ICOS INTEGRATED CARBON OBSERVATION SYSTEM

LIÈGE université Gembloux Agro-Bio Tech Biosystems Dynamics and Exchanges

ICOS Science Conference 2022

Modelling winter wheat carbon assimilation from sun-induced fluorescence (SIF)

Quentin Beauclaire

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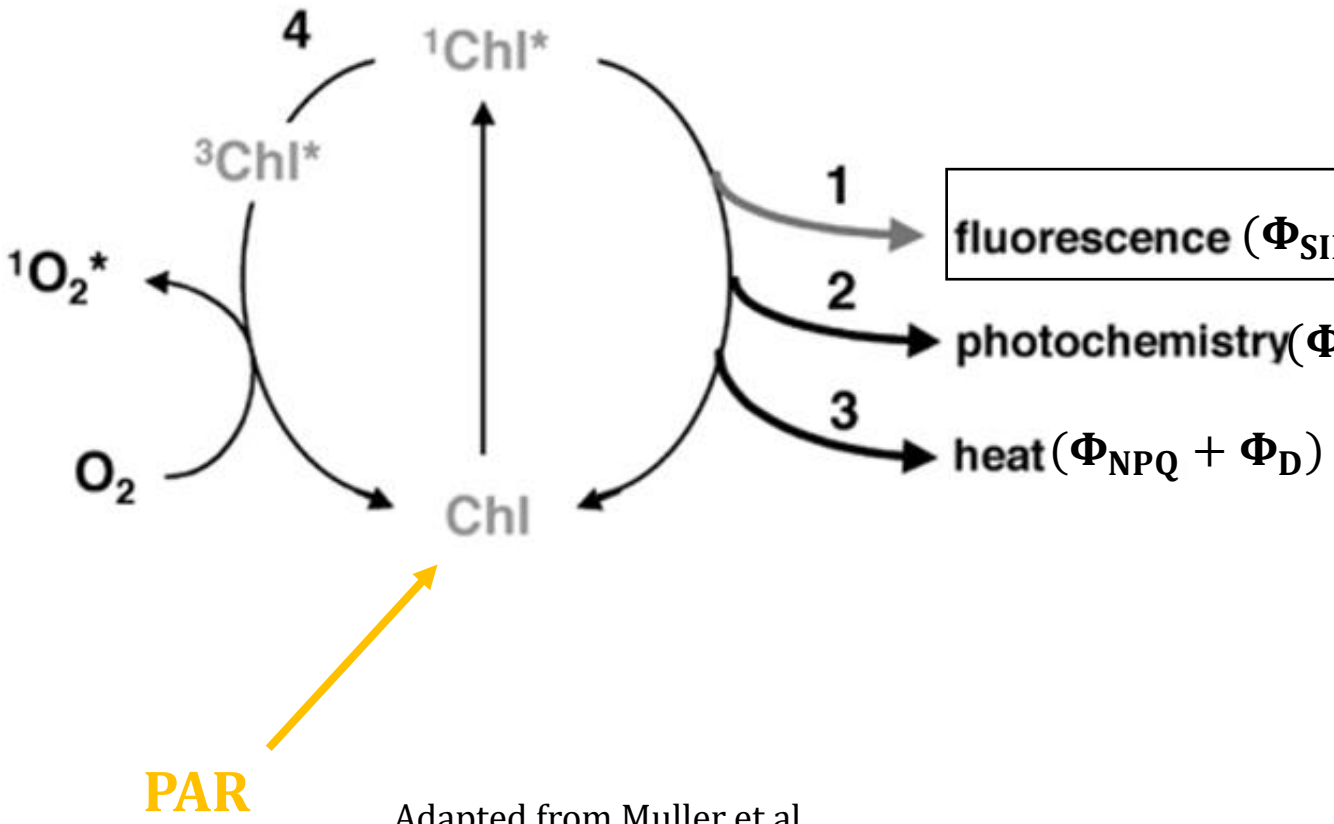
Introduction

Introduction
Relationship between SIF and carbon assimilation (GPP)



Adapted from Muller et al. (2001)

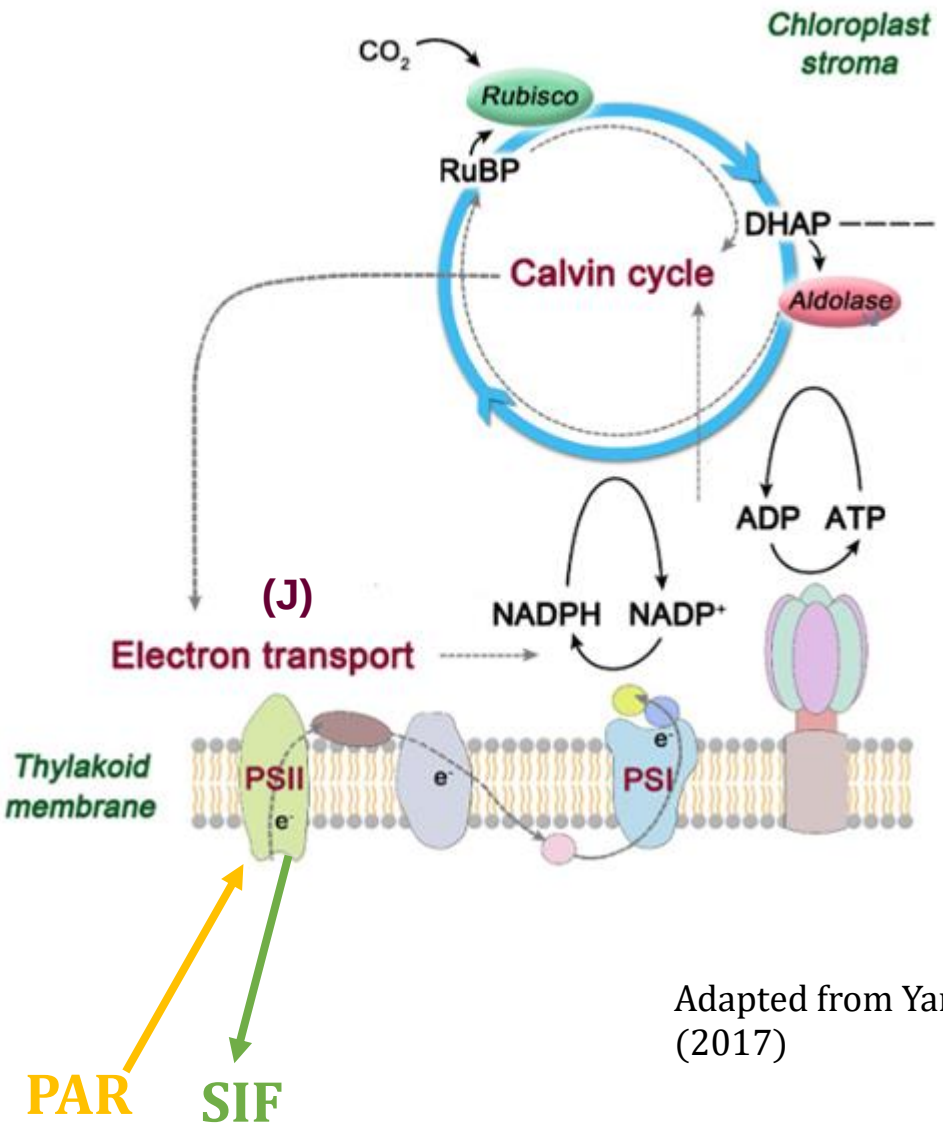
~PSII : 650 and 800 nm

Low yield (from 0.6% to 3%)

$$\Phi_F + \Phi_{PSII} + \Phi_{NPQ} + \Phi_D = 1$$

$\Phi_{PSII} \rightarrow$ electron transport rate (J)

Introduction
Relationship between SIF and photosynthesis



Adapted from Yang et al. (2017)

Gu et al. (2019):

$$J = \Phi_{PSII}\beta\alpha_{grn} \times PAR$$

$$SIF = \Phi_{SIF}\varepsilon\beta\alpha_{grn} \times PAR$$

$$\Phi_{PSII} = \frac{k_P}{k_D + k_F + k_{NPQ} + k_P}$$

$$\Phi_{SIF} = \frac{k_F}{k_D + k_F + k_{NPQ} + k_P}$$

$$J = \frac{k_P}{k_F}\frac{SIF}{\varepsilon}$$

Related to leaf-level fluorescence parameters

$$GPP = \frac{C_c - \Gamma^*}{4C_c + 8\Gamma^*} q_L \frac{\Phi_{PSIImax}(1 + k_{DF})}{(1 - \Phi_{PSIImax})\varepsilon} \times SIF$$

Introduction
Modelling of GPP from SIF : MLR model

$$GPP = \frac{C_c - \Gamma^*}{4C_c + 8\Gamma^*} q_L \frac{\Phi_{PSIImax}(1 + k_{DF})}{(1 - \Phi_{PSIImax})\varepsilon} \times SIF$$

CO_2 concentration (Ca/Ci)

Broadband emitted SIF from PSII

Fraction of open PSII centers

Escape probability of an emitted photon to reach the top of the canopy

Maximum photochemical quantum yield

FLOX device

LI6400XT

Introduction
Objectives

Evaluation of the robustness of the MLR model

- Do MLR parameters dynamics depend on climate conditions ?
- Do MLR predictions correlate with EC data for winter-wheat ?
- Is MLR robustness impacted by drought ?

Only few studies have already evalutated the robustness of the MLR model :
- Liu et al. (2022) on winter-wheat
- Shi et al. (2022 - preprint) on wild rye, wild poplar, siberian elm

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Material and methods

Material and methods
Experimental set-up

BE-Lon (ICOS station class 2) + SIF device (FLOX)

Province of Namur (BE)
12 ha crop
4 years rotation : sugar beet, **winter wheat** and potato

Experimental setup :
- EC station
- Meteo variables (PAR, SWC, Tair…)
- SIF sensor (FLOX)
- LI6400 XT
- Ancillary measurements (GAI, root biomass)

Data analysis from late February to late June 2022 and from 8 am to 18 pm

Material and methods
From top-of-canopy SIF to SIF emitted from PSII

SIF measured at 760 nm (PSI+PSII)

Separating the contribution of PSII (FLR)

Downscaling the signal to the canopy level (ε - FLOX)

Integration over the broadband range of SIF emission (Chl emission spectra – SCOPE)

Broadband SIF emitted by PSII (SIFCAN)

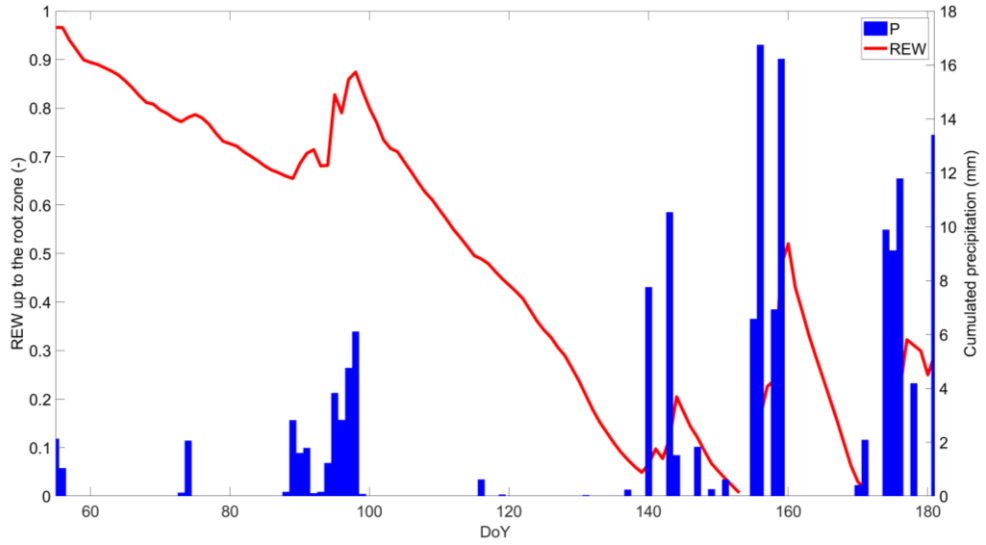
Material and methods
Soil water availability

Relative extractable water (REW) up to the root zone and weighted by the root biomass:

$$REW = \frac{\sum \alpha_i \, (\theta_i - \theta_{wp,i})}{\sum \alpha_i \, (\theta_{fc,i} - \theta_{wp,i})}$$

Calculated from :

- Continuous SWC measurements (θ_i), at BE-Lon for 5 different depths
- Soil sampling campaigns for root biomass density (α_i), field capacity ($\theta_{wp,i}$) and wilting point ($\theta_{wp,i}$)



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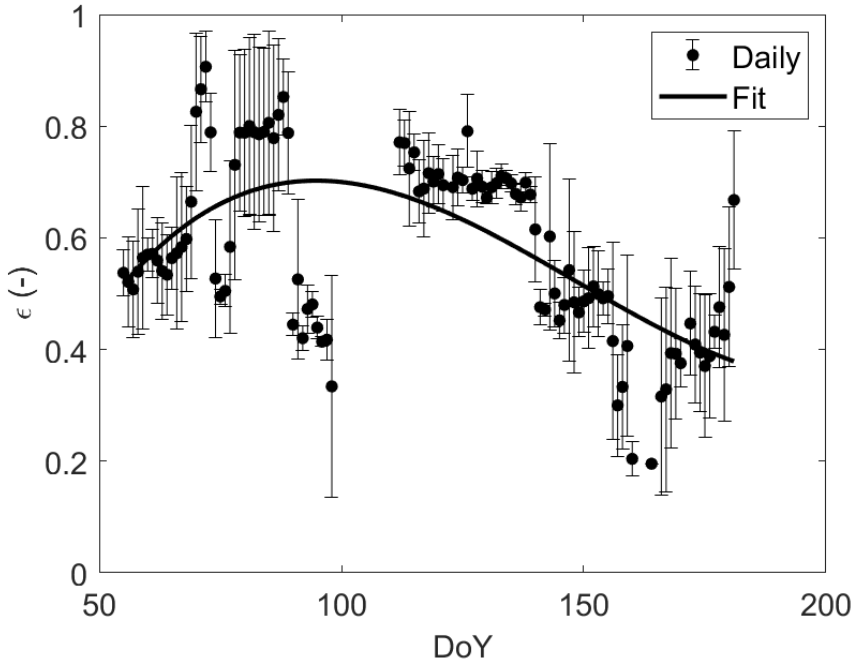
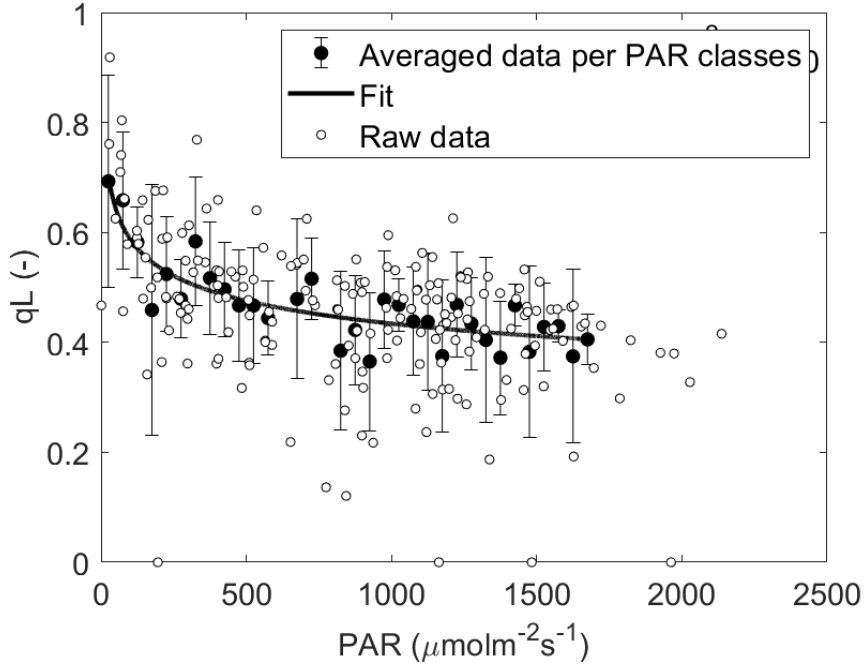
Results

Results
MLR parameters

$$\mathrm{GPP} = \frac{C_c - \Gamma^*}{4C_c + 8\Gamma^*} q_L \frac{\Phi_{PSIImax}(1 + k_{DF})}{(1 - \Phi_{PSIImax})\varepsilon} \times \mathrm{SIF}$$



ε=f(fAPAR,NIRv) -- FLOX

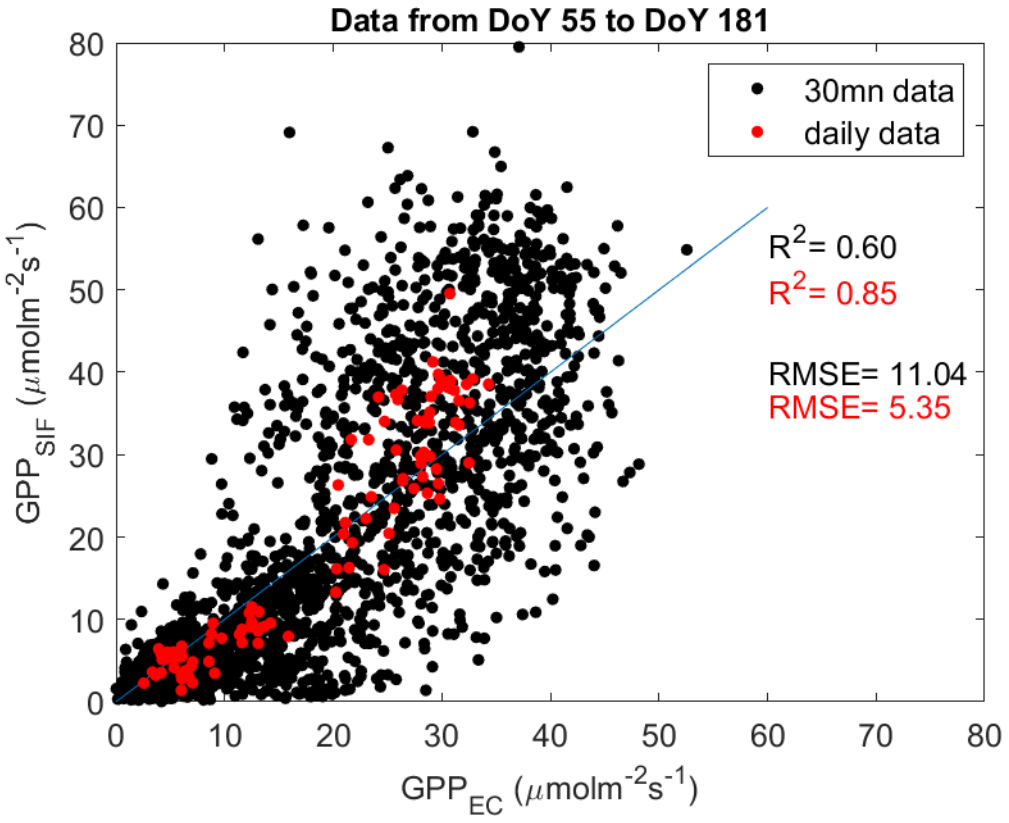


qL : FLR -- LI6400 XT

$\phi_{PSII,max} = \overline{\phi_{PSII,max}} = 0.76$ (around 0.83 (Gu et al., 2019))

$k_{DF} = 19$ (Liu et al., 2022)

Results
Robustness of the MLR model



- Better correlation for averaged data
- Data points more scattered for half hourly data
- Did PAR and REW influence MLR robustness?

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Results

Robustness of the MLR model

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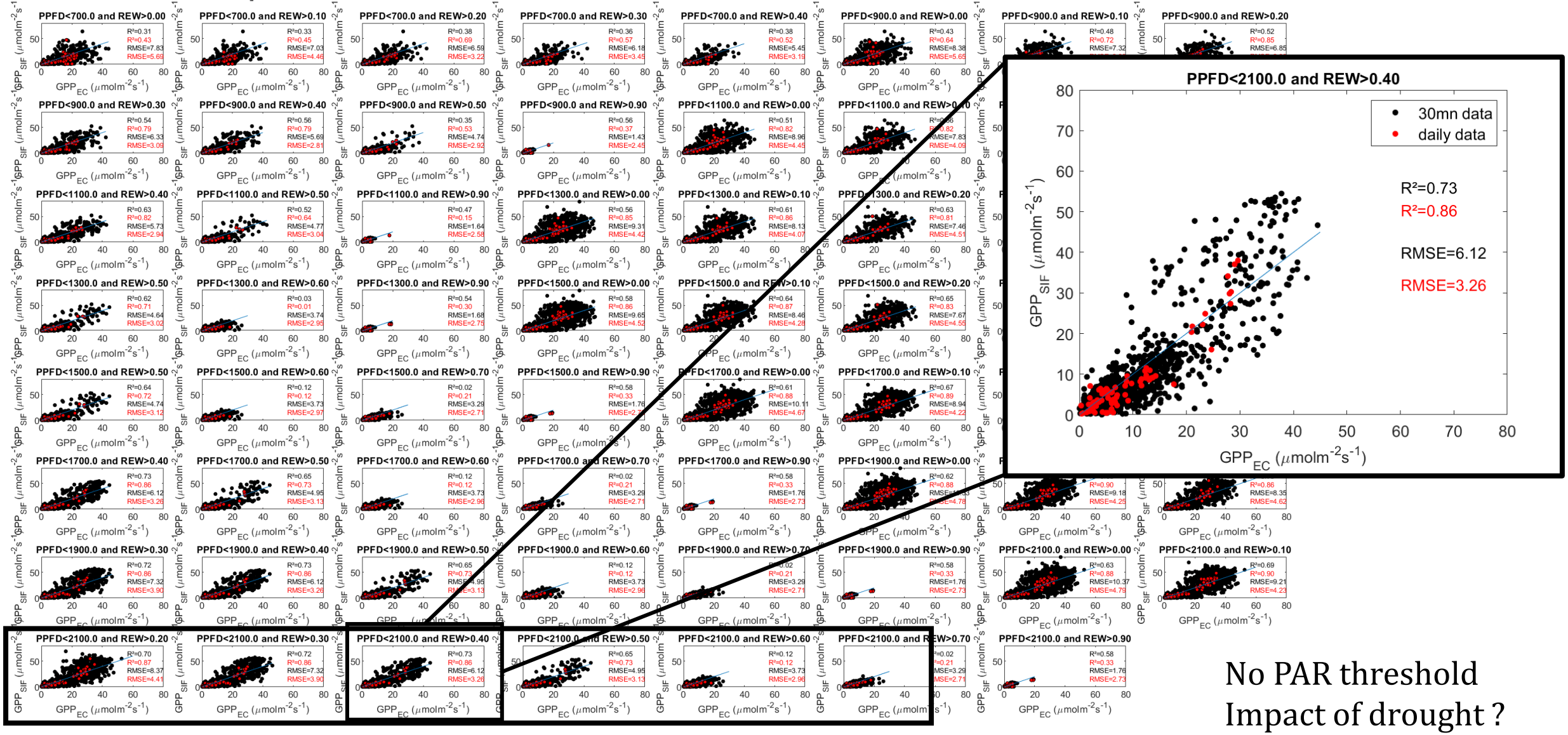
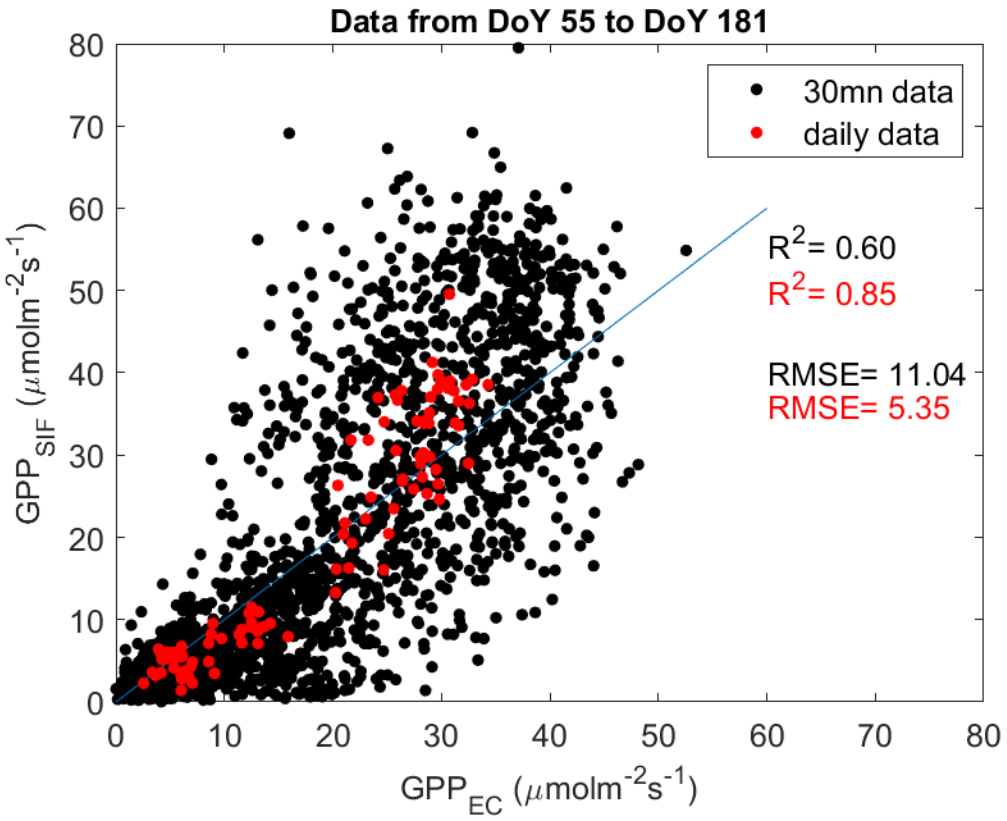
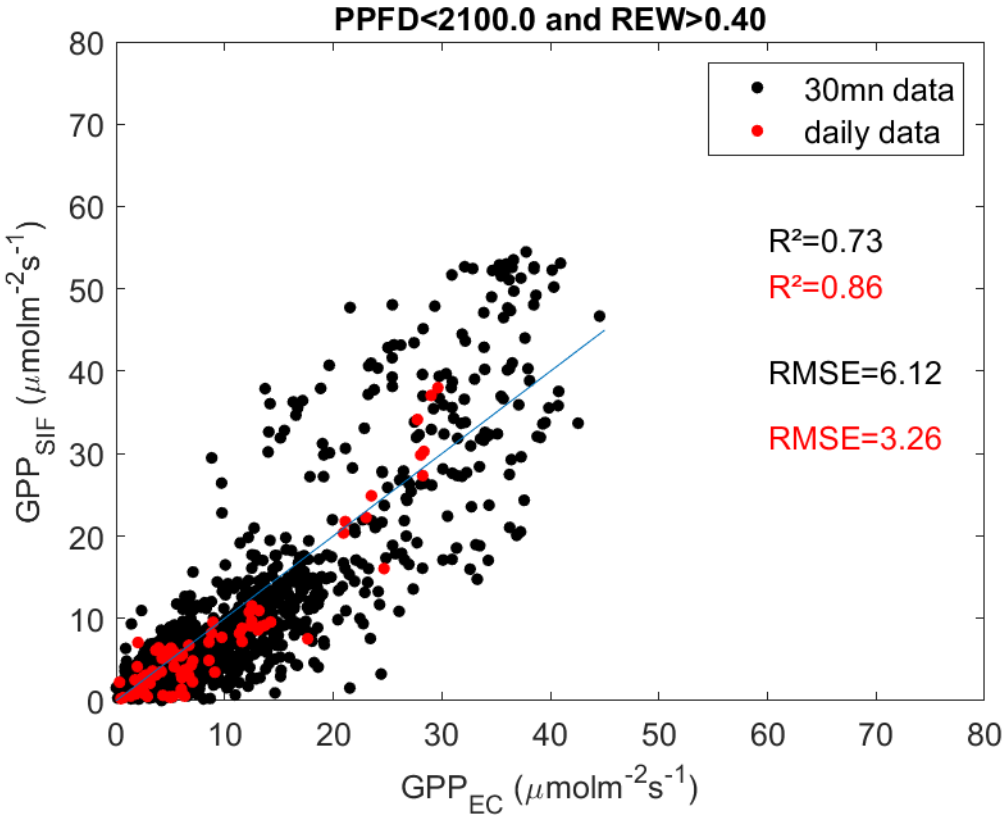


No PAR threshold
Impact of drought ?

Results
Robustness of the MLR model





Drought decreased model performances
Overestimation of GPP_{SIF} for high GPP_{EC}

SIF unsensitive to stomatal closure ?
Impact of drought on q_L, $\phi_{PSII,max}$ not quantified ?

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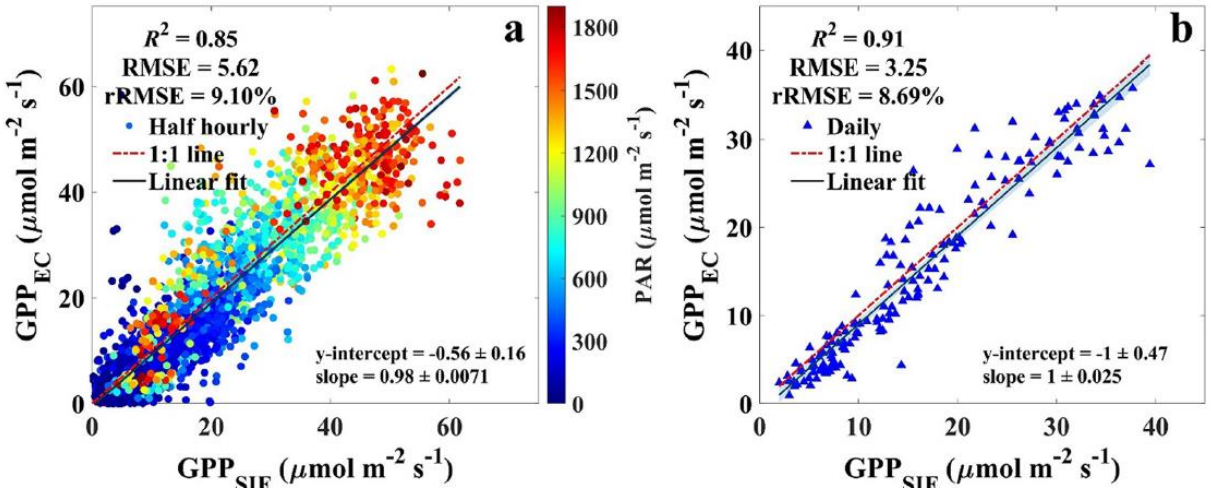
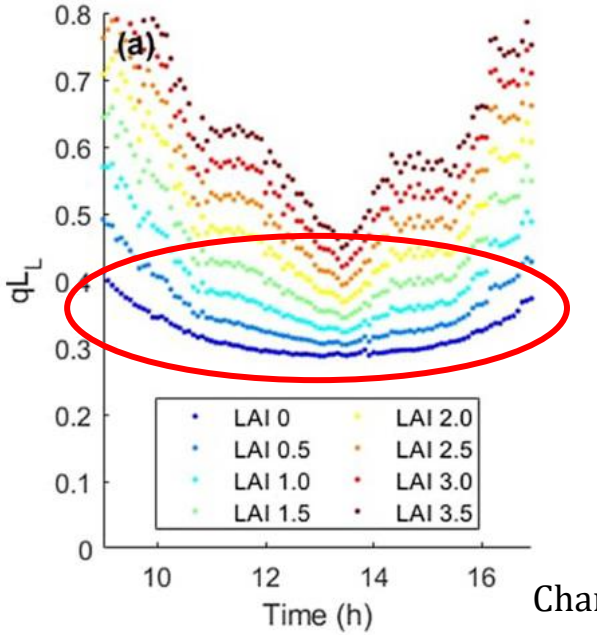
Conclusion

Conclusion

Strong correlation between MLR model predictions and EC data for daily GPP values.
Drought induced a decrease of MLR model performances



Liu et al. (2022)



Chang et al. (2021)

Next step / Perspectives

Identify the effect of drought on GPP predictions (effect of stomatal closure)
Impact of VPD on MLR parameters ?
Measurements of MLR parameters in various conditions and ecosystems for future use

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Thank you for your attention

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