LMWG Activities Relevant to Polar Climate Working Group

1. Snow model
2. Permafrost
3. Cold region hydrology
4. Soil Carbon
- Change to freezing temperature constant
- forcing height at atm plus z0+d on each tile
- Effective porosity divide by zero fix
- X. Zeng sparse/dense canopy aerodynamic parameters
- Stability formulations
- ground/snow emissivity
- organic soil
- init h2osol=0.3
- snow compaction fix
- snow T profile during layer splitting fix
- new FGR12 diagnostic
- snow burial fraction
- snow cover fraction
- SNICAR (snow aging, black carbon and dust deposition, vertical distribution of solar energy)
- remove SNOWAGE, no longer used
- deep soil (15 layers), including changes for bed rock
- Koichi ground evap (beta), stability, and litter resistance
- Swenson organic/mineral soil hydraulic conductivity percolation theory
- Zeng/Decker Richards equation modifications
- normalization of frozen fraction of soil formulation
- Swenson one-step solution for soil moisture and qcharge
- changes to rsub_max for drainage and decay factor for surface runoff
- back to old lakes and wetlands datasets
- changes to pft physiology file from CN
- possible changes to surface dataset due to CN?
- new grass optical properties
- new surface dataset from Peter Lawrence assuming no herbaceous understory
- direct versus diffuse radiation offline
- new VOC model (MEGAN)
- modification to solar radiation penetration through snow (no solar to soil if snowdp<0.1m)
- new RTM rdirc file and change to QCHANR definition
- snow-capped runoff goes to ice stream
- dust model always on, LAI threshold parameter change from 0.1 to 0.3
- daylength control on vmax
- SAI and get_rad_dtime fix
CLM3.5 → CLM4

- **Snow model** (Flanner, Zender, Niu, Yang, Lawrence, Zeng)
  
  - snow density dependent snow cover fraction parameterization
  - snow burial fraction for short vegetation
  - adopt SNICAR
    
    snow age
    
    vertically resolved heating in snowpack (snowdp > 0.1m)
    
    aerosol deposition (dust, black carbon, organic carbon) – works with bulk or modal aerosols
  
  - snow compaction
  - snow layer splitting
  - (bug) – energy not always conserved during snow layer combination
Snow cover fraction

Snow cover fraction: CLM3.5 – Obs

Snow cover fraction: CLM4SP – Obs
CLM3.5 → CLM4

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~ +0.13°C to CCSM4 climate sensitivity
- **Ice stream in River Transport Model** (Lawrence, Craig)
  
  - For snow capped regions send excess water to ice stream (poor man’s ice sheet calving)
  - Reduces CCSM energy imbalance by ~0.15-0.2 W/m²
  - Unrealistic high sea-ice thickness in semi-closed bays

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**Ice runoff**

**Liquid runoff**
Near-surface Permafrost Extent and Active Layer Thickness

8.2 million km²

CLM3.5

14.2 million km²

CLM4SP

11.3 – 14.3 million km²

Observations

Organic soil thermal and hydraulic prop
Deep soil column (~50m deep)
Cold region hydrology problem in CLM4

Slow leak of
~+3.5 mm yr\(^{-1}\)
to Arctic Ocean
in early part of
CCSM4 1850
control
Cold region hydrology: impact of impedance factor for icy soil

Soil Moisture (0.4m) Impedance – Control

Soil Temperature (0.4m) Impedance – Control
Lakes drain, soil dries

Arctic warming

Global warming

Enhanced CO$_2$ efflux

CH$_4$ efflux

Permafrost warms and thaws

Expanded wetlands

Microbial activity increases

Shrub growth

Carbon sequester

Arctic runoff increases

Adapted from McGuire et al., 2006
CN Soil carbon compared to Global Soil Data Task obs

Obs ~2000 PgC

i1850cnNewNdep ~500 PgC

i1850cnNewNdep – Obs

CLM4CN GSDT Obs
Soil carbon: Issues from perspective of northern high latitudes

- In tundra zones, very low vegetation growth CLM4CN (at least partly due to hydrology problem)
- Soil decomposition rates
  - No limits due to anoxia at high saturation levels
  - Soil carbon is assumed to be in top ~0.5m, no frozen carbon
- Large carbon stores result of thousands of years of accumulation (with differing initiation dates) in peatlands or similar systems
- Not representing unique biogeochemistry of peatlands
Arbitrary point in Alaska Arctic
Results from global runs

Alaska Arctic

Amazonia
CN Soil carbon compared to Global Soil Data Task obs

Obs

i1850cnNewNdep – Obs

clm3_6_45.CN10r

clm3_6_45.CN10r – Obs
Heterotrophic soil respiration in CLM-CN

Base decomposition rates for each SOM pool are modified by functions of water and temperature

Thornton and Zimmerman, 2005
Proposed modifications

- Cold region hydrology modifications from Sean

- Connect organic soil thermal and hydrologic properties (Lawrence and Slater, 2008) with prognostic CN soil carbon
  - Represent vertical decrease in hyd. conductivity from fabric to sapric peat - wetter soil in organic rich regions

- Incorporate anoxia limitation on decomposition rates
  - Sync up CLM soil suction with CN soil suction

- Account for impact of vertical distribution of soil carbon on decomposition rates

- Change Q10 from 1.5 to 2 or ???

- Assume that Arctic C3 grass more like moss – grows in nutrient-limited environs

- Initialize model with ‘observed’ soil carbon and slowly turn on carbon pool transfers
Anoxia limitation on soil carbon decomposition

Thornton and Zimmerman, 2005

Bond-Lamberty et al., 2007
Carbon cycle

- Atmosphere CO₂
- Photosynthesis
- Respiration
- Litterfall & mortality
- Decomposition

Nitrogen cycle

- Nitrogen deposition
- Assimilation
- Denitrification
- Nitrogen leaching
- N fixation

Based on Biome-BGC, Thornton et al., 2009
### Table: Albedo Comparison

<table>
<thead>
<tr>
<th>Model</th>
<th>Snow-free</th>
<th>Snow depth &gt; 0.2m</th>
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<th>Snow depth &gt; 0.2m</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLM3.5</td>
<td>2.7</td>
<td>-5.0</td>
<td>4.1</td>
<td>11.9</td>
</tr>
<tr>
<td>CLM4SP</td>
<td>0.4</td>
<td>2.9</td>
<td>2.0</td>
<td>13.2</td>
</tr>
<tr>
<td>CLM4CN</td>
<td>0.7</td>
<td>1.3</td>
<td>2.2</td>
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</tr>
</tbody>
</table>

### Maps: Albedo

- **CLM3.5 – Obs**
- **CLM4SP – Obs**
- **CLM4CN – Obs**
Interannual variability (MAM)

\[ \sigma_2 - \sigma_1 \]

\[ \frac{(\sigma_2 - \sigma_1)}{\sigma_1} \]
Interannual variability (JJA): Latent Heat Flux

$\sigma_2 - \sigma_1$

$\frac{\sigma_2 - \sigma_1}{\sigma_1}$
CLM4
- CLM4SP: satellite phenology
- CLM4CN: carbon-nitrogen cycle phenology