The Launch Of GOSAT-2 and GHG/Air Quality Monitoring By GOSAT Satellite Series

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2. The University of Tokyo, 3. Japan Aerospace Exploration Exploration Agency (JAXA)
3. Tokai University
Successful Launch of GOSAT-2 on October 29, 2018 by H-IIA Rocket from JAXA Tanegashima Space Center

- (Left) H-IIA F-40 Launch from JAXA Tanegashima Space Center (13:08, October 29, 2018). DIWATA-2 was also onboard.

- (Top) Separated GOSAT-2 spacecraft taken from the launch vehicle (16 minutes after launch)

- CAI-2 first light images (Nov. 5 and 6, 2018)
- FTS-2 first data (Dec. 13, 2018)
### Satellites for Greenhouse Gases Observation (Column observation only)

<table>
<thead>
<tr>
<th>Mission</th>
<th>Country / Organization</th>
<th>Period</th>
<th>GHGs</th>
<th>Comments</th>
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<tr>
<td>ENVISAT / SCIAMACHY</td>
<td>ESA</td>
<td>2002-2012</td>
<td>CO2, CH4</td>
<td>Grating, CO</td>
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<td>GOSAT</td>
<td>Japan</td>
<td>2009-</td>
<td>CO2, CH4</td>
<td>FTS</td>
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<td>OCO-2</td>
<td>US</td>
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<td>CO2</td>
<td>Grating</td>
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<td>GHGSat-D/CLAIRE</td>
<td>GHGSat (Canada)</td>
<td>2016-</td>
<td>CO2, CH4</td>
<td>Fabry–Pérot</td>
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<td>TanSat</td>
<td>China</td>
<td>2016-</td>
<td>CO2</td>
<td>Grating</td>
</tr>
<tr>
<td>Sentinel-5p / TROPOMI</td>
<td>EC</td>
<td>2017-</td>
<td>CH4</td>
<td>Grating</td>
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<tr>
<td>FY-3D / GAS</td>
<td>China</td>
<td>2017-</td>
<td>CO2, CH4</td>
<td>FTS</td>
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<td>GF-5 / GMI</td>
<td>China</td>
<td>2018-</td>
<td>CO2, CH4</td>
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<td>ISS / OCO-3</td>
<td>US</td>
<td>2019-</td>
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<tr>
<td>MicroCarb</td>
<td>France</td>
<td>2021-</td>
<td>CO2</td>
<td></td>
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<tr>
<td>MethaneSAT</td>
<td>EDF (NPO in US)</td>
<td>2021-</td>
<td>CH4</td>
<td></td>
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<tr>
<td>Sentinel 5A, 5B, 5C</td>
<td>EC</td>
<td>2022-</td>
<td>CH4</td>
<td>CO</td>
</tr>
<tr>
<td>GOSAT-3</td>
<td>Japan</td>
<td>2022-</td>
<td>CO2, CH4</td>
<td>TBD</td>
</tr>
<tr>
<td>GeoCARB</td>
<td>US</td>
<td>2023-</td>
<td>CO2, CH4</td>
<td>Geostationary, Grating, CO</td>
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<td>MERLIN</td>
<td>France/ Germany</td>
<td>2024-</td>
<td>CH4</td>
<td>Laser</td>
</tr>
<tr>
<td>Copernicus CO2</td>
<td>EC</td>
<td>2025-</td>
<td>CO2, CH4</td>
<td>3 satellites</td>
</tr>
</tbody>
</table>

**Notes:**
- ENVISAT (2002-2012)
- GOSAT (2009-)
- OCO-2 (2014-)
- GHGSat-D (2016-)
- TanSat (2016-)
- Sentinel 5p (2017-)
- FY-3D (2017-)
- GF-5 (2018-)
- GOSAT-2 (2018-)
- OCO-3 (2019-)
- MicroCarb (2021-)
- MERLIN (2021-)
GOSAT Global CO2 Trend in Past Ten years

No sign of Stabilizing ...

Paris Agreement

Monthly mean CO₂
CO₂ trend

Whole-atmosphere mean CO₂ concentration (ppm)
### Volume 1
**General Guidance and Reporting**

### Chapter 6
**Quality Assurance / Quality Control and Verification**

#### 6.10.2
**Comparisons with Atmospheric Measurements**

- **6.10.2.5** Use of Complimentary Observations and Global Modelling Product
  - Comparing National Inventory to the Global Inverse Model Products
  - **Satellite Observations**

- **6.10.2.6** Procedures for Inventory Comparison to Estimates based on Atmospheric Measurements

- **6.10.2.7** Check List for Applying Inverse Model Estimates for Comparison with National Inventories

- **6.10.2.8** Necessary Steps for Comparing National Inventory to the Global / Regional Inverse Modelling Products

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**Satellite Observations**

“Satellite observations by GOSAT were used for national scale methane emission estimates with regional inverse models by (Ganesan et al. 2017) for India and (Turner et al. 2015) for the US. “

“Local GHG concentration enhancements observed by the GOSAT satellite correlate well with transport model simulations (Janardanan et al. 2016; Janardanan et al. 2017),”

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# GOSAT and GOSAT-2 Specifications / Requirements

<table>
<thead>
<tr>
<th>GOSAT and GOSAT-2 Specifications / Requirements</th>
<th>GOSAT</th>
<th>GOSAT-2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Launch year and life time</strong></td>
<td>Jan. 2009, 5 years</td>
<td>Oct. 2018, 5 years</td>
</tr>
<tr>
<td><strong>Satellite (Dimension, mass, power)</strong></td>
<td>3.7 x 1.8 x 2.0 m, 1750 kg, 3.8 KW (EOL)</td>
<td>5.3 x 2.0 x 2.8 m, 1784 kg, 5.0 KW</td>
</tr>
<tr>
<td><strong>Orbit (Type, altitude, repeat cycle, equator crossing time)</strong></td>
<td>Sun synchronous, 666 km, 3 days, 13:00</td>
<td>Sun synchronous, 613 km, 6 days, 13:00 ± 15 min</td>
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<tr>
<td><strong>Target gases</strong></td>
<td>CO₂, CH₄, O₂, O₃, H₂O</td>
<td>CO₂, CH₄, O₂, O₃, H₂O, CO</td>
</tr>
<tr>
<td><em><em>Fourier Transform Spectrometer (FTS</em> and FTS-2)</em>*</td>
<td>Band 1 : 0.758 – 0.775 µm, Band 2 : 1.563 – 1.724 µm, Band 3 : 1.923 – 2.083 µm, Band 4 : 5.56 – 14.3 µm, Spectral resolution = 0.24 - 0.37 cm⁻¹, IFOV = 10.5 km⁻¹, Pointing = ±20° (AT), ±35° (CT), Polarimetry = Band 1, 2, 3</td>
<td>Band 1 : 0.754 – 0.772 µm, Band 2 : 1.563 – 1.695 µm, Band 3 : 1.923 – 2.381 µm, Band 4 : 5.56 – 8.42 µm, Band 5 : 8.42 – 14.29 µm, Spectral resolution = 0.2 cm⁻¹, IFOV = 9.7 km⁻¹, Pointing = ±40° (AT), ±35° (CT), Polarimetry = Band 1, 2, 3</td>
</tr>
<tr>
<td><strong>Cloud and Aerosol Imager (CAI and CAI-2)</strong></td>
<td>Nadir</td>
<td>B1-5: Forward (+20°), B6-10: Backward(-20°)</td>
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<tr>
<td></td>
<td>B1 = 380 nm, B2 = 674 nm, B3 = 870 nm, B4 = 1600 nm, B1-B3 = 500 m / 1000 km, B4 = 1500 m / 750 km</td>
<td>B1 = 343 nm, B6 = 380 nm, B2 = 443 nm, B7 = 550 nm, B3 = 674 nm, B8 = 674 nm, B4 = 869 nm, B9 = 869 nm, B5 = 1630 nm, B10= 1630 nm, B1-B4, B6-B9= 460 m / 920 km, B5, B10 = 920 m / 920 km</td>
</tr>
<tr>
<td><strong>Other new features of GOSAT-2 FTS-2</strong></td>
<td>Intelligent pointing using FTS-2 FOV camera, fully programmable (target mode) observation, and improved SNR.</td>
<td></td>
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</tbody>
</table>
5-point Mode Observation by GOSAT-2

≈ 7 km/sec

≈ 10 km
≈ 4 sec

≈ 150 km
NIES GOSAT FTS and GOSAT-2 FTS-2 SWIR Level 2 Products

GOSAT (April 2009 - )
- CO₂ column amount product
- CH₄ column amount product
- H₂O column amount product

~ XCO₂, XCH₄, and XH₂O over the cloud-free region are simultaneously retrieved by the full-physics based algorithm.

GOSAT-2 (March 2019 - )
- Chlorophyll fluorescence and proxy-method product
  ~ SIF, proxy-based XCH₄ & XCO, and aerosol/cloud related information are retrieved under the cloud-free assumption.
- Column-averaged dry-air mole fraction product
  ~ XCO₂, XCH₄, XCO, and XH₂O over the cloud-free region are simultaneously retrieved by the full-physics based algorithm.

Yoshida et al., EGU, 2019
GOSAT-2 SWIR L2: Proxy-based XCH4 & XCO
March, 2019 (2.5 deg average)

Based on L1B V002.004

Cloud-screening is insufficient because CAI-2 L2 cloud mask is not used. Only FTS-2 2 µm-band cloud-screening is applied.

The proxy method uses a ratio of the column concentrations of two gases whose absorption bands are adjacent to each other. It can obtain relatively accurate column concentrations even if clouds and aerosols somewhat affect the optical path length. But its target gases of retrieval are limited, and CO$_2$ is not applicable.

http://www.nies.go.jp/whatsnew/20190705/20190705.html
GOSAT-2 FTS-2 SWIR Level 2 Proxy in March 2019
Column Concentration of Carbon Monoxide
Comparison between GOSAT Full Physics XCH4 and GOSAT-2 Proxy XCH4

provided by Yukio Yoshida, NIES
Validation of GOSAT Series Column Concentration Using Total Carbon Column Observing Network (TCCON)

https://tccon-wiki.caltech.edu

Photo from EDC archive

Pasadena, CA, US

Sodankylä, Finland

Tsukuba, Japan

High Resolution FTS

Burgos, Philippines

Tsuneo Matsunaga, National Institute for Environmental Studies (NIES), Japan

Land Use/Cover Changes, Environment and Emissions in South/Southeast Asia,

July 22-24, 2019, Johor Bahru, Malaysia

Combination of forward and backward viewing data provides more information on aerosols than nadir-only data.

Images of Ganges River in India taken by GOSAT-2 CAI-2 on Nov. 6, 2018.

Strong UV absorption (441 nm / 339 nm) indicates the presence of black carbon by fires.

GOSAT-2 CAI-2 Level 2 Aerosol Product (Sample) Ocean / Fine mode, Feb. 10 - 15, 2019

See Hashimoto-san’s presentation tomorrow
GOSAT Air Pollution Watch
Sample 1: Indonesia June 20, 2013 (P9F31)

Using Beijing/Shenyang regression
2nd GOSAT Series Research Announcement

Merits of becoming GOSAT RA PI and Co-I

1. Submitting observation requests for FTS and FTS-2
2. Requesting a delivery of standard products before the release to the public.
3. Requesting a delivery of research products and internal products
4. Requesting a “forced” processing of FTS and FTS-2 L2 products
5. PIs can obtain additional information and the technical materials.
6. Requesting a delivery of the FTS or FTS-2 L2 data products generated with less strict screening criteria than the products for general users.
7. PIs are entitled to participate in the “PI Meeting”.

- 36 proposals were adopted in 1st RA.
- 2nd RA Application deadline: November, 2019
Future Plan

- Test of GOSAT-2 Level 2 processing and validation of Level 2 products using TCCON and other data
  - FTS-2 SWIR Level 2 proxy (XCH4, XCO)
  - FTS-2 SWIR Level 2 full physics (XCO2, XCH4, XCO)
  - FTS-2 TIR Level 2
  - CAI-2 Level 2 Cloud Discrimination and Aerosol

- Evaluation of Level 1 products through Level 2 processing

- Public release of GOSAT-2 standard products from NIES website.
  - Level 1 products (July/August 2019 - )
  - Level 2 products (October/November 2019 - )
  - Level 4 Flux Products (FY2020 - )
  - Level 1 products are already available from NIES for GOSAT RA PIs.

- GOSAT Series Research Announcement (GOSAT RA)
  - 1st GOSAT Series RA = 36 joint research contracts
  - 2nd GOSAT Series RA will be issued around September, 2019.
Thank you for your attention.

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Website
http://www.gosat-2.nies.go.jp

GOSAT standard products are freely available from
GOSAT Data Archive Service
https://data2.gosat.nies.go.jp