Soil Carbon modeling in CLM4CN

David Lawrence,
Sean Swenson
NCAR, Boulder, CO
Lakes drain, soil dries

Arctic warming

Potential Arctic terrestrial climate-change feedbacks

Global warming

Enhanced [nitrogen]

CO₂ efflux

CH₄ efflux

Permafrost warms and thaws

Shrub growth

Expanded wetlands

Microbial activity increases

Lakes drain, soil dries

Arctic runoff increases

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

Obs \( \sim 2000 \text{ PgC} \)

i1850cnNewNdep \( \sim 500 \text{ PgC} \)

i1850cnNewNdep – Obs

CLM4CN

GSDT Obs
Vegetation carbon compared to Olson et al. (1985) (updated by Gibbs et al. 2007)

- Olson max, ~1000 PgC
- Olson mean, ~500 PgC
- CLM4CN, ~900 PgC
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 water levels
  - Location of soil carbon is ‘virtual’ within top 5 model levels

- 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
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

Bond-Lamberty et al., 2007

Thornton and Zimmerman, 2005
Proposed modifications

- Cold region hydrology modifications from Sean
- Shallower rooting profile for Arctic C3 grass and boreal shrubs
- 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, leaf litter C:N ratio
- Initialize model with ‘observed’ soil carbon and slowly turn on carbon pool transfers
Vertical distribution of carbon and impact on decomposition rates

**Siberia peatland**

Organic Matter Profile

Soil Temperature

**Tropical Africa**

Organic Matter Profile

Soil Temperature

$T_{sc} = 0.45$

$T_{sc} = 0.40$

$T_{sc} = 1.12$

$T_{sc} = 1.13$
Proposed modifications

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At each time step:

- Calculate saturated fraction of vegetated portion of grid cell (Sean’s work)
- For unsaturated fraction of grid cell, soil respiration calculated as above
- For saturated fraction of grid cell, soil respiration at 10% of temperature regulated base rate
What about wetland vegetation?

Ideally, need a new ‘moss-like’ PFT

- Assume that moss preferentially inhabits the saturated fraction of grid cell
- Dead moss goes to recalcitrant litter pool
- Short cut: skip moss PFT and simply assume that litter from grass growing in saturated zone goes to recalcitrant litter pool
Arbitrary point in Alaska Arctic
Some results from global tests

Polar(60-90N, -180W-180E)

- Net Ecosystem Exchange
- GPP
- NPP
- Autotrophic Respiration
- Heterotrophic Respiration
- Ecosystem Respiration

CLM4CN
w/ mods
Results from global runs

Alaska Arctic

- TOTSOMC: 31
- TOTVEGC: 2-4
- TOTLITC

Amazonia

- TOTSOMC: 14
- TOTVEGC: 11-23
- TOTLITC

Legend:
- CLM4CN
- w/ mods
- w/ mods + $f_{sat} = 25\%$
Results from global runs

Western US

Global

- TOTSOMC: 15
- TOTVEGC: 5-9
- TOTLITC

CLM4CN
w/ mods
w/ mods + $f_{sat} = 25\%$
CN Soil carbon compared to Global Soil Data Task obs

Obs

i1850cnNewNdep

clm3_6_45.CN10r

clm3_6_45.CN10r – Obs
Microtopography

Osterkamp et al., 2009
Surface Water Component Concept

![Graphs showing surface water and snow layers.](image)
Surface Water Component Concept

Microtopography PDF and Cumulative Probability

Height above mean grid cell elevation (m)
• When storage is large compared to microtopography, “wet” areas are well connected, and surface runoff is high.

• When storage is small compared to microtopography, “wet” areas are generally not connected, and surface runoff is low.
Parameterizing Thermokarst

Microtopography PDF

Low relief: e.g. Arctic coastal plains

Height above mean surface (m)

σ₁

σ₂

Thermokarst