Yale 耶鲁大学-南京信息工程大学大气环境中心

Yale-NUIST Center on Atmospheric Environment

Improving the perform of a low-cost CO_2 monitoring system for urban research

OUTLINE

Brief introduction

Specific experiments are as follows

1. Calibration in the lab.
2. Calibration during the urban CO_2 observation.
3. Tank gas observation(416ppm CO_2) .
4. Observation in buffer.
5. Atmosphere observations compare compared with Picarro.

conclusion

Brief introduction

Objective

We want to observe the temporal and spatial distribution of CO_2 concentration in Nanjing urban area.

Challenge

The most important factor influencing the instrument measurement is temperature. LI-840A has a self heating system, but only for the optical cavity. Optical cavity temperature will change if the rapid change of ambient temperature and rapid air flow happen, and then make the measurement inaccurate.

Instrumental measurements have great drift, We need to know the calibration frequency.

The box

Function ：Heating insulation; automatic calibration.

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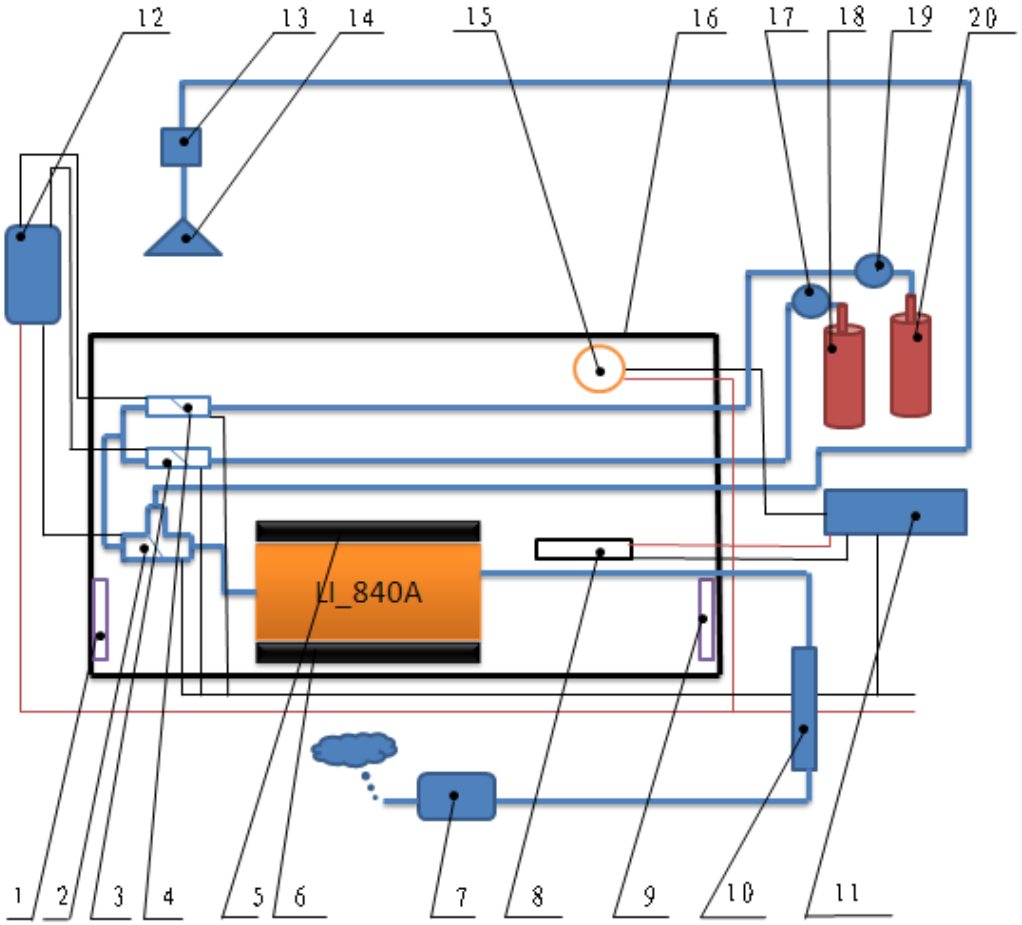

1	fan
2	electromagnetic valves
3	electromagnetic valves
4	electromagnetic valves
5	Metal plate
6	Metal plate
7	Pump
8	Temperature sensor
9	Fan
10	Flow meter（500cc/min）
11	Temperature control circuit
12	Calibration controller
13	Filter
14	Rain shield
15	Heater
16	Case
17	Reducing valve
18	Standard gas
19	Reducing valve
20	Standard gas

The cost of the box

Part	Price	Amount
SOLENOID VALUES	$ 35x3	$ 105
PUMP	$ 300X1	$ 300
FLOWMETER	$ 40X1	$ 40
CROSS UNION	$ 13.6X4	$ 54.4
DEKABON TUBING	$ 0.66x10	$ 6.6
BOX	**500￥x1**	**$ 82.2**
Value and temperature control unit	**100￥x1**	**$ 16.4**
other	**200￥**	**$ 32.9**
Bought in America		$ 506
Bought in China		**$ 131.5**
TOTAL		$ 637.5

1. Calibration in the lab

We calibrated all the instruments before urban CO_2 observation.

Table.1 Calibration on June 4th

	Zero CO_2	490ppmCO_2	Zero H_2O	22℃ H_2O	1℃ H_2O
LI-840A_No. 1	-1.4ppm	480.6ppm	-0.00017ppt	26.98ppt	6.45ppt
LI-840A_No. 2	-0.4ppm	478.6 ppm	-0.00085ppt	28.22ppt	7.92ppt
LI-840A_No. 3	-0.06ppm	476.0ppm	0ppt	28.17ppt	6.33ppt
LI-840A_No. 4	-7.6ppm	488.2ppm	-0.001ppt	27.56ppt	6.34ppt
LI-840A_No. 5	-2.7ppm	498.1ppm	-0.00033ppt	29.19ppt	6.00ppt
standard	**0ppm**	**486.1ppm**	**0ppt**	**26.54ppt**	**6.60ppt**

We did not test the 490ppm CO_2 standard gas at that time, the true concentration of the gas is 486.1ppm CO_2.

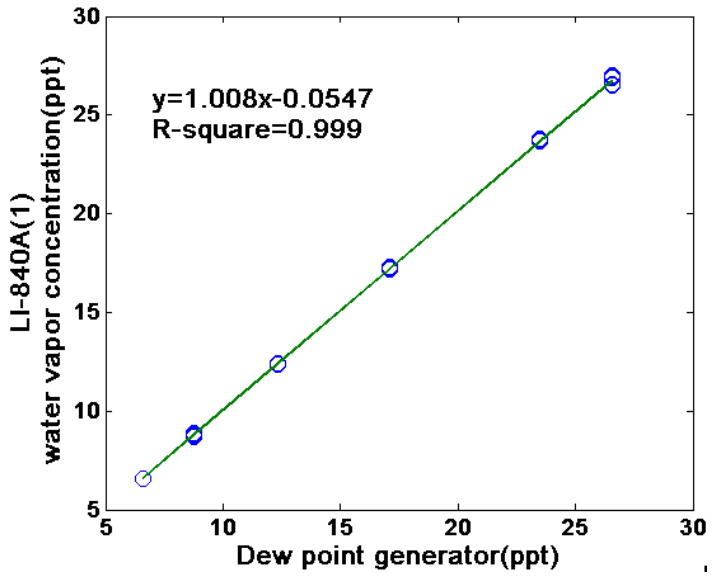

Fig.1

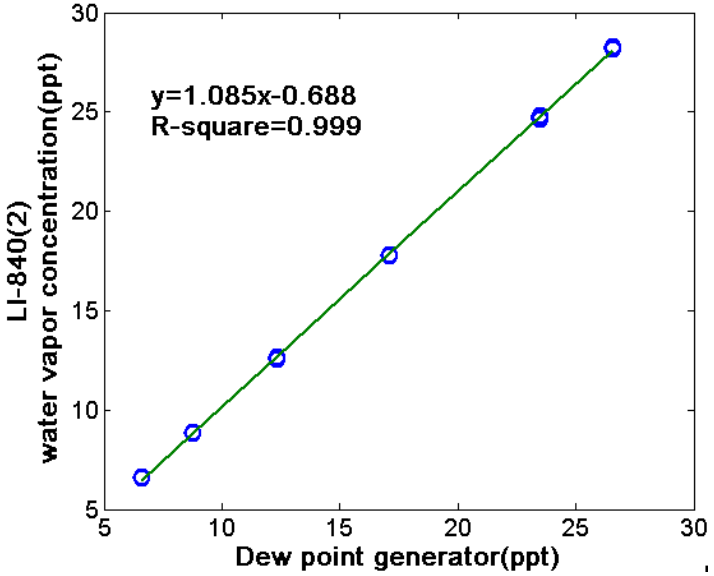

Fig.2

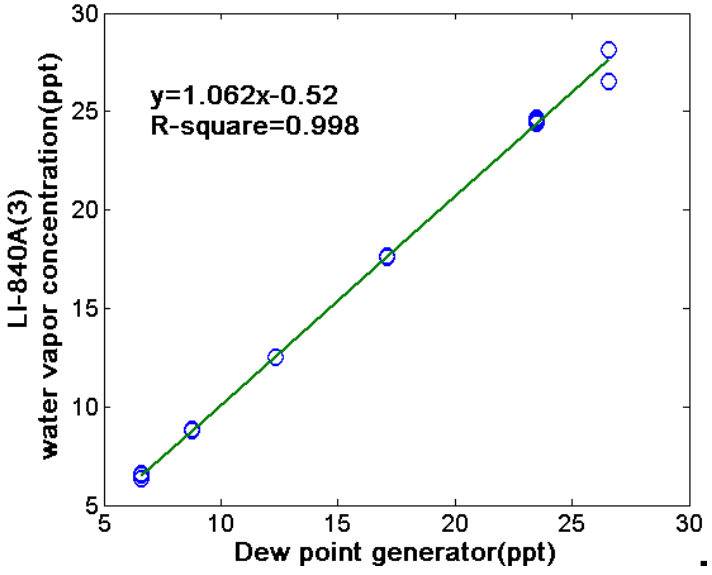

Fig.3

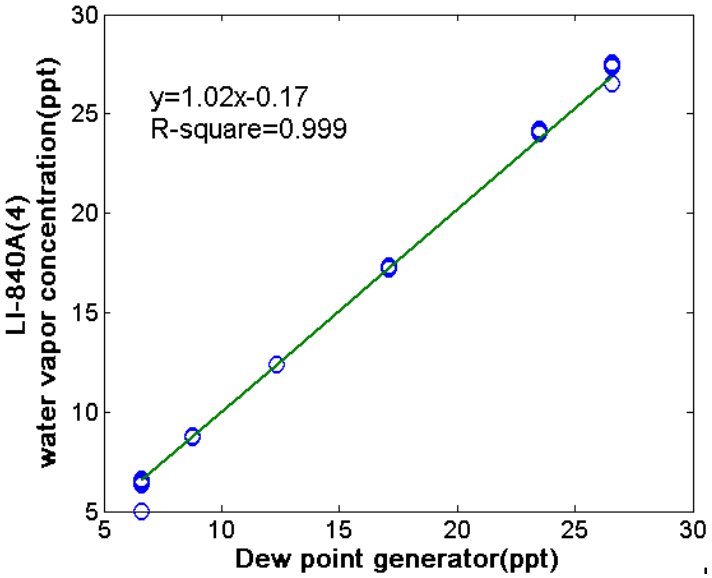

Fig .4

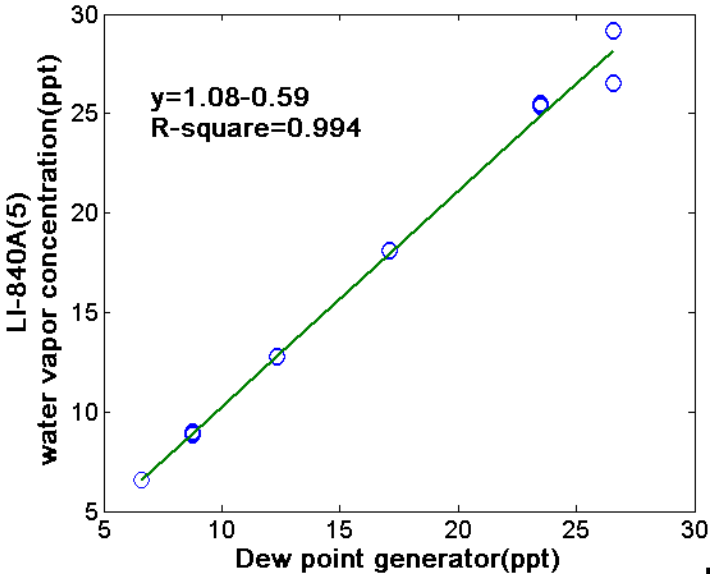

Fig.5

Table.2 Before calibration water vapor concentration

	1℃	5℃	10℃	15℃	20℃	22℃）
LI-840A_No. 1	6.45ppt	8.76ppt	12.34ppt	17.23ppt	23.79ppt	26.98ppt
LI-840A_No. 2	7.92ppt	8.82ppt	12.60ppt	17.74ppt	24.77ppt	28.22ppt
LI-840A_No. 3	6.33ppt	8.80ppt	12.53ppt	17.65ppt	24.69ppt	28.17ppt
LI-840A_No. 4	6.34ppt	8.78ppt	12.38ppt	17.36ppt	24.19ppt	27.56ppt
LI-840A_No. 5	6.00ppt	8.88ppt	12.76ppt	18.10ppt	25.51ppt	29.19ppt
Standard vapor concentration	**6.60ppt**	8.76ppt	12.33ppt	17.12ppt	23.47ppt	**26.54ppt**

2. Calibration during urban CO_2 observation

Urban CO_2 observation lasted from June 6th to June 23th.
Only four instruments was used during the 5 times observation with calibration.

Table.3 Calibration during the urban CO_2 observation

	Zero CO_2 （ppm）			490ppmCO_2 （ppm）			Zero H_2O （ppt）		
Five times calibration	Average	min	max	Average	min	max	Average	min	max
LI-840A_No. 1	-0.87	-0.25	-1.5	488.43	486.2	490.5	0.14	-0.01	-0.68
LI-840A_No. 3	-0.64	-0.1	-1.66	488.75	487.2	490.2	0.10	0.03	0.31
LI-840A_No. 4	-1.08	0.3	-2.52	488.20	486.5	490.2	0.20	-0.03	-0.75
LI-840A_No. 5	-0.07	1.01	-4.15	490.364	485.3	496.6	0.06	-0.03	0.9
standard	**0ppm**			**486.1ppm**			**0ppt**		

Table.4 The last calibration during urban CO_2 observation was on June 23rd

Standard gas: N_2	**CO_2 before calibration**	**CO_2 after calibration**	**H_2O before calibration**	**H_2O after calibration**
LI-840A_No. 1	-0.5ppm	0	-0.02ppt	0
LI-840A_No. 2	-4.5ppm	0	0.02ppt	0
LI-840A_No. 3	-0.1pm	0	0.05ppt	0
LI-840A_No. 4	-1.5ppm	0	-0.04ppt	0
LI-840A_No. 5	-2.1ppm	0	-0.03ppt	0
Standard gas: 490ppm CO_2	**CO_2 before calibration**	**CO_2 after calibration**		
LI-840A_No. 1	486.2ppm	490ppm		
LI-840A_No. 2	500.0ppm	490ppm		
LI-840A_No. 3	487.5ppm	490ppm		
LI-840A_No. 4	487.5PPm	490ppm		
LI-840A_No. 5	485.3ppm	490PPm		

Experience

LI-840A was in the worst conditions during urban CO_2 observation. Violent vibration in the car, switching power frequently and the change of voltage make the instrument performance not satisfactory.

In the June 13th 490ppm CO_2 calibration, we found large gap between instruments.

But the rest of the time, the difference of CO_2 was less than ±2ppm.

The LI-840A_NO.5 performance is the worst, we need to pay attention to it.

3. Tank gas observation(416ppm CO_2)

The observation started from June 23rd to the end of June 26th, lasted 58 hours. We are concerned about the error between instruments. 416ppm is nominal concentration, we do not know the true concentration of the gas.

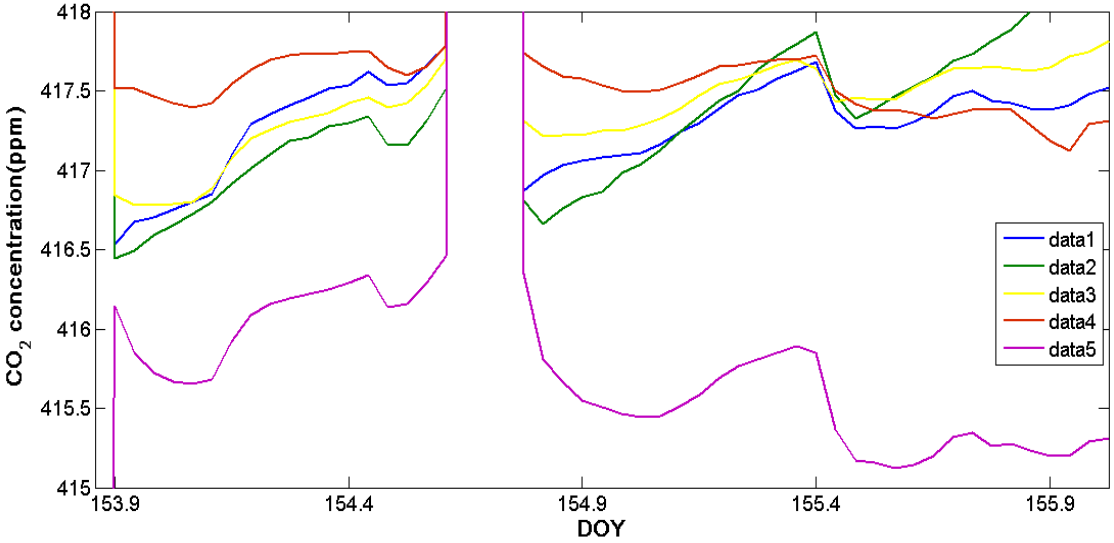

Fig.6 Tank gas observation, hourly average of CO_2 concentration.

Table.5 The mean value of tank gas observation.

Instruments	Mean CO_2
LI-840A_No. 1	417.2ppm
LI-840A_No. 2	417.0ppm
LI-840A_No. 3	417.1ppm
LI-840A_No. 4	417.6ppm
LI-840A_No. 5	416.0ppm

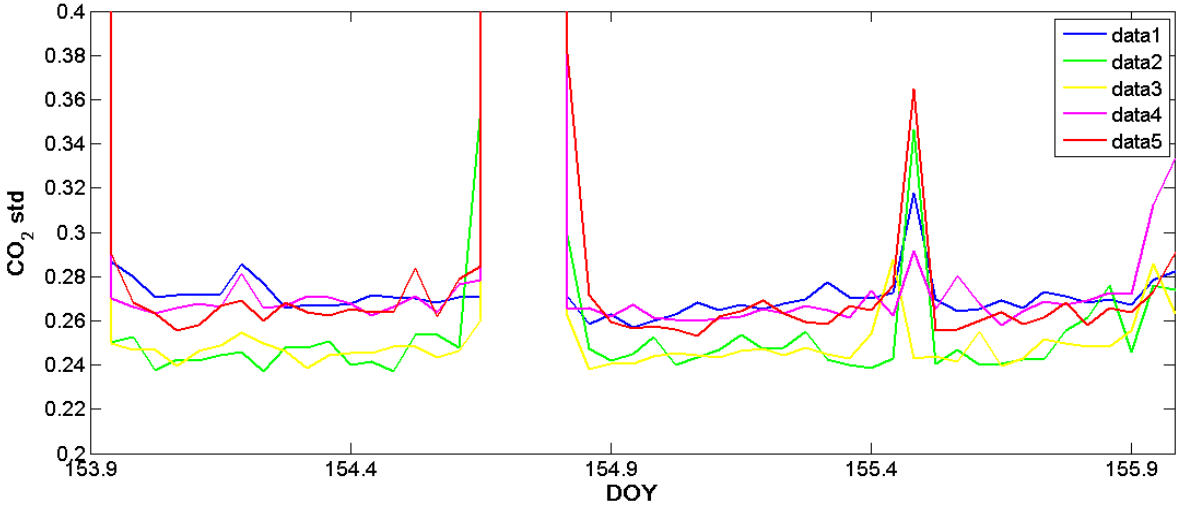

Fig.7 Hourly CO_2 concentration standard deviation .

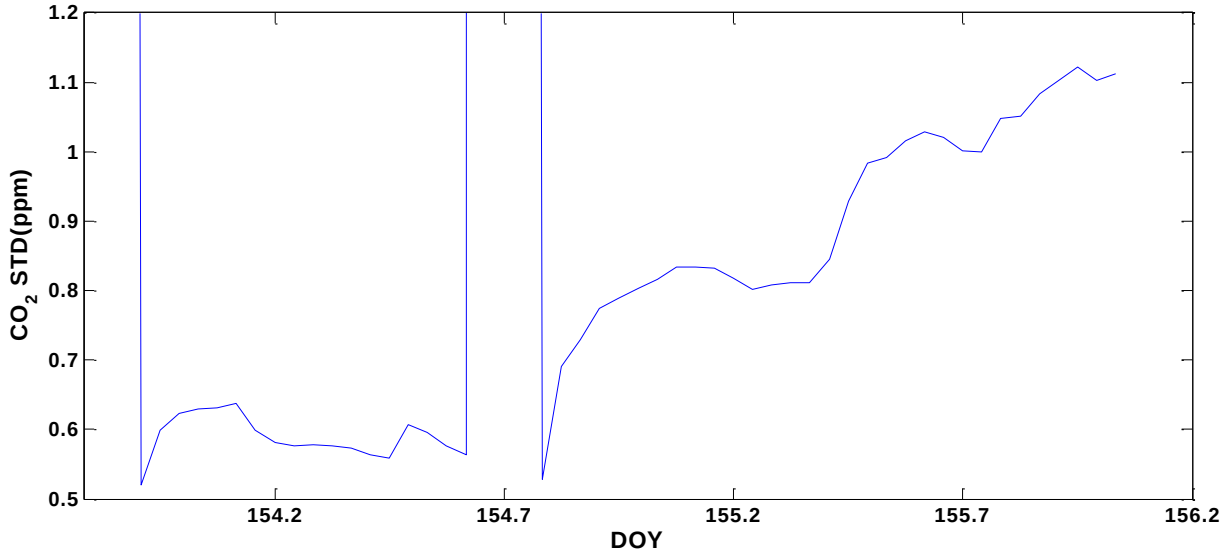

Fig.8 CO_2 concentration standard deviation among instruments.

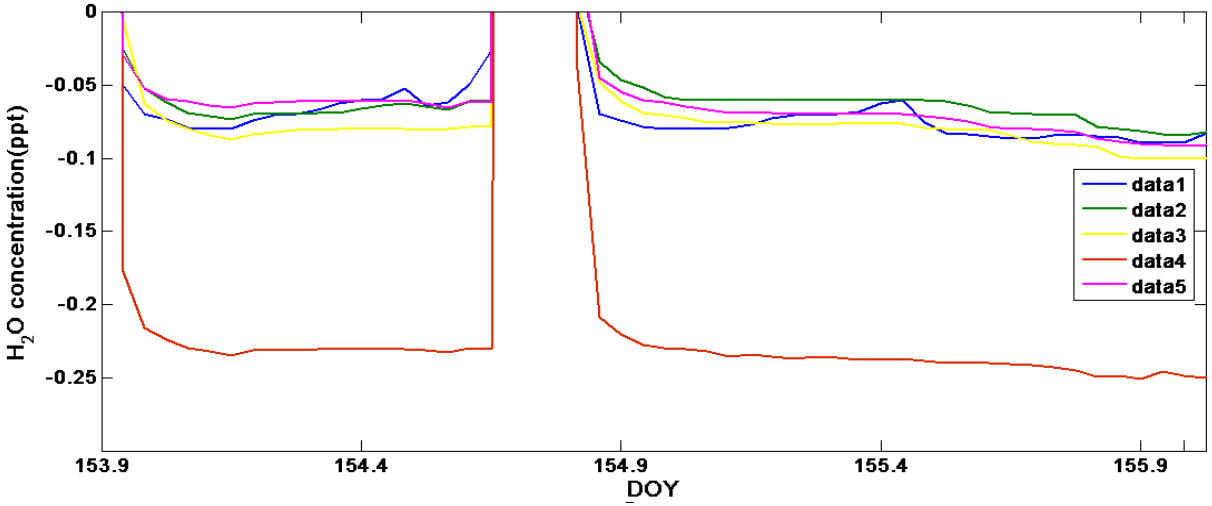

Fig.9 Tank gas observation, hourly H_2O concentration.

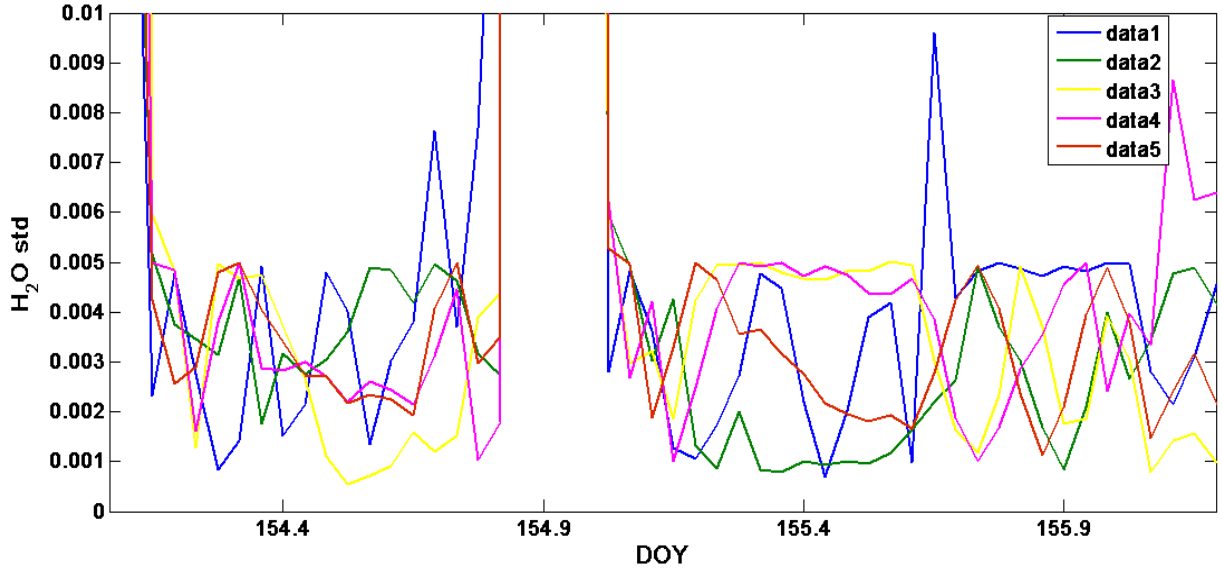

Fig.10 H_2O concentration standard deviation of hourly average.

Table.6 The mean value of H_2O in tank gas observation.

Instruments	Mean H_2O
LI-840A_No. 1	-0.061ppt
LI-840A_No. 2	-0.067ppt
LI-840A_No. 3	-0.08ppt
LI-840A_No. 4	-0.23ppt
LI-840A_No. 5	-0.06ppt

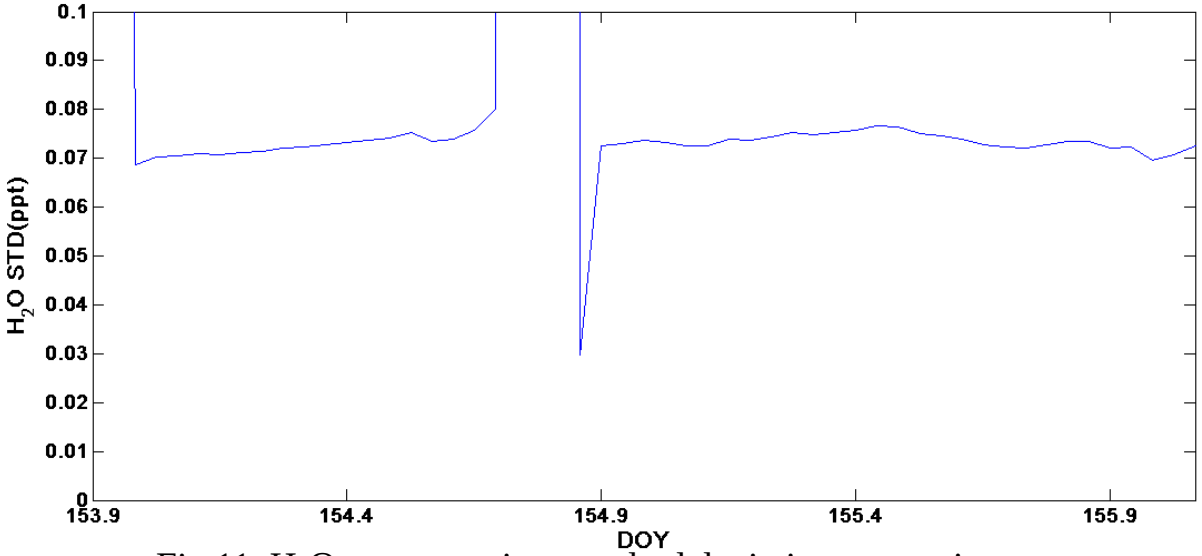

Fig 11. H_2O concentration standard deviation among instruments..

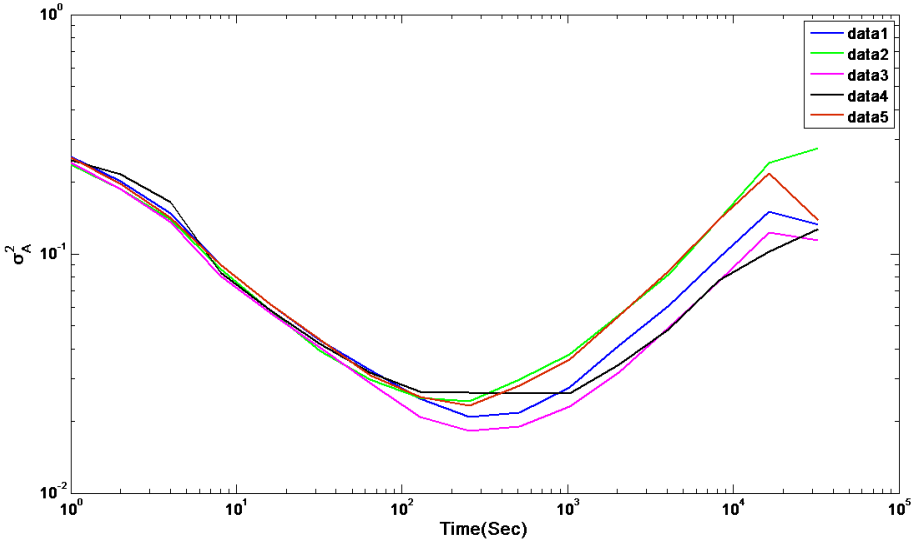

Fig12. Alan variance of CO_2

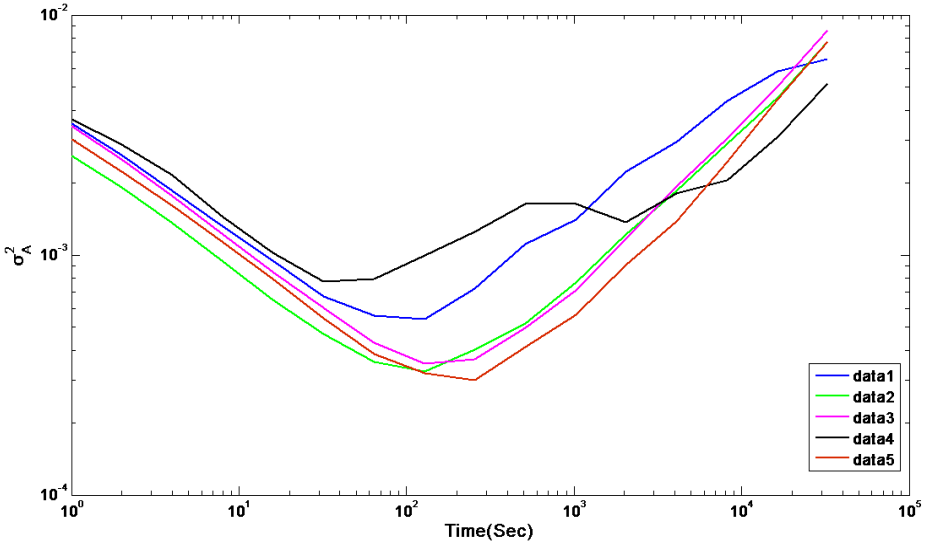

Fig13. Alan variance of H_2O

Experience

This experiment was carried out in the most ideal environment.

Water vapor measuring is stable while the drift of CO_2 measurement is obvious.

Drift of CO_2 measurement is about 1ppm per day and accumulates over time. The drift may be unacceptable if the instrument works more than three days without calibration.

CO_2 measurement of instrument No. 5 and water vapor measurement of instrument No. 4 seems different from the others.

4. Observation in buffer

Buffer observation started on June 27th, four days after calibration, followed by the 416ppm CO_2 stable gas observation.

Observation lasted for 6days. All data correction use July 3rd calibration data, and water vapor correction were also conducted.

When we conducted calibration in July 3rd, LI-840_NO.3 has something wrong so that we must restore factory default settings. As it's parameters of the calibration and observation were different, the NO.3 CO_2 data is not displayed.

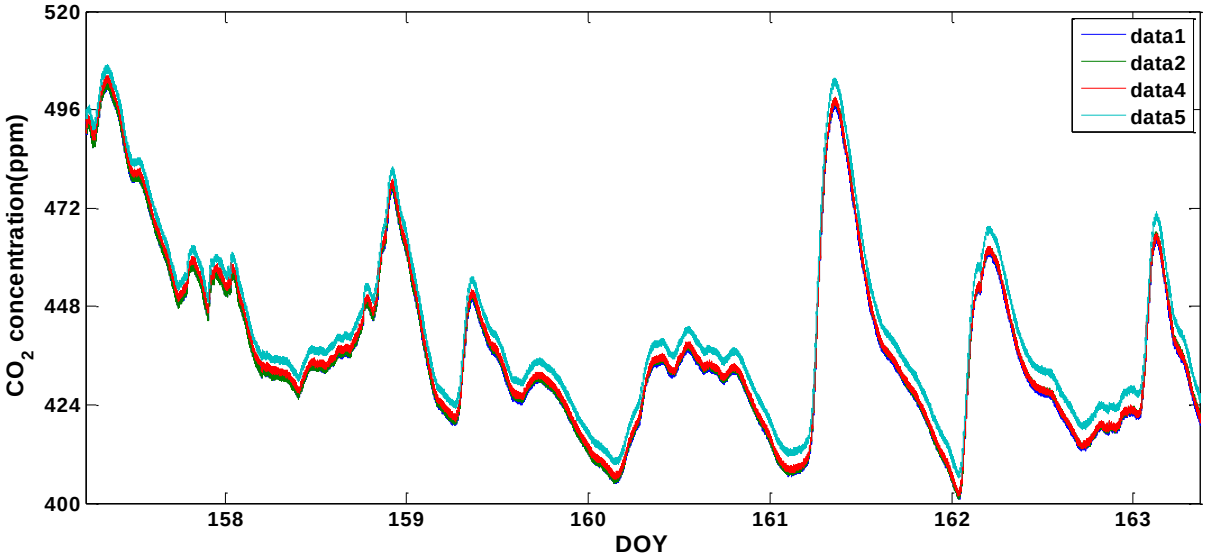

Fig.13 Observation in buffer, dry CO_2 concentration time series.

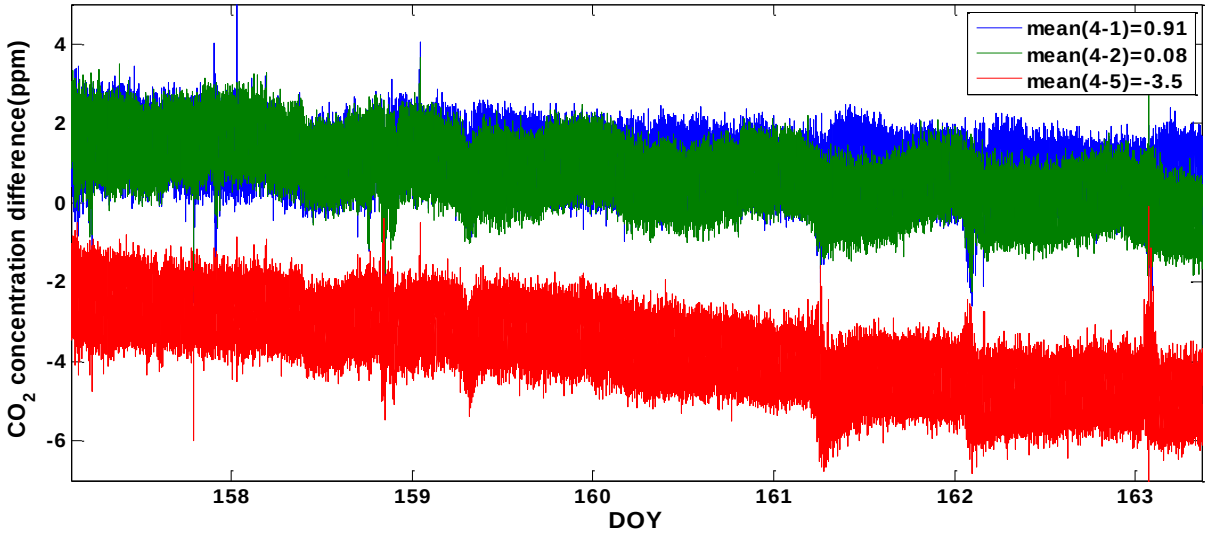

Fig.14 Observation in buffer, dry CO_2 concentration difference.

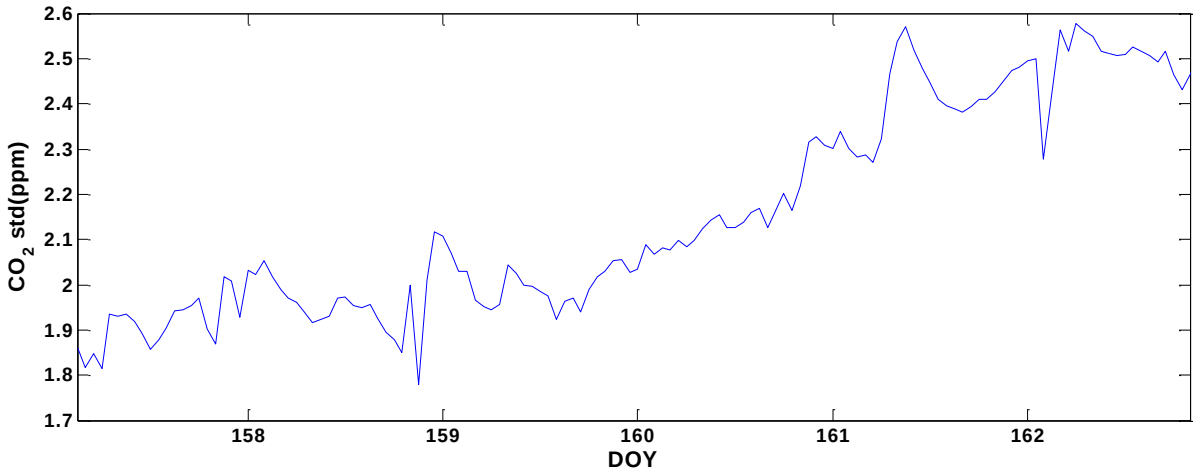

Fig.14 Observation in buffer, dry CO_2 concentration standard deviation of hourly average.

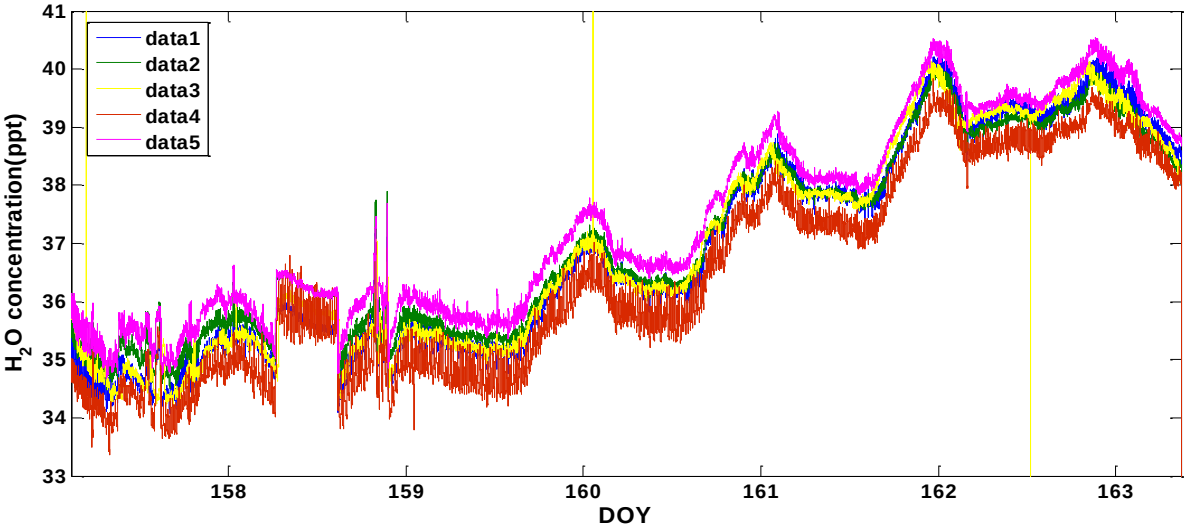

Fig.15 Observation in buffer, H_2O concentration time series.

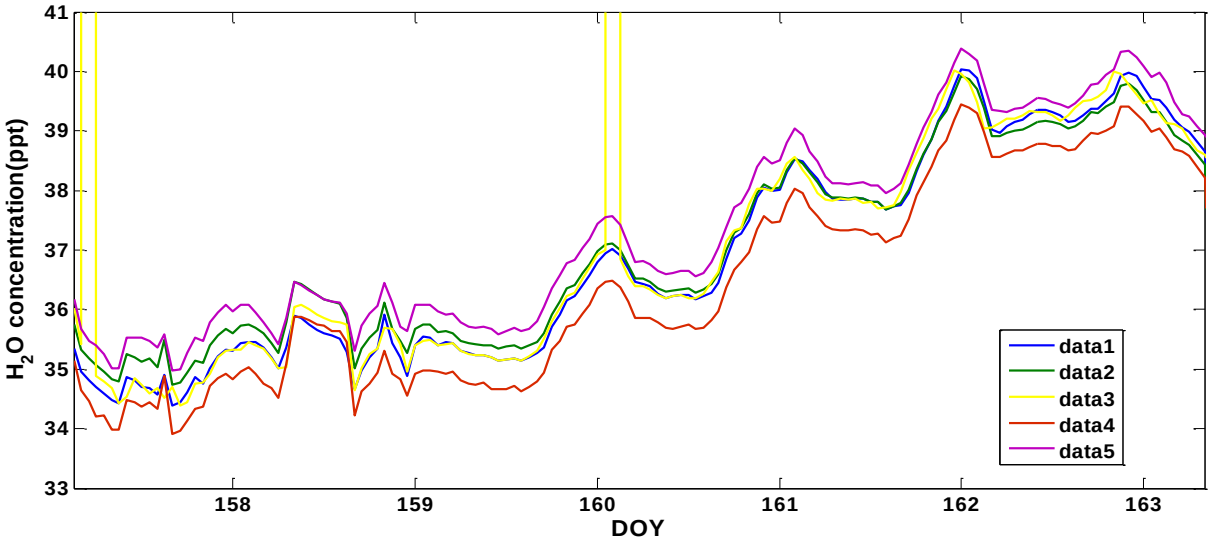

Fig.16 Observation in buffer, dry CO_2 concentration hourly average.

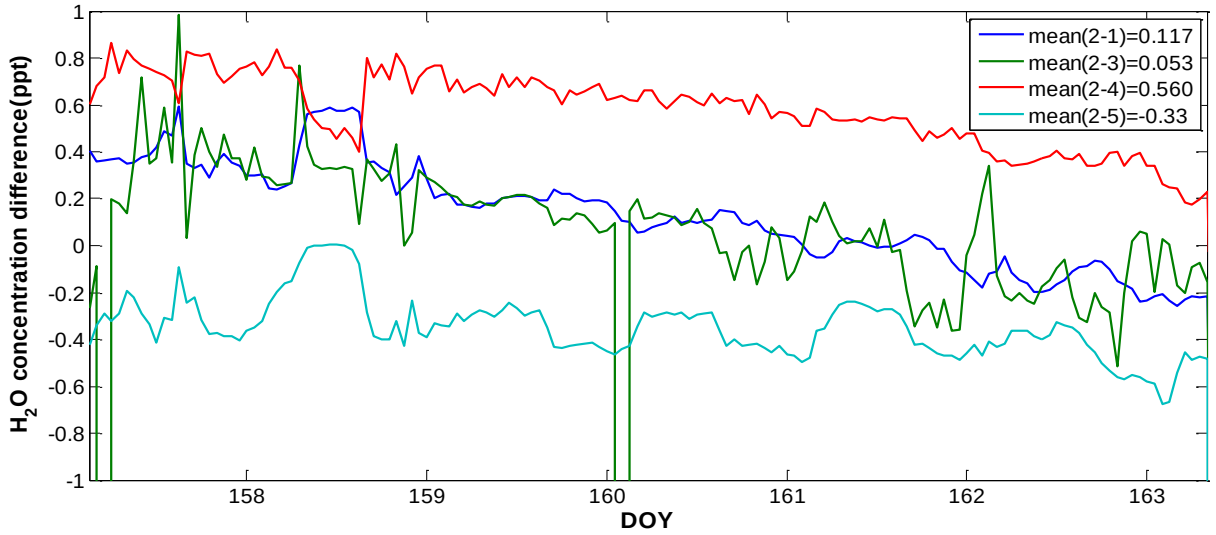

Fig. 15 Observation in buffer, H_2O concentration difference.

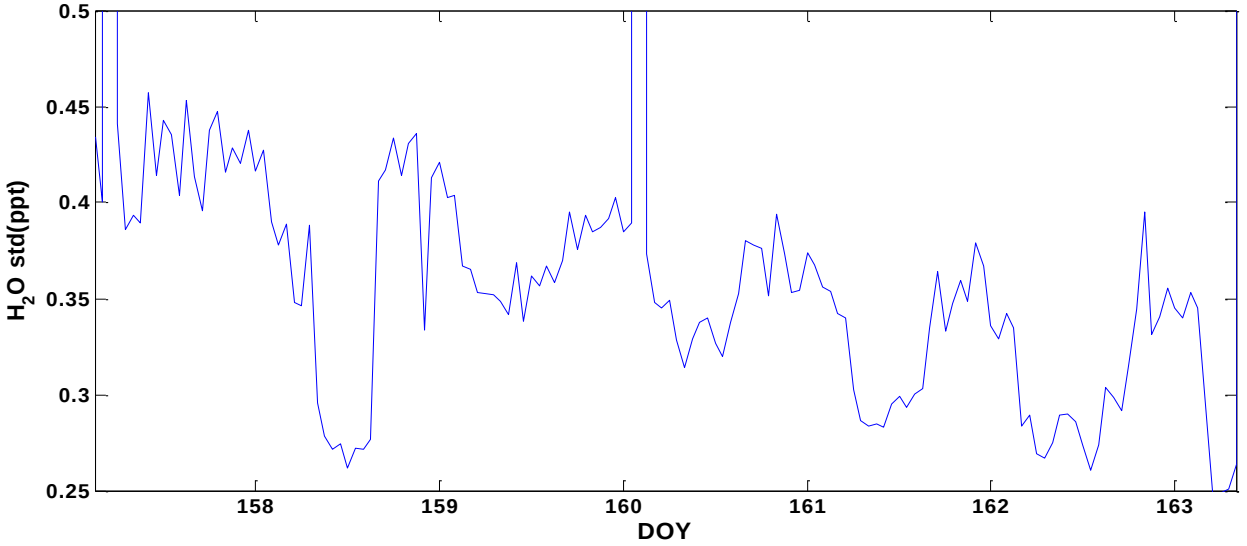

Fig.16 H_2O concentration standard deviation among instruments.

Experience

Combined with the last experiment, the measurement of water vapor concentration is stable though the water vapor concentration variation range is large.

There are obvious noise for LI-840A .

Factory setting is an important data in the maintenance process.

5. Atmosphere observations compared with picarro.

The experiment lasted from July 5th to July 25th .
We carried out calibration on July 2nd and July 21st .

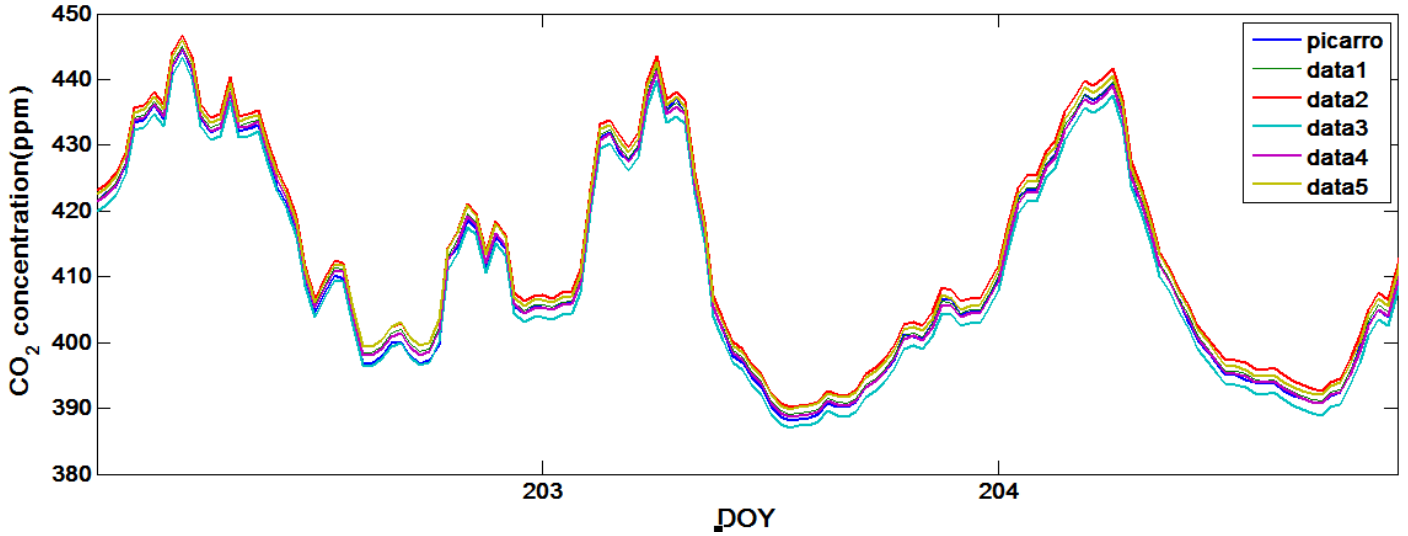

Fig.17 Atmosphere observations, hourly dry CO_2 concentration.

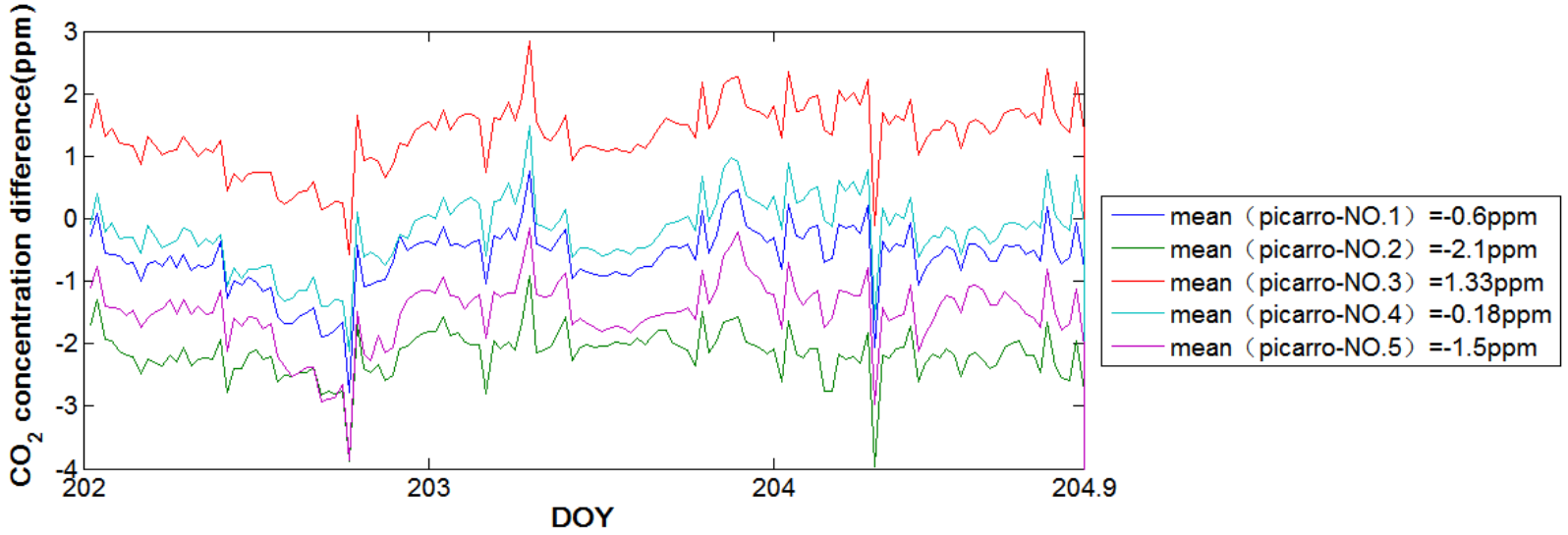

Fig.18 Atmosphere observations, hourly dry CO_2 concentration difference.

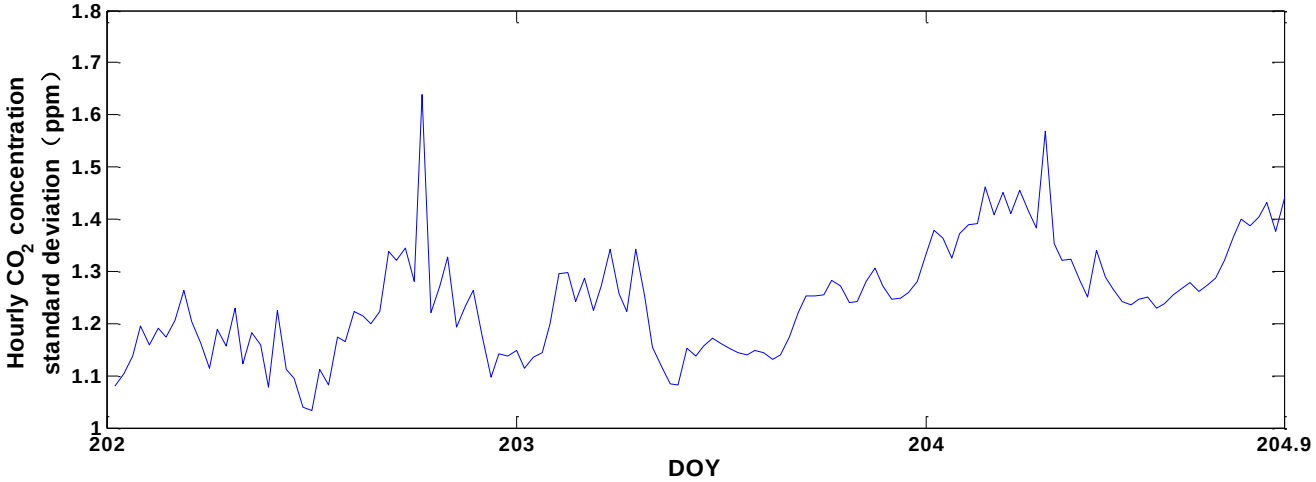

Fig.19 Atmosphere observations ,hourly CO_2 concentration standard deviation.

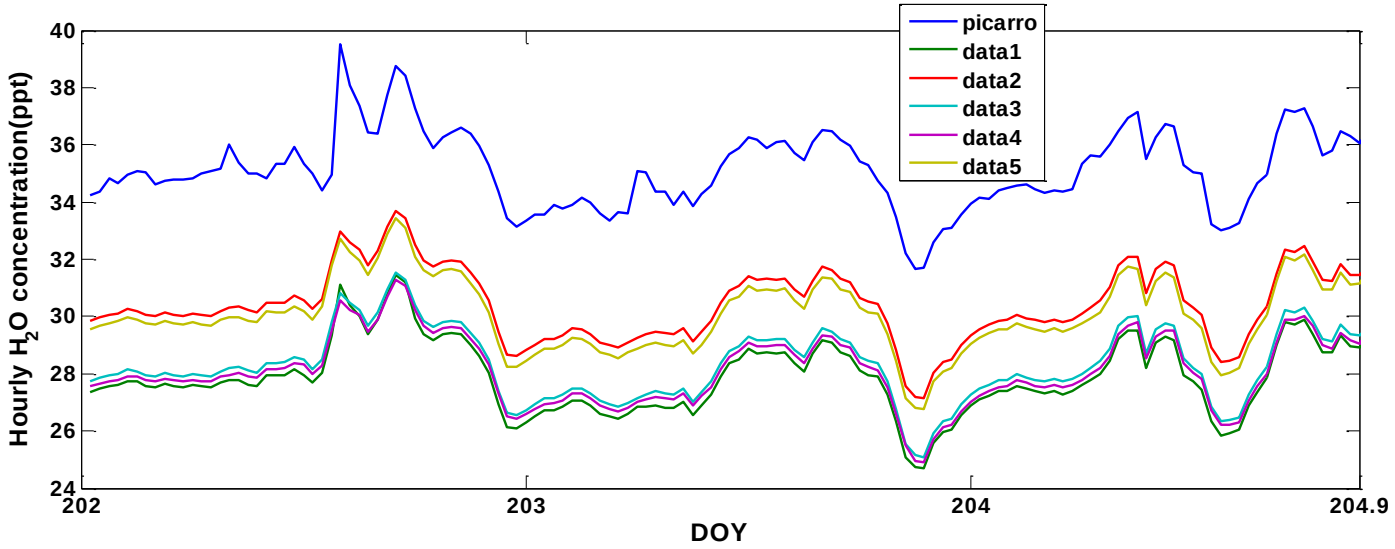

Fig.20 Atmosphere observations, hourly H_2O concentration.

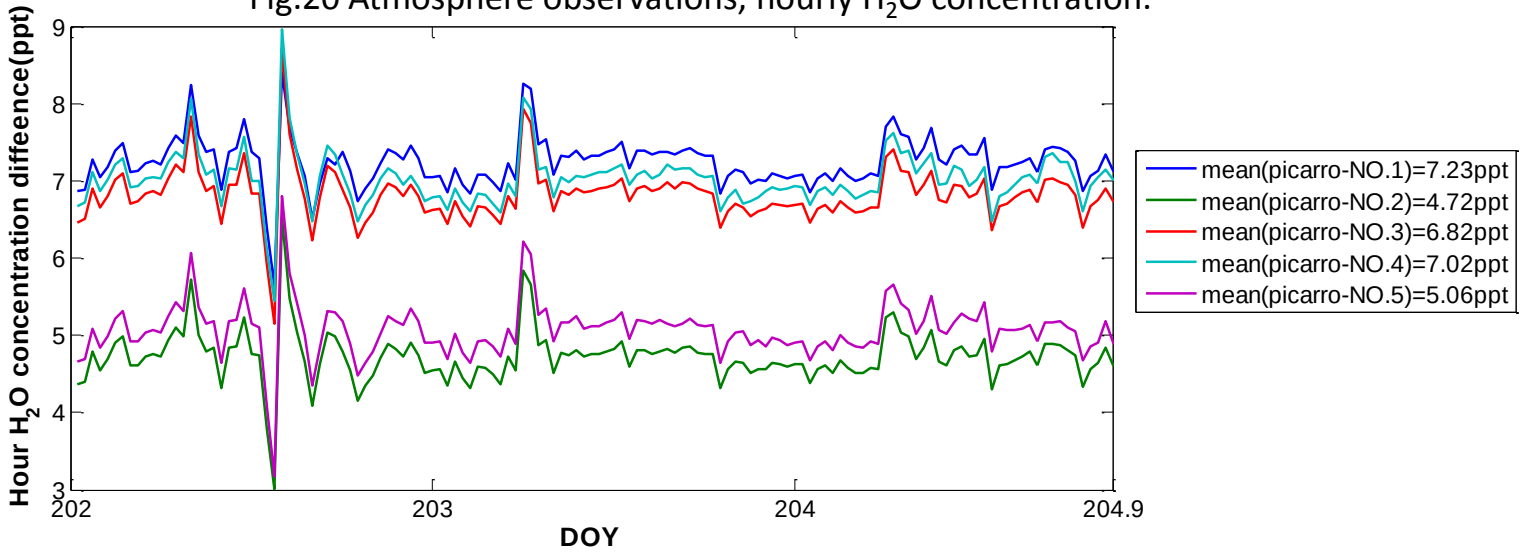

Fig.21 Atmosphere observations, hourly dry H_2O concentration difference.

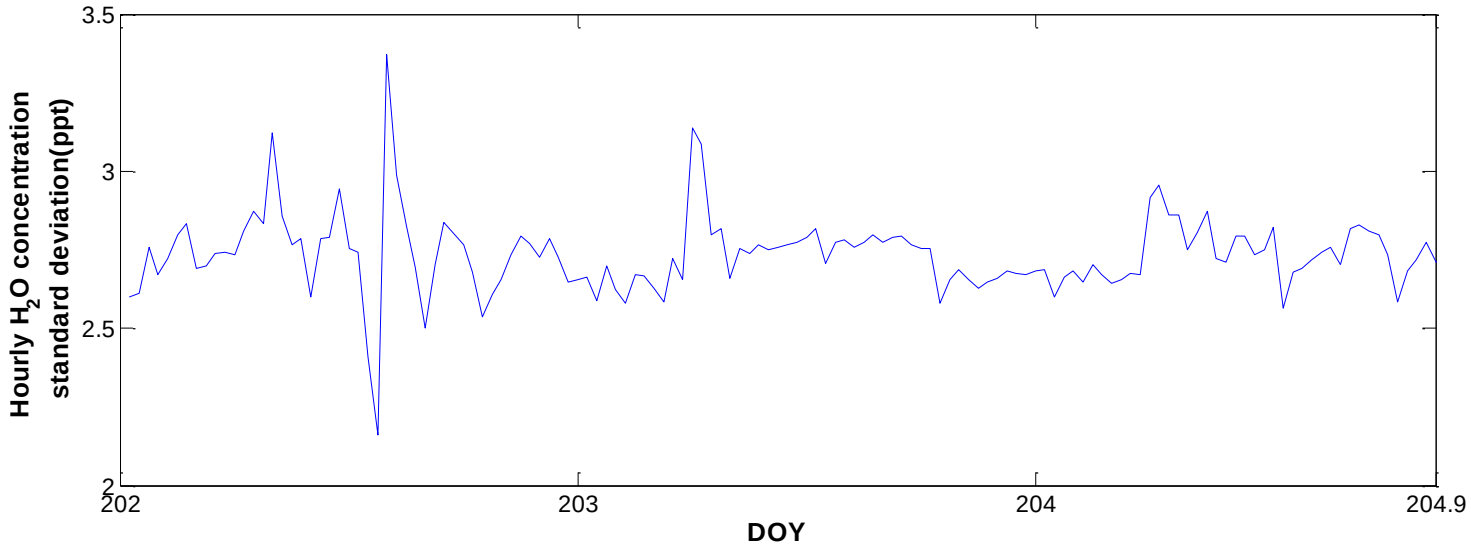

Fig.21 Atmosphere observations ,hourly H_2O concentration standard deviation.

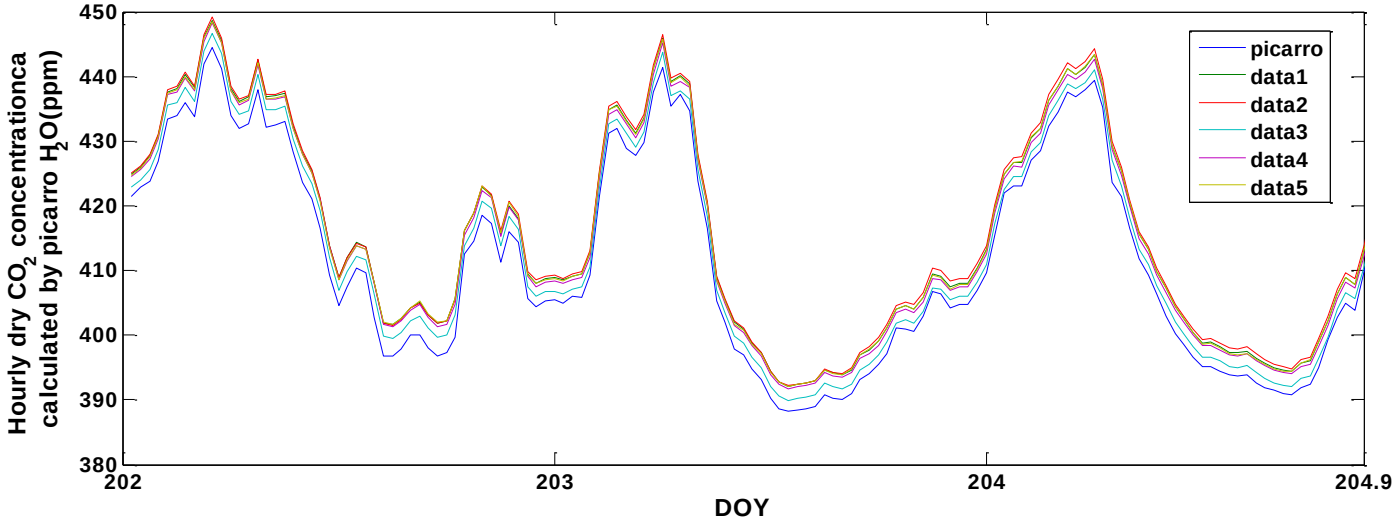

Fig.22 Atmosphere observations, hourly dry CO_2 concentration calculated by picarro H_2O

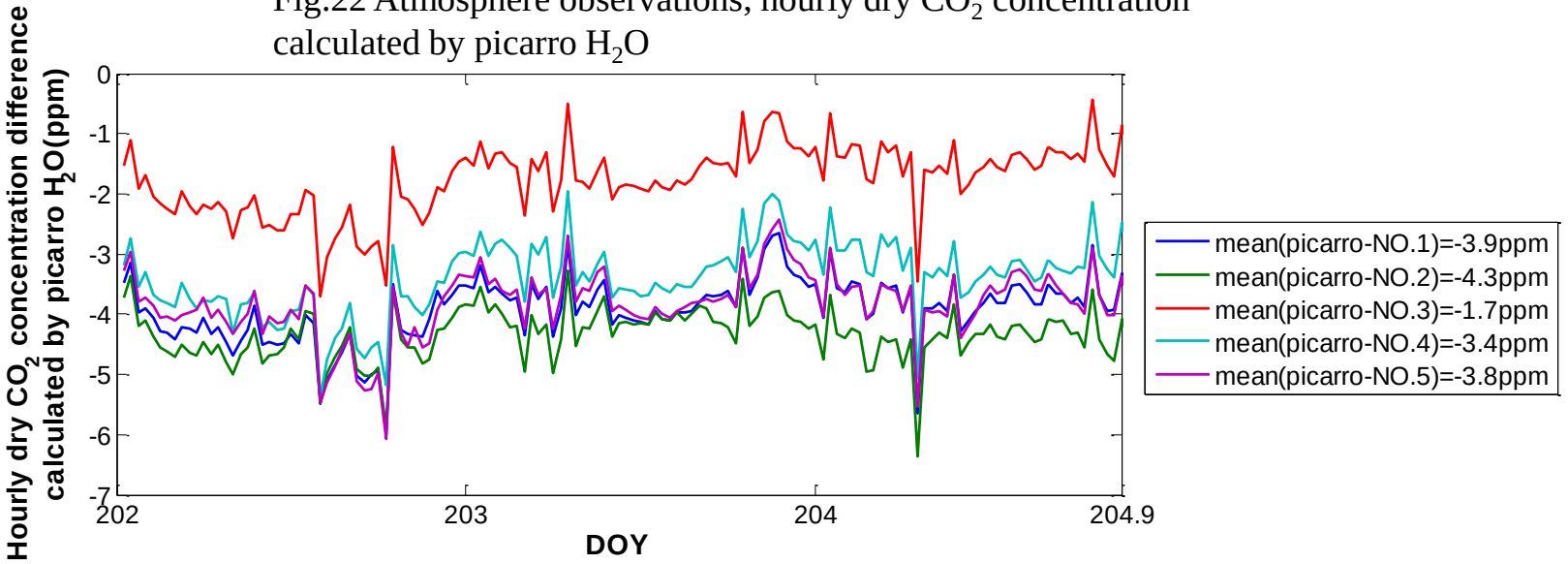

Fig.23 Atmosphere observations, hourly dry CO_2 concentration difference calculated by picarro H_2O.

Conclusion

We can take observation with this insturment if someone take care of it.

Calibration everyday when the instrument works, So that we can control the drift of CO_2 in ±3ppm.

Thank you