Committee on Earth Observation Satellites

# Lessons learned from a-decade long GOSAT observations

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CEOS WGClimate

Marrakech, Morocco

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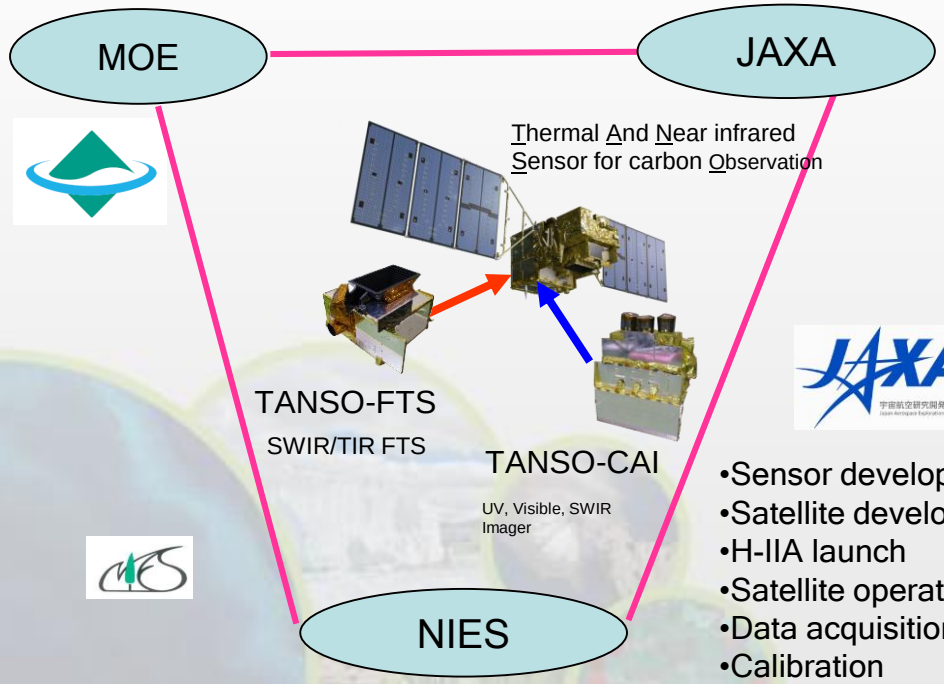
# Decade-long Observation by GOSAT
# 10th anniversary on Jan. 23, 2018

## GOSAT & GOSAT-2 Organization

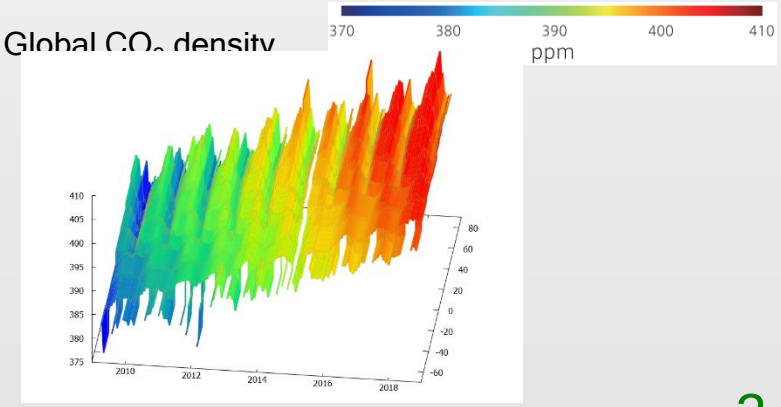
GOSAT is the joint project of JAXA, MOE (Ministry of the Environment) and NIES (National Institute for Environmental Studies).




- Sensor development
- Satellite development
- H-IIA launch
- Satellite operation
- Data acquisition
- Calibration

- Algorithms development
- Data use for science
- Validation


Global $CO_2$ density



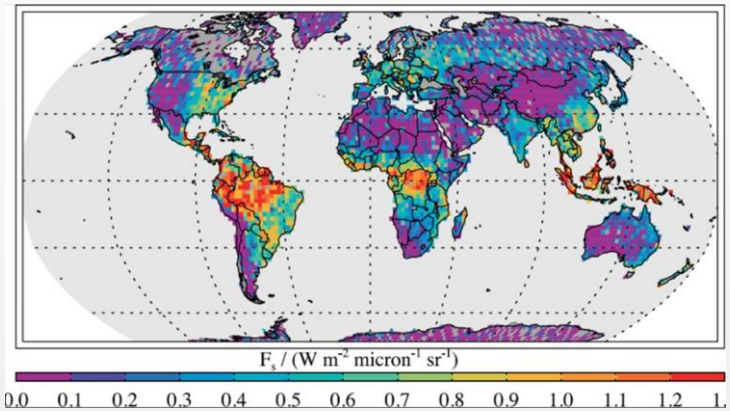

https://data2.gosat.nies.go.jp/gallery/fts_l2_swir_co2_gallery_en.html

# Before 2009 GOSAT Launch
# The first 5 years in space 2009 – 2014 design life

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

**2003** GOSAT project started

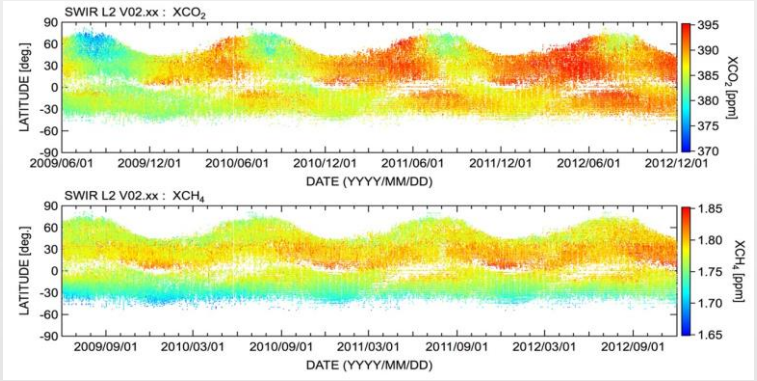
**2009** The Greenhouse Gases Observation Satellite
"IBUKI" (GOSAT) is the world's first spacecraft to measure the concentrations of carbon dioxide and methane, the two major greenhouse gases, from space.




2009, June Frankenberg et al., GRL 2011

**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

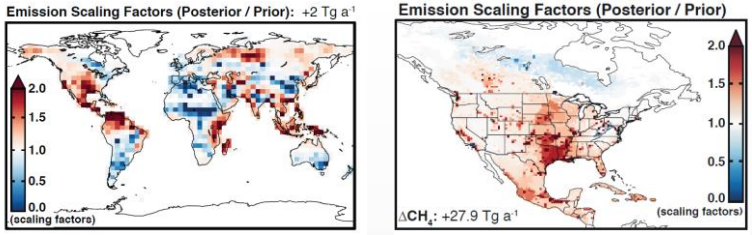


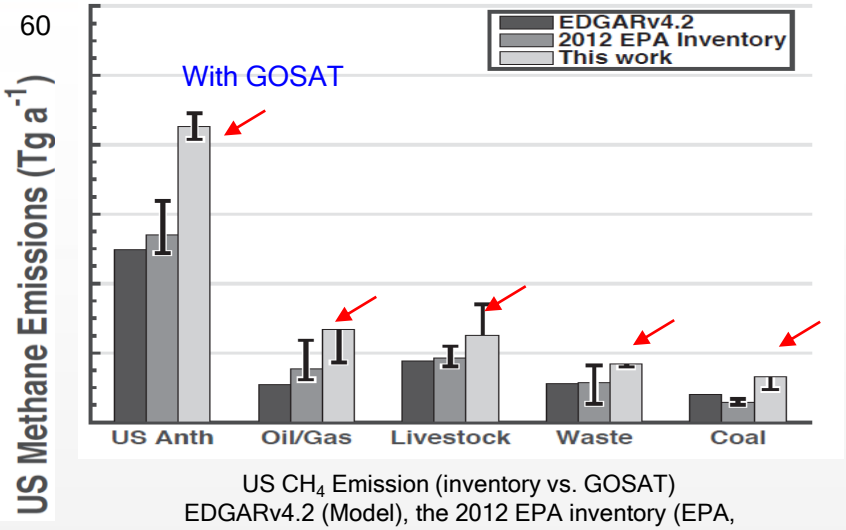

by Y. Yoshida (NIES))

**2014** GOSAT 5-year design life
Fully redundant system

# The next 5 years in space
# 2014 – until now

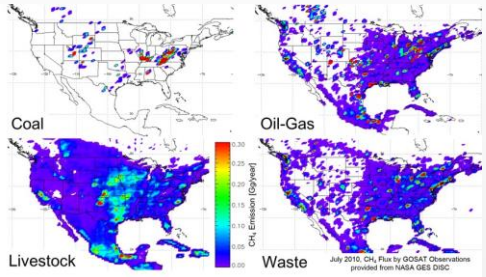
## 2015




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

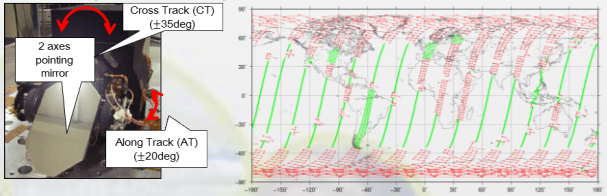
## 2016




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.

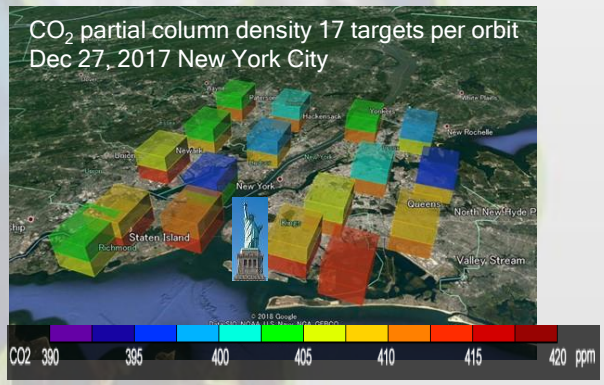
https://mirador.gsfc.nasa.gov/ July 2010

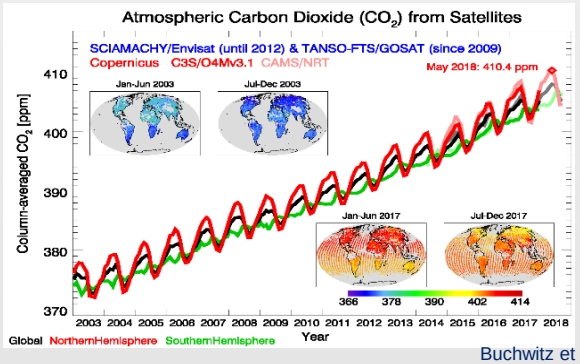
## 2017




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

## 2019




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

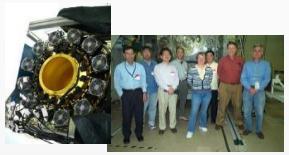
Buchwitz et al.

# Inter comparison
# GOSAT, GOSAT-2, OCO-2, OCO-3

2008 09 10 11 12 13 14 15 16 17 18 19

Radiometric calibration

Prelaunch X-CAL



Annual Vicarious Calibration at the desert playa in Nevada

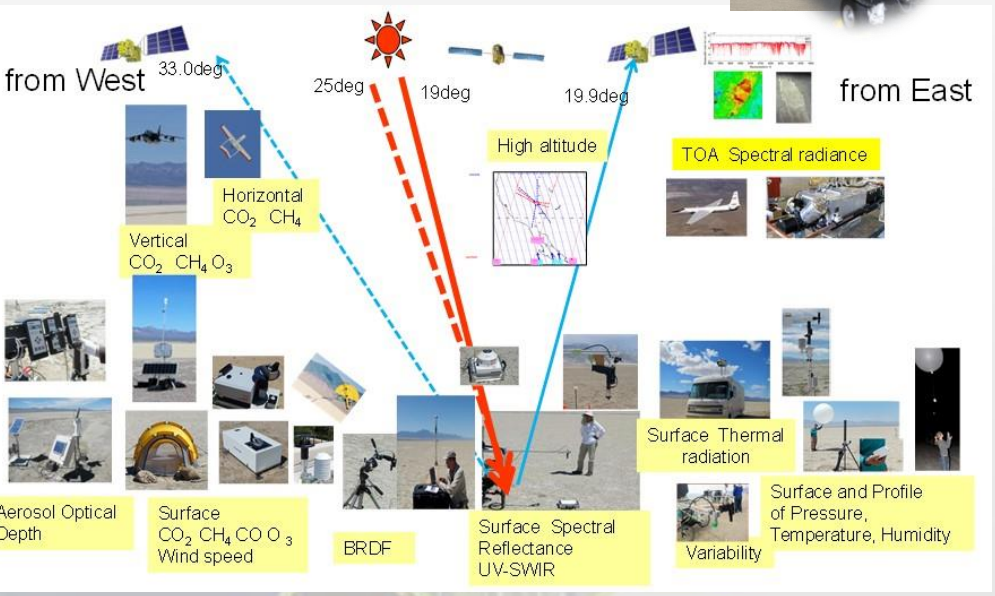
$CO_2$ & $CH_4$ profile

In situ $CO_2$ and $CH_4$ on AJAX

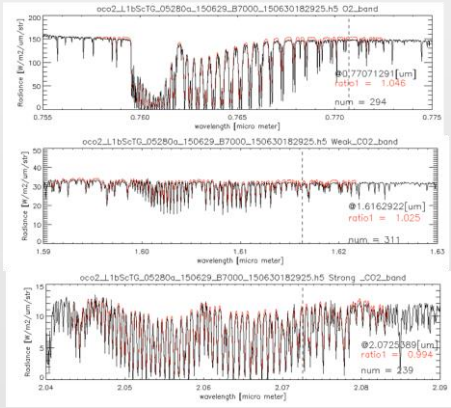
$XCO_2$ & $XCH_4$

Column with EM-27 FTS

Coincident Target



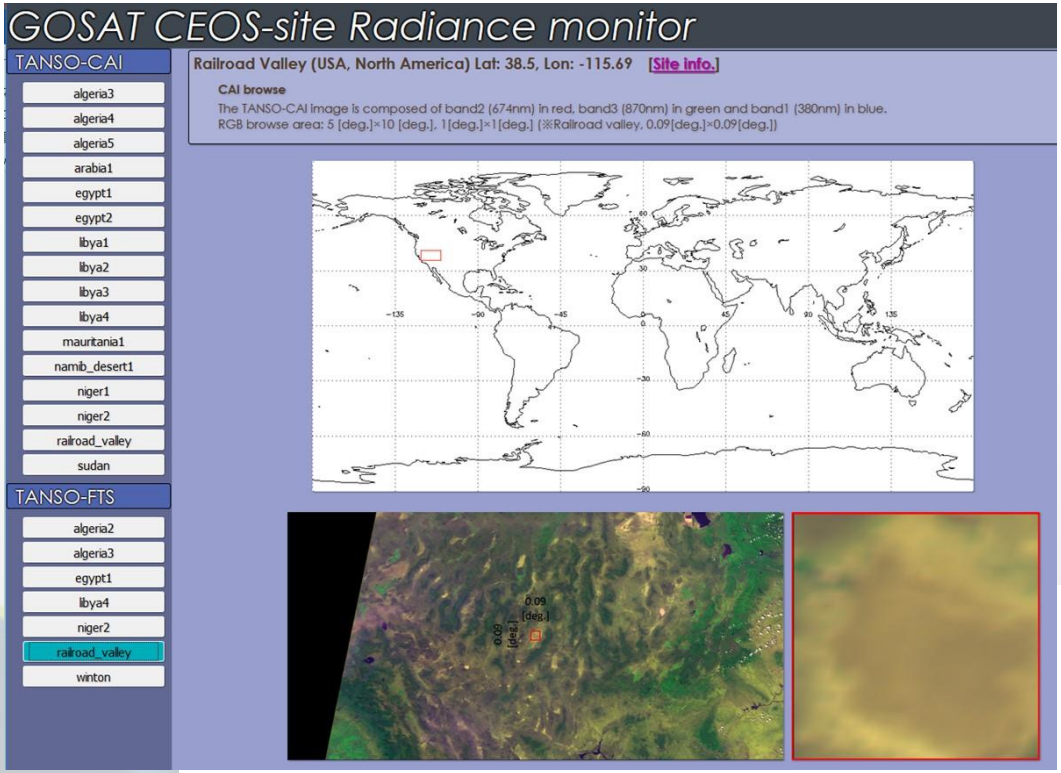

GOSAT OCO-2




Calibrated GOSAT and OCO-2 radiance spectra agrees within 5% for all bands.

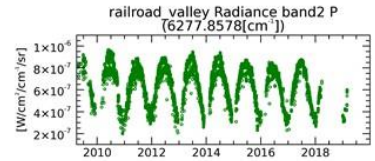
# A Decade long GOSAT radiance spectra data over CEOS calibration sites

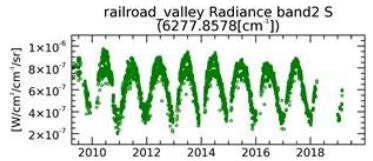
https://www.eorc.jaxa.jp/GOSAT/CEOS_monitor/

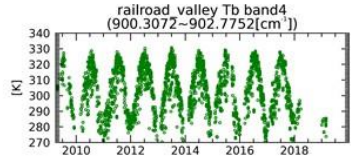


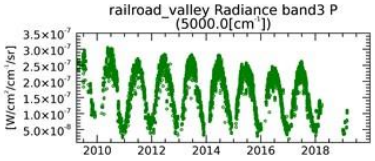


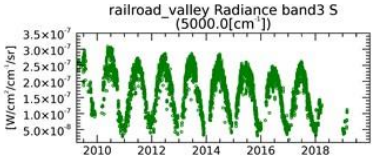


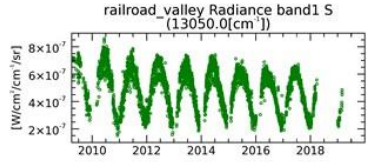


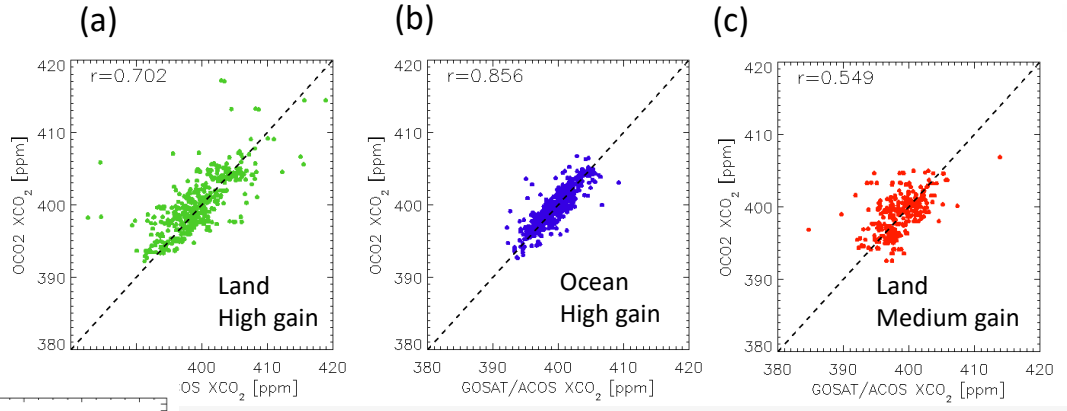



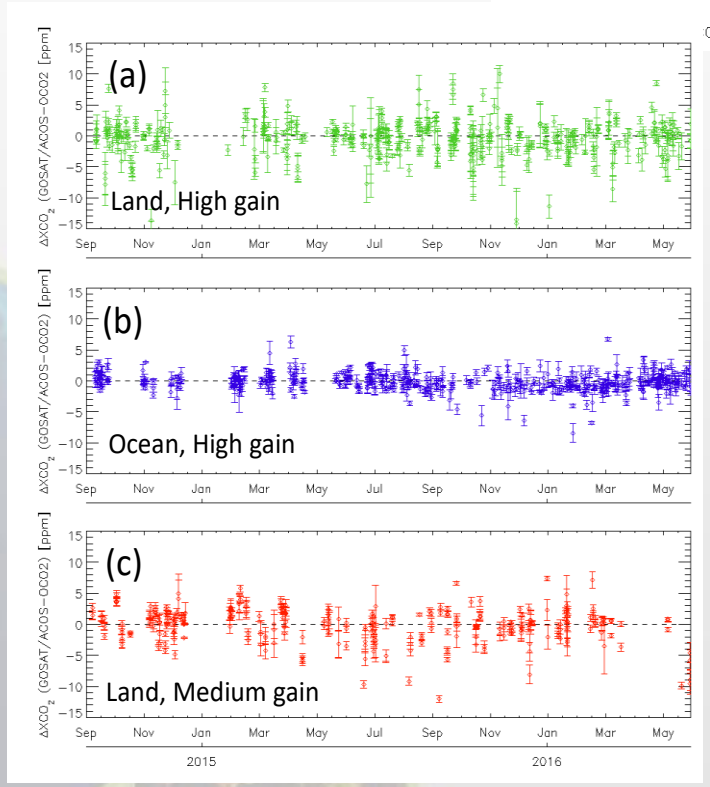
# $XCO_2$ Scatter plots of ACOS GOSAT (B7) - OCO-2 and time dependency of their difference

(a) ± 3.33 ppm

(b) ± 1.48 ppm

(c)± 2.79 ppm




The time series of Δ $XCO_2$ from Sep. 2014

$$\Delta X_{CO_2} = \text{GOSAT/ACOS}\ X_{CO_2} - \text{OCO-2}\ X_{CO_2}$$

2014/09～2016/05 $XCO_2$ Level2 matchup Agreement: (ACOS-GOSAT B7.3 vs. OCO-2 B7)

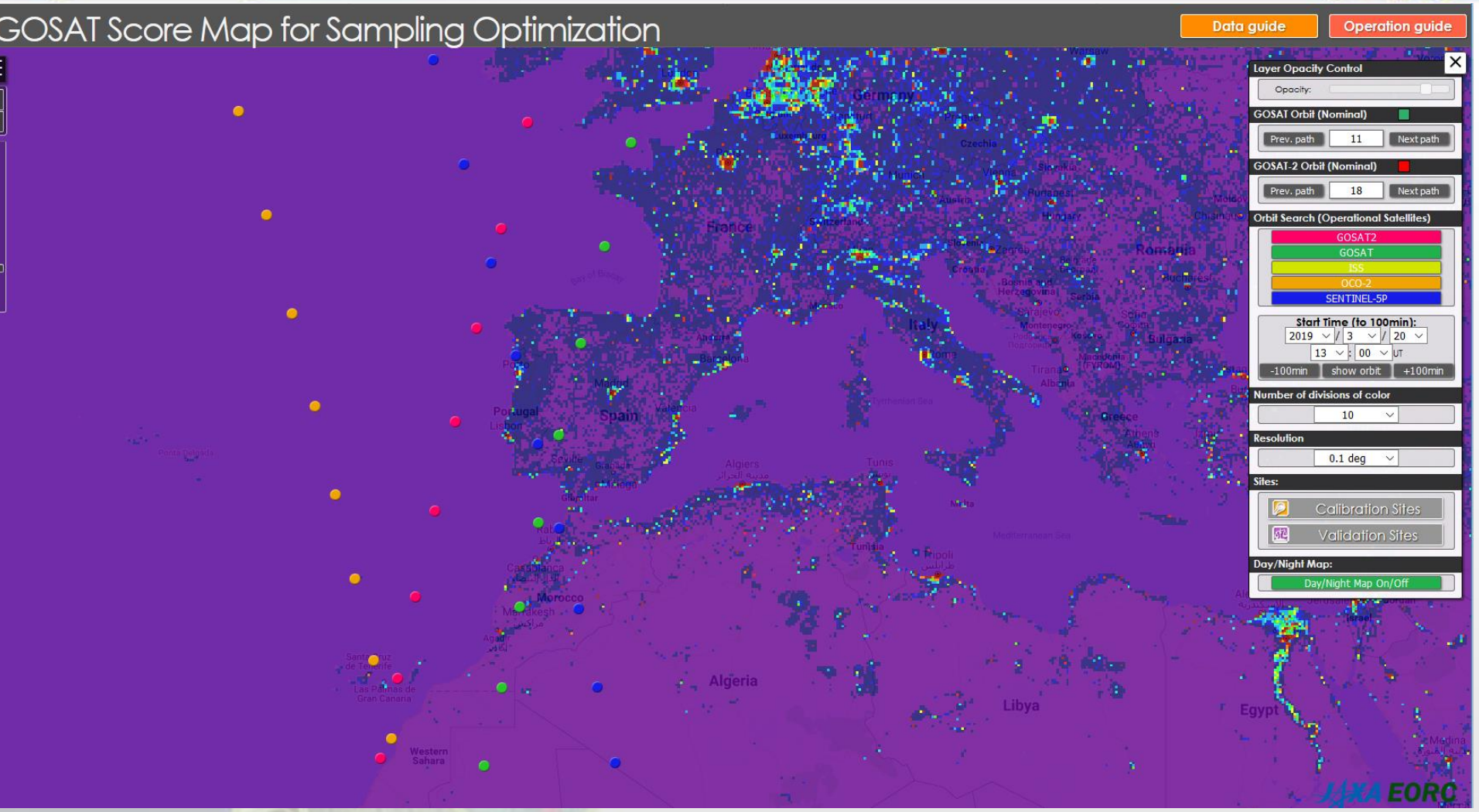
< 0.57 ppm over Land (high gain) Error probably due to ono-flat Topography

< 0.17 ppm over Ocean

< 0.19 ppm over Land (desert)

Kataoka et al. (2017) MDPI

# GHG Satellites Constellation as of UT12, March 20, 2019




GOSAT, GOSAT-2, Sentinel 5, OCO-2, TanSat, ISS

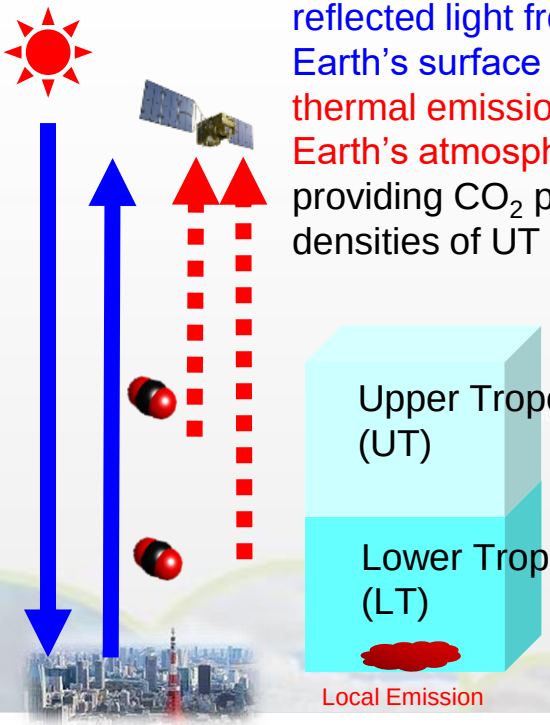
https://www.eorc.jaxa.jp/GOSAT/GOSAT_Optimization/index.html

ODIAC $CO_2$ emission source map and Calibration and Validation site

# A decade long dataset and new research products

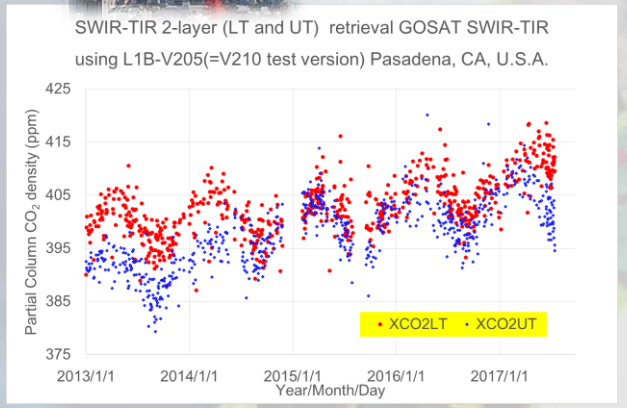
http://www.eorc.jaxa.jp/GOSAT/product.html#trendviewer

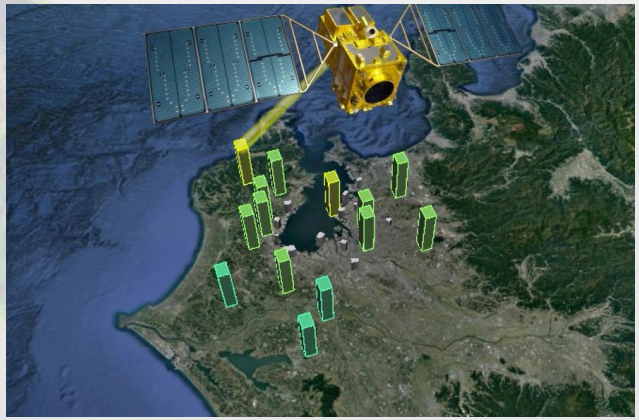
GOSAT measures both solar reflected light from the Earth's surface (SWIR) and thermal emission from the Earth's atmosphere (TIR) providing $CO_2$ partial-column densities of UT and LT.

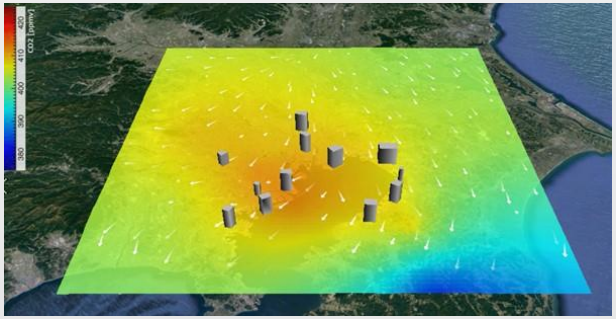




long-term trend data of the selected targets, including the large point sources of methane ($CH_4$) and intensive observations of selected mega cites.

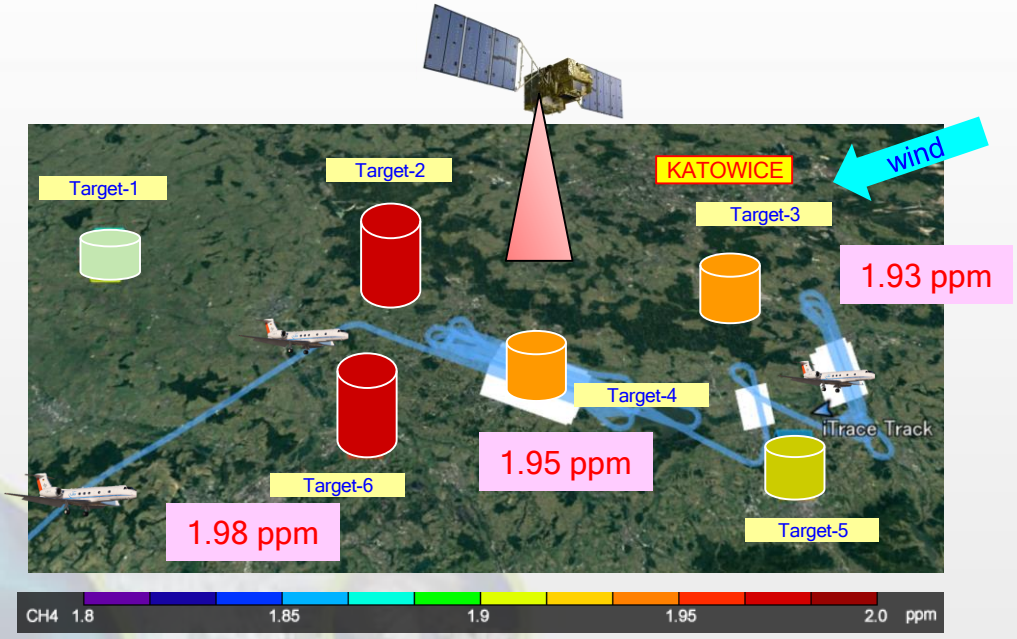




# DLR-JAXA Joint CoMet 2018 Campaign and Joint COP 24 Presentation

Comet coincident flight with GOSAT over Silesian Coal Mine on June 6, 2018 GOSAT targeted 6 points and captured whole emissions that spread horizontally and vertically from 666 km.


Joint presentation "On the pathway to new greenhouse gas monitoring systems" in the side event at the German Pavilion at UNFCCC COP24 on Dec. 6, Katowice, Poland

Joint team demonstrated direct $CH_4$ emission estimation from Silesian Coal Mine using GOSAT partial column density of lower Troposphere.

$$Emission_{CH_4} = A(XCH_4(source)-XCH_4(background))\times WindVelocity$$

Courtesy of Friedemann Call, DLR

# Air-bone demonstration model

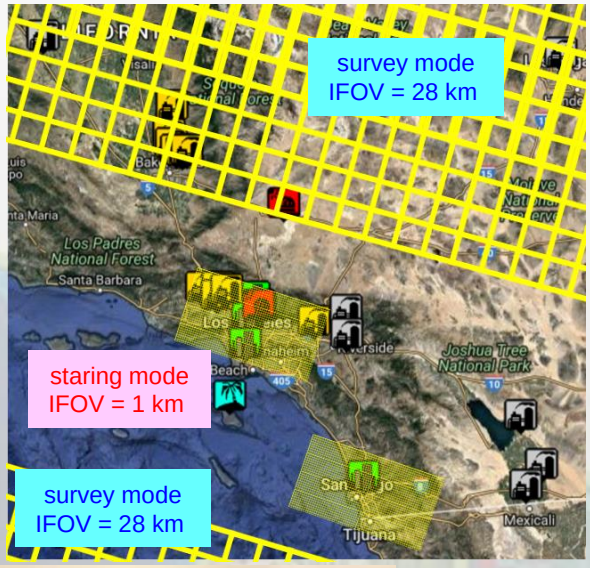
## Combination of staring and coverage

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




0.76 µm surface pressure, cloud height and solar induced chlorophyll fluorescence

1.6 µm for $CO_2$, $CH_4$

2-axis pointing system

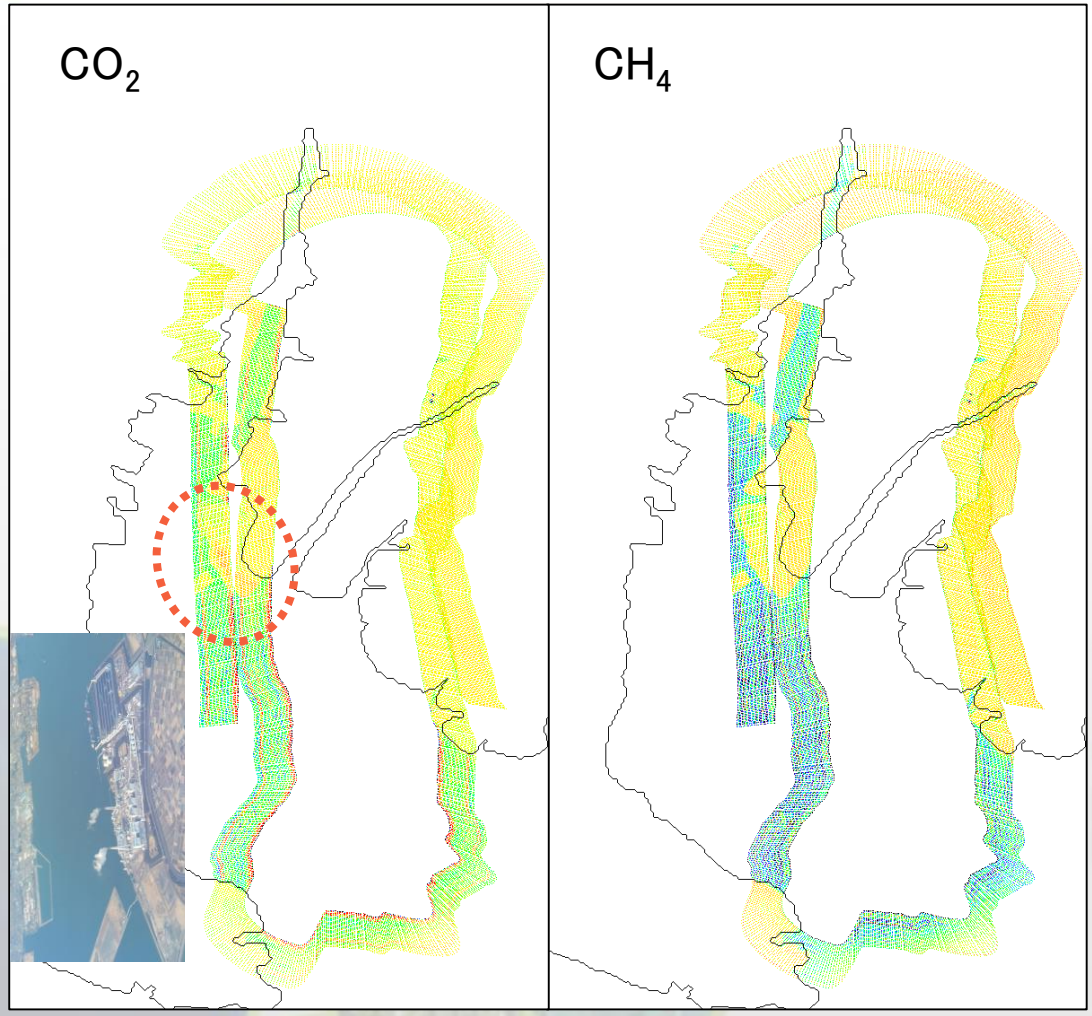


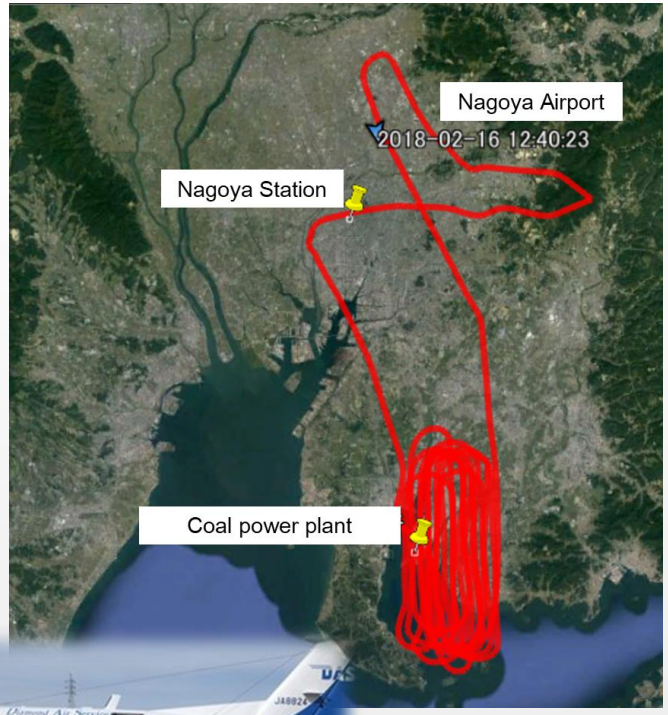
0.47 µm for $NO_2$

Survey mode

Staring mode

# Demonstrate local flux estimation from different source sectors
## Feb 2018 flight over greater Nagoya




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.

# CEOS AC-VC TOKYO 2019

Nakano Sun Plaza (conference and hotel)

CEOS AC-VC TOKYO 2019
June 10 (Mon) GHG June 11-12 (Tue-Wed) AQ

https://www.sunplaza.jp/en/