New Hydrological Parameterizations in CLM5

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CLM5 includes a number of new parameterizations related to hydrology:

- Soil evaporation
- Canopy evaporation
- Soil water redistribution (Richards equation)
- Lateral subsurface flow (Baseflow)
In addition, there are changes to the vertical structural of the soil column and the lower boundary condition:

- Deeper soil column (8.5 m default)
- Spatially variable soil thickness
- Elimination of “aquifer” layer
Soil Evaporation

- Based on observations of a dry surface layer
- Meant to represent transition to vapor diffusion dominated transport
- Function of soil moisture
New Soil Evaporation Parameterization

CLM evapotranspiration too large and too variable compared to observations
New Soil Evaporation Parameterization

New CLM evapotranspiration more closely follows observations
Latent Heat Global Comparison

From CLM diagnostics package: red = control has lower RMSE relative to observations, green = modified model has lower RMSE relative to observations
Canopy Hydrology

- Interception / throughfall
- Leaf water storage and wetted fraction
- Evaporation from leaf surfaces
Canopy Hydrology And Evapotranspiration Partitioning

Ground Evaporation: 24%
Canopy Evaporation: 23%
Transpiration: 53%
Precipitation Interception and Leaf Wetted Area
Precipitation Interception and Leaf Wetted Area

**CLM5 default in blue**
Ground Evaporation: 21%
Canopy Evaporation: 18%
Transpiration: 61%

Canopy Hydrology and Evapotranspiration Partitioning
Richards Equation

- describes the vertical redistribution of water through soil
- currently implemented the moisture-based form of Richards equation
- adaptive time stepping
Adaptive time stepping method for soil water distribution

- Similar results to Zeng & Decker method
- Tested globally and at points with relatively high numerical error

Slide courtesy of John Volk
Adaptive scheme removed numerical errors in soil water

- (Left) Locations with negative soil moisture using Zeng & Decker method in 1990-2000, 1° simulation.

- Error tolerance was adjusted to remove any instance of significant numerical error (< -0.5 kg/m^2) for twenty year simulation, at small computational cost.

<table>
<thead>
<tr>
<th>Numerical Scheme</th>
<th>Error tolerance (kg/m^2) water</th>
<th>Max no. of neg. moisture per column</th>
<th>CLM run time in seconds</th>
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<tbody>
<tr>
<td>Zeng &amp; Decker</td>
<td>NA</td>
<td>32</td>
<td>1759</td>
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<tr>
<td>Adaptive</td>
<td>1e9</td>
<td>720</td>
<td>1802</td>
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<tr>
<td>Adaptive</td>
<td>1e-2</td>
<td>0</td>
<td>1815</td>
</tr>
</tbody>
</table>

Table data for 1° resolution, 10 year (1990-2000) global runs.  

*Slide courtesy of John Volk*
Groundwater and Water Table Dynamics

- deeper soil column
- bedrock (zero vertical flux) lower boundary
- removed bulk aquifer layer
- modified baseflow equation
Removing the Aquifer: Finite Lower Boundary

Aquifer Layer

Water Table

zero flux boundary condition
Soil Depth

- deep soil / variable soil depth
- high vertical resolution soil
Overall Depth to Bedrock (~1 km resolution)

0 - 2 meters
2 - 10 meters
10 - 20 meters
20 - 30 meters
30 + meters

Slide courtesy M. Brunke, U. Arizona
Spatially Variable Soil Depth
Water Storage Components

After a wet period, groundwater does not drain fast enough to match GRACE observations.

Soil moisture alone agrees better with observations.
Total Water Storage: Central Australia
Power Law Baseflow Equation w/ Lower Boundary

\[ Q_{\text{baseflow}} = K \times (z_{\text{bot}} - z_{\text{wt}})^n \]

Example w/ lower boundary at 8 meters

Linear (n = 1)

Quadratic (n = 2)
Summary

• In most semiarid regions, the new soil evaporation scheme brings the simulated latent heat fluxes closer to observations

• Changes to canopy interception and leaf wetted fraction improve the partitioning of ET between canopy evaporation and transpiration

• Moisture-based Richards equation with adaptive time-stepping reduces occurrences of instabilities (i.e. negative soil moisture)

• Removing “limitless” groundwater parameterization and implementing a finite lower boundary improves water storage agreement with observations
Further Work / Caveats

- Saturated areas, impermeable areas, and infiltration
- Parameter tuning
- Further assessments
Impermeable Areas

Saturated

Impermeable Bedrock
Mean Water Table

Annua Mean ZWT

CLM4.5

CLM5.0
Larger Baseflow Coefficient

Smaller Baseflow Coefficient