

Evaluation of carbonyl sulfide biosphere exchange in the Simple Biosphere Model (SiB4): can the biosphere sink explain the imbalanced COS budget?

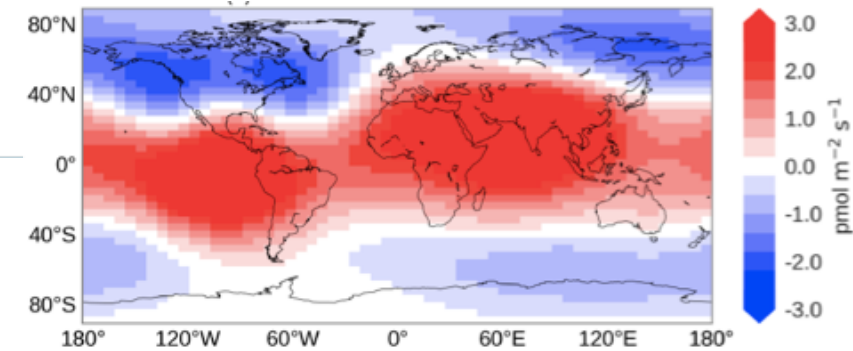
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Kukka-Maaria Kohonen, Timo Vesala, Ivan Mammarella, Huilin Chen, Felix Spielmann, Georg Wohlfahrt, Max
Berkelhammer, Kadmiel Maseyk, Ulli Seibt, Roisin Commane, Rick Wehr, Maarten Krol

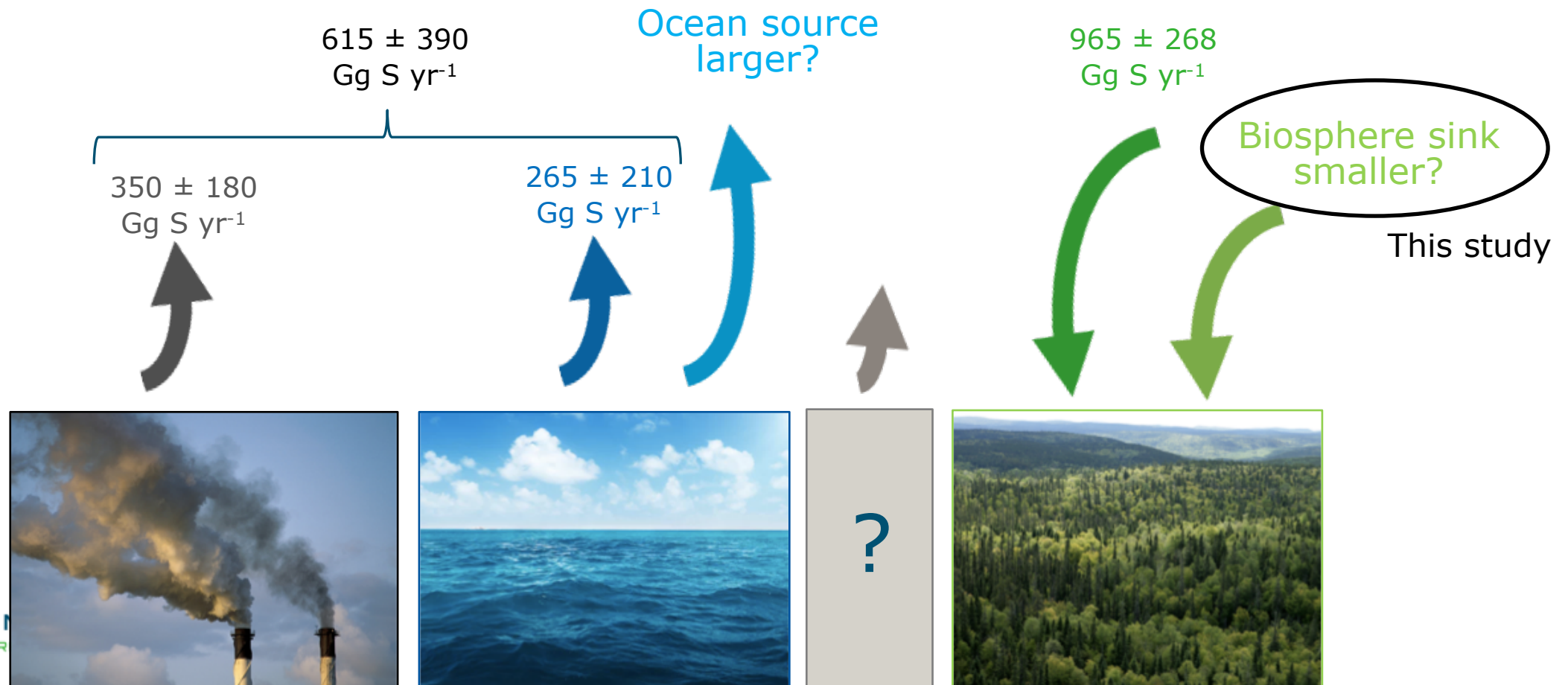


Unknowns in the COS budget

Ma et al. 2021, ACP

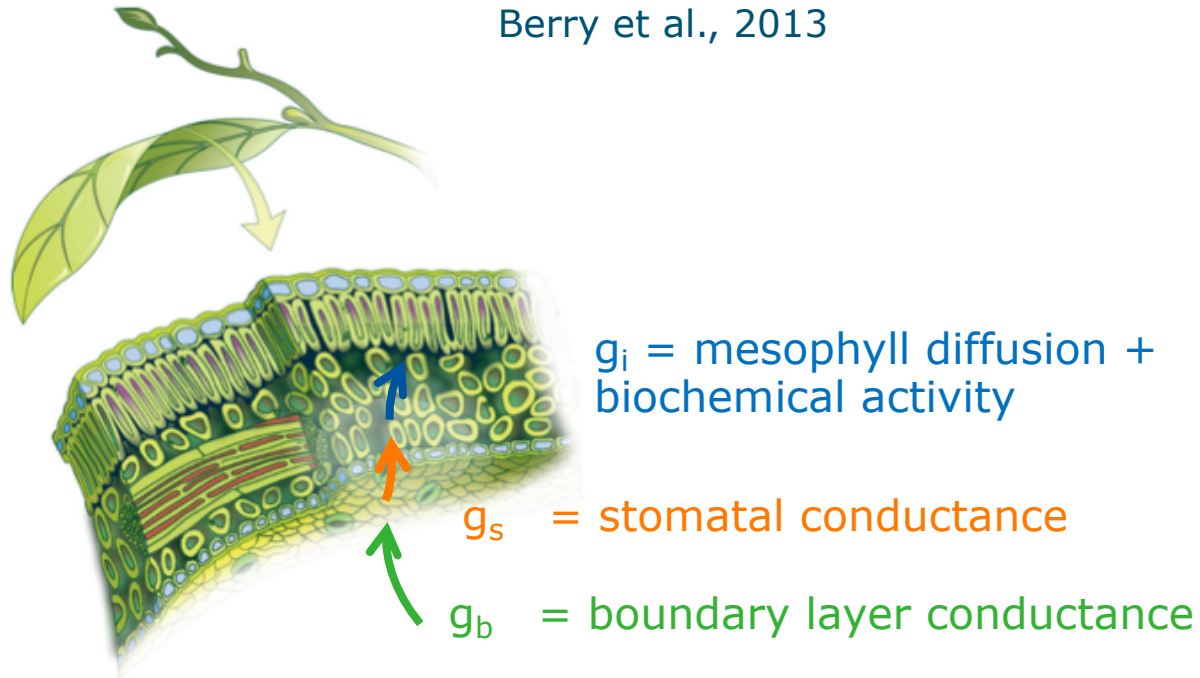


Missing emissions from **tropical** regions



Modelling COS exchange in SiB4

Berry et al., 2013



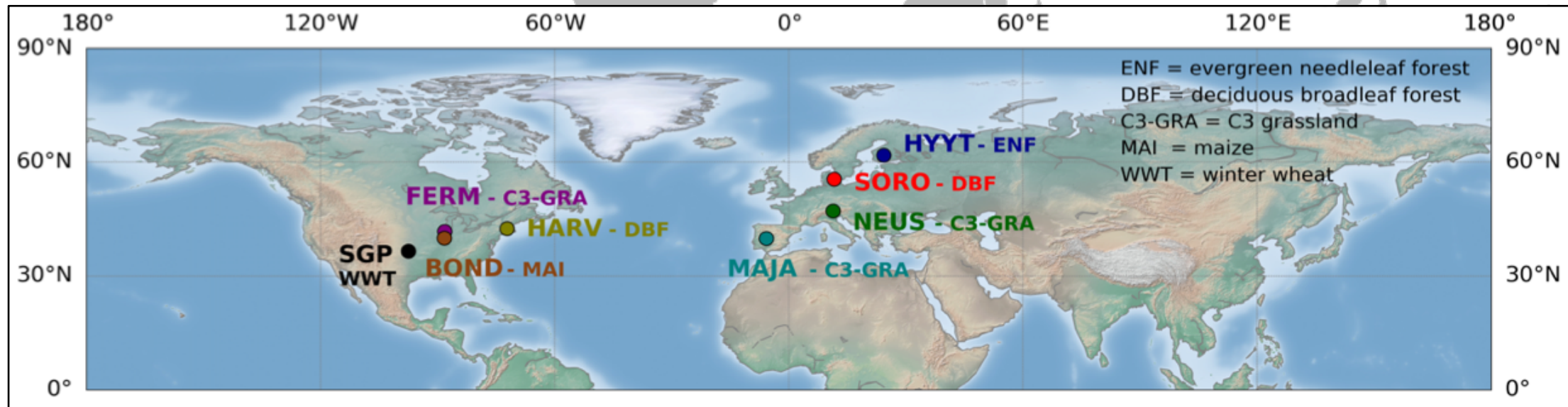
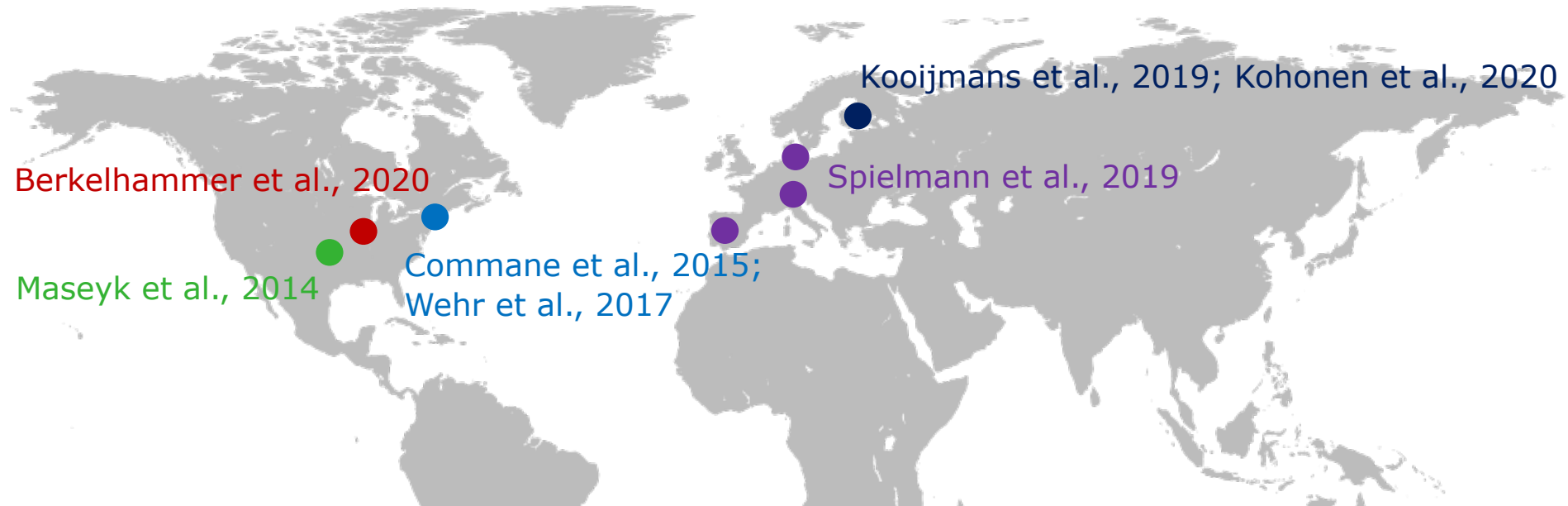
COS biosphere fluxes are used for global modelling studies, but not validated against field observations.

$$F_{cos} = [COS] \left[\frac{1.56}{g_b} + \frac{1.94}{g_s} + \frac{1}{\alpha g_i} \right]^{-1}$$

Annotations for the equation:

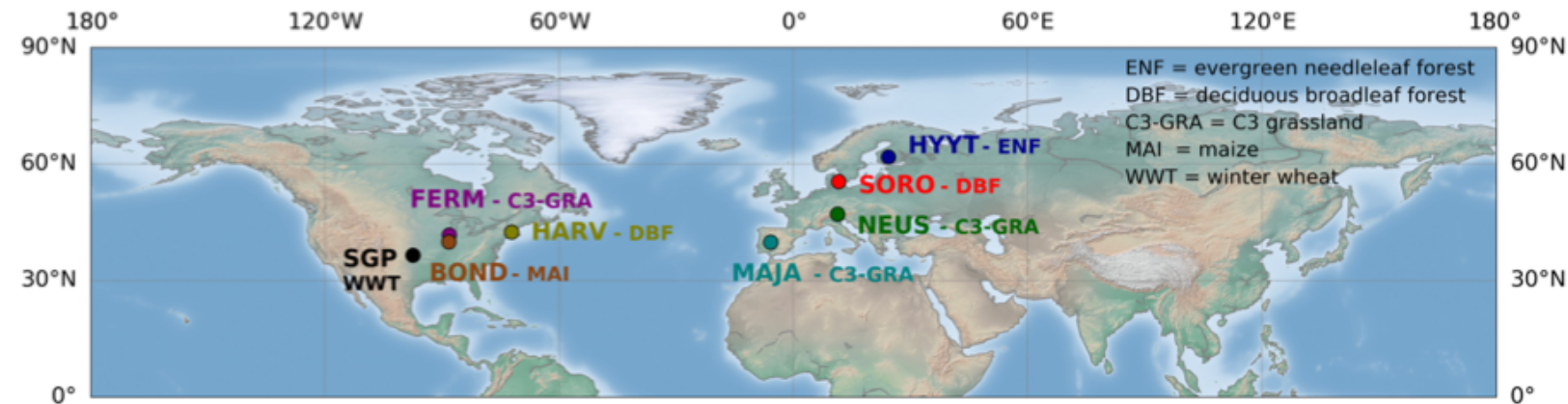
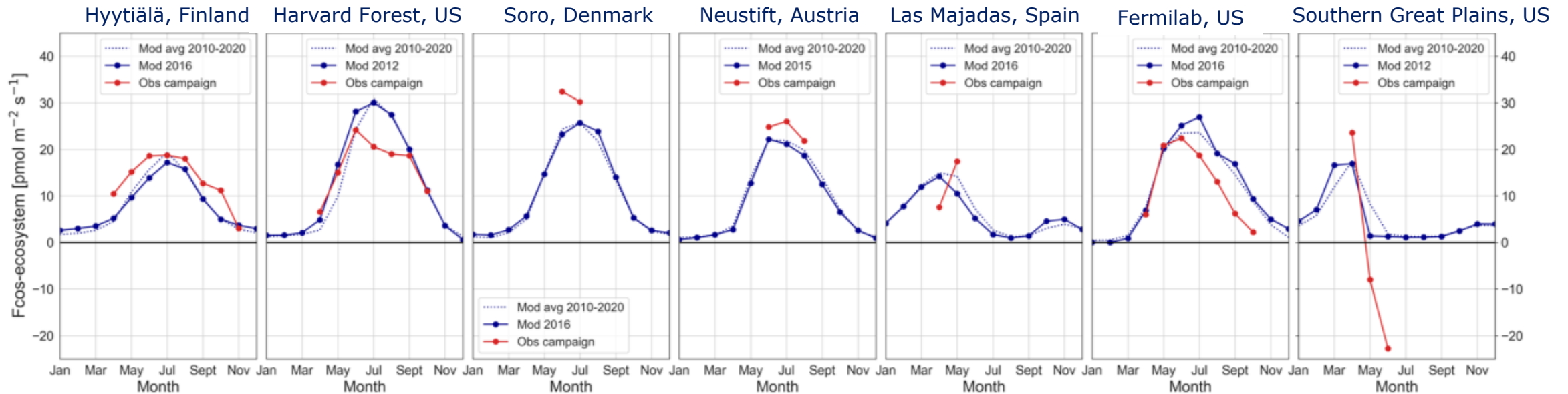
- $[COS]$: 500 ppt
- 1.56: This study: changed to COS varying in space and time. See slide 6.
- 1.94: Ball-Berry
- α : calibration factor = 1400
- g_i : This study: is it constant? See slides 12-13
- V_{max} : GPP

Field observations used for SiB4 COS flux evaluation



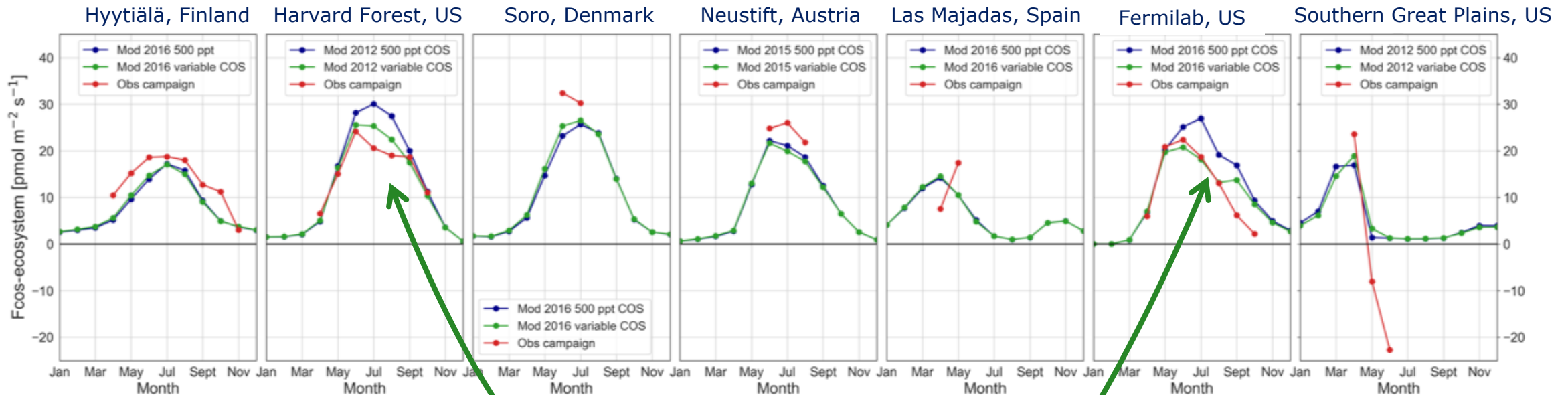
Seasonal cycle of COS ecosystem fluxes

[COS] = 500 ppt



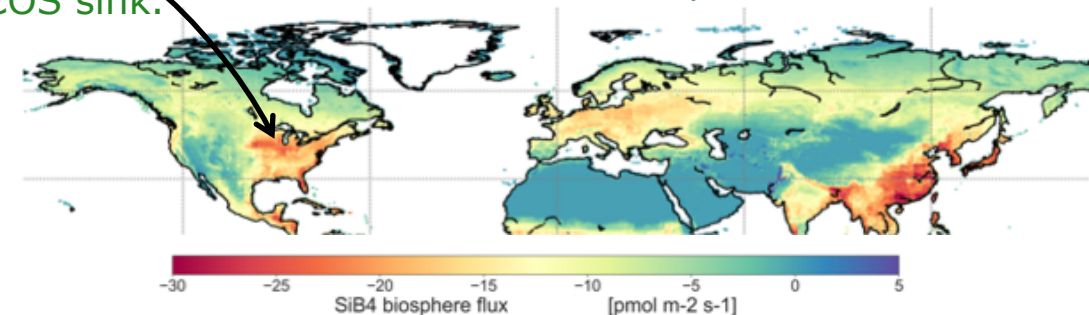
Sensitivity to COS mixing ratios

[COS] = variable



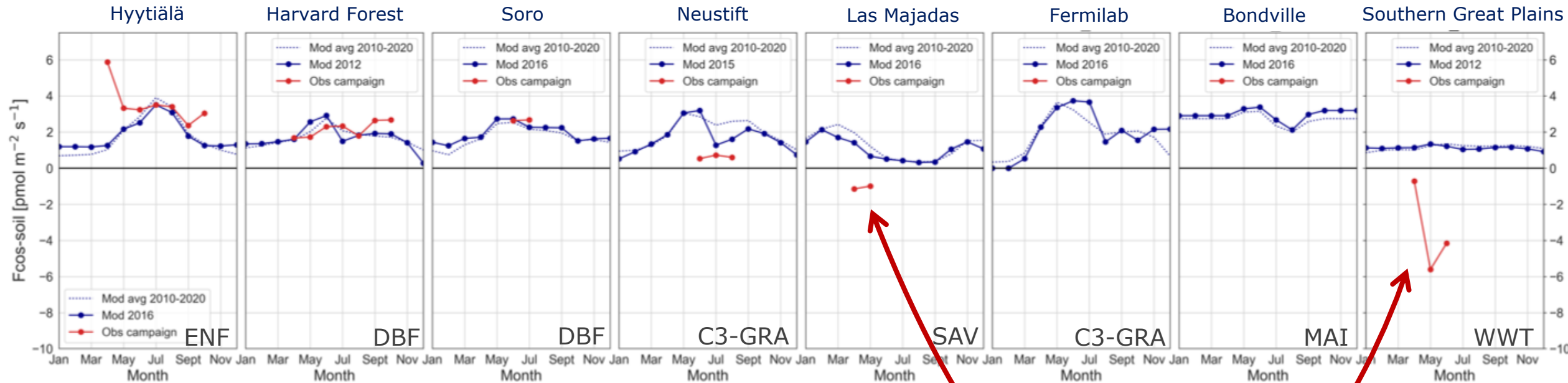
Lower COS ecosystem flux in second half of the growing season, when [COS] is lower. Especially in regions with a strong biosphere COS sink.

Fig: Distribution of the COS biosphere flux in summer



COS soil flux – SiB4 original

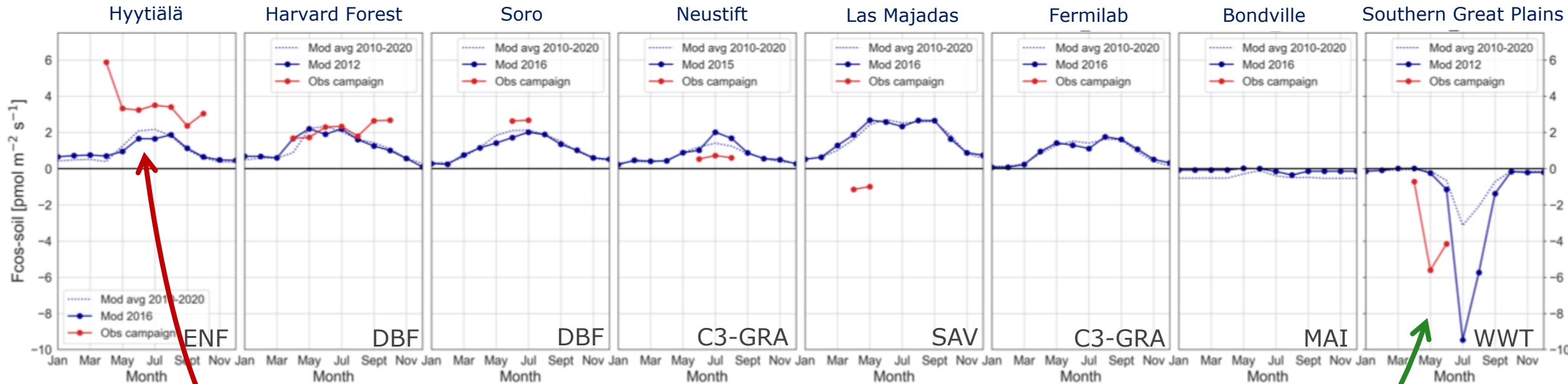
SiB4 COS soil uptake proportional to respiration (Berry et al. 2013)



COS soil emissions not captured by the original SiB4 model

COS soil flux - updated

Ogee et al. (2016) mechanistic soil model implemented in SiB4

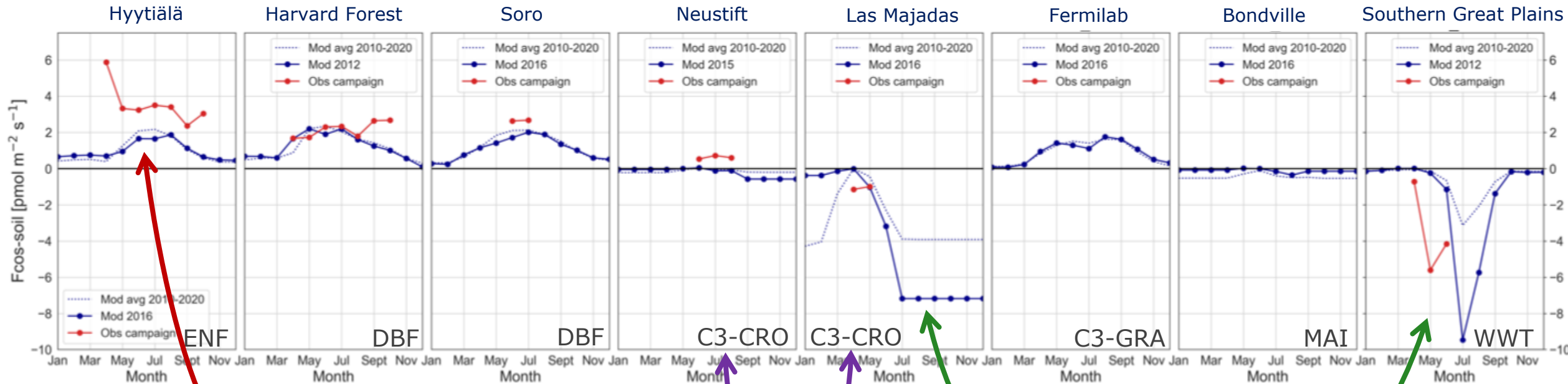


Underestimated COS soil
flux at Hyytiälä

COS soil emissions
simulated by Ogee et al.
(2016) model, especially
large emissions in
agricultural soil

COS soil flux - updated

Ogee et al. (2016) mechanistic soil model implemented in SiB4

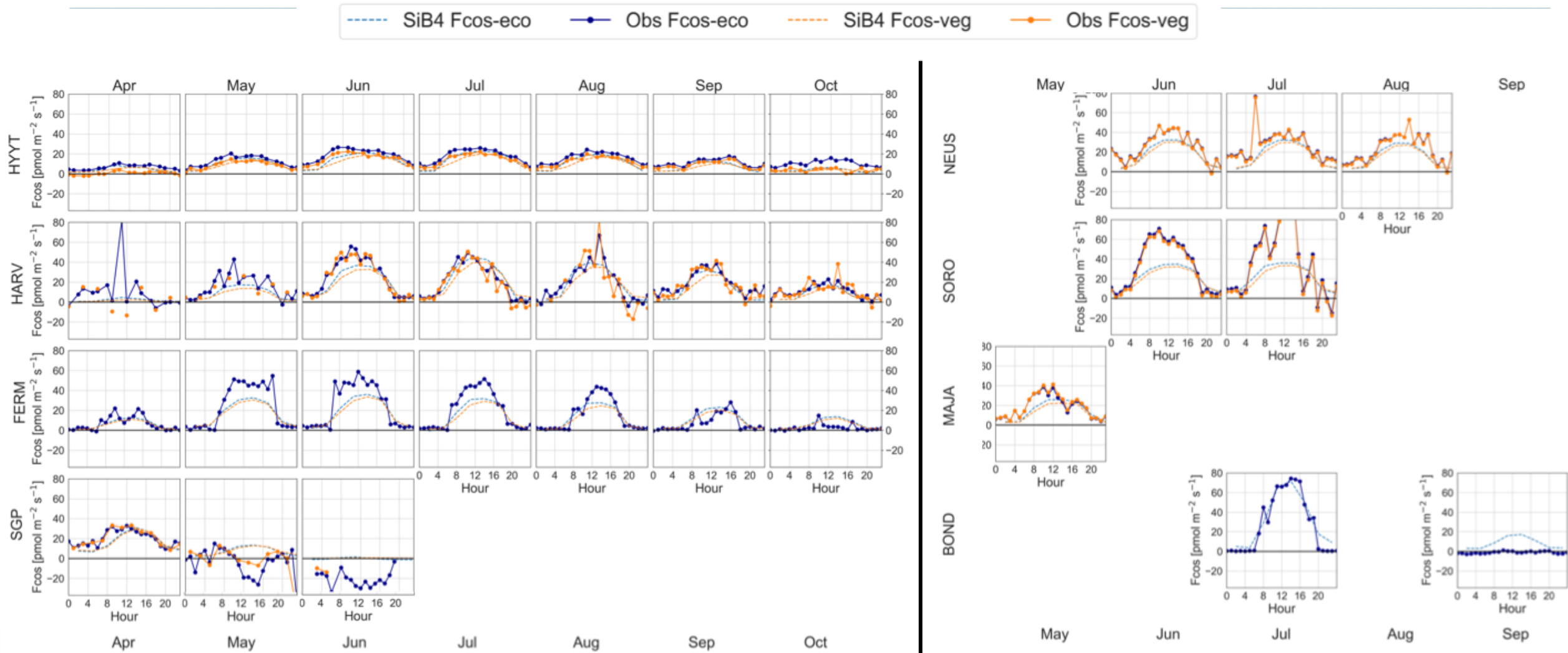


Underestimated COS soil flux at Hyytiälä

Larger emissions when the site is considered to have an agricultural soil (as it is fertilized)

COS soil emissions simulated by Ogee et al. (2016) model, especially large emissions in agricultural soil

Diurnal cycles of COS vegetation and ecosystem uptake



Day- and nighttime model-observation biases

SiB4 COS vegetation fluxes:

Daytime: 8 % underestimated; Nighttime: 22 % underestimated

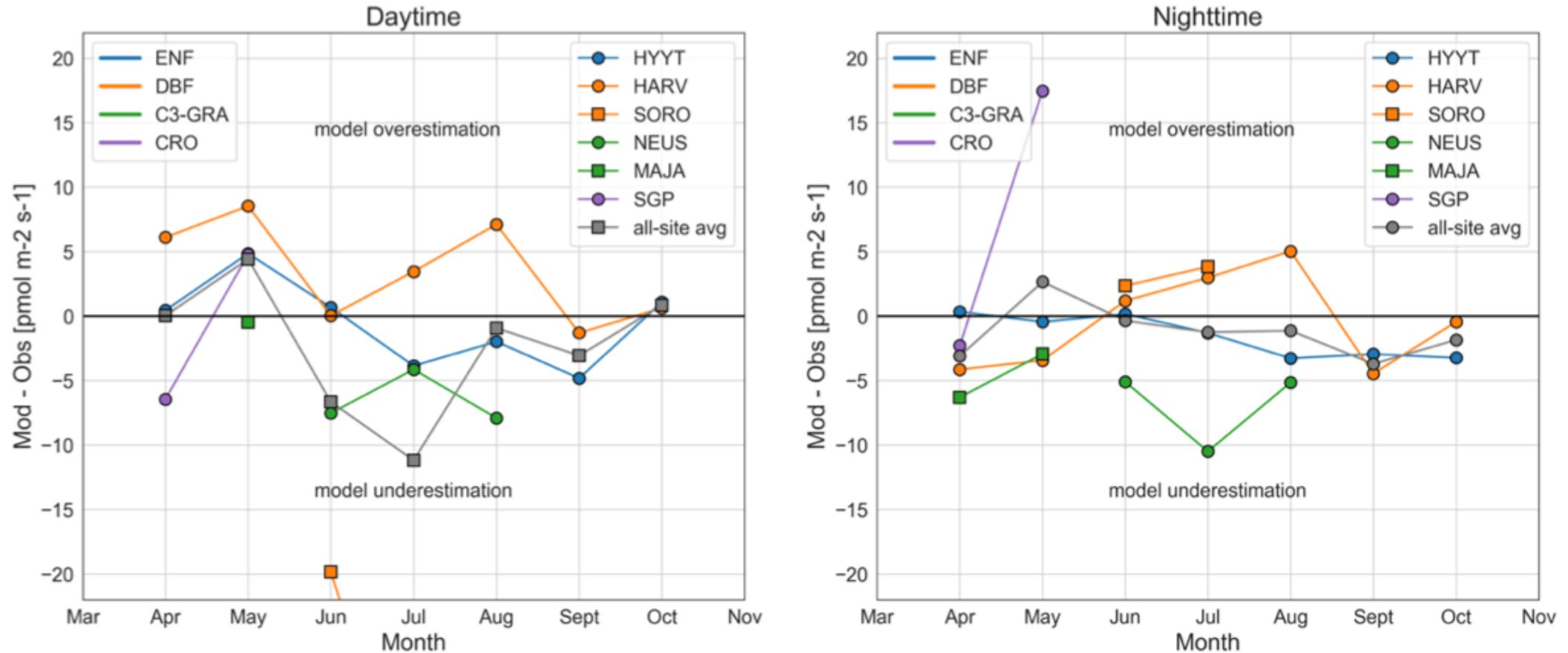


Fig: Difference between model simulations and observations of monthly average COS vegetation fluxes (ecosystem – soil) for daytime data (10 – 15 hr; left) and nighttime data (21 – 03 hr; right).

Calibration factor α derived from field observations

We derive α from COS field observations and investigate its variability over time and the necessity to define a PFT-dependent α :

$$g_t = \frac{1}{\frac{1.94}{g_s} + \frac{1.56}{g_b} + \frac{1}{\alpha \cdot g_i}}$$

$$g_{t,obs} = \frac{F_{COS,veg}}{[COS]} \quad \text{Observed}$$

$$\alpha = \frac{-1}{\frac{g_i}{g_{t,obs}} \left(g_{t,obs} \frac{1.94}{g_s} + g_{t,obs} \frac{1.56}{g_b} - 1 \right)}$$

α has been constant in SiB4, but not all variability from observations is captured.

We do not find patterns in α that apply to all PFTs in the same way that would have helped to update α in SiB4. However....

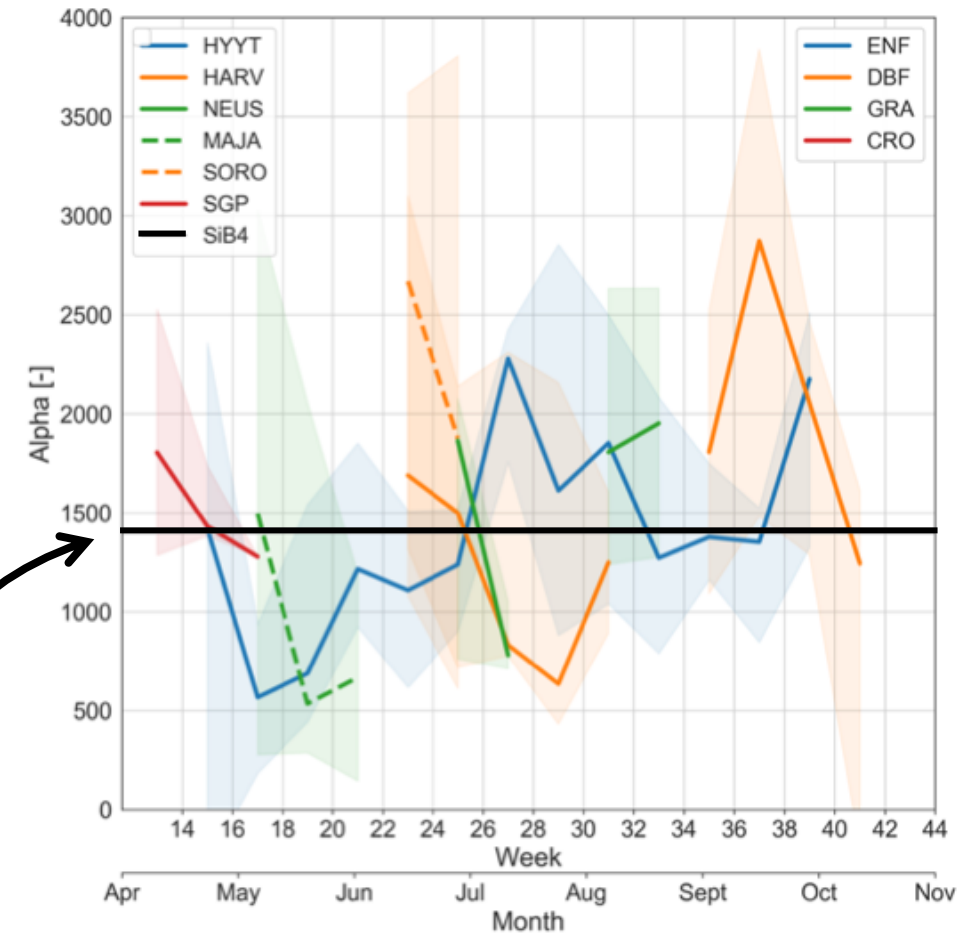
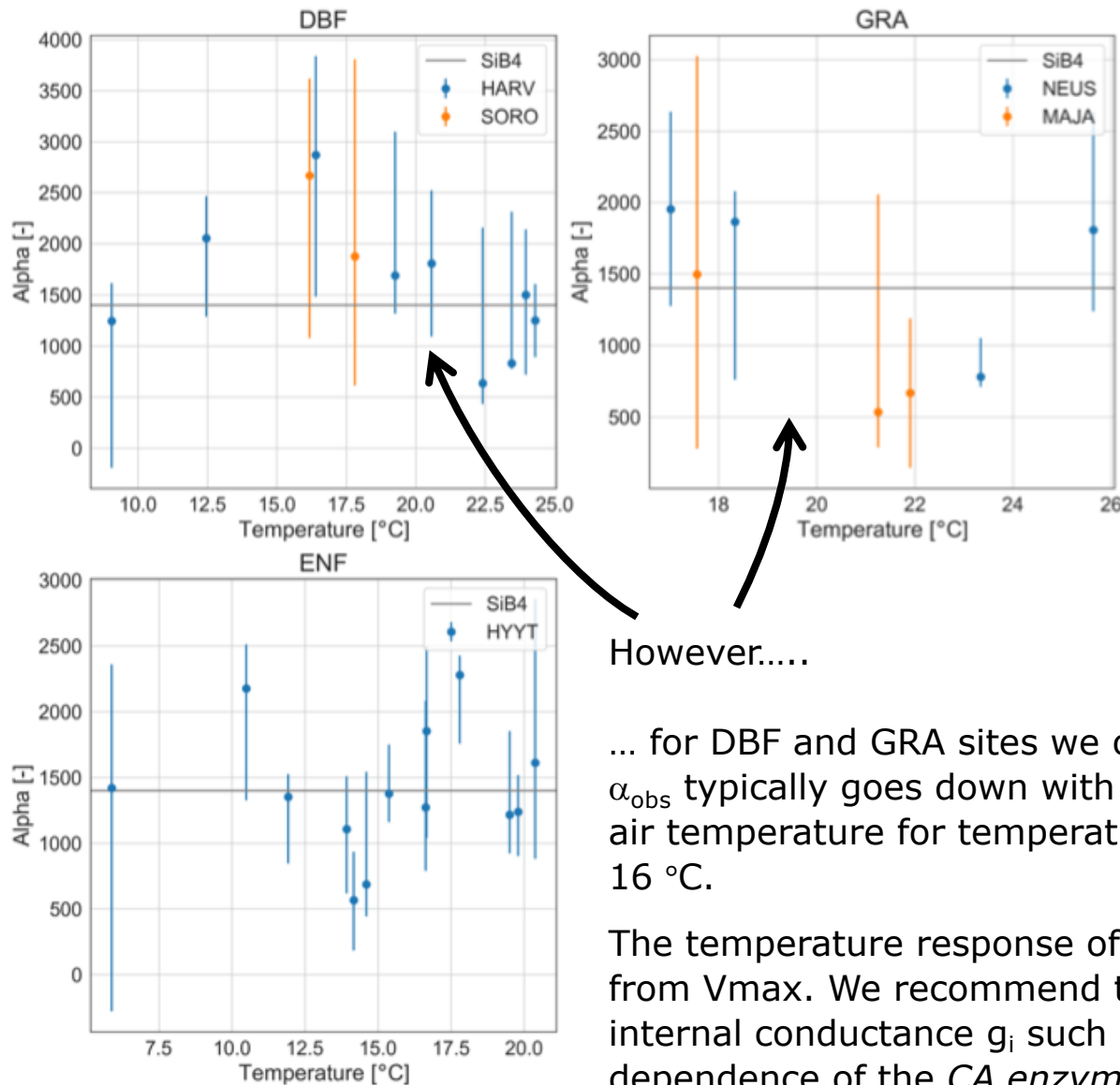


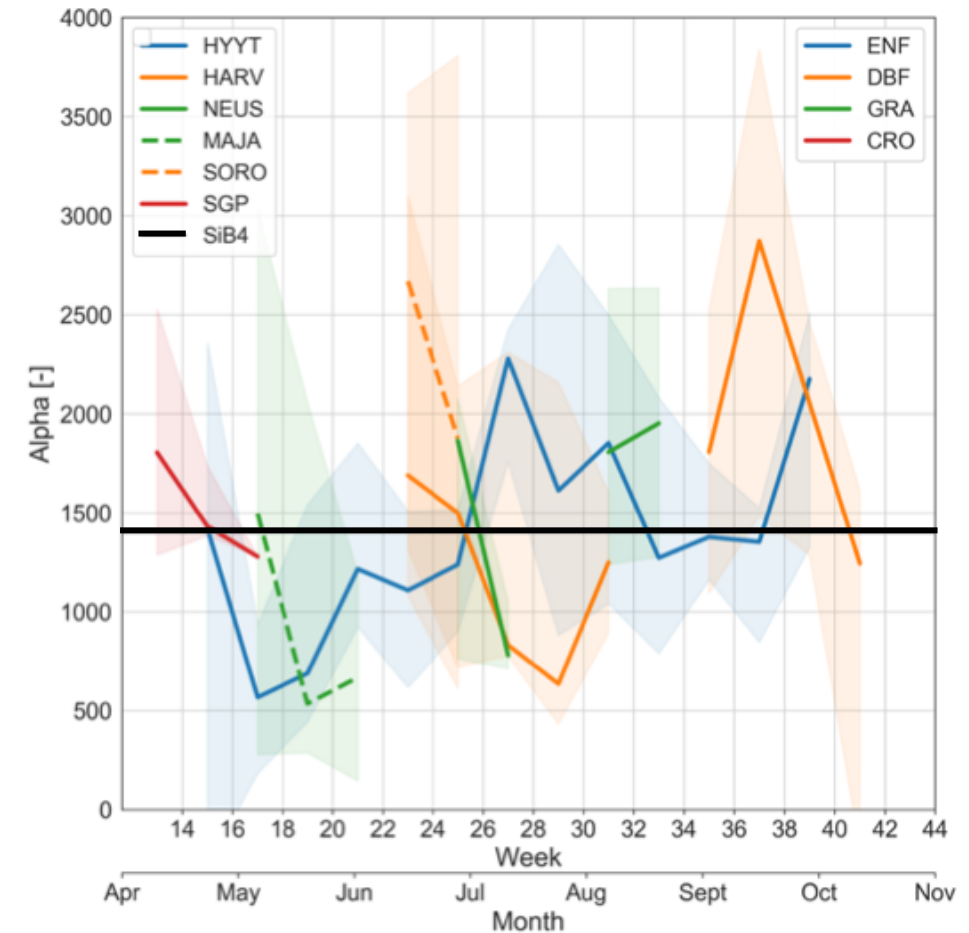
Fig: Seasonal change of observation-based α (α_{obs}) per site in which colors are separated by PFT. Points indicate the median α_{obs} over a period of two weeks. The shaded areas represent the 25th-75th percentiles.

Calibration factor α against temperature



... for DBF and GRA sites we observe that α_{obs} typically goes down with increasing air temperature for temperatures above ~ 16 °C.

The temperature response of the COS uptake is currently taken from V_{max} . We recommend to do a refined calibration of the internal conductance g_i such that it captures the temperature dependence of the *CA enzyme activity*.

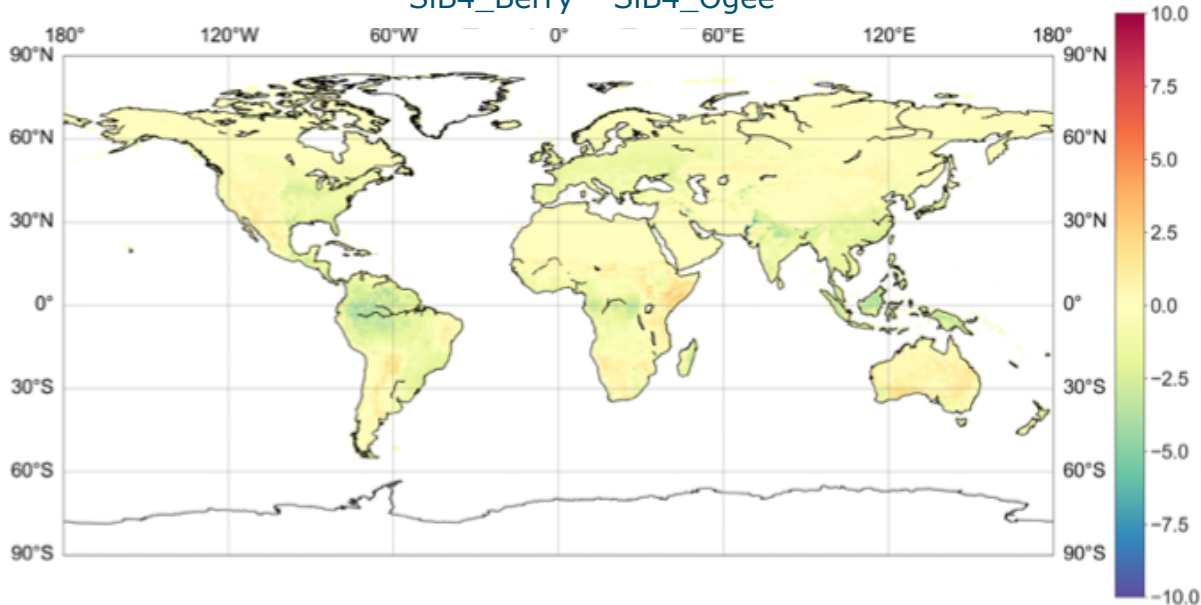


So, is the COS biosphere flux overestimated?

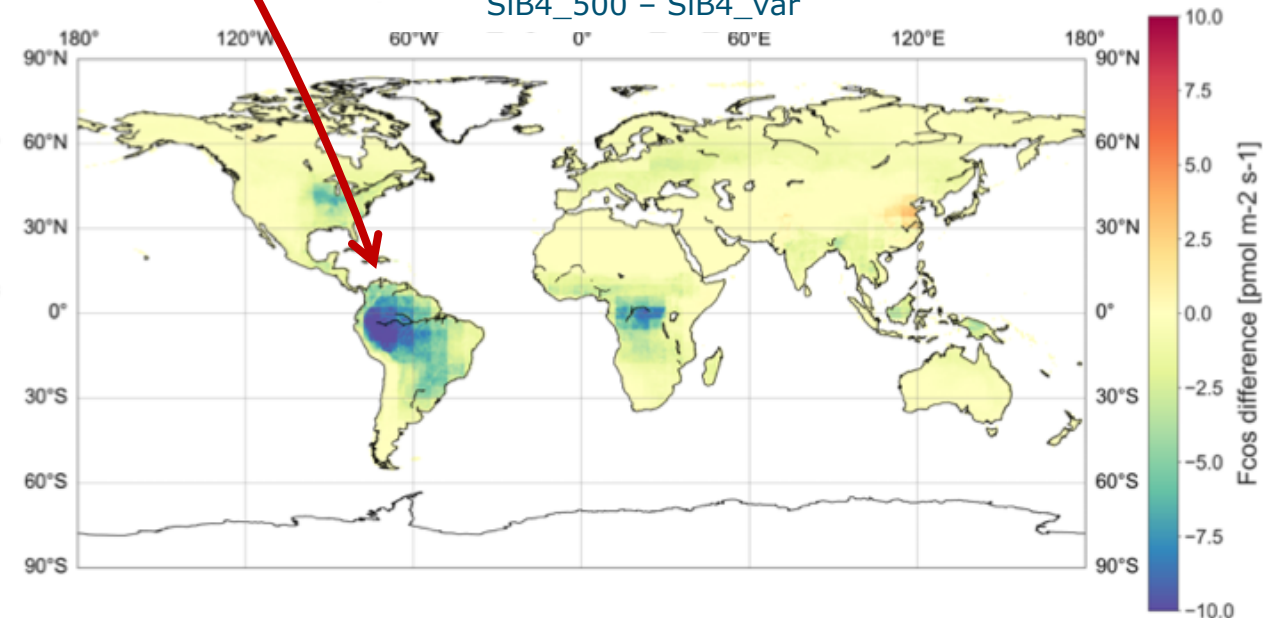
With the updated soil model and COS mole fraction: global COS biosphere uptake reduces from 967 to 788 GgS yr⁻¹.

Reduction mainly in the tropics (123 GgS yr⁻¹)
due to variable (lower) COS mole fractions

$F_{\text{COS-biosphere}}$ difference between soil models
SiB4_Berry – SiB4_Ogee



$F_{\text{COS-biosphere}}$ difference between COS mole fractions
SiB4_500 – SiB4_var



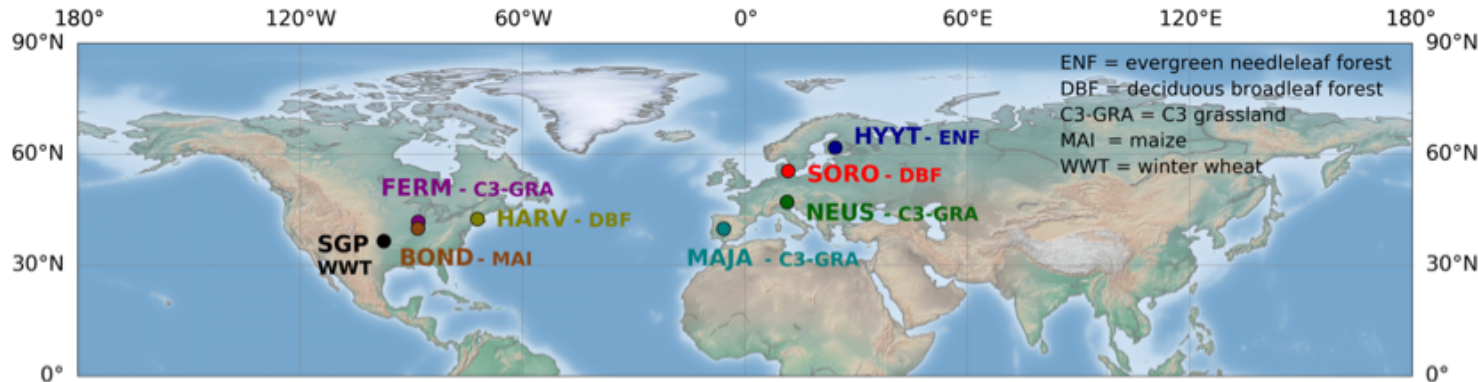
But observations in the tropics missing! ☹️

“Take home” messages

SiB4 capable of simulating seasonal and diurnal variability of COS exchange.

We updated the model with a mechanistic COS soil model and variability of COS mixing ratios.

Variable (lower) COS mole fractions reduce the COS uptake mainly in the tropics, but this reduction is not enough to explain the “missing source” in the COS budget.



But we lack observations in the tropics ☹️