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

Research Announcement

August 2012

Japan Aerospace Exploration Agency (JAXA)

National Institute for Environmental Studies (NIES)

Ministry of the Environment (MOE)

Japan

Foreword

The Fourth Assessment Report issued by the Intergovernmental Panel on Climate Change (IPCC) in 2007 states that most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic Green House Gas (GHG) concentrations. The drastic increase in the concentration of GHGs, particularly carbon dioxide (CO_2), caused directly and indirectly by human activities, is attributed to the fact that the emission of CO_2 into the atmosphere in the process of the mass consumption of fossil fuel, deforestation, etc., significantly surpasses the absorption by the land ecosystem and the oceans. Thus, it is imperative to balance the emission due to human activities and the absorption by the nature, in order to stabilize the climate for the future. In the meantime, however, we, humans, have not grasped, to a sufficient level, the mechanisms of the absorption by land ecosystem and ocean, and the climatological feedback in the carbon cycle involving atmosphere, land ecosystem and ocean. This lack of understanding comprises a substantial part of the uncertainty in predicting future climate change.

The clarification of these problems involves not only an ascertainment of the spatial and temporal variations in the CO_2 emission from human activities but also a calculation of the spatial distribution and temporal variation of CO_2 and also methane (CH_4), which is the second largest contributor to global warming after CO_2, and the spatial distribution and temporal variation of the source and sink in land ecosystem and oceans, based on earth observation, and ultimately an attainment of adequate scientific knowledge on the underlying mechanisms. These efforts to observe GHG concentrations and to analyze the causes of their variations at some locations are, though still limited, in progress. On top of these attempts, it is vital to observe the distributions of CO_2, CH_4, and other GHG concentrations, which fluctuate both spatially and temporally, on the global scale, using satellite platforms, in a continuous and systematic manner, and to elucidate the current issues, with a goal to elevate the reliability of prediction of future climate change and climate system models effective for assessing the consequences of climate change.

Aiming for fulfilling the above requirements, the Japan Aerospace Exploration Agency (JAXA), the National Institute for Environmental Studies (NIES) and the Ministry of the Environment (MOE) (hereinafter referred to as the “Three Parties” collectively) is jointly promoting the GOSAT (Greenhouse gases Observing SATellite) Project. The Three Parties have revised the application method of the research announcement (hereinafter referred to as the “RA”) made in the past with a view to promote the further use of the GOSAT data and shall start inviting research proposals at anytime from August 2012.

The spacecraft “GOSAT” (IBUKI) was successfully launched on January 23, 2009 and more than three years have passed since GOSAT started its on-orbit operation. In the GOSAT Project, the RA was made for three times, and consequently, numerous research outcomes were achieved by both domestic and abroad RA researchers while high-quality GOSAT data were accumulated. From now on, with the objectives of improving convenience for the RA candidates and enhancing variability and possibility of research outcomes, such as creative research outcomes from a new point of view are accomplished through the use of GOSAT data by wider range of researchers around the world, the Three Parties shall start inviting applications and research proposals anytime from August 2012. The details of this RA are provided in the following RA documents. Note that the RA Office is set up inside NIES as was in the past.

RA Document

GOSAT Research Announcement (main text)

Appendix A	Outlines of GOSAT and TANSO Sensor
Appendix B	GOSAT/TANSO Calibration and Validation Plan and Overview of Processing Algorithms
Appendix C	Operation Policies of GOSAT and Basic Observation Plan of the TANSO Sensor
Appendix D	Contents of Research Proposal and Application Forms
Appendix E	General Contractual Conditions for the Joint Research on the GOSAT data
Appendix F	User Category, Glossary and Abbreviation List

Schedule for the 4th RA is shown hereunder as an example of such RA that the Three Parties invite research proposals anytime without setting up the deadline.

Release of the RA	August 31, 2012
Period for research proposal acceptance (The 4th RA)	August 31~ October 26, 2012*
Period for research proposal review (The 4th RA)	August 31~ November 11, 2012
Date of the selection board (The 4th RA)	November 16, 2012
Notification of the selection results	November 30, 2012
Sign up of the agreement	December 3, 2012 or later
Submission of interim reports (The 4th RA)	December 28, 2013

*Applications and research proposals will be accepted even after October 26, 2012. Schedules of acceptance and selection for following RAs will be posted on the NIES GOSAT Project webpage in an appropriate timing.

For more information, please contact:

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National Institute for Environmental Studies
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Acceptance time: Weekday (excluding Japanese national holidays) 10:00-17:00

August, 2012

Japan Aerospace Exploration Agency (JAXA)
National Institute for Environment Studies (NIES)
Ministry of the Environment (MOE)

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GOSAT/TANSO Research Announcement

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Appendix A	Outlines of GOSAT and Overview of TANSO Sensors
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*Please note that Appendices A, B, and C have not revised since the first research announcement was made. Consequently, some descriptions differ from current conditions; such as, a version-up of the processing algorithm has not explained in Appendix B. Updates are provided at the GOSAT User Interface Gateway, a website for GOSAT data distribution (GUIG).

1. Introduction

The Fourth Assessment Report issued by the Intergovernmental Panel on Climate Change (IPCC) in 2007 states that most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic Green House Gas (GHG) concentrations. The drastic increase in the concentration of GHGs, particularly carbon dioxide (CO_2), caused directly and indirectly by human activities, is attributed to the fact that the emission of CO_2 into the atmosphere in the process of the mass consumption of fossil fuel, deforestation, etc., significantly surpasses the absorption by the land ecosystem and the oceans. Thus, it is imperative to balance the emission due to human activities and the absorption by the nature, in order to stabilize the climate for the future. In the meantime, however, we, humans, have not grasped, to a sufficient level, the mechanisms of the absorption by land ecosystem and ocean, and the climatological feedback in the carbon cycle involving atmosphere, land ecosystem and ocean. This lack of understanding comprises a substantial part of the uncertainty in predicting future climate change.

The clarification of these problems involves not only an ascertainment of the spatial and temporal variations in the CO_2 emission from human activities but also a calculation of the spatial distribution and temporal variation of CO_2 and also methane (CH_4), which is the second largest contributor to global warming after CO_2, and the spatial distribution and temporal variation of the source and sink in land ecosystem and oceans, based on earth observation, and ultimately an attainment of adequate scientific knowledge on the underlying mechanisms. These efforts to observe GHG concentrations and to analyze the causes of their variations at some locations are, though still limited, in progress. On top of these attempts, it is vital to observe the distributions of CO_2, CH_4, and other GHG concentrations, which fluctuate both spatially and temporally, on the global scale, using satellite platforms, in a continuous and systematic manner, and to elucidate the current issues, with a goal to elevate the reliability of prediction of future climate change and climate system models effective for assessing the consequences of climate change.

Under such circumstances, the GOSAT (Greenhouse gases Observing SATellite) Project was initiated and has been promoted jointly by the Japan Aerospace Exploration Agency (JAXA), the National Institute for Environmental Studies (NIES) and the Ministry of the Environment (MOE) (hereinafter referred to as the “Three Parties” collectively). One of the missions of the Project is to increase the accuracy of the flux (source and sink) estimation of the GHGs on the sub-continental basis (a few thousand kilometers square), thereby to contribute to environmental administration efforts such as ascertainment of fluxes per region and evaluation of the carbon balance in forests. The Project will further contribute, through research on applications of the data acquired by GOSAT, to an accumulation of scientific knowledge regarding the global distribution of GHG concentrations and its temporal variations as well as the global carbon cycle mechanism and its impact on climate change, which will assist the prediction of climate change and evaluation of consequences therefrom. At the same time, the Project aims to maintain and further evolve conventional earth-observing technologies to develop new methodologies to measure GHGs and enable engineering development necessary for future earth-observing satellites.

To achieve these goals, JAXA takes charge of developing and launching the satellite with the sensors on board, calibrating and operating the sensors, acquiring observation data, and processing the acquired data to Level 1 (spectral) products, whereas NIES undertakes the examination of requirements for the sensor specifications, development and operation of the higher-level product processing system, development of the data processing algorithms, generation of Level 2 (GHG concentrations), Level 3 & 4 (global distribution of GHG concentrations, and distribution of carbon source/sink based on them, etc) products, validation of data quality, and storage and provision of the generated data products. Furthermore, the MOE supplements the development of the sensors and bears the responsibility for utilization of the GOSAT data in its environmental administration through the acquisition of validation data and scientific use of mission data. The Three Parties have been and will continue to be vigorously carrying forward the research and development necessary for fulfilling these tasks with the help and advice from the GOSAT Science Team, which was established and is administered by the Three Parties.

The Research Announcement to be made herein (hereinafter referred to as the “RA”) solicits proposals for research on the data processing algorithms, calibration, validation, carbon balance estimation/atmospheric transport models, and scientific use with respect to the GOSAT data from the public, on top of the basic research and development topics to be performed by the Three Parties, with an aim to make the outcomes of the Project more effective. All research teams responding to this RA whose proposals are selected by the Three Parties based on the results of evaluation by the RA Selection and Evaluation Committee (hereinafter referred to as the “Committee”) will be granted a priority in data distribution, the right to make observation requests (within a predetermined scope), accommodation in obtaining other related data, and so forth. Incidentally, the Committee will consist of the members selected and requested by the Three Parties from among Japanese and non-Japanese experts and specialists.

The succeeding chapters in this document describe the contents of the GOSAT Project in detail, including items ranging from the equipment onboard the satellite, overview of data processing algorithms, calibration and validation plans to data utilization plans. Applicants to this RA are encouraged to read the contents of this document carefully and make active efforts to write research proposals.

2. Definitions of the GOSAT/TANSO Research Announcement (RA)

2.1 GOSAT Project

GOSAT carries an observing instrument called Thermal And Near-infrared Sensor for carbon Observation (TANSO). The GOSAT/TANSO is composed of two sensors called Fourier Transform Spectrometer (FTS), which measures greenhouse gases (GHGs), and Cloud and Aerosol Imager (CAI), which collects information on cloud and aerosol.

The primary purpose of GOSAT is to measure the global distribution of GHG concentrations and its temporal variation and to increase the accuracy of the flux estimation of GHGs on the sub-continental scale, thereby contributing to the sustention and development of systemized observation in accordance with the Kyoto Protocol, while at the same time facilitating the environmental administration efforts, including ascertainment of the flux per region and evaluation of the carbon balance in forests during the first period (2008-2012) as specified by the Protocol. In the meantime, the Project is intended to develop GHGs-measurement technologies and other technologies necessary for future earth-observing satellites, by standing on and further evolving the existing earth-observing technologies.

2.2 Purpose

The purpose of the RA is to open to public an opportunity for researching on the data processing algorithms, calibration, validation, carbon balance estimation/atmospheric transport models, and scientific use of the GOSAT data, in addition to the basic research and development topics to be performed by the Three Parties, with a goal to make more use of the outcomes from the Project. The research topics selected by the Committee and adopted by the Three Parties will be subject to preferential data distribution, the right to make observation requests (of reasonable amount), and accommodations in obtaining other related data, etc.

The implementation of the RA is expected to bring about additional researches by other parties than JAXA and NIES, which will supplement the research to be conducted in accordance with the calibration and validation plans of the Project, facilitation of studies on the processing algorithms, carbon balance estimation/atmospheric transport models, and utilization of the GOSAT/TANSO data, objective evaluation of the research concerning the effectiveness and usefulness of the data, expansion of opportunities for researchers and scientists inside and outside Japan to access the GOSAT data, and so on.

2.3 Scope

The GOSAT/TANSO RA is open to all countries across the world, not limited to Japan. All individual researchers, educational organizations, research institutes, and governmental bodies who are willing to use the GOSAT data for non-profit and peaceful purposes are entitled to participate in the RA. In this manner, private companies are also qualified for submitting research proposals as long as their themes are for non-profit and peaceful purposes.

Investigators involved in carrying out the research themes selected in the RA are called "RA

Investigators” for the purpose of the RA. A team of RA Investigators working on a research theme will elect one principal investigator (hereinafter referred to as “PI”) who will represent the team. The PI will act as the contact person with the Three Parties in carrying out the research on the selected theme, such as communication, data transfer, submission of necessary documents, etc. In principle the research organization (hereinafter referred to as “RO”) to which the PI belongs shall also be responsible for signing the joint research contract with the Three Parties, as provided in Appendix E hereto, when selected for the RA. The signer may be the PI himself/herself only in case if the PI does not belong to any organization.

Incidentally, the research teams selected for the RA may be requested to conclude a separate contract in order to strengthen the cooperative relationship between the team and the Three Parties.

2.4 Basic Policies

The GOSAT/TANSO RA will be conducted based on the following policies:

1) The Three Parties will establish a committee to select the research proposals and to follow their results. This committee will be referred to as “the Committee” hereinafter. Research proposals submitted in response to the RA will be evaluated by the Committee, and they will be selected by the Three Parties based on the evaluation results by the Committee. The Committee shall be responsible for not only evaluating the submitted proposals but also, as shown in Chapter 8.2.1 hereof, evaluating the progress and adequacy of the adopted researches.
2) The research period shall be the operational period of GOSAT/TANSO plus the operational period of its ground system — five years after the launch, in principle (until January 22, 2014) —. Any long-term research to be conducted, which goes beyond one year, will be subject to interim reporting to the Three Parties, basically once a year.
3) The GOSAT/TANSO RA took place in April to August 2008 for the first time, in April to August 2009 for the second time, and in August 2010 to February 2011 for the third time. Taking into account the success of the past RAs, applicants are invited to submit their research proposals anytime from August 2012 aiming to improve convenience of the candidates and to give opportunities to become new GOSAT RA Investigators.
4) PI of a research team may make multiple research proposals on different themes during the mission period. (In other words, a single person may submit proposals on more than one research themes to be carried out under this RA scheme.)
5) The PI may submit observational requests to the extent determined by the Committee per research theme.
6) The PI may request for distribution of GOSAT data free of charge to the extent designated by the Committee per research theme.
7) Applications for the GOSAT/TANSO RA and research plans shall be submitted via the Websites run by the RA Office or by e-mail, in principle; those documents sent by conventional mail or other means may also be accepted according to the situation.
8) Research themes to be conducted under the RA scheme were selected in August 2008 for the first RA, in July and August 2009 for the second RA, and in January 2011 for the third RA. From the RA starting from August 2012, the selection will be administered at each time the Committee meeting is held semiannually in principle.
9) Proposal titles and names of PIs and their ROs will be disclosed on the websites run by the NIES GOSAT Project office when their research themes are selected for the RA.

10) Outcomes of the GOSAT/TANSO RA must, in general, be disclosed to the public in the form of papers published on academic journals and other media and at the same time be reported at the research result reporting meetings held by the Three Parties.
11) The Three Parties do not provide any financial assistance to PIs, in principle, under the RA scheme.
12) RO (or PI in case he/she does not belong to any organization) must conclude the joint research contract, as provided in Appendix E, with the Three Parties prior to the start of research activities on the selected research theme.

2.5 Implementing Organization of the GOSAT/TANSO RA

The Three Parties have set up an office in charge of the RA within the NIES GOSAT Project office, for firm and efficient implementation of the GOSAT/TANSO RA. The RA Office carries out the following tasks in accordance with the basic policies set forth by the Three Parties.
1) Prepares the RA procedures and release them to the world.
2) Carries out administrative works as the secretariat of the Committee.
3) Accepts proposals submitted in response to the RA and requests the Committee for due evaluation for selecting research themes.
4) Notifies the selection results to all PIs who submitted research proposals and assists those selected PIs in signing the joint research contract (see Appendix E) necessary for carrying out the research.
5) Receives the outputs of the research from the PIs by the deadline designated in the contract and distributes them among the Three Parties.
6) Assists in organizing the research result report meetings to be held by the Three Parties.
7) Notifies the completion of the joint research agreement to the RO (or the PI in case if he/she does not belong to any organization) in writing when the Committee confirms and accepts the Final Report of Research Result submitted by the PI in accordance with section 8.2.2 of this Research Announcement.

See Chapter 14 hereof for the contact information of the RA Office.

3. Outline of GOSAT and TANSO Sensors

3.1 Outline of GOSAT

An outline of GOSAT is provided in Chapter A.1 of Appendix A hereto.

3.2 Outline of GOSAT/TANSO-FTS

GOSAT/TANSO-FTS is one of the two sensors onboard GOSAT and is a Fourier interferometer which observes GHGs such as CO_2 and CH_4. An outline of TANSO-FTS is provided in Chapter A.2 of Appendix A hereto.

3.3 Outline of GOSAT/TANSO-CAI

GOSAT/TANSO-CAI is one of the two sensors onboard GOSAT and is an imager which collects cloud and aerosol information. An outline of TANSO-CAI is provided in Chapter A.3 of Appendix A hereto.

4. GOSAT/TANSO Data Policies

Each PI is entitled to obtain the GOSAT data necessary for his/her respective research activities (up to a limited number) without any cost, from the Three Parties on the condition that he or she agrees to the following provisions:

1) The use of the data for any purpose in opposition to peaceful use is prohibited.
2) The use of the data for any other purpose than his/her research purpose is prohibited.
3) Redistribution of the data to any third party is prohibited.
4) The data obtained can only be distributed among the PI and RA Investigators.
5) Any publication of the outcomes obtained in consequence of the use of the data must be accompanied by an indication of the data source.
6) The use of the data under the mechanisms of the Kyoto Protocol, namely the Joint Implementation (Article 6 thereof), Clean Development Mechanism (Article 12 thereof), and the International Emission Trading (Article 17 thereof), without consent of the Three Parties is prohibited, provided that any use for such a purpose may be allowed if the PI obtains an approval of and concludes a contract with the Three Parties in advance.

The data to be distributed will be subject to the operational status of the satellite and the physical restrictions of the sensors. The invisible areas by FTS and CAI are explained in Chapters A.2 and A.3 of Appendix A hereto, respectively.

The Three Parties shall not be liable for any missing data, degradation of data quality, delay in data delivery, or any other situation in which the data cannot be provided, as a result of problems that occurs to the spacecraft or the ground facilities.

The ownership of the original data acquired with GOSAT/TANSO belongs to the Three Parties. The "original data" here means the products provided by JAXA or NIES and should be distinguished from the data obtained by RA Investigators as an outcome from their research activities.

RA Investigators are entitled to access the GOSAT data prior to the release of the data to the public. They are also entitled to use the data planned to be acquired in accordance with the Basic Observation Plan of the TANSO sensor attached hereto as Appendix C.

Although the RA Investigators and the Three Parties shall confer with respect to the content of new observation requests after the selection, the RA Investigators drawing up research plans in response to the RA should carefully examine the "Operation Policies of GOSAT and Basic Observation Plan of the TANSO Sensor", as provided in Appendix C, and plan acquisition and distribution requests for the GOSAT data, with due consideration given to the constraints of each sensor in its observation (more concretely, invisible areas, observation mode switching, etc.)

RA Investigators are entitled to access the following data products:

1) L1 and L2 Standard products (See Table 1)
The "standard" products mean the calibrated Level 1B products, and all Level 2 or higher level products generated from the validated L1B products and are released to general users. There are four

calibration stages for L1 and four validation stages for L2 products, and they are explained in Table 2 and 3, respectively. All L1 and L2 products are released to general users at the “Confirmed” stage.

2) L2 Research products (See Table 1 as well as Table 6 described in Chapter 8)
The “research” products are the data products intended to be used in the research fields of calibration, validation, data processing algorithms, data application, and other scientific researches. Their validation stage goes up until (V) “Validated” and no further. They are available to RA Investigators, to an extent necessary for their respective researches, at suitable timing. However, it should be noted that because the research products are basically not the subjects for the validation activity, the research products at the “Validated” stage are the comparable quality to the “Preliminarily checked” stage with feedback from RA* Investigators as supplementary explanation.

3) L3 Products (See Table 1)
L3 products are the global-scale products calculated from L1 and L2 products. L3 products are not “validated”, but they are released to RA Investigators prior to the public for preliminary evaluation.

4) L4 Products (See Table 1)
L4 Products consist of L4A (global CO_2 flux) and L4B (global CO_2 distribution) data products as the standard products and L4A (global CH_4 flux) and L4B (global CH_4 distribution) data products as the research products. As for the standard products, at first, they are disclosed to the RA Investigators in the research field of “carbon balance estimation, atmospheric transport models” explained in section 12.1, in order to obtain the investigators’ feedback and reflect them on the products’ release notes and other documents. Then, prior to their release to the public, the products are distributed to all other RA Investigators for a purpose of quality confirmation.

5) JAXA’s satellite data other than the GOSAT data
Those selected PIs who are willing to use the satellite data owned by JAXA, other than the GOSAT data, may so request to JAXA. When the request is made to JAXA, it shall also be informed to the RA office.

Table 1 List of GOSAT/TANSO data products (as of 31 August 2012)

Processing Level	Sensor / Band	Product Name	Category	Unit	Format
L1A	FTS	FTS L1A data	Internal (*1)	FTS scene	HDF5
	CAI	CAI L1A data	Internal (*1)	CAI scene	
L1B	FTS	FTS L1B data	Standard	FTS scene	
	CAI	CAI L1B data	Standard	CAI flame	
L1B+	CAI	CAI L1B+ data (*3)	Standard		
L2	FTS SWIR	L2 CO_2 column amount (SWIR)	Standard	Scan	
		L2 CH_4 column amount (SWIR)	Standard		
		L2 H_2O column amount (SWIR)	Research		
	FTS TIR	L2 CO_2 profile (TIR)	Standard		
		L2 CH_4 profile (TIR)	Standard		
		L2 CO_2 column amount (TIR)	Research		
		L2 CH_4 column amount (TIR)	Research		
		L2 temperature profile(TIR)	Research		
		L2 H_2O profile (TIR)	Research		
		L2 H_2O column amount (TIR)	Research		
	CAI	L2 cloud flag	Standard	CAI flame	
		L2 cloud property	Research		
		L2 aerosol property	Research		
L3	FTS SWIR	L3 global CO_2 distribution (SWIR)	Standard	Global (monthly)	
		L3 global CH_4 distribution (SWIR)	Standard		
	FTS TIR	L3 global CO_2 distribution (TIR)	Standard		
		L3 global CH_4 distribution (TIR)	Standard		
	CAI	L3 global radiance distribution	Standard	Global (per 3 days)	
		L3 global reflectance distribution (clear sky)	Standard		
		L3 global cloud property	Research	Global (monthly)	
		L3 global aerosol property	Research		
		L3 NDVI	Standard	Rectangle (30°x 60° (lat. x lon.)) (per 15 days)	
L4A	-	L4A global CO_2 flux (*2)	Standard	Global (64 regions & 1 degree) (annually)	Text
		L4A global CH_4 flux	Research		
		L4A global CO_2 flux (*2)	Standard	Global (1 degree) (annually)	NetCDF
		L4A global CH_4 flux	Research		
		L4A global CO_2 flux	Research	Global (1 degree) (monthly)	
		L4A global CH_4 flux	Research		
L4B	-	L4B global CO_2 distribution (*2)	Standard	Global 2.5 degree (monthly)	
		L4B global CH_4 distribution	Research		

(*1) Internal products are available only to the investigators and organizations working with the GOSAT Project in the field of calibration.

(*2) Browse images are also attached with these products at release.

Products colored yellow are those having been released to the public; products colored green are those having been distributed only to RA Investigators; and products colored blue are those having been distributed only to the RA Investigators specializing in the field of carbon balance estimation and atmospheric transport models (as of 31 August 2012.)

Table 2　Definitions of the calibration stages for L1 standard products

Calibration Stage	Definition
Unchecked (U)	Data products generated by simply processing the observation data.
Preliminarily checked (P)	Data products visually checked and judged as reliable.
Calibrated (Ca)	Preliminarily checked data products having been verified by the initial sensor calibration activity.
Confirmed (C)	Calibrated data products which have been used by a limited community of users for a certain period of time and for which no problem has been reported by the users.

Table 3　Definitions of the validation stages for L2 standard products

Validation Stage	Definition
Unchecked (U)	Products generated by simply processing the observation data.
Preliminarily validated (P)	Products visually checked and judged as reliable.
Validated (V)	Preliminarily validated products which were compared with other observation data having higher-accuracy (e.g., ground-based observation) and judged as sufficiently accurate accordingly.
Confirmed (C)	Validated products which have been used by a limited community of users for a certain period of time and for which no problem has been reported by the users.

These validation stages apply when major changes in the processing algorithms are implemented and version of the product is changed.

Table 4　Definitions of the evaluation stages for L3 standard products

Evaluation Stage	Definition
Unchecked (U)	Products generated by simply processing L1 or L2 products.
Evaluated (E)	Products generated by processing L1 or L2 products and visually checked and judged as reliable.
Confirmed (C)	Evaluated products which have been used by a limited community of users for a certain period of time and for which no problem has been reported by the users, and for which their comments are reflected on documents like product release notes.

Table 5 Definitions of the check stages for L4 standard products

Validation Stage	Definition
Unchecked (U)	Products simply generated based on the carbon balance analysis using both L2 products and the data of the ground-based observation stations.
Preliminarily checked (P)	The above unchecked products which have been visually checked and judged as reliable.
Checked (Ch)	Preliminarily checked products which have been checked by the expert users for a certain period of time and for which no problem has been reported by the users, and for which their comments are reflected on documents like product release notes, if any.
Confirmed (C)	Checked products which have been used by a limited community of users for a certain period of time and for which no problem has been reported by the users, and for which their comments are reflected on documents like product release notes, if any.

5. Data Distribution of GOSAT/TANSO Products and Standards for their Use

5.1 List of Products

Table 1 shown in Chapter 4 outlines the GOSAT/TANSO products, by product type, for which RA Investigators can submit data distribution requests.

5.2 Data Format and Distribution Media

1) Data format
Of the GOSAT data, L1 to L3 products will be provided in the following format, which is commonly used for distributing earth-observing sensor data.

- HDF 5 (Hierarchical Data Format 5)

Higher-level data (L4 products) will be provided in the following format, considering that it is used by TRANSCOM.

- NetCDF
- Text

2) Distribution media
The GOSAT data will be distributed online via the Internet, in general.

6. Funding

The Three Parties do not provide any kind of financial assistance to PIs, in principle.

7. Qualifications

As long as the research proposals are designed for peaceful and non-profit purposes, any research institute, educational organization, governmental body, private company or individual researcher who belongs or does not belong to any sort of organization, in any country, can apply for the RA, regardless of nationality, group or individual.

8. Rights and Obligations of the Principal Investigator (PI)

As explained in Chapter 2.3 above, the PI (one person) shall be responsible for communicating with the Three Parties when applying for the RA and also researching on the research theme, if adopted. Furthermore, as described in 12) of Chapter 2.4 above, the RO to which the PI belongs shall conclude the joint research contracts, attached hereto as Appendix E, with the Three Parties, with respect to the implementation of the research on the theme selected in the RA. The signer may be the PI himself/herself only in case the PI does not belong to any organization.

8.1 Rights

The PI shall be entitled to the following rights:

1) Submitting observation requests necessary for the implementation of the research on the selected theme.
2) Requesting a delivery of standard products without any cost, before the release to the public. (This applies when major changes in the processing algorithms are implemented and version of the product is changed.)
3) Requesting a delivery of research products without any cost. However, note that the number of such requests will be determined in consideration of the conformity to the research purpose.
4) Requesting a "forced" processing of FTS L2 data and a distribution of its results if the L2 data are not generated by any reasons. The "forced" means the processing condition applying neither filtering nor screening to the data in its processing. For making such request, browse images including the targeted observation point shall be visually confirmed beforehand so that there is no cloud over the point. The request will be accepted only in case if those data are necessary for the progress of the adopted RA research.
5) In addition to the FTS L2 data products (column abundances of CO_2, CH_4, and H_2O (SWIR)), PIs can obtain additional information so-called "sub-datasets" of these products.
6) Accessing the NIES "large-volume data distribution system" server to download the GOSAT data collectively. This privilege, however, is only granted to those PIs whose specific applications for its use are approved.
7) Requesting a delivery of the FTS L2 data products which are applied less strict criteria of screening than usual to the public.
8) PIs are entitled to participate in the "PI Meeting" being held by the Three Parties.

Note: PIs' rights over the products which will be distributed after the release of this document will be announced via appropriate means such as the NIES GOSAT Project webpage or e-mail.

In addition, Table 6, 7, 8 and 9 below summarize the timing of product distribution by user categories which mainly consist of two categories; RA users and general users. As far as the RA users, those RA Investigators who study on calibration, validation, or data processing algorithm are grouped as RA* users, while those who study on carbon balance estimation and atmospheric transport models or data application are grouped as RA+ users. Further, those particularly specializing in the field of carbon balance estimation and atmospheric transport models are categorized as RA-Mo users.

Table 6 L1 data distribution conditions for standard/research products

User Category	Standard product	Research product (*1)
RA* Investigator	To be distributed from the P (preliminarily checked) stage	-
RA+ Investigator	To be distributed from the Ca (calibrated) stage	-
General user	To be released at the C (confirmed) stage	-

Table 7 L2 data distribution conditions for standard/research products

User Category	Standard product	Research product (*1)
RA* Investigator	To be distributed from the P (preliminarily checked) stage	To be distributed from the P (preliminarily checked) stage
RA+ Investigator	To be distributed from the V (validated) stage	To be distributed from the V (validated nominally) stage (*2)
General user	To be released at the C (confirmed) stage	Not available

Table 8 L3 data distribution conditions for standard/research products

User Category	Standard product	Research product (*1)
RA Investigator	To be distributed from the E (evaluated) stage	To be distributed from the E (evaluated) stage
General user	To be released at the C (confirmed) stage	Not available

Table 9 L4 data distribution conditions for standard/research products

User Category	Standard product	Research product (*1)
RA-Mo Investigator	To be distributed from the P (preliminarily checked) stage	To be distributed from the P (preliminarily checked) stage
RA Investigator other than RA-Mo	To be distributed from the Ch (checked) stage	To be distributed from the Ch (checked) stage
General user	To be released at the C (confirmed) stage	Not available

(*1) The research products are made available to RA Investigators, to an extent necessary for their respective researches, at suitable timing. The Three Parties do not guarantee their product quality. At this moment, invention of the L1 research product is not planned (See Table 1).

(*2) Because the research products are not the subjects for the validation activity, as far as L2 research products are concerned, the V (validated) stage shall be stated as the V (validated nominally) (See Chapter 4, 2. L2 research products).

8.2 Obligations

8.2.1 Interim reporting

PI shall report the progress of his/her RA research, once a year in principle, in the way designated by the Three Parties, such as submitting the report in writing or presenting the report at GOSAT-related workshops, symposiums, interim report meetings, and conferences to be held by the Three Parties. The Three Parties shall evaluate the interim research result report and the progress report in the Interim Evaluation based on the results of deliberation by the Committee and notify the evaluation results to the RO (or the PI if the PI does not belong to any organization) in accordance with Article 2 of the General Contractual Conditions for the Joint Research on the GOSAT data.

Moreover, if the Committee deems the research purpose or data application of the RA Investigators as deviant from the initial research plan or in breach of the joint research contract, as a result of the examination of the progress reported, the Three Parties may terminate the said agreement.

8.2.2 Final reporting and termination of the contract

When the research period scheduled and stated in the research proposal comes to the end, all PIs are required to submit the Final Report of Research Result to the Three Parties in accordance with the instructions provided in the contract. Timing of the submission is generally within one year from the last interim research result report. When the RA Office receives the Final Report of Research Result from the PI and the Committee confirms and accepts the report, the RO will be informed (or the PI if the PI does not belong to any organization) about the completion of the joint research agreement in writing. The report shall be prepared in English.

9. Preparation and Submission of Research Proposals

9.1 Notes to the preparation of research proposals

The documents to be submitted in response to the RA must be prepared in accordance with the following procedures. Those proposals that are prepared in disregard of these conditions may be excluded from the succeeding evaluation process. In addition, none of the submitted documents will be returned to the proposers for any reason whatsoever.

- Prepare a research proposal in accordance with the procedure for submission defined in this Chapter and the "Contents of Research Proposals and Application Forms" provided as Appendix D hereto. The application forms in Appendix D will be selected and used as necessary, except Forms 1a, 1b and 2 that are mandatory for all applicants.
- Submit your research proposal in the PDF format, in the way that it is ready for printing in A4 or letter size, together with necessary references, such as relevant theses, via e-mail to the GOSAT/TANSO RA Office's e-mail address (gosat-prj1@nies.go.jp). Note that the size of the submission e-mail should not exceed 10 MB, including the main text. Should your proposal exceed this limit, prepare six copies of the proposal documents as well as the references, record the proposal in the PDF format on an electric medium, such as CD-R, and send the whole package to the RA Office by conventional mail.
- Letters on the documents should all be typed in 10- to 12-point size.
- Indicate the page number at the bottom center and the name of applicant in the upper right corner on each page of the documents.

9.2 Language

The research proposal and accompanying reference documents must all be prepared in either English or Japanese. Those who are native speakers of Japanese shall prepare and submit Forms 1a and 1b of Appendix D, which are cover sheets of the proposal, in both English and Japanese.

9.3 Volume

The research proposal must be compiled in the most simplified way, focusing on the minimally necessary contents. The total volume of the proposal, excluding appendices, must be 20 pages or less. See Appendix D for further specific rules.

9.4 Contents to be included in research proposals and the preparation procedure

See Appendix D

9.5 Submission of research proposals

As mentioned in Chapter 9.1 above, the applicants for the RA should submit the proposal and other necessary documents basically via e-mail. However, in a case that the applicant is unable to use e-mail, insert all documents necessary for the application in an envelope, and send it to the following address by conventional mail.

GOSAT RA Office
Center for Global Environmental Research (CGER)
National Institute for Environmental Studies (NIES)
16-2 Onogawa, Tsukuba-shi, Ibaraki
305-8506 Japan

TEL: 81-29-850-2966 (Japanese)
TEL: 81-29-850-2035 (English)
FAX: 81-29-850-2219
E-mail: gosat-prj1@nies.go.jp

10. Selection of Research Proposals

10.1 Evaluation and Selection Procedure

The research proposals submitted in response to the RA will be evaluated by the Committee. The Three Parties will make a final decision on the selection of research themes, based on the evaluation results of the Committee. The applicants may be requested to modify or rectify the contents of the proposed research plan, in the course of the selection by the Committee, with a view to enriching the expected scientific results from the proposed research. In addition, the Committee may solicit advice of the GOSAT Science Team in the process of evaluation. All applicants will be notified of the selection results by the scheduled date announced; the schedule of the fourth RA is given in Chapter 13.4 of this document while the schedules for the following RAs will be publicized via the NIES GOSAT Project website in an appropriate timing.

10.2 Evaluation Criteria

The submitted research proposals will be examined and selected based on the following evaluation criteria.

1) The contents of the proposed research conform to the purpose of the RA.
2) The methods and approaches adopted in the proposed research are appropriate and the underlying concept is original and/or innovative.
3) The RA Investigators are qualified in terms of research capability, experience, facility/equipment, and skills necessary for accomplishing the purpose of the proposed research.
4) The proposed research is consistent and relevant with the purpose of the GOSAT Project.
5) The purpose of the proposed research can be accomplished within the research period.

10.3 Post-selection Procedure

The RO of the selected PI shall sign the joint research contract with the Three Parties, in principle, based on the "General Contractual Conditions for the Joint Research on the GOSAT data", attached as Appendix E hereto. The RO and the PI shall observe all the clauses, in connection with the performance of the research, as stipulated in the General Contractual Conditions.

The RA Office shall carry out the administrative work necessary for concluding such a contract, in line with the intentions of the Three Parties.

11. Cancellation and Postponement of RA

The Three Parties reserve the right to cancel the RA and joint research projects based on the RA by notifying in writing, and shall not be liable for any delay in the RA schedule or cancellation of the RA program itself or to those who did not receive any notice regarding such delay or cancellation.

12. Expected Research Topics

The Three Parties have been and will be continually promoting the GOSAT Project by playing the respective roles in the research and development deemed as necessary for achieving its purpose with the advice and help from the GOSAT Science Team. The specific research and development activities within the Project include; the calibration of the GOSAT/TANSO equipment, validation of higher-level products (observation and analysis for validation), development and improvement of the data processing algorithms, development of atmospheric transport models and land ecosystem models, generation of source inventories, and development of carbon flux estimation models, etc. Also, the analysis methods for such basic phenomena that have influence on evaluation of the characteristics and quality of data such as temporal variation of concentrations and carbon balance distributions are studied. Furthermore, with the GOSAT Project, research on advanced application of the GOSAT/TANSO data, for example, detection of CH_4 leakage from natural gas pipelines or local forest fires, and so forth, is conducted. More details are provided in the succeeding section.

Through the implementation of the RA, the GOSAT Project expects to benefit from the RA research outcomes for developing higher level data products. At the same time, the Project wants to see the research field of data application being further facilitated, and the data acquired by the GOSAT will contribute to resolve the global-warming issues through the effective utilization. Therefore, the GOSAT Project is open and willing to accept new research proposals from all parts of the world.

In this Chapter hereunder is provided a summary of research topics to be or to have been carried out in the GOSAT Project. It is anticipated that a large number of research themes, that will supplement the research topics of the GOSAT Project, that will utilize the applicant’s own validation data, or that are based on very original and unprecedented perspectives, will be proposed.

12.1 Research Topics conducted or targeted by the GOSAT Project

1) Calibration
   The calibration-related research topics conducted or targeted by the GOSAT Project include calibration (including wavelength calibration) when interferogram is transformed into spectra, calibration in relation to correction of the variation of the observation sensors’ field of view, instrument function calibration, radiance calibration, etc. as for TANSO-FTS, and radiometric calibration, geometric correction, calibration of the sensor sensitivity, etc. as for TANSO-CAI.
2) Data processing algorithms
   The processing algorithm-related research topics conducted or targeted by the Project include development of fast data processing algorithms, sunglint observation data processing methods, processing algorithms using polarized data, and algorithms to extract parameters from thermal-infrared data, evaluation of spectral parameters of gaseous molecules and sunlight spectra, combined use of short wavelength infrared and thermal infrared data, etc.
3) Carbon flux estimation, atmospheric transport models
   The model-development-related research topics conducted or targeted by the Project include development and refining of source inventory databases, refining of atmospheric transport and land ecosystem models, etc., development of carbon flux estimation models with high temporal/spatial resolution, etc.

4) Validation

*Before the launch

The research topics targeted by the GOSAT Project included validation by ground-based high-resolution and by small-sized FTSs with airborne in-situ instruments, evaluation of sunglint observation algorithms using airborne or ground-based FTSs, development of validation methods based on data taken by LIDAR, sky radiometers or other equipment for validating aerosol, etc.

*After the launch

The research topics conducted or targeted by the GOSAT Project include acquisition and analytical validation of data taken at validation sites on land and on ocean (including island and cape), analytical validation of data taken by instruments on board private aircraft, comparison with data taken by other satellites or computed by models, etc., for the purpose of validating the quality of data on the CO_2 and CH_4 column abundances, as well as validating the quality of data on vertical distributions of CO_2 and CH_4 concentrations to be derived from the thermal-infrared data. Validation of CAI data products is also included.

5) Data application

FTS: The research topics conducted or targeted by the Project include analysis of basic phenomena that have influence on evaluation of the characteristics and quality of data such as temporal/spatial variation of concentration distributions and carbon balance distributions, possible advanced applications, such as detection of CH_4 leak from pipelines, local high-volume exhaust due to forest fires and detection of the fluorescence from vegetation, possibility of observing atmospheric trace components, such as N_2O, CFC, etc., and so on.

CAI: Generation and utilization of the global vegetation index map based on the CAI data, and others.

12.2 Expected Research Topics to be proposed in the RA

1) Calibration
2) Data processing algorithm
3) Carbon balance estimation, atmospheric transport models
4) Validation
5) Data application

13. Schedule

13.1 1st Announcement

Release of RA	April 7, 2008
Deadline for submission of proposals	July 7, 2008
Notification of the selection results	August 29, 2008
Sign up of the agreement	August 30, 2008 and later
PI meeting/workshop	November 5-7, 2008
Launch of GOSAT	January 23, 2009
Submission of interim reports	December 28, 2009

13.2 2nd Announcement

Release of RA	April 7, 2009
Deadline for submission of proposals	June 1, 2009 for RA* users June 23, 2009 for RA+ users
Notification of the selection result	July 31, 2009 for RA* users August 28, 2009 for RA+ users
Sign up of the agreement	August 3, 2009 or later for RA* users August 31, 2009 or later for RA+ users
2nd PI meeting/workshop	January 28-29, 2010
Submission of interim reports	September 30, 2010

13.3 3rd Announcement

Release of RA	August 20, 2010
Deadline for submission of proposals	October 29, 2010
Notification of the selection result	January 31, 2011
Sign up of the agreement	February 1, 2011 and later
3rd PI meeting/workshop	May 19-20, 2011
Submission of interim reports	March 1, 2012

13.4 4th Announcement (Current Announcement)

(Memos bracketed are the principle for RAs following the 4th RA)

Release of RA — August 31, 2012

[See * for the 5th and following RAs.]

Period for proposal acceptance — August 31, 2012 ~ October 26, 2012*

[More than 50 days shall be secured for this period in principle.]

Evaluation Period — August 31 ~ November 11, 2012

[Evaluation is, in principle, completed within the period between the release of RA and until two weeks after proposal submission due.

Date of the selection board — November 16, 2012

[After the evaluation, the selection board is held in the RA committee meeting.]

Notification of the selection result — November 30, 2012

[Notification is made in a prompt manner.]

Sign up of the agreement — December 3, 2012 and later

[The Three Parties and the RO of the PI whose research proposal was accepted shall execute the contract. If the PI does not belong to any organization, the PI shall execute the contract instead.]

Submission of interim reports December 28, 2013

[In principle, the first interim report shall be submitted within one year after the acceptance of the proposal.]

* Applications and research proposals are always invited - even after October 26, 2012. Schedules for the fifth RA and all of following RAs will be posted on the NIES GOSAT Project website in an appropriate timing.

In case no proposal is submitted or no proposal is selected during the above period, the Three Parties will continue to invite research proposals under the ongoing RA instead of making a new announcement. For example, if no research proposal is submitted in response to the fourth RA, the Three Parties will carry the selection board over to the next RA committee meeting and continue to invite research proposals under the fourth RA. The schedule revised by adjustment will be publicized via the NIES GOSAT Project website or other appropriate means.

14. Contact Information

GOSAT RA Office
Center for Global Environmental Research (CGER)
National Institute for Environmental Studies (NIES)
16-2 Onogawa, Tsukuba-shi, Ibaraki
305-8506 Japan

TEL: 81-29-850-2966 (Japanese)
TEL: 81-29-850-2035 (English)
FAX: 81-29-850-2219
E-mail: gosat-prj1@nies.go.jp

Further Note

The attached Research Announcement (RA) was issued in August 2012. There happened some changes in 2013, but the required updates are not completed in these documents for RA. Because of new General Contractual Conditions for the Joint Research (Appendix E), the data products distribution status, and the schedule of the 7th Research Announcement, some terms in "Research Announcement" shall be deemed to be replaced with the writings shown in Table 1.

Table 1 List of writings to be replaced

Page	Section	Writings in the Research Announcement (main text)	Writings to be replaced
P4	2.4 2)	The research period shall be the operational period of GOSAT/TANSO plus the operational period of its ground system – five years after the launch, in principal (until January 22, 2014) -.	The research period shall apply from the day of the signature of the last authorized representative of the Parties to the Contract and continue for a maximum of four (4) years under the condition that the GOSAT ground system remains operational.
P8	4. 3)	L3 products are the global-scale products calculated from L1 and L2 products. L3 products are not "validated", but they are released to RA Investigators prior to the public for preliminary evaluation.	L3 products are the global-scale products calculated from L2 products. L3 products are not "validated." Only the image data are released to the public.
P9	Table 1	List of GOSAT/TANSO data products (as of 31 August 2012)	List of GOSAT/TANSO data products (as of February 17, 2014) Please refer the Attachment 1 for more details.)
P17	8.2.1	PI shall report the progress of his/her RA research, once a year in	PI shall report the progress of his/her RA research, once a year in

		principle, in the way designated by the Three Parties, such as submitting the report in writing	principle, in the way designated by the Three Parties, such as submitting the report in writing in English or Japanese (Added)
P17	8.2.2	Timing of the submission is generally within one year from the last interim research result report.	(This sentence is deleted.)
P25	13.4	4th Announcement (Current Announcement)	7th Announcement (Current Announcement) (Please refer the Attachment 2 for more details.)

Attachment 1 List of GOSAT/TANSO data products

Attachment 2 Schedule of the 7th Research Announcement

Attachment 1

Table 1 List of GOSAT/TANSO data products (as of February 17, 2014)

Processing Level	Sensor / Band	Product Name	Category	Unit	Format
L1A	FTS	FTS L1A data	Internal (*)	FTS scene	HDF5
	CAI	CAI L1A data	Internal (*)	CAI scene	
L1B	FTS	FTS L1B data	Standard	FTS scene	
	CAI	CAI L1B data	Standard	CAI flame	
L1B+	CAI	CAI L1B+ data	Standard		
L2	FTS SWIR	L2 CO2 column amount (SWIR)	Standard	Scan	
		L2 CH4 column amount (SWIR)	Standard		
		L2 H2O column amount (SWIR)	Research		
	FTS TIR	L2 CO2 profile (TIR)	Standard		
		L2 CH4 profile (TIR)	Standard		
		L2 CO2 column amount (TIR)	Research		
		L2 CH4 column amount (TIR)	Research		
		L2 temperature profile(TIR)	Research		
		L2 H2O profile (TIR)	Research		
		L2 H2O column amount (TIR)	Research		
	CAI	L2 cloud flag	Standard	CAI flame	
		L2 cloud property	Research		
		L2 aerosol property	Research		
L3	FTS SWIR	L3 global CO2 distribution (SWIR)	Standard	Global (monthly)	
		L3 global CH4 distribution (SWIR)	Standard		
	FTS TIR	L3 global CO2 distribution (TIR)	Standard		
		L3 global CH4 distribution (TIR)	Standard		
	CAI	L3 global radiance distribution	Standard	Global (per 3 days)	
		L3 global reflectance distribution	Standard		
		L3 global cloud property	Research	Global (monthly)	
		L3 global aerosol property	Research		
		L3 NDVI	Standard	Rectangle [30° lat. x 60° lon.] (for a month and shifted every 3 days)	
L4A	–	L4A global CO2 flux	Standard	Global [64 regions with 1° grid] (annually, including every month data)	Text/ NetCDF
		L4A global CH4 flux	Research		
L4B	–	L4B global CO2 distribution	Standard	Global 2.5 degree (monthly, including every 6 hours data)	NetCDF
		L4B global CH4 distribution	Research		

Remarks: ”L” is an abbreviation for “Level.” E.g., “L1” means “Level 1.”

(*) Internal products are for internal use only in the GOSAT project.

Attachment 2

Schedule of the 7th Research Announcement

Period of proposal acceptance	February 18, 2014 - March 15, 2014
Evaluation Period	March 16, 2014 - April 11, 2014
Date of the selection board	April 21, 2014
Notification of the selection result	April 23, 2014
Sign up of the agreement	May 7, 2014 or later
Submission of interim reports	May 1, 2015

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

Research Announcement

Appendix A

Outlines of GOSAT and TANSO Sensor

GOSAT (Greenhouse gases Observing SATellite) carries an observing instrument called Thermal And Near infrared Sensor for carbon Observation (TANSO), which is composed of a Fourier Transform Spectrometer (TANSO-FTS) and a Cloud and Aerosol Imager (TANSO-CAI)

A.1 Outline of GOSAT

GOSAT is scheduled to be launched into space by JAXA's H-IIA rocket in early 2009 and will acquire data on the global distribution of carbon dioxide (CO_2) and methane (CH_4) (column abundance and altitude distribution) for at least five years. Two observation sensors, TANSO-FTS and TANSO-CAI, are placed in the earth-facing (+Z) plane of the satellite and operated by a three-axis attitude control system in such a way that the sensors keep looking toward the geocentric direction. GOSAT secures power supply needed for the operation of itself and the sensors on board with two sets of solar paddle to be deployed facing towards the sun, records and playbacks the mission data acquired by the sensors on the Mission Data Processor (MDP) subsystem, and transmits the data down to the ground stations.

Figure A.1-1, Table A.1-1 and Table A.1-2 show an overview of GOSAT in orbit, its major specifications and orbital parameters, respectively. Figure A.1-2 represents nominal orbits of GOSAT.

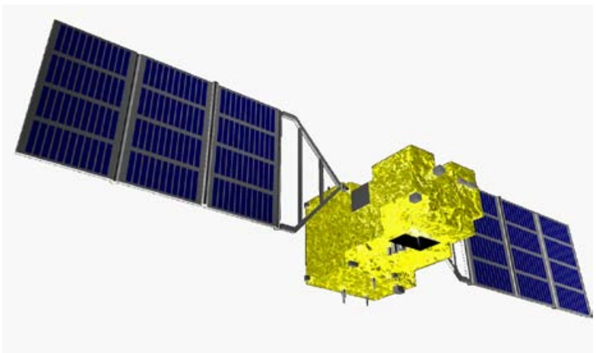


Figure A.1-1 Overview of GOSAT in orbit

Table A.1-1 Major Specifications of GOSAT

Specification items	Description
Size	Main body: H3.7m(X) × W1.8m(Y) × D2.0m(Z) (except for its extrusions) Wing span: 13.7m
Mass	1,750 kg
Power	3.8 kw (EOL)
Life time	5 years
Launch schedule	January 23, 2009

Table A.1-2 Orbital Parameters of GOSAT

Parameters	Description
Orbit type	Sun-synchronous, quasi-recurrent
Altitude against the earth	666 km at Equator
Inclination angle	98.06 deg
Orbits/day	14 + 2/3 revolutions/day
Orbits/recurrence	44 revolutions/3 days
Descending node time	13 hours ±15 minutes

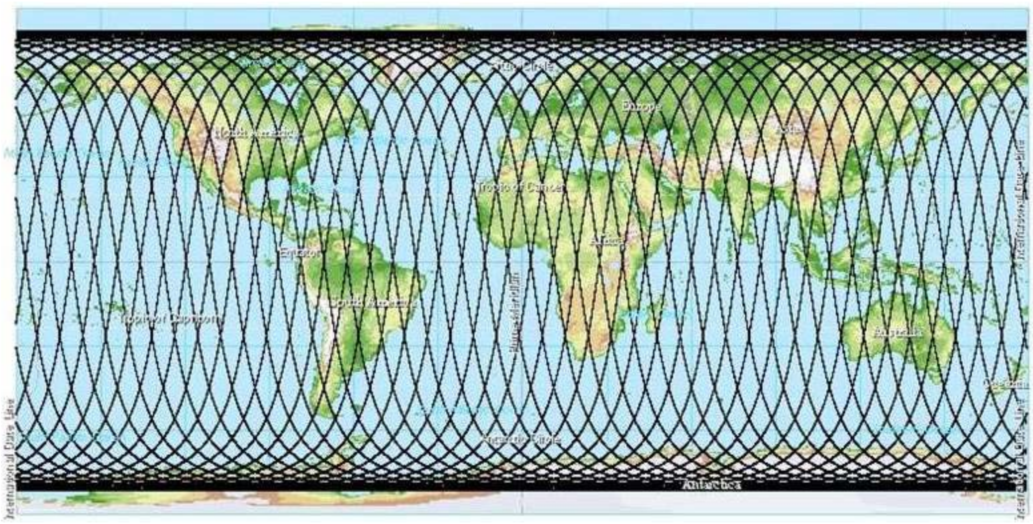


Figure A.1-2 GOSAT's nominal orbits

A.2 Outline of GOSAT/TANSO-FTS

A.2.1 Outline of TANSO-FTS

Table A.2-1 below provides an outline of TANSO-FTS.

Table A.2-1 Outline of TANSO-FTS

Observation method	Earth-looking observation
Method of measurement	Spectral measurement of atmospheric absorption by the Fourier transform interferometer
Functions	1. Observes the atmosphere in visible, short wavelength infrared and thermal infrared bands looking toward the earth center. 2. Carries out observation over the land on lattice points. 3. Observes the same footprint during one interferogram measurement while the satellite is moving. 4. Multiple observations are carried out for a same footprint to improve SNR. 5. Observes at a fixed angle (or fixed distance) interval in cross-track direction during the lattice observations. 6. Returns to the same footprint after three days. 7. Observes sea area where sunglint is expected, using the two-axis (AT/CT) mechanism. 8. Conducts a combination of observations in lattice point, sunglint and specific point modes. 9. Performs the following in-orbit calibrations: (1) Solar irradiance calibration in the visible and short wavelength infrared bands and blackbody calibration in the thermal infrared band (2) Deep-space calibration in the visible-, short wavelength- and thermal-infrared bands (3) Annual lunar calibration on the sensitivity by pointing the satellite and the two sensors to the moon

TANSO-FTS is composed of the following three units:

(1) TANSO-FTS Optical Unit

(2) TANSO-FTS Control Unit

(3) TANSO-FTS Electrical Circuit Unit

Figure A.2-1 shows a block diagram of TANSO-FTS. Considering that the mission of this Project is to get useful results, redundancy is employed in the design of sensors wherever possible. Figure A.2-2 shows an overview and the internal structure of the optical unit of the sensor.

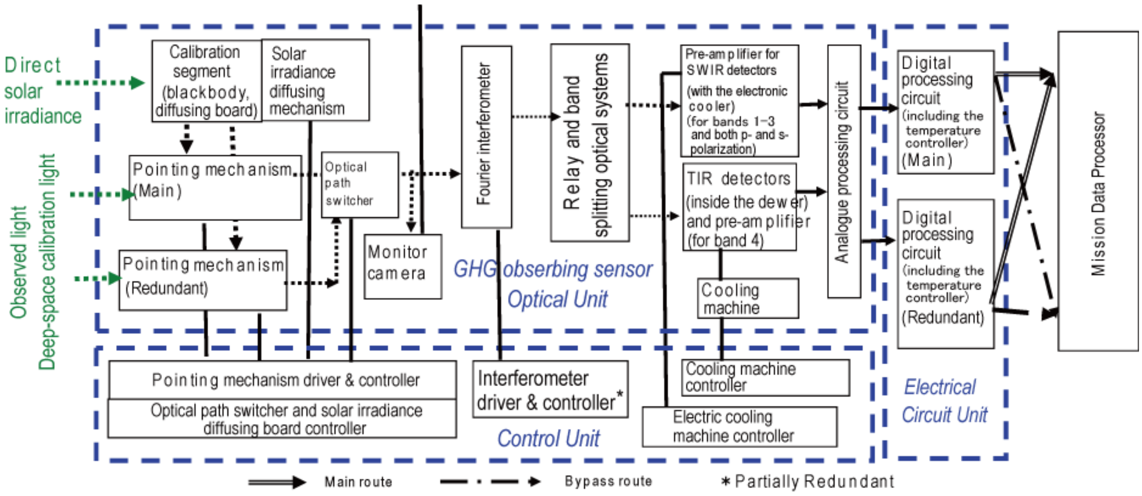


Figure A.2-1 Block Diagram of TANSO-FTS

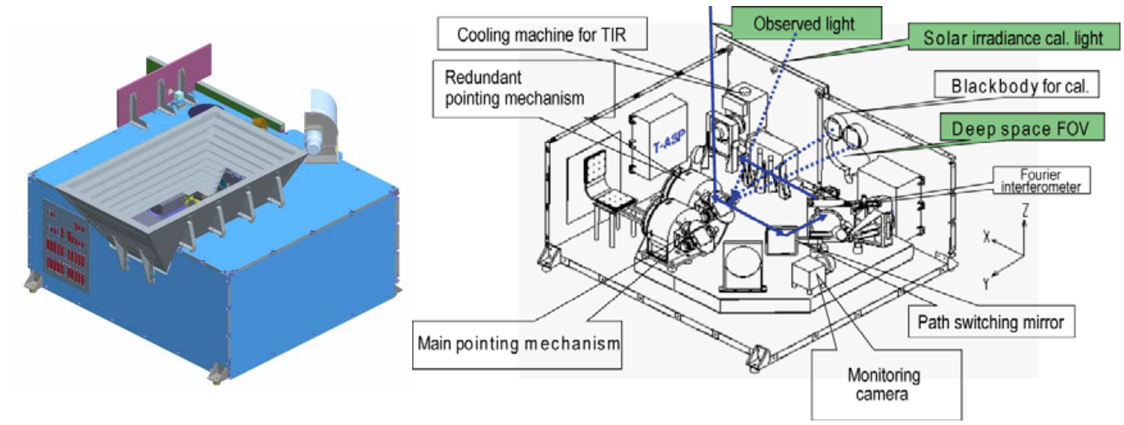


Figure A.2-2　Overview and Internal Layout of the Optical Unit of TANSO-FTS.

A.2.2 Specifications of TANSO-FTS

(1) Fourier interferometer mechanism

Table A.2-2 summarizes the specifications of the Fourier interferometer mechanism and outlines the scanning method.

Table A.2-2 Outline of the specifications of the Fourier interferometer and its scanning method

Spectroscopy	Fourier interferometer
No. of ports	2 (single-pass)
Scanning method	Two corner cubes are attached to the ends of the V-shaped swing arm. The arm swings to scan with the supported flexible blades acting as the axis. (See Figure A.2-4.)
Data acquisition method	Scanning on both sides and data acquisition on one way
Beam splitter	ZnSe (without coating)
Sampling	Sampling by laser diodes
Signal processing	Interferogram data are transmitted down to the earth.

Figure A.2-3 illustrates the structure of the scanning mechanism. The scanning speed stability required is 1% or lower. The interferometer acquires interferogram on both sides of the zero (optical) path difference (ZPD) location.

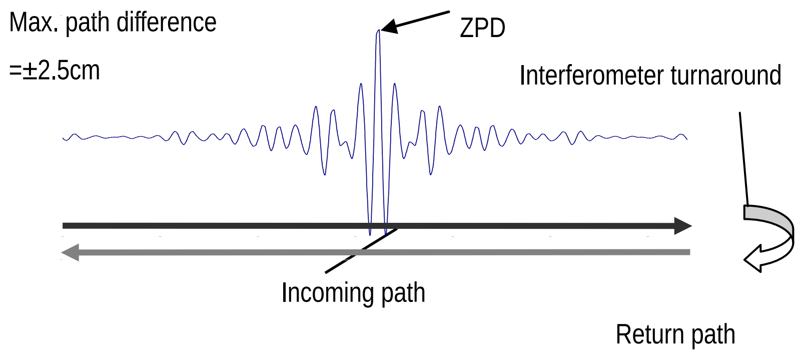


Figure A.2-3 Scanning by the Fourier interferometer

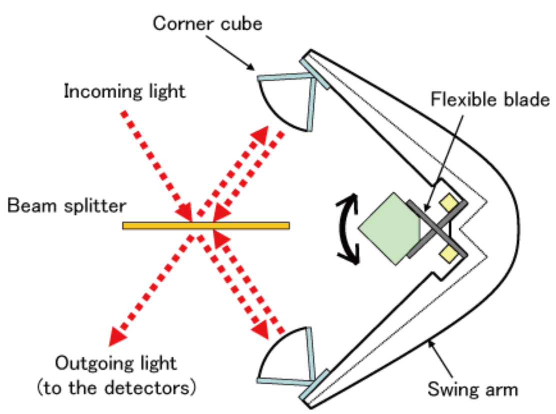


Figure A.2-4 Layout of the double corner cubes, swing arm and flexible blades

(2)Band configuration

TANSO-FTS has detectors for four bands, all of which have the same field of view (FOV). Table A.2-3 tabulates the wave number range, spectral resolution, and other parameters for each band.

Table A.2-3 Wave number range and spectral resolution of the four bands used by FTS

Band	Band 1	Band 2	Band 3	Band 4
Band name	Visible	SWIR	SWIR	TIR
Polarimetric observation	Yes	Yes	Yes	No
Wave number Range (Note 1)	12900 - 13200 cm^{-1}	5800 - 6400 cm^{-1} (Note 5)	4800 - 5200cm^{-1}	700 - 1800 cm^{-1}
Out-of-band characteristics (Note 2)	Transmittance of 0.1% or less in the ranges of <12700cm^{-1} >13400cm^{-1}	Transmittance of 0.1% or less in the ranges of <5000cm^{-1} >6800cm^{-1}	Transmittance of 0.1% or less in the ranges of <4500cm^{-1} >5500cm^{-1}	Transmittance of 0.1% or less in the ranges of <600cm^{-1} >3800cm^{-1}
Spectral resolution (Note 3)	0.2 cm^{-1}	0.2 cm^{-1}	0.2 cm^{-1}	0.2 cm^{-1}
FWHM of the instrument function (Note 4)	0.6 cm^{-1} or less	0.27 cm^{-1} or less	0.27 cm^{-1} or less	0.27cm^{-1} or less
Targets of the measurement	(O_2) →information on air pressure & cirrus cloud	CO_2, CH_4, H_2O	CO_2, CH_4, H_2O, information on cirrus cloud	CO_2, CH_4, H_2O, etc.

Note 1: 80% or above of the maximum efficiency can be achieved within the wave number ranges of Bands 1, 2 and 3. As for Band 4, 60% or above of the maximum efficiency can be achieved in the designated wave number range by converting the sensitivity of the detector into the quantum efficiency. The efficiency here means the product of the efficiency of the optical unit, the quantum efficiency of the detector, and the response of the amplifier.

Note 2: In the wave number range corresponding to the signal turn-around in the Fourier transform, less than 0.01% is assumed.

Note 3: The spectral resolution is defined as (1 / (2 * Max. path difference)).

Note 4: The full width at half maximum (FWHM) of the instrument function is defined as the FWHM when radiation from a monochromatic light source is introduced in the full FOV and the measured data are inverse-Fourier-transformed without apodization.

Note 5: In Band 2, the transmittance must be 0.1 or higher when the laser wavelength is 1.55μm (6460 cm^{-1}), which is for measuring the instrument function in orbit.

(3) Methods of optics, band splitting and polarimetric observation

Table A.2-4 lists the summary of specifications for TANSO-FTS in terms of optics, spectroscopy and polarization, whereas Figure A.2-5 provides an overview of the optical system.

Table A.2-4 Summary of specifications for optics, band splitting and polarization

Optics	Effective aperture	φ 68 mm (Bands 1-3), φ 60 mm (Band 4)
	F value	F=2 (F value for the optics-detector system to be installed between the FTS sensor and the detector.)
	Optical system	Reflective optical system. However, a refractive optical system is used in the case of focusing on the detectors for Bands 1-3.
	Aperture control	As for Bands 1-3, the corner cubes provide a control of the aperture. While the aperture diameter is 68 mm, the movement of light flux in association with FTS's scanning remains within 1 mm in the direction perpendicular to the optical path. For Band 4, an aperture control is introduced inside the optical system of the detector so as to suppress background light.
	FOV control	The FOV is determined with the slit common to all bands, after the light is modulated by the Fourier interferometer and concentrated. (15.8 mrad: corresponds to 10.5 km when projected on the earth's surface.)
Band splitting	Band splitting	After FOV being narrowed through the slit and the light collimated, the light is splitted through the dichroic filter one after another starting with Band 1.
	Removal of out-of-band light	A narrow band pass filter is set up at the optical system of the detector for each of Bands 1-3.

Polarization	Polarization	For Bands 1-3, the polarization beam splitter is installed in the optical system of the detector for simultaneous observation of two polarizations.

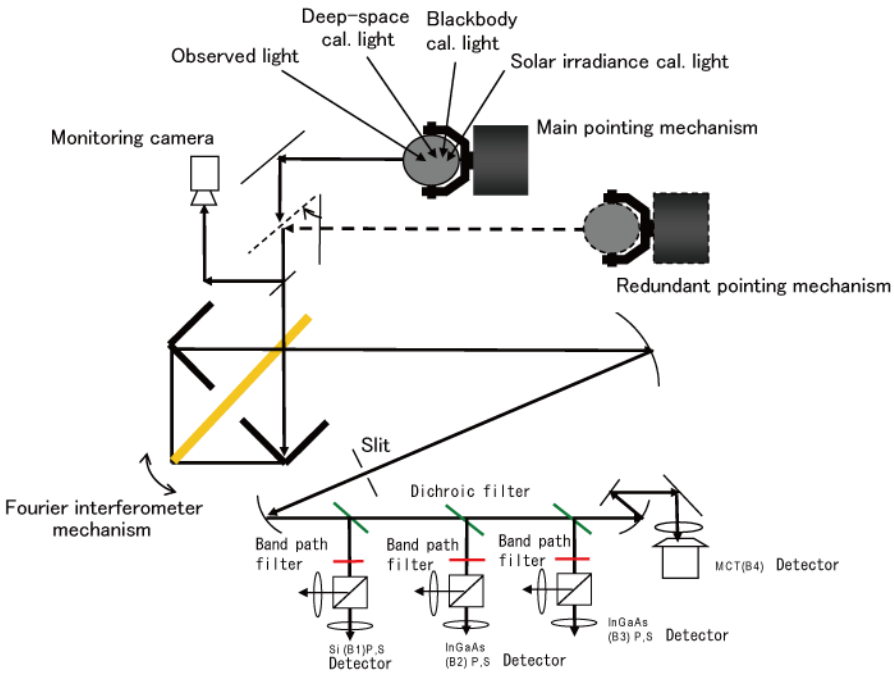


Figure A.2-5 Overview of the optical system

(4) Band-to-band/sensor-to-sensor registration

Band-to-band/sensor-to-sensor registrations are determined as follows:

(1) Band-to-band registration within FTS: 0.05 pixels or less

(2) Registration between TANSO-FTS and TANSO-CAI: 0.5 pixels of TANSO-CAI or less

(3) A monitoring camera (for checking the FOV of FTS) is attached at the light entrance section of FTS for the sake of determining registration with TANSO-CAI.

A.2.3 Observation mechanism of TANSO-FTS

(1) Principles of TANSO-FTS observation

The sun can be regarded as a blackbody light source which has an absolute temperature of slightly less than 6,000 K. It emits light mainly in the range covering from ultraviolet to visible and short wavelength infrared bands. Most of visible and short wavelength infrared light emitted by the sun reaches the earth's surface while some is absorbed and scattered by clouds and aerosols on the way. An earth-observing satellite detects light reflected by the ground and returned to the satellite through the atmosphere. The measured light provides information on the concentrations of CO_2, CH_4, and water vapor (H_2O), whose absorption bands are in the visible and short wavelength infrared range.

The ground surface and clouds radiate thermal infrared waves with intensities commensurate with their temperatures and their own wavelength characteristics. There are numerous absorption bands of major and minor atmospheric constituents in these bands. Each atmospheric constituent has its own absorption bands within the visible and short wavelength infrared bands or thermal-infrared band. Though the strength of absorption varies with spectra of each constituent, the use of databases established in laboratories will help identify the relationship among the wave number within the absorption bands, absorption strength, and constituent concentration. The basic principle of molecular spectroscopy goes as follows: spectroscopic observation is performed by detecting the absorption spectra of the atmospheric molecules of interest, the detected light is converted into electric signals (photoelectric transfer), radiance per spectrum is calculated, and the amount of atmospheric molecules is derived from the radiance level.

A space-borne observing sensor points its scanning mirror at the target to be observed, introduces the observed light into the system, converts it into electric signals at the detector assigned to each bandwidth through the diffraction grating, interferometer or another types of spectrometer, and transmits electric signals onto the ground. The data received on the ground will be analyzed to extract necessary information, which will then be transformed into spectral data, based on which the volume of each atmospheric constituent is calculated.

(2) Principles of the Fourier interferometer

The Fourier interferometer first splits the light with its beam splitter (BS) into two with different optical path lengths, which interfere with each other. It acquires the spectra of the light source by inverse-Fourier-transforming the interferograms obtained while changing continuously the path length difference.

This method is characterized by the following two factors:

(1) High gain of the light

(2) Acquisition of spectra over a wide wavelength range at a high spectral resolution

The Fourier interferometer has come into practical use owing to the development of advanced computers, which has made inverse Fourier transform faster, and higher-accuracy mechanical scanning by means of laser range finders. Figure A.2-6 shows a diagram describing the principles of the Michelson interferometer. Typically, M1 and M2 are a fixed mirror and a moving mirror, respectively. In case of TANSO-FTS, however, M1 and M2 are installed on a single swinging arm so that the two mirrors move by the same distance with opposite phases. As a result, the path difference is doubled, making it possible to scan faster. Thus, the interferometer can achieve both a high spectral resolution and a high spatial resolution without sacrificing one or the other.

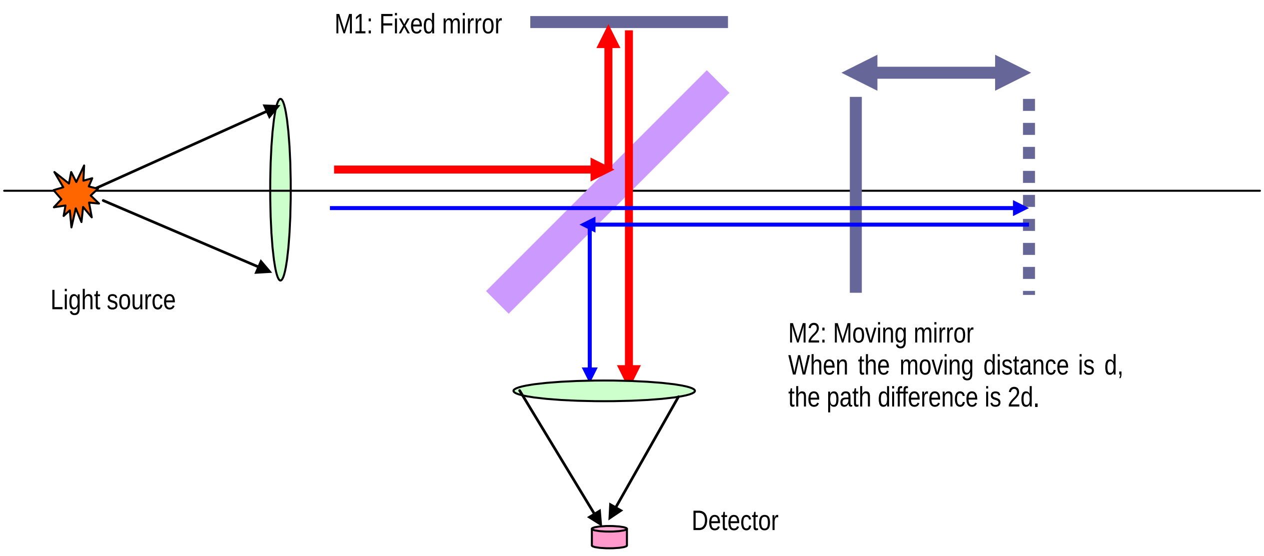


Figure A.2-6 Principles of Michelson Interferometer

Further, space-borne interferometers are designed with attention paid to the vibration environment while being launched on rockets and the thermal environment in outer space.

The Fourier interferometer acquires signals called interferogram as shown in Figure A.2-7 below.

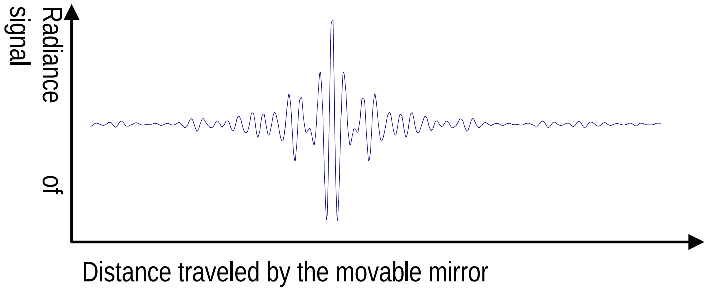


Figure A.2-7 Interferogram data

When this interferogram is inverse-Fourier-transformed, the spectra absorbed in the air are obtained, as shown in Figure A.2-8. The spectra depicted here are those of the sunlight absorbed by H_2O, CO_2, and CH_4 in the atmosphere as observed by the GOSAT ground test model in November 2005.

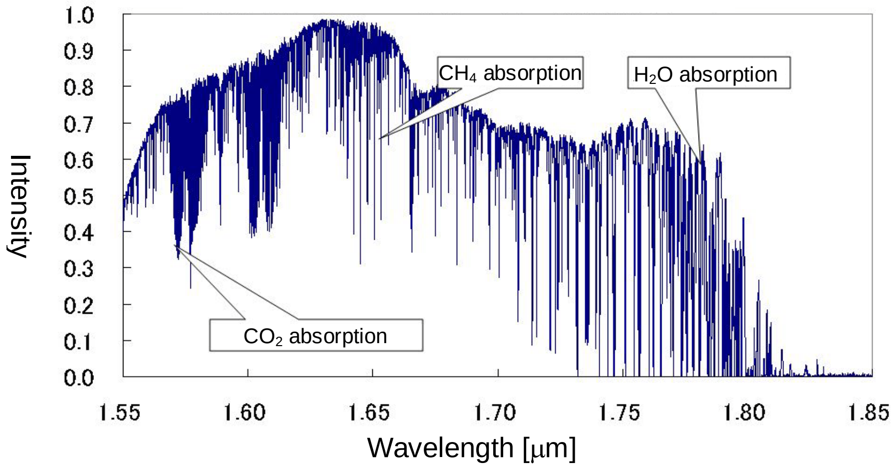


Figure A.2-8 Atmospheric scattering spectra observed by the GOSAT ground test model at the top of Mt. Tsukuba in November 2005

Since the satellite can acquire observation data fairly frequently, the amounts of atmospheric constituents can be derived from the above spectral data and plotted into a global distribution diagram, as shown in Figure A.2-9. There has been no such example of global distribution data provided by satellites.

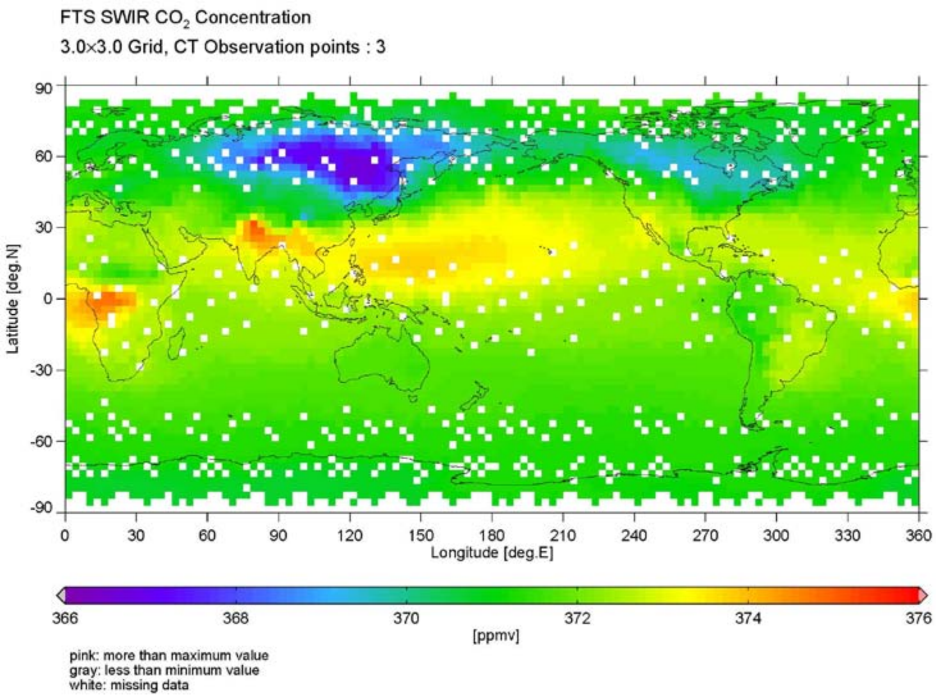


Figure A.2-9 Global distribution of carbon dioxide (CO_2)

The global distribution of net CO_2 flux, as shown in Figure A.2-10, can also be derived from the satellite data referred to above, and by using atmospheric inverse transport models.

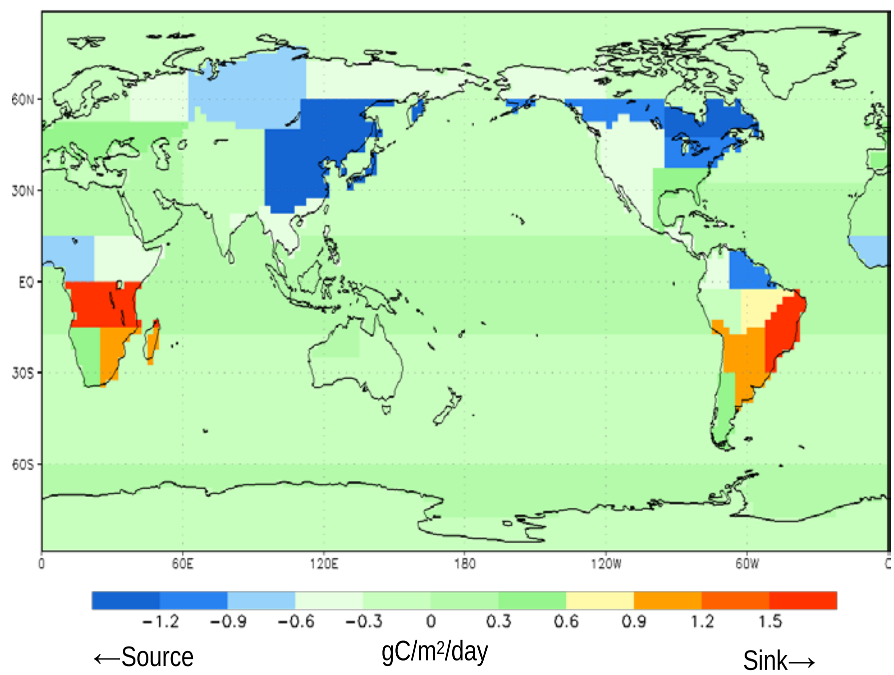


Figure A.2-10 Global distribution of net CO_2 flux

Furthermore, a global distribution of CO_2 can also be obtained, as shown in Figure A.2-11 in three-dimensional (3D) image, using the above net CO_2 flux distribution and atmospheric transport models.

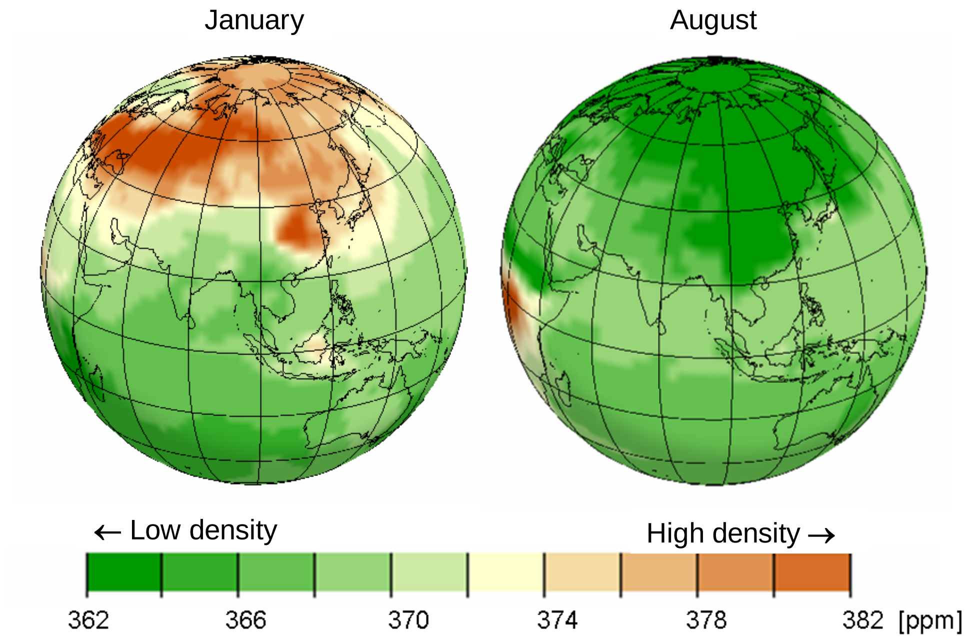


Figure A.2-11 3D global distribution of CO_2 obtained based on the net CO_2 flux distribution using atmospheric transport models

(3) Observation by GOSAT

In case of GOSAT, Figure A.2-12, GOSAT observes visible and SWIR radiation of the sun reflected by the earth's atmosphere and by the earth surface and thermal radiation in TIR band from the earth surface and the atmosphere.

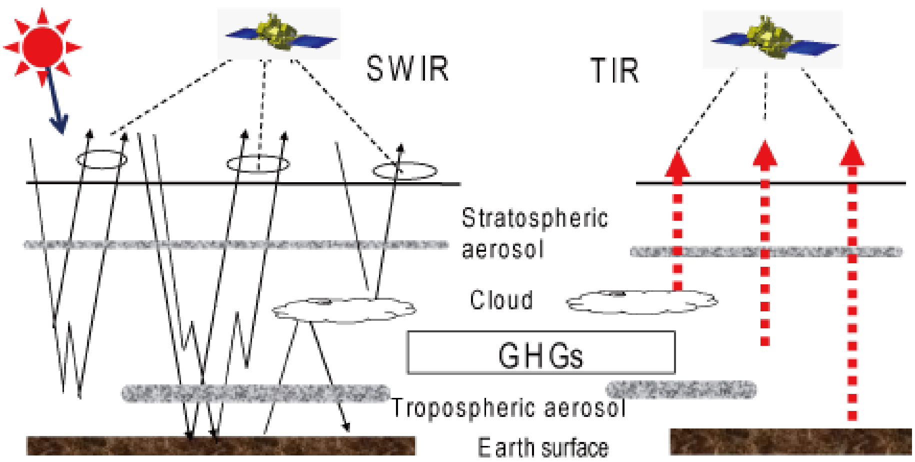


Figure A.2-12 Observation by GOSAT

TANSO-FTS observes the light reflected by the earth in the range covering from visible 0.76 μm to thermal infrared 4.3 μm. (See Figure A.2-13.) The vertical distribution of air temperature is measured in TIR bands, whereas the air pressure can be obtained from the absorption by oxygen molecules (O_2) and the air column abundance is derived by referring to the absorption by O_2, which has much higher concentration remaining constant than CO_2.

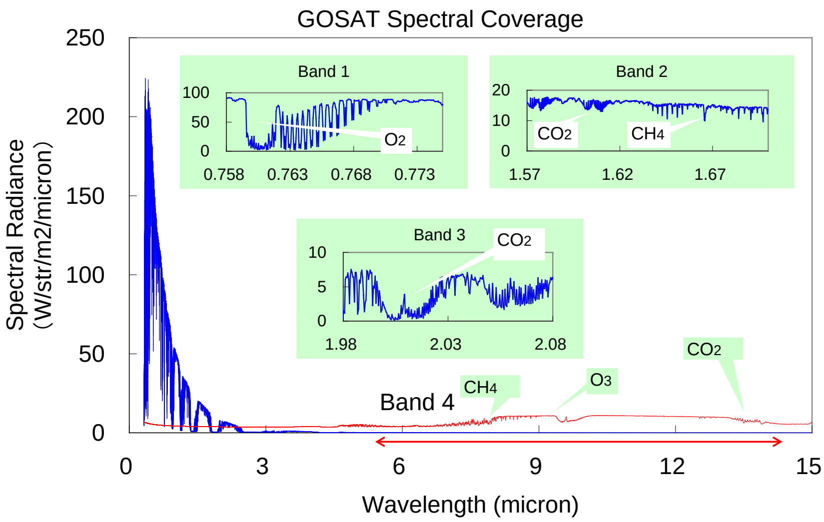


Figure A.2-13 Observation band of TANSO-FTS and air absorption bands

A.3 Overview of GOSAT/TANSO-CAI

A.3.1 Overview of TANSO-CAI

Table A.3-1 below explains the purposes of the TANSO-CAI sensor.

Table A.3-1 Purposes of TANSO-CAI

Purpose 1	Assessment of the effectiveness of FTS footprint area	Determines whether data should be discarded or not in case there is a thick cloud. It is desirable that the cloud thickness can be assessed in addition to the cloud coverage.
Purpose 2	Detection of clouds and aerosols in FTS footprint area and correction of resulting errors	Provides information necessary for correcting the errors caused by clouds and aerosols in FTS footprint area. Evaluates the characteristics of cloud and aerosol (e.g. optical thickness, type). Thus, it is desirable that the spectral characteristics of aerosol can be derived.

TANSO-CAI is expected to derive the types and optical thickness of aerosol of each type. To this end, the bands selected for CAI observation must be those where there is no absorption by atmospheric dominant constituents, and, consequently where the best signal-to-noise ratio (SNR) is attained, and where the spectral characteristics of the optical thickness of aerosols can be observed. In addition, scattering by aerosols is significantly polarized, in general; thus polarimetric observation is preferred. However, as TANSO-CAI observes at a fixed angle very close to the nadir, the degree of polarization is quite low, which makes it difficult to estimate the aerosol amount. Therefore, more stress is put on securing enough number of bands than polarimetric observation in choosing the bands. Given these considerations, the four bands shown in Table A.3-2 were selected for TANSO-CAI.

Table A.3-2 Observation bandwidth of TANSO-CAI and selection criteria

	Criteria
Band 1 (0.380 µm)	No O_3 absorption in the ultraviolet range where reflectance is low on the ground
Band 2 (0.674 µm)	No interference between the rise of reflectance on the vegetation and absorption by O_2 *B* and H_2O bands.
Band 3 (0.870 µm)	No interference with absorption by H_2O
Band 4 (1.60 µm)	The maximum wavelength width is achieved while avoiding the absorption by H_2O, provided that the absorption by CO_2 and CH_4 can be corrected. At the same time, the band should be free of any impact of possible effect on the detector cut-off due to temperature fluctuation.

TANSO-CAI is composed of the following two units.

(1) TANSO-CAI Optical Unit

(2) TANSO-CAI Electrical Circuit Unit

Figure A.3-1 is a block diagram of TANSO-CAI.

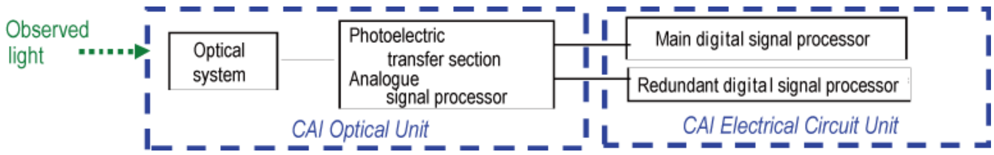


Figure A.3-1 Block diagram of TANSO-CAI

An overview of TANSO-CAI is given in Figure A.3-2 below.

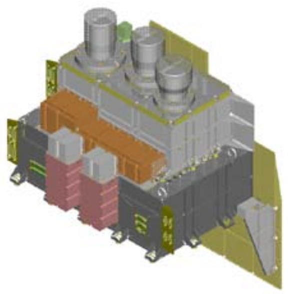


Figure A.3-2 Overview of TANSO-CAI

A.3.2 Specifications of TANSO-CAI

(1) Bandwidth and performance

Table A.3-3 below summarizes the specifications of TANSO-CAI.

Table A.3-3 Specifications of TANSO-CAI

	Band 1	Band 2	Band 3	Band 4
Center wavelength (μm) (Note 1)	0.380 ± 0.005	0.674 ± 0.005	0.870 ± 0.005	1.60 ± 0.01
Wavelength width (μm) (Note 1)	<0.02	<0.02	<0.02	<0.10
Out-of-band characteristics (i) (μm)(Note 2)	1% or lower in the ranges of <0.36 and >0.4	1% or lower in the ranges of <0.658 and >0.692	N.A.	1% or lower in the ranges of <1.0 and >1.69
Out-of-band characteristics (ii) (μm)(Note 2)	N/A	1% or lower in the range of >0.696	1% or lower in the ranges of <0.840 and >0.890	N/A
Out-of-band characteristics (iii) (μm)(Note 3)	0.15% or lower in the range of >0.45	N/A	N/A	N/A
Out-of-band characteristics (iv) (μm)(Note 3)	0.03% or lower in the range of >0.7	N/A	N/A	N/A
Polarization	None			

Note 1: The center wavelength and wavelength width are specified based on the first and second moments, taking into consideration the spectral characteristics of the optical system, filters and detectors for an overall efficiency.

Note 2: The sensitivities in the range specified in 'out-of band (i)' should be lower than 1% of that at the central wave length, and the sensitivity in the range specified in 'out-of-band (ii)' should be lower than 0.1% of that at the central wave length in order to avoid the H_2O absorption band in the above described bands.

Note 3: The sensitivity in the range specified in 'out-of-band (iii)' must be 0.15% or lower and in the range specified in 'out-of-band (iv)' 0.03% or lower, of that at the corresponding center wavelength.

(2) Instantaneous FOV and the look angle in the cross-track direction

The instantaneous FOV is set at 500 m (in Bands 1, 2, 3) and 1.5 km (in Band 4) at the nadir point. The look angle in the cross-track direction is set at ±35 degrees, with which the sensor can observe the entire globe during daylight hours in three days except band 4. Figure A.3-3 below illustrates the geometries of the instantaneous FOV and the normal FOV.

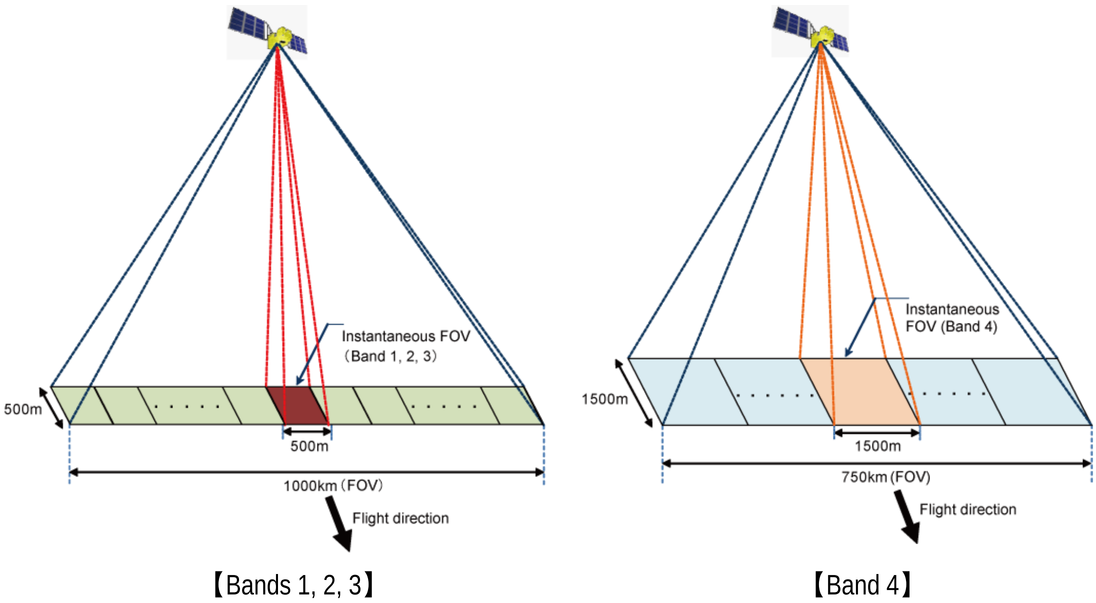


Figure A.3-3 Instantaneous and normal FOV of TANSO-CAI

A.3.3 Observation mechanism of TANSO-CAI

The column abundances of CO_2 and CH_4 are derived from the amount absorbed in the optical path between the sun, the ground surface and the satellite. The path length is obtained through the amount of absorption for the 0.76 μm band by O_2 whose density is known, with TANSO-FTS. As cloud or aerosol on the path affect the effective path length, correction is needed if there is any. In order to improve the accuracy of correcting errors caused by clouds and aerosols, electronic scanning imagers with multiple bands covering ultraviolet, visible and short wavelength infrared bands are installed, which also make it possible to observe cloud coverage and aerosols over the land and ocean areas. The FOV in the cross-track direction is used for ascertaining the spatial distribution of aerosols over a wide range (1,000 km).

Registration between TANSO-FTS and TANSO-CAI data should be performed after the launch using the FOV check camera installed in the TANSO-FTS sensor. Figure A.3-4 shows a sample of CAI observation data.

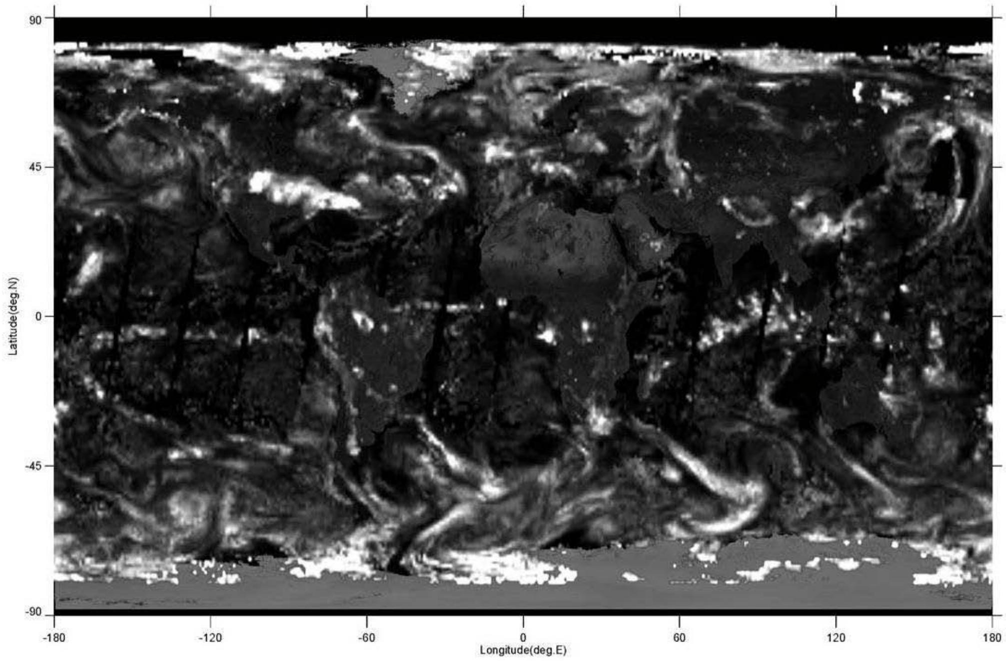


Figure A.3-4 A CAI observation image (equivalent to Band 2)
generated based on MODIS data

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

Research Announcement

Appendix B

GOSAT/TANSO Calibration and Validation Plan and Overview of Processing Algorithms

B-1 GOSAT/TANSO Calibration Plan

B-1.1 Outline

“Calibration” is an evaluation process to clearly characterize the sensor and to ensure that the accuracies of radiance, geometry, spectral characteristics, image quality, etc. meet the target values, using Level 1 (L1) products out of the standard products. The specific methods of evaluation include:

- Evaluation of performance in ground tests (before the launch, using ground test data)
- In-orbit calibration (after the launch, using cal-mode data), and
- Vicarious calibration (after the launch, using actual observation data, etc.)

Based on the results of these calibration activities, L1 products will constantly be upgraded by reflecting the revised calibration coefficients and the corrected L1 processing algorithm in the ground processing system.

B-1.2 Calibration Schedule

The evaluation of the sensor performance on the ground will be completed by approximately one year before the launch. The initial in-flight calibration will be carried out during the operational phase, between three and six months after the launch. The calibrated Level 1 products will be released as Version 1, expectedly within six months from the launch. Thus, the data to be collected and examined during the initial calibration period only covers a period of less than a year, and it is important to thoroughly examine match-up conditions, etc. for data acquisition during this period.

B-1.3 Pre-launch Performance Test

The main functions and capabilities of TANSO-FTS and TANSO-CAI will be evaluated before the launch. The evaluation is basically conducted by checking the following items in ground tests.

(1) Sensitivity and signal-to-noise ratio (SNR)
The sensitivities of FTS at short wavelength infrared bands and CAI, an indicator for the photoelectric conversion efficiency, and SNR are calibrated and evaluated by using an evaluated integrating sphere. The evaluation of the integrating sphere is carried out by using a comparative spectrometer in comparison with a fixed point blackbody furnace coated with such material as zinc. The sensitivity calibration for FTS thermal infrared (TIR) band and SNR evaluation are performed by using a blackbody cavity at the thermal vacuum test.

(2) Polarization sensitivity
The polarization sensitivity of FTS at short wavelength infrared bands and CAI will be carried out in the following steps: i) install a polarizer at the exit port of the integrating sphere to form linearly polarized light, ii) rotate the phase of the linearly polarized light by rotating the 1/2 wavelength plate attached behind, and iii) introduce rotating linearly polarized light so as to

obtain the polarization sensitivity. In case of TANSO-FTS, the incoming light is polarized mainly at the reflector of the pointing mechanism and the beam splitter of the Fourier interferometer mechanism.

(3) Instrument function
FTS's instrument function serves as an indicator for the spectral resolution. The function is obtained by introducing diffused light from a tunable laser for each band. As for CAI, the spectral characteristics are obtained by introducing monochromatic light.

(4) Field of View (FOV) and Modulation Transfer Function (MTF)
The FOVs of FTS and CAI, which serve as indicators for optical capabilities, and the MTF of CAI are evaluated by setting up a point light source and a slit light source at the collimator. The alignment to the sensor reference axis and band-to-band/pixel-to-pixel alignment are also evaluated at the same time.

In addition, FTS is equipped with a high-resolution monitoring camera (CAM) to check its FOV. The CAM has the same look direction as FTS. The alignment of the CAM to the sensor reference axis will also be evaluated.

B-1.4 Post-launch calibration

Calibrations after the launch will be carried out in two modes: in-orbit calibration and vicarious calibration. The former is performed on the calibration mode data, whereas the latter uses actual observation data.

The cal-mode data acquired during in-orbit calibration are precisely defined in Chapter C-2.4.3 "Operation in the calibration mode" of Appendix C "Operation Policies of GOSAT and Basic Observation Plan of the TANSO Sensor". The cal-mode data are acquired in accordance with the operation policies provided thereof and used for L1 processing, trend evaluation, etc.

B-1.4.1 Calibration of the TANSO-FTS (short wavelength infrared (SWIR) bands)

The in-flight calibration of TANSO-FTS will be carried out in three aspects: radiance, geometry and spectral characteristics. The following items will be evaluated with respect to each of P and S polarization bands in short wavelength infrared (SWIR) bands (Bands 1-3).

(1) Radiance evaluation
  (a) Calibration of the sensitivity
  In-orbit calibration of SWIR bands will be performed through solar irradiation calibration using the diffuser plate for every orbit, and deep-space calibration in parallel with TIR band is performed. In L1 processing, it is planned to convert the observed values into radiance values using the sensitivity calibration coefficients obtained from ground tests. The coefficients will be revised based on an analysis of the results from the solar irradiance calibrations, lunar calibrations (to be discussed in more details later), and vicarious calibrations.

(b) Lunar calibration

The purpose of lunar calibration is to calibrate the efficiency of the overall optical system for SWIR bands by using the reflected solar radiation from the moon surface as the calibration source. The lunar calibration will be performed on the orbit when the average of lunar surface radiance becomes the largest (at lunar age of 14.8±0.1). In this calibration, the satellite will be oriented to the moon so that FTS's FOV catches the moon on the full scale, and FTS will keep pointing at the moon with its pointing mechanism for at least two minutes.

The moon is an extremely stable reflector with a radiance variance of 10^{-7}/year. The stability has been reported so high that the fluctuation is less than 1%, based on the results from the sensitivity trend evaluations for those sensors observing ultra violet to short wavelength infrared bands, such as MODIS, ASTER, etc., that have been conducted as part of lunar calibrations (USGS, 2006). The evaluation methods adopted in these past evaluations are as follows:

- The sensitivity trend was evaluated at each time of calibration using a stable light source.
- The absolute sensitivity was evaluated based on ROLO data—ROLO (RObotic Lunar Observatory) is USGS's reflectance database for lunar calibration.

(c) Linearity

The linearity for the response of the optical system, including temperature dependence, will be checked based on the data observed while uniform light with different radiance levels is introduced into the FTS optical system. Listed below are candidate targets that have uniform radiances.

- Offset: Deep-space calibration
- Low radiance: Ocean, snow and ice (B2-3)
- Medium radiance: Forestry
- High radiance: Solar irradiation calibration, snow and ice (for B1 only), dry salt lakes (for B1 only), desert, playa

(d) Absolute radiance

The radiance observed by FTS is compared with the radiance of ground surface radiation obtained from the experiments in vicarious calibrations or synchronous observations with a well-calibrated sensor on board other spacecraft or aircraft. In order to match the radiances of the reference instrument and FTS, the sensor radiance model, and calibration coefficients are adjusted and absolute radiometric accuracies are evaluated.

There are two major approaches to this evaluation method:

- To use in-situ data
- To use global data

(i) Using in-situ data

Specific physical parameters, such as the ground-surface reflectance, as to a specific location on the earth are obtained accurately and synchronously in a vicarious calibration experiment. The GOSAT-observed radiance is evaluated in comparison with the radiance at the top of atmosphere computed by using the above mentioned parameters. Since the observation bands contain absorption bands of CO_2, CH_4 and other species, it is desirable to synchronize the validation experiments with this evaluation.

(ii) Using global data

The synchronized data are extracted from the data acquired by a well-calibrated sensor on board other spacecraft for radiance comparison. Since the radiance is influenced by the observation timing or geometry, the FTS data and the reference data may not easily fit when directly compared. In such a case, the radiance is evaluated by comparing the GOSAT-observed radiance with the radiance at the top of atmosphere computed based on the physical parameters, such as ground-surface reflectance.

Currently, Aqua/MODIS and OCO (Orbiting Carbon Observatory) are listed as candidates for reference satellites in this comparative evaluation.

(e) Relative radiance between the sensors

FTS and CAI both observe the 1.6μm band in Bands 2 and 4, respectively. The relative radiance accuracy between the two sensors is evaluated by assessing the temporal variation and temperature dependence per gain.

(2) Geometric evaluation

(a) Pointing accuracy

The alignment of the CAM, attached in the FTS sensor for checking its FOV, and FTS is assumed to be known and the CAM has an FOV of approximately 30 km and a spatial resolution of approximately 100 m in the VGA mode. FTS's geometric accuracy is evaluated using imagery taken by the CAM over GCPs with known coordinates as well as clear radiance boundaries between bright and dark. The following scenes are to be used in this evaluation:

- Land/sea boundaries (scenes containing coastal lines also covering projections from the land, such as peninsulas and capes)
- Islands (scenes containing the whole land of an island within the FTS's FOV of 10 km)

(b) Pointing stability

The pointing accuracy of the pointing mirror during an interferogram measurement (typically for four seconds) is evaluated by acquiring data by the CAM in the movie mode. The following scenes are to be used in this evaluation:

- Land/sea boundaries (scenes containing coastal lines also covering projections from the land, such as peninsulas and capes)

(c) Geometric accuracy between the sensors

The geometric accuracy between FTS and CAI is evaluated by assessing the displacements of common GCPs on CAM and CAI images. Further, since the sensors observe the same wavelength region, the geometric accuracy of FTS can be comparatively assessed against CAI by searching the position of FTS Band 2 (10-km resolution) on a CAI Band 4 (1.5-km resolution) image with the radiance matching function.

(3) Evaluation of spectral characteristics

(a) Instrument function

The instrument function of Band 2 is evaluated by irradiating 1.55μm semiconductor laser light onto the diffuser plate and observing the diffused light.

(b) Wavelength accuracy

The wavelength shift is evaluated by referring to the wavelength position of a known atmospheric absorption band.

(c) Polarization sensitivity

The radiance ratio between the P and S polarization bands of the target with known polarization characteristics is evaluated using the following data.

・Solar irradiation calibration data (natural light of the sun is unpolarized.)

(d) SNR

Targeting a uniform high-radiance range, the SNR is evaluated as to each band detector and gain. The following data will be accumulated and used for the evaluation.

- Solar irradiation calibration data
- Desert, snow and ice (for B1 only)

B-1.4.2 Calibration of TANSO-FTS (TIR band)

(1) Radiance evaluation

(a) Calibration of the sensitivity

In-orbit calibration of TIR band will be performed using deep-space radiation (equivalent to a radiance temperature of 3 K) and the blackbody on board the satellite (equivalent to a radiance temperature of app. 290 K). The L1 processing algorithm for this calibration is currently assumed to employ the following methods:

- The blackbody and deep-space radiances are assigned to the highest level and the lowest level, respectively, for fitting based on a high-order regression curve. The values obtained in the ground tests are used as the factors in the high-order terms.
- Since the sensitivity is subject to the influence of background radiances inside the instrument, phase correction should be taken into consideration, while at the same time directing attention to the combination of data to be used in the calibration, the monitored temperature of the sensor, etc.

(b) Linearity

The offset and linearity of the response of the optical system, including temperature dependence, will be checked based on the observation data taken while uniform light with different radiance levels is introduced into the FTS optical system. The following lists up candidate data to be used for this evaluation.

- Offset: Deep-space calibration
- Low radiance: Snow and ice
- Medium radiance: Forestry, oceanography
- High radiance: Blackbody calibration, deserts, playa

(c) Absolute radiance

Similarly to SWIR bands, the absolute radiance of TIR band will be evaluated by the following two approaches:

- To use in-situ data
- To use global data

(i) Using in-situ data

A high-accuracy calibration will be performed by acquiring the atmospheric profile, including temperature of air, water vapor, etc., while targeting the locations where the sea surface temperature is measured with buoys.

(ii) Using global data

The synchronized data are extracted from the data (equivalent to Level 1) acquired by a well-calibrated sensor on board other spacecraft for radiance comparison. Furthermore, the accuracy of calibration is evaluated over a wide area of the ocean by using sea-surface temperature and meteorological data on the global scale with a high, consistent accuracy.

Currently, Aura/TES and Aqua/AIRS are listed as candidates for reference satellites in this comparative evaluation, and NOAA's sea-surface temperature (SST) analysis of Reynolds, etc. are planned for the reference database.

(2) Geometric evaluation

Since the same optical system is used for acquiring FTS SWIR and TIR band data, the geometric evaluation of TIR band is conducted following that of SWIR bands.

(3) Evaluation of spectral characteristics

(a) Wavelength calibration

The wavelength shift is evaluated by observing known atmospheric absorption bands.

(b) SNR

Targeting a uniform high-radiance range, the SNR is evaluated as to each gain. The following data will be accumulated and used for the evaluation.

- Blackbody calibration
- Desert

B-1.5 Calibration of TANSO-CAI

(1) Radiance evaluation

(a) Calibration of the sensitivity

CAI does not carry any special functions associated with the sensitivity calibration in orbit. Thus, the calibration is performed only with the sensitivity calibration expression to be obtained in the ground tests. However, the following data will be acquired as solely for the offset (dark signal output).

- Nighttime observation
- Optical black element

(b) Lunar calibration

The lunar calibration for CAI will be performed on the same orbit as that of FTS. It is intended to calibrate the sensitivity of the devices of the linear array detectors where lunar calibration light enters. In this calibration, CAI imagery will be acquired while scanning an area of ±2.55deg or greater covering the entire moon surface twice in both ways (four scans) continuously at an angular velocity of 0.1 deg/sec or less in the Y-axis direction.

(c) Linearity

The linearity of the response of the optical system, including temperature dependence, is evaluated based on the observation data taken while uniform light with different radiance levels is introduced to the CAI optical system. Listed below are candidate targets that have uniform radiances.

- Offset: Nighttime observation, optical black element
- Low radiance: Ocean, snow and ice (for B4 only)
- Medium radiance: Forestry
- High radiance: Snow and ice (B1-3), dry salt lakes (B1-3), desert, playa

(d) Absolute radiance

Similarly to FTS, the absolute radiance of CAI will be evaluated by the following two approaches:

- To use in-situ data
- To use global data

(i) Using in-situ data

The calibration coefficients are determined through optimization based on aerosol data measured at as many locations as possible by the AERONET (NASA, 2006) and SKYNET (Chiba Univ., 2006), both of which are deployed worldwide.

(ii) Using global data

The synchronized data are extracted from the data (equivalent to Level 1) acquired by a well-calibrated sensor on board other spacecraft for radiance comparison. Furthermore, the accuracy of calibration is evaluated by using the ground surface reflectance, aerosol parameters, climatological values, and other physical values (equivalent to Level 2) or databases providing these values, acquired by other spacecraft on the global scale with a high, consistent accuracy.

Currently, Aqua/MODIS and Aura/OMI are listed as candidates for reference satellites in this comparative evaluation, and the ground surface reflectance datasets of GOME (Global Ozone Monitoring Experiment) and TOMS (Total Ozone Mapping Spectrometer), etc. are planned for the reference database.

(2) Geometric evaluation

(a) Pointing accuracy

The geometric accuracy of CAI imagery is evaluated using imagery taken over GCPs with known coordinates as well as clear radiance boundaries between bright and dark.

The GCP database to be used for GOSAT should be chosen beforehand from coastline database GSHHS.

The following scenes are to be used in this evaluation:

- Land/sea boundaries (scenes containing coastal lines also covering projections from the land, such as peninsulas and capes)

(b) Band-to-band registration

The offset between bands is determined relatively by evaluating the pointing accuracy as to each band, as described in (a) above.

(3) Image quality evaluation

(a) Calibration of the pixel-to-pixel sensitivity

The coefficients for correcting the pixel-to-pixel sensitivity are calculated by accumulating data in each pixel direction, deriving the average values, and comparing the averages in the line direction, using data taken over wide-area targets with uniform, high radiances. Since GOSAT's swath stretches for 750-1,000 km, it is infeasible to perform the calibration at once. Thus, more than one site must be selected for the calibration. The following lists up the candidate target sites.

- Snow and ice (B1-B3), desert

(b) MTF

In order to extract edge and point spectra, the MTF is calculated using geometrically-corrected observation data covering edges, such as coastal lines, and point sources, such as islands. Based on the derived MTF, the spatial resolution dependent on the optical characteristics is evaluated. The following scenes are to be used in this evaluation:

- Coastal lines
- Islands

(c) SNR

Targeting a uniform high radiance range, the SNR is evaluated as to each band detector and gain. The following data will be accumulated and used for the evaluation.

- Snow and ice (B1-3), dry salt lakes (B1-3), desert, playa

B-1.6 Preparation for Calibration

(1) Examination of the calibration approach with the use of in-situ data

In vicarious calibrations using TANSO observation data and ground observation data, it is important to select test sites in view of the uniformity (across the FTS's FOV of 10 km), temporal stability, probability of clear sky, and accessibility. The following candidate sites have been found as satisfactory for the calibration purpose.

- Railroad Valley Playa, Nevada, U.S.A.
- Strzelecki Desert (Tinga Tingana), South Australia, Australia

These sites have been scrutinized in terms of appropriateness as the calibration sites. Railroad Valley has constantly been used as a vicarious calibration site for Landsat, MODIS, ASTER, etc. by the University of Arizona for a long time. The OCO project likewise is considering the use of the valley as its calibration test site. Tinga Tingana in Strzelecki Desert is a highly uniform site where the CSIRO (Commonwealth Scientific and Industrial Research Organisation) of Australia has set up a part of the AERONET.

Figure B-1-1 below shows MODIS images over Railroad Valley and Tinga Tingana. The red circles indicate the FTS's FOV of 10 km when it is pointing at the sites. Each image stretches for 30 km×30 km. While the uniform area in Railroad Valley just barely covers the 10-km FOV of FTS, Tinga Tingana is covered with uniform land that amply extends over the FOV. Figure B-1-2 plots the probability of clear sky throughout 2004 at these sites, and the graph apparently suggests that the probability drops during wintertime at both sites. Thus, it is desirable to secure calibration sites in both north and south hemispheres in consideration of the launch schedule. It is still under examination whether these sites are selected for GOSAT's calibration sites or not.

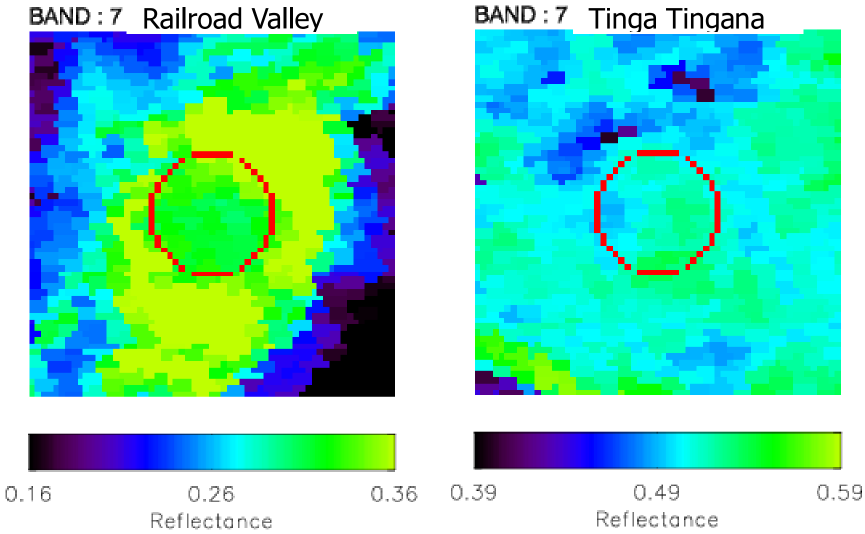


Figure B-1-1 MODIS band 7 (2.1μm) images over the candidate calibration sites

(2) Examination of the calibration approach with the use of global data

In order to select most appropriate sites for cross-calibration with data taken by other missions, the spatial uniformity, temporal stability, etc. at the candidate sites are evaluated based on the existing global data observing these sites.

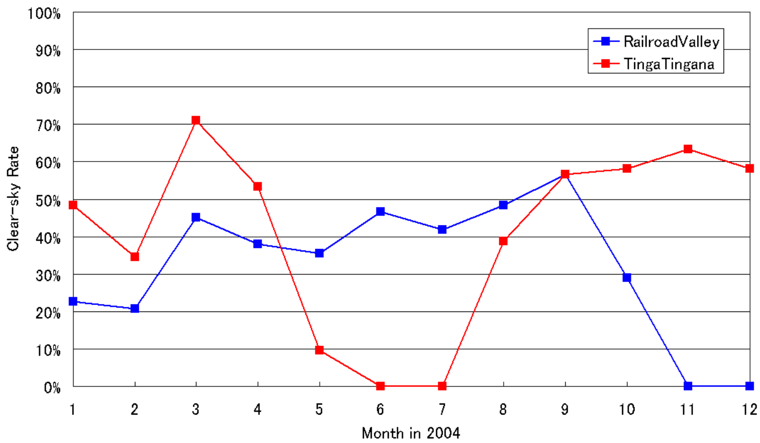


Figure B-1-2 Clear-sky rate at the candidate calibration sites
(Aqua/MODIS data in 2004)

Figure B-1-3 indicates an average reflectance distribution on the 5 x 5 pixel basis (app. 25 square kilometers) of MODIS band 7 (2.1μm) data and the standard deviation among 25 samples. The samples were retrieved from the global reflectance data (average of 16 days) of MODIS on board Aqua and Terra. There are several spots with uniform reflectance in the Sahara Desert and the Rub' al khali Desert. In addition, as the reflectance in this band is susceptible to soil moist and decreases with it, a high reflectance is obtained only in deserts or bare lands.

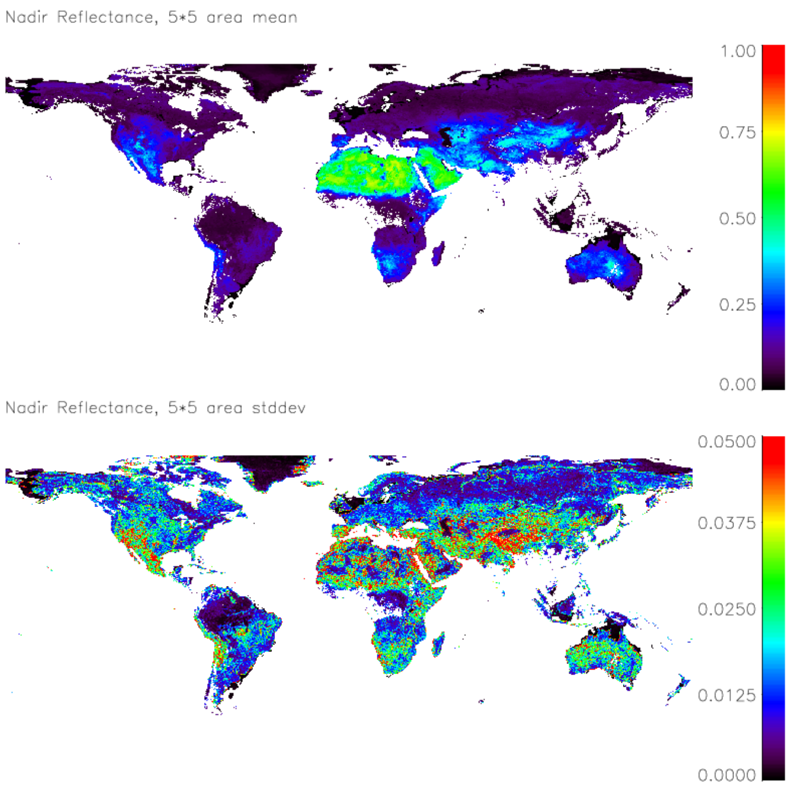


Figure B-1-3 Survey on the spatial uniformity using the ground surface reflectance data acquired by MODIS band 7 (2.1μm)
Upper: Average reflectance of 5×5 pixels (app. 25km)
Lower: Standard deviation of 25 samples

Figure B-1-4 shows an annual average of the ground surface reflectance in the Sahara Desert (of app. 22 samples), and the standard deviation for the year. POLDER (POLarization and Directionality of the Earth's Reflectances) targeted the sites marked with x, namely Egypt 1 (N27.12, E26.10) and Algeria 3 (N30.32, E7.66), in its vicarious calibration. (Hagolle, 1999) Figure B-1-5 plots the reflectance at Egypt 1 and Algeria 3 during the year in the time series. It reveals that those sites selected by POLDER have a high temporal stability and, as shown in Figure B-1-3, a high spatial uniformity.

Based on the analyses of these existing data, the GOSAT Project will select the most appropriate sites for its calibration activities in light of the resolutions and swaths of TANSO-FTS and CAI, and collect data accordingly.

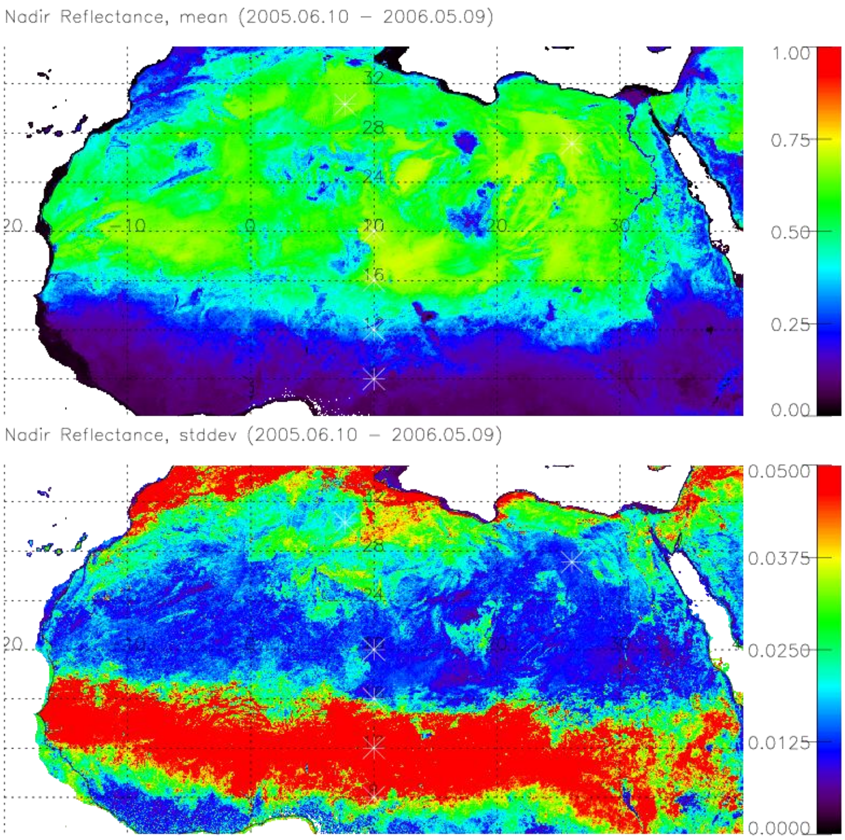


Figure B-1-4 Investigation on the temporal stability based on the ground-surface reflectance data of MODIS band 7 (2.1µm)
Upper: Annual average (app. 22 samples)
Lower: Standard deviation

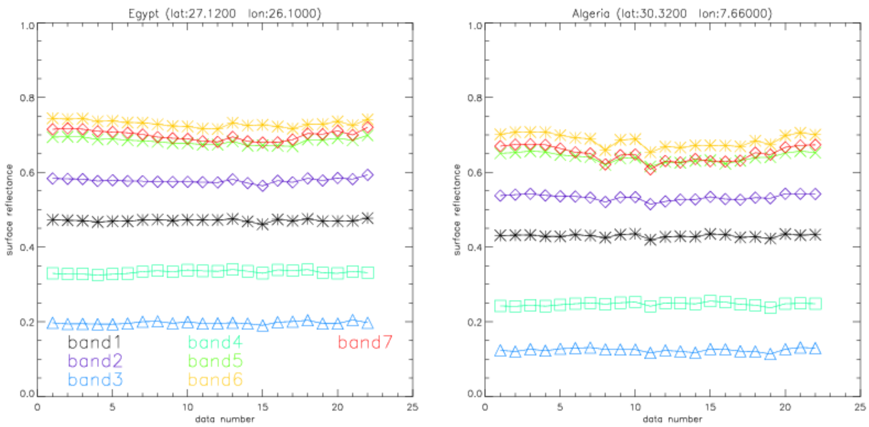


Figure B-1-5 Chronological plotting of the ground-surface reflectance at the specific observation points for one year
Left: Egypt 1 site Right: Algeria 3 site

B-2 GOSAT/TANSO Validation Plan

B-2.1 Basic philosophy for the validation

"Validation" of GOSAT products means an evaluation of uncertainties of GOSAT L2, L3 and L4 products, as provided in Table 1 of the Research Announcement document*, compared with other data with less uncertainties that were acquired independently of GOSAT. "Comparison", on the other hand, means an evaluation of uncertainties of GOSAT products against observation data with equivalent uncertainties or data estimated by simulation models; thus it should be distinguished from "validation" above. Both evaluation methods, however, are intended to assess the data quality of GOSAT products (data quality assurance), and at the same time play a significant role in evaluating the appropriateness of the data processing algorithms. Therefore, any findings from the evaluations will be reflected in revising the algorithms, as necessary.

Additionally, the "calibration" is an evaluation of L1 product data to be performed mainly by JAXA and focuses on calibration of radiance spectra (e.g., absolute radiance, linearity, offset, wavelength, instrument function, SNR, etc.) However, it excludes an evaluation of spectral parameters and the Fraunhofer lines, which are necessary for retrieval of the CO_2 and CH_4 column abundances based on the radiance spectra obtained from TANSO-FTS observation data, since these values have been evaluated at the algorithm development stage.

In formulating a validation plan for GOSAT TANSO, it is important first to assign priority orders to the validation items because the manpower and budget for observation and analysis activities in connection with the validation are not unlimited.

The appropriateness of the processing algorithms must be verified prior to the launch of the satellite. This evaluation is called "algorithm validation". The algorithm validation has been conducted through observational experiments by the FTS sensor installed at a high elevation and on an aircraft. These observational experiments must continually be performed in the future to improve the algorithms.

After launch, another important evaluation, in addition to product validation, is to verify the appropriateness of parameters, such as optical characteristics of aerosols, which are relevant to errors. This post-launch evaluation is called "parameter validation". Although GOSAT makes greater social contribution with its higher-level products than lower-level products (L2), validation of the latter is of primary importance as it provides the foundation for generating the former. Thus, it is preferred to perform validation of lower-level products first followed by that of higher-level products.

The priorities of GOSAT product validation and comparison have been set as follows:

(1) L2 SWIR CO_2 and L2 SWIR CH_4 column abundances
(2) L2 TIR CO_2 and L2 TIR CH_4 vertical profile of concentration
(3) Global distributions of L3 SWIR CO_2 and CH_4 column abundances
(4) Global distribution of L4A CO_2 flux
(5) Global distribution of L4B CO_2 concentration

$$\left(\text{uncertainty} = \sqrt{(\text{accuracy})^2 + (\text{precision})^2} \quad \text{accuracy} = \text{bias} \right)$$

The basic policy on collection of validation data is to prioritize the use of diverse observation data being acquired routinely in all parts of the world, considering that the GOSAT itself observes the entire earth on varied conditions in terms of ground surface, meteorology, and atmosphere. To this end, certain specific observation points will be set as "super sites" for focused and continued observation for the validation purposes of products and algorithm, and necessary observing equipment are installed at these sites. Furthermore, campaign observations will be planned and carried out, which include air-borne observation on various meteorological conditions.

The data to be validated are those that have been taken on the following geographical and meteorological conditions:

a. Land area with clear sky
b. Sea area with clear sky (sunglint observation)
c. Land area with thin cirrus clouds and aerosols
d. Sea area with thin cirrus clouds and aerosols (sunglint observation)

*Excluding areas covered with thick clouds.

In addition, the validation must be conducted in light of certain standards for match-up conditions in terms of space and time.

Of all the analytical work in the validation, NIES will be responsible for the basic validations analysis and incorporation of the results into the revision of algorithms, as part of the GOSAT Project. In the meantime, it is expected that more research activities concerning the validation analysis of the GOSAT data products will be carried out by the GOSAT Science Team members, scientists participating in the RA, and other users at large.

B-2.2 Experimental observation for the algorithm validation

The processing algorithm to derive the CO_2 column abundance must be verified prior to the launch through experiments simulating the satellite observation geometry, more specifically, by observing solar light reflections from the earth surface with an FTS, a similar sensor to the one on board the satellite, installed at a high-elevation ground point or on board an airplane.

(1) Observation at a high elevation

NIES carried out two observational experiments using an FTS sensor, similar to TANSO-FTS, installed near the summit of Mt. Tsukuba Japan at an elevation of 800 m in 2005 and 2006. In these experiments, the CO_2 concentration calculated from the data acquired by FTS was compared with the measurement made by a light airplane, which took off from near the farmland close to the foot of the mountain and flew up to an altitude of 3,000 m carrying the CO_2 in-situ instrument. The results demonstrated an accuracy of about 1% of the FTS's observation with respect to the CO_2 column abundance in the atmospheric layers at an altitude of 3 km and lower. It is vital to continue observational experiment in this manner on various meteorological conditions in the future, pursuing an improved accuracy.

(2) Air-borne observation

An algorithm validation is made by the spectroscopic observation using the FTS mounted on the aircraft at a very high altitude, simultaneously with the in-situ CO_2 concentration measurement onboard an aircraft. This method more directly simulates the behaviors of the FTS on board the satellite in nadir looking observation from a very high altitude than the observation at a high-elevation ground point, although the vibration of the aircraft remains as a problem.

B-2.3 SWIR/TIR Product Validation

(1) Validation of CO_2 and CH_4 column abundances by SWIR observation

The observing instrument to be used for validating the CO_2 and CH_4 column abundances must be based on fully-established technology with no bias, assuring data quality as well as achieving an excellent observation accuracy of about 1 %. An observation method which uses absorption of direct solar light is the best technique for observing the column abundance directly. Thus, a high-resolution FTS installed on the ground proves to be the most appropriate method among all available measuring instruments. FTS can observe spectrum anytime as long as there is direct solar irradiance for approximately 10 minutes.

The footprint of TANSO-FTS extends for as long as 10.5 km. In order to reduce observation errors, observation points where the surface cover is flat and uniform within this size are ideal for the purpose of the validation. Some of FTS's observation points are situated in mountainous areas; thus it is essential to collect surrounding information of the observation points and select flat areas that will least contribute to observation errors.

If there is an obvious bias in the TANSO-FTS retrieval results or if the measurement accuracy falls below a certain level, it is necessary to identify the cause of the error and improve the data processing algorithm. Of the various parameters that affect the retrieval of column abundances, namely cirrus cloud, aerosol, surface albedo, air pressure, air temperature, water vapor, and concentrations of other gases, the effects of cirrus cloud and aerosols are the most dominant. The surface albedo can be obtained fairly accurately from the TANSO-FTS observation data by means of a retrieval analysis and it does not substantially affect the derived column abundance value. Therefore, the priority of the surface albedo is set low. Furthermore, the priority of meteorological parameters, such as air pressure, air temperature, and water vapor, is also low since they are usually taken from meteorgical reanalysis data.

Measuring cirrus cloud and aerosol requires i) a sky radiometer that can estimate the optical thickness, the grain size distribution and the complex refraction index averaged in the nadir direction and ii) a polarized lidar that can identify the vertical distribution of cirrus clouds and aerosols and distinguish between sphericity and non-sphericity. Thus, it is important, in terms of validation strategy, to set up these instruments at the ground based FTS observation sites to enable simultaneous observation.

The vertical distribution data directly measured (sampled and analyzed) by a taking-off and landing regular passenger airplane provide an effective reference for the derived CO_2 column abundance. However, this measurement can gather data for the vertical profile of CO_2 concentration between the ground level and an altitude of approximately 11 km. As about 22 % of CO_2 exists above the 11-km altitude, other methods to either correctly estimate or measure the CO_2 level above this altitude are needed for calculating the column abundance. If the fluctuation of CO_2 abundance in the higher altitudes remains within 4 %, the model climatological values derived from the past actual measurements can be used. Furthermore, CO_2 concentration on the ground surface needs to be measured in order to ascertain the concentration between the ground level and the minimum altitude where aircraft can measure. Moreover, it is desirable to use the sky radiometer and lidar in the vicinity of the validation sites for measuring cirrus cloud and aerosol. At some airports, however, the air is significantly contaminated. Therefore, meteorological conditions of the sites must be carefully examined when selecting validation sites.

As for CH_4, there is a possibility that air-borne observation (bottle sampling) data is effective. Moreover, it can be effective in validation as there are most recent data up to an altitude of about 35 km based on balloon observation.

Sunglint observation basically takes place on the ocean. However, validation of product by sunglint observation may be replaced by data acquired by a high-resolution FTS installed near coastal lines and/or data obtained by aircraft flying above the vicinity of coastal lines.

WDCGG provides ground-based CO_2 and CH_4 measurements. This dataset may well serve as collateral evidence if used with consideration given to seasonal variation and spatial representativeness. Among others, in the south hemisphere, where the seasonal variation of concentration is very small, this dataset is highly effective and may even serve as validation data.

One of possible scientific validation methods is to synthesize (or assimilate) the CO_2 distribution in the surrounding of the observation point based on the concentration profile measured by air-borne using regional atmospheric transport models, calculate the concentration profile up in the sky over the flat place with uniform albedo, which corresponds to the GOSAT observation point, and compare the findings with GOSAT product. However, the appropriateness of the method itself needs to be verified, first of all, and there are several other problems that remain to be addressed with this method.

The following sets forth policies concerning validation data collection.

- Install a number of observation instruments (high-resolution FTS, lidar and sky radiometer) at several specific observation points and perform observation with priority at these "focal observation points".
- Effectively utilize "campaign observation with aircraft if necessary" for observation data on such meteorological and ground surface conditions that are not covered by the "focal observation points".
- Utilize the observation data routinely acquired, such as those taken by the existing high-resolution FTS installed on the ground, air-borne observation data, and WMO WDCGG ground observation data, as the GOSAT observation coverage is the entire globe.
- The column abundances in sea areas are derived based on sunglint observation. As the concentration variation is smaller in sea areas than land areas, data covering the validation

sites on the ground that are located near the sea can be used with consideration given to the wind direction. Moreover, observation data acquired in islands and by vessels can also be used for indirect evaluation.

Based on the above policies, data at typical observation points are acquired; the specific criteria for selecting such observation points can be summarized as follows:

- Latitude: low , middle , high
- Amount of water vapor: high, low
- Albedo: uniform, nonuniform
- Aerosols: variant, invariant

At present, if 10 validation points for ground-based FTS observation and another 10 for aircraft observation can be acquired, minimum requirements in the validation can be satisfied. The total 20 are expected as sufficient to minimally cover the above conditions. However, if a handy validation observation instrument which satisfies the validation requirements is developed, more points may be selected and the validation can more largely be deployed.

Data measured at each observation point will be evaluated in light of both temporal and spatial variations to identify the uncertainties in the products. However, the evaluation of biases requires roughly three months at the sites where seasonal variation is small and six months in general. The evaluation results will be sorted according to the above criteria and quality will be assured by data category. In case that this approach is difficult, alternative effective methods include a trajectory analysis with consideration given to temporal and spatial variations and a validation analysis based on regional CO_2 transport models.

The following describes specific plans of observation and data acquisition for the validation purpose.

a) Validation by FTS observation

(i) Observation by ground-based high-resolution FTS

Observation by ground-based high-resolution FTS will be performed at several observation points in Japan, on the regular basis.

In conducting the validation, it is additionally useful that the observation data acquired by the ground-based high-resolution FTSs are analyzed and evaluated using the same data processing algorithm (radiative transport equation) as the one used for the analysis of TANSO-FTS.

(ii) Utilization of data acquired by ground-based high-resolution FTS networks etc.

Data from the ground-based high-resolution FTS observation networks will be used. The Project will also arrange the use of data at other observation points through direct negotiation with the pertinent data providers, RA-based joint researches, and so forth.

When selecting ground observational sites for the GOSAT validation, the most ideal sites at the initial validation stage should preferably have flat and uniform surface and extend for a wide range commensurate with the 10.5-km footprint of TANSO-FTS, whereby error factors can maximally be avoided.

Thus, the validation sites will be selected based on the following criteria.

- Seasonal variation: small (south hemisphere)→ large (north hemisphere)
- Air pollution: minor → major
- Land surface: simple → complex

The options are:

- Sunglint
- Snow and ice

(iii) Observation by small FTSs

If moving observation is necessitated, these small-sized FTS can be used, after evaluating the measurement accuracy, data quality and operational stability.

b) Validation by air-borne/balloon-borne observation

(i) Utilization of data from the air-borne observation

The continuous CO_2 measurement equipment on board aircraft acquires the spatial (horizontal) distribution of CO_2 concentration at very high altitudes and the vertical profiles CO_2 concentration around the airports, since it can acquire data while not only flying horizontally but also taking off (ascending) and landing (descending).

Additionally, as aircraft travels in the horizontal direction for approximately 100 km while ascending up to an altitude of about 10 km where it flies horizontally, and 200 to 300 km while descending from the stable altitude, spatial representativeness of the concentration should be taken into consideration at the time of analysis. To this end, transport models can be used for this evaluation. Furthermore, since the concentration in the lower atmosphere near the airport grows due to effects from the urban air in many cases, it is necessary to judge effectiveness of data in view of the wind direction. Moreover, the fluctuation of the CO_2 concentration in the layers above the highest altitude that the aircraft can reach must also be evaluated. So far, the findings from balloon-borne observation for the stratosphere have revealed that the fluctuation of the column abundance is around 0.5%, very roughly. More details will be investigated in continued studies to follow.

(ii) Data acquisition by balloons

Balloon-borne observation data, including the past data, must be obtained in order to ascertain the characteristics of the variation of the CO_2 column abundance in the layers above the upper limit of air-borne observation.

c) Others

(i) Observation by small balloons

The CO_2 sonde to be installed on board a small-sized balloon, which is being developed, may be used for the validation after evaluating the measurement accuracy, data quality and operational stability and ensuring that it is practical in terms of cost, etc.

(ii) Observation by compact spectrometer

Fabry-Perot Etalons based spectrometer, currently being developed, may be used for the validation after evaluating the measurement accuracy, data quality and operational stability and ensuring that it is practical in terms of cost, etc.

(2) Validation of CO_2 and CH_4 products by TIR observation

The data acquired for validating L2 SWIR CO_2 and CH_4 will also be used for validating L2 TIR CO_2 and CH_4 products. Additionally, the validation will be more effective if combined with air temperature, air pressure, humidity profile, and ground emissivity data. As for nighttime observation, the data already acquired will be utilized as far as possible. The validation plan will be further detailed in consultation with the parties responsible for TIR.

In addition, since air temperature and H_2O and O_3 concentration profile by TIR are products to be generated internally by JAXA for the research purpose, JAXA will carry out necessary evaluations on data quality.

(3) Comparison in the global distribution of CO_2 and CH_4 column abundances based on SWIR observation

L3 products do not require special evaluation since they are derived by temporal and spatial averaging of the validated L2 products.

(4) Comparison of CO_2 flux

The global distribution of L4A CO_2 flux and L4B CO_2 concentration are positioned as subject to comparison due to the following reasons, and it is preferred that these are evaluated as part of research activities, including RA, instead of validating in the Project.

- L4A and L4B are both calculated by models.
- The reliability of the transport models to be used is not firmly established and is still under discussion among scientists. Ensemble averaging among multiple models will enable a comparative evaluation.
- Flux observation is intended for the research purpose, and it requires substantial efforts to obtain the necessary data.
- The comparison of the flux observation with models requires scaling-up, which is a process still at the research level.
- The sea flux varies with the exchange coefficient.

L4A products provide an estimation of the monthly average of CO_2 flux in each of the 64 regions into which the globe has been divided.

As for comparison of L4A products with other observation data, data acquired by vessels are effective since the flux in sea area (latitude 5° × longitude 5°) is regarded as almost uniform.

On the contrary, the flux in land area is calculated based on the mesh size of latitude 1°× longitude 1° in the calculation process, in assumption of the flux distribution patterns within the regions. On the other hand, the ground-based observation of CO_2 flux is made on the “point” basis, with a significant regional difference and the smallness in number and spatial unevenness of the observation points, and thus it is difficult to use these points directly for the validation of L4A products. In order to solve this problem, a scaling-up method using land-area ecosystem models plays a vital role. Many countries, including Japan, have been engaged in research on such scaling-up methods and further progress in this effort is expected to be seen in the near future.

As for research on CO_2, the following comparisons can be conducted.

a) Use of data on the CO_2 flux between the air and the ocean

The CO_2 flux between the air and the ocean is calculated by measuring the partial pressures of CO_2 in the surface sea water and in the air and applying the exchange coefficient. The exchange coefficient depends on the wind velocity, temperature of water at the sea surface and salinity.

b) Use of the observation data acquired at flux monitoring sites

There are several flux monitoring sites in Hokkaido, and although there is a problem in the unevenness in topography and vegetation, the data obtained there by utilizing the land-area ecosystem model may possibly be used in comparison with the flux (L4A) in GOSAT global carbon balance estimation model.

(5) Comparison of the global distribution of CO_2 concentration

L4B products to be offered are a monthly average of 3D concentration distribution obtained as mesh data of latitude 1°× longitude 1°. The comparison of the L4B products with other observation data is made on the one-hour value or monthly average value of the latitude1°× longitude1° grid, which is the base data of the L4B products. As for the reference data, the data used as the reference in the L2 validation (column abundances acquired by the ground-based FTSs and concentration profile acquired by air-borne observation) and data acquired by several other kinds of ground and marine observations can be generally and comprehensively utilized.

(6) Comparison with other satellite data

Comparison with CO_2 and CH_4 column abundance data acquired by other satellites, such as the OCO, is instrumental for evaluation of the data quality of GOSAT products.

a) OCO

OCO is scheduled to be launched in December 2008 by NASA/JPL (Jet Propulsion Laboratory). It will observe the CO_2 column abundance in short wavelength-infrared bands, as with GOSAT. The satellite will fly at the forefront of the so-called A-train constellation of the U.S. EOS program and it can obtain necessary physical quantities, such as aerosols, from the other member satellites. Therefore, it focuses only on observation of the CO_2 (and O_2) column abundance.

OCO's spectrometer is a grating type and the observation bands are 1.61, 2.06 and 0.76 μm, which almost coincide with those of GOSAT's.

In the future, it is necessary to scrutinize the possibility of concluding a cooperative agreement or framework between the two missions and examine detailed methods of data acquisition and other procedures.

b) SCIAMACHY

SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CartograpHY) is an on-board sensor of the ENVISAT of the ESA. Its primary purpose is to observe the atmospheric trace components necessary for chemistry in the troposphere and the stratosphere. The spectrometer is a grating type with eight channels sensitive to ultraviolet, visible, and short wavelength infrared bands. The observation modes range from nadir, solar/lunar occultation, and limb scattering. It observes both the concentration profiles and column abundances of O_3, CO, CH_4, etc.

In addition, as the derivation of CO_2 is also being attempted, it may serve as effective reference for comparison with the GOSAT data.

Even other satellites that are not originally intended to measure greenhouse gases, such as AIRS and IASI, can also be used as referential data sources.

B-2.4 Validation of parameters related to error factors in SWIR observation

(1) Aerosol, thin cirrus cloud

In order to evaluate the appropriateness of the L2 processing algorithm for TANSO-FTS (SWIR) data, the parameters related to error factors, namely the optical characteristics of aerosols, such as optical thickness, wavelength index, and single scattering albedo, and the vertical distribution, are extracted via the networks referred to hereunder or otherwise, in addition to the validation of data quality. It must be noted, however, that it takes a certain lead time for the latest data to be uploaded on the Website, and hence in case that it is urgent to obtain the data, a request for data acquisition must be made directly to the observer.

Furthermore, it is necessary to install sky radiometers and lidars at those locations where ground-based FTS or air-borne observation is carried out. The lidar can measure the vertical distribution of aerosols and thin cirrus clouds with an accuracy of approximately 15 m, and distinguish between sphericity and non-sphericity based on the extinction of polarization, thereby identifying whether the substance is rain cloud, cirrus cloud, or sand dust. The sky radiometer measures the direct solar irradiance and forward scattering in the sky. The measurements can also be used for estimating not only the optical thickness, particle size distribution, and complex refractive index, but also the single scattering albedo and phase function. These data are useful to the validation of TANSO-CAI products.

(2) Ground surface reflectance

The accuracy of the ground surface reflectance retrieved from SWIR data will be confirmed with the use of the following data. The observation points for this purpose must be selected where the land surface is homogeneous.

a) MODIS

MODIS (Moderate Resolution Imaging Spectroradiometer) is an optical sensor on board Terra and Aqua, NASA's earth observing satellites. It observes a wavelength range of 0.4 to 14 µm in 36 bands with a 2,330 km swath and spatial resolutions of 250 to 1,000 m. The Science Team at NASA developed the processing algorithms and each data center is generating various products including the ground surface reflectance.

b) ASTER

ASTER (Advanced Space-borne Thermal Emission and Reflection Radiometer) is an optical sensor on board Terra, NASA's earth observing satellite. It consists of the Visible Near-Infrared Radiometer (VNIR), Short-Wave Infrared Radiometer (SWIR) and Thermal Infrared Radiometer (TIR). It observes a wavelength range of 0.52 to 11.65 μm in 14 bands with a 60-km swath and spatial resolutions of 15 to 90 m. The standard products generated by the Japan side include the ground surface reflectance, land surface temperature, land surface emittance and DEM.

(3) Oxygen column abundance

The oxyten column abundance, obtained in Band 1(O_2 A band in 0.76 μm), will be validated.

a) Ground air pressure and rawinsonde data

The validation will be performed using the data routinely taken at observation points for the upper atmosphere together with new observation data to be acquired as necessary. The rawinsonde data will also be used for addional other validations.

b) Meteorogical data reanalysis

Since the observation points for thte upper atmosphere are not evenly distributed among the oceans, developing countries and polar areas, meteorogical reanalysis results are also used in the validation.

B-2.5 Validation of CAI Products

TANSO-CAI is a supplementary sensor to TANSO-FTS. In other words, the CAI products (concerning parameters related to error factors) that relates to the validation of TANSO-FTS L2 products should be validated with a priority because these CAI data are necessary for generating TANSO-FTS L2 products. On the other hand, the validation of the other CAI products is rated at a lower priority, while, in the meantime, the validation of cloud mask products is quite essential. CAI L1B products are generated by NIES, and the evaluation of the position, band-to-band registration, radiance, etc. is extremely important.

Since the CAI products and validation data of parameters related to error factors in short wavelength infrared are common in part, the detailed validation plan will be determined in coordination with the parties in charge of CAI.

B-2.6 Campaign Observation

Air-borne observation by the direct observation instrument is important to be performed simultaneously with observation by the remote sensing instruments, such as FTS, lidar or otherwise, in order to confirm the accuracy of TANSO-FTS measurements.

The evaluation will be performed as to whether temporal variation of the accuracy of each instrument is ascertained, by acquiring high-accuracy CO_2 concentration profile data by the aircraft which will ascend to a high altitude in synchronization with the satellite and calculating the column abundance obtained therefrom. The CO_2 concentration above the highest altitude where the aircraft can reach varies with the altitude of the tropopause. Therefore, it is crucial to calculate the altitude of the tropopause correctly. To this end, interpolation of simultaneous observation data taken by the rawinsonde or meteorological reanalysis data is performed. It is also needed to measure the CO_2 concentration at the ground level, because the aircraft cannot measure the concentration between the land surface and the lowest altitude which the aircraft can observe.

Moreover, it is considered as effective to simultaneously carry out direct observation by aircraft on aerosols, which act as error factors.

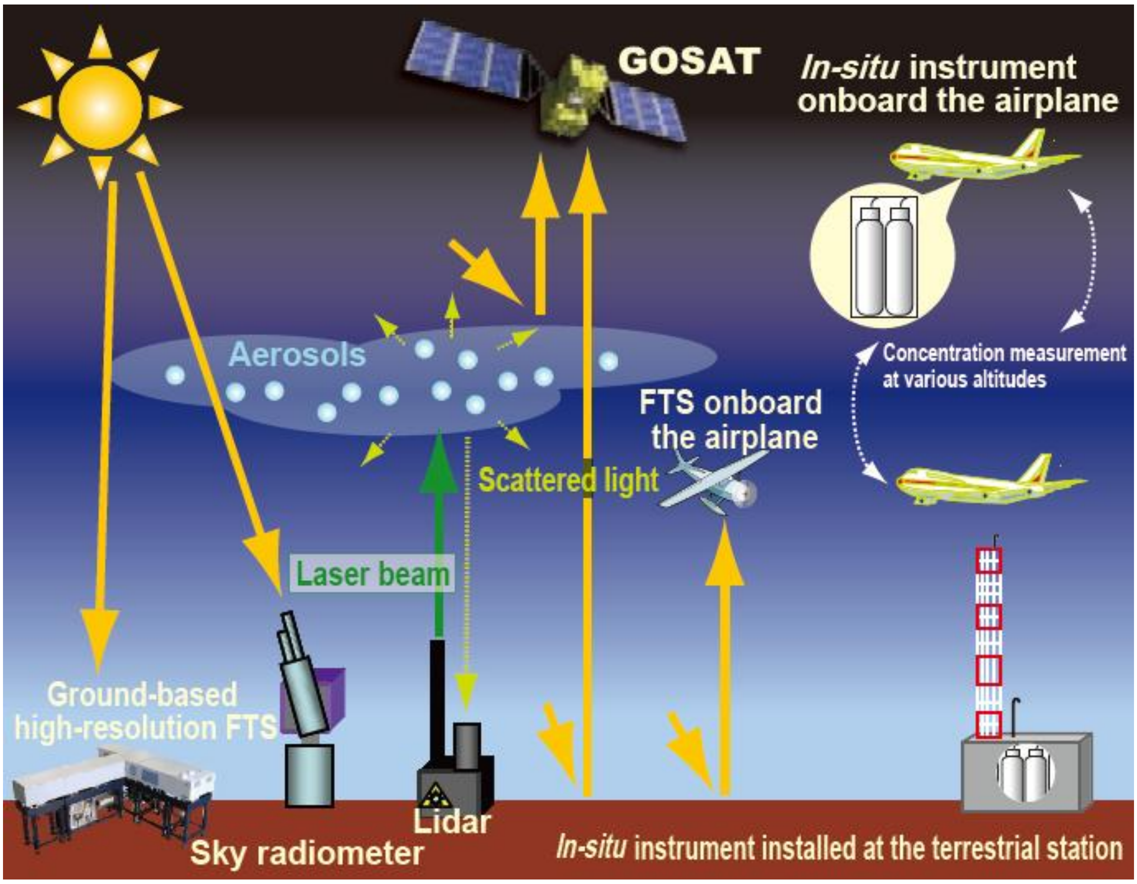


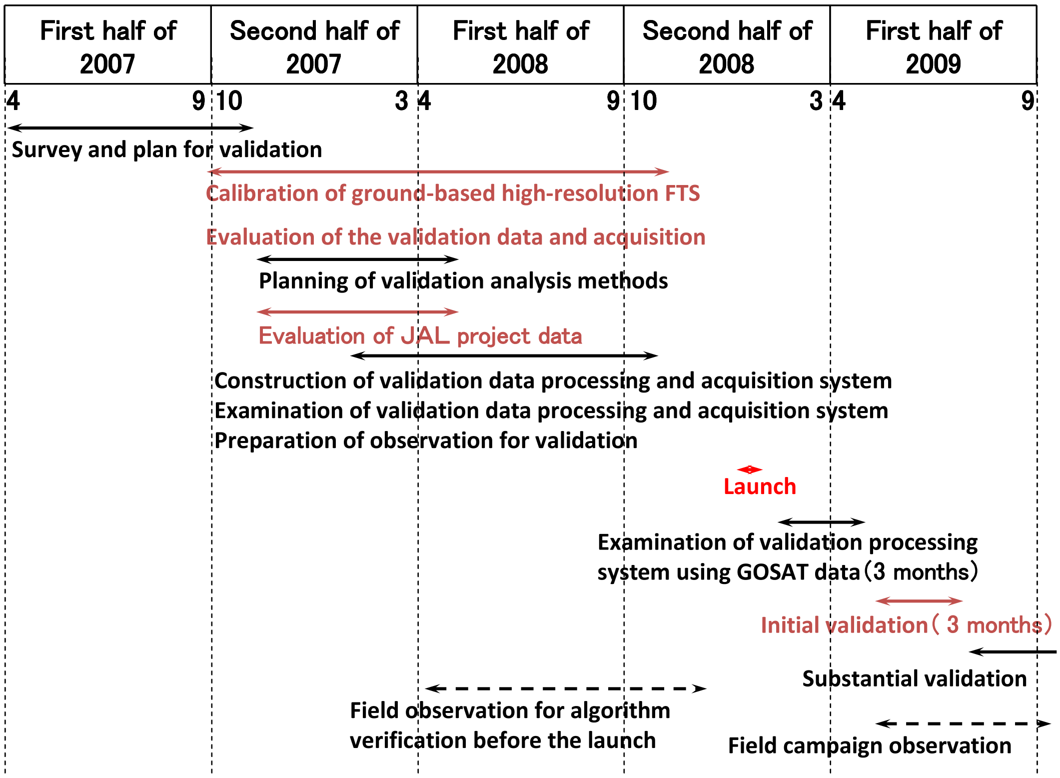
Figure B-2-1 Concept of the validation observation for CO_2 & CH_4 column abundances

B-2.7 Validation Schedule

Table B-2-1 lists the validation schedule based on the assumption that GOSAT will be launched January 2009.

This schedule is a plan for preparing the validation activities and securing the necessary data, as of the issuance of this document.

Table B-2-1 Validation Schedule



B-3 Overview of Processing Algorithms

This document describes processing flow and basic concepts of processing algorithms for GOSAT/TANSO data

B-3.1 Overview of the overall processing system

Figure B-3-1 shows an overview of the overall data processing flow together with the data level of the product produced at each step. More details of the processing levels (L1, L1A to L4B) of the GOSAT/TANSO data products are given in Table 1 of the RA Document.

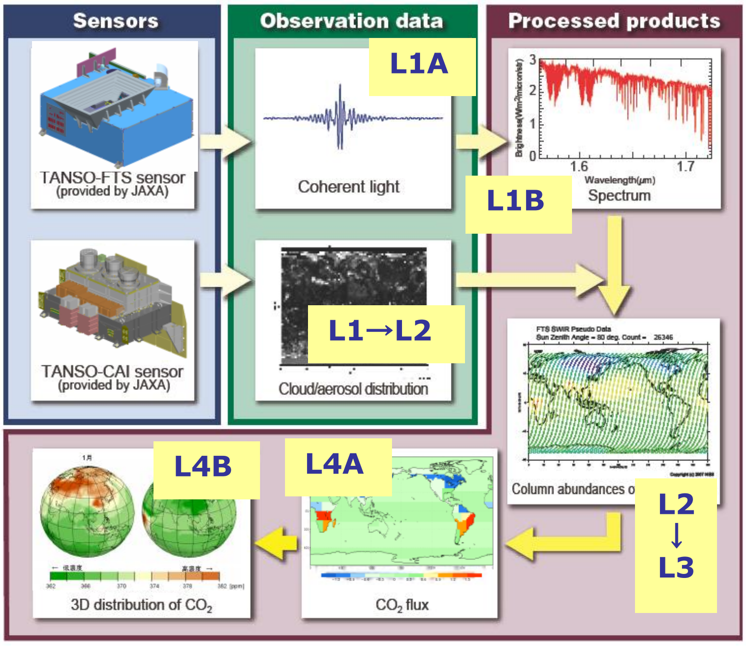


Figure B-3-1 Data processing flow and data product levels

The data measured with the TANSO-FTS and TANSO-CAI sensors are processed to several kinds of products according to the flow given in Fig. B-3-1. Interferograms (FTS L1A), observed values by FTS, are converted into spectra (FTS L1B), while the CAI L1 data are processed to cloud and aerosol properties (CAI L2). These data, at observation points under almost clear sky conditions, are combined to estimate the column abundances of CO_2 and CH_4 (FTS L2), and further to draw a global concentration map (FTS L3), and still further to estimate global carbon flux (emission and absorption) distribution (L4A) and three dimensional (3D) distribution of CO_2 (L4B) after analyses utilizing the atmospheric transport model.
The following sections of this Appendix outline the data processing steps and algorithms for the FTS and CAI data, focusing on L1 and L2 processing.

B-3.2 Level 1 processing of the TANSO-FTS data

(1) L1A data (interferogram)

L1A data consist of the interferograms of both observation data (the scattered light by earth-atmosphere system) and calibration data (the solar irradiation from outer space using the standard solar diffuser of the TANSO sensor), time data, mission telemetry data (temperature inside the instrument, pointing angle of the tracking mechanism, etc.), scale-conversion-related data, and so on. The L1A data, however, are regarded as "internal products", and will not be released to general users, but a part of them will be provided for the RA Investigators who research on themes in the field of calibration/validation or development of algorithms.

(2) L1B data (spectrum)

L1B data consist of basic data (number of datasets, gain value, scanning direction, etc.), spectra of observation data (voltage value per wave number [V/cm^{-1}]) for the short wavelength infrared "SWIR" bands, and spectral radiance [W/cm^2/cm^{-1}/str] for the thermal-infrared ("TIR") band), calibration data, instrument function, time data, mission telemetry data, scale-conversion coefficients, quality data, geometric information data (the latitude/longitude of the center of the observation point), and so on. Further, the calibration data on SWIR sensitivity will be provided.

(3) Overview of L1A to L1B processing

The data of the SWIR bands (Bands 1, 2, 3) are processed in the following steps.

・Engineering value conversion. (Conversion from discrete-valued digital numbers to voltage values)
・Spiky noises are detected and corrected. Basically, no non-linear correction is performed on the SWIR band data, though the correction function itself is equipped.
・The zero path difference (ZPD) position in the above interferogram is detected.
・Fourier-transformed.
・A flag is generated by confirming the low-frequency components in the spectrum. (A flag is set when the spectrum contains large values around the low-frequency region, to indicate that the FOV fluctuated and/or small vibration occurred during the scanning.)
・(In case that a flag is set) the interferogram is corrected by removing the low-frequency components of spectrum.
・By applying a given window function to decrease spectral resolution, the data are complex Fast-Fourier transformed (FFT) every 0.2 cm^{-1}. The phase angle is calculated from the ratio between real and imaginary parts after the transformation, while the phase information is derived from the transformed values.
・The interferogram is now zero-filled to yield 76,545 (= $3^7 \times 5 \times 7$) data points (after correction of the low-frequency components), complex Fourier-transformed without phase correction, and rotated by the phase angle derived from the above to produce the phase-corrected spectra (spectra of the real part). Note that the L1B data to be distributed will contain both real and imaginary parts.

The data of the TIR band (Band 4) are processed in the following steps. However, these steps represent just a method, and are subject to change in the future.

・Engineering value conversion. (Conversion from discrete-valued digital numbers to voltage values)

・Spiky noises are detected and corrected, followed by non-linear correction after subtracting direct current (DC) components.

・The zero path difference (ZPD) position in the above interferogram is detected, FFT shifted.

・(Similarly to the SWIR data) the necessity for correction for the low-frequency components due to FOV fluctuation is checked from their spectrum without phase correction, and the correction is made if necessary.

・After the phase correction, the number of data points in the interferogram is adjusted to 38,400 (= $2^9 \times 3 \times 5^2$) through zero-filling, and the data are Fourier-transformed. Furthermore, by using the deep-space and blackbody observation data in the TIR band, observation spectral data (the real part data after Fourier-transformation) are converted into spectral radiance ($W/cm^2/cm^{-1}/str$).

As for Bands 1, 2, 3, if the interferogram exhibits a DN value of 65,400 or larger at the ZPD position, the data are regarded as saturated and a quality flag is set. As for Band 4, if the digital DN at the ZPD position is 65,400 or larger or 136 or smaller, the interferogram is regarded as saturated and a quality flag is set.

Moreover, the wavelength calibration is performed for the TANSO-FTS, due consideration to (i) the oscillation wavelength (1310 nm (nominal)) of the semiconductor laser varies with the temperature, and (ii) the alignment may be affected by the temperature variation in orbit.

B-3.3 Level 1 processing of the TANSO-CAI data

TANSO-CAI has four observation bands: Bands 1-3 have a wavelength width of 20 nm, spatial resolution of 0.5 km, and 2,000 elements, and Band 4 (the center wavelength is 1.60μm) has a wavelength width of 90 nm, spatial resolution of 1.5 km, and 500 elements.

L1A data are provided with information necessary for radiometric correction and geometric correction.

L1A data ,however, are classified as internal products of the Project, and will not be released to general users. However, some of them will be provided for the RA Investigators who carry out research on calibration/validation or development of algorithms.

(1) Radiometric correction

L1A digital data are converted into radiance values ($W/m^2/\mu m/str$), using scale conversion coefficients. Since the detectors are of diode type, it is, in principle, not necessary to perform non-linear correction of the output values. In addition, the gain setting for the CAI observation bands will be adjusted, based on the gain switch table to be generated on the monthly basis, so as to avoid saturation of output signals.

(2) Geometric correction

Information on the relative scales (expansion, compression and rotation) for datasets of different bands makes it possible to determine the band-to-band registration. By making Band 3 the reference, other bands' data are expressed relatively as the displacement from the reference. The number of center pixels for Bands 1-3 is 1,024, and that for Band 4, 256, and the band-to-band registration error after correction is targeted at 0.2 pixel or lower. In addition, L1 data are supplemented with the latitude and longitude information of the representative elements.

(3) L1B data
TANSO-CAI L1 data are supplemented with the above-mentioned information necessary for correction before release. L1B data are generated as standard products with the observation positions corrected, after scale conversion based on the information, band-to-band registration, and ortho-rectification per pixel based on the elevation information (Digital Elevation Model: DEM).

(4) L1B+ data
CAI L1B data are then projected on a map, on a certain scene scale, and their stored radiance data per pixel/band are resampled to generate L1B+ image data (standard products) for release.

B-3.4 Level 2 processing of the TANSO-CAI data

The CAI data are processed to standard products which provide cloud flag information. Research products, which provide parameters of cloud and aerosol characteristics, are derived from these products.

First of all, optically thick clouds on the sea surface and on relatively dark land surfaces are discriminated by using two visible bands of the CAI sensor. If they are found to be clouds, specifically water clouds, cloud characteristics are analyzed. The cloud characteristics to be estimated are the cloud optical thickness (at a wavelength of 0.5μm) τ_c, which is a non-dimensional value that represents the optical thickness of clouds, and the effective radius of a cloud particle τ_e. Table B-3.4-1 lists up the cloud products to be derived from the CAI data.

Table B-3.4-1 Cloud products derived from the CAI sensor

Estimated parameter	Unit	Band No.	Remarks
Cloud flag	-	2, 3, 4*	Optically thick clouds on the sea surface and relatively dark land surface
Cloud optical thickness (@0.5μm)	-	2, 4	Water clouds and ice clouds
Effective radius of cloud particles	μm	2, 4	Water clouds and ice clouds
Vertically integrated total amount of cloud water	g/m^2	2, 4	

* Band 4 will be used for studies.

Secondly, aerosol characteristics are analyzed by combining data from all CAI observation bands with ancillary data, including meteorological data. There are various types of aerosols existing on the globe; the primary aerosols include anthropogenic aerosols, such as sulfates, black carbons, and organic carbons, and dust aerosols and sea salt aerosols. In estimating the aerosol characteristics, it is assumed that anthropogenic aerosols are composed of internal mixing of sulfates and black carbons, and the three types of aerosols, i.e. anthropogenic, dust, and sea salt aerosols, are mixed externally to constitute a particle system. Based on these assumptions, the optical thickness of each type of aerosol (at a wavelength of 550nm), τ_a, and the component ratio (volumetric ratio) of black carbon to anthropogenic aerosols, γ_{soot} will be estimated. These are summarized in Table B-3, 4-2.

Table B-3.4-2 Aerosol parameters estimated from the CAI data

Estimated parameters		
Aerosol optical thickness (Wavelength: 550nm)	Anthropogenic aerosol mode	τ_{acm}
	Dust aerosol mode	τ_{dst}
	Sea-salt aerosol mode (over the sea only)*	τ_{slt}
Volumetric ratio of black carbons in the anthropogenic aerosol mode		v_{soot}

*Except sunglint region

The following provides an outline of individual processing algorithms.

(1) Cloud flag algorithm

Multi-wavelength imagers, such as MODIS and GLI, have water vapor channels and infrared split windows to discriminate altostratus and cirrus, in addition to many visible channels, and thus can accurately discriminate clouds as a single sensor. In contrast, the CAI sensor has only four bands with a wavelength range of near-ultraviolet to short wavelength infrared, making its discrimination accuracy potentially inferior to MODIS or GLI. For this reason, users of cloud flags are recommended to appropriately select and employ the several types of cloud discrimination test results provided by CAI and the cloud flags provided separately by FTS observations and others. Of the CAI observation bands, Band 2 (0.670μm) and Band 3 (0.865μm) are the primary bands for discriminating clouds. Although it is possible to use the short wavelength infrared 1.6μm band (Band 4) to discriminate between ice clouds and water clouds in the presence of optically thick clouds, this is currently at the examination stage. Two types of threshold-value tests are currently planned using the cloud flag algorithm: tests to examine the reflectances in visible bands 2 and 3 and a color test for the ratio of the reflectances between these two bands. The former is a discrimination method that utilizes the fact that the reflectance on clouds is higher than that on the sea surface or on relatively dark land surfaces, while the latter stands on the fact that the reflectances on clouds in Bands 2 and 3 are almost equal.

The CAI cloud flag algorithm will be used to conduct the four tests listed in Table B-3.4-3 below, and the test results will be stored as data.

Table B-3.4-3 CAI cloud flag tests (Draft)

Test No.	Contents to be implemented
Test 1	R[B2] > (R2+A[B2])
Test 2	R[B3] > (R3+A[B3])
Test 3	0.9 < (R[B2]/R[B3]) < 1.1
Test 4	If “true” on Test 1 and Test 3, examine R[B4]/R[B2].

Here, R[B2], R[B3], and R[B4] represent the reflectance in CAI Bands 2, 3, and 4[Note 1)], respectively; A[B2] and A[B3] represent the ground-surface albedo in Bands 2 and 3; and R2 and R3 are the margin values of the ground-surface albedo. Tests 1 to 3 diagnose the possibility that object pixels are clouds. The results of Test 4 provide information conducive to discriminating between ice clouds and water clouds, on an examination basis. The accuracy of cloud flag achieved by the CAI sensor alone may be subject to the following limitations: Optically thin clouds, particularly cirrus, cannot be completely identified by this method; and discrimination of clouds by CAI is limited on bright ground surfaces, such as surfaces covered with snow and ice or desert, and in regions where the ground surface state changes rapidly with time.

Note 1) The reflectance is defined as $\pi L/(F_0 \cos\theta_0)$ here. L is observed radiance, F_0 is solar irradiance based on the instrument function, and θ_0 is the solar zenith angle.

(2) Cloud characteristics algorithm

The principle for obtaining optical thickness of the cloud and effective radius of cloud particles are as follows. Light is scarcely absorbed in CAI Band 2 (0.670μm) even if multiple scattering by cloud particles occurs since the imaginary part of the complex index of refraction of water droplets is very small and is approx. 10^{-8}. Therefore, the light injected into the cloud layer repeats scattering due to cloud particles and ultimately the light that scatters toward the satellite from the top of the cloud is observed. A greater amount of light is observed in CAI Band 2 as the cloud optical thickness increases, augmenting the light scattered upward from the top of the cloud. The probability of upward scattering as a result of multiple scattering will reach the upper limit when the optical thickness increases to around 70, and the observed radiance will be saturated in the meantime.

On the other hand, CAI Band 4 (1.6μm) is used to estimate the effective radius of cloud particles. The imaginary part of the complex index of refraction of water droplets in this wavelength range is over 10^{-5}, which is one thousand times greater than that in visible light. Therefore, the short wavelength infrared light that enters the cloud layer is absorbed during the multiple scattering due to cloud particles. The light observed by the CAI Band 4 gets weaker, when cloud particles become larger and therefore absorb light more strongly. The absorption in the cloud layer becomes gradually saturated when the effective radii of cloud particles increase to around 30μm, which is the upper limit.

In remote sensing of cloud characteristics, the optical thickness and effective radius of particles of clouds are calculated from observed radiances in visible and infrared bands. The radiances directly observed include radiative components that are essentially unnecessary for estimation of clouds characteristics, such as the ground surface reflection components and thermal radiation components from the cloud layer. These components are therefore removed in calculation by using the transmittance of the atmosphere and cloud, satellite zenith angle, solar zenith angle, relative azimuth angle, etc. Estimations of the physical values using satellite observations are accomplished by comparing the simulated radiance obtained by using the radiative transfer code (Nakajima and Tanaka, 1986, 1988) and the observed radiances by CAI. A database (lookup table, LUT) table of angle dependent radiance, transmittance of atmosphere and cloud, and spherical albedo has been prepared in advance for various optical thickness of cloud and the effective radius of cloud particles, and it is used in this algorithm which performs iterative calculations using the Newtonian method.

(3) Aerosol characteristics algorithm

CAI has observation bands at 670 nm and 870 nm, which are sensitive to aerosol scattering and often utilized for remote sensing of aerosols, as well as the band at 380 nm, which is insensitive to reflection from the ground surface and sensitive to absorptive aerosol, and the band at 1.6 μm, which is sensitive to large-particle aerosols. The aerosol characteristic parameters will be estimated by the maximum a posteriori (MAP) method, calculating the satellite signals of these four bands theoretically.

In addition, as the estimation of aerosol parameters based on the CAI data is tightly restricted, aerosol information on the locations which are not covered by CAI estimation will be obtained from the estimation results based on the aerosol transport model being developed by the GOSAT Project. This model is a 3D dynamic simulator for aerosols developed for the GOSAT Project, having Spectral Radiation-Transport Model for Aerosol Species (SPRINTARS) as its core.

B-3.5 Level 2 processing of the TANSO-FTS-SWIR data

In the three FTS SWIR bands, the sensor observes signals on the two polarization planes, which are perpendicular to each other, in each band. That is, it acquires data (interferogram) for six bands, in total. The FTS SWIR data, combined with various ancillary data, are used to calculate the column abundances of CO_2 and CH_4 within target accuracies (i.e. relative errors of 1% for CO_2 and 2% for

CH_4 in a certain period). The retrieved column abundance [molecules/cm^2] is converted to XCO_2 [v/v] (volumetric mixing ratio), which represents the ratio of CO_2 in the atmosphere with no water vapor, or a relative humidity of 0%, (dry atmosphere). In many cases it is this converted quantity that is used for application. This conversion requires ground-surface pressure information, thus the column abundance of oxygen (or ground-surface pressure) derived from FTS Band 1 data and the ground-surface pressure obtained from objective analysis data at the observation time and location are used.

Figure B-3-2 on the next page depicts the data processing flow for generating L2 column abundance products from L1B (spectra) data of FTS SWIR observation.

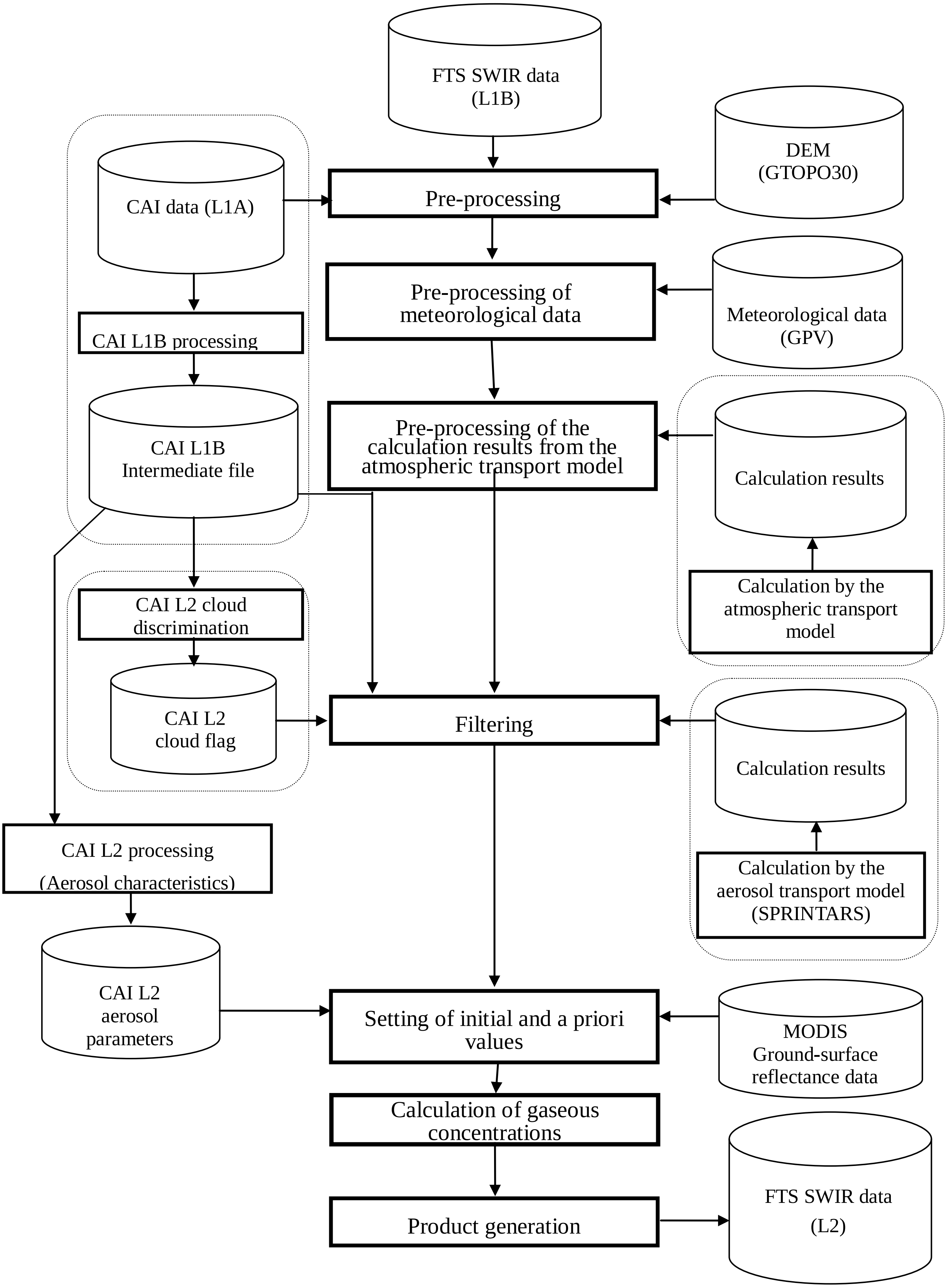


Figure B-3-2 Data processing flow from TNASO-FTS-SWIR L1B to L2 products

(1) Use of polarization information

The FTS SWIR observation can measure polarization signals on two perpendicular axes, which are called the P (parallel) axis and the S (senkrecht—a German word for "perpendicular") axis. The P and S observation data are planned to be applied in the data processing flow, by means of the following three approaches. "Approach 1" will be adopted in the initial version of the processing algorithm. A series of simulations have found that the degree of polarization is low in observation of reflection from the earth surface, whereas it is high in sunglint observation over the sea surface.

【Approach 1】 The two polarization components of the observed light are compounded to provide total intensities. In this approach, the scalar radiative transfer code, which does not take the polarization state into consideration, will be used in the theoretical calculation.

【Approach 2】 The radiance spectra of the two polarization components of the observed light are used independently. In this approach, the vector radiative transfer model (Pstar2b code), developed by the GOSAT Project, will be used in the theoretical calculation. The Pstar2b code runs at a speed a few times slower than conventional scalar radiative transfer codes, however, it is a code which runs much faster than any other polarization calculation code, after being improved for fast running.

【Approach 3】 The radiance spectra of the two polarization components of the observed light are approximated by total intensities. In this approach, it is assumed that polarization-related parameters, such as ground-surface albedo, scattering phase matrix, etc., are different between the two polarization components, whereas the other parameters, including the optical thickness and gaseous concentration, are identical. Based on these assumptions, the radiative transfer is calculated in an approximate manner, using a scalar radiative transfer code per polarization axis.

(2) Retrieval algorithm

In the processing algorithm to estimate column abundances from L1B to L2, the first calculation is for the vertical distribution of the volumetric mixing ratio of the gas of interest as an intermediate parameter, in preparation for achieving the column abundances of CO_2 and CH_4 as final outputs. The information necessary for this retrieval will be supplied by objective analysis data for the meteorological parameters, such as the vertical distributions of air temperature and pressure, measured at the same location at the same time as the GOSAT observation. In addition, absorption bands in the FTS SWIR bands do not have such radiance spectral signals that have a weighting function structure which is steep enough in the altitude direction to require vertical distribution. Therefore, the intermediate product, the vertical distribution of the volumetric mixing ratio, may have an extremely unstable structure. Nevertheless, the column abundance can be stably obtained. The reason is, though the explanation is not rigorous as it disregards the impact of multiple scattering or path radiances, that the size of the area obtained by integrating the absorption depth of the absorption line structure within the radiance spectrum observed is deeply linked with the amount of column abundance.

The L1B to L2 retrieval algorithm is based on a constrained Gauss-Newton method of a non-linear least squares method to the observed radiance spectra. In other words, the solutions are obtained stably from the observation information together with a priori information. The solutions to be derived consecutively are expressed as the following equation.

$$x_{i+1} = x_i + \left(K_i^T S_\varepsilon^{-1} K_i + S_a^{-1}\right)^{-1} \left[K_i^T S_\varepsilon^{-1} \left(y - F(x_i)\right) - S_a^{-1}(x_i - x_a)\right] \qquad \text{B-3-(1)}$$

Where x_i is the vector of the parameter to be estimated at the i^{th} time, x_a is its a priori information (the a priori value which can be used as the initial guess at the beginning of estimation), S_ε is the error variance-covariance matrix (no. of wavenumber points × no. of wavenumber points) of the observed spectra, S_a is the variance-covariance matrix (no. of parameters to be estimated × no. of parameters to be estimated) of the a priori information, y is the vector of observed spectrum (no. of wavenumber points), $F(x_i)$ is the simulated spectrum theoretically calculated using a radiative transfer code when the variable is x_i, and K_i is the Jacobian matrix (no. of wavenumber points × no. of parameters to be estimated), which expresses the divergence of spectra against the unit change of the target parameter. Note also that $K = \partial y / \partial x$ here.

Furthermore, Equation B-3-(1) above corresponds to an adoption of such a solution that gives the minimum value for the cost function given as below (Equation B-3-(2)). It is called the Maximum A Posteriori (MAP) estimation method.

$$J(x) = [y - F(x)]^T S_\varepsilon^{-1} [y - F(x)] + (x - x_a)^T S_a^{-1} (x - x_a) \rightarrow \min. \qquad \text{B-3-(2)}$$

The values of elements of S_ε will be determined based on the characteristics of the sensor (e.g. SNR). The values of the diagonal elements of S_a are given by a priori information regarding how freely the target parameters can vary with altitudes, while those of the non-diagonal elements are given by the information regarding the inter-constraints of variation among the target parameters (e.g., correlation between vertical distributions of each gaseous species).

Basically, the molecular spectroscopic parameters provided by the HITRAN 2004 database will be used for calculating theoretical spectra in B-3-(2), except CO_2 of Bands 2 and 3 and partly CH_4 of the 1.67-μm band, for which the 2008 version of line parameters and data generated in the GOSAT Project will be used, respectively. Moreover, when performing spectral-fitting in B-3-(2), channel selection will be performed in order to eliminate the impact of Fraunhofer lines in the solar atmosphere and of water vapor in the earth atmosphere. The information on solar Fraunhofer lines in the 1.6-μm and 2.0-μm bands will be supplied by the data generated by Dr. R. L. Kurucz, Harvard-Smithonian Observatory in the U.S., in response to the request from the GOSAT Project.

Research and development of this algorithm have been promoted using the radiative transfer code improved based on HSTAR code, an extended RSTAR code developed by Professor Teruyuki Nakajima and his research group at Center for Climate System Research, University of Tokyo, which can calculate the effects of (multiple) scattering and attenuation by atmospheric molecules, aerosol, and clouds particles present on the optical paths. With the help of this code, the column abundance can be estimated at an expected precision even in the presence of optically-thin clouds and aerosols, as demonstrated in numerical simulations. Consequently, the “filtering” process in the processing flow provided in Figure B-3-2 is the process carried out by the program to determine whether or not the observation data under processing is a clear-sky scene or a scene with optically-thin clouds or aerosols. The data processed in this way then undergo L2 processing.

In addition, the ground-surface albedo is also added as a target parameter and retrieved simultaneously by means of Equation B-3-(1). With this processing, it is possible to flexibly estimate the column abundances of CO_2 and CH_4 for any spectrum structure of the ground-surface albedo.

(3) Fast retrieval algorithm
In order to realize the above-mentioned estimation algorithm, a new data processing system which combines the discrete ordinate method as a radiative transfer and the MAP method, is being developed. Additionally, the Project is promoting the research and development on a fast and high-accuracy technique called the Photon Path-length Probability Density Function (PPDF) method, which is based on a simple radiation model by combining the Monte Carlo method and the Equivalence theorem and retrieves PPDF parameters simultaneously with other unknown quantities, such as CO_2, from the observed spectra, as a future version of GOSAT operational processing algorithm.

B-3.6 Level 2 processing of the TANSO-FTS (thermal-infrared band) data

Data from thermal-infrared sensors on board spacecraft platforms have been used mainly for analyzing CO_2 concentrations. With this technique, however, it is difficult to detect significant change in the CO_2 concentration in the boundary layer, such as decrease due to absorption by vegetation or increase due to artificial CO_2 sources, although the changes in concentration in the middle and upper layers of the troposphere can be analyzed with a high accuracy. This is because the difference between the atmospheric temperature at the altitude where concentration changes occur and the equivalent radiance temperature of the background radiation is smaller in the lower layers of the atmosphere, making it more difficult to detect.

For FTS thermal-infrared observation (referred to as “TANSO-FTS-TIR” hereafter), it is expected that the vertical profile of CO_2 concentrations down to altitudes of 700 to 750 hPa from the upper atmosphere can be obtained under clear-sky conditions, though it depends on the vertical profile of atmospheric temperatures. Figure B-3-3 plots a typical vertical resolution function (Averaging Kernel) in medium latitudes.

(1) Vertical profile of CO_2 concentrations
Independent temperature information is required for deriving the concentrations of CO_2 from the thermal-infrared band data. The TANSO-FTS TIR observation uses objective analysis data because there are no simultaneously-operated microwave sensors.

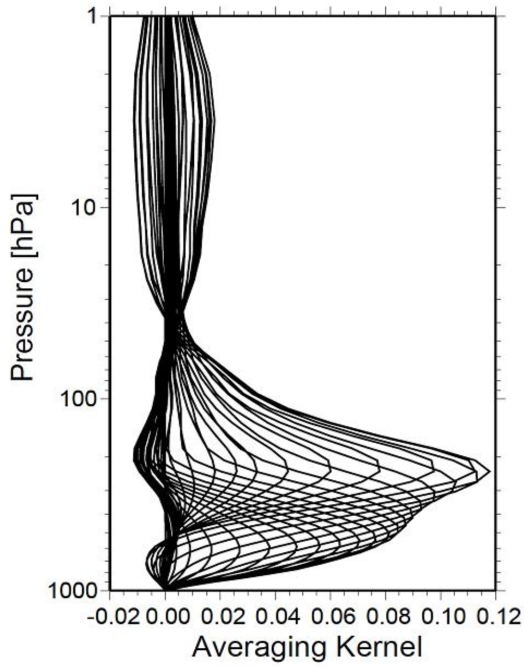


Figure B-3-3 Averaging kernel of CO_2 analysis based on the TANSO-FTS-TIR data -Typical example in mid- latitudes (Saitoh et al., 2006)

For retrieval analysis of CO_2 concentrations, a physical analysis technique, more precisely the Maximum A Posteriori (MAP) method as in Eq.B-3-(2), will be employed, similarly to FTS SWIR observation.

The results obtained by statistically processing the output of the CO_2 transport model will be used as the initial guess values and covariance values of the CO_2 concentration. Since the Jacobian matrix is a function of vertical profiles of atmospheric temperatures and CO_2 concentrations, the optimal Jacobian matrix is calculated for each region, season, and local time from the vertical profiles of atmospheric temperature and CO_2 concentration from the objective analysis and the above-mentioned initial guess value, respectively.

(2) CO_2 column abundance

The radiance spectrum of the CO_2 hot band close to 10 μm is utilized for this analysis; namely, the fact is used that the decrease in radiance depends on the column abundance of CO_2 with the background of a warm ground surface or sea surface as in Solar Occultation.

First, the Jacobian matrix in the 10 μm band of CO_2 is calculated based on the vertical profiles of atmospheric temperatures and volumes of water vapor in each FTS FOV that was analyzed using the objective analysis value as the initial guess value. To reduce errors in estimating the volume of water vapor, baseline compensation is performed such that the systemic gap between the simulated spectrum and the observed spectrum is compensated using a wavelength range with a small volume of absorption by gases. The column abundance of CO_2 is derived by applying the Jacobian matrix to the difference between the simulated spectrum and the observed spectrum after this baseline compensation. The wavelength dependence of the ground-surface emissivity is required to simulate the radiance spectrum; the results estimated from database for the ground-surface emissivity and the meteorological data obtained before and after the observation are utilized for such data. For the concentration of ozone, which influences this wavelength band, data of other satellite sensors such as OMI, are utilized.

(3) Cloud screening

The fractional cloud coverage in the FTS FOV is estimated based on the analysis results of the CAI sensor during the daytime. However, the analysis results of the FTS TIR data are also used concurrently because thermal infrared radiation spectra are superior in detecting thin ice clouds such as cirrus clouds. During the nighttime, however, clouds are discriminated solely by the FTS TIR band because the CAI sensor is not operated.

There are three methods for analyzing clouds using the FTS thermal-infrared data.

1. Slicing method
2. Threshold value method
3. Split window method

The slicing method estimates the altitude at the top of cumulus clouds by applying the method of Menzel et al. (1983), which uses the 15 μm band of CO_2. The threshold value method, the second item above, discriminates clouds based on the difference between the value provided by the sea-surface temperature database, storing the analyzed results of data from the AVHRR on NOAA satellite and/or MODIS, and the sea-surface temperature estimated from the FTS TIR data with the assumption of no cloud. Although this method is superior over the sea, these data will be used only as references for land areas due to a large error in the ground-surface temperature of objective analysis data. The split window method, listed last, performs an analysis using the combination of data of two wavelength bands, 8 to 10 μm and 11 to 13 μm, which enables to judge cloud altitudes and distinguish between ice and water particles in the areas that are identified as cloudy.

B-3.7 Level 3 processing and more advanced (higher-level) processing

L3 product is generated as a global map, by using the column abundances of CO_2 and CH_4 (L2) calculated from the TANSO-FTS-SWIR data after applying temporal/spatial interpolation and appropriate statistical processes to the GOSAT observation data for fixed sections (e.g. 2.5° meshes (TBD)) during a given period of time, to calculate the value for each section. Similarly, TIR L3 product is planned as a global map, but the details are yet to be determined.

L3 processing of the CAI data is also planned, though very roughly, to provide standard products on global radiance maps (with cloud cover), global radiance maps (without cloud cover), and vegetation index maps (for a certain observation period), and research products on aerosol characteristics maps and cloud characteristics maps (for a certain observation period) . Details will be fixed hereafter.

More advanced-level products are also planned, targeting the release just after one year, at the shortest, after the satellite launch. These include global flux maps (L4A) in 64 divided regions, which will be generated through inverse calculation, based on atmospheric transport models ,of GOSAT L2 or L3 data and CO_2 and CH_4 concentration data acquired at monitoring stations on the ground , and 3D distribution maps of CO_2 and CH_4 concentrations (L4B) calculated from L4A data using atmospheric transport models. The details of processing algorithms for these products have not been finalized yet, and hence are excluded from this Appendix.

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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.

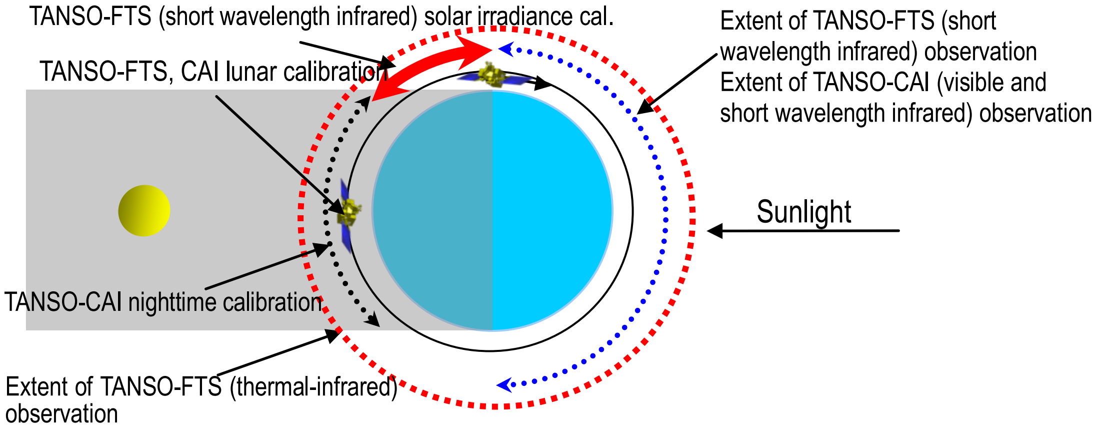

Figure C-2.3-1 In-orbit operation

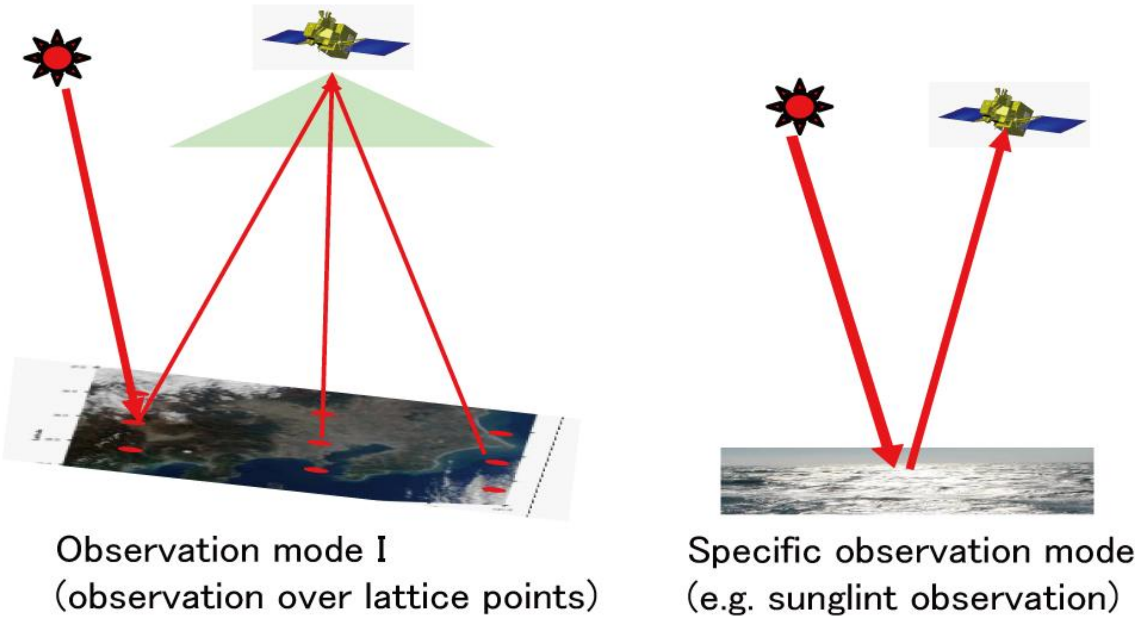

Figure C-2.3-2 Images of data acquisition for the observation over lattice points and specific observation modes

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

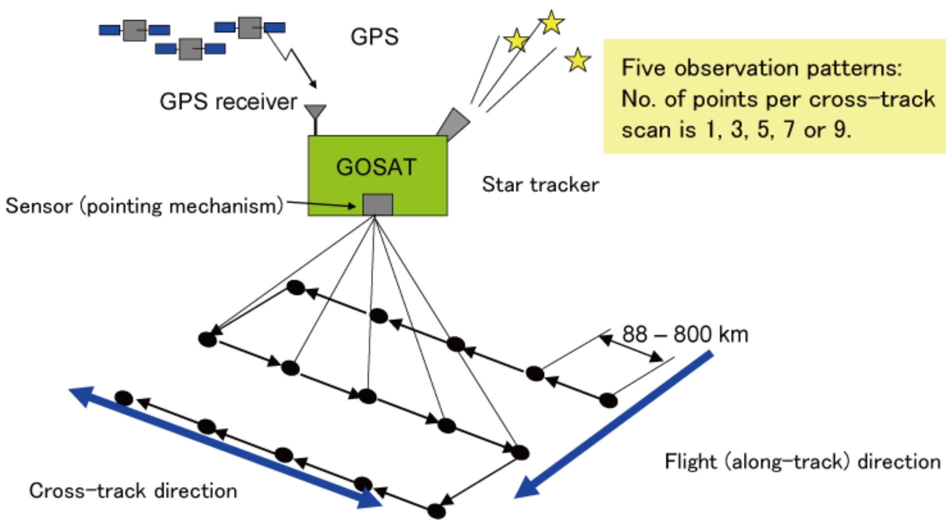

Figure C-2.4-1 Scanning pattern in cross-track direction

(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.

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Appendix D

Contents of Research Proposal and Application Forms

1. Cover sheet

1.1. Profile of investigators (Form 1a)

Fill in the following information in its entirety.

- Information about the Principal Investigator (PI): Name, title, department, affiliation, address, nationality, phone number, fax number, e-mail address
- Information about the RA Investigators other than the PI (Co-Is): Name, affiliation, and e-mail address of each RA Investigator
- The PI's background, experience in the selected research field, research papers, etc.
- Signature of the PI

1.2. Summary of the research proposal (Form 1b)

Fill in the following information in accordance with the instructions given in parentheses.

- Research field (Select one from the five given fields: Calibration/ Validation/ Processing algorithms/ Carbon balance estimation, atmospheric transport models/ Data application.)
- Research theme (Describe the contents of your proposed research in the most simple and adequate way.)
- Main sensor to be used (Select from FTS/ CAI/ None.)
- Sensors to be used in combination (Select from FTS+CAI / None, just in case.)
- New data acquisition request, if necessary. Detailed requirement will be specified later
- Data distribution request (If necessary, select the product name(s) from Table 1 "List of GOSAT/TANSO Products" in the RA Document.)
- Abstract of your research proposal (no more than 200 words) (Include the purposes, significance of the research in the selected research field, methods, time schedule, and expected benefits of the proposed research)

2. Main proposal (no more than five (5) pages)

Describe in detail the background, purposes, and technological level of the proposed research, the importance of the research compared with related researches carried out in the other fields, and the details of research activities, in the main body of the proposal. In addition, the details of research activities must include a rough plan of the work and experiments to be performed and an outline of the methods and procedures to be employed in the research. Having covered these items, describe the following items where necessary.

- Table of contents
- Purpose(s) of the proposed research
- Significance and importance of the proposed research in the selected research field
- Methodology
- Algorithms to be used
- Expected outcomes

- Distribution requests and acquisition plan for the GOSAT/TANSO data (area of interest, processing level, product name, acquisition window, etc.)
- Requests for the satellite data owned by JAXA (area of interest, processing level, acquisition window, etc.)

3. Work plan (Research schedule) (Form 2)

Submit the time schedule for your research activities on Form 2, with an explanation on the focus of research work and any associated schedules.

4. Data distribution request

Request for JAXA's satellite data (other than the GOSAT data) (Form 3)

In order to request a provision of datasets of any of the satellites listed below, fill out and submit Form 3. JAXA has the rights to distribute the observation data of the following satellites.

- Japanese Earth Resources Satellite (JERS) (global)
- Advanced Earth Observing Satellite (ADEOS) (global)
- Tropical Rainfall Measuring Mission (TRMM) (global)
- LANDSAT (around Japan)
- SPOT (around Japan)

In addition, the satellite data acquired in the past are archived and retrievable on the following website. Investigators who are willing to request for the satellite data are recommended to first check on the website if the data requested are available, before submitting a data request form.

- Search site for observation data of JERS, ADEOS, TRMM, SPOT**, LANDSAT*/**.
  https://www.eoc.jaxa.jp/iss/jsp/indexEn.html

*The LANDSAT archive (up to Landsat-5) includes data received up to March 31, 2001 (TBD).

**SPOT and LANDSAT-7 archives include data received up to March 31, 2002 (TBD).

5. Information about the Investigators

State the background, research papers or publications, and special skills and qualifications of the PI, as supporting information for the selection of research proposals. Likewise, present the same information about the other RA Investigators (Co-Is).

6. Data processing and analysis facility

List up major facilities and equipment available for carrying out the proposed research and additional facilities and equipment that the Investigators may procure. Also, describe the assistance from their organizations/affiliations, if any, for which the RA Investigators are qualified for the purpose of carrying out the proposed research.

Form 1a

Proposal No.
(For JAXA/NIES/MOE's use)

<Cover sheet>

Profile of Investigators

Principal Investigator (PI)

Name: ______________________________

Title: ______________________________

Department: ______________________________

Affiliation: ______________________________

Address: ______________________________

Nationality: ______________ E-mail address: ______________

Phone: ______________ Fax: ______________

Co-Investigators (Co-I)

Name	Affiliation	E-mail address

Background, experience in the pertinent research field, theses, etc. of the PI:

Signature (PI):

Form 1b

Proposal No.

(For JAXA/NIES/MOE's use)

Name of PI: ____________

Summary of Research Proposal

(Place "x" in the parentheses by the pertinent response.)

1. Research field (Choose one only.) *

   [ ] Calibration [ ] Validation [ ] Data processing algorithms

   [ ] Carbon balance estimation, atmospheric transport models [ ] Data application

   *Your choice of research field will not affect the selection of research proposals.

2. Main sensor to be used

   [ ] FTS [ ] CAI [ ] None

3. Sensors to be used in combination

   [ ] FTS [ ] CAI [ ] None

4. New data acquisition request

   [ ] Yes [ ] No

   →If yes, detailed requirement will be specified below.

   ____

5. Request for data distribution

   [ ] Yes [ ] No

   →If yes, select the product name(s) from "Table 1 List of GOSAT/TANSO Products" in the RA Document.

6. Research theme

   ____

7. Abstract of the research proposal (no more than 200 words)

   ____

   ____

   ____

   ____

   ____

   ____

   ____

   ____

   ____

Form 2

Proposal No.

Work Plan for the Joint Research (Research Schedule)

Name of PI: ____________________

	2012				2013						2014						
	6	8	10	12	2	4	6	8	10	12	2	4	6	8	10	12	2
Plan										Interim Evaluation							Interim Evaluation
Description																	

	2015				2016					
	6	8	10	12	2	4	6	8	10	12
Plan				Interim Evaluation						Interim Evaluation
Description										

Form 3

Proposal No.

Requests for JAXA's satellite data (other than the GOSAT data)

(For JERS, ADEOS, TRMM, ADEOS−II, SPOT, or LANDSAT)

Name of PI: ________________________

Sensor	Area of Interest (pass/row or lat./lon.)	Observation window	No. of scenes		Processing level
			Min.	Max.	

The distribution media for providing the requested data will be determined according to the data size.

General Contractual Conditions for the Joint Research with the GOSAT Data

The Japan Aerospace Exploration Agency (JAXA), the National Institute for Environmental Studies (NIES), and the Ministry of the Environment (MOE) of Japan (hereinafter referred to collectively as the "Three Parties") previously issued research announcements for the greenhouse gases observing sensors onboard the satellite (hereinafter referred to as the "RA"), aiming to further enhance and exploit the outcomes obtained from the Greenhouse gases Observing SATellite (GOSAT) Project, and in line with this aim to solicit research proposals with regard to the use of any products as defined in the GOSAT Data Policy (hereinafter referred to as the "GOSAT Data"). The Three Parties have adopted those proposals which were evaluated as being appropriate by the RA Selection and Evaluation Committee (hereinafter referred to as the "Committee") from among those which were submitted. At the time of drafting of this document, in acknowledgment that many of those proposals which were previously approved are nearing the end of their contract period, the Three Parties shall herein provide the general contractual conditions for the joint research with the GOSAT Data for the renewal of contracts for those researches which are currently ongoing, and with the additional aim of further soliciting new research proposals.

The Research Organization (hereinafter referred to as the "RO") is an organization to which the Principal Investigator (hereinafter referred to as the "PI") is affiliated, and whose research proposal has been approved. The Three Parties and the RO, each of which is hereinafter referred to as a "Party" or both of which are collectively as "Parties", hereby agree to and execute accordingly this contract (hereinafter referred to as the "Contract") to carry out Joint Research (hereinafter referred to as the "Joint Research") as provided for hereunder. In the case that the PI is not affiliated to any such RO, references to the "RO" should hereunder be substituted with "PI".

Article 1 (Definitions)

1.1 For the purposes of the Contract, the following terms shall have the meanings as provided for below.

1.1.1 The "Research Results" shall mean any outcomes obtained in the course of the execution of the Joint Research associated with the Contract. This shall refer to any deliverables, including reports, charts, and data acquired in the course of the execution of the Joint Research using GOSAT Data by the PI, in line with the work plan submitted with the proposal, or technical outcomes and scientific findings which are congruent with the purposes of the Joint Research, including but not limited to inventions, devices, designs, copyrighted literary works, and "know-how", which are indicated as Research Results in documents including, but not limited to, research reports prepared in accordance with the provisions of Article 6 hereof.

1.1.2 The "Intellectual Property Rights" shall refer to the rights stipulated in Article 2.2 of the Japanese

Intellectual Property Basic Law.

1.1.3 The “Interim Evaluation” shall refer to the evaluation by the Three Parties of the Research Results on the basis of the Progress Report and Interim Report on Research Results as compiled and submitted by the RO in accordance with Article 6.2 hereof.

1.2 For the purpose of the Contract, the “Invention(s)” shall specifically include inventions subject to patent rights, devices subject to utility model rights, creations subject to design rights, trademark rights, circuit layout access rights, and copyrighted literary work rights (including programs), as well as knowledge or skills designated as constituting “know-how” as defined in Article 7 hereof.

1.3 For the purposes of the Contract, the “Implementation” of the Intellectual Property Rights shall refer to any actions stipulated by Article 2.3 of the Patent Law; Article 2.3 of the New Utility Model Law; Article 2.3 of the Design Law; Article 2.3 of the Trademark Law; and Article 2.3 of the Law Concerning Semiconductor Integrated Circuit Layouts; the creation of derivative works as stipulated by Article 2.1.11 of the Copyright Law; and actions stipulated by Articles 2.1.15, Articles 2.1.19 and 2.1.20 of the same law as regards the implementation of “know-how”.

1.4 For the purpose of the Contract, the “PI” is the representative investigator who carries out the research based on his/her submitted and approved research proposal in the RA scheme. The “Co-Investigator(s)” (hereinafter referred to as the “Co-I”) indicates investigators who cooperate in the research activities represented by the PI and shall be approved by the RO and registered by the Three Parties. The Co-I is required to be sufficiently qualified in the relevant research field, and either have obtained a doctorate degree in a relevant field or currently be in the latter stages of attendance in graduate school doctoral course, or have experience or qualifications equivalent to or exceeding the aforementioned. The “RA Investigators” is the collective term to indicate the PI, the Co-I, and other supporting investigators, including students, research assistants, and postdoctoral fellows whose involvement has been conveyed by the RO and approved by the Three Parties.

Article 2 (Roles and Responsibilities in the Joint Research)

2.1 The Three Parties shall undertake the tasks defined in the following provisions in conjunction with the Joint Research.

2.1.1 Acceptance of data processing requests as submitted by the RO to the extent which has previously been acknowledged and approved and provision of the requested GOSAT Data to the RO

2.1.2 Provision of information on mission control data, etc. necessary for the RO to carry out its research activities under the RA scheme, to the extent possible

2.1.3 Evaluation of the Progress Report and Interim Report of Research Results in the Interim Evaluation and notification of the results of this evaluation to the RO

2.1.4 Organization of research report meetings and other assemblages of relevant persons necessitated in the course of the execution of the Joint Research

2.2 The RO shall undertake the tasks defined in the following provisions in conjunction with the Joint Research.

2.2.1 Implementation of the research in accordance with the work plan for the Joint Research

2.2.2 Submission of the Progress Report and Interim Report of Research Results (in principle once a year), and the Final Report of Research Results to the Three Parties

2.2.3 The PI or the Co-I's participation in the research report meetings and assemblages of relevant persons necessitated in the course of the execution of the Joint Research organized by the Three Parties

Article 3 (Term of the Joint Research)

The Contract for the Joint Research shall enter into force when the Three Parties acknowledge the application of the RO based on the application form. The term of the Joint Research under the Contract shall apply from the day of the signature of the last authorized representative of the Parties to the Contract and continue for a maximum of four (4) years under the condition that the GOSAT ground system remains operational. However, in the case that the Joint Research is evaluated as not being eligible for extension approval under the Interim Evaluation, it may be possible that the Joint Research will be terminated. Conversely, in the case that the RO wishes to extend the term of the Joint Research, the RO may indicate its intention to apply for such an extension to the Three Parties, and should such application be approved, the Joint Research will be extended with the same conditions to a maximum of three (3) additional years.

Article 4 (Investigators to be Engaged in the Joint Research)

4.1 The RO shall ensure that the PI, designated in the research proposal, participates in the Joint Research.

4.2 The Co-I is mutatis mutandis bound by the articles governing the RO in the Contract, and the PI shall be responsible for taking every possible measure to ensure that the Co-I observes the stipulations provided for in the Contract.

4.3 In the case that the PI intends to add an investigator as a Co-I, the PI shall apply to the Committee in writing for an approval for such by the Three Parties.

4.4 In the case that the PI intends to solicit the participation of an investigator, who is not registered as such by the Three Parties, in the Joint Research as an RA Investigator, the PI shall notify the Three Parties of such in writing and take the necessary measures to ensure that the new RA Investigator observes the stipulations provided for in the Contract.

4.5 The RA Investigators, excluding the PI and the Co-I, may access the GOSAT Data under the supervision of the PI and the Co-I for tasks necessitated in the fulfillment of the purposes as defined in the research proposal.

Article 5 (Research Expenses)

The Three Parties and the RO shall individually bear expenses incurred in the course of performing the respective tasks associated with the Joint Research.

Article 6 (Preparation of Research Result Report)

6.1 The RO shall collate and organize the Research Results produced during the term of the Joint Research in a written report (the Final Report of Research Results) in English and submit it to the Three Parties on completion of the Joint Research.

6.2 The RO shall in principle submit the Progress Report and Interim Report of Research Results once a year in English or in Japanese, to the Three Parties, for the purpose of the Interim Evaluation of the Research Results. Notwithstanding the foregoing, if the research term shall be completed within a year after the Joint Research is agreed, such submission is not necessary.

Article 7 (Designation and Definition of "Know-How")

7.1 The Three Parties and the RO shall promptly indicate any items, including knowledge, skills or facilities which are deemed as constituting "know-how". Specifically, know-how shall refer to any faculty or skill in a particular activity specifically relevant to the execution of the Joint Research and which is attained in the course of the execution of any aspect thereof (hereinafter referred to as the "Know-How"), from the items stated as Research Results in the research reports provided for in the previous provision, and agreement on such shall be reached by mutual discussion and consensus.

7.2 When indicating items constituting Know-How, the Parties hereto shall clearly stipulate the period over which the indicated Know-How shall be considered confidential (hereinafter referred to as the "Confidentiality Period").

7.3 The Confidentiality Period as set forth hereinabove shall be determined in consultation between the Three Parties and the RO, whereas it is set, in principle, at five (5) years from the day following the completion of the Joint Research, provided, however, that the Three Parties and the RO may extend or shorten the Confidentiality Period by mutual discussion and consensus agreement.

Article 8 (Transfer of Equipment, etc.)

8.1 The Three Parties and the RO may transfer equipment or commodities necessary for the implementation of the Joint Research into the facilities of any other Party, provided that such transfer is approved by the other Party in advance. When transferring the equipment, etc. the Party responsible for such transfer shall abide by the rules and regulations of the other Party.

8.2 The Three Parties and the RO shall not use the equipment or commodities transferred by the other

Party (hereinafter referred to as the “Transferred Commodities”) for any other purposes than the implementation of the Joint Research.

8.3 In case that the Transferred Commodities are lost or damaged, the Three Parties and the RO, regardless of the cause of such loss or damage, shall promptly notify the other Parties.

Article 9 (Information Exchange)

9.1 The Three Parties and the RO shall mutually provide its own technical documentation or proprietary objects, including but are not limited to, programs, other than the GOSAT Data (hereinafter the same applies), necessary for the implementation of the Joint Research (hereinafter referred to as the “Technical Documents”) free of charge to the other Party, allow the other Party to use the Technical Documents, and may request advice from the other Party as necessary in connection with any such documentation.

9.2 The Three Parties and the RO may not use the Technical Documents as set forth hereinabove provided by the other Party for any other purpose than the implementation of the Joint Research nor disclose them to any third Party not involved in the Joint Research without the other Party’s agreement.

9.3 The Three Parties and the RO shall return or appropriately discard the Technical Documents provided by any of the other Parties, after the expiration of the Contract, according to the instructions given by the other Party.

Article 10 (Provision of and Rights to the GOSAT Data)

10.1 The Three Parties shall provide the RO with the GOSAT Data free of charge, based on Article 2.1.2 hereof, conforming to the stipulations hereunder.

10.1.1 The RO shall be provided with the GOSAT Data to the extent approved for submitting data distribution requests by the Three Parties based on the proposal of the Committee.

10.1.2 The Three Parties shall not be liable for guaranteeing the quality or timely delivery of the GOSAT Data.

10.1.3. The Three Parties shall not be liable for any situation in which the RO is unable to access the GOSAT Data due to an anomaly of GOSAT, operational constraint, or other contingency.

10.2 The RO shall abide by the following provisions with regard to the acquisition and handling of the GOSAT Data to be provided by the Three Parties.

10.2.1 The RO shall be entitled to submit data acquisition requests to the extent predetermined per research theme by the Three Parties based on the proposal of the Committee.

10.2.2 The RO may use the GOSAT Data solely for the purpose of the implementation of the Joint Research.

10.2.3 The RO shall not duplicate all or any portion of the GOSAT Data for any other purpose than data backup, except for duplication of the data to distribute to the RA Investigators, and solely for the purpose of the implementation of the Joint Research.

10.2.4 The RO shall handle the GOSAT Data such that the original data are recoverable in accordance with the provisions of Article 16 “Confidentiality” hereof, and shall not provide or disclose all or any portion of such to any third party not involved in the Joint Research.

10.2.5 When the Contract has expired, the RO shall appropriately store the GOSAT Data provided by the Three Parties.

10.3 The ownership of the GOSAT Data provided by the Three Parties to the RO shall be managed in accordance with the following provisions.

10.3.1 The “Intellectual Property Rights” relating in any way to the GOSAT Data provided to the RO shall belong to the Three Parties.

10.3.2 Notwithstanding the previous provision, in case that the RO modifies the GOSAT Data and creates higher-level value-added data such that the original data is unrecoverable, by means of advanced data processing, in the process of implementing the Joint Research, the ownership of the “Intellectual Property Rights” of such data shall be determined upon consideration of the respective shares equivalent to intellectual contribution by each of the Three Parties and the RO to the data, along with any other contingent factors, in mutual consultation.

Article 11 (Ownership of the Intellectual Property Rights and Application for Rights to Invention(s))

11.1 In the case that any Invention(s) are derived in the course of the implementation of the Joint Research, the Three Parties and the RO shall promptly notify the other Party, and discuss the ownership of the Intellectual Property Rights and the formal application for rights to Invention(s).

11.2 In the case that the Three Parties or the RO is singly and independently responsible for an Invention(s) in the course of the implementation of the Joint Research, the Intellectual Property Rights relating to the Invention(s) shall belong solely to the inventing Party, and said Party may proceed with the application process at its own discretion, provided, however, that said Party obtains approval of the other Party prior to such application. In such case, the cost and expenses associated with the application procedure and the preservation of the rights shall be borne by said Party.

11.3 In the case that the Three Parties and the RO are jointly responsible for an Invention(s) in the course of the implementation of the Joint Research, both Parties shall co-own the Intellectual Property Rights relating to such Invention(s), in proportion to the share of the Intellectual Property Rights as mutually discussed and agreed on. The two Parties shall jointly undertake such actions as necessitated for the application for Intellectual Property Rights in accordance with the separate agreement regarding joint application to be executed between the Parties hereto. In such cases, the cost and expenses associated with the application procedure and the preservation of the rights shall be borne by both Parties in proportion to their respective portions of such Intellectual Property Rights.

11.4 In the case that the RO intends on ensuring protection regarding its Intellectual Property for the purpose of the Joint Research carried out under the Contract herein, the RO shall provide notice in writing to the Three Parties. The Three Parties shall agree that their approval for the RO to proceed with measures and procedures for the protection of its Intellectual Property will not be unreasonably withheld.

Article 12 (Overseas Application)

12.1 The provisions of the previous Article shall apply also to the application procedure and the preservation of the Intellectual Property Rights in countries overseas.

12.2 In case that the Three Parties and the RO jointly apply for the Intellectual Property Rights to be commonly owned by both Parties, in accordance with the third paragraph of the previous Article, in an overseas country, the two Parties shall sufficiently confer in advance.

Article 13 (Application of the Research Results)

13.1 In the case that the Three Parties or the RO intends to actively apply the Research Results, the Party may do so (or solicit a third party do so to serve the Party’s purpose) free of charge and without any obligation to obtain the prior consent of the other Parties, provided that any such use is for the purpose of facilitating its internal research and development, is not intended to generate profits, and is for peaceful ends.

13.2 In the case that the Three Parties or the RO intends to use commonly-owned Intellectual Property Rights, the Party shall obtain the advance consent of the other Party and pay any fees associated with this use as determined in the separate agreement regarding the application of the Intellectual Property Rights to be executed between the Parties hereto, excepting such cases as provided for in the previous provision.

13.3 Observing Article 17 hereof (Disclosure of the Research Result), the Three Parties may use, edit, duplicate or distribute the Progress Report, and Interim Report of Research Results, as well as the Final Report of Research Results submitted by the RO. In such cases, the PI and the Co-I shall not exploit the moral rights of authorship.

Article 14 (Licensing of the Intellectual Property Rights to Third Party)

14.1 In the case that the Three Parties or the RO intends to license commonly-owned Intellectual Property Rights resulting from the Joint Research to a third party, the Party shall obtain the advance consent of the other Party in writing and both Parties shall discuss and determine the details of licensing conditions.

14.2 In the case that the commonly-owned Intellectual Property Rights of the Parties hereto are licensed to a third party in accordance with the previous provision, the Three Parties or the RO shall collect the license fee as determined in a separate agreement regarding licensing of the Intellectual Property Rights to be executed between the Parties hereto, from the licensed third party. The license fee thus collected shall be distributed between the Three Parties and the RO in proportion to their respective shares of such Intellectual Property Rights.

Article 15 (Partial Transfer of Intellectual Property Rights)

15.1 The Three Parties and the RO may only execute a partial transfer of Intellectual Property Rights resulting from the Joint Research to a designated party, having first consulted with and received the consent of the other Party. Any such transfer shall be executed in accordance with a separate agreement regarding the transfer of Intellectual Property Rights to be executed between the Parties hereto.

15.2 In the case that the Three Parties or the RO intends to relinquish its share of commonly-owned Intellectual Property Rights the relinquishing Party shall first issue advance notification of such intention to the other Parties before completing such transfer, should the other Party so request.

Article 16 (Confidentiality)

16.1 For the purpose of the Joint Research, the “Confidential Information” shall include all information to which any of the following provisions applies.

16.1.1 Documents and tangible products, such as samples, taken from the outcomes obtained in the course of the implementation of the Joint Research, which are indicated as confidential, or any tangible and intangible items that have been identified as being confidential between the Three Parties and the RO in writing.

16.1.2 Any tangible or intangible information disclosed or provided, which is indicated as being of a classified nature by the other Party

16.2 The Three Parties and the RO shall manage the Confidential Information in an appropriate manner and shall not disclose or divulge it to any other party than the investigators who are engaged in the Joint Research, except in the following circumstances.

16.2.1 The Information is already in the public domain at the time of disclosure or at which the Party became aware

16.2.2 The Information became publicly known due to reasons not attributable to the Party after the time of disclosure or at which the Party became aware

16.2.3 Information that can be proven to have already been known to the Party at the time of disclosure or at which the Party became aware

16.2.4 The Information or contents can be proven to have been obtained by legal means from a third party with appropriate rights and without an obligation to confidentiality

16.2.5 The Information or materials can be proven to have been obtained by the Party independently of the disclosure of any such information by any of the other Party

16.2.6 The Information has been approved for disclosure in writing by the other Party

16.2.7 Information, the disclosure of which is required by a court order or legal authority; if required, the Party subject to such obligation shall promptly notify the other Party of any such requirement

16.3 The obligation to maintain confidentiality based on the previous paragraph shall remain effective for five (5) years after the expiration (including termination) of the Contract, provided, however, that the Three Parties and the RO may extend or shorten the Confidentiality Period based on mutual discussion and agreement.

Article 17 (Disclosure of the Research Results)

17.1 The Three Parties and the RO may disseminate or disclose the Research Results obtained in the course of the implementation of the Joint Research (hereinafter referred to as the “Disclosure of the Research Results”), provided that the obligations set forth in Article 16 above are strictly observed.

17.2 In any case corresponding to the previous provision, the Three Parties or the RO intending to disclose the Research Results (hereinafter referred to as the “Disclosing Party”) shall notify the other Party in writing of any such Disclosure of the Research Results and obtain prior written consent of the other Party in advance. In such cases the notified Party shall not reject such request for approval without justifiable reason. In respect to such notification from the RO to the Three Parties, in principle it shall be made at least thirty (30) days before submission to journals or presentation at conferences.

17.3 If the notified Party becomes aware that the contents to be disclosed have the potential to infringe on its future interests, the Party shall issue a written request to the Disclosing Party for appropriate modification of the contents to be disclosed, and the Disclosing Party shall sufficiently consult with the other Party in regard to such. The Disclosing Party shall not disclose any such contents as outlined above in the notice received from the other Party in accordance with this provision due to the potential of a future infringement of the other Party’s interests, without the express approval of the other Party.

17.4 In the case that the Disclosing Party carries out said Disclosure of the Research Results, that Party shall be required to make explicit the fact that the disclosed Research Results have been obtained in the process of the implementation of the Joint Research and indicate the source of the GOSAT Data.

17.5 The Three Parties and the RO shall be required to notify each other in accordance with the provision of the second paragraph above during the effective term of the Joint Research and also for one additional year from the day following the completion of the Joint Research, provided, however, that the Three Parties and the RO may choose to extend or shorten this period by mutual discussion and agreement.

Article 18 (Mutual Liability for Damage)

The Three Parties or the RO shall not claim for indemnification for any impediment or death that occurs to its staff or damage to or loss of its assets, caused by the other Party in the process of implementation of the Joint Research, unless such impediment or death occurring to its staff, or damage to or loss of its assets has resulted from the intentional malpractice or gross negligence of the other Party.

Article 19 (Temporary Suspension and Restart of the Joint Research)

The RO shall be permitted to temporarily suspend the Joint Research upon consultation with the Three Parties for any of the following reasons listed below, which can be considered as interruptions to the Joint Research beyond the control of the PI or RO. The duration of any such suspension and the timing of the restart of the Joint Research will be also decided upon consultation between the Three Parties and the RO. In such cases, none of the Parties hereto shall claim for any compensation whatsoever.

In the case that the duration of any such suspension exceeds the effective term of the Contract, or that the timing of the restart of the Joint Research cannot be anticipated, the RO shall request the termination of the Contract to the Three Parties, who shall agree with the request in the case of any of the circumstances outlined in Article 20.1.

(1) Devastating natural disasters such as earthquakes, fires, windstorms, flooding, etc.
(2) Retirement of the PI
(3) Long-term hospitalization or medical treatment due to sickness or an accident of the coordinating investigator for the research activity in question
(4) Parturition, maternity leave, or nursing leave of the coordinating investigator for the research activity in question
(5) Long-term business transfer or trip to another organization of the coordinating investigator for the research activity in question
(6) Difficulty to sustain the research system and its environment due to budgetary constraints, etc.
(7) Difficulty to sustain the research team due to organizational changes in the RO
(8) Other unavoidable reasons not provided for above which the Committee judges and the Three Parties confirm as constituting circumstances which hinder the effective implementation of the Joint Research

Article 20 (Termination of the Contract)

20.1 The Three Parties and the RO may terminate the Contract in any of the following circumstances:

20.1.1 The Three Parties and the RO mutually agree to termination of the Contract;

20.1.2 Any Party conducts improper or unlawful deeds in the process of executing the Contract and fails to remedy such deeds within seven (7) days from receipt of notice requesting the remediation of any such breach by the other Party; or

20.1.3 Any Party breaches the Contract and fails to remedy such breach within seven (7) days from receipt of notice requesting the remediation of any such breach by the other Party.

20.2 The Three Parties may terminate the Contract in any of the following cases:

20.2.1 The Joint Research is evaluated as not eligible for approval for continuation under the Interim Evaluation; or

20.2.2 The RA scheme comes to an end by mutual agreement of the Three Parties.

20.3 Even should the Contract be terminated in accordance with this Article, the RO shall still be remain obliged to compile all outcomes from the Joint Research performed to this point in time and to submit such in the form of the Final Report of the Research Results to the Three Parties.

Article 21 (Effective Term of the Contract)

21.1 The Contract shall be valid for the research period provided for in Article 3 hereof and effective until the date of expiration. That is, the time of commencement is the date of signature of the last authorized representative of the Three Parties and the RO, while the date of expiration will correspond with the date when the Committee confirms and accepts the Final Report of Research Results as submitted through the RA Office in accordance with Article 6 hereof.

21.2 The provisions of Articles 9, 10.2-3, and 11-15 shall survive after the effective term of the Contract stipulated by the previous paragraph for the effective period for the Intellectual Property Rights stipulated by the respective provisions, and Articles 16 and 17 shall remain valid for the period stipulated by the respective provisions.

Article 22 (Consultation)

In the case that any matter not provided for in the Contract herein, or questions regarding consistency or interpretation of the Contract arise, the Three Parties and the RO shall clarify and resolve any such matters through mutual consultation.

Article 23 (Change of RO)

23.1 The Contract between the RO and the Three Parties shall be automatically terminated when the PI leaves the RO due to his/her transfer to another organization etc.

23.2 For continuation of the RA research, the new RO to which the PI is then affiliated (or the PI him-/herself if he/she does not belong to any organization) and the Three Parties must agree anew to the Contract to carry out the Joint Research.

23.3 During any such subsequent contracting process conforming to that described in the previous section, in the case that the new RO itself or the country in which it is located is deemed as not being congruent with the purposes of the RA or as concerns exist that the GOSAT Data may be used for non-peaceful purposes, the Three Parties reserve the right to reject any subsequent execution of the Contract with the new RO.

Article 24 (Change of PI in Exceptional Circumstances)

In circumstances that the RO wishes to designate another employee as the PI of the RO due to compelling reasons to facilitate the continuation of the Contract, the PI candidate of the RO shall apply to the Three Parties in writing. Should the application be approved by the Committee and confirmed by the Three Parties, the Joint Research between the RO and the Three Parties will be continued with the same conditions continuing to apply.

The Greenhouse gases Observing SATellite (GOSAT)

Research Announcements
Joint Research Agreement

The Japan Aerospace Exploration Agency (JAXA), the National Institute for Environmental Studies (NIES) and the Ministry of the Environment (MOE) (hereinafter referred to as the "Three Parties" collectively) made the Research Announcements on GOSAT (hereinafter referred to as the "RA") in order to solicit research proposals with regard to the use of any products as defined in the GOSAT Data Policy, aiming to further exploit the outcomes obtained from the GOSAT Project. A following research proposal was selected by the RA Selection and Evaluation Committee and adopted by the Three Parties.

Title of Research Proposal:
(Principal Investigator (hereinafter "PI"):)

The Three Parties and the Research Organization (hereinafter referred to as the "RO") of the PI or PI himself/herself, who submitted the adopted research proposal, hereby enter into and execute this Joint Research Agreement pursuant to the terms and conditions of the "General Contractual Conditions for the Joint Research with the GOSAT Data" (Attachment A).

The PI will be delivered the GOSAT Data based on the "Provision of and Rights to the GOSAT Data" defined in Article 10 of the General Contractual Conditions mentioned above and the "GOSAT/TANSO Data Policies" described in Chapter 4 of the RA main text. (For the "JAXA's satellite data other than the GOSAT data", please refer to Attachment B.) As referred in Chapter 8.1 "Rights" of the PI in the RA main text, the number of observation requests and deliverable standard/research products will be determined in terms of the compliance with the purpose of the research. Also note that the technical information about sensors etc. is subject to change. When any change occurred, it will be informed to the PI by the GOSAT RA office.

The term of the Joint Research on this Contract shall be provided in Article 3 of the General Contractual Conditions, which is for a maximum of four (4) years under the condition that the GOSAT ground system remains operational. The time of commencement is the latest signing date among the authorized signers of the Three Parties and the RO. Whereas, the time of expiration is the date when the Committee confirms and accepts the Final Report of Research Results submitted by the PI at the completion of his/her Joint Research in accordance with Article 6.

IN WITNESS WHEREOF, the parties hereto have executed in duplicate by placing signatures of the representatives of the Three Parties and the Organization (or PI), and the RA office and the representative(s) of the Organization shall keep one copy of the originals.

(Signatures)

1. Representative(s) of the Organization of the PI (or the PI himself/herself in case he/she does not belong to any organization):

Name of Organization:

Contact Address:

Name of Representative(s):

Date:

Signature ____

2. Representative of the Three Parties:

Program Management and Integration Department
Satellite Applications Mission Directorate I
Japan Aerospace Exploration Agency
Director: Kazuo Tachi

Date:

Signature ____
Kazuo Tachi

Center for Global Environmental Research
National Institute for Environmental Studies
NIES GOSAT Project Leader: Tatsuya Yokota

Date:

Signature ____
Tatsuya Yokota

Research and Information Office, Policy and
Coordination Division, Global Environment Bureau
Ministry of the Environment, Japan
Deputy Director: Yoshihiro Nozaki

Date:

Signature ____
Yoshihiro Nozaki

Request for the Termination of the TANSO/GOSAT RA Joint Research Agreement

To: The Three Parties
(Japan Aerospace Exploration Agency (JAXA), National Institute for Environmental Studies (NIES), and Ministry of the Environment (MOE))

Because of the reason addressed below, (name of PI's research organization [RO]) requests to terminate the TANSO/GOSAT RA Joint Research Agreement, which was executed on (signing date) between (RO) and the Three Parties, on the research proposed by the (first, second, third fourth, etc.) RA Principal Investigator (PI), Dr. (PI's name) ______.

Name of the Principal Investigator (PI)	
Name of the Research Organization (RO)	
Title of the research	
Reason for the termination	

Name of the organization:

Contact address:

Representative of the organization:

Date:

Signature:

Acknowledgement of the Termination of the GOSAT RA Joint Research Agreement

The Three Parties (Japan Aerospace Exploration Agency (JAXA), National Institute for Environmental Studies (NIES), and Ministry of the Environment (MOE)), accept the submitted request for the termination of the GOSAT RA Joint Research Agreement on the research addressed on the other side of the page with signatures by the duly authorized officers.

Signatures

Representative of the Three Parties:

Program Management and Integration Department
Satellite Applications Mission Directorate I
Japan Aerospace Exploration Agency
Director: Kazuo Tachi

Date:

Signature ______________________________

Kazuo Tachi

Center for Global Environmental Research
National Institute for Environmental Studies
NIES GOSAT Project Leader: Tatsuya Yokota

Date:

Signature ______________________________

Tatsuya Yokota

Research and Information Office,
Policy and Coordination Division, Global Environment Bureau
Ministry of the Environment, Japan
Deputy Director: Yoshihiro Nozaki

Date:

Signature ______________________________

Yoshihiro Nozaki

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

Research Announcement

Appendix F

User Category, Glossary and Abbreviation List

F.1 User Category

Users of GOSAT products are categorized as follows.

F.1-1 Categories of GOSAT product users

User category	Description
Project staff (PS)	Researchers, scientists, staff members, etc. who belong to the GOSAT Project implementation body (Three Parties) or those who belong to other organizations but engage in the GOSAT Project as contractors to the Three Parties.
RA Investigator (RA)	A researcher carrying out the research on a theme accepted in the RA who is registered as PI (Principal Investigators) or Co-I (Co-Investigators) and given approval to obtain the GOSAT data by the Three Parties.
RA* Investigator (RA*)	An RA Investigator who researches on a theme in the data processing algorithm, calibration, or validation fields.
RA+ Investigator (RA+)	An RA Investigator who researches on a theme in the carbon balance estimation and atmospheric transport models or data application fields.
RA-Mo Investigator (RA-Mo)	An RA Investigator who researches on a theme in the carbon balance estimation and atmospheric transport models field.
Science Team member (ST)	Member of the GOSAT Science Team.
Science Team member* (ST*)	A Science Team member who especially researches on a theme in the data processing algorithm, calibration, or validation fields.
General user (GU)	A general GOSAT data user who does not fall under any of the above categories.

F.2 Glossary and Abbreviations List

The following tables list up and explain the terms and abbreviations used in the RA.

Table F.2-1 Glossary

Term	Description
RA Investigator	An investigator who carries out the research on a theme selected in the RA and is registered as PI (Principal Investigators) or Co-I (Co-Investigators) by the Three Parties.

Term	Description
RA Selection and Evaluation Committee (The Committee)	A committee which selects research proposals submitted in response to the RA and provides the Three Parties with advice in the process of selecting research themes. The committee also evaluates the research progress as well as results reported by the RA Investigators and advises the Three Parties of the evaluation results.
Apodization	It represents a convolution procedure using a pseudo weighting function (apodizing function) as a function of the optical path difference when the interferogram is Fourier-transformed into the spectrum. The interferogram is multiplied by the apodizing function before the Fourier transform. In the case of no apodization, the instrumental line shape function is the sinc function. Generally, the apodization makes the full width at half maximum of a instrumental line shape function larger, although unphysical oscillation of the sinc function is suppressed.
Along-track direction	Flight direction of the satellite on the spacecraft fixed coordinates.
Interferogram	Patterns of interferometric light obtained as a result of the following steps: i) split incident light into two beams using the beam splitter, ii) change one of the path lengths of the two split beams, and iii) let the two beams of light interfere with each other again.
Inverse model	A method (model) to estimate the sources and sinks and the emission and absorption of atmospheric constituents of interest, such as CO_2, using observation data such as the GOSAT data, with the combined use of atmospheric transport models and statistical techniques.
Aerosol	A microscopic liquid or solid particle floating in the atmosphere.
Original data	GOSAT data products provided by JAXA or NIES. This should be distinguished from the data obtained as a result of the research carried out by RA Investigators.
Observation request	A request for specific data acquisition for a specific purpose, such as an observation over a calibration/validation site, which is not covered by GOSAT's routine observation (in lattice point).
Geometric correction	A process of correcting the positional information in observation data, such as band-to-band registration, correction of the latitude and longitudes of observation points based on elevation information, etc.
Gaseous column amount (column abundance)	The total amount of gas present in the vertical air column per unit area. (Number of molecules per unit area).

Term	Description
Gaseous concentration profile	Vertical distribution of gaseous concentrations (Number of molecules per unit area or volumetric ratio of the target species per unit area)
Rectangle	A rectangle (60 deg. x 30 deg. (lat. x lon.)) is the unit to archive CAI L3 normalized-difference vegetation index (NDVI) product. The globe is divided into 36 rectangles, separating from 25 degree west by 60 degree in longitudinal eastward direction, and from 90 degree north by 30 degree in latitudinal southward direction.
Region	A region is the unit defined for L4A data product. The globe is divided into 64 sub-continental regions and a net source and sink of greenhouse gases is estimated per each region. L4A data product shows the monthly estimated net source and sink of greenhouse gases for 64 regions in a global map.
Cross-track direction	The direction perpendicular to the flight direction of the satellite on the satellite fixed coordinates.
Gain	The signal amplification factor used for amplifying signals to an appropriate signal processing level (voltage), set up by using commands for every brightness (light intensity) of observation targets. For GOSAT, there are three gain setting levels each for FTS and CAI: L (Low), M (Middle), and H (High).
Check stage	GOSAT L4 data products will undergo the following three check steps before released and distributed to users. (i) Initial check Visual check on the result of the product generated by the carbon balance analysis calculated from the L2 products and data of the ground-based observation stations. (ii) Check analysis: Check the preliminarily checked products by the expert users for a certain period of time. (iii) Confirmation after the distribution: Check to be performed after releasing the products to limited users, to see if any problem with the products is reported or not after a certain period of time. The products are categorized into four stages in the process of these check steps, namely U (Unchecked), P (Preliminarily checked), Ch (Checked), and C (Confirmed). These stages are termed the “check stages”.

Term	Description
Validation stage	GOSAT L2 and L3 products will undergo the following three validation steps before released and distributed to users. (i) Initial check Visual check on the result of processing of certain observation data, in order to confirm the validity of calibration of the sensor characteristics and data processing algorithms. (ii) Validation analysis: Comparison of GOSAT observation data with validation data, in order to evaluate the reliability of the products. (iii) Confirmation after the release: Check to be performed after releasing the products to limited users, to see if any problem with the products is reported after a certain period of time. The products are categorized into four stages in the process of these validation steps, namely U (Unchecked), P (Preliminarily checked), V (Validated), and C (Confirmed). These stages are termed the “validation stages”.
Co-I (Co-Investigator)	An investigator who carries out the research on a theme selected in the RA and is approved and registered as Co-I (Co-Investigators) by the Three Parties.
Calibration stage	GOSAT L1 data products will undergo the following three calibration steps before released and distributed to users. (i) Initial check Visual check on the result of processing of certain observation data, in order to confirm calibration results of the sensor characteristics. (ii) Calibration analysis: Check the preliminarily checked products after the initial sensor calibration activity. (iii) Confirmation after the release: Check to be performed after releasing the products to limited users, to see if any problem with the products is reported or not after a certain period of time. The products are categorized into four stages in the process of these calibration steps, namely U (Unchecked), P (Preliminarily checked), Ca (Calibrated), and C (Confirmed). These stages are termed the “calibration stages”.

Term	Description
Corner cube	A trihedral made up of three planer reflectors which are perpendicular to each other. The light injected into the trihedral bounces on each of the three planes and will always return to the incident direction.
Science Team	An organization established for the purpose of providing the GOSAT Project with scientific advice.
Sunglint	Specular reflection of the sunlight on the water surface, in general. In this phenomenon, the specular reflection point is on the same plane as the sun and the sensor, and the reflection angle is the same as the incidence angle. However, as the intensity of the reflected light reaching the sensor is the strongest in the vicinity of such a reflection point, FTS observes the vicinity of specular reflection points for its water-surface observation.
Scene	(i) FTS scene FTS scene of L1 data product is defiened to have a span covered by the observation performed in a time 1/60 of the one-revolution period; the start of the first scene corresponds to the ascending node passing time. A scene of FTS data is the unit to achive FTS L1 data products. (ii)CAI scene A CAI scene is defined to have a span covered by the observation performed in one-revolution; the start of the scene corresponds to the ascending node. A scene of CAI data is the unit to archive CAI L1A products. TANSO-CAI usually acquires data during the daytime area on the ground ; accordingly, a CAI scene has a strech of data for the continuous daytime area (nighttime area are not included).
Scan	The unit of acquisition of one interferogram by FTS.
Instrument function calibration	Calibration performed with consideration given to the wavelength dependence of the sensitivity.
Atmospheric transport model	A numerical model to estimate the distribution of an atmospheric constituent of interest (e.g., CO_2, CH_4) and its variation under certain condition. In case of CO_2 (or CH_4), the model simulates the variation of its concentration based on the existing flux data, with meteorological data (air temperature, wind parameters, etc.) and chemical reactions in the atmosphere taken into consideration.
Dichroic filter	An optical filter which passes only light with specific wave number band and reflects the other.

Term	Description
Sun-synchronous sub-recurrent orbit	An orbit combining a sun-synchronous orbit and a sub-recurrent orbit, having the characteristics of the two. In the former orbit, the orbital plane of the satellite rotates once while the earth revolves the sun once (one revolution). In the latter orbit, the satellite returns to almost the same orbit at a certain interval (recurrence). GOSAT returns to almost the same footprint after 44 orbits in three days. The descending node time (local solar time) is adjusted to around 13 o'clock, and the local time at the nadir point of the satellite is almost the same time at medium and low latitudes.
Carbon flux estimation model	A model to estimate the emission and absorption of carbons for a region (a certain scale which the entire globe is divided into), based on the distributions of CO_2, etc. in the atmosphere obtained by GOSAT or otherwise together with meteorological data.
Observation in lattice point	Regular observation of FTS on the fixed ground points (lattice points). In all the five pointing modes (depending on the number of points per scan, 1, 3, 5, 7, or 9), the sensor observes the same footprint every recurrence after three days.
Specific point observation	Observation over specific ground points other than the lattice points observed in the routine observation, such as calibration/validation sites, observation points along a natural gas pipeline, etc.
Carbon emission inventory	Information on the human-induced emission of carbon dioxide etc. for areas obtained based on the investigation.
(Light) Band pass filter	An optical filter which passes only light with a certain wavelength range and rejects (attenuates) light with wave numbers outside that range.
Full-width at half maximum (FWHM)	An indicator of the spread (width) of a chevron-shaped function, such as instrument function. It is defined as the difference in the wavelengths or wave numbers at the two points where the value of the unimodal function marks a half of its maximum.
PI (Principal Investigator)	The abbreviation of the Principal Investigator, who represents the group of investigators who engage in the research activities on the research theme adopted in the RA and serves as the contact person to the Three Parties on all matters relating to the joint research agreement.

Term	Description
Beam splitter	An optical device which splits a light flux into two. A part of the light injected into the beam splitter reflects back and the other part penetrates. A beam splitter which splits polarization components is called a polarized beam splitter.
Evaluation stage	GOSAT L3 products will undergo the following two evaluation steps before released and distributed to users. (i) Initial check Visual check of L3 products processed from certain L2 products, in order to evaluate the results. (ii) Confirmation after the release: Check to be performed after releasing the products to limited users, to see if any problem with the products is reported or not after a certain period of time. The products are categorized into three stages in the process of these validation steps, namely U (Unchecked), E (Evaluated), and C (Confirmed). These stages are termed the "evaluation stages".
Fourier Transform Spectrometer (FTS)	An observing instrument which observes the incident interfering signal (interferogram) acquired with the interferometer, and Fourier-transforms the signal into radiance spectra. In the GOSAT Project, the spectrometer is applied to measure the absorption or radiance spectra of CO_2, CH_4, etc.
Product	Digital information or its electronic file, containing the processed results of GOSAT observation data, prepared in the predetermined format for distribution to users. Product is also said as data product.
Product distribution request	A request made by an RA investigator for provision of data products necessary for implementing the research on the selected theme.
Frame	A frame is the unit for CAI products, defined by dividing one revolution length of GOSAT's trajectory mapped on the ground surface into 60. A frame of CAI data is the minimum unit to archive CAI L1B, CAI L1B+, and most of CAI L2 products.
Spectral resolution	The minimum difference in wavelength, in case of the wavelength resolution, or wave number, in case of the wave number resolution, that the spectrometer can determine.
Polarization	Light of which the electric or magnetic field oscillates in a specific direction.

Term	Description
Radiometric calibration	Conducting correct engineering conversion of integer numbers (digital numbers, DN) to radiance values, by using various kinds of observation data and conversion formula.
Maneuver	An activity to control the attitude, speed, etc., consequently orbit, of the spacecraft, by thrusting its control engine, etc. It is performed in order to maintain or change the spacecraft to the expected attitude or orbit.
Land ecosystem model	A model which expresses the exchange processes of heat, water, carbon, etc. (e.g., photosynthesis, respiration) between the land vegetation ecosystem, comprised of forest, pasture, etc., and the atmosphere.

Table F.2-2 Abbreviation List

Abbreviation	Description
ADEOS	ADvanced Earth Observation Satellite
ADEOS-II/GLI	ADvanced Earth Observation Satellite-II/GLobal Imager
AERONET	AErosol RObotic NETwork
AIRS	Atmospheric InfraRed Sounder
ALOS	Advanced Land Observing Satellite
ASE	Association of Space Explorers
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ASTER GDEM	ASTER Global Digital Elevation Model
AT	Along Track
CAI	(See TANSO-CAI)
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation
CAM	monitor CAMera
CME	Continuous CO2 Measuring Equipment
CNES	Centre National d'Etudes Spatiales (in French) : National Center of Space Studies (in English)
CSIRO	Commonwealth Scientific and Industrial Research Organization
CT	Cross Track
DB	Diode Box
DEM	Digital Elevation Model
ENVISAT	ENVIronmental SATellite
EOS	Earth Observing System (NASA Project)
FFT	Fast Fourier Transform
FTS	Fourier Transform Spectrometer, or see TANSO-FTS
GAW	Global Atmosphere Watch (WMO Project)
GCP	Ground Control Point
GOME	Global Ozone Monitoring Experiment
GOSAT	Greenhouse gases Observing SATellite
GSFC	Goddard Space Flight Center(NASA)
GSHHS	Global Self-consistent Hierarchical High-resolution Shorelines
HDF	Hierarchical Data Format
HITRAN	HIgh-resolution TRANsmission molecular absorption database

Abbreviation	Description
HSTAR	High-resolution System for Transfer of Atmospheric Radiation
IASI	Infared Atmospheric Sounding Interferometer
IGM	InterferoGraM
IIR	Imaging Infrared Radiometer
ILAS	Improved Limb Atmospheric Spectrometer
ILS	Instrument Line Shape
IMG	Interferometric Monitor for Greenhouse Gas
IRS	Indian Remote Sensing satellite
JAXA	Japan Aerospace Exploration Agency
JERS	Japanese Earth Resources Satellite
JPL	Jet Propulsion Laboratory
LLM	Light Load Mode
LUT	Look Up Table
MAP	Maximum A Posteriori
MDP	Mission Data Processor
MODIS	MODerate resolution Imaging Spectroradiometer
MOE	Ministry Of the Environment of Japan
MOS	Marine Observation Satellite
MTF	Modulation Transfer Function
NDACC	Network for the Detection of Atmospheric Composition Change
NDVI	Normalized Difference Vegetation Index
NetCDF	Network Common Data Form
NIES	National Institute for Environmental Studies (Japan)
NIR	Near InfraRed
NOAA	National Oceanic and Atmospheric Administration
OCO	Orbiting Carbon Observatory (NASA Spacecraft)
OMI	Ozone Monitoring Instrument
POLDER	POLarization and Directionality of the Earth's Reflectances
PPDF	Photon Pathlength Distribution Function
PRISM	Panchromatic Remote sensing Instrument for Stereo Mapping
RA	Research Announcement

Abbreviation	Description
RAMCES	Reseau Atmospherique de Mesure des Composes a Effet de Serre (in French) : Near Real Time CO2 Concentration (in English)
ROLO	RObotic Lunar Observatory
RSTAR	Remote sensing System for Transfer of Atmospheric Radiation
SAR	Synthetic Aperture Radar
SCIAMACHY	SCanning Imaging Absorption spectroMeter for Atmospheric CartograpHY
S-LLM	Super-Light Load Mode
SNR	Signal to Noise Ratio
SPOT	Satellite Pour l'Observation de la Terre
SPRINTARS	Spectral Radiation-Transport Model for Aerosol Species
SRTM	Shuttle Radar Topographic Mission
SST	Sea Surface Temperature
ST	Science Team
SWIR	Short Wavelength InfraRed / Short Wave Infrared Radiometer
TANSO	Thermal And Near infrared Sensor for carbon Observation
TANSO-CAI	TANSO－Cloud and Aerosol Imager
TANSO-FTS	TANSO－Fourier Transform Spectrometer
TCCON	Total Carbon Column Observing Network
TES	Tropospheric Emission Spectrometer
TIR	Thermal Infrared Radiometer
TOMS	Total Ozone Mapping Spectrometer
TRANSCOM	atmospheric tracer TRANSport model interCOMparison project
TRMM	Tropical Rainfall Measuring Mission
U, E, C	Unchecked, Evaluated, Confirmed (Stages of Evaluation)
U, P, Ca, C	Unchecked, Preliminarily checked, Calibrated, Confirmed (Stages of Calibration)
U, P, Ch, C	Unchecked, Preliminarily checked, Checked, Confirmed (Stages of Check)
U, P, V, C	Unchecked, Preliminary checked, Validated, Confirmed (Stages of Validation); Unchecked, Preliminary checked, Validated nominally (for L2 research products)
USGS	U.S. Geological Survey
VGA	Video Graphics Array

Abbreviation	Description
WDCGG	World Data Centre for Greenhouse Gases
WFC	high-resolution Wide Field Camera
WMO	World Meteorological Organization
WWW	World Wide Web
ZPD	Zero Path Difference