Global FLUXNET data-oriented models improve canopy processes in the Community Land Model (CLM4)

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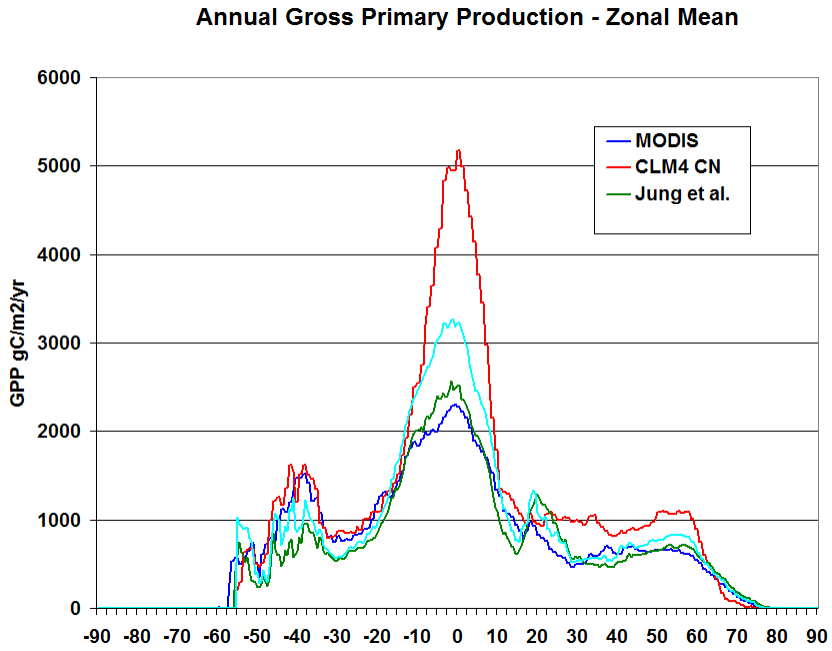
Is there a problem?
GPP and LAI biases in CLM4CN

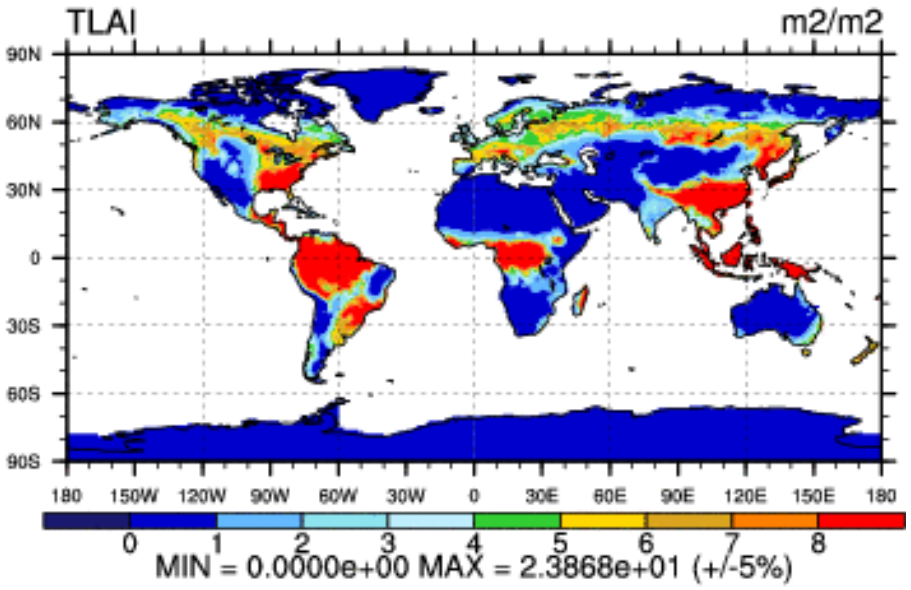


GPP is high compared with FLUXNET-derived product

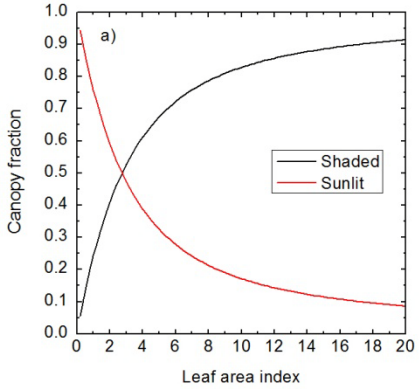
See Beer et al. (2010) Science, in press, for an analysis of FLUXNET GPP and multi-model comparison (Science Express [online], 8 July)

Leaf area index is high:
Amazon average LAI = 11-12
Maximum grid cell average = 24
But fAPAR ~ 0.95 at LAI ~ 6

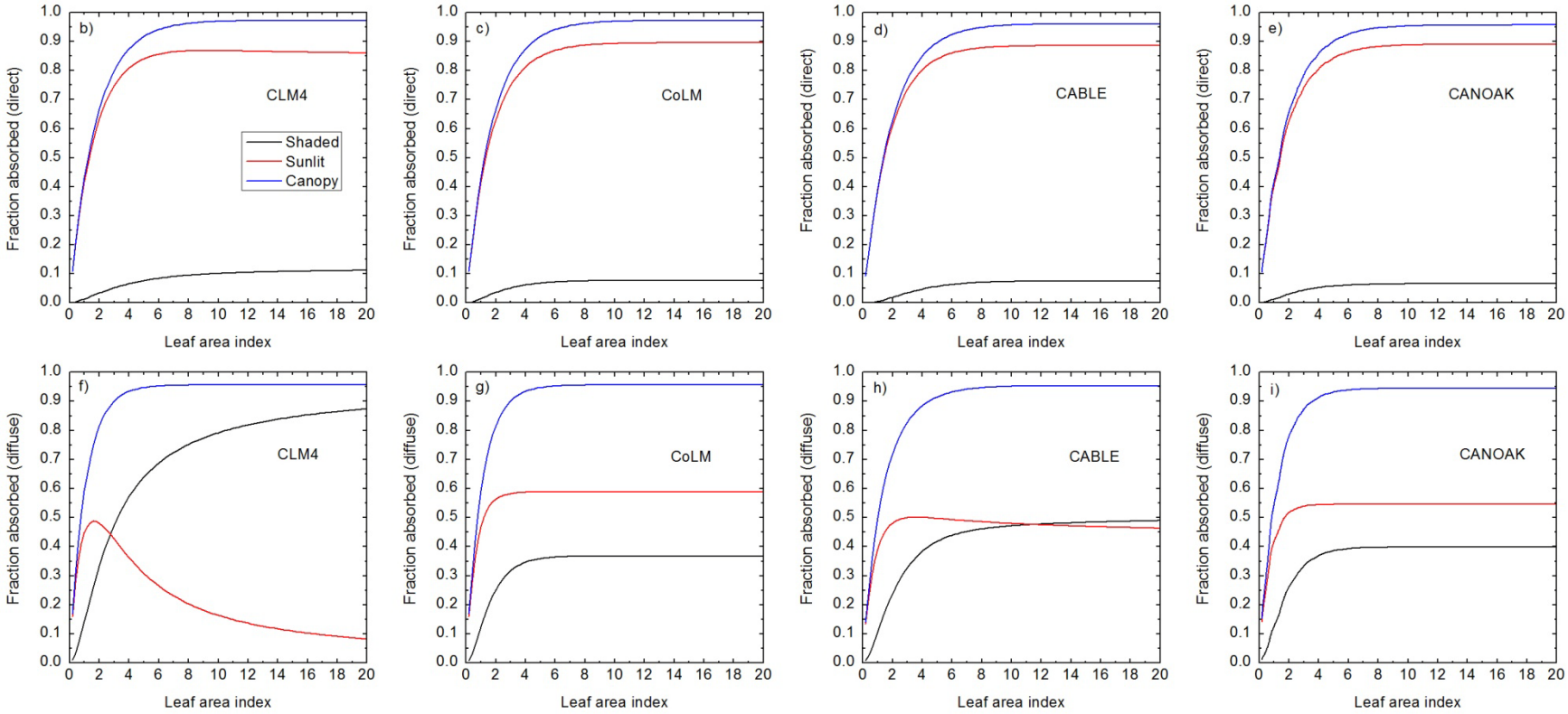
Jun/Jul/Aug Leaf Area Index



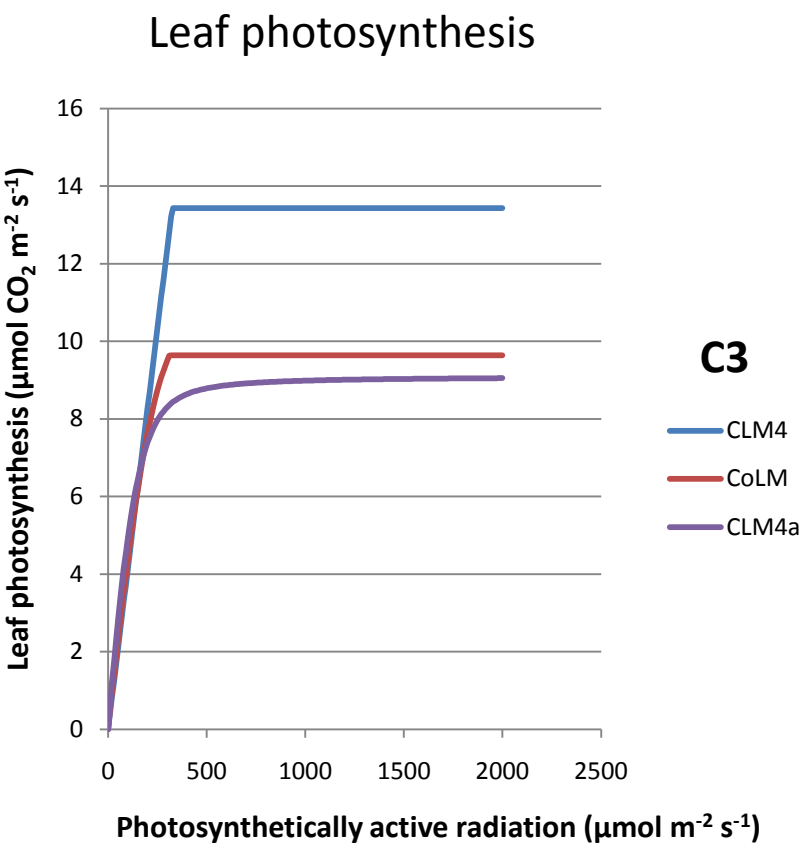
Radiative transfer

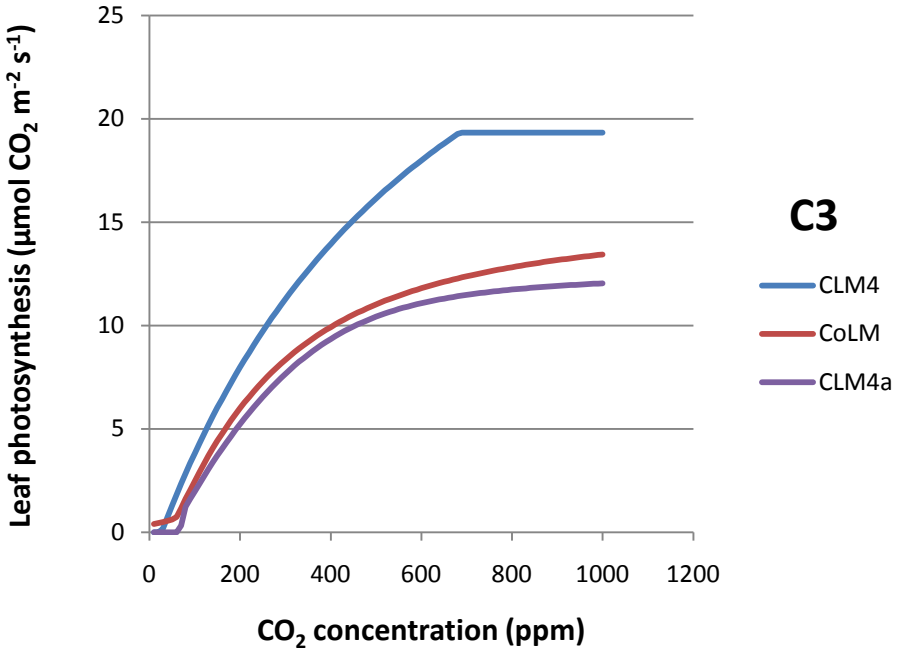


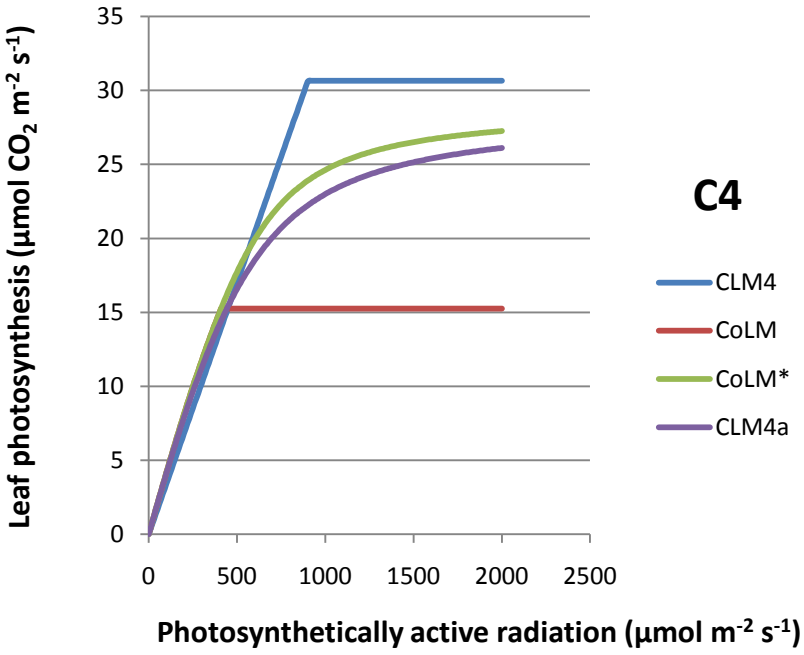
- Shaded fraction of canopy increases with greater LAI
- CLM4 has similar absorption of direct beam and diffuse radiation as in other models, but the partitioning of absorbed radiation between sunlit and shaded leaves is inconsistent
- This is most evident for diffuse radiation



Recommendation: Adopt CoLM two-stream sunlit/shaded numerical solution



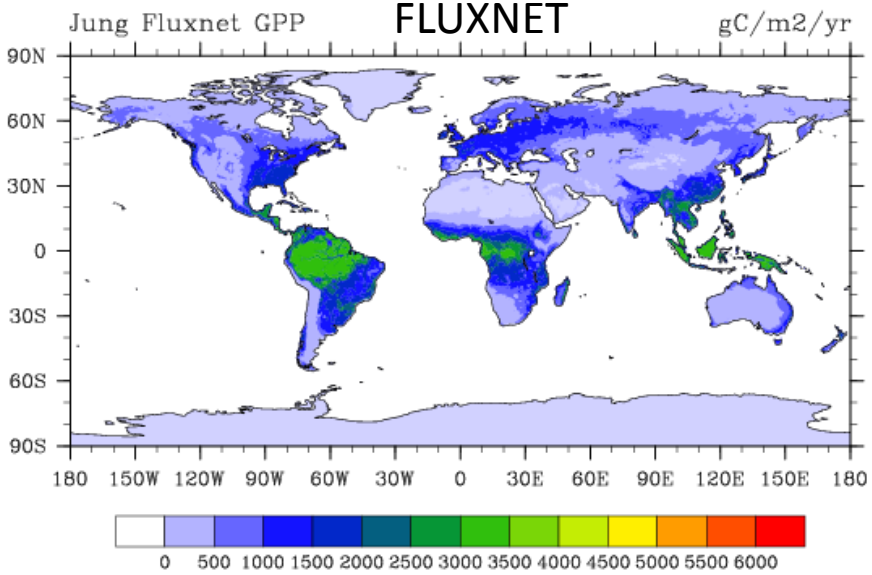




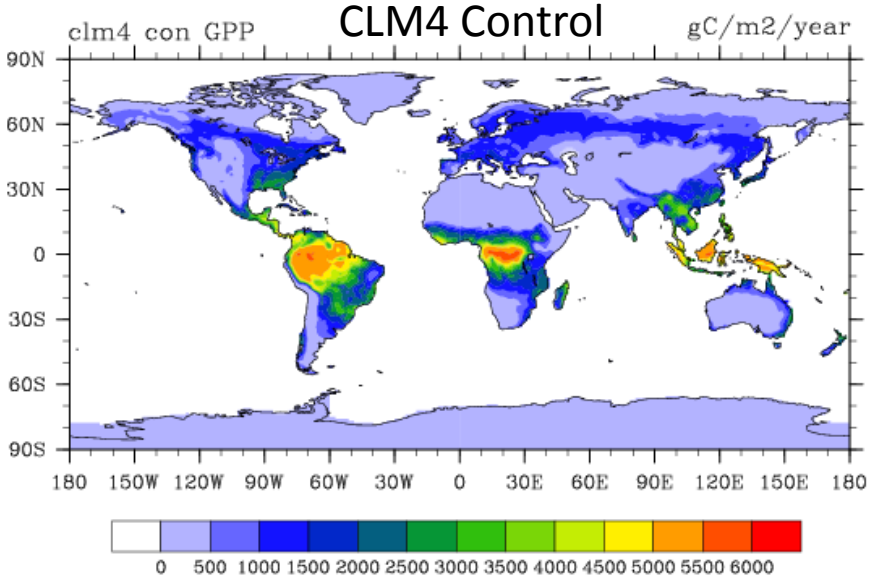
- Synthesis-derived leaf photosynthesis parameters and equations (CLM4a) reduce photosynthetic rate (similar result obtained for CoLM)
- Have not yet re-evaluated photosynthetic parameter Vcmax
- Recommendation: Adopt CLM4a parameterization

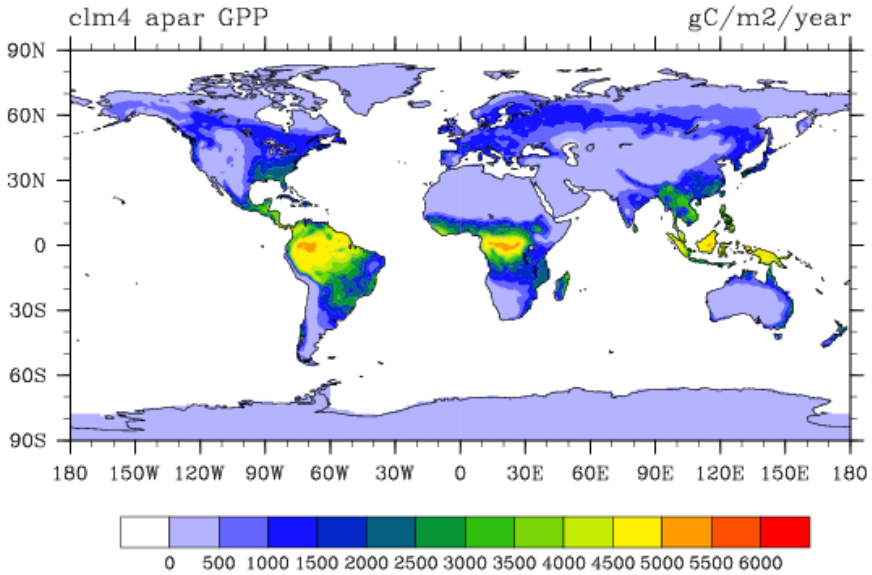
Annual GPP

~120 Pg C yr^{-1}
FLUXNET

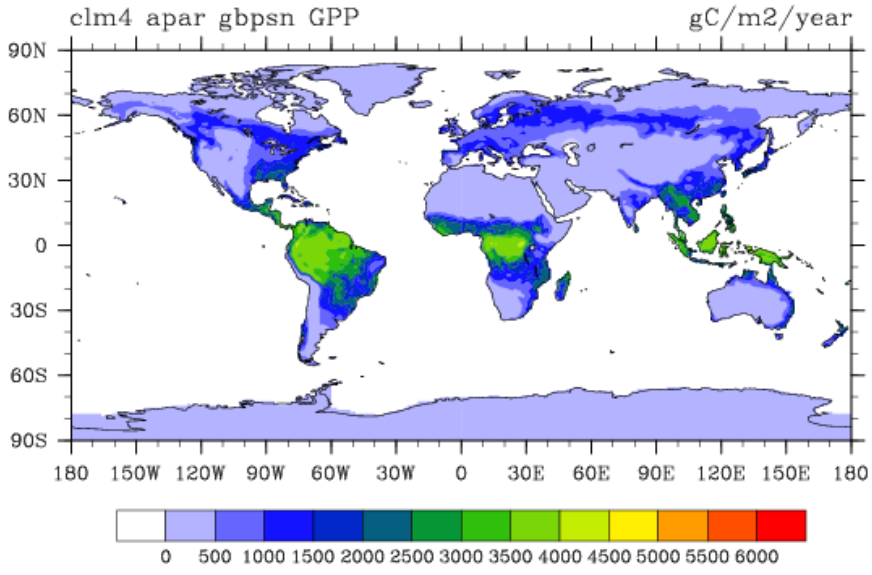


165 Pg C yr^{-1}
CLM4 Control

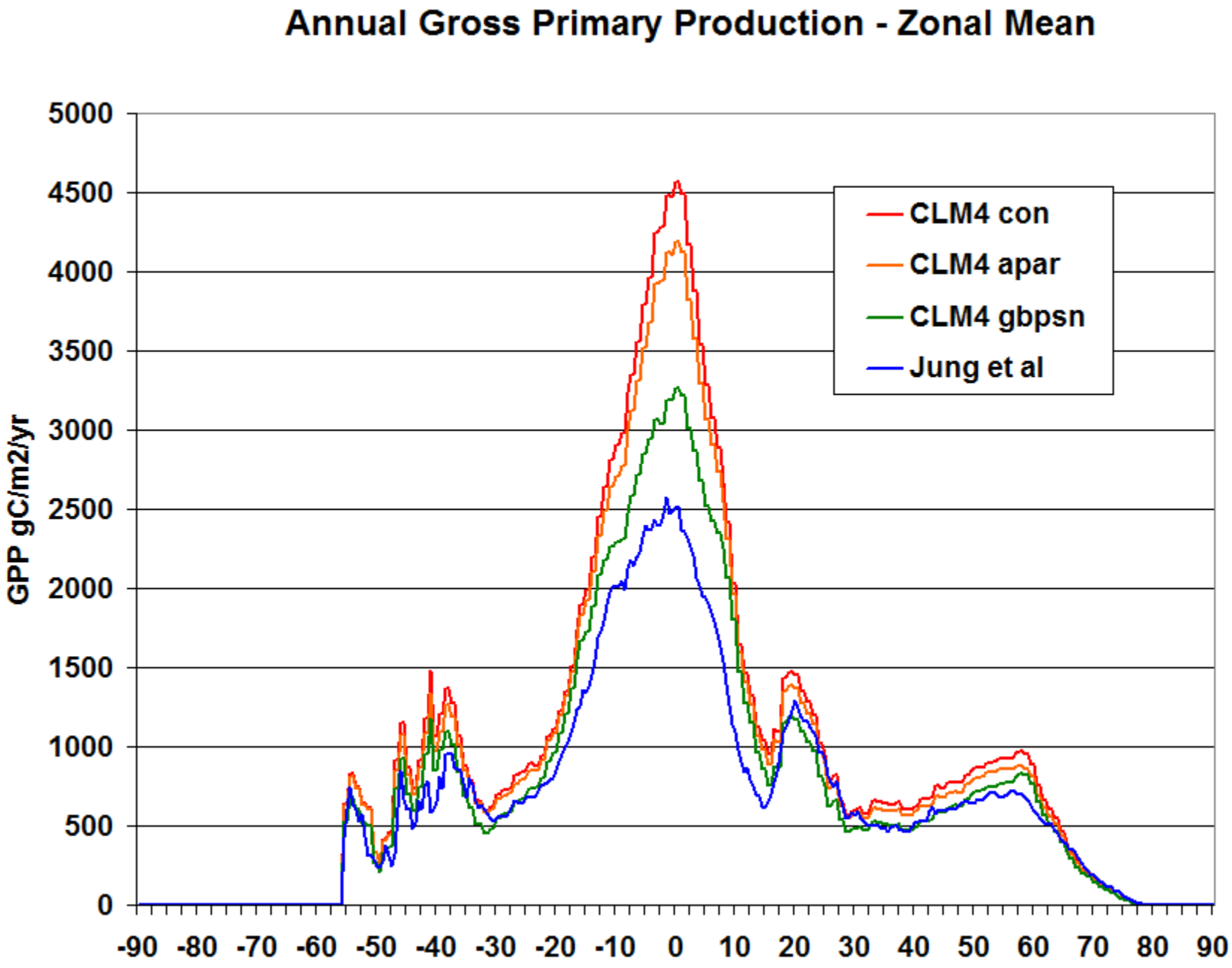




155 Pg C yr^{-1}
Sunlit/shaded radiation

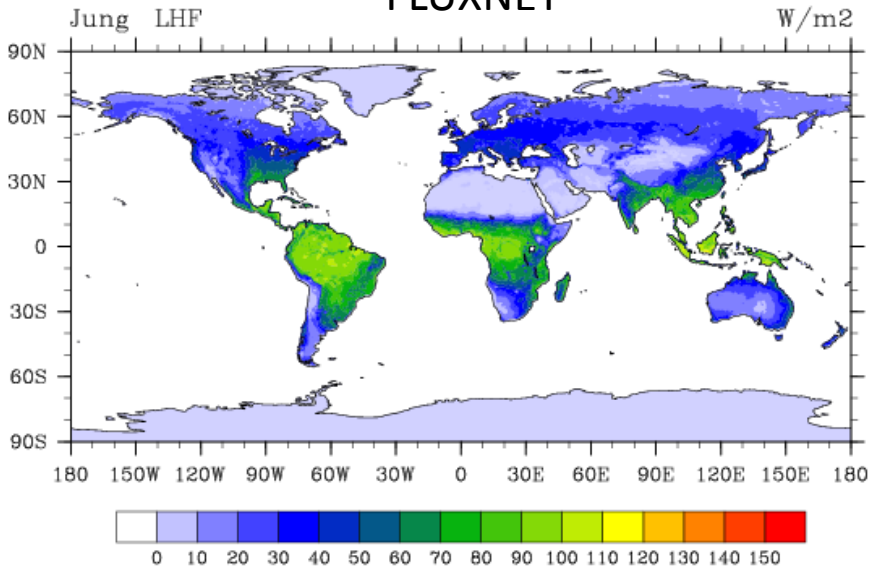


132 Pg C yr^{-1}
Radiation + Photosynthesis

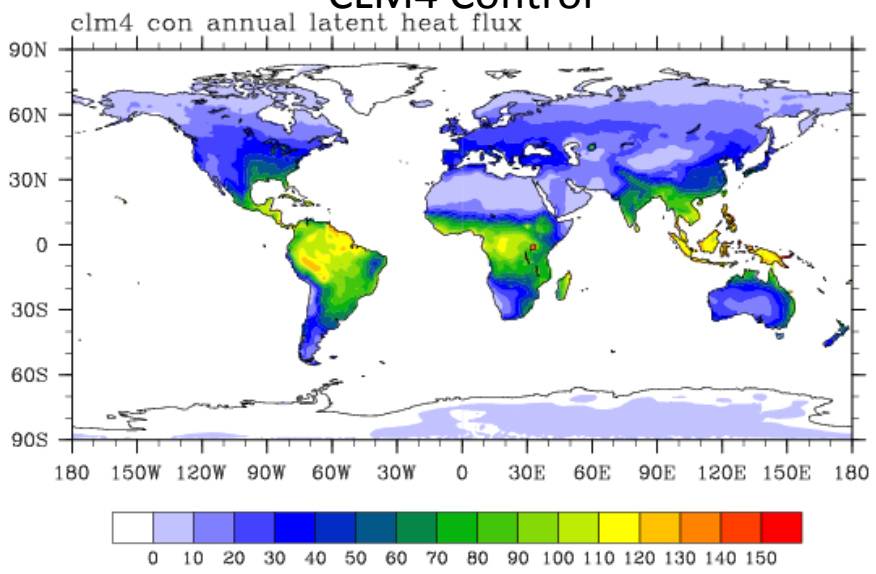

Annual Gross Primary Production - Zonal Mean
GPP gC/m2/yr
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
CLM4 con
CLM4 apar
CLM4 gbpsn
Jung et al

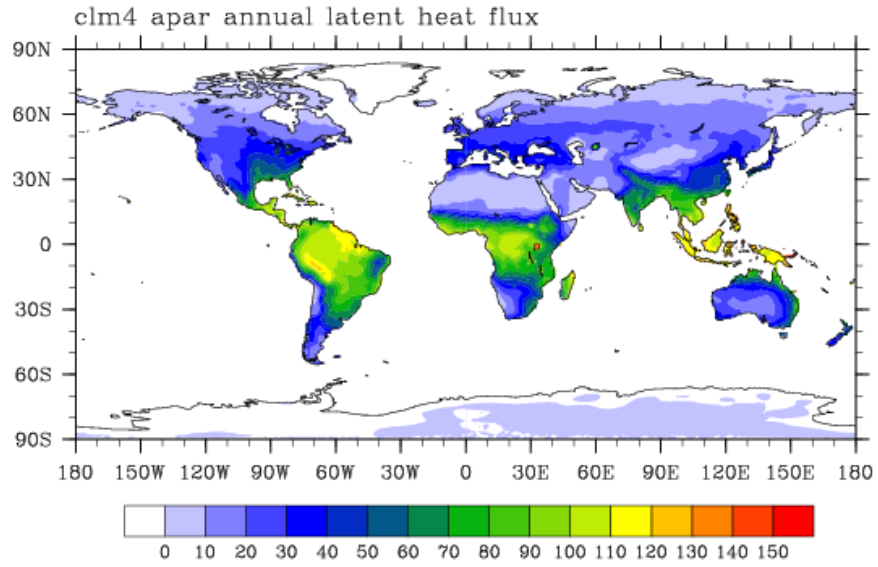
Annual latent heat flux

FLUXNET

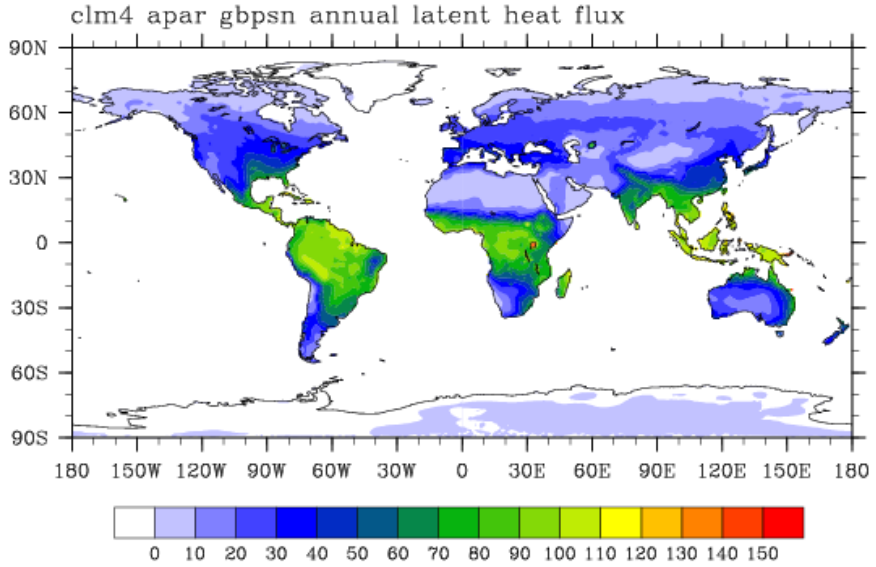


CLM4 Control

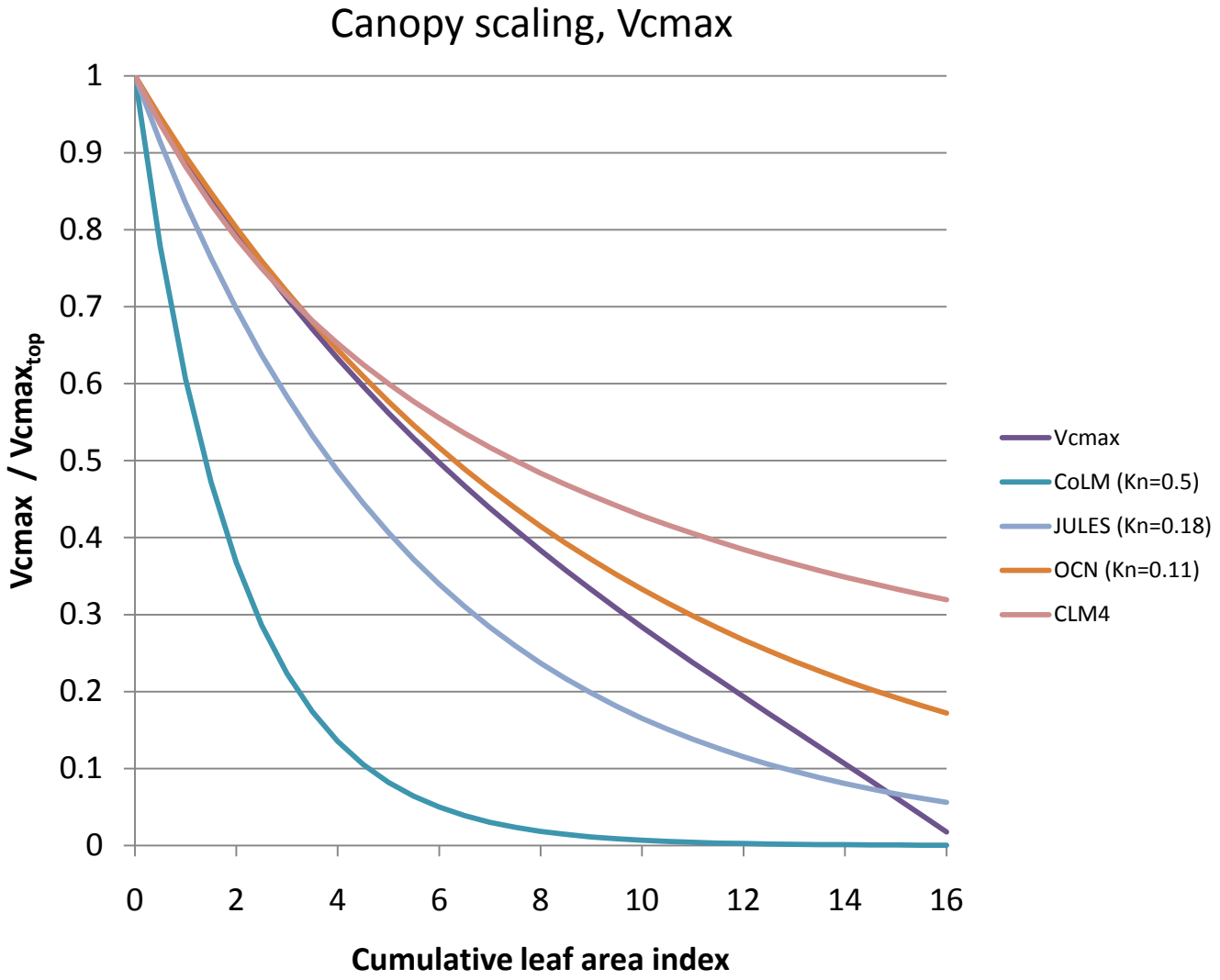




Sunlit/shaded radiation



Radiation + Photosynthesis



- Over a realistic range of LAI, CLM4 and OCN are similar and compare favorably with observations, but at high LAI CLM4 has high Vcmax
- CLM4 has no canopy scaling for shrubs, grasses, and crops (only for trees), but foliage N is observed to decrease with depth in the canopy for these PFTs
- Recommendation: Adopt OCN parameterization for all PFTs

Summary of Simulations

Gross Primary Production (GPP) and Net Primary Production (NPP) from various offline CLM4 simulations (PgC/yr). CO2 at 379 ppm except for transient runs.

		GPP	NPP
CLM4 doc-umentation	[1]CLM4 (Lawrence et al. 2010)	174	
	[1]CLM4CN (Lawrence et al. 2010, equilibrium)	181	63
	[1]CLM4CN (transient, Thornton's)	163	57
This study	[1,6,9]CLM4 (photosynthesis control) Control	165	
	[1,6,9]CLM4+Dai radiation Sunlit/shaded radiation	155	
	[1,6,9]CLM4+Dai radiation+Bonan photosynthesis Radiation + Photosynthesis	132	
	[1,6,9]CLM4+Dai radiation+Bonan photosynthesis+Colmsclkd Radiation + Photosynthesis + Scaling	130	
	[8,9]CLM4CN+Dai radiation+Bonan photosynthesis+Colmsclkd2, equilibrium CLM4CN+Radiation+Photosynthesis+Scaling	159	56

[1]1985-2004
[2]1949-1952
[6]ccsm4_0_rel07, transient CO2, aerosols
[8]ccsm4_0_rel07, last year of simulation (422)
[9]revised fnitr

Potential vs. actual leaf carboxylation rate, Vcmax25

		CLM4'	
Plant functional type	V_{cmax25}, potential	f(N)	V_{cmax25}, actual
NET Temperate	61	0.90	55
NET Boreal	54	0.77	42
NDT Boreal	57	0.51	29
BET Tropical	72	0.91	66
BET temperate	72	0.71	51
BDT tropical	52	0.69	36
BDT temperate	52	0.58	30
BDT boreal	52	0.77	40
BES temperate	72	0.50	36
BDS temperate	52	0.57	30
BDS boreal	52	0.37	19
C_3 arctic grass	52	0.40	21
C_3 grass	52	0.50	26
C_4 grass	52	0.49	25
Crop1	57	0.55	31
Crop2	57	0.55	31

CLM4' from Bonan and Levis (2010)

Still to do … re-evaluate and better define Vcmax

CLM-CN uses a potential Vcmax

CLM uses an actual Vcmax

f(N) is derived from a CLM-CN simulation as

$f(N)=GPP_{actual} / GPP_{potential}$

As $GPP_{potential}$ decreases, f(N) will increase