Moving toward hyperspectral canopy radiative transfer in Earth system modeling

Yujie Wang
Research Scientist, Caltech

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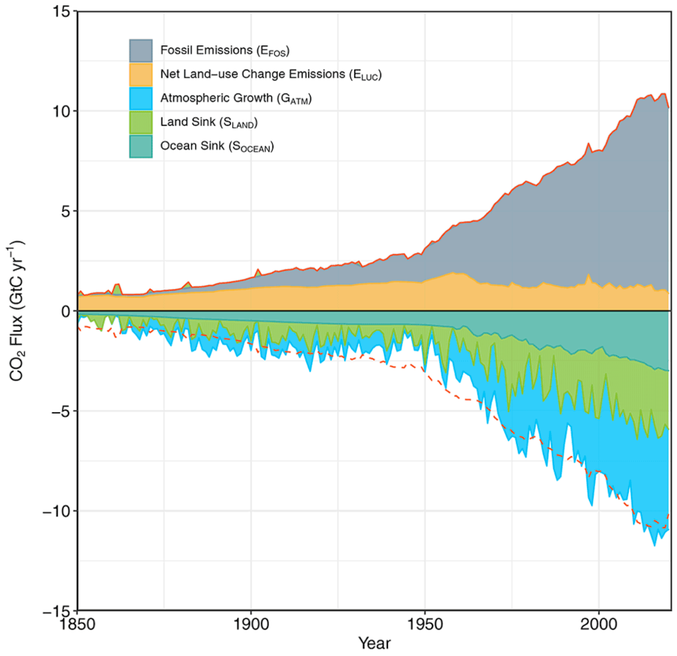
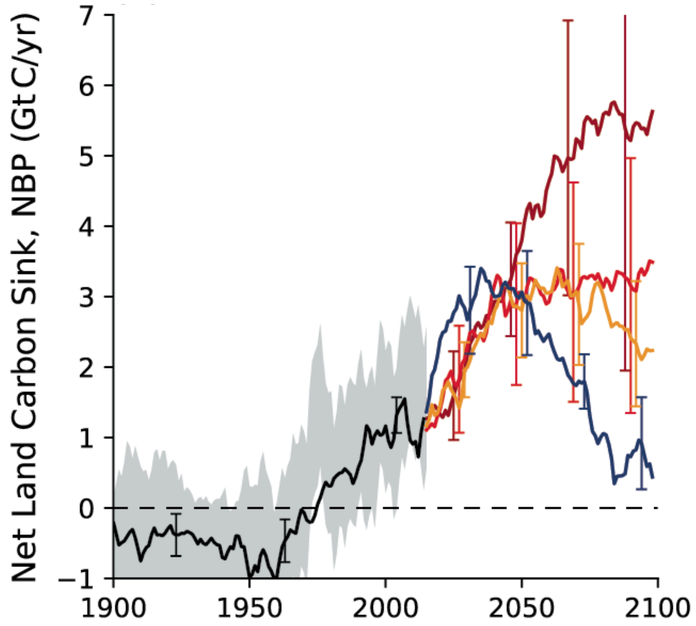
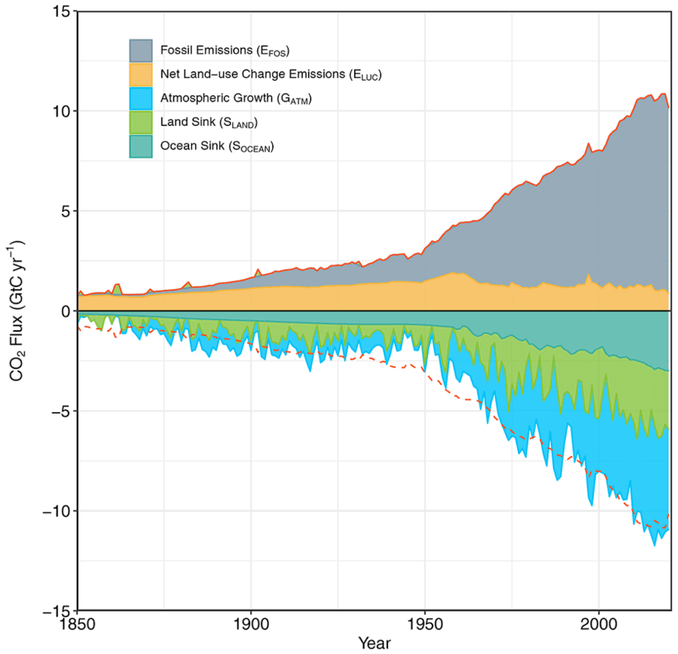
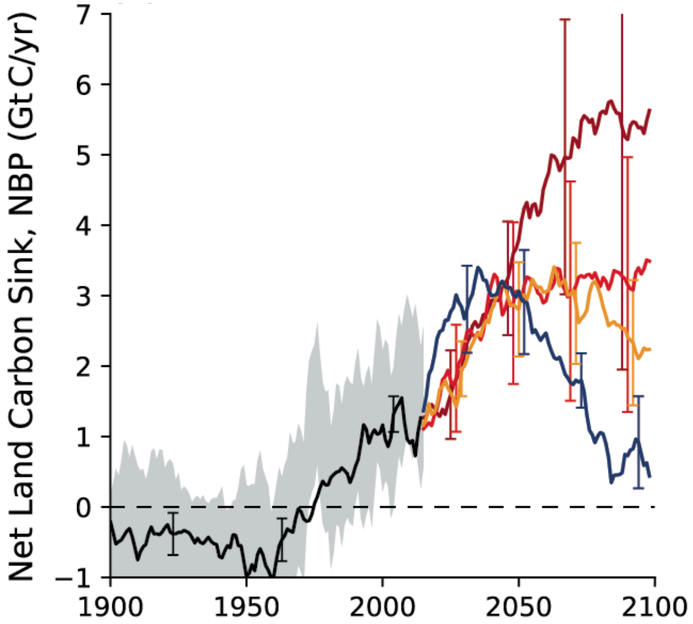

Fossil Emissions (E_{FOS})
Net Land–use Change Emissions (E_{LUC})
Atmospheric Growth (G_{ATM})
Land Sink (S_{LAND})
Ocean Sink (S_{OCEAN})
CO_2 Flux (GtC yr^{-1})
15
10
5
0
−5
−10
−15
1850
1900
1950
2000
Year


Net Land Carbon Sink, NBP (Gt C/yr)
7
6
5
4
3
2
1
0
−1
1900
1950
2000
2050
2100





Challenges:

- More Data
- Model Accuracy

Next-Generation

Land Surface Model

CliMA Land

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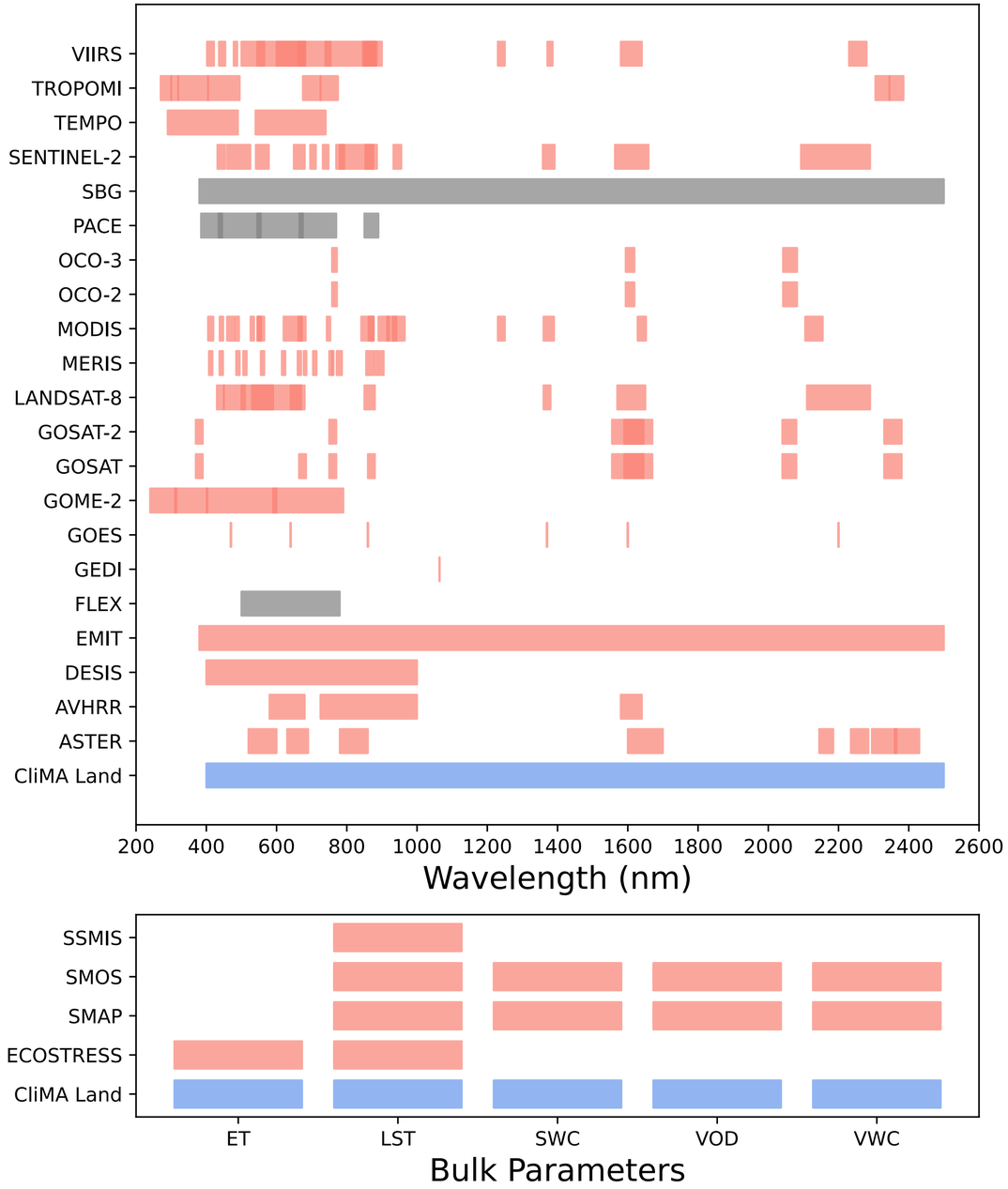
- Model Accuracy



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Land Surface Model

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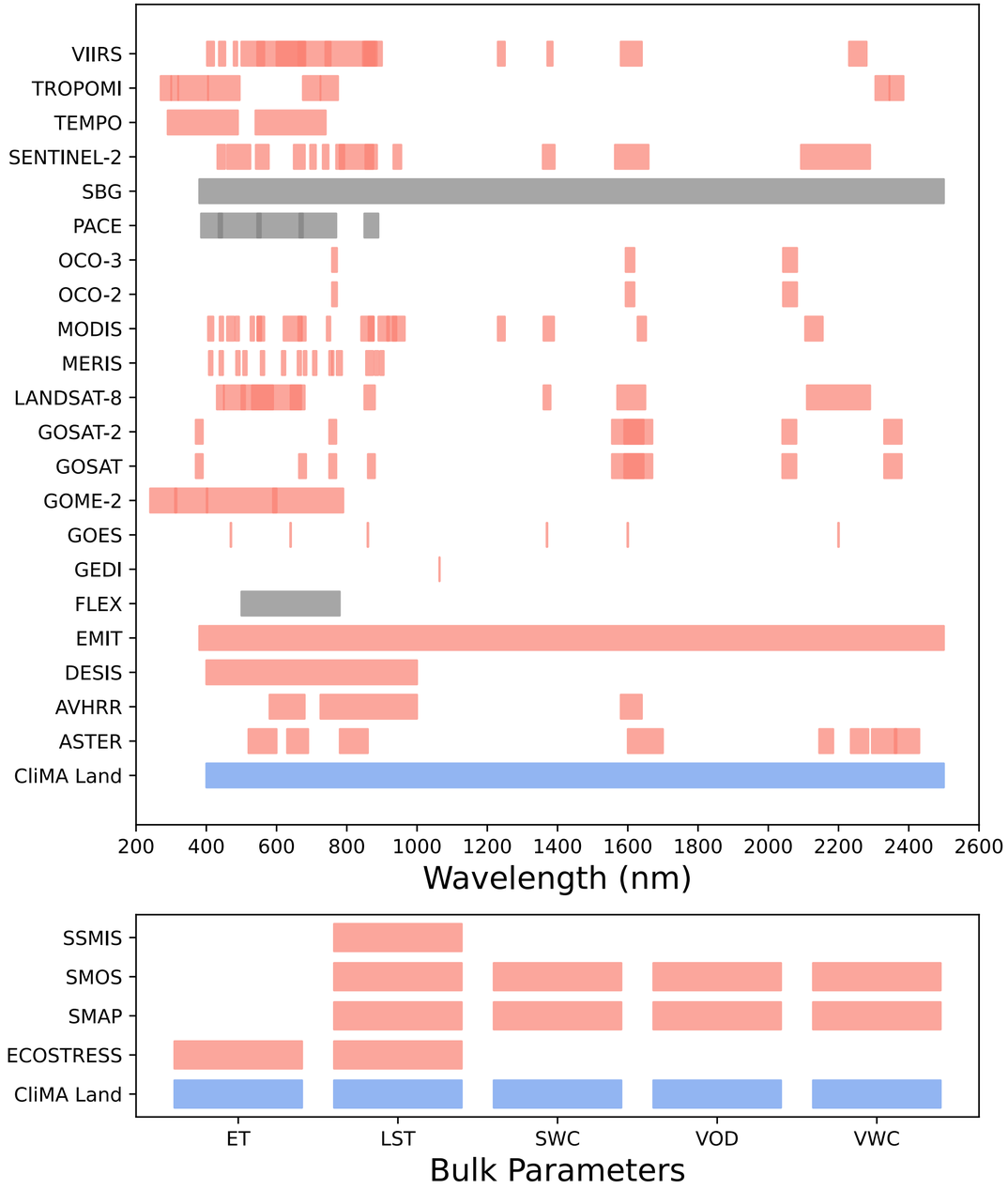
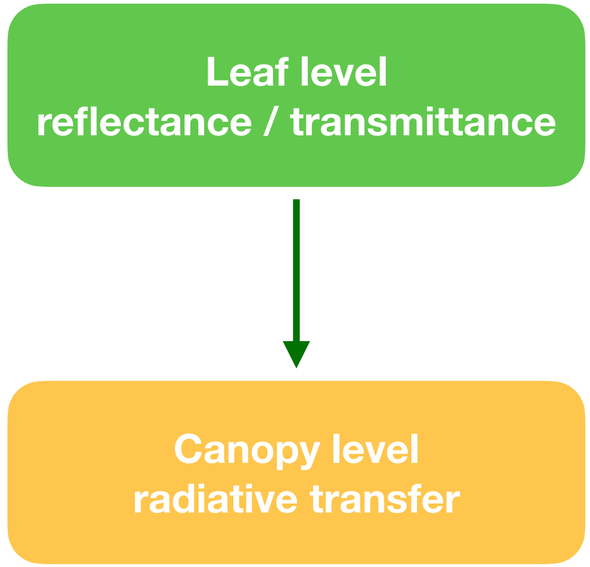


Leaf level
reflectance / transmittance

- Broadband (PAR and NIR)
- Hyperspectral



- Broadband (PAR and NIR)
- Hyperspectral

- Energy balance
- APAR calculation

Leaf level
reflectance / transmittance

- Broadband (PAR and NIR)
- Hyperspectral

Canopy level
radiative transfer

- Energy balance
- APAR calculation

Leaf level
photosynthesis

- Electron transport
- Photosynthesis

$$A_g = \min(A_c, A_j)$$

$$A_j = \frac{J}{4} \cdot \frac{P_i - \Gamma^*}{P_i + 2\Gamma^*}$$

$$J = f(J_{max}, J_{PSII})$$

Hyperspectral

$$J_{\mathrm{PSII}} = \int_{\lambda_1}^{\lambda_2} \mathrm{PAR}(\lambda) \cdot f_{\mathrm{APAR}}(\lambda) \cdot f_{\mathrm{PPAR}}(\lambda) \cdot f_{\mathrm{PSII}}(\lambda) \cdot \Phi_{\mathrm{PSII,max}} \cdot \mathrm{d}\lambda$$

Hyperspectral

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Broadband

$$J_{\mathrm{PSII}} = \mathrm{PAR} \cdot f_{\mathrm{APAR}} \cdot \frac{1}{2} \cdot \Phi_{\mathrm{PSII,max}}$$

Sources of J Bias

$$J_{\mathrm{PSII}} = \int_{\lambda_1}^{\lambda_2} \mathrm{PAR}(\lambda) \cdot f_{\mathrm{APAR}}(\lambda) \cdot f_{\mathrm{PPAR}}(\lambda) \cdot f_{\mathrm{PSII}}(\lambda) \cdot \Phi_{\mathrm{PSII,max}} \cdot \mathrm{d}\lambda$$

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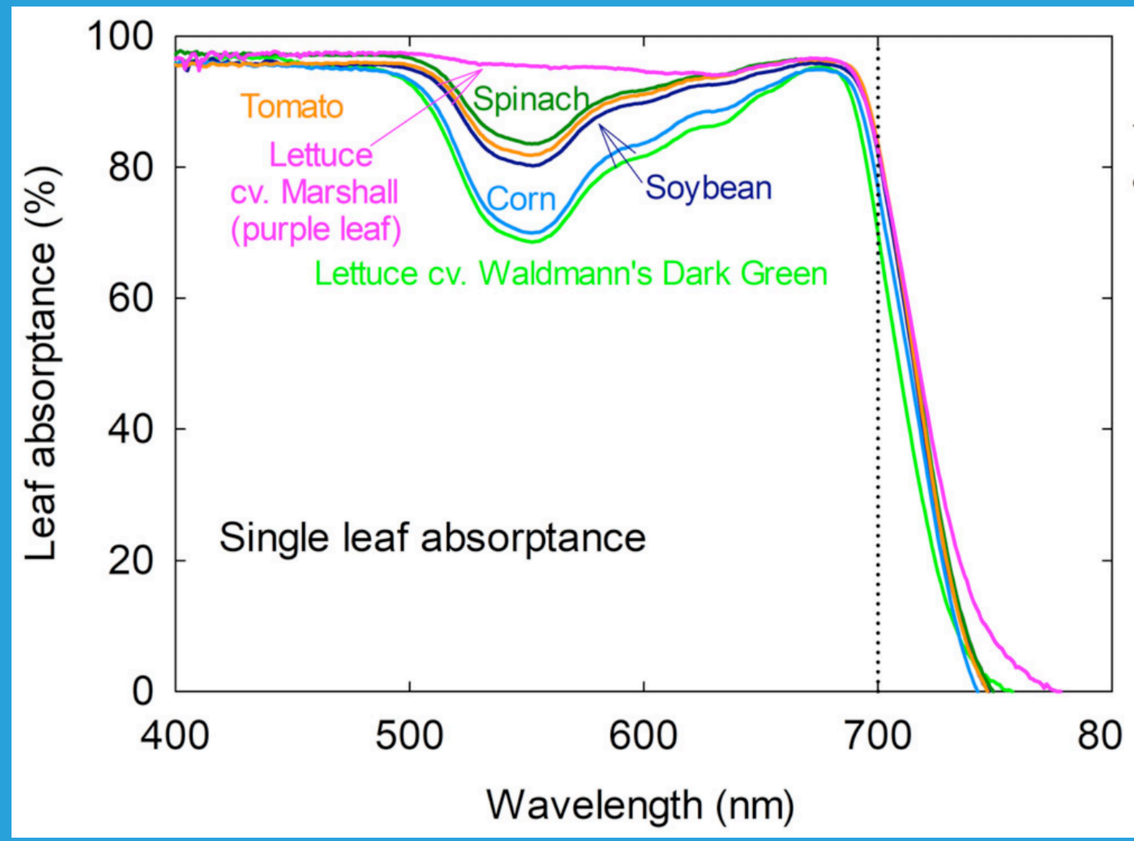

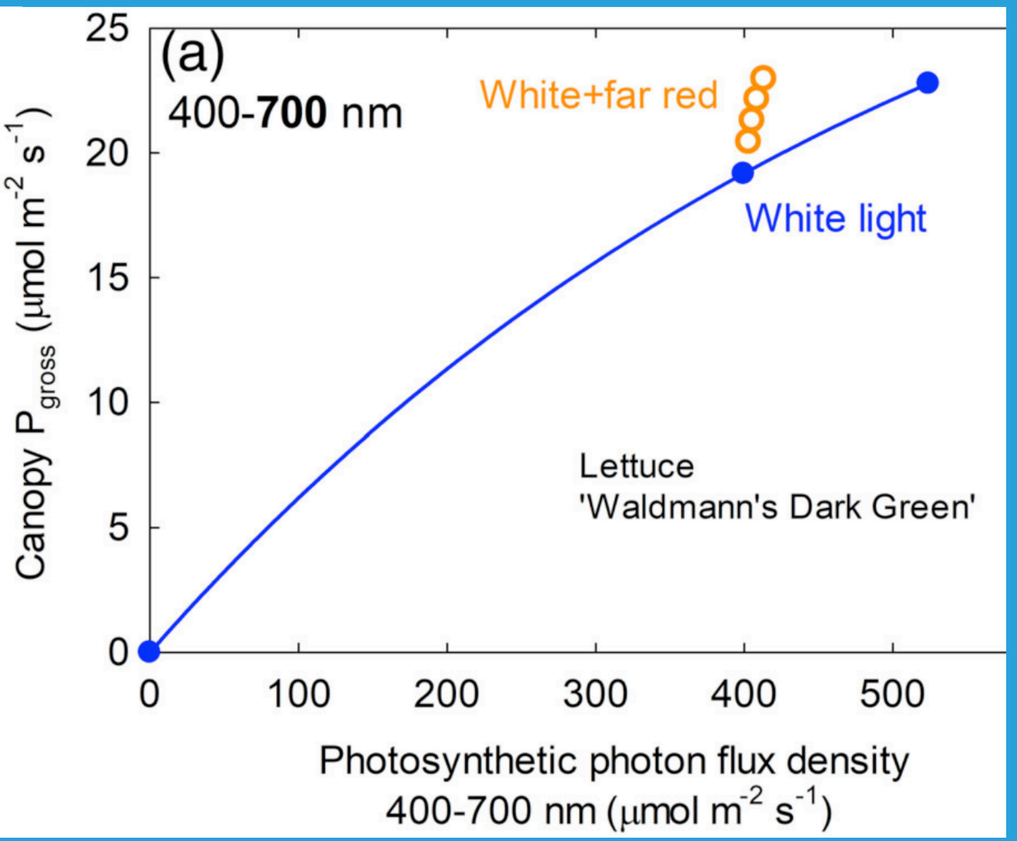

Zhen and Bugbee (2020) PCE

Sources of J Bias

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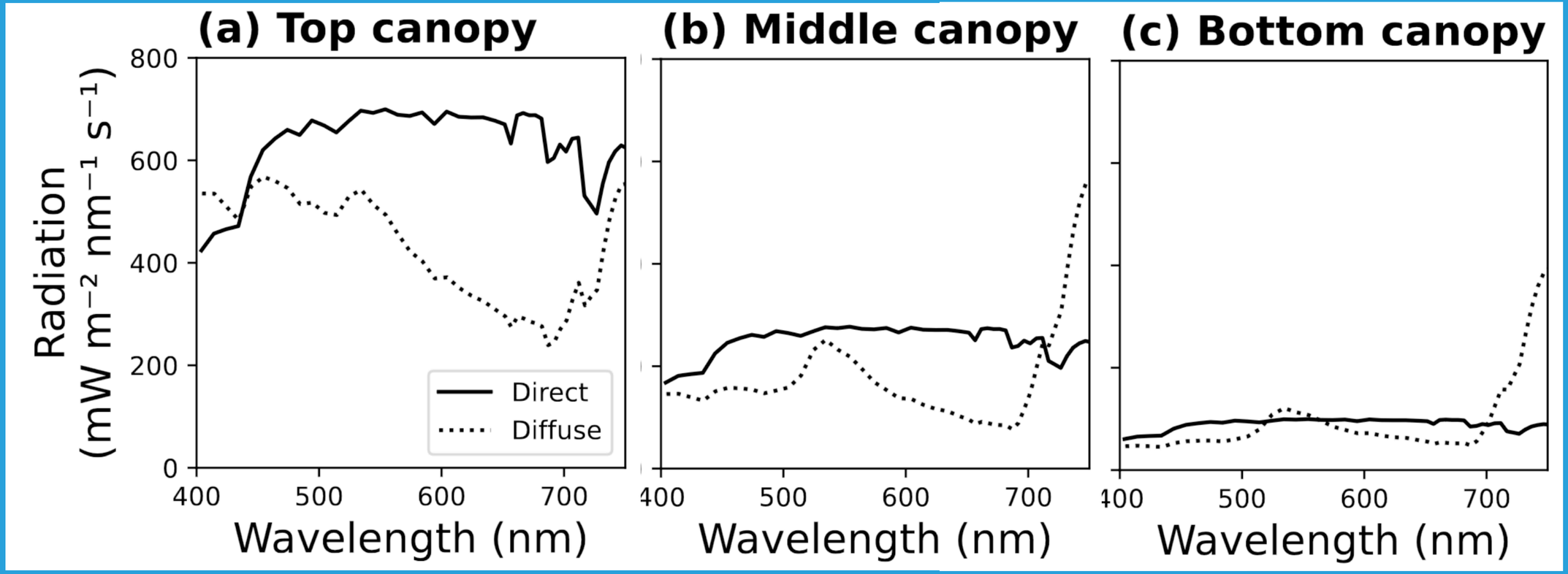

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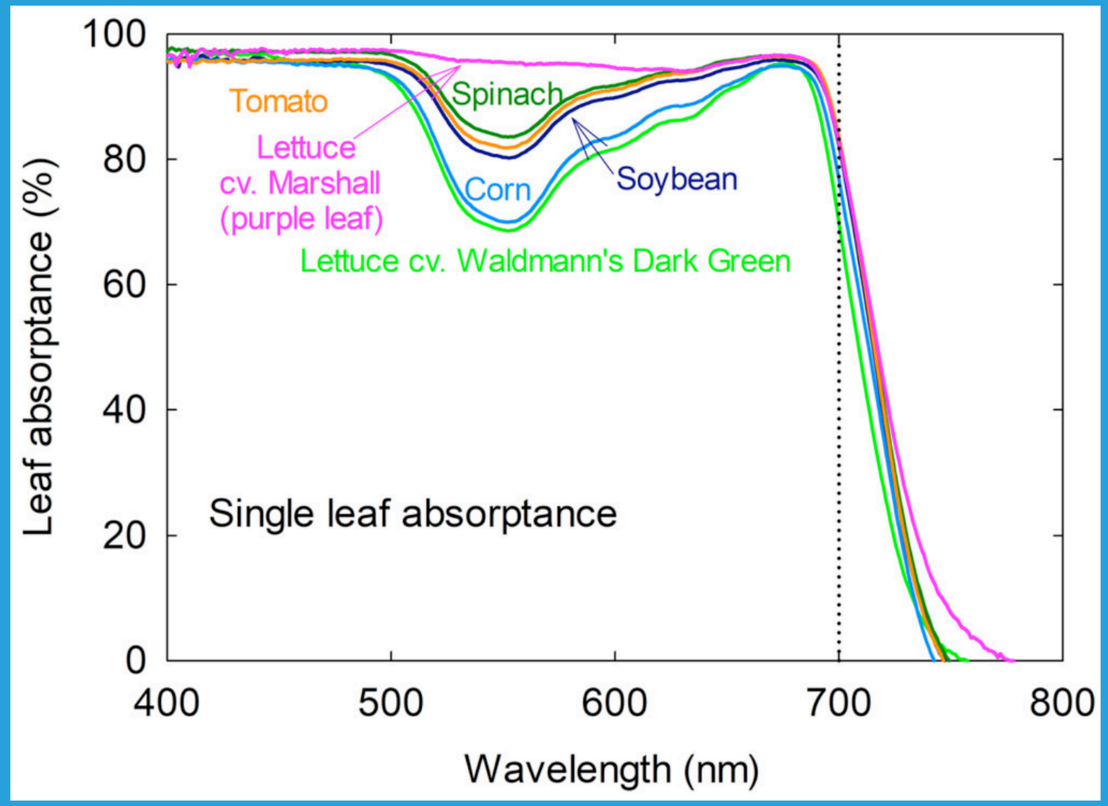

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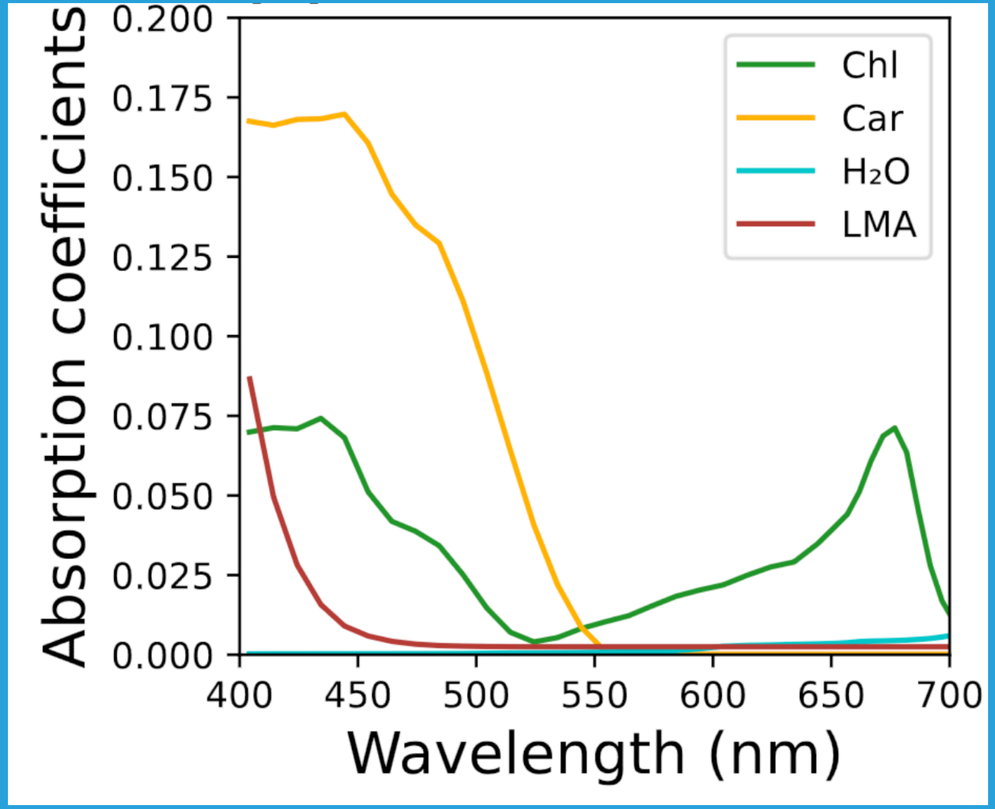

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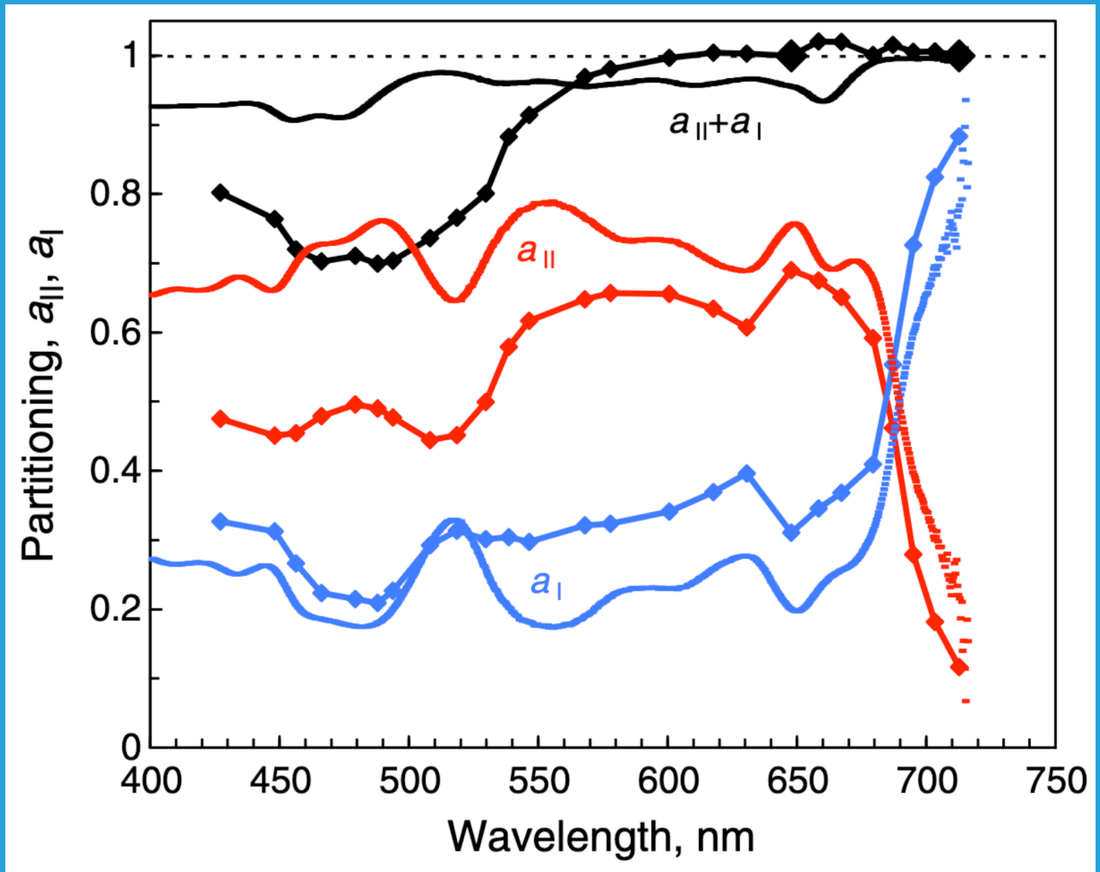

Laisk et al. (2014) BBA-B

Impacts on global carbon cycle

1. PPAR & A

- PAR, APAR, PPAR
- Photosynthesis

2. Energy Budget

- Leaf Temperature
- Surface Albedo

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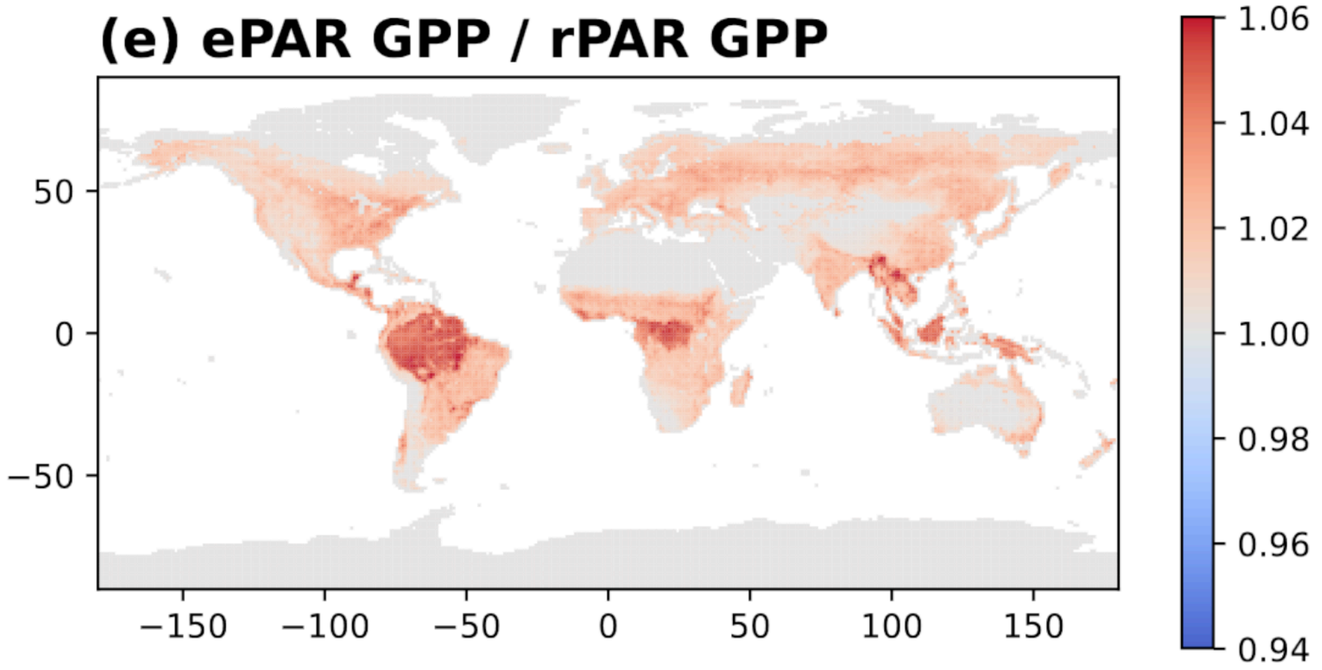
$$\mathrm{PPAR}_{\mathrm{rPAR}} = \int_{400}^{700} \alpha_{\mathrm{PPAR}}(\lambda) \cdot \mathrm{PAR}(\lambda) \cdot \mathrm{d}\lambda,$$

$$\mathrm{PPAR}_{\mathrm{ePAR}} = \int_{400}^{750} \alpha_{\mathrm{PPAR}}(\lambda) \cdot \mathrm{PAR}(\lambda) \cdot \mathrm{d}\lambda,$$



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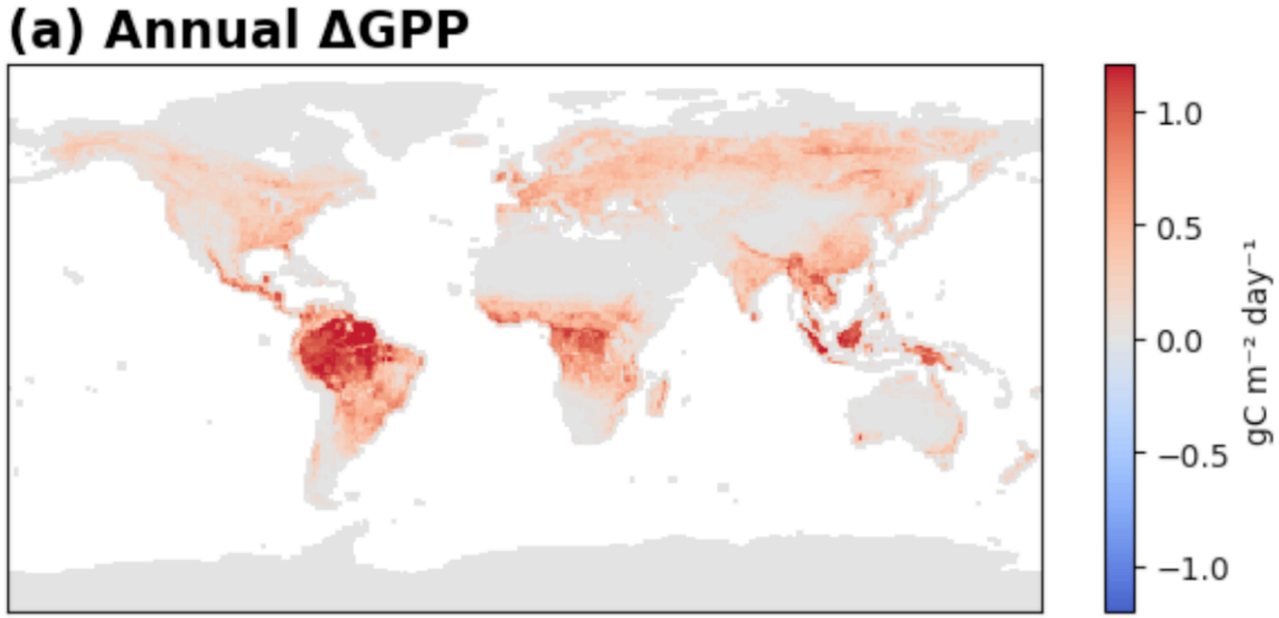

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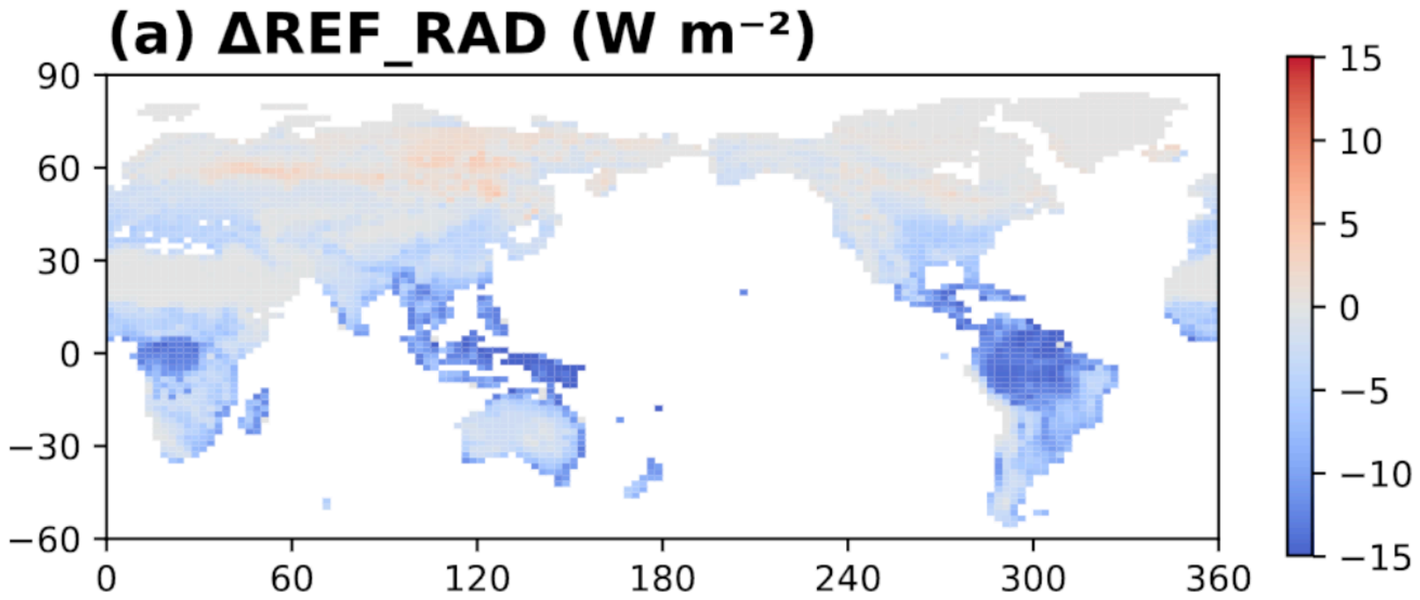

Implications for Broadband RT Models

$$J_{\mathrm{PSII}} = \int_{\lambda_1}^{\lambda_2} \mathrm{PAR}(\lambda) \cdot f_{\mathrm{APAR}}(\lambda) \cdot f_{\mathrm{PPAR}}(\lambda) \cdot f_{\mathrm{PSII}}(\lambda) \cdot \Phi_{\mathrm{PSII,max}} \cdot \mathrm{d}\lambda$$

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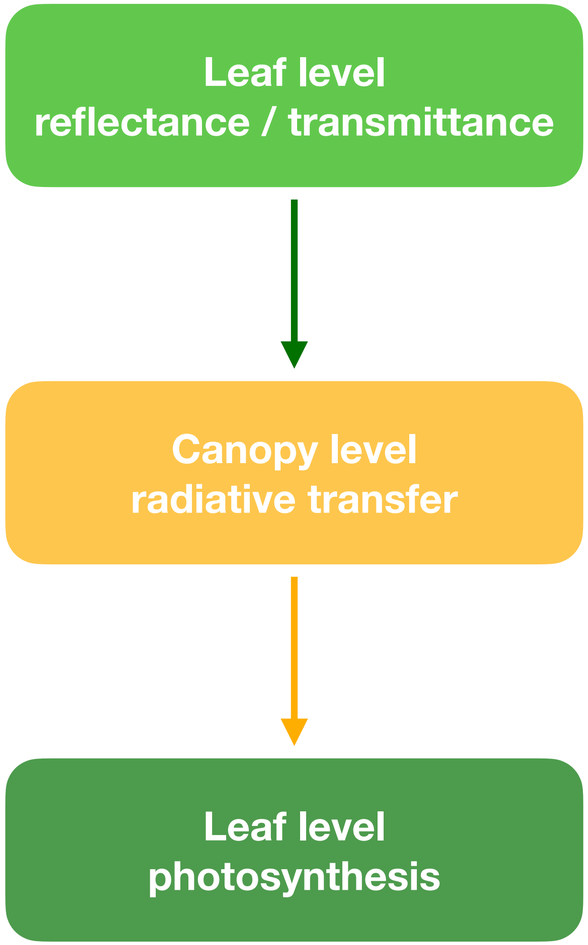


- Broadband

Plant Functional Type	χ_L	α_{vis}^{leaf}	α_{nir}^{leaf}	α_{vis}^{stem}	α_{nir}^{stem}	τ_{vis}^{leaf}	τ_{nir}^{leaf}
NET Temperate	0.01	0.07	0.35	0.16	0.39	0.05	0.10
NET Boreal	0.01	0.07	0.35	0.16	0.39	0.05	0.10
NDT Boreal	0.01	0.07	0.35	0.16	0.39	0.05	0.10
BET Tropical	0.10	0.10	0.45	0.16	0.39	0.05	0.25
BET temperate	0.10	0.10	0.45	0.16	0.39	0.05	0.25
BDT tropical	0.01	0.10	0.45	0.16	0.39	0.05	0.25
BDT temperate	0.25	0.10	0.45	0.16	0.39	0.05	0.25
BDT boreal	0.25	0.10	0.45	0.16	0.39	0.05	0.25

$$J_{\mathrm{PSII}} = \mathrm{PAR} \cdot f_{\mathrm{APAR}} \cdot f_{\mathrm{PPAR}} \cdot \frac{1}{2} \cdot \Phi_{\mathrm{PSII,max}}$$

Leaf level reflectance / transmittance - Broadband

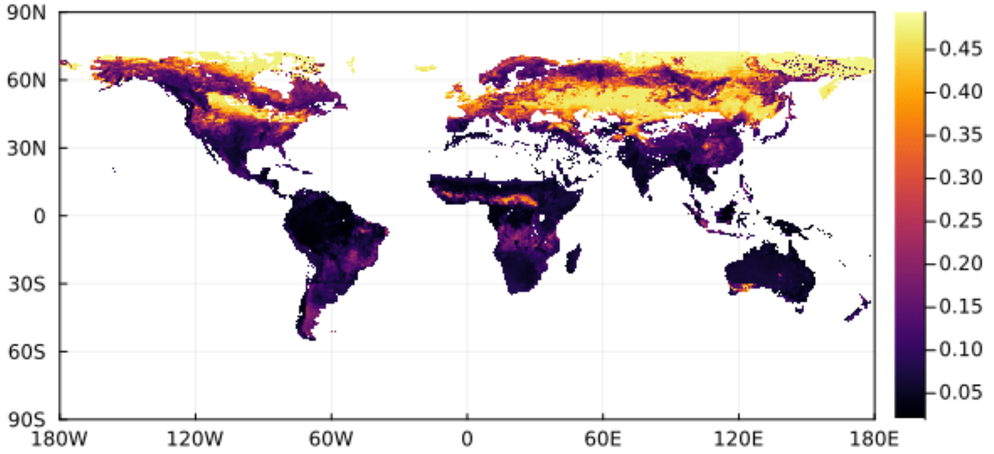
↓

Canopy level radiative transfer

↓

Leaf level photosynthesis

$\tau_{\mathrm{vis}}^{\mathrm{leaf}}$



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Leaf level reflectance / transmittance

↓

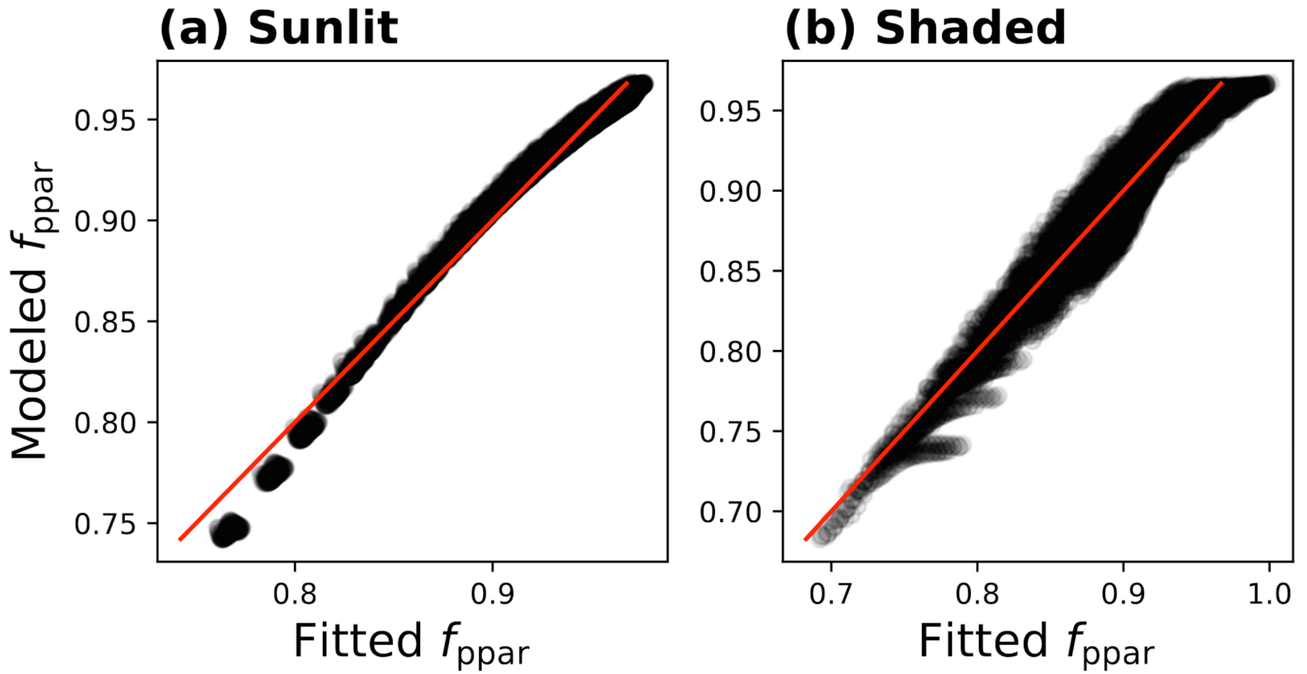
Canopy level radiative transfer

↓

Leaf level photosynthesis

- Corrections

$$f_{\mathrm{PPAR}} = k_{\mathrm{z}} \cdot z + k_{\mathrm{LAI}} \cdot \mathrm{LAI} + k_{\mathrm{chl}} \cdot \log[\log(\mathrm{chl})] + l.$$



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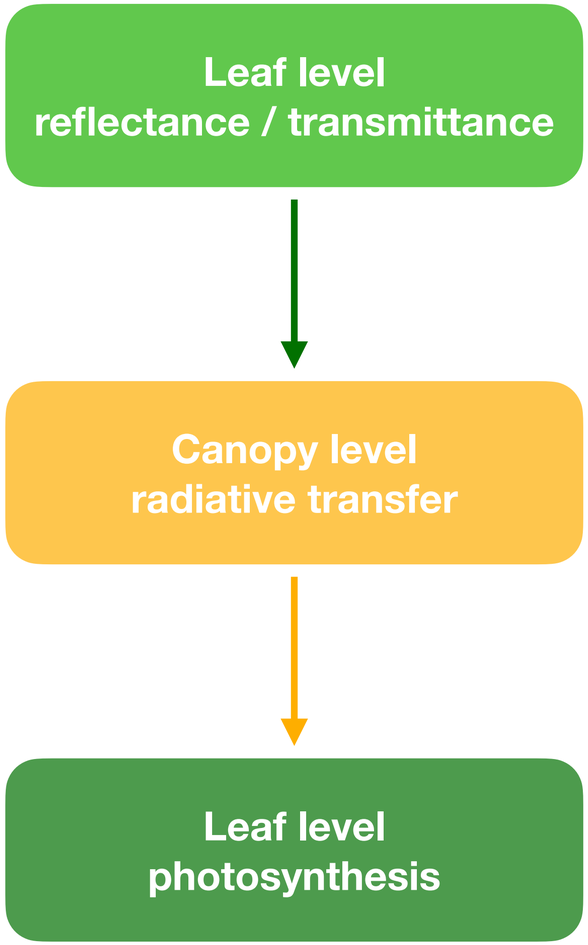

- PAR Definition

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