Evaluating litter decomposition and soil organic matter dynamics in earth system models: contrasting analysis of long-term litter decomposition and steady-state soil carbon

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The atmosphere accumulates too much carbon, because the land is mostly a source of carbon.
Soil carbon biases

Possible causes of soil carbon bias

Litterfall and litter chemistry
Turnover rates
- Model structure (pools)
- Abiotic controls (temperature, moisture, pH, texture, nitrogen)

CLM4cn has far too little soil carbon
Long-Term Intersite Decomposition Experiment (LIDET)

Observations
10-year study of litter dynamics for a variety of litter types placed in different environments
- 20 sites: 2 tundra, 2 boreal forest, 5 conifer forest, 3 deciduous forest, 3 tropical forest, 2 humid grassland, 3 arid grassland
- 9 litter types (6 species of leaves, 3 species of root) that vary in chemistry
Litter bags sampled once a year for C and N

Model simulations
- CLM4cn, DAYCENT
- Follow a cohort of litter (100 g C m\(^{-2}\)) deposited on October 1
- Specified climatic decomposition index (CDI) to account for temperature and moisture
- Soil mineral nitrogen
  *DAYCENT*
  SOM C:N ratios vary with mineral N. Use low and high C:N ratios
  *CLM4cn*
  Soil mineral N reduces decomposition rates, but only for flows with immobilization. Configure simulations so that N does not limit decomposition & immobilization (fpi=1) and so that N is rate limiting (fpi<1)

Leaf litter mass loss – conifer forest

5 sites & 6 leaf litter types
Shown are the site x litter mean and ± 1 SD

CLM underestimates carbon mass remaining (overestimates mass loss), especially during first several years. This is common to all sites.
Leaf litter mass loss – all sites

Tundra, leaf litter

Boreal forest, leaf litter

Conifer forest, leaf litter

Deciduous forest, leaf litter

Tropical forest, leaf litter

Humid grassland, leaf litter

Mass remaining (%)

Time (years)
CLM4cn overestimates immobilization. Larger biases for leaf litter types with lower initial %N

Observations are sampled once per year. Shown are data for maple leaf litter at all biomes except arid grassland. Model data are sampled similar to the observations.
N limitation reduces decomposition rates in CLM4cn and improves carbon dynamics. Here we use fpi = 0.05

Similar results can be obtained for other biomes using fpi=0.05-0.20

Decomposition rates in DAYCENT do not need to be similarly reduced

Different underlying philosophies for the two models, particularly with respect to the influence of soil mineral N on litter C-N dynamics
CLM4cn nitrogen limitation

Conifer forest, maple leaf litter (0.81 %N)

N not limiting

N limiting

N limitation (fpi=0.05) reduces bias. Similar results are obtained for other biomes and litter types using fpi=0.05-0.20
Is DAYCENT a solution to the soil carbon biases?

- **LIDET (10-year litter decomposition)**
  CLM4cn has too rapid carbon turnover, unless N severely restricts decomposition rates (fpi = 0.05-0.20)
  CESM/CLM4cn global simulations do not show such N limitation (fpi > 0.6 in many regions)
  DAYCENT has better litter decomposition. Would DAYCENT improve CLM soil carbon?

- **Steady-state analysis** (Xia et al. Geosci. Model Dev., 5, 1259-1271, 2012)
  but forced soil BGC models with litterfall

  - litterfall (Matthews, JGR 102:18771-18800, 1997)
  - soil temperature and moisture from a control CLM4cn simulation
  - soil texture and pH from HWSD (for DAYCENT)
Steady-state analysis

CLM4cn has more soil carbon than DAYCENT, but “deep” DAYCENT (0-100 cm) accumulates the most carbon.
Conclusions

**LIDET (10-year litter decomposition)**

DAYCENT better simulates litter C and N dynamics compared with CLM4cn (20 sites x 9 litter types)

CLM4cn has too rapid C loss and too high N immobilization, unless N severely restricts decomposition rates

but ...

**Steady-state analysis**

Both CLM4cn and DAYCENT significantly underestimate soil carbon, DAYCENT more than CLM4cn

DAYCENT simulation can be improved by adjusting the model to represent 0-100 cm depth

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5:45 PM - 6:00 PM
2006 (Moscone West)

William Wieder et al.
B34B-08. Integrating Observations to Inform Soil Biogeochemistry in CLM4