Current Status of GOSAT and GOSAT-2 Projects


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GOSAT (Greenhouse gases Observing Satellite) is the world’s first satellite dedicated to greenhouse gas monitoring from space.

GOSAT was successfully launched on January 23, 2009, and since then GOSAT has been monitoring the Earth’s atmosphere continuously.

The successor, GOSAT-2, will be launched in FY2017. GOSAT-2 design reviews for spacecraft, instruments, and ground data system are ongoing.
Gas molecules in the atmosphere, such as carbon dioxide, absorb sunlight at their specific wavelengths and the absorption intensities are determined by the number of gas molecules. So by inversely analyzing sunlight reflected at the Earth’s surface, we can estimate the amount and concentration of gas molecules.
**Time Line & Project Schedule**

**GOSAT**

![GOSAT Timeline Diagram]

- **Launch (L):** 2009.1.23
- **L+3 mo.:**
- **L+6 mo.:**
- **L+5 yrs:** Present

**GOSAT-2**

|--------------|--------------|--------------|--------|--------------|---------------|--------------|--------------|--------------|--------------|

*GCOS-2016, Amsterdam, the Netherlands, 2-4 March 2016*
Short Wavelength Infrared (SWIR) Band: Columnar Mixing Ratio (XCO$_2$ and XCH$_4$)

CO$_2$

Columnar mixing ratio
Monthly average
Data: 2009.8

CH$_4$

(“Parity“ 2010.1)
GOSAT captures CO₂ variation over US and Australia

Growth rates of CO₂ observed by GOSAT (2010 ~ 2013) are 1.9 ~ 2.0 ppm/yr

North America

Australia

Year/month

GOSAT (V02.21) (NorthAmerica)  GOSAT (V02.21) (Australia)
Latitudinal Distributions of $\text{XCO}_2$ and $\text{XCH}_4$
Validation of SWIR Products using TCCON Data (Evaluation of Bias)

TCCON: Total Carbon Column Observing Network (Wunch et al., 2011)

\[ \text{XCO}_2 \]

\[ \text{XCH}_4 \]

Bias & STD = -1.16 ± 1.78 [ppm]  
Bias & STD = -3.69 ± 12.02 [ppb]

Data: 2009.6~2010.7.  
TCCON: 11 sites  
Match up: Lat&Lon=±2°, Time=±30min.

(TCCON data were provided by TCCON Partners)  
(Courtesy of C. Iwasaki/AORI)
Surface Flux of CO$_2$ and CH$_4$ - Inversion Analysis -

Monthly CO$_2$ Flux Estimates
- Monthly-mean CO$_2$ data, Squares: GOSAT XCO$_2$ gridded to 5$^\circ$ × 5$^\circ$ cells, Circles: GLOBALVIEW data

Monthly CH$_4$ Flux Estimates
- Monthly mean XCH$_4$ data of GOSAT (input to flux estimation), gridded to 2.5$^\circ$ × 2.5$^\circ$ cells

Monthly flux estimate (GOSAT Level 4a CO$_2$, V02.03)

Monthly flux estimate (GOSAT Level 4a CH$_4$, V01.02)
Thermal Infrared (TIR) Band: Upper-Air Concentration of CO$_2$

2010 March 700 hPa

2010 August 700 hPa

200 hPa

(N. Saitoh et al., AMTD 2016)
Validation of TIR Products (CO$_2$) using CONTRAIL Data

CONTRAIL: Comprehensive Observation Network for TRace gases by AirLiner (Matchda et al., 2008)

(Contrail data were provided by T. Machida/NIES)

(N. Saitoh et al., AMTD 2016)
Retrieval of Minor Constituents from TIR Data ($O_3$)

【Columnar $O_3$】

September 16～18, 2009

September 17～19, 2010

(Imasu et al., 2010)
Retrieval of Minor Constituents from TIR Data (CFC-11, HCFC-12, HCOOH, NH₃)

(Inagoya, 2012)
GOSAT-2 Joint Project

Application of GOSAT-2 data to environmental policy

Design, development, test, launch, and operation of GOSAT-2 spacecraft, and the calibration and Level 1 processing of GOSAT-2 data

Level 2 to 4 processing, validation, and distribution of GOSAT-2 data
# Quick Overview of GOSAT and GOSAT-2

<table>
<thead>
<tr>
<th>Satellite Specifications</th>
<th>GOSAT Specifications</th>
<th>GOSAT-2 Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch year and life time</td>
<td>Jan. 2009, 5 years</td>
<td>FY2017, 5 years</td>
</tr>
<tr>
<td>Satellite (Main body size, mass, power)</td>
<td>3.7 x 1.8 x 2.0 m, 1750kg, 3.8KW (EOL)</td>
<td>5.3 x 2.0 x 2.8 m, &lt;2000kg, 5.0KW</td>
</tr>
<tr>
<td>Orbit (Type, altitude, repeat cycle, equator crossing time)</td>
<td>Sun synchronous, 666 km, 3 days, 13:00</td>
<td>Sun synchronous, 613 km, 6 days, 13:00±15 min</td>
</tr>
<tr>
<td>Target gases</td>
<td>CO₂, CH₄, O₂, O₃, H₂O</td>
<td>CO₂, CH₄, O₂, O₃, H₂O, CO</td>
</tr>
</tbody>
</table>

| Fourier Transform Spectrometer (FTS and FTS-20) | Band 1 : 0.76 – 0.78 μm | Band 1 : 0.75 – 0.77 μm |
| Band 2 : 1.56 – 1.72 μm | Band 2 : 1.56 – 1.69 μm |
| Band 3 : 1.92 – 2.08 μm | Band 3 : 1.92 – 2.33 μm |
| Band 4 : 5.6 – 14.3 μm | Band 4 : 5.5 – 8.4 μm |
| IFOV = 10.5 kmΦ | IFOV = 9.7 kmΦ |
| Pointing = ±20° (AT), ±35° (CT) | Pointing = ±40° (AT), ±35° (CT) |
| Polarimetry = Band 1, 2, 3 | Polarimetry = Band 1, 2, 3 |

| Cloud and Aerosol Imager (CAI and CAI-2) | B1 = 380 nm | B1-5: forward, B6-10: backward |
| B2 = 674 nm | B1 = 343 nm | B6 = 380 nm |
| B3 = 870 nm | B2 = 443 nm | B7 = 550 nm |
| B4 = 1600 nm | B3 = 674 nm | B8 = 674 nm |
| B1-B3 = 500 m / 1000 km, B4 = 1500 m / 750 km | B4 = 869 nm | B9 = 869 nm |
| B5 = 1630 nm | B5 = 1630 nm |
| B1-B4, B6-B9 = 460 m / 920 km | B10= 1630 nm |
| B5, B10 = 920 m / 920 km | |

| Other new features of GOSAT-2 FTS-2 | Intelligent pointing using FTS-2 FOV camera, fully programmable (target mode) observation, and improved SNR. |
FTS-2 is designed based on CrIS (Cross-track Infrared Sounder) onboard NASA’s Suomi NPP.
Intelligent Pointing System for Finding Clear-Sky Points

Intelligent Pointing (IP) uses a high-resolution RGB camera to identify cloud-free regions near the commanded LOS position.

As shown in the right-most images, onboard processing uses the raw camera image to create a cloud mask, and then determines via a convolution the least cloudy area of the FOV (images at right). The instrument LOS is then shifted to the cloud-free region before the interferogram is collected.

In the left-most example region, the percentage of usable cloud-free data collects increases from 20% (green locations) to 46% (green plus blue locations), which is a 2.3X improvement.

Globally, IP is expected to provide about a 2X improvement in cloud-free data yield.

(R. Glumb, TANSO-FTS-2 instrument performance for GOSAT-2, IWGGMS-11, 2015)

National Institute for Environmental Studies, Japan
GOSAT Air Pollution Watch

• Japan has a satellite (GOSAT) and will have satellites (GCOM-C and GOSAT-2) with sub km resolution UV imagers suitable for land aerosol / air pollution mapping (CAI, CAI-2, and SGLI).

• Combined use of these satellites will enable us to monitor land air pollution frequently (daily) in quasi-realtime.

• GOSAT Air Pollution Watch is being designed for rapid processing / distribution of GOSAT CAI data for monitoring of air pollution caused mainly by particulate matters. Its testbed is already developed.

• Data processing algorithms in GOSAT Air Pollution Watch are based on but modified from GOSAT/GOSAT-2 algorithms for aerosol product generation to realize faster and timely data processing.

• Data from GOSAT Air Pollution Watch will be used to inform the current distribution of the polluted air. In addition, they will contribute to short term prediction of air pollution using atmospheric transport models.
PM2.5 Estimation from CAI/GOSAT Data - Empirical Regression Method -

- Convert AOT(380nm) to PM2.5 concentration for non-cloud land pixels.
  - Empirical regression using AOT (380nm), observed spectral reflectances, PBL height, and humidity data is used in the conversion.
  - PM2.5 data measured in Beijing (3 years) and Shenyang (1.6 years), China, provided by US Embassy, are used in this study.
PM2.5 Estimation from CAI/GOSAT Data
- Comparison with In Situ Measurements -

Regression residuals for Beijing / Shenyang data suggest PM2.5 estimation error is about 30 – 40 %.

Blue : Beijing, winter
Orange : Beijing, summer
Gray : Shenyang, winter
Yellow : Shenyang, summer

PM2.5, Ground (µg/m³)

PM2.5, GOSAT (µg/m³)

PM2.5 = 0 – 100 mg/m³
RMSE = 21.4mg/m³
N = 145

PM2.5 = 0 – 500 mg/m³
RMSE = 67.8 mg/m³
N = 256
Call for **GOSAT Air Pollution Watch Partners**

- A testbed of **GOSAT Air Pollution Watch** was successfully developed using urban air pollution data from Beijing and Shenyang, China.

- NIES would like to issue “Call for new **GOSAT Air Pollution Watch partners**” to extend the coverage of the testbed to Southeastern and South Asian countries.
  - NIES will provide GOSAT raw and processed data (e.g.: air pollution maps) in quasi-real time.
  - Partners will provide local air pollution data (several years from 2009, hourly or higher sampling) such as BC and PM2.5 concentrations for regression analysis.

- The collaborative testbed will evolve into a multi-satellite system after GOSAT-2 and GCOM-C launches in coming years.

- These activities may have close relationships to JCM (Joint Crediting Mechanism) activities between Japan and asian countries.

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Thank you for your attention.

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or

Visit our website: http://www.gosat-2.nies.go.jp