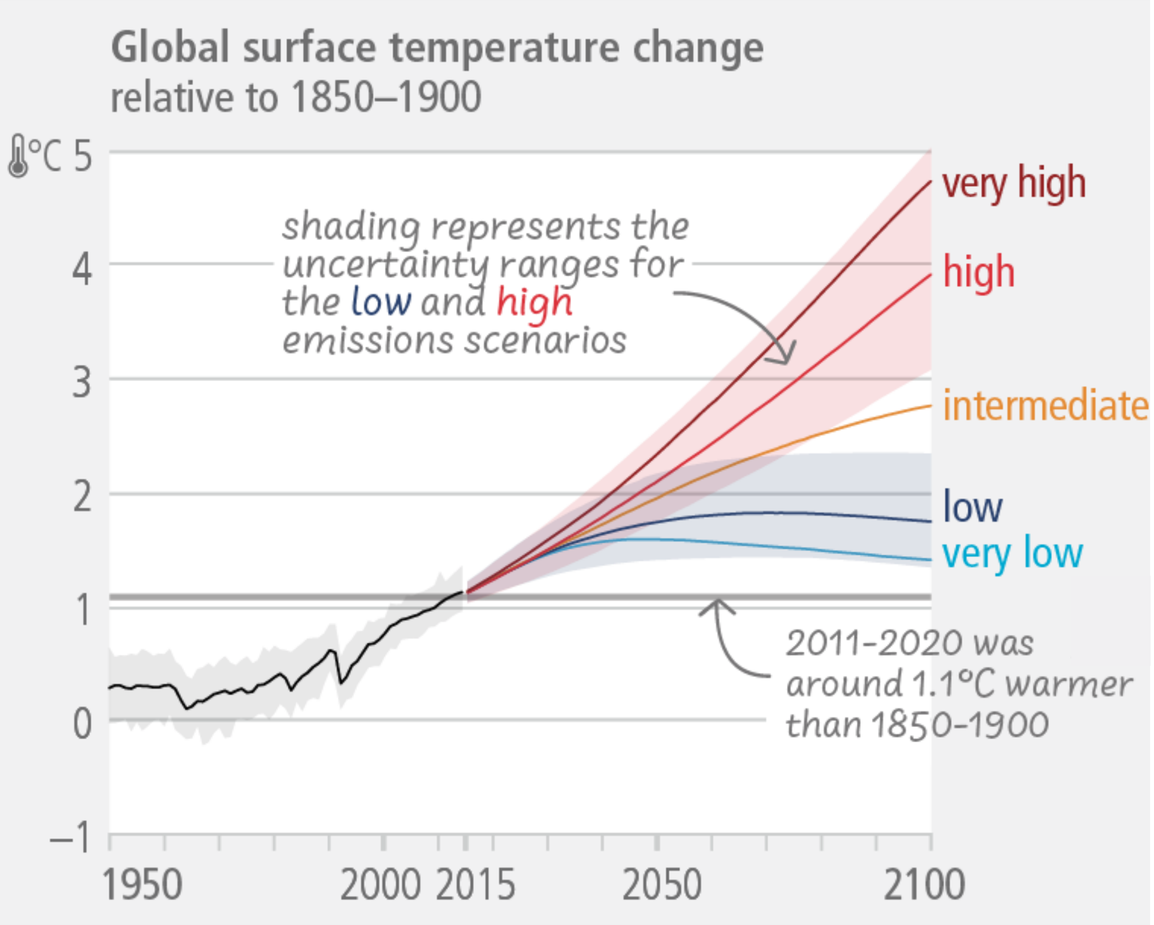
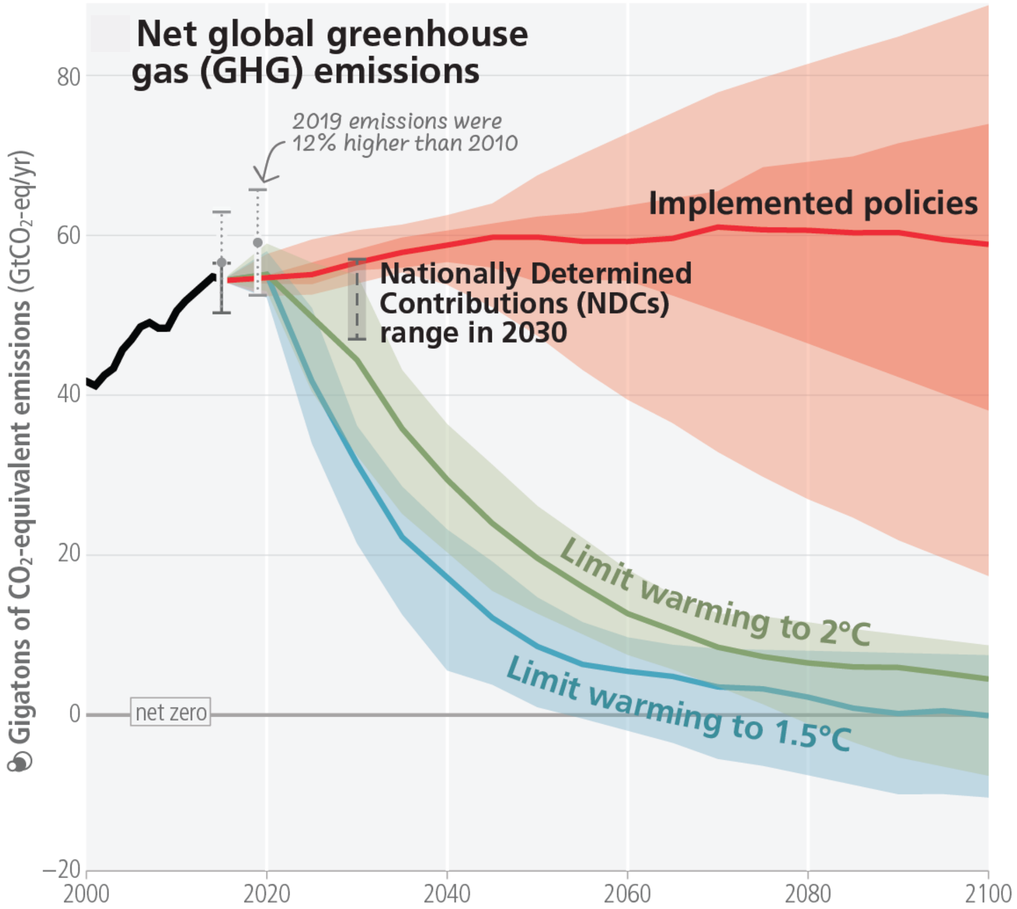
从“植物功能**类群**”到“植物功能**性状**”

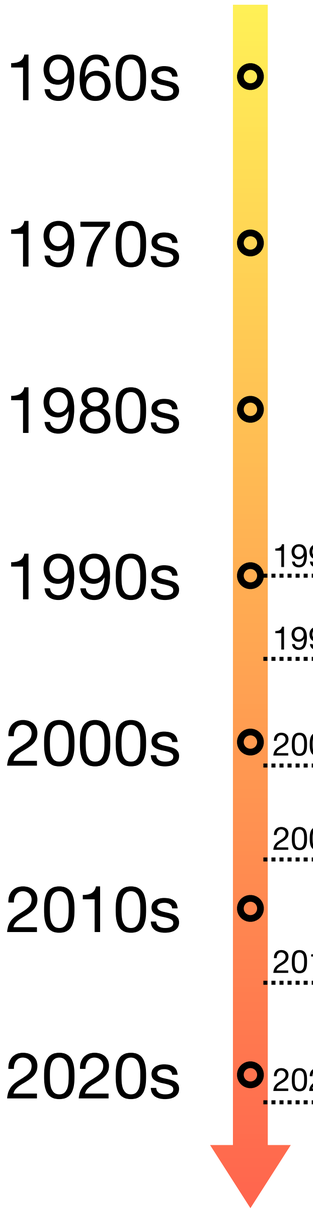
植物性状多样性对地球系统模拟的影响

中国科学技术大学　　王玉杰　　2025-04-19


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

陆面模式（LSM）只是气候模型的边界层



Bucket model (not yet standalone)

Simple model (vegetation cover, stomatal model)

More complicated model (carbon cycle)

Increasing complexity (DGVM, nutrients, LUC, City, Agriculture)

LSM: Land Surface Model

第一代LSM

1960s

1970s

1980s

1990s

2000s

2010s

2020s

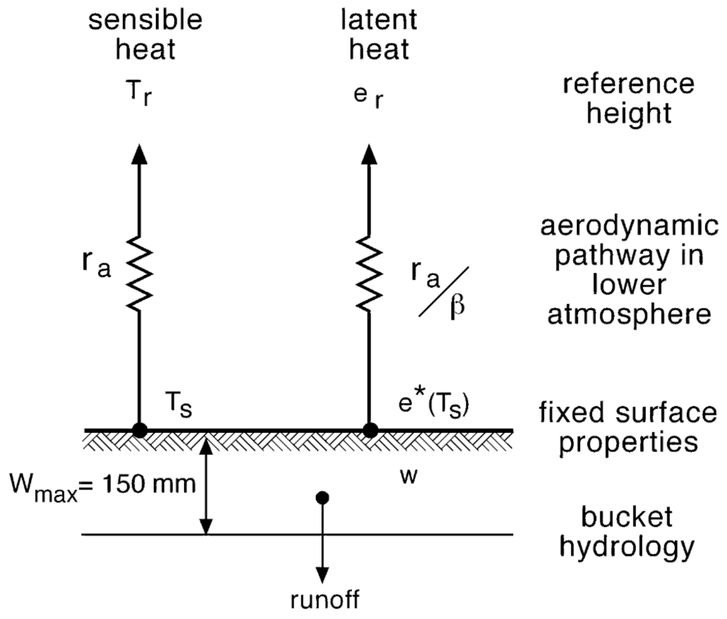
Manabe (1969)

Pros：

- Bucket model
- Energy budget
- Water budget

Cons：

- Vegetation



第二代LSM

1960s

1970s

1980s

Farquhar C3 Model

Ball Berry Stomatal Model

SiB BATS

1990s

Collatz C4 Model

Leuning Stomatal Model

2000s

2010s

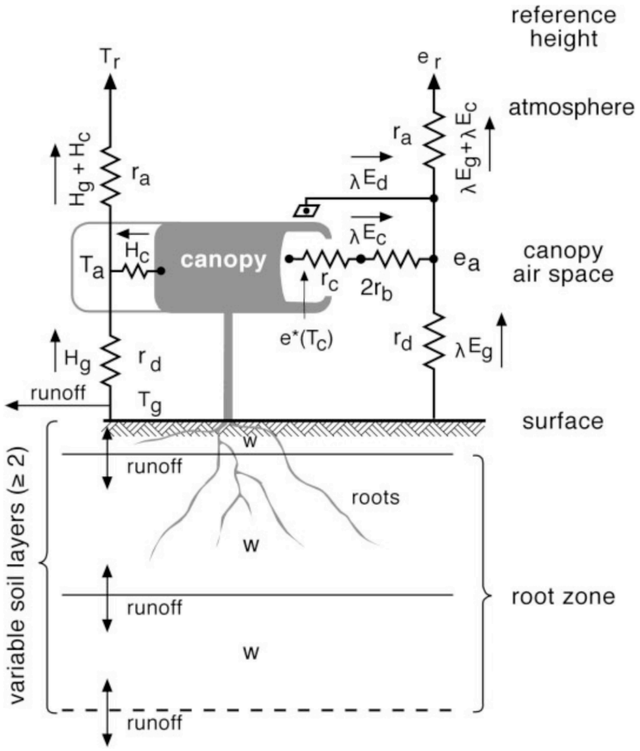
2020s

Pros：

- Multiple soil layering
- Vegetation

Cons：

- Carbon Cycle



第三代LSM

1960s

1970s

1980s

Photosynthesis Models
+
Stomatal Models

1990s

NCAR-LSM SiB2

2000s

2010s

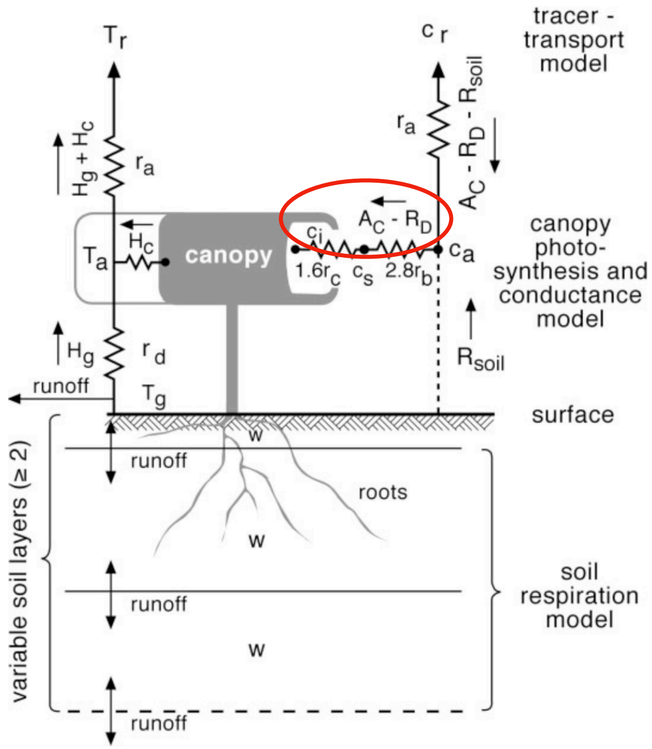
2020s

Pros：

- Photosynthesis
- Dynamic Growth

Cons：

- Too simplified
- Chemical processes



第四代LSM?

1960s

1970s

1980s

1990s

2000s

2010s

CLM4.5

2020s

CLM5

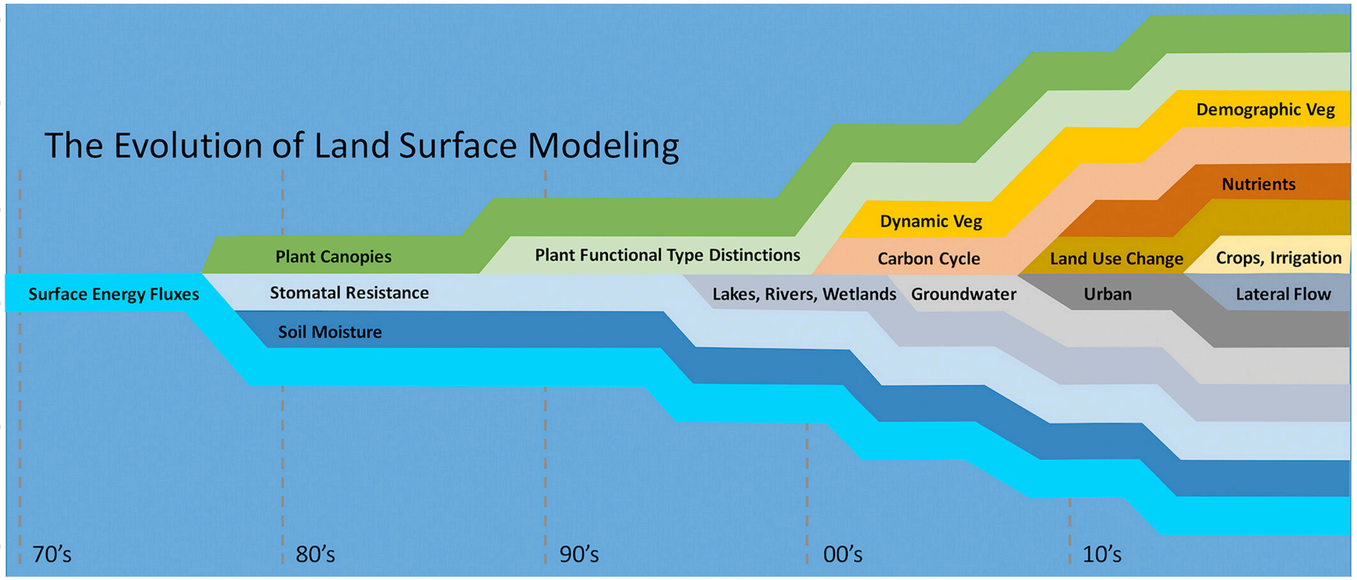
CoLM2024

Pros：

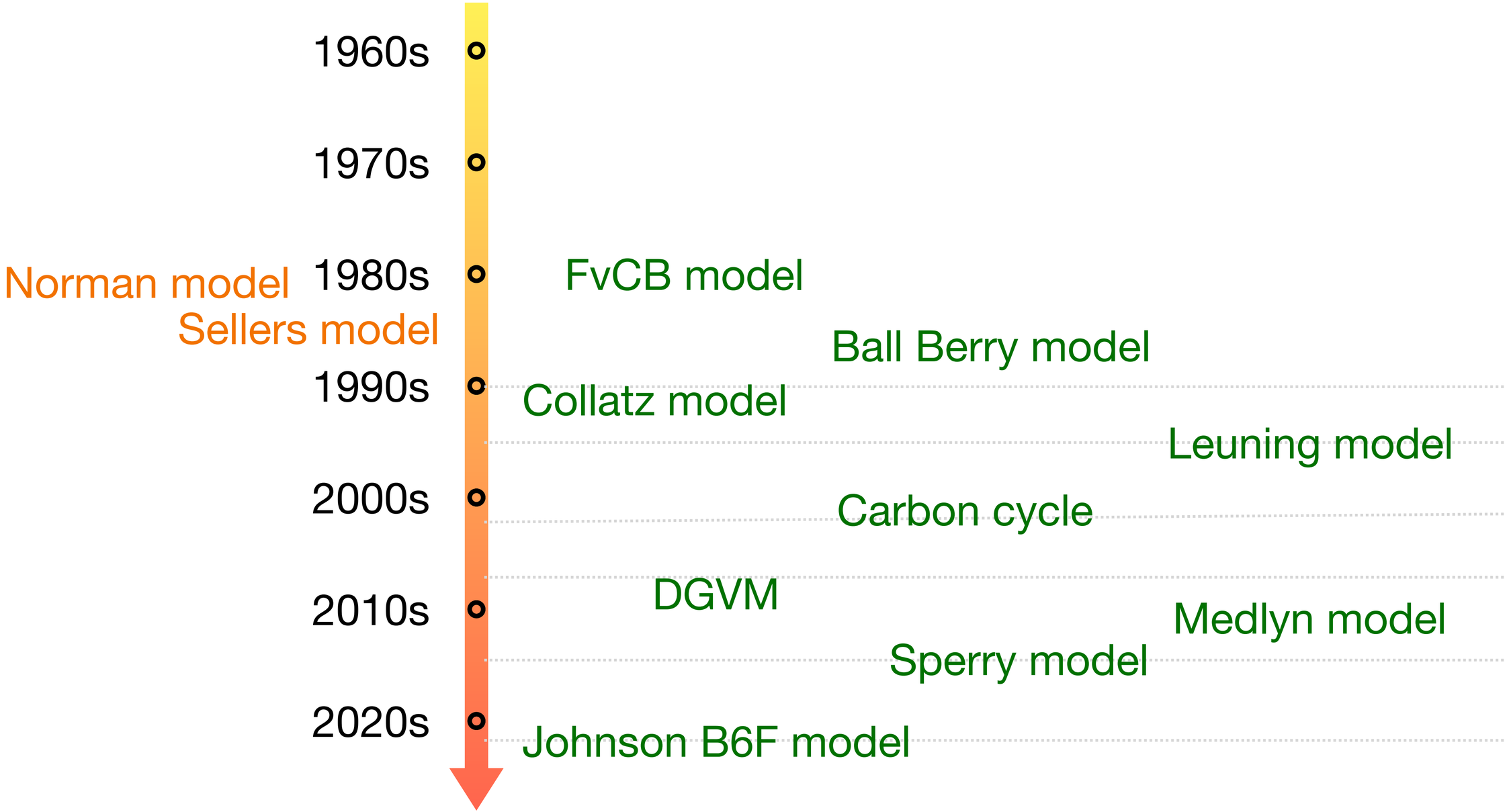
- Nutrients
- Chemical processes
- River & Lake
- City & Agriculture
- Fire
- Methane
- etc

Pros：

- Simple processes
- Calibration



不平衡的投入

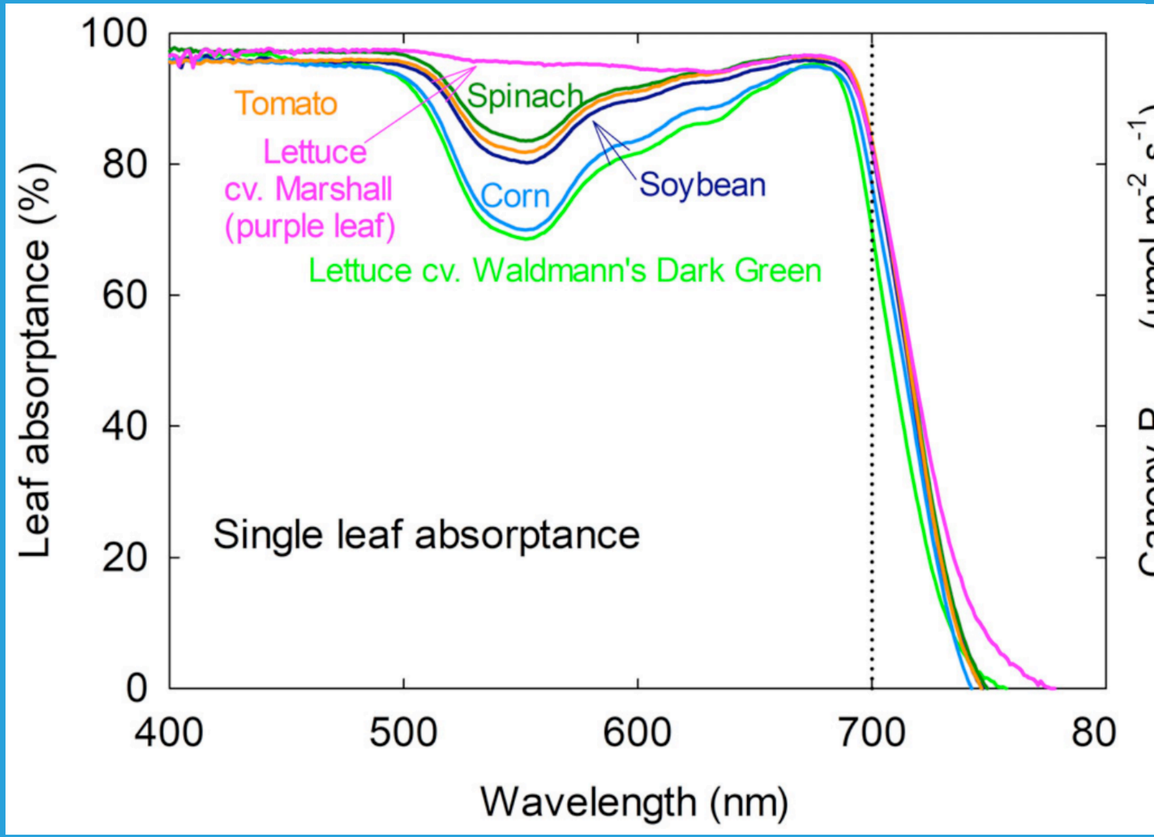

1960s
1970s
1980s
1990s
2000s
2010s
2020s
Norman model
Sellers model
FvCB model
Ball Berry model
Collatz model
Leuning model
Carbon cycle
DGVM
Medlyn model
Sperry model
Johnson B6F model

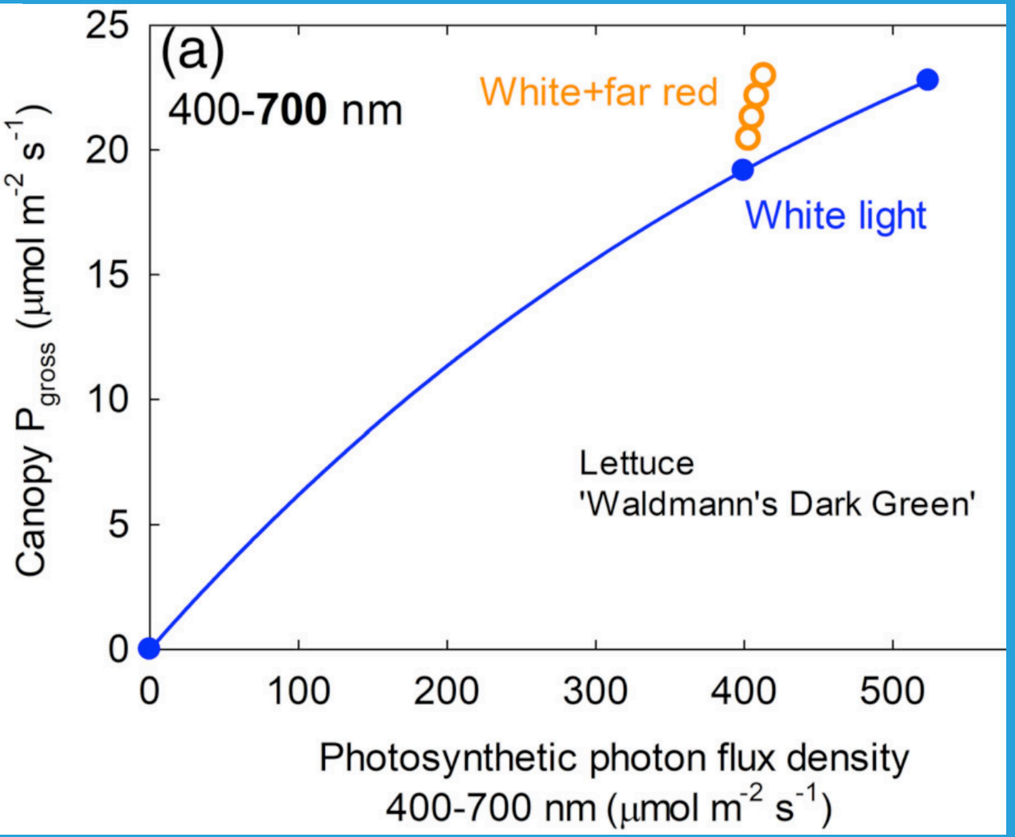
光合作用偏差来源

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

光合作用偏差来源

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





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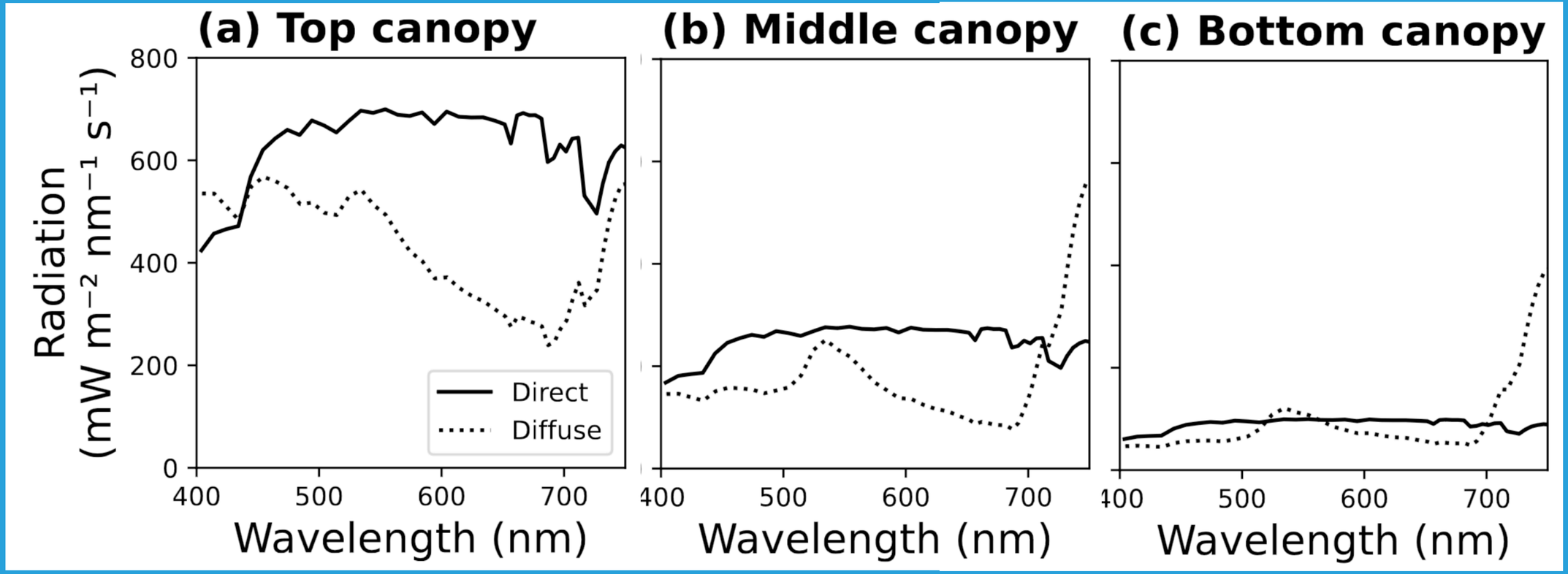

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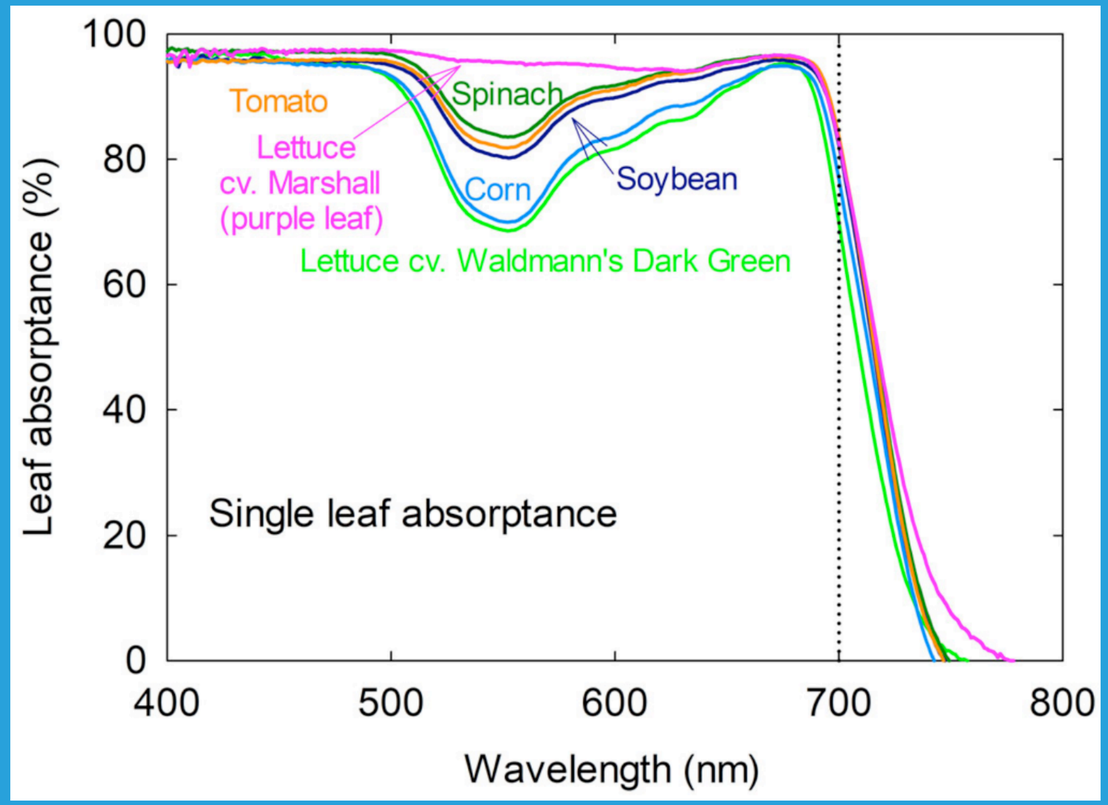

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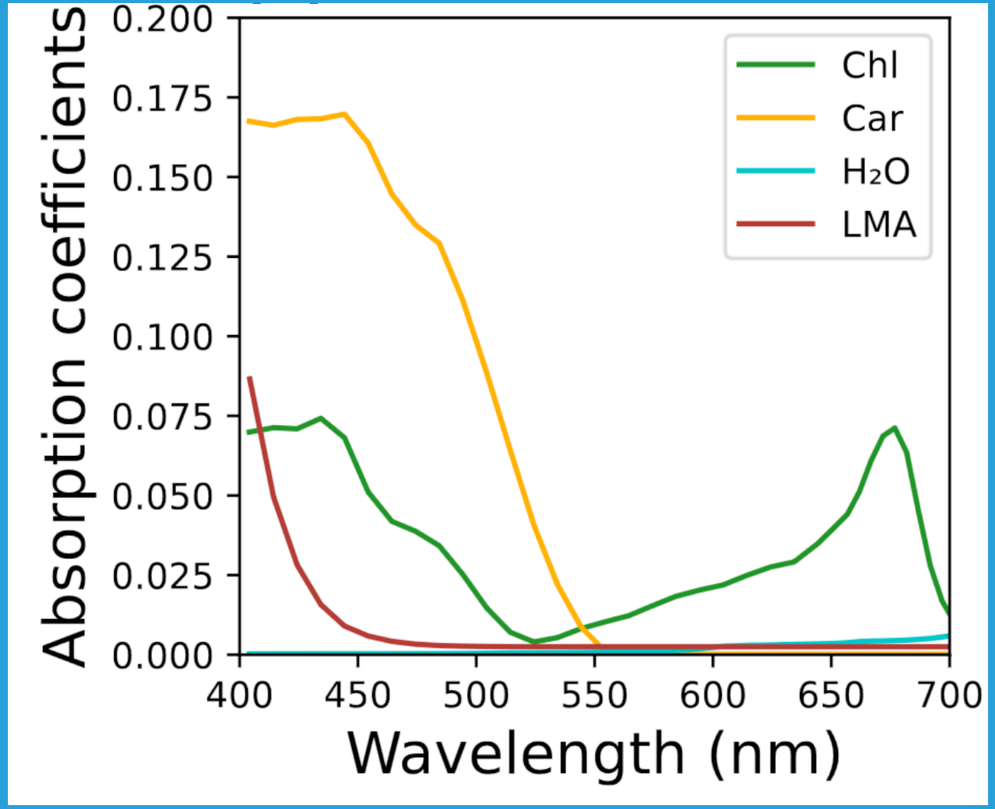

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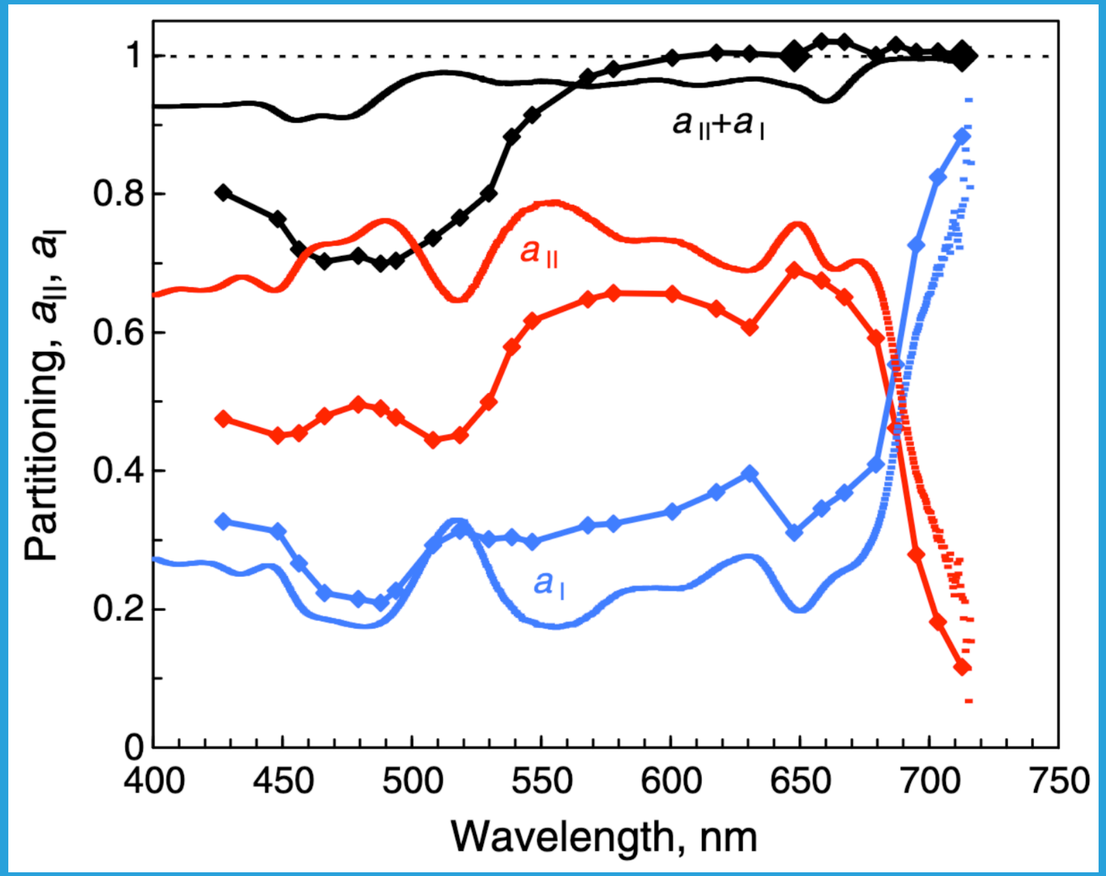

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RESEARCH ARTICLE

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

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能量平衡偏差来源

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

能量平衡偏差来源

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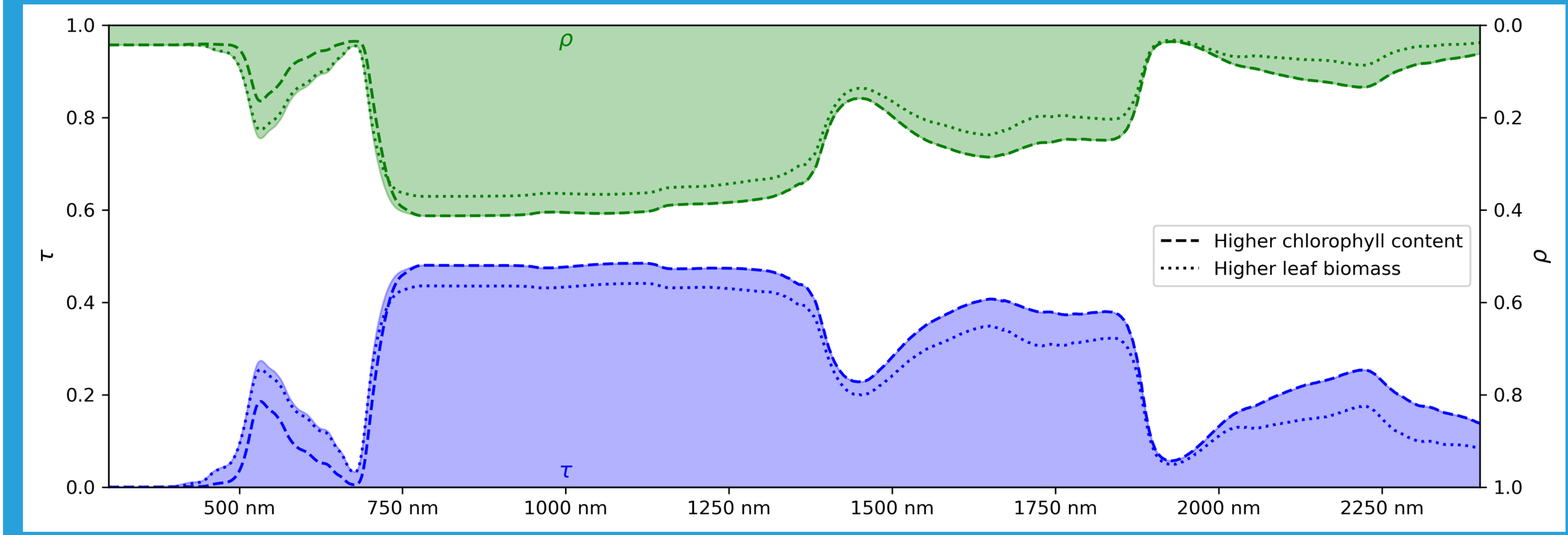
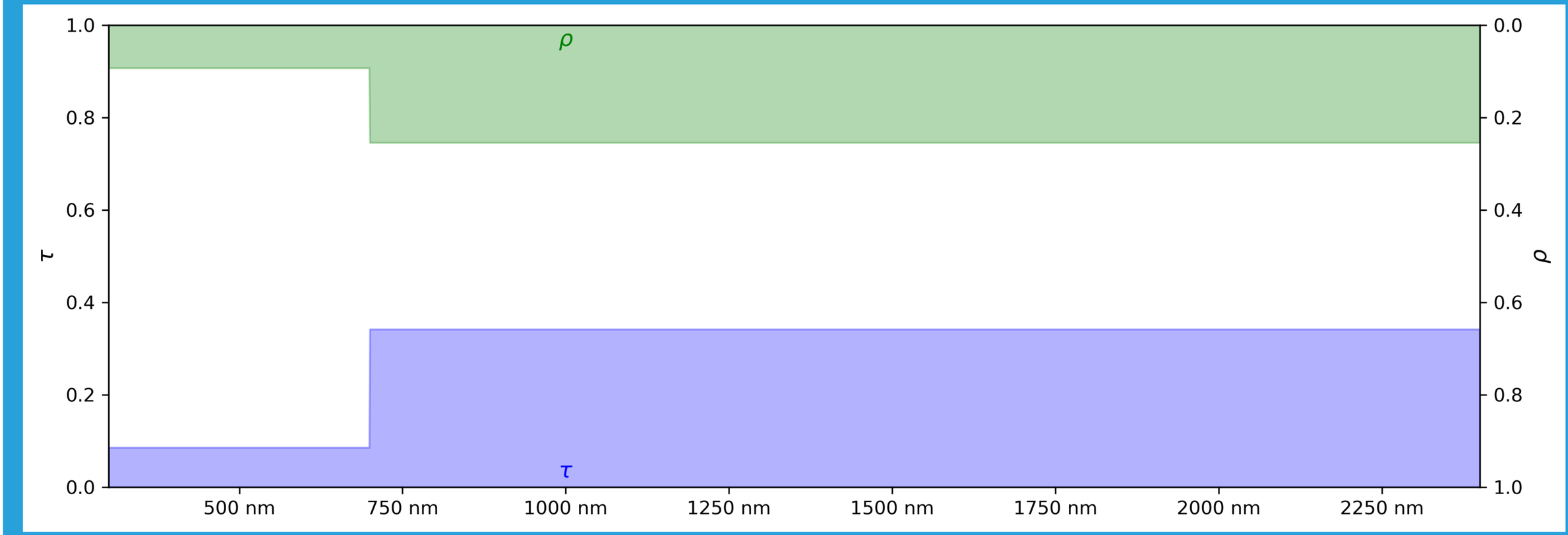
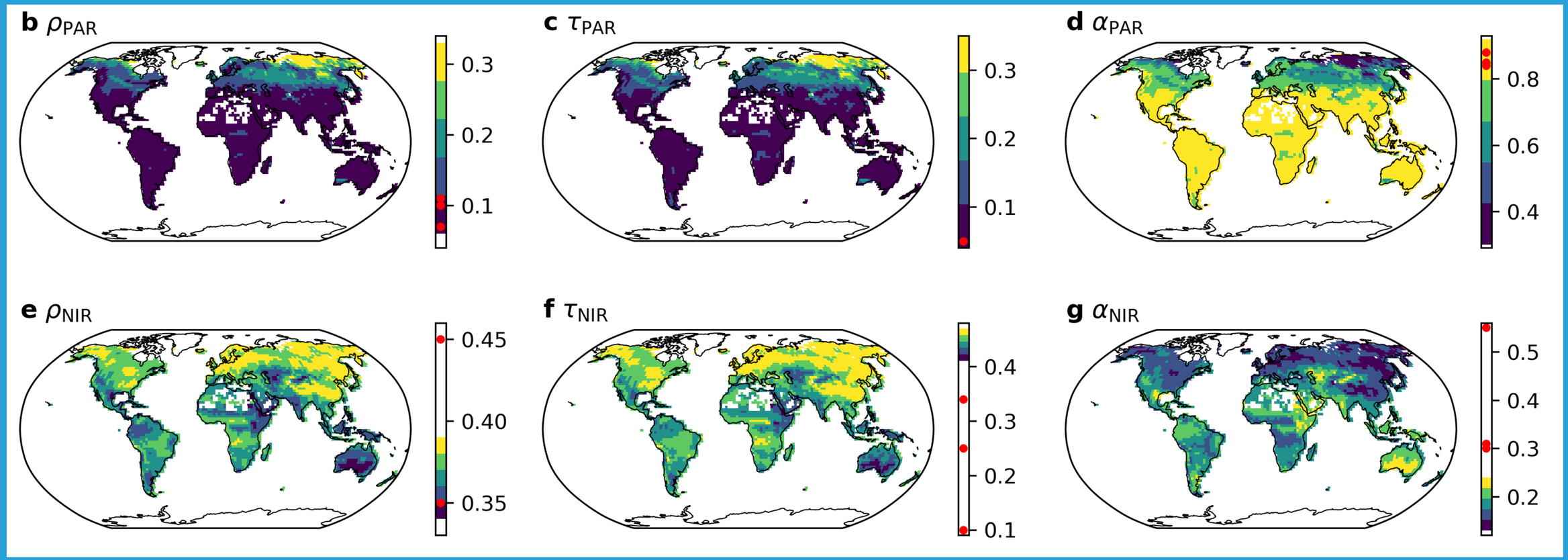


能量平衡偏差来源

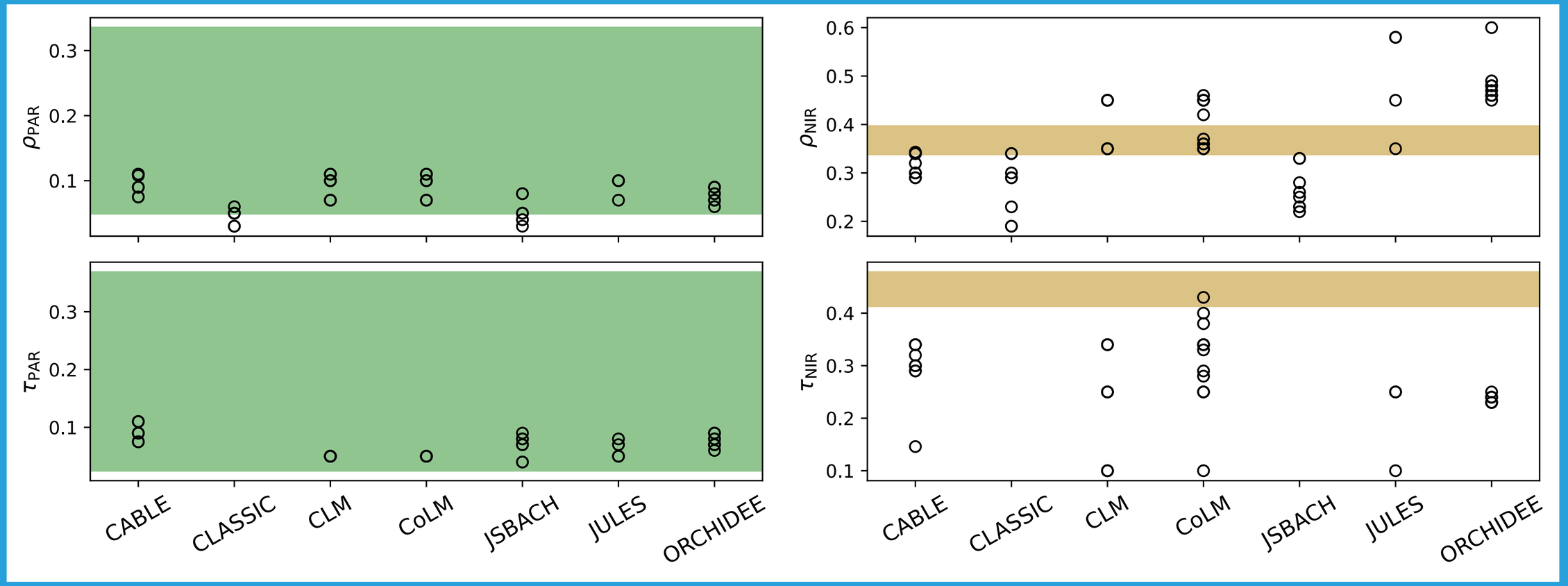
$$R_{\mathrm{SW}} = \int_{\lambda_1}^{\lambda_2} \mathrm{E}(\lambda) \cdot f_{\mathrm{absorption}}(\lambda) \cdot \mathrm{d}\lambda$$



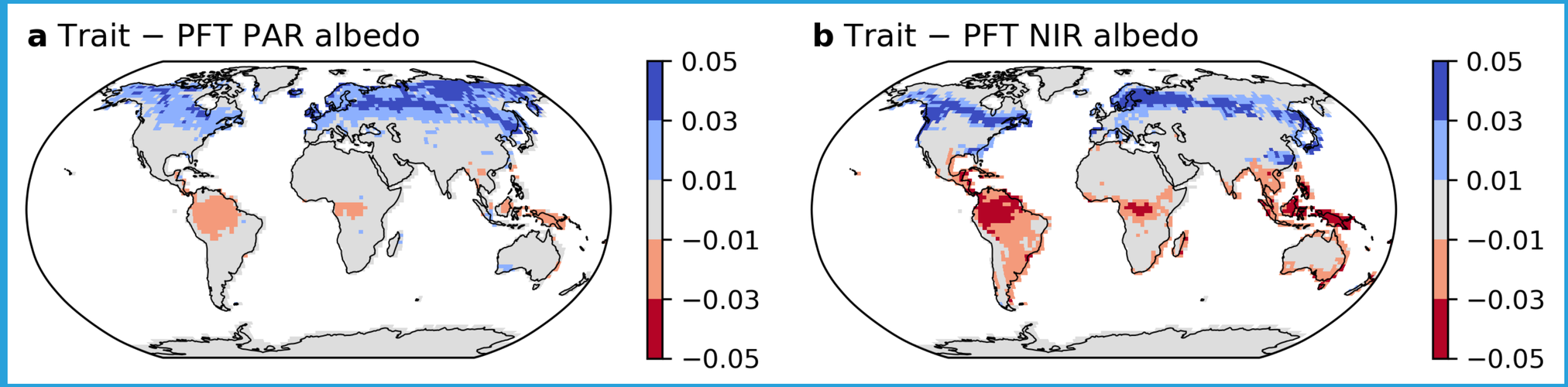
能量平衡偏差来源


b ρ_{PAR}
0.3
0.2
0.1
c τ_{PAR}
0.3
0.2
0.1
d α_{PAR}
0.8
0.6
0.4
e ρ_{NIR}
0.45
0.40
0.35
f τ_{NIR}
0.4
0.3
0.2
0.1
g α_{NIR}
0.5
0.4
0.3
0.2

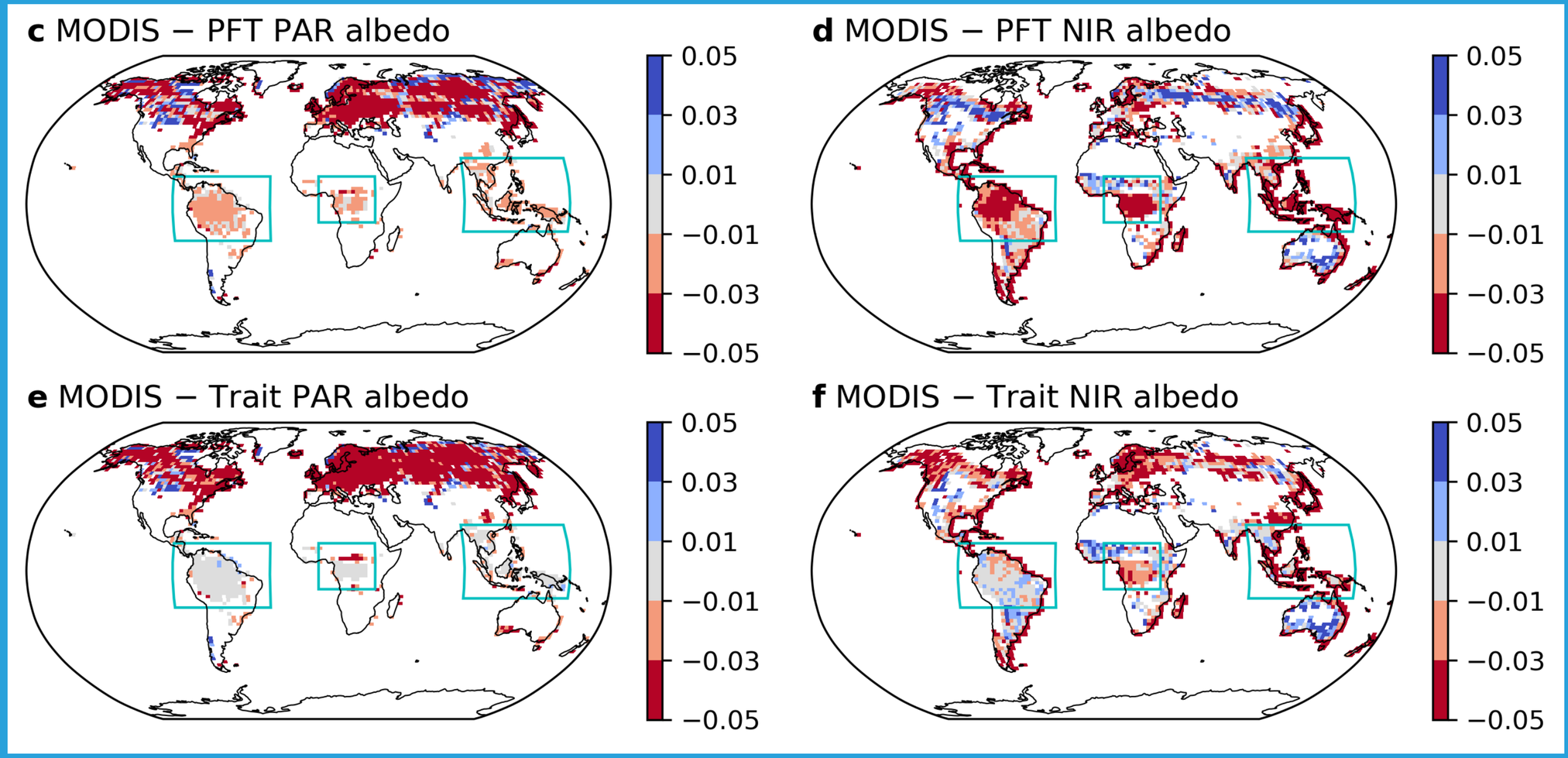
能量平衡偏差来源


ρ_{PAR}
τ_{PAR}
ρ_{NIR}
τ_{NIR}
CABLE
CLASSIC
CLM
CoLM
JSBACH
JULES
ORCHIDEE

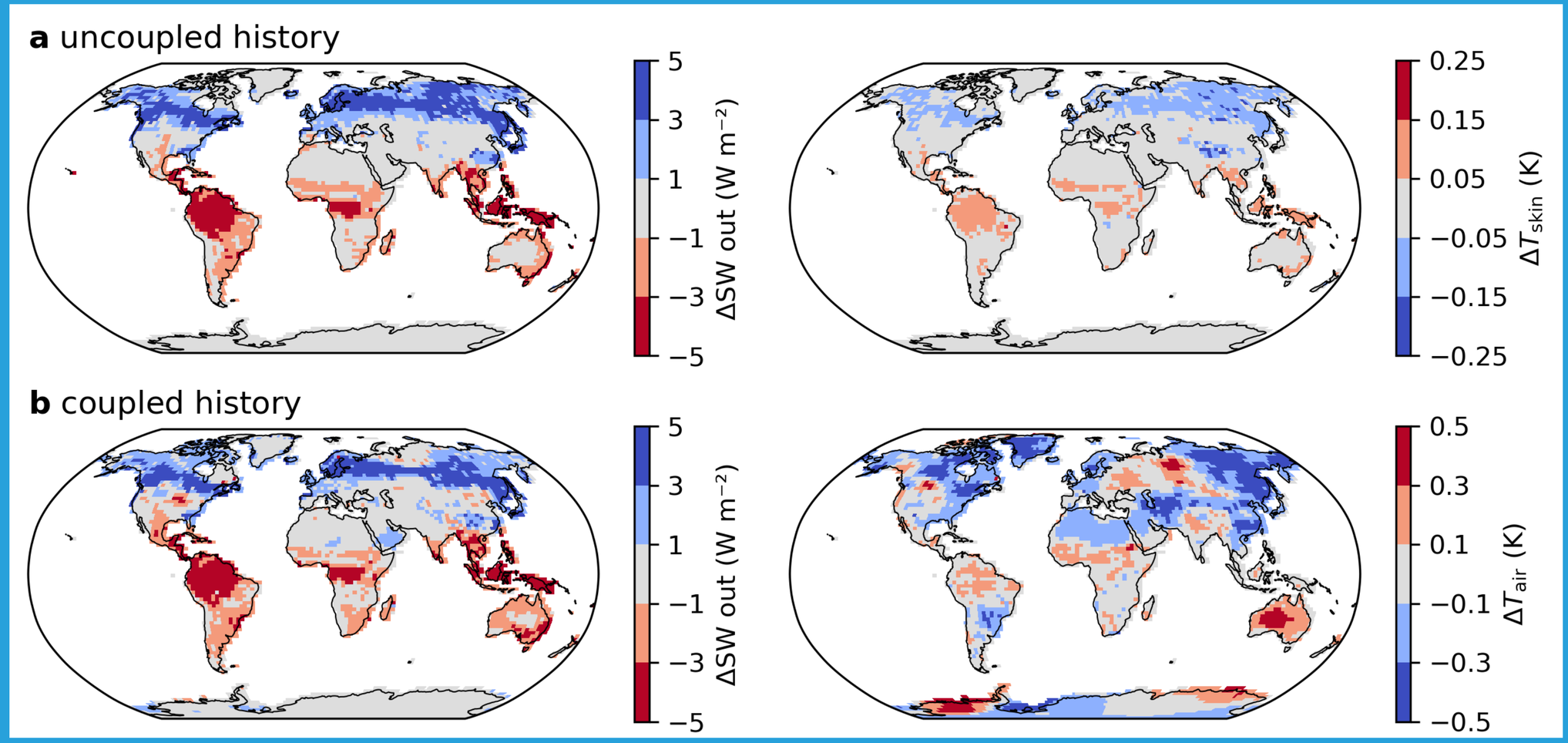
能量平衡偏差来源


a Trait − PFT PAR albedo
0.05
0.03
0.01
−0.01
−0.03
−0.05
b Trait − PFT NIR albedo
0.05
0.03
0.01
−0.01
−0.03
−0.05

能量平衡偏差来源


c MODIS − PFT PAR albedo
d MODIS − PFT NIR albedo
e MODIS − Trait PAR albedo
f MODIS − Trait NIR albedo
0.05
0.03
0.01
−0.01
−0.03
−0.05

能量平衡偏差来源


a uncoupled history
b coupled history
5
3
1
−1
−3
−5
ΔSW out (W m⁻²)
0.25
0.15
0.05
−0.05
−0.15
−0.25
ΔTskin (K)
0.5
0.3
0.1
−0.1
−0.3
−0.5
ΔTair (K)

结论

- 从“植物功能类群”到“植物功能性状”
- 从广谱辐射传输到高光谱辐射传输
- 更多的植物生理过程

致谢

第一届未来大气科学论坛
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