Detecting carbon cycle change using an integrated observation, modeling and analysis system

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Background and Needs

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 and analysis system is needed by combining satellite, aircraft, ship, and ground based observations and improved data assimilation systems for better estimation of C source/sink to evaluate mitigation and adaptation policies.

Focus of this presentation:

- Multiple approaches including different types of top-down models and bottom-up upscaling techniques contributed to designate uncertainties in the estimates of large emissions
- Detection of any changes that might be appearing in Asia under changing climate and society

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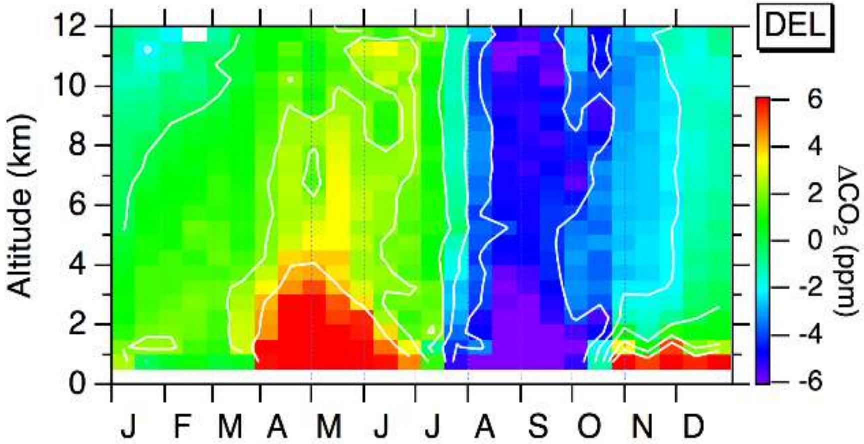
Reinforced aircraft observation in Asia

Next generation data assimilation system

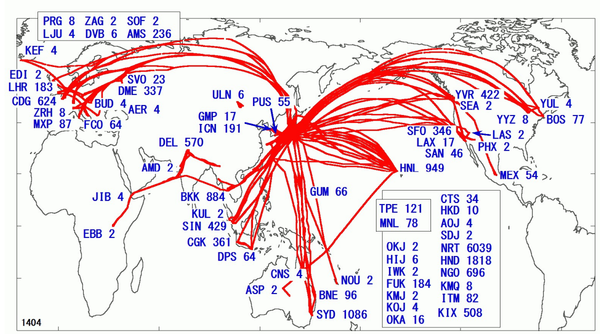
Multiple approaches to detect C-Cycle changes in Asia

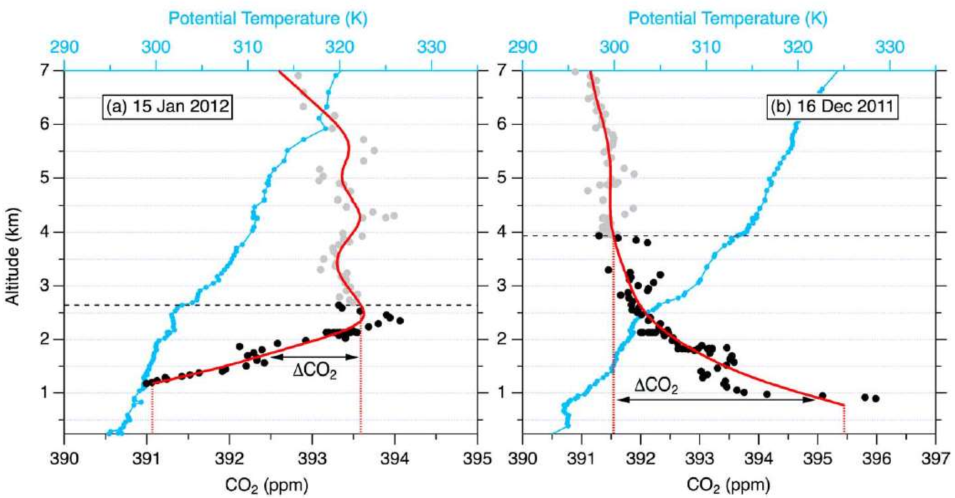
Detailed signals from terrestrial CO_2 flux detected by frequent CO_2 observations over Asia by CONTRAIL (NIES, MRI)



Seasonal changes in the vertical structure of atmospheric CO_2 concentration over Delhi, India observed by CONTRAIL

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



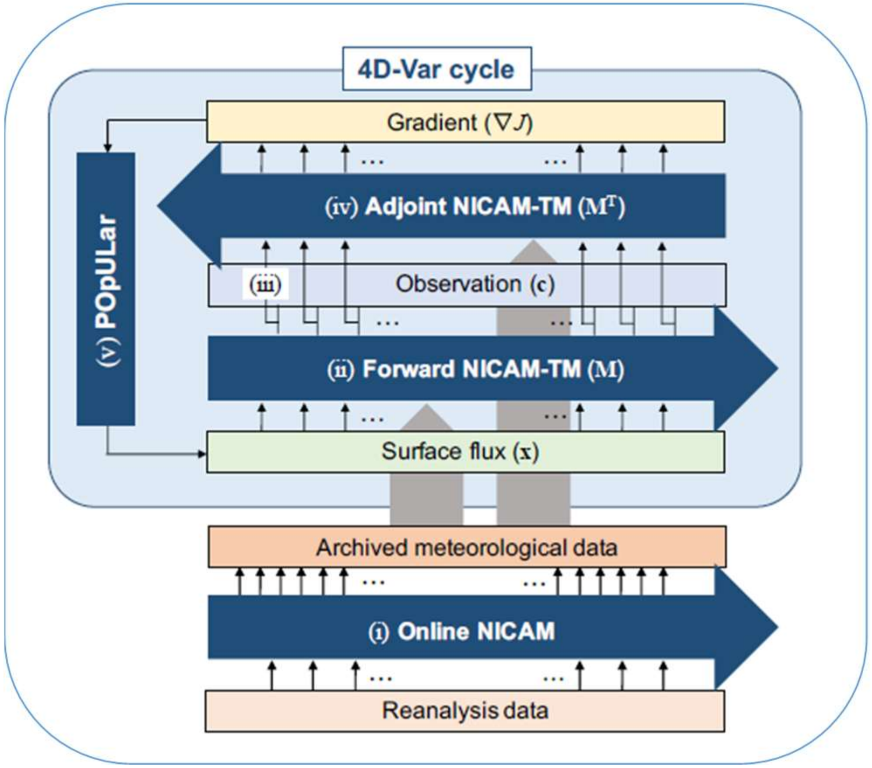


Observed CO_2 vertical profiles over Delhi for flights when (a) a decrease and (b) an increase toward the ground were observed. Convective boundary layer height shown as the horizontal dashed line was estimated by the profiles of potential temperature (blue lines).

(Umezawa, Niwa, Sawa, Machida, Matsueda, *GRL*, 2016)

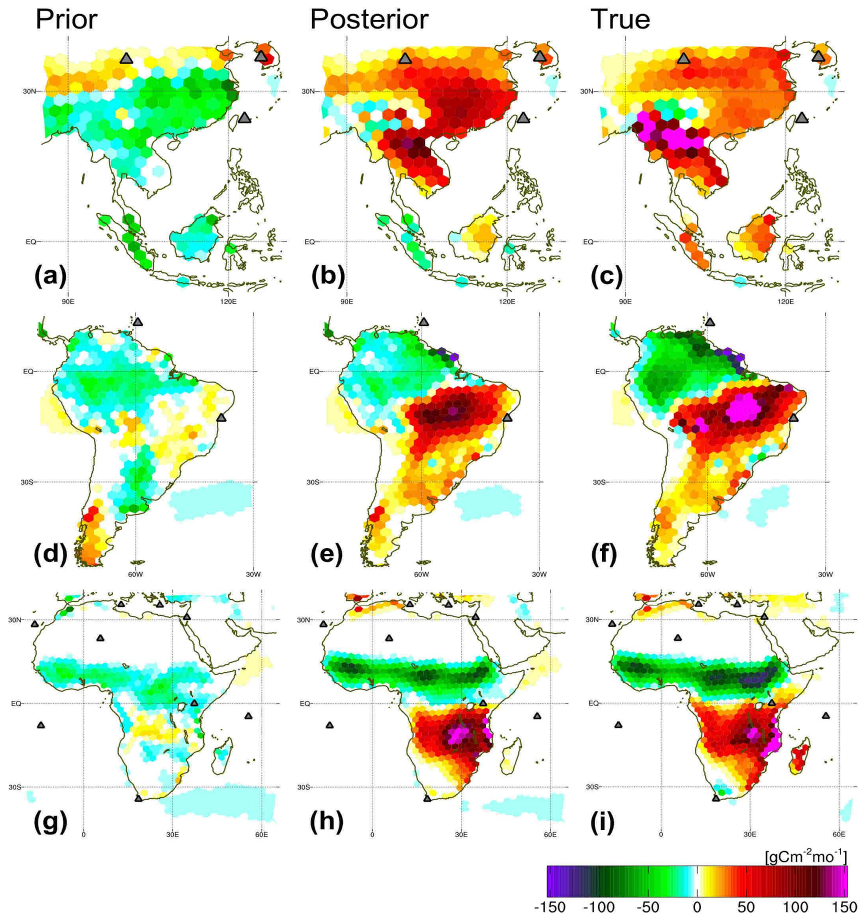
Successful development of a next generation CO_2 Data Assimilation System (MRI)

NICAM-TM 4D-Var



NICAM-TM (Nonhydrostatic ICOsahedral Atmospheric Model-based Transport Model)

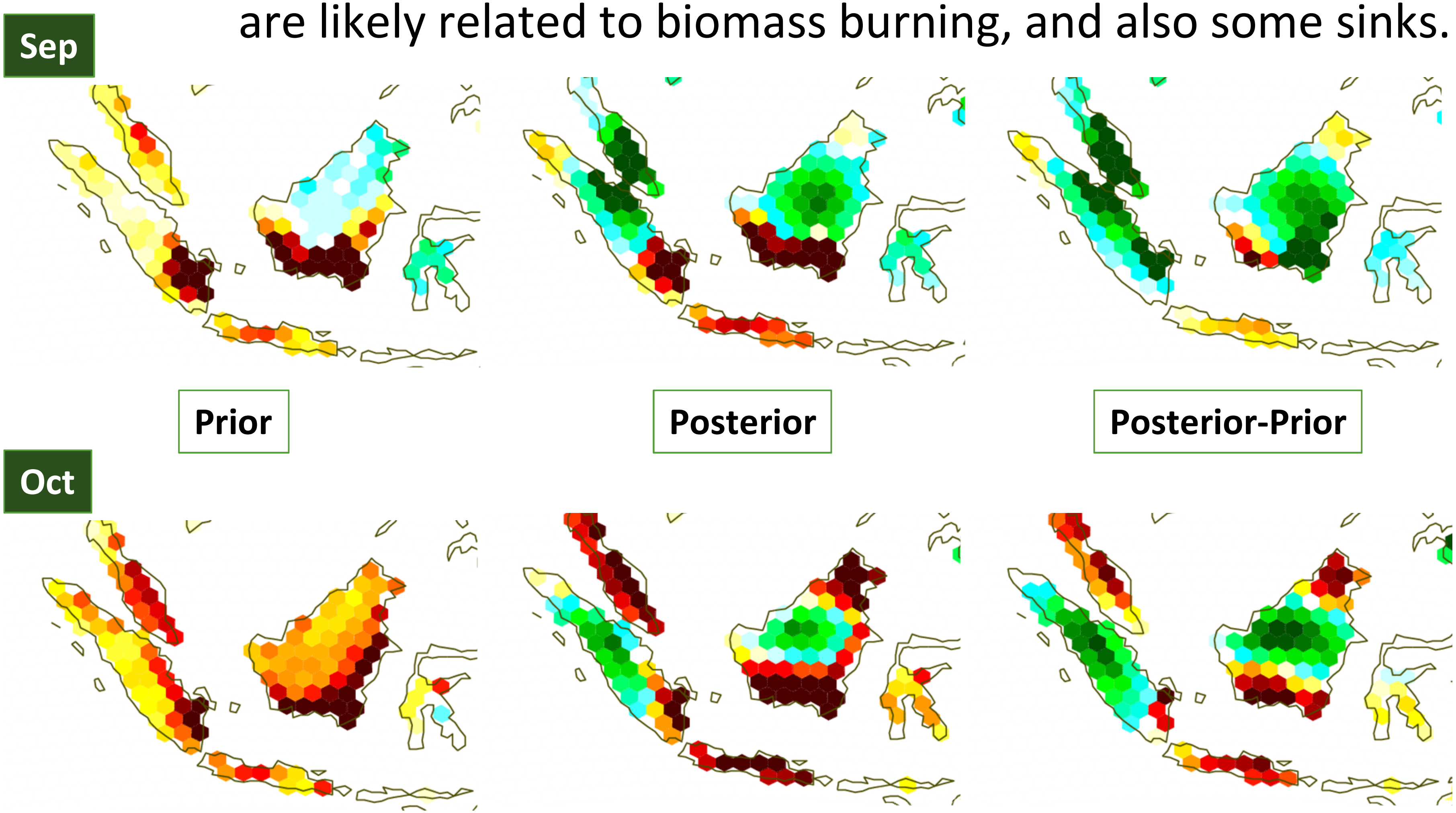
(Niwa et al., GMD, 2017a, 2017b)



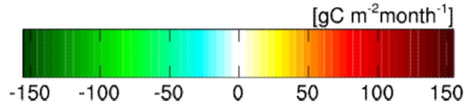
Sensitivity tests using "twin experiments". Monthly mean distributions of the prior (left), posterior (middle) and true (right) CO_2 fluxes focus on anomalies due to biomass burnings for Southeast Asia in March (a-c), South America in September (d-f), and Africa in September (g-i).

Southeast Asia for Sep-Oct 2015

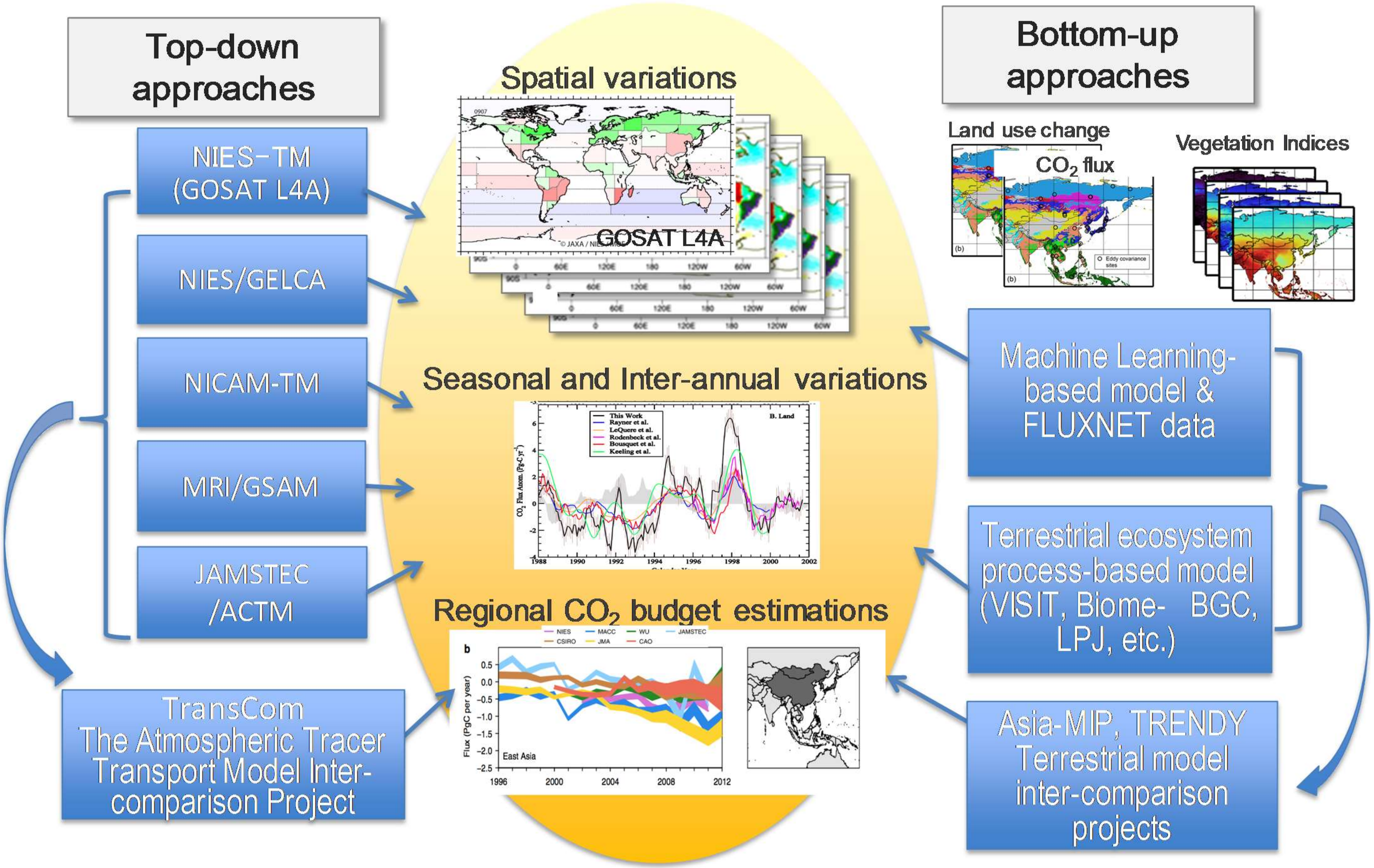
The inversion with CONTRAIL retrieved strong sources that are likely related to biomass burning, and also some sinks.



Slide provided by Niwa Y (MRI)
Presented at JpGU-AGU Joint Meeting 2017 (May 23, Chiba)



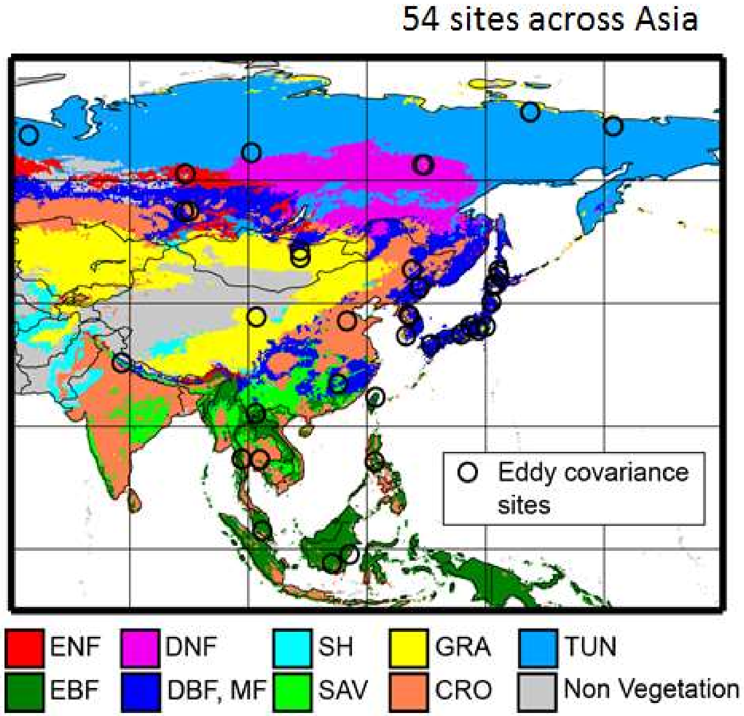
Inter-comparison among Top-down & Bottom-up approaches to designate uncertainties (JAMSTEC & Chiba Univ)



Detection of changes in terrestrial C budget using AsiaFlux/FLUXNET data upscaling (JAMSTEC/Chiba Univ)

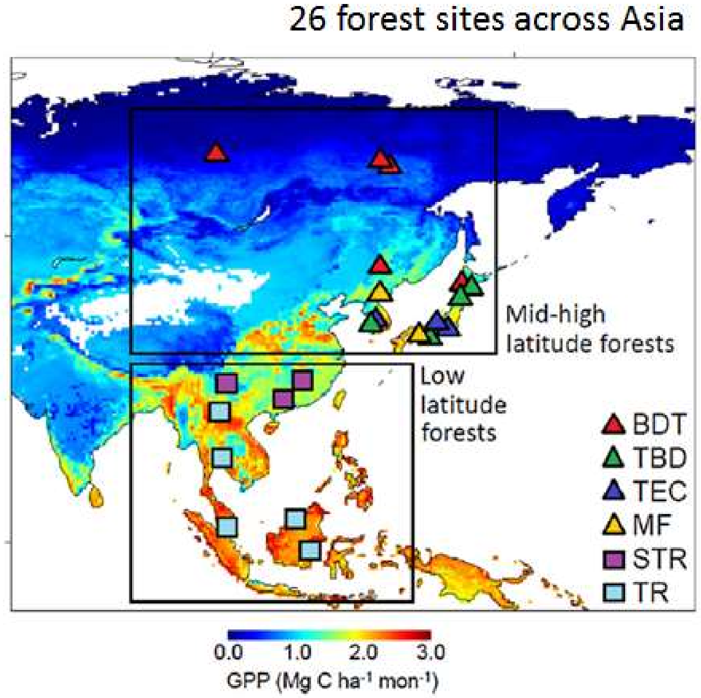
Location of the sites for data driven CO_2 flux estimations in Asia

CO_2 flux



(Ichii *et al. JGR*, 2017)

Ecosystem carbon cycle



(Kondo *et al. Agric For Meteorol*, 2017)

Detection of changes in terrestrial C budget using AsiaFlux/FLUXNET data upscaling (JAMSTEC/Chiba Univ)

Location of the sites for data driven CO_2 flux estimations in Asia

CO_2 flux

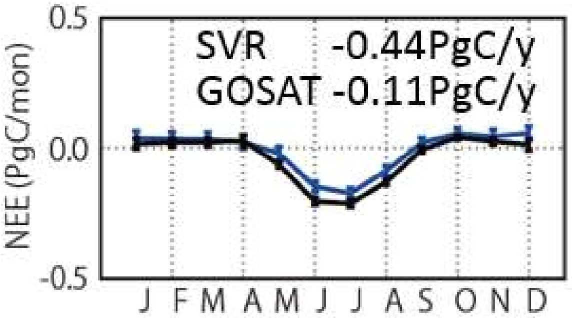
Ecosystem carbon cycle

54 sites across Asia

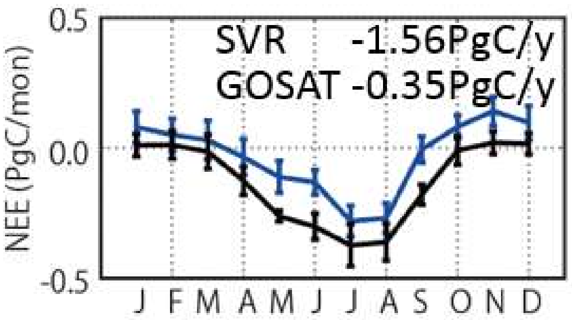
26 forest sites across Asia

Inter-comparison of bottom-up upscaling and top-down estimate or regional CO_2 flux

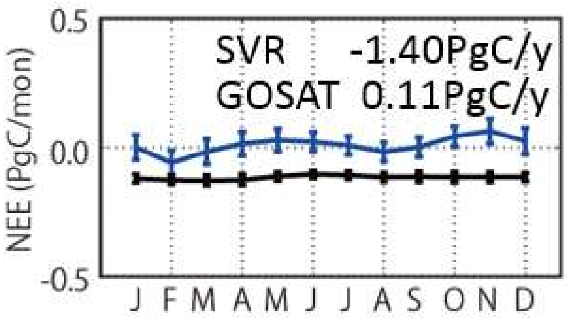
Boreal Eurasia, South West



Temperate Asia, North East



Tropical Asia, South

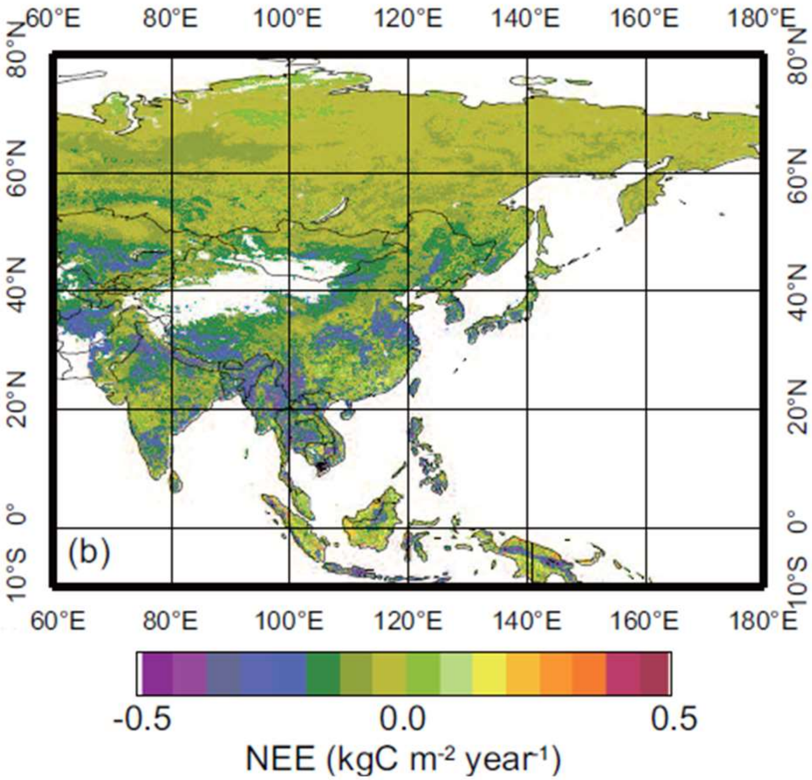


(Ichii *et al. JGR*, 2017)

(Kondo *et al. Agric For Meteorol*, 2017)

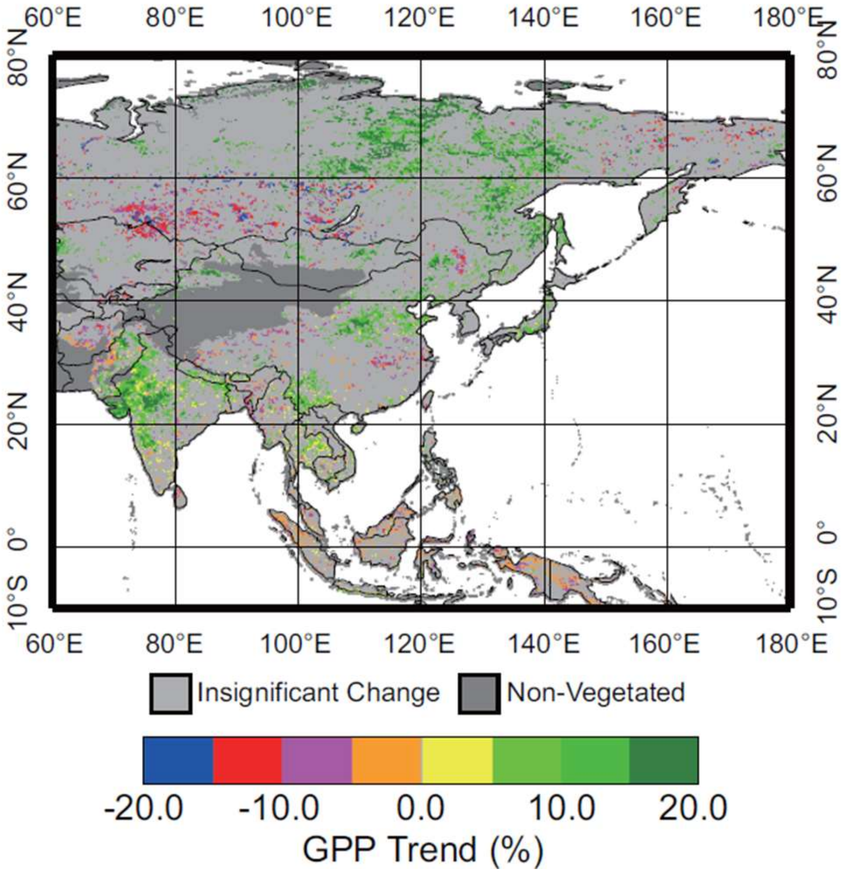
Detection of changes in terrestrial C budget using AsiaFlux/FLUXNET data upscaling (JAMSTEC/Chiba Univ)

NEE



Spatial distribution of estimated net annual ecosystem exchange (NEE) (2000-2015).

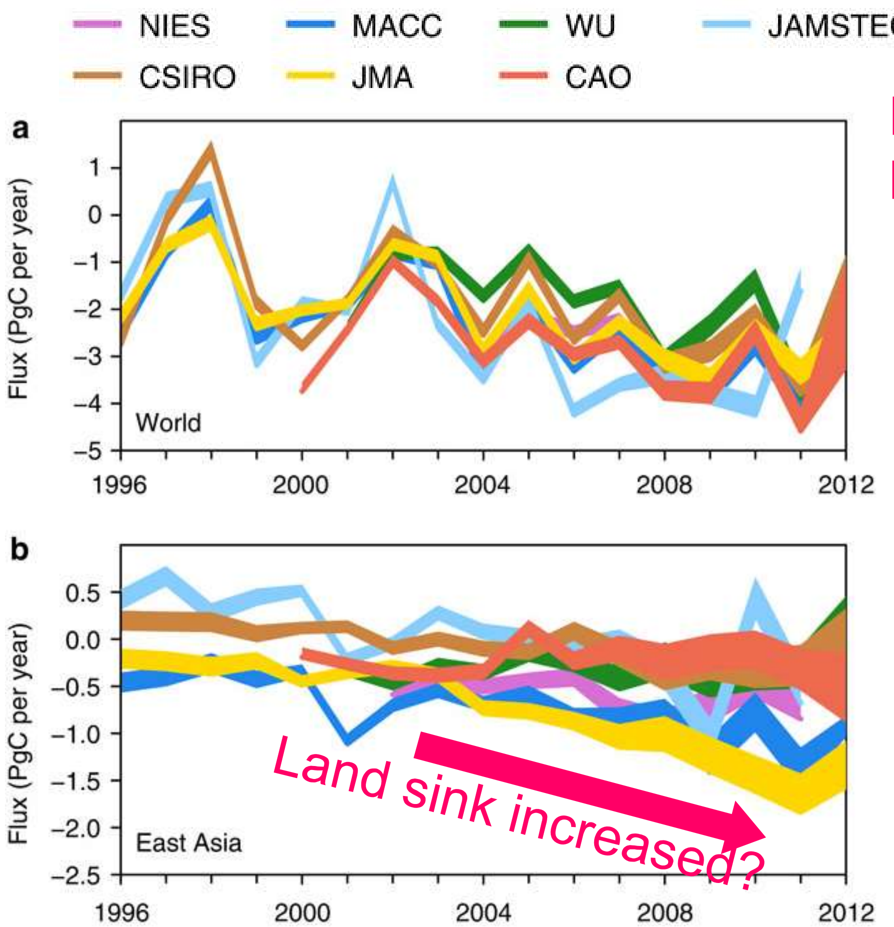
GPP trend



Spatial distribution of percentage change in estimated gross primary productivity (GPP) from 2000 to 2015.

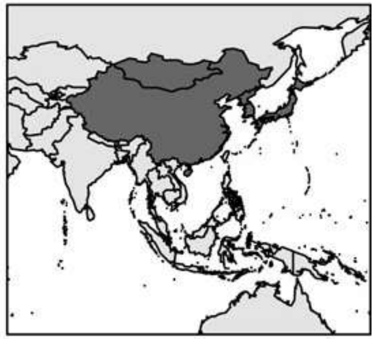
(Ichii *et al. JGR*, 2017)

Asian carbon budget since the mid 1990s, and uncertainty in the fossil fuel sources in East Asia (JAMSTEC)



Land biosphere fluxes estimated by 7 inversion models

The width of each curve:
Range obtained by different FFC emissions (CDIAC, EDGAR & IEA inventories)



East Asia: The annual CO_2 sink increased (between 1996–2001 and 2008–2012) by 0.56 (0.30–0.81) PgC, accounting for ~35% of the increase in the global land biosphere sink.

Uncertainty in the FF emissions contributes 32% to the uncertainty in land biosphere sink change.

(Thompson, Patra, *et al. Nature Comm.*, 2016)

Asian carbon budget since the mid 1990s, and uncertainty in the fossil fuel sources in East Asia (JAMSTEC)

Re-estimate C budget in East Asia

Apply the same scaling factor to lower anthropogenic CO_2 emission in China

Estimate “scaling factor” of 0.59 to lower anthropogenic CH_4 emission

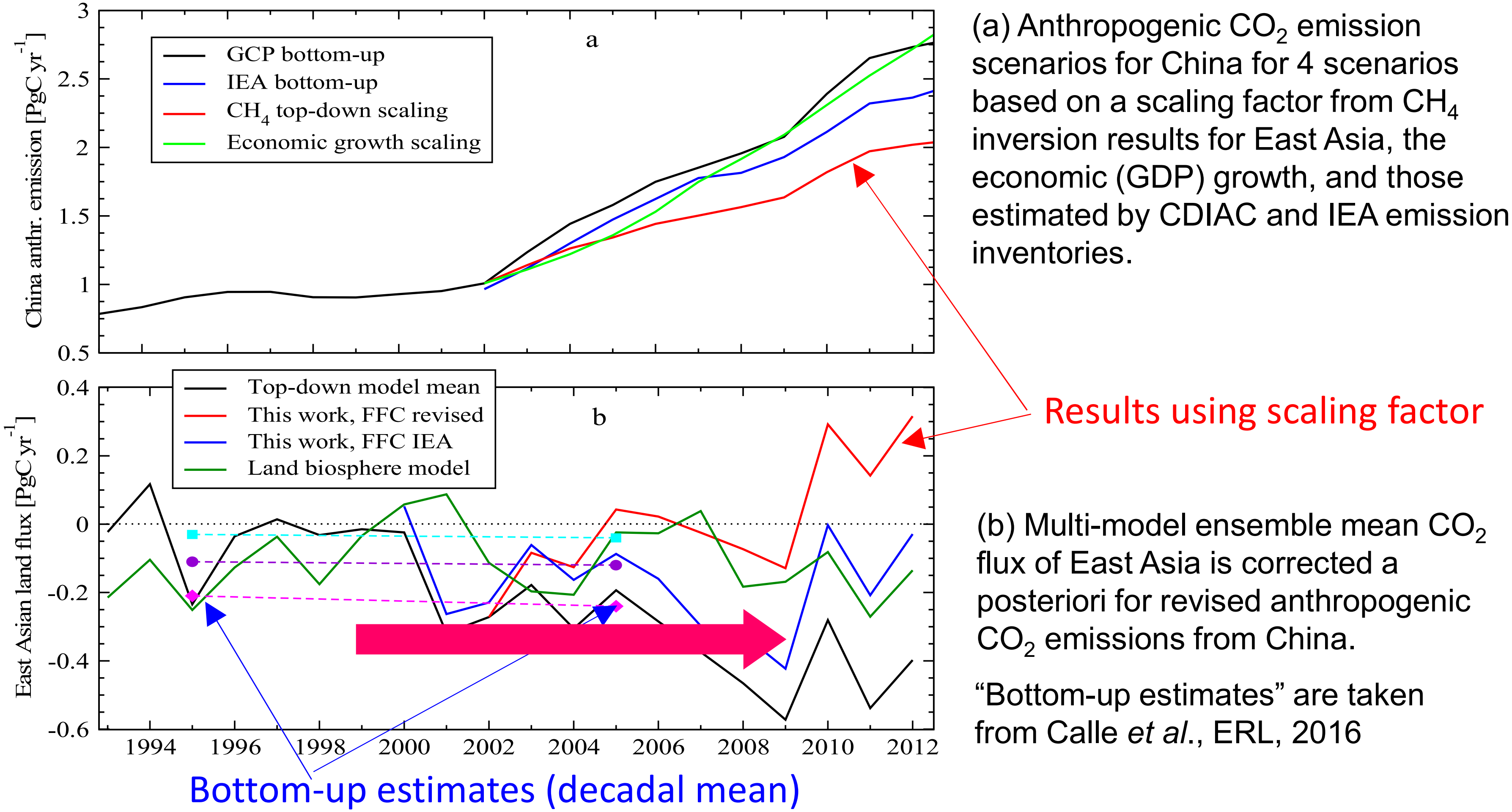
Inventory based CH_4 emission from China
>> Inverse analysis based CH_4 emission from East Asia

Estimate CH_4 emission increase rate by inverse analysis

(Saeki and Patra, *Geoscience Lett.*, 2017)

Asian carbon budget since the mid 1990s, and uncertainty in the fossil fuel sources in East Asia (JAMSTEC)

No significant increase in CO_2 uptake (~2009) in East Asia by modifying anthropogenic CO_2 emissions from China using a scaling factor of 0.59



(a) Anthropogenic CO_2 emission scenarios for China for 4 scenarios based on a scaling factor from CH_4 inversion results for East Asia, the economic (GDP) growth, and those estimated by CDIAC and IEA emission inventories.

(b) Multi-model ensemble mean CO_2 flux of East Asia is corrected a posteriori for revised anthropogenic CO_2 emissions from China.

"Bottom-up estimates" are taken from Calle *et al.*, ERL, 2016

(Saeki and Patra, *Geoscience Lett.*, 2017)

Summary of the project

1) Multiple approaches including different types of top-down models and bottom-up upscaling techniques contributed to designate uncertainties in the estimates of large emissions (e.g. fossil fuel use and land use changes).

2) Key target regions and events were identified as potential hot-spots in the Asia-Pacific where we need further targeted research. (e.g. potential increase in terrestrial carbon sink in Siberia and East Asia, uncertainty in the recent rapid growth of anthropogenic GHG emissions in East Asia, emissions from land use change and El Niño-induced extreme forest fires in Southeast Asia)

3) A prototype system was developed and tested for future operational monitoring (e.g. GOSAT-2 analysis system) to detect changes in regional, continental, and global GHGs budgets based on integration of observation and modeling.

Next Challenge

Inter-comparison, uncertainty reduction

Present

Biospheric sink/source = Total sink/source − Anthropogenic source

Bottom-up approach | Top-down approach | Statistical data

Future

Anthropogenic source ⇐ Total sink/source − Biospheric sink/source

Confirmation by global observations with higher temporal and spatial resolution | Top-down approach | Bottom-up approach