Integrating Ground Observation and Satellite Remote Sensing for Future Carbon Monitoring (Management) Systems

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

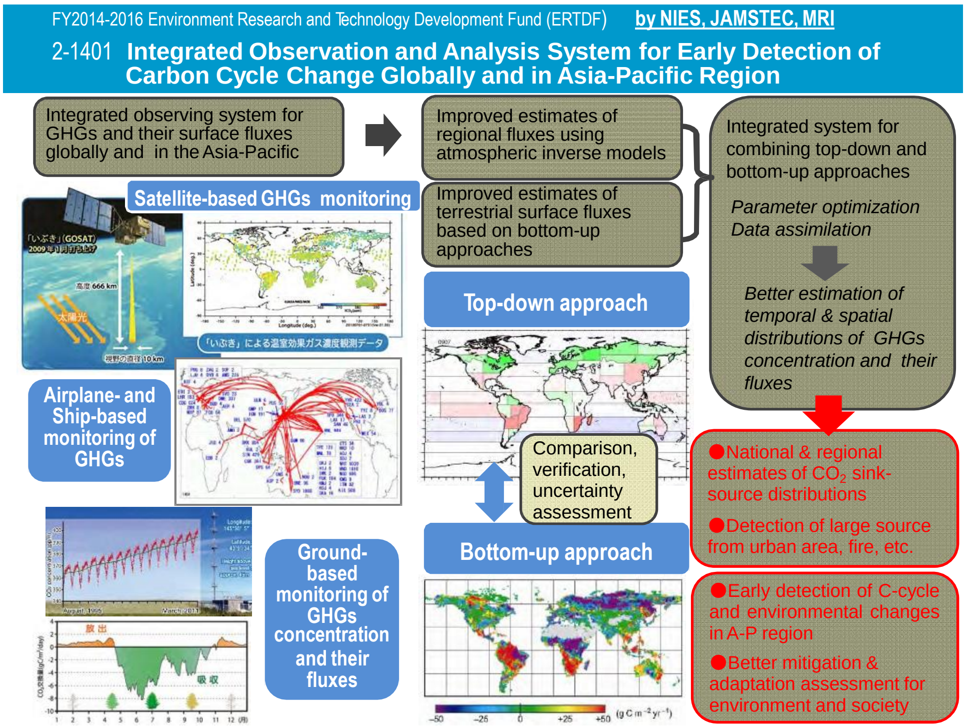
Background and Needs in Global C Management

Background:

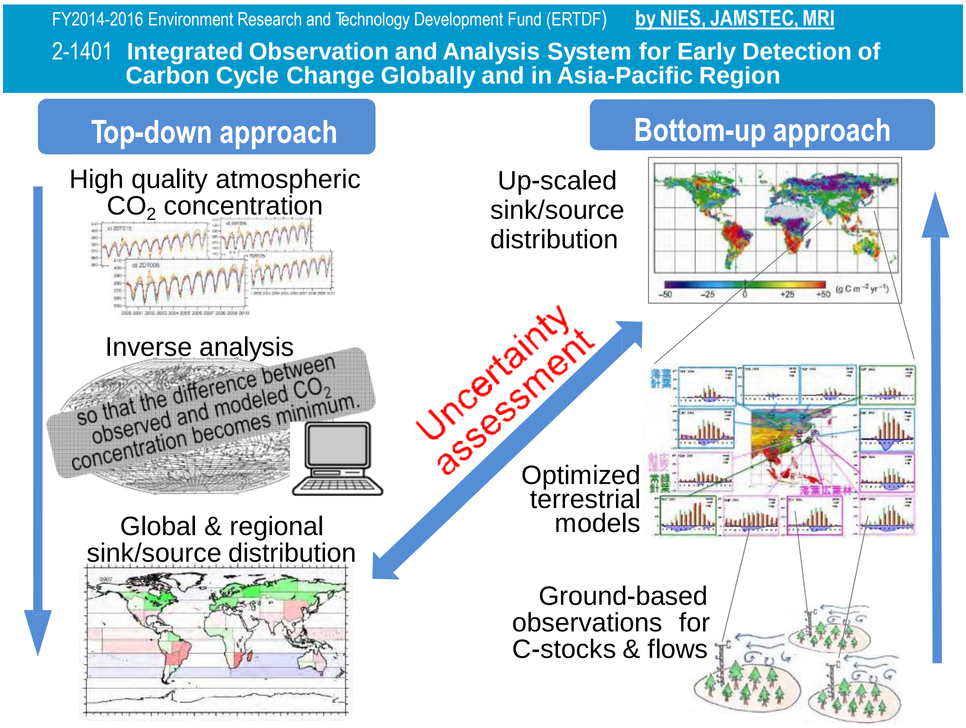
- High uncertainty still remains in global & regional C-budget due to limited spatial coverage in the observation and uncertainty in models
- Improved data analysis (assimilation) systems using multi-platform (satellites, aircraft, ship, and ground-based) observation data could lead better estimation 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
Improved estimates of regional fluxes using atmospheric inverse models
Improved estimates of terrestrial surface fluxes based on bottom-up approaches
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
Satellite-based GHGs monitoring
「いぶき」(GOSAT)
「いぶき」による温室効果ガス濃度観測データ
Airplane- and Ship-based monitoring of GHGs
Top-down approach
Comparison, verification, uncertainty assessment
Bottom-up approach
Ground-based monitoring 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



FY2014-2016 Environment Research and Technology Development Fund (ERTDF)
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2-1401 Integrated Observation and Analysis System for Early Detection of Carbon Cycle Change Globally and in Asia-Pacific Region
Top-down approach
High quality atmospheric CO_2 concentration
Inverse analysis
so that the difference between observed and modeled CO_2 concentration becomes minimum.
Global & regional sink/source distribution
Bottom-up approach
Up-scaled sink/source distribution
Uncertainty assessment
Optimized terrestrial models
Ground-based observations for C-stocks & flows

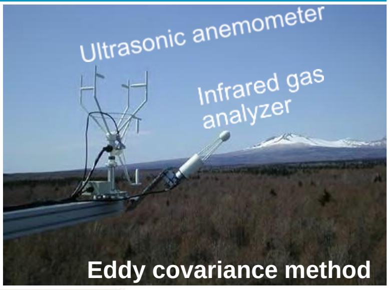
Recent progress in studies of Bottom-up approach

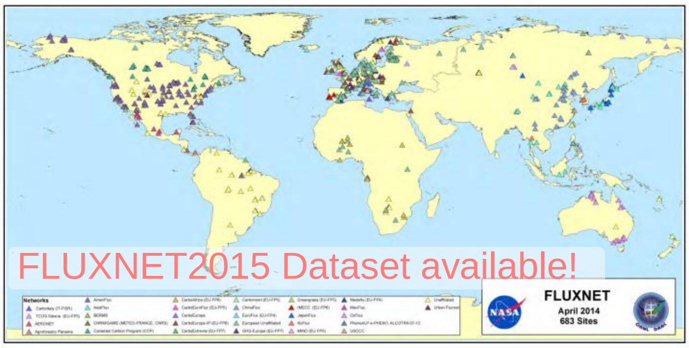
C-budget estimations based on network observation

FLUXNET (1996~)

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

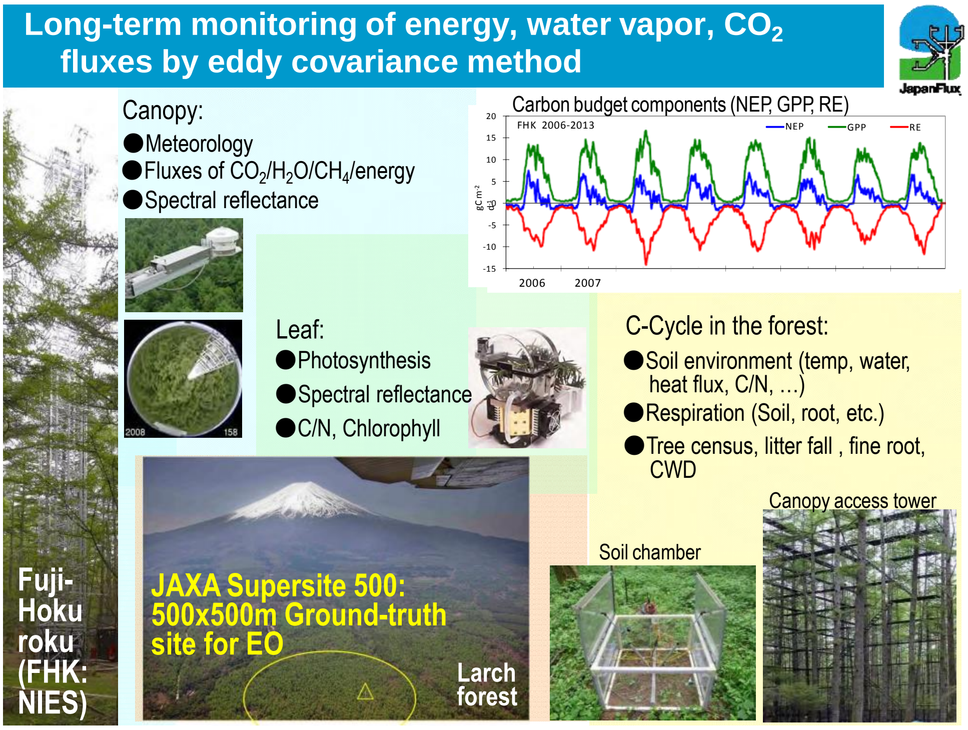
Archiving CH_4, N_2O flux data (started)

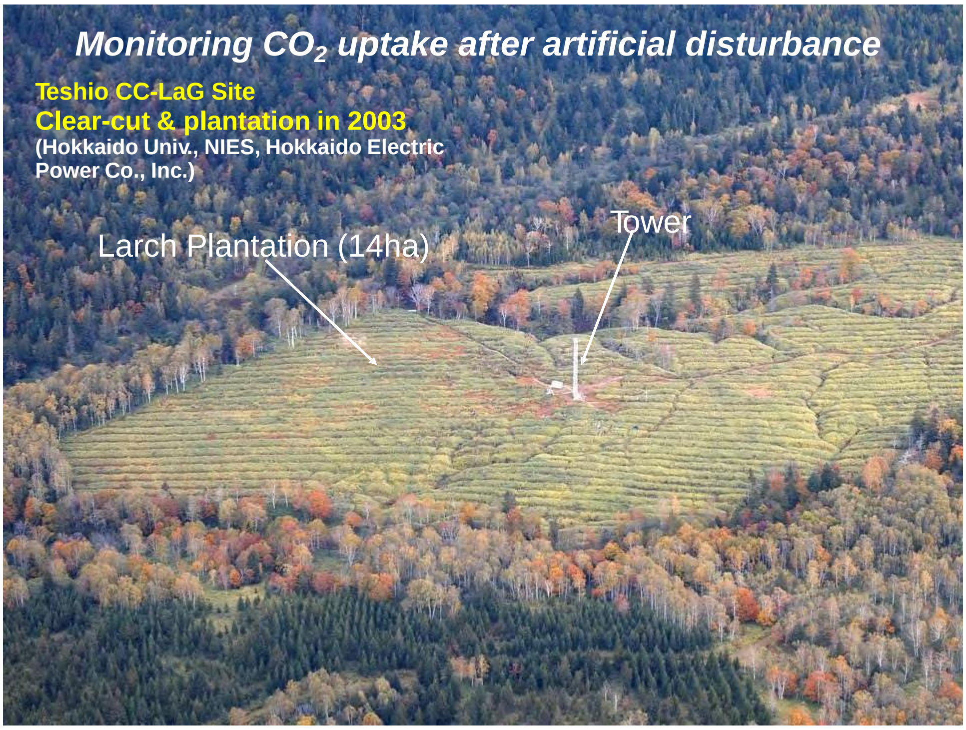


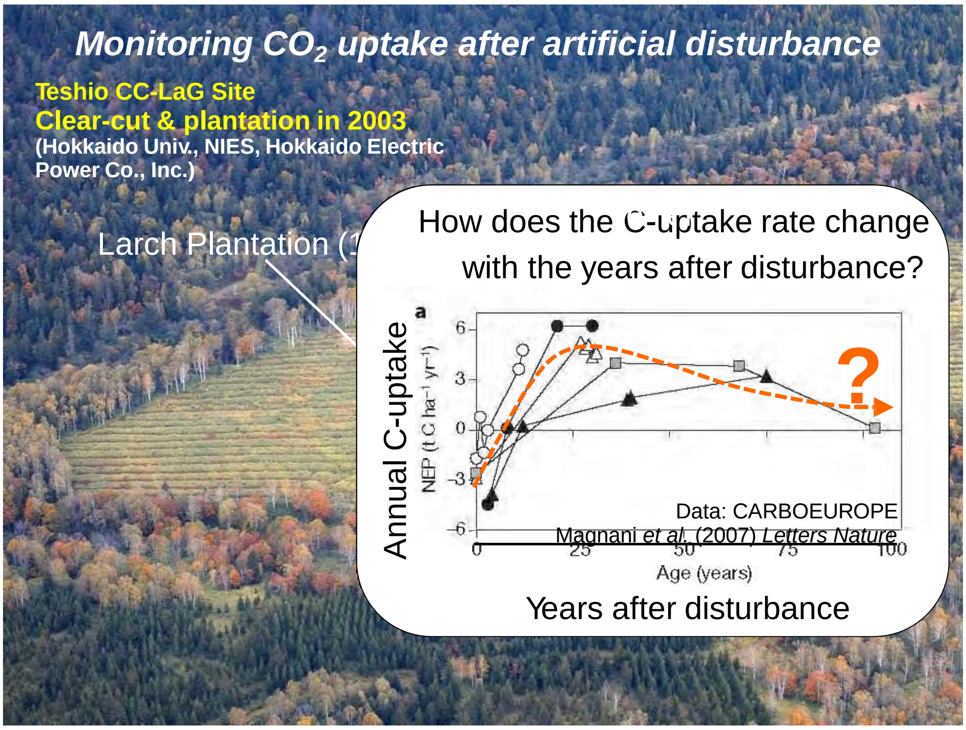


Location of FLUXNET sites

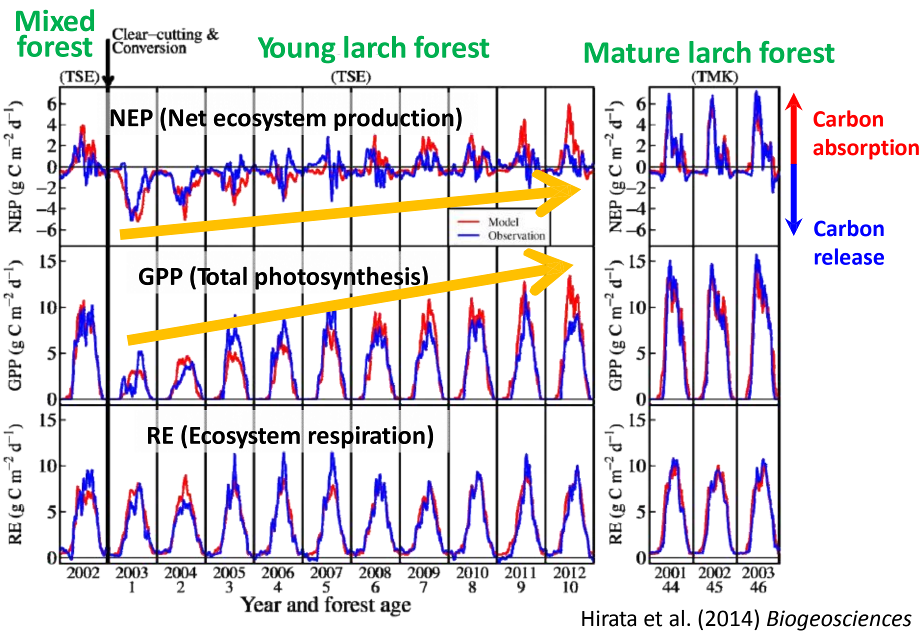
http://fluxnet.ornl.gov


Long-term monitoring of energy, water vapor, CO_2 fluxes by eddy covariance method
JapanFlux
Canopy:
●Meteorology
●Fluxes of CO_2/H_2O/CH_4/energy
●Spectral reflectance
Carbon budget components (NEP, GPP, RE)
FHK 2006-2013
NEP
GPP
RE
2006
2007
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
Canopy access tower
Soil chamber
JAXA Supersite 500: 500x500m Ground-truth site for EO
Larch forest
Fuji-Hokuroku (FHK: NIES)


Monitoring CO_2 uptake after artificial disturbance
Teshio CC-LaG Site
Clear-cut & plantation in 2003
(Hokkaido Univ., NIES, Hokkaido Electric Power Co., Inc.)
Larch Plantation (14ha)
Tower



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

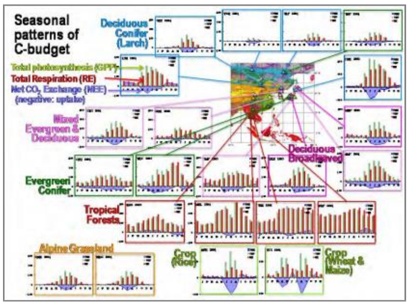
Number of sites registered: 102

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

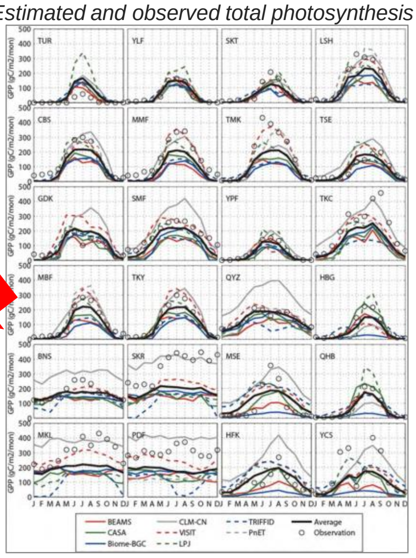
Promoting managed ecosystem monitoring (Rice paddy, etc.)

Model – Data Integration for C-budget Estimations

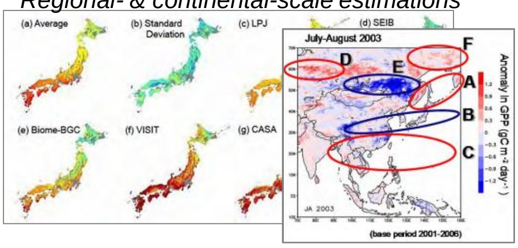
Eight different terrestrial models were validated using CO_2/H_2O/energy flux data obtained at 24 ecosystems (forests/grasslands/croplands) in Asia



Estimated and observed total photosynthesis

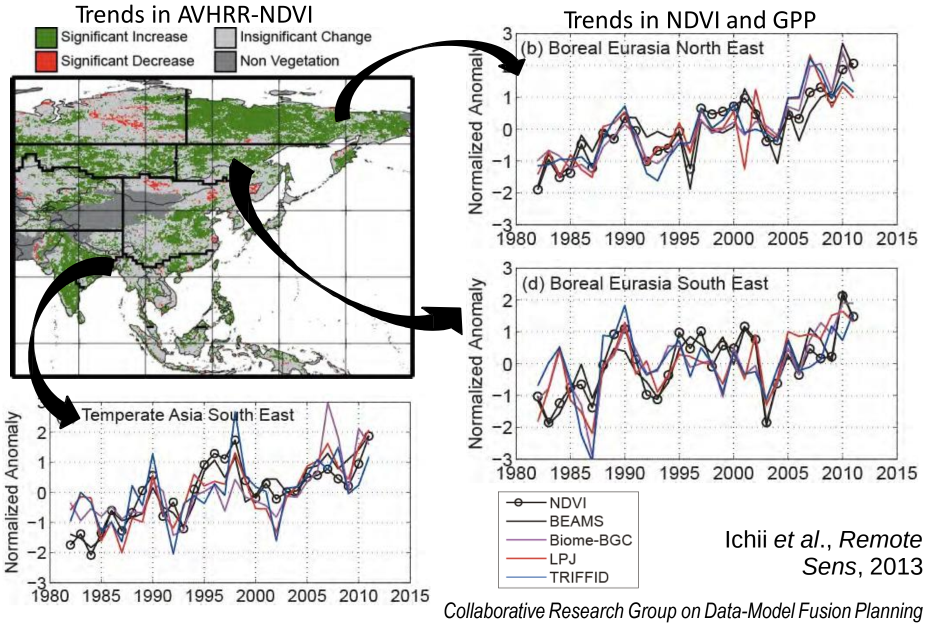


Regional- & continental-scale estimations



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

Trends in NDVI & Total Photosynthesis in Siberia



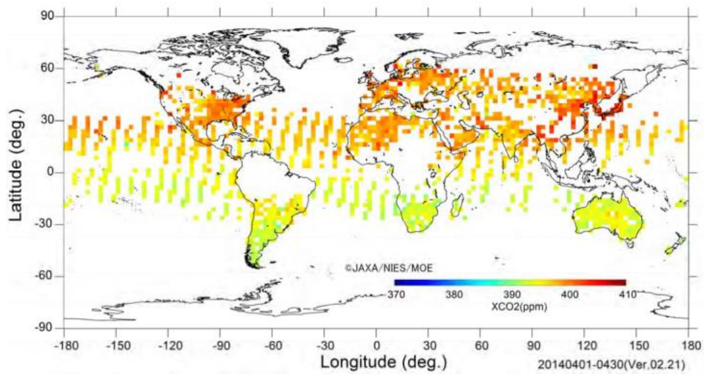
Ichii *et al.*, *Remote Sens*, 2013

Collaborative Research Group on Data-Model Fusion Planning 13

Recent progress in studies of Top-down approach

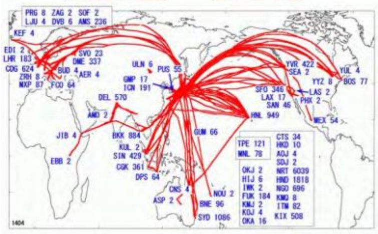
GOSAT Carbon Dioxide Concentration Map

http://www.gosat.nies.go.jp/en/

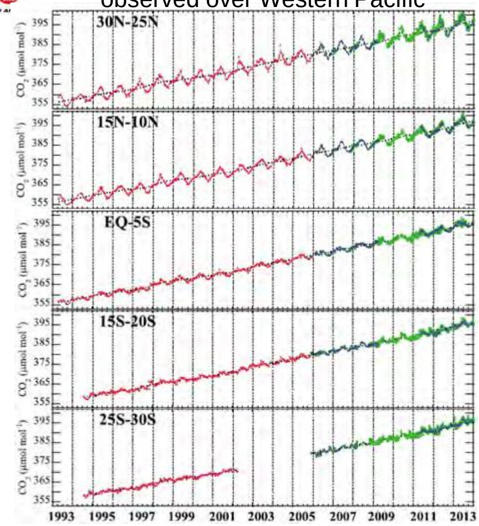


CONTRAIL: Atmospheric CO_2 and other trace gas observation using commercial airlines

CONTRAIL Group



Atmospheric CO_2 concentration observed over Western Pacific



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

Slide provided by Dr. Machida

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

Atmospheric CO_2 Inversion with Siberian Tall Towers

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.

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

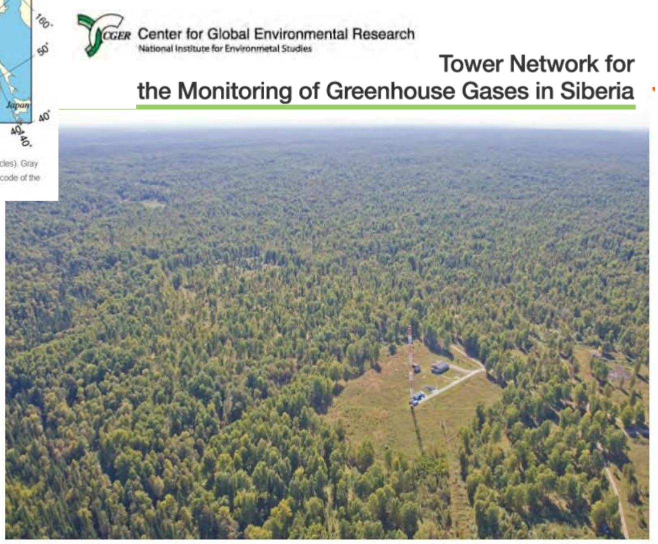


Photo 1 Monitoring tower in Berezorechka in the interior of West Siberian taiga

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

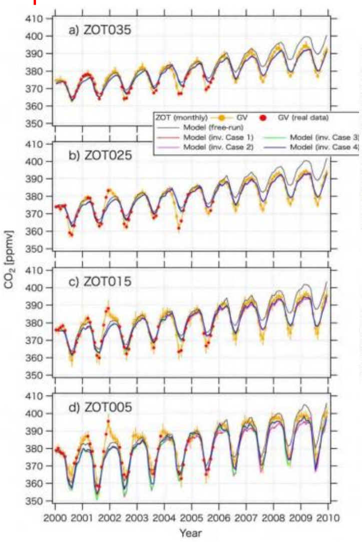
More high-quality atmospheric CO_2 data

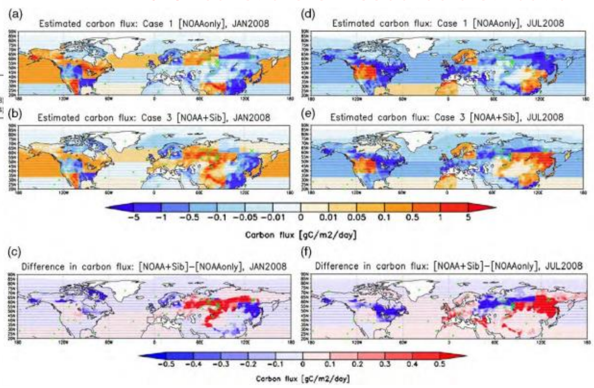
→ More realistic C sink/source distribution

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

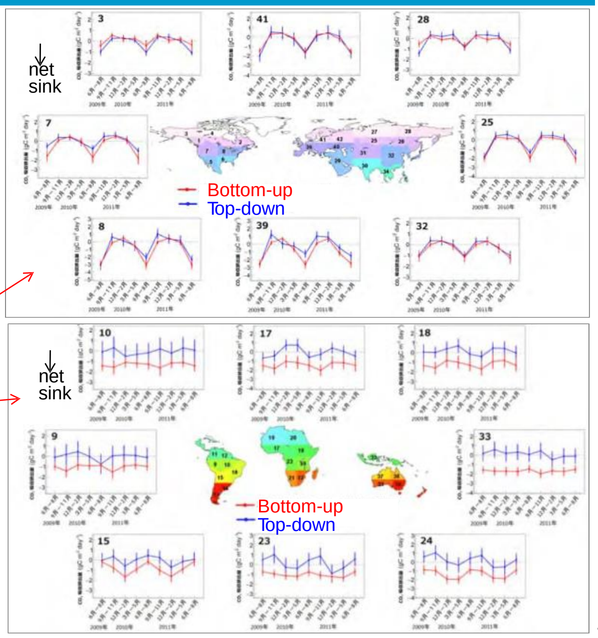
Data-Driven Top-down vs Bottom-up CO_2 Fluxes

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

Can changes in biomass be used as an independent validation of terrestrial C flux estimation?

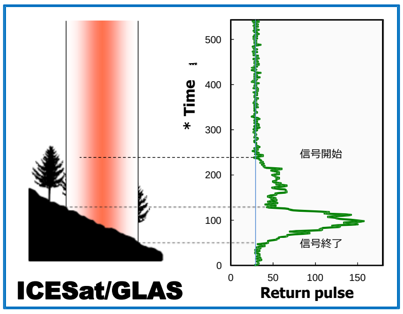
Biomass estimation using Spaceborne LiDAR (ICESat /GLAS)

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).

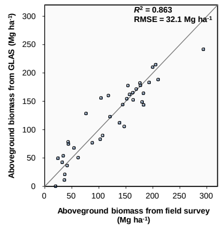
Hayashi et al., *ISPRS journal of photogrammetry and remote sensing*, 2013

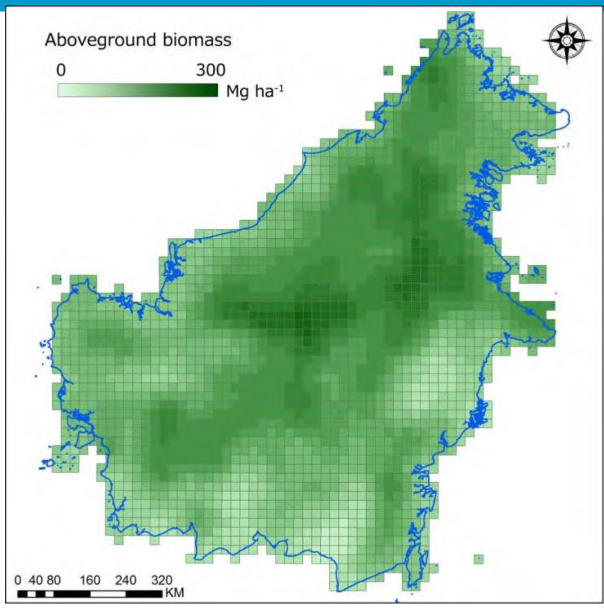
Forest biomass estimation in Borneo

1. AGB estimation @ 110,743 points

2. Average AGB @ 20 km mesh

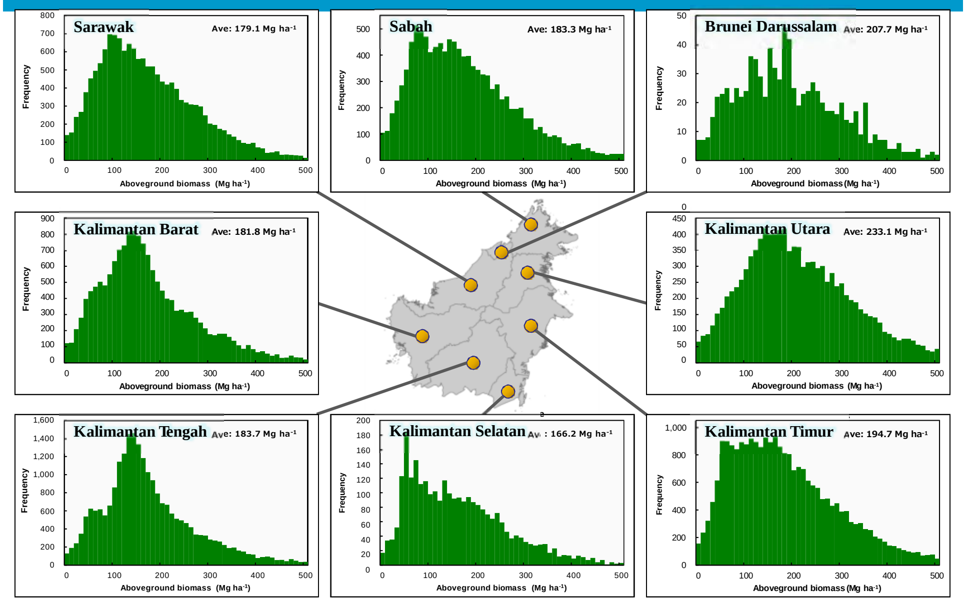
3. Interpolated AGB (Kriging method)





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

Summary

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

- Multi-platform observations & integration of such observations 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