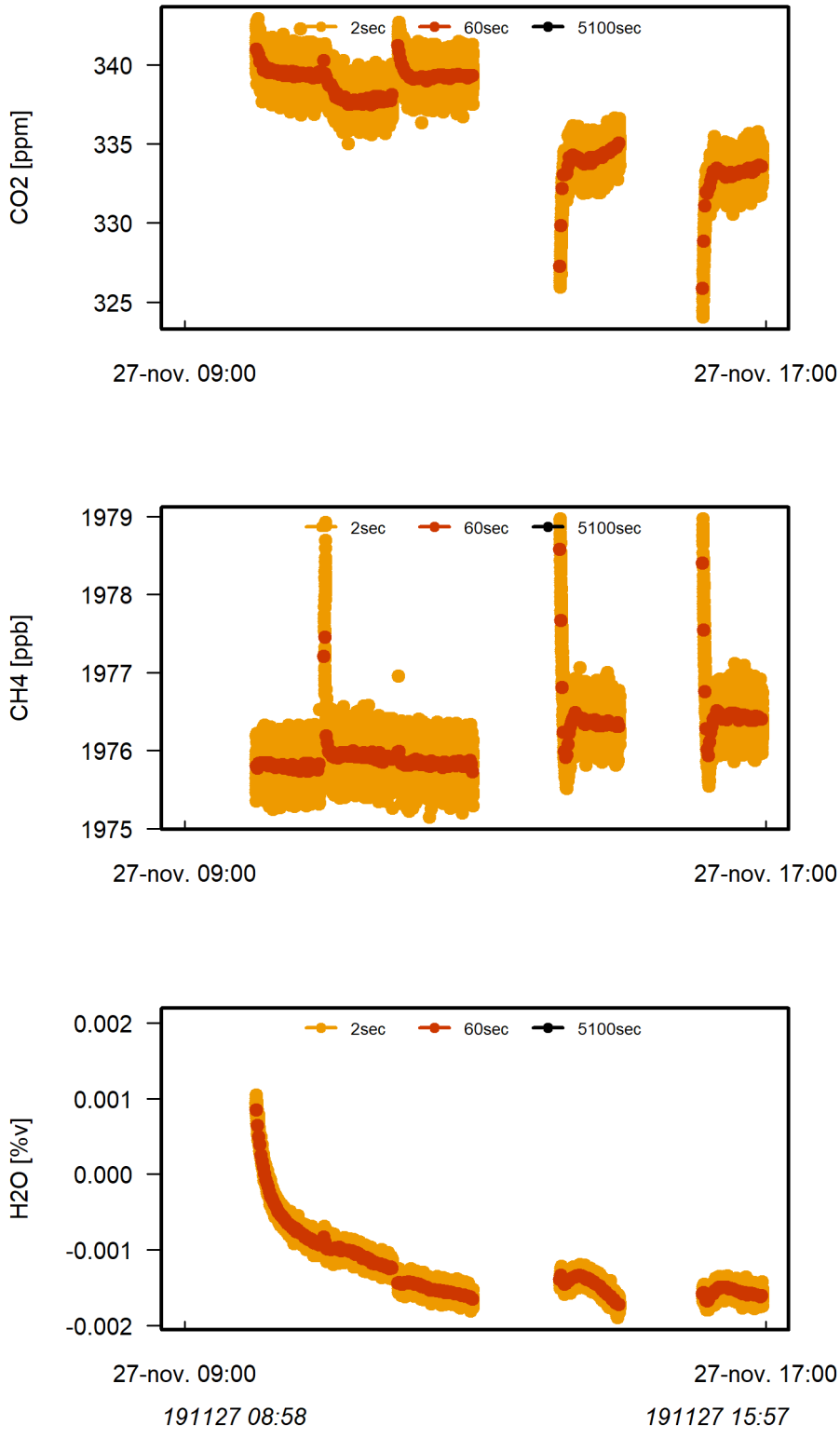


	CO2 (min)	CH4 (min)
Initialization time	20	20

3 Warm restart

Methodology: Measure continuously a tank filled with dry natural air after several restart. No calibration applied. No rejected data. Target gas measured right after turning the instrument on.

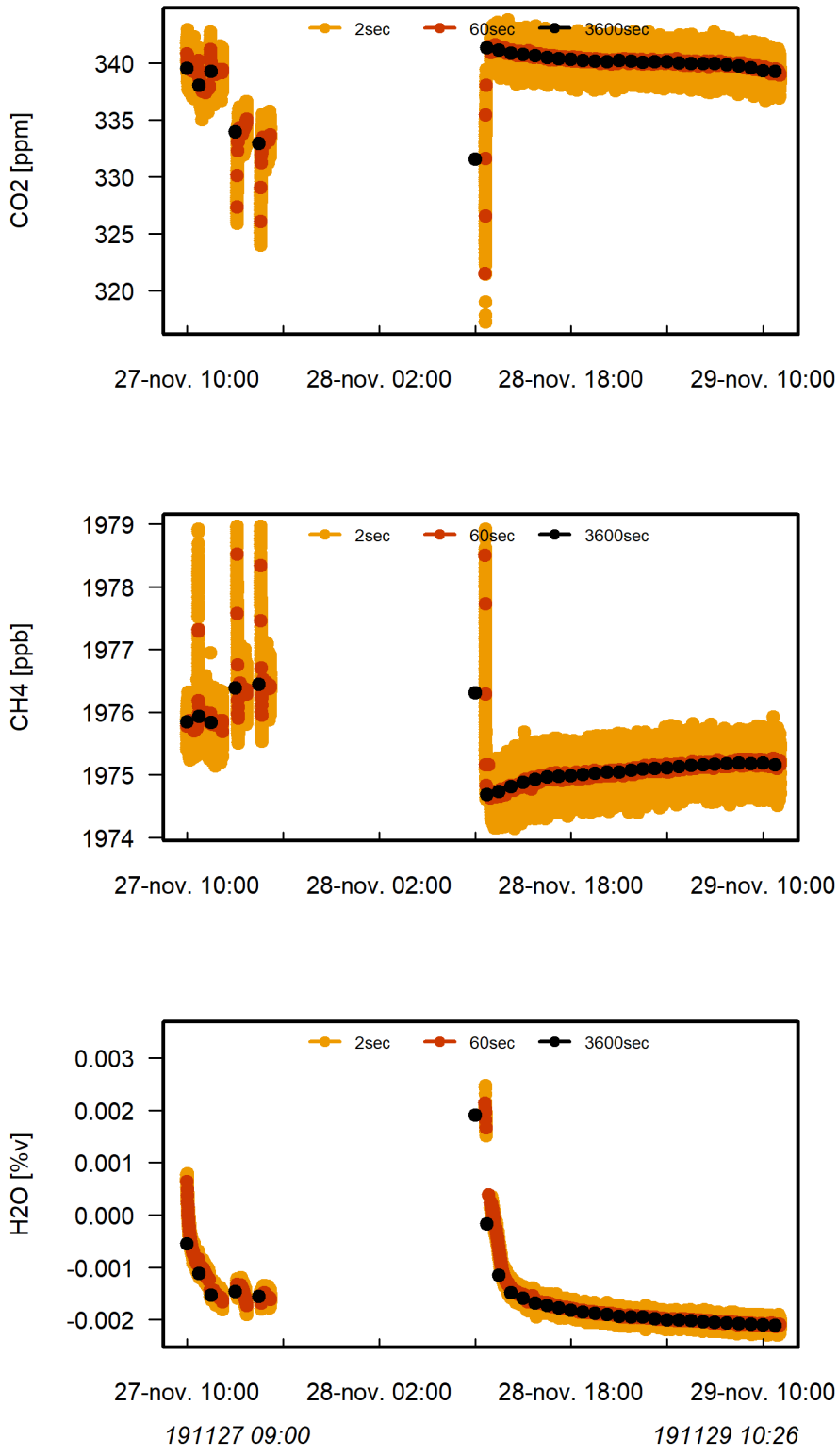
1 minute off then 1 hour on (3 times) ; 1 hour off then 1 hour on (2 times)



	CO2 [ppb]	CH4 [ppb]
Maximum offset between two successive restarts	6300	0.5

4 Cold restart

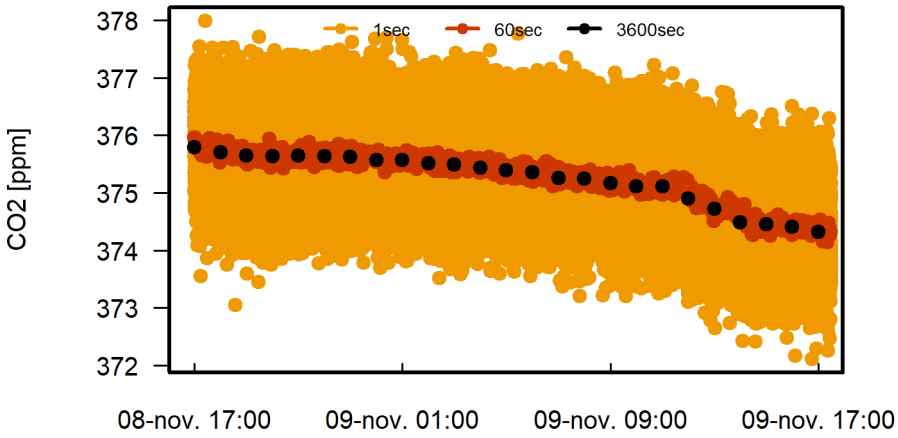
Methodology: Measure continuously a tank filled with dry natural air after 15 hours of shutdown. No calibration applied. No rejected data. Target gas measured right after turning the instrument on.

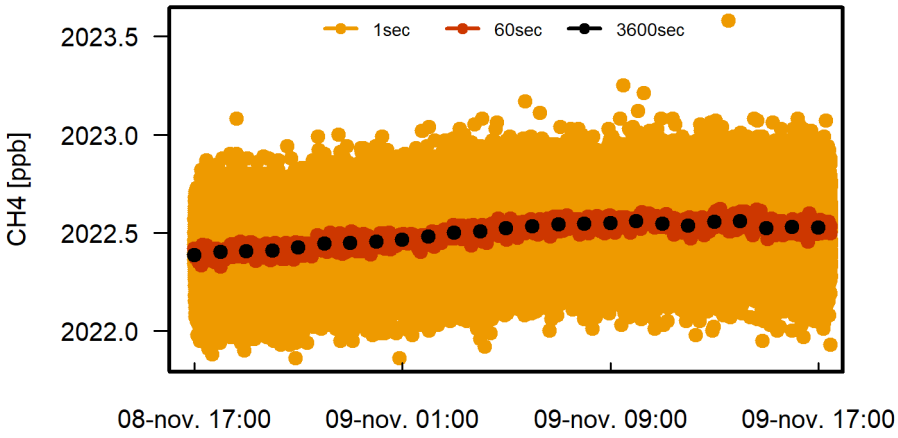


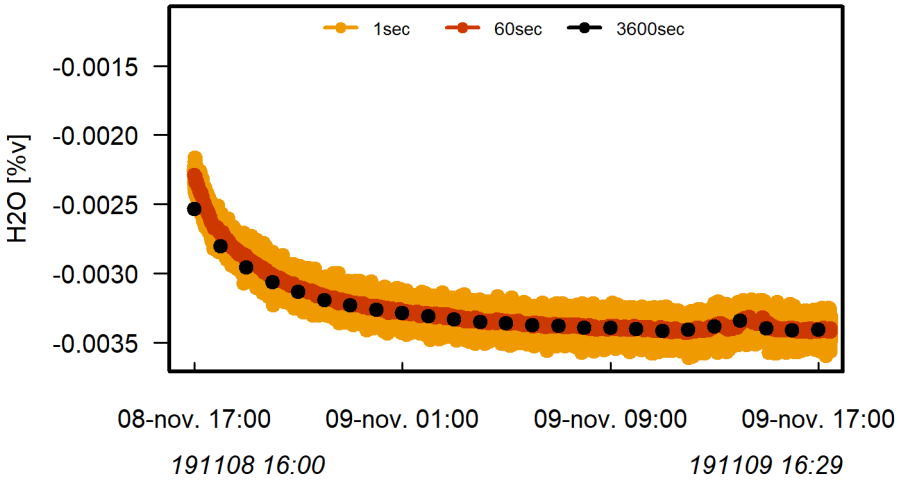
	CO2 [ppb]	CH4 [ppb]
Maximum offset between two successive restarts	7300	1.7

5 Continuous Measurement Repeatability (CMR) assessment

Methodology: Measure continuously a tank filled with dry natural air during at least 25 hours. Look at data distribution for different integration times. First hour not taken into account (stabilization time). No calibration applied.



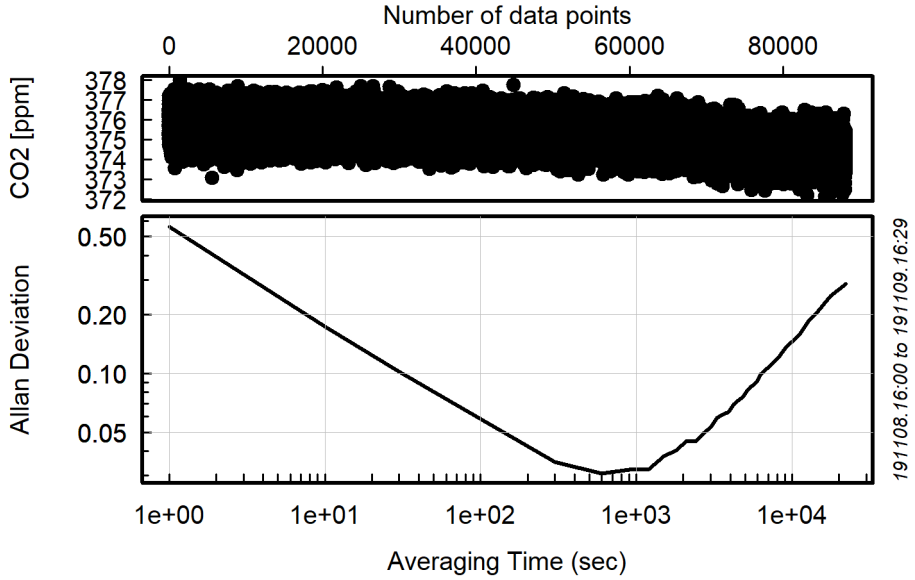


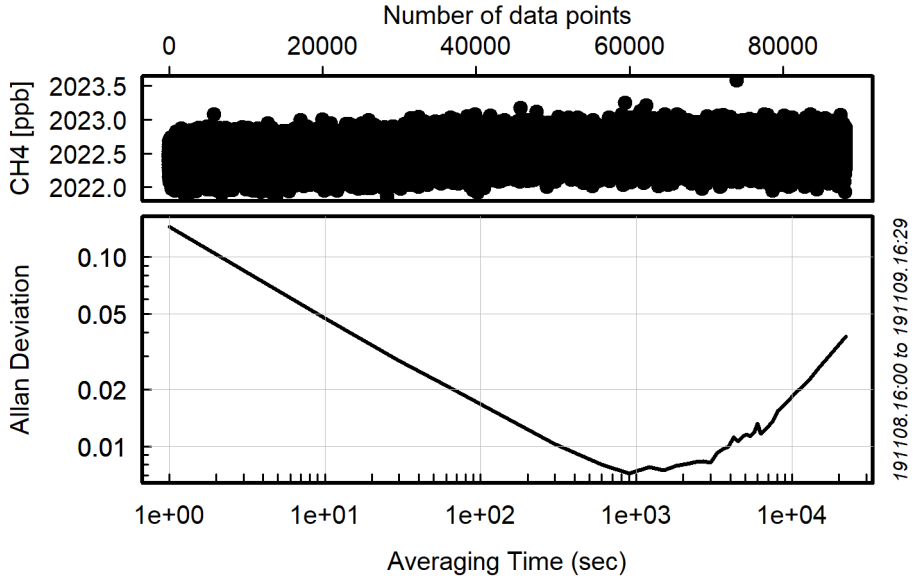


	CO2 [ppb]	CH4 [ppb]	H2O [%v]
Average of the standard deviations of raw data over a minute	556	0.14	0.0000
Minute averaged data CMR Precision (1σ)	433	0.06	0.0002
Hourly averaged data CMR Precision (1σ)	451	0.06	0.0002
Minute averaged data CMR MaxDrift (peak to peak)	1817	0.30	0.0011
Hourly averaged data CMR MaxDrift (peak to peak)	1469	0.17	0.0009

6 Short term stability and drift assessment

Methodology: Measure continuously a tank filled with dry natural air during at least 25 hours. Calculate Allan deviations. First hour not taken into account (stabilization time). No calibration applied.



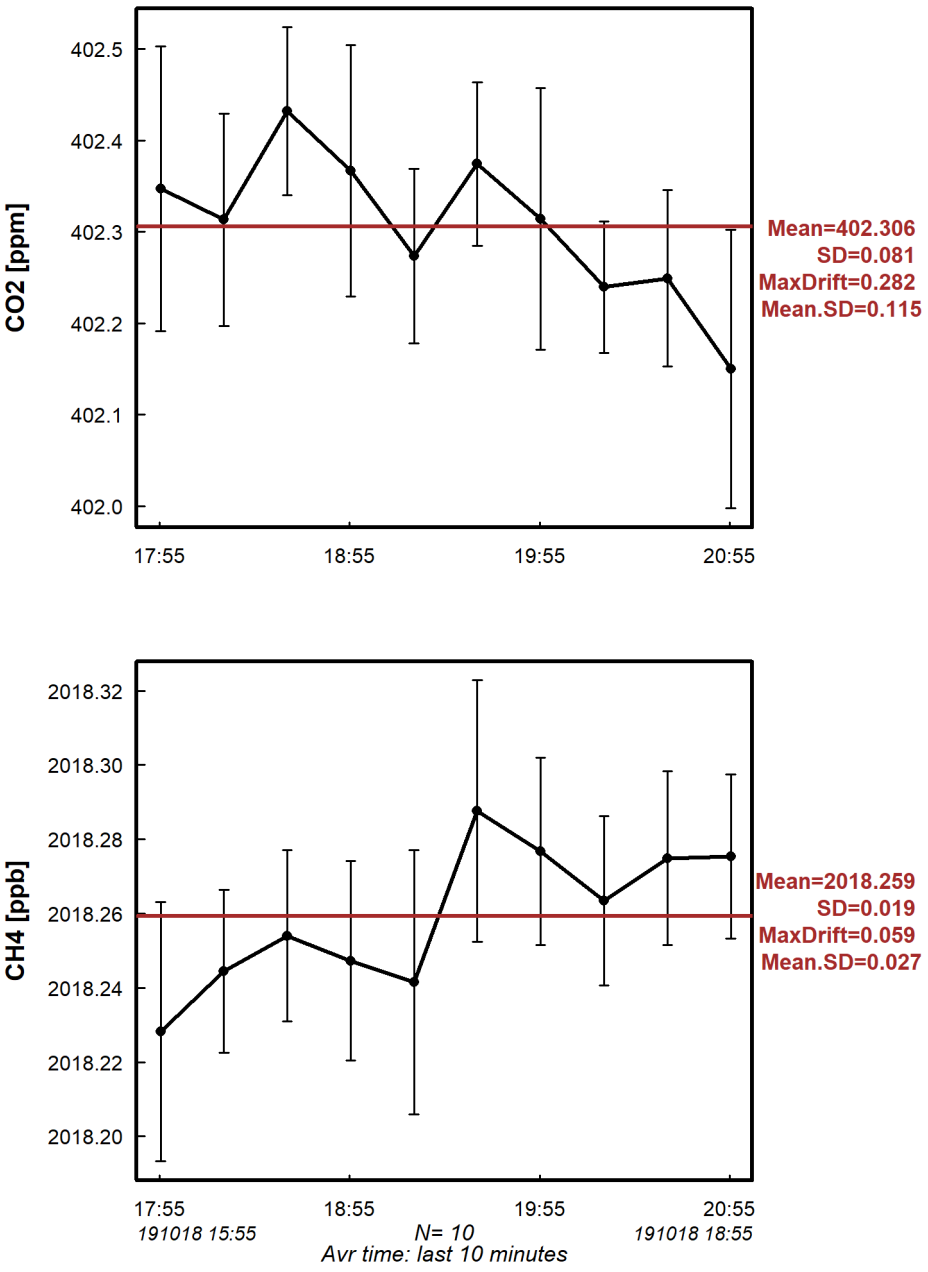


	CO2	CH4
Optimum Averaging time (s)*	600	900
Optimum Allan deviation [ppb]*	31	0.01
Allan deviation at 1 min [ppb]	74	0.02
Allan deviation at 5 min [ppb]	35	0.01
Allan deviation at 10 min [ppb]	31	0.01
Allan deviation at 15 min [ppb]	32	0.01
Allan Deviation at 1 hr [ppb]	62	0.01

* The optimum is searched in the first one hour window.

7 Short Term Repeatability (STR) assessment

Methodology: Measure a tank filled with dry natural air for 15 min and wet ambient air for 5 minutes alternatively 10 times. For each period of tank measurement, calculate a mean value (discard the first mintues for stabilization). Look at the dispersion (1σ) of the mean values (10 points). No calibration applied.

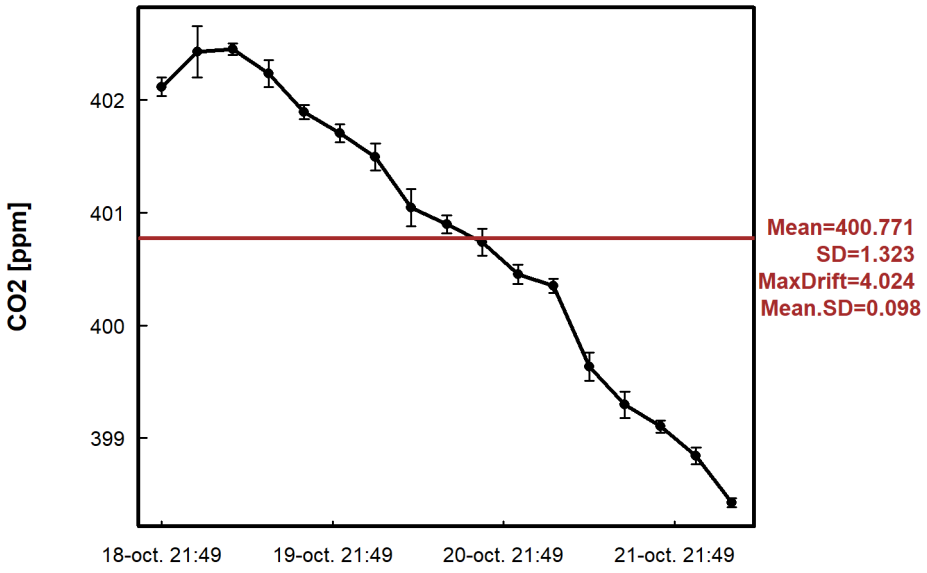


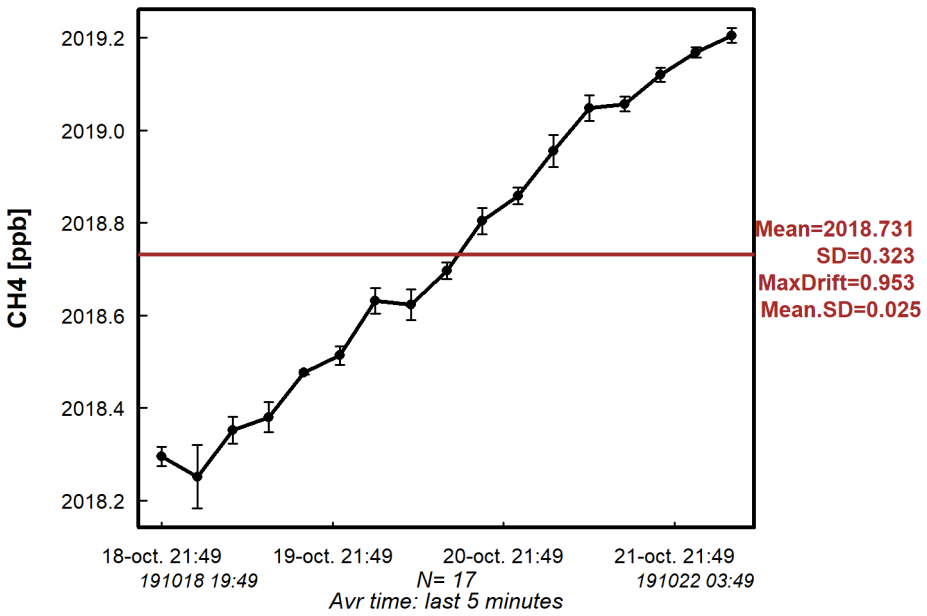
	CO2 [ppb]	CH4 [ppb]
Short term repeatability (1σ, 9 minute average raw data)	81	0.02
MaxDrift (peak to peak, 9 minute average raw data)	282	0.06

8 Long Term Repeatability (LTR) assessment

Methodology: Measure alternatively over 72 hours a tank filled with dry natural air for 30 minutes and 270 minutes of wet ambient air. For each period of tank measurement, calculate a mean value (discard the first mintues for stabilization). Look at the dispersion ($1\ \sigma$) of the mean values. No calibration applied.

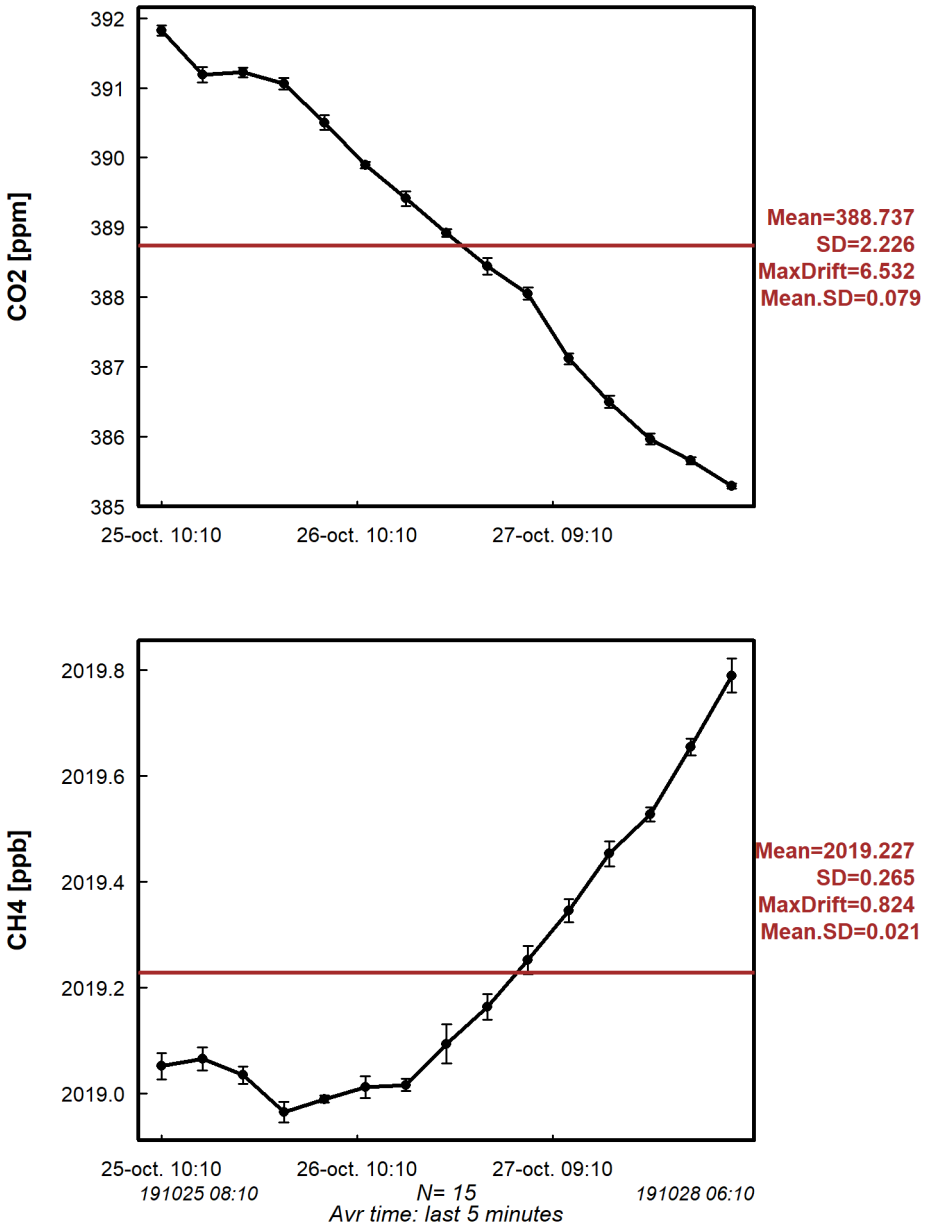
8.1 First period





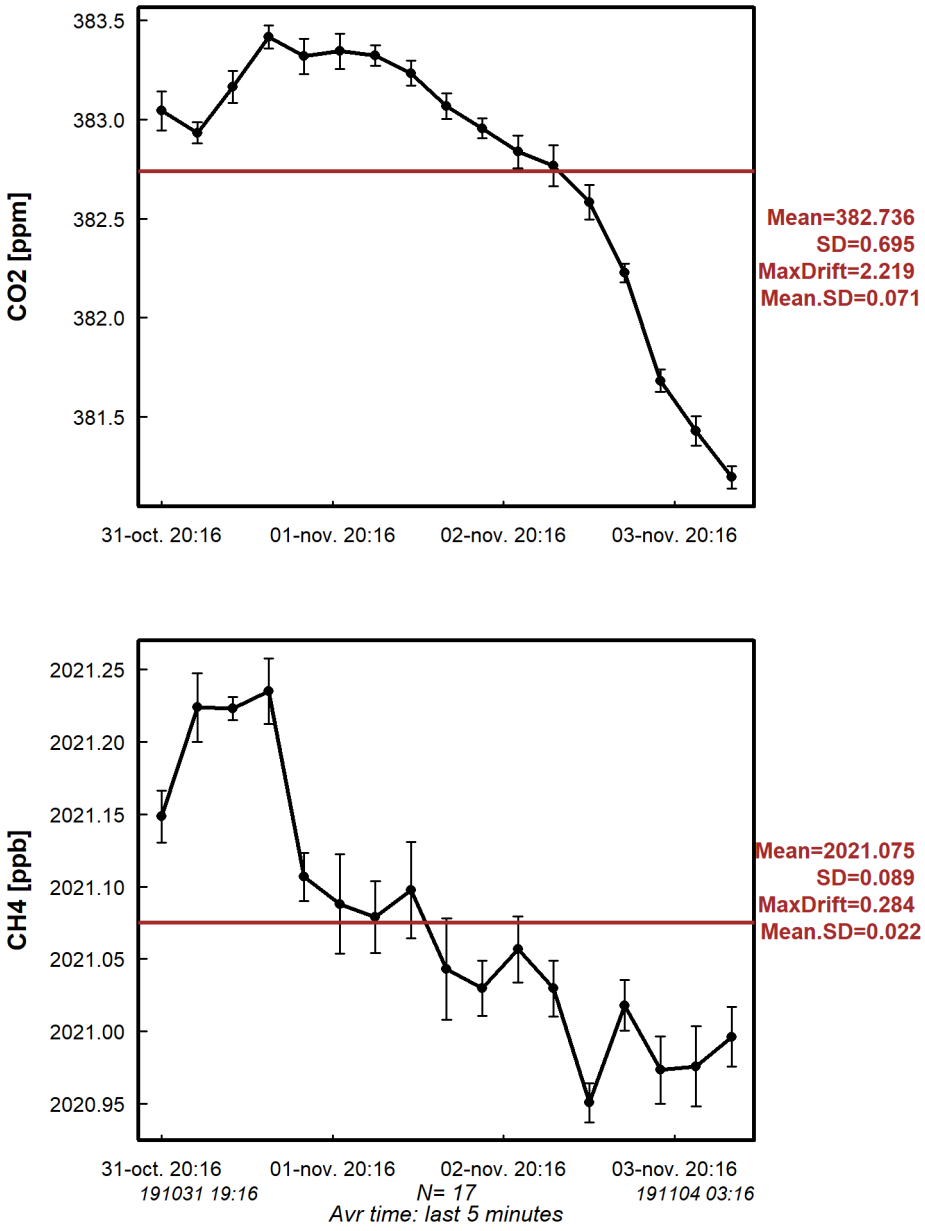
	CO2 [ppb]	CH4 [ppb]
Long term repeatability (1σ, 10 minute average raw data)	1323	0.32
MaxDrift (peak to peak, 10 minute average raw data)	4024	0.95

8.2 Second period



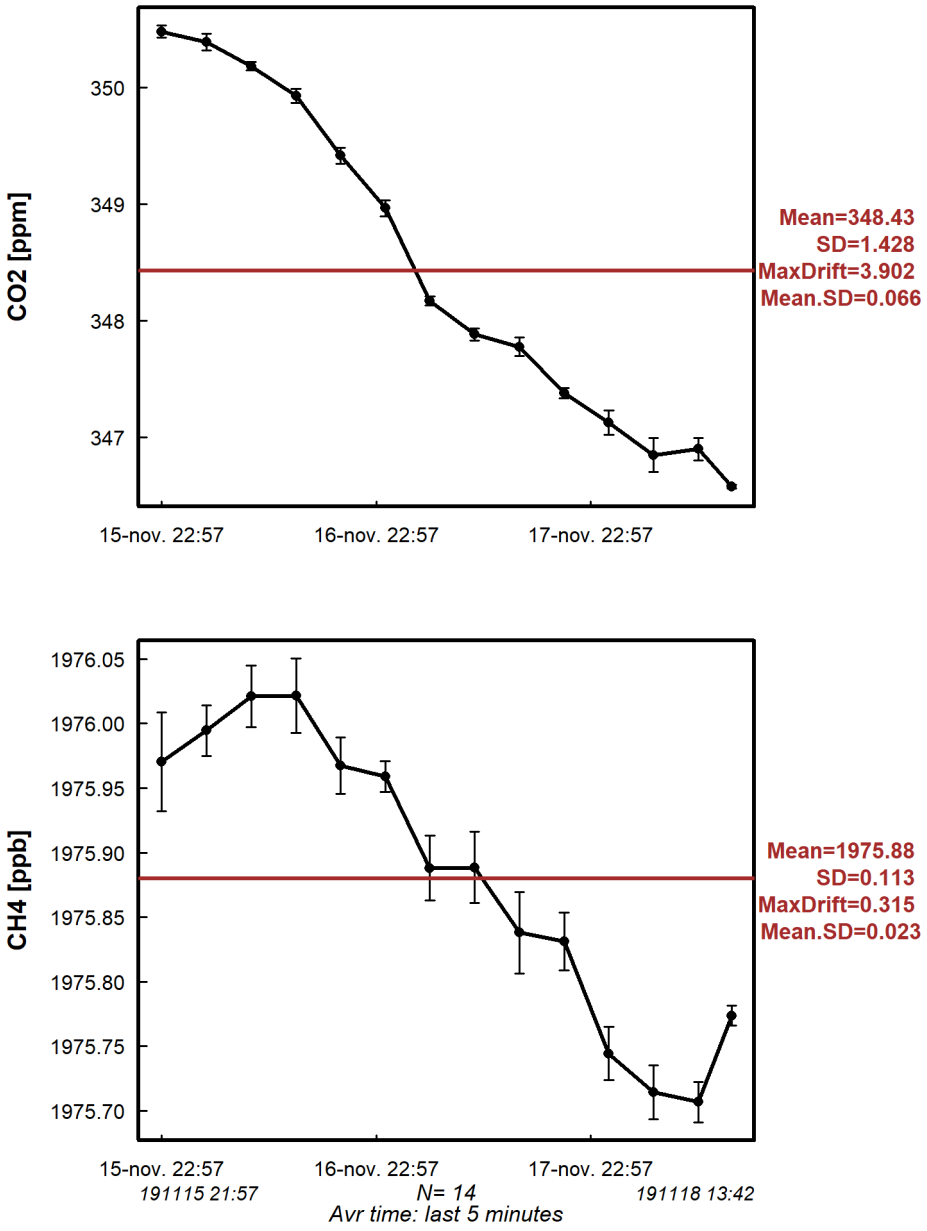
	CO2 [ppb]	CH4 [ppb]
Long term repeatability (1σ, 10 minute average raw data)	2226	0.26
MaxDrift (peak to peak, 10 minute average raw data)	6532	0.82

8.3 Third period



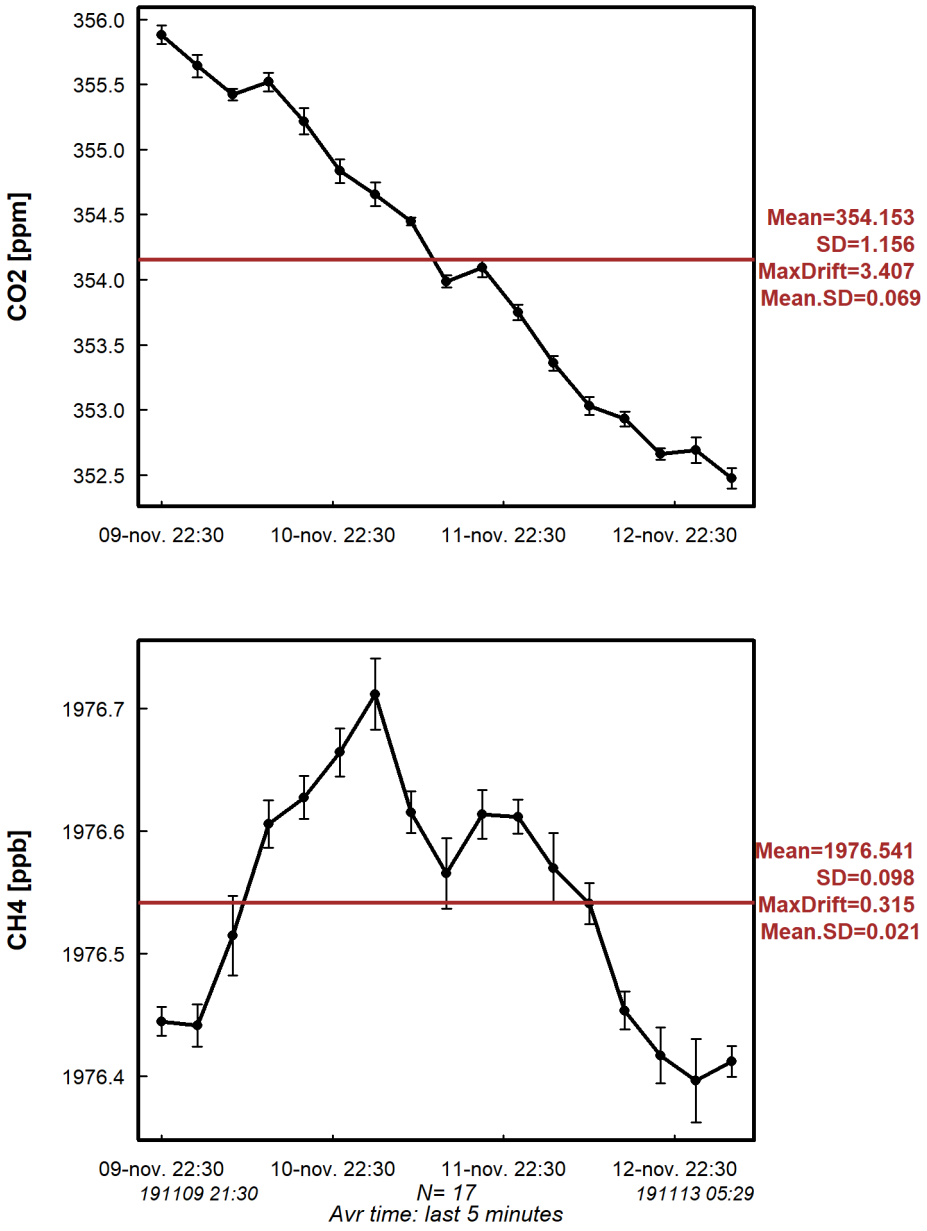
	CO2 [ppb]	CH4 [ppb]
Long term repeatability (1σ, 10 minute average raw data)	695	0.09
MaxDrift (peak to peak, 10 minute average raw data)	2219	0.28

8.4 Fourth period



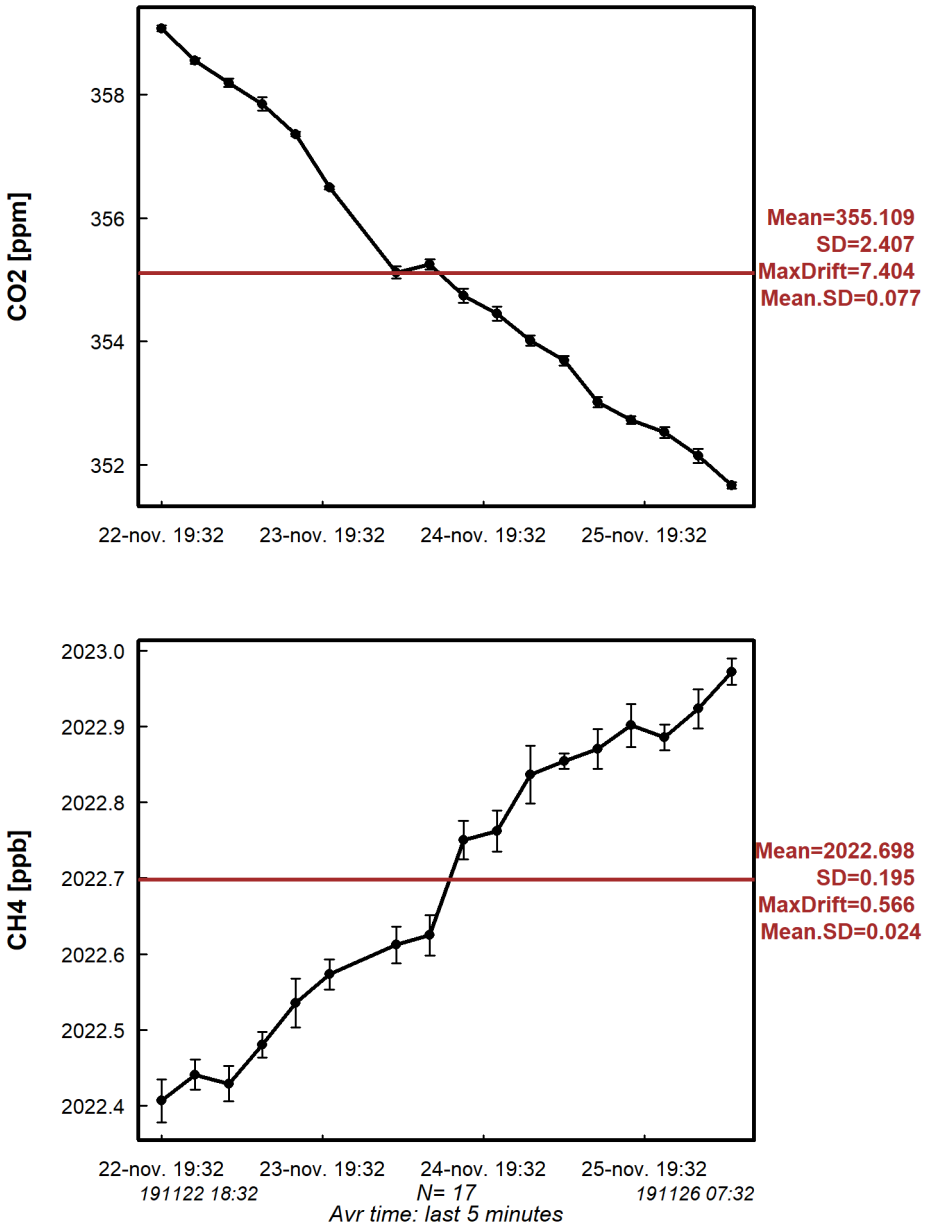
	CO2 [ppb]	CH4 [ppb]
Long term repeatability (1σ, 10 minute average raw data)	1428	0.11
MaxDrift (peak to peak, 10 minute average raw data)	3902	0.32

8.5 Fifth period



	CO2 [ppb]	CH4 [ppb]
Long term repeatability (1σ, 10 minute average raw data)	1156	0.10
MaxDrift (peak to peak, 10 minute average raw data)	3407	0.32

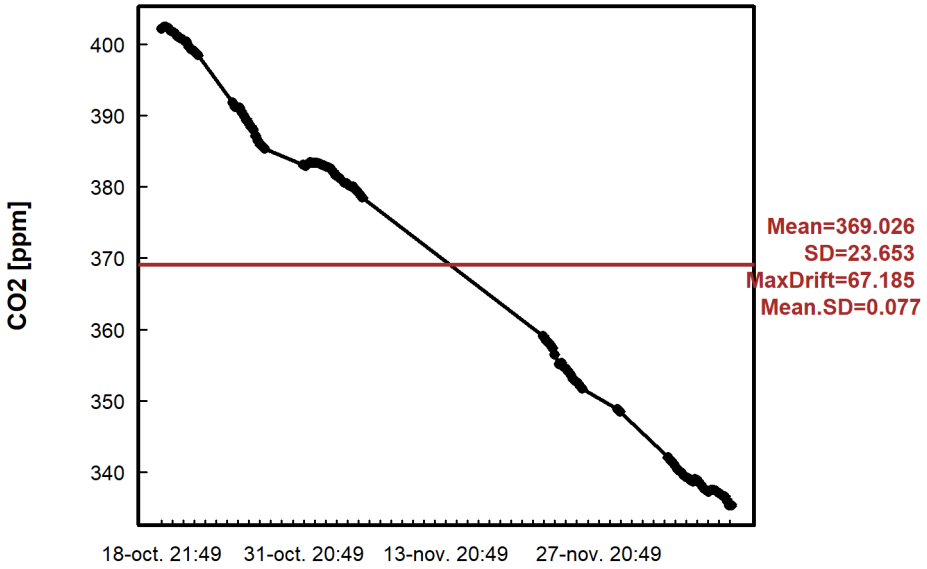
8.6 Sixth period

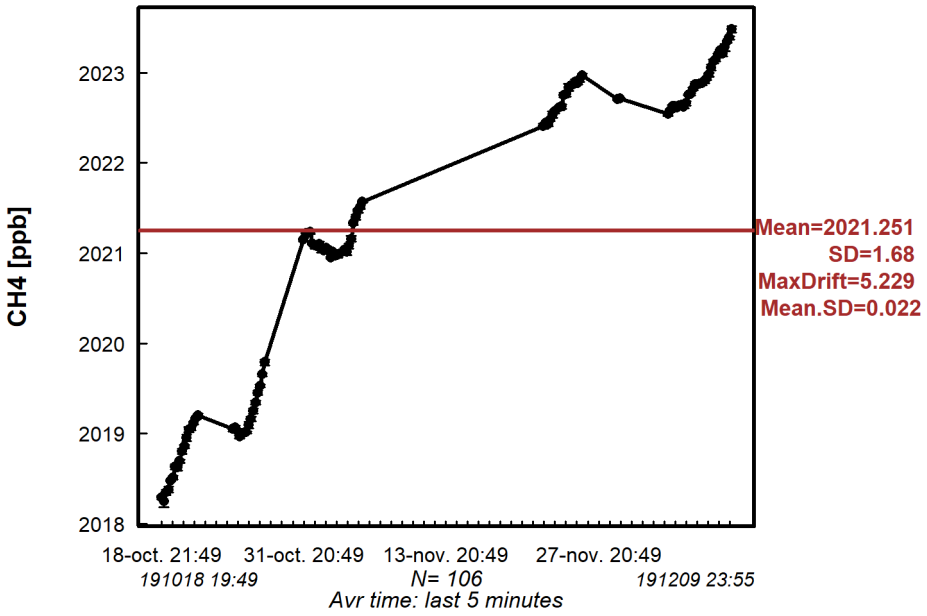


	CO2 [ppb]	CH4 [ppb]
Long term repeatability (1σ, 10 minute average raw data)	2407	0.20
MaxDrift (peak to peak, 10 minute average raw data)	7404	0.57

8.7 Over all Long Term Repeatability

Restarts performed from November 27th to 28th

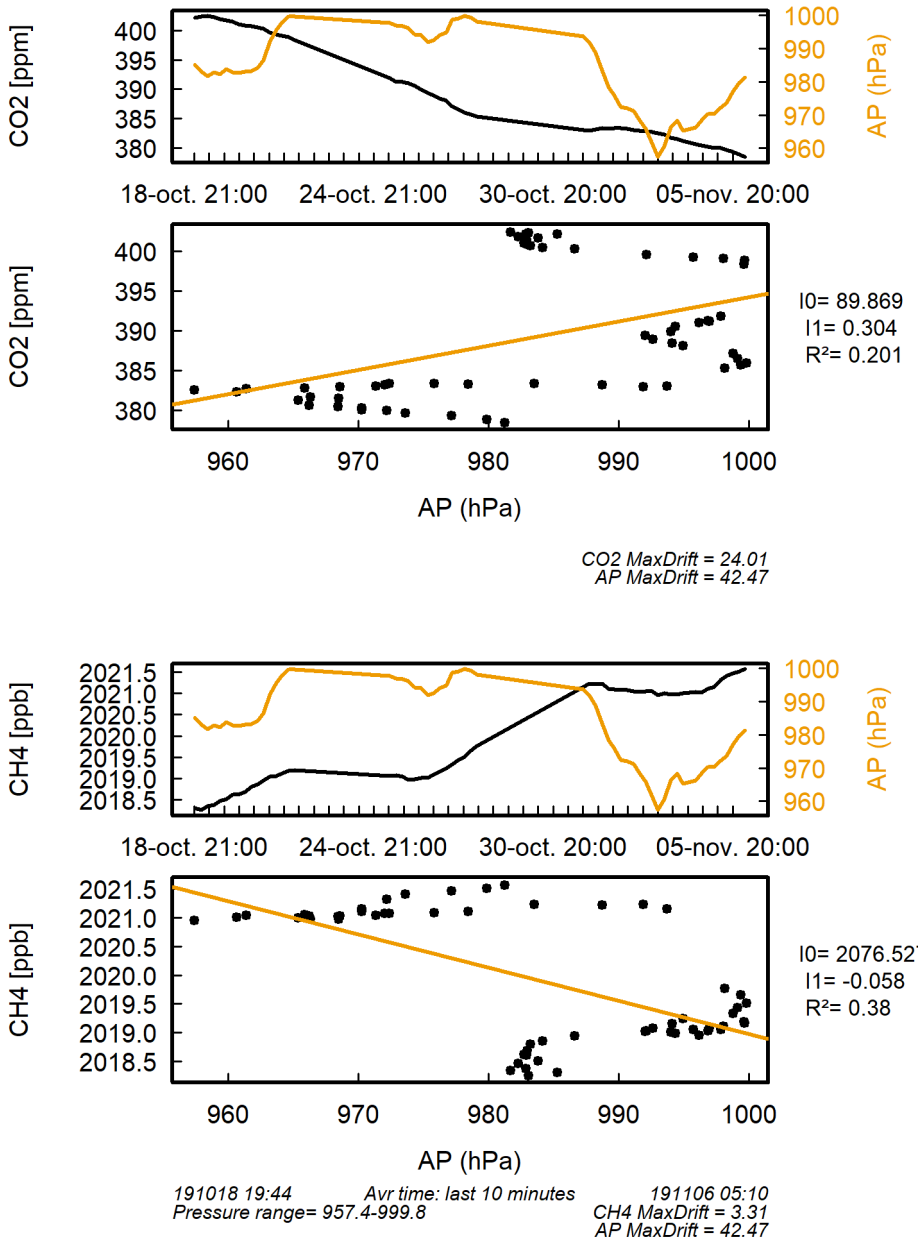




	CO2 [ppb]	CH4 [ppb]
Long term repeatability (1σ, 10 minute average raw data)	23653	1.68
MaxDrift (peak to peak, 10 minute average raw data)	67185	5.23

9 Atmospheric pressure sensitivity

Methodology: Measure alternatively over 72 hours a tank filled with dry natural air for 30 minutes and 270 minutes of wet ambient air. For each period of tank measurement, calculate a mean value (last 10 minutes) and look at the correlation of the tank measurement with atmospheric pressure (AP) variation.

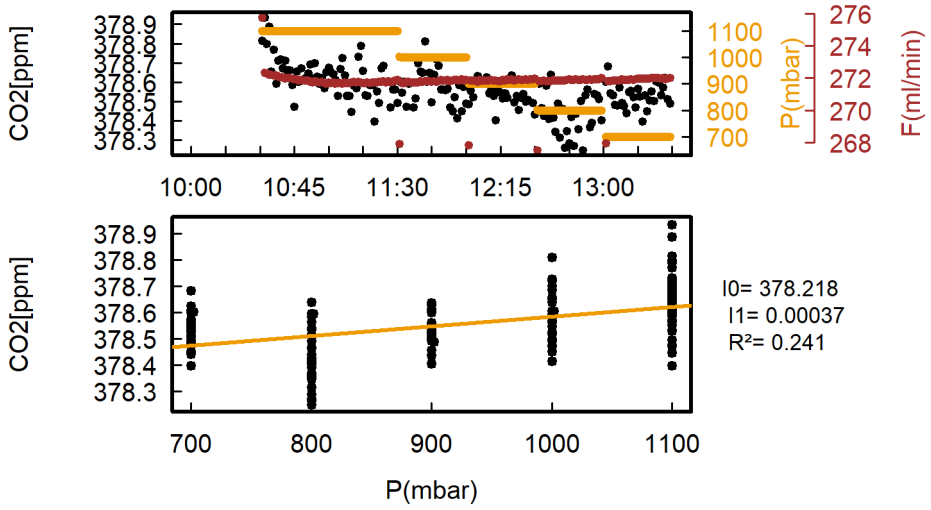


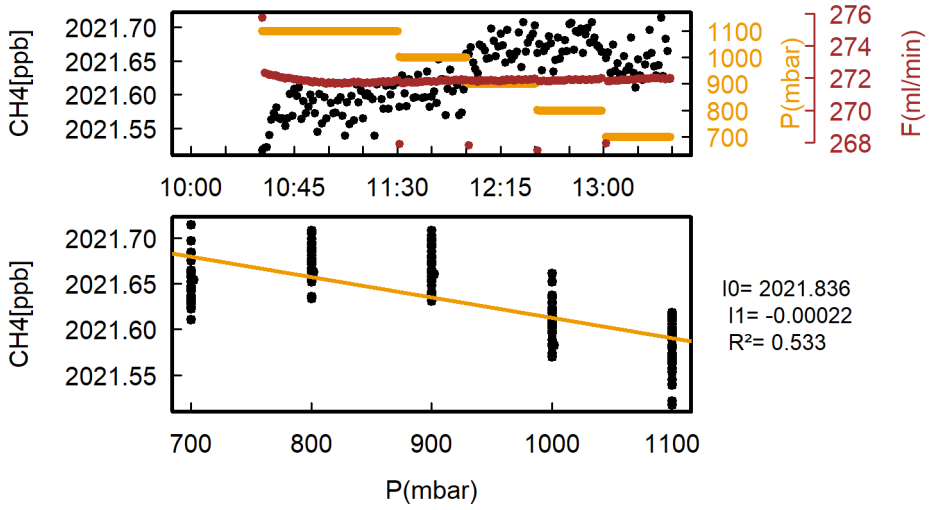
	CO2	CH4
Atmospheric pressure sensitivity (ppb/hPa)	NS	NS

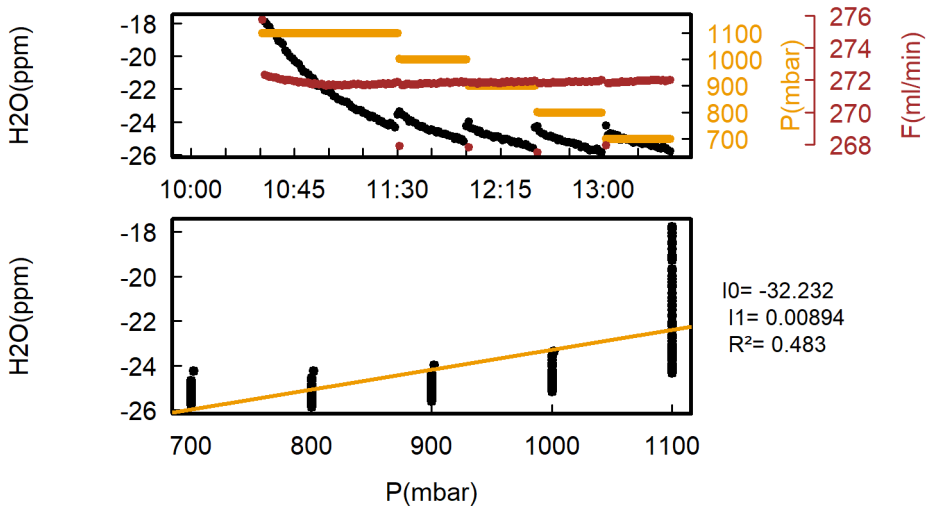
Not significant (NS) if R^2<0.5 or the absolute value of the slope lower than 1 and 0.02 for CO_2 and CH_4 respectively

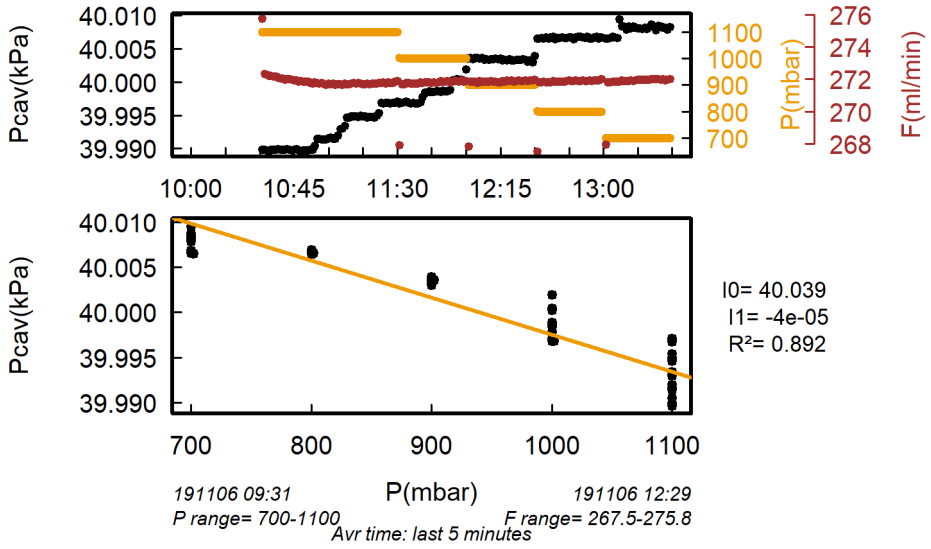
10 Inlet pressure sensitivity

Methodology: Measure continuously a tank filled with dry natural air through an electronic pressure controller at the instrument inlet. Change sequentially (step of 20 minutes) the instrument inlet pressure (maximum range from 1200 mbar absolute to 600 mbar absolute) thanks to the pressure controller. The valid range is evaluated as the range where CO_2 mixing ratios are
pm 0.02ppm from the mixing ratio at atmospheric pressure..







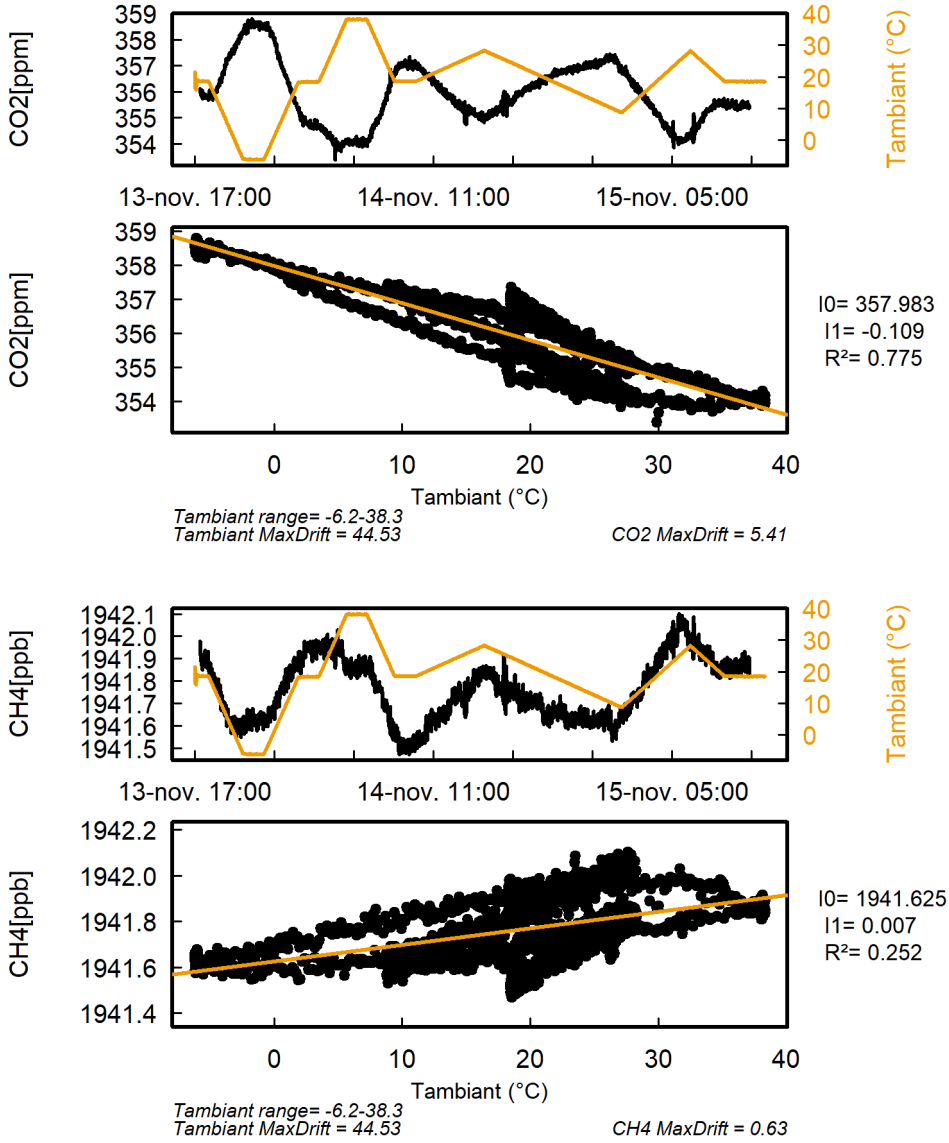


	Min	Max
Valid inlet pressure range (mbar absolute)	700	1100

11 Temperature sensitivity

Methodology: Measure a tank filled with dry natural air while changing the ambiant temperature (Tamb). Look at the correlation of the measurement stability with the instrument internal temperature (Tcav).

Drift of the CH4 measurement corrected using the target value at 20 °C at the beginning and end of the test



	CO2	CH4
Ambient temperature sensitivity (ppb/°C)	-109.241	NS

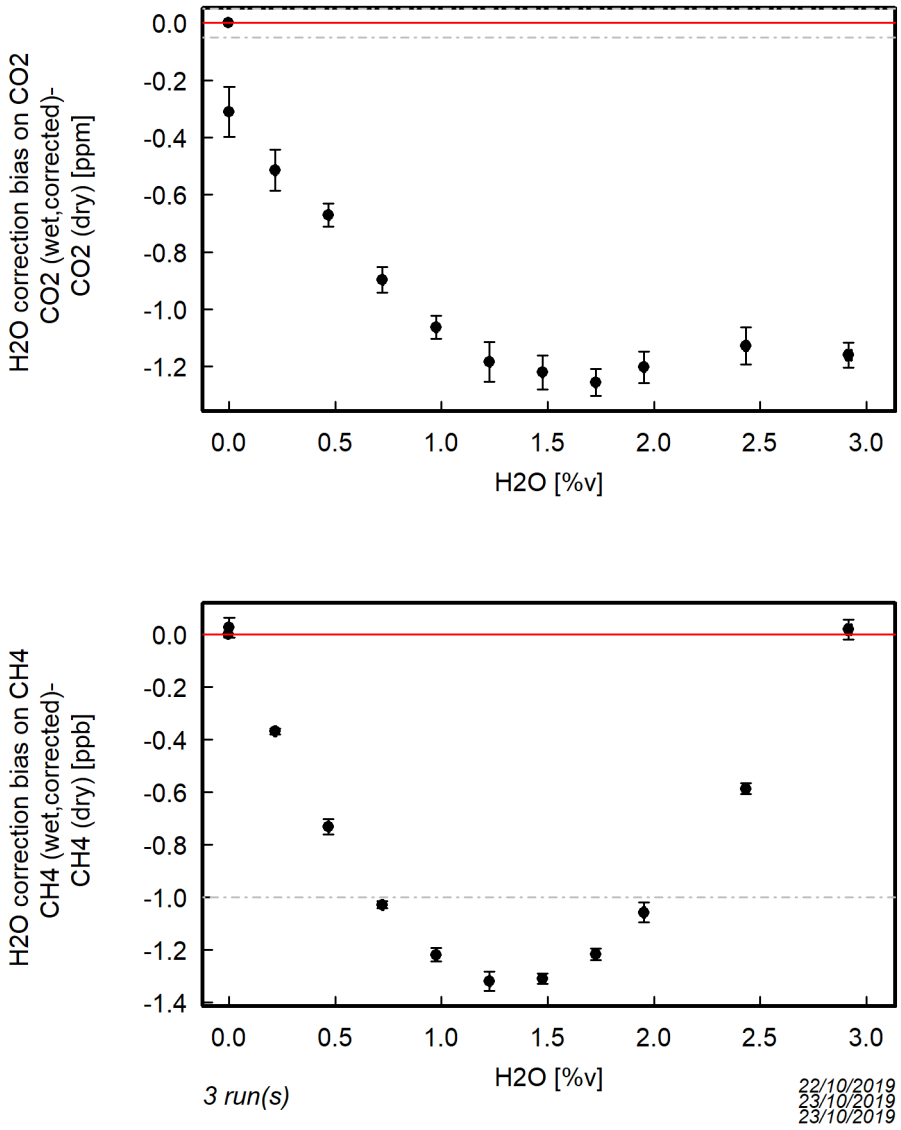
Not significant (NS) if R^2<0.45 or the absolute value of the slope lower than 5 and 0.1 ppb/°C for CO_2 and CH_4 respectively

12 Water vapor correction assessment

Methodology: Measure a tank filled with dry natural air during at least 1h. Then humidify by 20 minute steps the tank gas at 0.25/0.5/0.75/1/1.25/1.5/1.75/2/2.5/3 %v of water vapor. Finally, stop humidifying and measure the tank filled with dry natural air during more than 1 hour. Repeat the experiment at least twice, usually three times. Check the water vapor correction bias depending on the H_2O level. Determine an optimized water vapor correction bias.

$$H_2O\,correction\,bias = C_{humidifiedgas,\,water\,vapor\,corrected} - C_{not\,humidified\,gas} \quad (1)$$

12.1 Factory correction

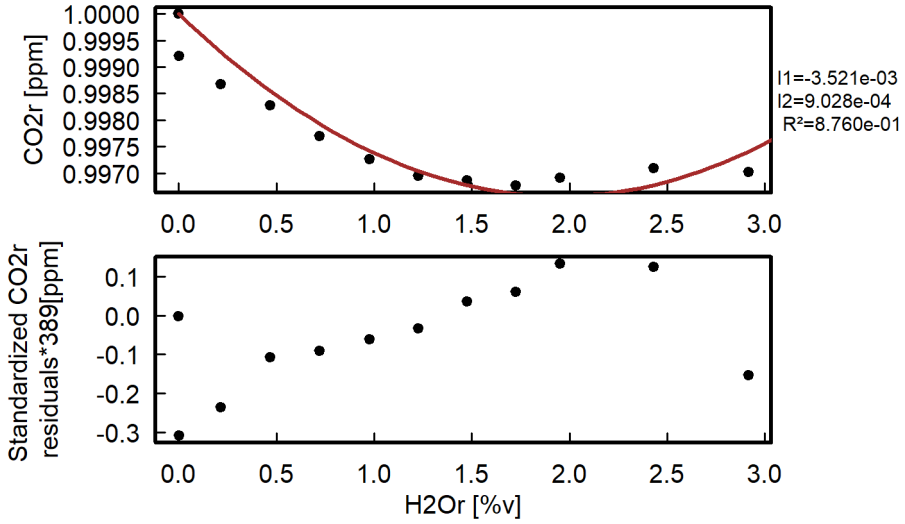


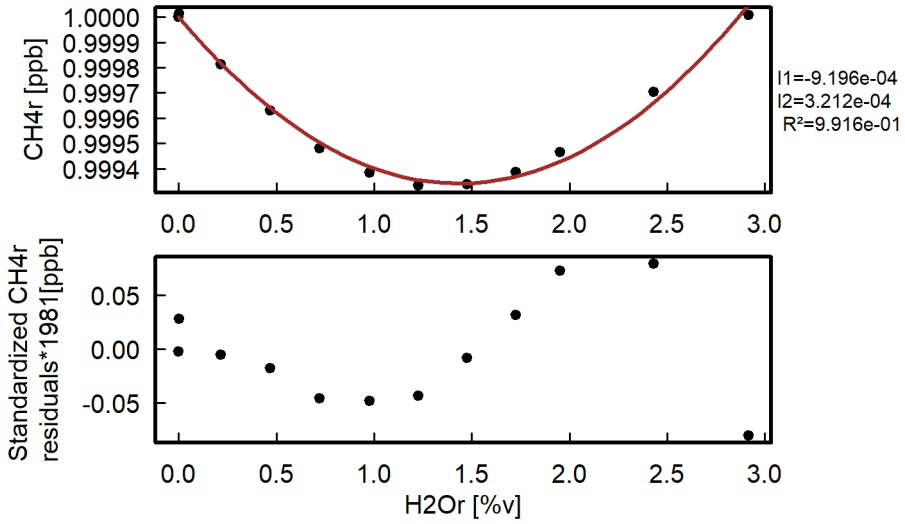
12.2 Determination of H_2O correction coefficients by the MLab

$$C_r = \frac{C_{wet}}{C_{dry}} = 1 + I_1 * H_2O_r + I_2 * H_2O_r^2 \tag{2}$$

with H_2O_r: Instrument reported value (not calibrated). The "calibrated" H_2O value is:

$$H_2O = 0.772 * H_2O_r + 0.019493 * H_2O_r^2 \tag{3}$$

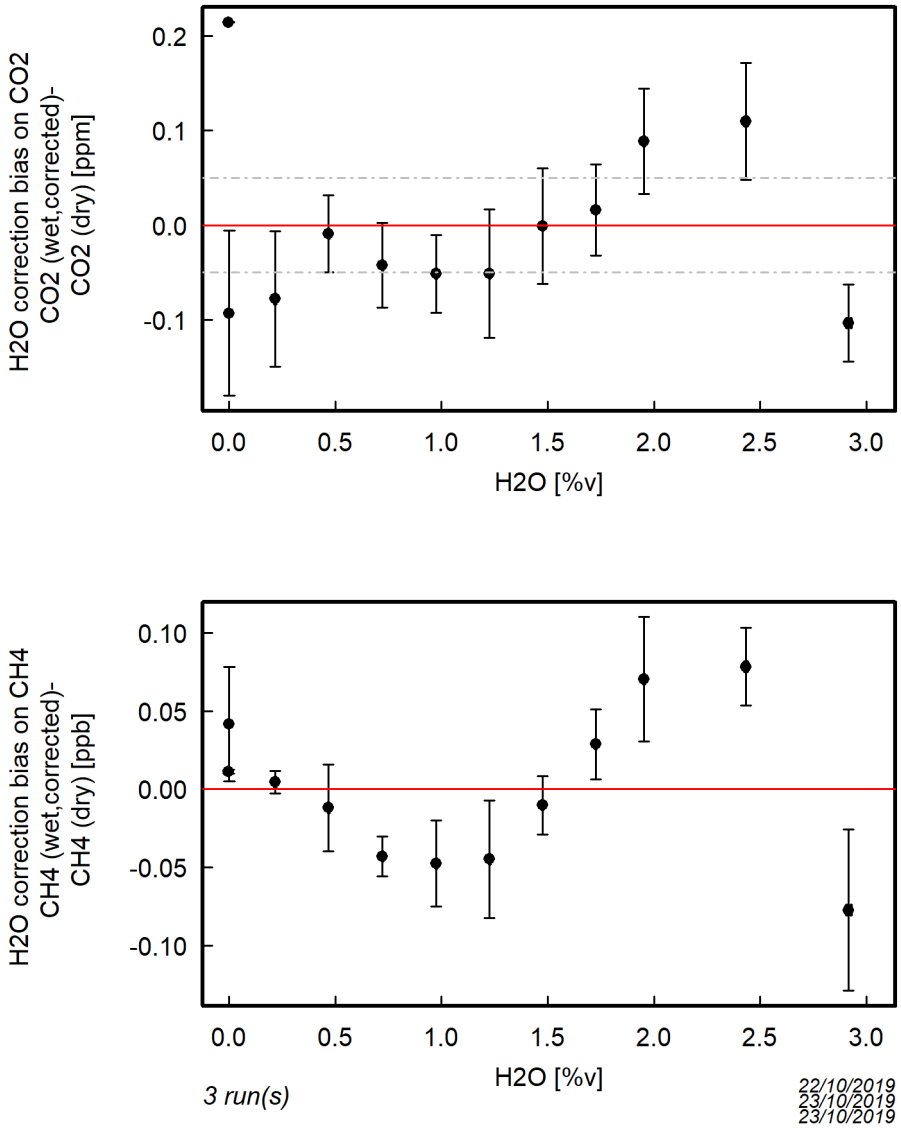




H_2O correction coefficients determined by ATC

	CO2	CH4
I1	-3.521e-03	-9.196e-04
I2	9.028e-04	3.212e-04

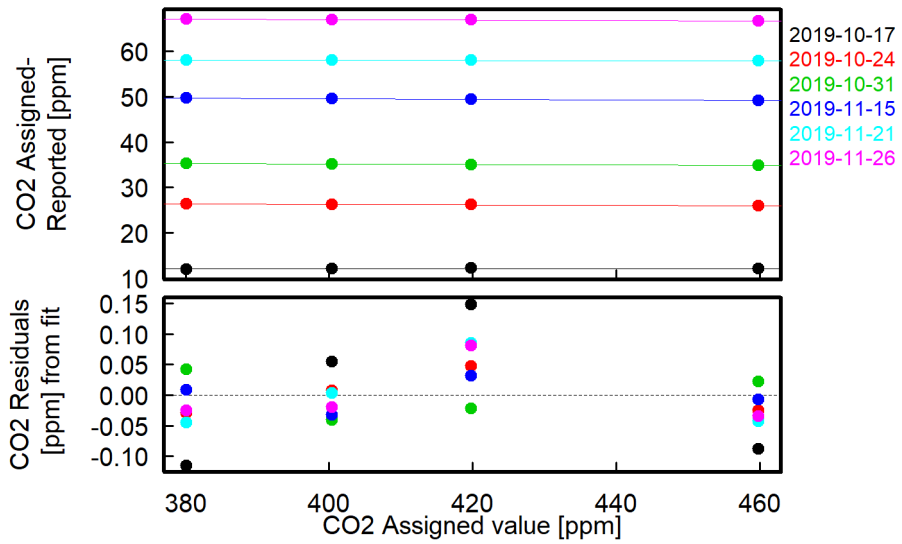
12.3 MLab correction

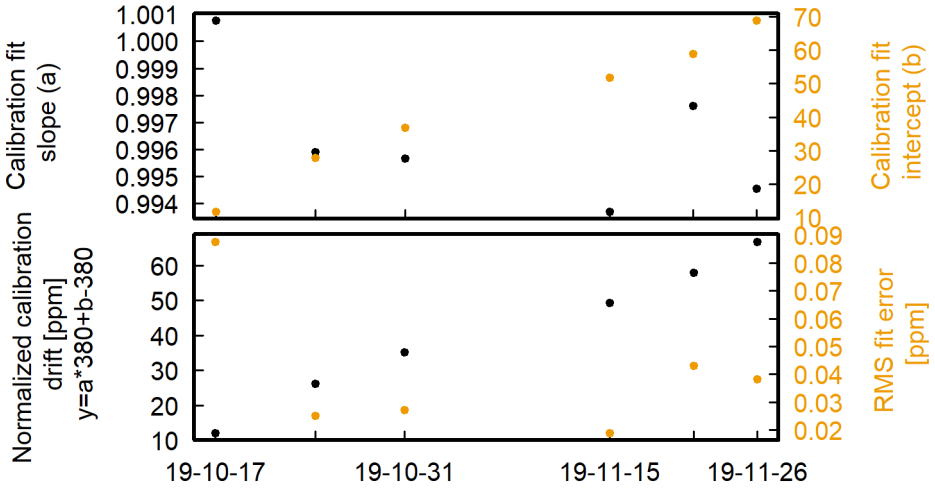


13 Calibration

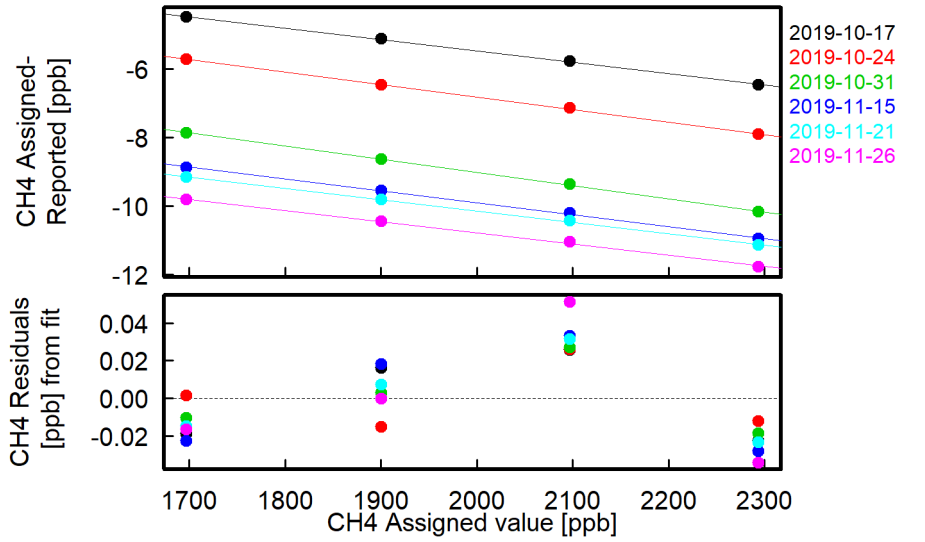
Methodology: Measure 4 times (during 20 minutes each time) 4 standards filled with known CO_2, CH_4 and CO concentrations. Compare reported values from the instrument and assigned values. Determine calibration functions. The residuals shown are the residuals from the calibration fit ($C_{Assigned}$-$C_{Reported}$=f($C_{Assigned}$)). Check the instrument drift. The value in the table is evaluated by calculating the temporal regression of the average differences (Assigned-Reported) for each calibration episode.

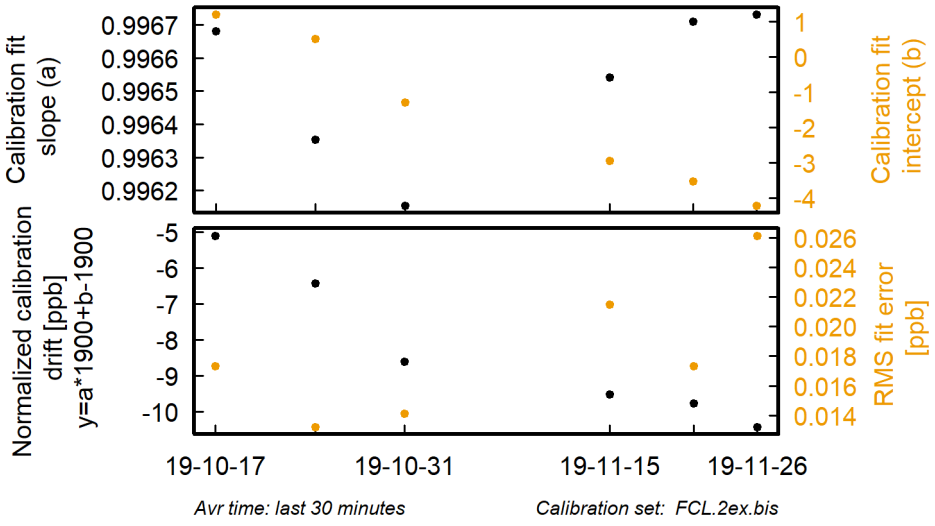
CO2





CH4

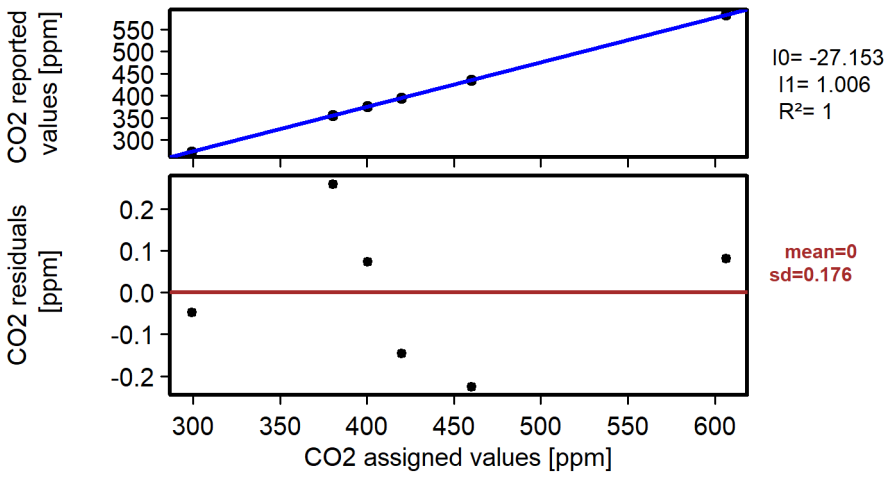


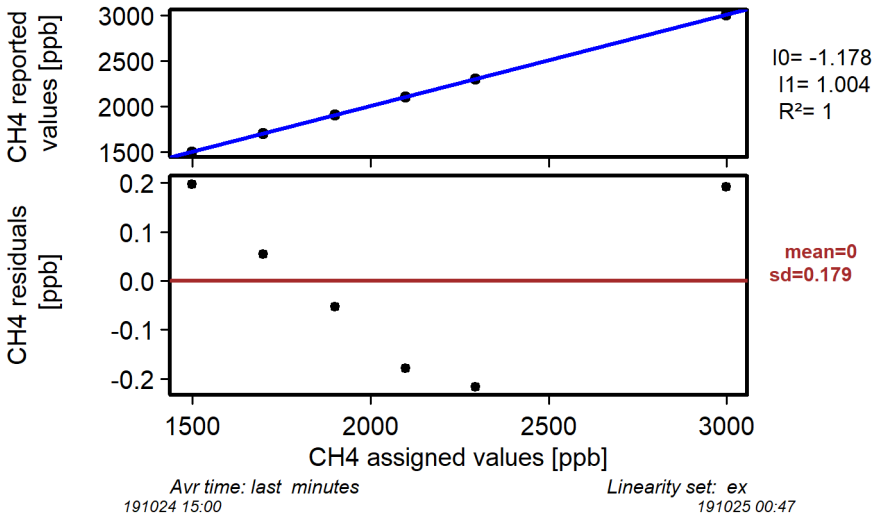


	CO2	CH4
Calibration drift trend (ppb/month)	37919.1	-3.7
Maximum residual from linear fit on calibration range [ppb]	148	0.1

14 Linearity

Methodology: Measure 4 times (during 20 minutes each time) 6 standards filled with known CO_2, CH_4 and CO concentrations within the range guaranteed by the manufacturer. The first minutes are not taken into account (stabilization time). No calibration applied.



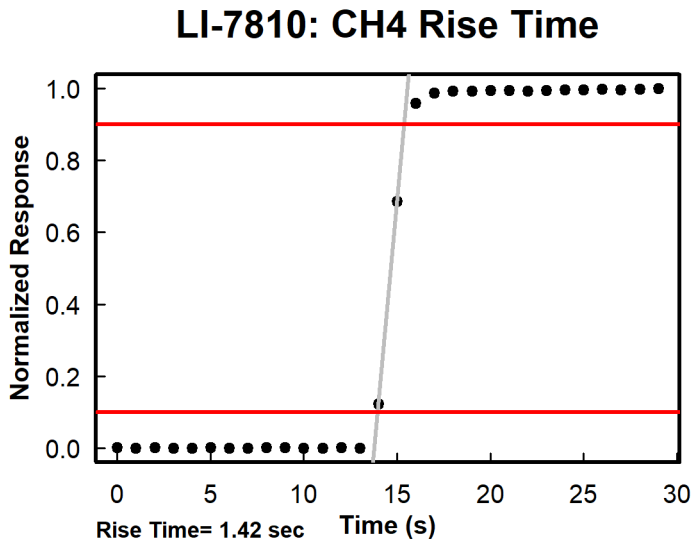


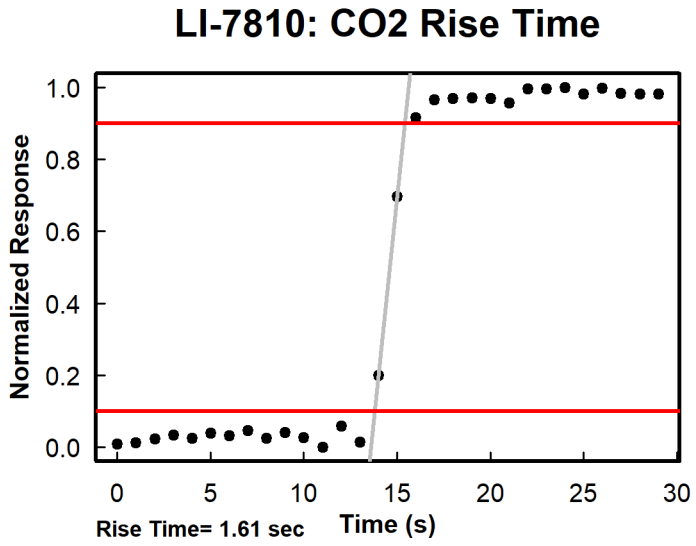
	CO2	CH4
Maximum residual from linear fit on extended mole fraction range [ppb]	261	0.22
Maximum residual from linear fit on extended mole fraction range [%]	0.069	0.009

15 Rise Time and Fall Time

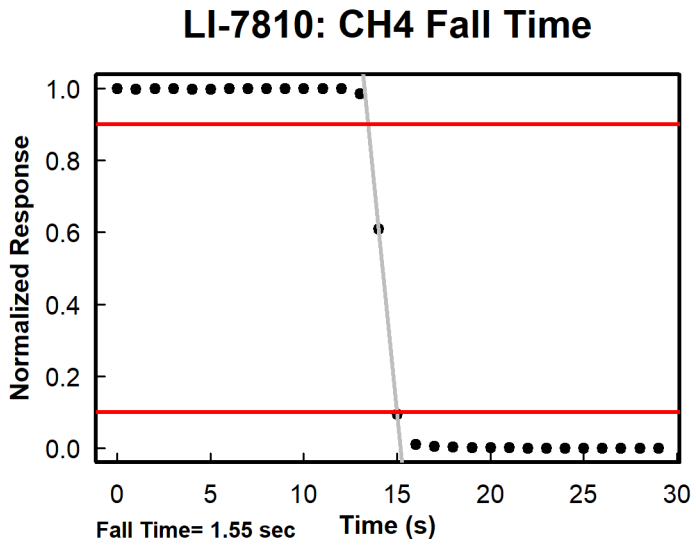
Methodology: Measure the rise time and fall time between two different tanks during a calibration.

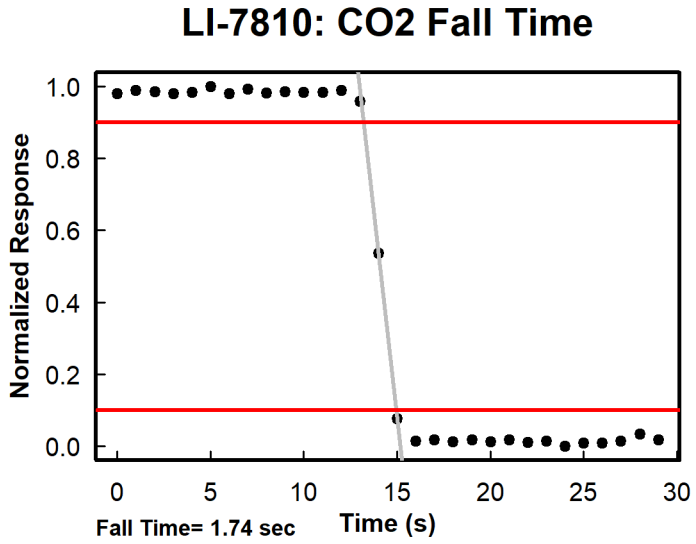
Rise time : Time taken for the response to rise from 10% to 90% of its final normalized value





Fall time : Time taken for the response to fall from 90% to 10% of its final normalized value





	CO2 (sec)	CH4 (sec)
Rise time	<2	<2
Fall time	<2	<2

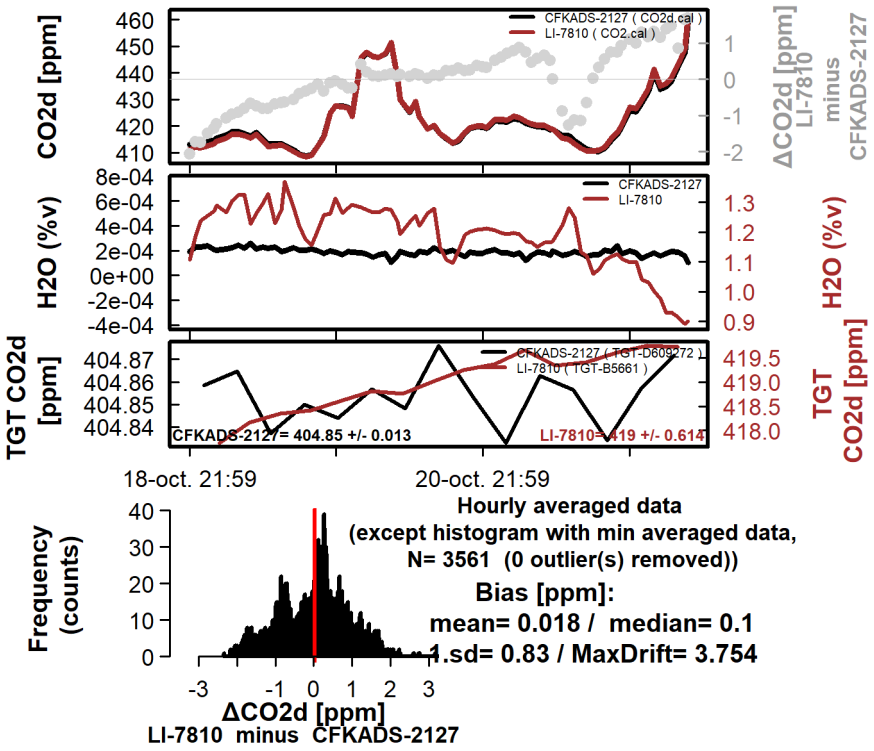
16 Laboratory inter-comparison

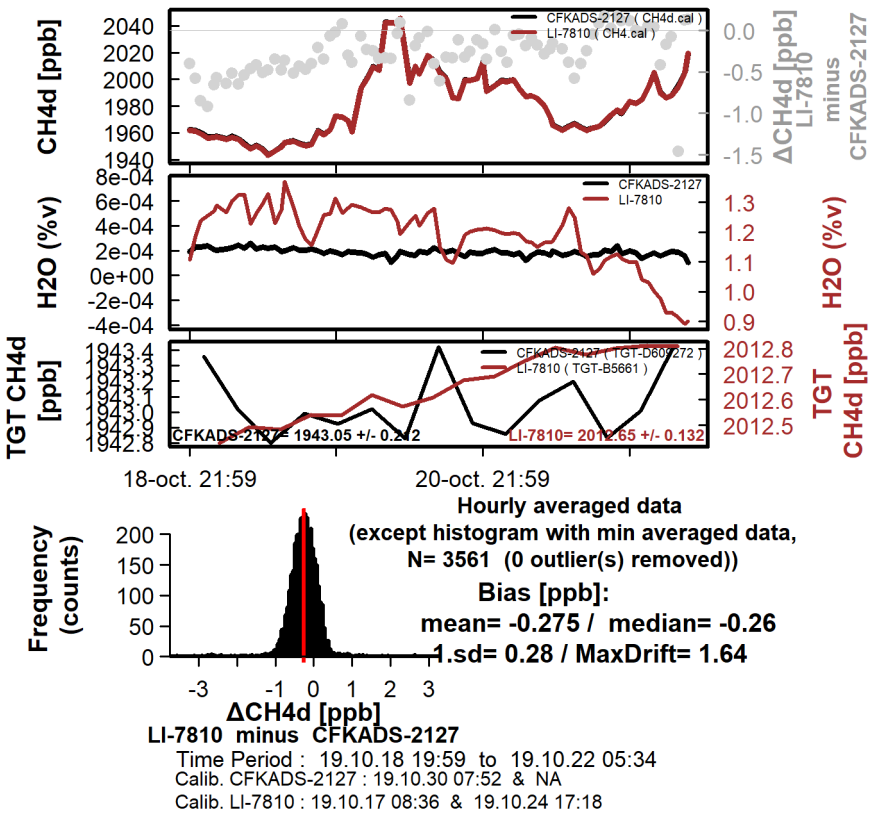
16.1 Without drying system

Methodology: Measure ambient air without drying system. Compare with a reference instrument with drying system. The 2 instruments are calibrated against the same set of calibration tanks. They are each equipped with a dedicated sampling line. If the MLab reference instrument is unavailable then the reference instrument is the instrument tested in parallel. In this case, they use the same sampling line and the ATC water vapor correction is applied to the reference. A target gas is measured on both instruments for quality control.

16.1.1 First period

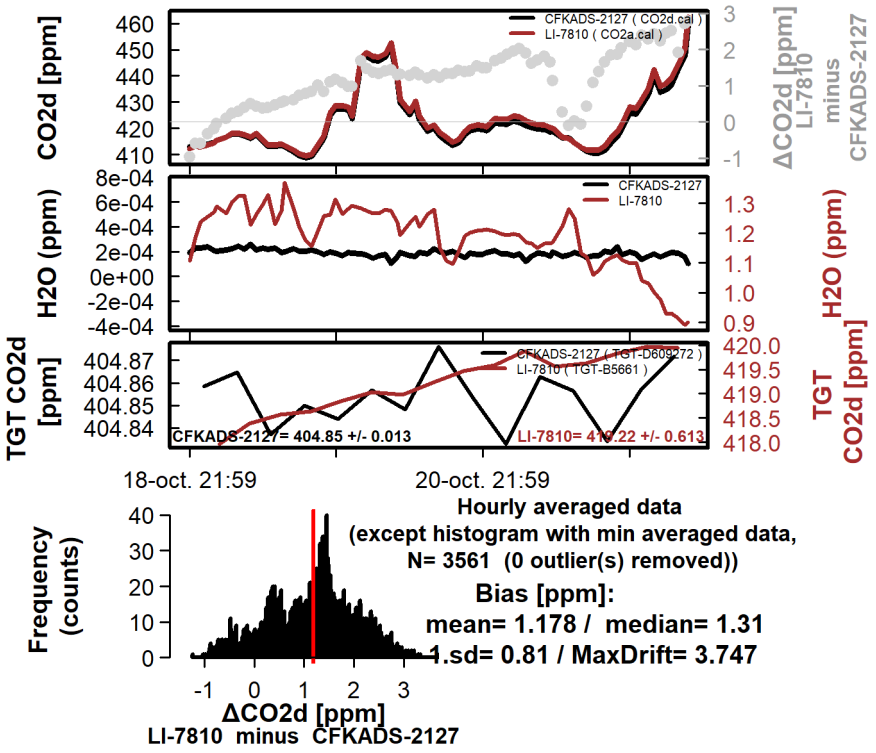
16.1.1.1 Factory water vapor correction

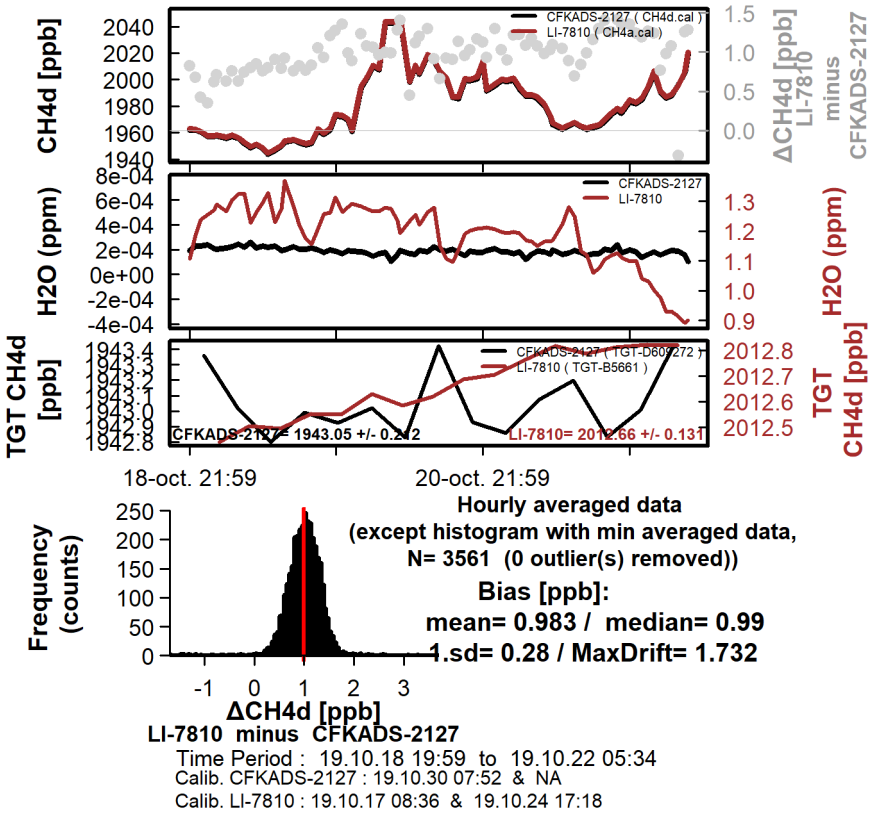




	CO2 [ppb]	CH4 [ppb]
Observed bias in ambient air:		
mean difference (LI-7810 - Ref Instrument)	18	-0.28
H_2O correction bias estimated by ATC		
for the mean H_2O during the test (11910 ppm H_2O)	-1184	-1.32
Remaining bias (not related to H_2O correction)	1202	1.05

16.1.1.2 Water vapor correction coefficients determined by ATC

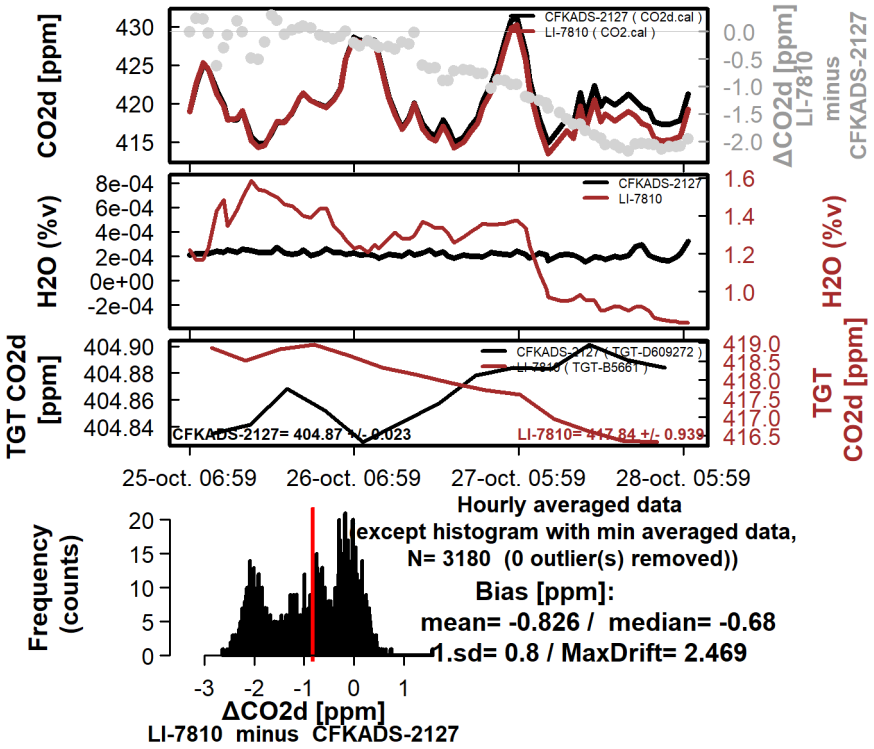


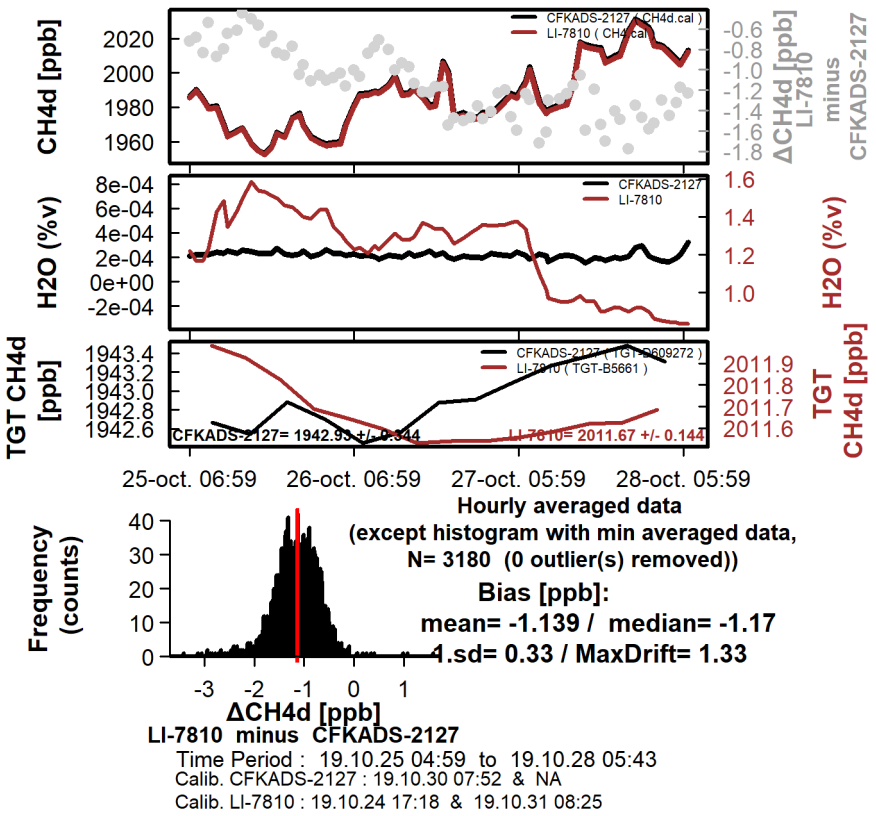


	CO2 [ppb]	CH4 [ppb]
Observed bias : mean difference (LI-7810 - Reference)	1178	0.98
H_2O correction bias estimated by ATC		
for the mean H_2O during the test (11910 ppm H_2O)	-51	-0.04
Remaining bias (not related to H_2O correction)	1229	1.03

16.1.2 Second period

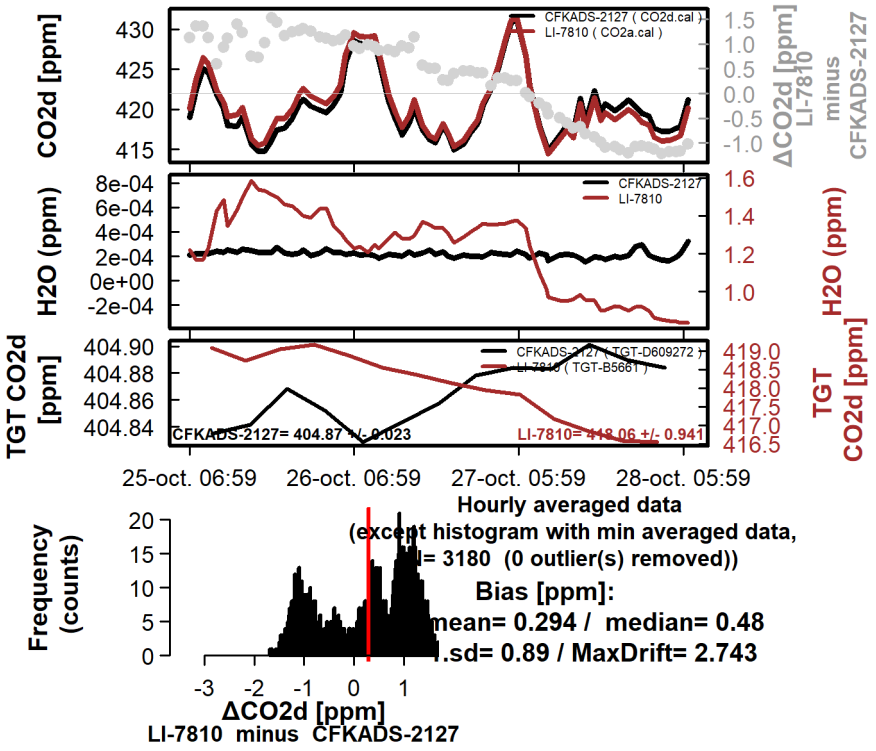
16.1.2.1 Factory water vapor correction

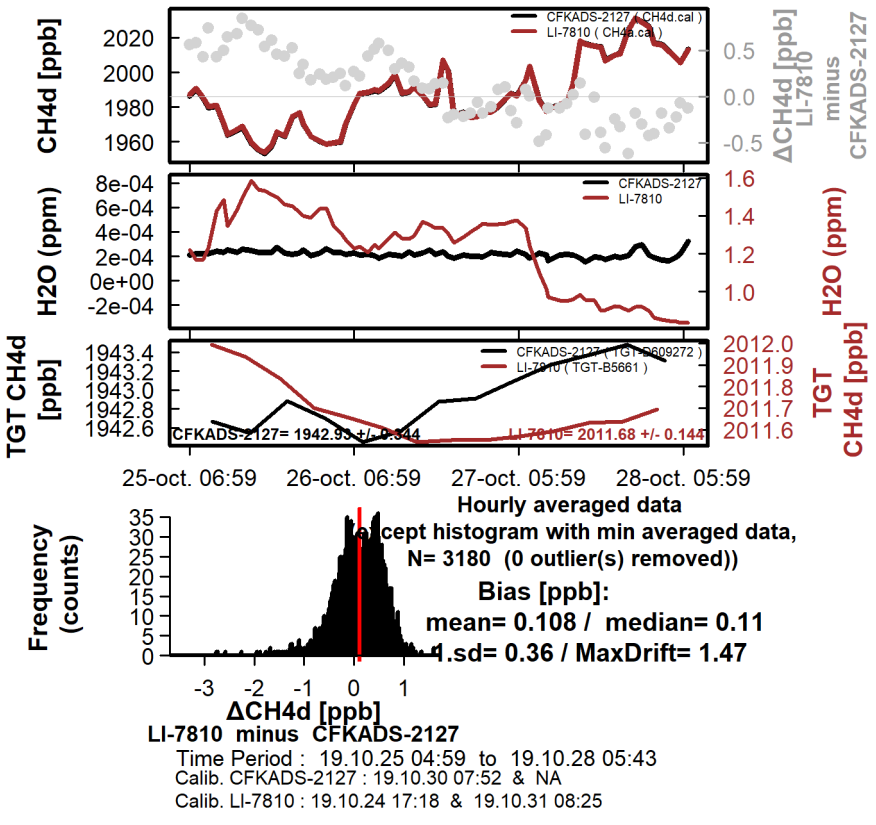




	CO2 [ppb]	CH4 [ppb]
Observed bias in ambient air:		
mean difference (LI-7810 - Ref Instrument)	-826	-1.14
H_2O correction bias estimated by ATC		
for the mean H_2O during the test (12143 ppm H_2O)	-1184	-1.32
Remaining bias (not related to H_2O correction)	358	0.18

16.1.2.2 Water vapor correction coefficients determined by ATC

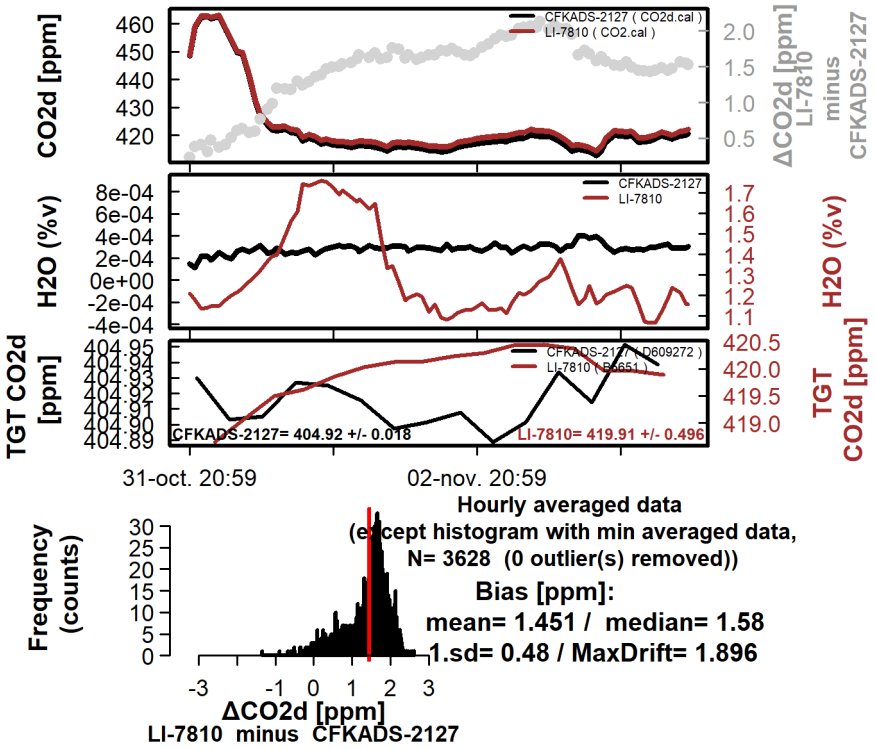


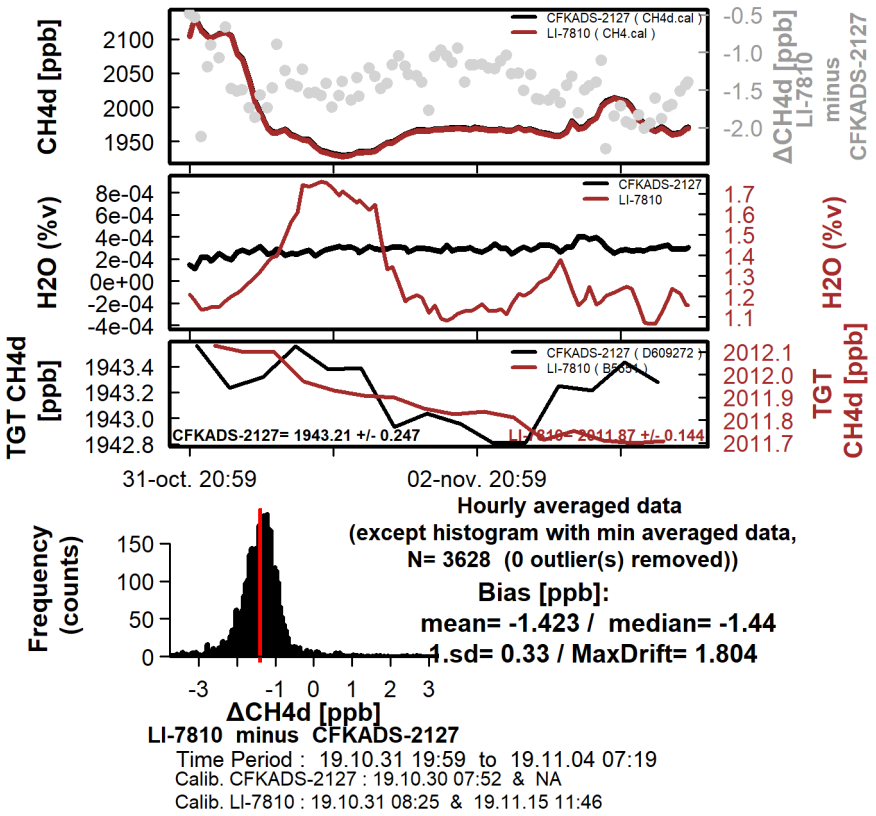


	CO2 [ppb]	CH4 [ppb]
Observed bias : mean difference (LI-7810 - Reference)	294	0.11
H_2O correction bias estimated by ATC		
for the mean H_2O during the test (12143 ppm H_2O)	-51	-0.04
Remaining bias (not related to H_2O correction)	345	0.15

16.1.3 Third period

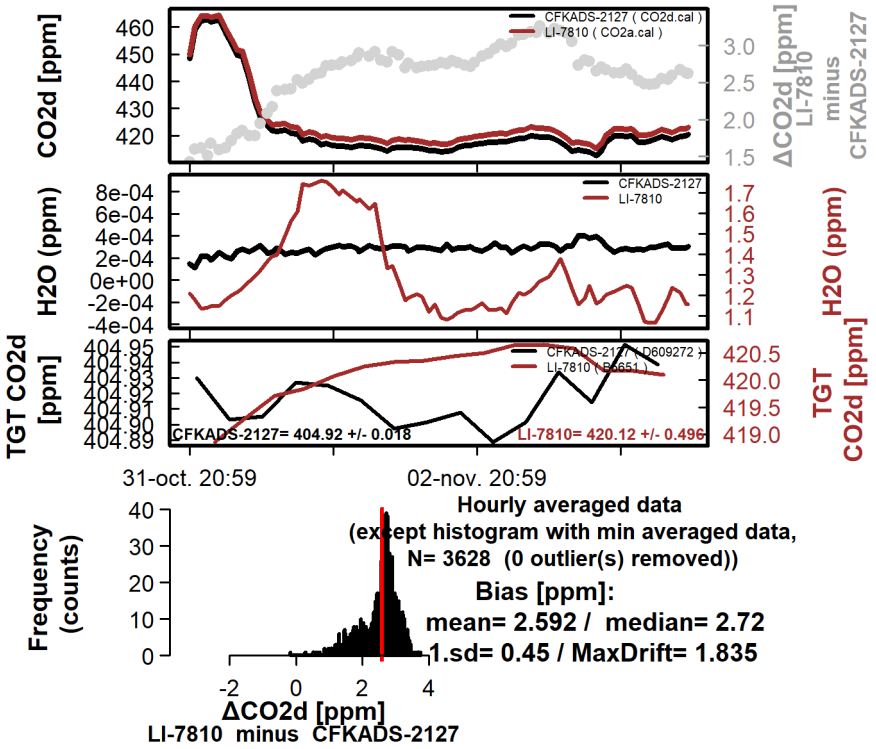
16.1.3.1 Factory water vapor correction

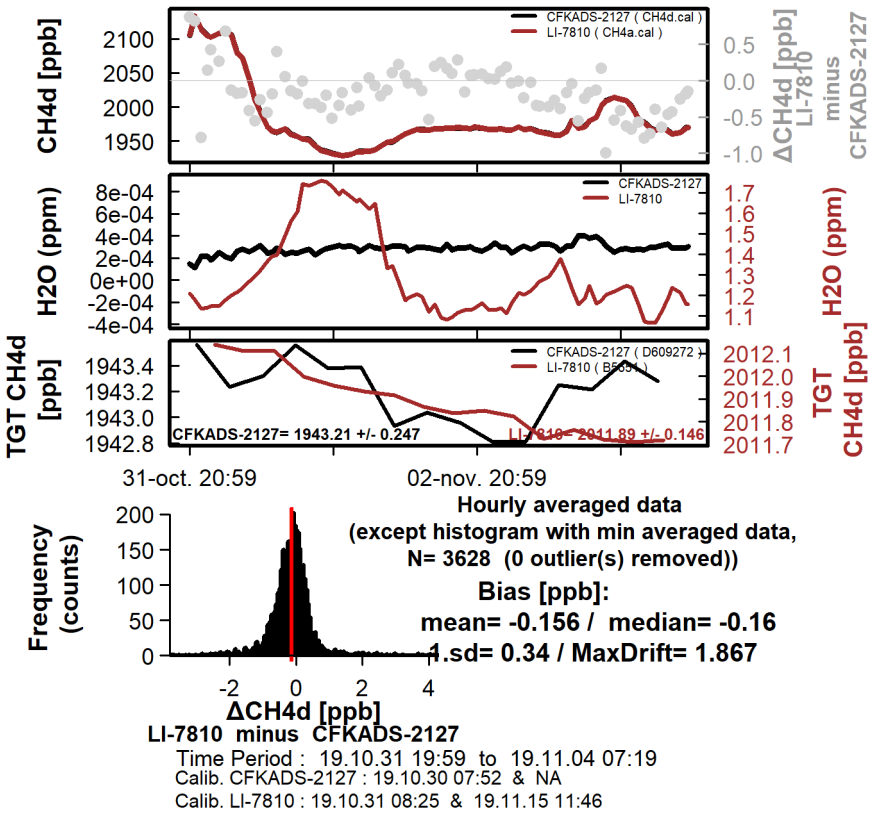




	CO2 [ppb]	CH4 [ppb]
Observed bias in ambient air:		
mean difference (LI-7810 - Ref Instrument)	1451	-1.42
H_2O correction bias estimated by ATC		
for the mean H_2O during the test (12931 ppm H_2O)	-1184	-1.32
Remaining bias (not related to H_2O correction)	2635	-0.10

16.1.3.2 Water vapor correction coefficients determined by ATC

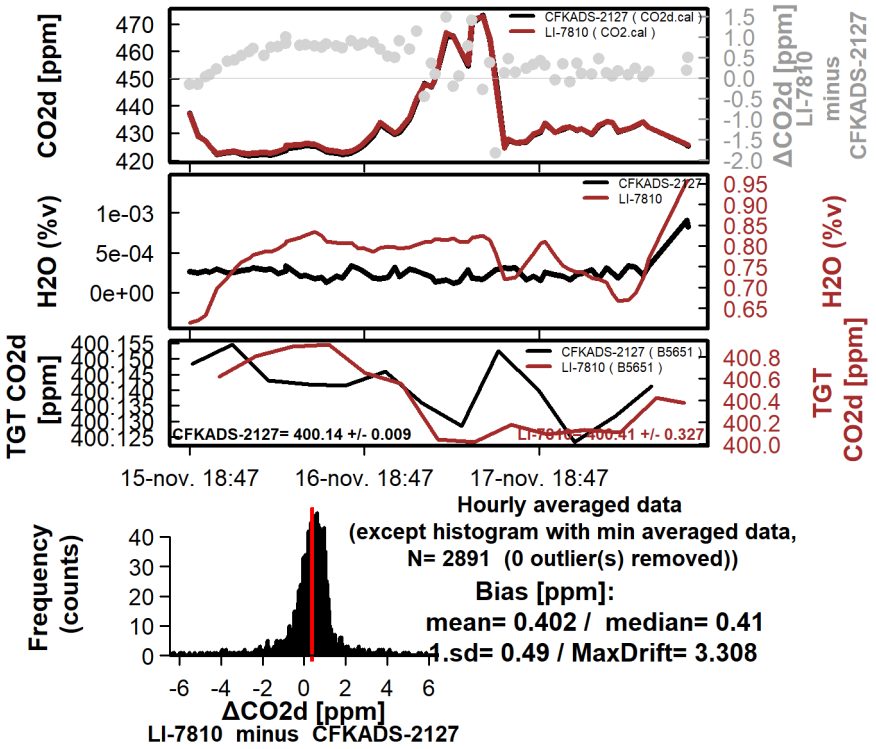


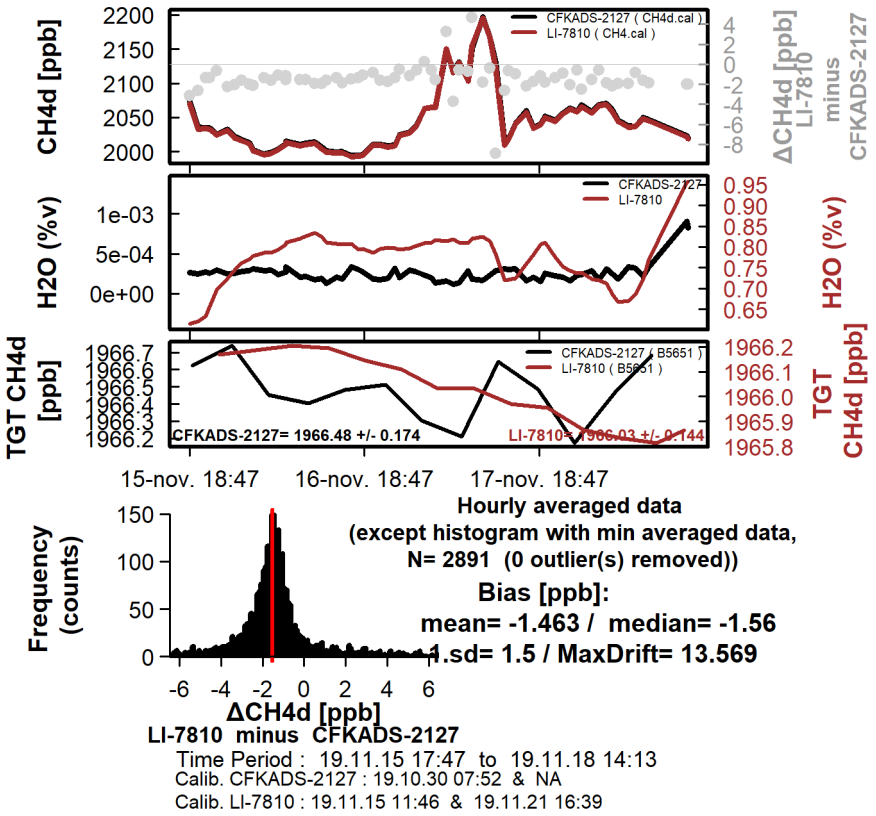


	CO2 [ppb]	CH4 [ppb]
Observed bias : mean difference (LI-7810 - Reference)	2592	-0.16
H_2O correction bias estimated by ATC		
for the mean H_2O during the test (12931 ppm H_2O)	-51	-0.04
Remaining bias (not related to H_2O correction)	2643	-0.11

16.1.4 Fourth period

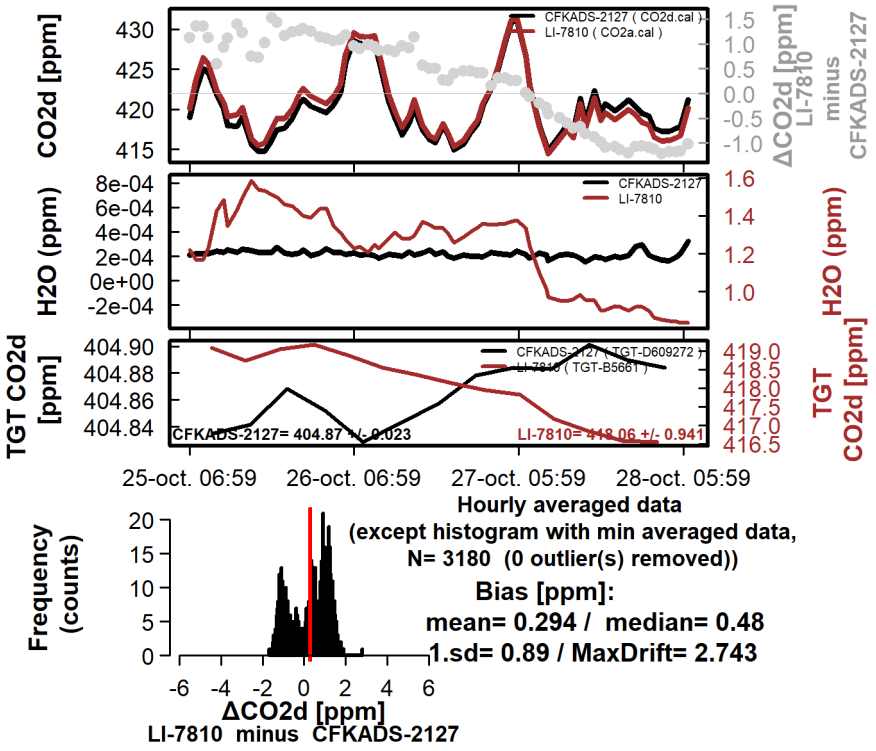
16.1.4.1 Factory water vapor correction

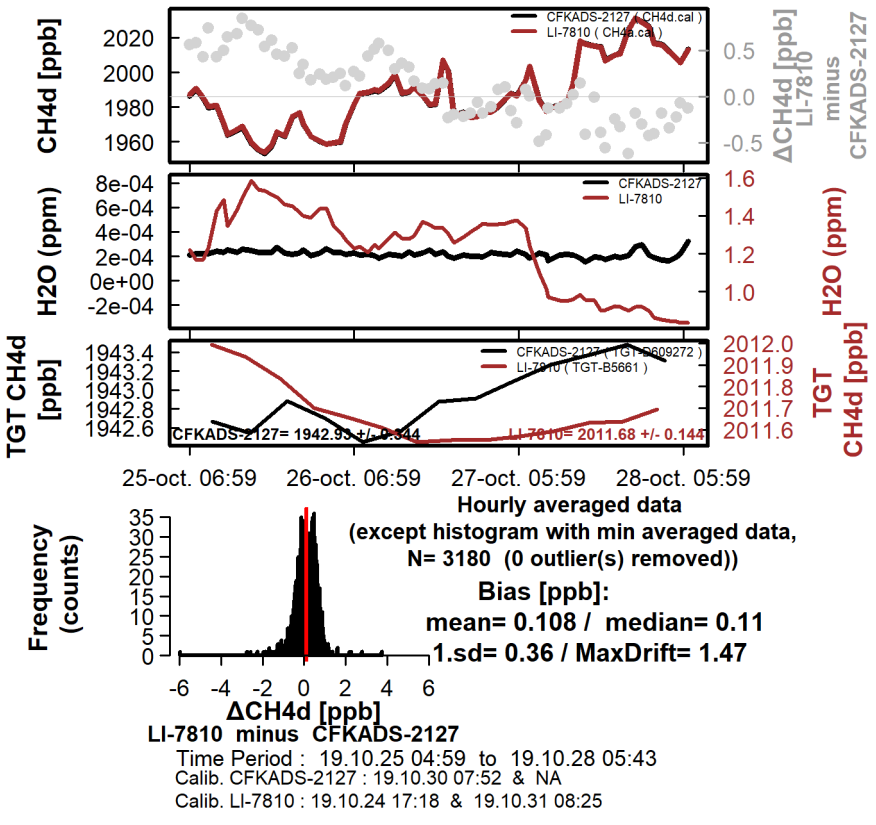




	CO2 [ppb]	CH4 [ppb]
Observed bias in ambient air:		
mean difference (LI-7810 - Ref Instrument)	402	-1.46
H_2O correction bias estimated by ATC		
for the mean H_2O during the test (7687 ppm H_2O)	-897	-1.03
Remaining bias (not related to H_2O correction)	1299	-0.43
Observed bias on TGT (dry air):		
mean difference (LI-7810 - Ref Instrument)	274	-0.45

16.1.4.2 Water vapor correction coefficients determined by ATC

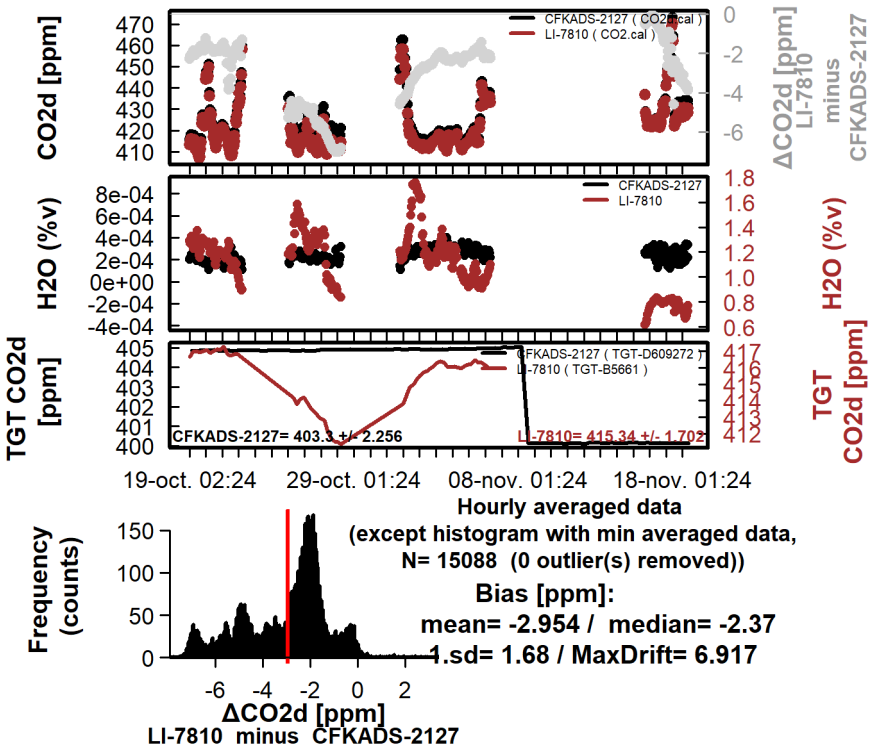


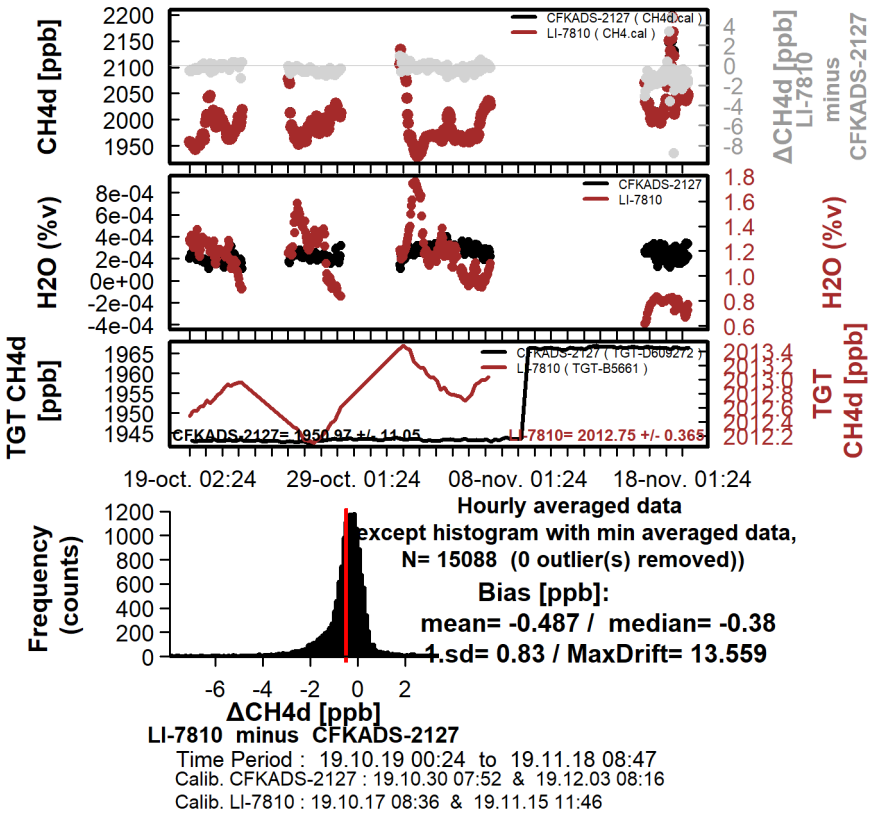


	CO2 [ppb]	CH4 [ppb]
Observed bias : mean difference (LI-7810 - Reference)	294	0.11
H_2O correction bias estimated by ATC		
for the mean H_2O during the test (12143 ppm H_2O)	-51	-0.04
Remaining bias (not related to H_2O correction)	345	0.15

16.1.5 Over all Laboratory inter-comparison

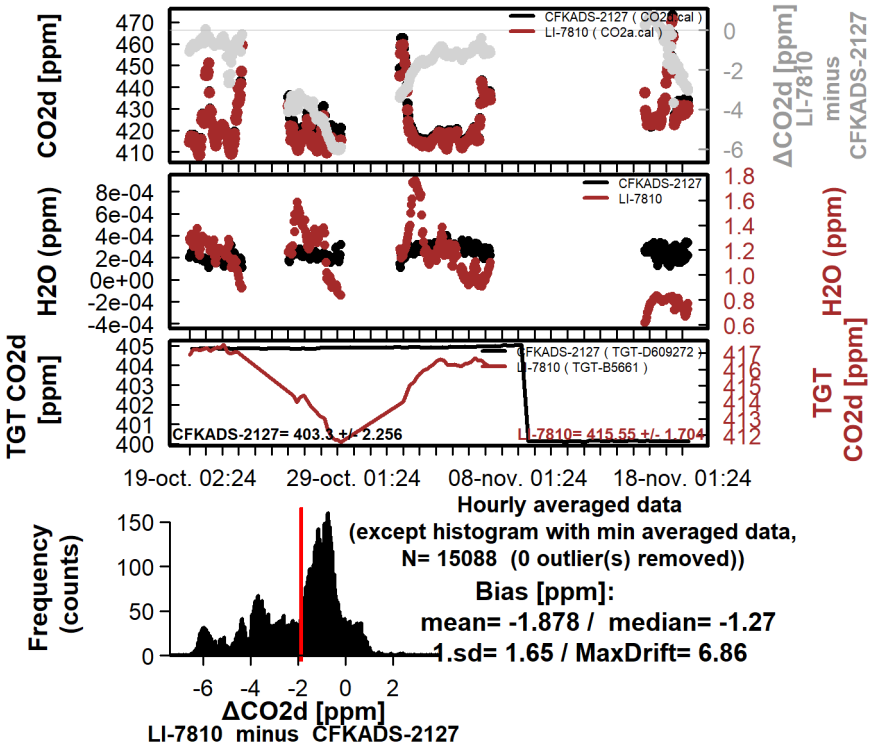
16.1.5.1 Factory water vapor correction

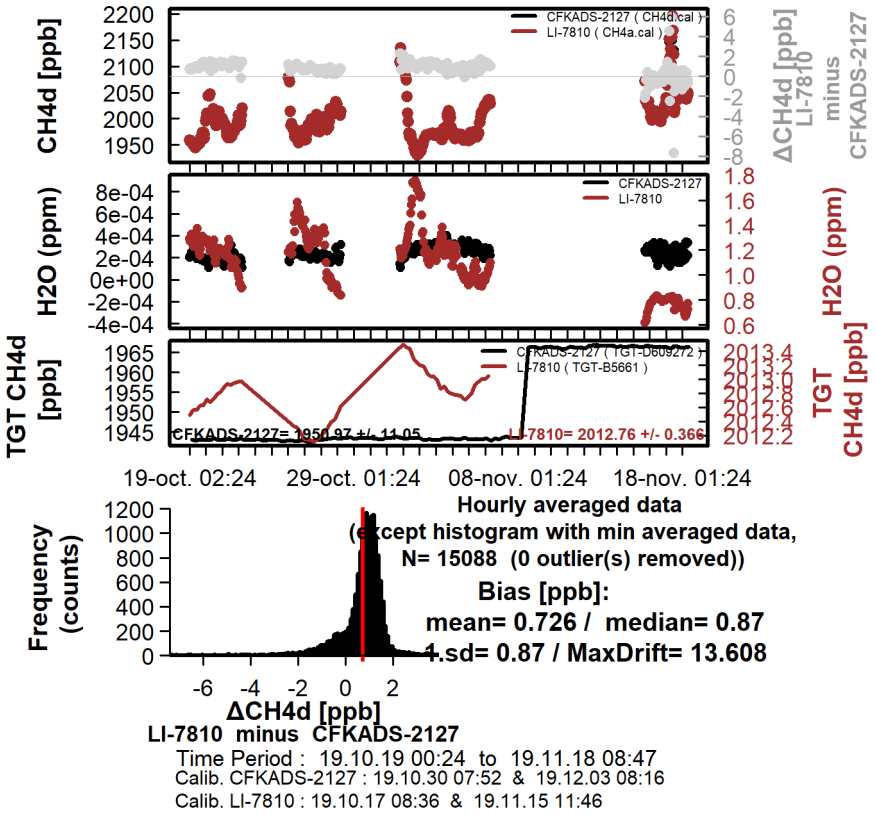




	CO2 [ppb]	CH4 [ppb]
Observed bias in ambient air:		
mean difference (LI-7810 - Ref Instrument)	-2954	-0.49
H_2O correction bias estimated by ATC		
for the mean H_2O during the test (11144 ppm H_2O)	-1184	-1.32
Remaining bias (not related to H_2O correction)	-1770	0.83

16.1.5.2 Water vapor correction coefficients determined by ATC



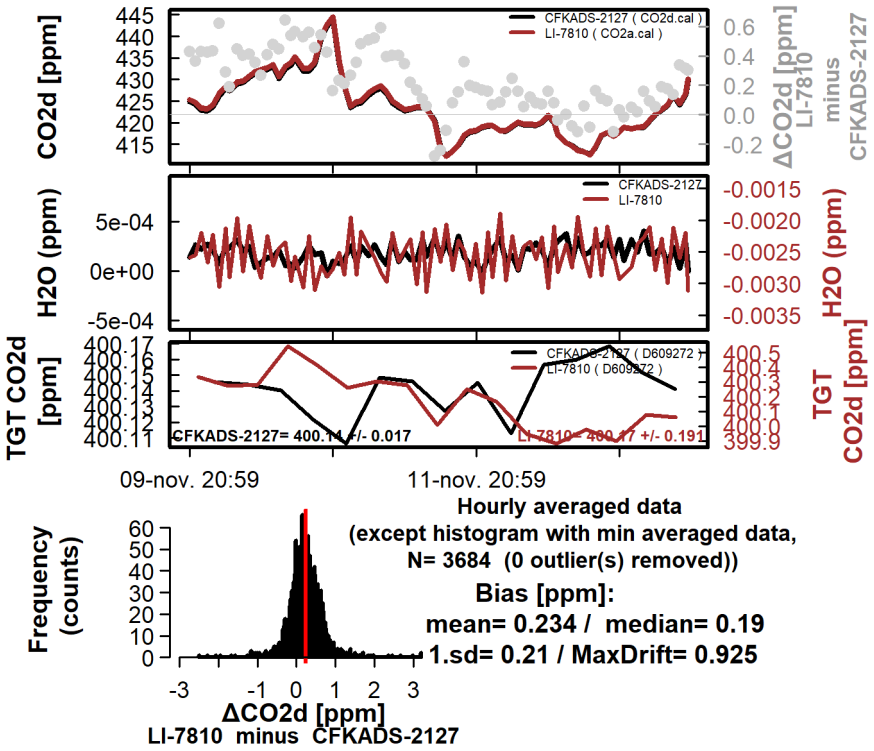


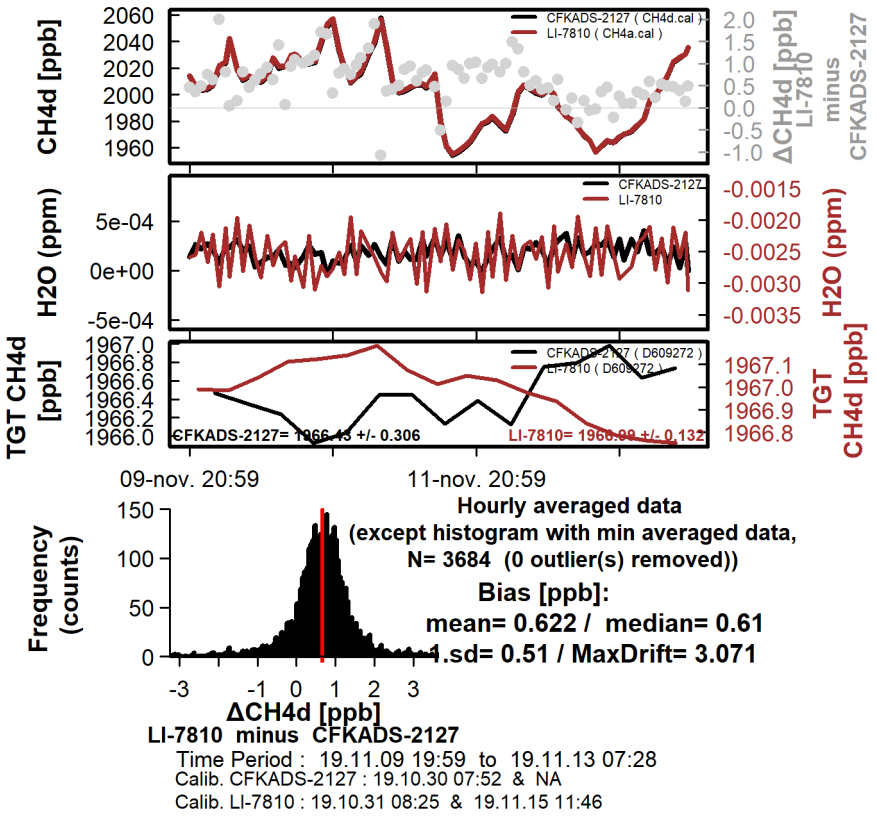
	CO2 [ppb]	CH4 [ppb]
Observed bias : mean difference (LI-7810 - Reference)	-1878	0.73
H_2O correction bias estimated by ATC		
for the mean H_2O during the test (11144 ppm H_2O)	-51	-0.04
Remaining bias (not related to H_2O correction)	-1827	0.77

16.2 With drying system

Methodology: Measure ambient air with drying system. Compare with a reference instrument. The 2 instruments are calibrated against the same set of calibration tanks. They are equipped with a dedicated sampling line. In this case, they use the same sampling line. A target gas is measured on both instruments for quality control.

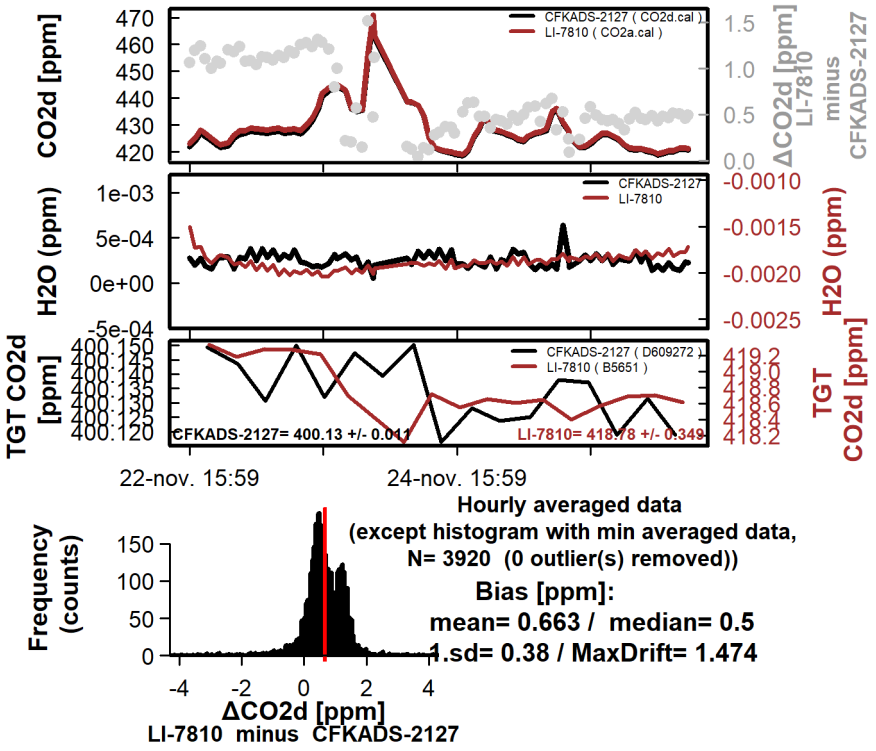
16.2.1 First period

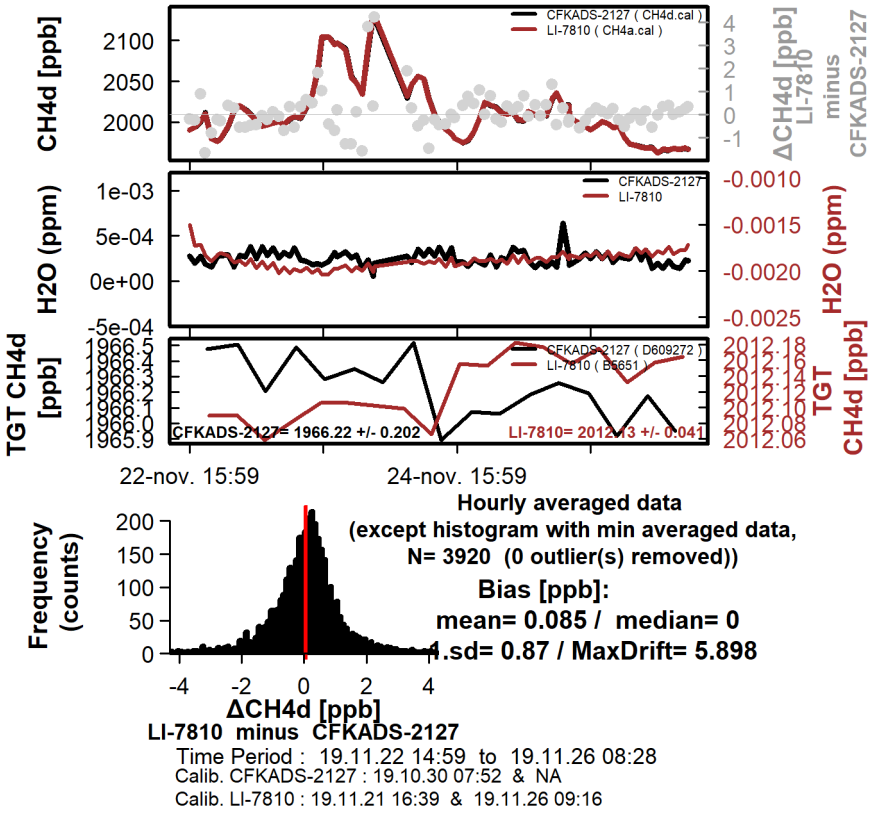




	CO2 [ppb]	CH4 [ppb]
Observed bias : mean difference (LI-7810 - Reference)	234	0.62
Intrinsic bias estimated in wet air conditions (ATC correction)	-1827	0.77
Observed bias on TGT (dry air):		
mean difference (LI-7810 - Ref Instrument)	33	0.56

16.2.2 Second period





	CO2 [ppb]	CH4 [ppb]
Observed bias : mean difference (LI-7810 - Reference)	663	0.08
Intrinsic bias estimated in wet air conditions (ATC correction)	-1827	0.77

17 Summary

For legibility purposes, the results are split into tables by species.
Only status in bold are taken into account for the final status.

	CO_2			
	Spec	ATC	unit	Status
Field CMR (average on min sd)	-	556	ppb	-
Minute CMR (1σ)	<50	**433**	ppb	**Fail**
Hourly CMR (1σ)	<25	**451**	ppb	**Fail**
Minute CMR MaxDrift (peak to peak)	<200	1817	ppb	Fail
Hourly CMR MaxDrift (peak to peak)	<150	1469	ppb	Fail
LTR-1 (1σ, 10 min avr raw data)	<50	**1323**	ppb	**Fail**
LTR-1 MaxDrift (peak to peak)	<200	4024	ppb	Fail
LTR-2 (1σ, 10 min avr raw data)	<50	2226	ppb	**Fail**
LTR-2 MaxDrift (peak to peak)	<200	6532	ppb	Fail
LTR-3 (1σ, 10 min avr raw data)	<50	695	ppb	**Fail**
LTR-3 MaxDrift (peak to peak)	<200	2219	ppb	Fail
LTR-4 (1σ, 10 min avr raw data)	<50	1428	ppb	**Fail**
LTR-4 MaxDrift (peak to peak)	<200	3902	ppb	Fail
STR (1σ, 9 min avr raw data)	-	81	ppb	-
Atm. pressure sensitivity	-	NS	ppb/hPa	-
Temperature sensitivity	-	-109.241	ppb/°C	-
Max res from fit in cal range	-	148	ppb	-
Max res from fit in extended range	-	261	ppb	-
Max res from fit in extended range 2	-	0.069	%	-
Calibration drift trend	-	37919.1	ppb/month	-
Water vapor corr: max bias ATC	-	214.14	ppb	-
Water vapor corr: max bias Factory	-	1255.87	ppb	-
Water vapor correction I1	-	-3.521e-03	-	-
Water vapor correction I2	-	9.028e-04	-	-

	CH_4			
	Spec	ATC	unit	Status
Field CMR (average on min sd)	-	0.14	ppb	-
Minute CMR (1σ)	<1	**0.06**	ppb	**Pass**
Hourly CMR (1σ)	<0.5	**0.06**	ppb	**Pass**
Minute CMR MaxDrift (peak to peak)	<2	0.30	ppb	Pass
Hourly CMR MaxDrift (peak to peak)	<1.5	0.17	ppb	Pass
LTR-1 (1σ, 10 min avr raw data)	<0.5	**0.32**	ppb	**Pass**
LTR-1 MaxDrift (peak to peak)	<2	0.95	ppb	Pass
LTR-2 (1σ, 10 min avr raw data)	<0.5	0.26	ppb	**Pass**
LTR-2 MaxDrift (peak to peak)	<2	0.82	ppb	Pass
LTR-3 (1σ, 10 min avr raw data)	<0.5	0.09	ppb	**Pass**
LTR-3 MaxDrift (peak to peak)	<2	0.28	ppb	Pass
LTR-4 (1σ, 10 min avr raw data)	<0.5	0.11	ppb	**Pass**
LTR-4 MaxDrift (peak to peak)	<2	0.32	ppb	Pass
STR (1σ, 9 min avr raw data)	-	0.02	ppb	-
Atm. pressure sensitivity	-	NS	ppb/hPa	-
Temperature sensitivity	-	NS	ppb/°C	-
Max res from fit in cal range	-	0.1	ppb	-
Max res from fit in extended range	-	0.22	ppb	-
Max res from fit in extended range 2	-	0.009	%	-
Calibration drift trend	-	-3.7	ppb/month	-
Water vapor corr: max bias ATC	-	0.08	ppb	-
Water vapor corr: max bias Factory	-	1.32	ppb	-
Water vapor correction I1	-	-9.196e-04	-	-
Water vapor correction I2	-	3.212e-04	-	-