CGMS

CGMS-35, JAXA-WP-02
Prepared by JAXA
Agenda Item: C.3
Discussed in Plenary

Status of Greenhouse Gases Observing Satellite (GOSAT)

The status of JAXA's Greenhouse Gases Observing Satellite (GOSAT) is updated. Preparing for launch in the next year, ground system, data policy and data distribution plan are also reported.

1. Introduction

The Greenhouse gases Observing Satellite (GOSAT) is a satellite to monitor the carbon dioxide (CO_2) and the methane (CH_4) globally from orbit, and it aims to contribute to the international efforts to prevent global warming, such as the Kyoto Protocol. It is a joint project of Japan Aerospace Exploration Agency (JAXA), Ministry of the Environment (MOE) and National Institute for Environmental Studies (NIES). JAXA is responsible for satellite development, launch, and satellite operation. JAXA and MOE are in charge of the sensor development. MOE and NIES are responsible for satellite data utilization. It is scheduled to be launched in 2008.

2. GOSAT Mission Objectives

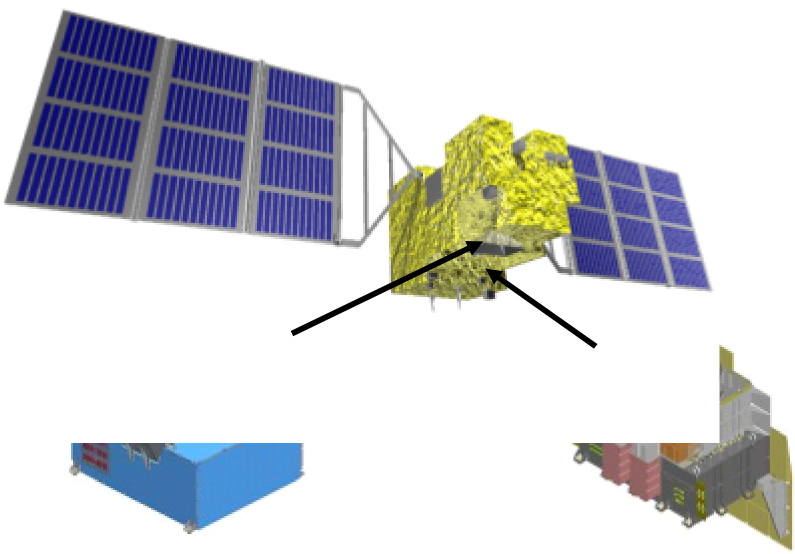
The objectives of the GOSAT mission are to contribute to envi ronmental administration by estimating the Green House Gases (GHGs) source and sink in Sub-continental scale and to advance earth observation technologies for future missions.

The targets of the mission are observation of CO_2 density in 3-month average with 1% (4ppmv) relative accuracy in 1000km spatial resolution during the first commitment period (2008 to 2012) of the Kyoto Protocol and reducing errors by half in iden tifying the GHGs net absorption in sub-continental scale with the data obtained by GOSAT in conjunction with the data gathered by the ground instruments.

Other applications of GOSAT are to provide earth radiation data with high spectral resolution, to monitor the CH4 gas leak distribution from the pipeline etc..

3. Satellite

GOSAT is a medium-size satellite which weighs 1750 kg. It will be launched by H-IIA rocket of JAXA in 2008. Fig. 1 illustrates the GOSAT spacecraft and sensors. Table 1 shows the summary of the GOSAT satellite. GOSAT will be placed in a 666 km sun-synchronous orbit of 13:00 local time, with an inclination angle of 98 deg.



TANSO-FTS:
Thermal And Near infrared Sensor for carbon Observation – Fourier Transform Spectrometer

TANSO-CAI:
Thermal And Near infrared Sensor for carbon Observation – Cloud and Aerosol Imager

Fig. 1. The GOSAT satellite and sensors.

Table 1. The GOSAT satellite characteristics.

Size	Main body	3.7 x 1.8 x 2.0 m
Mass	Total	1750kg
Power	Total	3.8 kW(EOL)
Life Span		5 years
Orbit	Sun Synchronous	
	Altitude	666 km
	Inclination	98 deg
	Local time	13:00 +/- 0:15
	Revisit	3 days
Launch	Vehicle	H-IIA
	Schedule	2008

Last year, GOSAT thermal-and-structure-model (STM) shown in Fig.2 was subjected to environmental tests such as acoustic tests, vibration tests, and thermal vacuum tests. Meanwhile GOSAT electric-model (EM) was used to validate electrical interface between a satellite bus and mission sensors. These tests were completed successfully.
Currently, GOSAT proto-flight model is being assembled at JAXA Tsukuba Space Center, and proto-flight tests are scheduled for January next year.

Fig. 2. GOSAT thermal and structure model

4. GOSAT Onboard Sensors

4.1 TANSO-FTS

TANSO-FTS (Thermal And Near infrared Sensor for carbon Observations - Fourier Transform Spectrometer), which is to be accommodated on GOSAT, is a Fourier Transform Spectrometer (FTS) with high optical throughput and spectral resolution. Table 2 shows the specification of the TANSO-FTS and Fig. 3 shows the engineering model of the instrument. The optical layout consist of the pointing mechanism, relay optics, FTS, and detectors. The two axes redundant pointing mechanism can view the earth's surface, deep space, blackbody, and diffusers. The FTS optics and the optics of the band separation and detector are illustrated in Fig. 4 and Fig. 5, respectively. The FTS is a double pendulum type interferometer with two corner cube reflectors, and it covers from 0.76 to 15 micron with a ZnSe beam splitter and the fully redundant 1.31 micron DFB laser sampling system is applied. The modulated light by the FTS is divided into four spectral bands with diachronic filters. Then, the SWIR bands (Band1-3) lights are divided into two detectors with the polarization beam splitters. The InGaAs detectors are cooled with thermo-electric coolers. The TIR light is collected on the HgCdTe (MCT) detector, which is cooled with the pulse tube cooler. The small camera is also installed on the optical bench to register the TANSO-FTS instantaneous field of view.

Table 2. The specification of TANSO-FTS.

Ground Pointing Mechanism and Fore optics	Configuration	2-axes scanner (fully redundant)			
	Scanning	Cross Track (+/- 35 deg) Along Track (+/- 20 deg)			
	Field of view	IFOV <10.5 km 790 km (scan width) (latitude of 30 deg)			
Fourier Transform Spectrometer	Speed	0.25, 0.5, 1 (Interferogram)/sec			
	Spectral band	1	2	3	4
	Coverage (cm-1)	12900-13200 (0.76-0.78µm)	5800-6400 (1.6-1.7µm)	4800-5200 (1.9-2.1µm)	700-1800 (5.5-14.3µm)
	Resolution (cm-1)	0.2 cm^{-1} (both sides) (MOPD +/-2.5 cm)			
	Detector	Si	InGaAs	InGaAs	PC-MCT
	Observation Target	O_2	CO_2, CH_4	CO_2	CO_2, CH_4, O_3
	Calibration	Solar Irradiance, Deep Space, Moon, Diode laser			Blackbody, Deep space

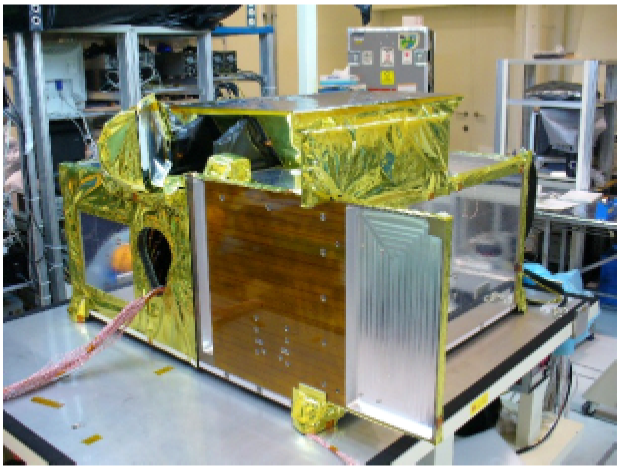
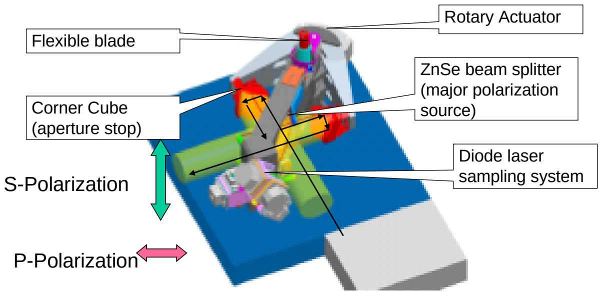


Fig. 3. The engineering model of TANSO-FTS



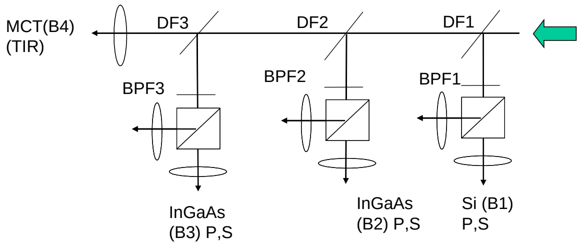


Fig. 4. The FTS optics. **Fig. 5. The band separation optics and the detectors.**

4.2 TANSO-CAI (Thermal And Near infrared Sensor for carbon Observations - Cloud and Aerosol Imager)

TANSO-CAI (Thermal And Near infrared Sensor for carbon Observations - Cloud and Aerosol Imager) to detect and correct the cloud and aerosol interference is also aboard together with the TANSO-FTS. Table 3 shows the specifica tion of the TANSO-CAI and Fig. 6 shows the engineering model of the TANSO-CAI. The TANSO-CAI has continuous spatial coverage, wider field of view, and higher spatial resolution than the TANSO-FTS in order to detect the aerosol spatial distribution and cloud coverage. Using the multi spectral bands, the spectral characteristics of the aerosol scattering can be retrieved together with optical thickness. In addition, the UV band data will provide the aerosol data over the land. With the TANSO-FTS spectra, TANSO-CAI data, and the retrieval algorithm to remove cloud and aerosol contamination, the column density of the gases can be retrieved with 1 % accuracy.

Table 3. The specification of TANSO-CAI.

	Band center wavelength (micron)	Band width (nm)	Spatial resolution (IFOV) (km)	No. of pixels (cross track)
1	0.380	20	0.5	2000
2	0.674	20	0.5	2000
3	0.870	20	0.5	2000
4	1.60	90	1.5	500

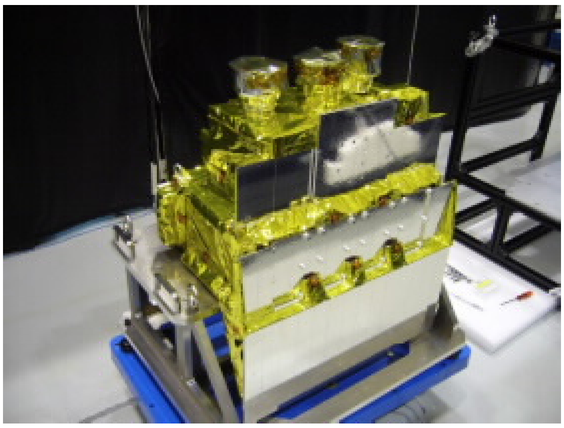


Fig. 6. The engineering model of TANSO-CAI

5. Sensor Operation

Fig. 7 shows the concept of the greenhouse gases observation. During the day, both the TANSO-FTS and the TANSO-CAI data are acquired, and at night only TANSO-FTS TIR (band 4) data is acquired. At the sunrise, the direct sun light is introduced into the TANSO-FTS through the Spectral on diffuser plates for SWIR radiance calibration. Two diffusers with different exposure time are introduced to correct the long term diffuser degradation. In addition, the 1.55 micron diode laser light is introduced through the diffuser plate into the TANSO-FTS to calibrate the instrument function onboard. The pointing mechanism views the deep space and inner blackbody periodically for the zero level and TIR radiance calibration.
By rotating the satellite, both the TANSO-FTS and the TANSO-CAI can view the moon surface, which provides the stable radiance source. This lunar calibration is scheduled once a year. Fig. 8 and Fig. 9 show the geometry of nadir-looking measurements and the concept of the GOSAT attitude control and pointing system, respectively. The pointing system and the FTS can point the same ground mesh footprint in every 3 days. Over the ocean in low latitude, the pointing mechanism point the sun glint point, where specular reflection occurs and reflectivity is high.

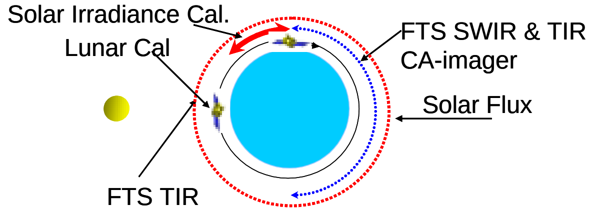


Fig. 7. The GOSAT operation.

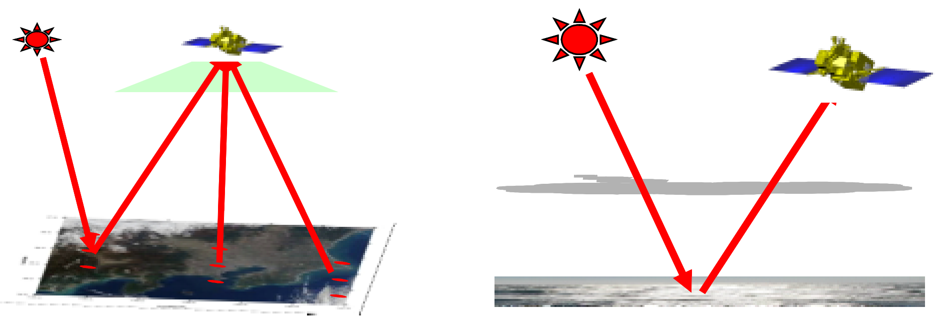


Fig. 8. The image of (a) nominal observation and (b) sun glint observation.

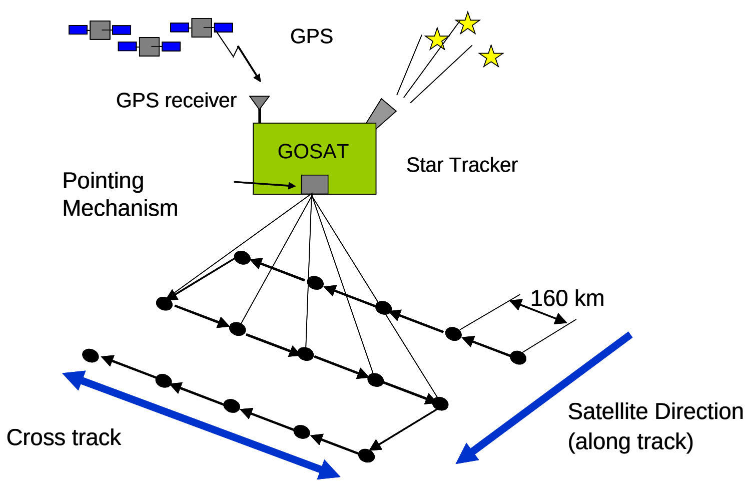


Fig. 9. The concept of attitude control and ground pointing.

6. Outline of the ground system

The obtained TANSO data accumulated on GOSAT data recorder are down linked to the ground stations in X-band at the data rate of 120 Mbps. Earth Observation Center (EOC) of JAXA and Svalbard ground station (Svalsat) of Kongsberg Satellite Services (KSAT) are assigned as the GOSAT ground stations. GOSAT data downlink is currently planned for every two satellite orbits (about every 200 minutes). All the down-linked data are decoded and divided to each APID (Application Process ID) data file and then transmitted to Earth Observation Research Center (EORC) of JAXA, in Tsukuba, where the level 1 processing for TANSO-FTS and CAI takes place. Production of level 1 products is one of the JAXA roles in GOSAT mission. Immediately after the creation, TANSO level 1 products are sent to NIES where higher level processing is applied to the TANSO data. With the higher level processing at NIES, not only column density products of GHGs including carbon dioxide and methane, also CO2 source/sink information in sub-continental scale are retrieved. Level 1 and 2 data are planned as in HDF5, while higher products are to be in NetCDF.
The latency of level 1 product is 3 to 6 hours from the observation for global data with the current operation scenario basis (one downlink per two orbits). With downlink per every orbit, latency would be 0.5-3 hours. For higher level products, the latency is over a week since the higher level processing needs to wait the delivery of subsidiary data such as pressure, temperature and so on.

7. Data policy and data distribution

JAXA, MOE and NIES are almost ready to finalize GOSAT Data Policy. Tentative outline of the GOSAT Data Policy is described as follows:

- GOSAT data will be available on Non-discriminatory basis.
- Charging dissemination fee for providing GOSAT data to scientific users (Free of charge via network).
- Minimum obligation to end-users; Indication of "GOSAT" credit on their publication, prohibiting re-distribution, etc.

NIES is responsible for the distribution of all GOSAT/TANSO products, while JAXA also has capability to distribute the TANSO FTS products. Besides, JAXA is ready to accept organizational users that will use GOSAT data systematically for their operation under MOU. JAXA is going to have a capability to distribute products shown in Table-4. Standard products will be distributed for general users. Research products will be distributed for specific users. (E.g. collaborating agency, research announcement users, and so on.)

A schedule for data distribution from NIES is not fixed yet unfortunately, but a tentative schedule from JAXA is available (see table 5). JAXA plans to start the distribution as soon as the products ready to distribute.

Currently, real-time data distribution is not planned; however, depending on the further requests from users, real-time service capability is possibly to be furnished. GOSAT TANSO data are open to the meteorological community utilization.

Table 4 GOSAT Products Lists （Tentative）

Product Level	Sensor	Product definition	Type of Data	Data Format	Data Segment
Level 1A	FTS	FTS Interferogram	Standard	HDF5	60 files per 1 orbit
	CAI	CAI Uncalibrated Digital Number Data	Standard	HDF5	1 file per Daylight area
Level1 B	FTS	FTS Spectral Radiance	Standard	HDF5	60 files per 1 orbit
	CAI	CAI Calibrated Radiance data	Standard	HDF5	1 file per Daylight area
Level2	FTS SWIR	CO_2 Column Amount	Standard	HDF5	Each scanning point
		CH_4 Column Amount	Standard	HDF5	
		H_2O Column Amount	Research	HDF5	
		O_2 Column Amount	Research	HDF5	
	FTS TIR	CO_2 Column Amount	Standard	HDF5	
		CH_4 Column Amount	Standard	HDF5	
		CO_2 Vertical Profile	Research	HDF5	
		CH_4 Vertical Profile	Research	HDF5	
		Temperature Profile	Research	HDF5	
		O_3 Vertical Profile	Research	HDF5	
		O_3 Column Amount	Research	HDF5	
		H_2O Vertical Profile	Research	HDF5	
		H_2O Column Amount	Research	HDF5	
	CAI	Cloud Property	Research	HDF5	1 file per Daylight area
		Global Aerosol Property	Research	HDF5	
Level 3	FTS SWIR	Global CO_2 Column Amount	Standard	HDF5	-
		Global CO_4 Column Amount	Standard	HDF5	-
	FTS TIR	Global CO_2 Column Amount	Standard	HDF5	-
		Global CO_4 Column Amount	Standard	HDF5	-
	CAI	Global Radiance Distribution (all pixcels)	Standard	HDF5	-
		Global Radiance Distribution （clear sky）	Standard	HDF5	-
		Global Cloud Property	Research	HDF5	-
		Global Aerosol Property	Research	HDF5	-
Level 4A	FTS	Global CO_2 Flux	Standard	NetCDF	-
		Global CH_4 Flux	Standard	NetCDF	-
Level 4B	FTS	Global CO_2 Distribution	Standard	NetCDF	-
		Global CH_4 Distribution	Standard	NetCDF	

Table 5. JAXA Data Distribution Schedule Plan

Products	Level 1 Products	Level 2 Products
Start of Distribution (plan)	6 months after launch	9 months after launch