GOSAT results

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GOSAT on orbit since 2009

Level 1
TOA (top of atmosphere) radiance

from OCO-2 Website

Level 2
Column-averaged dry air mole fraction of CO₂ and CH₄

Level 4
CO₂ and CH₄ emissions and sinks

TOA (top of atmosphere) radiance

GOSAT CO$_2$ and CH$_4$ over 7.5 years

Monthly mean global CO$_2$ and CH$_4$ since 2009

The typical accuracy of retrieved column-averaged dry air mole fractions of CO$_2$ and CH$_4$ are 2ppm or 0.5% and 13ppb or 0.7%, respectively.
**GOSAT 7.5-year operation**

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<td>FTS Nominal</td>
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<td>Pointing Pattern</td>
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<td>FTS Primary</td>
<td>5p-CT</td>
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<td>FTS interferogram</td>
<td>No bias</td>
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<td>FTS Operation</td>
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<td>FTS L1B V161.161</td>
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<td>Re-processing (no geometry correction)</td>
<td>Latest version</td>
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<tr>
<td>FTS L1B V201.202</td>
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<td></td>
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<td>Re-processing (pointing error, biased interferogram corrected)</td>
<td>Latest version</td>
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<tr>
<td>CAI L1A V130.131</td>
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<td>Latest version</td>
</tr>
</tbody>
</table>

- GOSAT is currently full-operated FTS and CAI by single solar paddle power, redundant pointing mirror, and obtains center-biased double-side interferogram.
- FTS L1 v201.202 processing is improved that weighting function is applied to asymmetrical interferogram to become the same ILS and the same sampling over the whole term data.
Vicarious calibration campaign at RRV

Path 37 from West

33.0° deg

25° deg

19° deg

Path 36 from East

19.9° deg

TOA Spectral radiance

High altitude

Surface and Profile of Pressure, Temperature, Humidity

Surface Thermal radiation

Variability

Surface Spectral Reflectance

BRDF

Column-averaged XCO₂ XCH₄

Vertical CO₂ CH₄

Horizontal CO₂ CH₄

Aerosol Optical Thickens

TOA  Spectral radiance

19.9° deg

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GOSAT radiances degradation

FTS radiances (0.76, 1.6, 2.0 um)

CAI radiances (0.38, 0.67, 0.87, 1.6 um)

- RDF for 6 years from seven annual vicarious calibration campaigns. The lines show the model derived from the onboard solar diffuser data.
- Latest FTS v201.202 records the best estimated radiances after degradation correction.

Kuze et al., AMT, 2016
GOSAT validation

from NIES GOSAT Website
### TCCON – XCO$_2$ and XCH$_4$ standards for space-based measurements

#### Group | Version | XCO$_2$ | XCH$_4$
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Bias[ppm]</td>
<td>STD[ppm]</td>
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<tr>
<td>NIES-FP</td>
<td>v2.0</td>
<td>-1.5</td>
<td>2.1</td>
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<tr>
<td>NIES-PPDF-DOAS</td>
<td>-</td>
<td>-0.43</td>
<td>1.8</td>
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<tr>
<td>ACOS</td>
<td>B3.5</td>
<td>0.1</td>
<td>1.7</td>
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<tr>
<td>RemoTeC-FP (bias correction)</td>
<td>v2.3.7</td>
<td>0.01</td>
<td>1.93</td>
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<tr>
<td>U-Leicester-Proxy</td>
<td>CH4 v4</td>
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<table>
<thead>
<tr>
<th>Source</th>
<th>Details</th>
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<tbody>
<tr>
<td>ACOS: Lindqvist et al., ACP, 2015,</td>
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- For long-term consistency, comparison of seasonal and annual trend around TCCON sites is performed in the recent papers. (Lindqvist, ACP, 2015 etc.)
Inter-comparison between GOSAT and OCO-2

Radiometric calibration

Annual Vicarious Calibration at the desert playa in Nevada

CO₂ & CH₄ profile

Prelaunch X-CAL

In situ CO₂ and CH₄ on AJAX

Retrieved XCO₂ & XCH₄

Coincident Target

Calibrated GOSAT and OCO-2 radiance spectra agrees within 5% for all bands.

Retrieved XCO₂ bias is much less than 0.5ppm over match up observations points.

Parameter Comparison over match up points (>200)
Optimization of observation points

FTS observation in June 22-24, 2016

Grid observation
Target observation

Expanding glint observation

Dithering among cloudy area

Tracing islands for covering land area

West US for emission targets

Target observation

Grid observation
GOSAT result – Anthropogenic CO₂ detection

GOSAT CO₂ observations are more enhanced than model data with inventories.

<table>
<thead>
<tr>
<th>Area No.</th>
<th>Country / City</th>
<th>Max. anthropogenic CO₂</th>
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<tbody>
<tr>
<td>1</td>
<td>China / Zhangjiakou, Anshan, Harbin, Tianjin</td>
<td>6.2 ppm</td>
</tr>
<tr>
<td>2</td>
<td>India / Kolkata</td>
<td>2.1 ppm</td>
</tr>
<tr>
<td>3</td>
<td>Uzbekistan etc.</td>
<td>2.8 ppm</td>
</tr>
<tr>
<td>4</td>
<td>North Saudi Arabia, Jordan</td>
<td>2.1 ppm</td>
</tr>
<tr>
<td>5</td>
<td>US / Pittsburgh</td>
<td>2.1 ppm</td>
</tr>
<tr>
<td>6</td>
<td>US / Los Angels</td>
<td>3.5 ppm (1x1deg, Jun2009)</td>
</tr>
<tr>
<td>7</td>
<td>Mexico / Acapulco</td>
<td>2.7 ppm (Jun2009)</td>
</tr>
<tr>
<td>8</td>
<td>Japan / Tokyo</td>
<td>0.5 ppm (Dec2014)</td>
</tr>
</tbody>
</table>

Large cities, oil fields have more emissions than a priori inventory*.

*Power plant, fossil fuel from ODIAC/CARMA
*Biomass burning from GFAS V1.2

GOSAT press release (Sep-01, 2016)
GOSAT CH$_4$ observation at anthropogenic emission areas such as large cities, agriculture, livestock, energy development shows higher event than the a priori inventory data*.

*EDGAR v.4.2 FT2010
Summary

(1) GOSAT operation
• Successful fully operation of FTS and CAI over 7.5 years since 2009

(2) GOSAT products
• Latest FTS L1 V201.202 and CAI L1 V130.131 are available in whole observation term.
• L2 XCO2 and XCH4 v02.xx are available for the previous L1 V161.161. L2 processing for L1 V201.202 has just started.
• L3 and L4 are also available corresponding to the latest L2.
• GOSAT L2 are also produced by other organization algorithms (ACOS, RemoTec, Leicester, Bremen, Yonsei etc.)

(3) Calibration, validation and inter-comparison with OCO-2
• Railroad valley campaign collaboration with OCO-2
• XCO2 and XCH4 validation with TCCON data
• Inter-comparison of GOSAT and OCO-2 in spectra and XCO2

(4) Observation points optimized by target observation
• Emission target in west US, Dithering in Amazon and Africa, Expanding sunglint observation
GHG coordination

CGMS-44:
• CMA, JAXA, and NASA reports on satellite CO$_2$ observation
• Recommendation of CGMS-CEOS cooperation for contribution to WMO Vision for WIGOS 2040

2016 CEOS SIT Technical WS:
• CEOS-CGMS CO$_2$ coordination – confirm at Plenary to write to CGMS noting AC-VC efforts and invitation to augment

• AC-VC might coordinates with CGMS in currently planned Carbon Workshop etc, not making new working group.
• Accuracy improvement is important for follow-on GHG mission progress and continuous GHG observation. GHG cal/val activities will be promoted by CEOS AC-VC and WGCV collaboration framework.
Backup
GOSAT FTS products release history

Oct. 2009  Level 1 (Observation spectra) to public
Feb. 2010  Level 2 (SWIR $X_{CO2}$ and $X_{CH4}$: column averaged dry air mole fraction, v00.**) to public
Aug. 2010  Level 2 (SWIR $X_{CO2}$ and $X_{CH4}$, v01.**) to public
Nov. 2010  Level 3 (SWIR $X_{CO2}$ and $X_{CH4}$ spatially interpolated global distribution in monthly mean) to public
Mar. 2012  Level 2 (TIR $CO_2$ and $CH_4$ density profiles) to public
Jun. 2012  Level 2 (SWIR $X_{CO2}$ and $X_{CH4}$, v02.**) to public
Dec. 2012  Level 4A (CO$_2$ flux estimation) and Level 4B (Simulated CO$_2$ 3-D distribution) to public.

↓ L1 version-up many times... 1 or 2 per year

Jun. 2012  Level 2 $X_{CO2}$ and $X_{CH4}$ v02.** release
May 2013  Level 1 v16*.160 release
Mar. 2014  Level 4A (CH$_4$ flux estimation) and Level 4B (Simulated CH$_4$ 3-D distribution) to GOSAT RA PIs (to public in this summer).
Jul. 2015  Level 1 v200.xxx release
Mar. 2016  Level 1 v201.202 release (latest version)