Atmospheric Pollution Monitoring Using GOSAT and GOSAT-2

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Today’s Topics

- Status of GOSAT and GOSAT-2
- GOSAT Air Pollution Watch
- Preparation of GOSAT-2 Validation
  - New TCCON site in Southeast Asia
  - Test of smaller FTS
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.
Announcement (August 4, 2015)

- Around the noon of August 2nd, 2015 (Japanese Standard Time), the operation of Thermal Infrared (TIR) part of Fourier Transform Spectrometer (FTS) onboard GOSAT was terminated due to the sudden stop of its mechanical cooler to cool TIR detector to -200°C (≈ 70K).

- No impacts have been found in Shortwave Infrared (SWIR) part of FTS and Cloud and Aerosol Imager (CAI) so far. Carbon dioxide and methane observation by SWIR and aerosol/cloud observation by CAI are continued without termination.

- The root causes of the sudden stop of the cooler and treatments are under investigation.

- GOSAT has finished its nominal operation period (5 years) in January 2014, and is currently in its extended operation period.
GOSAT-2 in Space

FTS-2

CAI-2

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# Quick Overview of GOSAT and GOSAT-2

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<th>GOSAT Specifications</th>
<th>GOSAT-2 Requirements</th>
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<tr>
<td><strong>Launch year and life time</strong></td>
<td>Jan. 2009, 5 years</td>
<td>FY2017, 5 years</td>
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<td><strong>Satellite</strong></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>
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<td><strong>Orbit</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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<td><strong>Target gases</strong></td>
<td>CO₂, CH₄, O₂, O₃, H₂O</td>
<td>CO₂, CH₄, O₂, O₃, H₂O, CO</td>
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| **Fourier Transform Spectrometer** | Band 1: 0.76 – 0.78 µm  
       Band 2: 1.56 – 1.72 µm  
       Band 3: 1.92 – 2.08 µm  
       Band 4: 5.6 – 14.3 µm  
       IFOV = 10.5 kmφ  
       Pointing = ±20° (AT), ±35° (CT)  
       Polarimetry = Band 1, 2, 3 | Band 1: 0.75 – 0.77 µm  
       Band 2: 1.56 – 1.69 µm  
       Band 3: 1.92 – 2.33 µm  
       Band 4: 5.5 – 8.4 µm  
       Band 5: 8.4 – 14.3 µm  
       IFOV = 9.7 kmφ  
       Pointing = ±40° (AT), ±35° (CT)  
       Polarimetry = Band 1, 2, 3 |
| **Cloud and Aerosol Imager**   | Nadir  
       B1 = 380 nm  
       B2 = 674 nm  
       B3 = 870 nm  
       B4 = 1600 nm  
       B1-B3 = 500 m / 1000 km,  
       B4 = 1500 m / 750 km | B1-5: forward, B6-10:backward  
       B1 = 343 nm  
       B2 = 443 nm  
       B3 = 674 nm  
       B4 = 869 nm  
       B5 = 1630 nm  
       B1-B4, B6-B9 = 460 m / 920 km  
       B5, B10 = 920 m / 920 km |
| **Other new features of GOSAT-2** | Intelligent pointing using FTS-2 FOV camera, fully programmable (target mode) observation, and improved SNR. |
GOSAT-2 FTS-2
Optical Layout and External View

FTS-2 is designed based on CrIS (Cross-track Infrared Sounder) onboard NASA’s Suomi NPP.
GOSAT-2 Joint Project

UNFCCC and UNEP CCAC

MOE

Application of GOSAT-2 data to environmental policy

JAXA

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

NIES

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

GOSAT-2 Science Team

GOSAT-2 Research Announcement (RA) PIs

International and Domestic Science Communities

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.
GOSAT CAI Processing Flow
(1) Cloud Mask

- Discriminate clouds from land, urban polluted air, dust, and smokes.
  - UV band brightness threshold (High UV reflectance => clouds)
  - UV band spatial smoothness (Smooth => other than clouds)
  - Current parameters are determined empirically using CAI images in Russia, China, and SE Asia.

China, October 9, 2014

- Dark grey pixels = Cloud
- Pink pixels = Urban polluted air
GOSAT CAI Processing Flow
(1) Cloud Mask (Smoke case)

Russia, July 17, 2015

Indonesia, June 20, 2013

Dark grey = Cloud, Yellow = Smoke
GOSAT CAI Processing Flow
(2) AOT(380nm) Estimation

- Estimate Aerosol Optical Thickness at 380 nm for non-cloud pixels.
  - Modified Kaufman Method (Fukuda et al., JGR, 2013) over land.
  - Use difference between observed and theoretical aerosol free surface reflectances in the UV region to estimate AOT (380).

China, October 9, 2014
(3) PM2.5 Estimation

- 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.
GOSAT CAI Processing Flow

(3) PM2.5 Estimation – Regression Residuals

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

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

- PM2.5 = 0 – 500 mg/m³
  - RMSE = 67.8 mg/m³
  - N = 256

Blue: Beijing, winter
Orange: Beijing, summer
Gray: Shenyang, winter
Yellow: Shenyang, summer
GOSAT Air Pollution Watch
Sample 1: Indonesia June 20, 2013 (P9F31)

Using Beijing/Shenyang regression
Using Beijing/Shenyang regression
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.

- Contact: Tsuneo Matsunaga (matsunag@nies.go.jp)
A New TCCON Site in Southeast Asia
(Total Carbon Column Observing Network)

**FY 2014**
- Potential sites were identified and visited.
- Bruker 125 HR FTS with solar tracker were installed in the container at NIES.

**FY 2015**
- Decide the site considering scientific, logistical, and human resource aspects.
- Negotiate with various stakeholders and conclude MOU.
- Adjust and evaluate the newly procured FTS at NIES

**FY 2016**
- Conclude all the contracts
- Move FTS from Tsukuba to the site and start its operation

a) Locations of three candidate sites in Philippines, b) Landscape at Burgos, c) Installation of a container for FTS at NIES, d) A high resolution FTS in the container.
Smaller (cheaper) FTS are being tested...

- Bruker 125 HR FTS is commonly used among TCCON stations. But it is so expensive and large to install many places.

- Currently, cheaper and smaller FTS such as Bruker EM27 are being tested to evaluate its observation performance as well as easiness of operation and maintenance.

- If smaller FTS work well, we may increase the number of validation sites especially in Southeast asia.

EM27 test in Railroad Valley, NV

EM27 test at Caltech, CA
Thank you for your attention.

For more information, send e-mails to gosat-2-info@nies.go.jp

or

Visit our website:
http://www.gosat-2.nies.go.jp
Forest Fires in Indonesia and Atmospheric Pollution in Singapore

Singapore, morning of June 21, 2013 (Reuter)

GOSAT CAI (June 20, 2013)
Urban Atmospheric Pollution in China Observed by GOSAT CAI

In Beijing (October 5, 2013)

Photo by W. Takeuchi (Univ. Tokyo)

PM2.5 Concentration at US Embassy in Beijing

GOSAT Observation on Oct. 2

GOSAT Observation on Oct. 5