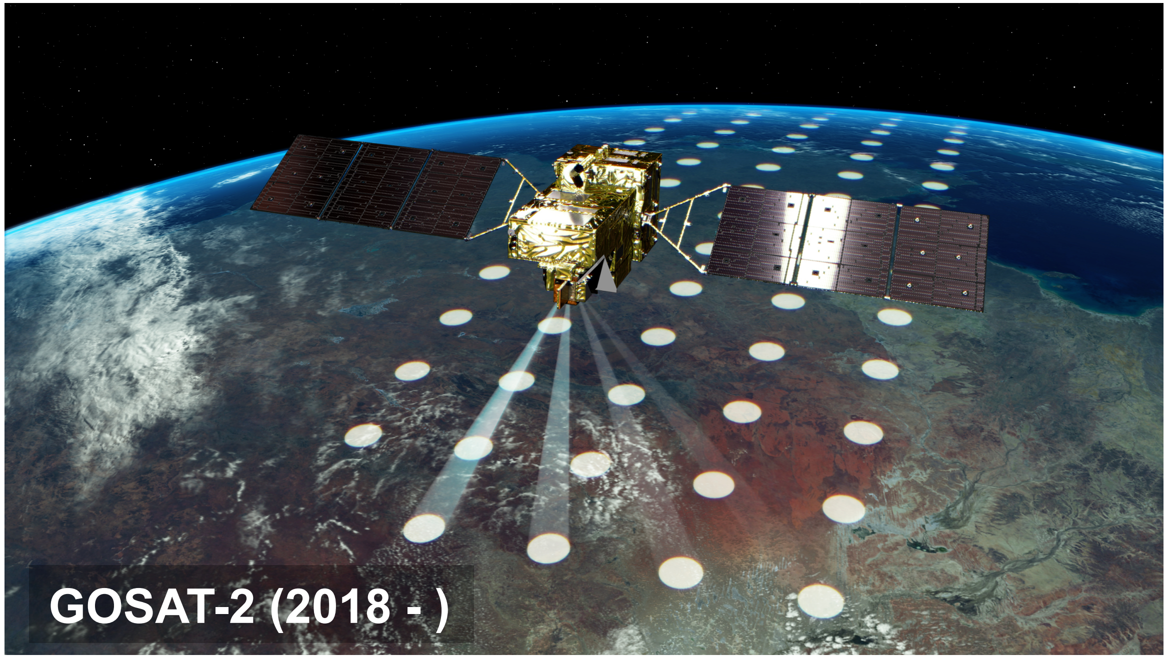
Comparison of GHG Concentrations and Fluxes Derived from GOSAT, Inventories, and Terrestrial Biosphere Models



Tsuneo Matsunaga
Director, Satellite Observation Center
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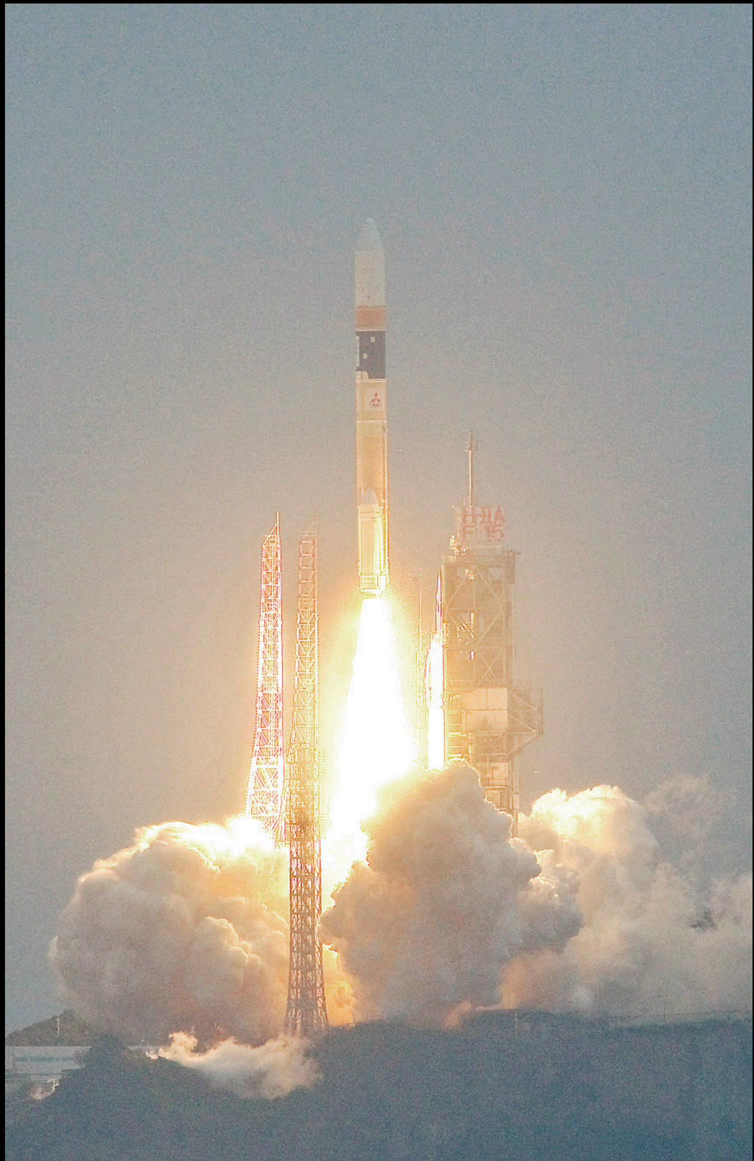


Launch of GOSAT by H-IIA Rocket from JAXA's Tanegashima Space Center in January 2009

GOSAT (Greenhouse gases Observing Satellite) is the world's first satellite dedicated to greenhouse gas monitoring from space.

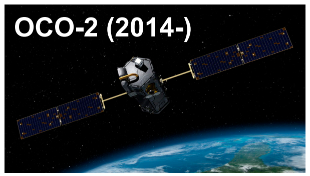
GOSAT was successfully launched in 2009, and has been monitoring the Earth's atmosphere and distributing data for almost eight years.

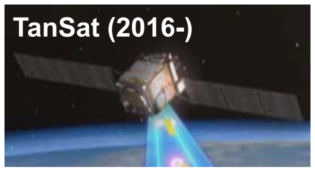
The successor, GOSAT-2, will be launched in FY2018 with more earth observation capabilities than GOSAT.

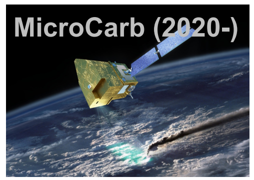
The discussion on GOSAT-3 has been already started.

Satellites for Greenhouse Gases Observation

Mission	Country	Period	GHGs	Comments
SCIAMACHY	(ESA)	2002 -2012	CO_2, CH_4	ENVISAT
GOSAT	Japan	2009 -	CO_2, CH_4	
OCO-2	US	2014 -	CO_2	
TanSat	China	2016 -	CO_2	
TROPOMI	(EC)	2017 -	CH_4	Sentinel 5p
GF-5	China	2017 -	CO_2, CH_4	
FY-3D	China	2017 -	CO_2, CH_4	
GOSAT-2	Japan	2018 -	CO_2, CH_4	
OCO-3	US	2018 -	CO_2	ISS
MicroCarb	France	2020 -	CO_2	
MERLIN	France/ Germany	2021 -	CH_4	Laser
geoCARB	US	2022-	CO_2, CH_4	Geostationary
GOSAT-3	Japan	2022 -	?	?

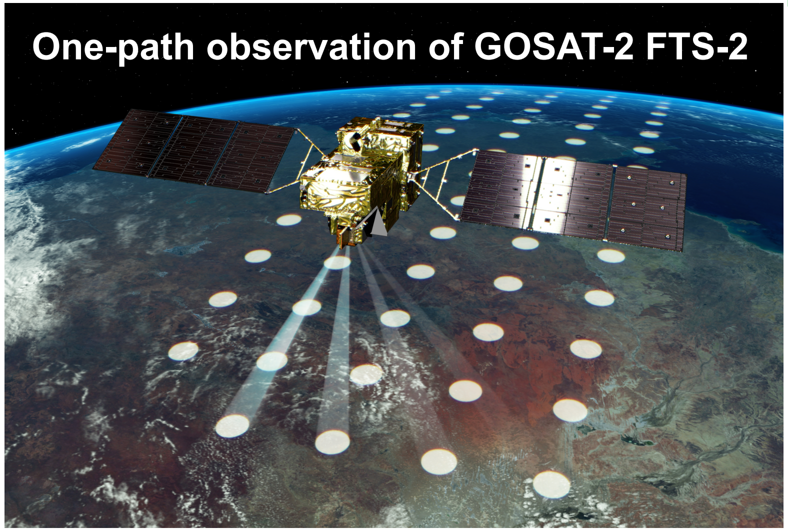


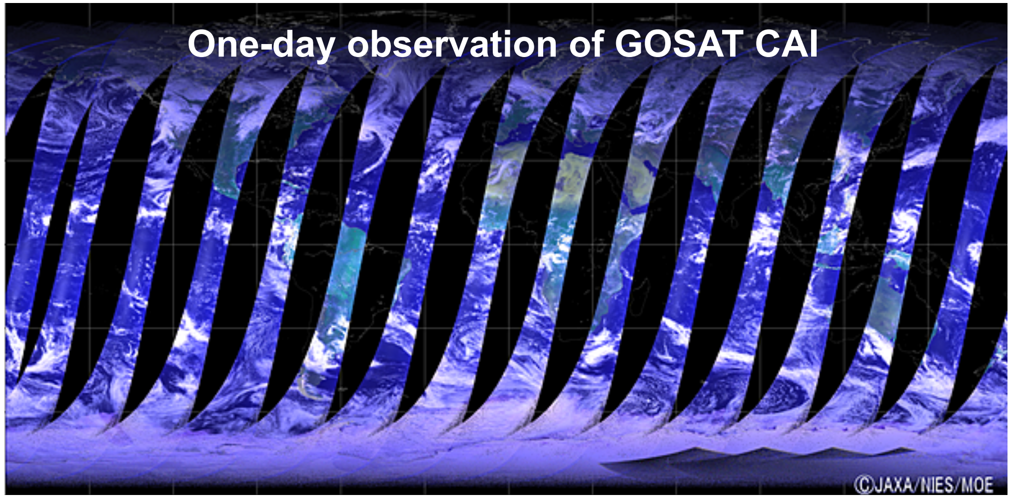




Atmospheric Observation by GOSAT and GOSAT-2

- GOSAT and GOSAT-2
  - Fourier Transform Spectrometer
    FTS and FTS-2
    - Trace gases
      - CO_2
      - CH4
      - H_2O
      - CO
  - Cloud and Aerosol Imager
    CAI and CAI-2
    - Clouds
    - Aerosols
      - AOT
      - PM2.5
      - Black carbon


One-path observation of GOSAT-2 FTS-2

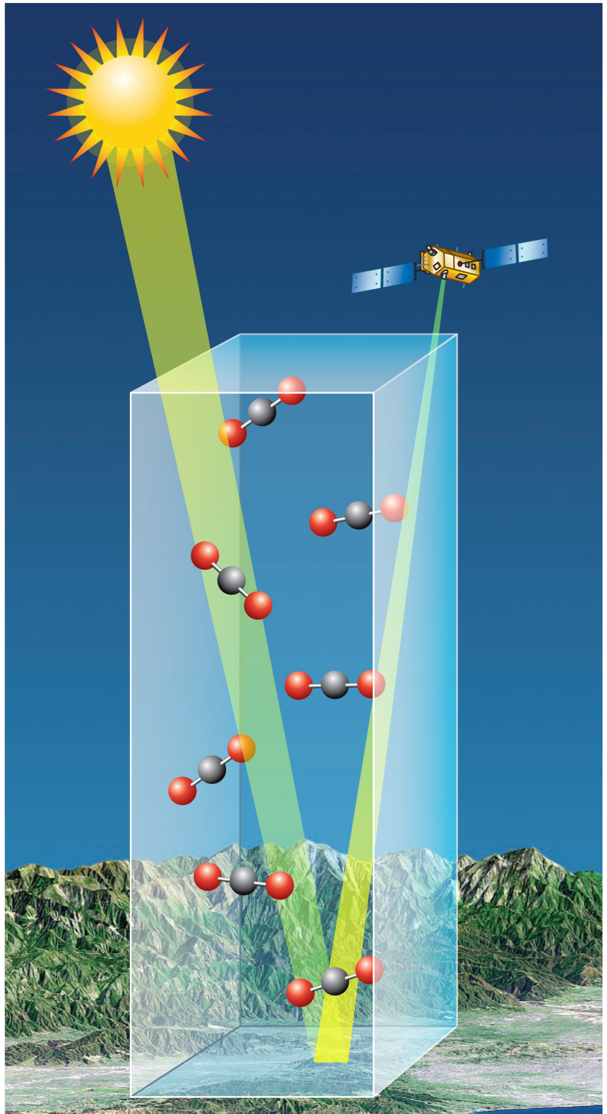


One-day observation of GOSAT CAI

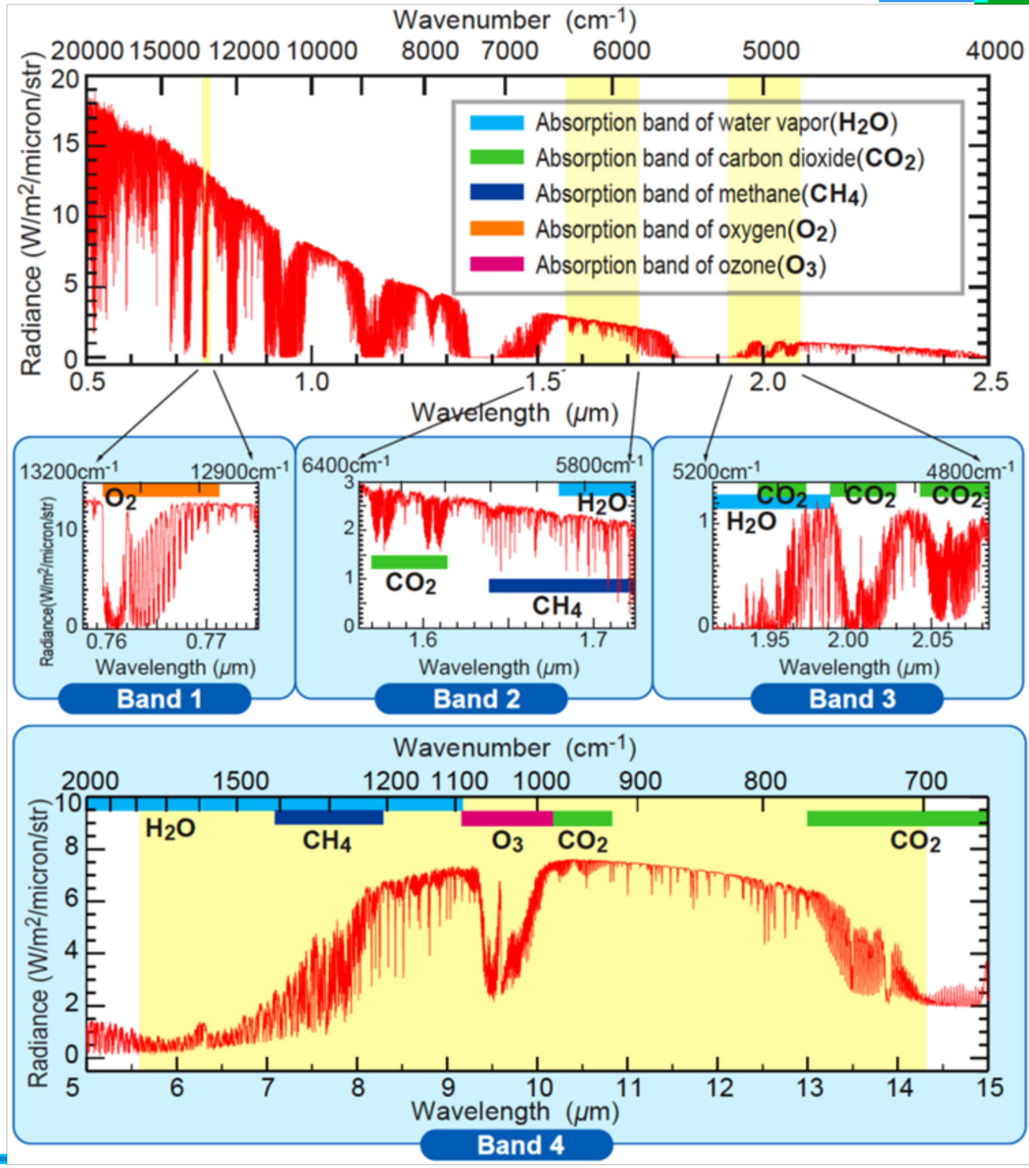
Quick Overview of GOSAT and GOSAT-2

	GOSAT Specifications	GOSAT-2 Requirements
Launch year and life time	Jan. 2009, 5 years	FY2018, 5 years
Satellite (Dimension, mass, power)	3.7 x 1.8 x 2.0 m, 1750kg, 3.8KW (EOL)	5.3 x 2.0 x 2.8 m, <2000kg, 5.0KW
Orbit (Type, altitude, repeat cycle, equator crossing time)	Sun synchronous, 666 km, 3 days, 13:00	Sun synchronous, 613 km, 6 days, 13:00±15 min
Target gases	CO_2, CH_4, O_2, O_3, H_2O	CO_2, CH_4, O_2, O_3, H_2O, CO
Fourier Transform Spectrometer (FTS and FTS-2)	Band 1 : 0.76 – 0.78 μm Band 2 : 1.56 – 1.72 μm Band 3 : 1.92 – 2.08 μm Band 4 : 5.6 – 14.3 μm Spectral resolution = 0.2 cm^{-1} IFOV = 10.5 kmϕ Pointing = ±20° (AT), ±35° (CT) Polarimetry = Band 1, 2, 3	Band 1 : 0.75 – 0.77 μm Band 2 : 1.56 – 1.69 μm Band 3 : 1.92 – 2.33 μm Band 4 : 5.5 – 8.4 μm Band 5 : 8.4 – 14.3 μm Spectral resolution = 0.2 cm^{-1} IFOV = 9.7 kmϕ Pointing = ±40° (AT), ±35° (CT) Polarimetry = Band 1, 2, 3
Cloud and Aerosol Imager (CAI and CAI-2)	Nadir B1 = 380 nm B2 = 674 nm B3 = 870 nm B4 = 1600 nm B1-B3 = 500 m / 1000 km, B4 = 1500 m / 750 km	B1-5: Forward (+20°), B6-10: Backward(-20°) B1 = 343 nm B6 = 380 nm B2 = 443 nm B7 = 550 nm B3 = 674 nm B8 = 674 nm B4 = 869 nm B9 = 869 nm B5 = 1630 nm B10= 1630 nm B1-B4, B6-B9= 460 m / 920 km B5, B10 = 920 m / 920 km
Other new features of GOSAT-2 FTS-2	Intelligent pointing using FTS-2 FOV camera, fully programmable (target mode) observation, and improved SNR.	

How to Measure Atmosheric Gas Concentration from Space



http://oco.jpl.nasa.gov/images/oco/OCO_column.jpg



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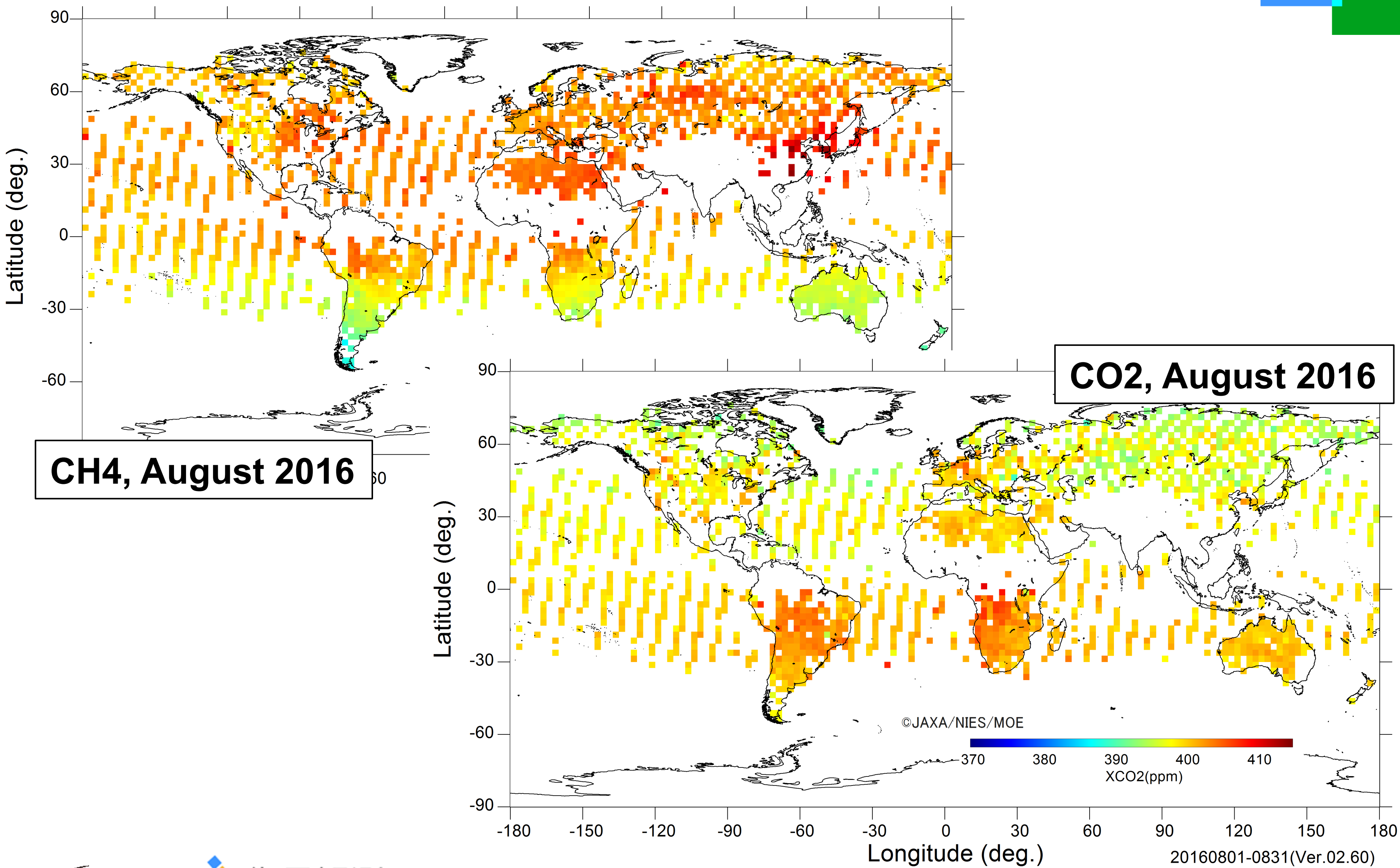
Latest Global Maps of GOSAT Monthly Concentration of CO2 and Methane (August 2016)



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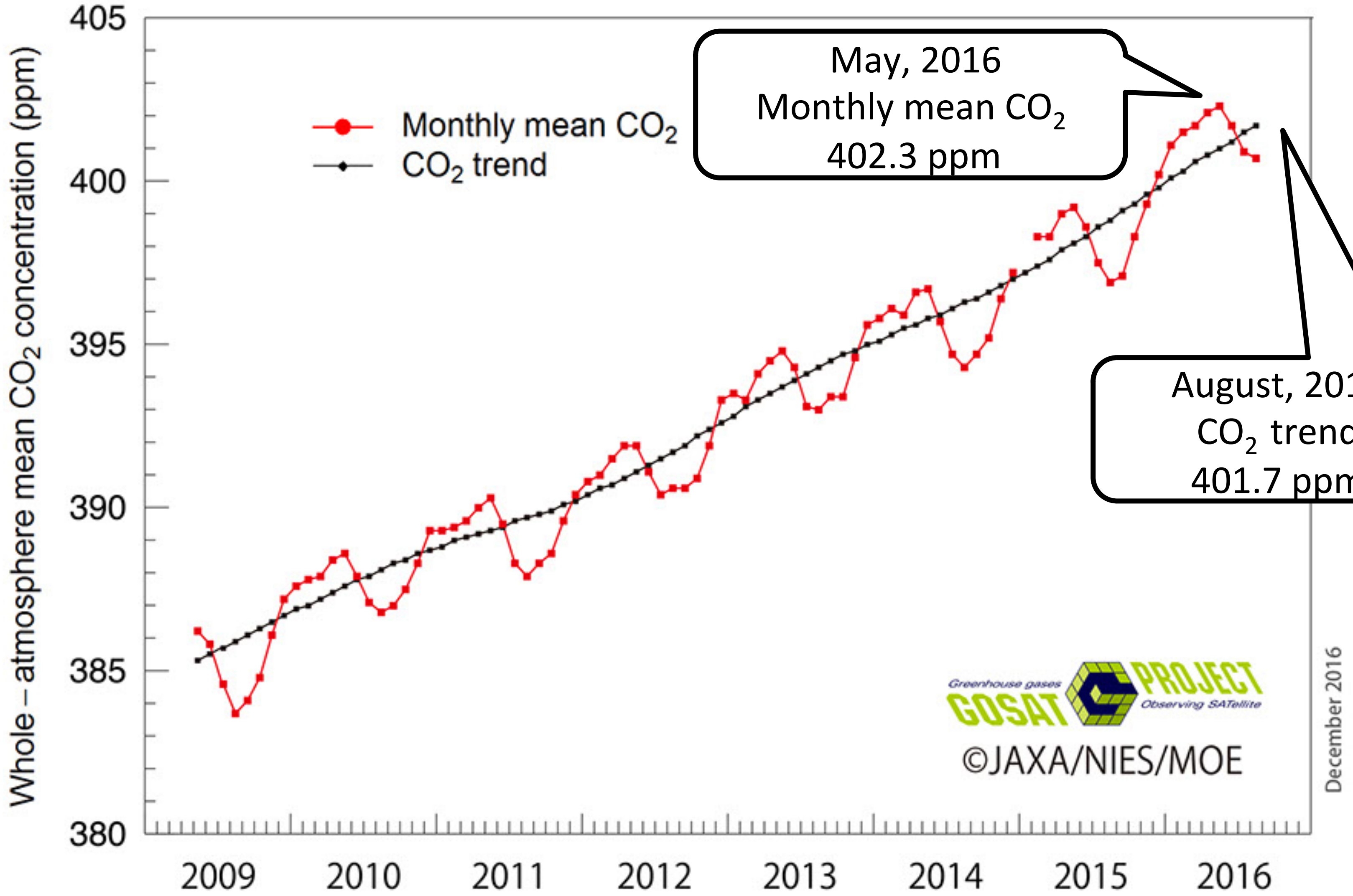
GOSAT Whole-atmosphere Mean CO2 Concentration



http://www.gosat.nies.go.jp/en/recent-global-co2.html

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Two Methods for Satellite / Inventory-Model Comparison

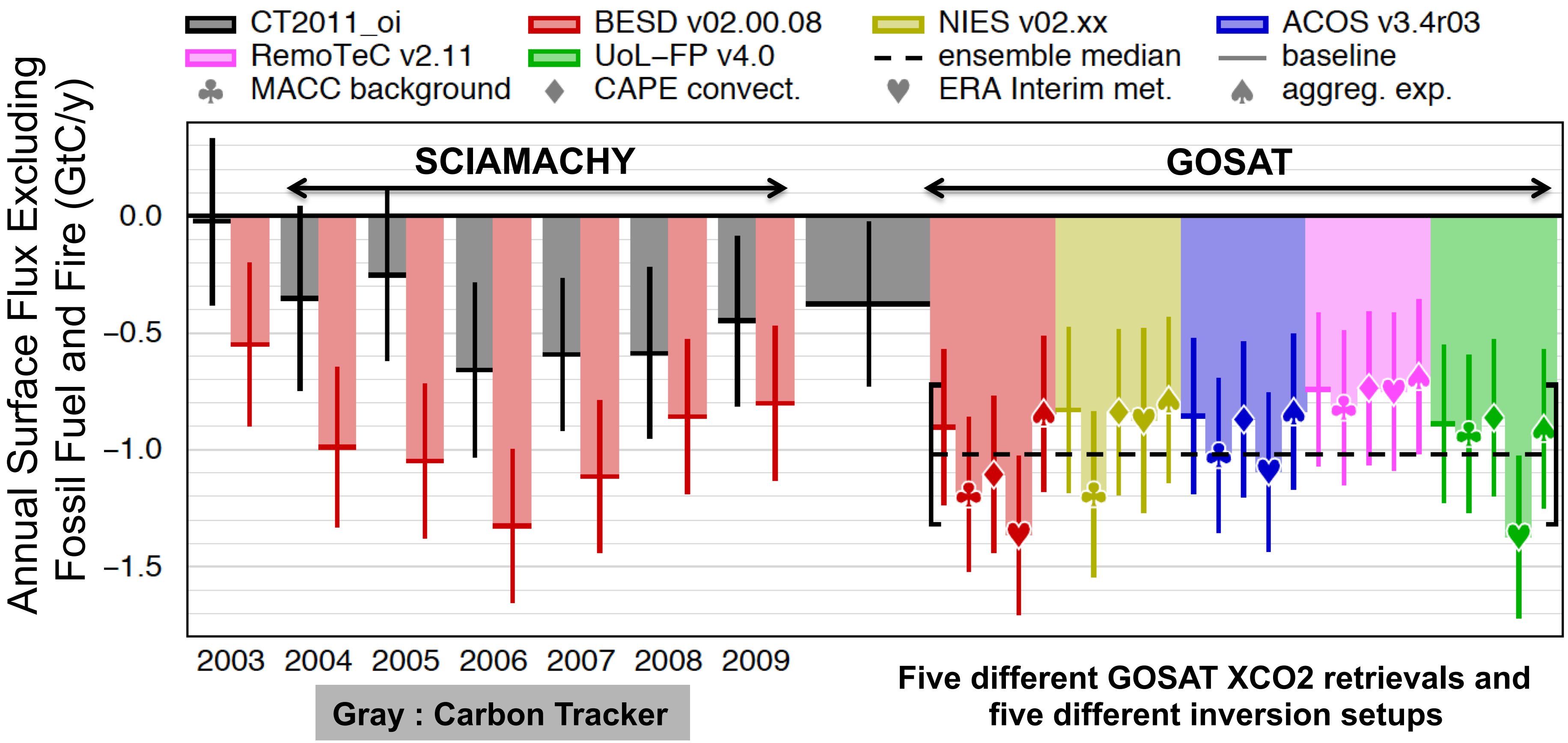
Flux-based Method

- Regional net flux can be obtained by inverse analysis using satellite data and atmospheric transport model (Backward) .
- This flux can be compared with the sum of anthropogenic emission (inventories) and natural source/sink flux data.

Concentration-based Method

- GHG concentration increase from background can be obtained from satellite data.
- This increase can be compared with GHG concentration which is calculated from emission inventories or biospheric models using atmospheric transport model (Forward).

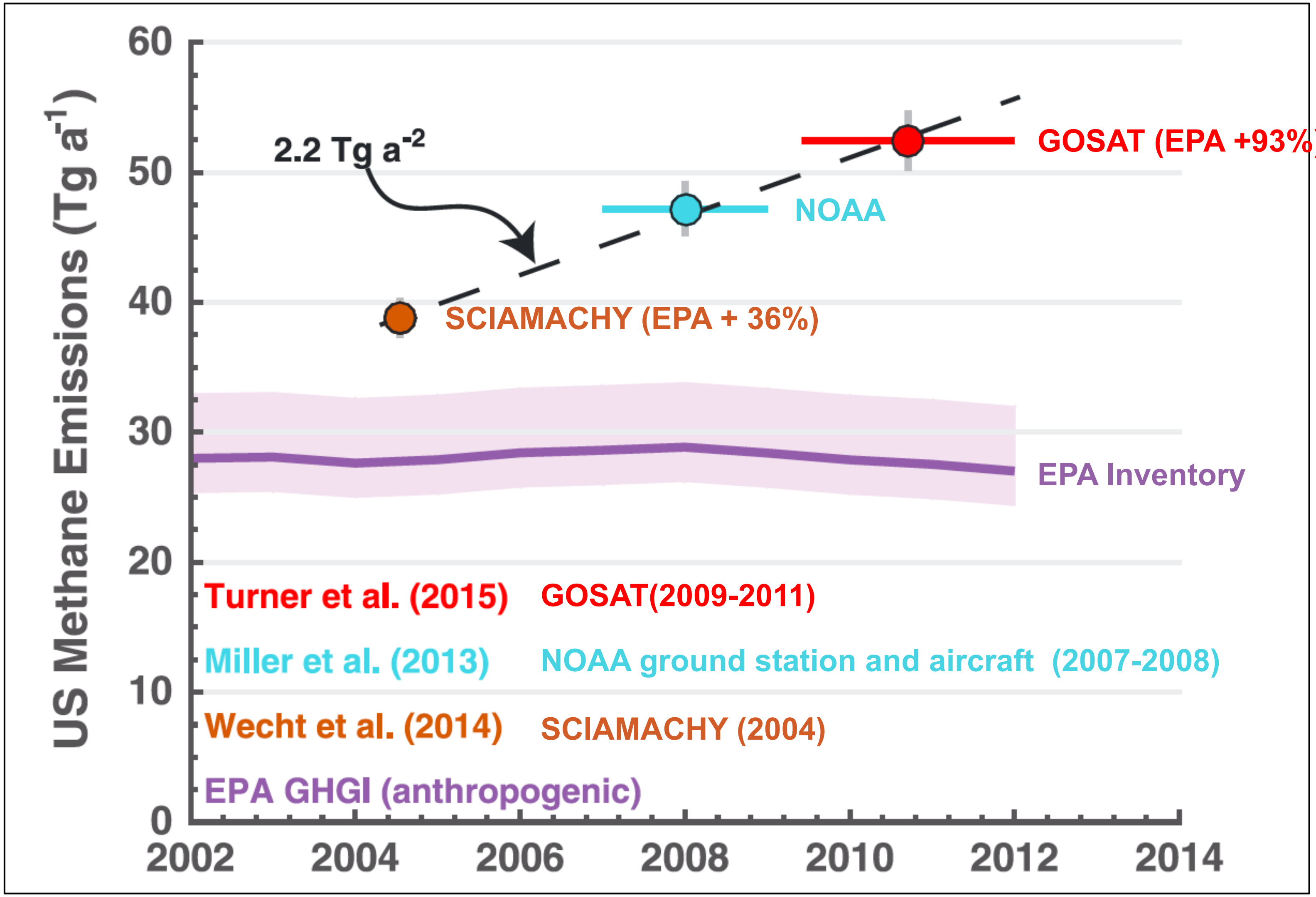
Flux-based method : European Biospheric Carbon Flux (Sink)



- Method : Regional inversion using short-range particle dispersion modelling
- Satellite-derived European terrestrial carbon sink (1.02 ±0.30 GtC/y in 2010) is much larger than assimilation results with surface CO2 data (Carbon Tracker, 0.38 ±0.35 GtC/y in 2010) and bottom-up inventories.

(Reuter et al., 2014)

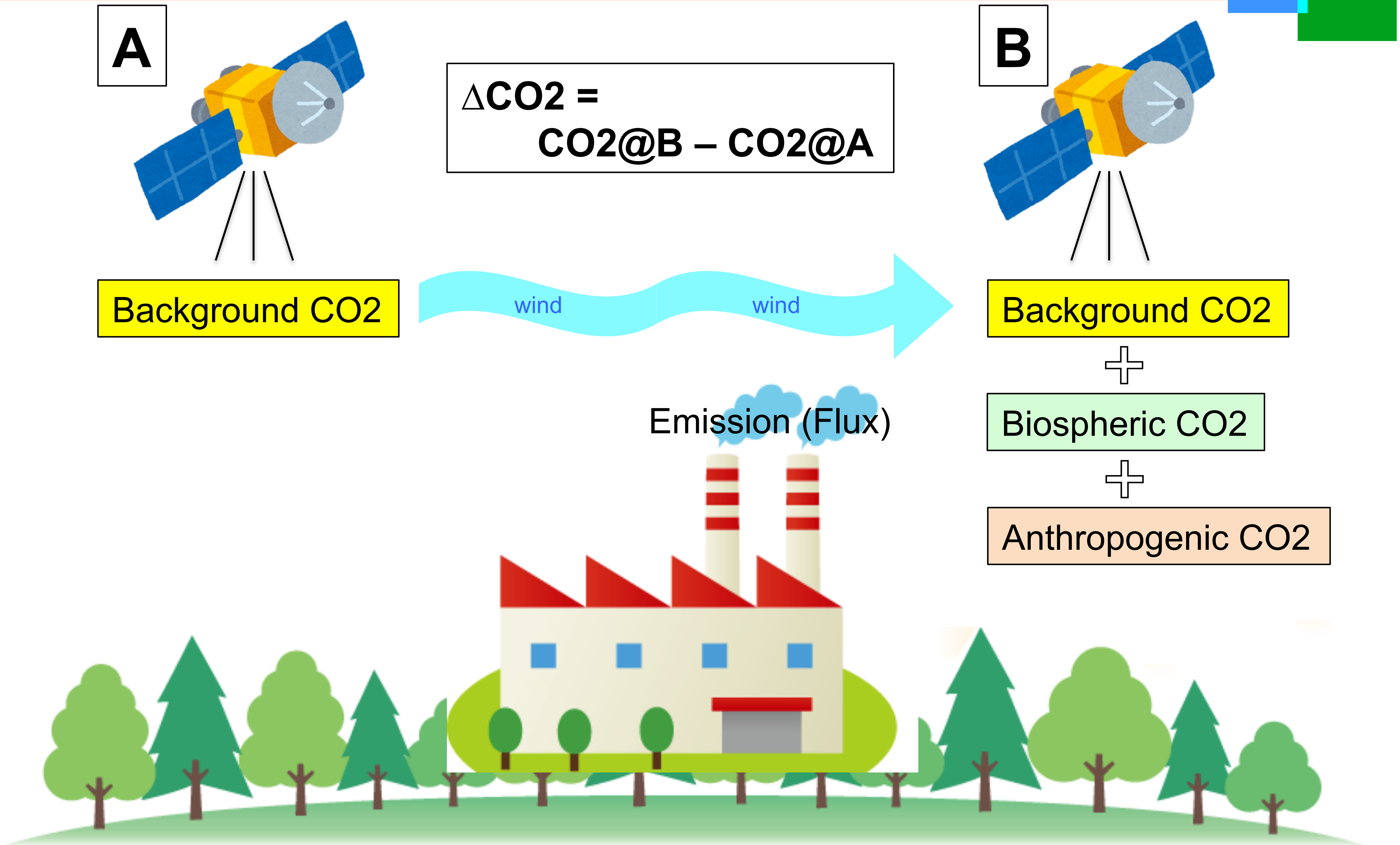
Flux-based method :
CONUS Methane Emission Comparison



Turner et al. (2016)

Concentration-based Method : GHG Concentration Increase from Background

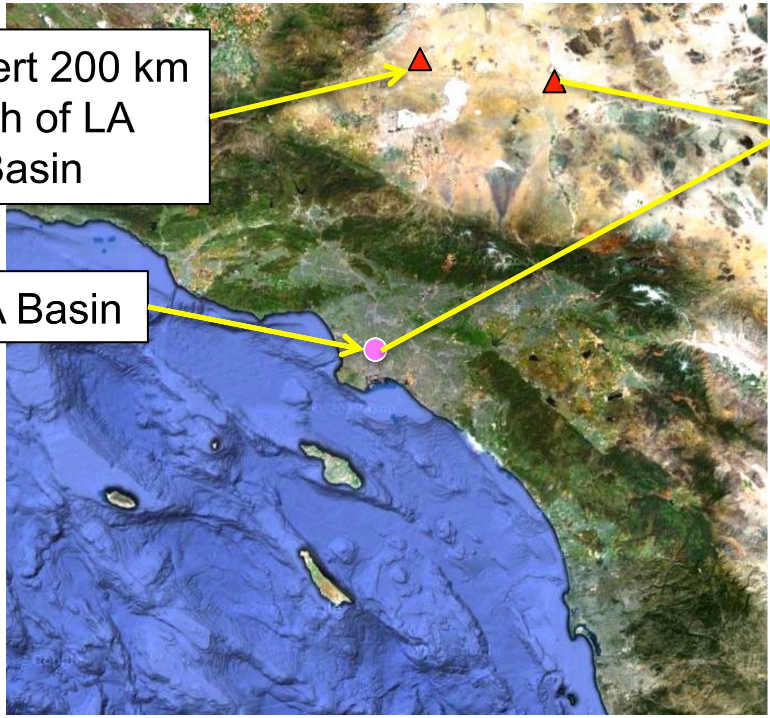
ΔCO_2 =
CO2@B – CO2@A

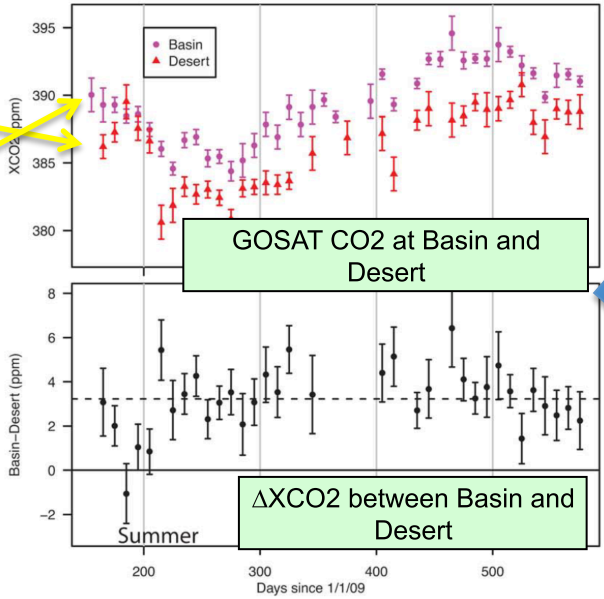


Concentration-based method
GOSAT Ovservation of Megacity CO2

▲Desert 200 km north of LA Basin

●LA Basin





GOSAT Data from June 2009 to August 2010

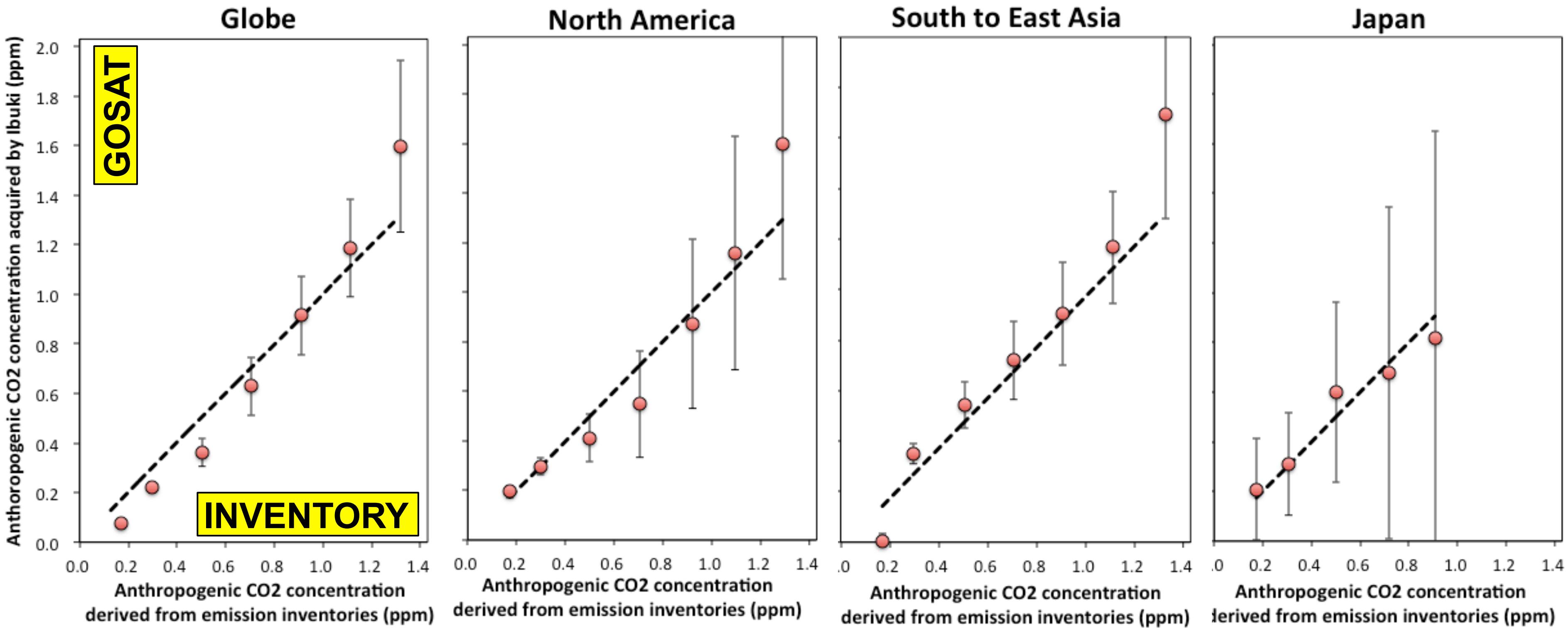
XCO2 in LA Basin was **3.2 ± 1.5 ppm** higher than Desert.

ΔXCO2 suggested from GHG inventory is about **3.8 ppm**

- ΔXCO2 differences between Los Angeles Basin and the desert 200 km north were investigated using GOSAT data.
- ΔXCO2 from GOSAT was about 3.2 ± 1.5 ppm and it was consistent to that from GHG emission inventory.
- This result suggests the possibility of verification of urban emission inventories by satellites.

Kort et al., 2012

Concentration-based Method : CO2 Emission Global / Country-scale Comparison



N = 13616	N = 4684	N = 5589	N = 396
Regression Slope	Regression Slope	Regression Slope	Regression Slope
1.08 ± 0.13	**0.99 ± 0.28**	**0.99 ± 0.17**	**0.95± 0.79**

Data = GOSAT (2009 – 2014). Method = Janardanan et al. (2016).

References (Recent peer-reviewed papers)

Flux-based Method

[Europe][SCIAMACHY and GOSAT]
Reuter et al, Satellite-inferred European carbon sink larger than expected, *Atmosperic Chemistry and Physics*, 2014

[Global and contiguous US][GOSAT]
Turner et al., Estimating global and North American methane emissions with high spatial resolution using GOSAT satellite, *Atmosperic Chemistry and Physics*, 2015

Turner et al., A large increase in U.S. methane emissions over the past decade inferred from satellite data and surface observations, Geophysical Research Letters, 2016

Concentration-based Method

[Los Angeles and Mumbai][GOSAT]
Kort et al., Space-based observations of megacity carbon dioxide, *Geophysical Research Letters*, 2012

[Global, Asia, and North America][GOSAT]
Janardanan et al., Comparing GOSAT observations of localized CO2 enhancements by large emitters with inventory-based estimates, *Geophysical Research Letters*, 2016.

[North America, Europe, and Asia][OCO-2]
Hakkarainen et al., Direct space-based observations of anthropogenic CO2 emission areas from OCO-2, *Geophysical Research Letters*, 2016

Way Forward
(A. Takemoto, MOE, Japan)

- GOSAT-2 will be launched in 2018
  - ✓ Data acquisition with higher resolution
- Will develop methodology to estimate anthropogenic GHG emissions and removals with satellites
- Will input to IPCC GHG Inventory Guidelines to enable all countries utilize GOSAT data for **validating national reports on GHG emissions**
  - ✓ Work for refinement of IPCC GHG inventory guidelines will be completed in 2019.
- Will promote training practitioners engaged in GHG inventories and accounting in developing countries with the guidebook.
- Will collaborate with other countries for monitoring GHG emissions

http://www.oecc.or.jp/cop22-jp/common/pdf/event/14/02_presentation2.pdf

Side Event at Japan Pavilion, UNFCCC COP22

Efforts to Use Satellite Data in IPCC Guidelines for National GHG Inventories

JAPAN PAVILION
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Event | Photos | Acces

Home > Event > Mon 14 November 13:00–14:30

Mon 14 November 13:00–14:30

Title	**Efforts to Use Satellite Data in IPCC Guidelines for National GHG Inventories**
Contents	Each country submitted targets to reduce GHG emissions to COP21. The Paris Agreement 2015 requires these countries to take action to address targets and report emissions. The IPCC Guidelines for National GHG Inventories to estimate emissions will be revised in 2019. This event is to report and discuss on the usefulness of satellite GHG data and its utilization methods in order to add descriptions on verification of the use of satellite data into revisions of the guidelines.
Organiser / Co-organiser	**Japan Aerospace Exploration Agency (JAXA) / Ministry of the Environment, Japan / National Institute for Environmental Studies (NIES)**

Programme

1. **Showing Video**
2. **Key Note Speech: Japanese Efforts to Paris Agreement**
   Dr. Takemoto, Director, Research and Information Office, Ministry of the Environment
3. **Theme#1 Current Status and Issues of GHG Inventory**
   Current Status of IPCC Guideline and Issues of GHG Inventory
   Dr. Kiyoto Tanabe, Co-chair, IPCC/ Task Force on National Greenhouse Gas Inventories (TFI)
   Expectations for Satellite Observation Data to Contribute to GHG Inventory
   Dr. Simon Eggleston, GCOS Terrestrial Observations, Global Climate Observing System
4. **Theme#2 How to use satellite GHG concentration data for verification of GHG emission inventories**
   Dr. Tsuneo Matsunaga, Director, Satellite Observation Center, National Institute for Environmental Studies
5. **Theme#3 Current Status of GHG Observation by Satellites and Future Plans**
   Dr. Kei Shiomi – Earth Observation Research Center, JAXA
   Dr. Lesley Ott – Global Modeling and Assimilation Office, NASA/Goddard Space Flight Center
   Dr. Pascale ULTRE-GUERARD – Head of Earth Observation Programme, CNES
6. **Questions and Answers**

Thank you for your attention