GOSAT results and status of the GOSAT-2 missions

Kei Shiomi (for Masakatsu Nakajima)

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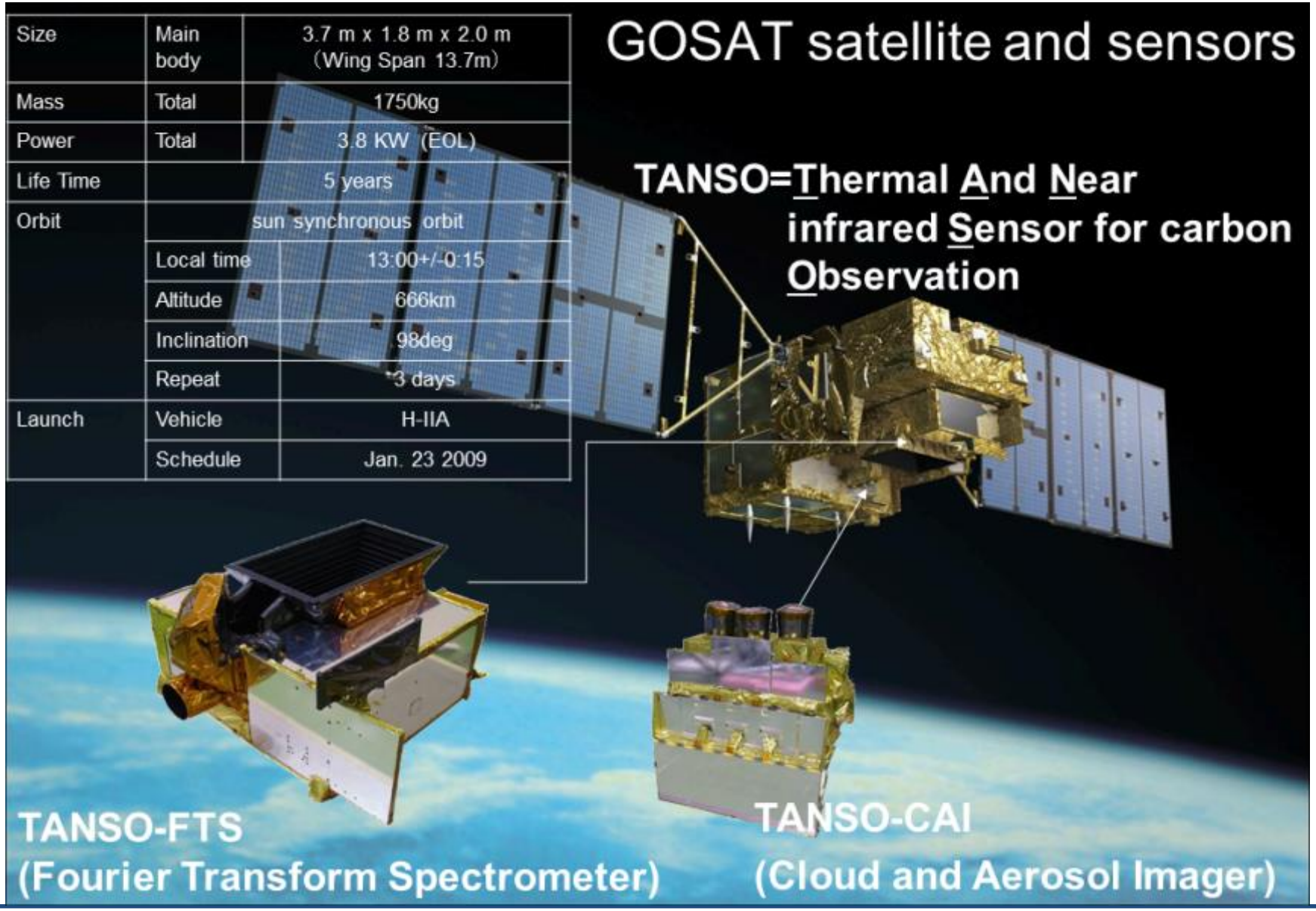
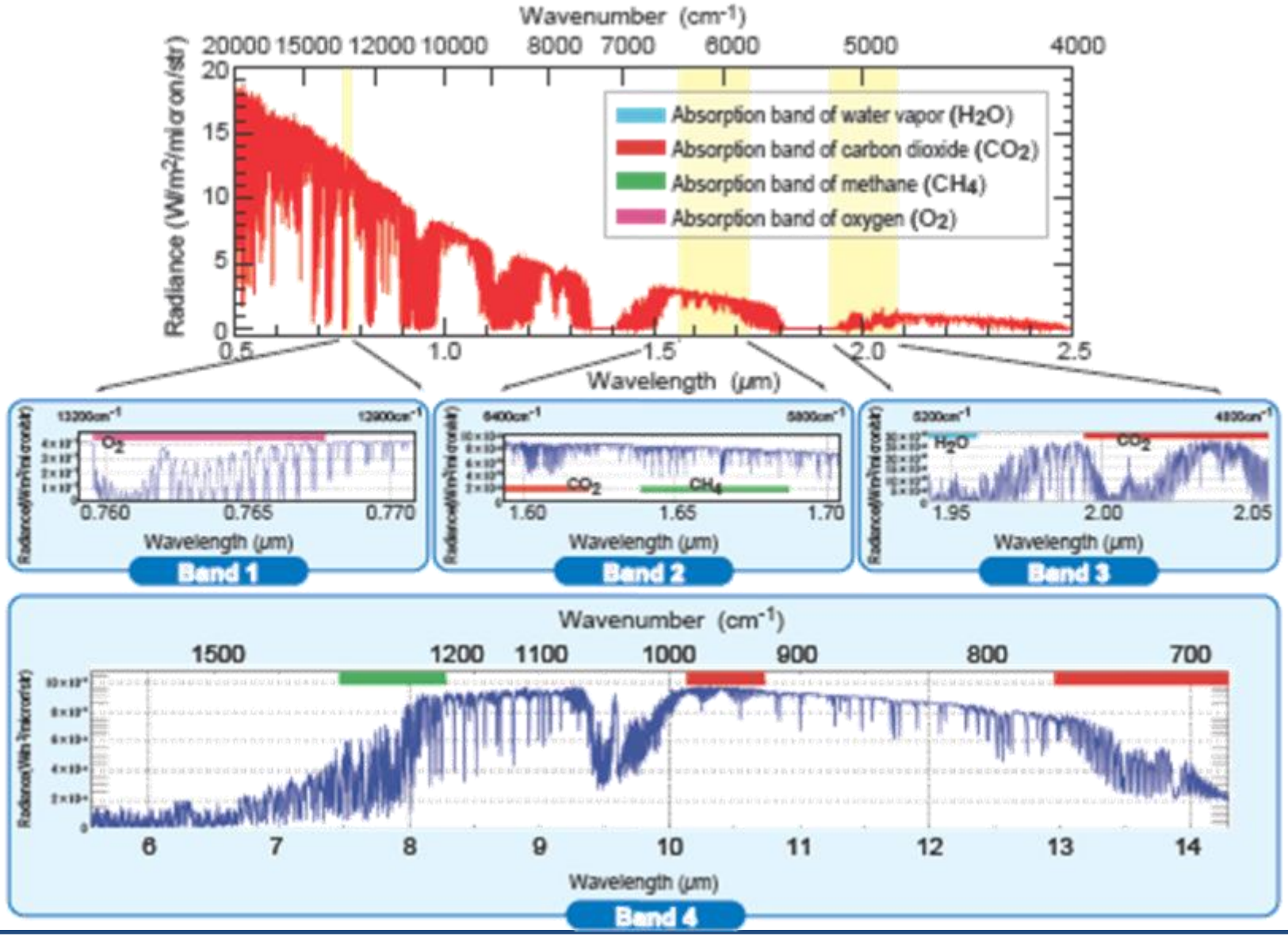
GOSAT on orbit from 2009



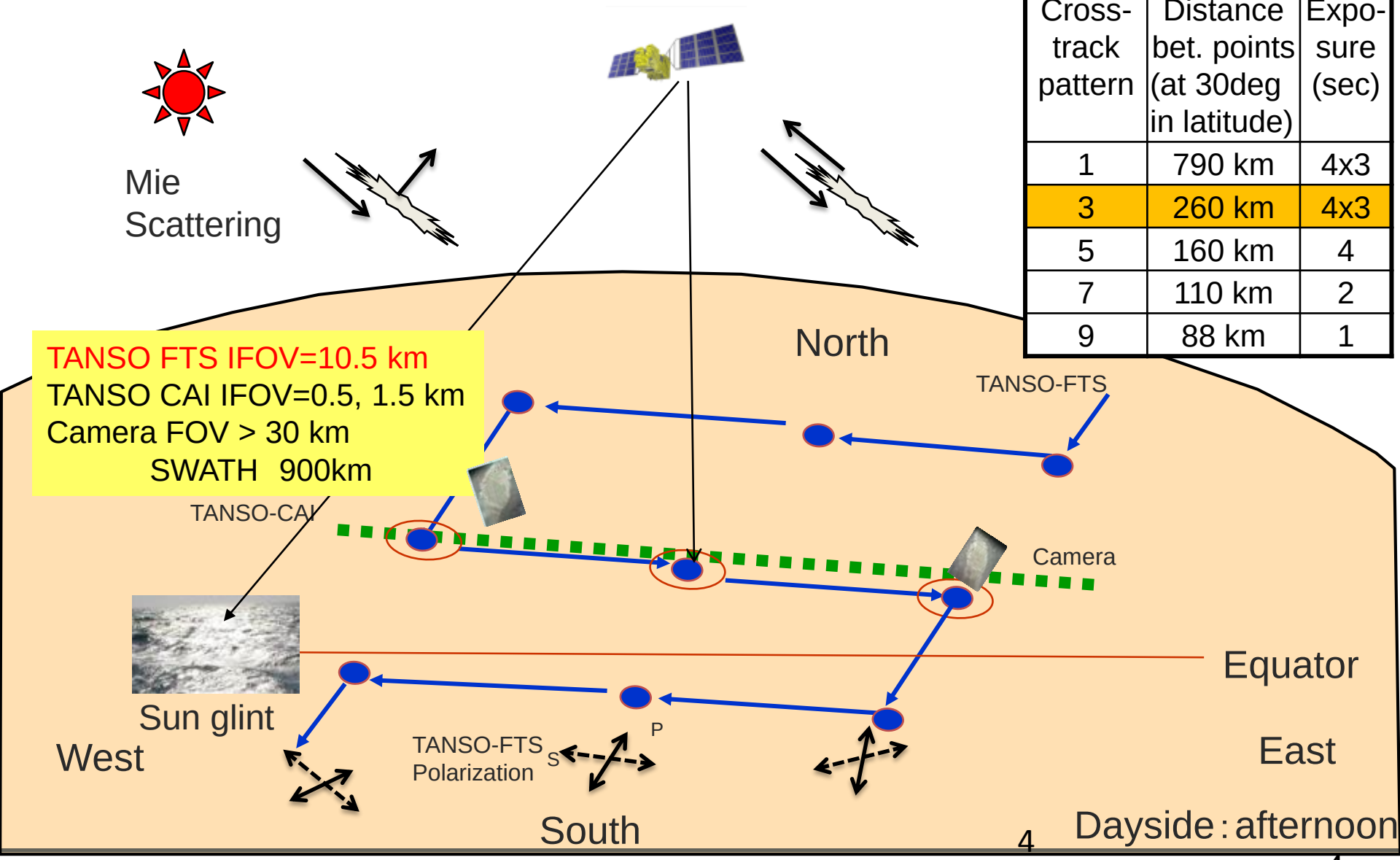
Size	Main body	3.7 m x 1.8 m x 2.0 m (Wing Span 13.7m)
Mass	Total	1750kg
Power	Total	3.8 KW (EOL)
Life Time		5 years
Orbit		sun synchronous orbit
	Local time	13:00+/-0:15
	Altitude	666km
	Inclination	98deg
	Repeat	3 days
Launch	Vehicle	H-IIA
	Schedule	Jan. 23 2009

TANSO-FTS spectral coverage



Pointing and footprints

Cross-track pattern	Distance bet. points (at 30deg in latitude)	Expo-sure (sec)
1	790 km	4x3
3	260 km	4x3
5	160 km	4
7	110 km	2
9	88 km	1

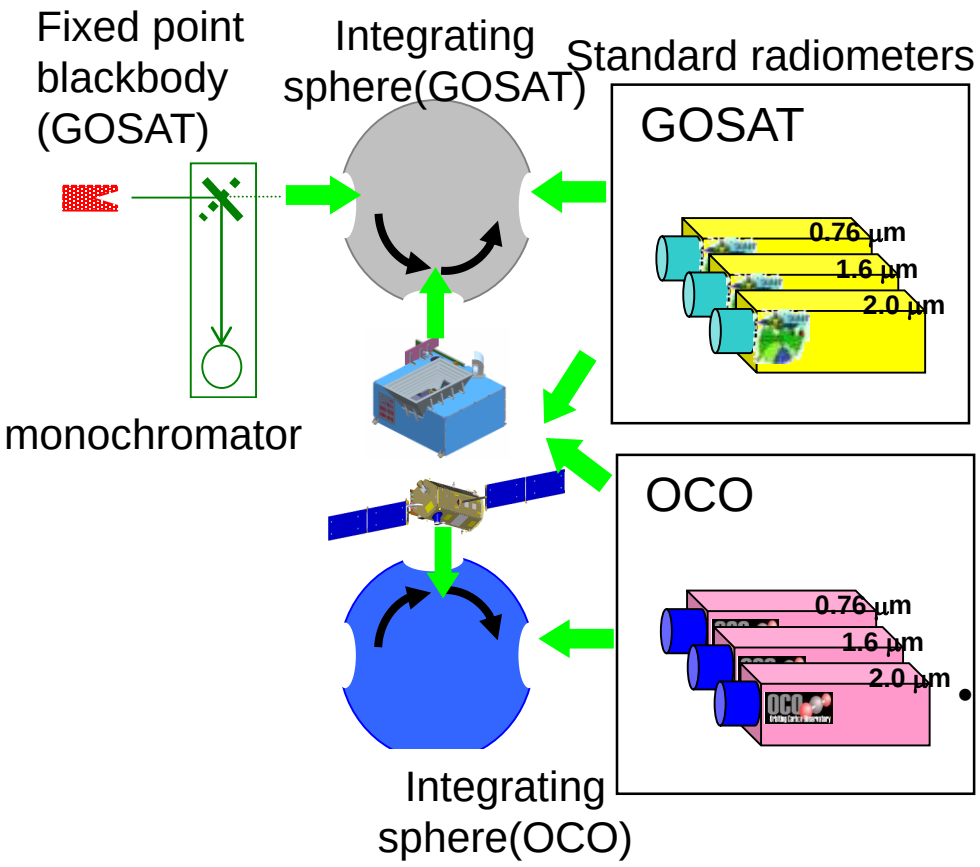


GOSAT TANSO Current Status

- GOSAT was successfully obtained over 6-year observation data of TANSO-FTS and CAI from 2009, currently in extended operation phase.
- The rotation of the one of the two solar paddles stopped on May 23, 2014, and currently continue to operate by single paddle power.
- FTS pointing mirror mechanics were switched to operate by redundancy from end of January 2015, because the main mechanics were not well-controlled. Currently, pointing performance is working well.

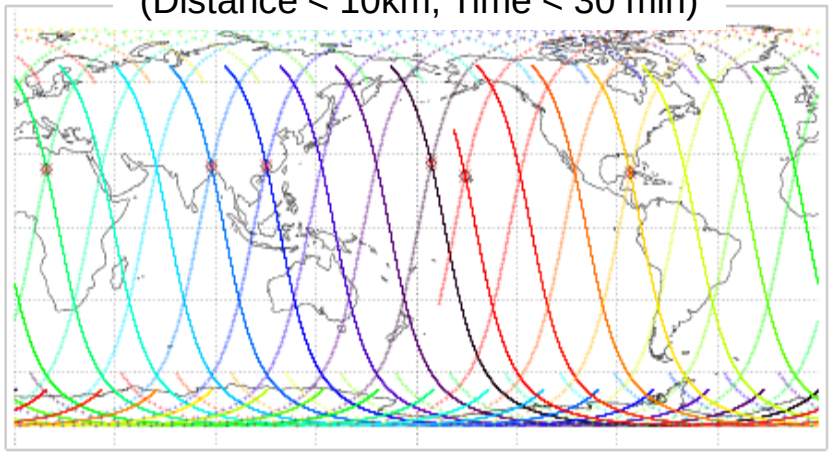
X-calibration with OCO(/-2)

- X-calibration with OCO/GOSAT standard radiometers

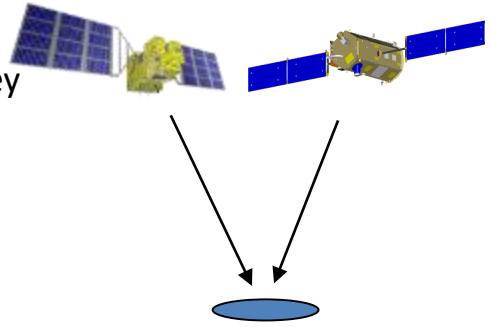


- Nadir coincidence of OCO-2 and GOSAT
  - Comparisons of L1 and L2 products
  - OCO-2: continuous swath at 13:30LT
  - GOSAT: separate pointing at 13:00LT

Match-up points in a day
(Distance < 10km, Time < 30 min)



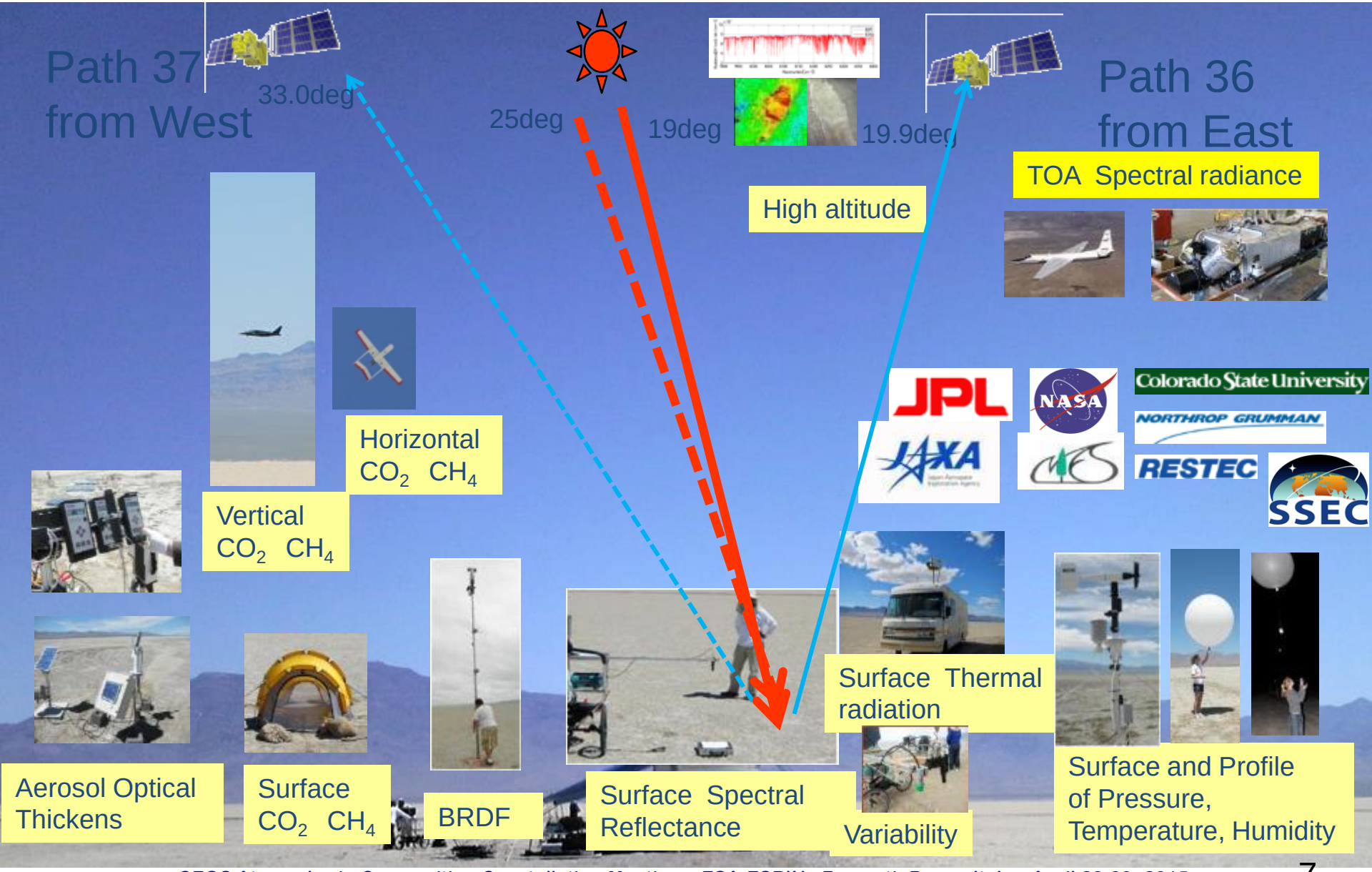
- Target observations with OCO-2 and GOSAT
  - Calibration sites
    - Railroad valley
  - Validation sites
    - TCCON



- 1st step @ JPL (Apr, 2008) ***Difference < 3%***
- 2nd step @ JAXA (Dec, 2008

Pre-launch ***Post-launch***

Vi-calibration campaign at RRV



GOSAT calibration

(1) Spectral correction

- Non-linearity response in SWIR band including electrical circuit is investigated after launch with EM and reflected to L1 processing.

(2) SWIR radiometric calibration (Sensitivity degradation factor)

- Onboard solar diffuser monitoring per month
- Vicarious calibration field campaign (with ACOS/OCO-2, Ames), Lunar calibration, Sahara desert monitoring

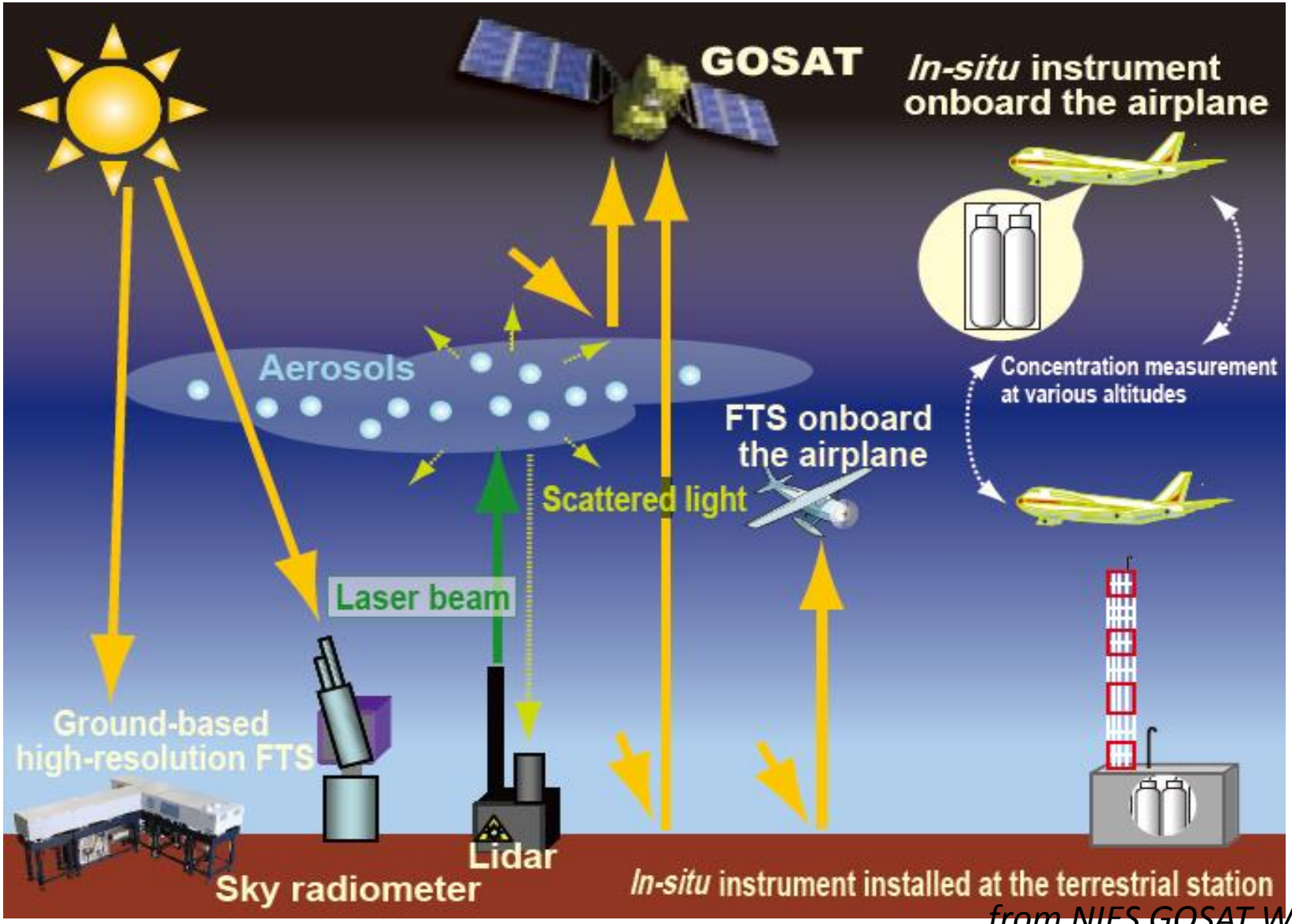
(3) TIR radiometric calibration (The latest L1B v160)

- Blackbody (BB) and Deep Space (DS) views for onboard calibration (2-time in dayside, 4-time in nightside)
- Polarization correction (mirrors, beamsplitter, dichroic filters)
- BB emissivity (EM evaluated by heated halo method at UW-SSEC)
- Sensor background temperature estimation

(4) Geometric correction (Estimated geolocation data)

- Pointing offset evaluated by onboard IFOV camera
- Estimated geolocation after correction

GOSAT validation

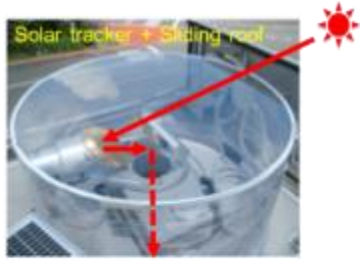


from NIES GOSAT Website

TCCON – X_{CO2} and X_{CH4} standards for space-based measurements

from TCCON and TCCON-wiki websites

TCCON sites (June-2013)



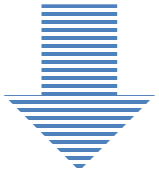
gbFTS@Saga

Group	Version	Num. of TCCON site	X_{CO2}		X_{CH4}	
			Bias[ppm]	STD[ppm]	Bias[ppb]	STD[ppb]
NIES-FP	2.0	13	-1.5	2.1	-6	13
NIES-PPDF-DOAS	-	11	-0.43	1.8	-	-
ACOS	B2.9	10	0.13	2.0	-	-
RemoTeC	1.0	6	-0.19	2.8	-5.4	15
Univ. of Leicester	3.0 for X_{CO2} 3.2 for X_{CH4}	7	-0.2	2.3	3.4	17

NIES-FP: Yoshida et al., 2013,
KIT/SRON : Butz et al., 2011,
NIES-PPDF-DOAS: Oshchepkov et al.,2012,
Univ. Leicester: Boesch et al., 2012
ACOS : Crisp et al., 2012,

GOSAT FTS products release history

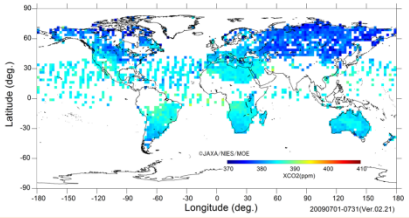
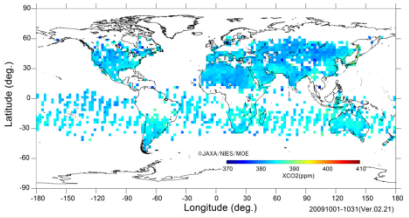
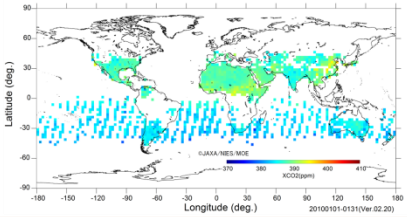
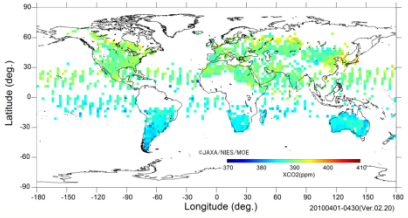
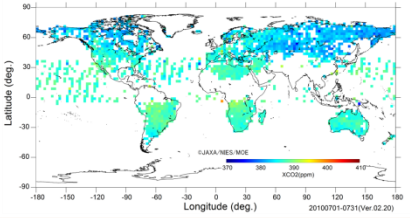
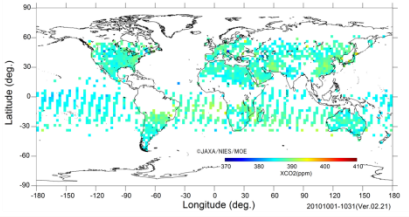
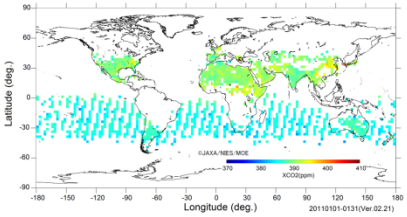
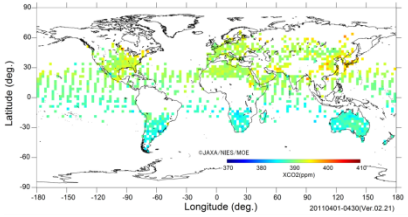
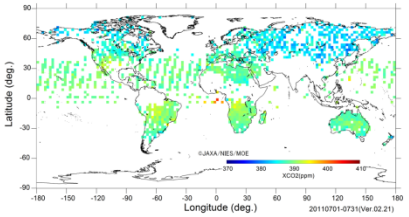
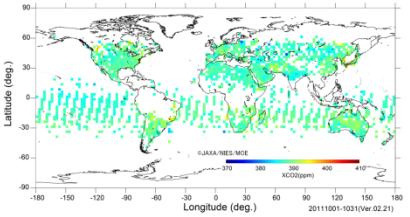
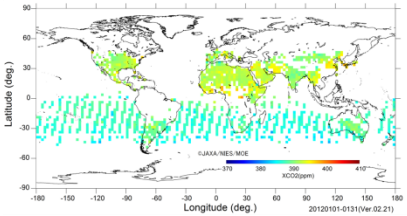
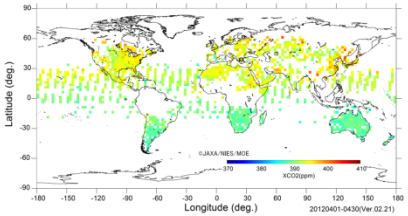
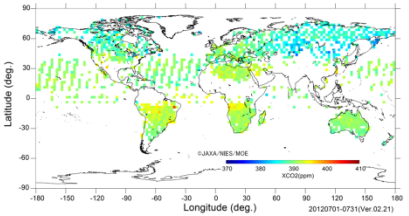
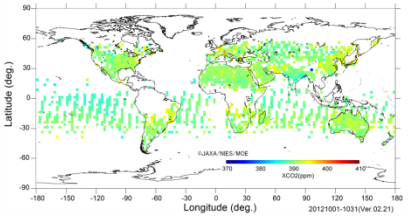
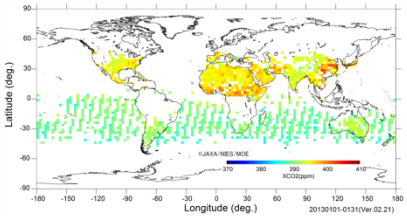
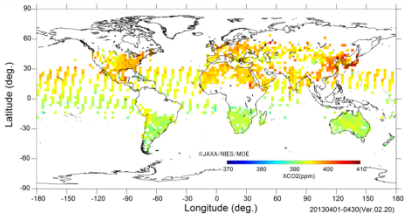
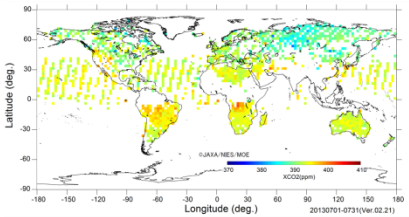
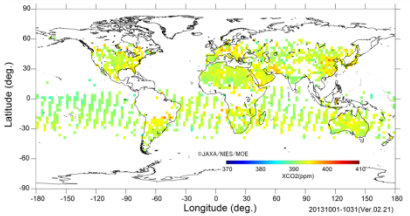
Oct. 2009	Level 1 (Observation spectra) to public
Feb. 2010	Level 2 (SWIR X_{CO2} and X_{CH4}: column averaged dry air mole fraction, v00.**) to public
Aug. 2010	Level 2 (SWIR X_{CO2} and X_{CH4}, v01.**) to public
Nov. 2010	Level 3 (SWIR X_{CO2} and X_{CH4} spatially interpolated global distribution 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.



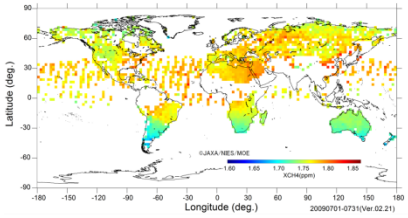
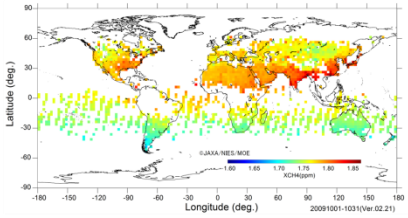
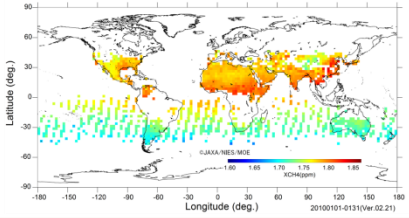
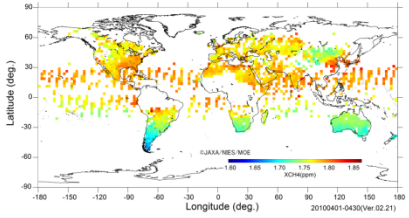
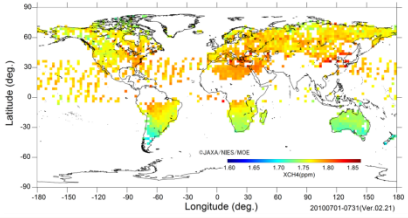
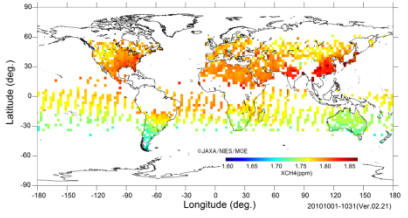
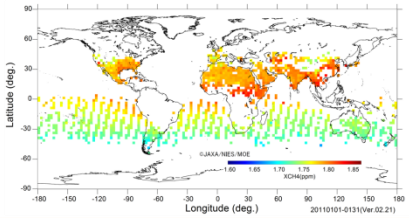
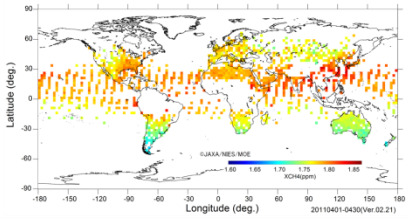
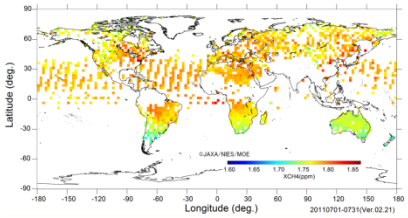
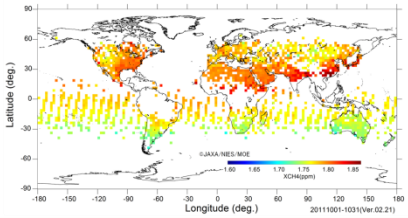
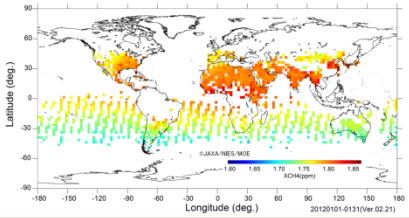
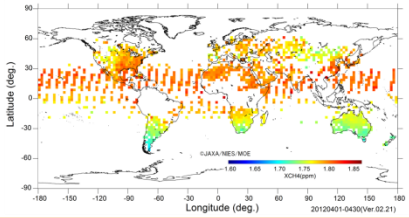
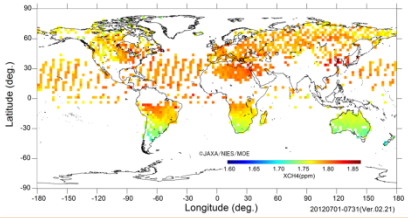
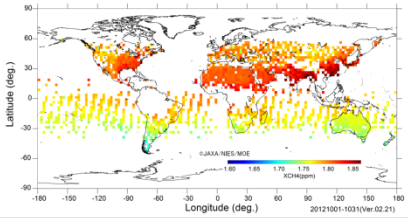
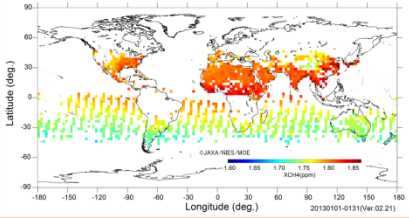
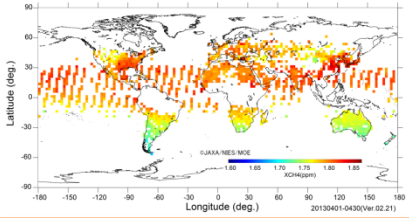
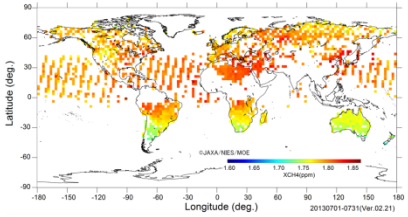
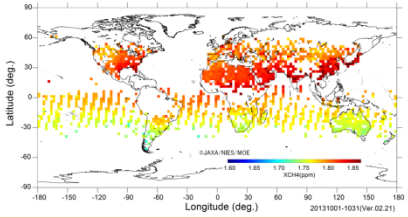
L1 version-up many times… 1 or 2 per year

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).
Summer 2015	Level 1 v200 will be released.

GOSAT Level 2 – global X_{CO2} distribution

	January	April	July	October
2009	The GOSAT SWIR X_{CO2} v02.xx is validated as bias +/- stdev = -1.2 +/- 2.0 ppm (-0.3 +/- 0.5%). *from GOSAT User Interface Gateway (GUIG)*			
2010				
2011				
2012				
2013				

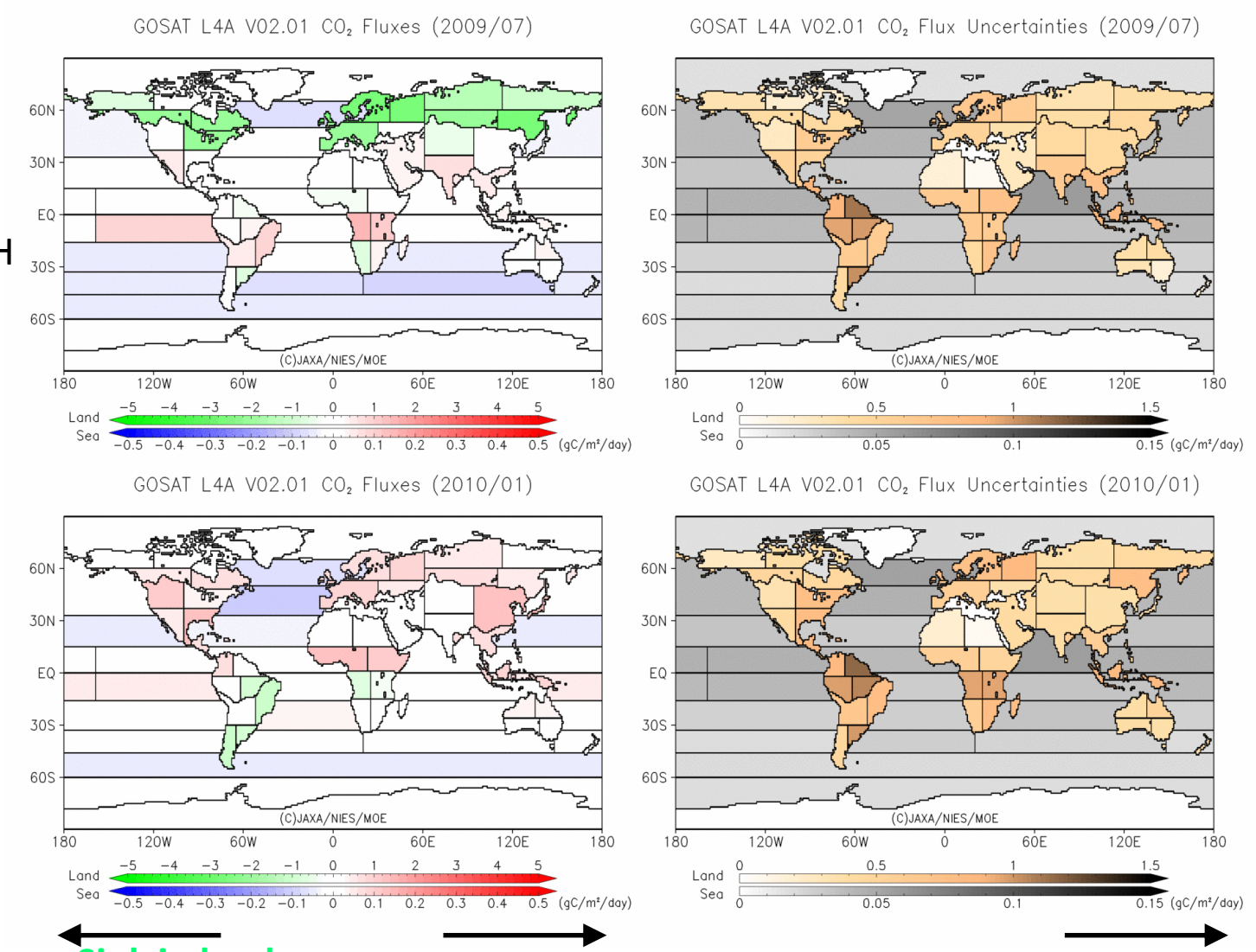
GOSAT Level 2 – global X_{CH4} distribution

	January	April	July	October
2009	The GOSAT SWIR X_{CH4} v02.xx is validated as bias +/- stdev = -7 +/- 12 ppb (-0.4 +/- 0.7%). *from GOSAT User Interface Gateway (GUIG)*			
2010				
2011				
2012				
2013				

GOSAT Level 4A - global CO_2 flux estimation

July 2009
Summer in NH

January 2010
Winter in NH



Sink in land
Sink in sea

Source

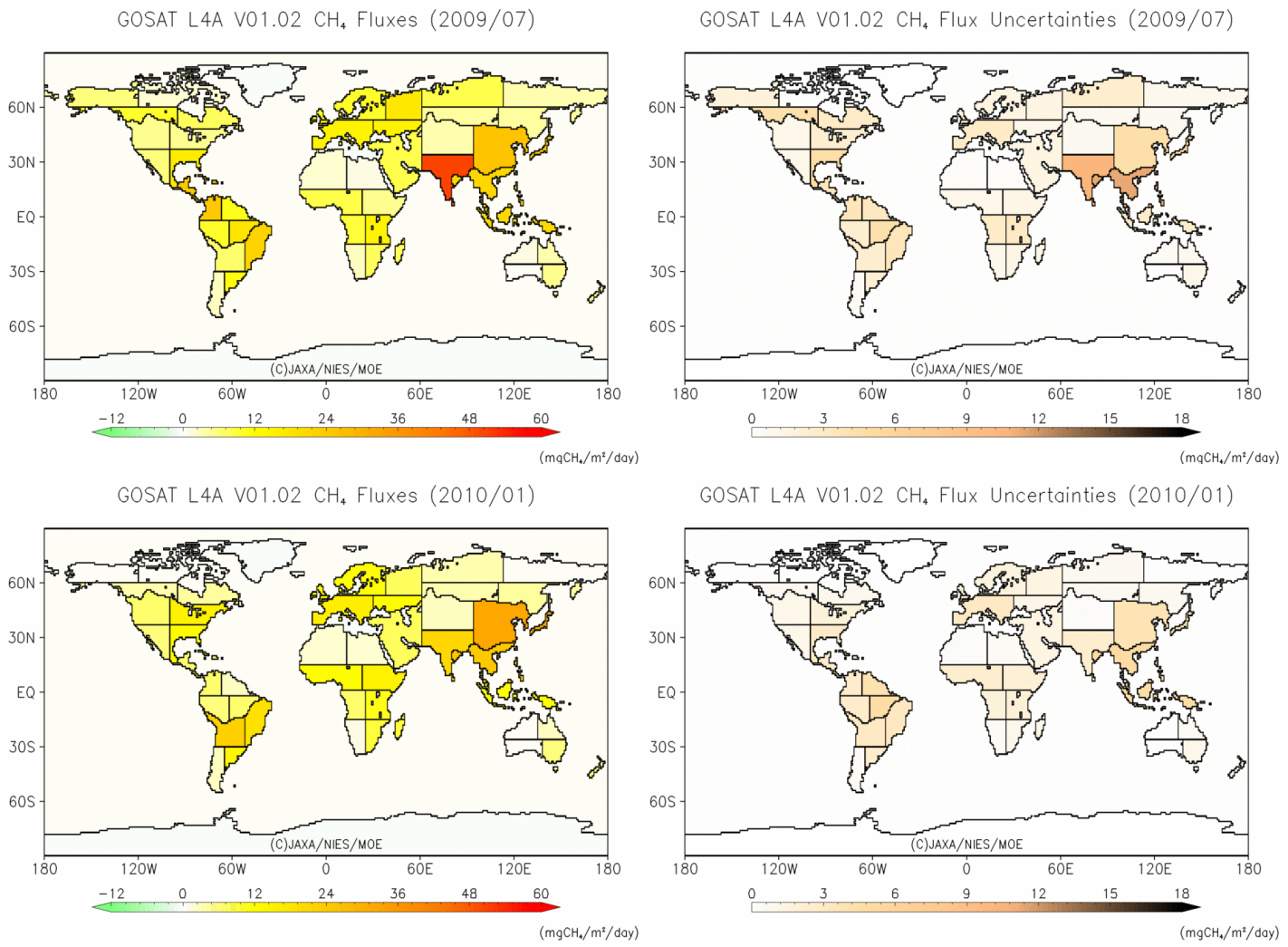
Large Uncertainty

from GOSAT User Interface Gateway (GUIG)

GOSAT Level 4A - global CH_4 flux estimation

July 2009
Summer in NH

January 2010
Winter in NH



Sink in land

Source

Large Uncertainty

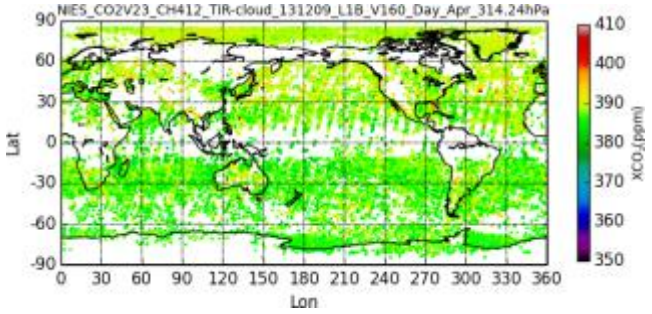
from GOSAT User Interface Gateway (GUIG)

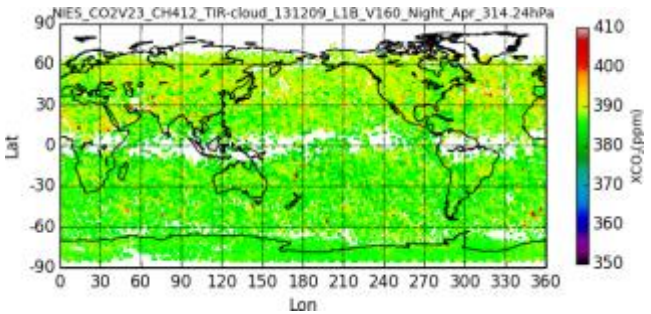
TANSO-FTS TIR, CO_2 profiles April 2010

Day

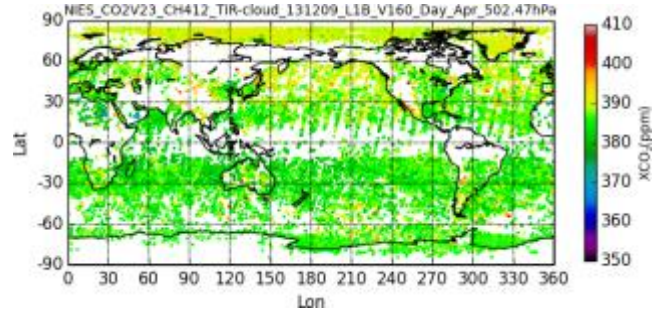
Night

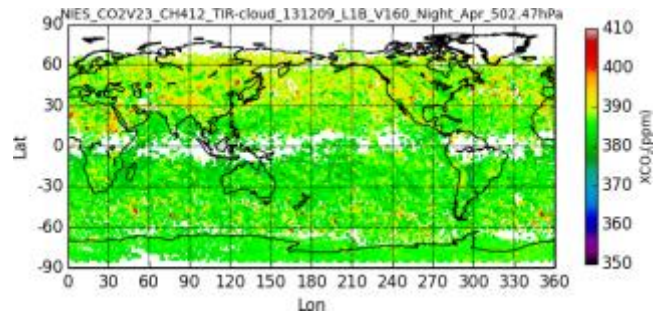
300hPa



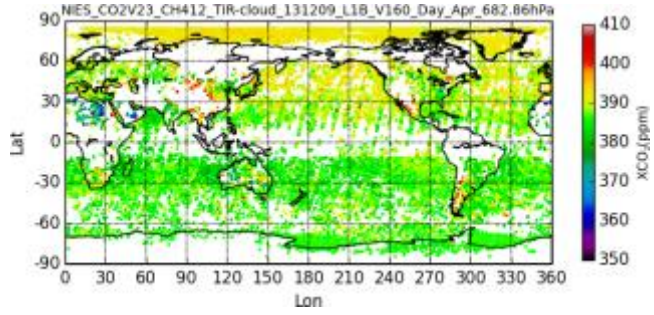


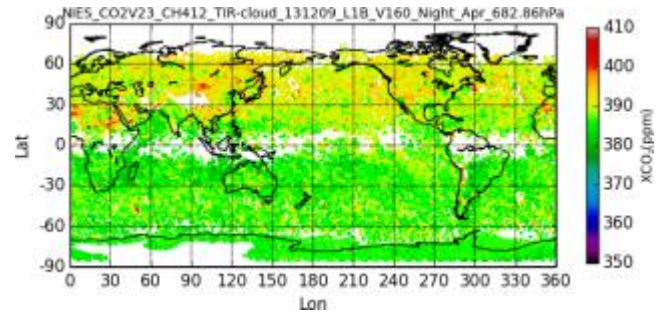
500hPa





700hPa





(by S. Kawakami (JAXA))

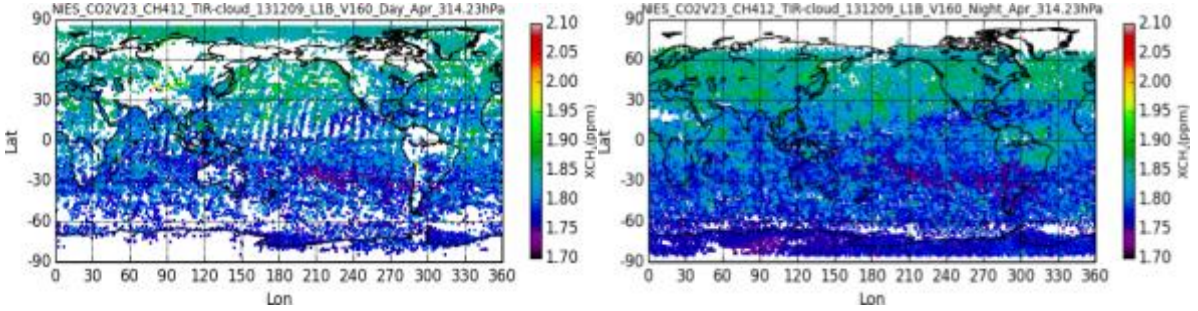
Data will be released to RA PI in June, 2014 and to the public in Spring 2015

TANSO-FTS TIR, CH_4 profiles April 2010

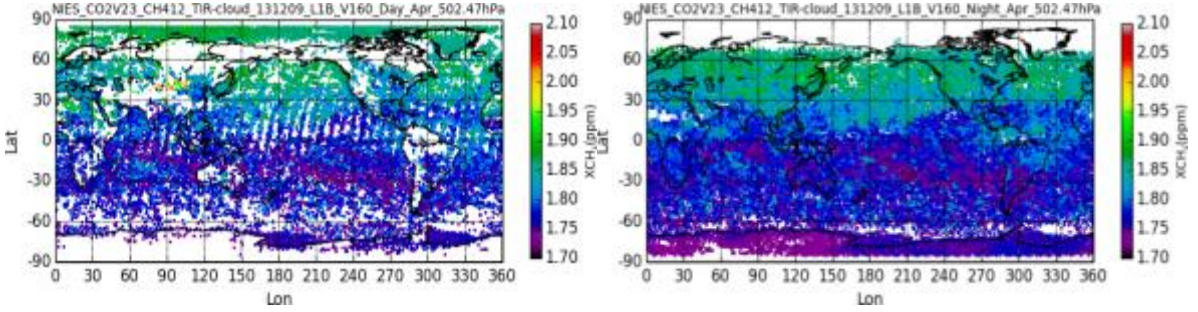
Day

Night

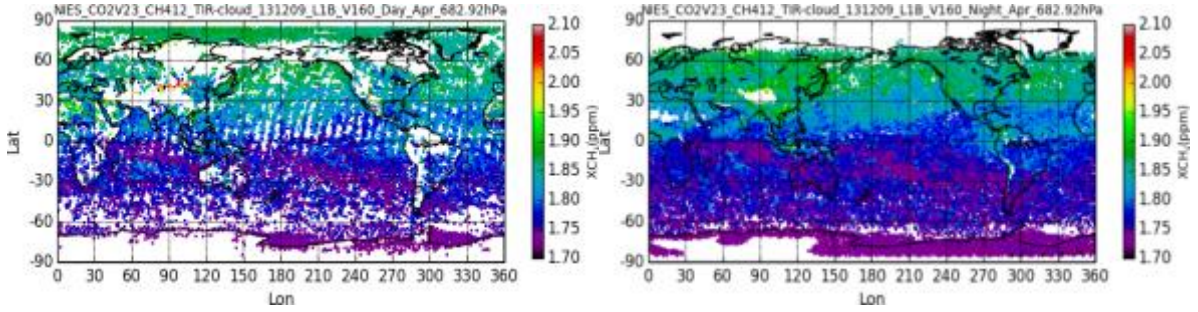
300hPa



500hPa



700hPa



(by S. Kawakami (JAXA))

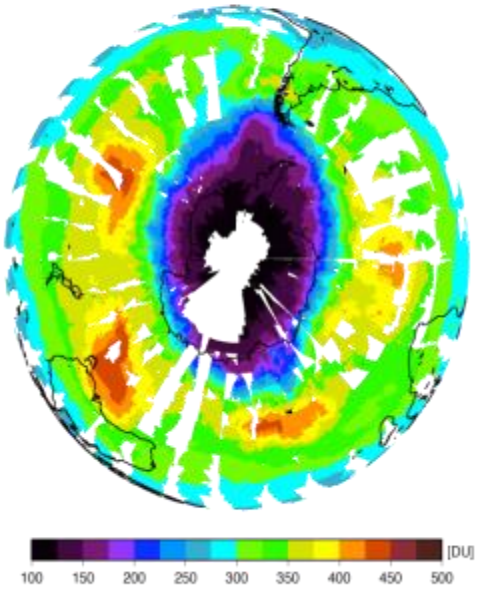
Data will be released to RA PI in June, 2014 and to the public in Spring 2015

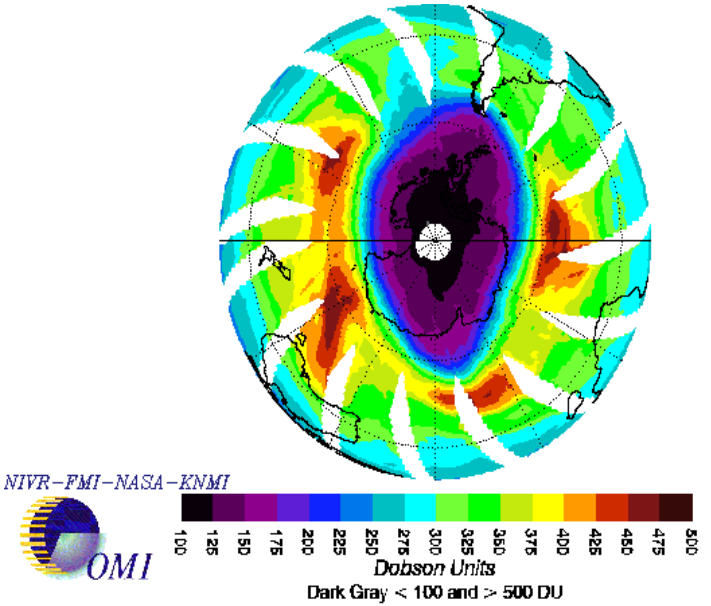
Observation of ozone hole (low total ozone)

TANSO-FTS/GOSAT

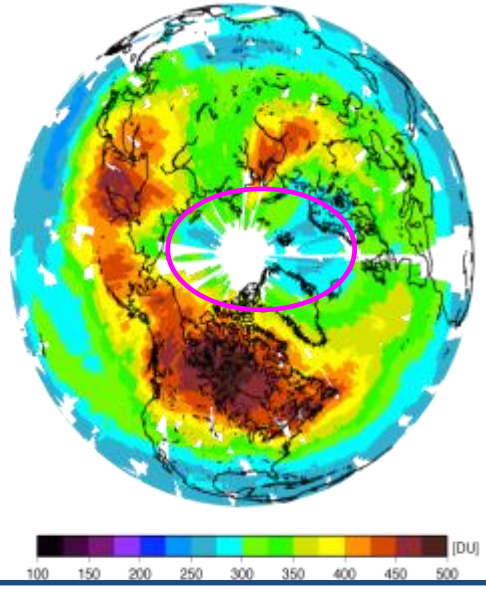
OMI/AURA

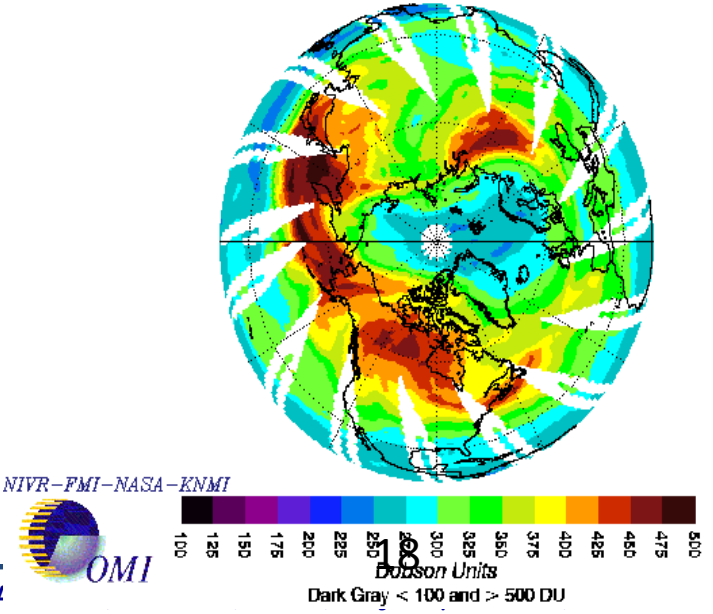
Ozone hole
in Antarctica
2009/09/25





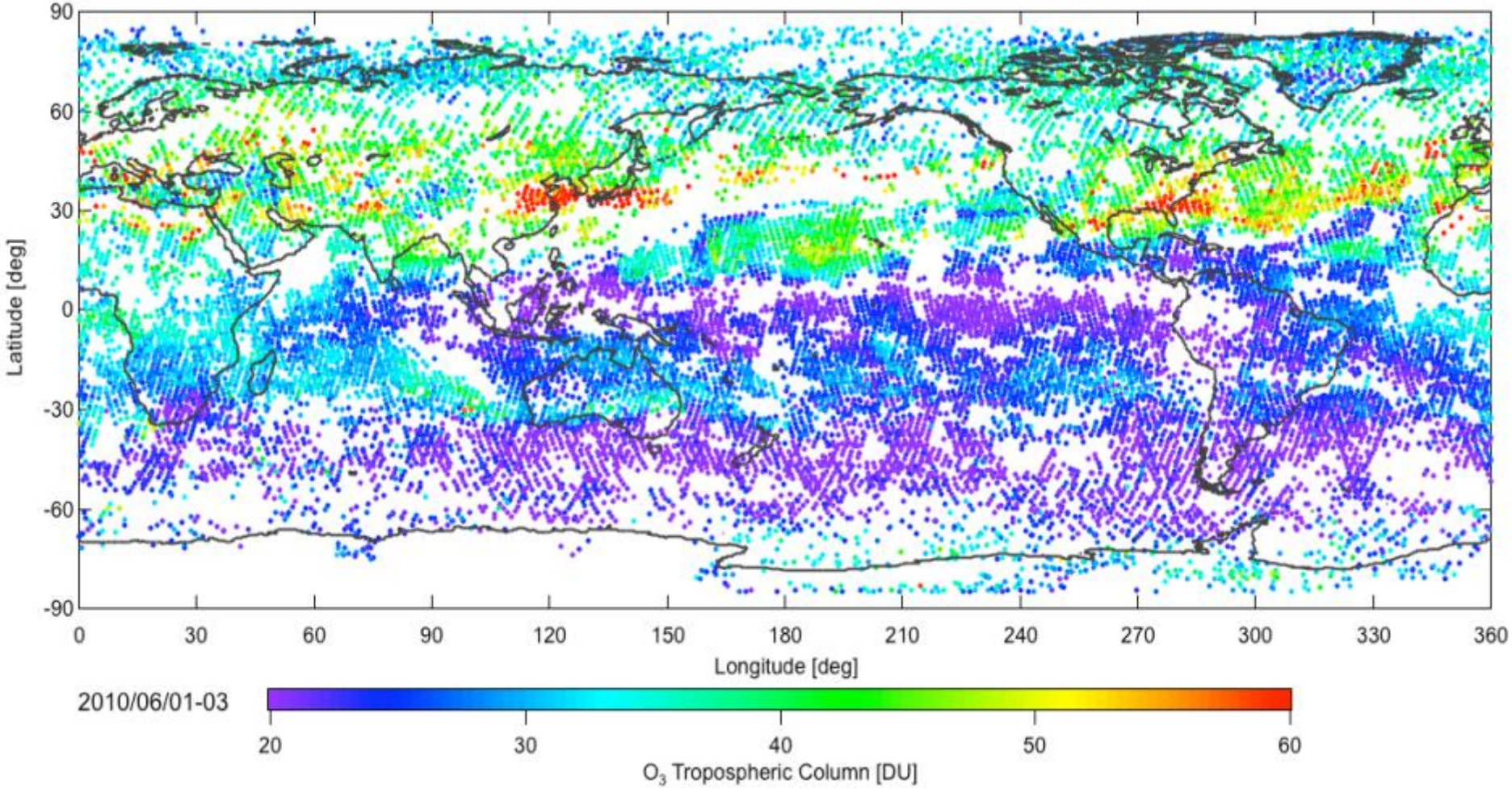
Ozone loss
in Arctic region
2011/03/26





Global distributions of tropospheric ozone column

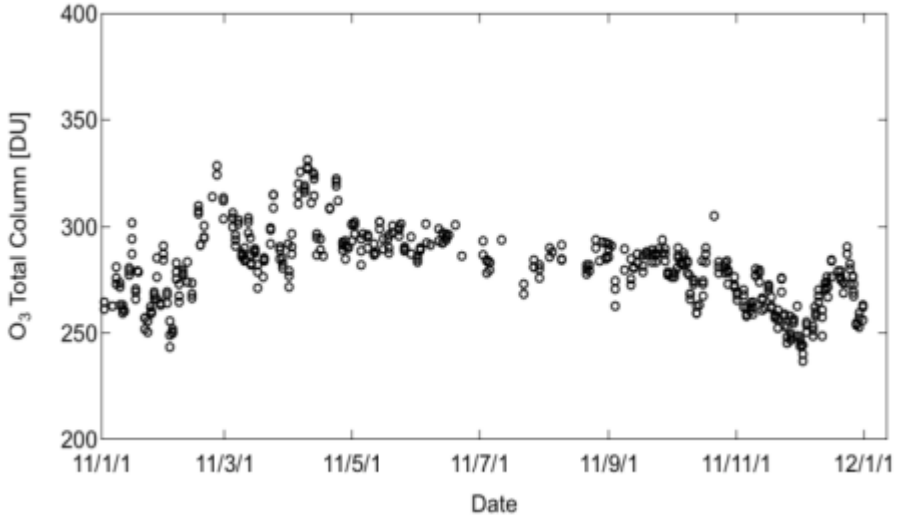
June 1-3, 2010



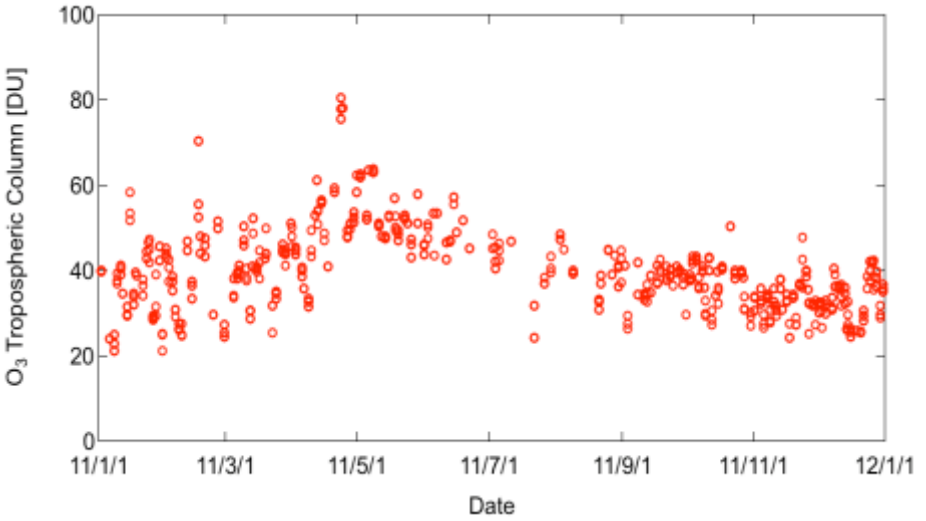
Seasonal variation around India (Delhi: 28.5°N, 77.0°E)

One of the most polluted regions in the world

Total ozone

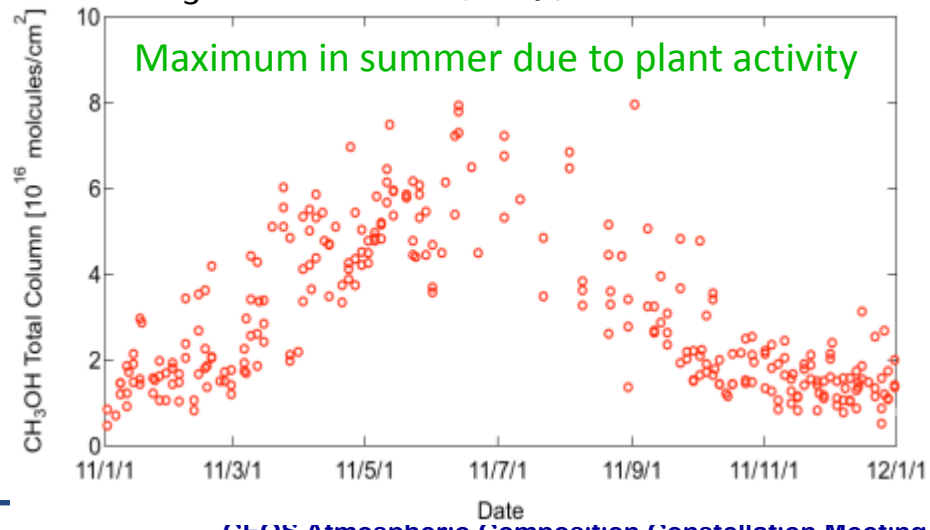


Tropospheric ozone column



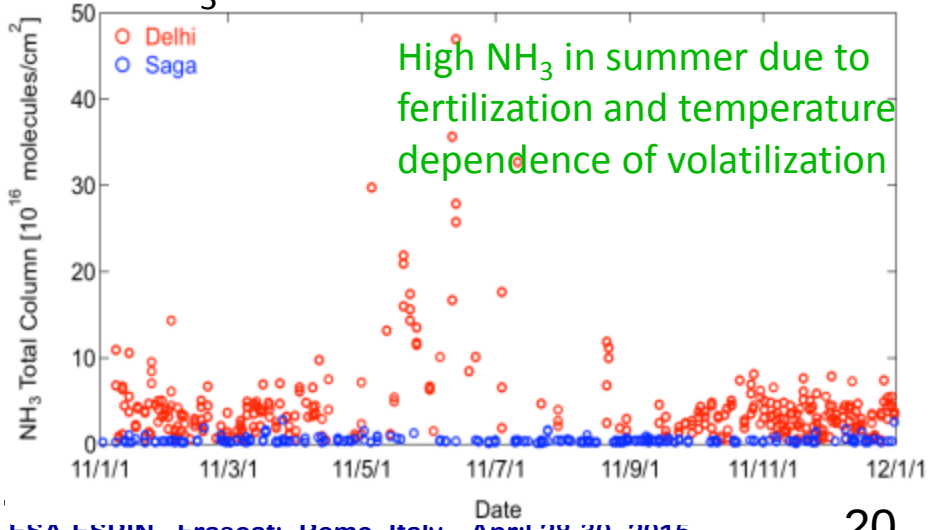
CH_3OH column (Day)

Maximum in summer due to plant activity



NH_3 column

High NH_3 in summer due to fertilization and temperature dependence of volatilization



GOSAT achievements

(1) GOSAT demonstrated the ability of CO_2 and CH_4 observation from space.

- more than 6-year global observation of X_{CO2} and X_{CH4}
- Precision of X_{CO2} retrieval ~ 2ppm (NIES, ACOS, RemotTeC, UoL, UoB with several algorithms)
- Significant uncertainty reduction in global CO_2 flux estimation (NIES, LSCE, SRON, UoE, CSU)

(2) New findings and challenges

- Sun-induced chlorophyll fluorescence from highly-resolved O_2A spectra
- Large point source detection (Megacity)

(3) Lessons learned from GOSAT

- Missing in high latitudes area (limited by pointing mechanism availability)
- Less observation in cloudy tropical forests (South-Asia, Amazon, etc.)

(4) GOSAT-2

- Science requirements (Based on GOSAT, +SNR, +CO, +Fluorescence, +Observation points, +Aerosol)

GOSAT-2:
mission and sensor systems

Observation Targets of GOSAT-2

	GOSAT-2	GOSAT
improvement of concentration measurement precision	**0.5 ppm (CO2)** **5 ppb (CH4)** **- 1 month** **- 500 km mesh (land)** **- 2,000 km mesh (ocean)**	4 ppm (CO2) 34 ppb (CH4) - 3 months - 1,000km mesh (land)
improvement of estimation accuracy of flux	**estimate the monthly net fluxes with the accuracy of ±100%** **- 1,000 km mesh (land)** **- 4,000 km mesh (ocean)**	reduce the annual estimation error to half compared with the existing estimation error -sub-continental scale
estimation of the anthropogenic emission	**examine the feasibility of the estimation of the anthropogenic emission with the observation of CO which is the correlated matter**	---------
monitoring of the aerosols in the atmosphere	**calculate the optical thickness of the aerosols at 550nm and 1.6μm with 0.1 accuracy**	---------

Approaches to Achieving the targets

Improvement of concentration measurement precision

⇨Increase of the number of the useful data

- **intelligent pointing**: steer the line of sight to the area where there is no cloud
- **increase of the SNR**: to acquire the data in the high latitude region

⇨Increase of the SNR of each data

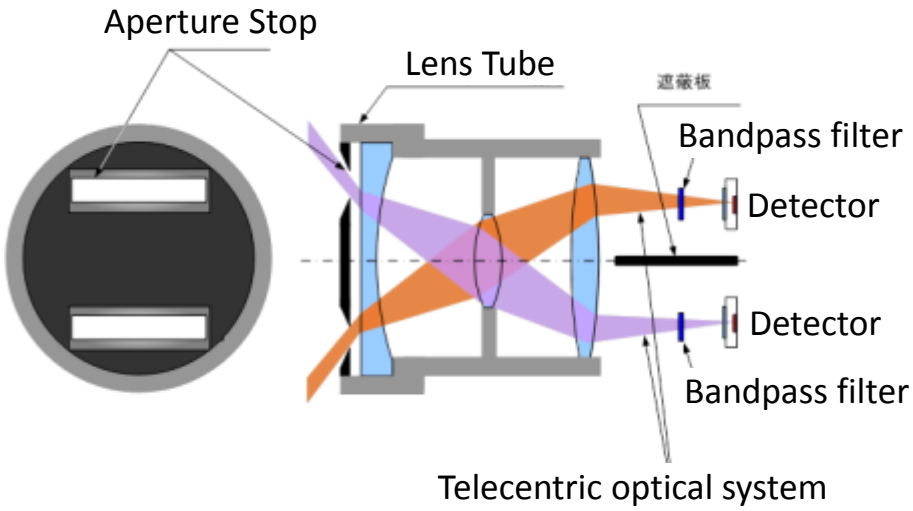
- **increase the signal level----------**
  - **expansion of the aperture**
- **reduction of the noise level------**
  - **over sampling for band 1**
  - **set the pre-amplifier to the detector directly**

TANSO-FTS-2 specifications

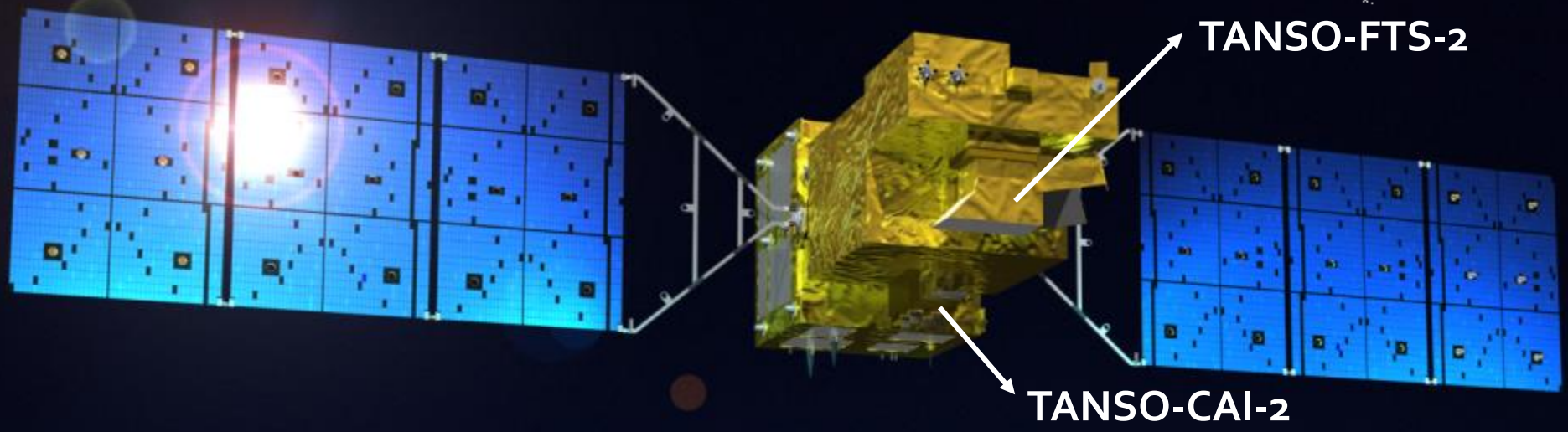
Items	GOSAT-2	GOSAT
Measurement Gases	CO_2, CH_4, O_3, H_2O, **CO**	CO_2, CH_4, O_3, H_2O
FOV/number	10.5 kmϕ / 1	10.5 kmϕ / 1
Spectral Ranges (μm)(cm-1)	band 1 : 0.75-0.77 (**12,950-13,250**) band 2: 1.56-**1.69** (**5,900**-6,400) band 3: 1.92-**2.33** (**4,200**-5,200) band 4: **5.5-8.4 (1,188-1,800)** band 5: **8.4-14.3 (700-1,188)**	band 1: 0.75-0.77 (12,900-13,200) band 2: 1.56-1.72 (5,800-6,400) band 3: 1.92-2.08 (4,800-5,200) band 4: 5.5-14.3 (700-1,800)
SNR	band 1: **528** (P@13,050cm^{-1}) (>400) band 2: **617** (P@6,200cm^{-1}) (>300) band 3: **454** (P@5,000cm^{-1}) (>300) **489** (P+S@4,250cm^{-1}) (>300) band 4: **1519** (@1,300cm^{-1}) (>300) band 5: 306 (@700cm^{-1}) (>300)	band 1: 345 (>300) band 2: 322 (>300) band 3: 412 (>300) band 4: 304 (>300)
Observation Mesh	160km (5 points in the CT direction)	160km (5 points in the CT direction)
Scan duration	**4 seconds / interferogram**	4, 2, 1.1 seconds / interferogram
Sampling resolution	0.2cm^{-1}	0.2cm^{-1}
Effective Aperture size	**Φ73mm**	Φ64mm
Gain steps	**16 (TBD)**	2
Quantization	**14 bits (16 bits equivalent by over sampling)**	16 bits
Avoidance of the cloud	**Intelligent pointing**	-------

TANSO-CAI-2 specifications

Items	GOSAT-2		GOSAT
Spectroscopic System	Band pass filter		Band pass filter
Spectral Ranges (nm)	Forward Viewing	Backward Viewing	
	band 1 : 330-350	band 6 : 370-390	**band 1 :** 370-390
	band 2: 425-445	**band 7 : 540-560**	**band 2 :** 664-684
	band 3 : 660-680	**band 8 : 660-680**	**band 3 :** 860-880
	band 4 : 860-880	**band 9 : 860-880**	**band 4 :** 1555-1645
	band 5 : 1555-1645	**band 10 : 1555-1645**	
Spatial Resolution/ swath	500m/1,000km (except band 4 and 8) **1km/1,000km** (band 4 and 8)		Band 1-3: 500m/1,000km Band 4: 1,500m/750km

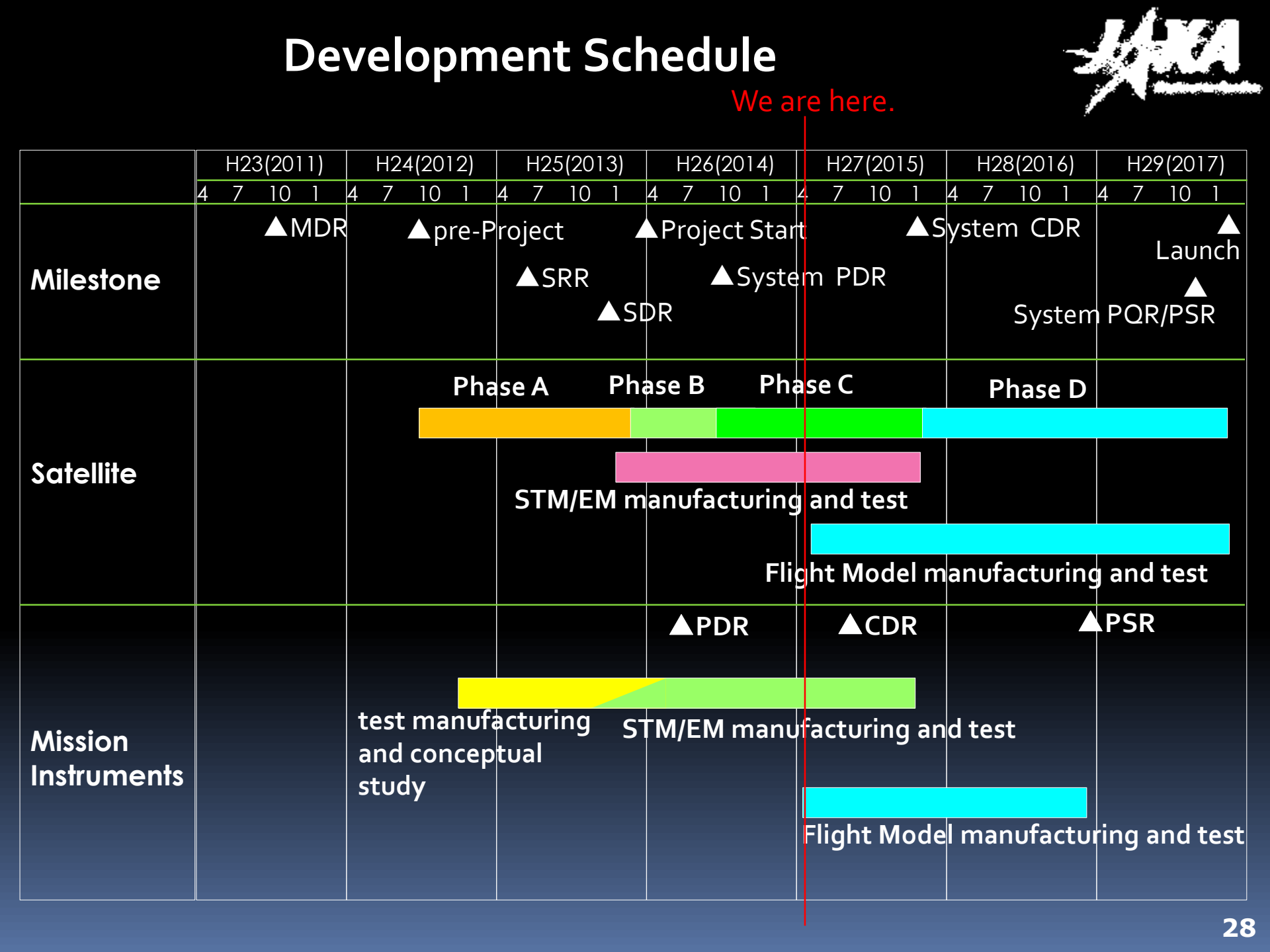


GOSAT-2 on Orbit from 2018



Size	Main body	3.7 m x 1.8 m x 2.0 m (Wing Span 13.7m)	➡ almost same
Mass	Total	1750kg	➡ around 1600kg
Power	Total	3.8 kW (EOL)	➡ around 4.5kW or more(EOL)
Life Time	5 years		
Orbit	sun synchronous orbit		
	Local time	13:00+/-0:15	
	Altitude	666km	➡ 617km
	Inclination	98deg	➡ same
	Repeat	3 days (44 rev.)	➡ 6 days (89 rev.)
Launch	Vehicle	H-IIA	
	Schedule	Jan., 2018	

Development Schedule



Summary

- GOSAT-2 science requirements are based on the GOSAT (CO_2, CH_4, TIR profile) and upgraded in:

  high SNR

  adding targets (CO, SIF, precise aerosol properties)

- GOSAT-2 development is currently in phase C study toward the launch in early 2018.

- GOSAT-2 will collaborate with other GHG satellites on orbit.