Multiscale Modeling of Land-Atmosphere Interactions in CESM

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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

SASL
- CAM
- CLM

Single Atmosphere Single Land
(standard CESM)

MASL
- CRM
- CLM

Multi-Atmosphere Single Land
(SP CESM)

MAML
- CRM
- CLMs

Multi-Atmosphere Multi-Land
(“multi-instance” SP CESM)
Tapajos Forest
Equatorial Amazon
SiB-SAM (not CLM!)
SASL, MASL, & MAML

10 km
Nonlinear Coupling

Photosynthetic Light Response

Soil Moisture Stress

\[ f(x) \neq \overline{f(x)} \]
Surface Hydrology

January 03 2003: 1400 Local time
Blue @ = 64 separate CLMs

MASL
$\$
MAML
resolved downpours
lots of throughfall
transpiration

grid-scale drizzle
lots of canopy evap
SASL

Transpiration (W m$^{-2}$)
Evaporation of Canopy Water (W m$^{-2}$)
Photosynthesis Light Response

September 03 2002: 1400 Local time

Blue @ = 64 separate CLMs

GPP (umol m\(^{-2}\) sec\(^{-1}\))

Canopy Net Radiation (W m\(^{-2}\))

very cloudy & dark!

dry & sunny

wet & sunny

SASL #

MASL

MAML
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 transpiration
Carbon Budgets

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

![Graphs showing carbon budgets with red = MASL, black = MAML](image)
Free troposphere

Sunrise

trade wind layer

residual layer

CO2
Convective tower

Mid-Afternoon

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

- Precipitation
- Runoff
- Canopy Evap
- Transpiration

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

Drier Rainforests, Wetter Monsoons
Solar Absorbed by Veg

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

DJF

JJA
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**

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