Thermal And Near infrared Sensor for carbon Observation (TANSO)
onboard
the Greenhouse gases Observing SATellite (GOSAT)

Research Announcement

Appendix C

Operation Policies of GOSAT and Basic Observation Plan of the TANSO Sensor

Operation Policies of GOSAT and Basic Observation Plan of the TANSO Sensor

This document describes the policies for the operation of GOSAT and the basic plan for the observation by the TANSO sensor. The contents of this document should be carefully confirmed or referred to in preparing research proposals to be submitted in response to the RA. RA Investigators, if they find any matter to be confirmed in more detail in the course of preparing proposals, are requested to contact the RA Office for clarification, at the contact address provided in Chapter 14 of the RA Document.

C-1 Operation of GOSAT

C-1.1 Orbital Parameters of GOSAT

Table C-1.1-1 specifies the nominal orbit of GOSAT.

Table C-1.1-1 Nominal orbit of GOSAT

Parameters	Description
Orbit type	Sun-synchronous, quasi-recurrent
Altitude against the earth at Equator	666 km
Inclination angle	98.06 deg
Orbital period	app. 98.2 minutes
No. of days per recurrence	3 days
Orbits per day	14 + 2/3 revolutions
Orbits per recurrence	44 revolutions
Descending node time	13 hours ±15 minutes (12:48)
Recurrence accuracy	±2.5km

See technical information for more detail.

C-1.2 Control and Maintenance of the Orbit

GOSAT will be maneuvered every three to six days (TBD) for orbit control to maintain the sun-synchronous quasi-recurrent orbit (as to the descending node time, altitude/recurrence, etc.), in order to secure a recurrence accuracy of ±2.5 km for the operation of the sensor observation.

C-2 Operation of TANSO-FTS/CAI

C-2.1 Functions of TANSO-FTS/CAI

(1) Functions of TANSO-FTS

- Observes the atmosphere in visible-, short wavelength-infrared and thermal-infrared bands looking toward the earth center.
- Carries out observation over the land in lattice points in general
- Observes the same footprint during one interferogram measurement while the satellite is moving.
- Observes the interferogram multiple times for the same footprint to improve the SNR in some lattice point observation.
- Observes at a fixed angle (or fixed distance) interval in cross-track direction during the lattice observations.
- Returns to the same footprint after three days in lattice point observation.
- Observes sea area where sunglint is expected, using the two-axis (AT/CT) mechanism.
- Performs solar irradiance calibration in the visible band and the short wavelength infrared bands and blackbody calibration in the thermal-infrared band in orbit.
- Performs deep-space calibration in the visible-, short wavelength- and thermal-infrared bands.
- Performs annual lunar calibration on the sensitivity by pointing the satellite and the two sensors to the moon.

(2) Functions of TANSO-CAI

- Observes cloud and aerosol with spatial resolutions of 0.5 to 1.5 km.
- Performs annual calibration on the sensitivity by pointing the +Z axis of the satellite to the moon.

C-2.2 Operation Mode

Tables C-2.2-1 and C-2.2-2 show the basic operation modes of TANSO-FTS and TANSO-CAI.

Table C-2.2-1 Basic operation modes of TANSO-FTS

Operation mode		Description
Observation mode I	Daytime observation	Observation in the short wavelength infrared bands and thermal-infrared band.
	Nighttime observation	Observation in the thermal-infrared band. Performs blackbody calibration and deep-space calibration.
Observation mode II		(In case of a failure of one of the solar paddles or other similar event) the operation of thermal-infrared observation is suspended and the pointing mechanism is locked to cope with the situation that the power supply level of the satellite becomes lower. *The observation time is set as ten minutes per orbit, and the sensor is set to the Standby II mode for the rest of the time. *TANSO-CAI is assumed as set to the All-Off mode.
Specific observation mode	Sunglint observation	Observes sunglint points according to the uplinked commands.
	Specific point observation	Observes specified points according to the uplinked commands. "Specific points" include lakes, validation sites, ground-based CO_2 observation points, etc.
Calibration mode	Lunar calibration	Performs observation in the short wavelength infrared bands once a year, as necessary. This calibration is performed by rotating GOSAT to point to the moon at around the time when the average radiance from the moon surface marks the highest, and orienting the sensor's FOV toward the moon using the pointing mechanism.
	Solar irradiance calibration	Performs solar irradiance calibration for every orbit when the satellite is in sunlight and the ground surface is in shade. Thus, this calibration takes place at rise of the sun.
	Instrument function calibration	Performs calibration on the instrument function by irradiating a 1.55-μm-long semiconductor laser light.
	Electrical calibration	Performs calibration of signal processing in the analogue-signal processing system and beyond, by inputting a reference voltage signal.

Table C-2.2-2 Basic operation modes of TANSO-CAI

Operation mode		Description
Observation mode		Performs observation by CAI.
Calibration mode	Lunar calibration	Performs lunar calibration once a year, as necessary. This calibration will be performed by rotating GOSAT to point to the moon at around the time when the average radiance from the moon surface marks the highest. It is performed concurrently with the lunar calibration of FTS.
	Electrical calibration	Performs calibration concerning signal processing in the analogue-signal processing system and beyond, by inputting a reference voltage signal.
	Nighttime calibration	Calibrates the offset level at nighttime.

C-2.3 In-orbit Operation

Figure C-2.3-1 illustrates the operation of TANSO-FTS and TANSO-CAI orbiting the earth for the observation over lattice points, whereas Figure C-2.3.2 below provides images of data acquisition in the observation mode I and the specific observation mode (sunglint observation). Sunglint observation is performed above the ocean, where sunglint occurs, at low or middle latitude.

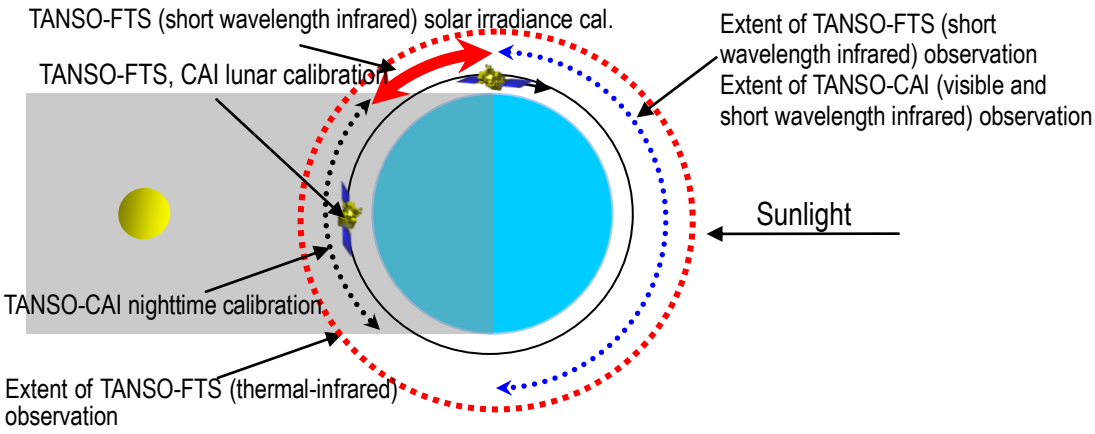

Figure C-2.3-1 In-orbit operation

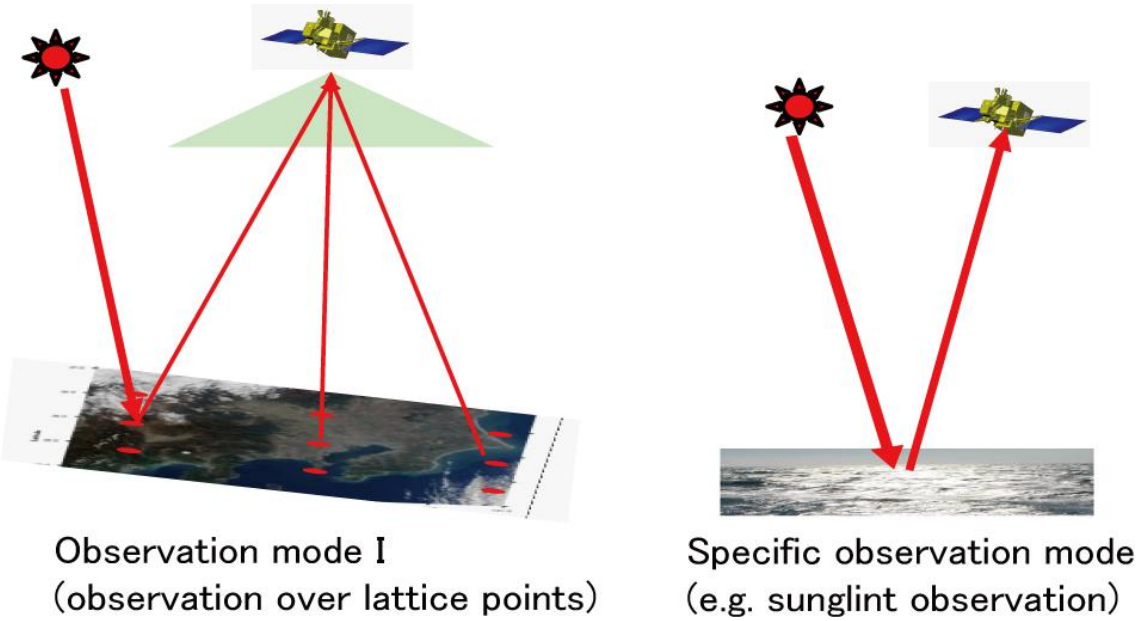

Figure C-2.3-2 Images of data acquisition for the observation over lattice points and specific observation modes

C-2.4 Nominal Operation

C-2.4.1 Nominal Operation of TANSO-FTS

(1) Observation over lattice points

TANSO-FTS performs observation in the short wavelength infrared bands when the target ground surface is in daylight, while, it can perform observation in the thermal-infrared band regardless of whether it is daytime or nighttime. However, the FTS operation in the light-load mode (LLM) or super-light load mode (S-LLM) is different, in both the short wavelength- and thermal-infrared bands. There are five modes for the FTS observation over lattice points, depending on the number of scans in cross-track direction, namely 1, 3, 5, 7, and 9. The sensor receives the ascending node time information from the satellite, based on which it performs the time adjustment (correction of the scanning cycle). It returns to the same footprint for every pointing mode observation, for every recurrence in three days, with a target accuracy of 4 km. The start and end times of FTS's daytime observation in the short wavelength infrared bands are specified by the stored commands uplinked from the ground.

Table C-2.4-1 and Figure C-2.3-1 on the next page show a sample scanning pattern for observation over lattice points and an overview of the scanning pattern in cross-track direction, respectively. In addition, the ratios of the distance between observation points along-track (AT) and cross-track (CT) directions are given in Table C-2.4-2.

Table C-2.4-1 Data acquisition cycle and cross-track scanning pattern

No. of observation points in cross-track direction	Observation time at a time (sec)	No. of times for observing the same footprint
1	4.0	3
3	4.0	3
5	4.0	1
7	2.0	1
9	1.1	1

*: For adjusting to the observation timing, it must be feasible to lock the pointing mechanism before the start time of a specific observation.

Table C-2.4-2 Time and location distances between observation points in AT and CT directions

No. of observation points in cross-track direction	Horizontal space at latitude 30 deg (km)	Vertical space at latitude 30 deg (km)	Observation time at one observation point (sec)	CT settling time (sec)	AT settling time (sec)	AT interval time	AT angular range (deg(+/-))
1	788.8	90.3	12.8	N/A	0.4	13.2	3.7
3	262.9	283.1	13.2	0.6	0.6	41.4	12.1
5	157.8	152.2	4.0	0.45	0.45	22.2	6.5
7	112.7	114.9	2.0	0.4	0.4	16.8	4.9
9	87.6	86.2	1.1	0.4	0.4	12.6	3.7

* Observation time at one observation point: In the observation modes with the number of observation points in CT direction being one and three, the observation time includes twice the turnaround time (=CT settling time = AT settling time), as the interferogram is measured over the same footprint in these modes.
*AT interval time = observation time at an observation point × No. of CT observation points + CT settling time × (No. of CT observation points - 1) ＋AT settling time = (observation time at one observation point＋turnaround time) × No. of CT observation points

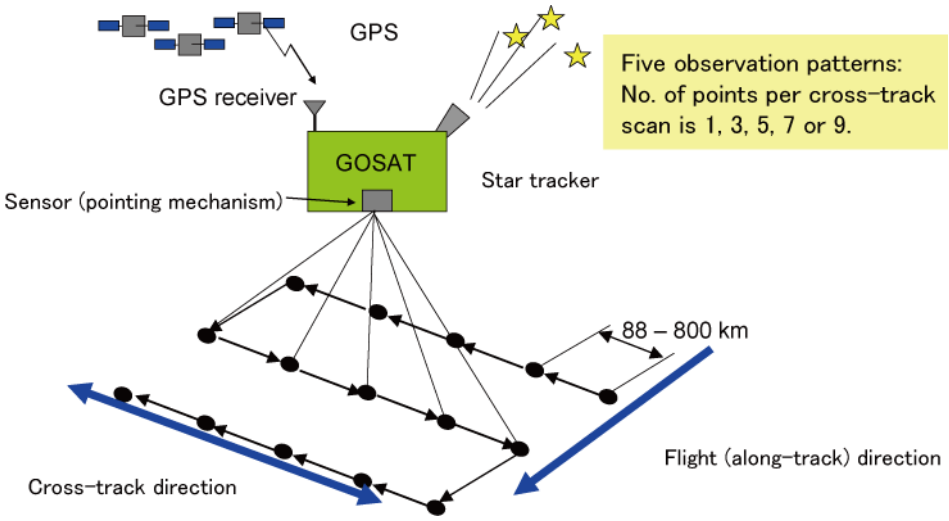

Figure C-2.4-1 Scanning pattern in cross-track direction

(2) Specific point observation

In the specific point observation mode, FTS makes observation over a specific ground point (one-point observation) for observing a relatively small coverage, such as calibration/validation sites. When observing a large coverage, such as natural-gas pipeline, it observes multiple specific points consecutively (consecutive observation). The same observation mode, however, is selected to perform both specific point observations (one-point and consecutive). The observation time and the AT and CT angles will be specified by the commands uplinked from the ground.

(3) Sunglint observation

In the sunglint mode, TANSO-FTS makes observation over the ocean. In this observation, the

sunglint point is computed on the ground and the angle of the pointing mirror is set to observe that point. The sensor then observes the sunglint point in strips. Sunglint observation is performed at low or middle latitudes, but the detailed latitude ranges for the FTS observation are still being examined. Incidentally, the latitude range varies with the seasons.

C-2.4.2 Nominal Operation of CAI

TANSO-CAI observes the target while the observation ground point is in daylight. The operation is different for LLM and S-LLM modes. The start and end times of TANSO-CAI daytime observation is specified by the stored commands uplinked from the ground.

C-2.4.3 Operation in Calibration Modes

(1) Blackbody, deep-space calibration mode

In FTS's deep-space calibration (in the short wavelength- and thermal-infrared bands) and blackbody calibration (in the thermal-infrared band), the data are acquired during the lattice or specific point observation mode operation, by designating arbitrary points (by specifying the elapsed time from the ascending node time, up to 16 points per orbit) using the commands to be uplinked from the ground. These points can be specified individually and do not have to be equally spaced. When acquiring data over the same calibration point as previous calibrations, it is not necessary to specify the point every time. In addition, in blackbody/deep-space observation, the observation time of the previous observation mode (1.1, 2, or 4 seconds) is applied, and it requires a total of four observation points, consisting of one for pointing to the blackbody, another for observing the blackbody, another for pointing to deep space and the other for observing deep space. Since the detectors continuously output data while changing the pointing direction, the data rate remains constant. (In order to distinguish these data from effective data, the pointing "completion" flag will be indicated as "uncompleted").

(2) Solar irradiance calibration mode

Solar irradiance calibration (using the diffuser plate) for FTS will be performed immediately before the target observation point on the ground comes into daylight, by selecting the diffuser plate for use and switching to the solar irradiance calibration mode with the stored commands (designating time as parameters).

(3) Lunar calibration mode

The sensitivity calibration of both FTS and CAI is performed using the reflection of sunlight from the moon surface as the light source. The integrated value of the reflection from the entire moon surface serves as the calibration light. Of the linear array detectors of CAI, the sensitivity of the

devices is calibrated where lunar calibration light enters. That of the other devices, which do not receive the calibration light, is calibrated by means of relative calibration based on the ground observation data over deserts, etc. In case that a device placed near the center of CAI fails down, another nominal device takes over the job by offsetting in the satellite's pointing direction.

C-2.5 Gain Setting

(1) Gain setting of FTS

Three levels (Low/Medium/High) of gain setting are available for Bands 1, 2, and 3 of FTS. However, only one level can be selected for all bands. In addition, the following settings are the basic preconditions in FTS observation.

- Observation over lattice points, specific point observation: High gain
  Note, however, that medium gain should be chosen for observing desert areas at low latitudes, as necessary.
- Sunglint observation: High gain
  Note, however, that medium gain may be chosen, as necessary.
- Solar irradiance calibration: Medium gain (fixed)
- Low gain will not be used, in principle.

The gain setting can be changed, as necessary, in the following scenarios, based on the pass or argument of latitude being the parameter.

- When passing over the zone at the designated argument of latitude.
- When observing sunglint points.
- When observing specific ground points

(2) Gain setting of CAI

Three levels (Low/Medium/High) of gain setting are available for Bands 1, 2, and 3 of CAI. In fact, the gain is adjusted by the integral time. The gain value can be set based on the pass or argument of latitude being the parameter. However, only one level can be selected for all bands. The gain setting value is maintained as a static parameter and is assumed to be readjusted about once a month.