Mitglied der Helmholtz-Gemeinschaft

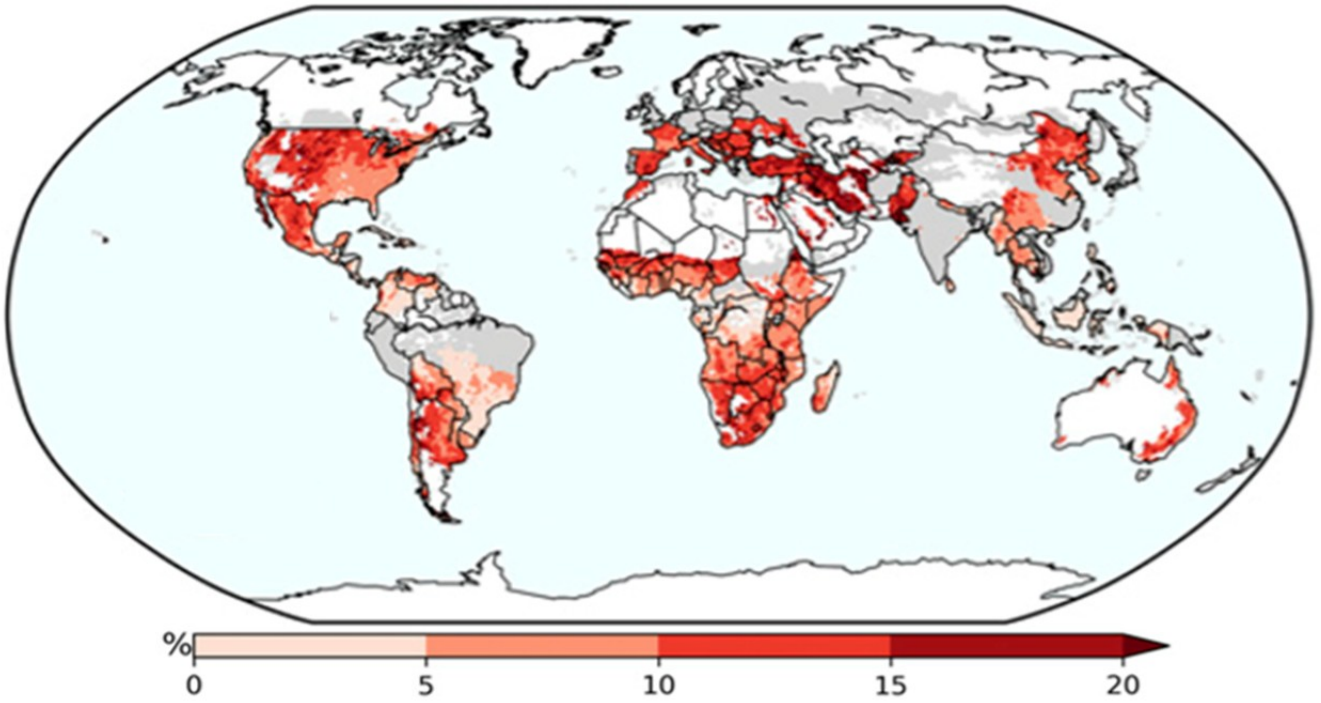
UCLouvain

JÜLICH
FORSCHUNGSZENTRUM

# Constraining a water stress function in a crop growth model using sun-induced chlorophyll fluorescence

*Simon De Cannière, Michael Herbst, Pierre Defourny, Harry Vereecken, François Jonard*

# Drought is an increasingly relevant problem in modern agriculture




Percentage of yield loss

Kimm et al., 2019

- 75% of global cropland
- affected

- 10% crop yield loss on average

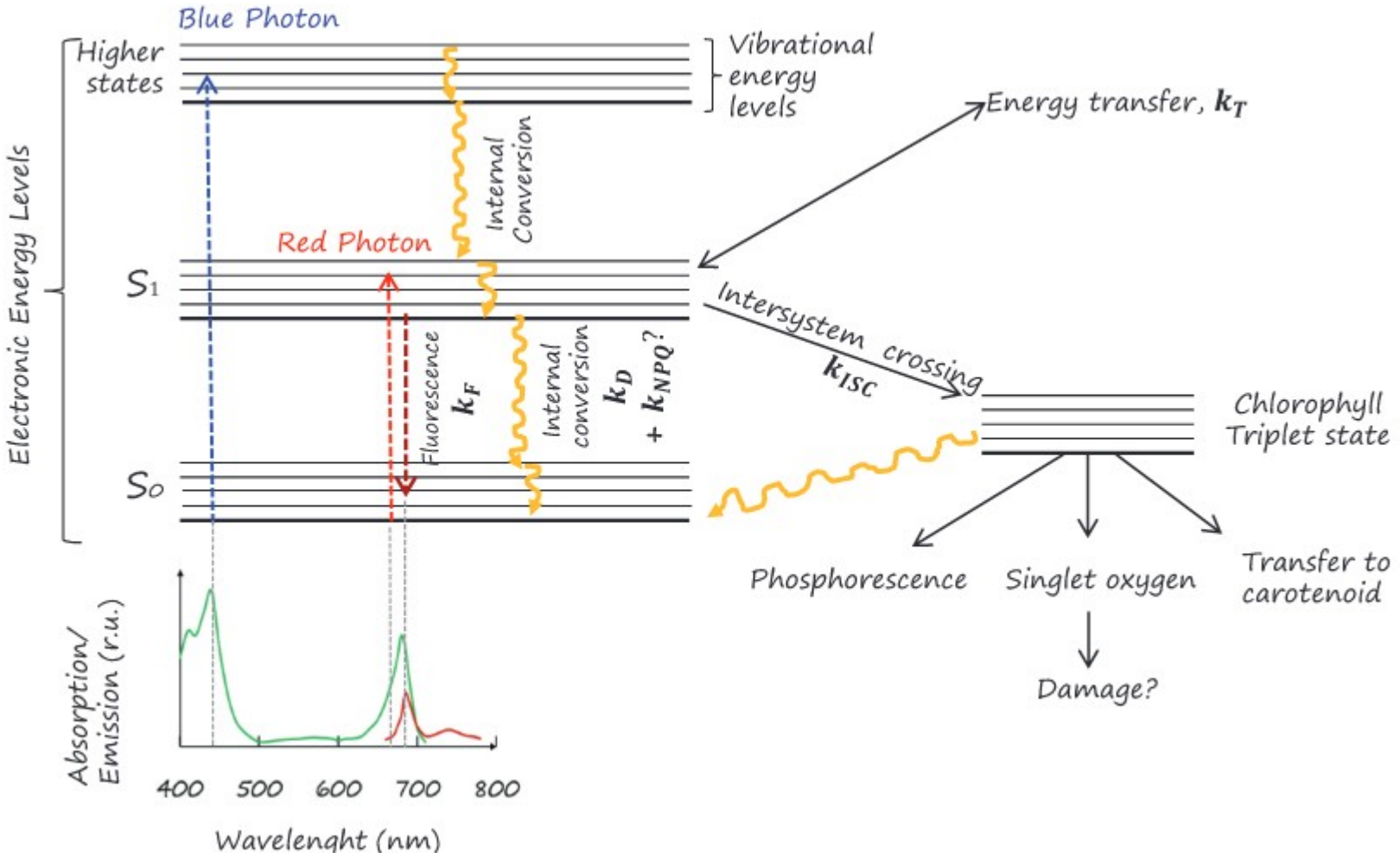
# Fluorescence: a remote sensing signal linked to photosynthesis

Chlorophyll absorbs red and blue photons

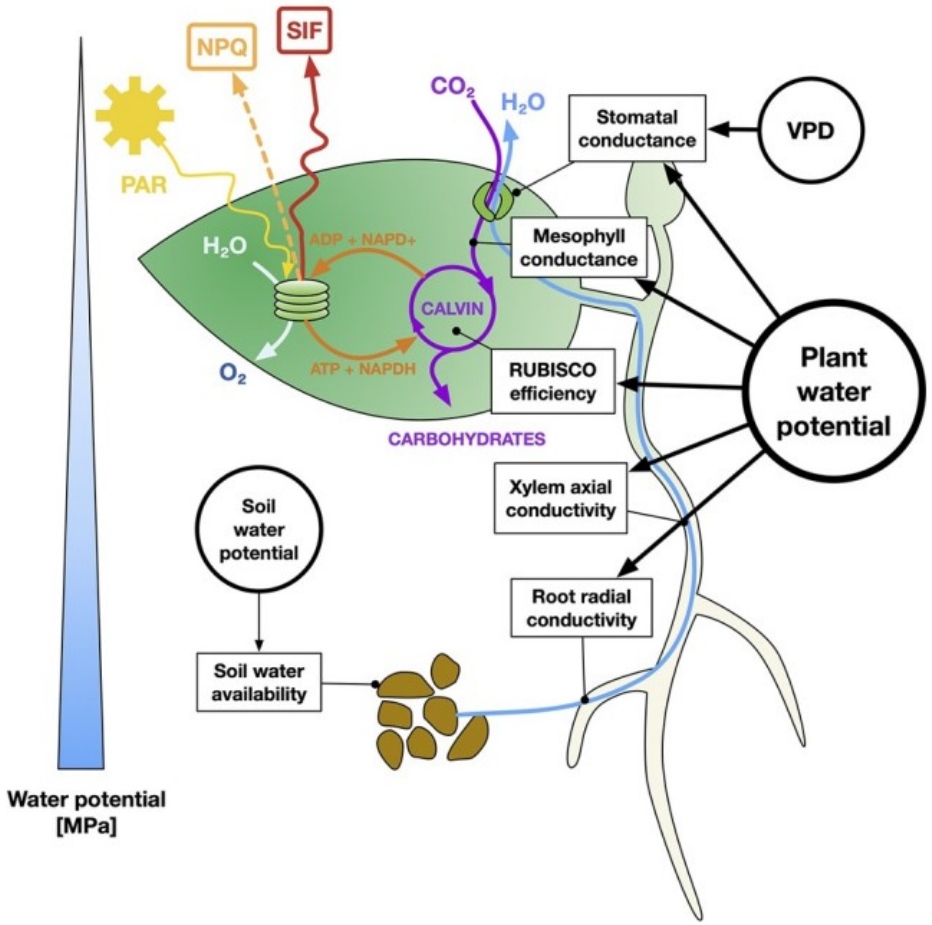
Excess of trapped photons is harmful

**Plant re-emits part of absorbed light**

Fluorescence is about 2% of absorbed light



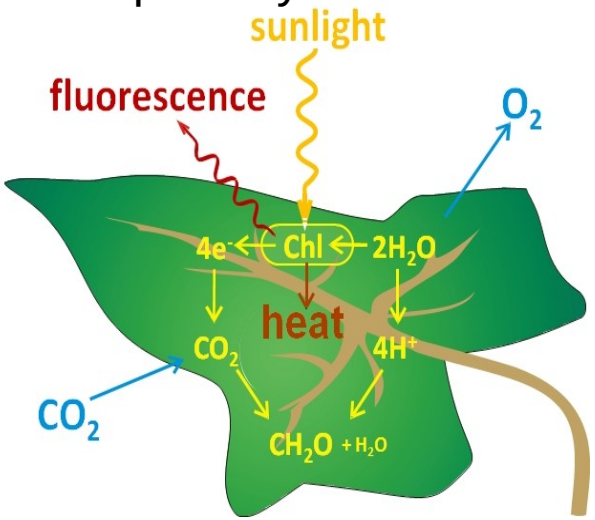
# Fluorescence drought reaction




- $H_2O$ and $CO_2$ are jointly exchanged through stomata
- Plants close stomata in to save water
- Stomatal closure reduces $CO_2$ uptake, photosynthetic rate, increasing heat dissipation lowering, fluorescence emission
- **Overall hypothesis: SIF is reactive to soil moisture and atmospheric dryness (VPD) conditions**

# SIF is an emerging signal for measuring photosynthetic efficency

Fluorescence is linked to photosynthesis



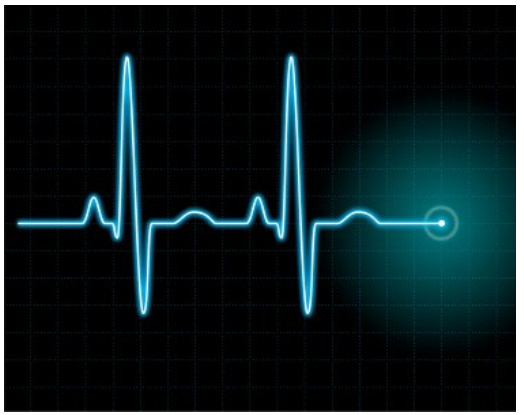

Maxwell & Johnson, 2000

+

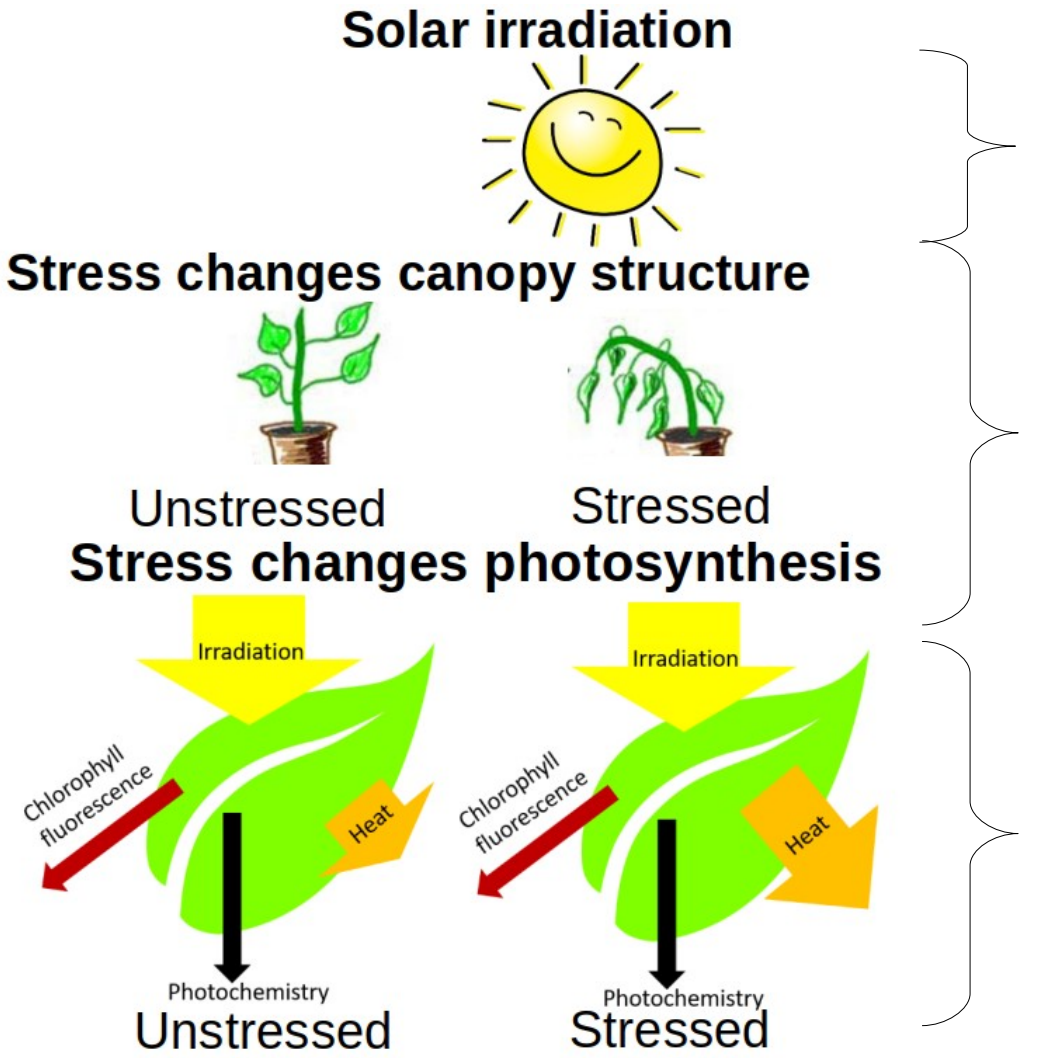
Measure SIF with state of the art spectrometers

FloX, JB hyperspectral, Düsseldorf, DE

Estimate of plant health



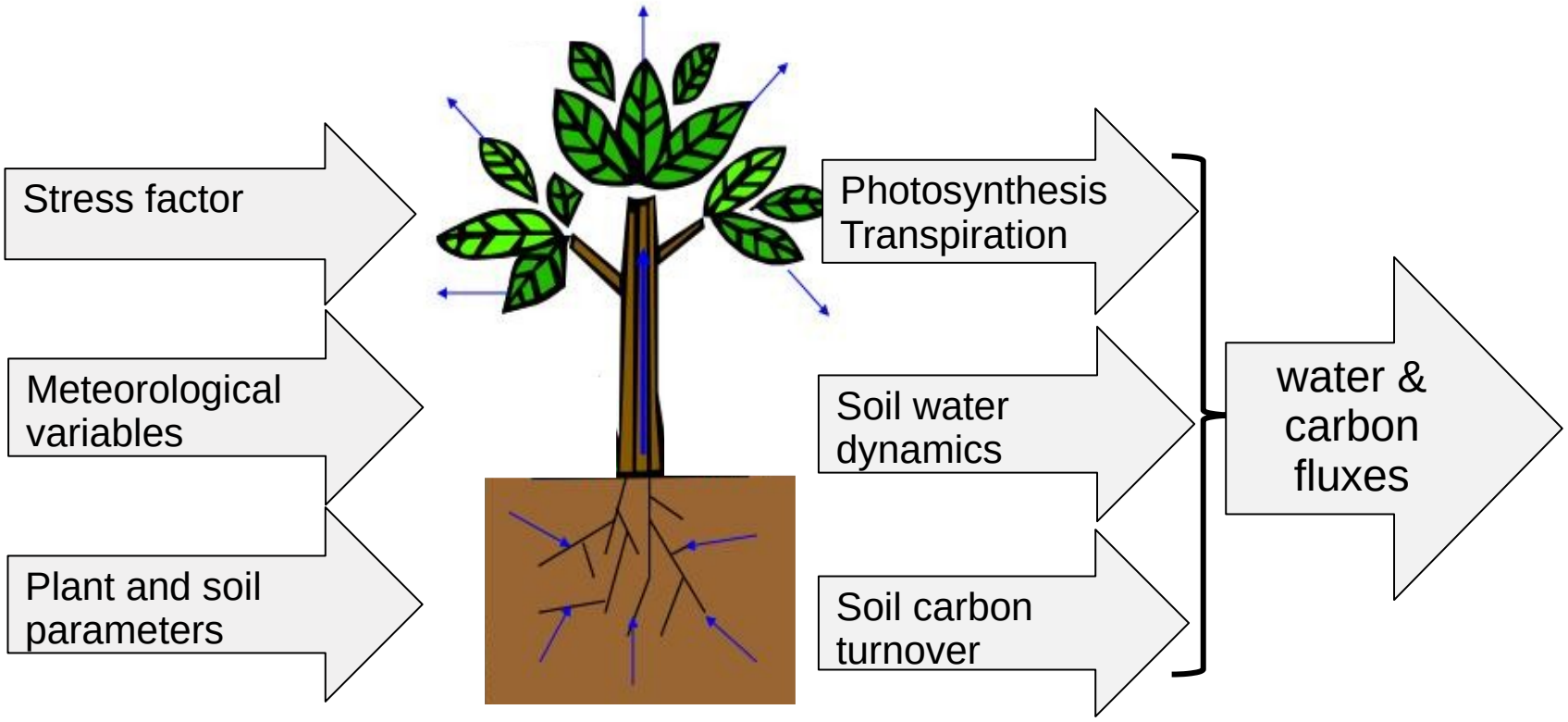
# Interpretation of the SIF signal




$SIF = PAR \times fPAR \times fesc_{\lambda} \times \varepsilon_{\lambda}$

We need to consider both dynamic canopy structure and leaf physiology when interpreting canopy-scale SIF data

# AgroC is a state of the art crop growth model



# Coupling the AgroC and SCOPE models

SIF observations

Modeled canopy-scale SIF

RTM SCOPE

Error

Fluore-scence

Stress factor

Photosynthesis
Transpiration

Meteorological variables

Soil water dynamics

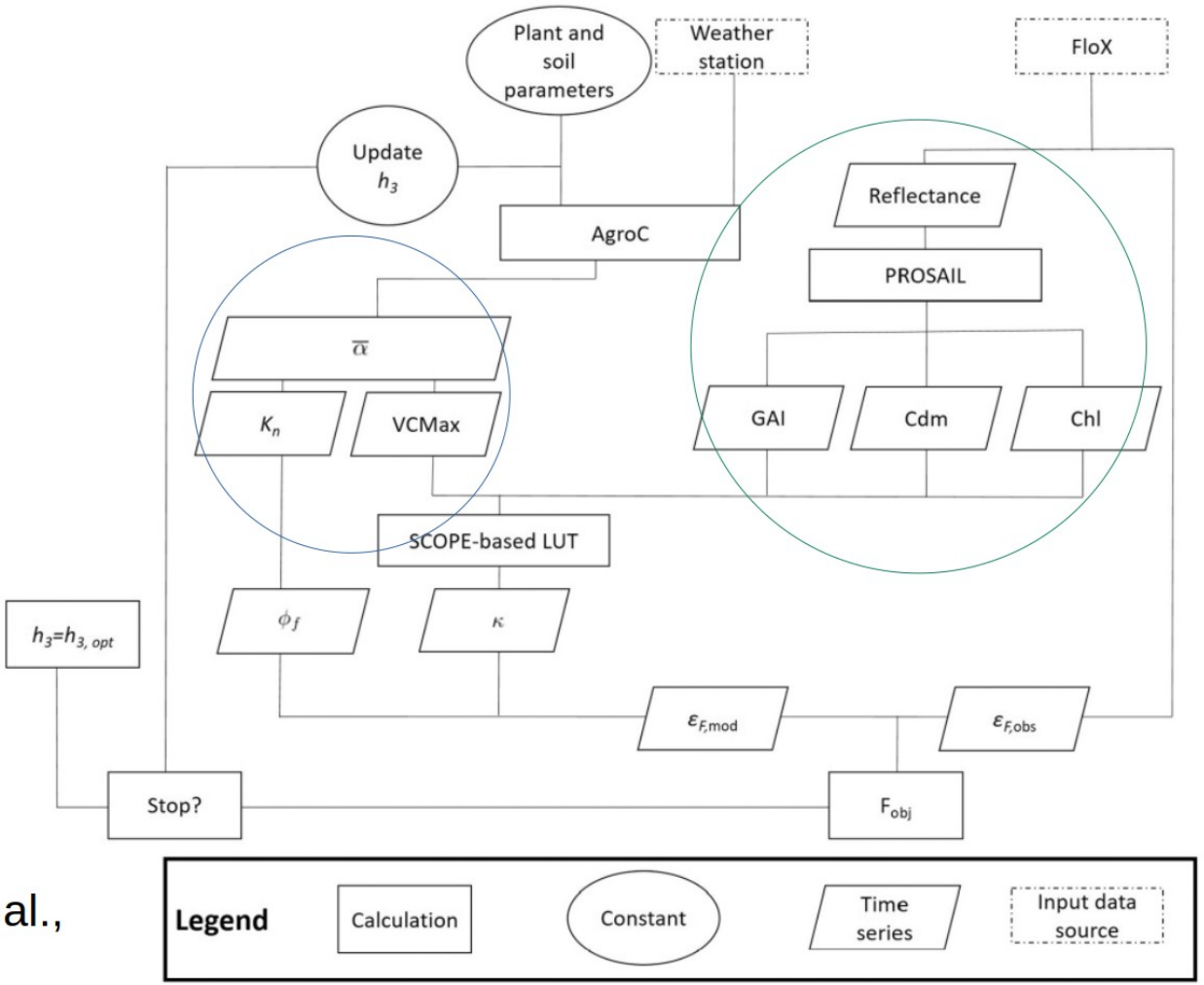
water & carbon fluxes

Plant and soil parameters

Soil carbon turnover

# Coupling the AgroC and SCOPE models

Modelling of $\Phi_F$ stress reaction in crop model




Consider dynamic canopy structure (leaf hanging, leaf rolling, ...)

De Canniere et al., RSE, 2021

# Field experiment to check model approach

Check fluorescence model with field spectrometer

August 2019

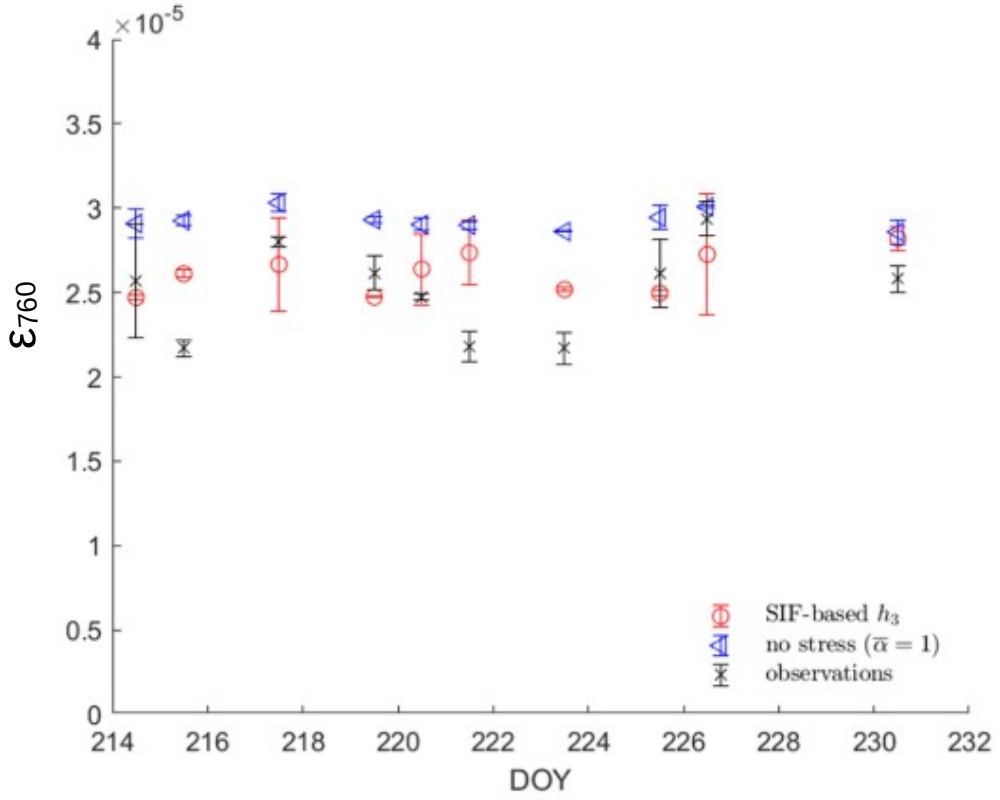
Measure water and carbon fluxes

March-November 2019

Goal: evaluate (I) capacity of $\varphi_F$ to constrain stress factor (II) improvement in carbon flux estimation

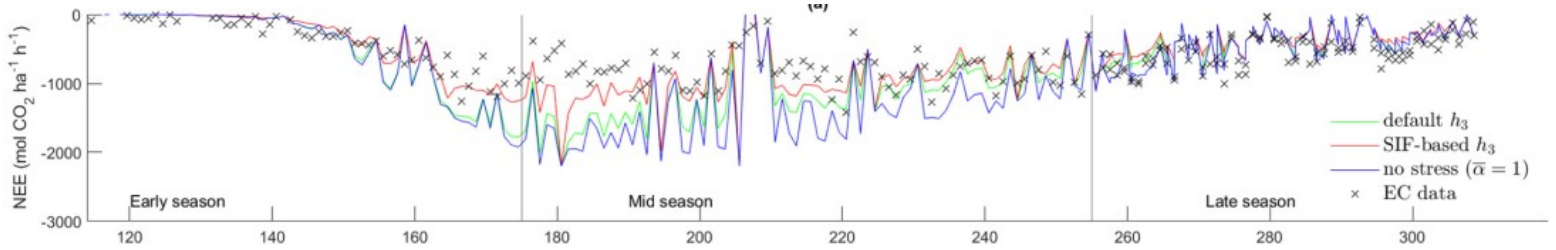
# Modelling fluorescence during measurment period

Comparison field data and modeled $\varphi_F$




- Inserting Feddes stress factor in photosynthetic equations improves $\varphi_F$ estimation
- Period in which SIF data are taken is a lot shorter than the growing season

# Calibrating $h_3$ improves NEE estimation




- Improvement mainly visible in the mid-season
- Mid-season is the hottest time of the year
- Improvement of stress factor leads to better $CO_2$ fluxes during stress

# Take home message

- Sun-Induced Chlorophyll Fluorescence (SIF) is an emerging remote sensing signal, providing information on photosynthetic efficiency
- Inserting Feddes stress factor in photosynthetic equations improves $\varphi_F$ estimation
- Improving the parametrization of the Feddes stress function improves the carbon flux estimation over the whole growing season