# Spaceborne canopy LiDAR measurements for the constraints of terrestrial carbon budget

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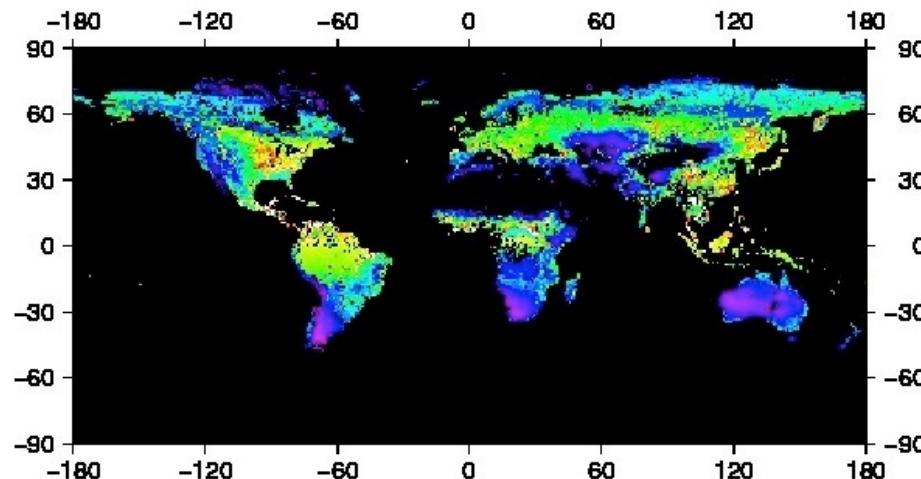
Acknowledgement

The recommendation on the improvement of terrestrial biosphere models
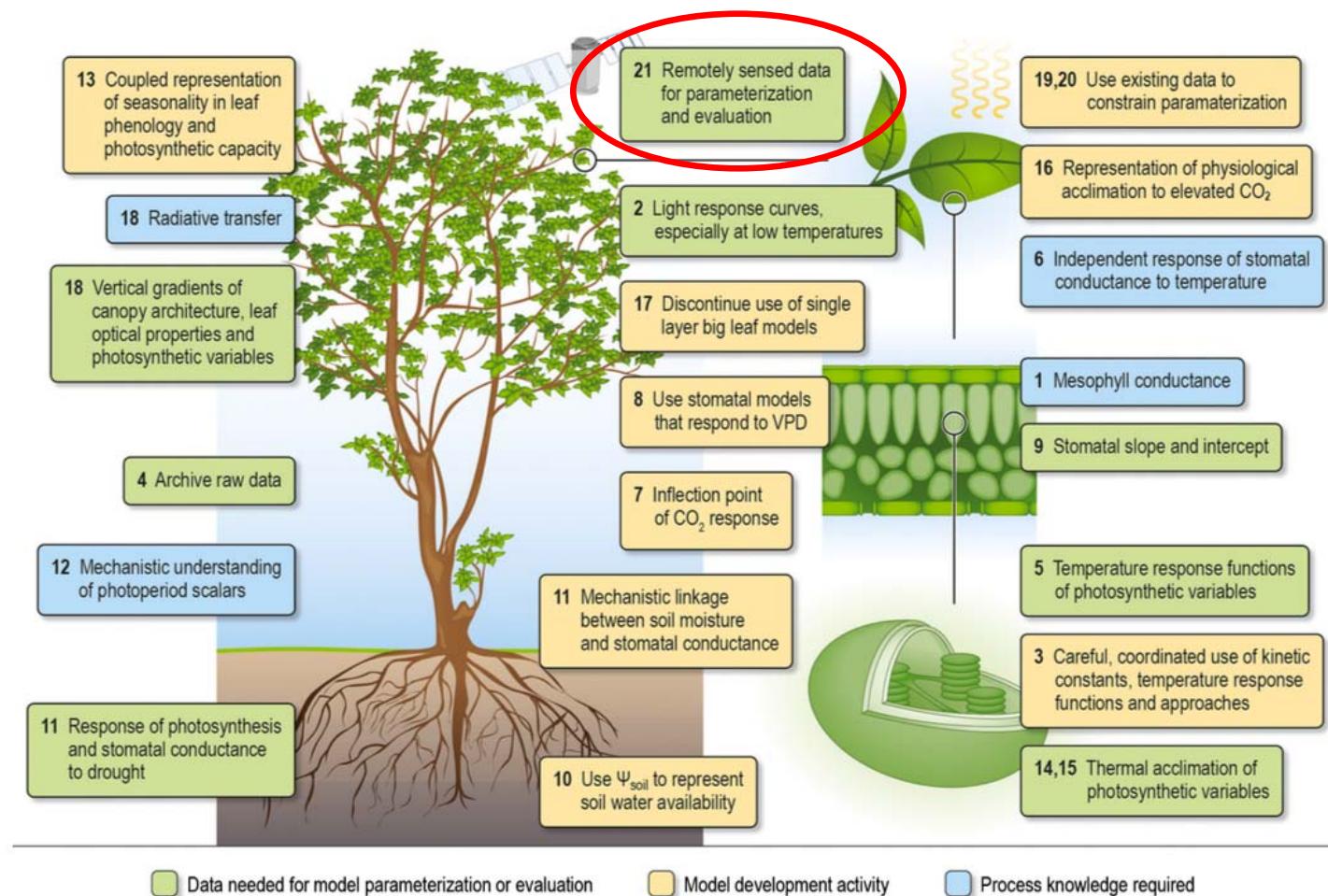
A roadmap for improving the representation of photosynthesis in Earth system models

Alistair Rogers ✉, Belinda E. Medlyn, Jeffrey S. Dukes, Gordon Bonan, Susanne von Caemmerer, Michael C. Dietze, Jens Kattge, Andrew D. B. Leakey, Lina M. Mercado, Ülo Niinemets, I. Colin Pre[...] Danielle A. Way, Sönke Zaehle

Rogers et al., New Phytologist ,2017

13 Coupled representation of seasonality in leaf phenology and photosynthetic capacity

18 Vertical gradients of canopy architecture, leaf optical properties and photosynthetic variables

4 Archive raw data

12 Mechanistic understanding of photoperiod scalars

11 Response and stoma to drought
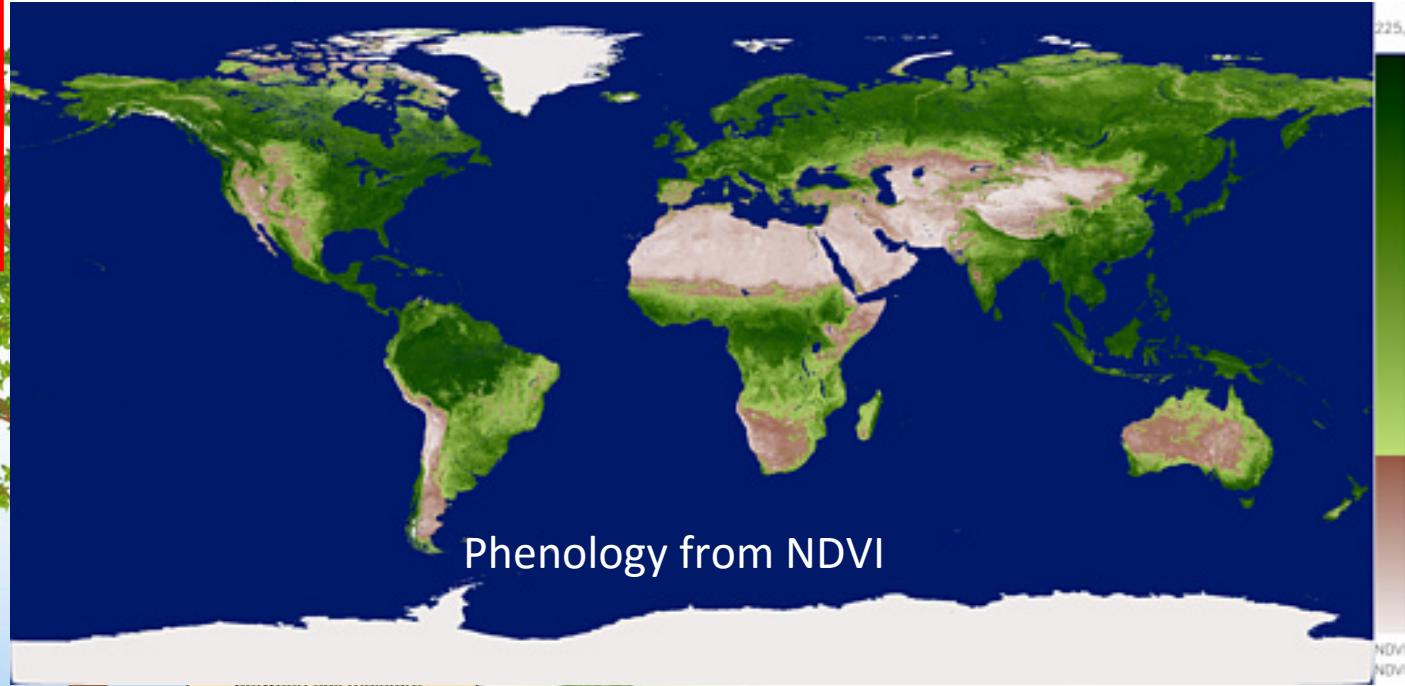
Fig. 6 Summary where fundamen development is evaluate alterna

Phenology from NDVI

Low

High
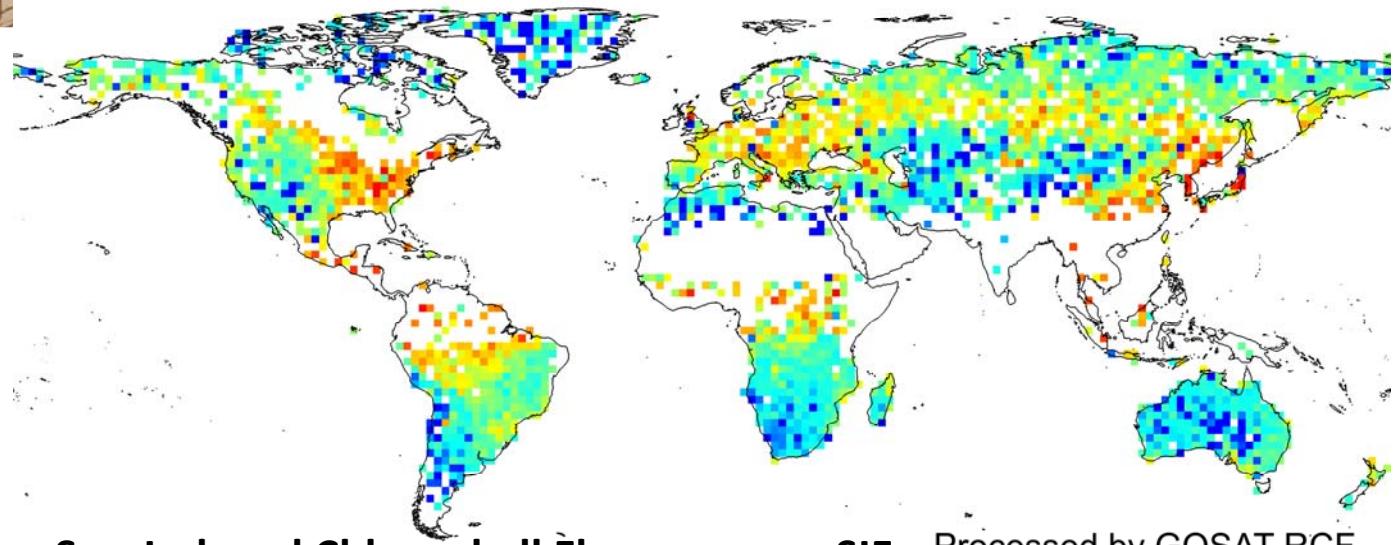
Sun-Induced Chlorophyll Fluorescence, SIF
(NIES-GOSAT team Drs. Oshio, Yoshida, Noda)

Processed by GOSAT RCF

13 Coupled representation of seasonality in leaf phenology and photosynthetic capacity

18 Radiative transfer

18 Vertical gradients of canopy architecture, leaf optical properties and photosynthetic variables

4 Archive raw data

12 Mechanistic understanding of photoperiod scalars

11 Response of photosynthesis and stomatal conductance to drought

Data needed for model parameter

Fig. 6 Summary of the main areas of scientific act where fundamental research is required to advand development is required to improve process repre evaluate alternative approaches. The numbers in

凡例

Global LAI
- 0
- 1
- 2
- 3
- 4
- 5
- Soil & snow
- Ocean

Global leaf area index (MODIS, GCOM-C)

Legend

Canopy height (m)
- 0
- 10
- 20
- 30
- 40
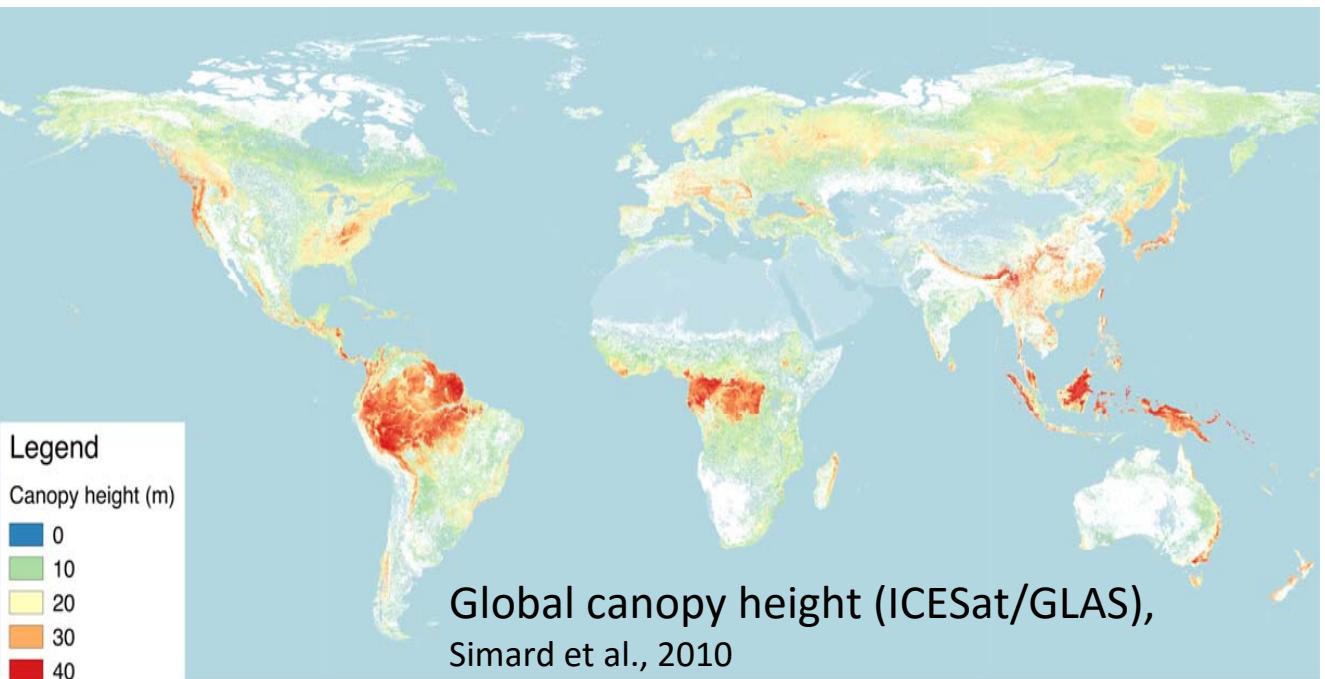
Global canopy height (ICESat/GLAS),
Simard et al., 2010
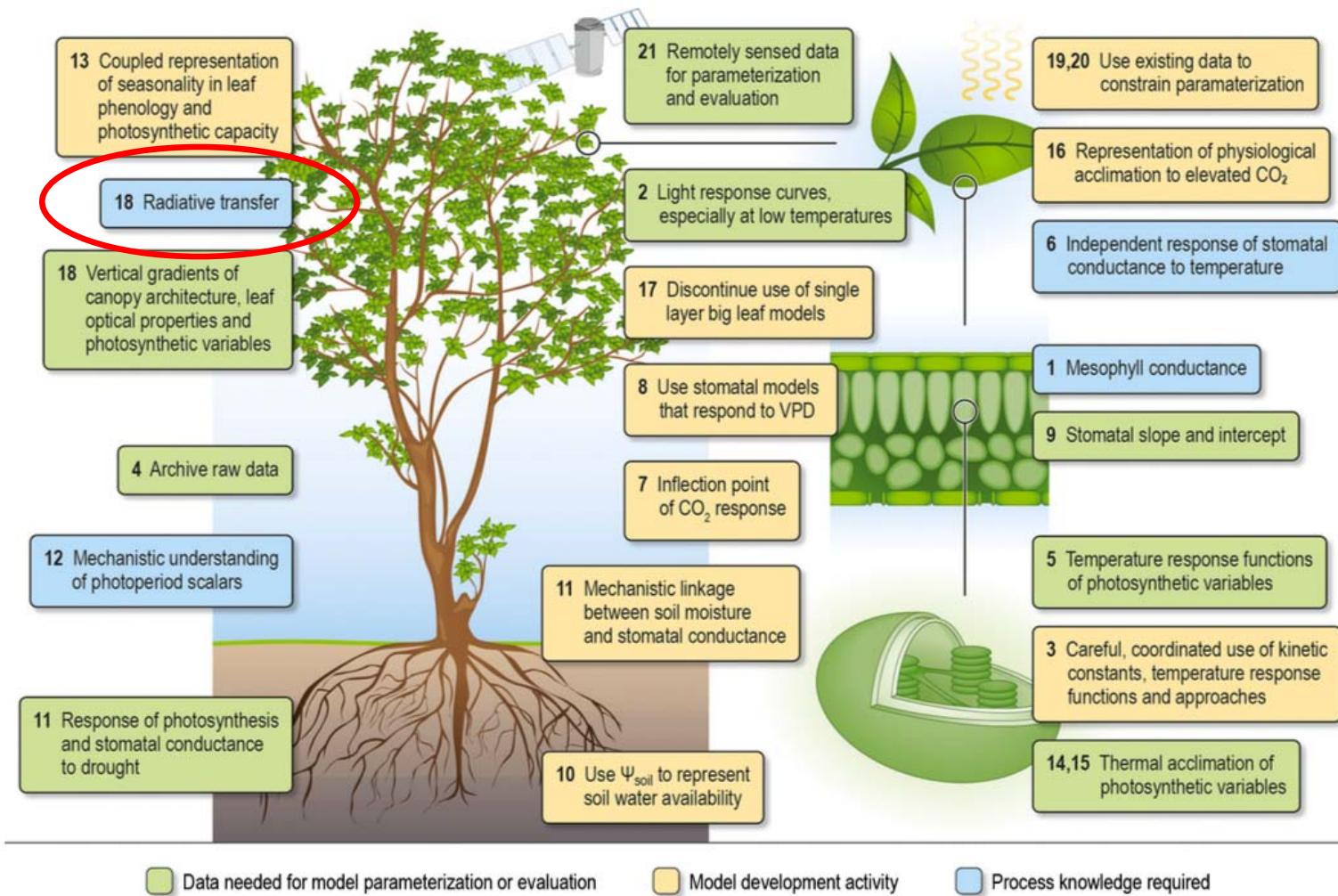
Fig. 6 Summary of the main areas of scientific activity required to advance representation of photosynthesis in Earth system models. Blue boxes show areas where fundamental research is required to advance understanding before incorporation into models. Yellow boxes show areas where model refinement or development is required to improve process representation. Green boxes highlight areas where data are needed to parameterize models or are required to evaluate alternative approaches. The numbers in the boxes are keyed to our recommendations in the text.

Rogers et al., New Phytologist ,2017

Remote sensing data and terrestrial biosphere models

- Remote sensing observations can be used for terrestrial biosphere model parameterizations and the interactions of plant and environment over the continental scale

- Improvement of radiative transfer contributes to improve the representation of the light environment and computation of carbon fluxes

- LiDAR observations, such as MOLI and GEDI, can be used to constrain forest structures

Global radiative transfer scheme with LiDAR observations

Canopy height
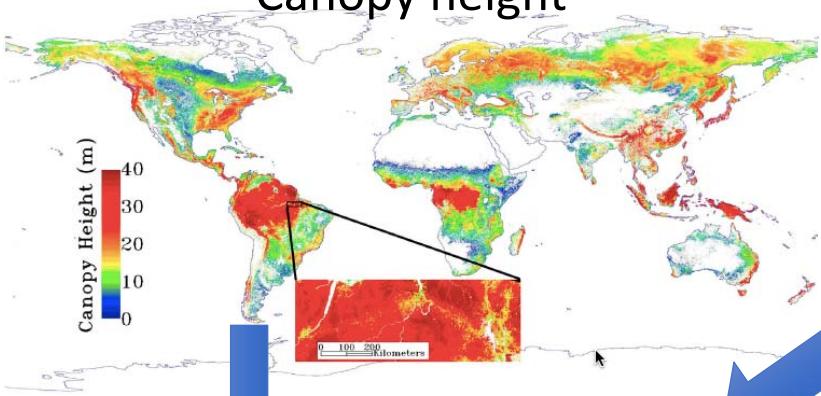
Tree density (Crowther et al., Nature 2015)

Simplified forest structure model
(Yang et al., submitted)

Tree Density

Canopy height
(Max and Min)

**Neyman /Possion
distribution**

Weibull distribution

# of tree in
each quadrat

Canopy Height

Crown Radius/Length

DBH

X-Y Coordinate
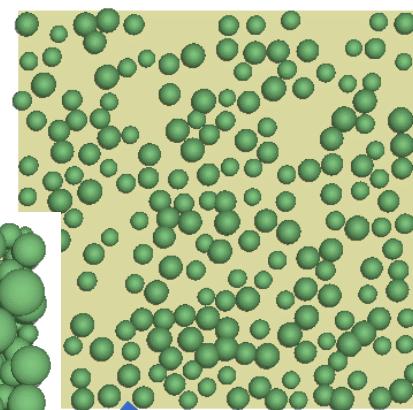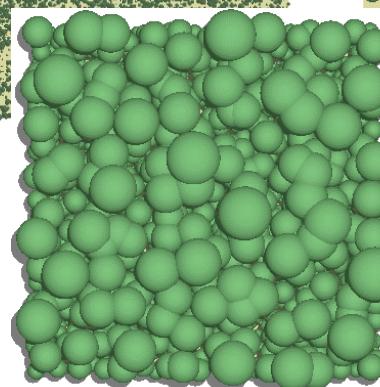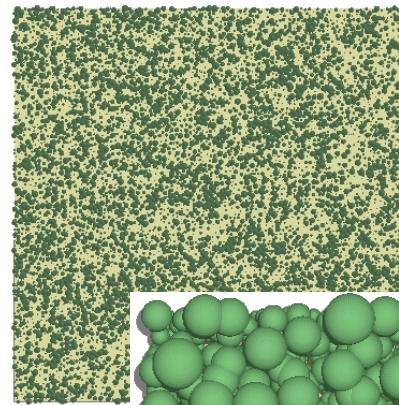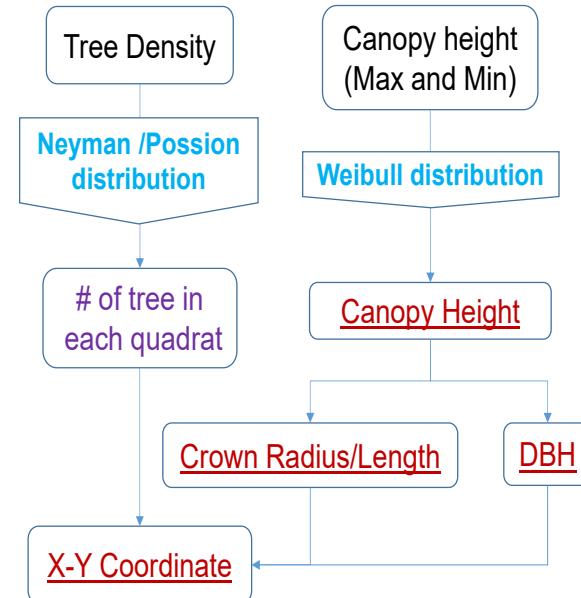
Global RT run

Validation and calibration of the forest landscape by airborne LiDAR

Aerial photograph At FKH AsiaFlux site

DCHM

Crown maps

comparison
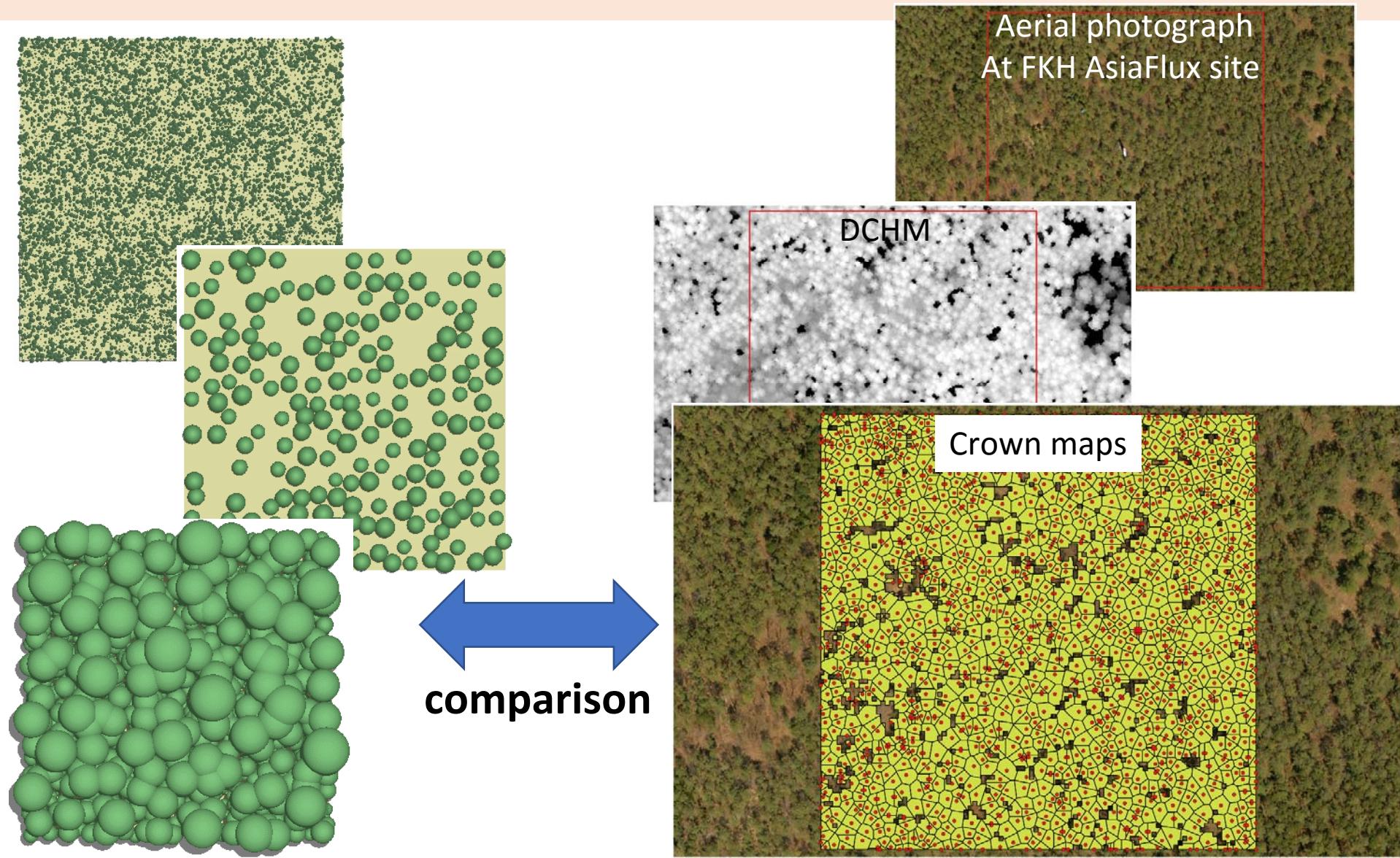
Global APAR simulated by 3D RT

August, 2009

Incident PAR

$(\mu$ mol m^{-2}s$^{-1})$
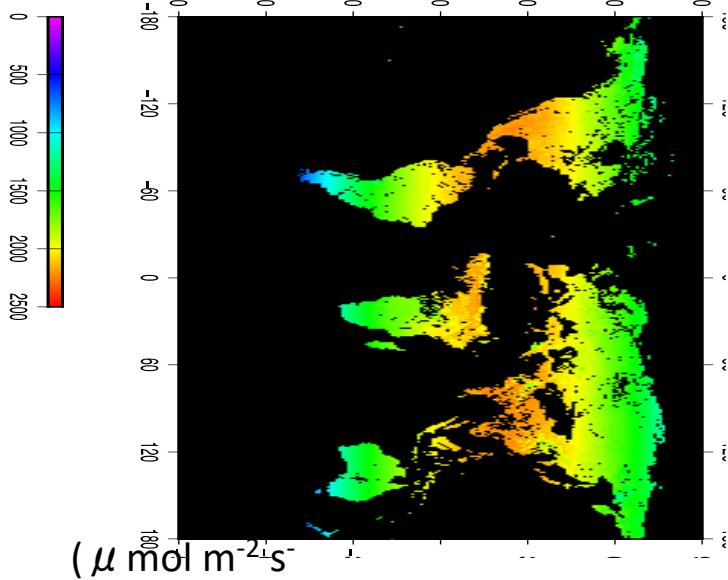
fAPAR
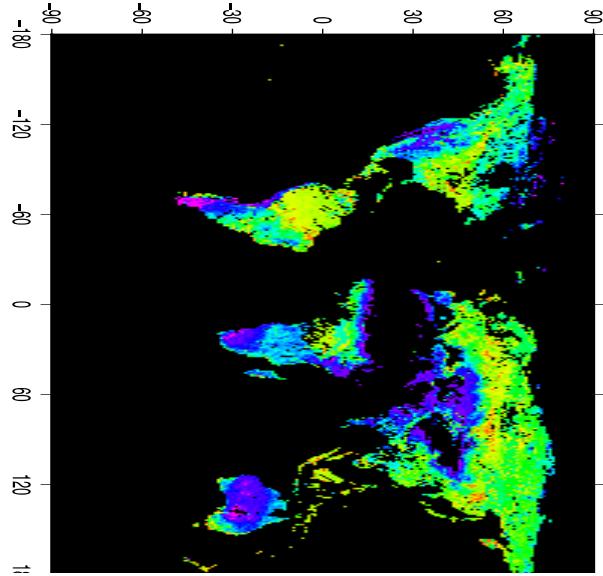
Input satellite data:
- Aerosol AOT
- LAI
- LiDAR canopy height
- Tree density

Currently, the forest structures are fixed for each biome. In the future, when LiDAR data are available, we can set the appropriate representation of forest structure in each grid and run the model

How much forest structure affects the canopy photosynthesis?

Sun-induced Chlorophyll Fluorescence
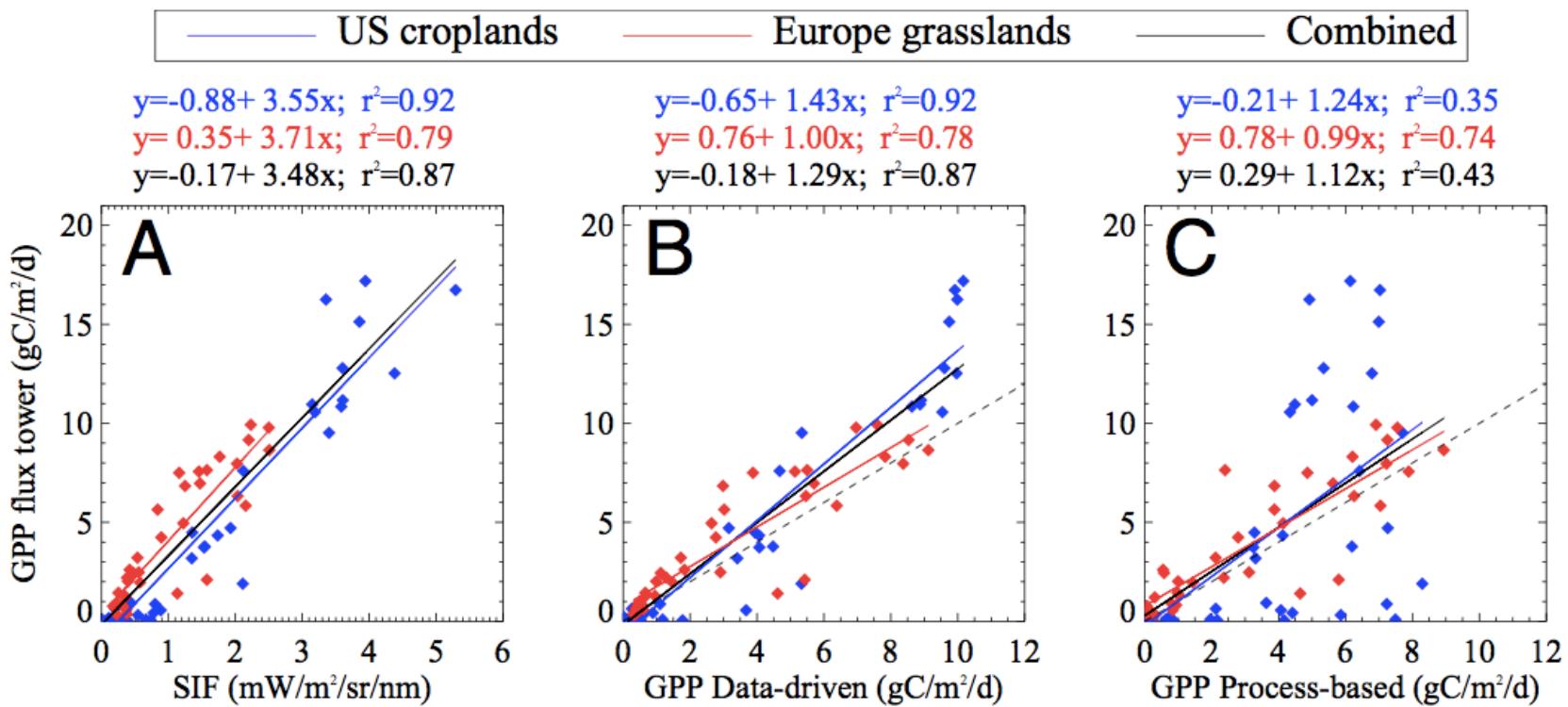
Guanter et al., PNAS 2014

$$GPP \approx SIF(\lambda) \times \frac{LUE_P}{LUE_F(\lambda)},$$

Data application schemes

Data

Global leaf area index

Global canopy height

Tree density

RT

Diffuse PAR
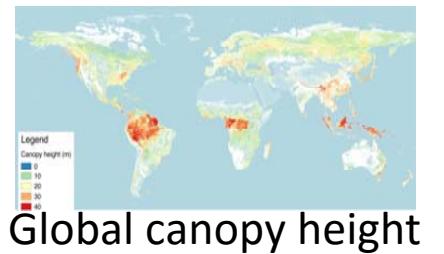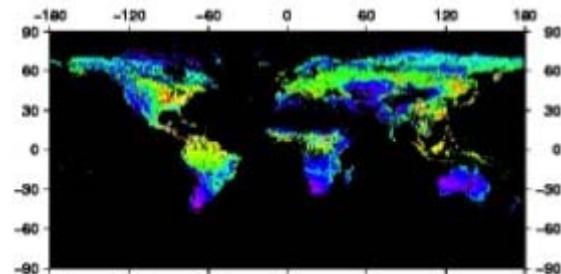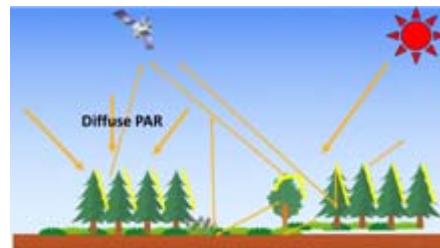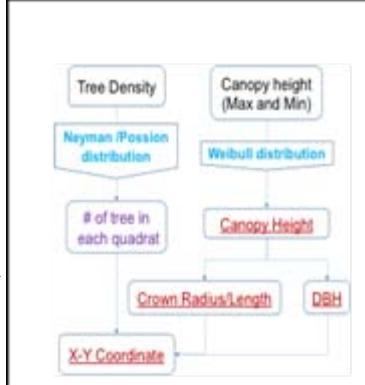
SIF (RT simulation)
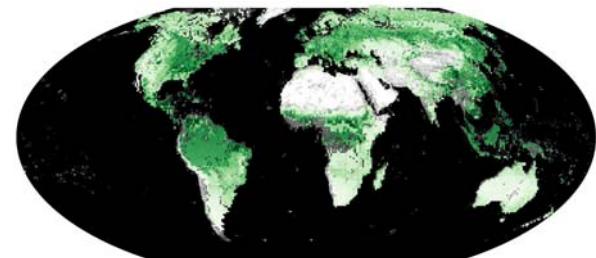
Validation

Downscaling to leaf leaf level properties
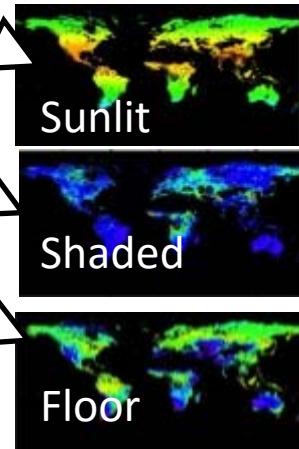
Sunlit
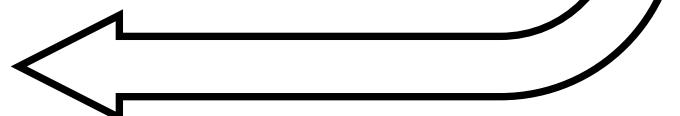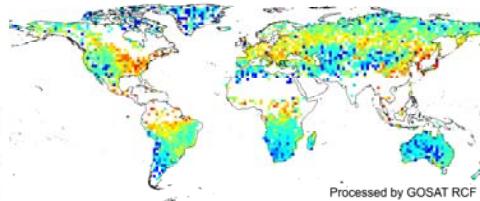
Shaded

Floor

Satellite-SIF

Processed by GOSAT RCF

Terrestrial biosphere model

3D radiative transfer simulation


Diffuse PAR

3D radiative transfer simulation, FLiES

760nm

Nadir view

760nm

sza=30
sza=60

SIF (arbitrary unit)

View angle
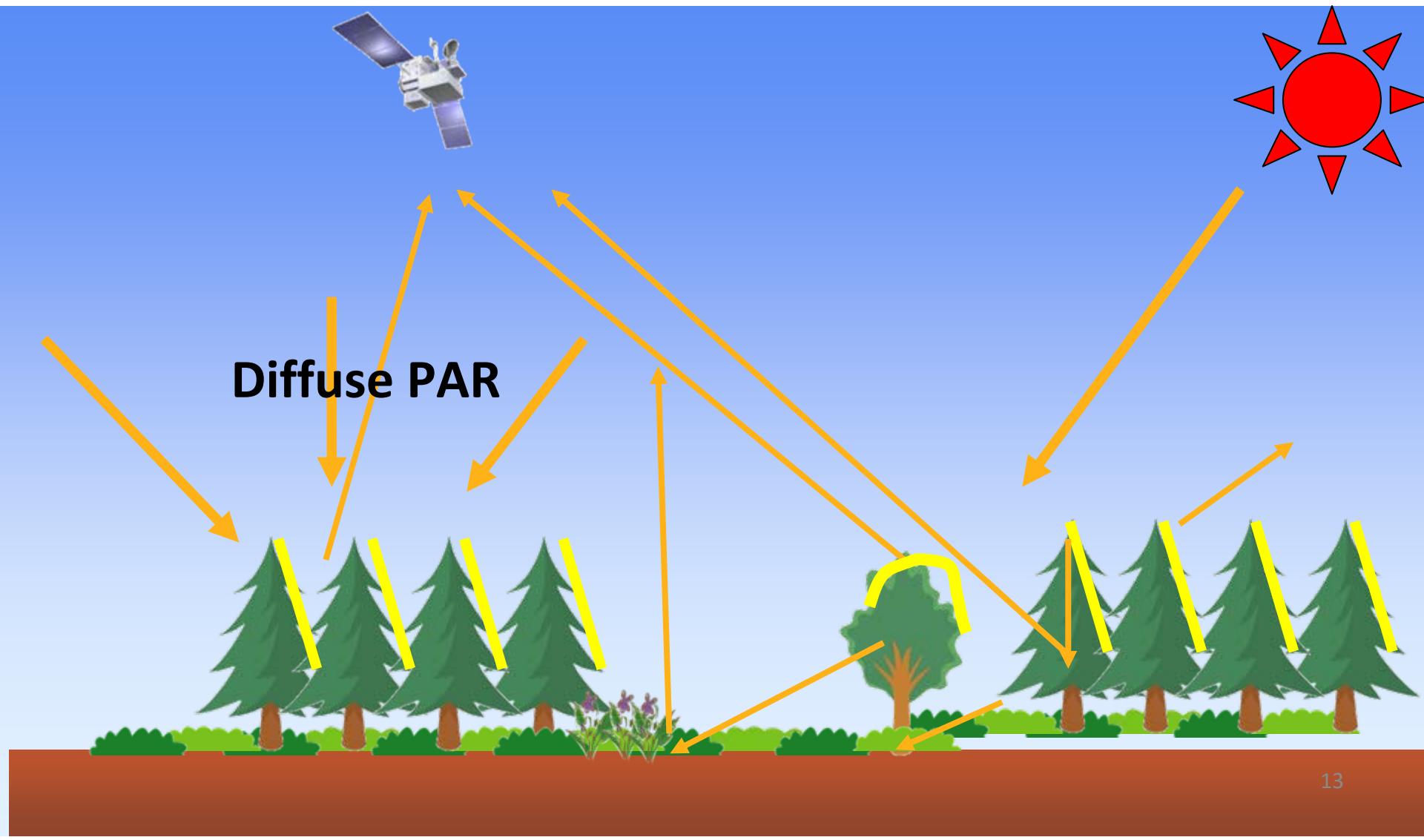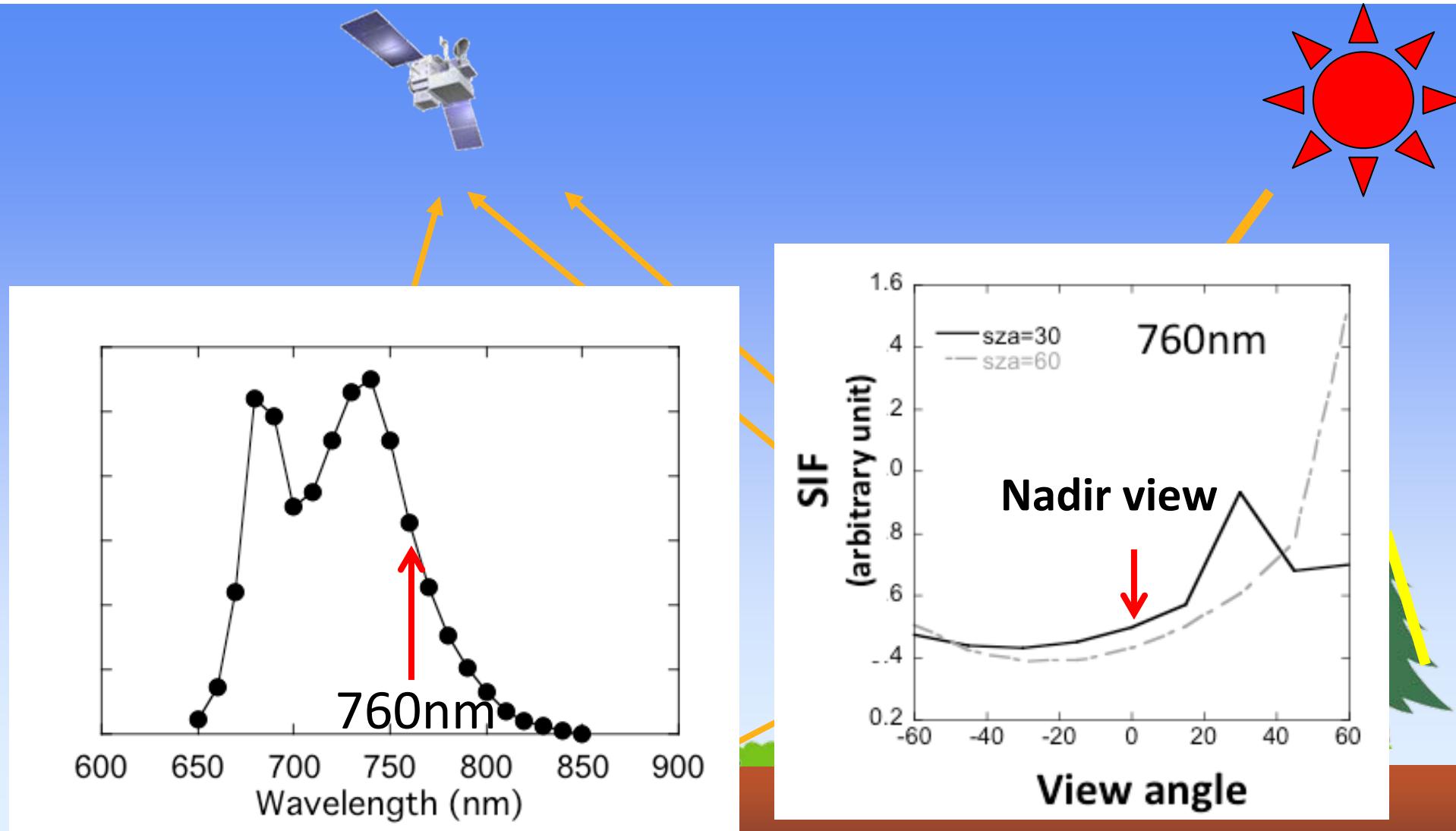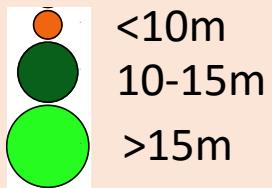
Simulation conditions

Leaf-level fluorescence yield
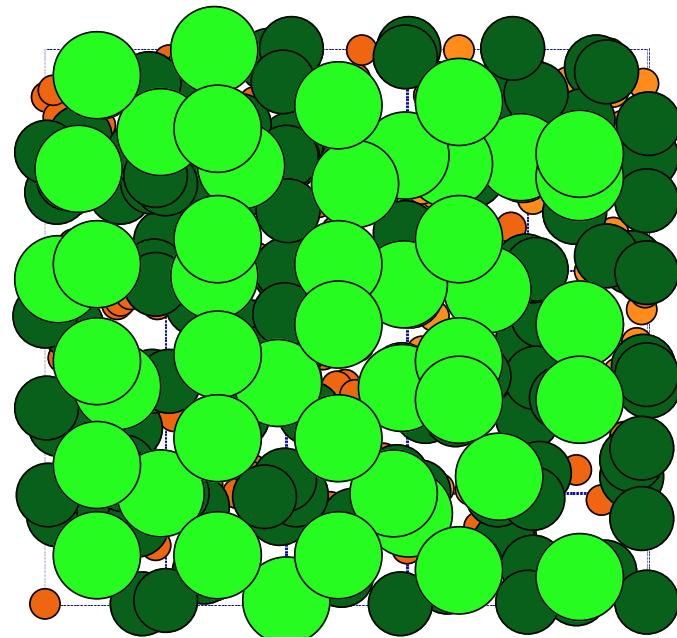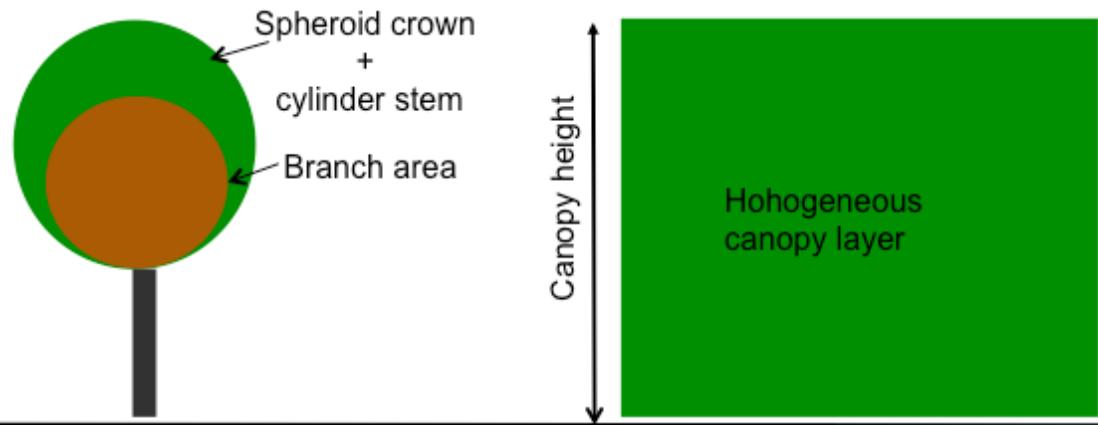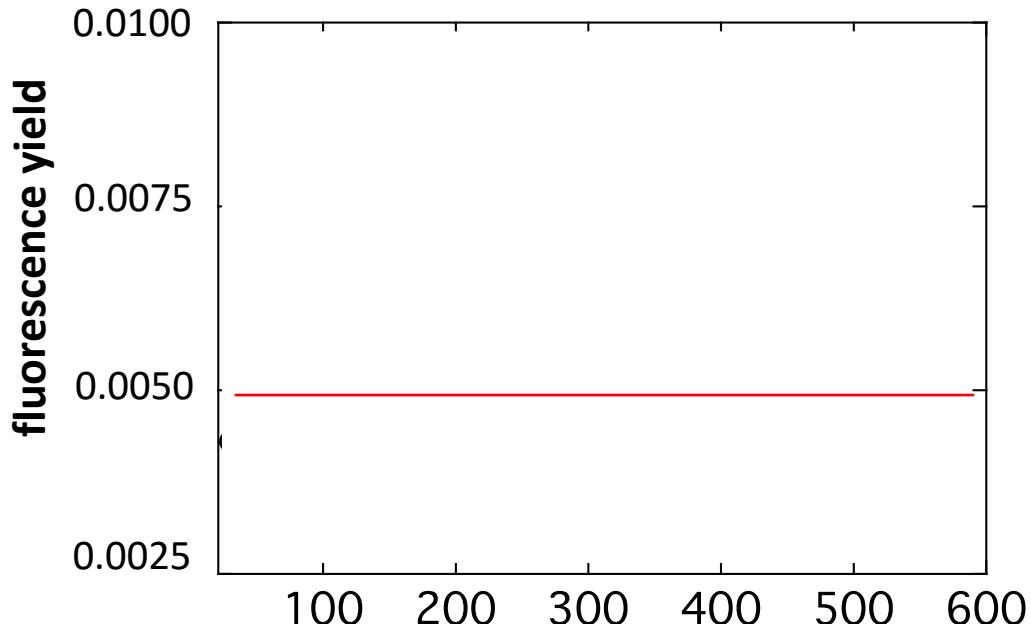
1. 3D no shoot clumping

2. 3D shoot clumping (γ =1.67)

3. 1D spherical leaf angle dist.

4. 1D erectrophle leaf angle dist.

5. 1D planophle leaf angle dist.

All LAI = 3.5

Spheroid crown + cylinder stem

Branch area

Canopy height

Hohogeneous canopy layer
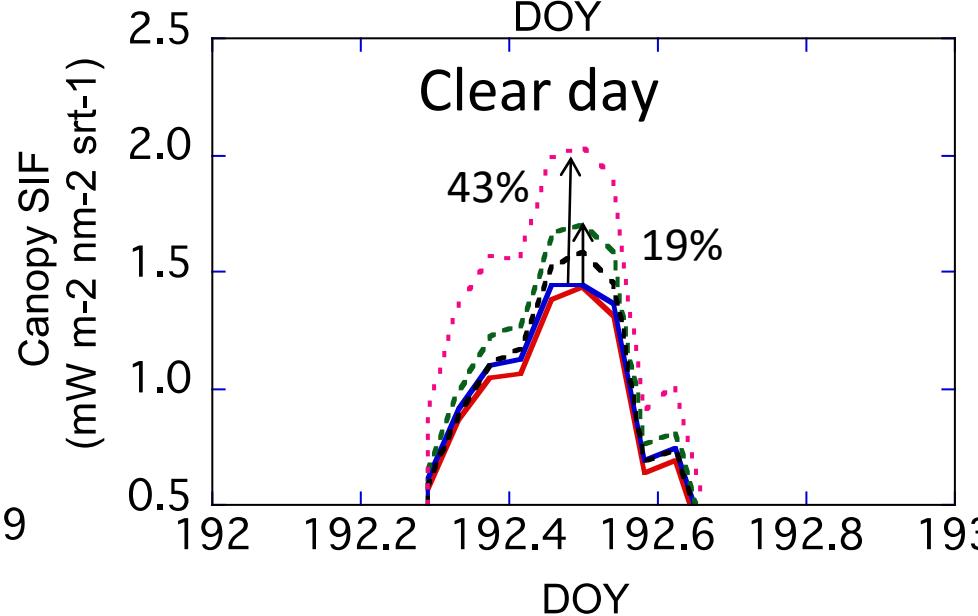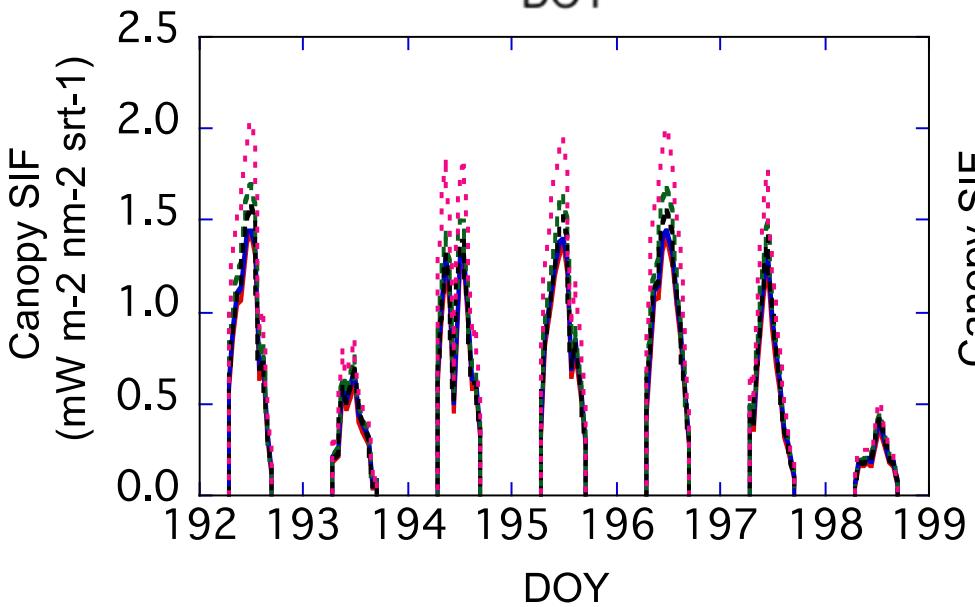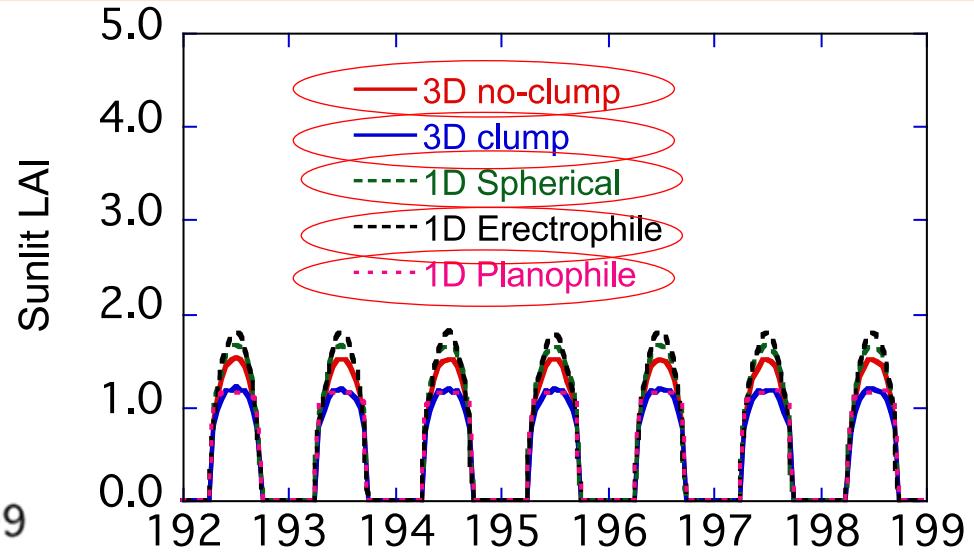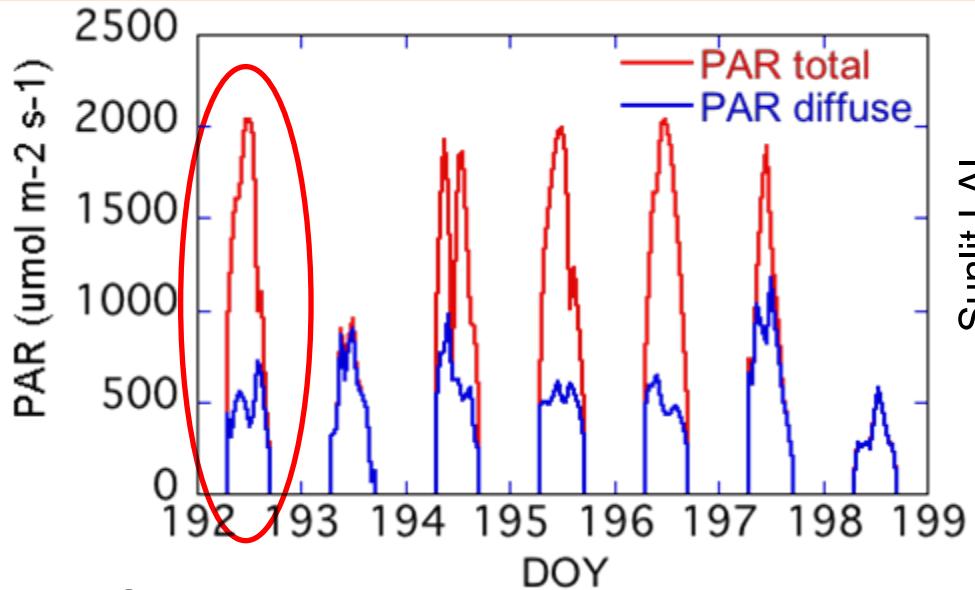
Diurnal SIF

Diurnal SIF
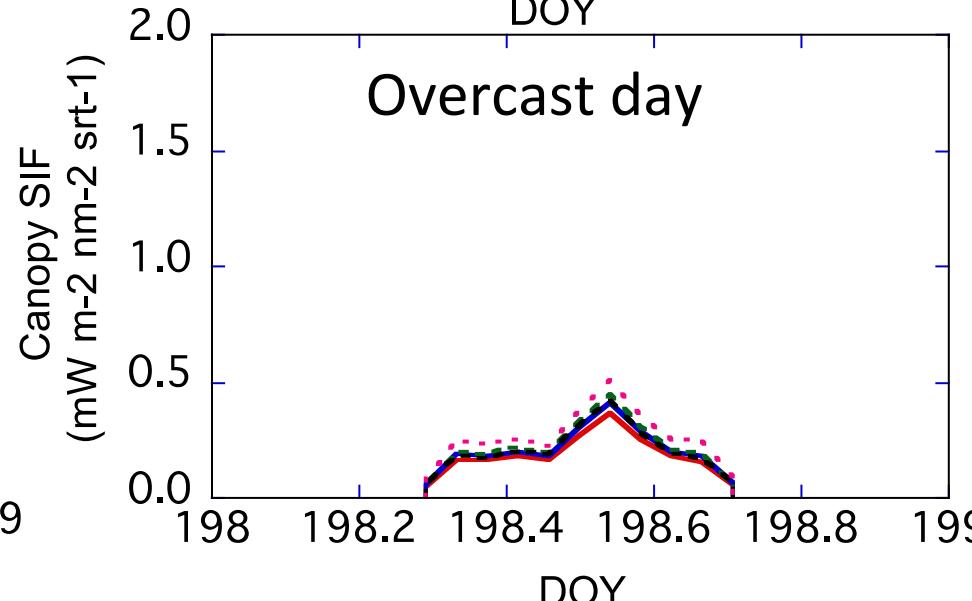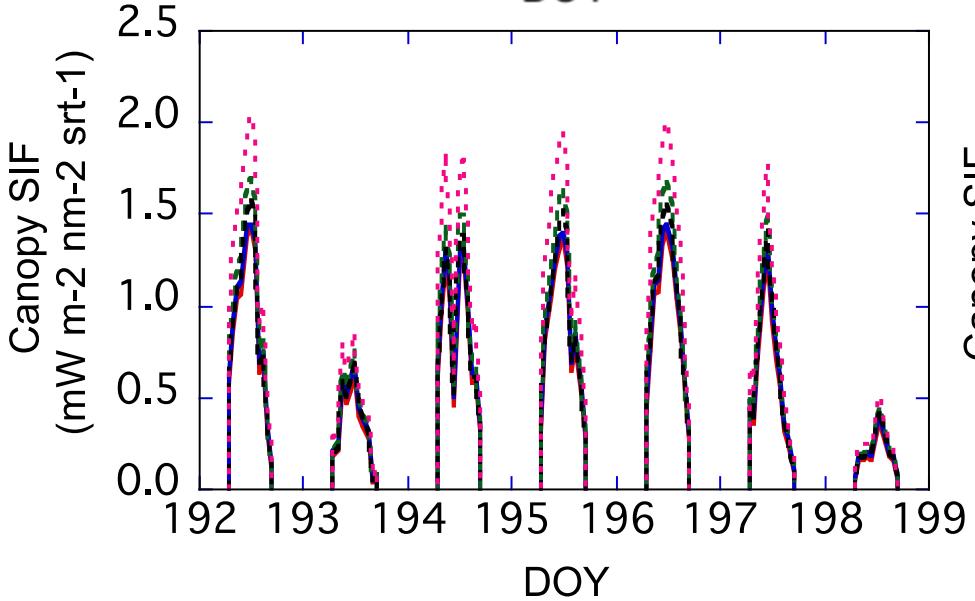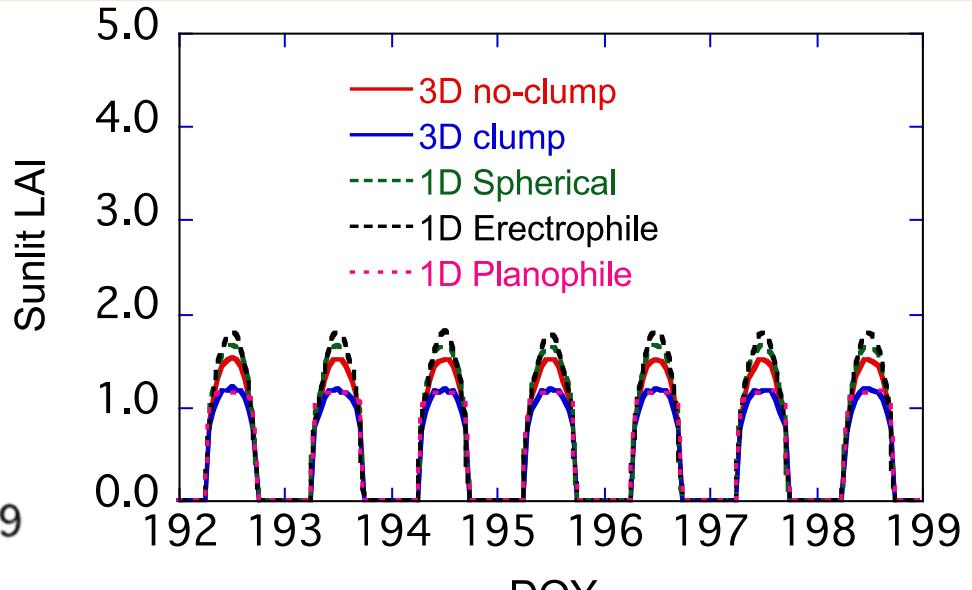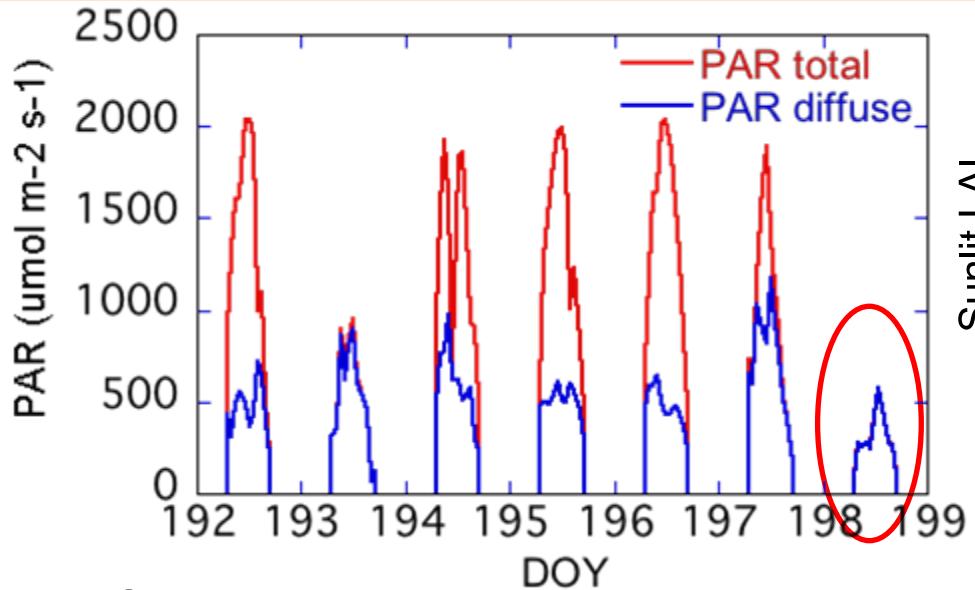
Contribution of sun/shade SIF

Sun
Shade

SIF
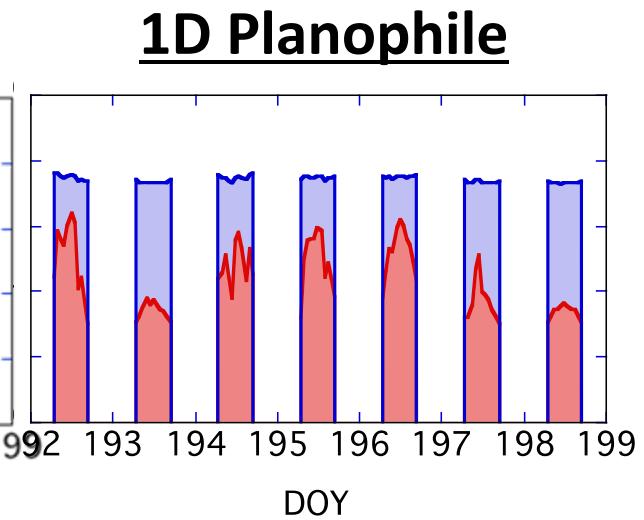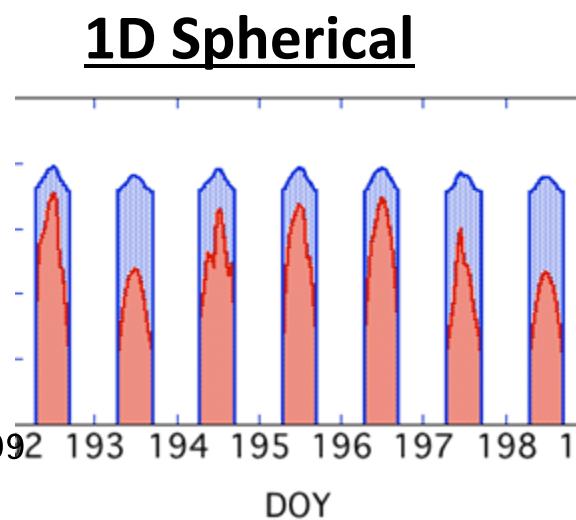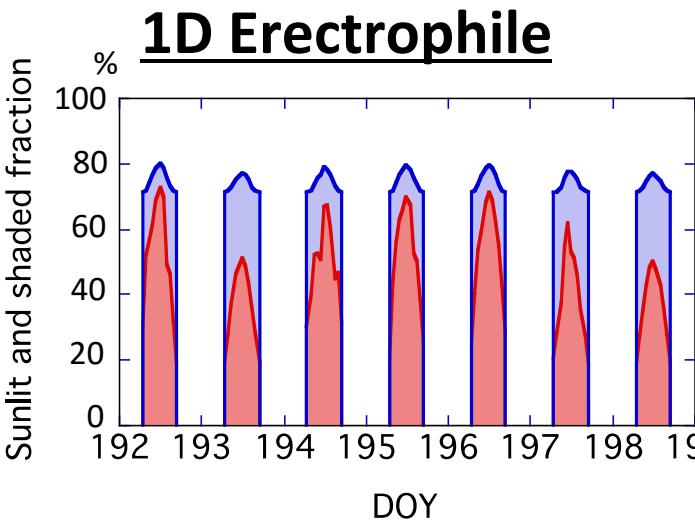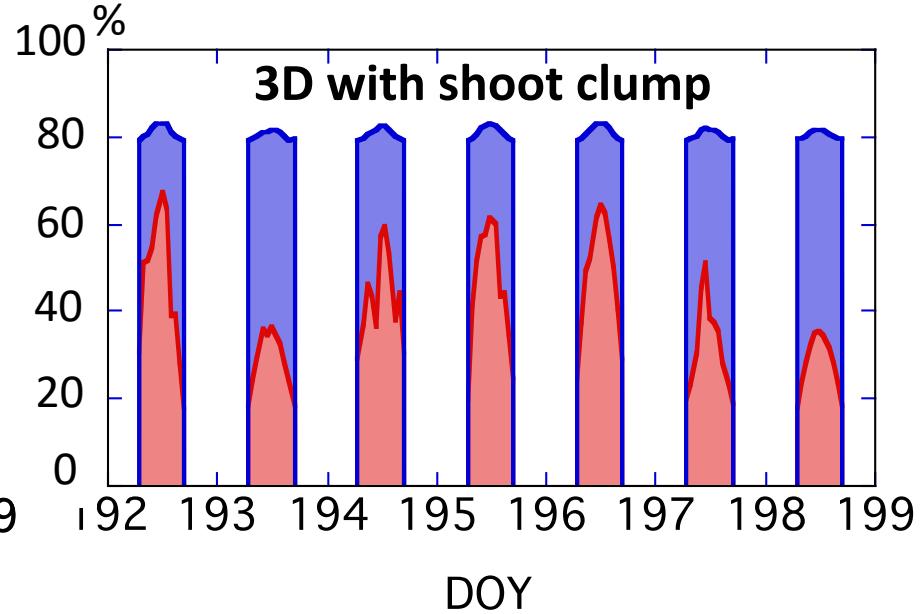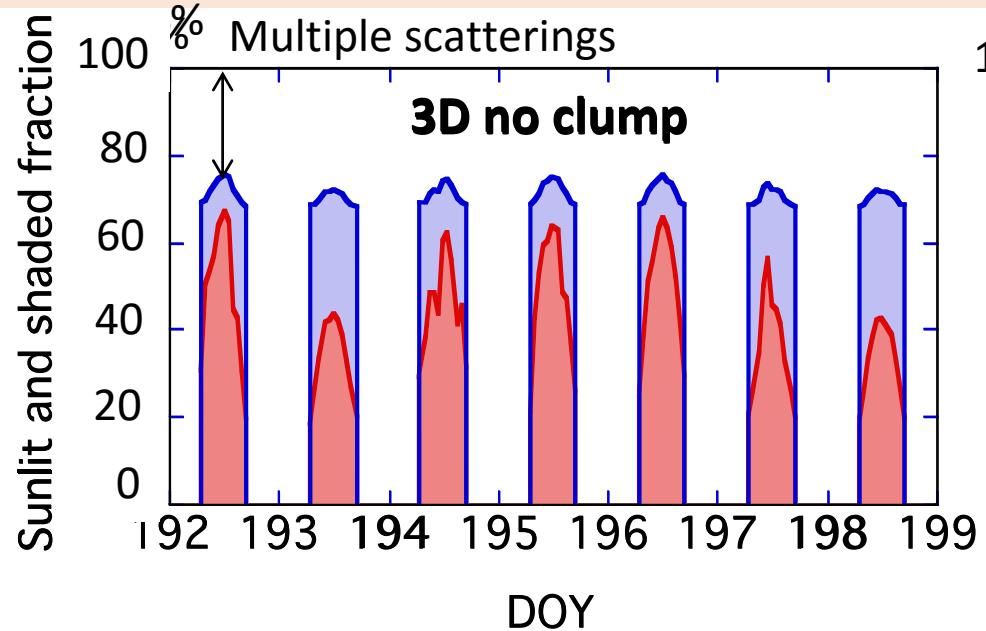
GOSAT-SIF



Low
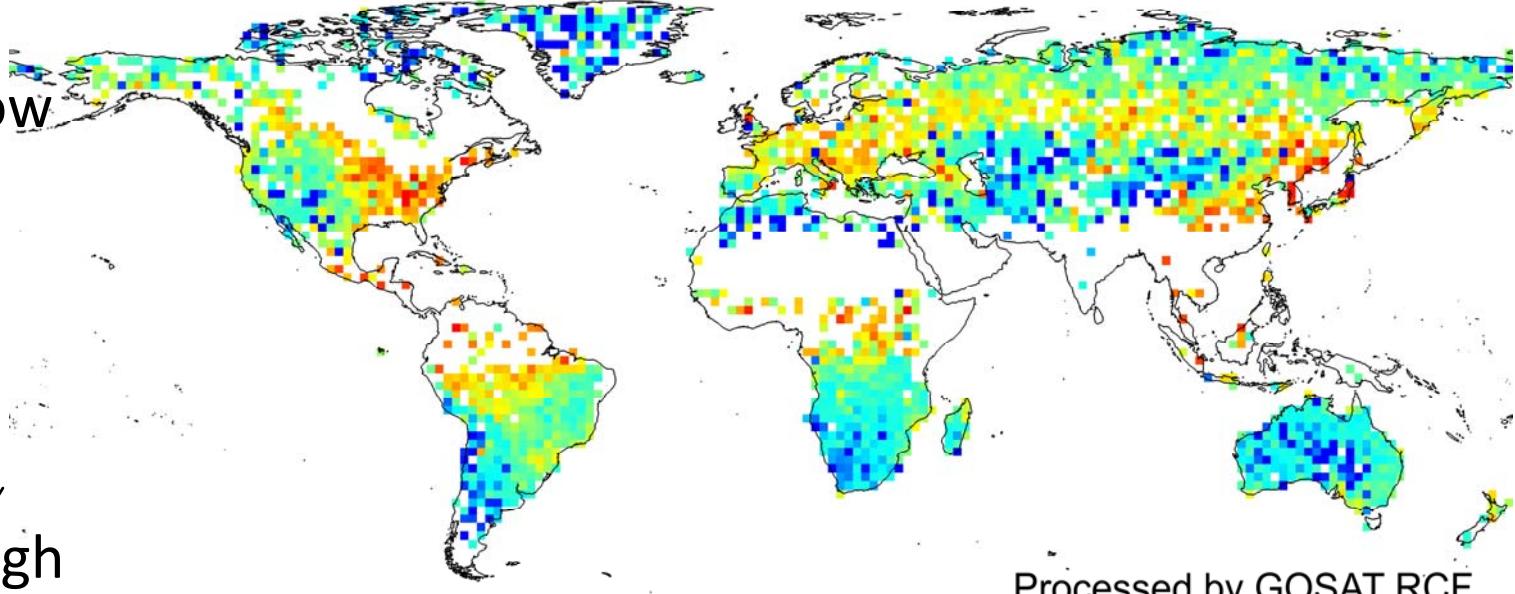
High

Processed by GOSAT RCF

SIF simulated by RT model
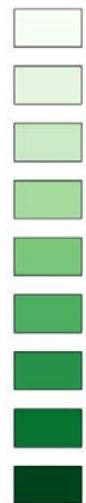
Low

High
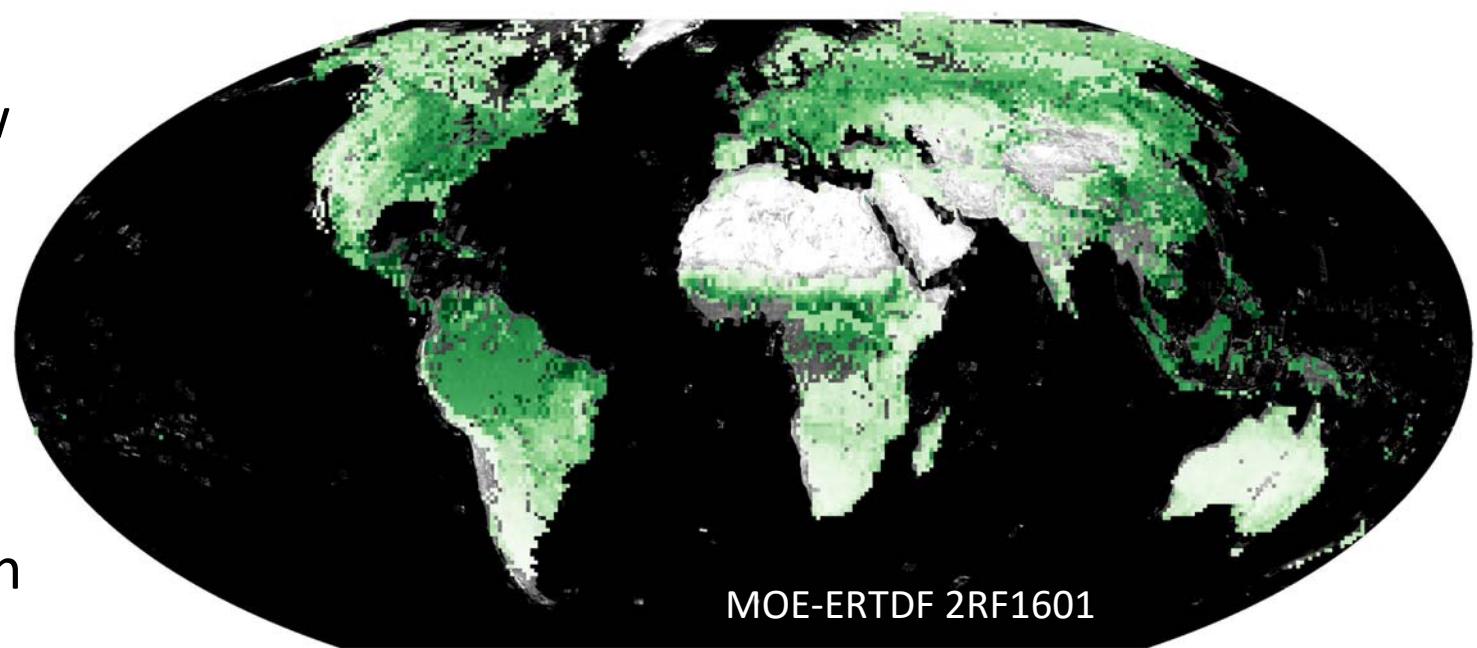
MOE-ERTDF 2RF1601

Summary

- Forest structure does matter to compute canopy scale SIF (and thus photosynthesis)

- LiDAR based canopy height is one of the essential variables to characterize the forest structure

- Preparing a model-data scheme to take advantage of using LiDAR data from MOLI and GEDI

- Collection of airborne LiDAR data is also necessary to validate the forest structure and spaceborne canopy height