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

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Contents:

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

Background and Needs in Global C Management

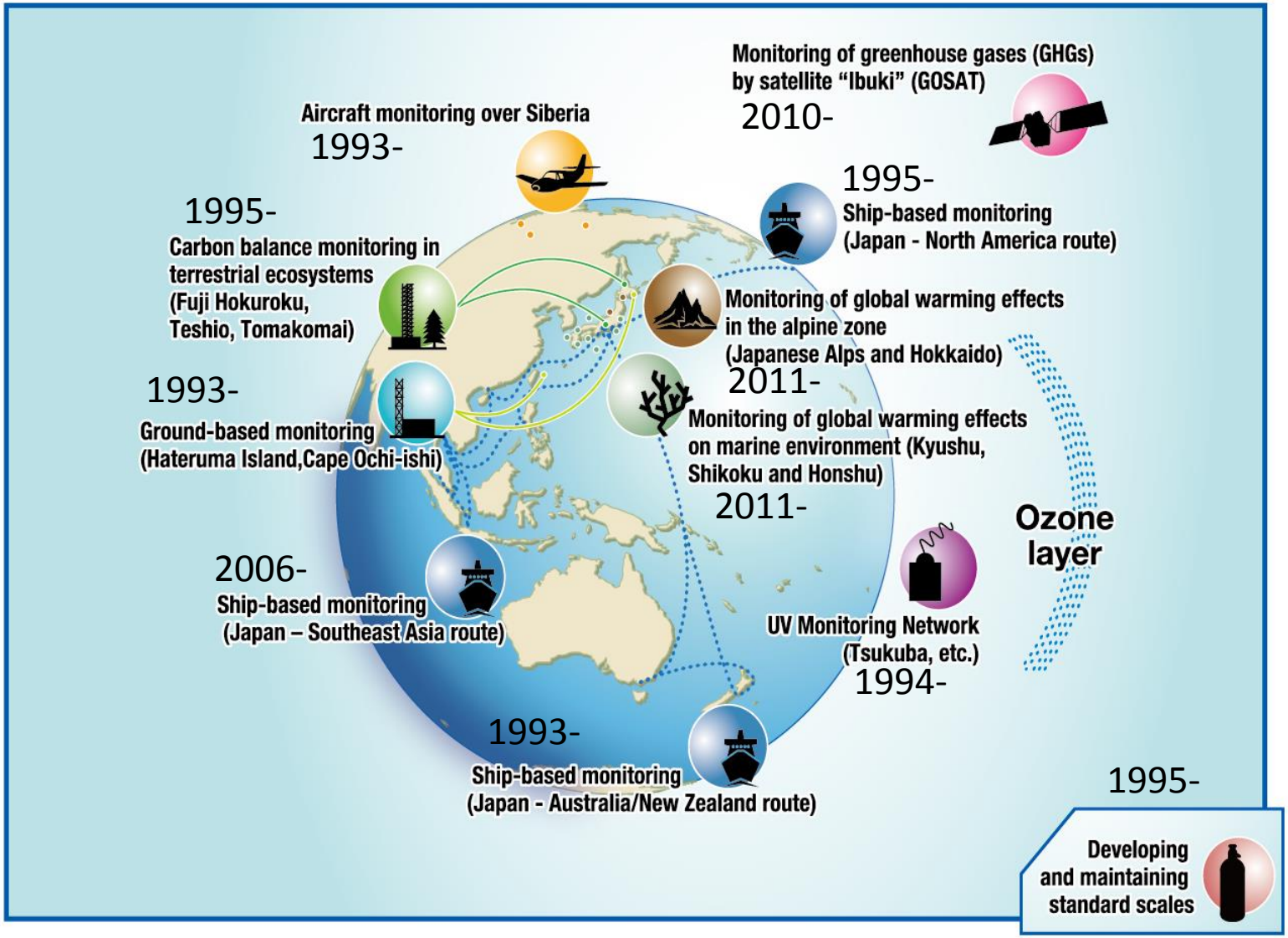
Background:

- High uncertainty still remains in global & regional C-budget due to limited spatial coverage in the observation and uncertainty in models
- Next-generation GHGs Observing Satellites is needed combined with aircraft, ship, and ground based observations.
- Improved data assimilation systems using multi-platform 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

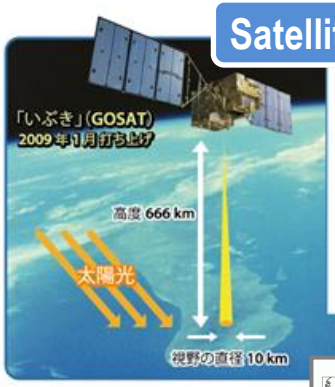
Strategic Monitoring of the Global Environment
(*Center for Global Environmental Research*)

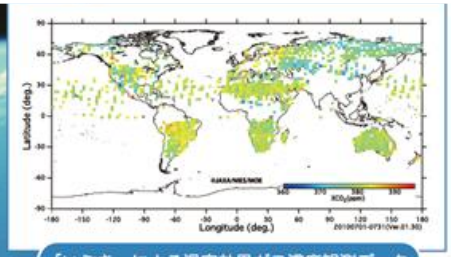


2-1401 Integrated Observation and Analysis System for Early Detection of Carbon Cycle Change Globally and in Asia-Pacific Region

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

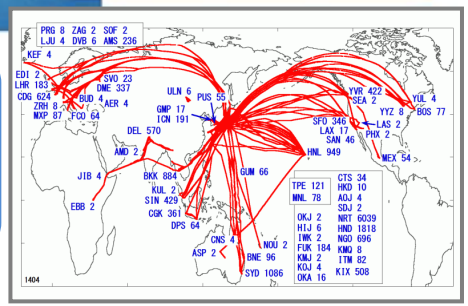
Satellite-based GHGs monitoring



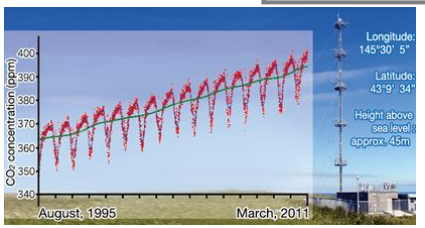


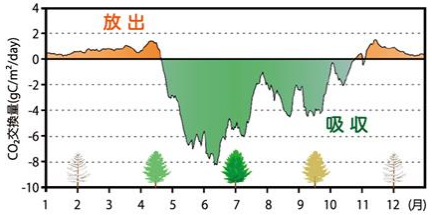
「いぶき」による温室効果ガス濃度観測データ

Airplane- and Ship-based monitoring of GHGs



Ground-based monitoring of GHGs concentration and their fluxes





Improved estimates of regional fluxes using atmospheric inverse models

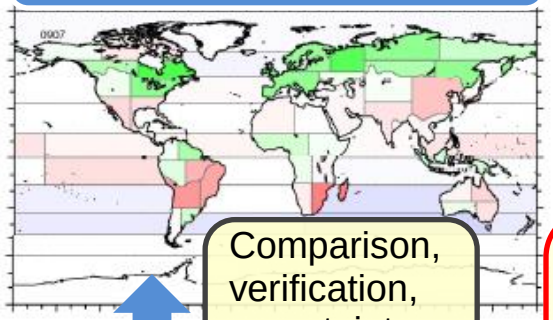
Improved estimates of terrestrial surface fluxes based on bottom-up approaches

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

Parameter optimization
Data assimilation

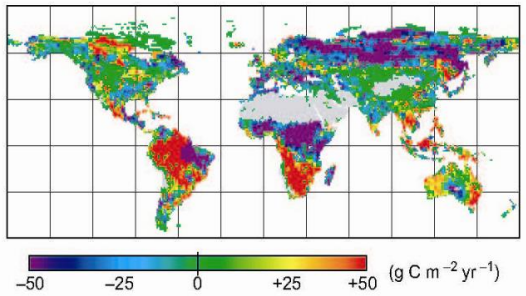
Better estimation of temporal & spatial distributions of GHGs concentration and their fluxes

Top-down approach



Comparison, verification, uncertainty assessment

Bottom-up approach



- 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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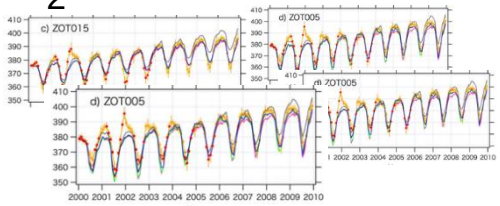
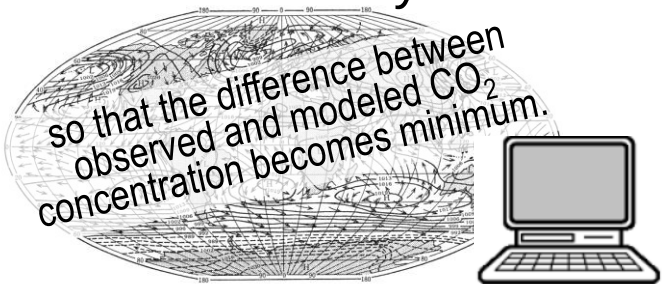
Top-down approach

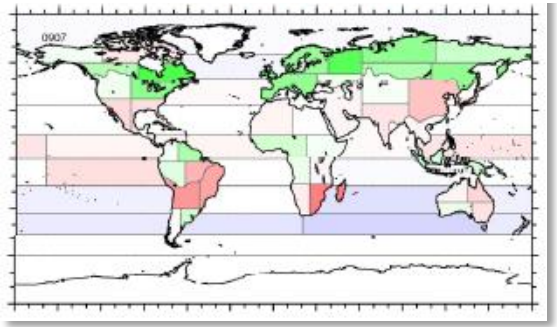
High quality atmospheric CO_2 concentration data



Inverse analysis



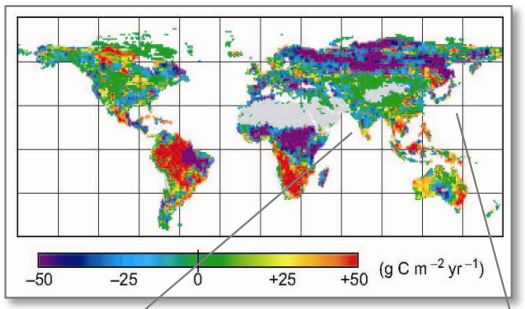
Global &regional sink/source distribution



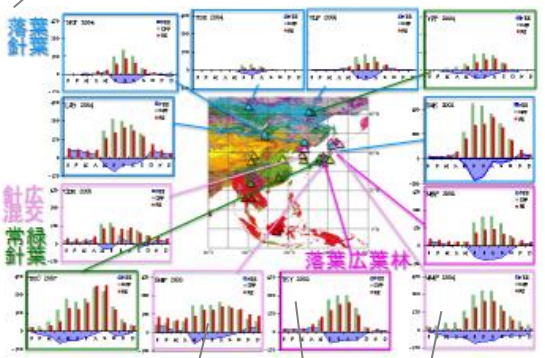
Comparison, Verification, Uncertainty assessment

Bottom-up approach

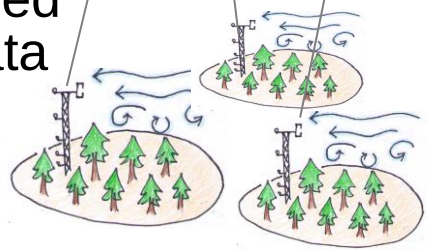
Up-scaled sink/source distribution



Improve and optimize terrestrial models



Ground-based CO_2 flux data



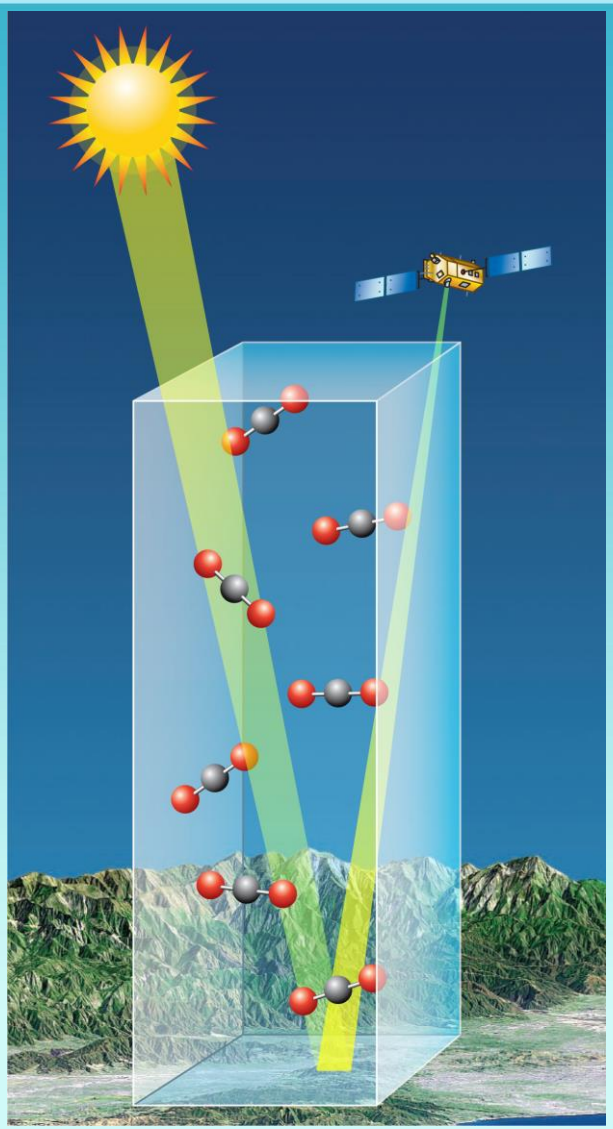
Recent progress in studies of Top-down approach

GOSAT-2 PROJECT
AT THE NATIONAL INSTITUTE FOR ENVIRONMENTAL STUDIES

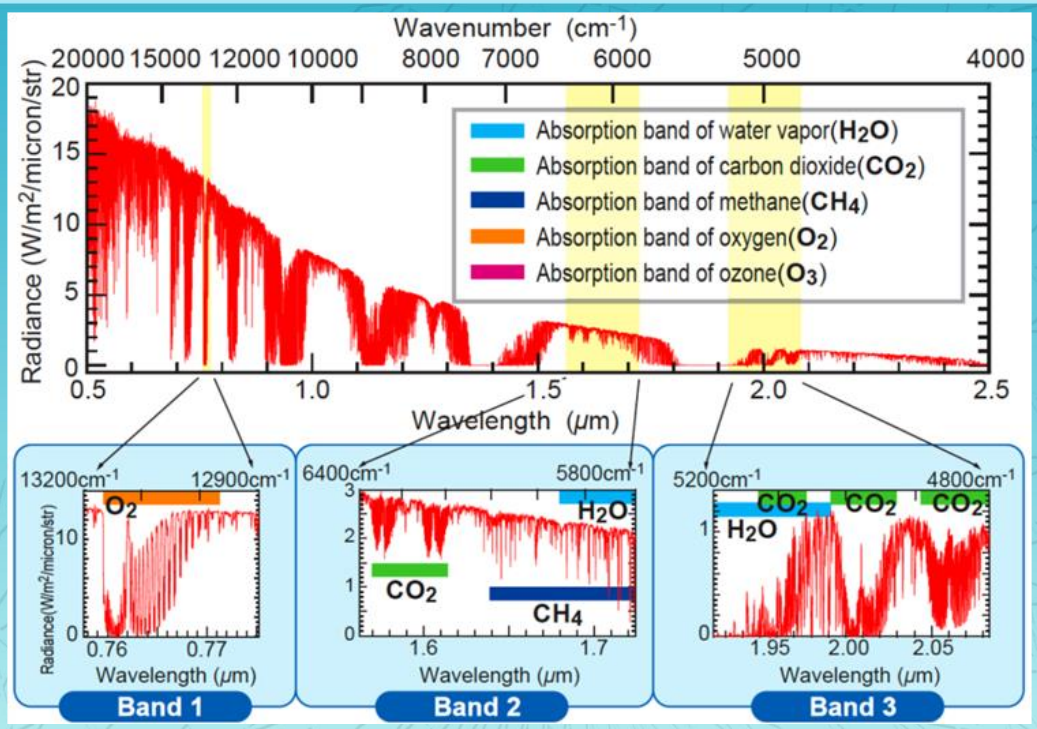
Greenhouse Gas Monitoring from Space -GOSAT, GOSAT-2, and REDD+ MRV-

Tsuneo Matsunaga and Tatsuya Yokota
National Institute for Environmental Studies (NIES)

How to Measure CO2 Concetration From Space

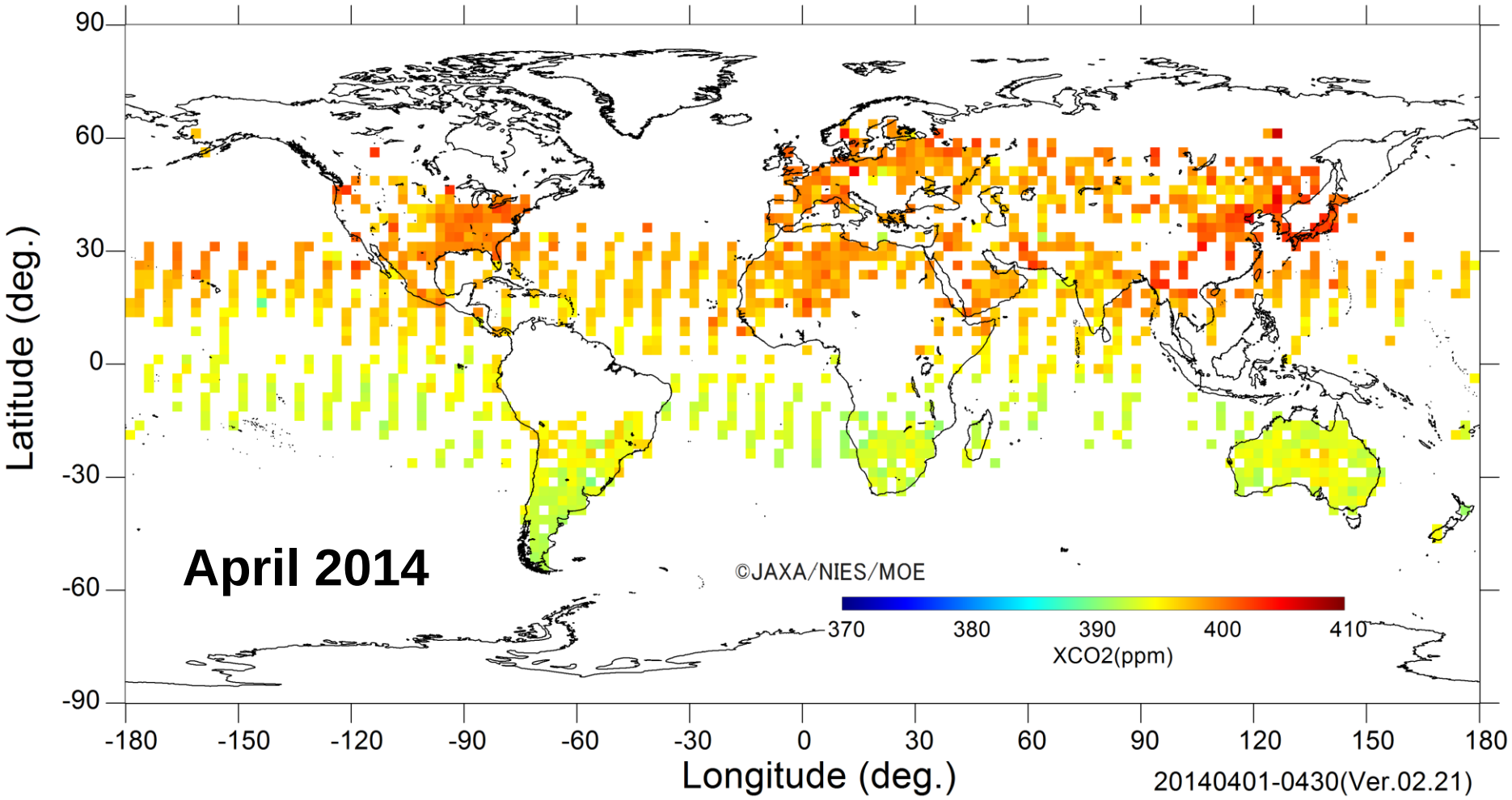


http://oco.jpl.nasa.gov/images/oco/OCO_column.jpg



Gas molecules in the atmosphere, such as carbon dioxide, absorb sun light at their specific wavelengths and the absorption intensities are determined by the number of gas molecules. So by inversely analyzing sun light reflected at the Earth's surface, we can estimate the amount and concentration of gas molecules.

GOSAT Carbon Dioxide Concentration Map

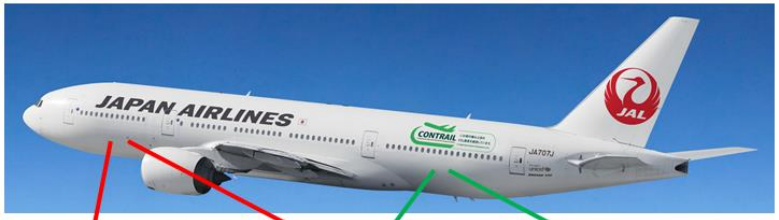


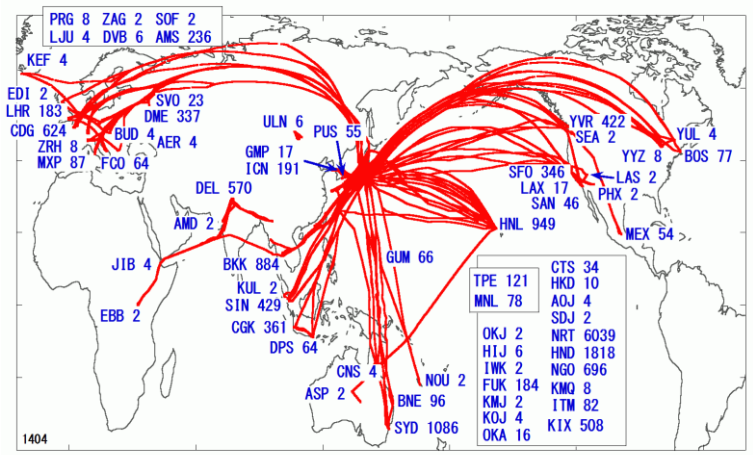
Slides provided by Drs. Matsunaga & Yokota

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

CONTRAIL Group

CONTRAIL Comprehensive Observation Network for Trace gases by Airliner

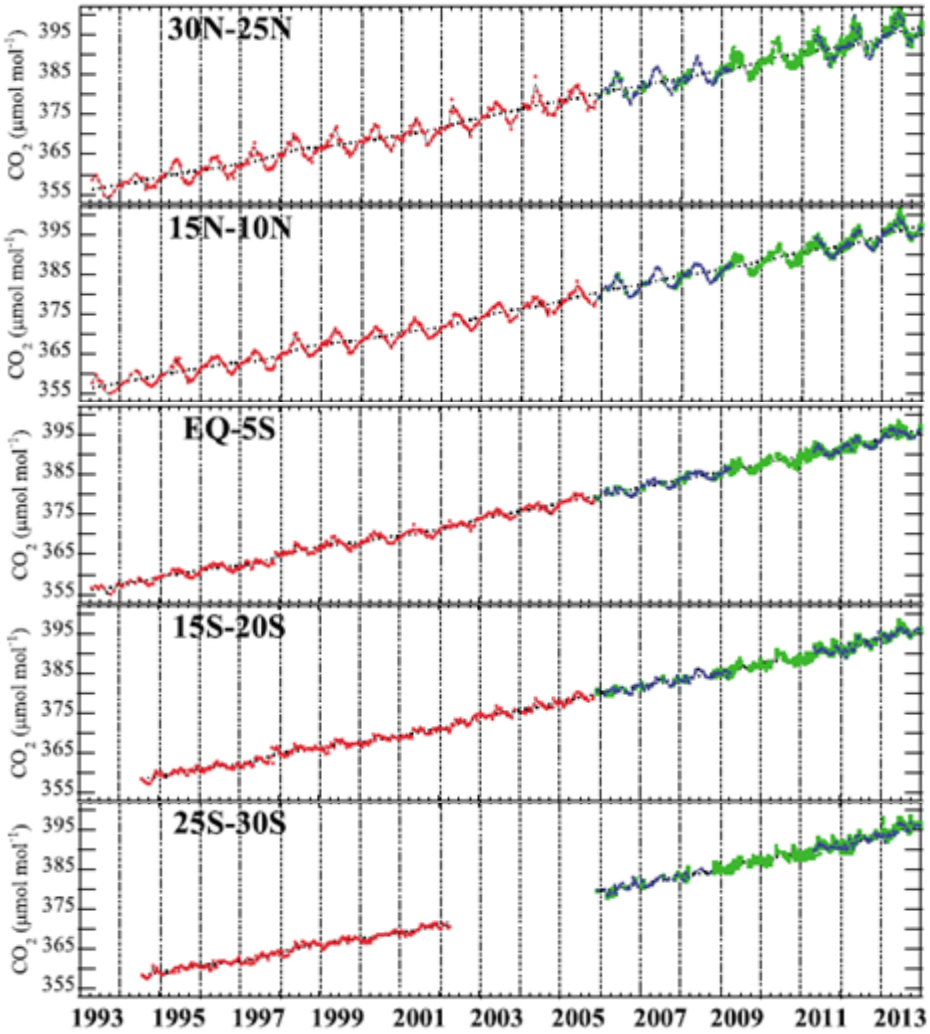




http://www.cger.nies.go.jp/contrail/

Slide provided by Dr. Machida

Atmospheric CO_2 concentration observed over Western Pacific



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

GROUP ON EARTH OBSERVATIONS

Atmospheric CO_2 Inversion with Siberian Tall Towers

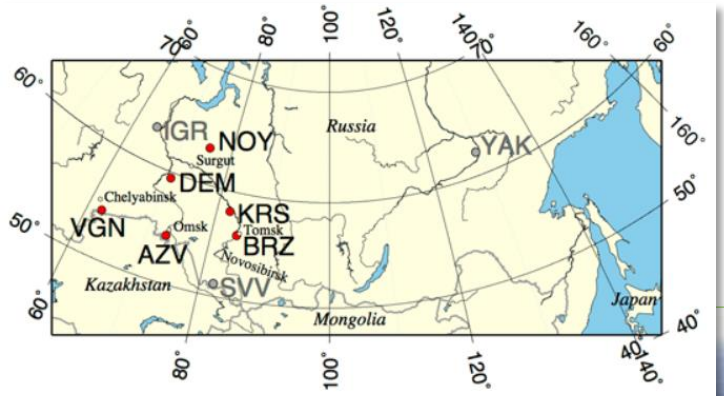


Figure 1 Locations of the monitoring towers in the network (JR-STATION) (red circles). Gray circles indicates former observation sites. The alphabet combination indicates the code of the sites (Table 1). Main cities are marked with white circles.

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

CGER Center for Global Environmental Research
National Institute for Environmetal Studies

Tower Network for
the Monitoring of Greenhouse Gases in Siberia

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

More high-quality atmospheric CO_2 data

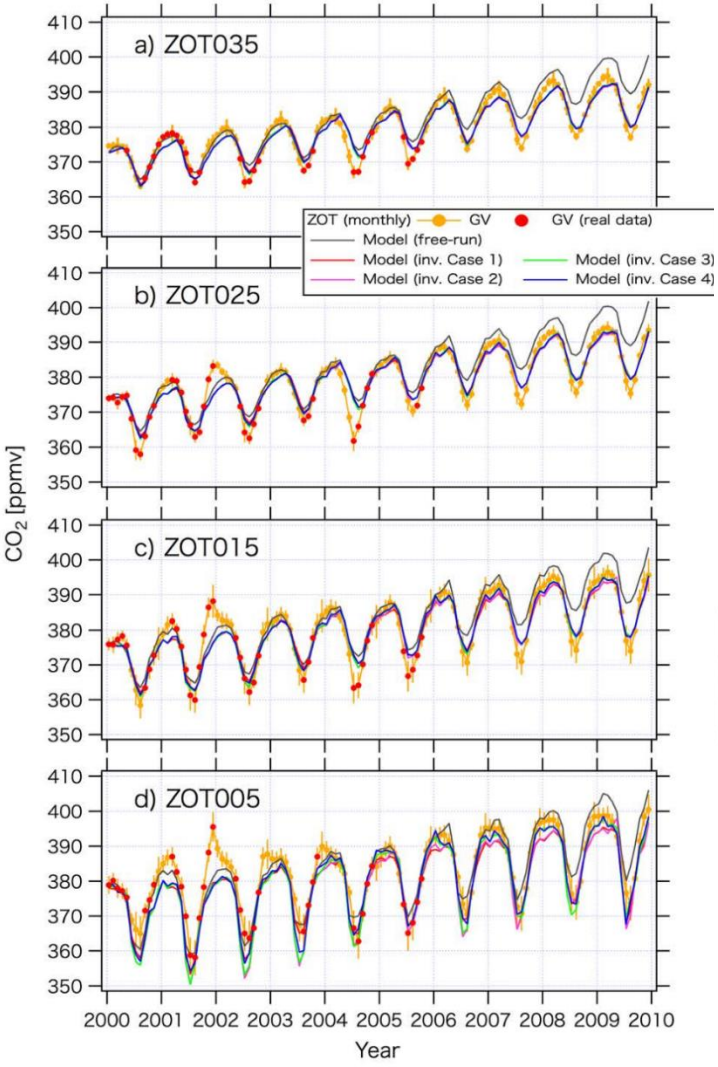
→ More realistic C sink/source distribution

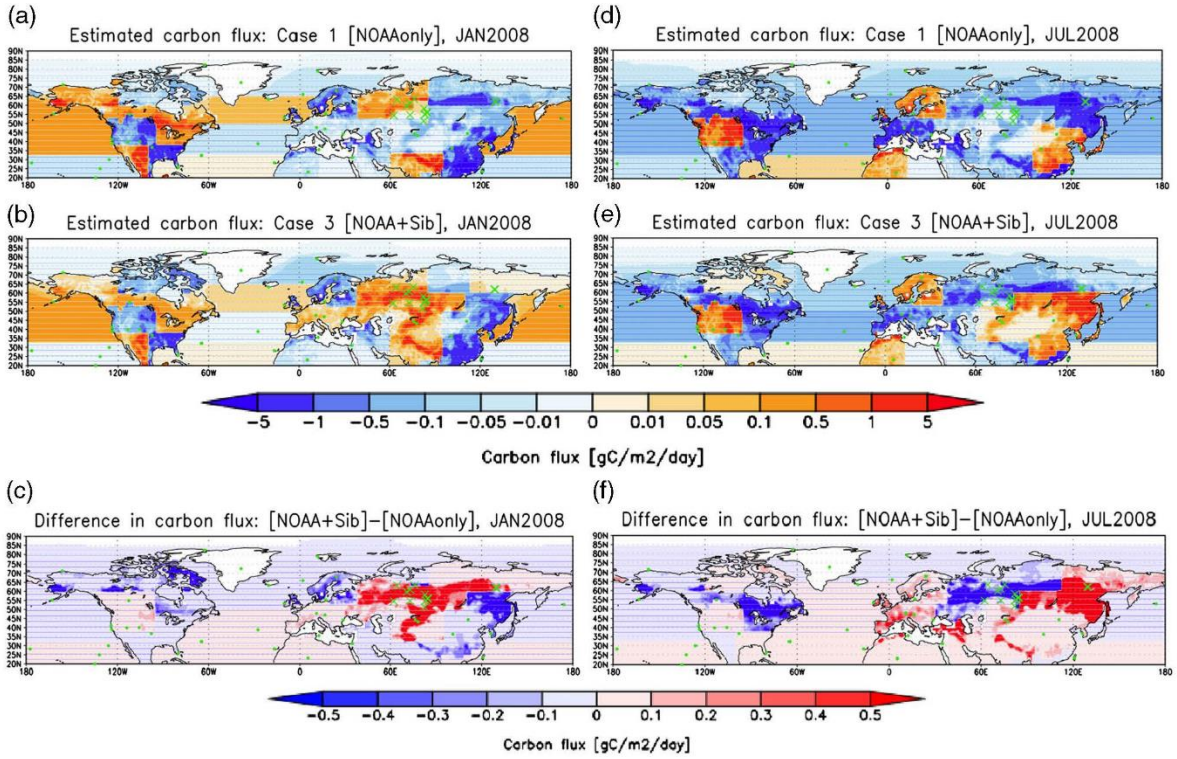
Photo 1 Monitoring tower in Berezorechka in the interior of West Siberian taiga

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

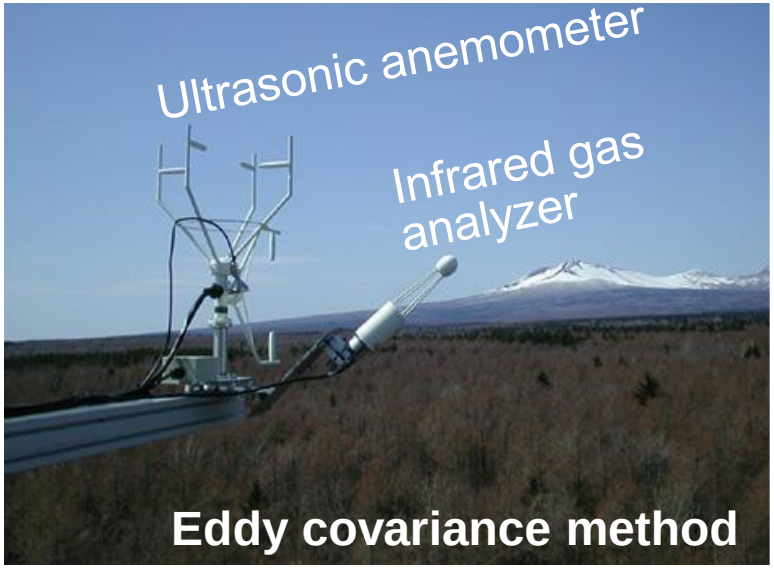
Recent progress in studies of Bottom-up approach

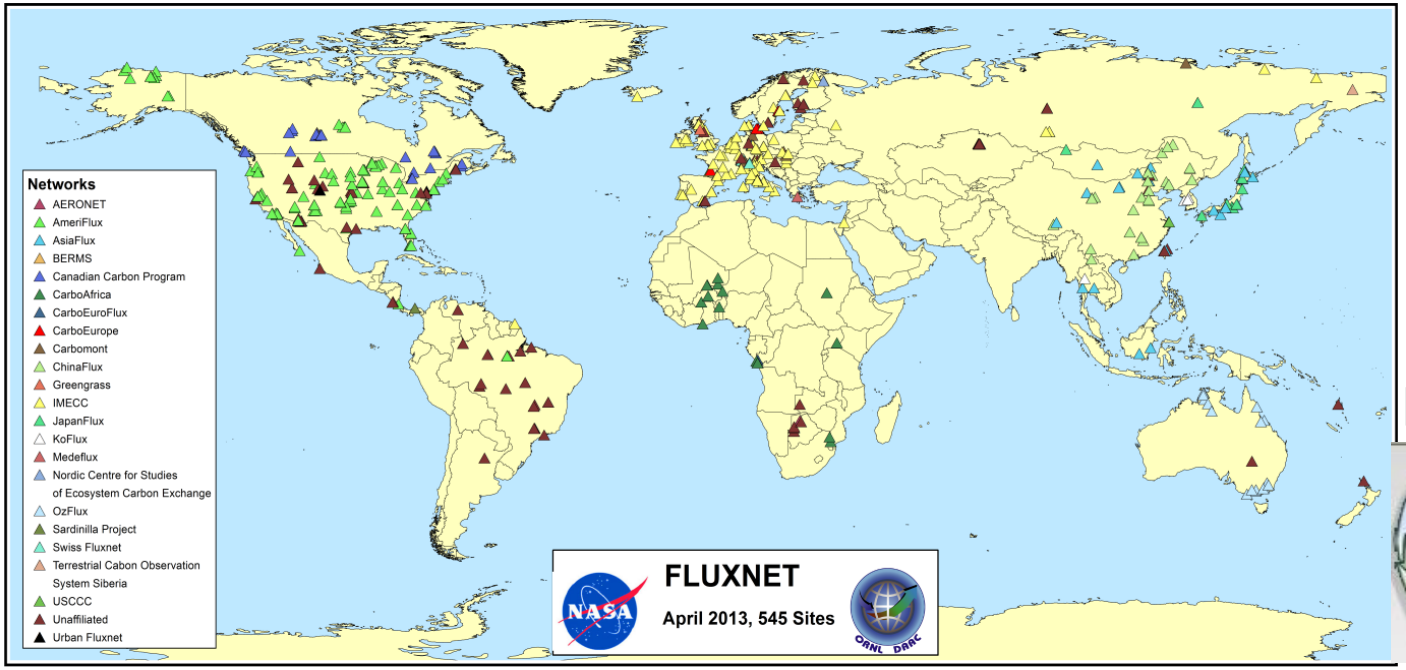
C-budget estimations based on network observation

FLUXNET (1996~)

World-wide network for monitoring CO_2, H_2O, and energy exchanges between terrestrial ecosystems and the atmosphere (> 500 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 EC method

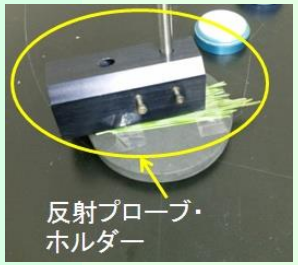
Canopy:

- Meteorology
- Fluxes of CO_2/H_2O/CH_4/energy
- Spectral reflectance
- Phenology (camera)

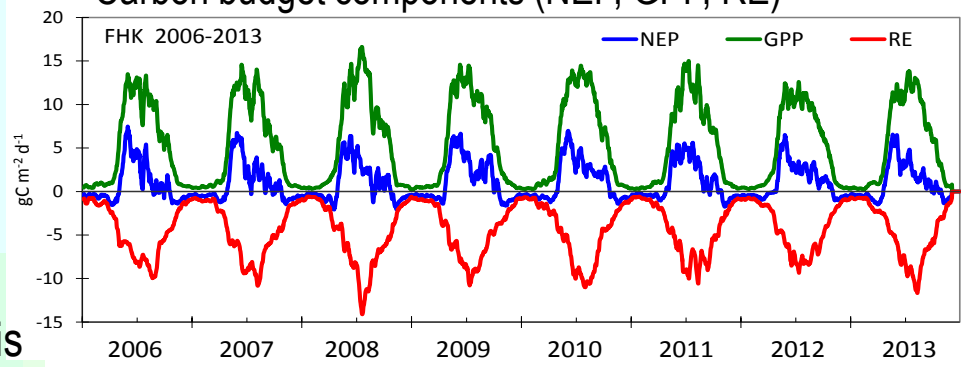
PEN

Leaf:

- Photosynthesis
- Spectral reflectance
- C/N, Chlorophyll



Carbon budget components (NEP, GPP, RE)



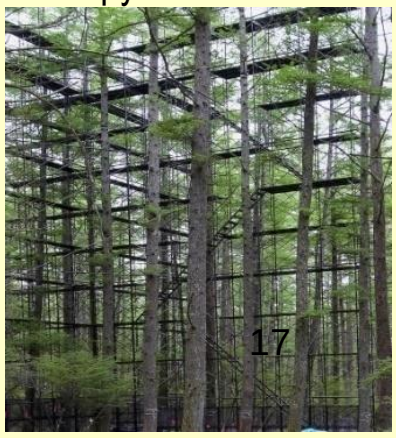
C-Cycle in the forest:

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

500x500m Ground-truth area for Earth Obs.

Soil chamber

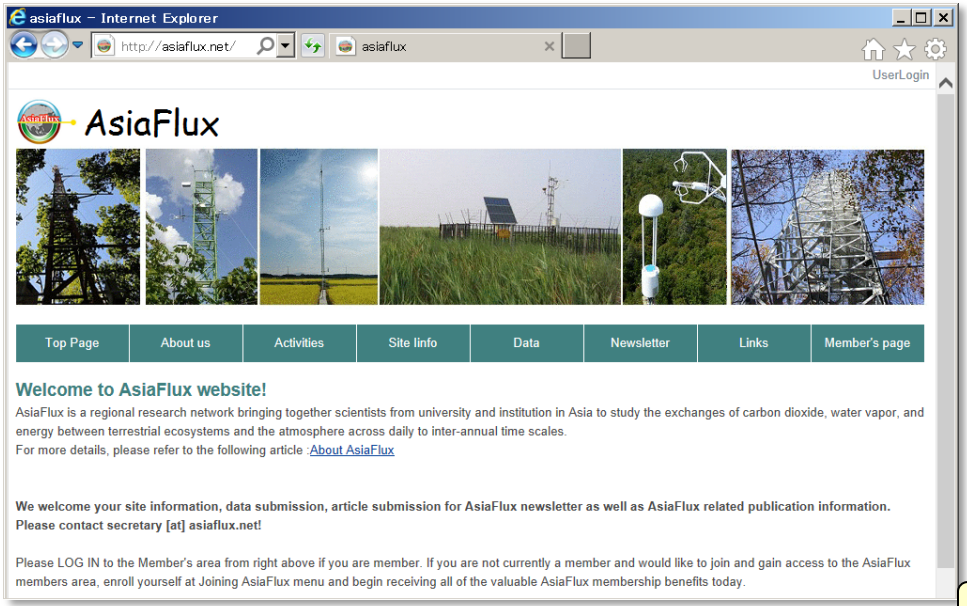
Canopy access tower



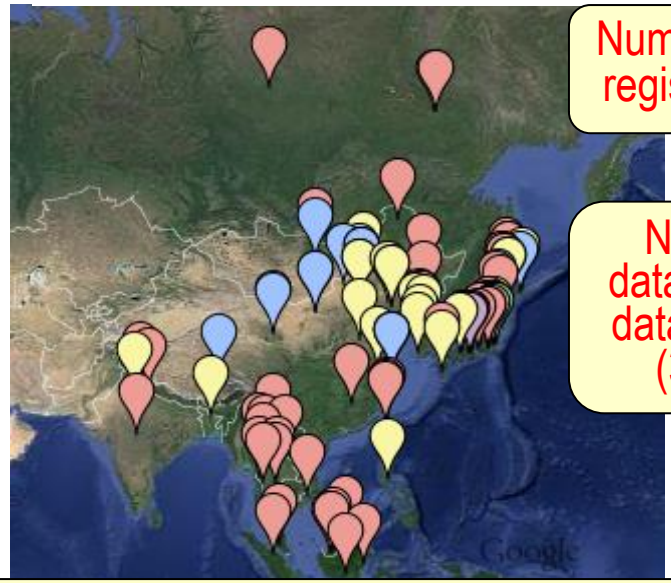
AsiaFlux: A Regional Network in FLUXNET

AsiaFlux Tsukuba Office (NIES)

http://asiaflux.net



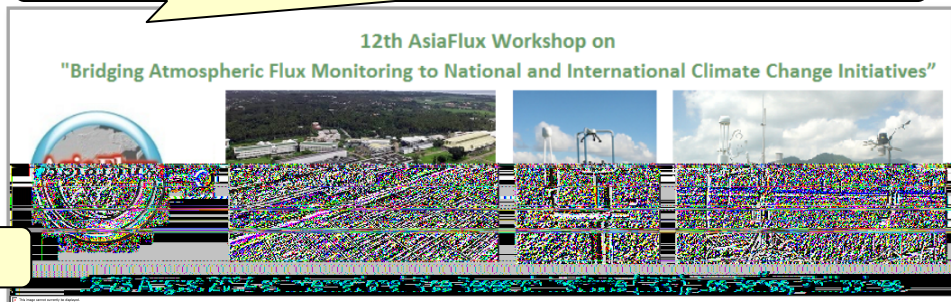
Location of AsiaFlux sites

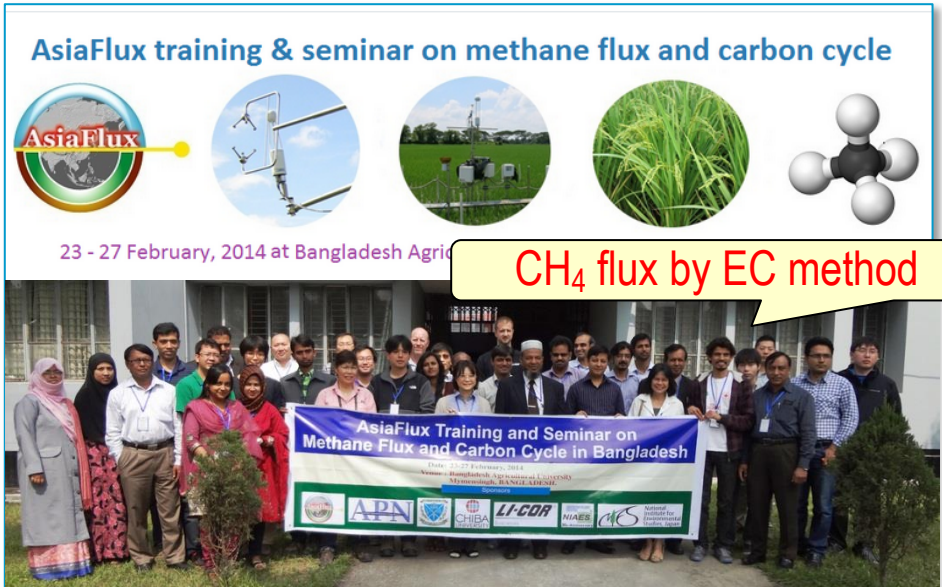


Number of sites registered: 101

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

Managed ecosystem monitoring (Rice paddy, etc.)





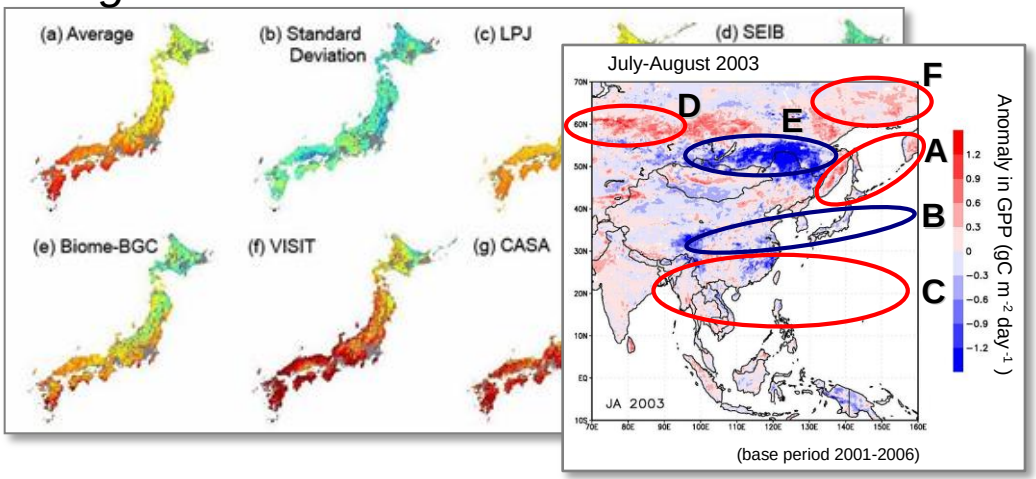
CH_4 flux by EC method

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

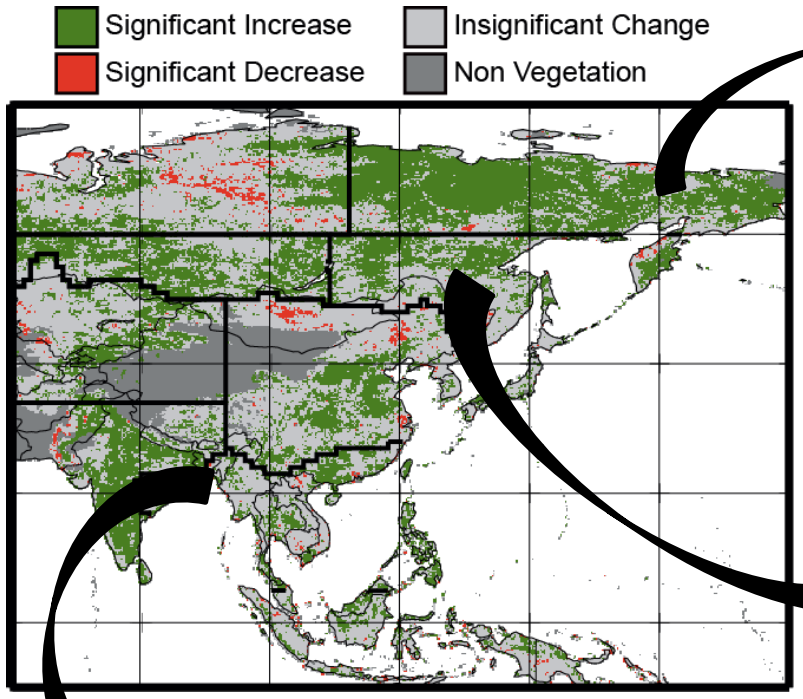


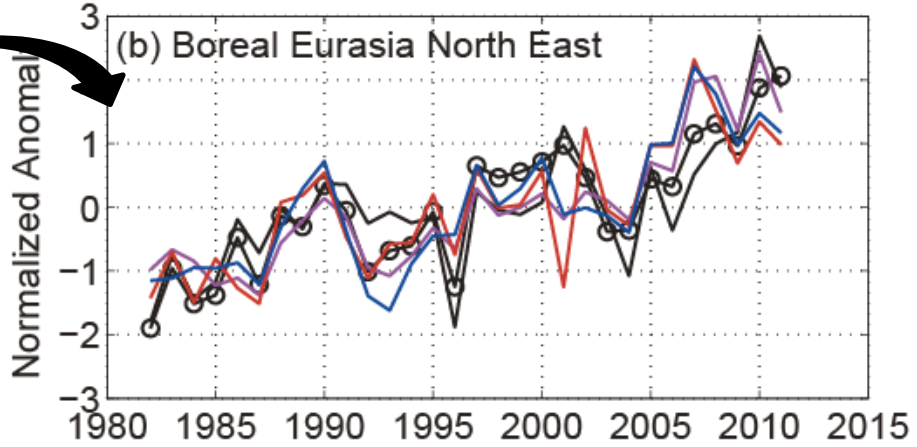
Saigusa *et al.* (2010) (2013); Ichii *et al.* (2010) (2013)

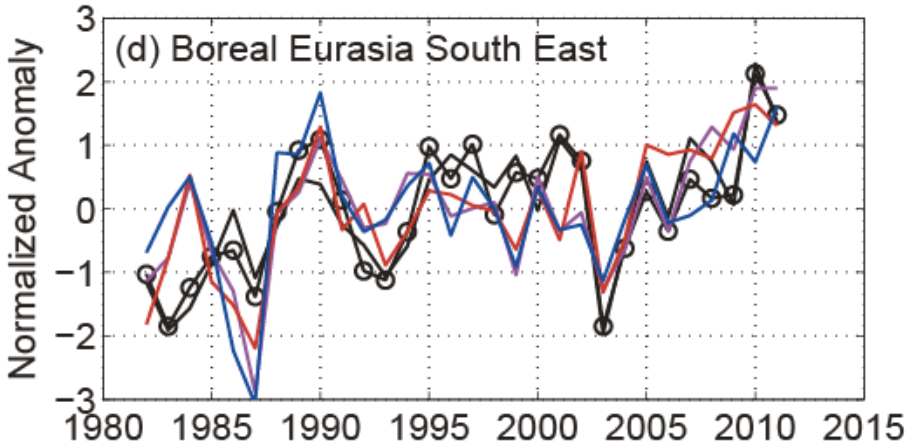
Long-term Trends in NDVI & Total Photosynthesis in Siberia

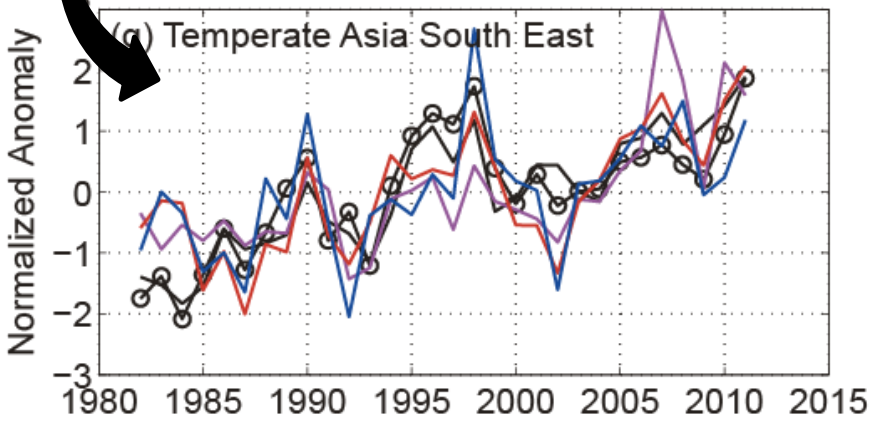
Trends in AVHRR-NDVI and modeled photosynthesis

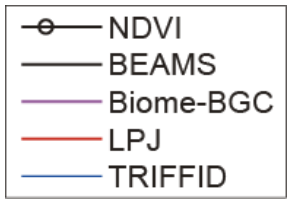
Slide provided by Dr. Ichii











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

Inter comparison between Top-down & Bottom-up

Uncertainty assessment

Improved estimates of surface fluxes

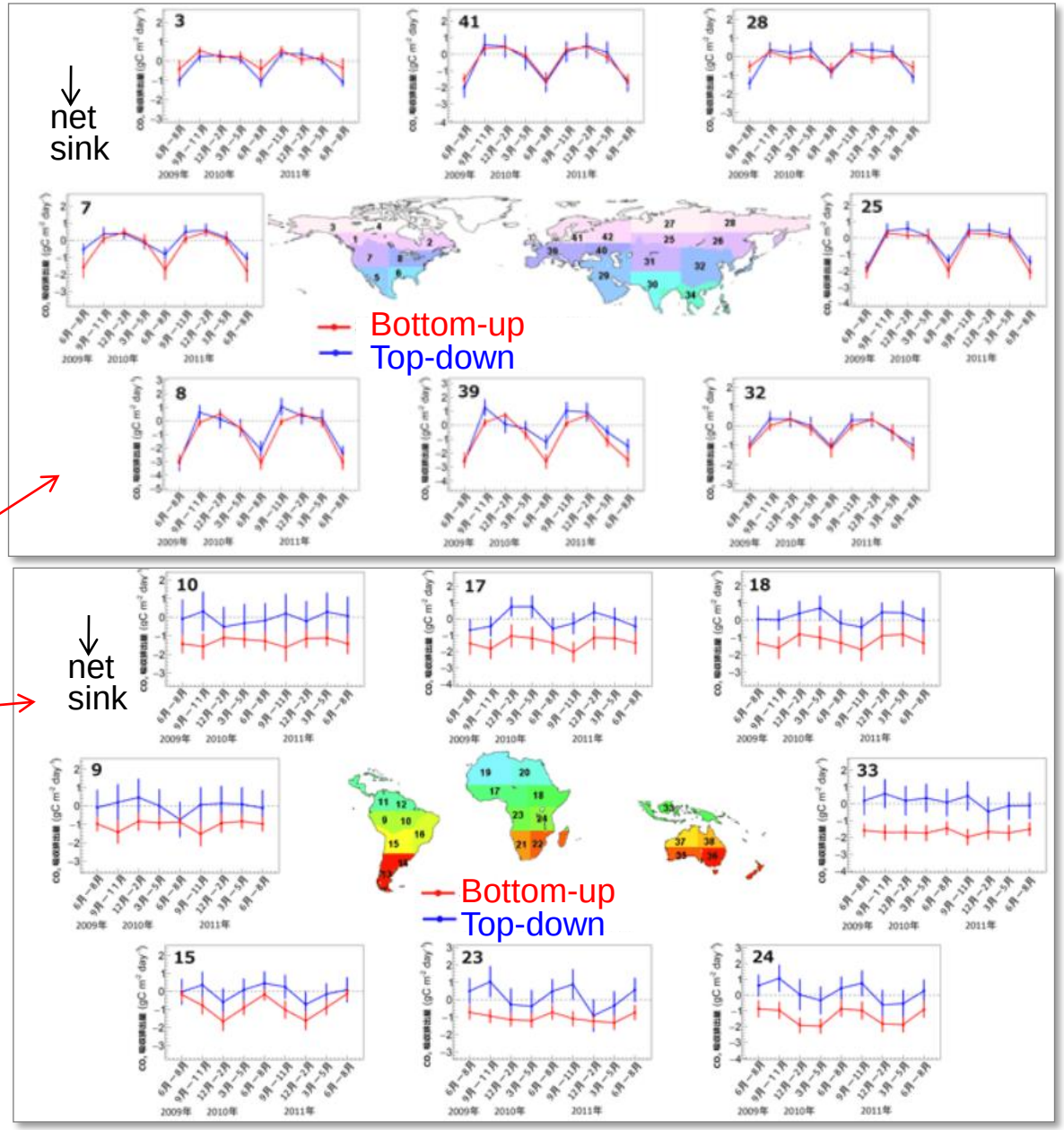
Data-Driven Top-down vs Bottom-up CO_2 Fluxes

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

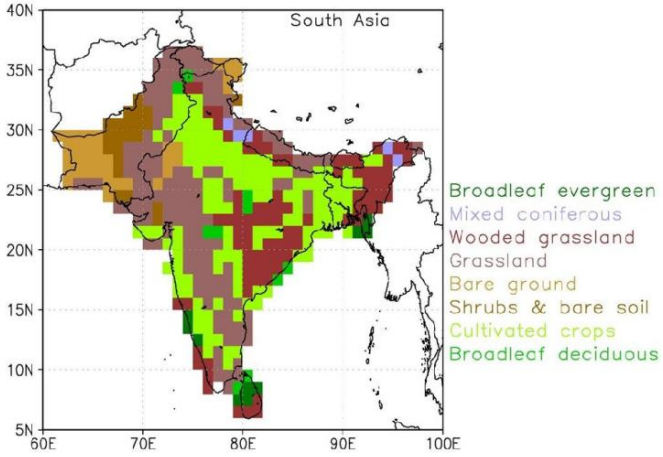
Kondo *et al*. *JGR*, 2015

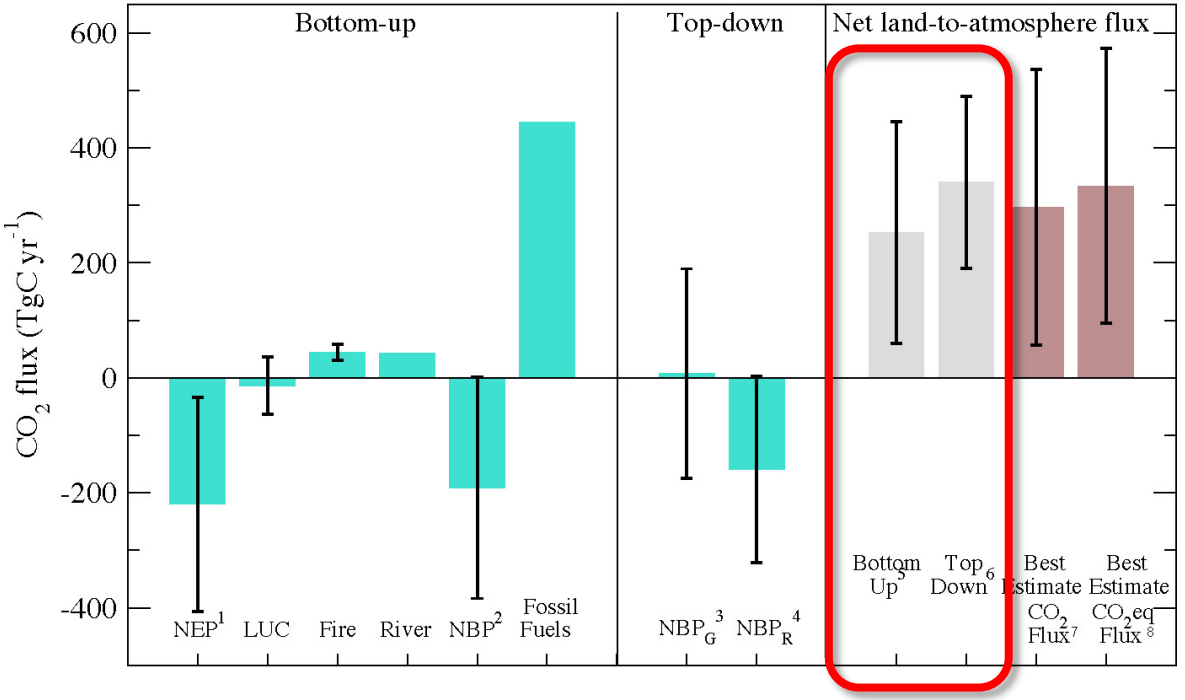
Regional CO_2 Budget by Top-down & Bottom-up Approaches

Bottom-up: NEP←NPP-Rh; LUC←plantation, cropland expansion; River export flux; Biomass burning; Emission from fossil fuels

Top-down: Global inversion & region specific inversion using reinforced aircraft data

Area of analysis: South Asia (Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka





(1) Net Ecosystem Productivity (NEP) = NPP – heterotrophic respiration
(2) Net Biome Productivity = Sum of NEP, LUC, Fire, River (NBP = NEP – disturbances and lateral transport)
(3) Equivalent to NBP based on global CO_2 atmospheric inversions (NBP_G)
(4) Equivalent to NBP based on region-specific CO_2 atmospheric inversions (NBP_R)
(5) Bottom Up = NBP^2 + Fossil Fuel emissions
(6) Top Down = Weighted mean of NBP_G^3 and NBP_R^4 + Fossil Fuel emissions
(7) Best estimate CO_2 flux (mean of bottom-up[5] and top-down[6] estimates)
(8) Best estimate CO_2-equivalent (CO_2eq) flux that includes CO_2 and CH_4 fluxes

Patra *et al.*
Biogeosciences, 2013
(RECCAP Special Issue)

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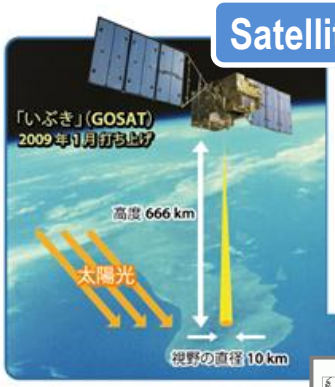
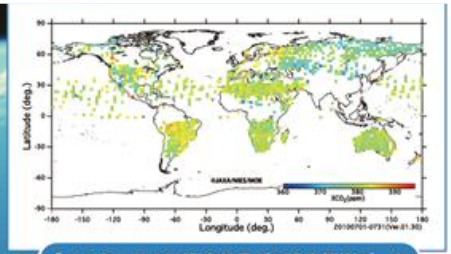
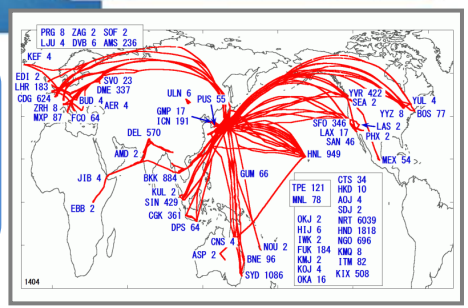
Integrated observing system for GHGs and their surface fluxes globally and in the Asia-Pacific

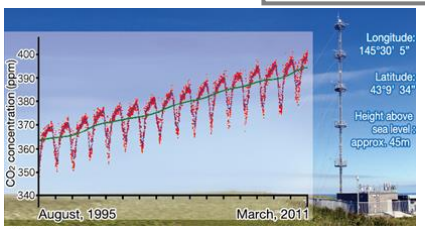
Satellite-based GHGs monitoring

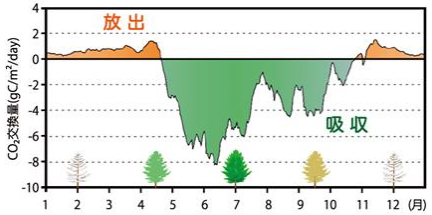




Airplane- and Ship-based monitoring of GHGs







Ground-based monitoring of GHGs concentration and their fluxes

Improved estimates of regional fluxes using atmospheric inverse models

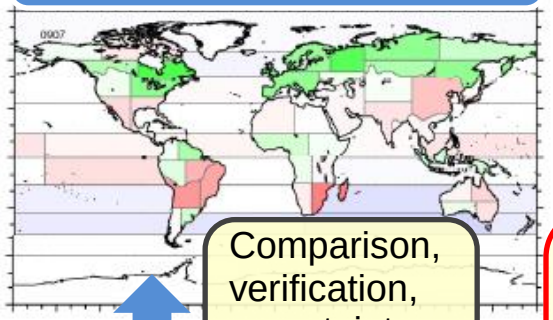
Improved estimates of terrestrial surface fluxes based on bottom-up approaches

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

Parameter optimization
Data assimilation

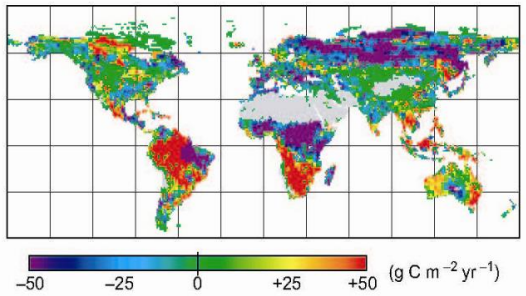
Better estimation of temporal & spatial distributions of GHGs concentration and their fluxes

Top-down approach



Comparison, verification, uncertainty assessment

Bottom-up approach



- 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

Summary and Suggestions

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

- Multi-platform observations of GHGs & improved data sharing
  Concentrations & fluxes based on next-generation GHGs
  Observing Satellites, aircrafts, ships, ground stations etc.
  particularly targeting the Asia-Pacific region
- Integration of such observations into improved data assimilation systems

To interpret the cause of changes in C-cycle and to evaluate human impacts on the changes, we have to have:

- Improved estimates of emissions from land-use change, fires, and other anthropogenic sources
- High-resolution regional analysis to detect large point sources
- Monitoring GHGs & SLCP (CH_4, O_3, BC…) in E- & SE- Asia