EGU General Assembly 2020

Max Planck Institute for Biogeochemistry

Evaluating Light Use Efficiency (LUE) Models and Parameter-upscaling Methods

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LUE model structure

$$GPP = \varepsilon_{max} \cdot APAR \cdot fT \cdot fVPD \cdot fW \cdot fL \cdot fCI$$

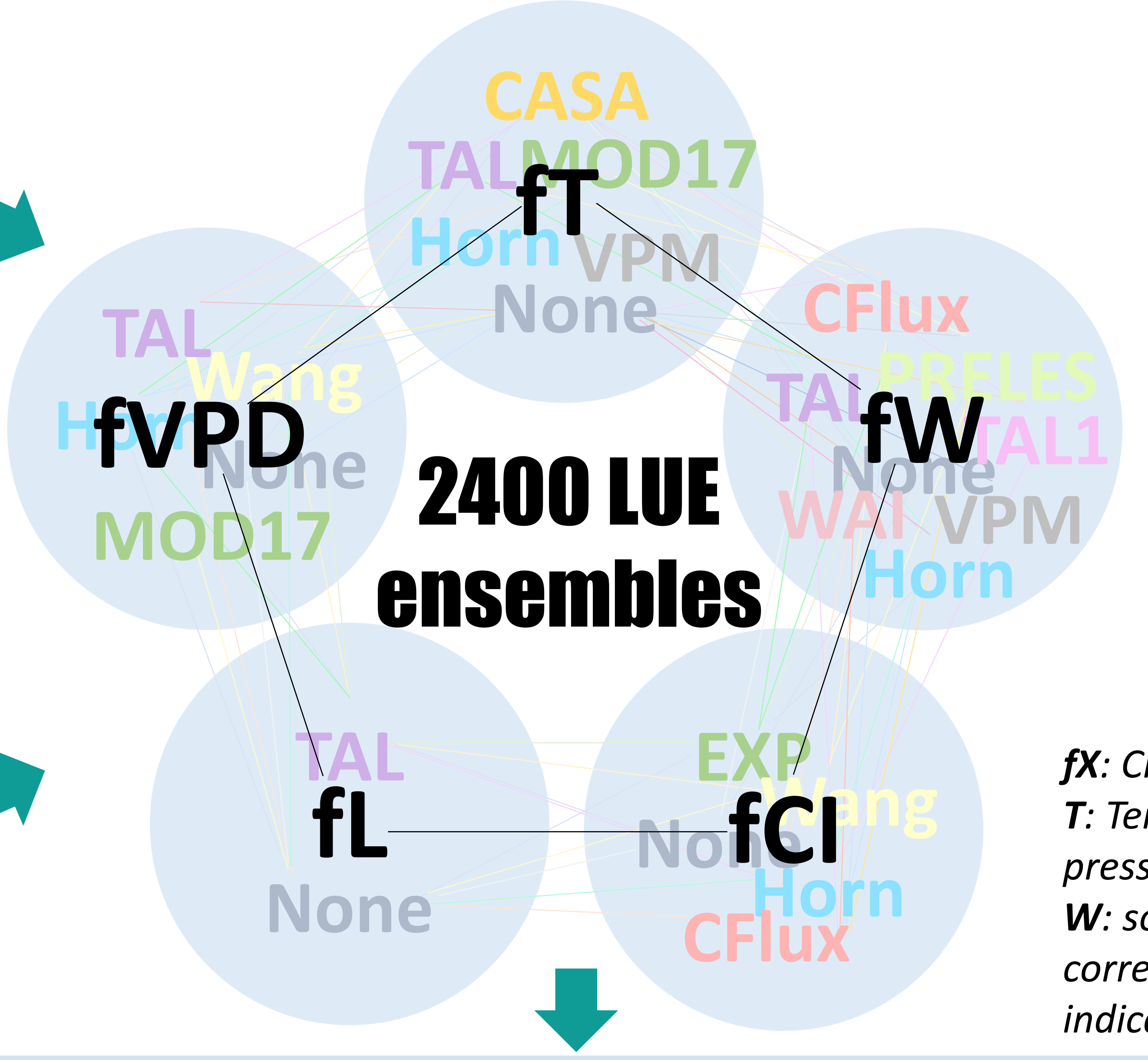
1. Which is the best model ?

Data

- 177 EC towers (Climate + GPP)
- MODIS

Parameters

- Optimization (Trust-Region-Reflective Least Squares Algorithm)
- Cost function (GPP, ET and fX)



Assessment

- Daily GPP
- Weekly GPP
- Monthly GPP
- Annual GPP

(Nash-Sutcliffe Model Efficiency, NSE)

fX: *Climate sensitivity function;* ***T***: *Temperature;* ***VPD***: *vapor pressure deficit;* ***W***: *soil water indicator;* ***L***: *APAR corrector;* ***CI***: *cloudiness indicator*

Best LUE model (NSEmedian,d/w/m/a = 0.73/0.79/0.84/0.54)

$$GPP = \varepsilon_{max} \cdot APAR \cdot fT_{CASA} \cdot fVPD_{TAL} \cdot fW_{Horn} \cdot fL_{TAL/None} \cdot fCI_{EXP}$$

2. How to upscale parameters ?

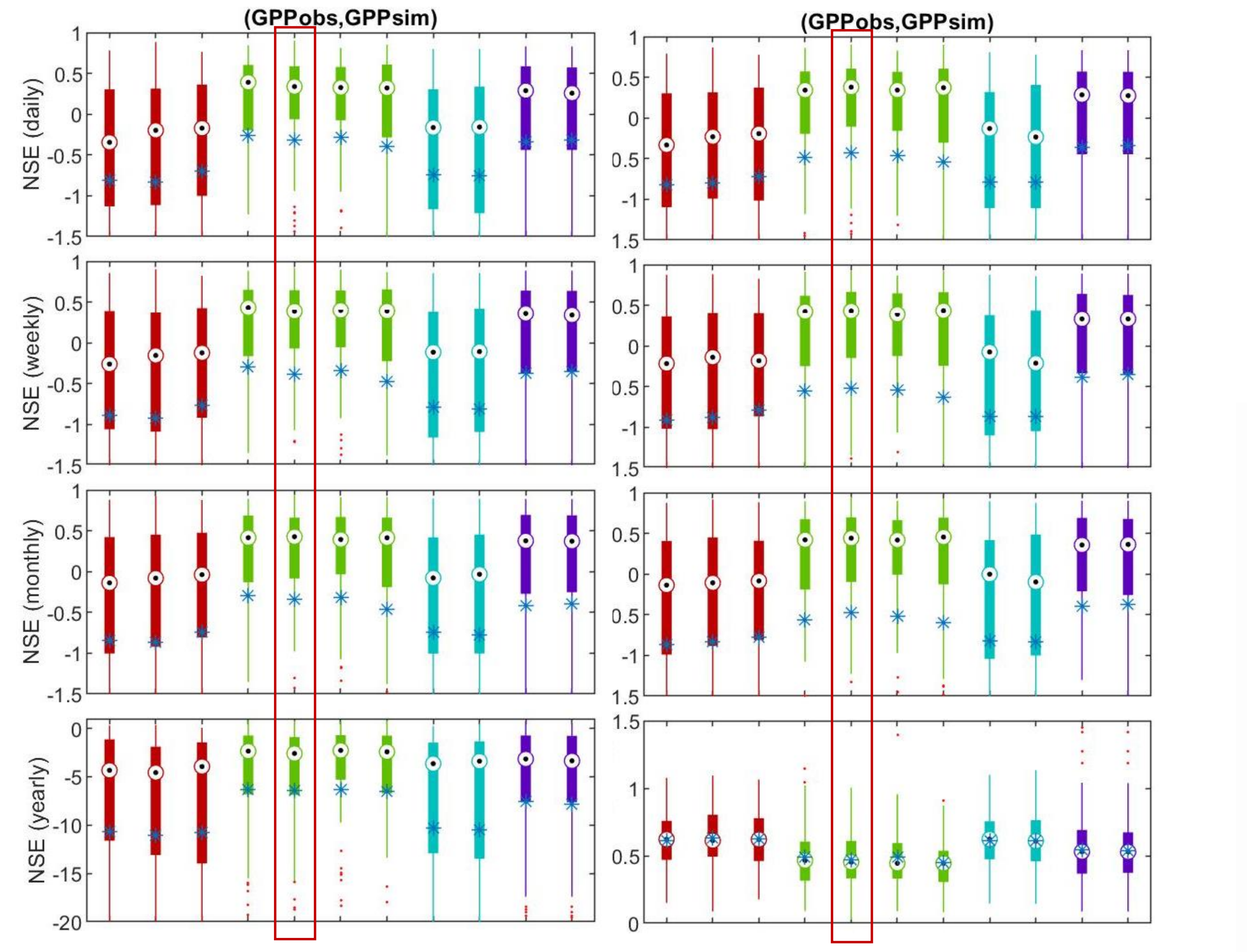


Fig.1 NSE of GPP using upscaled parameters in cross validation for model I (left) and model II (right)

- **Mean** of per climate type (Koeppen-Geiger, K-G)
- **Mean** of per Plant Functional Type (PFT)
- **Mean** of per PFT and K-G (first 2 characters)
- **Median** of per K-G
- **Median** of per PFT
- **Median** of per PFT and K-G (first 2 characters)
- **Median** of per plant type
- Random Forest (RF) **Regression** using bioclimatic variables and corresponding vegetation indexes (VI)
- RF **Regression** using bioclimatic variables
- **Site similarity** using PFT, VI and mean seasonal cycle (MSC) climate variables
- **Site similarity** using PFT, VI, MSC climate and ET

Take home message

- On daily, weekly, monthly and yearly scale, 36 models were significantly better than the others.
- The best two models as above had the best global NSE (NSE for all sites) over other models for the four time scales.
- Using the median parameters per PFT had the best performance to upscale parameters from site-level to global-level.
- We further explore the relationship between parameters/climate sensitivity functions and environmental drivers as well as biophysical plant traits using global retrieval of SIF.

Functional Responses of Primary Productivity to Climate

SHANNING BAO, FABIAN GANS, SIMON BESNARD, SUJAN KOIRALA, ALVARO MORENO, SOPHIA WALTHER, ULRICH WEBER, MARTIN JUNG, MIGUEL MAHECHA, AND NUNO CARVALHAIS

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Light Use Efficiency (LUE) models

$$GPP = \varepsilon_{max} \cdot APAR \cdot fT \cdot fVPD \cdot fW \cdot fL \cdot fCI$$

fT	$fVPD$	fW	fL	fCI
MOD17	MOD17	TAL	TAL	CFlux
TAL	TAL	Horn	none	Wang
CASA	CASA	VPM		EXP
Horn	Wang	CFlux		Horn
VPM	none	PRELES		none
none		none		

GPP: Gross Primary Productivity

ε_{max}: maximum light use efficiency

APAR: Active Photosynthetically Absorbed Radiation

fT: Temperature sensitivity function

fVPD: Vapor Pressure Deficit sensitivity function

fW: soil Water indicator sensitivity function

fL: Light (APAR) sensitivity function

fCI: Cloudiness Index sensitivity function

Questions

- Which is the best LUE model?
- Which are the best climate sensitivity functions of GPP?
- Does the climate sensitivity change with environmental condition and biophysical traits of vegetation?

Assumptions

- The LUE model which has the best model efficiency on different time scales and less parameters is the best model.
- The climate sensitivity functions (fXs) of the best LUE model can best represent the response of vegetation photosynthesis rate to climate change.
- The model parameters which controls the fXs trends change with environmental condition and biophysical traits of vegetation.

Experiment design

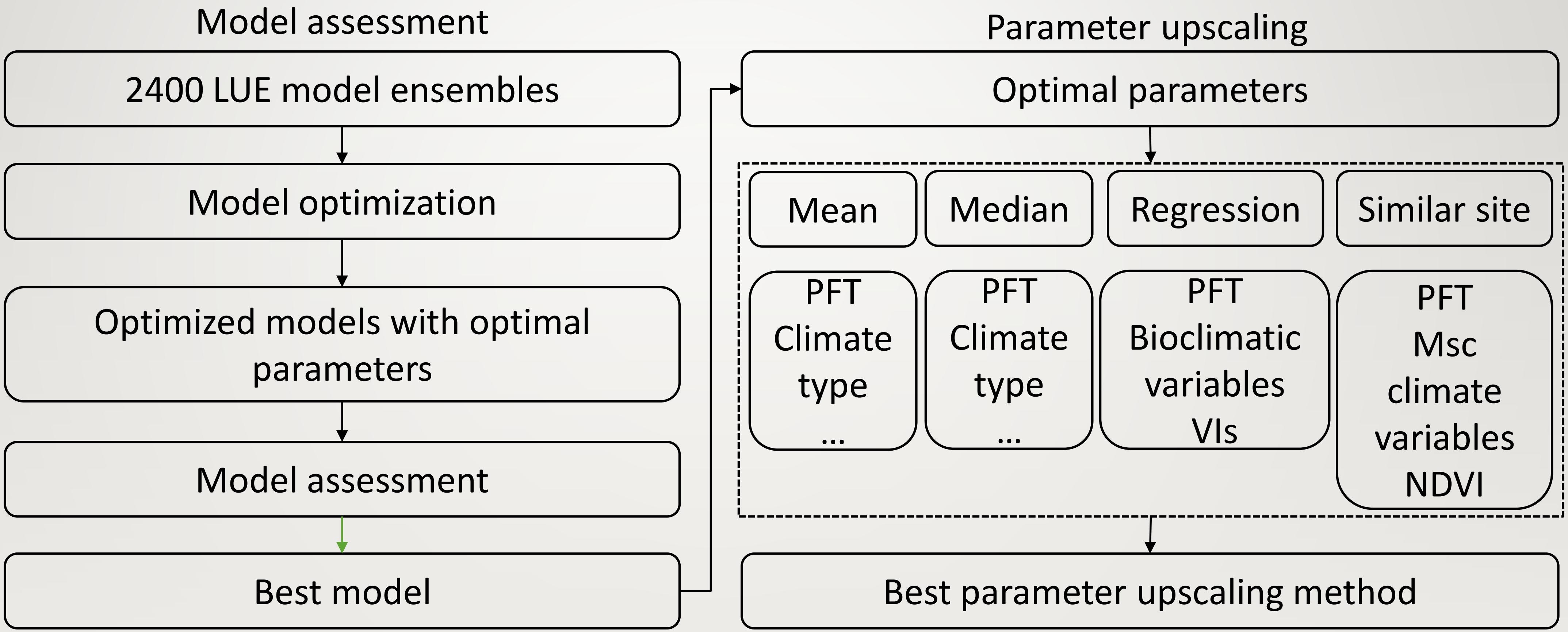
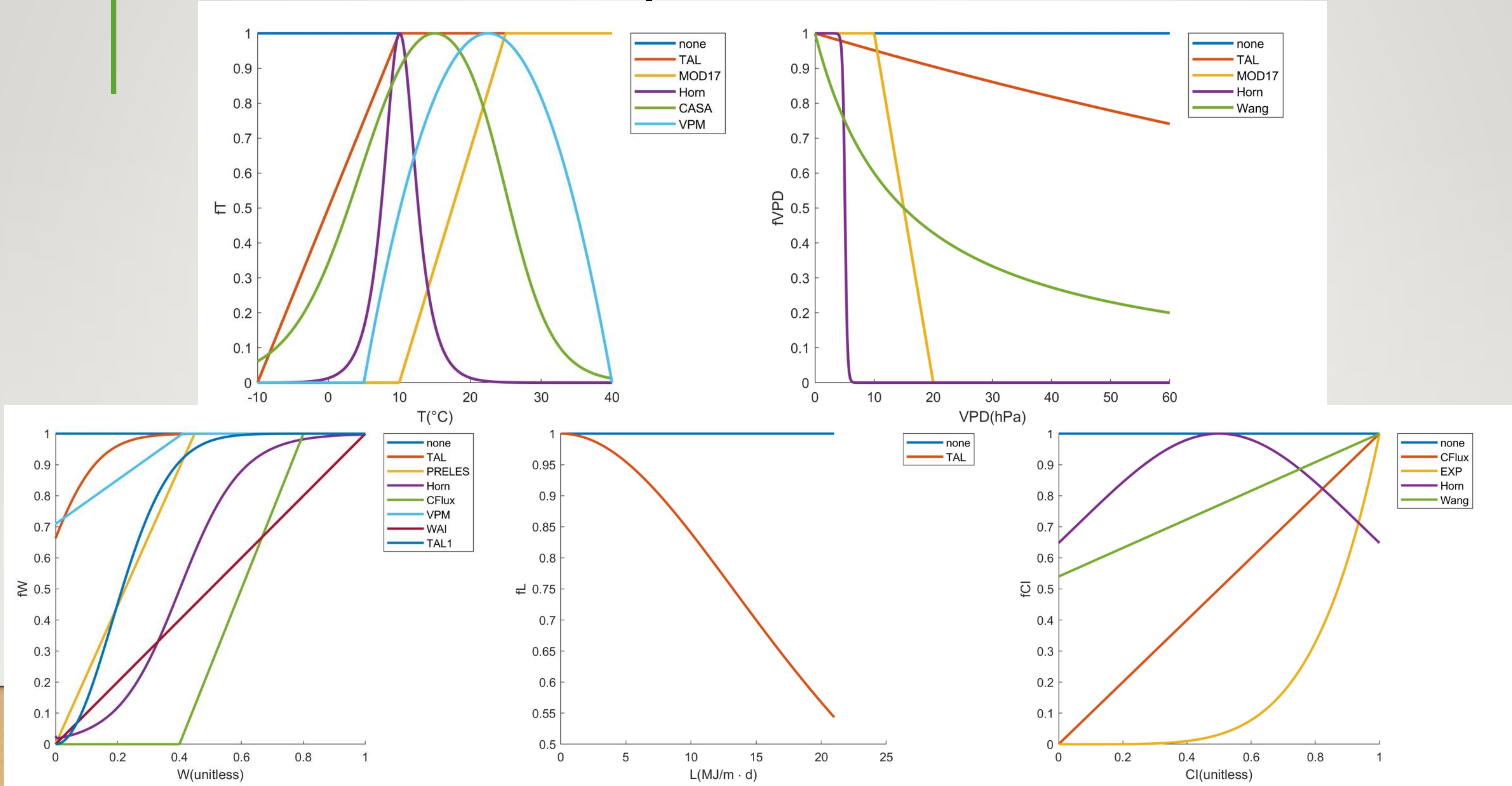


Fig.1 Workflow of this study

Climate sensitivity functions in LUE models



Results
1. Best model selection

$$GPP = \varepsilon_{max} \cdot APAR \cdot fT_{CASA} \cdot fVPD_{TAL} \cdot fW_{Horn} \cdot fL_{TAL} \cdot fCI_{EXP} \quad \text{(I)}$$

$$GPP = \varepsilon_{max} \cdot APAR \cdot fT_{CASA} \cdot fVPD_{TAL} \cdot fW_{Horn} \cdot fL_{None} \cdot fCI_{EXP} \quad \text{(II)}$$

fX	Equation	Reference
fT_{CASA}	$\frac{2 \times \cosh(5 \times T_{ab})^2}{\left(\cosh\left(T_{ab} \times \left(T_{opt} - T\right)\right) + \cosh(10 \times T_{ab})\right)}$, $T_{ab} = \left(T < T_{opt}\right) \times T_a + \left(T \geq T_{opt}\right) \times T_b$	(Potter, Randerson et al. 1993)
$fVPD_{TAL}$	$e^{\kappa \times VPD}$	(MÄKelÄ, Pulkkinen et al. 2007)
fW_{Horn}	$1/\left(1 + e^{k_W \times (WAI_f - W_I)}\right)$ $WAI_{f_k} = (1 - \alpha) \times WAI_k + \alpha \times WAI_{f_{k-1}}$, k is time	(Horn and Schulz 2011)
fL_{TAL}	$1/(\gamma \times APAR + 1)$	(MÄKelÄ, Pulkkinen et al. 2007)
fL_{None}	1	-
fCI_{EXP}	CI^{μ}	This study

Results
1. Best model selection

- The Nash-Sutcliffe Model Efficiency(NSE) of the two models:

NSE	Model	Daily	Weekly	Monthly	Annual
Median of site NSE	I	0.726	0.788	0.836	0.544
	II	0.724	0.782	0.834	0.510
Global NSE	I	0.755	-	-	-
	II	0.753	-	-	-

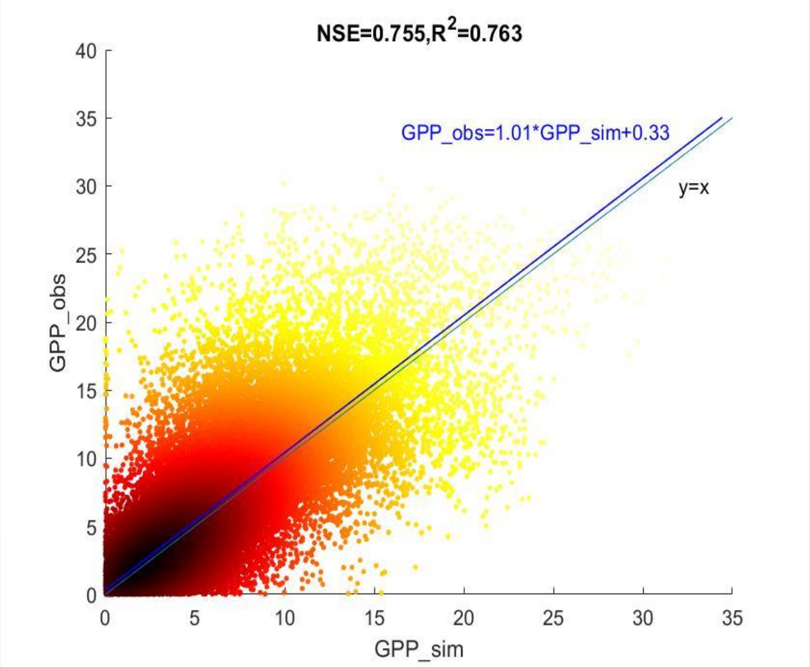


Fig.2 Model I simulated GPP against observed GPP (color represent the density)

Results
2. Parameter upscaling

- Mean of per climate type (Koeppen-Geiger, K-G)
- Mean of per Plant Functional Type (PFT)
- Mean of per PFT and K-G (first 2 characters)
- Median of per K-G
- Median of per PFT
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- Random Forest (RF) Regression using bioclimatic variables and corresponding vegetation indexes (VI)
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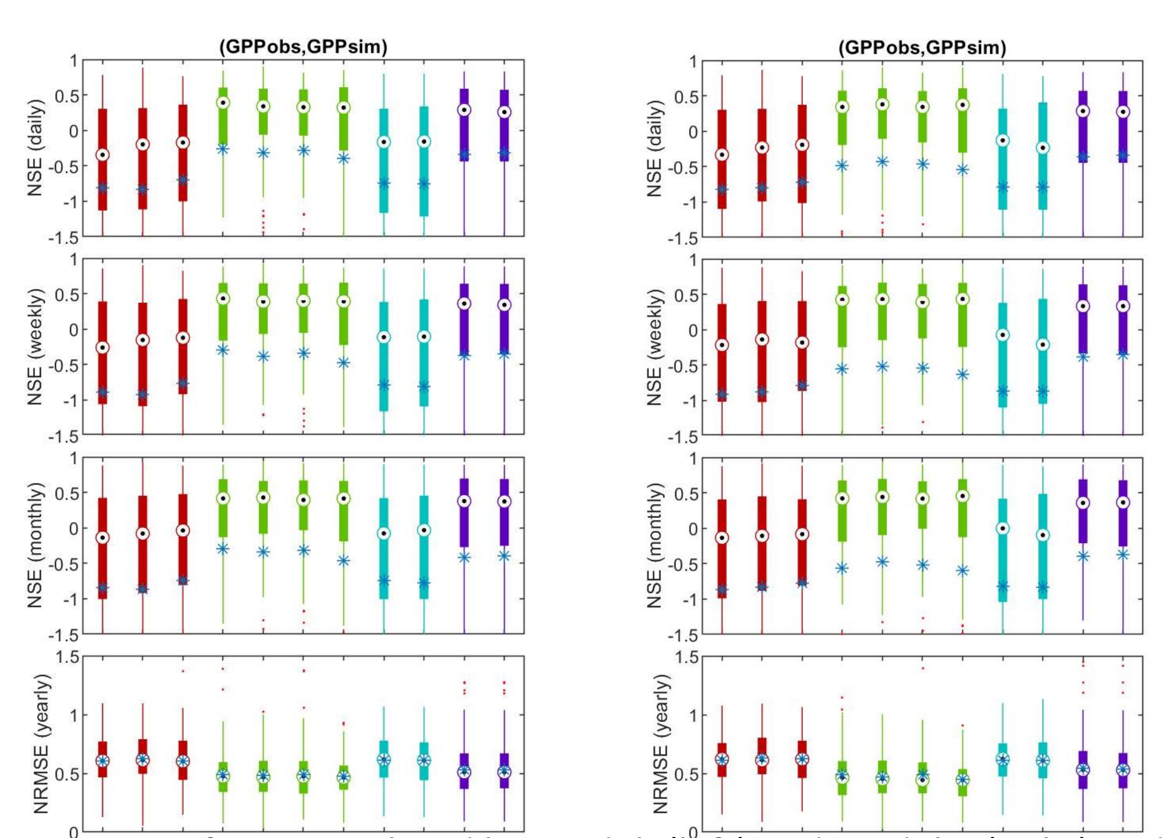

Fig. 3 NSE of GPP simulated by model I(left) and model II (right) and upscaled parameters

Conclusions

- On daily, weekly, monthly and yearly scale, 36 models were significantly better than the others.
- The best two models as above had the best global NSE (NSE for all sites) over other models for the four time scales.
- Using the median parameters per PFT had the best performance to upscale parameters from site-level to global-level.
- Since the limitation of sparse EC towers, we further explore the relationship between parameters/climate sensitivity functions and environmental drivers as well as biophysical plant traits using global retrieval of SIF.

Thanks for your attention!