International Workshop on "Inventory, Modeling and Climate Impacts of Greenhouse Gas emissions (GHG's) and Aerosols in the Asian Region", June 27, 2013 @ Epochal Tsukuba, Tsukuba, Japan

GOSAT

- CO_2 and CH_4 measurements from space -

(**GOSAT**: **G**reenhouse gases **O**bserving **SAT**ellite)

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National Institute for Environmental Studies (NIES), Japan

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- Significance and objectives of GHGs (CO_2 & CH_4) measurements from space
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- CO_2 & CH_4 monitoring status by GOSAT
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- GOSAT TANSO-CAI data contribution

GOSAT (IBUKI) launched by H-IIA F-15 vehicle on January 23, (Photo by Mr. Daitoh (NIES))

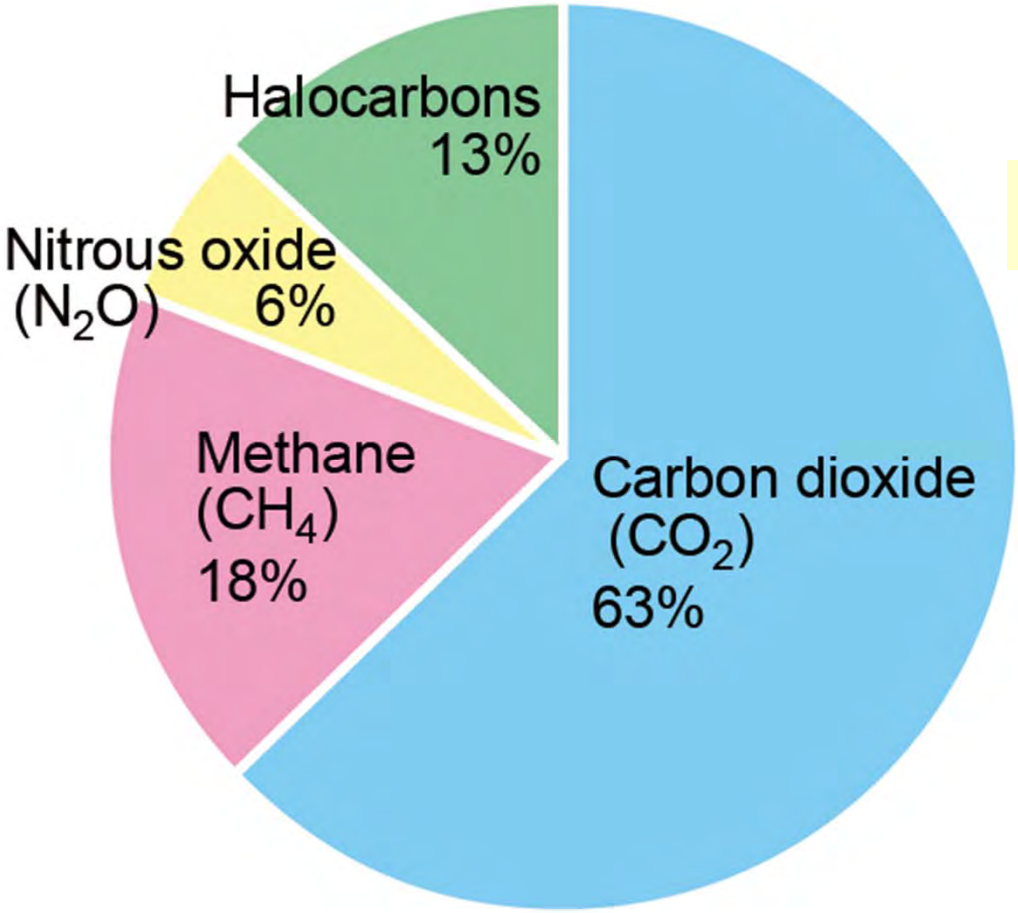
GOSAT Mission Status Overview

- GOSAT was launched on 23 January, and has been in operation for more than four years.
- GOSAT data are available from June 2009 successively.
- GOSAT is the world's first satellite designed specifically for monitoring greenhouse gases.
  - **<u>Researchers worldwide are using GOSAT data.</u>**
- GOSAT observations successfully filled out the gaps in the ground-based monitoring network, except for around the equator and the high-latitude regions.

Objectives of the GOSAT Project

1. To obtain the global distributions of greenhouse gas (GHG) concentrations (CO_2 and CH_4) and their temporal variations
   - To **visualize** changing GHG global distributions
   - To fill out the gaps in the network of ground monitoring stations
2. To **improve accuracy** of the carbon flux (net sources and sinks) estimation on a sub-continental scale
3. To develop technologies for future GHG observing satellites ⇒ **GOSAT-2**

Carbon Dioxide & Methane Measurements



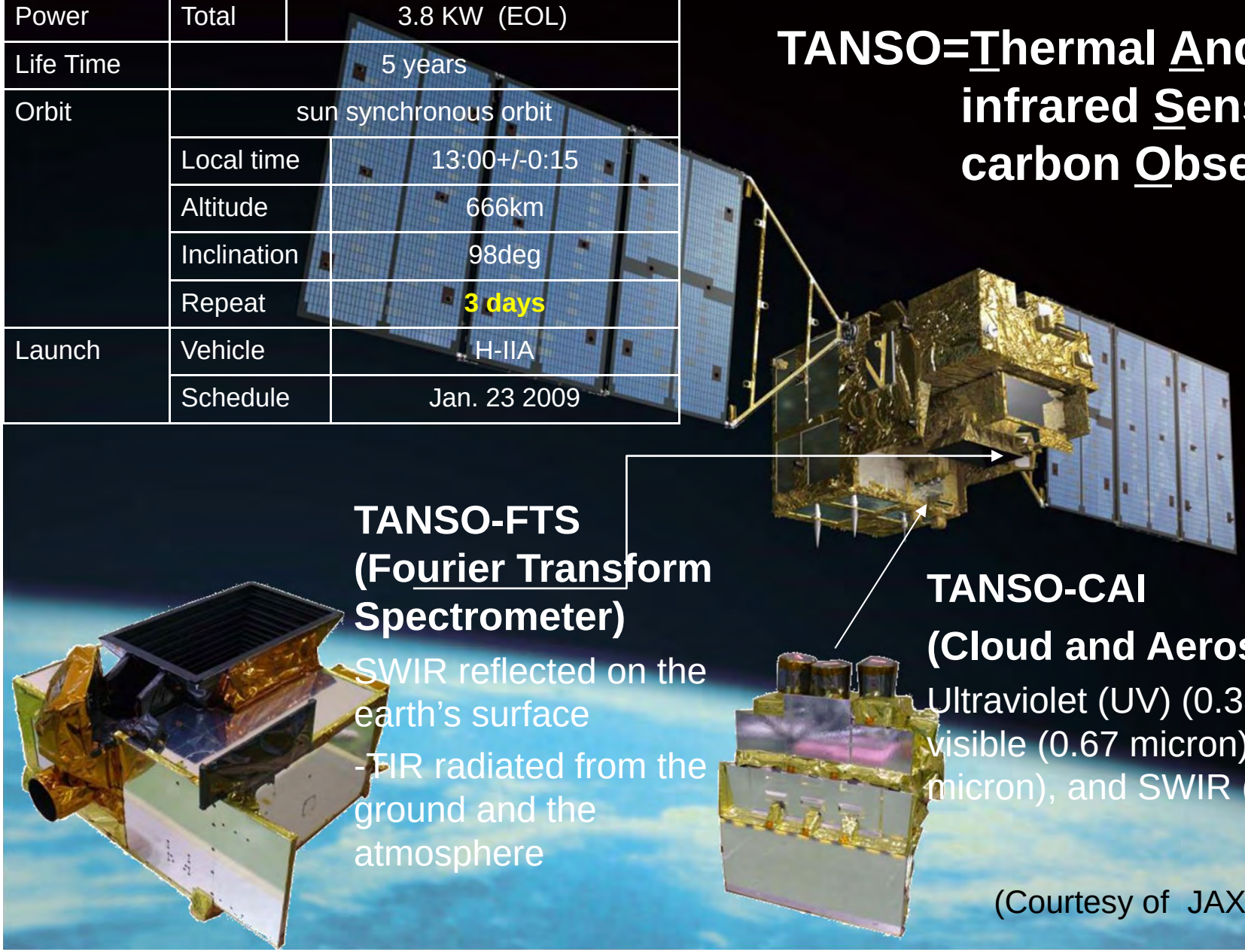
63+18=81%

Contributions of primary greenhouse gases to the increase in atmospheric temperatures based on the best estimates of radiative forcing from 1750 to 2005. (Source: IPCC AR4)

TANSO onboard GOSAT

TANSO=Thermal And Near infrared Sensor for carbon Observation

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

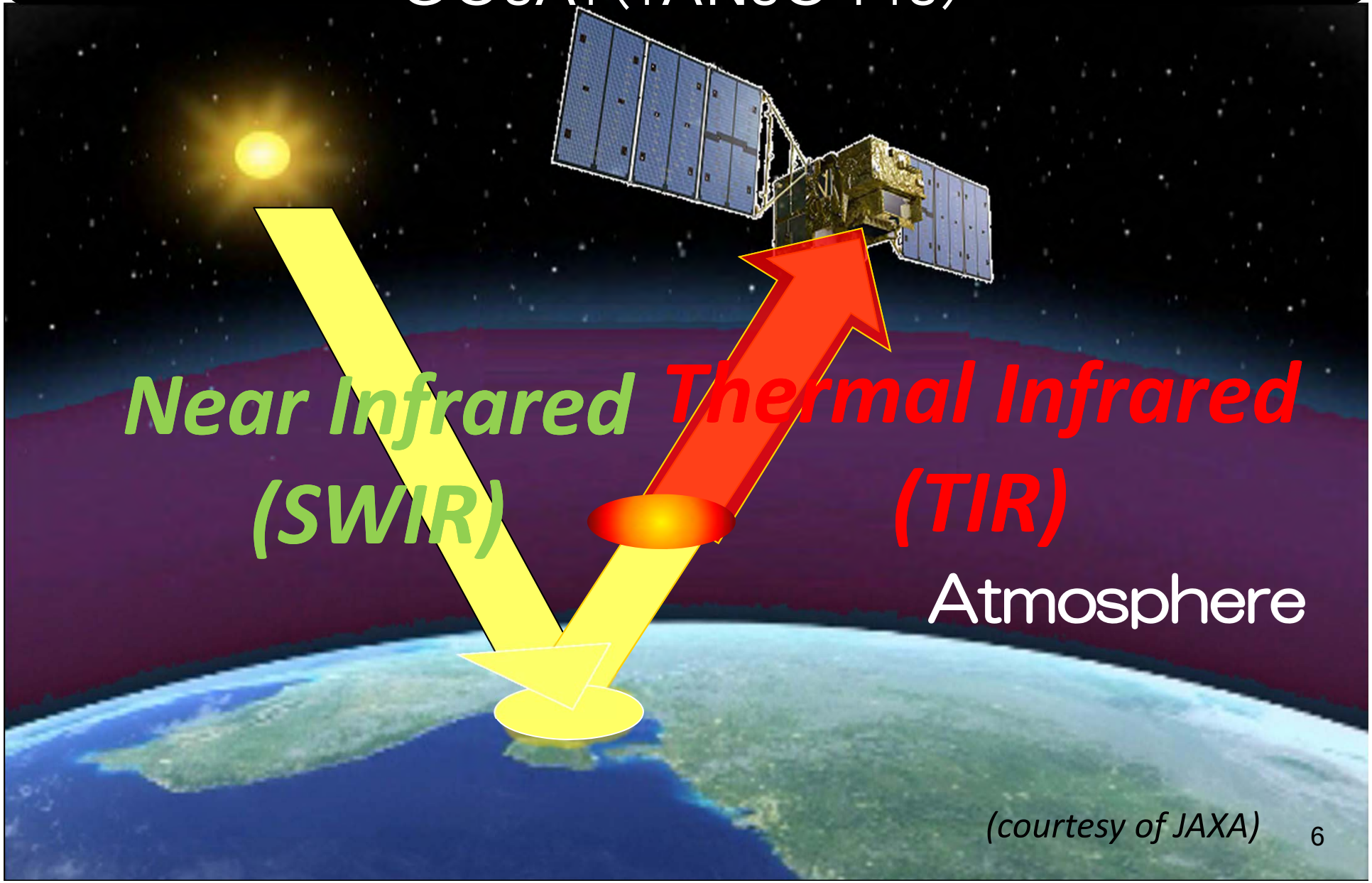
TANSO-CAI

(Cloud and Aerosol Imager)

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

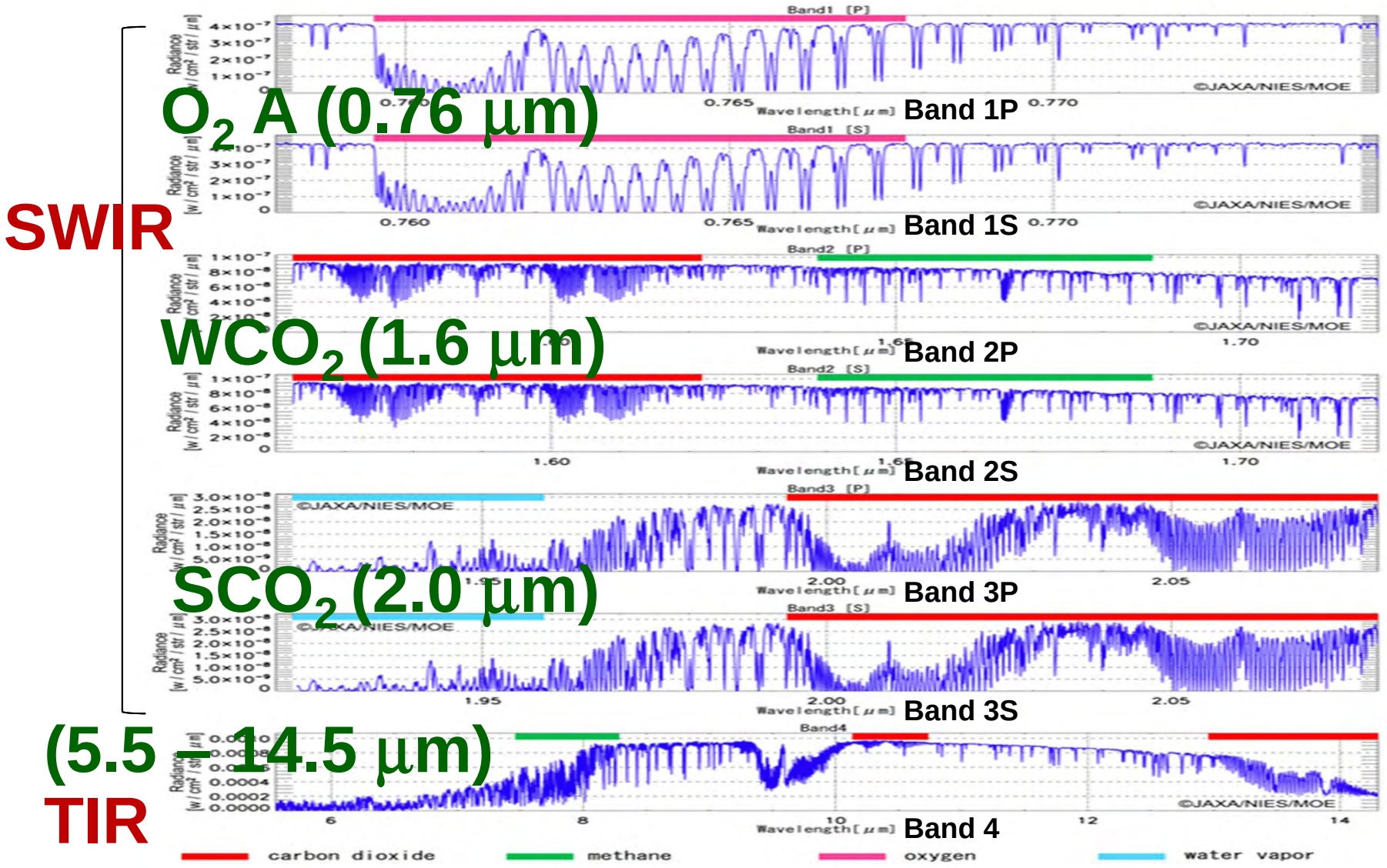
(Courtesy of JAXA)

Infrared Radiation measurements by GOSAT(TANSO-FTS)

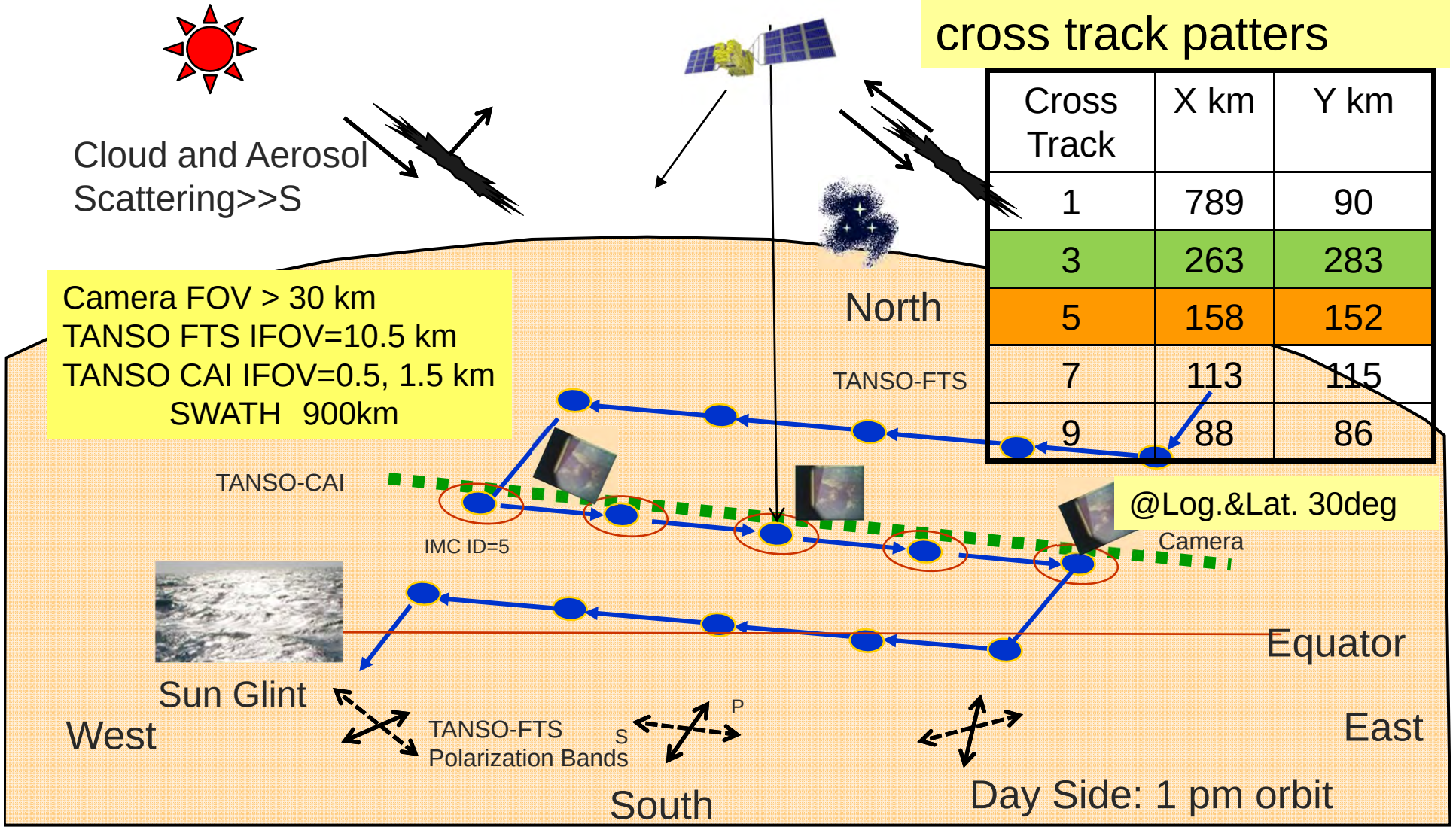


(courtesy of JAXA)

TANSO-FTS Level 1B spectra



Pointing and Footprints

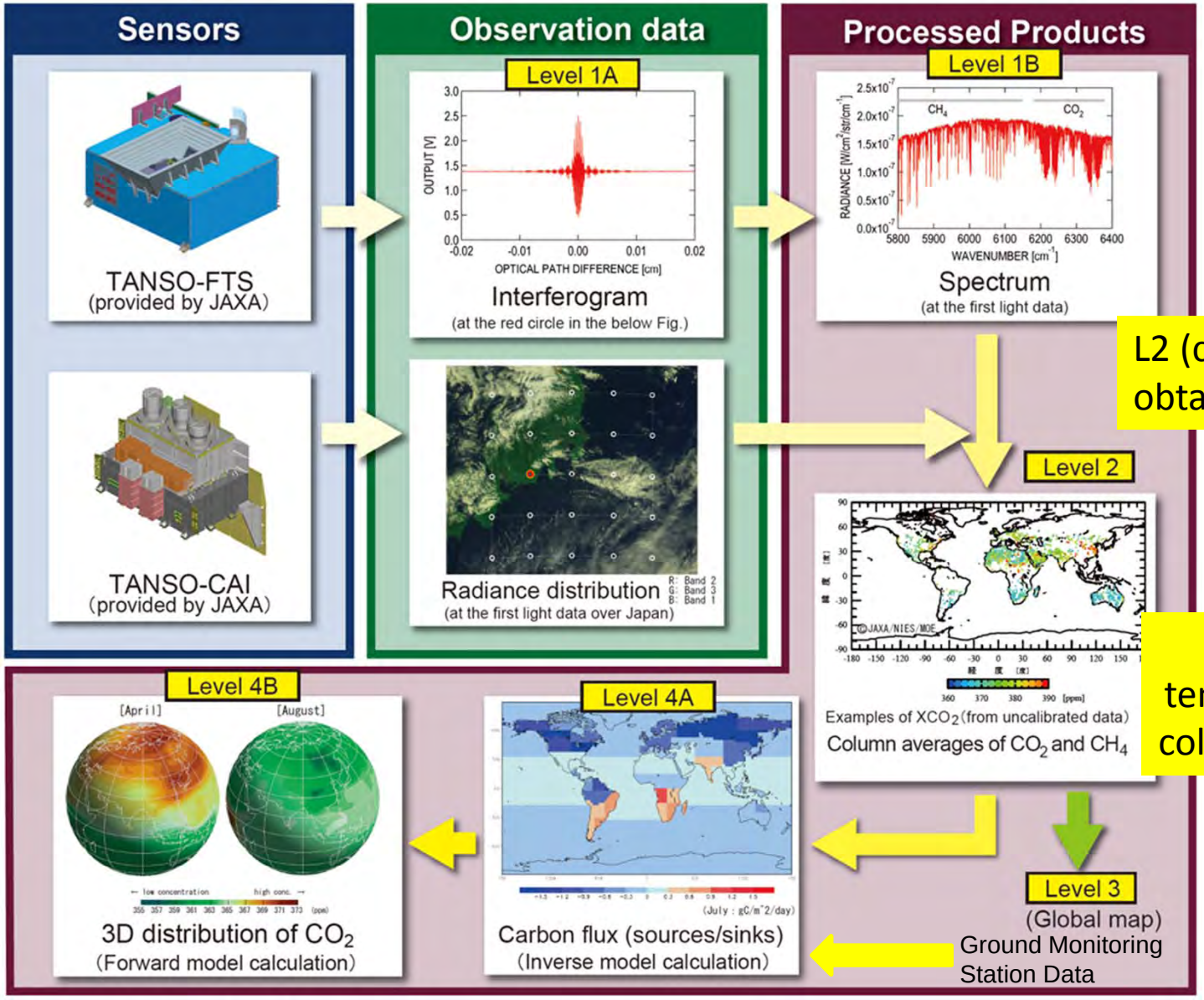


cross track patters

Cross Track	X km	Y km
1	789	90
3	263	283
5	158	152
7	113	115
9	88	86

(Courtesy by H. Suto (JAXA))

GOSAT Data Processing Flow



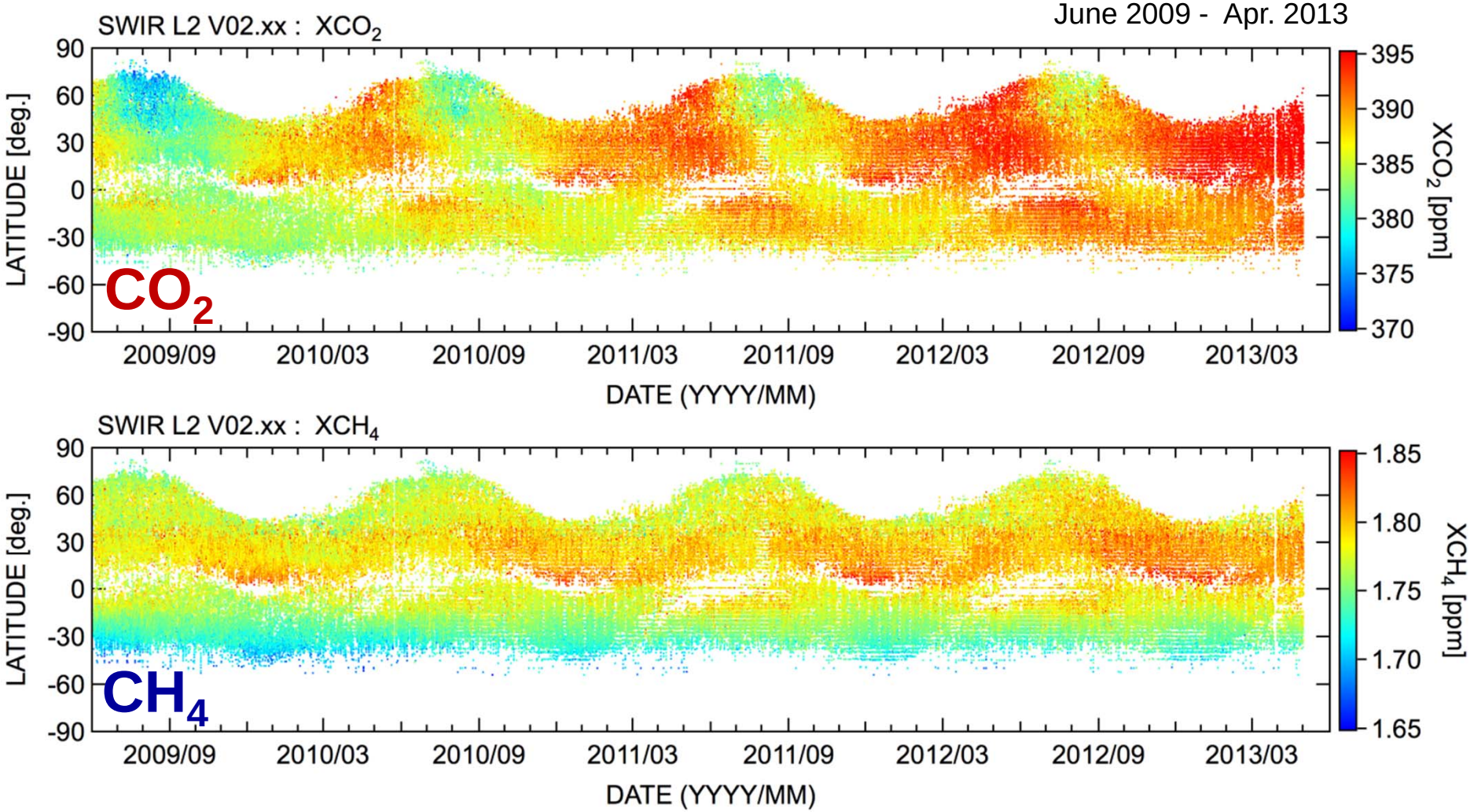
L2 (column abundance obtained by each scan)

L3 (spatial and temporal average of column abundances)

Source: NIES GOSAT project pamphlet

TANSO-FTS SWIR L2 (V02.**) XCO_2 & XCH_4

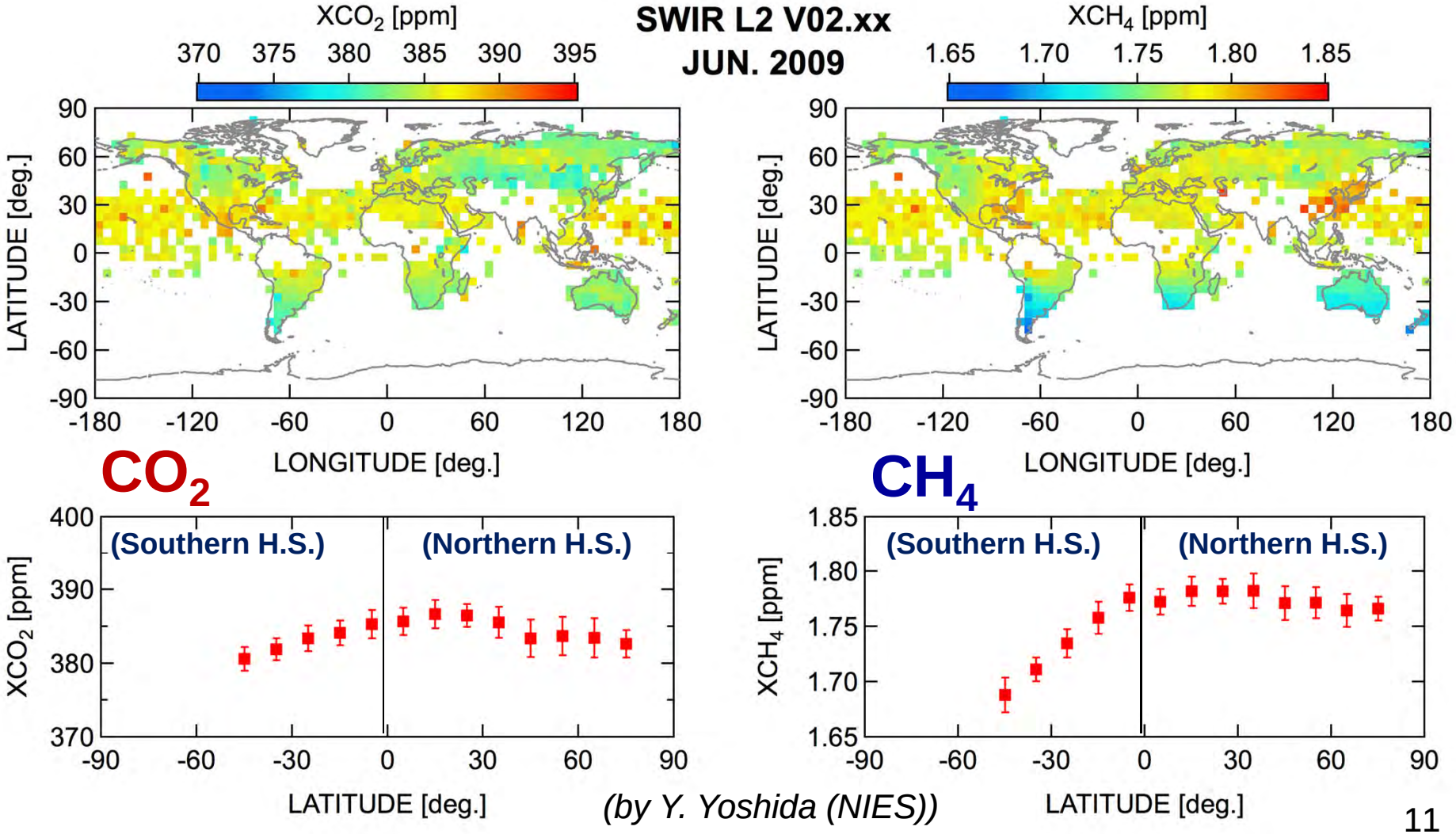
June 2009 - Apr. 2013



(by Y. Yoshida (NIES))

Monthly global map of XCO_2 and XCH_4 (V02.**) from TANSO-FTS SWIR data

June 2009 – April 2013



(by Y. Yoshida (NIES))

XCO_2 Monthly Average

JUN. 2009

GOSAT DATA

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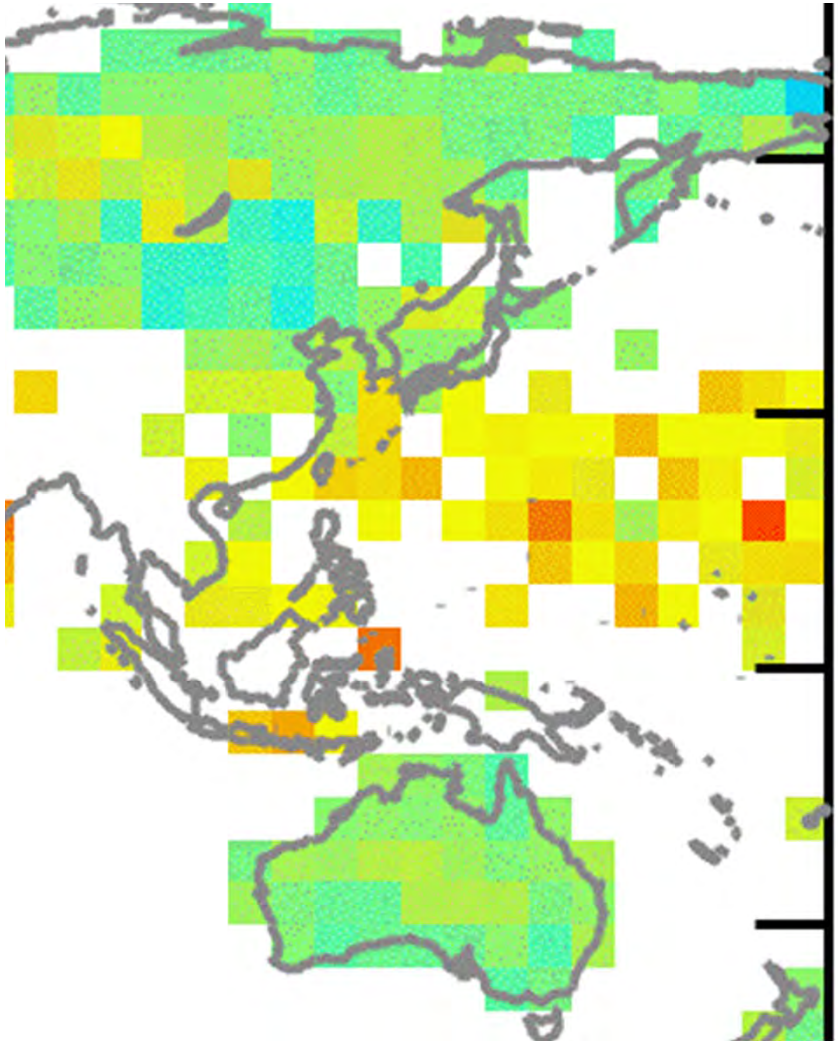

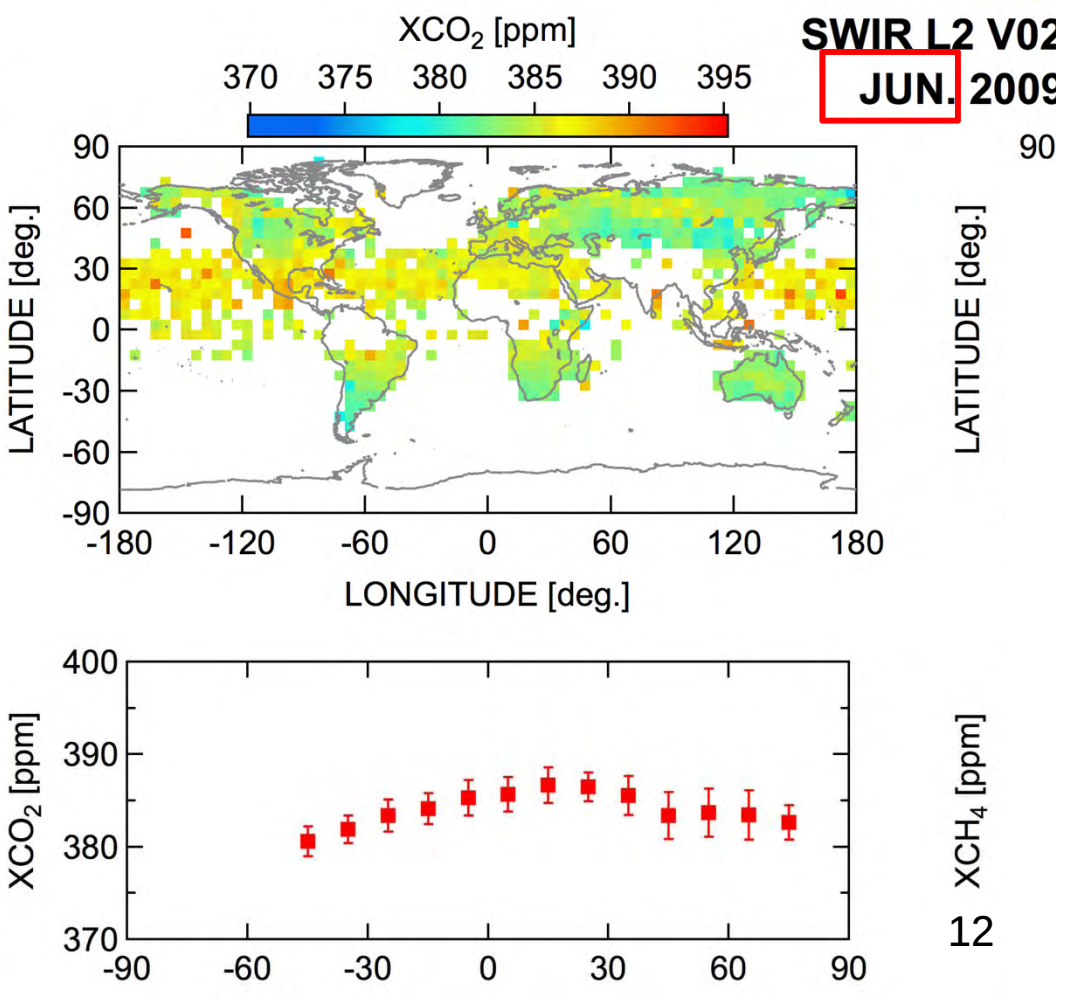

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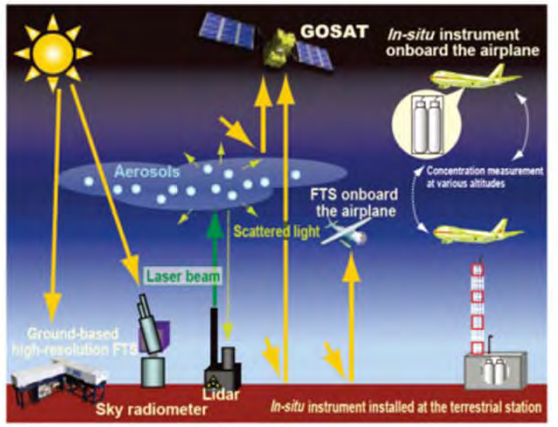
Data Validation of GOSAT XCO_2 and XCH_4

Data validation activities have conducted by worldwide research groups

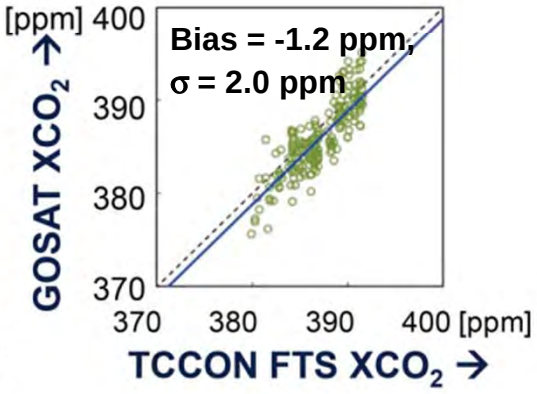
- Column concentrations of CO_2 and CH_4 have been retrieved by several groups (institutes and universities) in the world.
- These data are validated with TCCON FTS data and/or airplane data.
- Present GOSAT XCO_2 data quality is within -0.3% bias and 0.5% variation.

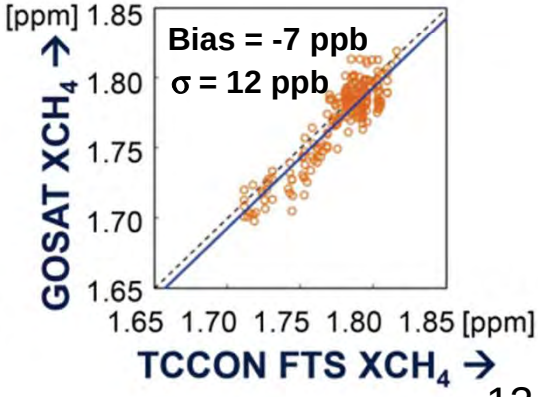


Data validation scheme

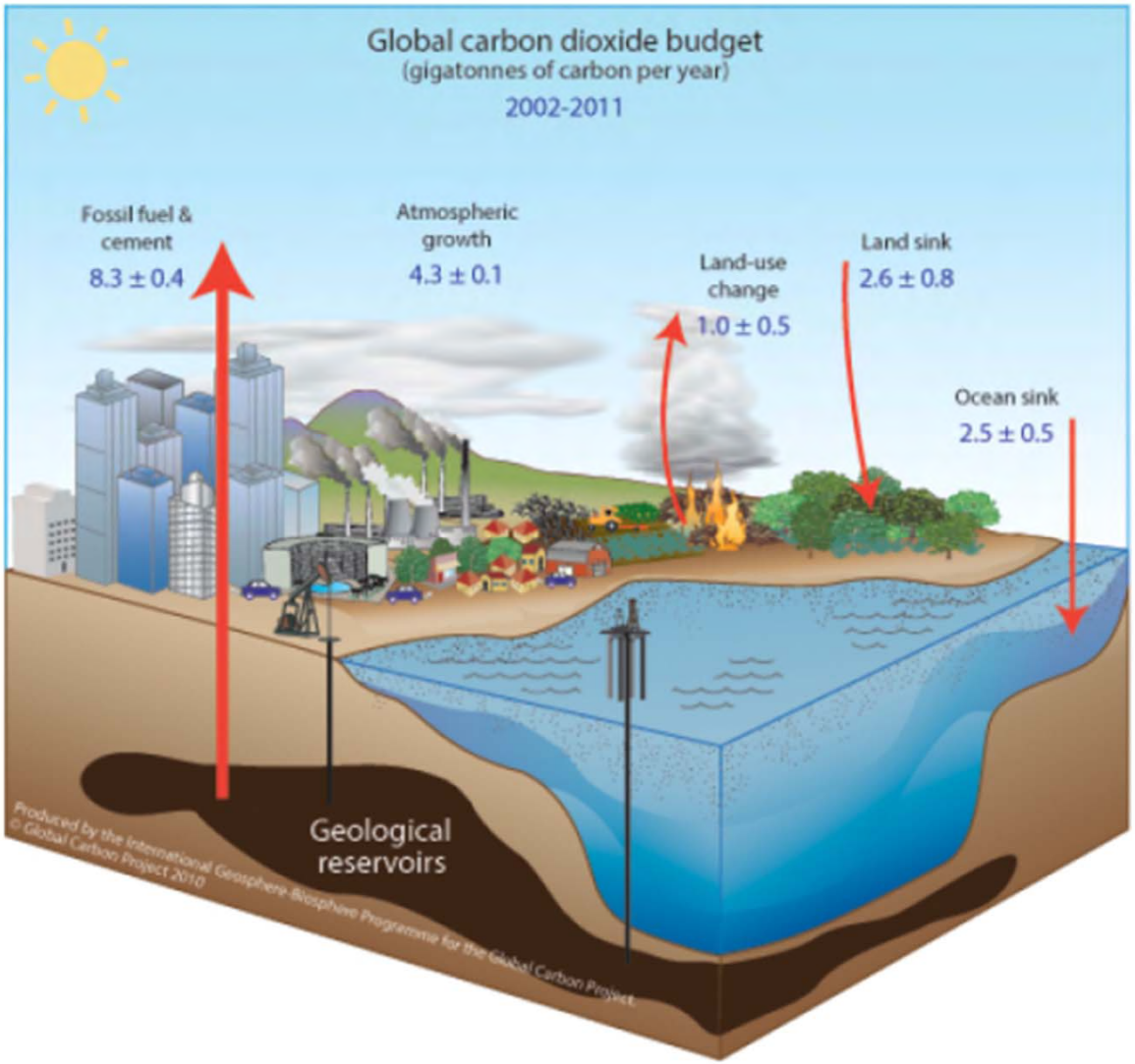
Data from ground-based FTS network

TCCON: Total Carbon Column Observing Network





Carbon fluxes in 2002 - 2011

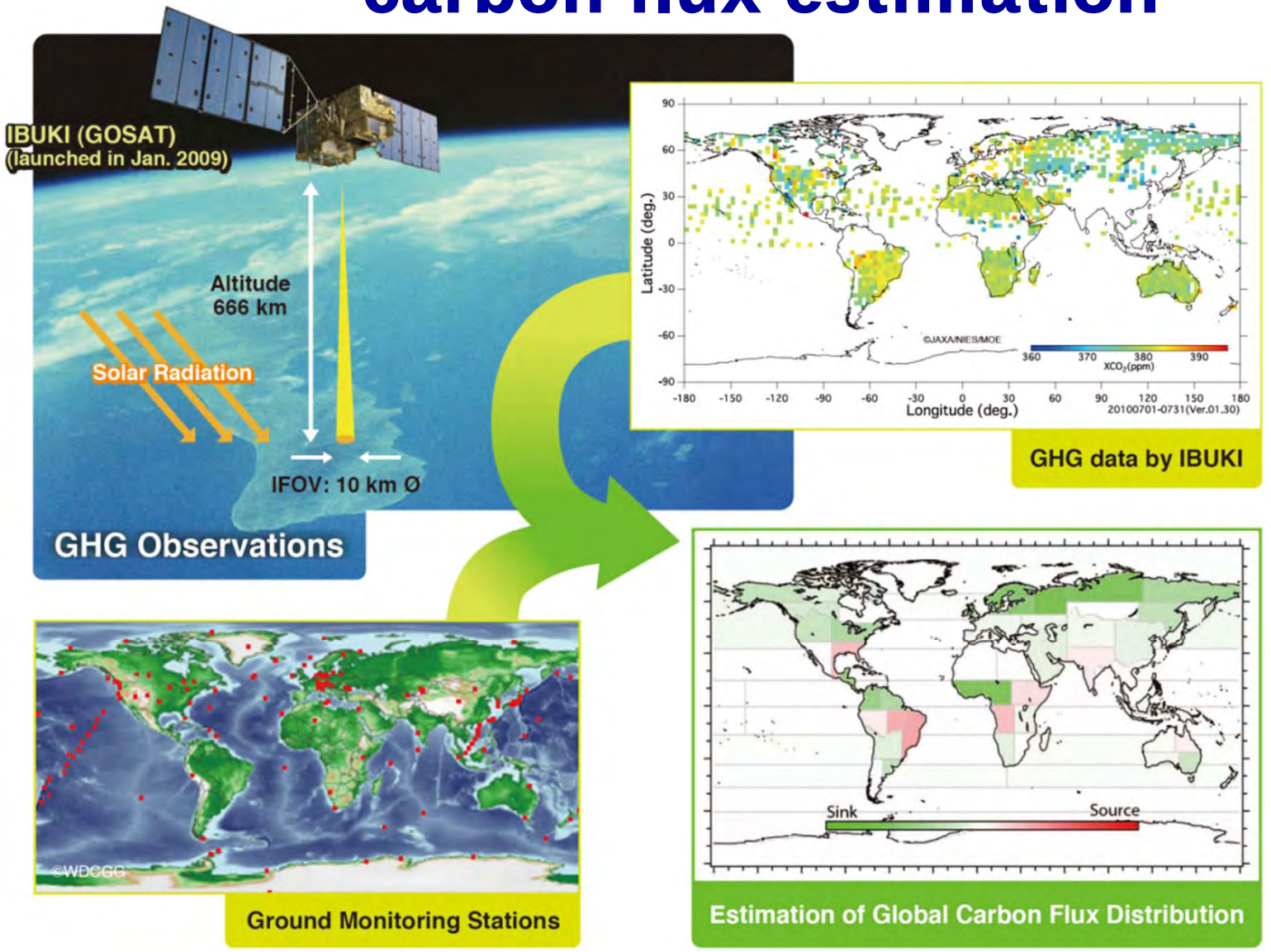


- Fossil fuel & cement:
  8.3±0.4 **(5%)**
  (GtC/yr)
- Land use change (incl. biomass burning):
  1.0±0.5 **(50%)**
  (9.3 GtC) ***GFED***

- Atmospheric growth:
  4.3±0.1 **(23%)**
- Land sink:
  2.6±0.8 **(31%)**
- Ocean sink:
  2.5±0.5 **(20%)**

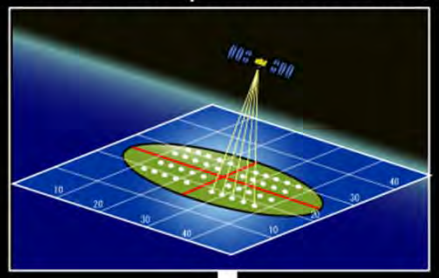
(C. Le Quéré et al. (2013): The global carbon budget 1959–2011, doi:10.5194/essd-5-165-2013)

Contribution of satellite data to carbon flux estimation



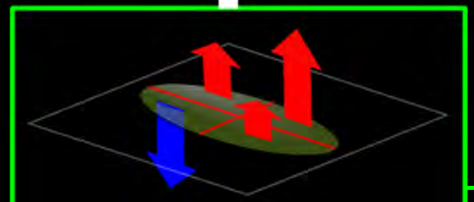
A Priori Flux Data Used in the Inversion

GOSAT's Footprint Information



JCDAS
Analysis Data

NIES-08.1
Transport Model

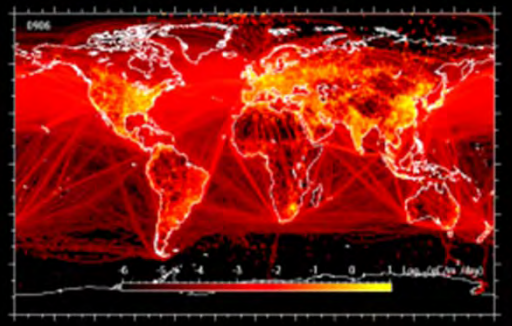


A Priori Flux
Datasets

Anthropogenic Emission Data ODIAC

- Monthly data
- Resolution: 1 km × 1 km
(→ Remapped to 1° × 1°)
- Ver. 3.0 includes emissions from ships and airliners
- Data prepared for 2009

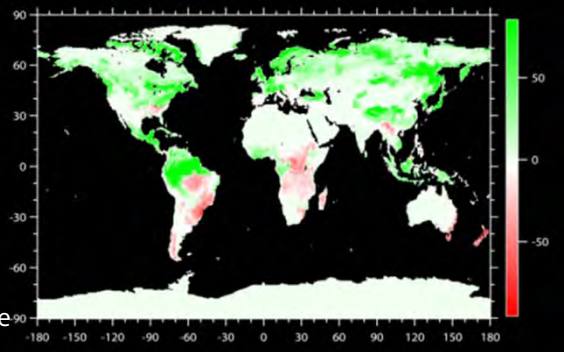
Oda et al., 2010 Atmos. Chem. Phys.



Terrestrial Biosphere-Atmosphere Flux Data

- Generated with vegetation process model VISIT
- **Biomass burning data (GFED ver.3.0) included**
- Daily data
- Resolution: 0.5° × 0.5°
(→ Remapped to 1° × 1°)

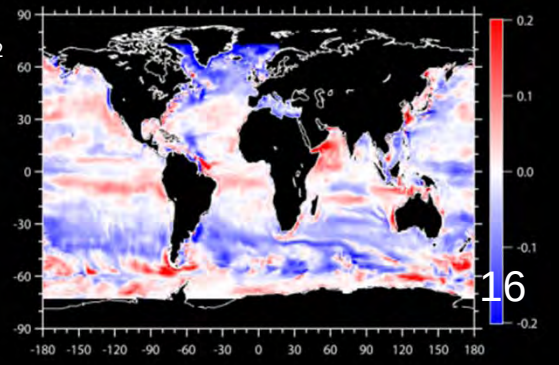
Ito, 2010 Saito et al., 2010 J. Climate
van der Werf et al. 2010 ACP



Ocean-Atmosphere Flux Data

- Generated with ocean pCO_2 data assimilation system
- Monthly data
- Resolution 1° × 1°

Valsala et al., 2008 J. Climate
Valsala et al., 2010 Tellus



(by T. Takagi & S. Maksyutov (NIES))

Improved regional CO_2 fluxes

Demonstrated the utility of satellite-based concentration data in the estimation of global CO_2 fluxes

Result of regional CO_2 flux estimation

Data released: estimates for June 2009 to May 2010

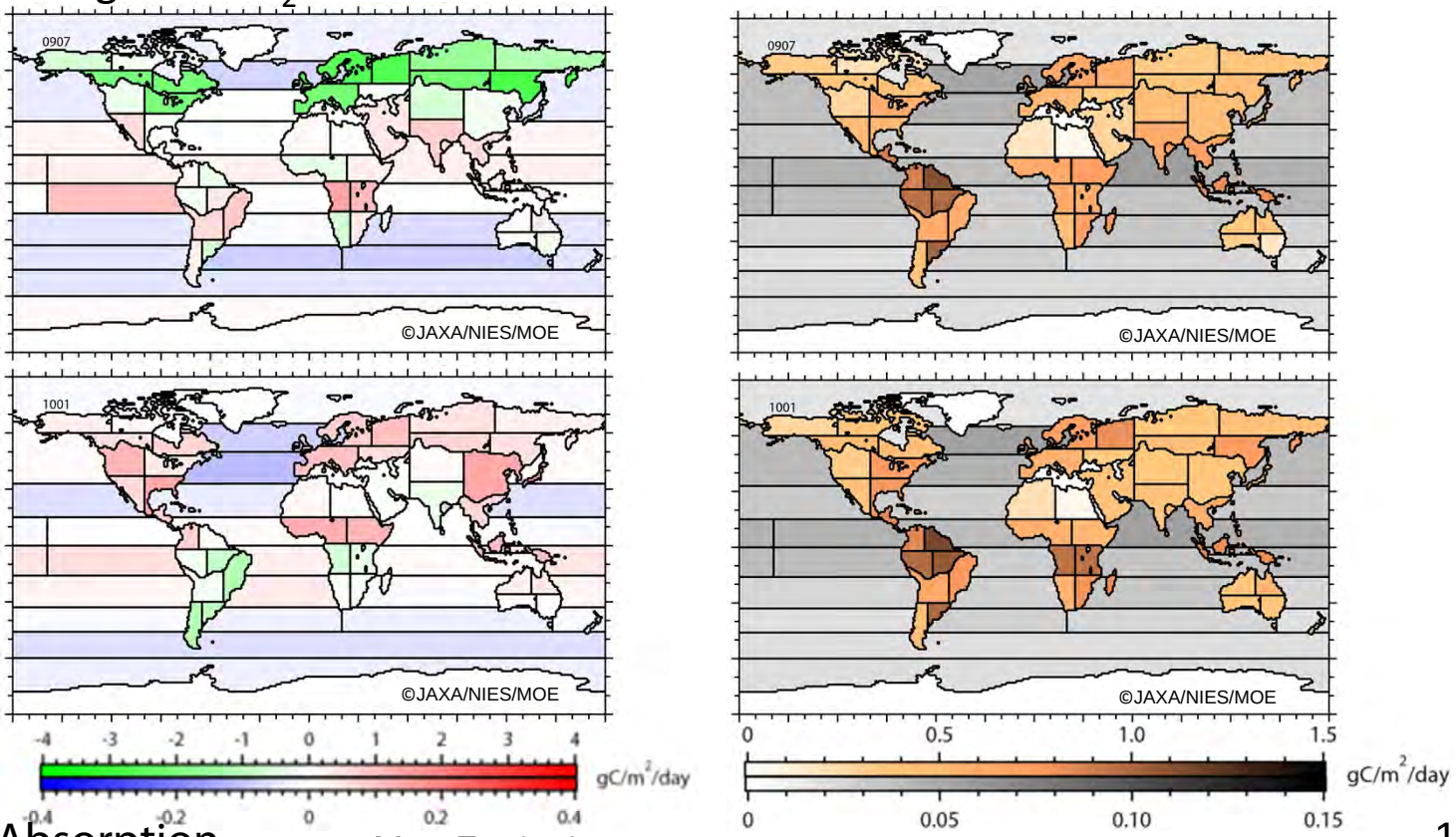
(Level 4A)

Regional CO_2 Flux Estimates

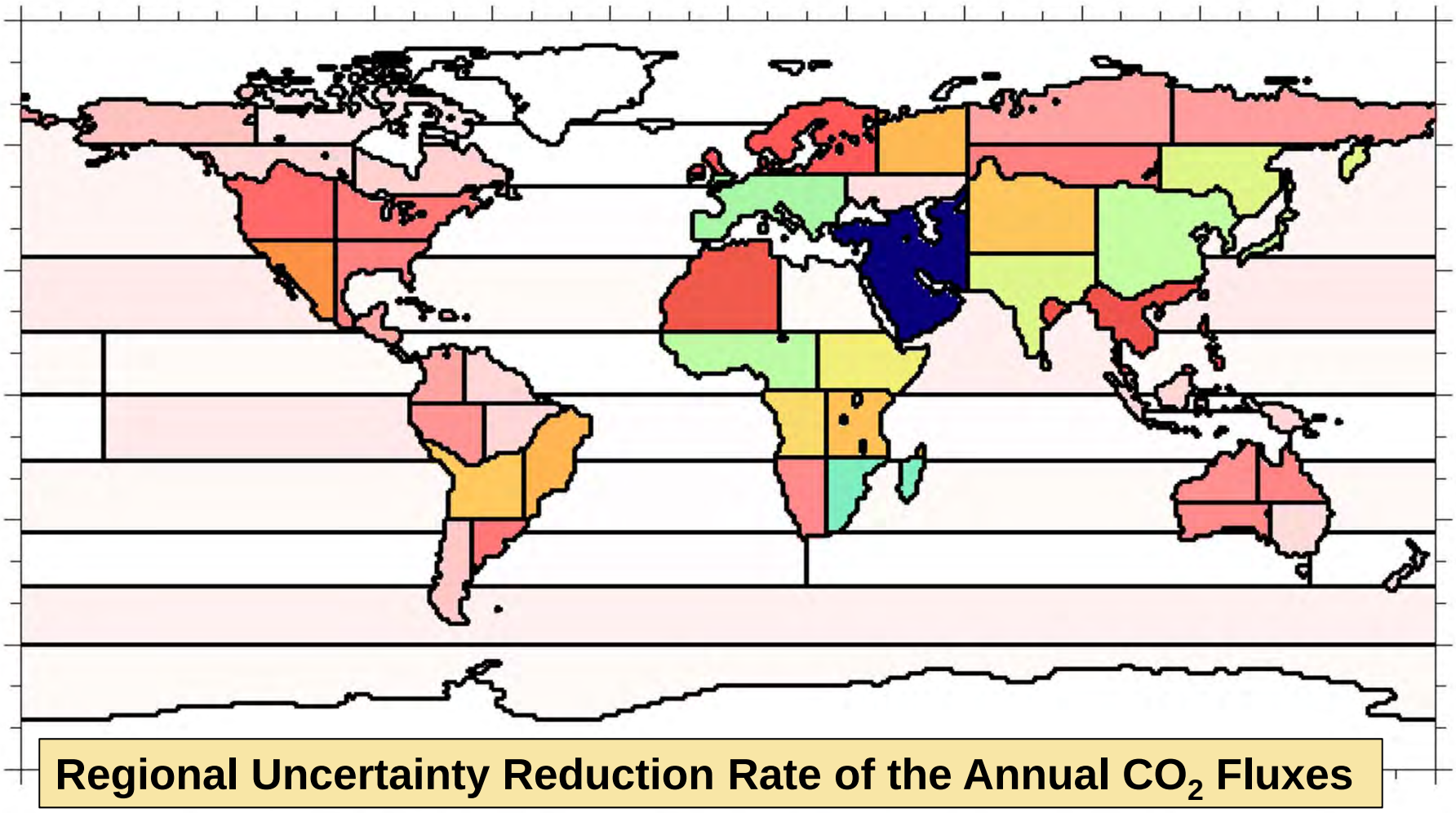
CO_2 Flux Uncertainties

<u>July 2009</u>
(Summer in Northern Hemisphere)

<u>January 2010</u>
(Winter in Northern Hemisphere)



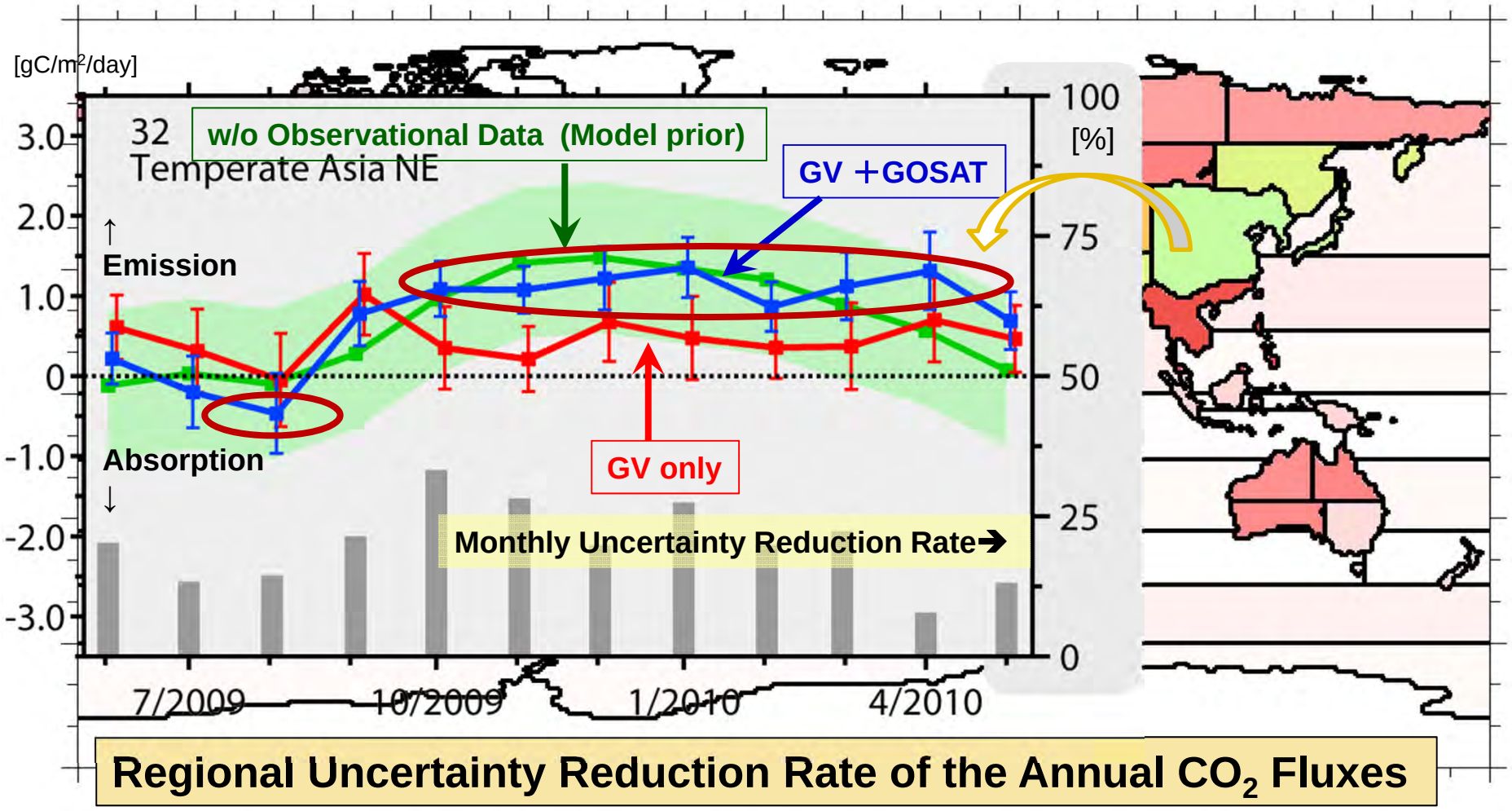
Regional CO_2 Flux Estimates and Improvement of the Uncertainties



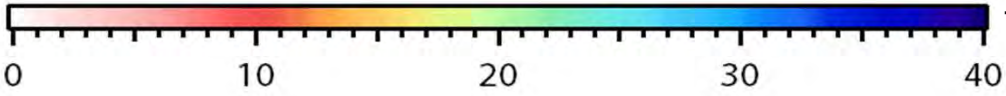
Regional Uncertainty Reduction Rate of the Annual CO_2 Fluxes

Takagi et al (2011).

Regional CO_2 Flux Estimates and Improvement of the Uncertainties

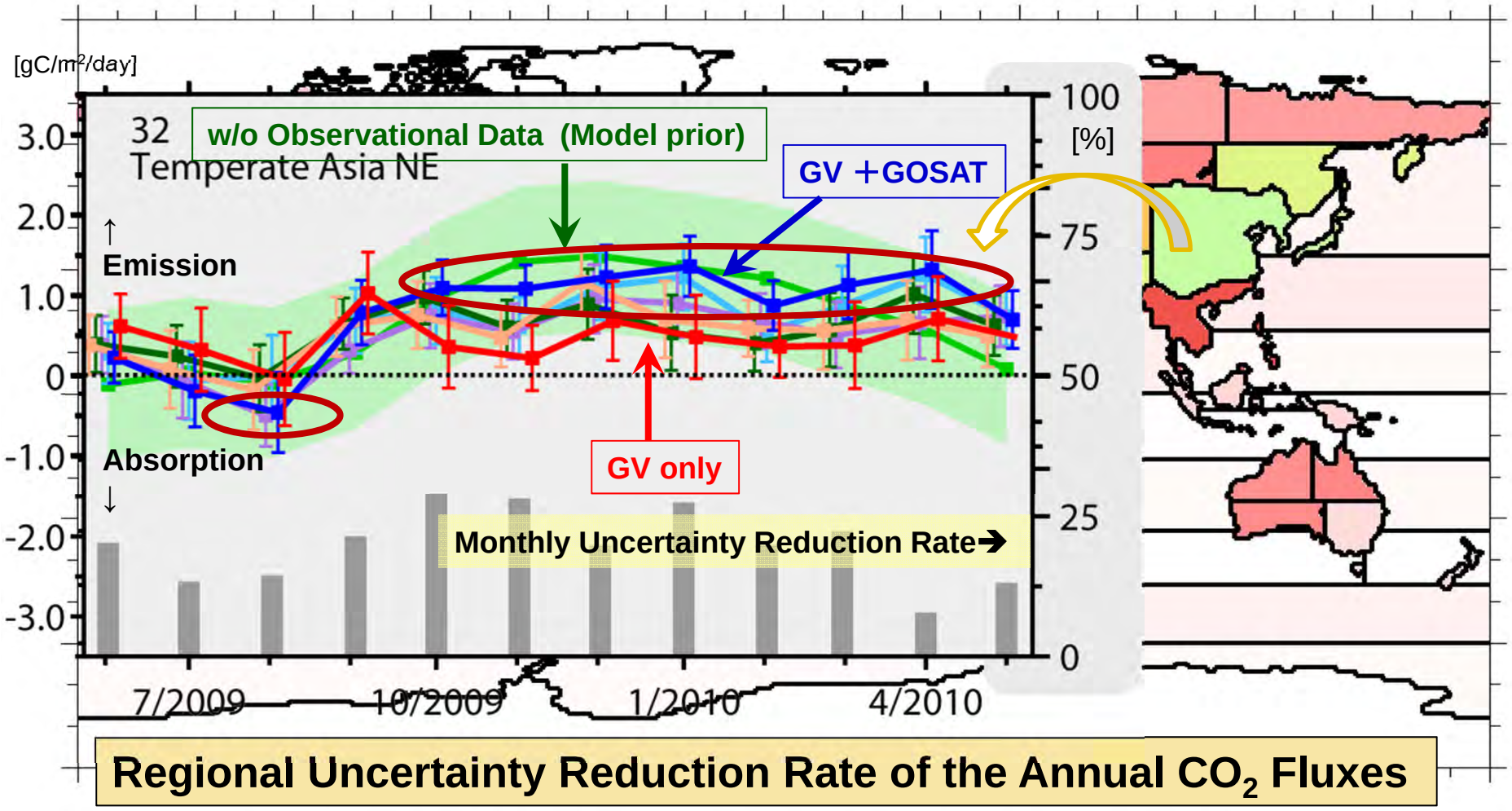


Regional Uncertainty Reduction Rate of the Annual CO_2 Fluxes

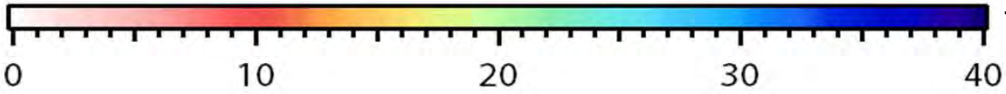


Takagi et al (2011).

Regional CO_2 Flux Estimates and Improvement of the Uncertainties



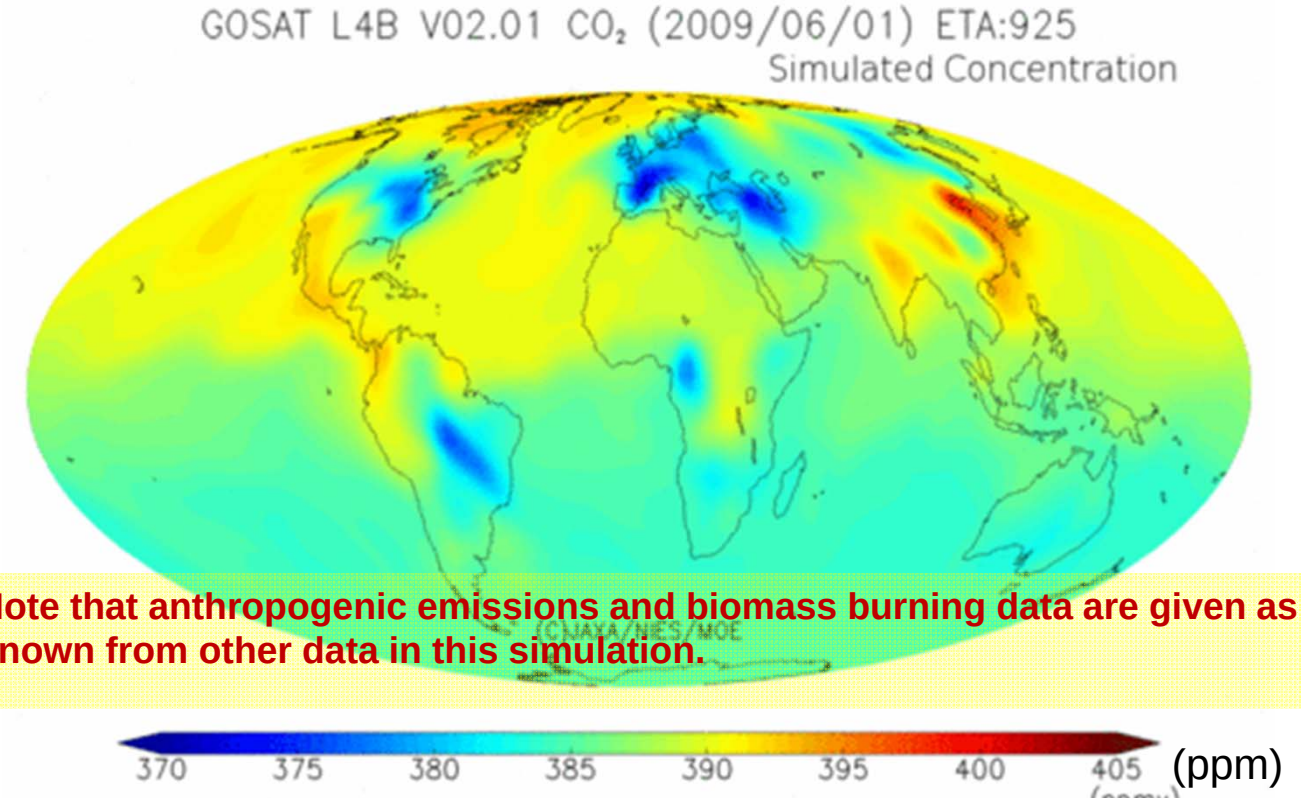
Regional Uncertainty Reduction Rate of the Annual CO_2 Fluxes



Takagi et al (2011).

Example of the GOSAT Level 4B Data Product

Model Simulated global CO_2 concentrations in three dimensions calculated from monthly regional CO_2 flux estimates (GOSAT Level 4A data product) by using an atmospheric tracer transport model.

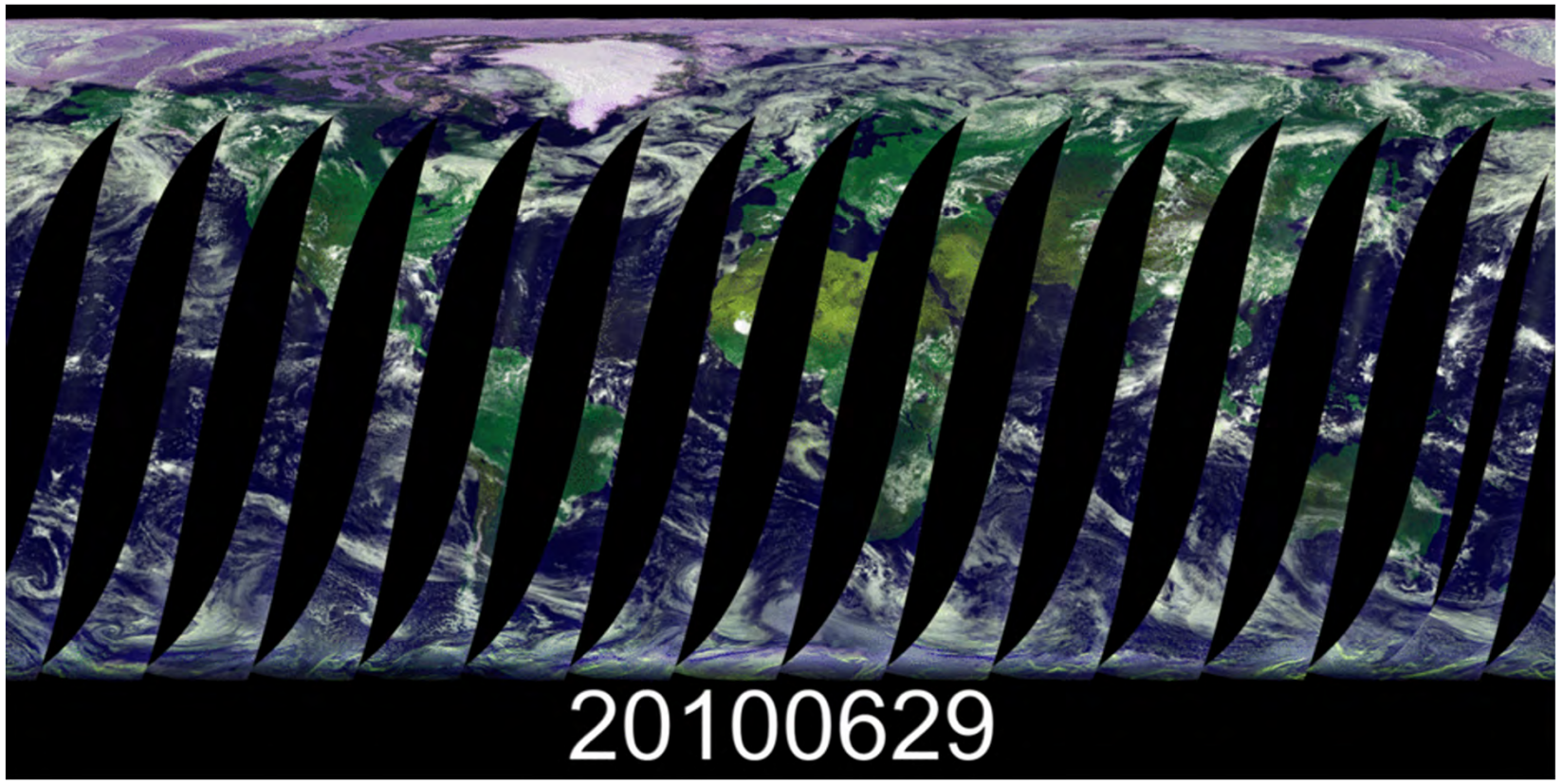


Note that anthropogenic emissions and biomass burning data are given as known from other data in this simulation.

Daily mean animation of global CO_2 on a 2.5° × 2.5° latitude-longitude grid at an altitude of ~ 800 m (June 2009 – May 2010)

Other GOSAT contributions

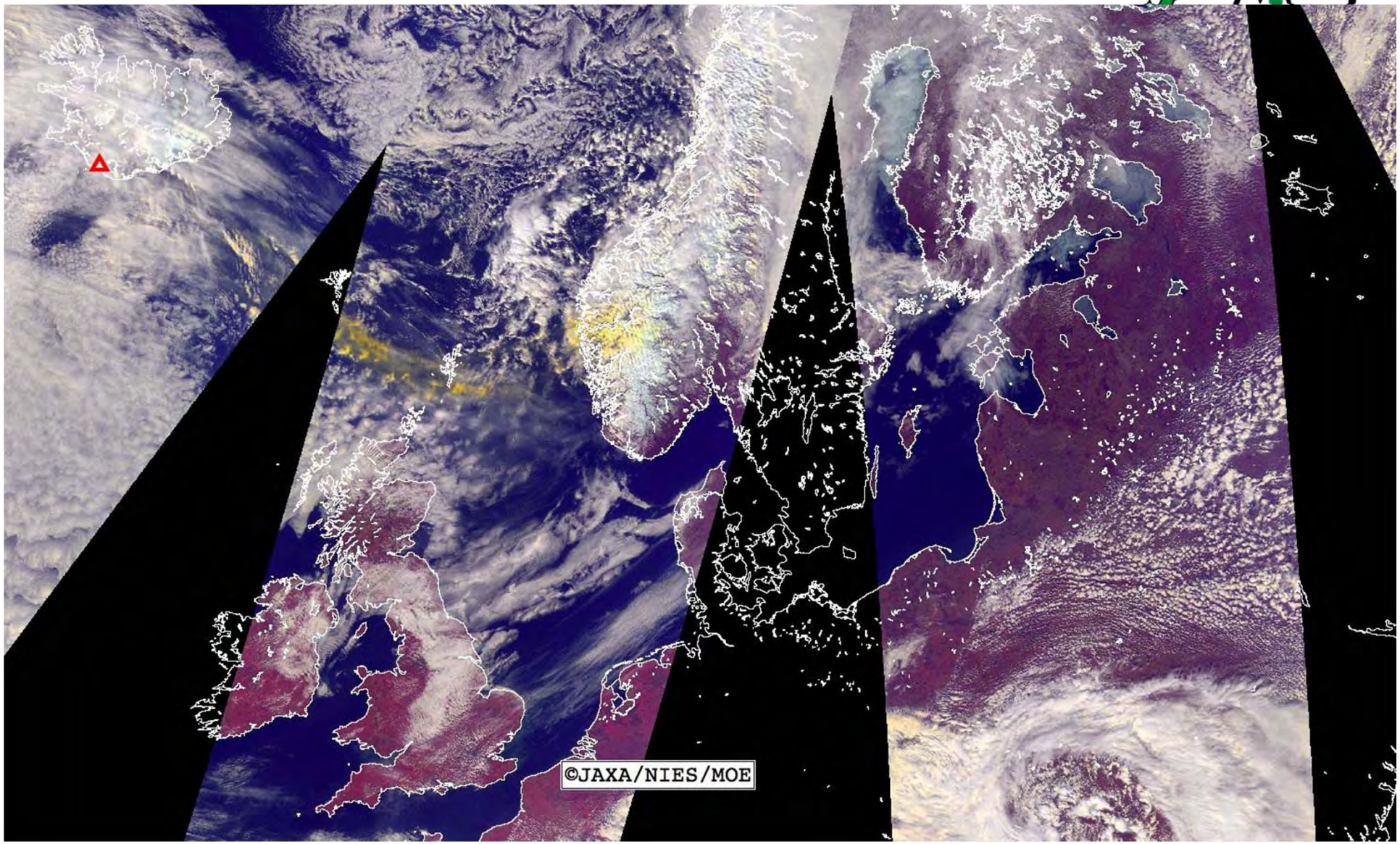
- TANSO-CAI data



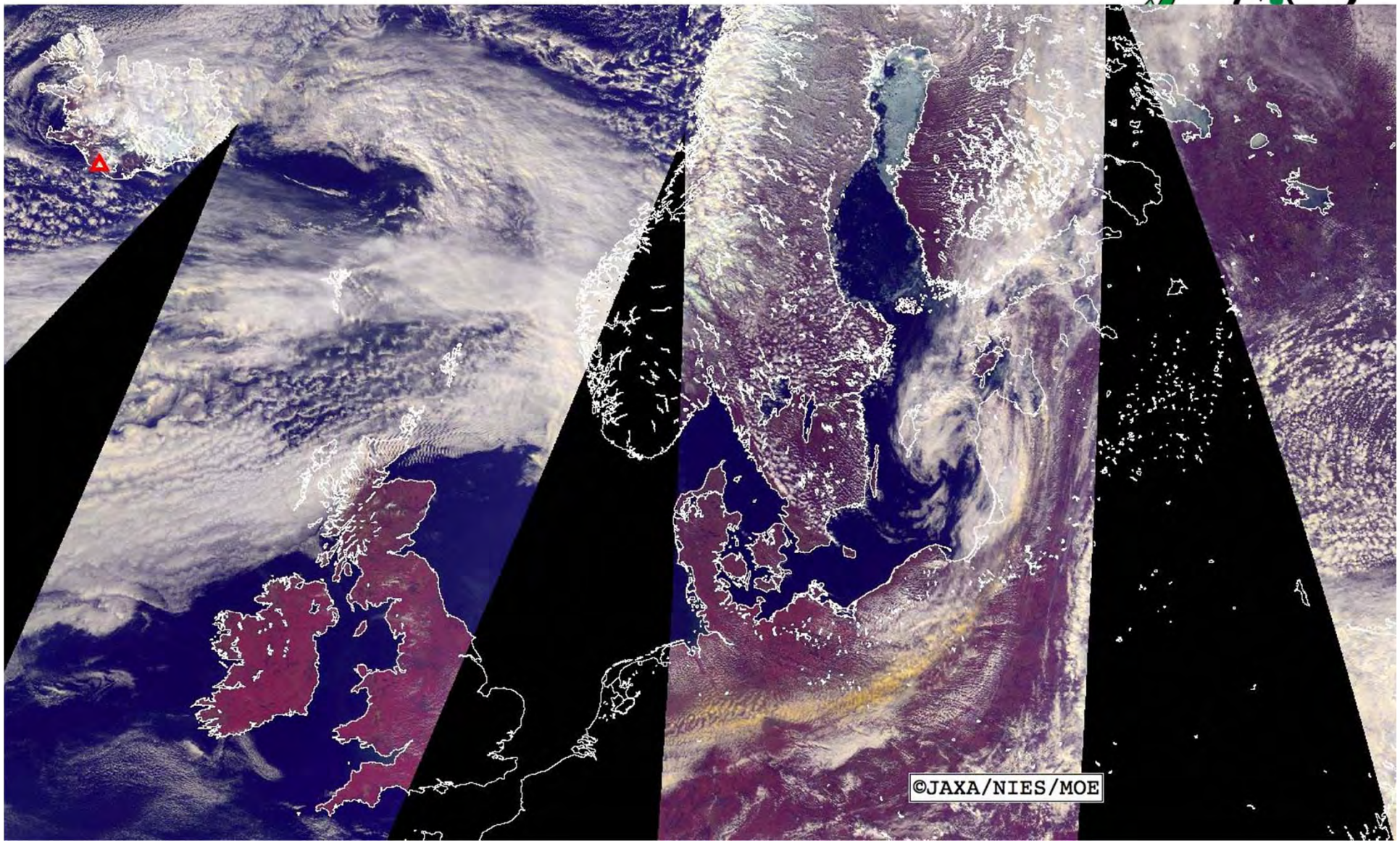
Ash plume Observation by GOSAT in April and May 2010

- **Eruption of Eyjafjallajokull Volcano**

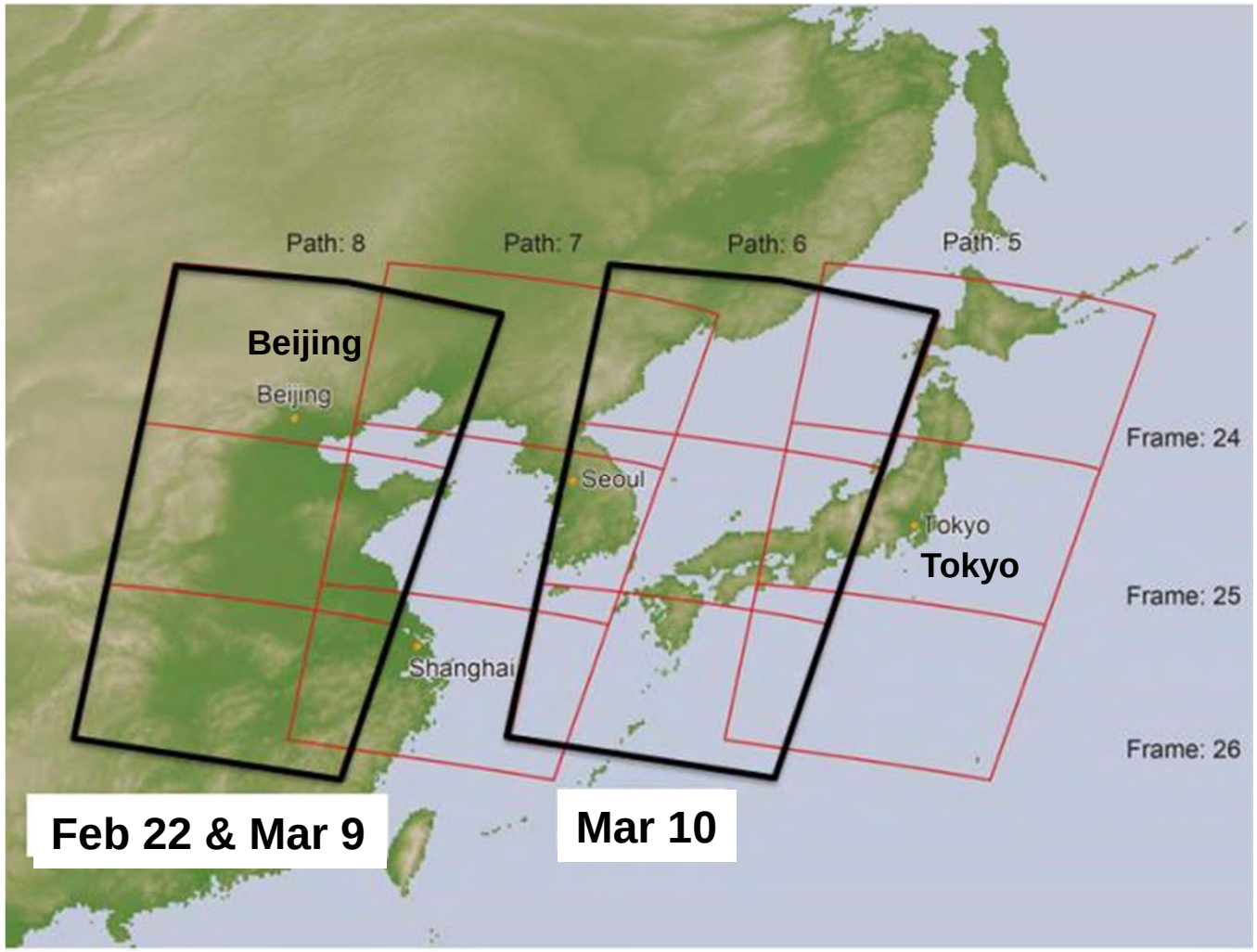
GOSAT TANSO-CAI Composite Image：2010/4/15



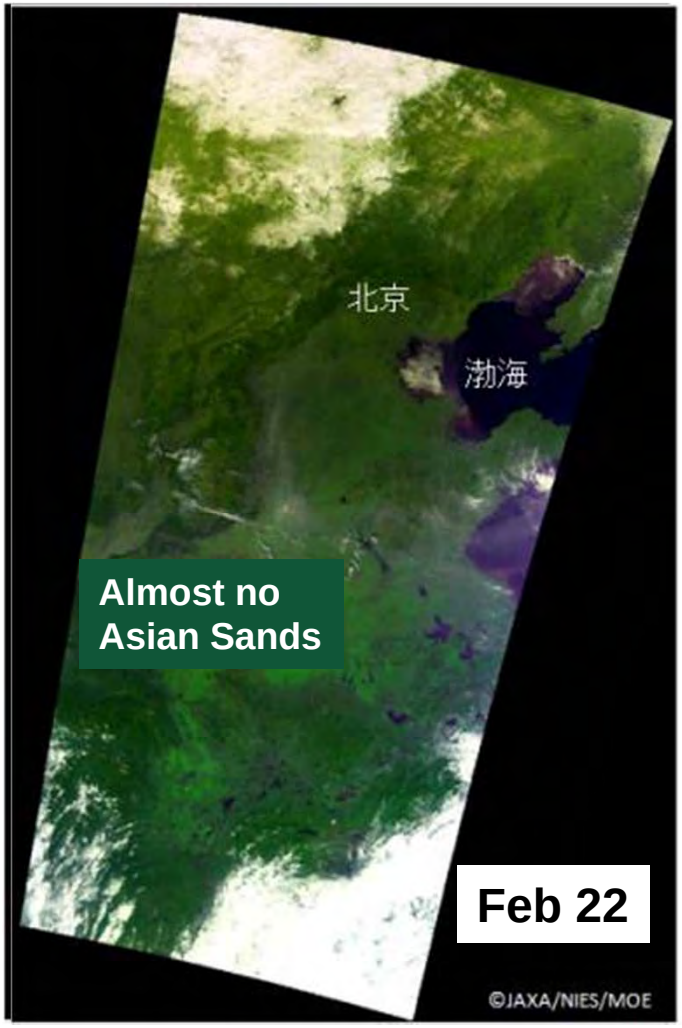
GOSAT TANSO-CAI Composite Image：2010/4/16

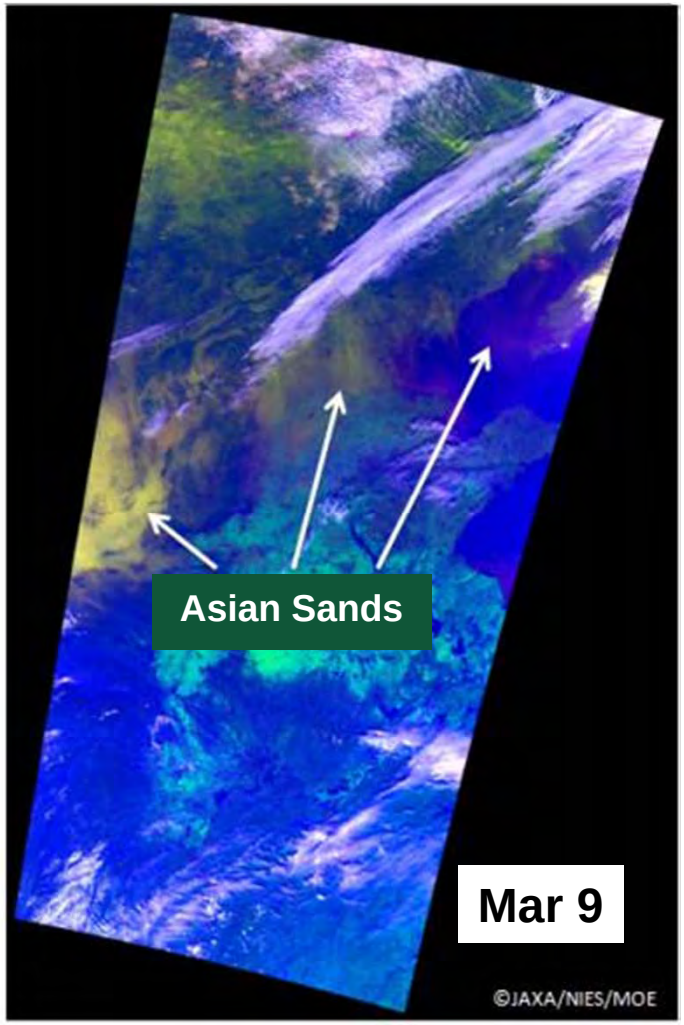


Observation of Asian Sands Advection

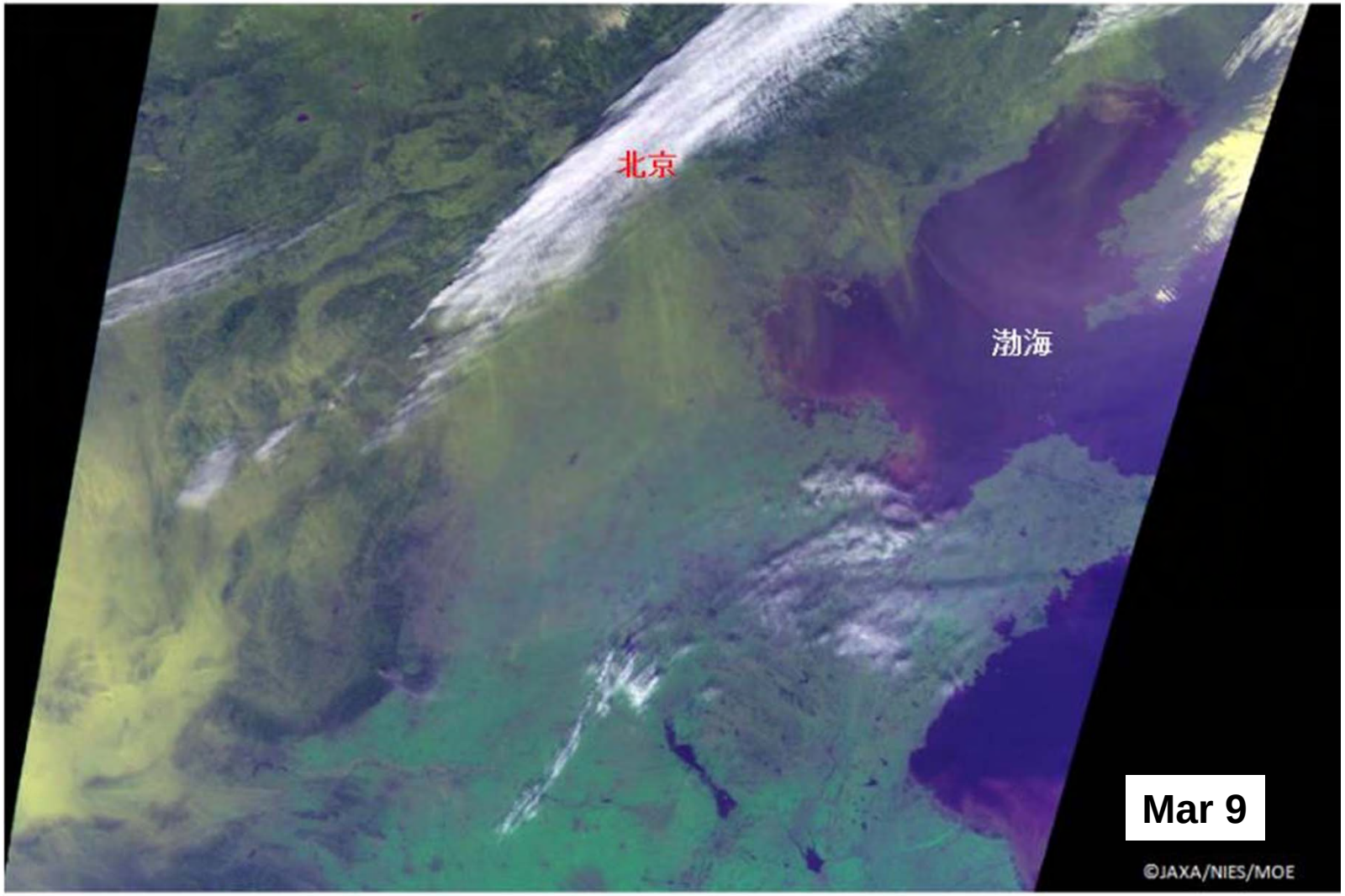


Observation of Asian Sands Advection



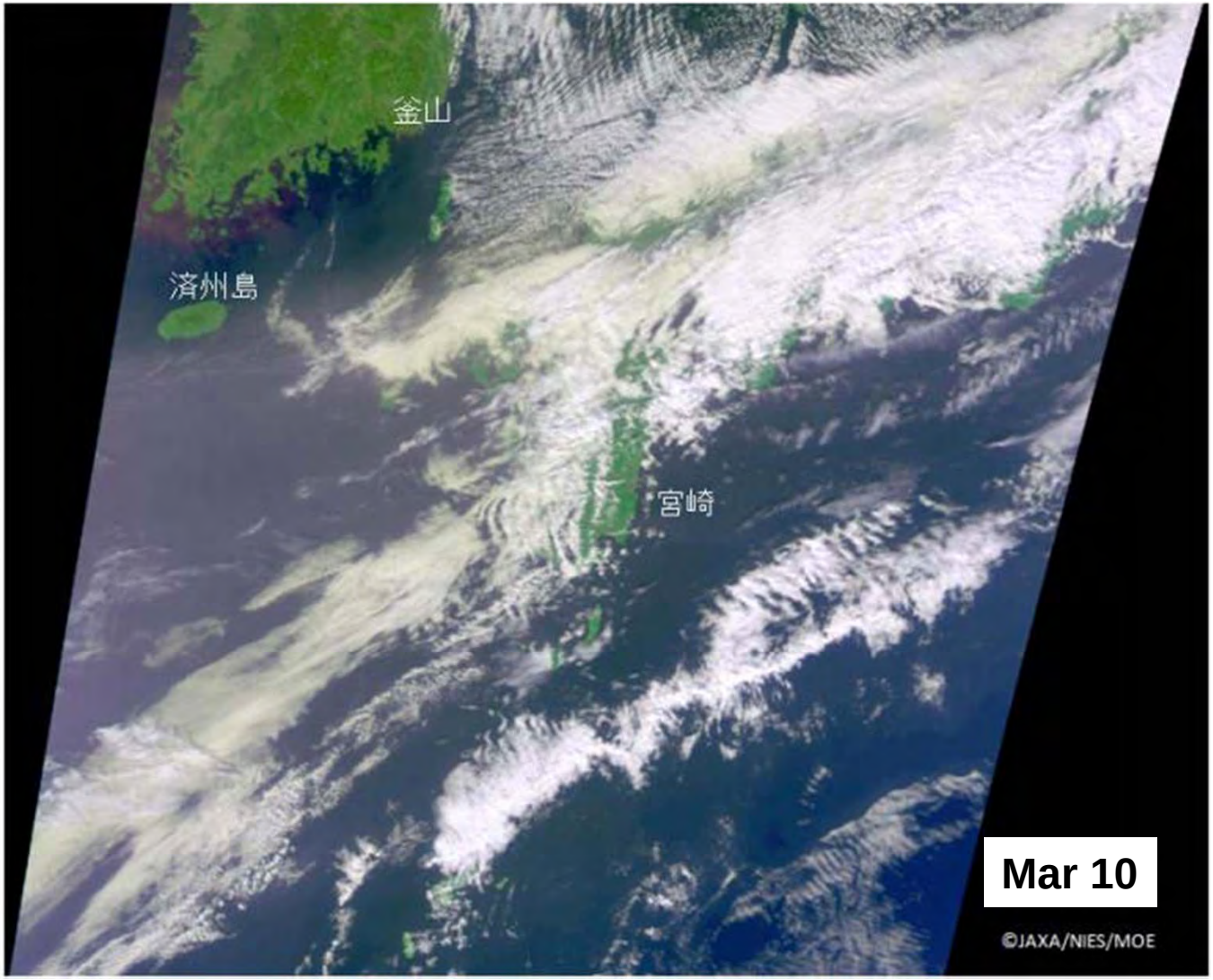


Observation of Asian Sands Advection



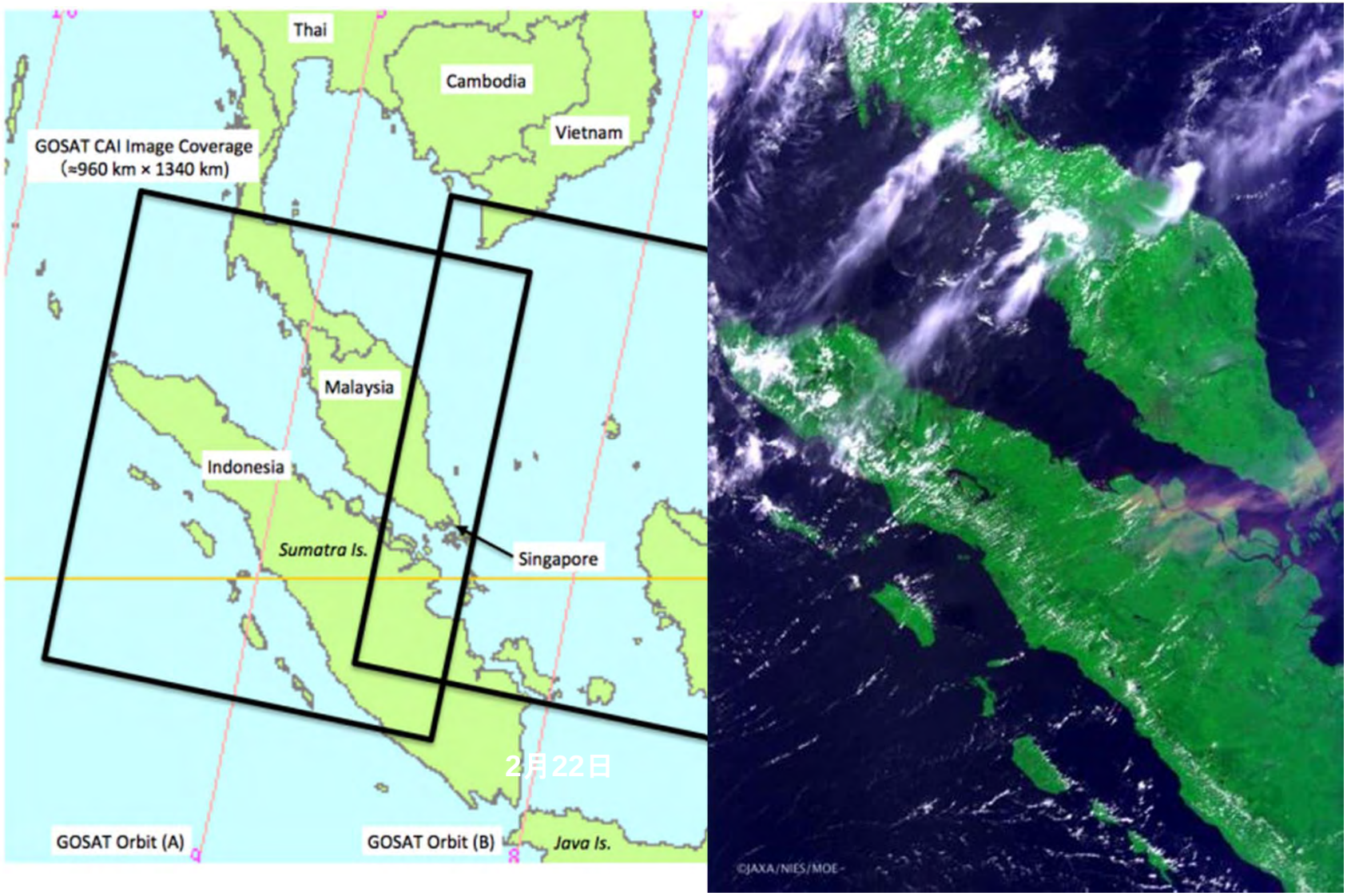
Observation of Asian Sands Advection

Asian Sands From China

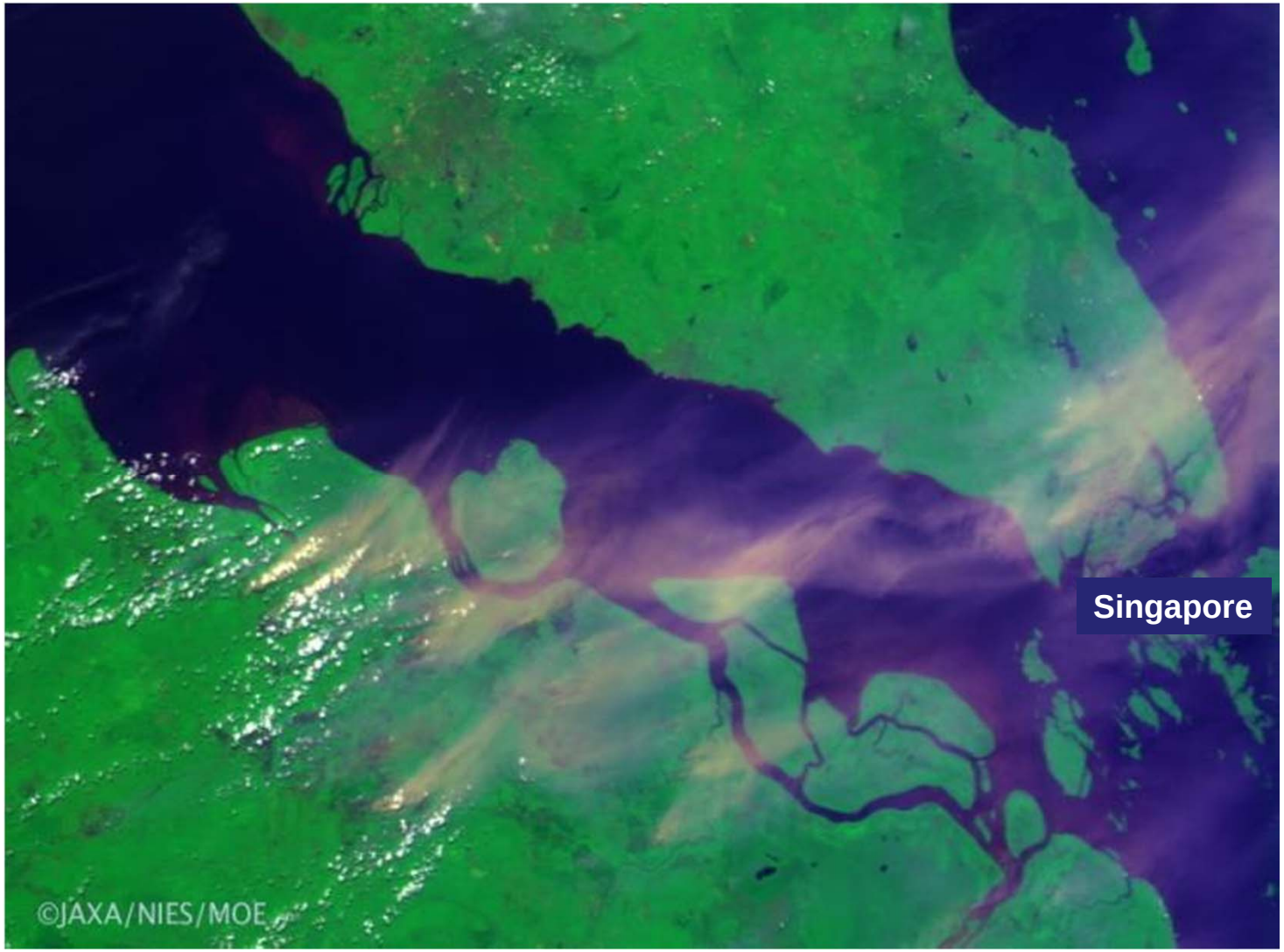


Smoke billowing from the forest fires on the Indonesian island of Sumatra (June 2013)

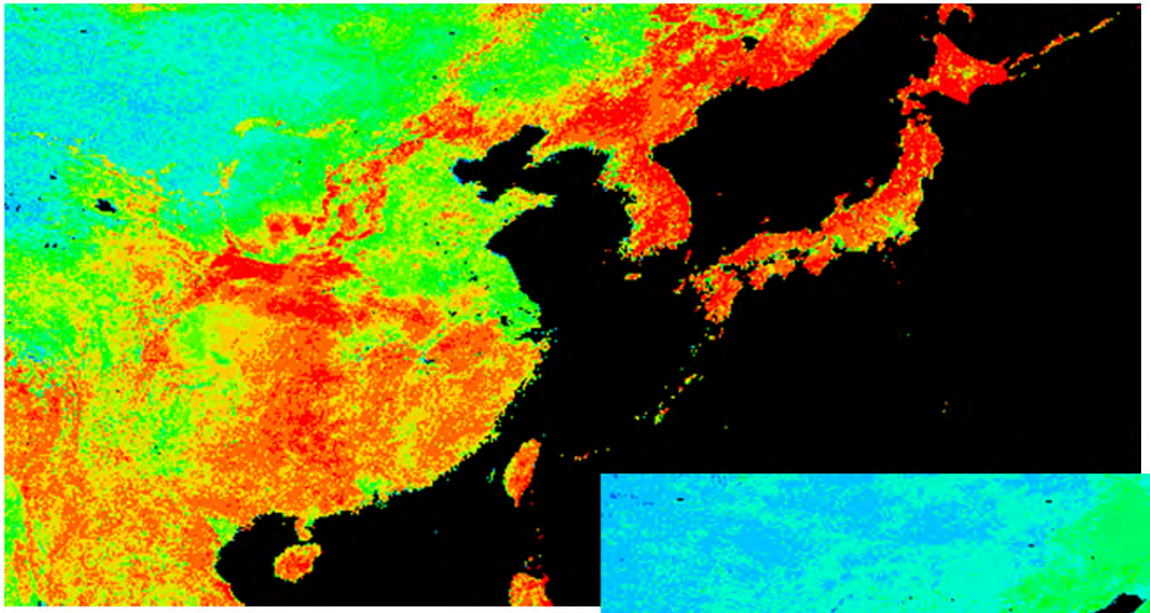
Smoke billowing from the forest fires on the Indonesian island of Sumatra (June 2013)



Smoke billowing from the forest fires on the Indonesian island of Sumatra (June 21, 2013)

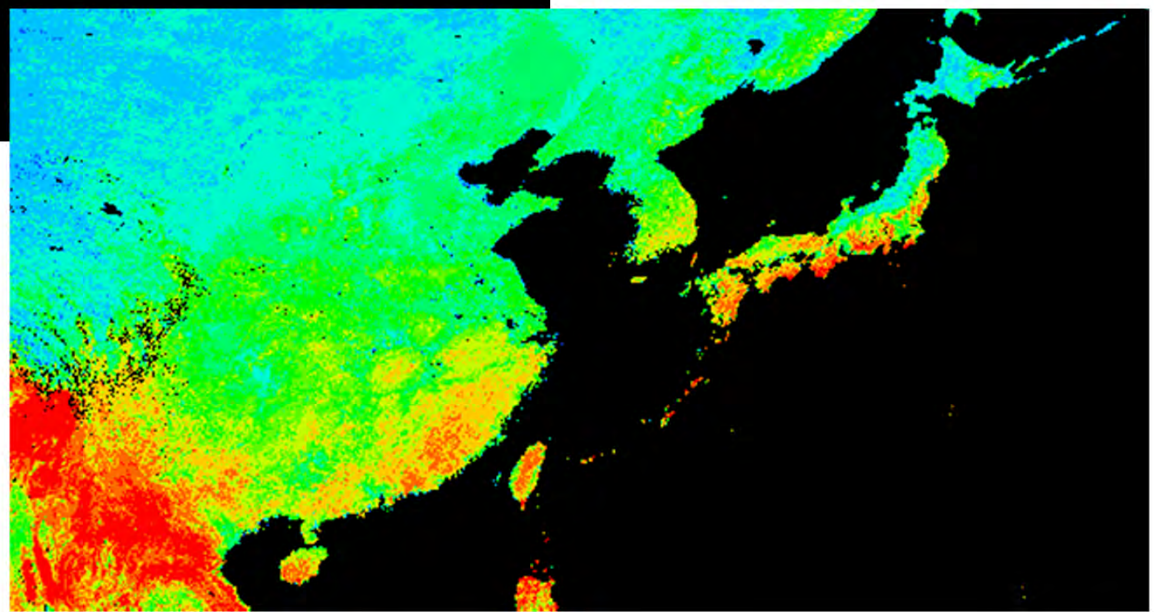


TANSO-CAI L3 NDVI (V01.00)



2009.06.03-07.02

2010.01.02-02.01

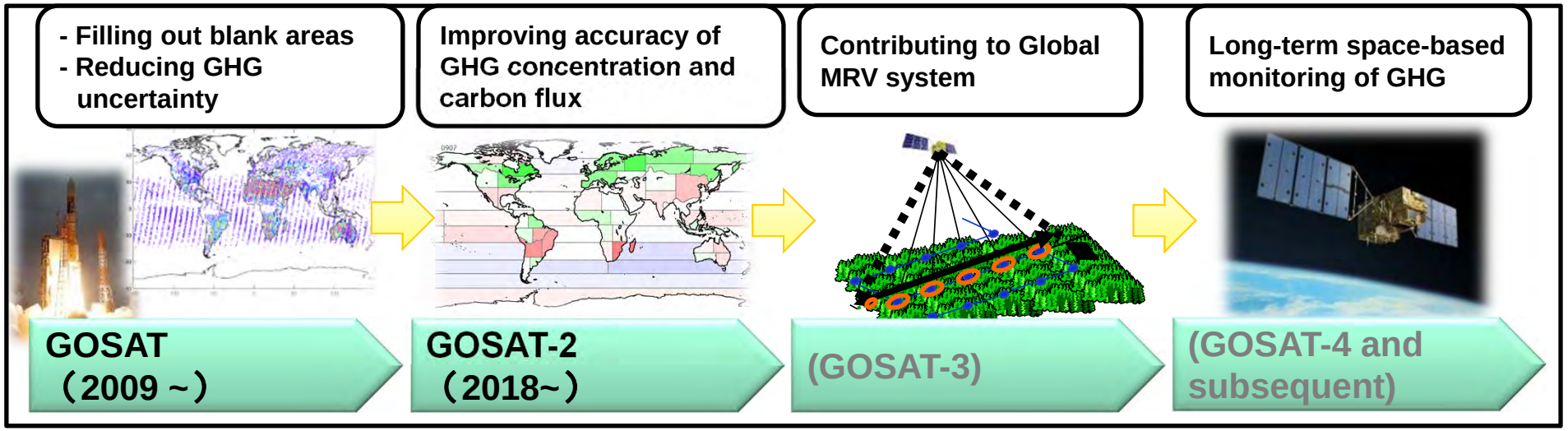


< -0.2
-0.2 - -0.1
-0.1 - 0.0
0.0 - 0.1
0.1 - 0.2
0.2 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
> 0.9

Future perspectives (Visions)

Perspective on future GOSAT missions

(modified slide by MOE @Rio+20 (2012))



Possible contribution of GOSAT series

- Elucidating global carbon cycle through precise observation of CO_2 and CH_4
  - ⇒ **Improvement in climate change prediction**
- Early detection of major changes in climate system
  - ⇒ **Identifying changes in global environment**
- Monitoring of GHG reduction (mitigation efforts) (Incl. REDD+ activities)
  - ⇒ **Contribution to climate policy making**

Concluding Remarks

- GHG concentrations estimated from satellite data are not so much highly accurate (1 ppm < x < 4 ppm (1%) for XCO_2) by now, but have increased the regional coverage of measurements and have contributed to reduce uncertainties in the carbon flux estimates.
- Aerosol and dust information obtained from the GOSAT TANSO CAI data would be also useful for environmental monitoring.

GOSAT Project Webpage:
http://www.gosat.nies.go.jp/index_e.html

Data distribution → http://data.gosat.nies.go.jp/

END