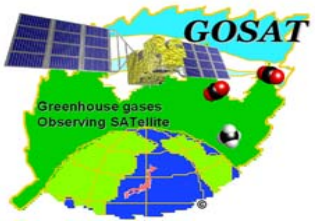

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JAXA
宇宙航空研究開発機構

Calibration Plan for GOSAT Sensors

Kei Shiomi and Shuji Kawakami

Japan Aerospace Exploration Agency

Contents

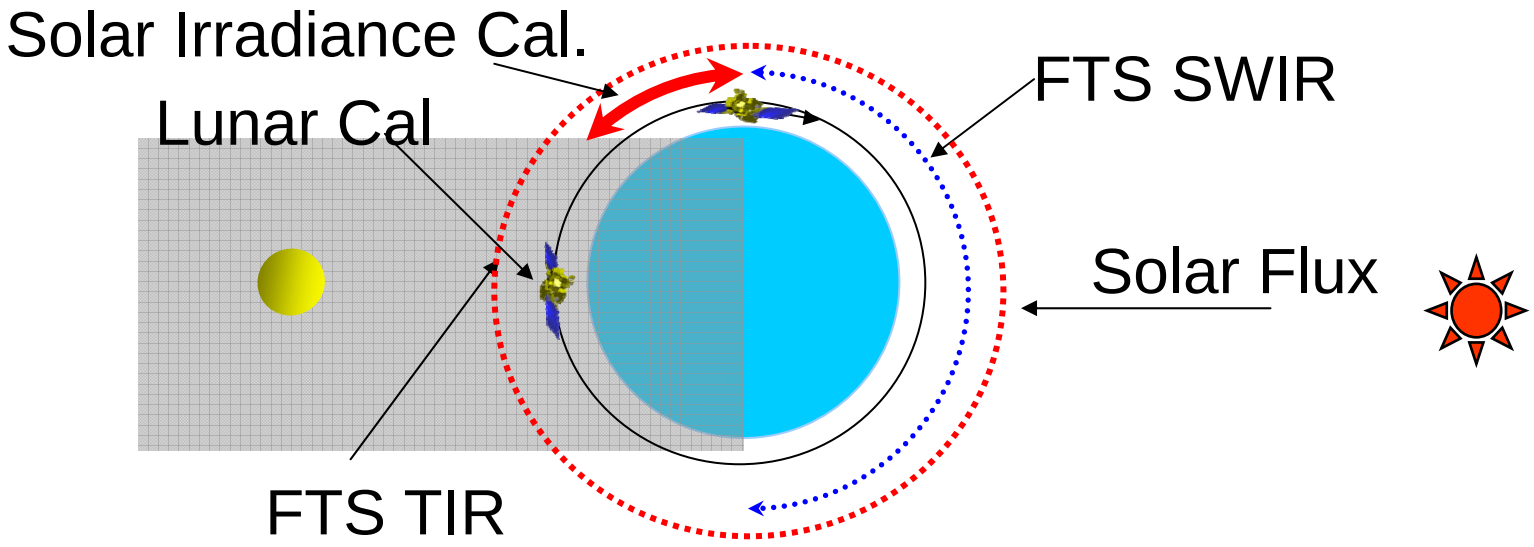
- FTS calibration
  - Calibration items
  - In-orbit operation
  - Onboard calibration
  - L1 processing
  - Vicarious calibration
- CAI calibration (briefly)
- Summary

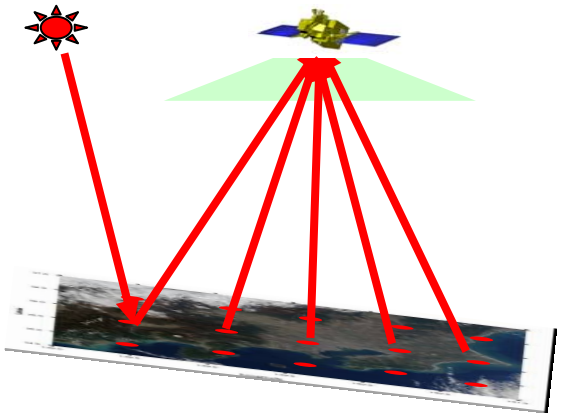

TANSO-FTS

Calibration overview of TANSO-FTS

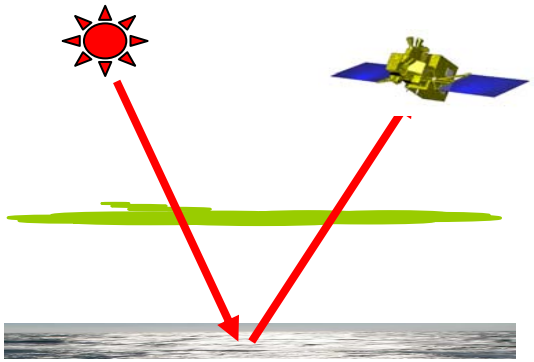
- Pre-flight Test (PFT)
  - Radiometric characterization
  - Spectral characterization
  - Alignment
- Onboard Calibration (OBC)
  - Dark target
    - Deep space (FTS-SWIR/TIR)
  - Bright target
    - Solar irradiance (FTS-SWIR)
    - Blackbody (FTS-TIR)
  - Spectral calibration for ILS
    - 1.55μm laser (FTS-B2)
  - Lunar observation
- Vicarious Calibration (VC)
  - Radiometry
    - Cross calibration – using DB and other satellite data
    - Cal/Val experiment – using in-situ experimental data
    - FTS-CAI relative radiance of 1.6μm band
  - Geometry
    - Pointing accuracy
      - Coastlines
    - Pointing stability
    - Band-to-band registration
    - FTS-CAI registration
      - IFOV monitoring camera
  - Spectral Quality
    - Spectral accuracy
      - Absorption lines
    - SNR
      - Desert

Operation of FTS

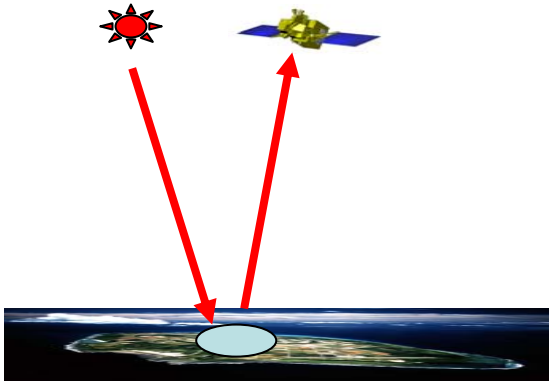




Nominal observation
(dayside land, nightside)



Sunglint observation
(dayside ocean)

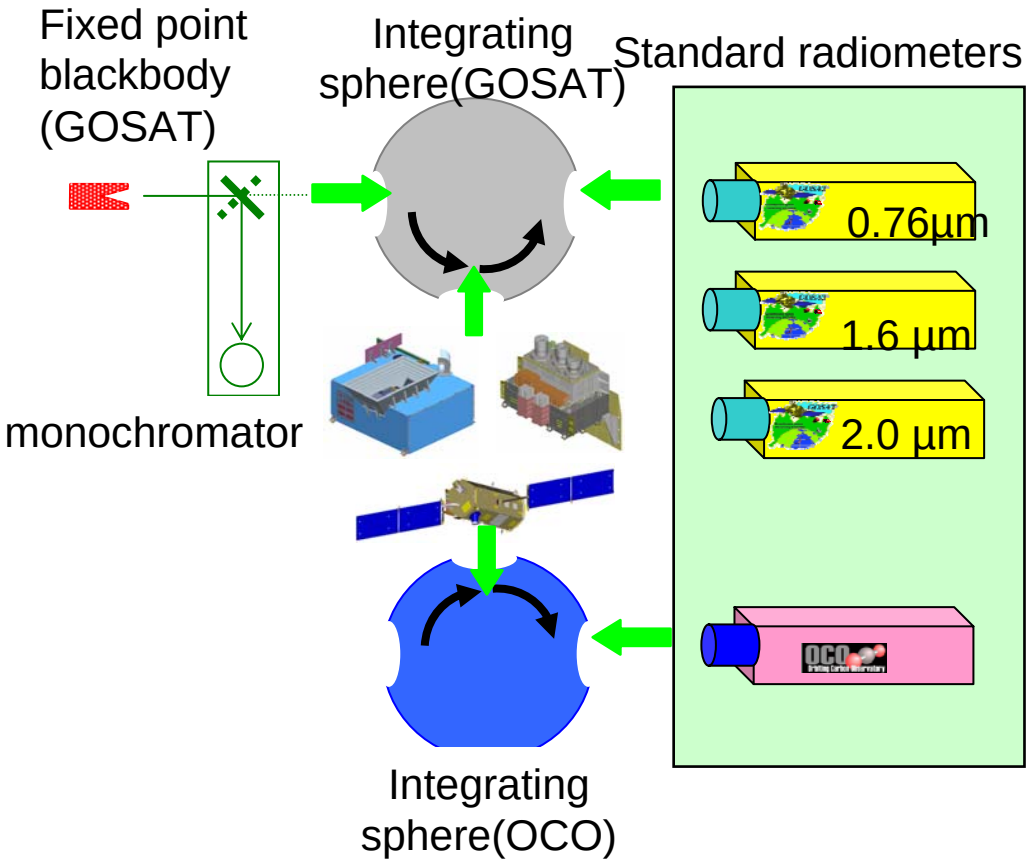


Specific observation
(calibration, validation, pipeline)

Pre-flight test characterization

Cross calibration with OCO and GOSAT

- X-calibration with OCO/GOSAT standard radiometers



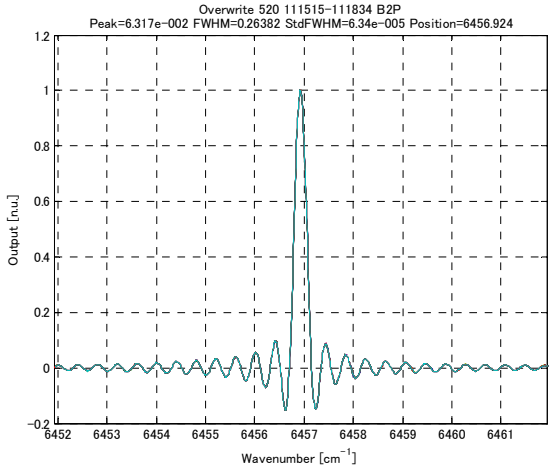
- 1st step @ JPL (Apr, 2008) ***Difference < 3%***

Pre-launch

- 2nd step @ JAXA (Aug, 2008)

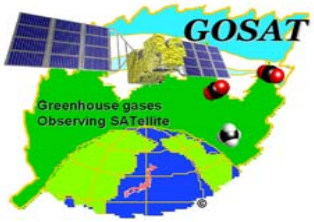
Pre-flight test characterization

- Instrument function
  - Integrated sphere (Ar lamp)
  - Tunable diode laser
- Sensitivity (also SNR)
  - Fixed-point blackbody and integrating sphere
  - Blackbody cavity
- IFOV
  - Collimator



Instrument function		
Band	Spec	Results
1P	<0.6 cm^{-1}	0.367
1S		0.356
2P	<0.27 cm^{-1}	0.258
2S		0.257
3P		0.262
3S		0.263

SNR				
Band	Wavenumber [cm^{-1}]	Radiance [$W/cm^2/sr/cm^{-1}$]	Specification	Result
1P	13050	5.5e-7	310	345
1S			---	246
2P	6200	5.2e-7	310	322
2S			---	257
3P	5000	3.8e-7	310	412
3S			---	287
4	700	280K	310	283



Pre-flight test characterization Data sheets

- Although the following data are not used for L1 processing, they are separately provided for users.

FTS	Data	Pre-launch	L+3M	L+6M	L+12M
IFOV (Response distribution within a pixel if exists)	PFT result	○			
Instrument Line Shape Function	PFT result	○	○	○	○
Sensitivity calibration coefficients	PFT result	○			
	Solar Irradiance Cal.		○	○	○
	Lunar Cal.			○	
	Vicarious cal.				○
A model for polarization	PFT result	○			

Onboard calibration

FTS OBC	FTS-B1 0.76μm	FTS-B2 1.6μm	FTS-B3 2.0μm	FTS-B4 TIR	Frequency
Electric Calibration	x	x	x	x	1 / month
Deep Space	x	x	x	x	Every pass
Solar Irradiance	x	x	x		Every pass
Blackbody				x	Every pass
Lunar Calibration	x	x	x		1 / year
1.55μm Laser for ILS		x			1 / month
(IFOV Monitoring Camera	x	x	x	x	Every scene)

- Deep space and blackbody data will be obtained 4 times nominally, 16 times at maximum in an orbit.
- Lunar calibration will be operated at full moon once a year.
- 1.55 μm ILS laser for B2 will be operated once a month.

FTS Level 1 Radiometric calibration

L1A Interferogram

SWIR band

I_{scene}, $I_{Solar\_irrad\_cal}$

TIR band

I_{scene}, $I_{deep\_space\_cal}$, $I_{blackbody\_cal}$

※sensitivity correction (gain, non-linear, phase correction)

Uncorrected spectrum

$$S(\sigma) = \int_{-MPD}^{MPD} I(x)\, e^{-2\pi i x \sigma}\, dx$$

※sensitivity correction（reflectance、polarization、BRDF correction）

Corrected spectrum

SWIR band

S_{scene}, $S_{solar\_irradi\_cal}$

TIR band

S_{scene}, $S_{deep\_space\_cal}$, $S_{blackbody\_cal}$

2-point calibration

L1B Spectral Radiance

SWIR band

S_{scene}, $S_{solar\_irradi\_cal}$

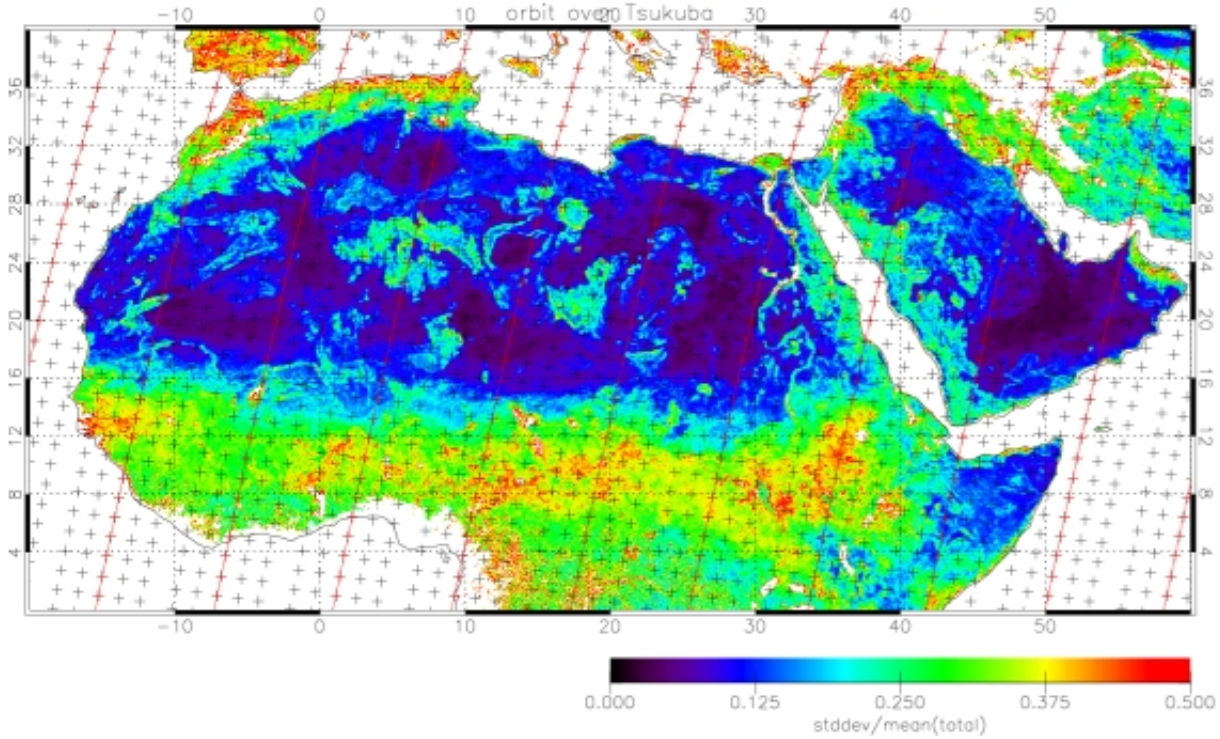
TIR band radiance

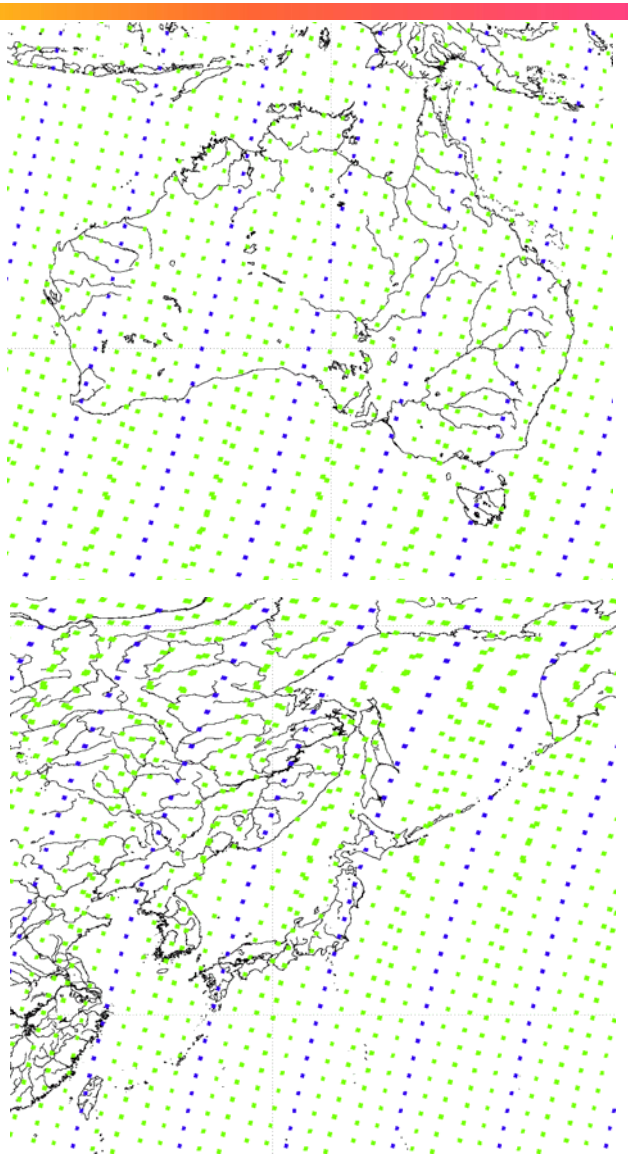
$$L_{scene}(\sigma) = \frac{S_{scene} - S_{deep\_space\_cal}}{S_{blackbody\_cal} - S_{deep\_space\_cal}}\, \varepsilon_{blackbody}\, B(T_{blackbody})$$

Vicarious calibration

- Comparison with other spectrometers
  - OCO-TANSO
    - OCO spectrum is an exact reference for TANSO.
- Comparison with other imagers
  - Aqua/MODIS-TANSO
    - Comparison between Aqua/MODIS and TANSO in 1.6μm band is possible with total radiance level.
- Comparison by using physical parameters
  - Reflectance DB at stable or well-known site (SWIR band)
    - Without appropriate active sensors for TANSO reference, the simulated radiance for reference is produced if we have reflectance DB from the analysis of past data.
  - Sea surface temperature DB (TIR band)
    - Estimated SST by split window is compared with Reynolds OI-SST or AMSR-E microwave radiometry SST.

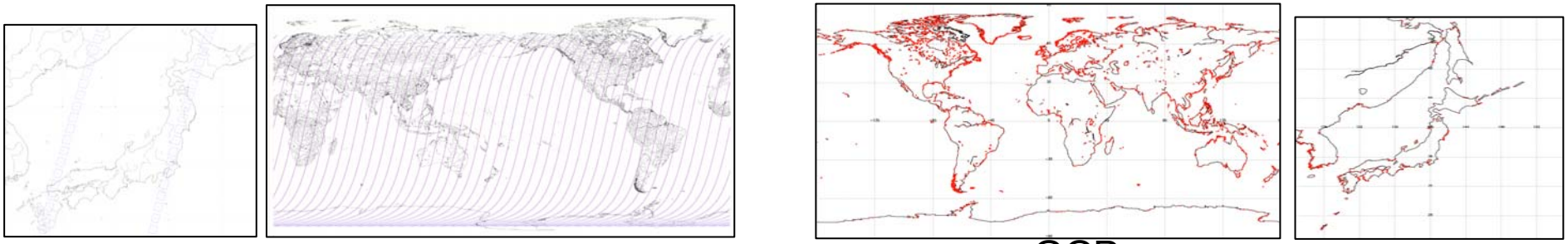
Preparation of Post-launch Cal/Val





- The radiometric and geometric accuracies will be estimated at nadir view at first.
  - Scene selection for
    - Radiance comparison with other similar sensor and DB simulation
    - Geolocation
    - Cal/Val locations

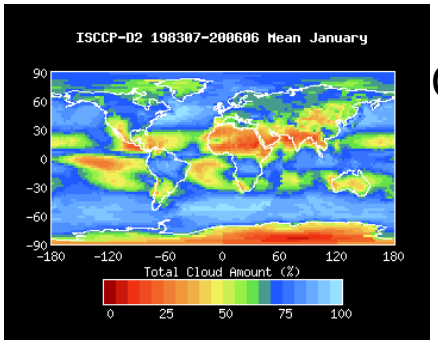
Geometric study of FTS



CAM scene

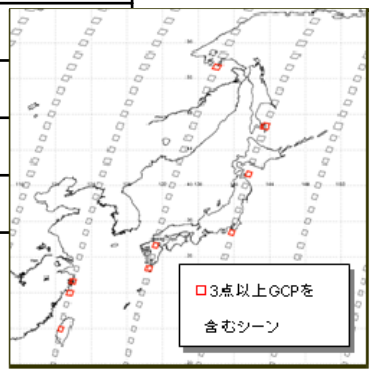
GCPs

Estimation of GCPs / scenes



Clear sky rate

	① Num of CAM scene (nadir)	② Num of CAM scene inc. 3 GCPs	③ ②×ISCCP clear sky rate Estimated CAM scenes
Mar	5192	125	40
Jun	5104	196	64
Sep	5148	198	69
Dec	5182	86	28



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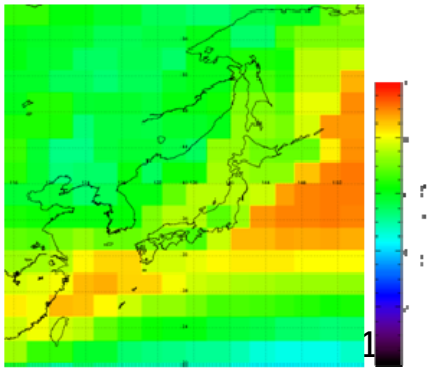
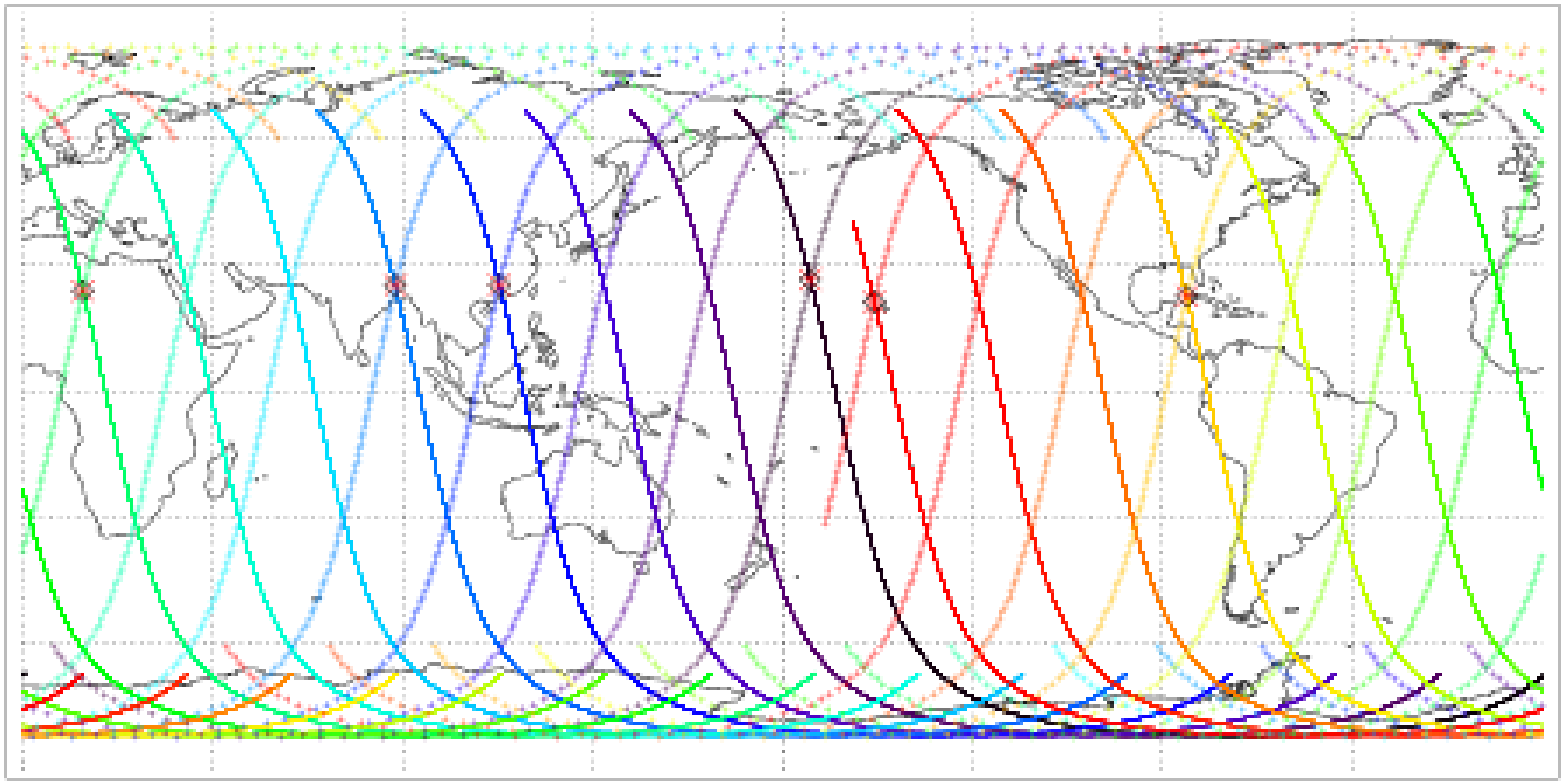
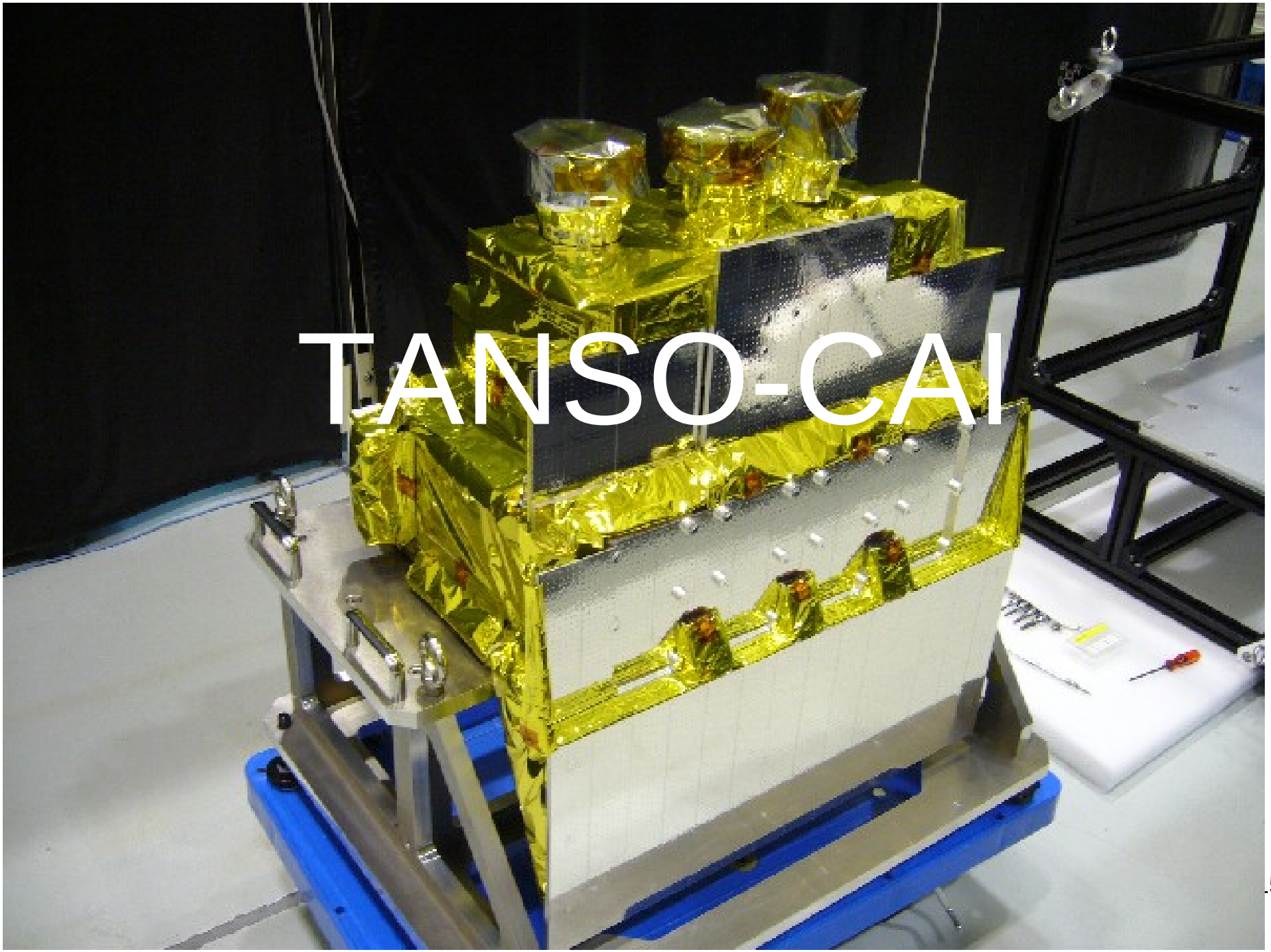


Comparison with OCO and GOSAT

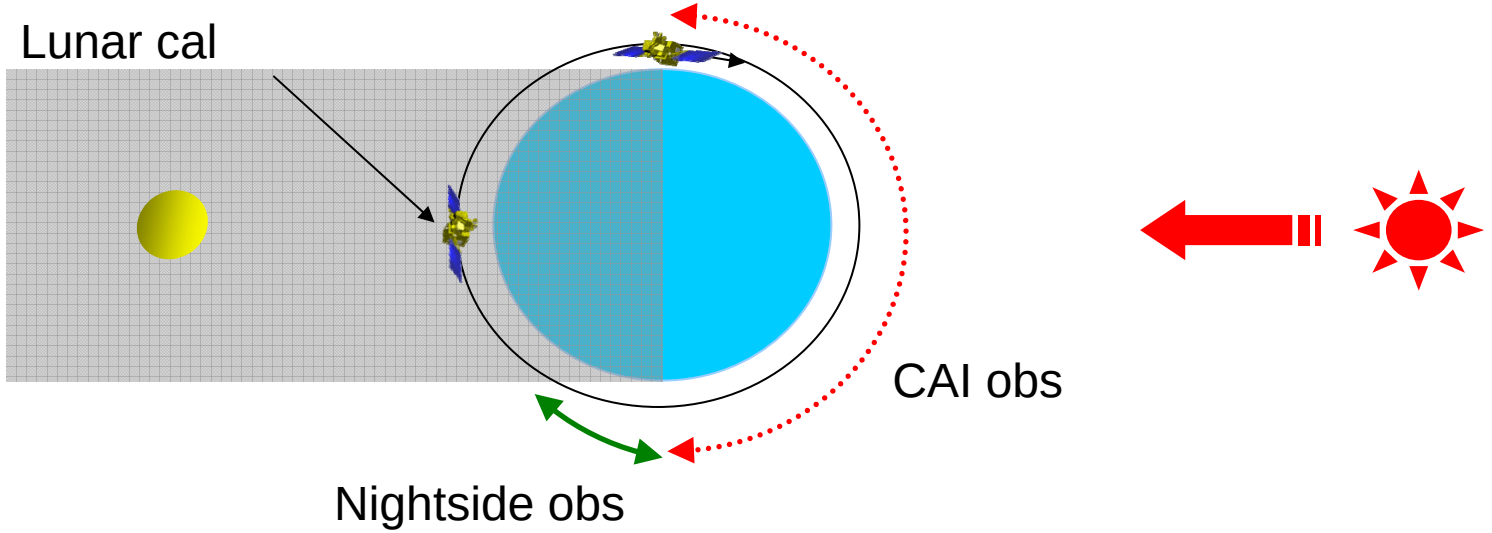
- Nadir match-up of OCO and GOSAT
  - OCO: continuous swath observation at 13:26LT
  - GOSAT: separate pointing observation at 13:00LT

Match-up points in a day (Distance < 10km, Time < 30 min)




TANSO-CAI

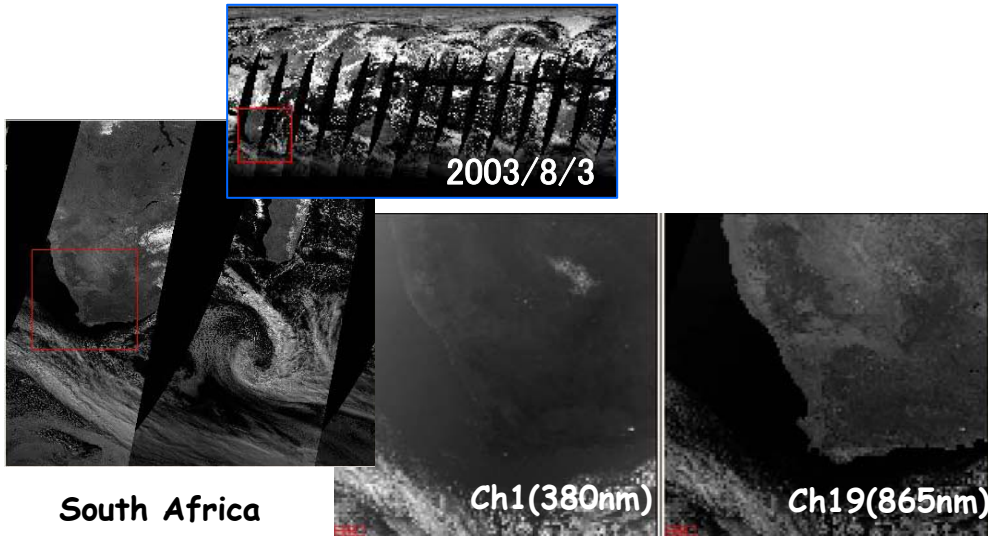
Operation of CAI

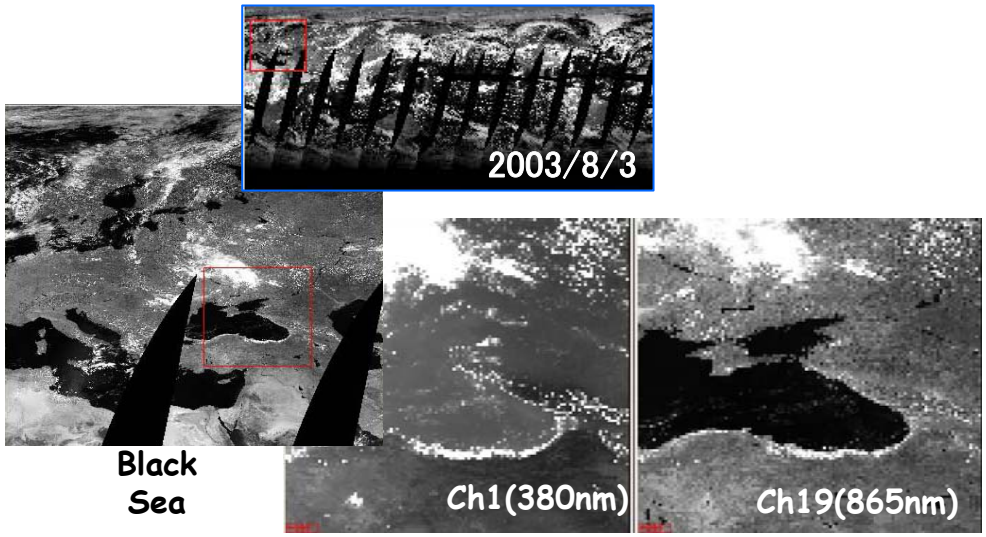


CAI onboard calibration

	B1	B2	B 3	B4
Offset	Nightside observation			
Radiance	Lunar observation (1 / year)			

Geometric study of CAI



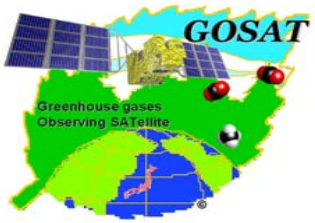


- It is difficult to identify the land/ocean features from UV channel.
- The GLI 380nm image data is available and preliminary checked.
- The identified points is white sand shore and snowfield shore.
- GCPs of 380nm channel is estimated less than the other visible and SWIR channels.

Summary

- TANSO calibration is conducted by PFT, OBC, and VC.
- Sensor performance is characterized in PFT and sensor parameters are provided for development of L1 processing system.
- Calibration factors are optimized using OBC data in operation of L1 processing.
  - Responsive gain and offset (Radiometric calibration)
  - Laser wavelength (Spectral calibration)

- The vicarious procedures are prepared for radiometric, geometric, spectrometric calibration.
- Accuracy of L1 spectra will be evaluated by comparison with other satellite observed radiance or physical parameters.



- backup

Pre-flight Test Items

Item	Configuration
Signal to Noise Ratio	Halogen lamp Integrating Sphere (SWIR) Large Aperture Cavity Blackbody in TVT (TIR)
Instrument Line Shape Function (shape and wavelength)	Ar lamp Integrating Sphere and Tunable diode laser
Radiometric Response (Non liner correction if exists)	Fix Point Blackbody and Integrating Sphere Large Aperture Cavity Blackbody (TIR)
IFOV (Response distribution within a pixel if exists)	Collimator with Alignment test
Diffuser BRDF	Spherical Distributed Detectors
Onboard Laser temperature dependency	Wavelength meter
Response Stability	Halogen lamp Integrating Sphere and light source monitoring radiometers
Stray Light	Halogen lamp Integrating Sphere and CO2 cell
Micro-vibration	Ar lamp Integrating Sphere and Shaker

FTS L1 processing flow of SWIR

Interferogram (FTS L1A)

Quality check (spike detection)

Low-freq correction

Corrected Interferogram

FFT

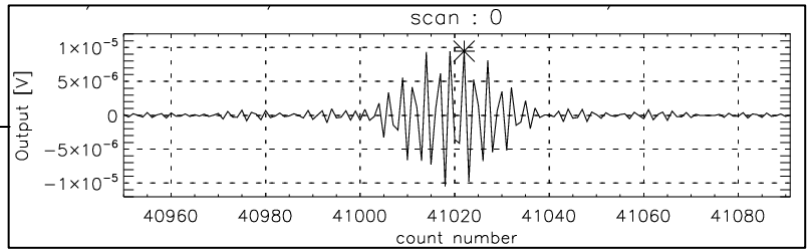
Phase correction

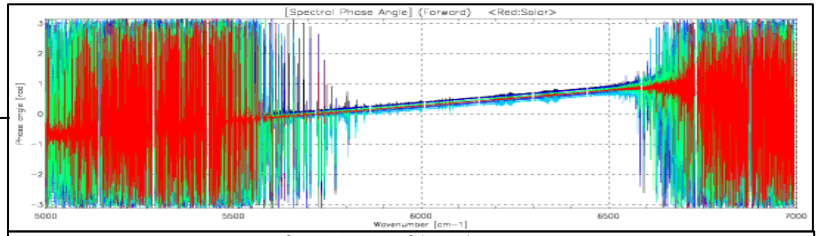
Corrected Spectrum

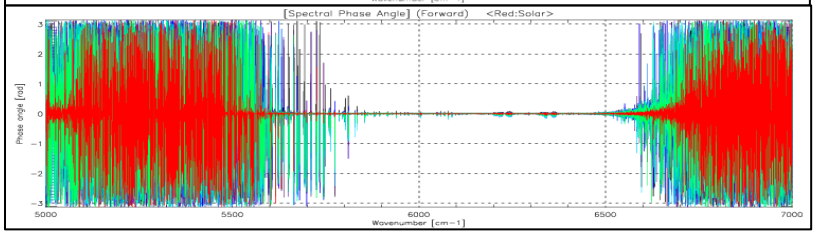
Spectral calibration

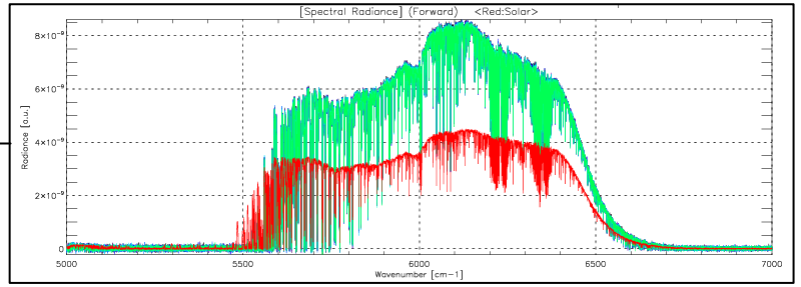
Final Spectral Radiance (L1B)

Conversion (output to radiance)





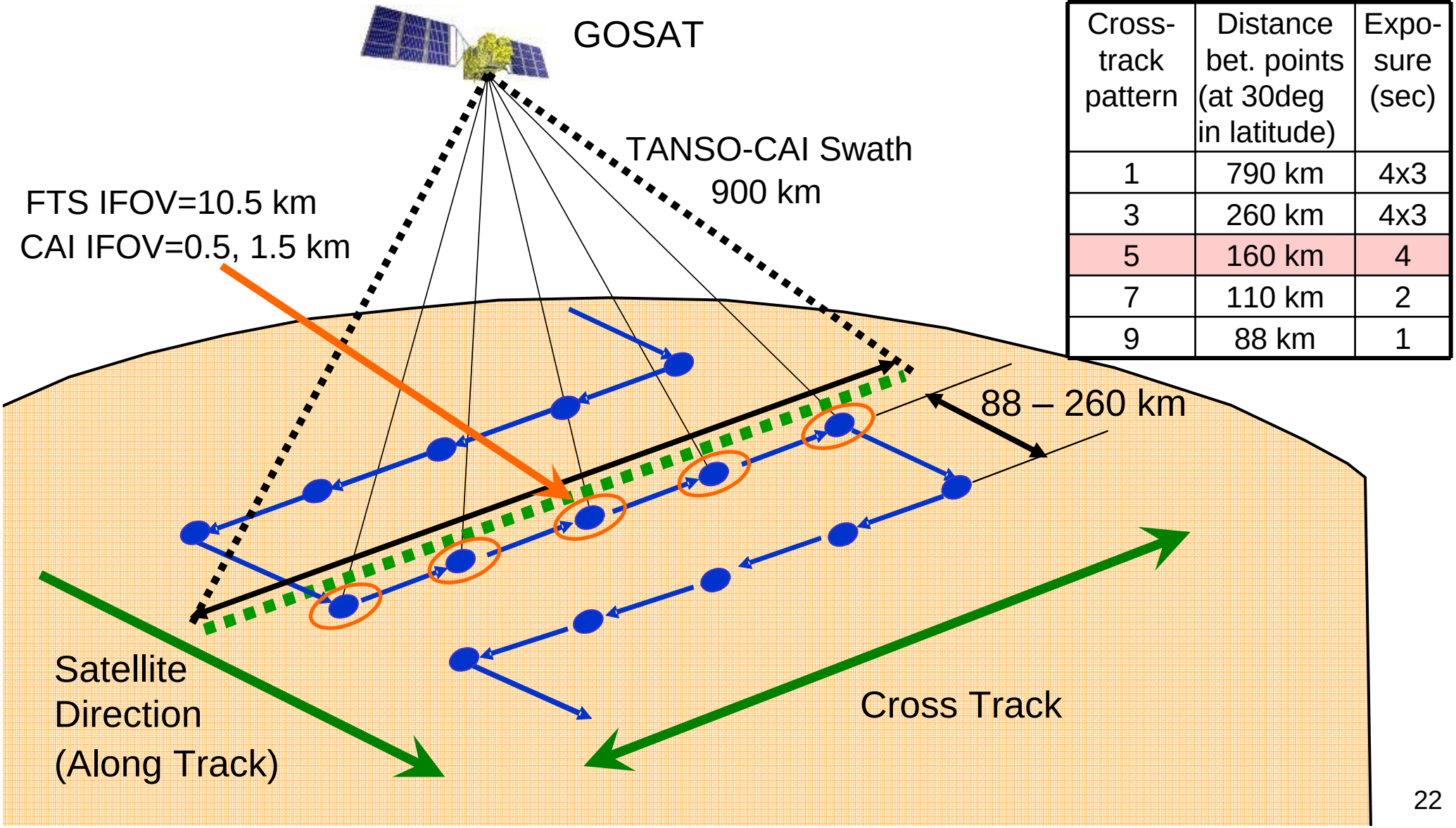




In PFT: Standard light source is calibrated by fixed-point blackbody.

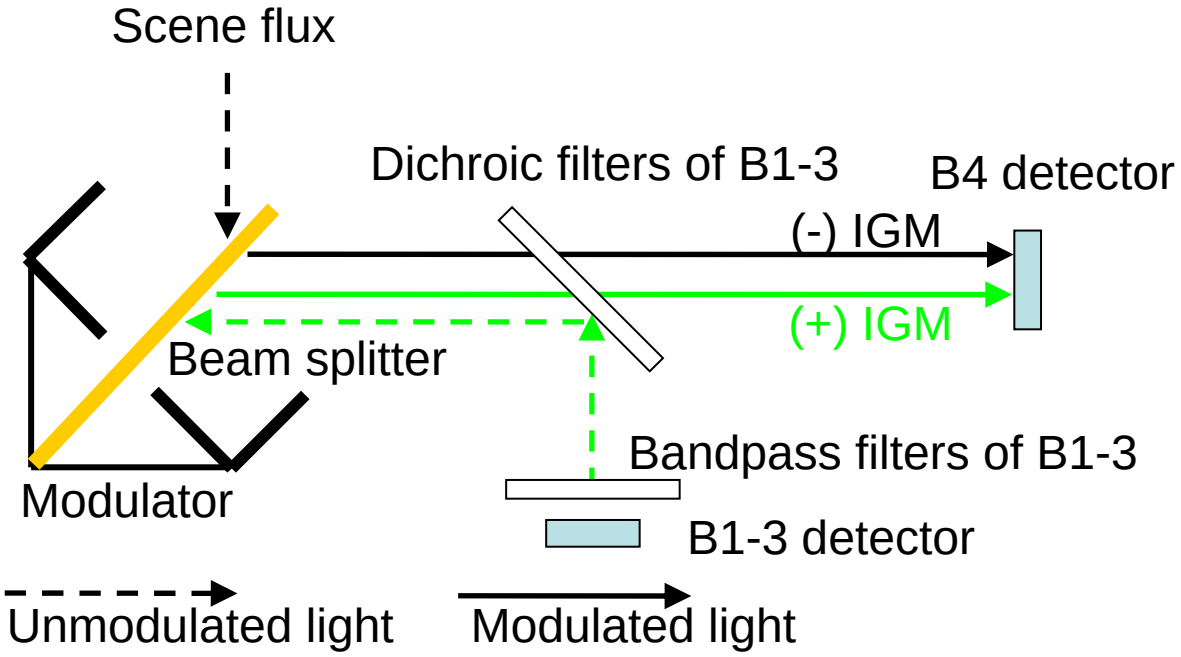
In orbit: Onboard calibration and *Vicarious calibration*

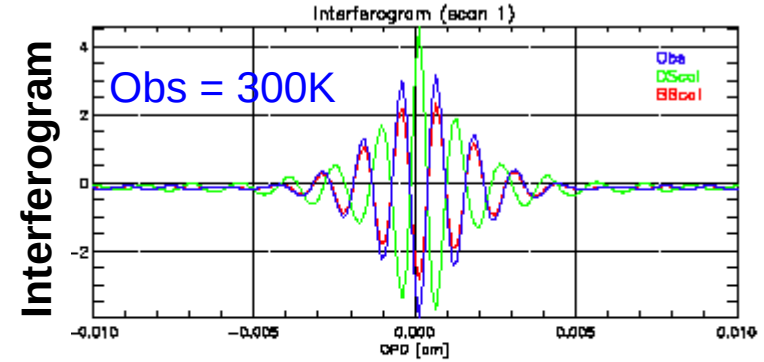
Pointing and footprints

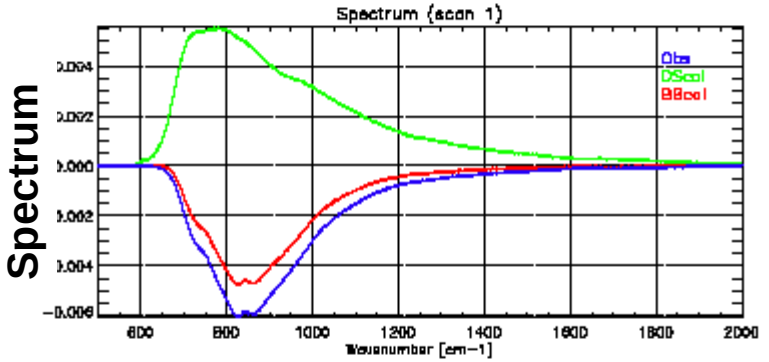


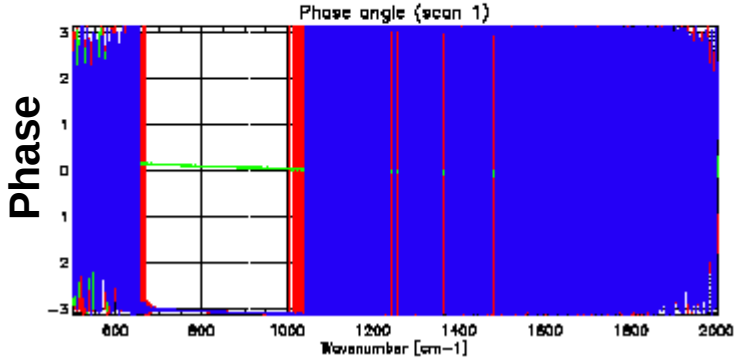
Cross-track pattern	Distance bet. points (at 30deg in latitude)	Expo-sure (sec)
1	790 km	4x3
3	260 km	4x3
5	160 km	4
7	110 km	2
9	88 km	1

TIR interferogram



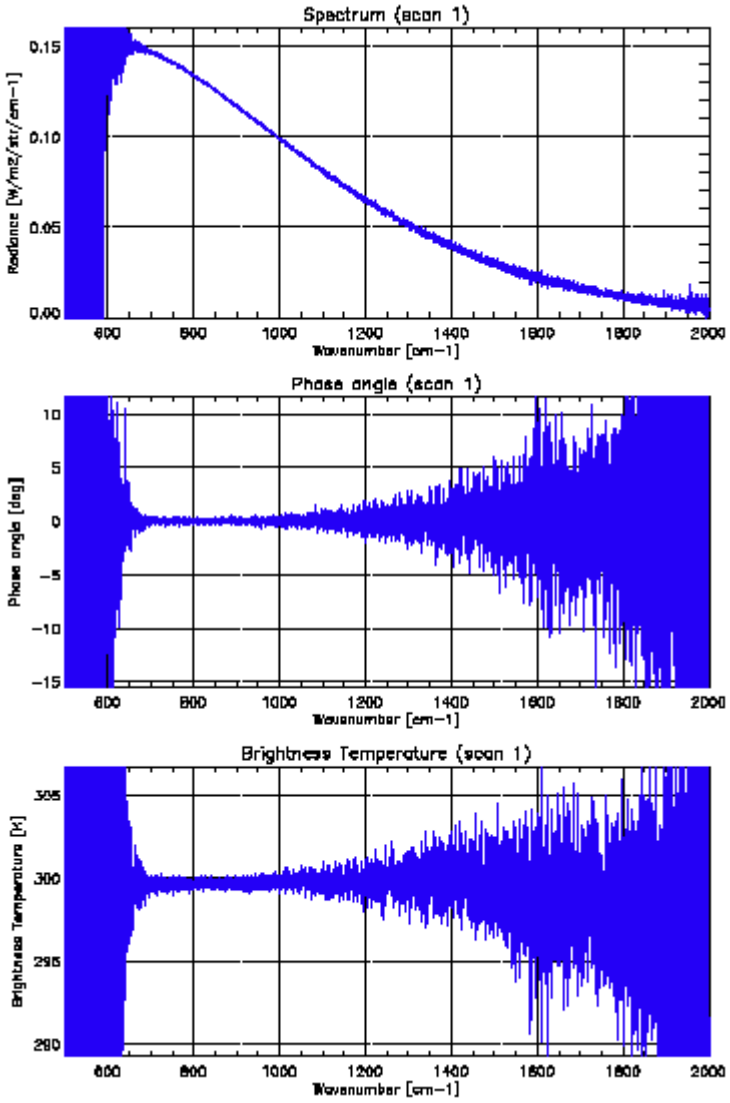






Target	*Relations bet. input and inner radiations*	*IGM*
Deep space	Input(3K) < Inner(265K)	+
Blackbody	Input(290K) > Inner(265K)	-
Observation	Input(270-320K) >=< Inner(265K)	+ -

TIR calibration

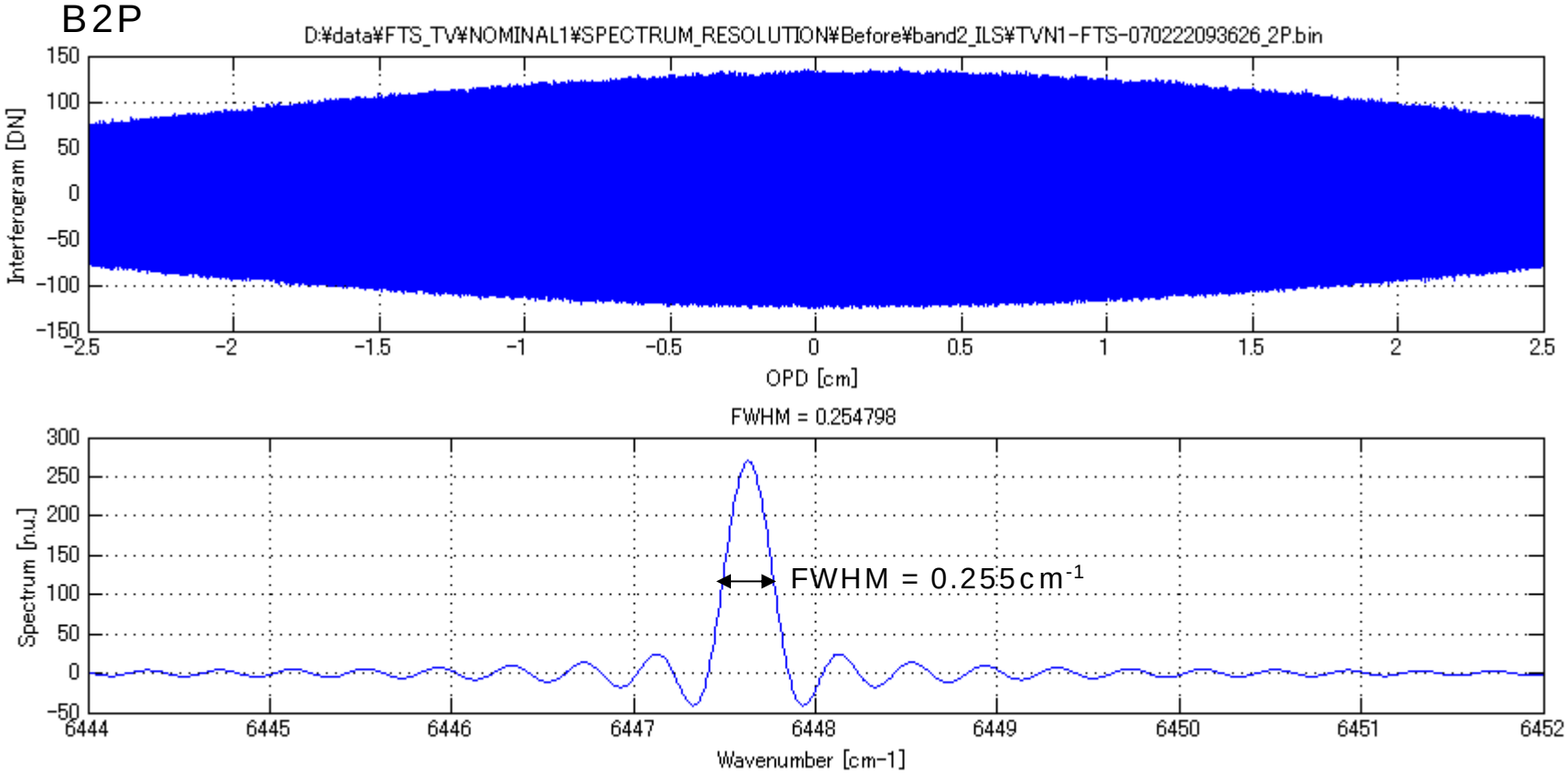


- Input radiance is injected by a vacuum blackbody source of 300 K.
- The calibration is operated by 2-point complex calibration using onboard blackbody and cooled shroud for deep space.

$$L_{Obs}(\sigma) = \frac{S_{Obs} - S_{DScal}}{S_{BBcal} - S_{DScal}} \varepsilon_{BB} \; B(T_{BB})$$

- The phase is approximately zero after calibration.
- The calibrated equivalent brightness temperature is estimated around 300K of input radiance.

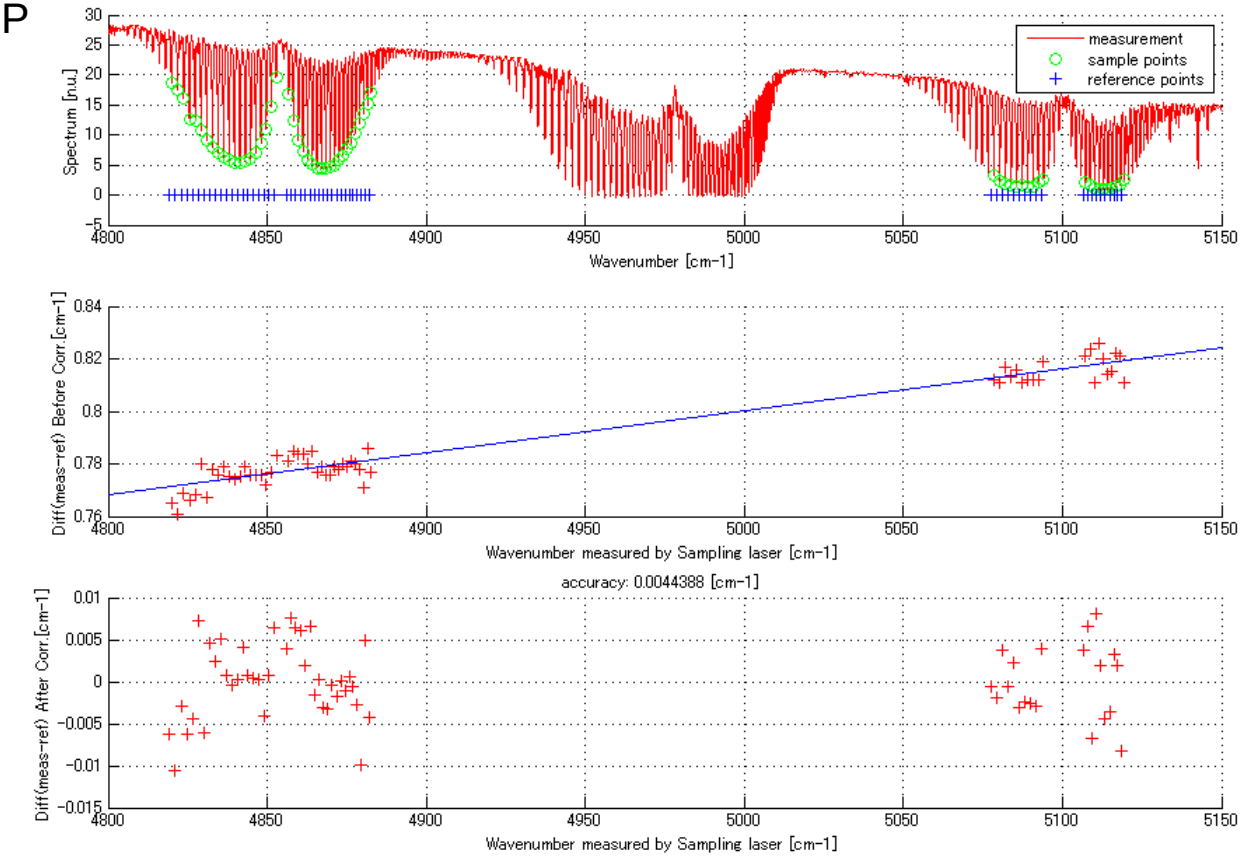
ILS measurement by onboard laser



- The ILS of B2P was estimated by using the onboard 1.55μm laser after reflection of the solar diffuser.
- Measured ILS (FWHM=0.255cm^{-1}) satisfies the specification requirement.

Spectral calibration from atmospheric absorptions

B3P



CO_2 cell measurement

- The sampling laser wavelength was estimated to an accuracy of 1E-4 %.
- As a result, the spectral axis was evaluated to an accuracy of 0.004 cm^{-1}.
- Simple procedure for spectral calibration will be implemented after selection of effective absorption lines.