Establishment of the Relationship between the Photochemical Reflectance Index and Canopy Light Use Efficiency Using Multi-angle Hyperspectral Observations

Zhang Q., Ju W., Chen J. M.*, Qiu F.

International Institute for Earth System Science, Nanjing University

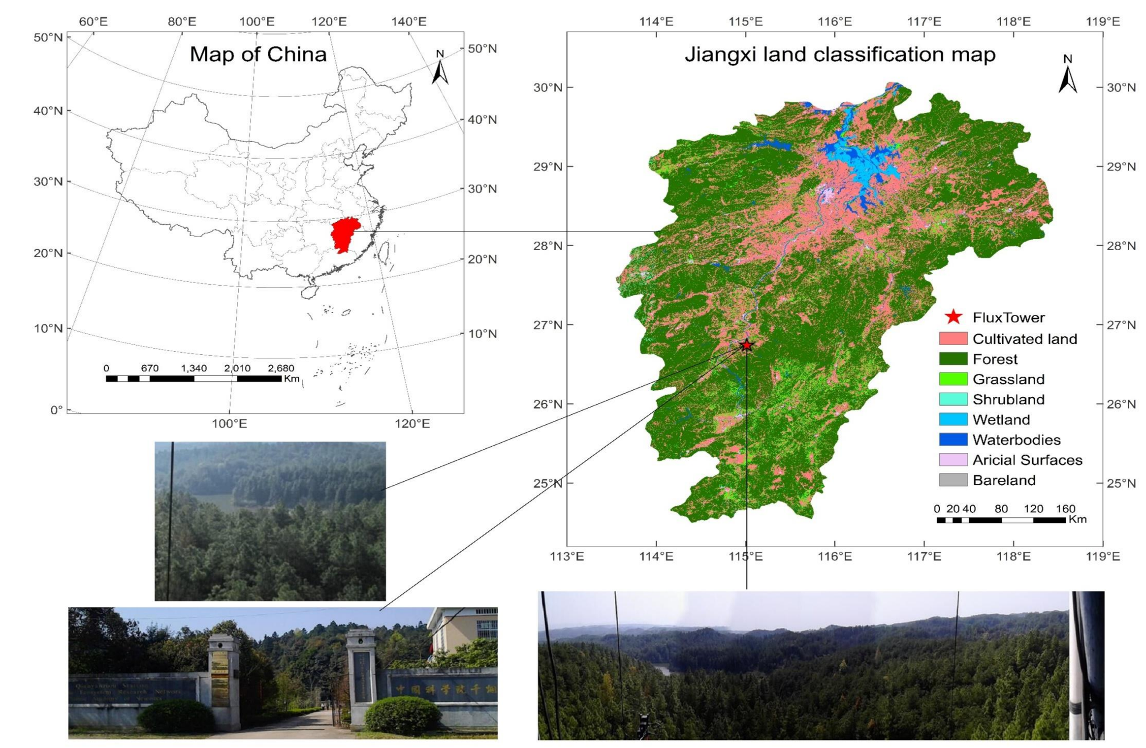
Introduction

The photochemical reflectance index (PRI) is a promising way to indicate light use efficiency (LUE). However, there are certainly some internal and external factors that affect PRI signals.

Considering the spectral difference between sunlit and shaded leaves, a two-leaf approach based on a four-scale optical transfer model is used to process multi-angle canopy reflectance for estimating fractions of sunlit and shaded leaves. A simple ratio of canopy reflectance to leaf reflectance to represent the fraction of sunlit leaves.

Two-leaf canopy PRI (PRIt) is retrieved using the least squares regression with different angles observations, and is compared to simply averaged big-leaf canopy PRI (PRIb) using observations acquired from April to September 2013 in a sub-tropical coniferous forest in Southern China.

Materials



Qianyanzhou, Jiangxi
Sub-tropic evergreen conifer forest

Pinus massoniana (5),
Pinus elliottii (3),
Cunninghamia lanceolata(1),
Schima superb(1)

Multi-angle observation

iAMSPEC II

Tower Module

Spectroradiometer (Unispec DC)

Pan-tilt unit (PTU-D46-17.5W)

Ground Module

Computer

Data preparation

Flux data: 2013

LUE calculation

Meterological observations:

PAR, FPAR

Bioclimatic parameters: VPD, CI, SM, Ta

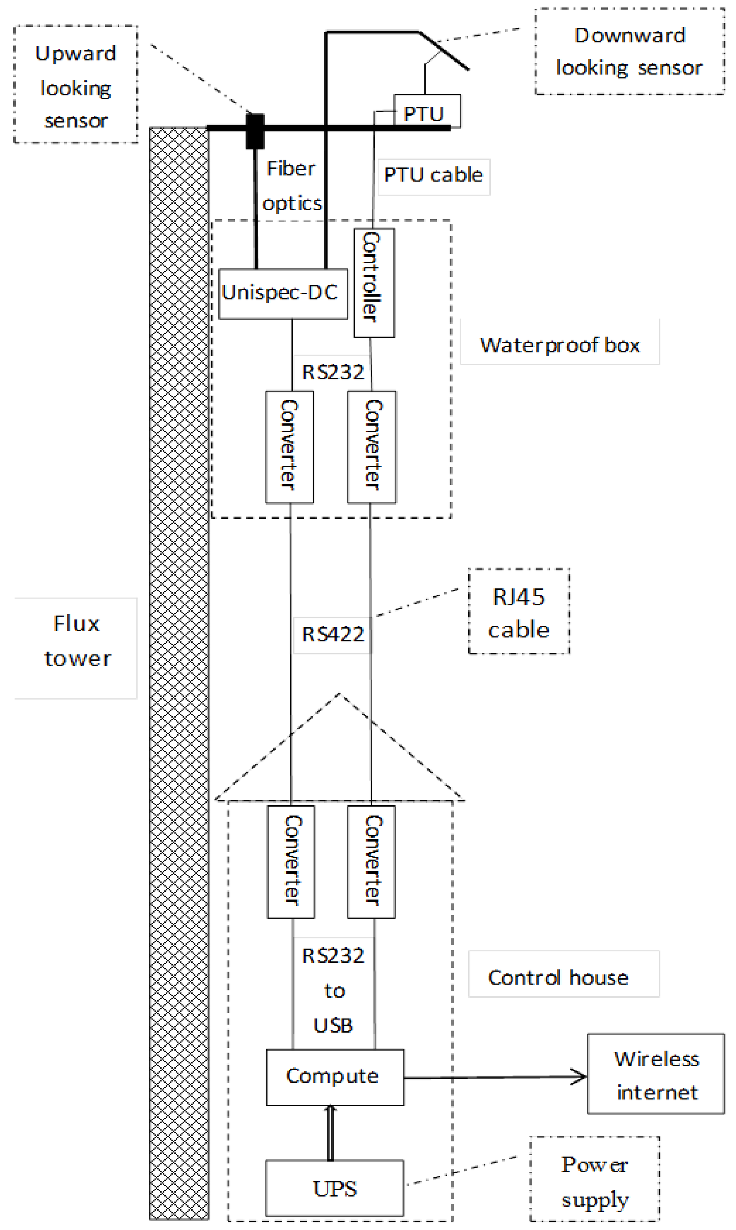
Spectral data: 2013.4.11-2013.10.02

Sensors and dark current calibration:

PRI calculation, Leaf reflectance

Field data: 2013.8

LAI, other structural parameters



Two-leaf Approach

Two-leaf LUE

APAR calculated separately: $APAR_{sun}$ and $APAR_{sh}$

$$L_{sun} = 2\cos\theta \times (1 - e^{\frac{-0.5\Omega \times LAI}{\cos\theta}}) \qquad L_{sh} = LAI - L_{sun}$$

$$APAR_{sh} = (1-\alpha)\times(1-\delta)\times((PAR_{dir} - PAR_{dif,u})/LAI + C) \qquad APAR_{sun} = (1-\alpha)\times(\frac{PAR_{dir}\times\cos\beta}{\cos\theta} + APAR_{sh})$$

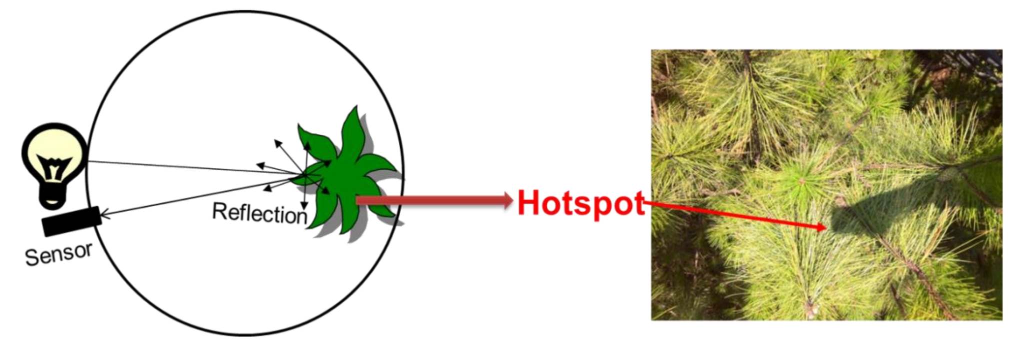
$$APAR_c = APAR_{sun}\times L_{sun} + APAR_{sh}\times L_{sh} \qquad LUE_c = \frac{GPP}{APAR_c}$$

Two-leaf PRI

Leaf Reflectance

Canopy Reflectance

$P_T = R_{SL} = R_{canopy}/R_{leaf}$



$$R_{can} = R_T \times P_T + R_G \times P_G + R_S \times P_S + R_Z \times P_Z$$

$$P_{VG} = e^{-0.5\Omega\times LAI/\cos\theta_V} \qquad P_S = 1 - P_T - P_{VG}$$

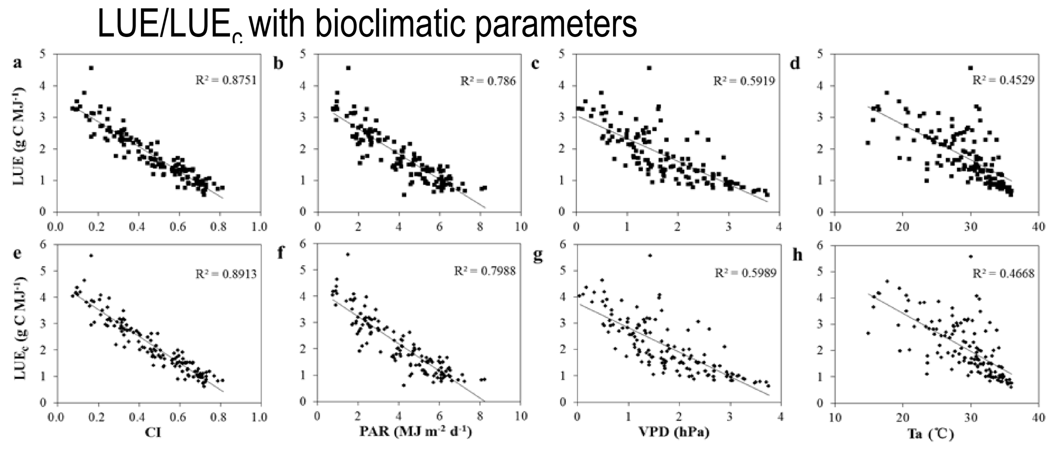
$$PRI_{obs} = P_T \times PRI_{sun} + P_S \times PRI_{sh}$$

$$PRI_t = PRI_{sun}\frac{L_{sun}}{LAI} + PRI_{sh}\frac{L_{sh}}{LAI}$$

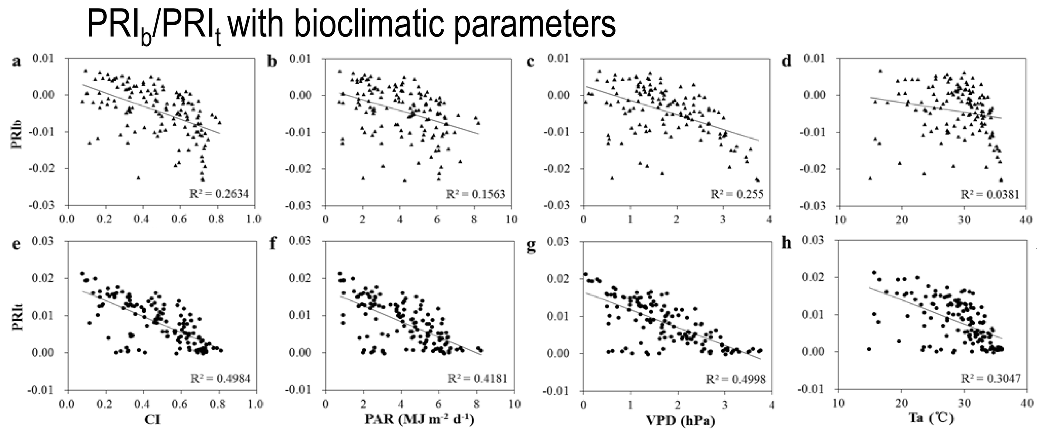
The reflectance of the canopy observed at a given view angle signifies the degree to which the observed canopy is sunlit, and the ratio (R_{SL}) is taken as the probability of observing sunlit leaves in the canopy

Results

LUE/LUE_r with bioclimatic parameters



PRI_b/PRI_t with bioclimatic parameters



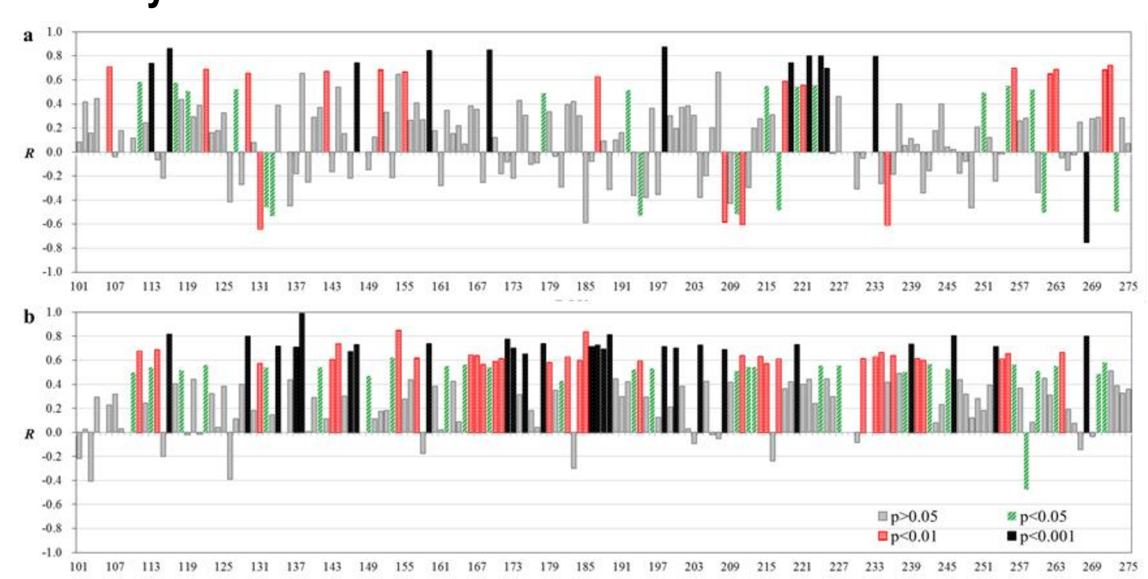
PRI_t *vs.* PRI_h

	DOY	129	178	184	187	220	240	255
R^2	PRI_{obs}-α_s	0.27n***	0.33***	0.17***	0.29***	0.37***	0.27***	0.26***
	PRI_b-LUE	0.43**	0.20*	0.09	0.39**	0.29*	0.00	0.30*
	PRI_t-LUE	0.65***	0.63***	0.36**	0.58***	0.54***	0.38**	0.43**
	PRI_h-LUE	0.28*	0.00	0.05	0.00	0.31*	0.32*	0.11n
	Daily CI	0.43	0.27	0.73	0.56	0.67	0.65	0.41

PRI_h (Hall et al., 2011) is the partial derivative of PRI with respect to shadow fraction

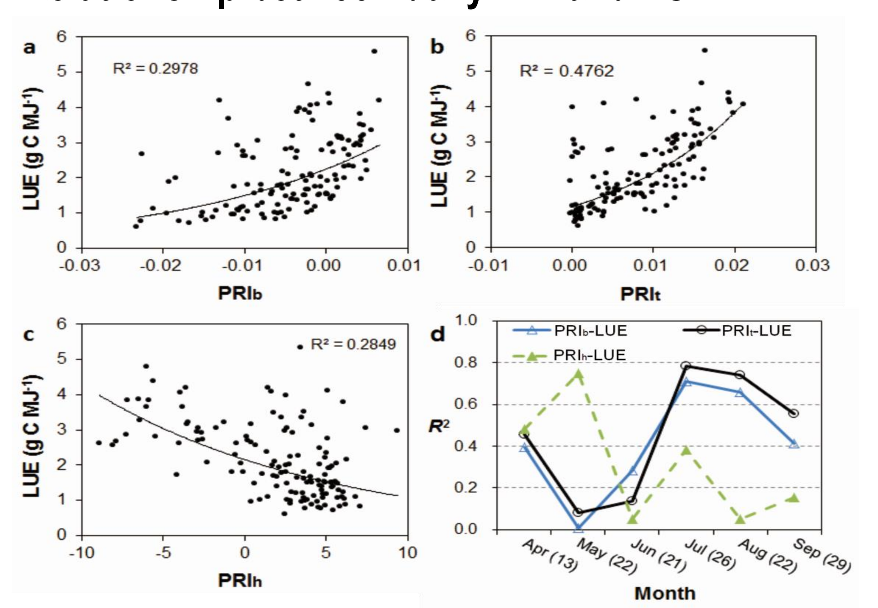
α_s is the shadow fraction or the fraction of shaded leaves

Ability of PRI to track diurnal LUE variations



At three significance levels, PRI_b-LUE positively correlated on 49, 30, 12 days, while PRI_t-LUE on 83, 55, 25 days

Relationship between daily PRI and LUE



The correlation between PRIt and LUE (a) is significantly enhanced over the big-leaf case (b) and PRIh (c).

Conclusions

- A ratio of canopy reflectance to leaf reflectance is used to represent the fraction of sunlit leaves, and the fraction of shaded leaves is calculated with a four-scale geometrical optical model;
- The canopy-level two-leaf PRI can effectively improve (>60%) the ability of PRI as a proxy of LUE over the big-leaf PRI in a given time interval;
- Overall, the two-leaf approach enhances the sensitivity of PRI to variations in LUE under most conditions by reducing the influence of some external factors (e.g. sun-target-view geometry) on the PRI signals.

References

Qian Zhang, Jing M. Chen, Weimin Ju*, Huimin Wang, Feng Qiu, Fengting Yang, Weiliang Fan, Qing Huang, et al. Improving the ability of the photochemical reflectance index to track canopy light use efficiency through differentiating sunlit and shaded leaves. Remote Sensing of Environment, 2017, 194: 1-15.