The CLM5 Community Nitrogen Cycle Development

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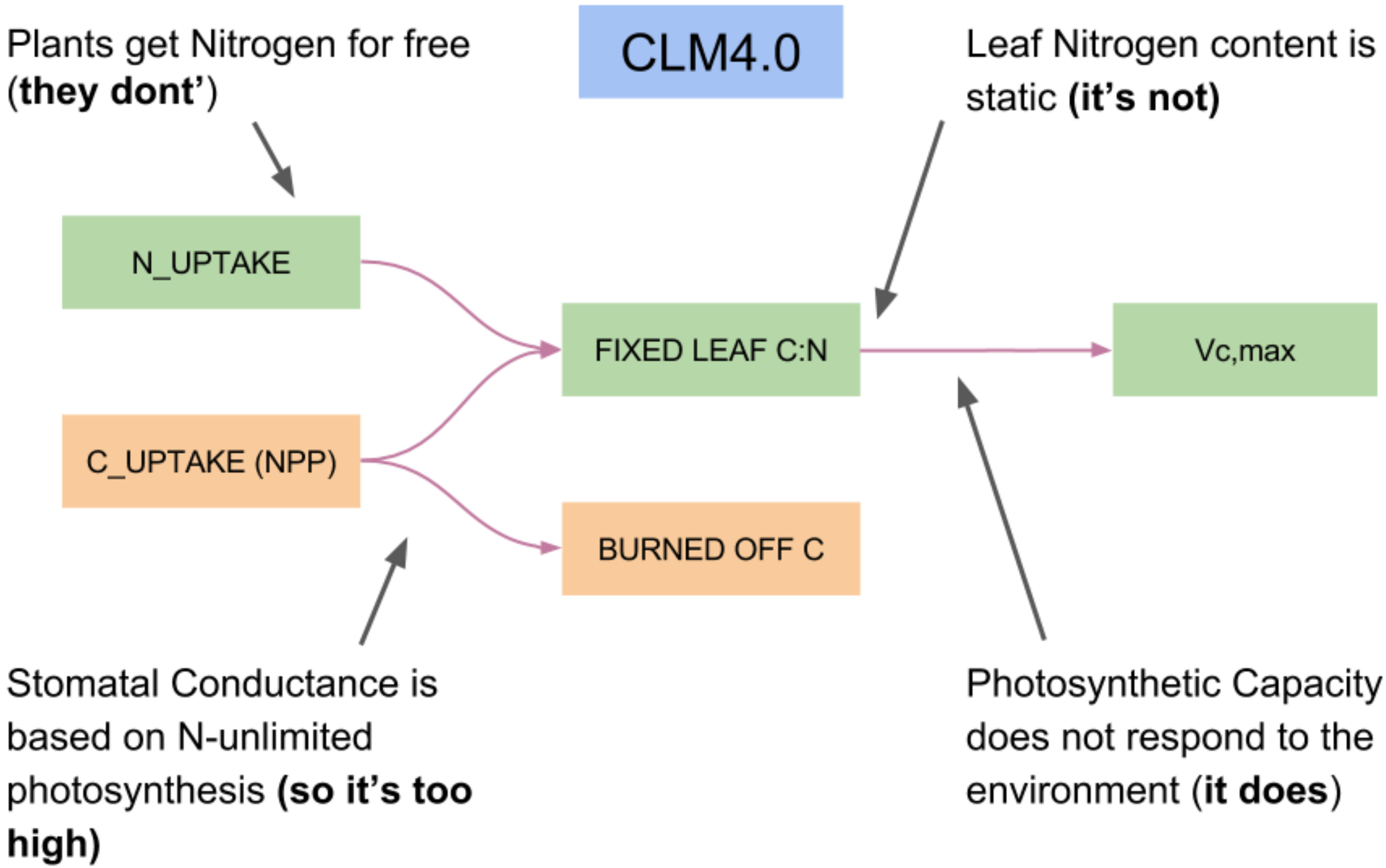
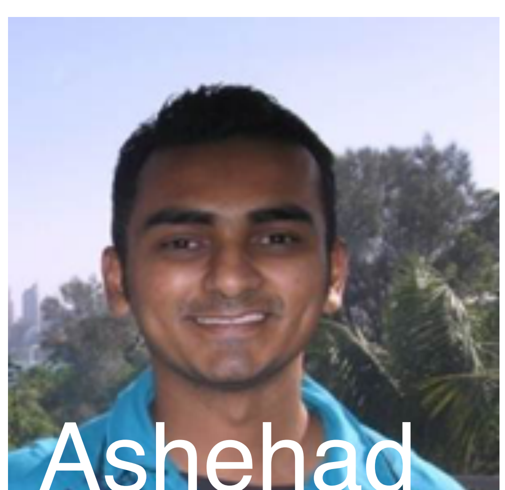


CLM4.0
Plants get Nitrogen for free (**they dont'**)
Leaf Nitrogen content is static **(it's not)**
N_UPTAKE
C_UPTAKE (NPP)
FIXED LEAF C:N
Vc,max
BURNED OFF C
Stomatal Conductance is based on N-unlimited photosynthesis **(so it's too high)**
Photosynthetic Capacity does not respond to the environment (**it does**)

Motivated Nitrogen Cyclers

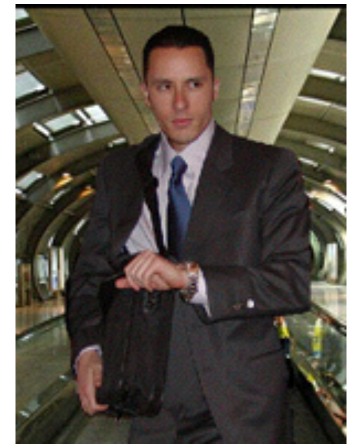


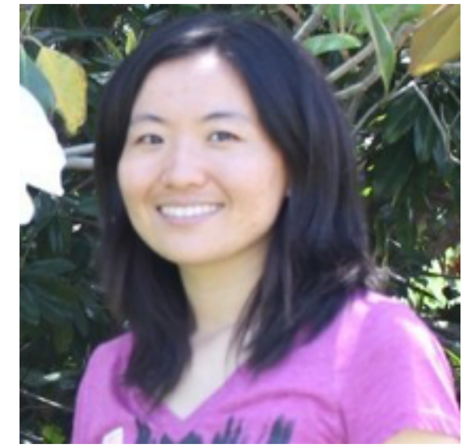
“Plants get Nitrogen for free”

The FUN* Model

A marketplace for Nitrogen Uptake

*__F__ixation and __U__ptake of __N__itrogen



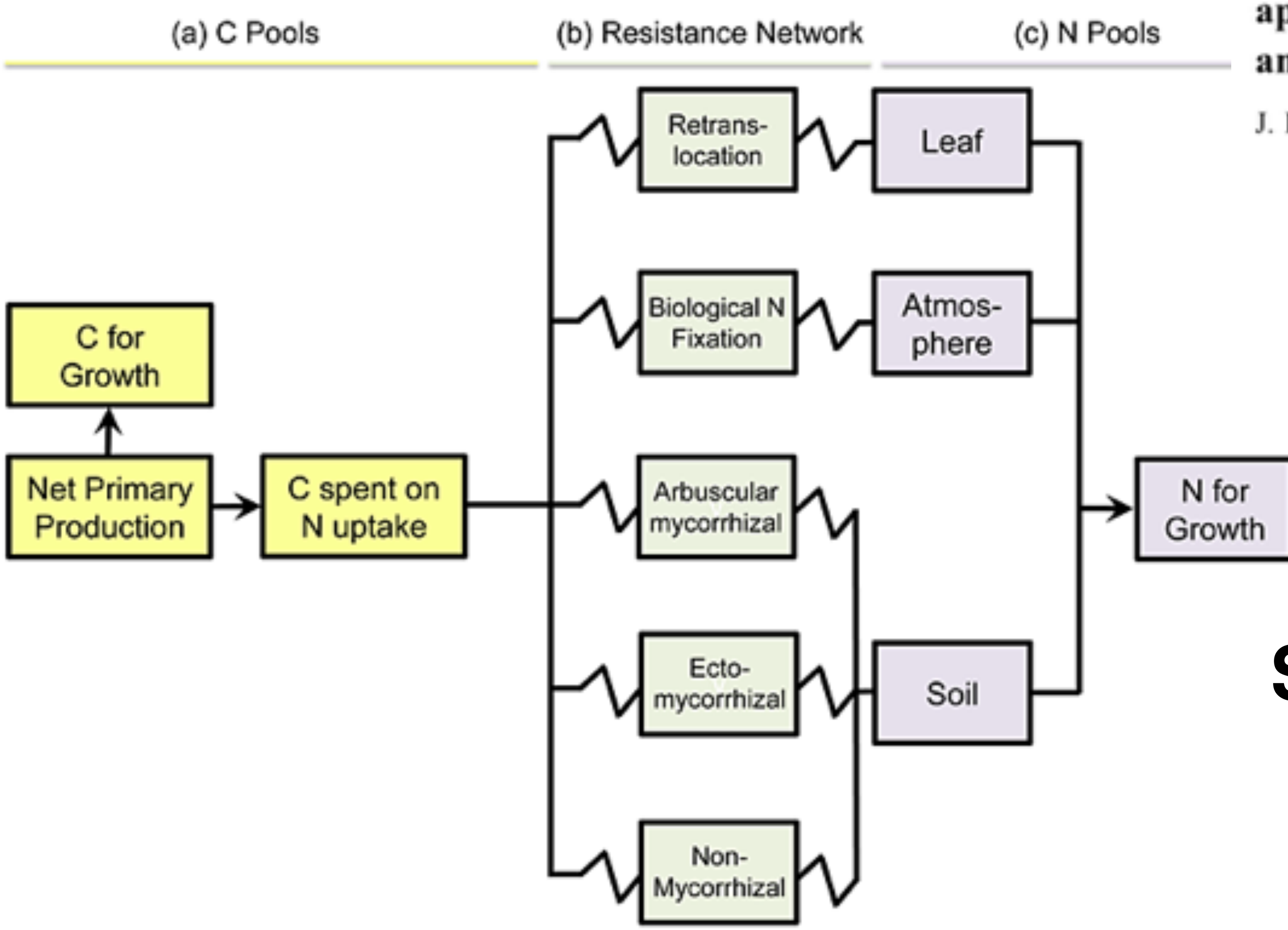


Carbon cost of plant nitrogen acquisition: A mechanistic, globally applicable model of plant nitrogen uptake, retranslocation, and fixation

J. B. Fisher,[1] S. Sitch,[2] Y. Malhi,[1] R. A. Fisher,[3] C. Huntingford,[4] and S.-Y. Tan[1]

Modeling the carbon cost of plant nitrogen acquisition: Mycorrhizal trade-offs and multipath resistance uptake improve predictions of retranslocation

Edward R. Brzostek[1], Joshua B. Fisher[2,3], and Richard P. Phillips[1]



Solve for maximum growth

$$C_{growth} = C_{npp} - C_{nuptake}$$

$$N_{growth} = N_{uptake}$$

$$N_{uptake} = C_{nuptake} / CN_{cost}$$

$$N_{growth} = C_{growth} / CN_{plant}$$

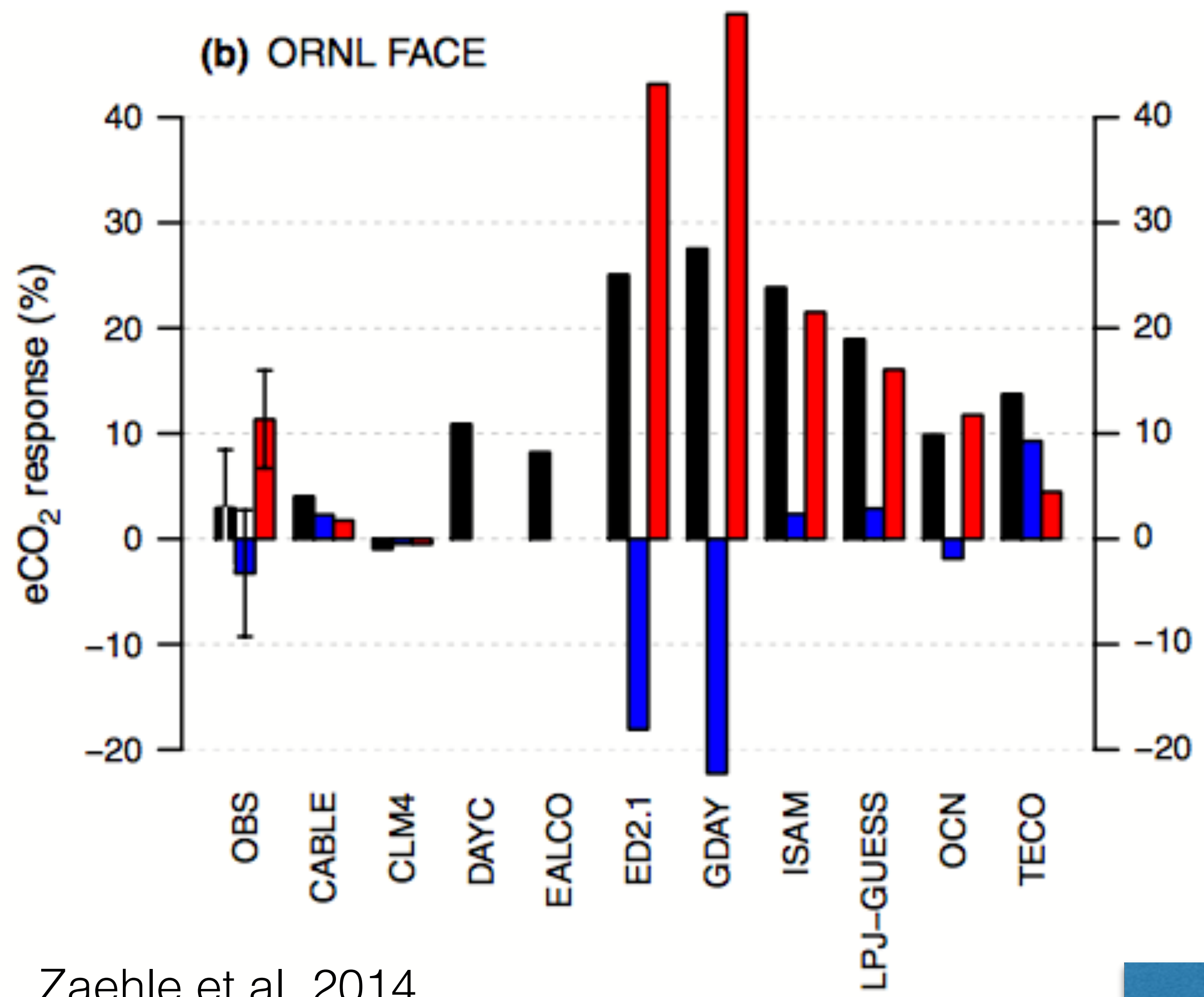
Hypothesis: Plants will take up N from the cheapest sources

“Leaf Nitrogen content is static”

The FlexCN Model

Variable carbon:nitrogen ratios

Red = increase in productivity due to change C:N ratio



Zaehle et al. 2014

Hypothesis: Plants will vary their tissue Carbon:Nitrogen ratio as N availability varies in space and time

“Photosynthetic capacity does not respond to the environment”

The LUNA* Model

How best to use the Nitrogen you have?

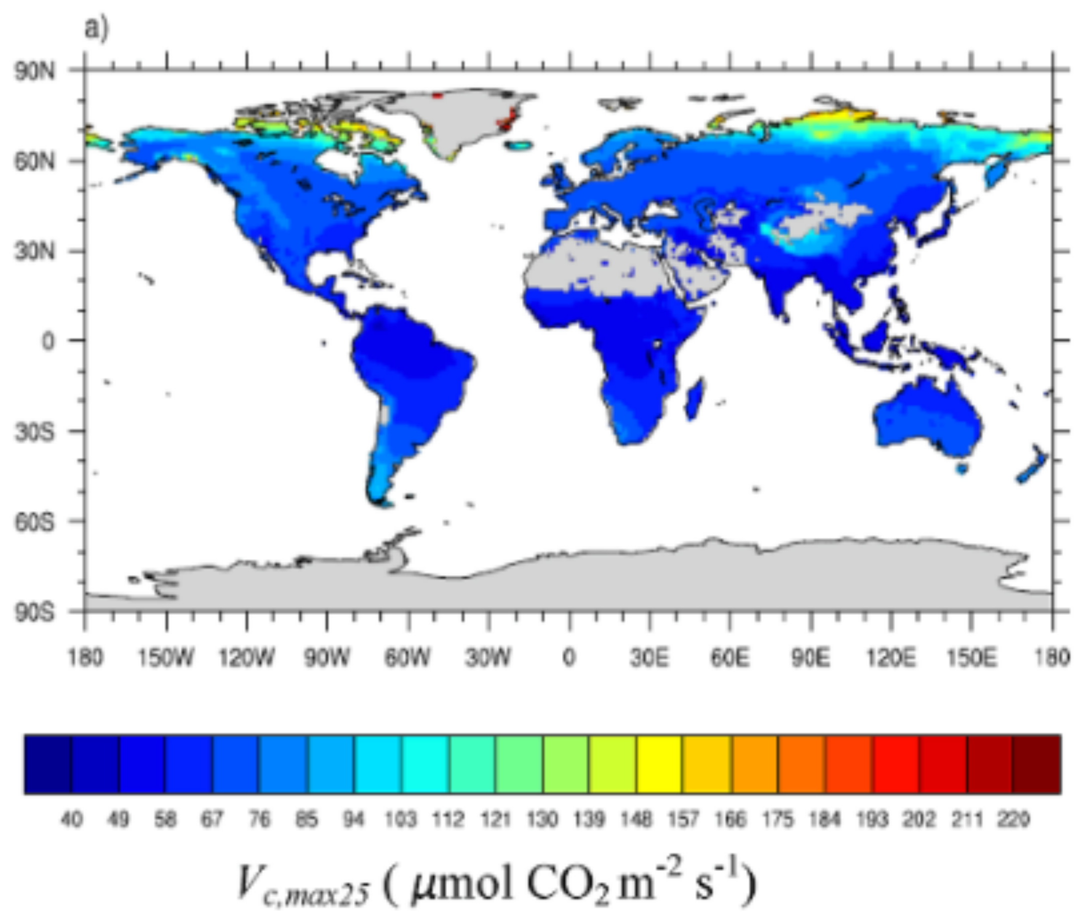
*__L__eaf __U__se of __N__itrogen for __A__ssimilation



Toward a Mechanistic Modeling of Nitrogen Limitation on Vegetation Dynamics

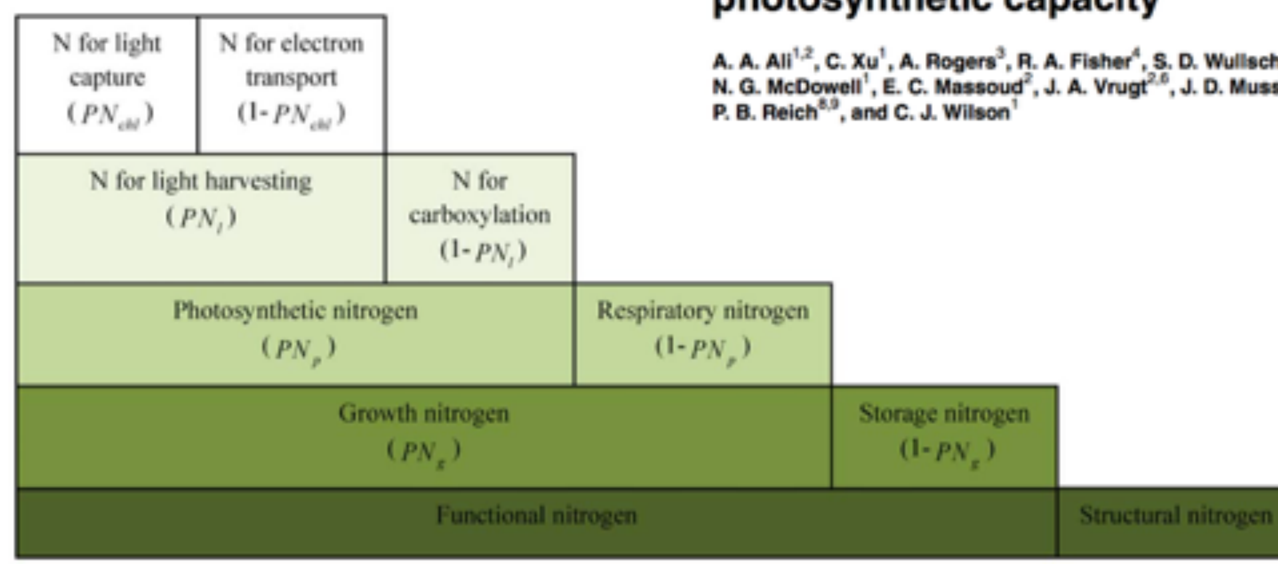
Chonggang Xu[1*], Rosie Fisher[2], Stan D. Wullschleger[3], Cathy J. Wilson[1], Michael Cai[4], Nate G. McDowell[1]

Predicted optimal photosynthetic capacity

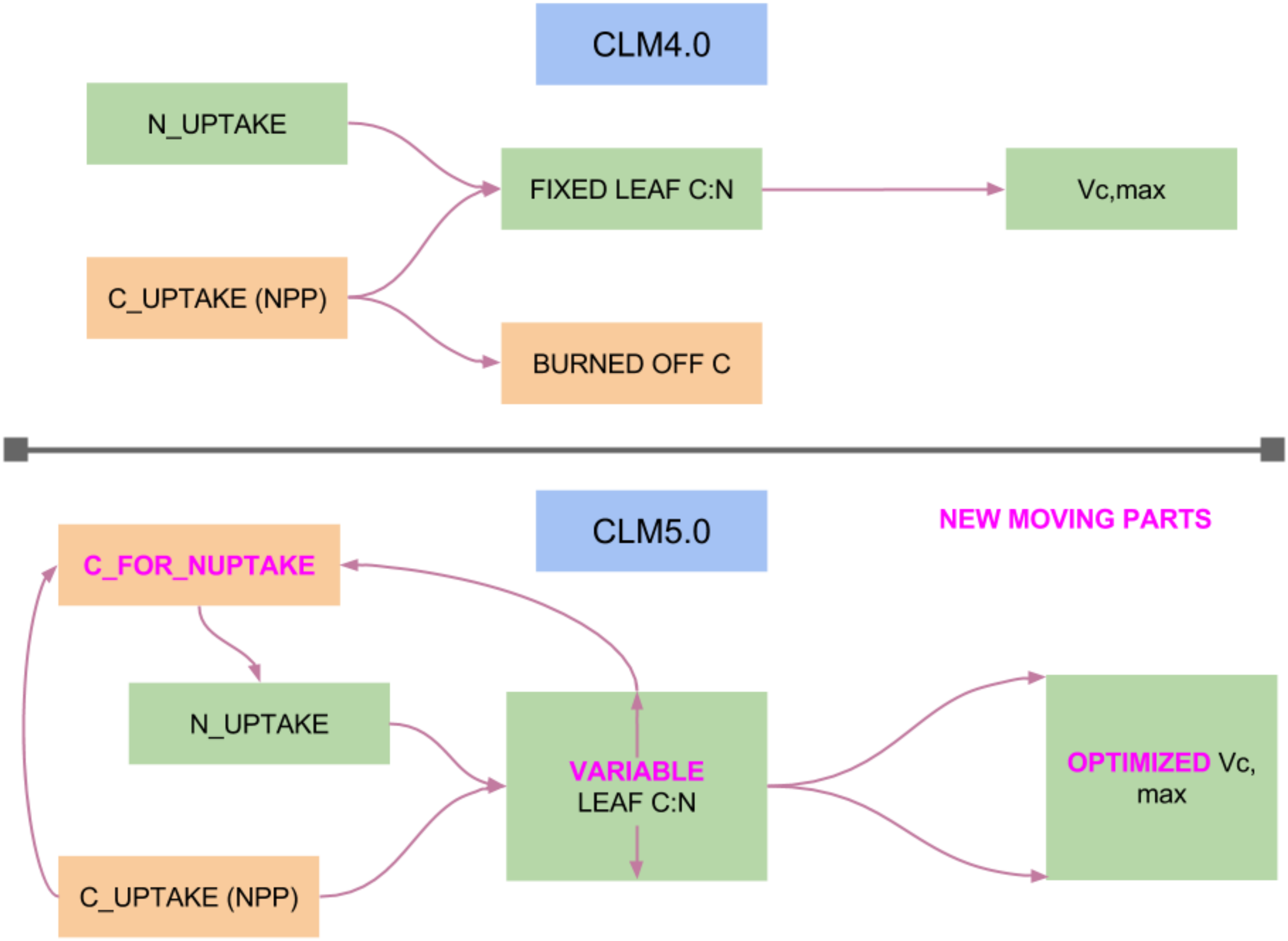


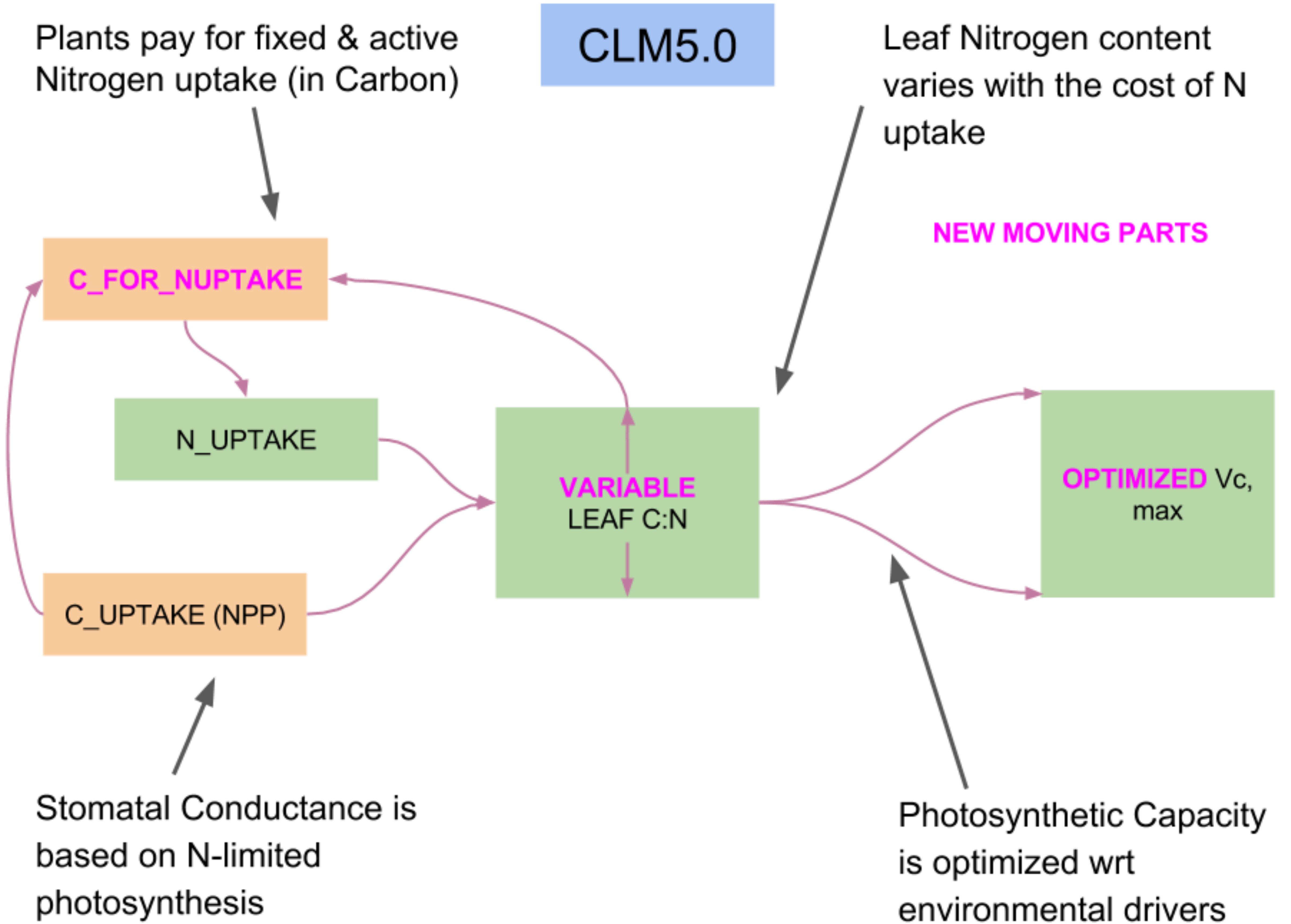
A global scale mechanistic model of the photosynthetic capacity

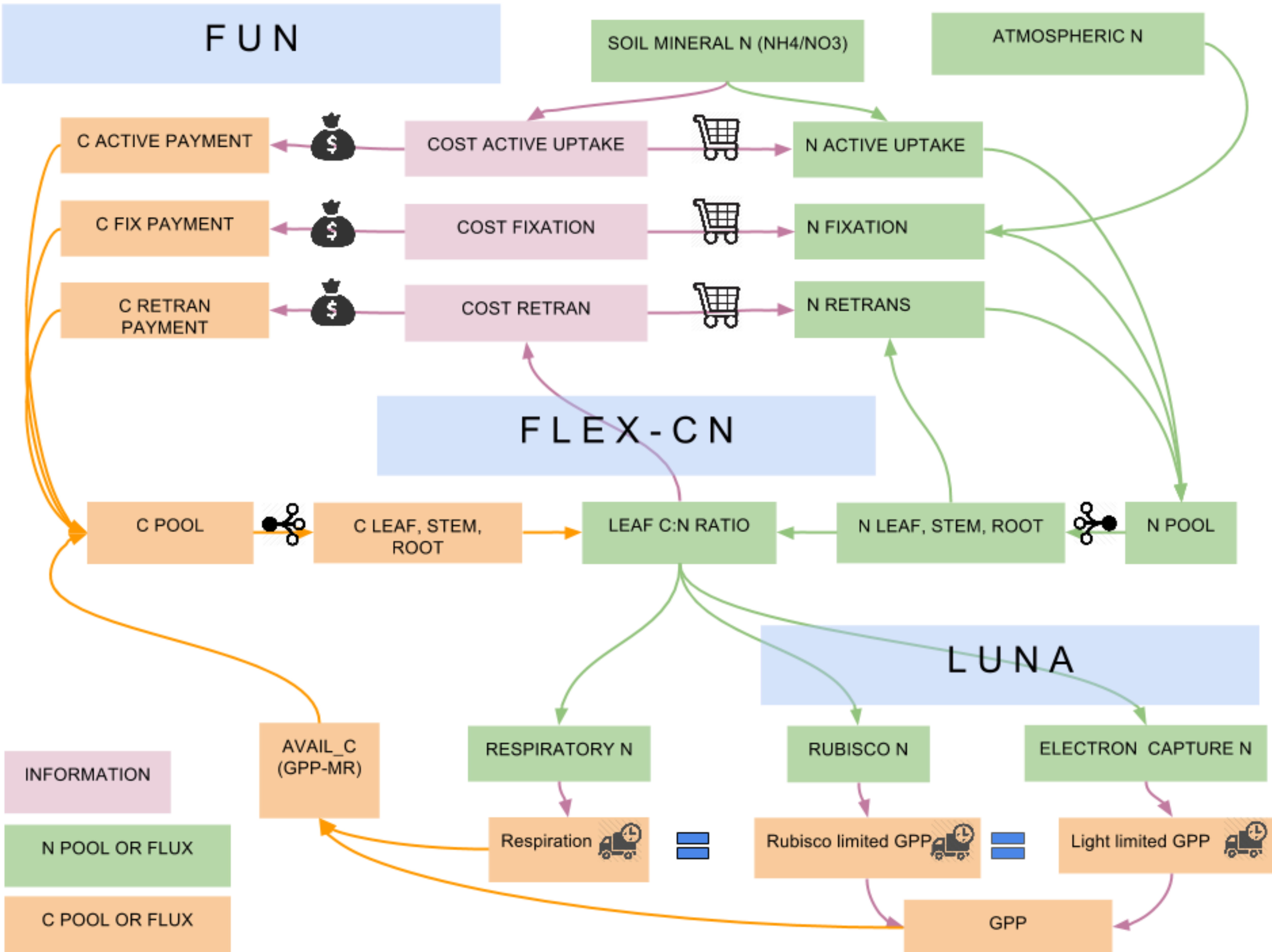
A. A. Ali[1,2], C. Xu[1], A. Rogers[3], R. A. Fisher[4], S. D. Wullschleger[5], N. G. McDowell[1], E. C. Massoud[2], J. A. Vrugt[2,6], J. D. Muss[1], J. B. Fisher[7], P. B. Reich[8,9], and C. J. Wilson[1]



Hypothesis: Leaf Nitrogen is distributed so that light capture, carboxylation and respiration are co-limiting


CLM4.0
N_UPTAKE
FIXED LEAF C:N
Vc,max
C_UPTAKE (NPP)
BURNED OFF C
CLM5.0
NEW MOVING PARTS
C_FOR_NUPTAKE
N_UPTAKE
VARIABLE
LEAF C:N
OPTIMIZED Vc,
max
C_UPTAKE (NPP)


CLM5.0
Plants pay for fixed & active Nitrogen uptake (in Carbon)
Leaf Nitrogen content varies with the cost of N uptake
NEW MOVING PARTS
C_FOR_NUPTAKE
N_UPTAKE
VARIABLE LEAF C:N
OPTIMIZED Vc, max
C_UPTAKE (NPP)
Stomatal Conductance is based on N-limited photosynthesis
Photosynthetic Capacity is optimized wrt environmental drivers


FUN
SOIL MINERAL N (NH4/NO3)
ATMOSPHERIC N
C ACTIVE PAYMENT
COST ACTIVE UPTAKE
N ACTIVE UPTAKE
C FIX PAYMENT
COST FIXATION
N FIXATION
C RETRAN PAYMENT
COST RETRAN
N RETRANS
FLEX-CN
C POOL
C LEAF, STEM, ROOT
LEAF C:N RATIO
N LEAF, STEM, ROOT
N POOL
LUNA
AVAIL_C (GPP-MR)
RESPIRATORY N
RUBISCO N
ELECTRON CAPTURE N
Respiration
Rubisco limited GPP
Light limited GPP
GPP
INFORMATION
N POOL OR FLUX
C POOL OR FLUX

- WILL’S SECTION

FUN-FlexCN coupling

- The FUN model targets a fixed C/N ratio
- This does not allow flexible CN ratio.
- We thus need to change $C_{nuptake}$ to allow for this

Solve for maximum growth

$$C_{growth} = C_{npp} - C_{nuptake}$$

$$N_{growth} = N_{uptake}$$

$$N_{uptake} = C_{nuptake} / CN_{cost}$$

$$N_{growth} = C_{growth} / CN_{plant}$$

C allocation to uptake responds to $CN_{uptake\text{-}cost}$ and CN_{actual}

Adjustment factor

FUN equation

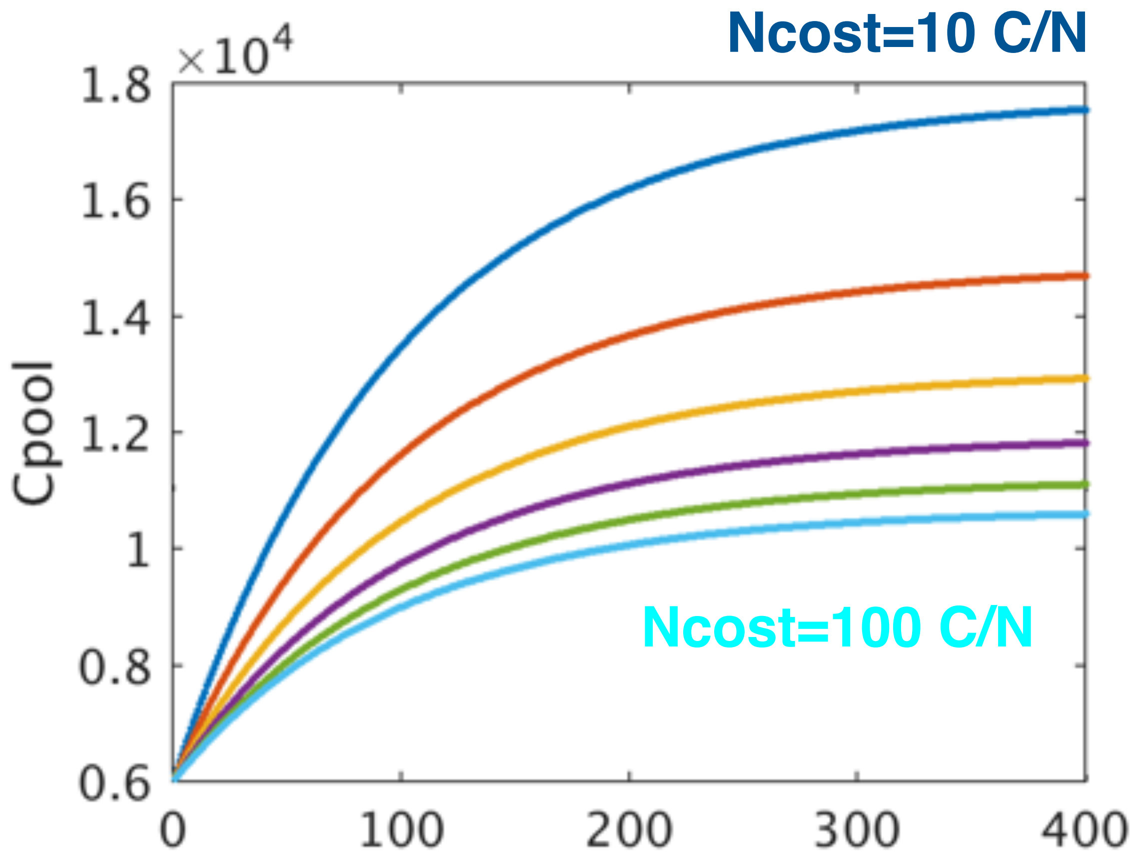
$$C\_for\_nuptake = \mathbf{C_{adj}} \times \frac{(GPP-MR)}{(CN_{target} / CN_{uptake\text{-}cost}) + 1.0}$$

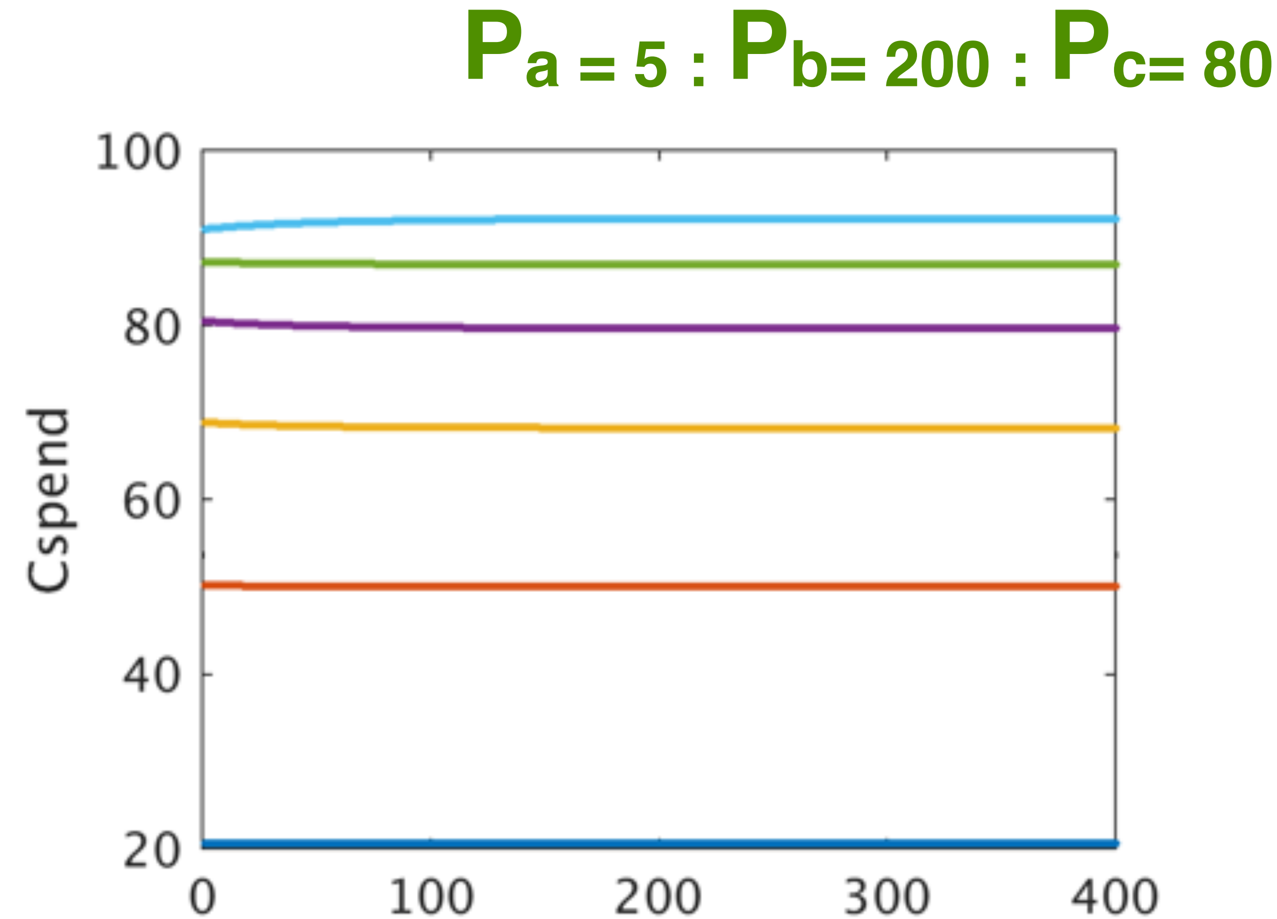
$$\mathbf{C_{adj}} = 1.0 - (CN_{uptake\text{-}cost} - P_a) / P_b$$

Reduce C allocation with cost

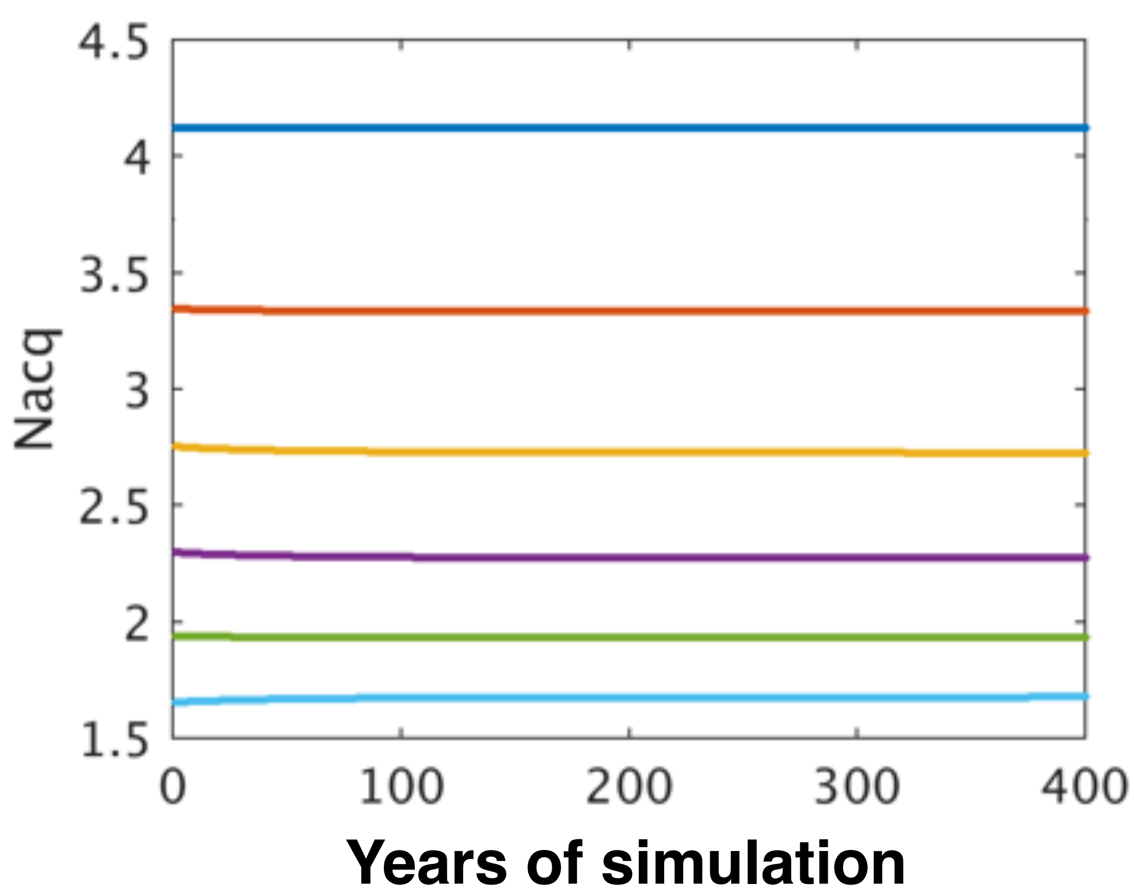
$$\mathbf{C_{adj}} = \mathbf{C_{adj}} + (1.0 - \mathbf{C_{adj}}) \times (CN_{actual} - CN_{target}) / P_c$$

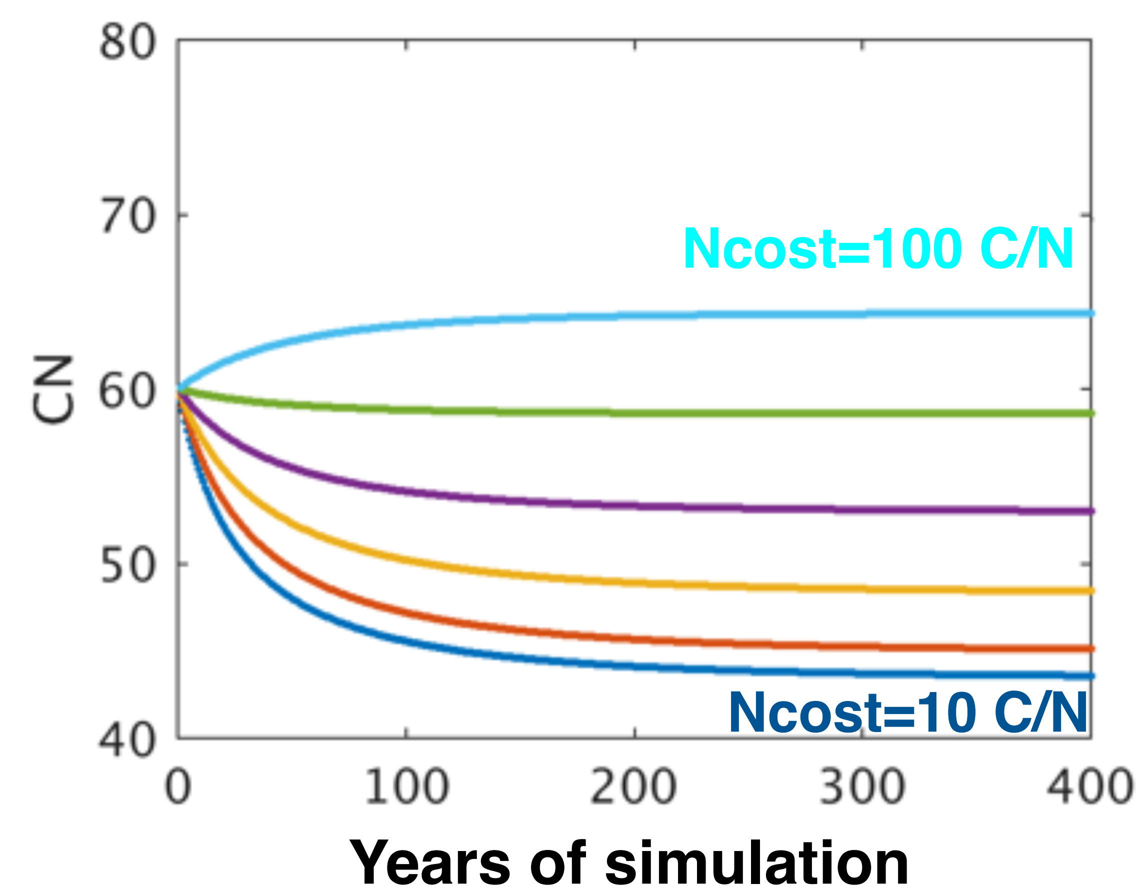
Increase C allocation with high C:N



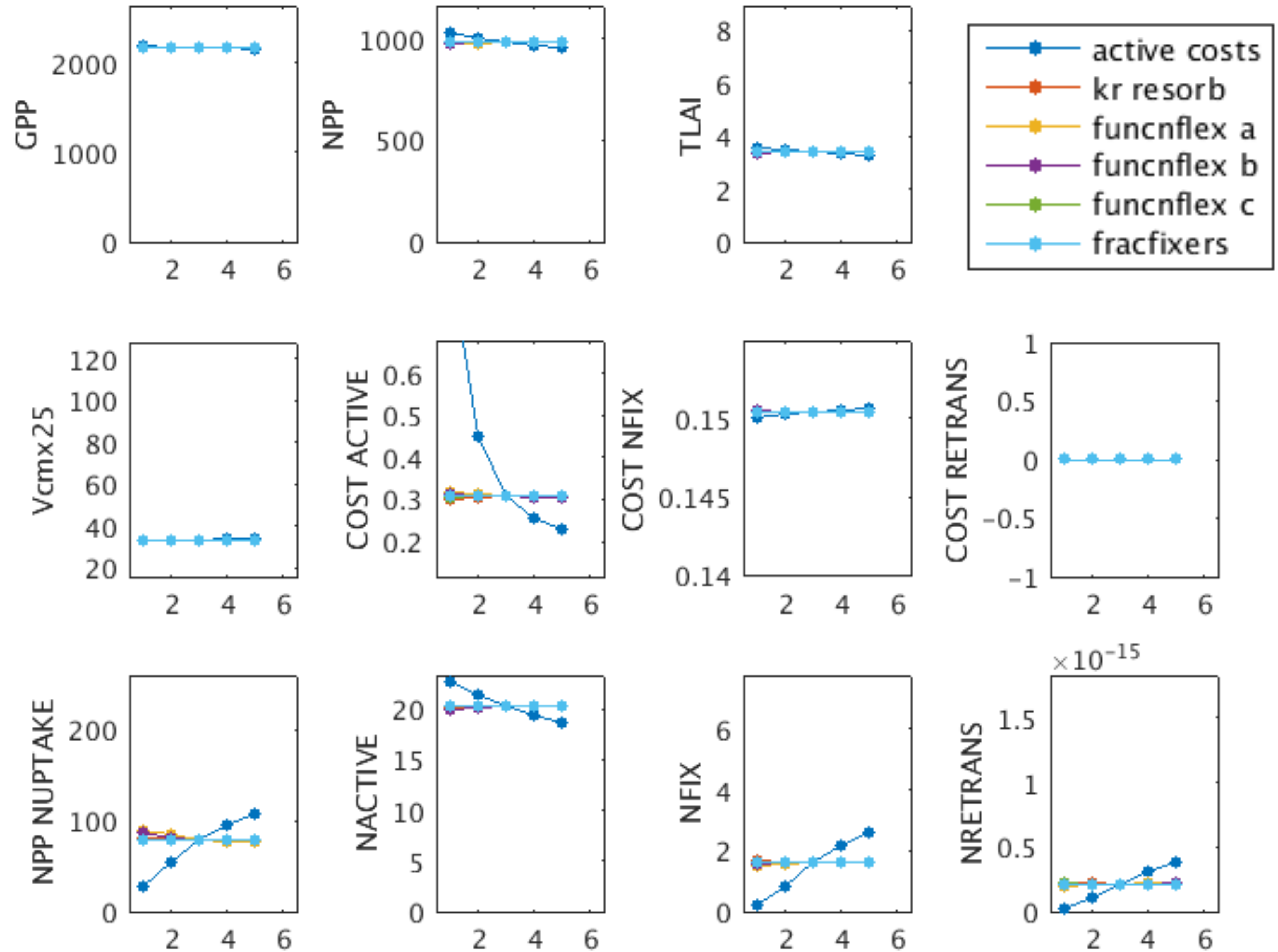


Offline FlexCN-FUN feedback behavior



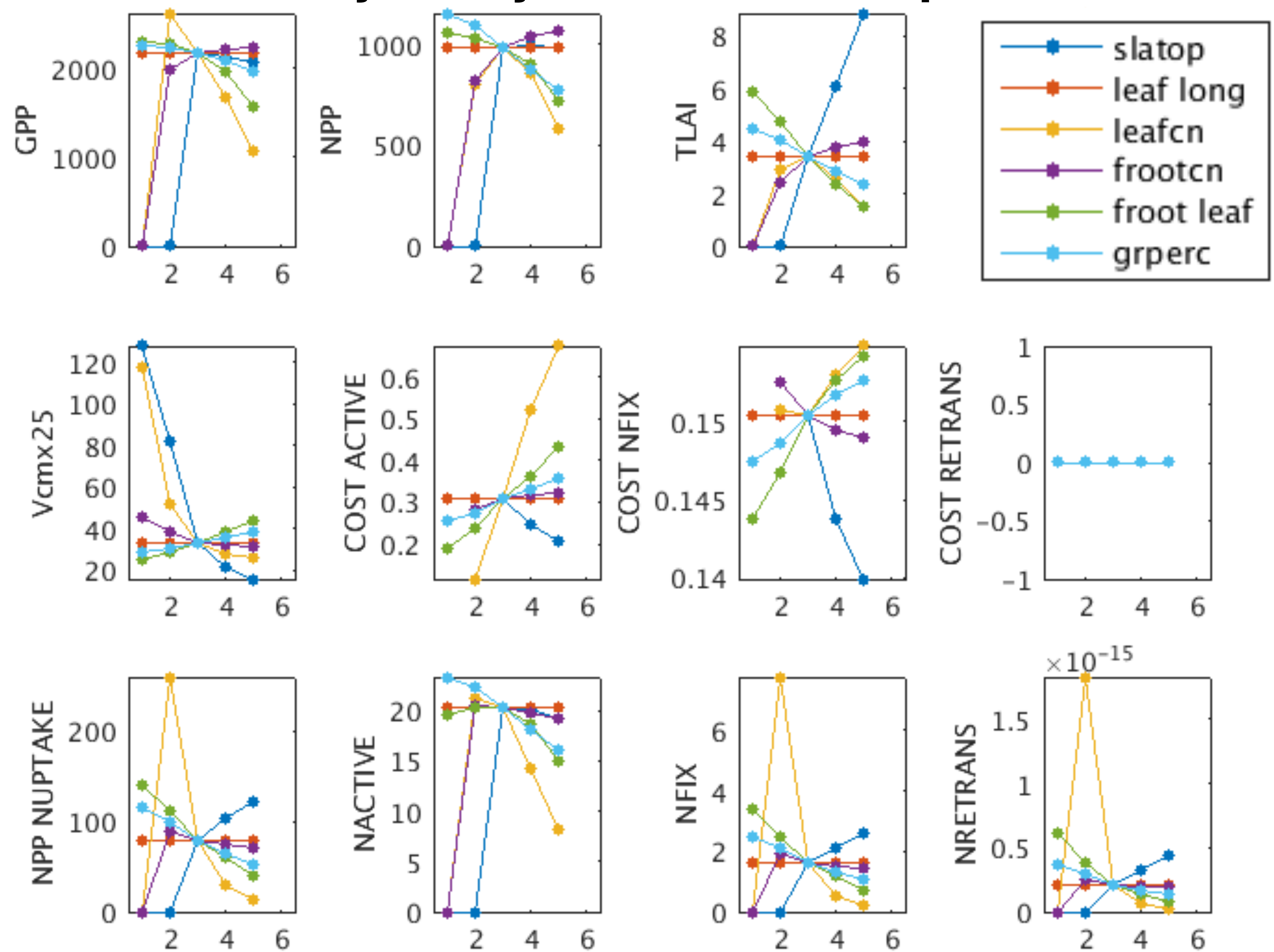


Sensitivity Analysis of FUN parameters



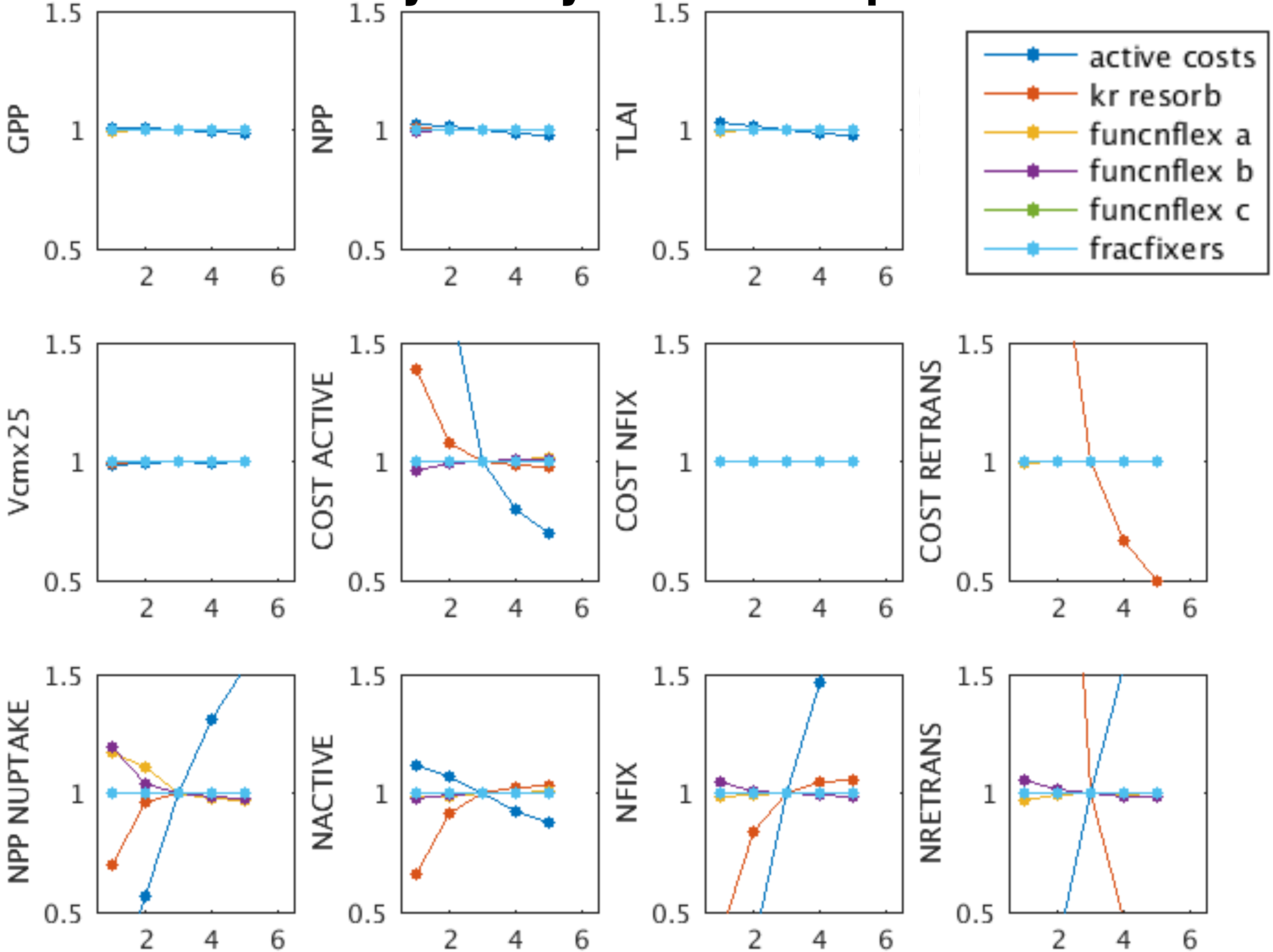
ITERATION (1-6 = 0.2 0.5 1.0 1.5 2.0)

Sensitivity Analysis of not-FUN parameters



ITERATION (1-6 = 0.2 0.5 1.0 1.5 2.0)

Sensitivity Analysis of FUN parameters



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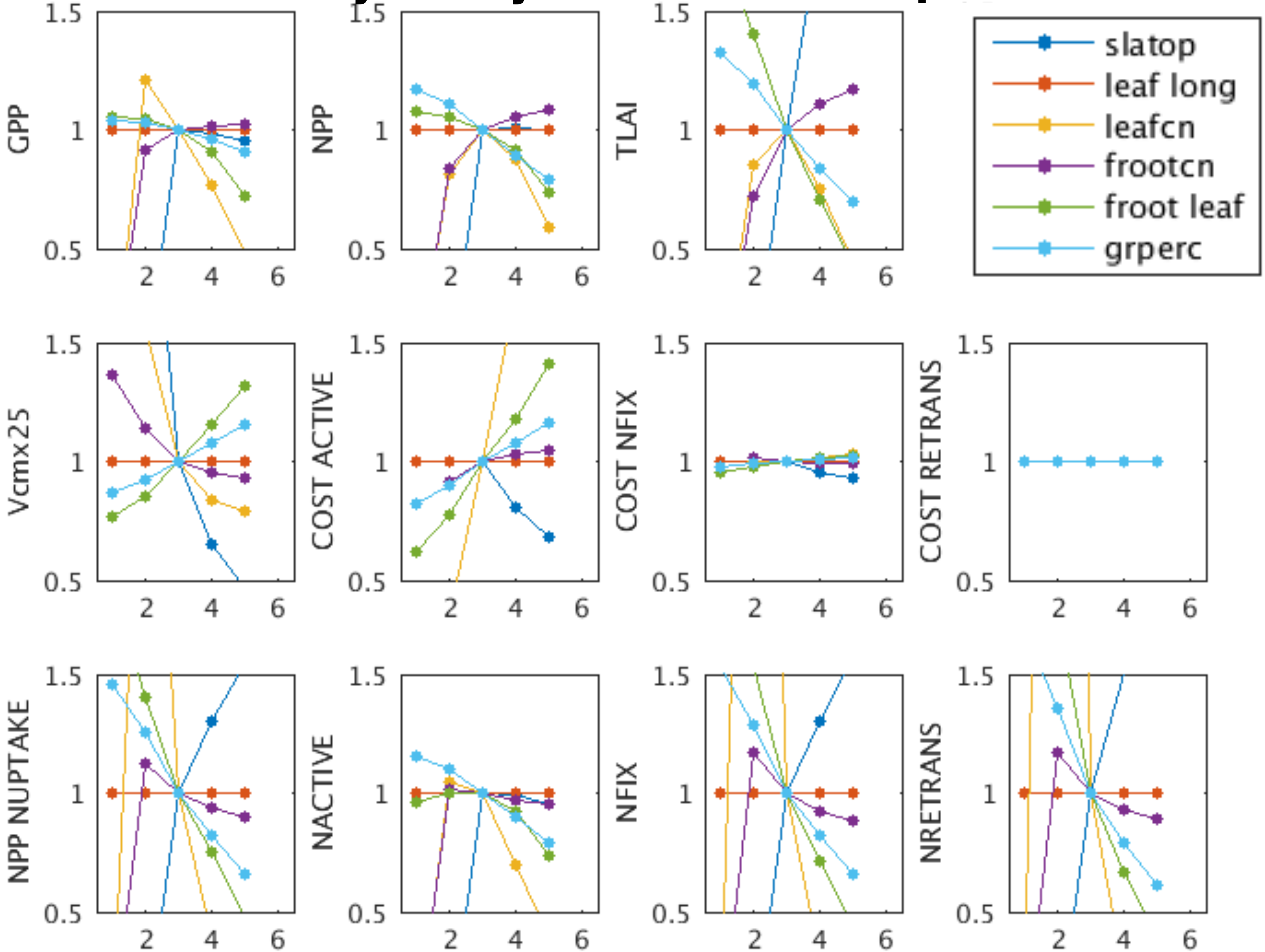
Sensitivity Analysis of not-FUN parameters



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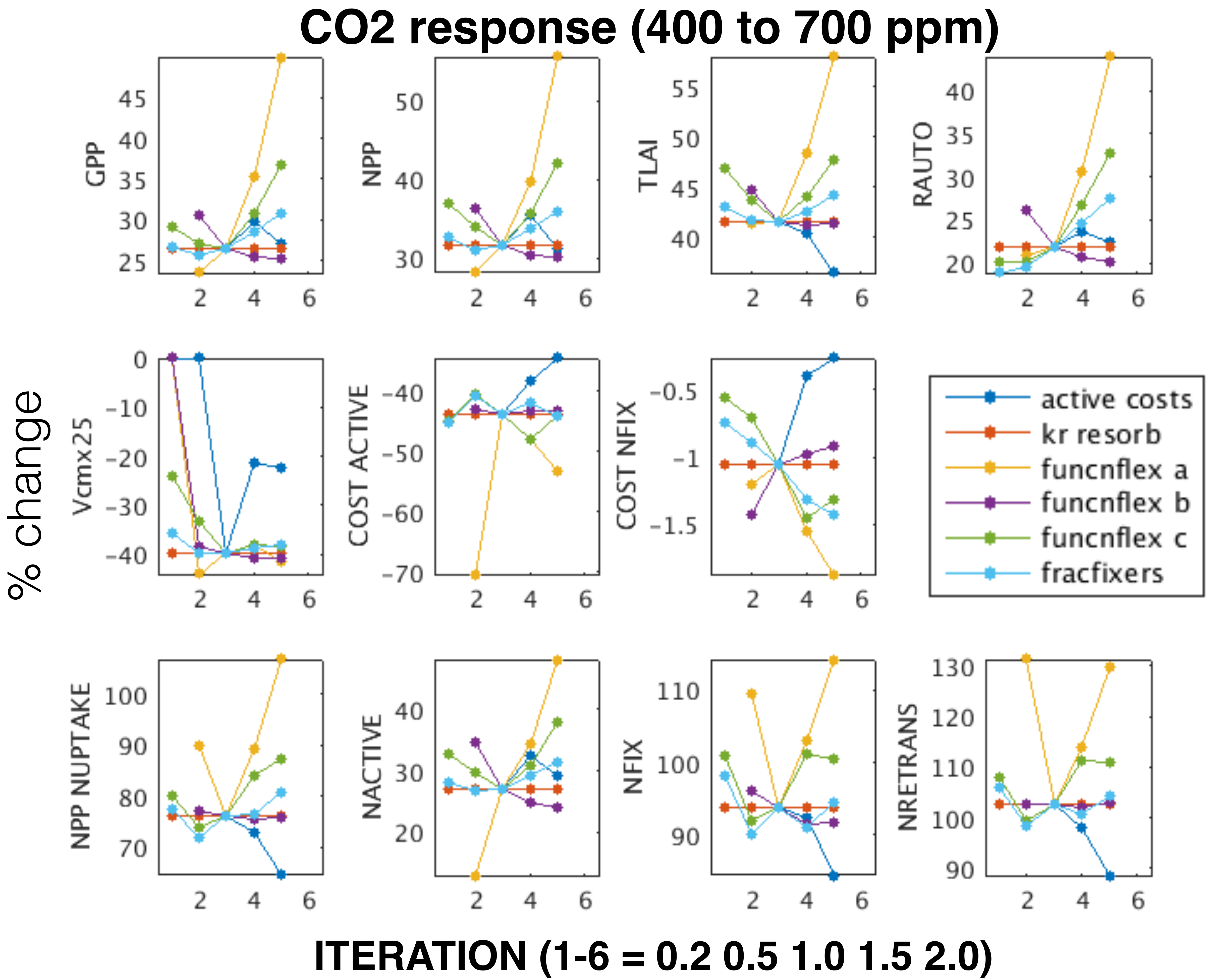
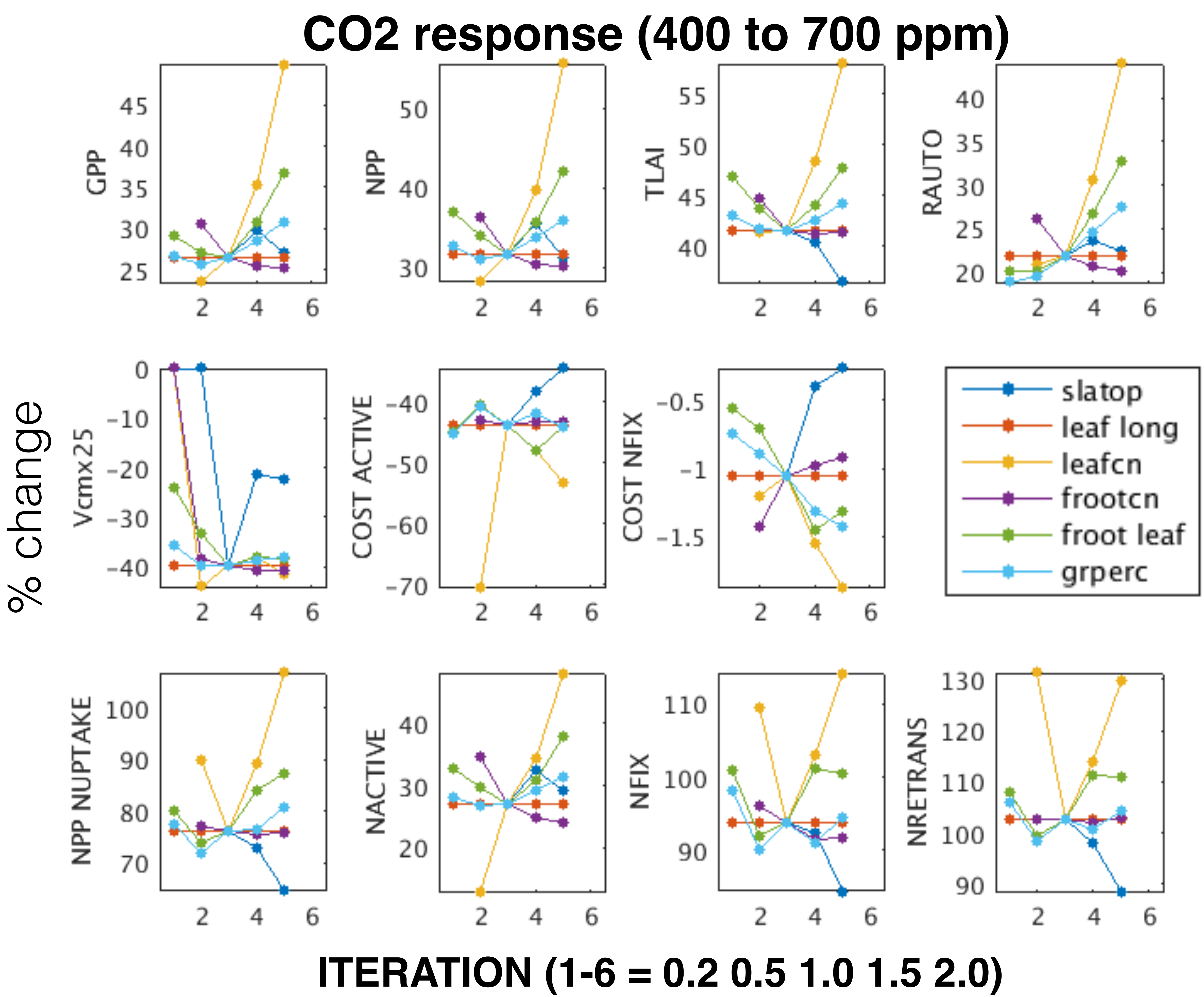
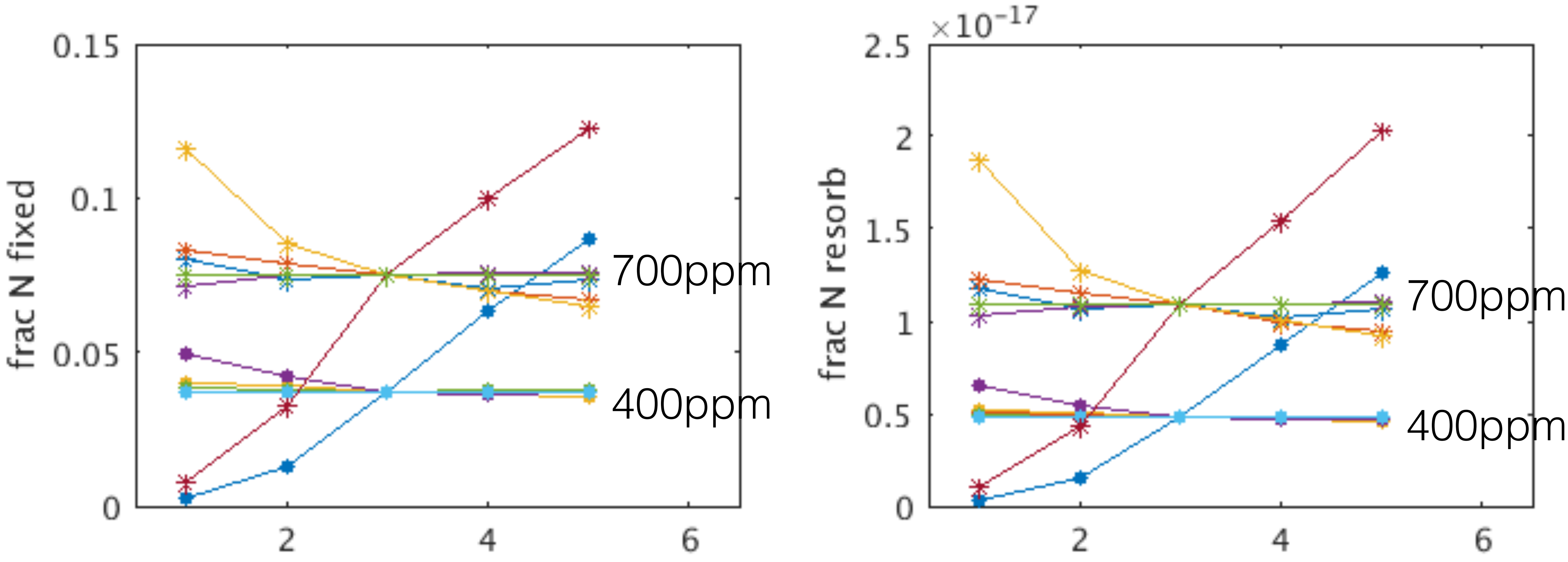
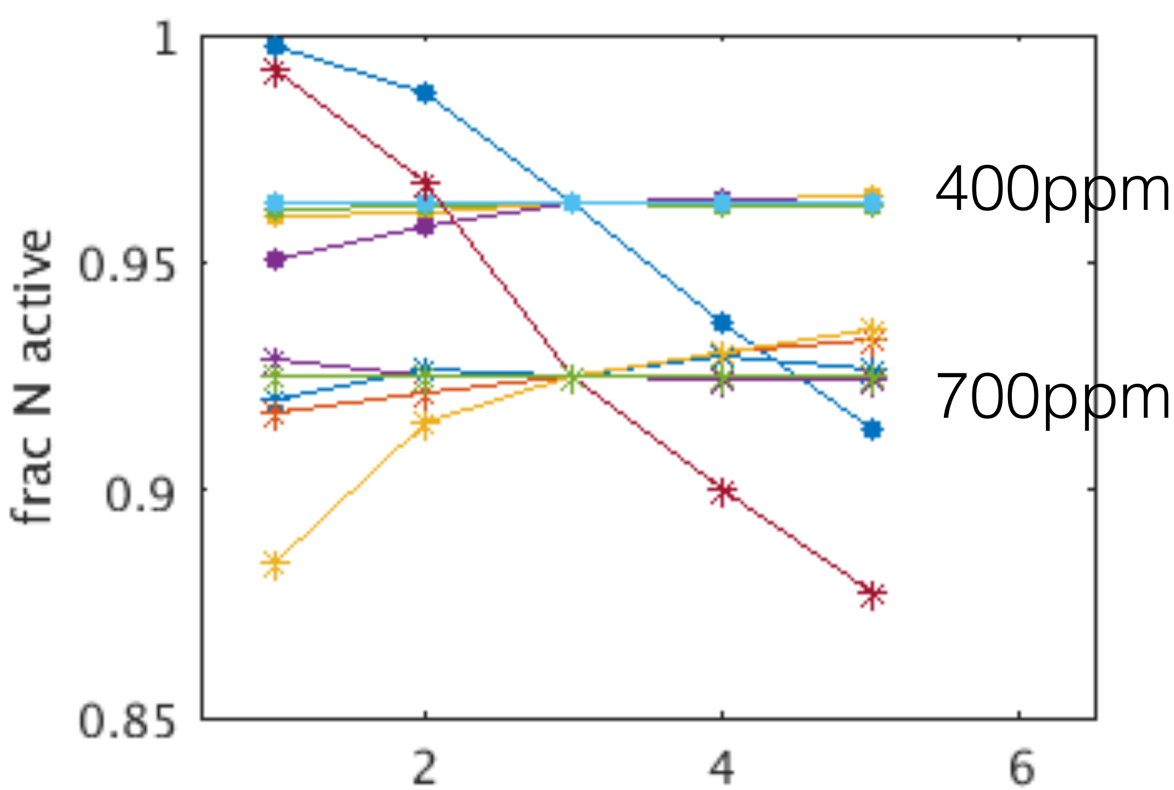
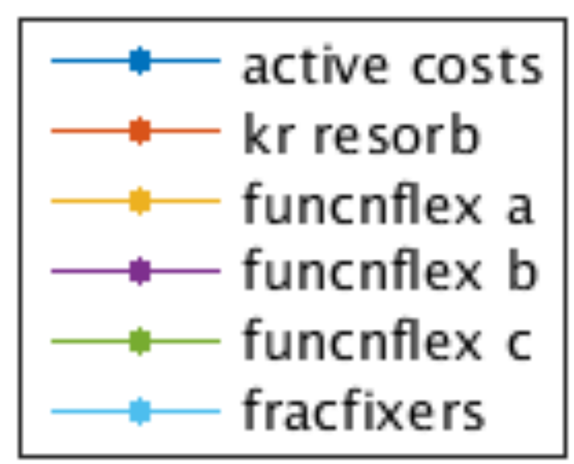

CO2 response (400 to 700 ppm)
GPP
NPP
TLAI
RAUTO
Vcmx25
COST ACTIVE
COST NFIX
NPP NUPTAKE
NACTIVE
NFIX
NRETRANS
% change
active costs
kr resorb
funcnflex a
funcnflex b
funcnflex c
fracfixers
ITERATION (1-6 = 0.2 0.5 1.0 1.5 2.0)


CO2 response (400 to 700 ppm)
% change
GPP
NPP
TLAI
RAUTO
Vcmx25
COST ACTIVE
COST NFIX
NPP NUPTAKE
NACTIVE
NFIX
NRETRANS
slatop
leaf long
leafcn
frootcn
froot leaf
grperc
ITERATION (1-6 = 0.2 0.5 1.0 1.5 2.0)



Division of uptake pathways





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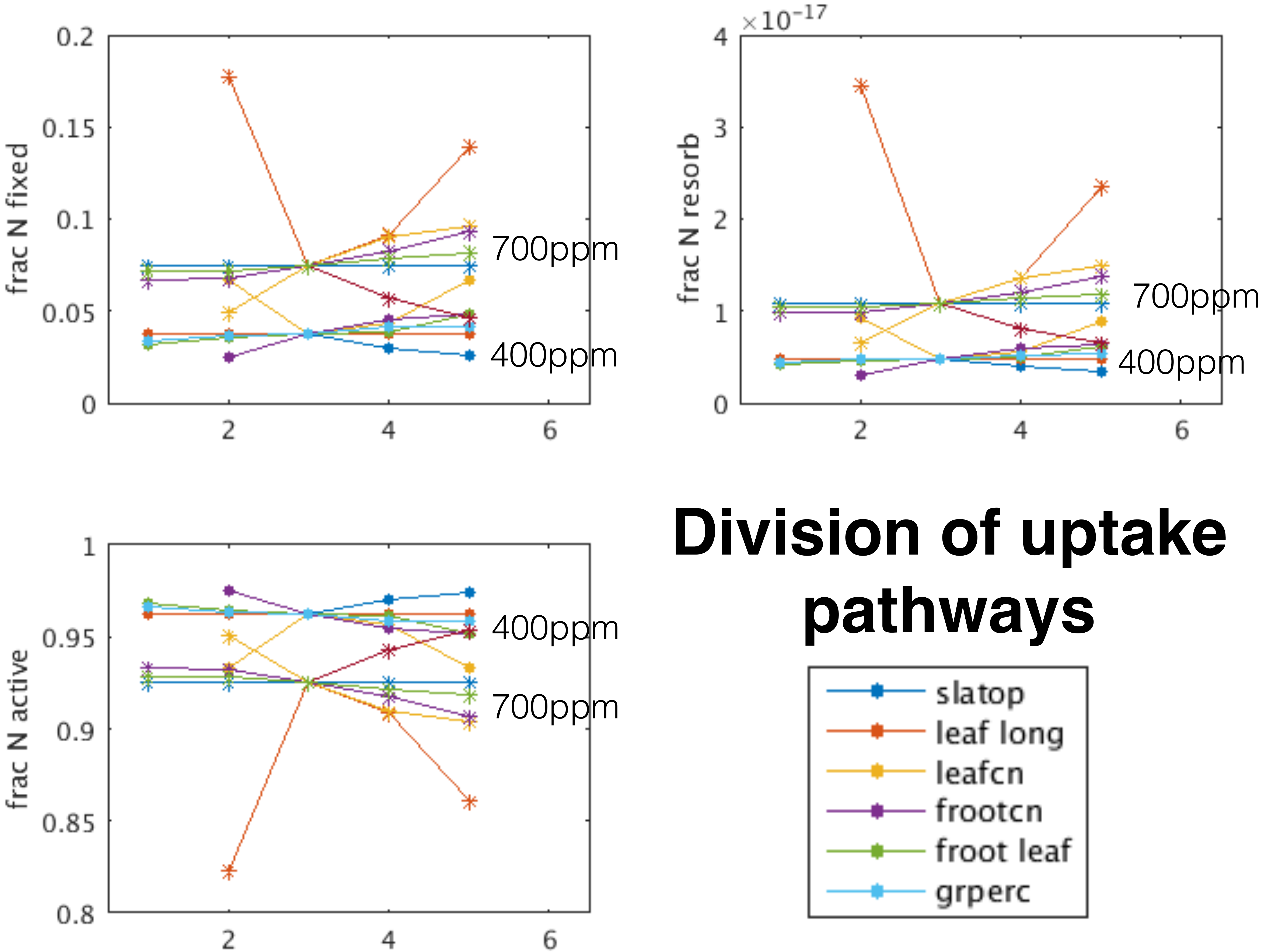
Division of uptake pathways



ITERATION (1-6 = 0.2 0.5 1.0 1.5 2.0)