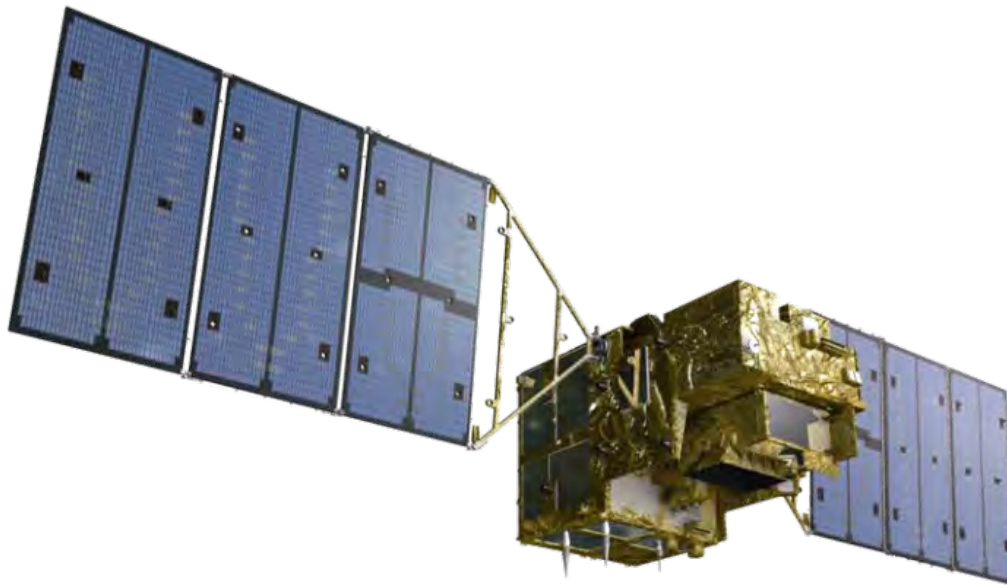


The GOSAT Project



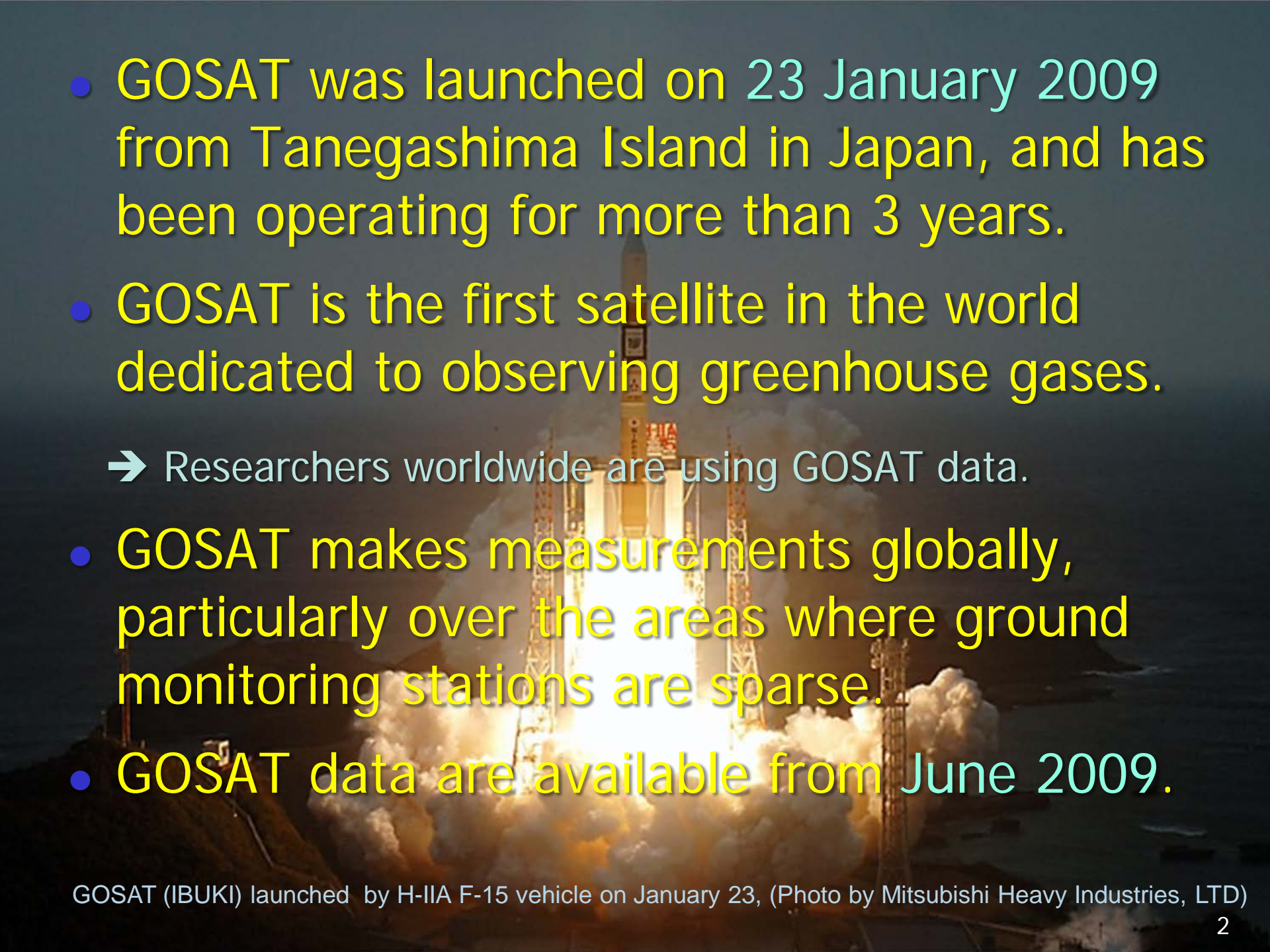
Tatsuya Yokota

Center for Global Environmental Research (CGER)
National Institute for Environmental Studies (NIES), Japan

Contents

- Status of the GOSAT observations
- TANSO-FTS SWIR CO₂ and CH₄ Level 2 (V01.xx) data products
- Validation summary and temporal variation of Level 2 (V01.xx) data products
- Collaboration with worldwide researchers

GOSAT (IBUKI) launched by H-IIA F-15 vehicle on January 23, (Photo by Mitsubishi Heavy Industries, LTD)

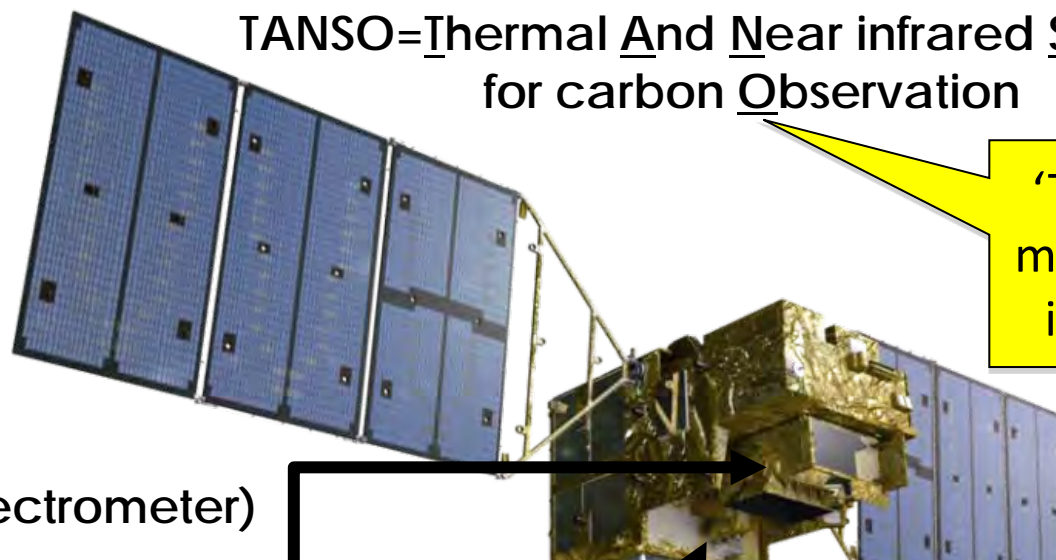
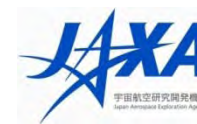
- 
- A photograph of the GOSAT (IBUKI) satellite being launched by an H-IIA F-15 vehicle. The rocket is ascending vertically, with a large plume of white smoke and fire at its base. The launch is taking place at night or dusk, with the sky dark and the launch pad structures visible in the background.
- GOSAT was launched on 23 January 2009 from Tanegashima Island in Japan, and has been operating for more than 3 years.
 - GOSAT is the first satellite in the world dedicated to observing greenhouse gases.
 - ➔ Researchers worldwide are using GOSAT data.
 - GOSAT makes measurements globally, particularly over the areas where ground monitoring stations are sparse.
 - GOSAT data are available from June 2009.



■ Status of the GOSAT observations



MISSION SENSORS



TANSO=Thermal And Near infrared Sensor
for carbon Observation

'TANSO' also means **carbon** in Japanese

TANSO-FTS
(Fourier Transform Spectrometer)

TANSO-FTS

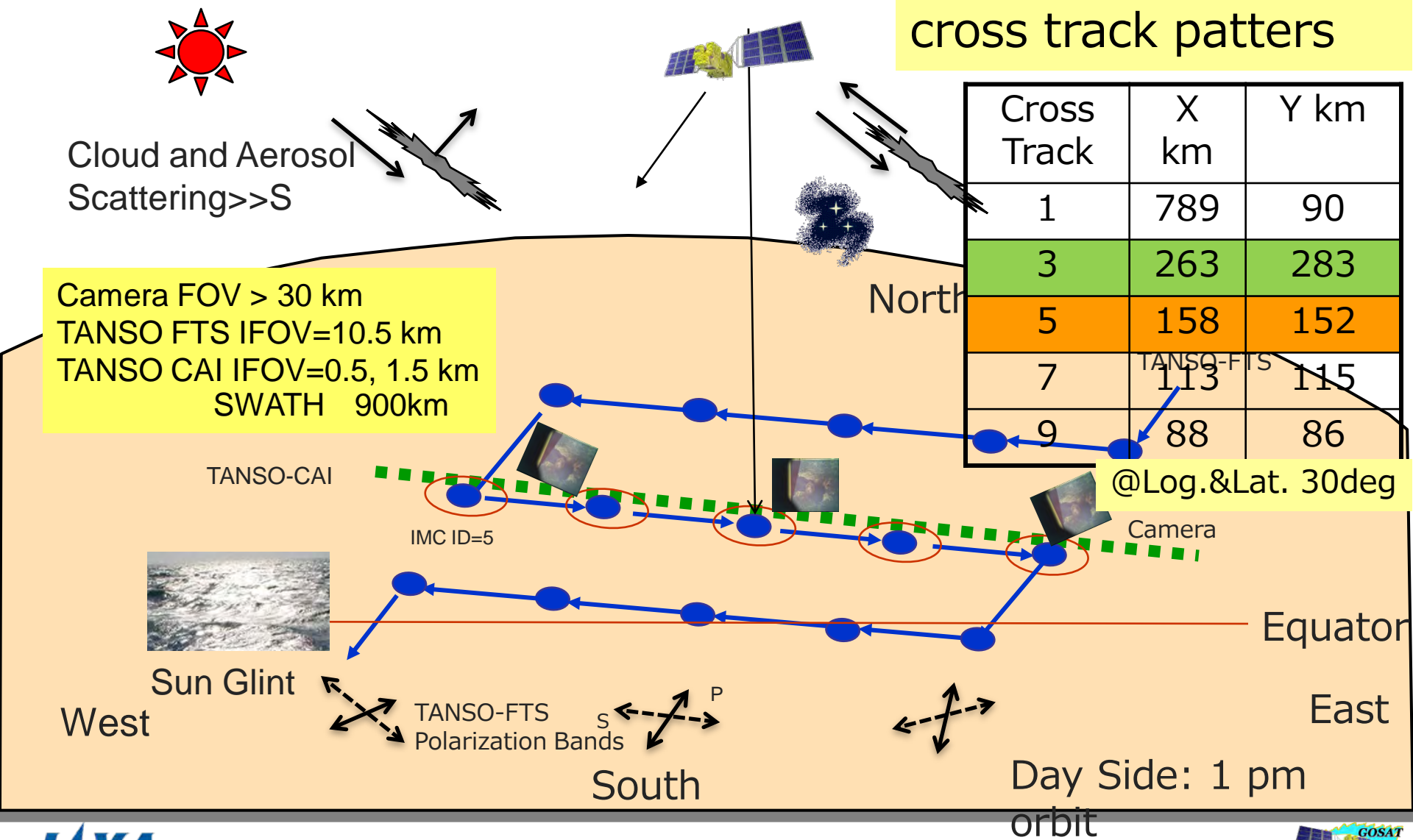
	Band 1	Band 2	Band 3	Band 4
Spectral coverage [μm]	0.758~0.775	1.56~1.72	1.92~2.08	5.56~14.3
Spectral resolution [cm^{-1}]	0.5	0.27	0.27	0.27
Target species	O ₂	CO ₂ · CH ₄	CO ₂ · H ₂ O	CO ₂ · CH ₄
Instantaneous field of view/ Field of observation view at nadir	Instantaneous field of view: 15.8 mrad Field of view for observation (footprint): diameter of app. 10.5 km			
Single-scan data acquisition time	1.1, 2.0, 4.0 seconds			

* 1 μm = 1/1000 mm

TANSO-CAI

	Band 1	Band 2	Band 3	Band 4
Spectral coverage [μm]	0.370~0.390 (0.380)	0.668~0.688 (0.678)	0.860~0.880 (0.870)	1.56~1.68 (1.62)
Target substance	Cloud, Aerosol			
Swath [km]	1000	1000	1000	750
Spatial resolution at nadir [km]	0.5	0.5	0.5	1.5

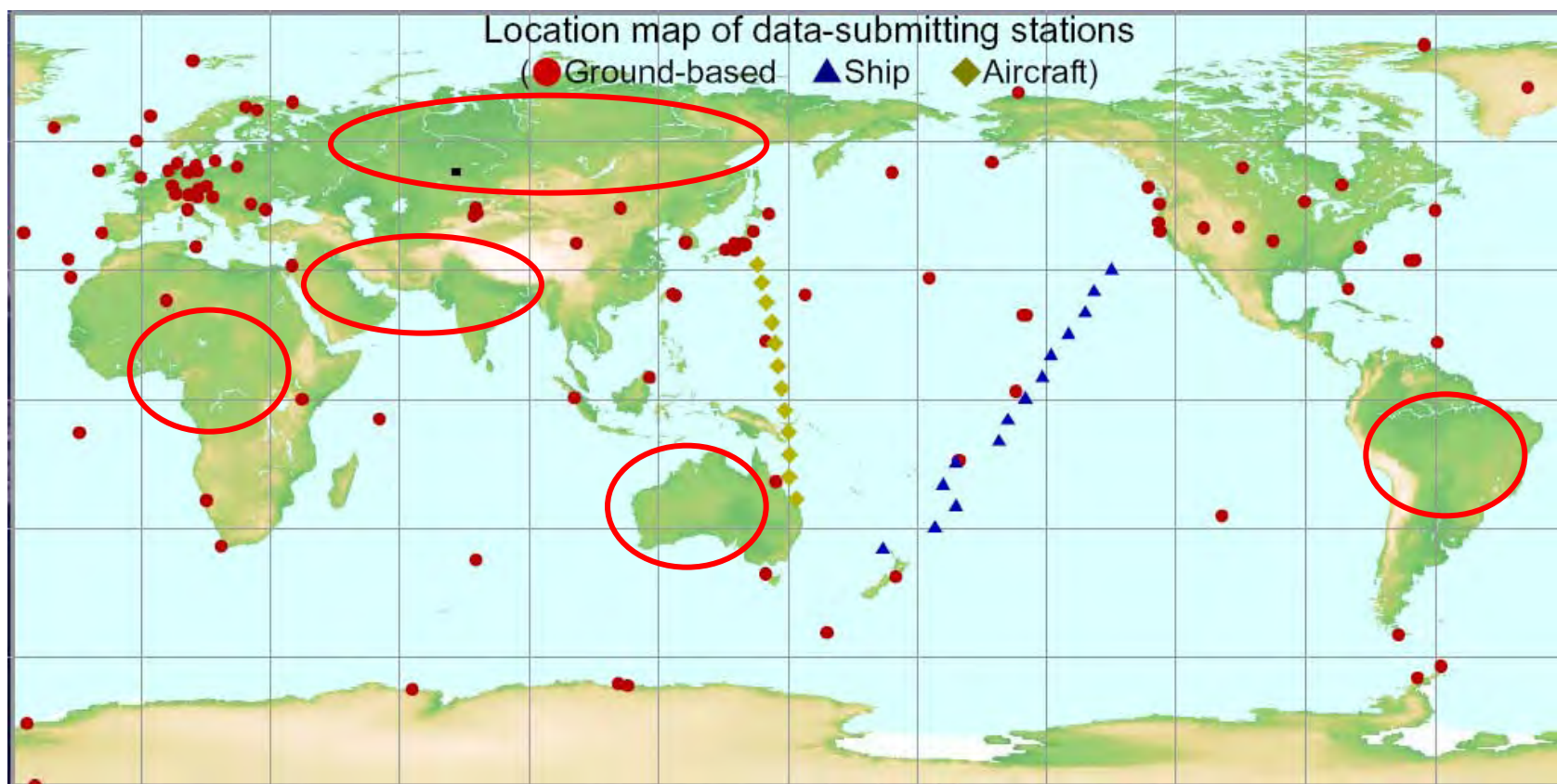
Pointing and Footprints



(Courtesy by H. Suto (JAXA))

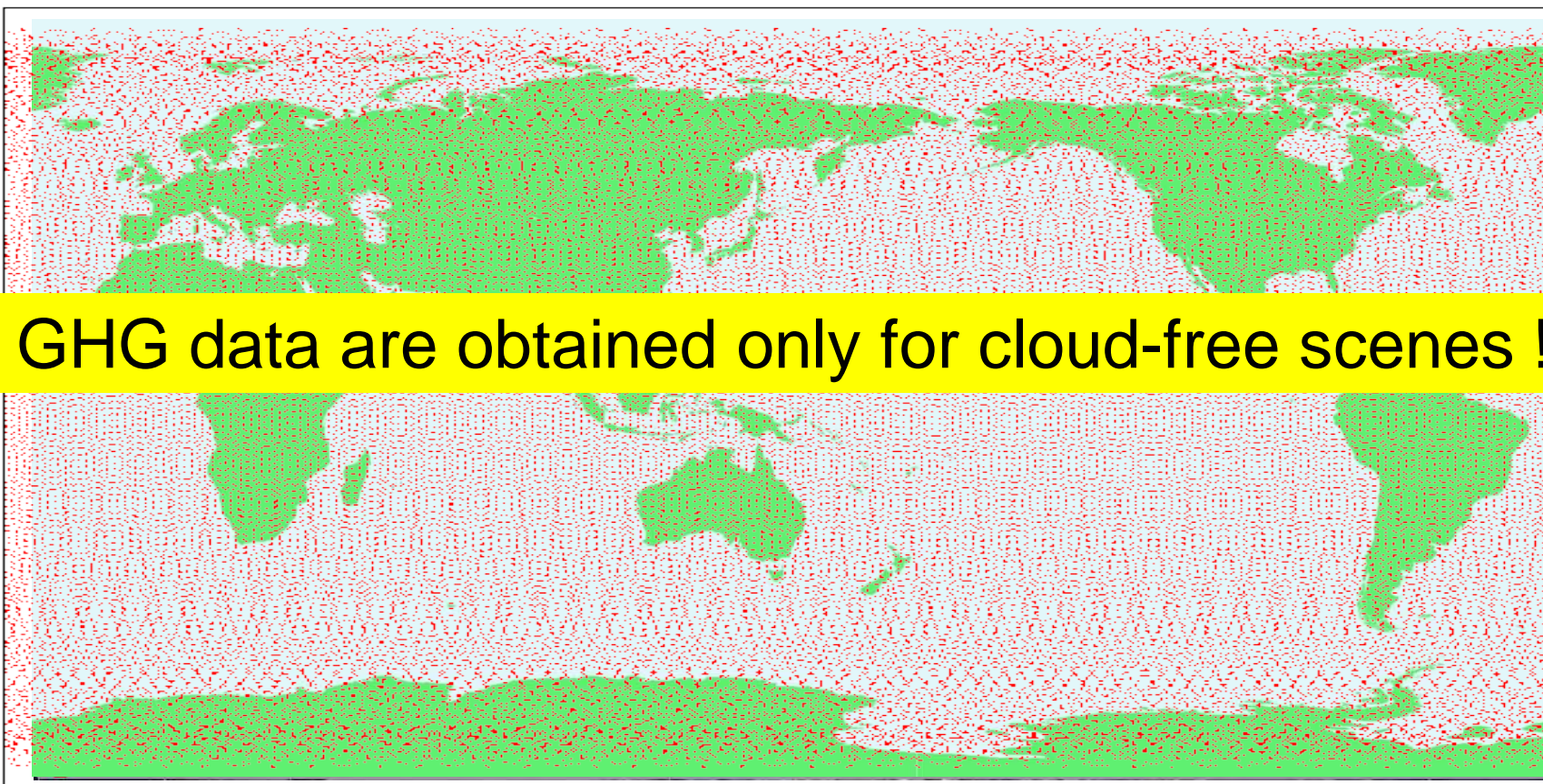
Status of ground measurements of GHGs

- (GHG monitoring stations: 325, CO₂ measurement: 214,
- CH₄ measurement: 195 as of 7 March 2012)



Status of ground measurements of GHGs

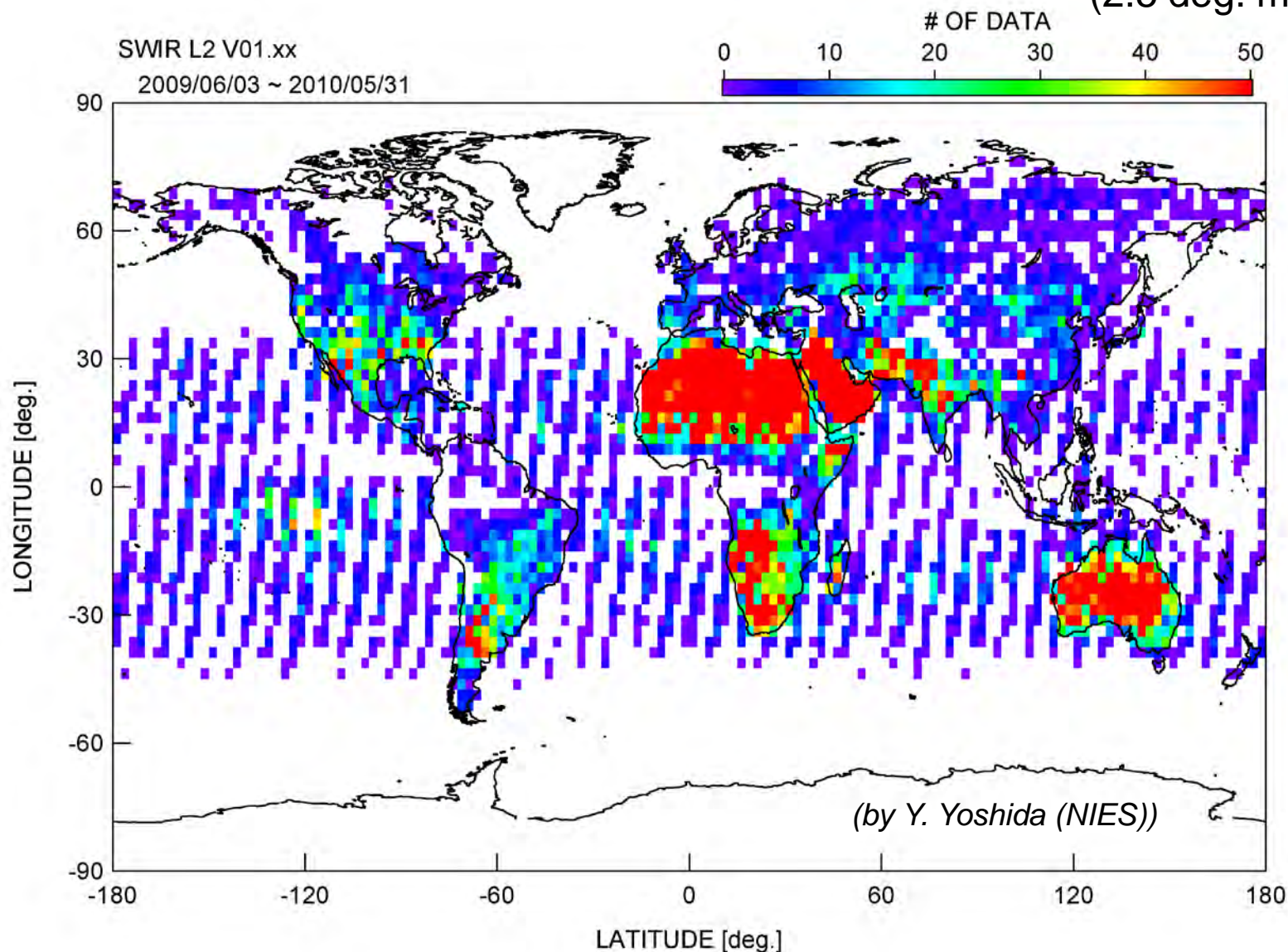
- (GHG monitoring stations: 325, CO₂ measurement: 214,
- CH₄ measurement: 195 as of 7 March 2012)



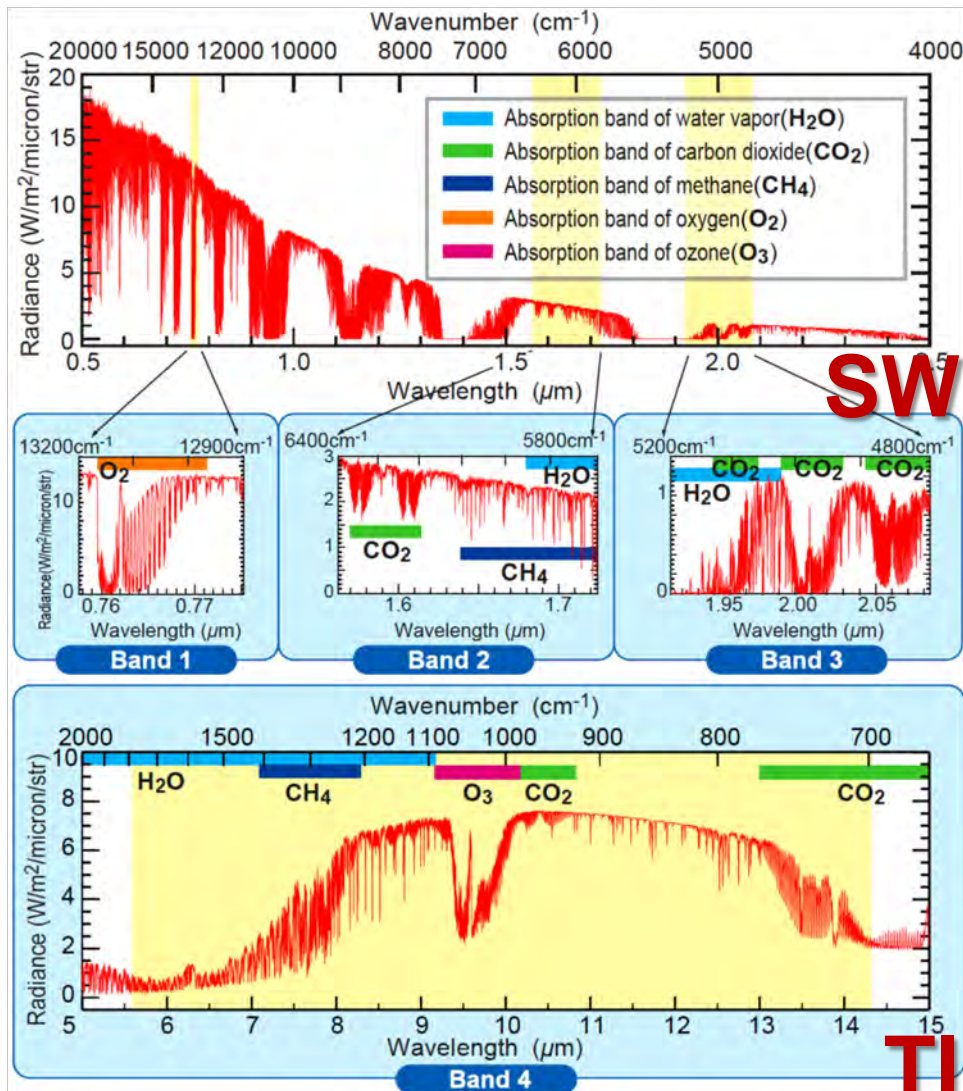


Measurement data numbers and coverage (June 2009 – May 2010)

(2.5 deg. mesh)

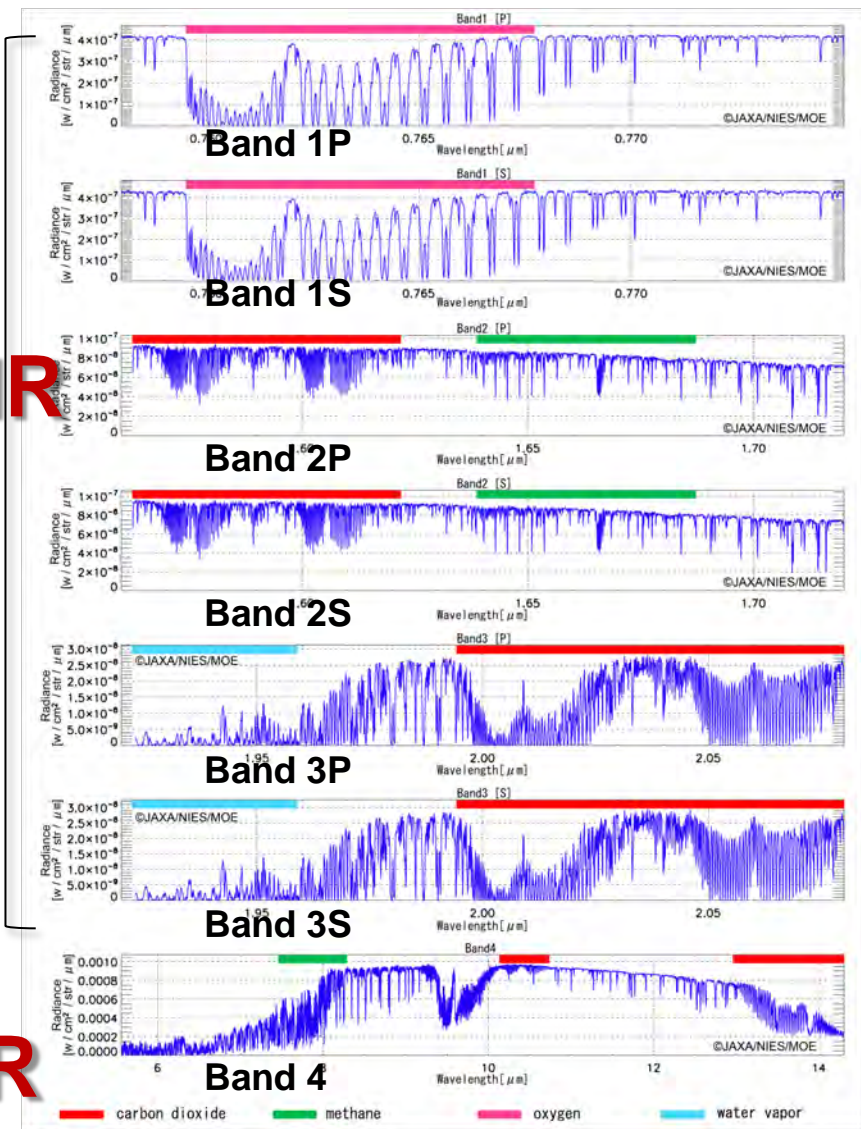


TANSO-FTS Level 1B

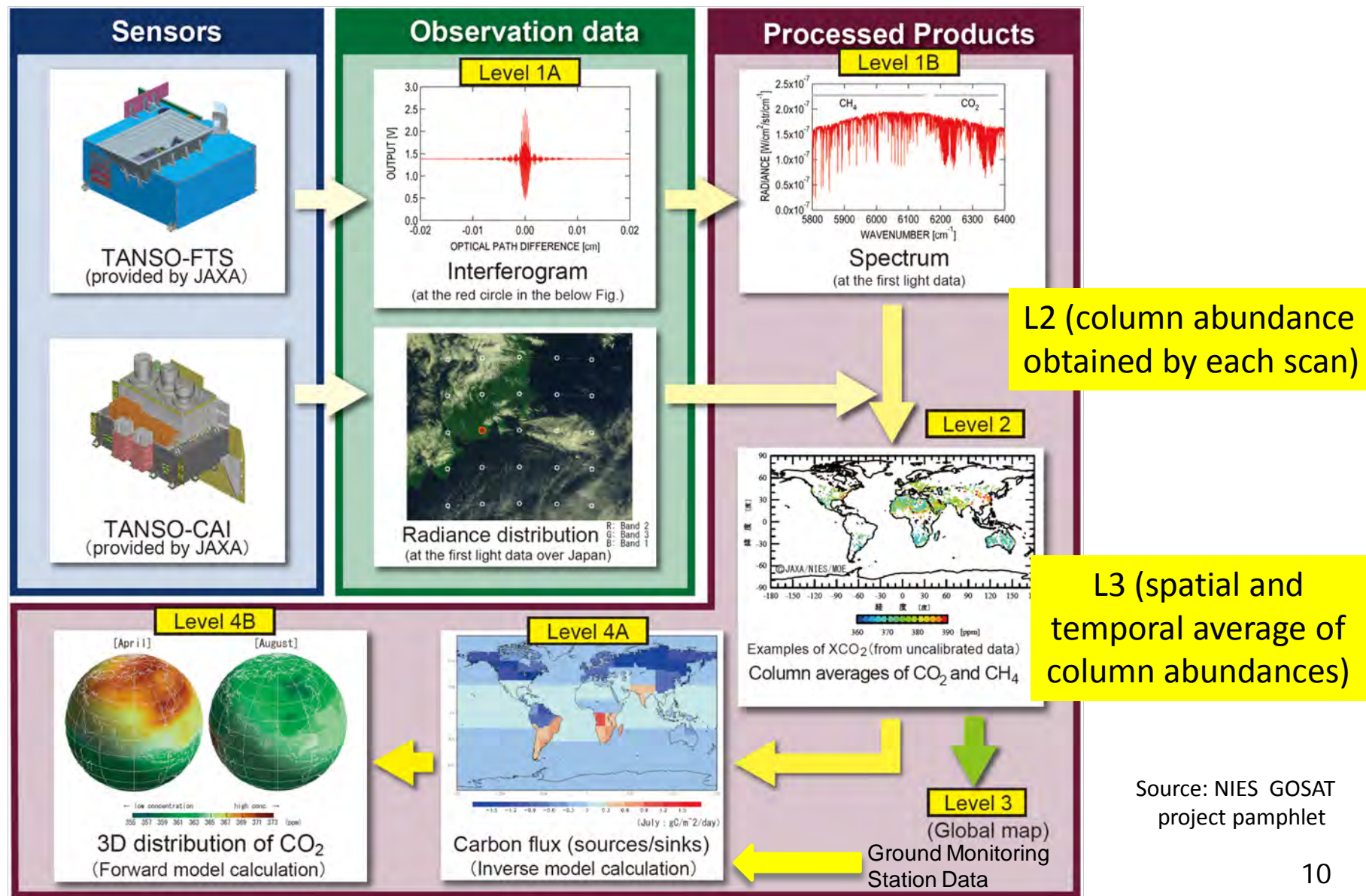


SWIR

TIR

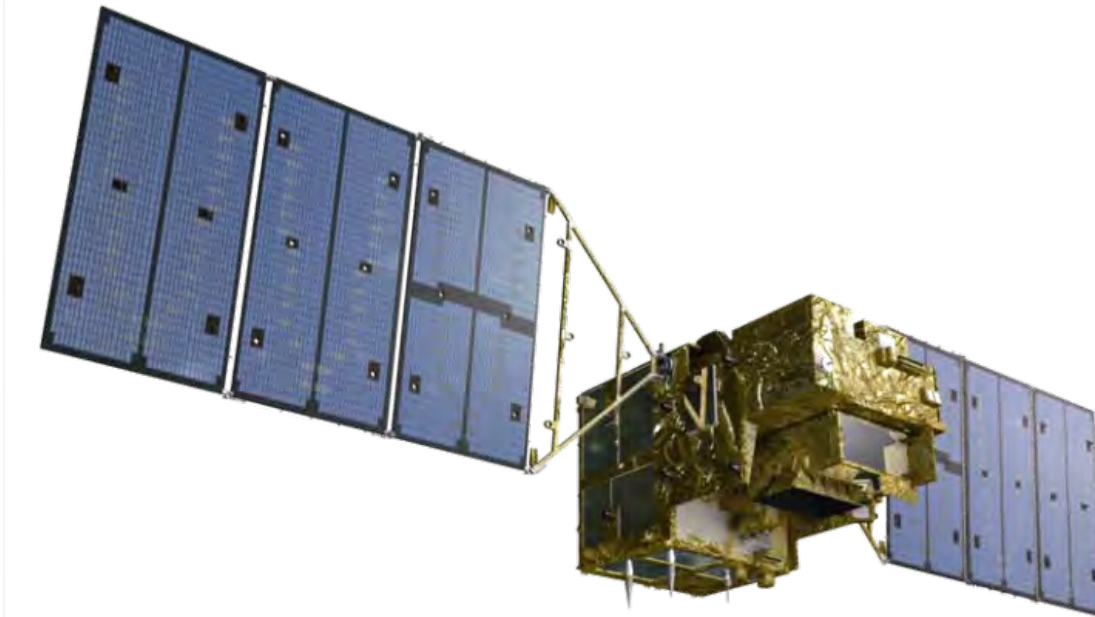


GOSAT Data Processing Flow



GOSAT Standard Data Products

	Product Level	Sensor / Band	Product Designation	Description	Product Provision Unit	Data Format	
Level 1 (L1)	L1B	FTS	FTS L1B data	Radiance spectral data obtained by performing Fourier transform on interferogram data	per FTS scene	HDF5	
		CAI	CAI L1B data	Radiance data (band-to-band and geometric corrections applied / data mapping not performed)	per CAI frame		
		L1B+	CAI	CAI L1B+ data			Radiance data (band-to-band and geometric corrections applied / data mapping performed)
Level 2 (L2)	L2	FTS SWIR	L2 CO ₂ column amount (SWIR)	CO ₂ column abundance data retrieved from SWIR radiance spectral data	can be selected	HDF5	
			L2 CH ₄ column amount (SWIR)	CH ₄ column abundance data retrieved from SWIR radiance spectral data			
		FTS TIR	L2 CO ₂ profile (TIR)	CO ₂ vertical profile data retrieved from TIR radiance spectral data			
			L2 CH ₄ profile (TIR)	CH ₄ vertical profile data retrieved from TIR radiance spectral data			
		CAI	L2 cloud flag	Cloud coverage data	per CAI frame		
Level 3 (L3)	L3	FTS SWIR	L3 global CO ₂ distribution (SWIR)	CO ₂ column-averaged mixing ratio data projected on a global map	per month (global)		HDF5
			L3 global CH ₄ distribution (SWIR)	CH ₄ column-averaged mixing ratio data projected on a global map			
		FTS TIR	L3 global CO ₂ distribution (TIR)	Monthly-averaged CO ₂ concentration at each vertical level projected on a global map			
			L3 global CH ₄ distribution (TIR)	Monthly-averaged CH ₄ concentration at each vertical level projected on a global map			
		CAI	L3 global radiance distribution	Global radiance distribution data (3 days worth, including data for cloudy segments)	per 3 days (global)		
			L3 global reflectance distribution (clear sky)	Clear-sky radiance data (composed only of clear-sky segments selected from a month worth of data)			
			L3 global NDVI	Vegetation index global distribution data (cloudy segments excluded)	per 15 days 30° × 60° (lat. × lon.)		
Level 4 (L4A, L4B)	L4A	-	L4A global CO ₂ flux	CO ₂ flux per each of the 64-divided global regions (monthly average)	per year (64 regions)	Text	
	L4B	-	L4B global CO ₂ distribution	Three-dimensional, global distribution of CO ₂ concentration	per month 2.5° × 2.5° grid (lat. × lon.)	NetCDF	



- TANSO-FTS SWIR CO₂ and CH₄ Level 2 (V01.xx) data products

TANSO-FTS SWIR Level 2 & Level 3

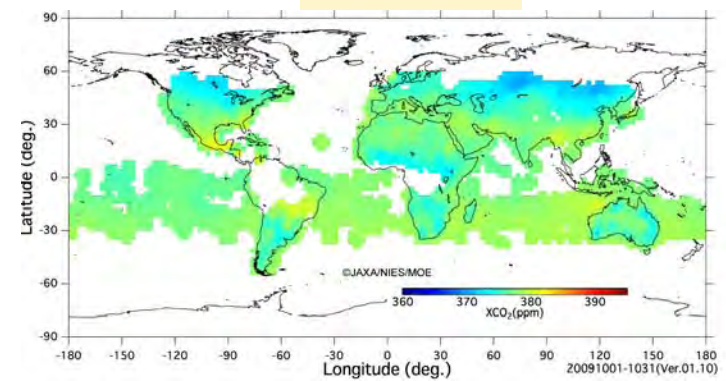
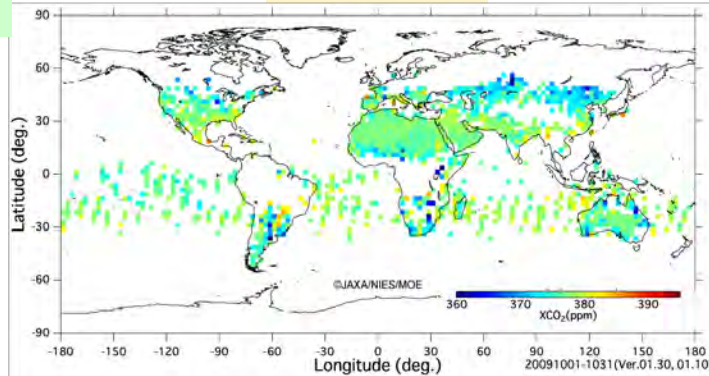
Annual Change of XCO_2 (October 2009, 2010, 2011)

XCO_2

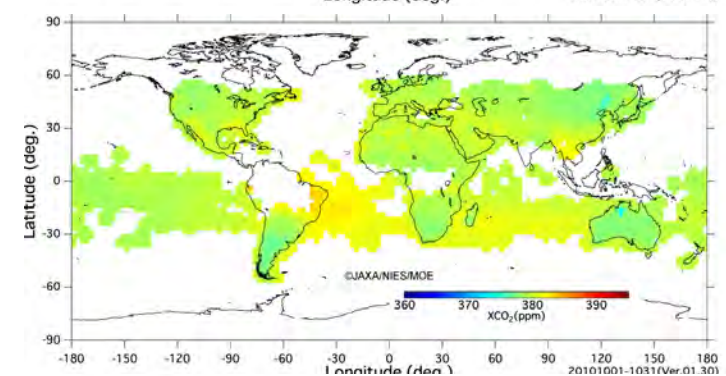
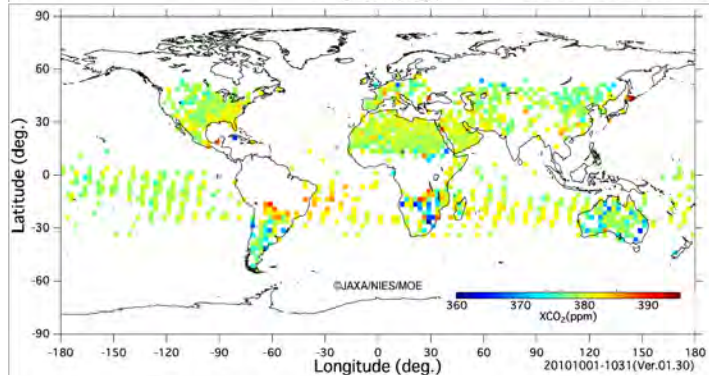
Level 2

Level 3

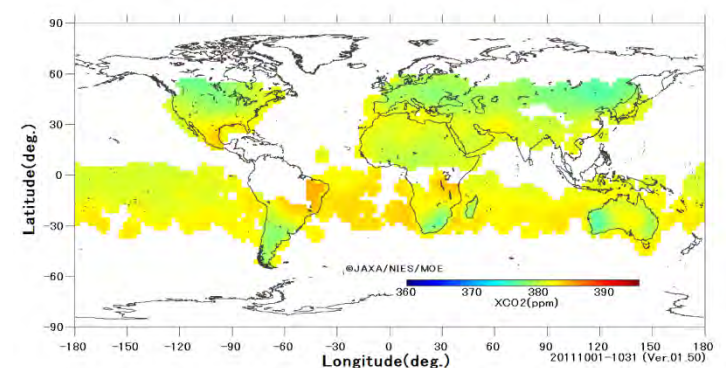
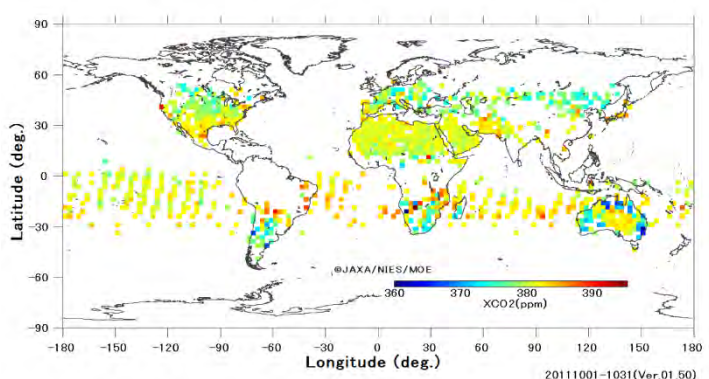
Oct.
2009



Oct.
2010



Oct.
2011



TANSO-FTS SWIR Level 2 & Level 3

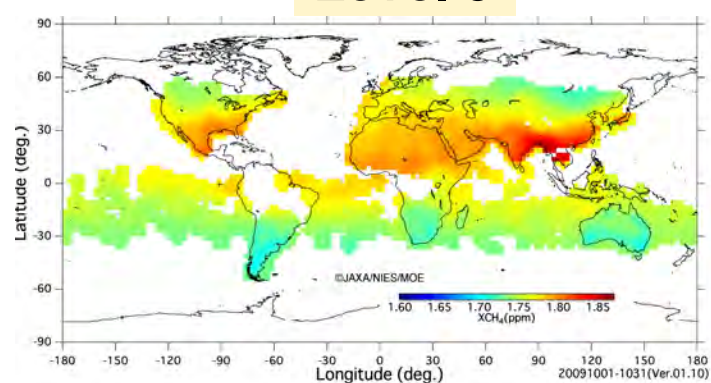
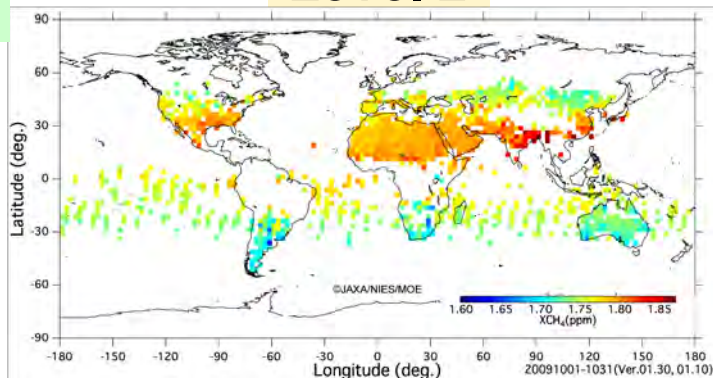
Annual Change of XCH_4 (October 2009, 2010, 2011)

XCH_4

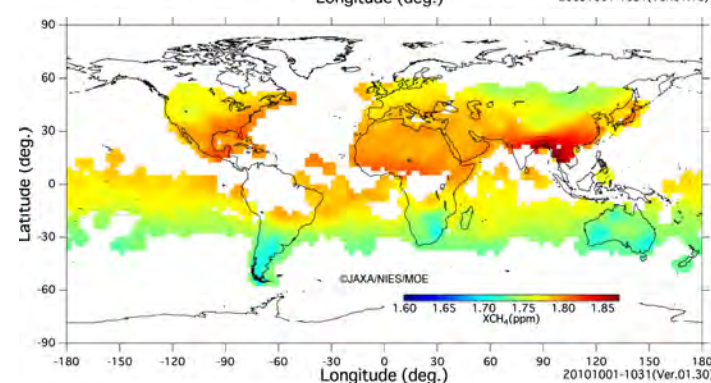
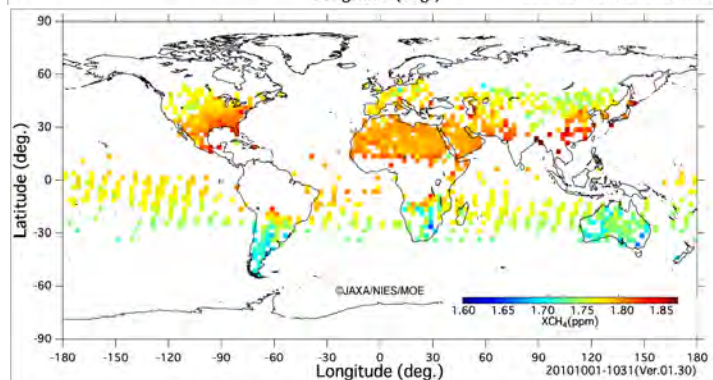
Level 2

Level 3

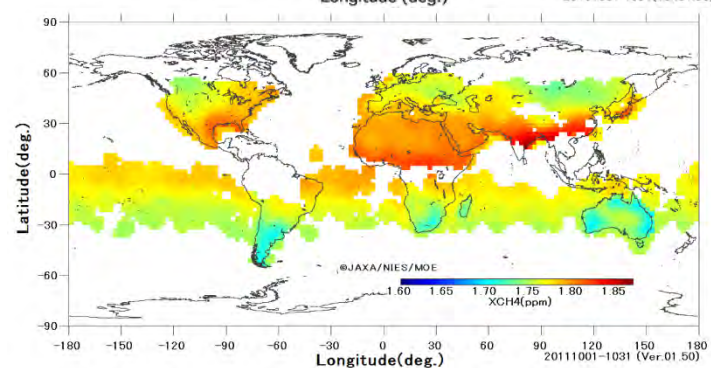
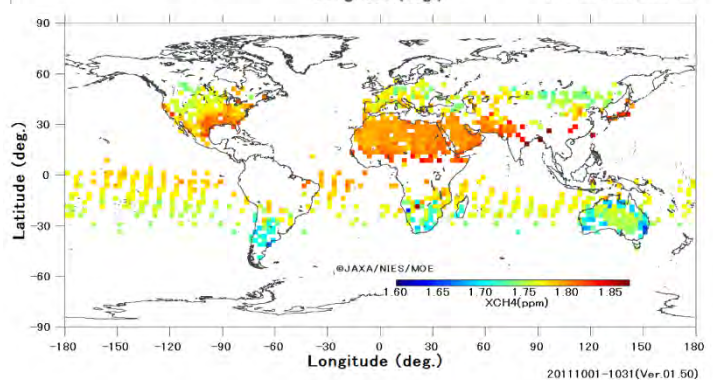
Oct.
2009



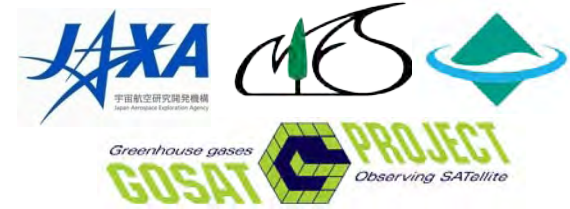
Oct.
2010



Oct.
2011

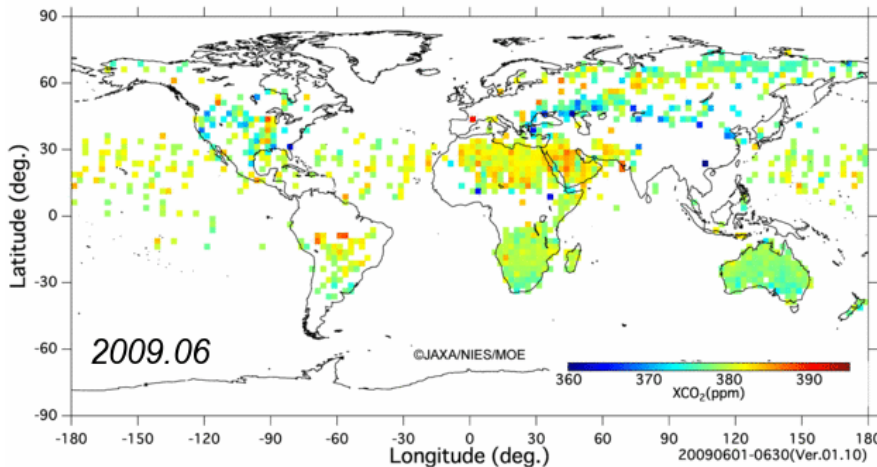


GIF Animation of Monthly Level 2 of XCO₂ and XCH₄

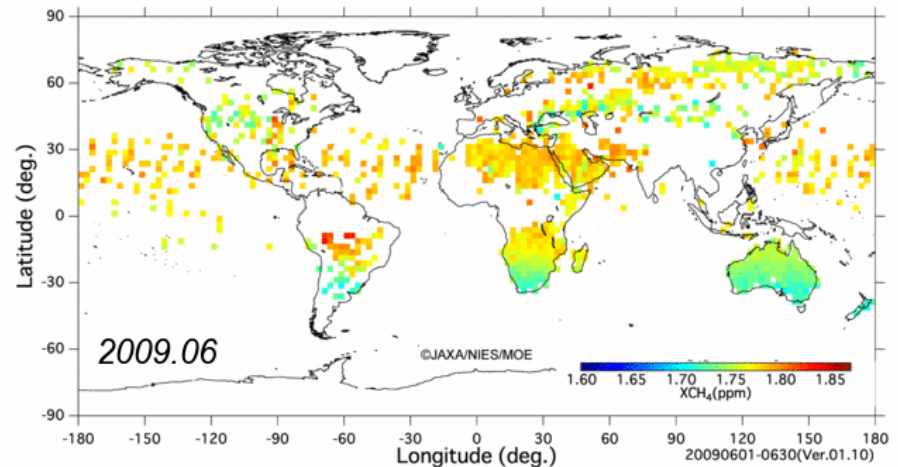


(2.5 deg. mesh, June 2009 – December 2010)

XCO₂



XCH₄

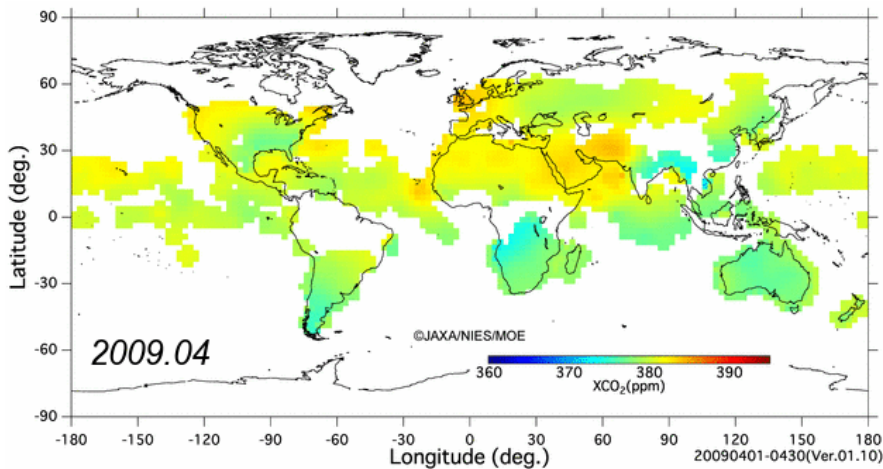


GIF Animation of Monthly Level 3 of XCO₂ and XCH₄

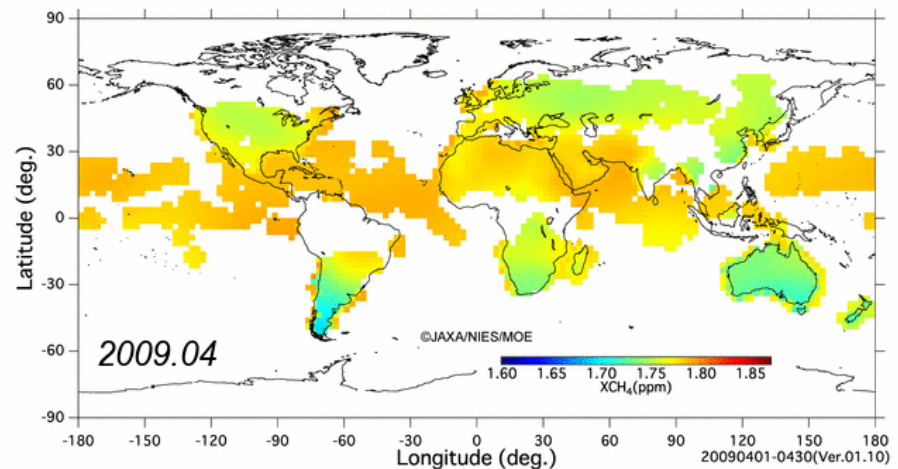


(2.5 deg. mesh, April 2009 – February 2011)
(for 22 months except for May 2009)

XCO₂



XCH₄



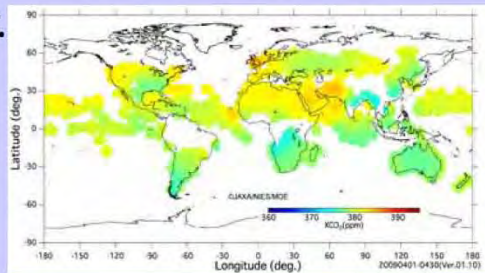
Available from “Gallery” page of <http://data.gosat.nies.go.jp/>

Greenhouse Gas Monitoring From Space by GOSAT

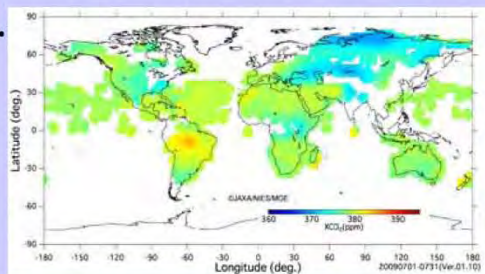
Monthly global map of the CO₂ column-averaged volume mixing ratios in four seasons for three years (April 2009 - July 2011)

2009

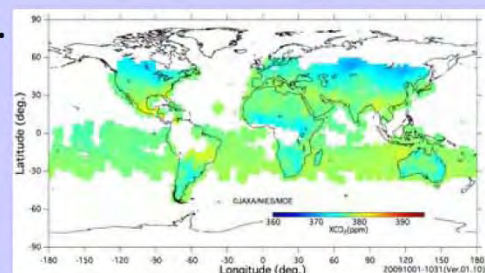
Apr.



Jul.

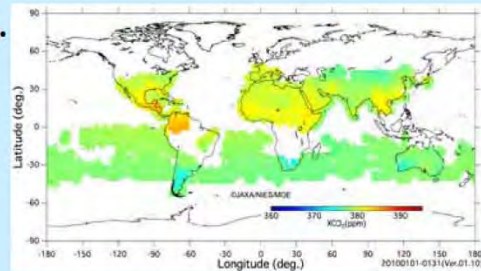


Oct.

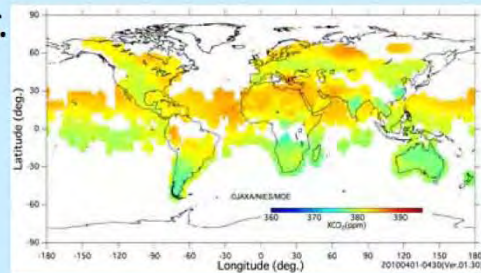


2010

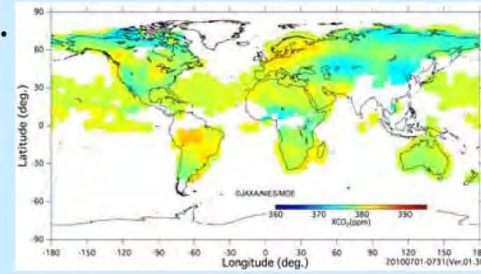
Jan.



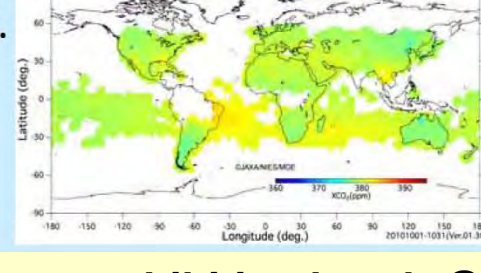
Apr.



Jul.

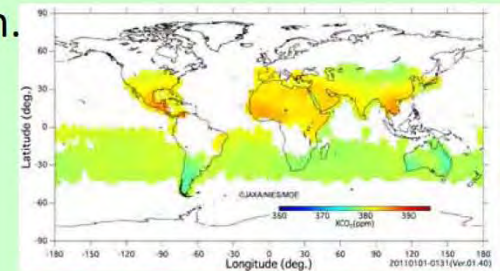


Oct.

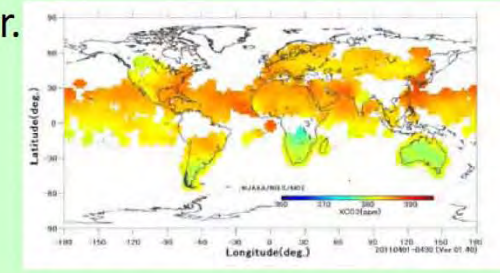


2011

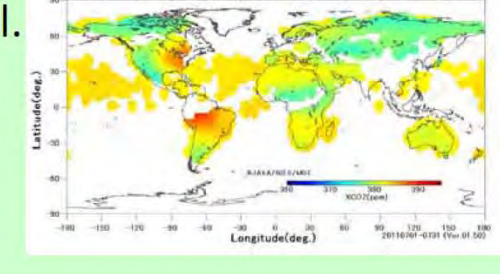
Jan.



Apr.

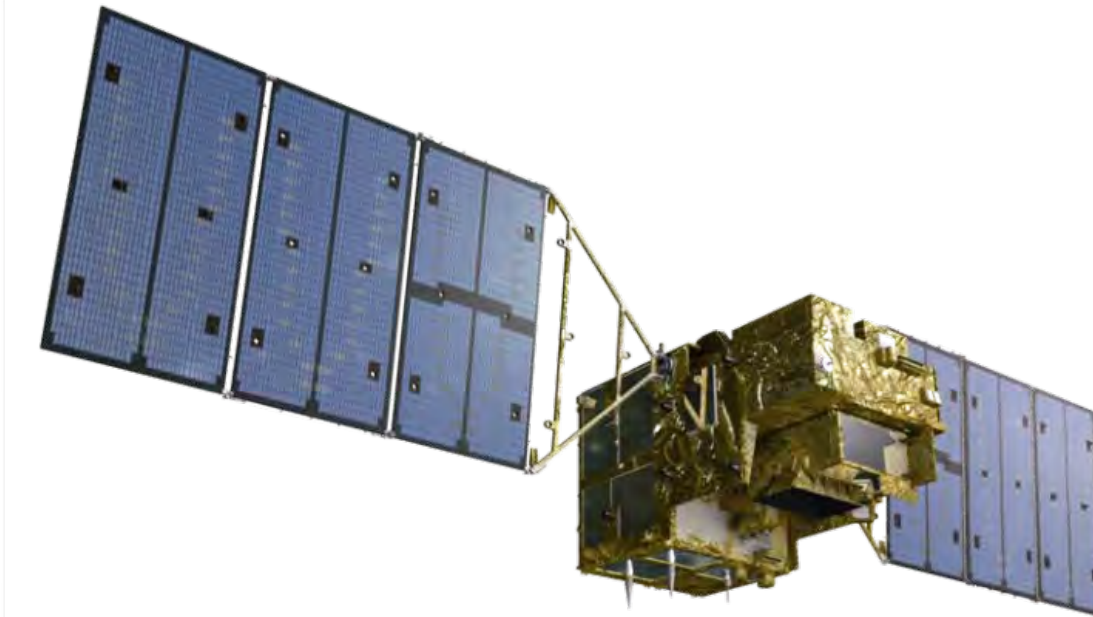


Jul.



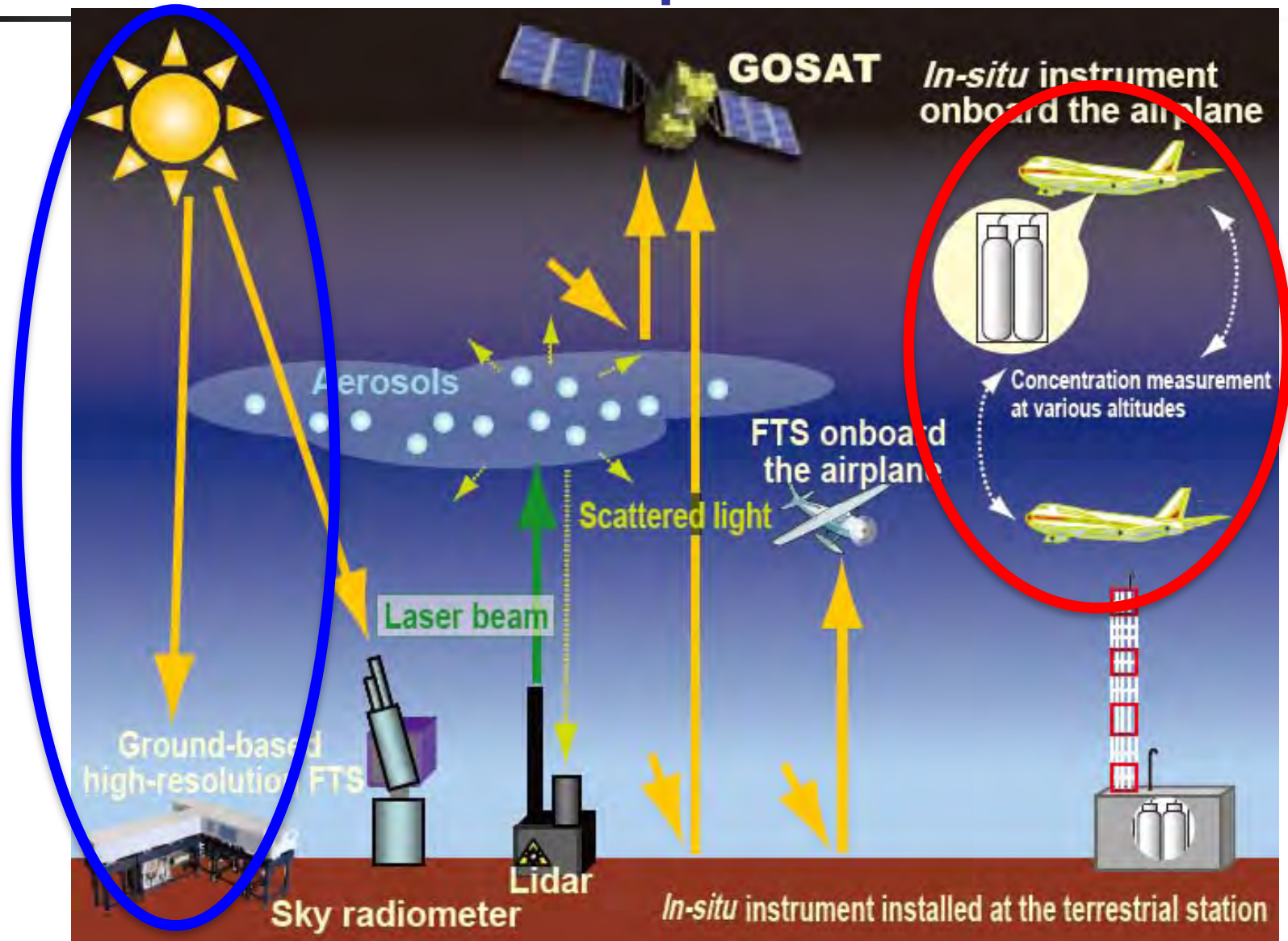
(Biases of the GOSAT XCO₂ data about 9 ppm lower than the ground-based validation data are not corrected in these figures.)

(Japan exhibition booth @ COP17)

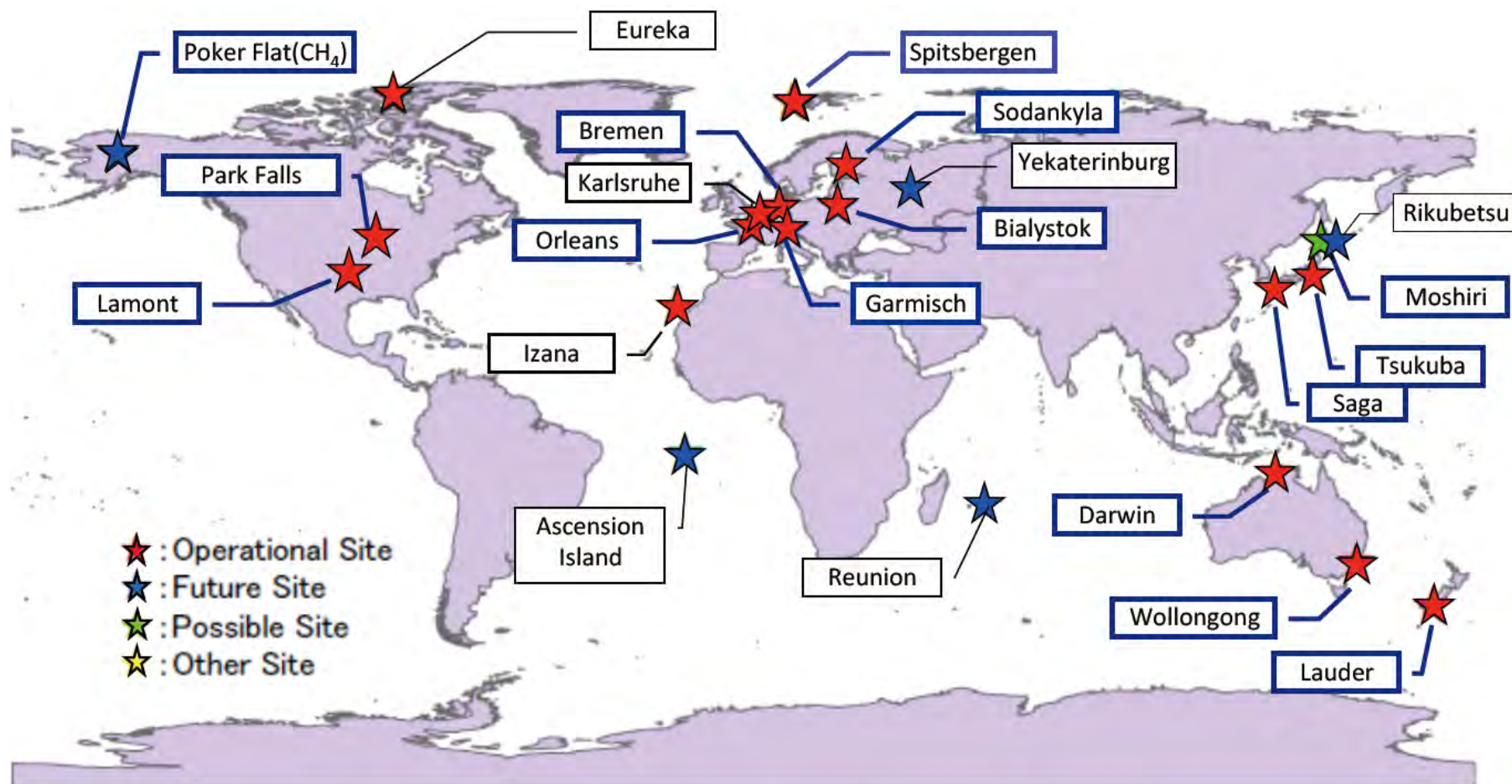


■ Validation summary

Schematic illustration of validation experiments

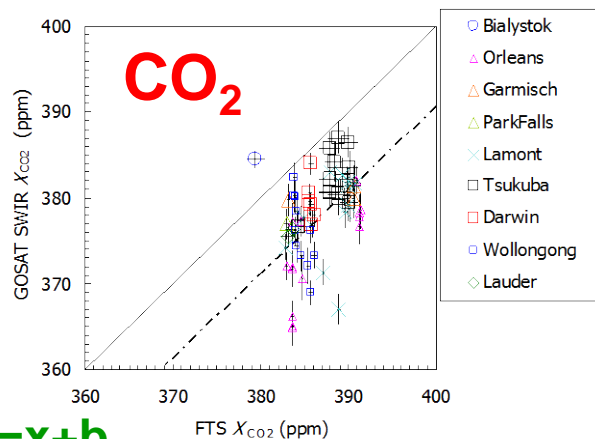


TCCON sites for GOSAT validation



TCCON :Total Carbon Column Observing Network
(<https://tccon-wiki.caltech.edu/>)

XCO₂ and XCH₄ comparing TCCON FTS sites & GOSAT



y=x+b

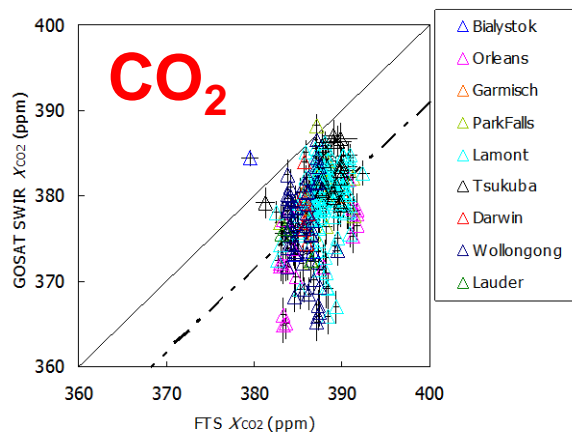
[Bias, STD]: [-8.85, 4.75] ppm

Coincidence Condition:

FTS: +/- 0.5 hr

GOSAT: 1~3 deg

Number: 62

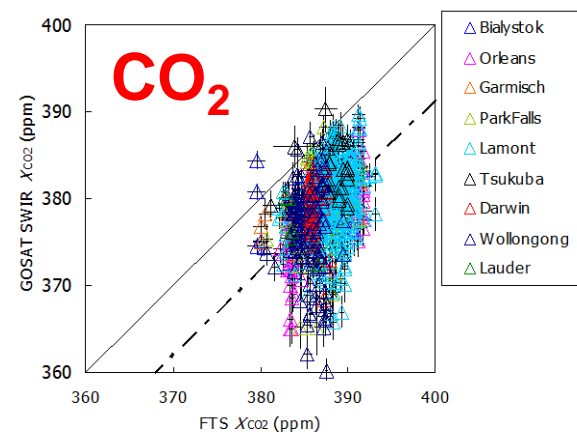


[-8.57, 4.44] ppm

+/- 1 hr

+/- 2 deg

256



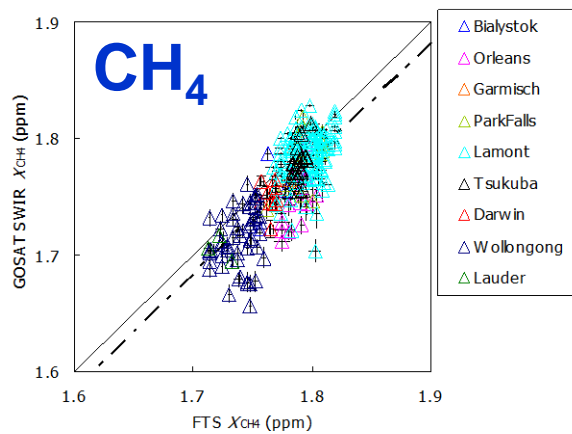
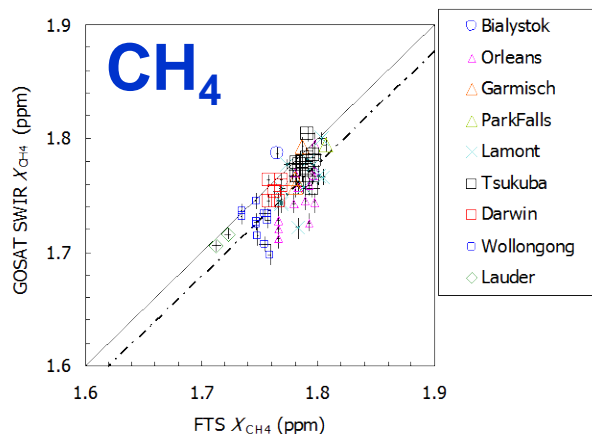
[-8.25, 3.97] ppm

+/- 1 hr

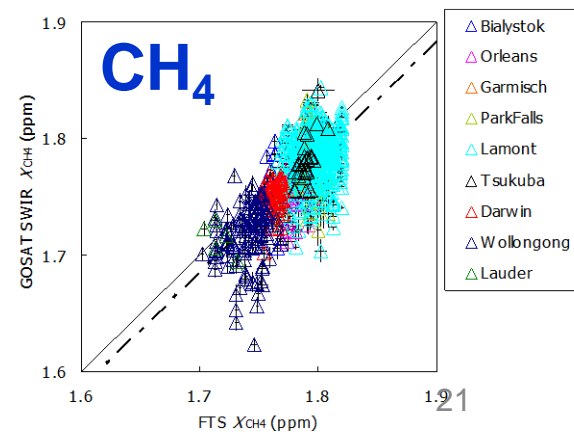
+/- 5 deg

966

[Bias, STD]: [-20.4, 18.9] ppb



[-15.8, 22.3] ppb



[-14.8, 22.6] ppb

TANSO-FTS SWIR Level 2 (V01.xx)

(validated by comparing with ground-based TCCON FTS)

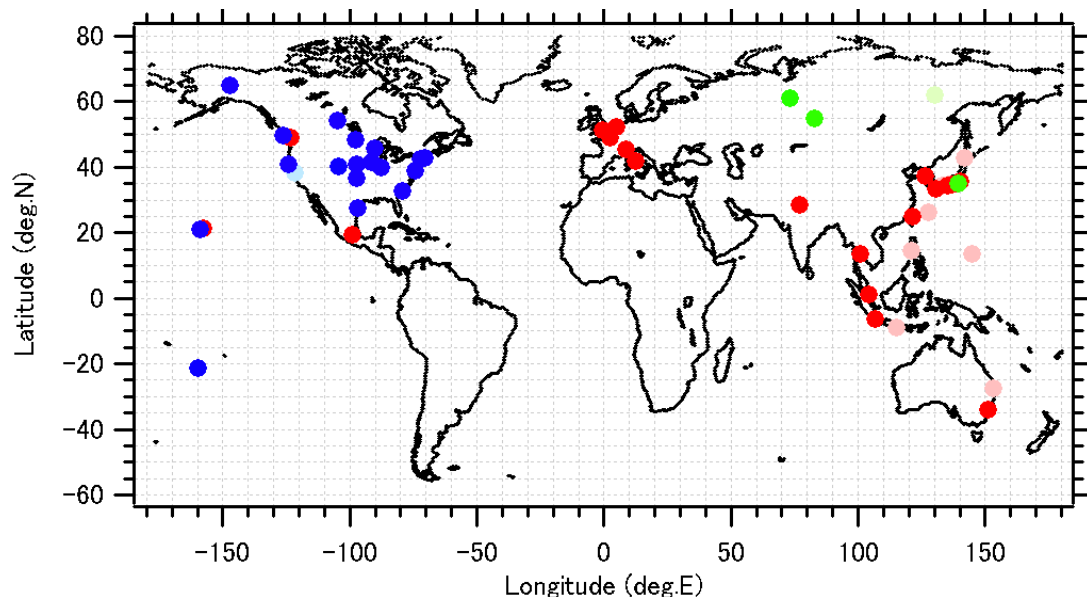
	Bias	Standard Deviation
X_{CO_2}	-8.85 ppm (-2.3 %)	4.75 ppm (1.2 %)
X_{CH_4}	-20.4 ppb (-1.2 %)	18.9 ppb (1.1 %)

(by Morino et al., Atmos. Meas. Tech., 4, 1061–1076, 2011)

- NIES has contracted with the following universities/institutes for the research support and/or technical assistance in order to obtain TCCON ground-based FTSs data in sync with GOSAT observations over the sites.
 - U. Bremen (Germany): Bremen, Bialystok, Orleans, Spitsbergen
 - Caltech (USA): Park Falls, Lamont
 - U. Wollongong (Australia): Darwin, Wollongong
 - NIWA (New Zealand): Lauder

Aircraft measurements by JAL, NOAA, and NIES

(by I. Morino & O. Uchino)



about 40-50 sites in the world

CONTRAIL data (so called JAL data) for CO₂

NOAA aircraft sampling data for CH₄

NIES aircraft sampling data for CO₂ and CH₄

2007-2010

Papers for calculating XCO₂ from a profile : Araki et al. Atmos. Chem. Phys., 10, 7659-7667, 2010 and Miyamoto et al. submitted to Atmos. Chem. Phys.

CONTRAIL: in situ CO₂ measurements
NOAA, NIES: flask sampling

Uncertainty of XCO₂ from profile: ~ 1 ppm

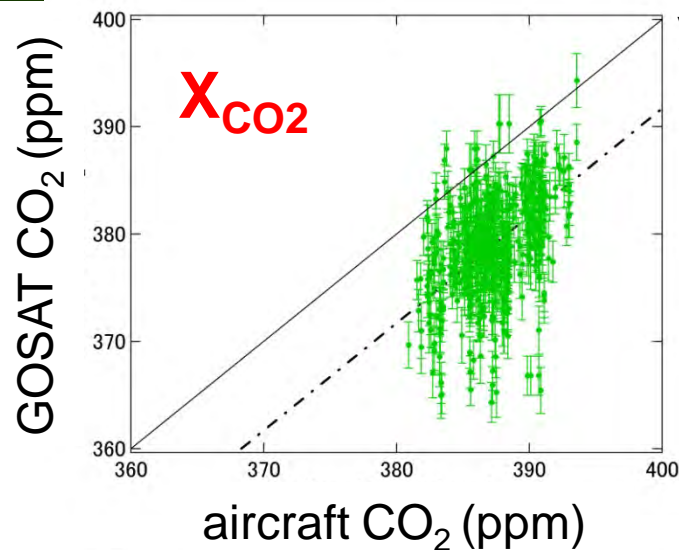
CONTRAIL Project

(Comprehensive Observation Network for
TRace gases by AirLiner)

(T. Machida et al., J. Atmos. Oceanic Technol., 25, 1744-1754, 2008.)



Validation by Using Aircraft Measurement Data



$y=x+b$

(by I. Morino & O. Uchino)

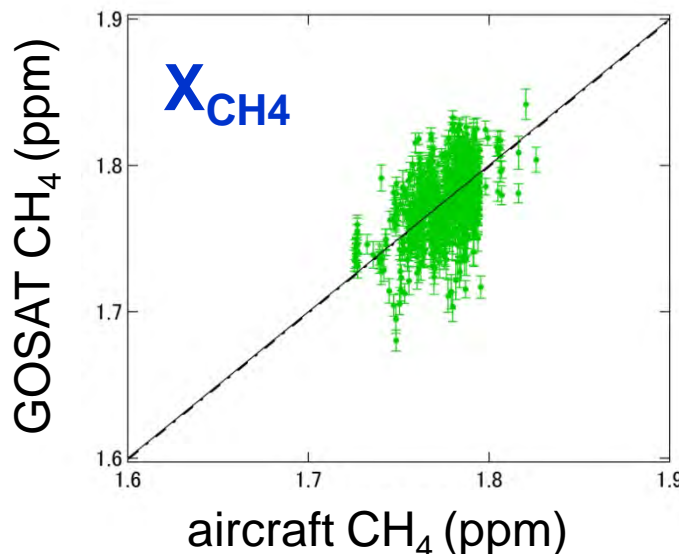
Data Number: 548

Bias: -8.3 ppm

STD: 4.4 ppm

- Using CONTRAIL & NOAA Data

- Coincidence: ± 2 deg. (Long. & Lat.)



Data Number: 926

Bias: -0.6 ppb

STD: 20 ppb

Solid line: one-to-one

Dashed line:

Regression line as

$y=x+b$

TANSO-FTS SWIR Level 2 (V01.xx)

(validated by comparing with ground-based TCCON FTS)

	Bias	Standard Deviation
X_{CO_2}	-8.85 (-8.3) ppm (-2.3 %)	4.75 (4.4) ppm (1.2 %)
X_{CH_4}	-20.4 (-0.6) ppb (-1.2 %)	18.9 (20) ppb (1.1 %)

(by Morino et al., Atmos. Meas. Tech., 4, 1061–1076, 2011)

() : by using Aircraft measurement data

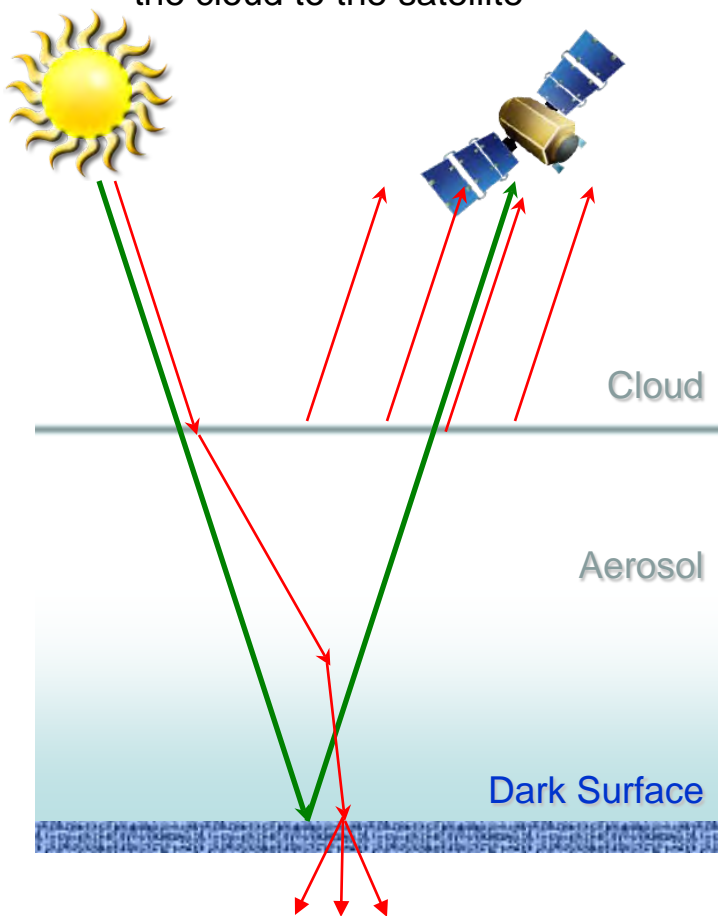
Illustration of how light scattering would impact data processing

(Major error sources: cirrus & aerosols)

(by S. Oshchepkov & A. Bril (NIES))

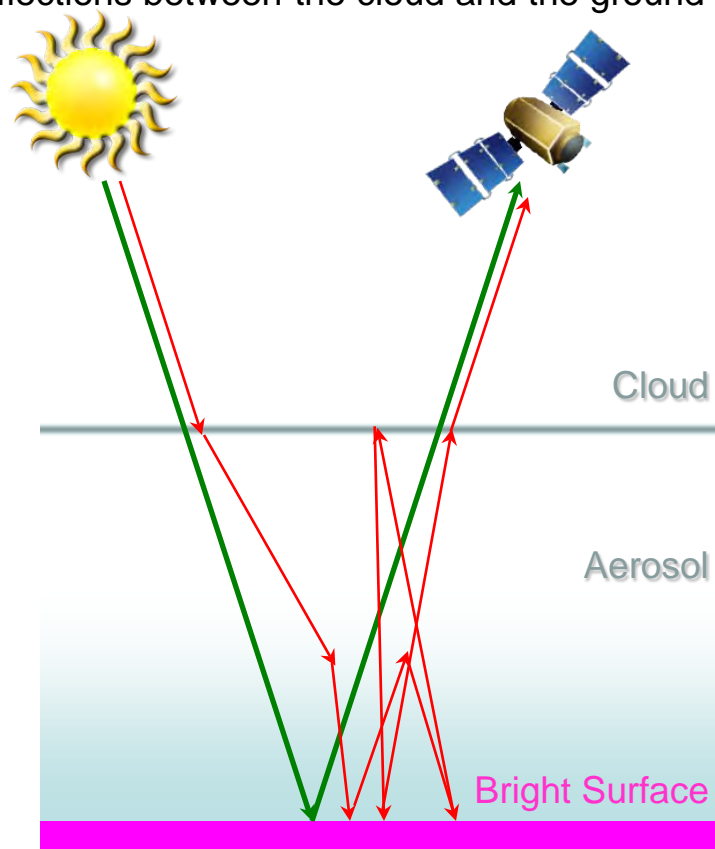
The light path can be modified by two mechanisms:

One is direct scattering of sunlight from the cloud to the satellite

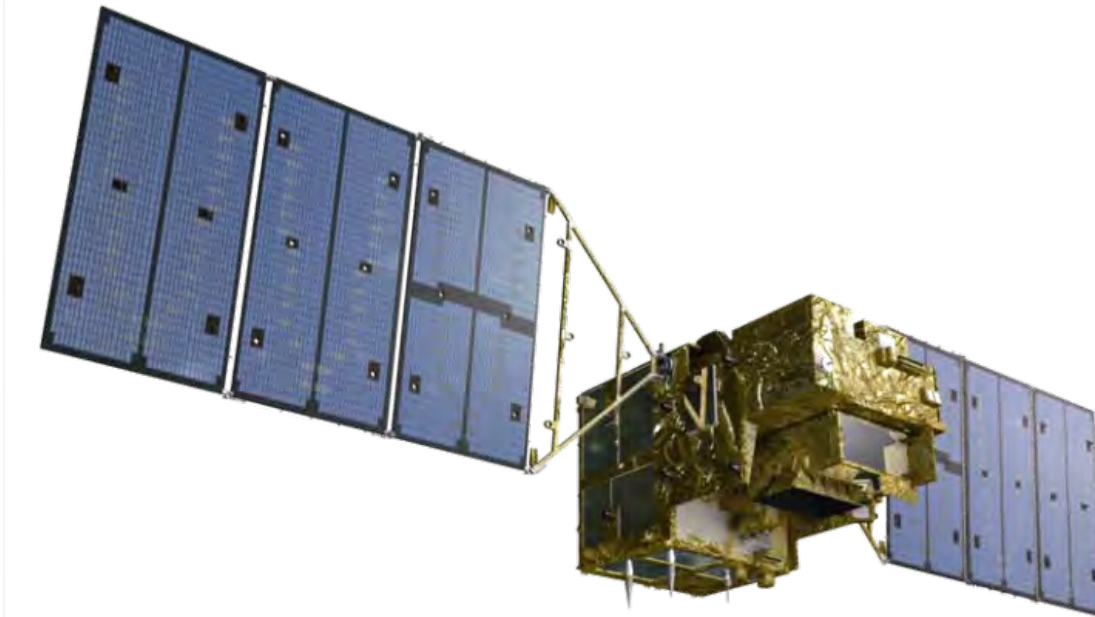


This effect is predominant for dark surface such as ocean and leads to **underestimation** of gas amount

The other mechanism is due to multiple light reflections between the cloud and the ground surface



This effect holds for bright surface like over desert and leads to **overestimation** of gas amount

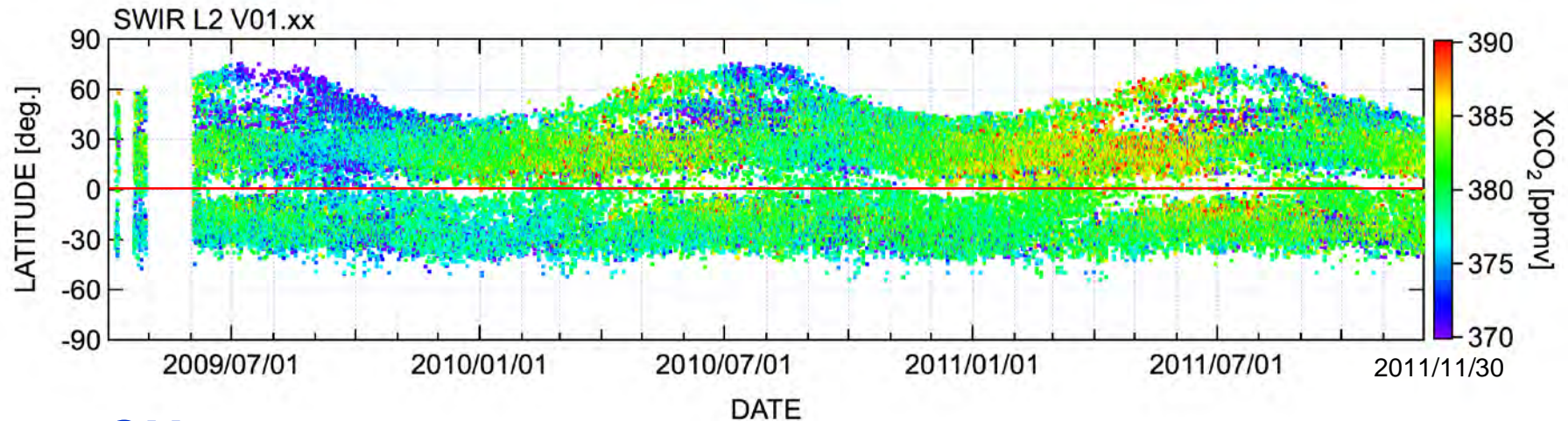


- Temporal variation of Level 2 (V01.xx)

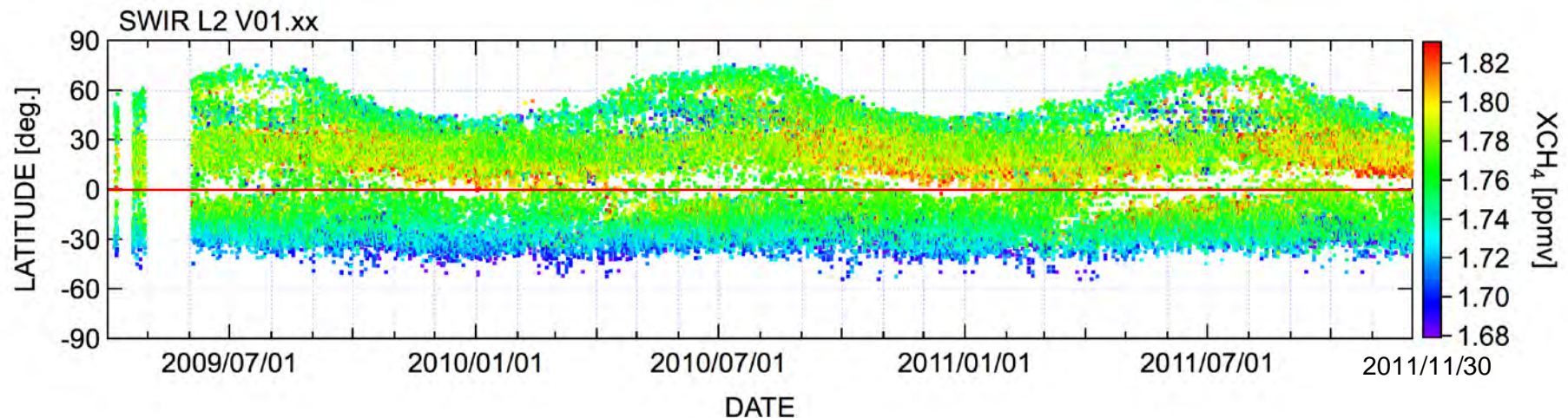
Temporal & latitudinal variation

CO₂

(for all data)

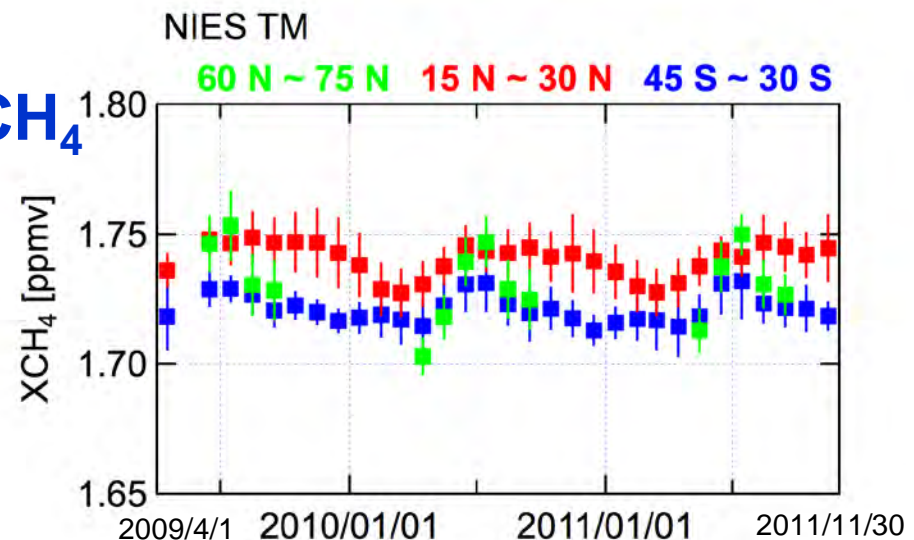
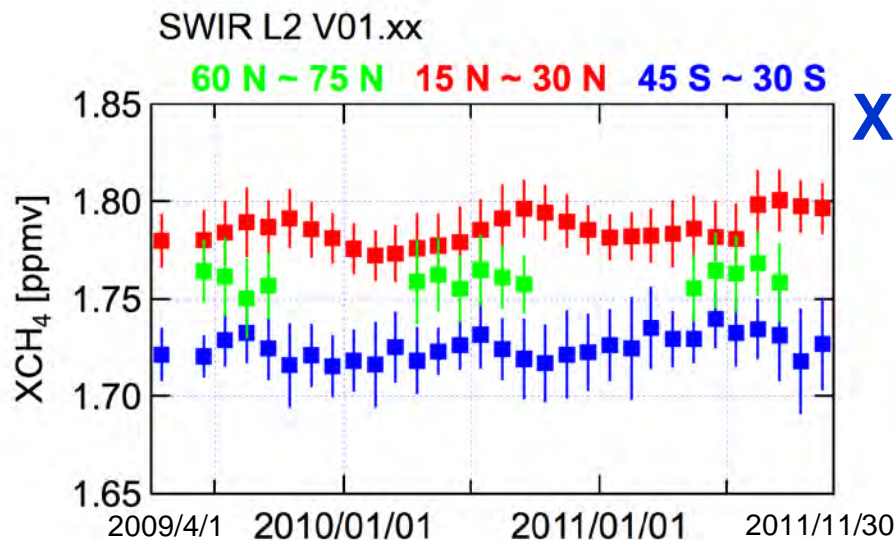
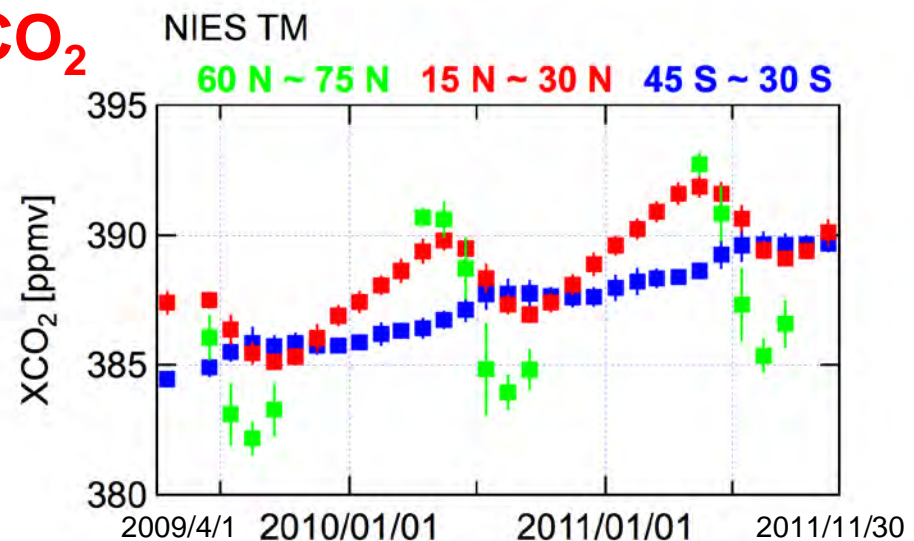
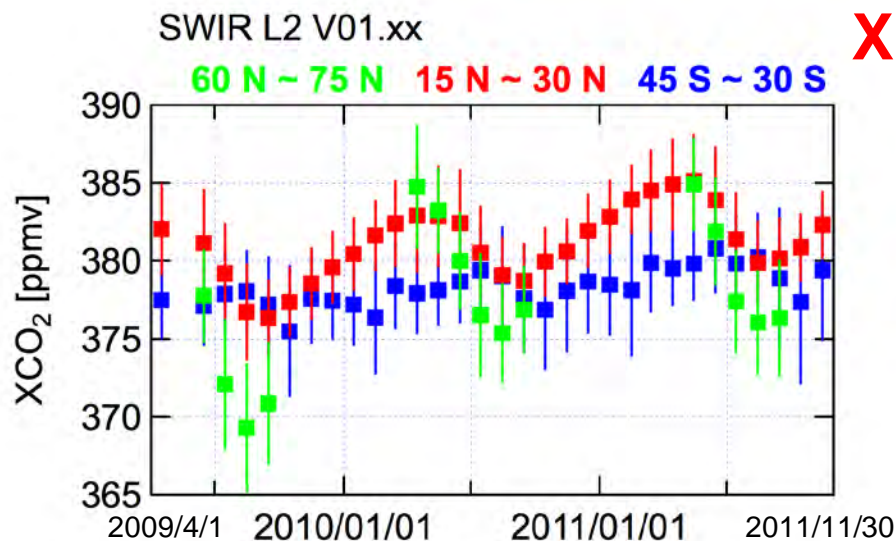


CH₄



(by Y. Yoshida (NIES))

Temporal variation of zonal mean, comparing with NIES TM (for all data)

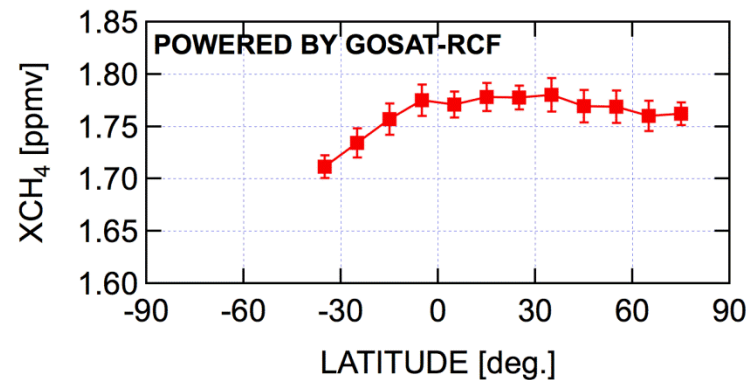
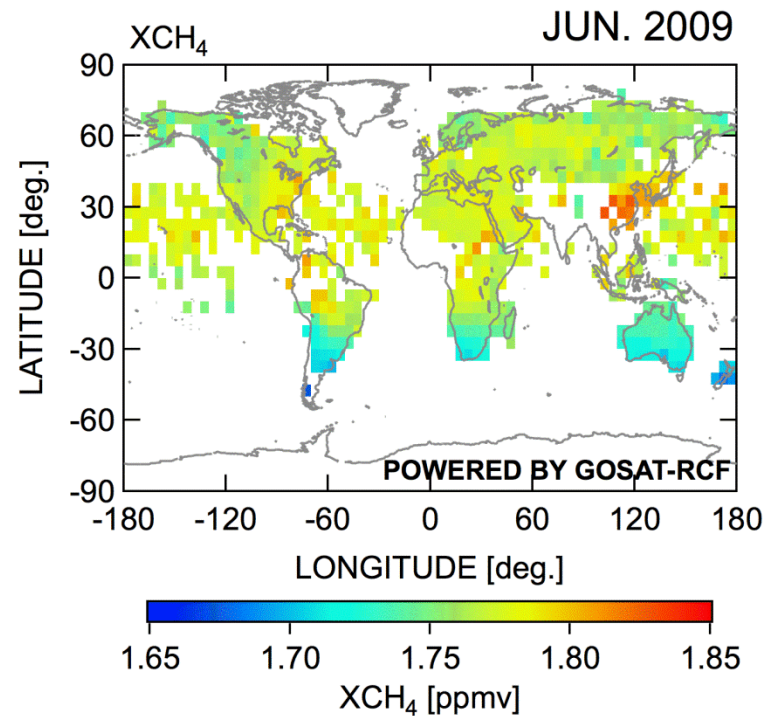
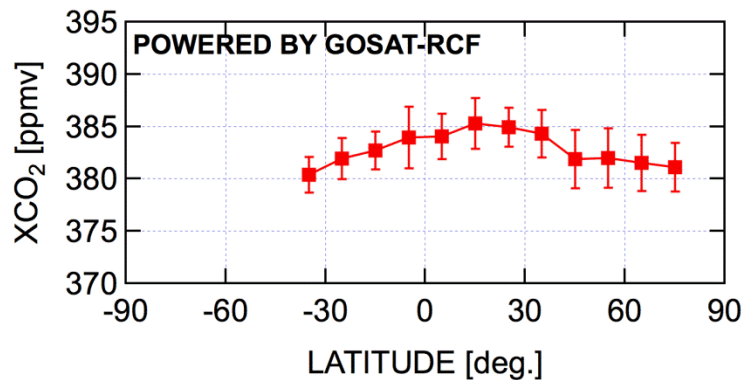
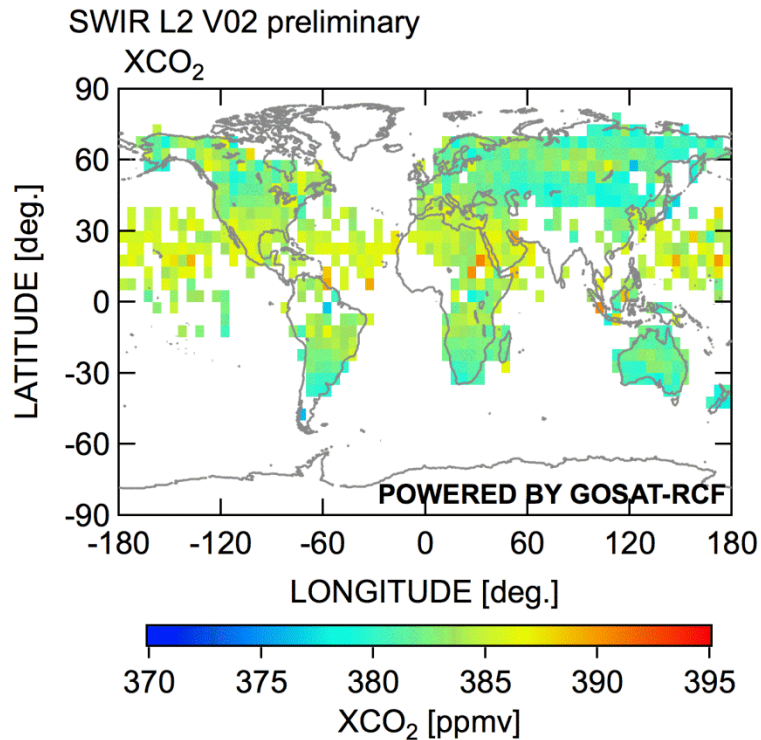


DATE

(by Y. Yoshida (NIES))

DATE

Preliminary results of SWIR L2 V02

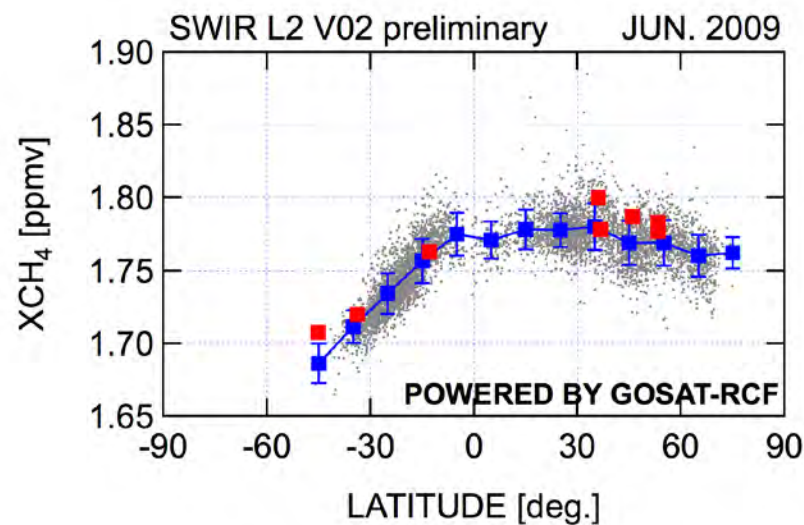
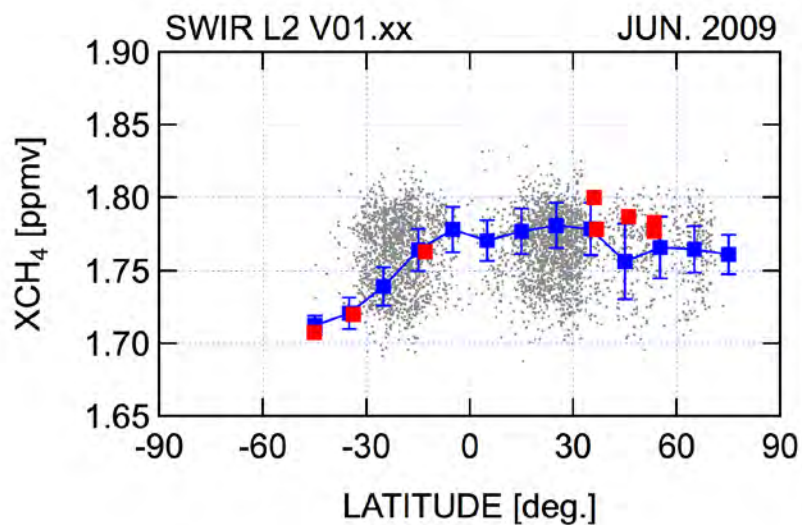
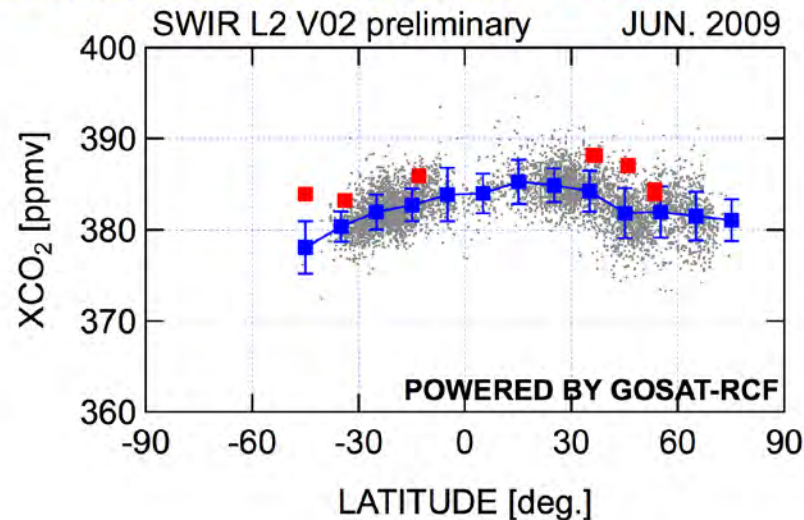
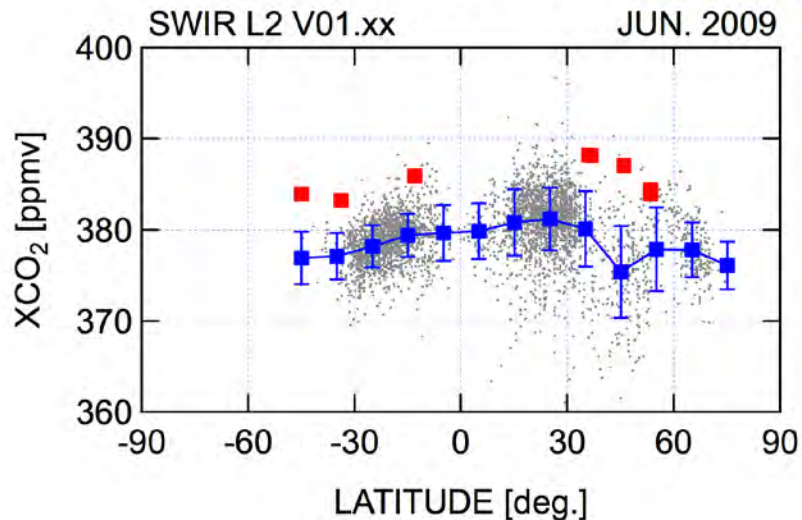


Preliminary results of SWIR L2 V02

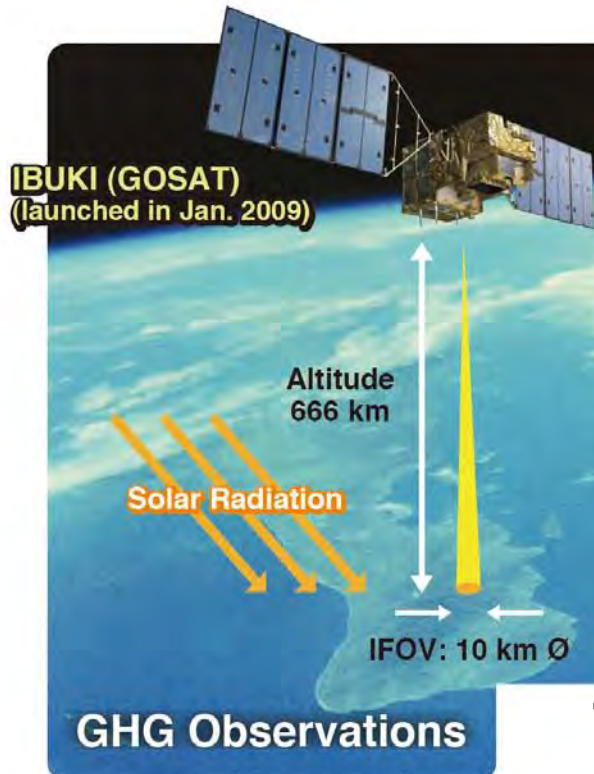
Retrieval results for single scan

Retrieval results averaged over 10-deg. lat.-bin

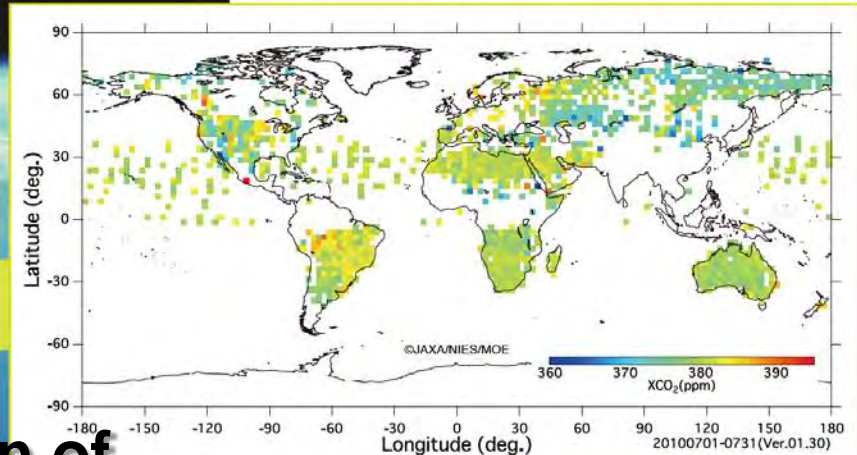
TCCON



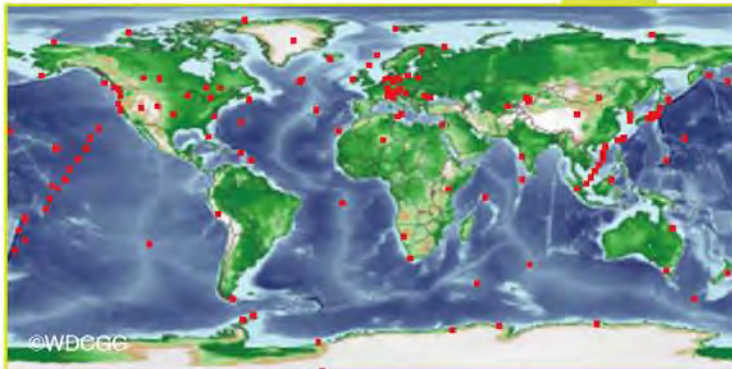
GOSAT contribution to carbon flux estimation



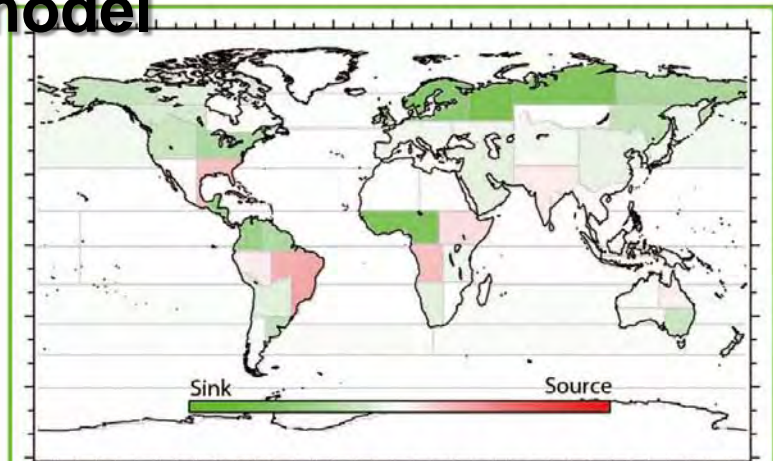
Inversion of
atmospheric
transport model



GHG data by IBUKI



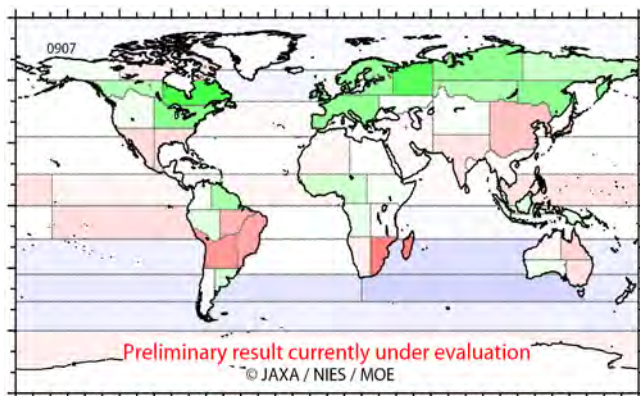
Ground Monitoring Stations



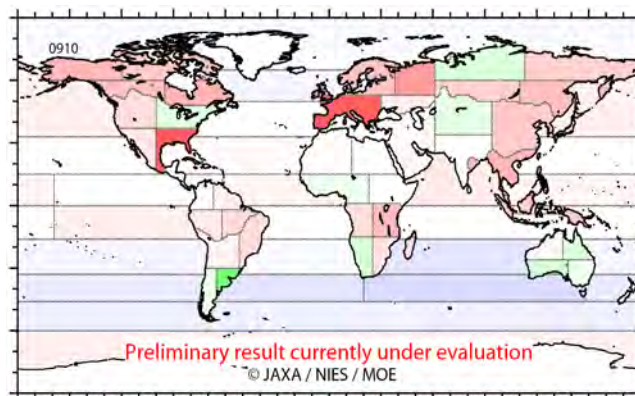
Estimation of Global Carbon Flux Distribution

Monthly CO₂ Flux Estimates

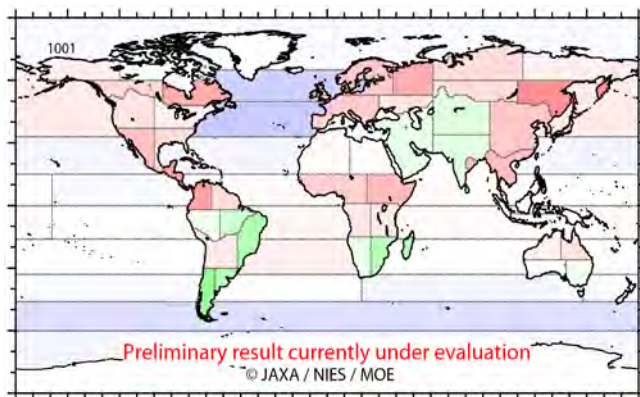
July 2009



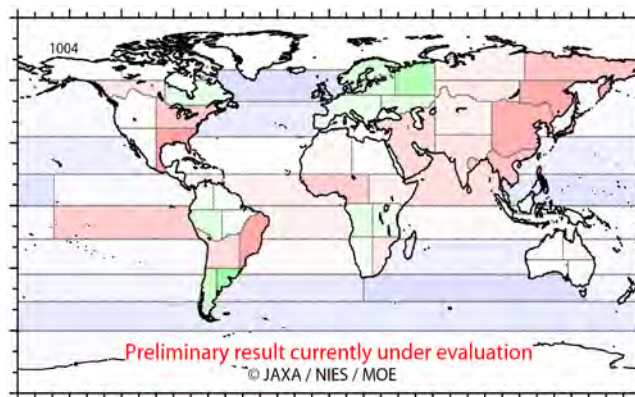
October 2009



January 2010



April 2010



(Level 4A data product)

64-regional monthly CO₂ fluxes estimated from ground-based network data* and GOSAT XCO₂ retrievals (currently under evaluation). Results for four months (July 2009, October 2009, January 2010, and April 2010) are presented.

*GLOBALVIEW-CO2 (2011), Cooperative Atmospheric Data Integration Project - Carbon Dioxide. CD-ROM, NOAA ESRL, Boulder, Colorado (Also available on Internet via anonymous FTP to <ftp.cmdl.noaa.gov>, Path: [ccg/co2/GLOBALVIEW](ftp://ccg/co2/GLOBALVIEW)).

GOSAT websites

JAXA GOSAT project

NIES GOSAT Project

Press conference statements

http://www.jaxa.jp/projects/sat/gosat/index_e.html

http://www.gosat.nies.go.jp/index_e.html

<http://www.gosat.nies.go.jp/eng/related/2011/201111.htm>



- Collaboration with worldwide researchers

GOSAT Research Promotion

■ Research Announcement

➤ Research Topics

- 1) Calibration
- 2) Data Processing Algorithm
- 3) Validation
- 4) Carbon Balance Estimation and Atmospheric Transport Models
- 5) Data application

➤ The 1st GOSAT RA in 2008

52 research themes were selected.

➤ The 2nd GOSAT RA in 2009

36 research themes were selected.

➤ The 3rd GOSAT RA in 2010

18 research themes were selected.

■ Data Release

- CAI & FTS-L1B data product: October 30, 2009
- CAI & FTS-L2 data product: February 18, 2010
- Improved FTS-L2 data product: August 24, 2010



Country	2008	2009	2010	Total
Japan	23	8	1	32
USA	7	8	3	18
Canada	3		2	5
UK	2	3		5
France	2	2	1	5
Finland		2	1	3
Norway		1		1
Russia	4			4
Germany	6	2		8
Italy		2		2
Belgium		1		1
Netherlands	3	1	1	5
Brazil		1		1
Czech		1		1
Spain		1	1	2
Singapore		1		1
China	1		2	3
Korea		1	1	2
New Zealand	1			1
India		1	1	2
Indonesia			1	1
Taiwan, ROC			1	1
Australia			2	2
Total	52	36	18	106



Observation data distribution and Observation request service are here



"NIES GOSAT PROJECT NEWSLETTER" issues are here



Global Greenhouse Gas Observation by Satellite

GOSAT Project

The NIES GOSAT Project was established by the National Institute for Environmental Studies (NIES) in April 2004, and since then has been working for the research and development with respect to GOSAT "IBUKI".

http://www.gosat.nies.go.jp/index_e.html



(If you click the above image, and it opens in another window.)

(July 2,2010)
[NIES GOSAT PROJECT NEWSLETTER JUN. 2010 Issue is published. \(PDF 3.1MB\)](#)

(June 2,2010)
[NIES GOSAT PROJECT NEWSLETTER MAY. 2010 Issue is published. \(PDF 3.1MB\)](#)

(April 30,2010)
[NIES GOSAT PROJECT NEWSLETTER APR. 2010 Issue is published. \(PDF 2.8MB\)](#)

(April 20,2010)
[Observation of volcanic eruptions in Iceland and their spreading ash plume by Greenhouse Gases Observing Satellite \(GOSAT or "IBUKI"\)](#)

What's New

Last Update: July 2, 2010

(July 2,2010)
[NIES GOSAT PROJECT NEWSLETTER JUN. 2010 Issue is published. \(PDF 3.1MB\)](#)

(June 15,2010)
["GOSAT related References" was updated.](#)

- GOSAT has continued observations more than 2 years and 9 month since June 2009.
- Biases of GOSAT TANSO-FTS SWIR Level 2 data product (V01.xx) are X_{CO_2} : -2 ~ -3% and X_{CH_4} : ~1 %. Standard deviations of them are ~1 %.
 - The L2 algorithm will be revised into V02.xx soon.
- GOSAT data have been used by worldwide researchers. We are collaborating on Cal/Val, retrieval, carbon source/sink estimation, and scientific data use.
- GOSAT project has continued collaborating with alliance organizations (AO1: JMA, NASA, ESA, CNES, ECMWF, ...)