The CLM5 Community Nitrogen Cycle Development

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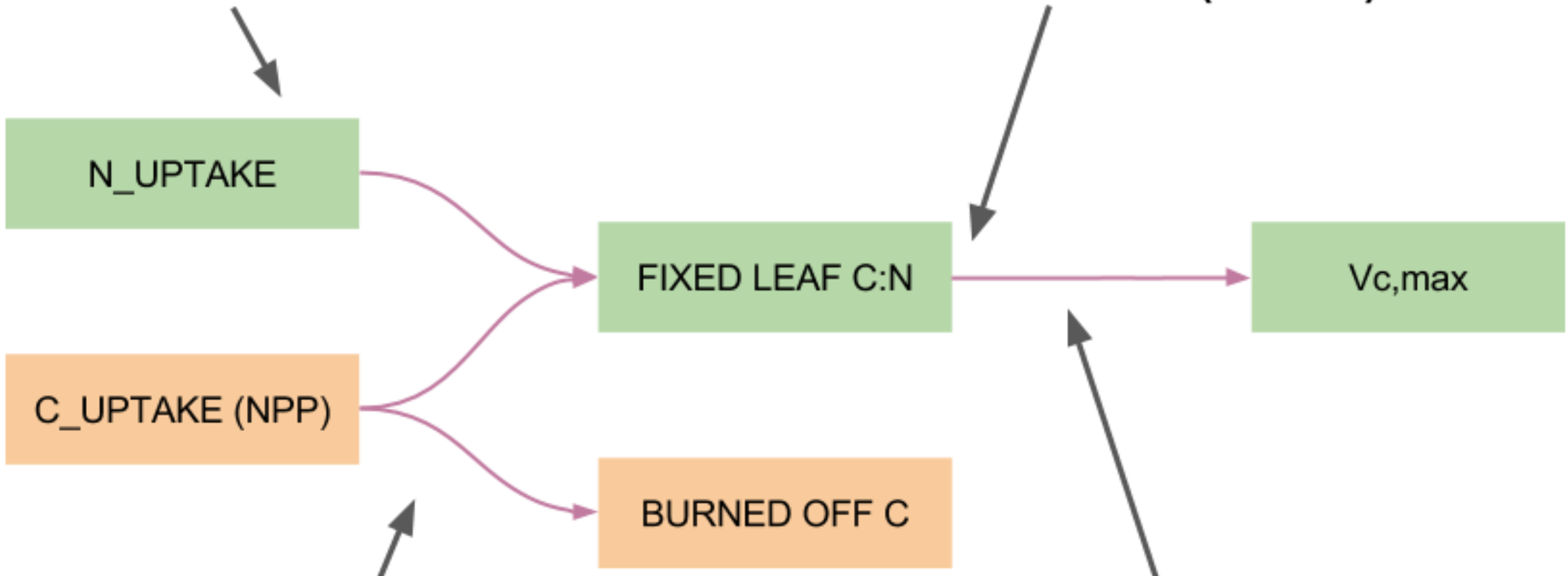
Plants get Nitrogen for free (**they dont'**)

CLM4.0

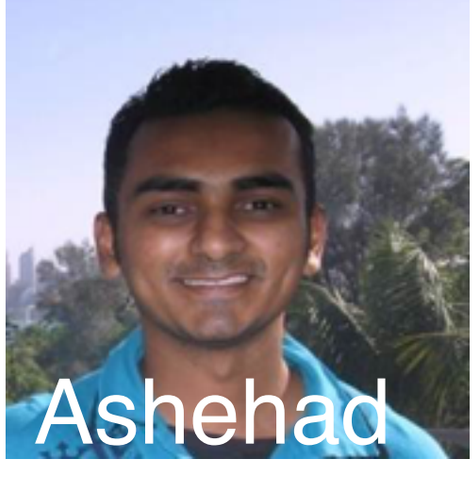
Leaf Nitrogen content is static **(it's not)**



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

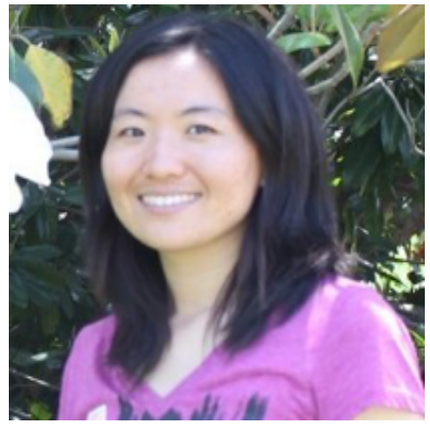


“Plants get Nitrogen for free”

The FUN* Model

A marketplace for Nitrogen Uptake

*__F__ixation and __U__ptake of __N__itrogen

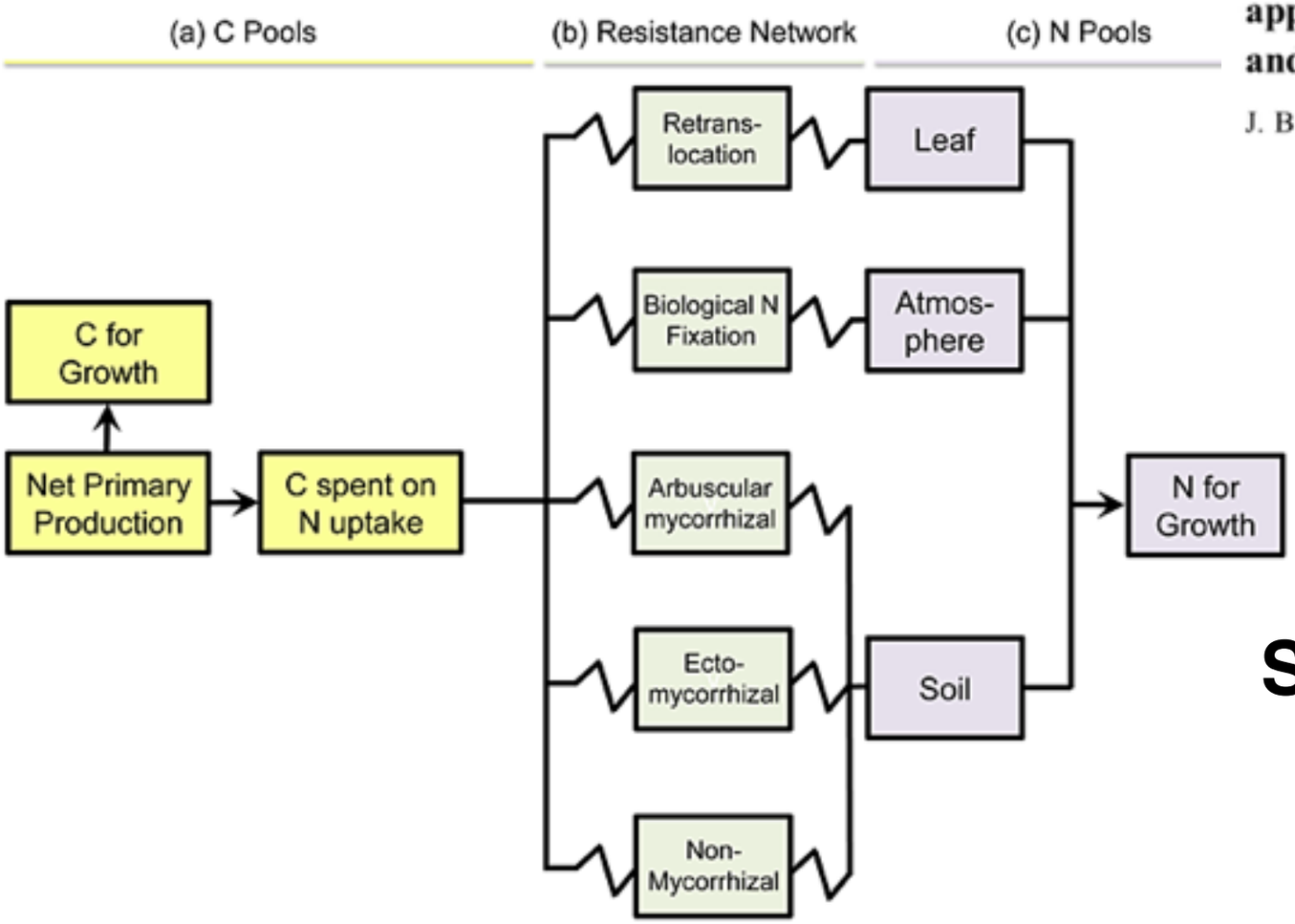




Carbon cost of plant nitrogen acquisition: A mechanistic, globally applicable model of plant nitrogen uptake, retranslocation, and fixation

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]



Hypothesis: Plants will take up N from the cheapest sources

Solve for maximum growth

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

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

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

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

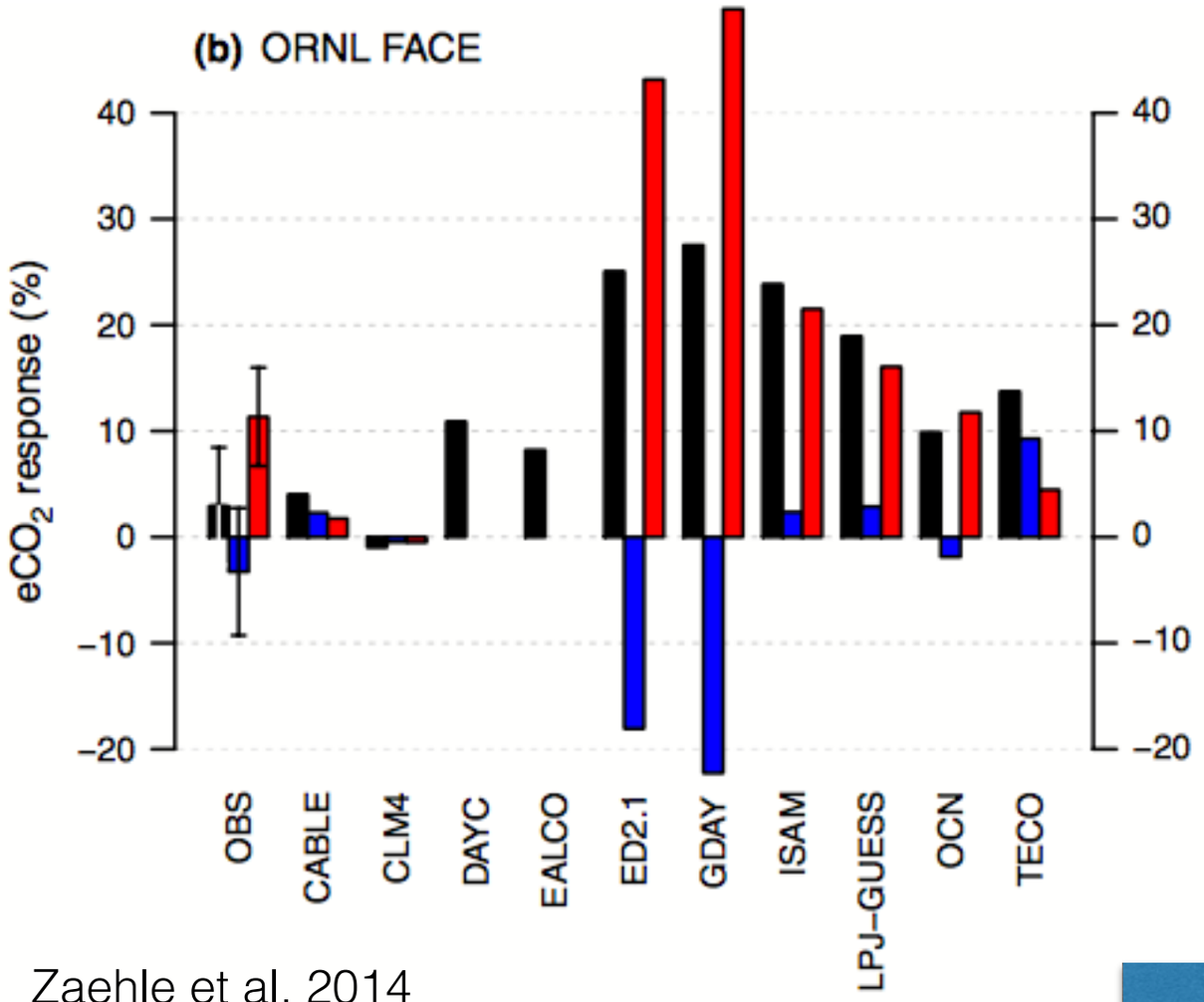
“Leaf Nitrogen content is static”

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

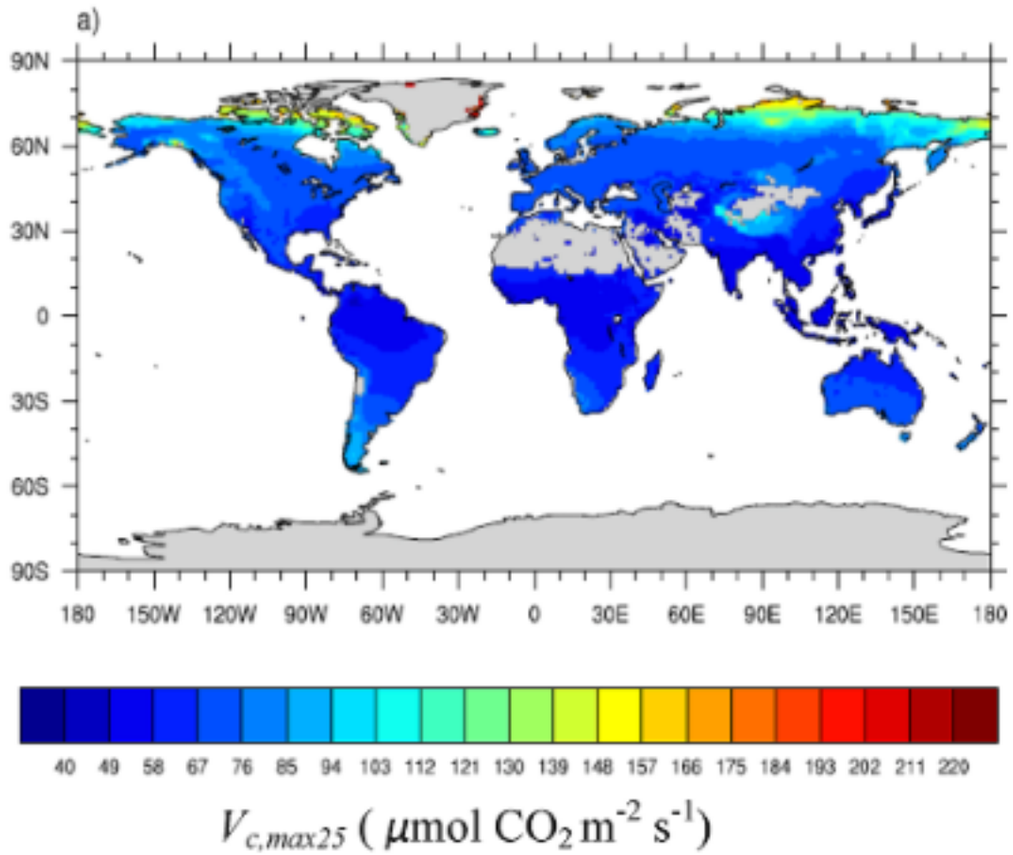
Toward a Mechanistic Modeling of Nitrogen Limitation on Vegetation Dynamics

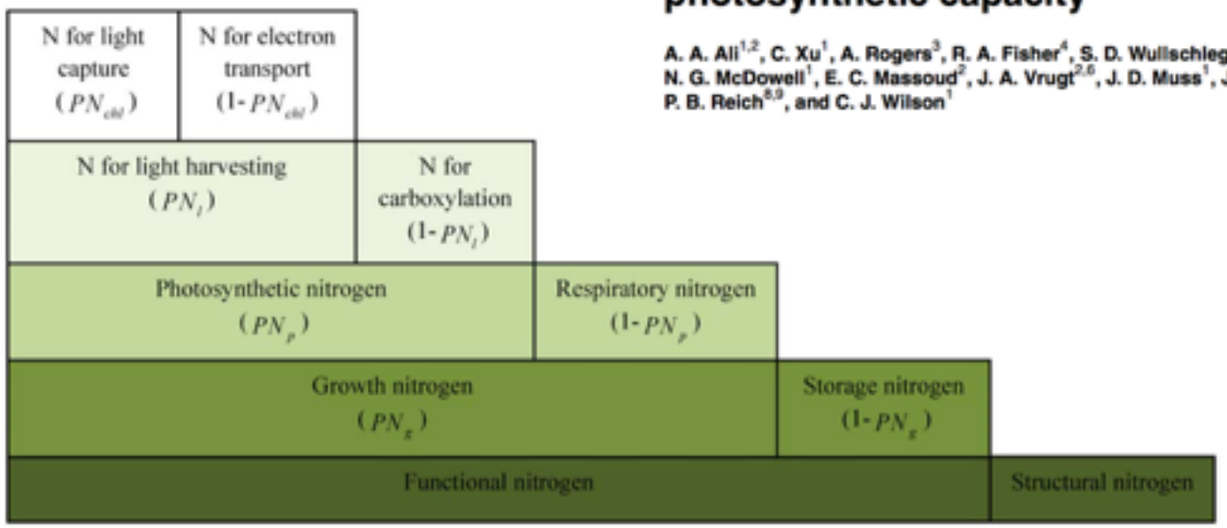
Chonggang Xu[1*], Rosie Fisher[2], Stan D. Wullschleger[3], Cathy J. Wilson[1], Michael Cai[4], Nate G. McDowell[1]

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]

Predicted optimal photosynthetic capacity





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

CLM4.0

N_UPTAKE

C_UPTAKE (NPP)

FIXED LEAF C:N

BURNED OFF C

Vc,max

CLM5.0

NEW MOVING PARTS

C_FOR_NUPTAKE

N_UPTAKE

C_UPTAKE (NPP)

VARIABLE
LEAF C:N

OPTIMIZED Vc, max

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

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

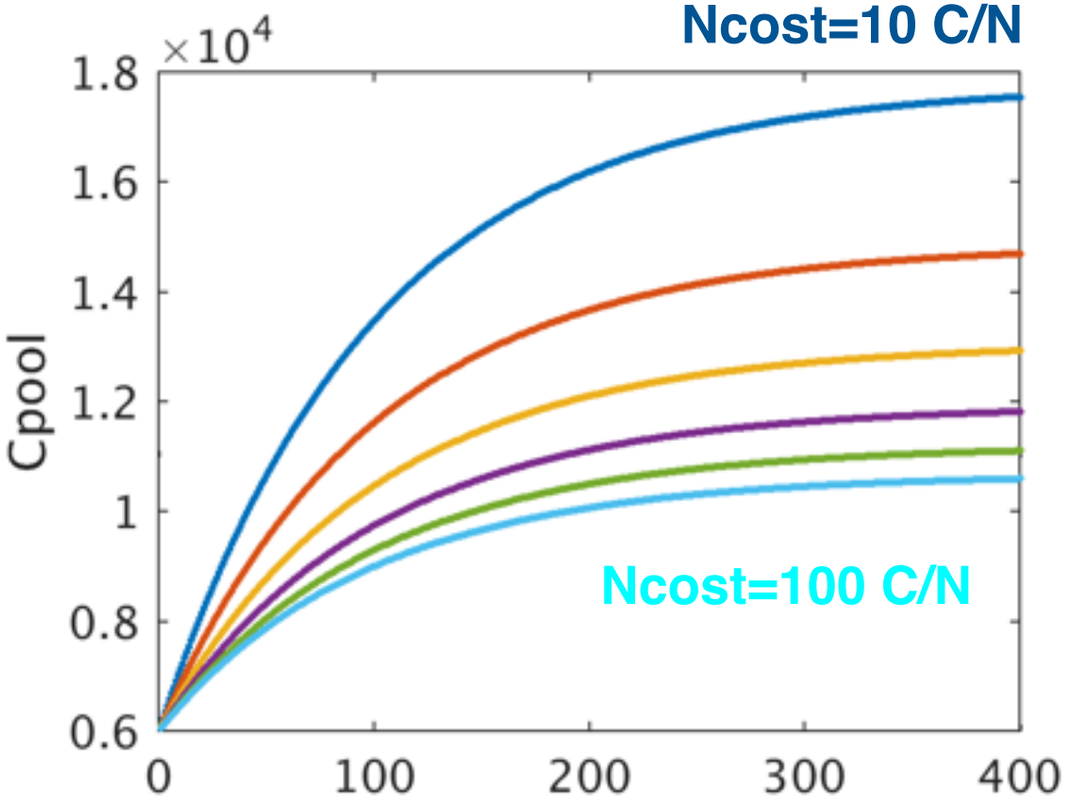
$$\mathbf{C_{adj}} = 1.0 - (\mathbf{CN_{uptake\text{-}cost}} - \mathbf{P_a}) / \mathbf{P_b}$$

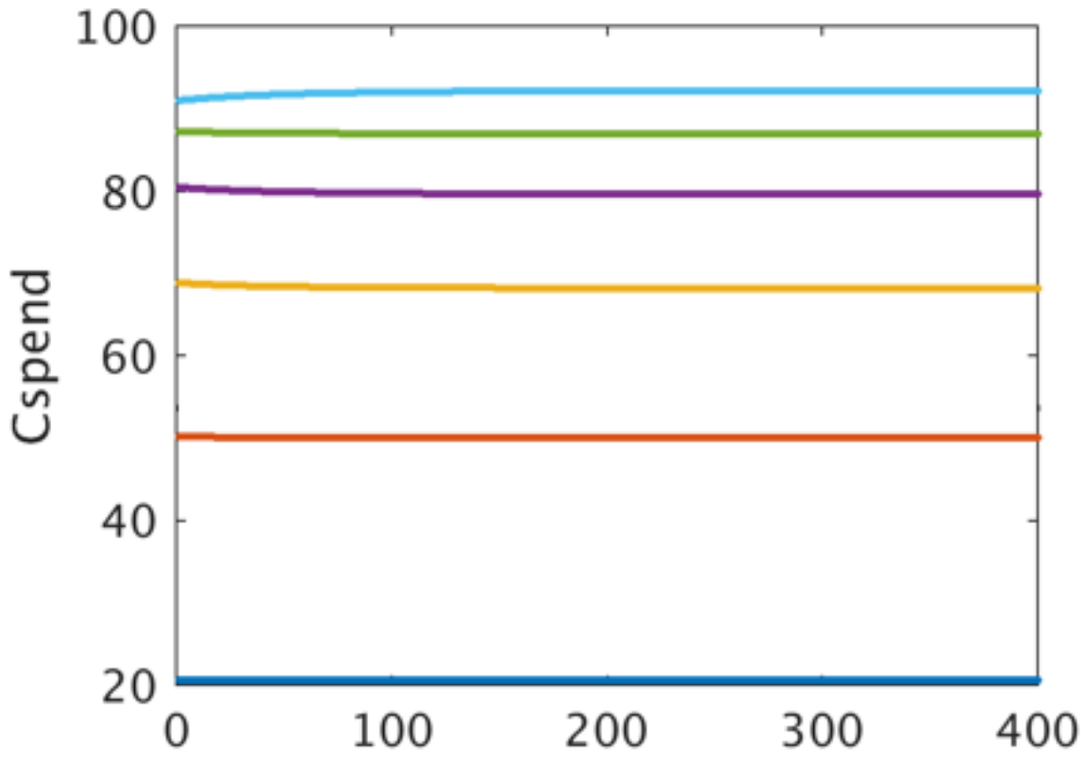
Reduce C allocation with cost

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

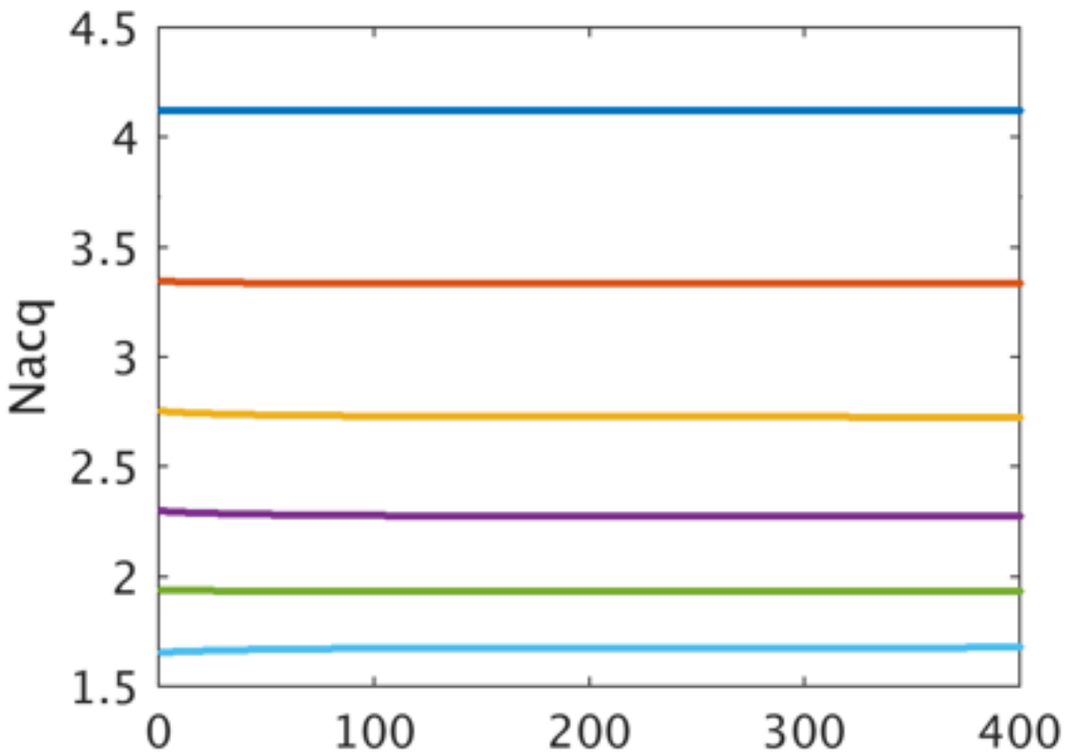
Increase C allocation with high C:N

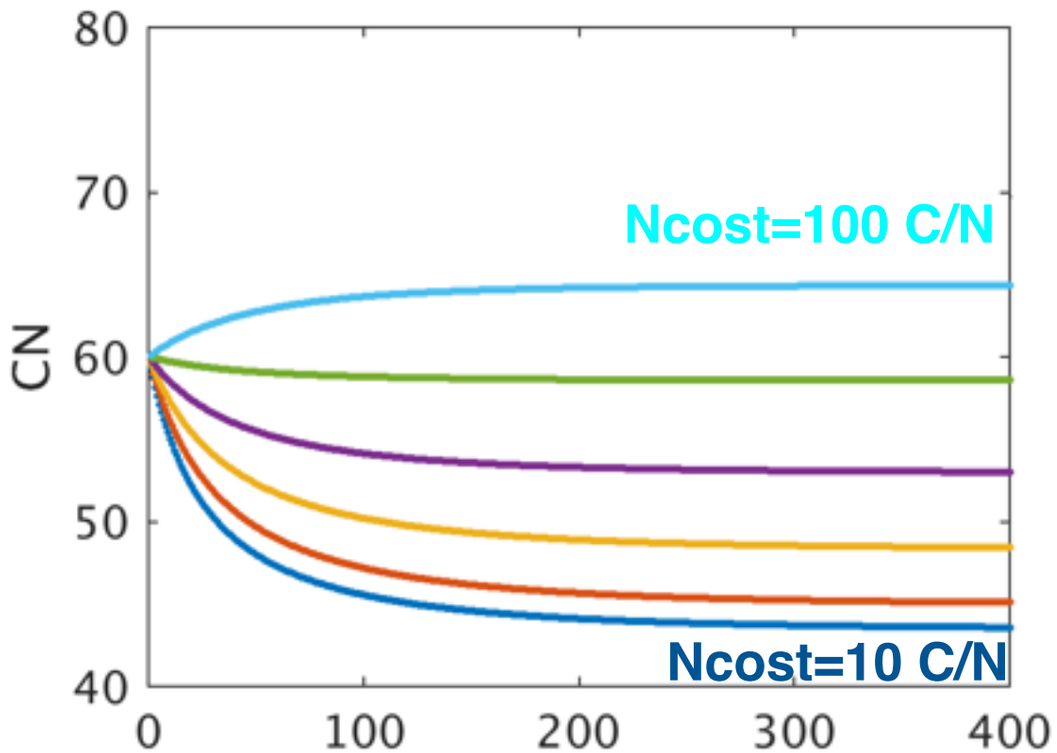
$P_{a=5} : P_{b=200} : P_{c=80}$



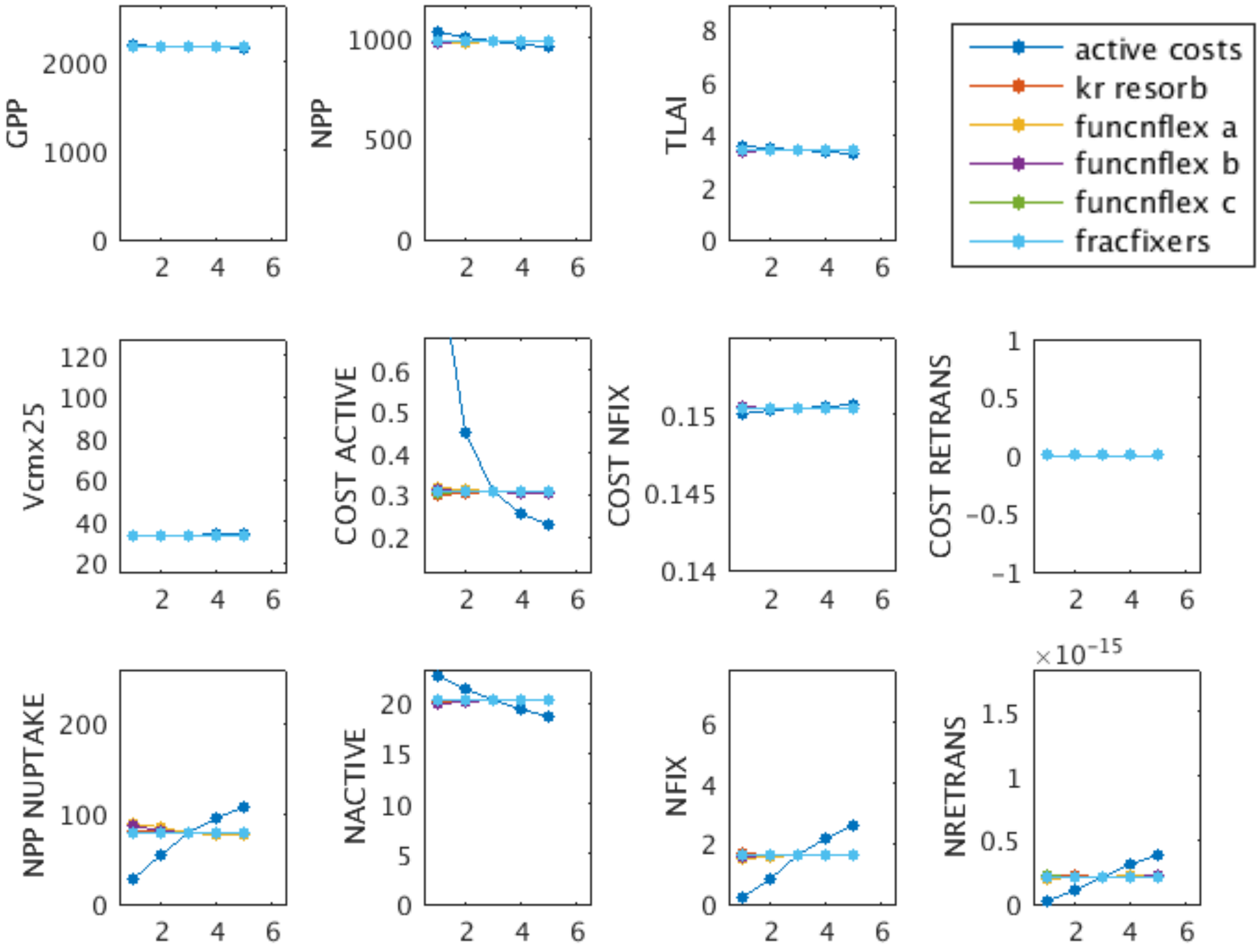


Offline FlexCN-FUN feedback behavior



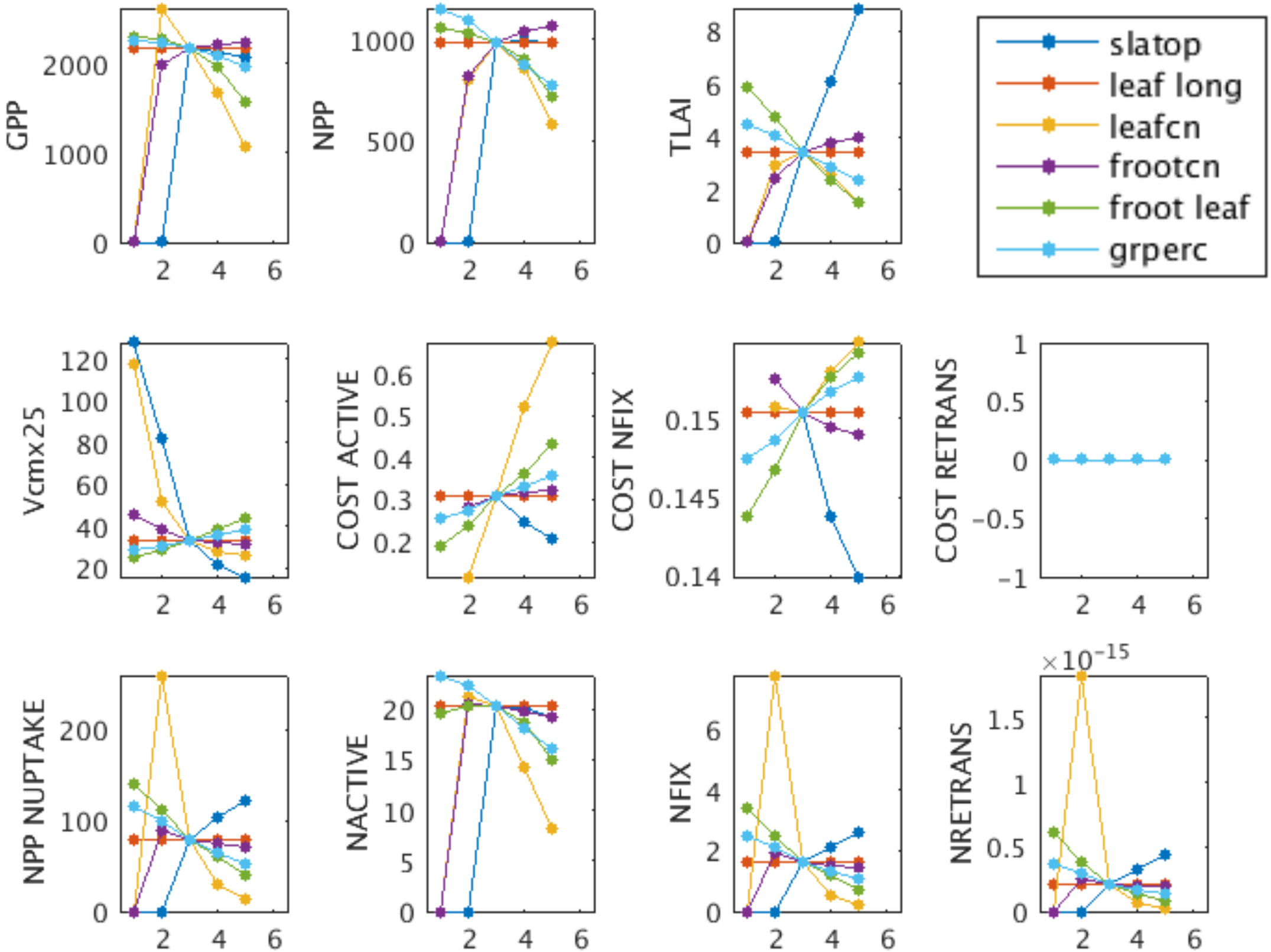


Sensitivity Analysis of FUN parameters



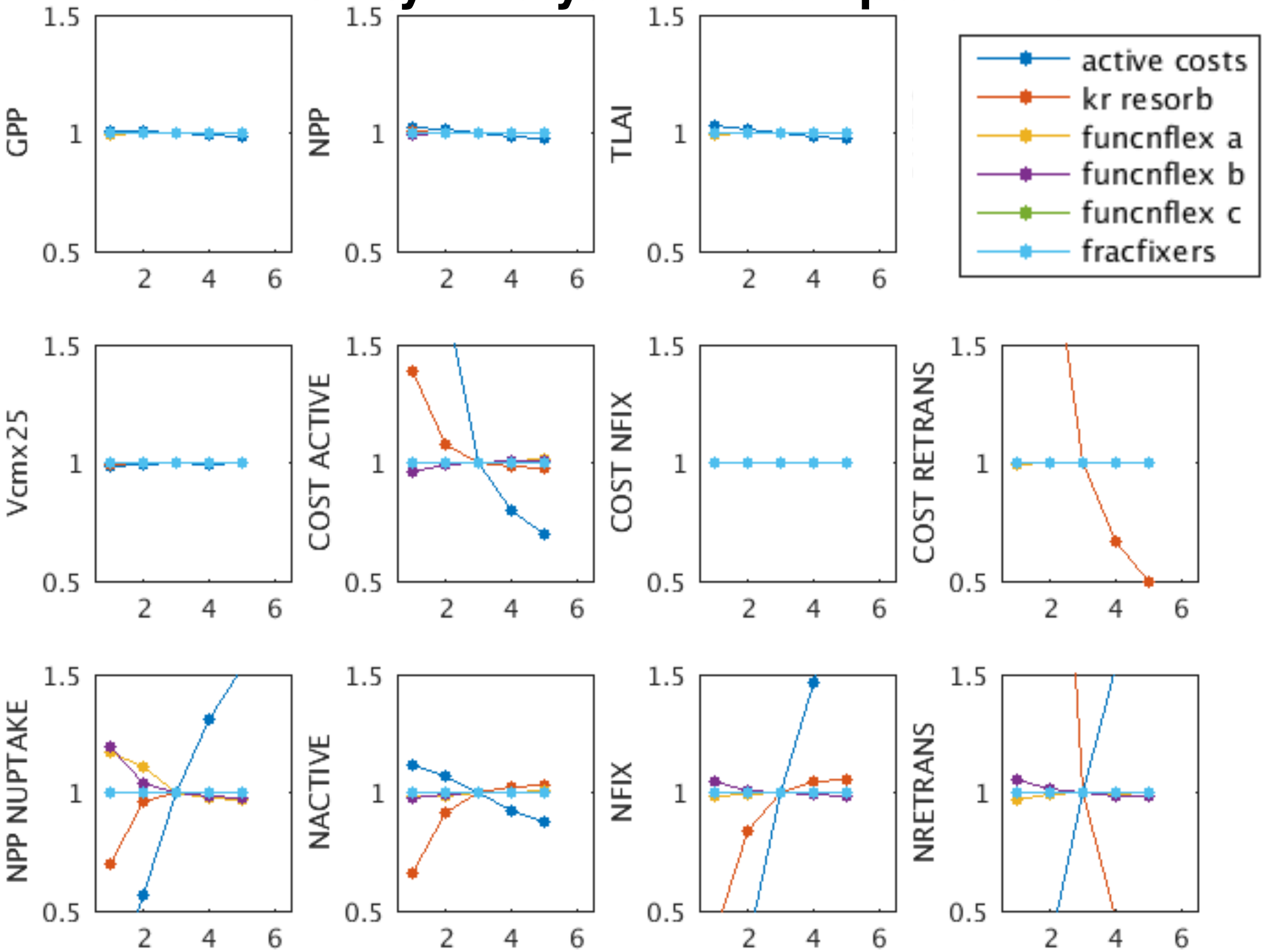
ITERATION (1-6 = 0.2 0.5 1.0 1.5 2.0)

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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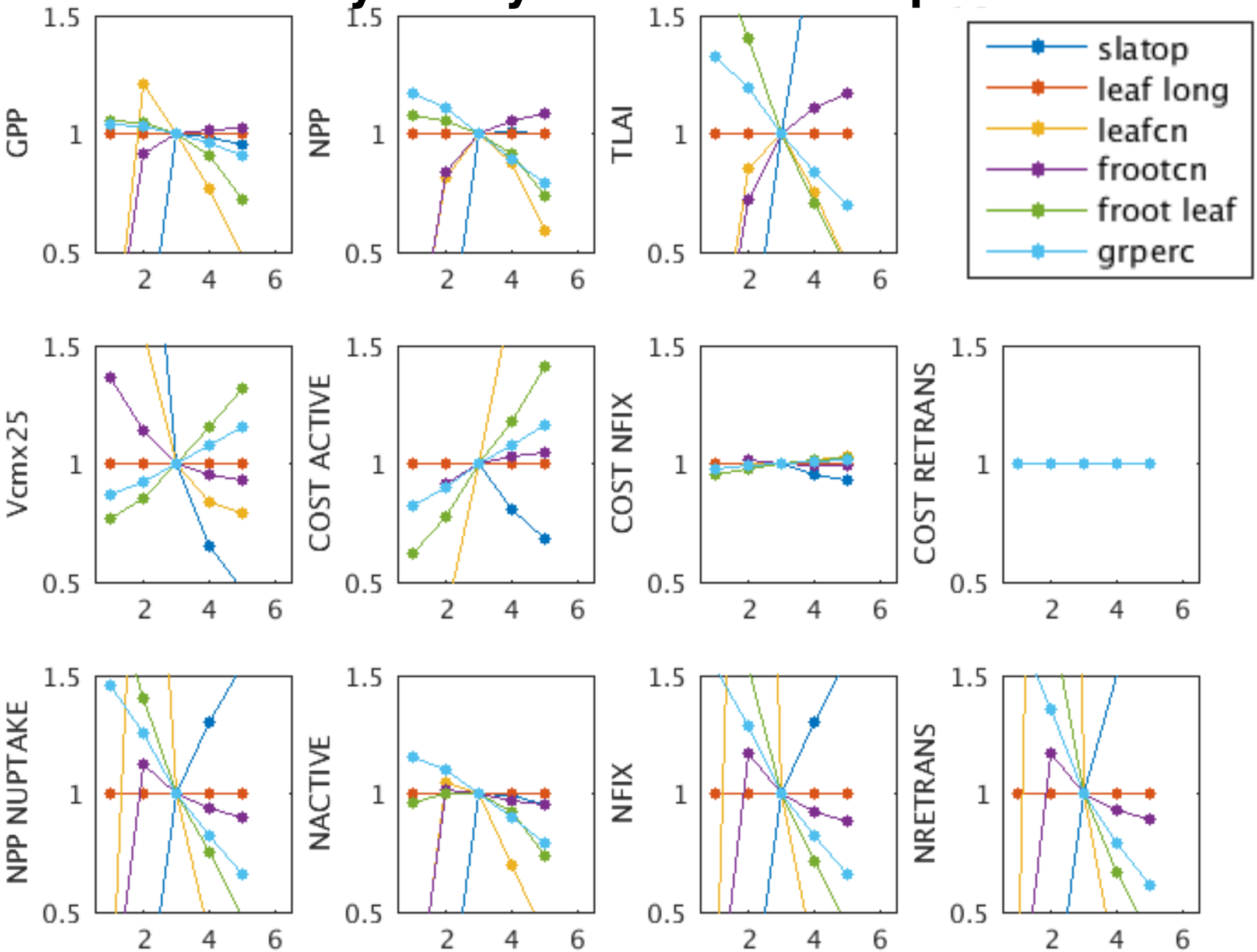
Sensitivity Analysis of not-FUN parameters



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

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

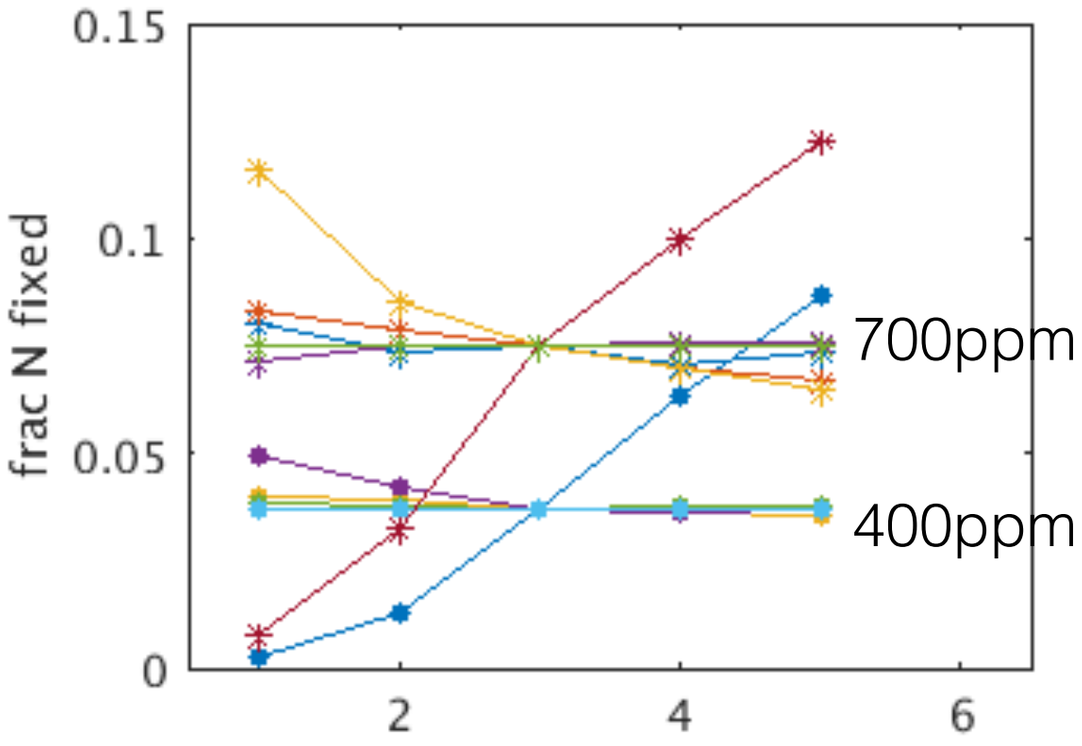
NACTIVE

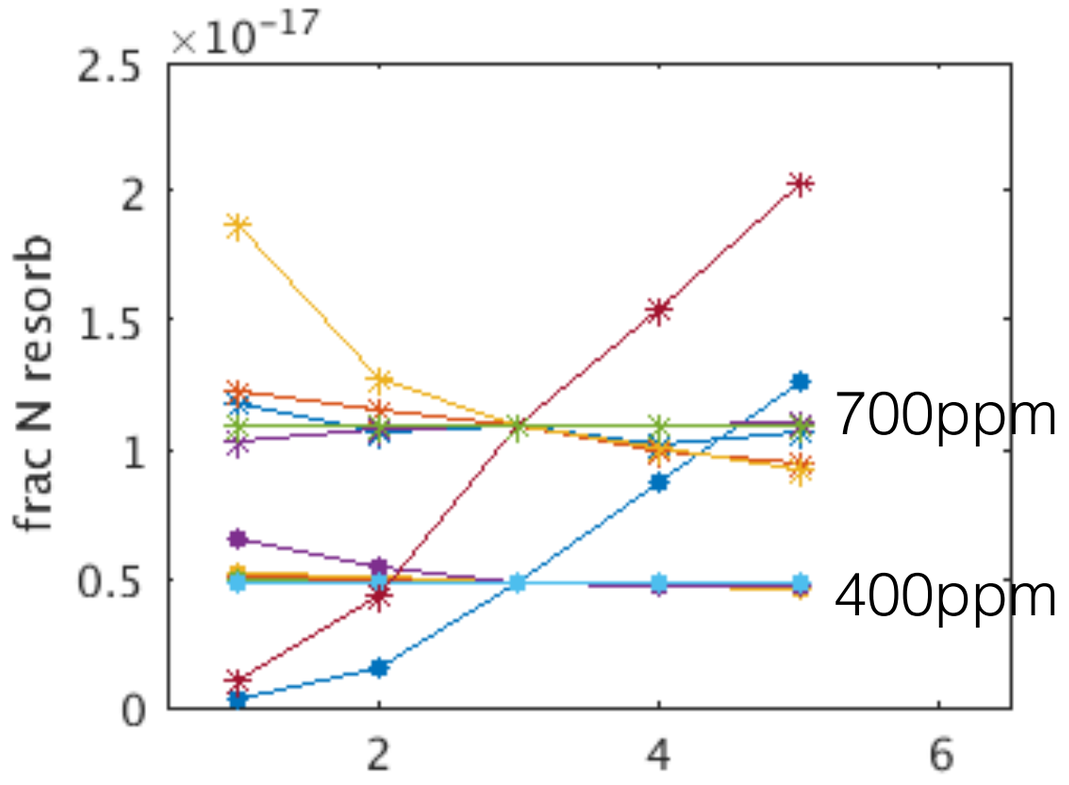
NFIX

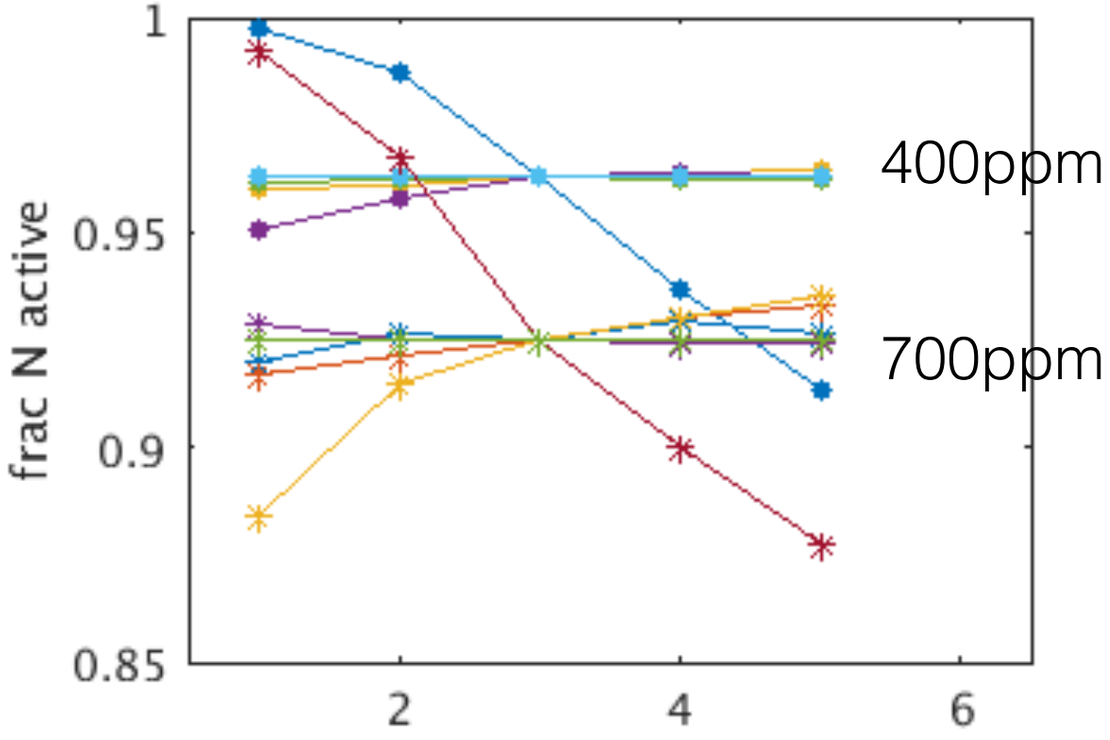
NRETRANS

slatop
leaf long
leafcn
frootcn
froot leaf
grperc

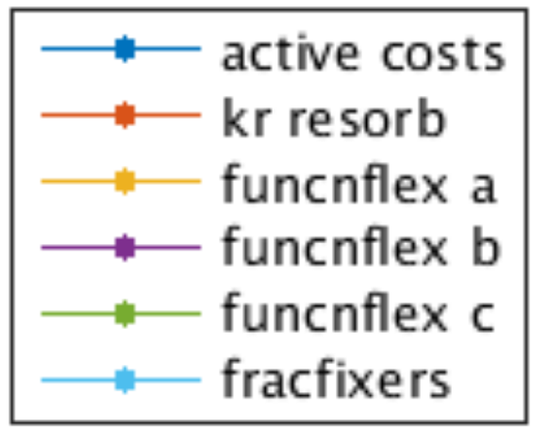
ITERATION (1-6 = 0.2 0.5 1.0 1.5 2.0)







Division of uptake pathways



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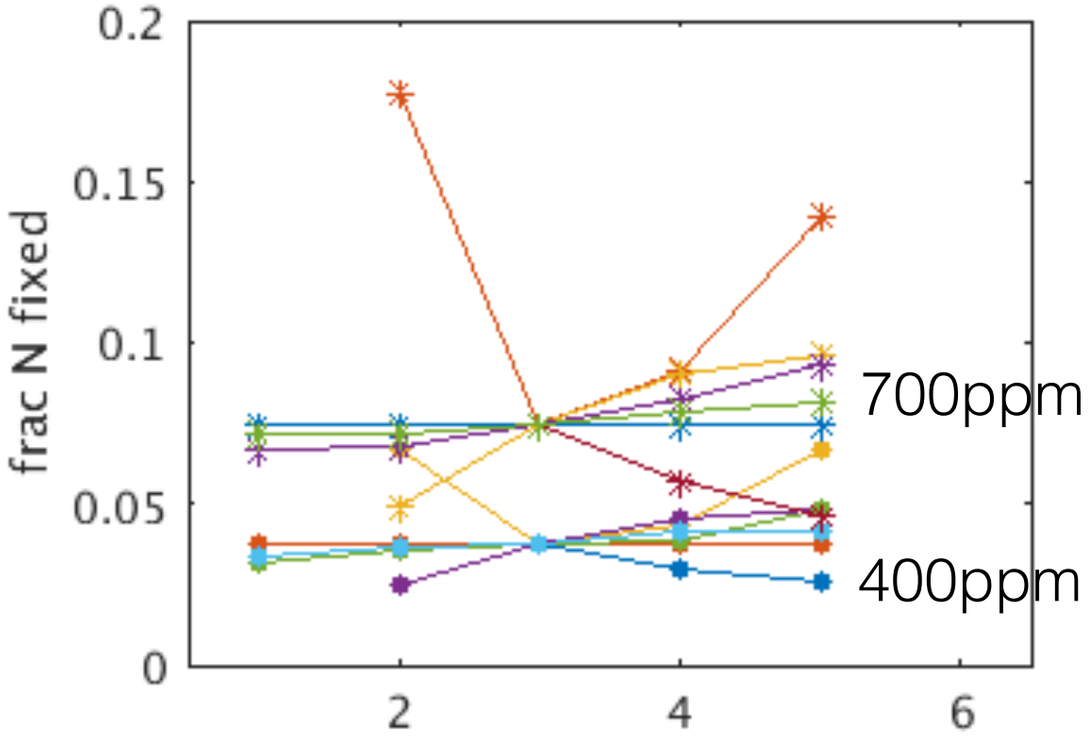

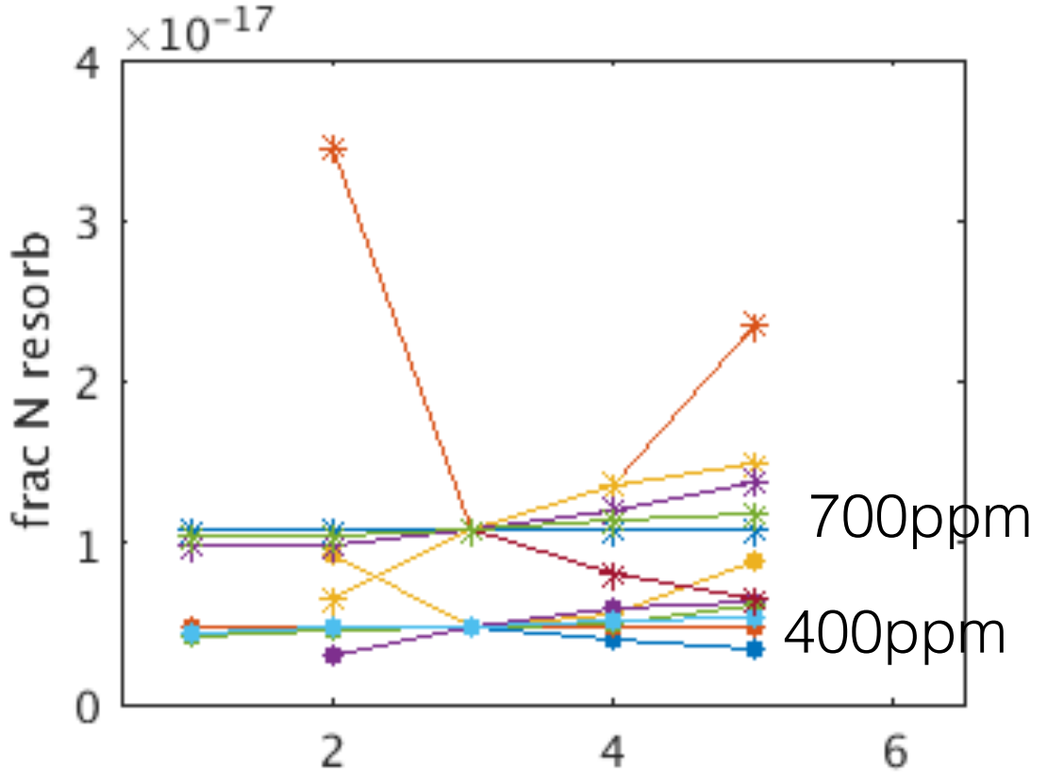

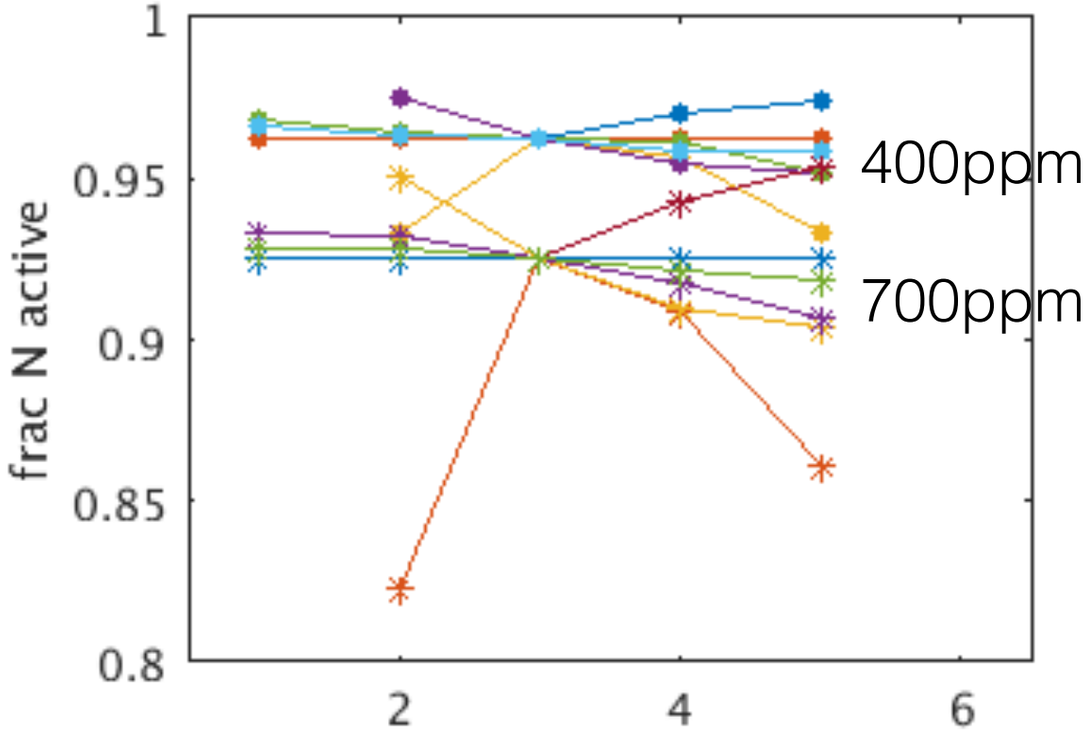

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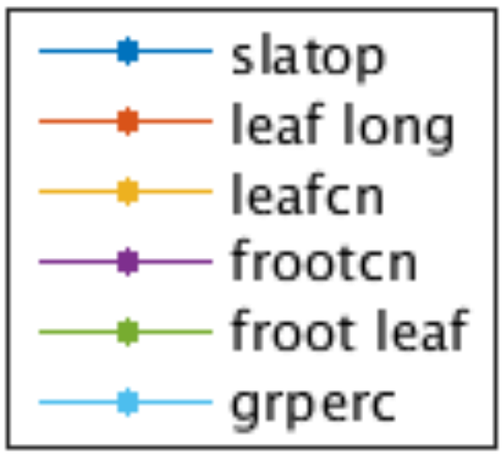

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