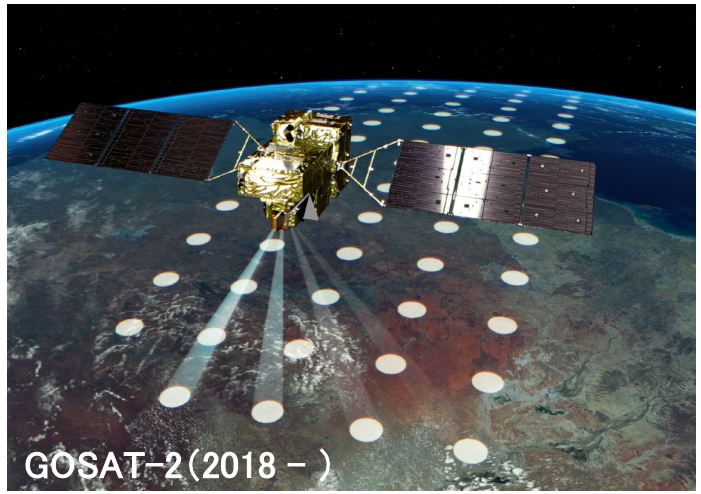
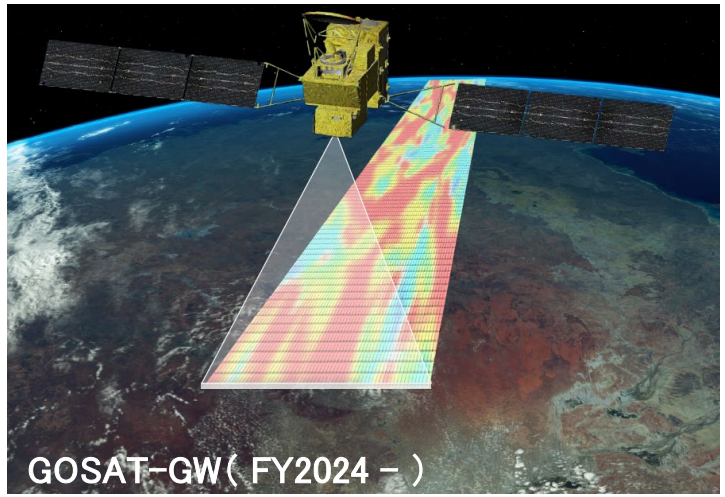
GOSAT-GW Observation of GHGs and Air Pollutants





Greenhouse gases GOSAT PROJECT Observing SATellite

GOSAT-2 PROJECT AT THE NATIONAL INSTITUTE FOR ENVIRONMENTAL STUDIES

GOSAT-GW NIES Project

Tsuneo Matsunaga
Satellite Observation Center (SOC)
National Institute for Environmental Studies (NIES), Japan

History of GOSAT Series and Earth Observation Satellite Projects at NIES

00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19

• ADEOS-2 (2002)

• **GOSAT (2009-)**

• **GOSAT-2 (2018-)**

• NIES GOSAT Research Team (2004-)

• NIES GOSAT Project Office (2006-)

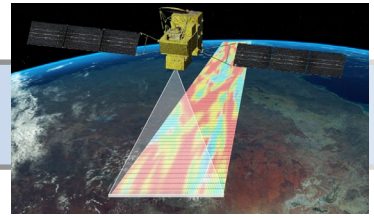
• NIES GOSAT-2 Project (2013-)

• NIES Satellite Observation Center (2016-)

• **Kyoto Protocol (1997)**

• **Paris Agreement (2015)**

20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39



• **GOSAT-GW (2024 -)**

• NIES GOSAT-GW Project (2021-)

• **1st Global Stocktake (2023)**

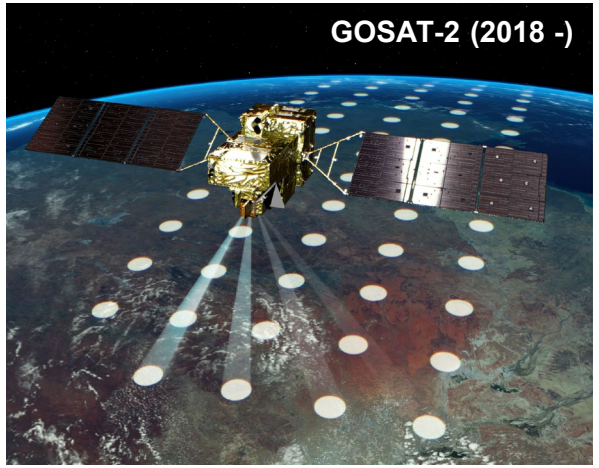
• **GST-2 (2028)**

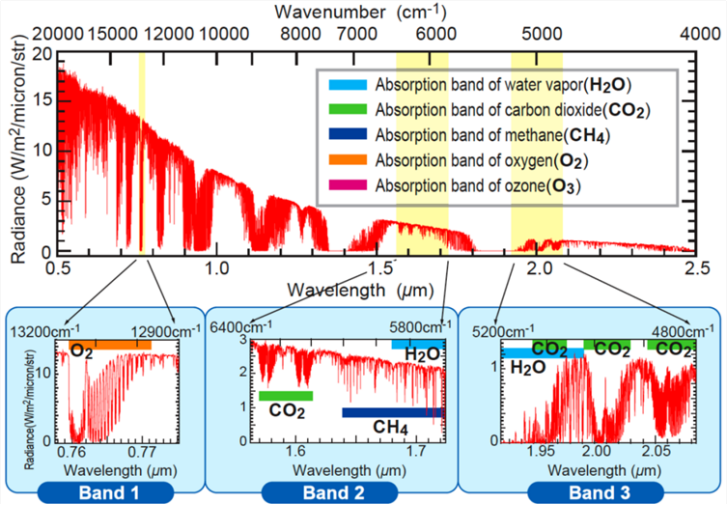
G4?

Tsuneo Matsunaga (matsunag@nies.go.jp), National Institute for Environmental Studies, Japan

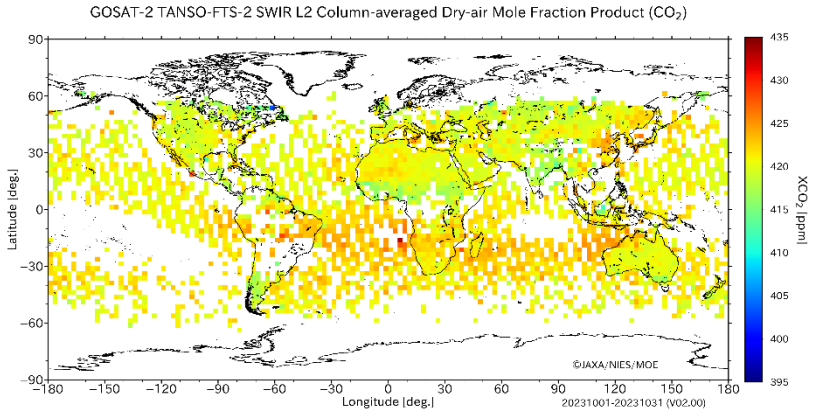
What is GOSAT Series?

- **Japanese earth observation satellite series for measurements of atmospheric concentrations of greenhouse gases**
  - **GOSAT** (2009 -)
    FTS for CO_2 and methane (CH_4)
  - **GOSAT-2** (2018 -)
    FTS for CO_2, CH_4, and carbon monoxide (CO)
  - **GOSAT-GW** (FY2024 -)
    Imaging spectrometer for CO_2, CH_4, and nitrogen dioxide (NO_2)

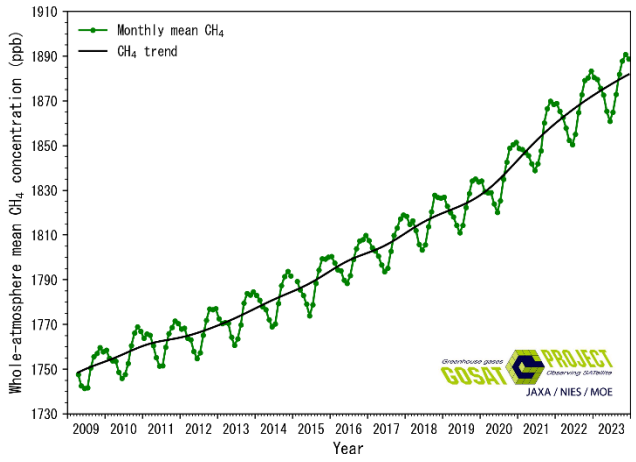




- **Organizations**
  - Joint projects by MOE, NIES, and JAXA
  - NIES is responsible for generation, validation, distribution, and archiving of gas concentration and flux data
  - Science Teams by domestic scientists
  - Collaboration agreements with foreign space agencies
  - Participation of overseas researchers via GOSAT Series RA.



GOSAT-2 FTS-2 SWIR L2 XCO_2 Map of October 2023
(V02.00, Full Physics)



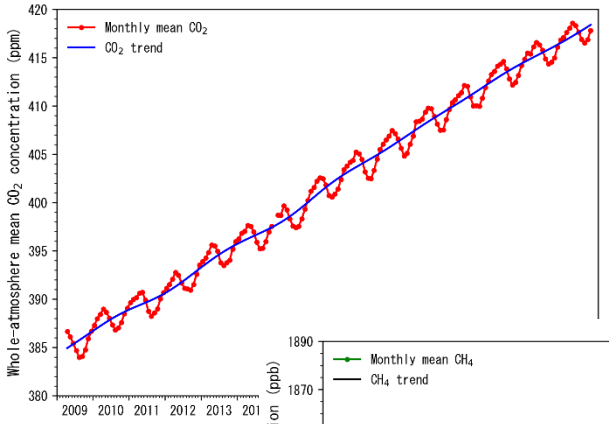
GOSAT Whole-atmosphere Monthly Mean CH_4 Concentration
(April 2009 – December 2023)

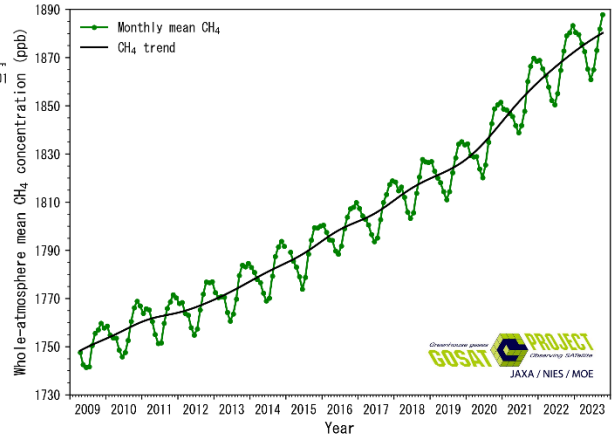
Tsuneo Matsunaga (matsunag@nies.go.jp), National Institute for Environmental Studies, Japan

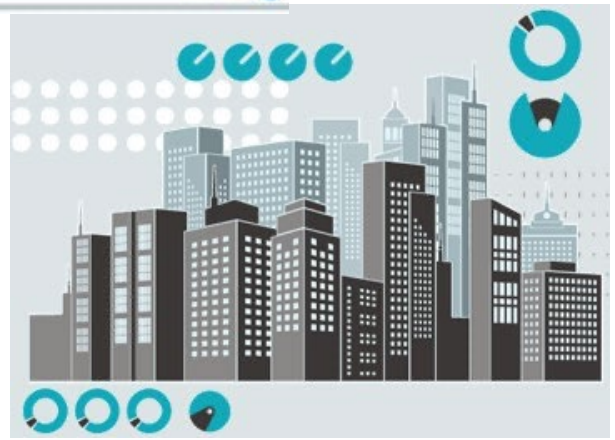
The GOSAT-GW Mission Objectives

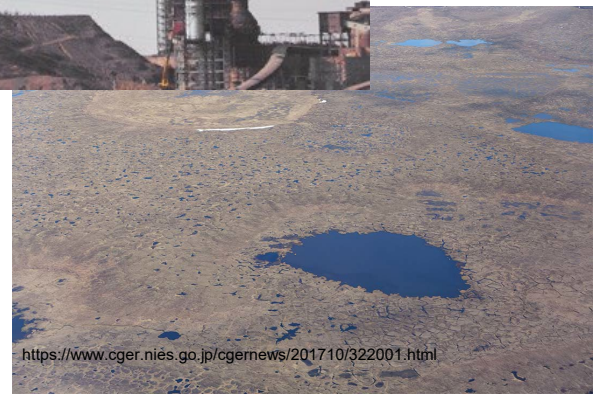
Three mission objectives of TANSO-3 (Total Anthropogenic and Natural emissions mapping SpectrOmeter -3) onboard GOSAT-GW (Global Observing Satellite for Greenhouse gases and Water cycle) are as follows:

1. **Monitoring of the global mean concentrations of GHGs**
2. **Evaluation of national (or country-specific) anthropogenic emission inventory of GHGs**
3. **Detection of large GHG emission sources such as megacities, power plants (>6.5 Mt CO_2/yr), and permafrost**









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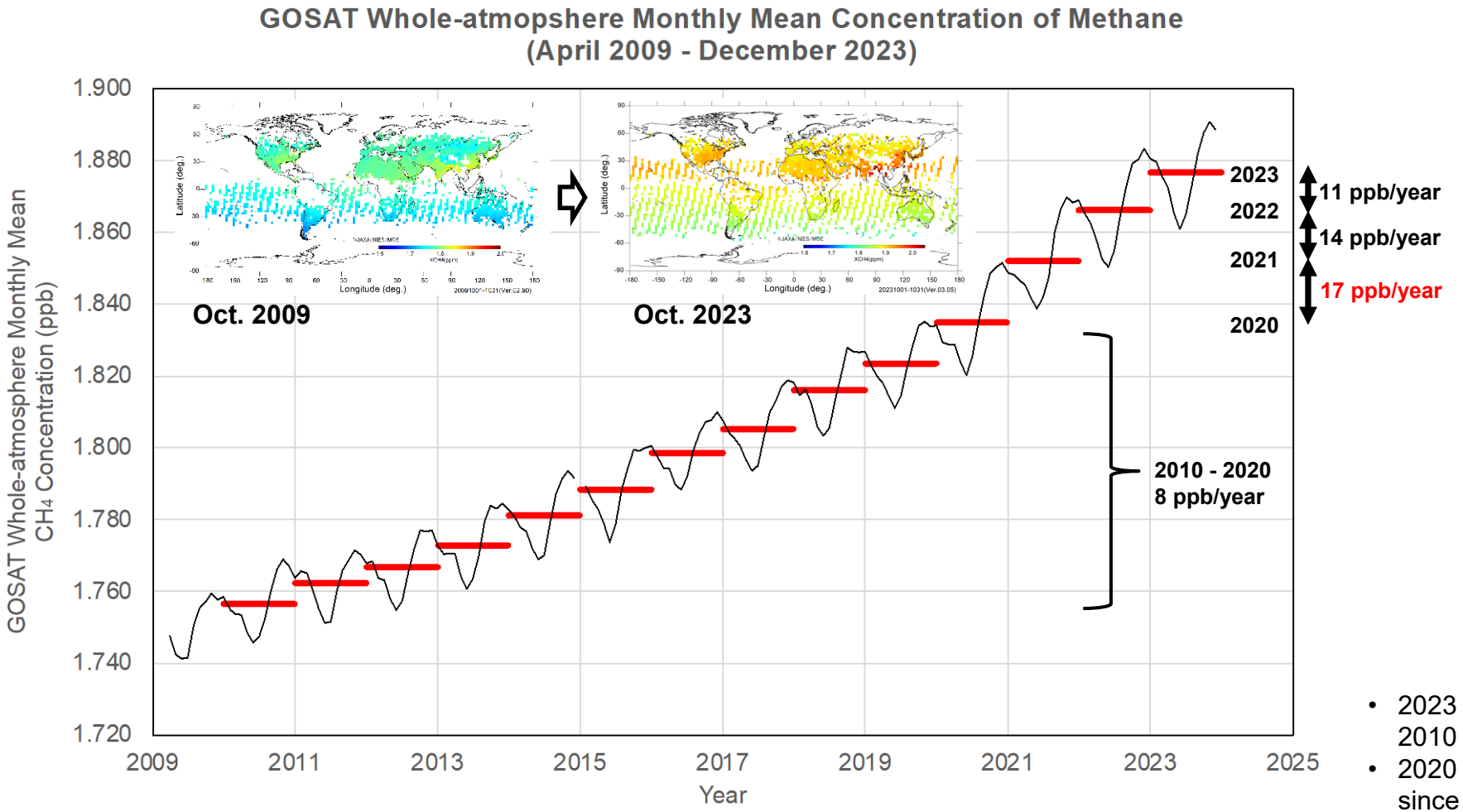
[Update] Recent Increase of GOSAT Whole-atmosphere Methane Concentration



Year	Annual Mean	Annual Increase
2010	1756.4	-
2011	1762.4	6.0
2012	1766.7	4.3
2013	1772.7	6.1
2014	1781.0	8.3
2015	1788.2	7.2
2016	1798.7	10.5
2017	1805.2	6.5
2018	1815.9	10.7
2019	1823.4	7.5
2020	1834.9	11.5
2021	1852.0	**17.1**
2022	1866.0	14.0
2023	**1876.8**	10.8

- 2023 annual average (**1876.8 ppb**) was the highest since 2010
- 2020 -2021 annual increase (**17.1 ppb**) was the highest since 2011. 2022 – 2023 increase was close to normal.
- Several studies reported that the contribution of the emission from the wetland, especially in the tropics, and OH- decrease due to COVID-19 was significant.

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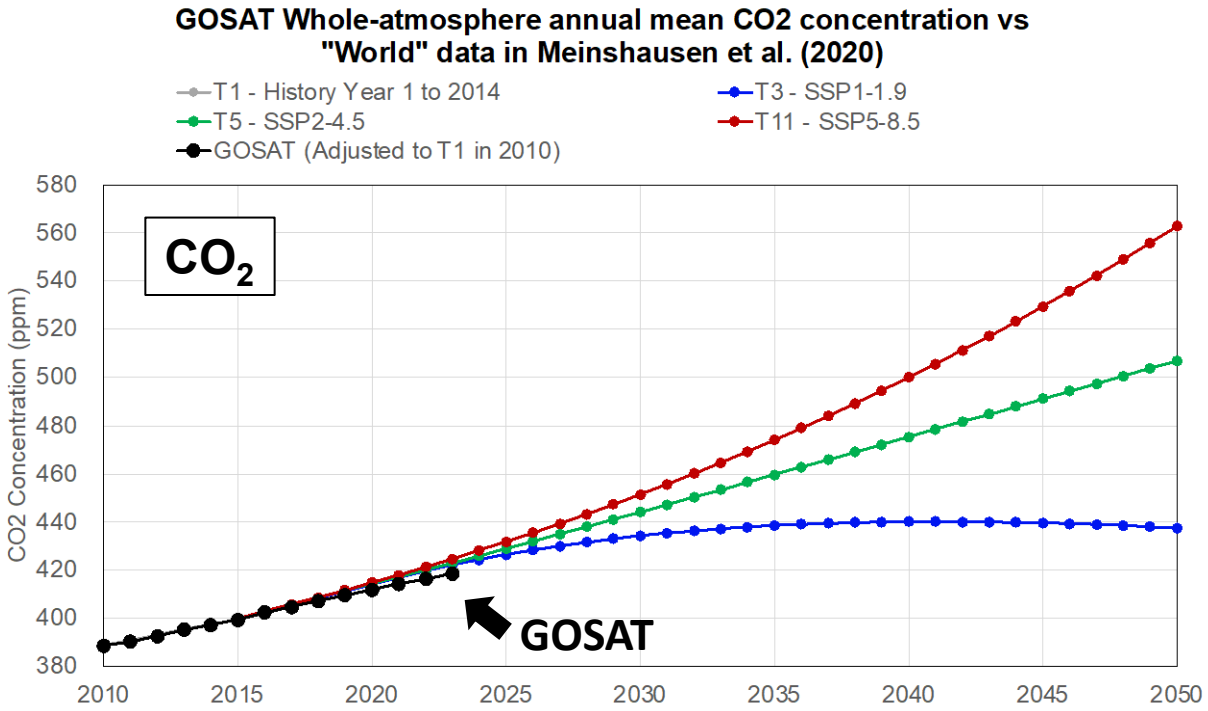
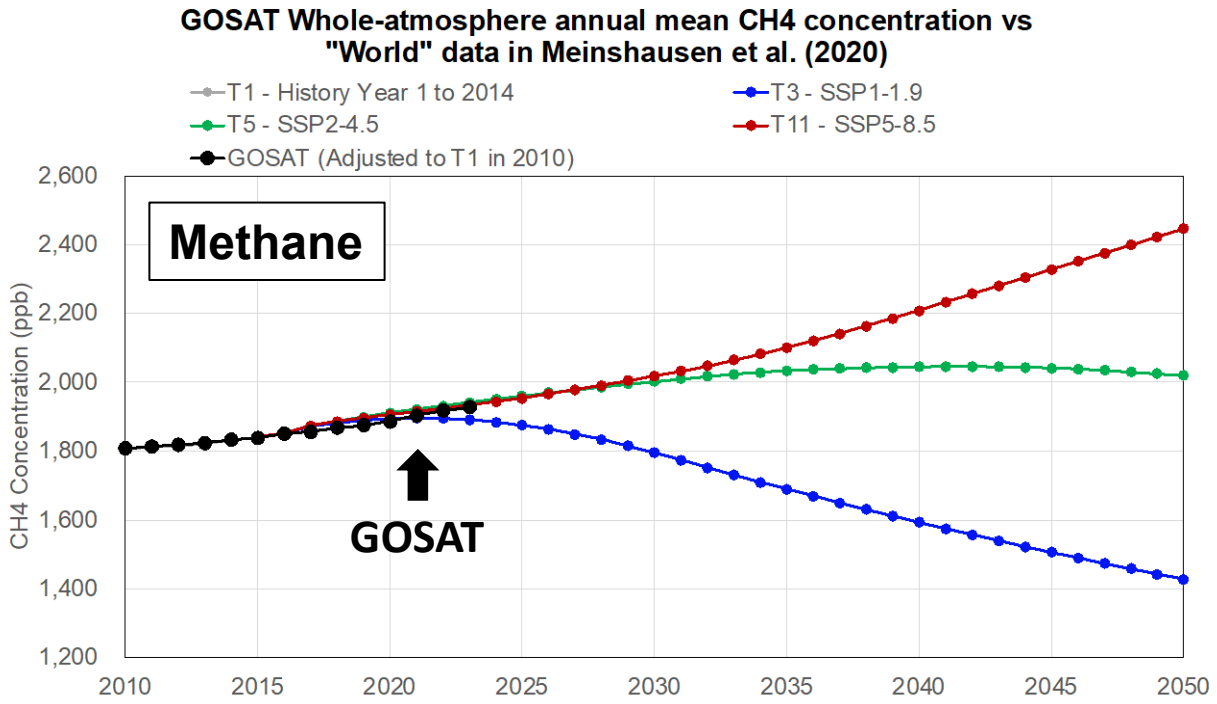
[Update] Global CO_2 and CH_4 Concentrations by GOSAT (2010 – 2023) and from Shared Socioeconomic Pathways (SSPs, 2010 - 2050)





Scenario	Near term, 2021–2040		Mid-term, 2041–2060		Long term, 2081–2100	
	Best estimate	Very likely range	Best estimate	Very likely range	Best estimate	Very likely range
SSP1-1.9	1.5 degC	1.2 to 1.7 degC	1.6 degC	1.2 to 2.0 degC	1.4 degC	1.0 to 1.8 degC
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

GOSAT whole-atmosphere annual mean CO_2 and CH_4 concentrations can be indicators of global climate change mitigation efforts.
GOSAT-GW will extend this dataset to 2030s.

https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

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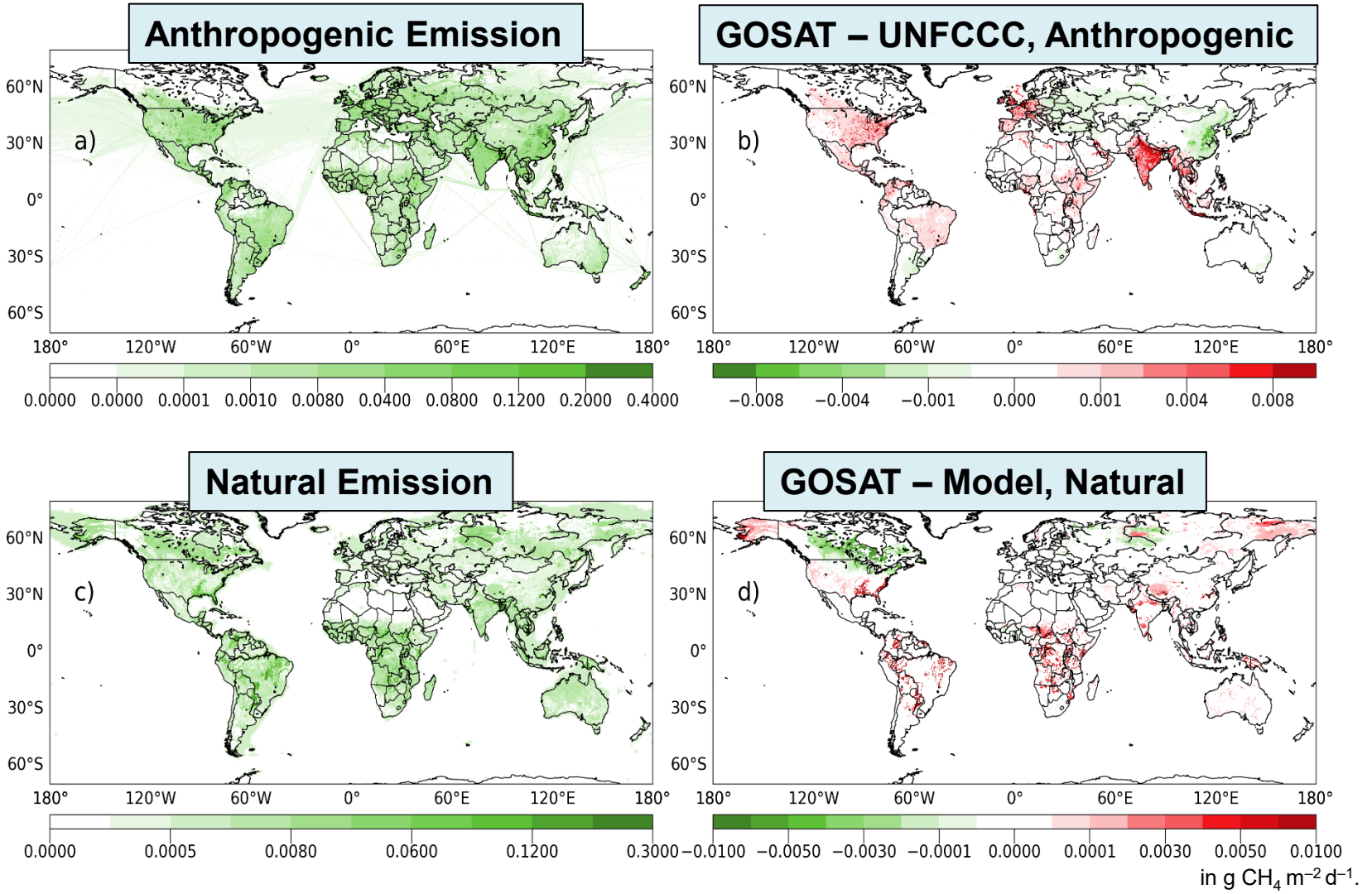
Country-Scale Analysis of Methane Emissions (2011 - 2017) with a High-Resolution Inverse Model Using GOSAT and Surface Observations (Janardanan et al., 2020)



Country	Total prior	Total posterior	Natural prior	Natural posterior	Anthropogenic Prior (Inventory)	Anthropogenic posterior
CHN	60.1	52.0	5.8	6.3	**54.3**	**45.7**
USA	51.6	55.7	23.8	25.9	27.8	29.8
RUS	47.8	45.2	13.6	13.2	34.2	31.9
BRA	45.6	56.2	**29.2**	**39.8**	16.4	16.5
IND	29.9	36.5	9.9	12.3	**20.1**	**24.2**
Global	552	573	209	233	343	341

in Tg CH_4 y^{-1}

- Inverse Model
  = NIES-TM-FLEXPART-VAR(NTFVAR), biweekly time step, 0.1 deg resolution
- Flux estimation error ≈ ±10 – 20 %

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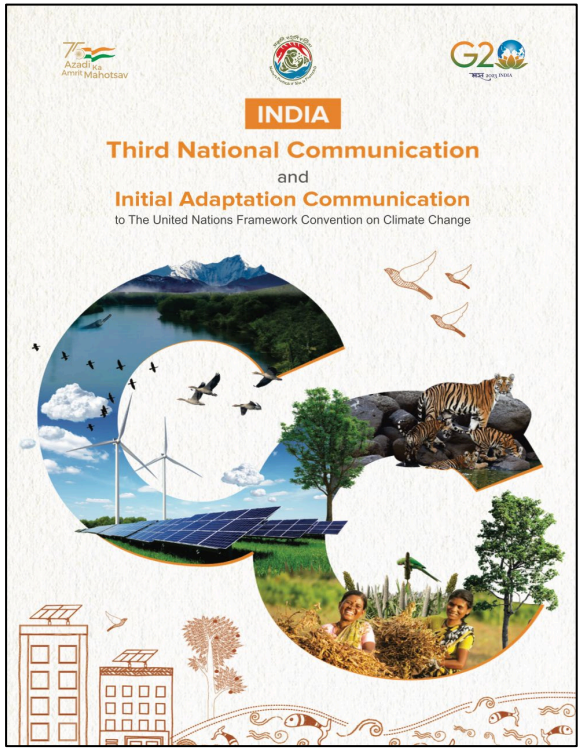
India's Third National Communication (NC3) submitted to UNFCCC (Nov. 2023)

https://unfccc.int/documents/636235

5.11 Estimation of CH_4 Fluxes During 2011-2017 Using Top-down Modeling and Observations



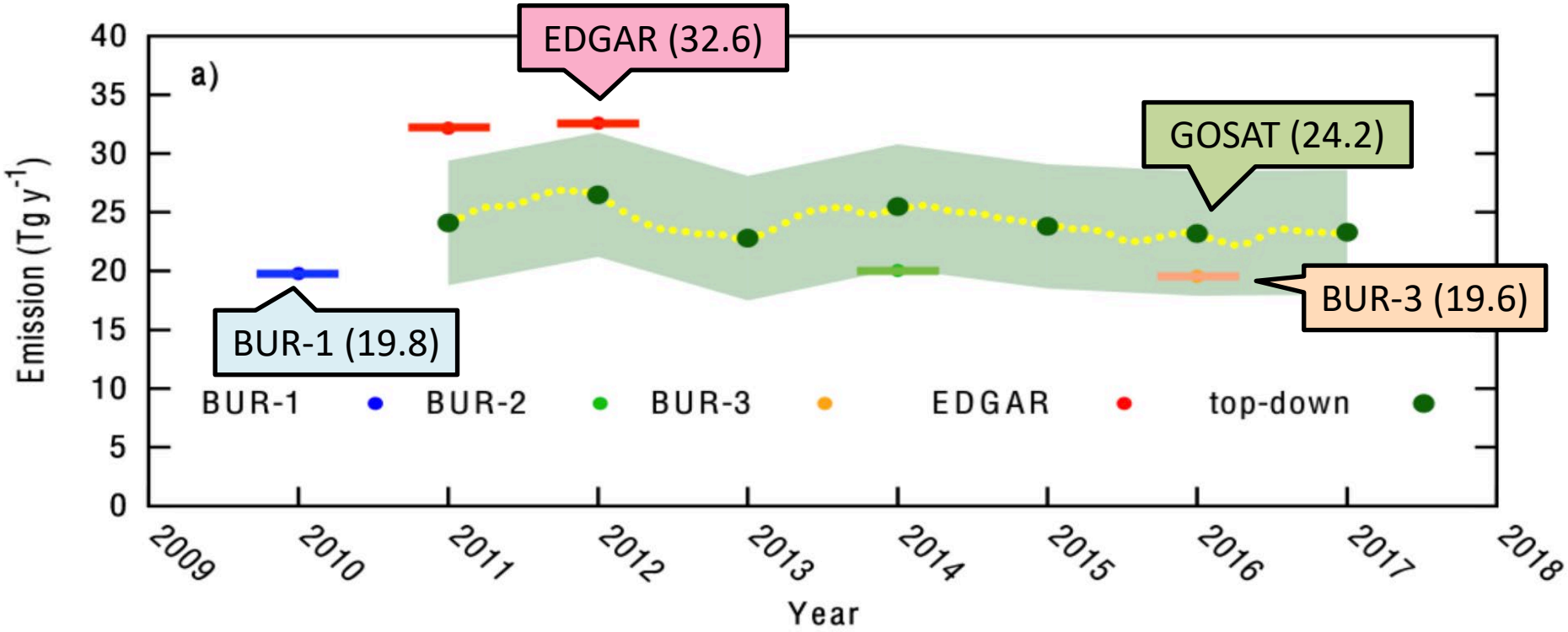


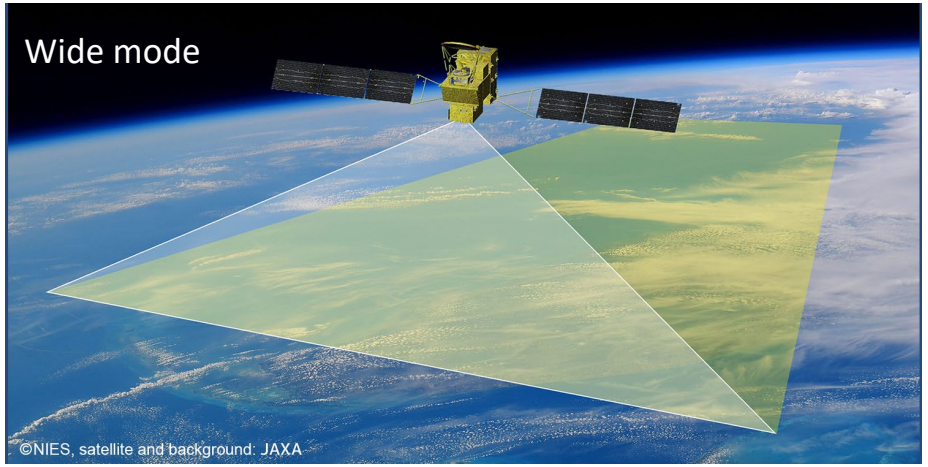
Figure 5.17: The average anthropogenic methane emission (2011-2017) for India (top-down) along with the emissions reported in 1st Biennial Update Report (BUR-1), BUR-2, BUR-3, and EDGAR.

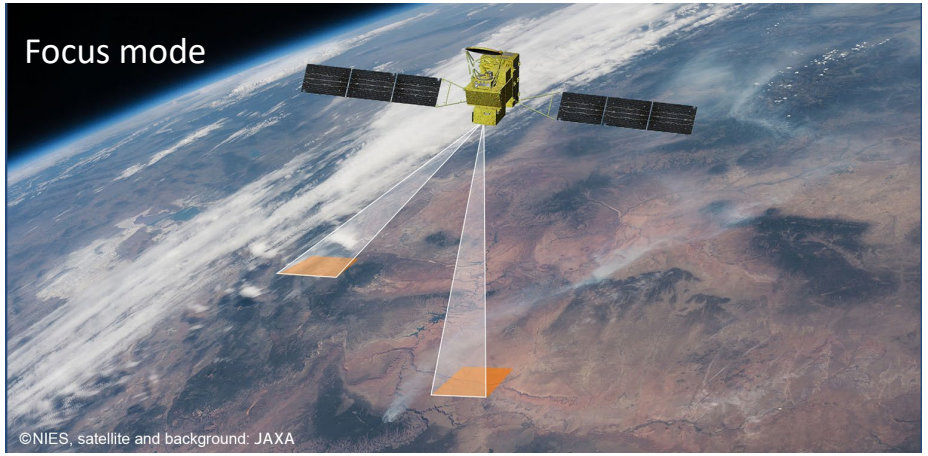
"A top-down modeling study (inversion) is being carried out for the estimation of country-wise methane (CH4) fluxes during 2011– 2017 (Janardanan et al., 2020). It uses **GOSAT** satellite and …"

GOSAT-GW data will be used in the inverse analysis of GHG emission and evaluation of national inventories.

Specification of GOSAT-GW

Launch/lifetime		FY2024/7 years
Orbit		666 km, ascending
Revisit cycle/observation time		3 days/13:30 LT
Spectrometer		TANSO-3
Targets		CO_2, CH_4, NO_2
Spectral bands		0.45, 0.7, 1.6 μm
Sampling intervals		< 0.5 nm@0.45 μm < 0.05 nm@0.7μm < 0.2 nm@1.6 μm
Observation modes		Wide, Focus
Swath	Wide mode	911 km
	Focus mode	90 km
Pixel size at nadir	Wide mode	10x10 km^2
	Focus mode	1x1 – 3x3 km^2
Pointing (Focus mode)		±40° / ±34.4° (AT/CT)
The other instrument onboard		AMSR3





GOSAT-GW: Wide Mode and Focus Mode

GOSAT
GOSAT-2

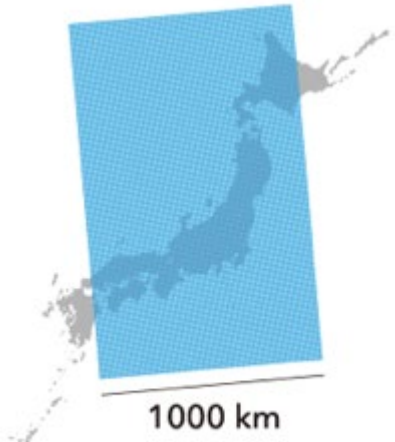
OCO-2

GOSAT-GW

Japan

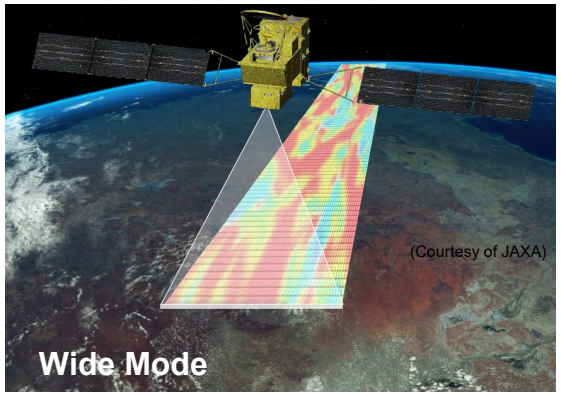
One data in 150 x 150 km

Swath ≈ 10 km



Wide Mode

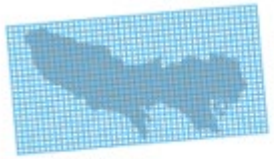
- Swath ≈ 911 km
- Footprint ≈ 10 km
- No AT/CT Pointing
- Default observation



Tokyo

Footprint ≈ ϕ10 km

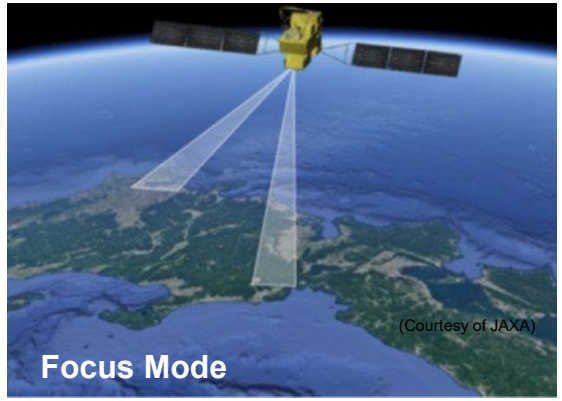
Footprint
≈ 2.3 x 1.3 km



Footprint
≈ 1 - 3 km

Focus Mode

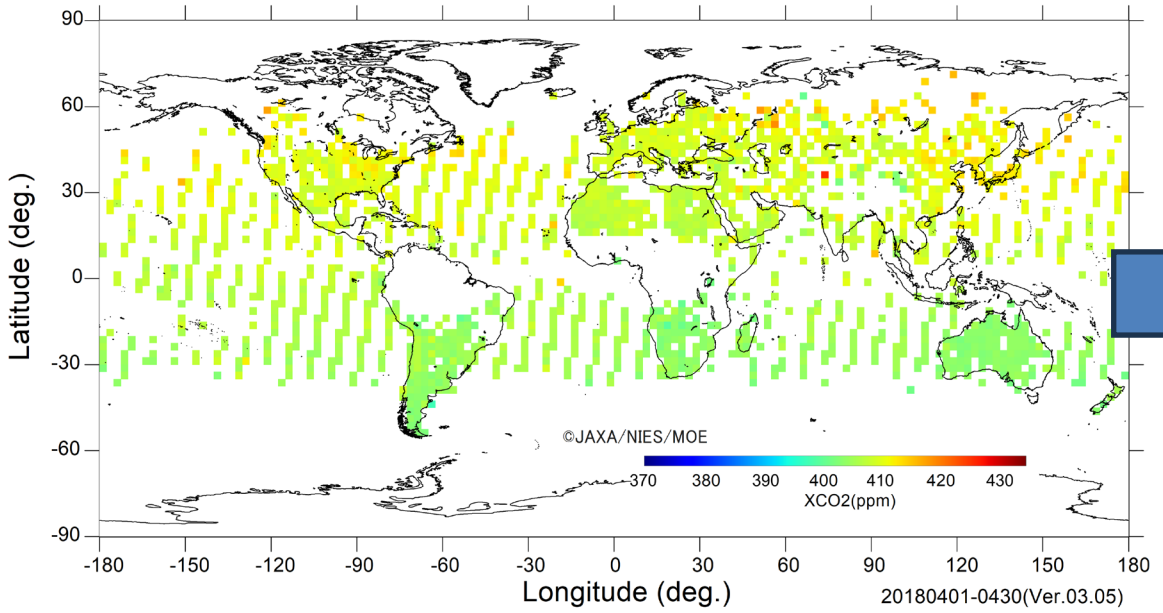
- Swath ≈ 90 km
- Footprint ≈ 1 - 3 km
- AT/CT Pointing
- Upon requests



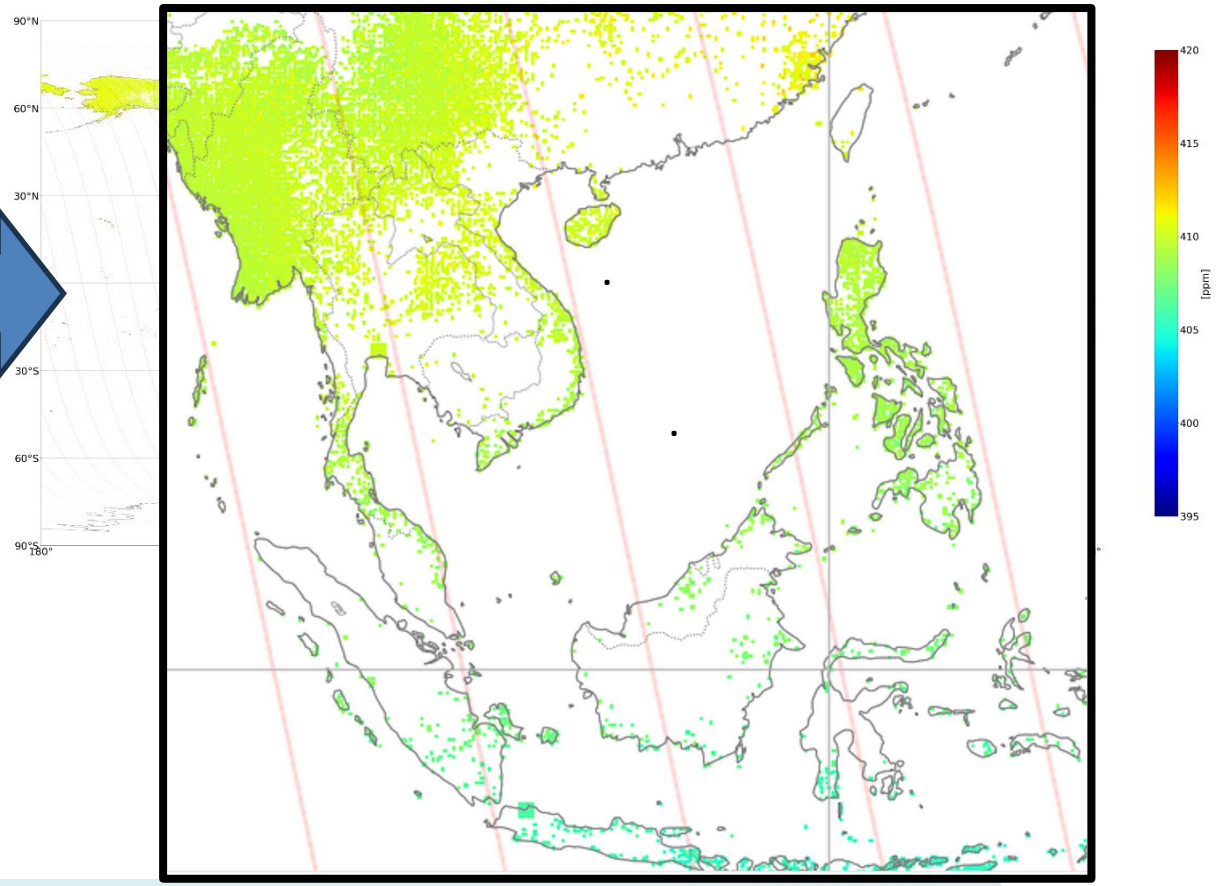
Tsuneo Matsunaga (matsunag@nies.go.jp), National Institute for Environmental Studies, Japan

GOSAT and simulated GOSAT-GW XCO2 Monthly Maps (April, 2018)

GOSAT



GOSAT-GW



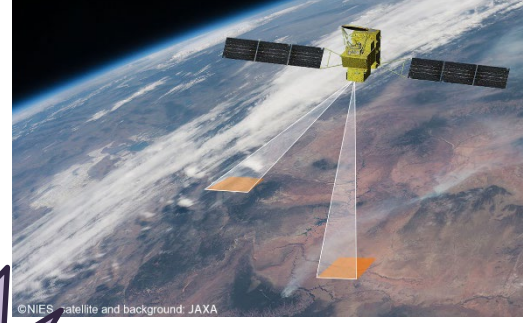
≈ 400 point/day (GOSAT, land + ocean)
≈ 800 point/day (GOSAT-2, land + ocean)

GOSAT-GW will be able to obtain 100-times more data and cover most land surface in much shorter time than GOSAT or GOSAT-2.

Tsuneo Matsunaga (matsunag@nies.go.jp), National Institute for Environmental Studies, Japan

GOSAT-GW to measure NO_2 besides GHGs: identifying large CO_2 combustion sources & elucidating ozone production and OH radical field (superior scientific target)

This slide is provided by
Yugo Kanaya (JAMSTEC, Japan)



1x1km^2 GOSAT-GW demonstrator, greater Tokyo area for instance

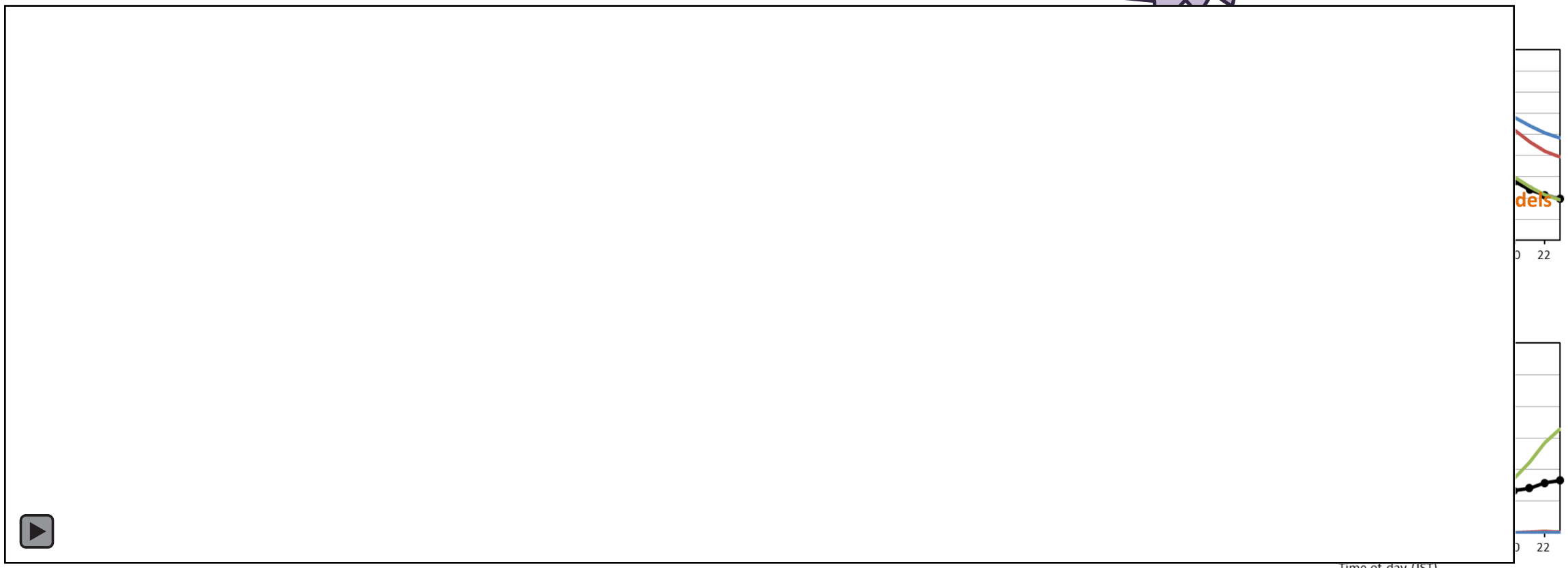
XCO_2

Tropospheric NO_2

Methane, VOCs

**UV light
OH radical
photochemical
reactions**

Tropospheric Ozone

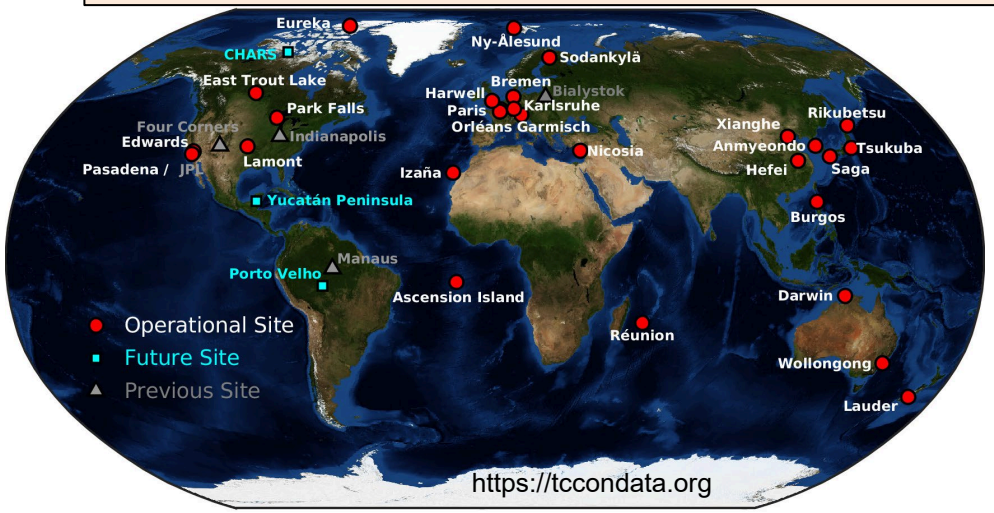


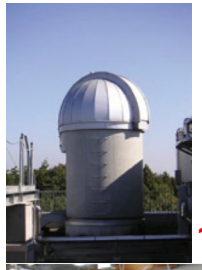
GOSAT-GW demonstrator, before adding sensor noise
WRF-Chem/GHG, M. Takigawa, M. Yamaguchi, J. Bisht, P. Patra, Y. Kanaya (JAMSTEC with ES4)

Akimoto et al., 2019

GOSAT-GW Validation: TCCON, COCCON and PGN

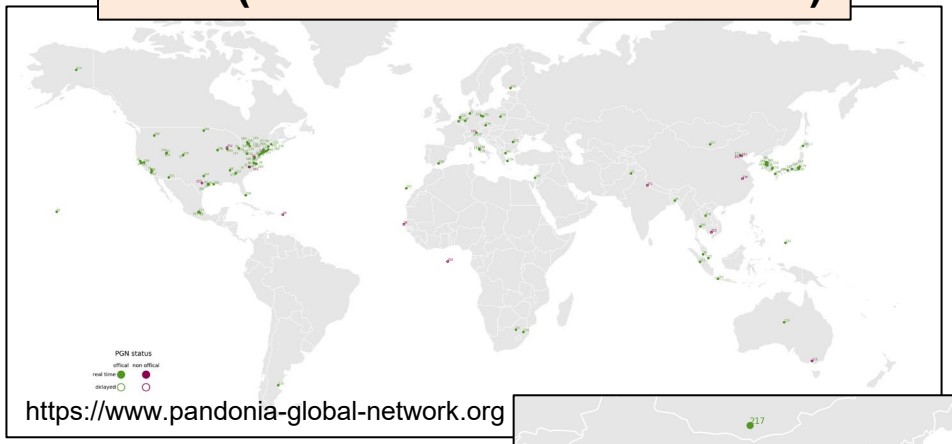
TCCON (Total Carbon Column Observing Network)



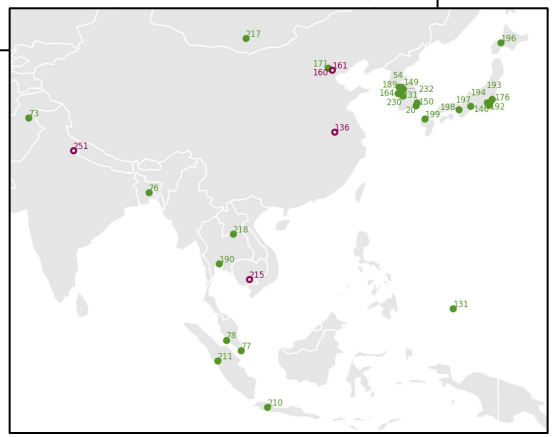


125HR

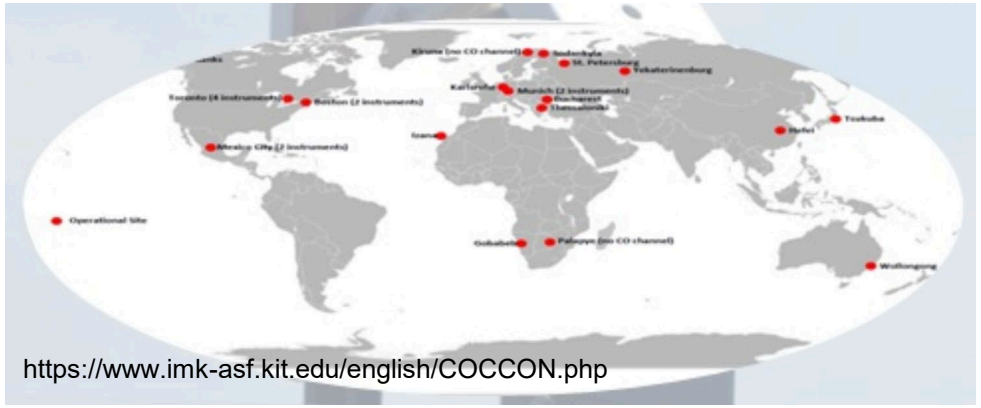
PGN (Pandora Global Network)



Pandora



COCCON (COllaborative Carbon Column Observing Network)



EM27/SUN

CO2, CH4, and NO2 data from GOSAT-GW will be validated using simultaneous ground-based remote sensing data from TCCON and COCCON for CO2 and CH4, and PGN for NO2.

International Meeting on Land Cover/Land Use Change in South/Southeast Asia and Synthesis (Jan. 31 to Feb. 2, 2024, Hanoi, Vietnam)
Tsuneo Matsunaga (matsunag@nies.go.jp), National Institute for Environmental Studies, Japan

Thank you for your attention

Contact
matsunag@nies.go.jp

Website
https://www.nies.go.jp/soc/en/ (Satellite Observation Center)
https://www.gosat.nies.go.jp/en/ (NIES GOSAT Project)
https://www.gosat-2.nies.go.jp (NIES GOSAT-2 Project)
https://gosat-gw.nies.go.jp/en/ (NIES GOSAT-GW Project)

GOSAT and GOSAT-2 standard products are freely available from
GOSAT Data Archive Service (GDAS: L1B, L2, L3, L4)
https://data2.gosat.nies.go.jp
GOSAT-2 Product Archive (L1B, L2, L4)
https://prdct.gosat-2.nies.go.jp/

From 2025 or later, GOSAT-GW TANSO-3 standard products will be freely available from
GOSAT-GW TANSO-3 Product Archive (G3PA: L1B, L2)
(URL: TBD)