Updates on GOSAT and Its Successor, GOSAT-2

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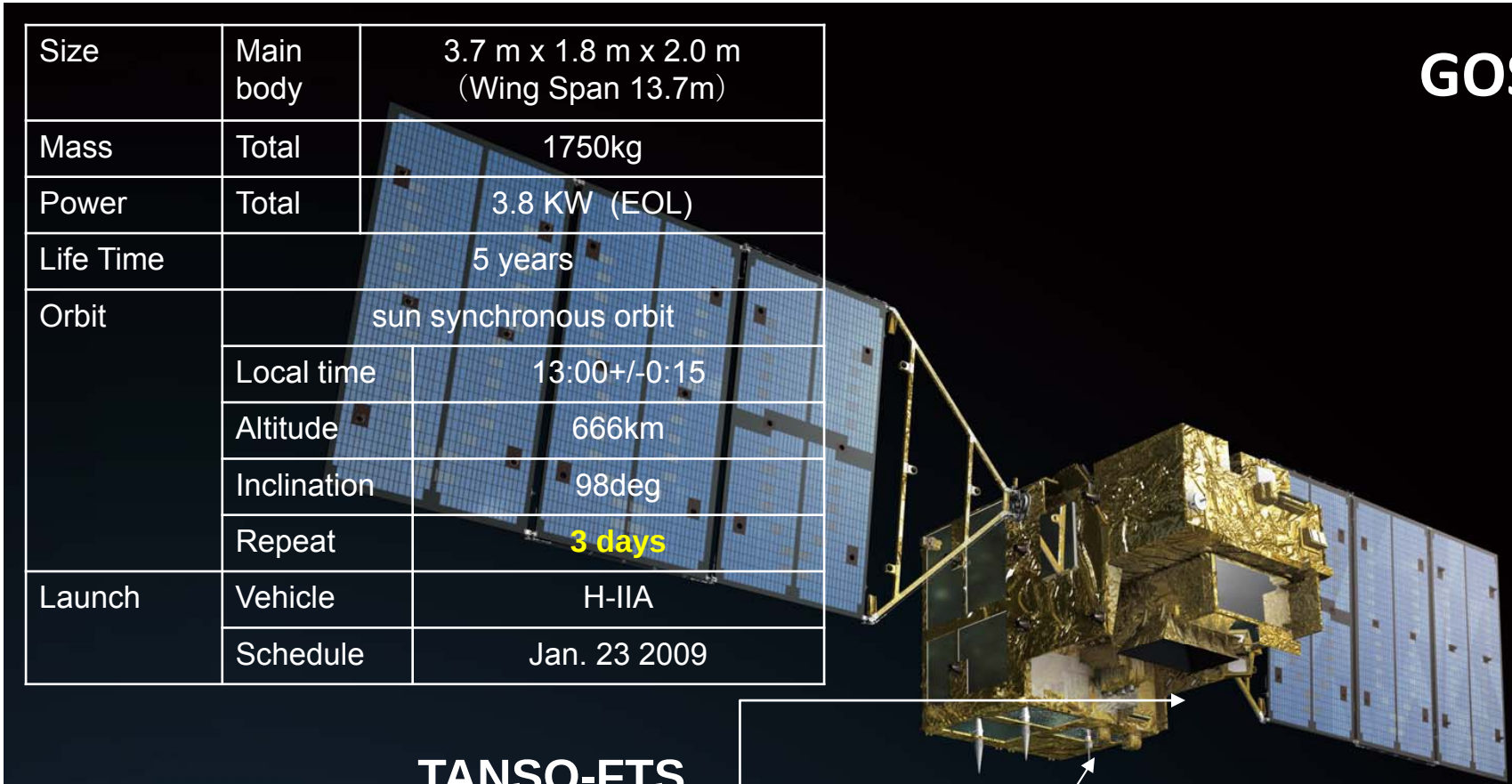
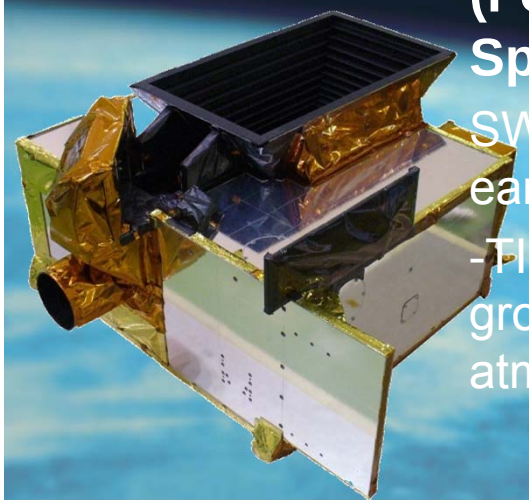
GOSAT

Size	Main body	3.7 m x 1.8 m x 2.0 m (Wing Span 13.7m)
Mass	Total	1750kg
Power	Total	3.8 KW (EOL)
Life Time	5 years	
Orbit	sun synchronous orbit	
	Local time	13:00+/-0:15
	Altitude	666km
	Inclination	98deg
	Repeat	**3 days**
Launch	Vehicle	H-IIA
	Schedule	Jan. 23 2009

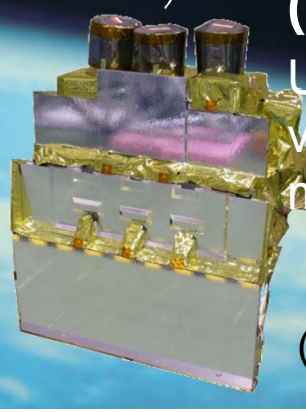




TANSO-FTS (Fourier Transform Spectrometer)

SWIR reflected on the earth's surface

-TIR radiated from the ground and the atmosphere



TANSO-CAI (Cloud and Aerosol Imager)

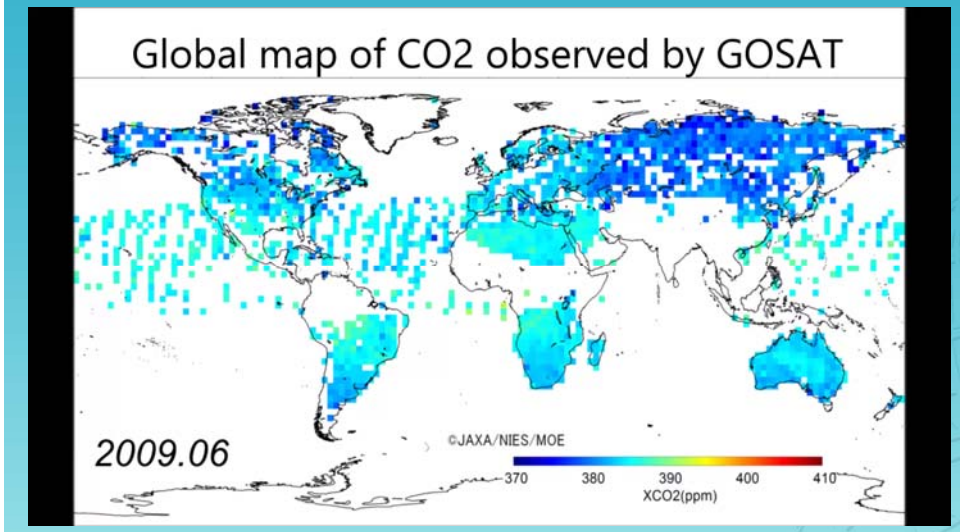
Ultraviolet (UV) (0.38 micron), visible (0.67 micron), NIR (0.87 micron), and SWIR (1.6 micron)

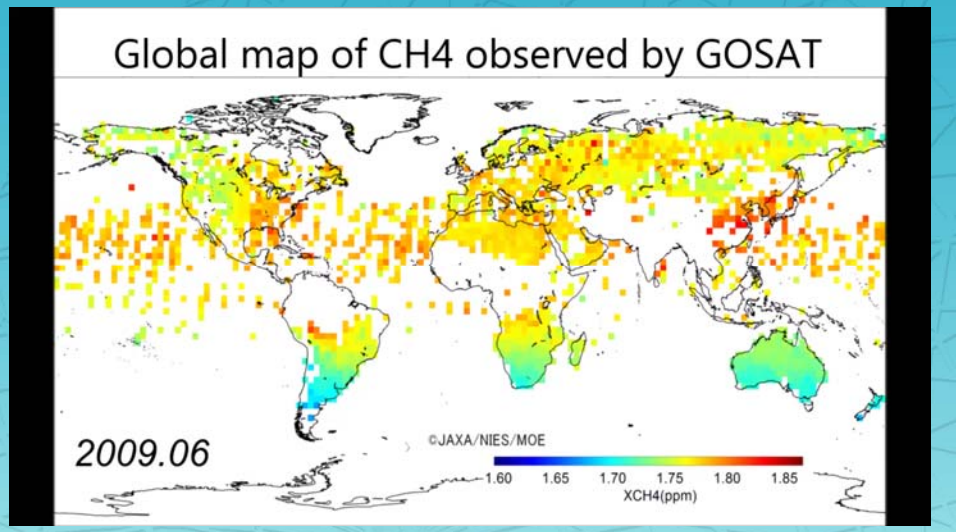
(Courtesy of H. Suto (JAXA))

Updates on GOSAT since June 2013

- GOSAT (Greenhouse Gases Observing Satellite) is a Japanese satellite dedicated to CO2 and CH4 measurement from space, and was launched in January 2009.
- GOSAT completed the nominal operation period of 5 years and started the extended operation in January 2014.
- The new version of GOSAT Level 4A CO2 flux product which covers 29 months from June 2009 – October 2011 were publicly released in March 2014.
  Visit https://data.gosat.nies.go.jp.
- A press release on GOSAT Level 4A CH4 flux product was issued on March 27, 2014. The first public release is scheduled in this summer.
- A critical malfunction of one of two solar paddles of the spacecraft occurred on May 25, 2014. Currently, GOSAT is being operated using one paddle only. This paddle can provide enough power for full operation of GOSAT. FTS is being operated in nadir observation mode (no pointing).

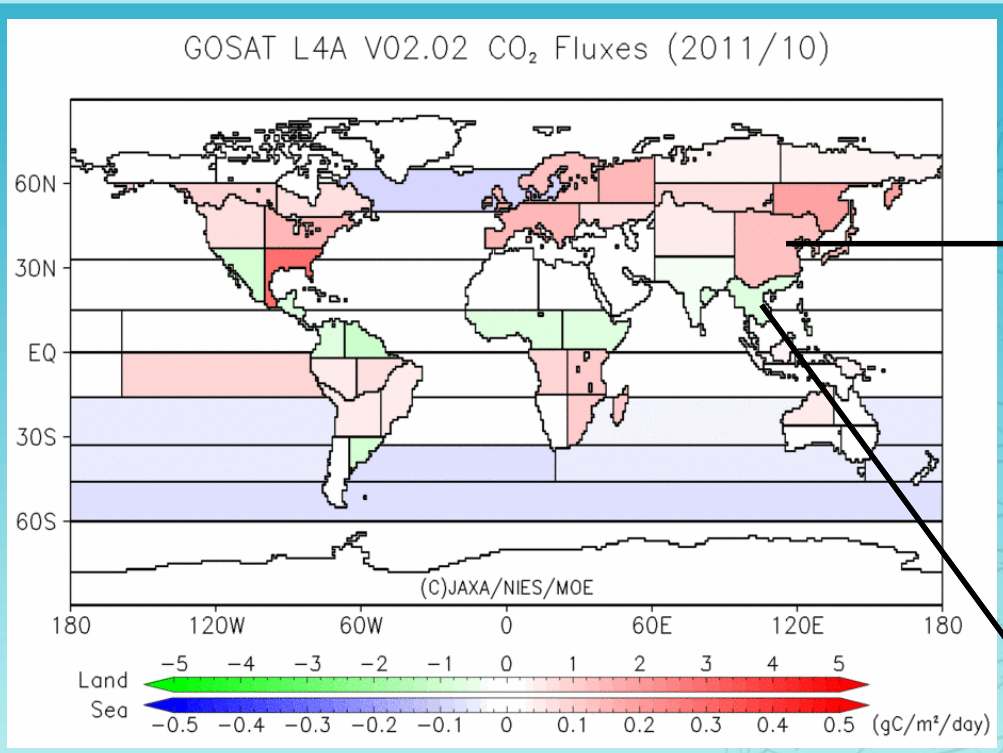
40-month-long GOSAT XCO2 and XCH4 (June 2009 – December 2013)

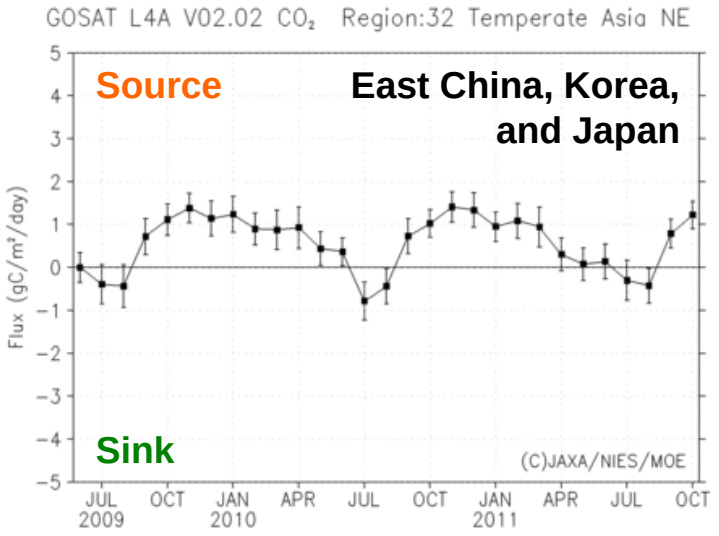


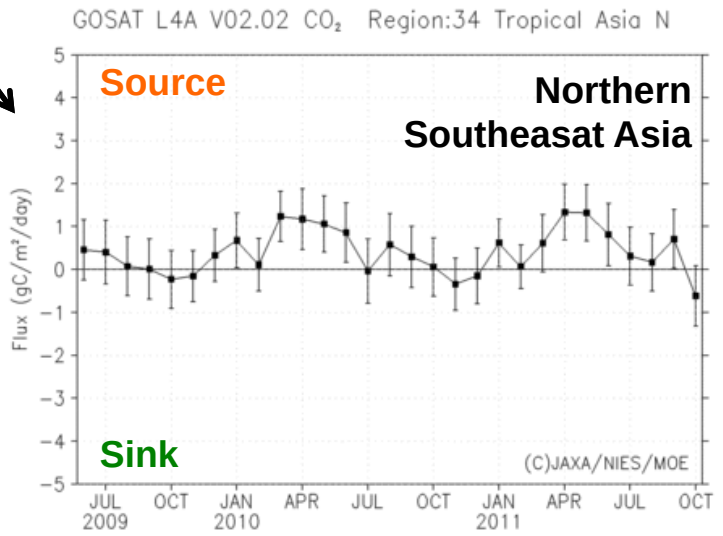


- GOSAT obtained XCO2 and XCH4 data for more than 5 years. Validation results suggest that relative accuracies of XCO2 and XCH4 are ≈ 2 ppm and 12 ppb, respectively.
- Above movies are 1-month-moving average GOSAT XCO2 and XCH4 with three-day interval. The mesh size is 2.5 degree.
- Various interesting features are shown in these movies such as annual and seasonal variations of XCO2 and localized anomalies of XCH4.

29-month-long GOSAT L4A CO2 Flux
(Global 64 regions, June 2009 – October 2011)

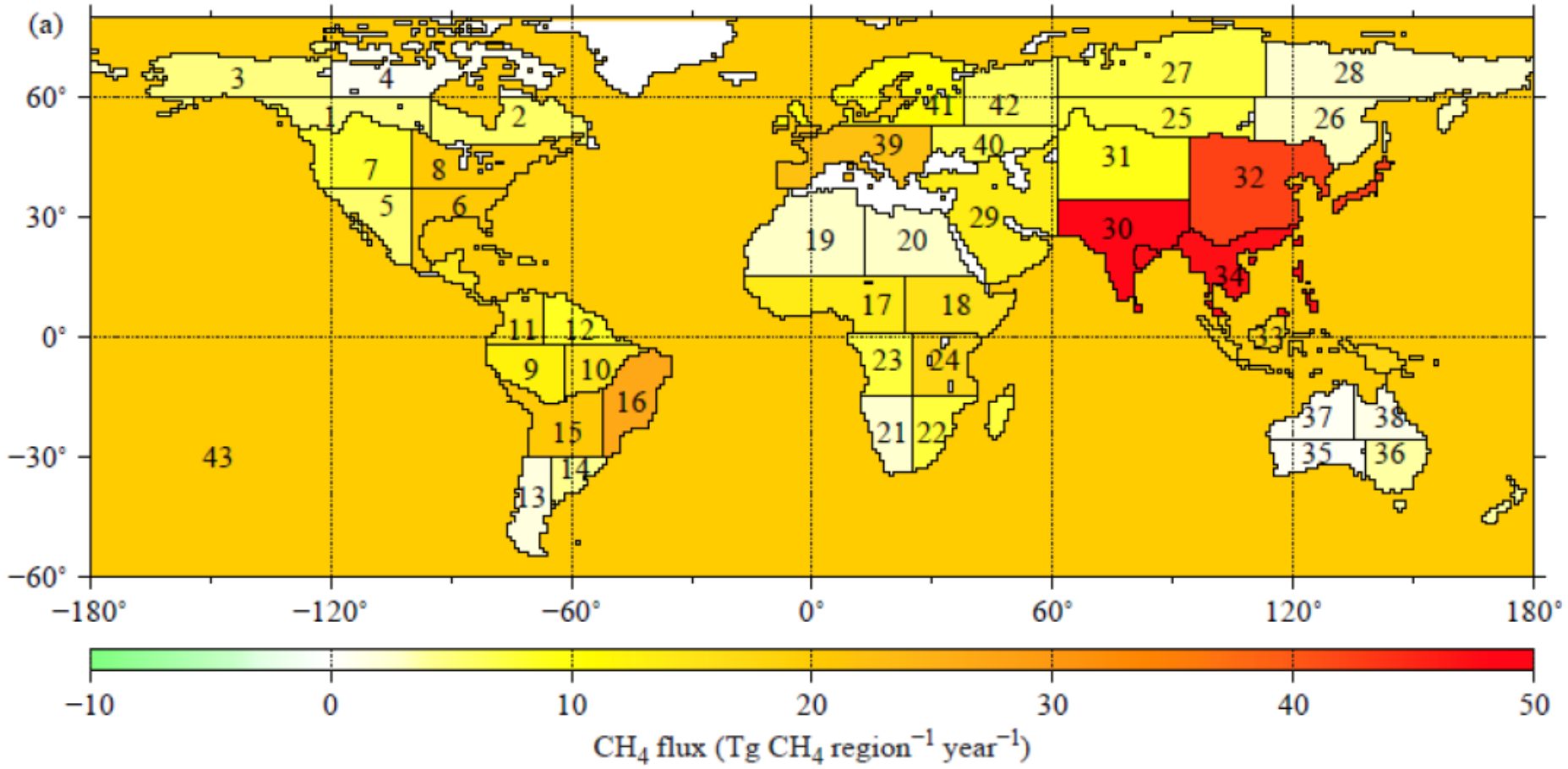






- See Maksyutov et al. (2013) for inversion methodology.
- These data are freely available at https://data.gosat.nies.go.jp
- CO2 flux data for November 2011 – October 2012 will be available by the end of 2014.

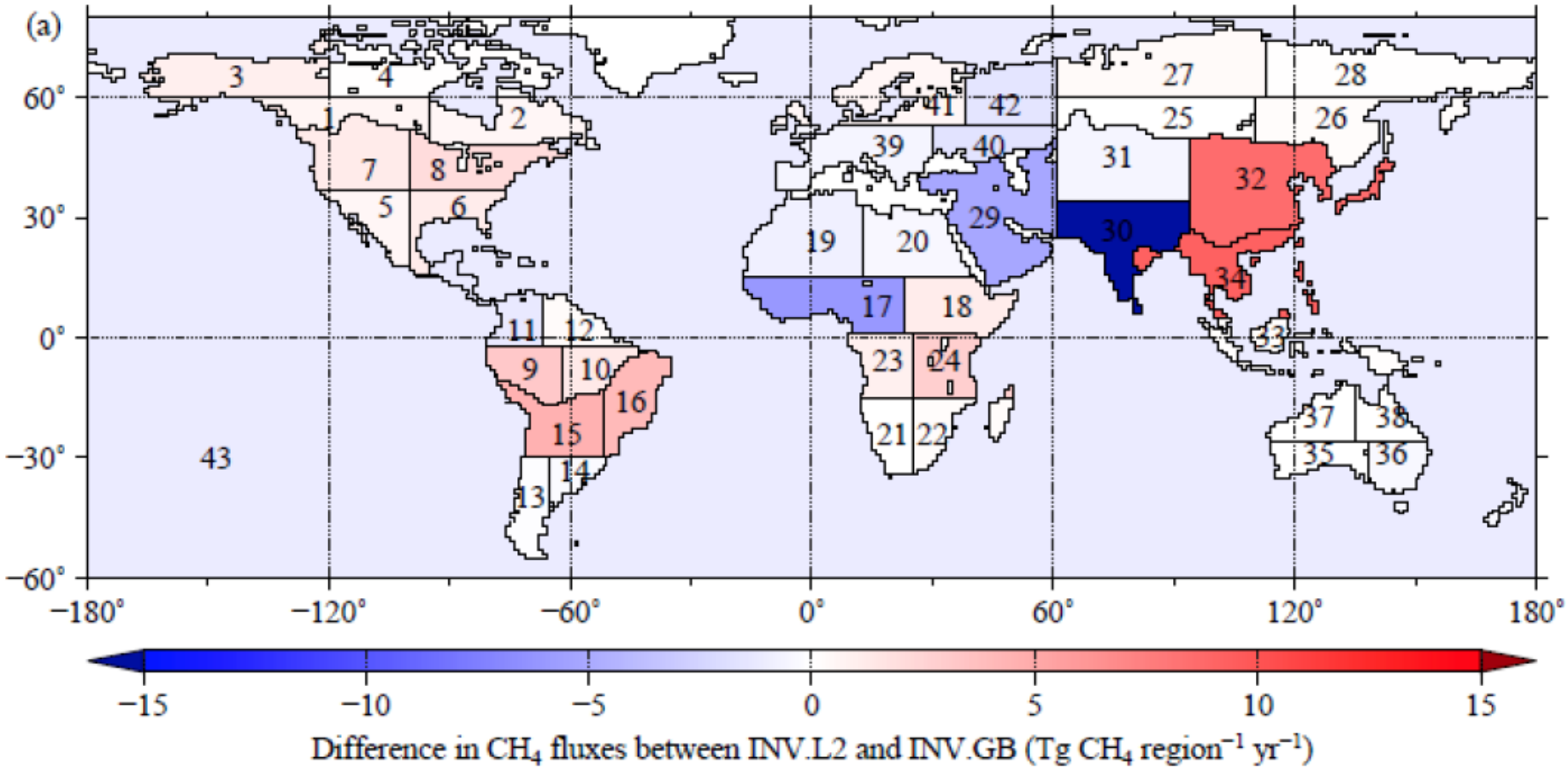
Newly Released GOSAT Global Methane Flux
Annual Net Methane Flux



Global estimates of the monthly net CH4 fluxes were generated for the two years from June 2009 to May 2011, using both GOSAT and ground-based data. This annual methane flux map shows **that CH4 emissions in east, southeast, and south asian regions (Region No. 30, 32, and 34) are significantly higher than other regions**.

http://www.gosat.nies.go.jp/eng/related/2014/201403.htm

Newly Released GOSAT Global Methane Flux
Flux Changes by Adding GOSAT Data in the Inversion



Global estimates of the monthly net CH4 fluxes were generated for the two years from June 2009 to May 2011, using both GOSAT and ground-based data. This annual CH4 flux difference map shows that **GOSAT data increase CH4 flux in east and south east asia and decrease CH4 flux in south asia**. These changes may suggest the importance of homogeneous spatial distribution of gas concentration data for CH4 inversion analysis.


GOSAT-2 CG
GOSAT-2
(c)MELCO

About GOSAT-2

- Based on the success of GOSAT, Ministry of the Environment, JAXA and NIES started the development of GOSAT-2. GOSAT-2 will be launched in FY2017.
- GOSAT-2 will extend spaceborne XCO2 measurement record to 2022. The measurement was first started by ENVISAT SCIAMACHY (2002 – 2012), then followed by GOSAT(2009-), and to be followed by US OCO-2(2014-) and Chinese TanSat (2016-).
- GOSAT-2 will also measure column concentrations of methane, water vapor, and carbon monoxide using FTS-2 instrument.
- Aerosol or atmosphric pollution by particulate matters now becomes one of GOSAT-2 targets.
  - A new imager (CAI-2) which is more suitable for aerosol observation.
  - CAI-2 Level 2 products will include black carbon and/or PM2.5.
- Your ideas on future GOSAT-2 observation of CO, black carbon, and PM2.5 are welcome.

FTS-2 Onboard GOSAT-2

- Fourier transform spectrometer based on CrIS onboard US Suomi/NPP satellite.
- Extended or adjusted spectral coverage for CO retrieval and fluorescence.
- Improved SNR to increase the number of successful gas retrievals with better accuracy.
- Extended along track pointing angles to have more ocean sunglint data
- "Intelligent Pointing" to avoid cloud contamination in the field of view of FTS-2
- Fully programmable (target) observation (19,000 points/day)

	Band 1	Band 2	Band 3	Band 4	Band 5
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	10.5 km				
Pointing	±40 deg (Along track), ±35 deg (Cross track)				
Polarimetry	Yes (P and S channels)				No

CAI-2 Onboard GOSAT-2

- Pushbroom imaging system with ten bands
- Five telescopes for five spectral regions. One telescope will accomodate both forward and backward viewing detectors.
- Forward/Backward viewing capability to avoid sunglint over ocean.
- Multiple UV bands for better aerosol characterization over land. Note that MODIS has no band in 300-400 nm region.
- Extended 1.6 μm band swath for better cloud mask

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Spectral Band (nm)	333 - 533	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	500 m				1 km	500 m				1 km
Swath	1000 km									

Recent GOSAT CAI Images of Atmospheric Pollution and Fires in Asia

Urban Atmospheric Pollution in China Observed by GOSAT CAI

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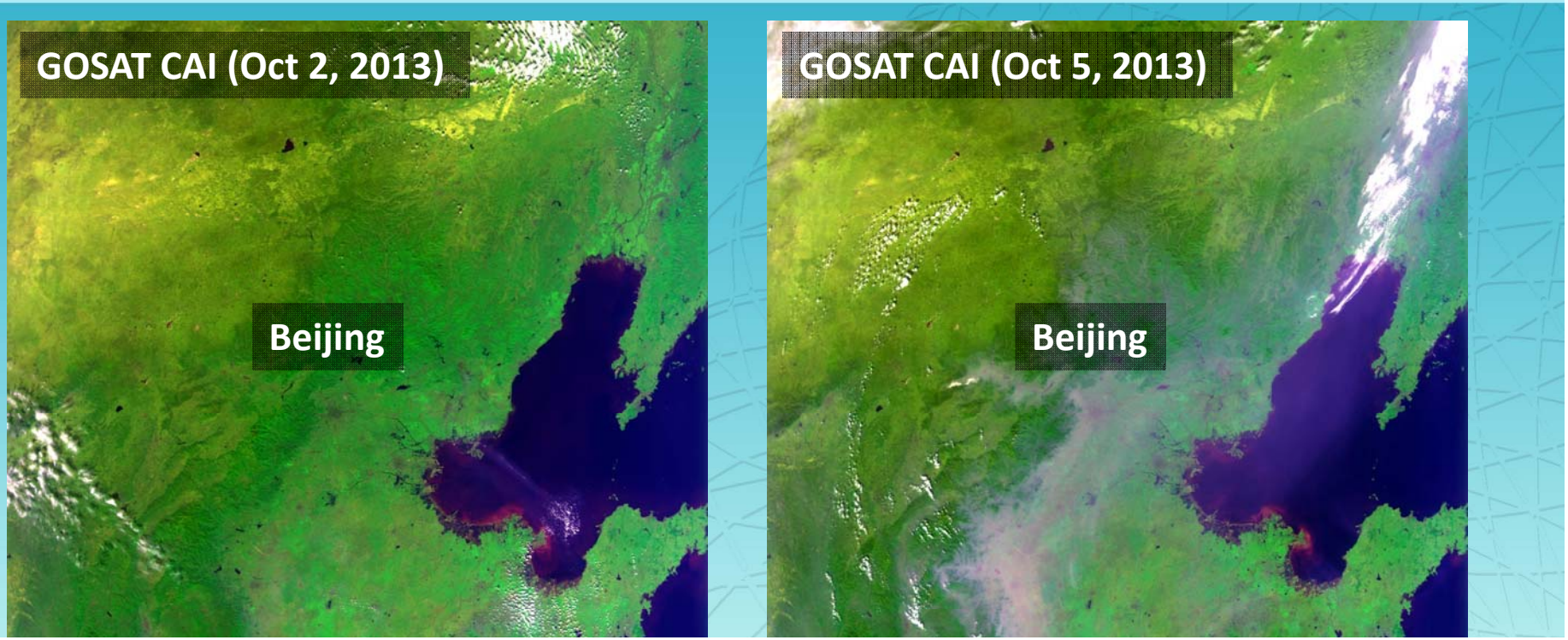
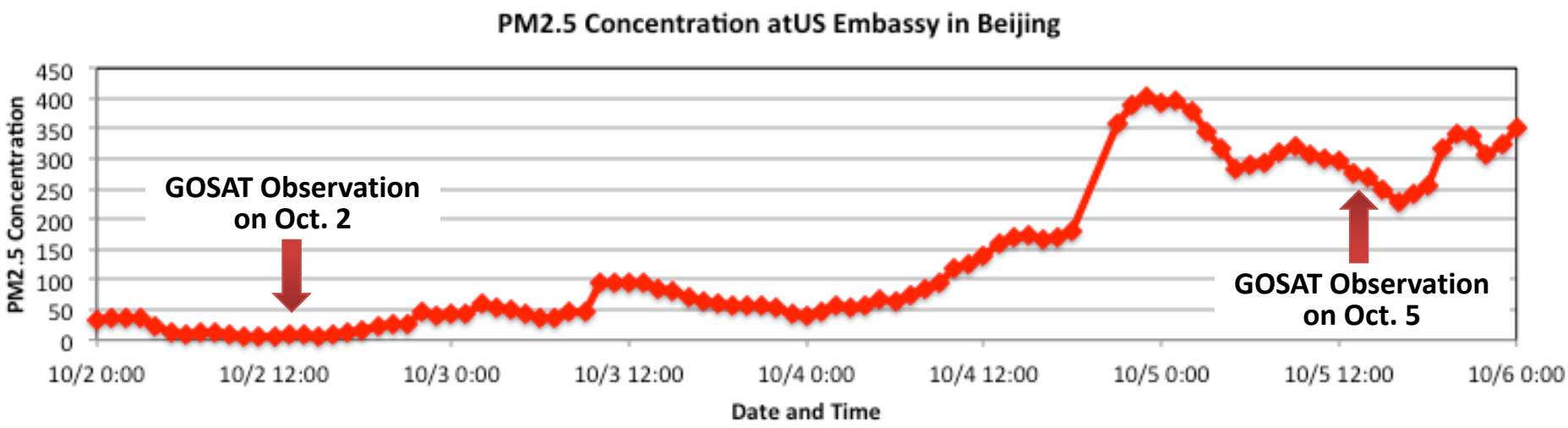
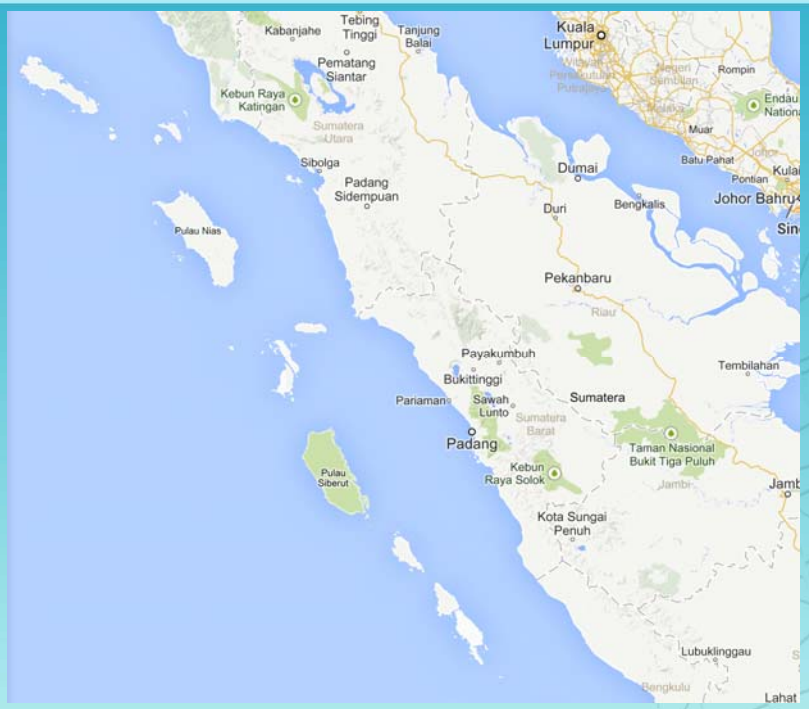
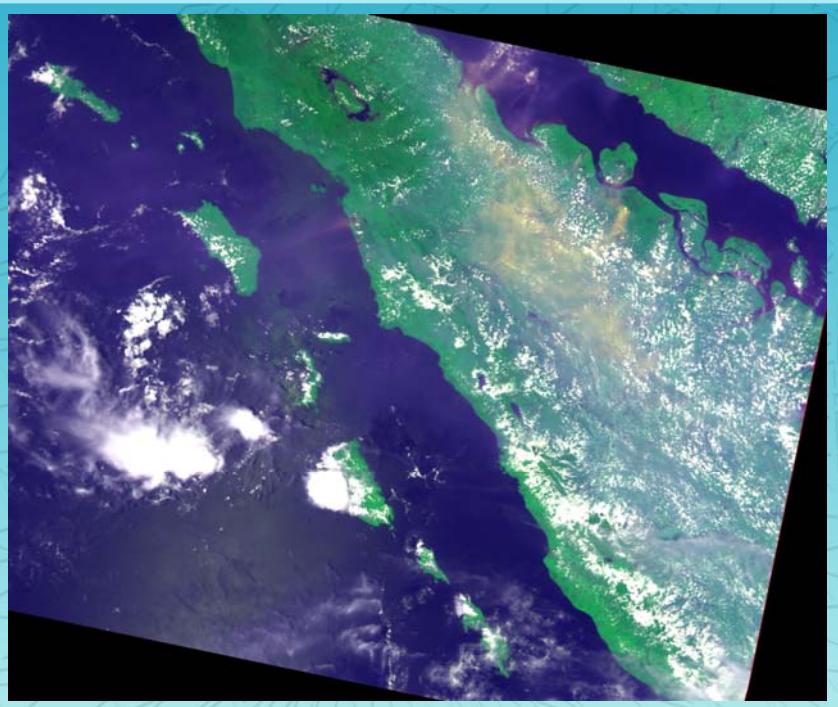




Forest Fires in Indonesia (March 8, 2014)





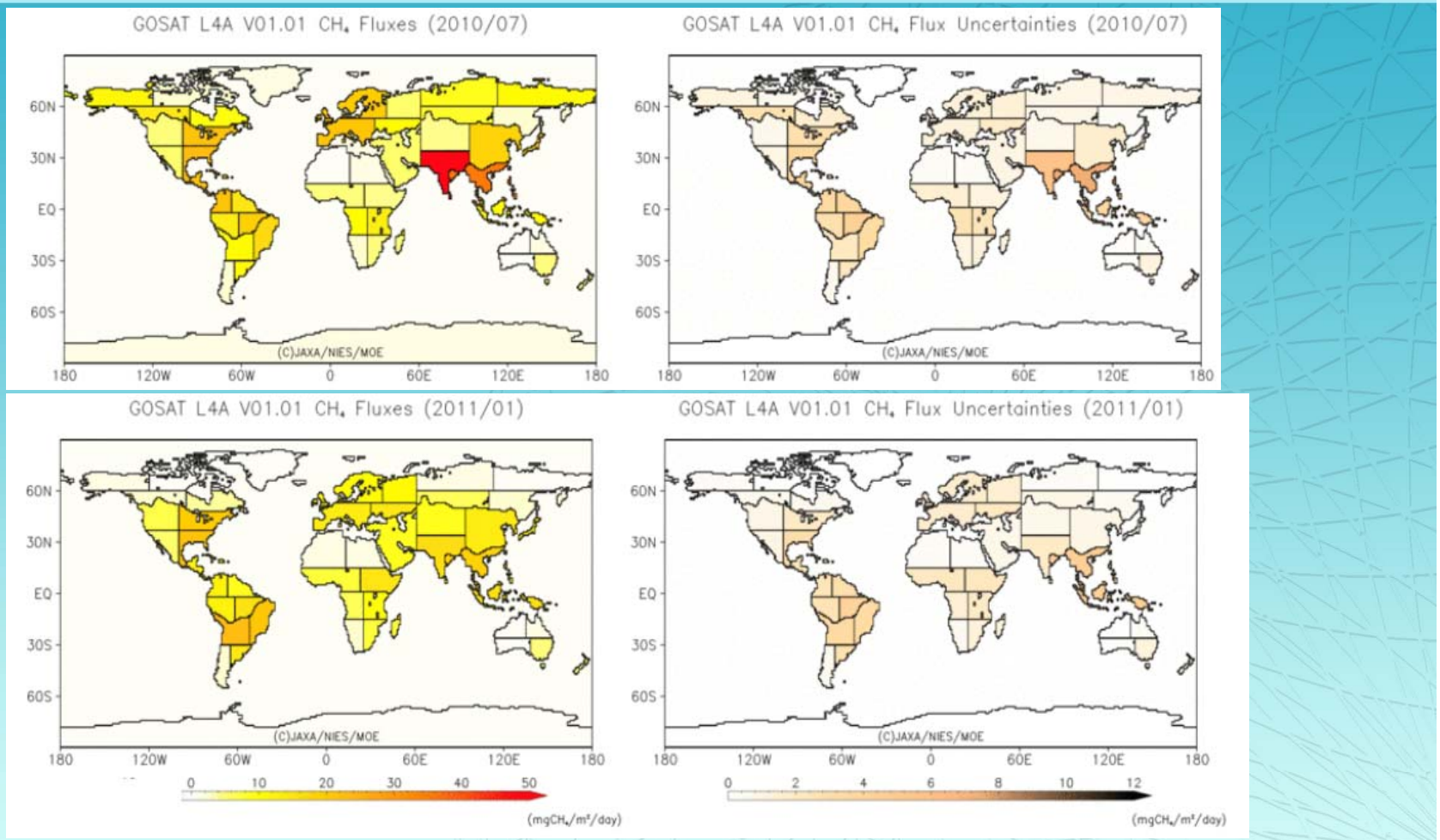
Smoke billowing in the forest area of â��â��Giam Siak Kecil Biosphere-Bukit Batu, Riau Province, Thursday (March 6, 2014).(ANTARA/FB Anggoro)

- Smokes from forest fires in Riau Province, Indonesia in early March, 2014, were clearly shown in yellow over land and in pink over ocean in GOSAT CAI image using a UV band.

Thank you for your attention

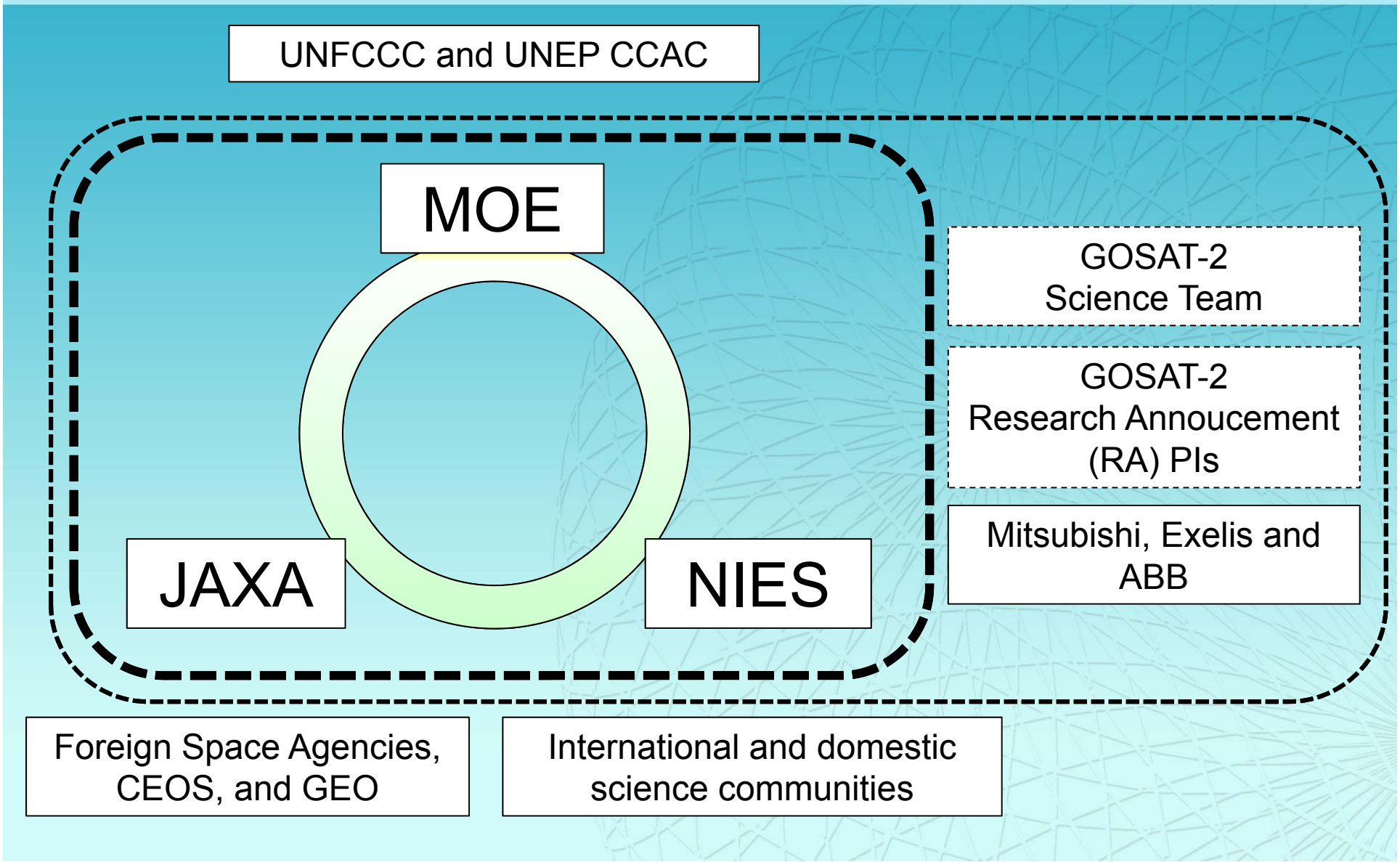
GOSAT-2 Level-2 Product Goals

Newly Released GOSAT Global Methane Flux Maps
Monthly Flux and Uncertainity Maps

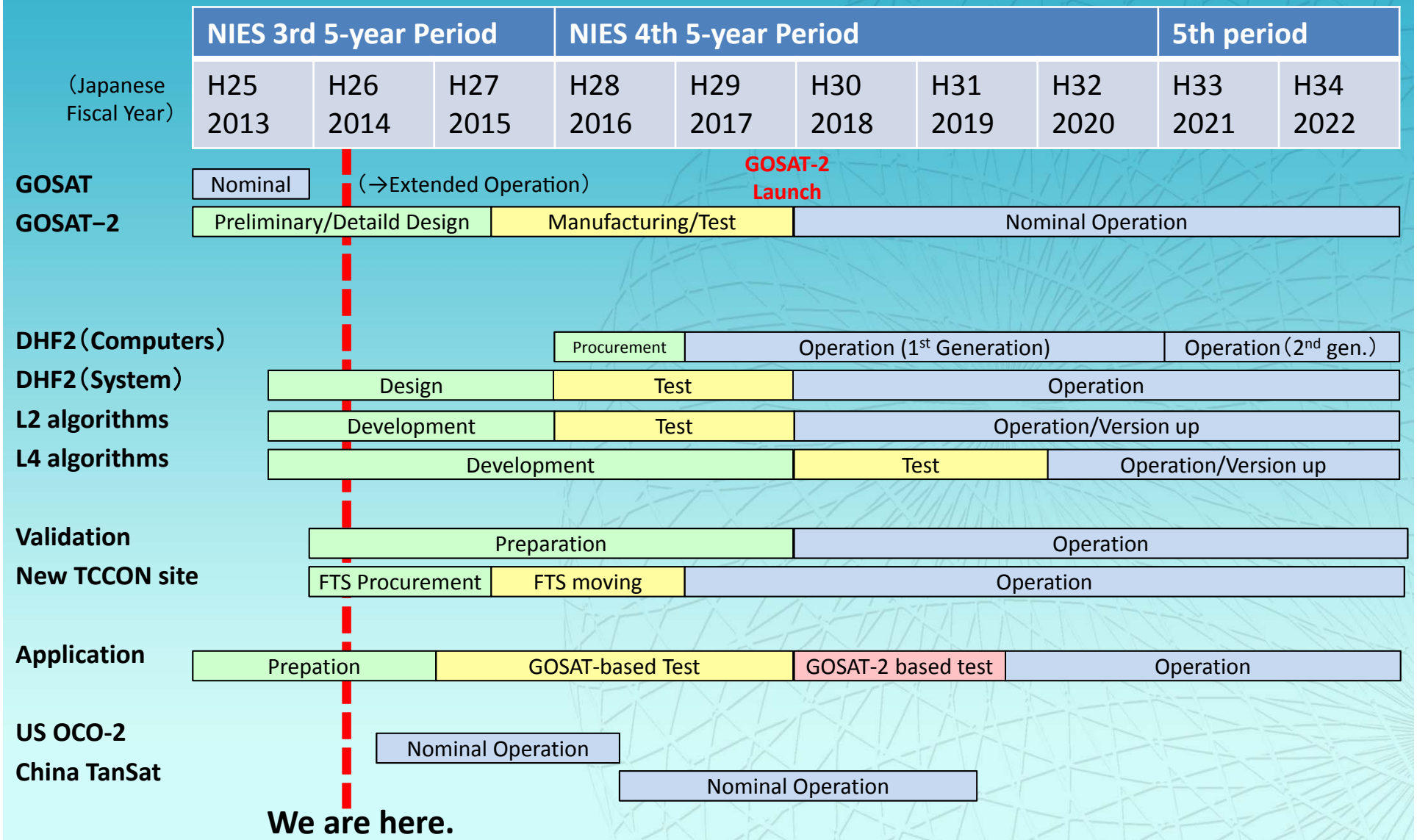


Global estimates of the monthly and regional net fluxes of methane (emission and absorption aggregates) were generated for the two years from June 2009 to May 2011, based on both GOSAT and ground-based data. There have been concrete demonstrations of the utility of GOSAT data. When compared with methane flux estimates generated using ground-based data alone, **estimates which incorporate GOSAT data have significantly lower temporal and spatial uncertainties.**

Overall Structure of GOSAT-2 Joint Project



GOSAT-2 Schedule



The (Original) Objective of GOSAT-2

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GOSAT-2 Observation and Carbon Cycle Science

Continue and enhance GOSAT observation

- Long-term global monitoring of GHGs from space

New scientific topics

- Improvement of terrestrial ecosystem models
- Monitoring and modelling of emission from forest/peat fire
- Monitoring of oceanic flux
- Monitoring of large (point) sources
- Detection of carbon cycle change in subcontinental scale
- Others (e.g. Chlorophyll fluorescence)

Contribute to carbon cycle related climate science

Reduce uncertainty in future climate prediction

Monitor carbon cycle changes due to climate change and human activities

Policies on emission reduction targets

Policies on emission reduction efforts (e.g. REDD+ and JCM) and adaptation to climate change

International collaboration

Climate Change Policies

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Greenhouse gases GOSAT PROJECT Observing SATellite

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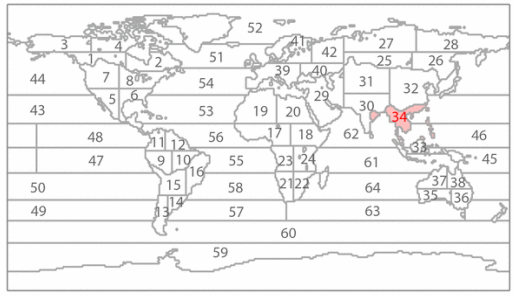
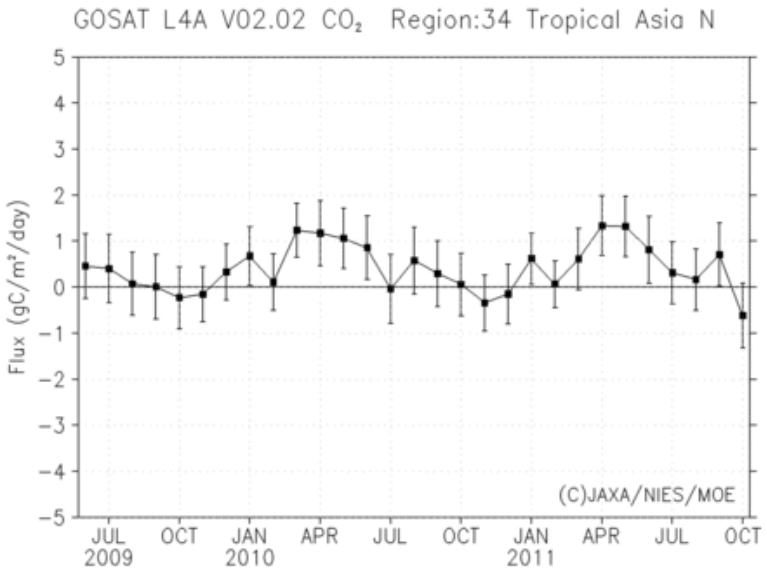
General User : matsunag@nies.go.jp

Gas Flux Time Series

Gas	Version	Area	Region
CO2	V02.02	region	34 Tropical Asia N





GOSAT L4A CO2 Flux
Monthly Flux and Uncertainty

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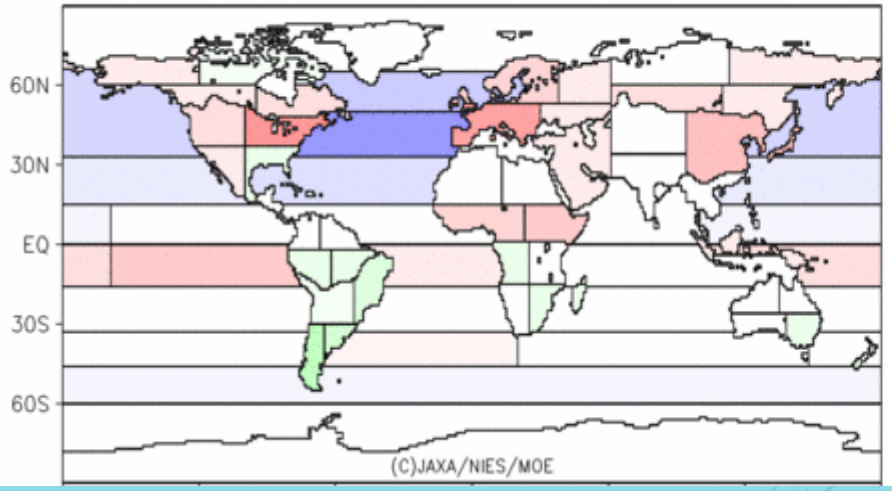
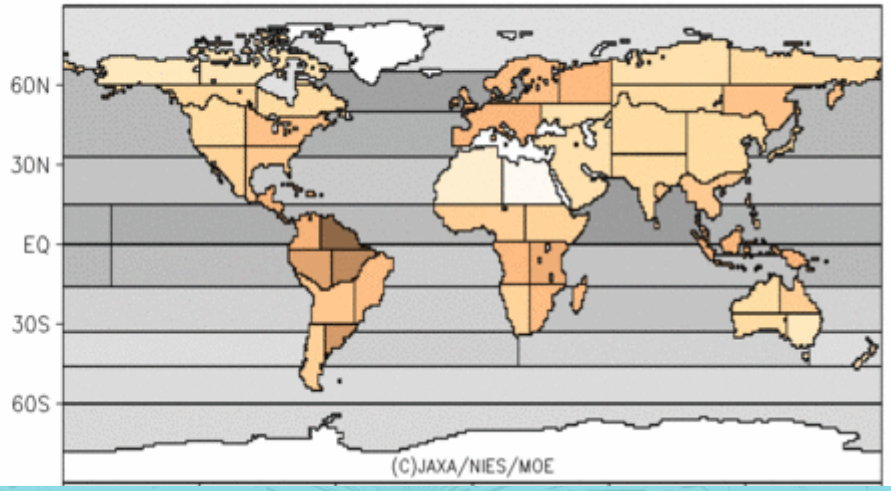
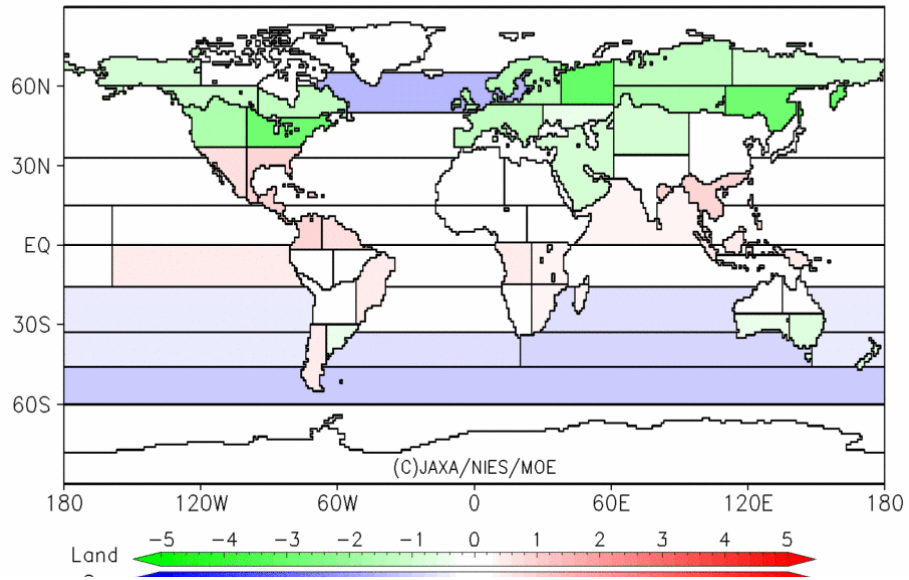
GOSAT L4A V02.02 CO_2 Fluxes (2010/12)



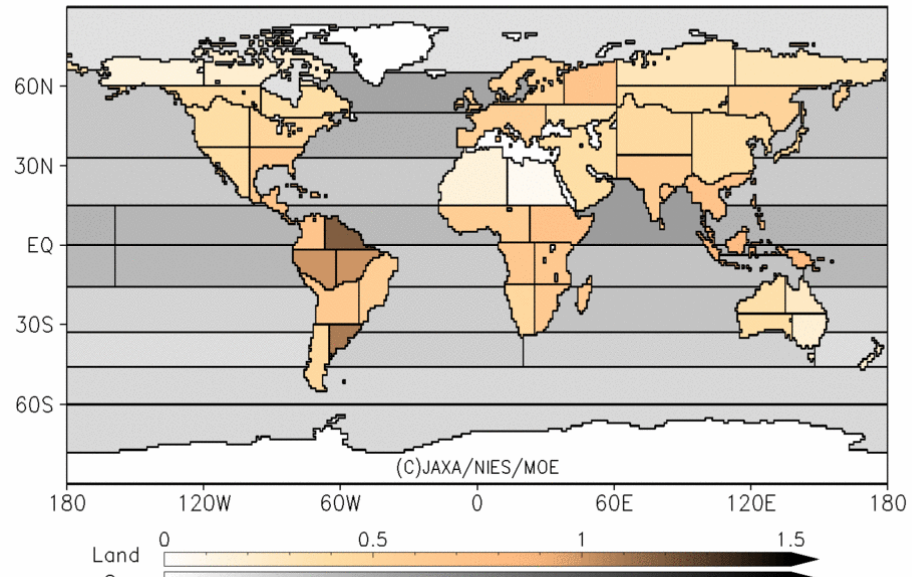
GOSAT L4A V02.02 CO_2 Flux Uncertainties (2010/12)



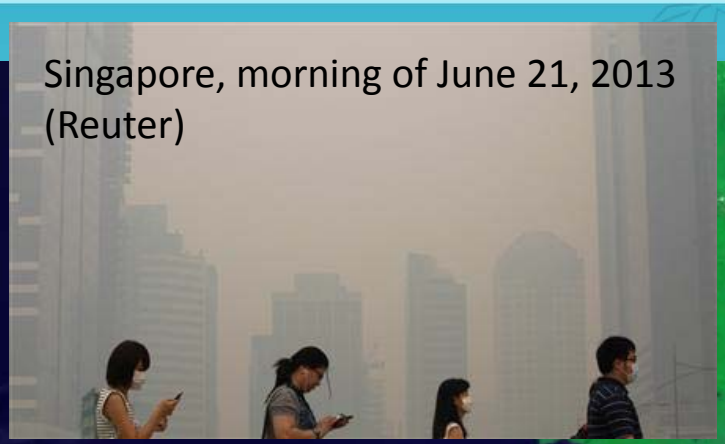
GOSAT L4A V02.02 CO_2 Fluxes (2011/06)



GOSAT L4A V02.02 CO_2 Flux Uncertainties (2011/06)



Forest Fires in Indonesia and Atmospheric Pollution in Singapore



Timeline of Column CO2 (Passive) Observation Satellites

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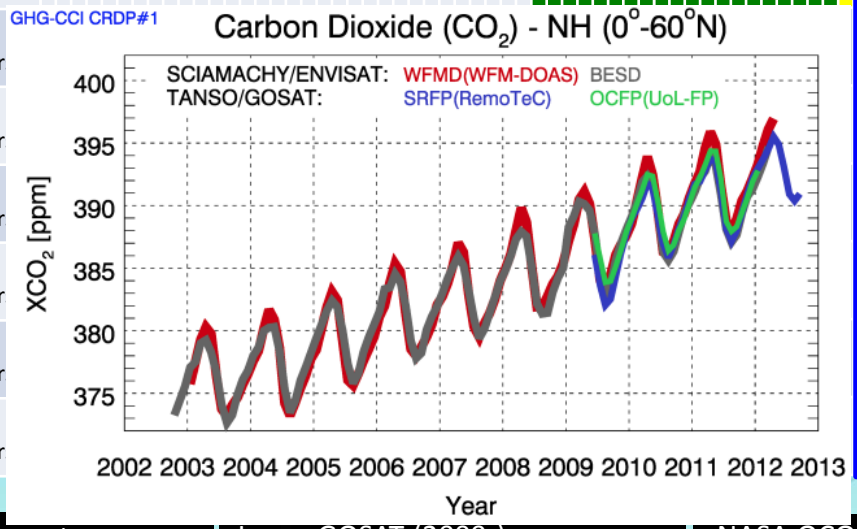
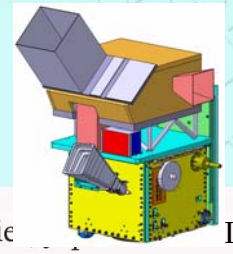
(Calender year)

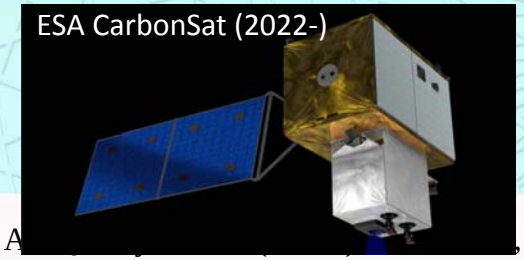
Mission	Period	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
ESA ENVISAT SCIAMACHY	2002/3 - 2012/4																									
Japan GOSAT	2009/1 + 5 years																									
NASA OCO-2	2014/7 + 2 year																									
China TanSat	2016/6 + 3 year																									
NASA OCO-3(ISS)	2017 Fall + 3 year																									
Japan GOSAT-2	2018/1 + 5 year																									
CNES MicroCarb	2018 + 3 year																									
ESA CarbonSat	2022 + 5 year																									

Green Designed life time
Yellow Extended operation
Pink End of mission





CNES MicroCarb (2018-)



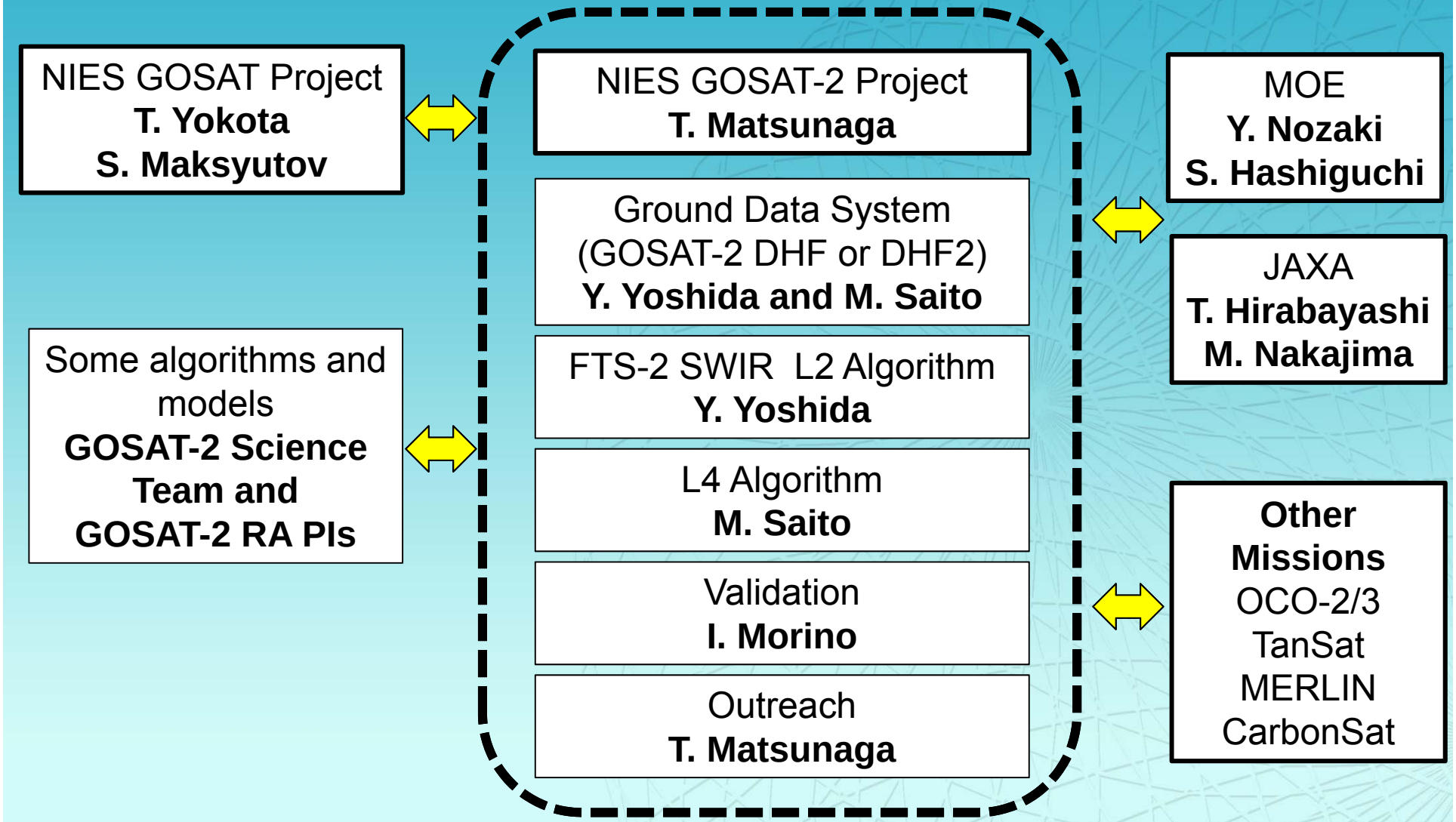
JAXA/MOE/NIES Responsibilities in GOSAT-2 Joint Project

	Responsibility	JAXA	MOE	NIES
1	Definition of GOSAT-2 Mission Requirements	○	○	○
2	Design/development/test/launch preparation of GOSAT-2 spacecraft and mission instruments	○		
3	GOSAT-2 launch	○		
4	Pre-flight test and related ground system development	○	△	△
5	Initial In-flight system functional tests	○	△	△
6	Calibration of mission instruments	○	△	△
7	Operation of mission instruments in nominal and extended mission phases	○		
8	Data reception from GOSAT-2 spacecraft and level 1 product generation	○		
9	Generation of level 2 – 4 products	△		○
10	Development and maintenance of network necessary for data transfer	○		○
11	Information exchange necessary for GOSAT-2 product generation	○	○	○
12	Distribution of GOSAT-2 products to reseaarchers and general public			○
13	Development and maintenance of level 1 algorithm	○		
14	Development and maintenance of level 2-4 algorithm	○		○
15	Development and maintenance of GOSAT-2 product database	△		○
16	Validation of selected GOSAT-2 standard products	△	○	○
17	Use of GOSAT-2 data in environmental policy making		○	
18	Promotion of GOSAT-2 data application	○	○	○
19	GOSAT-2 outreach activities	○	○	○

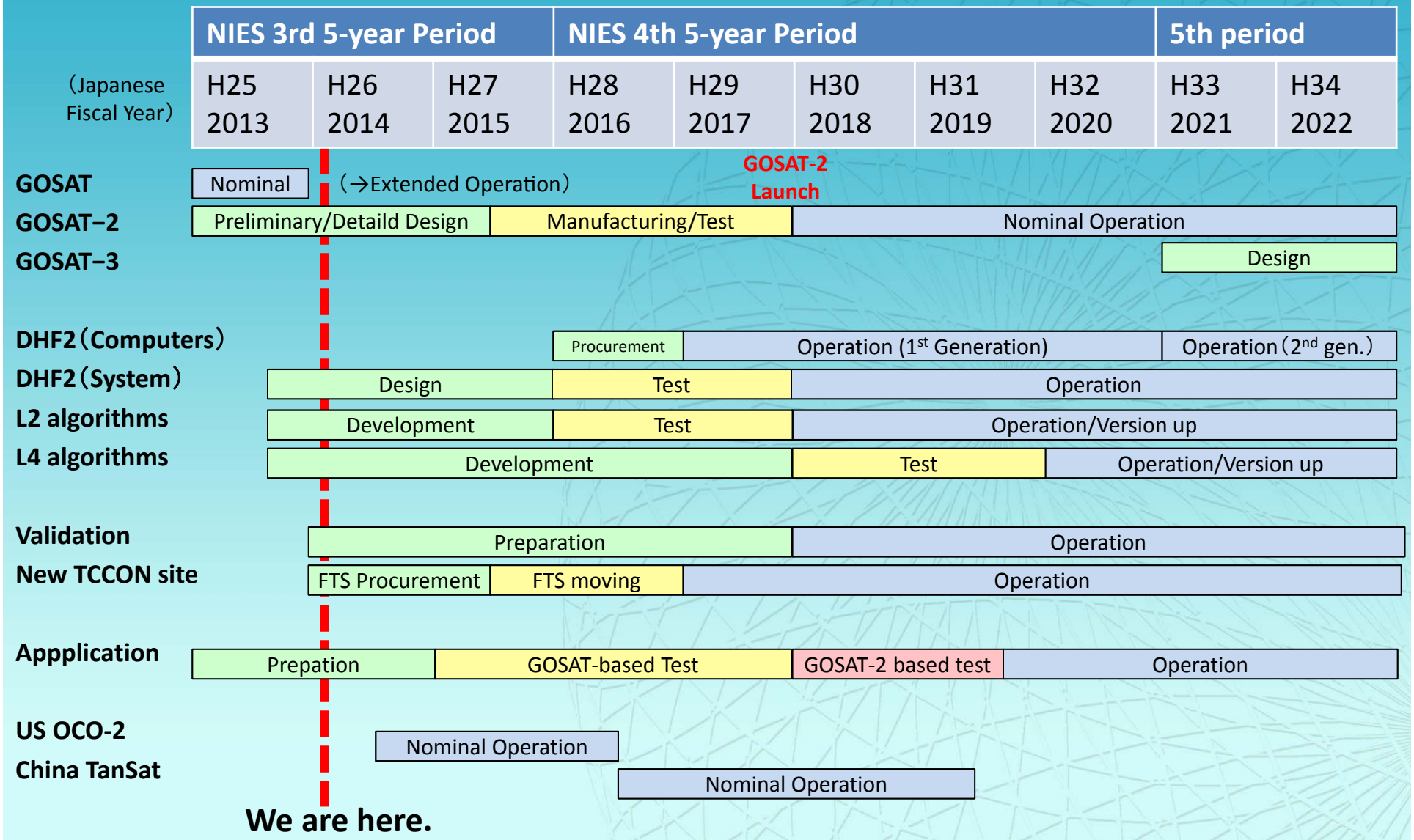
Major Missions of NIES GOSAT-2 Project

- Development of FTS-2 SWIR Level 2 (e.g. gas concentration) and Level 4 (e.g. gas flux) algorithms for GOSAT-2
  - Some algorithms will be provided by JAXA and GOSAT-2 Science Team members.
- Development and Operation of Level 2-4 product generation and distribution system for GOSAT-2.
- Validation / quality assessments of selected GOSAT-2 products
- Application of GOSAT-2 data to carbon cycle science, climate change related policies, and other environment issues including urban air pollution.
- Promotion of wider use of GOSAT-2 data within the framework of climate change related international agreements.
- Other outreach activities regarding GOSAT-2.

Organizational Structure of NIES GOSAT-2 Project



Long Term Schedule of NIES GOSAT-2 Project



GOSAT-2 Level 2/4 Product Plan

- FTS-2 SWIR Level 2 product
  - Simultaneous retrievals of XCO2, XCH4, XH2O, CO, SIF, cirrus height and optical depth, and other parameters
  - L2 data yield will be doubled due to intelligent pointing, improved SNR, extended AT pointing angle, and so on.
- FTS-2 TIR Level 2 product
  - CO2, CH4, H2O, and T profiles for upper air
  - Dust layer height information
- CAI-2 Level 2 product
  - Cloud mask for FTS-2 cloud-free data screening
  - Aerosol products for urban and transbounday air pollution watch.
- Level 4 product
  - Global CO2 flux estimation with ≈1000 km mesh
  - New atmospheric transport model and inversion scheme may be used.

GOSAT-2 as Urban and Transboundary Air Pollution Watch

- Urban air pollution
  - “PM2.5” in Asian mega cities
- Transboundary air pollution problem
  - From China via Korea to Japan
  - From Indonesia to Singapore
- CAI-2 will contribute to comprehensive monitoring and prediction of these phenomena.

GOSAT-2 Data Handling Facility (DHF-2)

GOSAT-2 PROJECT
AT THE NATIONAL INSTITUTE FOR ENVIRONMENTAL STUDIES

Purpose:

- Generate higher-level products from GOSAT-2 L1 data.
- GOSAT-2 data distribution including related documents / images.

Rough plan:

- Provide customer satisfaction services.
- Standard data processing is conducted at daily(L1) / weekly~monthly (L2, L3) / yearly (L4) basis.
- Expedited data processing for urgent case.

Services:

- User-friendly tools and interface with intuitive design and detailed explanation.
- Easy access to GOSAT-2 data.

GOSAT-2 FTS-2 SWIR Algorithm Plan

Target gases:

- CO_2, CH_4, CO

Retrieval method:

- Maximum A Posteriori (MAP) retrieval.
- Retrieve target gases simultaneously with auxiliary parameters such as surface albedo, surface pressure, aerosol optical thickness, etc.

Rough plan:

- First version of the GOSAT-2 retrieval algorithm is based on the GOSAT-1 SWIR L2 V02 (or V03) retrieval algorithm.
- Aerosol information from CAI-2 and/or FTS-2 TIR might be used in the future version after intensive investigation.
- XCO2 may be retrieved from FTS data contaminated with small or thin clouds

GOSAT-2 FTS-2 SWIR Algorithm Plan

- **Long-term Schedule**:
  - FY2014 - 2015 : Finalize the at-launch version
    - Based on GOSAT L2 algorithm
      - ATBD
      - Software Interface Control Document
      - Product File Format Document
  - FY2016 - 2017 :
      - Support of GOSAT-2 DHF(DHF-2) development (Algorithm implementation and test at DHF2)
      - Support of ground calibration activities (Chracterization of the instruments, reflection to the algorithm)

- **FY2014**:
  - Identification of new development issues
  - CH_4 spectral parameters update (1st year of three year plan.)
  - Drafts of the algorithm flow and related documents
  - Evaluation of retrieval accuracy based of FTS-2 specification as of SDR
  - Development of forward model for L2 processing

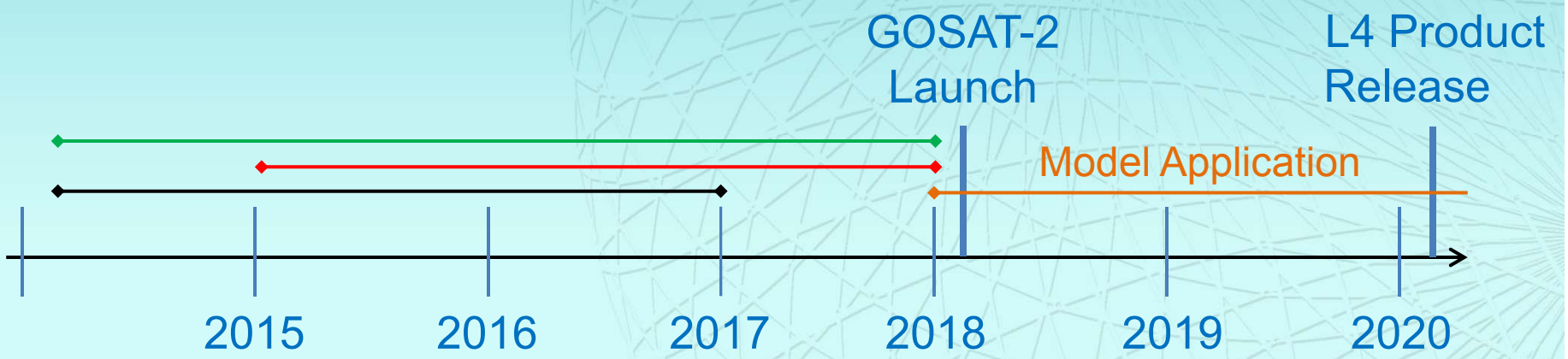
FY2014 Plan for Level 4 (Flux)

Model development towards GOSAT-2 Level 4 products

GOSAT Model Systm：NIES-TM + Kalman filter

GOSAT-2 Model System： NICAM-TM + 4D-Var

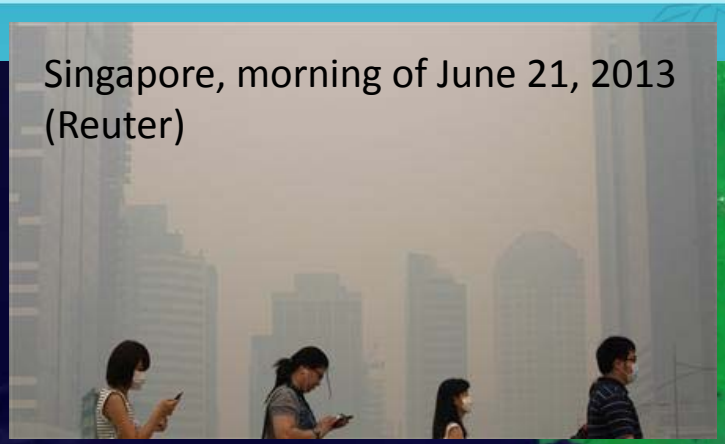
- Model Development（Transport to stratosphere, Methane chemical loss processes, data assimilation, etc）
- Model Validation（Use of GOSAT, TCCON, and other data, comparison with current L4 product）
- Updates on a priori data（land, ocean, anthoropogenic, forest fire）



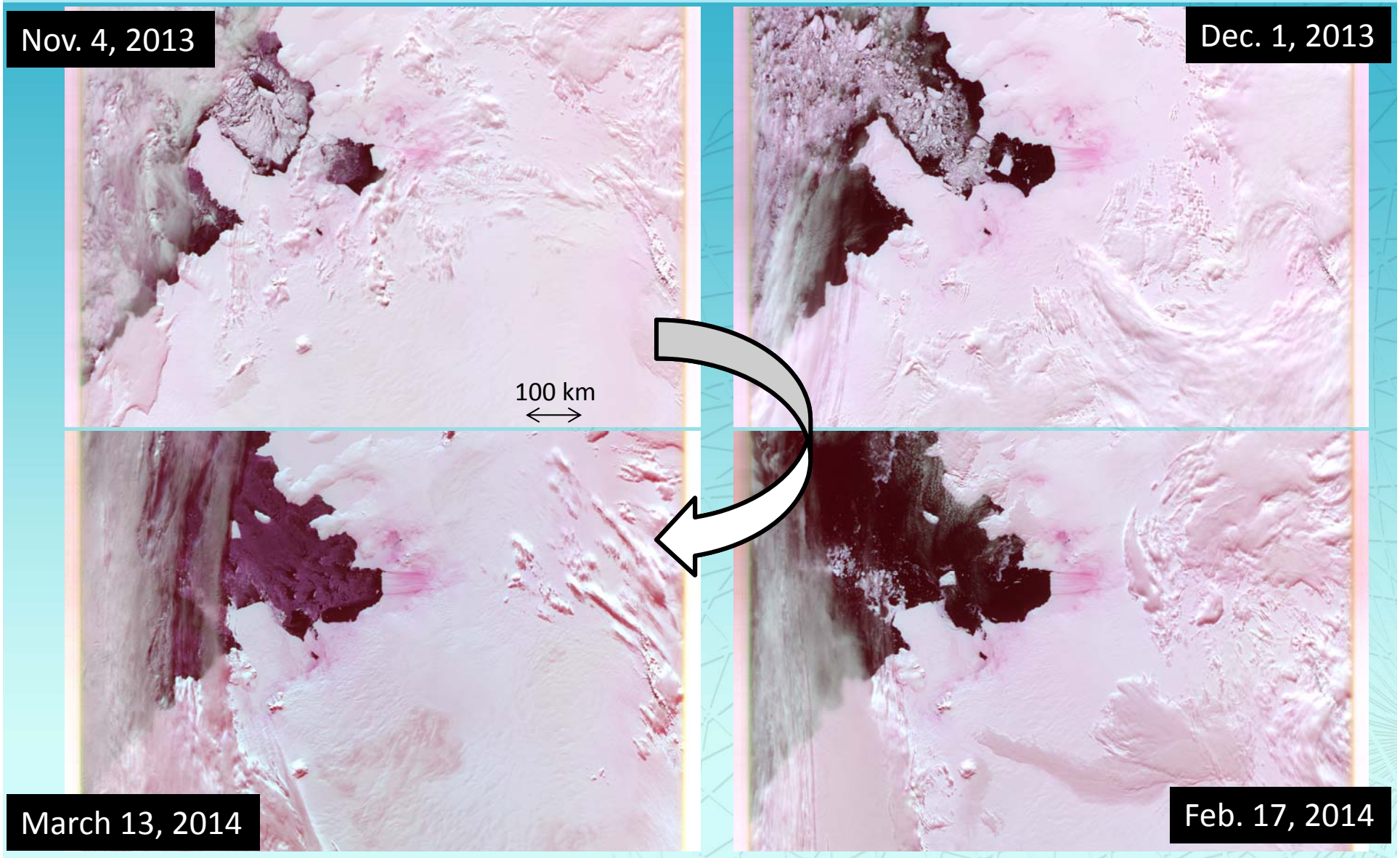
FY2014 Plan for GOSAT-2 Validation

- Establishment of GOSAT-2 validation analysis schemes through GOSAT validation activities
  - Validation of XH_2O => Towards public release
  - IDL tool preparation for validation activities
- GOSAT-2 Validation Plan
  - FY2014 Validation item list
  - FY2015 1st Draft of GOSAT-2 Validaiton Plan
  - FY2016 2nd Draft of GOSAT-2 Validation Plan, negotiations with foreign countries
- Instruments for GOSAT-2 Validation
  - Procurement of Full TCCON FTS for a new TCCON site
  - Investigation on the location of a new TCCON site
  - Table-top FTS and Laser heterodyne radiometer (if possible)

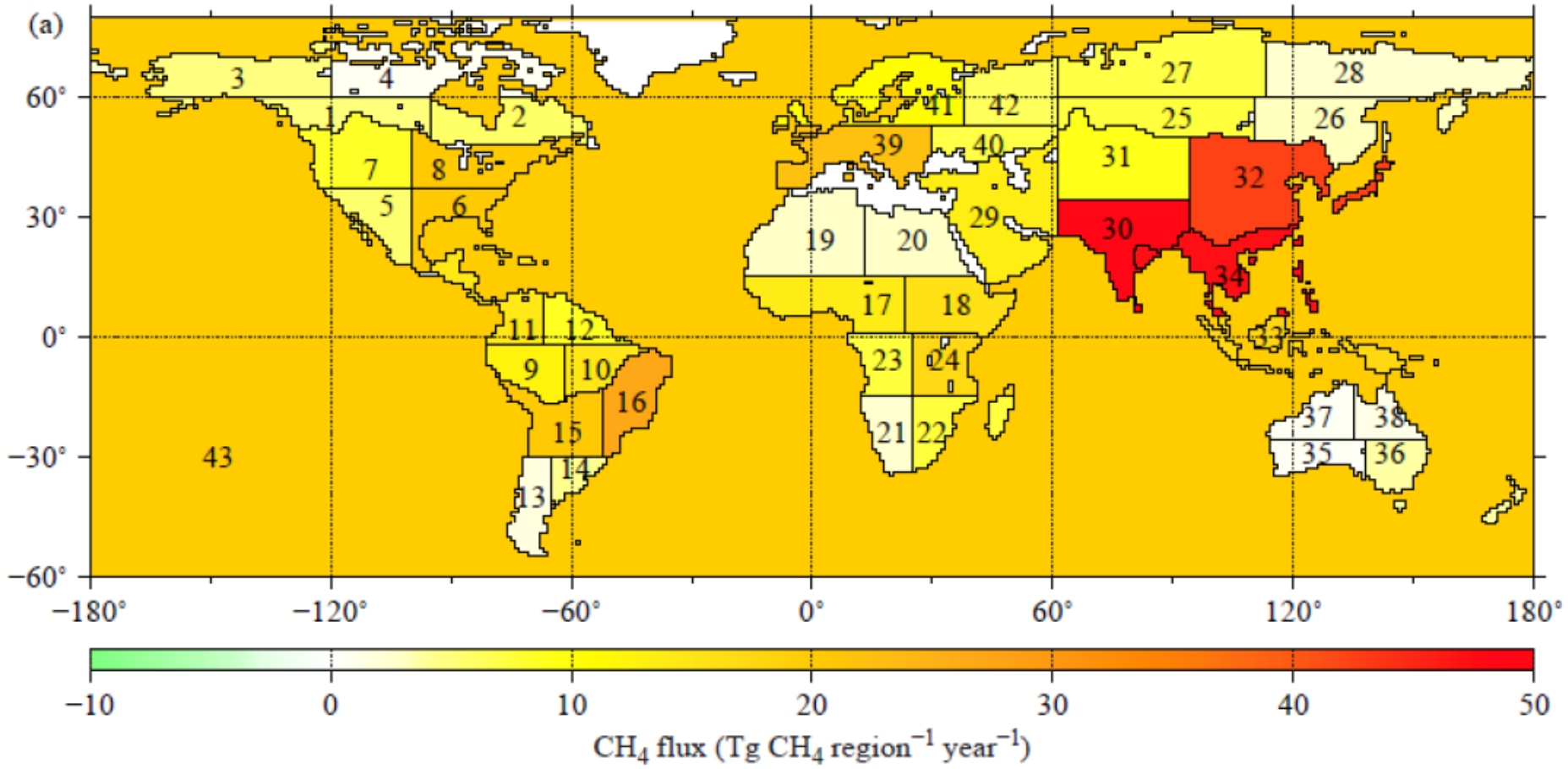
Forest Fires in Indonesia and Atmospheric Pollution in Singapore



B31 Iceberg in Antarctica Observed by GOSAT CAI



Newly Released GOSAT Global Methane Flux Maps
Annual Methane Flux



Global estimates of the monthly and regional net fluxes of methane (emission and absorption aggregates) were generated for the two years from June 2009 to May 2011, based on both GOSAT and ground-based data. There have been concrete demonstrations of the utility of GOSAT data. When compared with methane flux estimates generated using ground-based data alone, estimates which incorporate GOSAT data have significantly lower temporal and spatial uncertainties.

This annual methane flux map shows **that the methane emissions in East Asia and the Southeast Asia regions (Region No. 30, 32, and 34) are significantly high**.

http://www.gosat.nies.go.jp/eng/related/2014/201403.htm