Development of integrative information of the terrestrial ecosystem
総合的な陸域生態系情報の開発

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Cooperative Investigators:

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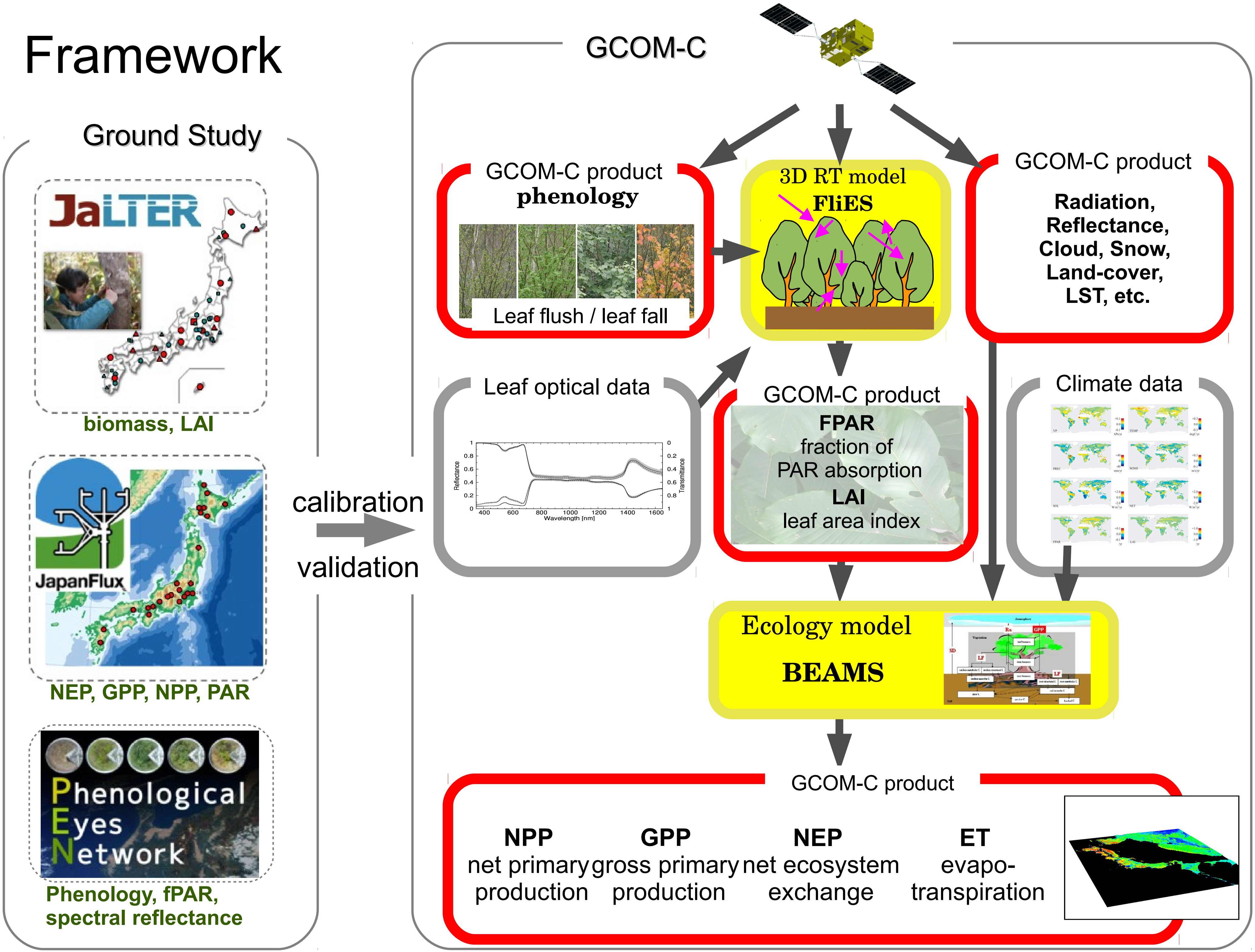
- Hideaki SHIBATA（柴田英昭）: Hokkaido Univ.
- Mitsuru HIROTA（廣田充）: Tsukuba Univ.
- Atsushi KUME（久米篤）: Kyushu Univ.
- Takahisa MAEDA（前田高尚）: AIST
- Yasuko MIZOGUCHI（溝口康子）: FFPRI
- Keisuke ONO（小野圭介）: NIAES
- Kanako MURAMATSU（村松加奈子): Nara WU
- Kazuma AOKI（青木一真）: Toyama Univ.
- Takeshi OHTA（太田岳史）: Nagoya Univ.
- Akira KATOH（加藤顕）: Chiba Univ.
- Naoko TOKUCHI（徳地直子）: Kyoto Univ.
- Tatsuro NAKAJI（中路達郎）: Hokkaido Univ.
- Hirofumi HASHIMOTO（橋本博文）: NASA
- Toshiya YOSHIDA（吉田俊也）: Hokkaido Univ.
- Ramakrishna NEMANI: NASA

Post-Doc Researchers:

- Tomoko AKITSU（秋津朋子）: Univ Tsukuba
- Yang WEI（楊偉）: JAMSTEC

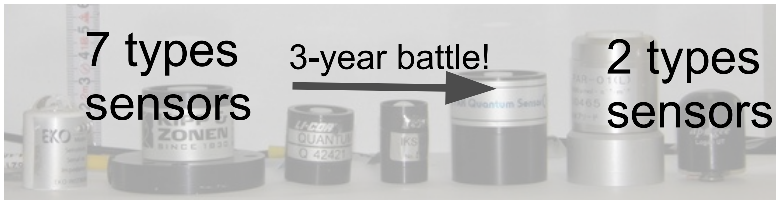
Framework



GCOM-C
Ground Study
JaLTER
biomass, LAI
JapanFlux
NEP, GPP, NPP, PAR
Phenological
Eyes
Network
Phenology, fPAR,
spectral reflectance
calibration
validation
GCOM-C product
phenology
Leaf flush / leaf fall
3D RT model
FLiES
GCOM-C product
Radiation,
Reflectance,
Cloud, Snow,
Land-cover,
LST, etc.
Leaf optical data
Reflectance
Transmittance
Wavelength [nm]
GCOM-C product
FPAR
fraction of
PAR absorption
LAI
leaf area index
Climate data
Ecology model
BEAMS
GCOM-C product
NPP
net primary
production
GPP
gross primary
production
NEP
net ecosystem
exchange
ET
evapo-
transpiration

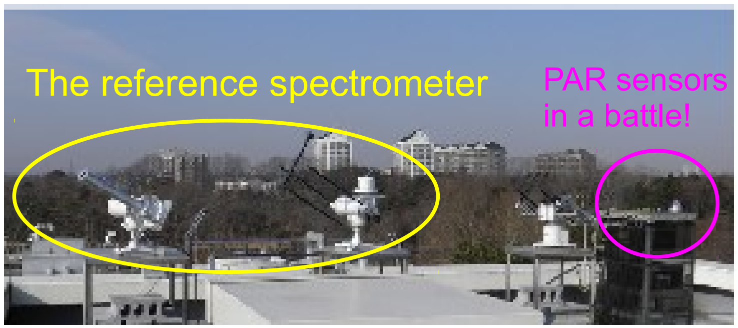
Tomoko AKITSU 秋津 朋子

Let's make a standard protocol for PAR measurement!



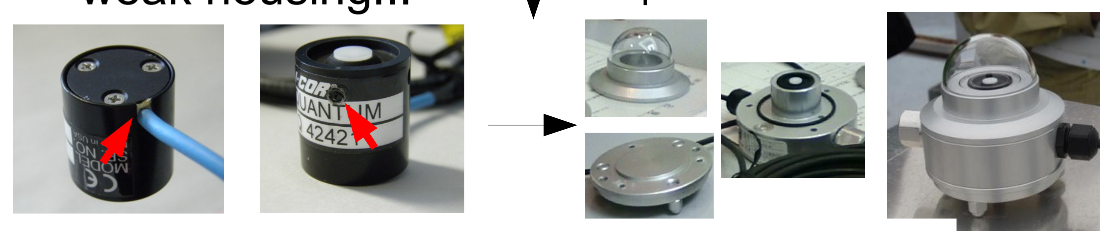
- Apogee: Stable! but inaccurate spectral band.
- LI-COR: Accurate! but unstable (sensitivity degrade).

… No perfect sensor yet

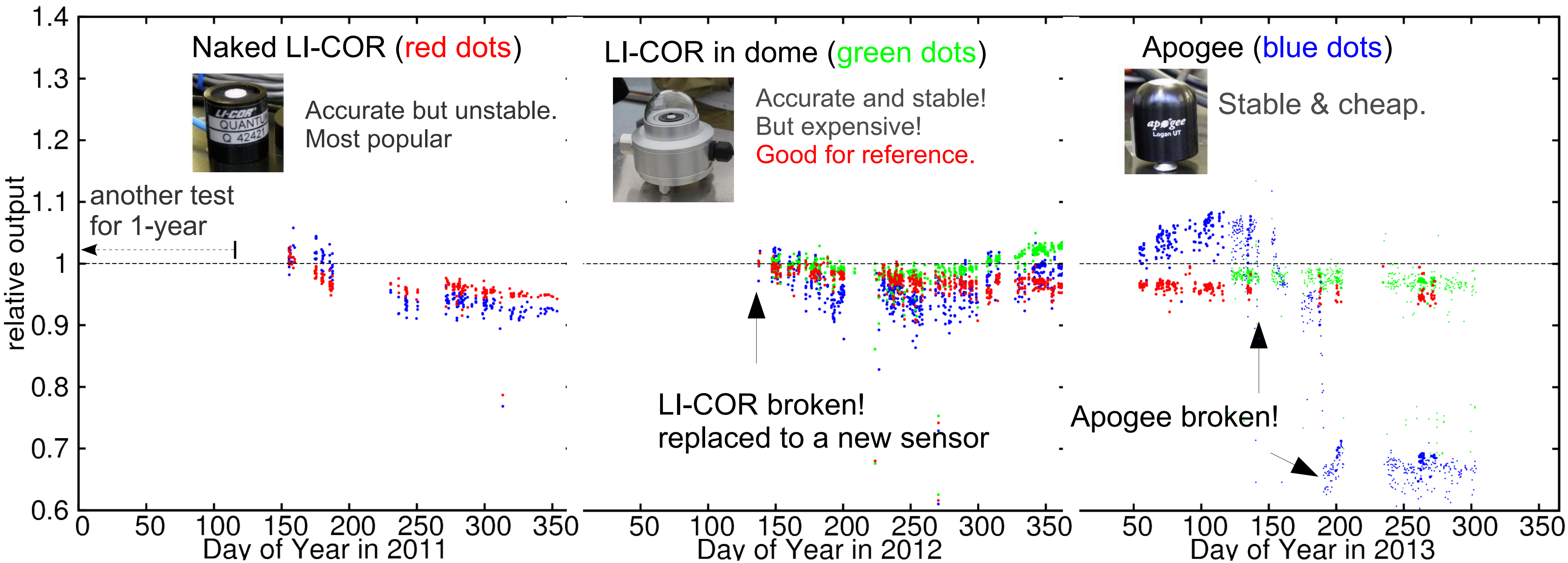


weak housing...

protected in a dome!



"LI-COR in dome" improved performance!



Recommendation: One "LI-COR in dome" and many Apogee for each site.

Development of the canopy radiative transfer model and LAI/FAPAR retrieval algorithm

Contributors

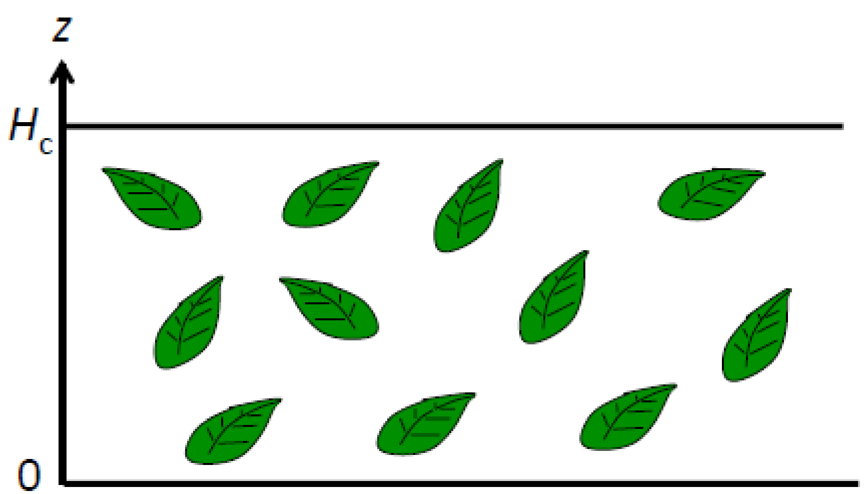
Kenlo Nasahara, Hideki Kobayashi, Wei Yang,
Yuhsaku Ono (JAXA), Hiroshi Murakami (JAXA), Koji Kajiwara (Chiba U.) and Yoshiaki Honda (Chiba U.)

Development of the canopy radiative transfer model and LAI/FAPAR

- Leaf Area Index (LAI)
  - One side total leaf area in a unit ground (m^2 m^{-2})
- Fraction of absorbed photosynthetically active radiation (FAPAR, fAPAR, FPAR)
- Possible users will be ecosystem and earth system modelers
  - Input parameter for BEAMS and other satellite-driven models
  - Validation and assimilation

Leaf Area Index (LAI)

- Leaf area index, L [$m^2\ m^{-2}$]
  - Total one side leaf area per unit ground
  - For needles, half of total needle area per unit ground is commonly used definition
- leaf area density, $u(z)$ [$m^2\ m^{-3}$]
  - Total one side leaf area per unit volume



$$L = \int_0^{Hc} u(z)\,dz$$

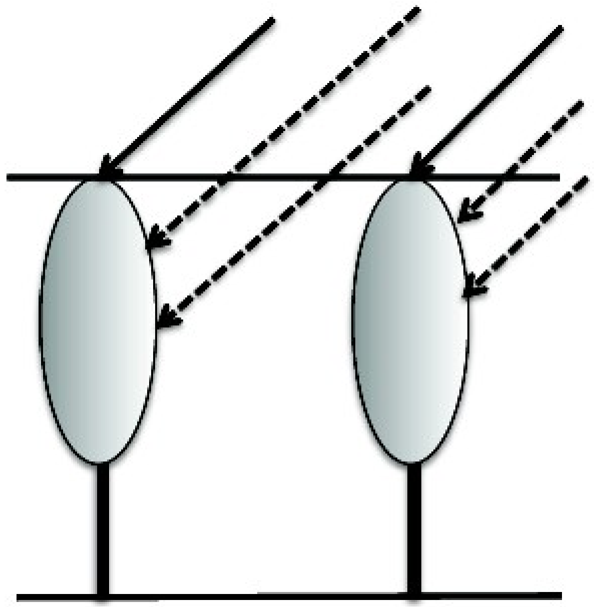
FAPAR definition in GCOM-C1

$$FAPAR_{1d} = APAR/PAR_{1d}$$

PAR_{1d} : Only solid lines

$$FAPAR_{3d} = APAR/PAR_{3d}$$

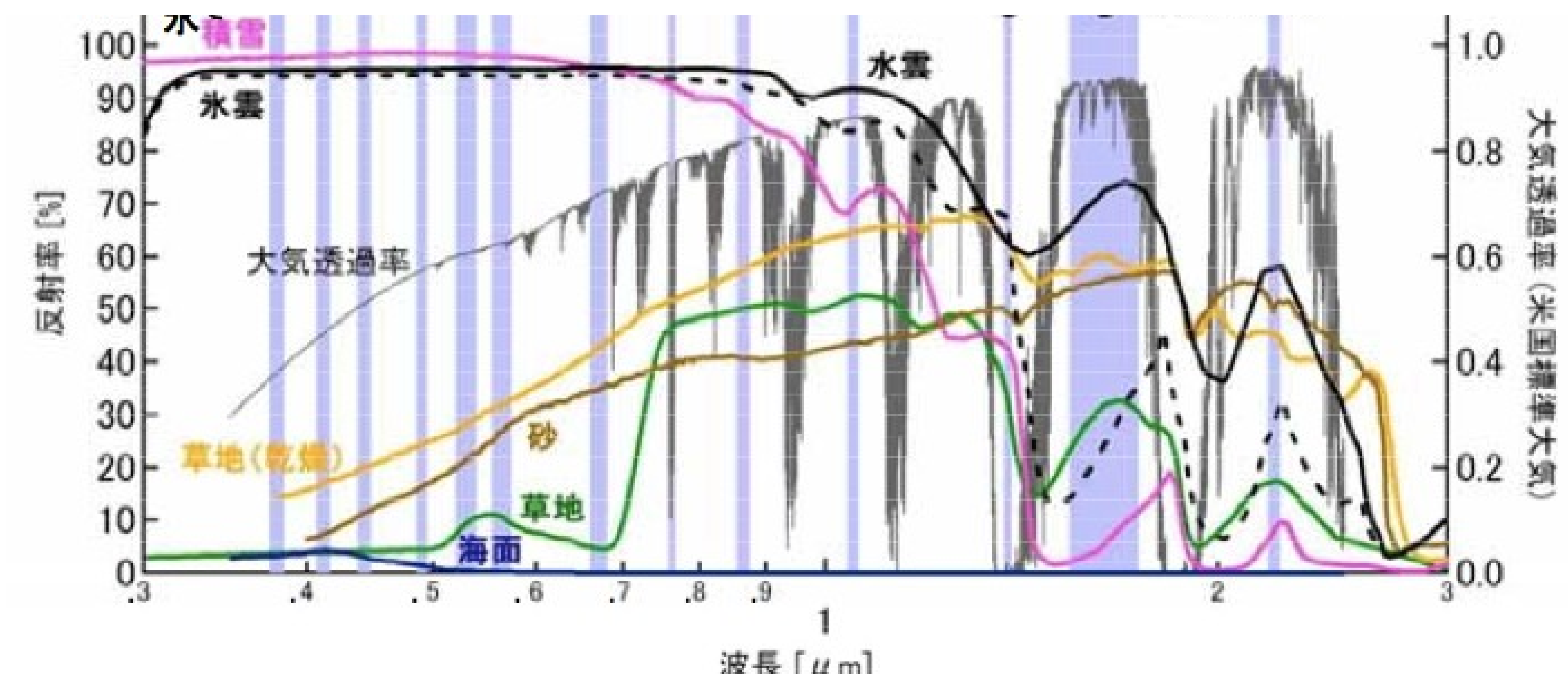
PAR_{3d} : solid + dotted lines



- FAPAR varies with solar zenith angles (diurnal and seasonal changes)
- In GCOM-C1 algorithm, FAPAR definition will be $FAPAR_{1d}$ and FAPAR at the time of the observation.

Kobayashi, Suzuki, Nagai, Nakai, Kim,(2014), IEEE Geoscience and Remote Sensing Letters.

General idea of LAI/FAPAR estimation



Inversion of the merit function

$$F = \sum_{i=1}^{n} w_i \left(R_{i,mes} - R_i(x_1, x_2, x_3, \ldots) \right)^2$$

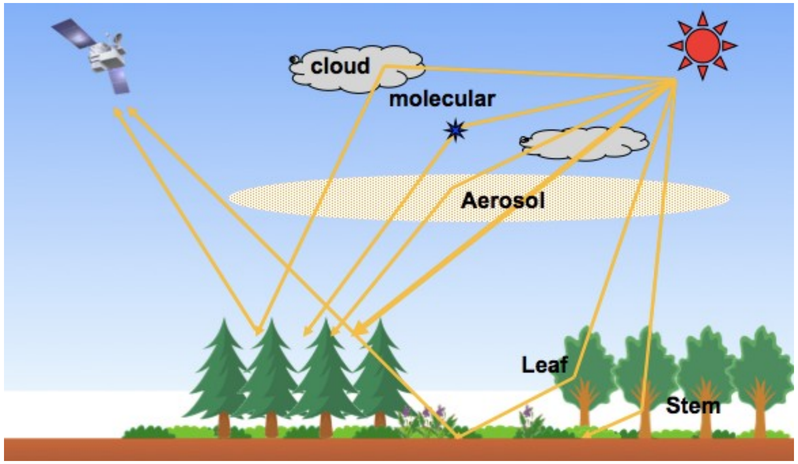
$R_{i,mes}$: GCOM-C1 observation
R_i: simulated BRF by the RT model
w_i: weight

Issues:

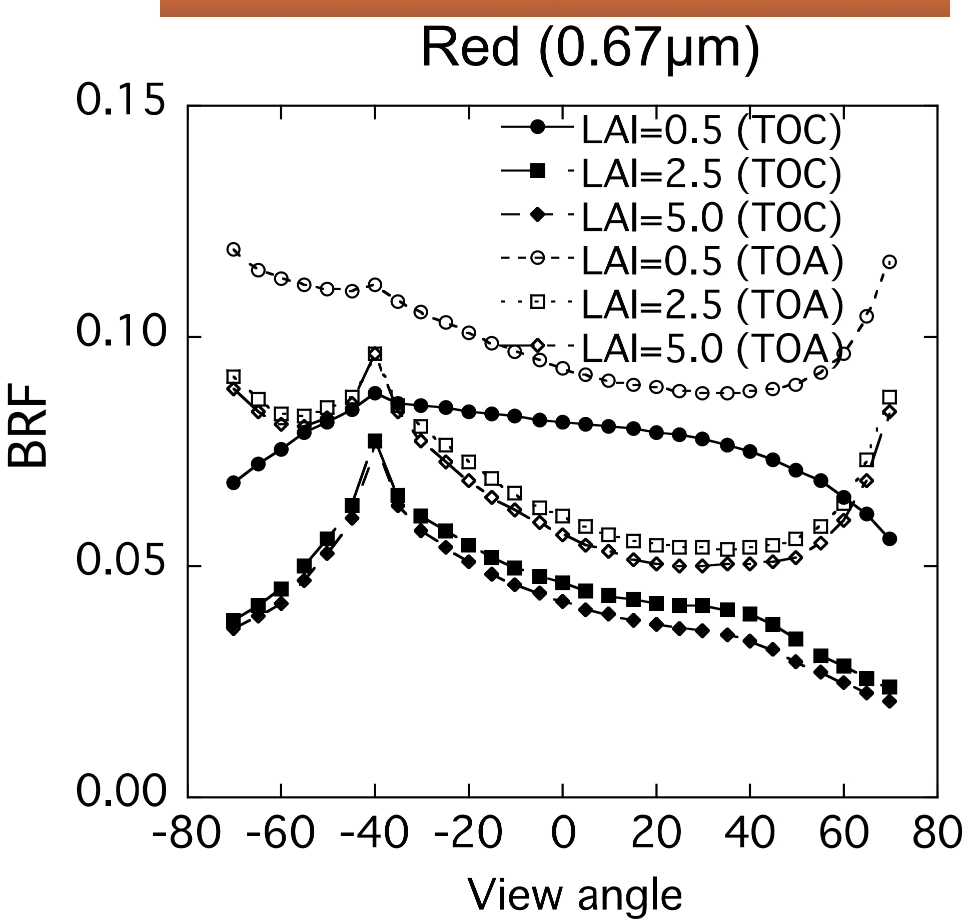
1. Improvement and optimization of the canopy RT model including input data sets
2. Optimization method (LUT, neural network, or others etc.)
3. Selection of spectral channels
4. Noise reduction, interpolations

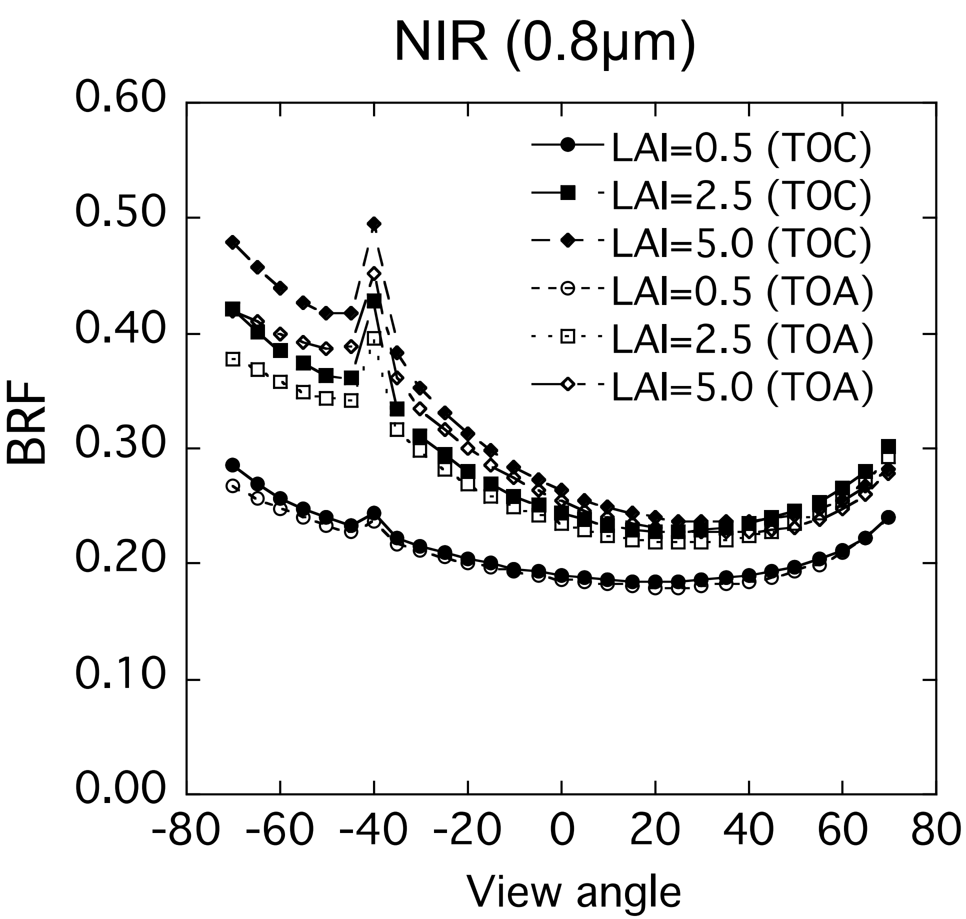
Hideki KOBAYASHI 小林 秀樹

3D RT model
Forest Light Environmental Simulator (FLiES)

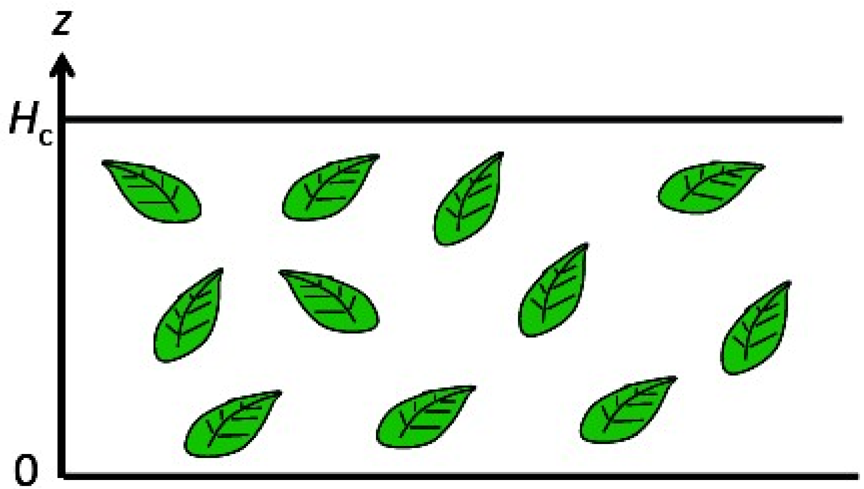


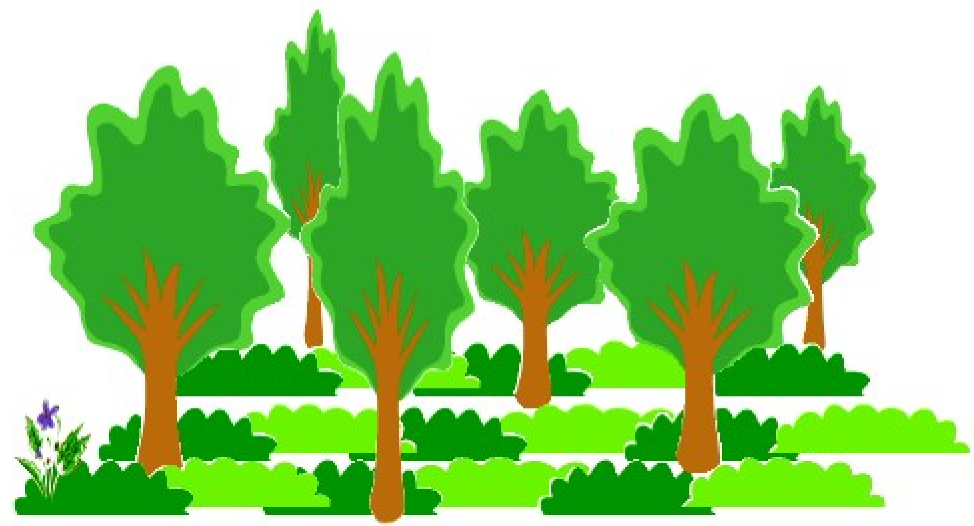
FLiES (Kobayashi and Iwabuchi 2008):
_three dimensional canopy RT model coupled with 1D version of MCARaTS atmospheric RT model (Iwabuchi, 2006)





3D Plant canopy





- Plant canopy structure, especially the forest canopy, is very complicated.
- 3D RT modeling is necessary to provide realistic surface BRF for inversion

Existing global LAI/FAPAR products

	ISLSCP II	Boston Univ
Satellite	NOAA-AVHRR	NOAA-AVHRR
Periods	1982-1998	??
Spatial resolution	1 degree	8 km
Method	NDVI, SR	NDVI
RT model	1-D (Two-stream, Dickinson, 1983)	3-D (Discrete Ordinate, Myneni et al., 1997)
References	Sellers et al 1996	Myneni, et al., 1997

	MOD15	CYCLOPES	GLOBCARBON
Satellite	MODIS and MISR	VEGETATION	VEGETATION, ATSR
Periods	2000-	1998-	1998-2006
Spatial resolution	1 km	1/112 degree	1 km
Method	Inversion	Inversion	Inversion
RT model	3-D (Discrete Ordinate, Myneni et al., 1997)	1-D (SAIL+PROSPECT)	1-D (Roujean et al., 1992)
References	Knyazilkhin et al, 1998	Baret et al., 2007	Deng et al., 2006

So far, only three groups have been succeeded to create "Global Operational and Long-term LAI/FAPAR data sets."

Summary of FY25

- Catching up phase
  - The first priority is to catch up to the level of existing products (NASA and ESA)
  - Yuhsaku Ono has created a preliminary map of LAI/FPAR in AsiaMIP (PI: Ichii) regions.
- Land cover categories to be used in inversion
- Improvement in temperate deciduous and needleleaf forests (will be explained by Dr. Ono)
- Improvement in Northern sparse needleleaf forest (Dr. Wei Yang)
- LUT preparation in rice field

Land cover categories

Vegetation structure used in the GCOM-C1 LAI/FAPAR algorithm (as of August 6, 2013)

	1. Broadleaf Forest (Deciduous and Evergreen)	2. Needleleaf Forest (Deciduous and Evergreen)	3. Grasses and Crops (except Rice paddy)	4. Rice paddy	5. Shrub	6. Savanna
Land Cover definition by IGBP-DIS	Lands dominated by trees with a percent canopy cover > 60% and height exceeding 2m.	Lands dominated by trees wit ha percent canopy cover > 60% and height exceeding 2m.	Grasslands: Lands with herbaceous types of cover, Three and Shrub cover is less than 10% Croplands: Lands covered with temporary crops followed by harvest and a bare soil periods. Note that perennial woody crops will be classified as the appropriate forest or shrubs land cover type.	This category is newly added and does not exist the IGBP-DIS category. This category is exclusively for rice paddy, which is one of the major staples in the Asian countries.	Closed shrub: Lands with woody vegetation less than 2m tall and with shrub-canopy cover > 60%. The shrub foliage can be either evergreen or deciduous. Open shrub: Lands with woody vegetation less than 2m tall and with shrub canopy cover between 10 -60%. The shrub foliage can be either evergreen or deciduous.	Lands with herbaceous and other understory systems, and with forest canopy between 10-30%. The forest height exceeds 2m.
Optical data	???（Takayama site）	Use larch (*Larix kaempferi*) needle reflectance and transmittance, and stem reflectance measured in the Fuji Hokuroku site.	???	Use leaf reflectance and transmittance in the summer measured in Mase, Ibaraki Pref. rice paddy.	???	???
Stem/branches (Yes/No)	Yes	Yes	N/A	N/A	Yes	Yes
Understory	Currently No	Currently No	Currently No	Currently No	Currently No	Currently No
Leaf angle distribution	Spherical	Spherical	Spherical	Erectrophile	Spherical	Spherical
Shoot level clumping	No	Currently No	No	No	No	No
Spatial heterogeneity	Yes (hexagonal configuration)	Yes (hexagonal configuration)	No	No	Yes	Yes
Vertical heterogeneity (Leaf angle and leaf area density vertical profile)	No	No	No	No	No	No

Land cover categories

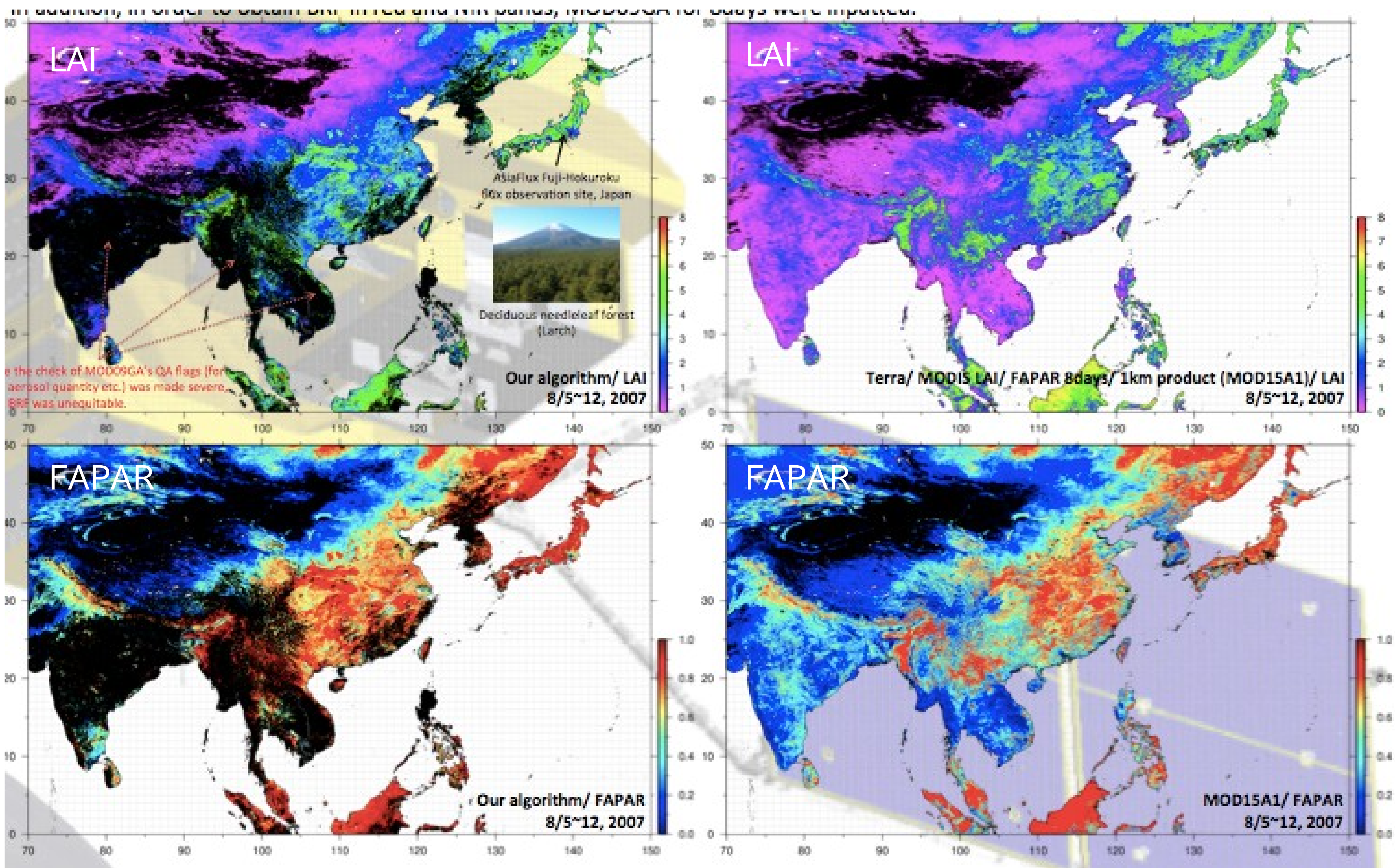
1. Broadleaf forest
2. Needleleaf forest
3. Grassland and Crops
4. Rice paddy
5. Shrub
6. Savanna (Open canopy woodland)

Vegetation structure used in the GCOM-C1 LAI/FAPAR algorithm (as of August 6, 2013)

	1. Broadleaf Forest (Deciduous and	2. Needleleaf Forest (Deciduous and	3. Grasses and Crops (except Rice paddy)	4. Rice paddy	5. Shrub	6. Savanna
Land Cover defir IGBP-DIS						s with herbaceous and understory systems, /ith forest canopy ;en 10-30%. The : height exceeds 2m.
Optical data						
Stem/branches ('						
Understory						ntly No
Leaf angle distribution	Spherical	Spherical	Spherical	Erectrophile	Spherical	Spherical
Shoot level clumping	No	Currently No	No	No	No	No
Spatial heterogeneity	Yes (hexagonal configuration)	Yes (hexagonal configuration)	No	No	Yes	Yes
Vertical heterogeneity (Leaf angle and leaf area density vertical profile)	No	No	No	No	No	No

Preliminary map (Dr. Ono)

GCOM-C1 algorithm | **MODIS (MOD15)**



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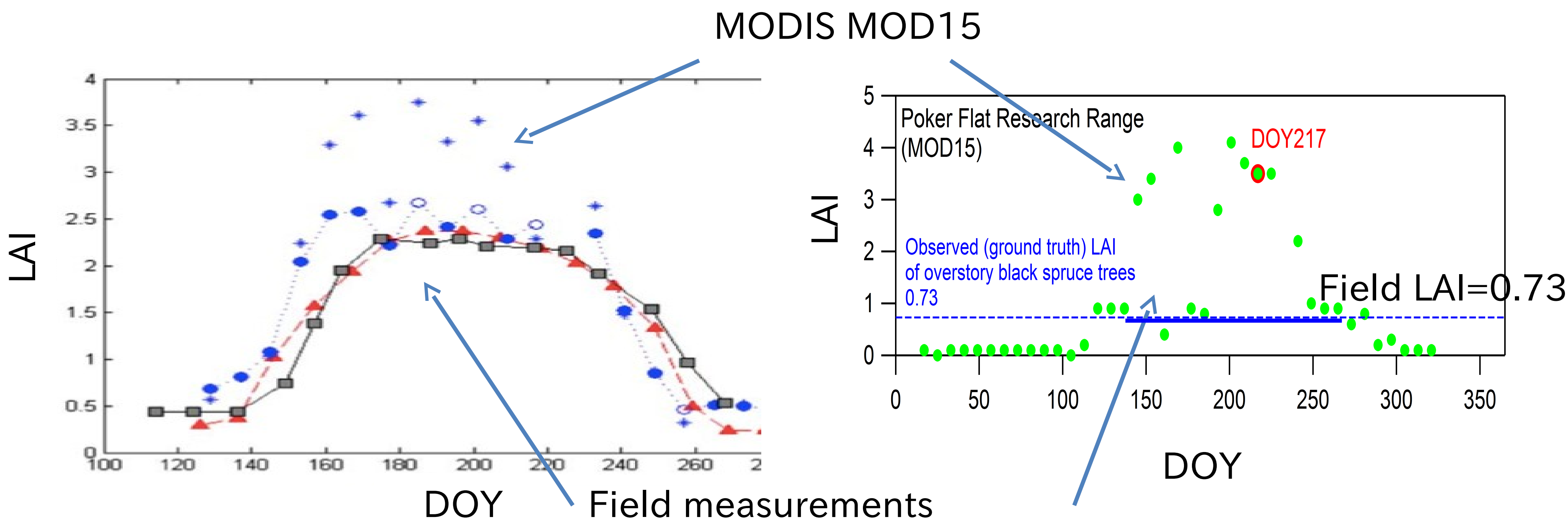
Estimation of LAI in sparse forests in northern forest (Yang)

Siberia larch forest

Black spruce forest in Interior Alaska

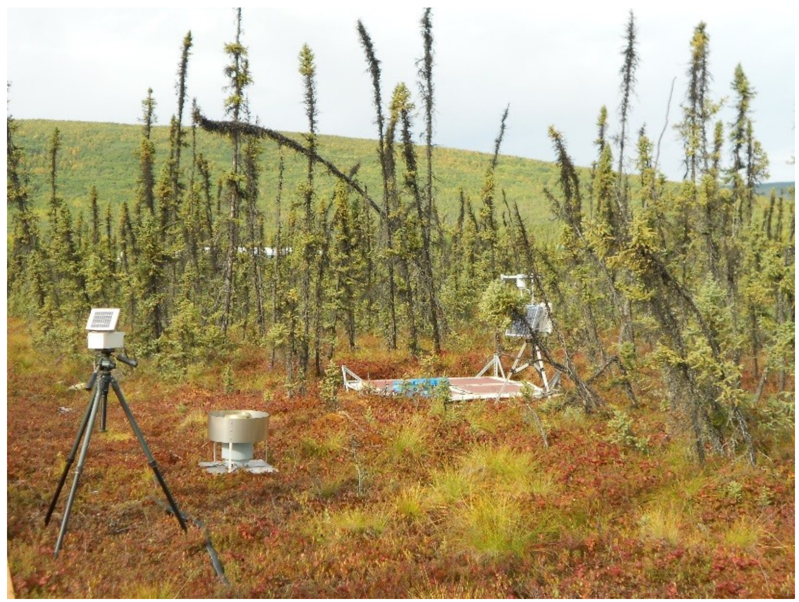


- In northern forests, MODIS (MOD15) LAI is likely to be overestimated

Estimation of LAI in sparse forests in northern forest (Yang)

Difficulty: Sparse crowns with seasonally and spatially variable understory layers

08/Jul/2010



26/Aug/2012

26/Aug/2012

This work has been done with the group of PI: Rikie Suzuki's group
(Investigation of carbon cycle of vegetation in cold districts through collaboration of SGLI and in-situ observations)

Basis 1: Retrieval of Understory Reflectivity

Geo-optical model-based Algorithm (Pisek and Chen, 2011):

$$R = R_T \cdot k_T + R_G \cdot k_G + R_{ZT} \cdot k_{ZT} + R_{ZG} \cdot k_{ZG}$$

Two directional observations:

$$R_n = R_T \cdot k_{Tn} + R_G \cdot k_{Gn} + R_{ZT} \cdot k_{ZTn} + R_{ZG} \cdot k_{ZGn}$$

$$R_a = R_T \cdot k_{Ta} + R_G \cdot k_{Ga} + R_{ZT} \cdot k_{ZTa} + R_{ZG} \cdot k_{ZGa}$$

giving $R_{ZT} = M \cdot R_T$ and $R_{ZG} = M \cdot R_G$

The understory reflectivity can be calculated as:

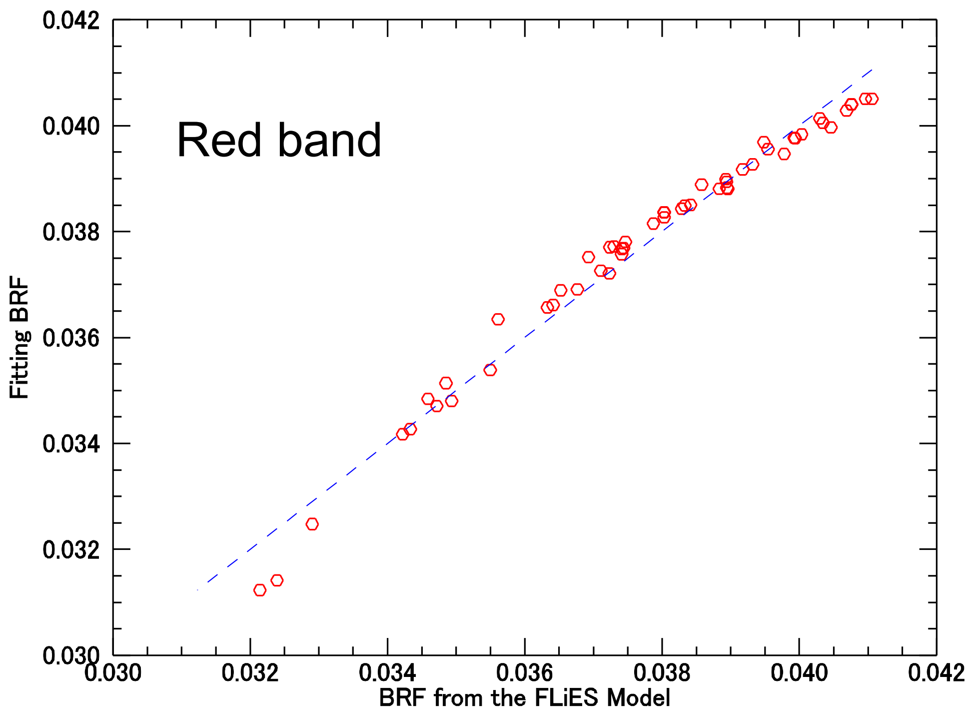
$$R_G = \frac{R_n(k_{Ta} + k_{ZTa} \cdot M) - R_a(k_{ZTn} \cdot M)}{-k_{Tn} \cdot k_{Ga} + k_{Gn} \cdot k_{Ta} + M(-k_{Tn} \cdot k_{ZGa} + k_{Gn} \cdot k_{ZTa} - k_{Ga} \cdot k_{ZTn} + k_{Ta} \cdot k_{ZGn}) + M^2(-k_{ZTn} \cdot k_{ZGa} + k_{ZGn} \cdot k_{ZTa})}$$

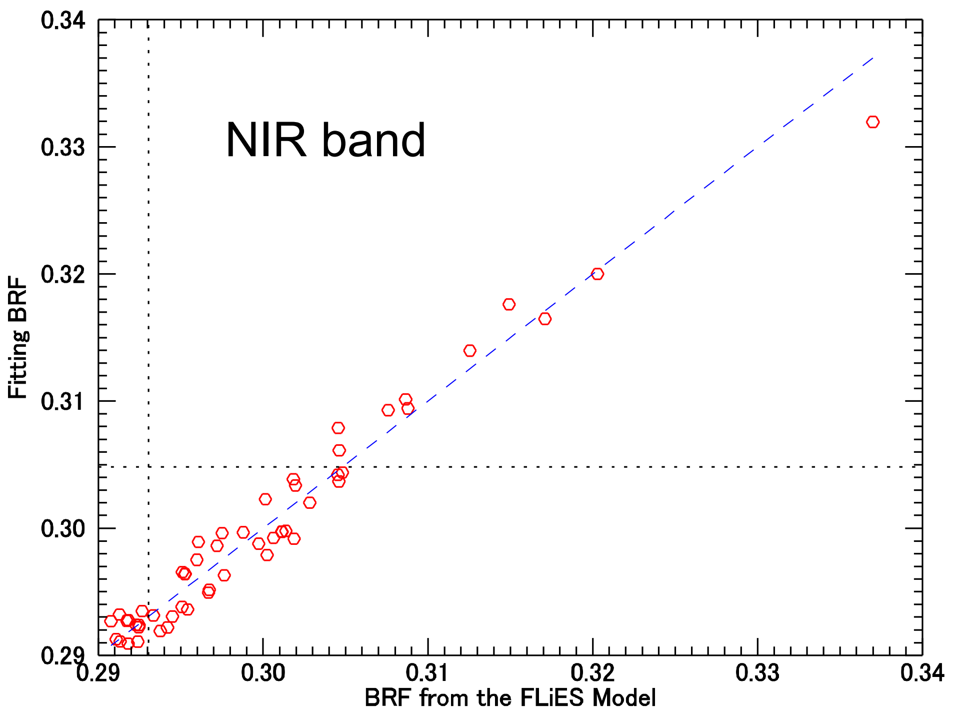
Basis 2: Linear Kernel-driven Model

The BRF of a canopy is expressed as:

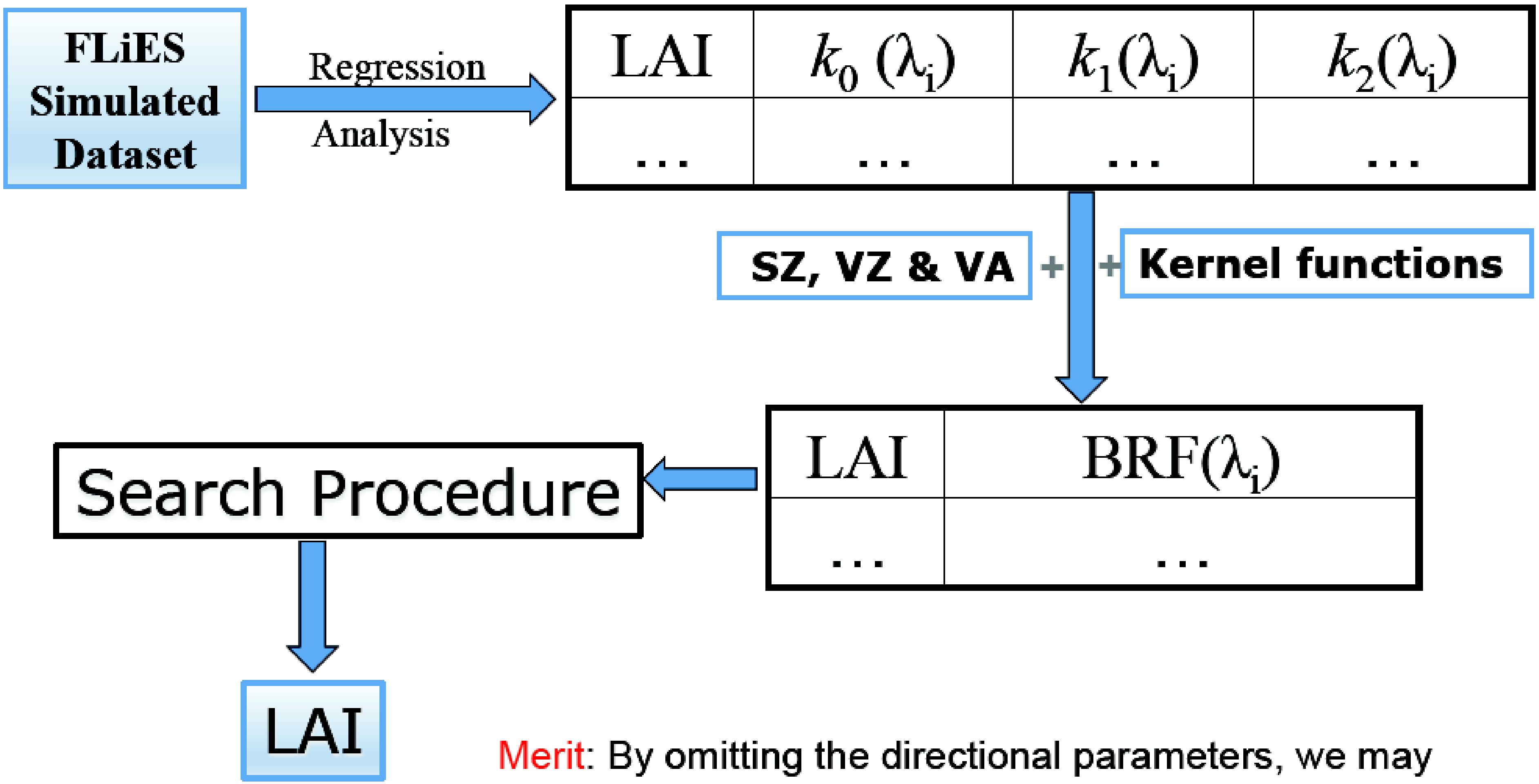
$$R(\theta_{out},\theta_{in},\phi)=k_0+k_1 f_1(\theta_{out},\theta_{in},\phi)+k_2 f_2(\theta_{out},\theta_{in},\phi) .$$

where the coefficients $k0$, $k1$ and $k2$ can be derived through regression analysis.





LUT Method based on Kernel-driven Model



Merit: By omitting the directional parameters, we may generate LUTs with finer intervals for LAI values.

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Rice paddy

April to June

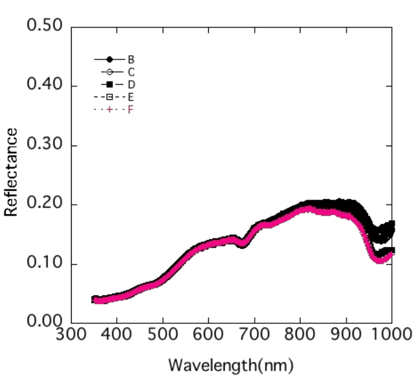


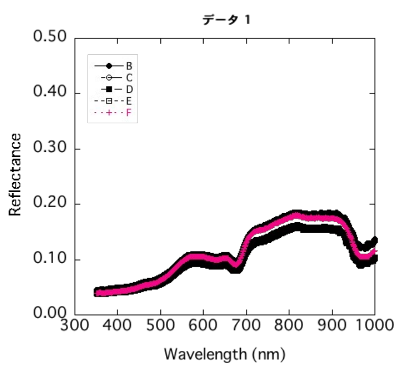


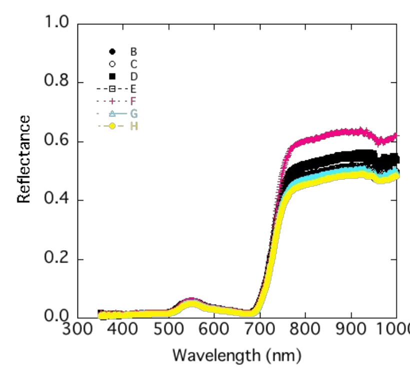

July to September

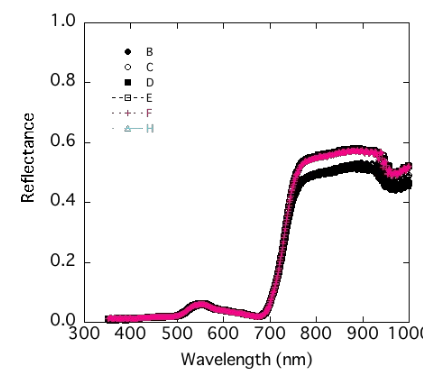



April to September



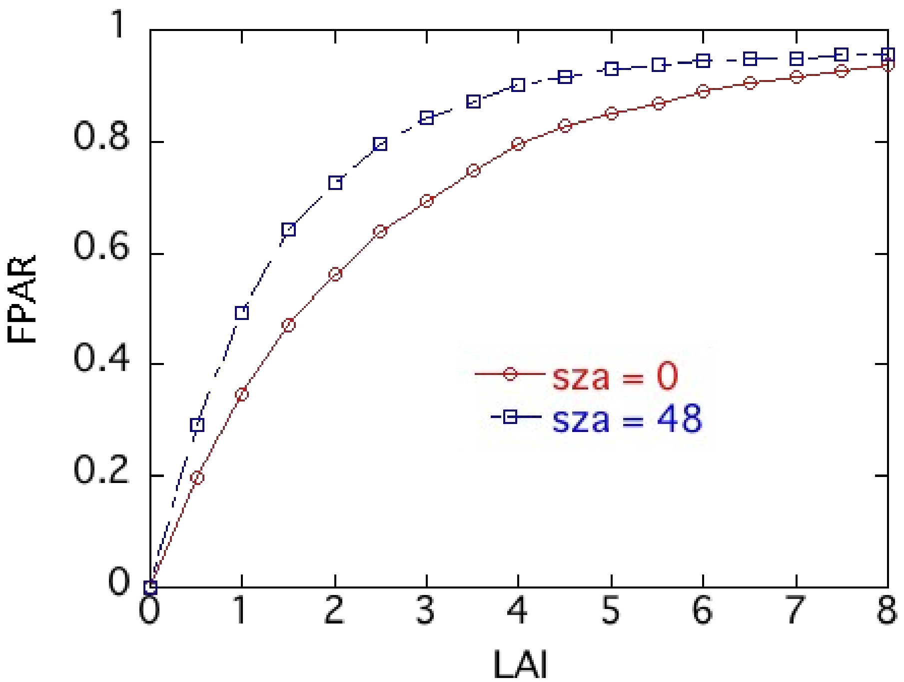


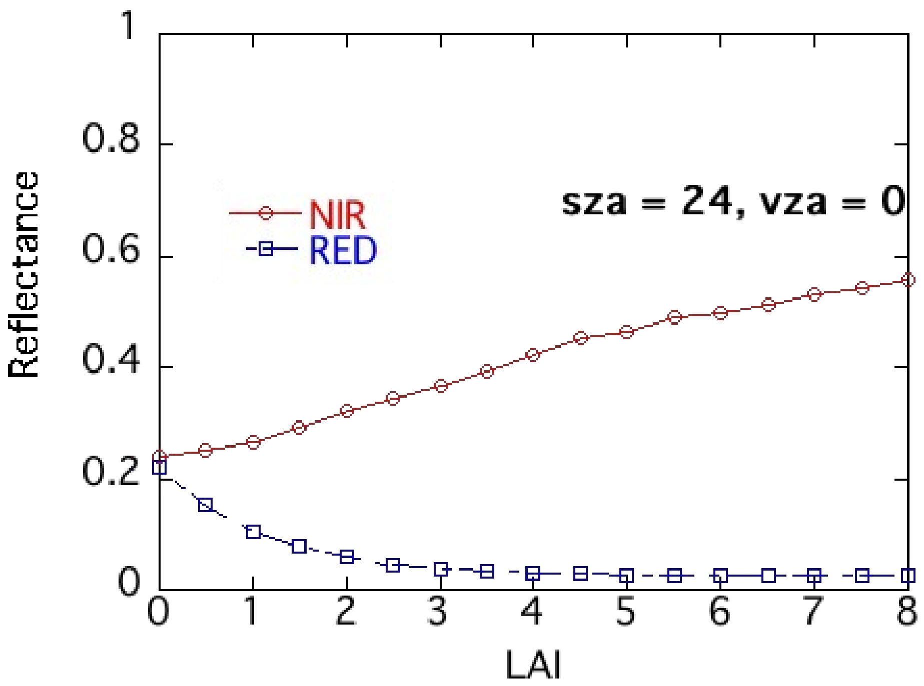




Development of Look up table for rice field

- Turbid medium
- Erectrophile leaf angle distribution
- Optical data
  - Leaf reflectance and transmittance from PRIMULAS
  - Soil reflectance is from the measurements in rice paddy



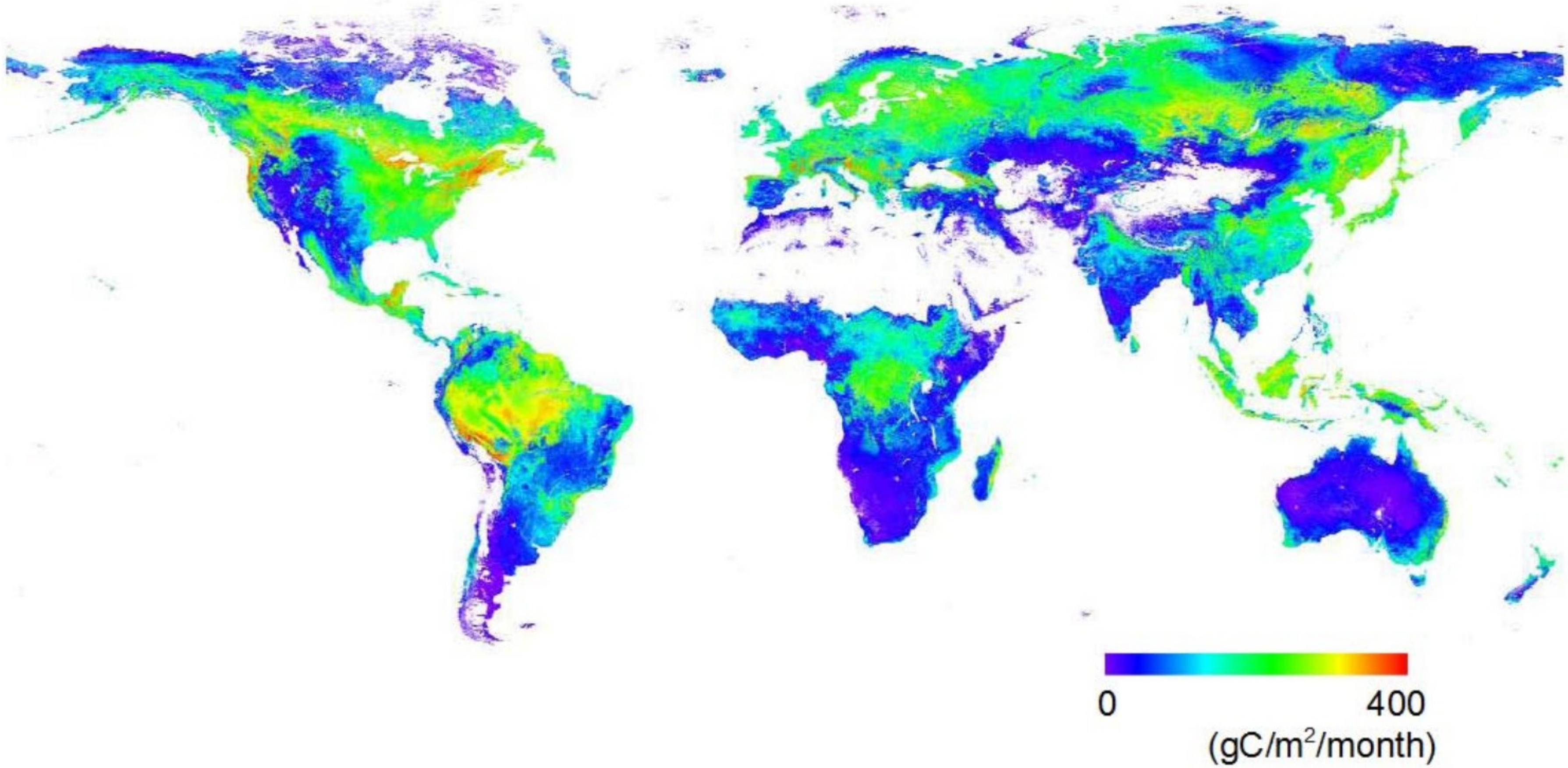


Upcoming issues

- Further improvement of the LAI/FAPAR algorithm
- Definition of LAI
  - True LAI, understory LAI
  - Consideration of understory LAI
    - What's the LAI of moss?
  - Effective LAI (LAI_e)
    - If this is the case, how to standardize LAI_e
- Validation
  - VARELI, TRY (Kattge et al., 2011), Iio's data (Iio et al., 2013)
  - Intensive field sites (Fuji, Tomakomai, Järvselja Estonia, Fairbanks, USA)

Estimation of carbon flux with 1km grid

Gross Primary Production（GPP）on August 2001



Estimation of carbon flux with 1km grid

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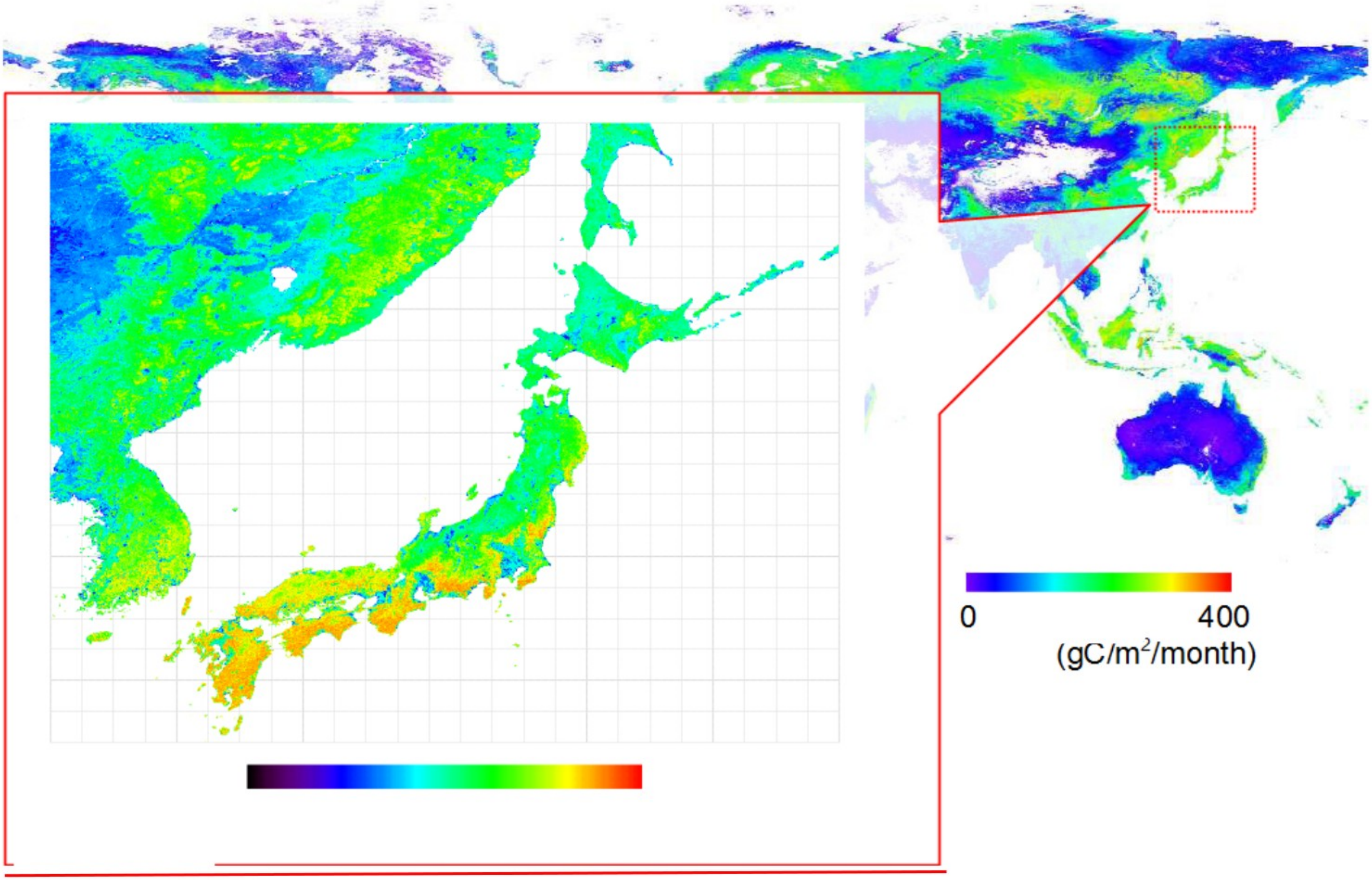
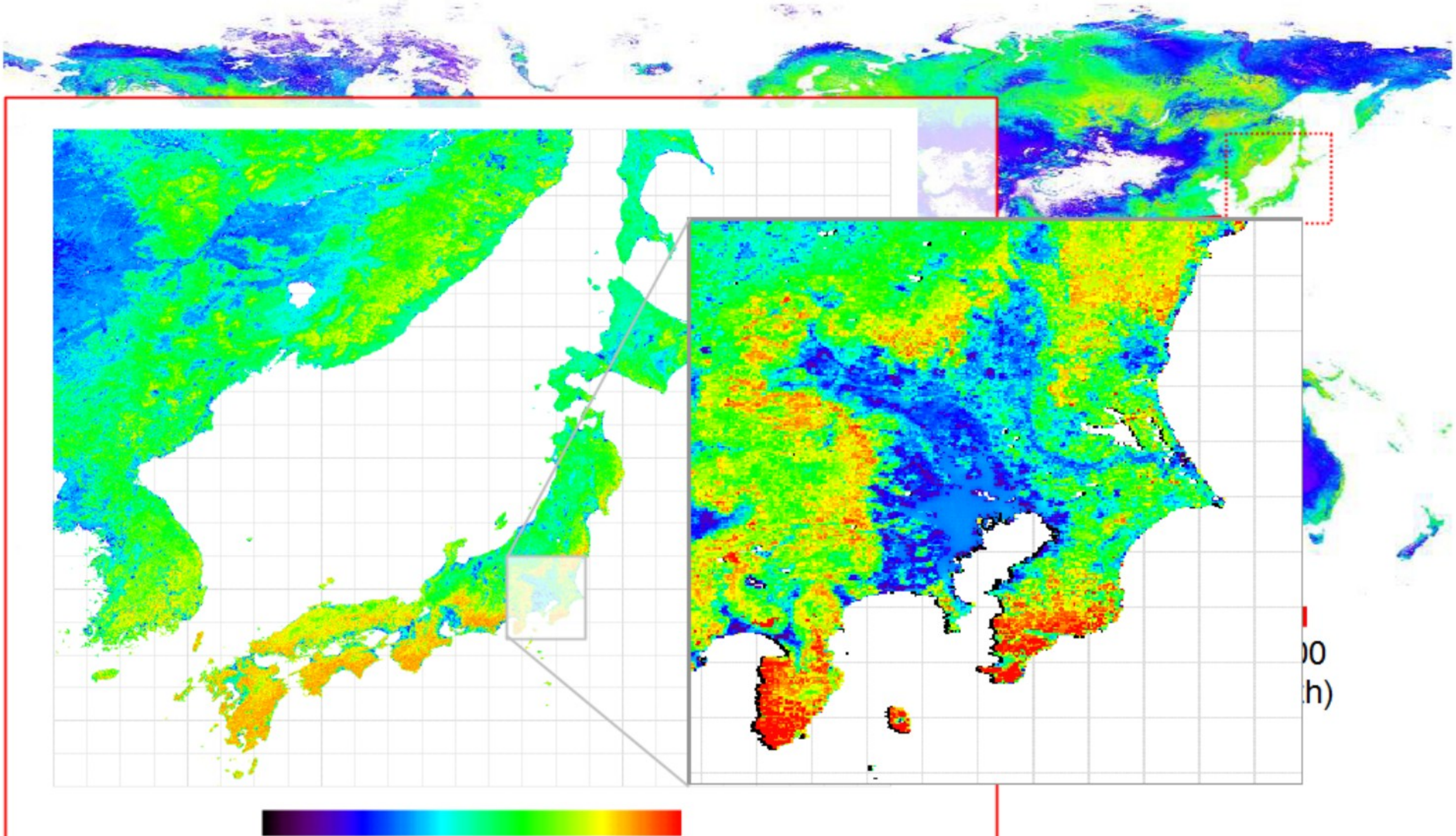


Estimation of carbon flux with 1km grid

Gross Primary Production（GPP）on August 2001



We can expect to estimate carbon fluxes at “**multi-scale**”.

Current condition and future issue for estimating GPP and NPP

Algorithm for computing GPP and NPP
- Source code (Sasai et al., RSE, 2011)
- Input dataset (Sasai et al., EM, 2012)

➡ We already submitted them to JAXA.

If we compute the carbon fluxes using the algorithm…

Work for computation load reduction;

Pre-processing 9 time-variable model inputs

→ Data volume: 9×3.7GB×120 month（10 years）＝4TB（+1TB for other inputs)

Step1：Extracting land area from all inputs

Step2：Equally-partitioning inputs to fit capacity of memory and multi-thread processing

Computational time

If computed with "single thread", it takes **28 years** to estimate 1km-grid and global.

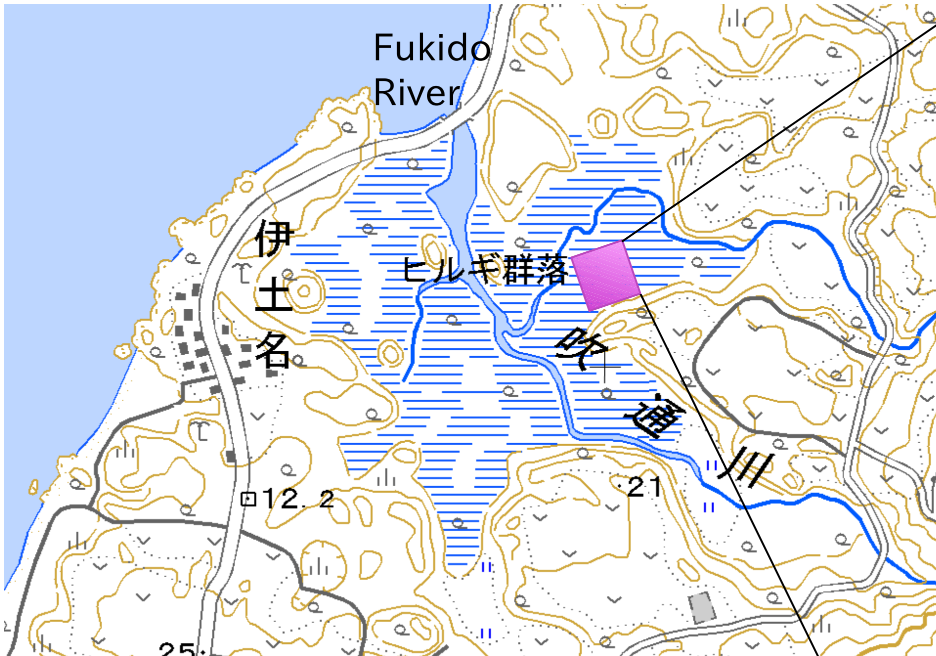
One-time renting the NIES supercomputer（128 node×8 core＝1024 threads）…

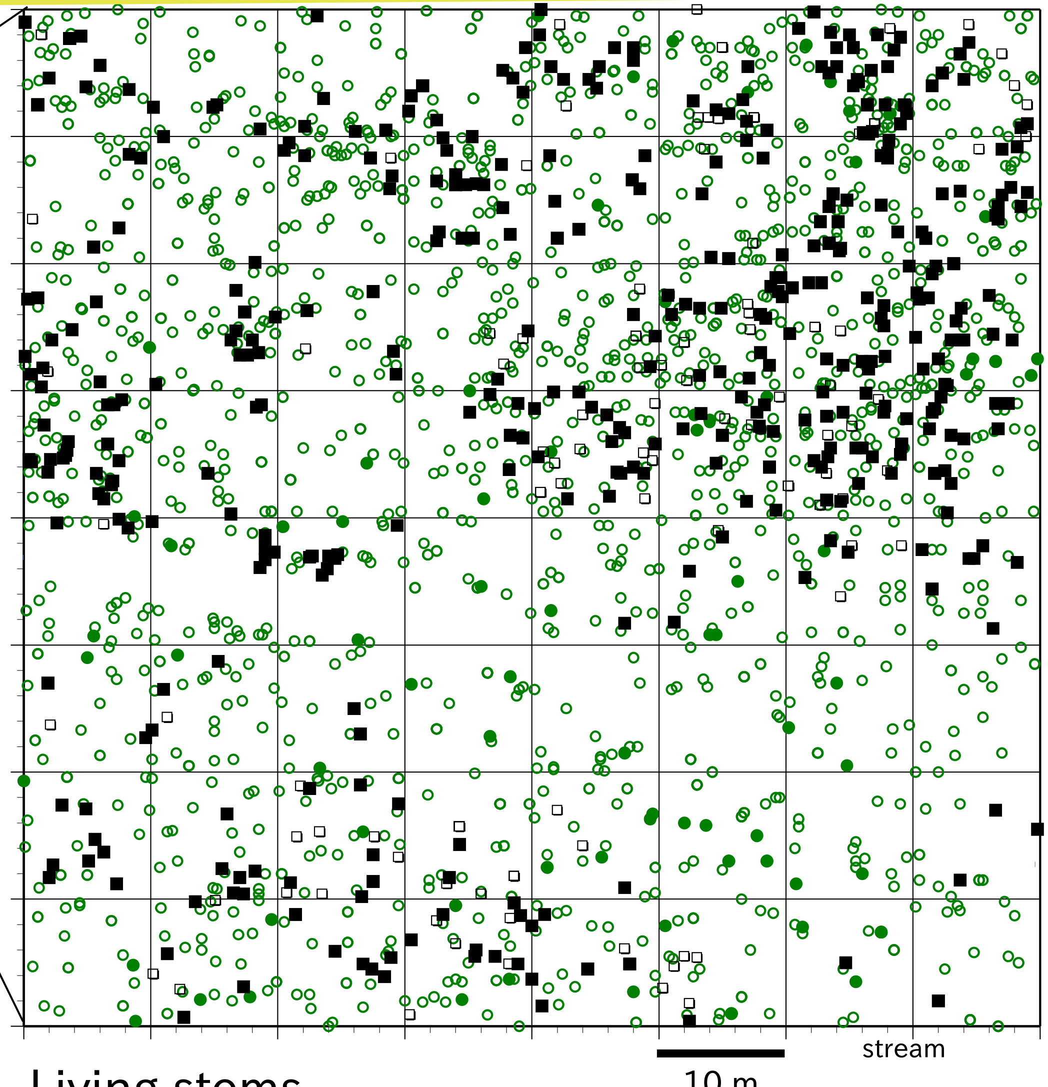
- Ideal computational time (continuous full-power operation) : 10 days
- Realistic time (including loads from interrupt processing like real-time backup)： **1 month**

Higher resolution products always require more enhanced computational resource!

Mitsuru HIROTA 廣田 充

Forest structure and carbon pool of a Mangrove forest in Ishigaki Island





Living stems
○ *Bruguiera*
□ *Rhizophora*
Dead stems
● *Bruguiera*
■ *Rhizophora*

Tree biomass
(dry weight base)
Aboveground: 231 t ha^{-1}
Belowground: 74 t ha^{-1}

Extensive field campaign to feel cool-temperate old-growth forests for researchers and students

Time & place

June 5 – 8, 2013 (4 days)

Kayanodaira (old-growth beech forest) and Otanomoustaira (sub-alpine coniferous forest) in Shigakogen, Nagano

Participants *more than 30!*

Researchers and their students (from undergraduate to post-doc) who have different background, such as plant ecology, forestry, soil science, microbiology, remote sensing, isotope geochemistry…

Objectives

To feel the old-growth forests

To expand exchange of people and field of study among participants for solving up-scaling issues

To establish new monitoring site (200m x 200m) in native beech forest… *UNDER CONSTRUCTION*

Papers in FY2013

- Hadano, M., Nasahara, K.N., Motohka, T., Noda, H., Murakami, K., Hosaka, M. (2013) High-resolution prediction of leaf onset date in Japan in the 21st century under the IPCC A1B scenario. Ecology and Evolution.

- Nagai S., Nakai T., Saitoh T.M., Busey R.C., Kobayashi H., Suzuki R., Muraoka H., Kim Y. (2013) Seasonal changes in camera-based indices from an open canopy black spruce forest in Alaska, and comparison with indices from a closed canopy evergreen coniferous forest in Japan. Polar Science, 7, 125-135.

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Contributions for GCOM-C project in FY2013

Algorithm & model development

- GPP, NPP, NEP, ET ... BEAMS model (+paddy). 1-km resolution global implementation.
- GPP ... Nara WU model. Calibration & validation with ground data.
- LAI ... FLiES model & BRDF LUT approach with JAXA (Dr. Ono) and Chiba U (Dr Honda).
- leaf optics ... New measurement technique published. Data paper published.

Ground study

- GPP, ET ... supersites (JapanFlux), continuously measured. AsiaFlux Database.

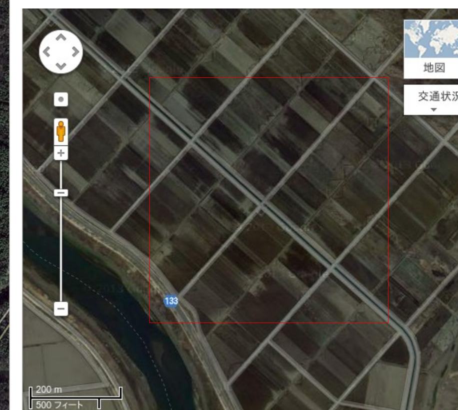
- LAI ... 13 sites + α. JaLTER database & JAXA database
- biomass ... 10 sites + α. JaLTER database & JAXA database
- PAR protocol ... "Li-COR in dome" and Apogee.
- phenology ... 28 sites (PEN). Takayama 20th anniv. workshop.
- 3D laser survey ... one new site (Hokkaido U Tomakomai flux site) … with ALOS G.
- Helicopter observation ... Tomakomai & Uryu by Chiba U group.
- Landcover reference data (ground truth) ... SACLAJ database.

Other

- Annual workshop skipped (sorry!)
- Field site tours for other PI groups (Fuji-Hokuroku, Fuji-Yoshida) in August.
- Biomass RS seminar: Tomakomai (Hokkaido U. & Chiba U.)
- Biomass ecologists: seminar in Nagano & field work in Ishigaki-jima.

Plan in 2014: 500 m-scale validation

Homogeneous topography & landcover in 500 m-scale (SGLI footprint!)



Tomakomai
苫小牧
Deciduous
broad leaf forest

Uryu
雨龍
Evergreen
needle leaf forest

Fuji-Hokuroku
富士北麓
Deciduous
needle leaf forest

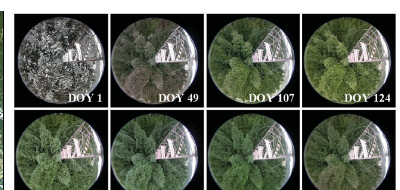
Mase
真瀬水田
Rice paddy

biometrics

flux

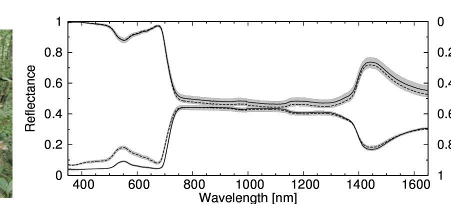
UAV

ALOS



PEN

LAI



spectrum

etc...