Satellite-based modeling of gross primary production and net ecosystem exchange in mangrove ecosystems

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Abstract: Mangrove ecosystems play an important role in the global carbon budget, however, the quantitative relationships between environmental drivers and productivity in these forests remain poorly understood. In this study, we develop a satellite-based vegetation productivity model to estimate the gross primary production (GPP) and net ecosystem exchange (NEE) in mangrove forests. The model considers sea surface temperature and salinity as environmental scalars in the mangrove light use efficiency (LUE) model. Besides, the LUEmax and PAR scalar were determined by different temperatures. Sentinel-2 images were used to map the fraction of absorbed photosynthetically active radiation (fAPAR) and validated with the data from two carbon flux towers in mangrove forests of China. The LUE, GPP and NEE predicted by the model generally agreed with observed values. These results demonstrate the potential of the satellite-driven productivity model for scaling-up GPP/NEE in mangrove forests, a key for exploring the carbon cycle in mangrove ecosystems at larger scales.

1 Introduction

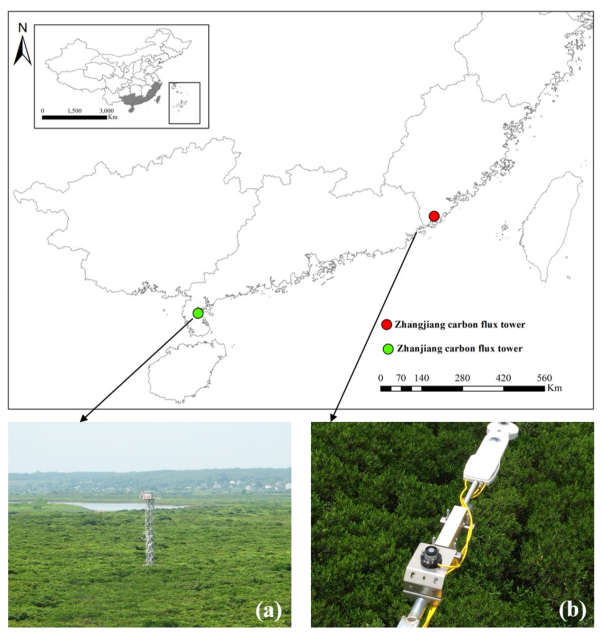

Fig. 1 Locations of two carbon flux towers in China: (a) Zhangjiang flux tower; (b) Zhanjiang flux tower.

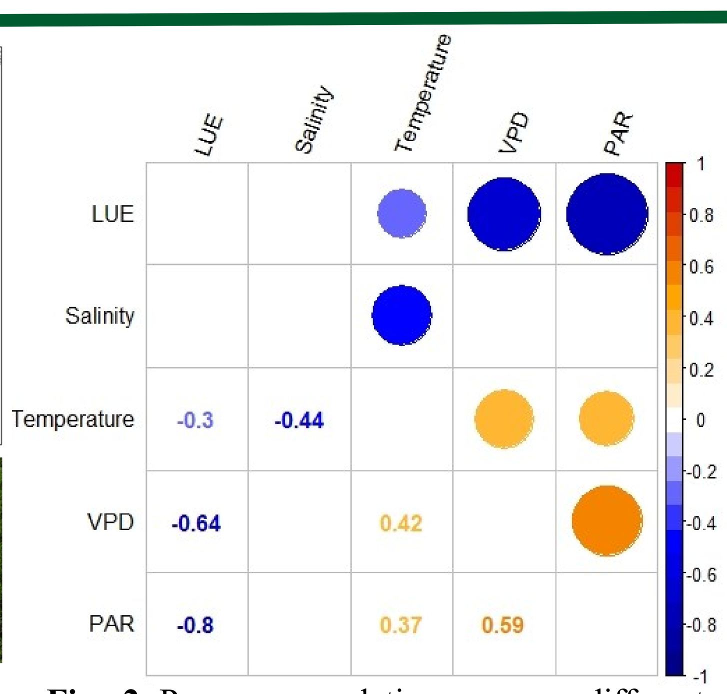

Fig. 2 Pearson correlations among different environmental variables and mangrove light use efficiency (LUE).

Objective:

Modeling the gross primary production (GPP) and net ecosystem exchange (NEE) of mangrove ecosystems by considering tidal effects on the light use efficiency model and using remote sensing data;

Originality:

1. The first study to estimate the maximum LUE of mangroves;
2. The first study to model the GPP and NEE in mangrove forests based on remote sensing data.

2 Methodology

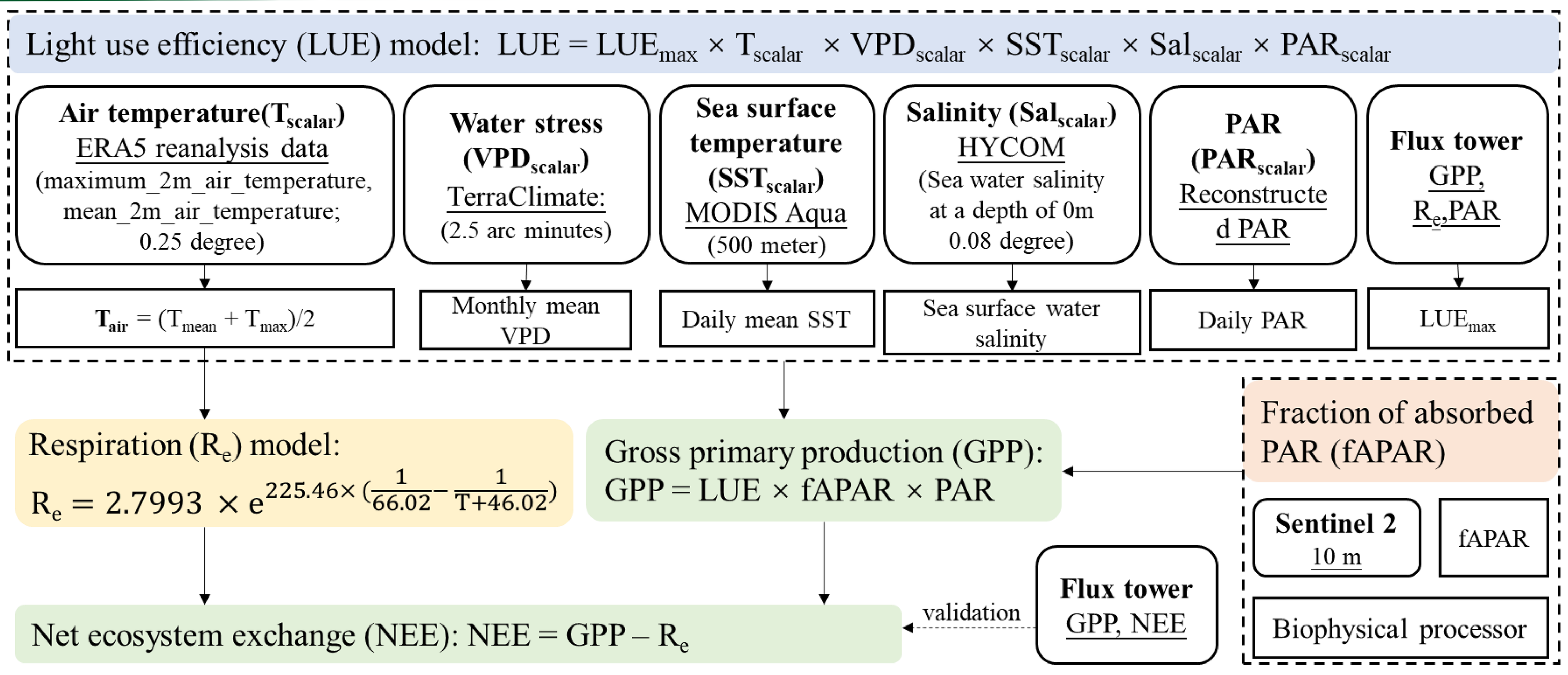

Fig. 3 Overall flowchart of mangrove GPP and NEE modeling.

3 Results

3.1 LUE modeling

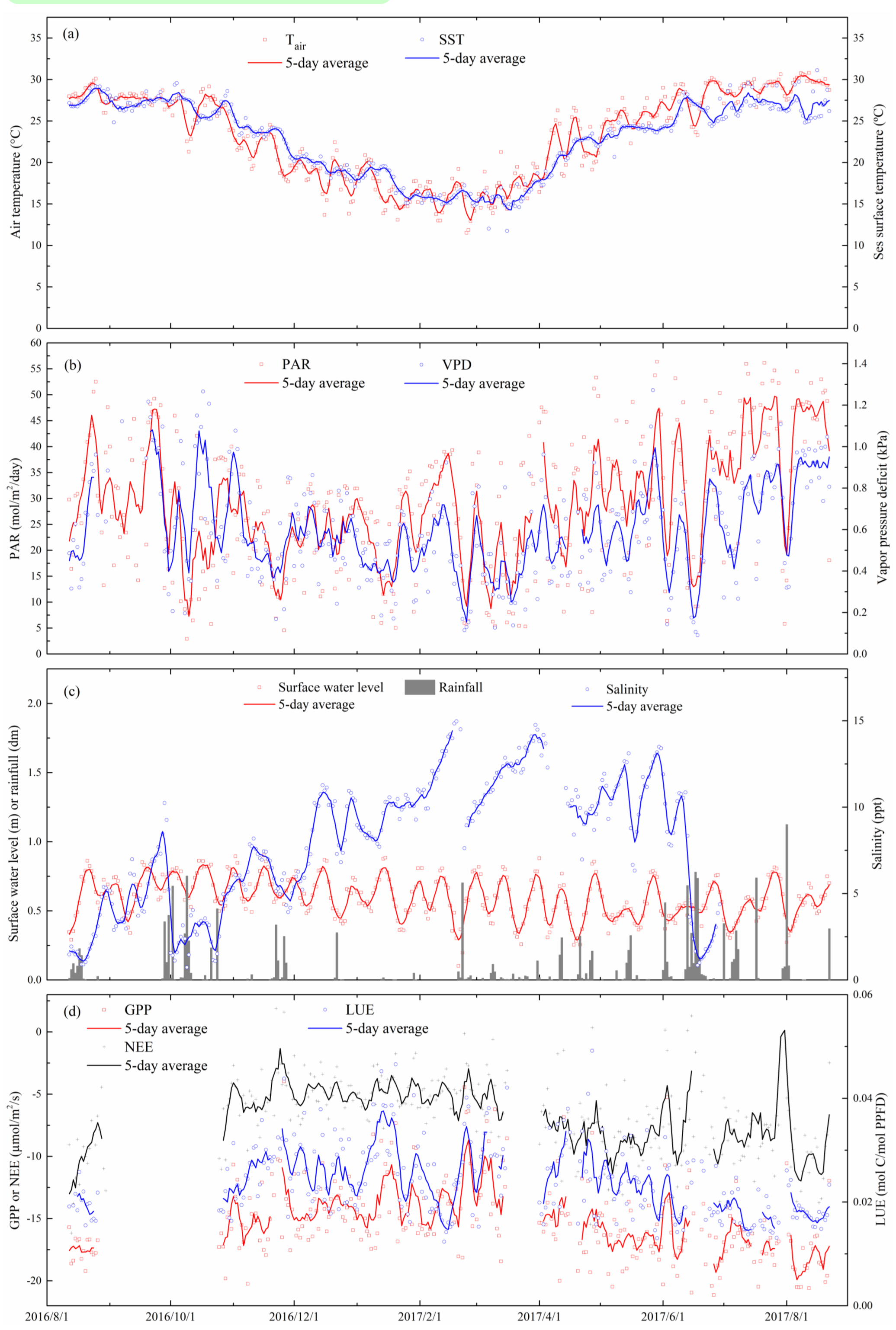

Fig. 4 Seasonal variations of (a) Temperature (Tair and SST), (b) PAR and VPD, (c) Salinity, Rainfall and surface water level, (d) GPP, NEE and LUE.

Table. 1 Validation of LUE by individual environmental variables specified in this study.

Environmental scalar	Pearson's r	RMSE
SST	0.48	0.0185
Salinity	0.49	0.0203
PAR	0.85	0.0048

Mangrove LUE and productivity are controlled by the climatic and environmental factors that regulate terrestrial forests, such as temperature, solar irradiance, and vapor pressure deficit, and by others like SST and salinity unique to coastal habitats. PAR shows the highest impact on LUE while salinity has low effect due to the low values in that region. (Fig.4, Table1)

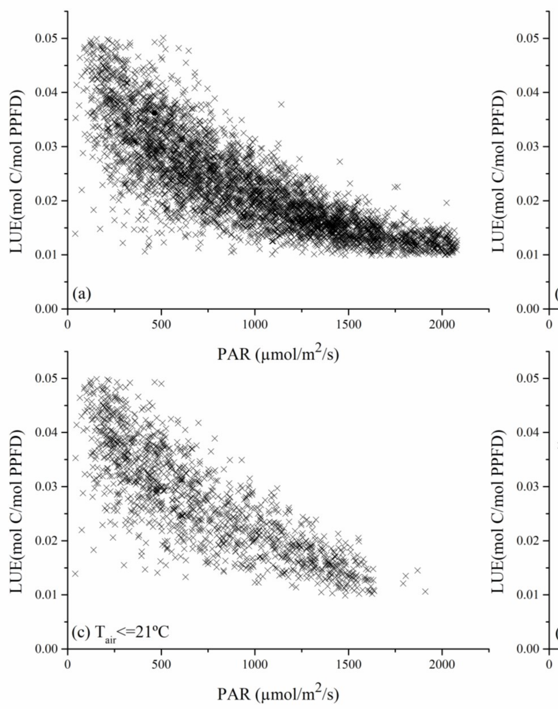

Fig. 5 LUE-PAR relationships.

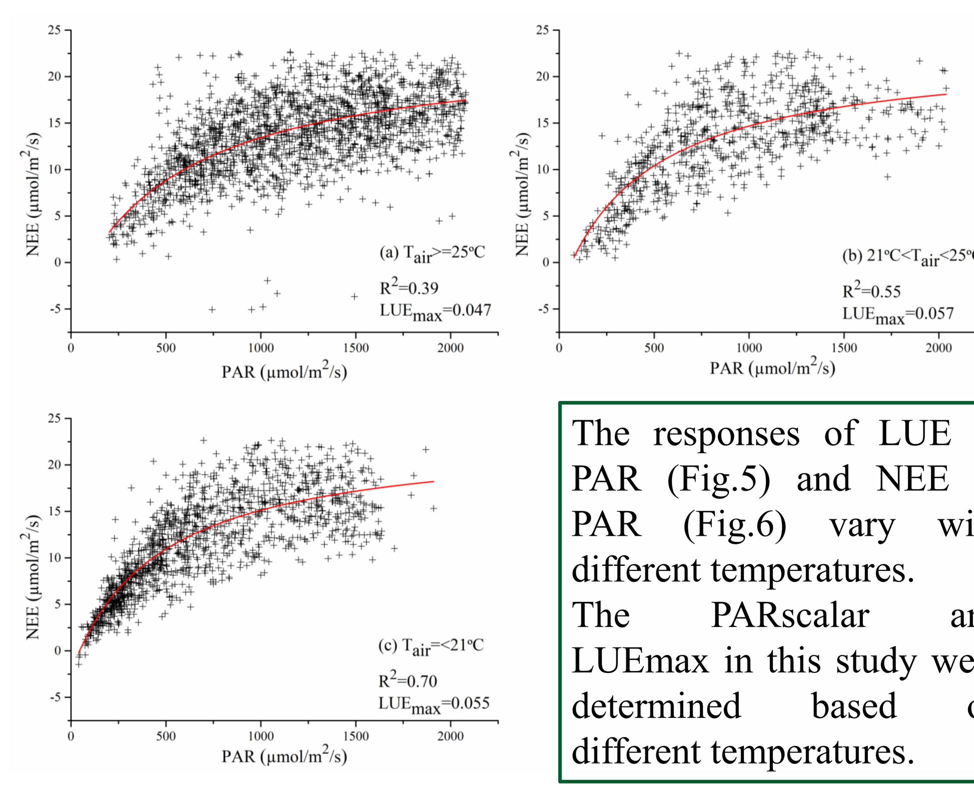

Fig. 6 NEE-PAR relationships.

The responses of LUE to PAR (Fig.5) and NEE to PAR (Fig.6) vary with different temperatures. The PARscalar and LUEmax in this study were determined based on different temperatures.

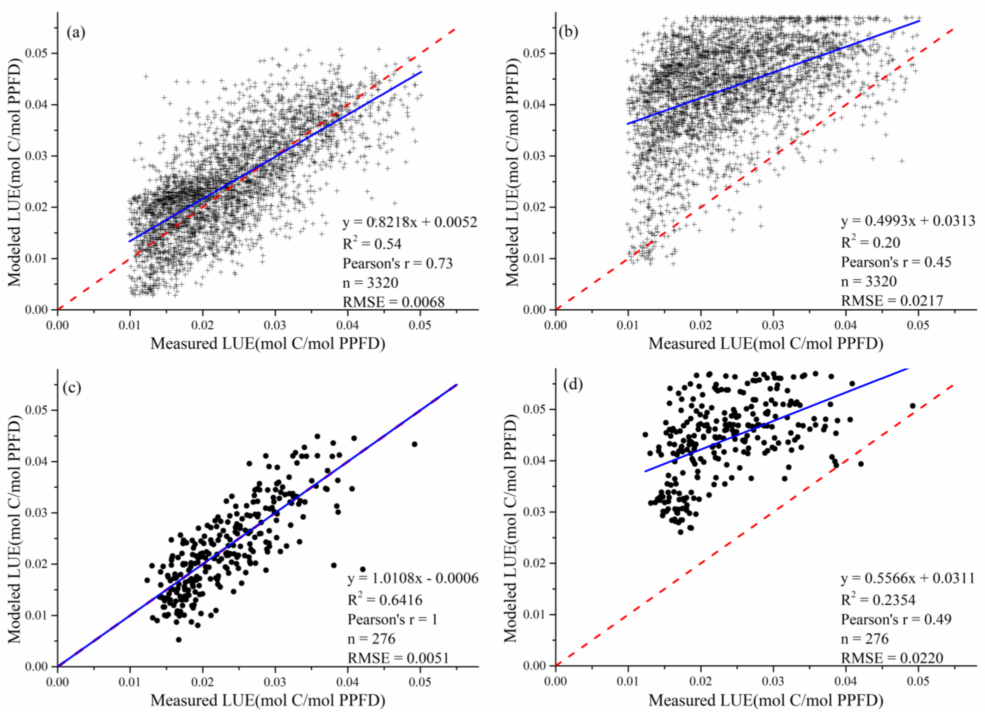

Fig. 7 Validation of LUE estimated from terrestrial model and tide-based mangrove model with daily-scale and hourly-scale data.

3.2 fAPAR

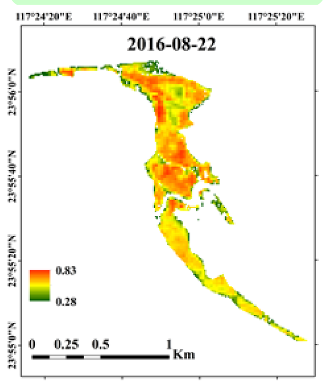

Fig. 8 fAPAR in Zhangjiang obtained from Sentinel 2 images.

3.3 PAR

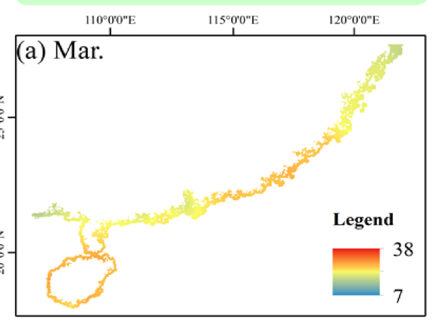

Fig. 9 Monthly average PAR distributions in the potential mangrove growing area of China interpolated from PAR station data.

3.4 R_e

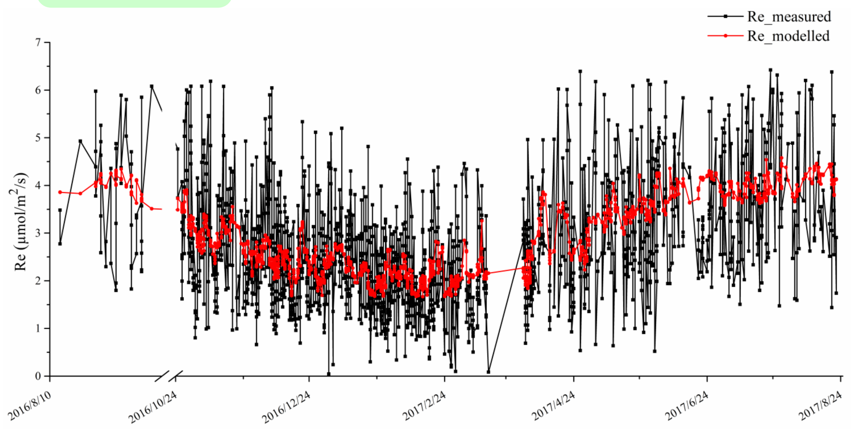

Fig. 10 Comparison of modeled respiration (R_e) and measured R_e.

3.5 GPP and NEE

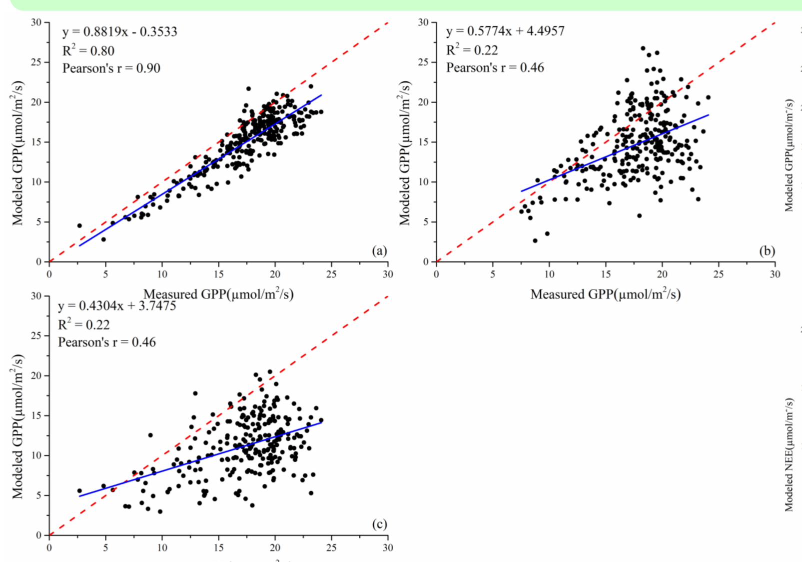

Fig. 11 Validation of modeled GPP with (a) measured LUE; (b) modeled LUE with is-situ data; (c) modeled LUE with satellite data.

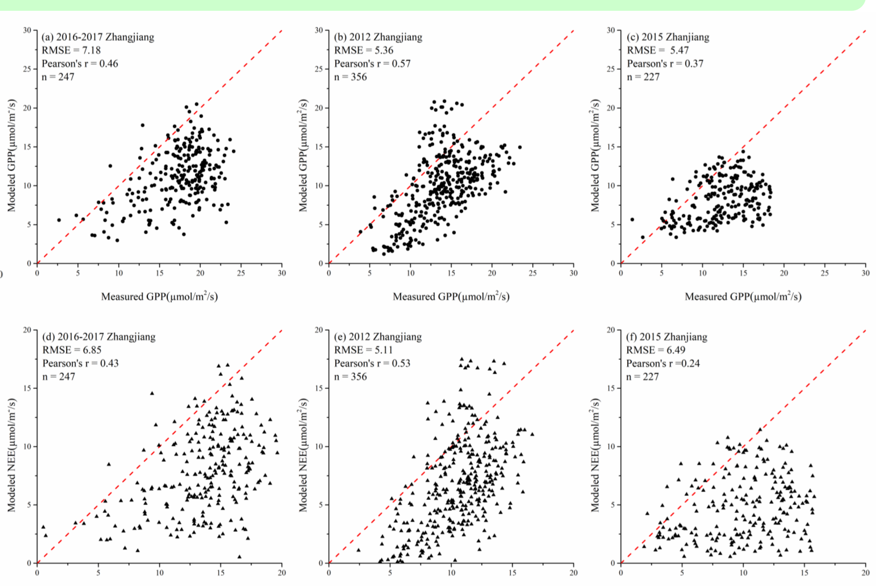

Fig. 12 Validation of modeled GPP and NEE with in-situ data from (a)&(d) Zhangjiang 2017; (b)&(e) Zhangjiang 2012; (c)&(f) Zhanjiang 2015.

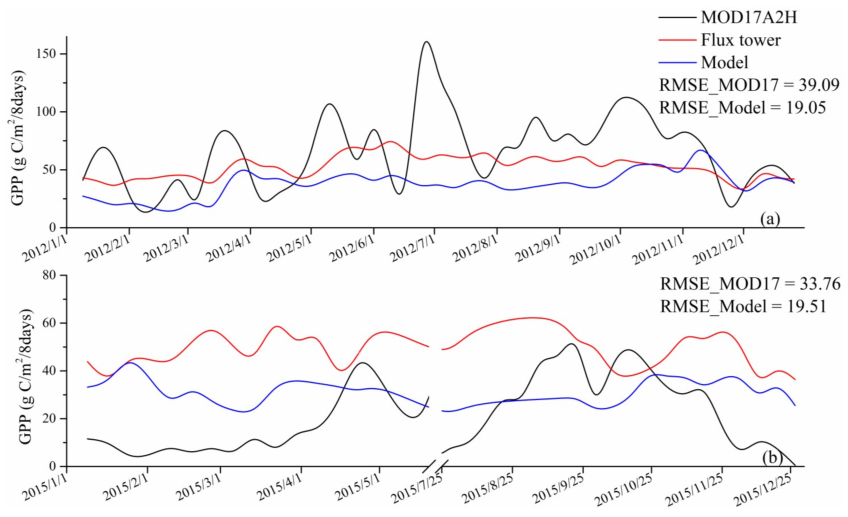

Fig. 13 Time-series GPP comparisons among MODIS products, in-situ measurement and established model in this research.

- GPP modeled with in-situ data performs better than satellite data;
- GPP and NEE models have similar results in different years and regions;
- GPP estimated from our model has more similar trend with the measured value, while MODIS GPP products have larger fluctuances.
- GPP modeled has higher accuracies compared with MODIS GPP products which improved the RMSE from 39.09 to 19.05 g C/m²/8days in 2012, and from 33.76 to 19.51 g C/m²/8days in 2015.

Uncertainties:

1. The satellite data available for VPD and salinity was not well validated with the in-situ data.
2. The relatively low spatial and temporal resolution of the environmental data would influence the accuracy of the model.
3. The determination of scalar parameters and fAPAR didn't consider the different species and ages of the mangrove.

4 Conclusions and future work

- Tide-based LUE model considering the effects of SST, PAR, salinity and different responses of LUEmax and PAR to temperature performs better than the existing terrestrial LUE model in estimating the mangrove LUE;
- The GPP and NEE estimated from satellite-based model generally agrees with the in-situ values which indicated the feasibility and applicability of this model.

Future work: Mapping the GPP and NEE for the mangroves in the whole coastal zone of China and estimating the annual biocapacity and carbon footprint of mangrove ecosystems.

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