Yale-NUIST Center on Atmospheric Environment

# Optimization of VPRM with the measurements at a coniferous-evergreen forest site

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# Outline

- Motivation and objectives
- Introduction of VPRM
- Data and method
- Results and discussion
- Summary
- On-going work

# Motivation and objectives

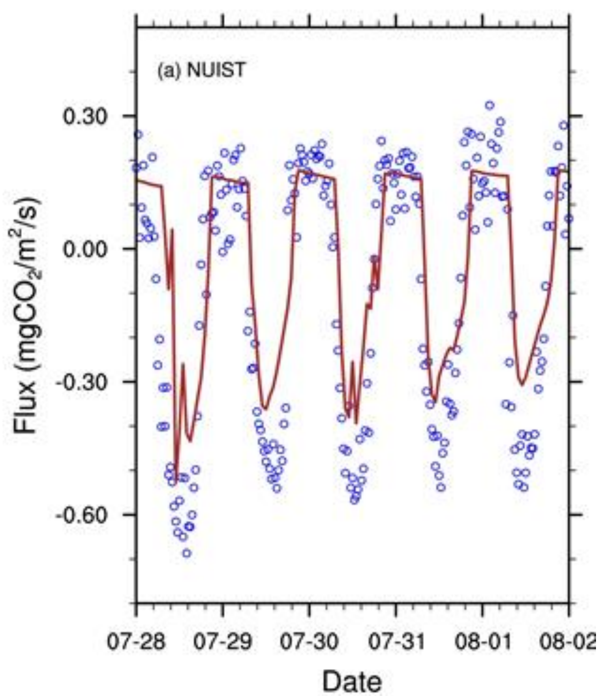
- Surface vegetation flux model is critical to accurate quantification of Net Ecosystem Exchange (NEE) of $CO_2$ (*Fung et al., 1987; Sellers et al., 1996; Xiao et al., 2002, 2004*). VPRM (Vegetation Photosynthesis and Respiration Model) is one of them.

- Features and application of VPRM:
  - Model structure is made simple to facilitate subsequent inverse analysis (just four adjustable parameters: $\lambda$, $PAR_0$, $\alpha$, $\beta$).
  - VPRM assimilates remote sensing, meteorological, and tower flux data, so it can provides a much finer representation of surface fluxes than in previous simple models.

# Motivation and objectives (cont.)

- The WRF-VPRM model has limited capability of capturing NEE diurnal pattern well with default parameters in VPRM (*Diao et al., 2014, under review*)
- Objectives:

To identify more realistic parameters for VPRM based on the surface or tower flux measurements and eventually better simulate spatial and temporal variations in $CO_2$.




(*Diao et al., 2014, under review*)

# VPRM model framework

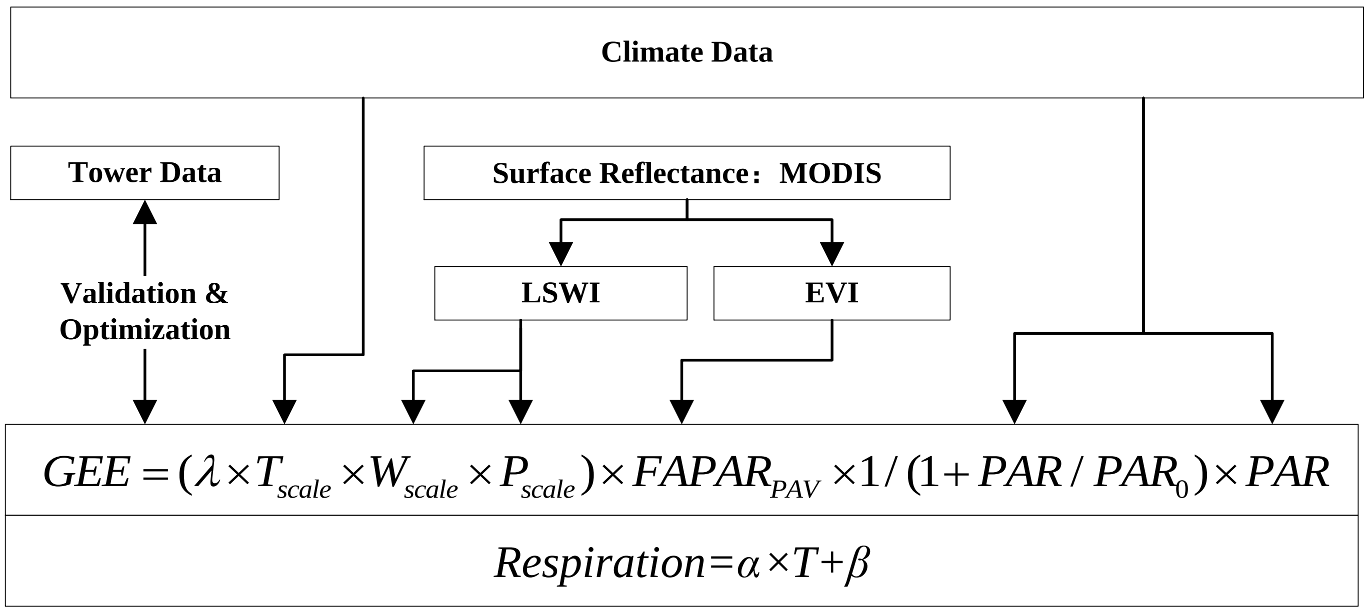



Fig.1 Schematic diagram of the VPRM model (*Mahadevan et al., 2008*)

- λ: The product of the maximum quantum yield (~1/6)
- $T_{scale}$: temperature; $P_{scale}$: leaf phenology; and $W_{scale}$: canopy water content
- $FAPAR_{PAV}$: The fraction of incident light absorbed by vegetation in the canopy
- $PAR_0$: half-saturation value of PAR
- α, β: adjustable by tower flux data for each vegetation type

# Data

- **Tower flux data**: $CO_2$ flux data ($F_c$) observed at half hour interval at QYZ site (2010-2011).
- **Meteorology data**: Radiation, temperature, precipitation, relative humidity, etc. (2010-2011).
- **Satellite data**: 8-d mean MODIS surface reflectance data (MOD09A1) for red (620–670 nm), NIR (841–876 nm), blue (459–479 nm), and SWIR (1628–1652 nm) to calculate EVI and LSWI (2010-2011).

$$\mathrm{EVI} = \mathrm{G} \times \frac{(\rho_{nir} - \rho_{red})}{\rho_{nir} + (C_1 \times \rho_{red} - C_2 \times \rho_{blue}) + L}$$

$$\mathrm{LSWI} = \frac{\rho_{nir} - \rho_{swir}}{\rho_{nir} + \rho_{swir}}$$

(*Xiao et al., 2004a, 2004b*)

# Method

- Tower observed data in 2010 at QYZ site are used to determine VPRM model parameters $\lambda$, $PAR_0$, $\alpha$, $\beta$; and the data in 2011 are used to validate the VPRM performance on NEE simulations.
- Parameter optimization method

➢ Approach 1: using traditional Michaelis-Menten equation to get $\lambda$ and $PAR_0$.

$$\mathrm{GEE} = \alpha \times \mathrm{PPFD} \times \mathrm{GEE}_{\mathrm{max}} / (\alpha \times \mathrm{PPFD} + \mathrm{GEE}_{\mathrm{max}})$$

➢ Approach 2: using VPRM calculate equation to optimize $\lambda$ and $PAR_0$.

$$\mathrm{GEE} = (\lambda \times \mathrm{T}_{\mathrm{scale}} \times \mathrm{W}_{\mathrm{scale}} \times \mathrm{P}_{\mathrm{scale}}) \times \mathrm{FAPAR}_{\mathrm{PAV}} \times 1/(1 + \mathrm{PAR}/\mathrm{PAR}_0) \times \mathrm{PAR}$$

# Flux data processing

- 1. Coordinate rotation and the WPL correction, calculate the $CO_2$ storage within the canopy;
- 2. Flux values were excluded if rain or snow was falling;
- 3. Set the threshold of flux data to [-1, 1] mg $m^{-2}s^{-1}$;
- 4. Flux values were excluded if ustar ($u^*$) was below a threshold of 0.2 m/s at night;

# Model setup

- For evergreen forest, plants should grow all year round, so we set $P_{scale}$ to 1.0.
- For parameters $\lambda$, $PAR_0$, $\alpha$, $\beta$, we use the optimized value, for $T_{min}$, $T_{max}$, $T_{opt}$, we adopt default value.
- The model input and output resolution is half hour, so we generate half hourly data from the smoothed time series of vegetation indices (EVI and LSWI).

# Results and discussion

Table1. A comparison between the default parameters and the parameters derived from observed data at QYZ site

| Approach\value | $\lambda$ (μmol $CO_2$ $m^{-2}s^{-1}$/ μmol PPFD $m^{-2}s^{-1}$) | $PAR_0$ (μmol PPFD $m^{-2}s^{-1}$) | $\alpha$ (μmol $CO_2$ $m^{-2}s^{-1}$/℃) | $\beta$ (μmol $CO_2$ $m^{-2}s^{-1}$) |
|---|---|---|---|---|
| Default[1] | 0.114 | 790 | 0.153 | 1.56 |
| Approach 1 | 0.0604 | 379 | 0.156 | 0.944 |
| Approach 2[2] | 0.197 | 550 | 0.156 | 0.944 |

1.Default: **DONALDSON site** (slash pine forest), (29.755°N, 82.163° W), Florida, United States. *Clark et al., 1999, 2004.*

2. Approach 1,2: **QYZ site**: (26.733°N, 115.05° E), JiangXi province, China. *Liu et al., 2006.*

# Sunny days

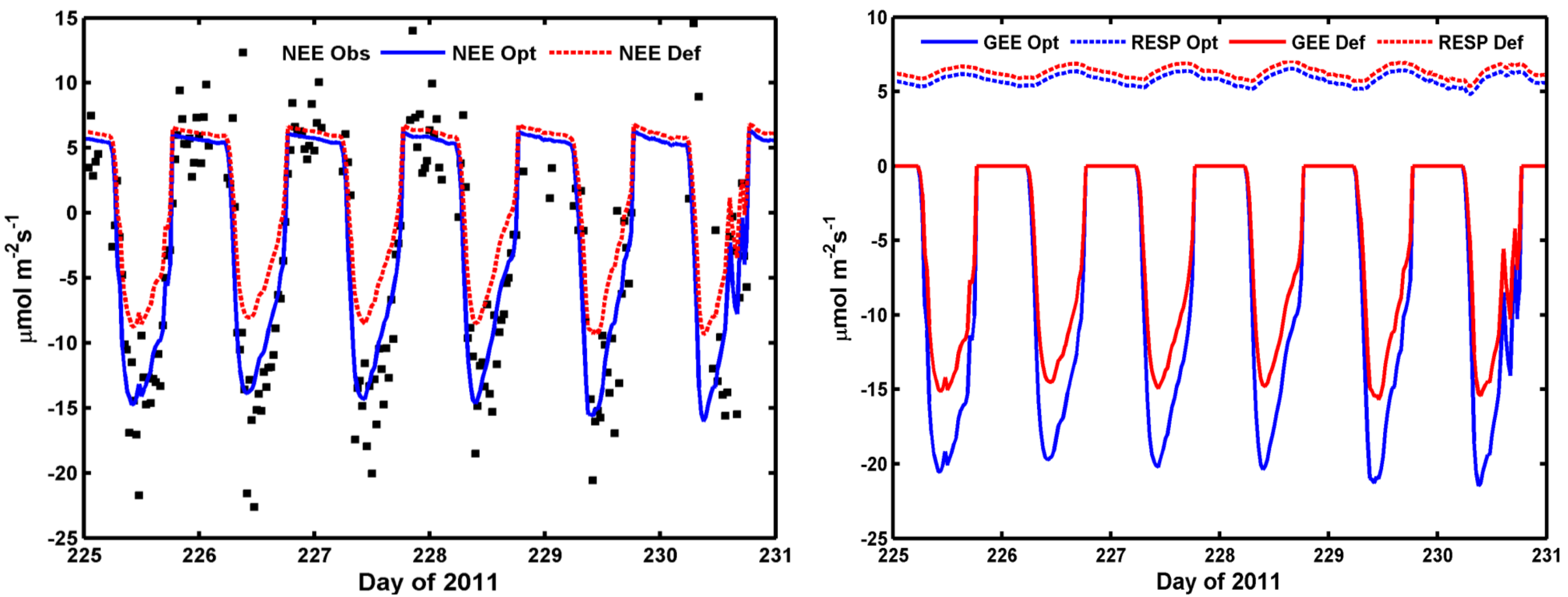



Fig.1 Comparison of simulated NEE, GEE, RESP with observations at QYZ site during the day 225-230 of 2011

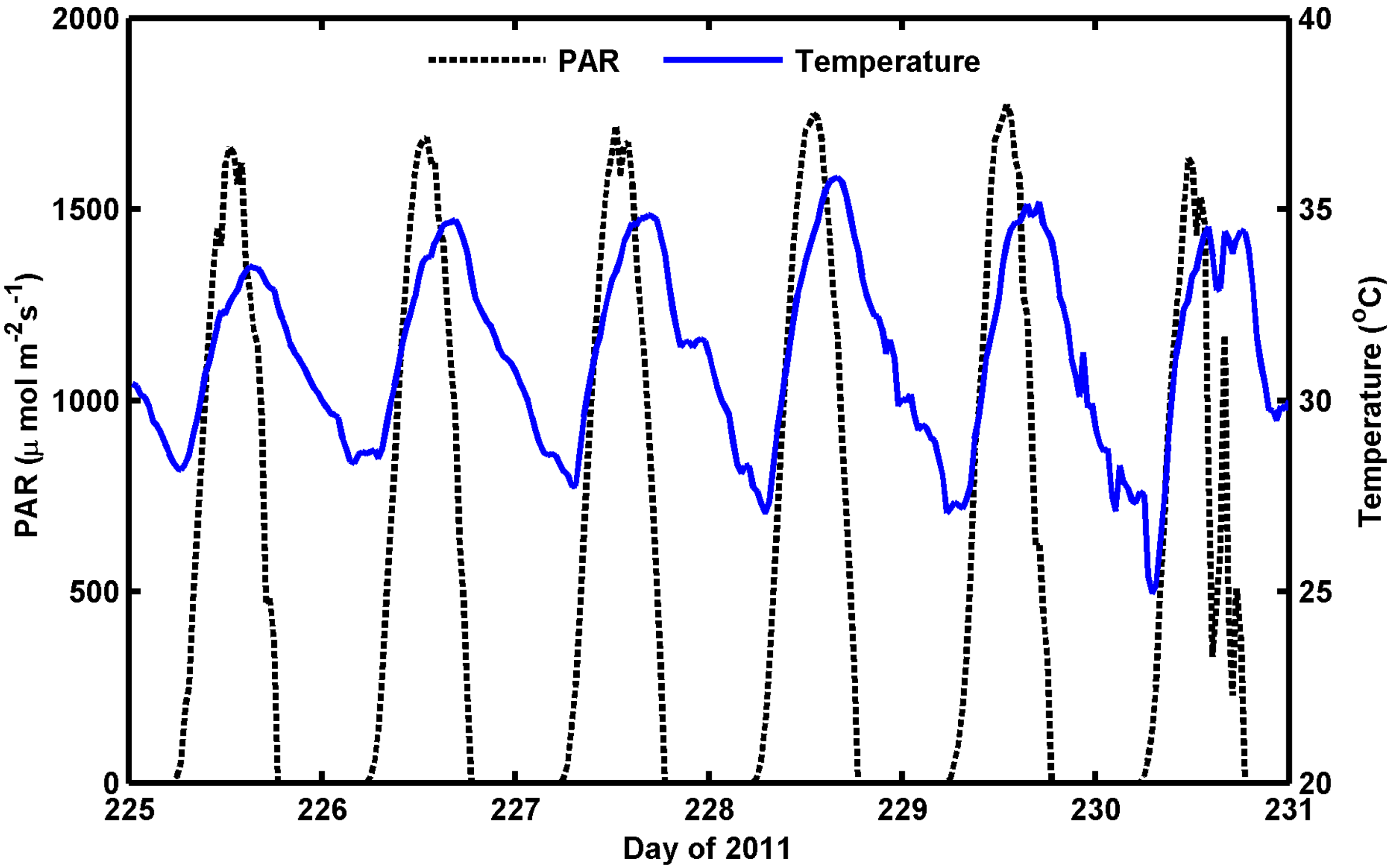



Fig.2 Time series of PAR and temperature at QYZ site during the day 225-230 of 2011

# Cloudy and rainy days

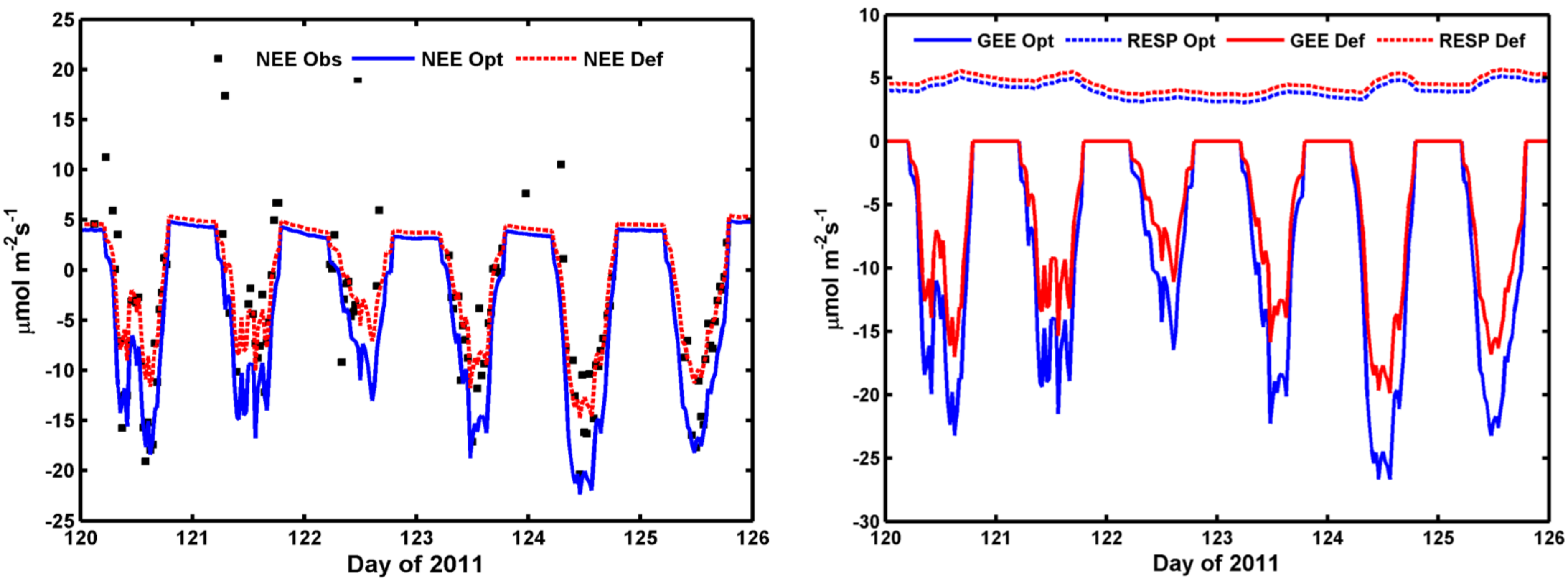



Fig.3 Comparison of simulated NEE, GEE, RESP with observations at QYZ site during the day 120-125 of 2011

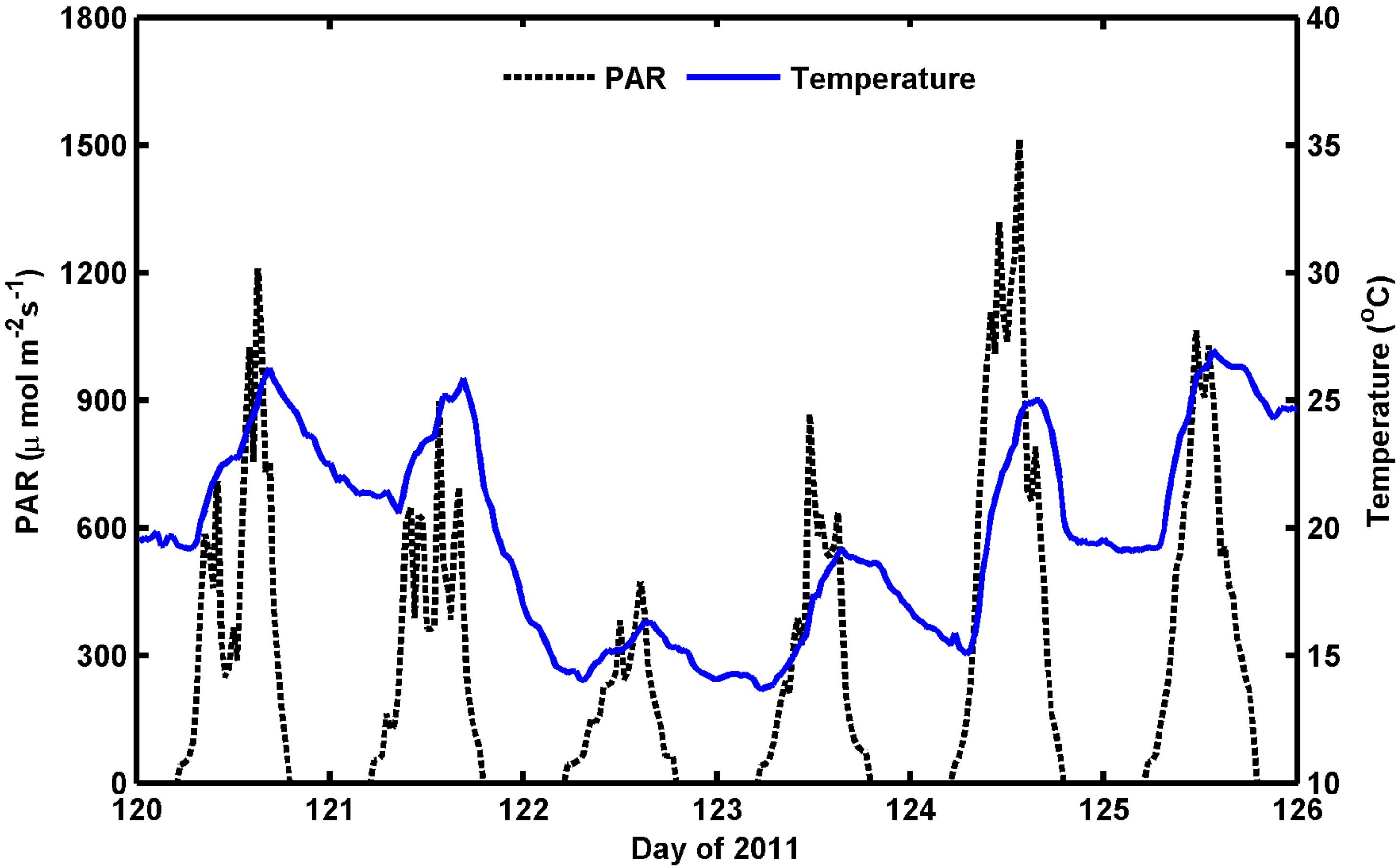



Fig.4 Time series of PAR and temperature at QYZ site during the day 120-125 of 2011

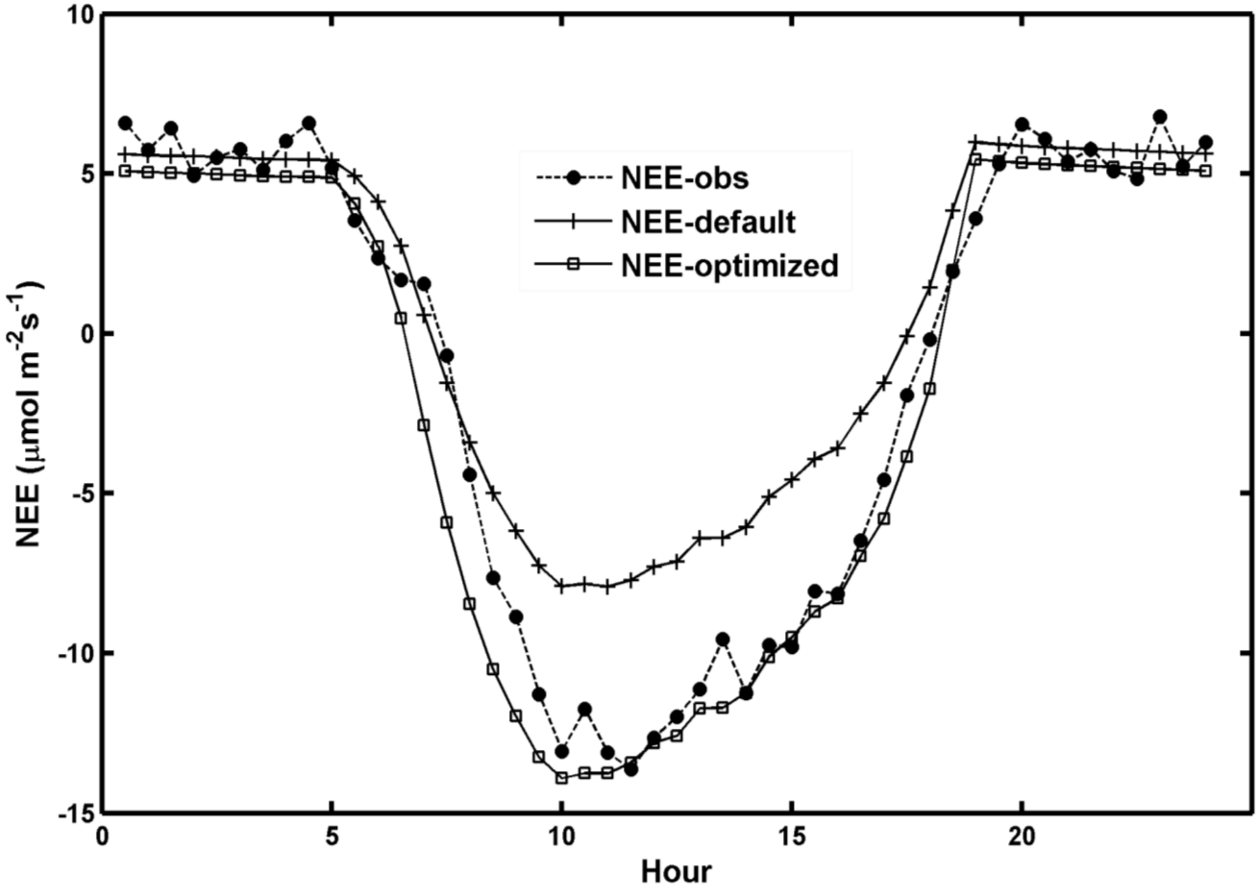



Fig.5 A comparison between the observed and VPRM mean diurnal variation of NEE during the peak growing season (april-september) of 2011 at QYZ site

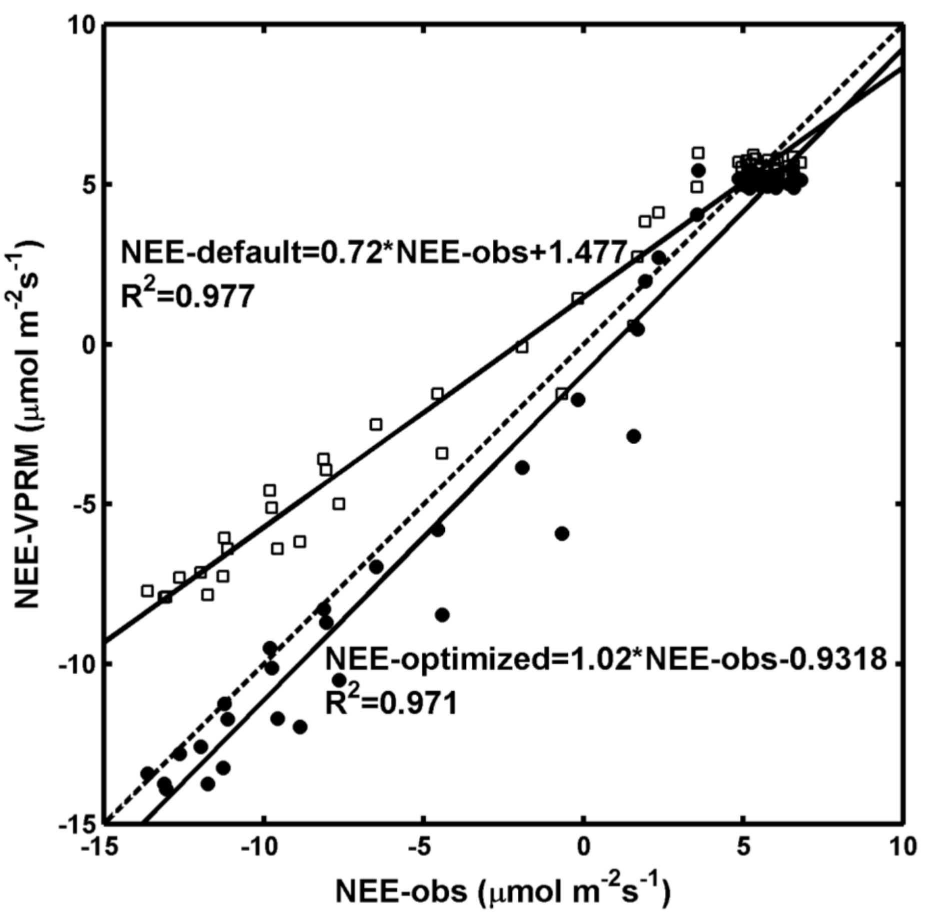



Fig.6 Regression analysis between the observed and VPRM mean diurnal variation of NEE during the peak growing season (april-september) of 2011 at QYZ site

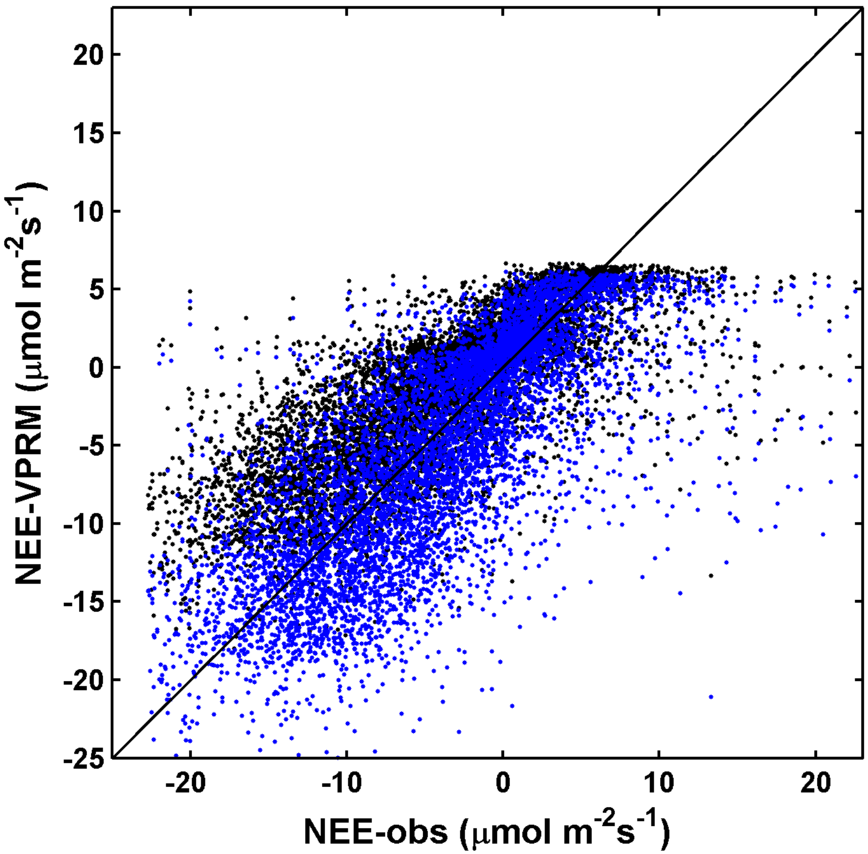



Fig.7 Regression analysis between the observed and modeled half hourly NEE during all year of 2011 at QYZ site (black dot is default value, blue dot is optimized value)

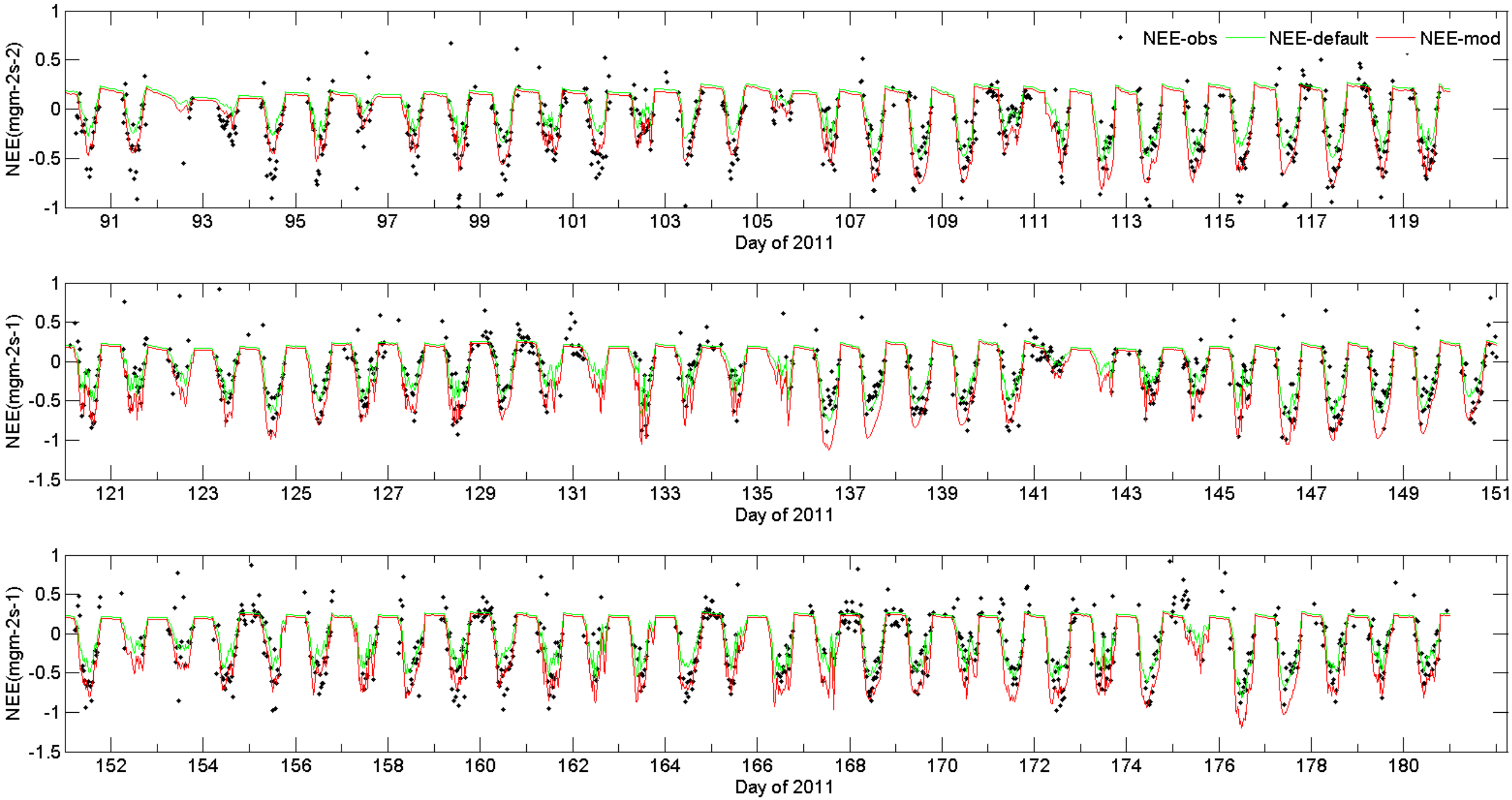



Fig.8 Time series of the observed and modeled half hourly NEE during April, May, June of 2011 at QYZ site

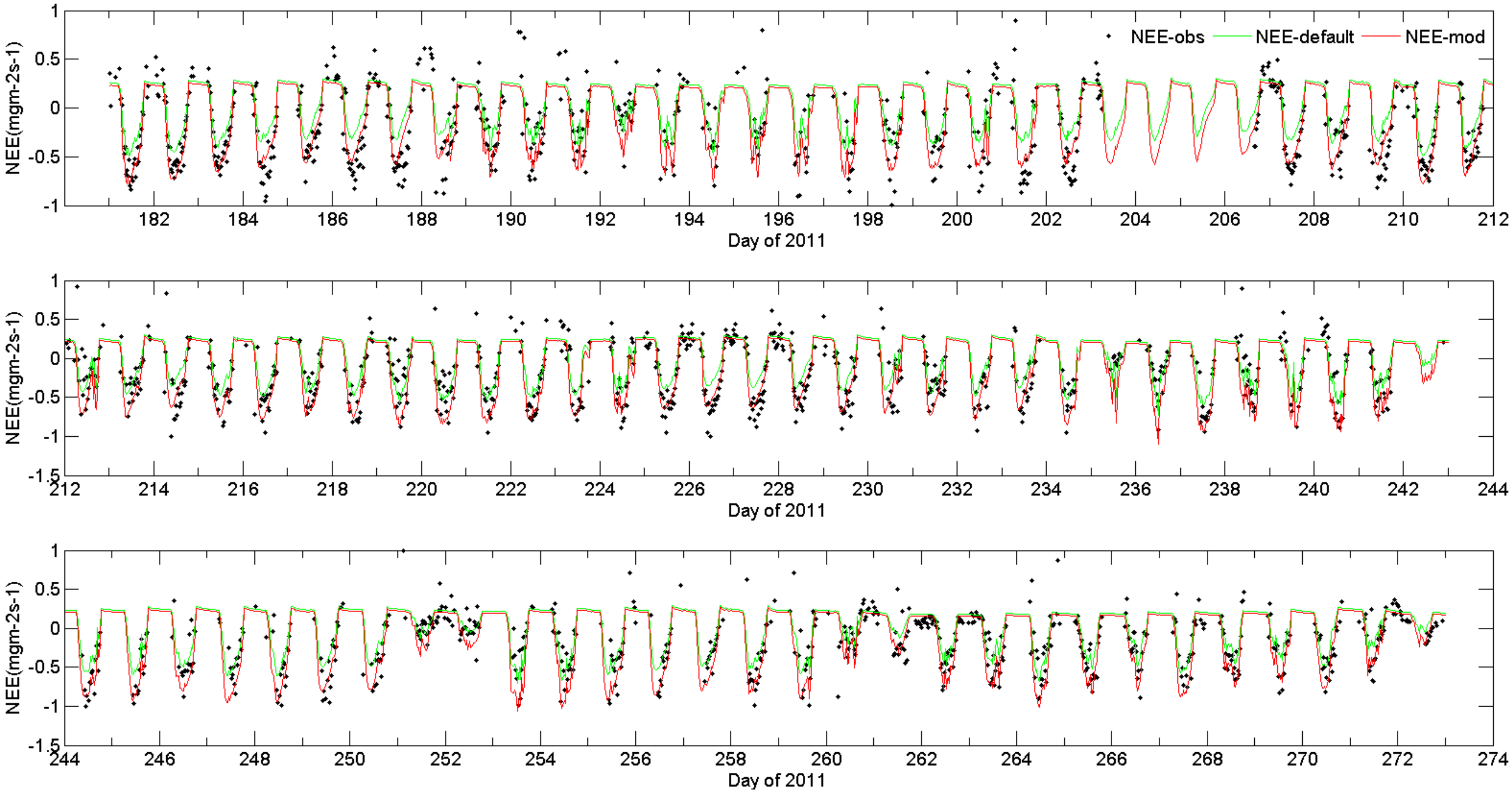



Fig.9 Time series of the observed and modeled half hourly NEE during July, August, September of 2011 at QYZ site

Table 2. Statistical results between simulation and observation

| Year 2011 | | slope | Intercept ($\mu mol\ m^{-2}s^{-1}$) | $R^2$ | RMSE ($\mu mol\ m^{-2}s^{-1}$) | Mean Bias ($\mu mol\ m^{-2}s^{-1}$) | N |
|---|---|---|---|---|---|---|---|
| Optimized | Hourly NEE of growing season | 0.77 | -6.042 | 0.630 | 4.705 | -2.216 | 4178 |
| | Hourly NEE of all year | 0.73 | -2.091 | 0.563 | 4.636 | -0.975 | 7392 |
| | Mean diurnal variation | 1.019 | -0.9318 | 0.970 | 1.318 | -0.955 | 48 |
| Default | Hourly NEE of growing season | 0.566 | -0.0975 | 0.644 | 3.341 | 1.934 | 4178 |
| | Hourly NEE of all year | 0.53 | 0.4091 | 0.586 | 3.182 | 2.386 | 7392 |
| | Mean diurnal variation | 0.724 | 1.472 | 0.977 | 0.8409 | 1.818 | 48 |

# Summary

- Two different methods are used to derive VPRM parameters. Using VPRM calculate equation to optimize $\lambda$ and $PAR_0$ is better than traditional Michaelis-Menten equation.
- Four parameters ($\lambda$, $PAR_0$, $\alpha$, $\beta$) of VPRM model are optimized using tower measurements at QYZ site; After optimization, $\lambda$ is 0.197μmol $m^{-2}s^{-1}$/μmol $m^{-2}s^{-1}$ , $PAR_0$ is 550 μmol $m^{-2}s^{-1}$ , $\alpha$ is 0.156 μmol $CO_2$ $m^{-2}s^{-1}$/℃, $\beta$ is 0.944 μmol $CO_2$ $m^{-2}s^{-1}$.
- Using the optimized parameters, VPRM has much better performance on capturing NEE diurnal pattern, especially for the daytime NEE peak value.

# On-going work and next step

- To apply the similar method to determine VPRM parameters for more types of representative vegetation in China.

- To test the impact of the VPRM parameters on simulations of $CO_2$ in WRF/GHG (i.e., WRF/VPRM).

# Thank you !