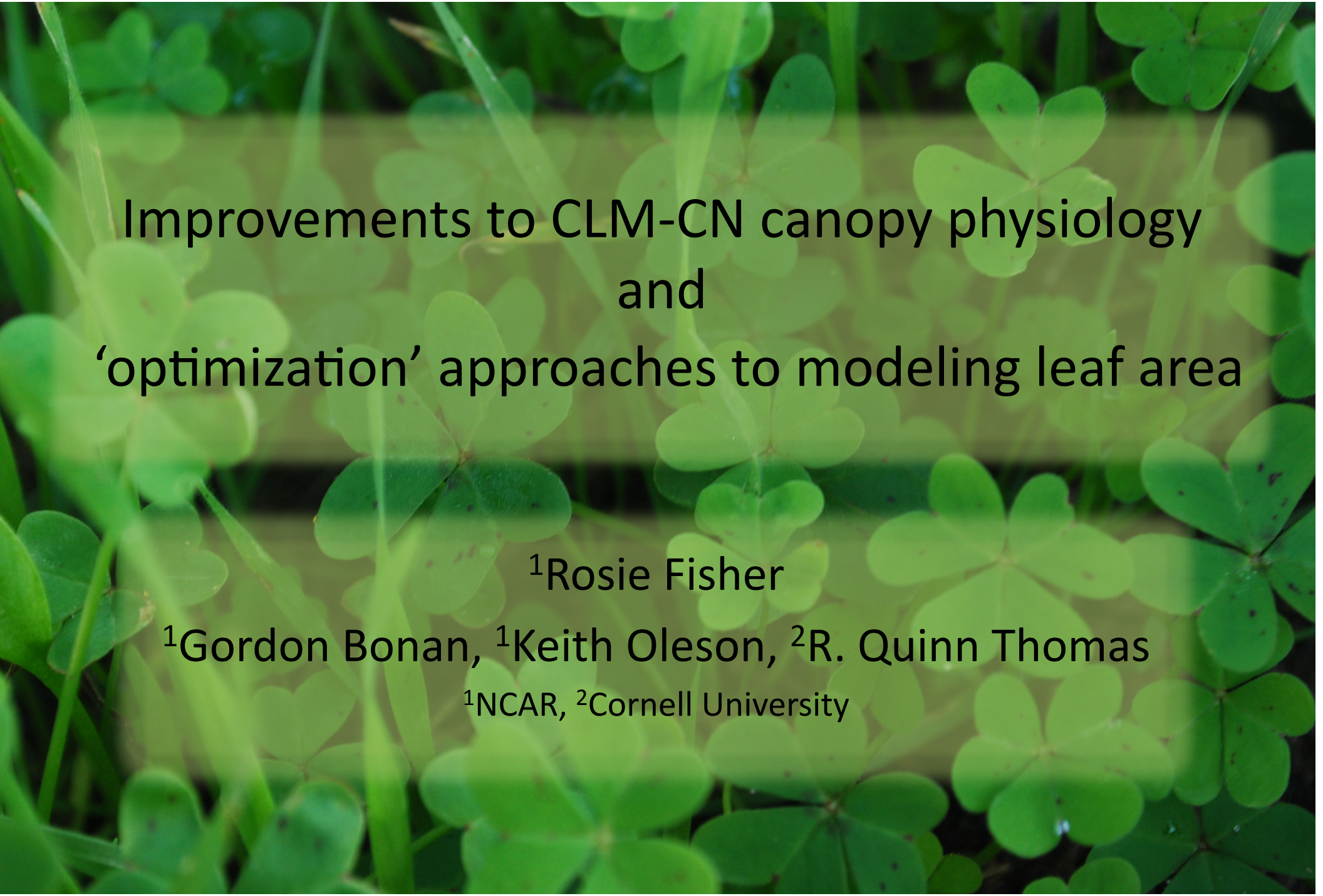


Improvements to CLM-CN canopy physiology and 'optimization' approaches to modeling leaf area

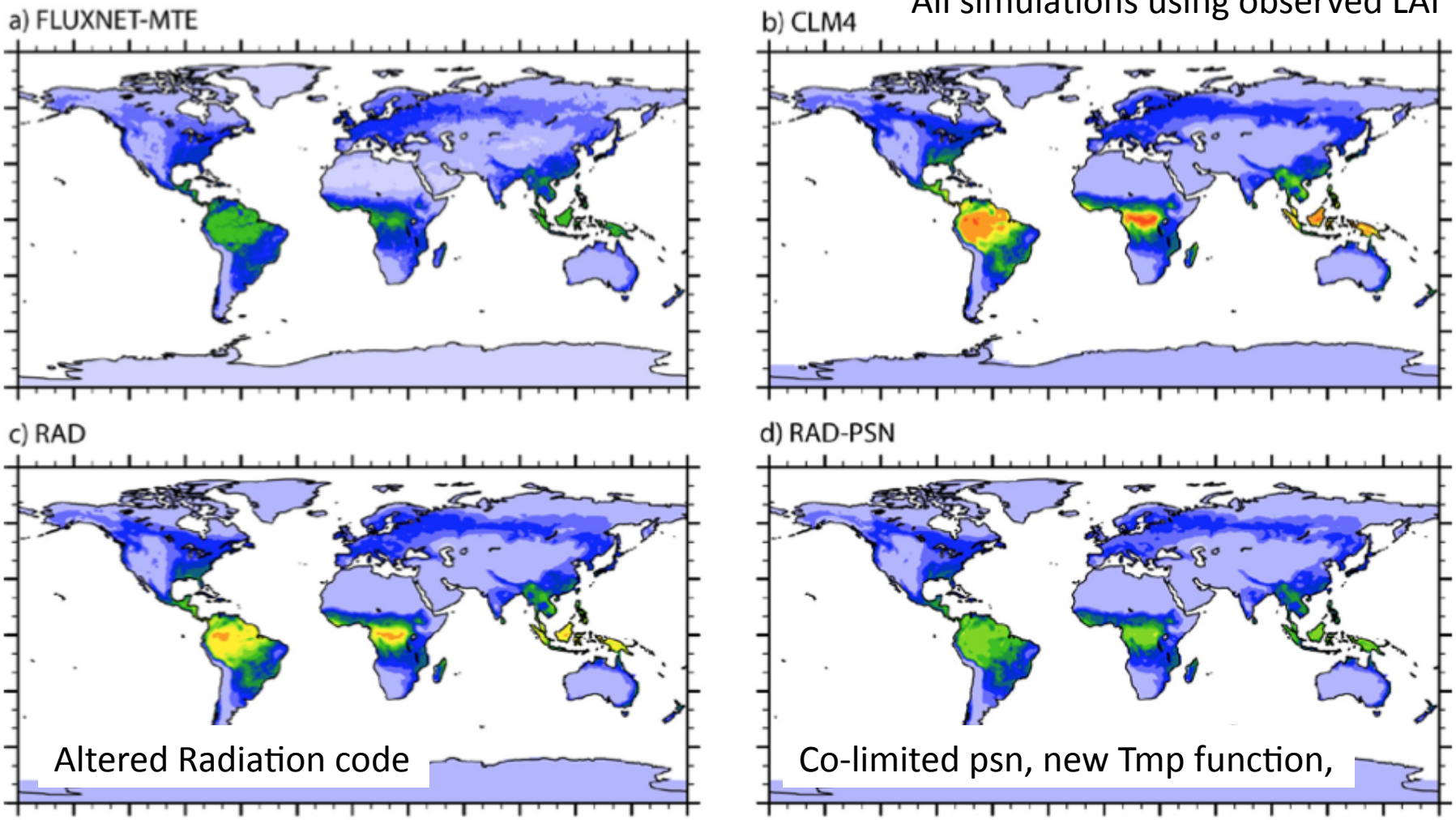
[1]Rosie Fisher

[1]Gordon Bonan, [1]Keith Oleson, [2]R. Quinn Thomas

[1]NCAR, [2]Cornell University

Improved GPP model…

All simulations using observed LAI



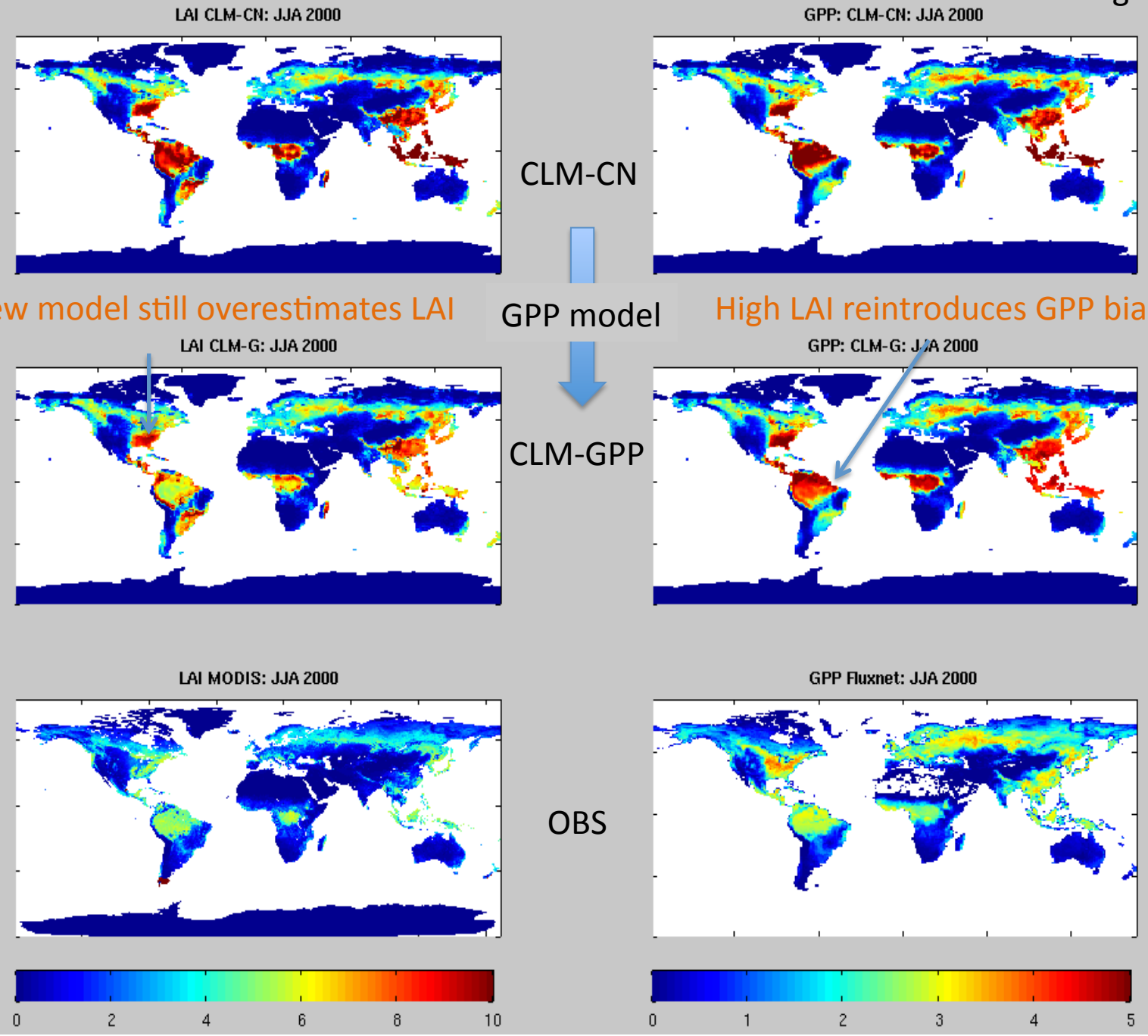
Bonan et al. in press

Does the new GPP fix the high LAI?

- Start with CLM-CN standard spin-up
- Add in new GPP & Radiation routines
- Turn on prognostic CLM-CN LAI
- Test GPP -> NPP -> LAI -> GPP feedback

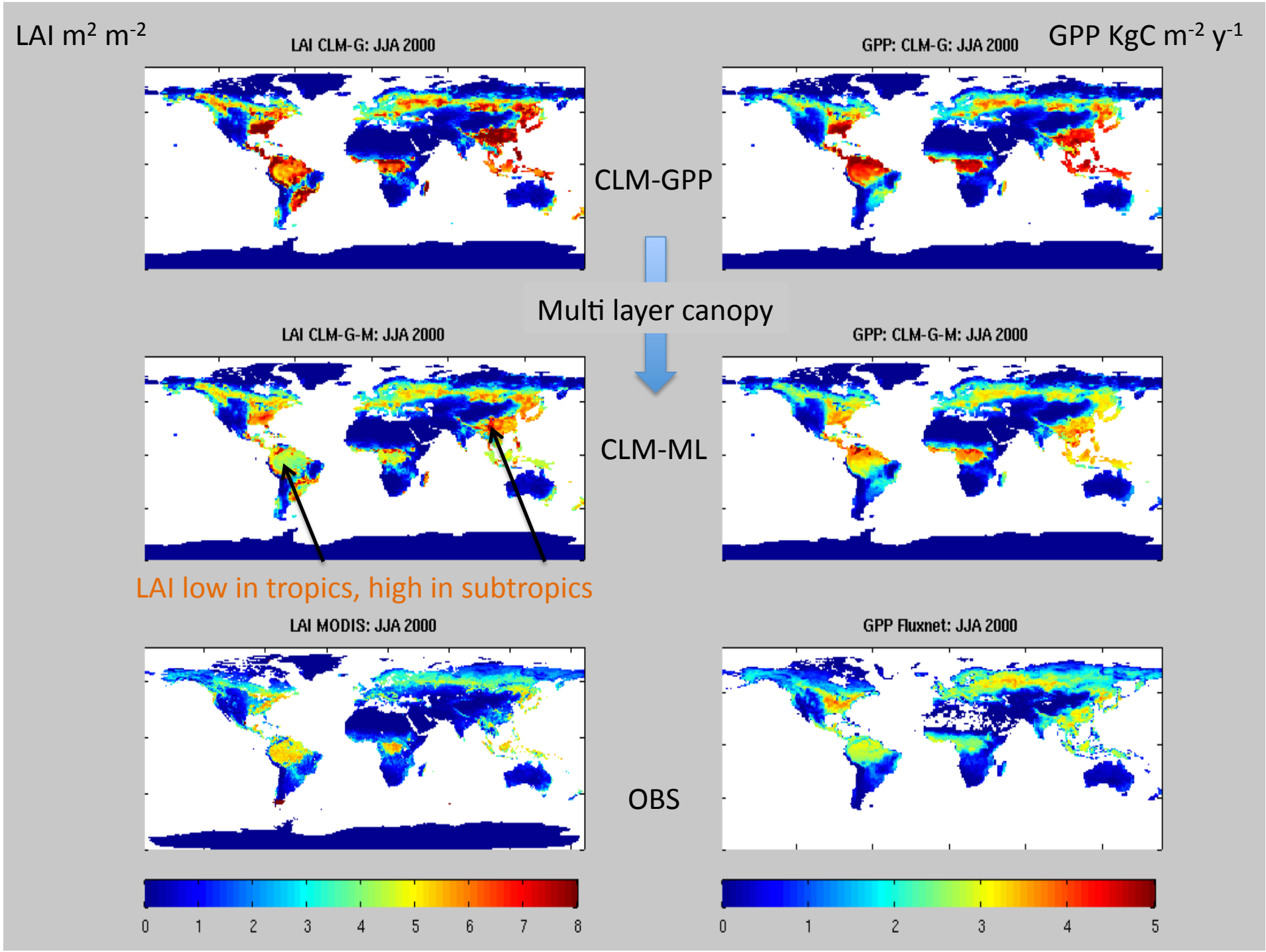
LAI m^2 m^{-2}

GPP KgC m^{-2} y^{-1}



Modification 1: Multi-layer canopy

- How do leaves persist at such low light levels?
- Resolved canopy at each 0.25 leaf area unit
- 2-stream equations (Direct & Diffuse radiation)
- Sunlit and Shaded leaf fraction
- Multi-layer leaf respiration calculations
- Vertical profile of leaf Nitrogen
  - $N = N_0 \exp^{-k\mathrm{N.LAIa}}$
  - $k_N = 0.11$ (Lloyd et al. 2009)

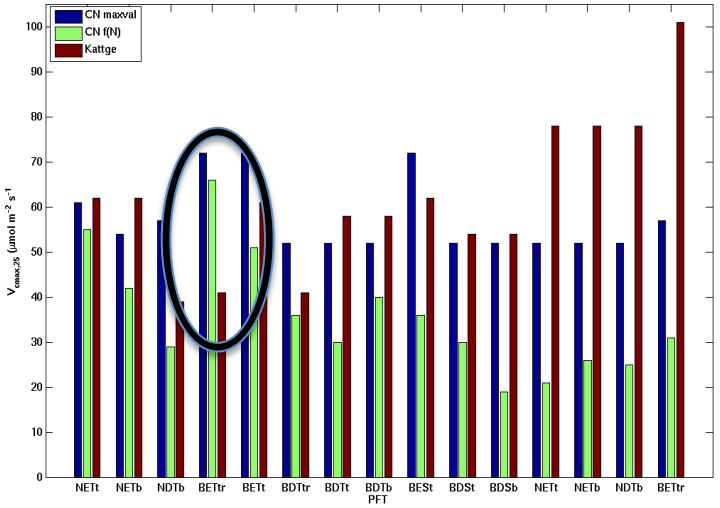

LAI m^2 m^{-2}
LAI CLM-G: JJA 2000
GPP: CLM-G: JJA 2000
GPP KgC m^{-2} y^{-1}
CLM-GPP
Multi layer canopy
LAI CLM-G-M: JJA 2000
GPP: CLM-G-M: JJA 2000
CLM-ML
LAI low in tropics, high in subtropics
LAI MODIS: JJA 2000
GPP Fluxnet: JJA 2000
OBS
0 1 2 3 4 5 6 7 8
0 1 2 3 4 5

Modification 2: Physiologically Consistent $V_{c,max}$

Global Change Biology (2009) **15**, 976–991, doi: 10.1111/j.1365-2486.2008.01744.x

Quantifying photosynthetic capacity and its relationship to leaf nitrogen content for global-scale terrestrial biosphere models

JENS KATTGE*, WOLFGANG KNORR†, THOMAS RADDATZ‡ and CHRISTIAN WIRTH*
*Max-Planck-Institute for Biogeochemistry, Hans-Knöll Street 10, 07745 Jena, Germany, †QUEST, Department of Earth Sciences, University of Bristol, Wills Memorial Building, Queen's Road, BS8 1RJ, UK, ‡Max Planck Institute for Meteorology, Bundesstraße 53, 20146 Hamburg, Germany



- 723 $V_{c,max}$ observations constrain N vs. $V_{c,max}$ (N use efficiency)
- 1966 leaf N observations account for sampling biases in $V_{c,max}$
- Best constrained $V_{c,max}$ estimates available…
- Should include the impacts of N limitation
- Leaf C:N ratio also altered for consistency

Modification 3: Respiratory acclimation

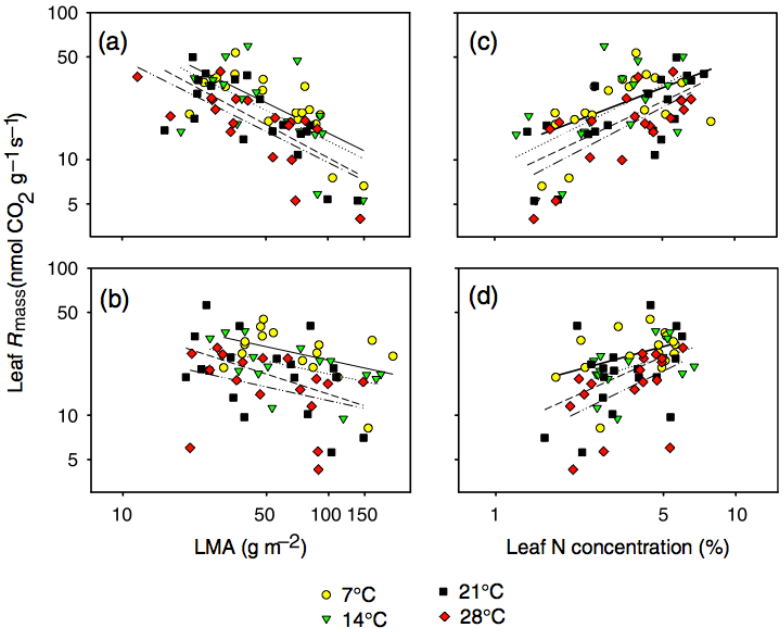
Global Change Biology (2008) **14**, 2709–2726, doi: 10.1111/j.1365-2486.2008.01664.x

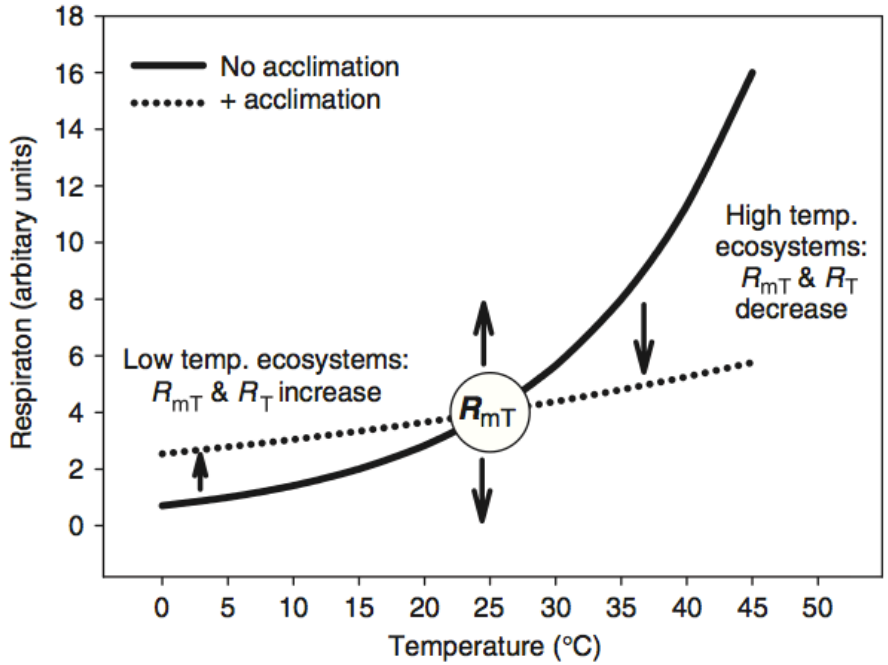
Using temperature-dependent changes in leaf scaling relationships to quantitatively account for thermal acclimation of respiration in a coupled global climate–vegetation model

OWEN K. ATKIN*, LINDSEY J. ATKINSON†, ROSIE A. FISHER‡, CATHERINE D. CAMPBELL§, JOANA ZARAGOZA-CASTELLS¶, JON W. PITCHFORD¶, F. IAN WOODWARD‡ and VAUGHAN HURRY§

$$R_{acc} = R \times 10^{C \times (T - T_{ref})}$$

C = -0.007935

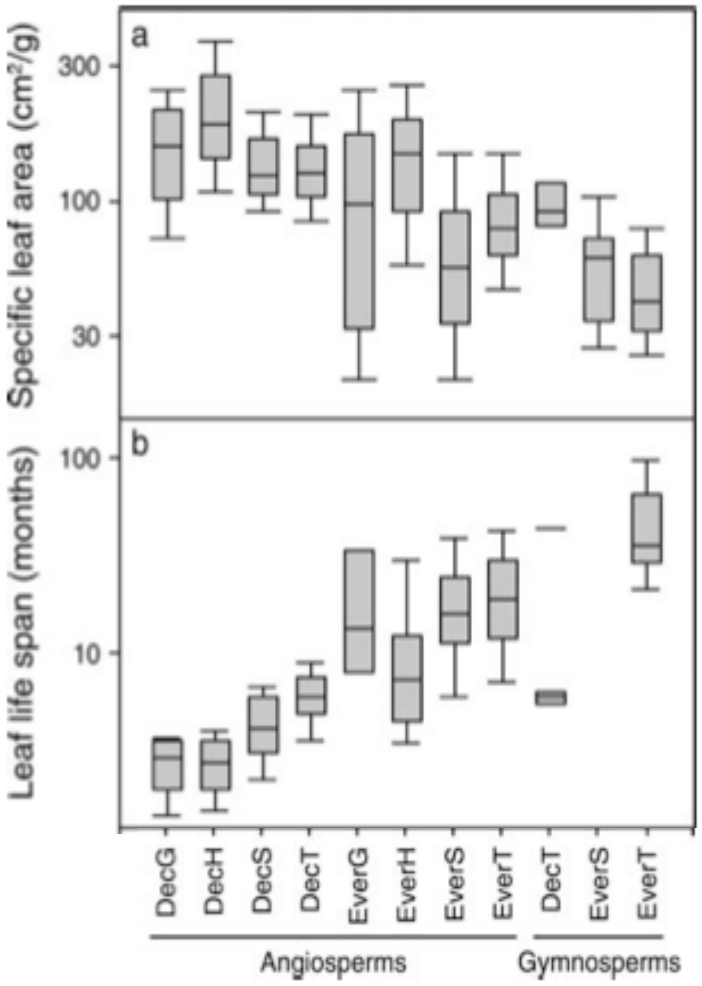


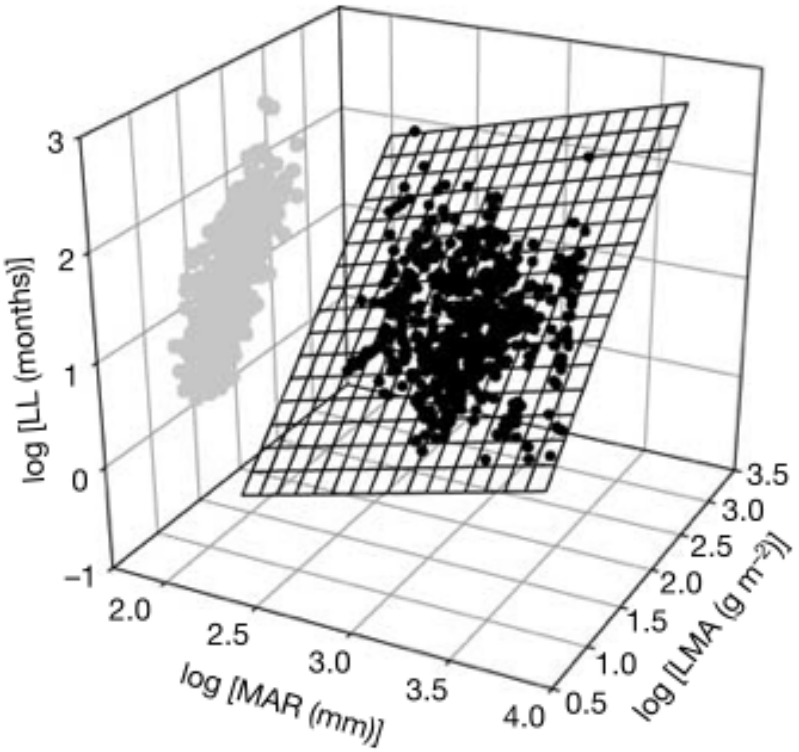


Modification 4: Data-derived leaf economics

PREDICTING LEAF PHYSIOLOGY FROM SIMPLE PLANT AND CLIMATE ATTRIBUTES: A GLOBAL GLOPNET ANALYSIS

Peter B. Reich,[1,3] Ian J. Wright,[2] and Christopher H. Lusk[2]



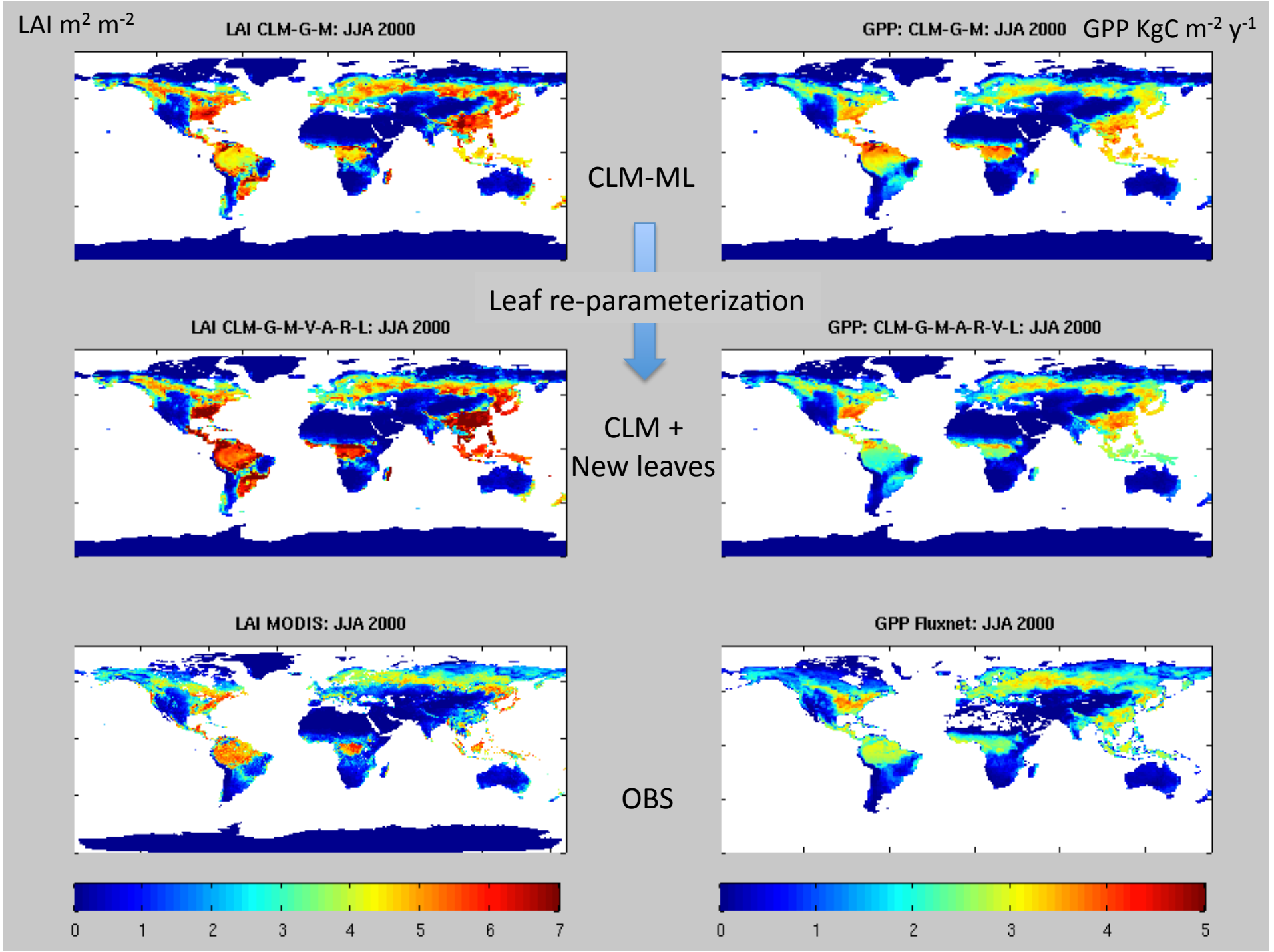


Wright et al. Nature 2004.

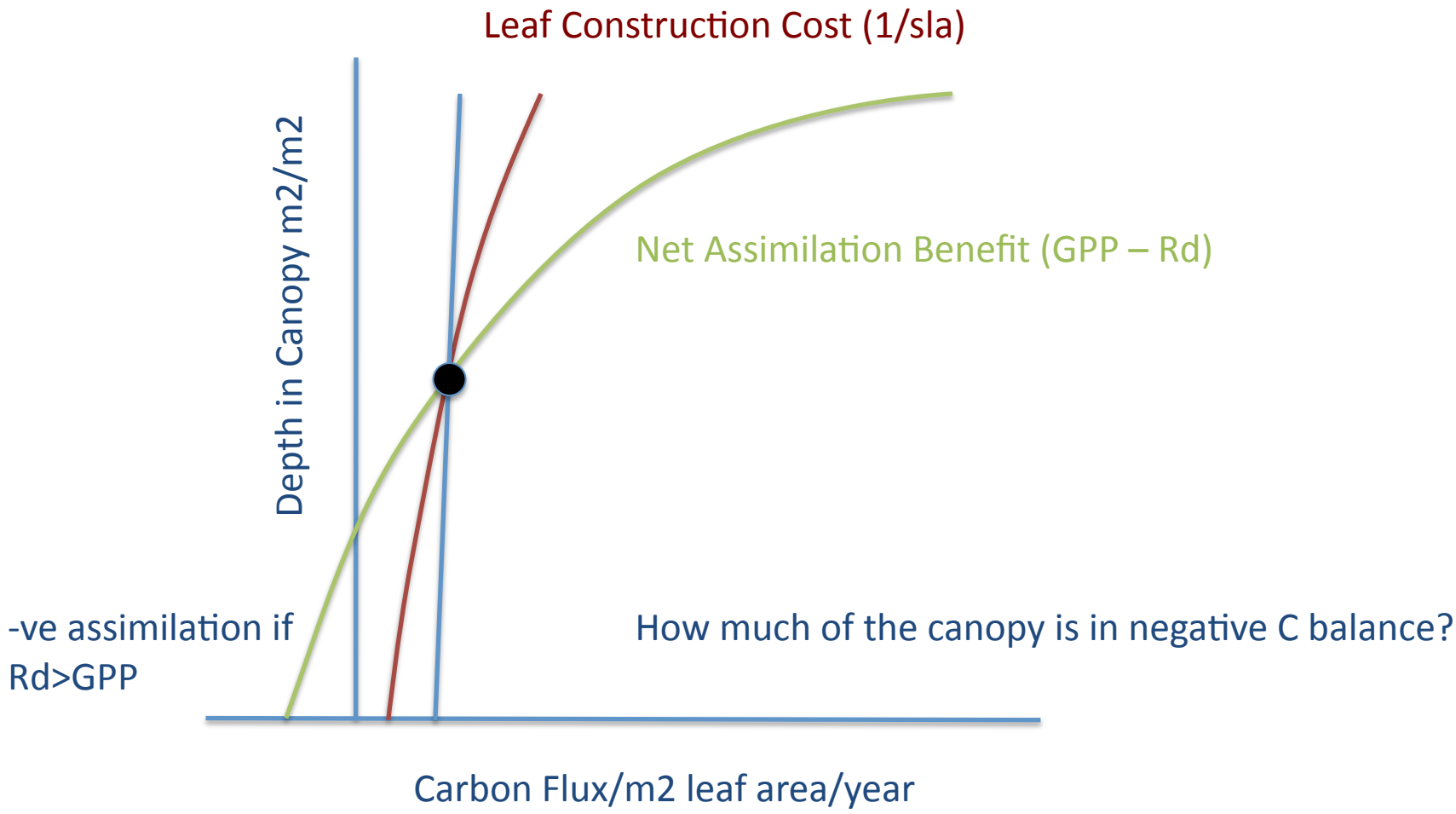
Modification 5: Respiration changes

- Existing model (Bonan et al. 2011):
- R_d = 0.015 or 0.025 x $V_{c,max}$

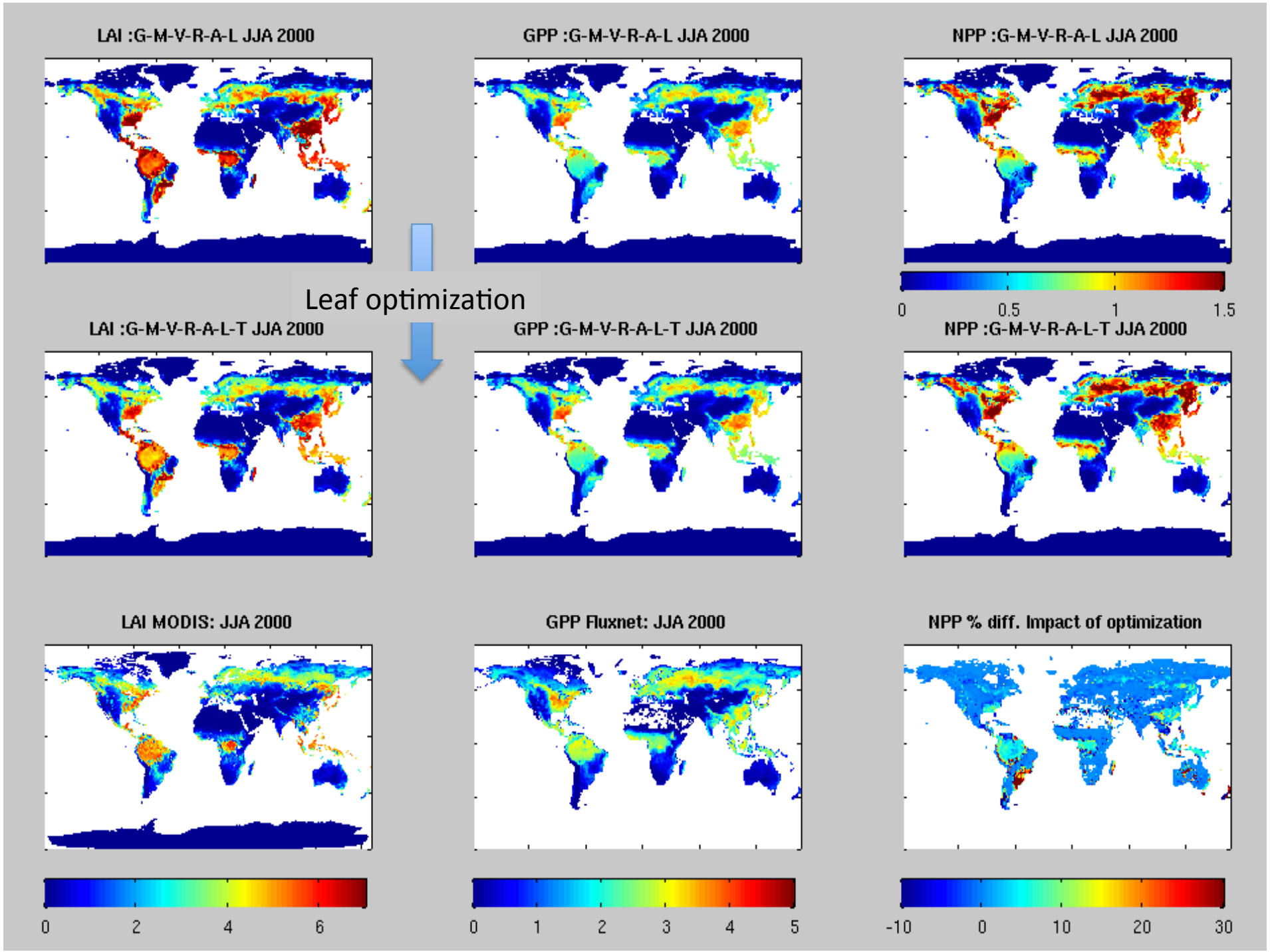
- Revert to previous Nitrogen mass based respiration values, that are lower…
- M. Ryan, 1991. Ecological Applications, 1(2), 157-167.
- 2.525e-6 gC/(gN s)
- (probably will be updated to Reich 2009 analysis)


LAI m^2 m^{-2}
LAI CLM-G-M: JJA 2000
GPP: CLM-G-M: JJA 2000
GPP KgC m^{-2} y^{-1}
CLM-ML
Leaf re-parameterization
LAI CLM-G-M-V-A-R-L: JJA 2000
GPP: CLM-G-M-A-R-V-L: JJA 2000
CLM +
New leaves
LAI MODIS: JJA 2000
GPP Fluxnet: JJA 2000
OBS
0 1 2 3 4 5 6 7
0 1 2 3 4 5

Modification 6: Leaf optimization

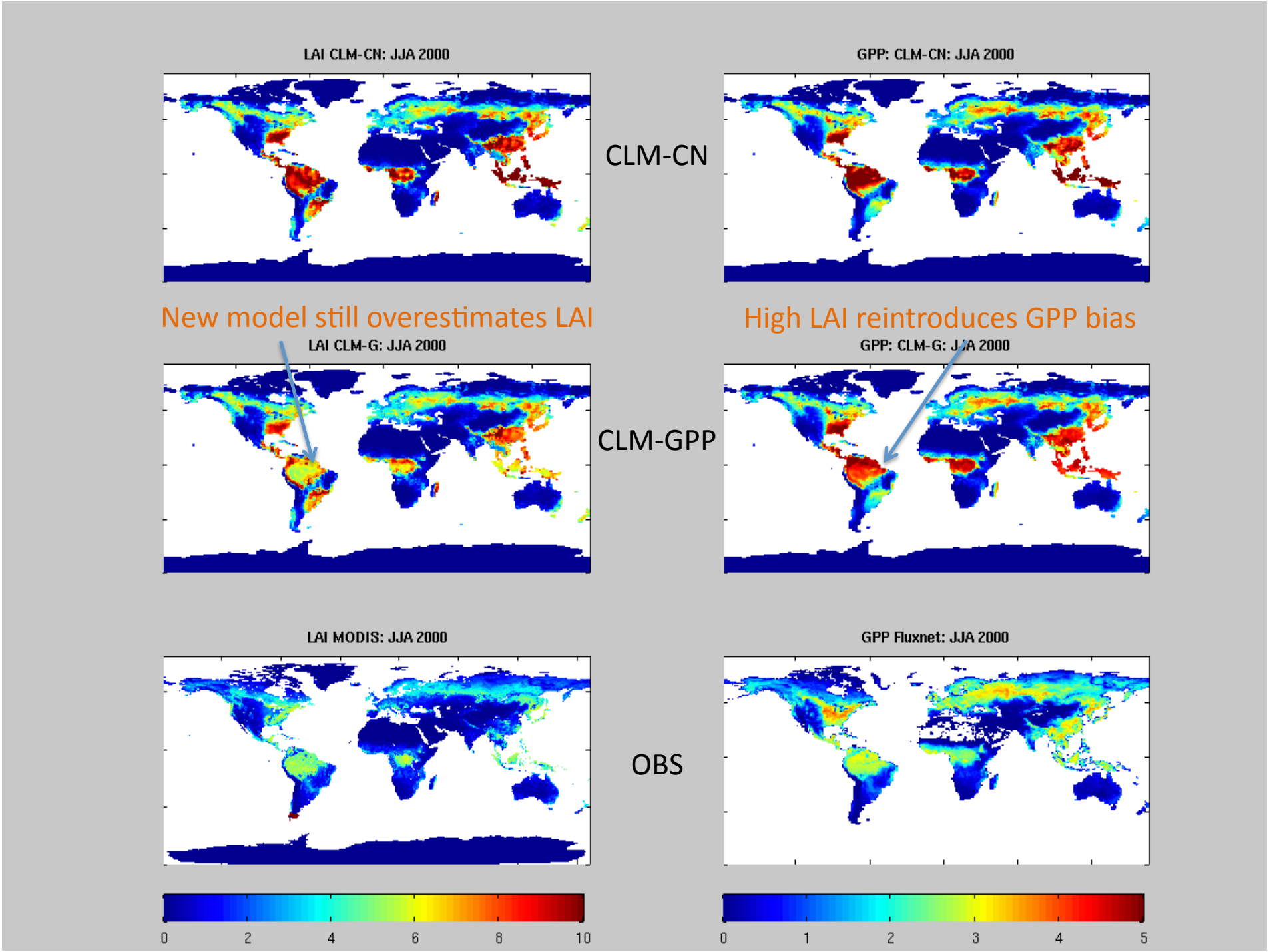


LAI can be limited either by the balance of allocation and turnover, or by light limitation


LAI :G-M-V-R-A-L JJA 2000
GPP :G-M-V-R-A-L JJA 2000
NPP :G-M-V-R-A-L JJA 2000
0
0.5
1
1.5
Leaf optimization
LAI :G-M-V-R-A-L-T JJA 2000
GPP :G-M-V-R-A-L-T JJA 2000
NPP :G-M-V-R-A-L-T JJA 2000
LAI MODIS: JJA 2000
GPP Fluxnet: JJA 2000
NPP % diff. Impact of optimization
0
2
4
6
0
1
2
3
4
5
-10
0
10
20
30

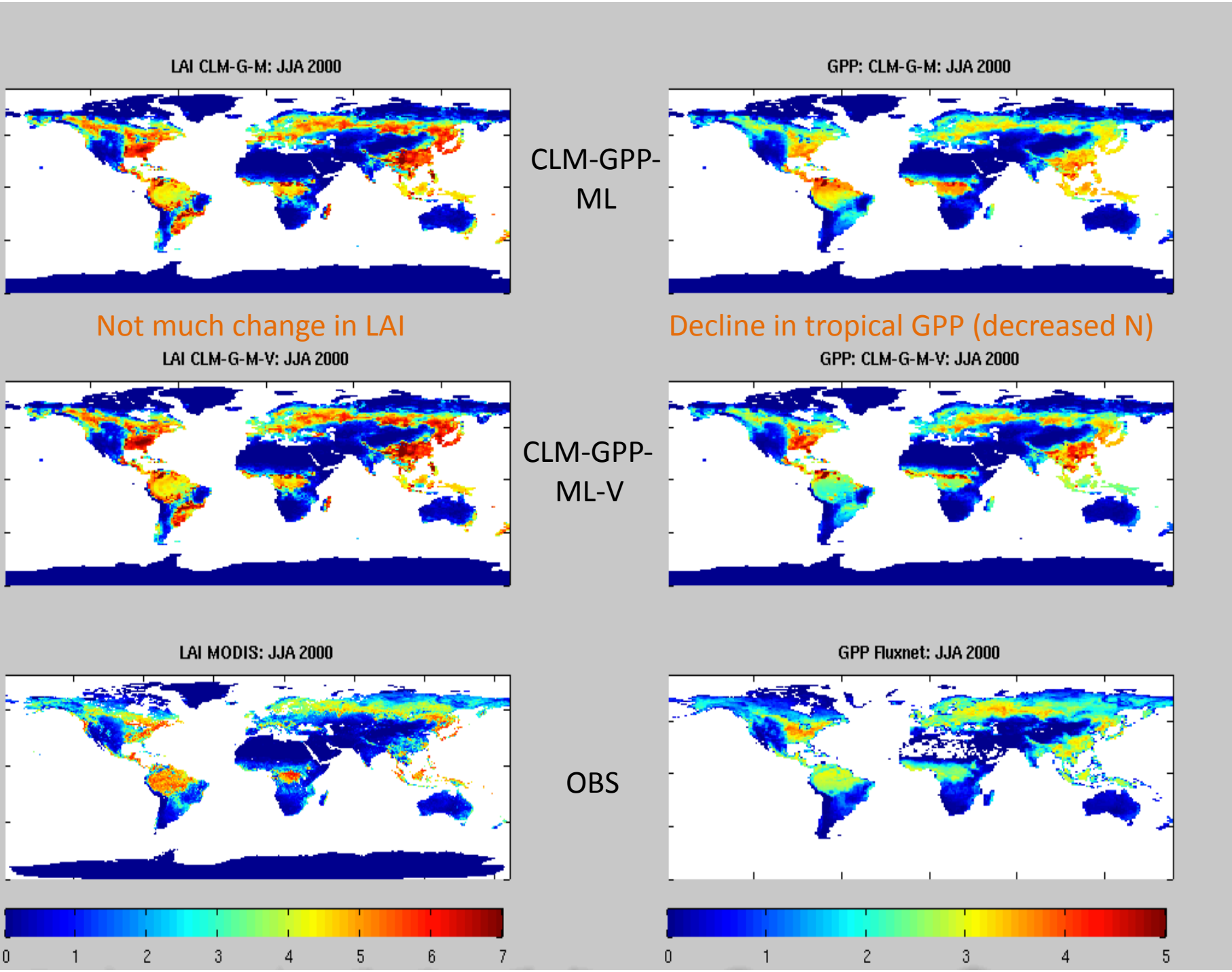
Conclusions

- Improvements can be made to the CLM canopy physiology by using global leaf trait analyses (Kattge, GLOPNET, Wright, Reich, Atkins)...
- … and by using common sense. Removal of light limited leaves makes canopy more efficient
- Next steps:
  - Global respiration analysis (Reich 2009)
  - Transient behavior & N limitations
  - Increase range of benchmarks (ILAMB)
  - Entrain newer leaf trait datasets (TRY)
  - Optimal allocation of carbon and nitrogen
  - Ecosystem Demography

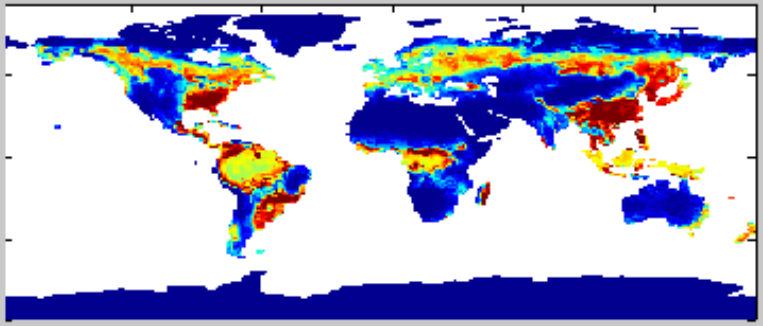

LAI CLM-CN: JJA 2000
GPP: CLM-CN: JJA 2000
CLM-CN
New model still overestimates LAI
High LAI reintroduces GPP bias
LAI CLM-G: JJA 2000
GPP: CLM-G: JJA 2000
CLM-GPP
LAI MODIS: JJA 2000
GPP Fluxnet: JJA 2000
OBS
0 2 4 6 8 10
0 1 2 3 4 5

Leaf Area Index simulation

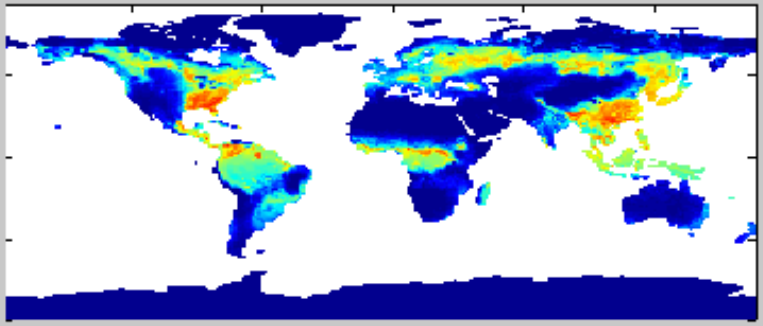
- AvailC => leafC + frootC + stemC + crootC
- Allocation ratios = 1+r:l+s:l(1+cr:s) = 1.0
- s:l = f(NPP), r:l = 1.0, cr:s = 0.1


LAI CLM-G-M: JJA 2000
GPP: CLM-G-M: JJA 2000
CLM-GPP-ML
Not much change in LAI
Decline in tropical GPP (decreased N)
LAI CLM-G-M-V: JJA 2000
GPP: CLM-G-M-V: JJA 2000
CLM-GPP-ML-V
LAI MODIS: JJA 2000
GPP Fluxnet: JJA 2000
OBS
0 1 2 3 4 5 6 7
0 1 2 3 4 5

LAI CLM-G-M-V-R: JJA 2000

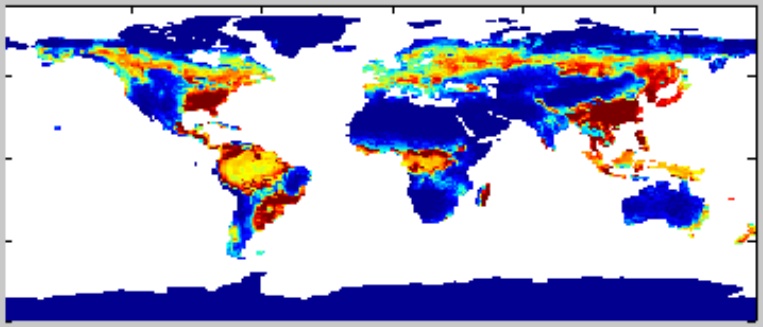


GPP: CLM-G-M-V-R: JJA 2000

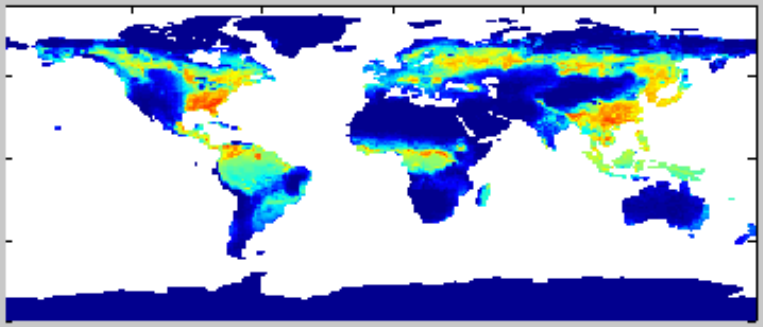


CLM-GPP-ML-V-R

LAI CLM-G-M-V-R-A: JJA 2000



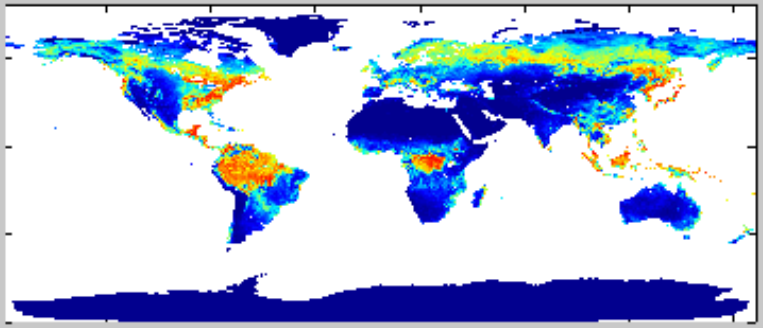
GPP: CLM-G-M-V-R-A: JJA 2000



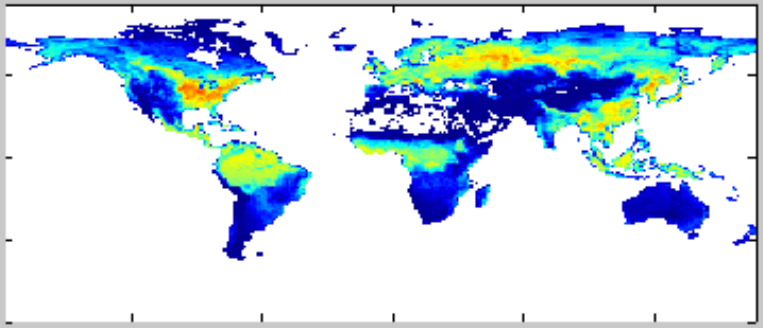
CLM-GPP-ML-V-R-A

Now there is too much LAI!

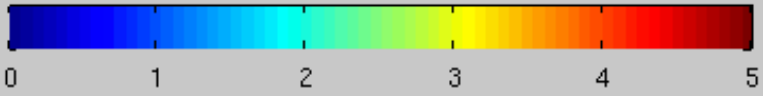
LAI MODIS: JJA 2000

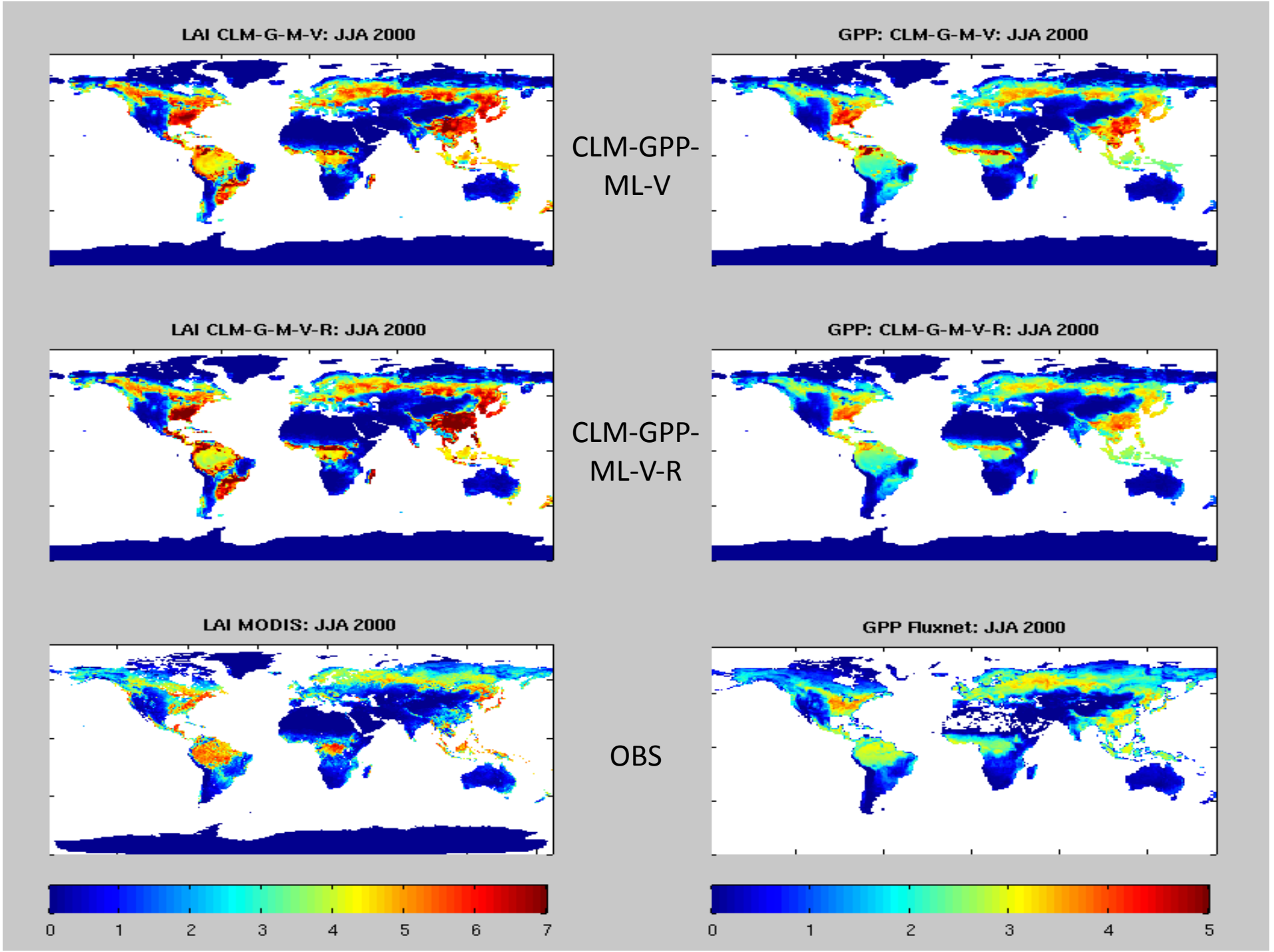


GPP Fluxnet: JJA 2000



OBS




LAI CLM-G-M-V: JJA 2000
GPP: CLM-G-M-V: JJA 2000
CLM-GPP-ML-V
LAI CLM-G-M-V-R: JJA 2000
GPP: CLM-G-M-V-R: JJA 2000
CLM-GPP-ML-V-R
LAI MODIS: JJA 2000
GPP Fluxnet: JJA 2000
OBS
0 1 2 3 4 5 6 7
0 1 2 3 4 5