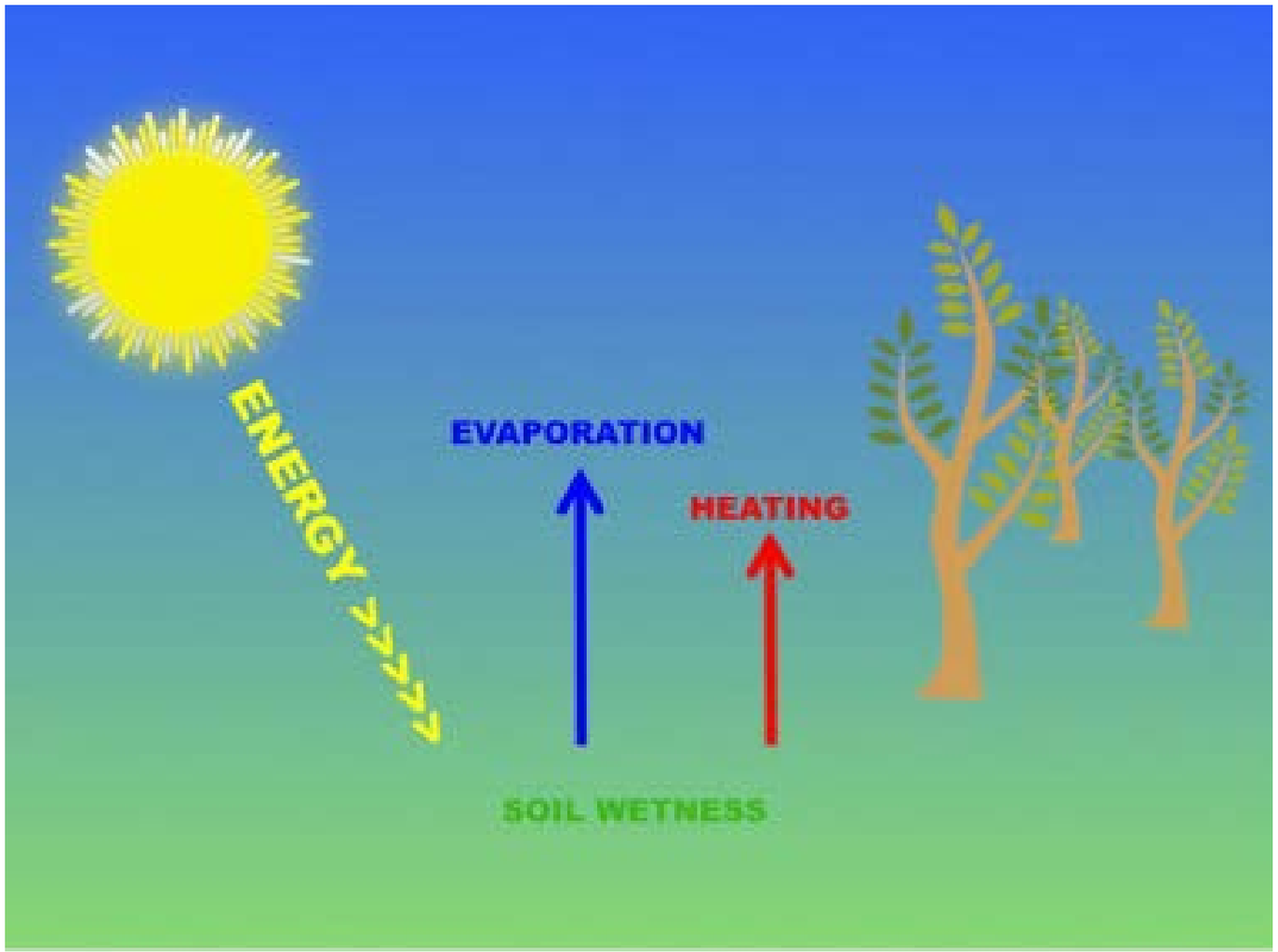
Multiscale Modeling of Land-Atmosphere Interactions in CESM

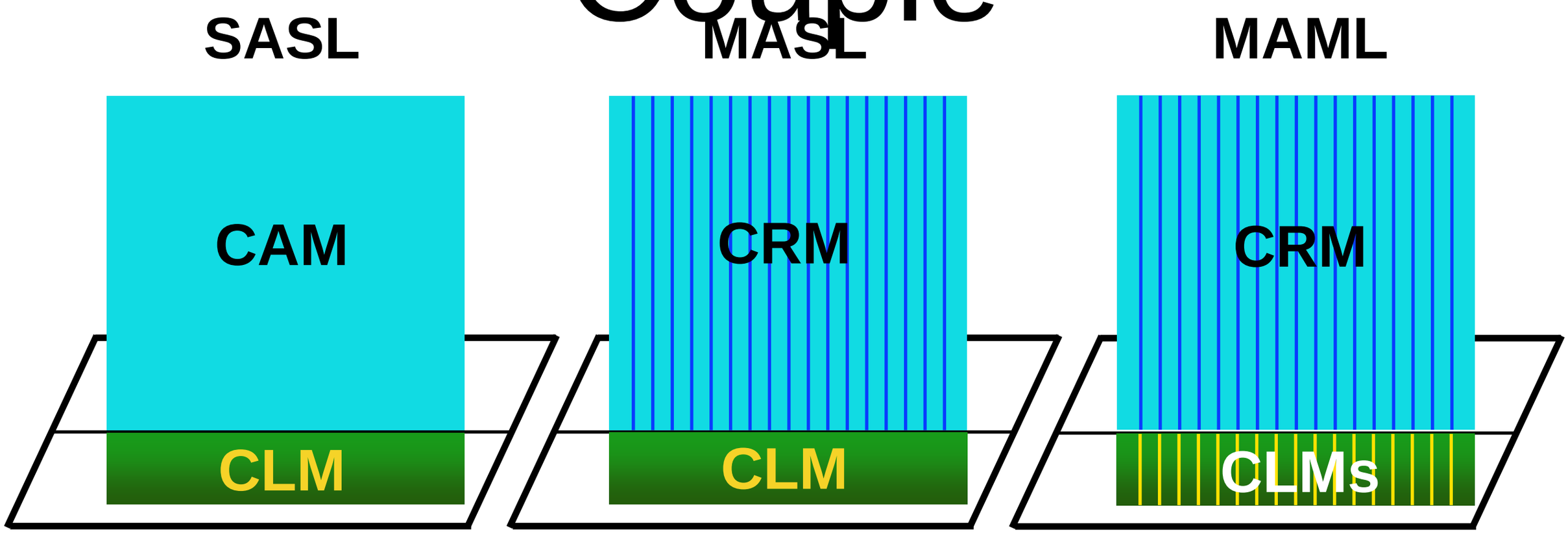
Scott Denning
David Randall
Ian Baker
Mark Branson
Joe Berry
Don Dazlich

Land-Atmosphere Coupling in the Real World, and in Observations

- Stomates -> Leaves -> Plants -> Ecosystems -> Landscapes
- Leaf cuvettes -> soil probes -> greenhouses -> eddy covariance
- Satellite Imagery
- CAM Grid Cells?
- CLM tuning?



Three Ways to Couple



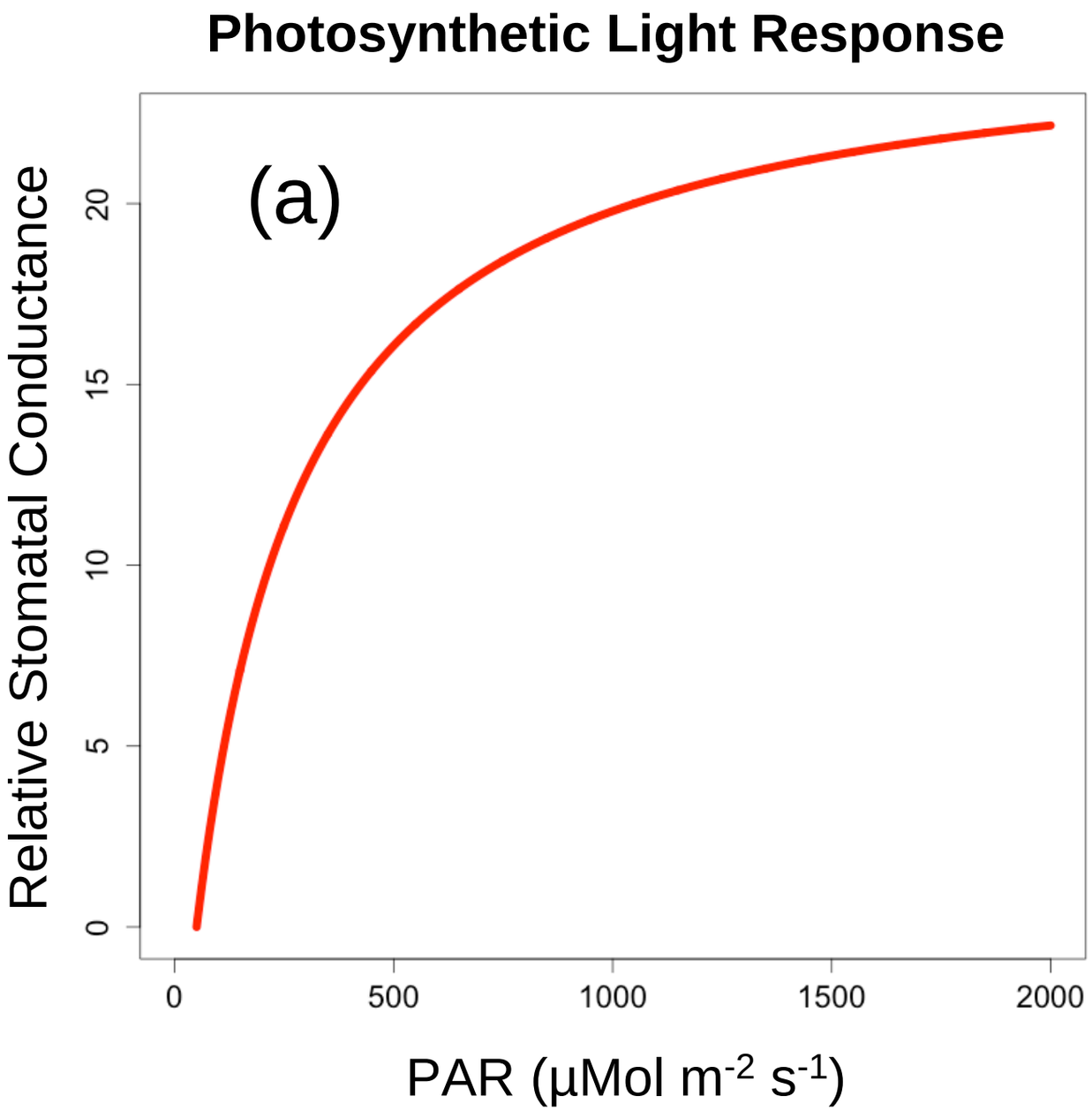
Single Atmosphere Single Land	Multi-Atmosphere Single Land	Multi-Atmosphere Multi-Land
(standard CESM)	(SP CESM)	(“multi-instance” SP CESM)

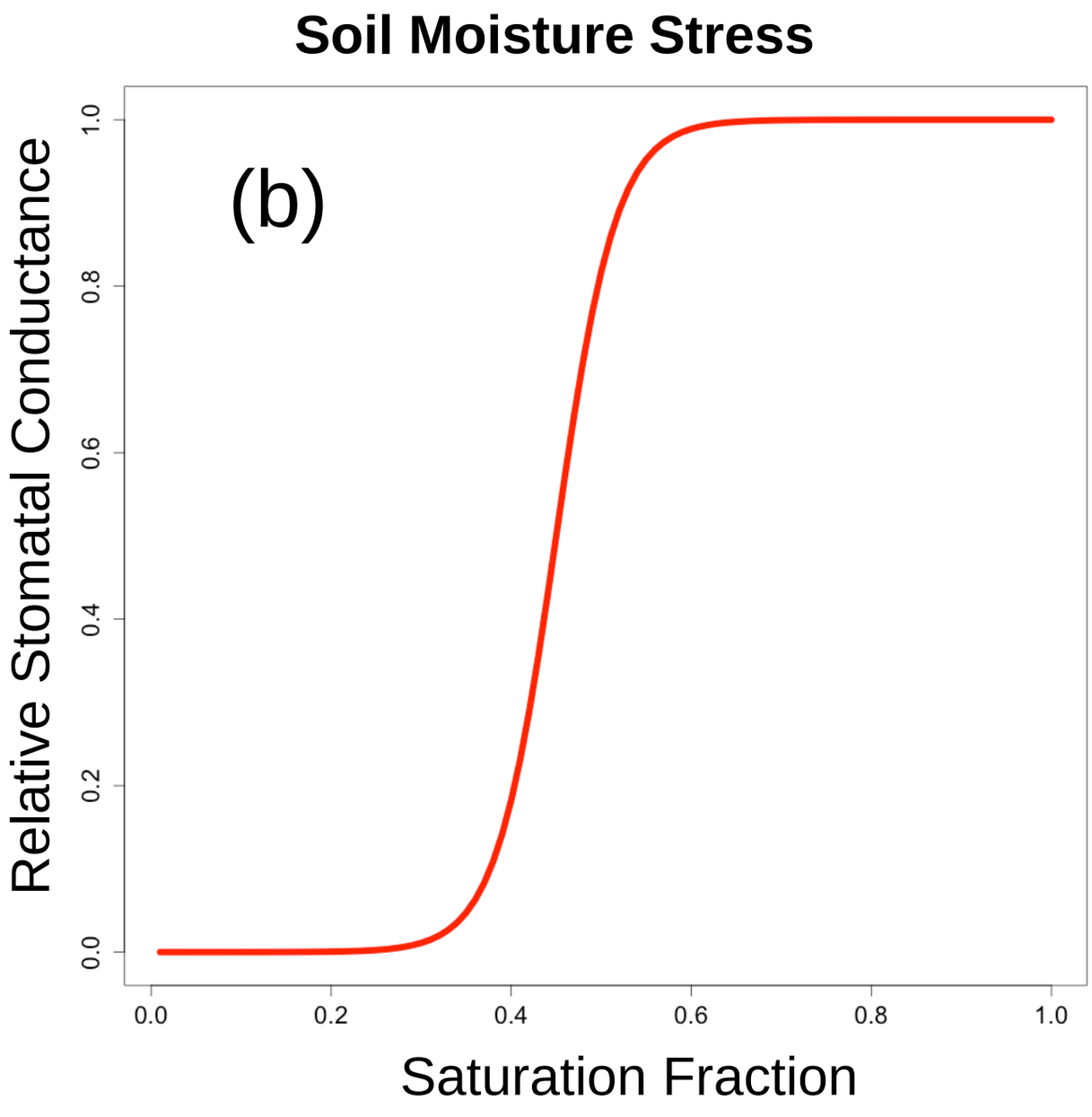
10 km

Tapajos Forest Equatorial Amazon

SiB-SAM (not CLM!)
SASL, MASL, & MAML

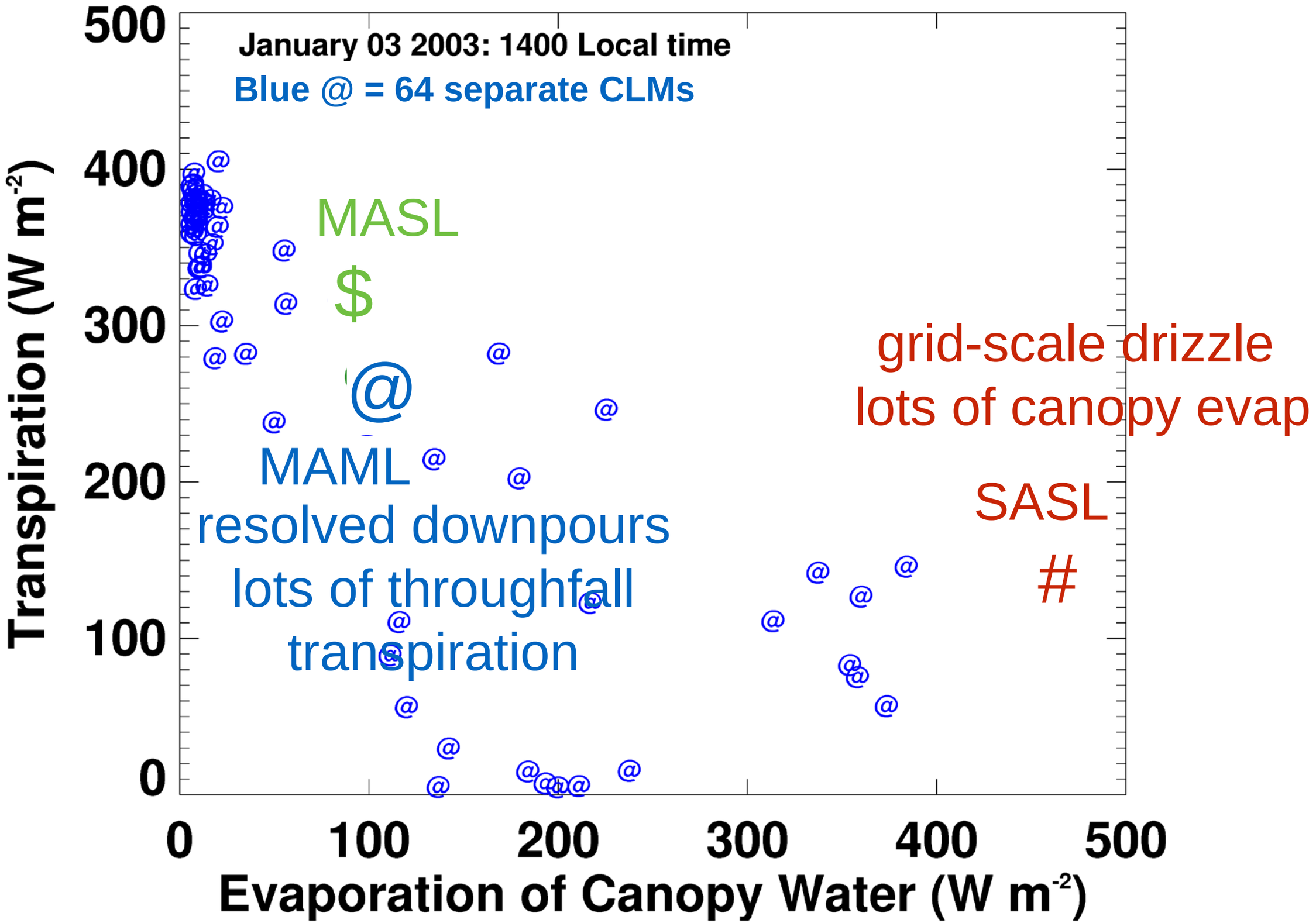
Nonlinear Coupling



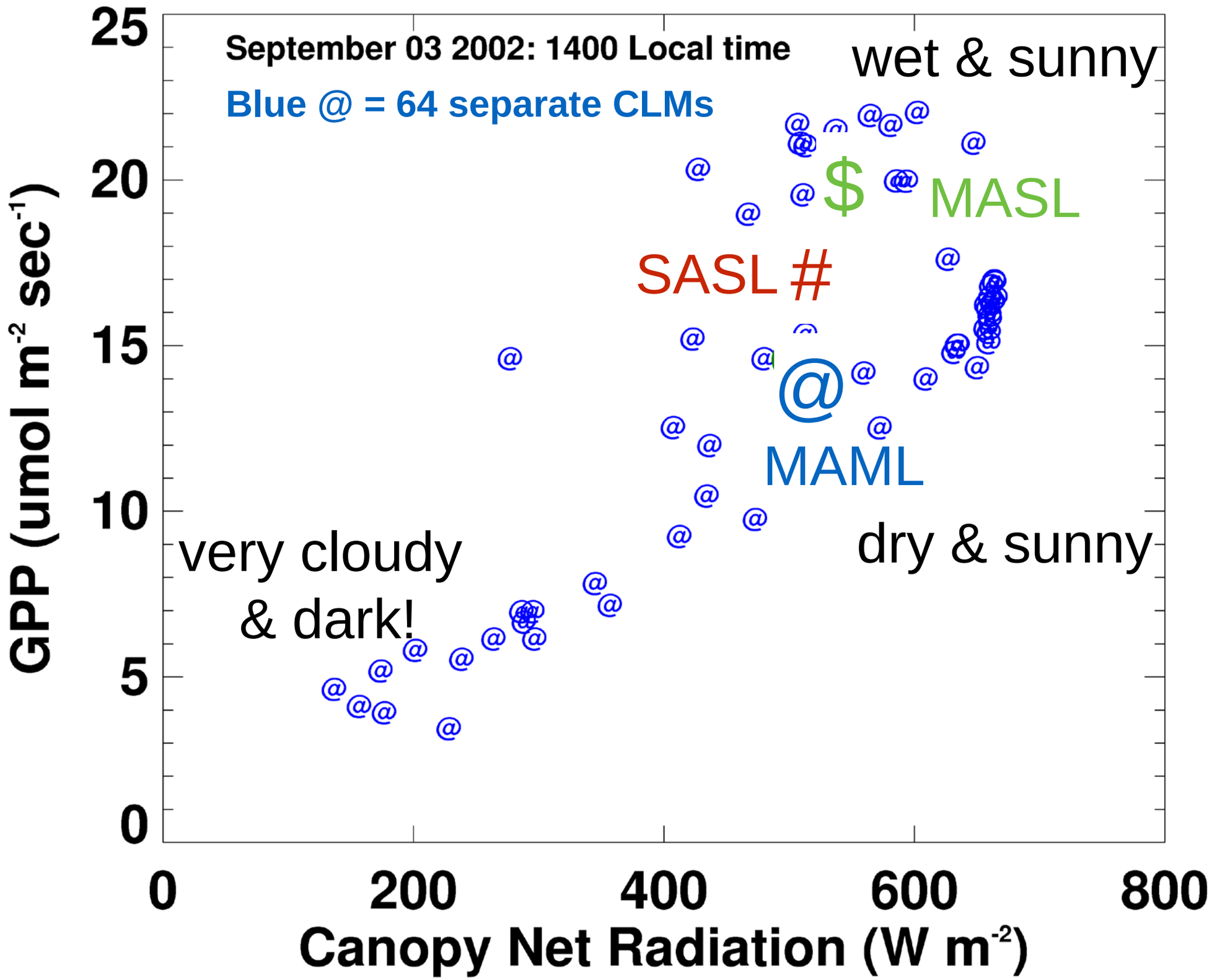


$$f(\bar{x}) \neq \overline{f(x)}$$

Surface Hydrology

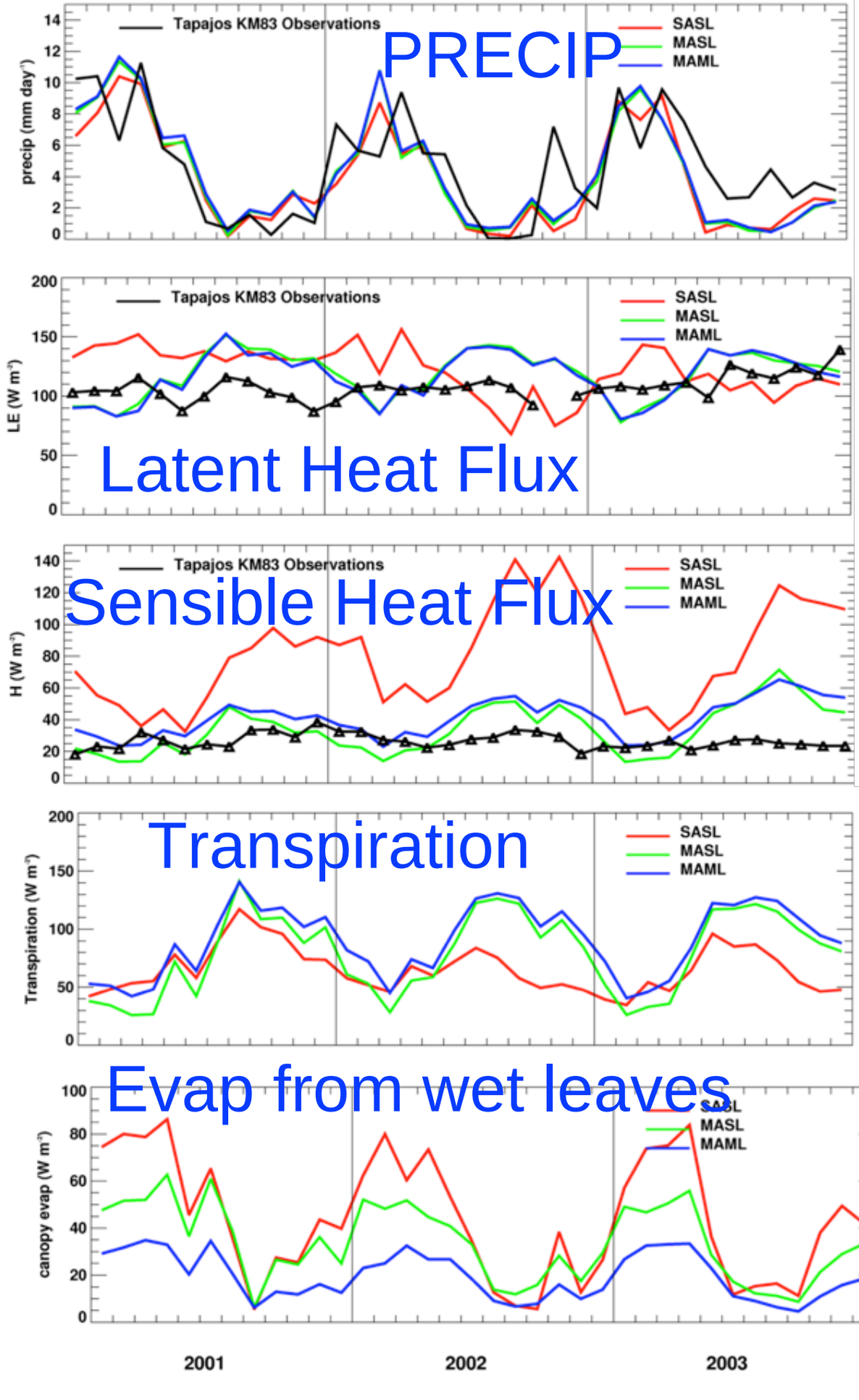


Photosynthesis Light Response

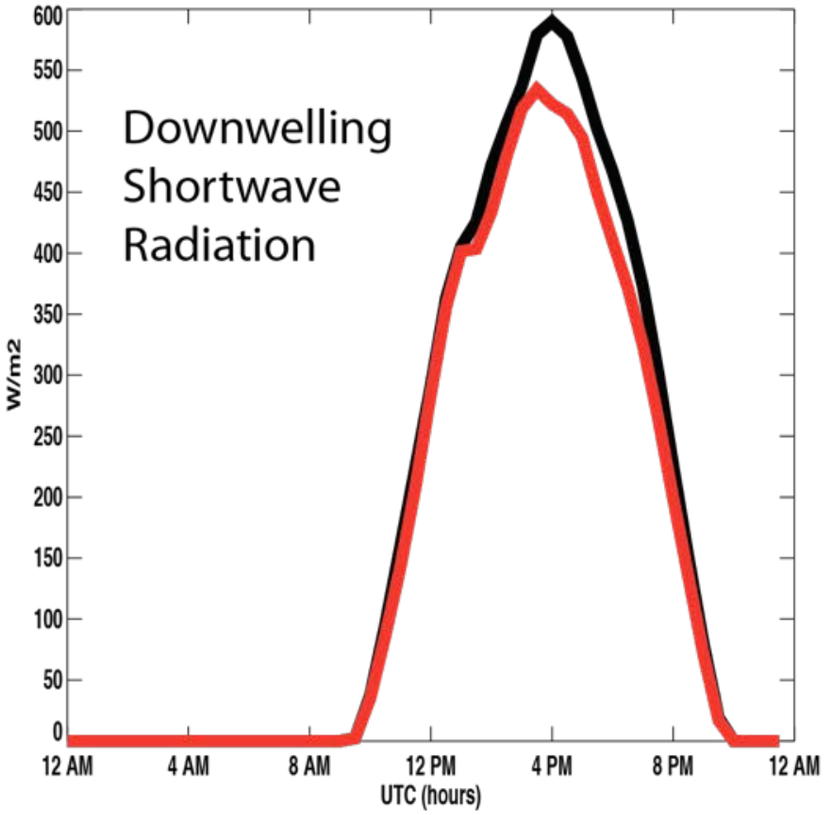


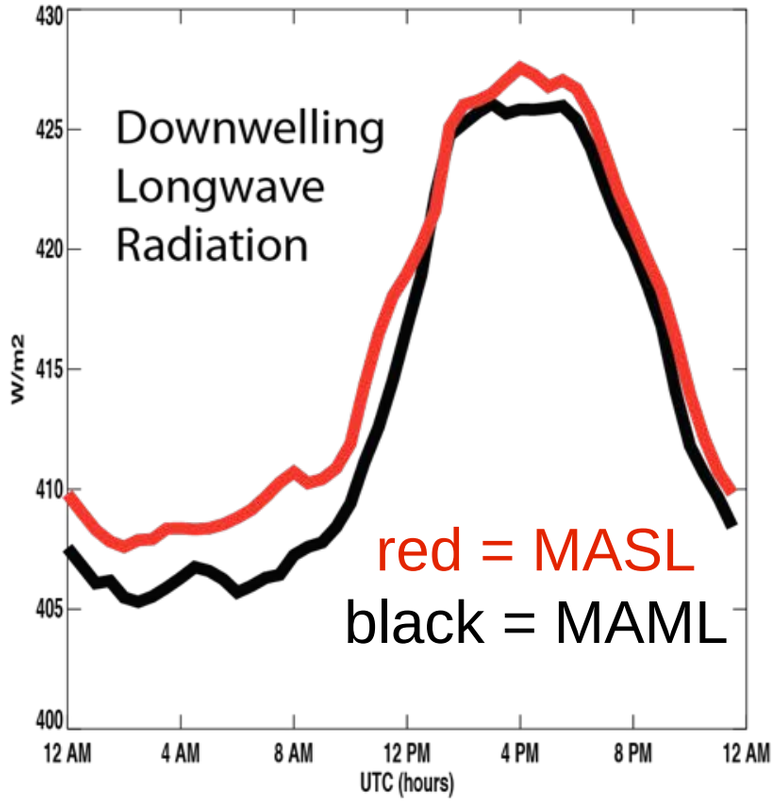
Three Years at a Flux Tower

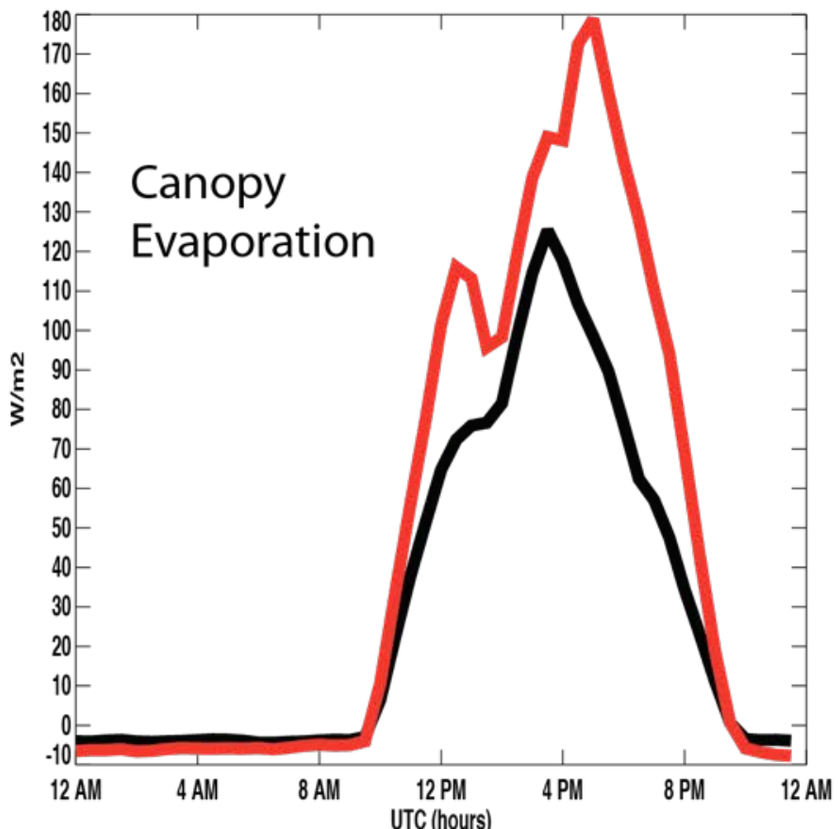
- Precipitation essentially unchanged because it's driven by lateral BC
- Wet-season LE dominated by canopy evaporation in SASL
- Dry-season transpiration collapses in SASL, but not in MASL or MAML
- **Dry-season H way too high in SASL**, much better in MASL/MAML
- Partition of water very different depending on scale of coupling, strongly affects monthly means

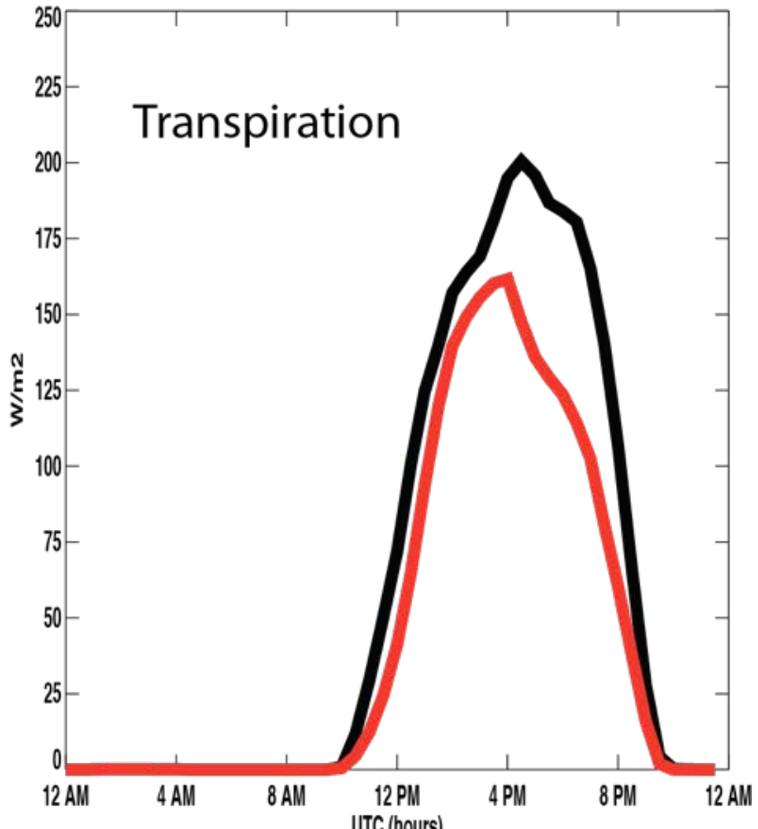


Energy Budgets



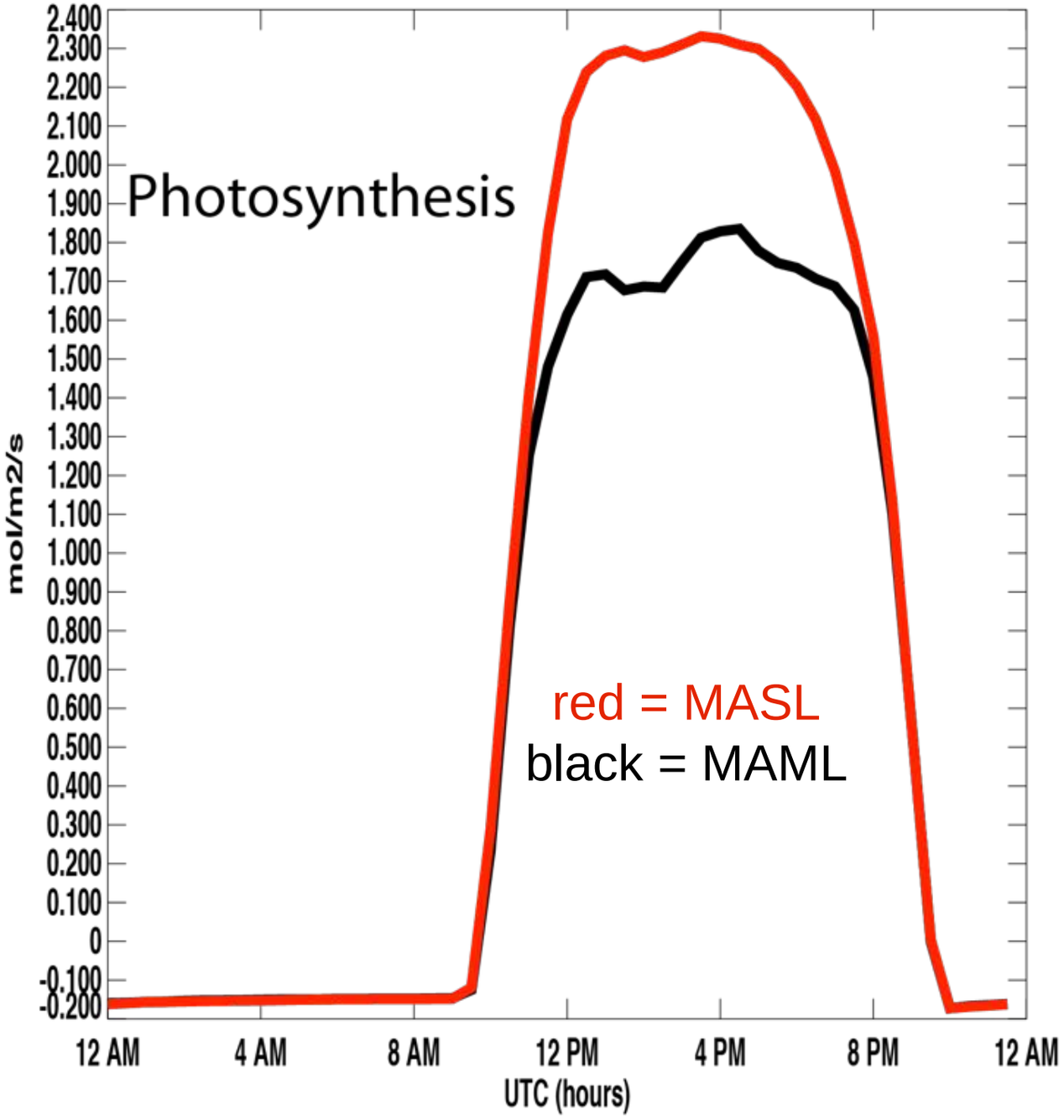


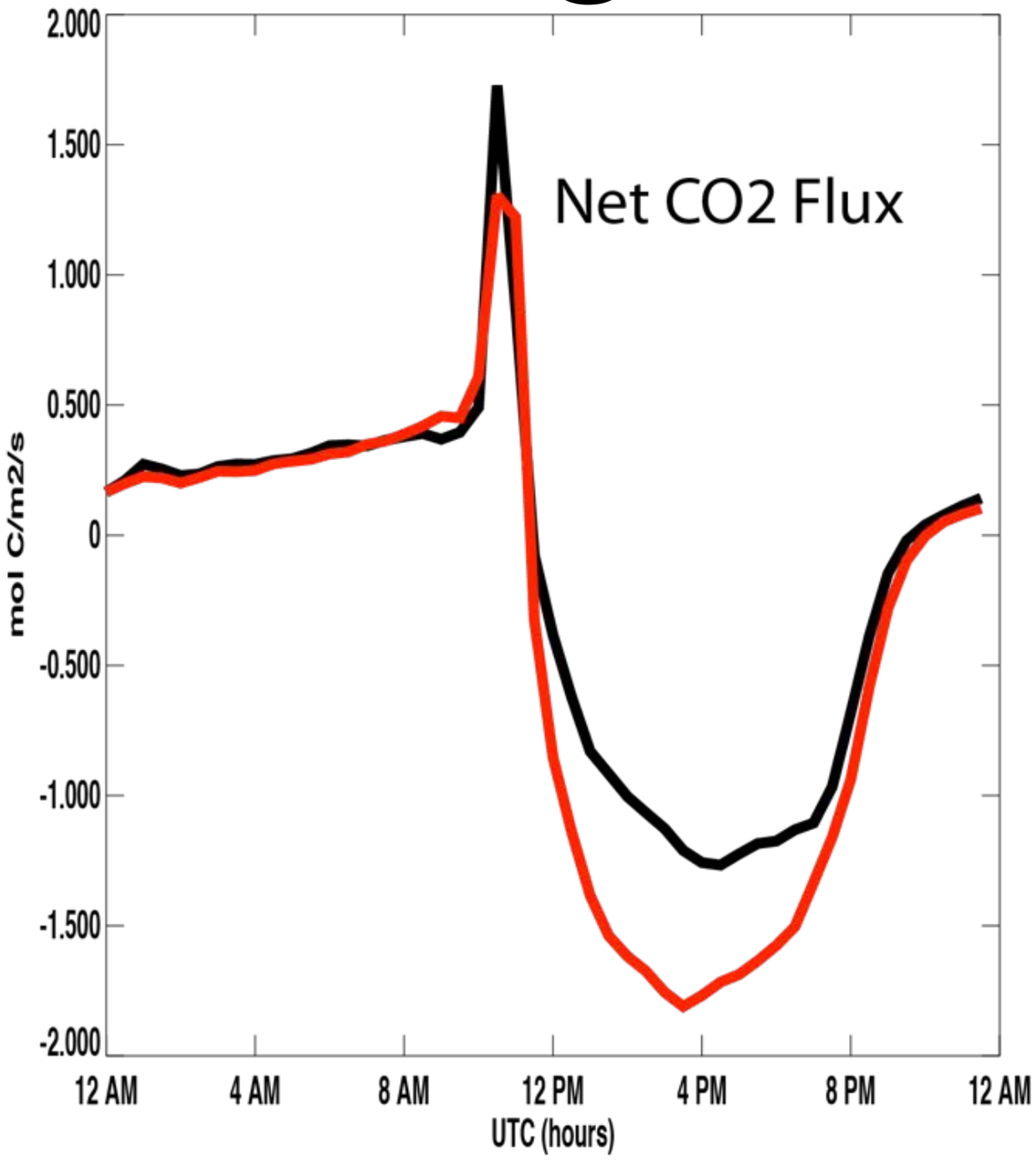




- 20 days, mean diurnal cycles
- Changes to clouds, radiation, and surface fluxes
- Huge shift of latent energy from canopy evaporation to transpioration

Carbon Budgets





- MAML model shows 20% less photosynthesis, 50% less net CO2 flux from atmosphere!

DB: SAM-SiB3_TAPAJOS.nc
Cycle: 360 Time:8.37083

CO2

Pseudocolor
Var: CO2
Units: ppmv
390.0
385.0
380.0
375.0
370.0
Max: 388.2
Min: 366.6

Contour
Var: W
Units: m/s
5
3
1
-1
Max: 0.3165
Min: -0.3708

Sunrise

Free troposphere

trade wind layer

residual layer

height (x10^3 m)
14
12
10
8
6
4
2

20
40
60
80
100
120
x (x10^3 m)

DB: SAM-SiB3_TAPAJOS.nc
Cycle: 365 Time:8.475

CO2

Mid-Morning

Pseudocolor
Var: CO2
Units: ppmv
390.0
385.0
380.0
375.0
370.0
Max: 385.0
Min: 355.8

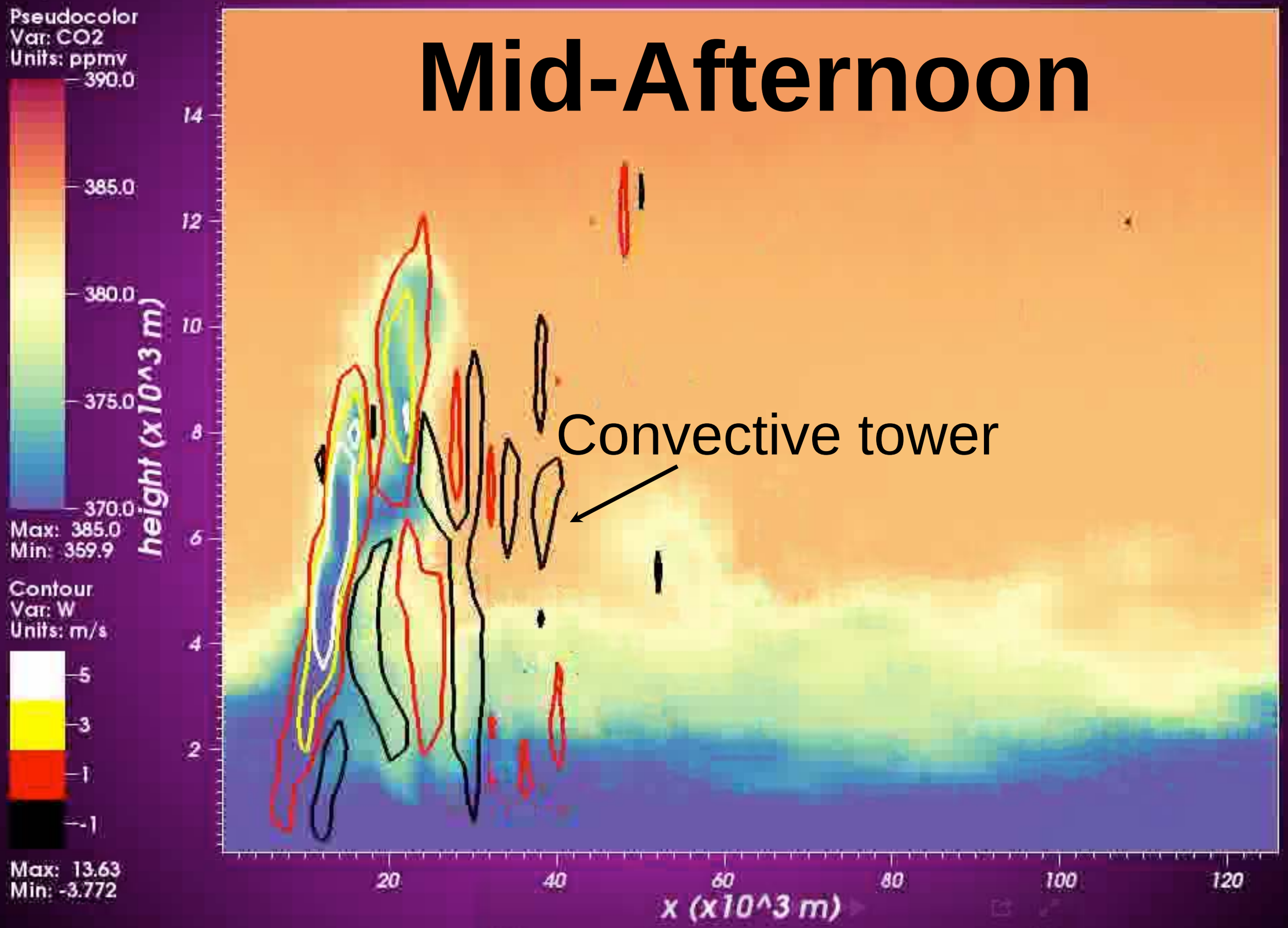
Contour
Var: W
Units: m/s
5
3
1
-1
Max: 1.896
Min: -1.385

height (x10^3 m)
14
12
10
8
6
4
2

20
40
60
80
100
120
x (x10^3 m)

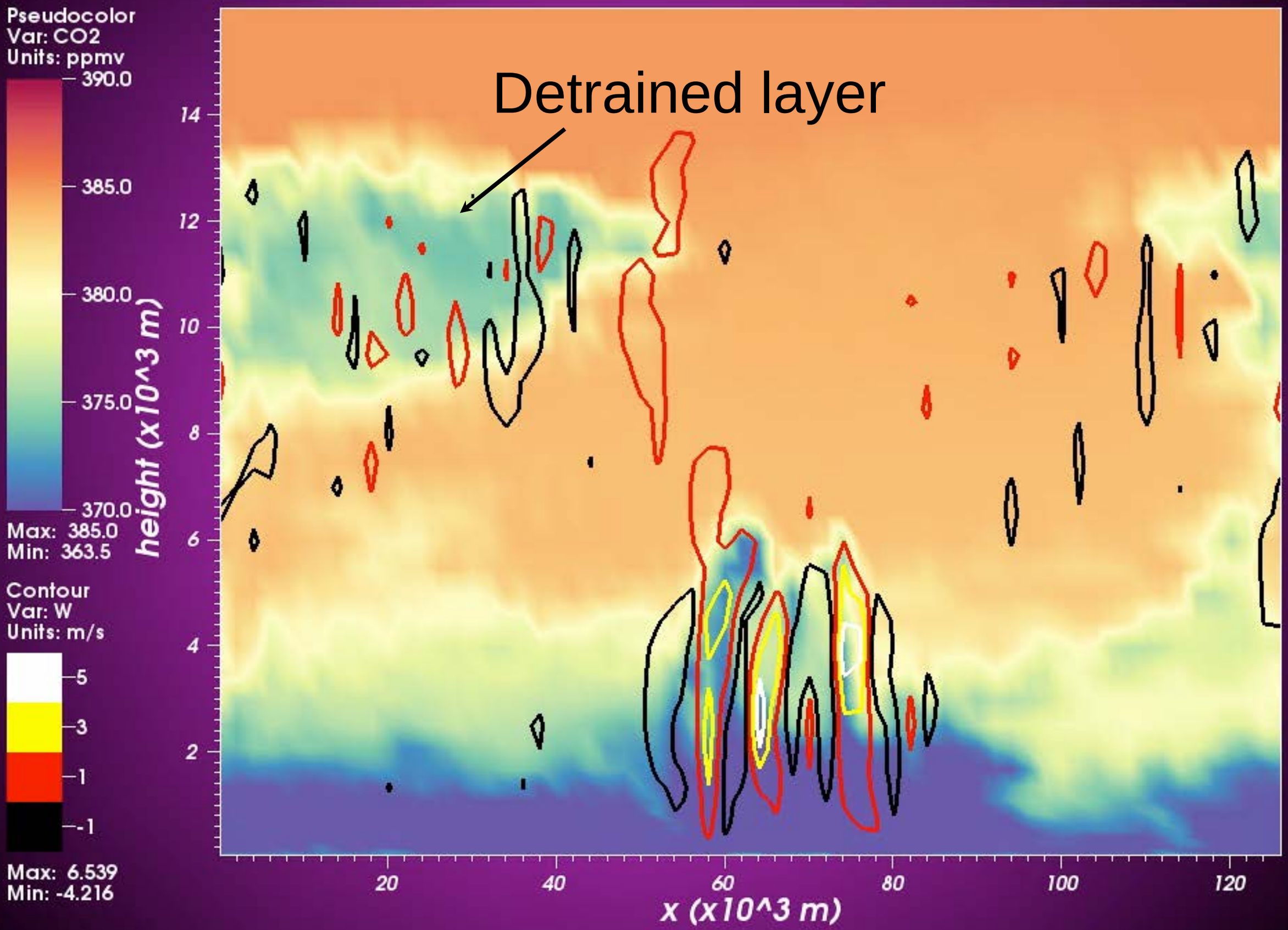
CO2

Mid-Afternoon



DB: SAM-SiB3_TAPAJOS.nc
Cycle: 385 Time:8.89167

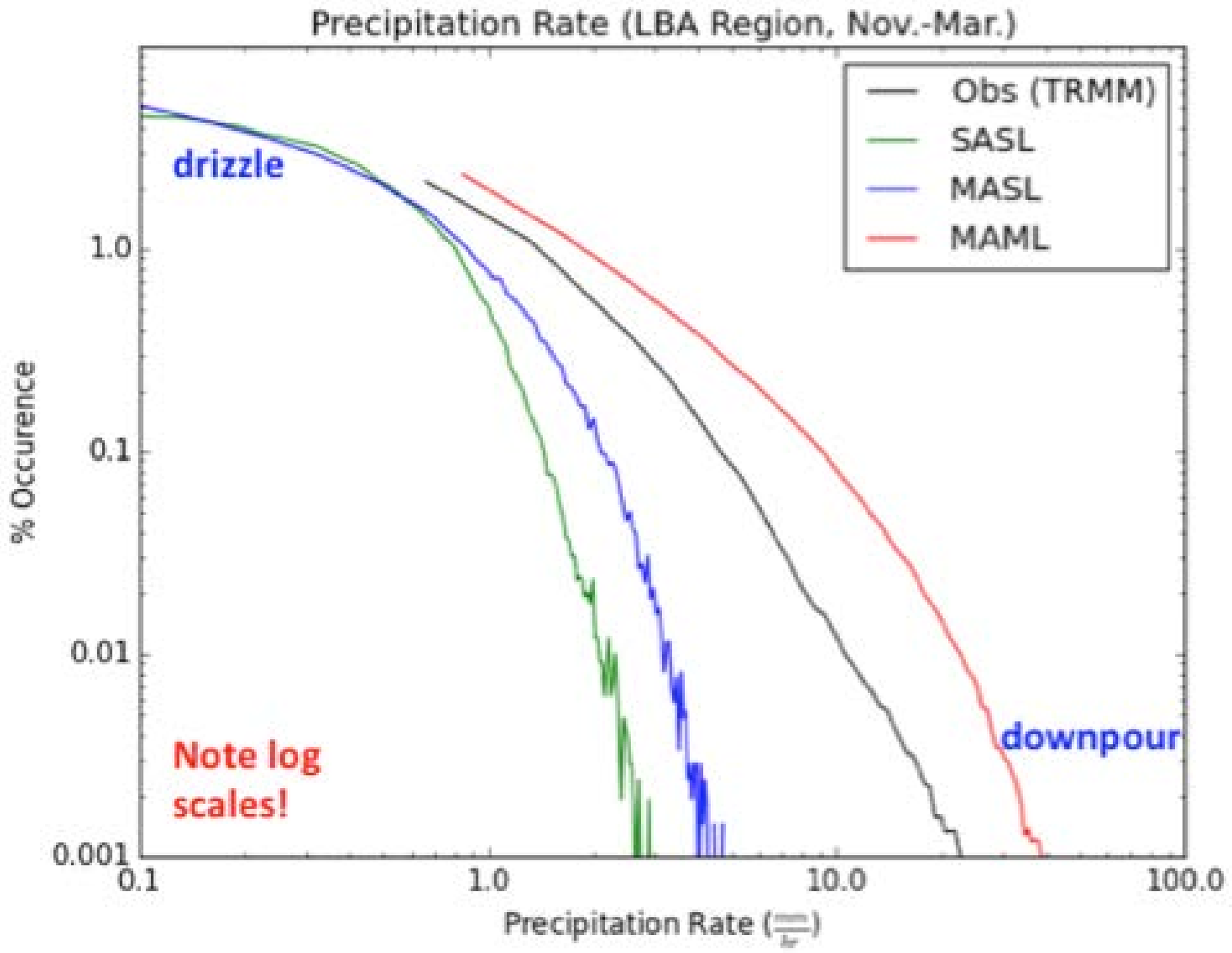
CO2



Global Multiscale Climate Simulations with SP-CESM

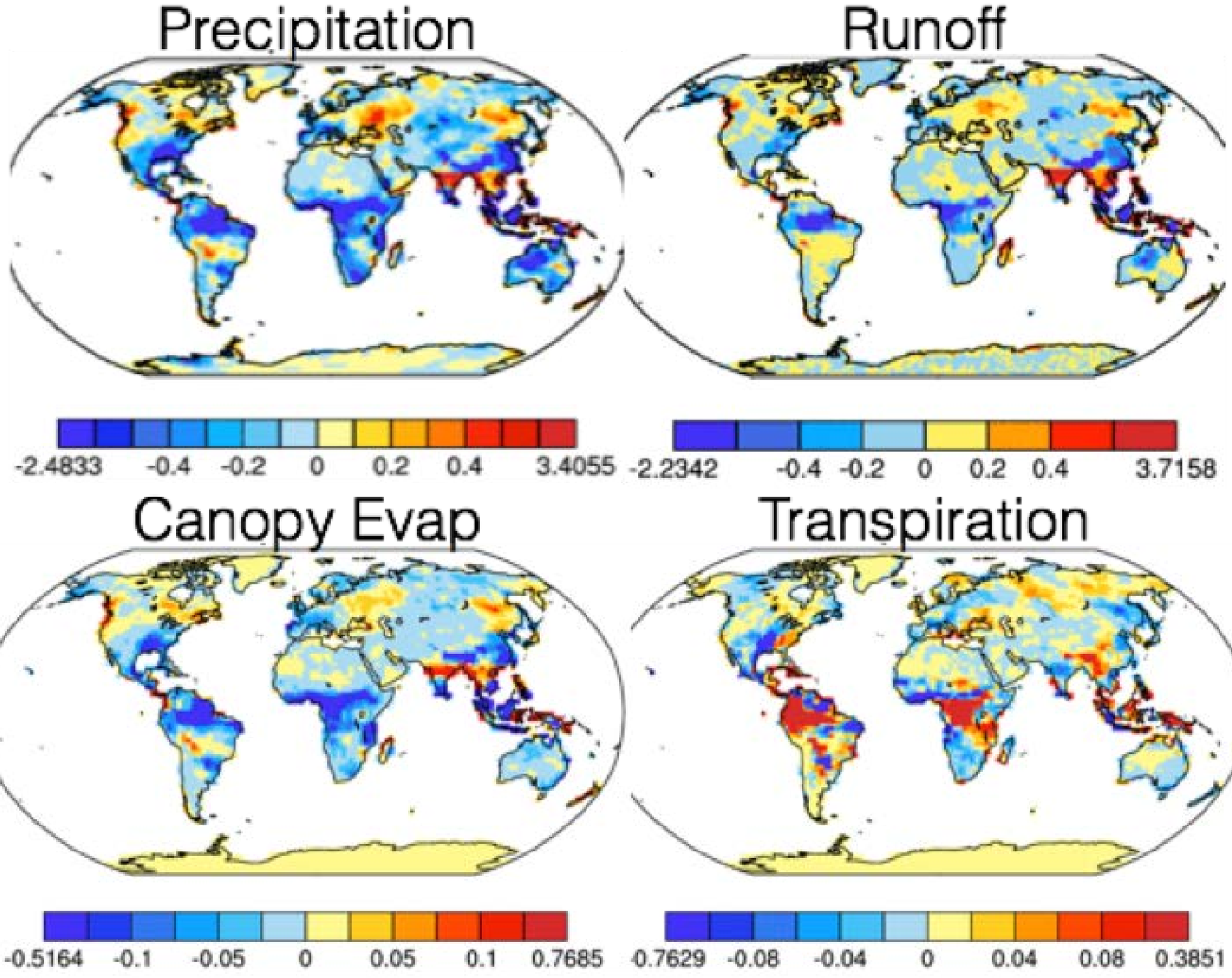
- **Five-year integrations** of SP-CESM
  - Prescribed SSTs
  - Coupled two ways: **MASL and MAML**
  - MAML run uses **32 instances of CLM** with identical parameters in each CAM column, each coupled to its own CRM column
  - Plots show multiyear ***differences***: **MAML minus MASL**

More Intense Rainfall



What do we mean by intensity on different scales?

Land Hydrology

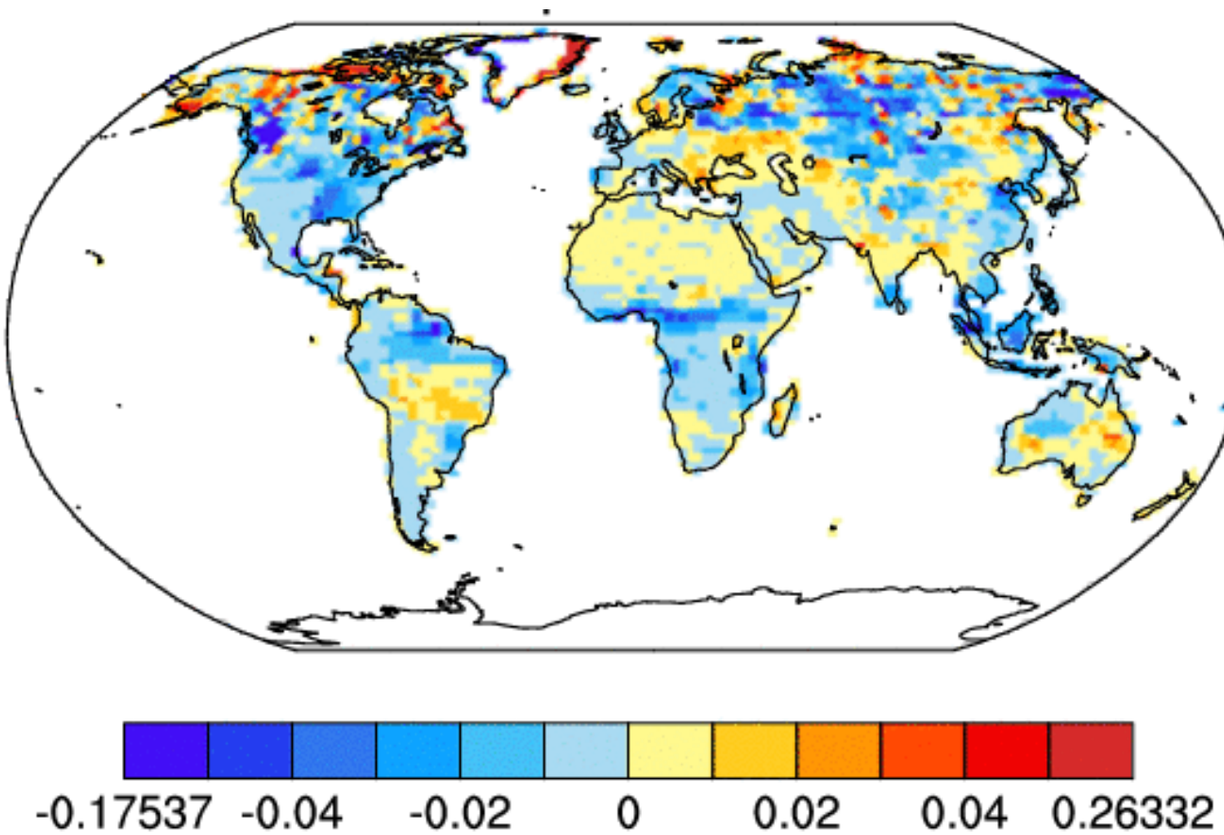


5-year mean differences (MAML - MASL) in mm/day

Surface Wetness

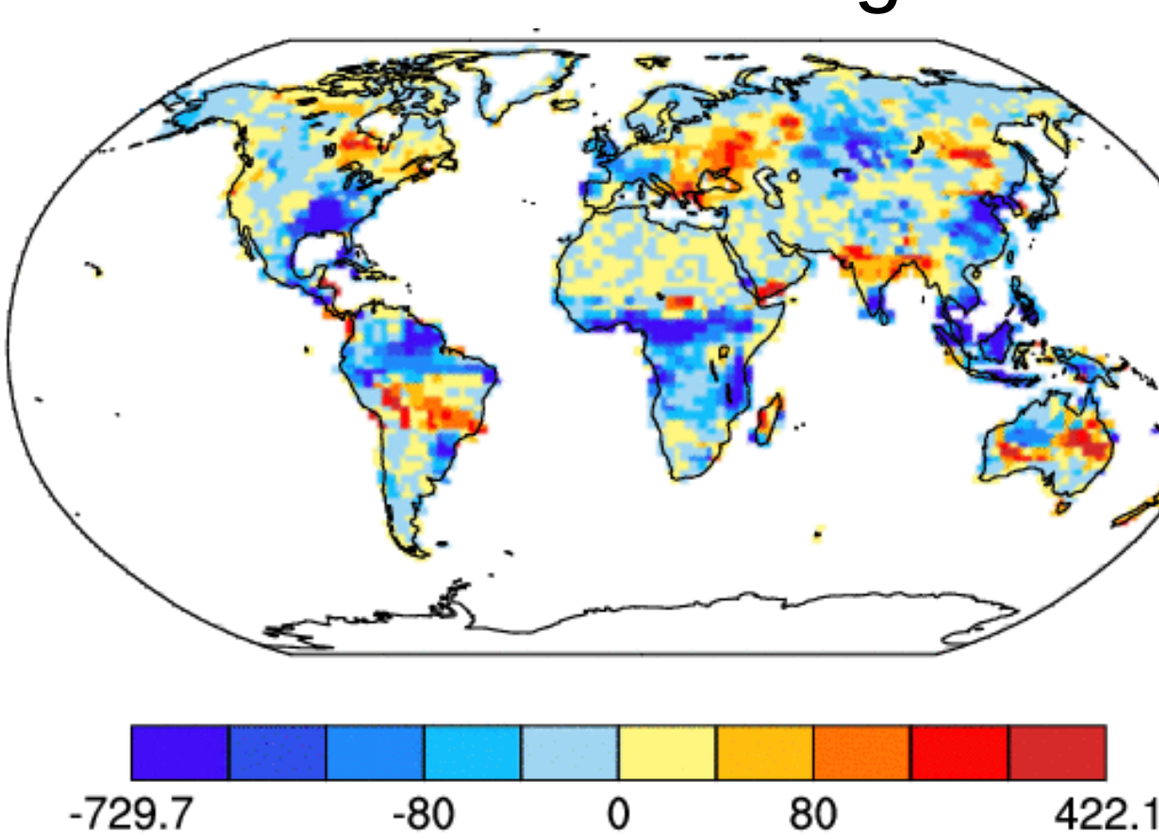
5-yr mean

Water Table at Surface



fraction of grid cell

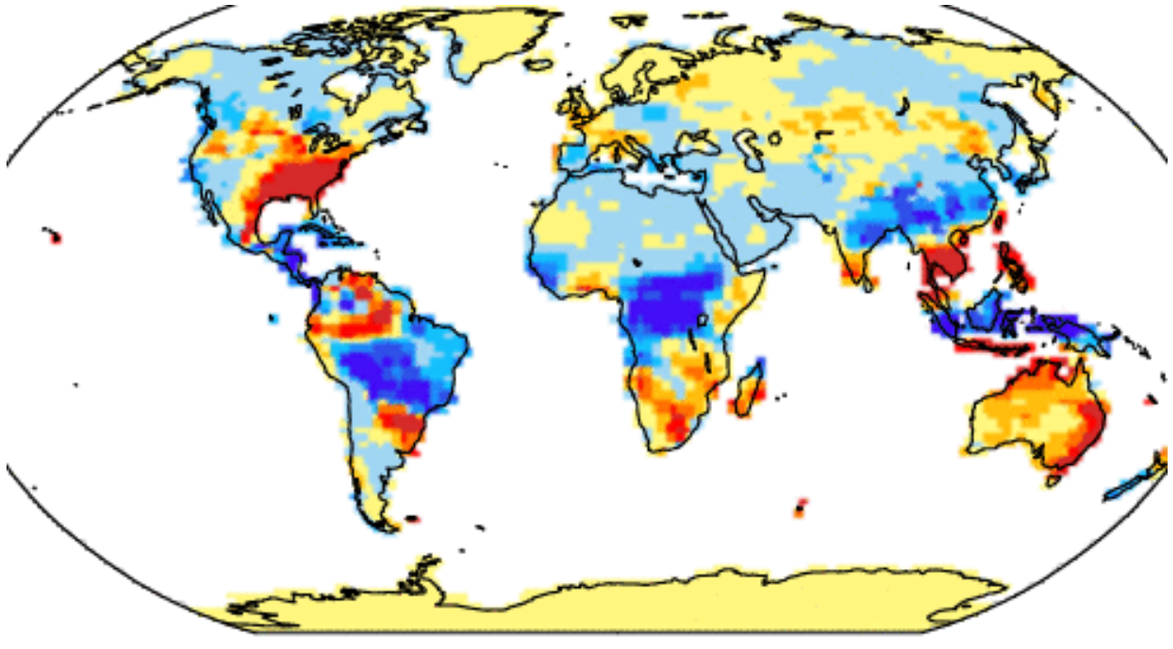
Total Water Storage



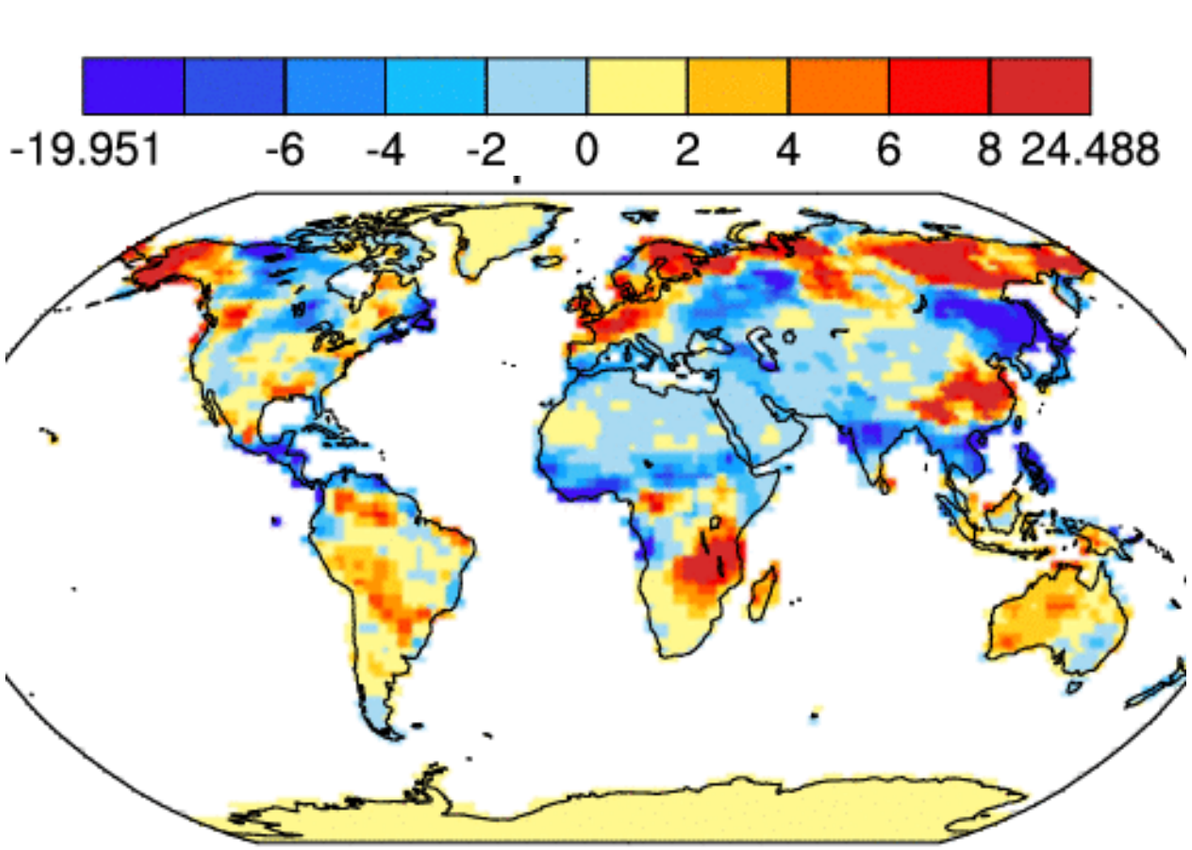
mm

Drier Rainforests, Wetter Monsoons

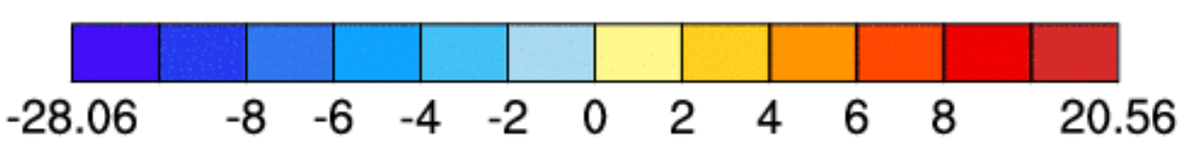
Solar Absorbed by Veg



DJF



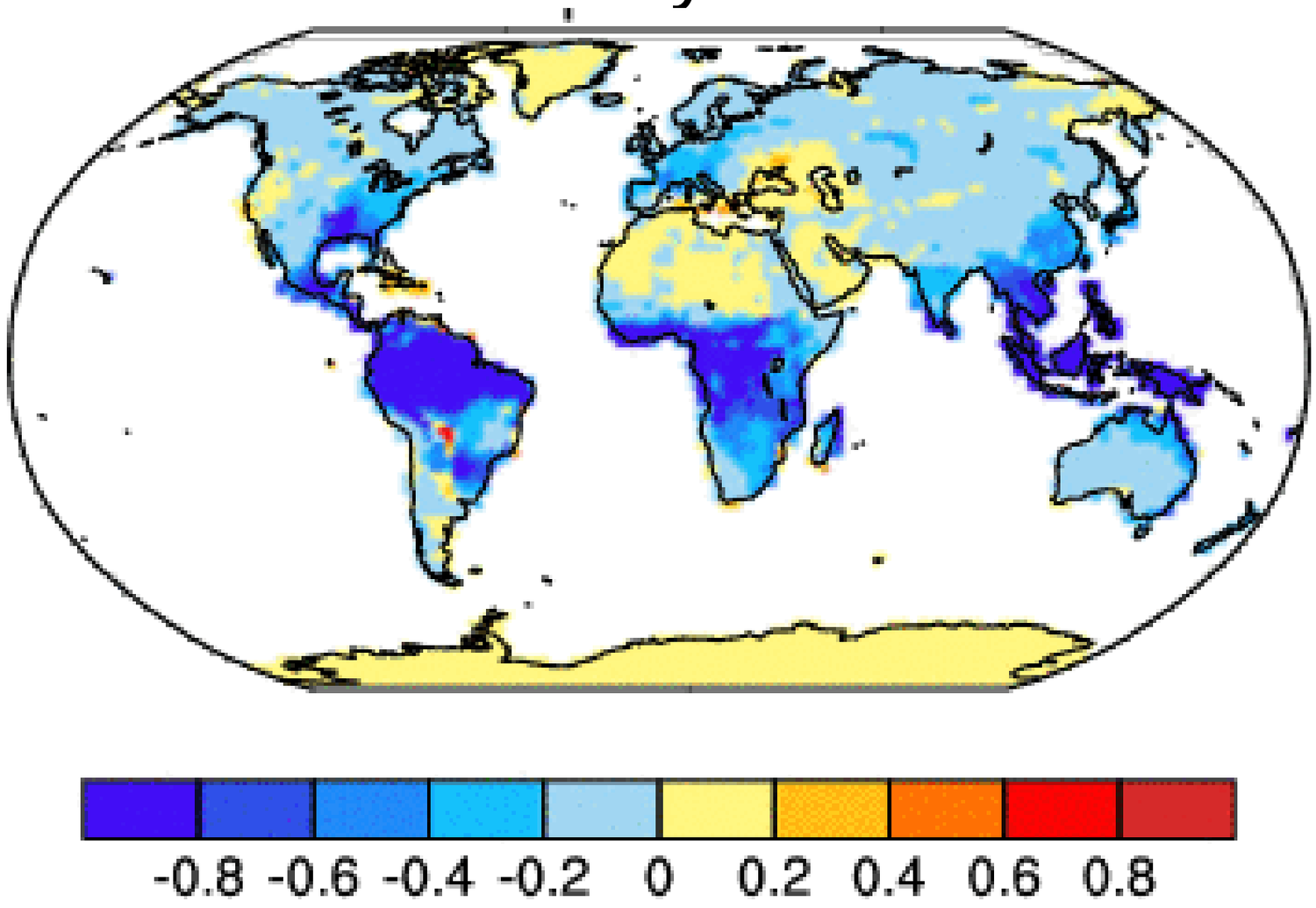
JJA



- Less light in tropical forests during wet season
- More light in mid- and high latitude summer growing seasons

Photosynthesis

Gross Primary Production



- Less precipitation, more transpiration, less light over wettest forests
- About 10% lower ~ roughly = global FF!

Summary

- Multi-scale means **sampling, not averaging**
- A new way to represent subgrid-scale processes in climate models, more **expensive but more realistic**
- Available **now in CESM** (special release)
- Coupling land to atmosphere at km-scale produces substantial **changes in light, water, & carbon**
- **Less interception, more transpiration** esp in tropics
- **Less tropical GPP**

scott.denning@colostate.edu