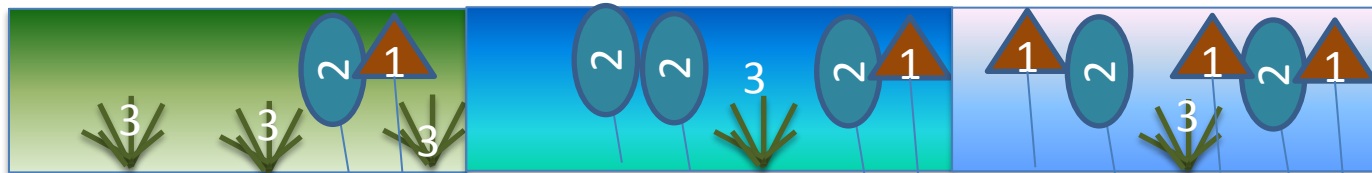


A mechanistic nitrogen limitation model for CLM(ED)

Recruitment Growth Competition
Co-existence Mortality
Exclusion

Chonggang Xu, Ashehad Ali, Rosie Fisher,
Alistair Roger, Stan Wullschleger, Nate
McDowell, Cathy Wilson, Jasper Vrugt



15 year-old forest

50 year-old forest

150 year-old forest

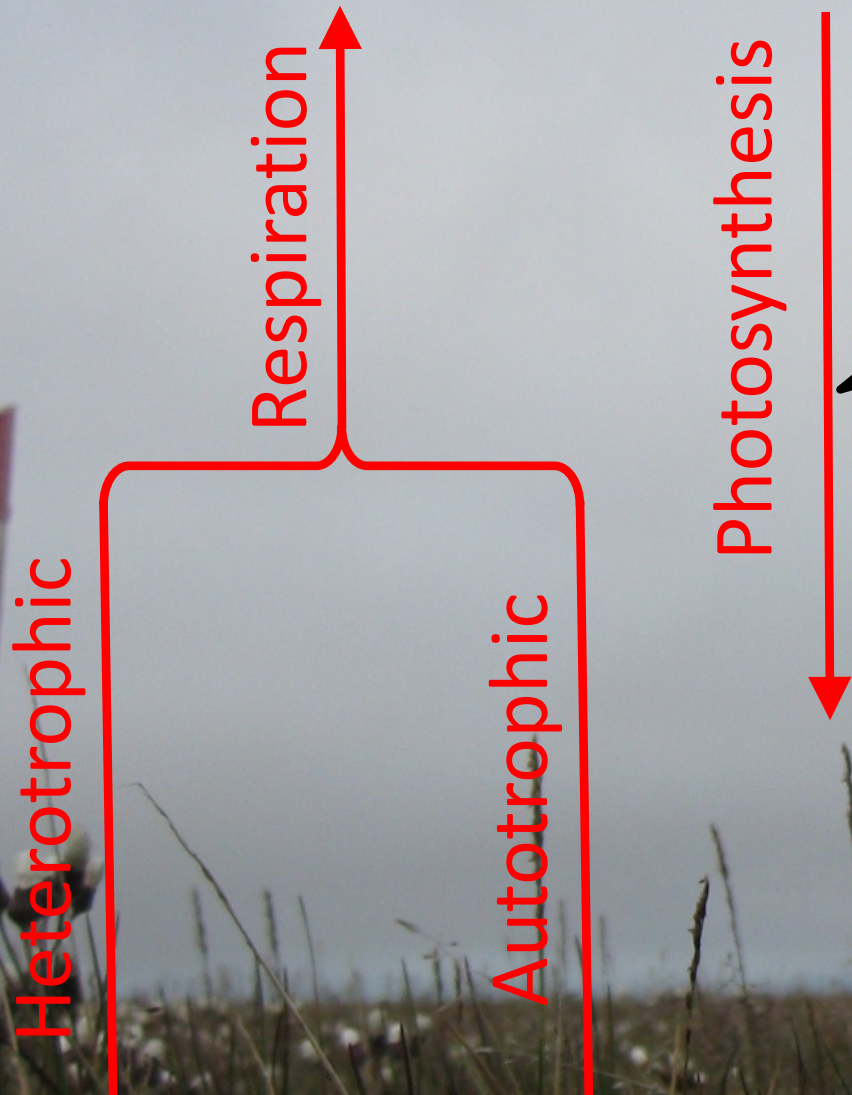


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The Community Land Model (CLM) uses an estimate of $V_{c,max25}$ (maximum carboxylation rate at 25°C limited by nitrogen) to drive projection of photosynthesis (Gross Primary Productivity)

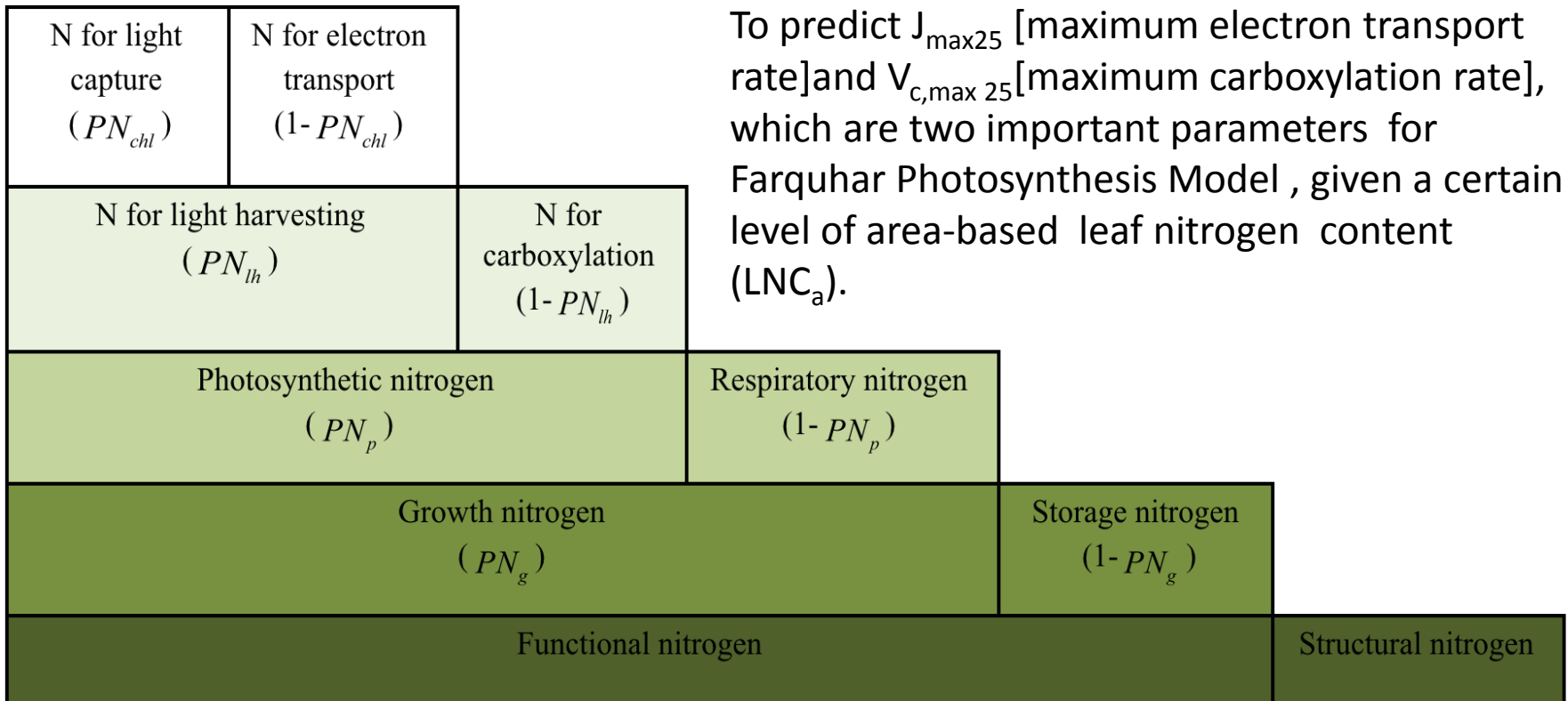


Uncertainty in the photosynthetic parameter $V_{c,max25}$ results in a 110% variation in GPP

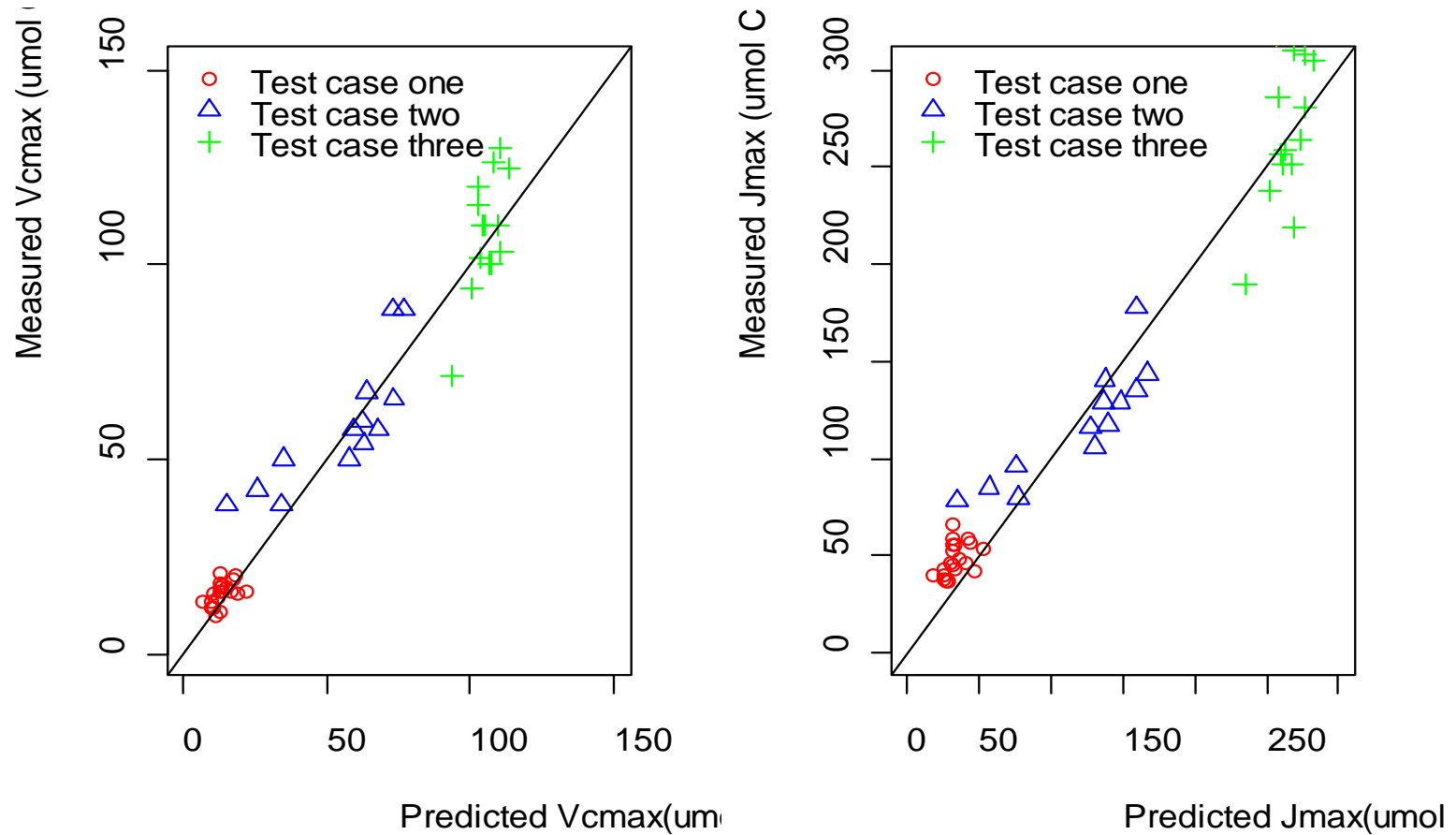
Roger 2014.

Barrow, AK

“Optimal” nitrogen allocation at the leaf level



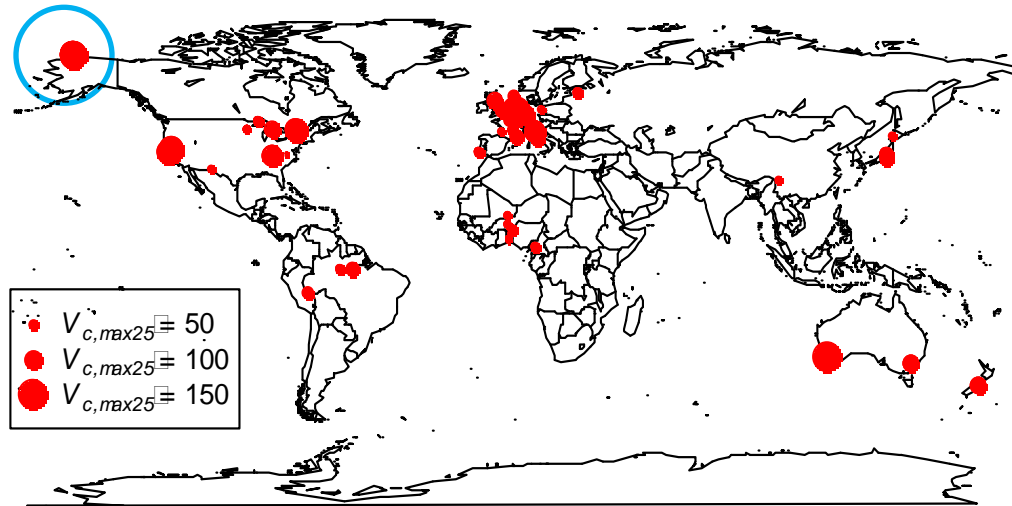
Model validation



For test case 1, nitrogen allocation change for CO_2 enrichment for loblolly pine (*Pinus taeda*) [Crous et al 2008] ; For test case 2, $V_{c,max}$ and J_{max} were measured for poplar (*Populus tremula*) leaves located at a light radiation levels in the canopy [Niinemets et al 1998] ; For test case 3, Japanese plantain (*Plantago asiatica*) was grown in pots from seeds within greenhouses for about 1–2 months at two contrasting temperatures: 30°C and 15°C [Hikosaka 2005] .

Global survey of $V_{c,max25}$

Number of field studies: 57



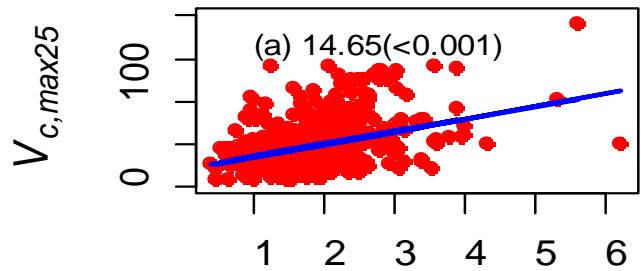
Number observations: 831

Number of species: 121

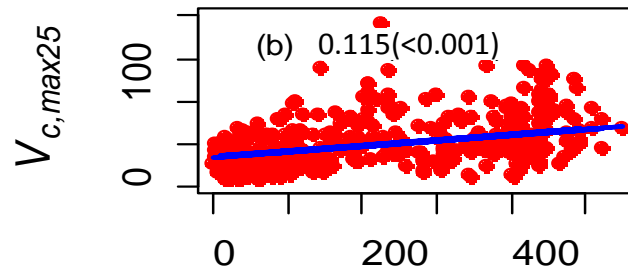
Time range: 1989-2013

Ali, Xu et al. In Review.

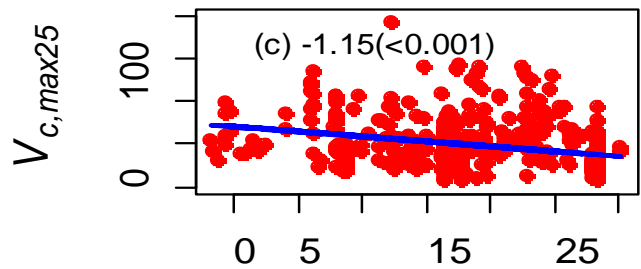
Environmental control of $V_{c,max25}$



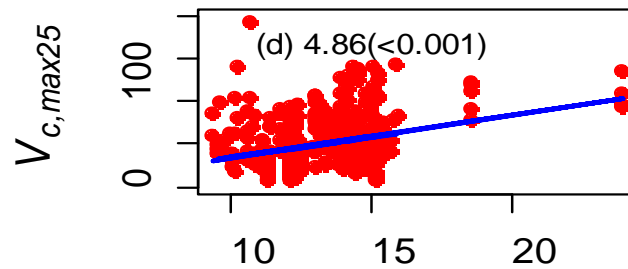
Leaf nitrogen content (g/m^2)



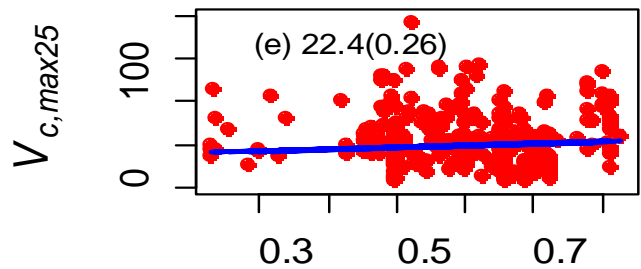
Daytime radiation (w/m^2)



Growth temperature ($^{\circ}\text{C}$)



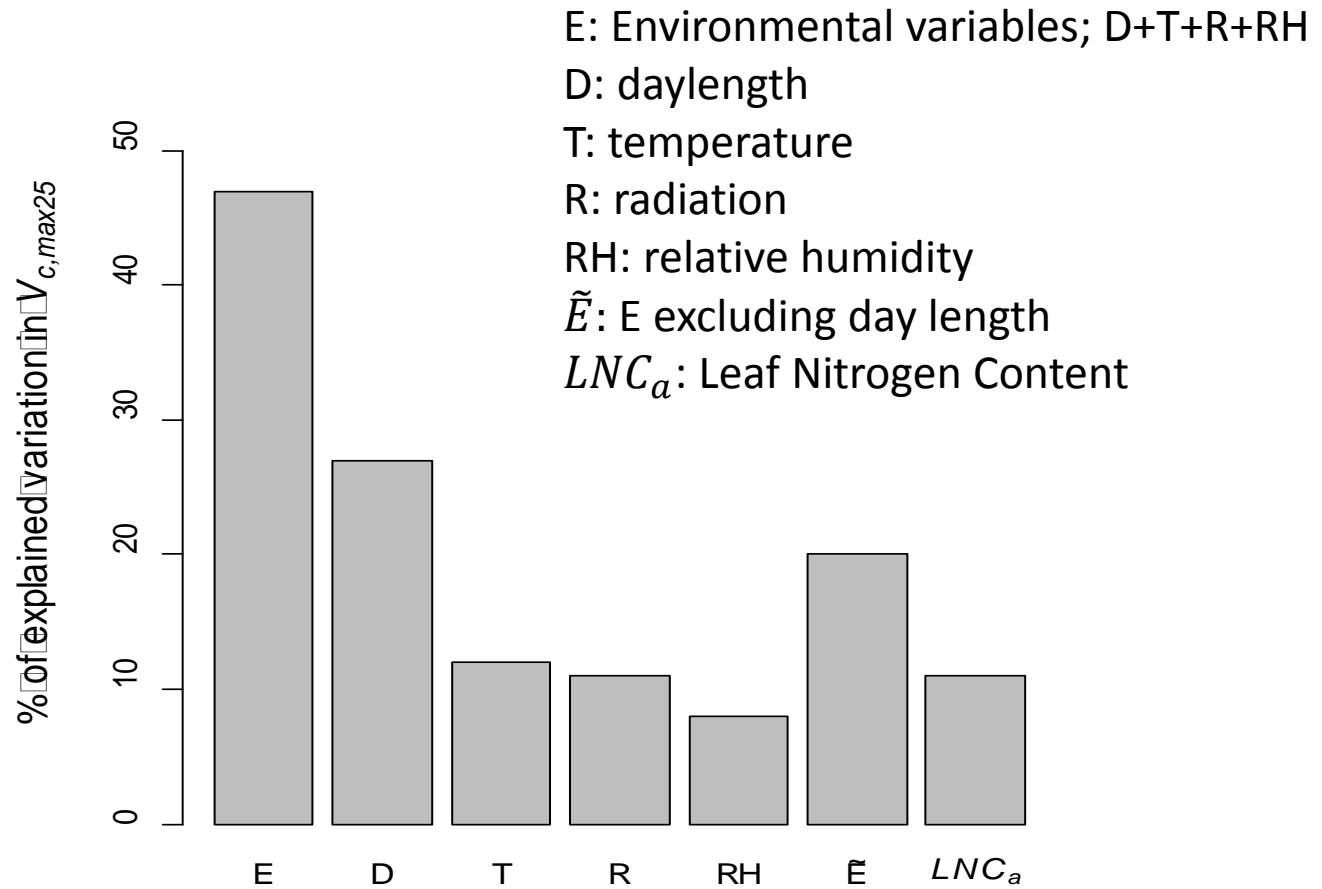
Daytime duration (hours)



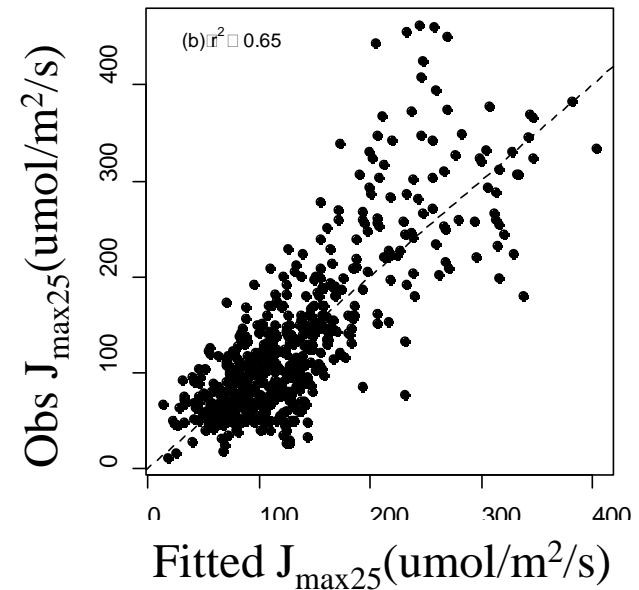
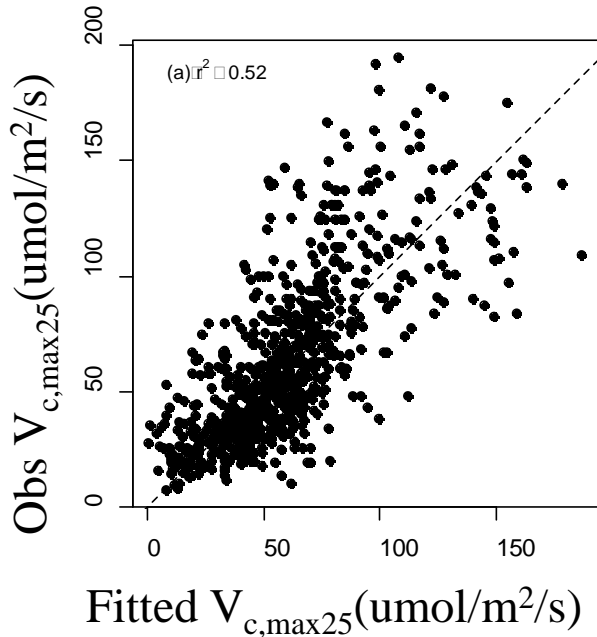
Relative humidity

Use linear mixed model fitting to account temporal and spatial autocorrelations, based on monthly climate data

Environmental control vs leaf nitrogen



Nitrogen allocation model fitting (MCMC)



Baseline proportion of nitrogen for electron transport rate

Electron transport rate response to light

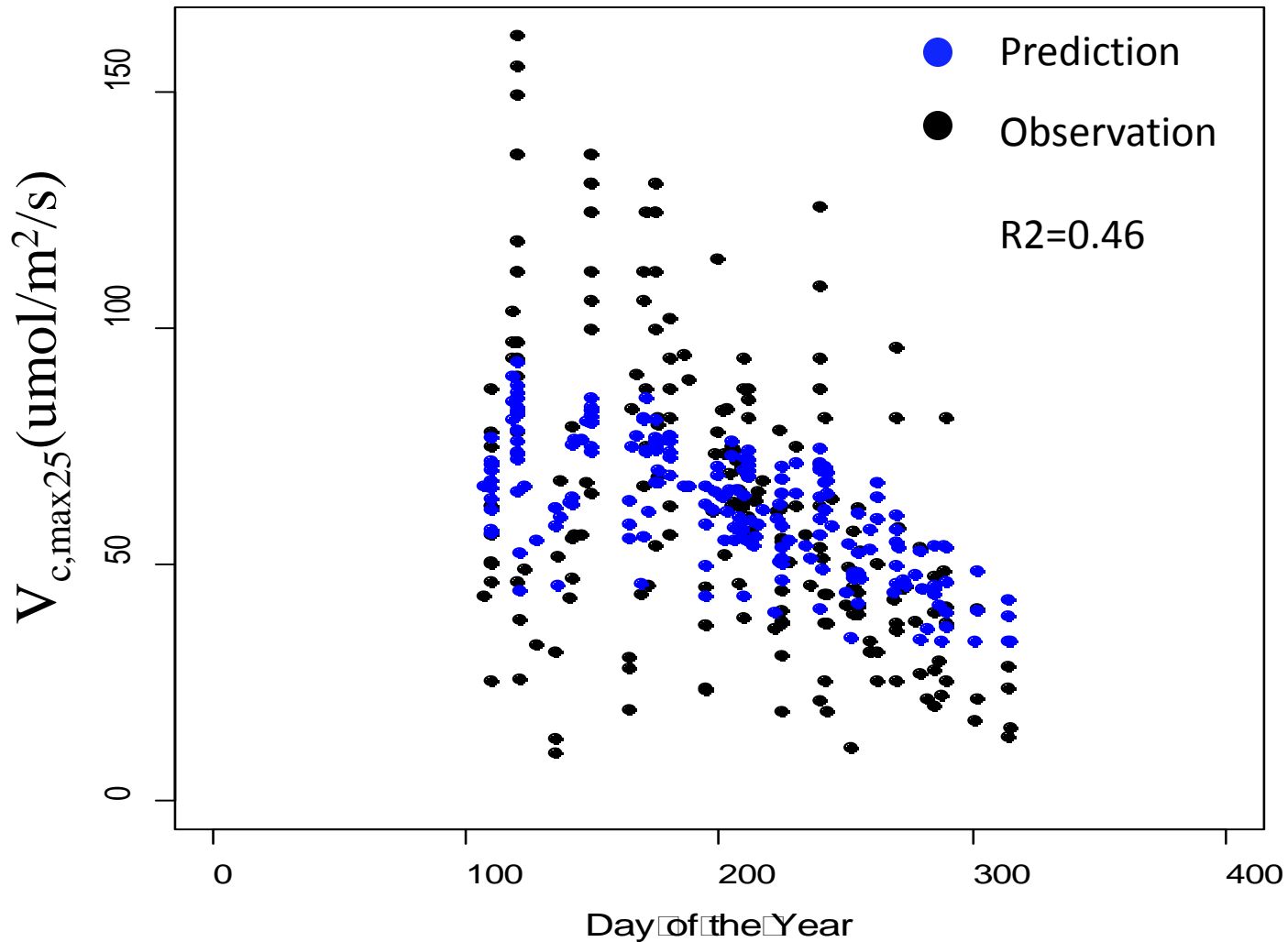
Baseline proportion of "storage" nitrogen

Response of "storage" nitrogen to photosynthetic rate

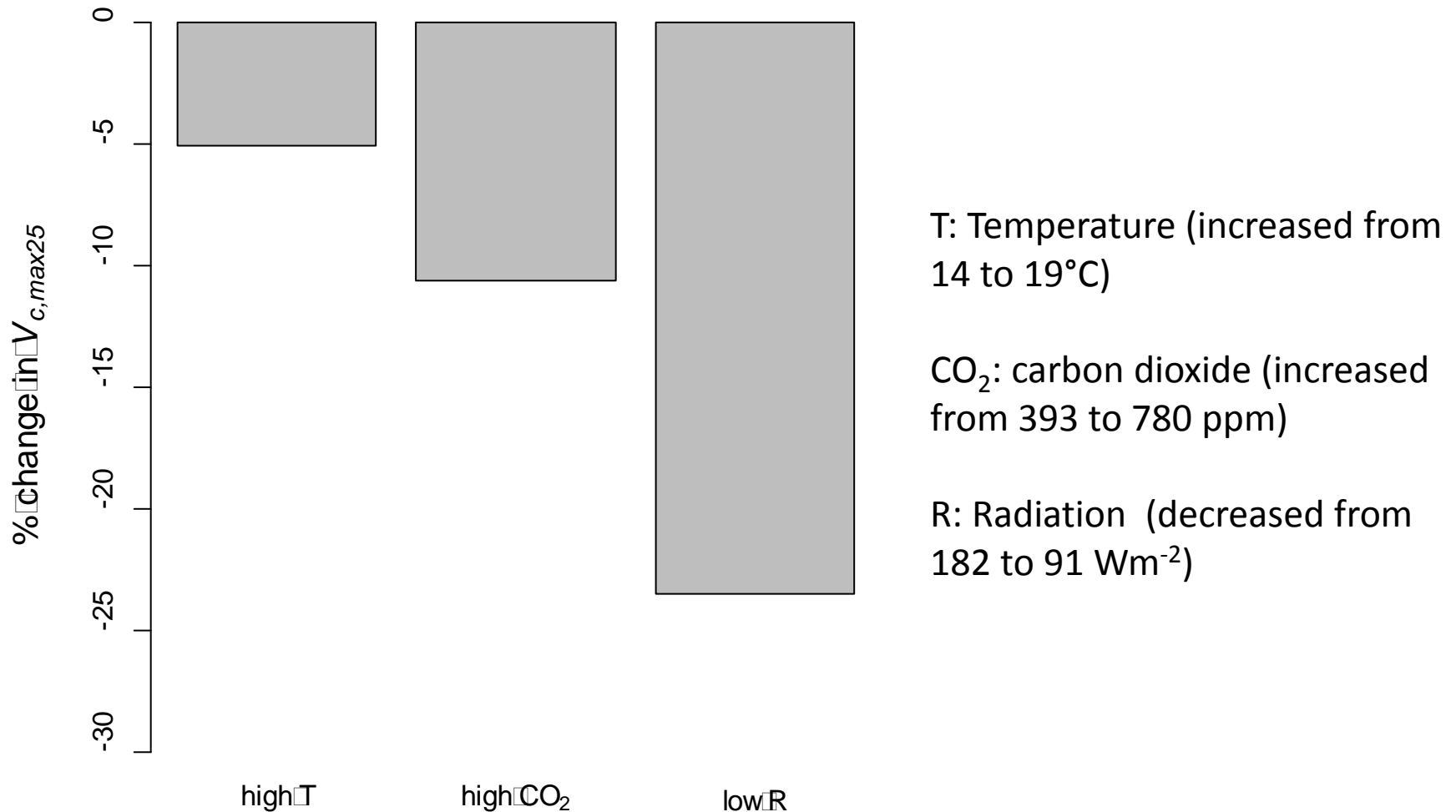
Ratio of Rubisco-limited rate to light limited rate

Statistics	Jmaxbo	Jmaxb1	Nstoreb0	Nstoreb1	Wc/Wj
mean	0.0298	0.1270	0.0103	1.99E-5	0.7833
std	0.0002	0.0007	0.0004	1.65E-5	0.0025

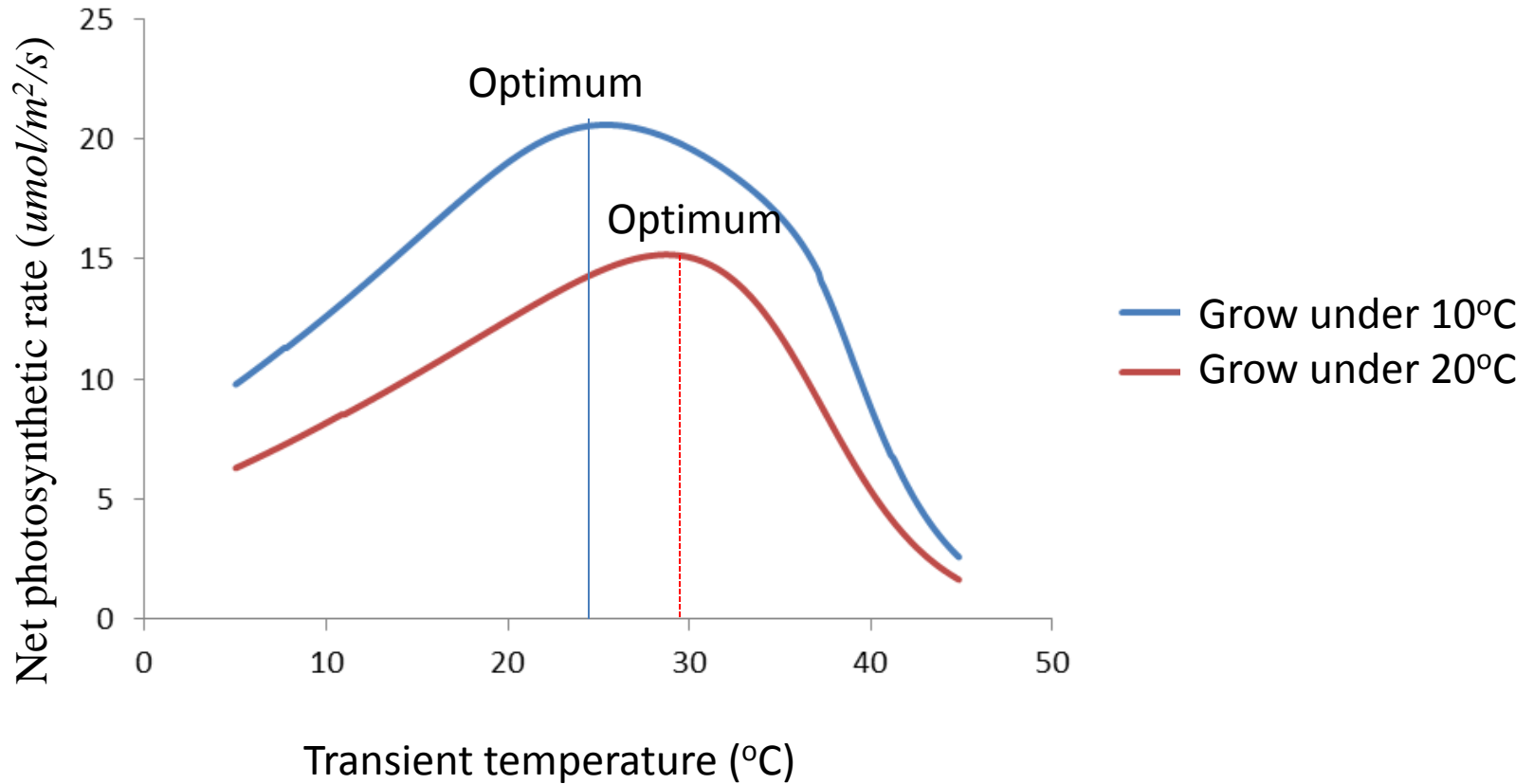
$V_{c,max25}$ across the growing season



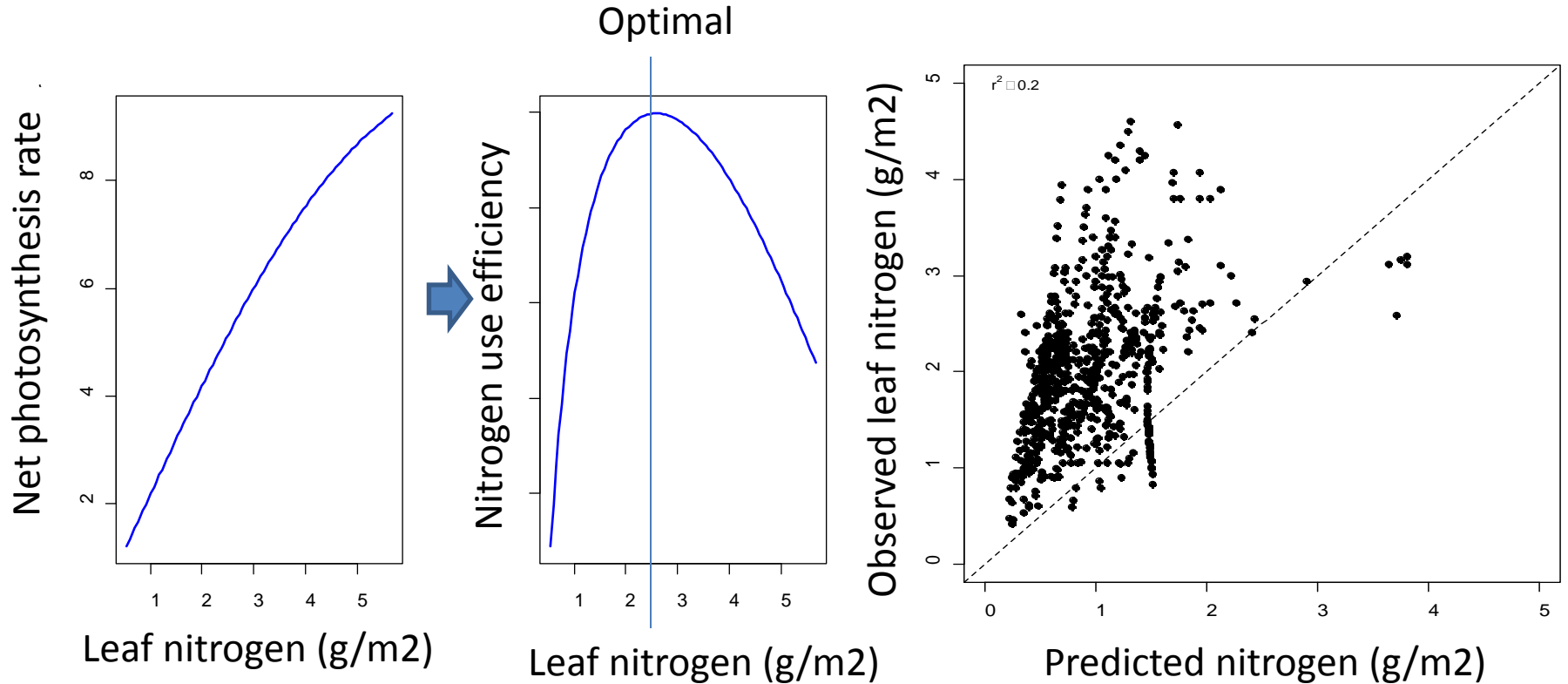
Model sensitivity analysis and implications for climatic change



Temperature acclimation

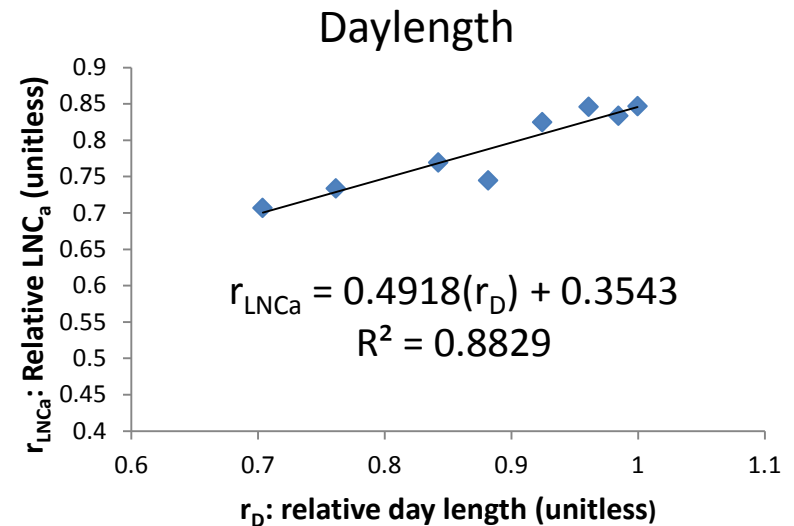
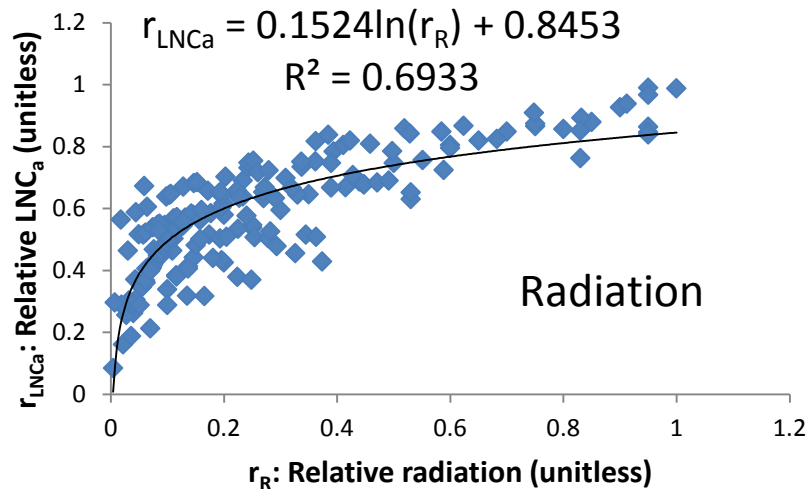


Leaf nitrogen optimization fails

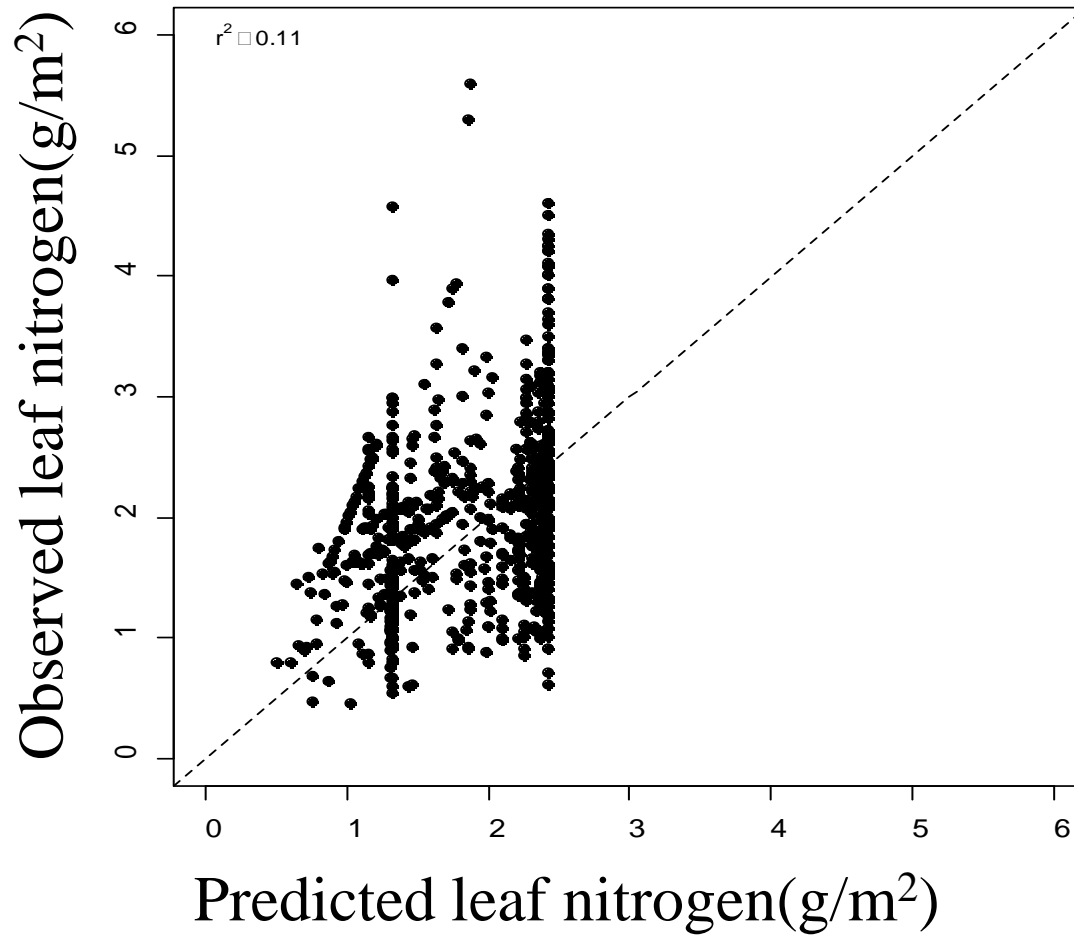


Area-based leaf nitrogen content

PFT grouping 1: growth form	LNC _a (top of the canopy & peak growing season)
Herbaceous	1.32
Shrubs	1.88
Trees	2.42



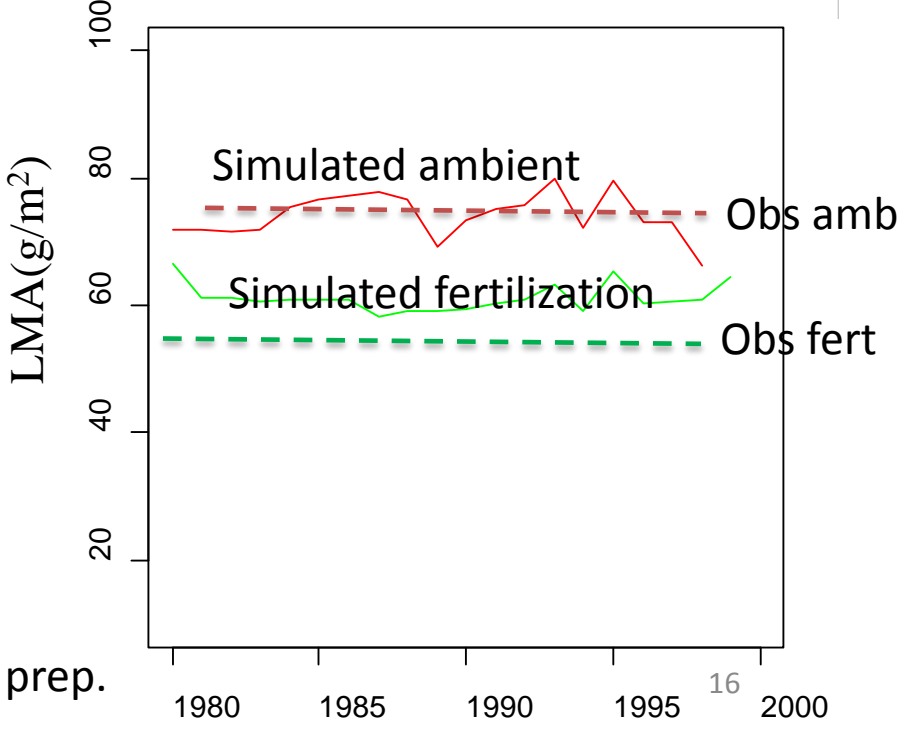
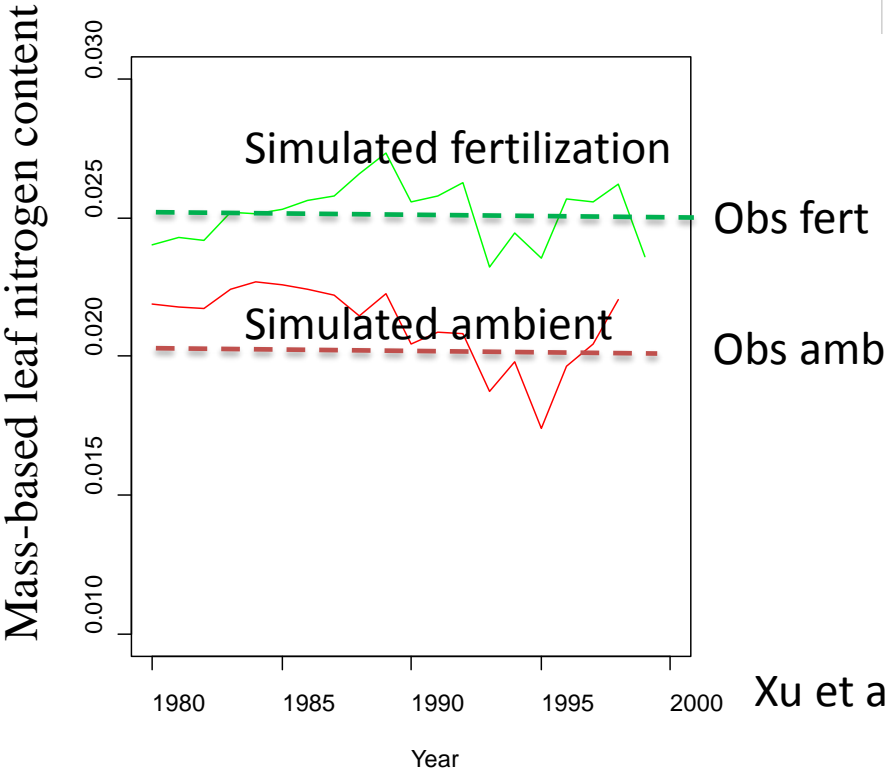
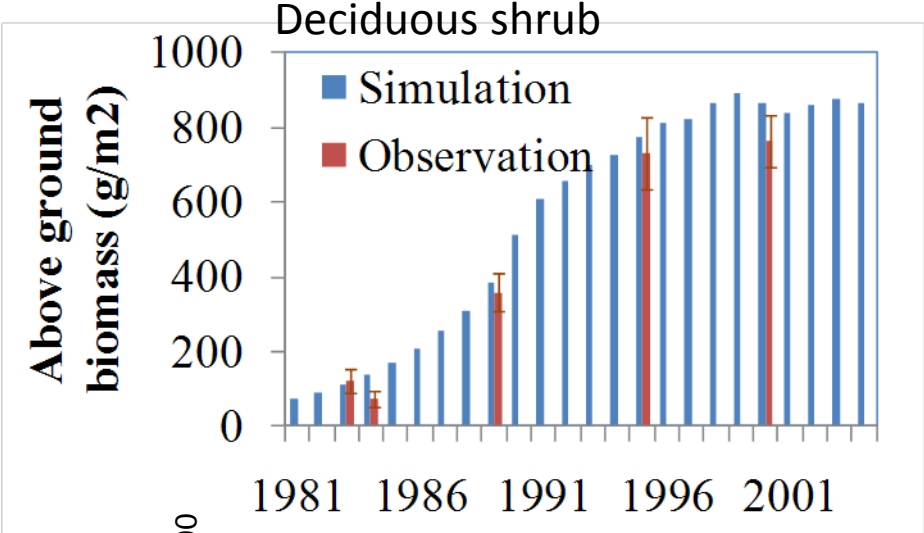
Goodness of fit of LNCa



Implementation of nitrogen limitation in CLM(ED)

- Prescribed area-based leaf nitrogen content
- Dynamic mass-based leaf nitrogen content
- Dynamic leaf thickness
- Dynamic $V_{c,max25}$ and J_{max25}
- Cohort-based photosynthesis

Test ED-N model against nitrogen fertilization observations



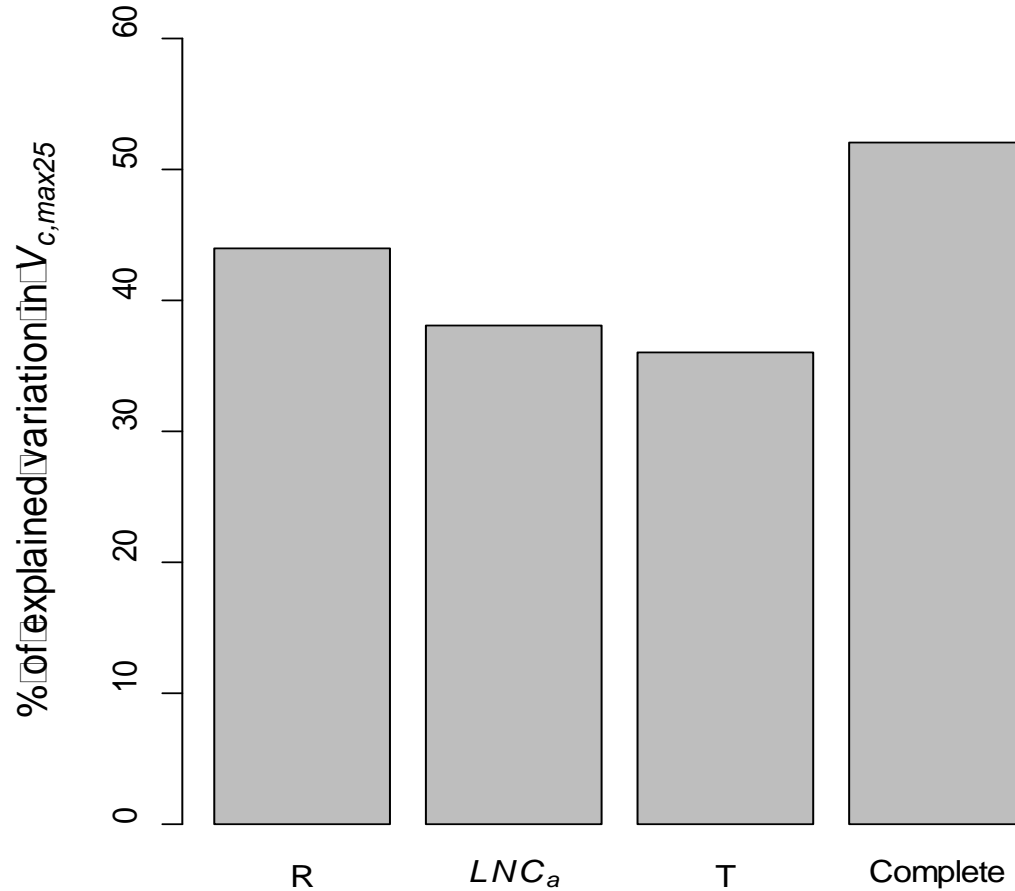
Xu et al. In prep.

Acknowledgments

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- **Key collaborators:** Stan Wullschleger(ORNL), Alistair Roger (BNL), Rosie Fisher (NCAR), Peter Thornton (ORNL), Bryan Travis (LANL), Bill Riley (LBL), Jasper Vrugt (UCI), Sanna Sevanto (LANL)



Model sensitivity analysis



R: Radiation

LNC_a : Leaf Nitrogen Content

T: Temperature

Complete: All environmental variables + LNC_a