Monitoring and Detection of Carbon Cycle Change using an Integrated Observation, Modeling and Analysis System

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National Institute for Environmental Studies (NIES), Japan

1. Background and Needs
2. Recent Progress in Integrated Observation and Analysis System
3. Summary

Background and Needs in Global C Management

Create Low Carbon Society

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Monitor C-cycle changes globally and in the Asia-Pacific

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Reduce uncertainties in future climate prediction

limited data coverage, uncertainties in models

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Reduce uncertainties in future climate prediction

limited data coverage, uncertainties in models

Monitor C-cycle changes globally and in the Asia-Pacific

Background and Needs in Global C Management

Create Low Carbon Society

Evaluate mitigation and adaptation policies in multi-scale

Global (multi-scale) Carbon Management System

with GEO Strategic Plan (2016-2025), Global Carbon Project (GCP), etc.

Reduce uncertainties in future climate prediction

limited data coverage, uncertainties in models

Monitor C-cycle changes globally and in the Asia-Pacific

Background and Needs in Global C Management

Background:

- High uncertainty still remains in global & regional C-budget due to limited spatial coverage in the observation and uncertainty in models
- Improved data analysis (assimilation) systems using multi-platform (satellites, aircraft, ship, and ground-based) observation data could lead better estimation of C source/sink.

Needs:

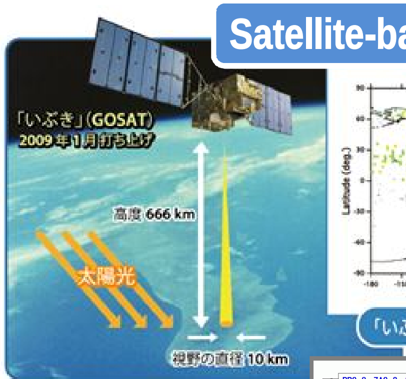
- Accurate C source/sink estimates to evaluate mitigation and adaptation policies, with higher resolution, more operationally
- Detection of near real-time changes in C-cycle globally and in the Asia-Pacific

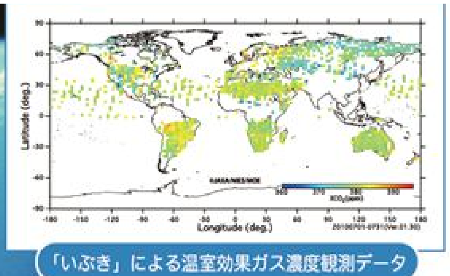
FY2014-2016 Environment Research and Technology Development Fund (ERTDF) **by NIES, JAMSTEC, MRI**

2-1401 Integrated Observation and Analysis System for Early Detection of Carbon Cycle Change Globally and in Asia-Pacific Region

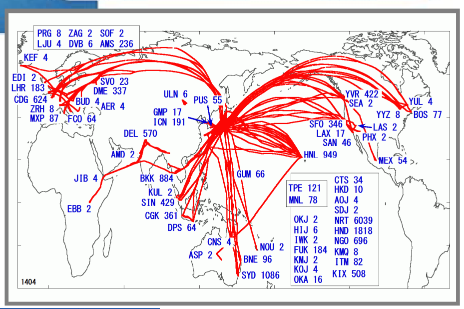
Integrated observing system for GHGs and their surface fluxes globally and in the Asia-Pacific

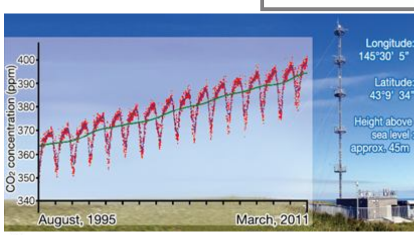
Satellite-based GHGs monitoring

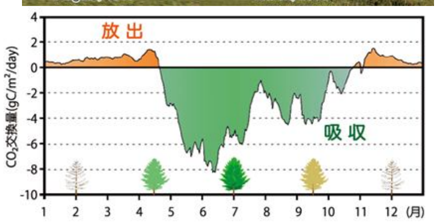




Airplane- and Ship-based monitoring of GHGs





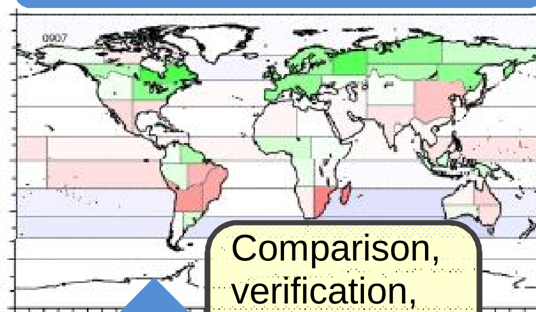


Ground-based monitoring of GHGs concentration and their fluxes

Improved estimates of regional fluxes using atmospheric inverse models

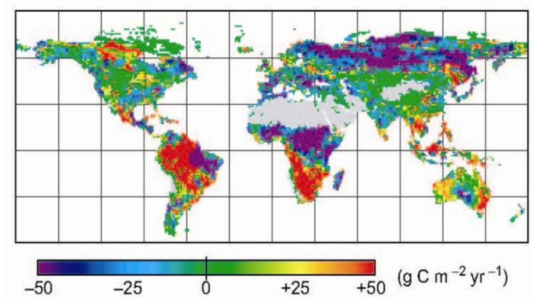
Improved estimates of terrestrial surface fluxes based on bottom-up approaches

Top-down approach



Comparison, verification, uncertainty assessment

Bottom-up approach



Integrated system for combining top-down and bottom-up approaches

Parameter optimization
Data assimilation

Better estimation of temporal & spatial distributions of GHGs concentration and their fluxes

- National & regional estimates of CO_2 sink-source distributions
- Detection of large source from urban area, fire, etc.

- Early detection of C-cycle and environmental changes in A-P region
- Better mitigation & adaptation assessment for environment and society

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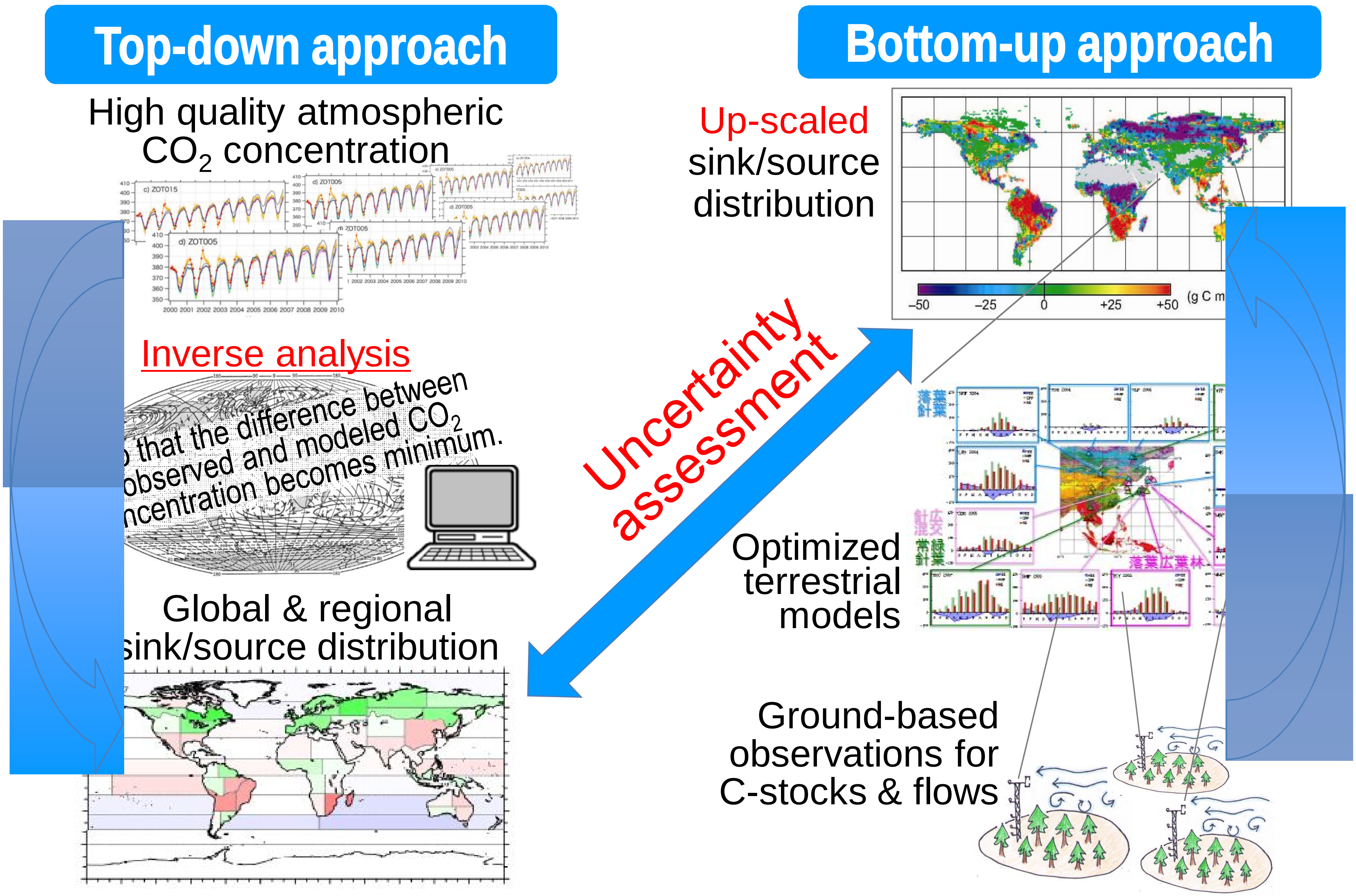
2-1401 Integrated Observation and Analysis System for Early Detection of Carbon Cycle Change Globally and in Asia-Pacific Region



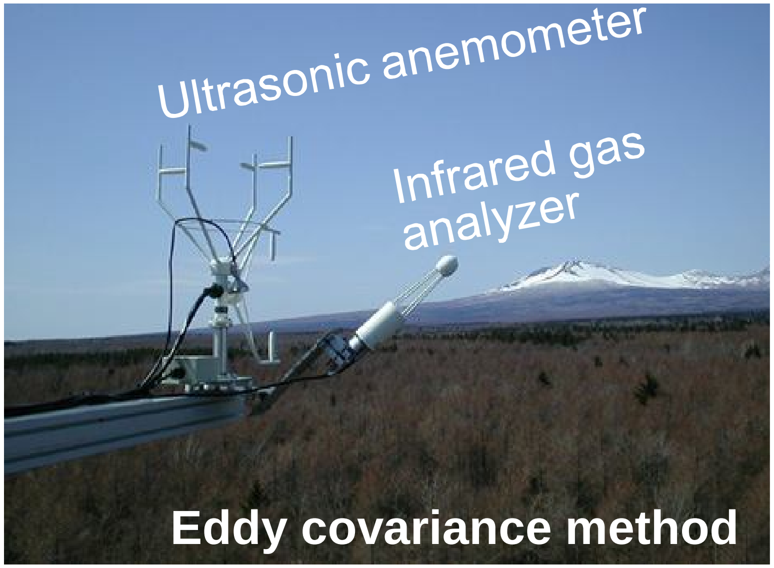
Recent progress in studies of Bottom-up approach

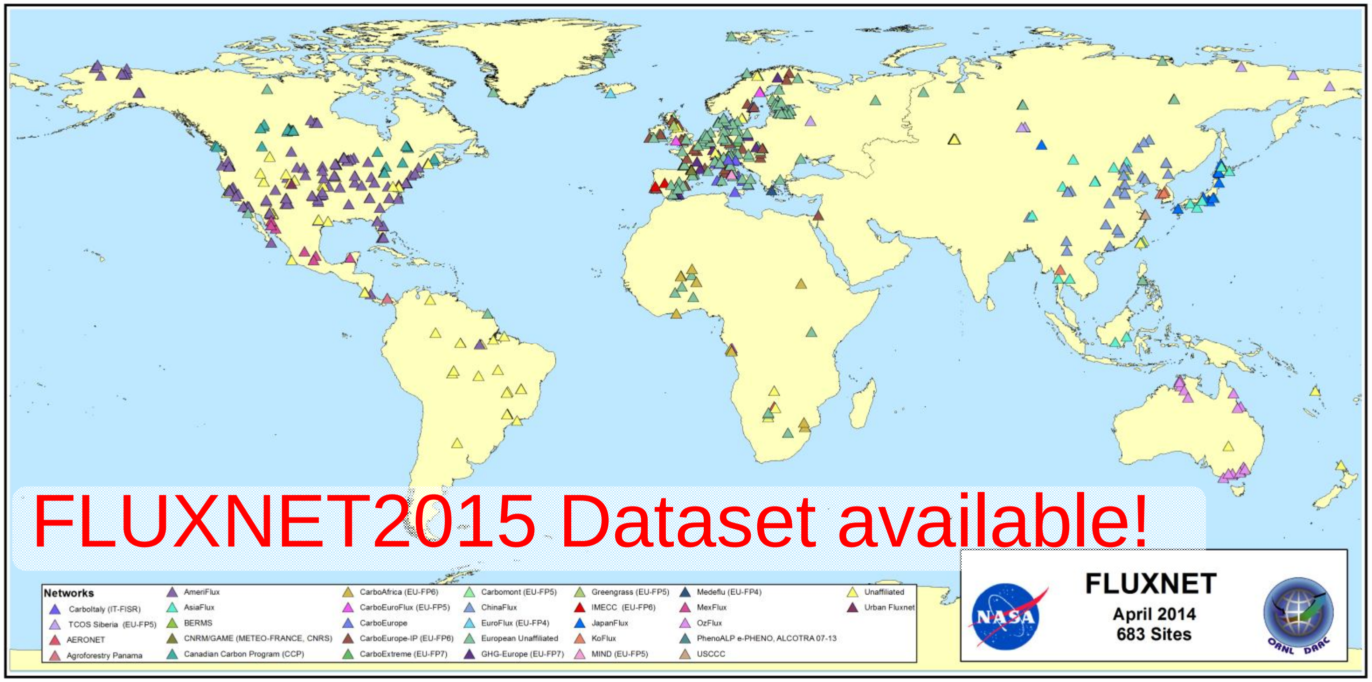
C-budget estimations based on network observation

FLUXNET (1996~)

World-wide network for monitoring CO_2, H_2O, and energy exchanges between terrestrial ecosystems and the atmosphere (> 600 sites)

Archiving CH_4, N_2O flux data (started)





FLUXNET2015 Dataset available!

Location of FLUXNET sites

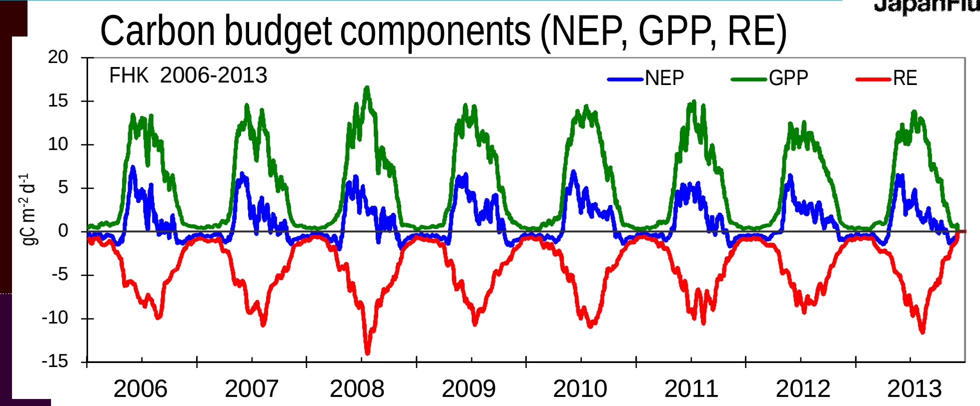
http://fluxnet.ornl.gov

Integrating Worldwide CO_2, Water and Energy Flux Measurements

Long-term monitoring of energy, water vapor, CO_2 fluxes by eddy covariance method

Canopy:

- Meteorology
- Fluxes of CO_2/H_2O/CH_4/energy
- Spectral reflectance

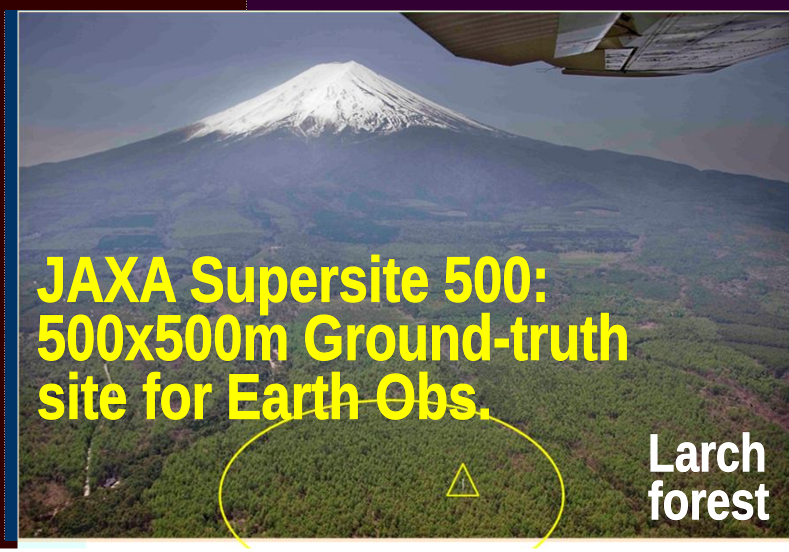


Leaf:

- Photosynthesis
- Spectral reflectance
- C/N, Chlorophyll

C-Cycle in the forest:

- Soil environment (temp, water, heat flux, C/N, …)
- Respiration (Soil, root, etc.)
- Tree census, litter fall , fine root, CWD

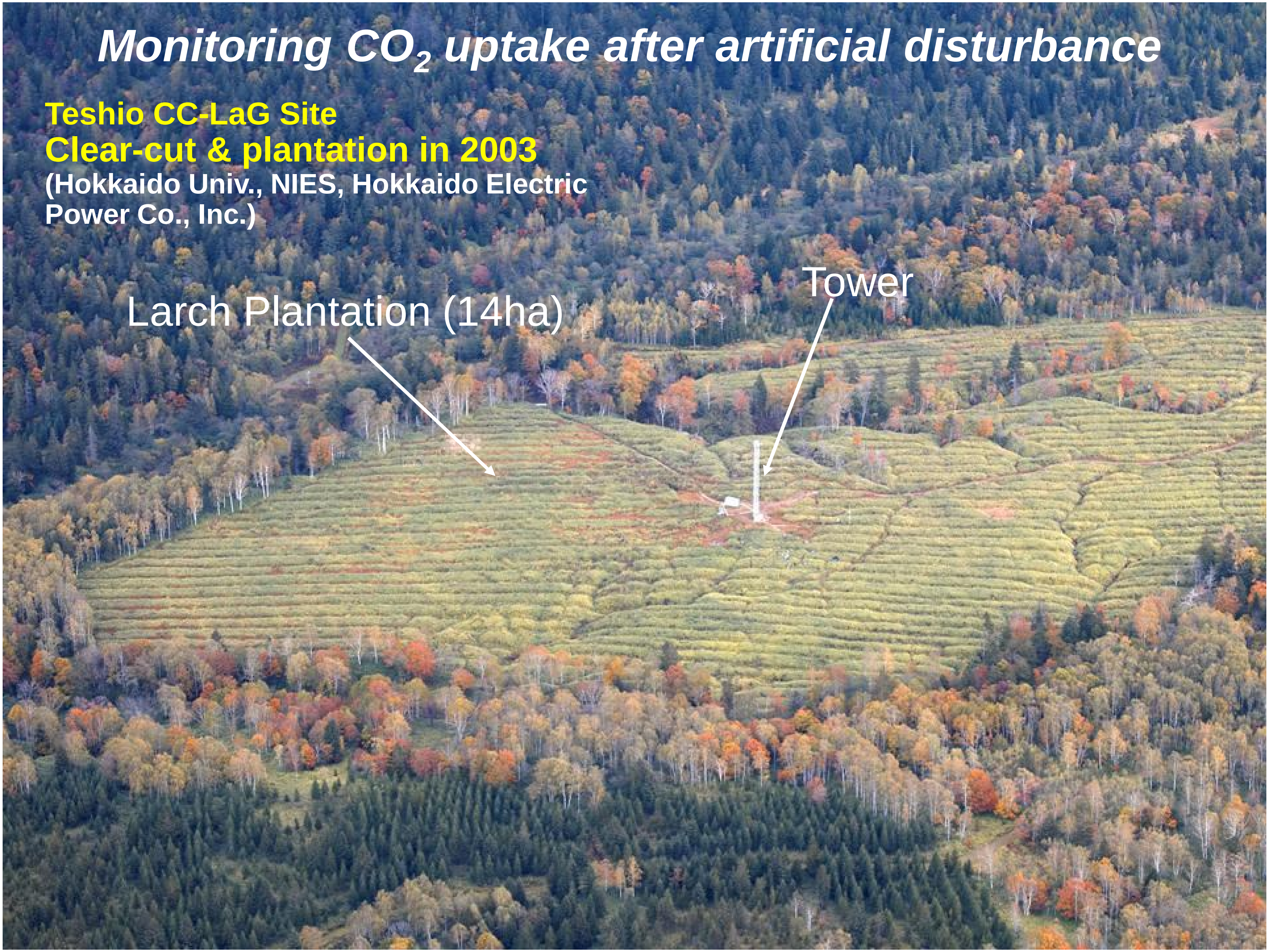


Soil chamber

Canopy access tower

Monitoring CO_2 uptake after artificial disturbance

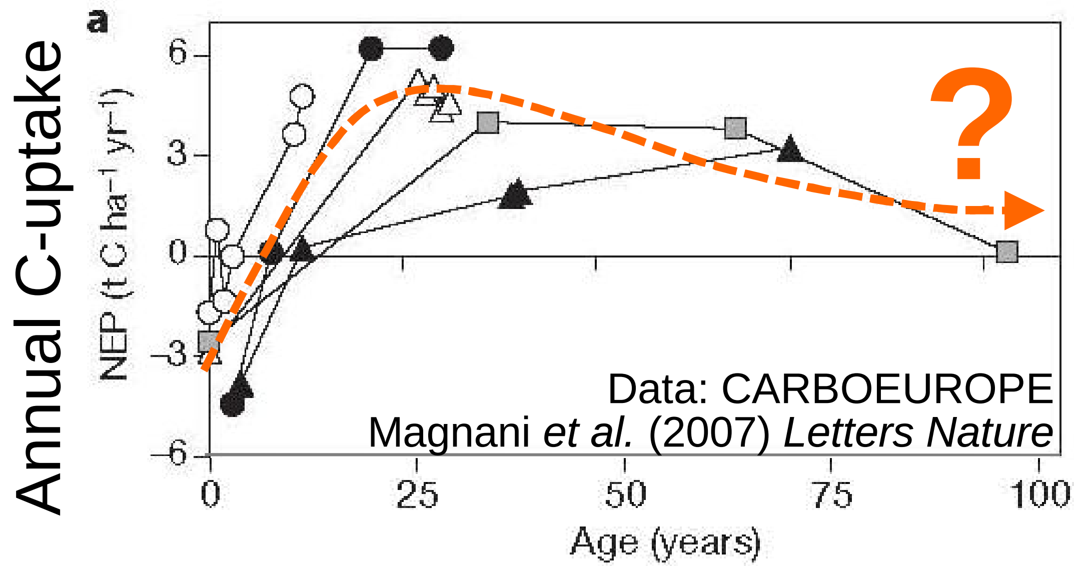
Teshio CC-LaG Site
Clear-cut & plantation in 2003
(Hokkaido Univ., NIES, Hokkaido Electric Power Co., Inc.)



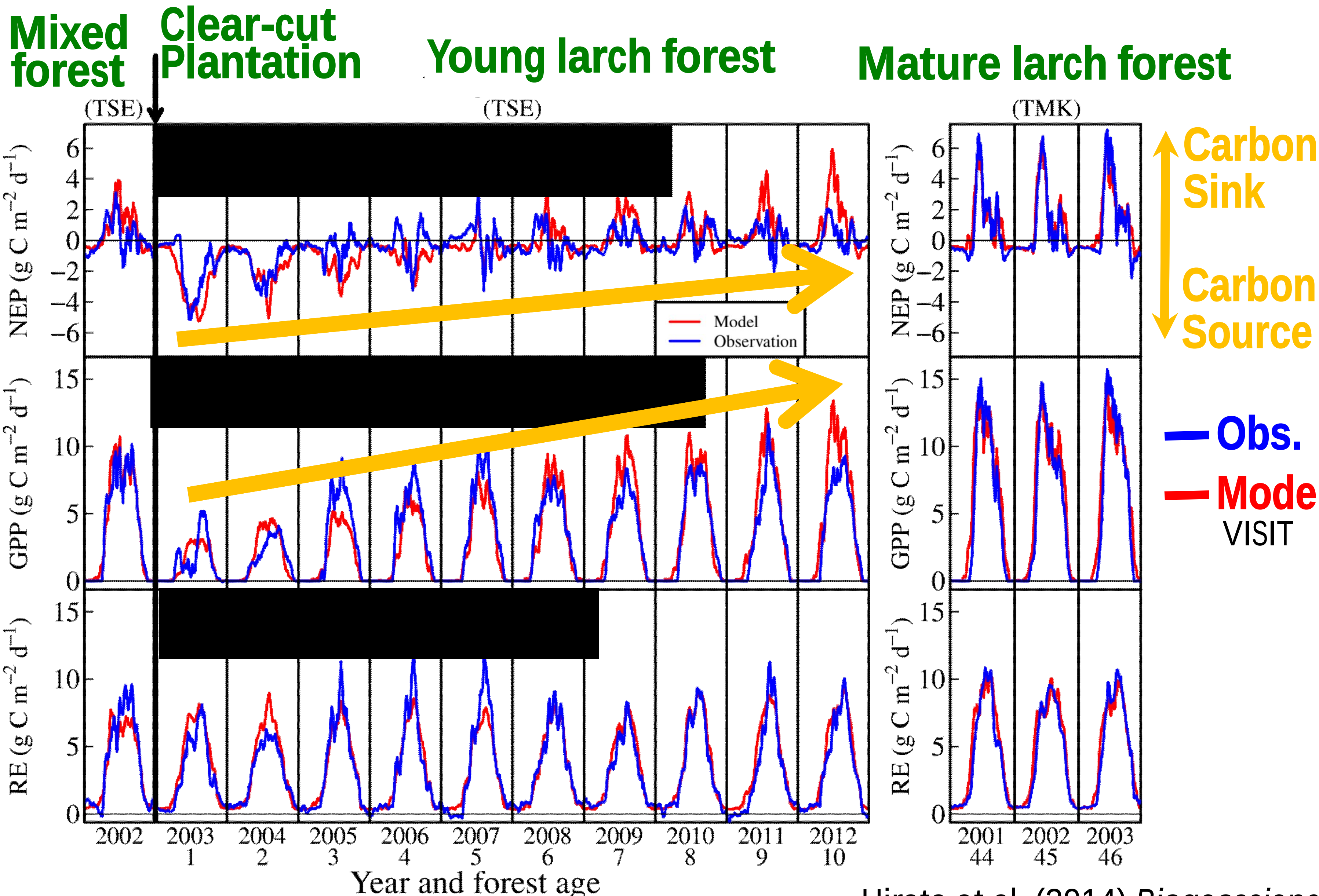
Monitoring CO_2 uptake after artificial disturbance

Teshio CC-LaG Site
Clear-cut & plantation in 2003
(Hokkaido Univ., NIES, Hokkaido Electric Power Co., Inc.)

How does the C-uptake rate change with the years after disturbance?



Terrestrial model validation to improve disturbance impacts

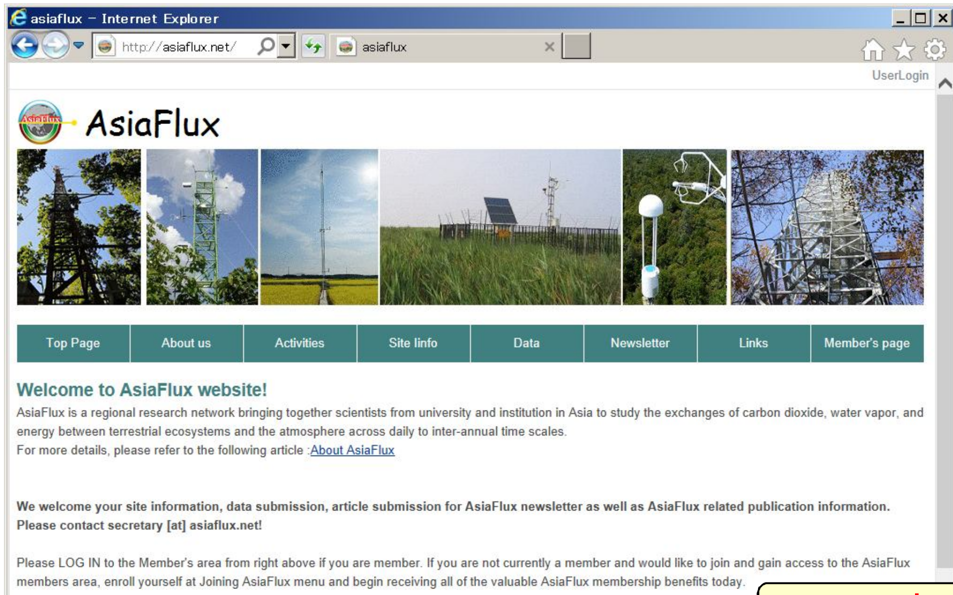


Hirata et al. (2014) *Biogeosciences*

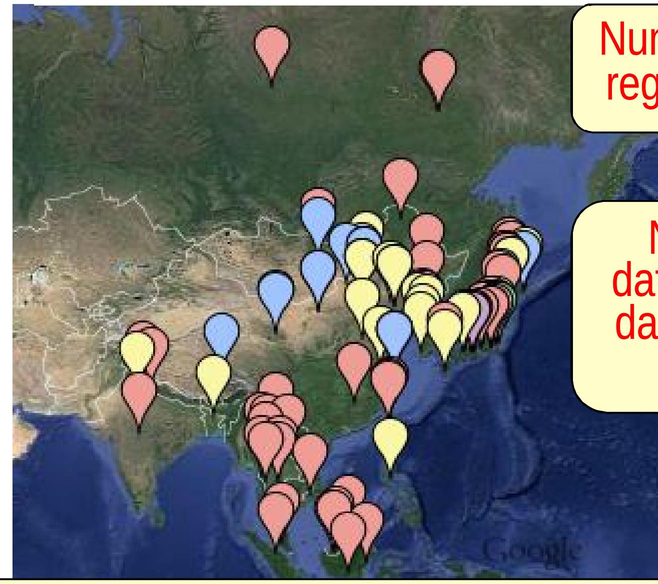
AsiaFlux: A Regional Network in FLUXNET

AsiaFlux Tsukuba Office (CGER/NIES)

http://asiaflux.net



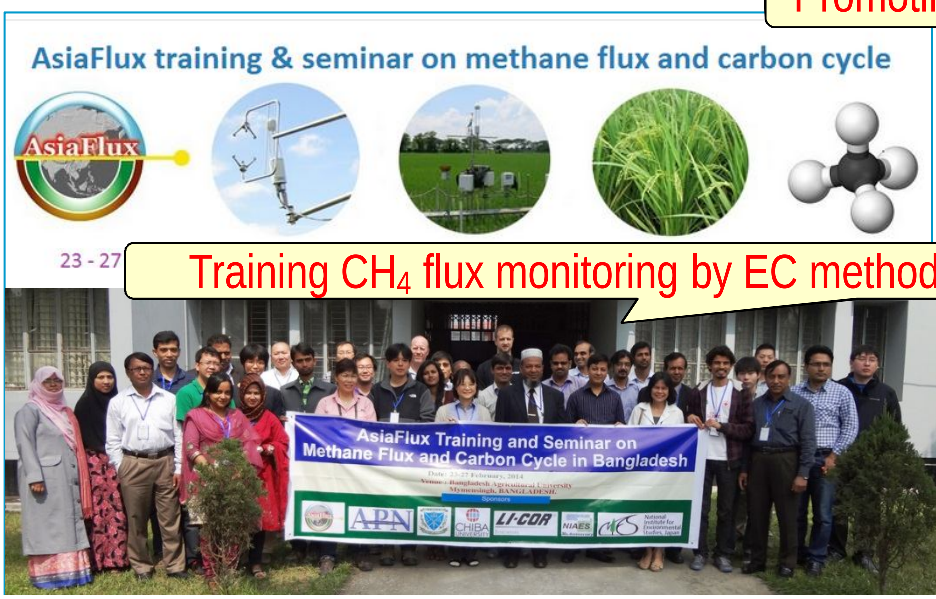
Location of AsiaFlux sites



Number of sites registered: 102

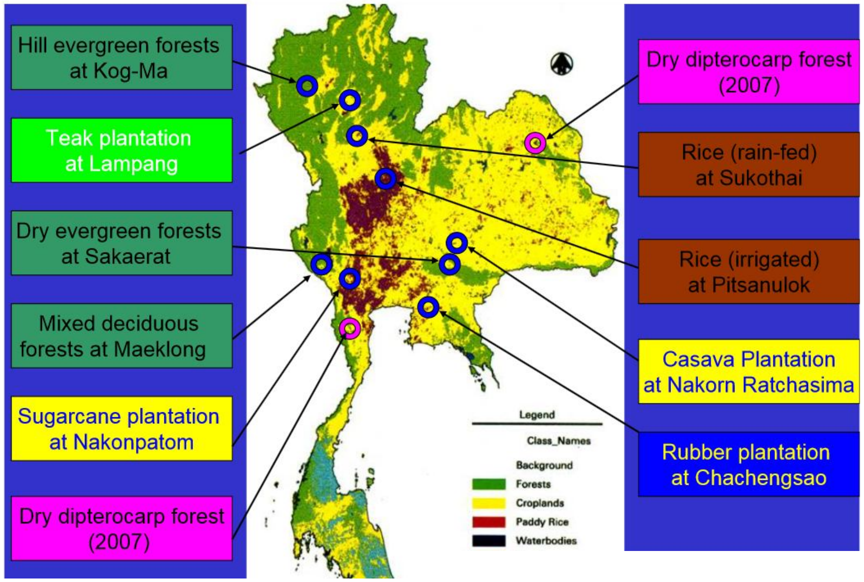
Number of datasets in the database: 125 (34 sites)

Promoting managed ecosystem monitoring (Rice paddy, etc.)



Training CH_4 flux monitoring by EC method

ThaiFlux (2006~)



http://www.jgsee.kmutt.ac.th/Apn/Day1/CountryReports/ThailandCountryReport.pdf

International Workshop on Flux Estimation over Diverse Terrestrial Ecosystems in Asia
-AsiaFlux Workshop 2006-

Date:29 November -1 December 2006
Venue:Chiang Mai, Thailand

ThaiFlux hosted AsiaFlux WS.

ThaiFlux sites (AsiaFlux Site info: http://asiaflux.net/)

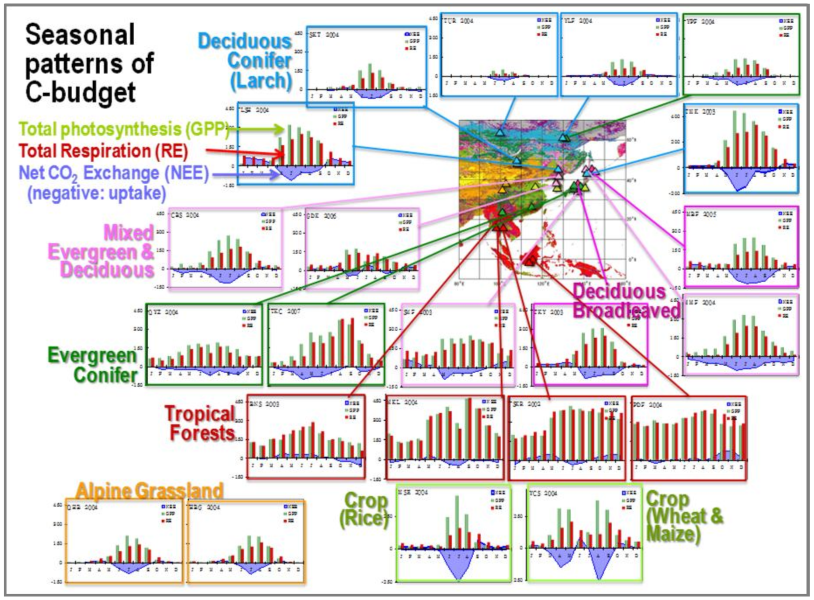
←King Mongkut's University of Technology Thonburi (KMUTT)

←Kasetsart University

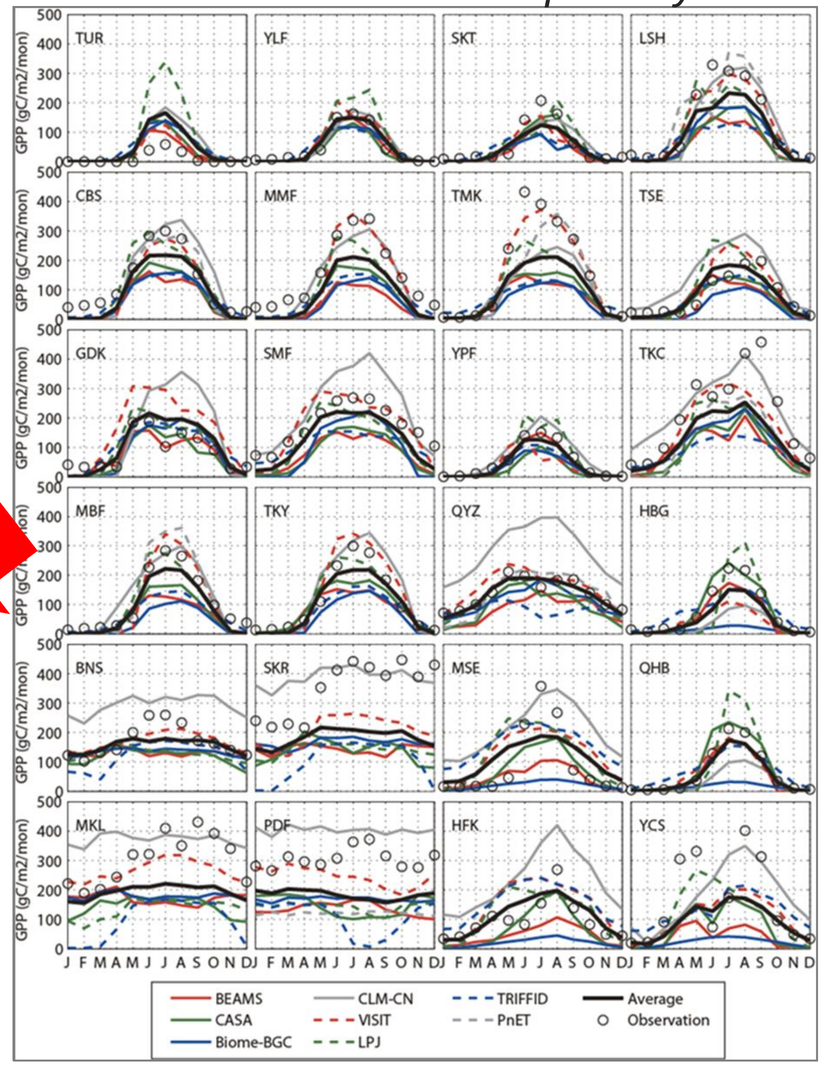
↓AIST Japan; Watershed Conservation & Management Office National Park

Model – Data Integration for C-budget Estimations

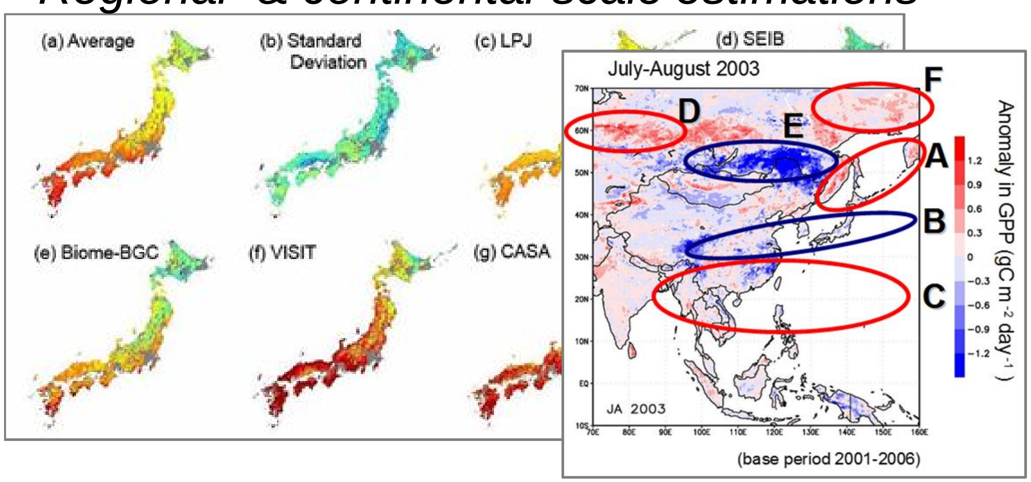
Eight different terrestrial models were validated using CO_2/H_2O/energy flux data obtained at 24 ecosystems (forests/grasslands/croplands) in Asia



Estimated and observed total photosynthesis



Regional- & continental-scale estimations

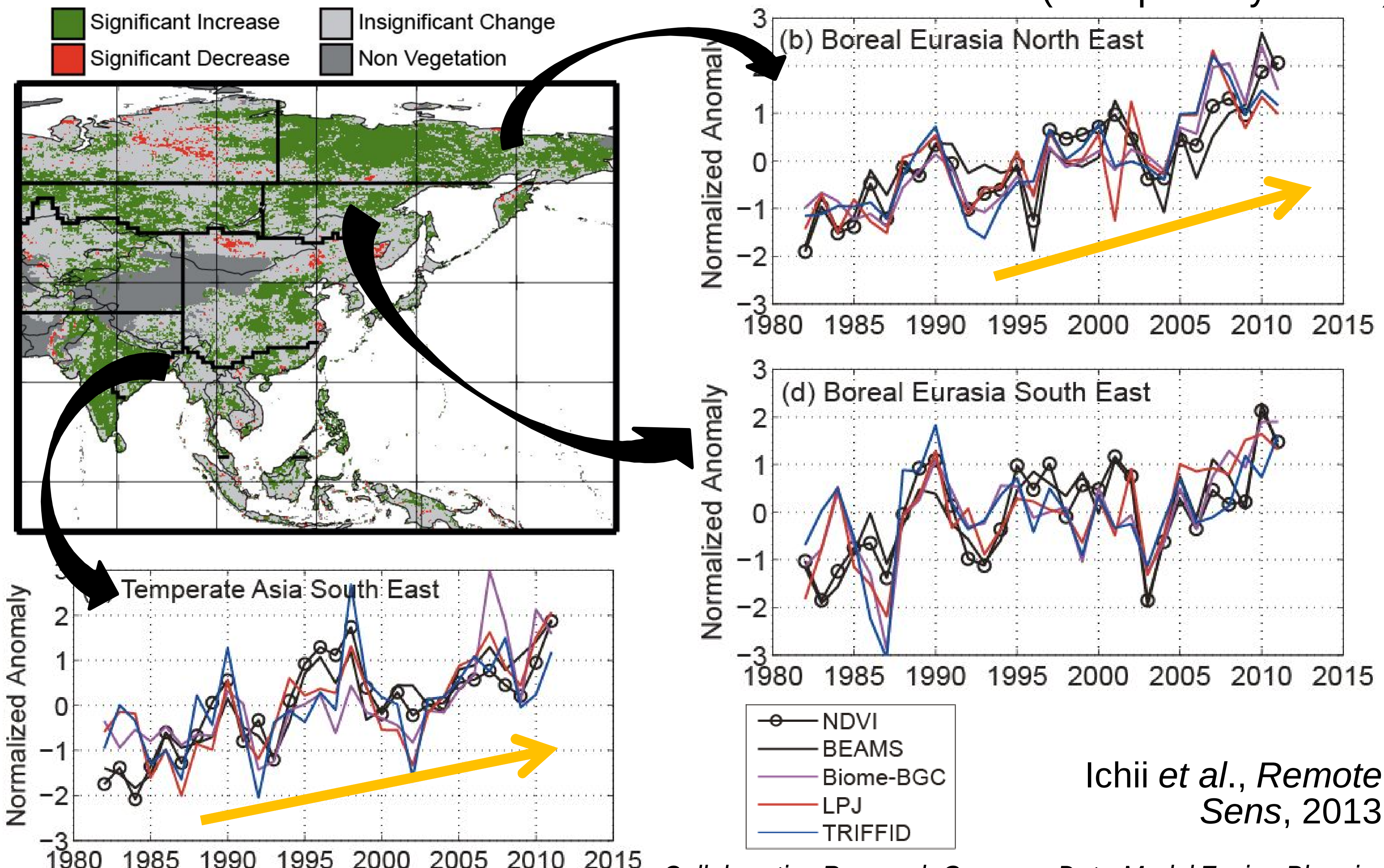


Saigusa *et al.* (2010) (2013); Ichii *et al.* (2010) (2013)

Detect Increasing Trends in NDVI & Productivity in Siberia

Trends in AVHRR-NDVI

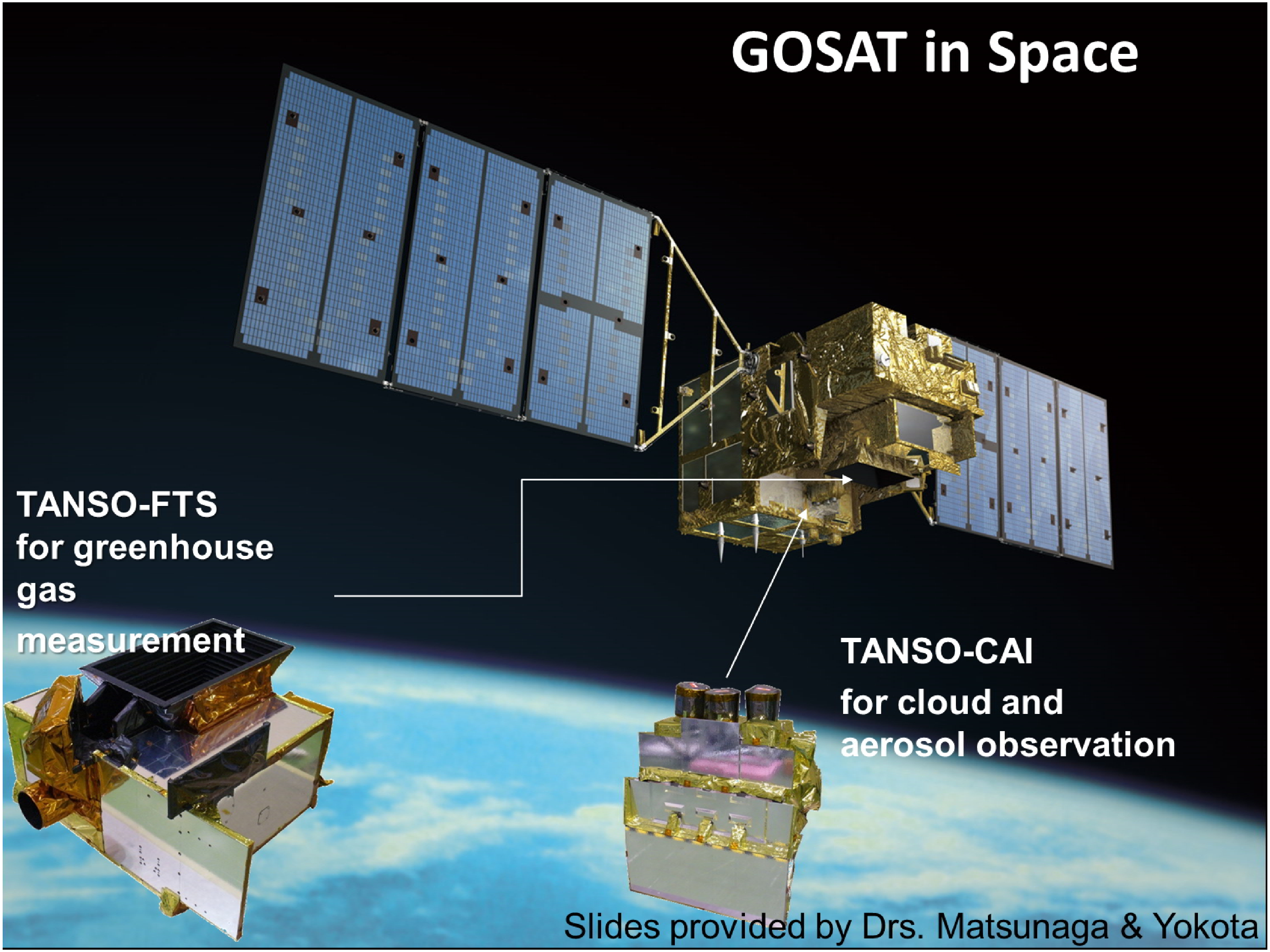
Trends in NDVI and GPP (total photosynthesis)



Ichii *et al.*, *Remote Sens*, 2013

Collaborative Research Group on Data-Model Fusion Planning

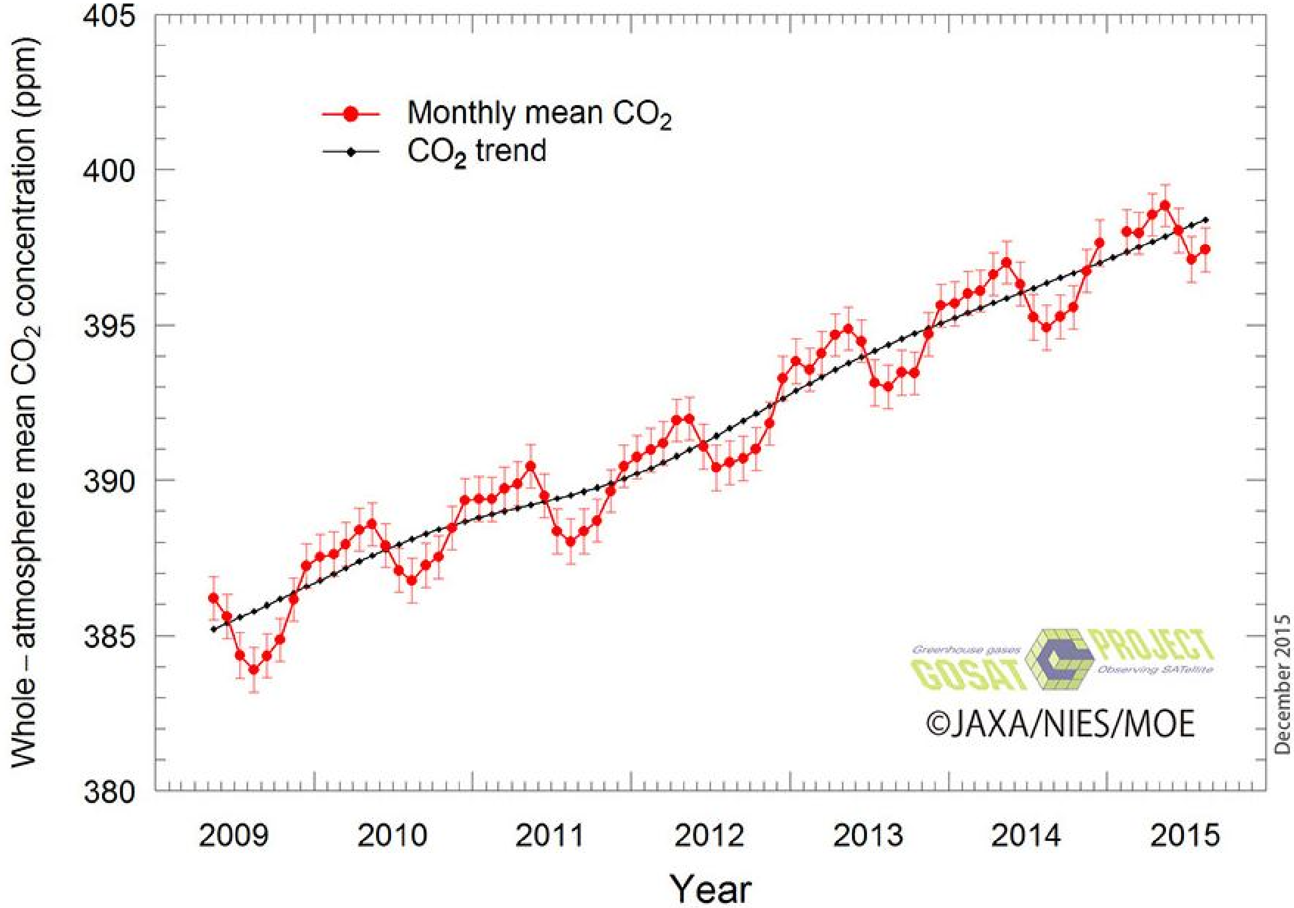
Recent progress in studies of Top-down approach



GOSAT in Space
TANSO-FTS
for greenhouse
gas
measurement
TANSO-CAI
for cloud and
aerosol observation
Slides provided by Drs. Matsunaga & Yokota

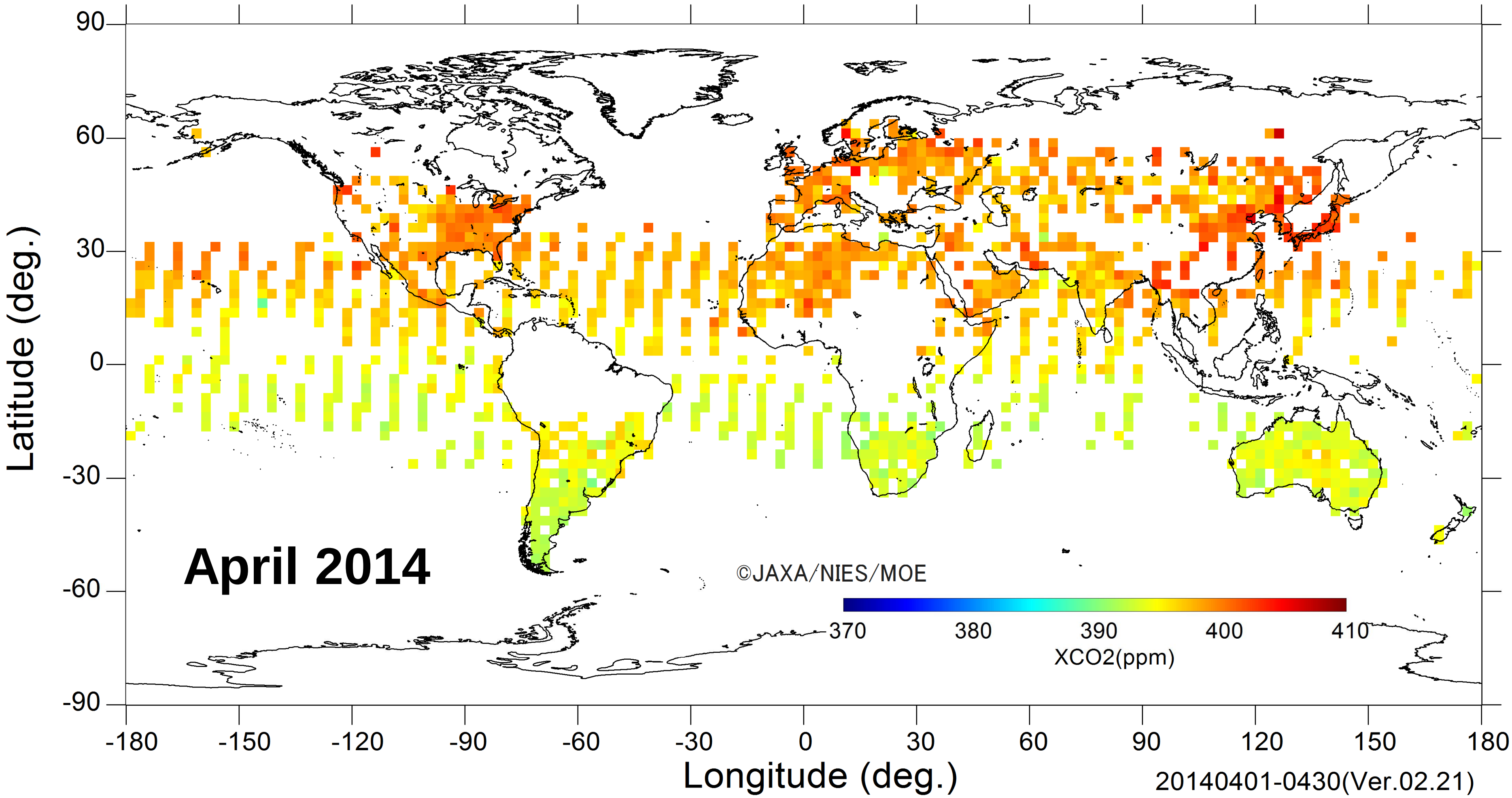
Whole-atmosphere monthly mean CO_2 concentration

Monthly mean CO_2 August 2015	397.4 ppm
CO_2 growth in the past one year (**) August 2015 - August 2014	2.1 ppm/yr



NIES GOSAT Project (http://www.gosat.nies.go.jp/en/recent-global-co2.html)

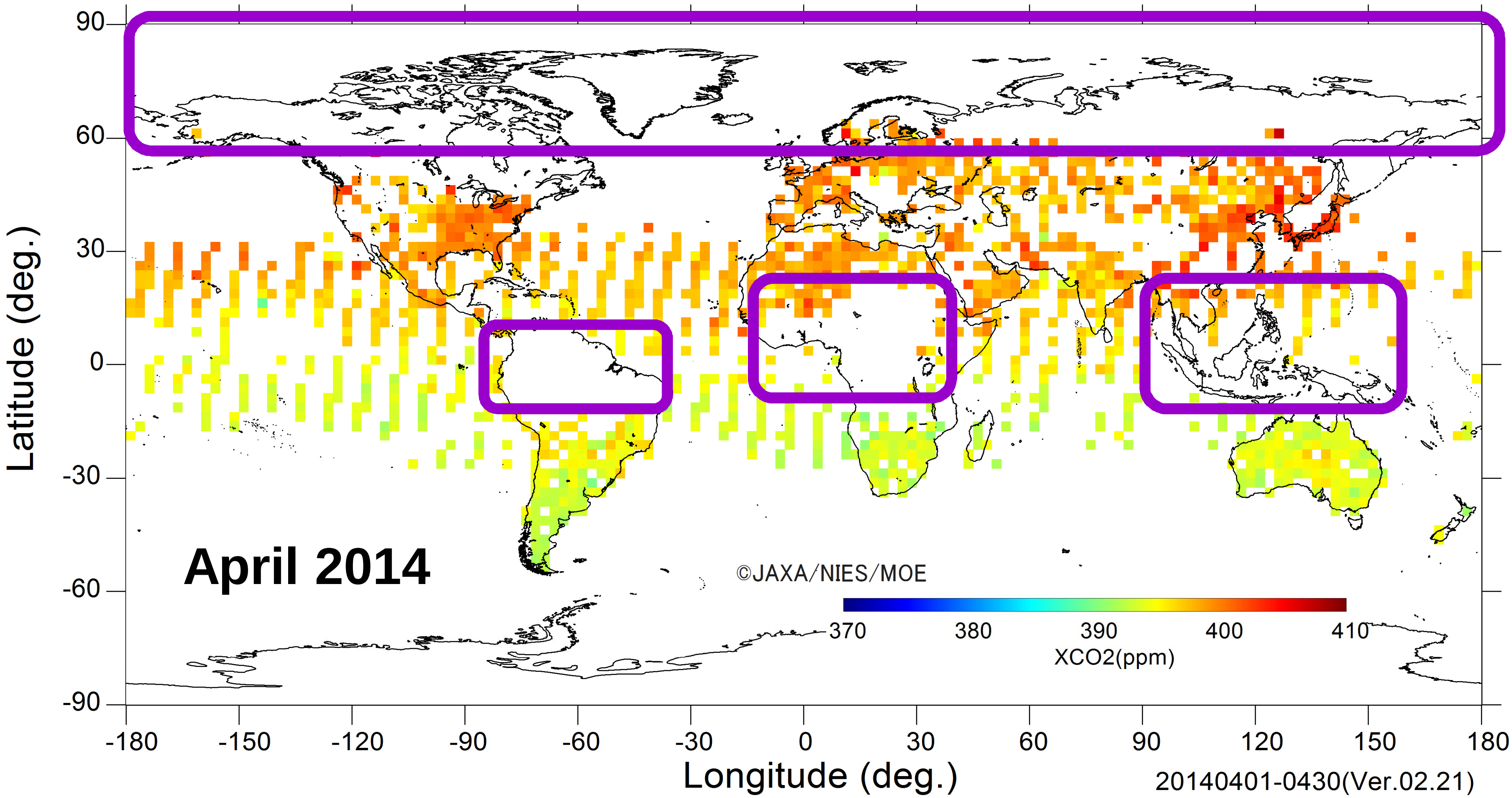
Spatial distribution of CO_2 concentration from GOSAT



Slides provided by Drs. Matsunaga & Yokota

Spatial distribution of CO_2 concentration from GOSAT

Ground- & airplane-based data are required to improve spatial coverage.

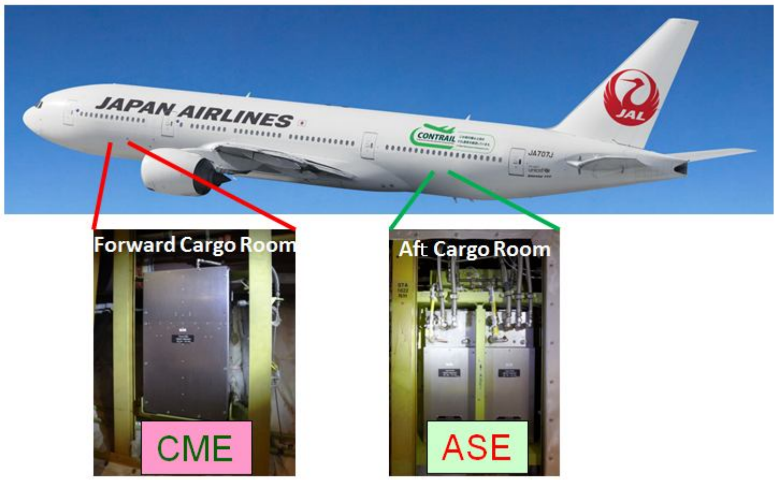


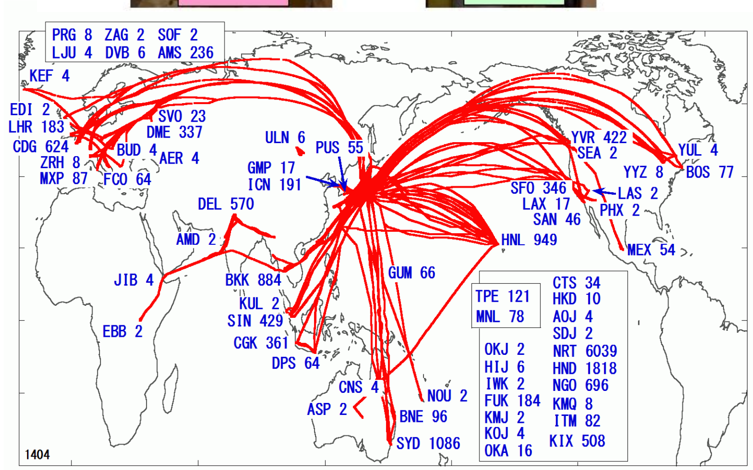
Slides provided by Drs. Matsunaga & Yokota

CONTRAIL: Atmospheric CO_2 and other trace gas observation using commercial airlines

CONTRAIL Comprehensive Observation Network for Trace gases by Airliner

CONTRAIL Group

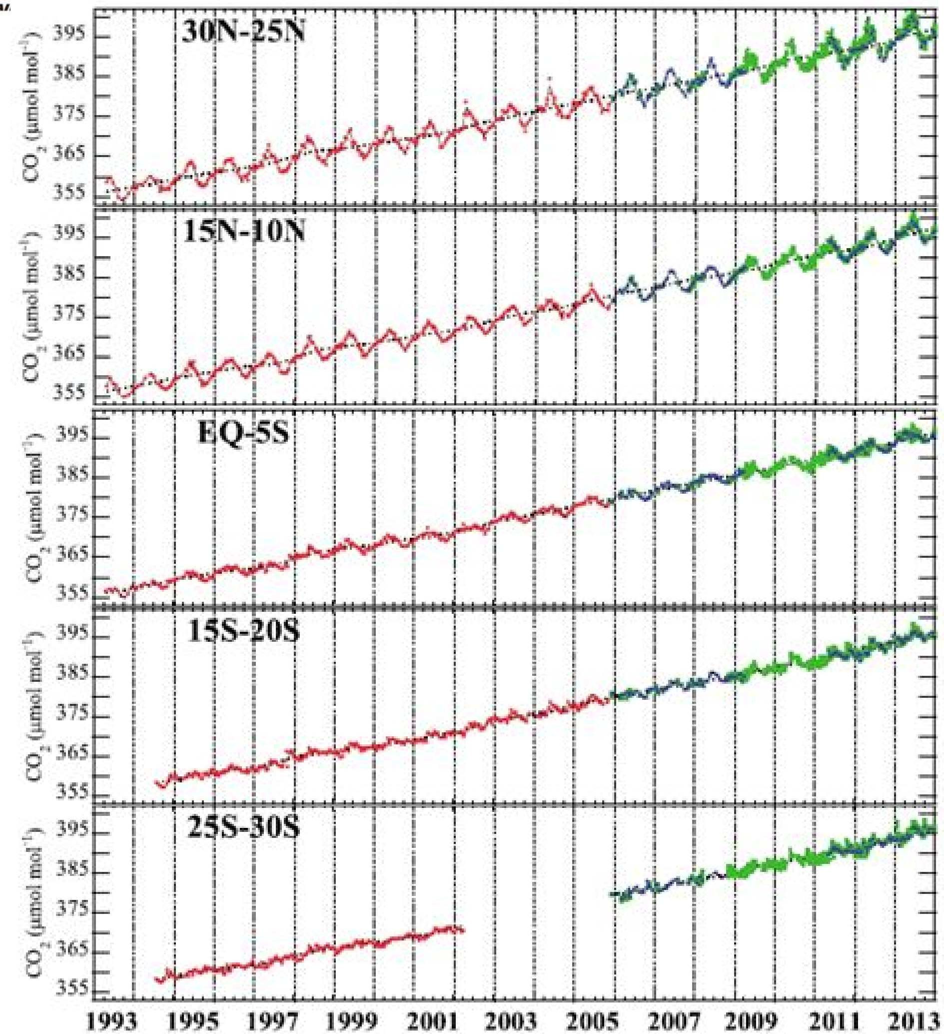




http://www.cger.nies.go.jp/contrail/

Slide provided by Dr. Machida

Atmospheric CO_2 concentration observed over Western Pacific



Matsueda *et al.*, *GRL,* 2015

Atmospheric CO_2 Inversion with Siberian Tall Towers

http://www.cger.nies.go.jp/en/climate/pj1/tower/

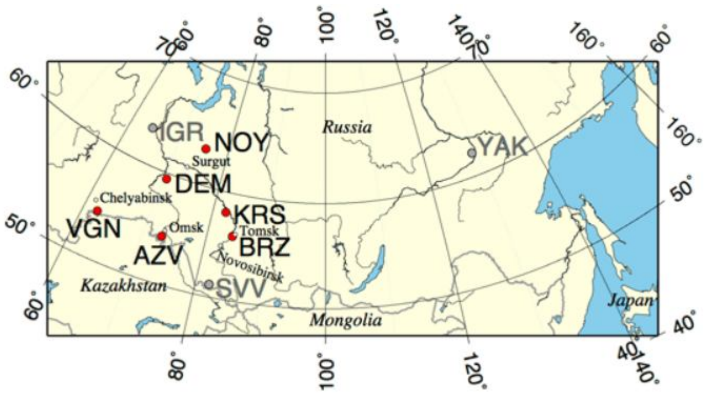


Figure 1 Locations of the monitoring towers in the network (JR-STATION) (red circles). Gray circles indicates former observation sites. The alphabet combination indicates the code of the sites (Table 1). Main cities are marked with white circles.

CGER Center for Global Environmental Research
National Institute for Environmetal Studies

Tower Network for
the Monitoring of Greenhouse Gases in Siberia

Photo 1 Monitoring tower in Berezorechka in the interior of West Siberian taiga

Japan-Russia Siberian Tall Tower Inland Observation Network (JR-STATION)

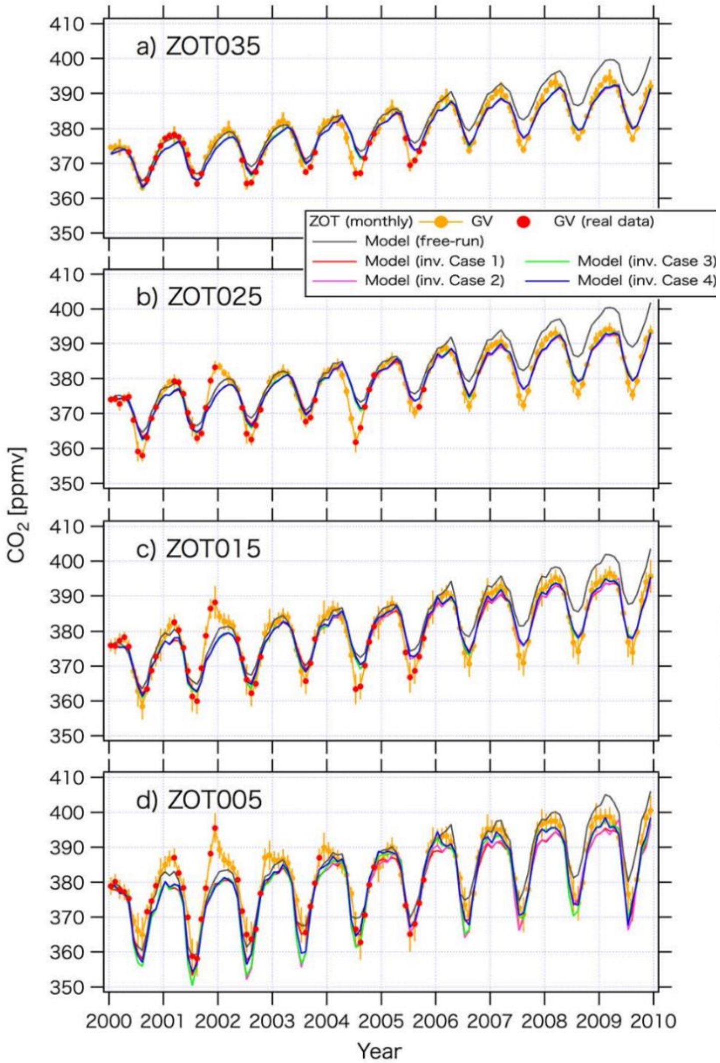
More high-quality atmospheric CO_2 data

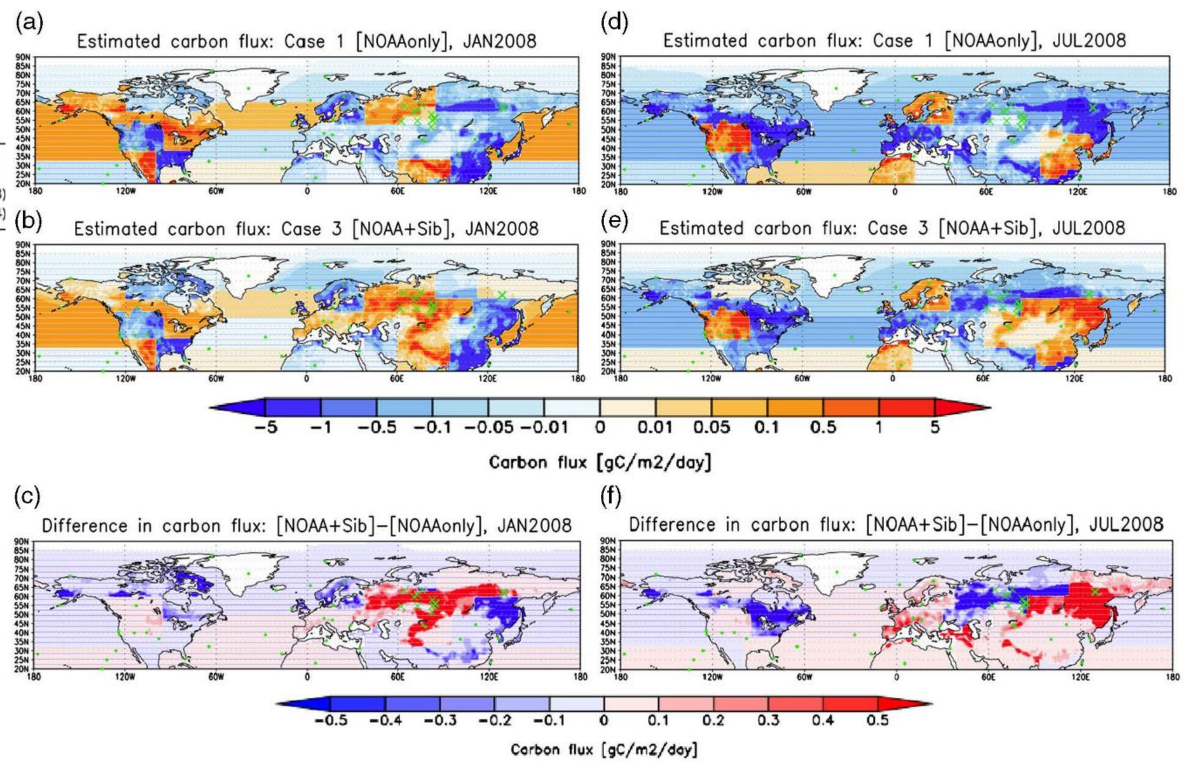
→ More realistic C sink/source distribution

Atmospheric CO_2 Inversion with Siberian Tall Towers

Japan-Russia Siberian Tall Tower Inland Observation Network (JR-STATION)

→ more realistic C sink/source distribution





Saeki *et al.*, *JGR*, 2013

Case 1: NOAA flask data.
Case 2 used NOAA data and the Siberian aircraft over three sites
Case 3 used all data (i.e., case 2 + BRZ aircraft + all nine towers).
Case 4 used all data, as in case 3, and was solved by the truncated SVD method

Inter-comparison between Top-down & Bottom-up

Uncertainty assessment

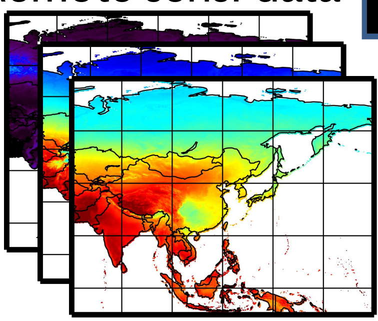
Improved estimates of surface fluxes

Data-Driven Top-down vs Bottom-up CO_2 Fluxes

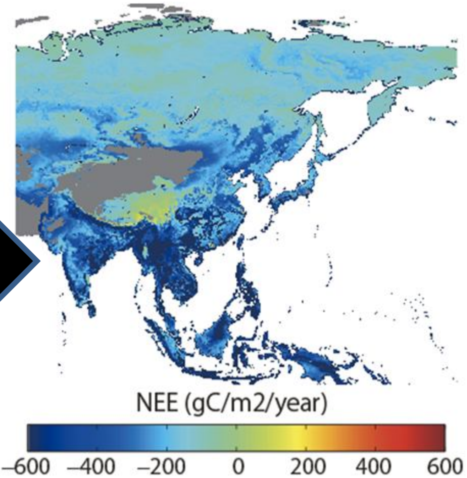
Bottom-up: Empirical Upscaling

Observation (46 sites)
(e.g. AsiaFlux)

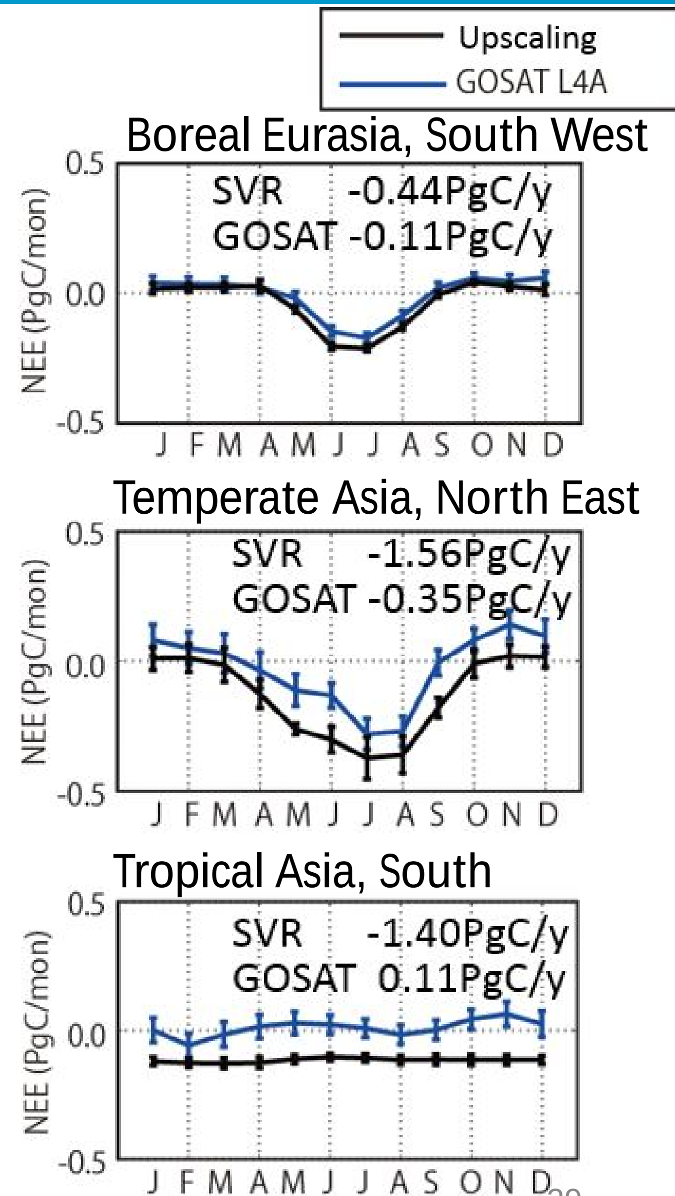
Remote sens. data



[Support Vector Regression]
Net CO_2 Flux

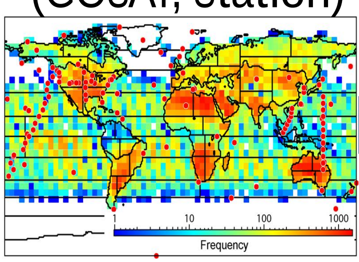


Comparison

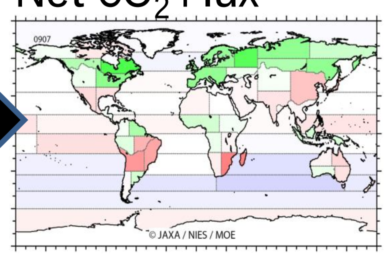


Top-down: GOSAT Level 4A

CO_2 concentration
(GOSAT, Station)



[Inversion]
Net CO_2 Flux



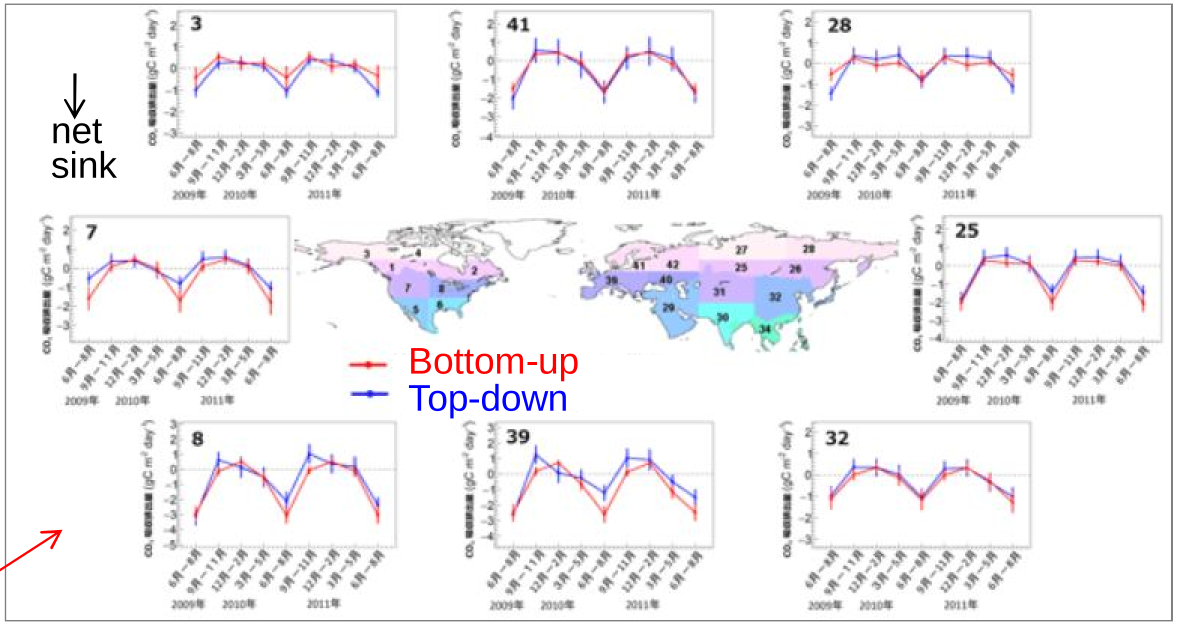
Slide provided by Dr. Ichii, Collaborative Research Group on Data-Model Fusion Planning Leader

Data-Driven Top-down vs Bottom-up CO_2 Fluxes

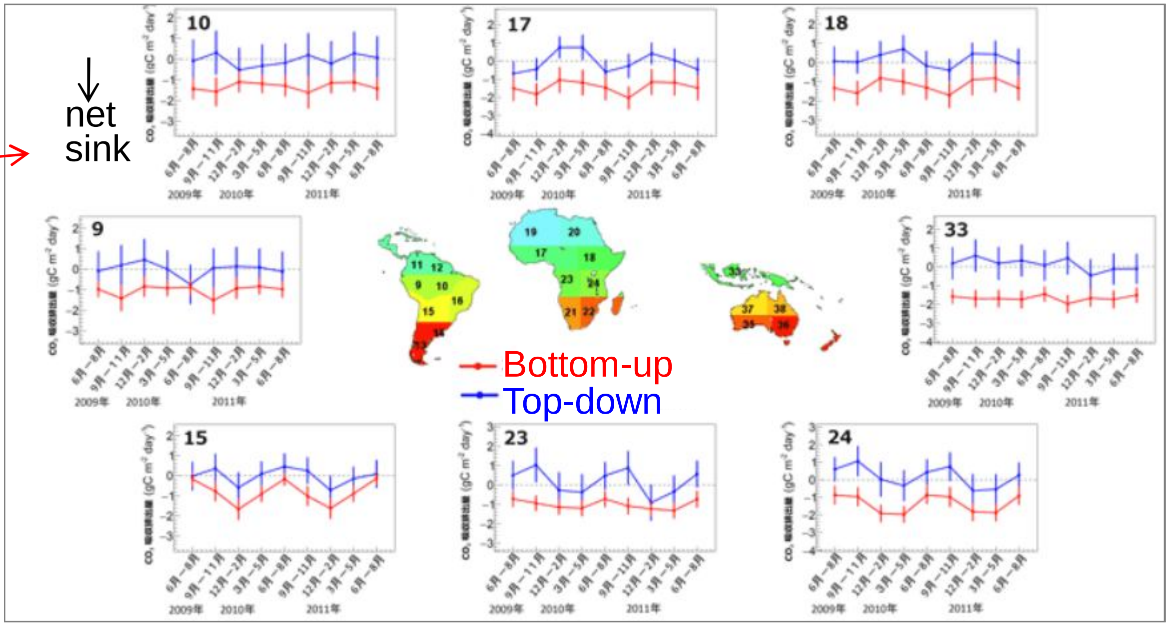
Net Atmosphere-Land CO_2 Fluxes (seasonal changes):

GOSAT Level 4A vs Upscaling with FLUXNET & remote sensing data

Consistent in boreal and temperate regions



Large differences in tropical regions

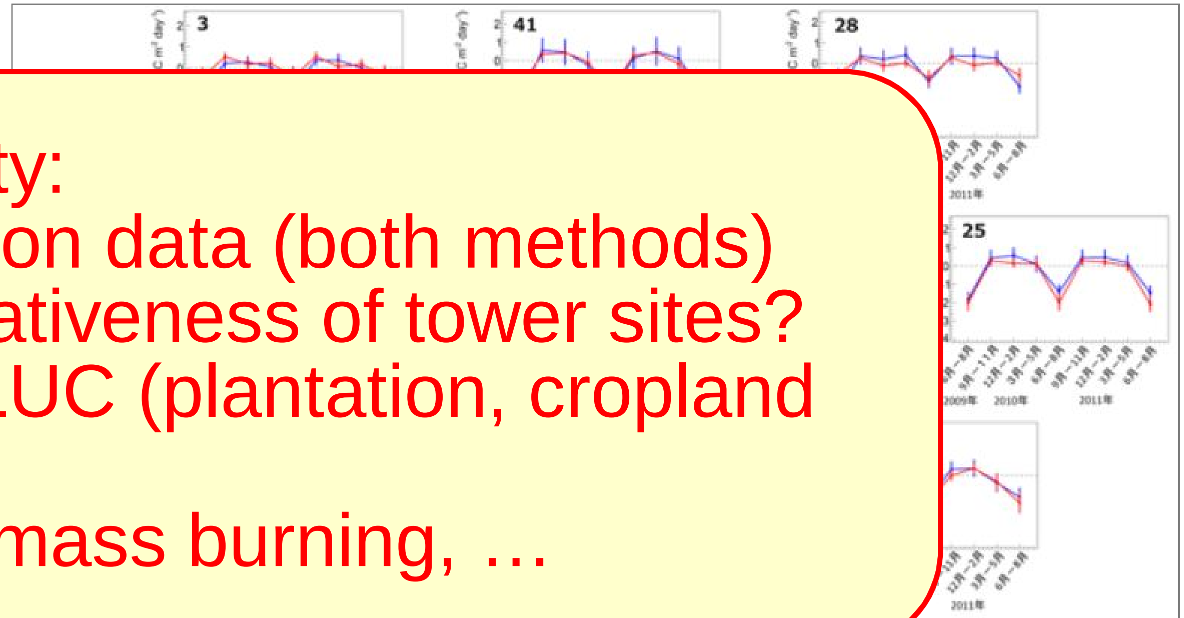


JAMSTEC-NIES Press release: http://www.nies.go.jp/whatsnew/2015/20150717/20150717.html

Kondo *et al*. *JGR*, 2015

Data-Driven Top-down vs Bottom-up CO_2 Fluxes

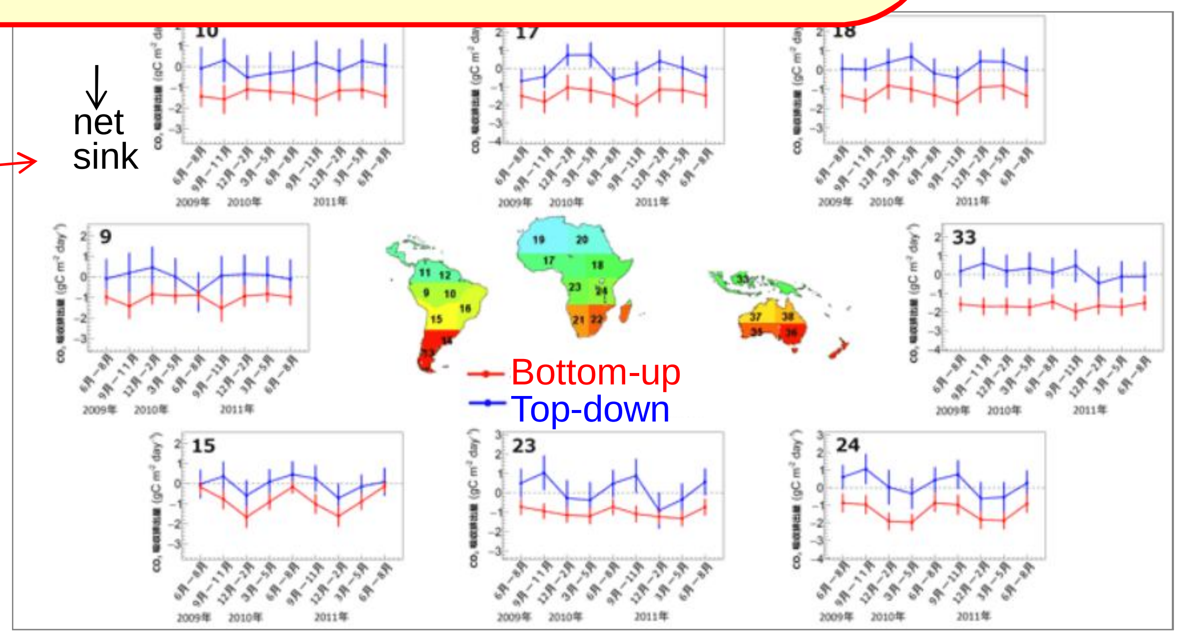
Net Atmosphere-



Source of uncertainty:

- ✓ Limited observation data (both methods)
- ✓ Space representativeness of tower sites?
- ✓ Emissions from LUC (plantation, cropland expansion, etc.),
- ✓ River export, Biomass burning, …

Large differences in tropical regions



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http://www.nies.go.jp/whatsnew/2015/20150717/20150717.html

Kondo *et al*. *JGR*, 2015

Next Challenge:

Detect Large C Emissions from Land Use Change

- **Plantation, Cropland expansion**
- **Biomass burning**
- **River export…**

Next Challenge:

Detect Large C Emissions from Land Use Change

- Plantation, Cropland expansion
- Biomass burning
- River export…

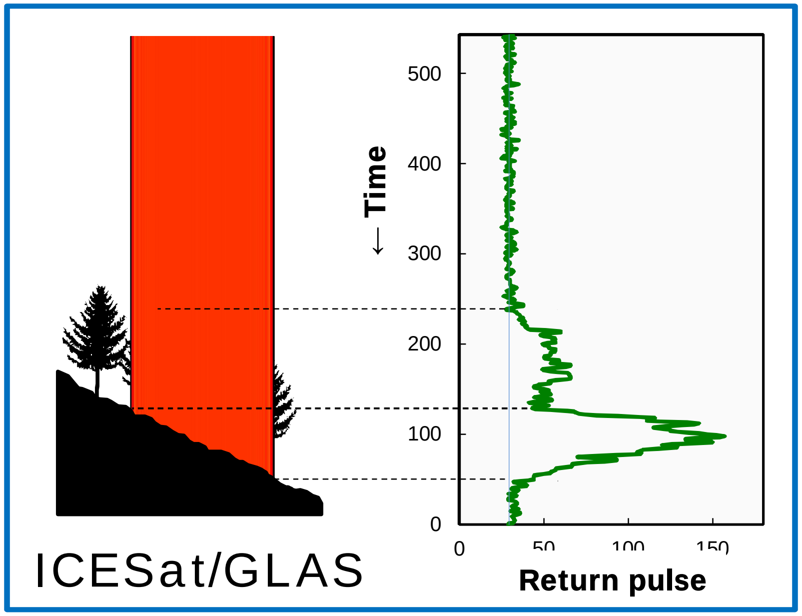
Biomass & Canopy height estimated by LiDAR (ICESat /GLAS)

Background

The increased demand for large-scale monitoring of forest carbon stocks, for clarifying the global carbon cycle and REDD+ implementation.

Measure

Spaceborne LiDAR directly measures vertical forest structure. So, it is expected to measure forest resources accurately.



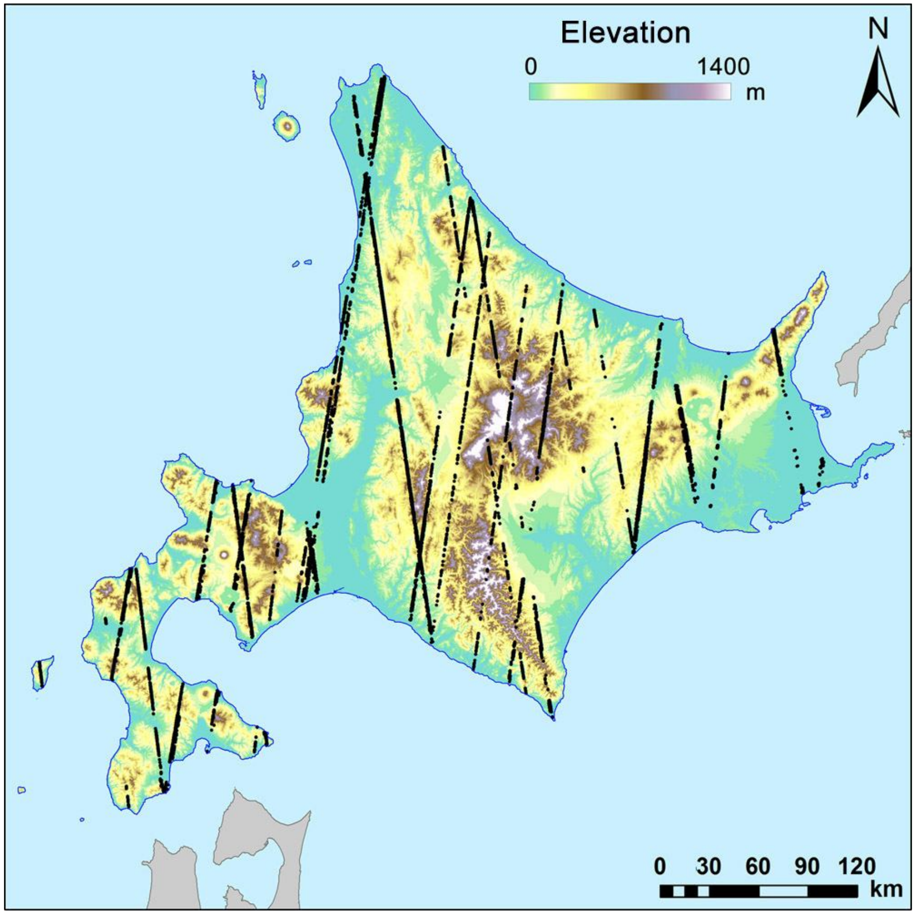
Objective

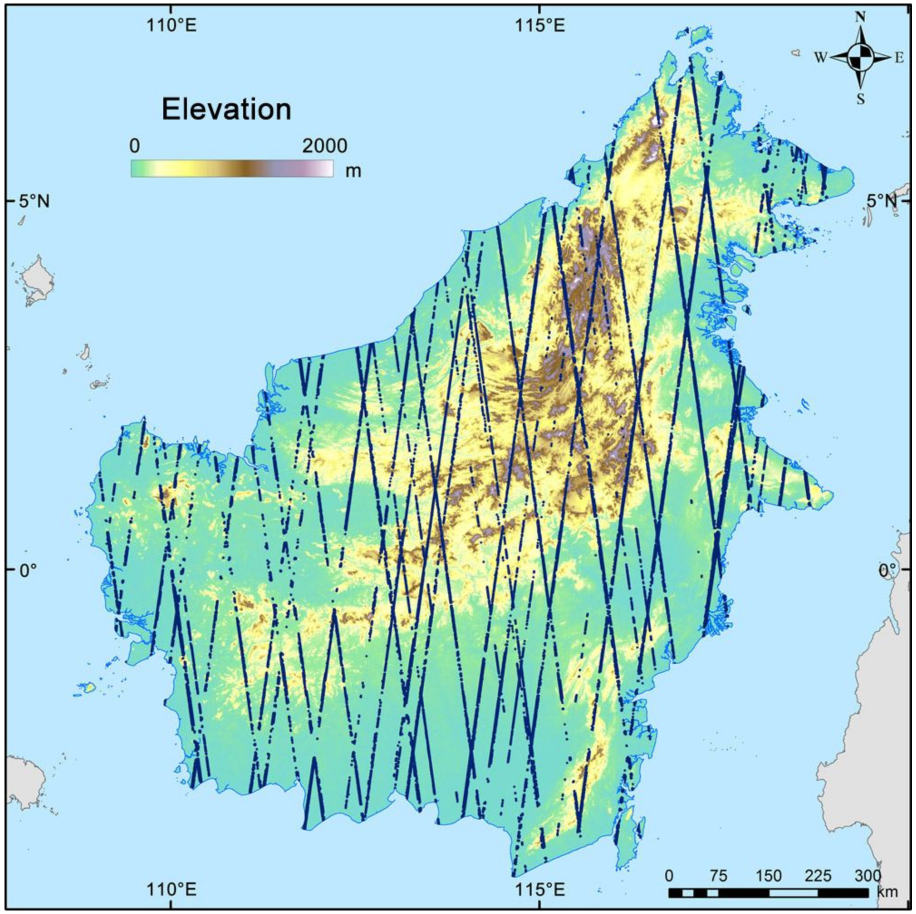
To demonstrate the potential of spaceborne LiDAR to observe large-scale forest resources (canopy height and aboveground biomass).

Hayashi et al., *ISPRS journal of photogrammetry and remote sensing*, 2013

Biomass & Canopy height estimated by LiDAR (ICESat /GLAS)

- ❖ GLAS data exclusion: cloud covered area, non-forested area
- ❖ Valid data: Hokkaido = 14,000 points, Borneo = 130,000 points





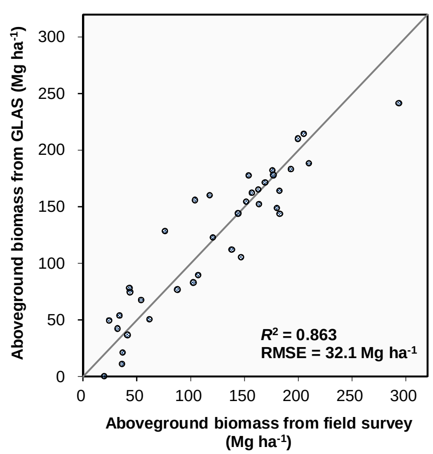
Hayashi et al., *Carbon Management*, 2015

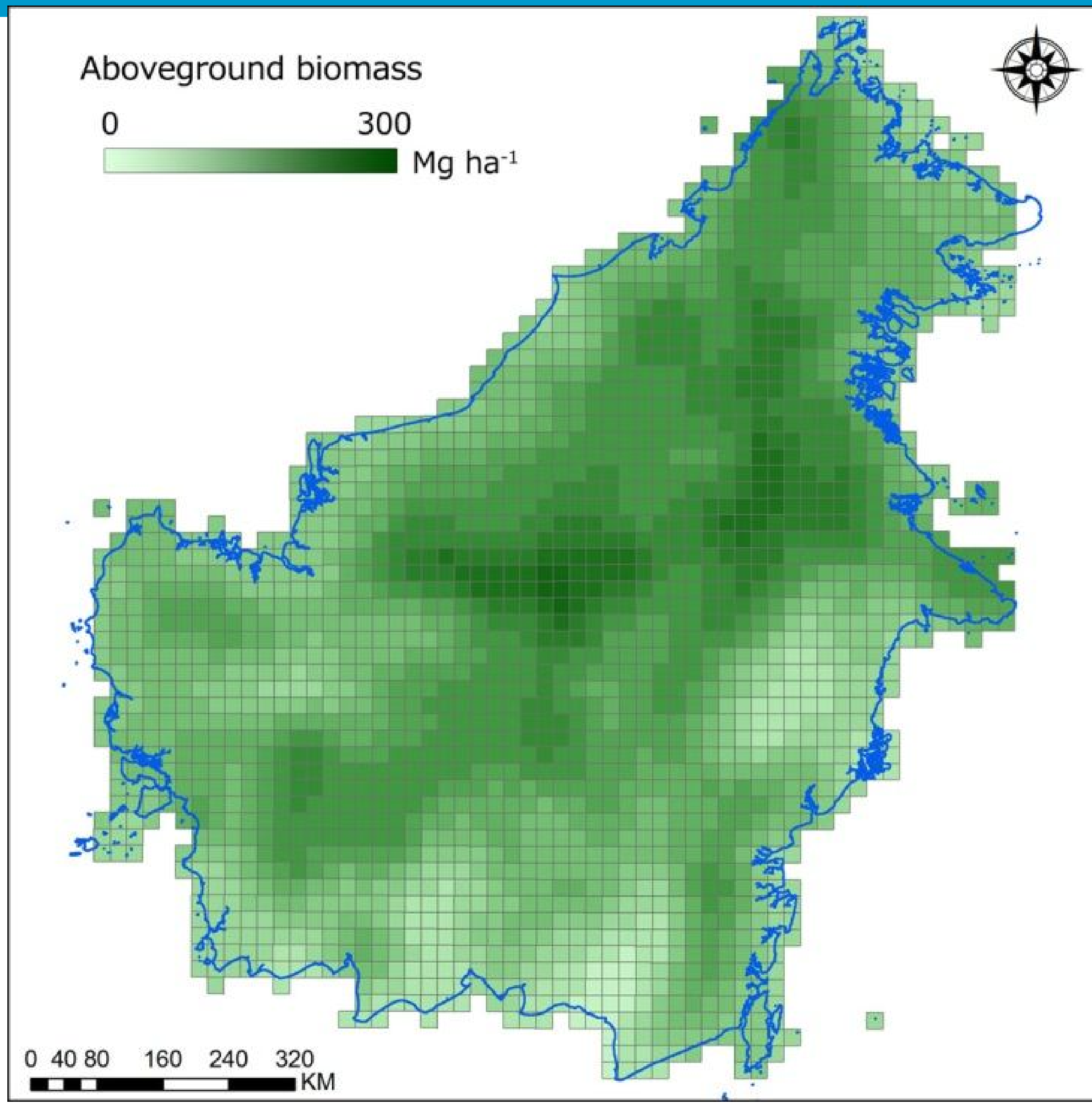
Forest biomass estimation in Borneo

1. AGB estimation
   @ 110,743 points

2. Average AGB
   @ 20 km mesh

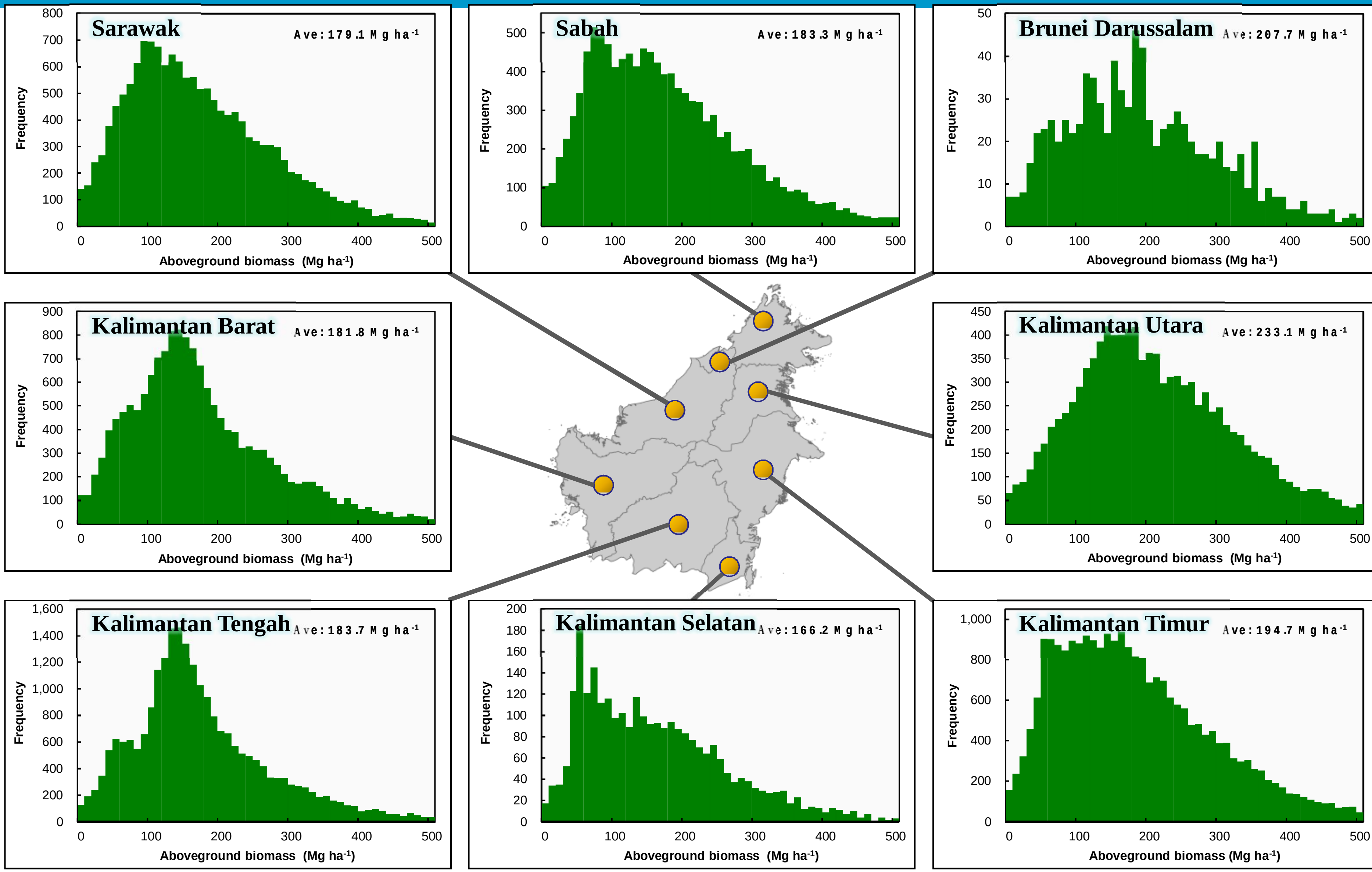
3. Interpolated AGB
   (Kriging method)





Hayashi et al., *Carbon Management*, 2015

Histograms of biomass in Borneo



Hayashi et al., *Carbon Management*, 2015

Estimated forest loss in Borneo

- ❖ [GLAS-estimated canopy height < 2 m] → [non-forested area]
- ❖ Forest loss rate = [Ratio of non-forested points in 2005-2009] – [Ratio of non-forested points in 2003-2005]
- ❖ The forest loss rate was enhanced by forest fire related to El Niño in 2006.

References	Forest loss rate (% y^{-1})	Period
This study	**1.6**	**2004-2007**
- Malaysian Borneo	**0.8**	**2004-2007**
- Indonesian Borneo	**2.1**	**2004-2007**
Langner et al., 2007	**1.7**	**2002-2005**
Miettinen et al., 2011	**1.3**	**2000-2010**
Bontemps et al., 2012	**1.3–2.7**	**2000-2008**
Hansen et al., 2013	**1.1**	**2000-2012**

Hayashi et al., *Carbon Management*, 2015

GOSAT Air Pollution Watch
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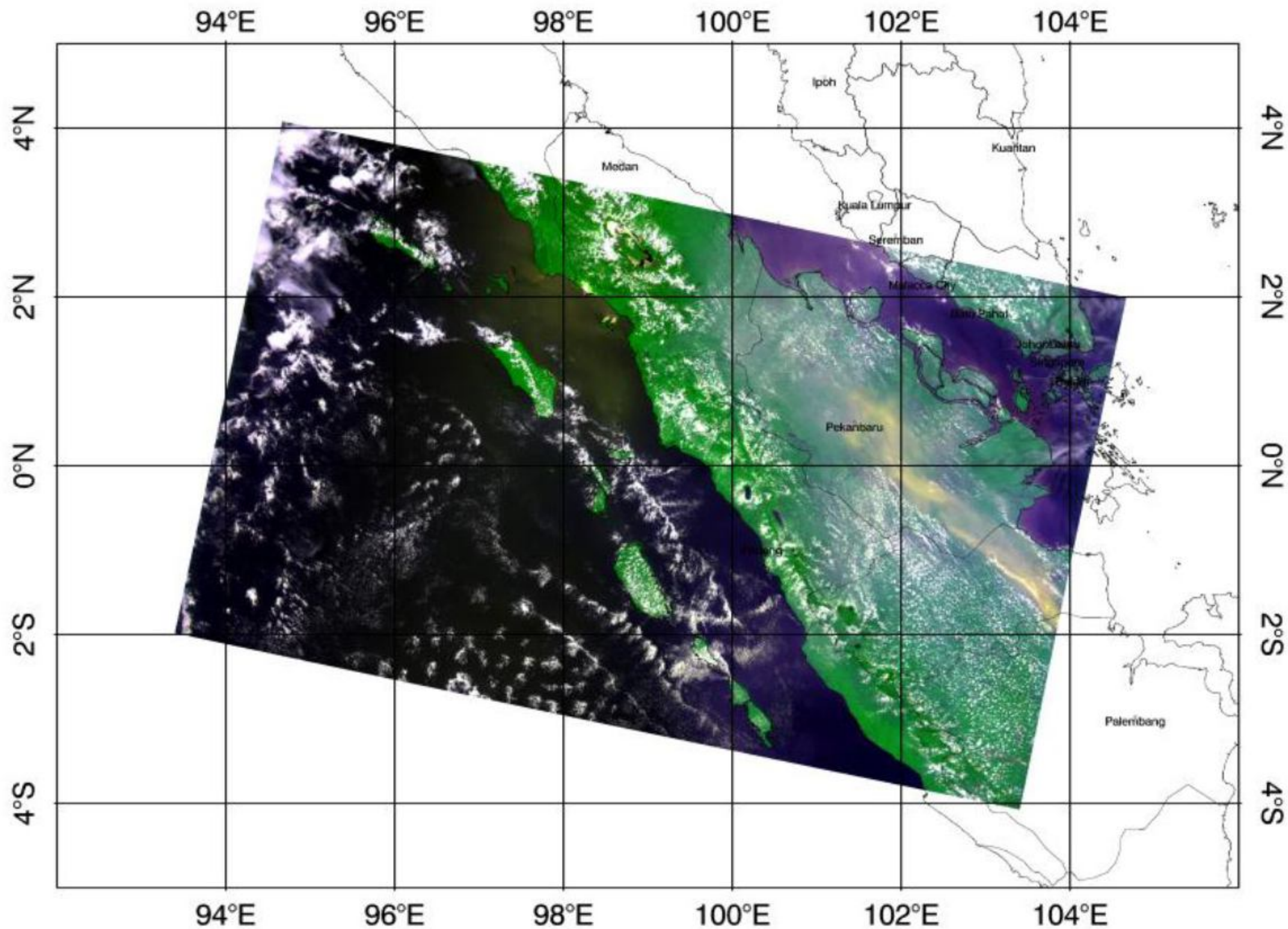

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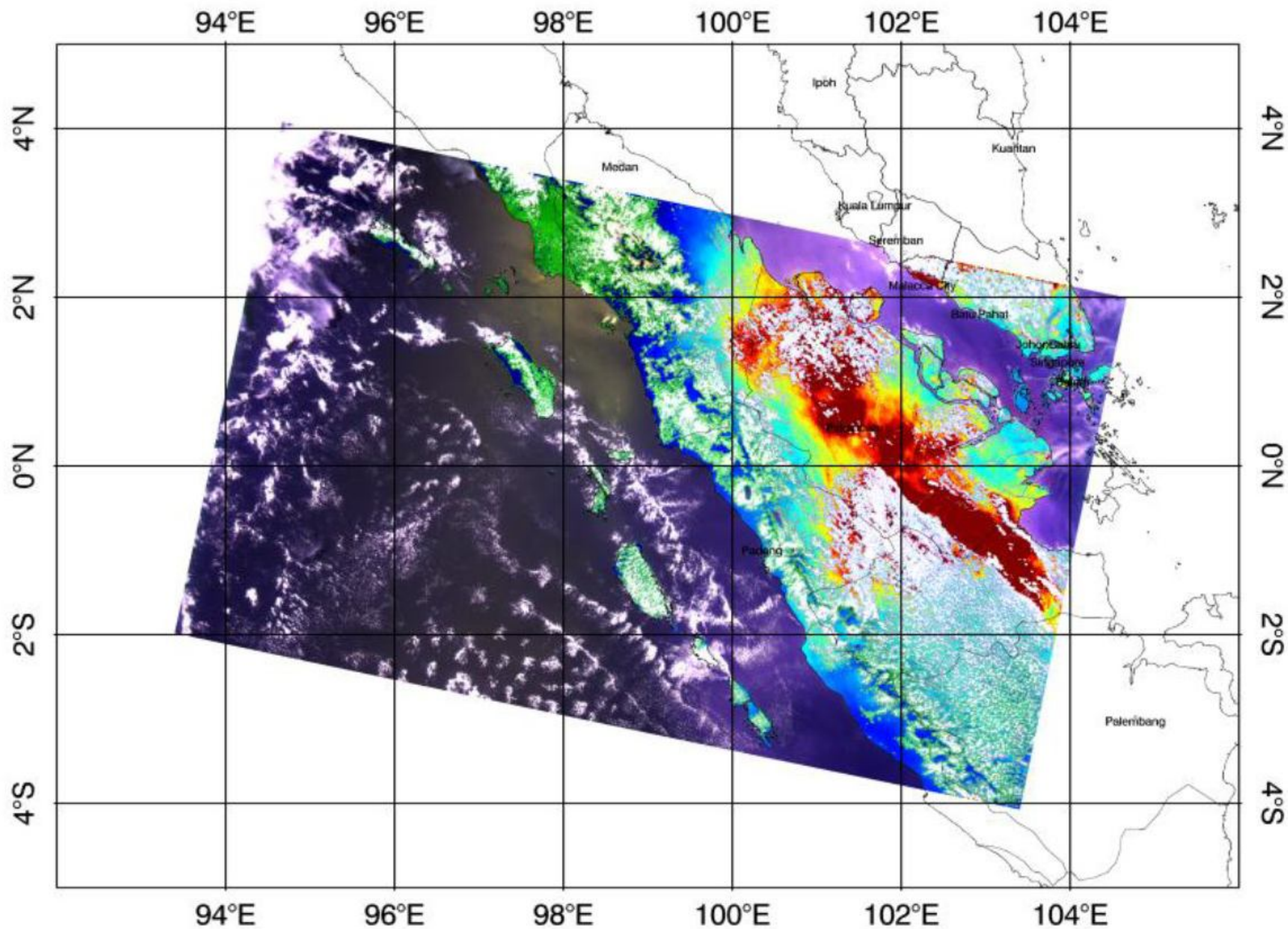

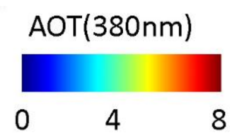

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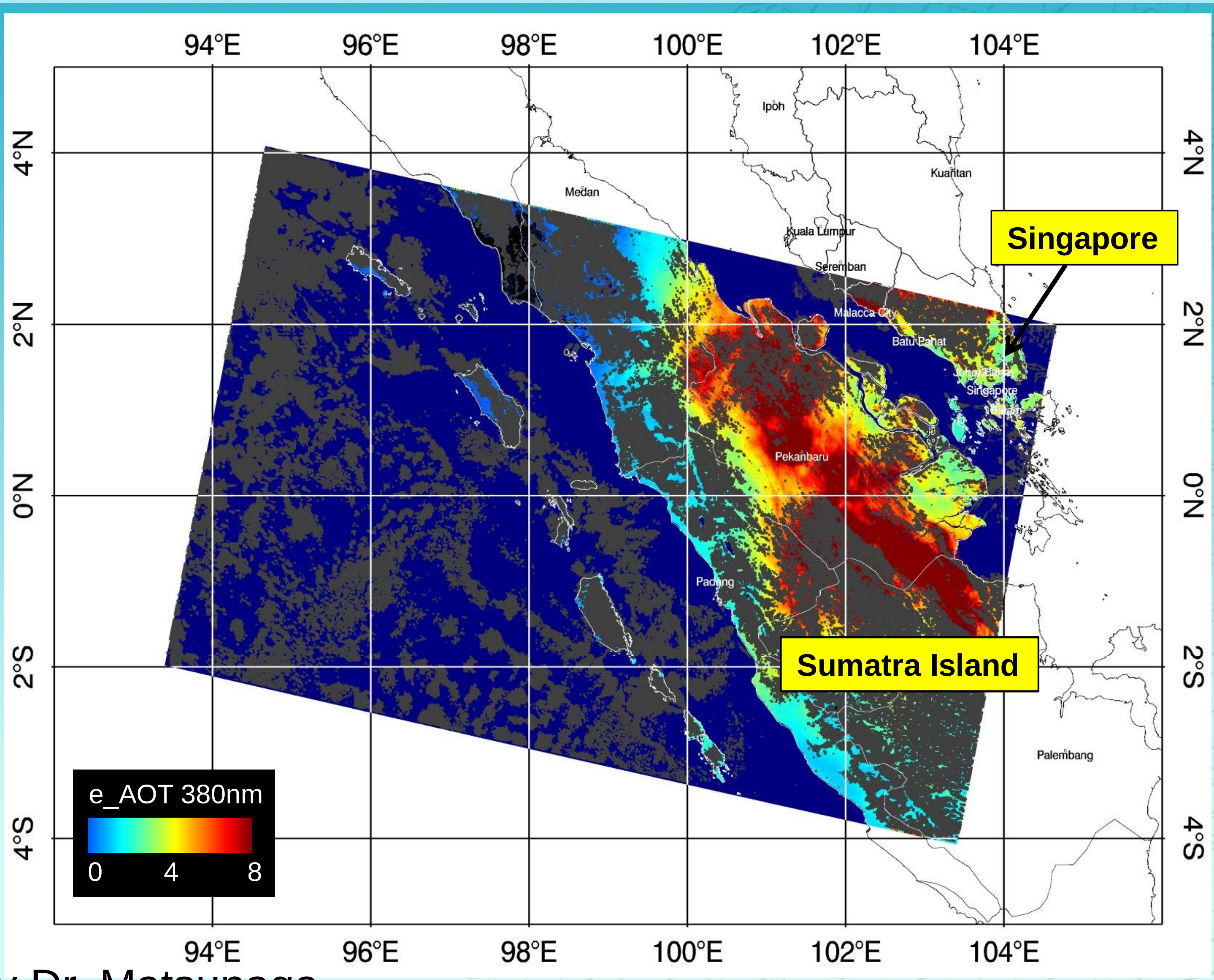

Provided by Dr. Matsunaga

Summary

For accurate C source/sink estimates for Global C Management to assess mitigation and adaptation policies, we urgently need:

- Multi-platform observations & integration into improved data analysis/assimilation systems for C-fluxes particularly in Asia-Pacific
- Changes in biomass to be used as an independent validation of terrestrial C-flux estimation

To evaluate human impacts on the changes in C-fluxes and stocks, we have to have:

- Improved estimates of **emissions from land-use change**, **fires**, and **other anthropogenic sources**