CLM-related model evaluations and improvements at the University of Arizona

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CLM-Related Progresses

**CLM4 improvement**
- Skin temperature diurnal cycle over arid regions (Zeng et al.)

**Land-atmosphere interaction**
- Land-precipitation coupling strength (Zeng et al.)
- Impact of interannual climatic variabilities on vegetation (Shao et al.)

**CLM evaluations**
- Monthly river flow prediction (or simulation) (Zeng et al.)
- CMIP5 carbon cycle (Shao et al.)
- Steady state of Fractional Cover/carbon (Sakaguchi et al.)
- Dynamic root function (Christoffersen et al.)
- PFT distribution across Amazon (Moreno et al.)

**Ongoing work (not discussed here)**
- Global 1 km hybrid 3-D hydrological modeling
- B2 Landscape Earth Observatory (LEO)
Improve the Skin Temperature Diurnal Cycle over Arid Regions (Zeng et al. 2012; in press)

\[
\ln\left(\frac{z_{om}}{z_{ot}}\right) = 0.36 \left(u_* z_{om}/v\right)^{0.5}
\]

\[
u_{\text{min}} = 0.07 \rho_o/\rho \left(z_{om}/z_{og}\right)^{0.18}
\]

minimum \(K_{\text{soil}} = 0.75 \text{ Wm}^{-1}\text{K}^{-1}\)

Mean absolute deviation (K)

<table>
<thead>
<tr>
<th></th>
<th>Desert Rock</th>
<th>Gaize</th>
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<tbody>
<tr>
<td>Con</td>
<td>1.9</td>
<td>4.6</td>
</tr>
<tr>
<td>New</td>
<td>0.7</td>
<td>1.8</td>
</tr>
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</table>
The same formulation for roughness length has been implemented and tested in NCEP GFS operational Model (Zheng et al. 2012; in press)

Significant improvement over semi-arid regions

Significant increase in the number of surface-sensitive satellite brightness temperature data assimilated (not shown)
Land-atmosphere interaction

• *Land-precipitation coupling strength* (Zeng et al.)

• Influence of interannual climatic variabilities on vegetation (Shao et al.)
\[ \Gamma = \frac{\Sigma P' E'}{\Sigma P' P'} \]

\( E', P' \) are monthly deviations from climatology

**ECMWF 45yr Reanalysis**
Γ provides a simple indicator to characterize a GCM’s coupling strength

CCSM3 coupling is too strong

2*CO₂ increases the coupling strength over high latitudes in summer
Land-atmosphere interaction

- Land-precipitation coupling strength (Zeng et al.)

- Impact of interannual climatic variabilities on vegetation (Shao et al.)
  - CLM/DGVM forced by observations from 1950-1999 versus from climatology.
Impact of Climatic Interannual Variabilities on Vegetation (Shao et al. 2011)

Is grass so sensitive to the climatic variability?
fractional cover distribution along the P&T

the expansion of grass is mainly due to the reduction of tree and shrub
Percent coverage differences in relation to mean and standard deviation of climatic factors

Color -- Percent coverage differences

interannual variability of precipitation

Evergreen

Deciduous
CLM evaluations

• *Monthly river flow prediction (or simulation)* (Zeng et al.)

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• PFT distribution across Amazon (Moreno et al.)
A water-balance based “toy” model (Zeng et al. 2012; in revision) as good as a neural network for monthly river flow prediction, but the toy model is more robust. They are both much better than CLM4 simulation.

Modified coefficient of efficiency: 0.55-0.93 for Toy model <0.1 for CLM4
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CMIP5: GPP /NBP in historical and RCP4.5 exp (Shao et al.)

GPP (Gross Primary Productivity)

NBP (Net Biosphere Productivity)

general pattern: similar
magnitude: very different
discrepancies exist
last 30 year average of global GPP and NBP

GPP : increased in every model; NBP: close to 0 for balance
Trend

correlations between global historical NBP and climatic variables
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Years to Reach the Steady State of Fractional Cover (Sakaguchi et al.)

Evergreen Tree PFTs

Average of the three evergreen PFTs

NET Temperate

FPC < 5% is not included

NET Boreal

BET Tropical

- Longer years for dry regions and for NET Boreal
Steady State of Fractional Cover

% of global grid boxes to reach steady state for tree PFTs.

Example: NET temperate

grid boxes with steady state in 201 ~ 300 yrs

grid boxes with steady state in > 500 yrs

<table>
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<tr>
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<th>1 - 100</th>
<th>101 - 200</th>
<th>201 - 300</th>
<th>301 - 400</th>
<th>401 - 500</th>
<th>501 - 599</th>
<th>&gt; 600 or unstable</th>
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<tr>
<td>NET temp</td>
<td>0</td>
<td>17</td>
<td>37</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>37</td>
</tr>
<tr>
<td>NET boreal</td>
<td>0</td>
<td>1</td>
<td>36</td>
<td>16</td>
<td>5</td>
<td>5</td>
<td>37</td>
</tr>
<tr>
<td>BET tropical</td>
<td>0</td>
<td>69</td>
<td>12</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>BDT tropical</td>
<td>0</td>
<td>77</td>
<td>14</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>BDT temp</td>
<td>1</td>
<td>30</td>
<td>36</td>
<td>8</td>
<td>5</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>BDT boreal</td>
<td>0</td>
<td>9</td>
<td>30</td>
<td>19</td>
<td>6</td>
<td>5</td>
<td>30</td>
</tr>
</tbody>
</table>

Fractional Vegetation Cover

Total Vegetation Carbon

year

year
CLM evaluations

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• PFT distribution across Amazon (Moreno et al.)
Dynamic root function (Christoffersen et al., in prep)

Amazon: Observations indicate root uptake shifts to deeper layers during dry season

Tapajos site, observed changes in soil moisture attributed to root uptake

- **Can CLM and other models capture this dynamic aspect of root function?**
- Use a suite of models:
  - CLM3.5-DGVM, IBIS, JULES, ED2, SiB3, SPA
  - standardized soil physics
  - span range of complexity in treatment of root function

80% of total uptake: wet season = -4m

Fraction of total root uptake

Taken from Bruno et al., 2006
Amazon: Observations indicate root uptake shifts to deeper layers during dry season.

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- **Fraction of total root uptake**
  - Taken from Bruno et al., 2006
Which model best captures dynamic root behavior?

Difference between wet & dry season depth of root uptake across 4 forest sites

- Deeper uptake in dry season

Christoffersen et al., in prep
Which model best captures dynamic root behavior?

Difference between wet & dry season depth of root uptake across 4 forest sites

Deeper uptake in dry season

Only model with soil-root-leaf hydrodynamics
CLM evaluations

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- **PFT distribution across Amazon (Moreno et al.)**
• PFT distribution, after 200 years, shows coverage of both tropical evergreen and deciduous trees.

• CLM4 over-represents deciduous tree cover in Amazonia.
PFT Establishment

- Initially CLM populates the forest composition with the deciduous tropical trees
- Tropical evergreen trees are slow to establish and do not overtake the deciduous composition.
**Summary**

**CLM4 improvement**
- Developed formulations to improve skin temperature over arid regions

**Land-atmosphere interaction**
- Proposed a simple index for land-precipitation coupling strength
- Demonstrated the impact of interannual climate variability on plant distribution in CLM/DGVM

**CLM evaluations**
- Identified CLM deficiencies in monthly river flow simulation
- Analyzed the CMIP5 carbon cycle
- Analyzed the spinup time in carbon/biomass in CLM-CNDV
- Demonstrated the need for dynamic root function
- Identified the PFT distribution deficiency across Amazon in CLM-CNDV