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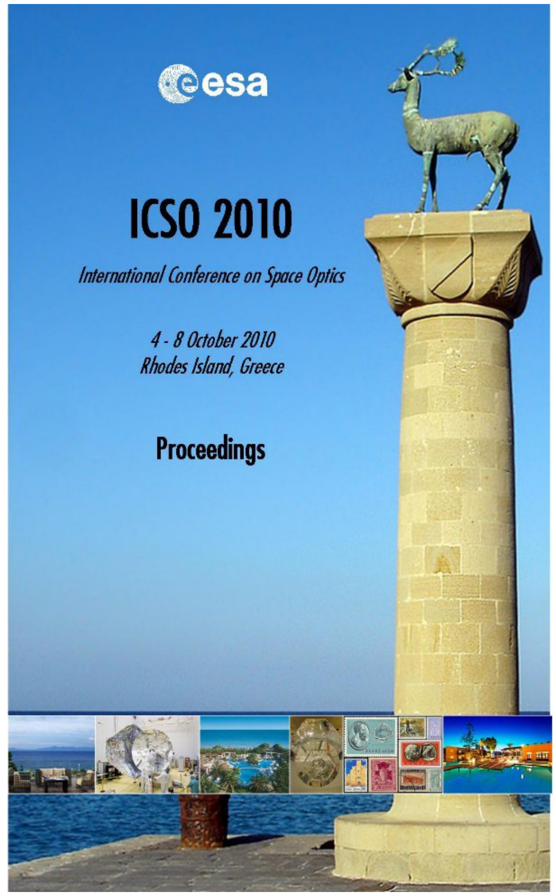

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ONE-YEAR OPERATION OF TANSO-FTS ON GOSAT AND FOLLOW-ON MISSION FEASIBILITY

Kei Shiomi[1], Masakatsu Nakajima[1], Akihiko Kuze[1], Toshiaki Takeshima[1], Shuji Kawakami[1] and Hiroshi Suto[1]
[1]*Japan Aerospace Exploration Agency, Japan.*

I. INTRODUCTION

The Greenhouse gases Observing SATellite (GOSAT) was developed to contribute to monitoring of carbon dioxide and methane from space [1]. The mission objectives are global greenhouse gas measurements from space with precision of 1 % for CO_2 and 2 % for CH_4 in seasonal mean. The GOSAT carries Thermal And Near infrared Sensor for carbon Observation (TANSO) for precise measurement of greenhouse gases. Main instrument is Fourier Transfer Spectrometer (TANSO-FTS) to observe atmospheric absorption spectra of CO_2 and CH_4 with high spectral resolution of 0.2 cm^{-1}, broad wavelength coverage of 0.76 – 14.3 microns, wide swath of 790 km and frequent revisit of 3 days. Cloud and Aerosol Imager (TANSO-CAI) is simultaneously on board for cloud detection and correction of optical thin cirrus and aerosol interference within the FTS instantaneous field of view. The GOSAT satellite was launched by H2A-15 rocket on January 23, 2009. The Level 1B products of calibrated spectra were released from September 2009 in public. The Level 2 products of CO_2 and CH_4 column densities were released from February 2010 [2]. The normal observation data is acquired over one year regularly from April 2009. The mission lifetime is 5 years.

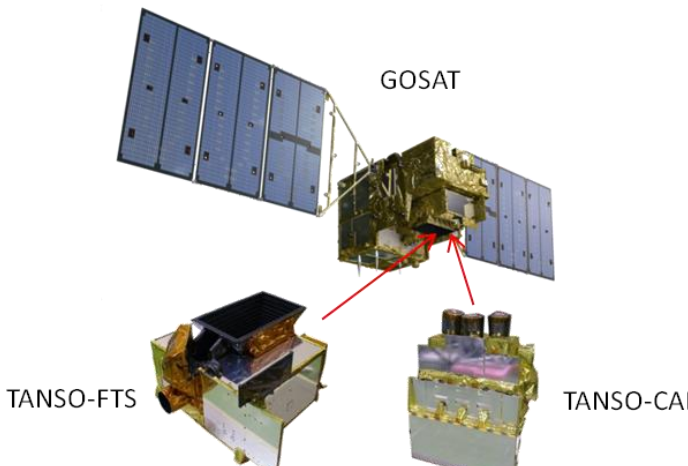

Fig. 1. TANSO-FTS and CAI on GOSAT

II. TANSO-FTS ON GOSAT

The TANSO-FTS observes at wide spectral range from shortwave infrared (SWIR) to thermal infrared (TIR) with the same optics. The modulated lights by double cube corner mirrors are separated into 3 SWIR bands with P and S polarizations and TIR band by dichroic mirrors settled after-optics. The FTS specifications are shown in Table 1. The observation band width is optimized to increase the SNR at target gas absorptions. The spectral resolution is determined by a maximum optical path difference +/- 2.5 cm and a finite pupil of ZnSe beamsplitter with a diameter of 68 mm corresponding to instantaneous filed of view (IFOV) of 15.8 mrad. The IFOV is projected onto the earth with a diameter of 10.5 km. The metrology sampling is due to 1.33 μm diode laser. Normal observation is operated as 5 points cross track with 4 sec exposure with image motion compensation. The FTS observed spectra with fine spectral resolution are shown in Fig. 2.

Table 1. TANSO-FTS specifications

Band	**Band 1**	**Band 2**	**Band 3**	**Band 4**
Polarization	P, S	P, S	P, S	-
Wavelength	0.75-0.78 μm	1.56-1.73 μm	1.92-2.09 μm	5.5-14.3 μm
Target gases	O_2	CO_2, CH_4	CO_2	CO_2, CH_4, O_3
Spectral resolution	0.5 cm^{-1}	0.2 cm^{-1}	0.2 cm^{-1}	0.2 cm^{-1}
SNR	> 300	> 300	> 300	> 300
Time resolution	4 sec / interferogram (5-point observation cross track)			
Spatial resolution	10.5 km (nadir view at sub-satellite)			
Swath width	750 km (5-point observation cross track)			

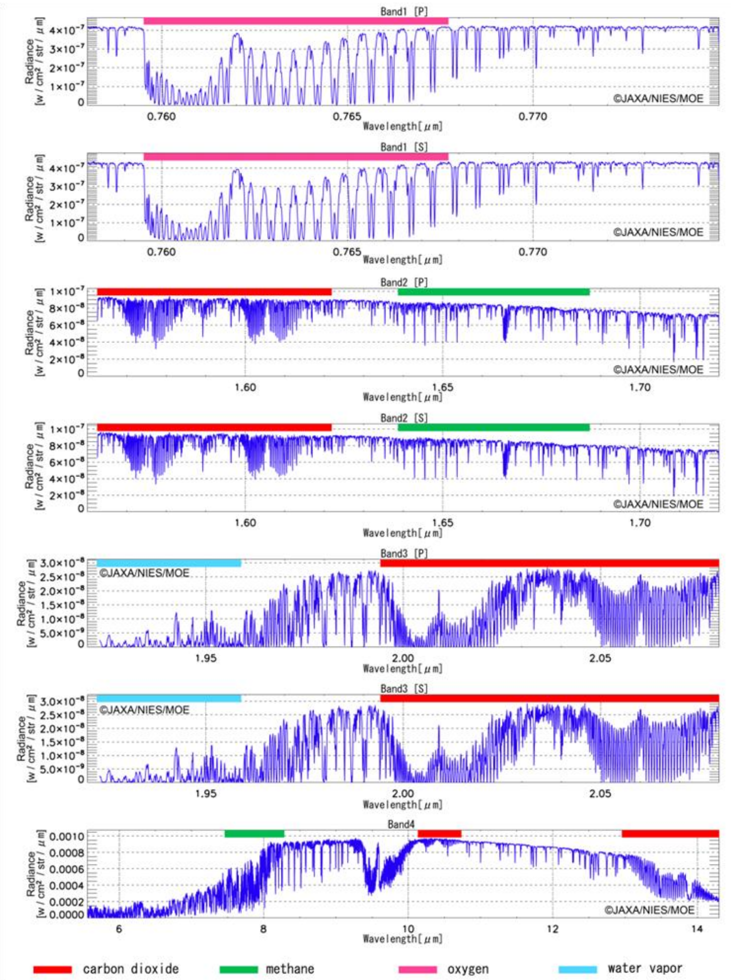

Fig. 2. TANSO-FTS spectral radiances observed over Tsukuba, Japan on April 23, 2009

III. GOSAT OPERATION

The TANSO operation on GOSAT orbit is illustrated in Fig. 3. The FTS SWIR and CAI observations are operated in dayside. The FTS TIR band is operated both in dayside and nightside. As for the FTS, solar irradiance, blackbody and deep space calibrations are operated regularly for monitoring radiometric stability and the TIR radiometric calibration. The instrument line shape (ILS) calibration and nighttime observation are operated once a month. The lunar calibration is operated once a year for the FTS SWIR channels and the CAI.

The TANSO-FTS operation is combined with gird observations of 5 points in cross track direction, on-orbit calibration, sunglint observations over ocean, and target observations for calibration and validation sites. Fig. 4 shows an observation pattern in daytime path. The grid observations are normally operated in global. The sunglint observation is done in oceanic glint area from satellite view within approximately +/- 20 degrees of solar zenith by continuous tracking mode. The target observation is operated for calibration and validation points regularly. The observation request of target mode by the GOSAT research PIs are coordinated and combined in the nominal operation.

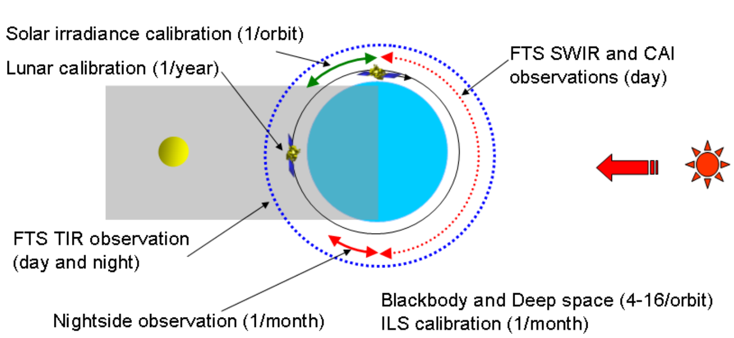

Fig. 3. TANSO-FTS and CAI operations on orbit

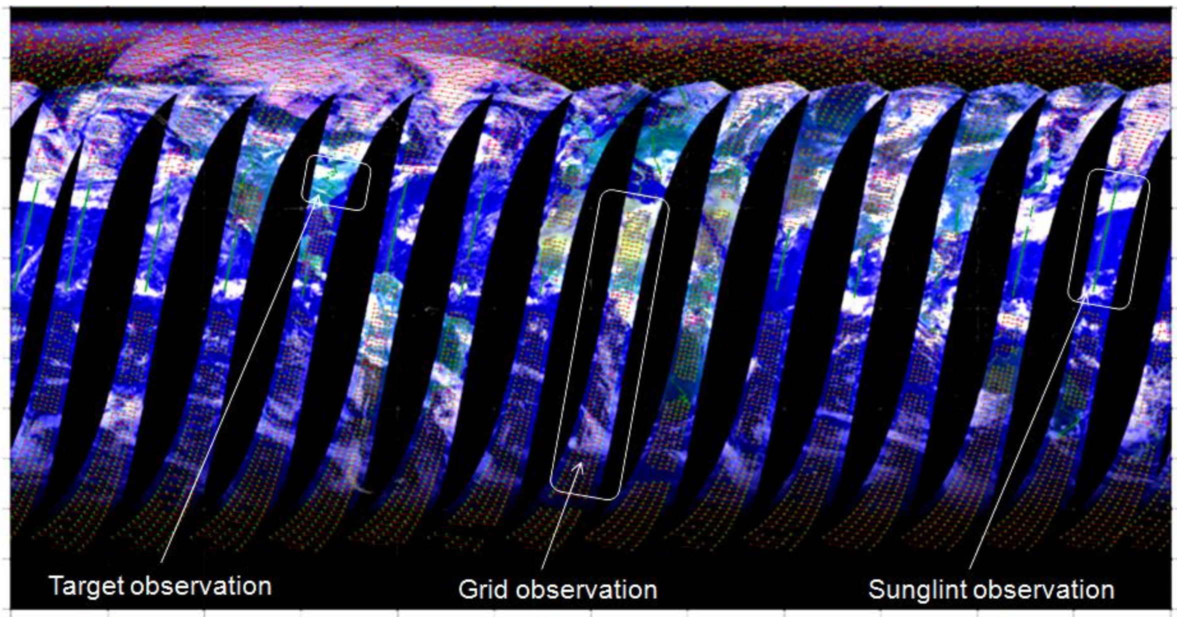

Fig. 4. FTS observation pattern with CAI browse image on June 5, 2010 in daytime path

IV. ON-ORBIT PERFORMANCE OF TANSO-FTS

On-orbit performance is evaluated for spectral, radiometric, and geometric characteristics by monitoring onboard calibration data and comparison with reference data.

The ILS of spectral characteristics is a significant parameter of the FTS. The ILS calibration by using 1.55 micron onboard laser is operated once a month for Band 2 P and S. Fig. 5 shows the ILS calibrations over one year from the launch. It is confirmed they are not significantly changed on orbit.

Radiometric accuracies of the SWIR channels are evaluated by analysis of the on-orbit solar irradiance calibration by comparison with the Kurucz solar model [3]. The onboard solar irradiance data is acquired after reflection of the spectralon diffuser. The radiometric sensitivity is evaluated by the back surface of diffuser, which is operated once a month with less exposure of solar light. Fig. 6 shows the radiometric sensitivity degradation estimated from the solar irradiance calibration. The result is after the correction of solar distance and incident angle to the diffuser in each data. However, there is a trend corresponding to the incident angle, which means there is an anisotropic reflective property of the diffuser surface. The Band 1 and 2 are respectively degraded in 5 % and 2 % sensitivity just after the launch. The Band 1 is degraded in 5 % in one year after the launch and band 2 and 3 in 2 %.

Radiometric calibration of the TIR channel is improved by correction of the mirror polarization effect dependent on incident angles and wavelength. The current TIR radiometric accuracy is evaluated within 0.7 K by comparison with line-by-line simulation using sea surface temperature. The geometric accuracy is evaluated within the size of one IFOV by comparison with onboard monitoring camera fine-resolution image and well-calibrated ALOS/AVNIR-2 reference image.

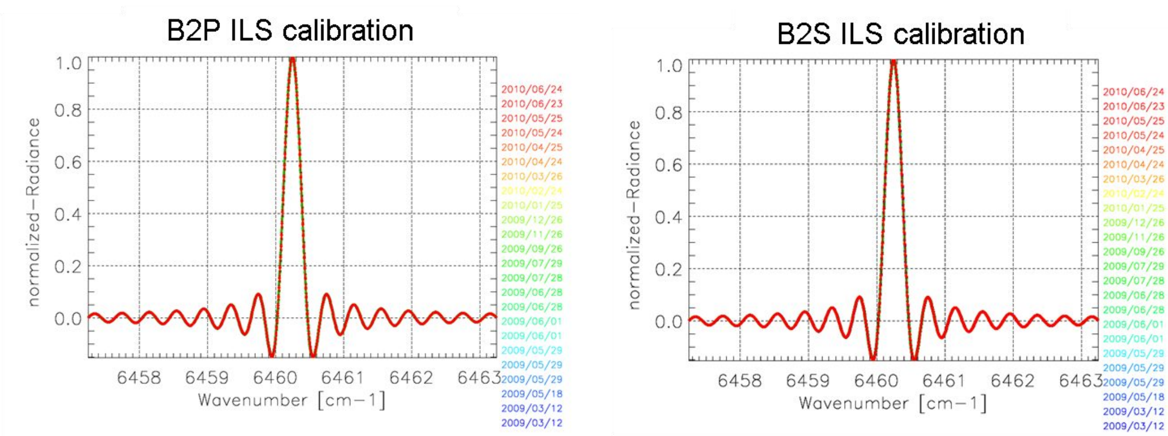

Fig. 5. ILS calibrations of Band 2 P and S by 1.55 micron on-board laser in one year

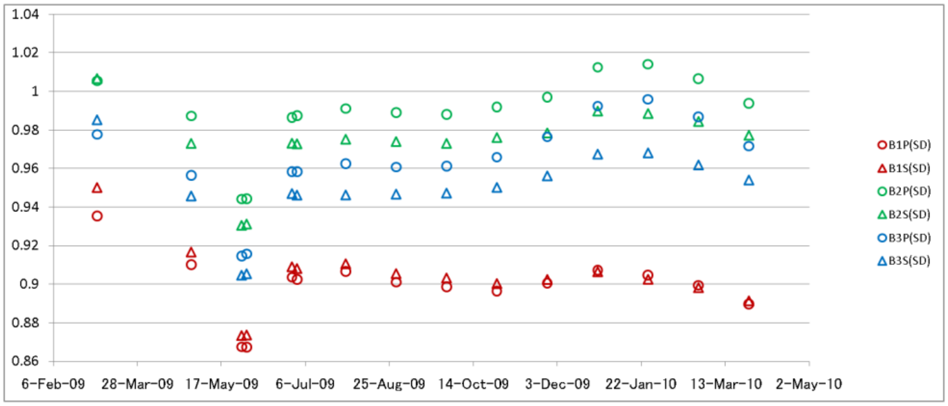

Fig. 6. Radiometric sensitivity of SWIR channels estimated from solar irradiance calibration in one year

V. FEASIBILITY OF GOSAT FOLLOW-ON MISSION

JAXA has started a feasibility sensor study for the GOSAT follow-on mission. Mission design approach is illustrated in Fig. 7. The mission baseline is the on-orbit GOSAT TANSO in operation. Improvement elements from baseline include FTS specification upgrade, characterization for robustness, and CAI calibration upgrade. Candidates of target expansion are CO and N_2O measurements. CO is measured by an additional 2.3 micron band for help to the CO_2 source information. N_2O is measured in TIR band of 1300 cm^{-1} with high SNR for an additional target of GHG. The TANSO-FTS upgrade has feasibilities to be advanced on specifications of higher spectral resolution, spatial resolution (small FOV) and time resolution (short accumulation) and additional observation channels after trade-off study of sensor system design. Several target specifications are on feasibility study by preproduction of the detector band-pass filter and additional characterization test of the TANSO laboratory model. CO_2 lidar and expanded objectives for trace gas measurements and atmospheric sounding will be achieved by another newly developed sensors onboard the GOSAT follow-on satellite.

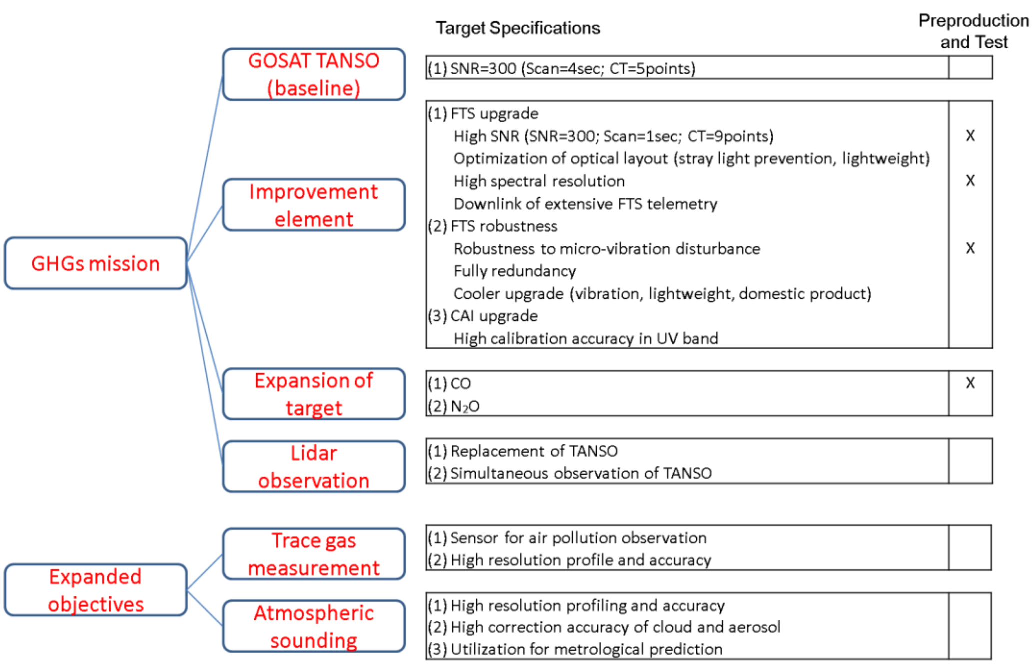

Fig. 7. Feasibility of GOSAT follow-on mission

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