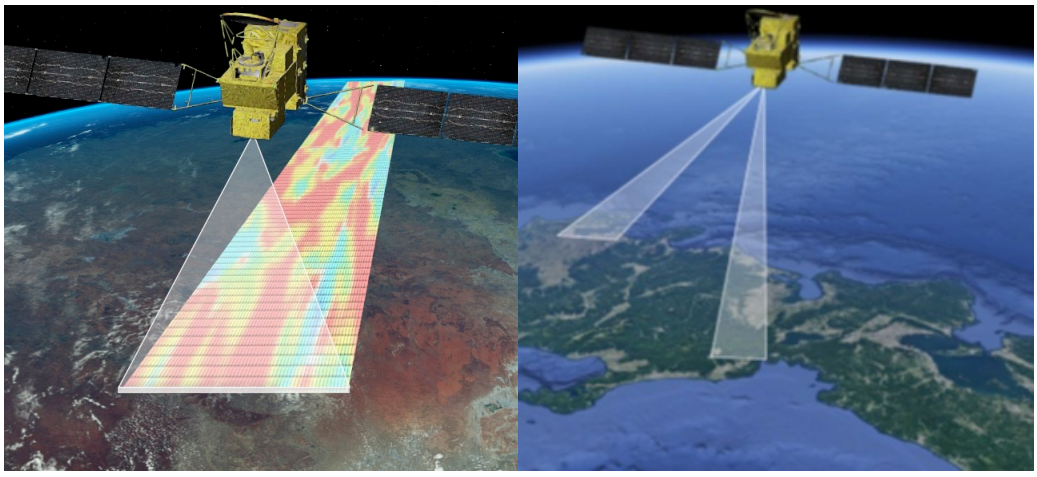
GOSAT-GW mission

Background, Aims and Mission Requirement



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Note

This document is prepared based on the early draft of the Mission Requirements (in Japanese) by the Ministry of Environment, Japan, dated November 2018. The contents were translated to English, updated by incorporating the latest information, for sharing with the international scientific community interested in the GOSAT-GW mission by Hiroshi Tanimoto (with help from Dr. Edit Nagy-Tanaka). Therefore, this document in English does not necessarily provide an accurate view of the Ministry of the Environment, Japan. The document is not officially approved by the Ministry of Environment, Japan, nor by National Institute for Environmental Studies, Japan.

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1. Background

1-1. Japan's Contributions to the International Efforts on Climate Change Mitigation

Since the United Nations Climate Summit held in September 2014, Japan expressed its willingness to contribute to global warming countermeasures, in particular, by operating satellite to monitor greenhouse gases in the atmosphere toward verifying their emissions.

The Paris Agreement, which requires countries around the world to regularly report their greenhouse gas emissions and implement greenhouse gases reduction efforts, was adopted at the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21, November 2015). At present, 175 countries are members. Japan joined on November 8, 2016. In May 2016, at the G7 Toyama Environment Ministers' Meeting, climate change and related measures were discussed as one of the agenda items and the results were summarized in a communiqué, stating that "We recognize the need for steadfast earth observation in order to strengthen our ability to measure and monitor greenhouse gas emissions." Further, in 2017, at the 23rd Conference of the Parties to the United Nations Framework Convention on Climate Change (COP23, November 2017), Mr. Nakagawa, Environment Minister, announced that "We will further strengthen our efforts in FY2018, such as the launch of the Ibuki-2 satellite for monitoring global greenhouse gas emissions." Ibuki is the Japanese nick name of Greenhouse gases Observation SATellite (GOSAT). In April 2018, the Fifth Basic Environment Plan was approved by the Cabinet to determine the outline of a comprehensive and long-term policy for the government's environmental conservation efforts. In this Plan it is stated that "In response to the Paris Agreement, it is important to improve the transparency of information on climate change countermeasures in each country. Continued observations by the Ibuki satellite series and the development and wider-use of monitoring technologies using information and communication technologies will contribute to the improvement of the transparency of each country's GHG emissions and reduction efforts."

In the meantime, the discussions on the implementation of the Paris Agreement have made substantial progress. The first Global Stocktake to confirm the status of implementation of GHG reduction efforts reported by countries around the world is planned to take place in 2023 and the second in 2028, and to be continued at a five-year cycle. Verification of country-level emissions in a highly-accurate and transparent manner is required from a number of methods. Based on the latest Global Stocktake, each country in the world is planning to review its NDC (Nationally Determined Contribution) in 2025 and 2030. In order to set appropriate and ambitious targets, it is necessary to understand the present status of emissions and to reduce the uncertainty in future projections.

Following the launch of GOSAT in 2009, the United States, China, and Europe have launched eight satellites equipped with sensors that monitor major GHGs, such as carbon dioxide (CO_2) and methane (CH_4). Currently, six satellites are in operation. Further launches by individual countries are planned in the future.

1-2. GOSAT: Pioneering efforts and achievements

GOSAT is the world's first greenhouse gases observing satellite launched by the Ministry of the Environment of Japan, the Japan Aerospace Exploration Agency (JAXA), and the National Institute for Environmental Studies. Since its launch in 2009, it is in successful operation, providing us with the column-averaged atmospheric concentrations of CO_2 and CH_4 with high accuracy, thus contributing to the development of climate science and climate-change policy. The GOSAT observations played a key role in capturing the global-mean concentration of CO_2 and its long-term trends. In December 2015, the GOSAT data revealed that global-mean CO_2 concentrations had exceeded 400 ppm (http://www.gosat.nies.go.jp/recent-global-co2.html). In June 2017, the GOSAT observations disclosed the trend of global-mean CH_4 concentrations. The potential of the GOSAT data in the verification of the emissions inventory estimates was examined, demonstrating that the anthropogenic CO_2 concentrations inferred from the GOSAT data and that from the emission inventory data are in good agreement at the national level in Japan. This warrants further studies that other countries around the world can use satellite observational data in preparing and reporting their GHG emissions mandated by the Paris Agreement.

1-3. GOSAT-2: Fine tuning measurement capability

Following the GOSAT experience and achievements, the GOSAT-2 mission was planned and launched in 2018. The GHG observation sensor of GOSAT-2 (TANSO-FTS-2) is based on Fourier Transform Spectrometer, inherited from the GOSAT sensor but also includes new functions such as "Intelligent pointing" (i.e., automatically avoiding cloudy areas), simultaneous observation of carbon monoxide (CO), and improvement of the specific point observation function for selective observations of large-scale emission sources. Furthermore, the observations of PM2.5 and black carbon were added to the cloud/aerosol imager TANSO-CAI-2, which was installed to correct the effects of clouds/aerosols. The aim of GOSAT-2 was to improve the accuracy of CO_2 observations from 4 ppm for 3-month average in a 1000 km mesh on land to 0.5 ppm for 1-month average. It also aimed to improve the accuracy of CH_4 observations to be 5 ppb in a 500 km mesh at land and 2000 km mesh at the sea. In the estimates of CO_2 emissions and update, it was aimed to improve the accuracy of the net emissions and uptakes from the sub-continental level to a 1000 km mesh. Through these improvements of the GOSAT-2 functions, the project aimed to increase the observation accuracy, observe greenhouse gas emissions from metropolitan areas and large-scale emission sources, and improve the accuracy in estimating anthropogenic GHG emissions in Japan, where inventory preparation is well-established.

1-4. GOSAT-GW: Putting forward ambitious goals

In addition to the continued operations of GOSAT and GOSAT-2, GOSAT-GW (Global Observing SATellite for Greenhouse gases and Water cycle) will be launched in 2023 to make GHGs observations with higher spatial information (see below) with the hope to help improve the verification of GHG emissions.

- Spatial refinement of observational data

GOSAT and GOSAT-2 observe 3 to 5 points scattered over an area with a width of 930 km in a visual field of about 10 km in diameter. Therefore, the observation data may be subject to the mixed influence from multiple emission sources. In order to quantify the GHG emissions from each emission source, it is important to increase the spatial resolution of the satellite observations, highlighting the needs to identify the emission sources based on the observations widely covering the earth's surface by reducing the size of the visual field, increasing the number of pixels, and reducing the distance between observation points.

- Increasing the number of valid observation data

In contrast to the targeted uncertainty of 0.13 ppm in estimating the 1 ppm CO_2 concentration gradient due to anthropogenic origins, with the GOSAT data over the whole globe, the estimated uncertainty for Japan was much larger to be 0.79 ppm, due to small number of observation data (396) over the period of 5.5 years. In order to improve the accuracy, transparency, and reliability of the emission verification, the challenge should be to establish an observation system that can secure the number of data required to make highly-accurate emission estimations for Japan on yearly basis.

- Verification of country-specific anthropogenic GHG emissions

Based on GHG observing satellite data it is expected to make highly-accurate emission estimates and establish an emission verification system for Japan. Once a prototype is established, it is expected to apply the system to other countries.

Since the GOSAT-GW will be a joint mission that will put together TANSO-3 (Total Anthropogenic and Natural emissions mapping SpectrOmeter-3) and AMSR3 (Advanced Microwave Scanning Radiometer 3), following decisions were made between the Ministry of Environment and the Ministry of Education, Culture, Sports, Science, and Technology (MEXT),

- The orbit of the satellite shall be the ascending mode.
- The orbit altitude shall be at approximately 666 km (3-day cycle), the same as GOSAT.
- The local solar time when the ascending mode passes shall be 13:30.

2. Mission Requirements

The planned lifetime of GOSAT-GW shall be more than 7 years and operation will start immediately after the launch. The spatial and temporal scales of the GOSAT-2 target values shall be drastically reduced to result in a standard error of the valid data collected during 1 week in a 100 km mesh on land, of no more than 1.0 ppm for CO_2 and no more than 10 ppb for CH_4. It shall be possible to derive column-averaged concentrations of CO_2 and CH_4.

2-1. Monitoring of monthly average concentrations of global atmospheric GHGs

It remains important to continue monitoring of the whole atmosphere global-mean concentrations. Therefore, GOSAT-GW shall continue the long-term observations of GHGs and provide global

atmospheric concentrations of these species, following the GOSAT and GOSAT-2 missions.

- The main target gas is CO_2, the most important among the anthropogenic greenhouse gases.
- The efforts of global GHG observation mission to be continued.
- It shall be possible to update each month the calculation of the average global atmospheric concentrations.
- The observation sensor shall observe a wide area and maintain a field of view equivalent to that of GOSAT and GOSAT-2 (about 10 km in terms of direct view on the ground).
- It shall make observations in 3-day cycles around the globe similarly to GOSAT and GOSAT-2.

2-2. Verification of country-specific anthropogenic GHG emissions

GOSAT-GW shall improve the accuracy, transparency, and reliability of GHG verifications prepared and published by countries under the Paris Agreement.

- The target GHGs shall be CO_2 and CH_4.
- GOSAT-GW shall make it possible to verify anthropogenic emissions in Japan every year. The uncertainty in the estimation shall not exceed 15% (1σ).
- Assessment of major CO_2-emitting countries (Eighteen countries listed in the World Energy Source CO_2 Emissions (2014) published by the Ministry of the Environment. http://www.env.go.jp/earth/ondanka/cop/co2_emission_2014.pdf) shall be made using the above method to the extent possible with regard to observability.
- To improve the reliability of country-specific verifications, verification of CO_2 emissions from metropolitan areas participating in the C40 Cities Climate Leadership Group (92 cities as of 2018), shall be conducted to the extent possible with regard to observability.

2-3. Monitoring of large-scale emission sources

In addition to monitoring emissions from large-scale emission sources that can have substantial impacts on the anthropogenic GHG emissions estimates, GOSAT-GW shall try to detect unknown emission sources that have not yet been elucidated by current observational techniques or included in the traditional inventory emission database.

- The target GHG shall be CO_2 and CH_4.
- Observation area and conditions shall include metropolitan areas and power plants and permafrost.

Metropolitan areas and power plants

GOSAT-GW shall be able to observe the Tokyo Metropolitan Area (all wards and the Tama district) in the same orbit. It shall also be able to observe C40 cities across the world at least once every three days. Furthermore, it shall be able to observe power plants (those with emissions of 6.5 $MtCO_2$/year or more, which account for about half of the total emissions

of power plants around the world) in a spatial resolution equivalent to less than 3 km (desirably less than 1 km) of surface distance.

Permafrost

For permafrost at northern high latitudes in the Northern Hemisphere, GOSAT-GW shall be able to capture the target gases possibly emitted from the thawing of the soil surface layer during the northern summer (around June-August).

- GOSAT-GW shall be able to simultaneously observe NO_2 that helps identify the sources of CO_2 emissions originating from fossil fuel combustion, with the same observation width and spatial resolution as CO_2 observations.

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