JAXA Activities for CO_2 Column Measurement Using Differential Laser Absorption Sensor (LAS)

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Objective

- Development of DIAL/LAS as A candidate of next generation trace gas sensing from space (GOSAT-III, ISS-JEM) in order to quantify and understand the global sinks/sources of CO_2 to improve forecasting of climate change.
  - Advanced telecom laser technology in 1.57 μm region used for multi-wavelength laser transmitter for CO_2 measurement.
  - Advanced detector technology or COTS detector used for improved detection of ground/cloud reflected laser return.
  - Advanced measurement techniques used in analysis of high precision CO_2 measurement.

- Comparison/Validation of GOSAT TANSO-FTS
  - Ground-based Differential LAS measurement

Time schedule of Differential LAS system

~ 2007	Conceptual study Build the prototype system
2008.7 2008.9	Check basic instrument parameters Re-build for observation wavelength
2009.1 2009.5 2009.8	Added Range measurement function Complementary measurement with high accurate in situ sensor on the Ground. First aircraft measurement to evaluate system performance
2010.2	Second aircraft measurement to synchronize the GOSAT

Engineering

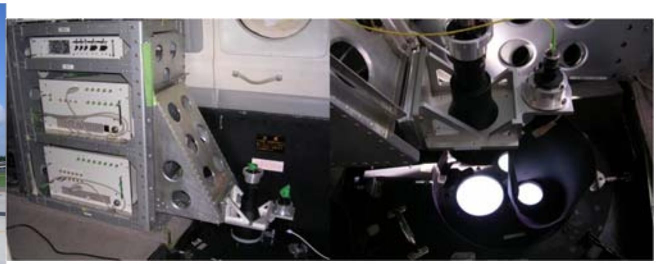
- H/W development
- Ground/Aircraft measurement
- Detail analysis
- Define TRL

Science

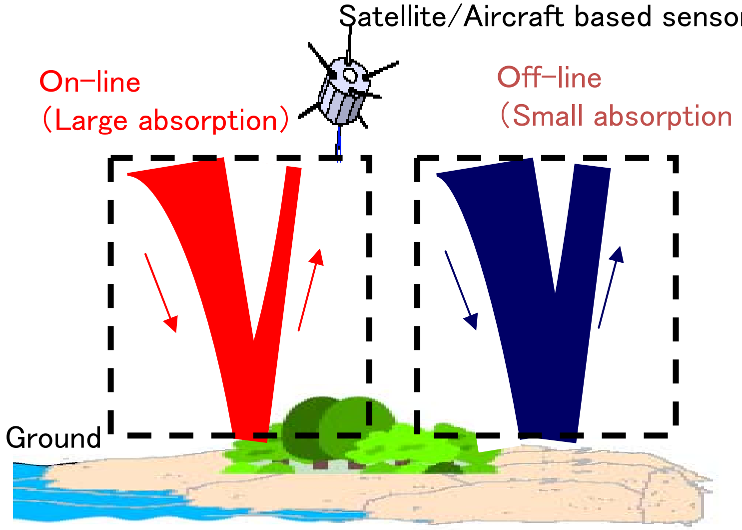
- Measurement requirement
- Accuracy/Precision ?
- Spatial resolution ?
- Time resolution ?
- Monthly/Anual average?

Understanding gaps and matching to feedback scientific approach & H/W

Principle of Differential LAS



ON-line : Large CO2 absorption
Off-line : Small CO2 absorption



Measurement space

Transmit two laser liht (On-line, Off-line)

CO_2 absorbance (On-line)

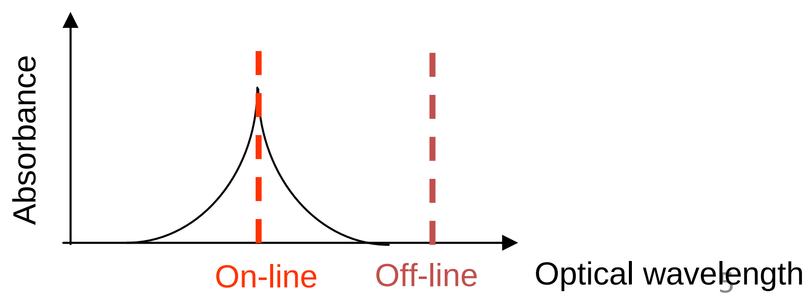
Ground-scattering

Receive signals

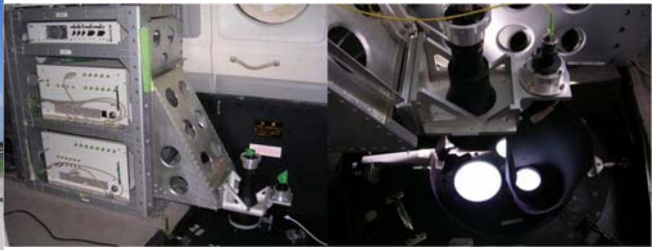
Evaluate CO2 mixing ratio

CO2 density ∝
Absorbance (from receiving signals)

・Absorption line of CO2 & Laser oscillation wavelength



Principle of Differential LAS



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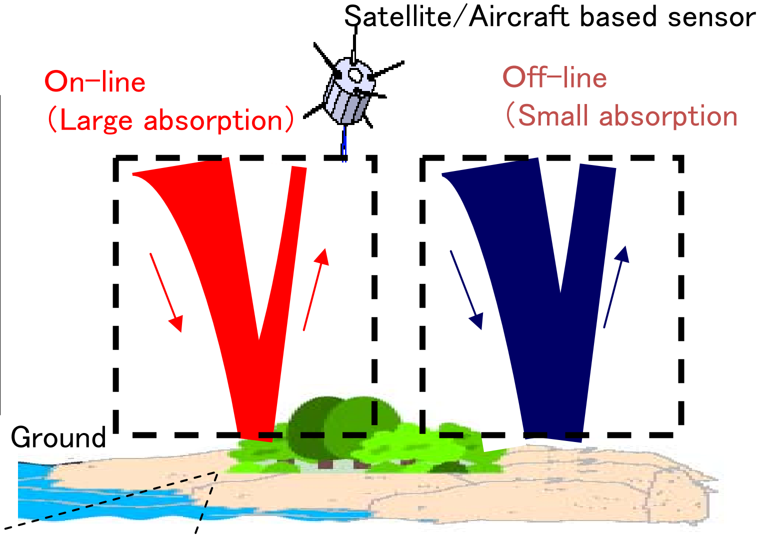


Measurement space

Transmit two laser liht (On-line, Off-line)

CO_2 absorbance (On-line)

Ground-scattering

Receive signals

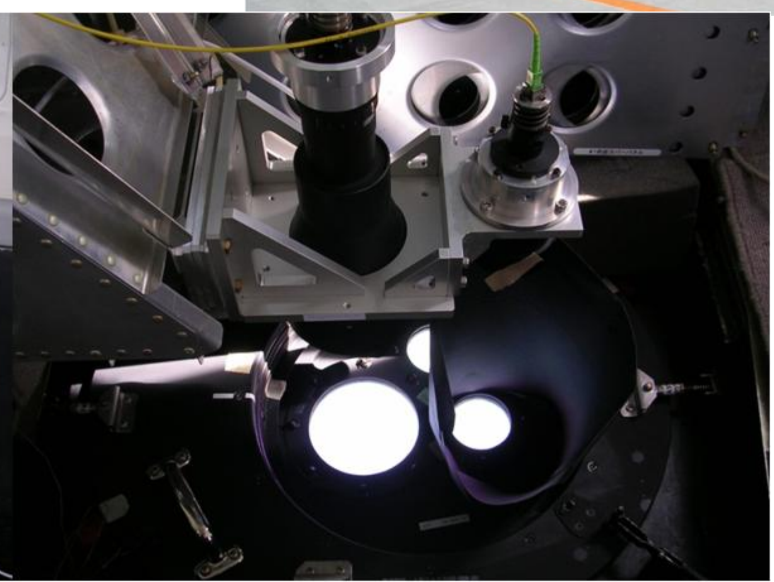
Evaluate CO2 mixing ratio

No impact of the variation of surface reflectance along/cross track on CO2 density measurement

Absorbance of CO2 and range from aircraft/satellite can be observed

Aircraft measurement

JAXA/MELCO Engineering Development system used to validate end-end system performance model; technology readiness algorithms to evaluate CO2 MXR for future Mission; and capability for high precision CO2 measurement.



Aircraft measurement

- Complementary Measurements
  - High-precision in situ CO2 profiles and Flask sampling.
  - Nearby, contemporaneous radiosonde temperature, moisture, and pressure profiles.
  - Accurate GPS unit with aircraft attitude information.
- Measurement Conditions
  - Wide range of surface (land and water) types.
  - Ability to operate from several aircraft altitudes.
  - Evaluate measurements in presence of scattered clouds.
  - Ability to do horizontal laser calibrations between flights on the ground

Flight tracking (August 2009, February 2010)

#	Date	Flight	Take off /landing	Clouds condition
1-1	August 24, 2009	Middle of Japan -> North of Japan	0731 / 1200	Fully clouds
1-2	August 25, 2009	Spiral	1215 / 1415	Many clouds
1-3	August 26, 2009	Spiral (Ground-FTS, Radiosonde)	1155 / 1605	Mostly Clear: Taiki Clouds: Moshiri
1-4	August 29, 2009	Spiral	1200 / 1430	Mostly Clear
1-5	August 30, 2009	Spiral	1200 / 1430	Partially Clouds
1-6	August 30, 2009	Middle of Japan -> North of Japan	1500 / 1800	Fully clouds

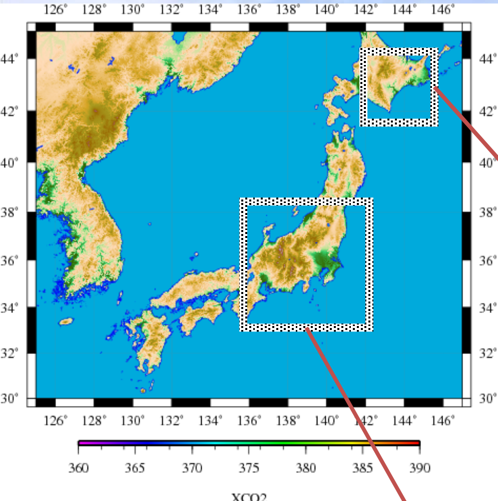
#	Date	Flight	Take off /landing	Clouds condition
2-1	February 14, 2010	Near Tokyo	1030 / 1500	Many clouds
2-2	February 20, 2010	Near Tokyo	1030 / 1500	Mostly clear But haze in boundary layer
2-3	February 23, 2010	Near Tokyo	1030 / 1450	Mostly clear But haze in boundary layer

Location

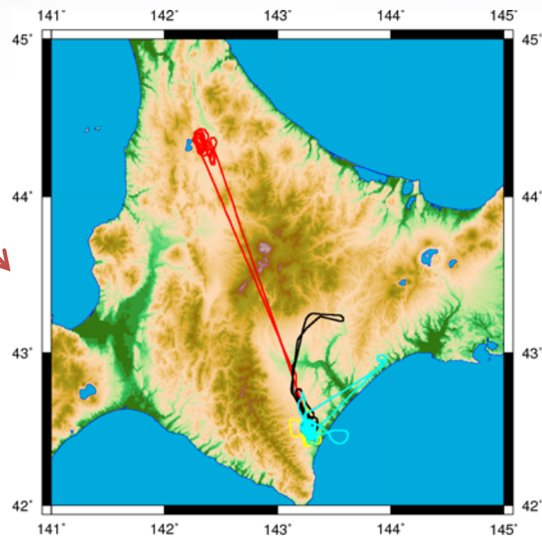
Moshiri(Aug. 26)

Taiki(Aug. 26)

Aircraft measurement of Active CO2 instrument

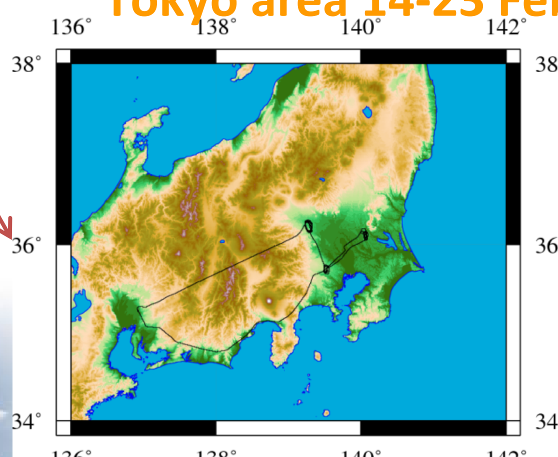


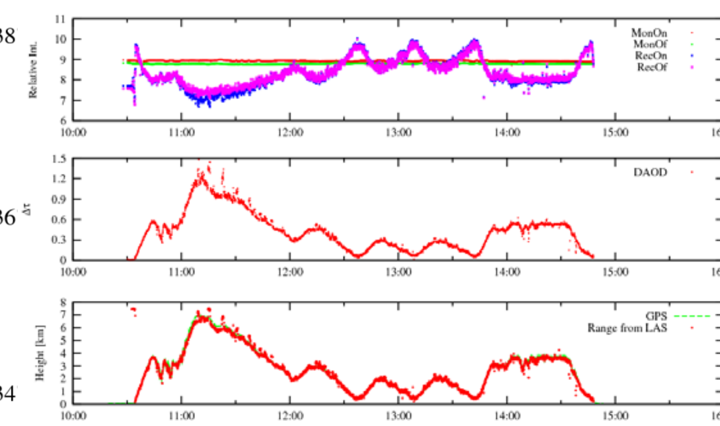
North of Japan 24-30 August 2009 (6 flight)



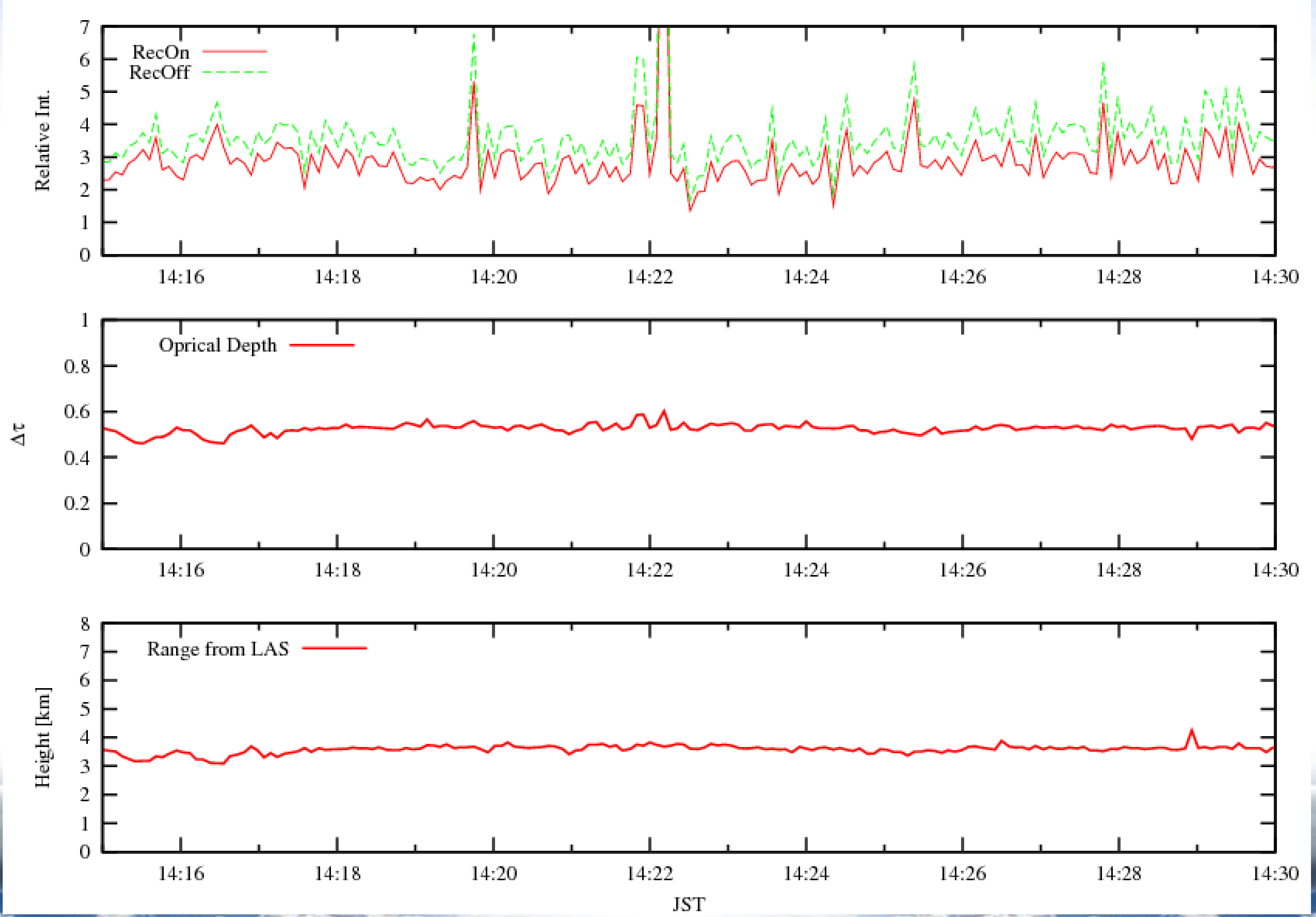
- ✓ Airborne instrument is very stable and is able to obtain high precision data
- ✓ Radiometric performance of CO2 lidar instrument model compares well with observed measurements
- ✓Obtained high-quality remote and in situ data and initial indications are that the remote CO2 measurements are within 3% of modeled optical depths from in situ measurement.

Tokyo area 14-23 February, 2010 (3 flight)

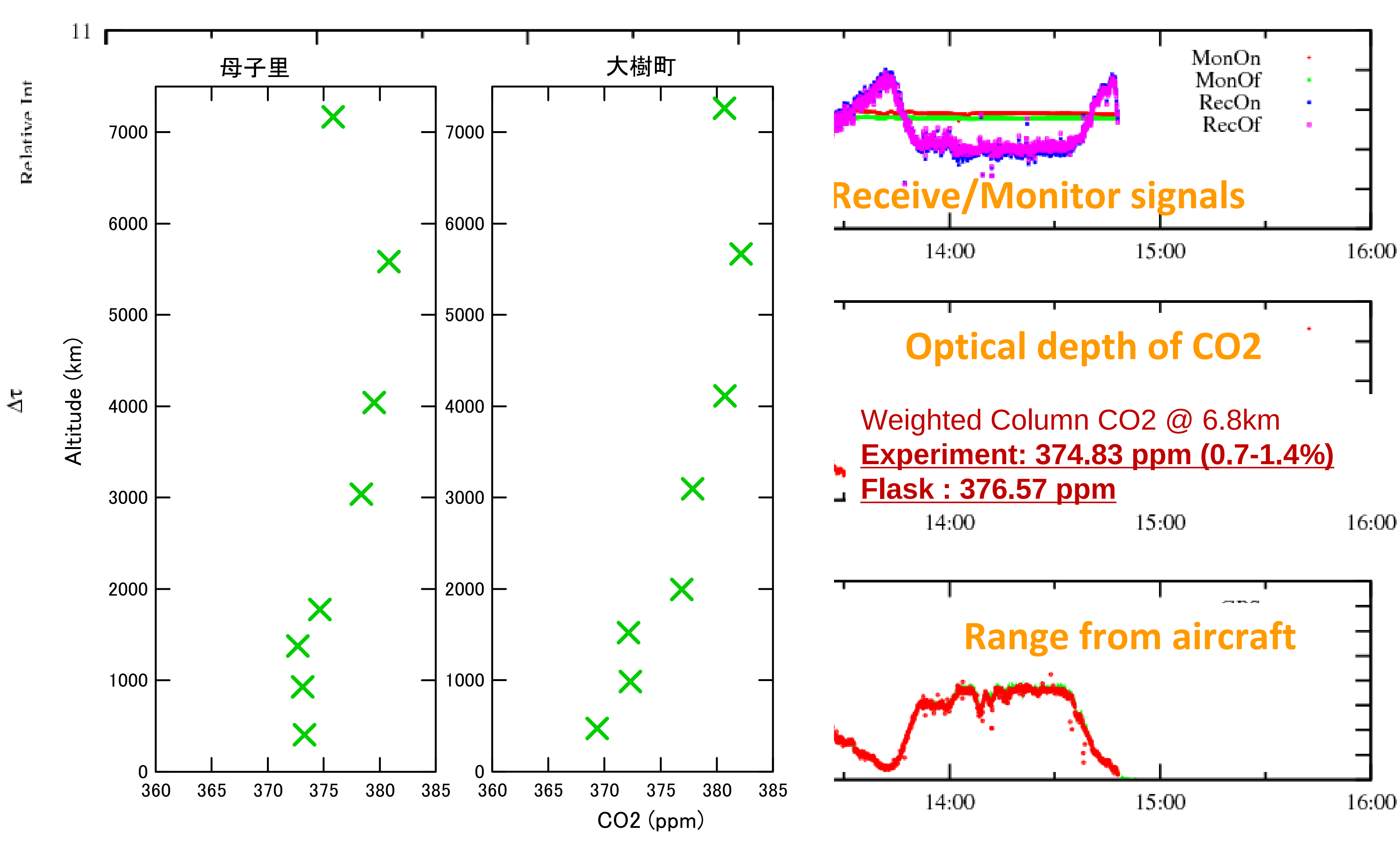




Aircraft measurement of Active CO2 instrument

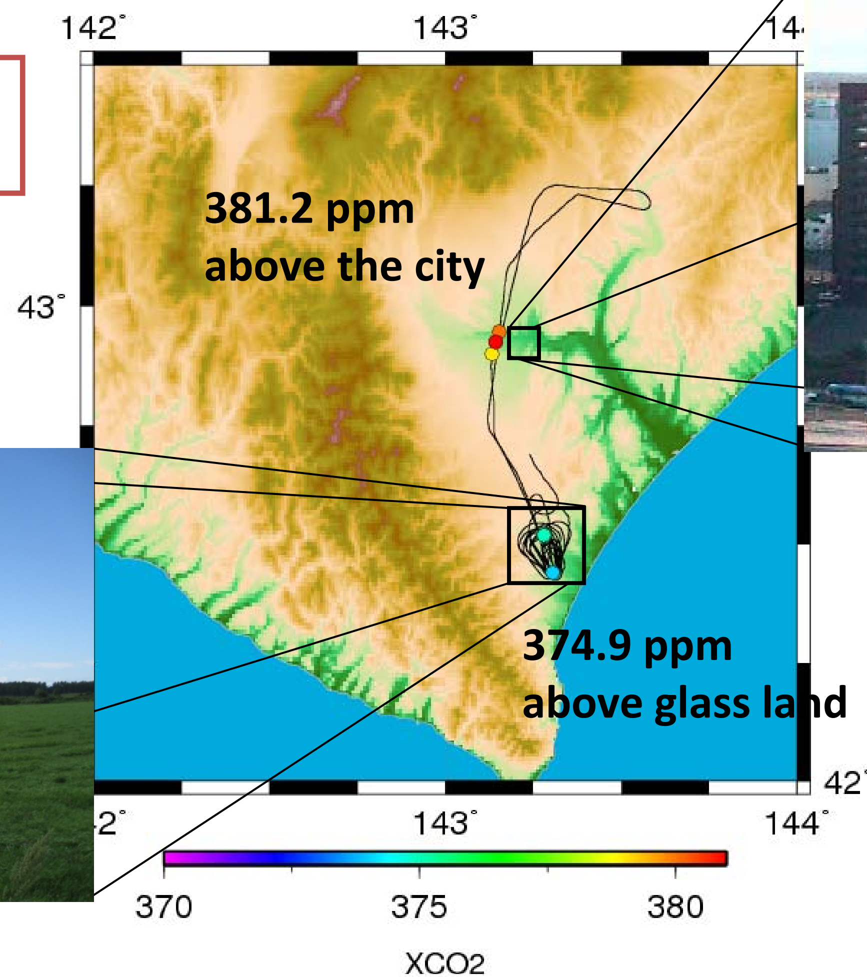


Aircraft measurement of Active CO2 instrument



CO2 column amounts above the city and glass land

Ex.) Airborne flight measurement



Obihiro city

Glass land

We observe the difference between CO2 column amounts above the city and glass land

Summary

- We obtained data set for airborne flight instrument performance evaluation

- Flight measurements conducted over wide range of surface reflectances, including measurements in presence of water clouds, and determined their effective backscatter reflectance at 1.57 micron.

- Initial indications are that the CO2 column amounts are within 1.7 ppm of the expected column amounts calculated from flask CO2. It is expected that these results will improve even further as higher order instrument characteristics are accounted for.

Future work

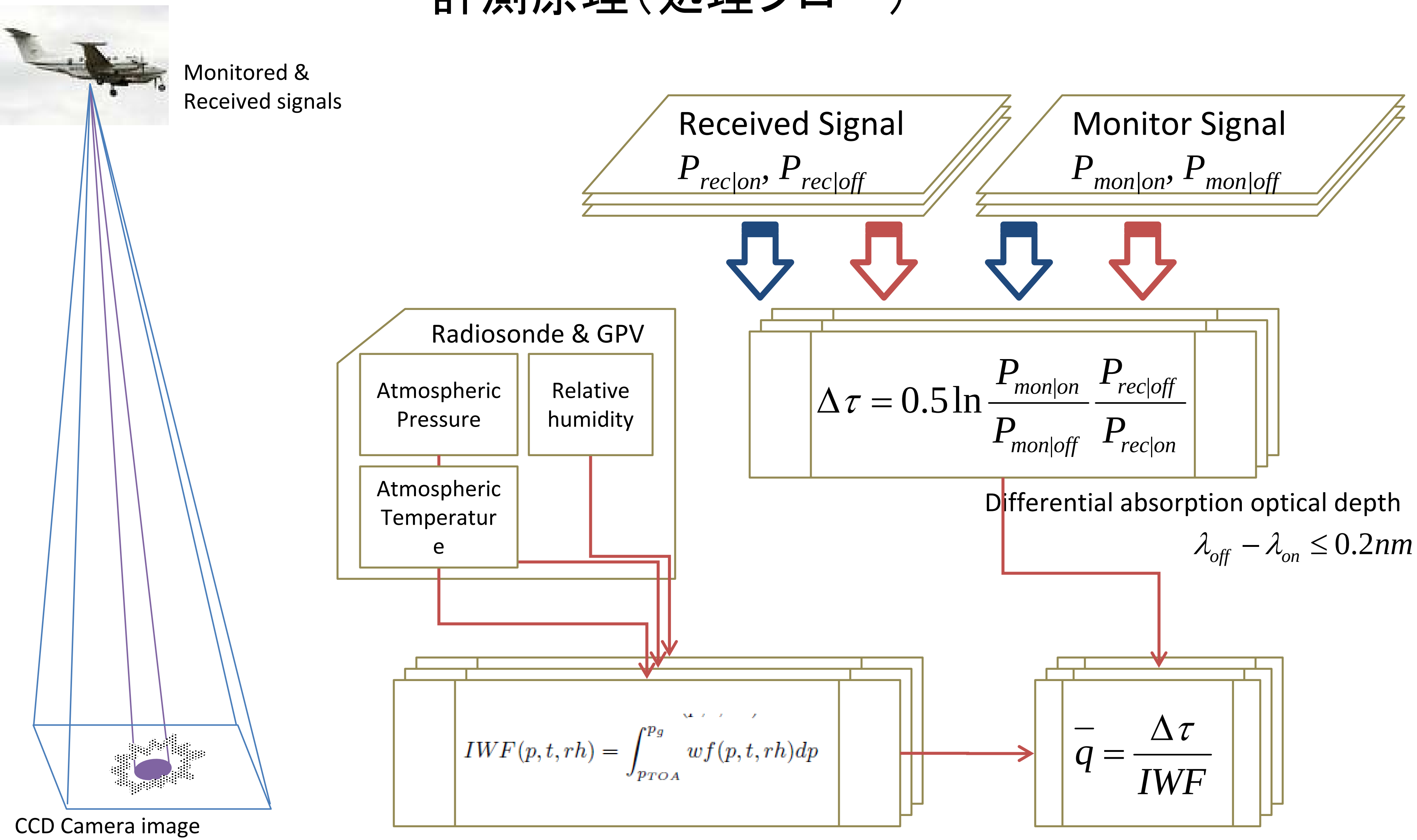
- Our small group started the conceptual study for active laser sensing of CO, N_2O

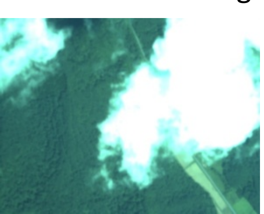
- GOSAT Cal/Val measurement

航空機観測の感度解析

	August 2009	February 2010	
SNR	1.2%	0.51%	Random
Meteorological parameters	0.438 (T 1K) 0.062 (P 1hPa) 0.02 (RH 10%)	0.23% (T 1K) 0.34% (P 1hPa) 0.03% (RH 10%)	Bias
Range accuracy	0.12 %	0.13%	Random
Spectroscopic Parameters	0.12 %	0.12%	Bias
Wavelength fluctuation	**0.576 %** **(+ g shift)**	**0.15%** **(Center wavelength)**	**Random**
Wavelength Drift			**Bias**
Uncertainty (Random & Bias)	1.40%:	0.69%	Random

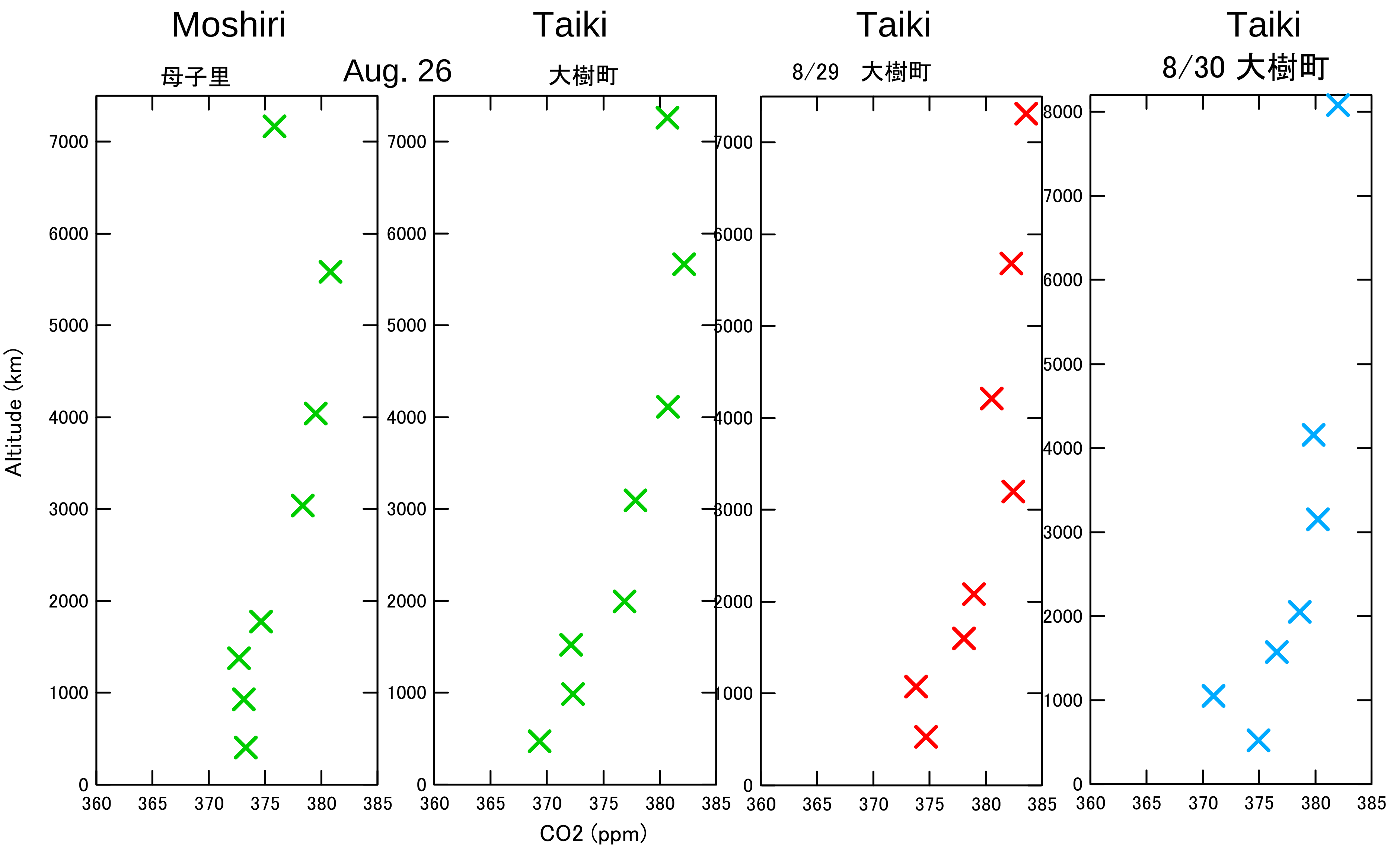
計測原理(処理フロー)





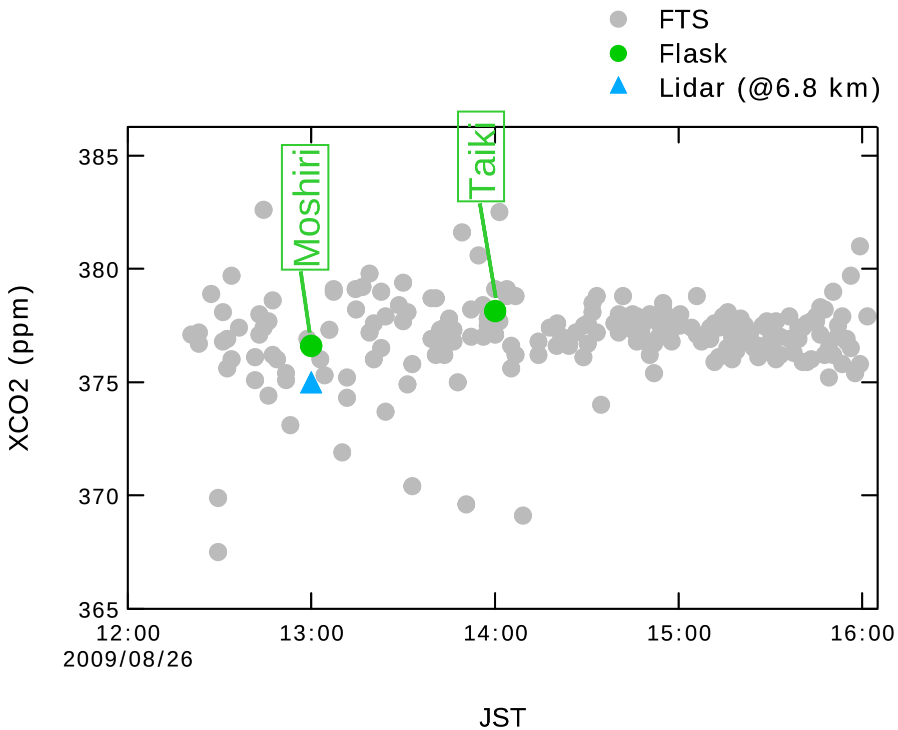
$$wf(p,t,XH2O) = \frac{\Delta\sigma_{CO2}(p,t)}{m_d g}\left(1 + \frac{m_{H2O}}{m_d} XH2O\right)^{-1}$$

フラスコサンプリングデータ

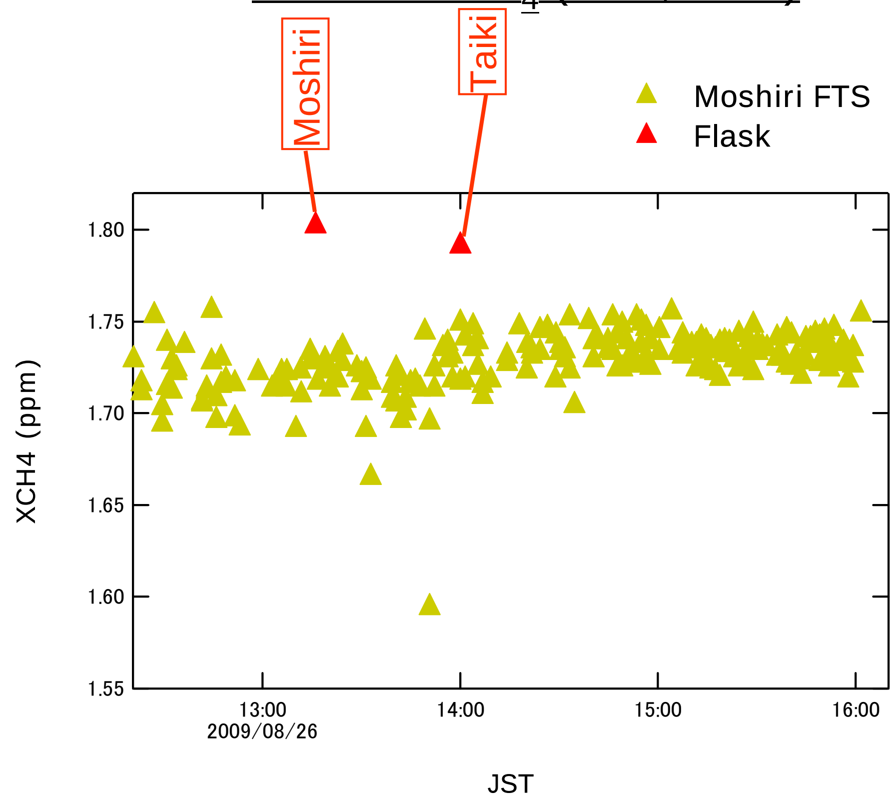


FTS データとの比較

Moshiri XCO_2 (FTS, flask, lidar)



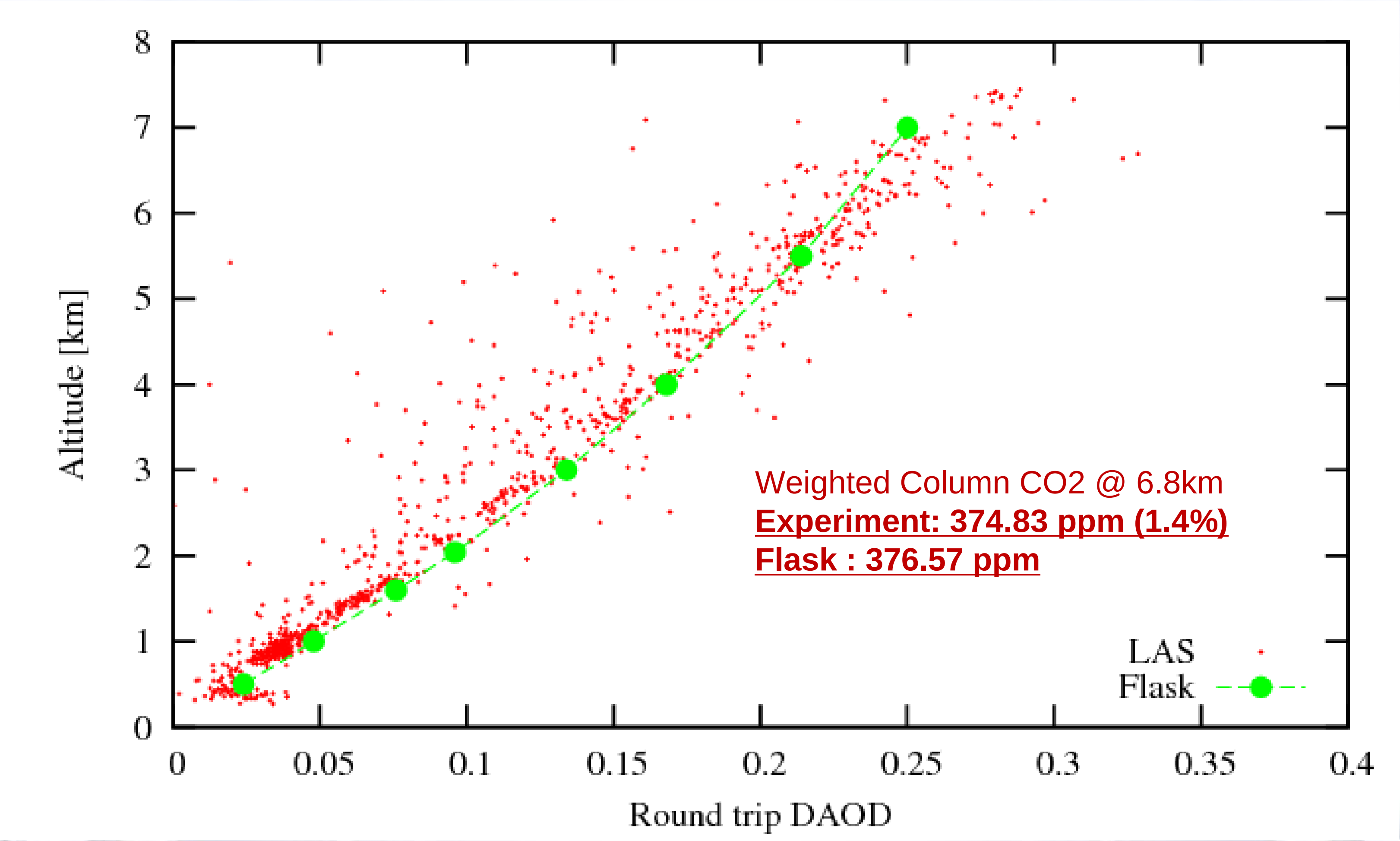
Moshiri XCH_4 (FTS, flask)



		VMR (ppm)	observation time
FTS (GFIT)		376.9±2.61	12:36 – 13:57
Flask	Moshiri	376.61	12:36 – 13:57
	Taiki	378.14	14:34 – 15:46
Lidar (0–6.8 km)		374.83	12:36 – 13:57

		VMR (ppm)	observation time
FTS (GFIT)		1.715±0.021	12:36 – 13:57
Flask	Moshiri	1.802	12:36 – 13:57
	Taiki	1.791	14:34 – 15:46

高度-OD プロット



Altitude [km]
Round trip DAOD
Weighted Column CO2 @ 6.8km
Experiment: 374.83 ppm (1.4%)
Flask : 376.57 ppm
LAS
Flask