GOSAT results

Shuji Kawakami* and Shiomi Kei (JAXA)

and status of the GOSAT-2 missions

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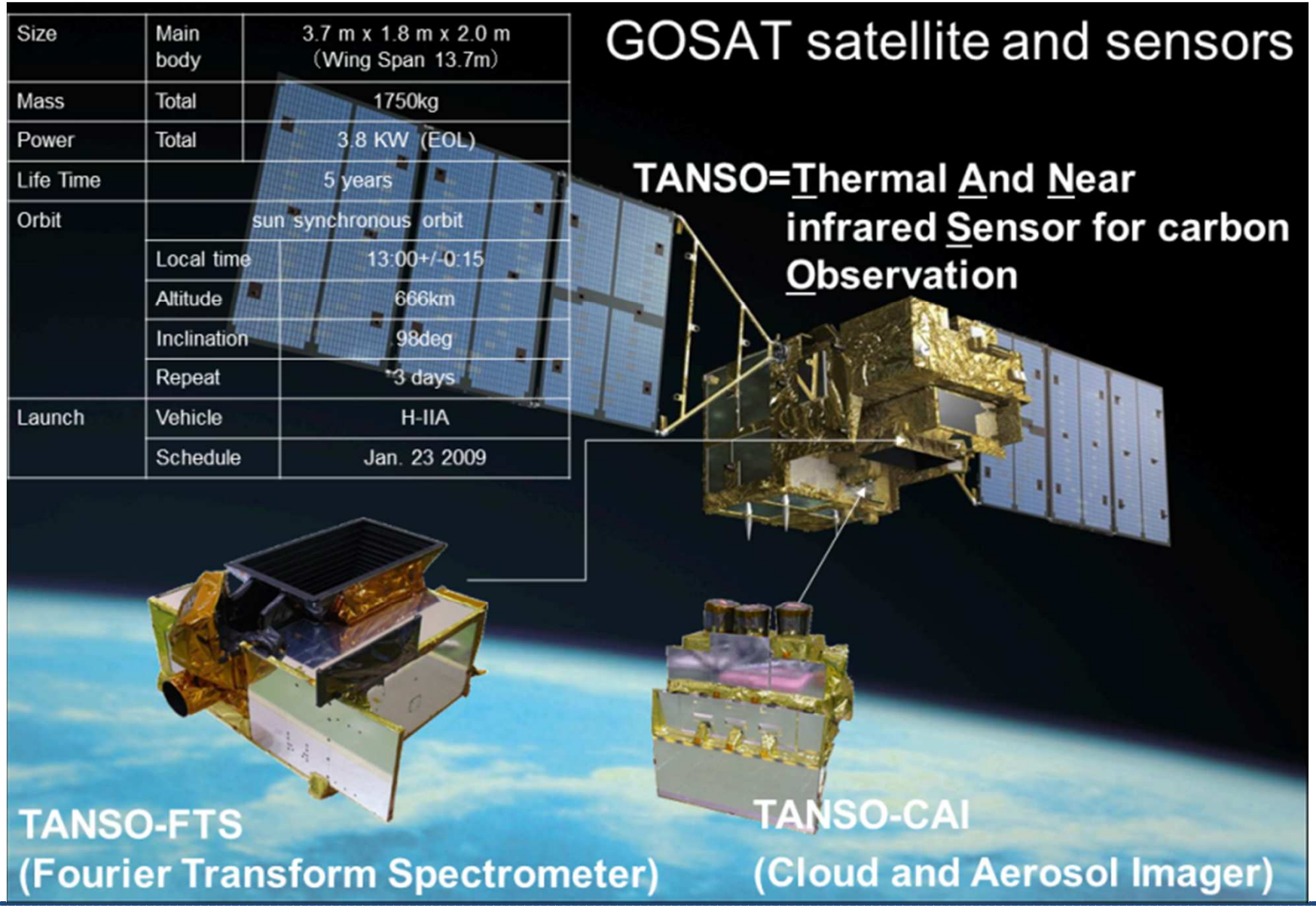
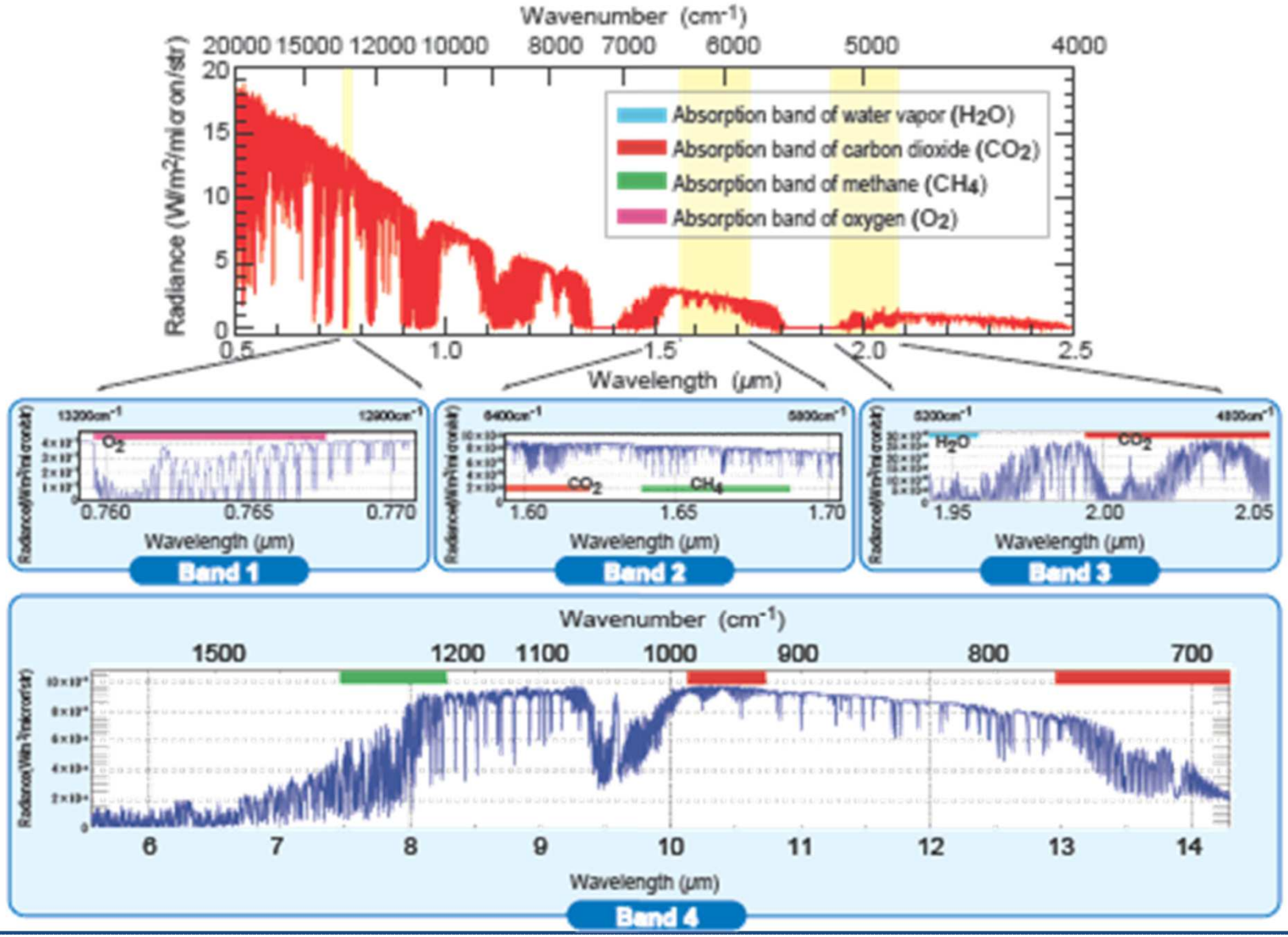
GOSAT on orbit



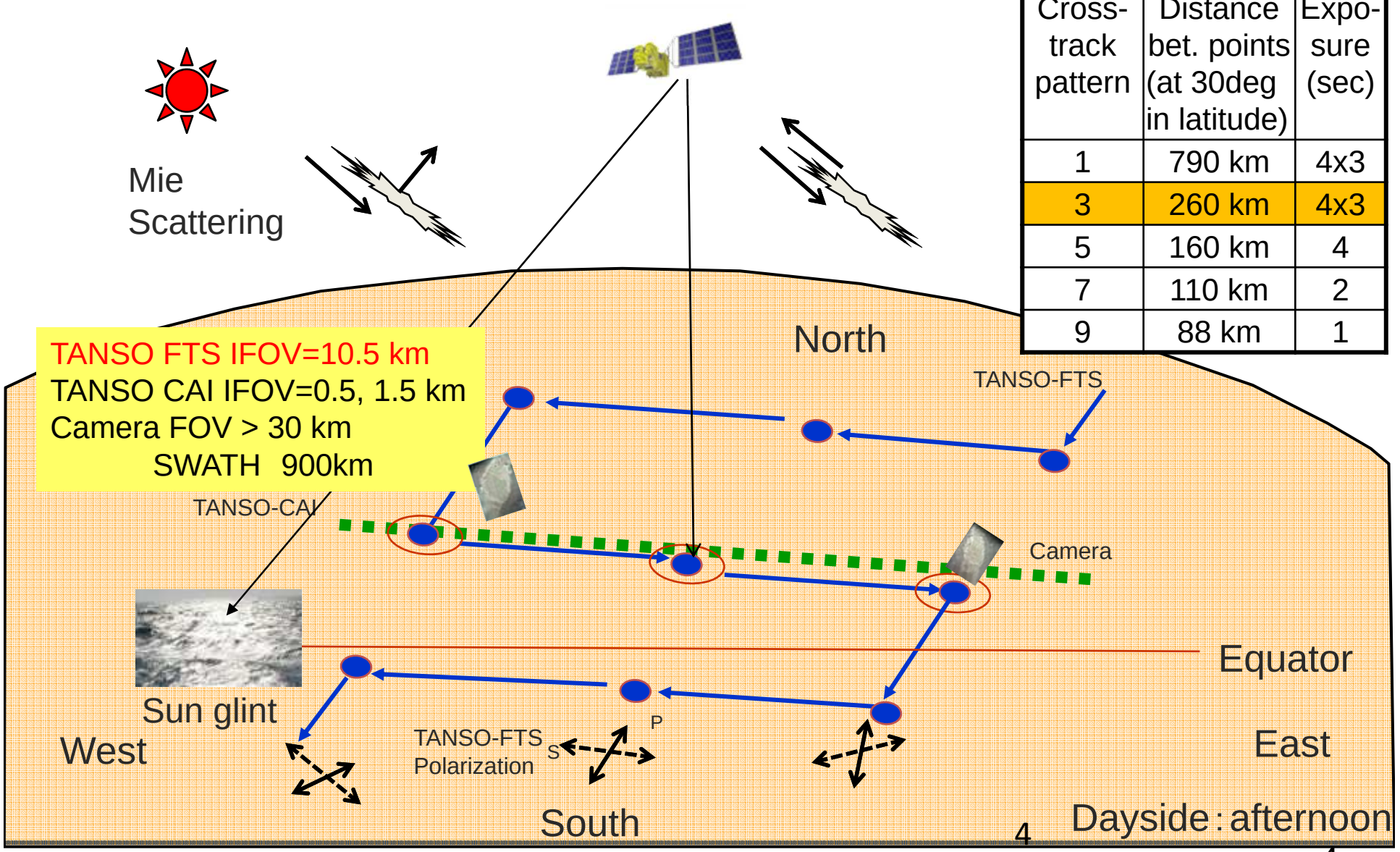
Size	Main body	3.7 m x 1.8 m x 2.0 m (Wing Span 13.7m)
Mass	Total	1750kg
Power	Total	3.8 KW (EOL)
Life Time	5 years	
Orbit	sun synchronous orbit	
	Local time	13:00+/-0:15
	Altitude	666km
	Inclination	98deg
	Repeat	3 days
Launch	Vehicle	H-IIA
	Schedule	Jan. 23 2009

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 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)

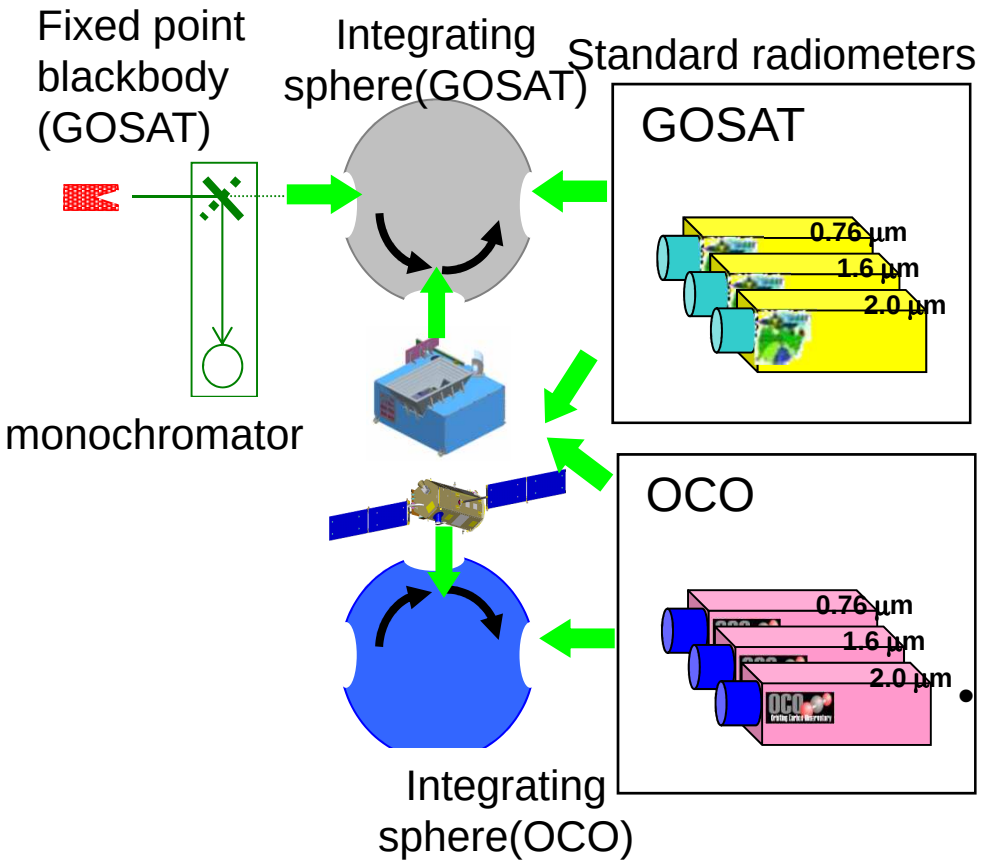
- Blackbody (BB) and Deep Space (DS) views for onboard calibration (2-time in dayside, 4-time in nightside)
- Polarization correction (mirrors, beamsplitter, dichroic filters)
- BB emissivity (EM evaluated by heated halo method at UW-SSEC)
- Sensor background temperature estimation

(4) Geometric correction (Estimated geolocation data)

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

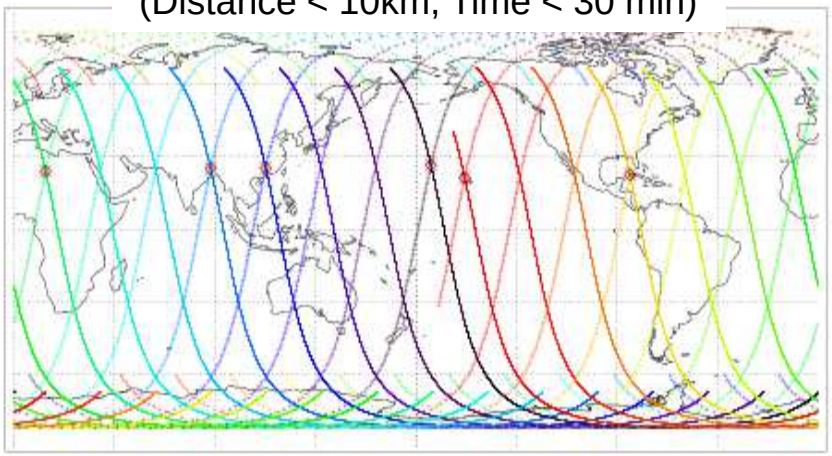
X-calibration with OCO(/-2)

- X-calibration with OCO/GOSAT standard radiometers

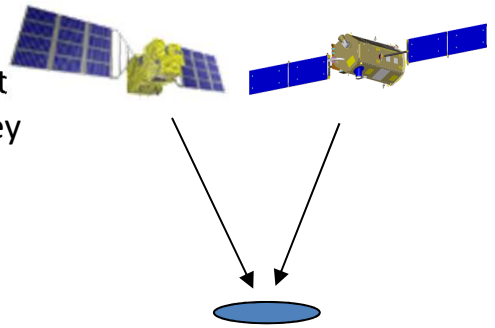


- Nadir coincidence of OCO and GOSAT
  - Comparisons of L1 and L2 products
  - OCO: continuous swath at 13:26LT
  - GOSAT: separate pointing at 13:00LT

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



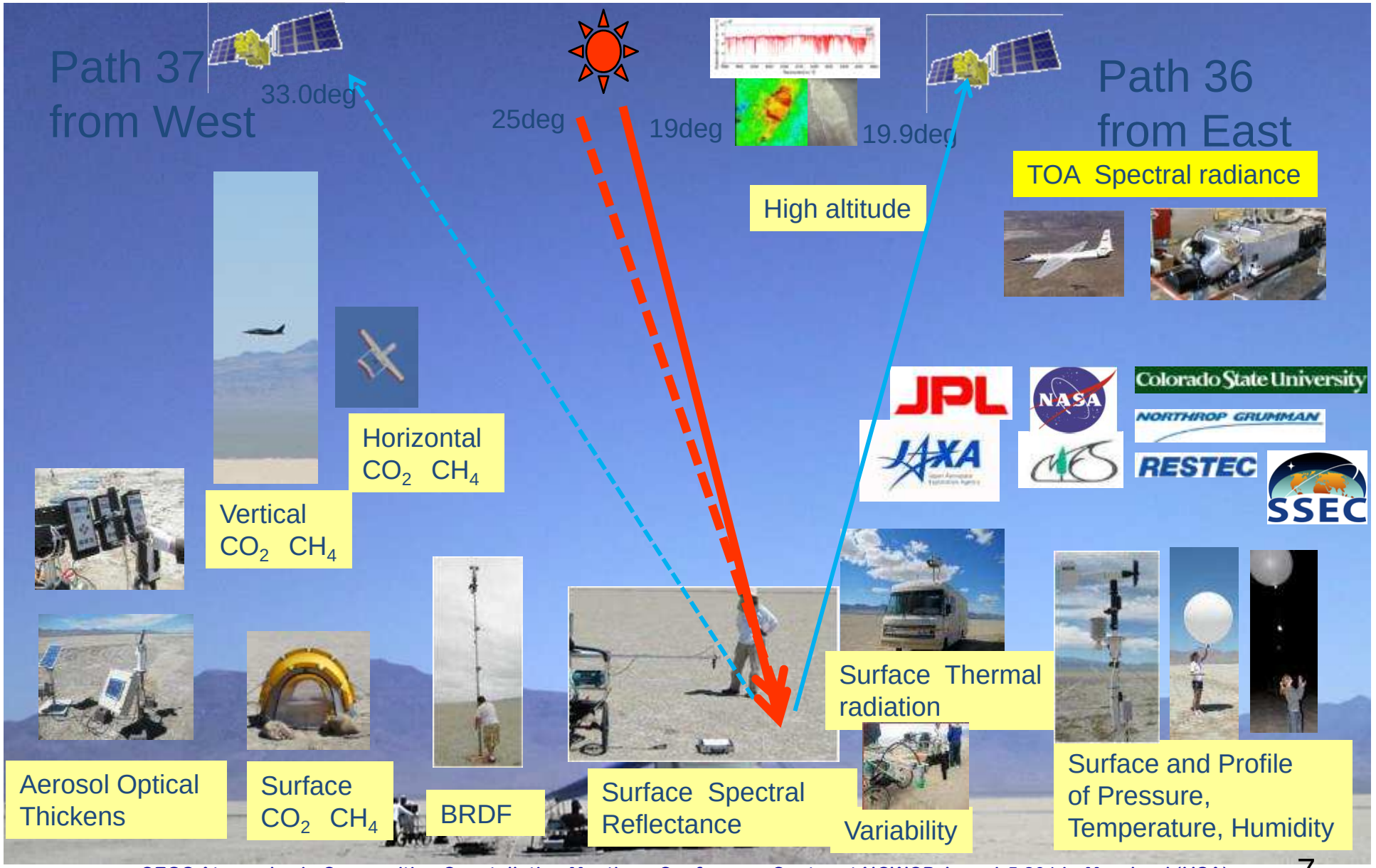
- Target observations with OCO and GOSAT
  - Calibration sites
    - Sahara desert
    - Railroad valley
  - Validation sites
    - TCCON



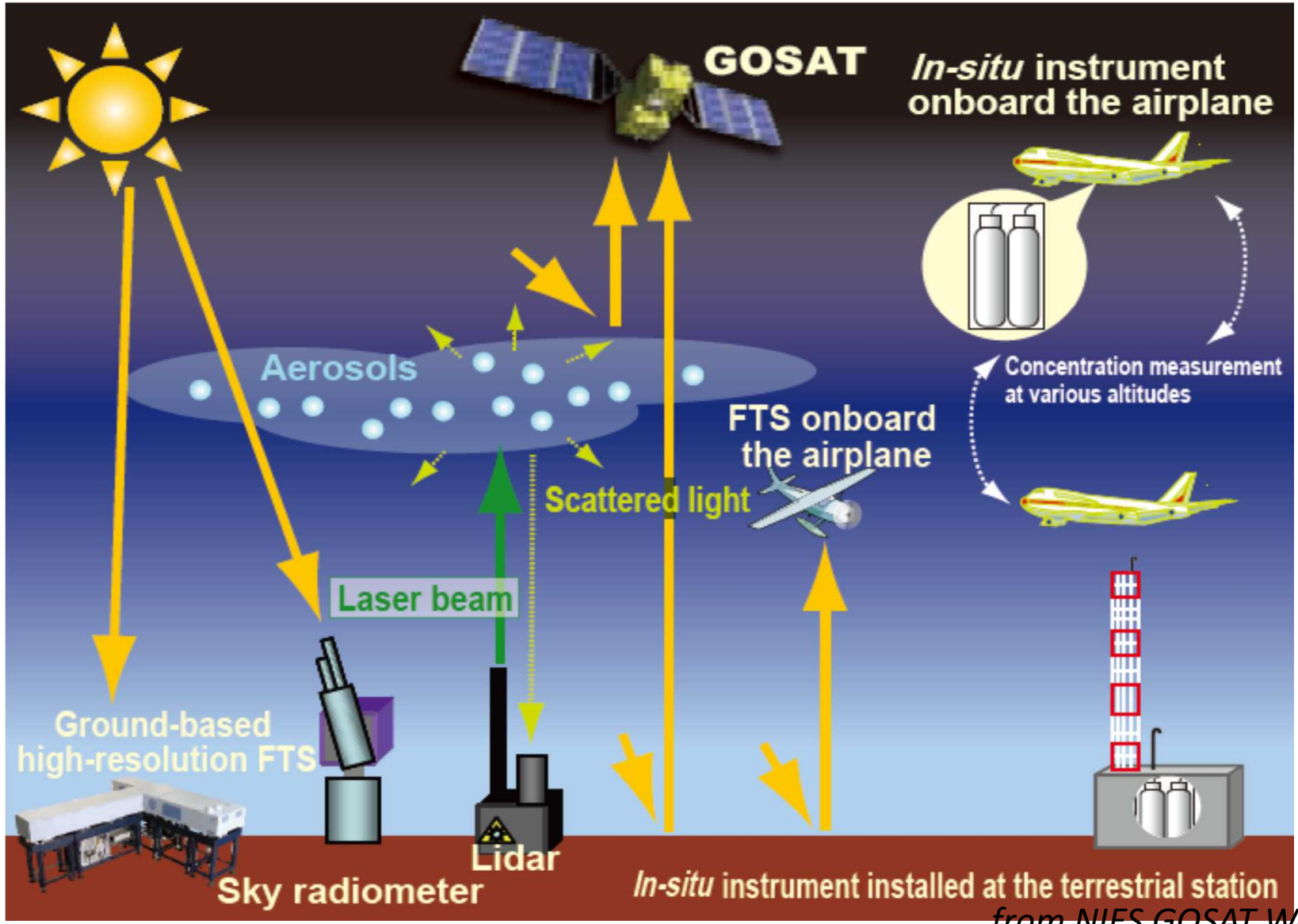
- 1st step @ JPL (Apr, 2008) ***Difference < 3%***
- 2nd step @ JAXA (Dec, 2008

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

Vi-calibration campaign at RRV



GOSAT 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

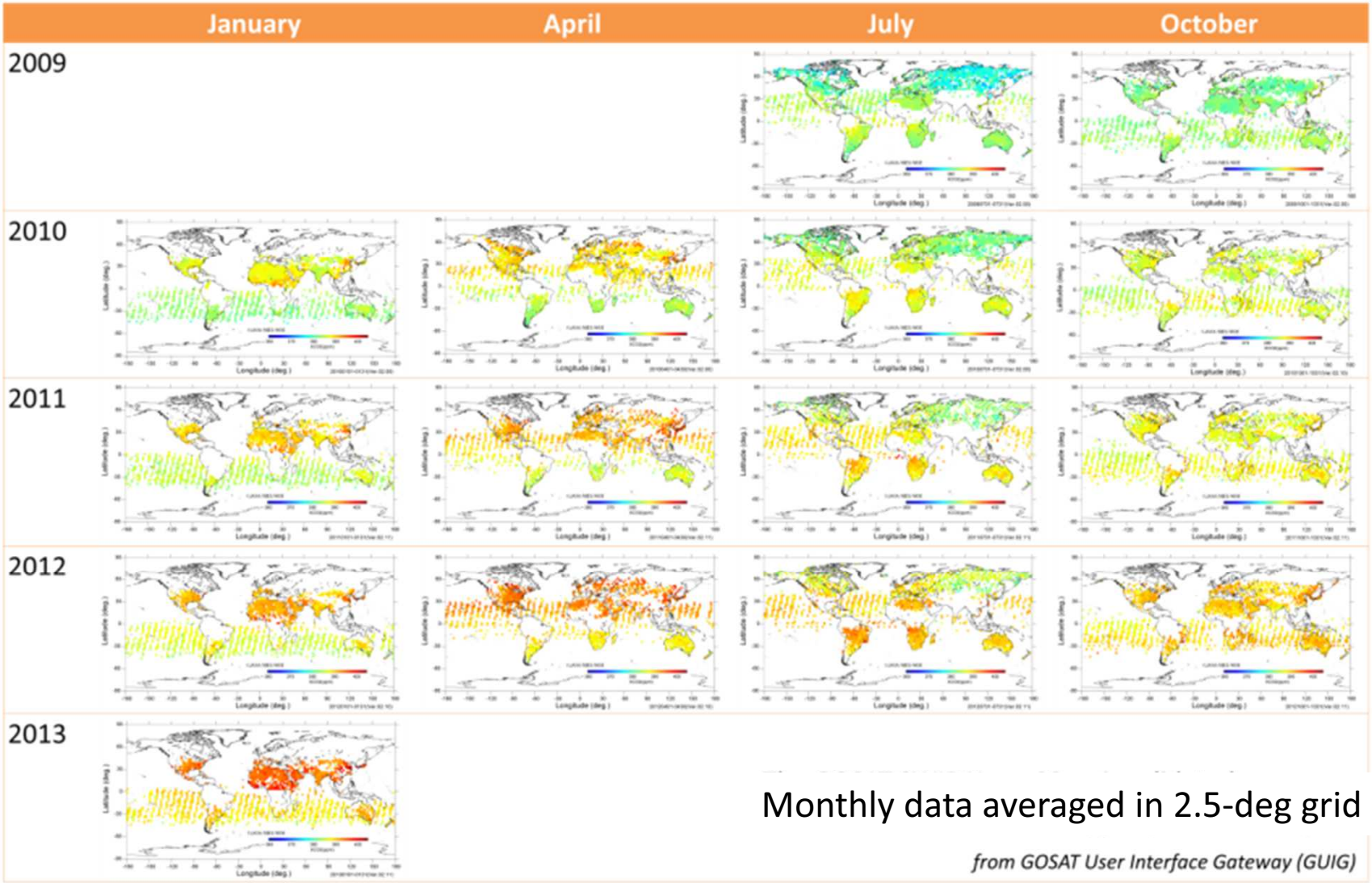
Oct. 2009	Level 1 (Observation spectra) to public
Feb. 2010	Level 2 (SWIR X_{CO2} and X_{CH4}: column averaged dry air mole fraction, v00.**) to public
Aug. 2010	Level 2 (SWIR X_{CO2} and X_{CH4}, v01.**) to public
Nov. 2010	Level 3 (SWIR X_{CO2} and X_{CH4} spatially interpolated global distribution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

GOSAT Level 2 – global X_{CO2} and X_{CH4} distribution

Monthly mean GOSAT X_{CO2} (CO_2 column-averaged dry air mole fraction) from 2009 (Level 2)



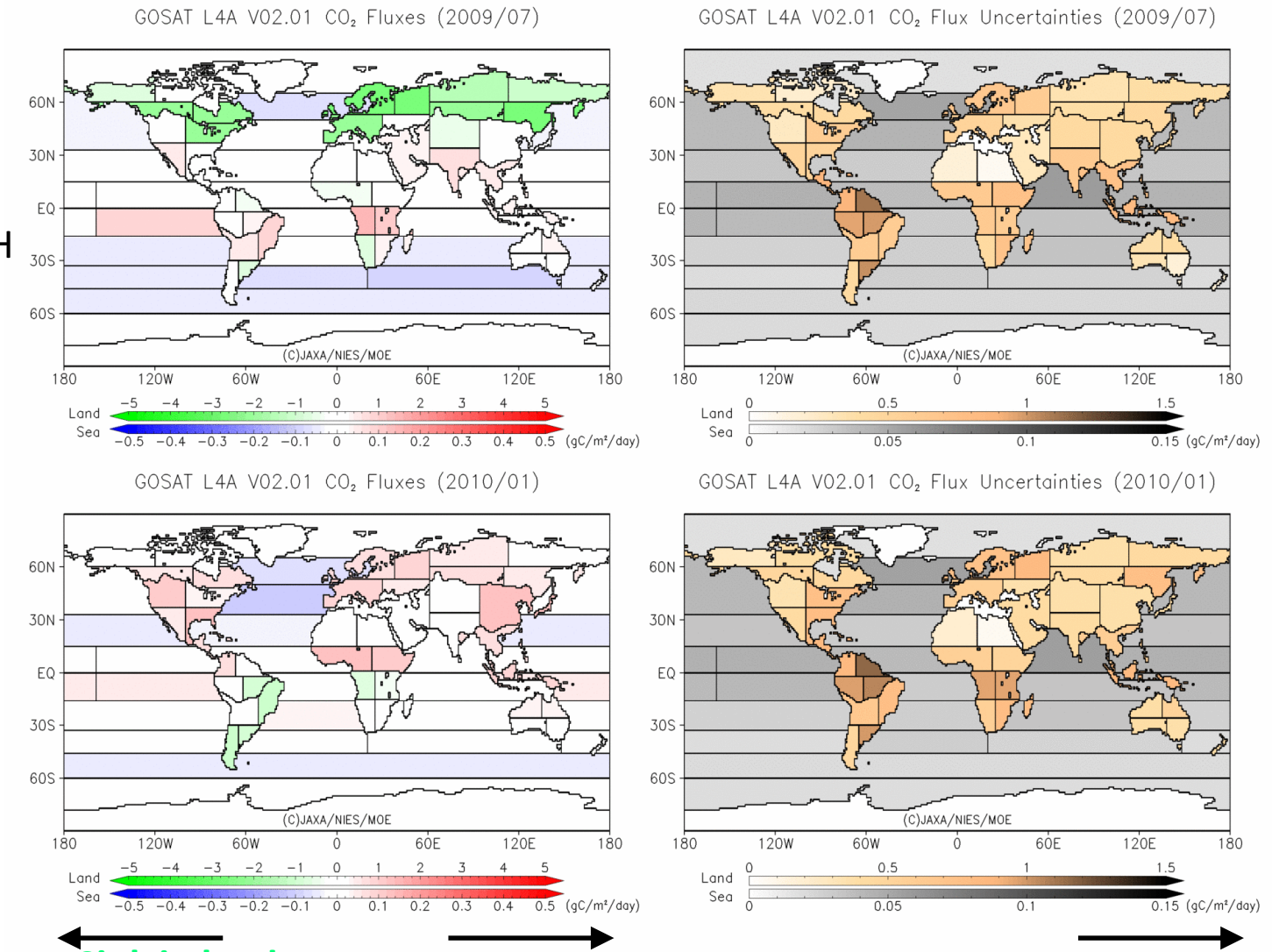
Monthly data averaged in 2.5-deg grid

from GOSAT User Interface Gateway (GUIG)

GOSAT Level 4A - global CO_2 and CH_4 flux estimation

July 2009
Summer in NH

January 2010
Winter in NH



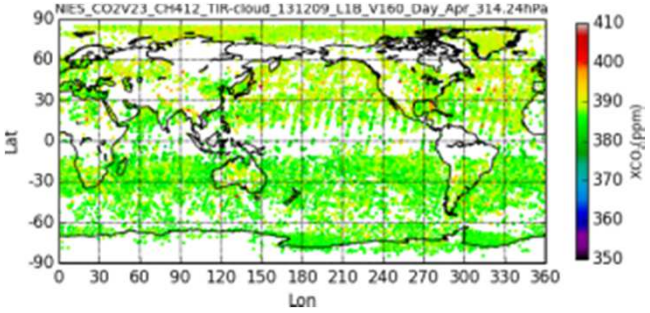
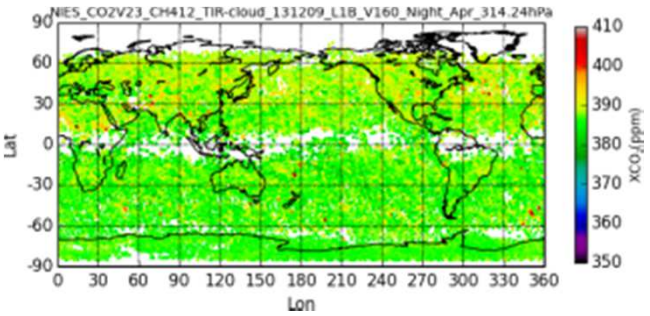
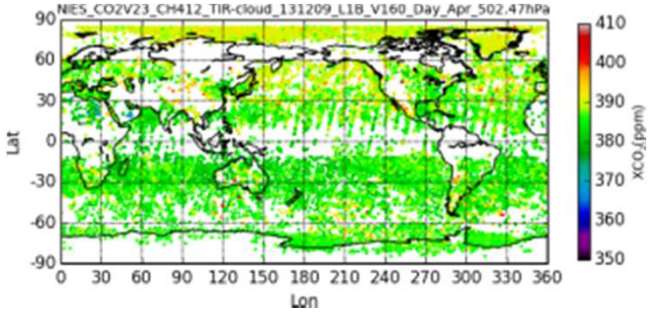
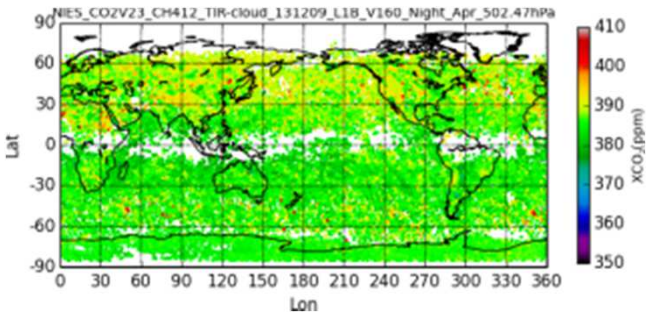
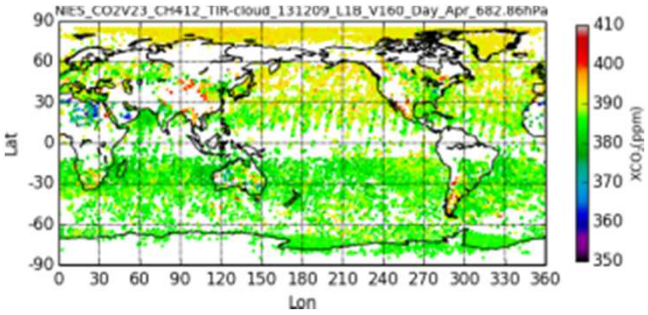
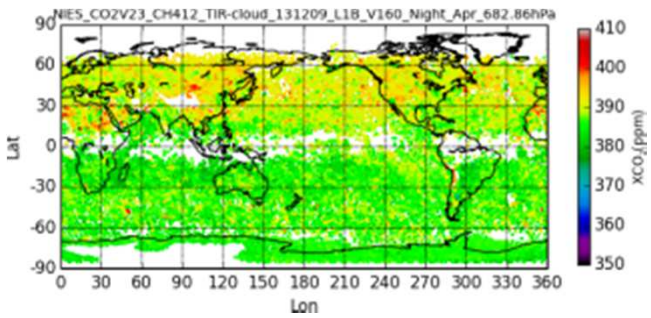
Sink in land
Sink in sea

Source

Large Uncertainty

from GOSAT User Interface Gateway (GUIG)

TANSO-FTS TIR, CO_2 profiles April 2010

	Day	Night
300hPa		
500hPa		
700hPa		

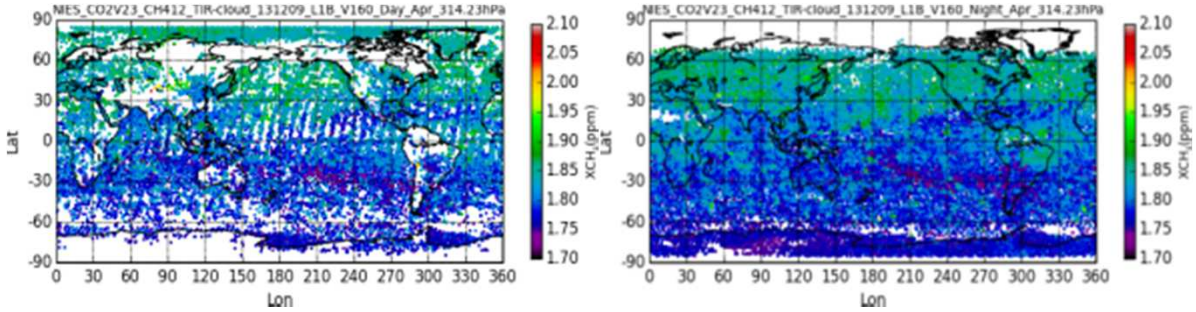
Data will be released to RA PI in June, 2014 and to the public till the end of 2014

(by S. Kawakami (JAXA))

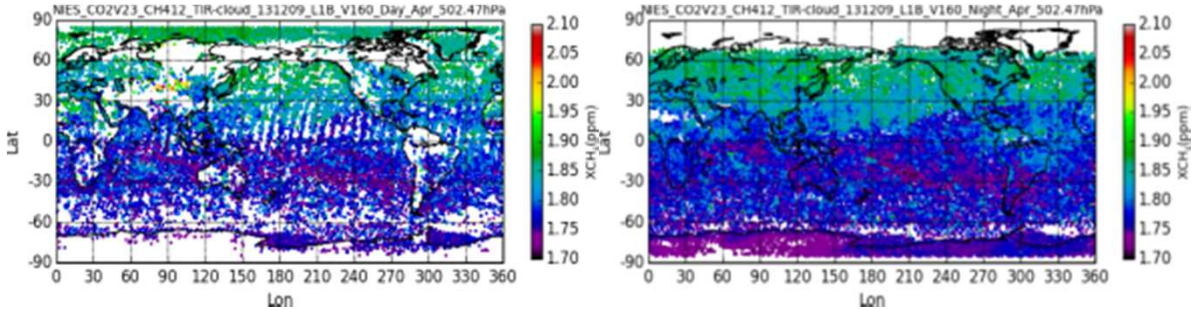
TANSO-FTS TIR, CH_4 profiles April 2010

Day Night

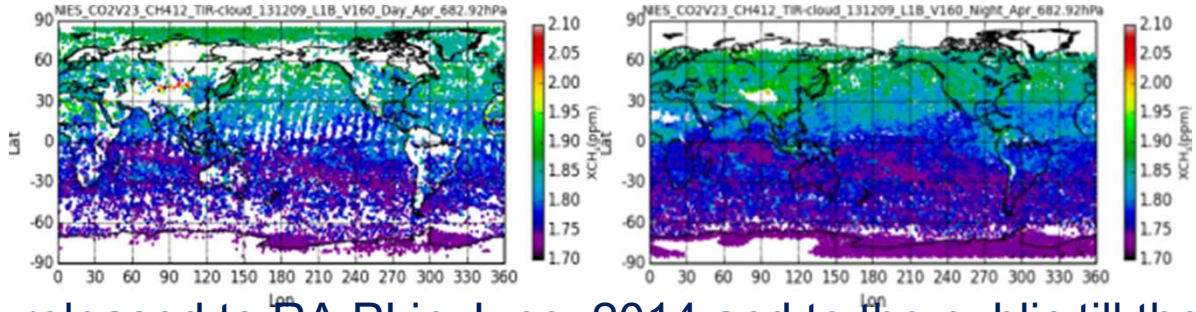
300hPa



500hPa



700hPa



Data will be released to RA PI in June, 2014 and to the public till the end of 2014

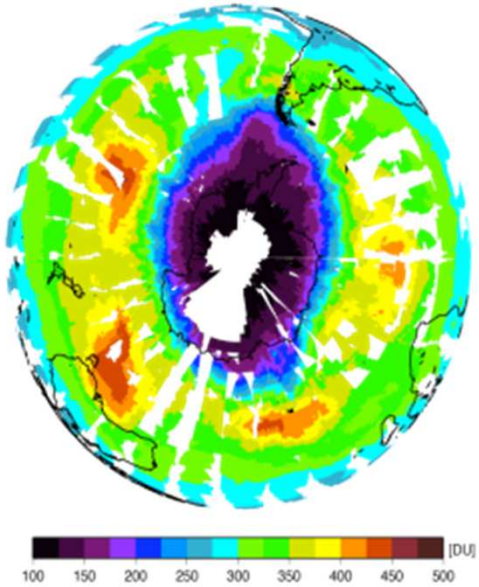
(by S. Kawakami (JAXA))

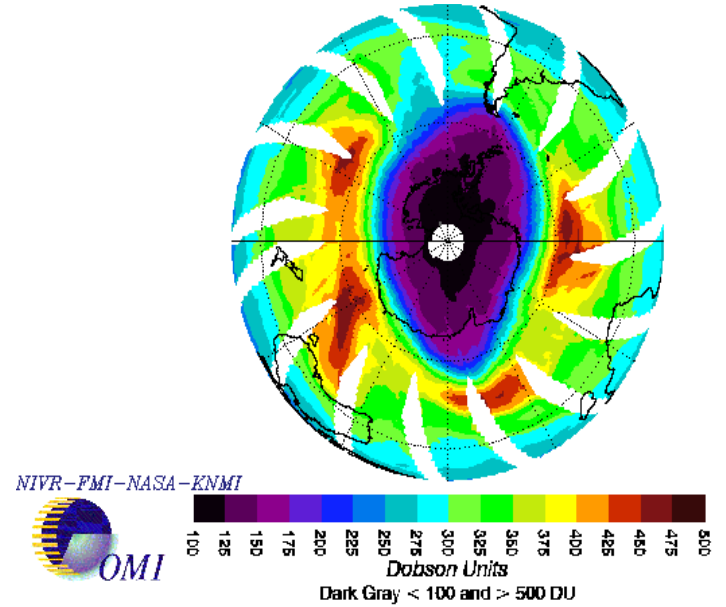
Observation of ozone hole (low total ozone)

TANSO-FTS/GOSAT

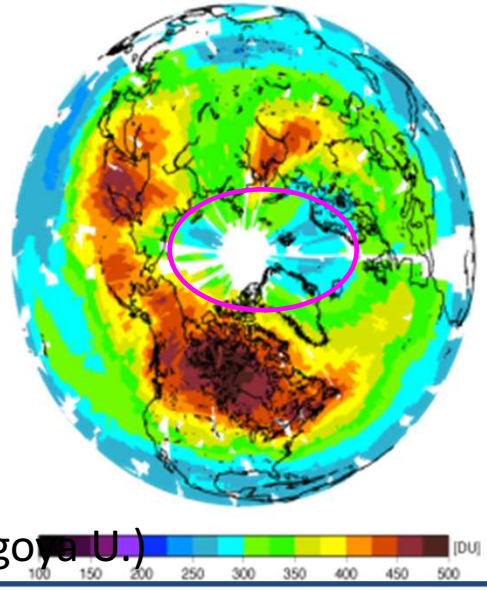
OMI/AURA

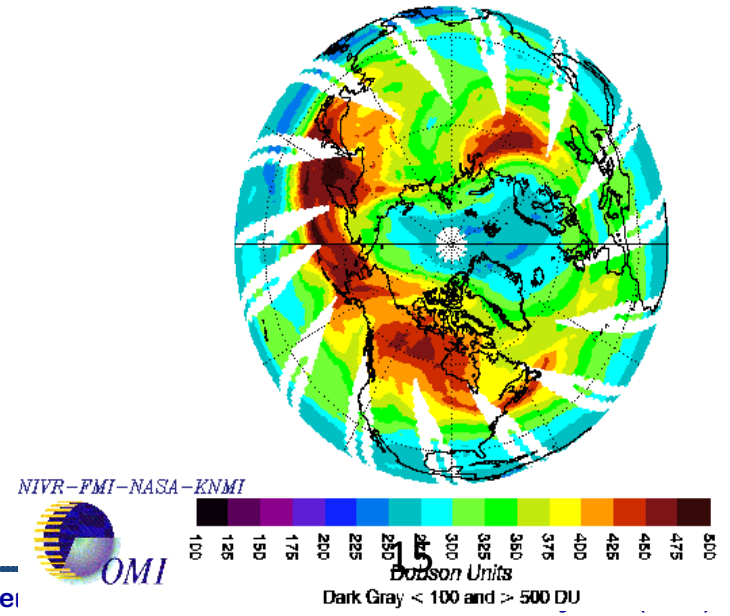
Ozone hole
in Antarctica
2009/09/25





Ozone loss
in Arctic region
2011/03/26

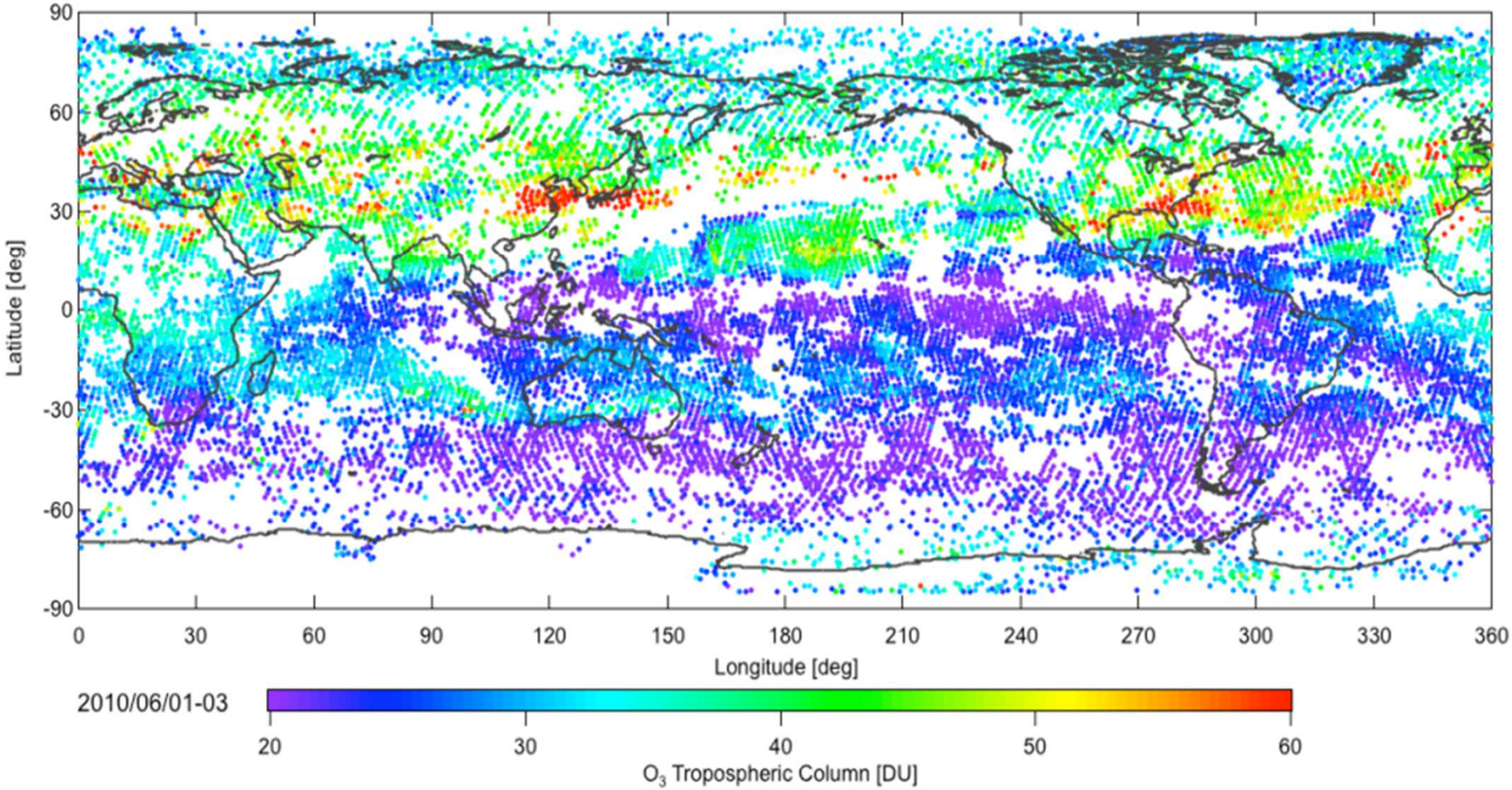




By Dr H. Ohyama(Nagoya U.)

Global distributions of tropospheric ozone column

June 1-3, 2010



By Dr H. Ohyama(Nagoya U.)

GOSAT achievements

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

- more than 5-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

Masakats AKAJIMA
Japan Aerospac oration Agency

Mission Requirements on GOSAT-2 and Objectives of Observation

Mission Requirements

Contribution to the policies on the climate changes (Especially global warming)

decision about the emission reduction targets based on the scientific fact	reduction of the future forecast uncertainty concerning the global warming (more detailed understanding of the global carbon circulation)
evaluation of the emission reduction efforts and the effectiveness of global warming countermeasures - forest preservation - extinction and prevention action of the peat fire - REDD+ action	Monitoring of the emission of the greenhouse gases
	Detection of the earth system change on the sub-continental scale
	evaluation of the REDD+ actions
	Monitoring of the Hot spots
monitoring of the air pollution	monitoring of the dynamic states of the particle matter and SLCP(short-lived climate pollutants)

Objectives of Observation

- improvements of the concentration measurement precision
- improvement of estimation accuracy of flux
- estimation of the anthropogenic emission
- improvement of the natural emission estimation accuracy
- grasp of the flux of the forest area in the developing countries which have large forest area
- Monitoring of the Hot spots
- Monitoring of the aerosols in the atmosphere

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

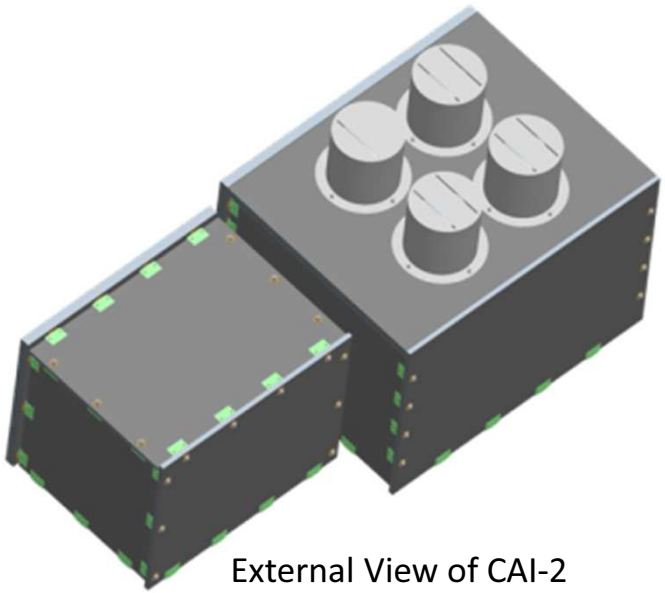
- **increase the signal level----------**
  - **expansion of the aperture**
- **reduction of the noise level------**
  - **over sampling for band 1**
  - **set the pre-amplifier to the detector directly**

TANSO-FTS-2 specifications

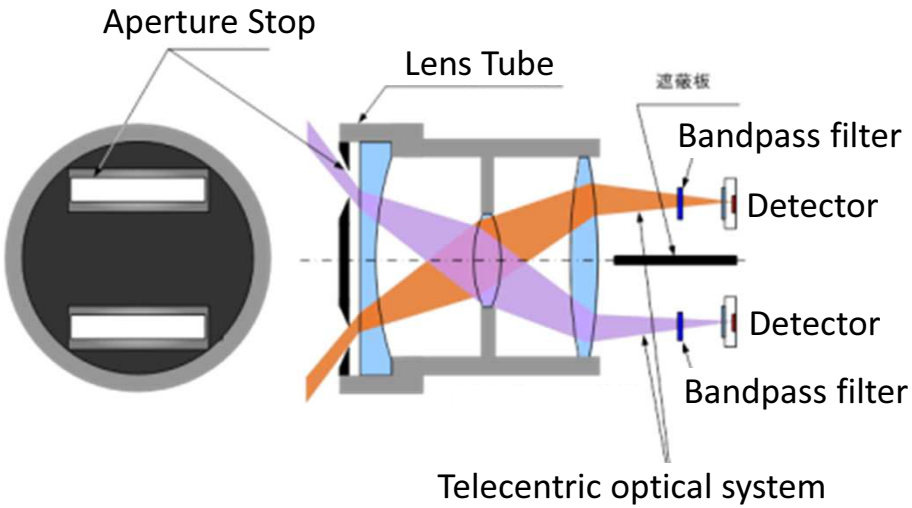
Items	GOSAT-2	GOSAT
Measurement Gases	CO_2, CH_4, O_3, H_2O, **CO**	CO_2, CH_4, O_3, H_2O
FOV/number	10.5 kmϕ / 1	10.5 kmϕ / 1
Spectral Ranges (μm)(cm-1)	band 1 : 0.75-0.77 (**12,950-13,250**) band 2: 1.56-**1.69** (**5,900**-6,400) band 3: 1.92-**2.33** (**4,200**-5,200) band 4: **5.5-8.4 (1,188-1,800)** 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	Nadir Viewing	Backward Viewing	
	band 1 : 330-350	**band 9 : 425-445**	band 5 : 370-390	**band 1 :** 370-390
	band 2 : 660-680	**band 10 : 540-560**	**band 6 : 660-680**	**band 2 :** 664-684
	band 3 : 860-880		**band 7 : 860-880**	**band 3 :** 860-880
	band 4 : 1555-1645		**band 8 : 1555-1645**	**band 4 :** 1555-1645
Spatial Resolution/ swath	500m/1,000km (except band 4 and 8)			Band 1-3: 500m/1,000km
	1km/1,000km (band 4 and 8)			Band 4: 1,500m/750km

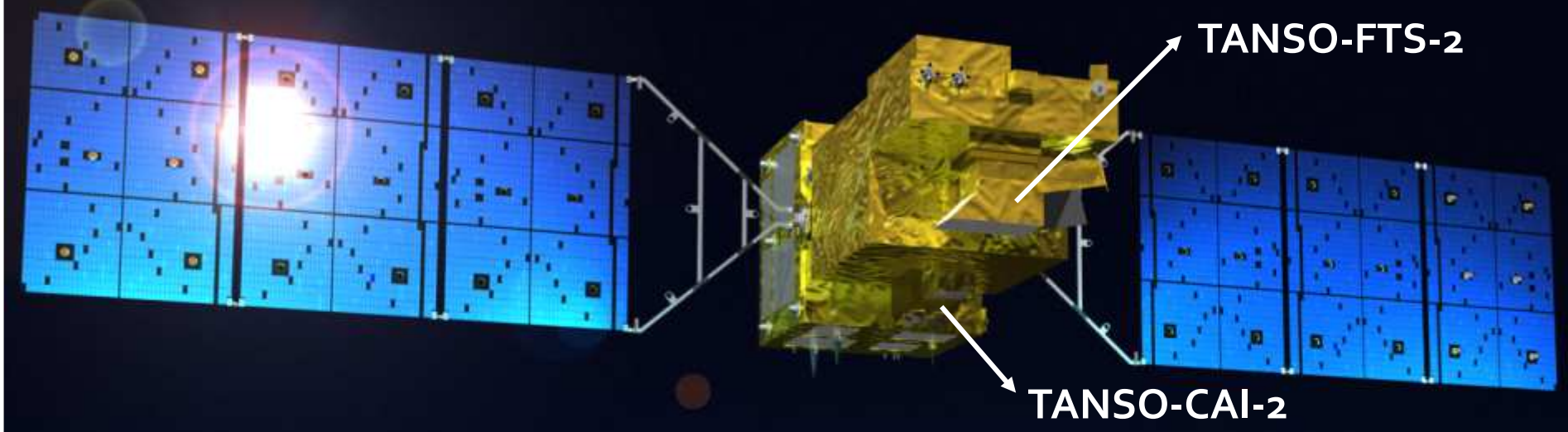


External View of CAI-2



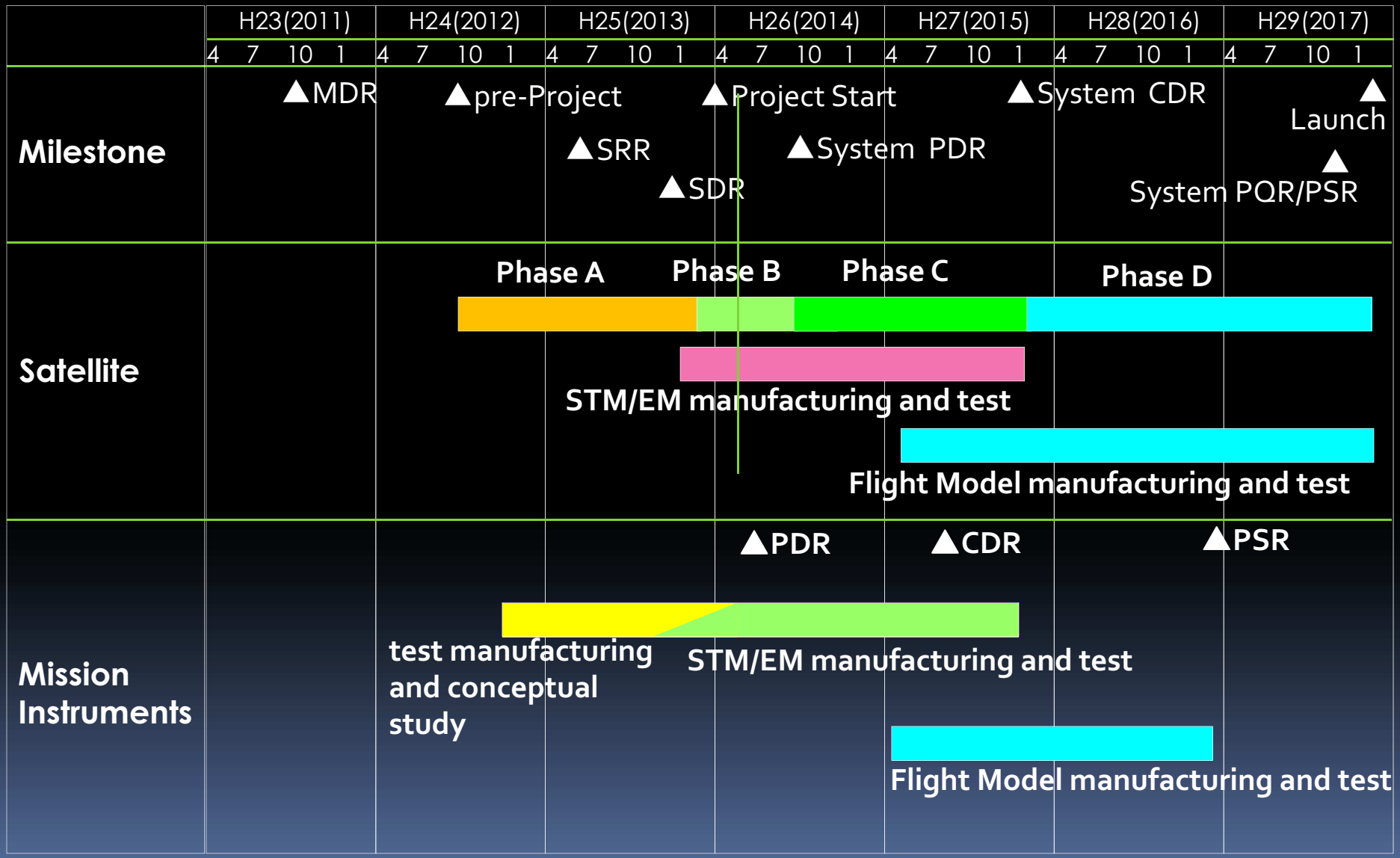
Telecentric optical system

GOSAT-2 on Orbit



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	➡ depends on the repeat cycles
	Inclination	98deg	➡ depends on the repeat cycles
	Repeat	3 days (44 revol.)	➡ more (?)
Launch	Vehicle	H-IIA	
	Schedule	Jan., 2018	

Development Schedule



Summary

- Through the results of the GOSAT, it has emerged that which observation performance should be improved to use in the global warming countermeasures.
- The observation performances which should be improved from the view point of contribution to the global warming issue became concrete.
- In October 2013, the manufacturer of GOSAT-2 was selected and GOSAT-2 system was defined in December, 2013.
- In April 2014, GOSAT-2 was shifted to phase B and the launch date will be in early 2018.
- Around end of this decade, GHG observing satellites will work on orbit, and it's necessary to establish the platform to collaborate and provide reliable data to the policy makers and so on.

International Cooperation in Global Observation

- GOSAT-1, 2 are the only platform in space which provides high resolution Solar spectra and both column amounts and profiles of major GHGs (CO_2, CH_4, O_3).
- GOSAT can play a key role of ACC-GHG constellation.
- ***Important is Establishing a platform for cooperation in data inter-comparison and verification, etc.***

⇒ **It leads Improvement in data reliability and accessibility**

Possible collaboration in exchanging information among space carbon missions

For providing quality controlled and less bias data for all users , especially model users

Space-based carbon data keeps quality continuously between carbon missions by maintaining the common standards of calibration, validation and algorithm database.

Based on collaboration between GOSAT-ACOS/OCO projects

1. Pre-launch calibration for ensuring traceability to standards

- Pre-launch X-calibration in laboratory by standard radiometers of both projects
- Sharing the technical insights (PFT characterization, calibration requirements, methods, traceability to international standards)

2. Post-launch calibration for ensuring stability on orbit

- Vi-calibration at same sites (with also validation), solar and lunar calibrations
- X-calibration in coincident cross orbit points

3. Comparison of X_{CO2} retrieval method

- Exchanging retrieval ATBD
- Comparing input data (solar spectrum, atmosphere and surface state, fix or optimize)
- Comparison of algorithm output by common test case
- Exchanging of spectral databases of the gas absorption X-sections for O_2, CO_2, etc.

4. Validation

- TCCON ground-based standard for space-based SWIR X_{CO2} and X_{CH4} measurements
- X-validation in coincident cross orbit points