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.
- $\text{CO}_2$ 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
Cold bias in the bare soil skin temperature

Bare soil thermal roughness lengths revisited

\[ z_{0h,g} = z_{0m,g} e^{-a(\mu^2 z_{0m,g}/\nu)^{0.45}} \]

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 $\rightarrow$ at nodes

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

Niu et al., submitted
Land Surface Modeling with 3D Soil Hydrology

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 CO₂ 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 $\Psi$-based and combined $\Psi$- and $\theta$-based methods?

- $\Psi$-based: Pan & Wierenga 1995
- combined $\Psi$- & $\theta$-based: Ross 2003
- $\theta$-based (CLM4): Zeng & Decker 2009
- $\theta$-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 $\Psi$-based and combined $\Psi$- and $\theta$-based methods?

$\Psi$-based: Pan & Wierenga 1995

combined $\Psi$- & $\theta$-based: Ross 2003

$\theta$-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 $\Psi$ (which is continuous) at the layer interfaces.
Physical consistency in the aquifer: water table depth variability

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

70-80° N

Sub-surface drainage

Soil T (10th layer)

Soil ice fraction (10th layer)

\[ q_{\text{drai}} = (1 - f_{\text{imp}}) q_{\text{drai,max}} \exp(-f_{\text{drai}} z_{\text{v}}) \]

Subsurface drainage spike under mostly frozen conditions
River Discharge

Sensitivity of CLM4-River Transport Model to river velocity

- 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

GPP = 3330 g C m⁻² yr⁻¹
Rₚ = 2180 g C m⁻² yr⁻¹
NPP = 1150 g C m⁻² yr⁻¹

GPP = 3220 g C m⁻² yr⁻¹
Rₚ = 1610 g C m⁻² yr⁻¹
NPP = 1610 g C m⁻² yr⁻¹

GPP = 2900 g C m⁻² yr⁻¹
Rₚ = 1990 g C m⁻² yr⁻¹
NPP = 900 g C m⁻² yr⁻¹

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

CLM3.5, Randerson et al., 2009

CLM3.5, Sakaguchi et al., 2011
Plant Carbon Allocation

Bias toward stem & root relative to leaf mass

Stem mass v.s. root mass

\[ M_S = 2.59 M_R^{1.09} \]

Leaf mass v.s. stem mass

\[ M_L = 0.12 M_S^{0.75} \]

Enquist & Niklas, 2002, Science

Offline CLM4-CN annual average from year 2000
**CO₂ Diurnal Cycle**

**Strong diurnal cycle of CO₂ in the canopy air**

Map from Restrepo-Coupe et al.

**Hypothesis:** Adding a canopy airspace CO₂ diurnal cycle would affect latent, sensible, and NEE fluxes.

\[ A = \frac{c_g - c_i}{(1.37r_b + 1.65r_s)P_{atm}} \]
CO₂ Diurnal Cycle

Strong diurnal cycle of CO₂ in the canopy air

Comparison between prognostic and fixed canopy air CO₂ concentration

For this tropical site with SiB3, fluxes are not strongly affected by adding CO₂ diurnal cycle.
Re-Overview

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  Wang, A., et al.

- **3D Soil Hydrology**  
  Niu, G.-Y., et al.

- **Soil Hydrology scheme intercomparison**  
  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\textsubscript{2} diurnal cycle in the canopy air**  
  Moreno, G., Rosolem, R., et al.

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