Sharing not permitted

# Improved data-driven ecosystem carbon fluxes under moisture stress through synergistic Earth observations?

Sophia Walther[1,*], Wouter Dorigo[2], Gregory Duveiller[1], Sofia L. Ermida[3] , Fabian Gans[1], Darren Ghent[4], Basil Kraft[1], Mirco Migliavacca[5], Jacob A. Nelson[1], Wolfgang Preimesberger[2], Karen L. Veal[4], Ulrich Weber[1], Ruxandra-Maria Zotta[2], Martin Jung[1]

## A: the problem

Atmospheric water demand and soil moisture supply shape the carbon (C) balance of many terrestrial ecosystems, but their reactions are complex and diversified, and **model estimates of C fluxes suffer from low accuracy under moisture limitation.**

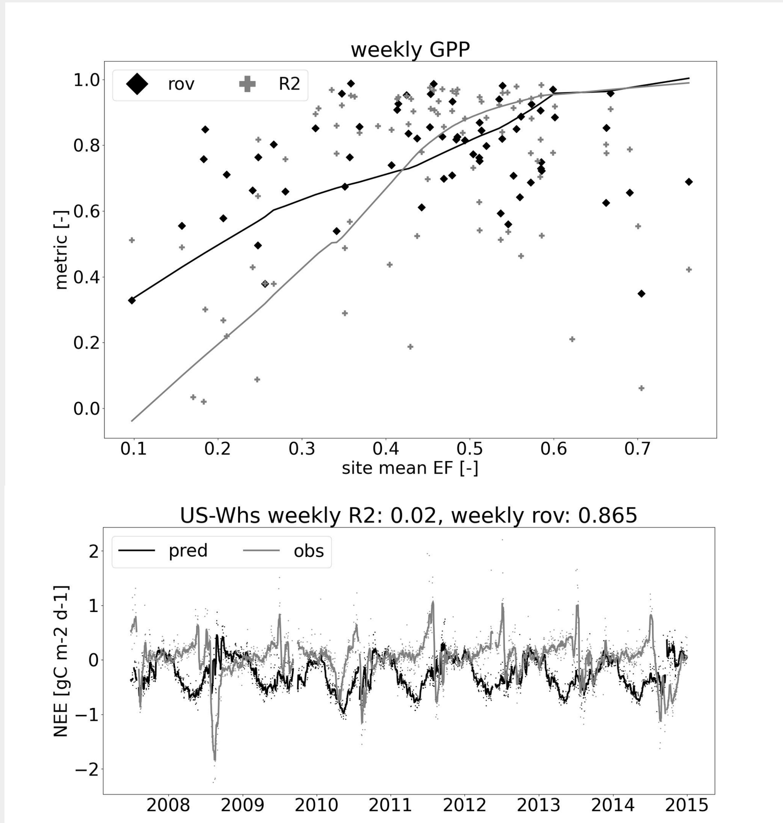
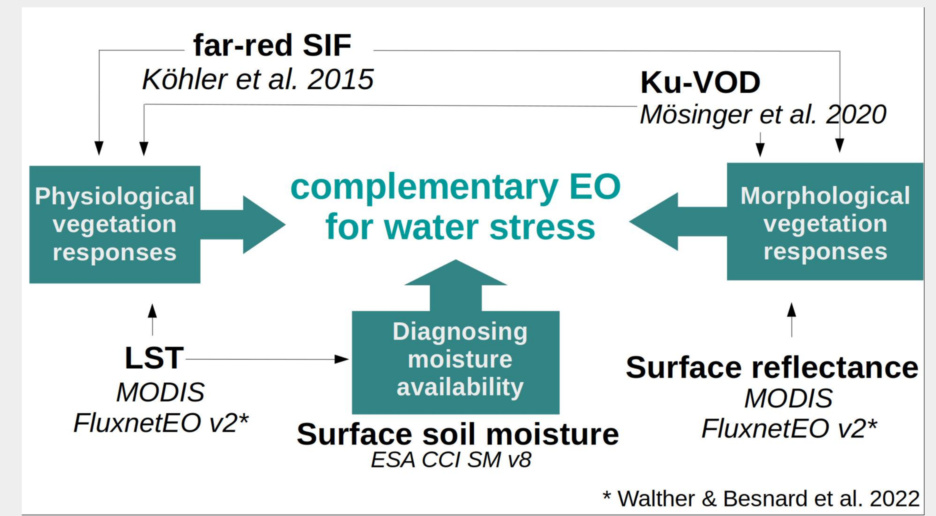



*Fig.1: Accuracy decline of GPP for sites with relatively lower average evaporative fraction (EF, top). NEE in a semi-arid shrubland (US-Whs, bottom) based on a simulation from FLUXCOM-X.*

## B: idea & questions

simulations with direct Earth observations (EO) of both moisture availability and ecosystem reactions to it




**1) How relevant are the additional EO predictors SIF, ku-VOD and soil moisture (SM) for the flux accuracy?**
**2) How strongly do the additional EO predictors influence the model output?**

## C: approach

1) hourly net ecosystem exchange (NEE) at ~140 eddy-covariance sites estimated in FLUXCOM-X.
**Quantify accuracy** of
i) a baseline predictor set (meteorology, surface reflectance, EVI, NIRv, NDWI, LST)
ii) the baseline plus SIF, VOD, SM
iii) baseline* using coarsened MODIS predictors 0.25°

2) **predictor importance from SHAP values** for noon-time fluxes

## D: main insights

→ inconsistent accuracy change from either of the new EO predictors, worse spatial patterns

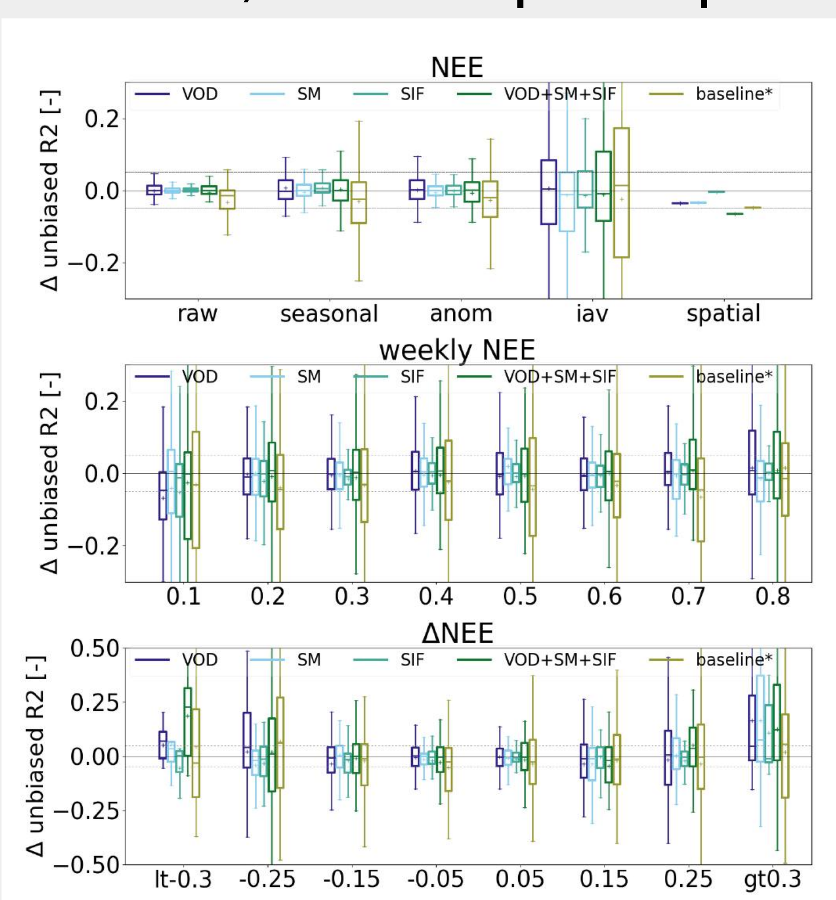



*Fig.2: ΔR2 upon inclusion of additional EO predictor variables (experiment – baseline) across sites for a range of temporal scales, for weekly fluxes along a gradient in weekly evaporative fraction (EF), and weekly ΔNEE along weekly ΔEF.*

→ moderate influence of additional EO predictors on noon NEE, water-related importance changes in VPD, incoming light, LST, SIF

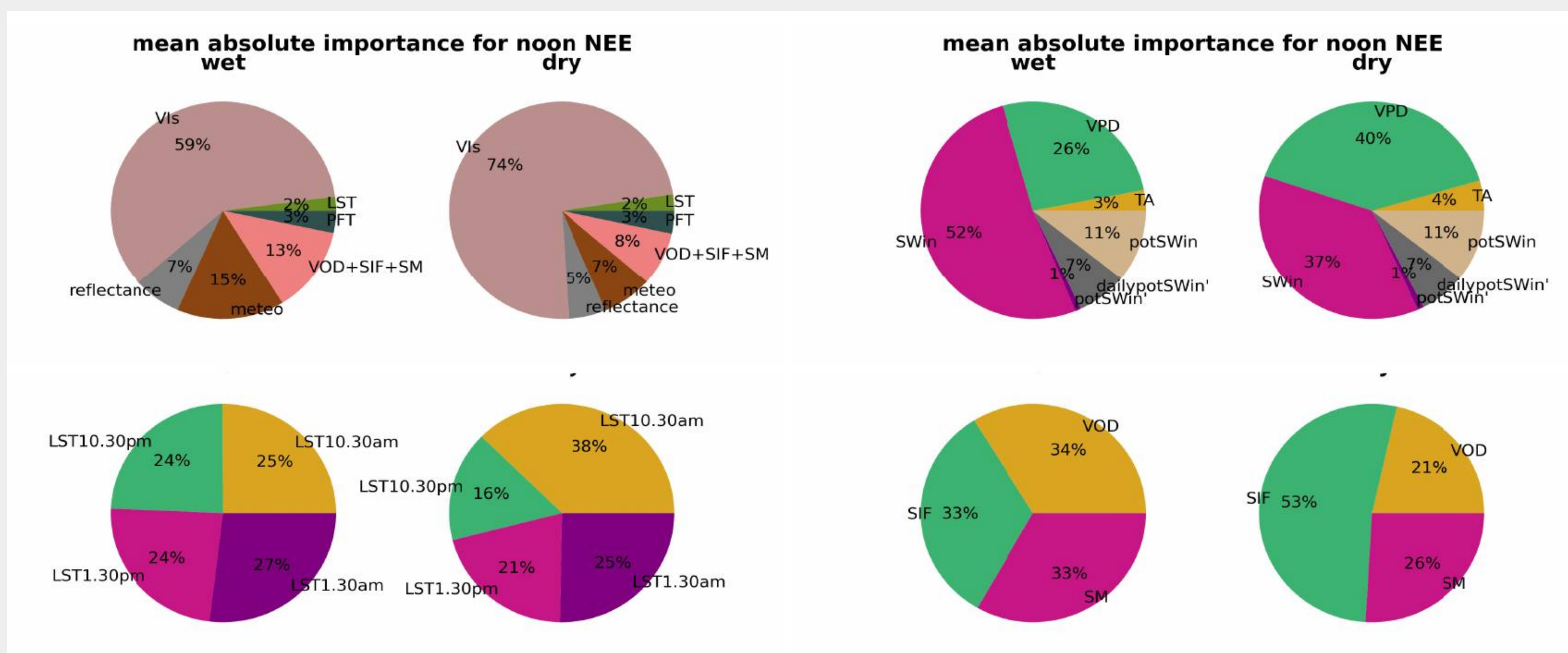



*Fig.3: Predictor importance for noontime NEE during wet (EF≥0.65) and dry weeks (EF≤0.25). The aggregation across groups across predictors (top left): $mean_{samples}(abs(mean_{predictors}(SHAPvalues)))$. The detailed pie charts show $mean_{samples}(abs(SHAPvalues))$.*

→ water effect encoded in light, VPD & NIRv, no physically interpretable importance of new EO predictors regarding water effects

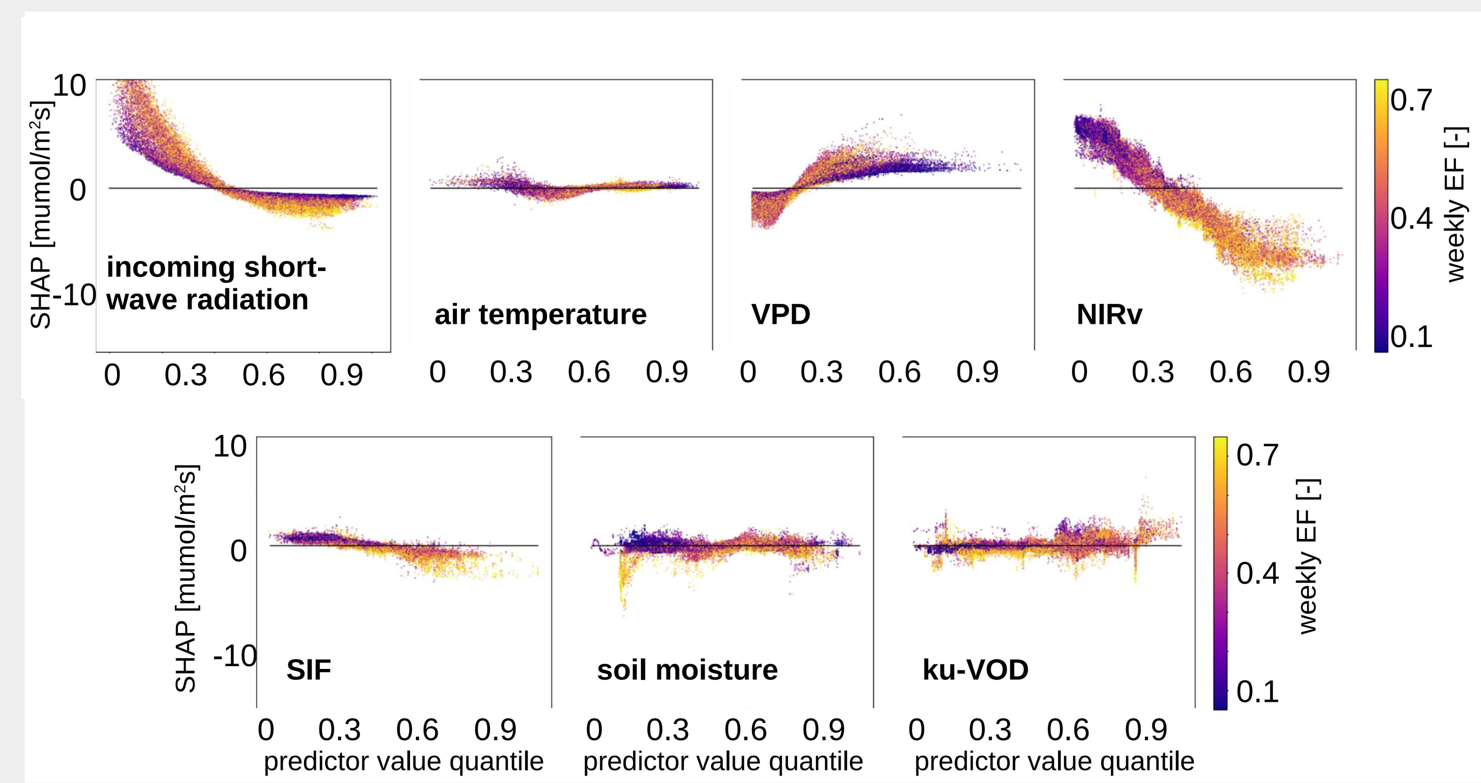



*Fig.4: Predictor importance of selected variables for noon time NEE in dependence on the value of the predictor and water availability during the given week.*

## E: conclusions & further steps

- Representation of water effects on terrestrial carbon flux estimates remains a scientific challenge.
- **unclear whether data quality** of additional EO predictors is **limiting** or their **complementary information content** to the baseline is **too low**
- analysis of the role of site heterogeneity
- other ML-methods and predictors

* sophia.walther@bgc-jena.mpg.de
[1] Max-Planck-Institute for Biogeochemistry, Jena, Germany, [2] TU Vienna, Austria, [3] Instituto Português do Mar e da Atmosfera and Instituto Dom Luiz, [4] National Centre for Earth Observation, Leicester, UK, [5] Joint Research Centre of the European Commission, Ispra, Italy

European Space Agency

MAX PLANCK INSTITUTE FOR BIOGEOCHEMISTRY