Recent CLM-related Progress at the University of Arizona

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Overview

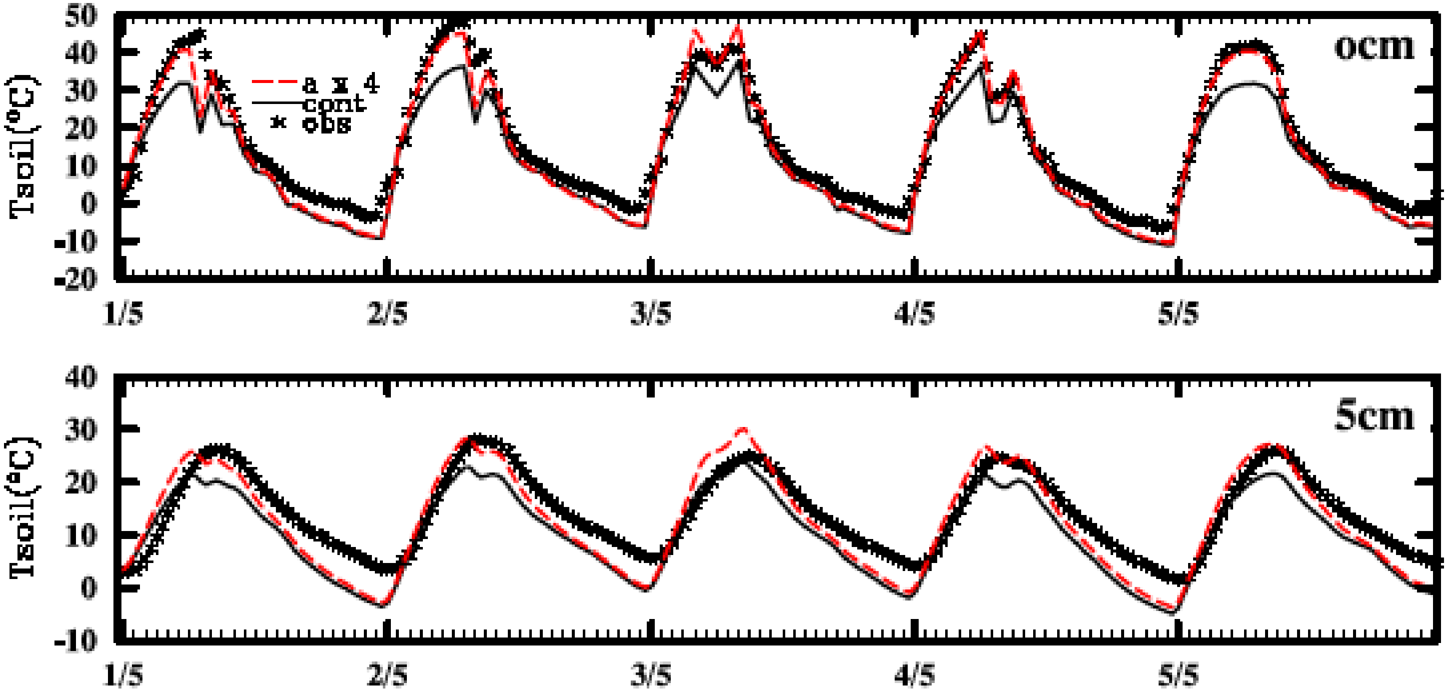
Goal: Improve the Energy, Water, and Biogeochemical Cycles

- Soil Skin Temperature	Wang, A., et al.
- 3D Soil Hydrology	Niu, G.-Y., et al.
- Soil Hydrology Scheme Comparison	Decker, M., et al.
- Ground Water	Sakaguchi, K (Brunke, M), et al.
- River Discharge	Sakaguchi, K., et al.
- Plant Carbon Allocation	Zeng, X., et al.
- CO_2 diurnal cycle in the canopy air	Moreno, G., Rosolem, R., et al.

Other research projects at the Land-Atmosphere-Ocean Interaction (LAOI) Group:
http://www.atmo.arizona.edu/index.php?section=research&id=laoi

Soil Skin Temperature

Cold bias in the bare soil skin temperature



CLM4, Tibet

Bare soil thermal roughness lengths revisited

$$z_{0h,g} = z_{0m,g} e^{\enclose{circle}{-a}\left(u_* z_{0m,g}/\nu\right)^{0.45}}$$

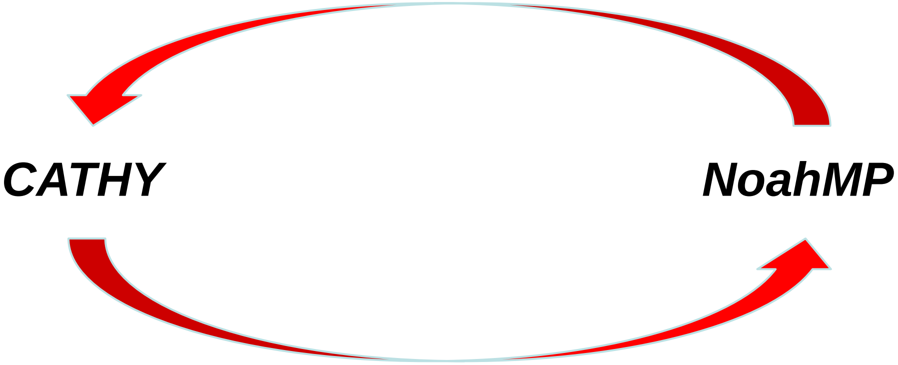
motivated by our previous study with Noah model (Zheng et al., submitted)

a=0.13 was verified by limited observations

Land Surface Modeling with 3D Soil Hydrology

CATHY + NoahMP models for hillslope, catchment, and regional scales

2D effective infiltration
3D root-zone transpiration
3D soil moisture (frozen)
at boxes → at nodes

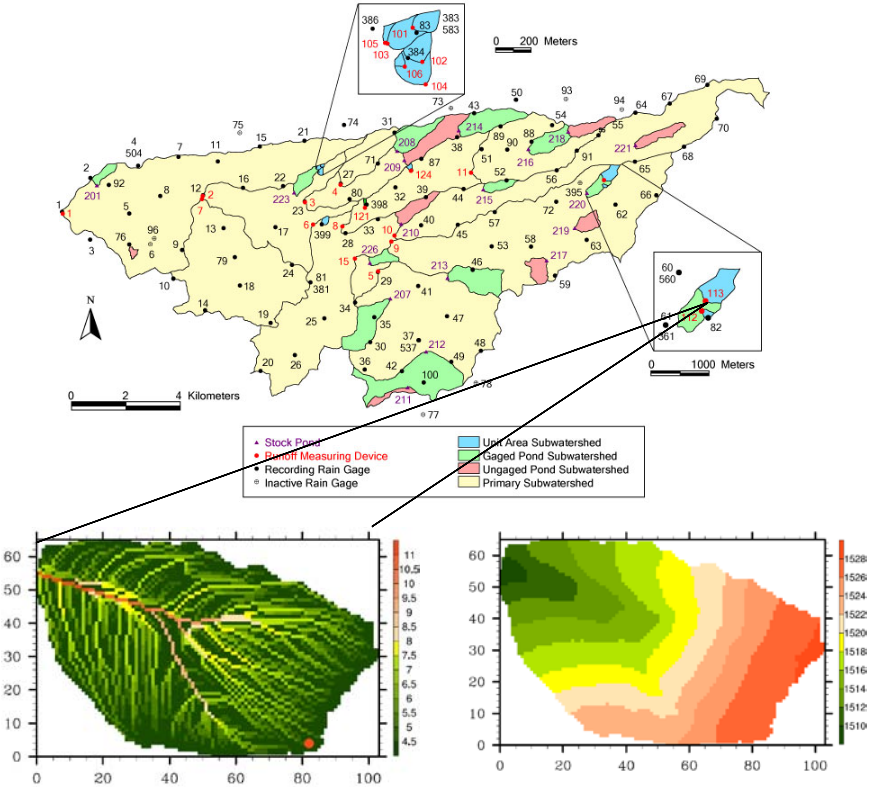


CATHY

NoahMP

3D soil moisture
at nodes → at boxes

An experiment at a water-limited catchment: Walnut Gulch, AZ

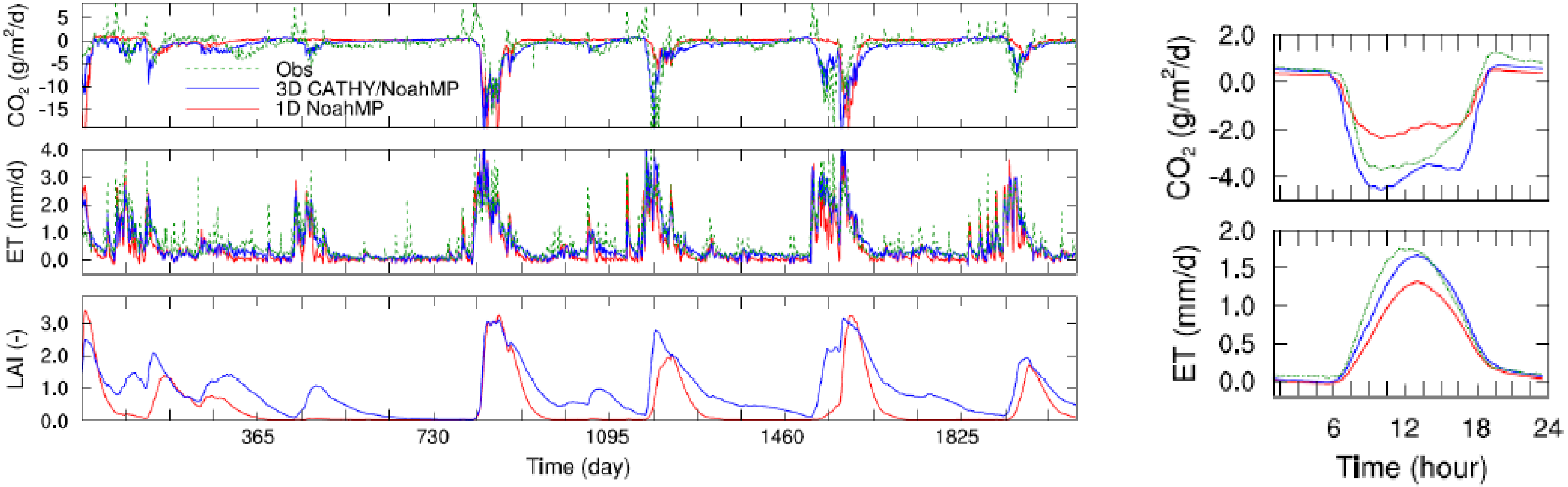


Niu et al., submitted

Land Surface Modeling with 3D Soil Hydrology

THE UNIVERSITY OF ARIZONA

CATHY + NoahMP models for hillslope, catchment, and regional scales

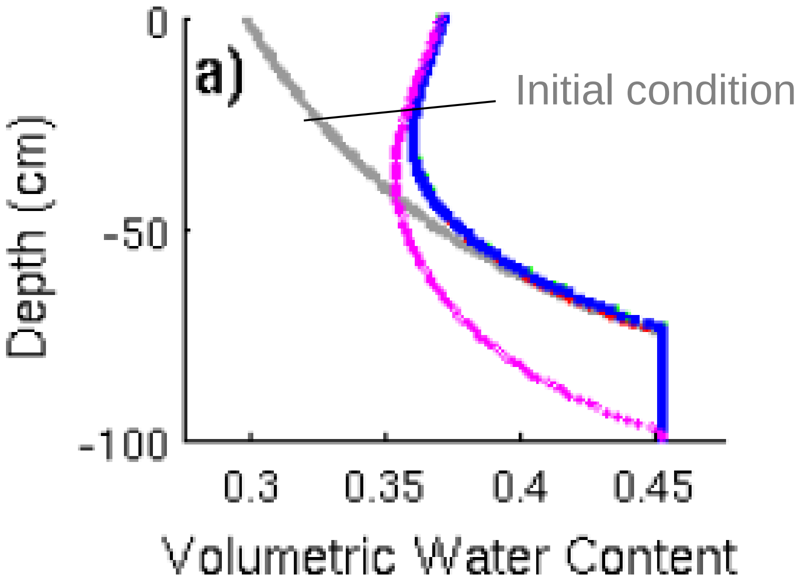


- Overland flow and lateral water redistribution provide plants with moisture low lying areas; sustain ET and CO$_2$ fluxes in dry-down periods to better agree with observation.

-The 3-D hydrology will be coupled to CLM4 through an upcoming NSF (macrosystem biology) funded project

Comparison of Soil Hydrology Schemes

How efficient is the revised Richards eqn in CLM4 in variably saturated soils, as compared to the Ψ-based and combined Ψ- and θ-based methods?

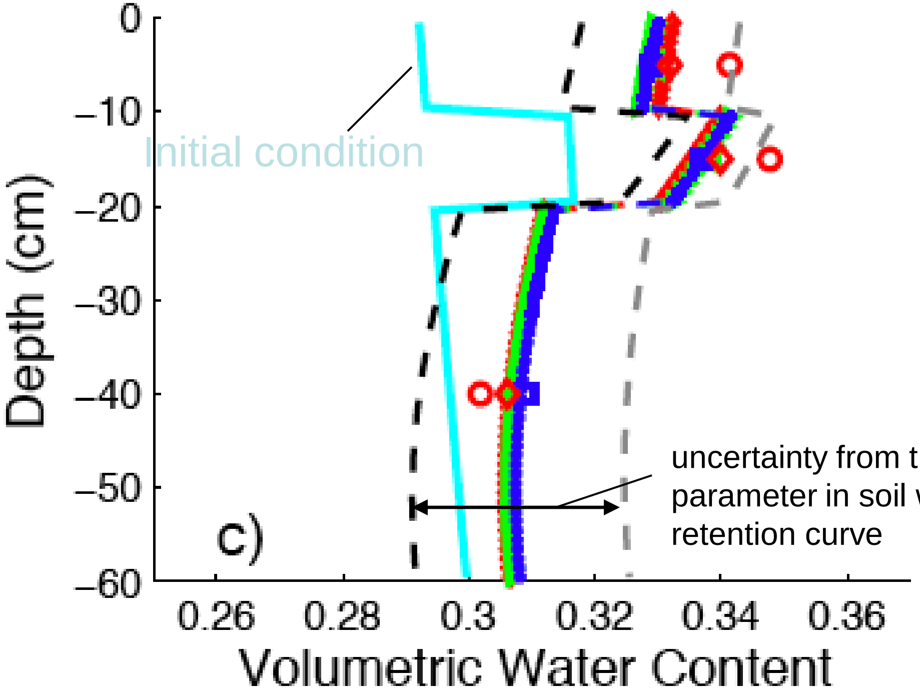


	Computer time relative to Z&D
Ψ-based: Pan & Wierenga 1995	381(8.2)
combined Ψ- & θ-based: Ross 2003	1.3(1.2)
θ-based (CLM4): Zeng & Decker 2009	1
θ-based (CLM3&3.5)	

Z&D (CLM4) produces identical solutions much faster

Comparison of Soil Hydrology Schemes

Is the revised Richards eqn in CLM4 valid in **heterogenous** soils, as compared to the Ψ-based and combined Ψ- and θ-based methods?



uncertainty from the parameter in soil water retention curve

Ψ-based: Pan & Wierenga 1995

combined Ψ- & θ-based: Ross 2003

θ-based (CLM4): Zeng & Decker 2009

with: ○ hydraulic conductivity as in CLM4

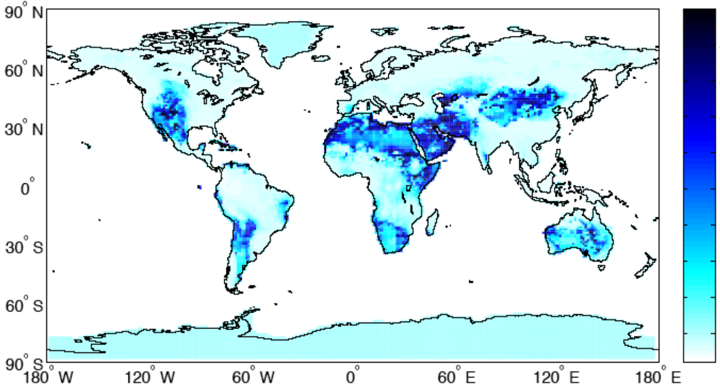
◇ modified hydraulic conductivity

Z&D produces nearly identical solutions, given the hydraulic conductivity based on Ψ (which is continuous) at the layer interfaces.

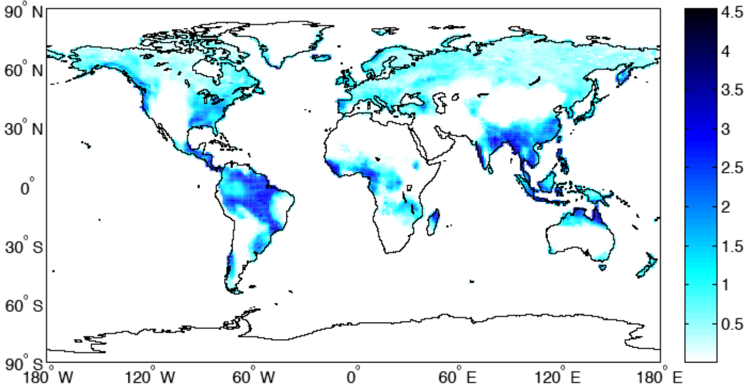
Ground Water

Physical consistency in the aquifer: water table depth variability

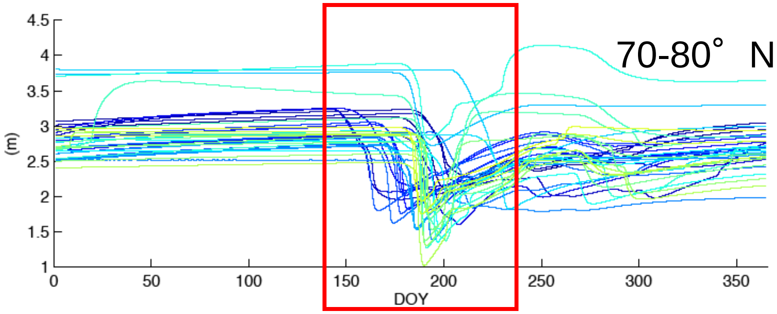
annual mean water table depth (m)

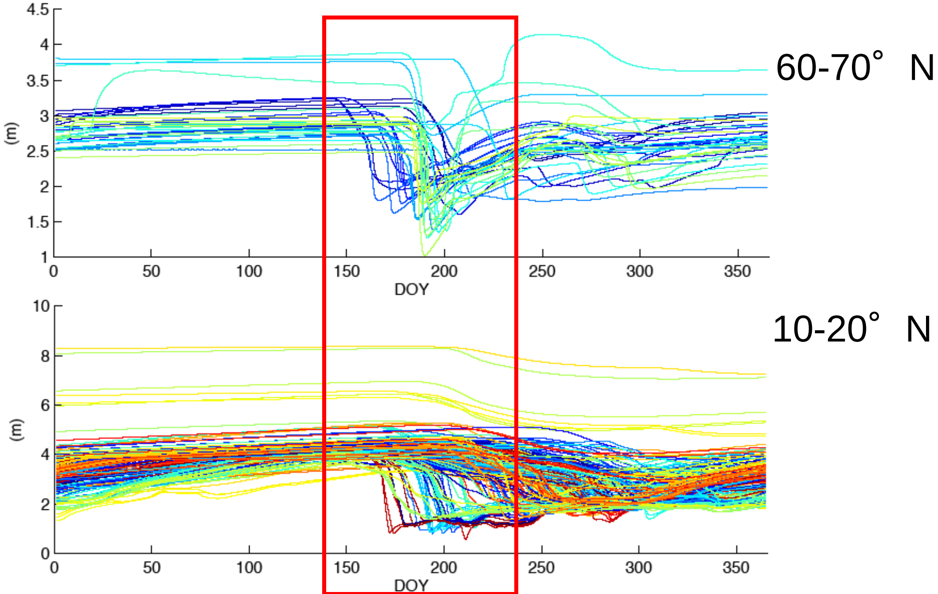


annual [max]-[min] range (m)



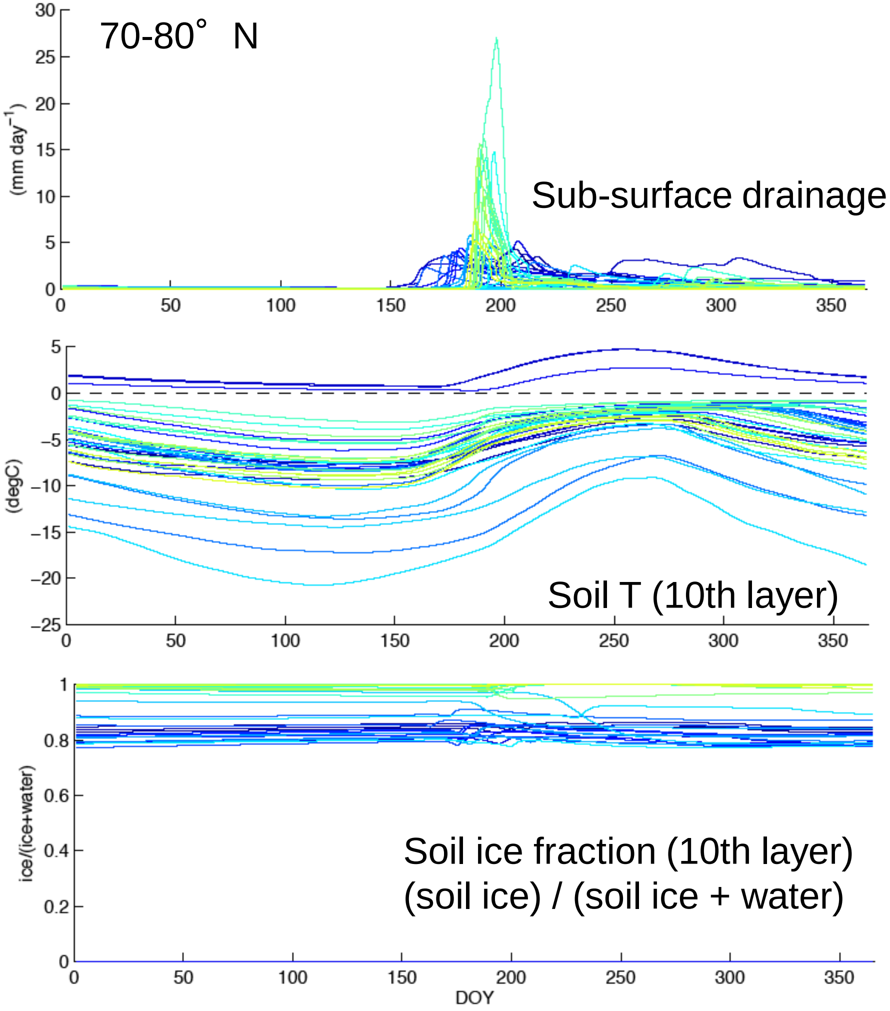
Abrupt drop in the water table depth (daily mean) over the grids with [max]-[min] > 1m

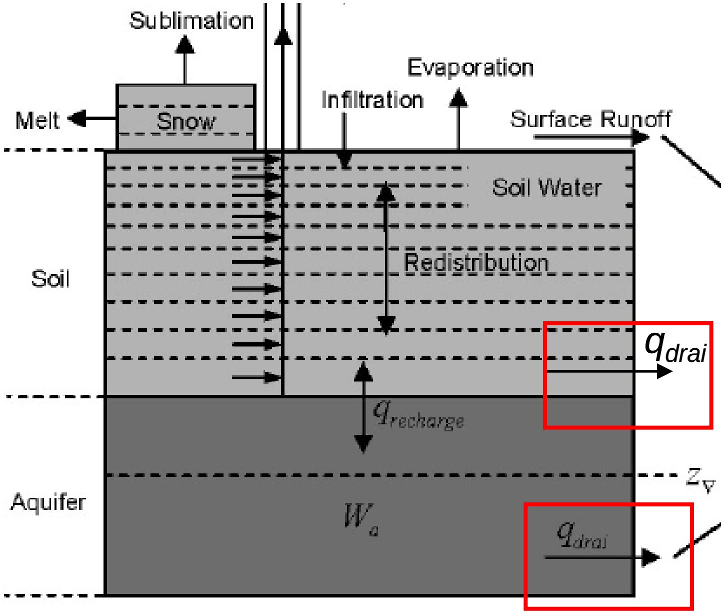




Ground Water

Physical consistency in the aquifer: water table depth variability & frozen water treatment



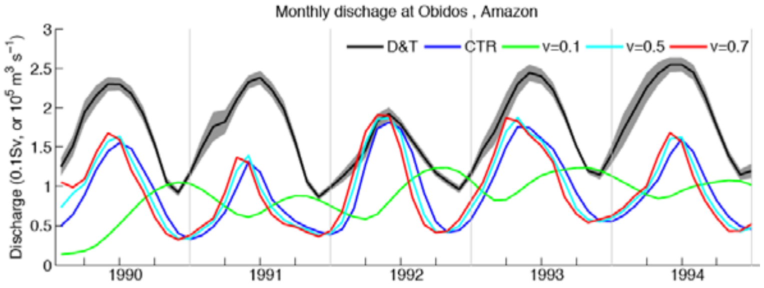


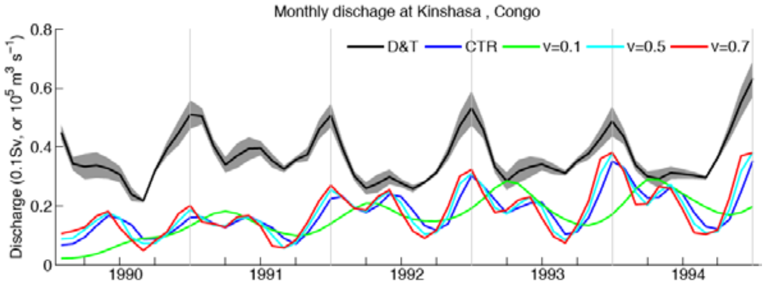
$$q_{drai} = (1 - f_{imp})\, q_{drai,\max} \exp(-f_{drai} z_\nabla)$$

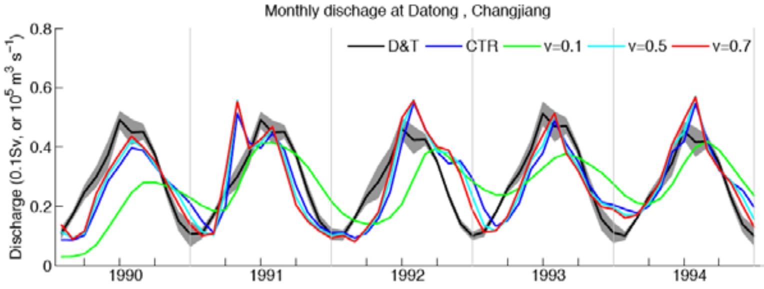
Subsurface drainage spike under mostly frozen conditions

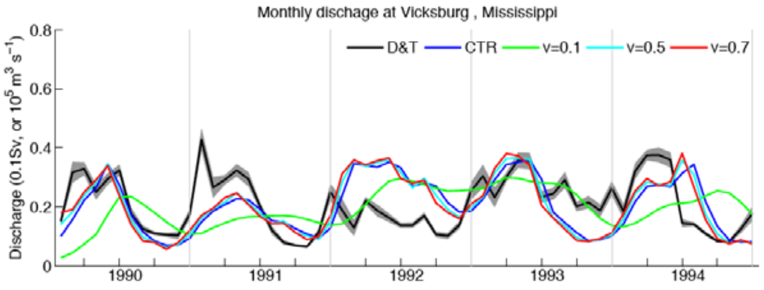
River Discharge

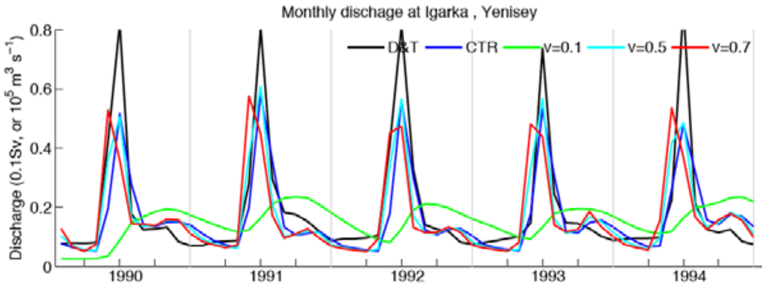
Sensitivity of CLM4-River Transport Model to river velocity


Monthly dischage at Obidos , Amazon


Monthly dischage at Kinshasa , Congo


Monthly dischage at Datong , Changjiang


Monthly dischage at Vicksburg , Mississippi

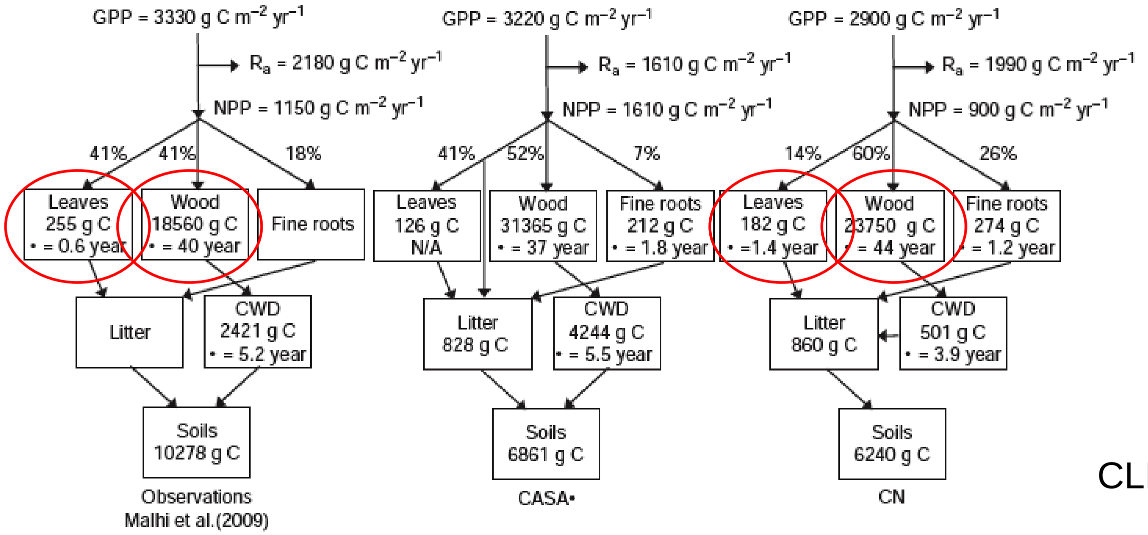

Monthly dischage at Igarka , Yenisey

- Compared to soil and snow hydrology, the river routing schemes is much simpler with room for improvement.

- The model is sensitive to "effective river velocity" (constant 0.35 m s^{-1}), but changing it does not necessarily improve the performance or make significant difference in these tests.

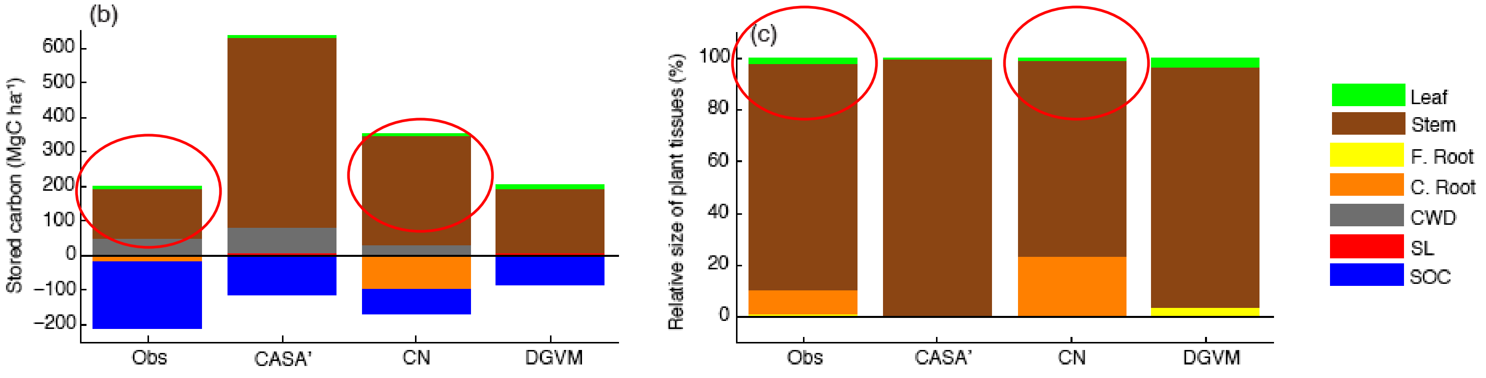
Plant Carbon Allocation

Bias toward stem & root relative to leaf mass



CLM3.5, Randerson et al., 2009

Fig. 6 Carbon pools and fluxes in tropical forests from a synthesis of observations from the Amazon (Malhi et al., 2009) compared with the models.

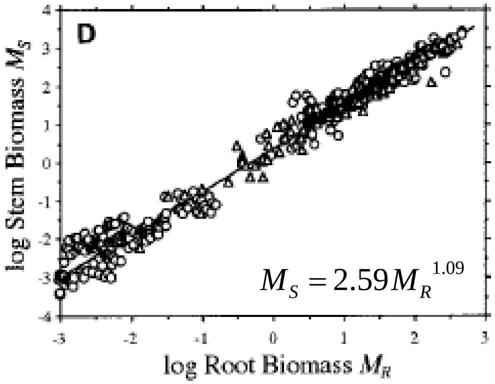


CLM3.5, Sakaguchi et al., 2011

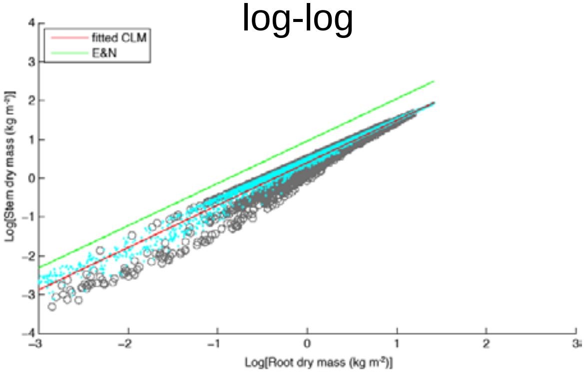
Plant Carbon Allocation

Bias toward stem & root relative to leaf mass

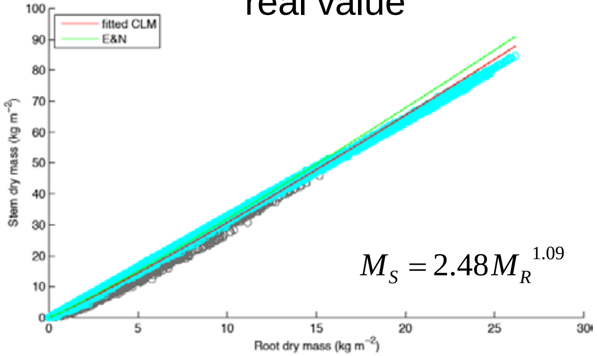
Stem mass v.s. root mass



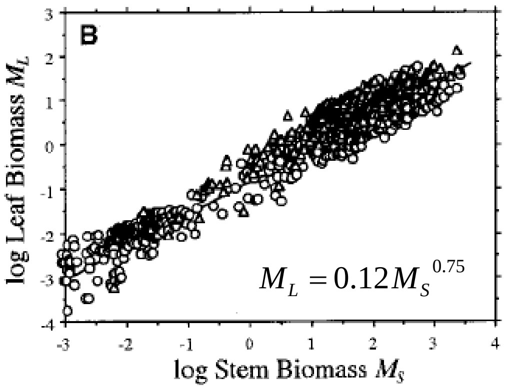
log-log

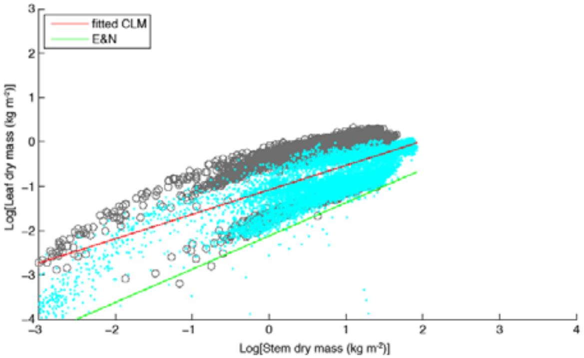


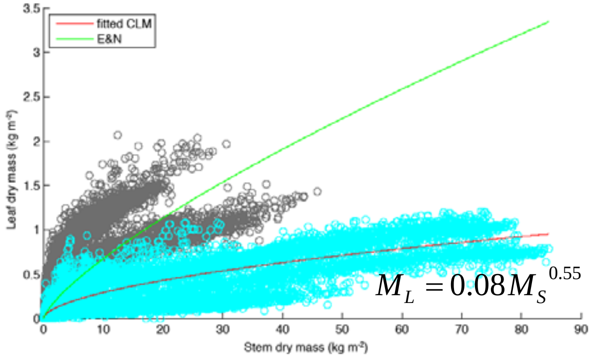
real value



Leaf mass v.s. stem mass





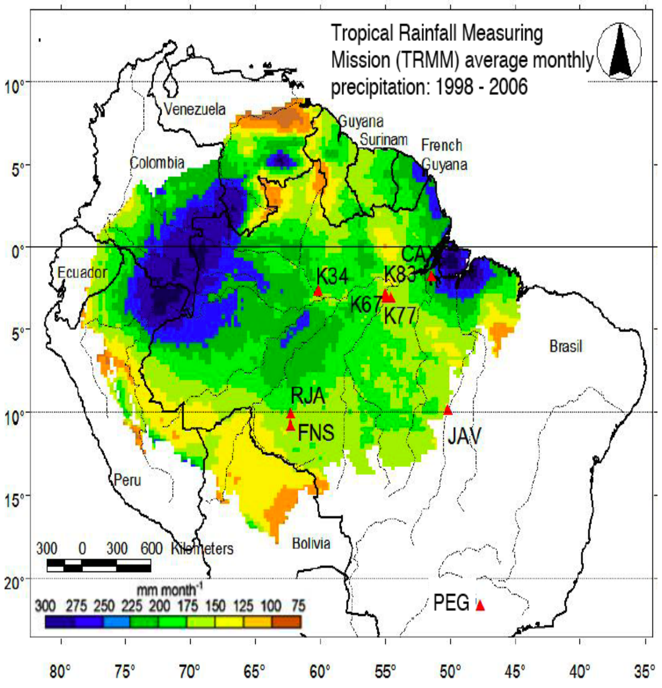


Enquist & Niklas, 2002, Science

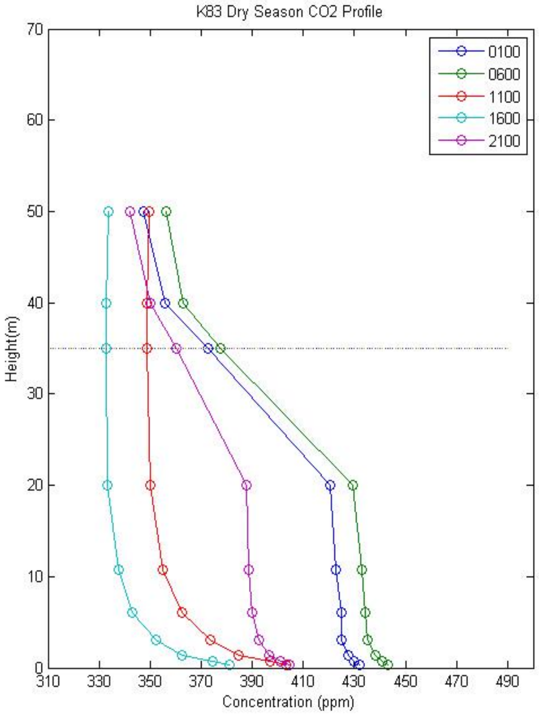
Offline CLM4-CN annual average from year 2000

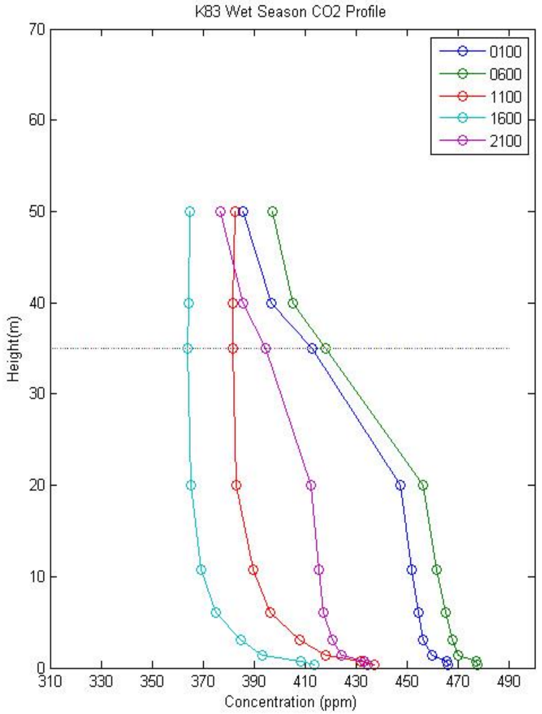
CO_2 Diurnal Cycle

Strong diurnal cycle of CO_2 in the canopy air



Map from Restrepo-Coupe et al.





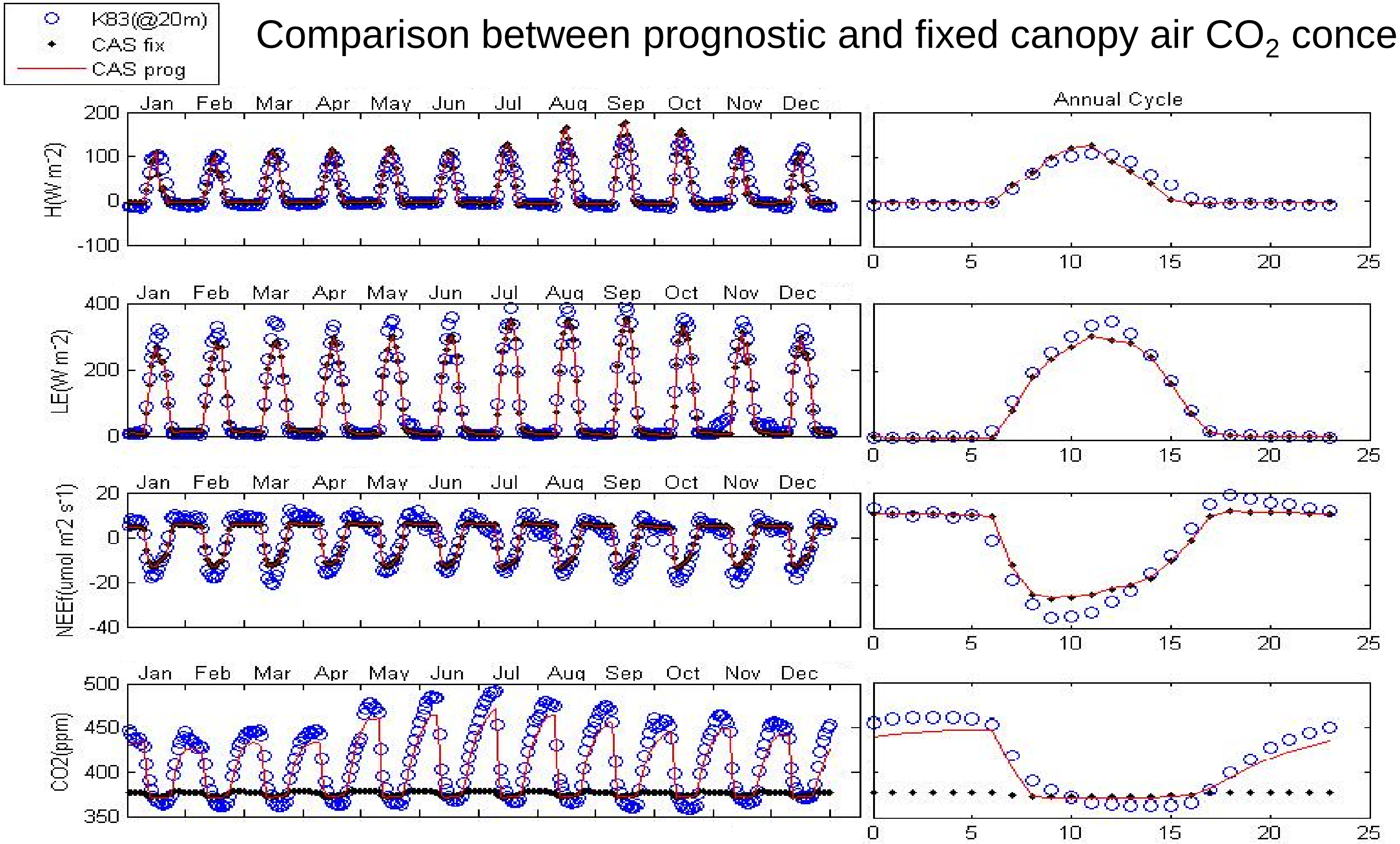
Hypothesis: Adding a canopy airspace CO_2 diurnal cycle would affect latent, sensible, and NEE fluxes.

$$A = \frac{\boxed{c_a} - c_i}{(1.37 r_b + 1.65 r_s) P_{atm}}$$

CO_2 Diurnal Cycle

Strong diurnal cycle of CO_2 in the canopy air

Comparison between prognostic and fixed canopy air CO_2 concentration



For this tropical site with SiB3, fluxes are not strongly affected by adding CO_2 diurnal cycle.

Re-Overview

The University of Arizona

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