Revealing carbon-water trade-offs in Daisy crop model using Pareto-based calibration

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Study site

Agricultural plot that has integrated **ICOS** network since 2018, but data has been recorded since 2004.

→ **Flux**: Net Ecosystem Exchange (NEE), heat fluxes (H and LE) and N_2O

→ **Meteorological** monitoring

→ **Biomass** measurements: Dry Matter (DM of leaf, stem, storage organs), Green Area Index (GAI), Specific Leaf Area (SLA)...

→ Others: Soil water content (SWC), BBCH stages, water table depth...

4-year rotation (winter wheat – potato – winter wheat – sugar beet) cultivated for more than 85 years under conventional practices.

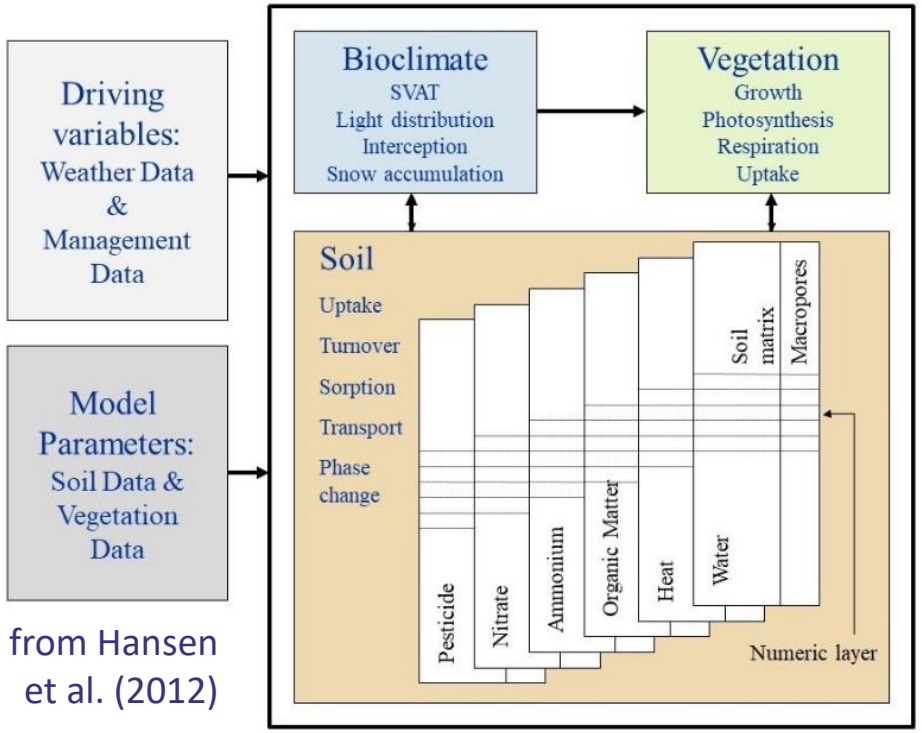
→ Focus on **4 growing seasons of winter wheat** with different cultivars and constrating hydric conditions

BE-Lon ICOS station (Lonzée, Belgium)

Daisy crop model

Process-based model simulating carbon, nitrogen and water cycles of the soil–vegetation–atmosphere continuum

SVAT: Soil-Vegetation-Atmophere Transfer



from Hansen et al. (2012)

→ Estimation of organ biomass as well as carbon and water fluxes

→ Includes Farquhar and Leuning models (stomatal coupling)

→ Computes the surface energy budget using a SVAT scheme

→ Integrates agricultural practices (tillage, fertilisation, etc.)

→ Open-source

Applied a Global Sensitivity Analysis (GSA) on 200 model parameters

→ 22 parameters need to be calibrated against biomass and flux data

Pareto-based calibration

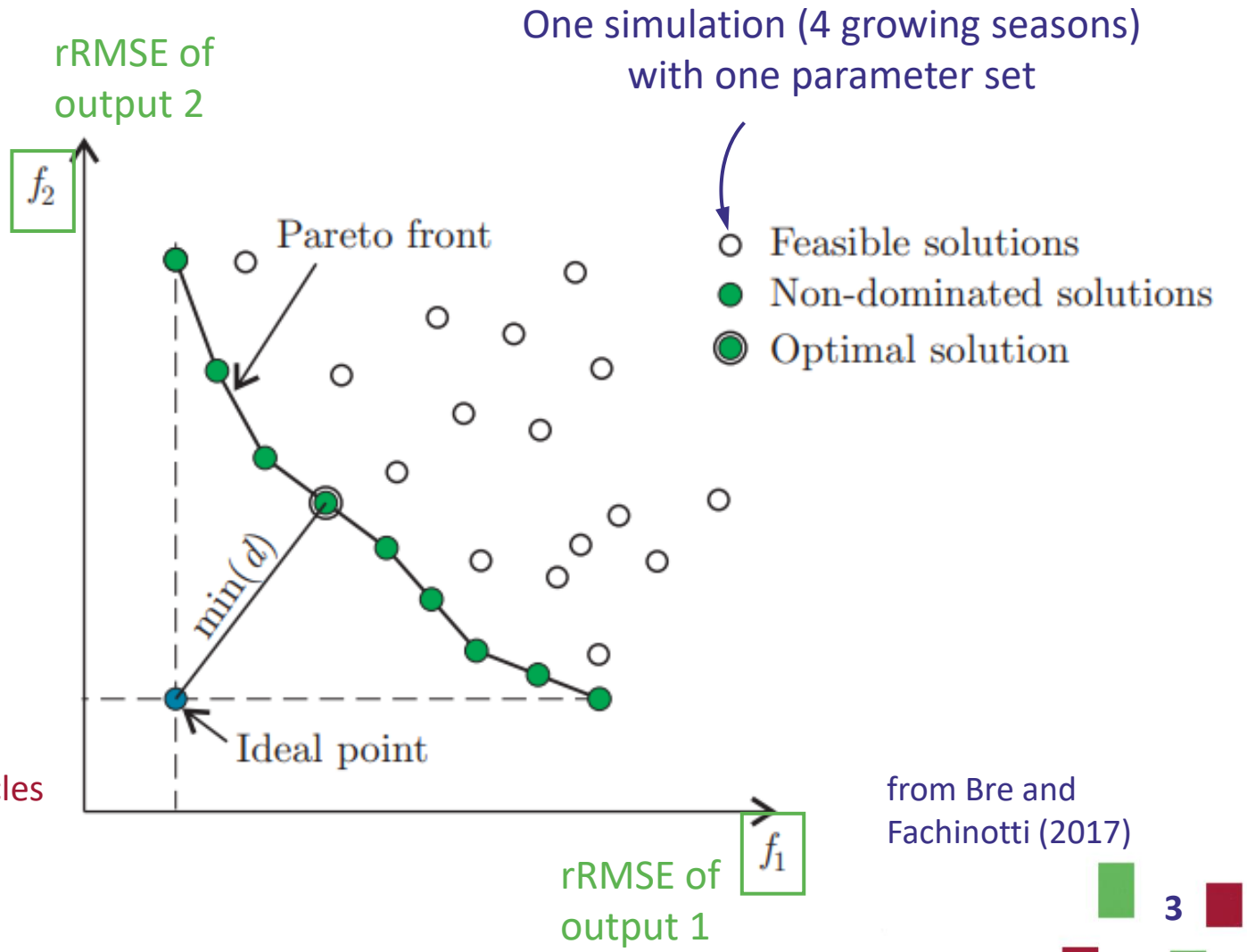
Multi-Objective Optimisation

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

For model calibration, objective functions are goodness-of-fit measures.

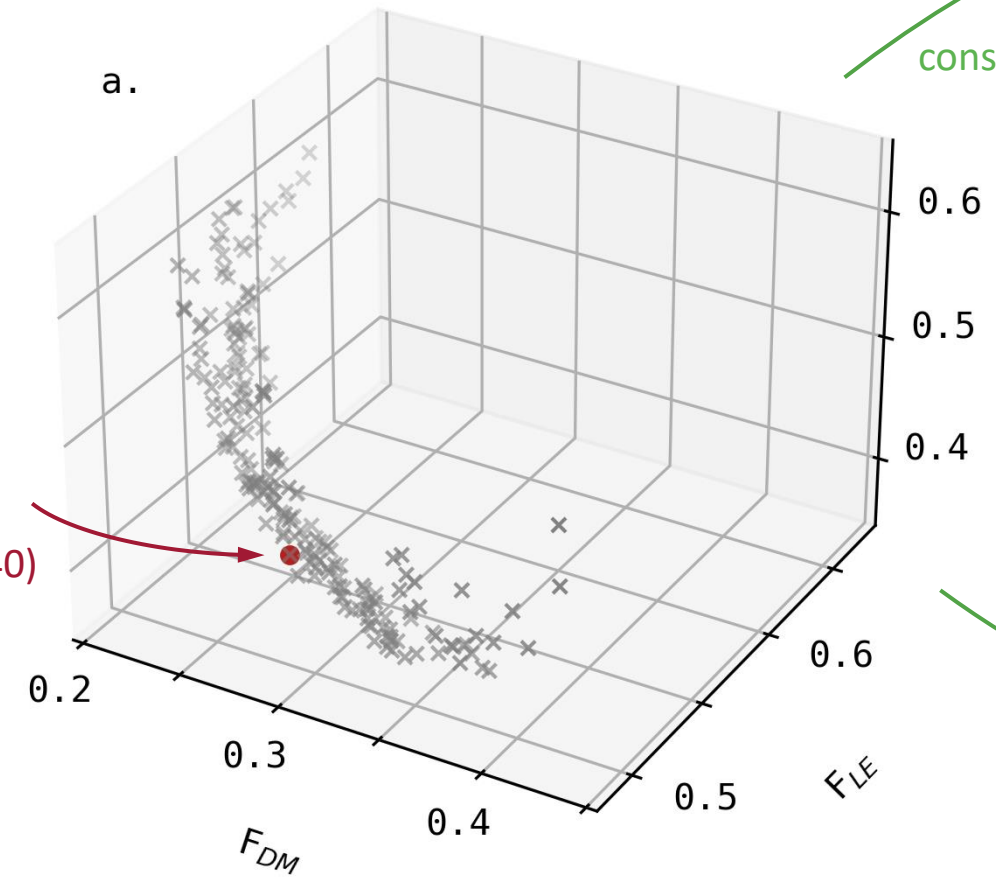
→ rRMSE of three objectives : DM, NEE and LE

Capturing the coupling between carbon and water cycles and assessing the crop carbon budget



from Bre and Fachinotti (2017)

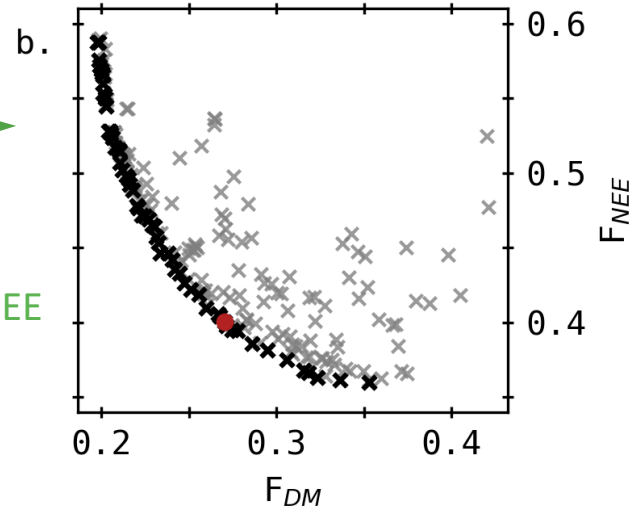
Pareto front



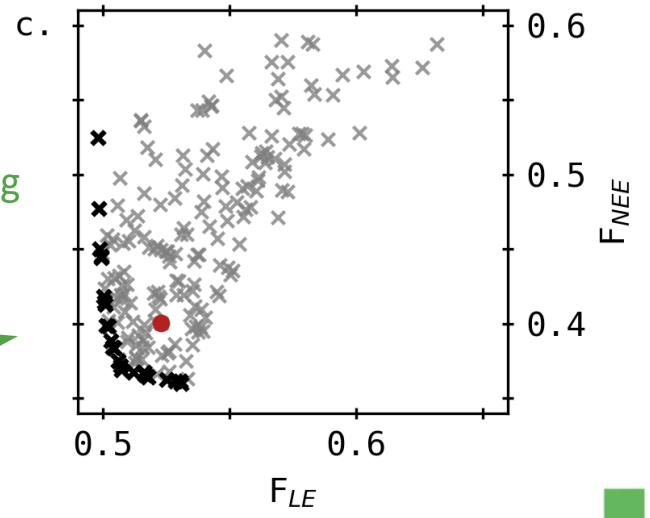
3D Pareto front to the rRMSE of DM, LE and NEE

Compromise solution (0.27, 0.52, 0.40)

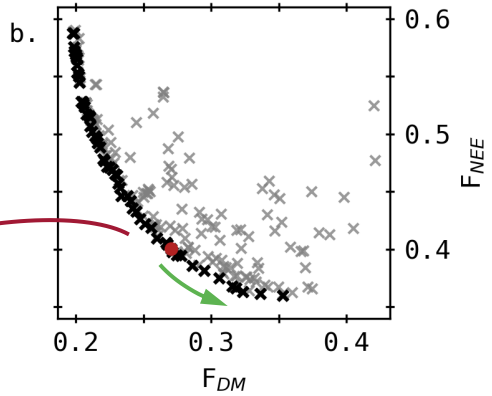
2D projection considering DM and NEE



2D projection considering LE and NEE

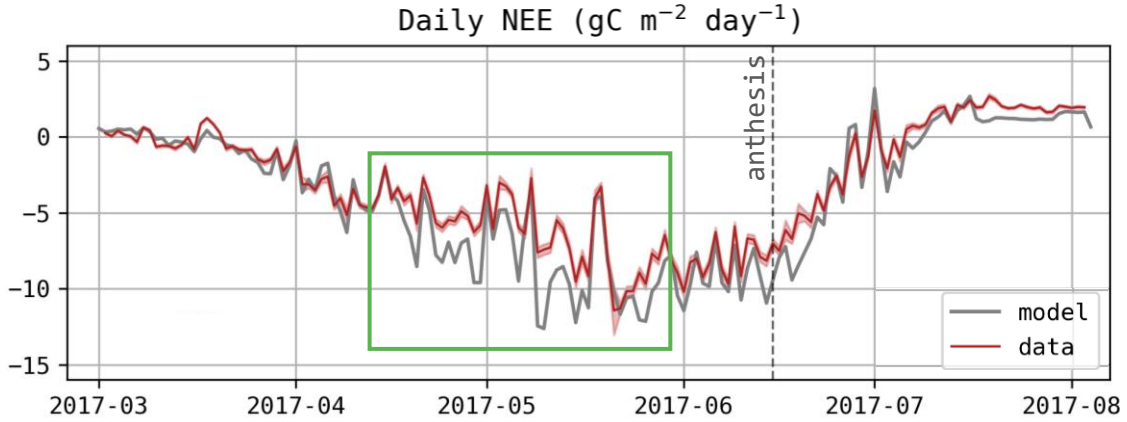


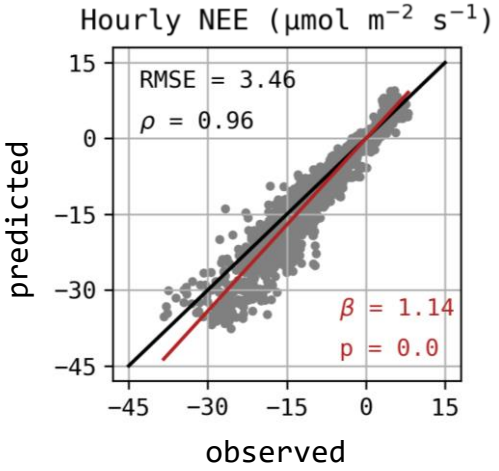
NEE-DM trade-off

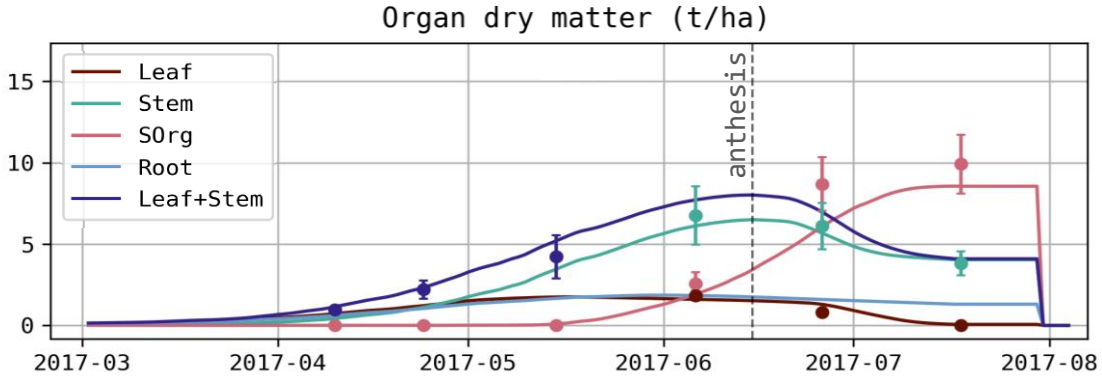


Impossible to accurately simulate NEE and DM simultaneously

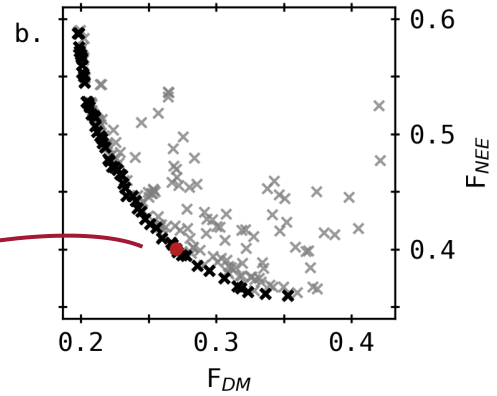
Clearly defined trade-off with a curved Pareto front







Where does the carbon go ?



Impossible to accurately simulate NEE and DM simultaneously

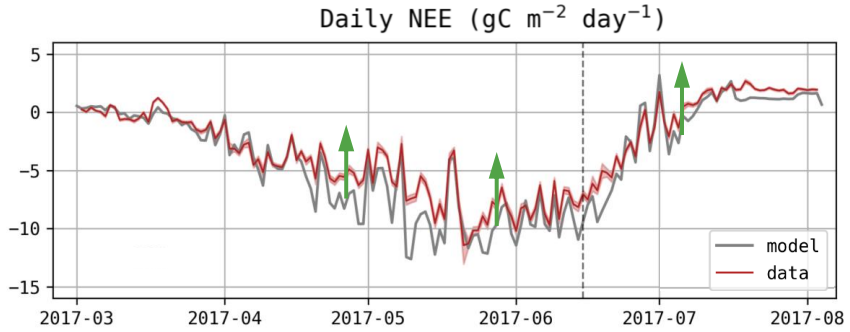
Clearly defined trade-off with a curved Pareto front

→ Underestimation of heterotrophic respiration

*Difficult to confirm as NEE is the **net** carbon flux*

→ Biases in NEE measurements

Could CO_2 fluxes be underestimated and need correction as for energy fluxes ?

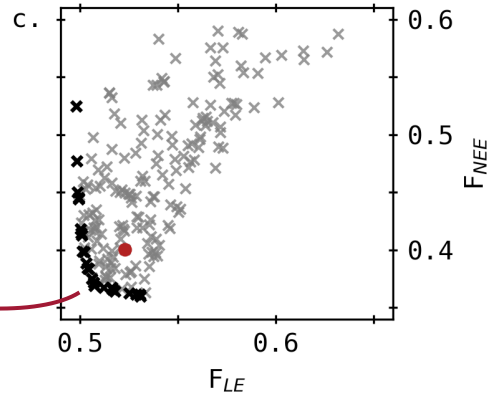


Normalised mean error for bare soil period

Season	2014	2017	2019	2022
NME (%)	1.39	-2.82	-4.03	-18.4

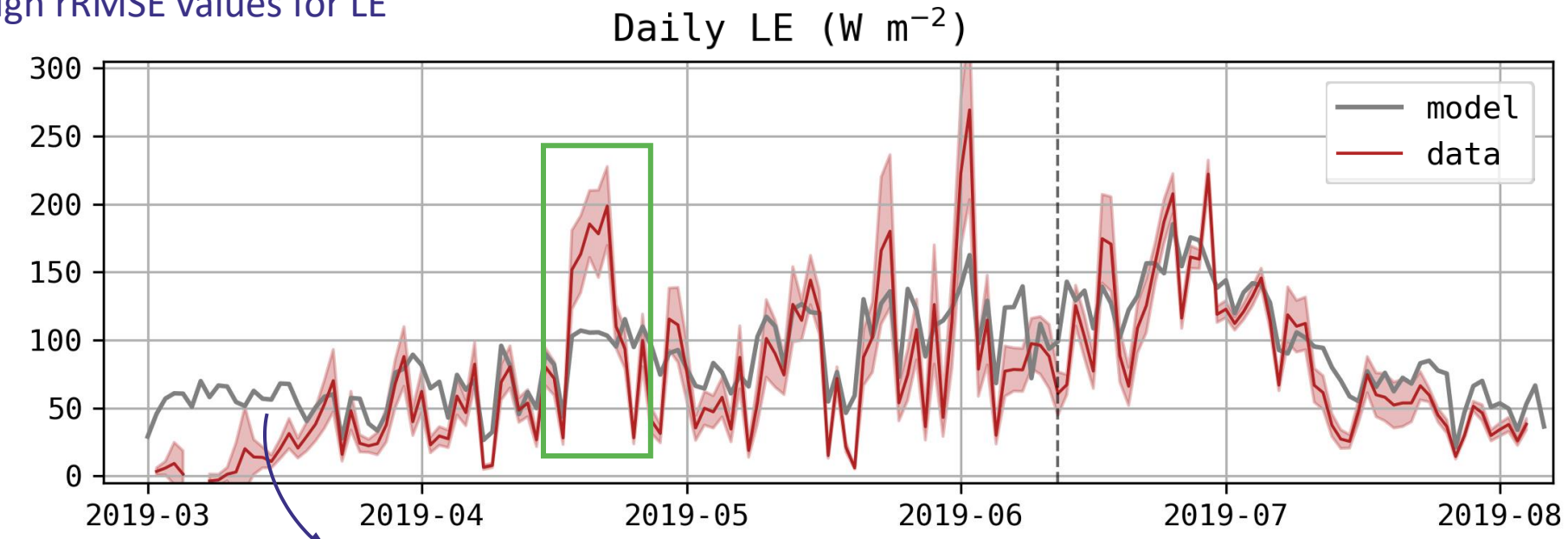
NEE-LE trade-off

possible to optimise both objective functions



Angular Pareto front

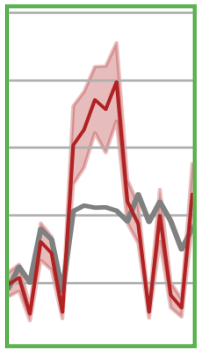
→ High rRMSE values for LE

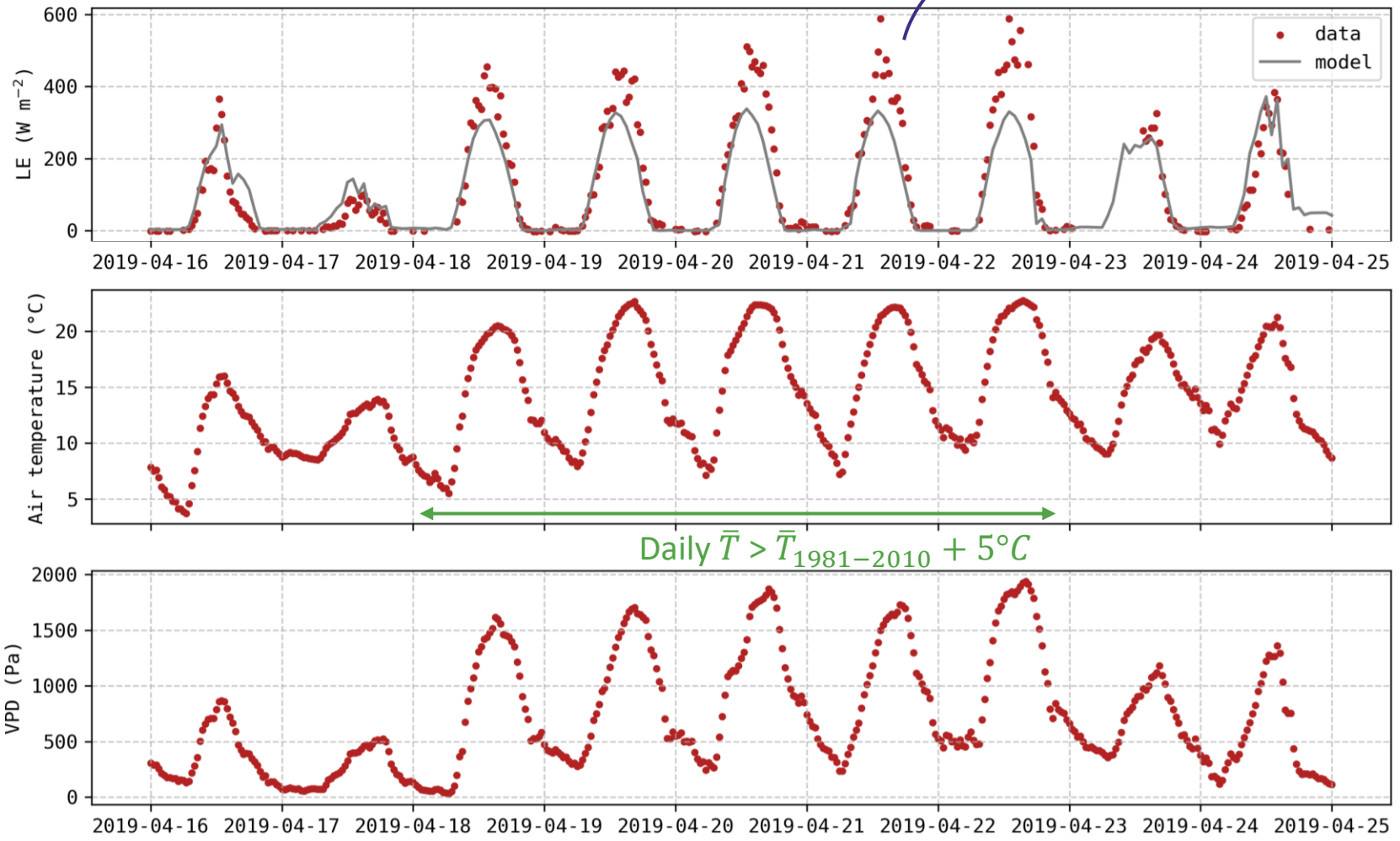


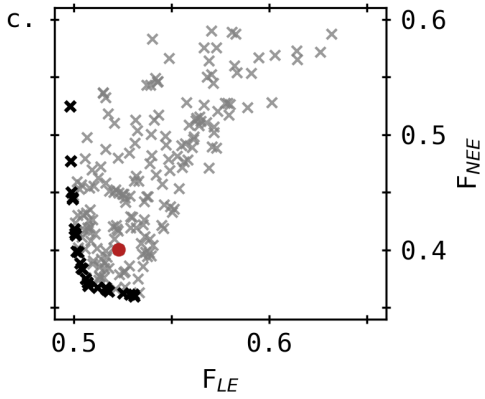
Predicted LE remains relatively stable compared to observations

Heatwave

cannot capture these values, even with a LE-optimised solution

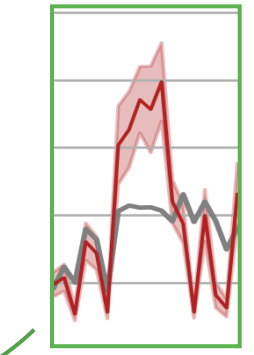


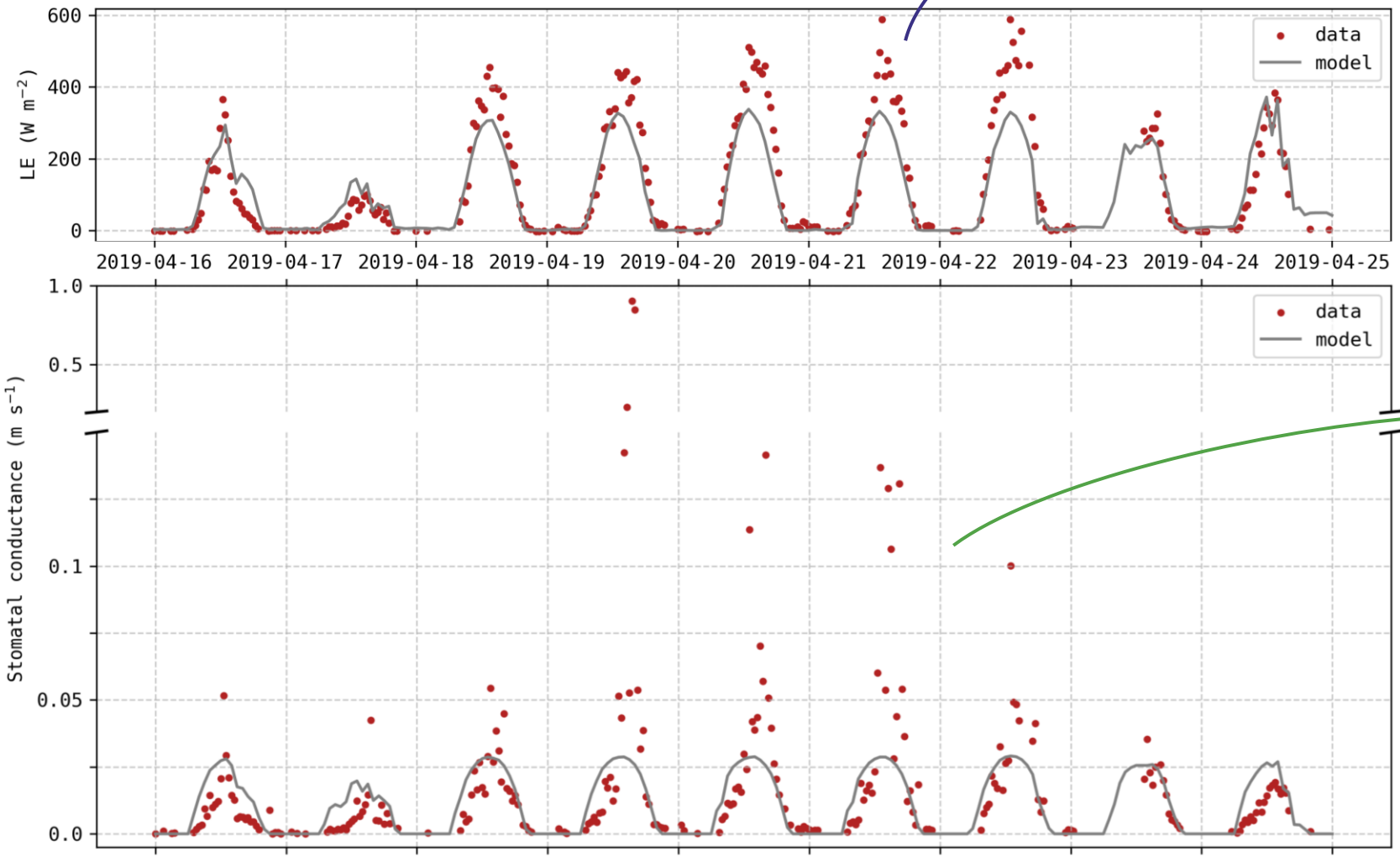




Heatwave

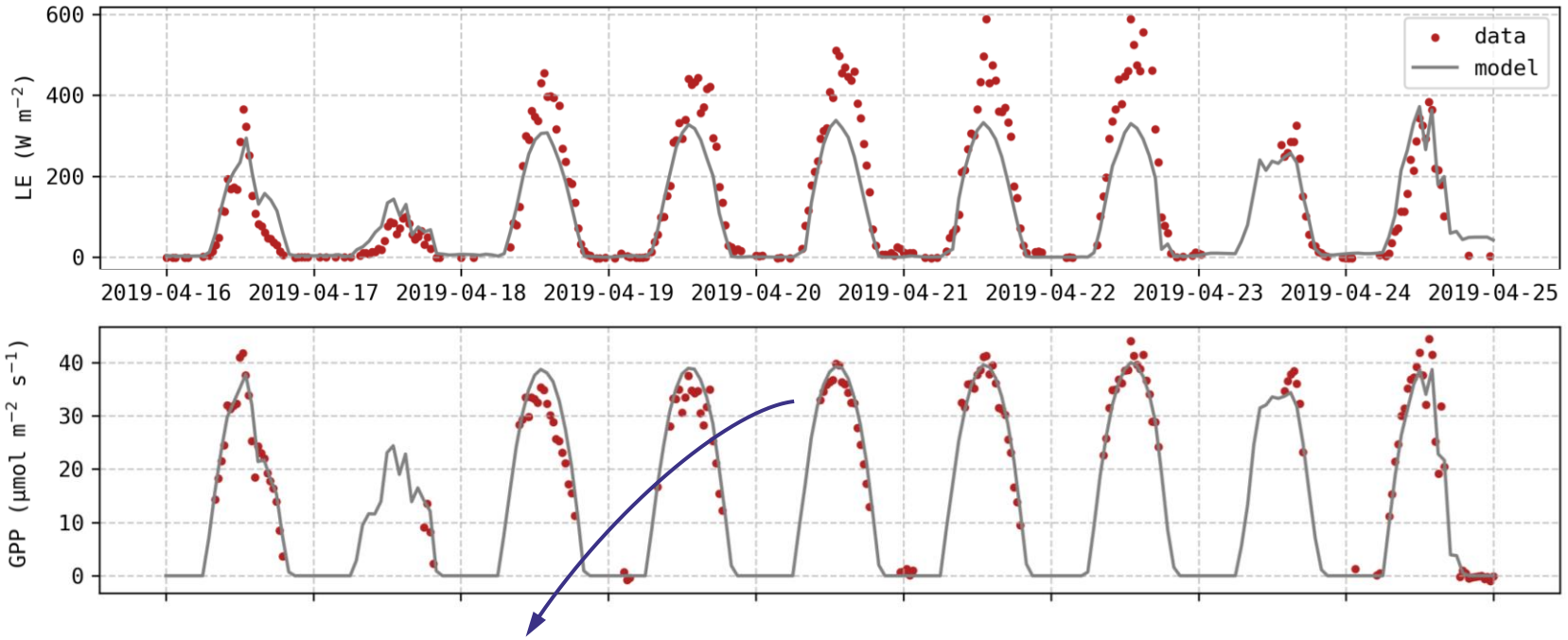
cannot capture these values, even with a LE-optimised compromise

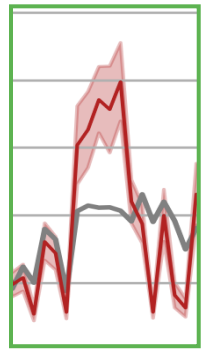




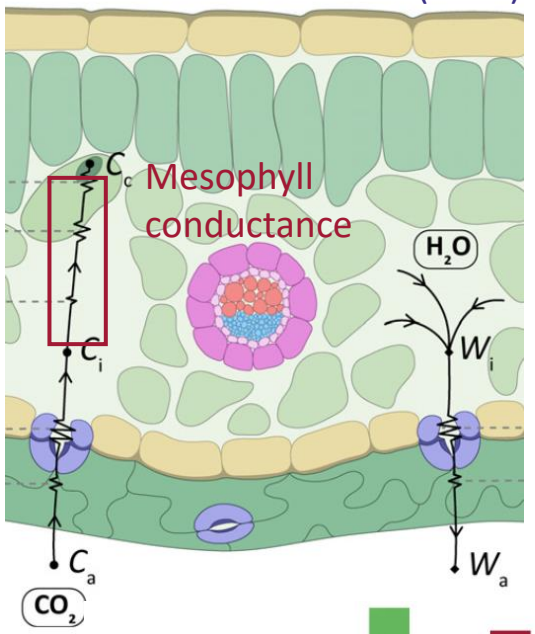
Plants open their stomata

Carbon-water coupling





from Harrison et al. (2019)



No particular increase in photosynthesis, which is accurately simulated

→ *Reduction in water use efficiency*

→ *Stomatal decoupling*

Are there non-stomatal limitations?

Thank you for listening

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