

Exploring the representation of PFTs in JULES

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JULES general science meeting

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JULES PFTs

- 5 currently: Broadleaf, Needle leaf, C3 grass, C4 grass, Shrubs
- 3 New: Split Broadleaf into Deciduous and Evergreen; same for needle leaf and shrubs
- Very preliminary work on new traits

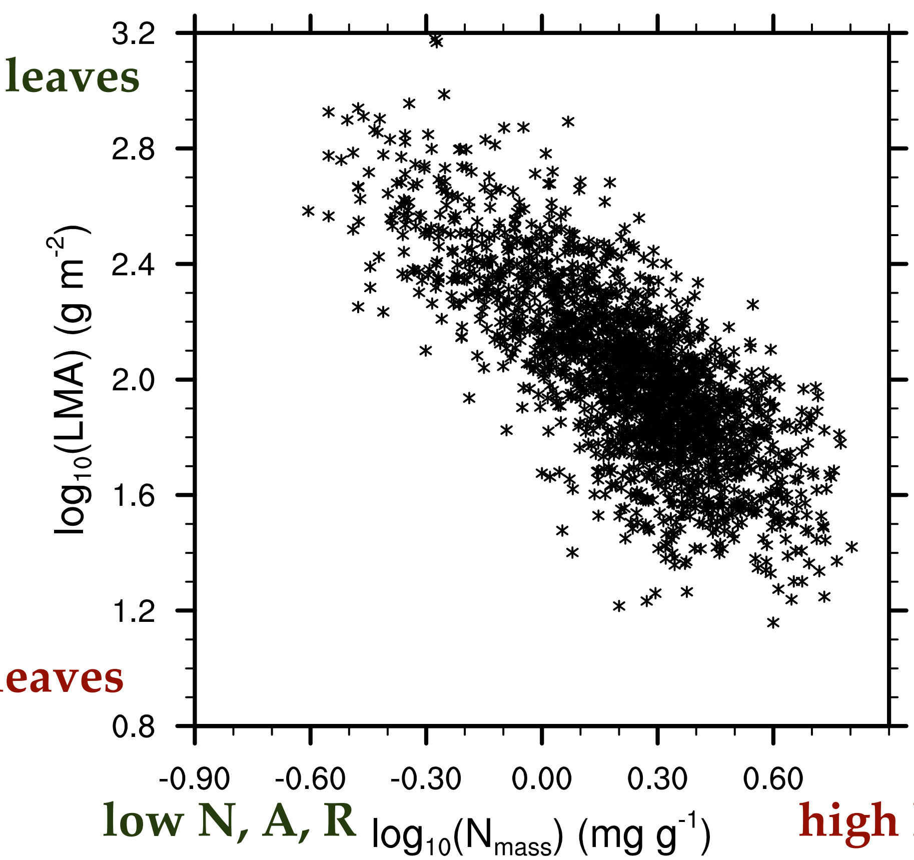
How?

- Combination data analysis and parameter optimization.
- Leaf traits: Relate leaf nitrogen, life span, and mass/area to photosynthesis and respiration rates.
- Address soil moisture stress, root depths, and drought deciduous phenology for Tropical forests
- Parameter optimization for other photosynthetic properties.
- Adjust competition scheme to allow for generic # of PFTs.

Leaf Economics

- Quick return: short life span, high nutrient content, low mass/area, and high assimilation and respiration rates.

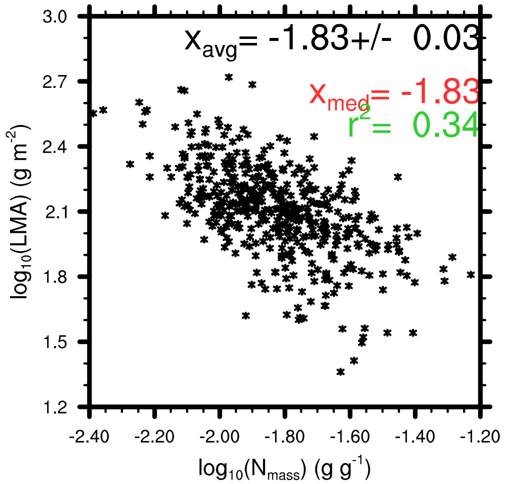
- Slow-return: long life span, low nutrient content, high mass/area, and low assimilation and respiration rates



Wright et al. 2004

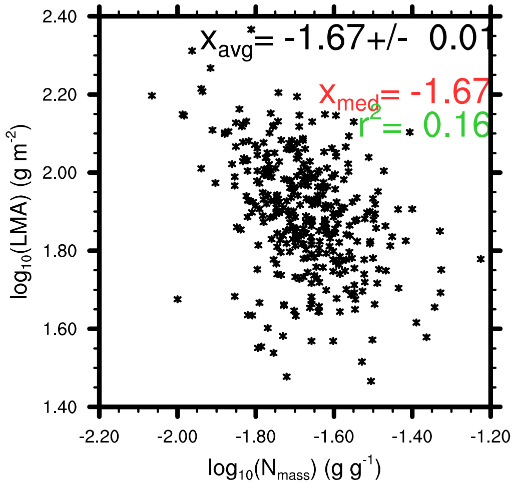
Leaf Economics by PFT

Evergreen broadleaf



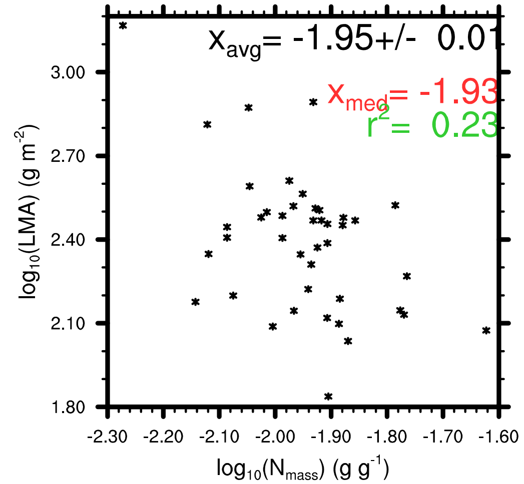
N=0.016; LMA=130

Deciduous Broadleaf



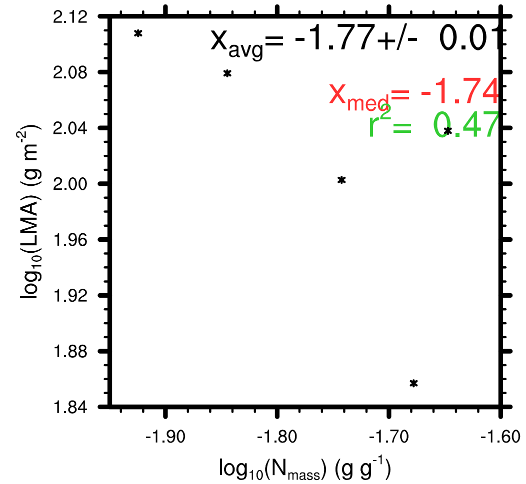
N=0.021; LMA=79

Evergreen Needle



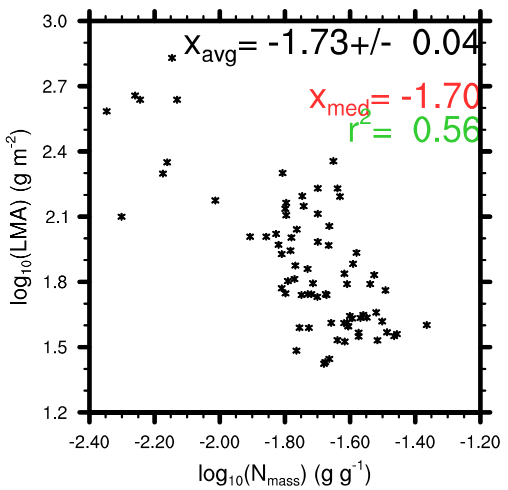
N=0.012; LMA=267

Deciduous Needle



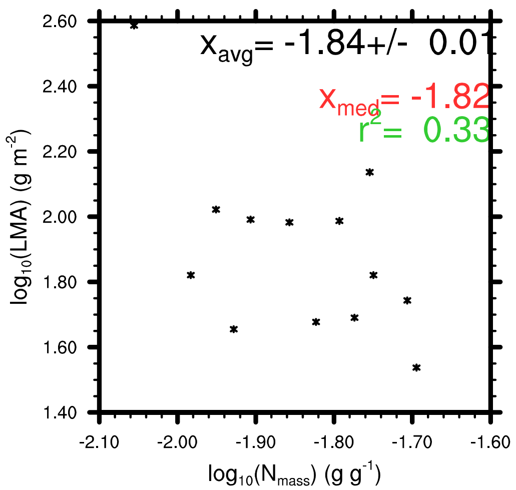
N=0.020; LMA=109

C3 Grass



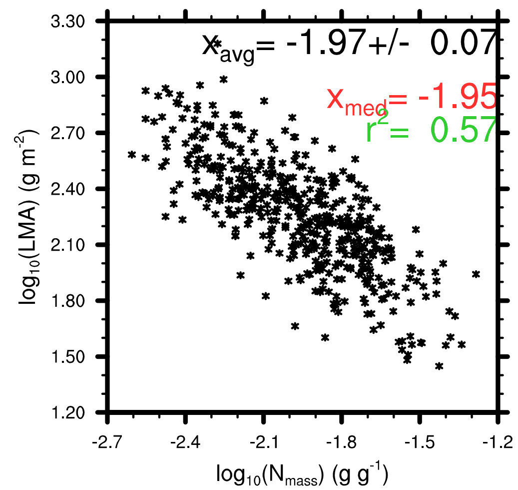
N=0.018; LMA=63

C4 Grass



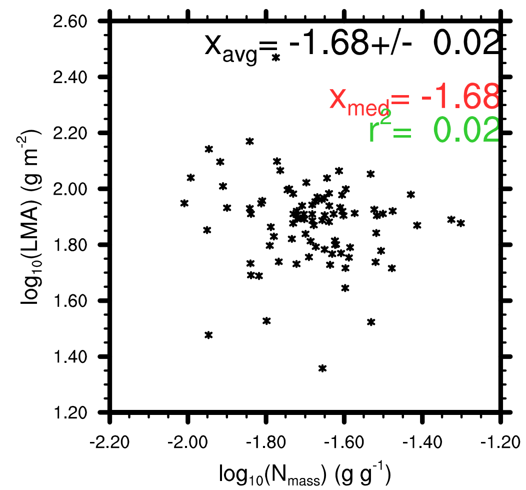
N=0.014; LMA=66

Evergreen Shrub



N=0.012; LMA=187

Deciduous Shrub



N=0.021; LMA=80

- Use LMA:Nmass relationship for each PFT.
- LMA -> Nmass -> Narea -> Vcmax

- Quick return
- Slow-return

Source: Nmass from TRY dataset (Kattge et al. 2011); LMA from Wright et al. 2004

Vcmax and Photosynthesis

- Vcmax is maximum rate of carboxylation of Rubisco
- Calculated from maximum rate at 25C
- Affects Wc, We, and respiration.

$$V_{\mathrm{cmax}} = \frac{V_{\mathrm{cmax25}}\, f_{\mathrm{T}}(T_{\mathrm{c}})}{\left[1+e^{0.3(T_{\mathrm{c}}-T_{\mathrm{upp}})}\right]\left[1+e^{0.3(T_{\mathrm{low}}-T_{\mathrm{c}})}\right]} \quad (4)$$

1. Rubisco-limited rate (W_c)

$$W_{\mathrm{c}} = \begin{cases} V_{\mathrm{cmax}}\left(\dfrac{c_{\mathrm{i}}-\Gamma}{c_{\mathrm{i}}+K_{\mathrm{c}}(1+O_{\mathrm{a}}/K_{\mathrm{o}})}\right) & \text{for } C_3 \text{ plants} \\ V_{\mathrm{cmax}} & \text{for } C_4 \text{ plants} \end{cases} \quad (1)$$

2. Light-limited rate (W_l)

$$W_{\mathrm{l}} = \begin{cases} \alpha(1-\omega)\, I_{\mathrm{par}}\left(\dfrac{c_{\mathrm{i}}-\Gamma}{c_{\mathrm{i}}+2\Gamma}\right) & \text{for } C_3 \text{ plants} \\ \alpha(1-\omega)\, I_{\mathrm{par}} & \text{for } C_4 \text{ plants} \end{cases} \quad (2)$$

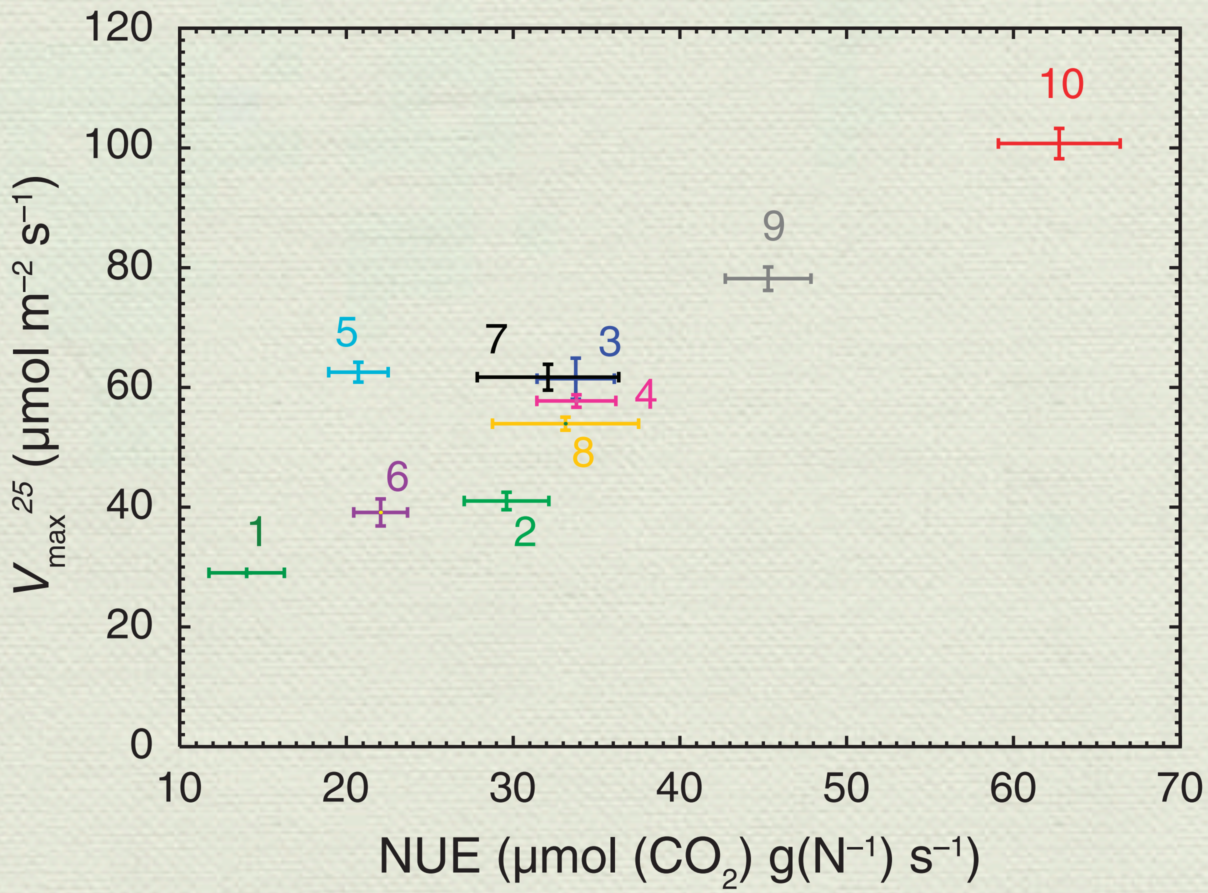
3. Rate of transport of photosynthetic products (in the case of C_3 plants) and PEPCarboxylase limitation (in the case of C_4 plants) (W_e)

$$W_{\mathrm{e}} = \begin{cases} 0.5\, V_{\mathrm{cmax}} & \text{for } C_3 \text{ plants} \\ 2\times 10^4\, V_{\mathrm{cmax}}\, \dfrac{c_{\mathrm{i}}}{P_*} & \text{for } C_4 \text{ plants} \end{cases} \quad (3)$$

From Nitrogen to Vcmax

- Linear relationship between N_area and Vcmax(25).
- Replace:

$$V_{\mathrm{cmax25}} = n_{\mathrm{e}} n_{\mathrm{l}}$$



1. Tropical trees (oxisols)
2. Tropical trees (non-oxisols)
3. Temperate broadleaf evergreen
4. Temperate broadleaf deciduous
5. Evergreen coniferous
6. Deciduous coniferous
7. Evergreen shrub
8. Deciduous shrub
9. C3 herbaceous
10. C3 crops

Kattge et al. 2009

New leaf N: Increases assimilation and respiration

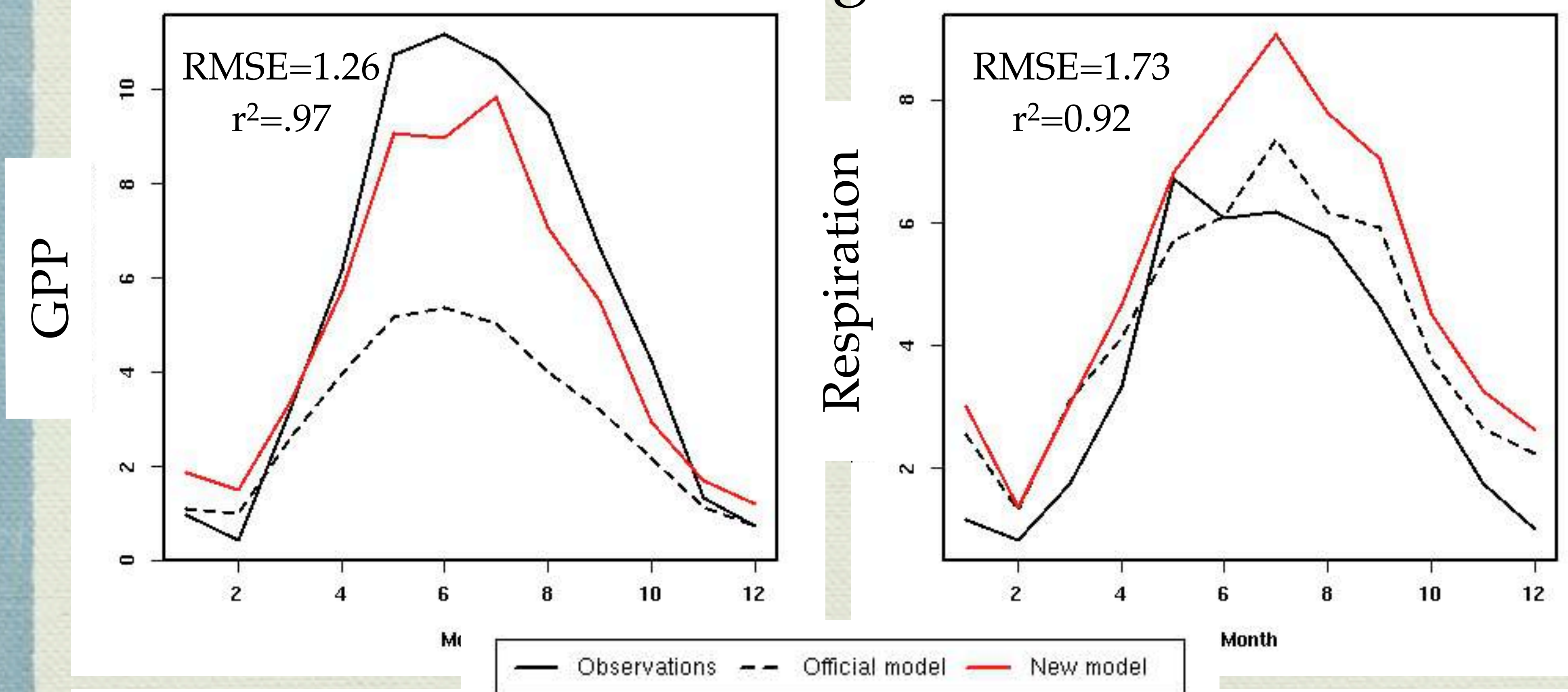
	EBT	DBT	ENT	DNT	C3	C4	ESh	Dsh	
N_area	2.02	1.69	3.26	2.20	1.13	0.90	2.28	1.68	kg/m2
Vcmax	57	55	65	46	53	43	67	54	umol/ m2/s
Vcmax in Lit.*	41-66	30-58	42-62	29-39	21-78	25	36-62	19-54	umol/ m2/s
current Vcmax	36.8		26.4		58.4	24	48		umol/ m2/s

**Kattge et al. 2009 (data) and the CLM model (Bonan et al. 2012)*

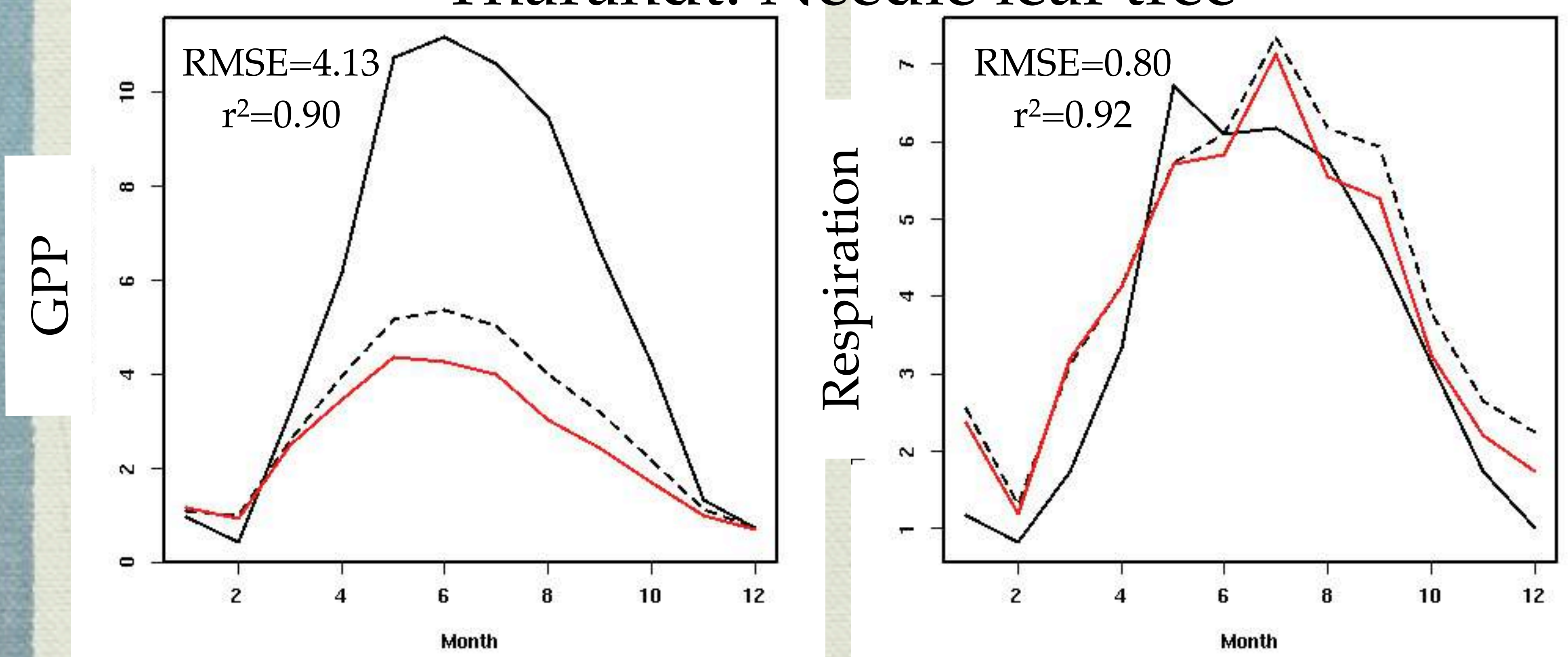
Model Evaluation

- Run benchmarking suite at 10 sites
- Use can_rad_mod = 5 (multi-layer with sunlit and shaded leaves, diffuse/direct radiation), set diff_frac=0.4.
- Generally: GPP is improved but Respiration is worse (LH is also worse). This is just a starting point.

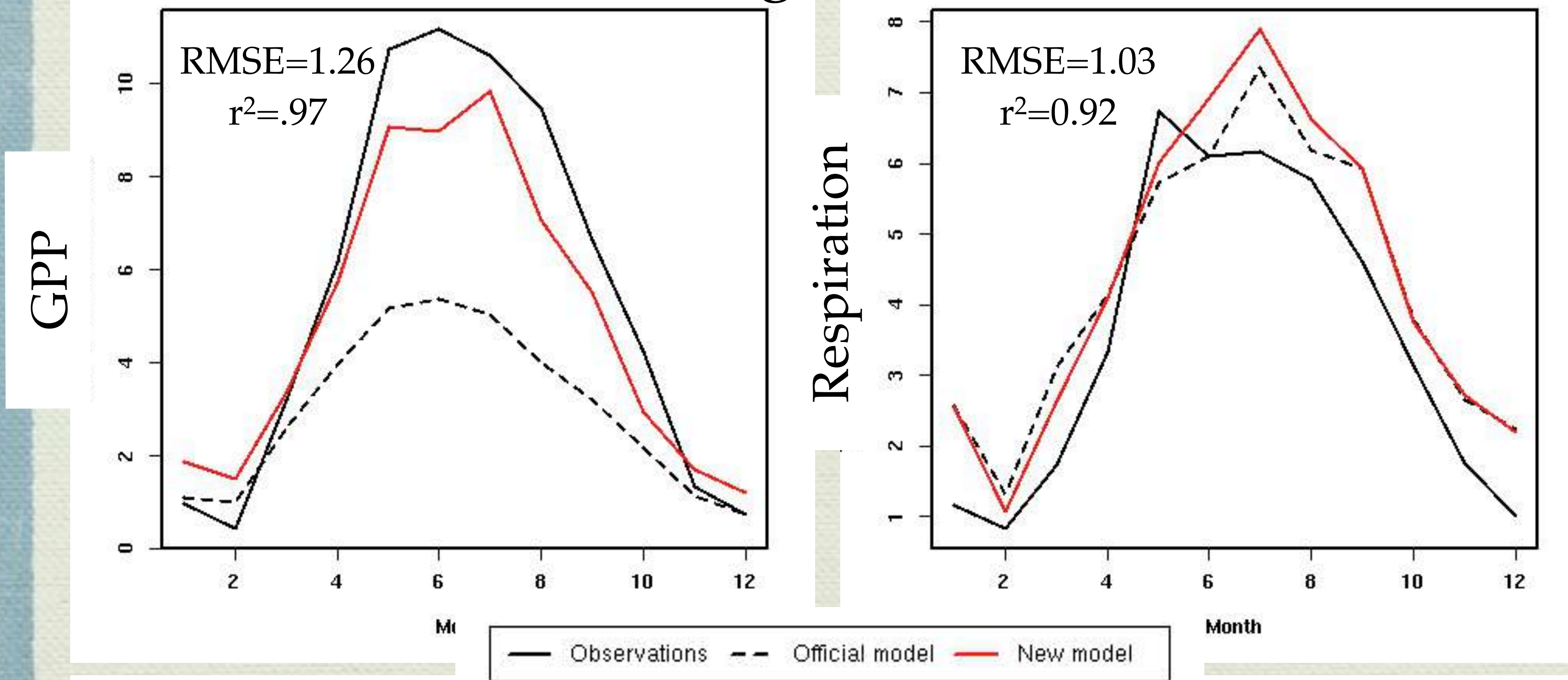
Tharandt: New, Evergreen needle leaf tree



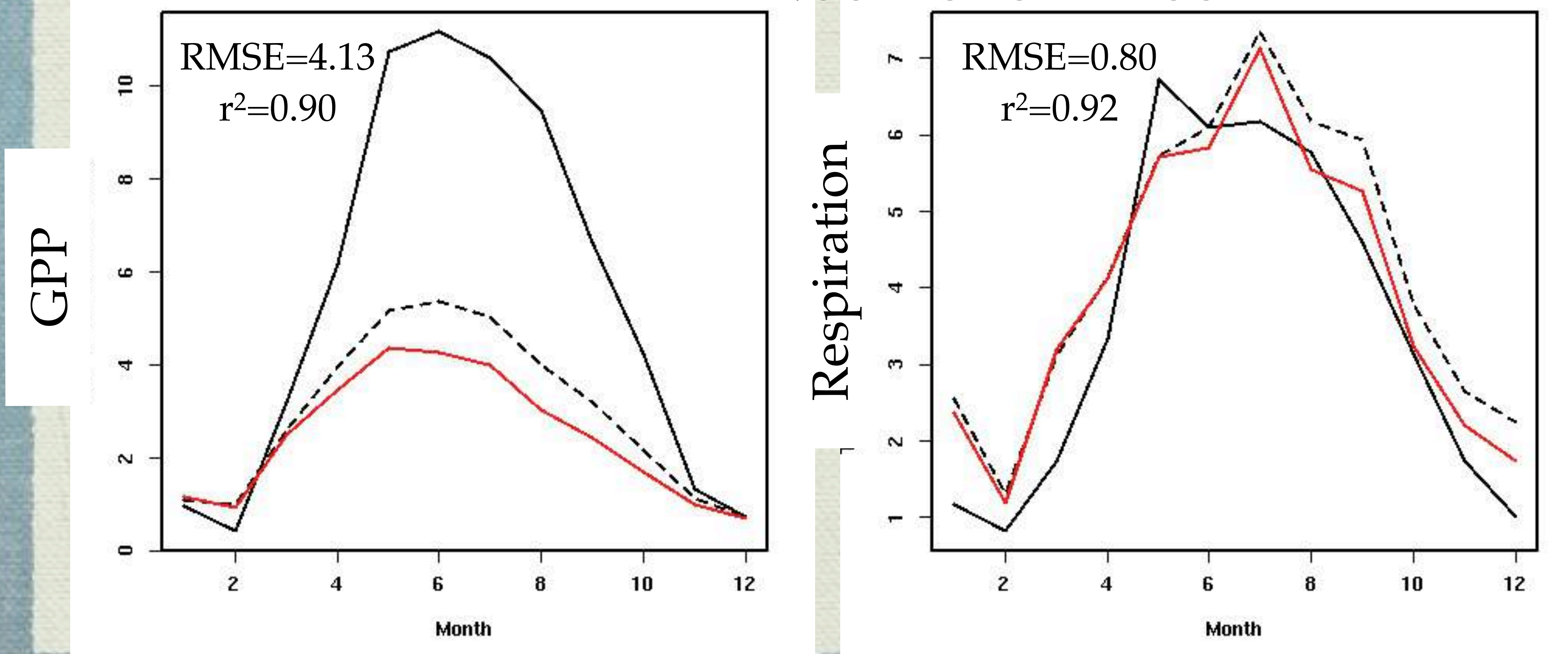
Tharandt: Needle leaf tree



Tharandt: New, Evergreen needle leaf tree (fd)



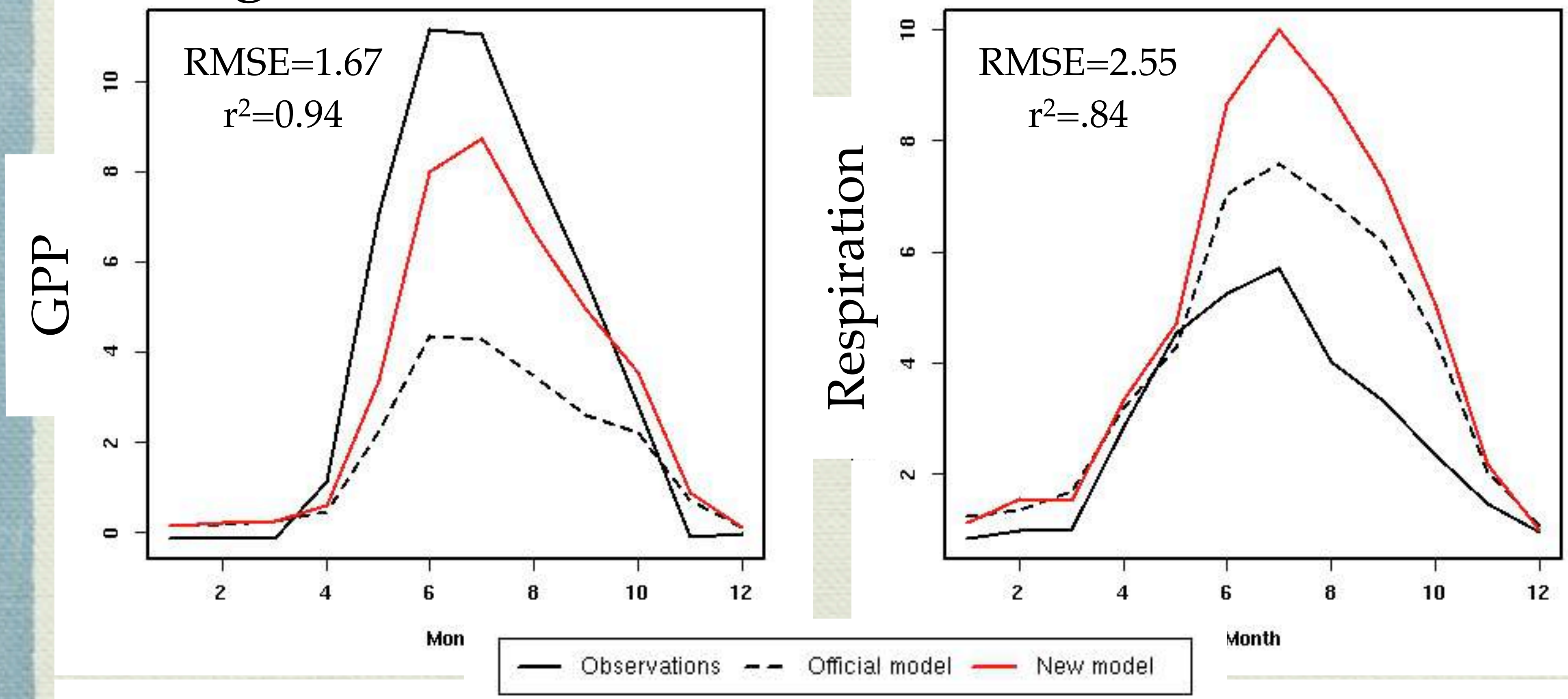
Tharandt: Needle leaf tree



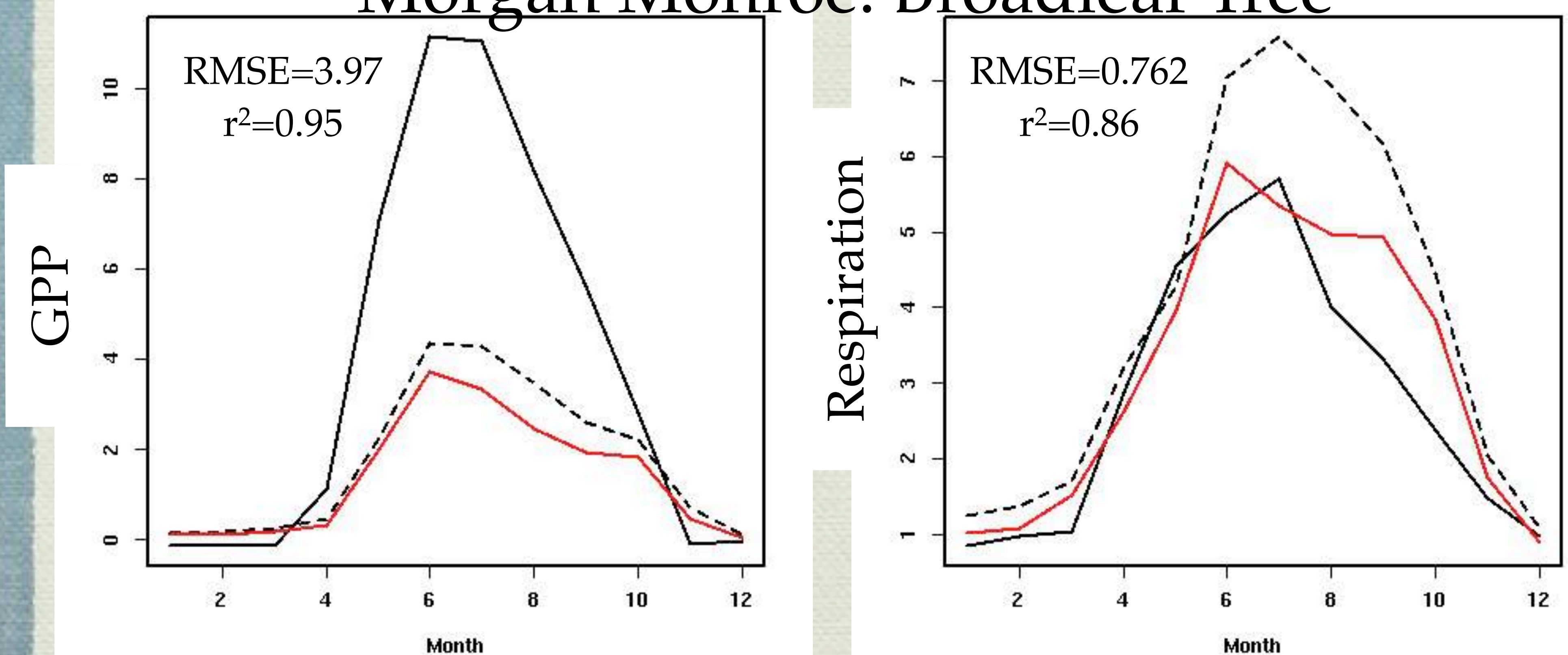
- Reduce fd
- Room for improvement

$$R_{\mathrm{d}} = f_{\mathrm{dr}} V_{\mathrm{cmax}}$$

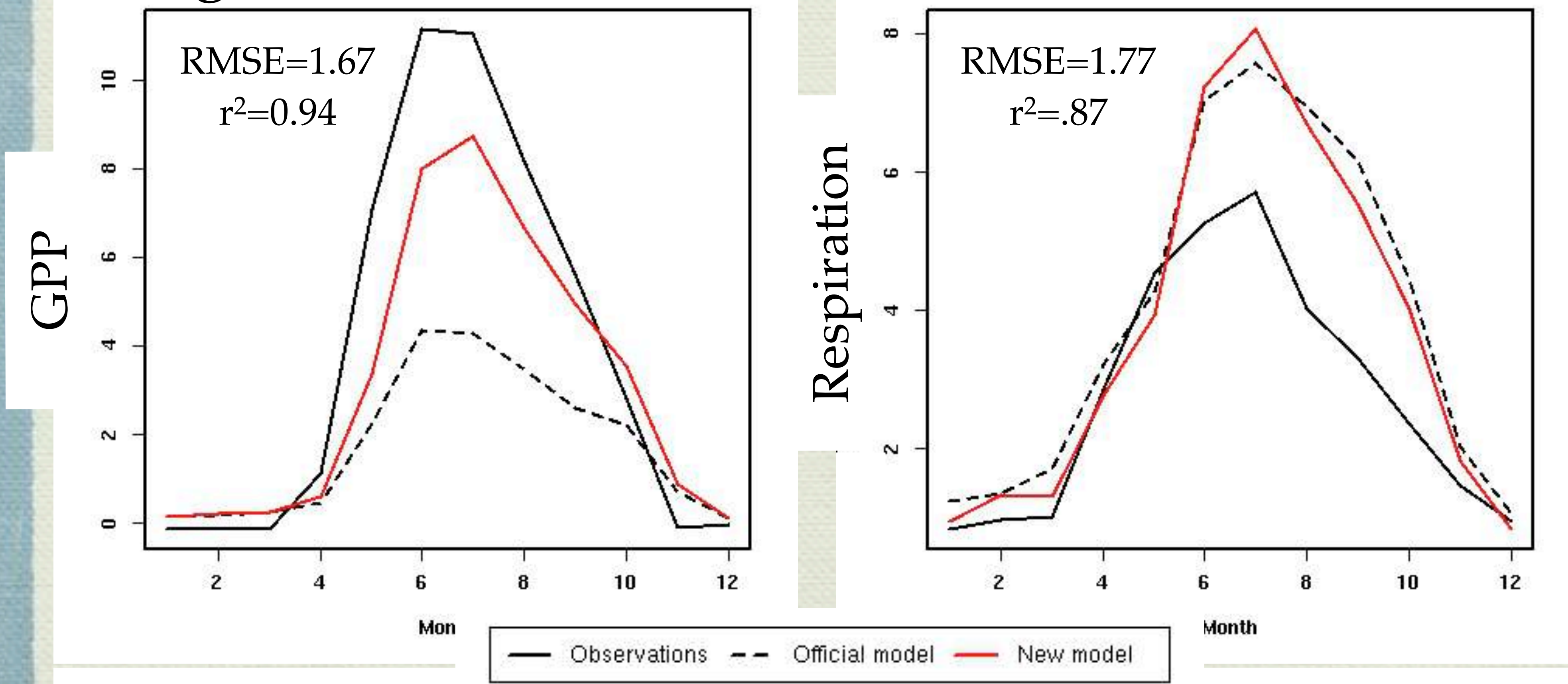
Morgan Monroe: New, Deciduous broadleaf tree



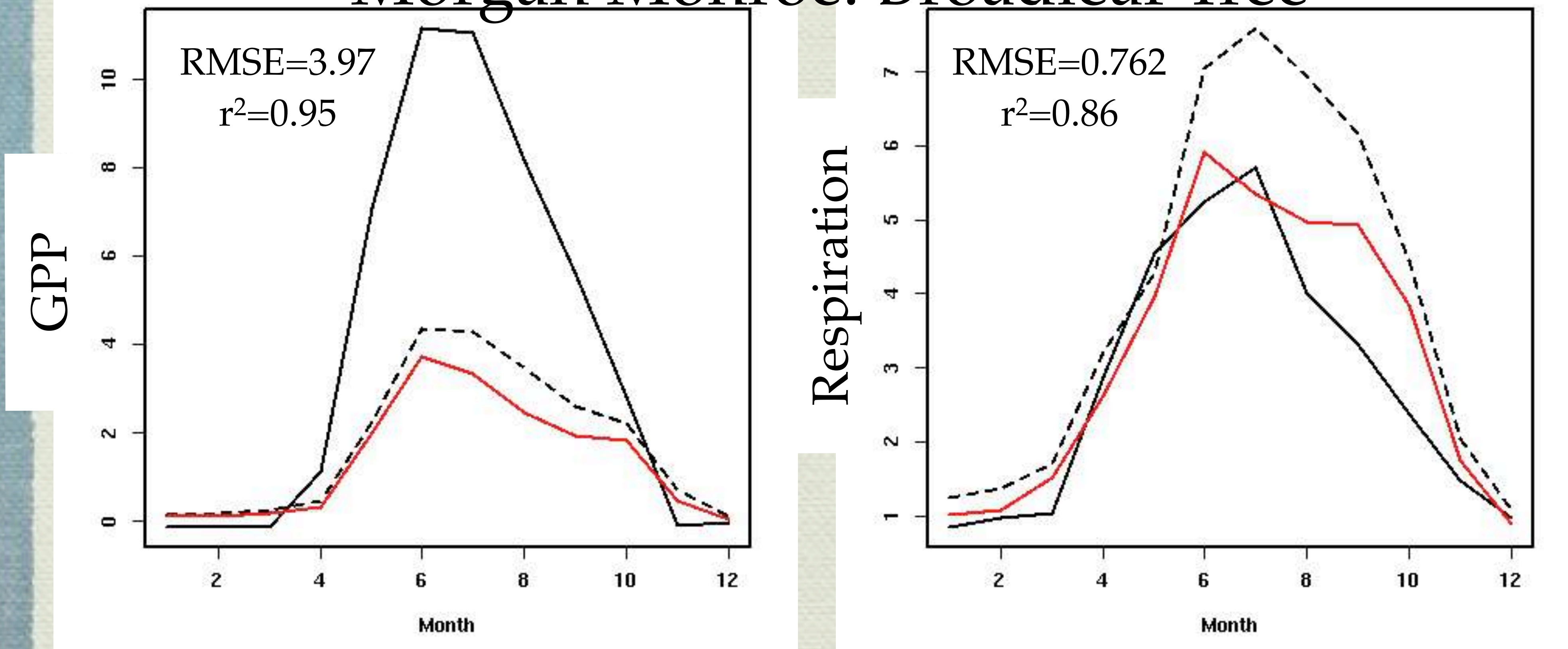
Morgan Monroe: Broadleaf Tree



Morgan Monroe: New, Deciduous broadleaf tree (fd)

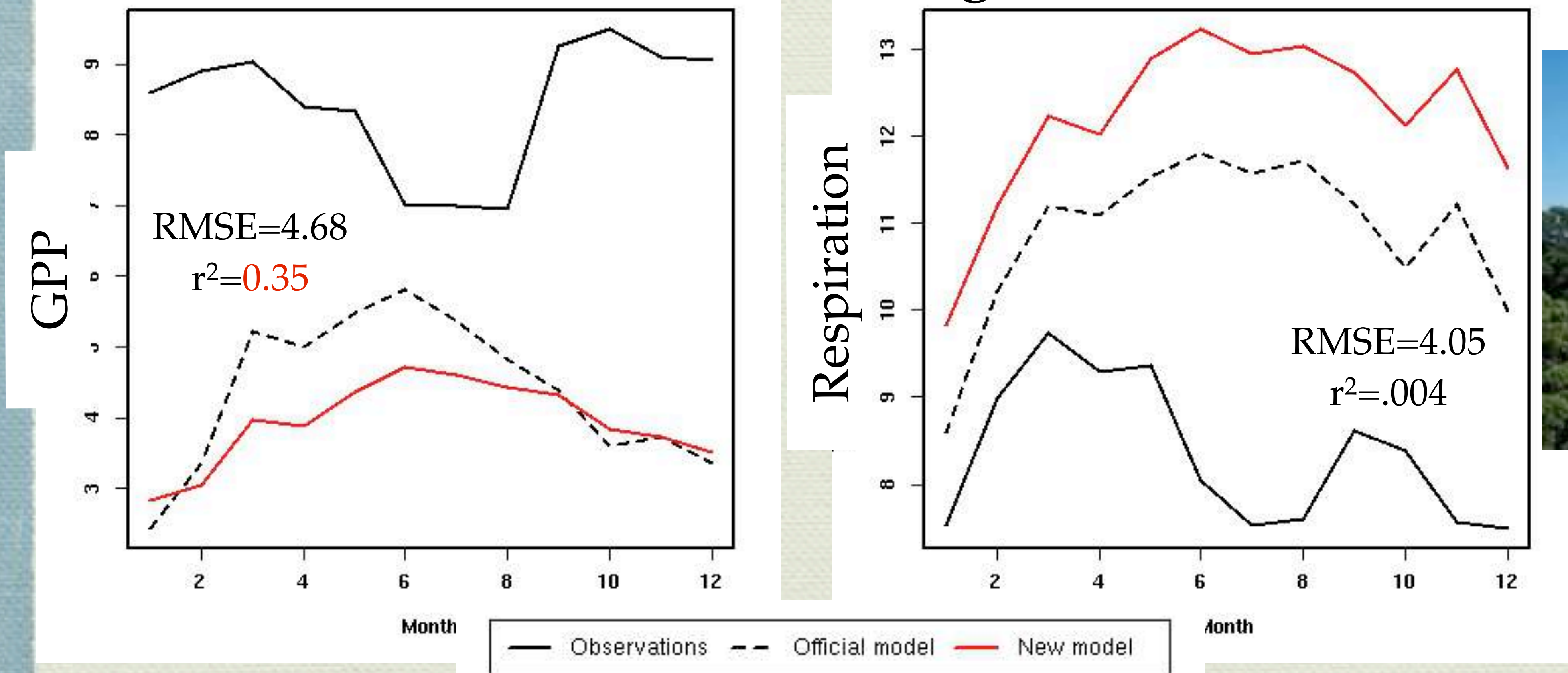


Morgan Monroe: Broadleaf Tree

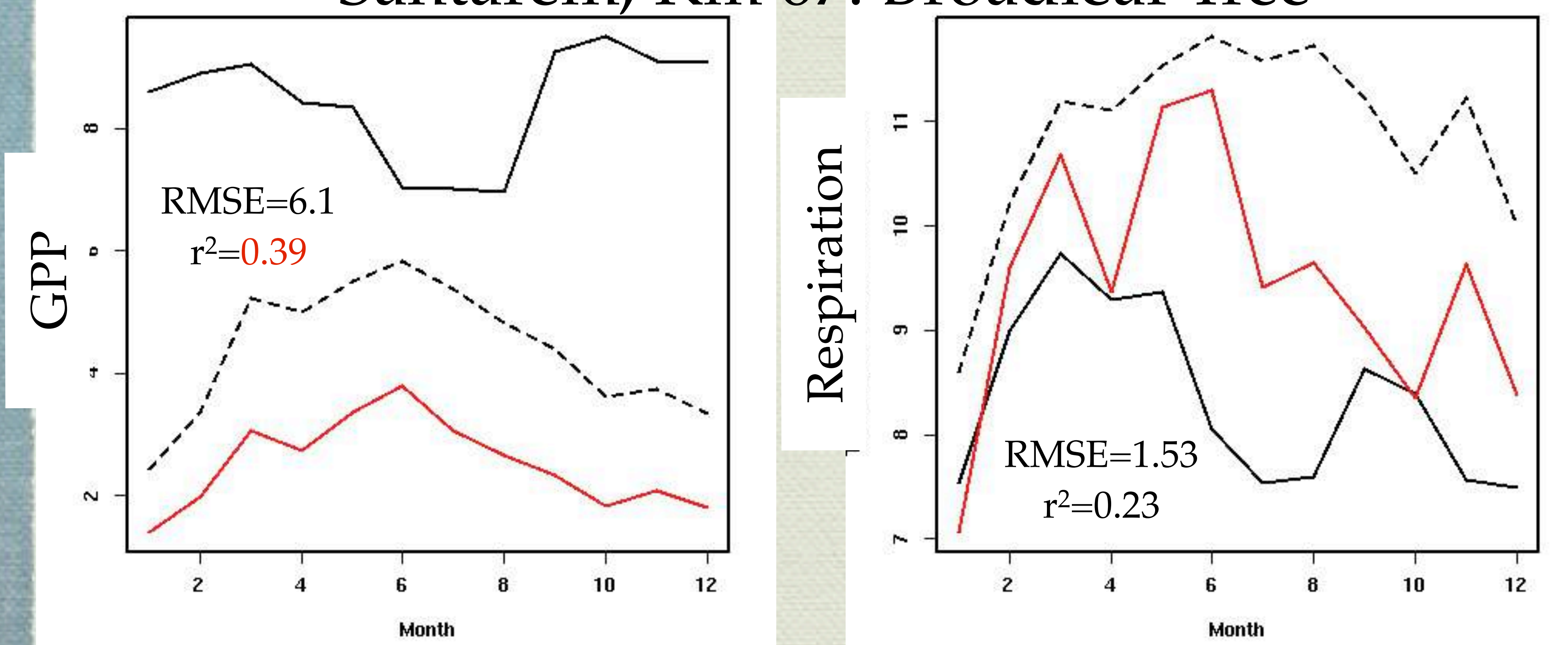


- Reduce fd

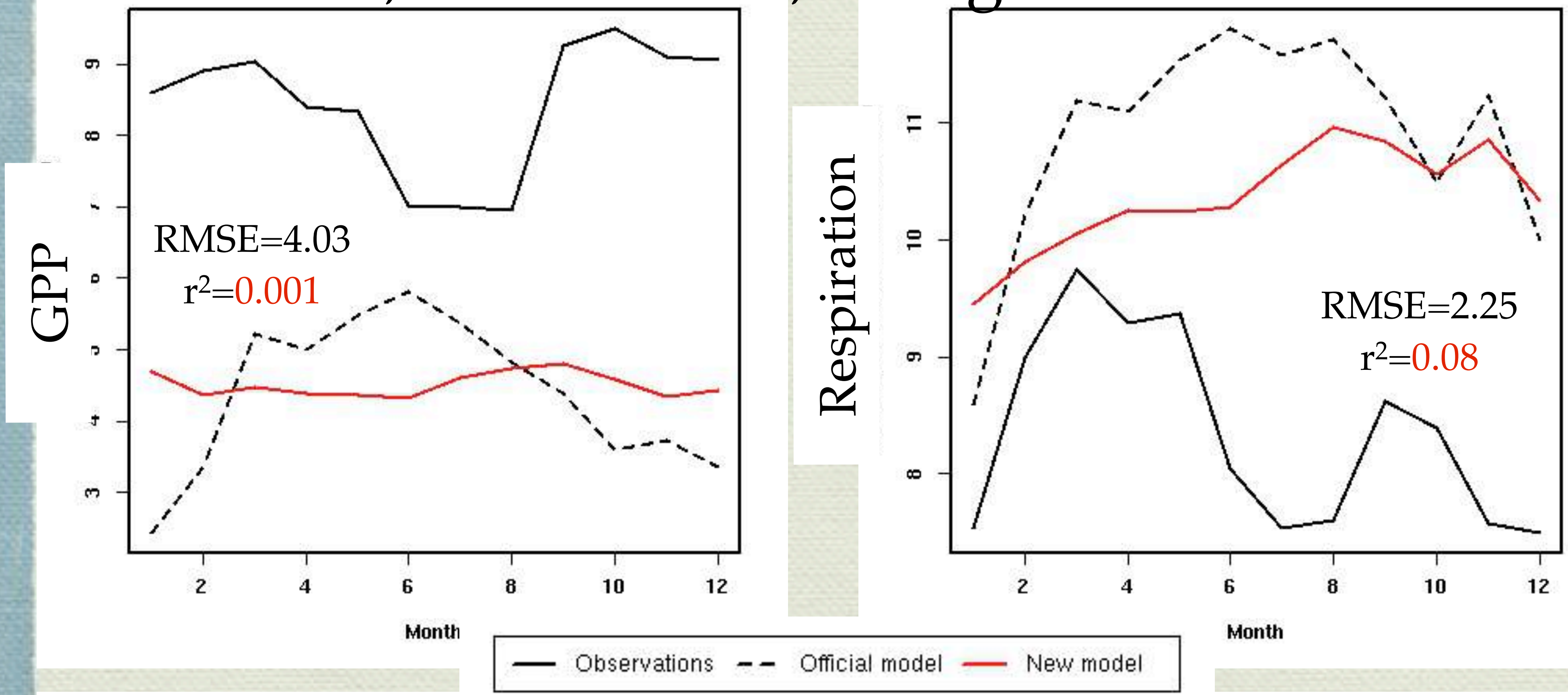
Santarem, Km 67: New, Evergreen broadleaf tree



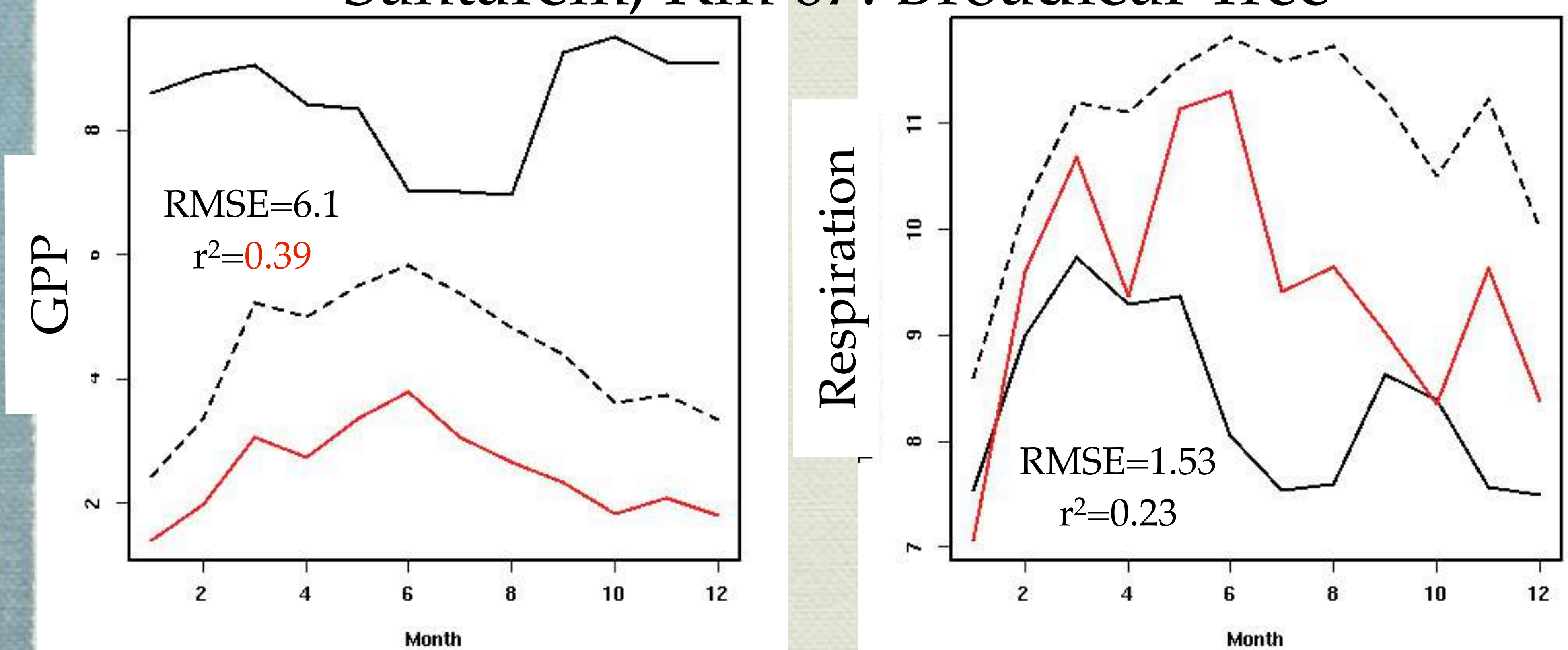
Santarem, Km 67: Broadleaf Tree



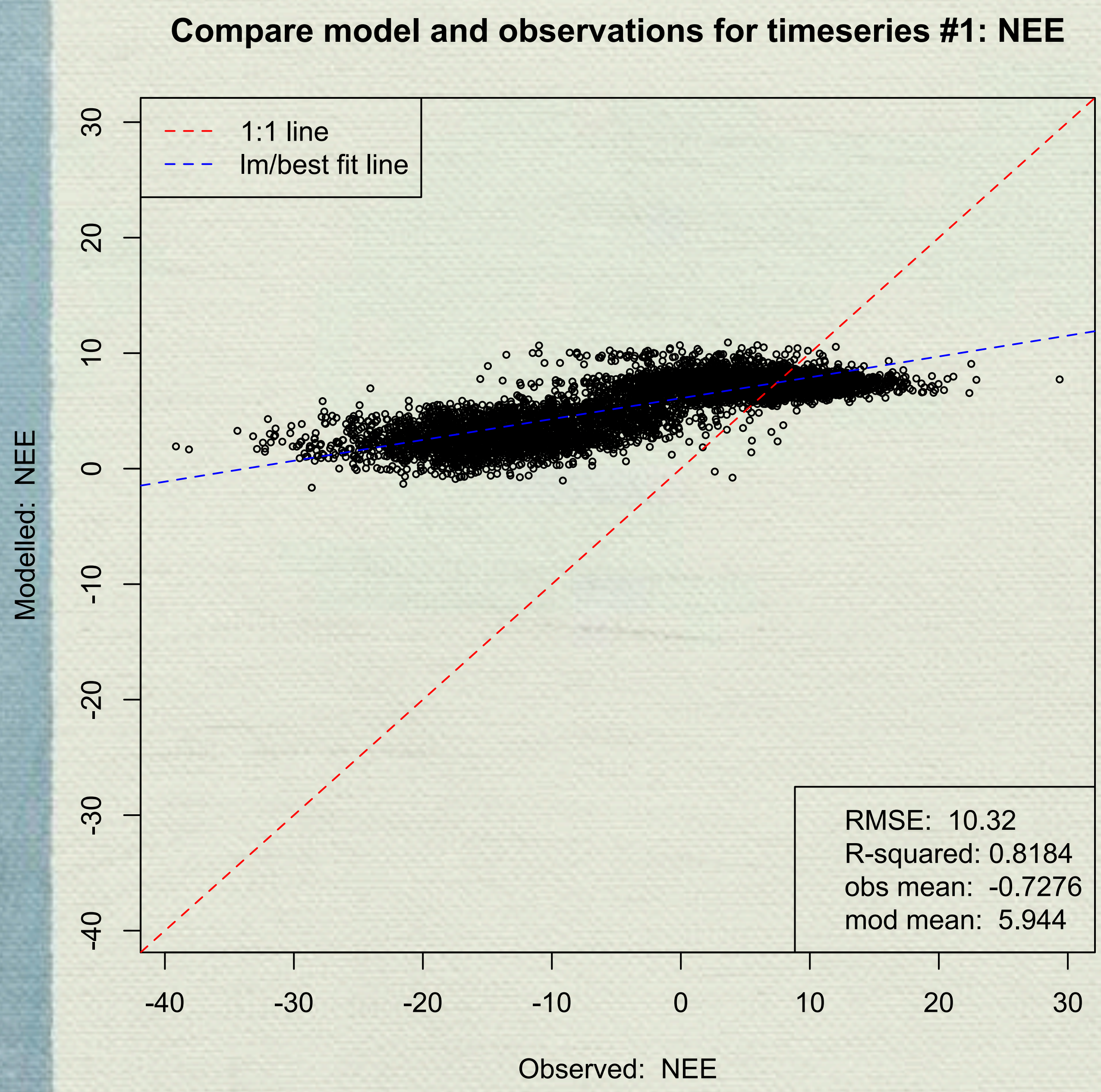
Santarem, Km 67: New, Evergreen broadleaf tree



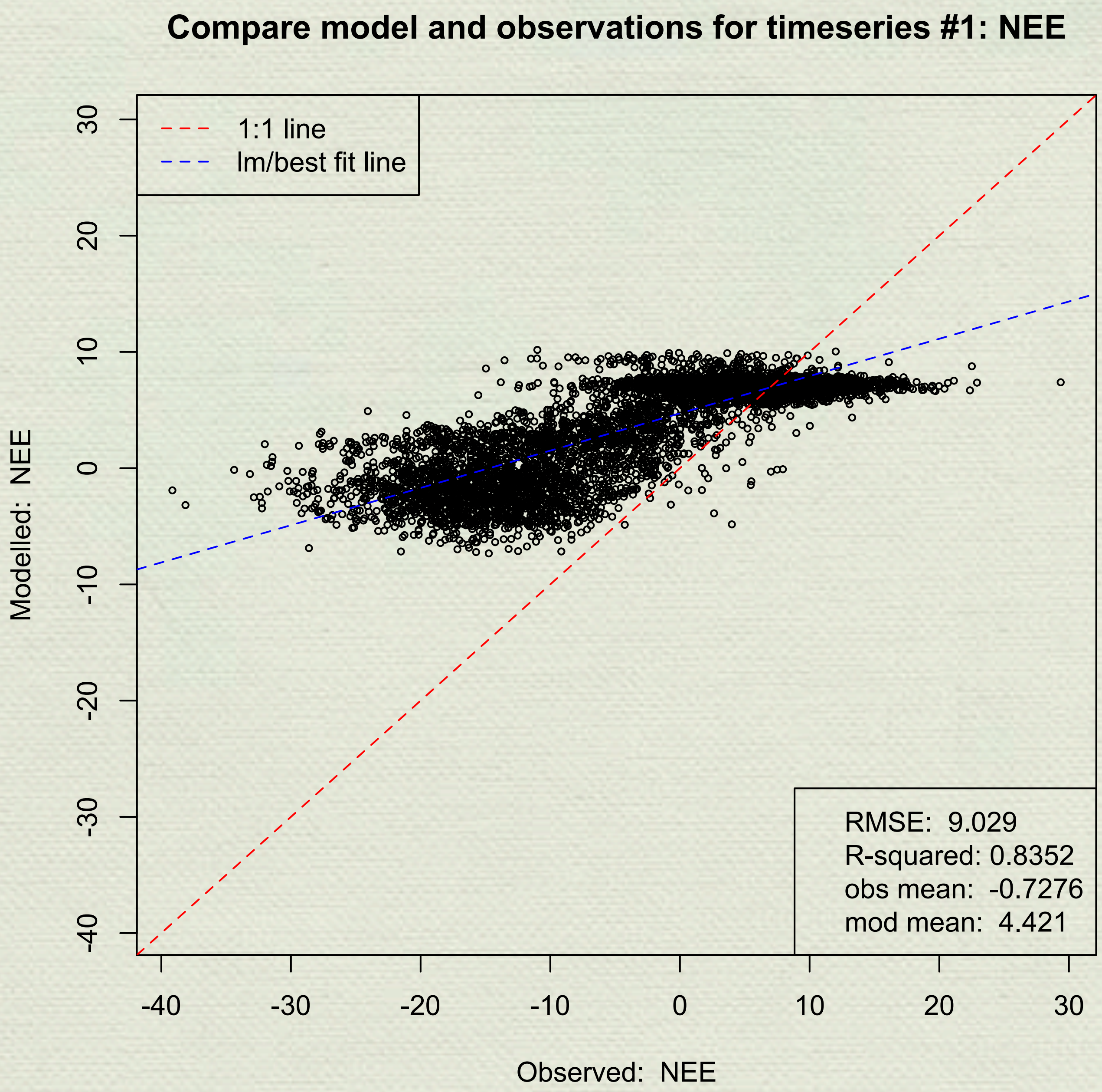
Santarem, Km 67: Broadleaf Tree



- Reduce fd
- 8m soil depths
- Relaxed soil moisture stress



- can_rad_mod=5



- can_rad_mod=5
- new leaf N
- deeper soil
- observed diffuse frac
- site soil texture

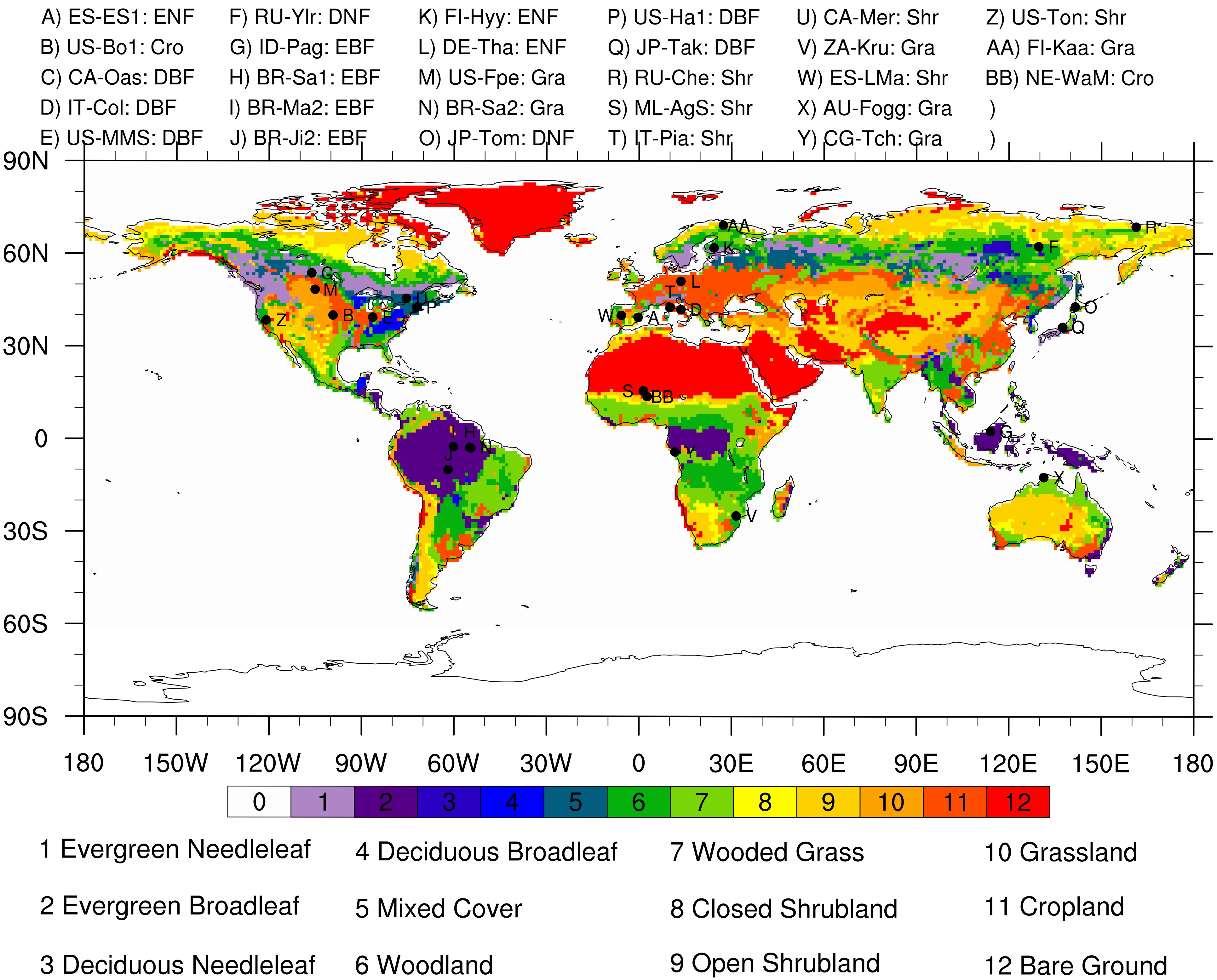
Competition between PFTs

- Currently hard-wired for 5 PFTs: Trees>shrubs>grasses.
- Replace co-competition with pure height-dominance.
- Regardless of the plant type, the tallest plants win.
- Generic number of PFTs will allow for detailed regional analysis or added PFTs later.

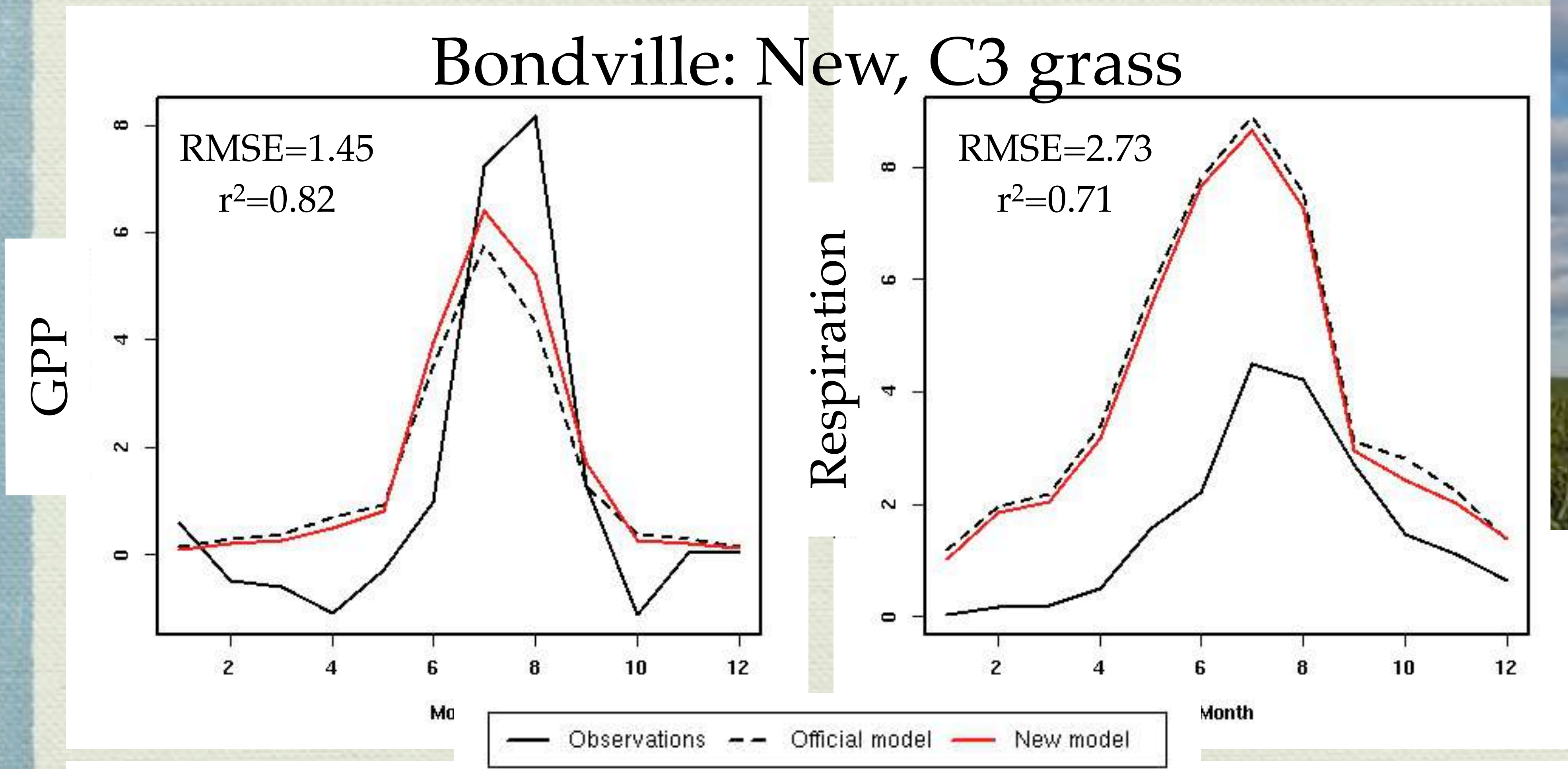
$$c_{ij} = \frac{1}{1 + e^{20(h_i - h_j)/(h_i + h_j)}}$$

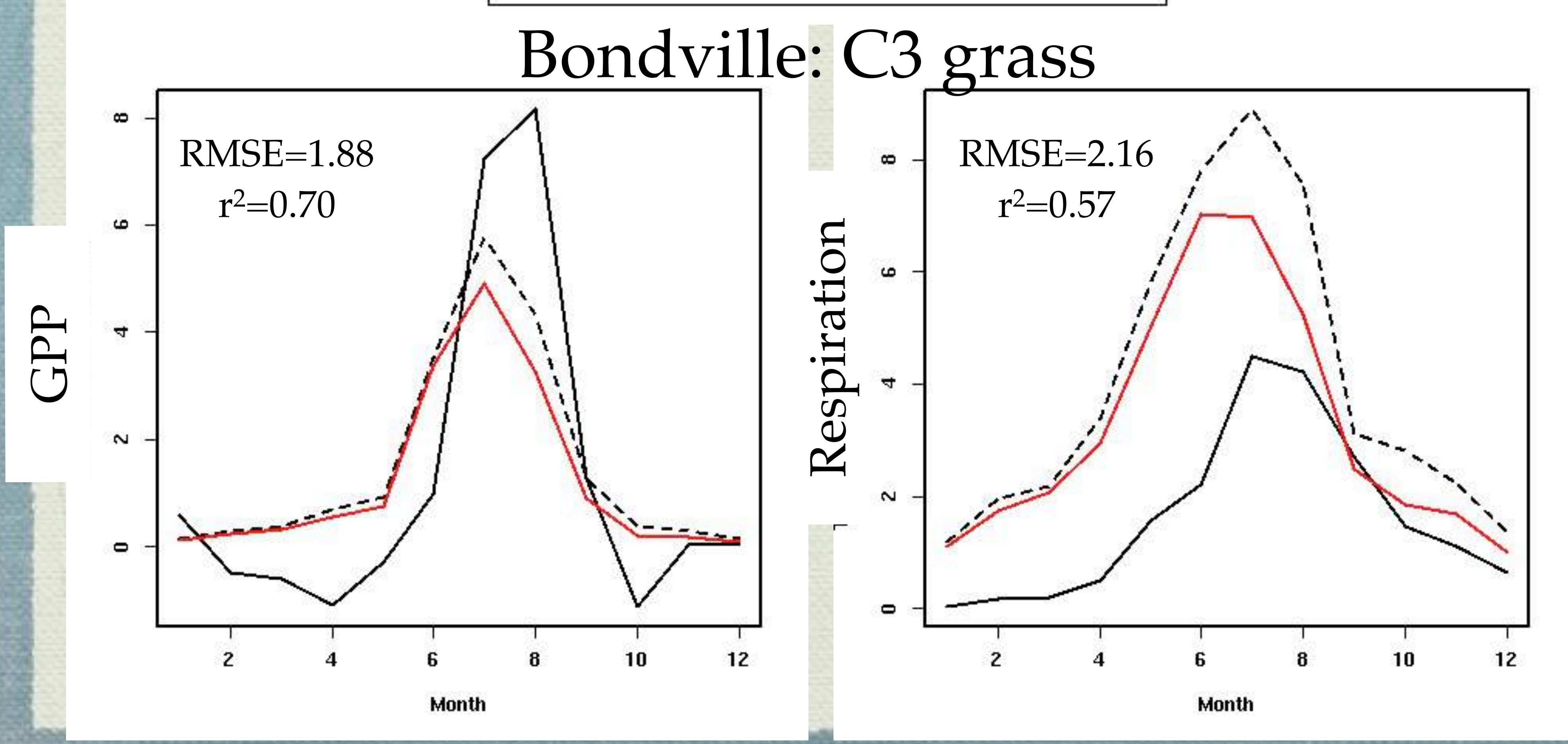
Conclusions

- Huge dataset provides insight into leaf investments into assimilation versus longevity.
- New Vcmax shows promise for photosynthesis but respiration is too high.
- Amazon broadleaf evergreen trees: assimilation is too low, and seasonal cycles are wrong. Maybe too much soil moisture stress, other controls on respiration, etc.
- Lots of testing, data analysis, and parameter optimization left!

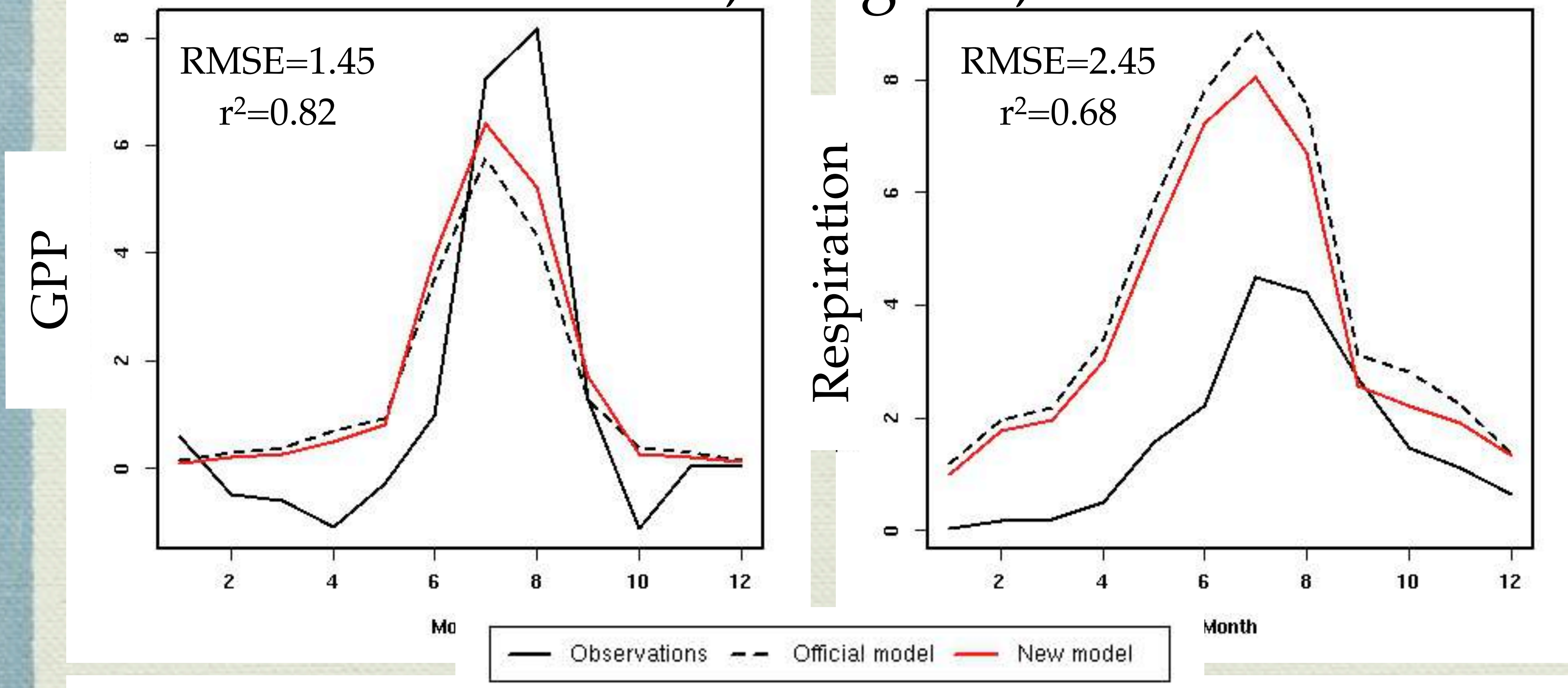

A) ES-ES1: ENF
B) US-Bo1: Cro
C) CA-Oas: DBF
D) IT-Col: DBF
E) US-MMS: DBF
F) RU-Ylr: DNF
G) ID-Pag: EBF
H) BR-Sa1: EBF
I) BR-Ma2: EBF
J) BR-Ji2: EBF
K) FI-Hyy: ENF
L) DE-Tha: ENF
M) US-Fpe: Gra
N) BR-Sa2: Gra
O) JP-Tom: DNF
P) US-Ha1: DBF
Q) JP-Tak: DBF
R) RU-Che: Shr
S) ML-AgS: Shr
T) IT-Pia: Shr
U) CA-Mer: Shr
V) ZA-Kru: Gra
W) ES-LMa: Shr
X) AU-Fogg: Gra
Y) CG-Tch: Gra
Z) US-Ton: Shr
AA) FI-Kaa: Gra
BB) NE-WaM: Cro
90N
60N
30N
0
30S
60S
90S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180
0 1 2 3 4 5 6 7 8 9 10 11 12
1 Evergreen Needleleaf
2 Evergreen Broadleaf
3 Deciduous Needleleaf
4 Deciduous Broadleaf
5 Mixed Cover
6 Woodland
7 Wooded Grass
8 Closed Shrubland
9 Open Shrubland
10 Grassland
11 Cropland
12 Bare Ground

Thank you

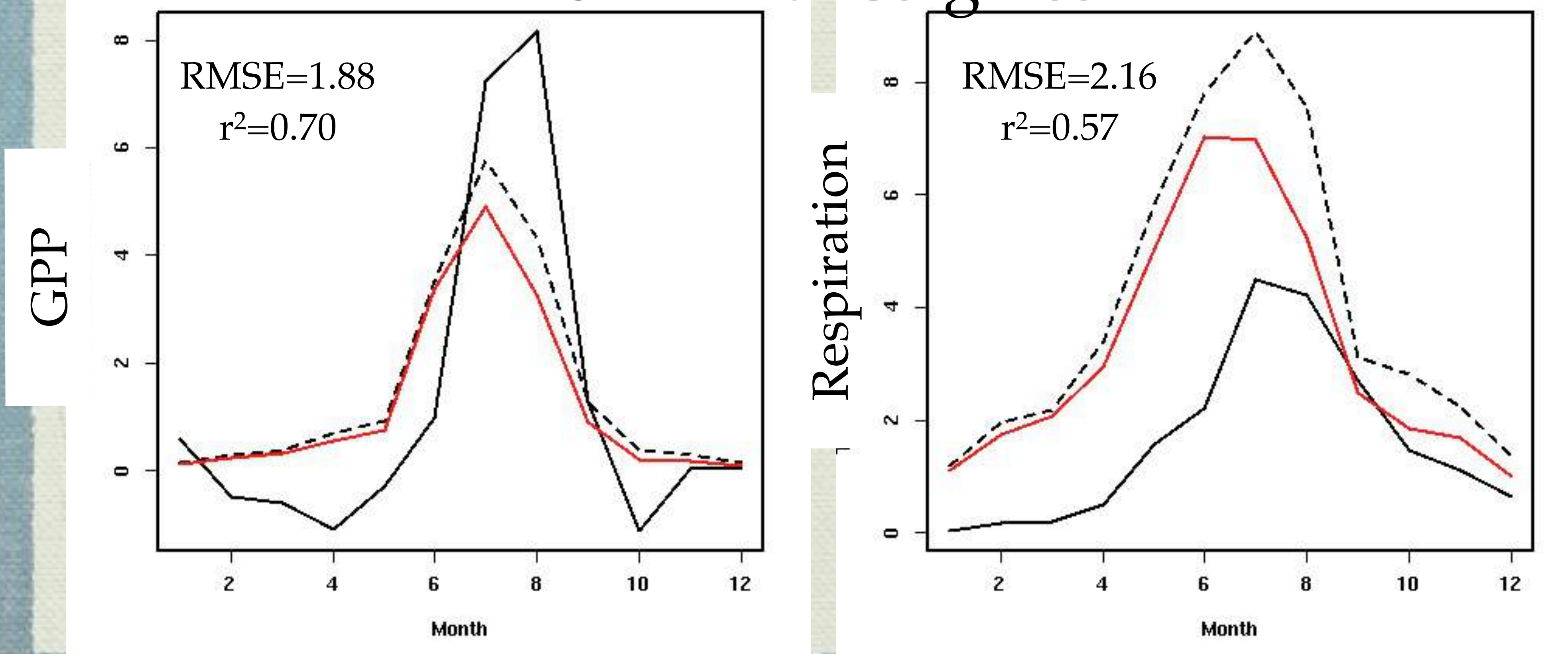

Bondville: New, C3 grass
RMSE=1.45
r²=0.82
GPP
RMSE=2.73
r²=0.71
Respiration
Month
Observations
Official model
New model


Bondville: C3 grass
RMSE=1.88
r²=0.70
GPP
RMSE=2.16
r²=0.57
Respiration
Month
Month

Bondville: New, C3 grass, Reduced fd



Bondville: C3 grass



Why?

- Average values for broadleaf or shrub doesn't capture deciduous vs/ evergreen characteristics.
- If JULES GPP seems low, start with photosynthesis.