Joint Conference of AsiaFlux Workshop 2017 and
the 15th Anniversary Celebration of ChinaFLUX

Development and validation of a two leaf light use efficiency model based on flux measurements

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August 16-19, 2017, Beijing

Outline

- Background
- Model structure
- Model validation
- Model Parameterization
- Conclusions

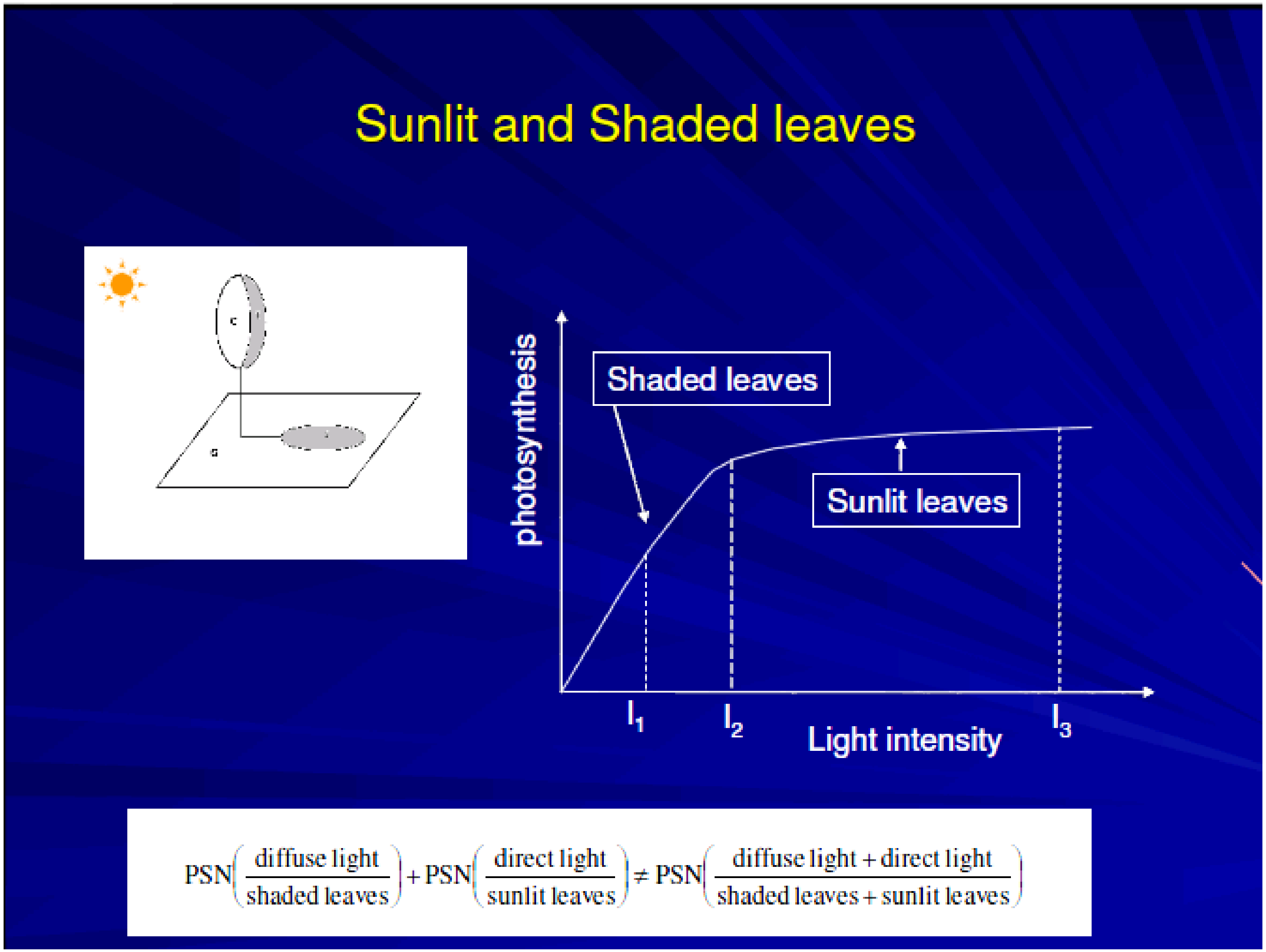
Background

- Light use efficiency model assume that GPP linearly increases with incoming PAR

模型	NPP/GPP 计算	APAR 计算	FPAR 计算	ε 计算	文献
CASA	$NPP = APAR \times \varepsilon$	$S \times FPAR \times 0.5$	$\min[\frac{SR - SR_{min}}{SR_{max} - SR_{min}}, 0.95]$	$\varepsilon_{max} f(T) f(\theta)$	Potter et al., 2003, GGC
C-Flux	$GPP = APAR \times \varepsilon$	$S \times FPAR \times c$	$a \times NDVI + b$	$\varepsilon_{max} f(T) f(CO_2)$	Veroustraete et al. , 2002, RSE
CFLUX	$GPP = APAR \times \varepsilon$	$PAR \times FPAR$		$\varepsilon_{max} f(T_{min}) f(VPD)$ $f(\theta) f(Age)$	Turner, 2006, Tellus
GLO-PEM	$NPP = APAR \times \varepsilon$ $\times Y_g \times Y_m$	$PAR \times FPAR$	$1.08 \times NDVI - 0.08$	$\varepsilon_{max} f(T_{min}) f(VPD)$ $f(\theta)$	Prince, 1995, Biogeography
BEAMS	$GPP = APAR \times \varepsilon$			$\varepsilon_{max} \times s$ $s = \frac{P(temp, hs, Fsoil1, Fsoil2)}{P(temp_{\_opt}, hs_{\_opt}, Fsoil1_{\_opt}, Fsoil2_{\_opt})}$	Sasai et al., 2005, JGR
VPM	$GPP = APAR \times \varepsilon$	$PAR \times FPAR_{PAV}$	EVI	$\varepsilon_{max} f(T) f(W) f(P)$	Xiao et al., 2004, RSE
MODIS-GPP 算法	$GPP = APAR \times \varepsilon$	$PAR \times FPAR$	$1 - e^{-K \times LAI}$	$\varepsilon_{max} f(T_{min}) f(VPD)$	Zhao et al., 2005, RSE

Background

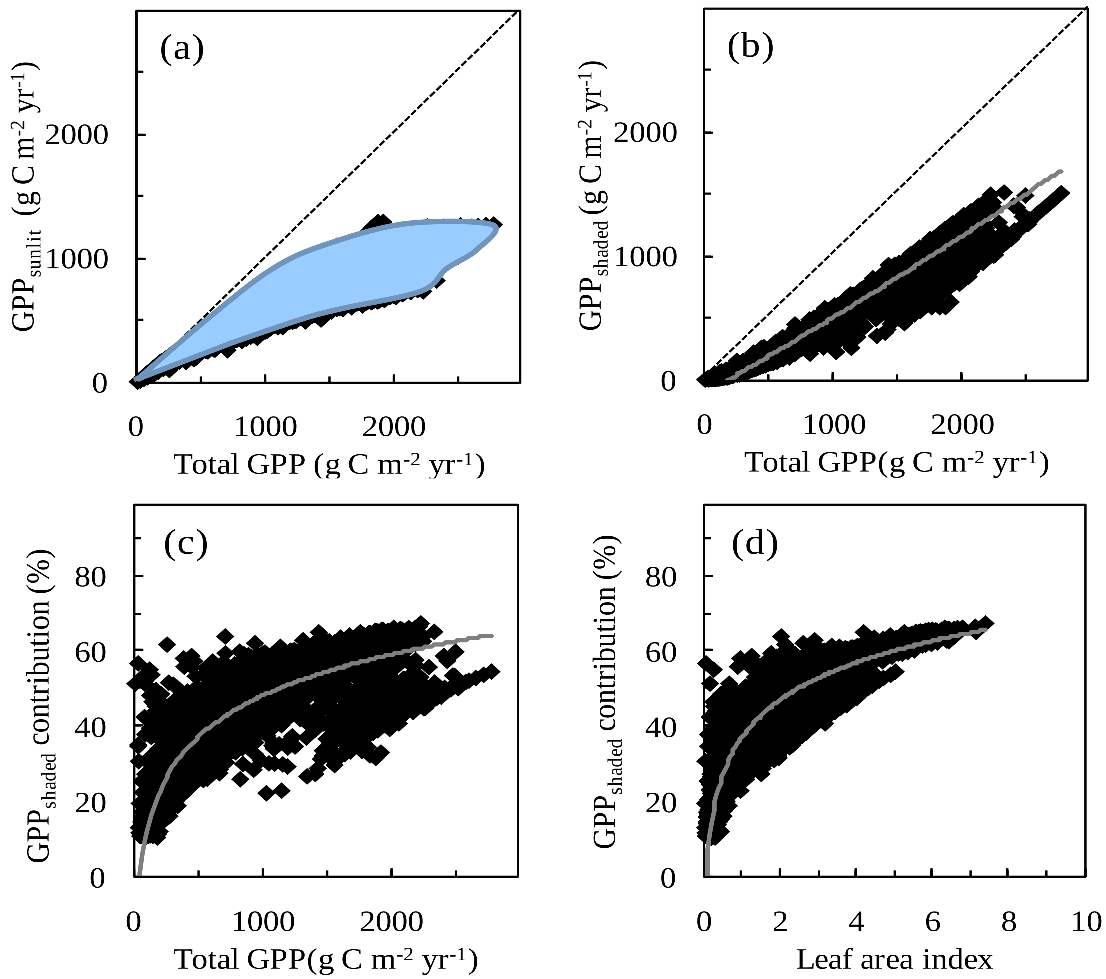
◆ Response of photosynthesis to light intensity



Song， 2010

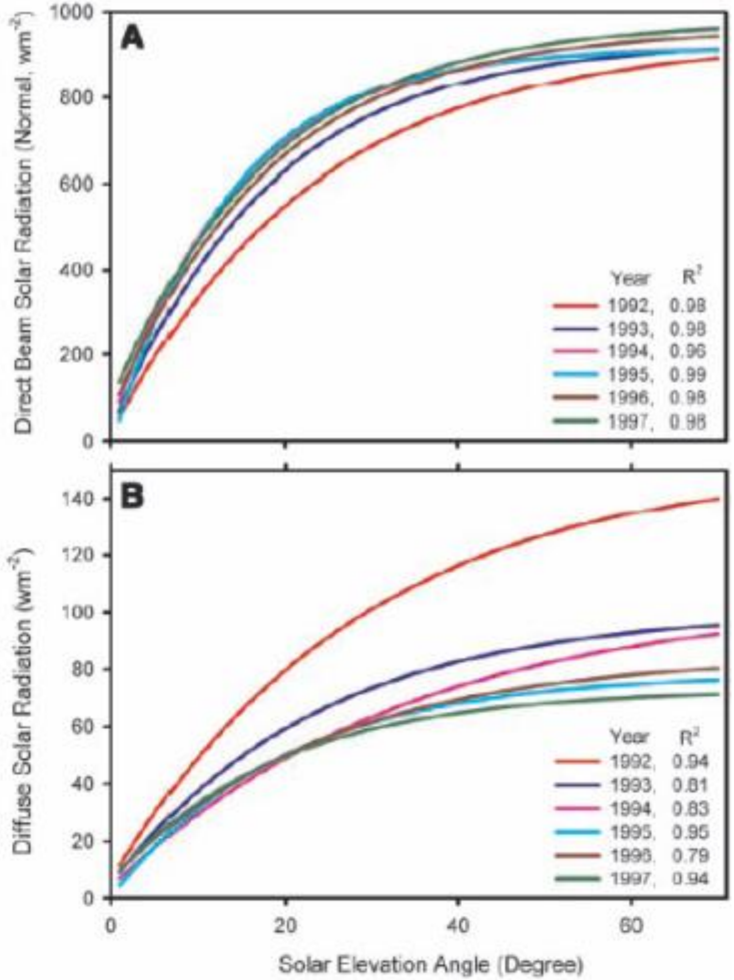
Background

◆ **Contributions of Sunlit and Shaded Leaves to the Total GPP (BEPS, Needleleaf Forests)**

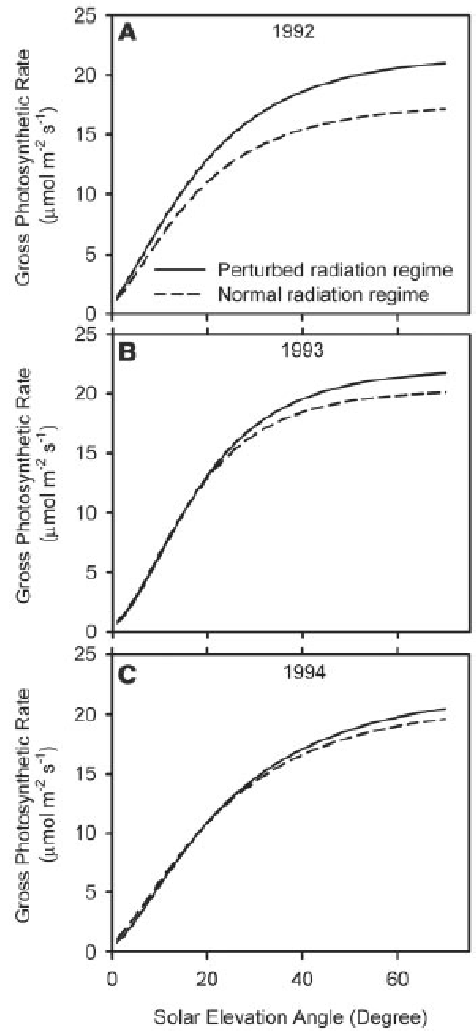


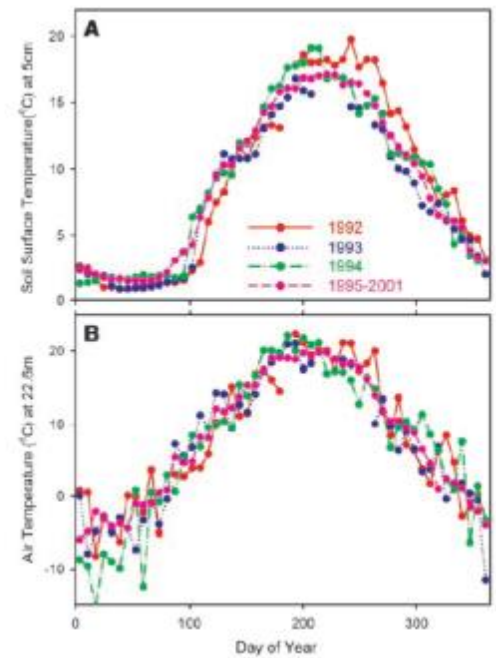
Background

◆ **Effect of radiation change on net terrestrial carbon sequestration after Pinatubo volcanic eruption**



Gu et al., Science, 2003



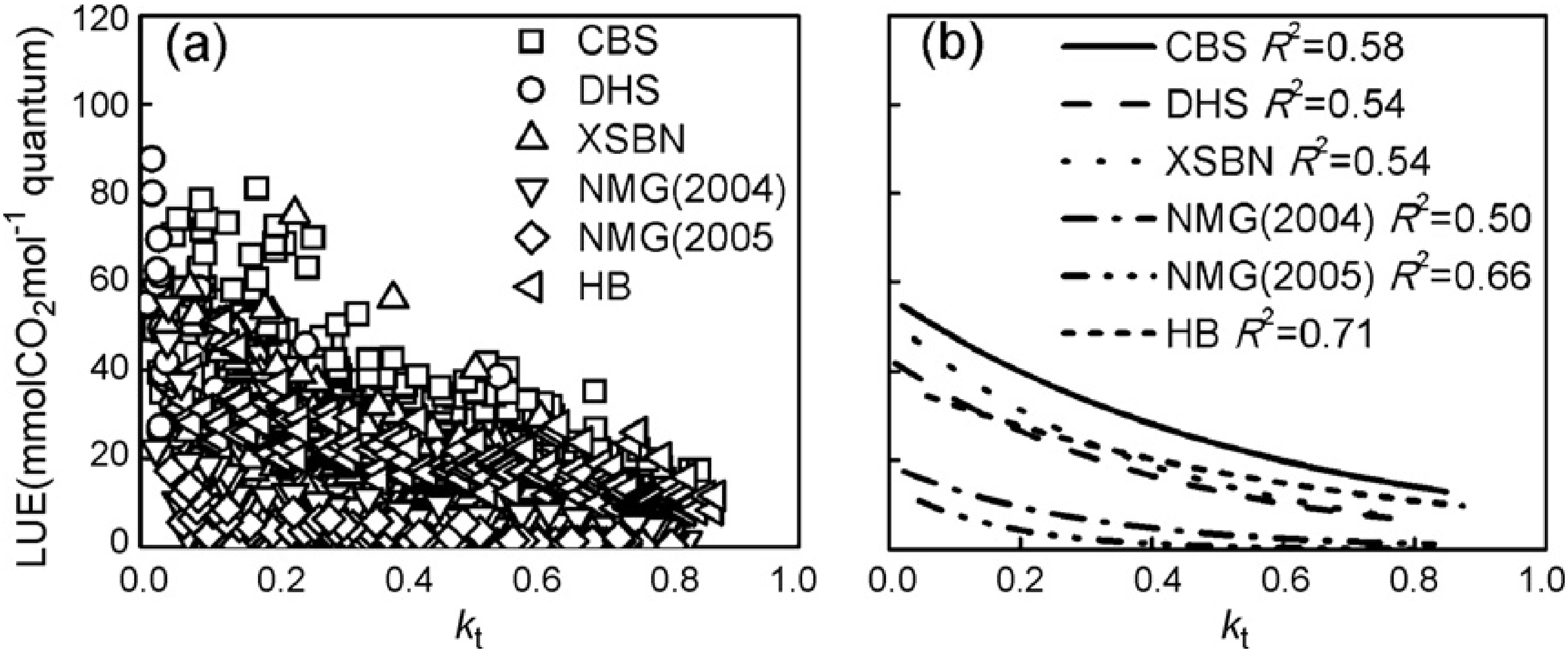


Harvard Forest

GPP increased by 23% and 8% on clear days in 1992 and 1993, respectively.

Background

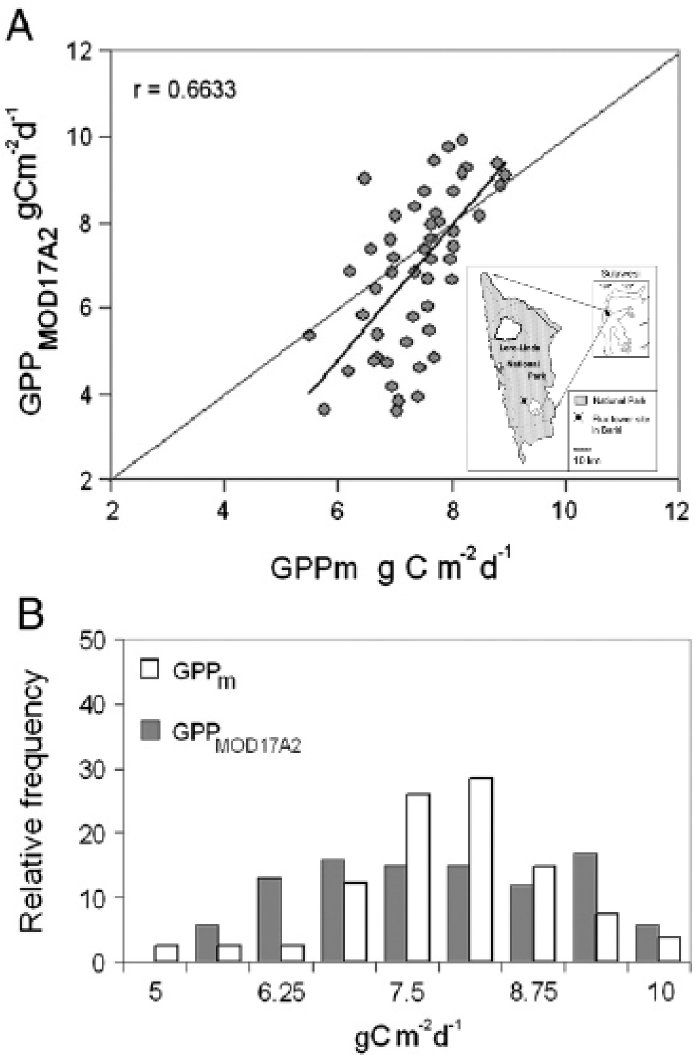
◆ **Canopy LUE decreases with sky clearness ChinaFlux sites**

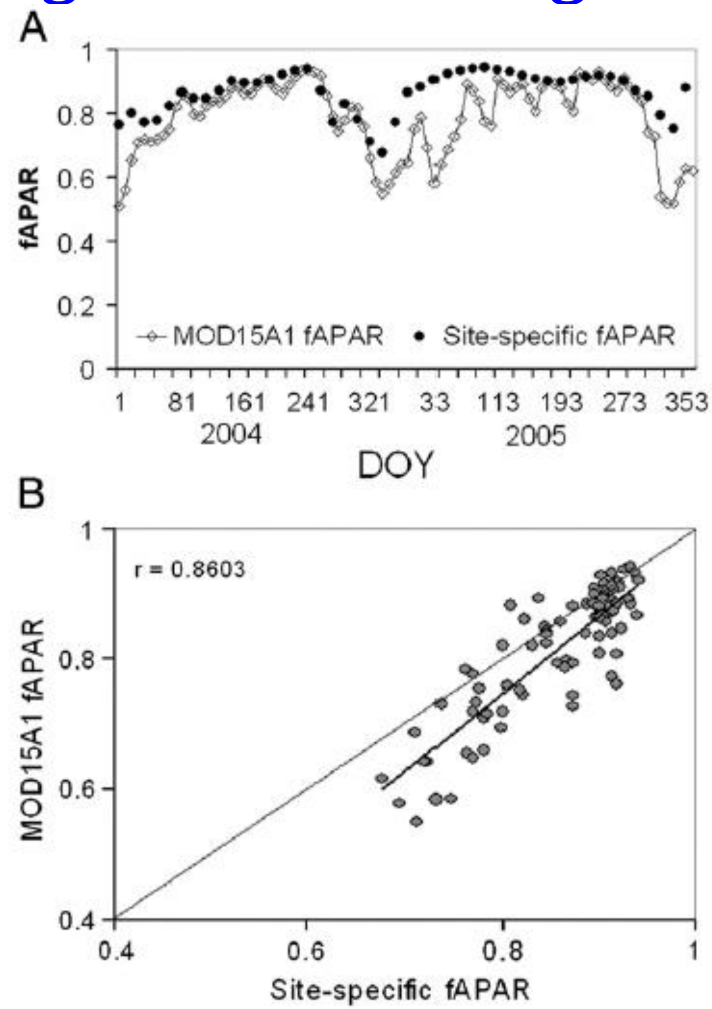


Zhang et al., AFM, 2011

Background

- **Bias of GPP calculated using the MOD17 algorithm**





Propastin et al., RSE, 2012

Two-leaf light use efficiency model

$$\mathbf{GPP}=\varepsilon_{max\_sun} f(\mathrm{VPD}) g(\mathrm{T_{amin}})\mathrm{APAR}_{sun}+\varepsilon_{max\_shaded} f(\mathrm{VPD}) g(\mathrm{T_{amin}})\mathrm{APAR}_{shaded}$$

$$APAR_{shaded} = (1-\alpha)[(PAR_{dif} - PAR_{dif\_under})/LAI + C]LAI_{shaded}$$

$$APAR_{sun} = [(1-\alpha)PAR_{dir}\cos(\beta)/\cos(\theta) + PAR_{shaded}]LAI_{sun}$$

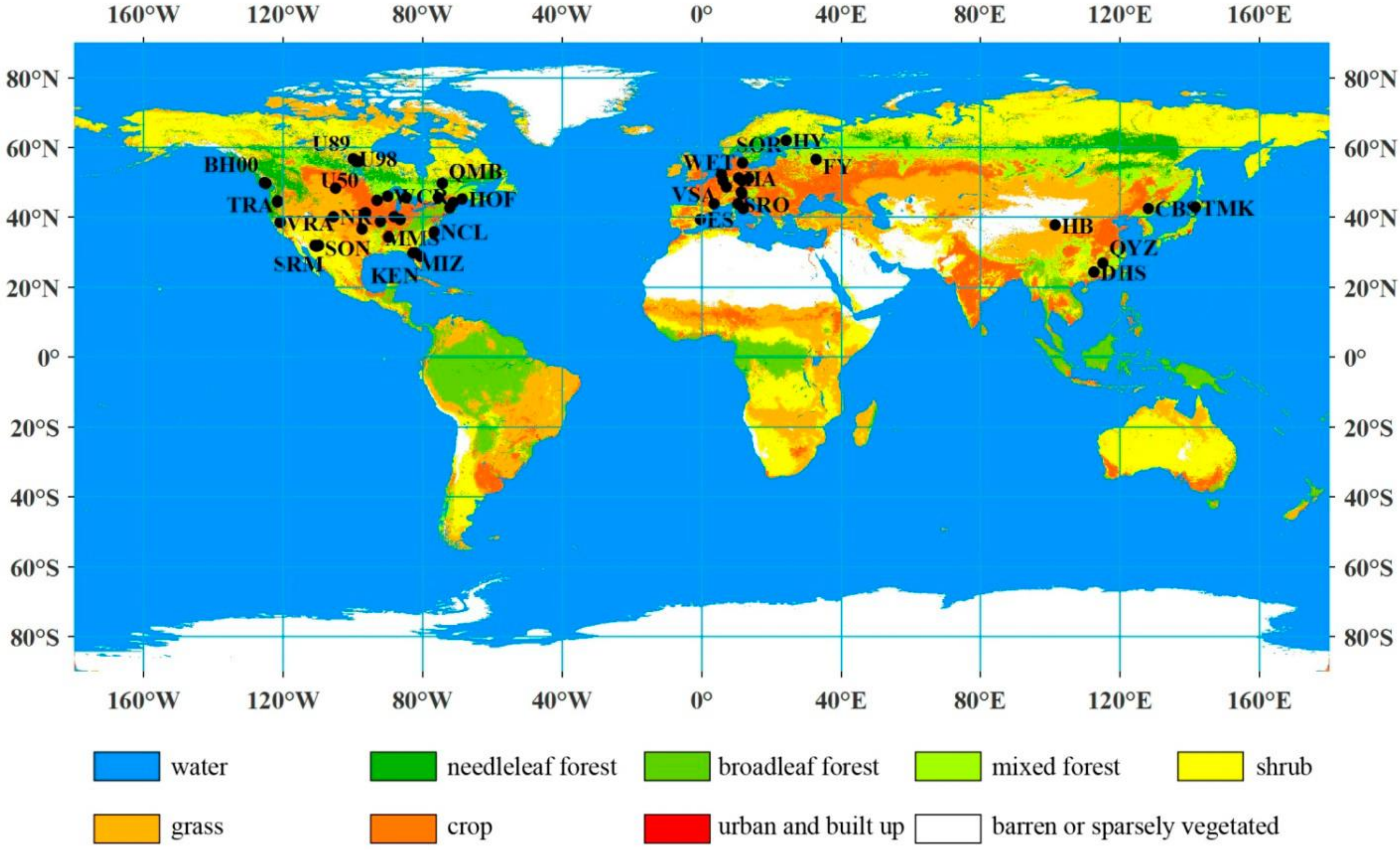
$$\mathrm{S_{dif}} = \mathrm{S}_g(0.7527+3.8453\mathrm{R}-16.316\mathrm{R}^2+18.962\mathrm{R}^3-7.0802\mathrm{R}^4)$$

$$LAI_{sun} = 2\cos(\theta)(1-\exp(-0.5\Omega LAI/\cos(\theta)))$$

$$LAI_{shaded} = LAI - LAI_{sun}$$

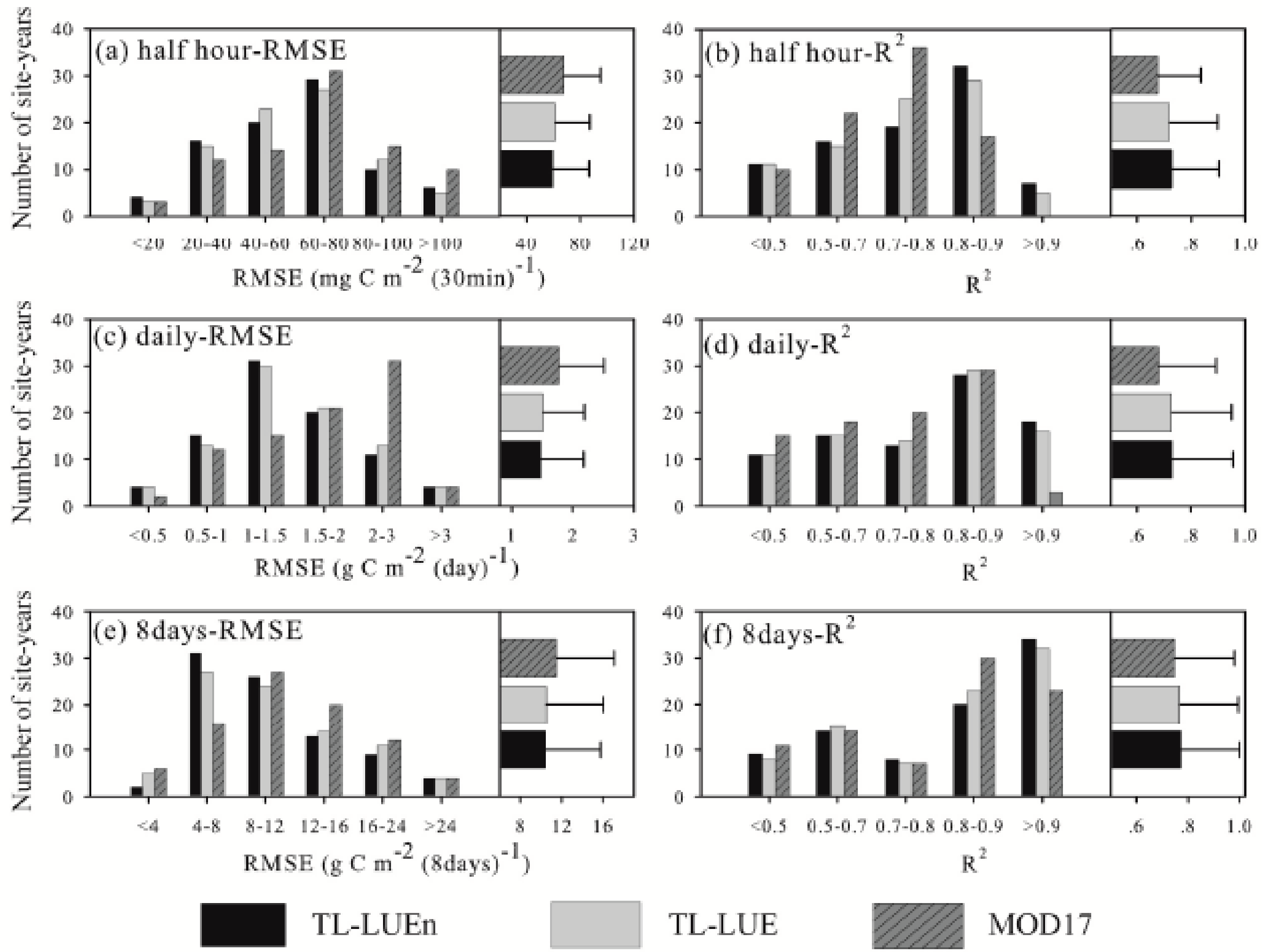
He , Ju et al., 2013, AFM

Validation of the TL-LUE model



Validation of the TL-LUE model

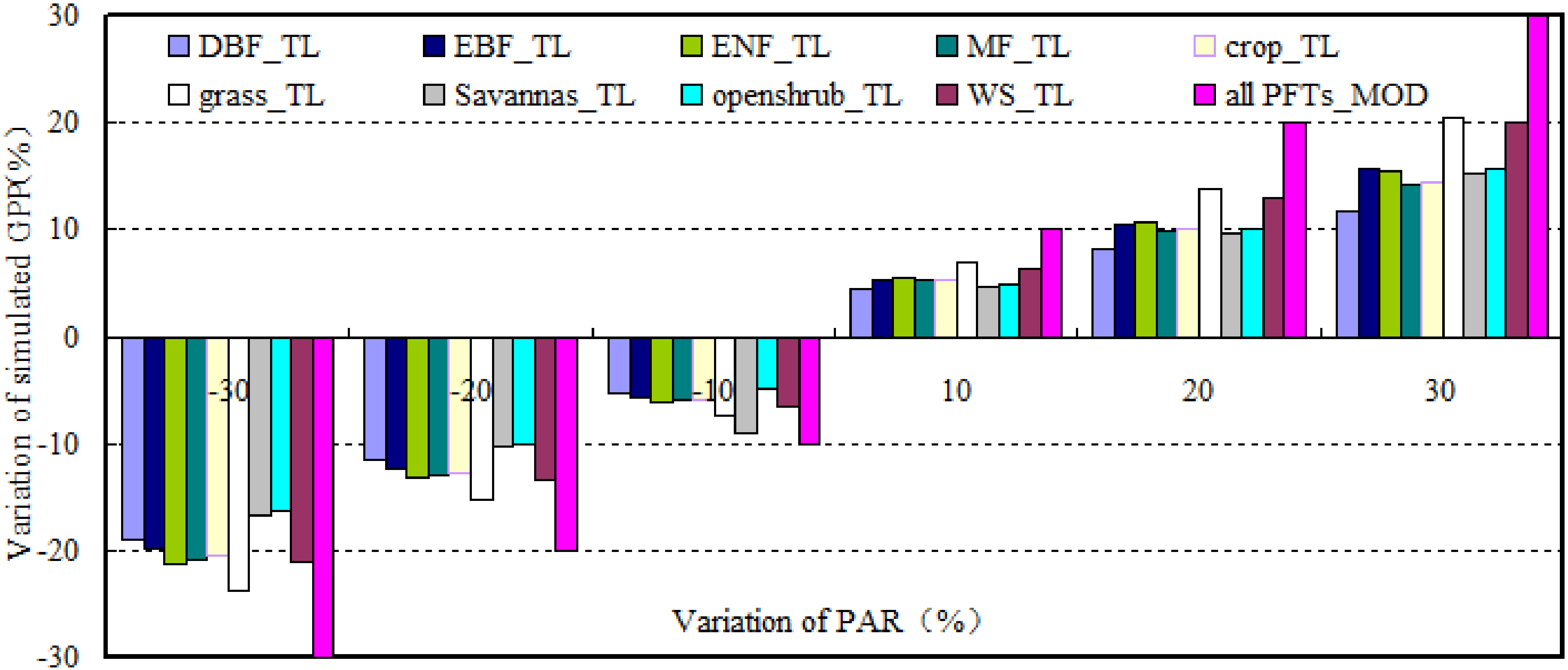
- **TL-LUE model outperformances the MOD17 algorithms at half-hour, daily and 8-day time scales**



Wu , Ju et al., 2015, Remote Sensing

Validation of the TL-LUE model

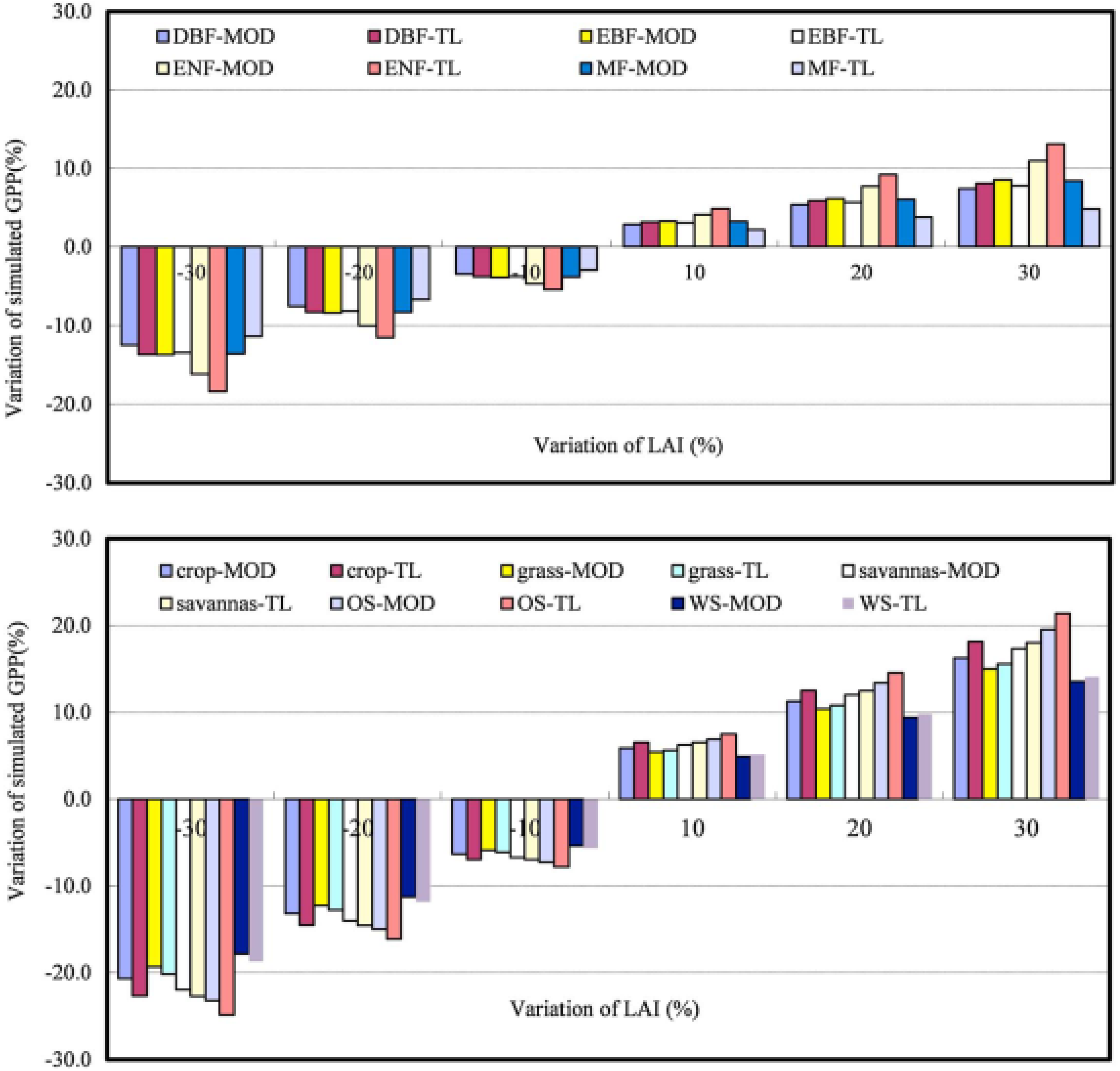
- **Low sensitivity of the TL-LUE to incoming PAR**



Zhou , Ju et al., 2016, JGR-Biogeosciences

Validation of the TL-LUE model

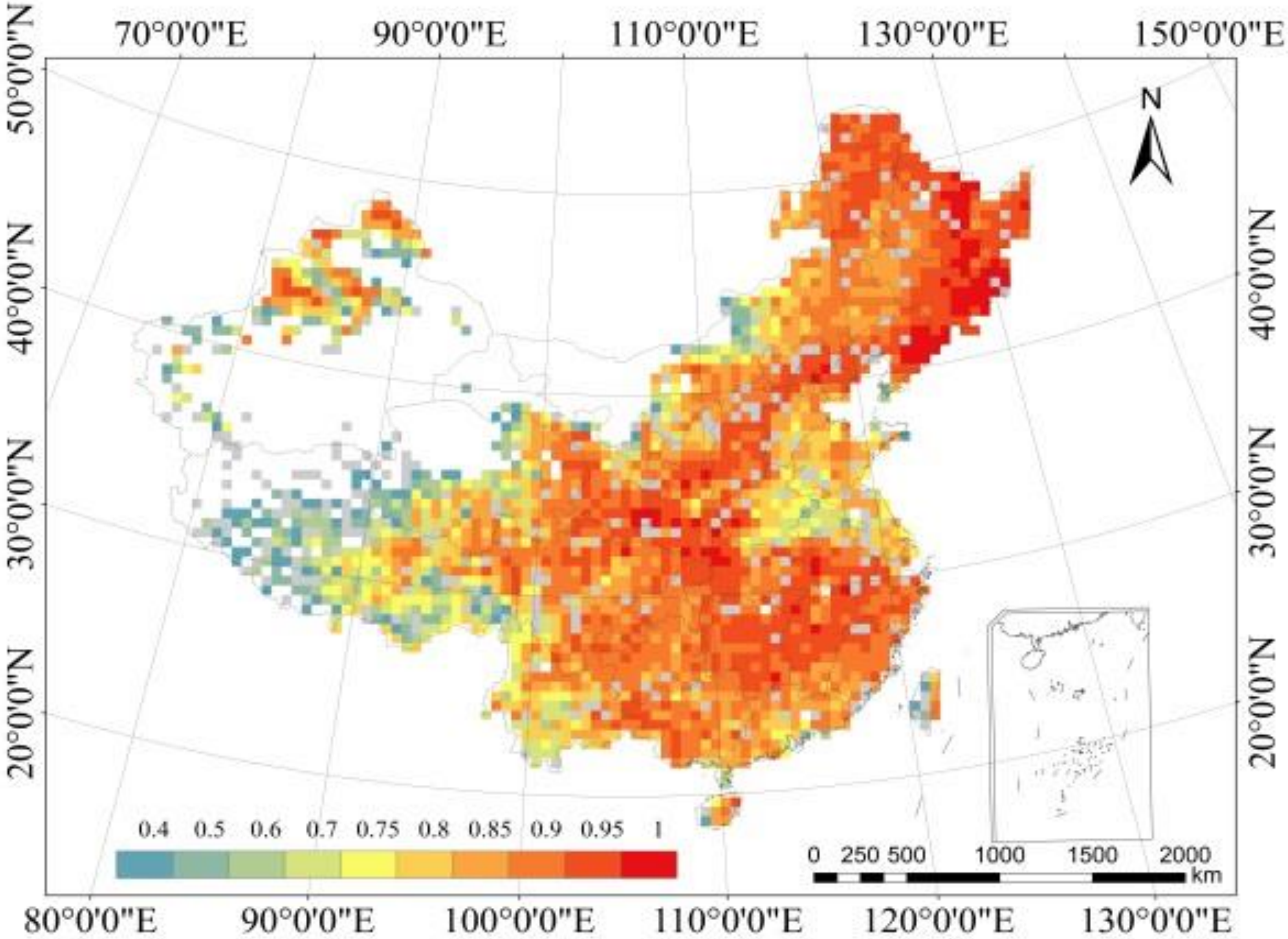
- **Slightly higher sensitivity of the TL-LUE to LAI**



Zhou , Ju et al., 2016, JGR-Biogeosciences

Validation of the TL-LUE model

◆ Validation of the TL-LUE model at regional scale using SIF data



The correlation coefficient between monthly GPP simulated by the TL-LUE model and SIF

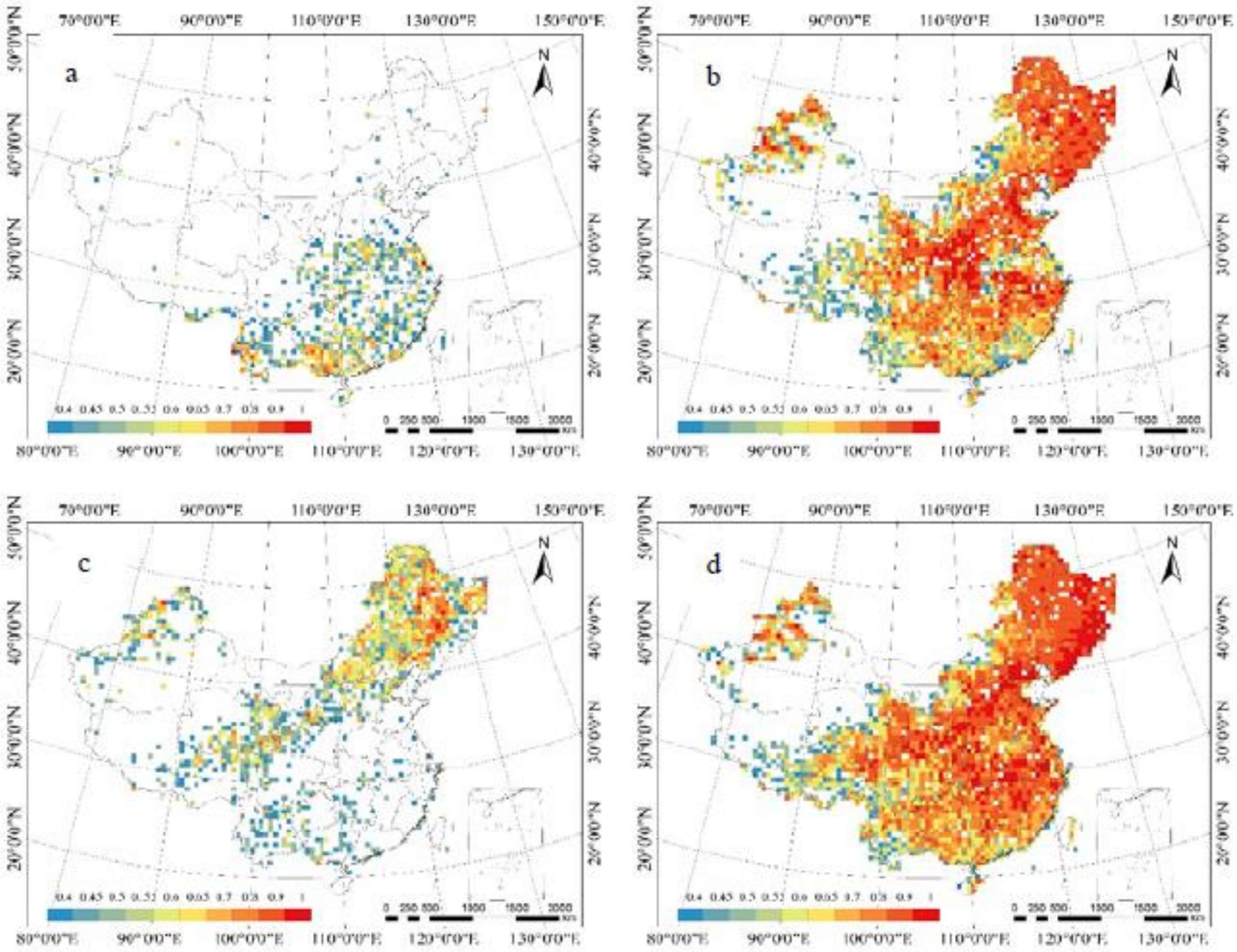
Zhan, Zhou, Ju et al., 2017, STE, revised

Validation of the TL-LUE model

◆ **The correlation coefficient between monthly GPP simulated by the TL-LUE model and SIF ($n=3\times8=24$)**

Winter

Summer



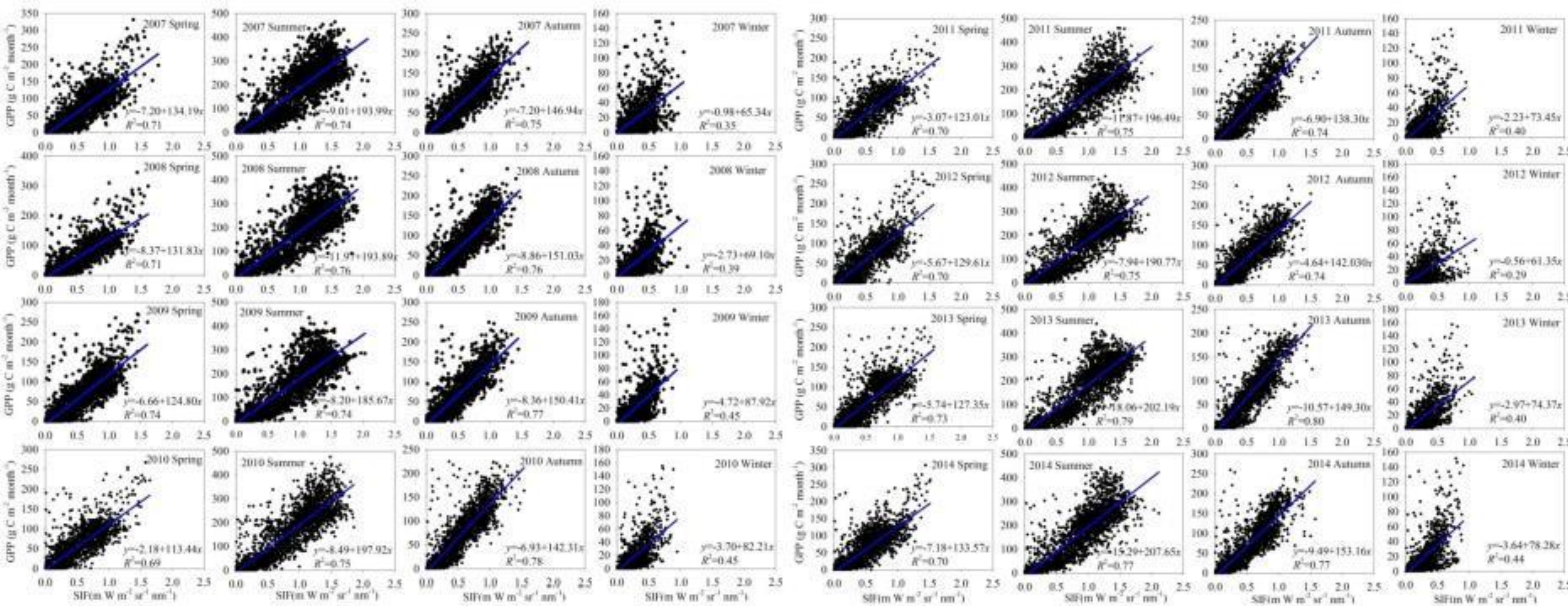
Summer

Autumn

Zan, Zhou, Ju et al., 2017, STE, revised

Validation of the TL-LUE model

- **Spatial similarity between monthly GPP simulated by TL-LUE and SIF in different seasons**

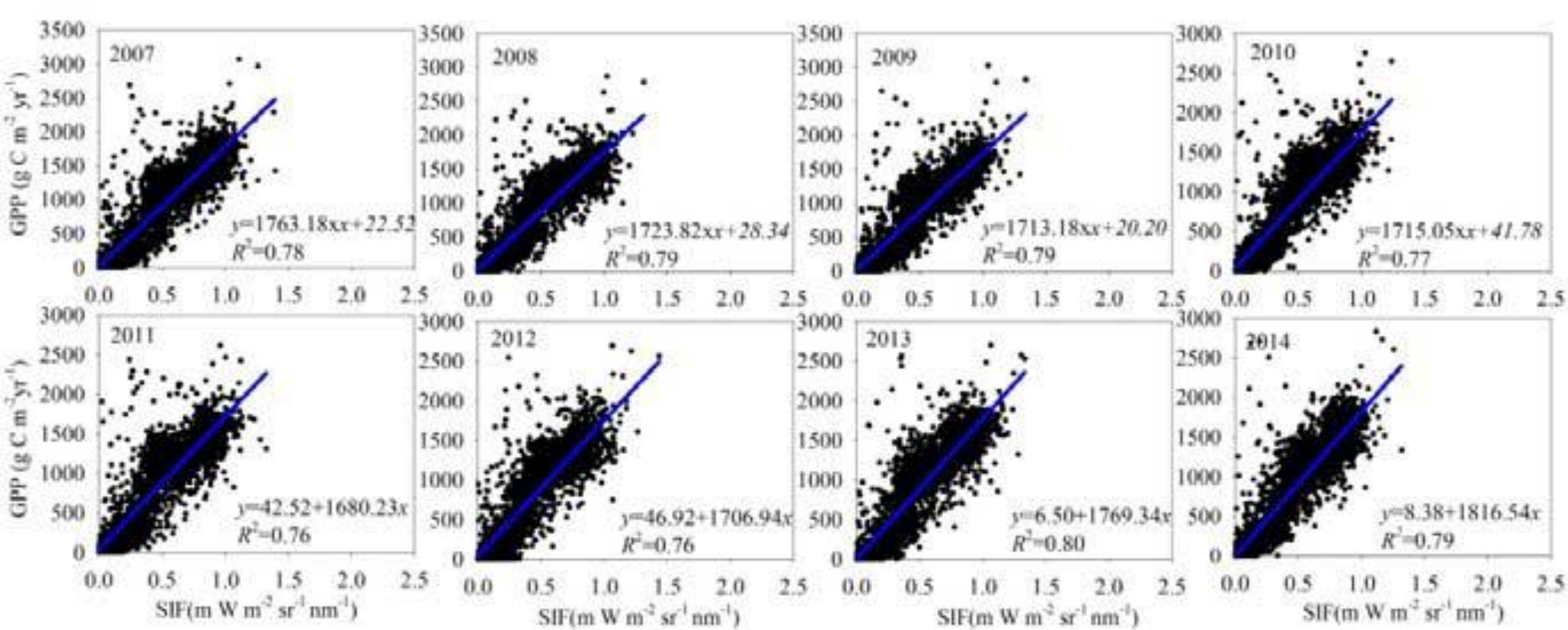


Spring Summer Autumn Winter Spring Summer Autumn Winter

Zan, Zhou, Ju et al., 2017, STE, revised

Validation of the TL-LUE model

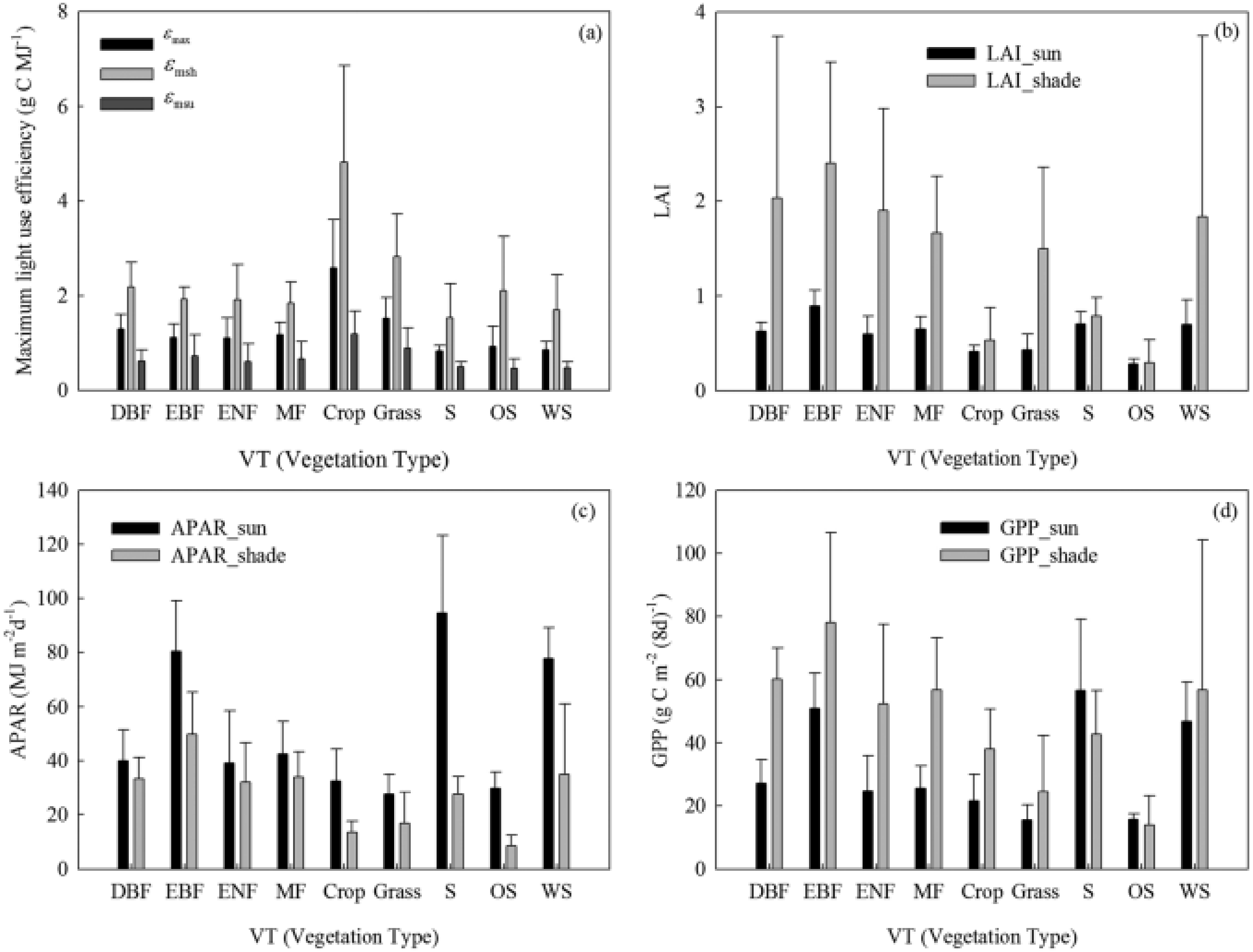
- **Spatial similarity between annual GPP simulated by TL-LUE and SIF in different years**



Zan, Zhou, Ju et al., 2017, STE, revised

Model Parameterization

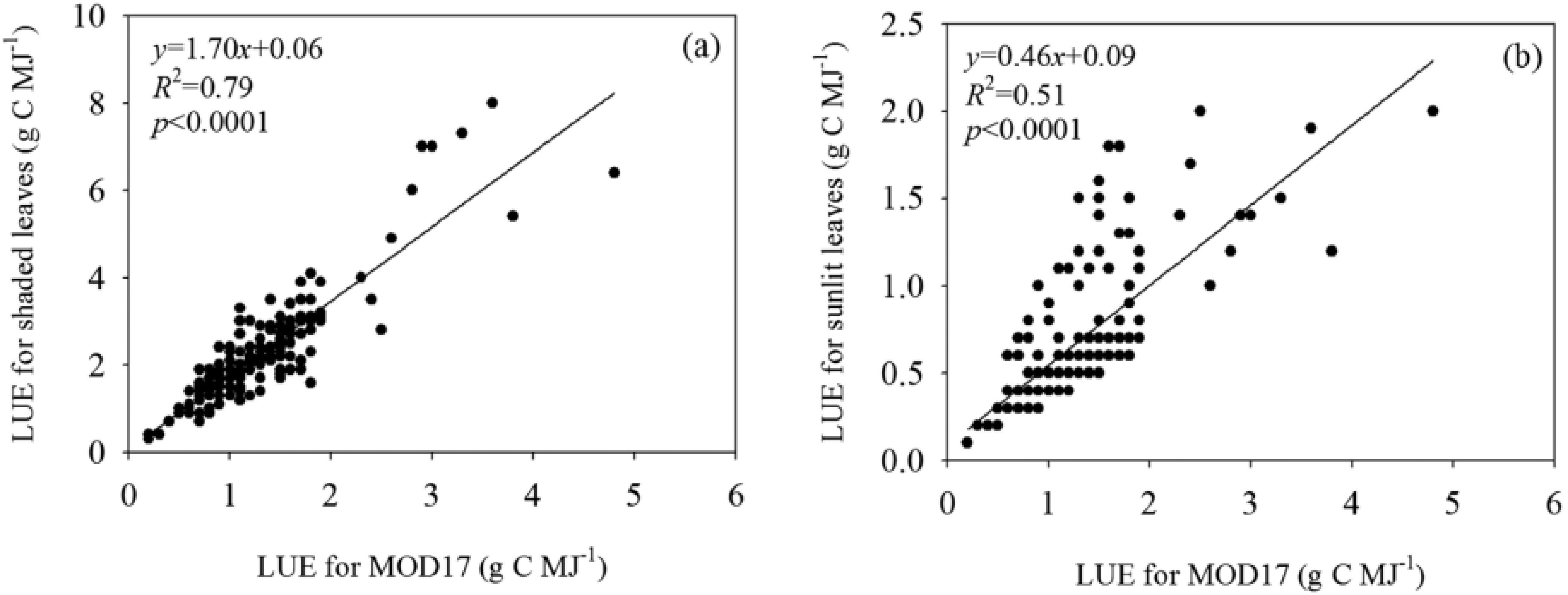
- **Differences of sunlit and shaded leaves in maximum LUE, LAI, APAR, and GPP for different land cover types**



Zhou , Ju et al., 2016, JGR-Biogeosciences

Model Parameterization

◆ **Shaded leaves dominate the maximum LUE of canopy**



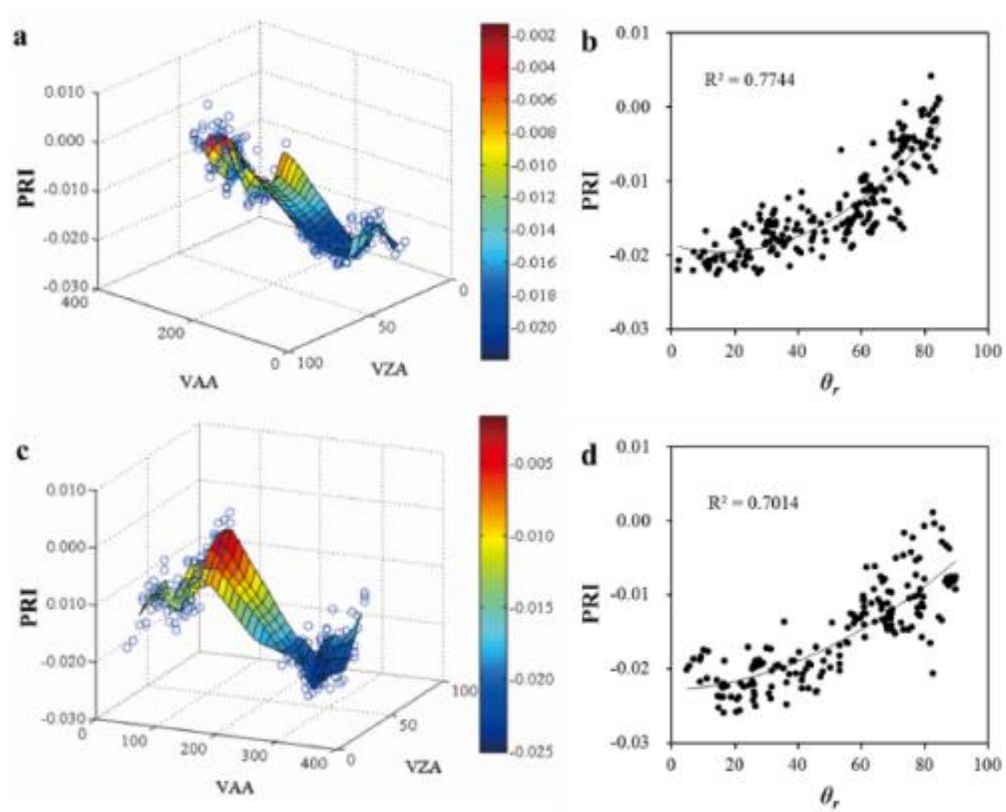
Zhou , Ju et al., 2016, JGR-Biogeosciences

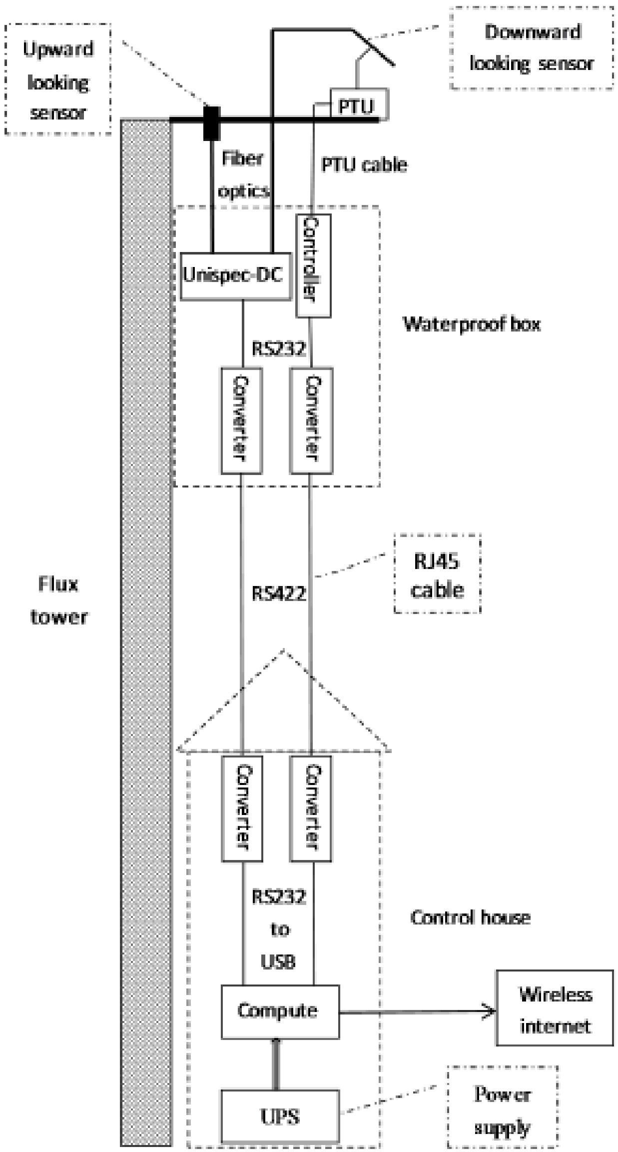
Model Parameterization

- **Tracking LUE using PRI at Qianyanzhou site**

$$PRI = (R_{531}-R_{570})/(R_{531} + R_{570})$$

- **Dependence of PRI on observational angles**





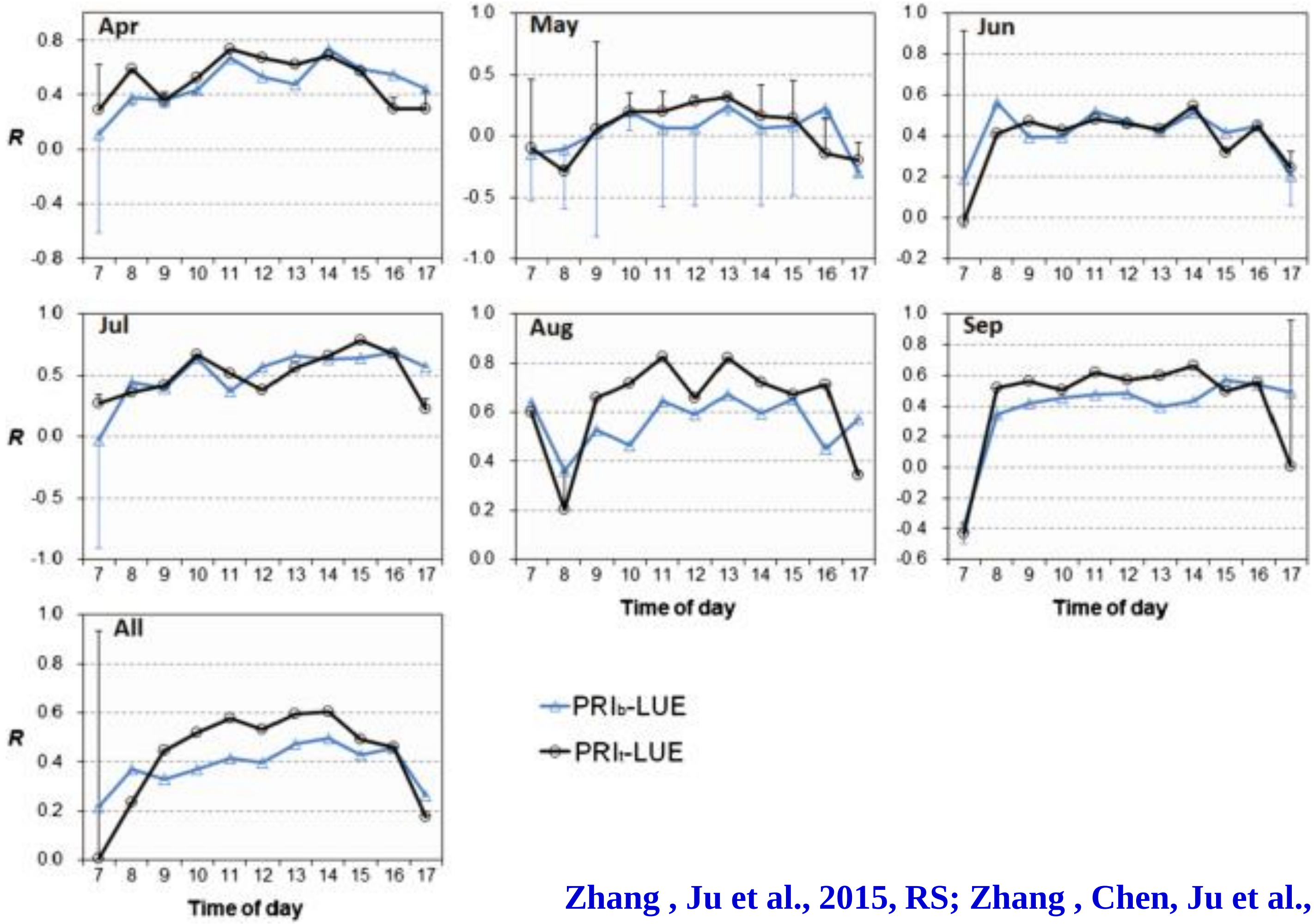
Zhang , Ju et al., 2015, RS; Zhang , Chen, Ju et al., 2017, RSE

Model Parameterization

- **Two methods for deriving canopy PRI from observations at different angles**

(1) $PRI_{obs} = P_T\ PRI_{sun} + P_S\ PRI_{sh}$ $PRI_t = PRI_{sun} \times L_{sun}/LAI + PRI_{sh} \times L_{sh}/LAI$

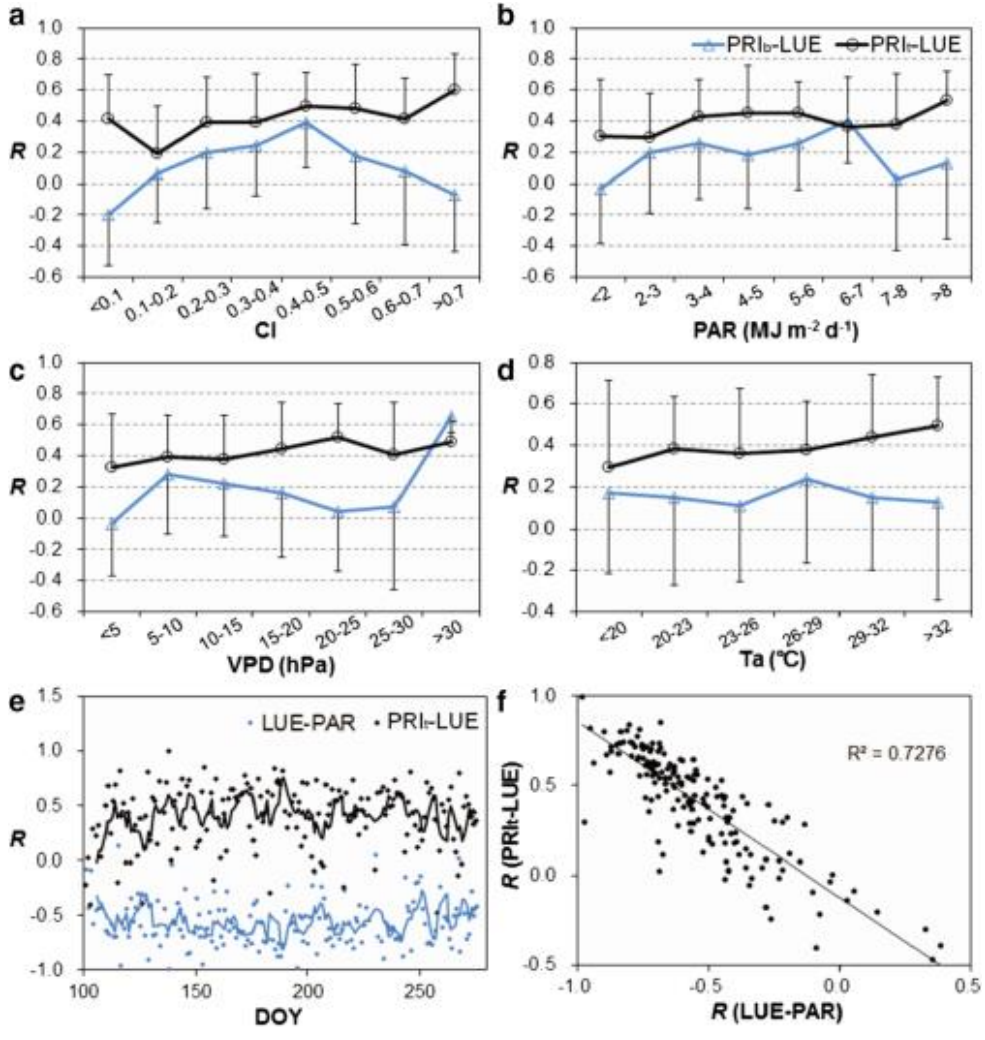
(2) $PRI_b = \frac{1}{N}\sum_{i=1}^{N} PRI_i$ N is the number of observational angles



Zhang , Ju et al., 2015, RS; Zhang , Chen, Ju et al., 2017, RSE

Model Parameterization

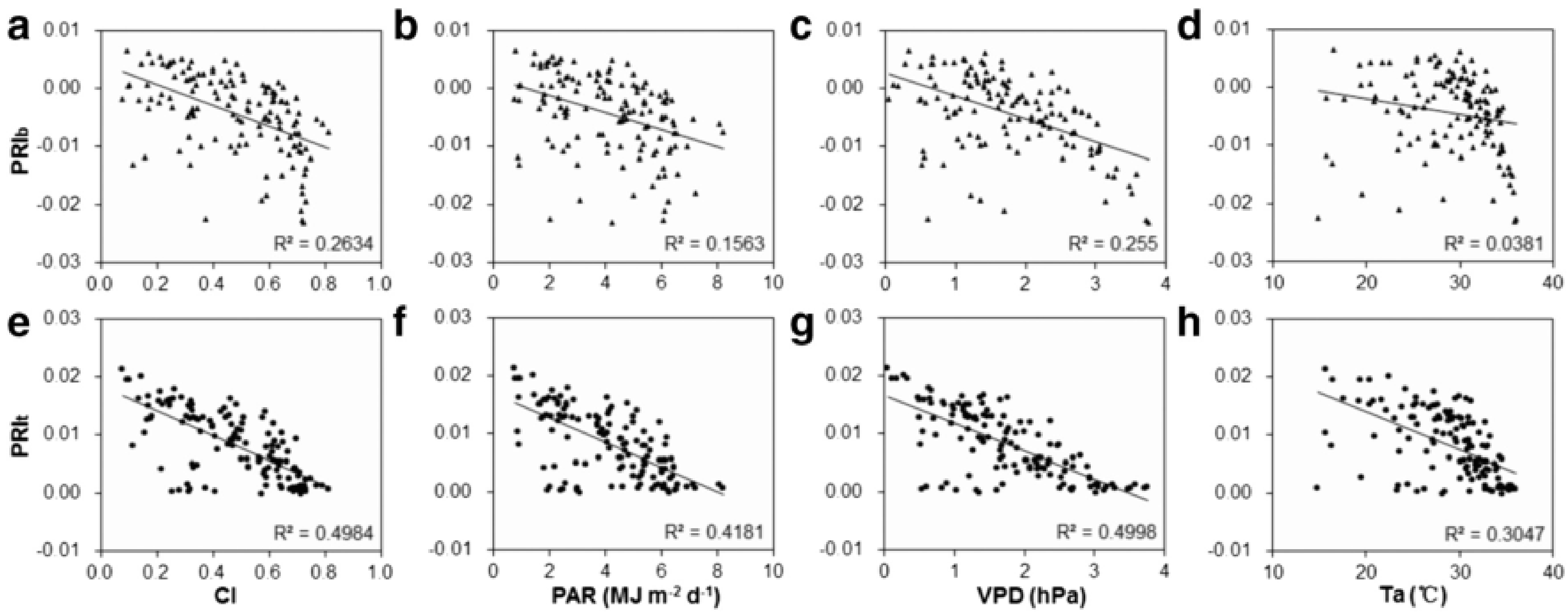
- **Average diurnal correlation coefficients (R) between half-hourly PRI_b and LUE and between half-hourly PRI_t and LUE**



Zhang , Ju et al., 2015, RS; Zhang , Chen, Ju et al., 2017, RSE

Model Parameterization

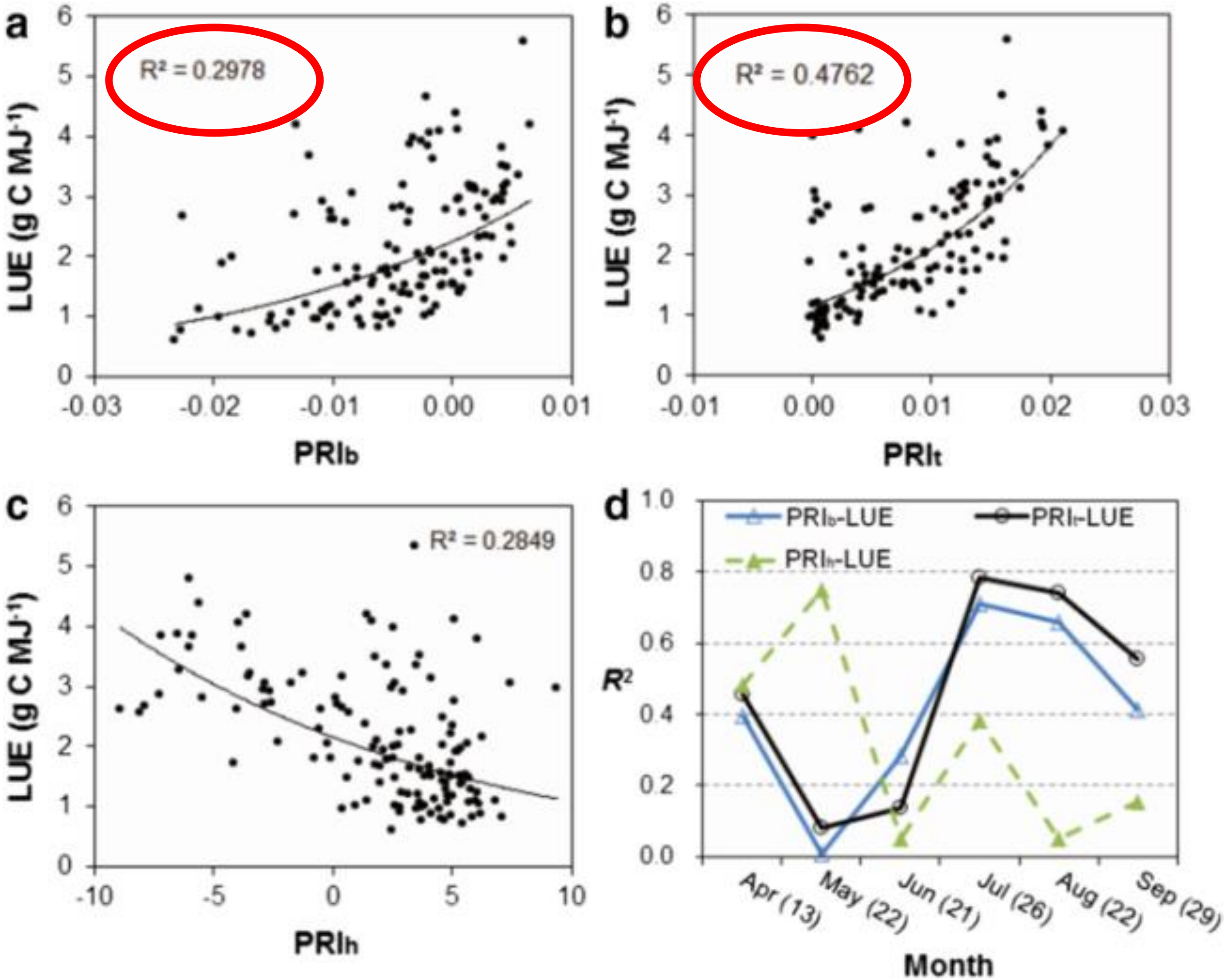
- **Relationships of daily mean PRI_b and PRI_t with four bioclimatic factors on 133 non-rainy days over the growing season.**



Zhang , Ju et al., 2015, RS; Zhang , Chen, Ju et al., 2017, RSE

Model Parameterization

- **Relationships between (a) daily PRIb and LUE, (b) between daily PRIt and LUE, (c) between daily PRI_h and LUE, and (d) their variations .**



Numbers in parentheses in plot (d) are the sample numbers in each month.

Zhang , Ju et al., 2015, RS; Zhang , Chen, Ju et al., 2017, RSE

Model Parameterization

- **Modeling Gross Primary Production for Sunlit and Shaded Canopies Across an Evergreen and a Deciduous Site in Canada**

✓ A bidirectional reflectance distribution function (BRDF) was used to model PRI as the linear combination of isotropic, geometric, and volumetric scattering components

$$\mathrm{PRI}(\theta_v, \theta_s, \emptyset) = K_i + K_g F_g(\theta_v, \theta_s, \emptyset) + K_v F_v(\theta_v, \theta_s, \emptyset)$$

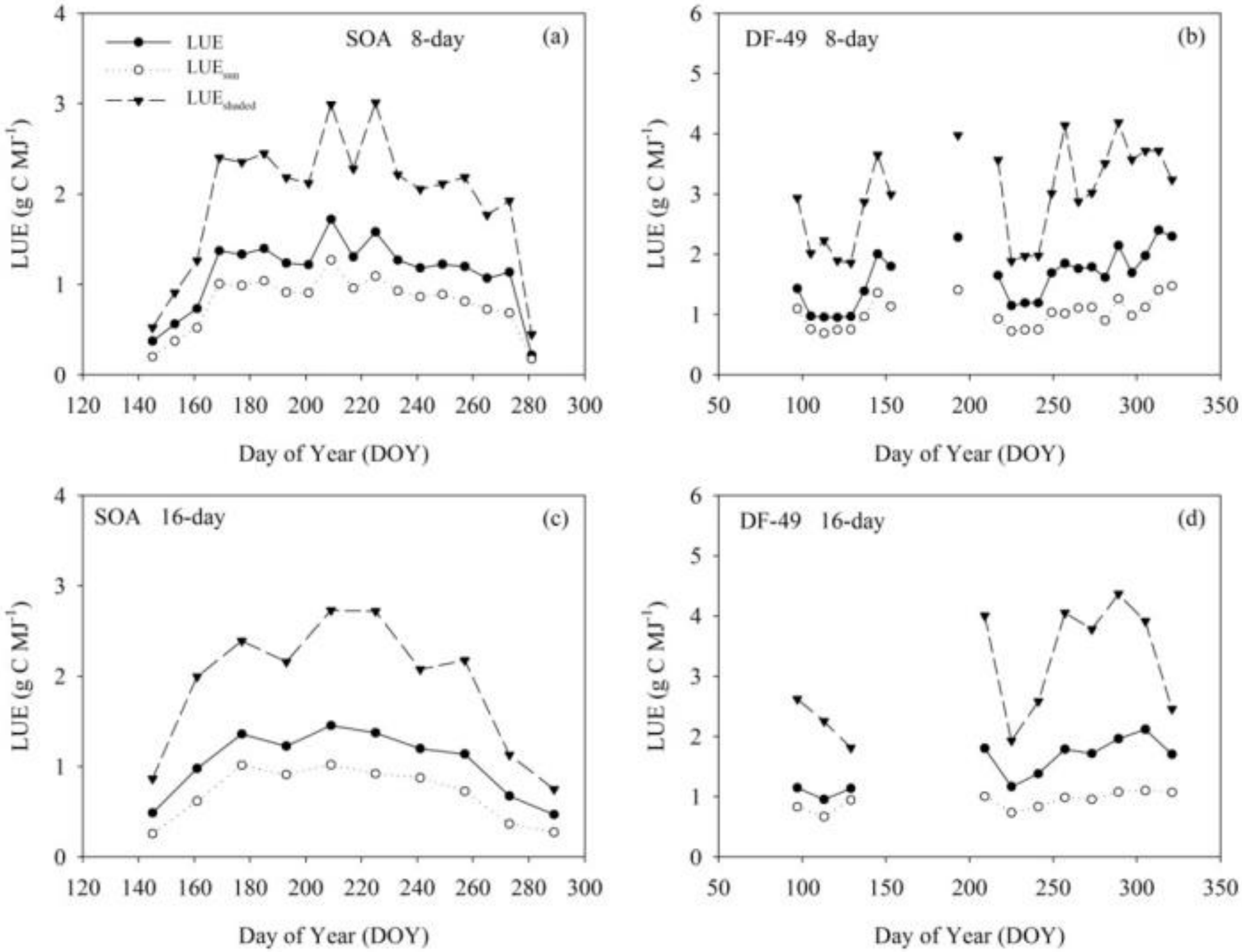
✓ **PRI at hotspot as PRI_{sunlit}**

✓ **PRI at darkspot as PRI_{shaded}**

Zhou , Hilker, Ju et al., 2017, IEEE TGARS

Model Parameterization

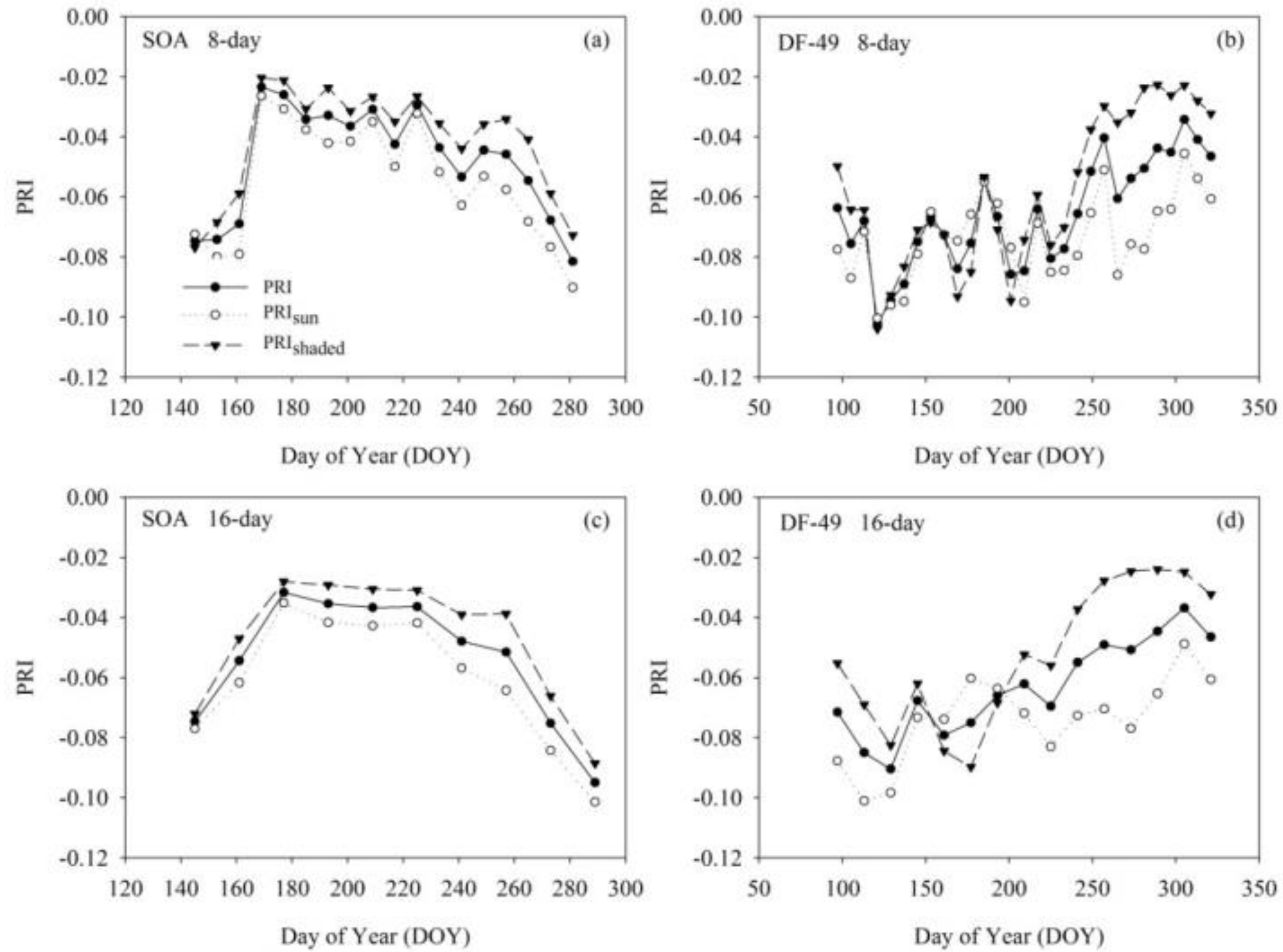
◆ Seasonal variations of LUE



Zhou , Hilker, Ju et al., 2017, IEEE TGARS

Model Parameterization

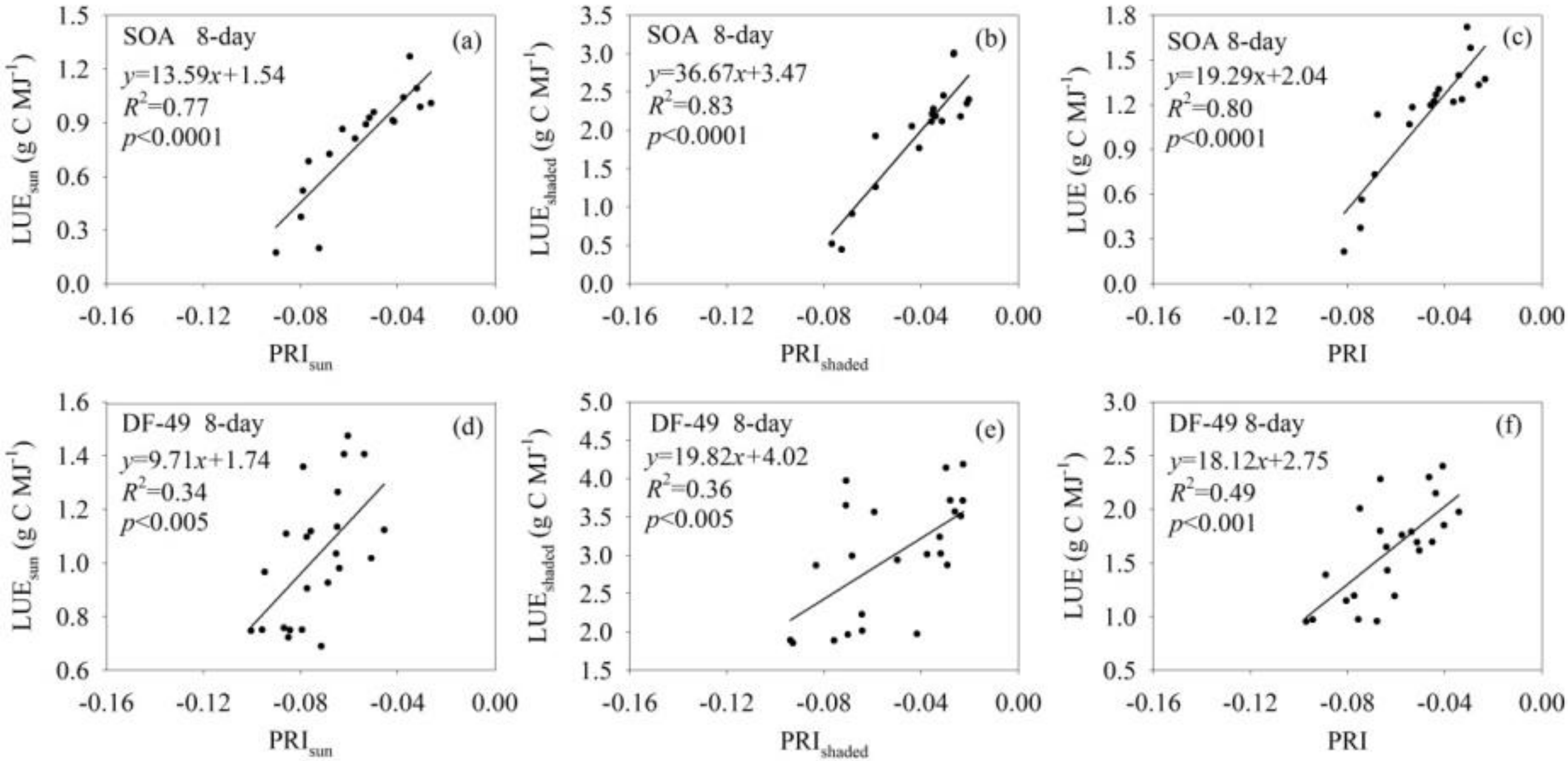
◆ Seasonal variations of PRI



Zhou , Hilker, Ju et al., 2017, IEEE TGARS

Model Parameterization

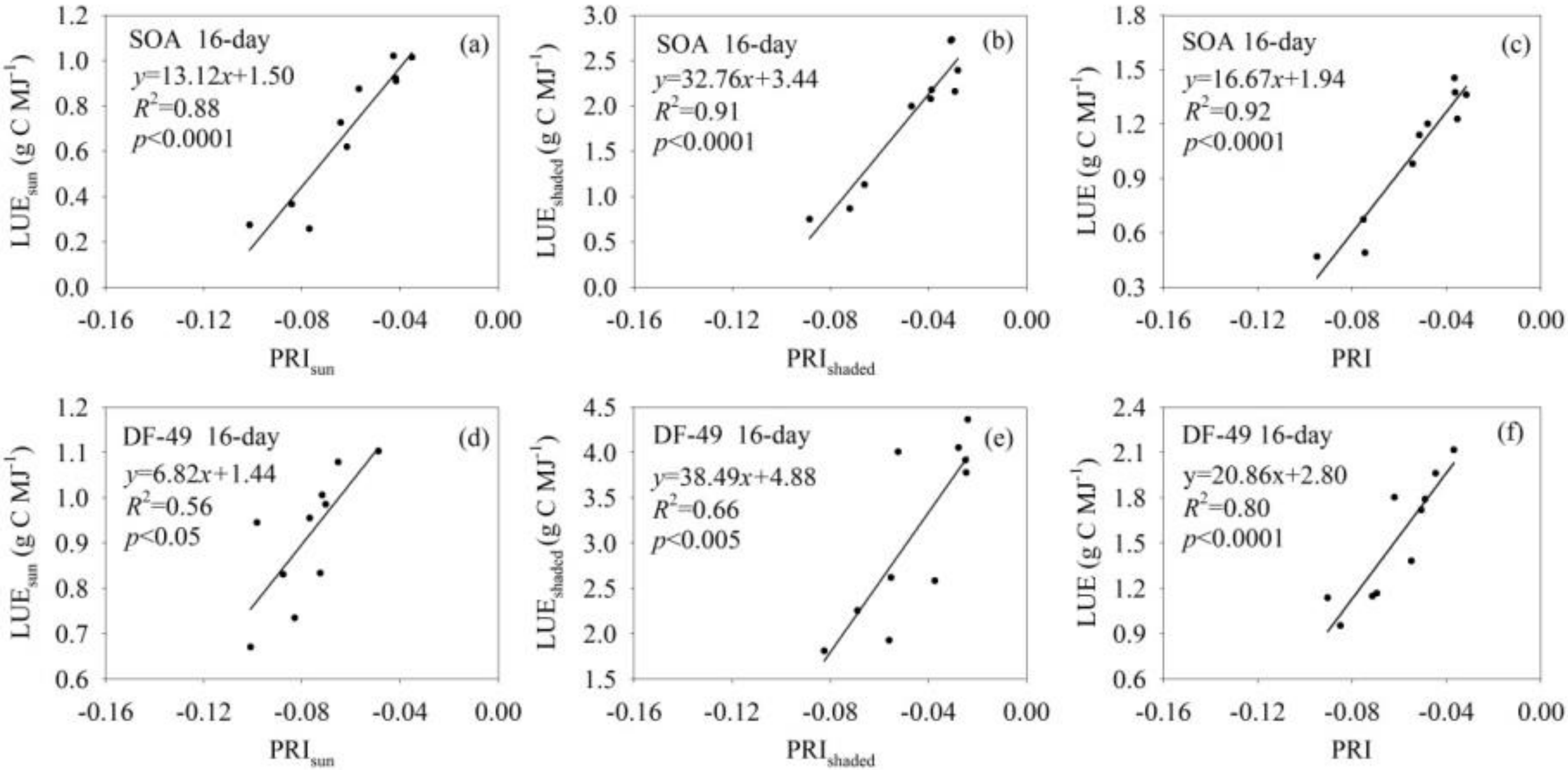
- **Relationships between and at 8-day periods at SOA (a, b and c) and DF-49 (d, e and f), respectively**



Zhou , Hilker, Ju et al., 2017, IEEE TGARS

Model Parameterization

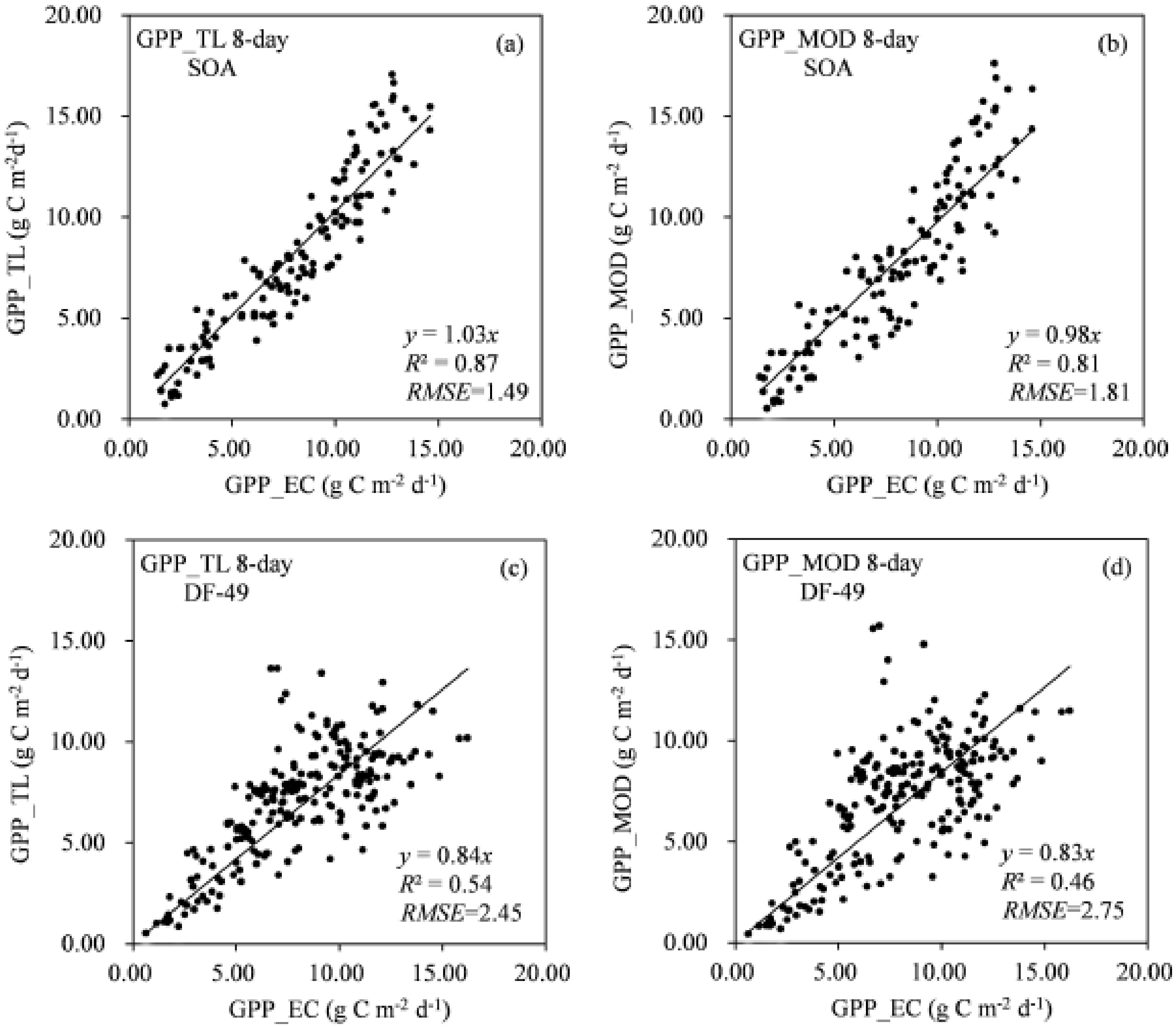
- **Relationships between and at 16-day periods at SOA (a, b and c) and DF-49 (d, e and f), respectively**



Zhou , Hilker, Ju et al., 2017, IEEE TGARS

Model Parameterization

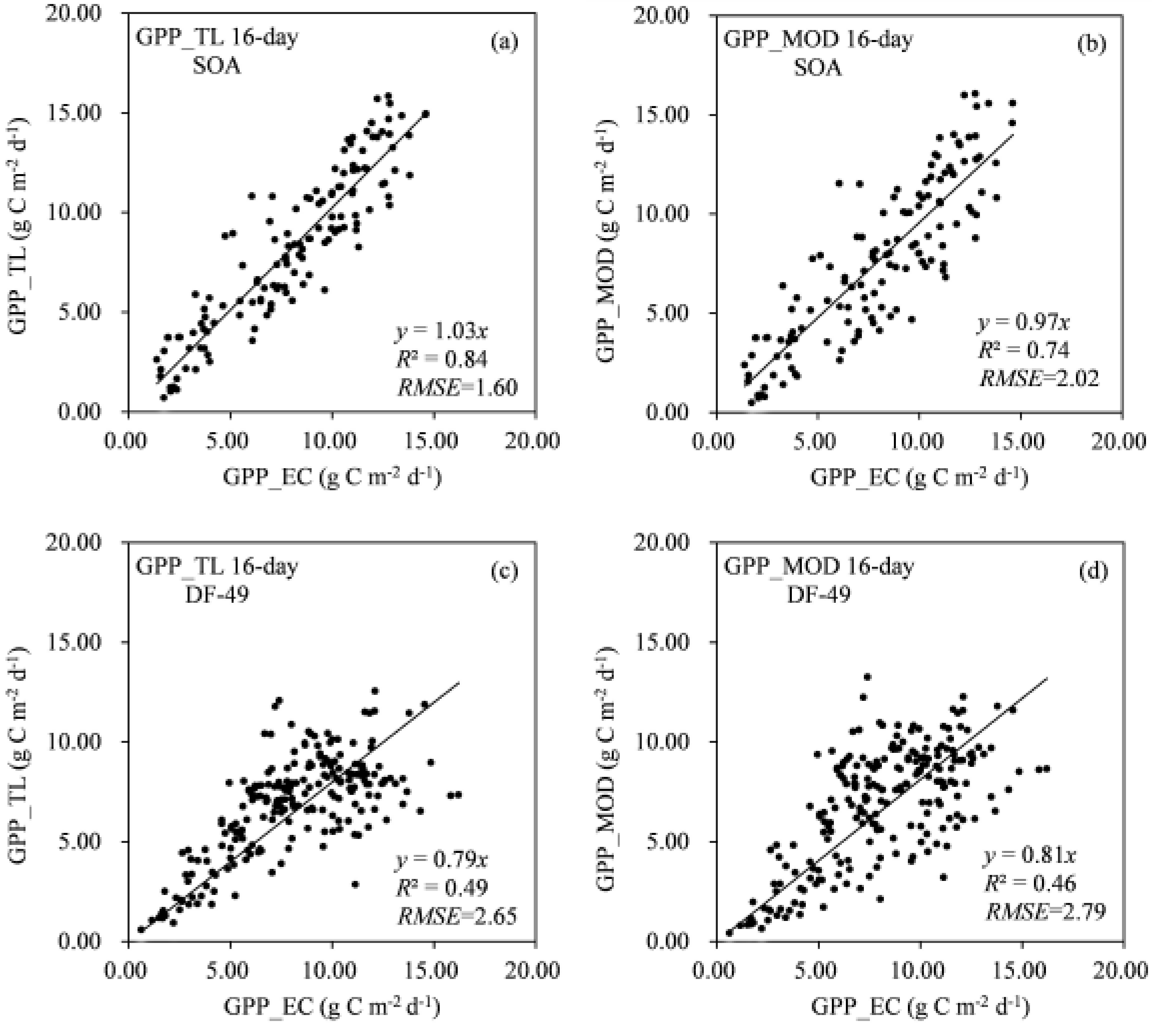
- **Tower-based GPP against GPP simulated using 8-day mean LUE (LUE_{sun}, LUE_{shaded}, and LUE) based on observed PRI (PRI_{sun}, PRI_{shaded}, and PRI)**



Zhou , Hilker, Ju et al., 2017, IEEE TGARS

Model Parameterization

- **Tower-based GPP against GPP simulated using 16-day mean LUE (LUE_{sun}, LUE_{shaded}, and LUE) based on observed PRI (PRI_{sun}, PRI_{shaded}, and PRI)**



Zhou , Hilker, Ju et al., 2017, IEEE TGARS

Conclusions

- **The TL-LUE outperforms the MOD17 algorithm at half-hour, daily, and 8-day temporal scales**
- **Optimized model parameters vary significantly with land cover types**
- **For a give land cover type, optimized model parameters vary largely across different sites**
- **PRI is able to track LUE, useful for improving GPP simulations**

Relevant publications

1. Zhan Q, Chen JM, **Ju WM***, Wang HM, Qiu F, Yang FT, Fan WL, Huang Q, Wang YP, Feng YK, Wang XJ, and Zhang FM, 2017. Improving the ability of the photochemical reflectance index to track canopy light use efficiency through differentiating sunlit and shaded leaves. ***Remote Sensing of Environment***, 194: 1-15.

2. Zhou YL, Hilker T, **Ju WM**, Coops NC, Black TA, Chen JM, and Wu XC, 2017. Modeling gross primary production for sunlit and shaded canopies across an evergreen and a deciduous site in Canada. ***IEEE Transactions on Geosciences and Remote Sensing***, 55(4):1859-1873.

3. Zhou YL, Wu XC, **Ju WM***, Chen JM, Wang SQ, Wang HM, et al., 2016. Global parameterization and validation of a two-leaf light use efficiency model for predicting gross primary production across FLUXNET sites. ***Journal of Geophysical Research-Biogeosciences***, 121: 1045–1072.

4. Zhang Q, Ju WM, Chen JM, Wang HM, Yang FT, Fan WL, Huang Q, Zheng T, Feng YK, Zhou YL, He MZ, Qiu F, Wang, XJ, Wang J, Zhang FM, Chou SR, 2015. Ability of the photochemical reflectance index to track light use efficiency for a sub-tropical planted coniferous forest. ***Remote Sensing***, 7(12): 16938-16962.

5.Wu XC, **Ju WM***, Zhou YL, He MZ, et al., 2015. Performance of linear and nonlinear two-leaf light use efficiency models at different temporal scales. ***Remote Sensing***,7(3): 2238-2278.

6. He MZ, **Ju WM***, Zhou YL, Chen JM, He HL, Wang SQ, Wang HM, Guan DX, Yan JH, Li YN, Hao YB, Zhao FH, 2013. Development of a two-leaf light use efficiency model for improving the calculation of terrestrial gross primary productivity. ***Agricultural and Forest Meteorology*** ,173, 28-39.

7. He MZ, Zhou YL, Ju WM*, Chen JM, Zhang L, Wang SQ, Saigusa N, Hirata R, Murayama S, Liu YB, 2013. Evaluation and improvement of MODIS gross primary productivity in typical forest ecosystems of East Asia based on eddy covariance measurements. Journal of Forest Research, 18, 31-40.

Thanks!