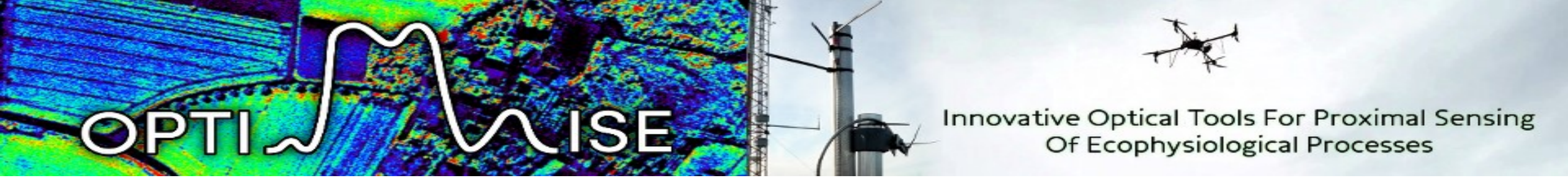

Foliar optical indices exploring the photosynthetic spring recovery of boreal evergreen trees

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2017-02-23

OPTICS OF PHOTOSYNTHESIS LAB

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- SIF can scale leaf measurement to canopy and ecosystem scales.
- **Nevertheless, no study so far has evaluated the seasonal relationship between leaf level spectral F and photosynthesis.**

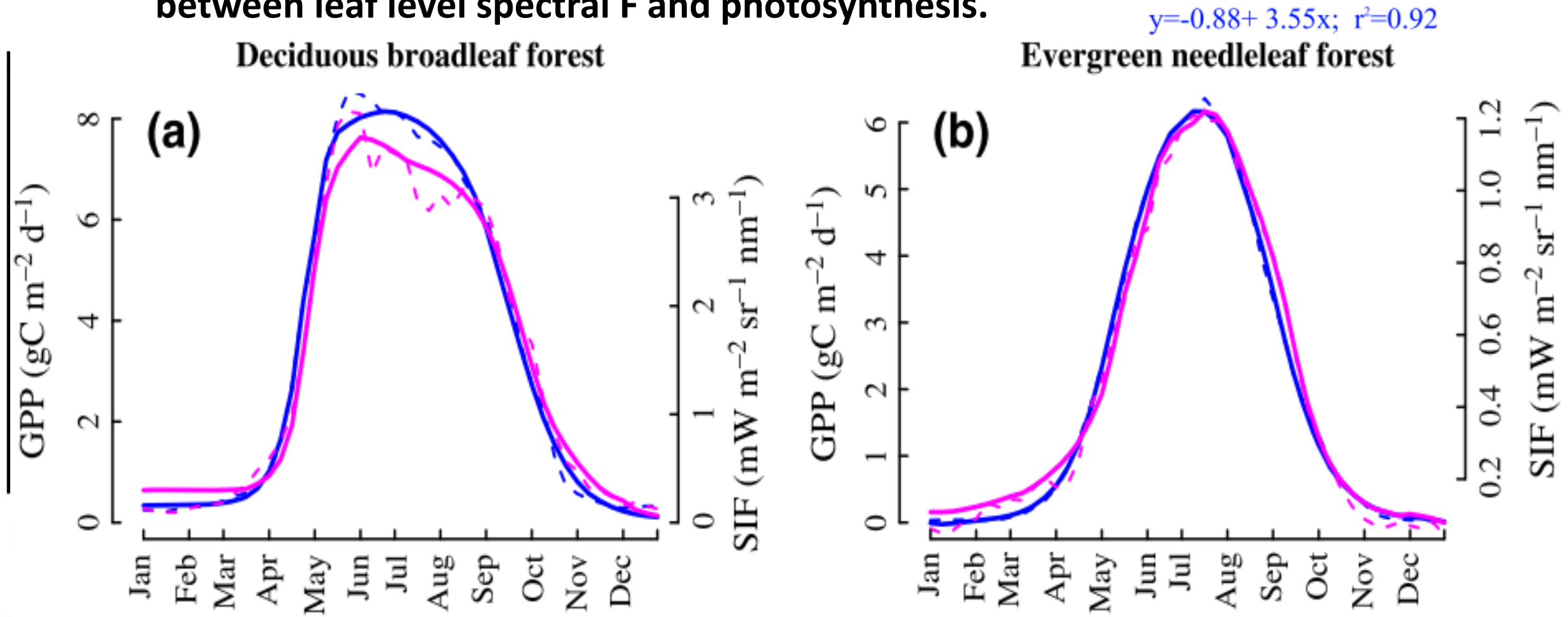


Fig. 1. Global map of m… cence (SIF) per 0.5° grid box for 2009.

Walther et al., 2015

Guanter et al., 2014

Foliar optical indices exploring the photosynthetic spring recovery of boreal evergreen trees

Objectives

- To characterize the spectral changes in ChlF and needle reflectance during the critical spring recovery of photosynthesis of boreal evergreen trees;
- To compare the performance of multiple optical indices including spectral F, PRI, NDVI, and WI;
- To assess the information content of different fluorescence wavelengths for tracking leaf level seasonal dynamics of photosynthesis.

Foliar optical indices exploring the photosynthetic spring recovery of boreal evergreen trees

- Site: SMEAR II station, Hyytiälä, Finland.
- Campaign duration: 2015-02-24 to 2015-07-20.
- Species: *Pinus sylvestris* (52-year old in 2015).

Tower

Fv/Fm (Measured by FMS2)

Fv/Fm (Measured by MoniPAM)

Laboratory

Needles (keep fresh in liquid nitrogen)

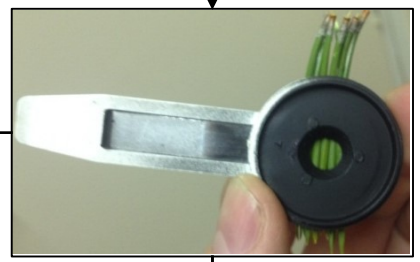
Pigment extraction and analysis: **Chlorophyll a and b and Carotenoid**

Needles

Needle water content (WC)

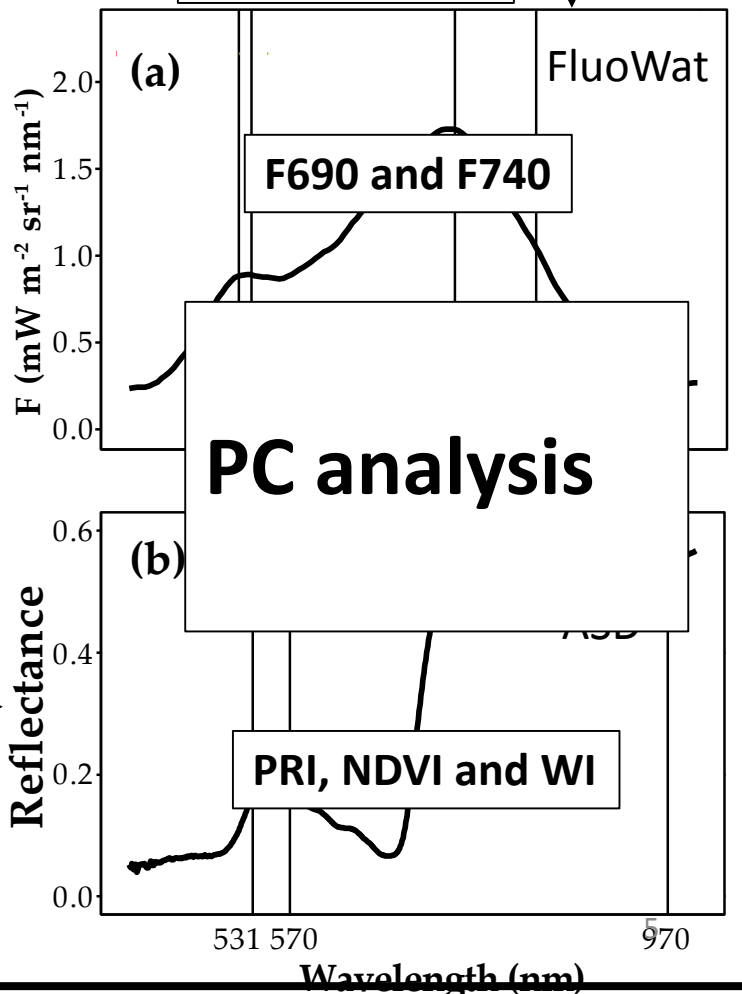
Measure the fresh weight

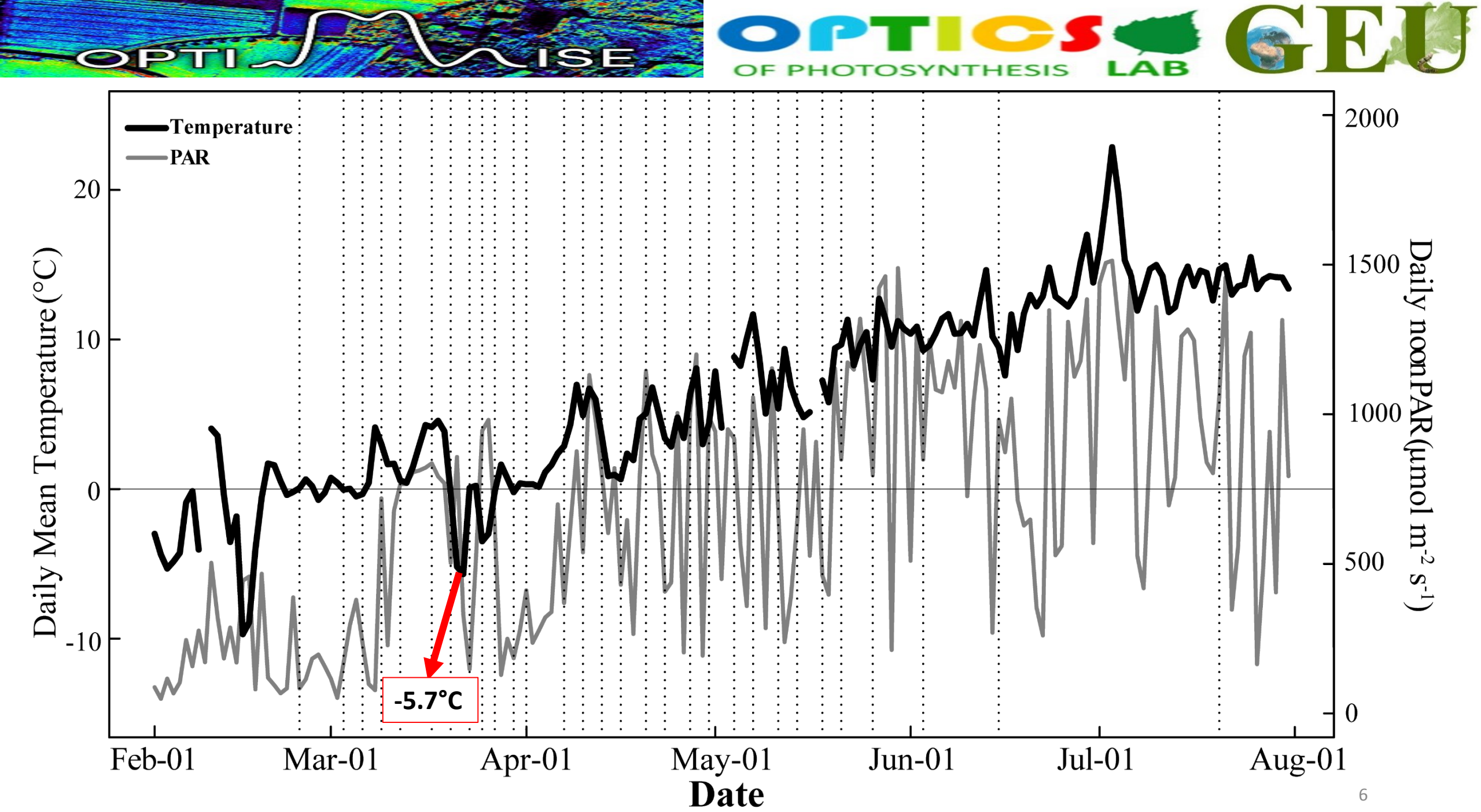
Dry the needles in the oven at 70 °C

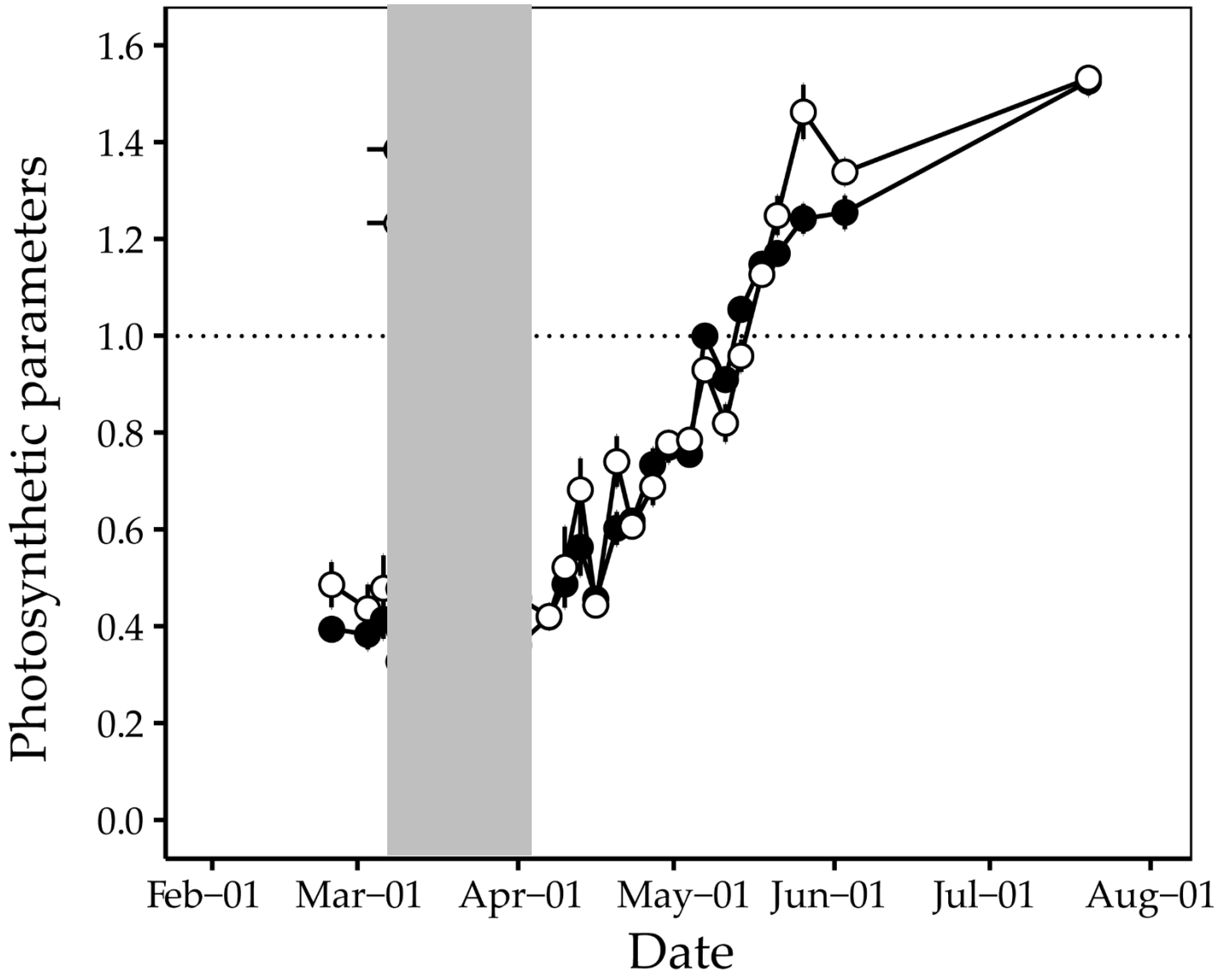


Fv/Fm (Measured by FMS2)

Needle mats




Temperature
PAR
Daily Mean Temperature (°C)
Daily noon PAR (µmol m-2 s-1)
20
10
0
-10
2000
1500
1000
500
0
-5.7°C
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Date

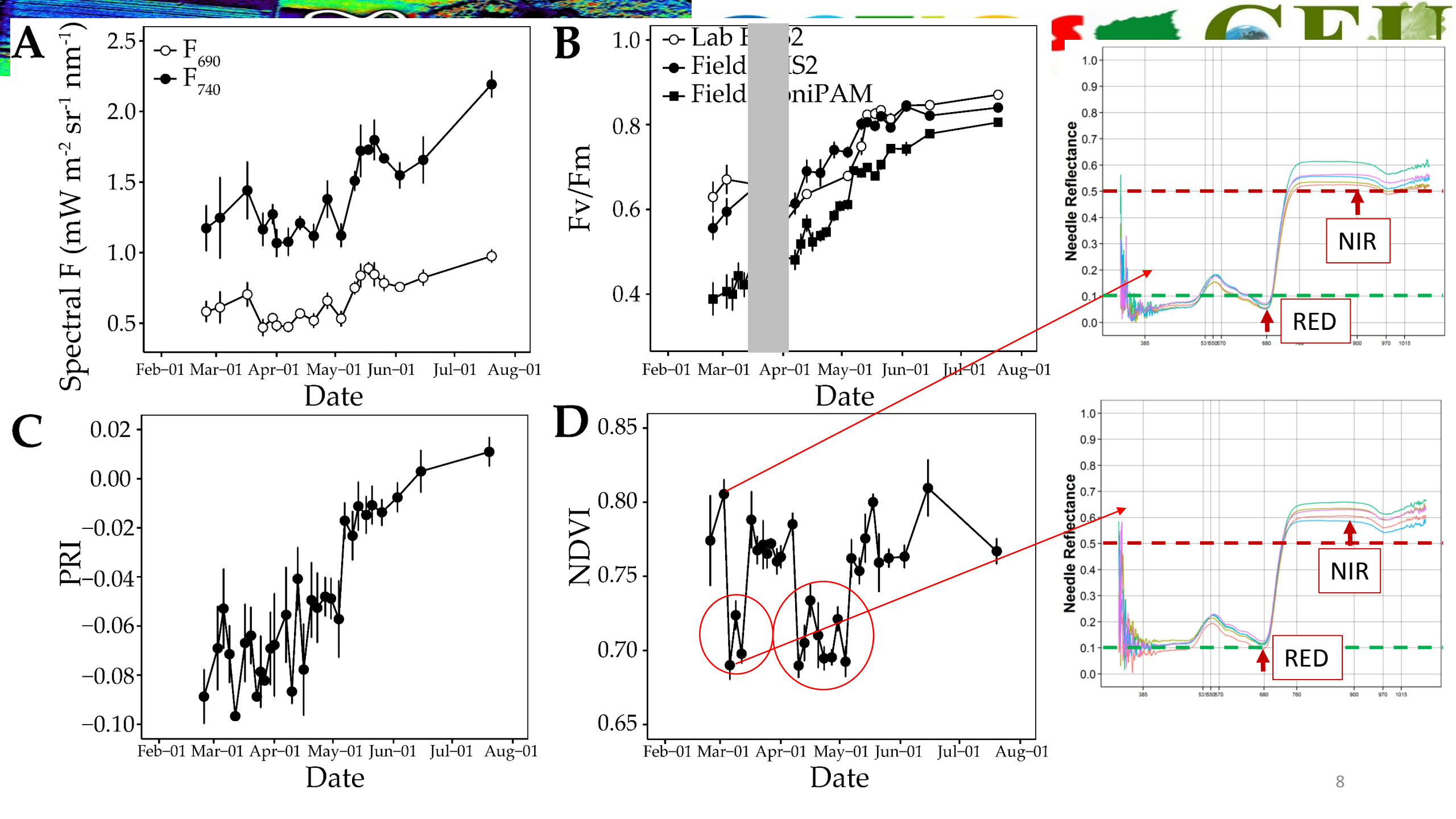


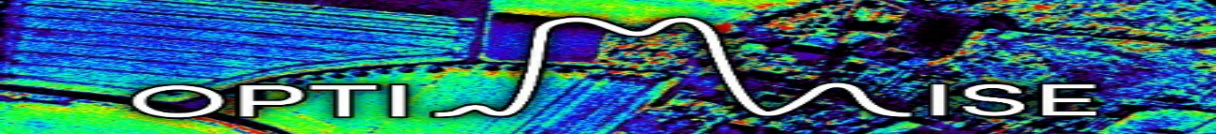
Photosynthetic parameters were estimated in 3-day time window:

β (m s^{-1}), photosynthetic efficiency in the optimal stomatal control model (Hari et al. 1986, see also Kolari et al. 2007). The parameter is essentially the rate of light-saturated photosynthesis (Amax) per unit inter-cellular CO2 concentration (Ci).

α (µmol CO_2/µmol PAR), the slope of linear function fitted to the photosynthetic light response with low incident PAR (<300 µmol m^{-2} s^{-1}) before noon (Kolari et al., 2014).

The time series of β and α were normalized for each studied shoot with the respective parameter values between May 3 and 24, and denoted as β_n and α_n .


A
Spectral F (mW m-2 sr-1 nm-1)
F690
F740
Feb–01 Mar–01 Apr–01 May–01 Jun–01 Jul–01 Aug–01
Date
B
Fv/Fm
Lab F
Field
Field
Feb–01 Mar–01 Apr–01 May–01 Jun–01 Jul–01 Aug–01
Date
Needle Reflectance
NIR
RED
C
PRI
Feb–01 Mar–01 Apr–01 May–01 Jun–01 Jul–01 Aug–01
Date
D
NDVI
Feb–01 Mar–01 Apr–01 May–01 Jun–01 Jul–01 Aug–01
Date
Needle Reflectance
NIR
RED



OPTICS OF PHOTOSYNTHESIS LAB

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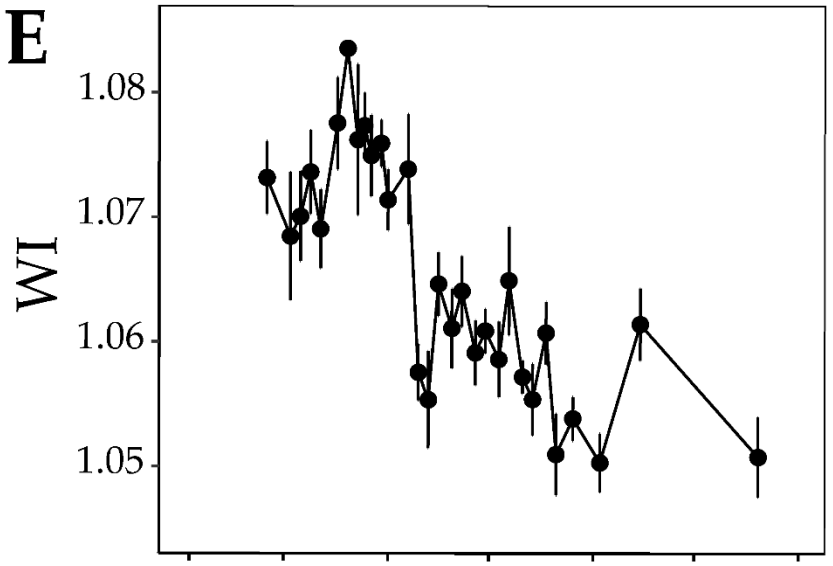
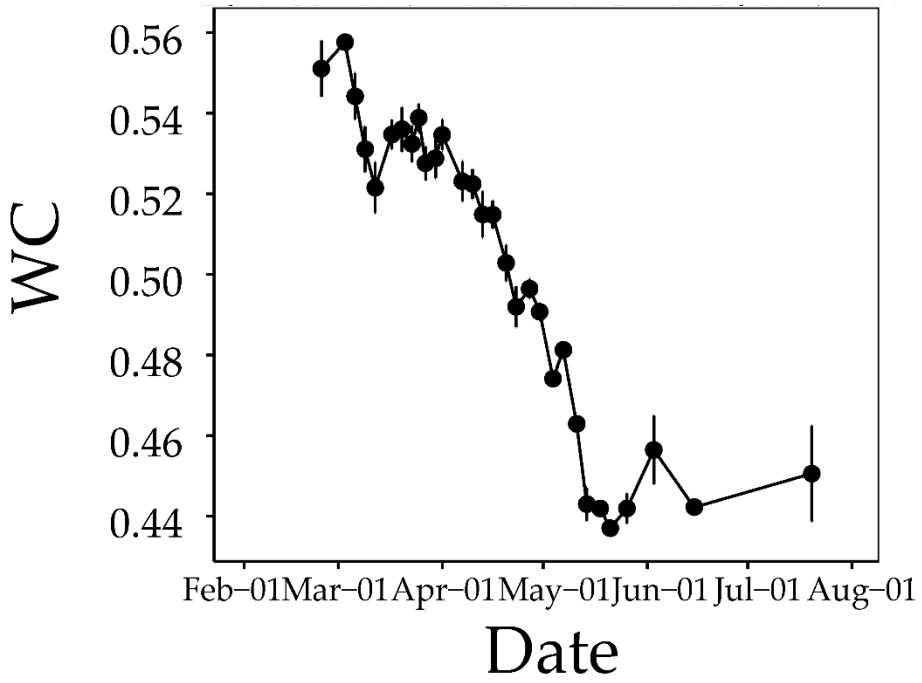
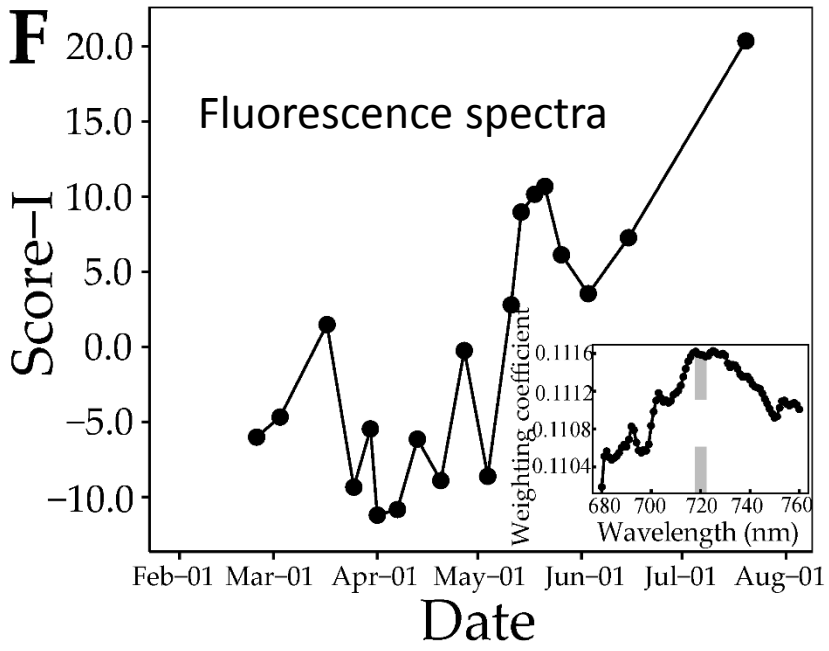
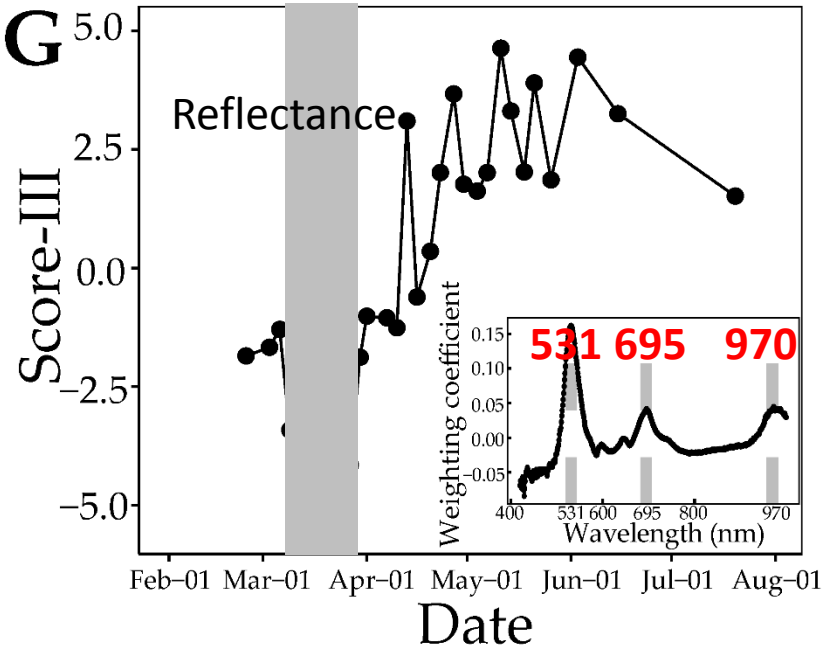




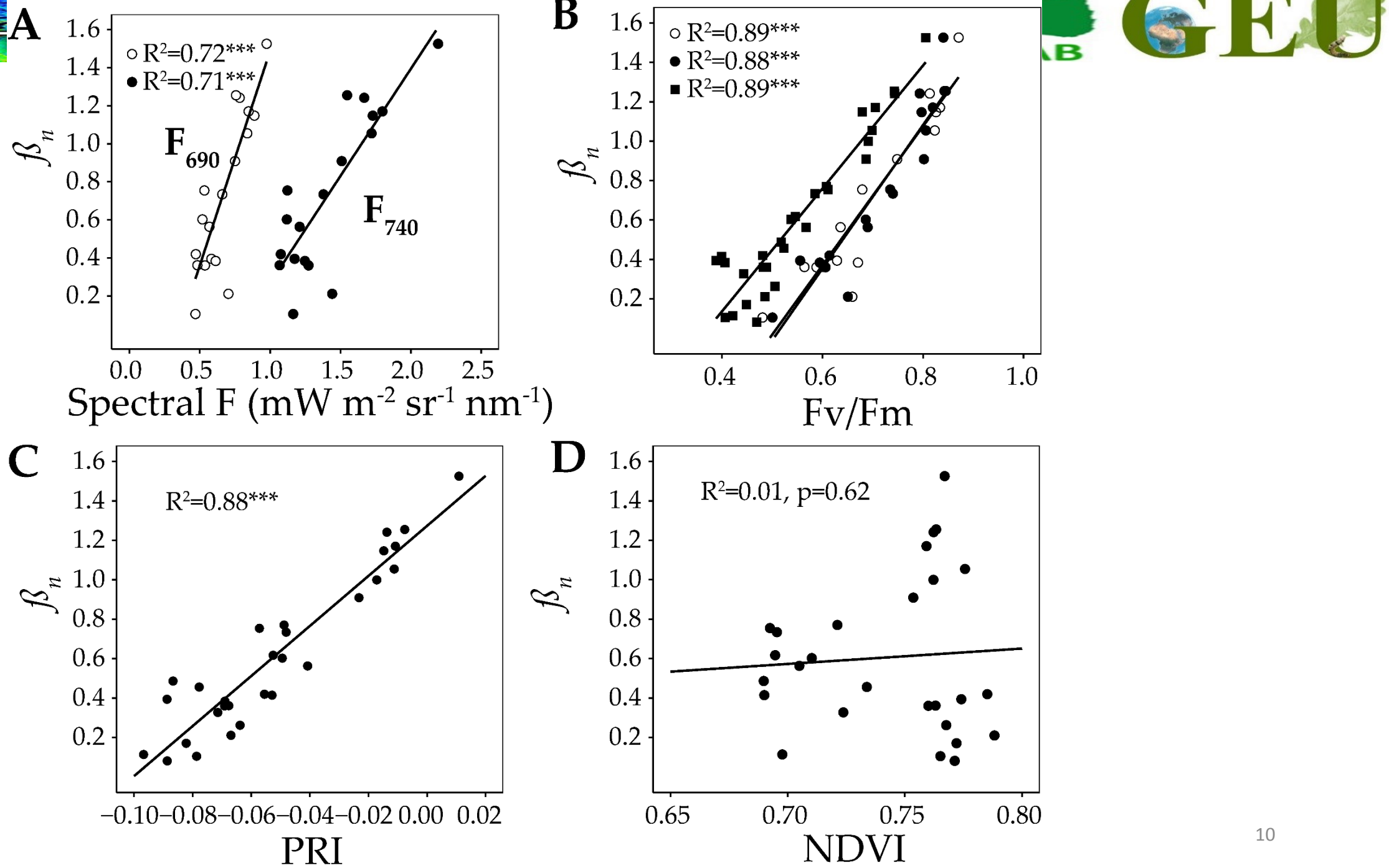


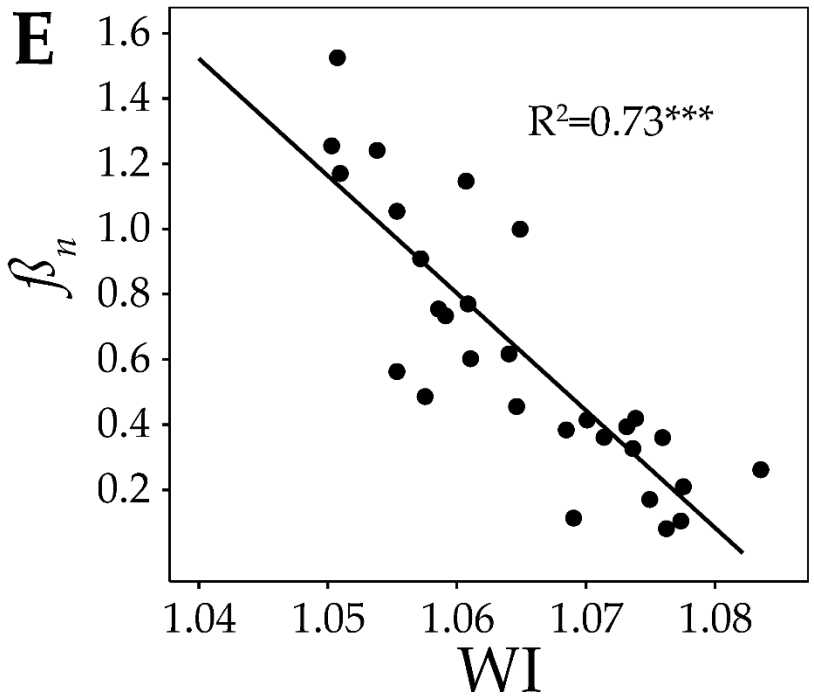


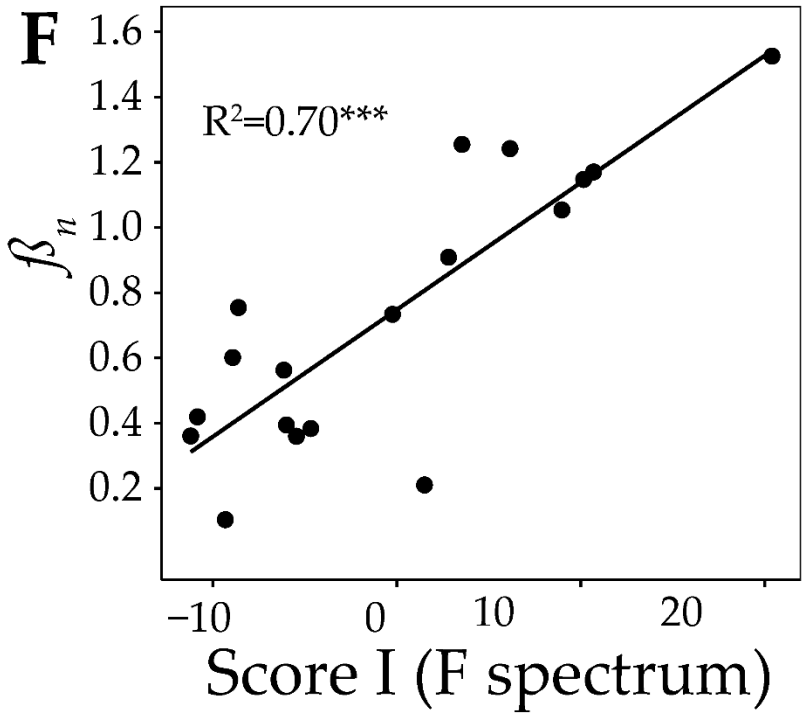
531nm → **PRI**

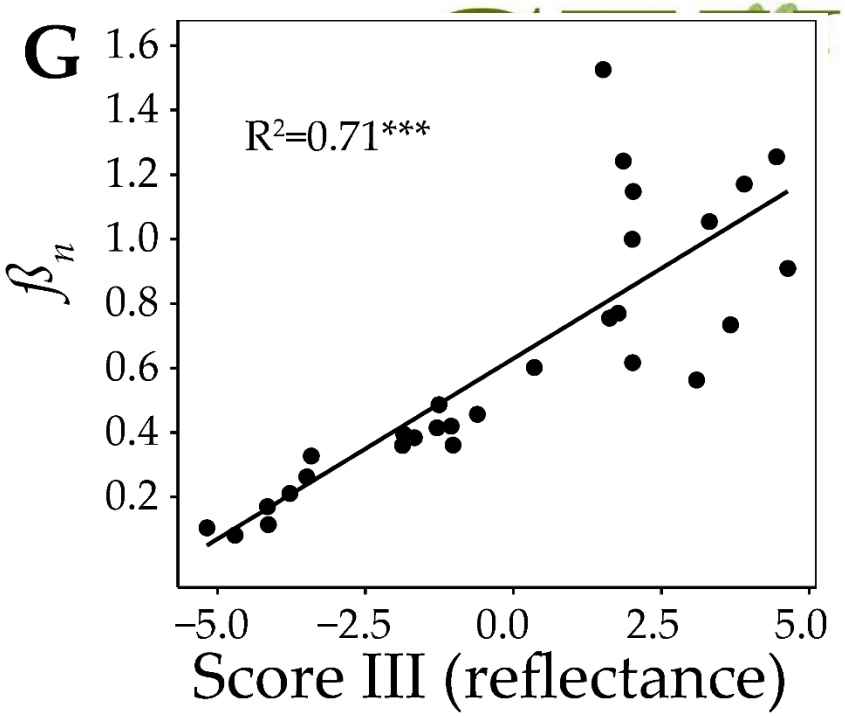
695nm → **Chlorophyll or superimposition of the Chl F**

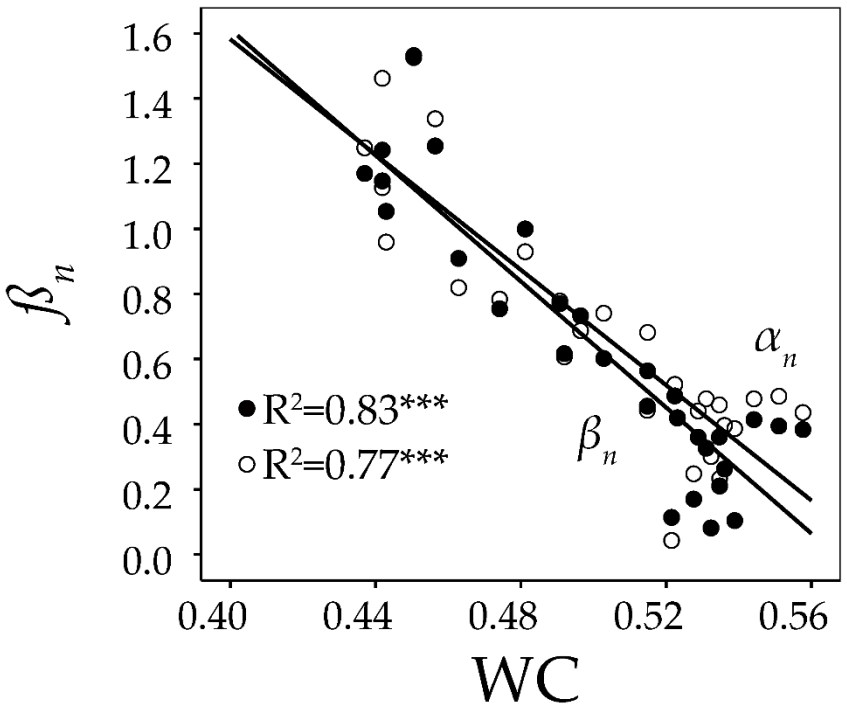
970nm → **Water absorption**

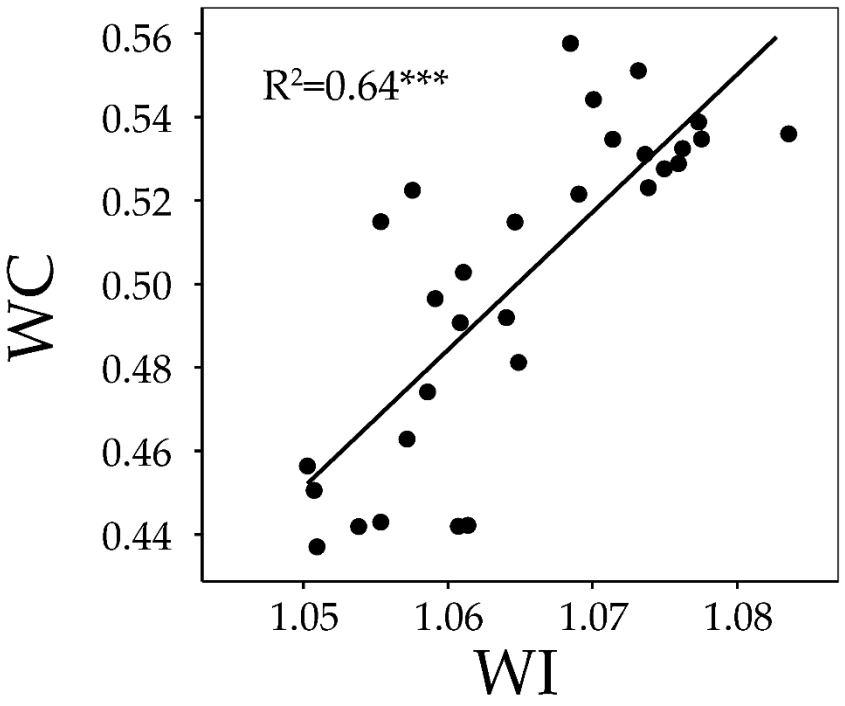

A
B
C
D
R^2=0.72***
R^2=0.71***
F_{690}
F_{740}
$ß_n$
Spectral F (mW m^{-2} sr^{-1} nm^{-1})
R^2=0.89***
R^2=0.88***
R^2=0.89***
Fv/Fm
R^2=0.88***
PRI
R^2=0.01, p=0.62
NDVI


E
R²=0.73***
ßn
WI

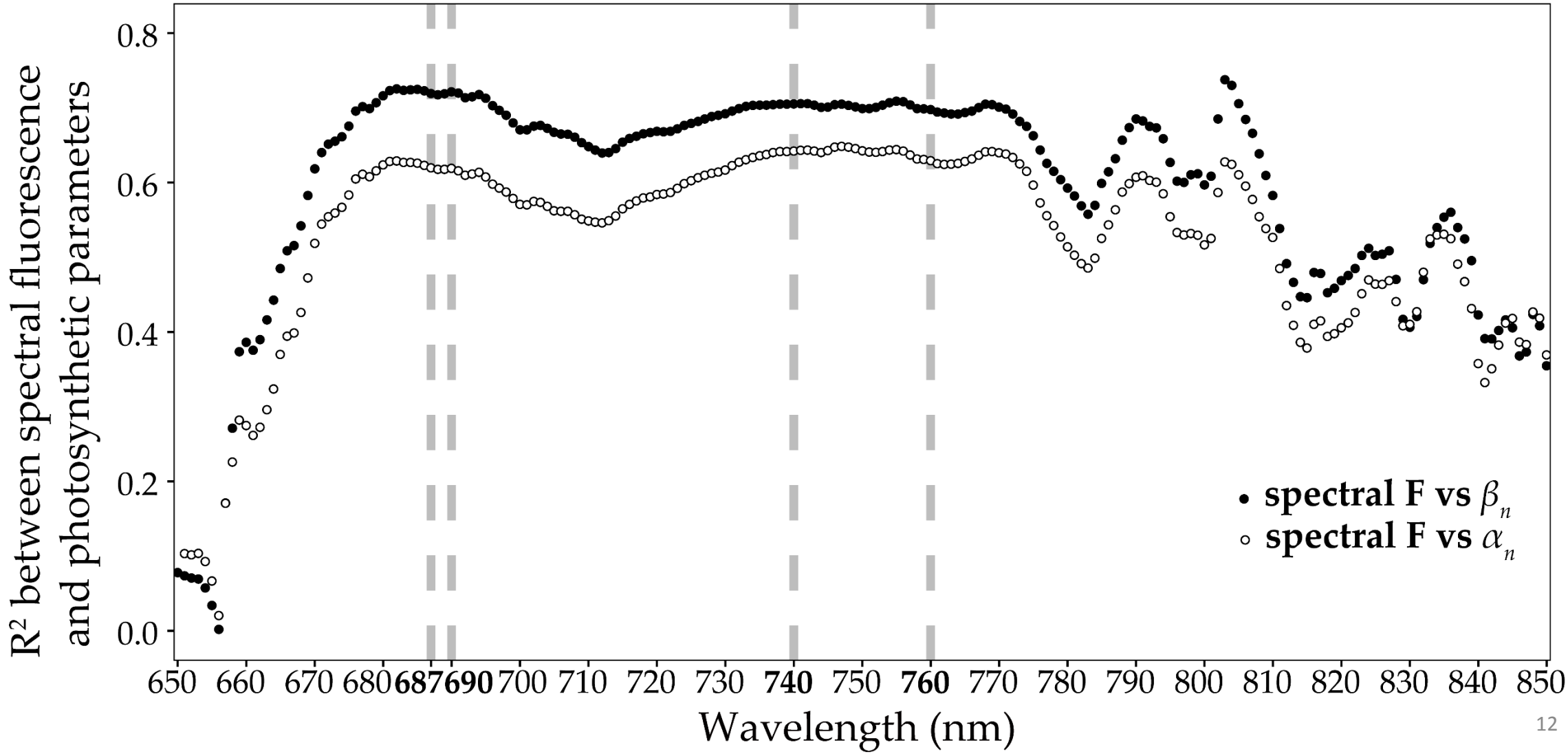

F
R²=0.70***
ßn
Score I (F spectrum)

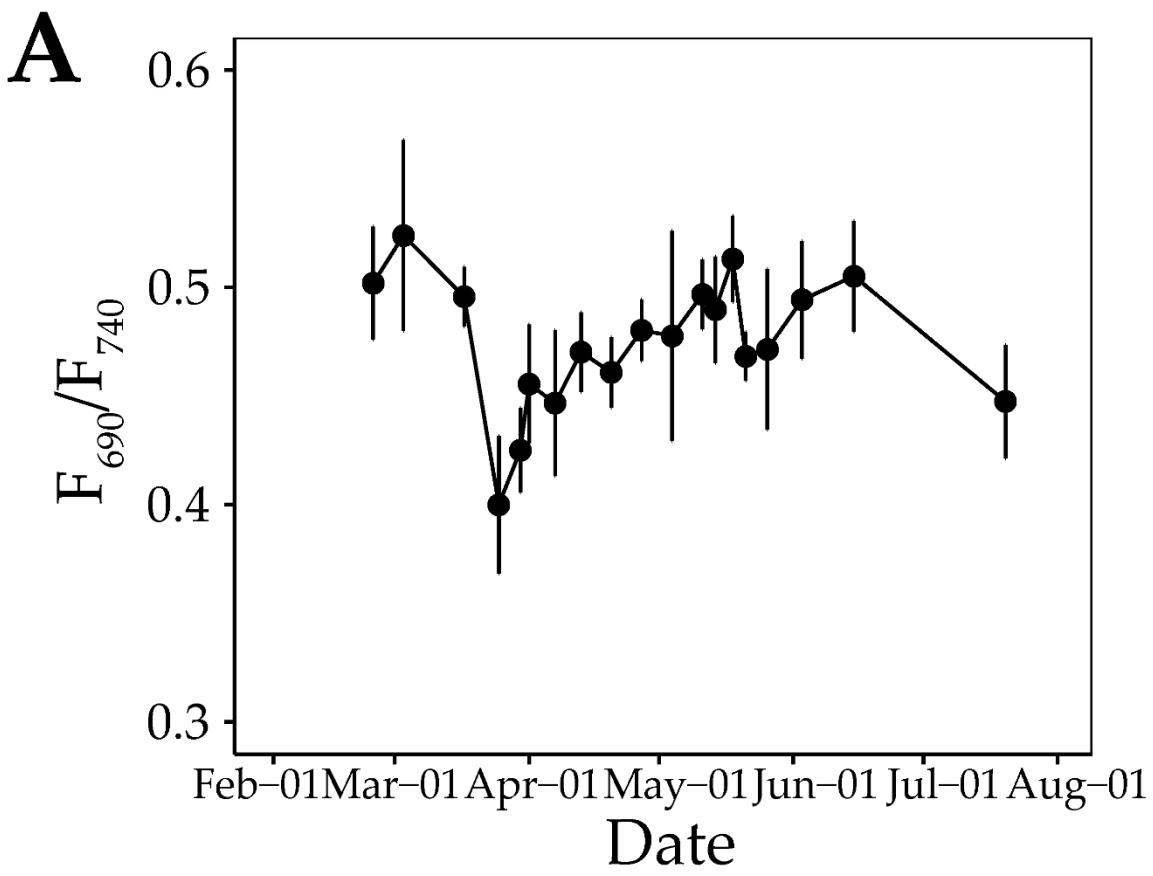

G
R²=0.71***
ßn
Score III (reflectance)

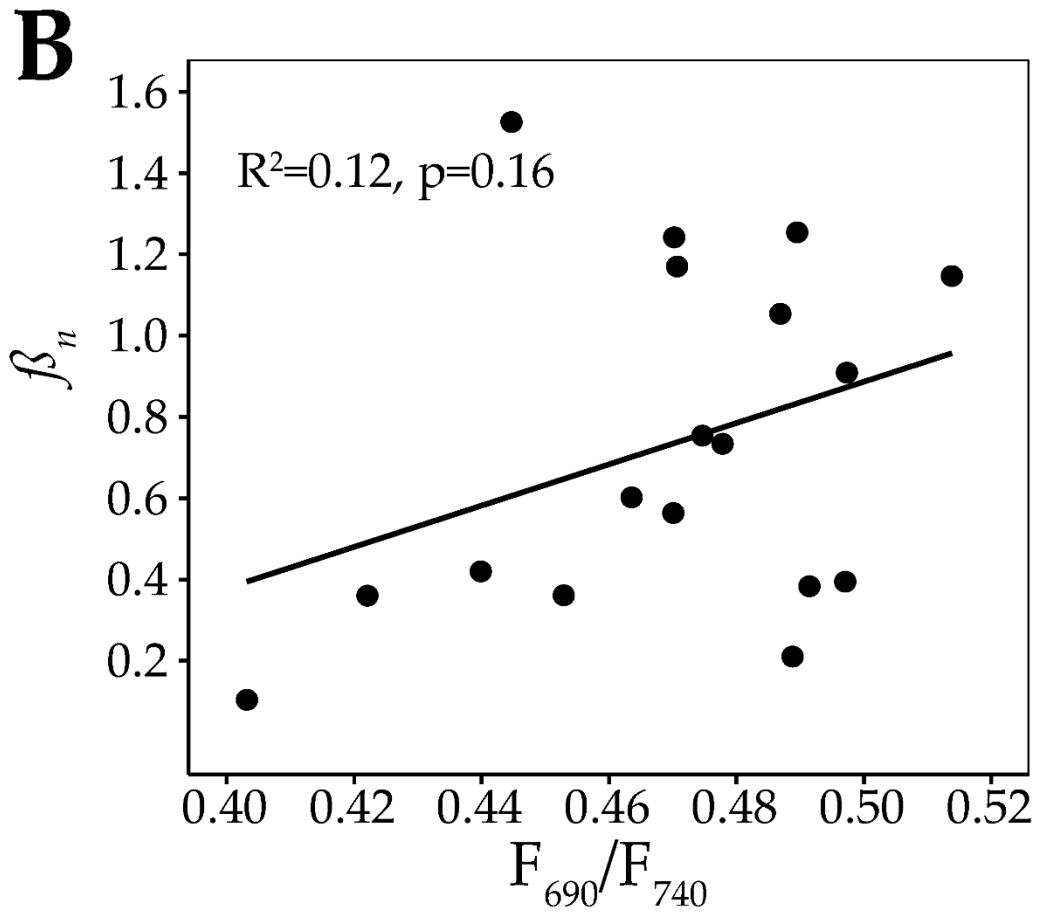

ßn
αn
βn
R²=0.83***
R²=0.77***
WC


WC
R²=0.64***
WI

All the spectral F variables (F670 to F780) could be used to detect seasonality of photosynthesis.

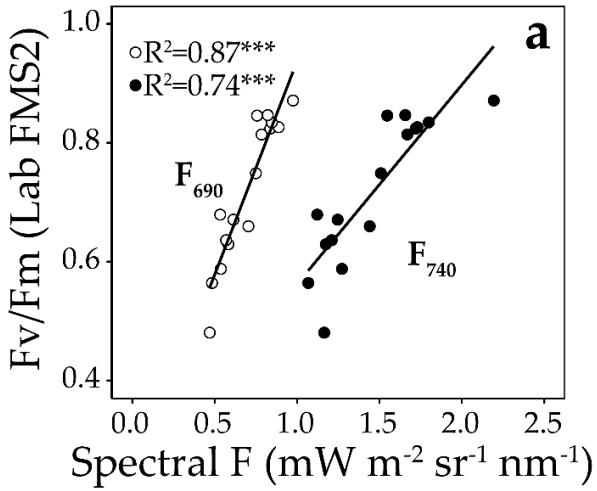


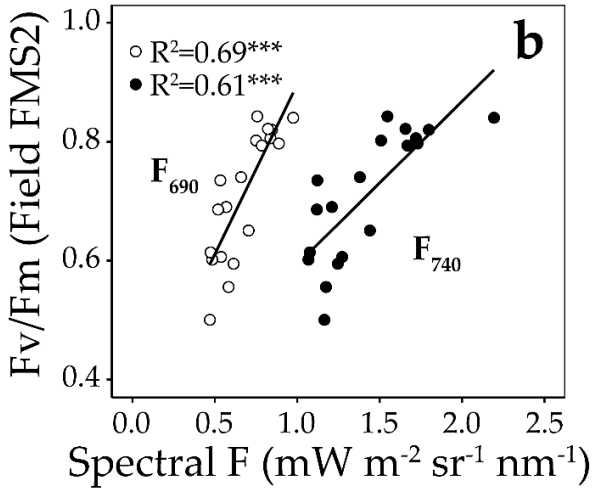

A
0.6
0.5
0.4
0.3
F690/F740
Feb–01 Mar–01 Apr–01 May–01 Jun–01 Jul–01 Aug–01
Date

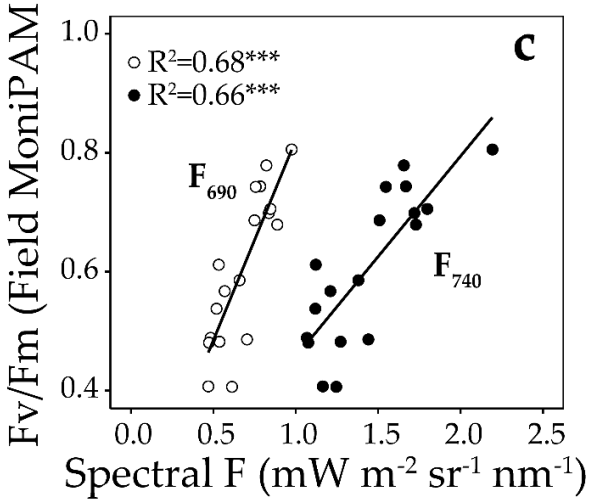

B
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
ßn
R²=0.12, p=0.16
0.40 0.42 0.44 0.46 0.48 0.50 0.52
F690/F740

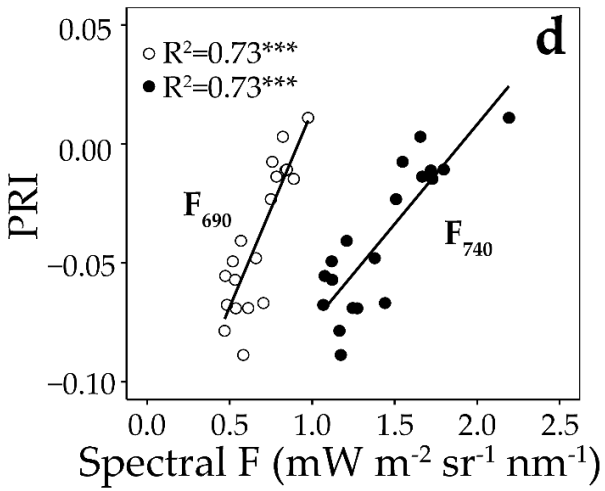
Seasonal correlation coefficients (*r*) of photosynthetic parameters, spectral F, PRI and NDVI with pigments

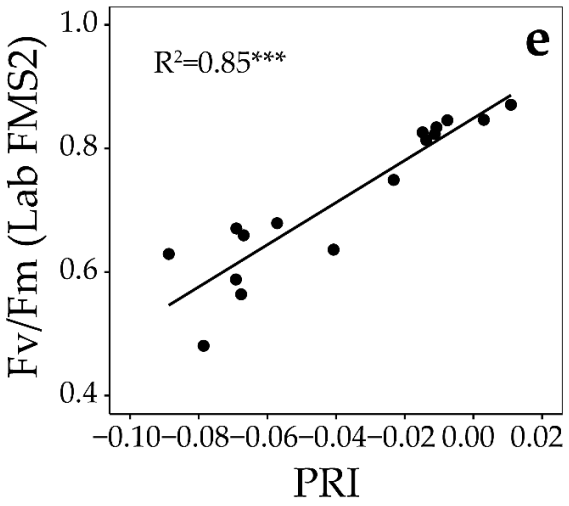
	Chlorophyll ($\mu g\ mg^{-1}\ DW^{-1}$)	Chlorophyll a/b ($mol\ mol^{-1}$)	Carotenoid ($\mu g\ mg^{-1}\ DW^{-1}$)	Carotenoid/ (Chlorophyll-a+Chlorophyll-b) ($mol\ mol^{-1}$)
β_n	-0.39*	0.78***	**-0.95*** **	-0.78***
α_n	N.S.	0.78***	**-0.92*** **	-0.77***
F_{690}	N.S.	0.56*	**-0.87*** **	**-0.88*** **
F_{740}	N.S.	0.50*	**-0.85*** **	**-0.90*** **
PRI	-0.38*	0.78***	**-0.91*** **	-0.77***
NDVI	N.S.	N.S.	N.S.	-0.39*

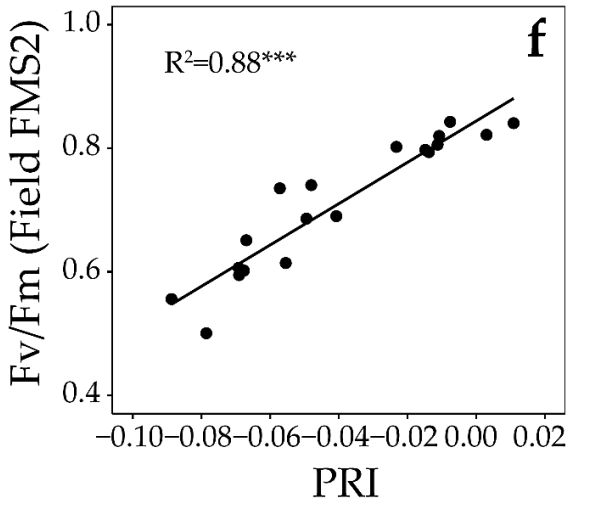

a
○R²=0.87***
●R²=0.74***
F690
F740
Fv/Fm (Lab FMS2)
Spectral F (mW m-2 sr-1 nm-1)

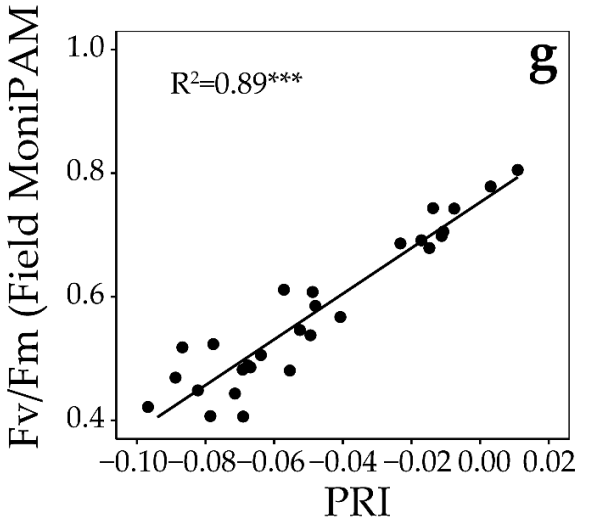

b
○ R²=0.69***
● R²=0.61***
F690
F740
Fv/Fm (Field FMS2)
Spectral F (mW m-2 sr-1 nm-1)

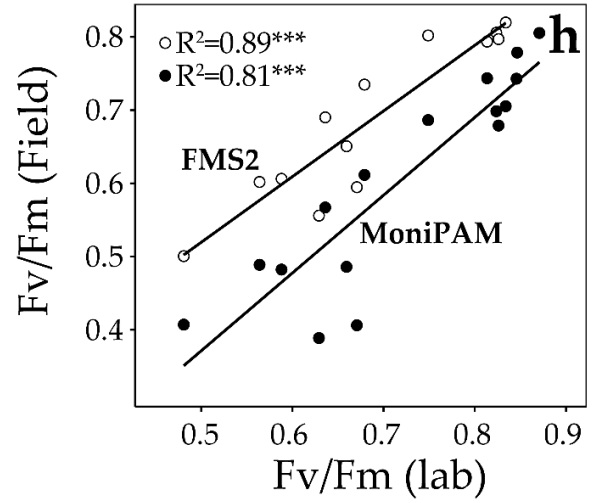

c
○ R²=0.68***
● R²=0.66***
F690
F740
Fv/Fm (Field MoniPAM
Spectral F (mW m-2 sr-1 nm-1)


d
○ R²=0.73***
● R²=0.73***
F690
F740
PRI
Spectral F (mW m-2 sr-1 nm-1)


e
R²=0.85***
Fv/Fm (Lab FMS2)
PRI


f
R²=0.88***
Fv/Fm (Field FMS2)
PRI


g
R²=0.89***
Fv/Fm (Field MoniPAM
PRI


h
○ R²=0.89***
● R²=0.81***
FMS2
MoniPAM
Fv/Fm (Field)
Fv/Fm (lab)

Seasonal correlation coefficients (*r*) of photosynthetic parameters, NDVI and pigments with the first three PC scores of reflectance spectra.

	Score-I	Score-II	Score-III
β_n	N.S.	N.S.	0.84***
α_n	N.S.	0.38*	0.77***
NDVI	0.83***	0.50**	N.S.
Chlorophyll (μg mg^{-1} DW^{-1})	N.S.	N.S.	-0.58***
Chlorophyll a/b (mol mol^{-1})	N.S.	N.S.	0.71***
Carotenoid (μg mg^{-1} DW^{-1})	N.S.	N.S.	-0.76***
Carotenoid/(Chlorophyll-a+Chlorophyll-b) (mol mol^{-1})	N.S.	-0.42*	-0.50*

The limitations of the methodology caused the failure responses of PC-1 and PC-2 of reflectance spectra to photosynthetic seasonality?

Conclusions

- The seasonal relationship between leaf level spectral F and photosynthesis was assessed for the first time in boreal evergreen trees during critical spring recovery period;

- All main F emission wavelengths are equally useful for exploring photosynthetic dynamics, and could be tested to assess carbon uptake at larger spatial scales;

- PRI was a good indicator of photosynthetic reactivation in boreal evergreens in field conditions, carotenoids played key roles in connecting the significant correlations.

- WI could be used to measure plant water status and probably provide a new way to non-destructively detect spring recovery from space.

Thanks for your attention!