

Data-driven estimation of terrestrial CO₂ fluxes across Asia using AsiaFlux observation network and remote sensing data

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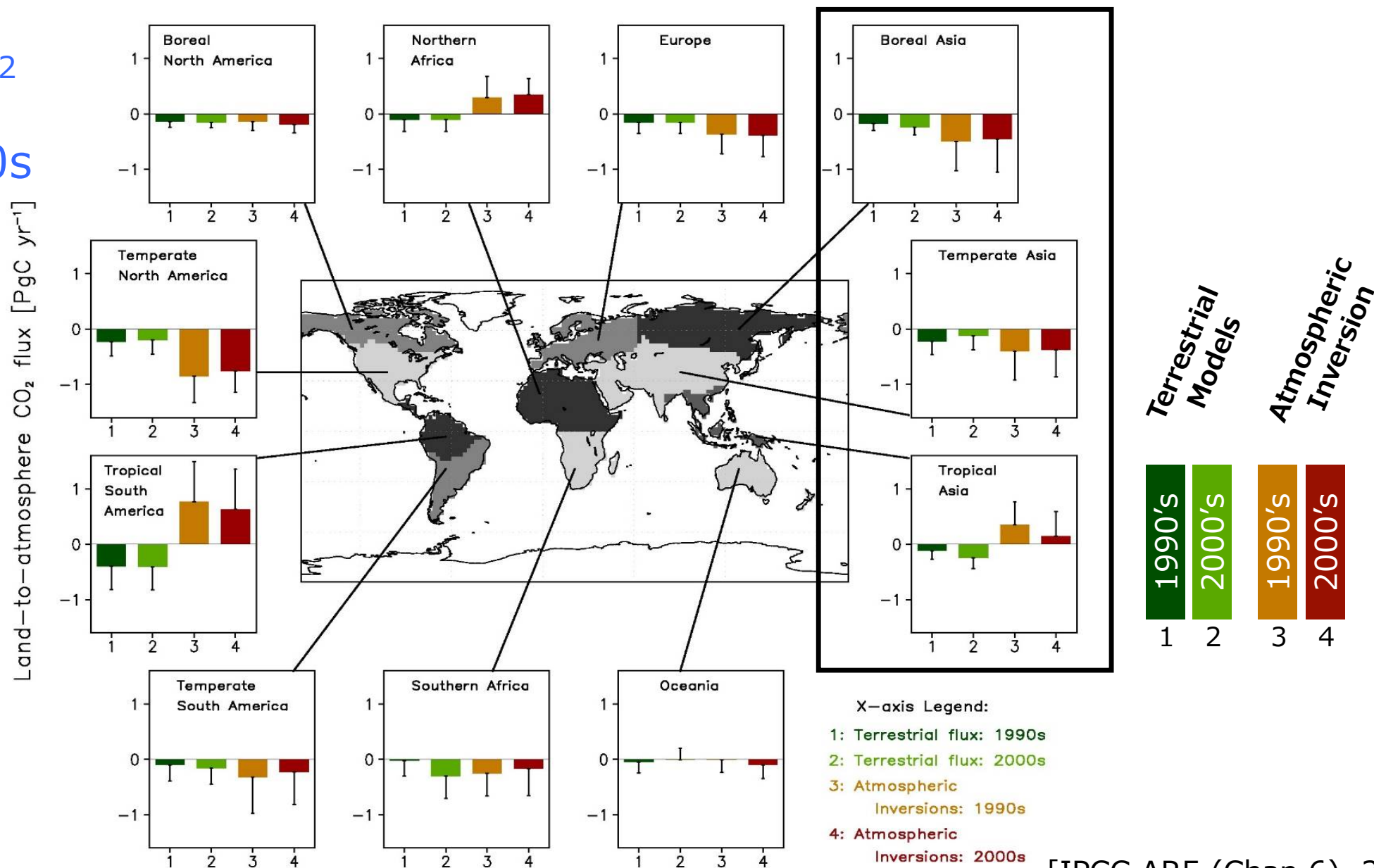


Outline

1. Introduction (recent studies of CO₂ budget estimation)
2. AsiaFlux, JapanFlux (observation network)
3. Data-driven CO₂ fluxes in Asia
4. Comparing top-down (inverse) and bottom-up (this study) estimation

Terrestrial CO₂ budget; Large gaps among approaches..

Terrestrial CO₂ budget in 1990s & 2000s (11 regions)



[IPCC AR5 (Chap 6), 2013]

Focus on Southeast Asia

Inter-decadal variation of terrestrial CO₂ budget

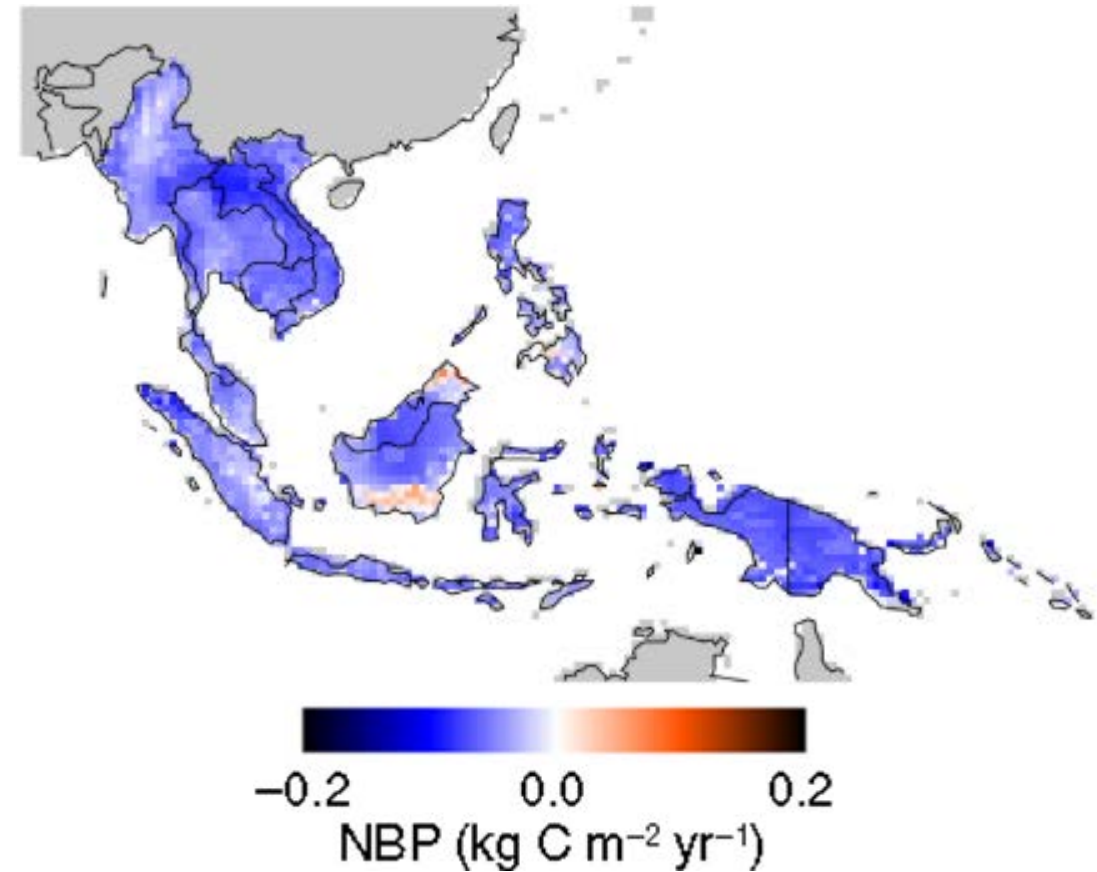
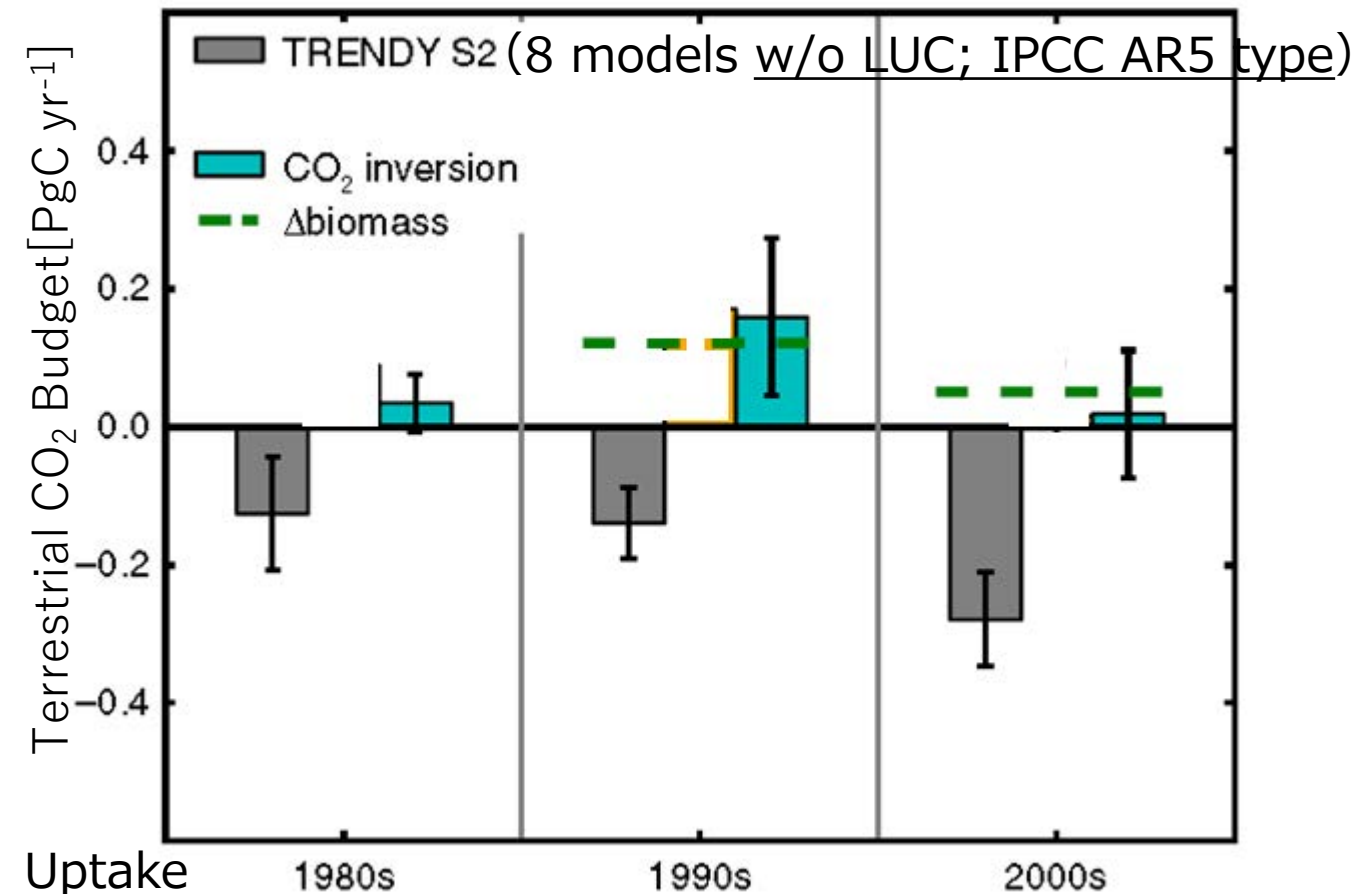
- Models (without LUC)
- CO₂ Inversion
- RS-biomass [Liu et al. 2015] (1993-2012)

Land use change and El Niño-Southern Oscillation drive decadal carbon balance shifts in Southeast Asia

Masayuki Kondo^{1,2}, Kazuhito Ichii^{1,2,3}, Prabir K. Patra^{2,22}, Joseph G. Canadell⁴, Benjamin Poulter^{5,6}, Stephen Sitch⁷, Leonardo Calle⁵, Yi Y. Liu^{8,9}, Albert I.J.M. van Dijk¹⁰, Tazu Saeki³, Nobuko Saigusa³, Pierre Friedlingstein⁷, Almut Arneth¹¹, Anna Harper⁷, Atul K. Jain¹², Etsushi Kato¹³, Charles Koven¹⁴, Fang Li¹⁵, Thomas A.M. Pugh^{11,16}, Sönke Zaehle¹⁷, Andy Wiltshire¹⁸, Frederic Chevallier¹⁹, Takashi Maki²⁰, Takashi Nakamura²¹, Yosuke Niwa²⁰ & Christian Rödenbeck¹⁷

[Kondo et al. 2018; Nature Comm.]

Release



Focus on Southeast Asia

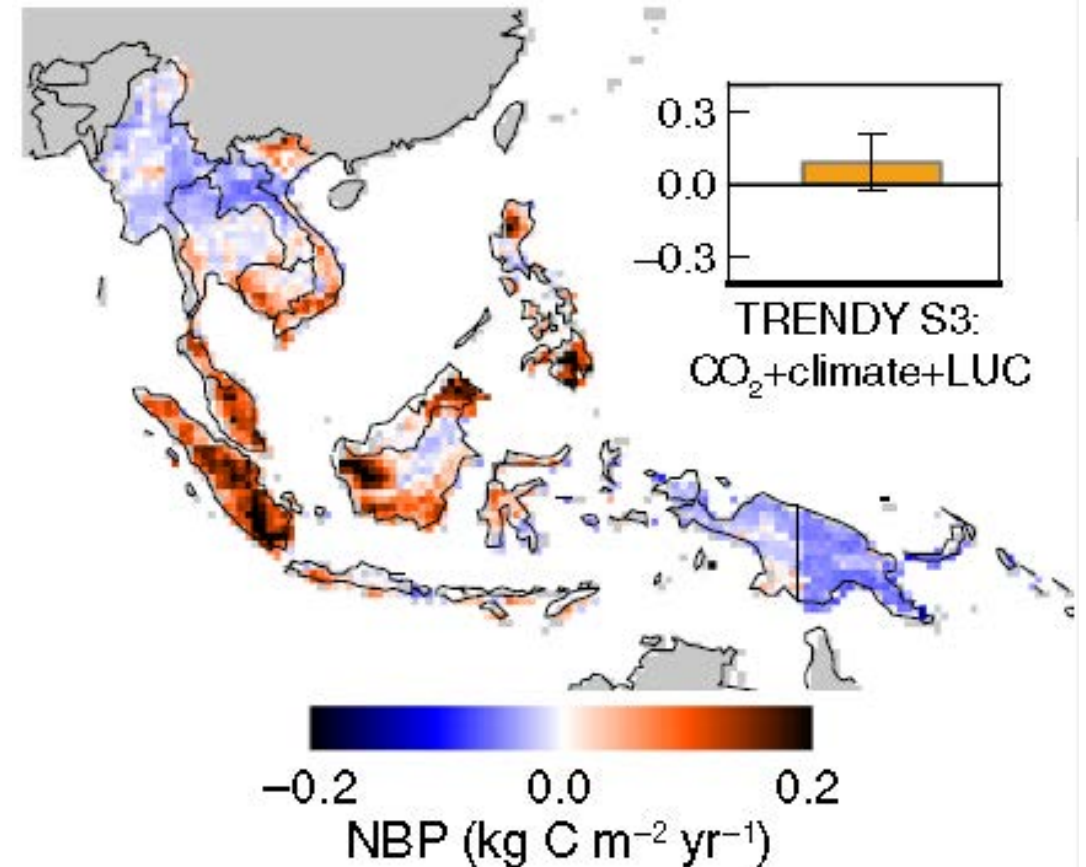
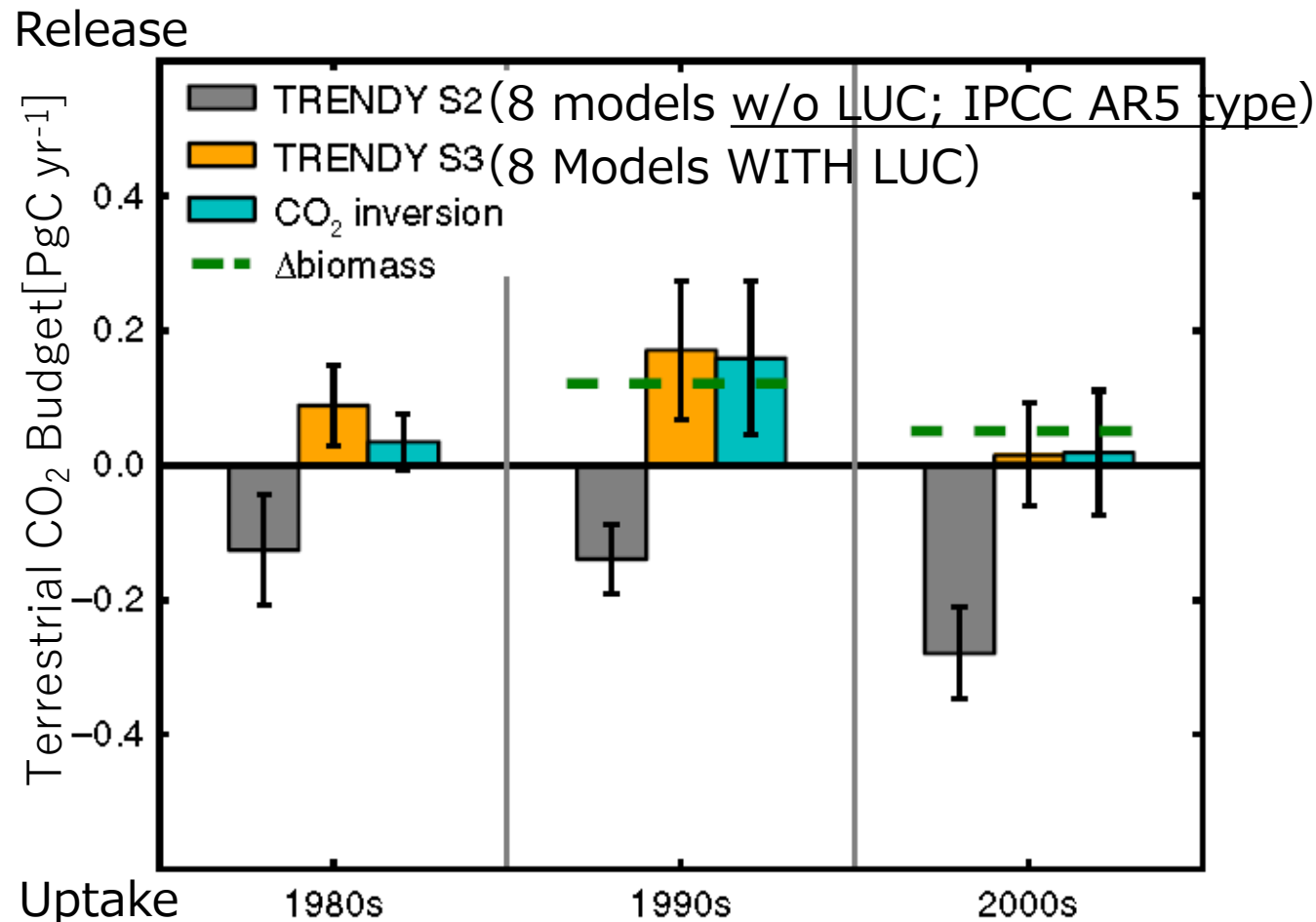
If we used models with LUC,

- good agreement with CO₂ inversion, biomass
- improvement to current IPCC report

Land use change and El Niño-Southern Oscillation drive decadal carbon balance shifts in Southeast Asia

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[Kondo et al. 2018; Nature Comm.]



Where did we use AsiaFlux?

Registered Sites



Data Available Sites



AsiaFlux DB (from AsiaFlux web)

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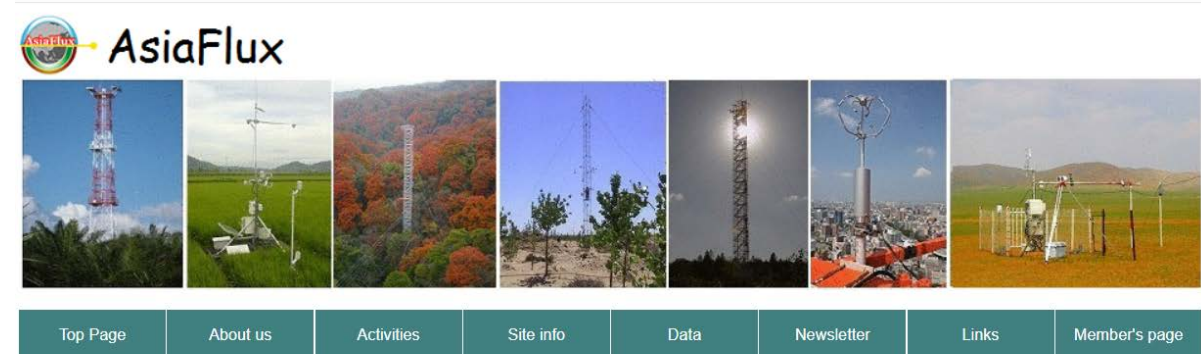
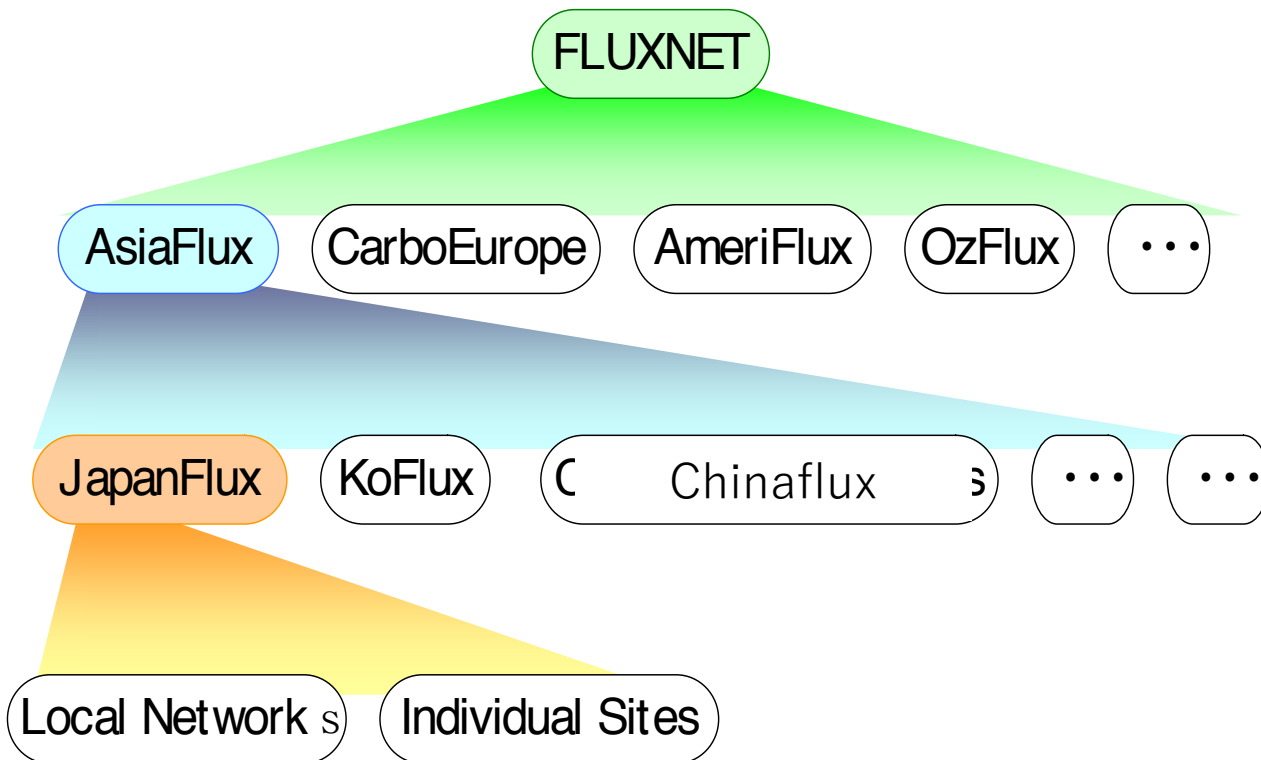
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AsiaFlux, JapanFlux

Measuring land-atmosphere fluxes (energy, water, gases)
based on micrometeorological methods (eddy-covariance, chamber etc.)



Welcome to AsiaFlux website!

AsiaFlux is a regional research network bringing together scientists from universities and institutions in Asia to study the exchanges of carbon dioxide, water vapor, and energy between terrestrial ecosystems and the atmosphere across daily to inter-annual time scales.

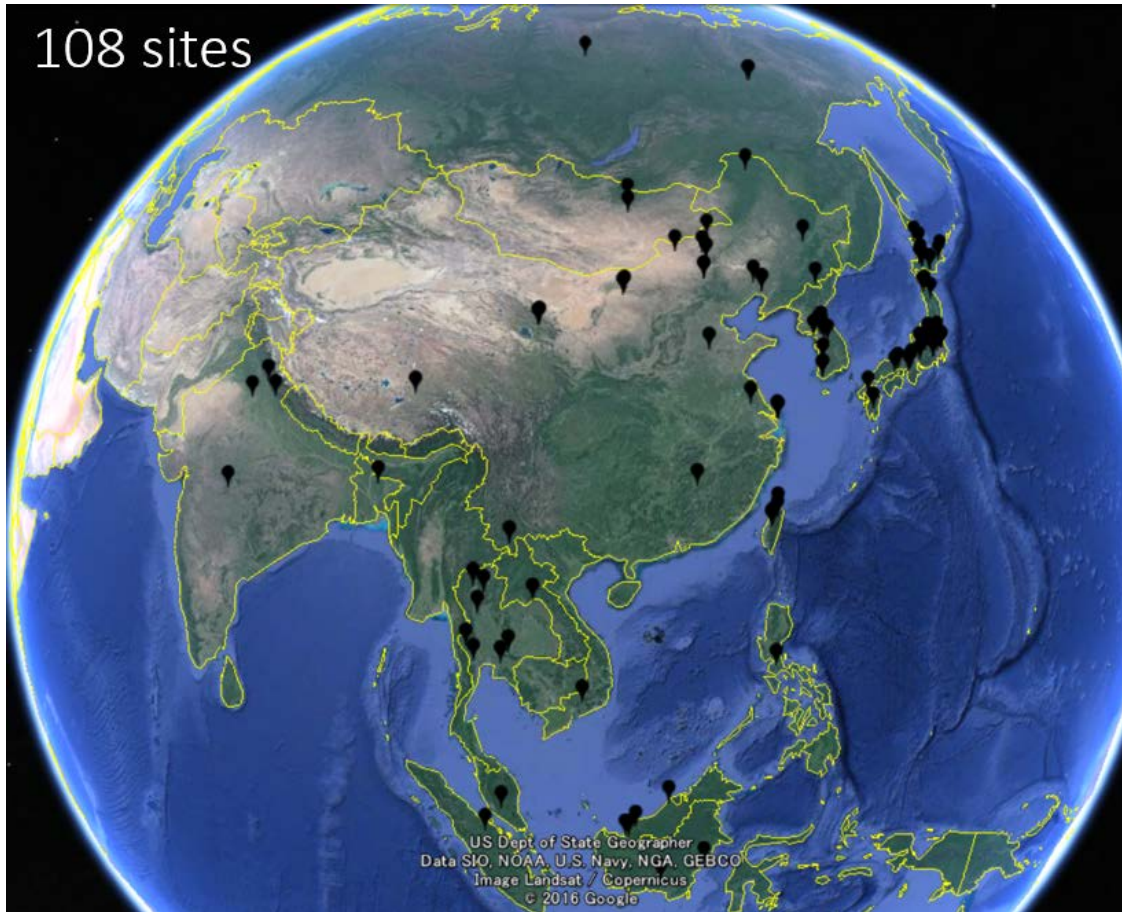
[<http://asiaflux.net/>]



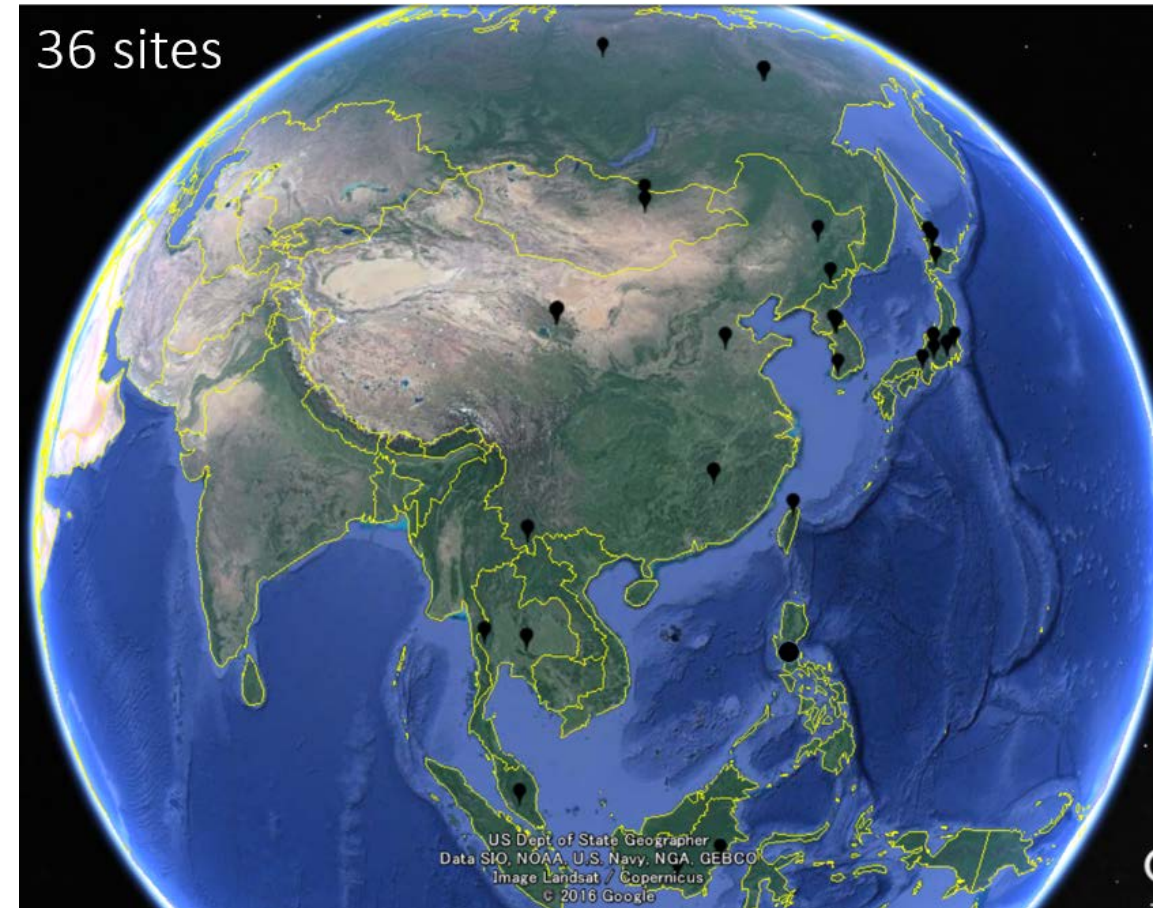
[<http://www.japanflux.org/>]

AsiaFlux Site distribution

Registered Sites



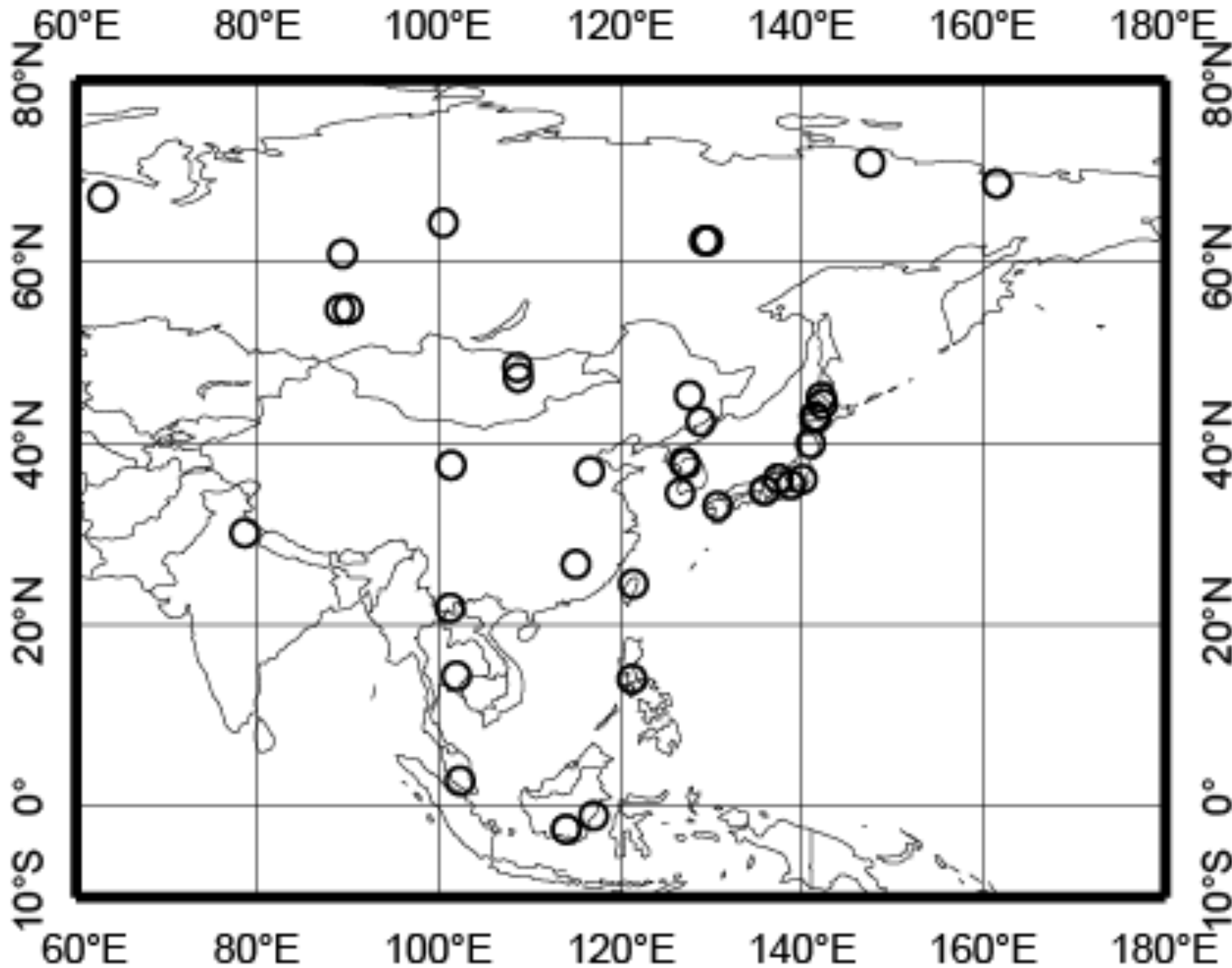
Data Available Sites



AsiaFlux DB (from AsiaFlux web)

Latest: Available Flux obs data across Asia

AsiaFlux+FFPRI(Japan)+CarboEurope etc. (54) (for upscaling)

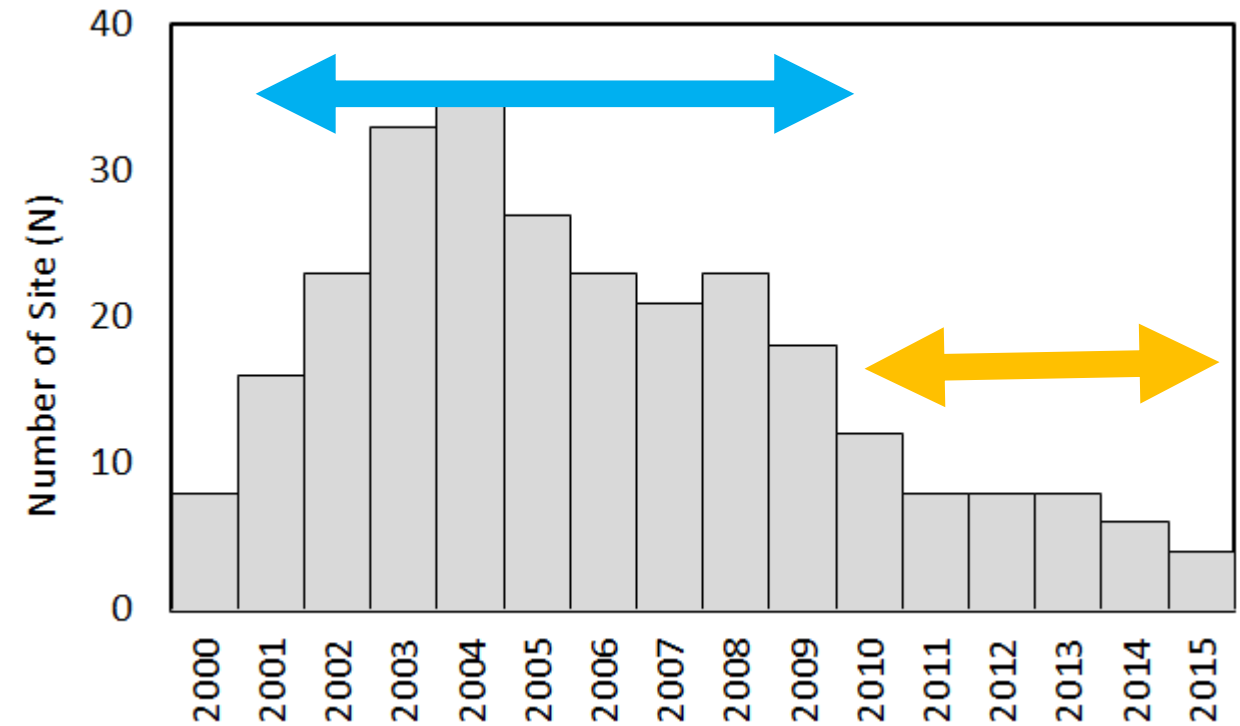
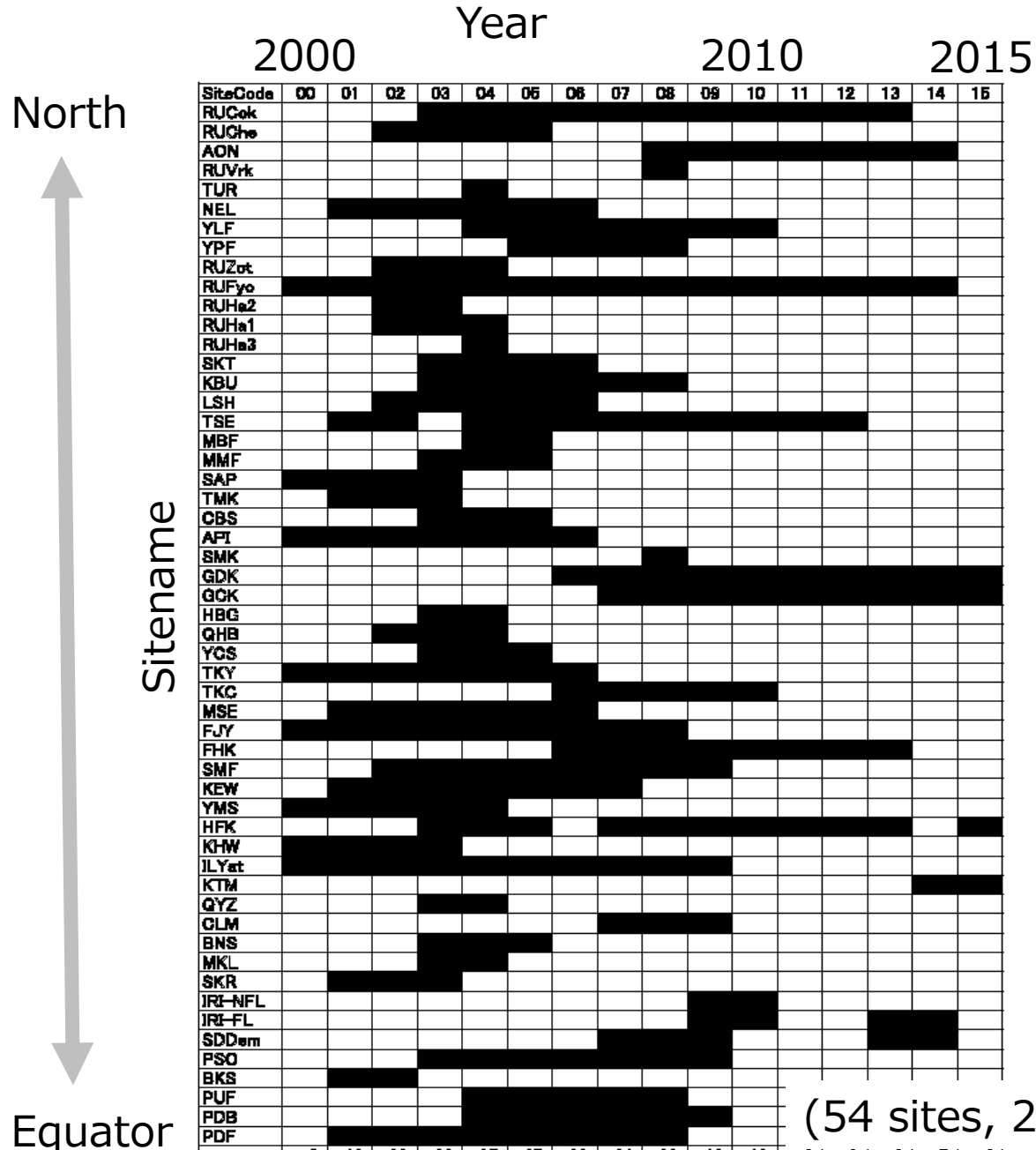


Wide coverage
(Tundra, India,
Israel, Sudan etc.)

≥10years; 6 sites
RUCok, RUFyo,
TSE, GDK,
HFK, ILYat

[Ichii et al. 2017; JGR-Biogeosci]

Asia Fluxdata Availability



- ☑ Less submitted data in recent years
- ☑ Difficulty: Many countries, policies
(no strong obligation for data submission)
- ☑ Tasks: Promotion of data submission

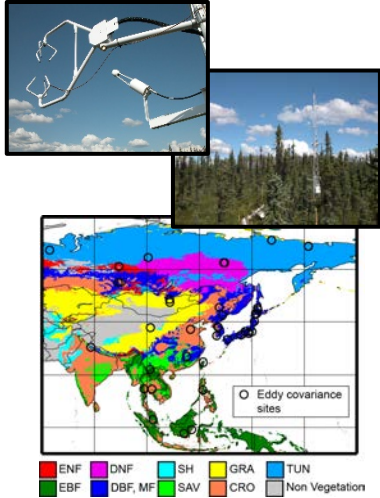
[Data: Ichii et al. 2017]

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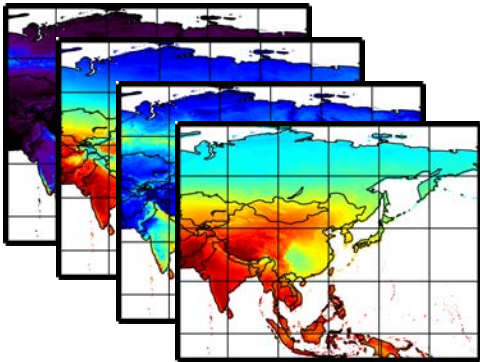
Spatial Upscaling

Site-observation

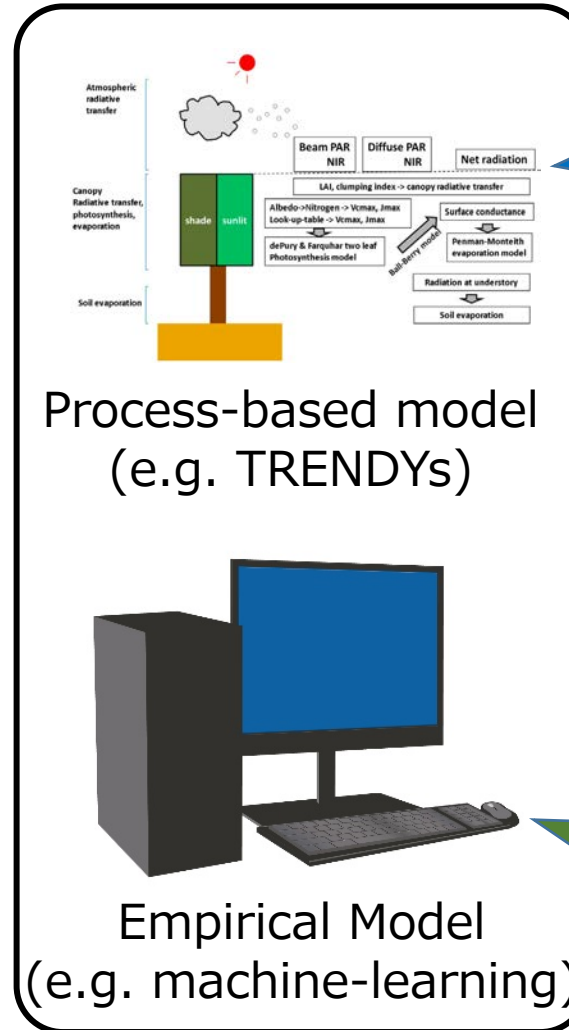


[AsiaFlux, FLUXNET]

Input Variables

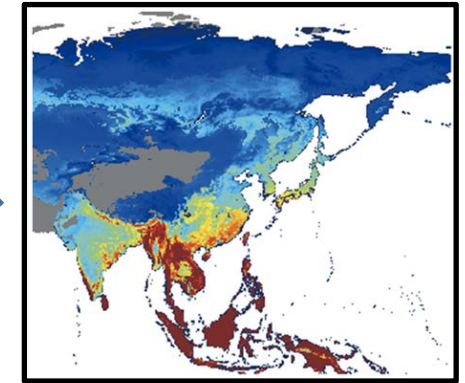


[Remote Sensing, Climate]



- Commonly used
- Problems in performance
- Hard to incorporate observation data (many obs, parameters...)

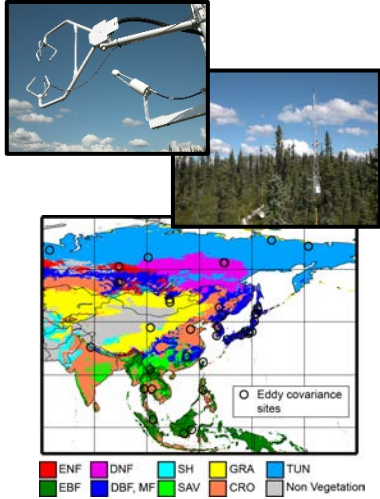
Upscaled Fluxes



- Simple concept
- Easy to use many data
- Drastic increases in obs data
- Improve of machine learning

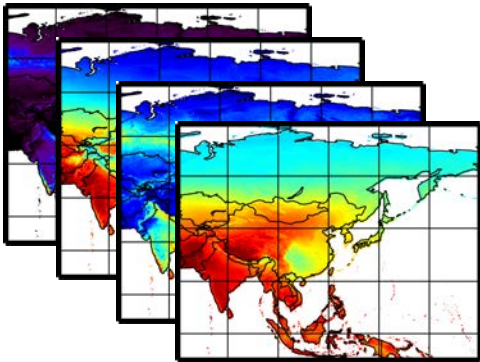
Data-driven Spatial Upscaling

Site-observation

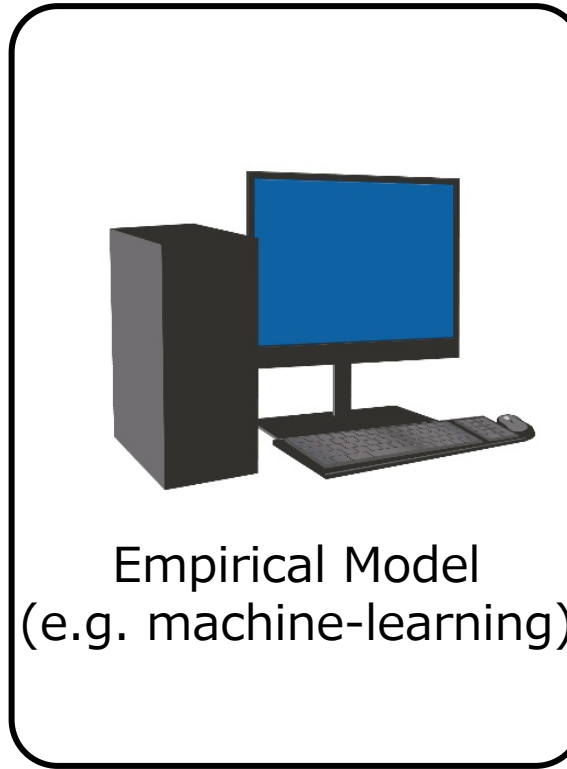


[AsiaFlux 54 sites]

Input Variables

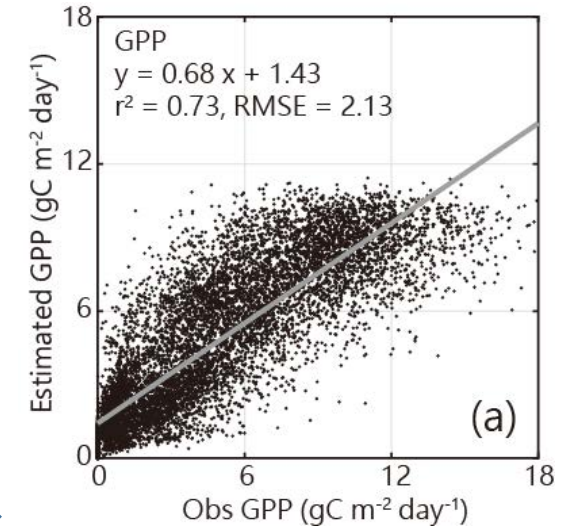


[Remote Sensing; MODIS]

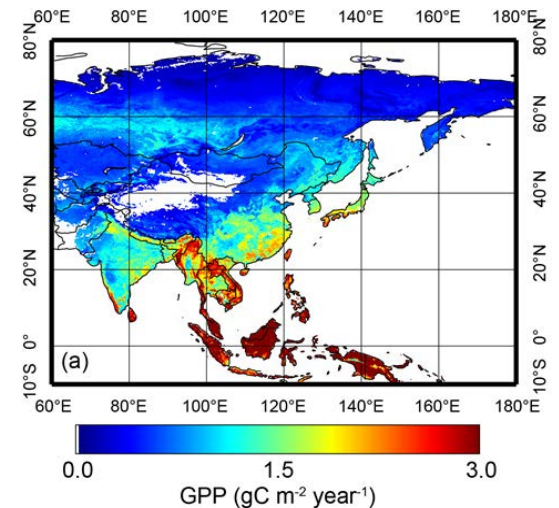


Input : RS-data only
(e.g. VIs, LST, Srad, Water Index)
Output: GPP, NEE
8-day products (multi-year)

Site-level evaluation

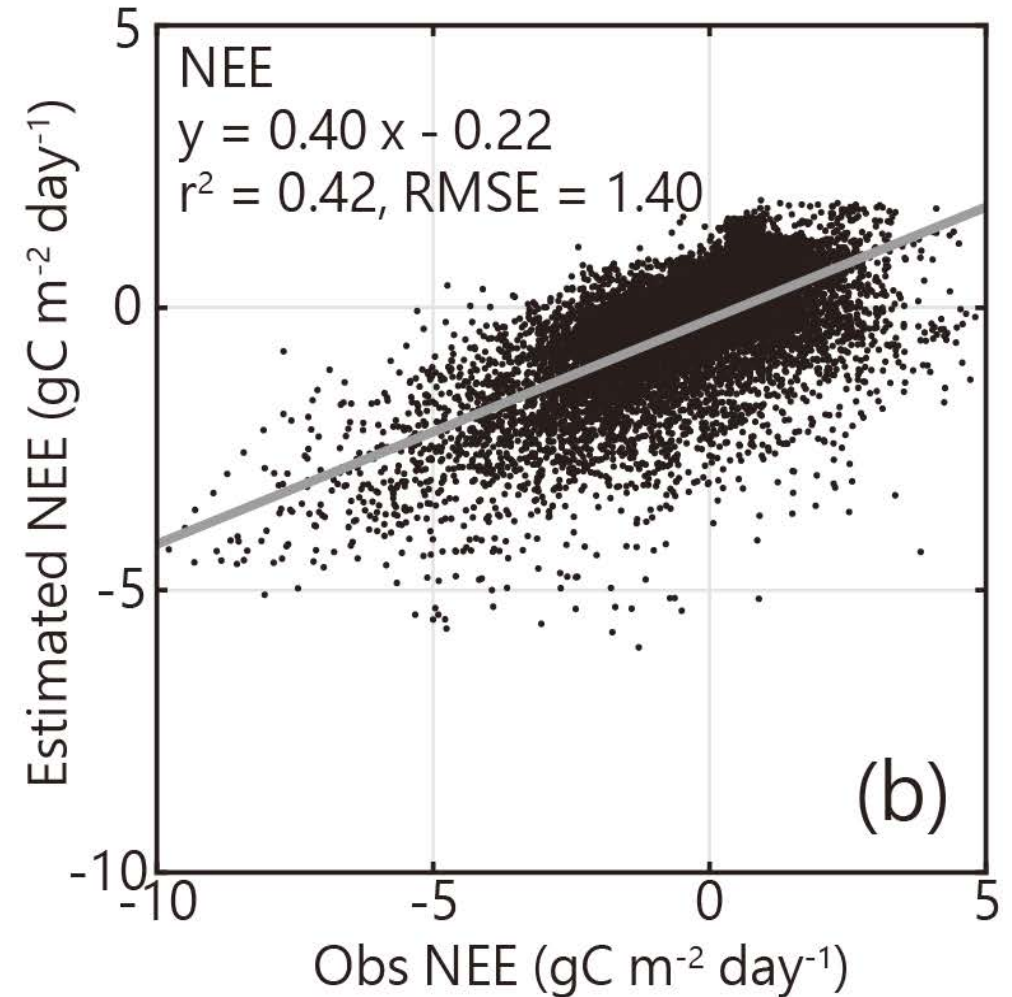
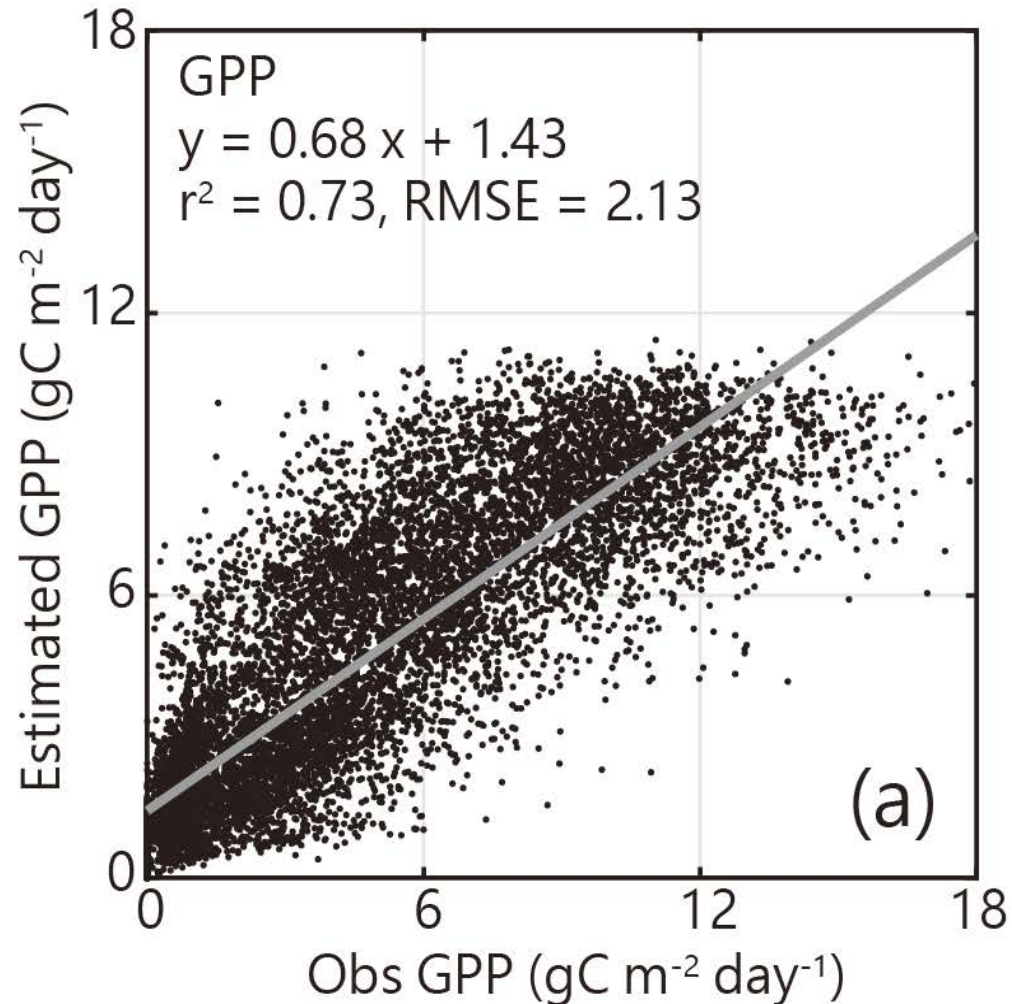


Spatial Estimation



Result: Site-level evaluation

8-day GPP, NEE (by SVR) (all 54 sites)



Issues of Data-driven estimations

8-day GPP, NEE by Plant Functional Types (PFTs)

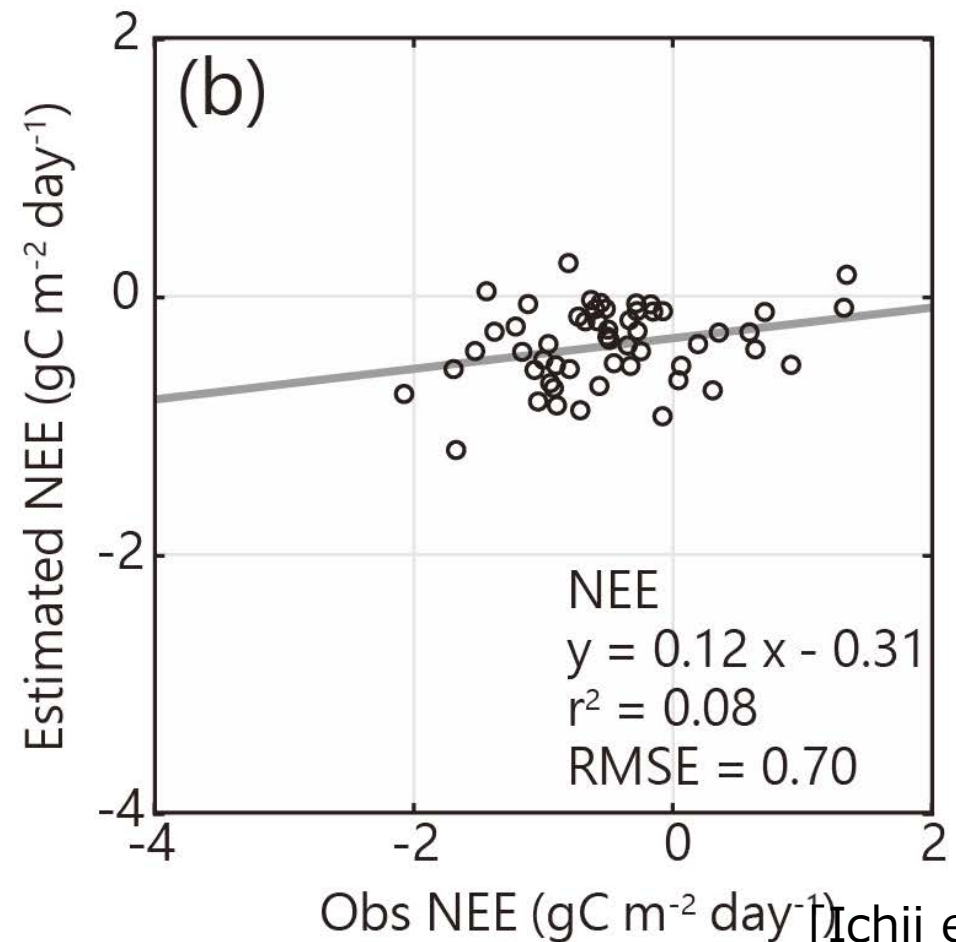
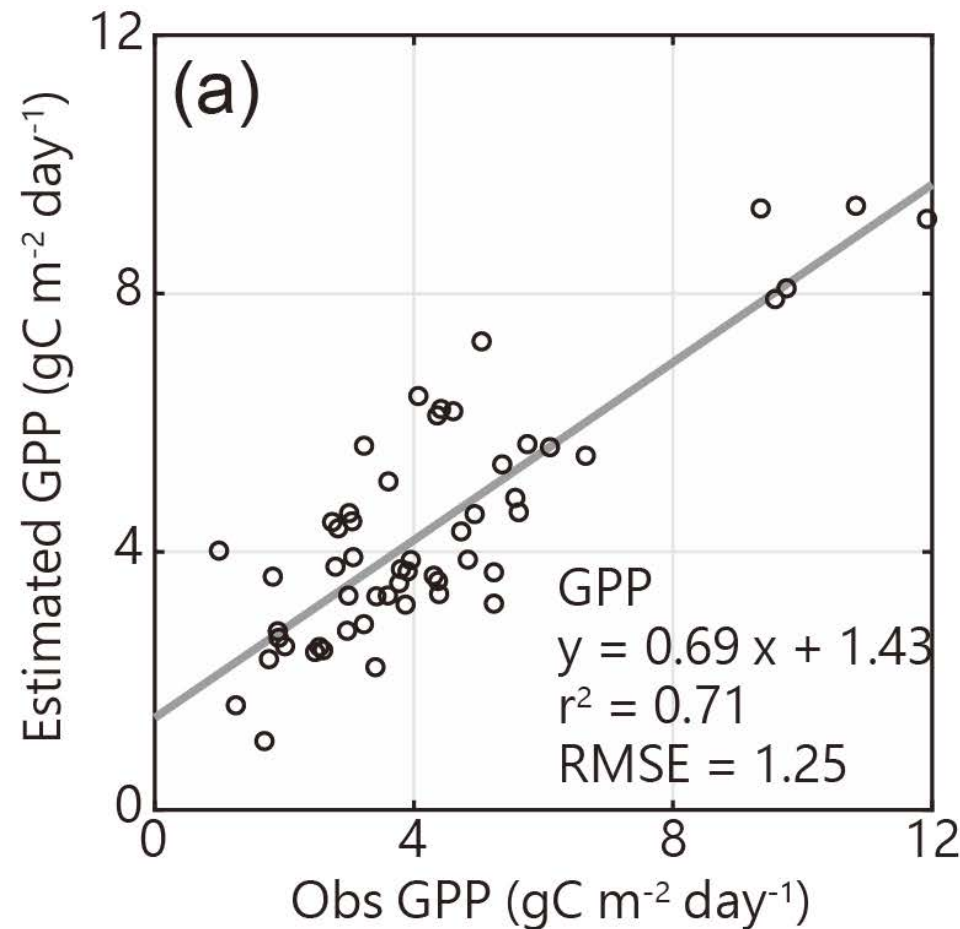
	GPP		NEE	
	r^2	RMSE	r^2	RMSE
All	0.73	2.13	0.42	1.40
ENF	0.78	1.84	0.29	1.28
EBF	0.33	2.62	0.00	1.86
DNF	0.72	2.36	0.54	1.42
DBF	0.84	1.76	0.78	1.50
MF	0.73	1.94	0.37	1.27
GRA	0.44	2.35	0.37	1.09
TUN	0.75	0.96	0.66	0.68
CRO	0.57	2.48	0.60	1.59

Evergreen
Broadleaf
Forest
(mostly tropical)

Result: Site-level evaluation

Site-mean (all 54 sites) GPP, NEE

(→ testing spatial extrapolation capability)

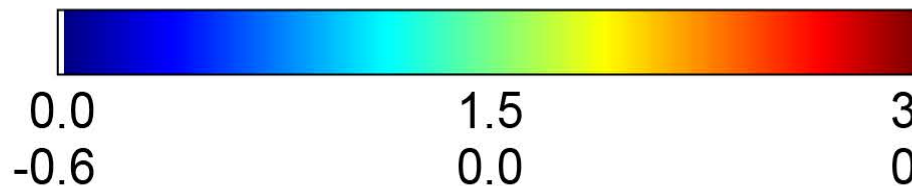
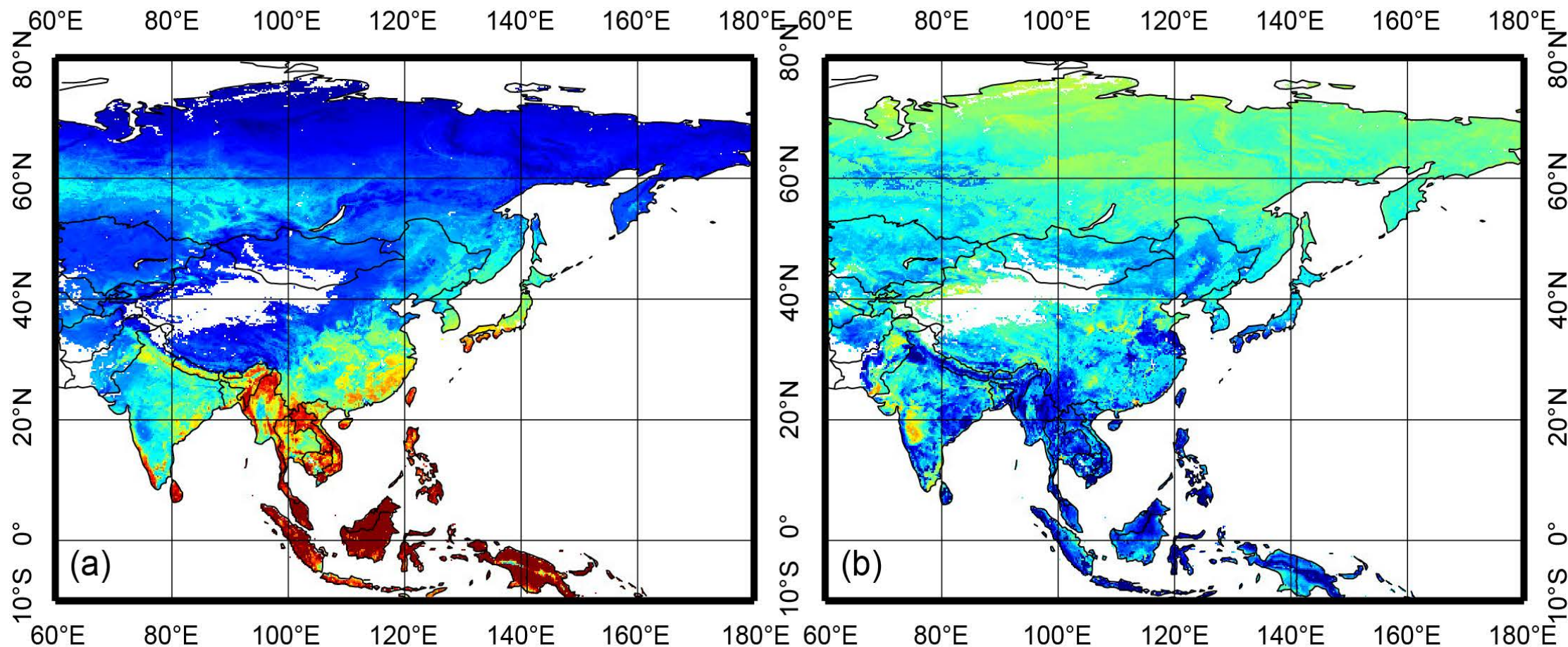


Spatial pattern in SVR-GPP and NEE

GPP (Photosynthesis)

NEE (Reco – GPP)

(2000-2015 mean, 0.25 deg)



GPP (gC m⁻² year⁻¹)

NEE (gC m⁻² year⁻¹)

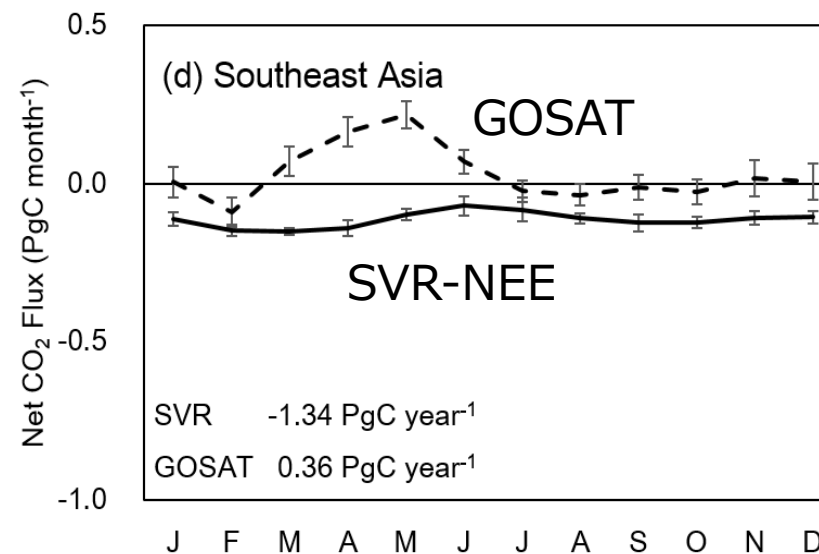
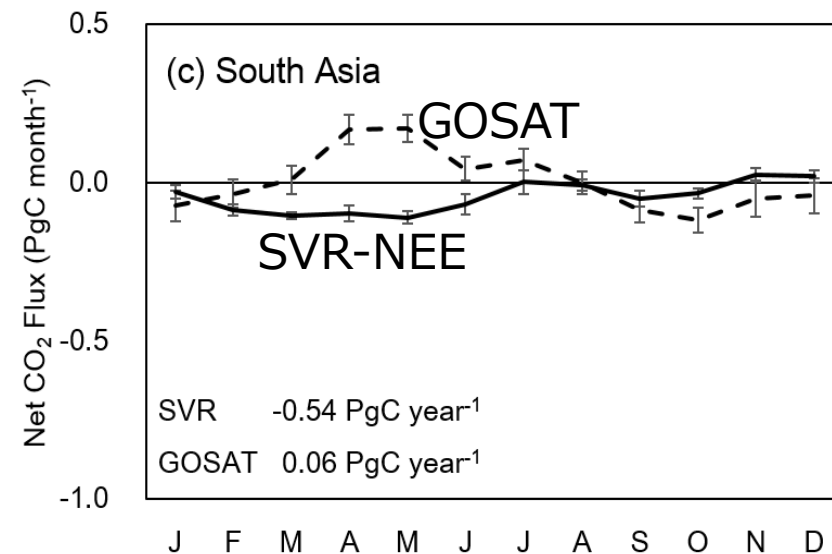
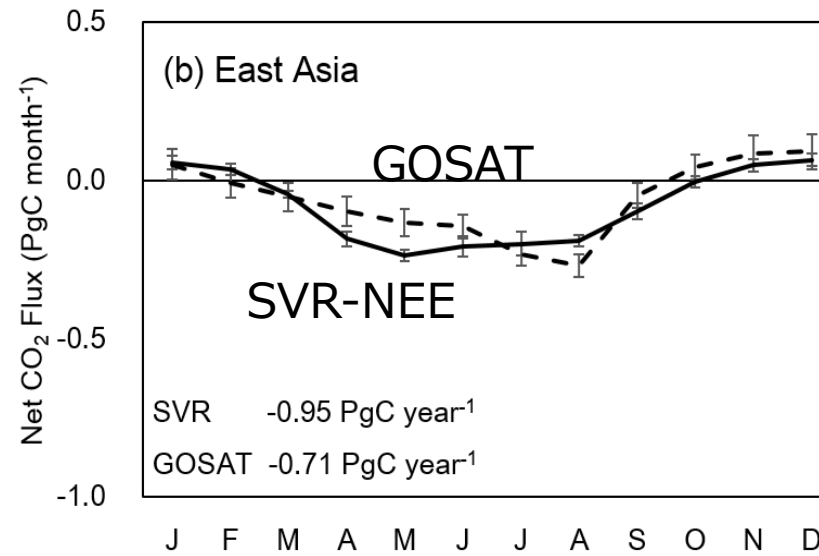
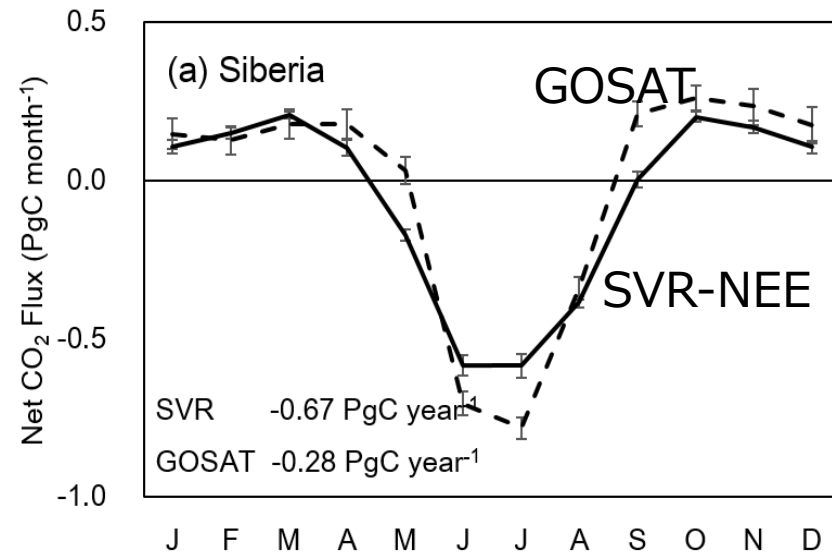
[Ichii et al. 2017]

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Net CO₂ Flux (SVR-Asia vs GOSAT L4A)

Top-down : GOSAT L4A, Bottom-up: Data-driven (upscaling) (SVR-Asia)



☑ Consistency in Siberia, E. Asia.
Differences in S Asia, SE Asia.

☑ Different Definition:
Flux (ML): NEE (Resp-GPP)
GOSAT (Inv): NBP (net totalflux)

☑ Although.. We know
some issues in data-driven
estimation (e.g. poor NEE)

Summary

AsiaFlux (FLUXNET) Data:

So far, not included in global CO₂ budget synthesis analysis
(e.g. global carbon project)

AsiaFlux Data: 54 sites (incl. other DB)

More data submission is needed.
(How to promote submission?)

AsiaFlux + RS + Machine Learning:

Spatial Upscaling (Data-driven products)
Issues in tropical forests, and NEE

Data-driven products are ready to use for CO₂ budget estimation.

Similar Product: MTE [Jung et al. 2011]

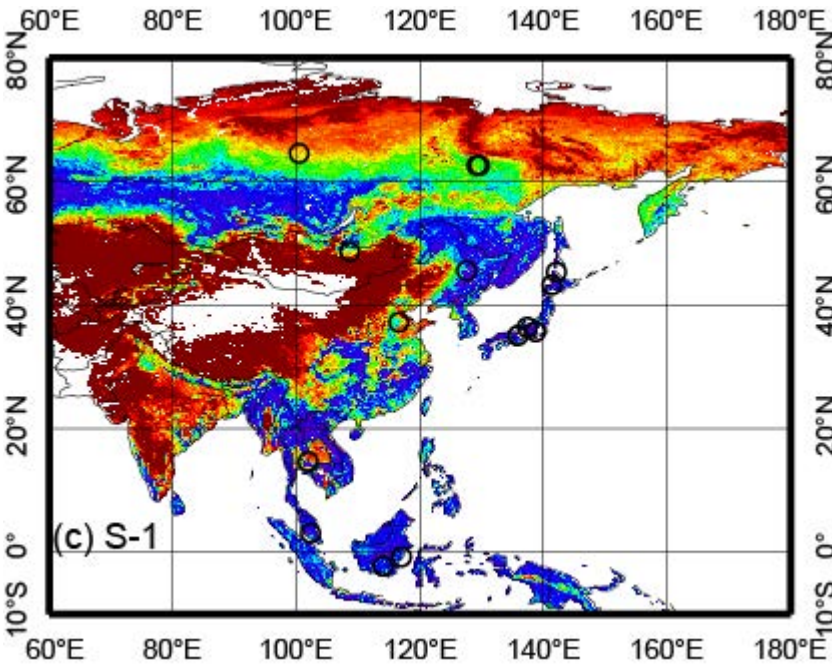
SVR-Global [Kondo et al. 2015]

FLUXCOM [Tramontana et al. 2016]

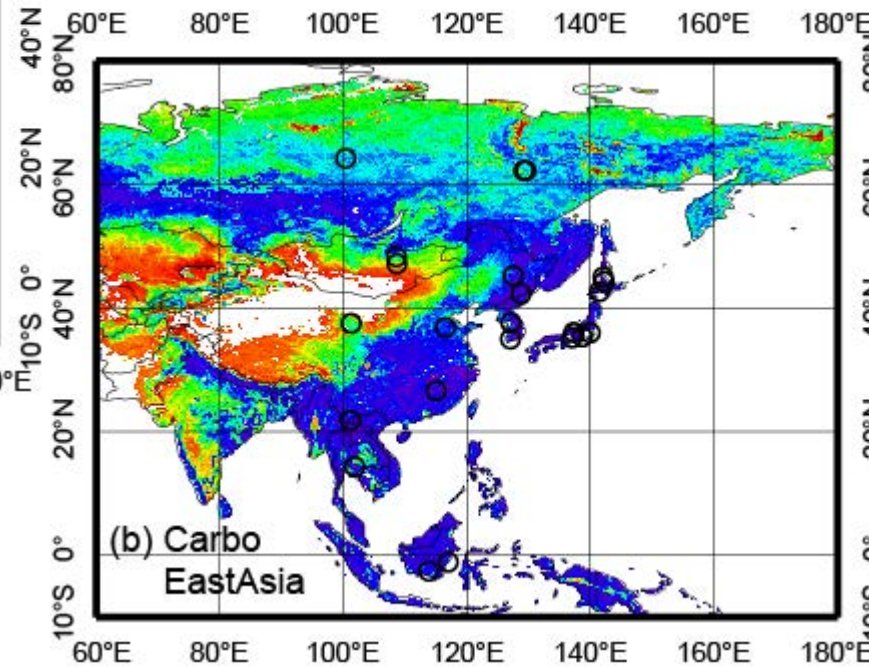
Effect of denser observation network on CO₂ flux constrain

Test GPP extrapolation variability (by machine learning)
with 10 different input data combination
different network density

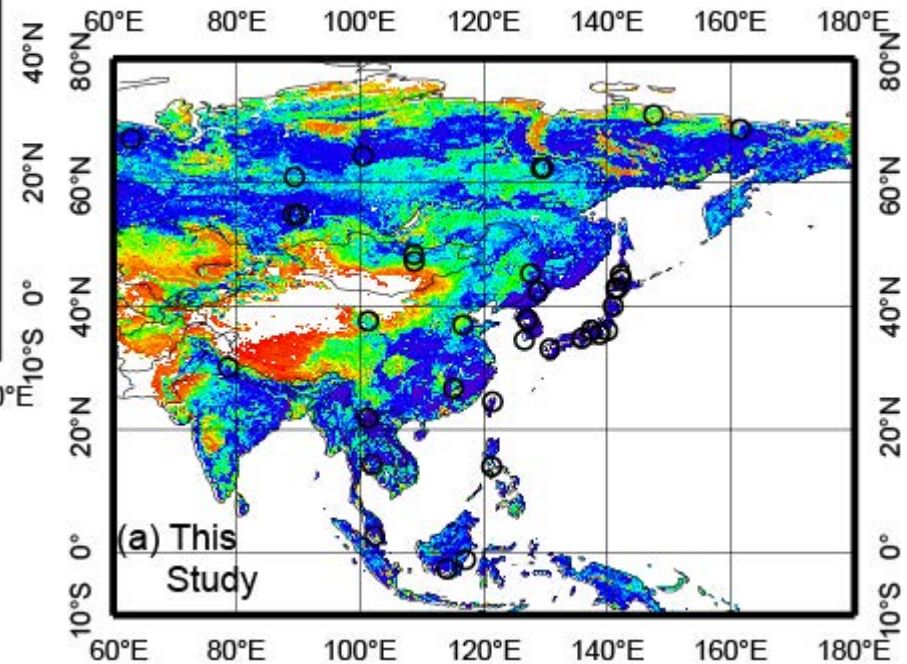
(YR2013 26 sites)



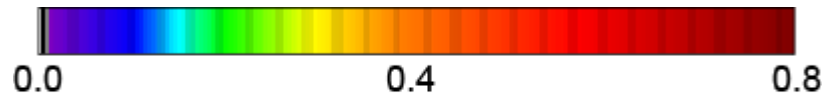
(YR2008 13 sites)



(YR2017 54 sites)



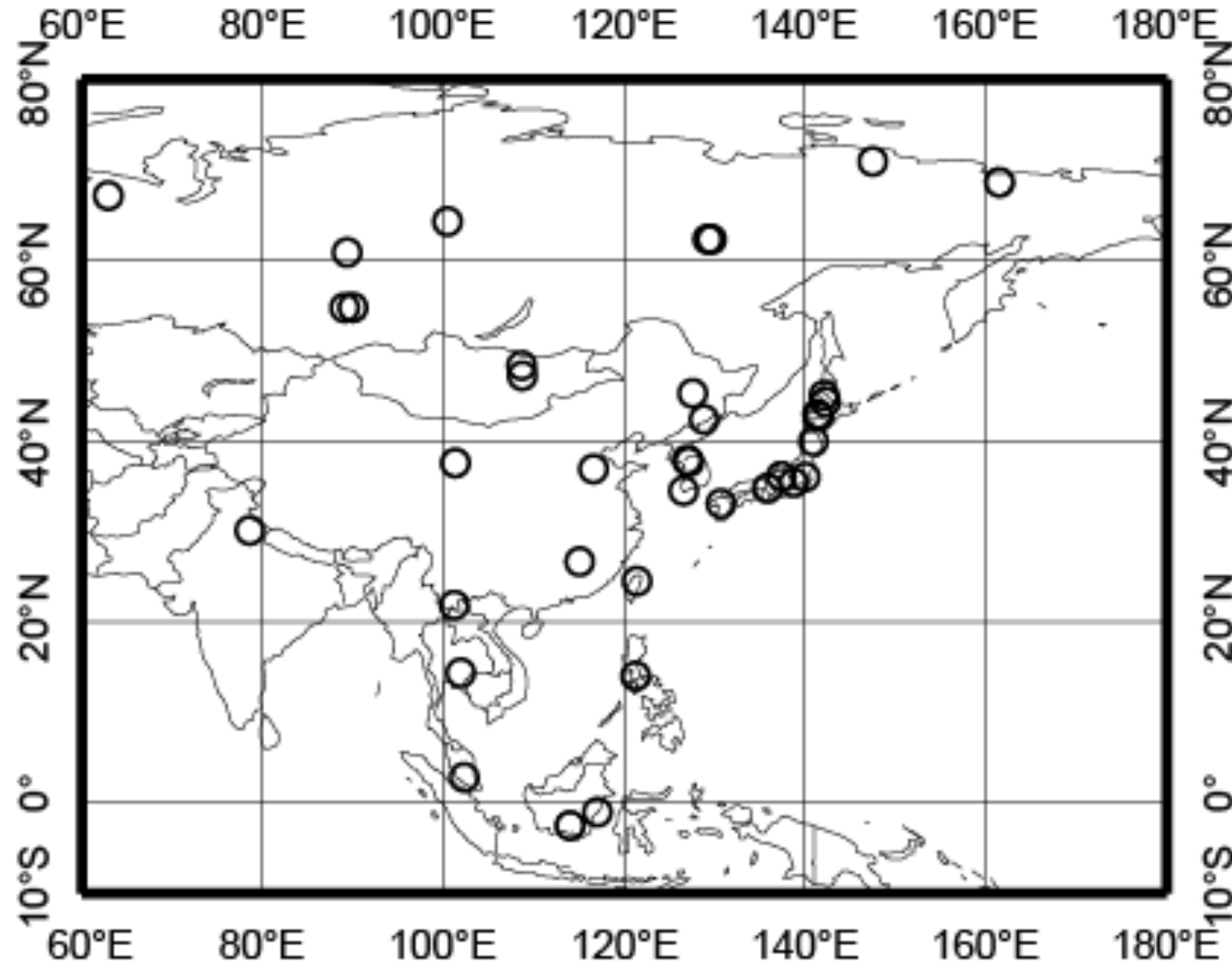
well-constrained unconstrained



[Ichii et al. 2017] Coefficient of Variation (σ_{GPP}/GPP)

Basic Data: Asia Integrated EC dataset

AsiaFlux+FFPRI+CarboEurope etc. (54) (for upscaling)

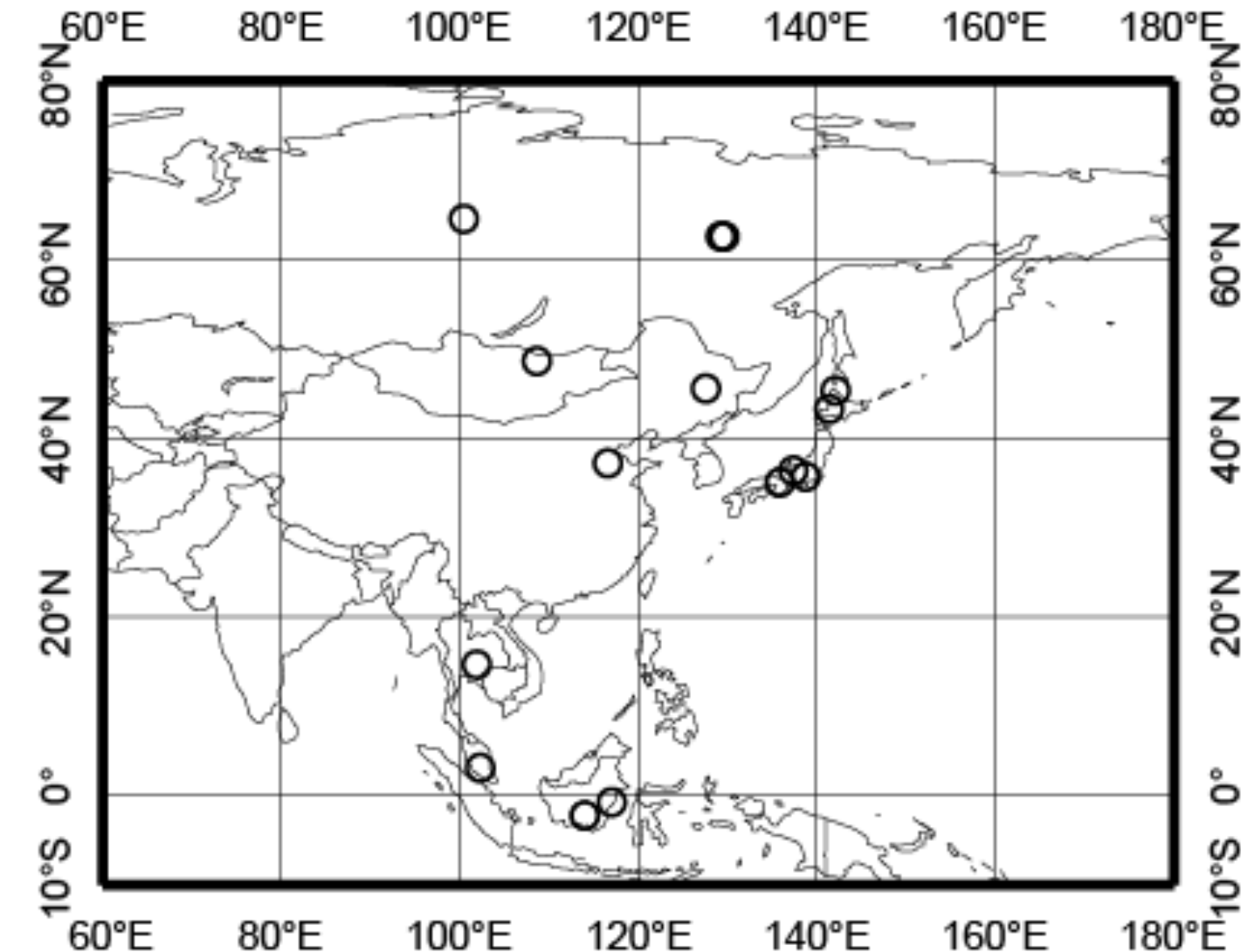


Wide coverage
(Tundra, India,
Israel, Sudan etc.)

≥ 10 years; 6 sites
RUCok, RUFyo,
TSE, GDK,
HFK, ILYat

Expansion of AsiaFlux, JapanFlux

Stage 1: First AsiaFlux (JapanFlux) multi-site synthesis (13)



Spatial distribution of carbon balance in forest ecosystems across East Asia

Ryuichi Hirata^{a,*}, Nobuko Saigusa^b, Susumu Yamamoto^c, Yoshikazu Ohtani^d, Reiko Ide^a, Jun Asanuma^e, Minoru Gamo^b, Takashi Hirano^f, Hiroaki Kondo^b, Yoshiko Kosugi^g, Sheng-Gong Li^{e,h,j}, Yuichiro Nakai^d, Kentaro Takagiⁱ, Makoto Tani^g, Huimin Wang^{b,j}

[Hirata et al. 2008]



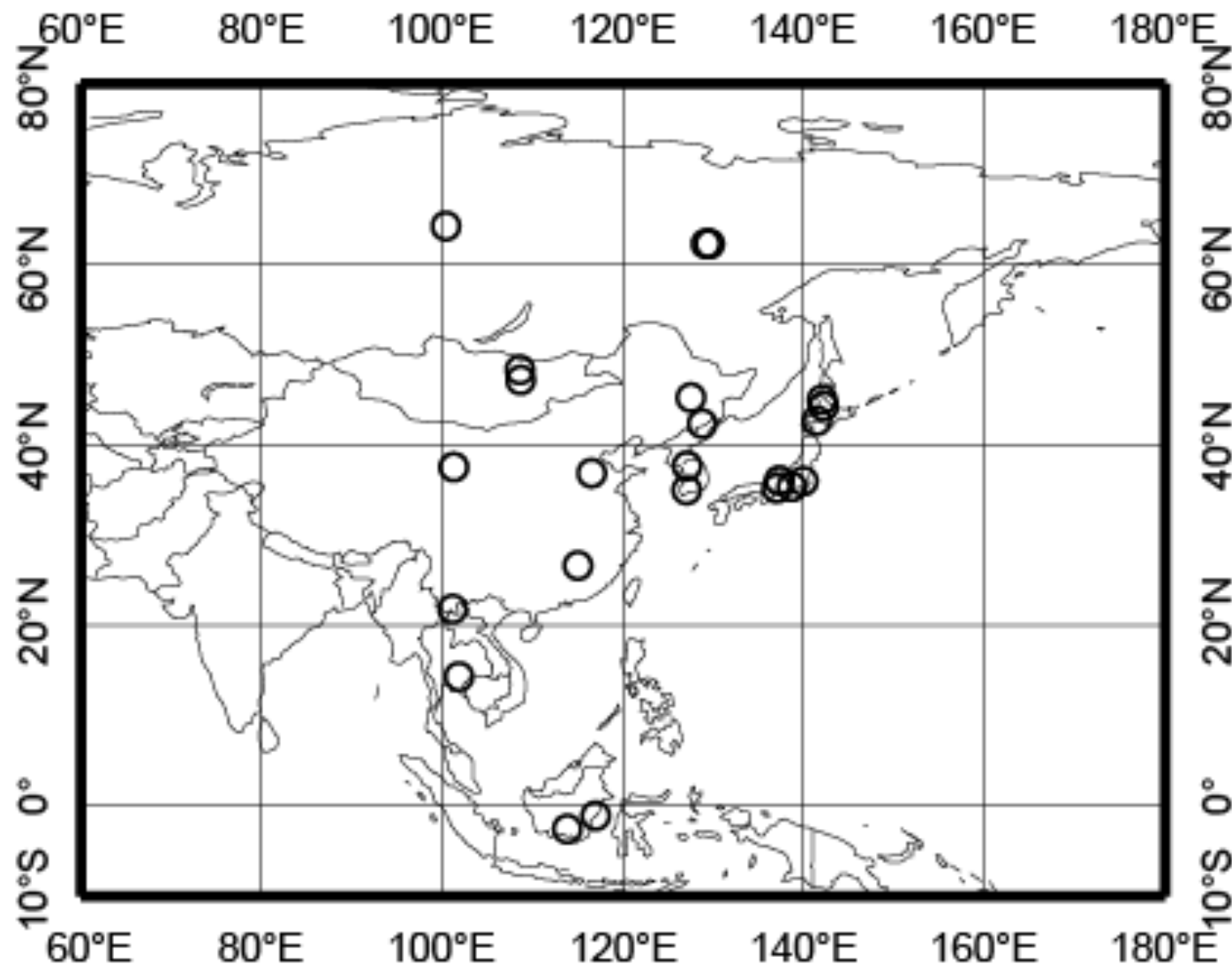
Temporal and spatial variations in the seasonal patterns of CO₂ flux in boreal, temperate, and tropical forests in East Asia

Nobuko Saigusa^{a,*}, Susumu Yamamoto^b, Ryuichi Hirata^c, Yoshikazu Ohtani^d, Reiko Ide^c, Jun Asanuma^e, Minoru Gamo^a, Takashi Hirano^f, Hiroaki Kondo^a, Yoshiko Kosugi^g, Sheng-Gong Li^{e,h,j}, Yuichiro Nakai^d, Kentaro Takagiⁱ, Makoto Tani^g, Huimin Wang^{a,h}

[Saigusa et al. 2008]

Expansion of AsiaFlux, JapanFlux

Stage 2: CarboEastAsia (Japan-China-Korea Joint Program) multi-site synthesis (26)



J For Res (2013) 18:41–48
DOI 10.1007/s10310-012-0378-6

SPECIAL FEATURE: ORIGINAL ARTICLE

Lessons learned from CarboEastAsia: Carbon and water cycles in East Asian terrestrial ecosystems

Dataset of CarboEastAsia and uncertainties in the CO₂ budget evaluation caused by different data processing

Nobuko Saigusa · Sheng-Gong Li · Hyojung Kwon · Kentaro Takagi · Lei-Ming Zhang · Reiko Ide · Masahito Ueyama · Jun Asanuma · Young-Jean Choi · Jung Hwa Chun · Shi-Jie Han · Takashi Hirano · Ryuichi Hirata · Minseok Kang · Tomomichi Kato · Joon Kim · Ying-Nian Li · Takahisa Maeda · Akira Miyata · Yasuko Mizoguchi · Shohei Murayama · Yuichiro Nakai · Takeshi Ohta · Taku M. Saitoh · Hui-Ming Wang · Gui-Rui Yu · Yi-Ping Zhang · Feng-Hua Zhao

[Saigusa et al. 2013]

J For Res (2013) 18:13–20
DOI 10.1007/s10310-012-0367-9

SPECIAL FEATURE: ORIGINAL ARTICLE

Lessons learned from CarboEastAsia: Carbon and water cycles in East Asian terrestrial ecosystems

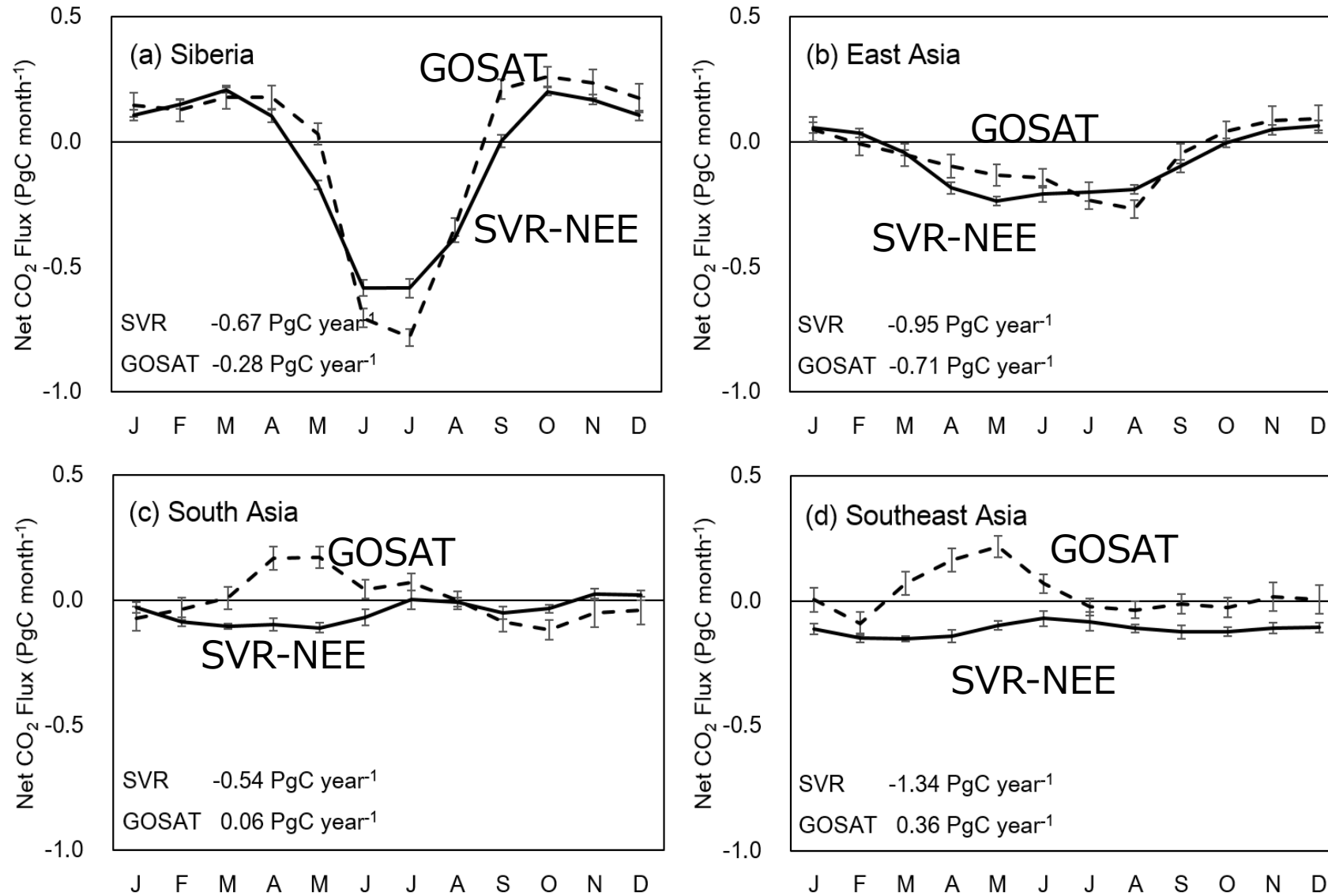
Site-level model–data synthesis of terrestrial carbon fluxes in the CarboEastAsia eddy-covariance observation network: toward future modeling efforts

Kazuhito Ichii · Masayuki Kondo · Young-Hee Lee · Shao-Qiang Wang · Joon Kim · Masahito Ueyama · Hee-Jeong Lim · Hao Shi · Takashi Suzuki · Akihiko Ito · Hyojung Kwon · Weimin Ju · Mei Huang · Takahiro Sasai · Jun Asanuma · Shijie Han · Takashi Hirano · Ryuichi Hirata · Tomomichi Kato · Sheng-Gong Li · Ying-Nian Li · Takahisa Maeda · Akira Miyata · Yojiro Matsuura · Shohei Murayama · Yuichiro Nakai · Takeshi Ohta · Taku M. Saitoh · Nobuko Saigusa · Kentaro Takagi · Yan-Hong Tang · Hui-Min Wang · Gui-Rui Yu · Yi-Ping Zhang · Feng-Hua Zhao

[Ichii et al. 2013]

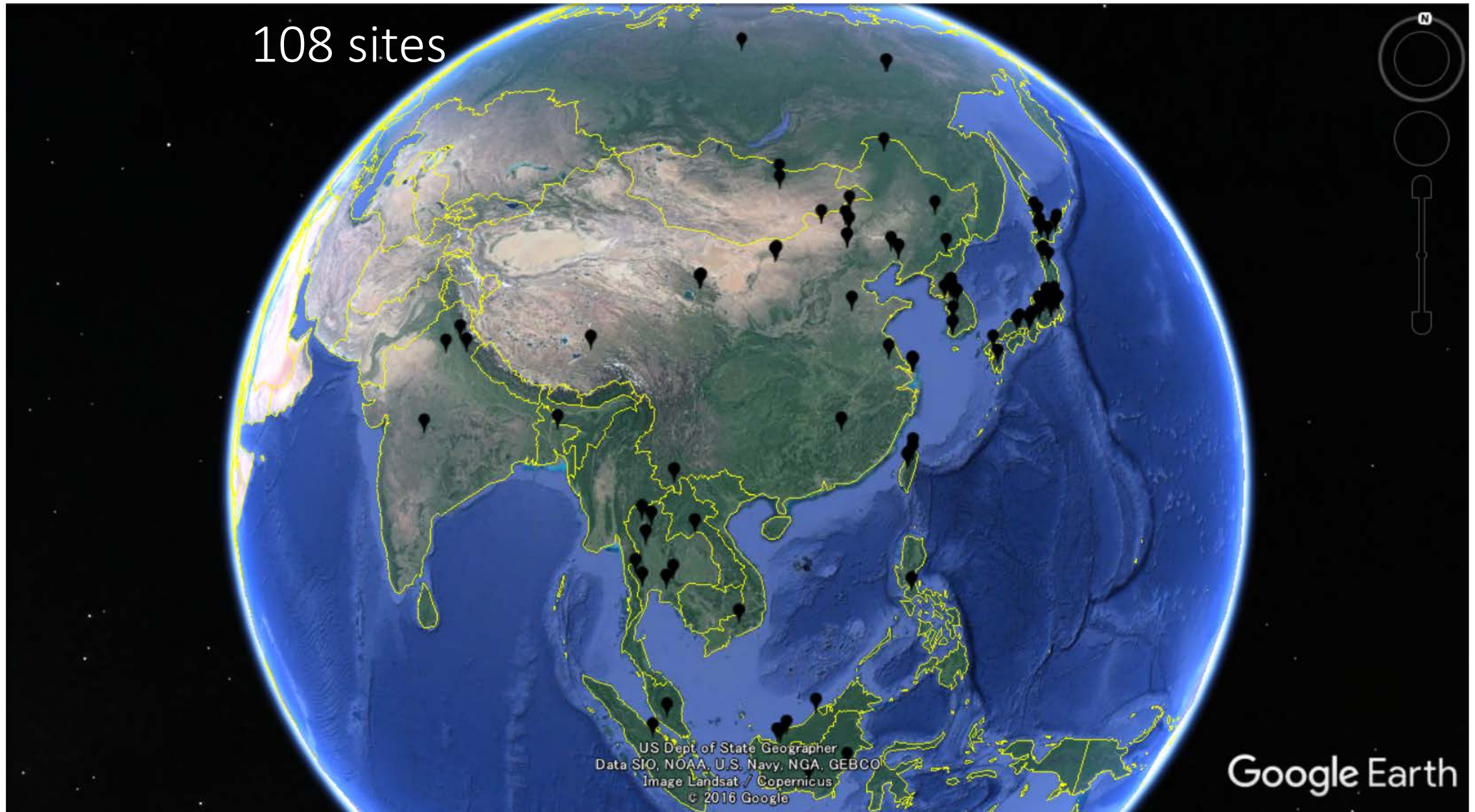
Net CO₂ Flux (SVR-Asia vs GOSAT L4A)

Top-down : GOSAT L4A, Bottom-up: Data-driven (upscaling) (SVR-Asia)



AsiaFlux Registered Sites [Site-Registered]

[Oct 2018]



36 sites

