What’s new for CLM5*

David Lawrence

and the Land Model Working Group

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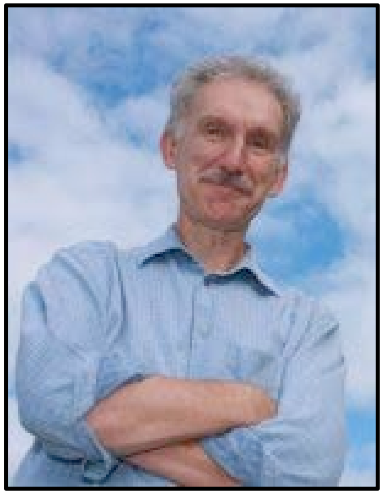
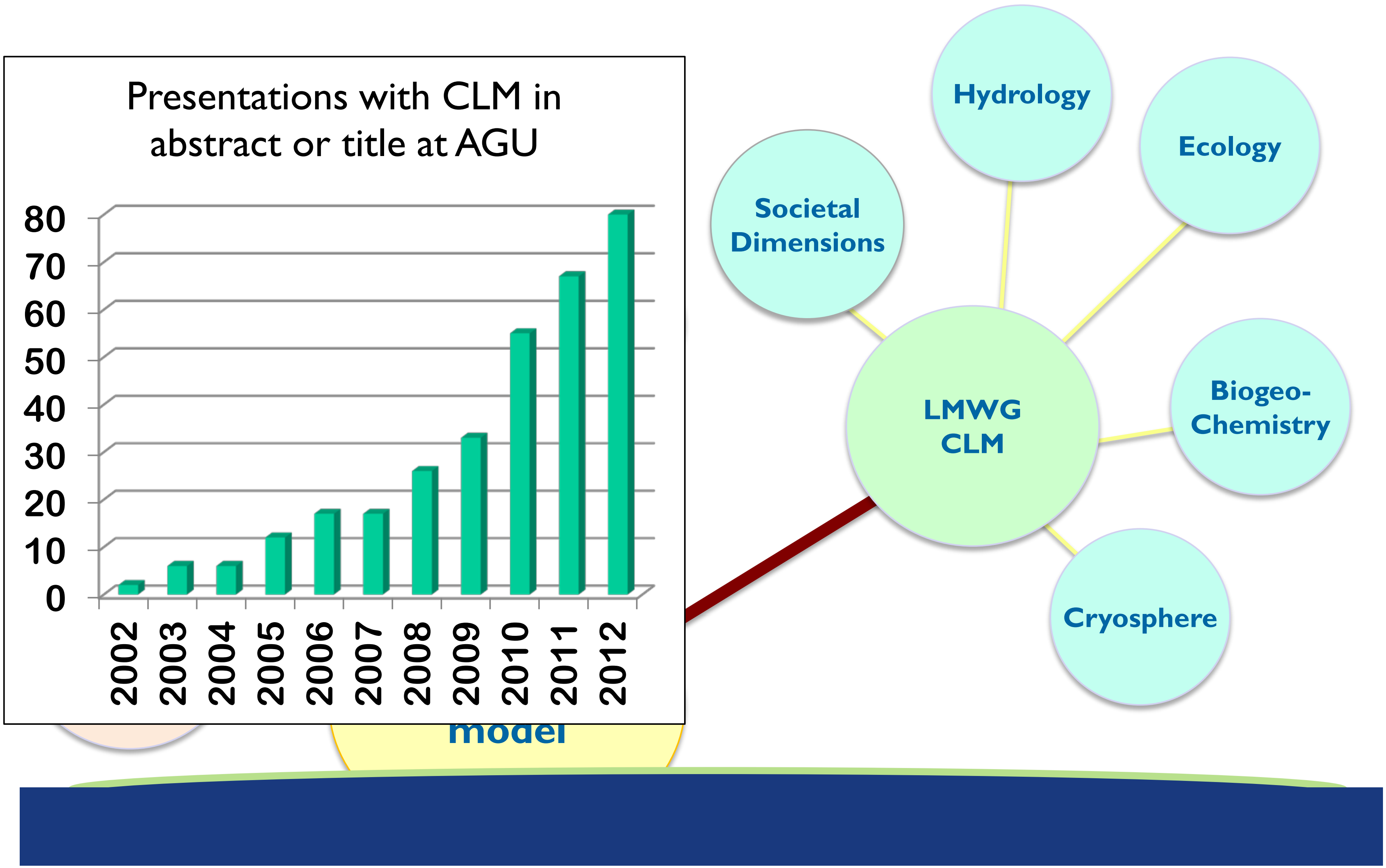
* "Pulling a Phil Rasch"



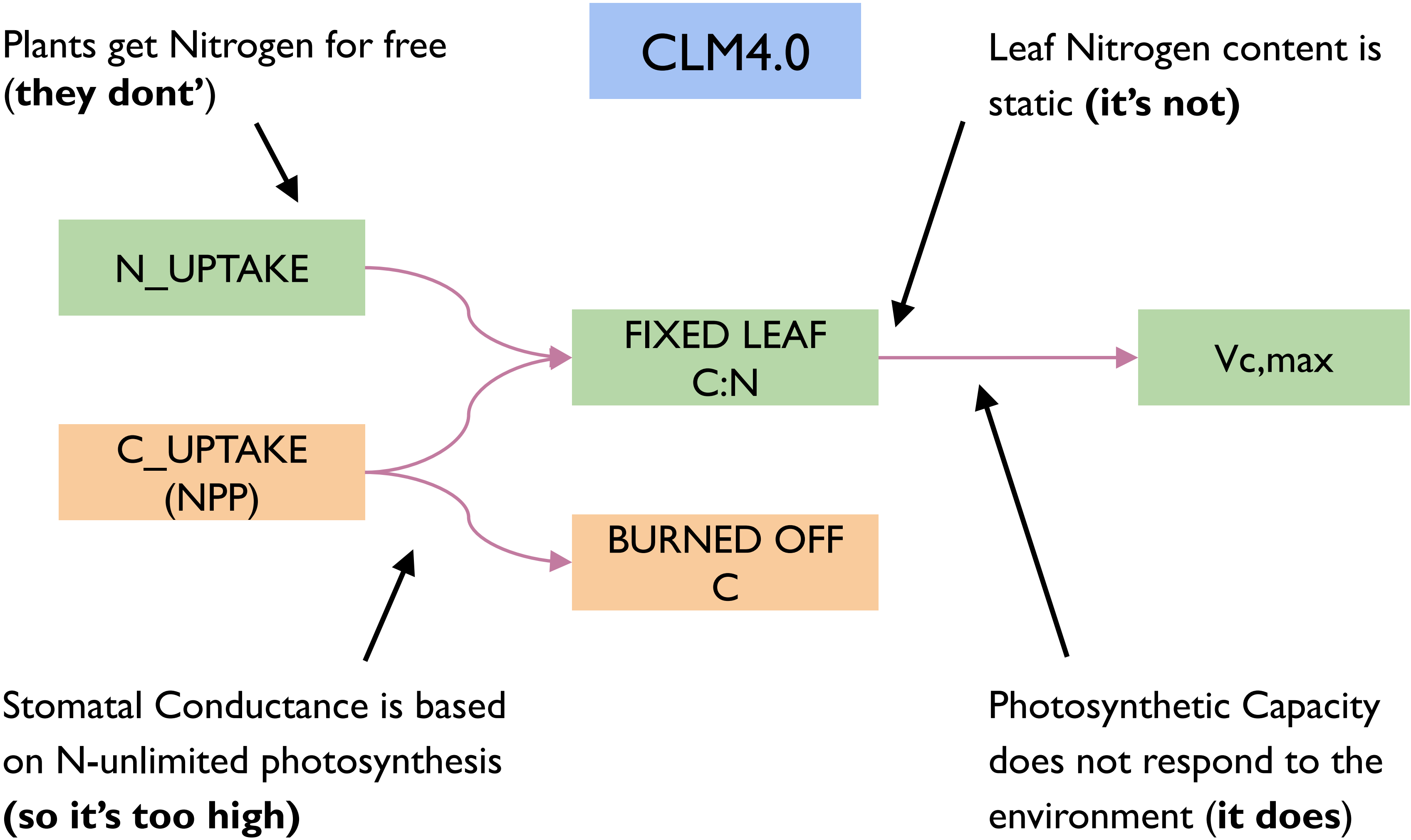
Development targets for CLM5

- Carbon and nutrient cycles
  - Improved 20thC land carbon stocks and carbon stock trends
  - Address ecological stones thrown at CLM4 (plants don't get N for free , leaf N isn't static, photosynthetic capacity should respond to environment, stomatal conductance not linked to N-limitation)
- Hydrology
  - Hydrology representation closer to state-of-art hydrology understanding
  - Increase utility for use in water resource and water-carbon interaction research
- Land cover and land use change
  - Global / transient crop capability with irrigation, fertilization, and cultivation of crops (land management) as default for historical and projection runs
  - More realistic land cover change impact on water and energy fluxes
- Land-atmosphere chemistry coupling
  - Enhanced interactions, fire emissions, ozone damage to plants, CH_4 emissions
- Ecosystem Demography model – future biogeochemical core of CLM
  - Functional CLM5(ED) for use in studies of biome boundaries, trait filtering, etc

CLM as a community modeling tool



Community Nitrogen Cycle Project



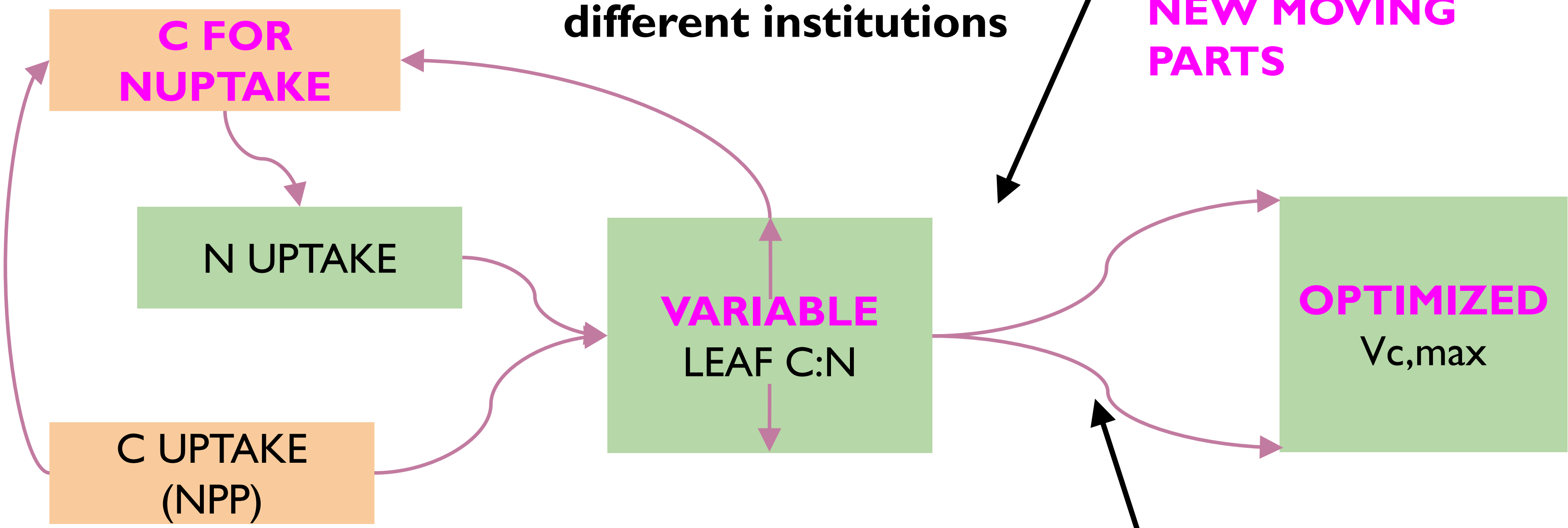
Plants pay for fixed & active Nitrogen uptake (in Carbon)

CLM5.0

Contributions from 4 different institutions

Leaf Nitrogen content varies with the cost of N uptake

NEW MOVING PARTS

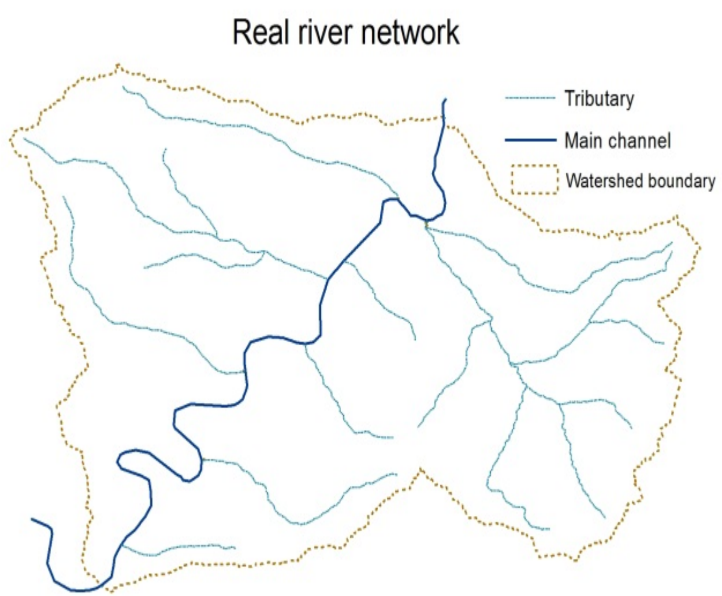


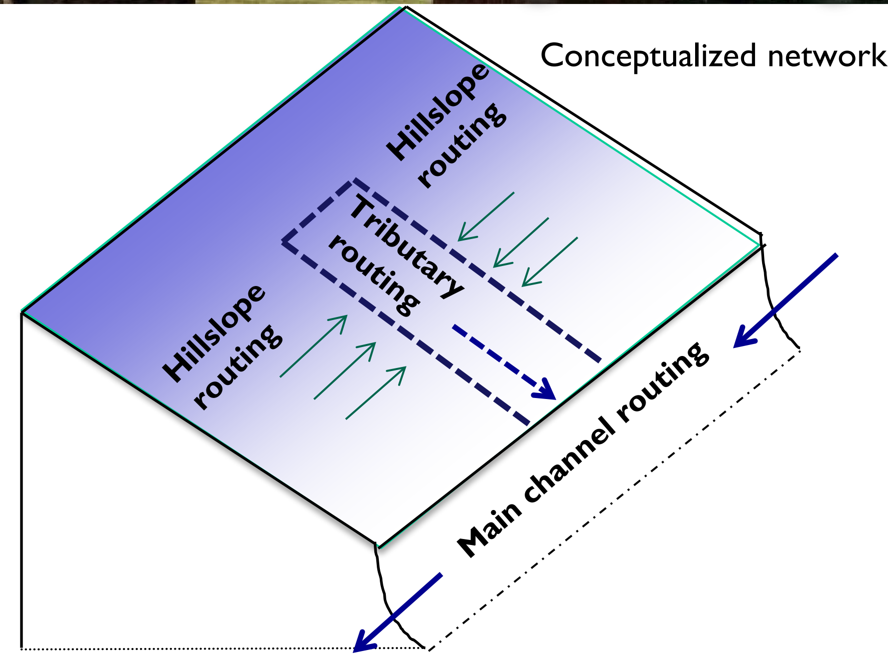
Stomatal Conductance is based on N-limited photosynthesis

Photosynthetic Capacity is optimized wrt environmental drivers

What's New for CLM5

Model for Scale Adaptive River Transport (MOSART)



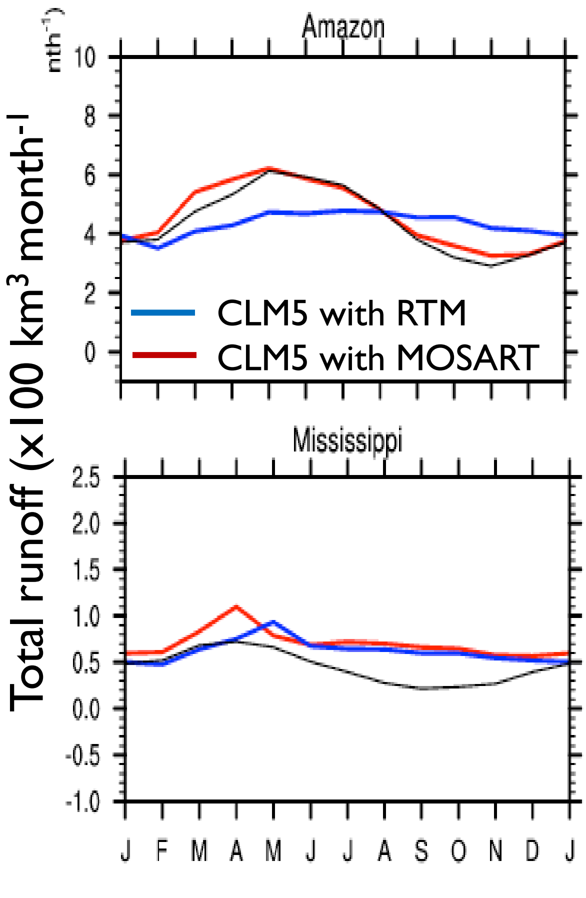


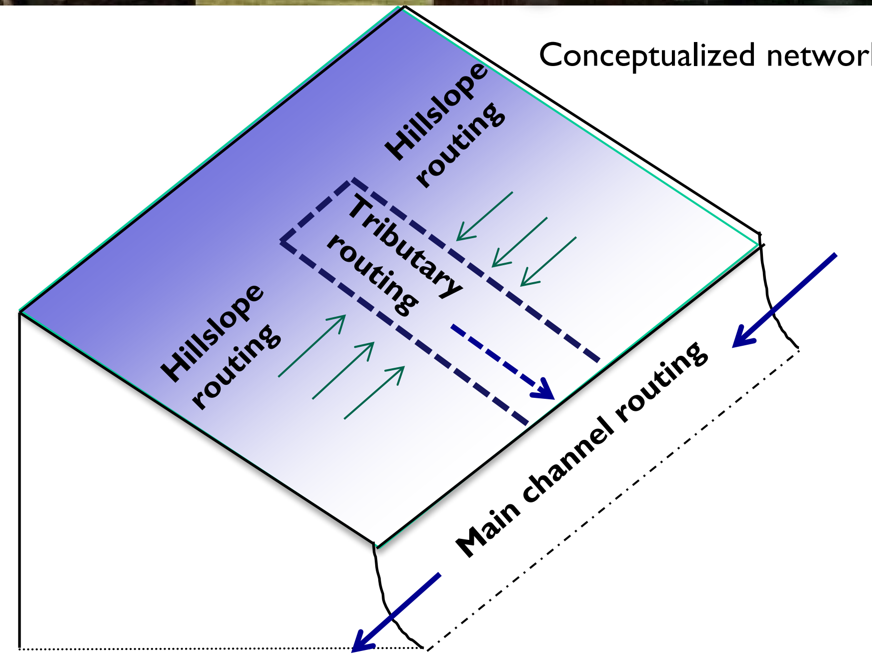
- Manning's equation is applied to estimate the velocities of water traveling across hillslopes, subnetwork, and main channel
- Hillslope routing accounts for event dynamics and impacts of overland flow on soil erosion, nutrient loading etc.
- Main channel routing: explicit estimation of in-stream status (velocity, water depth etc).

Li et al., JHM, 2014

Model for Scale Adaptive River Transport (MOSART)

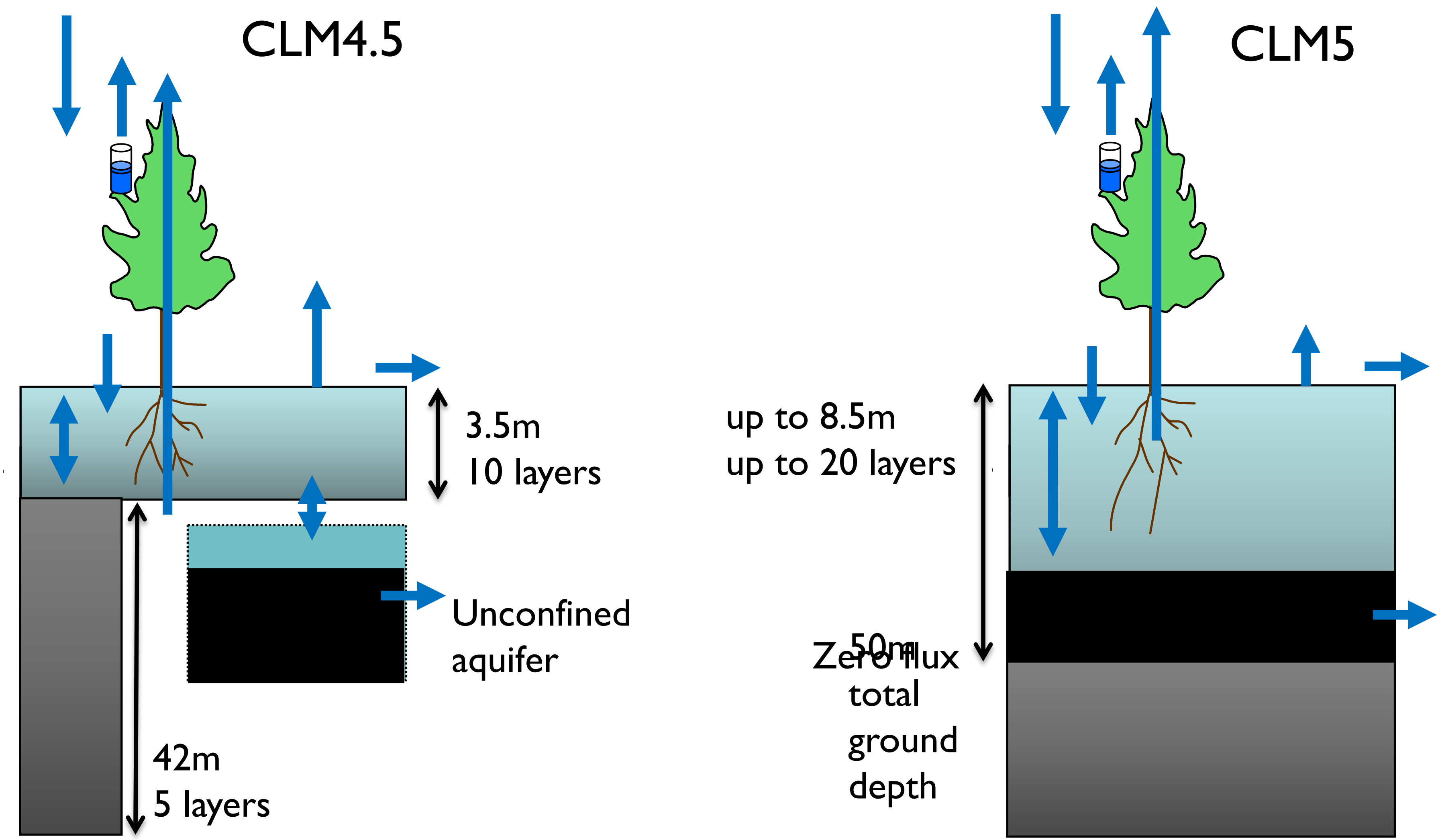
Annual cycle of river flow





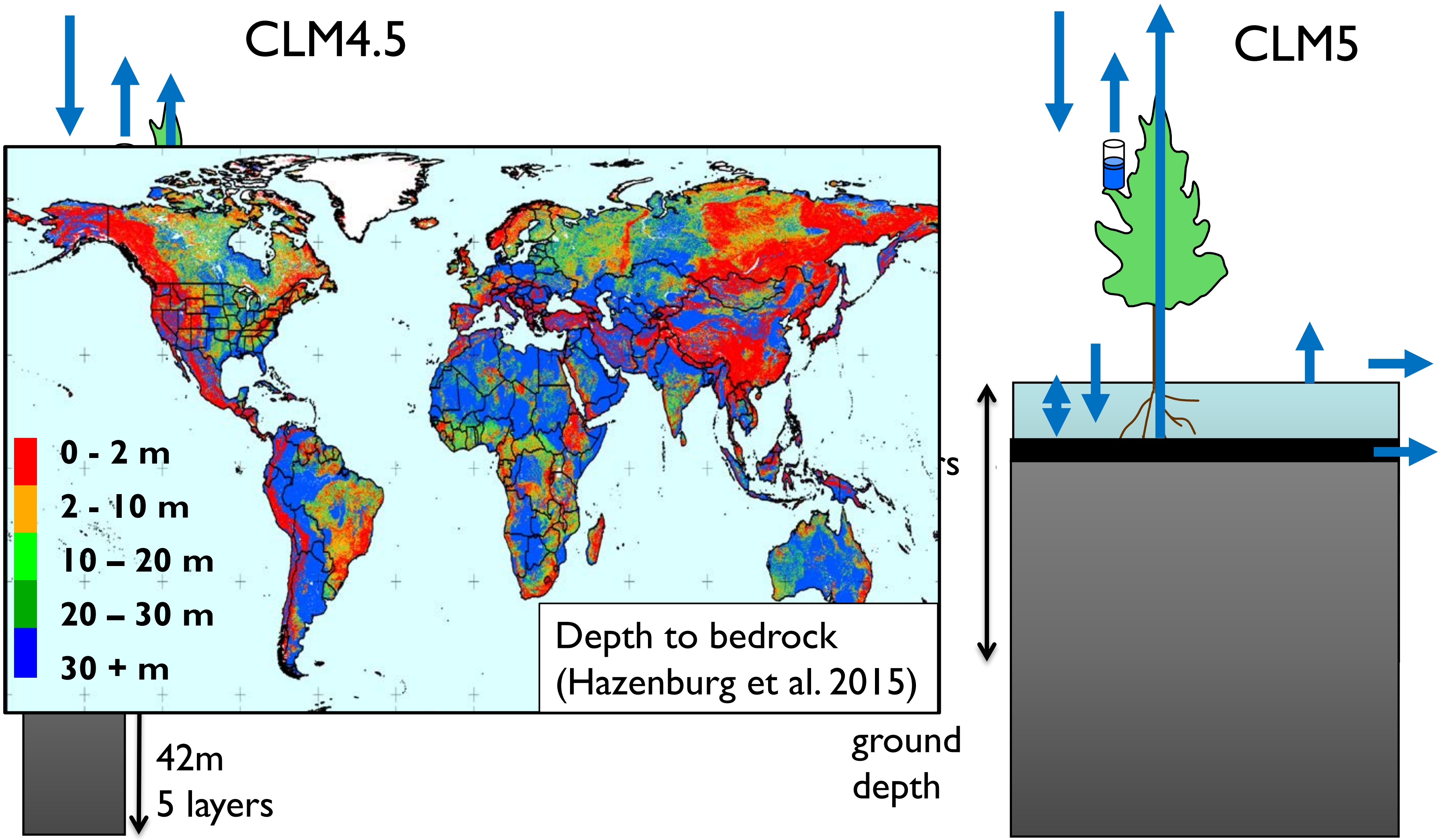
Li et al., JHM, 2014

CLM5: Soil hydrology updates

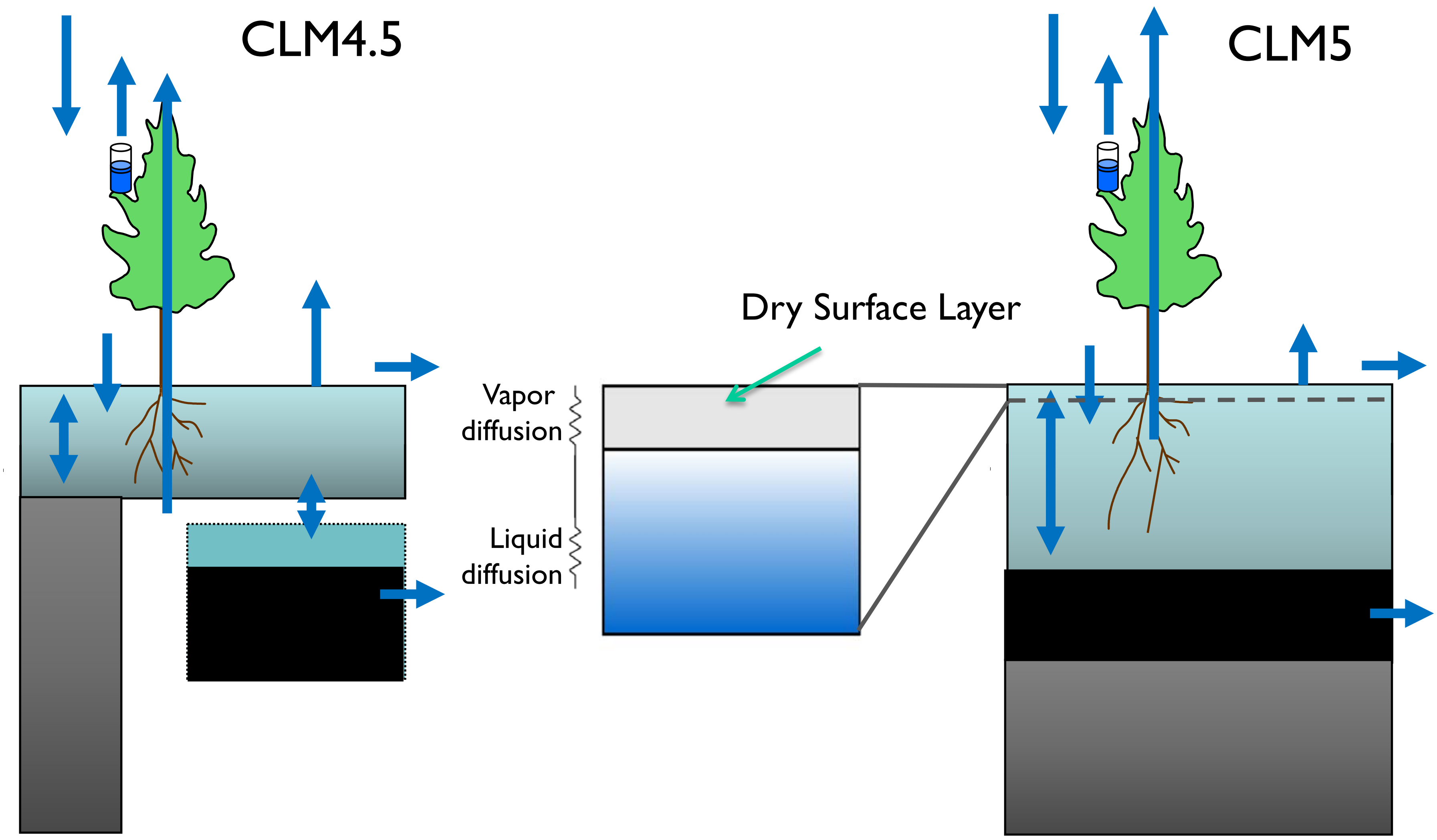


Brunke et al., submitted; Swenson and Lawrence, submitted

CLM5: Soil hydrology updates



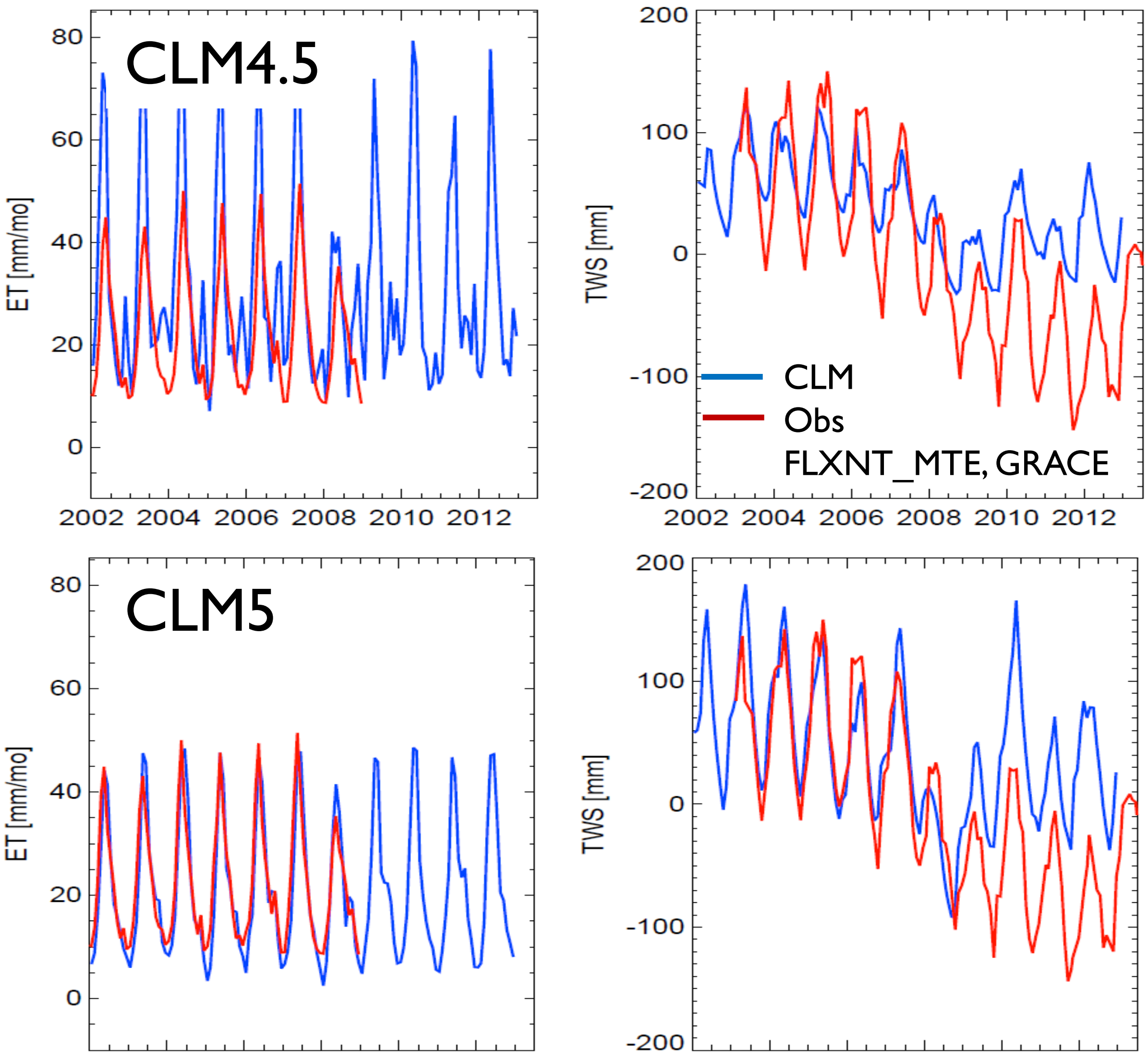
CLM5: Soil hydrology updates

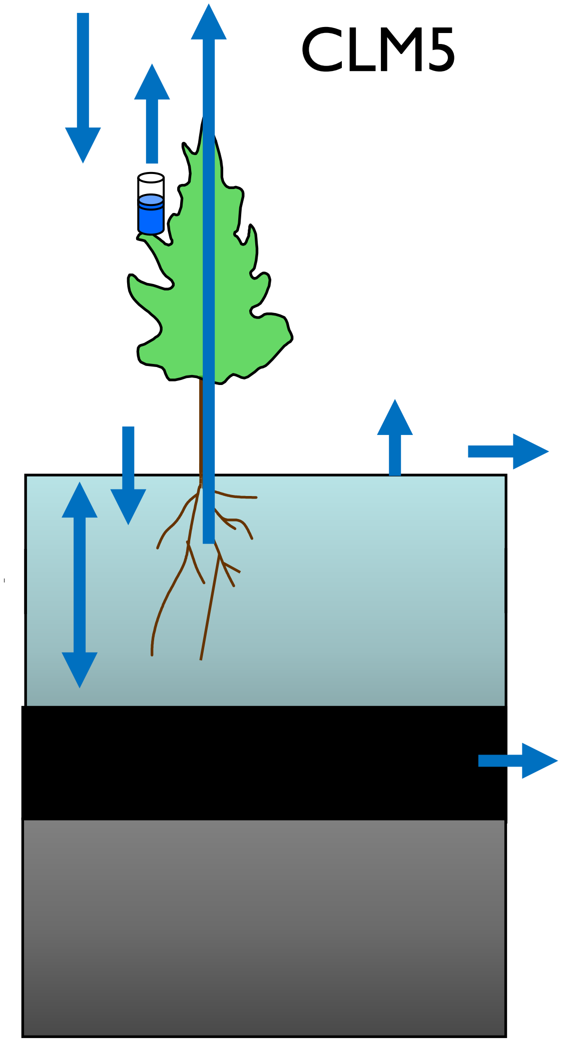


Swenson and Lawrence, 2014

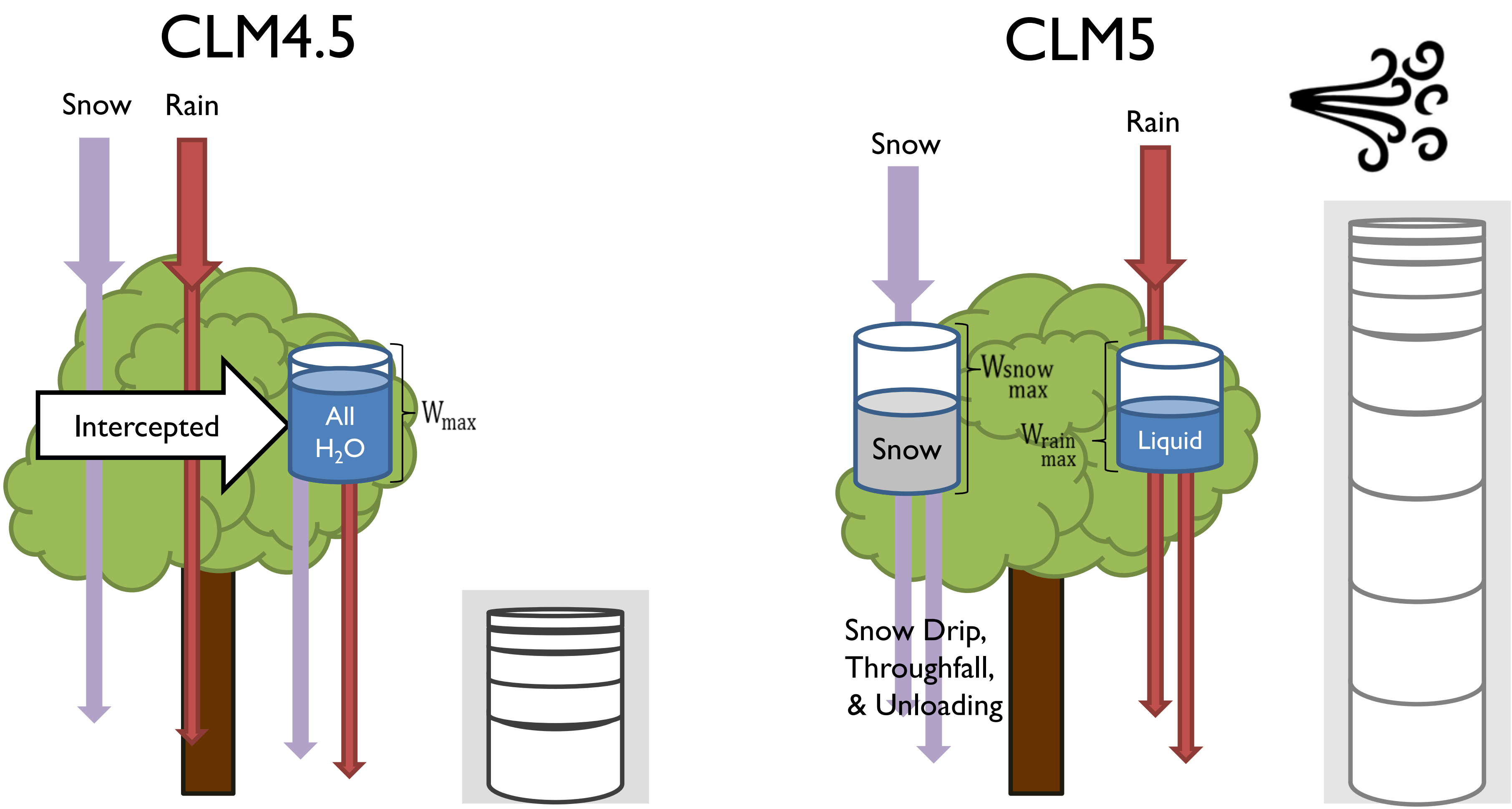
CLM5: Soil hydrology updates

Semi-arid region: Iran





CLM5: Snow updates

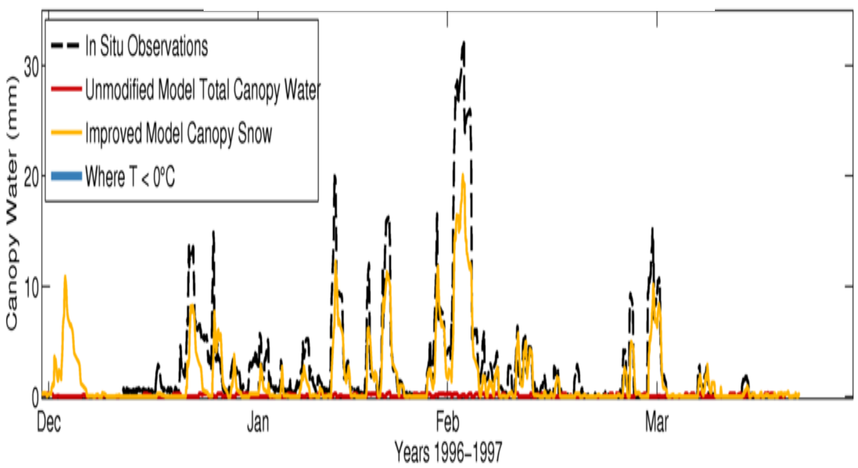


1m max SWE
up to 5 layers

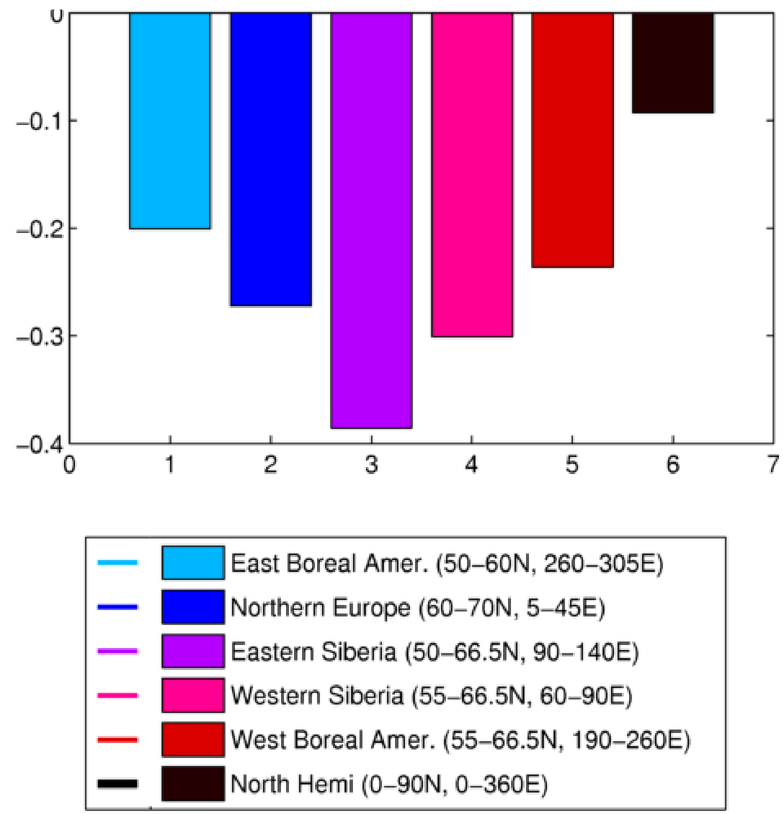
10m max SWE
up to12 layers

CLM5: Snow updates

Umpqua forest, Oregon



Cumulative annual RMSE change: albedo



Model	SS_{tot}	SS_{alb}	SS_{scf}
CCSM4	0.83	0.76	0.89
CLM4	0.82	0.72	0.92
CLM4.5	0.83	0.72	0.94
CLM4.5-snowvegdev	0.90	0.87	0.93

Perket et al., in prep

CLM5-Crop

Corn*

Wheat

Sugarcane

Soy*

Cotton

Rice

* *Temperate and tropical varieties*

Crop Management in CLM5

Fertilize

Plant

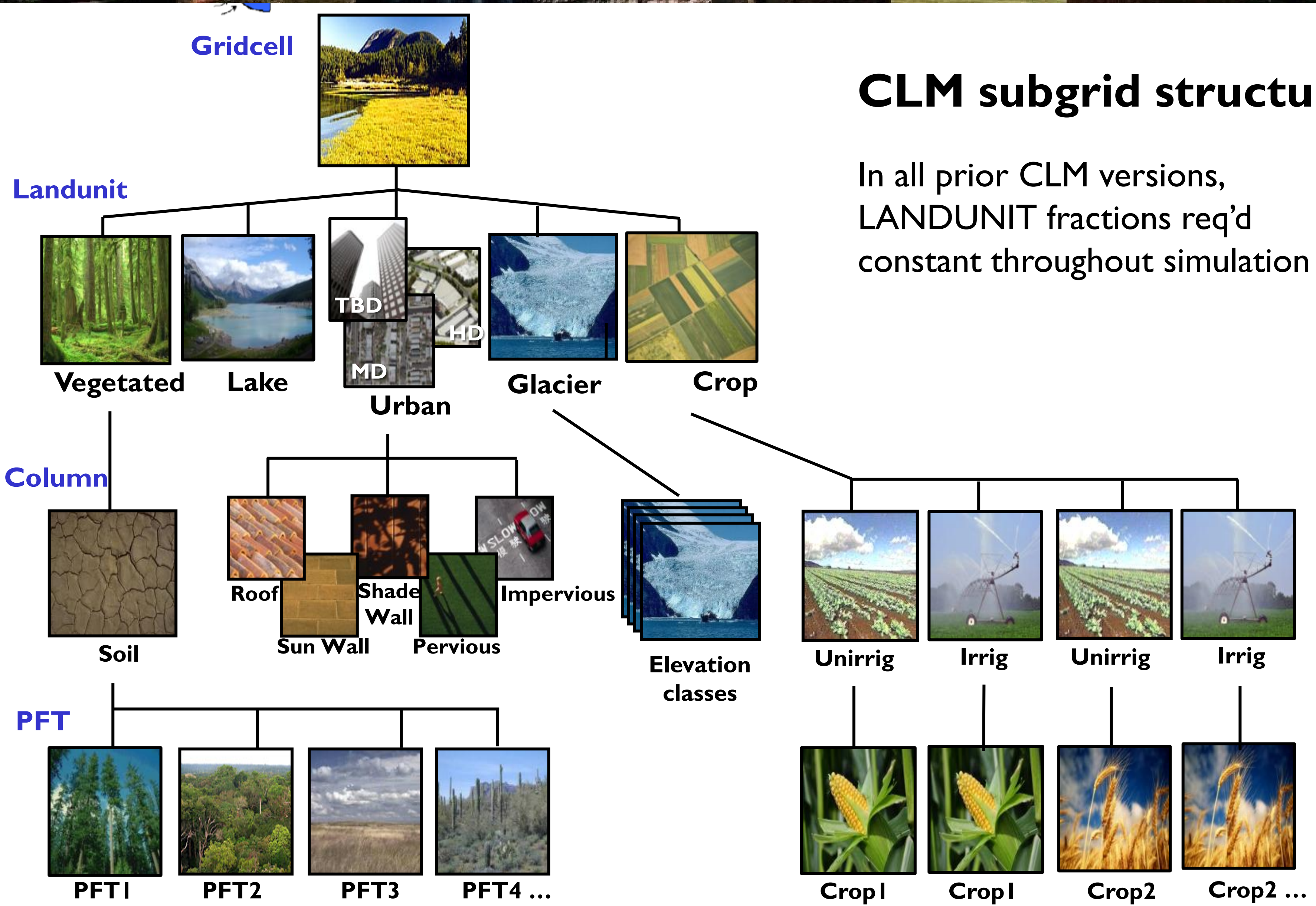
Harvest

Irrigate

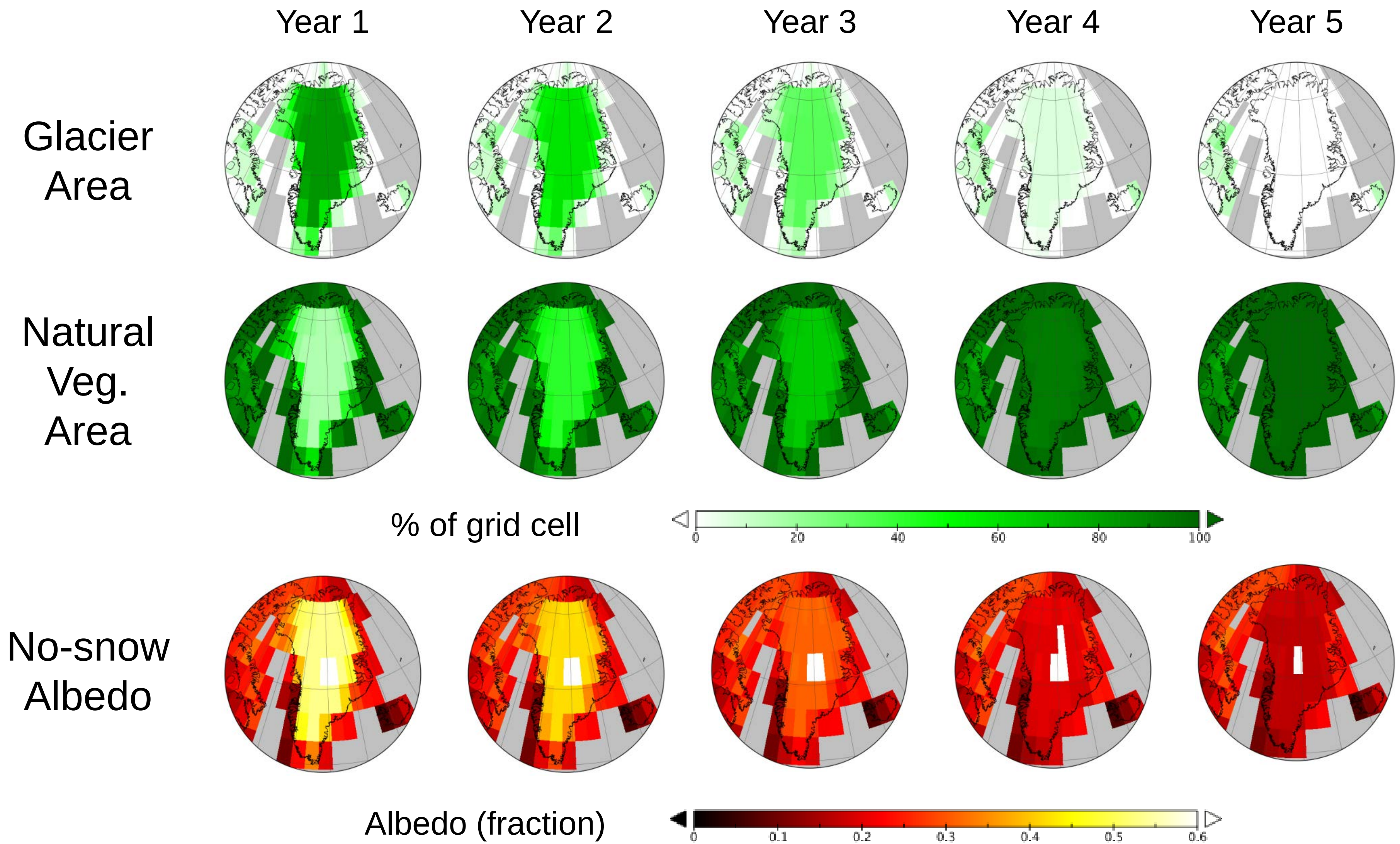
Dynamic Landunits

CLM subgrid structure

In all prior CLM versions, LANDUNIT fractions req'd constant throughout simulation



Fast deglaciation experiment: 100% to 0% in 5 years



What's New for CLM5

Crops: global crop model with transient irrig. and fertilization (8 crop types), grain prod. pool

Hydrology: dry surf. layer, var. soil depth w/ deeper (8.5m) max soil, revised GW, canopy interc

Snow: canopy snow updates, wind effects, firn model (12 layers), glacier MEC

Rivers: Model for Scale-Adaptive River Transport (hillslope → tributary → main channel)

Nitrogen: flexible leaf C:N ratio, leaf N optimization, C cost for N (FUN)

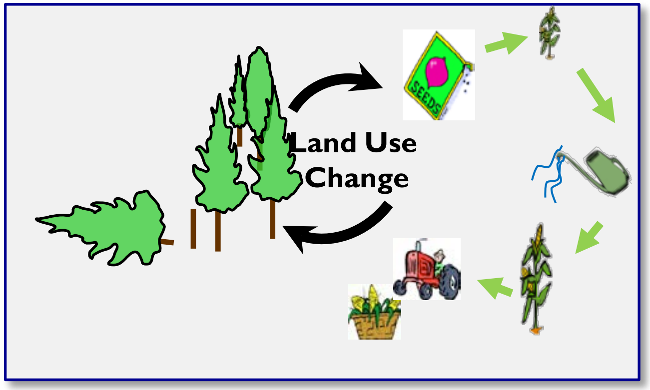
Carbon: carbon allocation revised

Fire: updates, trace gas and aerosol emissions

Vegetation: Ecosystem Demography, plant hydraulics, prognostic roots, ozone damage

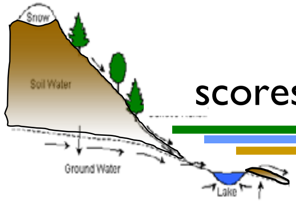
Land cover/use: dynamic landunits, revised PFT-distribution, wood harvest by mass

Isotopes: carbon and water isotope enabled



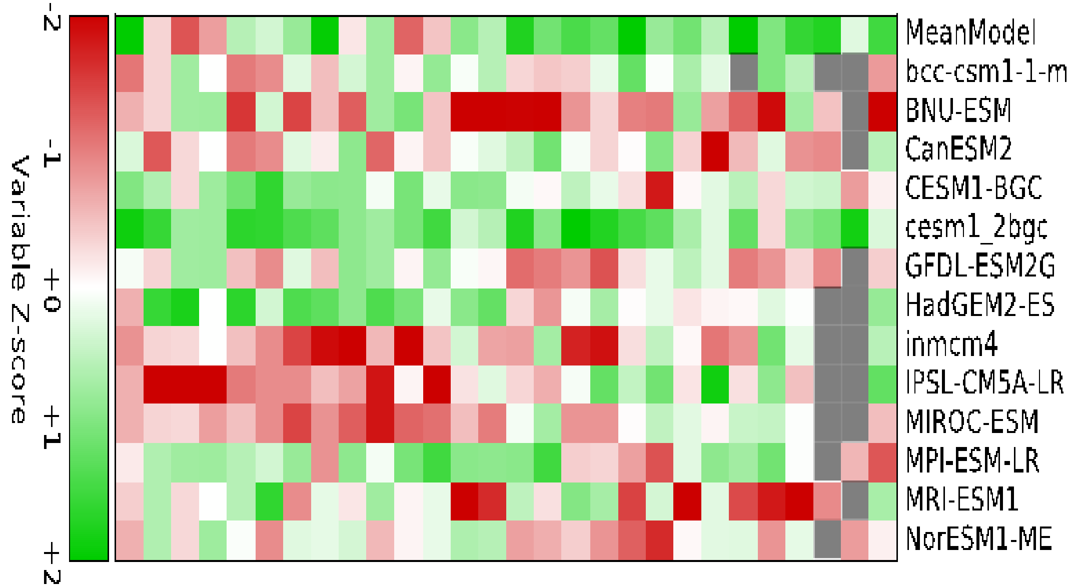
Land simulation in CESM2

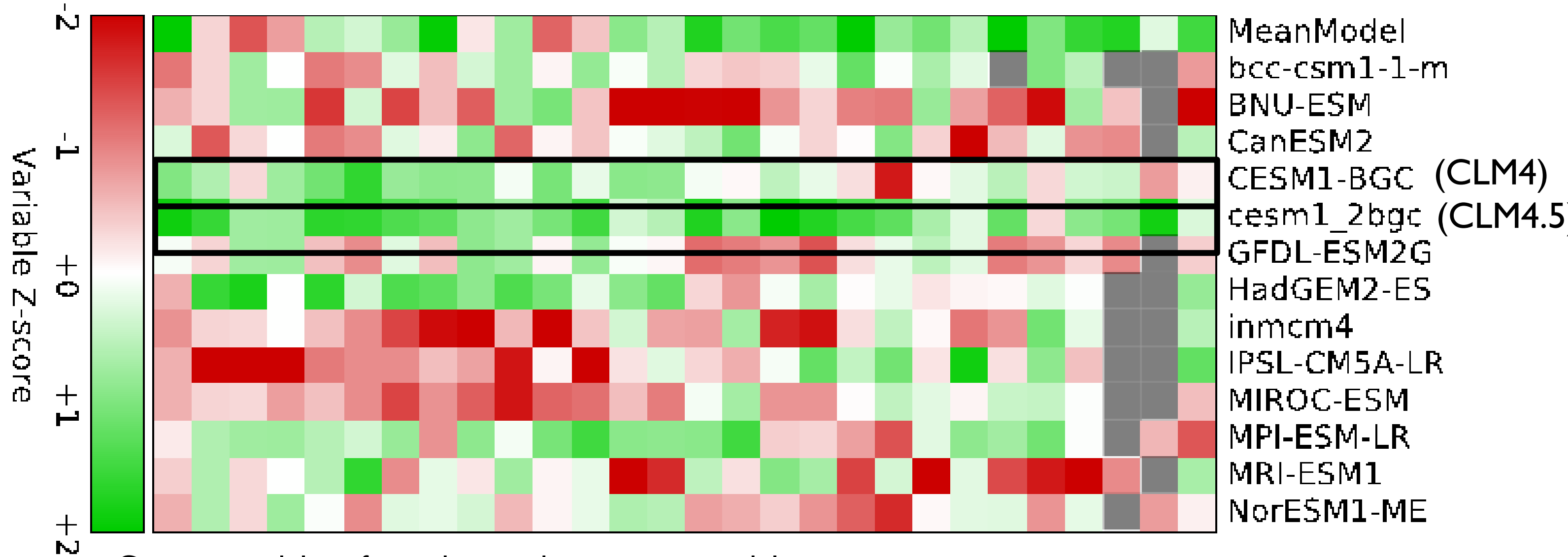
David Lawrence and the Land Model Working Group



International LAnd Model Benchmarking (ILAMB) package

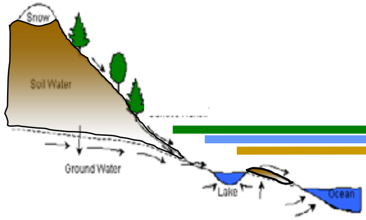
scores for RMSE, interannual variability, pattern correlation, variable-to-variable comparisons, +





Green: model performs better than average model

Red: model performs worse than average model



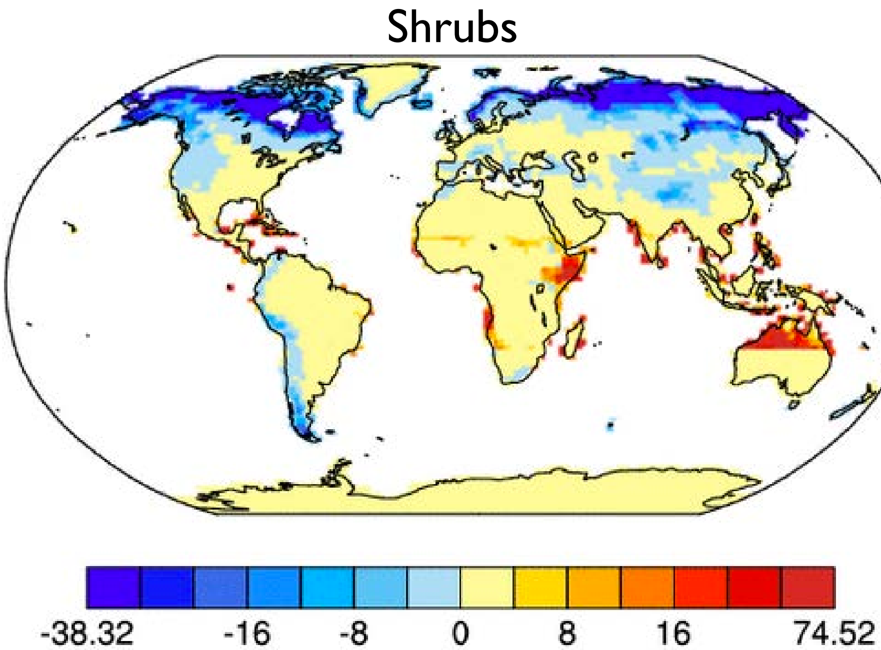
CLM5 versus CLM4.5
International Land Model Benchmarking Package

Despite significant improved physics and biology, latest version of CLM5 not showing much if any improvement in scores

	CLM45bgc_2degGSWP3	CLM5bgc01_2degGSWP3
Global Variables	0.70	0.68
Variable to Variable	0.73	0.68
Overall	0.71	0.68

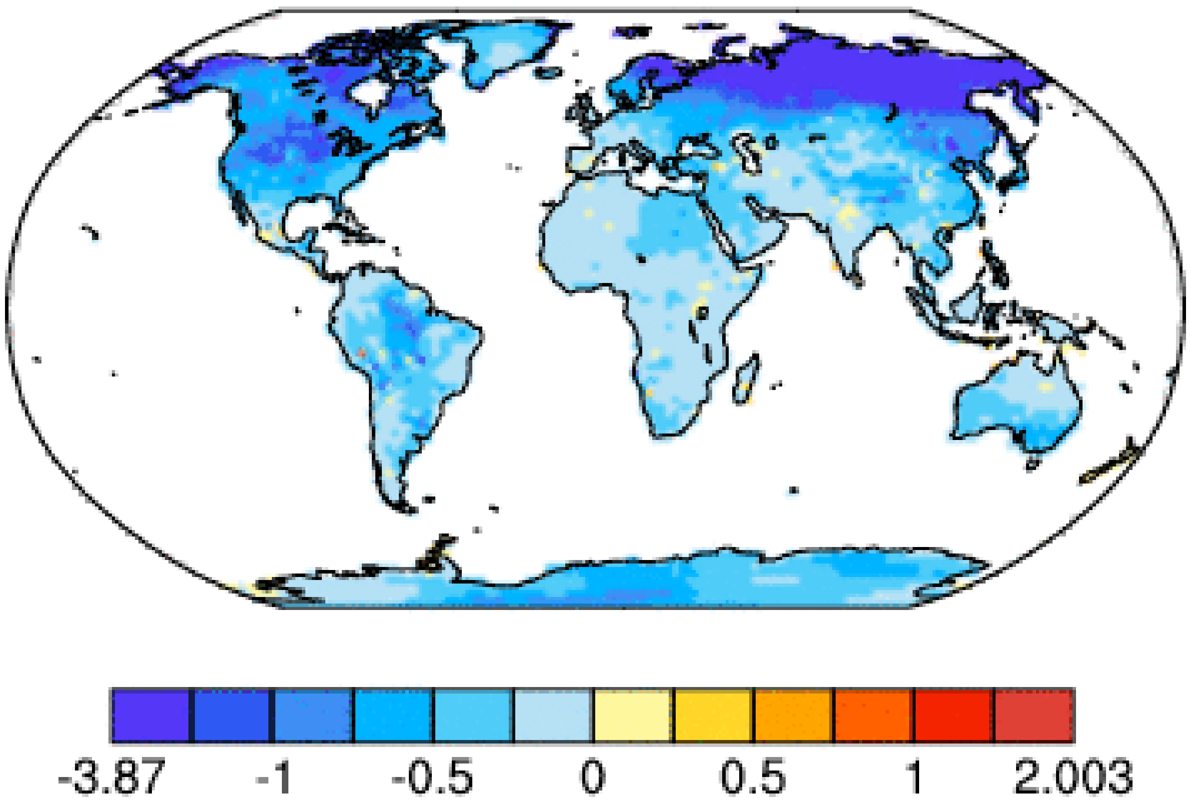
	CLM45bgc_2degGSWP3	CLM5bgc01_2degGSWP3
Aboveground Live Biomass	0.71	0.64
Burned Area	0.51	0.42
Gross Primary Productivity	0.75	0.72
Leaf Area Index	0.57	0.58
Global Net Ecosystem Carbon Balance	0.47	0.45
Net Ecosystem Exchange	0.49	0.51
Ecosystem Respiration	0.73	0.70
Soil Carbon	0.56	0.58
Summary	0.60	0.58

Changes in percentage vegetation cover
CLM5 versus CLM4.5



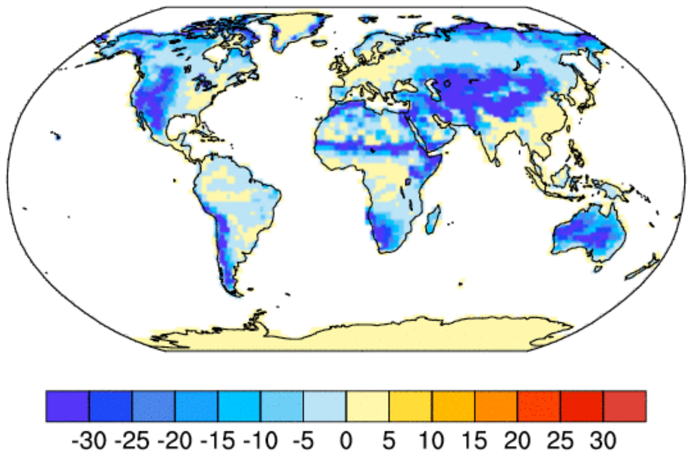
Annual air temperature

CESM1.5 (31) – CESM1.5 (28)
High CLM4.5 Shrub – Low CLM5 Shrub

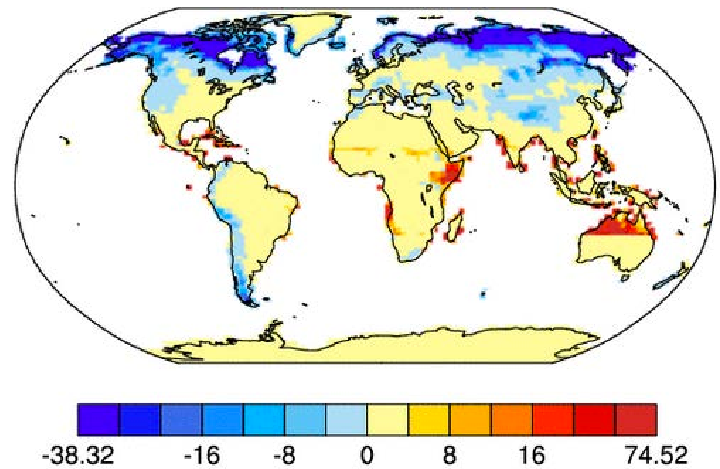


Change in percentage vegetation cover
CLM5 versus CLM4.5

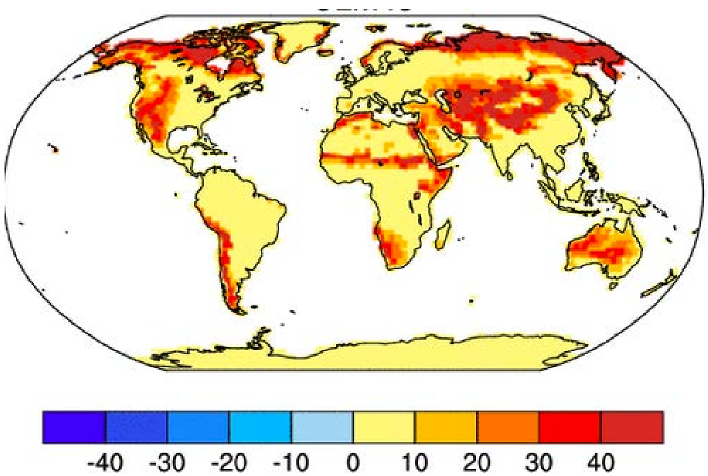
Bare Soil



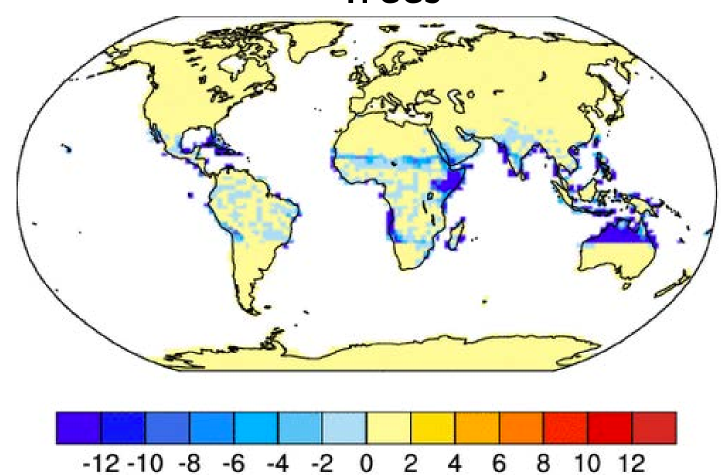
Shrubs



Grasses

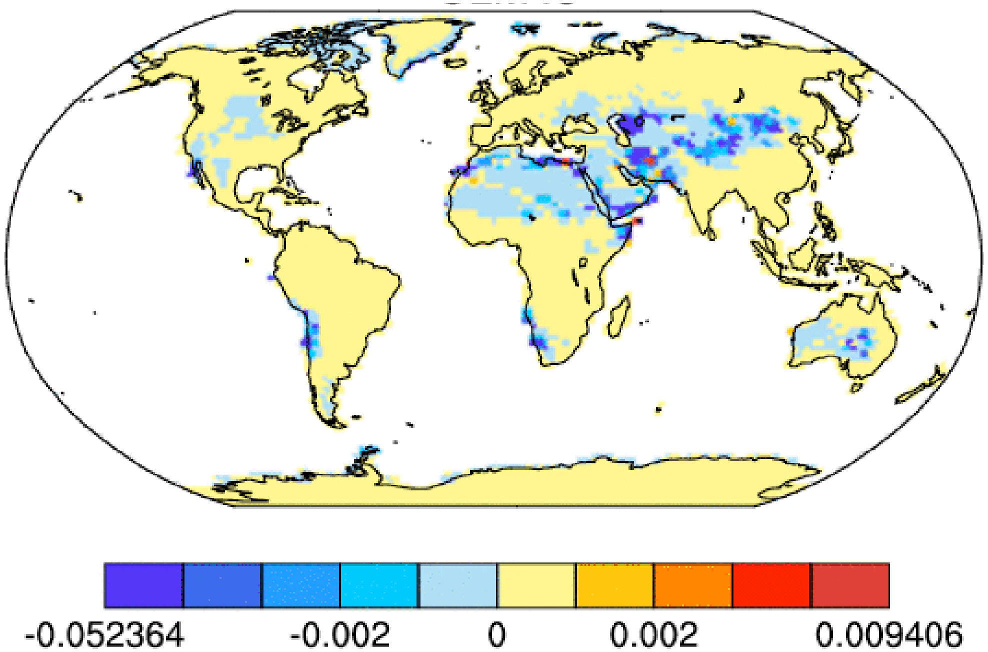


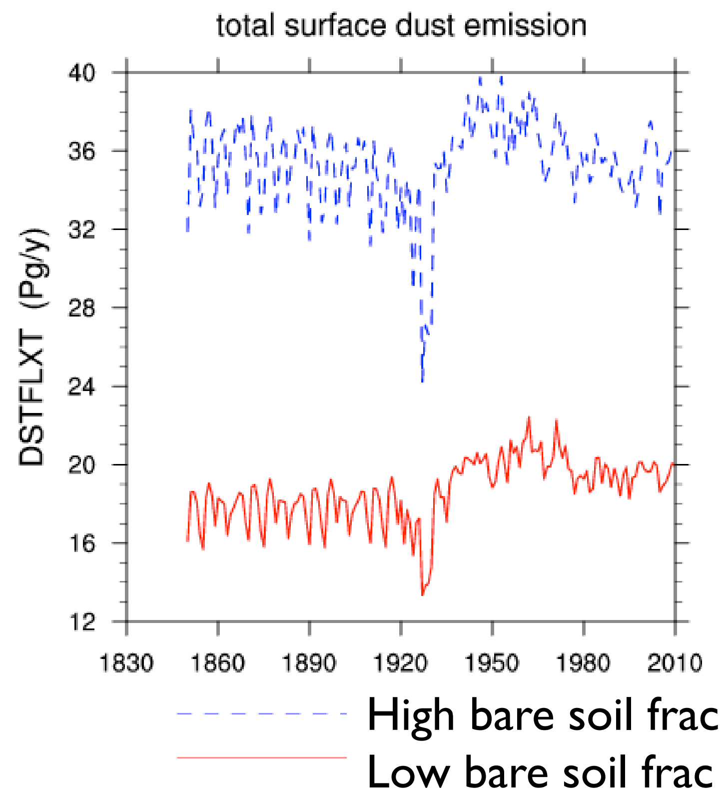
Trees



Dust emissions

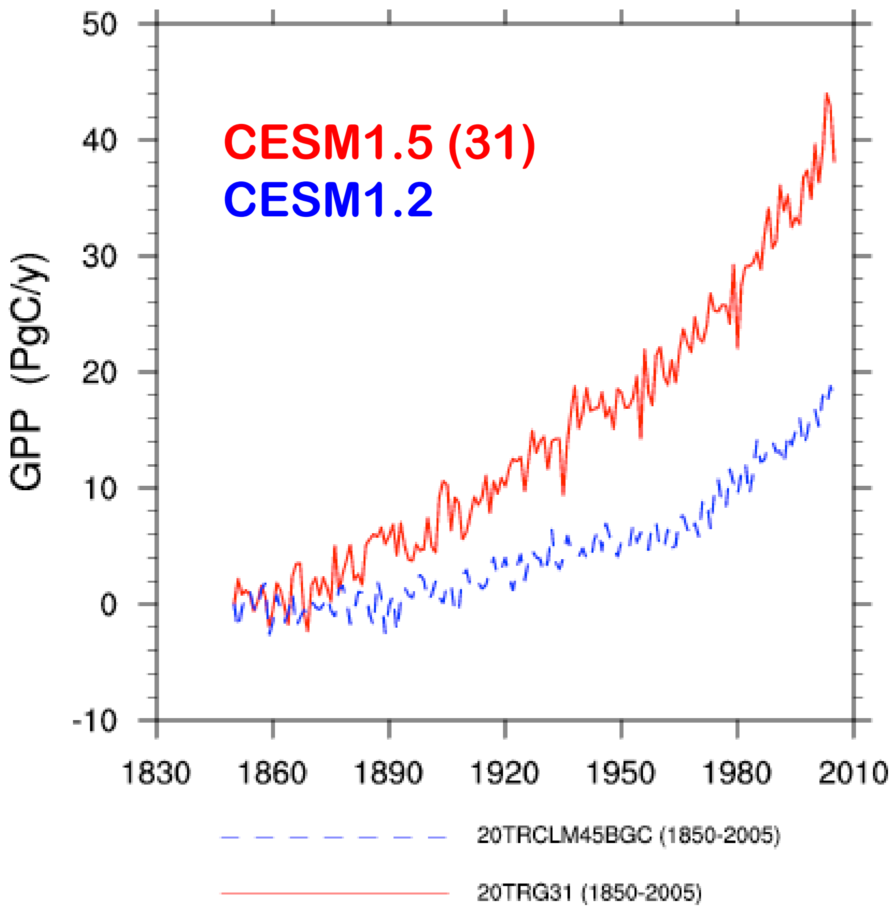
Impact of reduced bare soil fraction on dust emissions in CLM5 offline



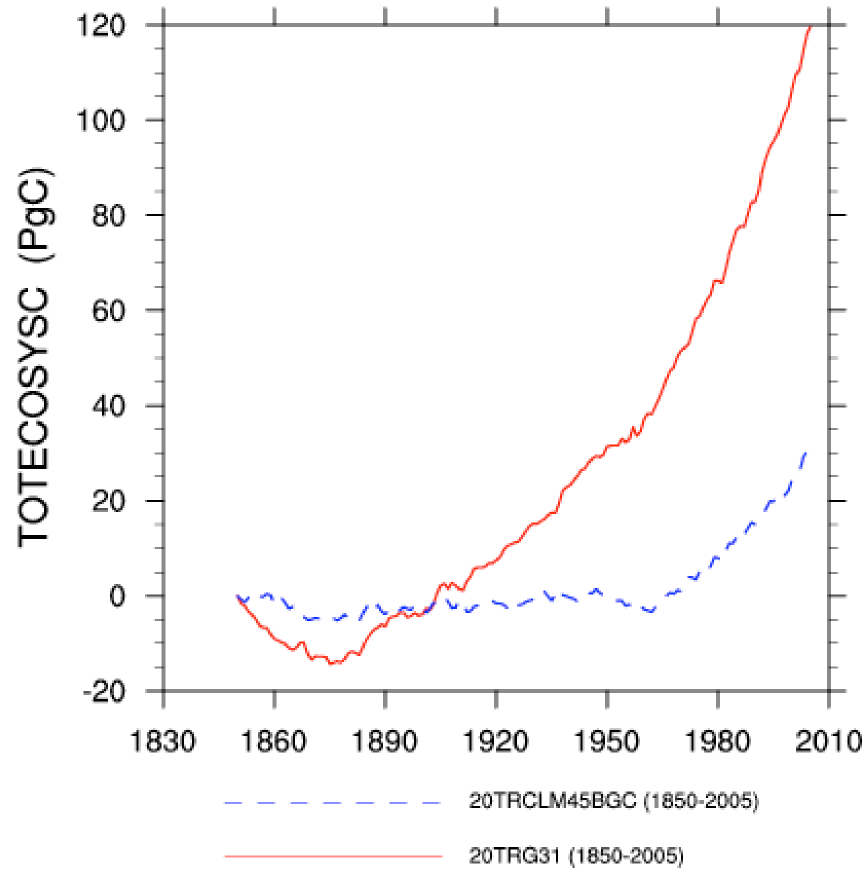


Global Land Carbon Cycle

Trends in GPP



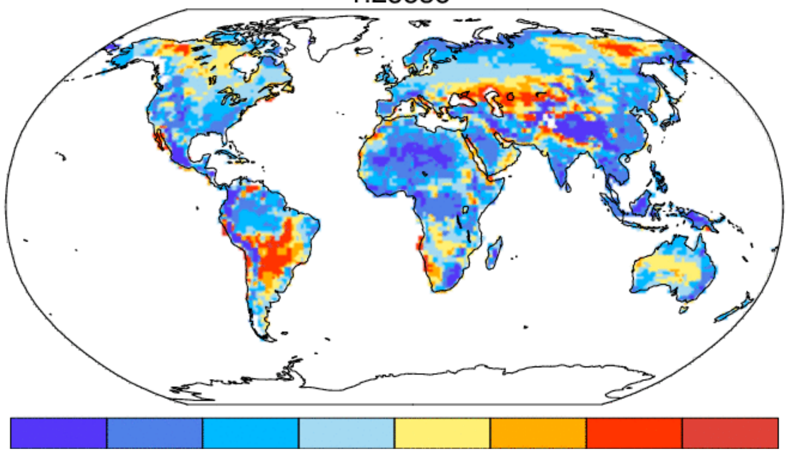
Trends in Total Ecosystem C



Annual Air Temperature Bias

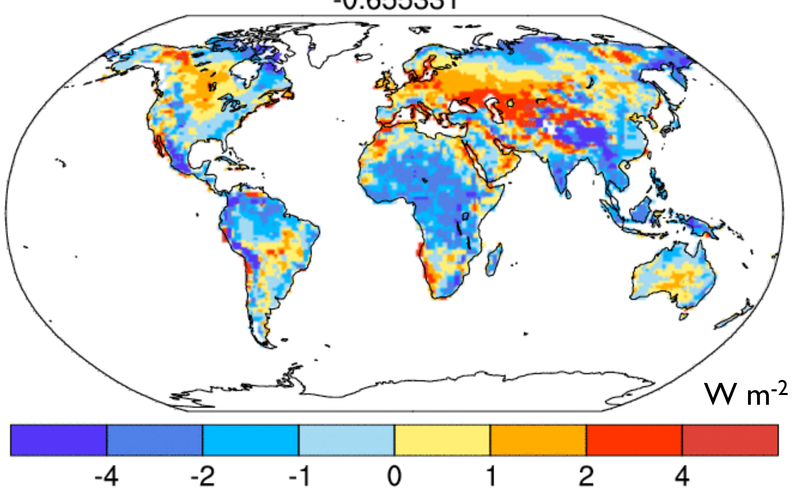
CESM1.5 (28)

-1.25838



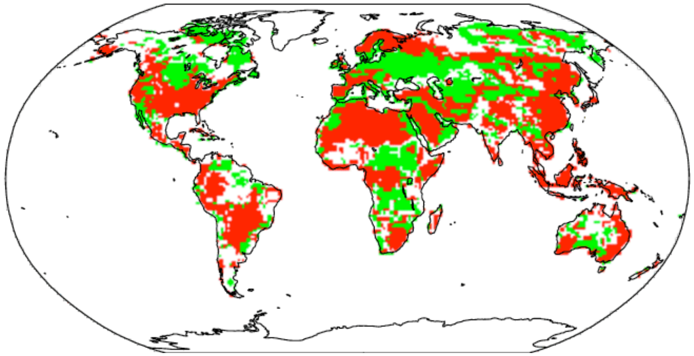
CESM1.2

-0.655331



Improvement relative to obs
Green: CESM1.5; Red: CESM1.2

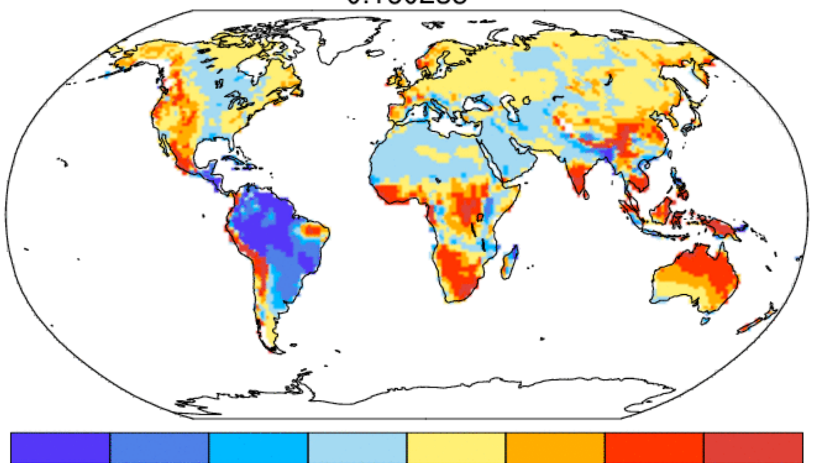
Model relative to Obs
28.2852% - 46.7994%



Annual Precipitation Bias

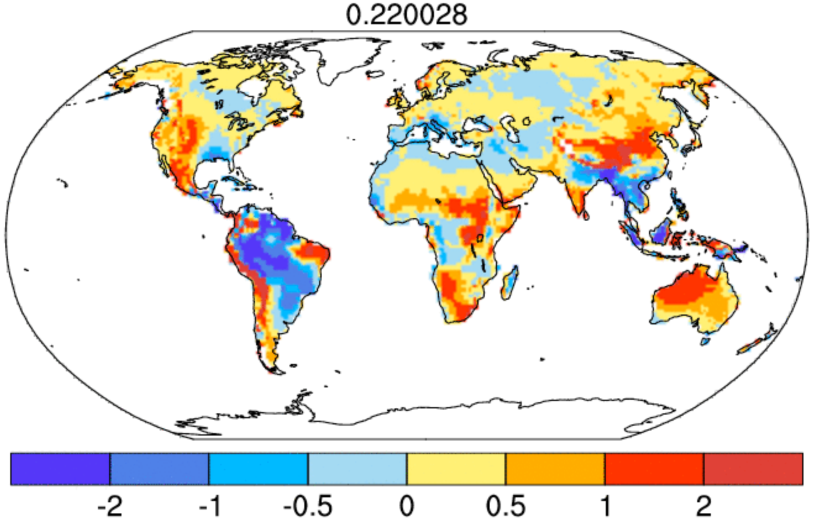
CESM1.5

0.160235



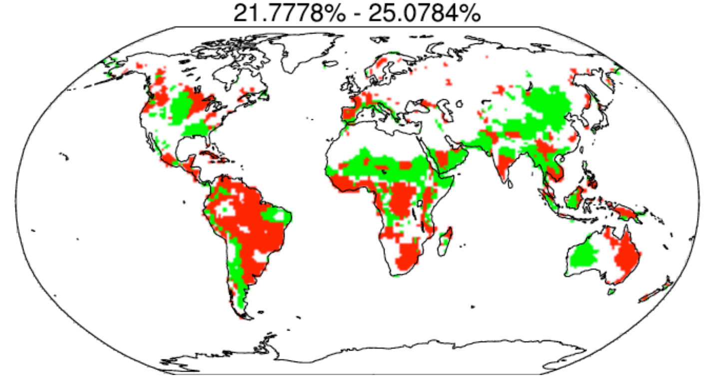
CESM1.2

0.220028



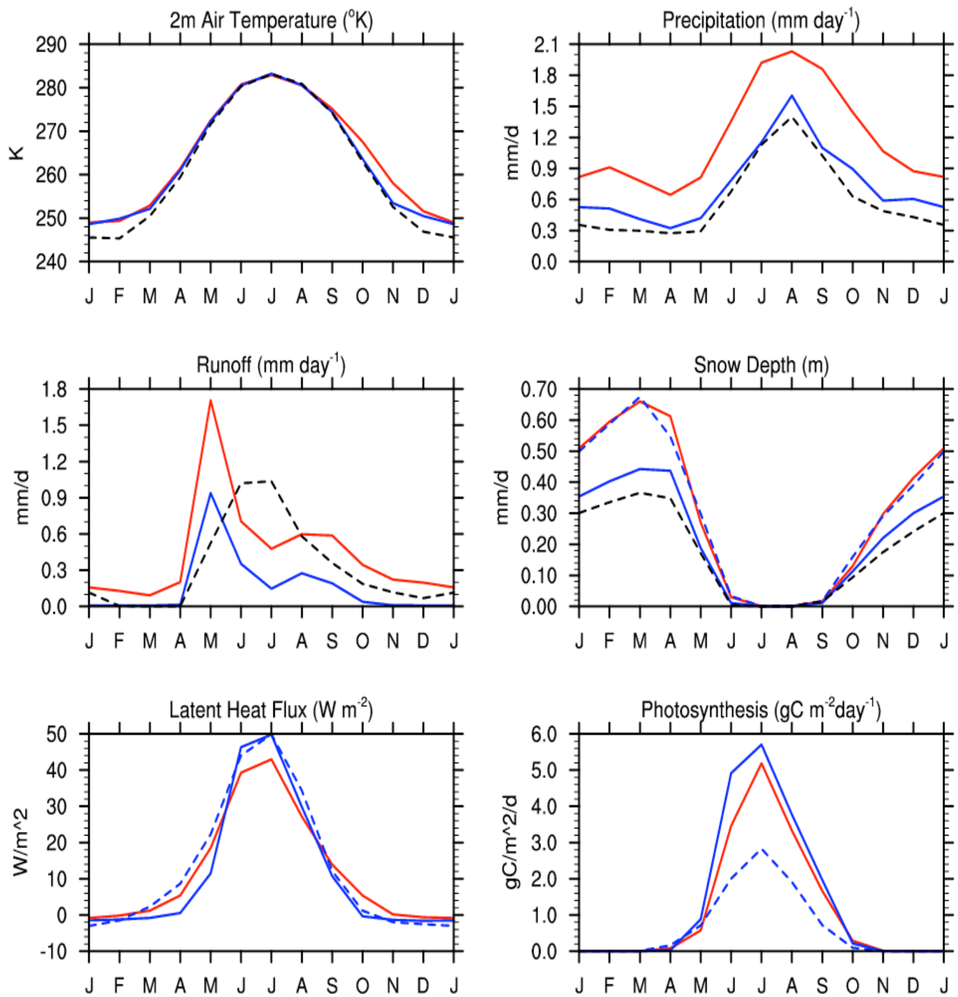
Improvement relative to obs
Green: CESM1.5; Red: CESM1.2

21.7778% - 25.0784%



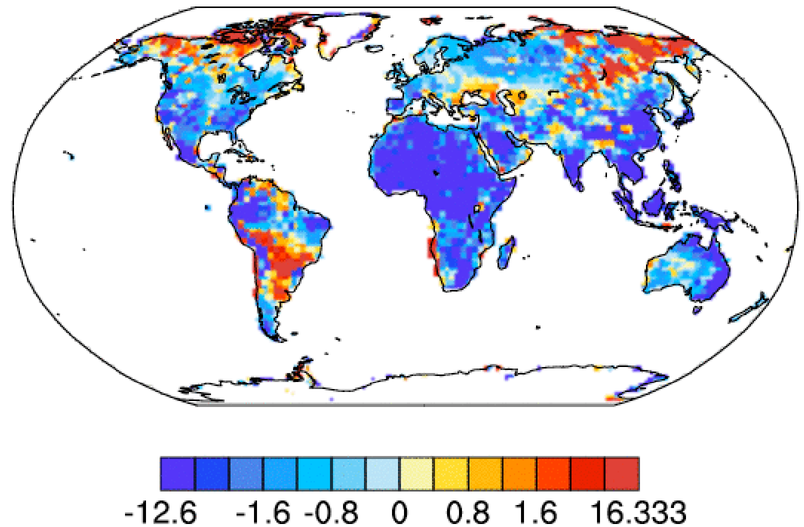
High latitude climate

Alaskan Arctic (66.5-72N,170-140W)



CESM1.5 (28) **CLM5** **OBS**

Soil Temperature
CESM1.5 (28) – CLM5

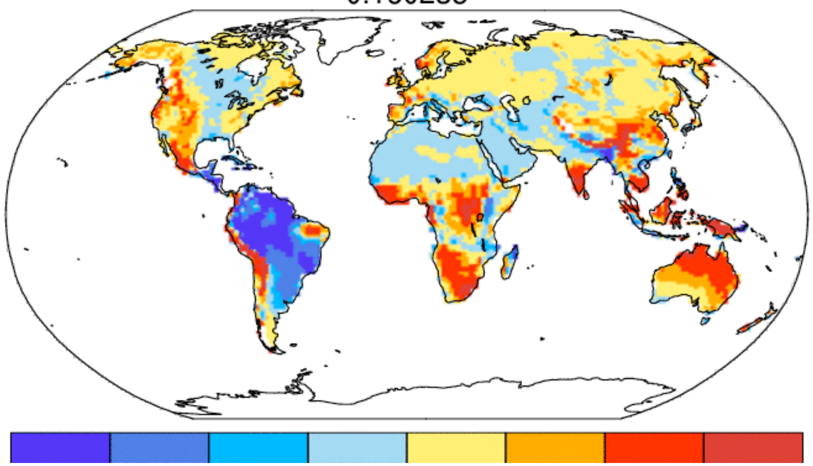


Too much snow insulation warms soils and degrades permafrost simulation

Annual Precipitation Bias

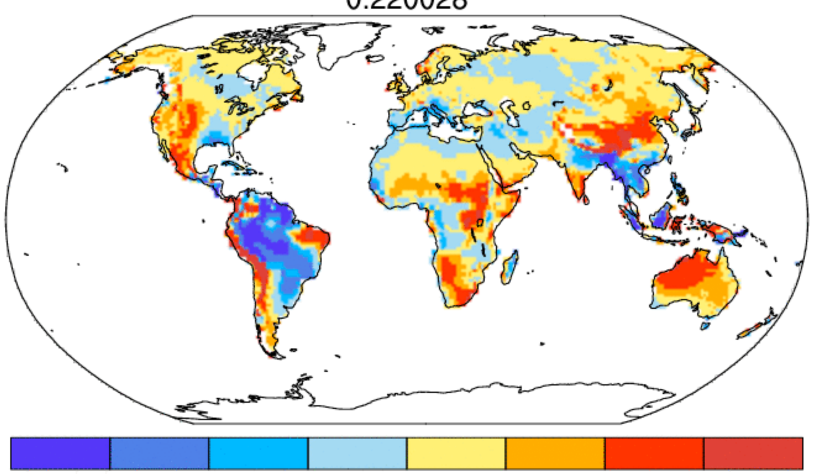
CESM1.5

0.160235



CESM1.2

0.220028



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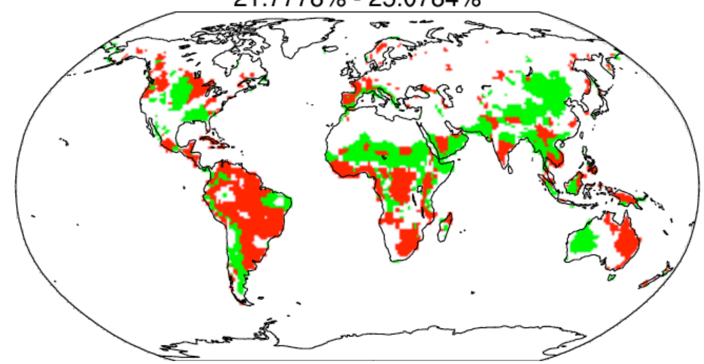
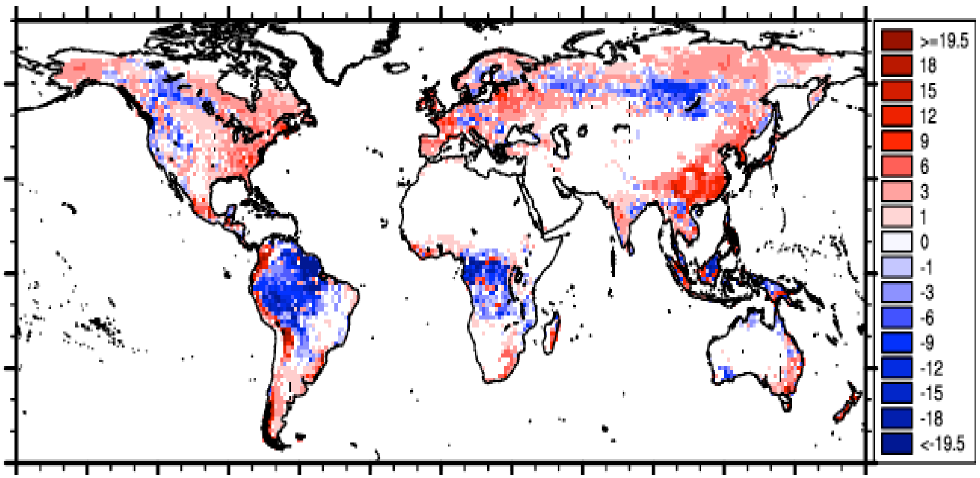
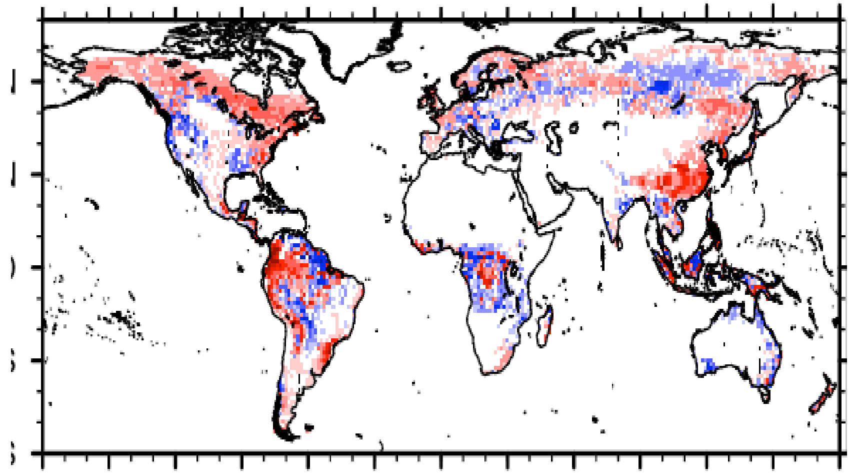


Aboveground Biomass Bias vs GEOCARBON (Avitabile et al. 2015)

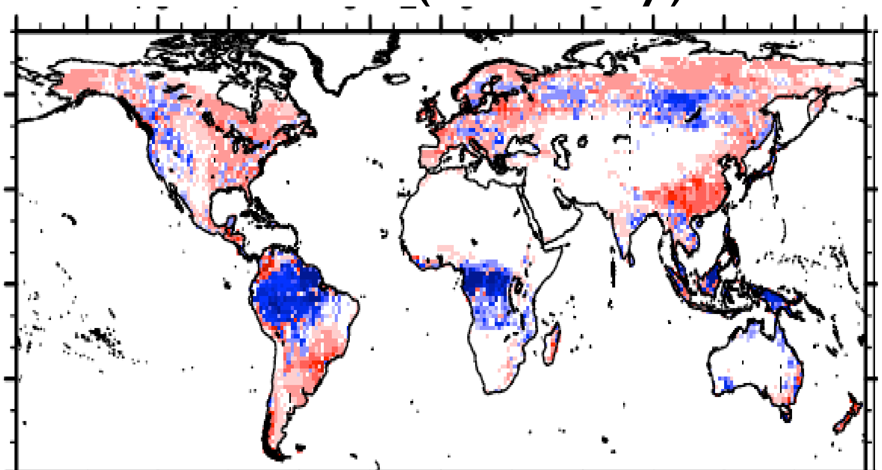
CESM1.5



CESM1.2



CLM5 (land-only)

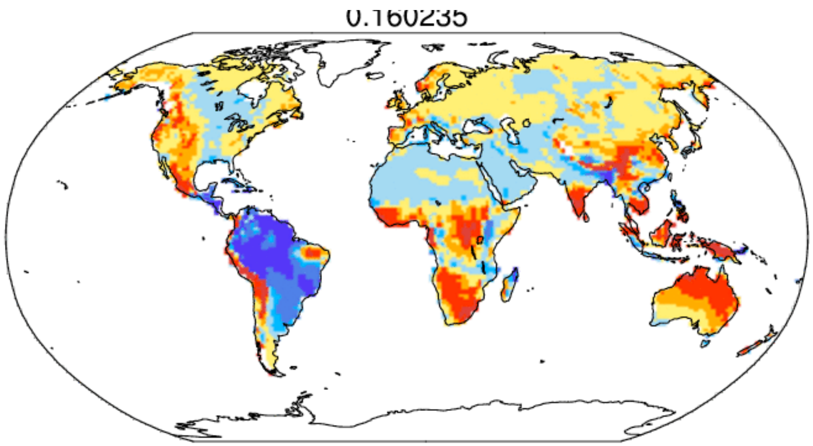


Biomass bias more sensitive to CLM parameterizations than climate

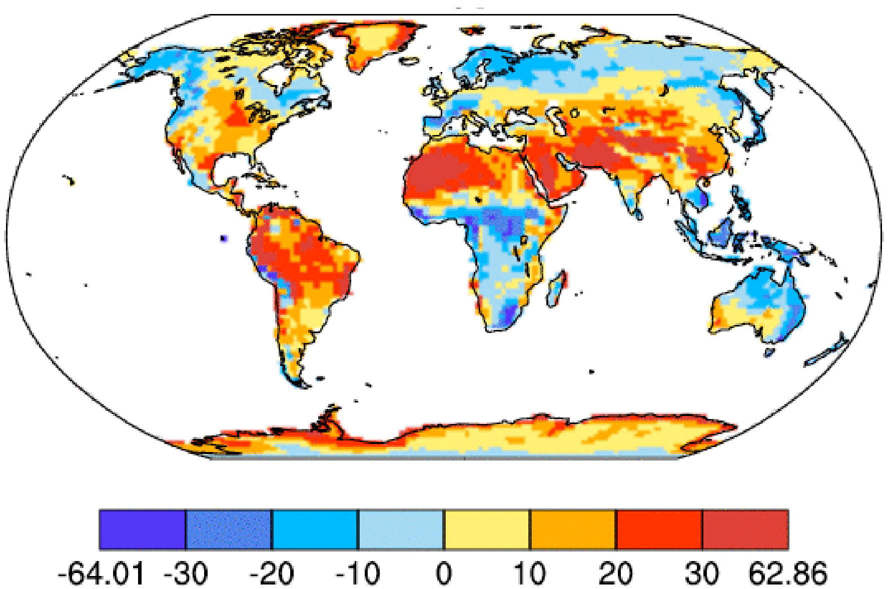
Tuning and tweaking of CLM5 parameterizations ongoing including fire and methane especially

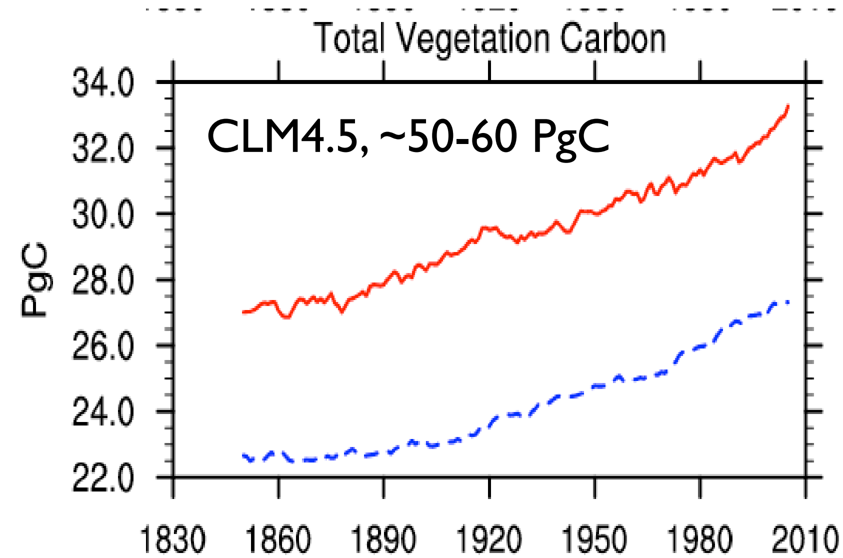
Amazon rainforest in CESM1.5

ANN precipitation bias



ANN Incident Surface Solar Radiation bias





CESM1.5 (28)   CLM5

Despite poor Amazon precip, carbon stocks similarly poor in CESM1.5

But, will sensitivity to climate change be reasonable

Improving Amazonian Precipitation in CESM1.5

Ben Sanderson

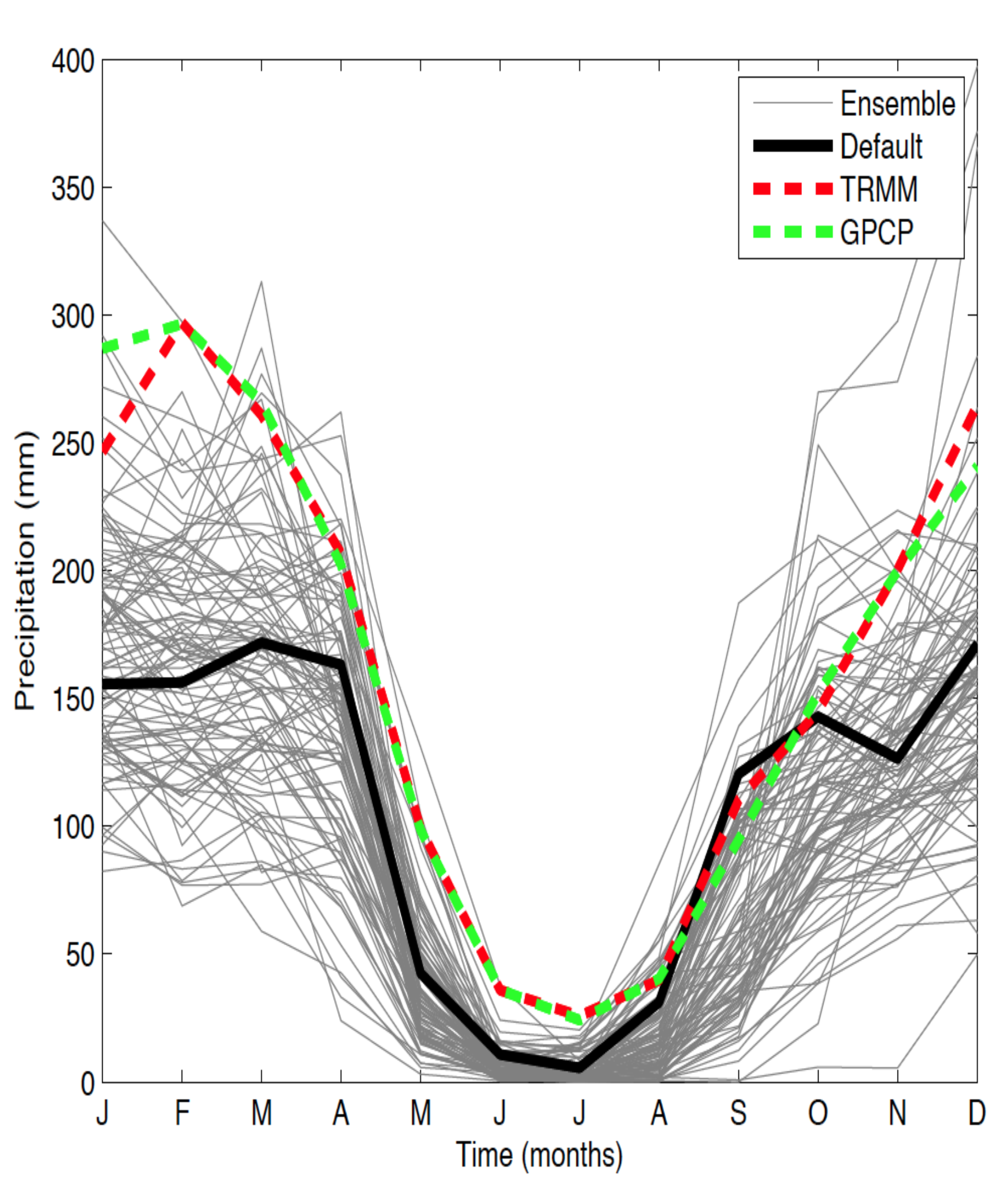
PPE: In CESM1.2 at least, this wasn't a tuning issue

100 member PPE with CESM1.2 explored

- dmpdz, tau, c0 (convection scheme)
- rh_low, rh_hgh, bt_min, bt_max (lin fire scheme)
- rsubtopm (soil hydrology)

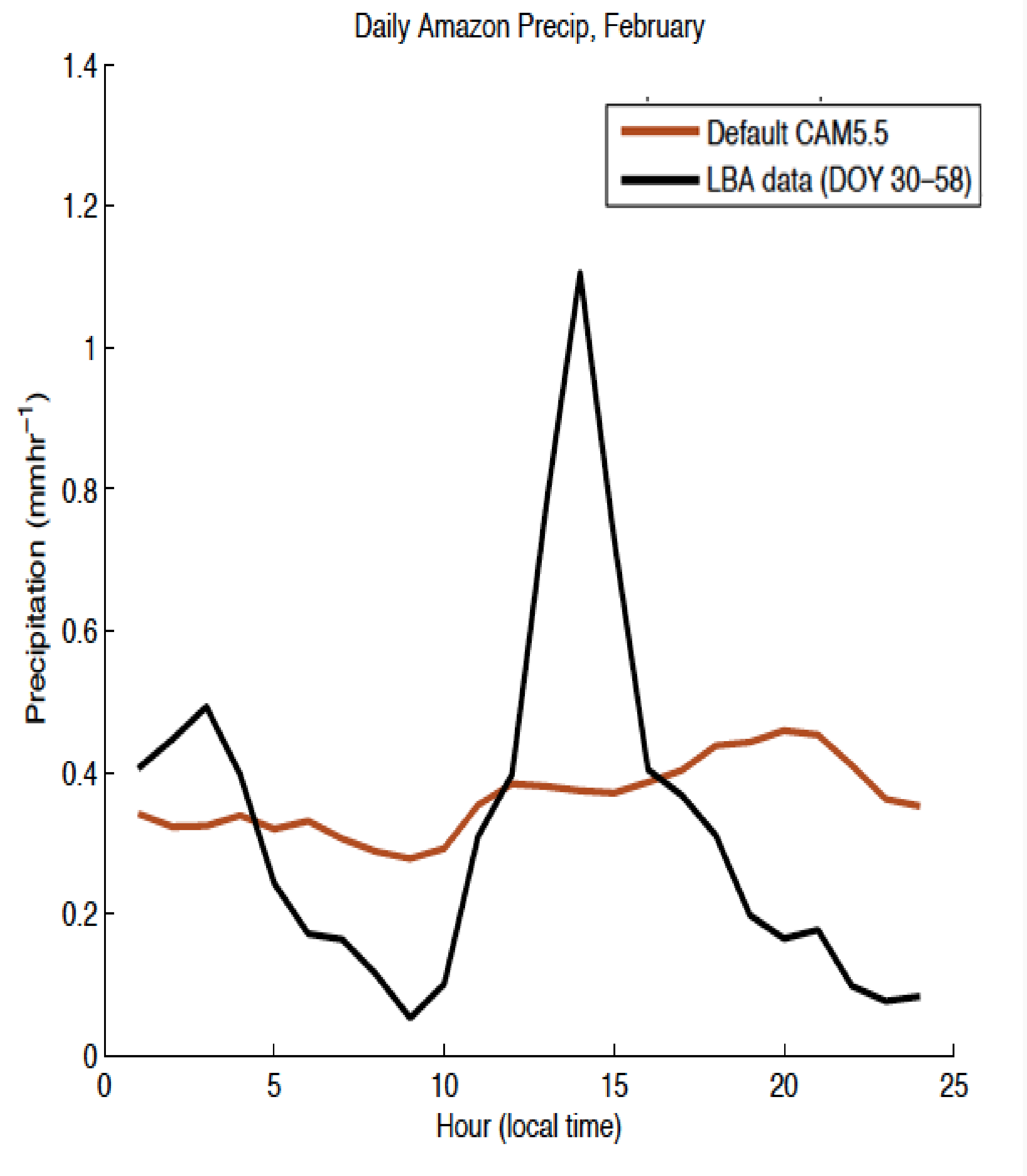
low dmpdz/low tau simulations could reproduce wet season values, but only at the expense of unrealistic ITCZ. All ensemble members were biased low in dry season.

Amazonia Monthly Precipitation (mm)



CESM1.5 Diurnal cycle bias

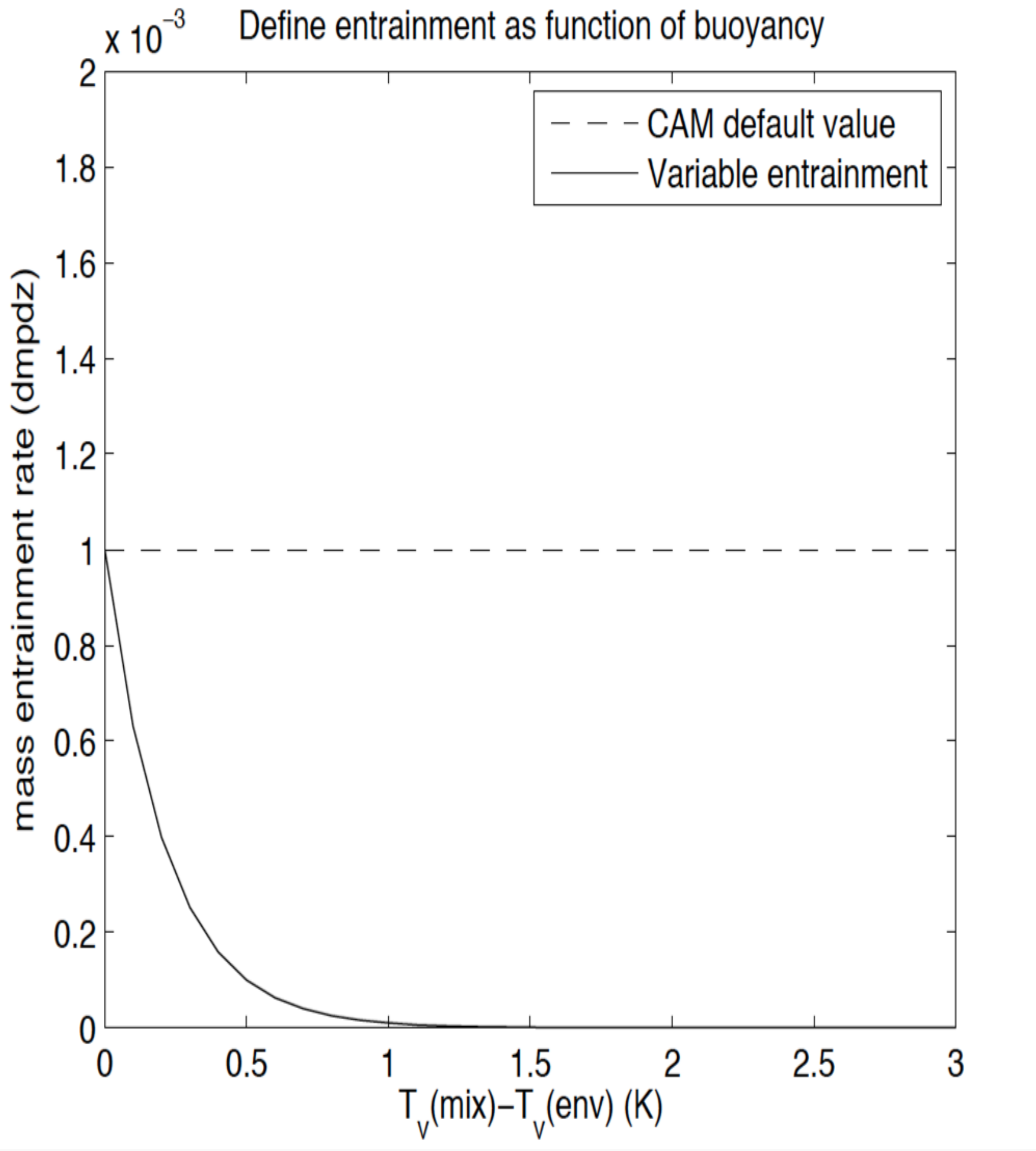
Current development model fails to reproduce daily cycle of precipitation in the Amazon, which should ramp up convective activity in the late morning with storms peaking mid afternoon



Proposal: Variable entrainment parameterization

Mass entrainment (dmpdz) is defined as a constant in the ZM convection scheme. Instead, we allow it to vary as a function of local buoyancy, such that when air becomes unstable, entrainment into the convective column is increasingly reduced.

This has the effect of reducing the dilution of CAPE in the afternoon without producing overly intense convective precipitation in more stable environments.



Variable Entrainment Parameterization

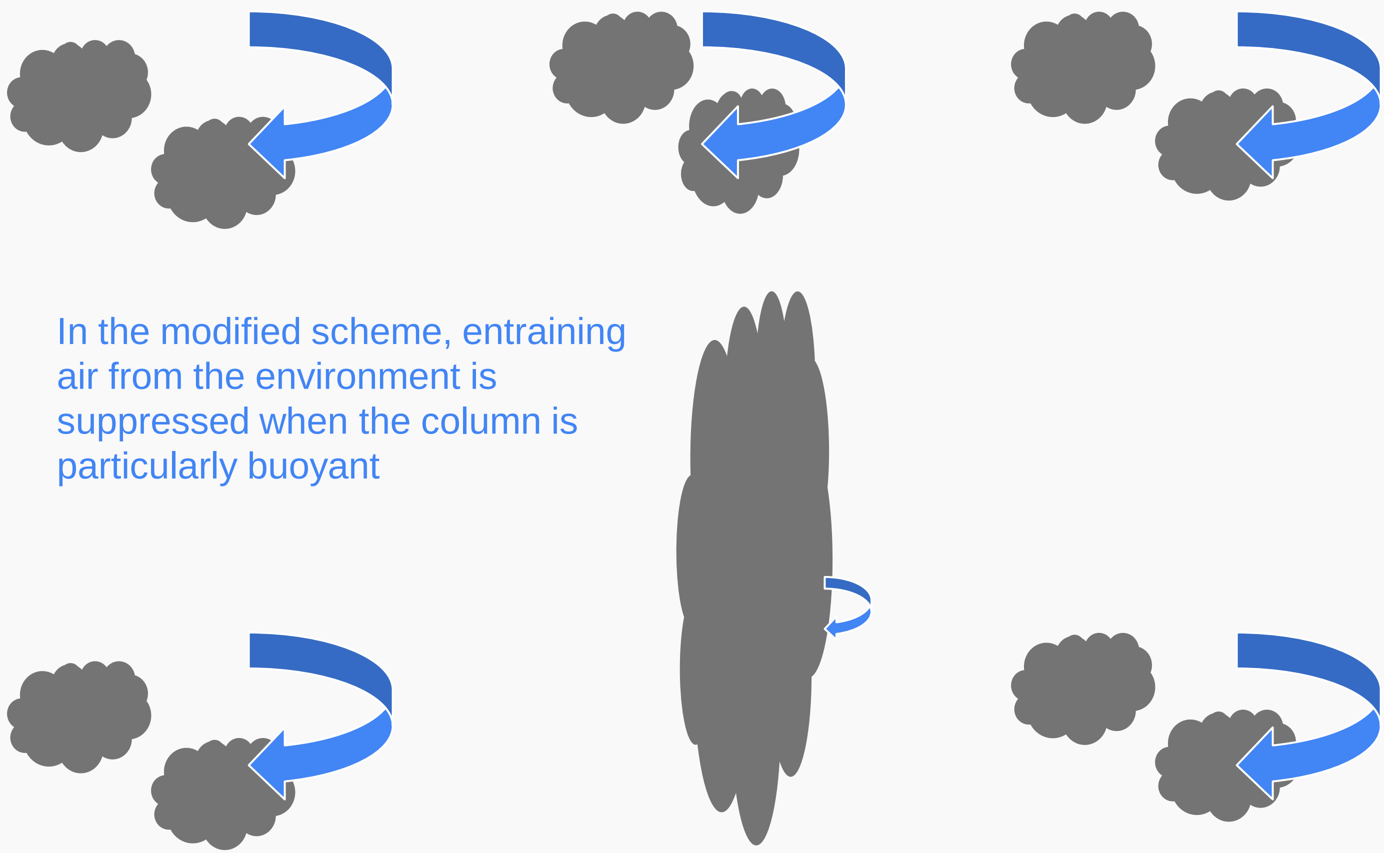
	morning	noon	afternoon	evening

At present, CAPE is diluted by constant entrainment, preventing the formation of significant instability

CAM5.5

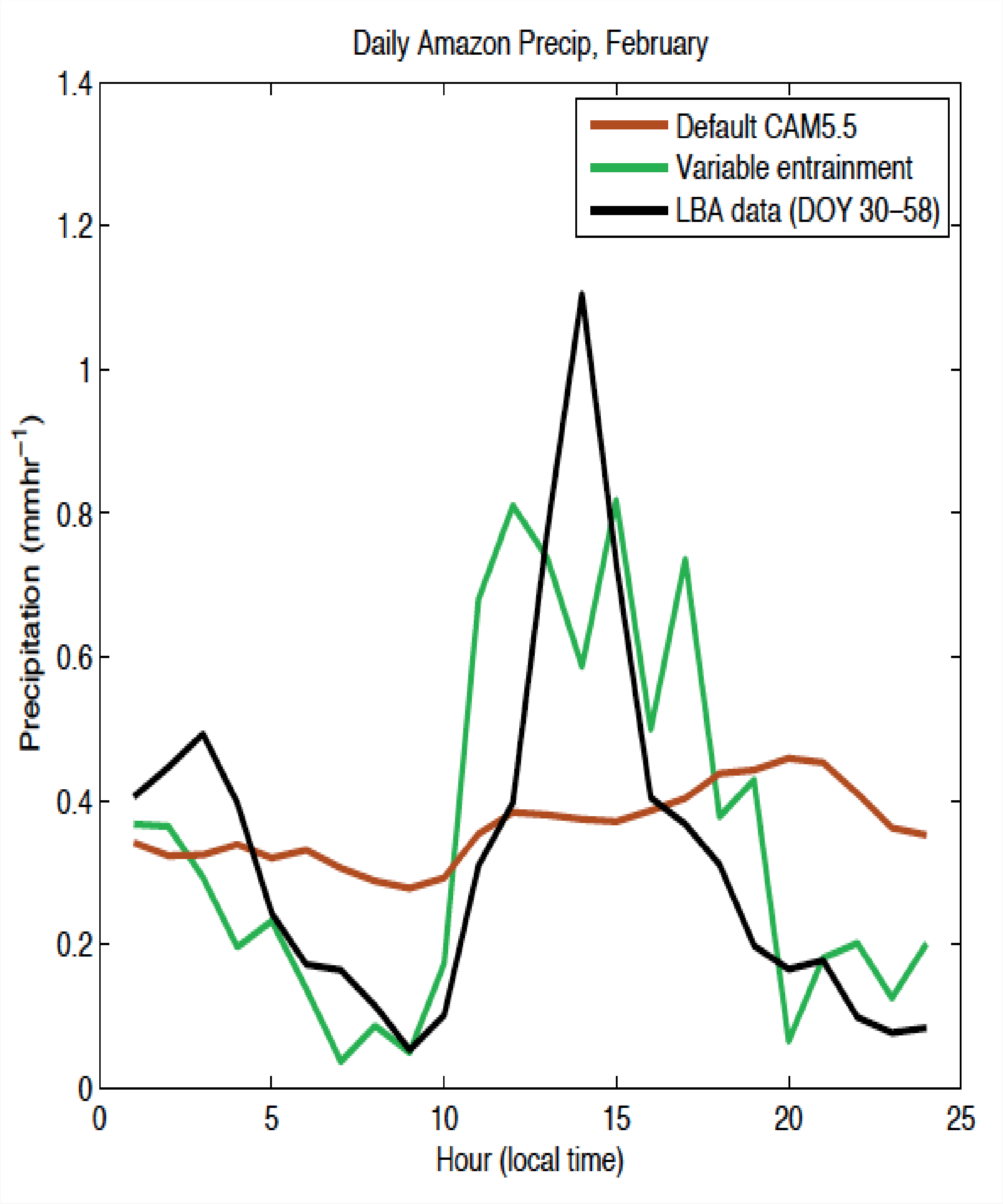
In the modified scheme, entraining air from the environment is suppressed when the column is particularly buoyant

Variable entrainment



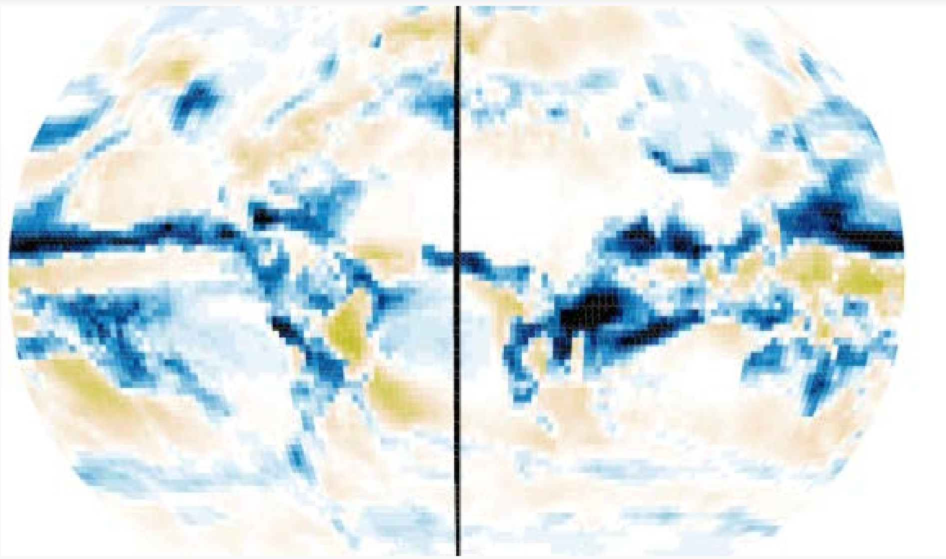
Variable entrainment parameterization

Reducing entrainment levels when local CAPE values become large improves diurnal cycle - correctly representing initiation of afternoon storms in the wet season.

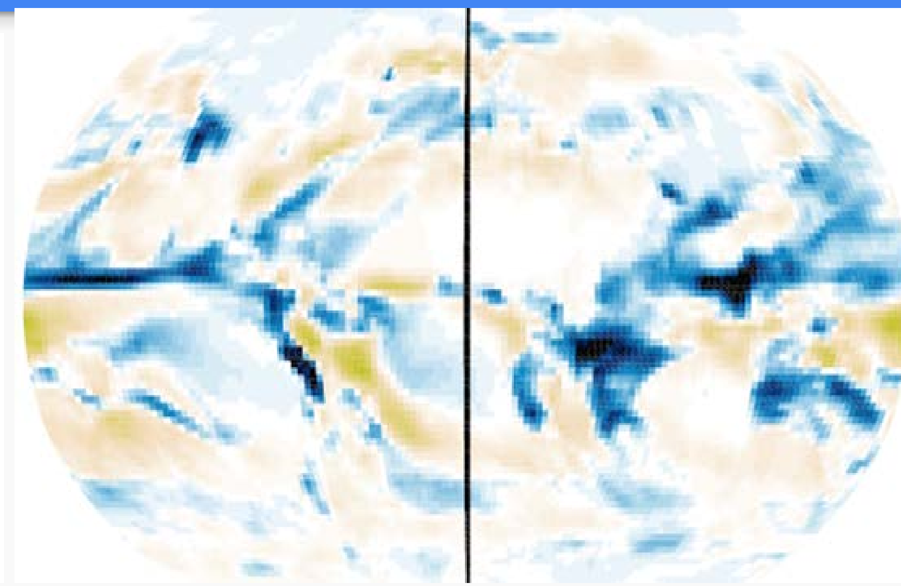


Looking globally. Precip bias in Amazon is eliminated, but…

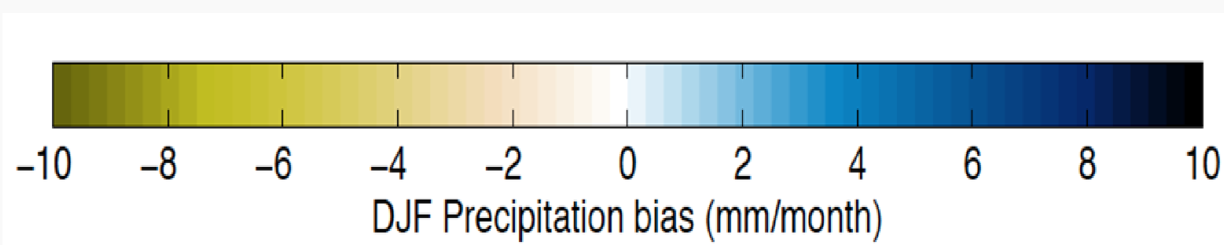
- SE Brazil dry bias persists - not sensitive to convective parameters and possibly addressable with CLUBB tuning
- South Pacific wet bias introduced, further tuning of entrainment relationship required.



Variable Entrainment



Default CAM5.5



Collaborative Nitrogen Cycle Project