MIND THE GAPS

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University of Toronto

FIFE and BOREAS Workshop
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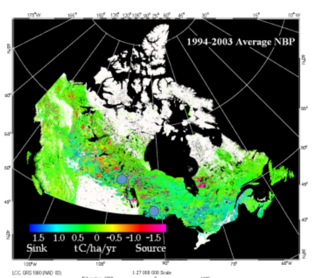
Where Are the Gaps?

Gaps within a canopy
(between and within tree crowns)



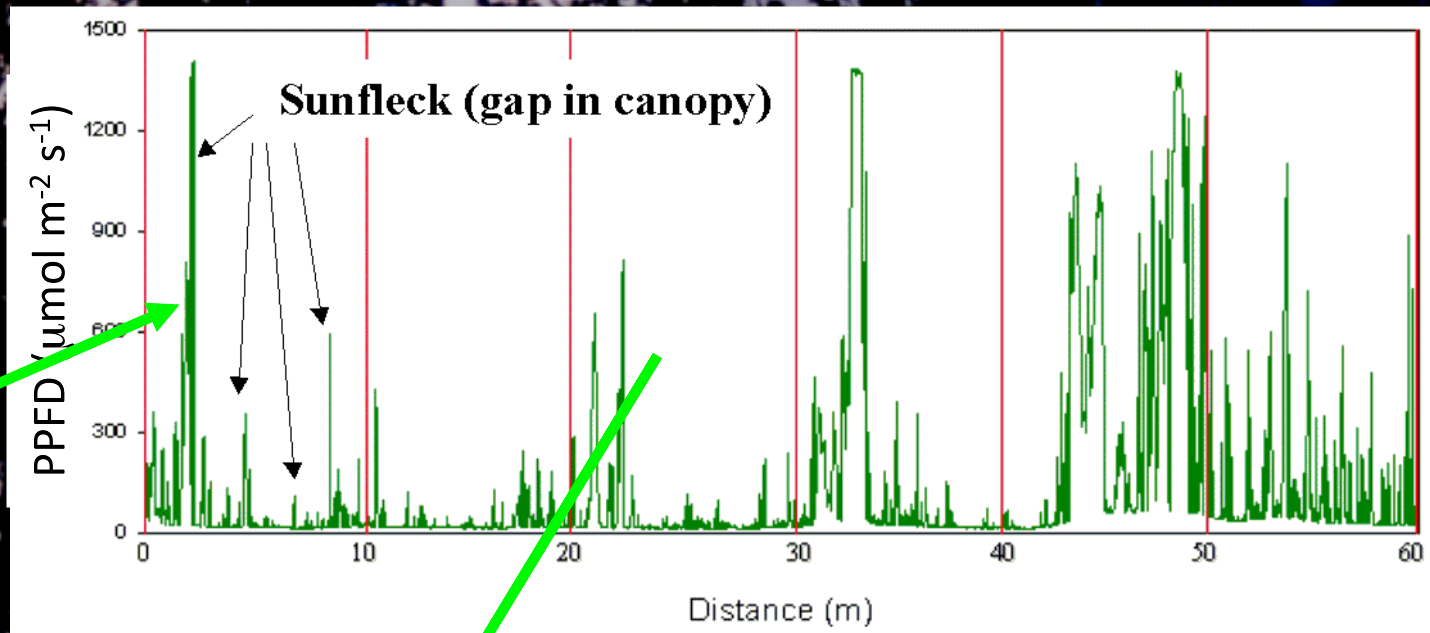
Gaps between sites
(density, cover type)

Remote Sensing

Canopy structural parameters

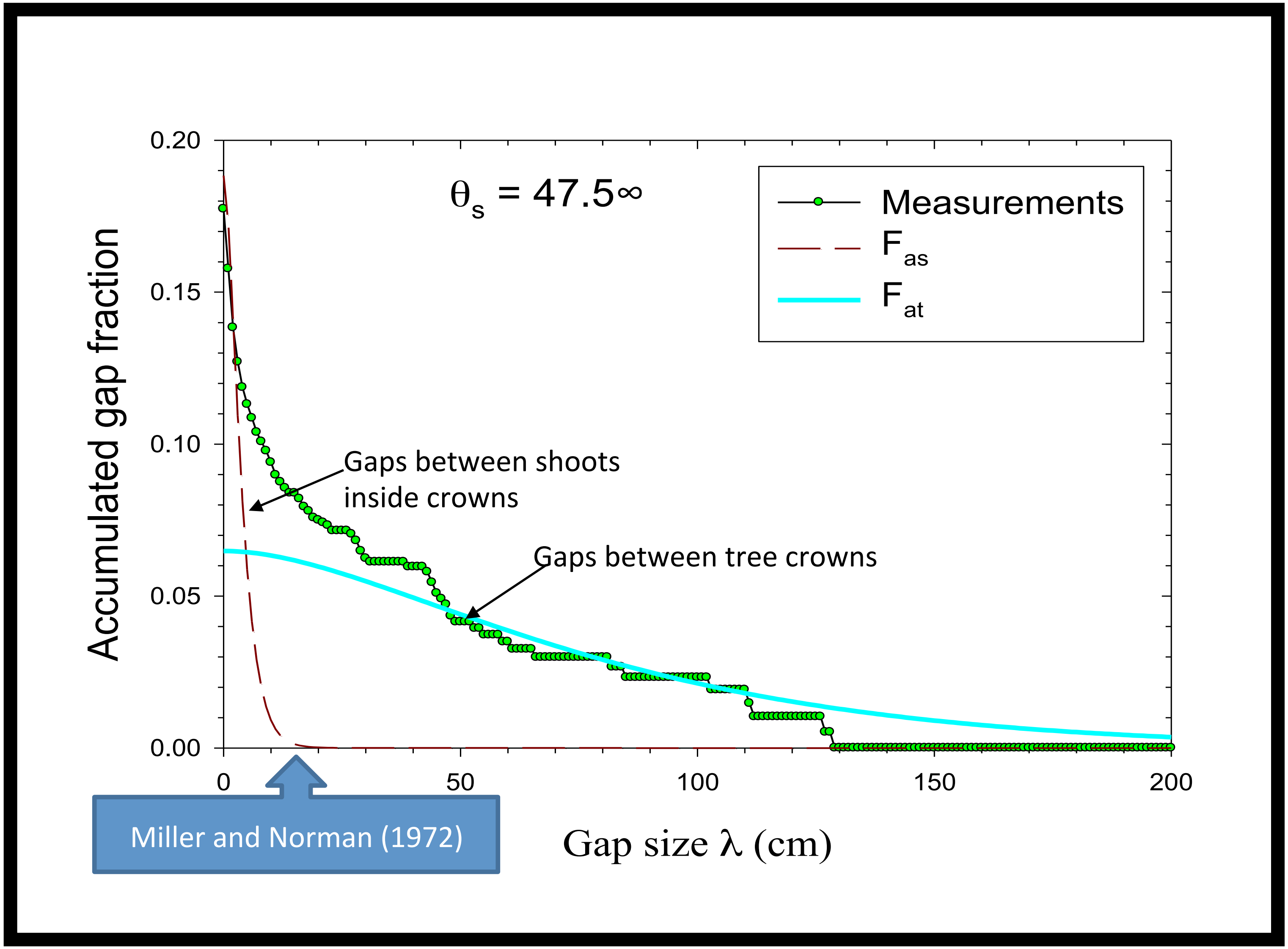
Leaf biophysical traits and function

TRAC for Measuring LAI

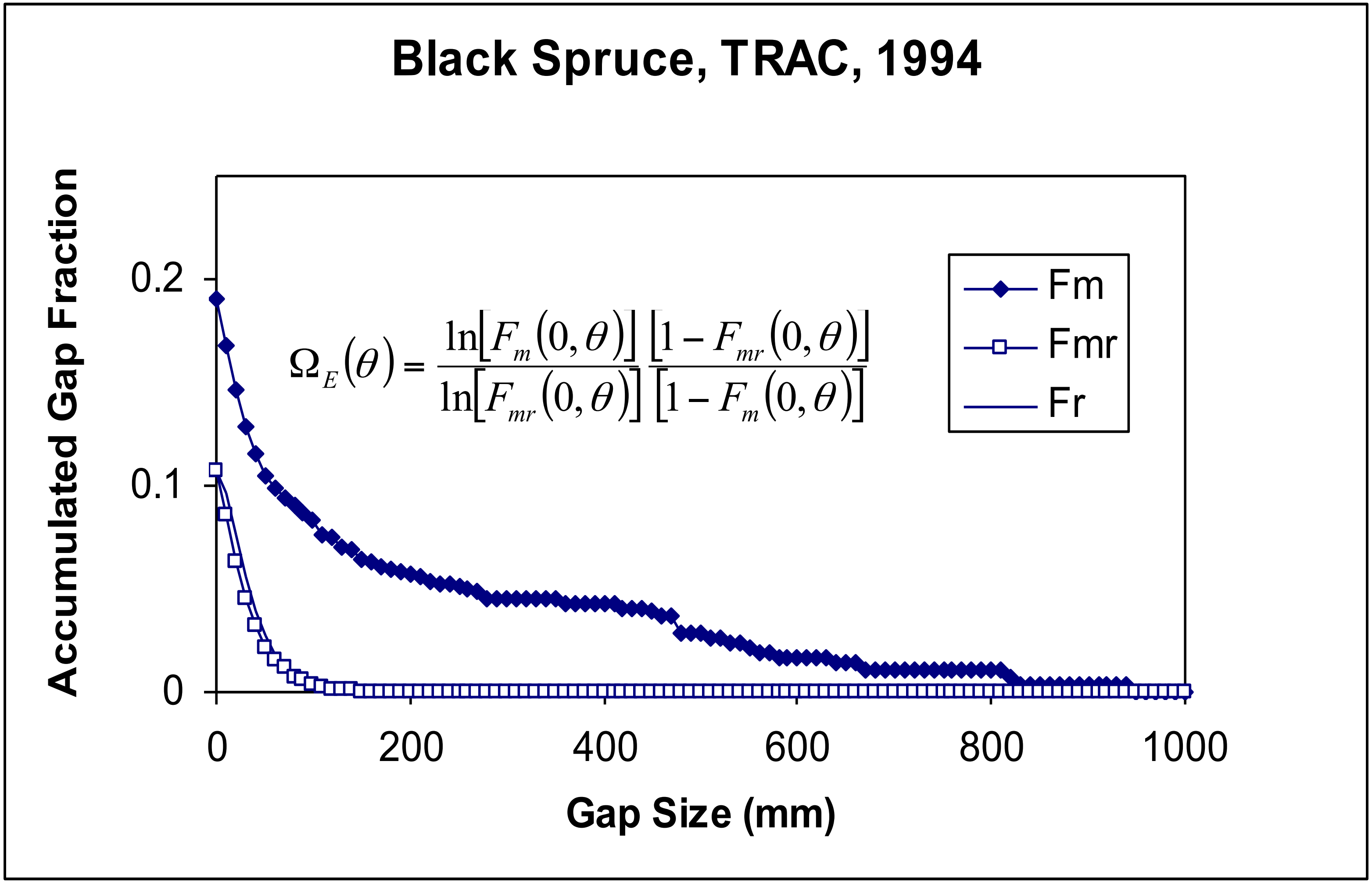


$\Omega_E \rightarrow$ LAI

Accumulated Gap Fraction in a Black Spruce Stand



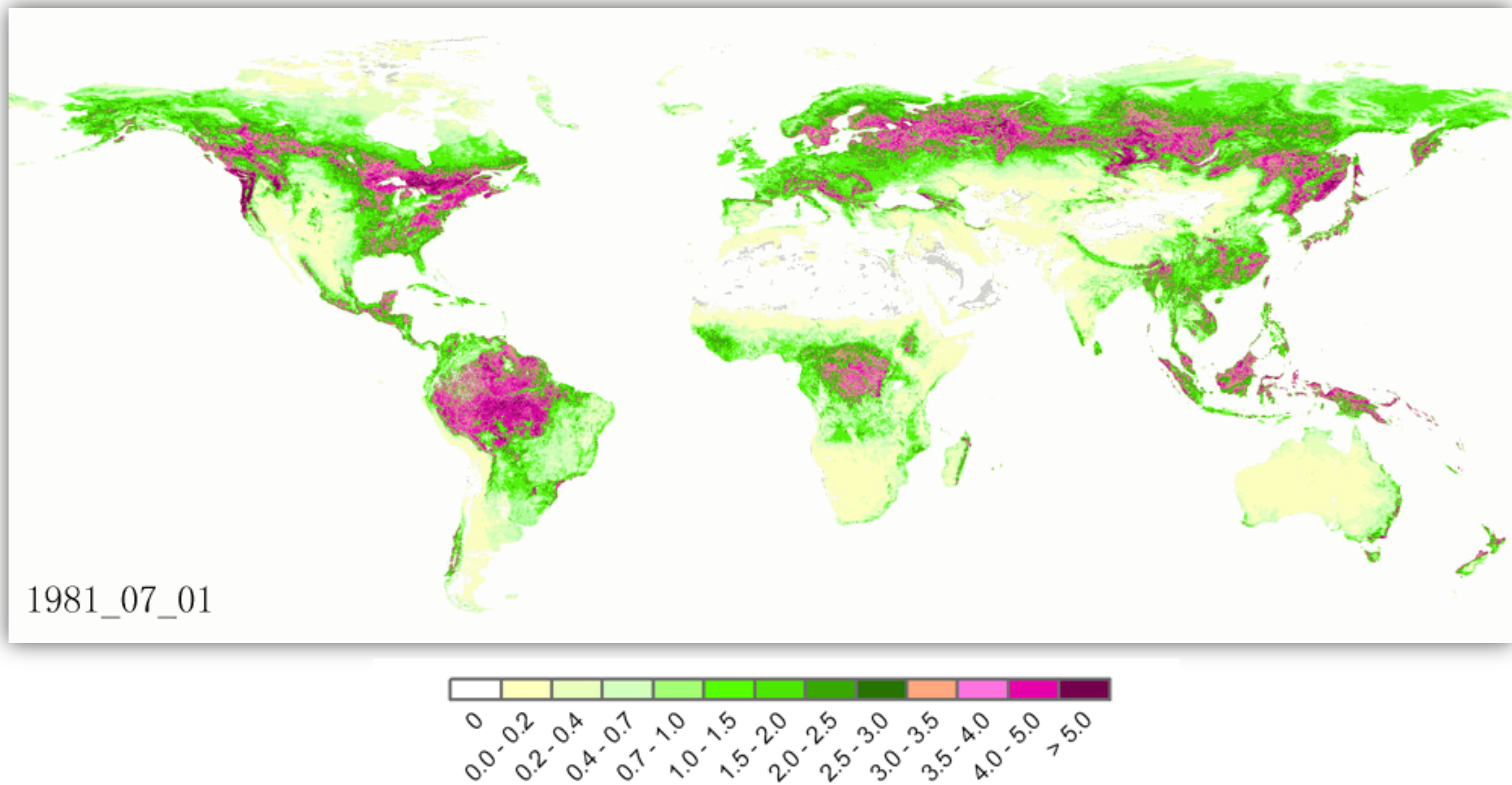
Clumping Index (Ω) Derived After Gap Removal



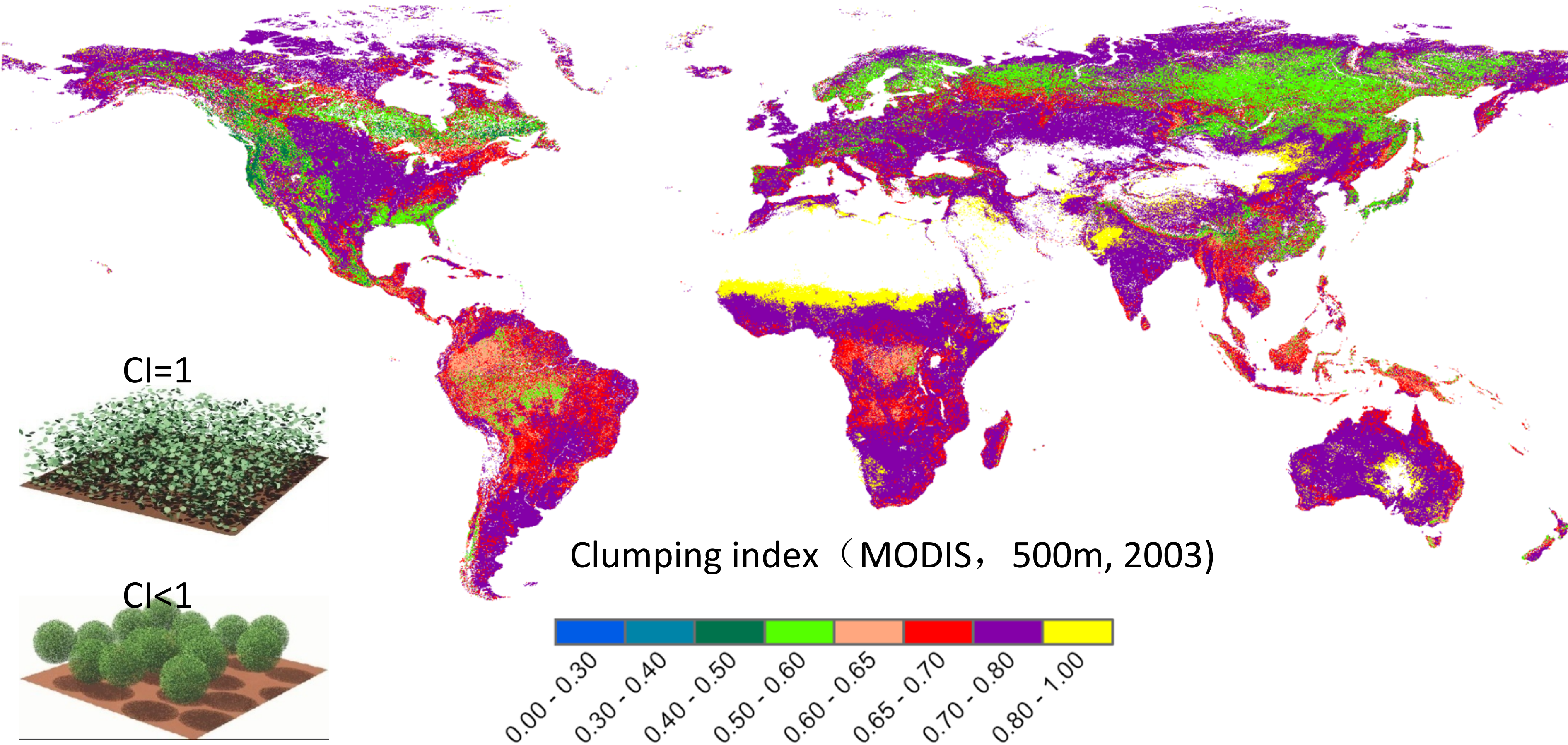
Chen and Cihlar (1995); Leblanc (2002)

Global LAI Time Series

(1981-2010, AVHRR+MODIS, 8 km, 8-day interval)

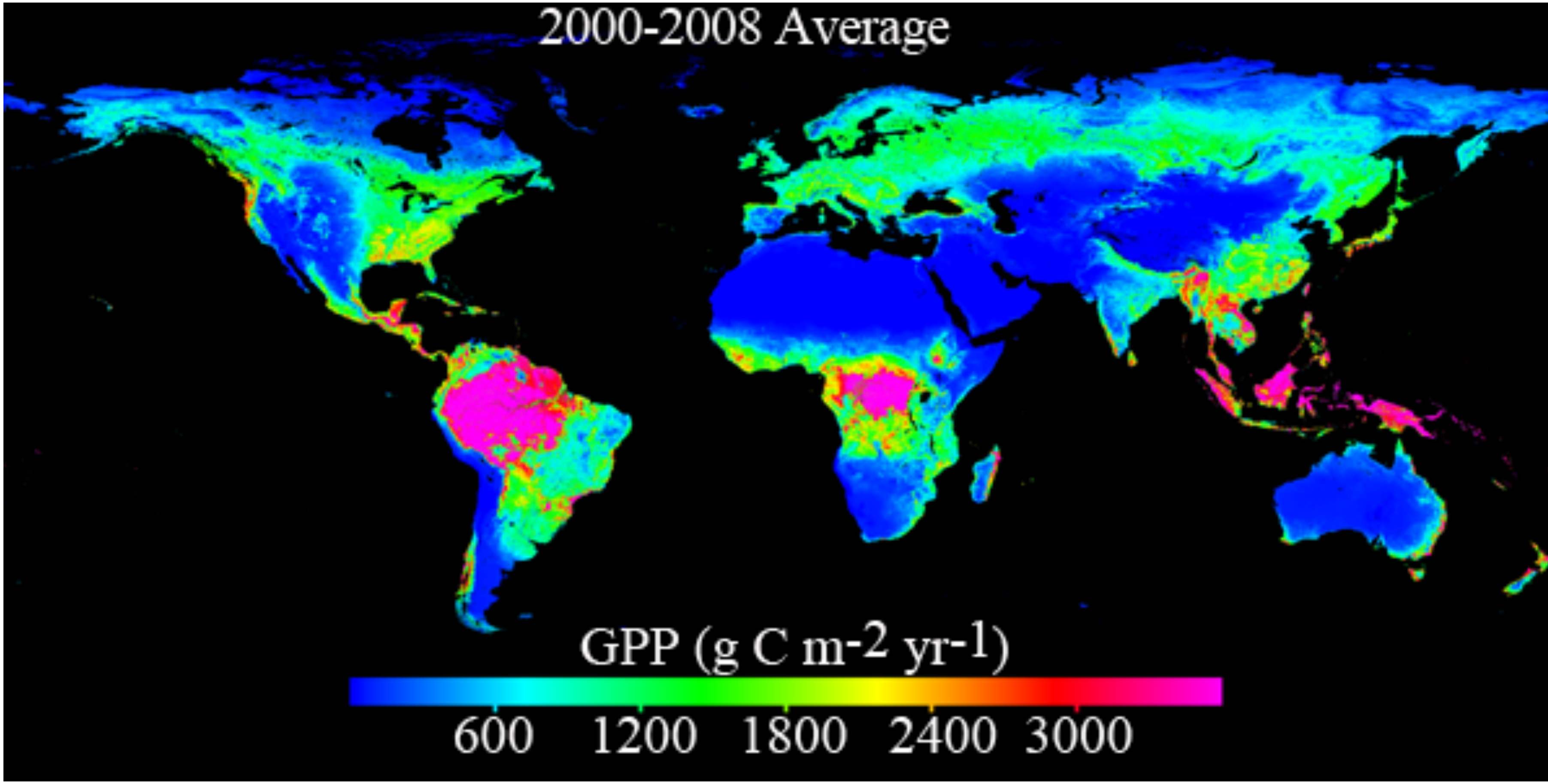


Clumping Index Mapping



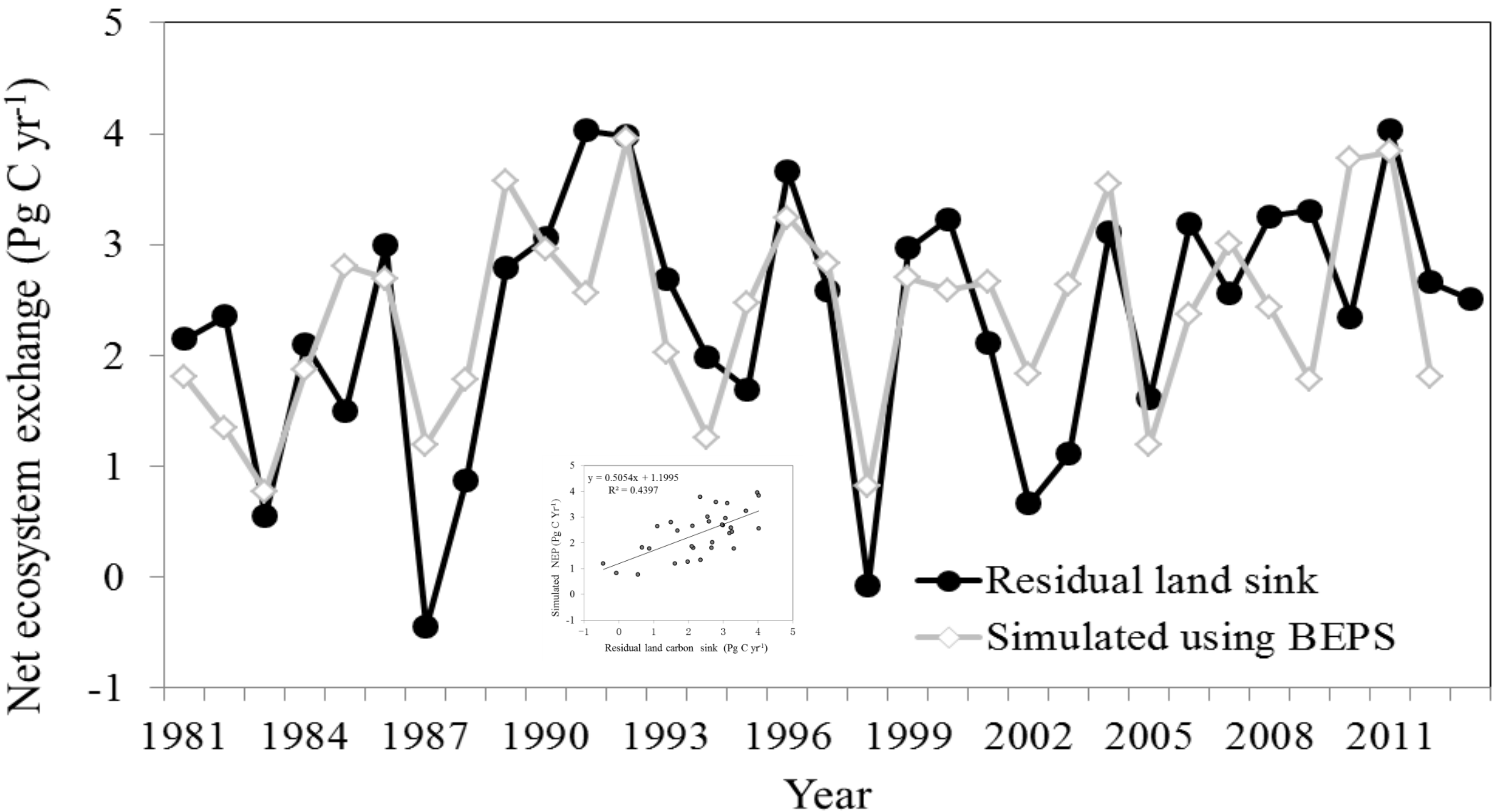
He, L., J. M. Chen, J. Pisek, C. B. Schaaf, A. H. Strahler. 2012. Global clumping index map derived from the MODIS BRDF product. *Remote Sensing of Environment,* 119, 118–130.

Spatial Distribution of GPP Averaged over 2000-2008



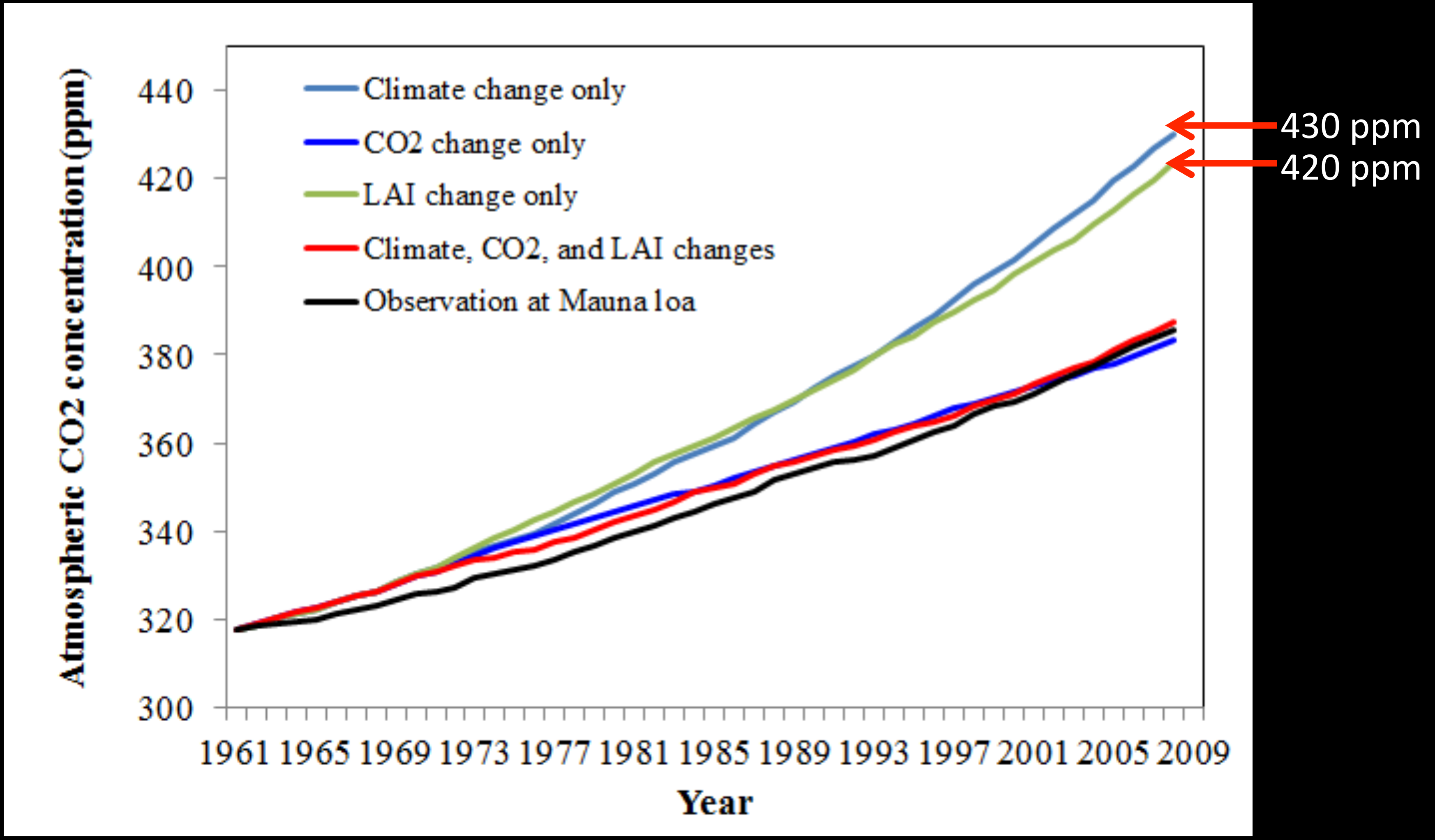
Chen, J. M., G. Mo, J. Pisek, F. Deng, M. Ishozawa, D. Chan, 2012. Effects of foliage clumping on global terrestrial gross primary productivity. *Global Biogeochemical Cycles,* VOL. 26, GB1019, 18 PP., doi:10.1029/2010GB003996.

Comparison of Modelled NEP with the Residual Land Sink from Global Carbon Project Office



Ju, Chen et al., in preparation

Atmospheric CO_2 Concentration Affected by the Various Factors



$$CO_2 = E_{FF} + E_{LUC} - (S_{ocean} + S_{land})$$

So far we only used structural parameters in the global terrestrial carbon cycle modeling.

Can we do more with remote sensing data?

A Major Bottleneck in Global Ecology

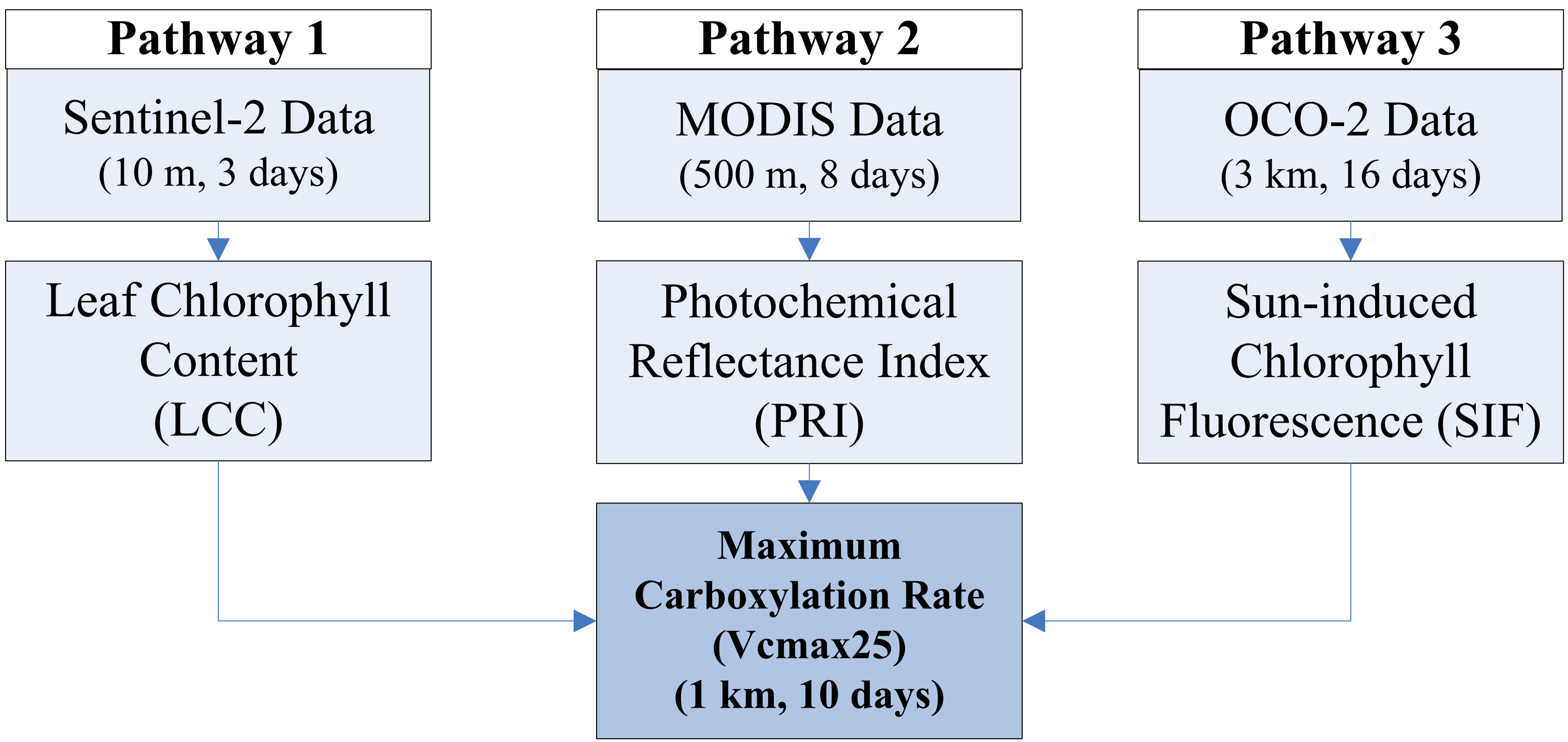
- Vcmax—a key parameter in carbon modelling.
- Large variation even within the same PFT and hard to obtain field measurements
- Seasonal variation

		$N_{a,nat}$					V_{max}^{25}						NUE			
PFT	$n_{Na,nat}$	Mean	SD	SE	Sk	Ku	Mean	SD	SE	Sk	Ku	BQ	Mean	SE	Sk	Ku
1 Tropical trees (oxisols)	371	2.17	0.80	0.04	0.66	0.30	29.0	7.7	0.4	0.61	0.56	*62	14.02	2.26	1.72	4.72
2 Tropical trees (nonoxisols)	107	1.41	0.56	0.05	1.76	5.41	41.0	15.1	1.5	1.88	6.45	**94	29.60	2.54	0.54	2.45
3 Temperate broadleaved. evergreen trees	65	1.87	0.93	0.11	0.88	0.14	61.4	27.7	3.4	0.89	0.18	41	33.75	2.32	1.4	3.00
4 Temperate broadleaved deciduous trees	404	1.74	0.71	0.04	0.77	0.78	57.7	21.2	1.1	0.78	0.83	35	33.79	2.37	2.94	14.93
5 Evergreen coniferous trees	220	3.10	1.35	0.09	0.74	1.38	$\boxed{62.5}$	$\boxed{24.7}$	1.7	0.77	1.53	29	20.72	1.78	1.38	3.93
6 Deciduous coniferous trees	27	1.81	0.64	0.12	1.08	0.49	39.1	11.7	2.3	1.08	0.61	53	22.05	1.61	0.53	0.61
7 Evergreen shrubs	130	2.03	1.05	0.09	1.60	2.65	61.7	24.6	2.2	1.68	3.19	52	32.09	4.24	0.64	1.23
8 Deciduous shrubs	179	1.69	0.62	0.05	0.61	0.47	54.0	14.5	1.1	0.67	0.76	160	33.14	4.38	1.27	3.21
9 C3 herbaceous	254	1.75	0.76	0.05	1.42	2.94	78.2	31.1	2.0	1.44	3.10	42	45.29	2.57	1.79	8.83
10 C3 crops	***209	1.62	0.61	0.04	0.41	0.31	100.7	36.6	2.5	0.43	0.40	120	62.75	3.65	3.13	27.42

Kattge et al. (2009)

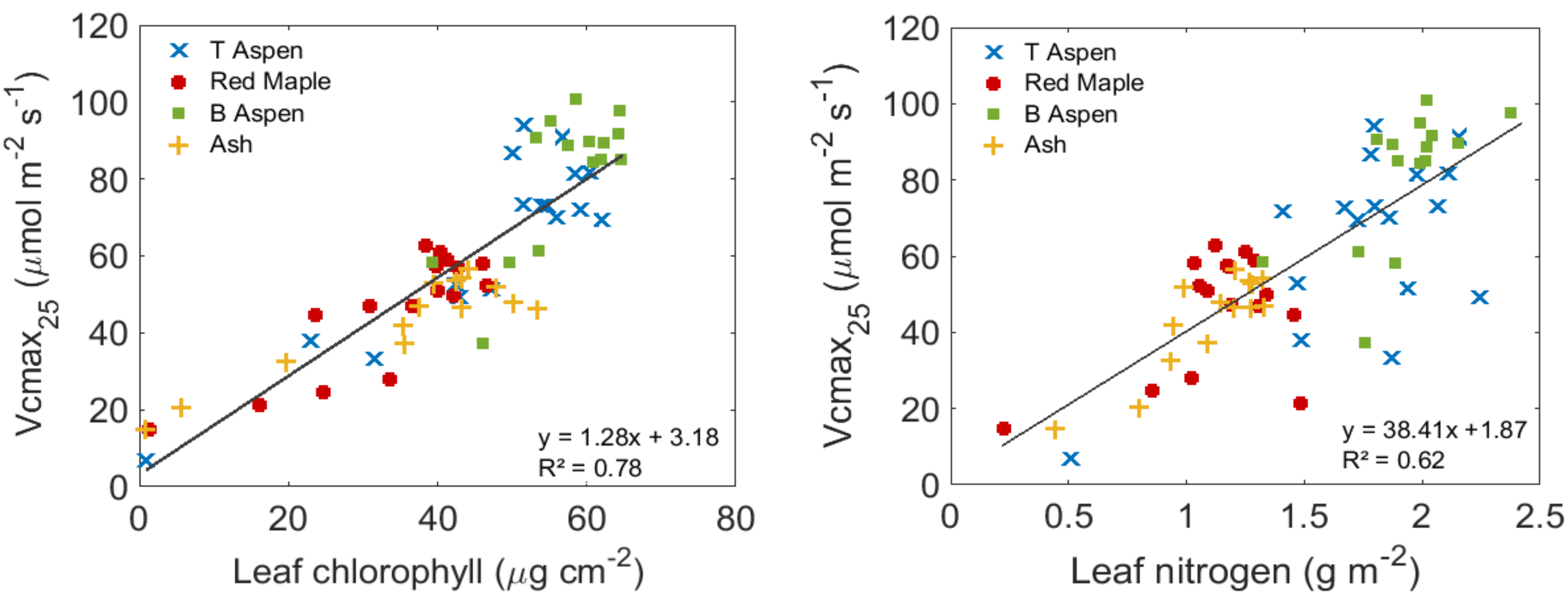
Only 67% of data fall in the range from 38.2 to 87.2

It may be possible to retrieve Vcmax using remote sensing data



Pathway 1
Retrieving Vcmax25 via LCC

LCC-Vcmax25 relationship is better than nitrogen-Vcmax25 relationship

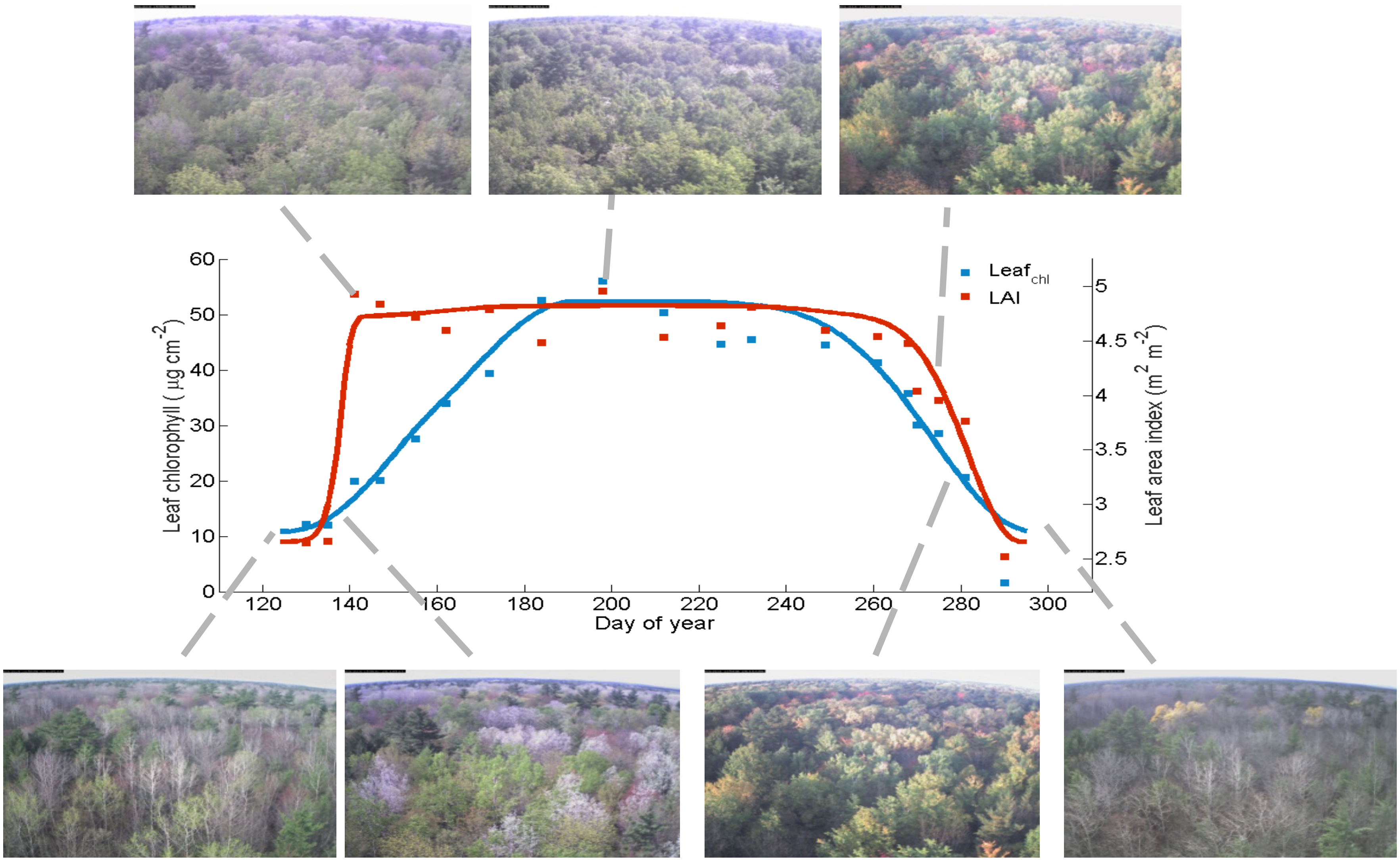


It is also far more reliable to retrieve LCC than leaf nitrogen from remote sensing data.

Croft, Chen, et al. (submitted, GCB)

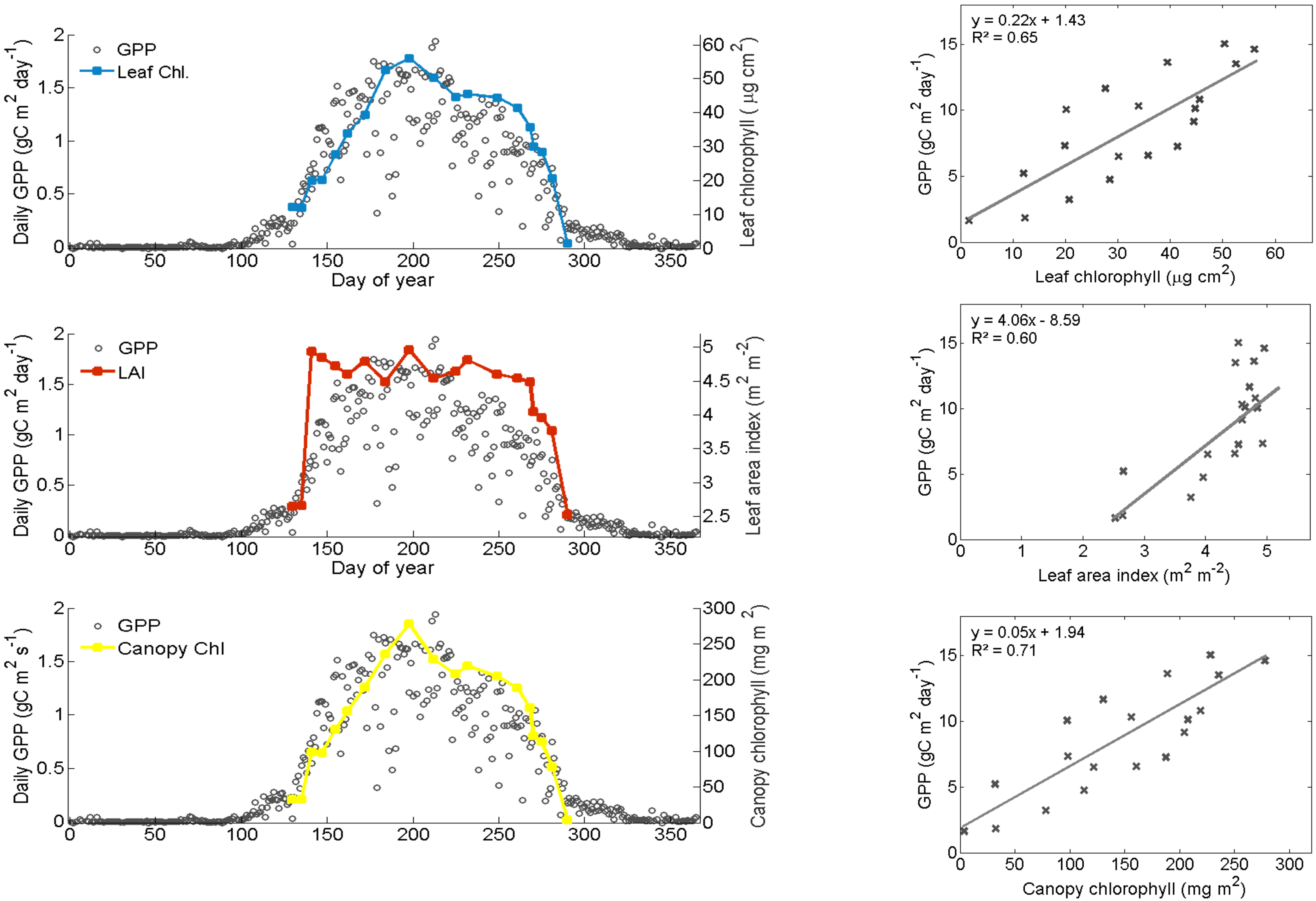
LAI and Leaf Chlorophyll Seasonal Dynamics

Borden Forest Site, Ontario, 2013



Croft, Chen, et al. (2015, JGR-BGS)

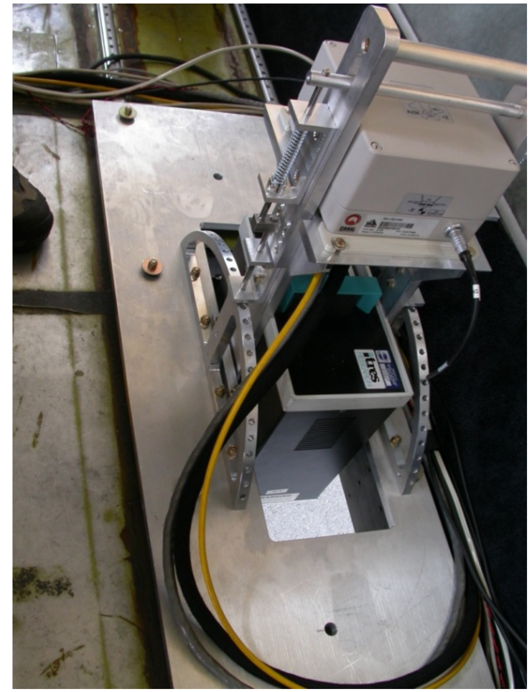
Physiological impacts on carbon assimilation



Croft, Chen, et al. (2015, JGR-BGS)

An Airborne Multi-angle RS Field Campaign

For Validating a Chlorophyll Retrieval Algorithm, Sudbury, Ontario, 2007

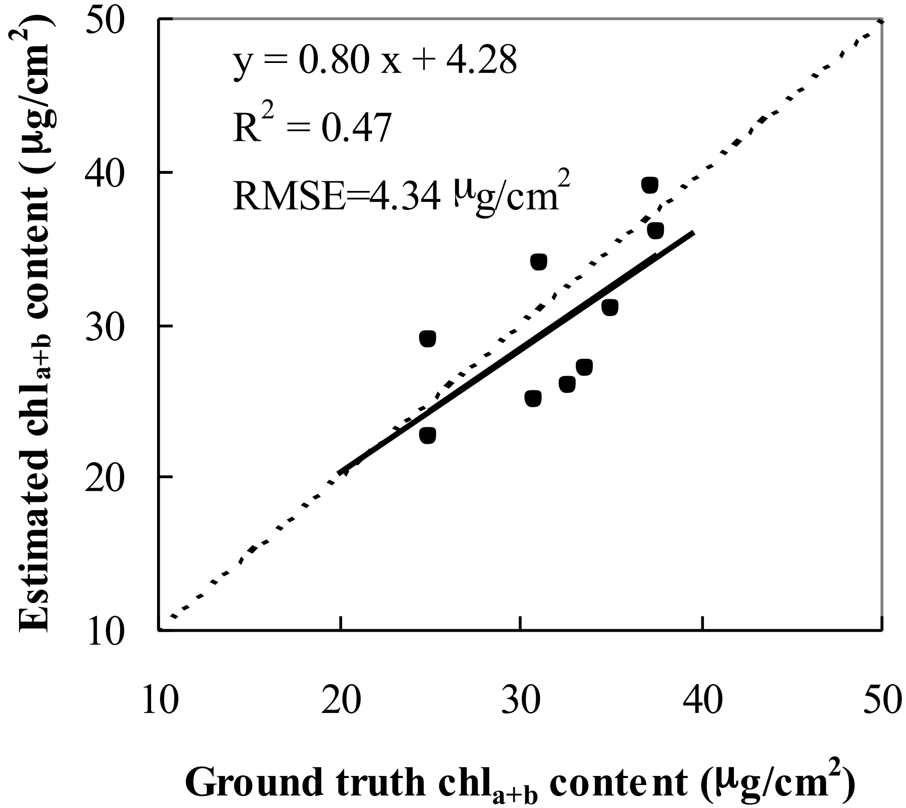


Compact Airborne Spectral Imager (CASI)
operated by John Miller
York University

CASI – push-broom scanner

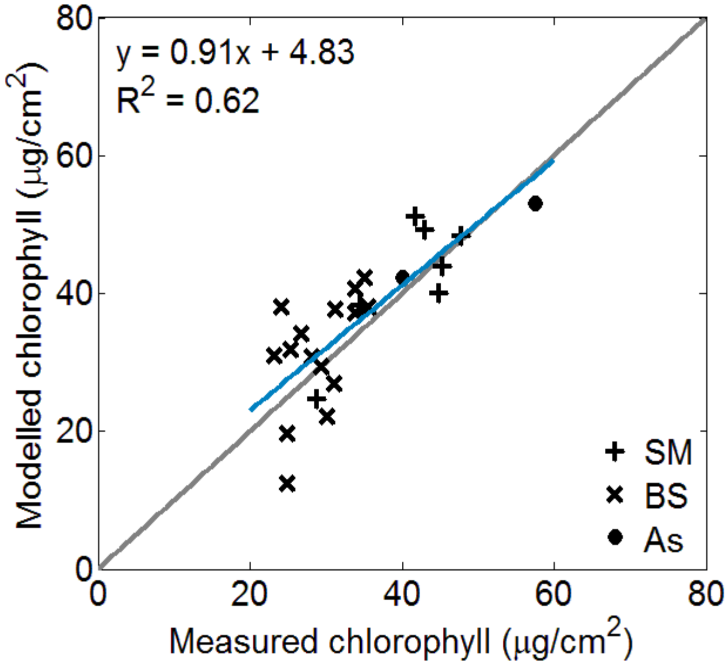
- operated in hyperspectral mode (7.5 nm bandwidth)
- 2 m spatial resolution
- Bands aggregated to simulate
- MISR-like red and NIR bands

Validation of Retrieved Chlorophyll Content Per Unit Leaf Area Using CASI Data

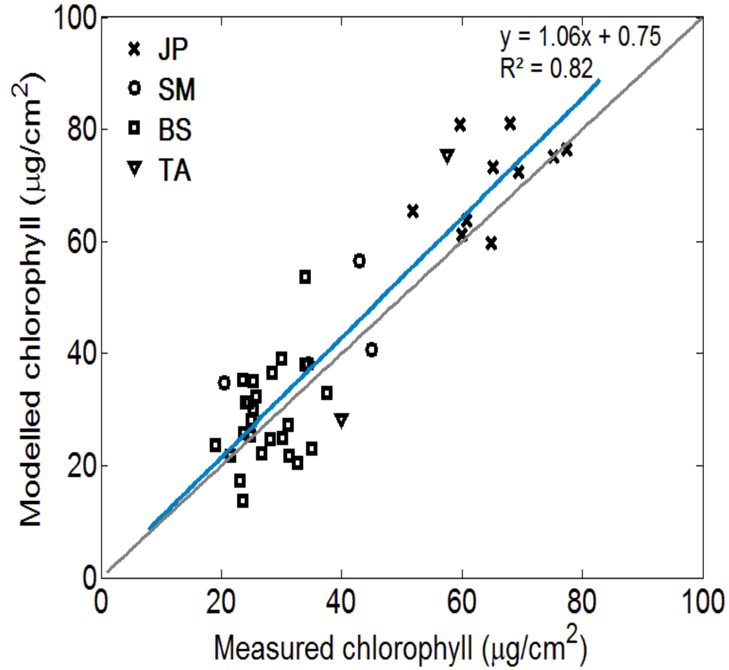


Zhang et al. (2008), RSE

Validation of Retrieved Chlorophyll Content Per Unit Leaf Area Using Satellite Data



MERIS



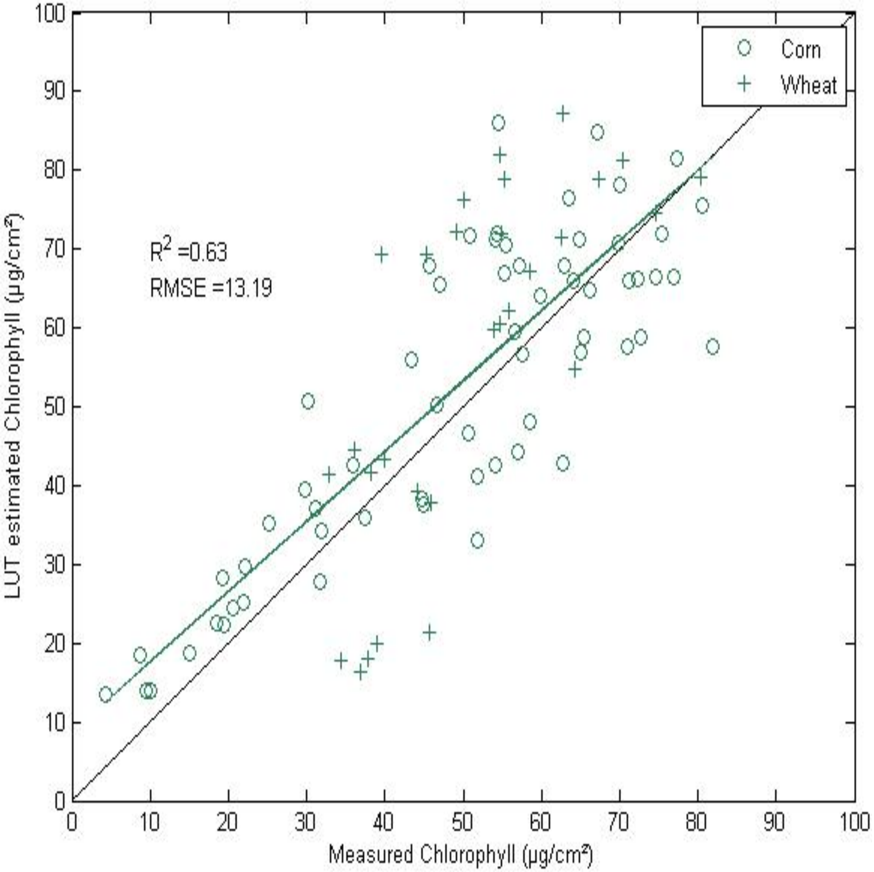
Landsat

Croft et al. (2013, *RSE*); Croft et al. (2015, *ISPRS*)

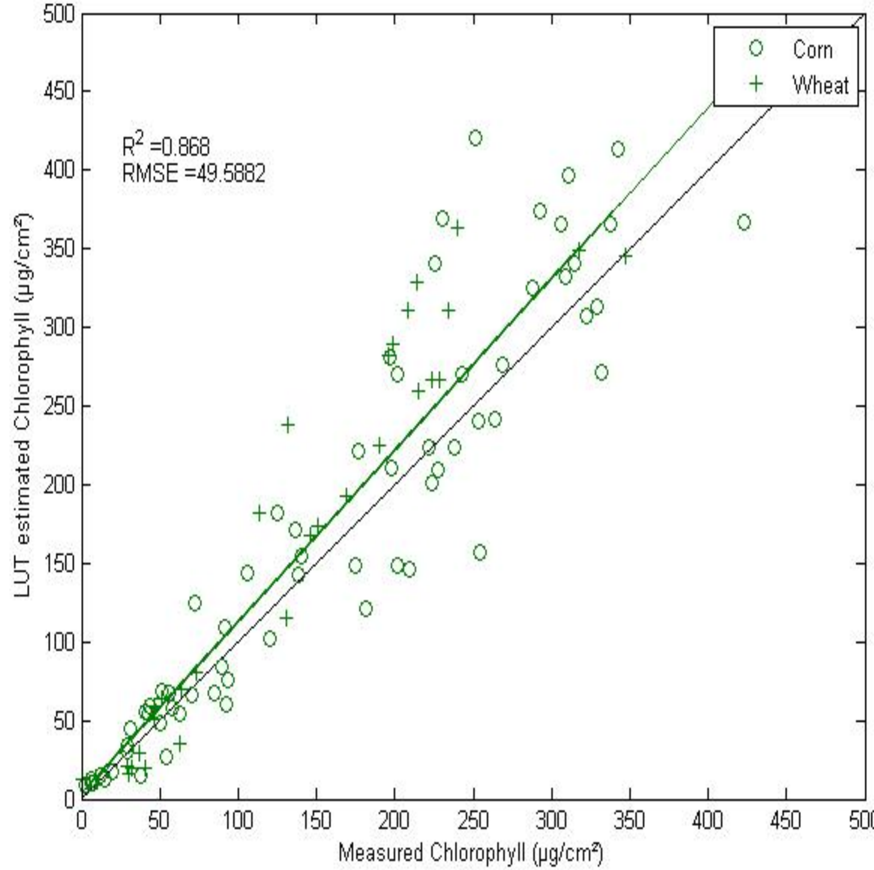
Validation of the Algorithm for Crop Sites

Corn and Wheat, Stratford, Ontario, 2014, Landsat

Leaf Level Chlorophyll

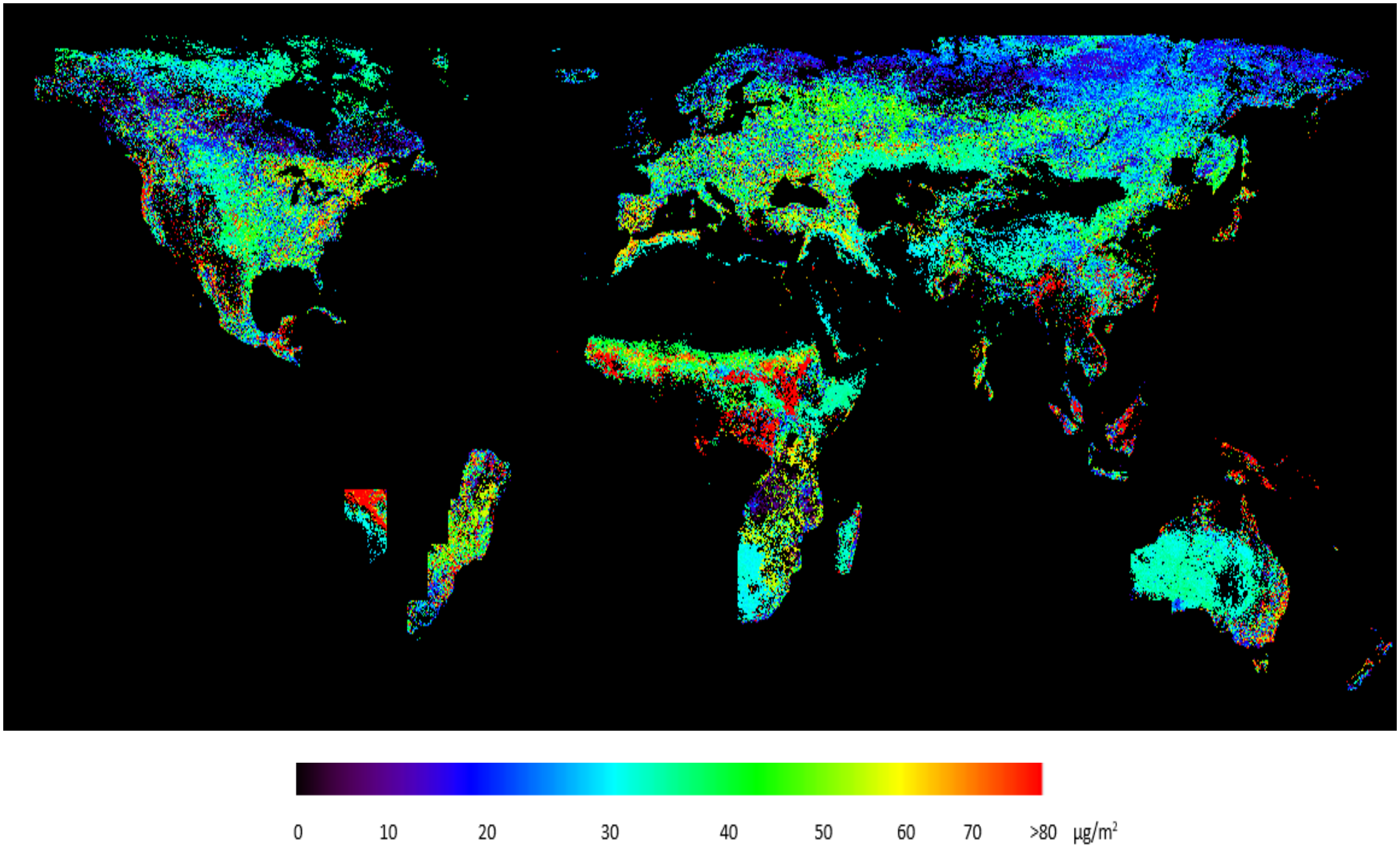


Canopy Level Chlorophyll



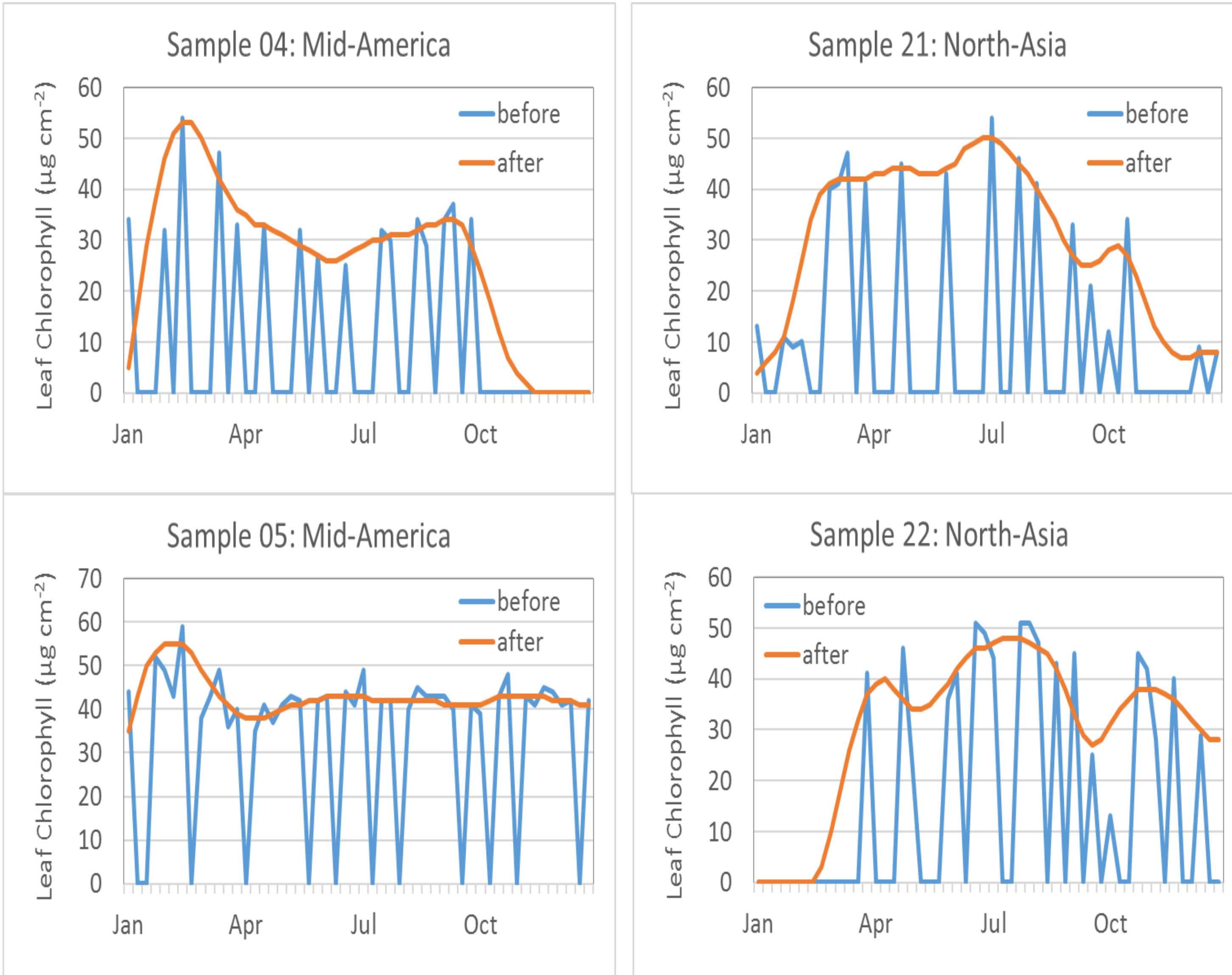
Arabian et al., 11 June 2015, 36th CRSS

Chlorophyll Content Per Unit Leaf Area
August 2012, 300 m resolution, MERIS data



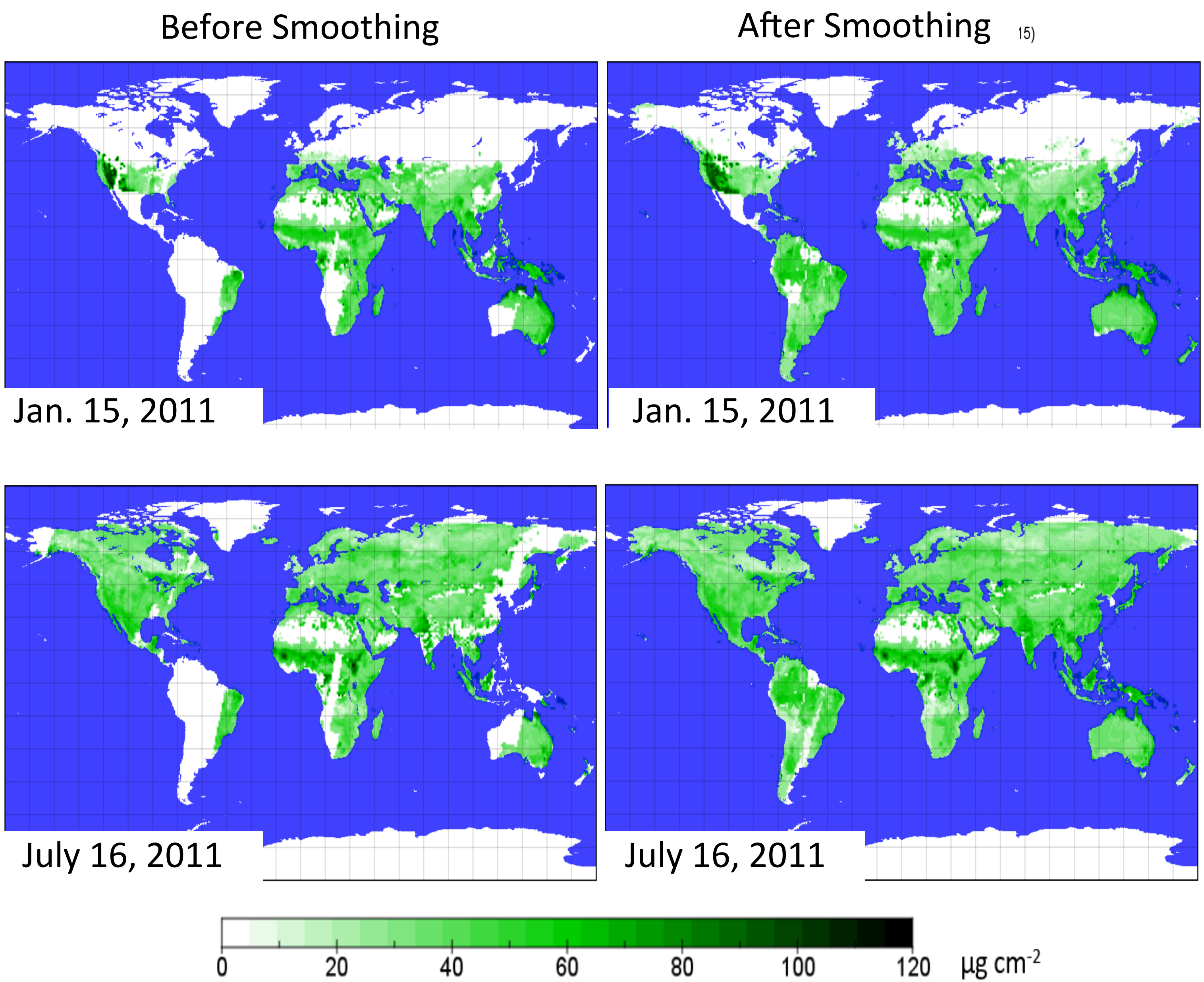
Croft, Chen, et al. (in preparation)

Samples of LCC trajectories before and after smoothing

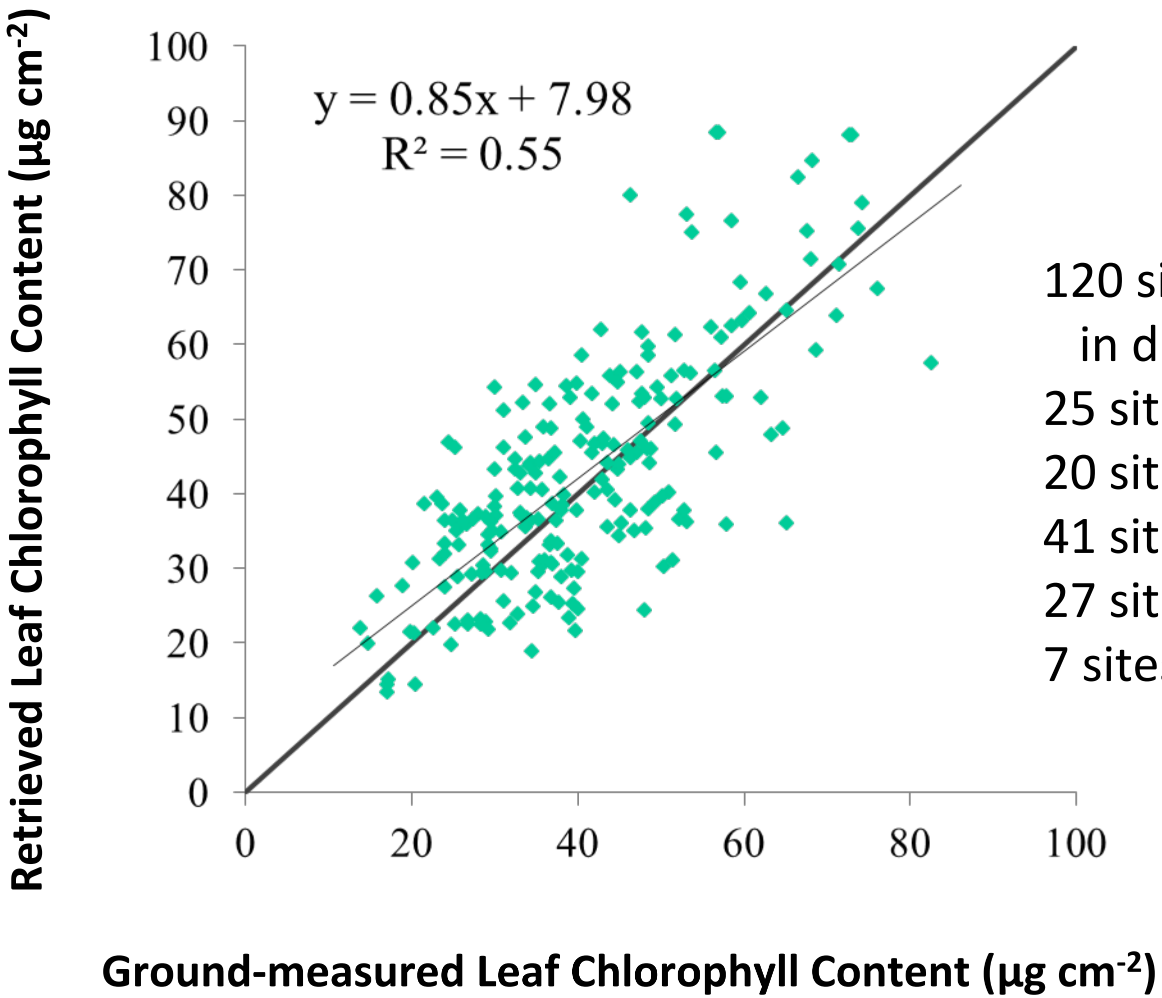


Locally Adjusted by Cubic-Spline Capping (LACC), Chen et al. (2006, *IEEE-TGARS*)

Leaf Chlorophyll Content Maps

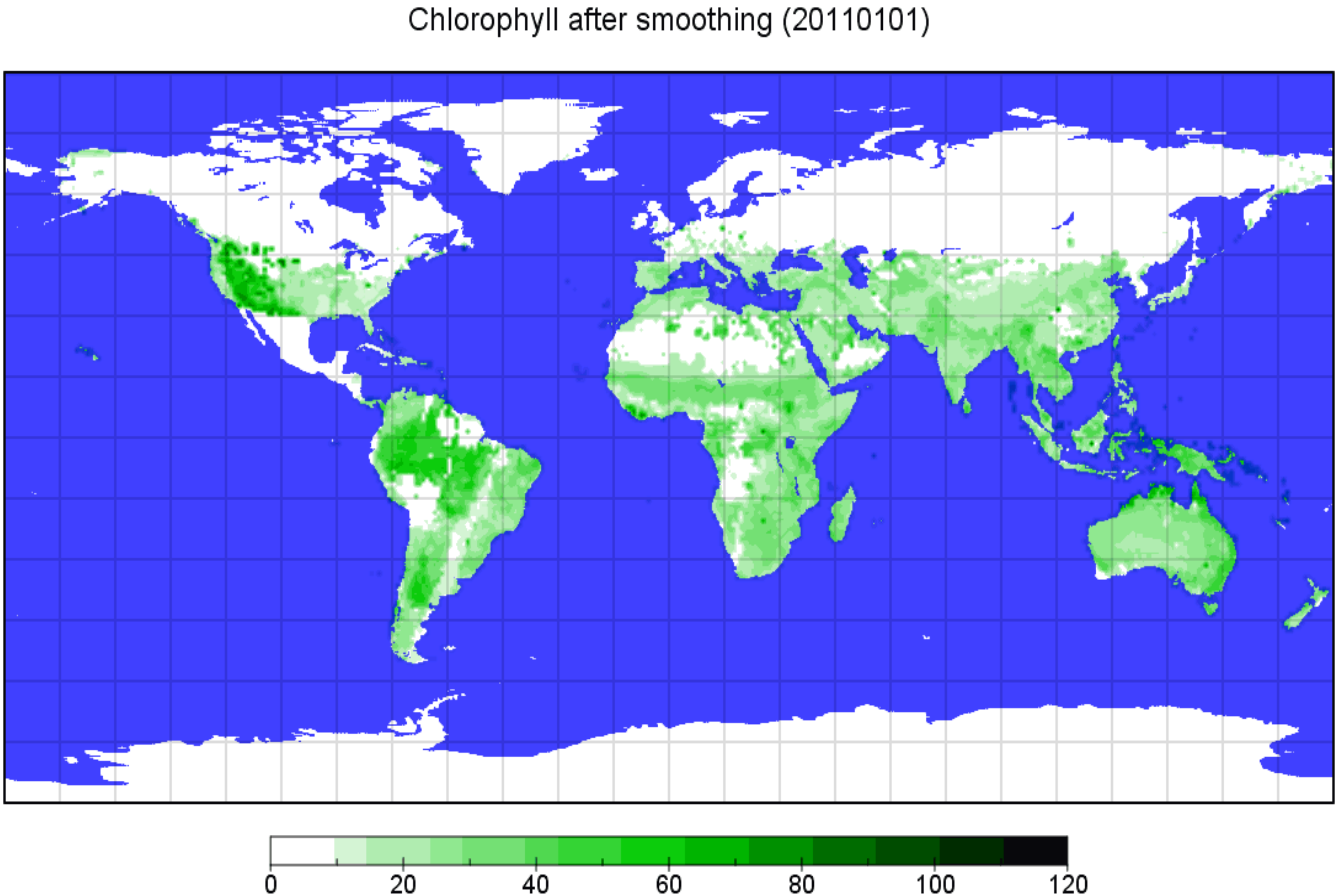


Validation Using Ground Data

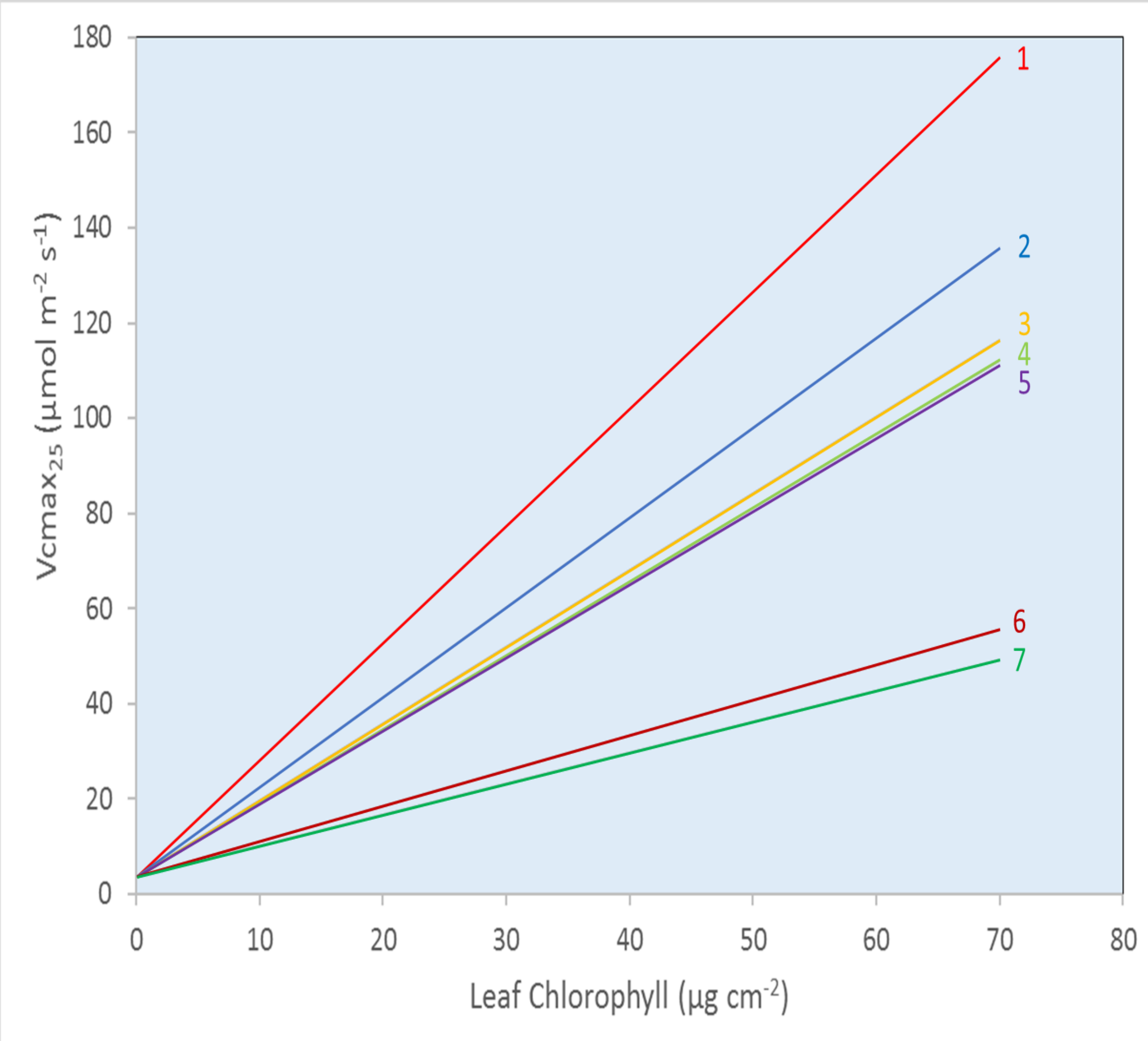


120 sites in total
in different years:
25 sites in grassland,
20 sites in broadleaf forests,
41 sites in conifer forests,
27 sites in crops,
7 sites in shrubland.

Croft, Chen, et al. (in preparation)


Chlorophyll after smoothing (20110101)
0
20
40
60
80
100
120

Relationship of $Vcmax_{25}$ and Chlorophyll for each PFT



1 Others
Vcmax = 2.46*chl +3.72

2 Evergreen Conifers
Vcmax = 1.88*chl +3.72

3 Deciduous Conifers
Vcmax = 1.61*chl +3.72

4 Broadleaf Deciduous
Vcmax = 1.55*chl +3.72

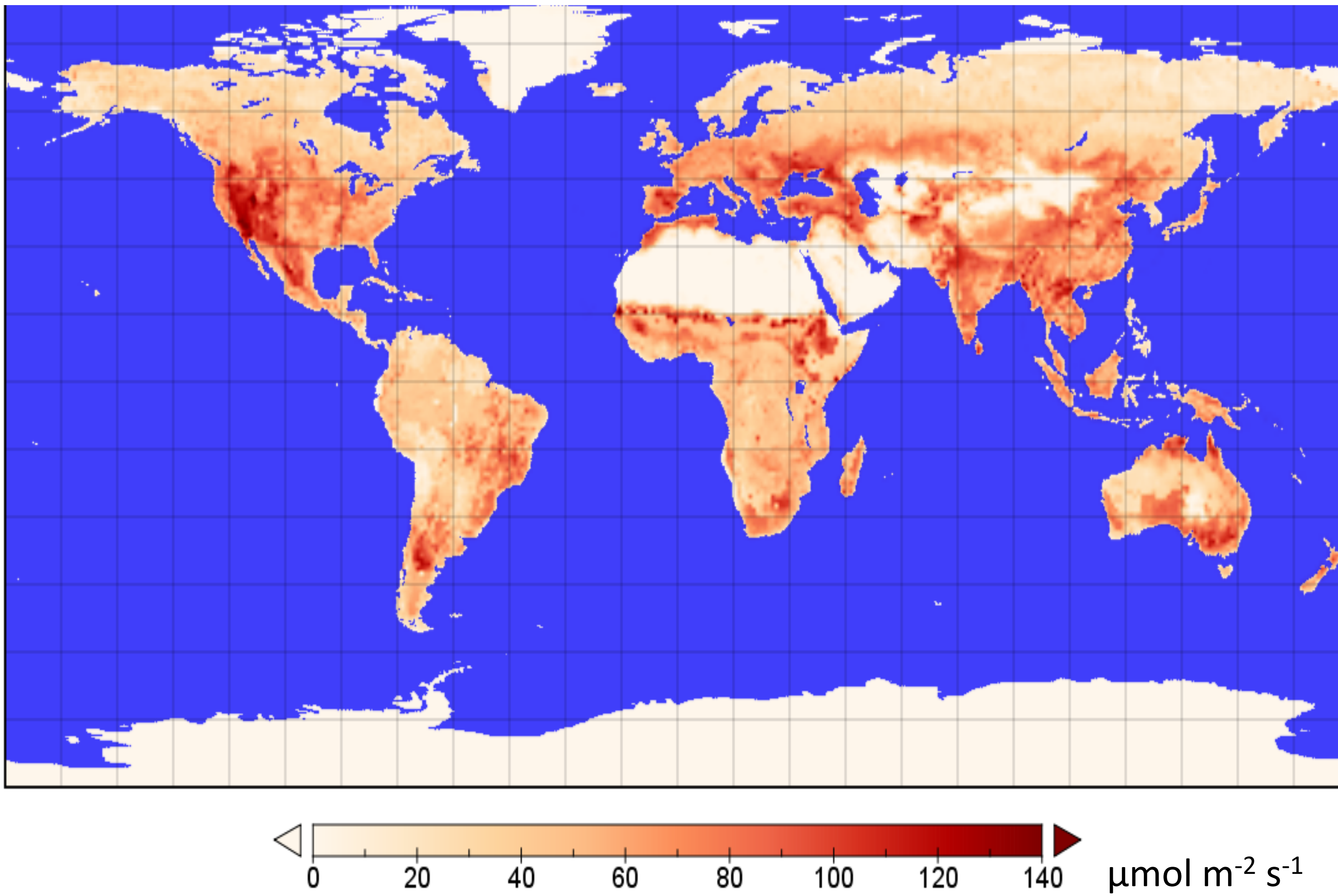
5 Shrub
Vcmax = 1.53*chl +3.72

6 C4 Plants
Vcmax = 0.74*chl +3.72

7 Broadleaf Evergreen
Vcmax = 0.65*chl +3.72

$Vcmax_{25}$ Derived from Chlorophyll

Annual Mean, 2011



Conclusion

- Flux towers are solid anchors for mapping regional carbon and other fluxes;
- The gaps between the anchor points are being effectively filled using remote sensing techniques which are not only useful for mapping structural parameters but also beginning to provide critical biological parameters directly related to the fluxes.