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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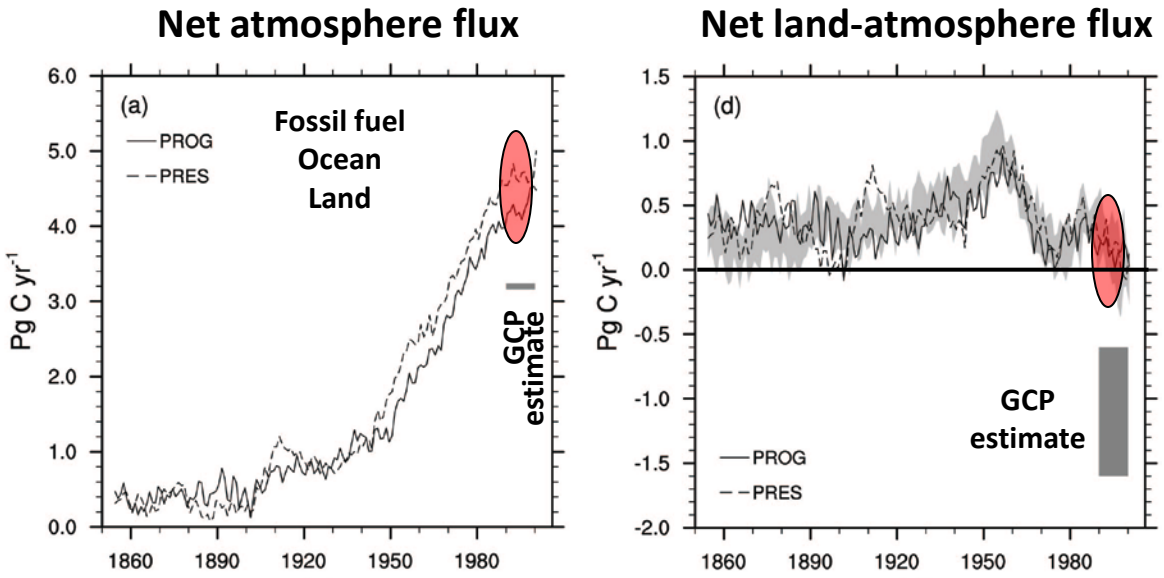
CESM/CLM4cn 20th century carbon cycle

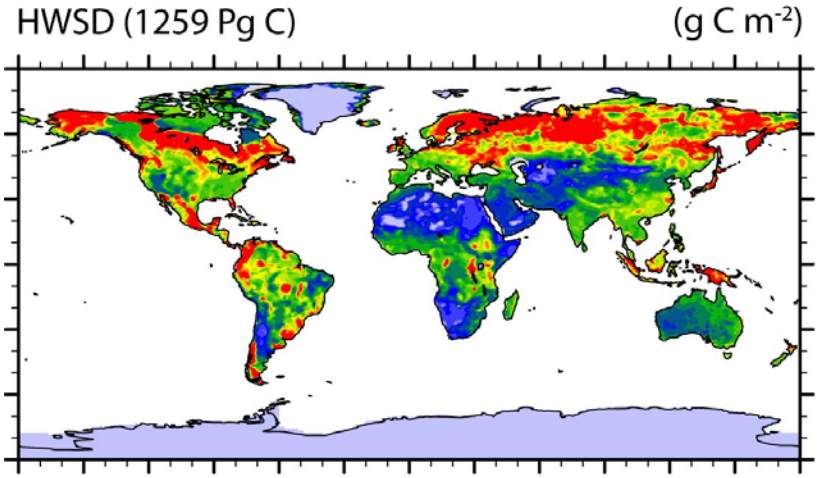


The atmosphere accumulates too much carbon, because the land is mostly a source of carbon.

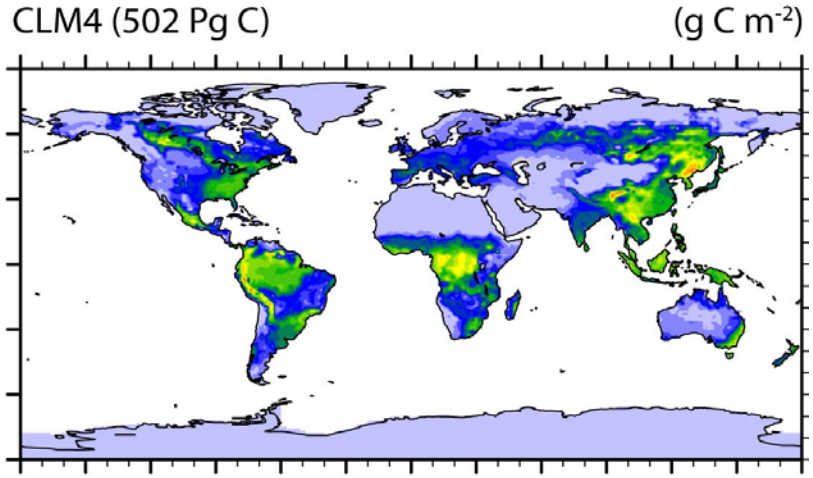
Lindsay et al. (2012) J Climate, submitted

Soil carbon biases

Harmonized World Soil Database



Model



CLM4cn has far too little soil carbon

Possible causes of soil carbon bias

Litterfall and litter chemistry
Turnover rates

- Model structure (pools)
- Abiotic controls (temperature, moisture, pH, texture, nitrogen)

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

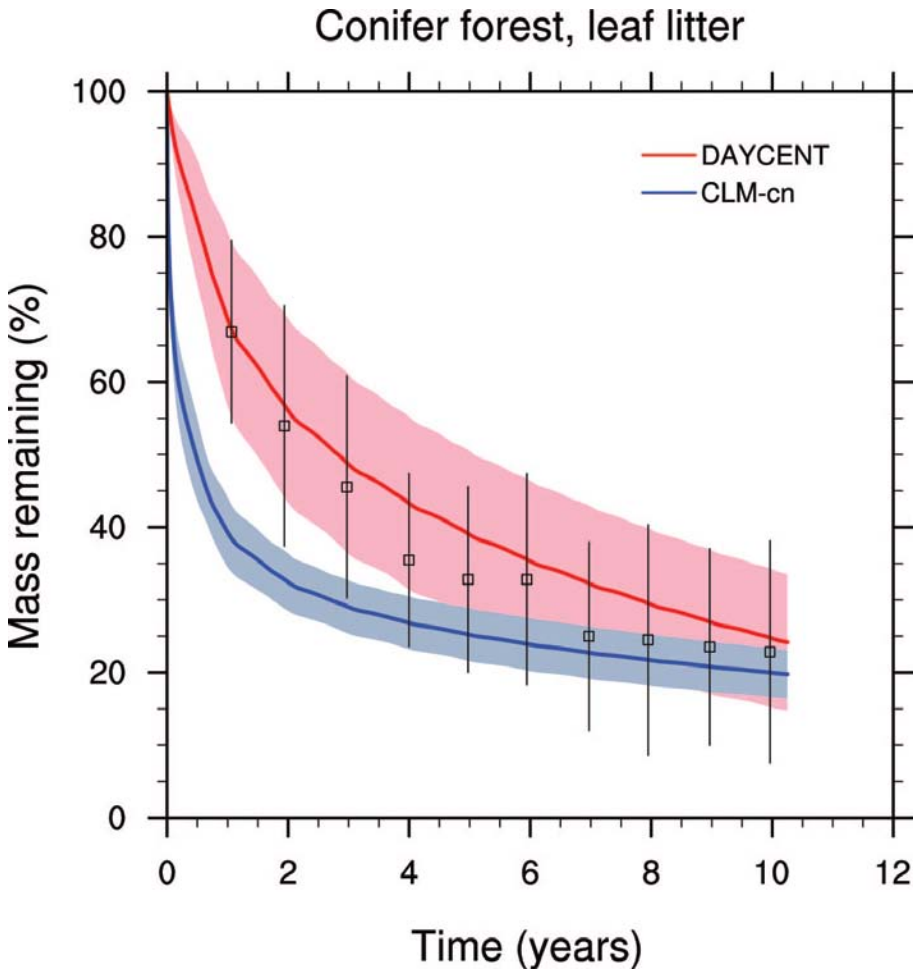
SOM C:N ratios vary with mineral N. Use low and high C:N ratios

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)

Bonan et al (2012) Global Change Biol, doi: 10.1111/gcb.12031

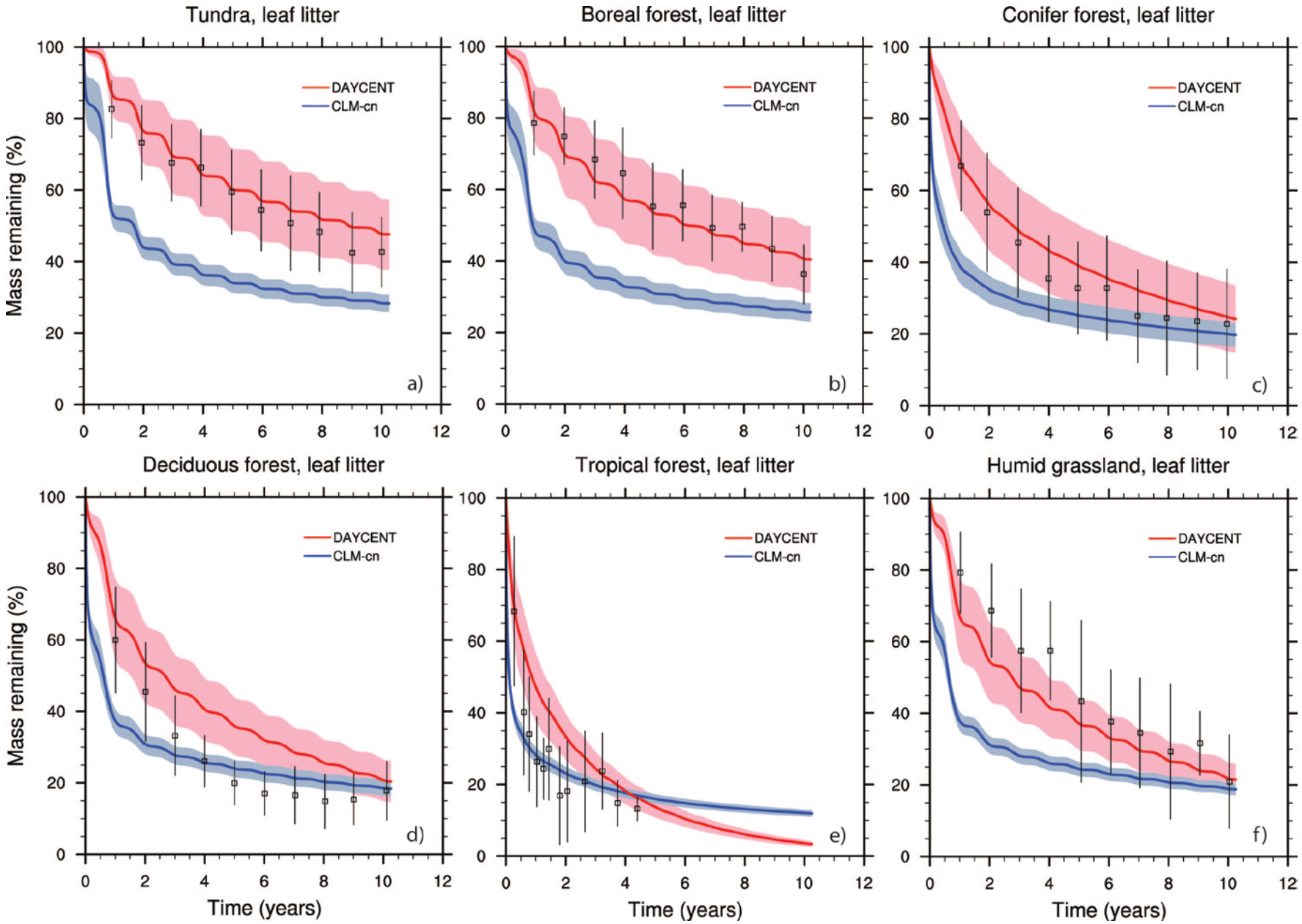
Leaf litter mass loss – conifer forest



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

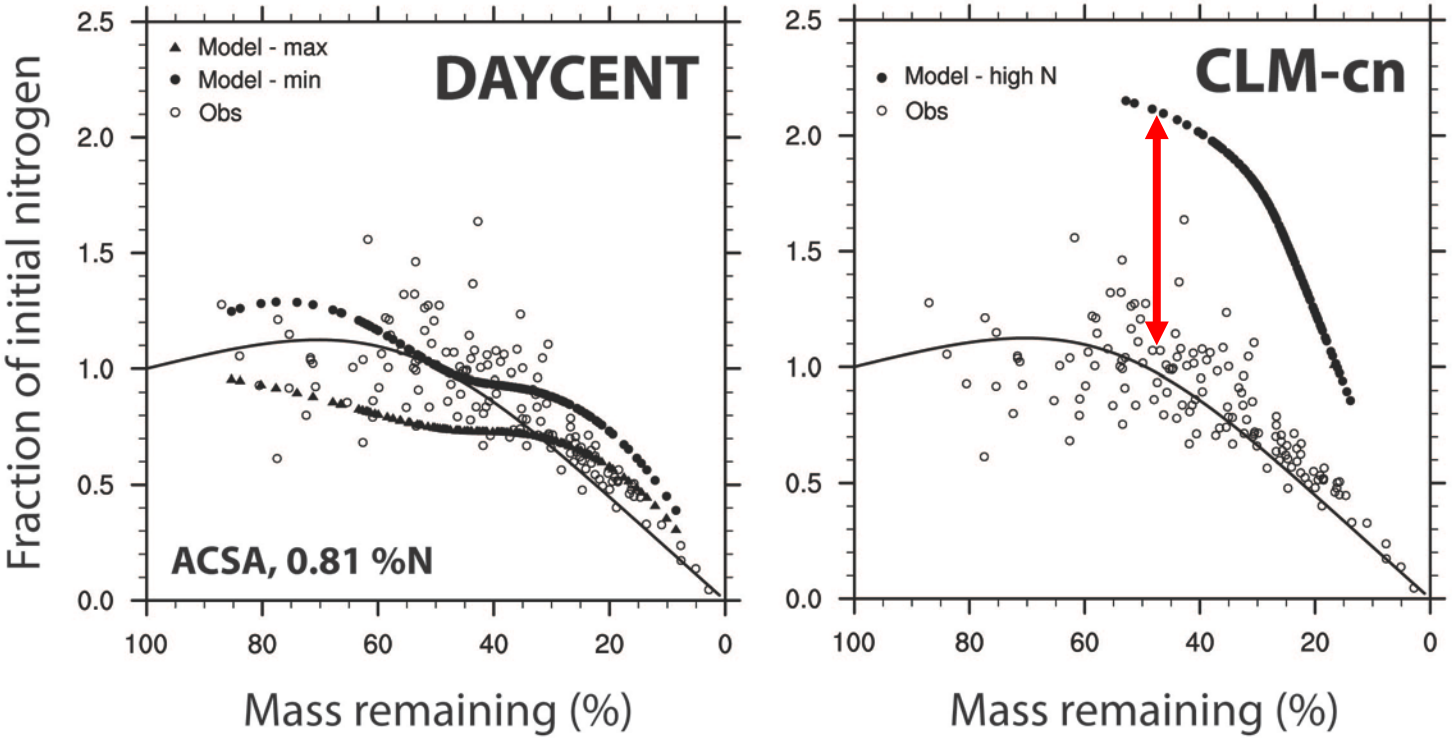
CLM underestimates carbon mass remaining (overestimates mass loss), especially during first several years. This is common to all sites.

Leaf litter mass loss – all sites



Nitrogen dynamics

Maple, 0.81 %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.

CLM4cn overestimates immobilization. Larger biases for leaf litter types with lower initial %N

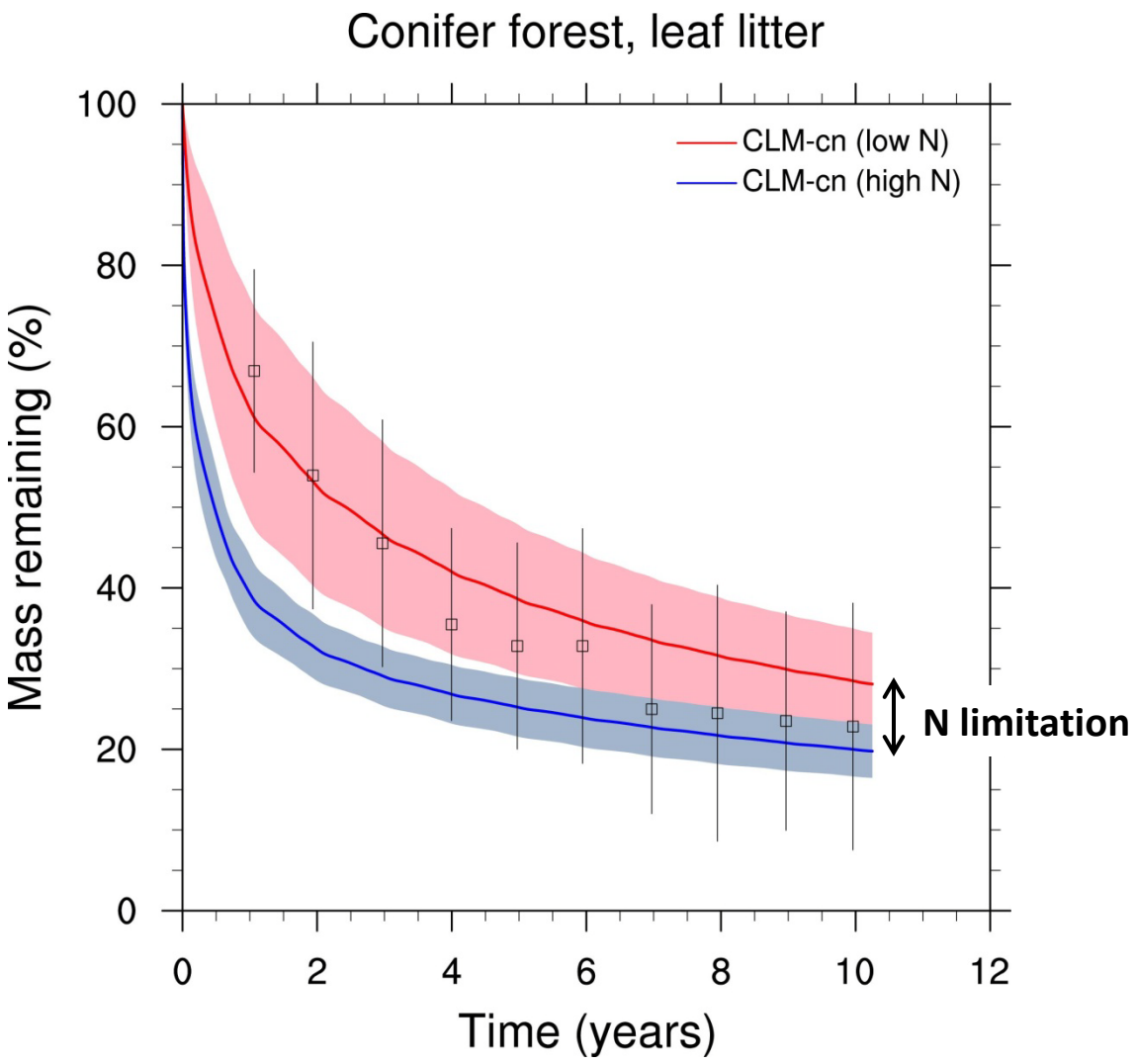
CLM4cn nitrogen limitation

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

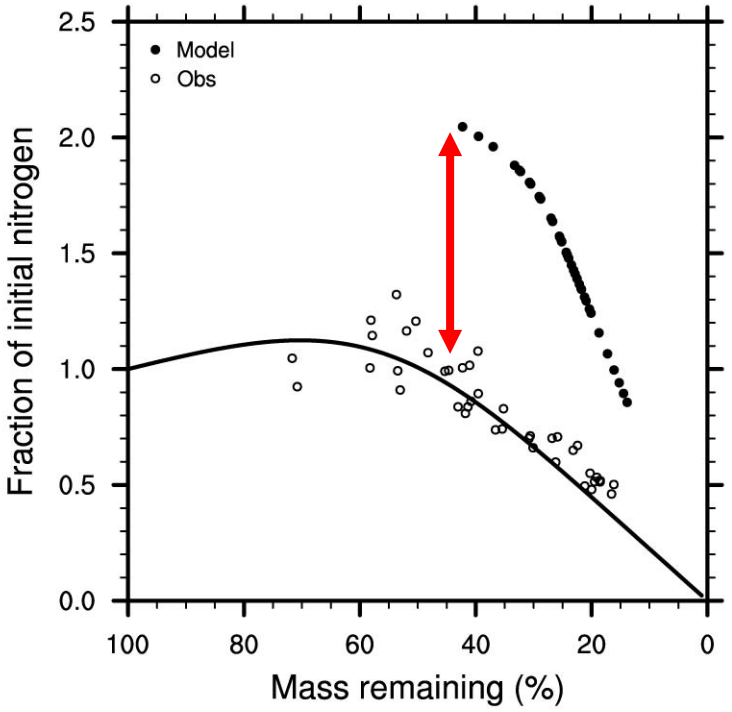
Different underlying philosophies for the two models, particularly with respect to the influence of soil mineral N on litter C-N dynamics



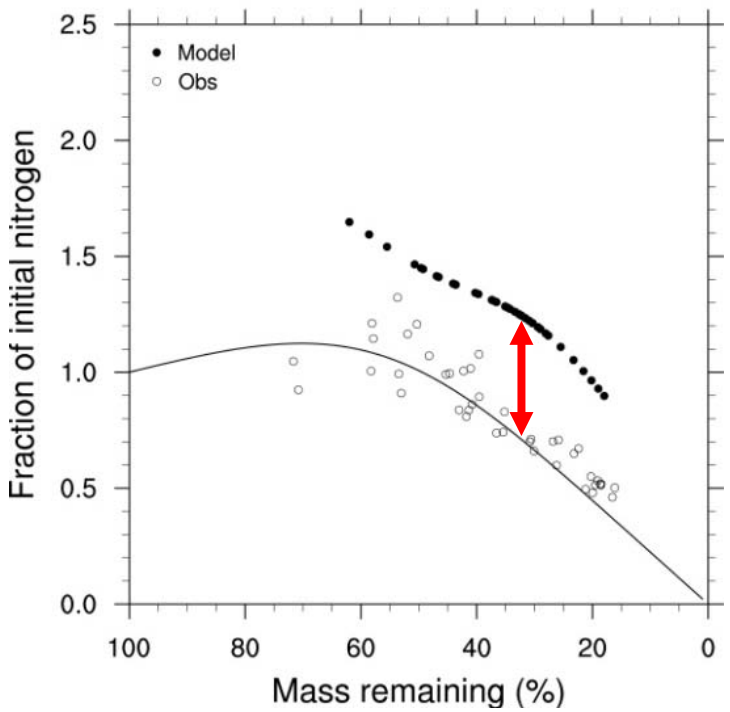
CLM4cn nitrogen limitation

Conifer forest, maple leaf litter (0.81 %N)

N not limiting

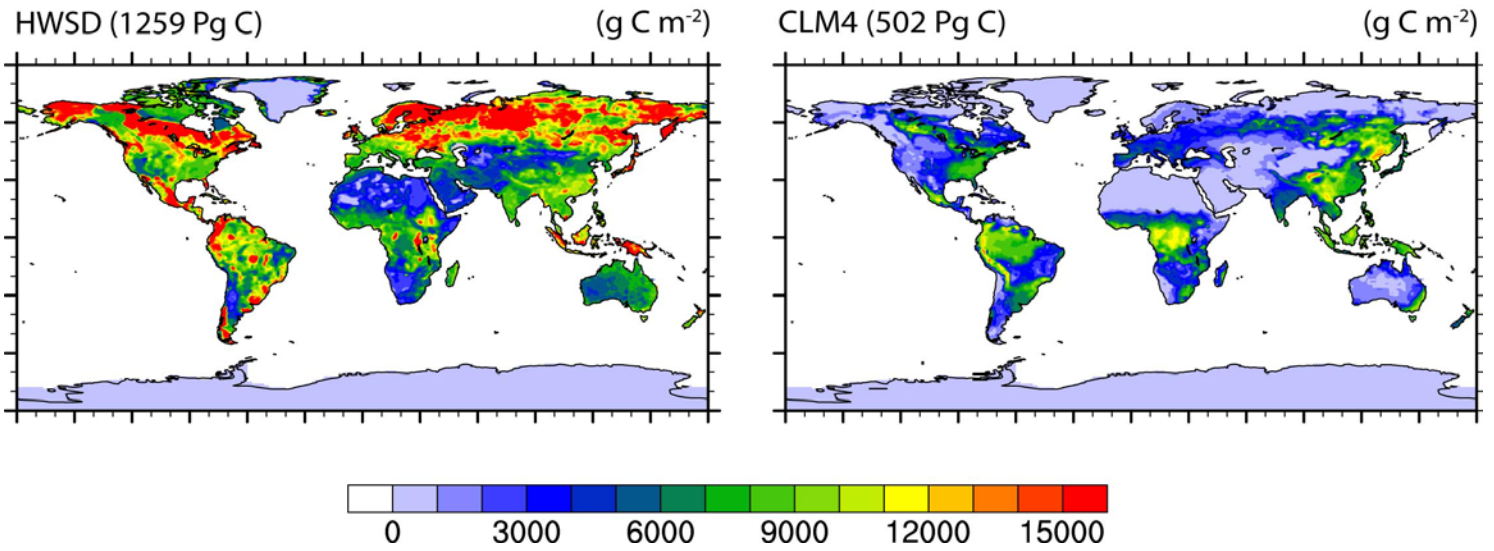


N limiting



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?



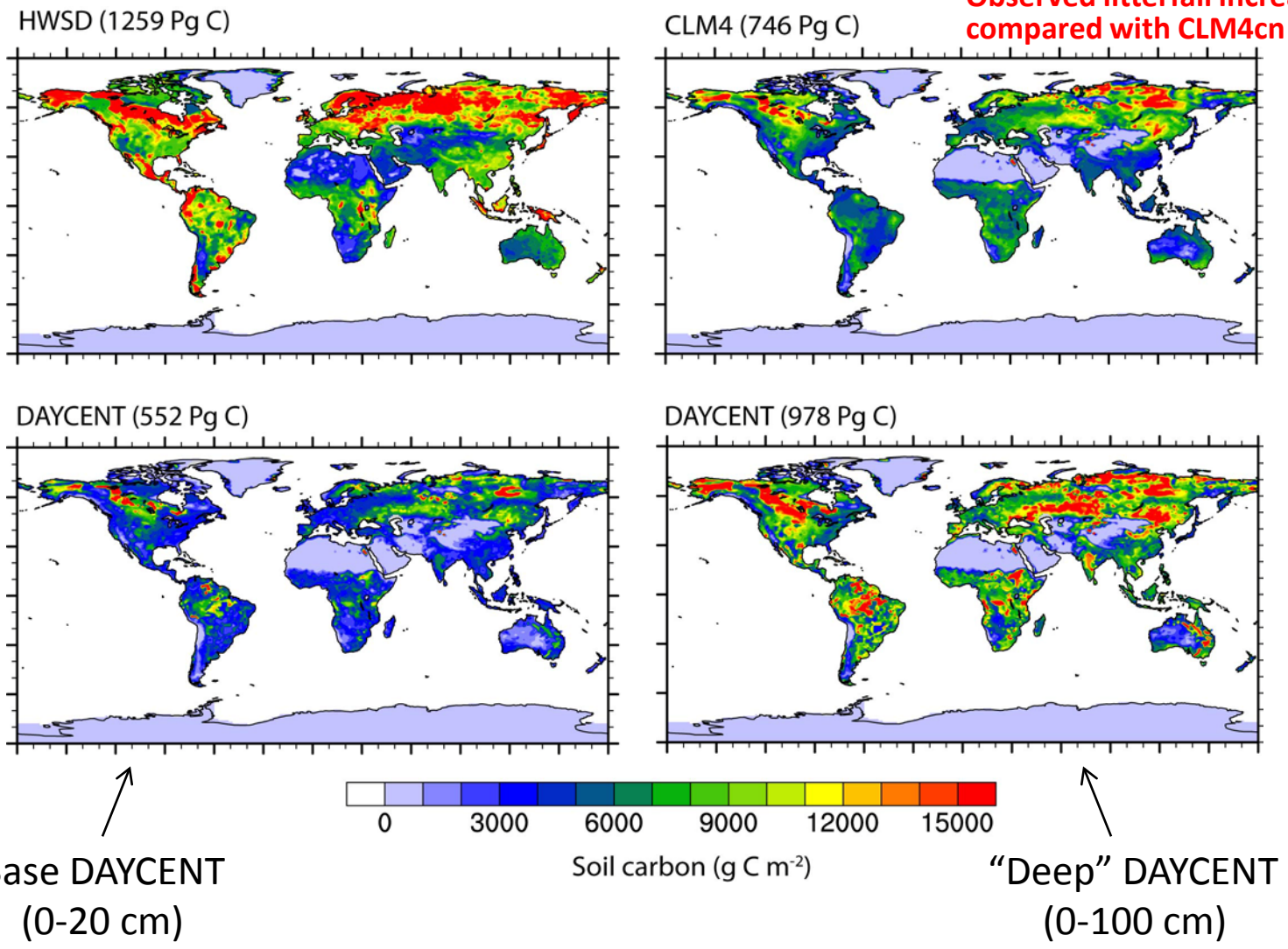
LIDET (10-year litter decomposition)
CLM4cn has too rapid carbon turnover, unless N severely restricts decomposition rates (fpi = 0.05-0.20)
CESM/CLM4cn global simulations do not show such N limitation (fpi > 0.6 in many regions)
DAYCENT has better litter decomposition. Would DAYCENT improve CLM soil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

Observed litterfall increases soil C compared with CLM4cn litterfall



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 to 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

WEDNESDAY, DECEMBER 05, 2012
5:45 PM - 6:00 PM
2006 (Moscone West)

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

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