Daisy soil plant atmosphere model

Temporal Global Sensitivity Analysis (GSA) and Pareto based calibration

Delhez Laura, Longdoz Bernard, Dumont Benjamin, Laloy Eric

INTRODUCTION

Gembloux Agro-Bio Tech – Biosystems Dynamics and Exchange

Better understand the functioning of temperate agrosystems

Impact of hydric conditions on carbon and latent heat flux through modelling

MONITORING SITE

ICOS Network – Class 2 station

Meteorological measurements

(AirTemp, GlobRad, RelHum, Wind, Precip)

Flux measurements

(NEE, LE, H, N_2O)

Biomass measurements

(WLeaf, WStem, WSOrg, LAI, SLA, etc.)

Other measurements

(WTD, SWC, BBCH, etc.)

MODELLING – WHY DAISY ?

- Simulates carbon, water and nitrogen hourly dynamics
- Integrates the agricultural practices (tillage, fertilisation, crop residues, etc.)
- Open source
- Computes the soil and plant energy budget coupled with a biochemical photosynthesis model

using a Soil Vegetation Atmosphere Transfer (SVAT) scheme

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ELSEVIER

Modelling of root ABA synthesis, stomatal conductance, transpiration and potato production under water saving irrigation regimes

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A R T I C L E I N F O

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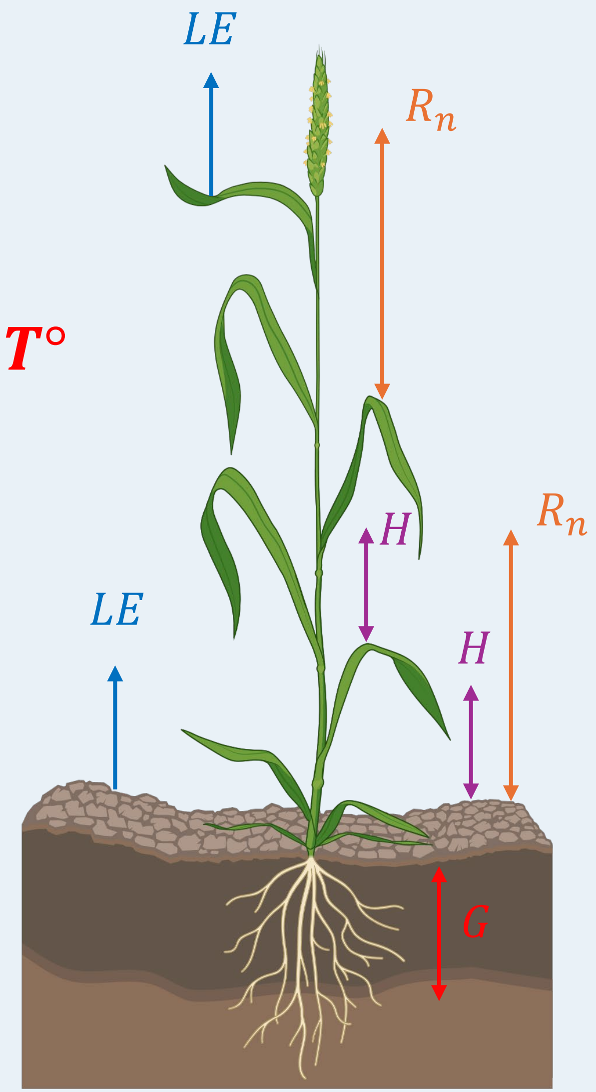
Evapotranspiration
ABA signalling
Leaf gas exchange
PRD irrigation
Soil water content
Potato yield

A B S T R A C T

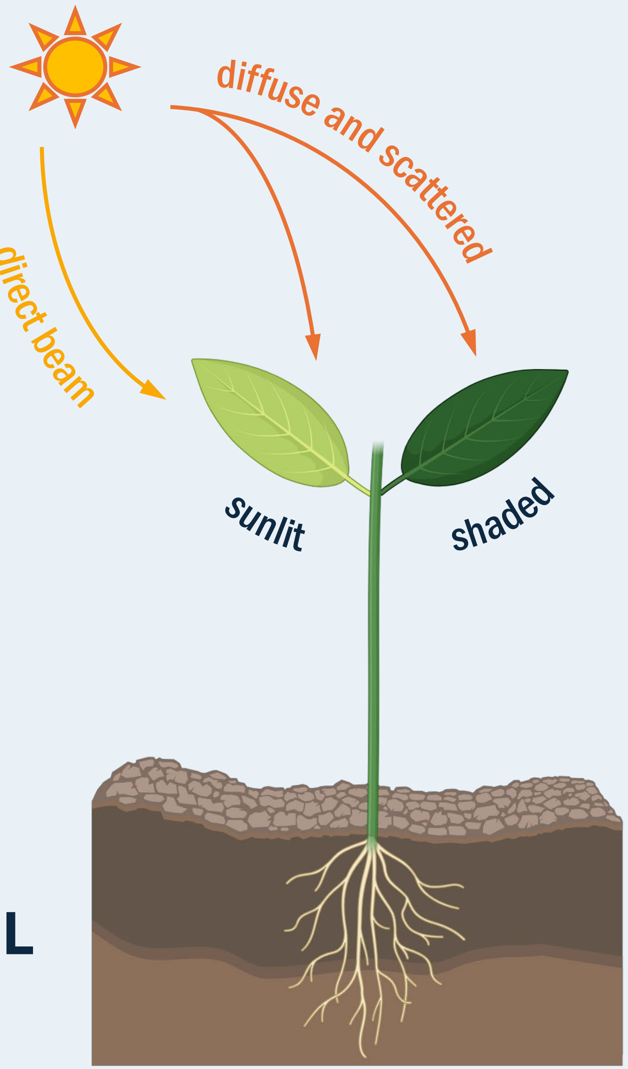
Application of water saving irrigation strategies in agriculture has become increasingly important. Both modelling and experimental work are needed to gain more insights into the biological and physical mechanisms in the soil–plant system, which regulates water flow in the system and plays a central role in reducing crop transpiration. This paper presented a mechanistic model (Daisy) developed based on data obtained in the SAFIR project on measured leaf gas exchange and soil water dynamics in irrigated potato crops grown in a semi-field environment subjected to different irrigation regimes. Experimental data was compared to simulated results from the new enhanced Daisy model which include modelling 2D soil water flow, abscisic acid (ABA) signalling and its effect on stomatal conductance and hence on transpiration and assimilation, and finally crop yield. The results demonstrated that the enhanced Daisy model is capable of simulating the mechanisms underlying the water saving effects of the partial root-zone drying (PRD) irrigation as compared with the conventional full irrigation (FI). However the simulated effect on both crop yield and water use in this particular experiment was negligible indicating more experimental studies are necessary in order to improve on the model.

DAISY SVAT – SSOC



ENERGY BUDGET

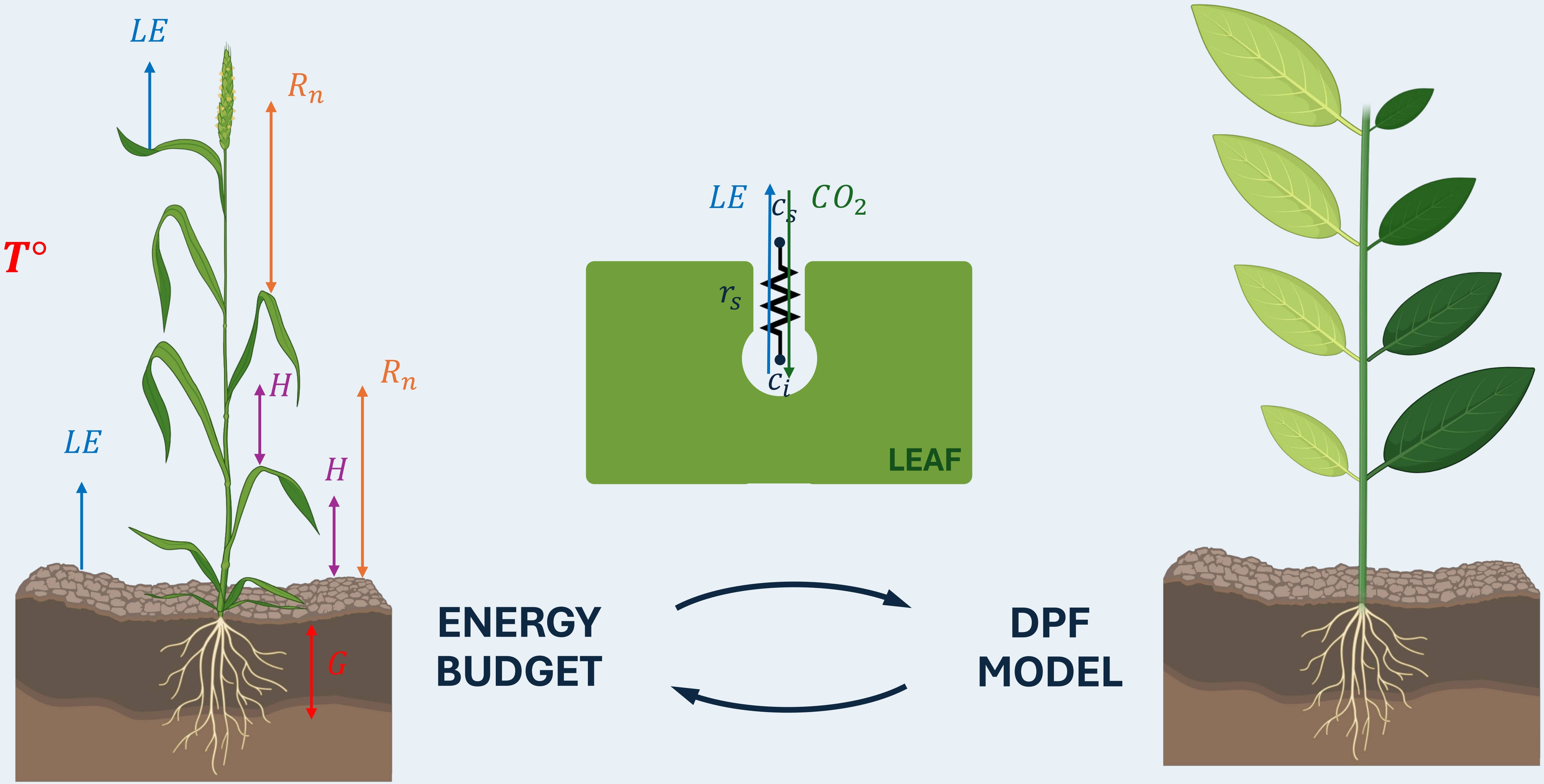
$$R_n = G + H + LE$$



DPF MODEL

DAISY SVAT – SSOC

A LOT OF PARAMETERS !



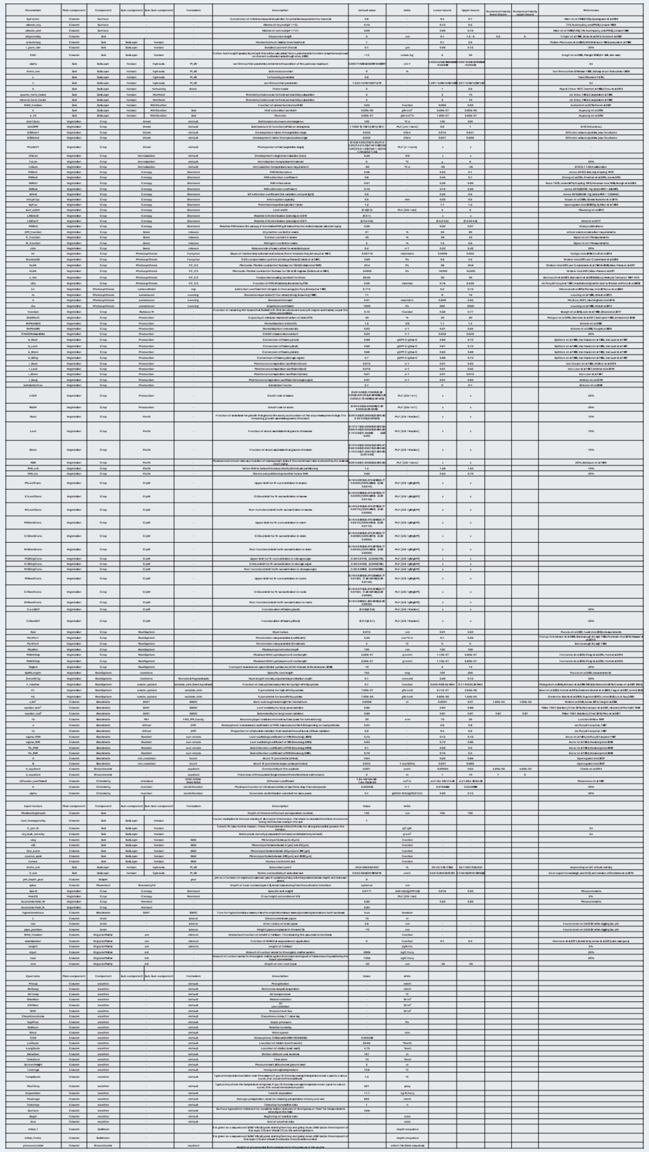
$$R_n = G + H + LE$$

$$A_{gross} = min(A_J, A_V)$$

GLOBAL SENSITIVITY ANALYSIS

Around 200 parameters

- Which parameters are influential ? For which output ?
- Which parameters can be set to their default value ?
- How does this influence change during the whole simulation ?



GLOBAL SENSITIVITY ANALYSIS

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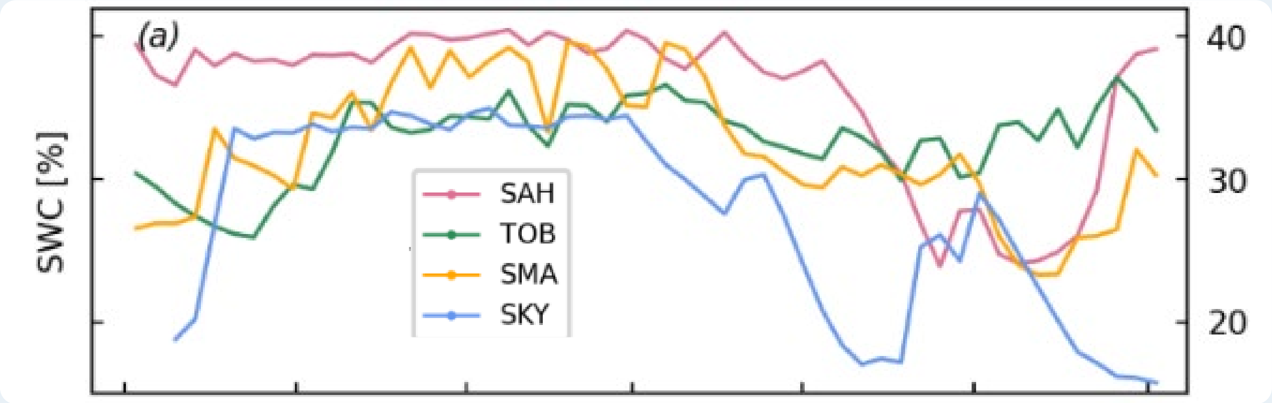
Four cropping seasons of winter wheat → 200 parameters

WSOrg, NEE, LE, H & N_2O



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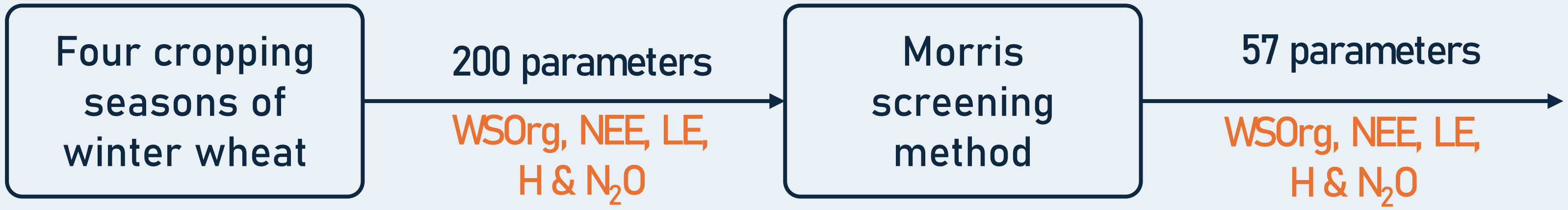

Morris screening method

Also called Elementary Effects Test (EET), it is a computationally efficient GSA technique based on the One-At-a-Time (OAT) sampling design. This method allows to screen out non-influential from influential parameters and rank parameters in order of importance.

GLOBAL SENSITIVITY ANALYSIS

- Which parameters are influential ? For which output ?
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- How does this influence change during the whole simulation ?

NEE

Temporal analysis

Weekly and hourly

Four cropping seasons of winter wheat

200 parameters

WSOrg, NEE, LE, H & N_2O

Morris Screening method

57 parameters

WSOrg, NEE, LE, H & N_2O

Sobol' variance-based method

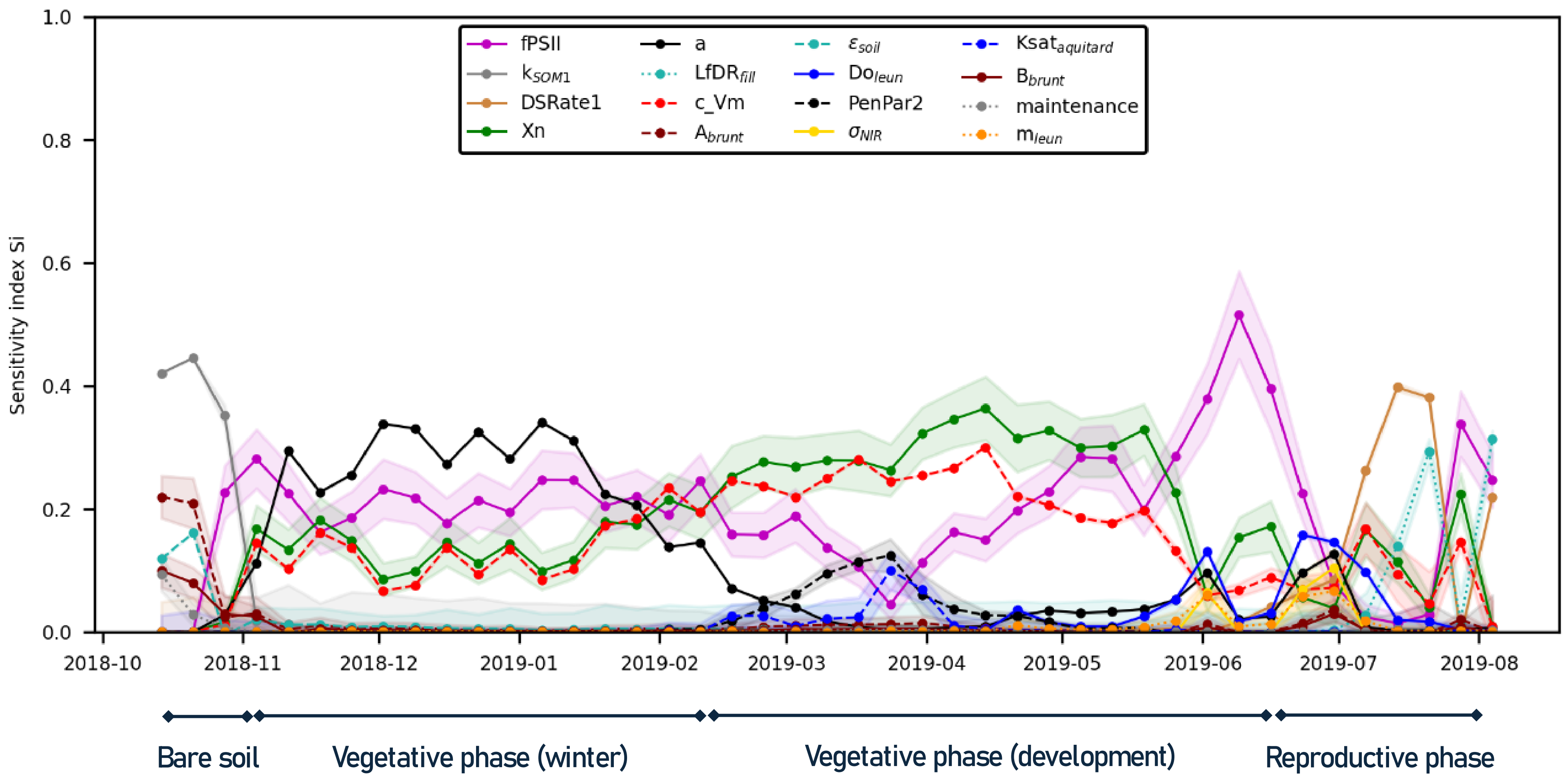
CUM and RMSE

Aggregated analysis

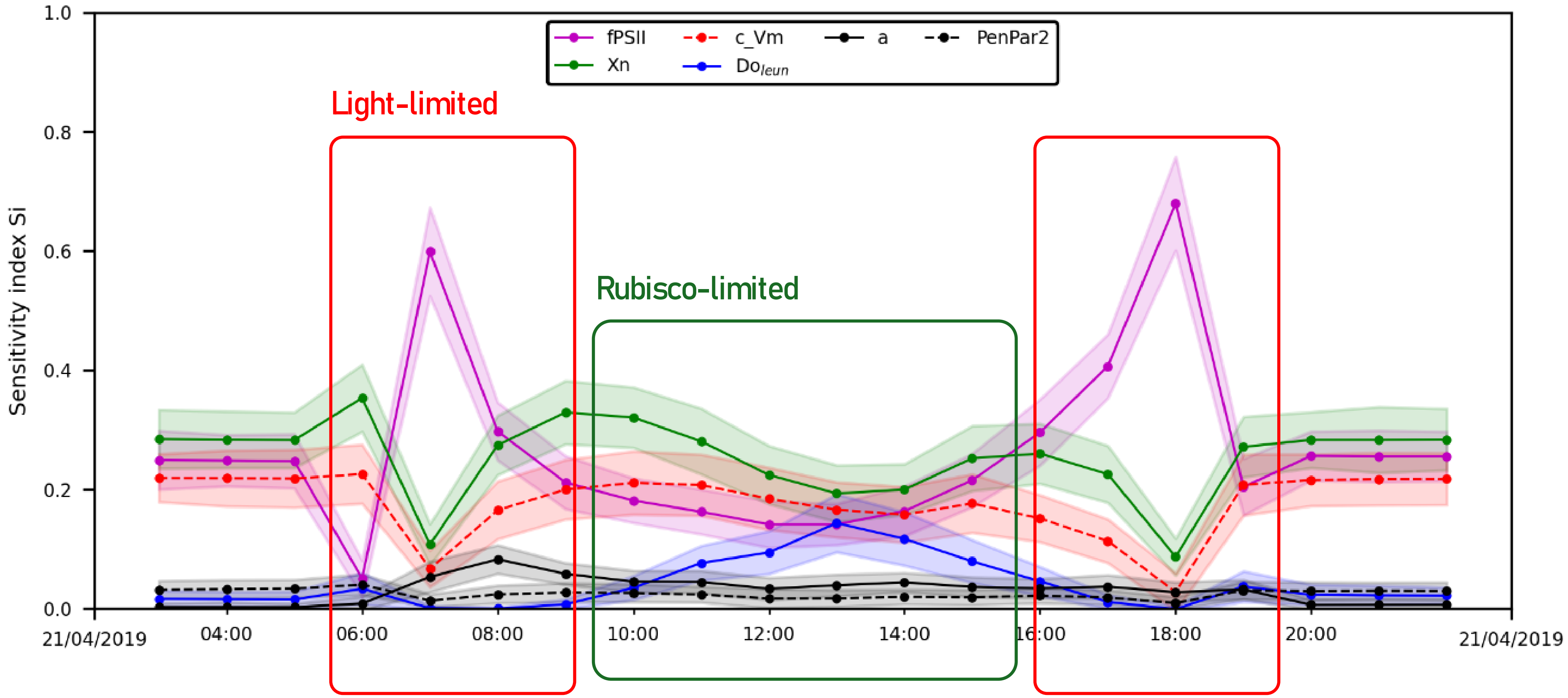
Sobol' variance-based method

Variance-based methods aim to decompose the output variance of a model into relative contributions from each parameter and its interactions. The direct contribution of a parameter is denoted S_i and the total contribution (including its interactions) is denoted S_{Ti}.

TEMPORAL GSA – WEEKLY NEE



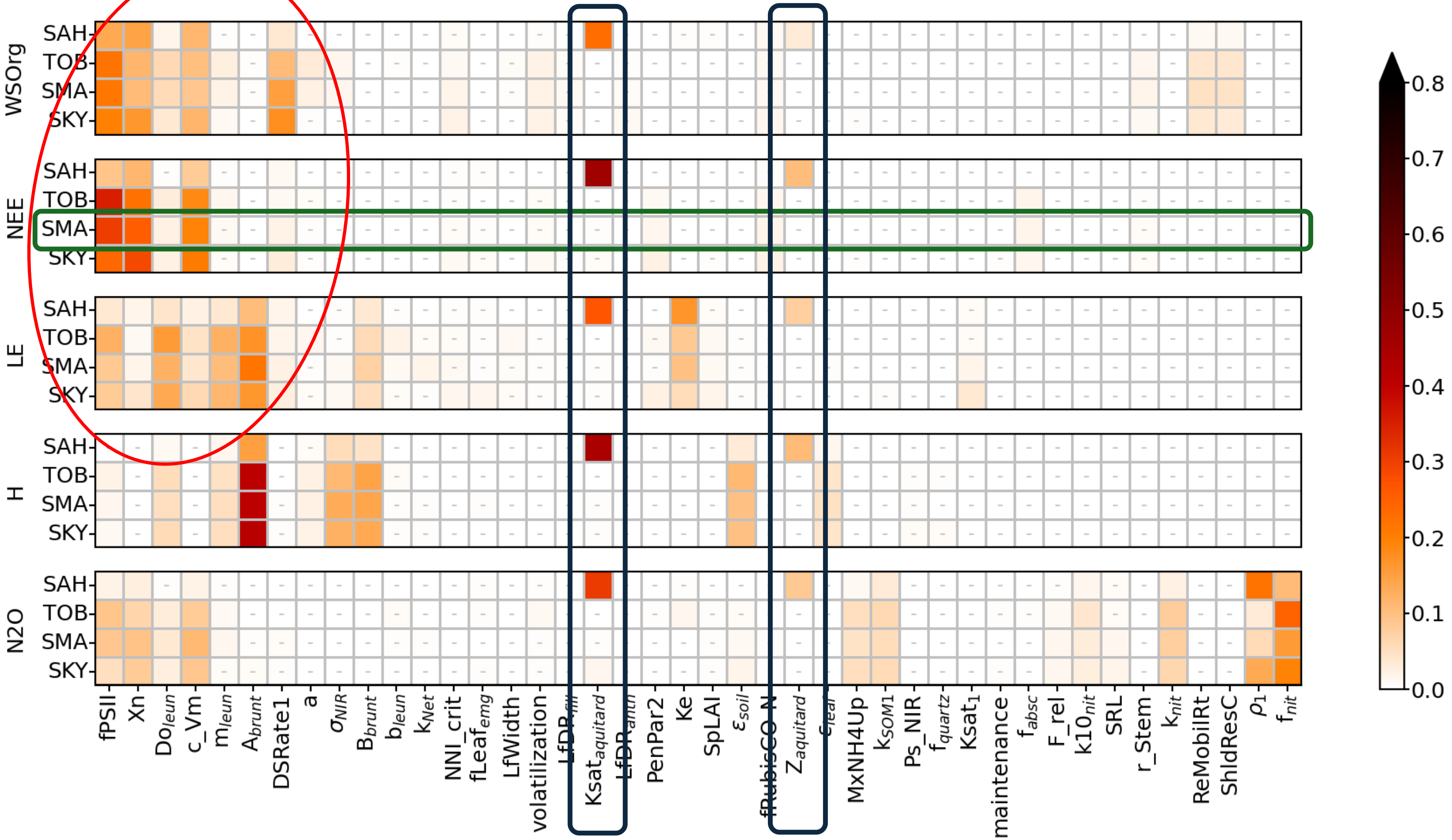
TEMPORAL GSA – HOURLY NEE



$$A_{gross} = min(A_J, A_V)$$

GLOBAL SENSITIVITY ANALYSIS - AGGREGATED

Few parameters have a high impact on WSOrg, NEE and LE



Sobol' first-order sensitivity indices Si of significant parameters for all cumulative outputs (CUM) over each cropping season.
Non-significant indices (Si < 0.01) are labelled with a grey dash.

GLOBAL SENSITIVITY ANALYSIS

Screening method

57 selected parameters out of 200

Sobol' method

Photosynthetic parameters ($fPSII$, Xn, c_Vm) are greatly influential in both temporal and aggregated analysis

Some parameters gain influence shortly due to local events and are not considered in the aggregated analysis

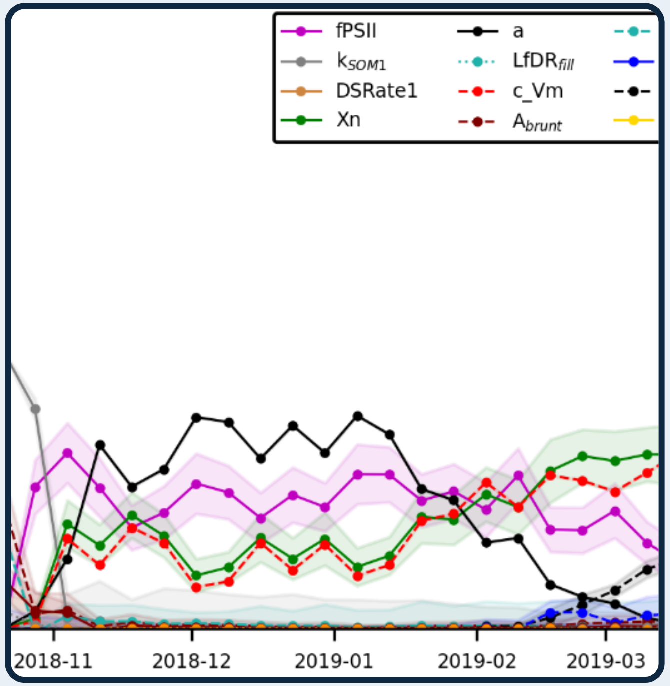
Beyond identifying influential parameters

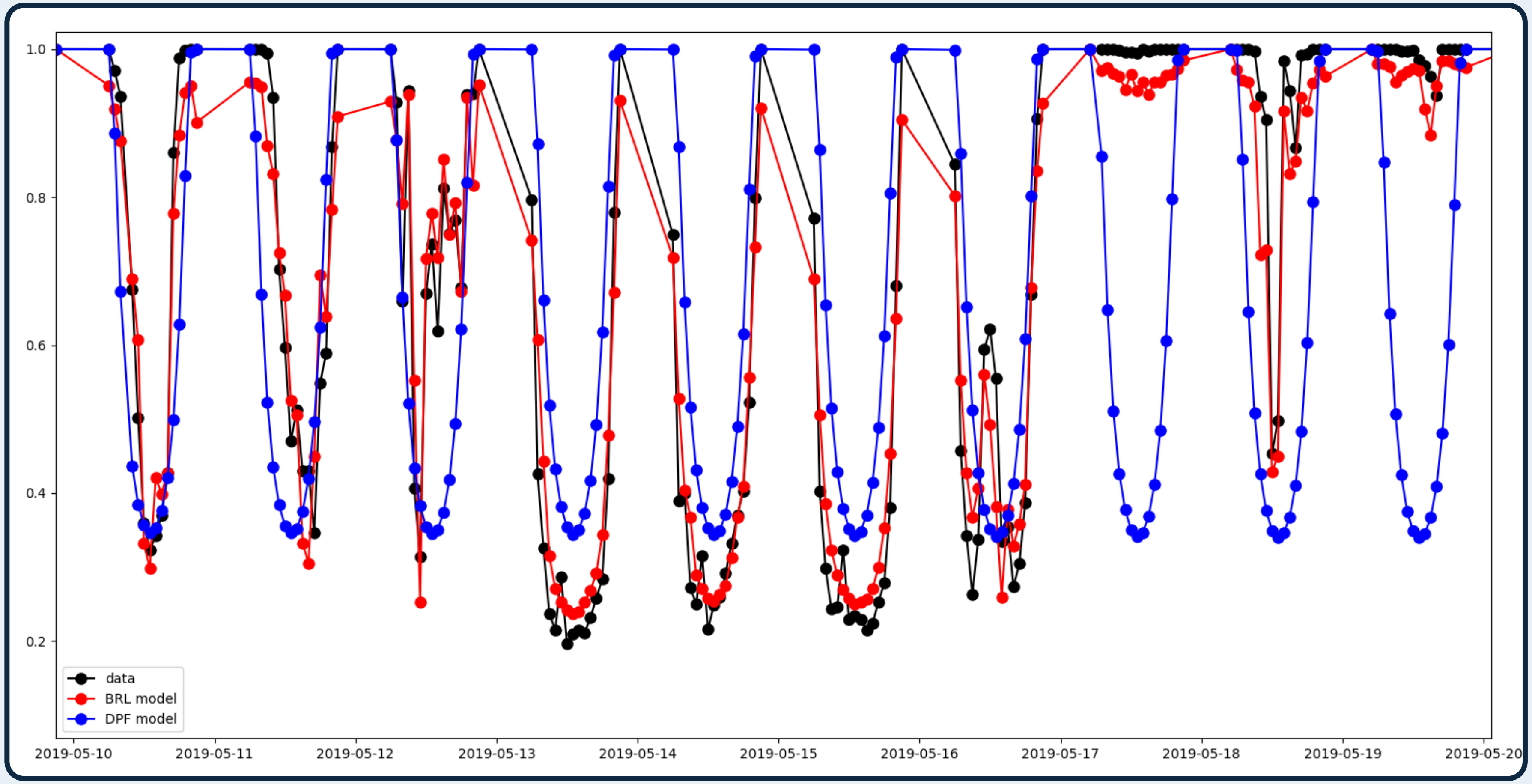
Improve our understanding of the model structure and behaviour

Help us detect an error that would have gone unnoticed when checking the model outputs

MODEL MODIFICATIONS

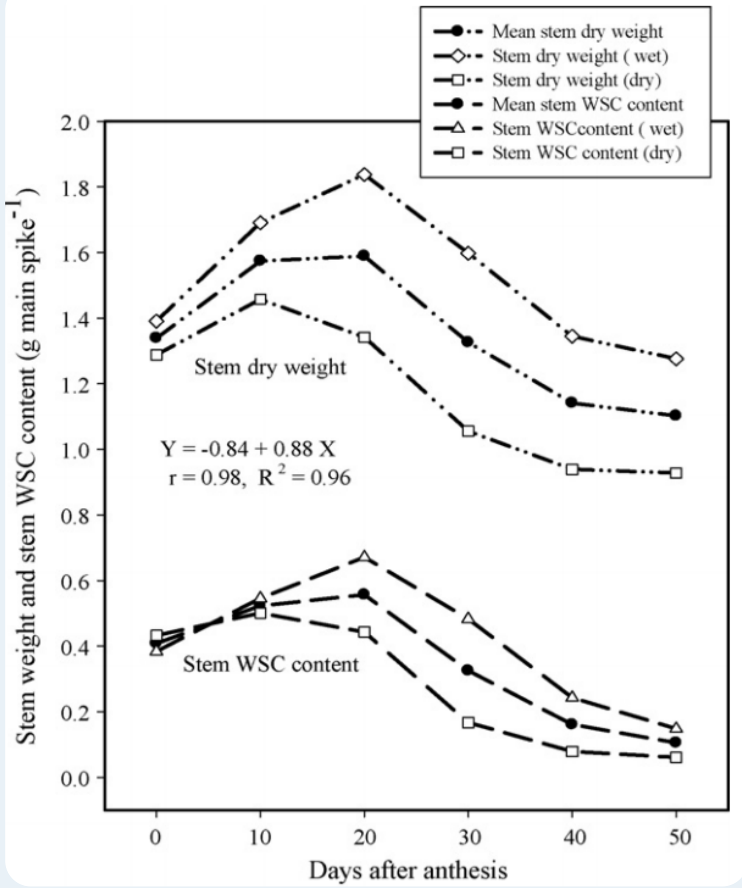
- Distinction between diffuse and direct radiation according to the BRL model (Ridley et al., 2010)





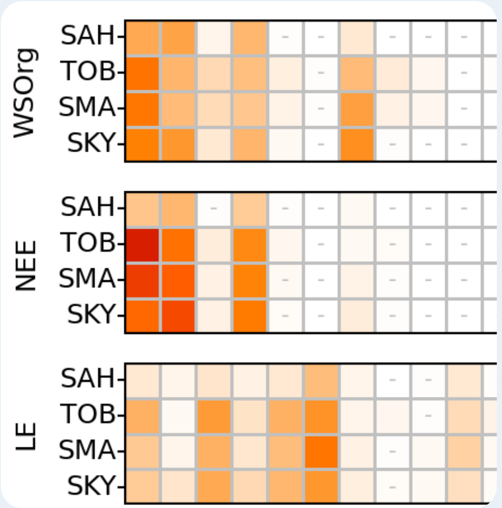
MODEL MODIFICATIONS

- Distinction between diffuse and direct radiation according to the BRL model (Ridley et al., 2010)
- Carbon reserve remobilisation dynamics so ReMobilRt is no longer constant (Ehdaie et al., 2008)
- Maintenance respiration can be reduced with crop senescence (Amthor, 2025)
- When Stem and SOrg are involved in photosynthesis, so does their nitrogen for Rubisco
- Correction of nighttime stomatal conductance (Leuning parameter b)

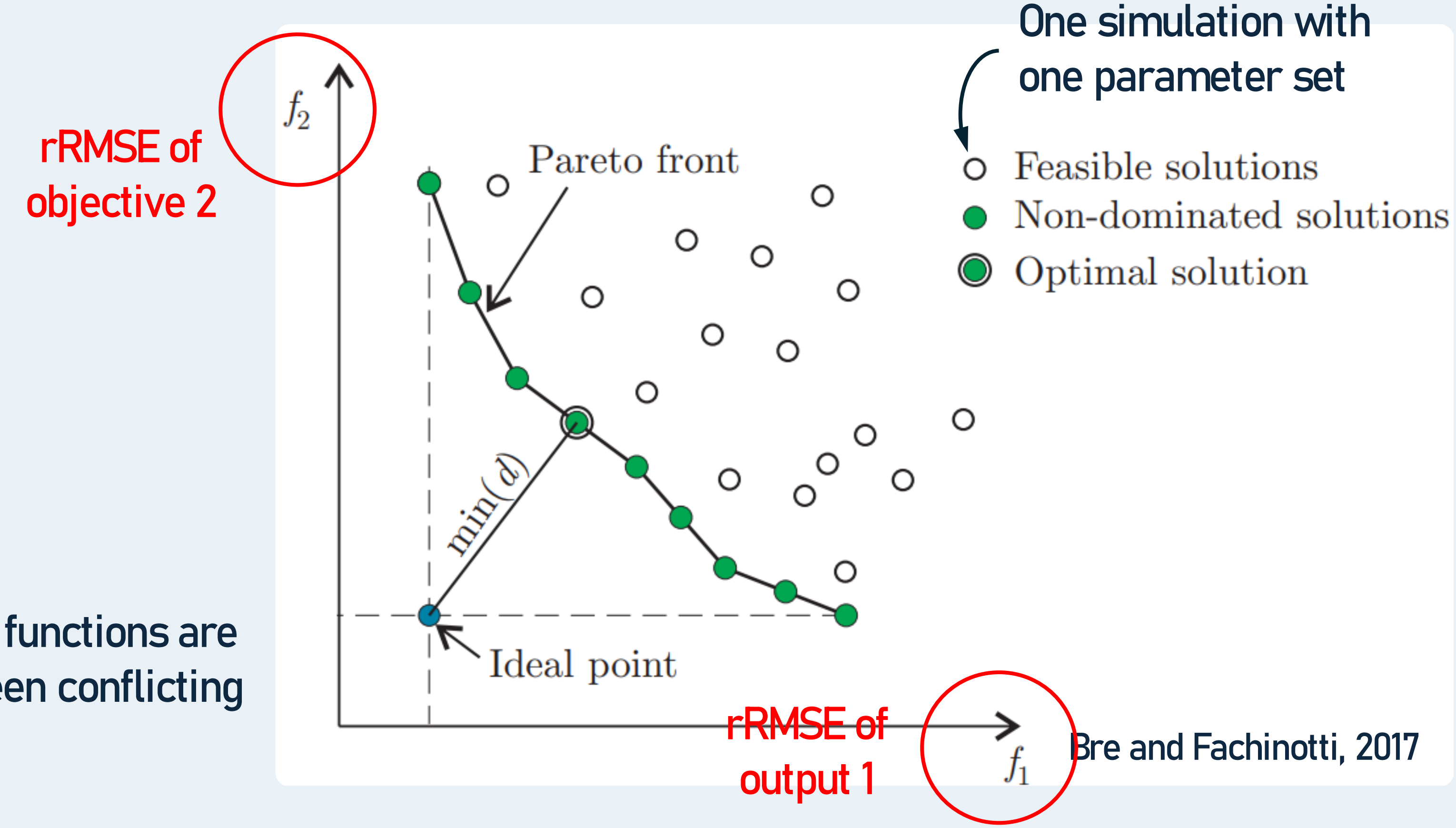


CALIBRATION

WSOrg, NEE and LE are all mainly influenced by similar parameters



→ **Multi-objective optimisation**
considering dry matter of all organs (DM), NEE and LE

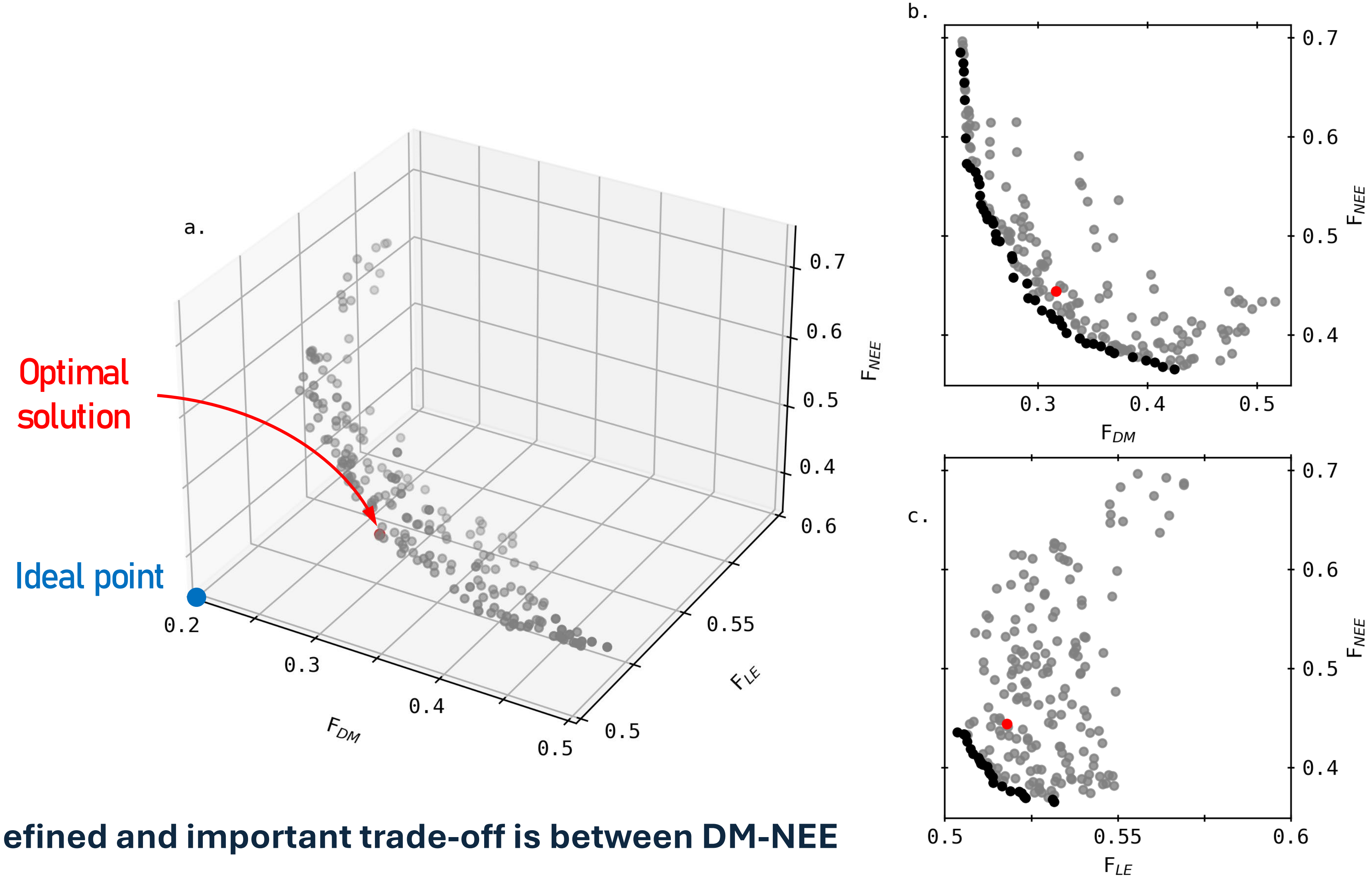


Bre and Fachinotti, 2017

Multi-Objective Optimisation (MOO)

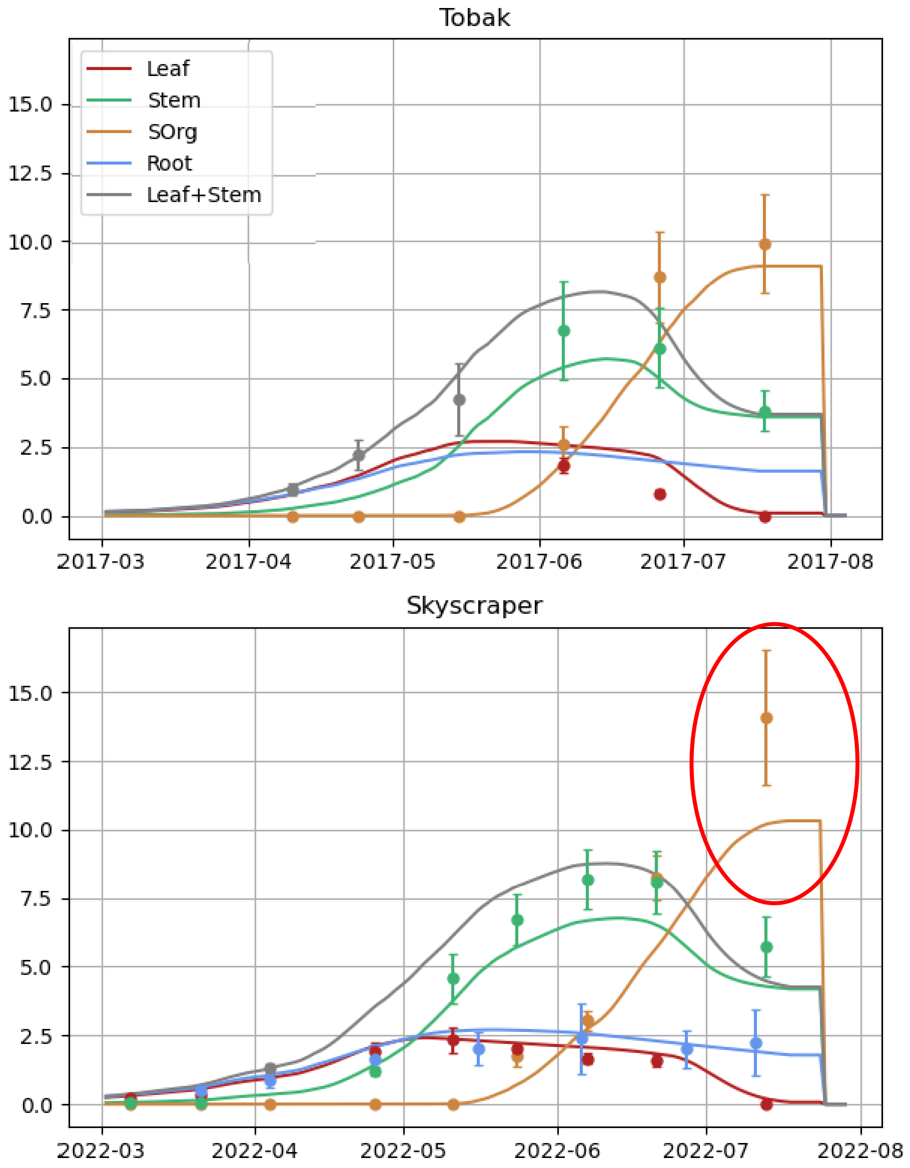
Problem optimisation where multiple objective functions are optimised simultaneously and trade-offs between conflicting objectives can be identified

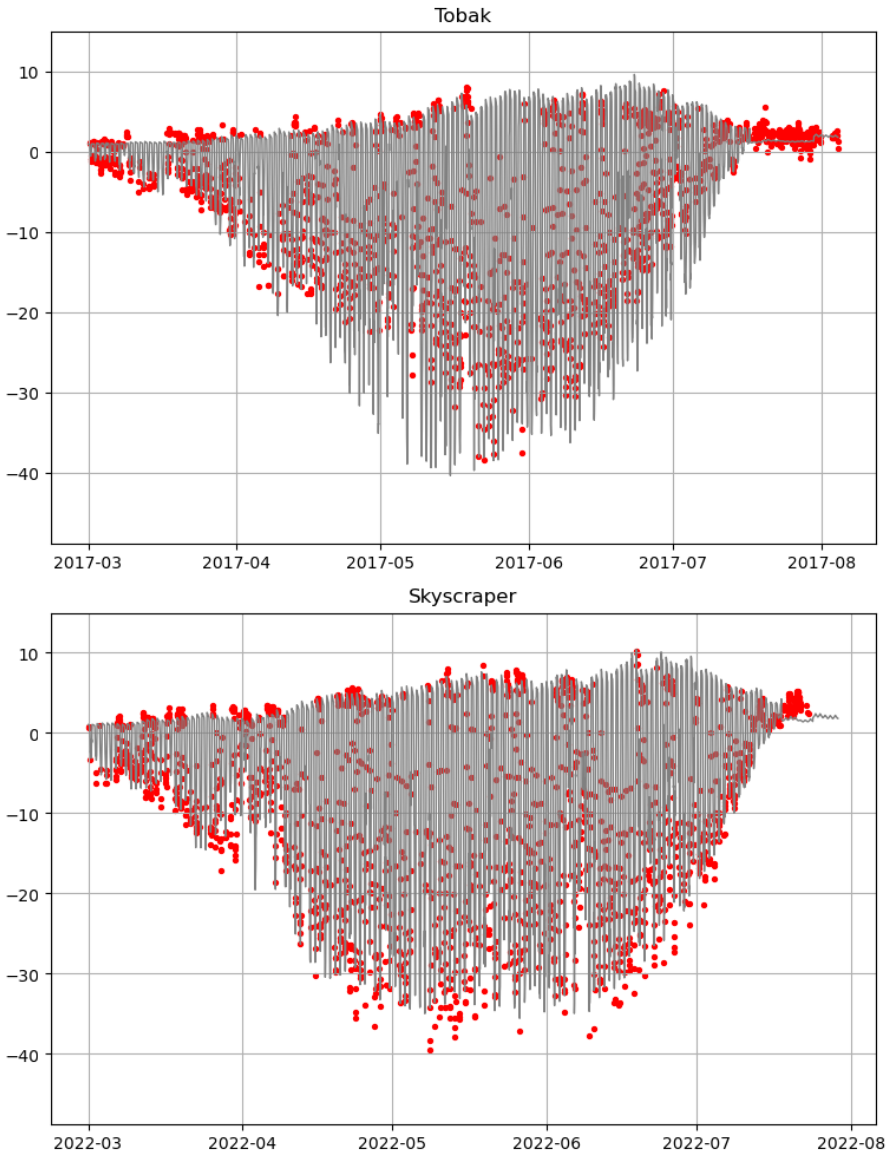
MULTI-OBJECTIVE CALIBRATION



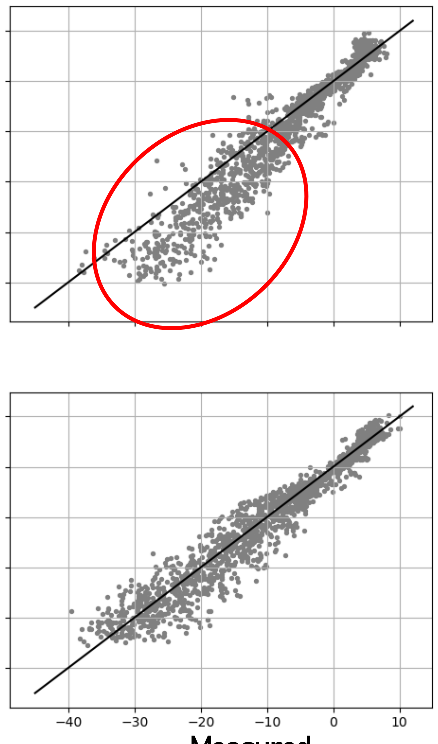
Most defined and important trade-off is between DM-NEE

OPTIMAL SOLUTION – DRY MATTER and NEE



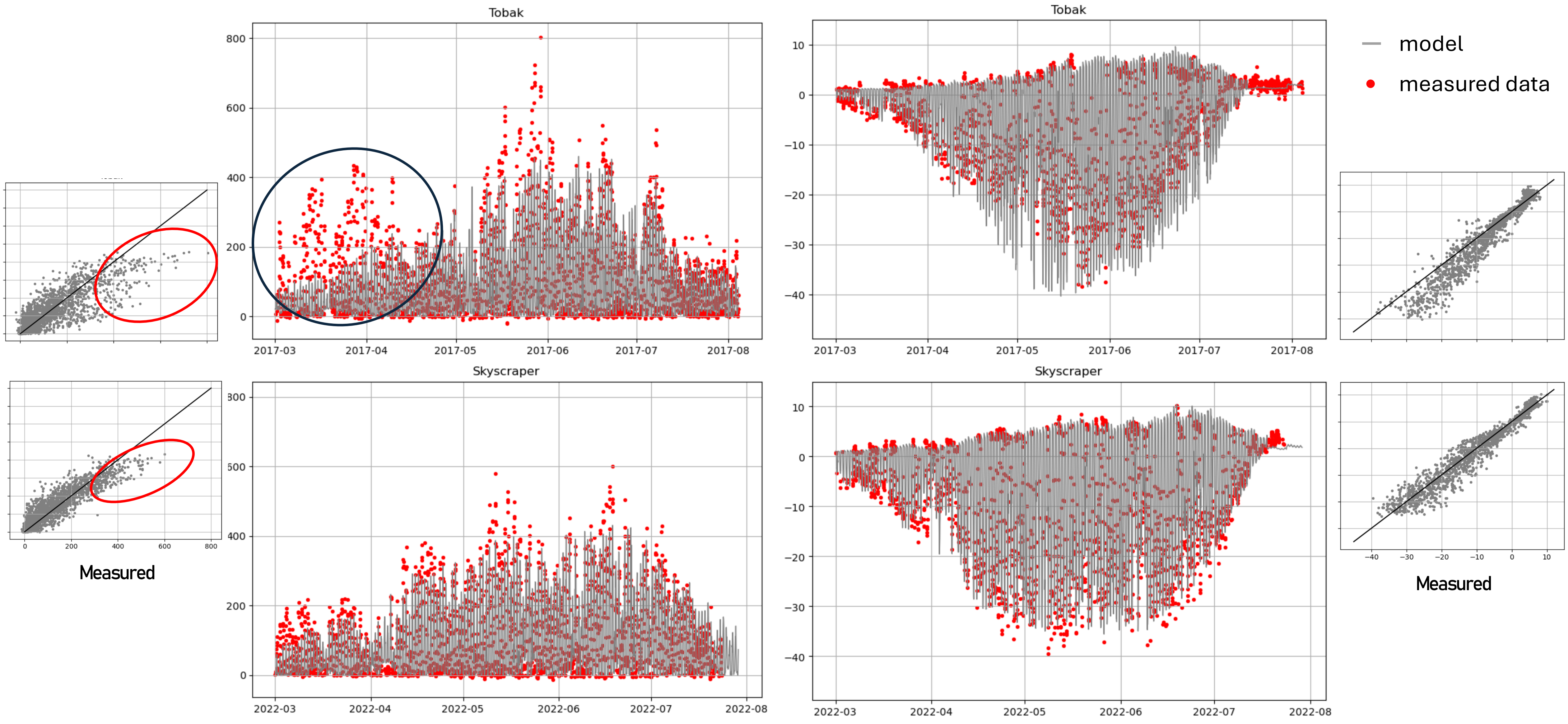


model
measured data



Bad parameterisation ?
Different varieties ?

OPTIMAL SOLUTION – LE and NEE



FUTURE WORK

Sun-induced chlorophyll fluorescence (SIF) measurements

$$\boldsymbol{A_{gross} = min(A_J, A_V)}$$

$$\downarrow$$

$$A_{gross} = q_L \frac{\phi_{PSII,max} \cdot (1 + k_{DF}) \cdot SIF_{TOT}}{1 - \phi_{PSII,max}} \cdot \frac{c_i - \Gamma^*}{4c_i + 8\Gamma^*}$$

Includes the physiological response to environmental conditions
→ Less parameters, more mechanistic but one additional measurement

THANK YOU !