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Influence of Diffuse Radiation and Its Timescale Effects on Gross Primary Productivity in a Mid-Subtropical Planted Coniferous Forest Ecosystem




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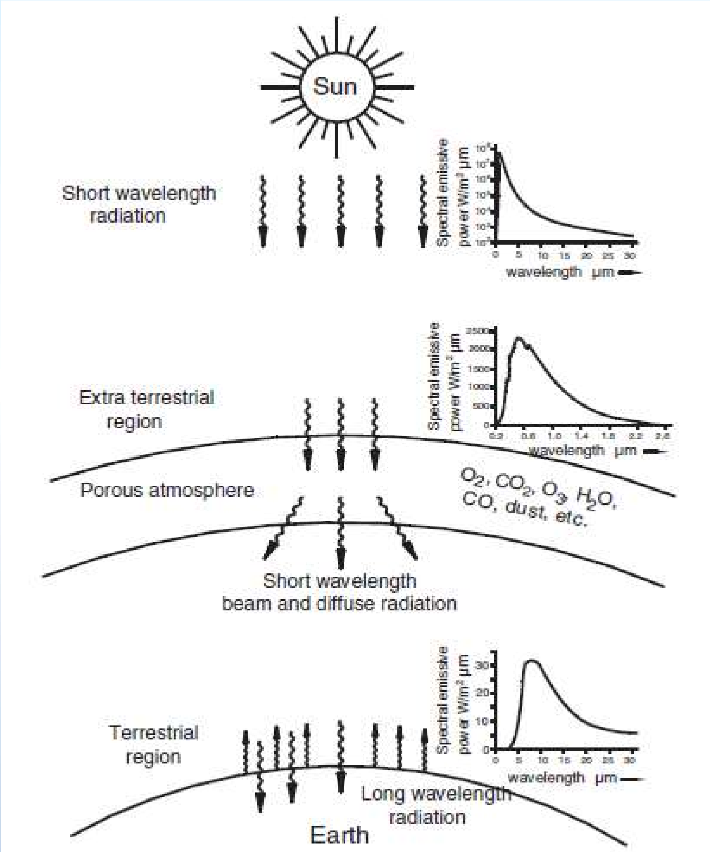
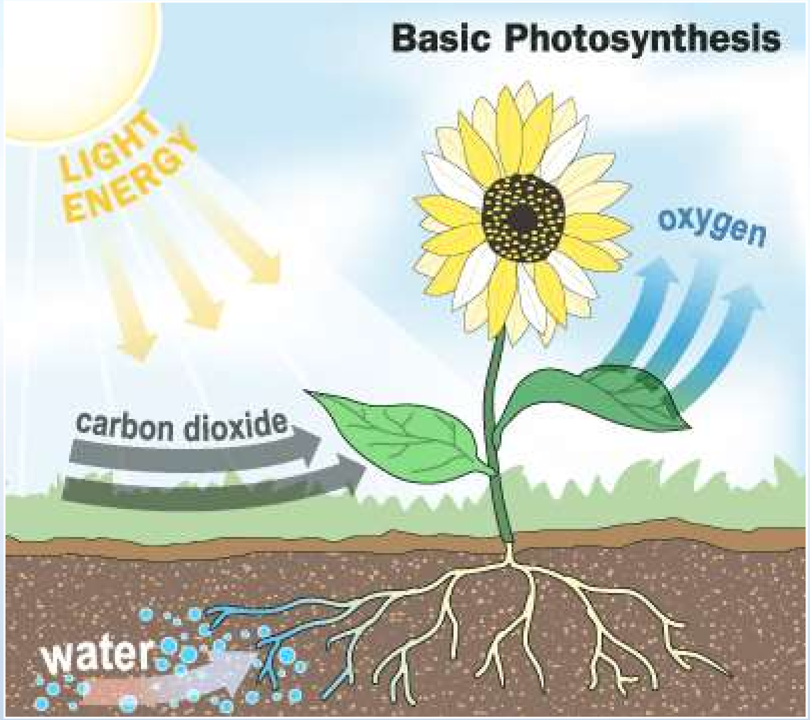
Outline

1. Introduction
2. Materials and methods
3. Results
4. Conclusion

Introduction

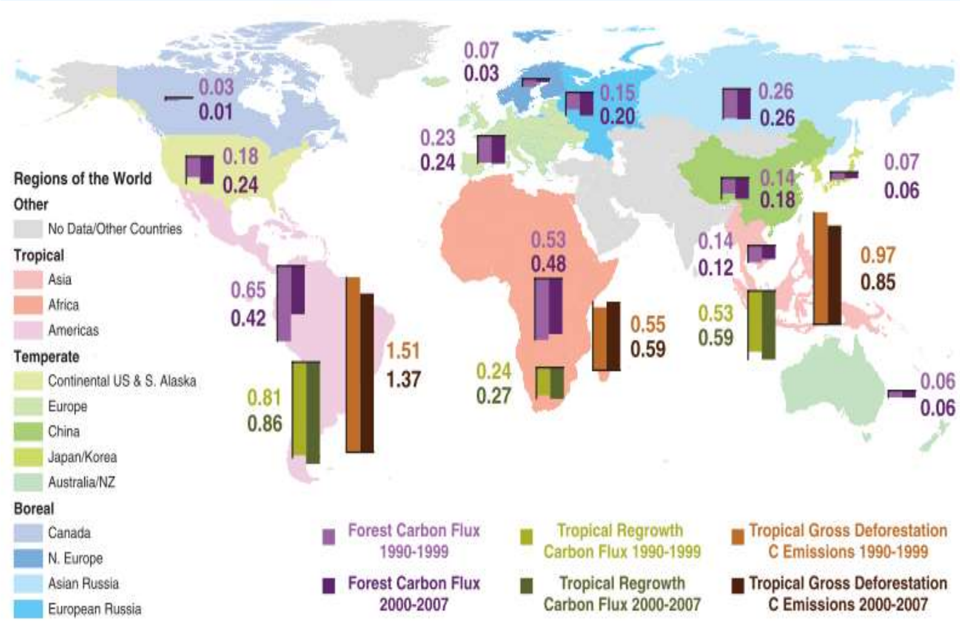


(M. Jamil Ahmad, 2011)

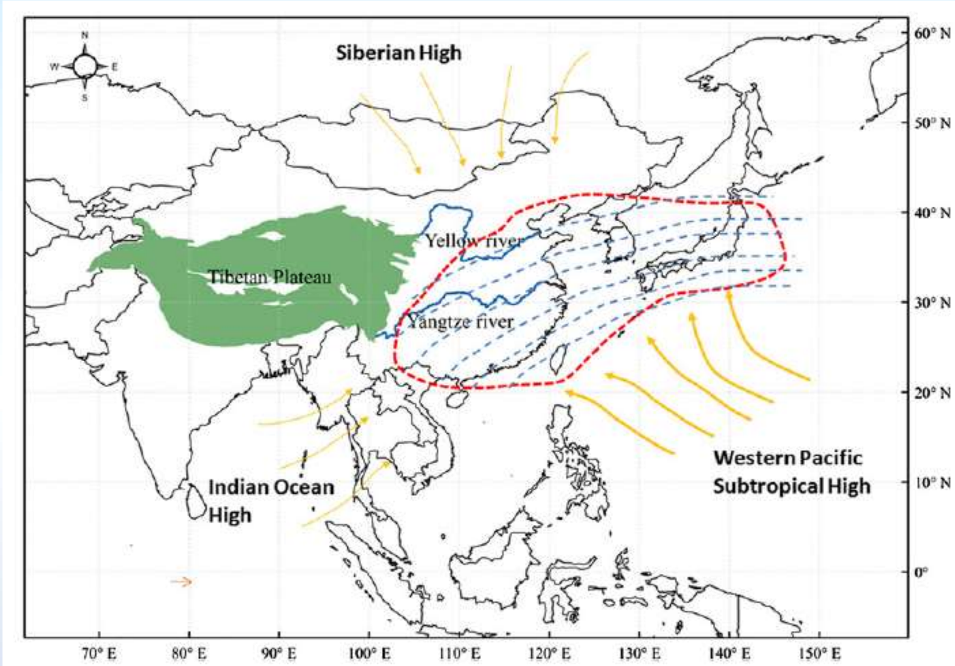


- The dynamic changes of the **solar radiation** have an important effect on photo-synthesis of plants. (Monteith, 1972)

Introduction



(Pan et al., 2011)



(Yu et al., 2014)

- Forest ecosystem is an important **carbon sink** in the world. (Pan, 2011)
- Planted coniferous forest in Qianyanzhou area is an important **carbon sink** in China. (Yu, 2014)

Introduction

- The influence of diffuse radiation on land carbon sink is **not clear**. (Gu, 1999; Alton, 2007; Knohl, 2008; Zhang, 2010; Urban, 2012)

- The general LUE model **rarely** considers diffuse radiation. (Huang, 2014; Donohue, 2014; Wang, 2015; Zhou, 2015)

- **Aims**:

   1. How do environmental factors affect on GPP and their variabilities at different timescales?

   2. Does LUE model improved by diffuse fraction have a significant impact on simulating GPP?

   3. What is the cause of the difference between simulation and observation?

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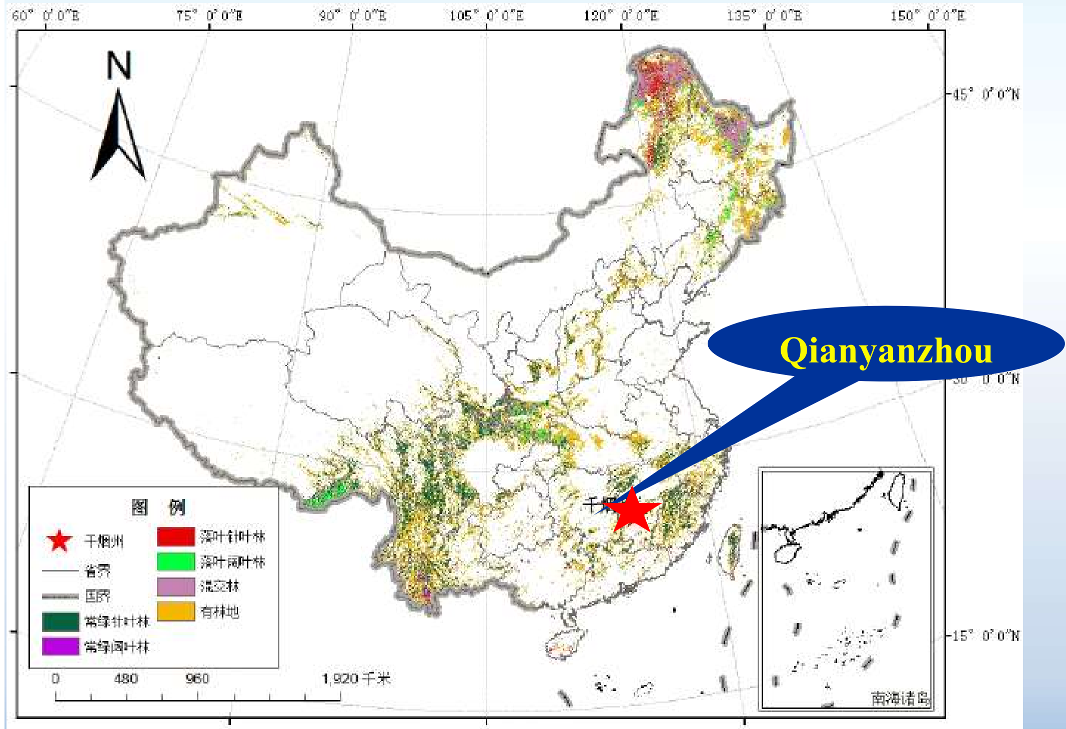
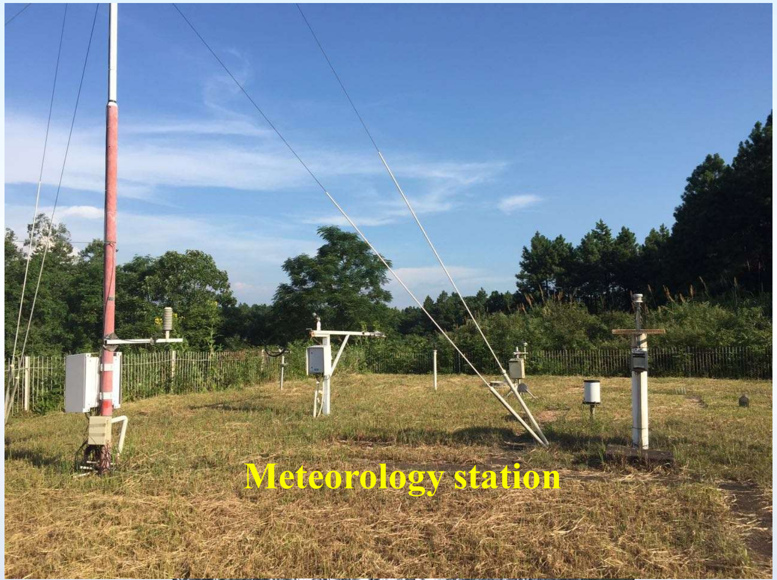
Materials and methods





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Materials and methods

- Qianyanzhou Station
- Carbon flux data: **2003-2015** (13 years)
- Diffuse radiation data: **2012-2015** (4 years)
- Calculating **2003-2015** diffuse radiation data by Reindl model:

$$k_d = 1.02 - 0.254k_t + 0.0123\sin\beta \qquad (k_t \le 0.3)$$
$$k_d = 1.4 - 1.749k_t + 0.177\sin\beta \qquad (0.3 < k_t < 0.78)$$
$$k_d = 0.486k_t - 0.182\sin\beta \qquad (k_t \ge 0.78)$$

k_d, diffuse fraction; k_t, clearness index; β, solar elevation angle

$$k_d = I_d / I_g$$
$$k_t = I_g / I_e$$

I_d, diffuse radiation; I_g, global radiation; I_e, extraterrestrial radiation

- LAI data: **MOD15A2**, **2003-2015** (13 years)

Materials and methods

- Light response curve
  - Rectangular hyperbolic function

$$GPP = \frac{\alpha P_{\max} PAR_g}{P_{\max} + \alpha PAR_g}$$

α, the initial slope of the light response curve; $P_{\max}$, the maximum photosynthetic capacity.

- Defining sunny and cloudy sky conditions at daily scale
  - Sunny sky:

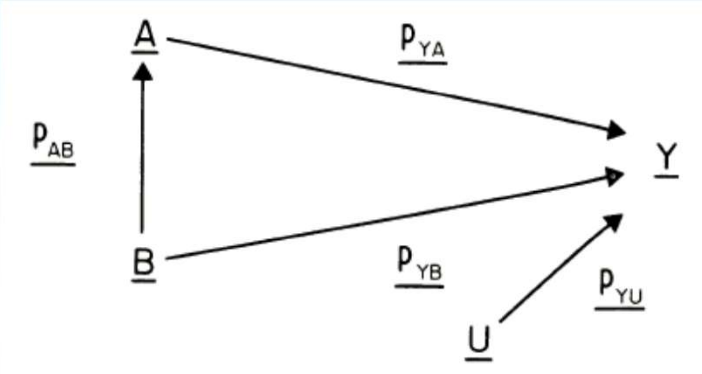
$$k_t \geq 0.6$$

  - Cloudy sky:

$$k_t < 0.6$$

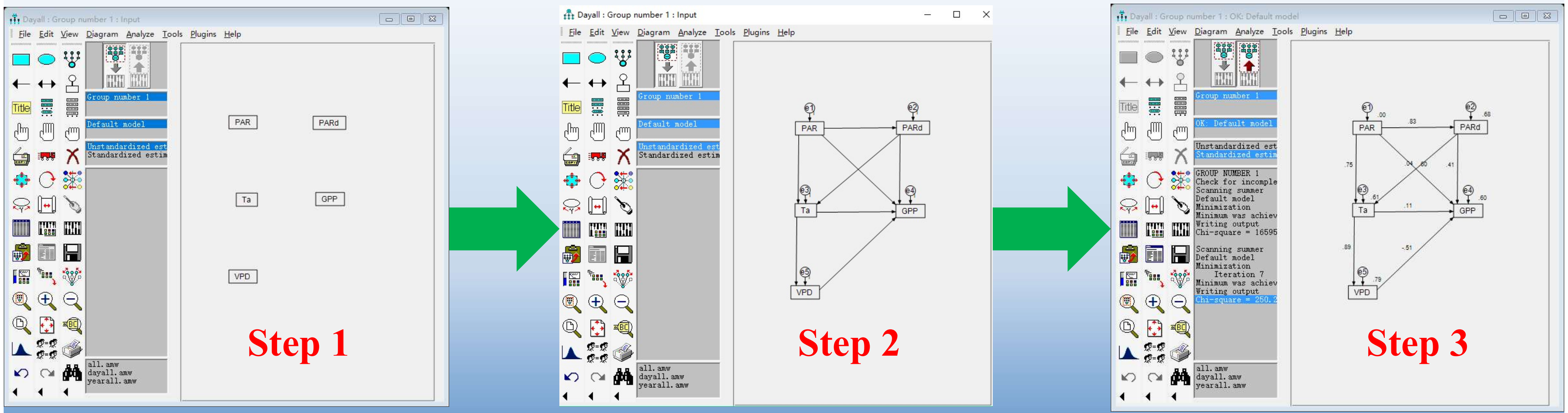
Materials and methods

- Path analysis



Path analysis is similar to multiple regression approaches and is especially useful when a priori causal or correlative information is known among variables.

- Software: IBM SPSS Amos 17



- Standardized total effects (STE): combining direct and indirect effects.

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Materials and methods

- LUE model

$$GPP = LUE_0 \times PAR$$

$$GPP = LUE_0 \times FAPAR \times PAR$$
$$FAPAR = 1 - \exp(-k \times LAI)$$

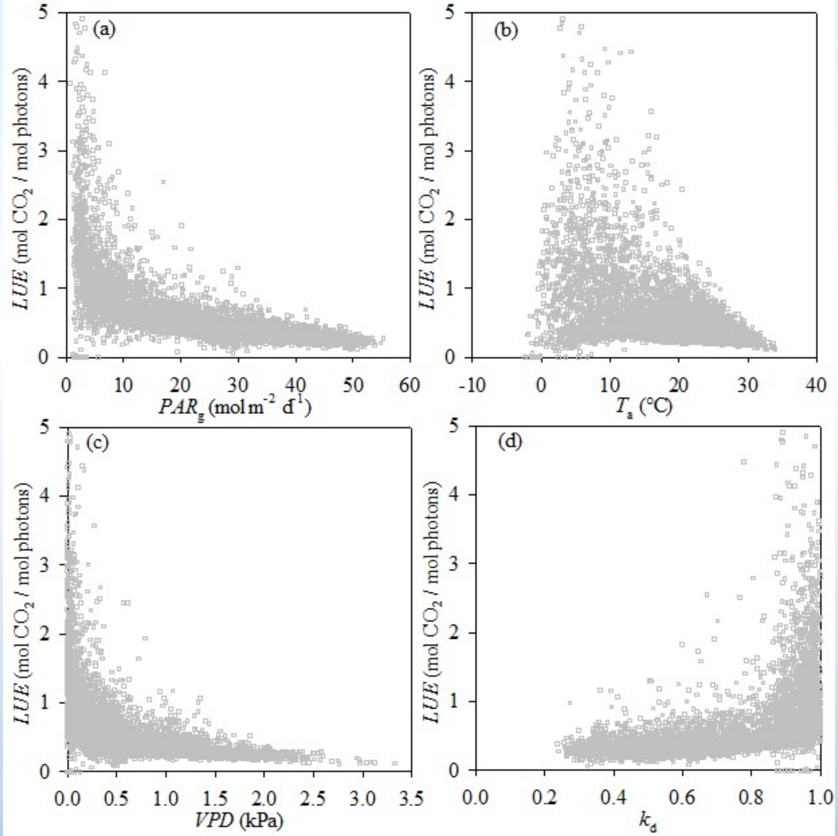
$$GPP = LUE_0 \times FAPAR \times PAR \times f_{PAR} \times f_{T_a} \times f_{VPD}$$

$$GPP = LUE_0 \times FAPAR \times PAR \times f_{PAR} \times f_{T_a} \times f_{VPD} \times f_{k_d}$$

- Training data: 2004, 2006, 2008, 2010, 2012, 2014 (6 years)
- Validating data: 2003, 2005, 2007, 2009, 2011, 2013, 2015 (7 years)

Materials and methods

- Relationship between LUE and environmental variables



$$GPP = LUE_0 \times FAPAR \times PAR \times \frac{1}{1+\frac{FAPAR \times PAR}{a}} \times \left[1 + b(T_a - 10)^2\right] \times \frac{1}{1+\frac{VPD}{c}} \times \frac{1}{1-\frac{k_d}{d}}$$

Materials and methods

- Evaluation indicators

$$R^2 = \frac{\left[\sum\left(Y_{sim} - \overline{Y_{sim}}\right)\left(Y_{obs} - \overline{Y_{obs}}\right)\right]^2}{\sum\left(Y_{sim} - \overline{Y_{sim}}\right)^2 \sum\left(Y_{obs} - \overline{Y_{obs}}\right)^2}$$

$$SS_T = \sum_{i=1}^{N}\left(y_{i,obs} - \overline{y_{obs}}\right)^2$$

$$MBE = \frac{\sum\left(Y_{obs} - Y_{sim}\right)}{n}$$

$$SS_{sim} = \sum_{i=1}^{N}\left(y_{i,obs} - y_{i,sim}\right)^2$$

$$RMSE = \sqrt{\frac{\sum\left(Y_{obs} - Y_{sim}\right)^2}{n}}$$

$$SS = \left(1 - \frac{SS_{sim}}{SS_T}\right) \times 100\%$$

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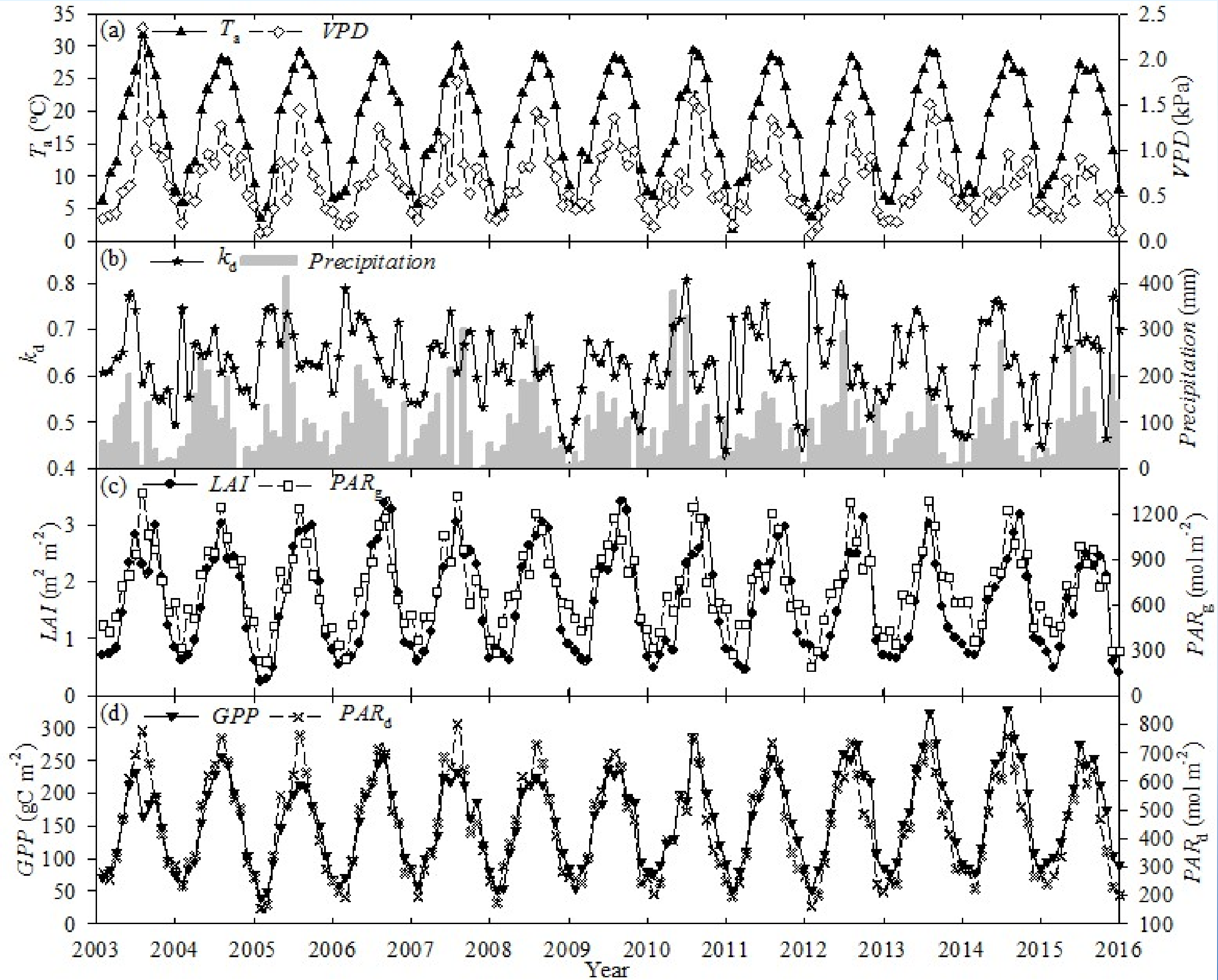
Results

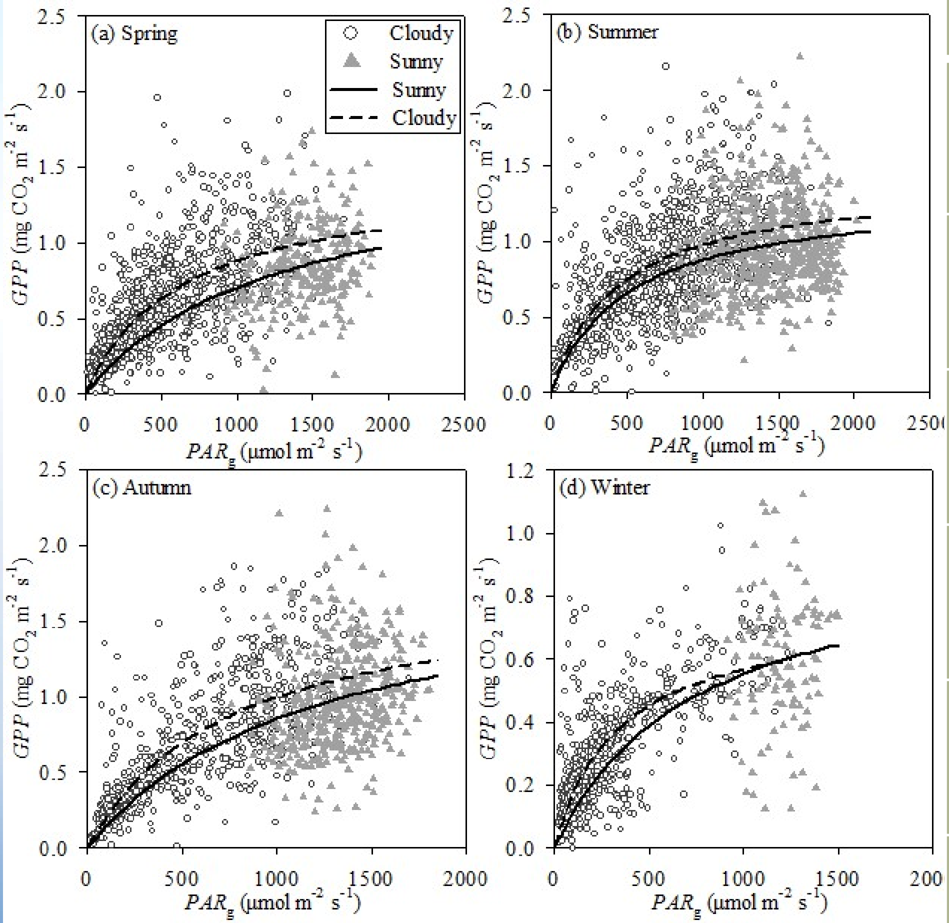
- Dynamic change of environmental variables



- T_a, *VPD*, *LAI*, PAR_g, PAR_d, *GPP* has a tendency to change in a single peak over the year, with obvious seasonal variations.
- k_d has no discernible change characteristic in a year, but in winter it is usually the minimum of a year.
- In some special periods, such as July 2003 and July 2007, it is prone to seasonal drought, resulting in a sudden drop in *GPP* and *LAI*.

Results

- Light response curves under different weather conditions at half hour scale



Parameters of light response curves.

Season	Weather conditions	P_{max} (mg CO_2 m^{-2} s^{-1})	α (mg CO_2 μmol^{-1})	n	P_{n500} (mg CO_2 m^{-2} s^{-1})	P_{n1200} (mg CO_2 m^{-2} s^{-1})
Spring	Sunny	**1.58**	**1.28*10^-3**	**277**	**0.46**	**0.78**
	Cloudy	**1.44**	**2.27*10^-3**	**1178**	**0.64**	**0.94**
Summer	Sunny	**1.31**	**2.66*10^-3**	**560**	**0.66**	**0.93**
	Cloudy	**1.41**	**3.21*10^-3**	**1013**	**0.75**	**1.03**
Autumn	Sunny	**1.87**	**1.58*10^-3**	**437**	**0.55**	**0.94**
	Cloudy	**1.76**	**2.31*10^-3**	**714**	**0.70**	**1.08**
Winter	Sunny	**0.96**	**1.30*10^-3**	**110**	**0.38**	**0.60**
	Cloudy	**0.76**	**2.23*10^-3**	**814**	**0.45**	**0.59**
Whole year	Sunny	**1.58**	**1.62*10^-3**	**1384**	**0.54**	**0.87**
	Cloudy	**1.65**	**2.16*10^-3**	**3719**	**0.65**	**1.01**

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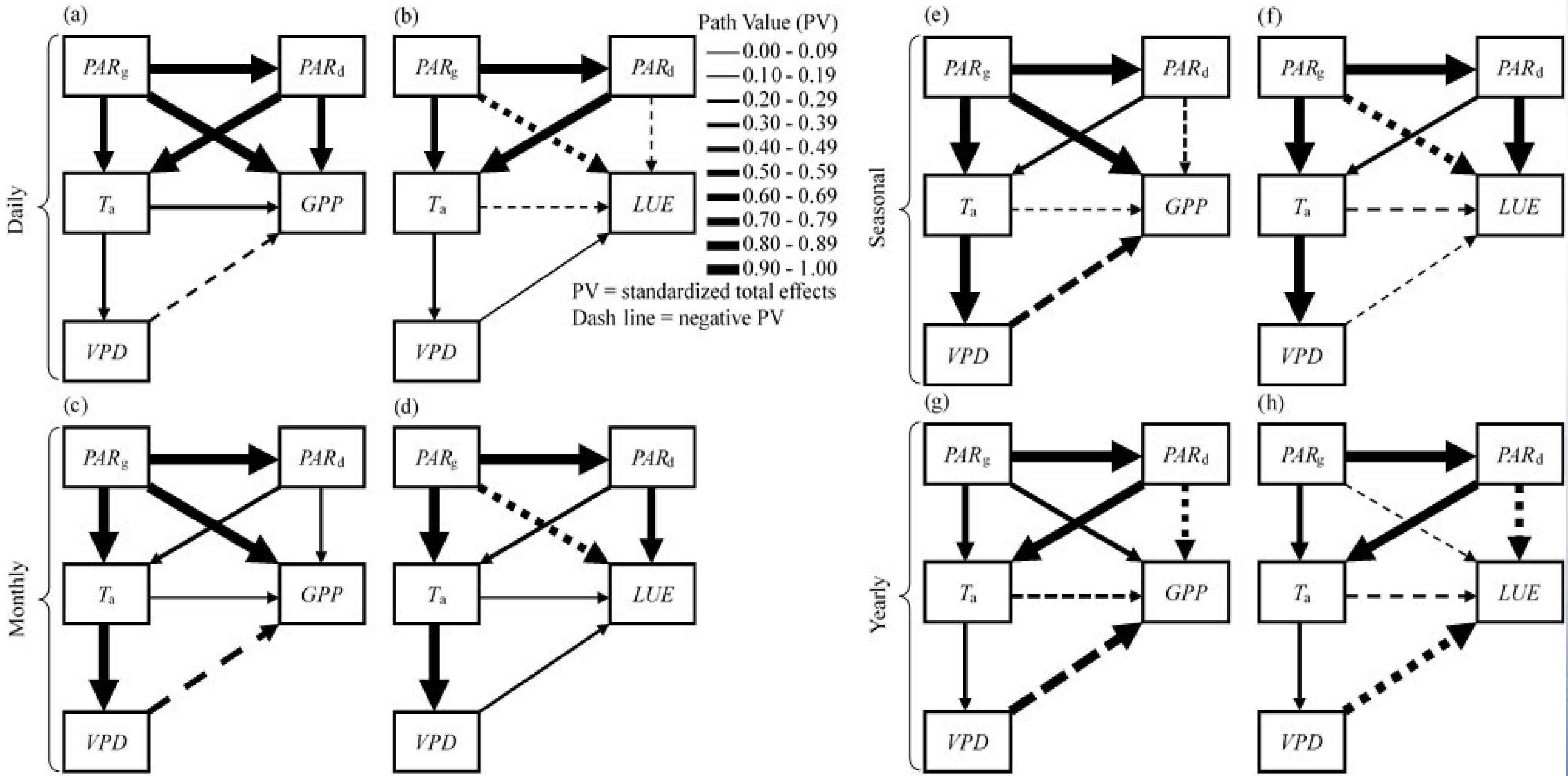
Results

- The influence of environmental variables on photosynthesis at timescales (daily, monthly, seasonal, yearly)



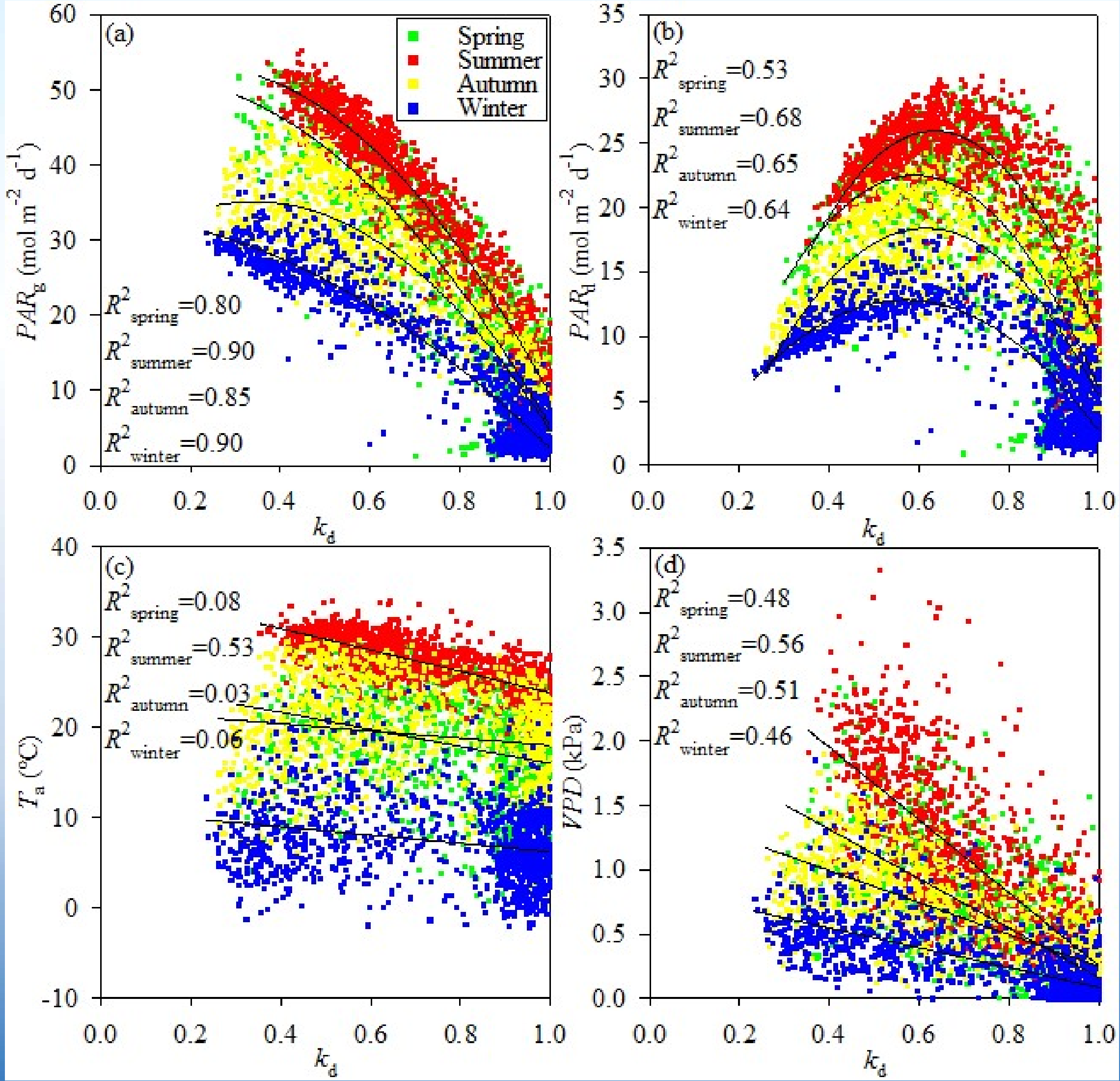
Results

- The influence of environmental variables on photosynthesis at timescales (daily, monthly, seasonal, yearly)

Standardized total effects of environmental variables on *GPP* and *LUE* on time scales.						
	Time scales	PAR_g	PAR_d	T_a	VPD	n
GPP	Daily	**0.98***	**0.70***	**0.32***	**-0.29***	**4748**
	Monthly	**0.90***	**0.23***	**0.07***	**-0.56***	**156**
	Seasonal	**0.90***	**-0.23**	**-0.08***	**-0.67***	**52**
	Yearly	**0.44***	**-0.68**	**-0.33**	**-0.81***	**13**

Results

- Relationship between environmental variables and k_d



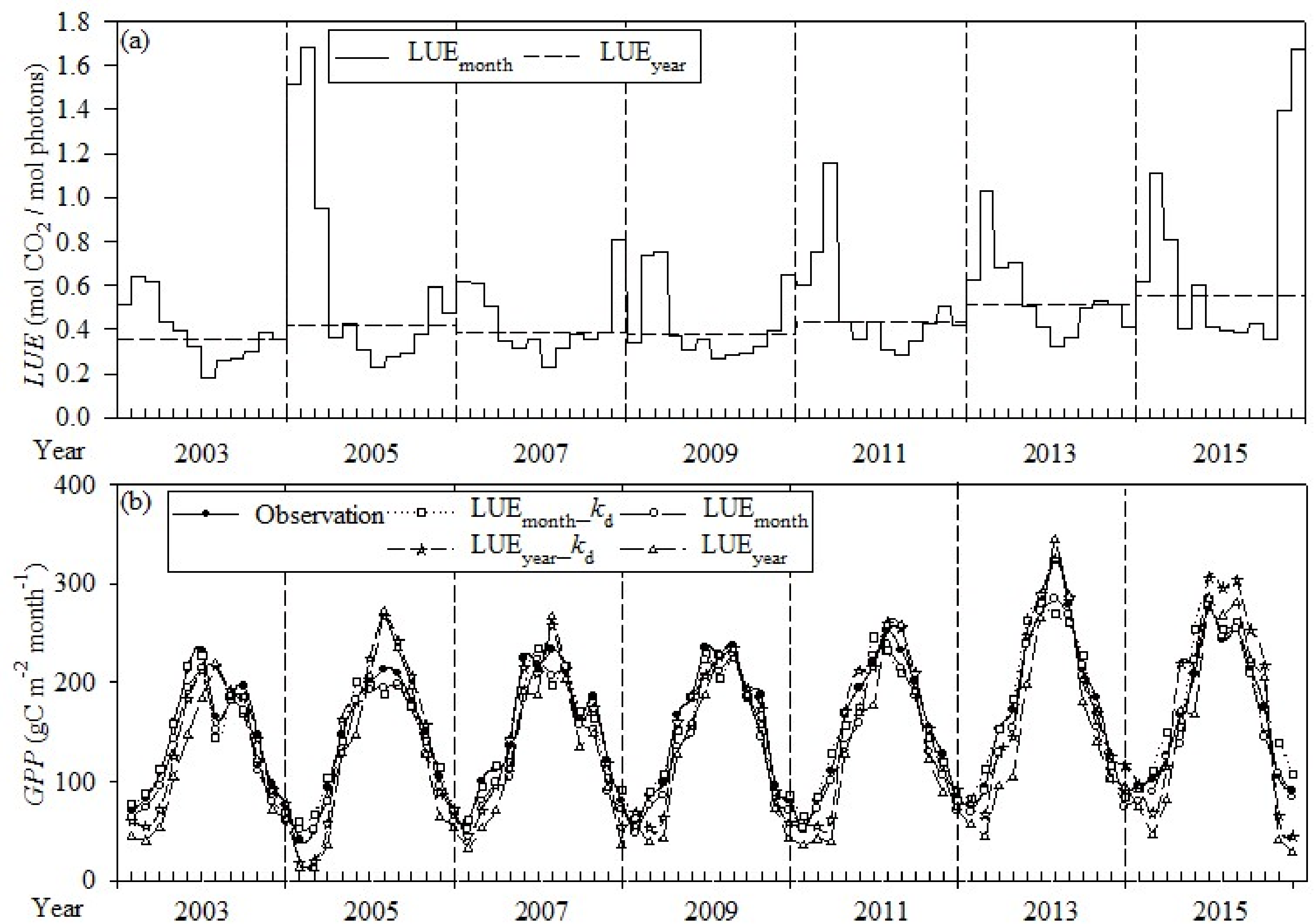
Results

- Effects of diffuse radiation on GPPin seasons

Seasonal variations of standardized total effects of daily environmental variables on *GPP* and *LUE*						
		PAR_g	PAR_d	T_a	VPD	n
GPP	Spring	**0.98***	**0.77***	**0.20***	**-0.27***	**1196**
	Summer	**0.78***	**0.41***	**-0.25***	**-0.53***	**1196**
	Autumn	**0.97***	**0.58***	**0.19***	**-0.22***	**1183**
	Winter	**0.83***	**0.59***	**0.38***	**-0.24***	**1173**
	Whole year	**0.98***	**0.70***	**0.32***	**-0.29***	**4748**

Results

- Improvement and validation of LUE model



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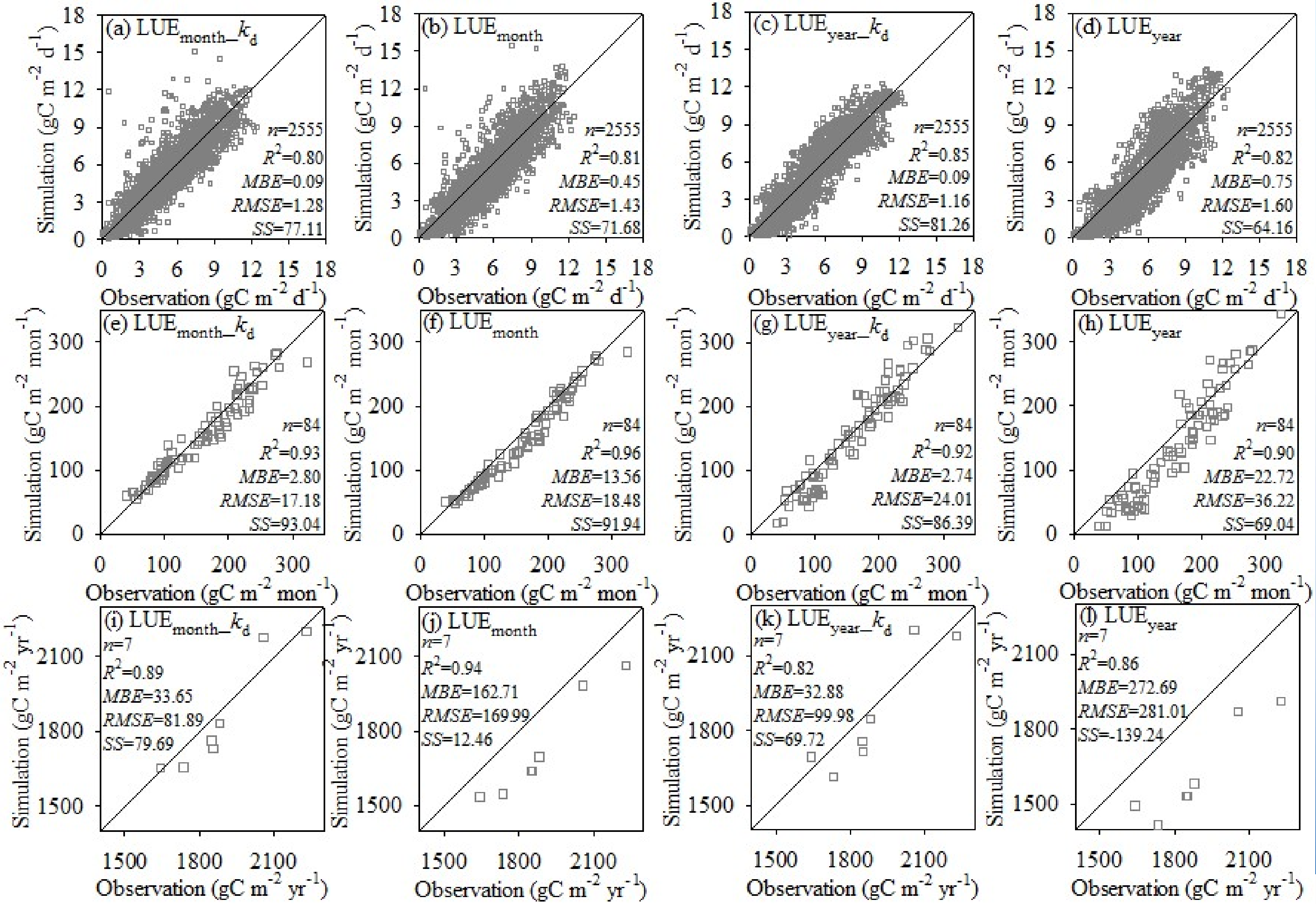
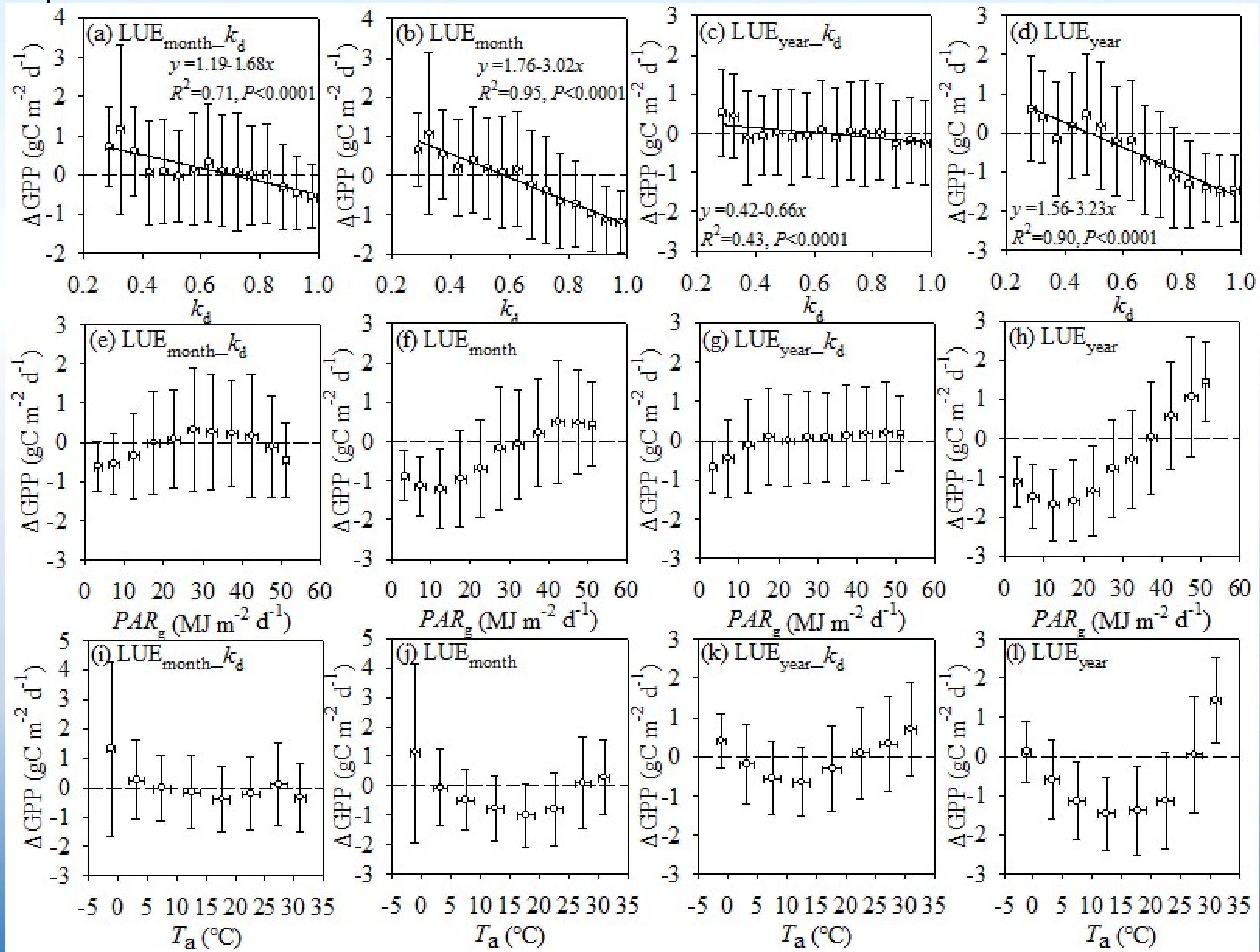
Results

- Improvement and validation of LUE model



Results

- Relationship between ΔGPP and environmental variables



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Conclusion

- From daily to yearly scales, PAR_g had the positive STE with GPP, but such STE was gradually reduced toward yearly scale; PAR_d or T_a had the positive STE with GPP at daily and monthly scales, while negative STE occurred at seasonal and yearly scales. *VPD* exhibited the negative STE with GPP at all timescales, and such STE increased gradually toward the yearly scale.

- Based on the simulation results by the LUE model, it indicated that modelled GPP agreed well with the measurements when the influence of the seasonal variations of LUE and diffuse radiation were incorporated into the model, especially at the yearly scale.

- The cause of the difference between simulation and observation maybe is the limitations of the model form itself under the special circumstances.

THANKS FOR YOUR ATTENTION!

ANY QUESTION?