IMPROVING REPRESENTATION OF NITROGEN UPTAKE, ALLOCATION AND CARBON ASSIMILATION IN THE COMMUNITY LAND MODEL

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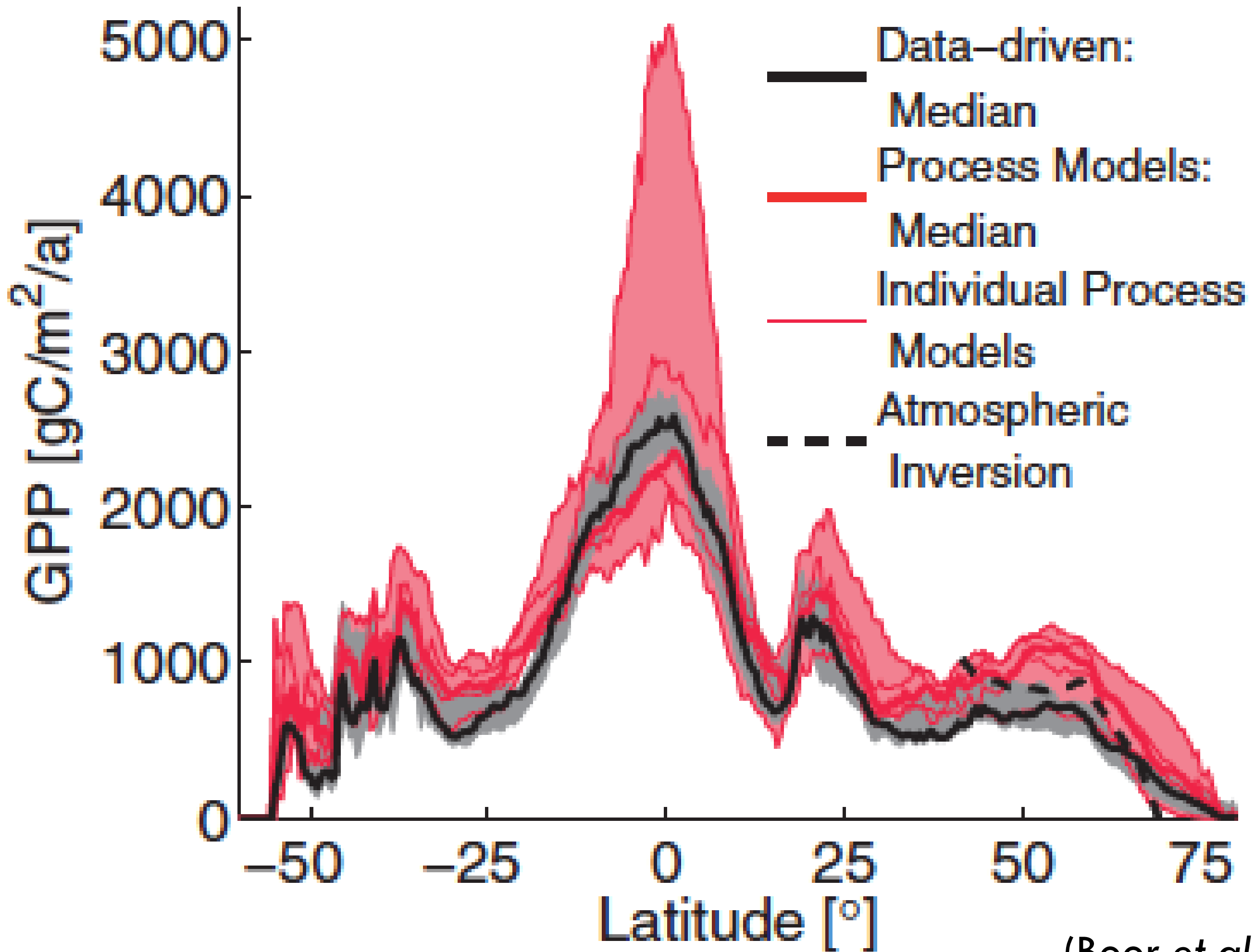
Improvements of Plant Nitrogen Cycle Processes

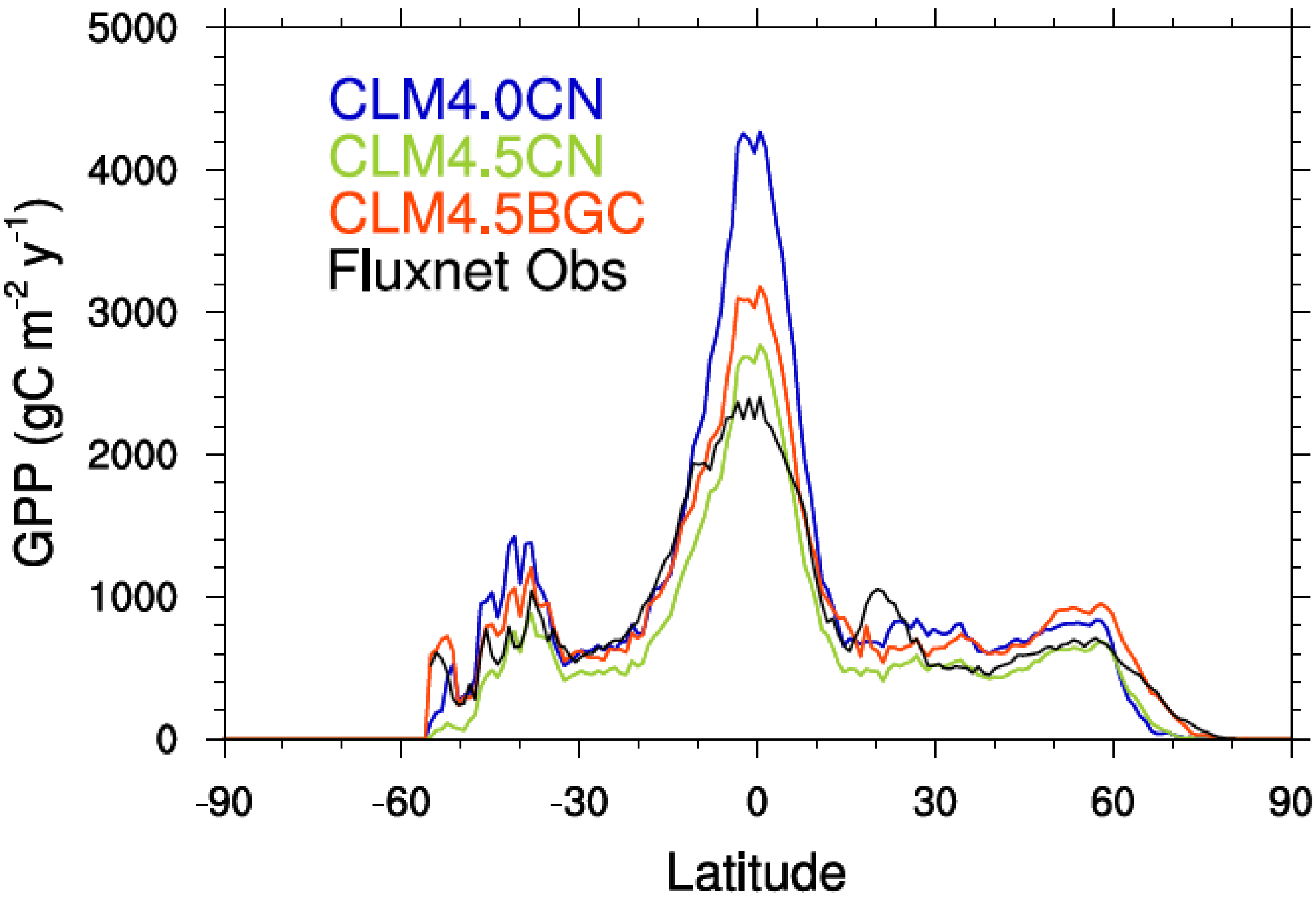
- Nitrogen allocation
  - Plant organs (root, stem, leaf)
  - Functions (photosynthesis, respiration, structure)
- Carbon assimilation
  - Strongly linked to leaf nitrogen allocated to photosynthetic enzymes

Large uncertainty in model predictions of carbon sinks



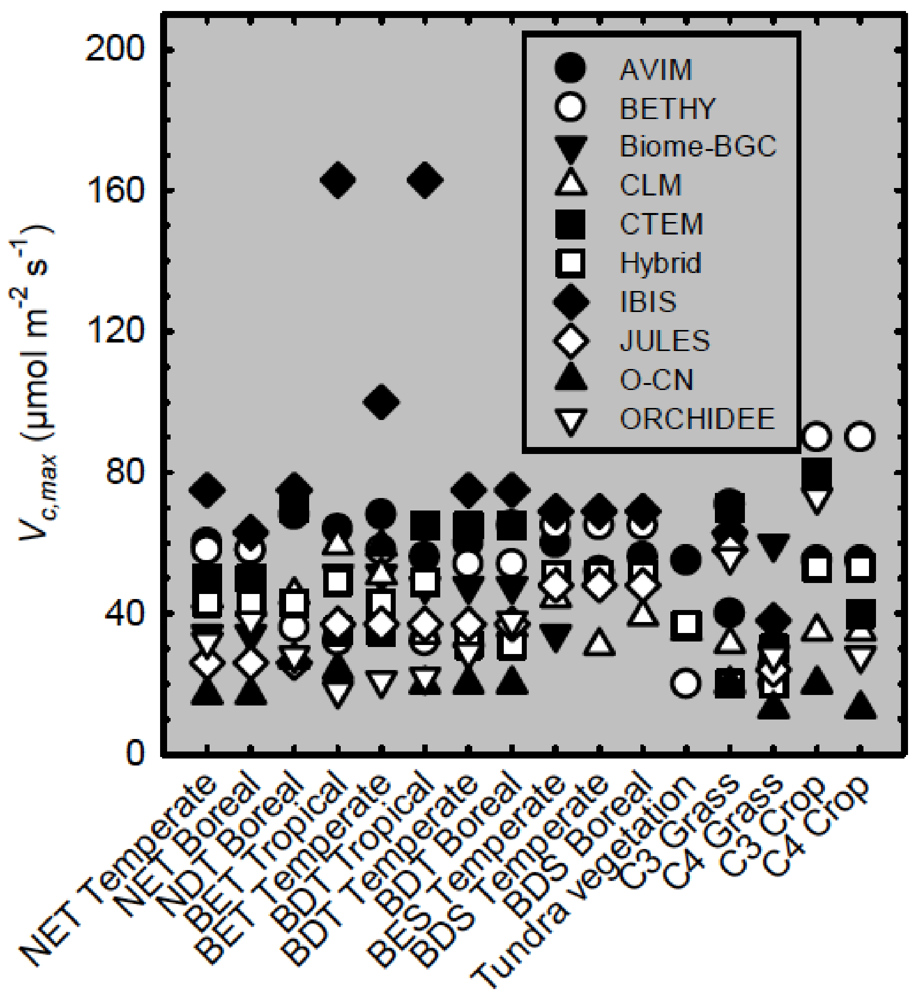
(Beer *et al.* 2010, Science)

CLM predictions of historical carbon sinks



Large variation of Vcmax in models lead to variations in GPP among models

Vcmax is maximum rate of Rubisco-mediated carboxylation



(Rogers 2014, PR)

Modeling Carbon Assimilation

- Farquhar Model

$$A_g = \min\left(W_c, W_j, W_p\right)$$

Rubisco limited carboxylation

$$W_c = \frac{\max\left(C_i - C_p, 0\right)}{(C_i + K_{ct})(1 + \frac{O_2}{K_{ot}})} V_{cmaxt}$$

Electron transfer limited carboxylation

$$W_j = \frac{\max\left(C_i - C_p, 0\right)}{(4C_i + 8C_p)} J$$

End product utilization

$$W_p = 0.5 V_{cmaxt}$$

(Farquhar *et al.* 1980, Planta)

Calculation of Vcmax in CLM

$$V_{cmax} = a_{r25}.F_{NR}.F_{LNR}.N_L$$

$$N_L = \frac{1}{CN_L.SLA}$$

a_{r25} = specific activity of Rubisco at 25^{U}C

F_{NR} = nitrogen fraction of Rubisco

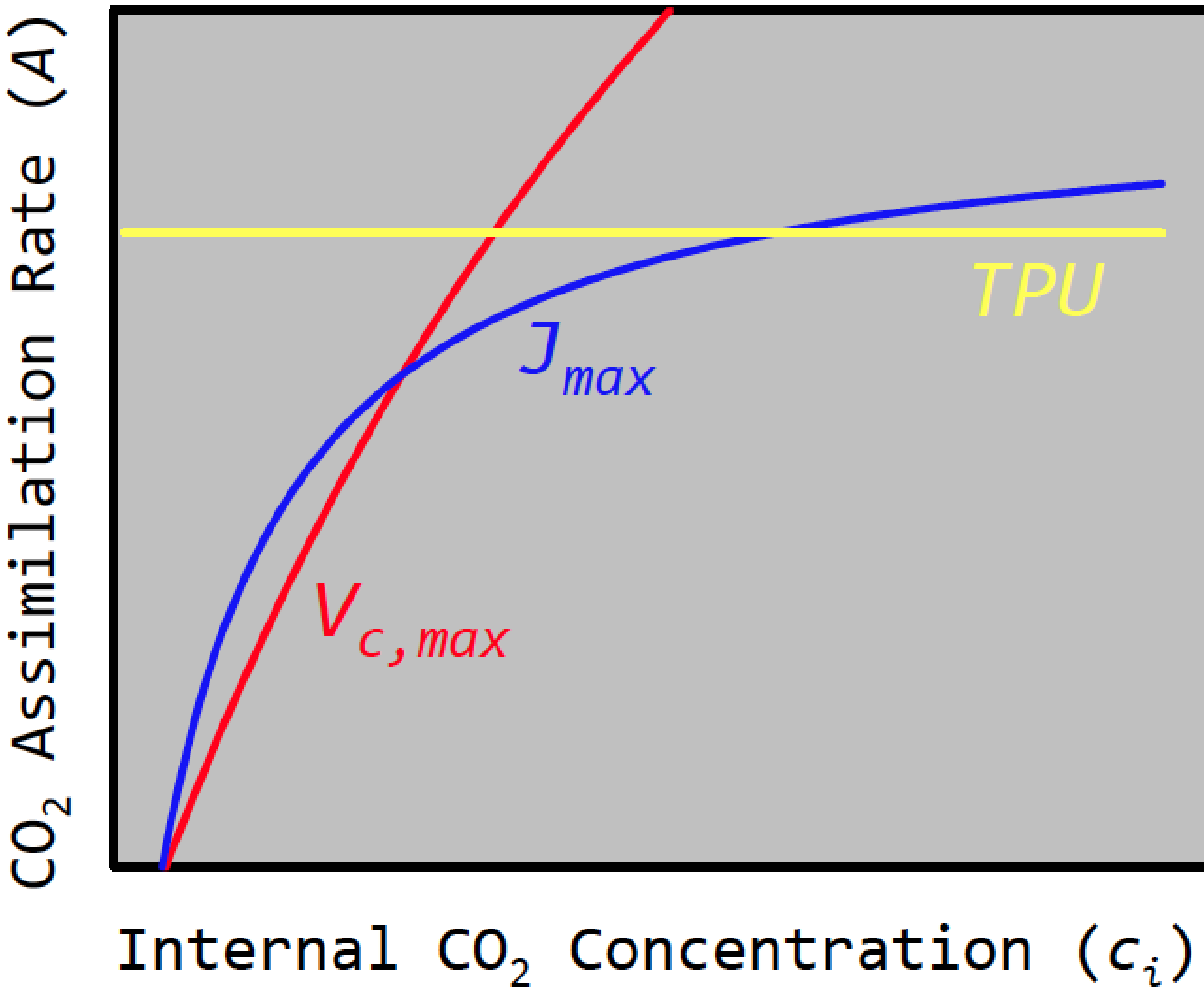
F_{LNR} = fraction of leaf nitrogen in Rubisco

N_L = leaf nitrogen content

CN_L = carbon to nitrogen ratio of leaf

SLA = specific leaf area

Parameters estimated from A-C_i curve



CLM GPP downregulation

- Downregulation of potential GPP based on nitrogen availability
- Potential Vcmax used to calculate potential GPP
- Problems with potential Vcmax
  - Hard to define what we mean by potential Vcmax
  - Inconsistent with field observations of actual Vcmax
  - Difficult to select a function type for performing downregulation

Modifications to CLM4.5

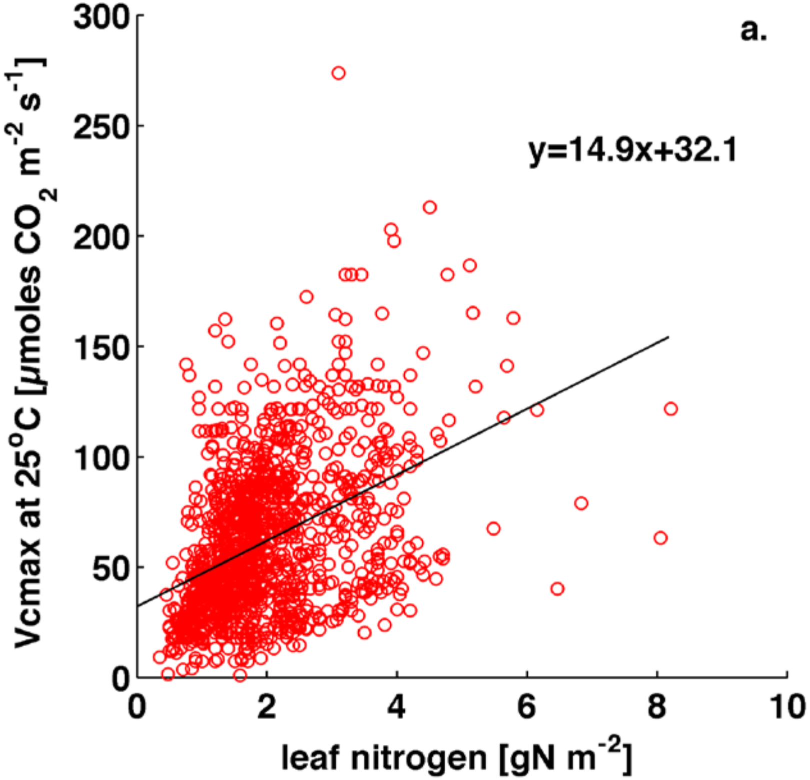
- Removal of GPP downregulation
  - Prognostic leaf nitrogen
  - Dynamic Vcmax linked to prognostic leaf nitrogen
- Nitrogen allocation
  - Plant scale N allocation based on carbon allocation and C:N ratio
  - Leaf scale functional N allocation for reaction enzymes
- Flexible C:N ratio

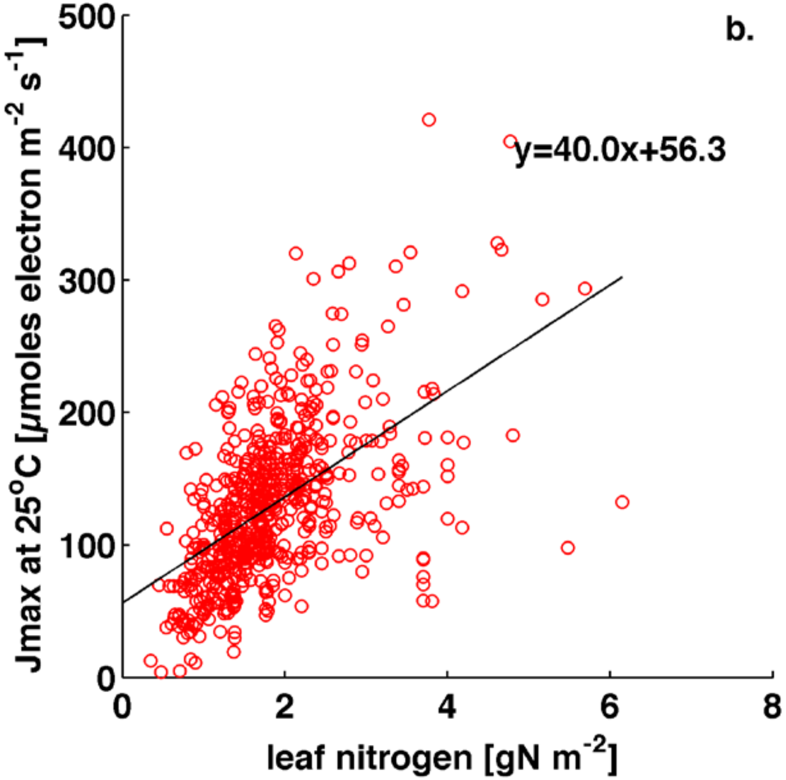
Two methods to remove GPP downregulation

- Method1:
  - Flexible C:N ratio for storage pools for all plant parts
  - Fixed C:N ratio for growth pools for all plant parts

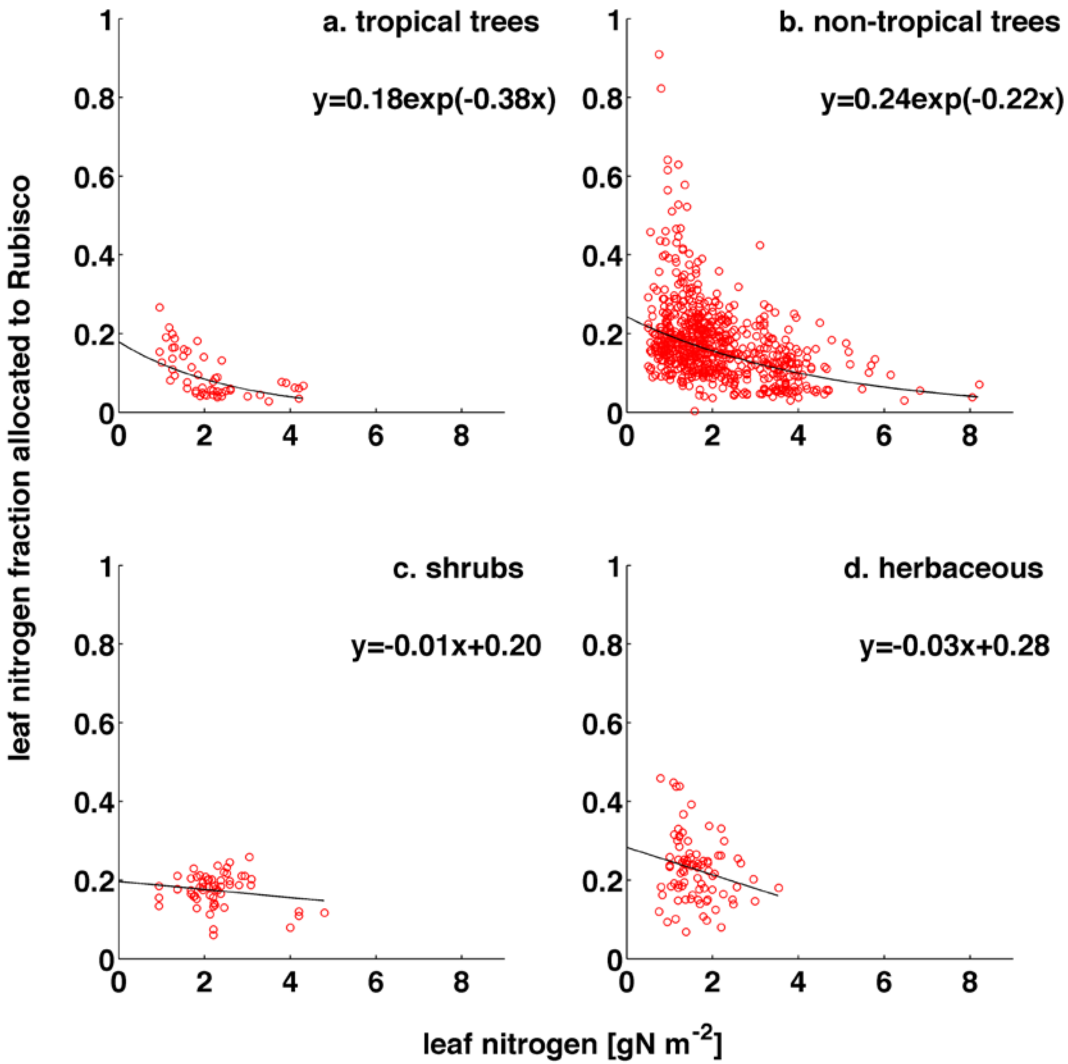
- Method 2:
  - Flexible leaf C:N ratio for both storage and growth/display pools
  - Fixed C:N ratio for both storage and growth/display pools for all other plant parts

Photosynthetic parameters increase with increase in leaf nitrogen at global scale based on TRY data

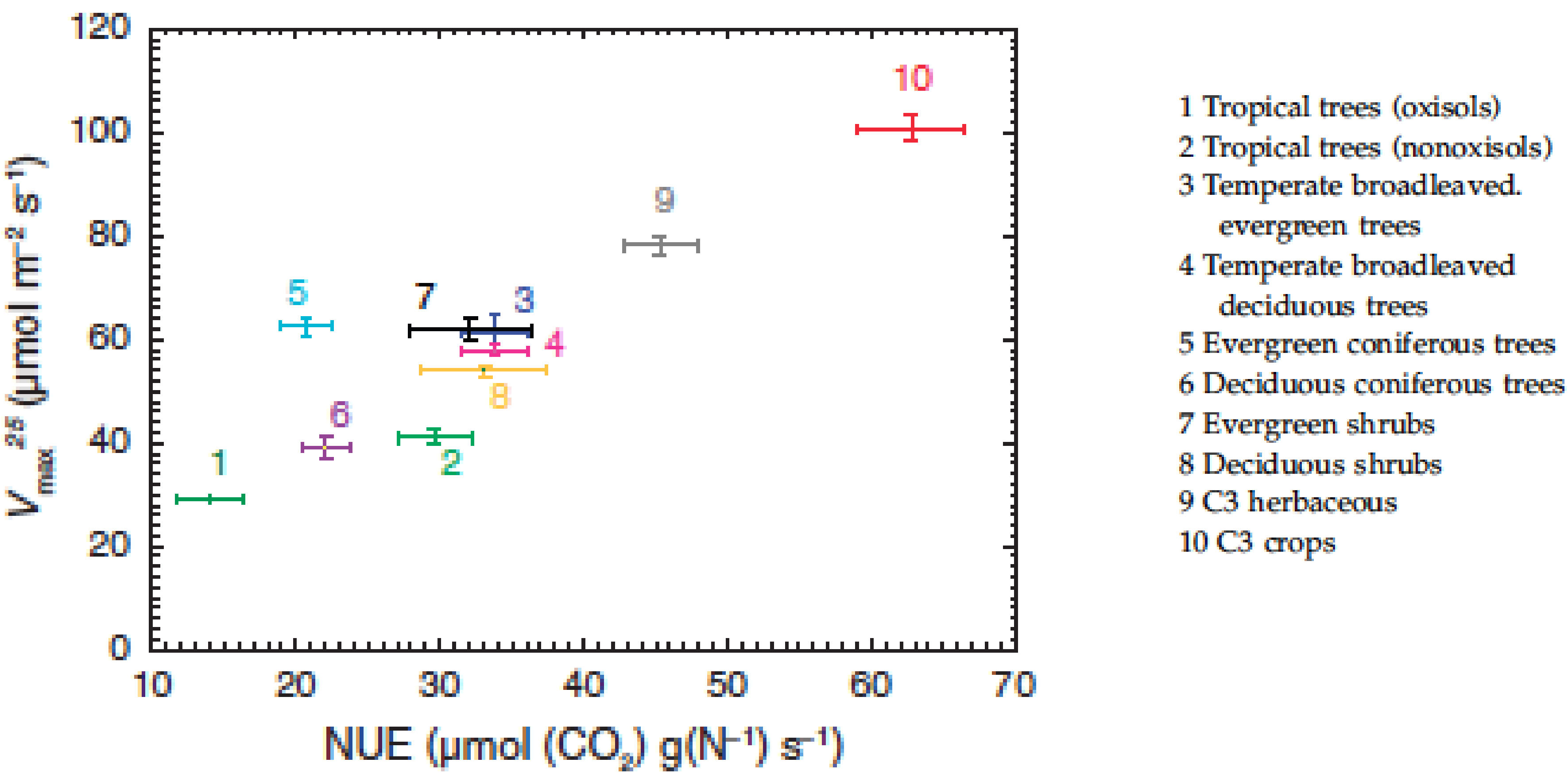




Fraction N allocated to Rubisco decreases with leaf N at global scale



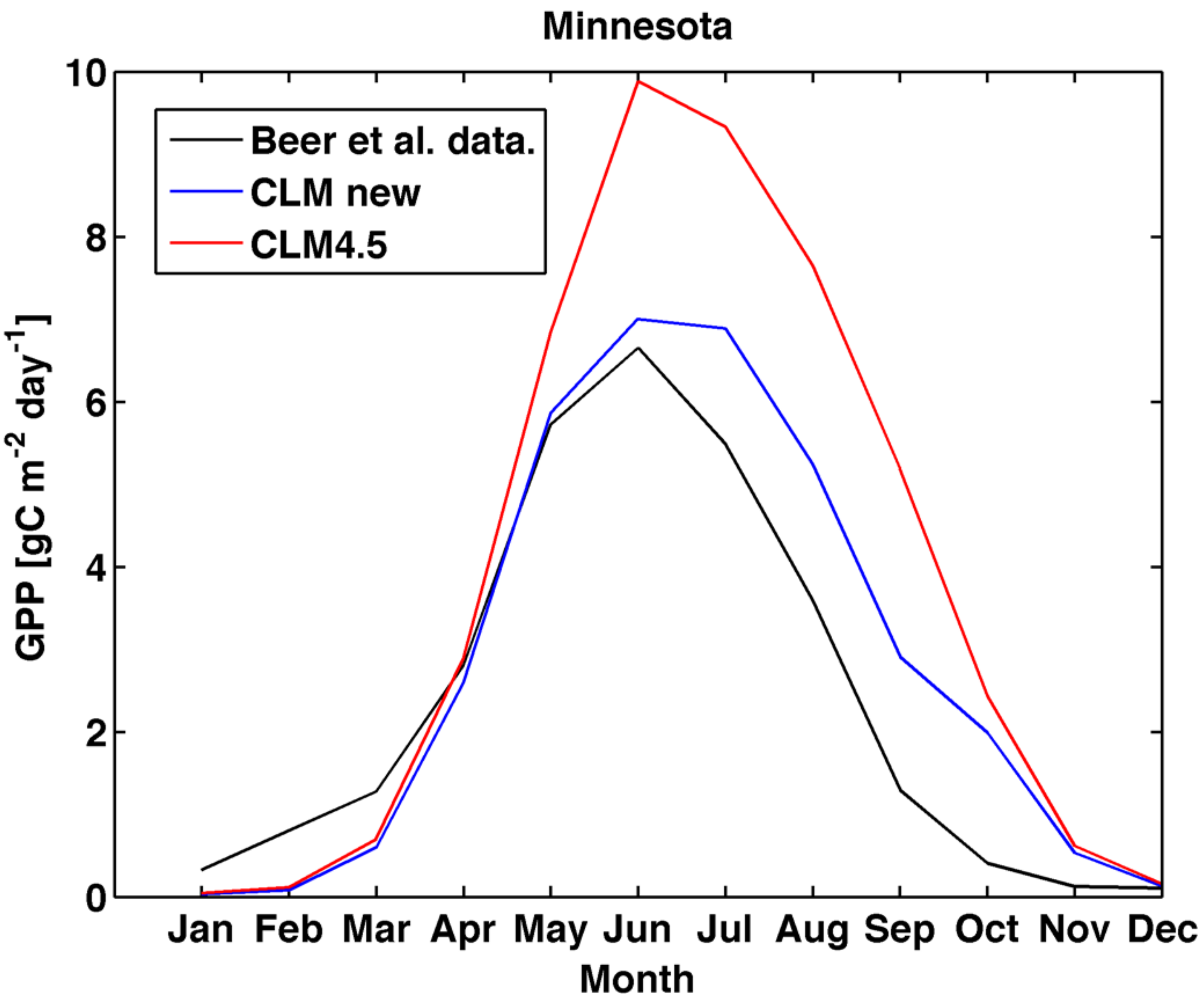
Nitrogen Use Efficiency varies by PFT



(Kattge *et al.* 2009, GCB)

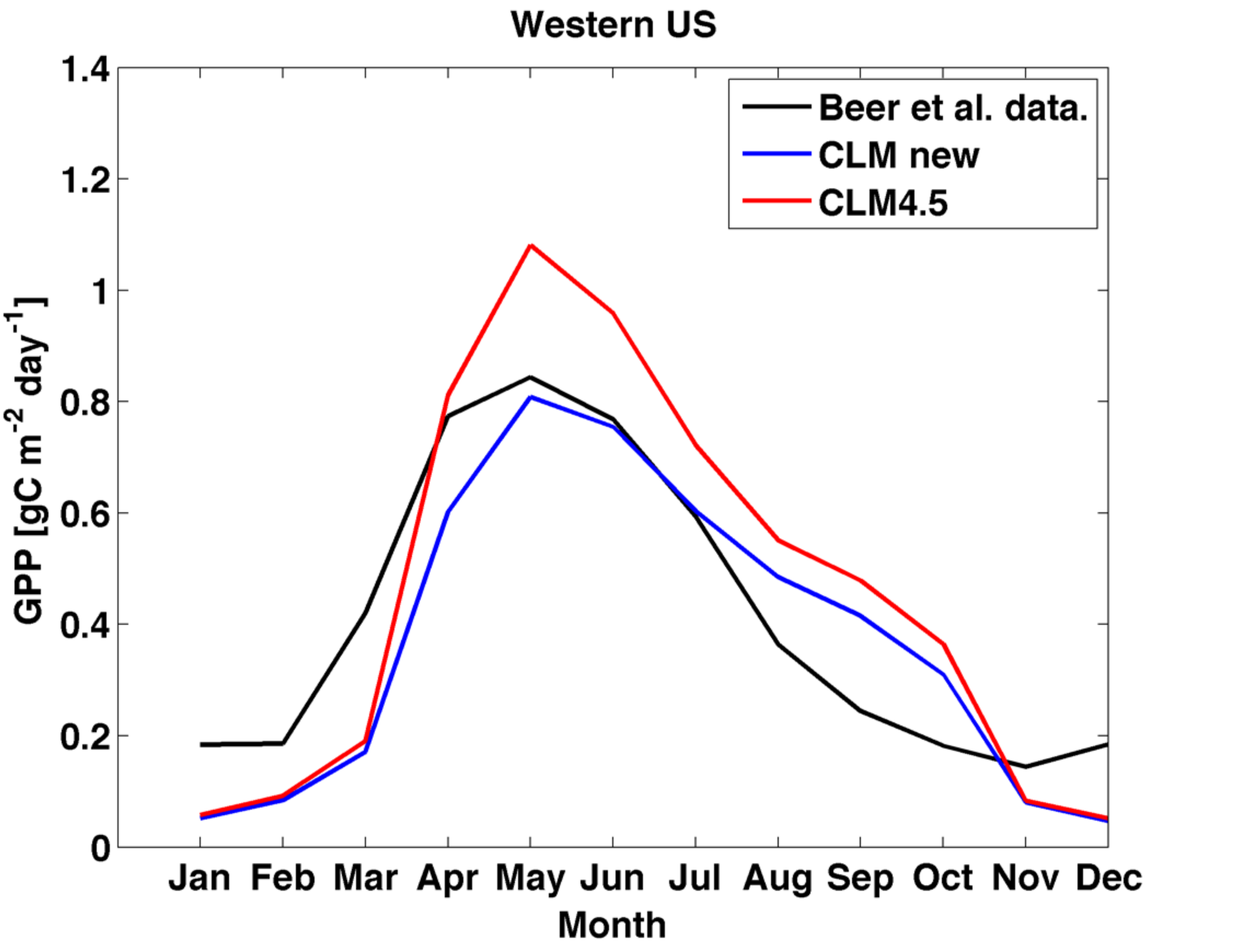
CLM Site Level Evaluation

CLM new has better fit to the Beer *et al.* data than CLM 4.5.



CLM Site Level Evaluation

CLM new has better fit to the Beer *et al.* data compared to CLM4.5, especially in mid- and late-growing seasons.



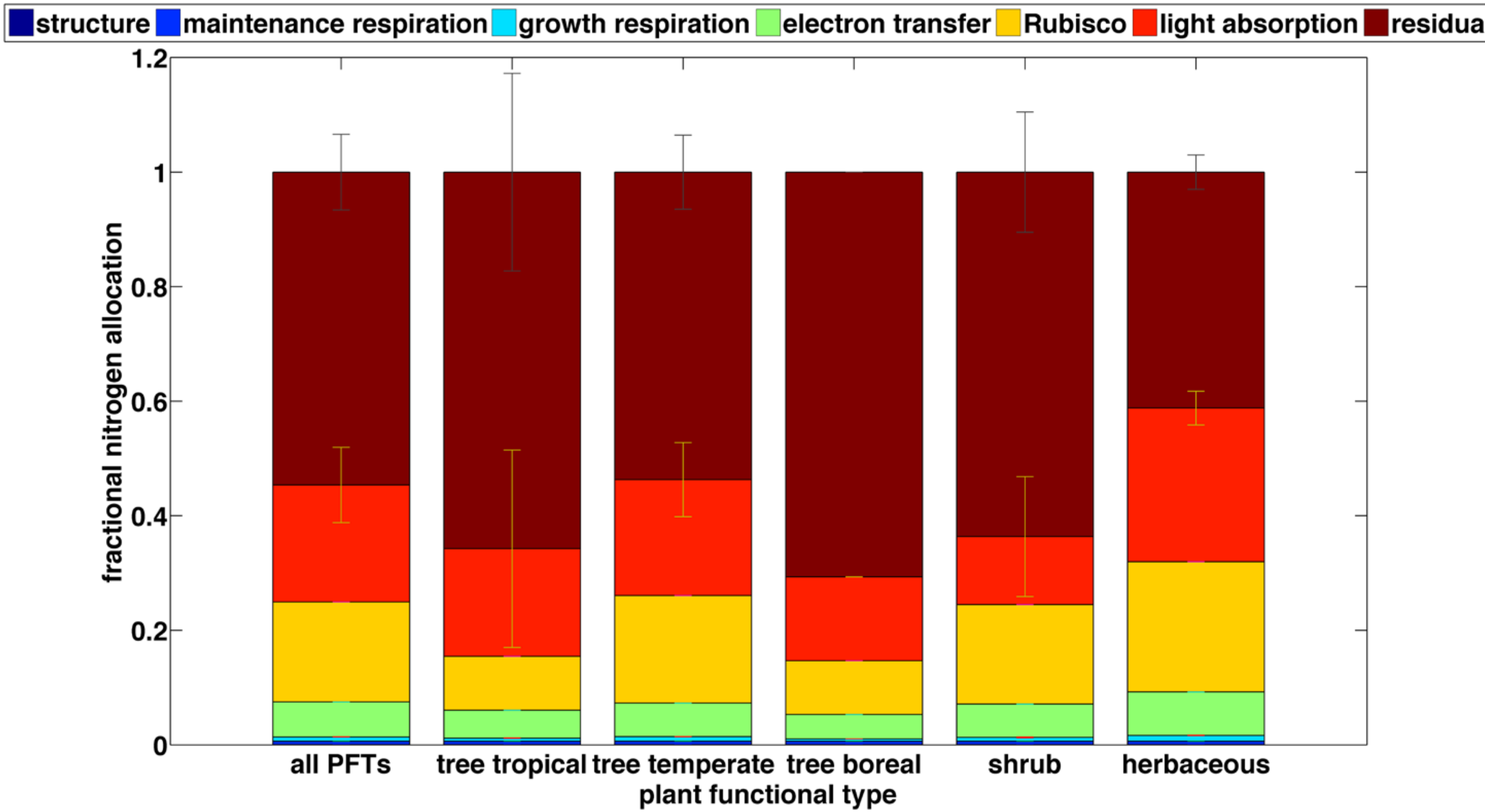
Calculation of Leaf Nitrogen Allocation

- Global Plant Traits Database (TRY)
- Allocation to different processes
  - Photosynthesis
    - Carboxylation
    - Electron transfer
    - Light capture
  - Respiration
    - Maintenance
    - Growth
  - Structure
  - Residual

$$Nitrogen\ Allocation = \frac{Process\ Rate}{Nitrogen\ use\ effiency}$$

$$Nitrogen\ use\ efficiency = (enzyme\ activity)\ (nitrogen\ fraction\ of\ enzyme)$$

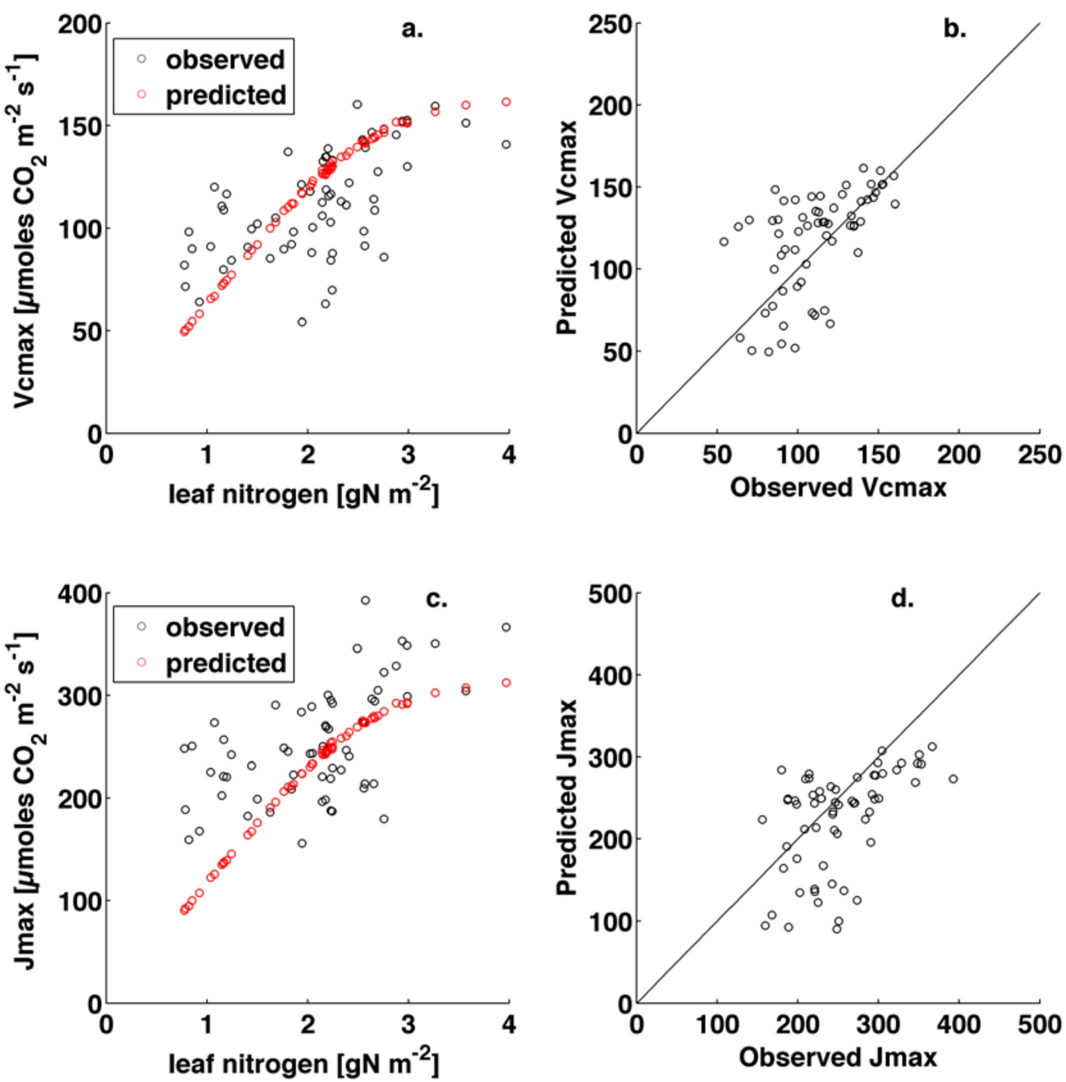
Global patterns of leaf nitrogen allocation by PFT



Optimal Leaf Nitrogen Allocation

- CLM has fixed nitrogen allocation for Rubisco
- Optimal leaf photosynthetic nitrogen allocation relies on dynamic allocation for enzymes which varies with environmental conditions
- Optimality framework
  - Maximizes nitrogen-use efficiency given environmental conditions [Niinemets and Tenhunen 1997; Xu *et al.* 2012]

Optimal Leaf Nitrogen Allocation Model Evaluation: Barrow Alaska



Optimization based on mean environmental conditions at the site

Vcmax predicted by the optimal allocation model has reasonable fit with observed Vcmax (see figure b).

Summary

- Current Model Developments
  - Integration of different plant N cycle mechanisms in the Community Land Model
  - Model structure uses actual photosynthetic parameters rather than potential rates
- Additional Model Developments
  - Dynamic C and N allocation based on resource availability
  - Carbon costs of nutrient acquisition
  - Belowground N competition between plants and microbes
- Scientific Contribution
  - Prognostic leaf nitrogen dynamically linked to carbon assimilation
  - Leaf nitrogen allocation to processes using optimality theory
  - New understanding of N effects on plant productivity and growth
    - Nitrogen deposition
    - Permafrost thawing

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