How GOSAT has provided uniform-quality spectra and optimized global sampling patterns for seven years

June 7, 2016, Kyoto
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GOSAT status
“New Tatami mat is fine. New ??? is also fine. “
But Older instrument becomes much better.

Well characterized and calibrated.
(1) Very slow radiometric degradation after two years in space

(2) More stable secondary pointing mechanism than the primary one.
Three anomalies: root cause and solutions are made clear.

(3) Minimized calibration errors in both SWIR and TIR

(4) Well-calibrated and user-convenient L1B V201 (approximately 7 years) is being reprocessed in order to provide the same spectral quality and seamless data.
One of the two solar paddles stopped its rotation. (June 2014)

(1) Metrology alignment changed  >  Biased interferogram (2014)
(2) Pointing mechanism switched (2015)

More detailed information
Lunar calibration after the 2014 solar paddle accident has been canceled.
Orbit control scheduled in 2016 summer will be postponed.
GOSAT orbit and local time

Out-of-plane orbit control for the adjustment of the inclination of the orbit phase: to be postponed to avoid rapid ZPD shift (FTS mechanism anomaly) and continue glint and target observations.
Level 1 V201 and Calibrations
Radiometric Calibration
-very slow after rapid degradation for the first 2 years-

TANSO-FTS
(0.76, 1.6, 2.0 μm)

TANSO-CAI
(0.38, 0.67, 0.87, 1.6 μm)

(1) Radiometric Degradation Factors using RRV (Nevada) campaign data
(2) FTS L1B V201 provide both classic (unit of V/cm\(^{-1}\)) and radiance converted and degradation corrected (unit of W/cm\(^2\)/str/cm\(^{-1}\)) radiance spectra
Spectroscopic Calibration

-Precisely the same spectral resolution has been maintained-

Zero path difference (ZPD) shift (half laser fringe) since launch.

For all retrieved spectra either by repositioning ZPD or by applying an asymmetric weighting function when the shift is too large.
Geometric Calibration
- Stable secondary pointing mechanism -

<table>
<thead>
<tr>
<th>Pointing system</th>
<th>Pointing offset</th>
<th>L1B V201 Geolocation</th>
<th>Best-estimate geolocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary (PM-A)</td>
<td>Time dependent</td>
<td>Not corrected</td>
<td>Corrected</td>
</tr>
<tr>
<td></td>
<td>(correction table of every two week)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(AT and CT angles independent)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary (PM-B)</td>
<td>Constant since Feb. 2015</td>
<td>Corrected</td>
<td>Corrected</td>
</tr>
<tr>
<td></td>
<td>CT angle dependent</td>
<td></td>
<td>(The same as the geolocation)</td>
</tr>
</tbody>
</table>

Pointing offset since launch.

(1) No offset the angular resolver has as yet been detected.

(2) The axes of the optical path and CT rotation are slightly misaligned: repeatable and L1B V201 product corrected geolocations better than 0.5 km.

(3) When planning target observations, offset correction is implemented. No need for additional correction using the CAM data.
Level 1 V210 for TIR
Modified non-linearity correction

Greenland Mar23, 2015 Double Difference
SSEC S-HIS FTS onboard ER-2 vs GOSAT (V203)

\[
\tilde{R}_{OBS}^{GOSAT} - \tilde{R}_{CALC}^{GOSAT} - (\tilde{R}_{OBS}^{SHIS} - \tilde{R}_{CALC}^{SHIS})
\]

Known issue @14.5 micron GOSAT(V161161) – AIRS SNOs

\[
V_{NLcorrected} = V_{Pamp} + a_{nlc} V_{Pamp}^2
\]

\[
a_{nlc} = 0.6056 > 0.7057
\]

\[
V_{Pamp} = V_{DCoffset}(time) + \left(\frac{V_{DC} - V_{DCoffset}(time)}{g_{DC}}\right) + \frac{V_{AC}}{g_{AC}}
\]

New V203 sample for 201
(7 year data set in JAXA JSS2)
Spectral bias were removed by applying new DC electrical circuit model to nonlinearity correction.

Courtesy of R. Knuteson, F. Kataoka, J. Yoshida

June, 2016, IWGGMS
- optimized global sampling patterns
Present pattern with an agile secondary pointing system

March 2011 Grid & Specular Reflection
Further modifications

Simple 1deg grid is not appropriate to retrieve emission amount from point source

Different optimized spatial and temporal sampling pattern.
- CO$_2$ (missing sink) vs CH$_4$ (localized different emission sources)
- Surface (emission sources) vs. Atmosphere (transportation)

> GOSAT observed spatial and temporal pattern with measurement errors (typically 0.5%) must be characterized first.

Gauss model proposed to present Oil Field in California (Turner et al., 2015 ACP)

Red: underestimated without GOSAT
Blue: overestimated (Turner et al.)
- Conclusion and Future plan
Conclusion and Future plan

Remaining errors and the next Update

(1) 7.5 years dataset of V201 are available

(2) 7 year sample V203 product for V210 in review.
   - New TIR non-linearity correction applied.
   - Glint flag in extended region modified.
   - Will be released as V201 after fulltime data are reprocessed.

(3) Radiometric calibration errors were much reduced but still exist due to:
   - SWIR spectral feature within a band in prelaunch calibration (minor modification may be applied)
   - TIR polarization sensitivity correction in CH$_4$ band (correction factor to be provided)

(4) Target observation can be added more and optimized.
2015/6/29 RRV, path 37 gain M
・V161 (v007)
・V201 (v201)
・V201 (v007) = BestEstimated
(radiance conversion) table : available from NIES GUIG
# Wavenumber in L1B and radiance conversion table

## Radiance Conversion Table (prelaunch data was reprocessed with V070, V150, V201)

<table>
<thead>
<tr>
<th></th>
<th>WL start (cm(^{-1}))</th>
<th>WL corrected (cm(^{-1}))</th>
<th>Number of rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>V070 (July 2009)</td>
<td>12400.143 (0.5 cm(^{-1}) interval)</td>
<td>(not shown)</td>
<td>2601</td>
</tr>
<tr>
<td>(V070c) (May 2010)</td>
<td>12400.143</td>
<td>(not shown)</td>
<td>2601</td>
</tr>
<tr>
<td>V150 (May 2012)</td>
<td>12400.143</td>
<td>12402.586</td>
<td>2601</td>
</tr>
<tr>
<td>V201 (March 2016)</td>
<td>12400.143</td>
<td>12402.586</td>
<td>2601</td>
</tr>
</tbody>
</table>

## Level 1B product

<table>
<thead>
<tr>
<th></th>
<th>WL start (cm(^{-1}))</th>
<th>Interval (cm(^{-1}))</th>
<th>Number of rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>V150, 161 (raw)</td>
<td>12400.078</td>
<td>0.19949</td>
<td>6565</td>
</tr>
<tr>
<td>V201 (raw)</td>
<td>12400.078</td>
<td>0.19949</td>
<td>6565</td>
</tr>
<tr>
<td>(best estimated)</td>
<td>Converted with V070c V150 table</td>
<td>12900.008</td>
<td>1504</td>
</tr>
<tr>
<td>V201 (Best estimated)</td>
<td>Will be converted with V201</td>
<td>12900.008 (T.B.D.)</td>
<td>1504</td>
</tr>
</tbody>
</table>

The original radiance conversion table was made in 2008 using the catalogue-base laser-wavelength of 1.31 as shown below. “The corrected” uses the actually measured wavelength of the primary laser. L1B wavenumber is calculated with the above primary sampling laser (prelaunch) vacuum vale. Please note that the small change due to gradual alignment change (0.999978 in 2009 and 0.999970 in 2012) described in Fig.12, Kuze et al., 2012, AMT is NOT considered in L1B V201 as it is very small.

Initial Pre-launch calculation until 2008, 1.31 micron (diode laser catalogue value).
Primary Sampling laser (prelaunch) Vacuum (used since launch until now), 1.309742 micron (measured prelaunch).
Secondary Sampling laser (pre-launch) Vacuum (never used in orbit), 1.309688 micron (measured prelaunch).
V201 note: spectral range selection, calibration accuracy, noise estimation

<V201 Best estimated radiance, spectral range selection>
We are providing the best estimated radiance for the users who are not familiar with the instrument and degradation in orbit. We asked the optical vendor to provide an optical bandpass filter that has high and flat transmittance between 12900 cm\(^{-1}\) (775.2nm) and 13200 cm\(^{-1}\) (757.6nm). So this range has white (spectrally flat) noise even after radiance conversion. But outer the spectra is located, the radiance-converted noise becomes larger if we provide wider range.

<V201 Best estimated radiance, calibration accuracy>
For professional users, we recommend to use (1) raw data with spectrally white noise (\(\text{V/cm}^{-1}\)), (2) the Radiance Conversion Factor of Feb 2016 (excel file) and (3) radiance degradation correction (1/(radiance conversion factor)) by Tommy Taylor-san). The best estimated radiance is not perfect yet as radiance conversion factor used is an older version. But it is not so bad. The difference between the above-mentioned manually-converted value and the best estimated one is smaller than 1%.

<V161 vs V201, Chi^2>
Noise level can be estimated for out of band spectra. V161 out of band spectra include both real noise and artifact from non-linearity. V201 ones are close to noise. Therefore in some case, V161 Chi^2 look smaller.