

# Mechanistic modelling of gross primary production and transpiration using sun-induced fluorescence observations in different water and light limitation conditions

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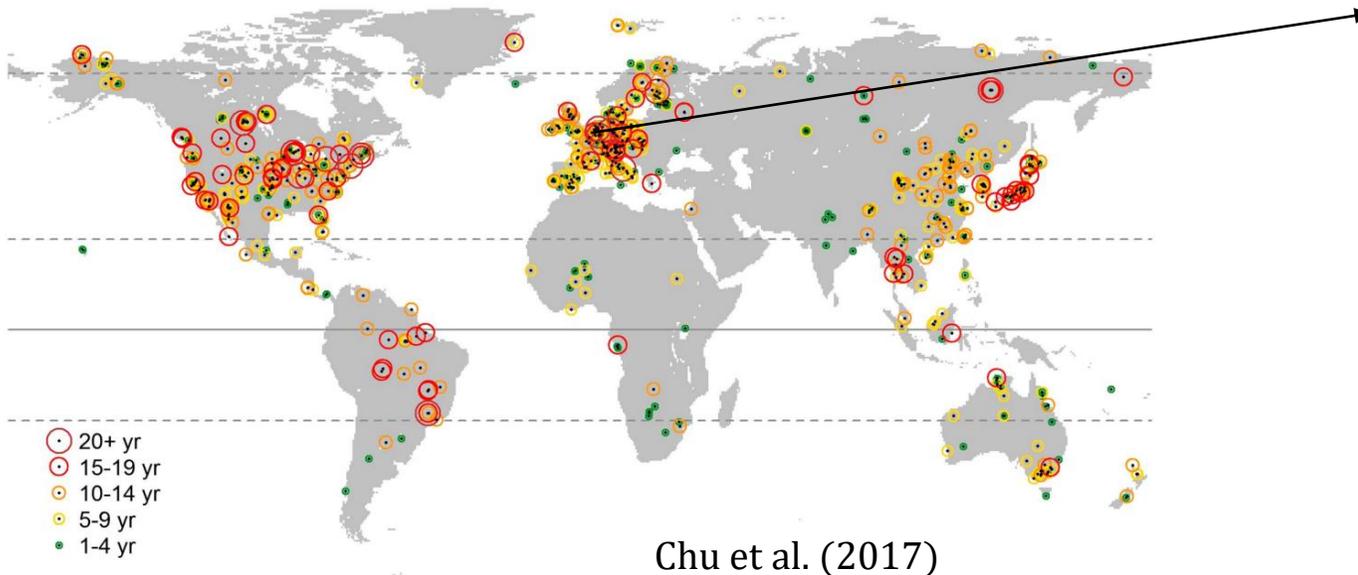
### Gross Primary Production (GPP)

- most important flux in the C cycle
- ~1/3 of C emitted by human activities
- Regulation of atmospheric [CO<sub>2</sub>]

### Transpiration (T)

- 2<sup>nd</sup> most important flux in the H<sub>2</sub>O cycle
- Tightly coupled to GPP
- Drives local/global climate

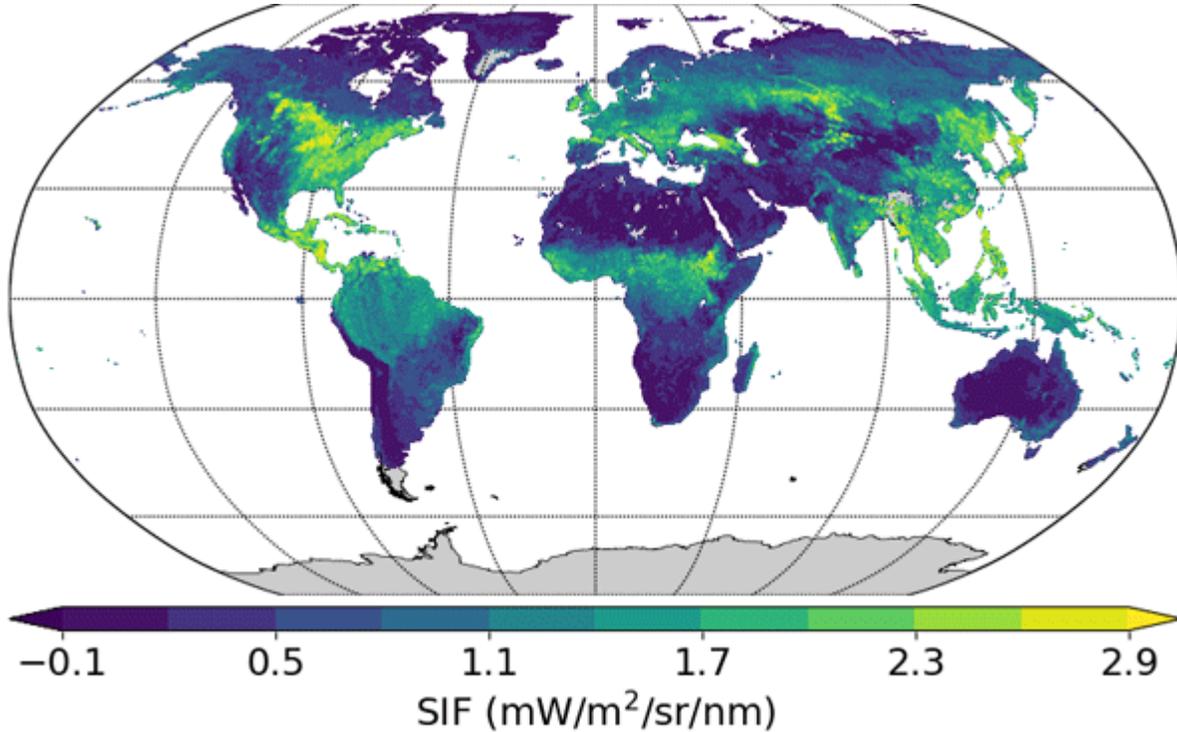
### Eddy-covariance (EC) measurements



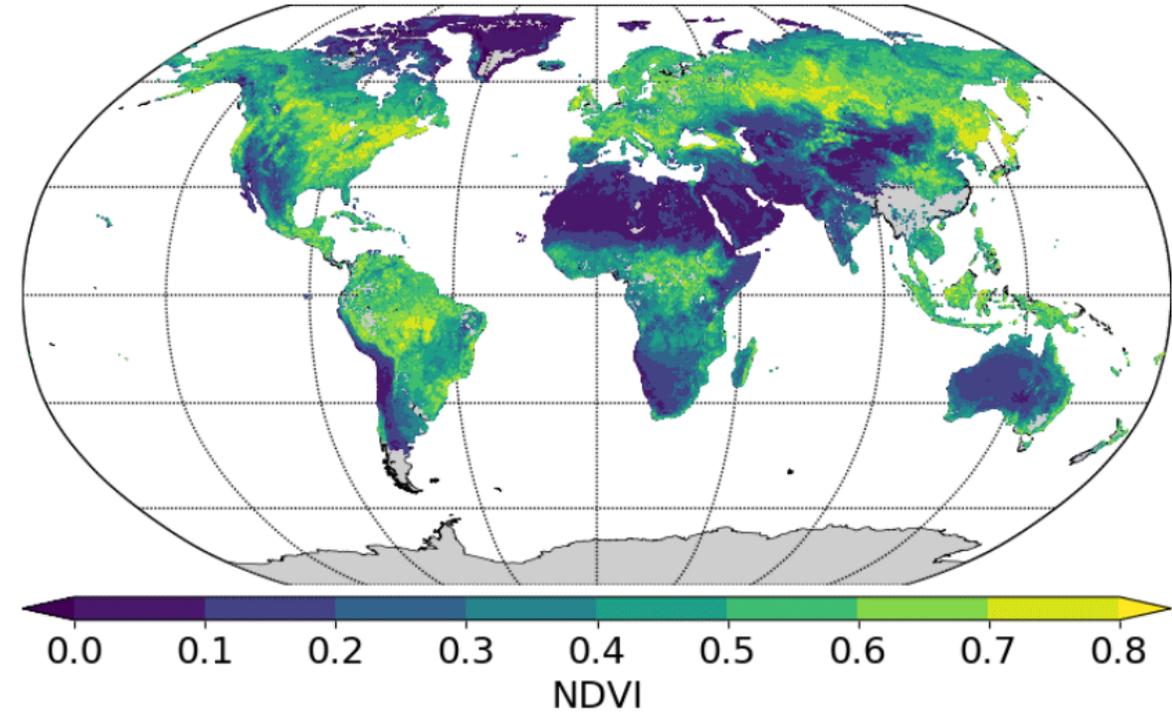
BE-Vie, BE-Dor, BE-Mas, BE-Bra, BE-Loc, BE-Yan

**Figure 1.** Map of active and historical FLUXNET tower sites used in the study. The color and size of the circle indicate the lengths of measurements as of December 2015. The solid and dashed lines denote equator, Tropic of Cancer/Capricorn, and the Arctic Circle, respectively. For data sources and details refer to Table S1.

TROPOSIF (0.2°)



TROPOMI NDVI (0.2°)



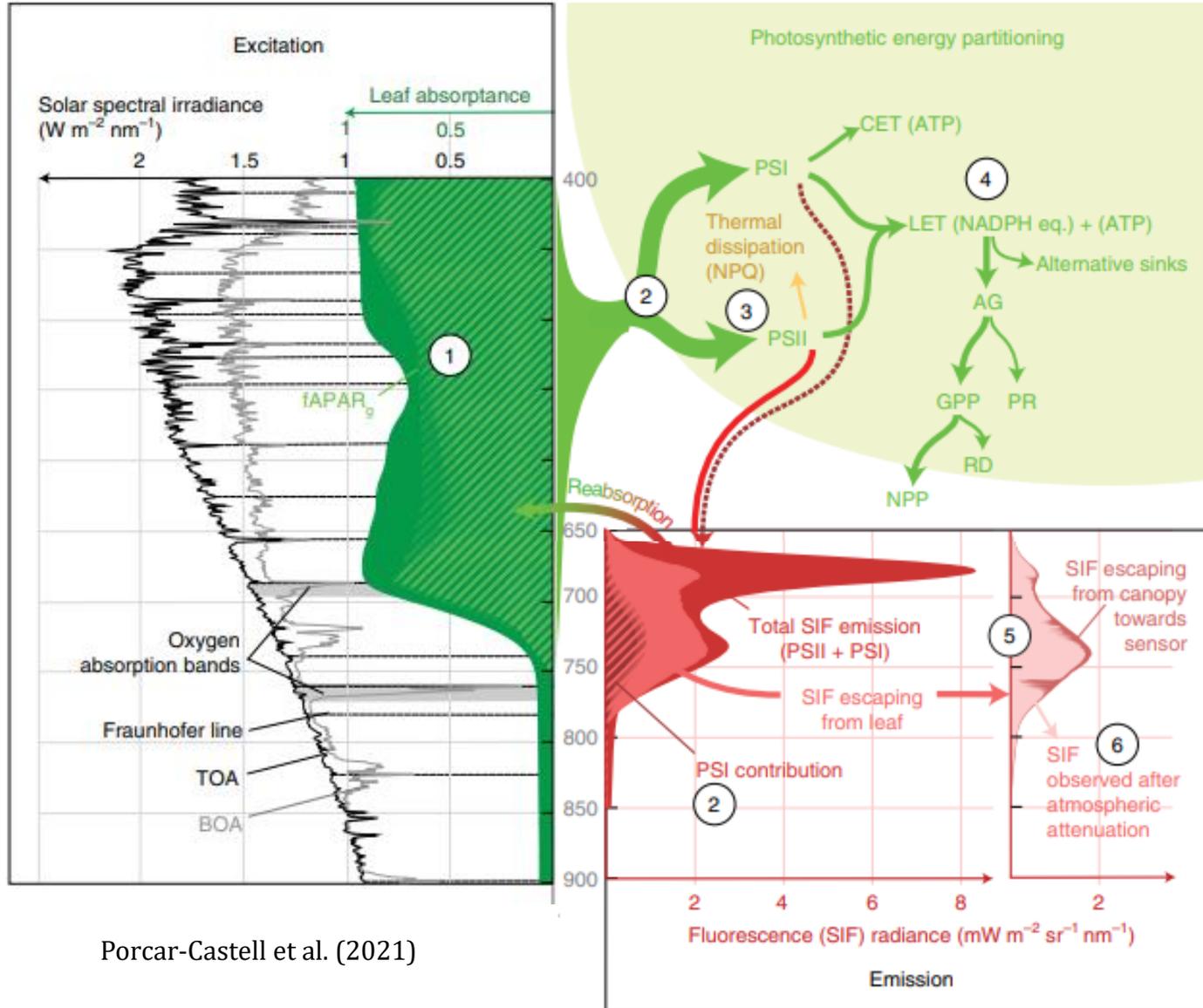
Guanter et al., 2021

Vegetation indexes are undirected related to ecosystem physiology (surface greenness)

SIF provides a window on photosynthesis

# Introduction

## What is SIF ?



Porcar-Castell et al. (2021)

Light absorption by leaves

Photosystem excitation by photons

SIF

Photosynthesis

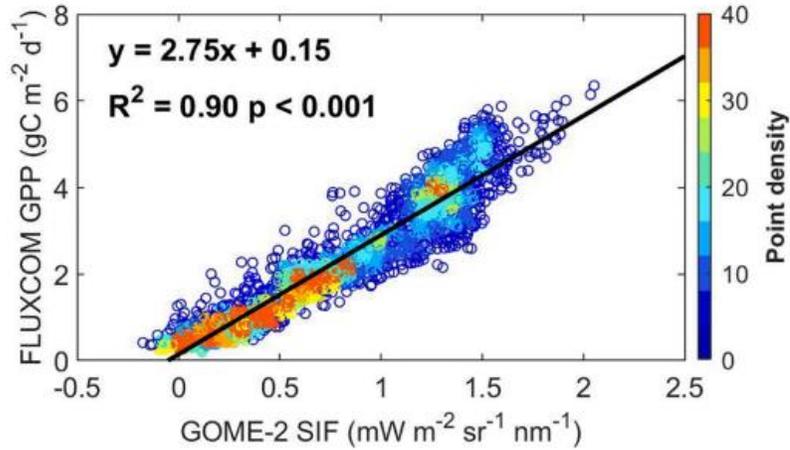
Heat

Only a fraction of the emitted SIF signal is measured by the sensor (atm/canopy scattering and absorption effects)

# Introduction

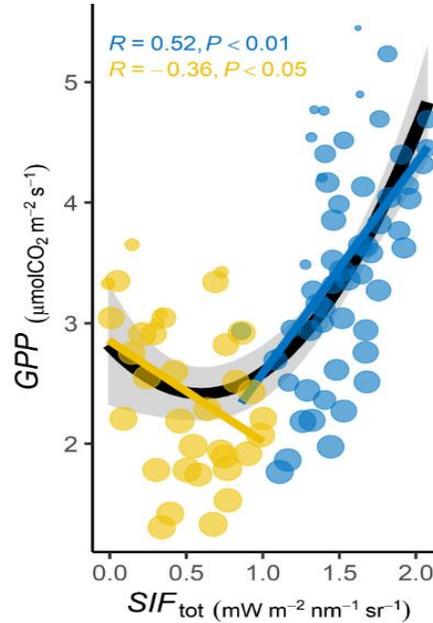
## SIF-GPP relationship across scales

Regional scale (China) – Satellite data



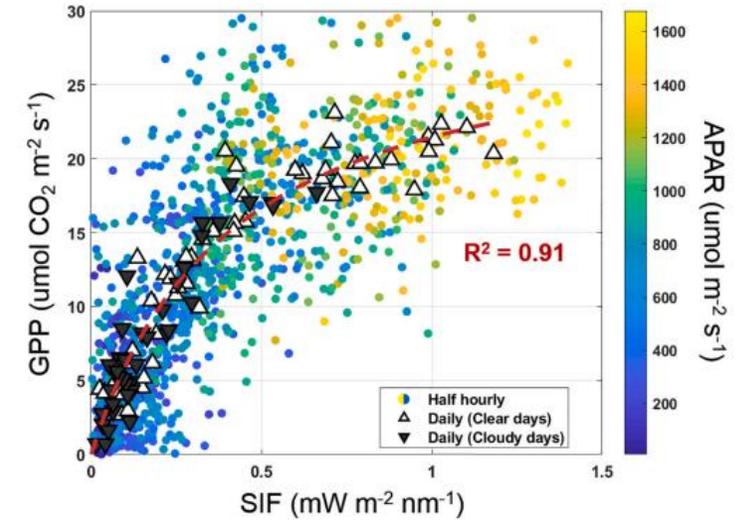
Chen et al., (2020)

Plot scale (Open woodland – heatwave)



Martini et al., (2022)

Plot scale (Evergreen needleleaf forest – fall transition)



Kim et al., (2021)

- Climate conditions and phenology influence SIF-GPP relationship.
- Empirical approaches are limited
- Process-based model ?

- Stomata opening controls carbon and water exchanges
- Photosynthesis and transpiration are closely related through stomatal conductance
- 3 modeling components

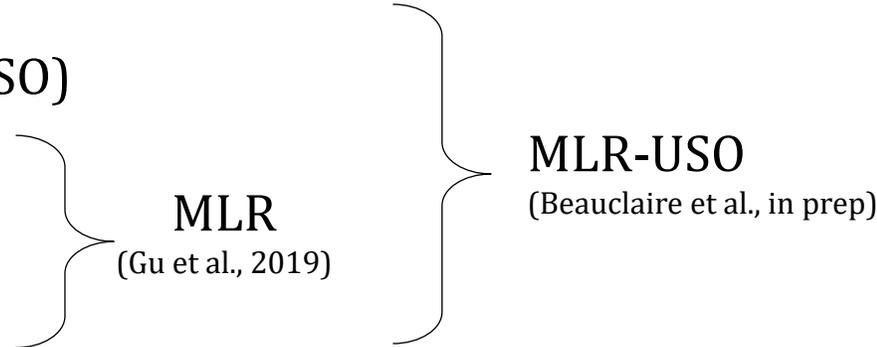
- Stomatal conductance (USO)

(Medlyn et al., 2011)

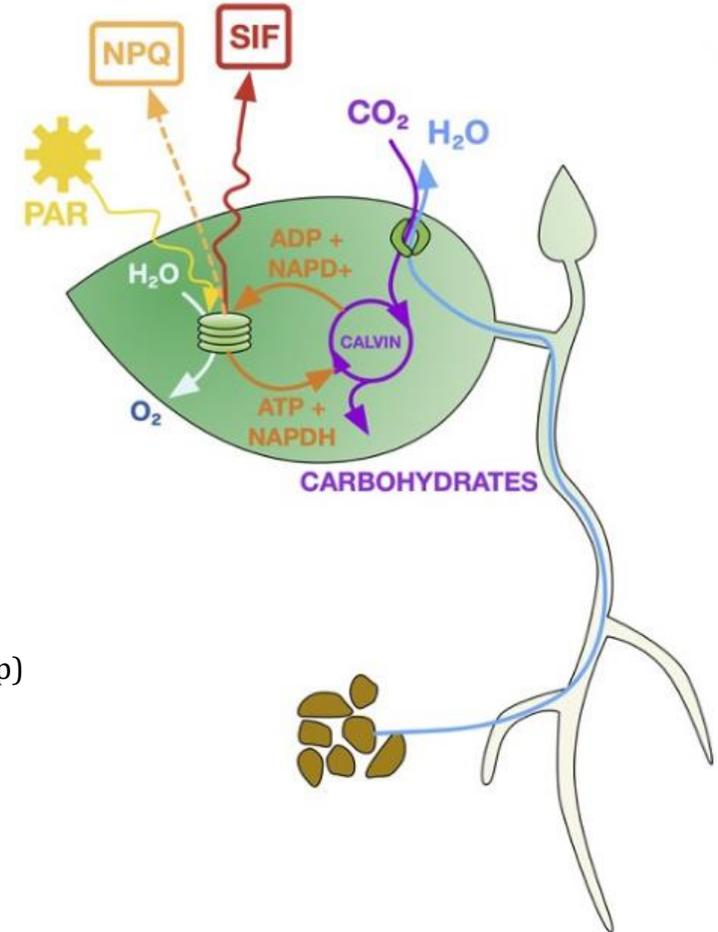
- Photosynthesis (FvCB)

(Farquhar et al., 1980)

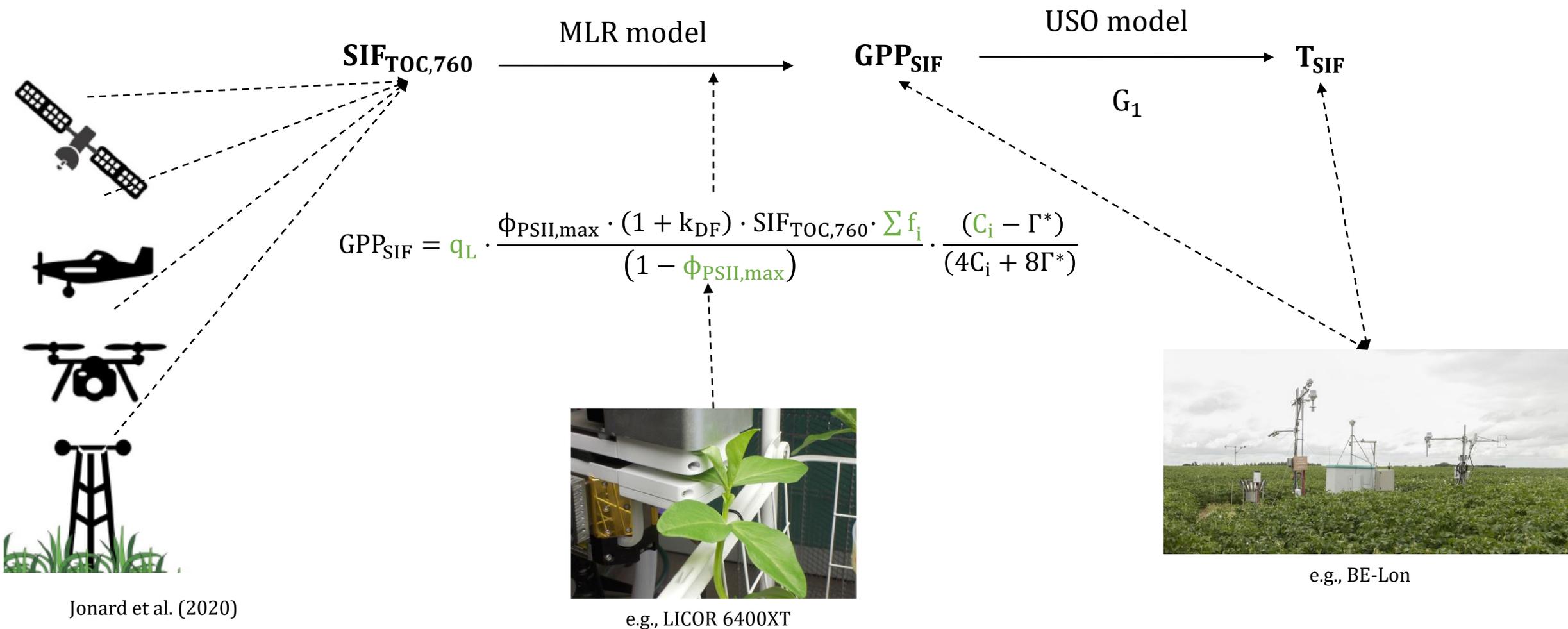
- SIF



- MLR-USO : using SIF observations, photosynthesis processes and stomatal optimality to estimate GPP and T



Jonard et al. (2020)

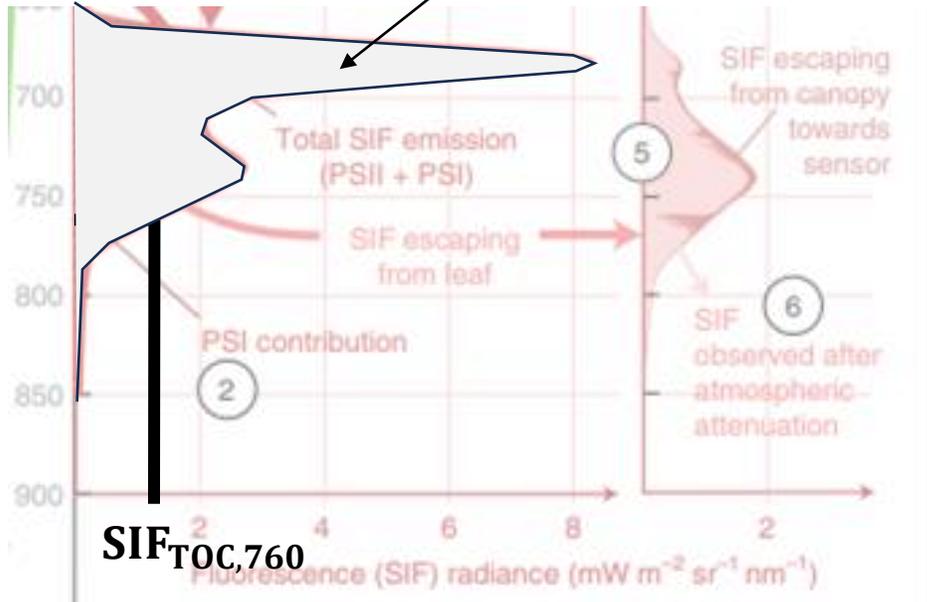
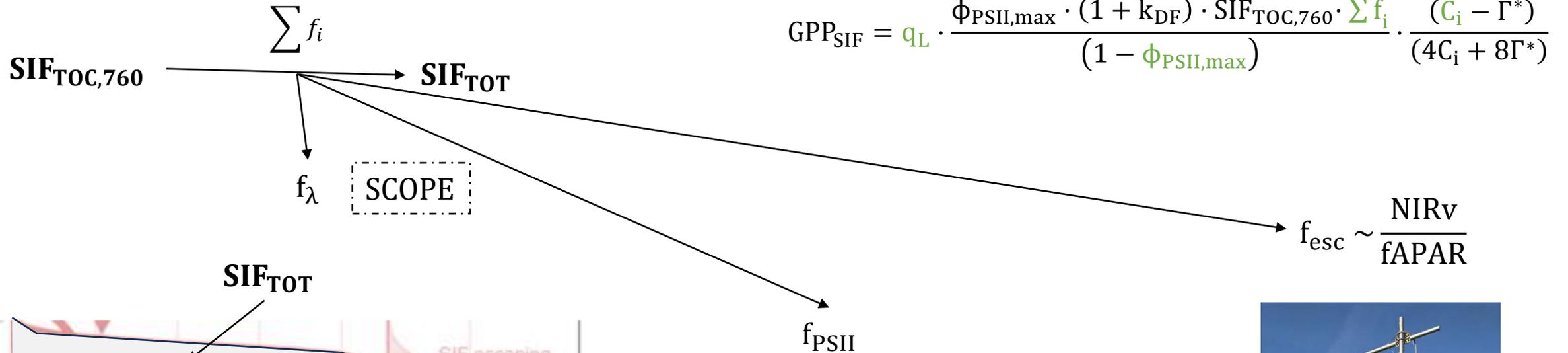


SIF measurements

Measurements of MLR parameters

USO calibration on EC data

Validation on EC data



LICOR 6400XT



FloX

- How do MLR-USO model predictions correlate with EC data at the plot scale ?
- Is the MLR-USO model robustness impacted by climate conditions (temp, irradiance, edaphic/atm dryness) ?

## Experimental setup

**Scale :** plot

**EC site for validation :** BE-Lon (ICOS station class 2)

**PFT :** C3 crop (winter wheat)

**Date :** February to July 2022

**SIF :** FloX (JB hyperspectral)

**MLR parameters :** LI6400 XT

**Soil water status :** relative extractable water (REW) from SWC and root biomass measurements

**Meteo data:** meteo station (EC)



BE-Lon



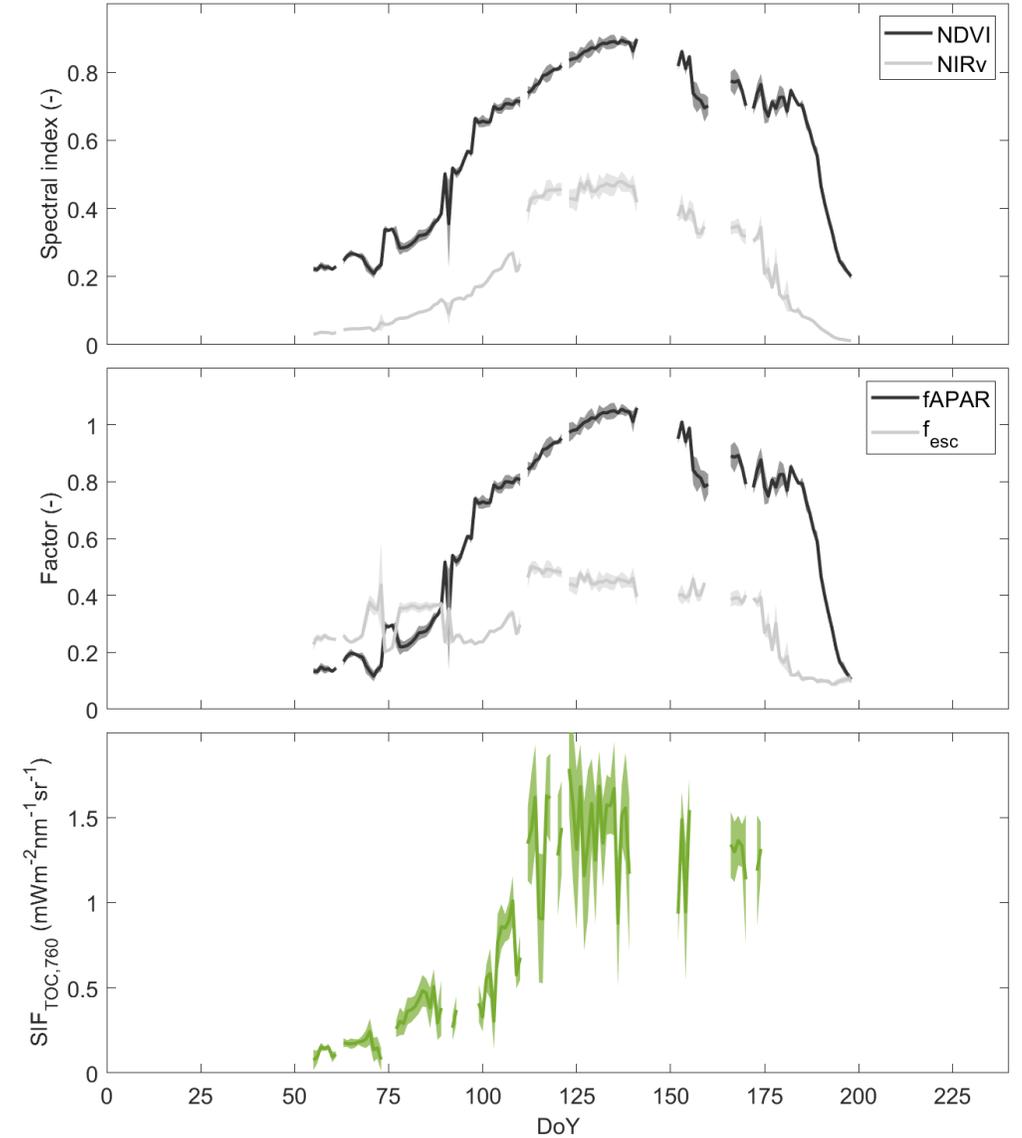
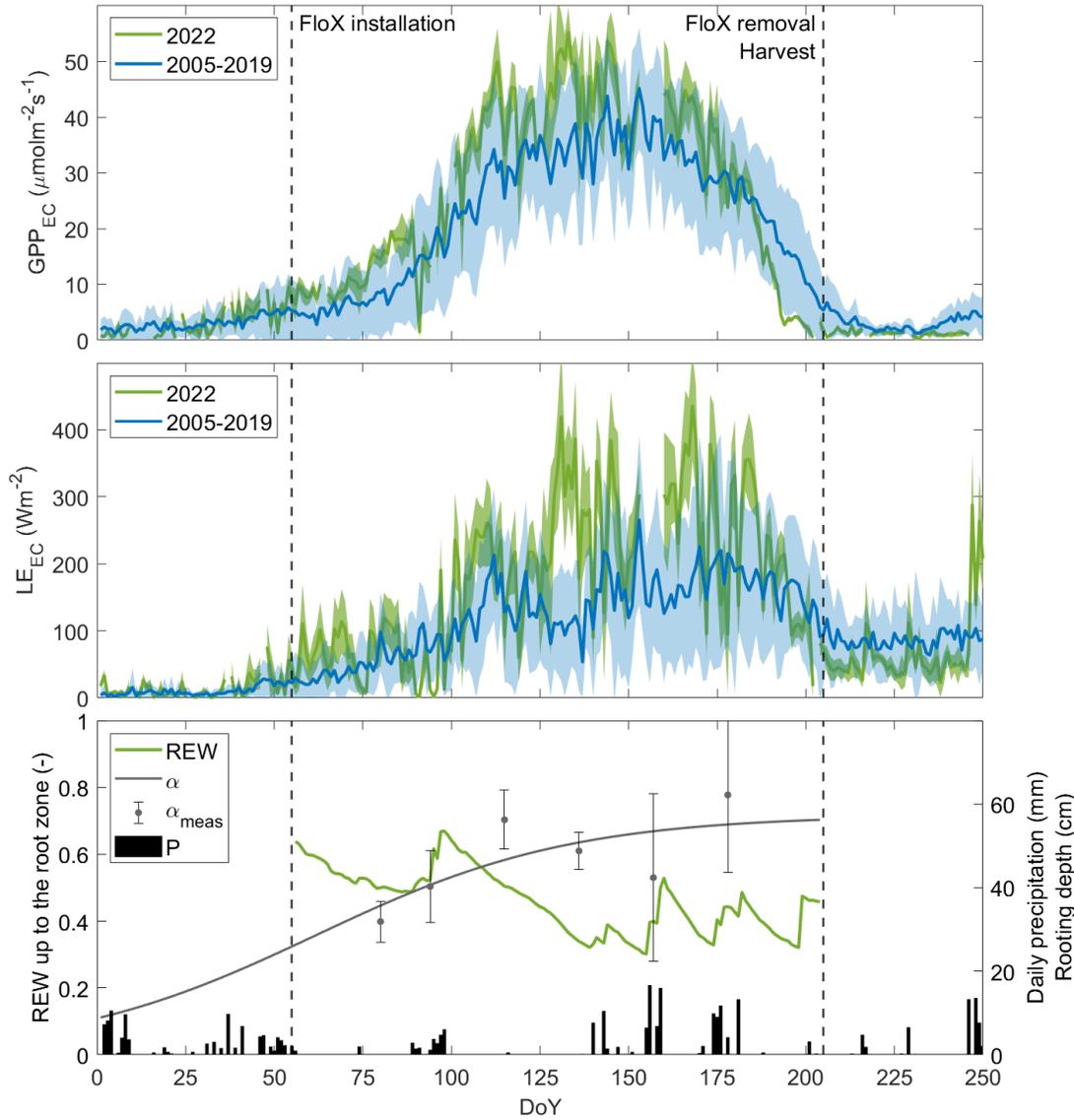
FloX

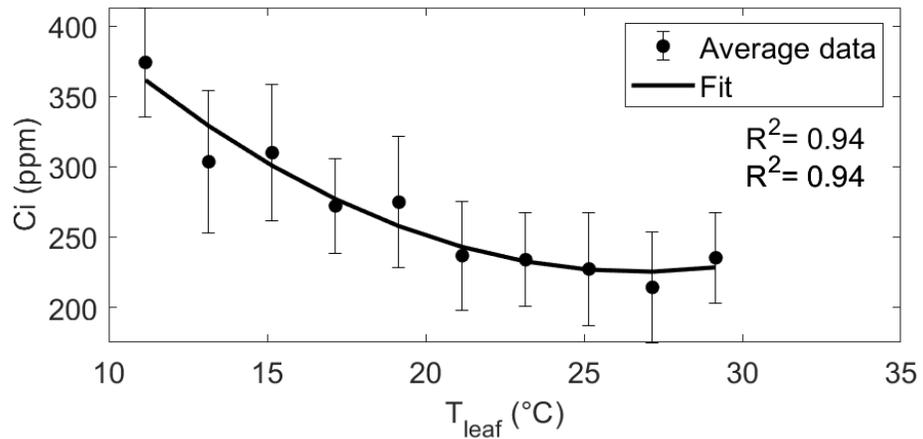
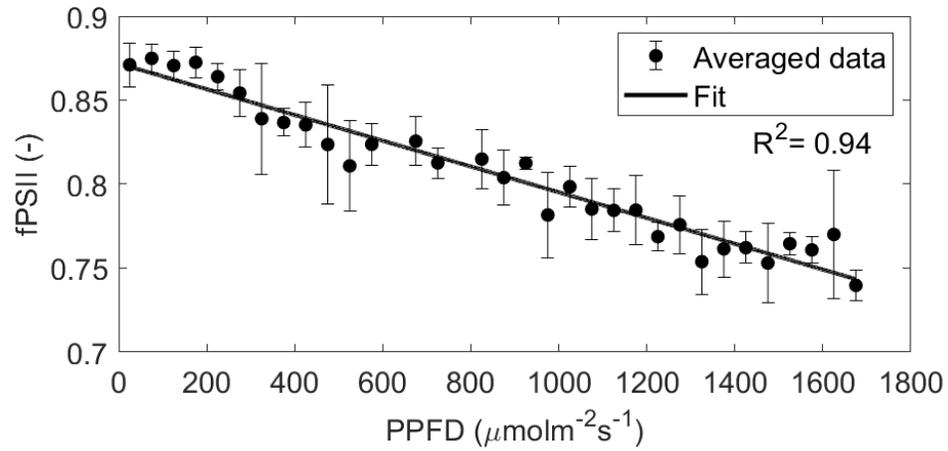
## EC data selection

**Source :** ICOS carbon portal (OneFlux)

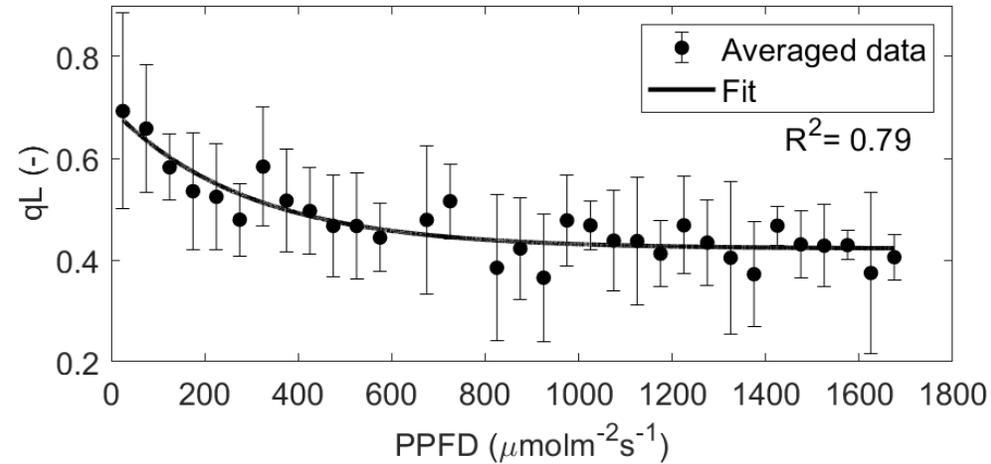
**GPP :** nighttime partitioning method

No gapfilling





$$\text{GPP}_{\text{SIF}} = q_L \cdot \frac{\Phi_{\text{PSII,max}} \cdot (1 + k_{\text{DF}}) \cdot \text{SIF}_{\text{TOC},760} \cdot \sum f_i}{(1 - \Phi_{\text{PSII,max}})} \cdot \frac{(C_i - \Gamma^*)}{(4C_i + 8\Gamma^*)}$$



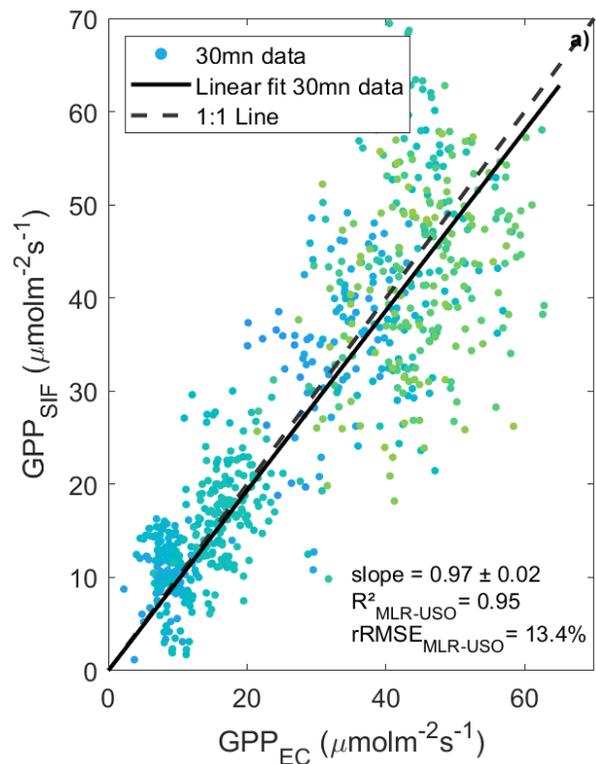
$$q_L = f(\text{PPFD})$$

$$C_i = f(T_{\text{can}})$$

$$f_{\text{PSII}} = f(\text{PPFD})$$

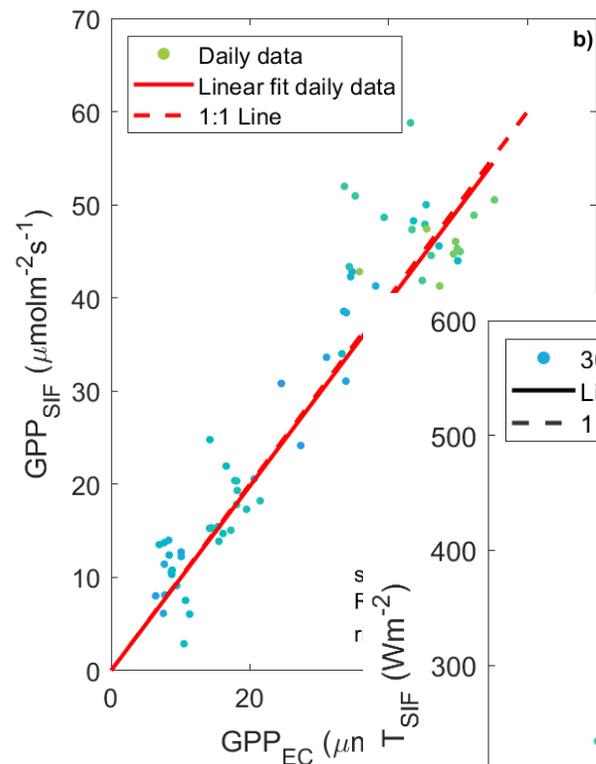
$$\Phi_{\text{PSII,max}} = 0.76$$

$$G_1 = 4.38 \text{ kPa}^{0.5}$$



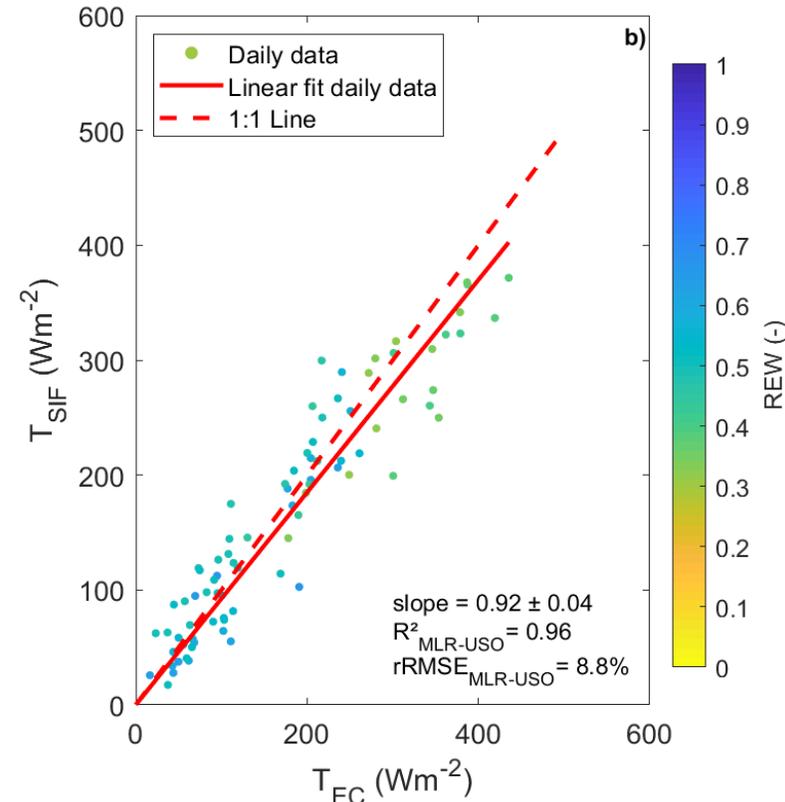
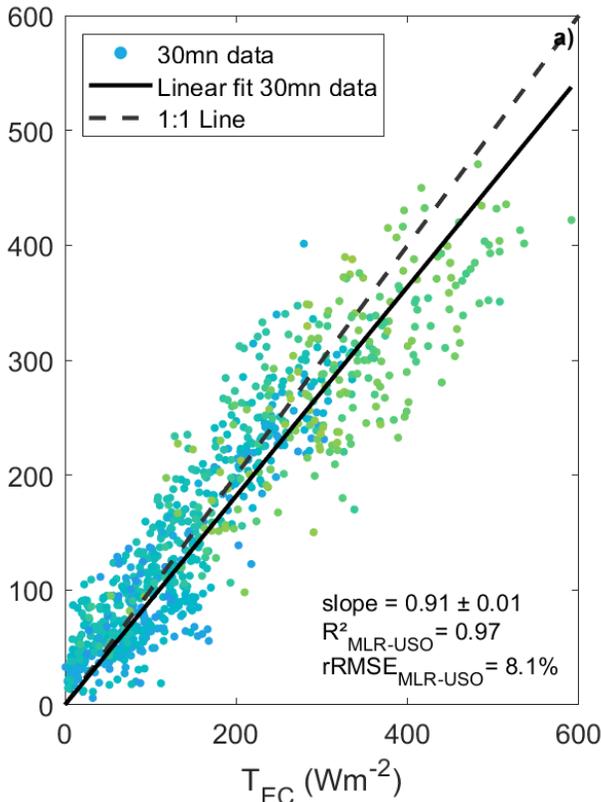
**GPP**

Slopes ~ 1  
High  $R^2$ , low rRMSE



Slopes < 1

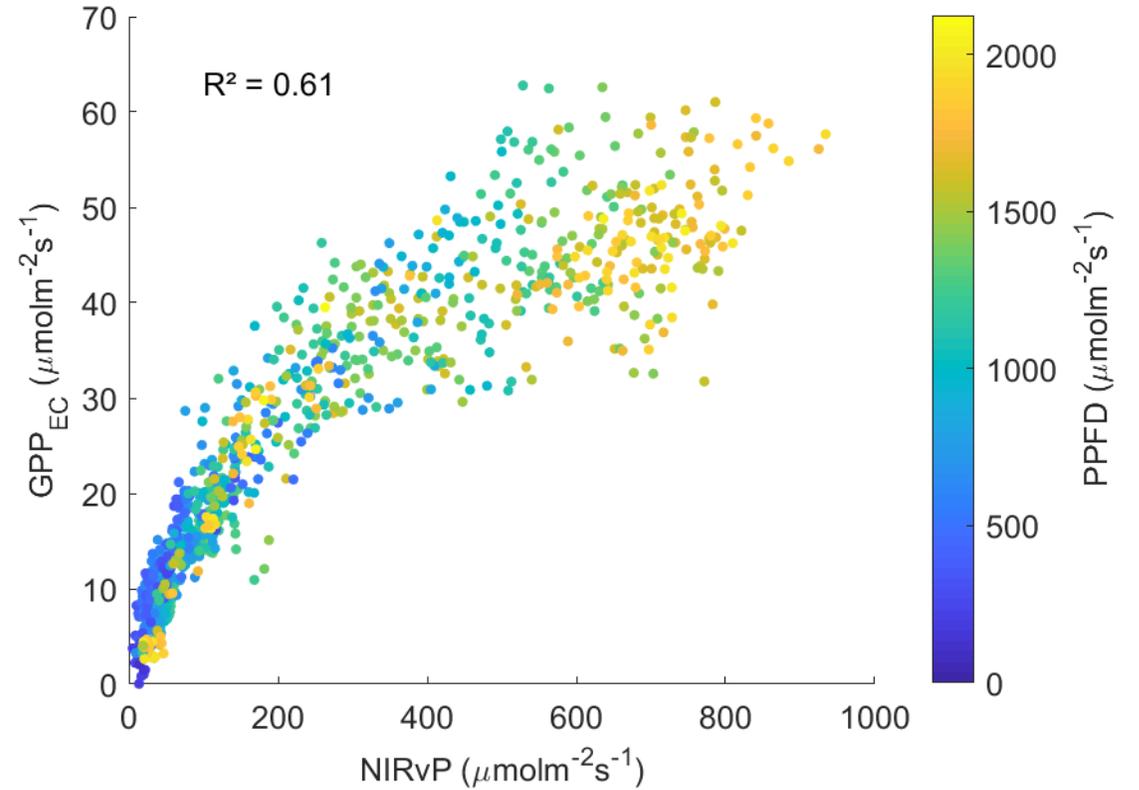
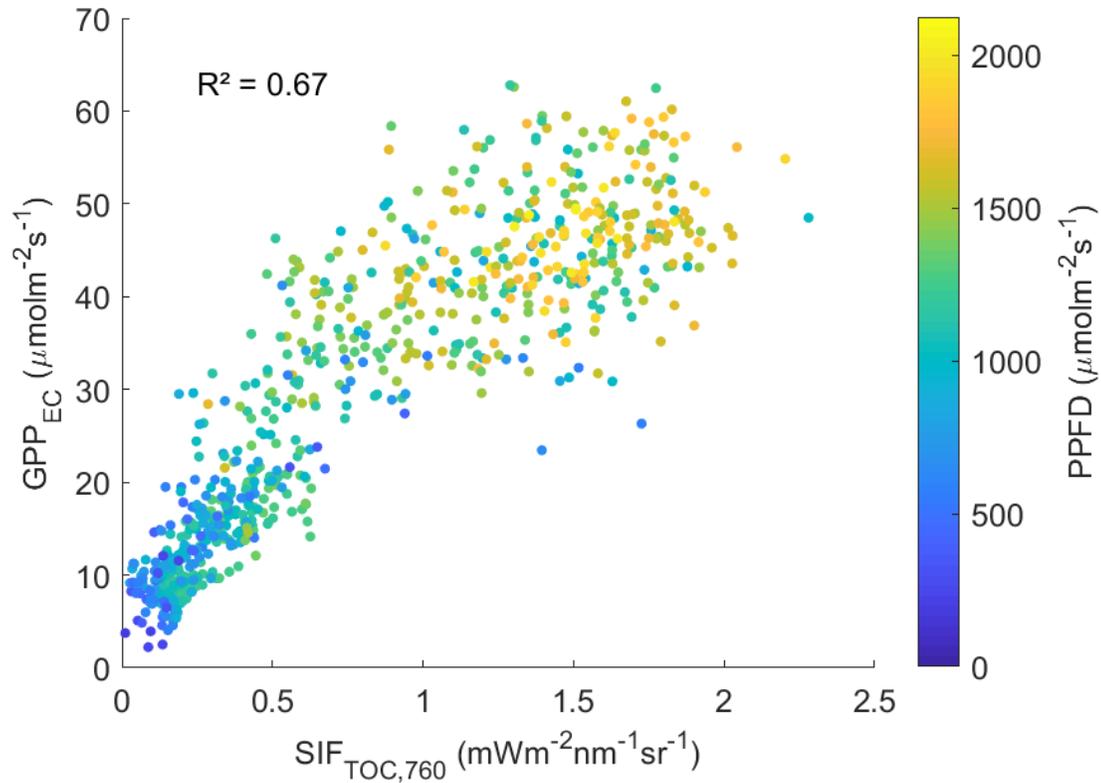
(--> calibration of USO model using constant  $G_1$ )  
High  $R^2$ , low rRMSE



**T**

REW (-)

## Advantage of using MLR-USO model over empirical approaches



$$NIRvP = NIRv \cdot PPFD$$

NIRvP: PAR and chlorophyll content. No physiology.  
 Increase in  $R^2$  when using SIF with MLR-USO model

## Conclusion

- MLR-USO model predicted carbon and water fluxes from SIF at a high accuracy ( $R^2 > 0.9$ ,  $rRMSE < 15\%$ )
  - Parcel scale (winter wheat)
  - Broad range of irradiance, vapor pressure deficit, REW, temperature...

## Future perspectives

- Applicability of the MLR-USO model :
  - at larger space scales (RS data – FLEX)
  - for other ecosystems (forests)
- Estimation of GPP and T at regional scales by coupling climate models, satellite data and the MLR-USO model

Thank you for listening!

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