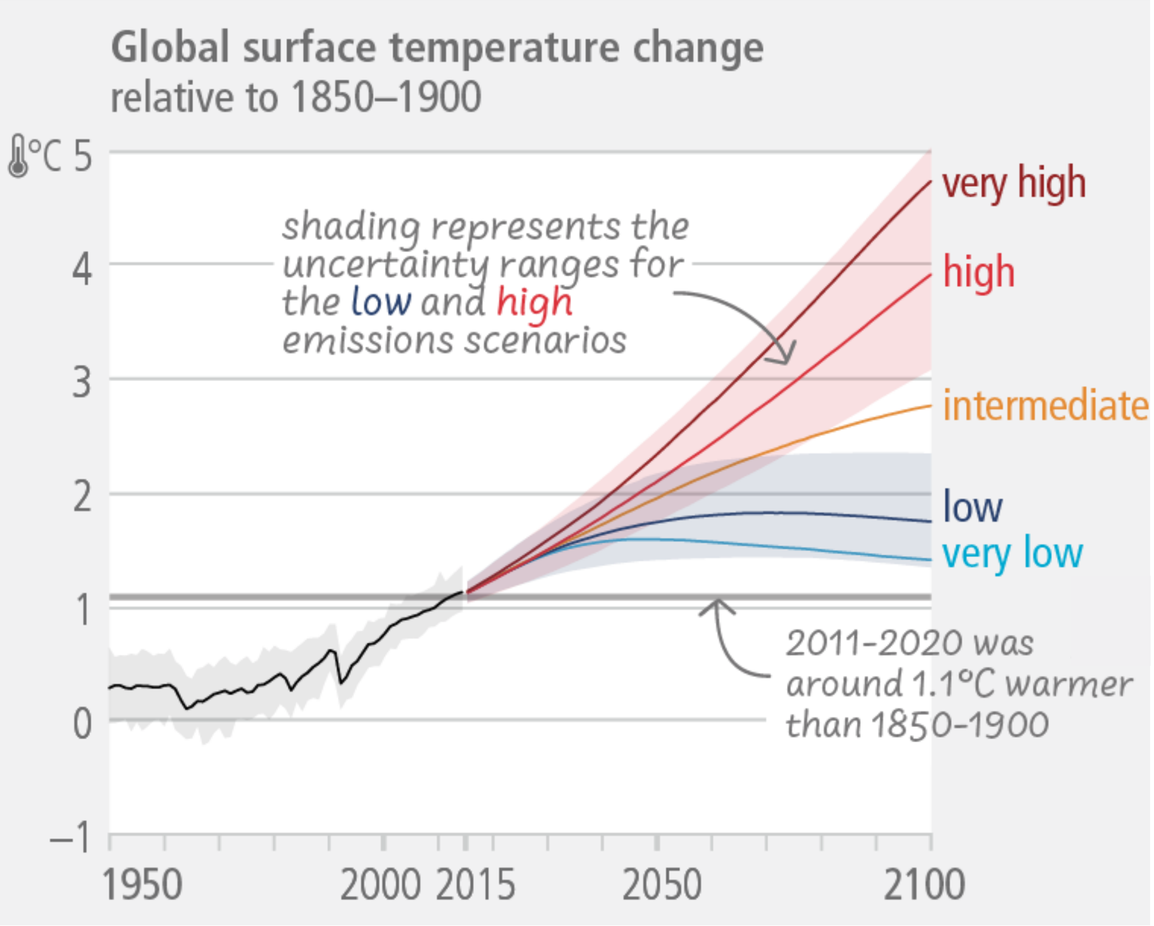
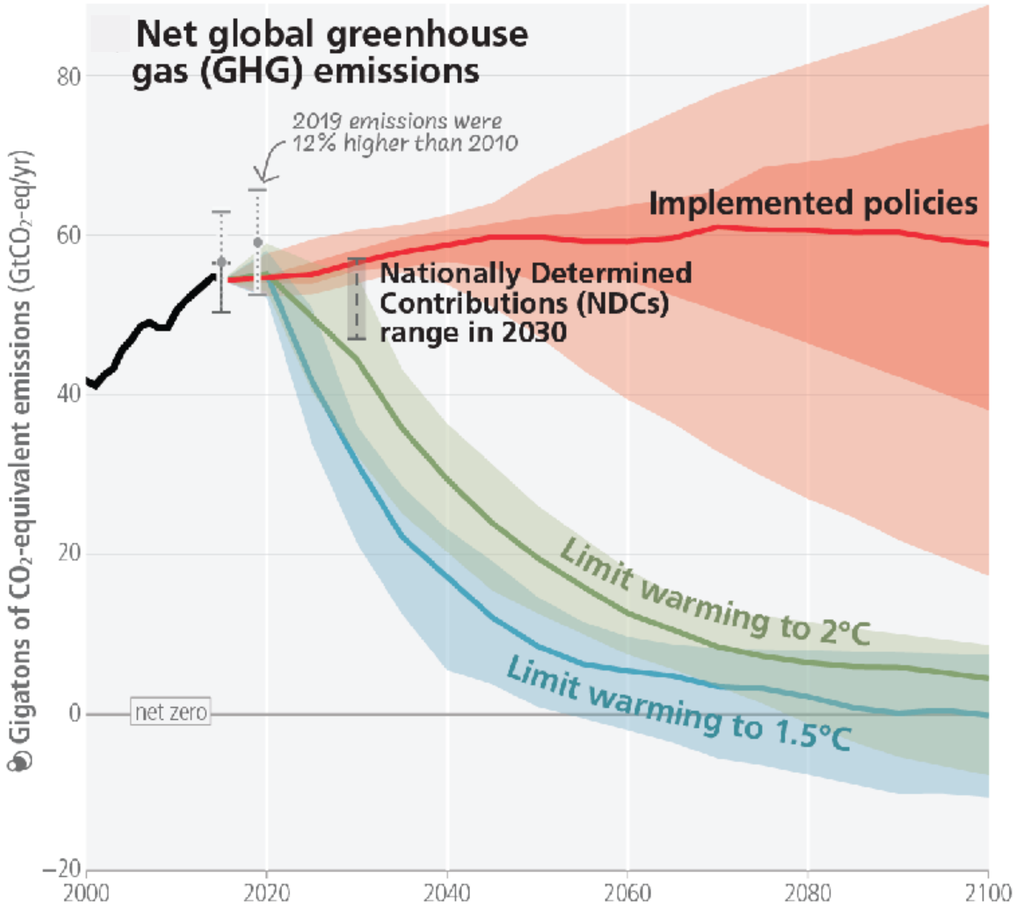
From PFT to traits

Improving the canopy radiative transfer in Earth system modeling

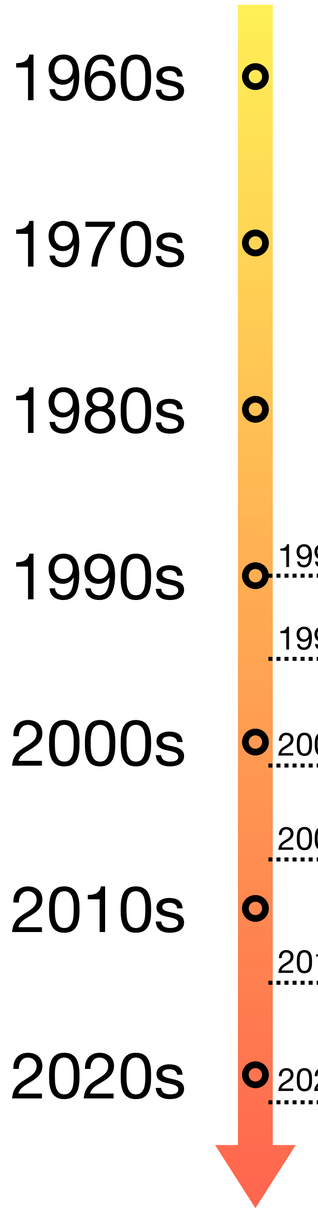
Yujie WANG

Dec/10/2024


Global surface temperature change
relative to 1850–1900
°C
5
4
3
2
1
0
−1
1950
2000
2015
2050
2100
shading represents the uncertainty ranges for the low and high emissions scenarios
very high
high
intermediate
low
very low
2011-2020 was around 1.1°C warmer than 1850-1900


Net global greenhouse gas (GHG) emissions
Gigatons of CO2-equivalent emissions (GtCO2-eq/yr)
80
60
40
20
0
−20
2000
2020
2040
2060
2080
2100
2019 emissions were 12% higher than 2010
Implemented policies
Nationally Determined Contributions (NDCs) range in 2030
Limit warming to 2°C
Limit warming to 1.5°C
net zero

LSMs as the boundary condition of GCMs



1990 IPCC 1st assessment	Bucket model (not yet standalone)
1995 IPCC 2nd assessment	Simple model (vegetation cover, stomatal model)
2001 IPCC 3rd assessment	More complicated model (carbon cycle)
2007 IPCC 4th assessment	
2014 IPCC 5th assessment	Increasing complexity (DGVM, nutrients, LUC, City, Agriculture)
2021 IPCC 6th assessment	

LSM: Land Surface Model

1st Gen LSM

1960s

1970s

1980s

1990s

2000s

2010s

2020s

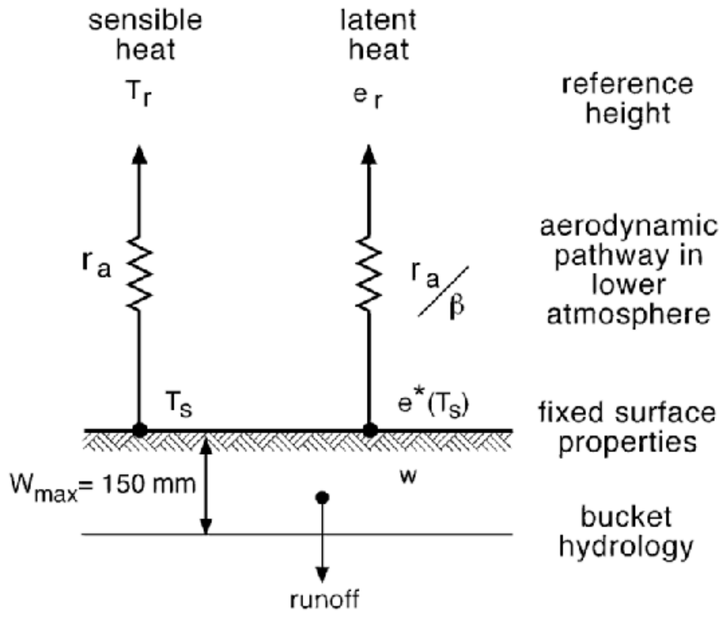
Manabe (1969)

Pros:

- Bucket model
- Energy budget
- Water budget

Cons:

- Vegetation



2nd Gen LSM

1960s

1970s

Farquhar C3 Model 1980s

Ball Berry Stomatal Model

SiB BATS

Collatz C4 Model 1990s

Leuning Stomatal Model

2000s

2010s

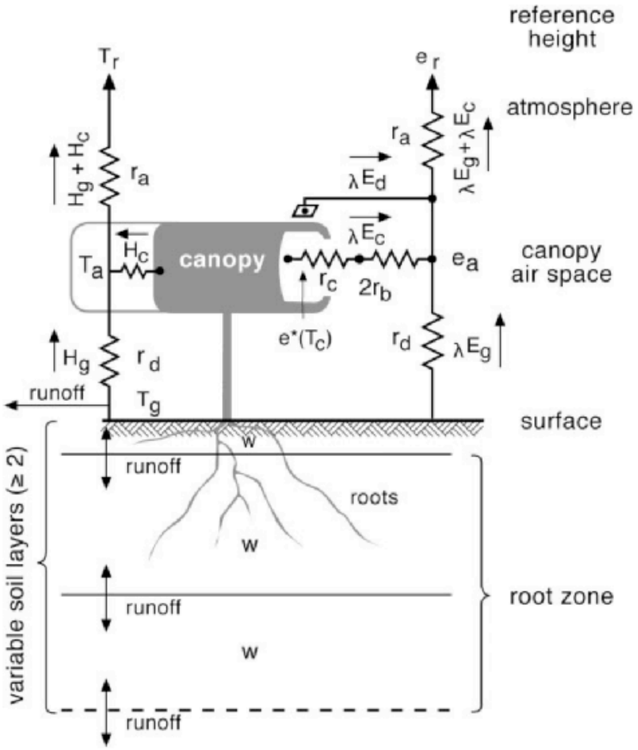
2020s

Pros:

- Multiple soil layering
- Vegetation

Cons:

- Carbon Cycle



3rd Gen LSM

1960s

1970s

1980s

Photosynthesis Models

+

Stomatal Models

1990s

NCAR-LSM SiB2

2000s

2010s

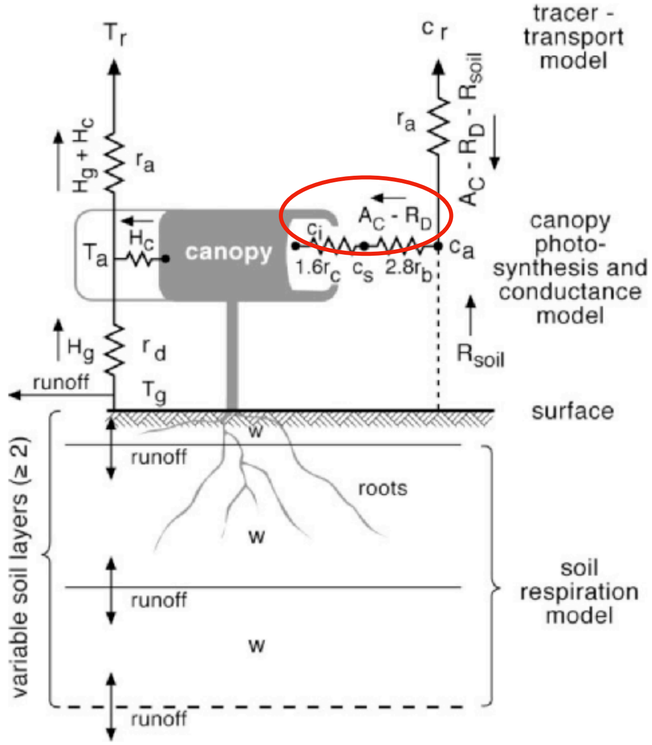
2020s

Pros:

- Photosynthesis
- Dynamic Growth

Cons:

- Too simplified
- Chemical processes



4th? Gen LSM

1960s

1970s

1980s

1990s

2000s

2010s

CLM4.5

2020s

CLM5

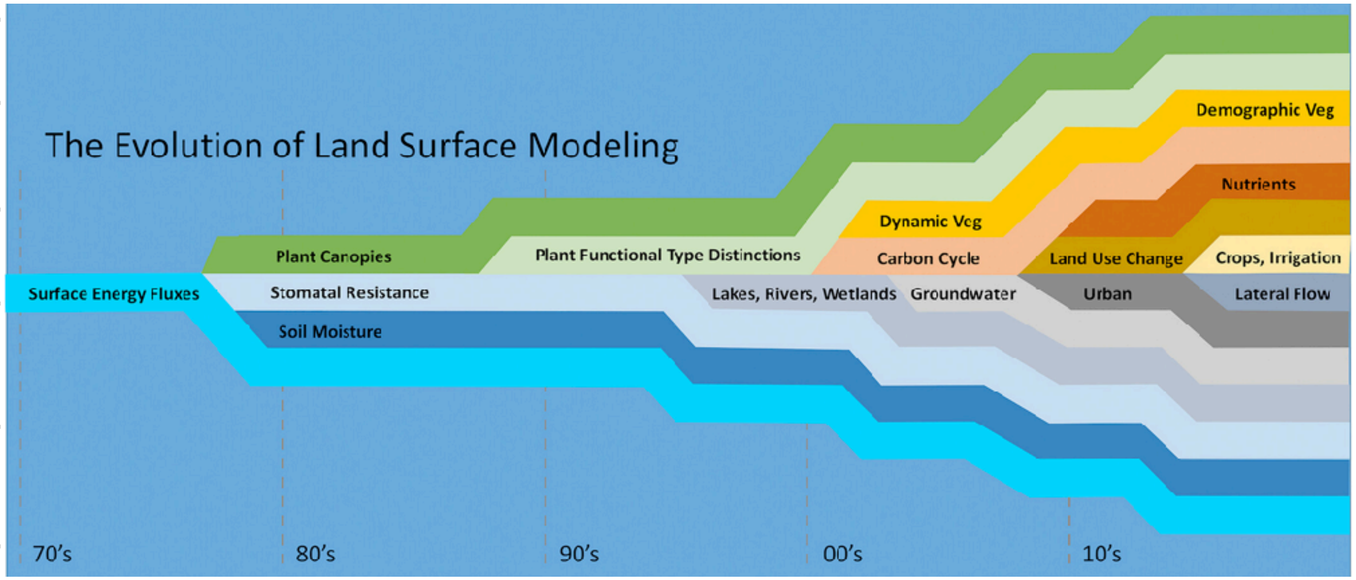
CoLM2024

Pros:

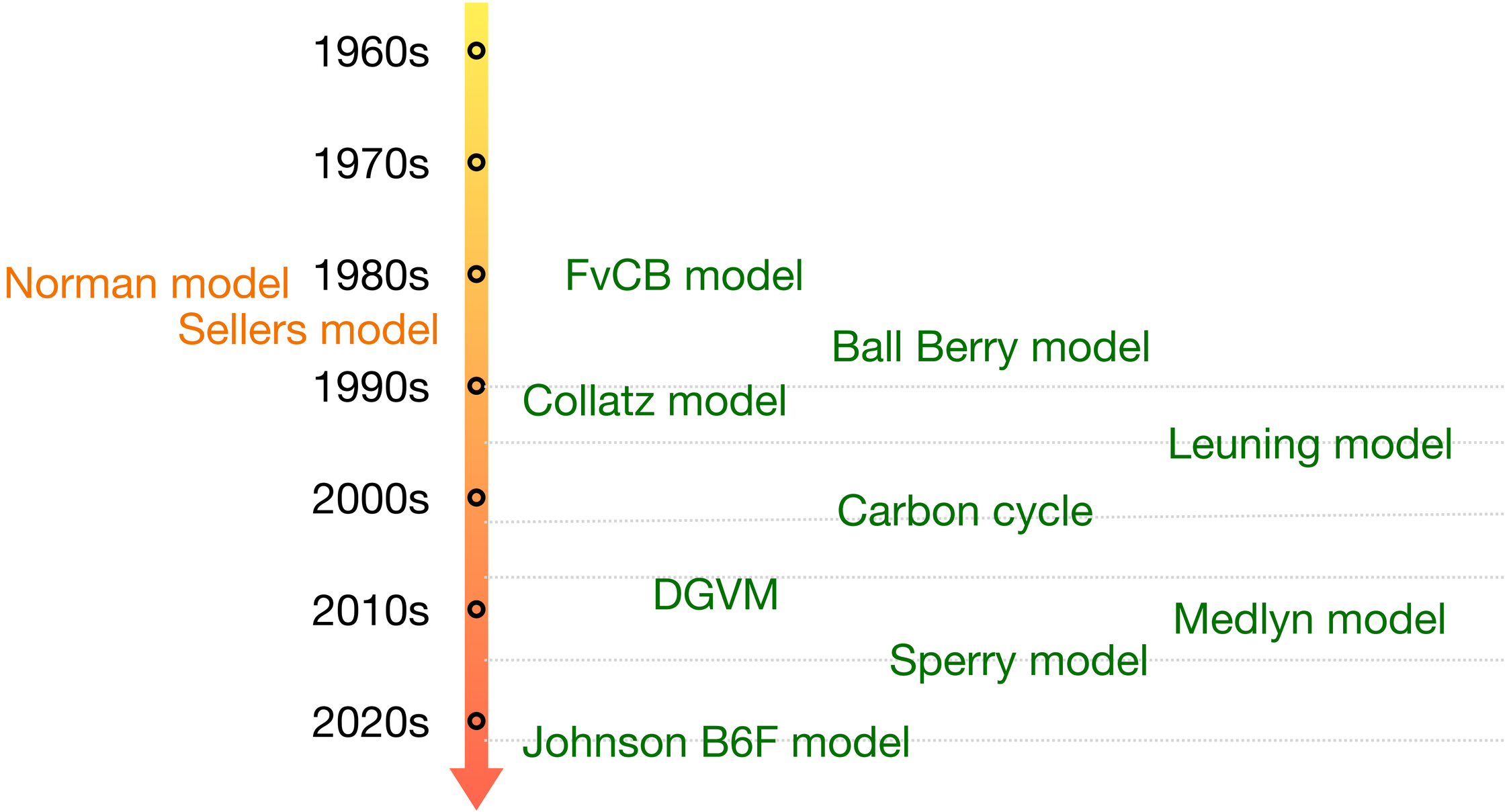
- Nutrients
- Chemical processes
- River & Lake
- City & Agriculture
- Fire
- Methane
- etc

Pros:

- Simple processes
- Calibration

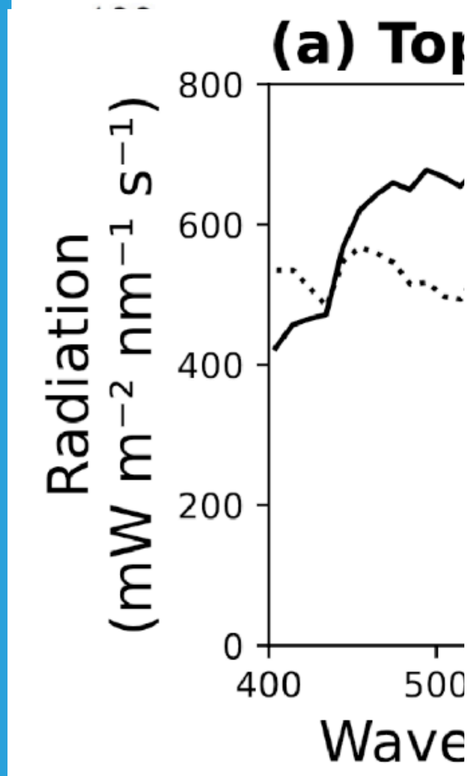


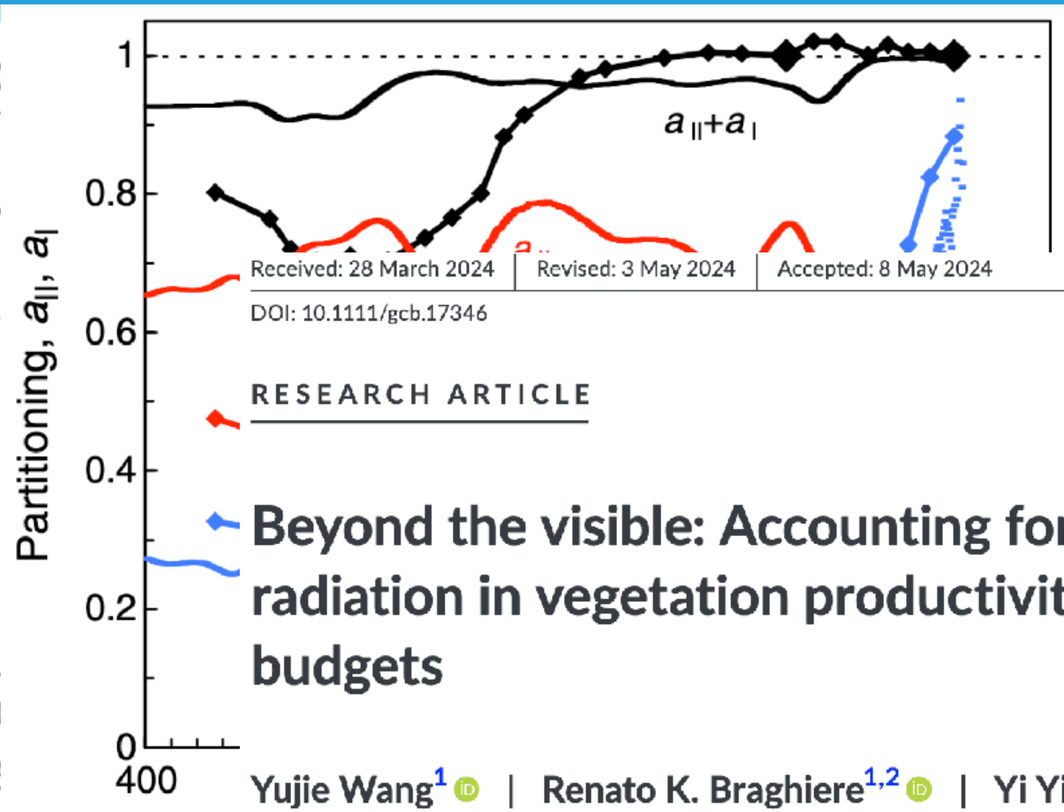
LSMs

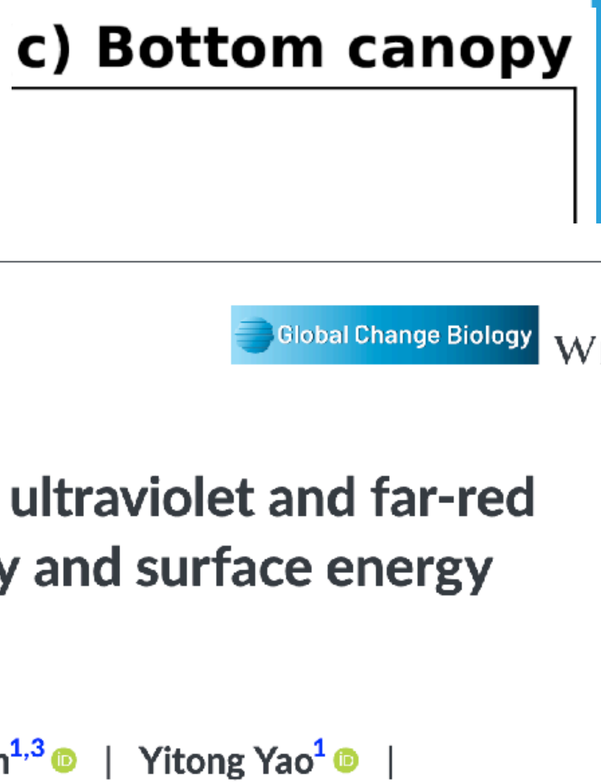

1960s
1970s
1980s
1990s
2000s
2010s
2020s
Norman model
Sellers model
FvCB model
Ball Berry model
Collatz model
Leuning model
Carbon cycle
DGVM
Medlyn model
Sperry model
Johnson B6F model

Sources of Photosynthesis 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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RESEARCH ARTICLE

Beyond the visible: Accounting for ultraviolet and far-red radiation in vegetation productivity and surface energy budgets

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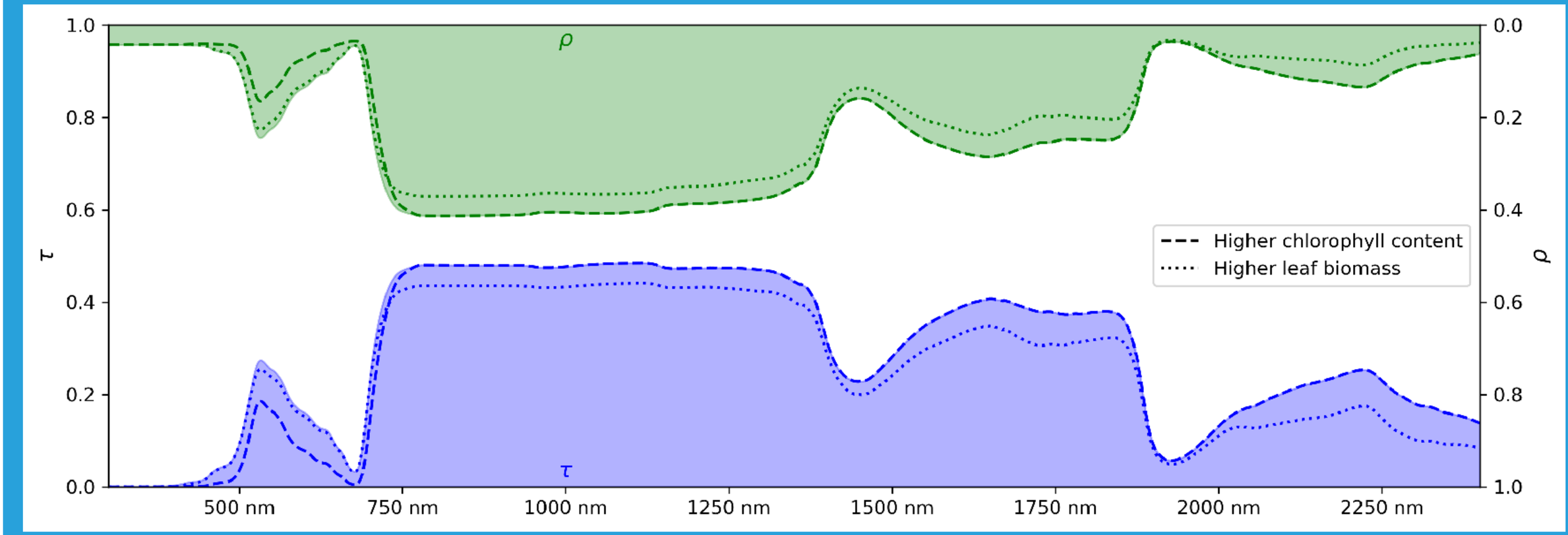
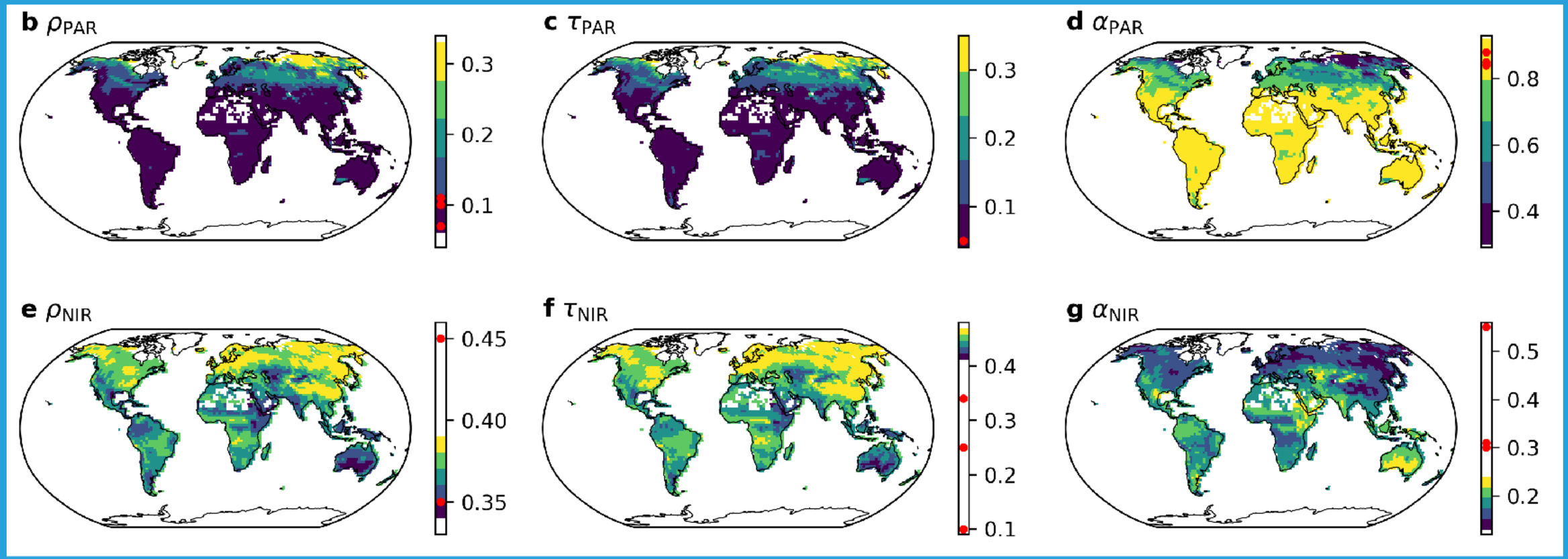
Sources of Energy Budget Bias

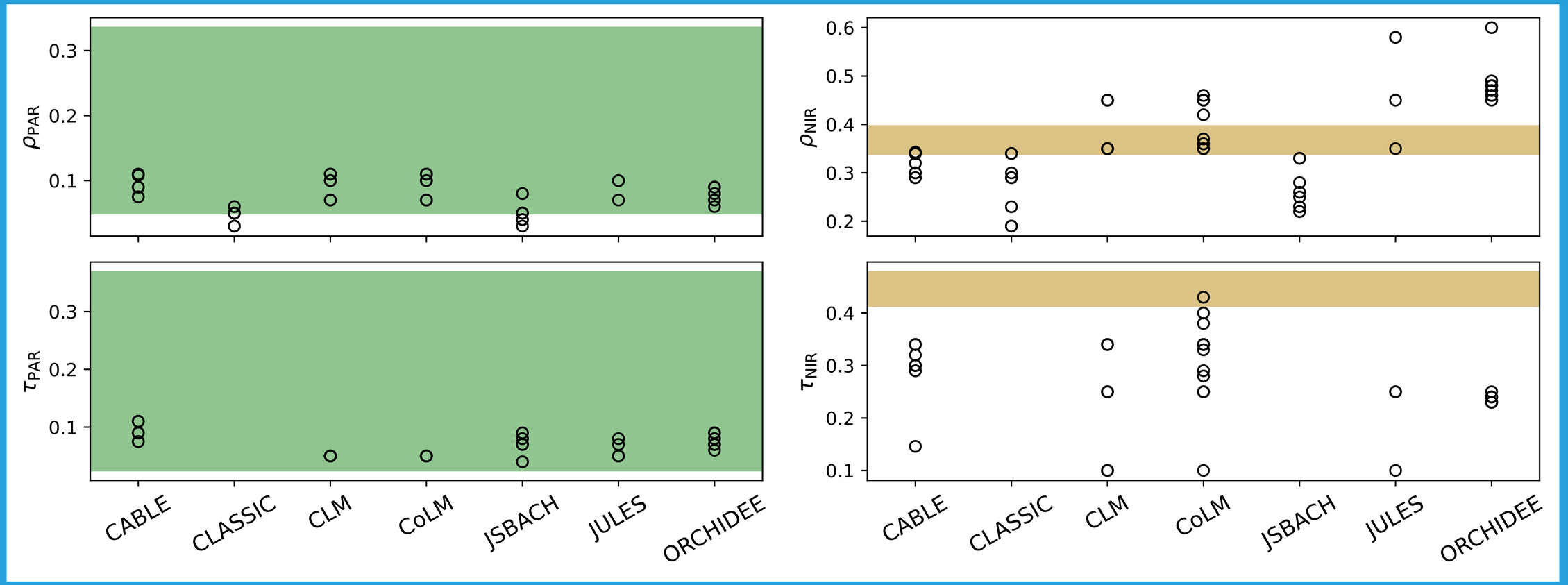
$$R_{\mathrm{SW}} = \int_{\lambda_1}^{\lambda_2} \mathrm{E}(\lambda) \cdot f_{\mathrm{absorption}}(\lambda) \cdot \mathrm{d}\lambda$$



Sources of Energy Budget Bias



Sources of Energy Budget Bias



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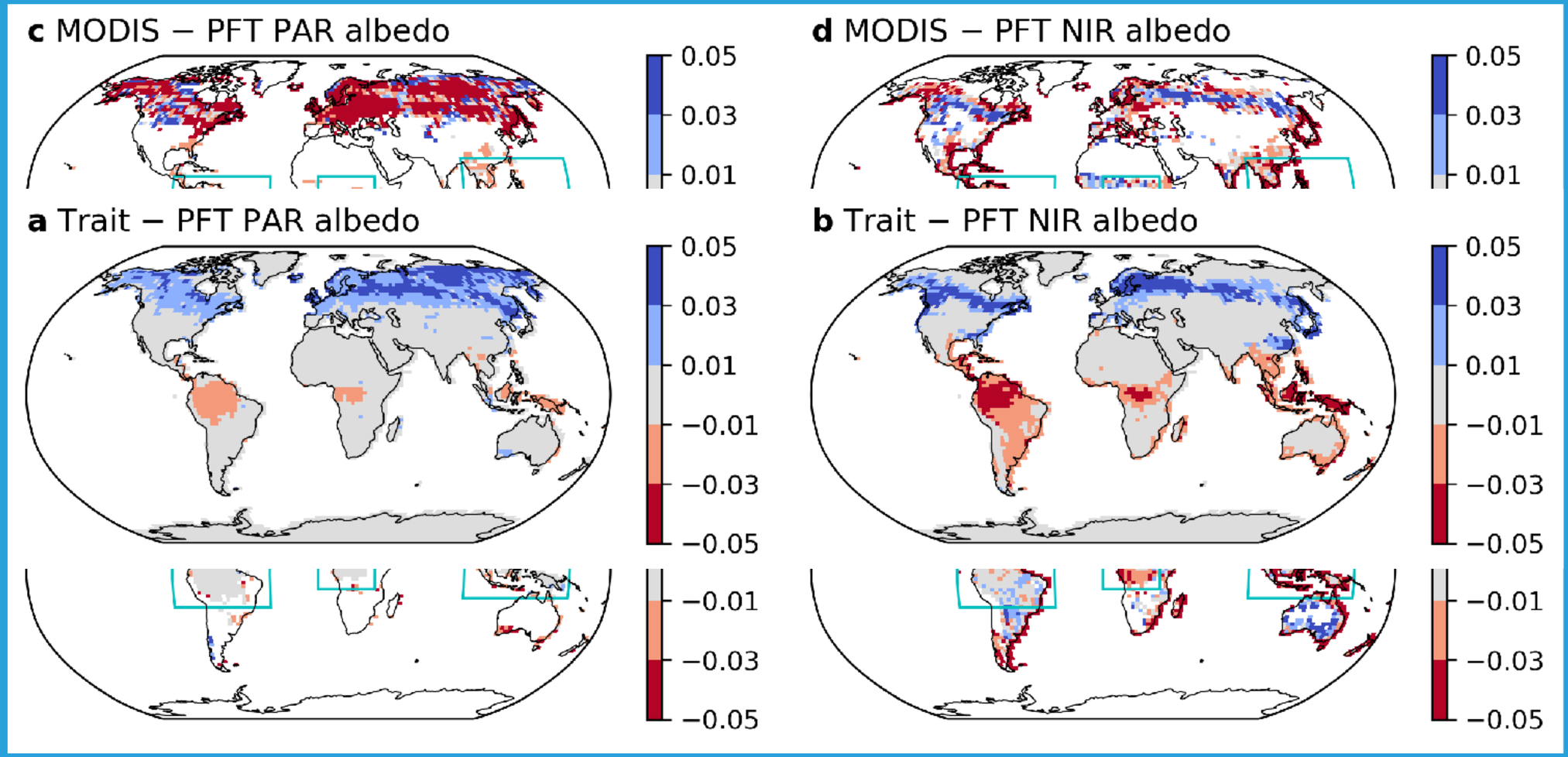
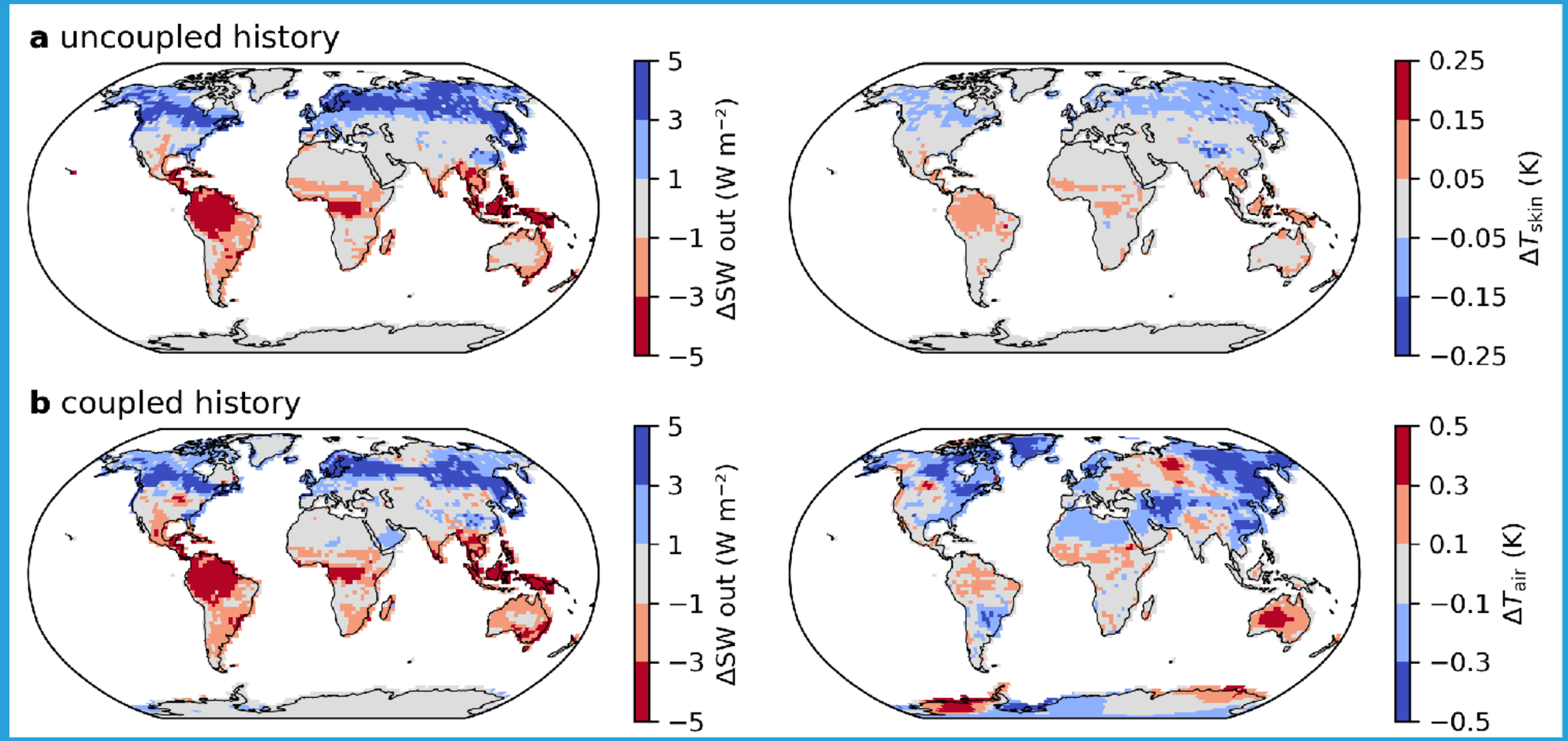


Sources of Energy Budget Bias



Take-home messages

- Move from PFT- to trait-based configurations
- Go hyperspectral
- More ecophysiology processes

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