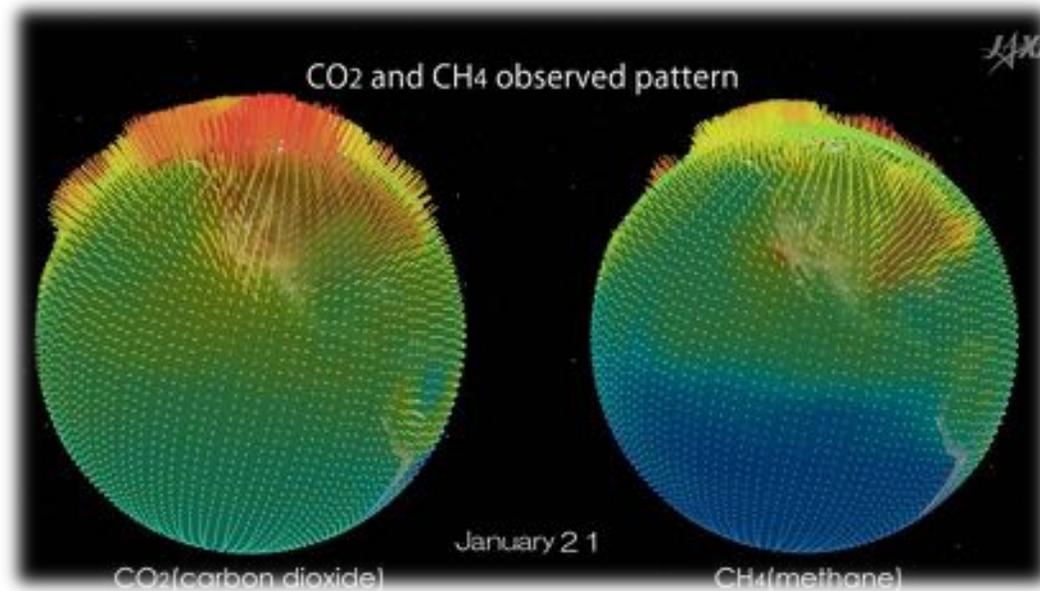# How GOSAT has provided uniform-quality spectra and optimized global sampling patterns for seven years

June 7, 2016, Kyoto

Akihiko KUZE, Kei Shiomi, Hiroshi Suto

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 yeas 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.
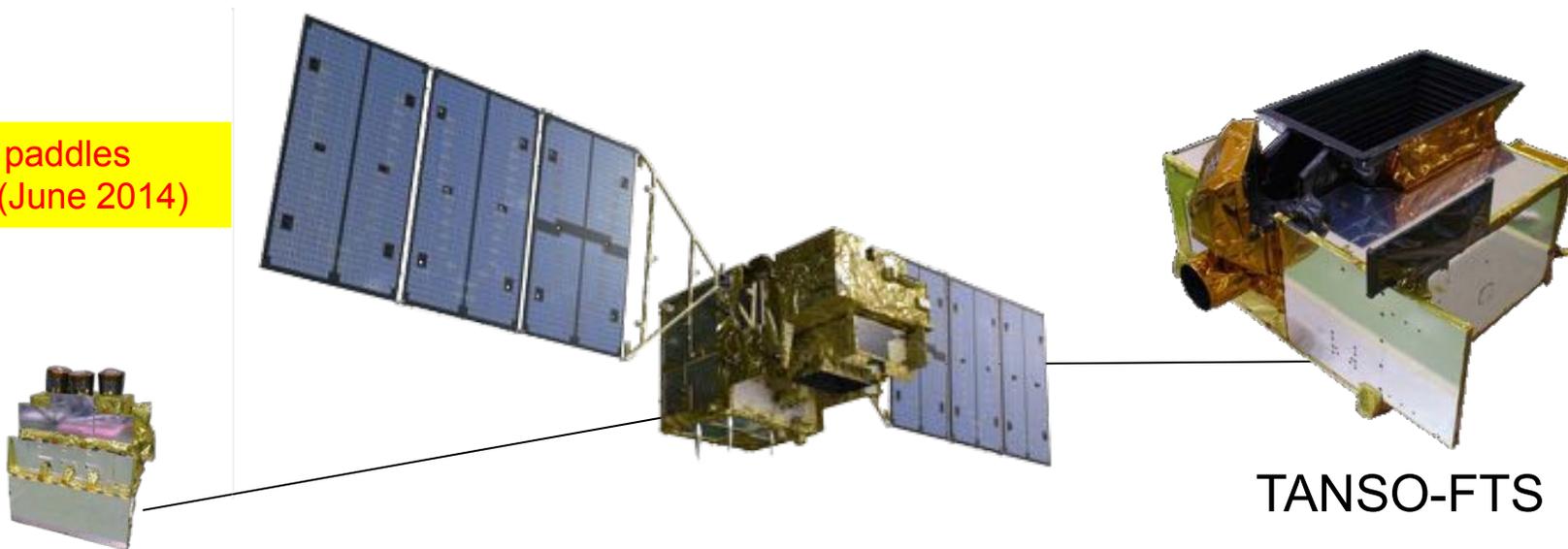
GOSAT and TANSO status in space

One of the two solar paddles stopped its rotation. (June 2014)

TANSO-CAI

Healthy

TANSO-FTS

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

More detailed information
A. Kuze et al.: Update on GOSAT TANSO-FTS in space,
Atmos. Meas. Tech., 2016

GOSAT 7.5 years operation

	2009	2010	2011	2012	2013	2014	2015	2016
Milestone	*Launch					* * Solar paddle accident Unstable Pointing	* * Switching Pointing mechanism Cryocooler suspend	
FTS Nominal Pointing Pattern	5p-CT		3p-CT				1, 3 p-CT	3p-CT
FTS Pointing	Primary						Secondary	
FTS interferogram	No bias					800 fringes bias	650	1100
FTS Operation	SWIR (S) and TIR (T)						S	S & T
FTS L1B V161.161	Re-processing (no geometry correction)				Latest version			
FTSL1B V201.202	Re-processing (pointing error, biased interferogram corrected)							Latest version
CAI L1A V130.131	Latest version							

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.
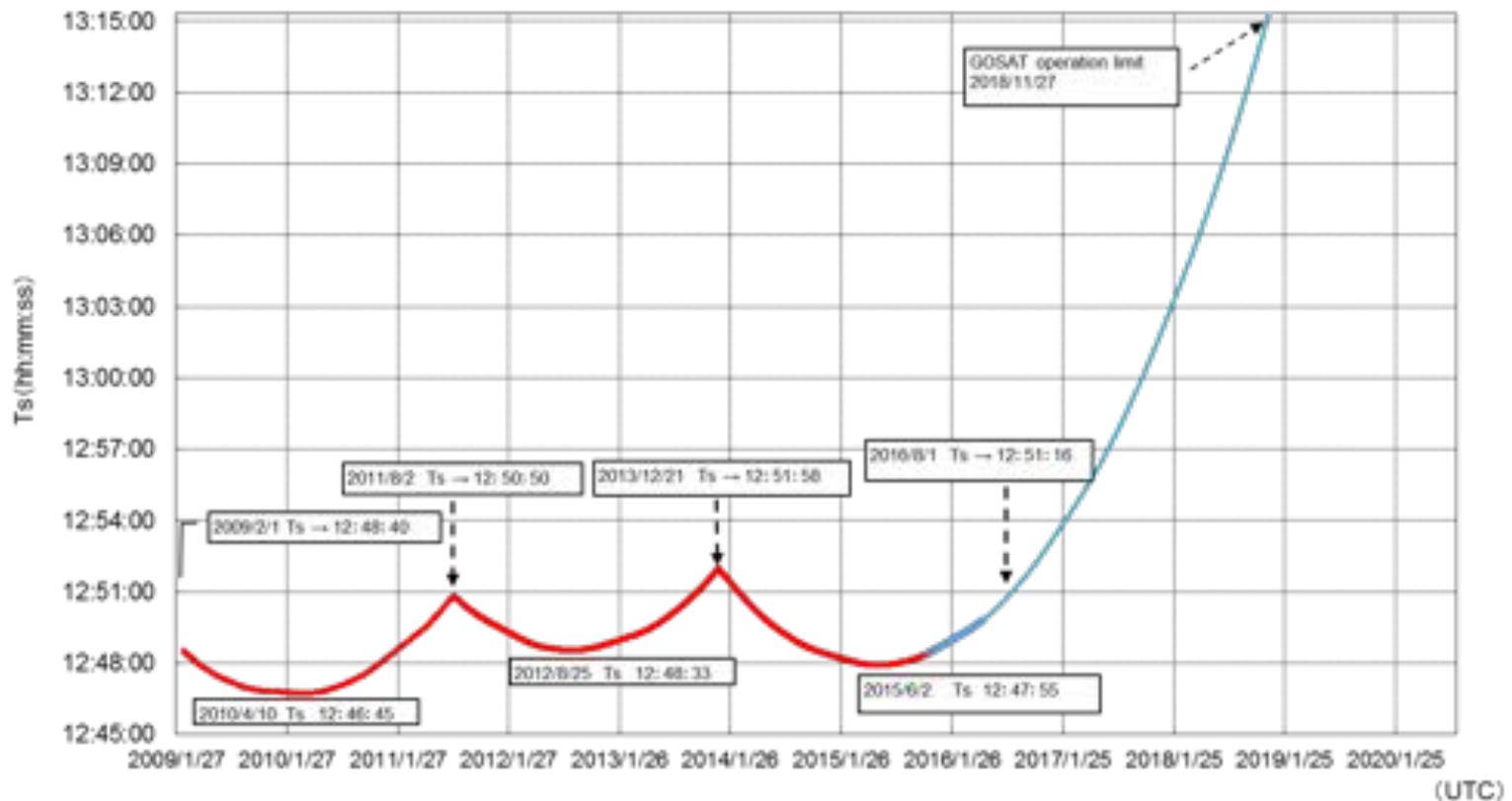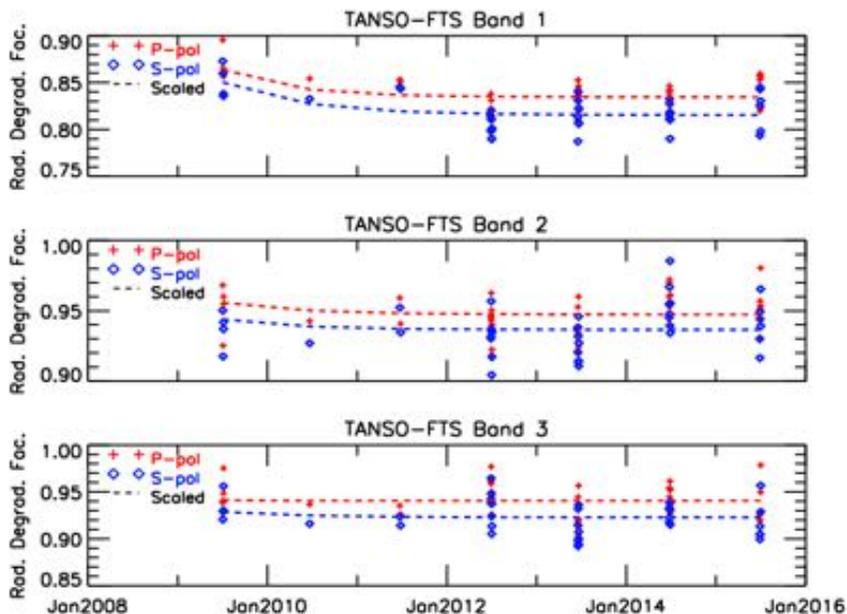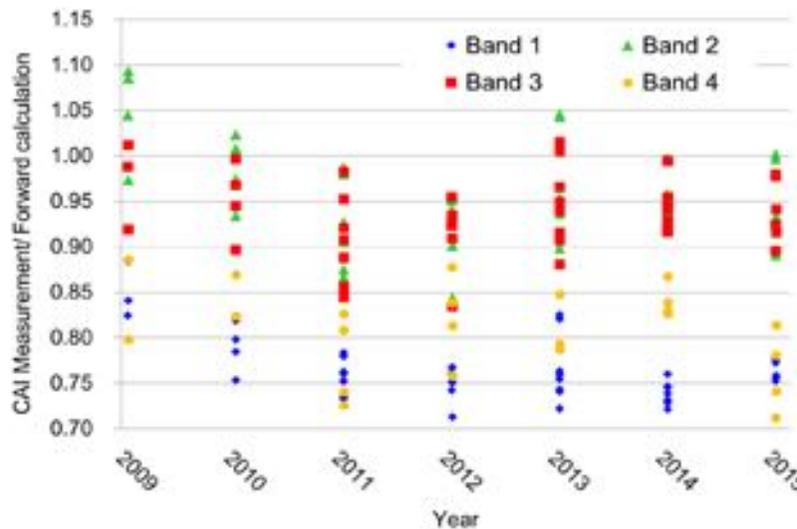
Level 1 V201and Calibrations

Radiometric Calibration
-very slow after rapid degradation for the first 2 years-
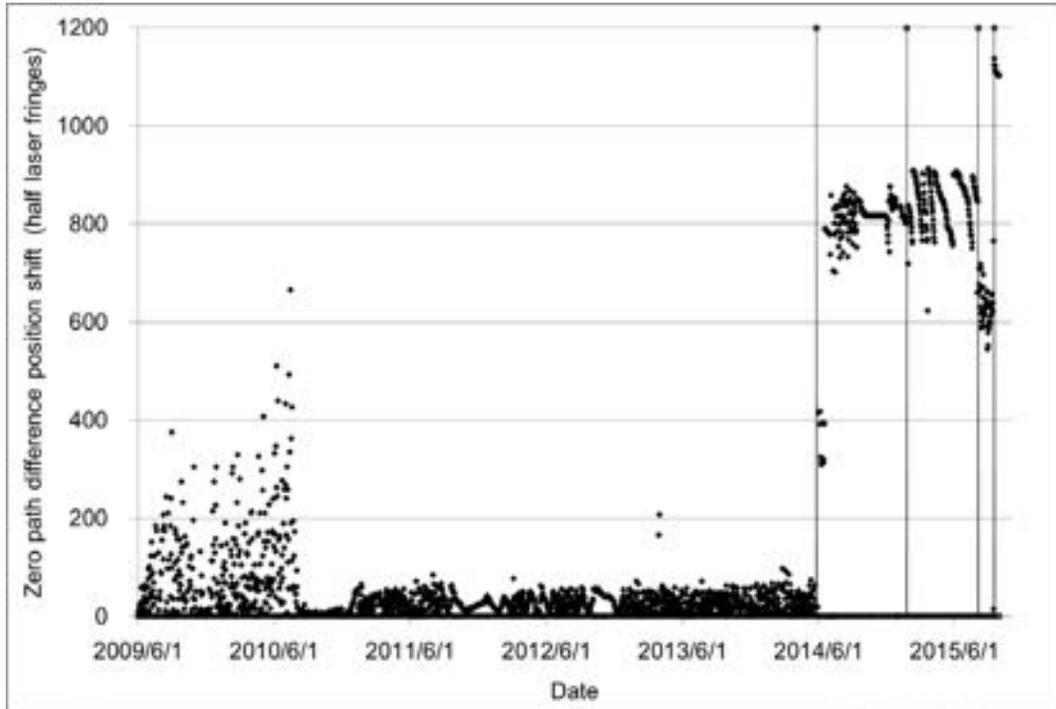

TANSO-FTS
(0.76, 1.6, 2.0 μm)

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
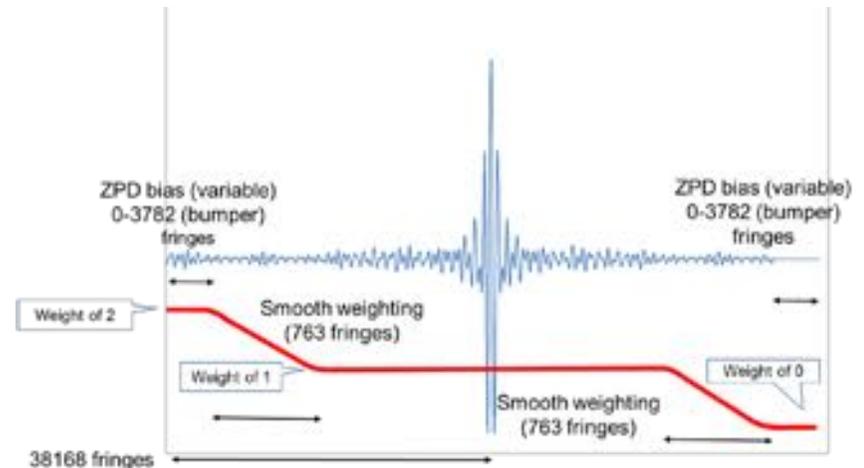and degradation corrected (unit of W/cm^2/str/cm^{-1}) radiance spectra

Spectroscopic Calibration
-Precisely the same spectral resolution has been maintained -

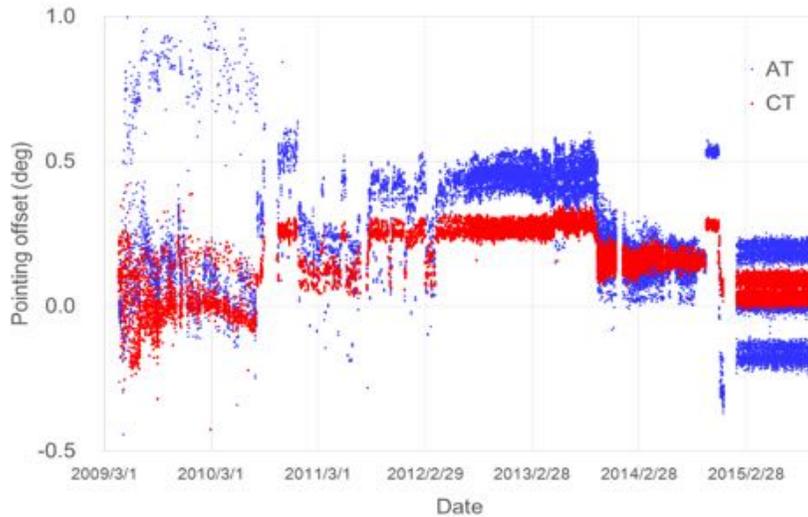Zero path difference (ZPD) shift (half laser fringe) since launch.

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 -

Pointing offset since launch.

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

(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.
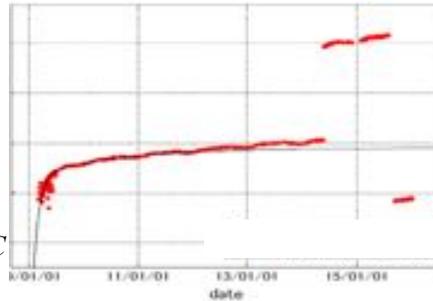
Level 1 V210 for TIR
Modified non-linearity correction

GOSAT v161 and AIRS SNOs: 14.5 μm Brightness Temperature
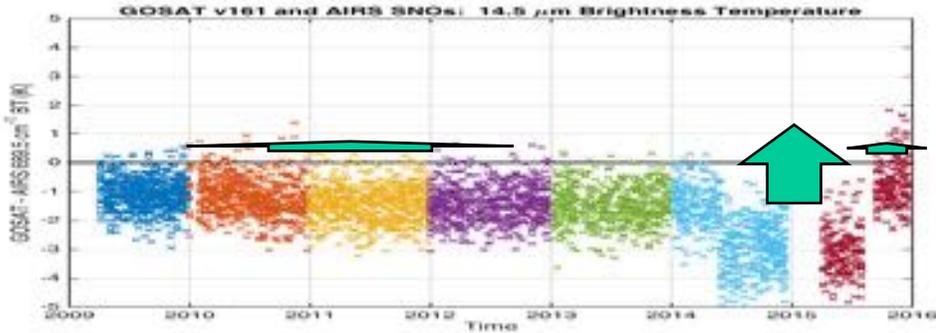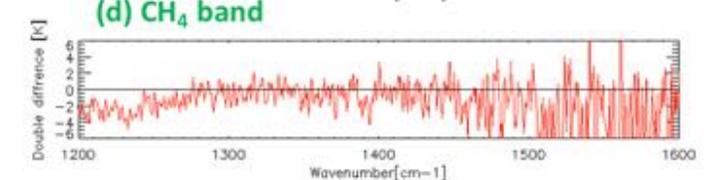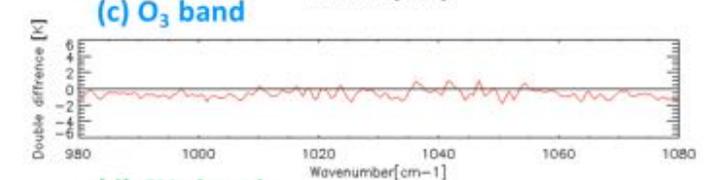
Known issue @14.5 micron   GOSAT(V161161) – AIRS SNOs

$$V_{NLcorrected} = V_{Pamp} + a_{nlc}V_{Pamp}^2$$ $a_{nlc} = 0.6056 > 0.7057$

$V_{DCoffset}(time)$

$$V_{Pamp} = -\left((V_{DC} - V_{DCoffset}(time)) \middle/ g_{DC} \right) - V_{AC} \middle/ g_{AC}$$

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

$$= (\widetilde{R}_{OBS}^{GOSAT} - \widetilde{R}_{CALC}^{GOSAT}) - (\widetilde{R}_{OBS}^{SHIS} - \widetilde{R}_{CALC}^{SHIS})$$

(a) CO_2 band

(b) window ch.
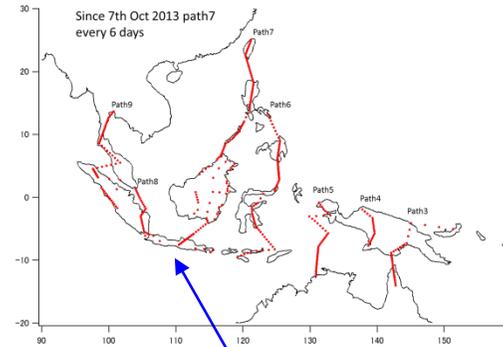
(c) O_3 band

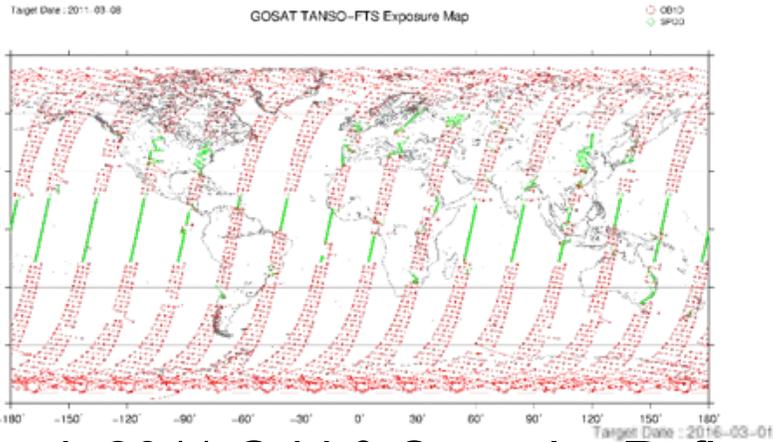(d) CH_4 band
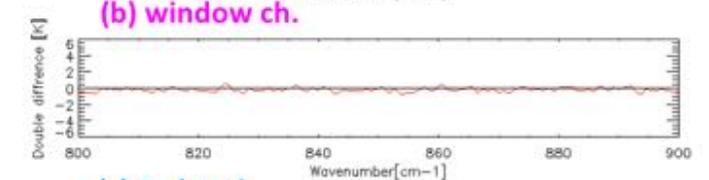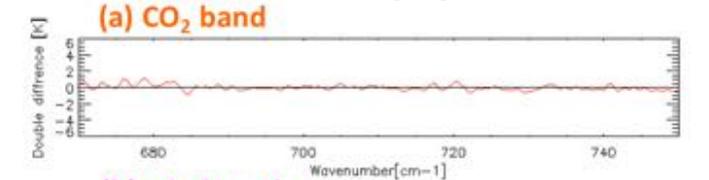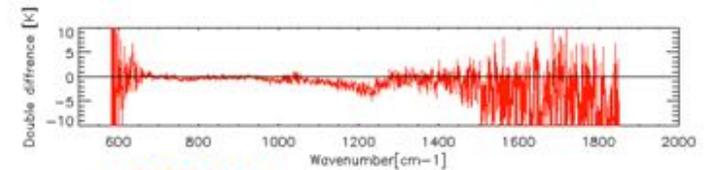
New V203 sample for 201
(7 year data set in JAXA JSS2)
Spectral bias were removed by applying new DC
electrical circuit model to nonlinearity correction.
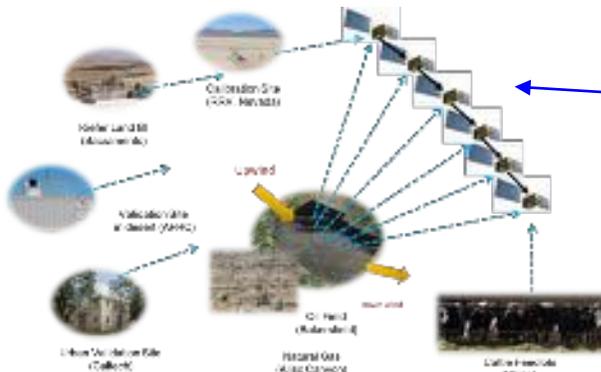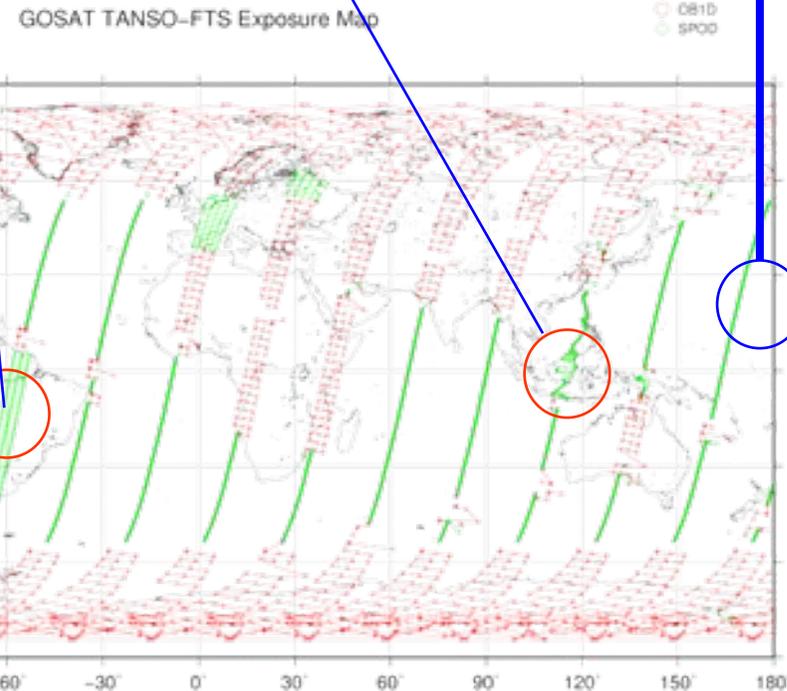
June, 2016, IWGGMS

Courtesy of R. Knuteson, F. Kataoka, J. Yoshida   11

- optimized global sampling patterns

Present pattern with an agile secondary pointing system

March 2011 Grid & Specular Reflection
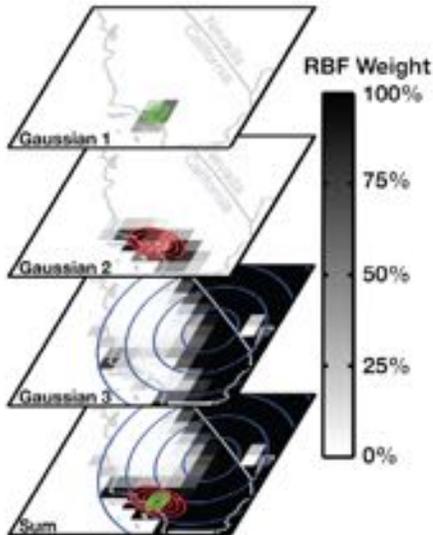
Mar., 1 2016

Further modifications

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

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

Emission Scaling Factors (Posterior / Prior)

ΔCH_4: +27.9 Tg a^{-1}
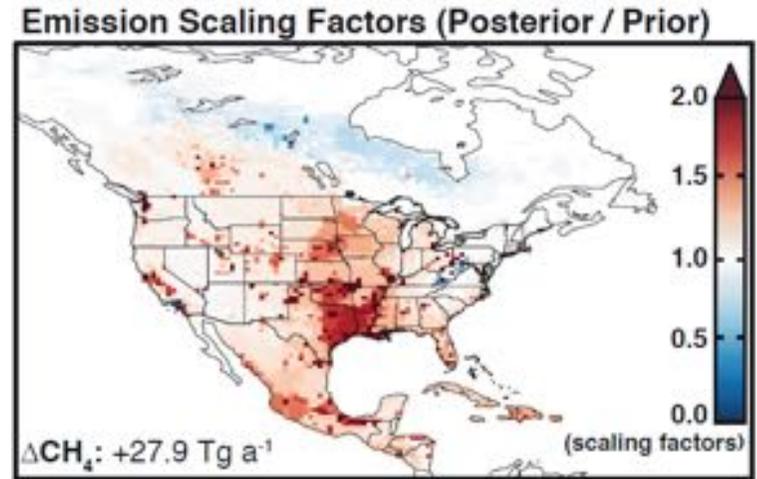
Red: underestimated without GOSAT
Blue: overestimated (Turner et al.)

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.

- 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.
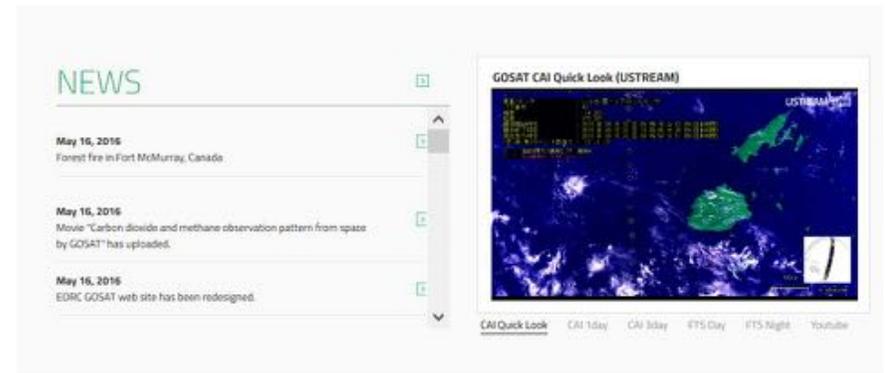
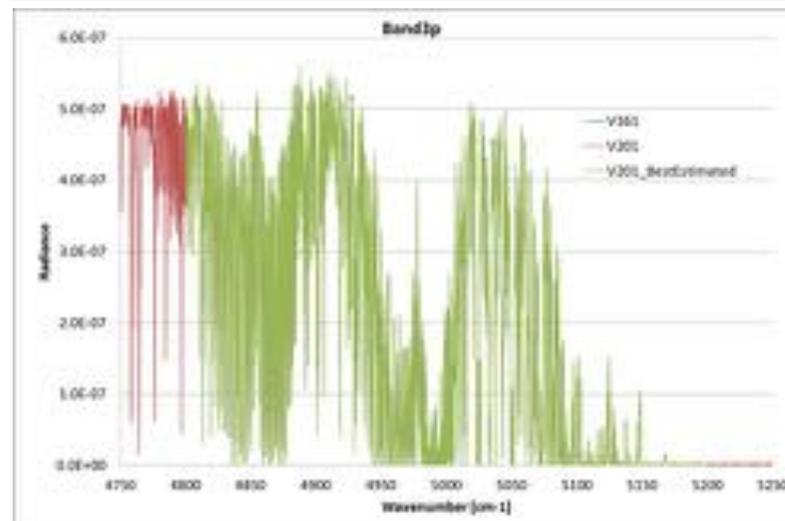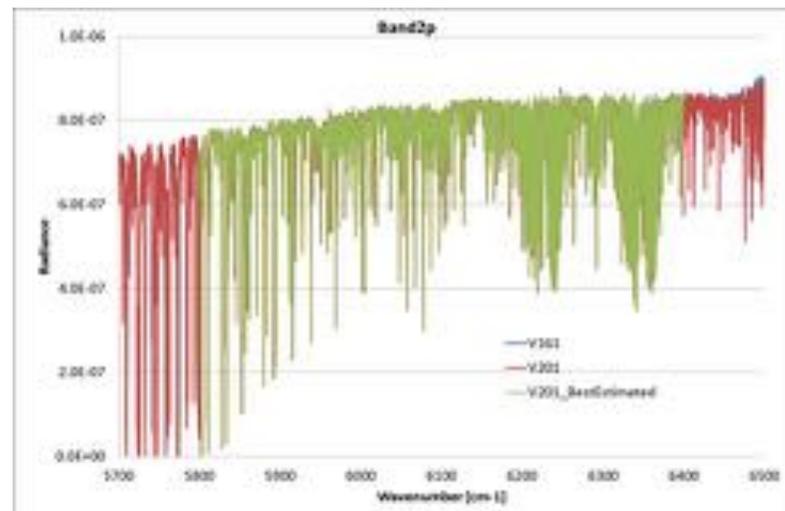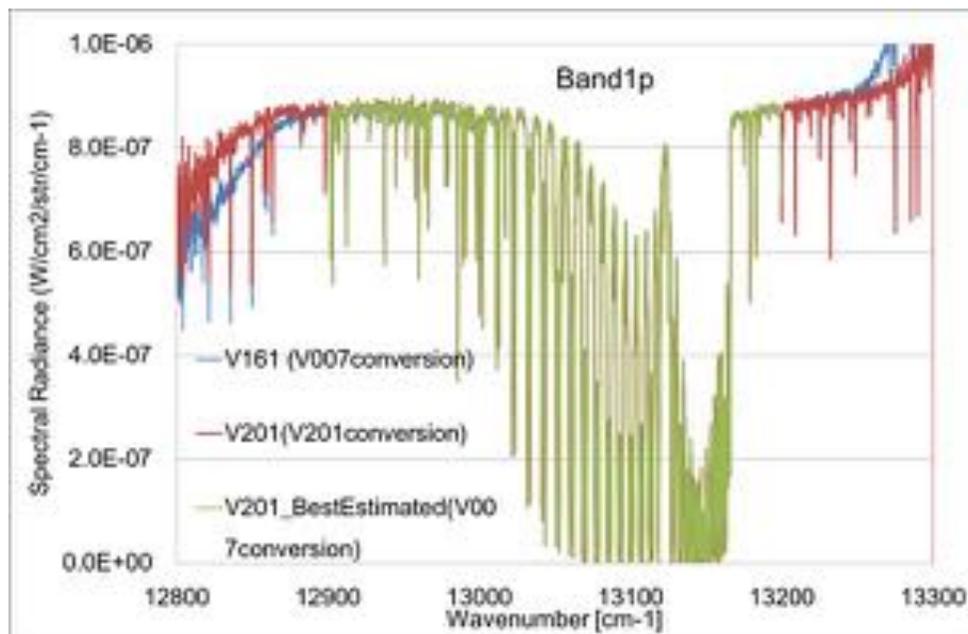*New, status update, L1 algorithm*
http://www.eorc.jaxa.jp/GOSAT/index.html

- Backup-

V161 vs V201, Conversion tables of V007 vsV201 Gain M site (RRV)

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)				
prelaunch data (Feb. 2008) was reprocessed with		WL start (cm^{-1})	WL corrected (cm^{-1})	Number of rows
V070 (July 2009)	Absorption	12400.143 (0.5 cm^{-1} interval)	(not shown)	2601
(V070c) (May 2010)	Envelope, released from NIES GUIG	12400.143	(not shown)	2601
V150 (May 2012)	Envelope, released by request	12400.143	12402.586	2601
V201 (March 2016)	Envelope, will be released from NIES GUIG (wavenumber corrected)	12400.143	12402.586	2601
Level 1B product				
		WL start (cm^{-1})	Interval (cm^{-1})	Number of rows
V150, 161 (raw)	Radiance Degradation Factor in Kuze et al., 2014 used V150 data	12400.078	0.19949	6565
V201 (raw)		12400.078	0.19949	6565
(best estimated)	Converted with V070c ~~V150~~ table	12900.008	0.19949	1504
V210 (Best estimated)	Will be converted with V201	12900.008 (T.B.D.)	0.19949 (T.B.D,)	1504

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 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 vender to provide an optical bandpass filter that has high and flat transmittance between 12900 cam-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 （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.