14:30-14:50
2. Toward Domain-Overarching Carbon Cycle and GHGs Monitoring System: Atmosphere

What we have monitored from space by the decade-long GOSAT observation and how we improve by GOSAT-2

Akihiko KUZE (JAXA)

October, 24, 2018 Kyoto

Before 2009 GOSAT Launch

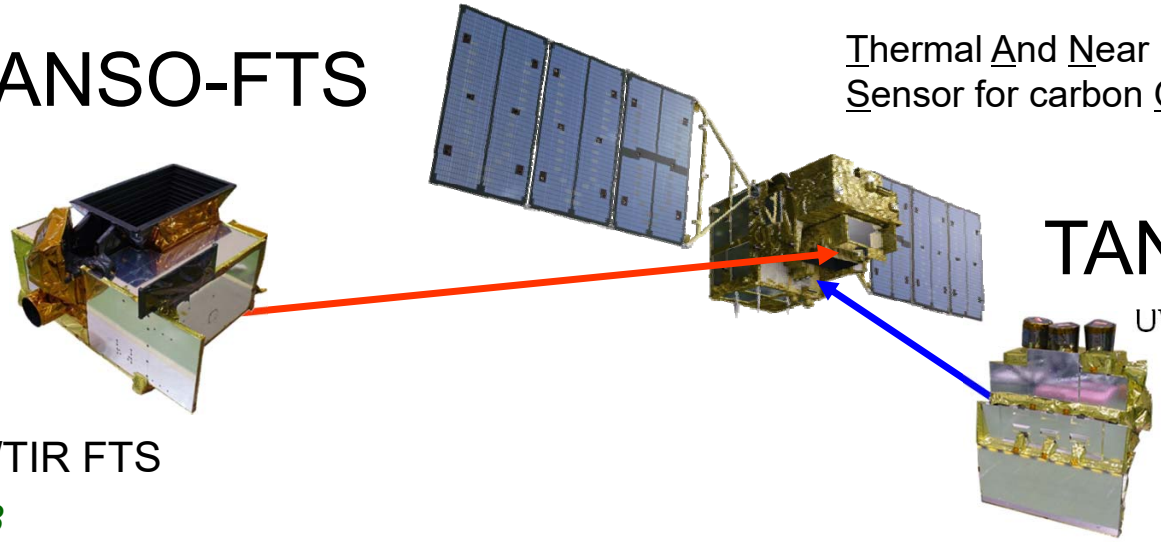
1997 The Kyoto Protocol at COP 3, GHG observation by a laboratory FTS

2003 GOSAT project started

2009 The Greenhouse Gases Observation Satellite
"IBUKI" (GOSAT) is the world's first spacecraft to measure the concentrations of carbon dioxide and methane, the two major greenhouse gases, from space.

TANSO-FTS

Thermal And Near infrared Sensor for carbon Observation



TANSO-CAI

UV, Visible, SWIR Imager

SWIR/TIR FTS

The first 5 years in space
2009 – 2014 design life

2011

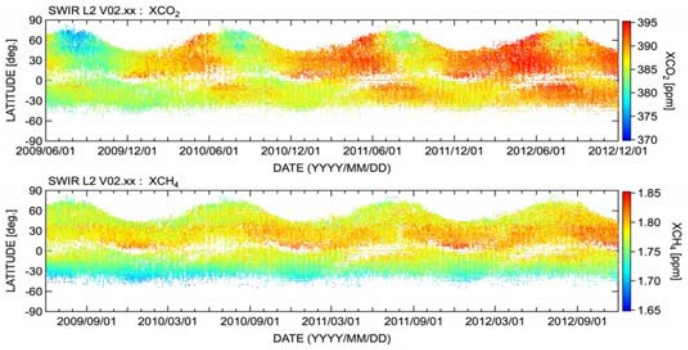
The accuracy of 2 ppm or 0.5% for CO_2
and 13 ppb or 0.7% for CH_4

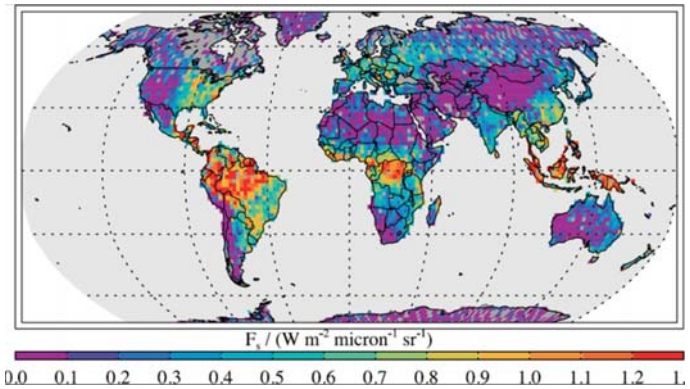
Chlorophyll Fluorescence measurement from Space

2014

GOSAT 5-year design life
Fully redundant system

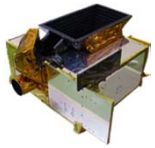
by Y. Yoshida (NIES))





2009, June Frankenberg et al., GRL 2011

One of the two solar paddles stopped its rotation. (June 2014)
The primary Command and Data Management System (CDMS) failed and switched to the secondary (May 2018)



(1) Metrology alignment changed
> ZPD (Zero Path Difference) -position Biased interferogram (2014)

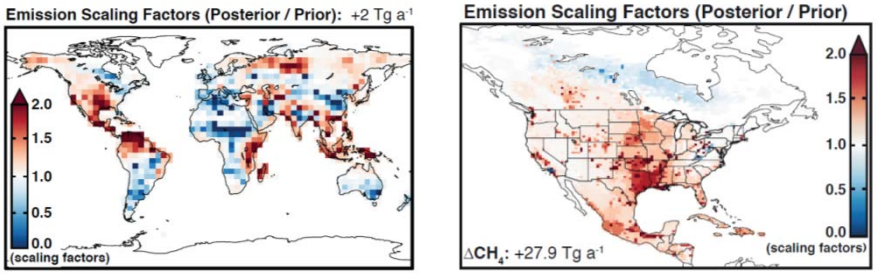
(2) Pointing mechanism switched (2015)

Healthy

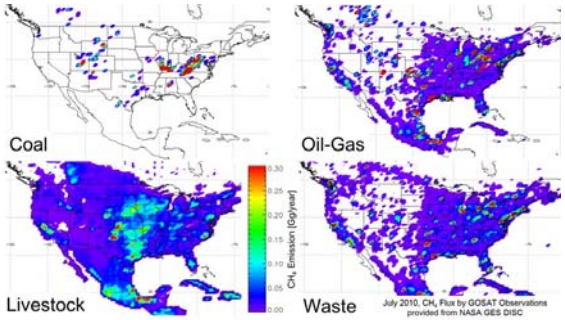
October, 2018

The next 5 years in space
2014 – until now

2015



2016

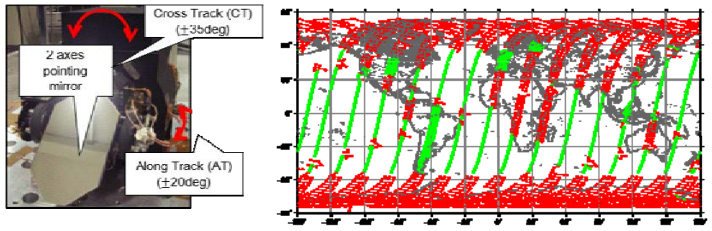


https://mirador.gsfc.nasa.gov/

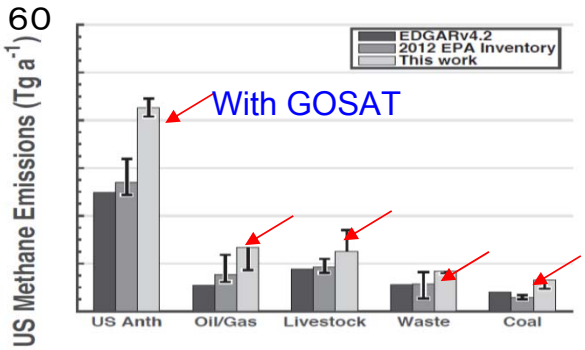
The Carbon Monitoring System (CMS) CH_4 Flux for North America data set contains estimates in North America based on an inversion of the GEOS-Chem chemical transport model constrained by GOSAT.

July 2010

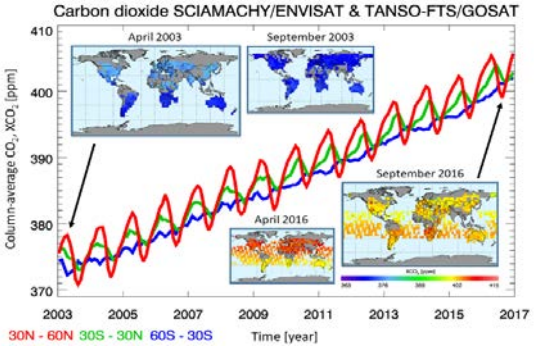
2017



Targeting CH_4 large emission source and mega cities with an agile pointing system by uploading the pointing-angle table every day.



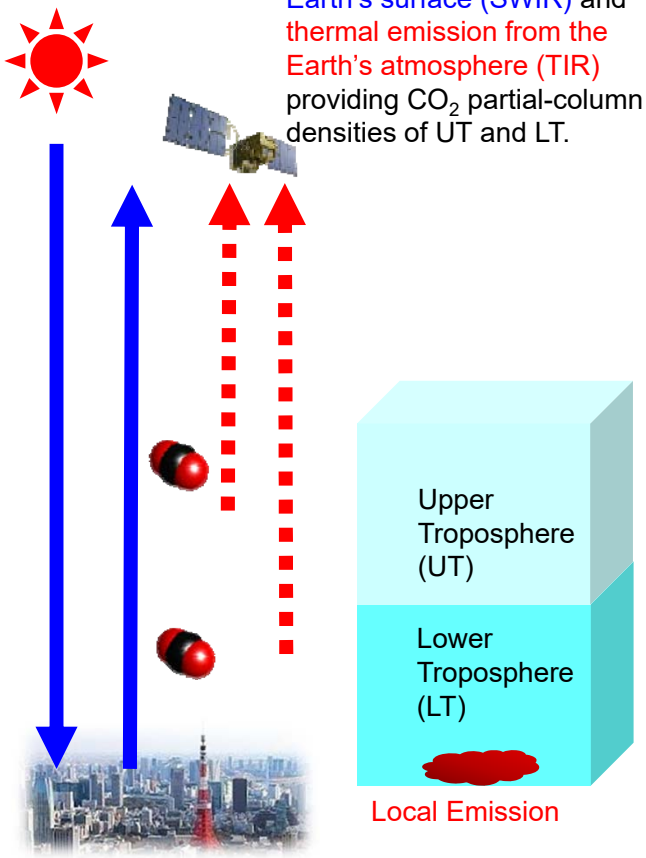
US CH_4 Emission (inventory vs. GOSAT) EDGARv4.2 (Model), the 2012 EPA inventory (EPA, 2014) and GOSAT (Turner et al., 2015, ACP)

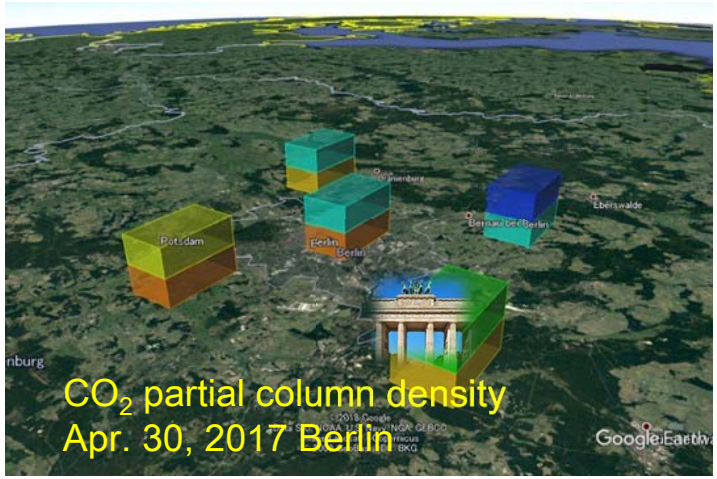


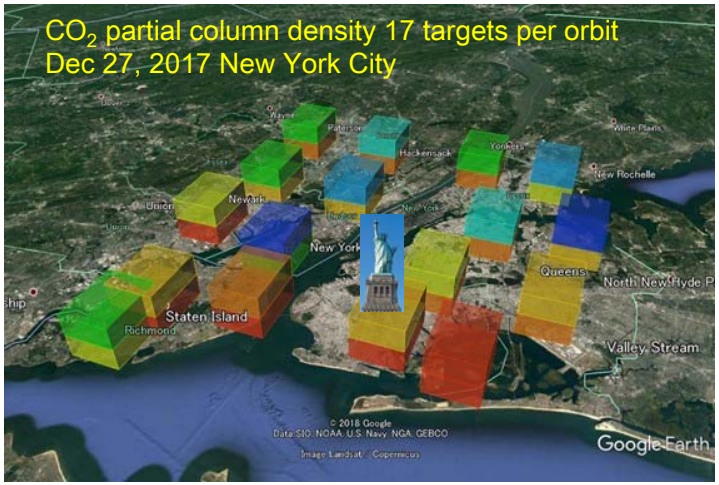
An ensemble of SCIAMACHY/ENVISAT (until April 2012) and TANSO-FTS/GOSAT (since mid 2009)(Buchwitz et al.)

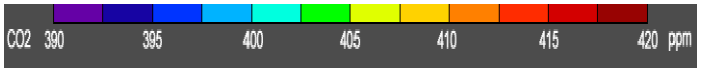
The next 5 years in space
2014 – until now (mega city data)

GOSAT measures both solar reflected light from the Earth's surface (SWIR) and thermal emission from the Earth's atmosphere (TIR) providing CO_2 partial-column densities of UT and LT.









We will release megacity 2-layer data from EORC web-site

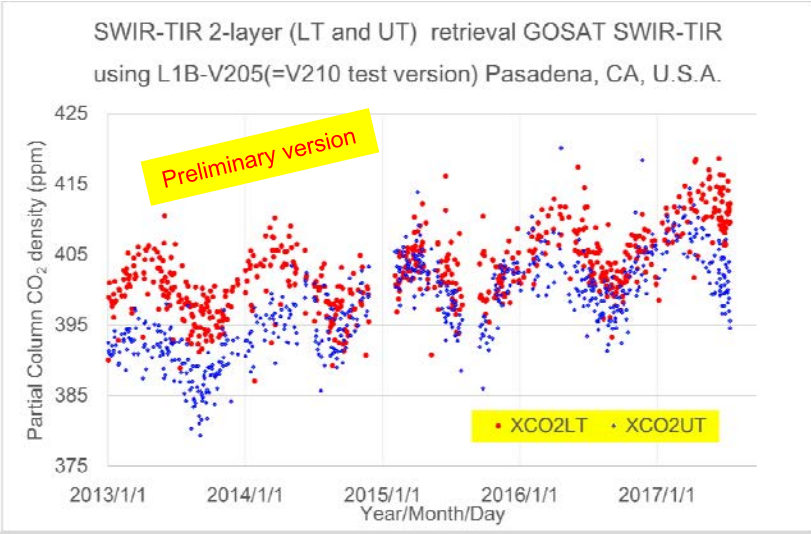
A decade long dataset and new research products

http://www.eorc.jaxa.jp/GOSAT/product.html#trendviewer

long-term trend data of the selected targets, including the large point sources of methane (CH_4) and intensive observations of selected mega cites.

- Contents: Long term CO_2, CH_4, SIF, AOD by GOSAT
- 4 produces : NIES V02.72, ACOS B7.3 FULL, RemoTeC V2.3.8, EORC research (2018)
- Trend figure & can be downloaded in csv format

Solar-Induced chlorophyll Fluorescence (SIF), Aerosol Optical Depth (AOD), Population density

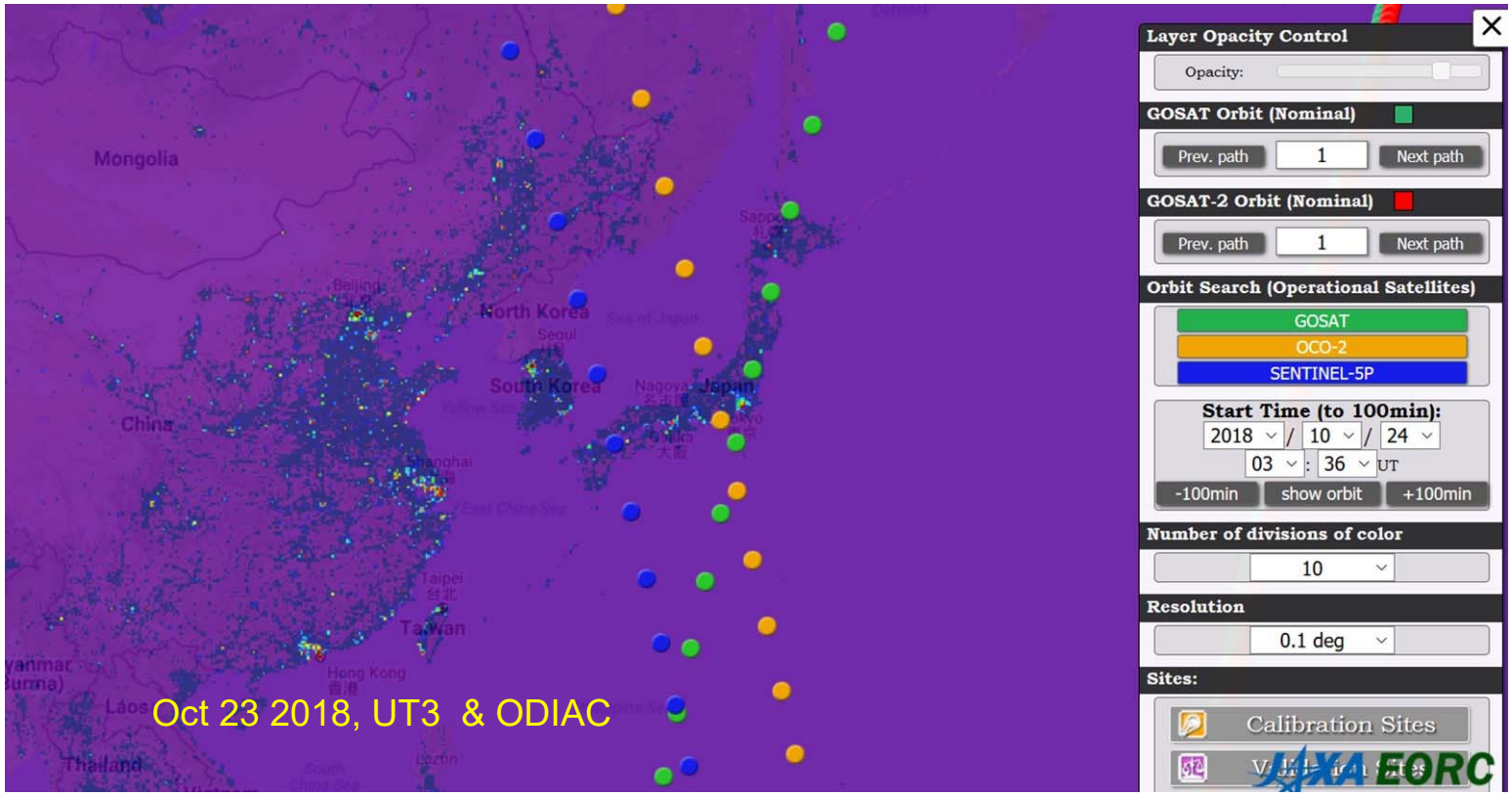


2018

Long term research product of partial column of lower and upper troposphere and SIF of selected targets: “Mega city 4D”, CAL&VAL, point source

October, 2018

GHG Satellites Constellation

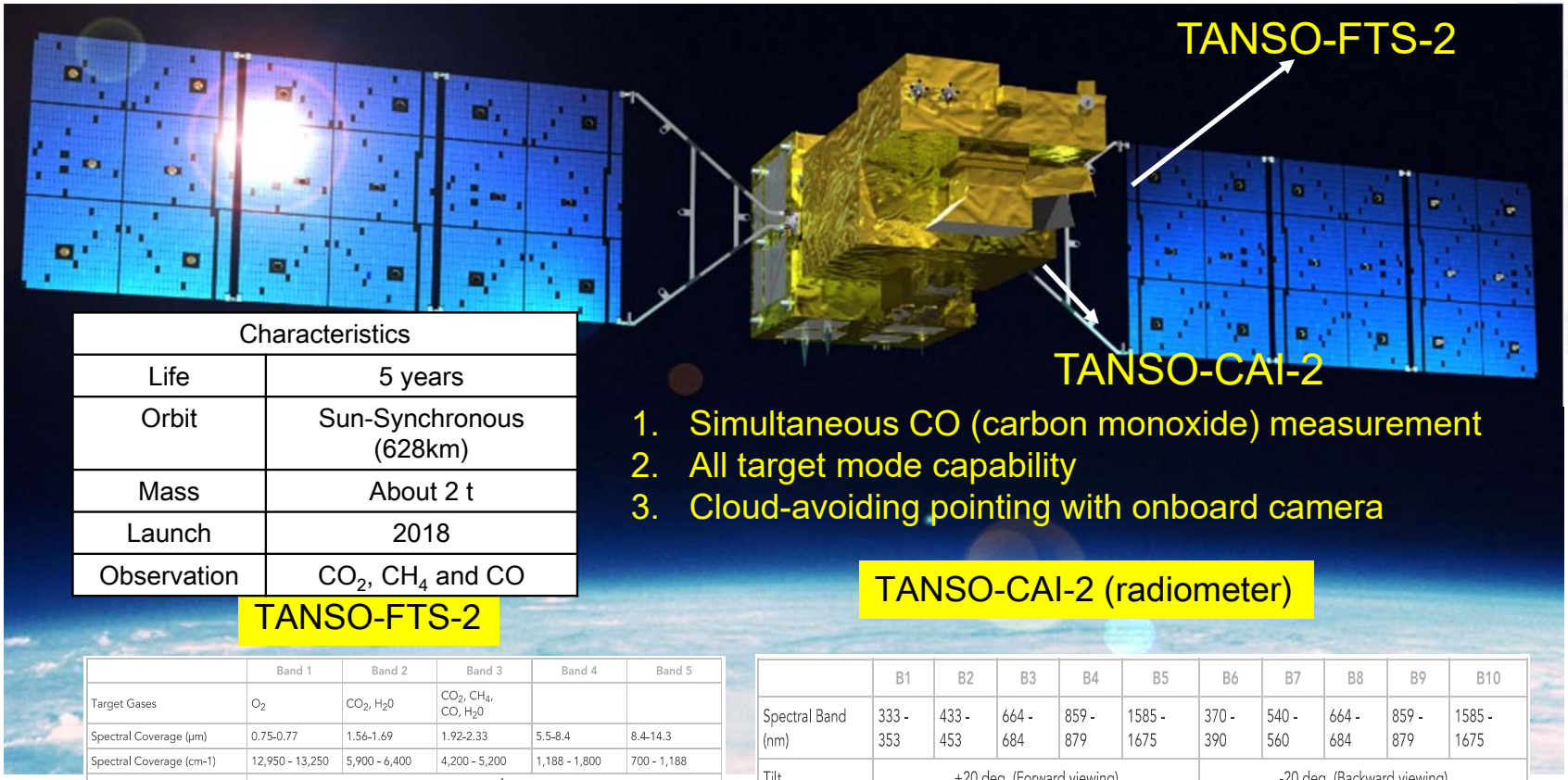


Match-up point check tool
http://www.eorc.jaxa.jp/GOSAT/GOSAT_Optimization/index.html

together with
GOSAT, GOSAT-2,
OCO-2 orbits (=TanSat),
Sentinel 5P

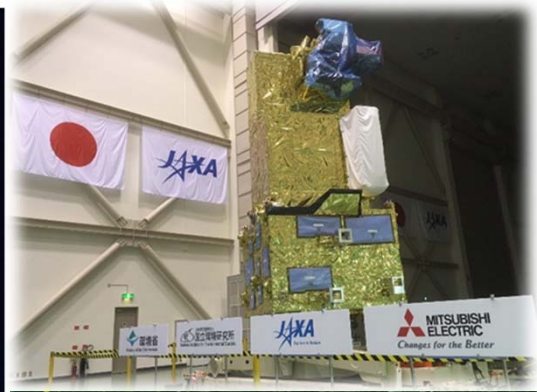
2018
Matched-up data set
Common database for GHG observation instruments from space:
Match up database of radiance spectra that include data quality, uncertainty, time, location of each instrument (GOSAT-OCO-2, GOSAT-AIRS, ……) will be provided.

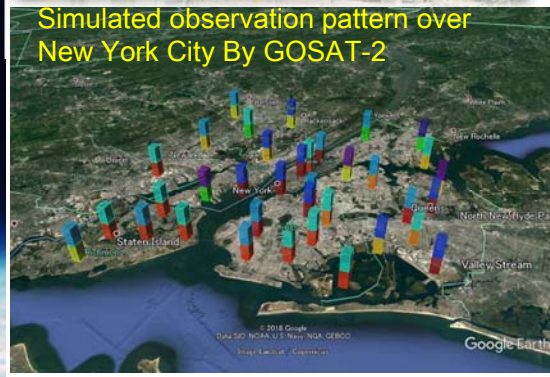
GOSAT-2 (2018-) will be launched on Oct. 29 (Mon)
TANSO-FTS-2 and CAI-2



Characteristics	
Life	5 years
Orbit	Sun-Synchronous (628km)
Mass	About 2 t
Launch	2018
Observation	CO_2, CH_4 and CO

1. Simultaneous CO (carbon monoxide) measurement
2. All target mode capability
3. Cloud-avoiding pointing with onboard camera





TANSO-FTS-2

	Band 1	Band 2	Band 3	Band 4	Band 5
Target Gases	O_2	CO_2, H_20	CO_2, CH_4, CO, H_20		
Spectral Coverage (μm)	0.75-0.77	1.56-1.69	1.92-2.33	5.5-8.4	8.4-14.3
Spectral Coverage (cm-1)	12,950 - 13,250	5,900 - 6,400	4,200 - 5,200	1,188 - 1,800	700 - 1,188
Spectral Resolution	0.2 cm^{-1}				
Exposure	4 sec				
IFOV	9.7 km				
Pointing	±40 deg. (Along track), ±35 deg. (Cross track)				
Polarimetry	Yes (P and S channels)			No	

TANSO-CAI-2 (radiometer)

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Spectral Band (nm)	333 - 353	433 - 453	664 - 684	859 - 879	1585 - 1675	370 - 390	540 - 560	664 - 684	859 - 879	1585 - 1675
Tilt	+20 deg. (Forward viewing)					-20 deg. (Backward viewing)				
Spatial Resolution	460 m				920m	460 m				920m
Swath	920 km									

Optimizing observation pattern with full target mode capability and wider pointing angles

October, 2018

Future Plans: Next Generation Instruments

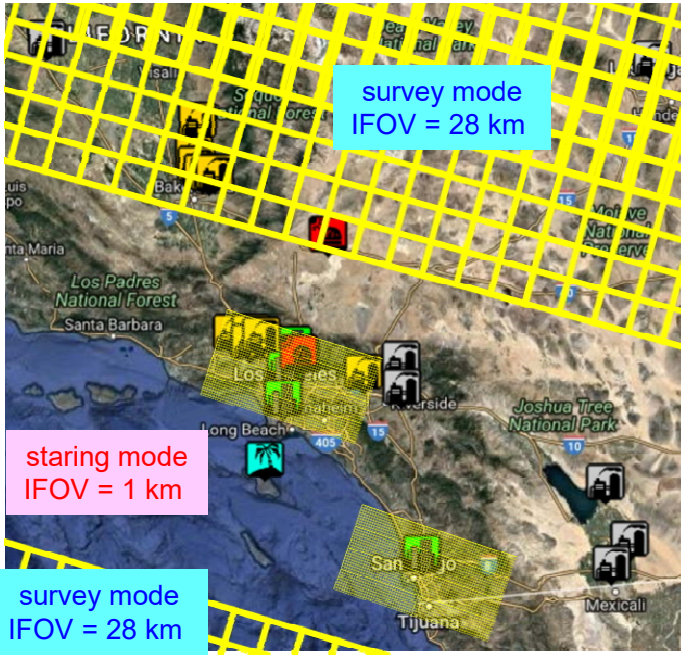
Combination of staring and coverage

Survey entire earth's surface

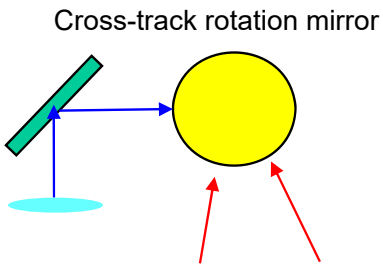
Selecting Proper reference

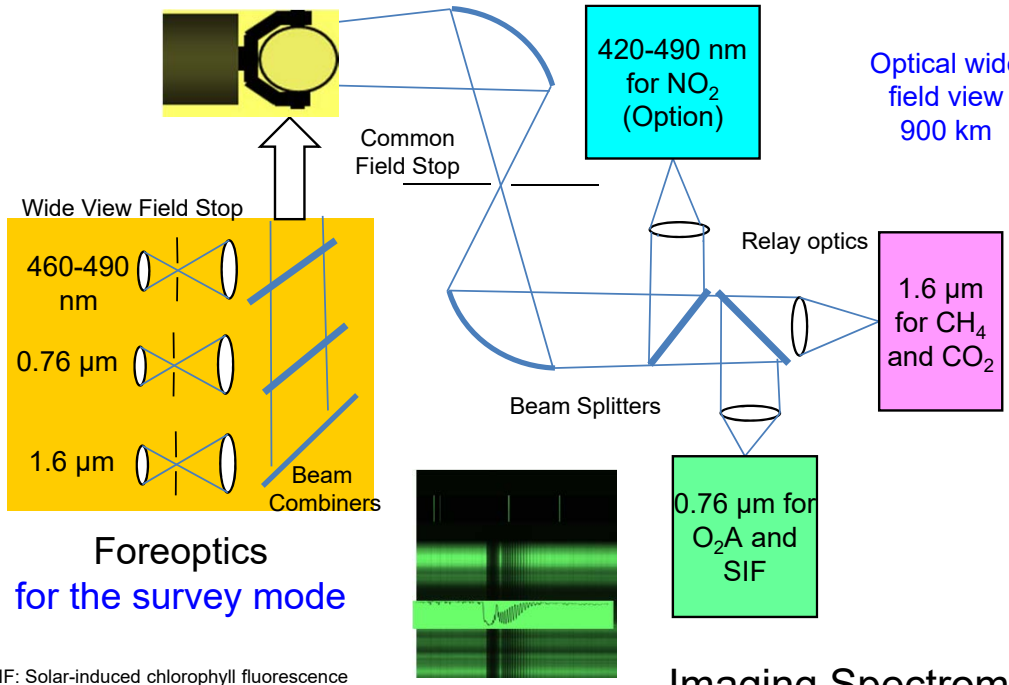
Staring

- 1 km resolution will enhance dCO_2 and dCH_4
- Image can detect plume and has closer reference
- Estimate plume direction



2-axis pointing system
for the staring mode
the side view for the survey mode



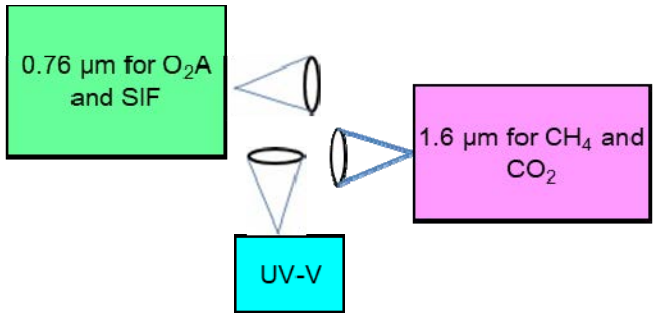


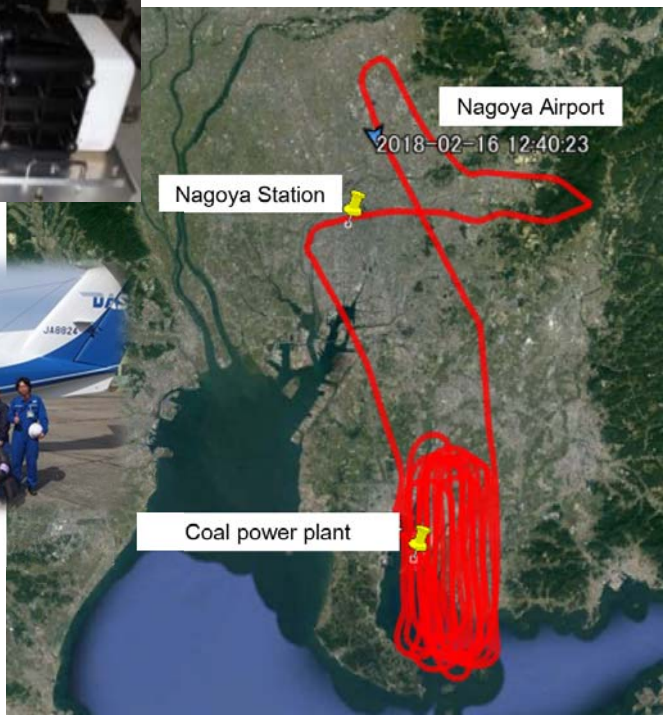
Foreoptics
for the survey mode

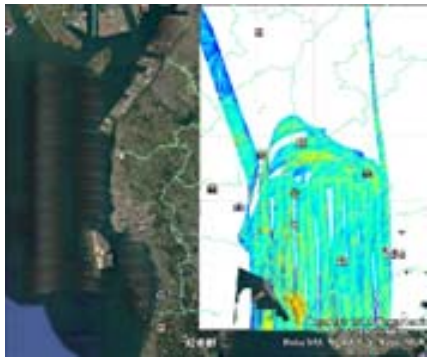
SIF: Solar-induced chlorophyll fluorescence

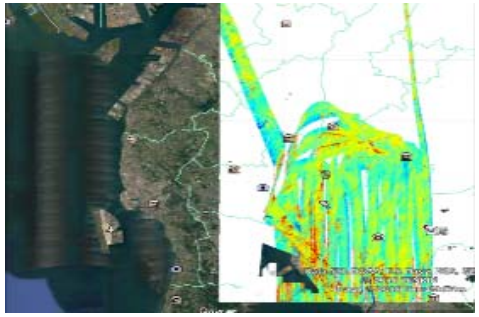
Imaging Spectrometer Suites

To demonstrate local flux estimation from different source sectors
Feb 2018 flight over greater Nagoya

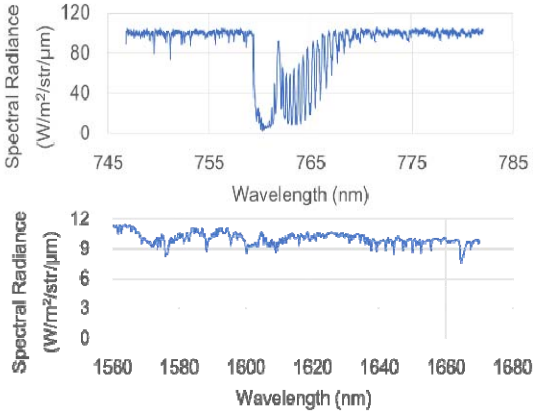




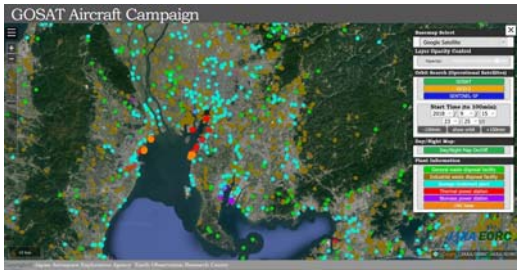




3 imaging spectrometers (1.6, 0.76 and UV)
CO_2, CH_4, O_2 (NO_2)



Large CO_2 emission sources, including a coal power plant and the transportation sector, and possible CH_4 sources from agriculture, energy manufacturing, and waste that are geographically mixed.



Different GHG source sector location of greater Nagoya
CO_2: Poser plant, traffic, industry
CH_4: Waste water, liver stock, Gas production

Summary

GOSAT (2009- now)

- Global, Frequent and long term: once or twice per 3-day of re-visit cycle, almost decade
- Uncertainty has been reduced to CO_2 1.6 ppm (0.4 %) CH_4 13 ppb (0.7 %)
- Recently improved: Targeting large emission source and partial column density using solar reflected light and thermal emission from atmosphere.
- Regional and Flux still have large uncertainty mostly due to lack of fluctuated enhancement and accurate wind information.

GOSAT-2 (next week)

- Full target observation capability with wider pointing angles
- Identify CO_2 enhancement by combustion with simultaneous measured CO.

Next generation demonstrated by airborne model

- Higher spatial resolution improves enhancement and imaging capability provide proper reference.
- Local flux estimation from various emission sectors of CO_2 and CH_4 to provide the data for making effective emission reduction policies.