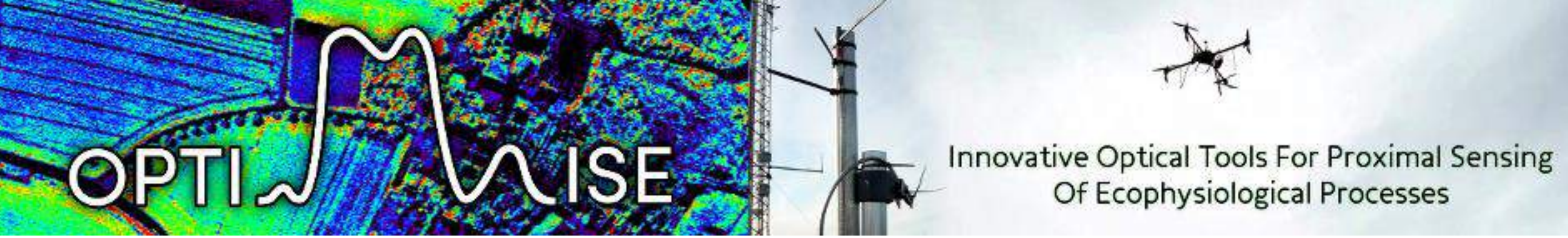


Analysis of short-term vegetation dynamics combining hyperspectral measurements and RTMs inversion

Marco Celesti

Christiaan van der Tol, Sergio Cogliati, Roberto Colombo, Franco Miglietta, Cinzia Panigada, Francisco Pinto, Uwe Rascher, Dirk Schüttemeyer, Giulia Tagliabue , Peiqi Yang, Micol Rossini

Remote Sensing of Environmental Dynamics Laboratory
Department of Earth and Environmental Sciences
University of Milano-Bicocca
Milano, Italy

marco.celesti@unimib.it

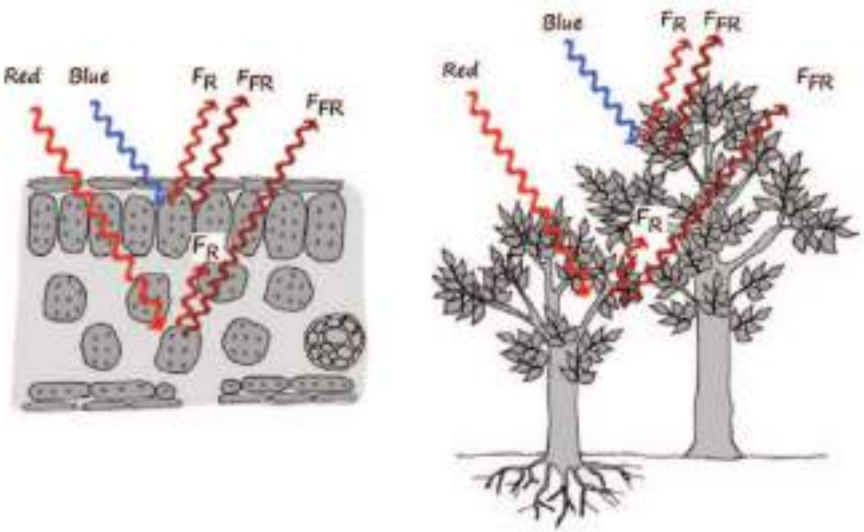
Sun-Induced Chlorophyll Fluorescence

- Sun-induced chlorophyll fluorescence is emitted as a function of absorbed excitation energy (APAR) and fluorescence quantum efficiency (Φ_F)

Sun-Induced Chlorophyll Fluorescence

- Sun-induced chlorophyll fluorescence is emitted as a function of absorbed excitation energy (APAR) and fluorescence quantum efficiency (Φ_F)

- it is then propagated through the leaf and the canopy -> Top Of Canopy (TOC) fluorescence



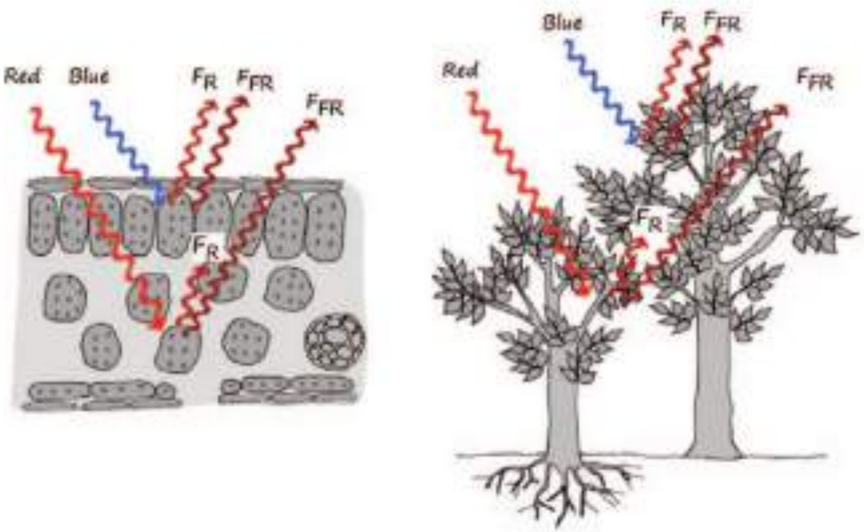
Porcar-Castell et al. (2014) JEB

Sun-Induced Chlorophyll Fluorescence

- Sun-induced chlorophyll fluorescence is emitted as a function of absorbed excitation energy (APAR) and fluorescence quantum efficiency (Φ_F)

- it is then propagated through the leaf and the canopy -> Top Of Canopy (TOC) fluorescence

→ leaf pigments/structure + canopy structure + physiology + environmental condition ...



Porcar-Castell et al. (2014) JEB

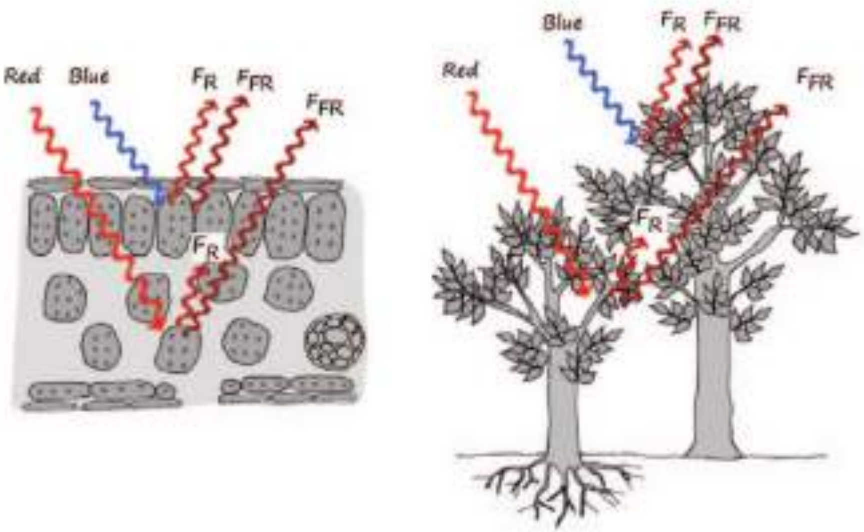
Sun-Induced Chlorophyll Fluorescence

- Sun-induced chlorophyll fluorescence is emitted as a function of absorbed excitation energy (APAR) and fluorescence quantum efficiency (Φ_F)

- it is then propagated through the leaf and the canopy -> Top Of Canopy (TOC) fluorescence

→ leaf pigments/structure + canopy structure + physiology + environmental condition ...

→ growing amount of products



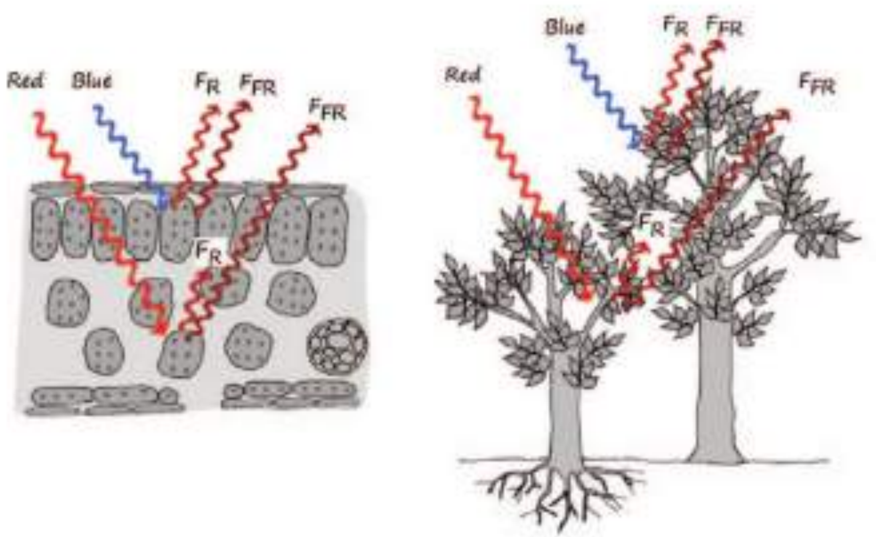
Porcar-Castell et al. (2014) JEB

Sun-Induced Chlorophyll Fluorescence

- Sun-induced chlorophyll fluorescence is emitted as a function of absorbed excitation energy (APAR) and fluorescence quantum efficiency (Φ_F)

- it is then propagated through the leaf and the canopy -> Top Of Canopy (TOC) fluorescence

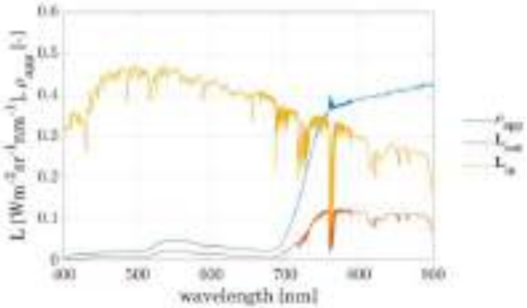
→ leaf pigments/structure + canopy structure + physiology + environmental condition ...
→ growing amount of products



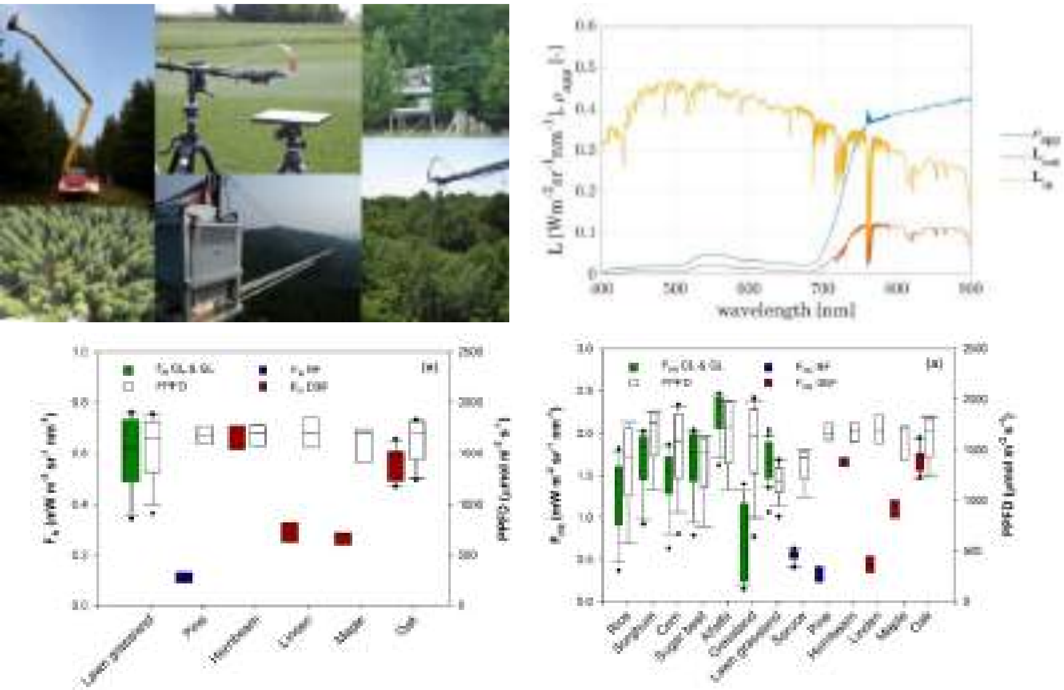
Porcar-Castell et al. (2014) JEB

Developing a flexible modeling framework for integrating several sources of information at different scales

Motivation

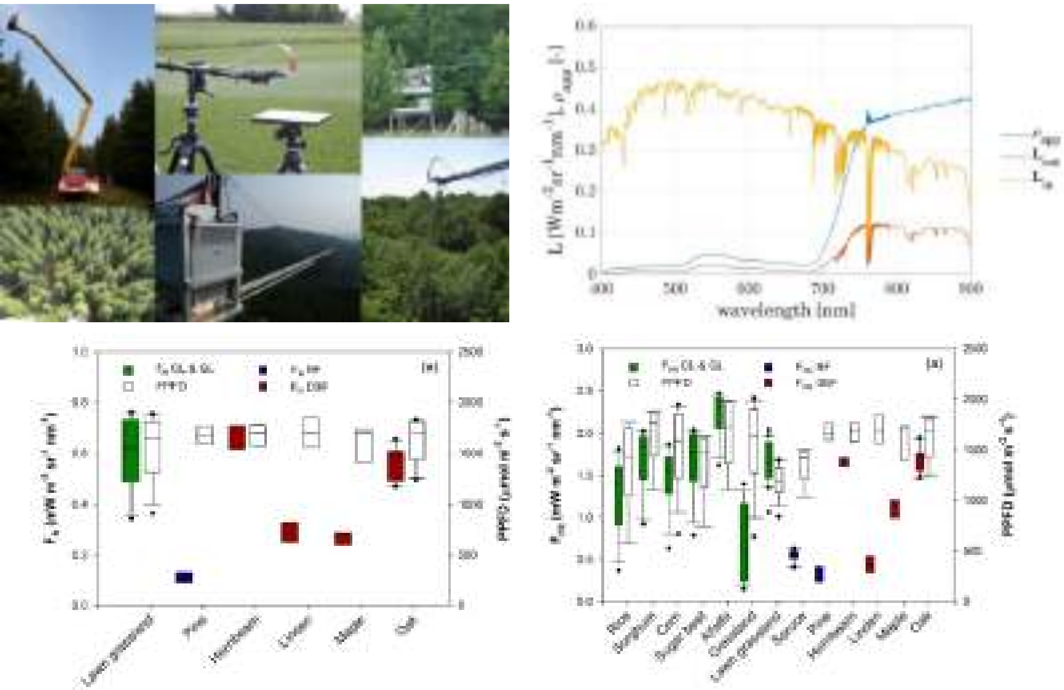


Motivation

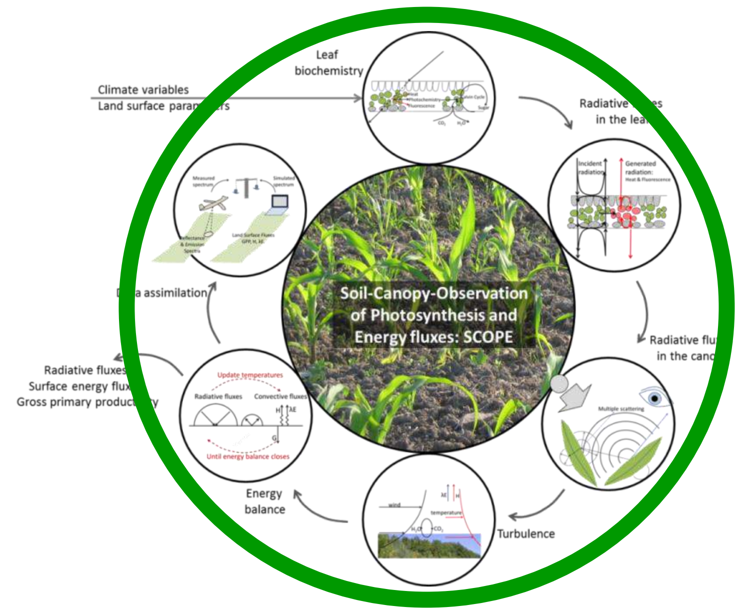


Rossini et al. (2016) RS

Motivation

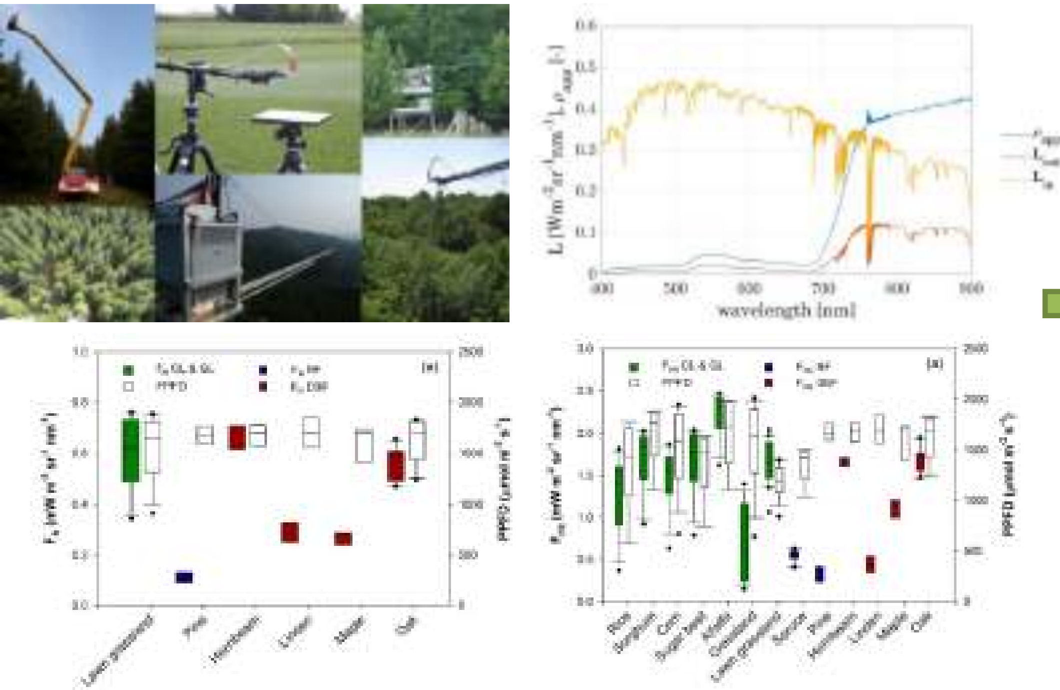


Rossini et al. (2016) RS

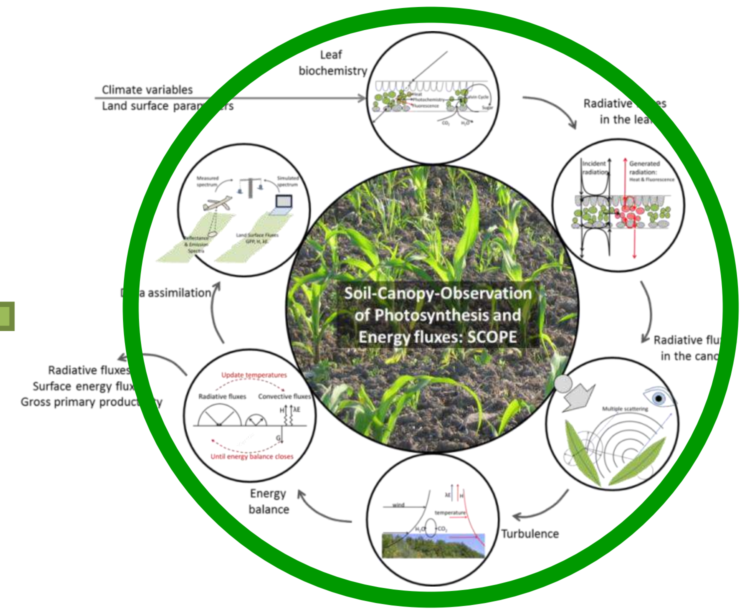


van der Tol et al. (2009,2014)
Vilfan et al. (2016)

Motivation



Rossini et al. (2016) RS

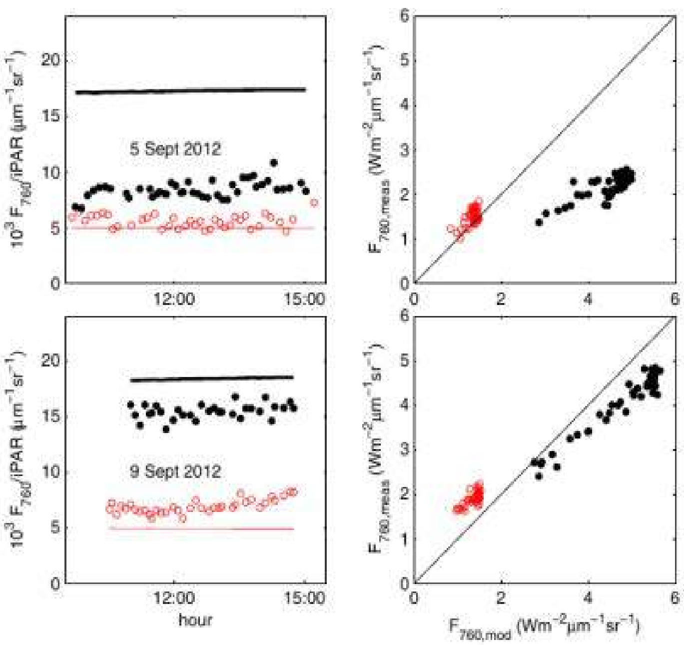


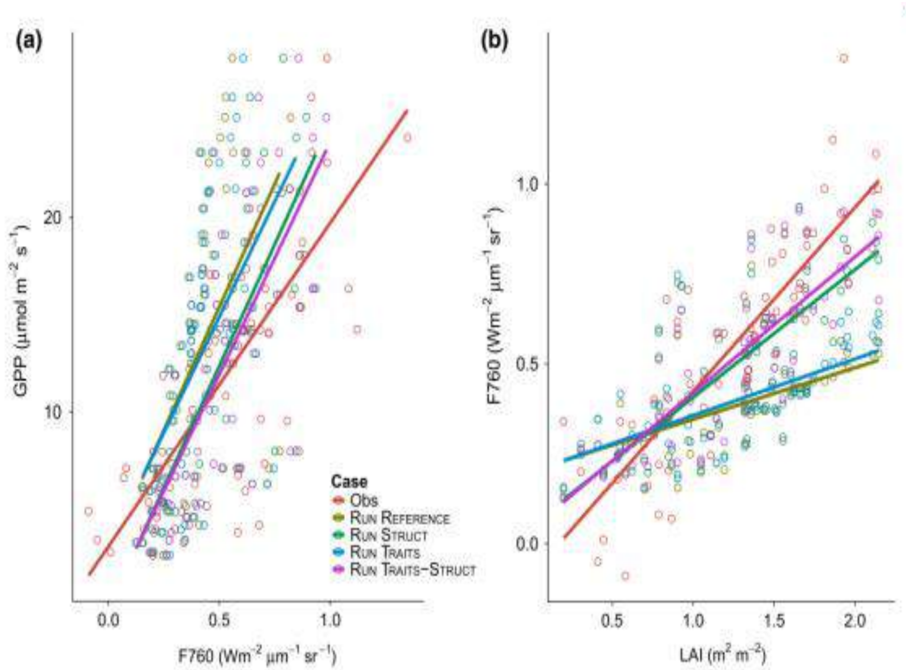
van der Tol et al. (2009,2014)
Vilfan et al. (2016)

LTDA

Motivation

van der Tol et al. (2016) RSE & Migliavacca et al. (2017) New Phyt.
Using far-red fluorescence (F_{760}) and reflectance ≈ 1nm FWHM





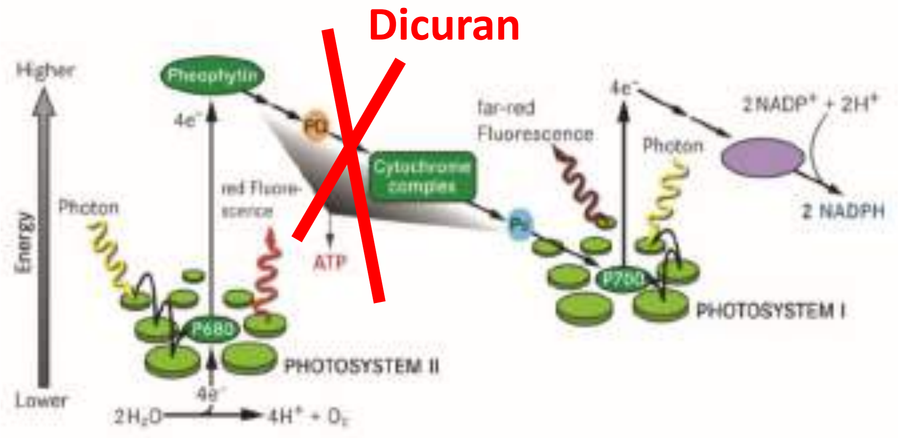
Objectives

- to retrieve F and Φ_F from SCOPE inversion on very high resolution TOC measurements, together with “classical” vegetation parameters

- to compare modeled F values (red and far-red) with state of the art independent radiance-based retrievals (Spectral Fitting Method and SpecFit)

- to evaluate temporal evolution of retrieved parameters for assessing vegetation status during an induced stress experiment

Material and Methods – data acquisition

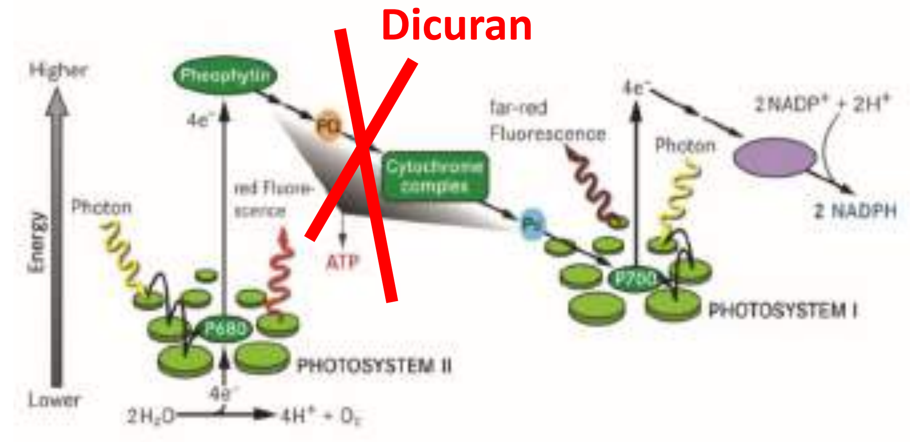


Different doses applied over ~30 days

~ 1600 measurements

→ ~1400 after filtering

Material and Methods – data acquisition

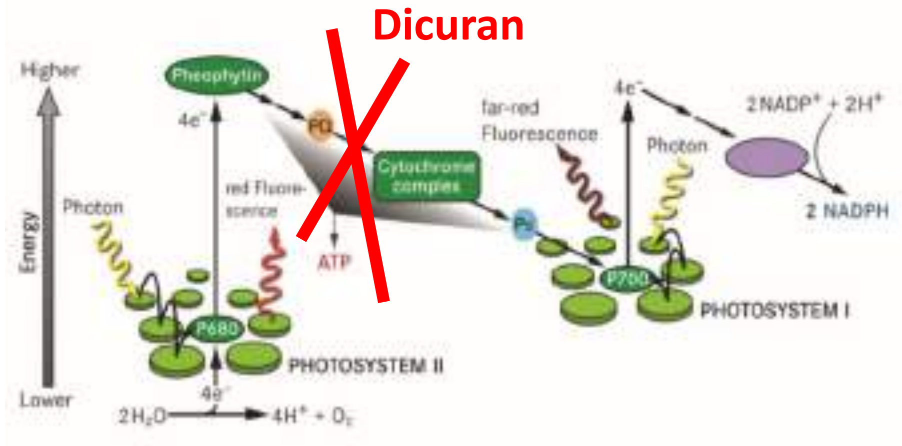


Different doses applied over ~30 days
~ 1600 measurements
→ ~1400 after filtering

H. above ground (cm)	**~130 cm**
Observed diam.(cm)	**~58 cm**

Spectrometer	Range (nm)	FWHM (nm)	Application
1 – HR4000f	350-1050	1	ρ and VIs computation
2 – QE65000	657-740	0.25	F at O_2-B
3 – HR4000a	700-800	0.1	F at O_2-A

Material and Methods – data acquisition



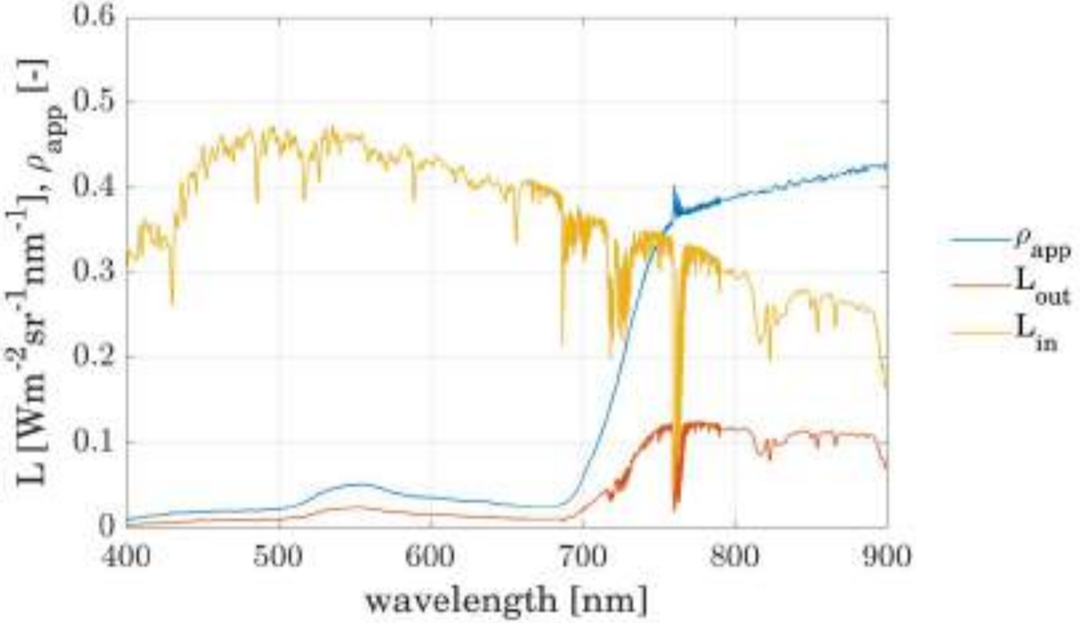
Different doses applied over ~30 days
~ 1600 measurements
→ ~1400 after filtering

H. above ground (cm)	**~130 cm**
Observed diam.(cm)	**~58 cm**

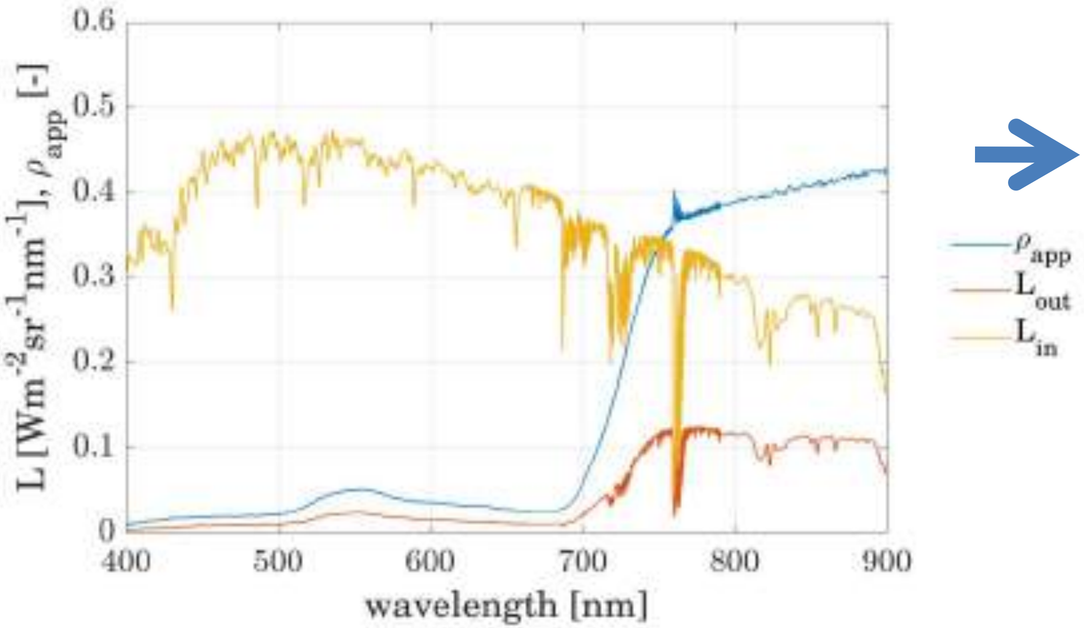
Spectrometer	Range (nm)	FWHM (nm)	Application
1 – HR4000f	350-1050	1	ρ and VIs computation
2 – QE65000	657-740	0.25	F at O_2-B
3 – HR4000a	700-800	0.1	F at O_2-A

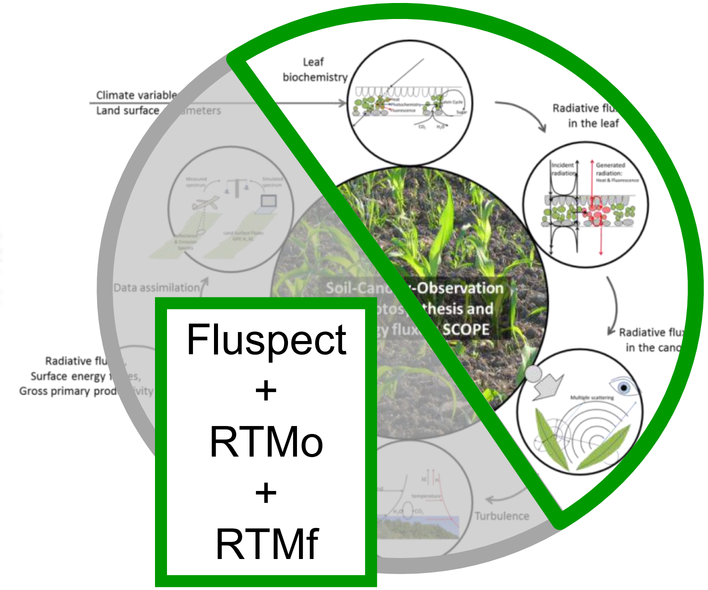
Merged together

Material and Methods – F retrieval



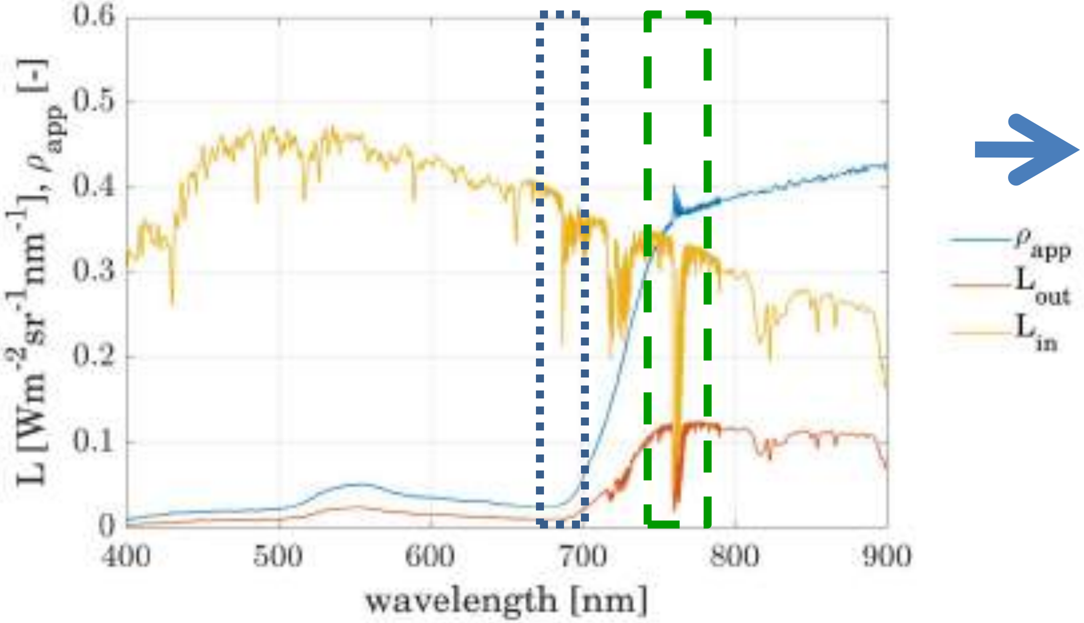
Material and Methods – F retrieval

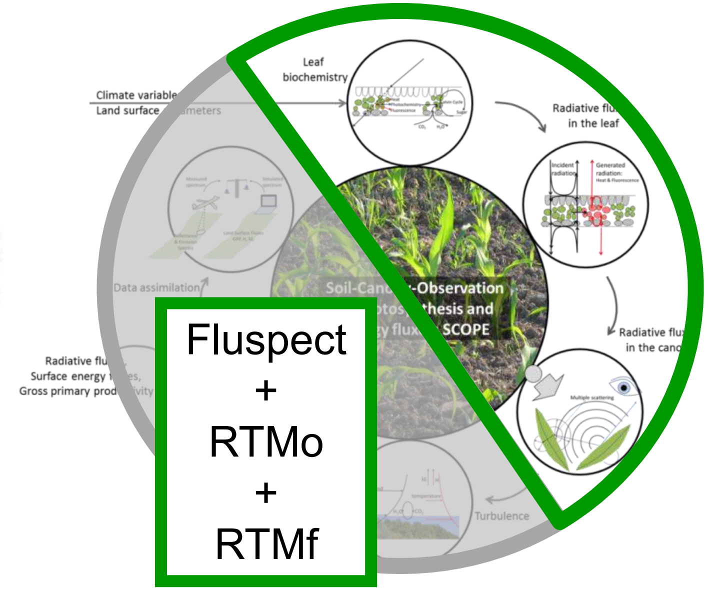




Numerical inversion:
Cab, Cca, Cdm, Cw …
LAI, APAR …
Φ_F → fluorescence quantum efficiency

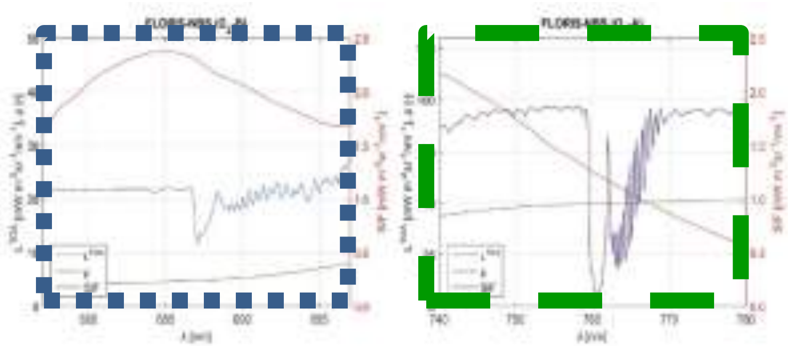
Material and Methods – F retrieval





SFM (Cogliati et at., 2015)

→ F_{687} and F_{760}



Numerical inversion:

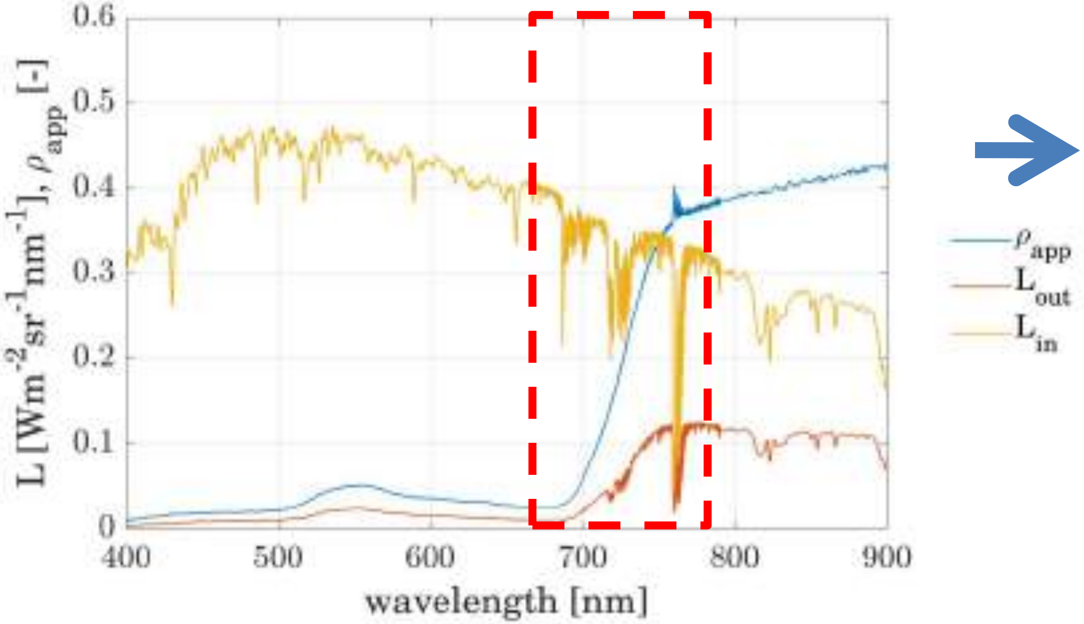
Cab, Cca, Cdm, Cw …

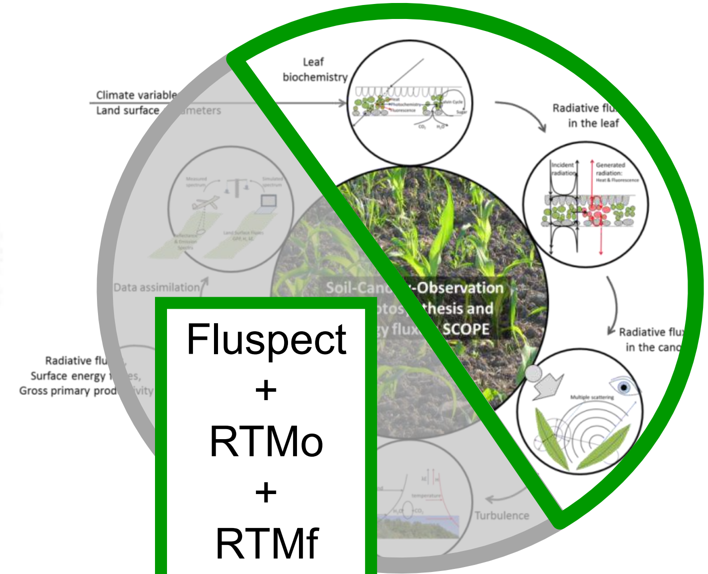
LAI, APAR …

$\mathbf{\Phi_F}$ → fluorescence quantum efficiency

Cogliati et al. (2015) RSE

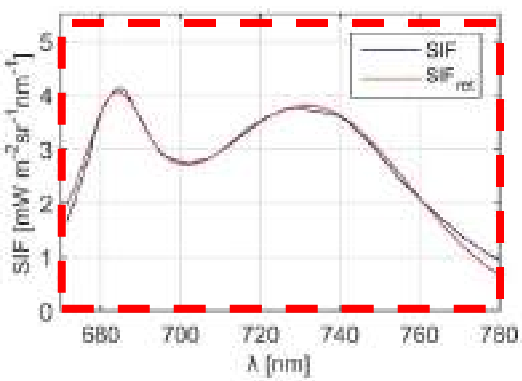
Material and Methods – F retrieval





Fluspect
+
RTMo
+
RTMf

SFM (Cogliati et at., 2015)
→ Full spectrum of F



Numerical inversion:
Cab, Cca, Cdm, Cw …
LAI, APAR …
Φ_F → fluorescence quantum efficiency

Cogliati et al. (2015) RSE

Material and Methods – Inversion cost function

$$f = \mathrm{ER1}^T \mathrm{ER1} + w * \mathrm{ER2}^T \mathrm{ER2}$$

$$\mathrm{ER1} = \begin{cases} \rho^{*,RTM}(\lambda) - \rho^{*,meas}(\lambda) & ,\lambda \in \lambda_{noabs} \\ (\rho^{*,RTM}(\lambda) - \rho^{*,RTM}_{BL}(\lambda)) + & ,\lambda \in \lambda_{abs} \\ \quad -(\rho^{*,meas}(\lambda) - \rho^{*,meas}_{BL}(\lambda)) & \end{cases}$$

$$\mathrm{ER2} = \frac{p - p_0}{\sigma_{p_0}}$$

Celesti et al., under review in RSE

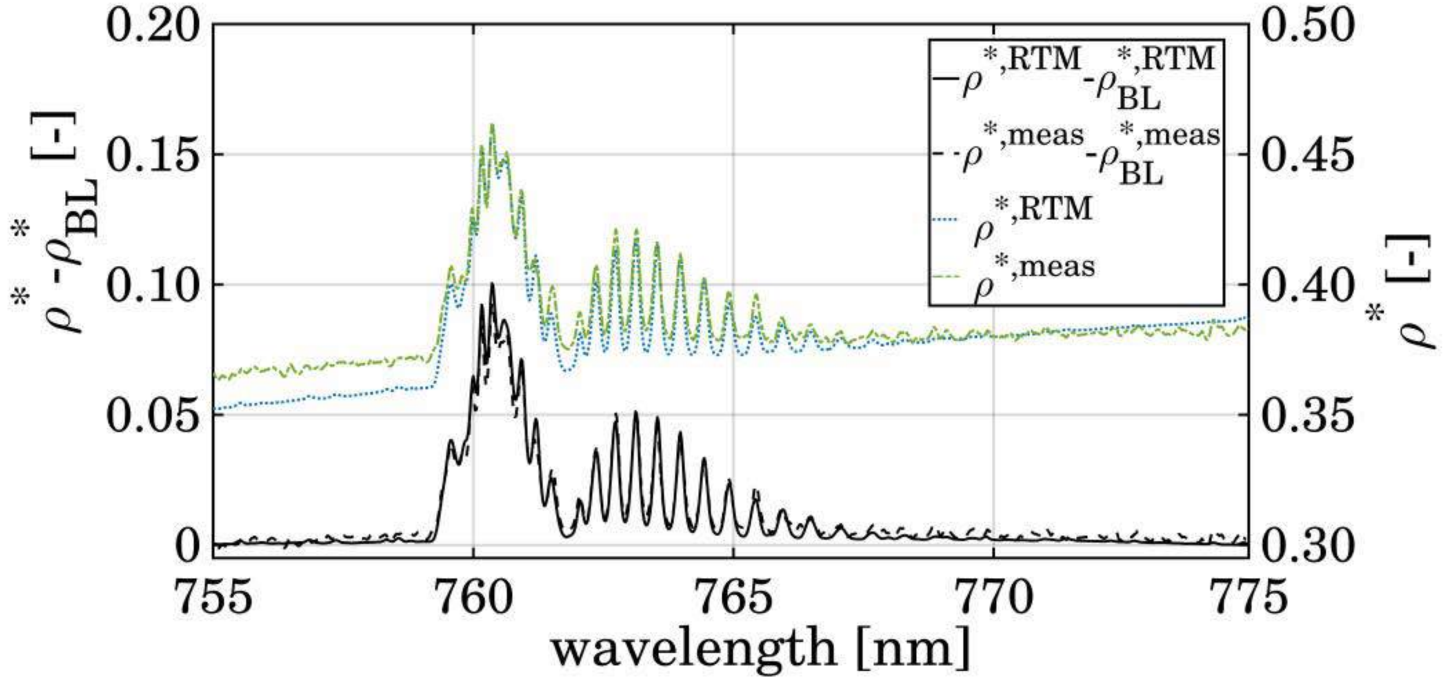
LTDA

Material and Methods – Inversion cost function

$$f = ER1^{T}ER1 + w * ER2^{T}ER2$$

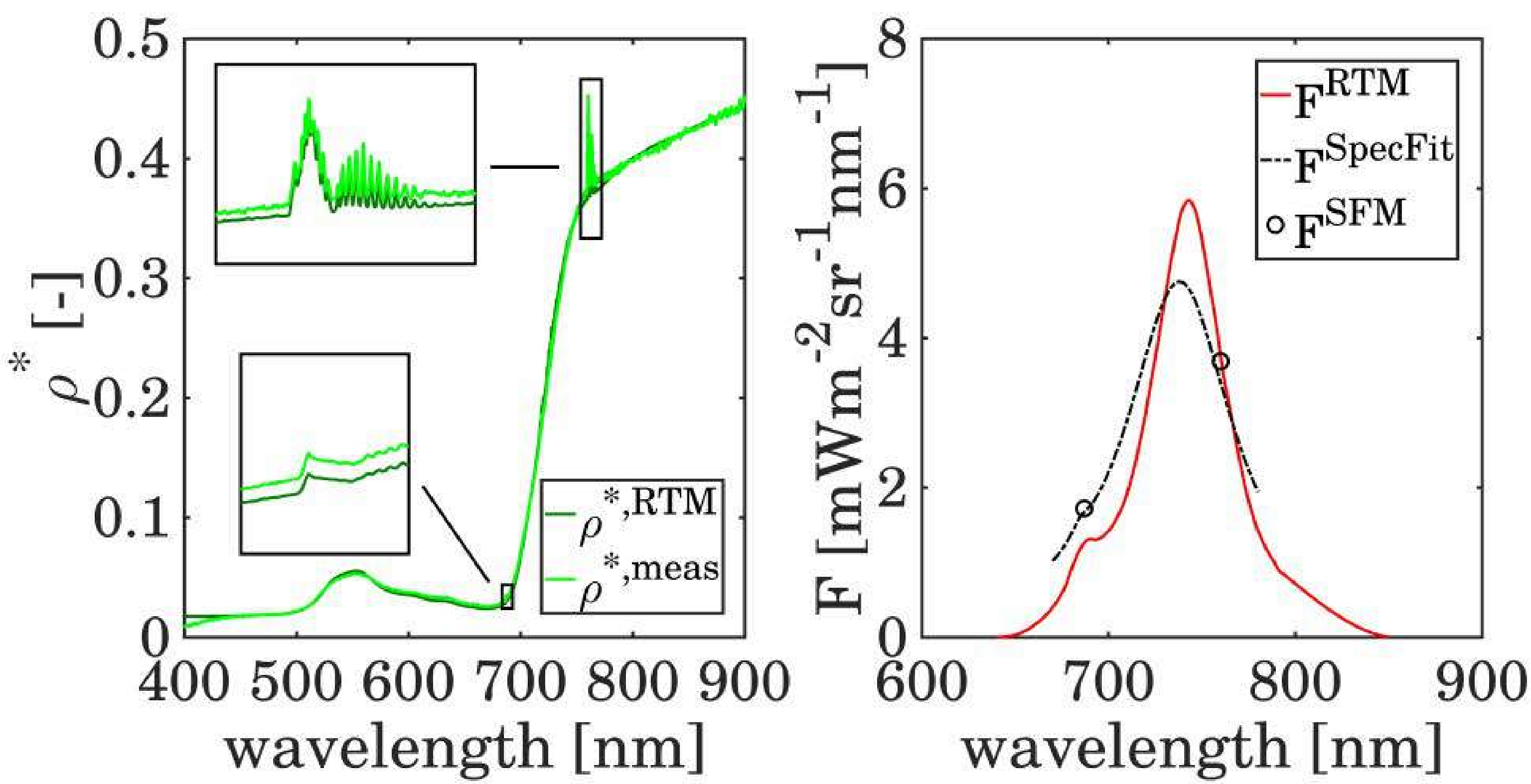
$$ER1 = \begin{cases} \rho^{*,RTM}(\lambda) - \rho^{*,meas}(\lambda) & ,\lambda \in \lambda_{noabs} \\ (\rho^{*,RTM}(\lambda) - \rho^{*,RTM}_{BL}(\lambda)) + & ,\lambda \in \lambda_{abs} \\ \quad -(\rho^{*,meas}(\lambda) - \rho^{*,meas}_{BL}(\lambda)) & \end{cases}$$

$$ER2 = \frac{p - p_0}{\sigma_{p_0}}$$



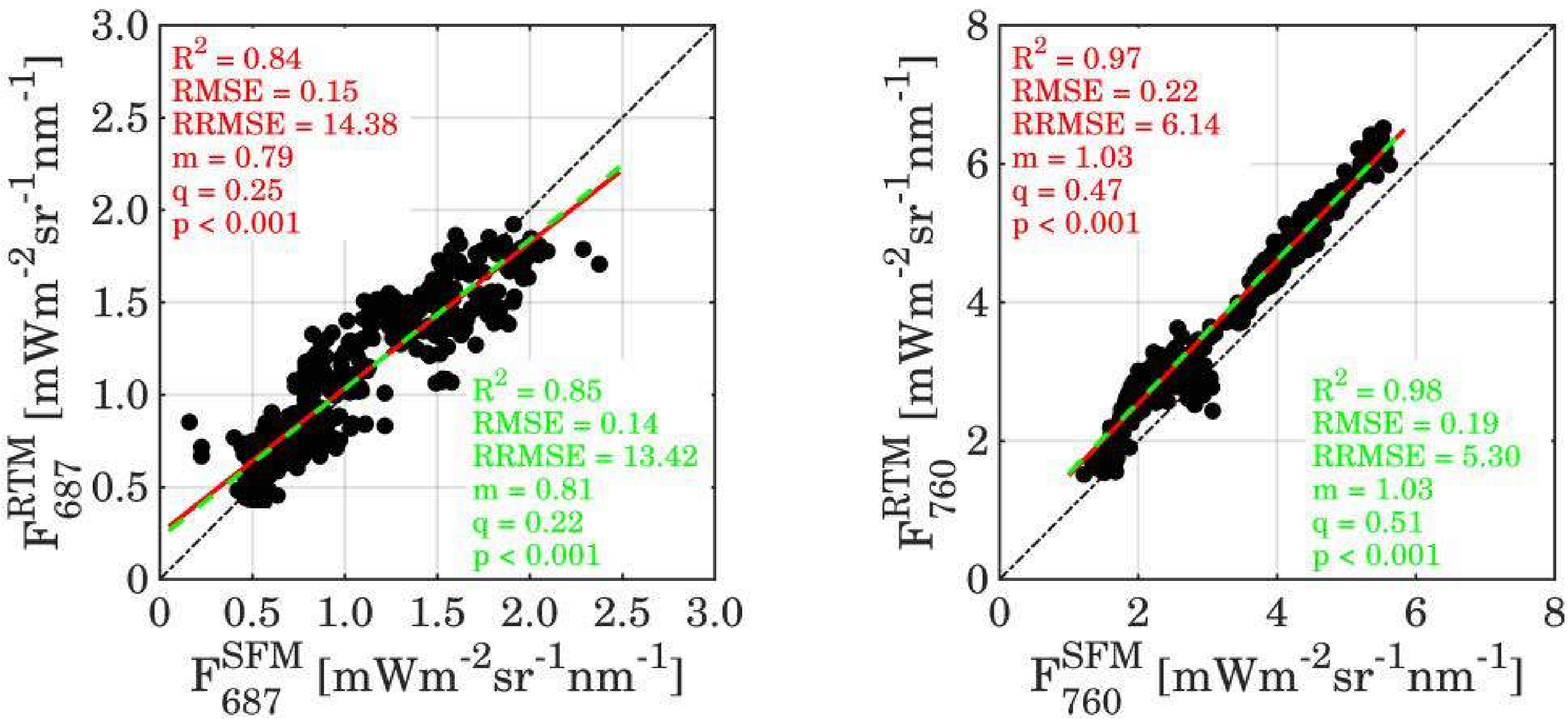
Celesti et al., under review in RSE

Results – example of modeled ρ* and F



- Generally good agreement between modeled and measured reflectance
- Different shapes for full spectrum F modelling

Results – F values comparison



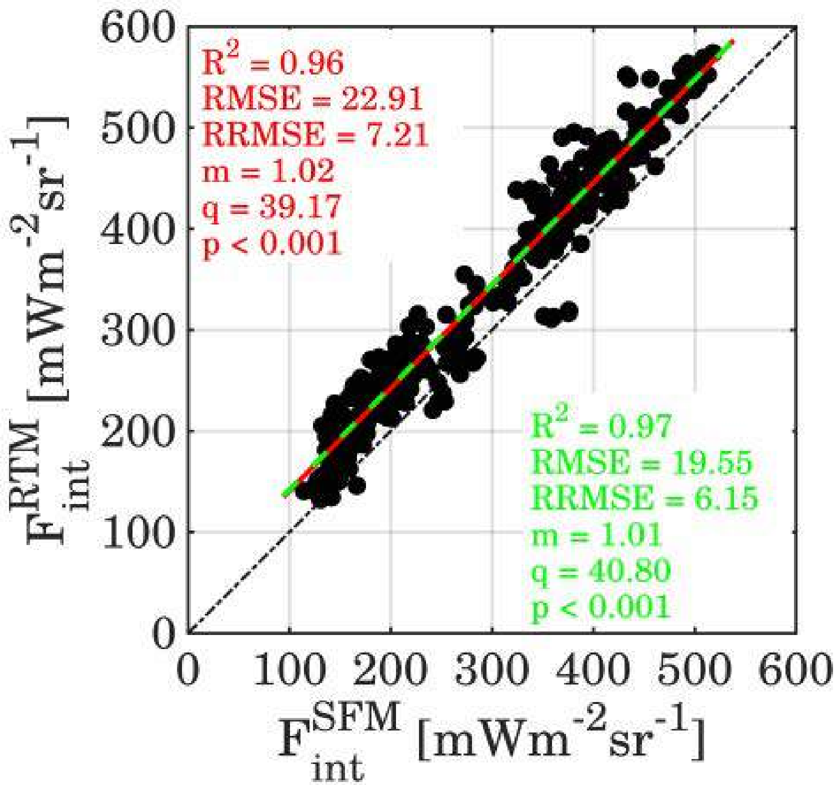
No systematica bias in F_{687} but overestimation of F_{760}

→ inherent to fluorescence optipar shape

→ Overestimation of F_{760} can be also linked to general slight overestimation of Φ_F

Celesti et al., under review in RSE

Results – F values comparison



Systematic overestimation of F_{int} reflects results values of F_{760}

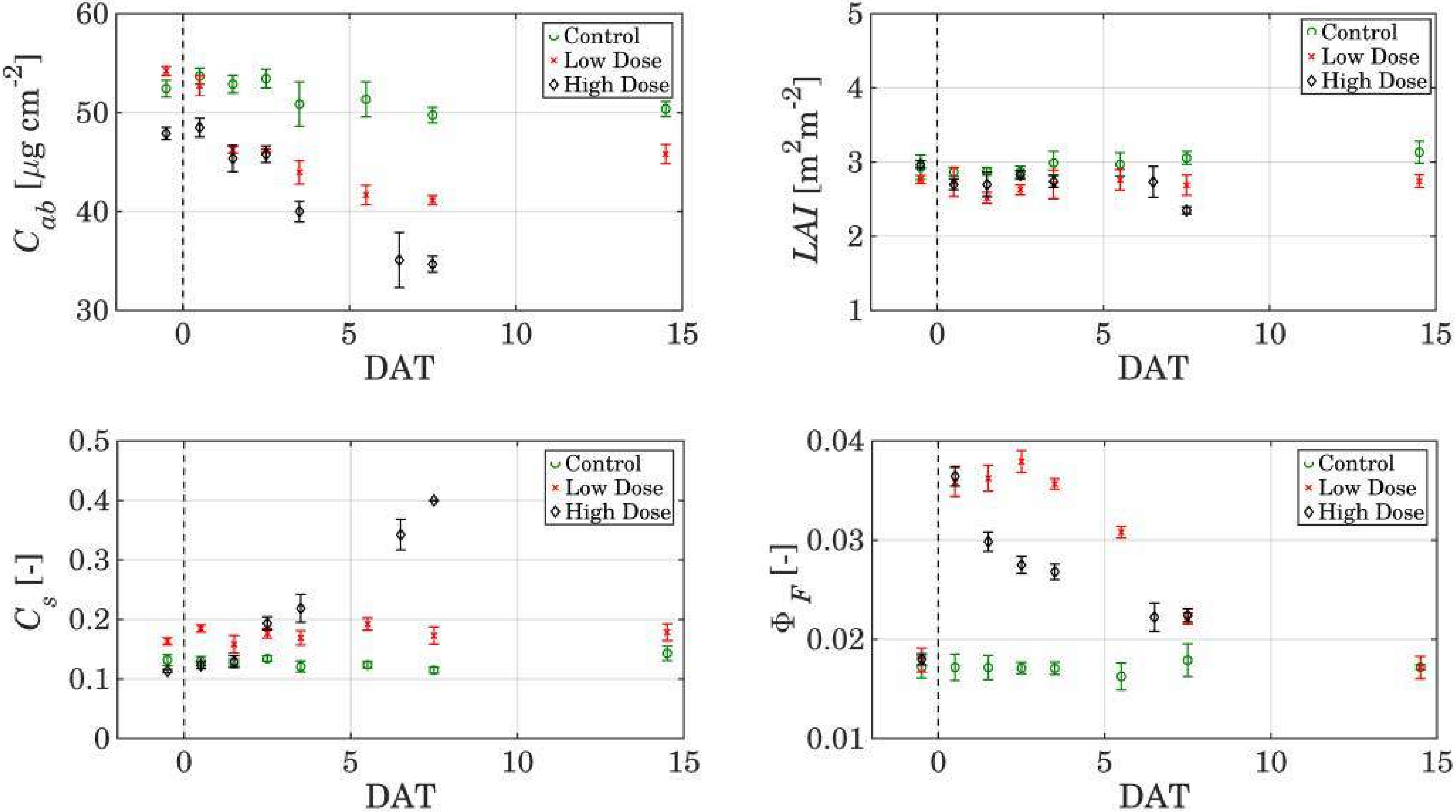
→ Strong overall weight of far-red fluorescence

Celesti et al., under review in RSE

Results – time series

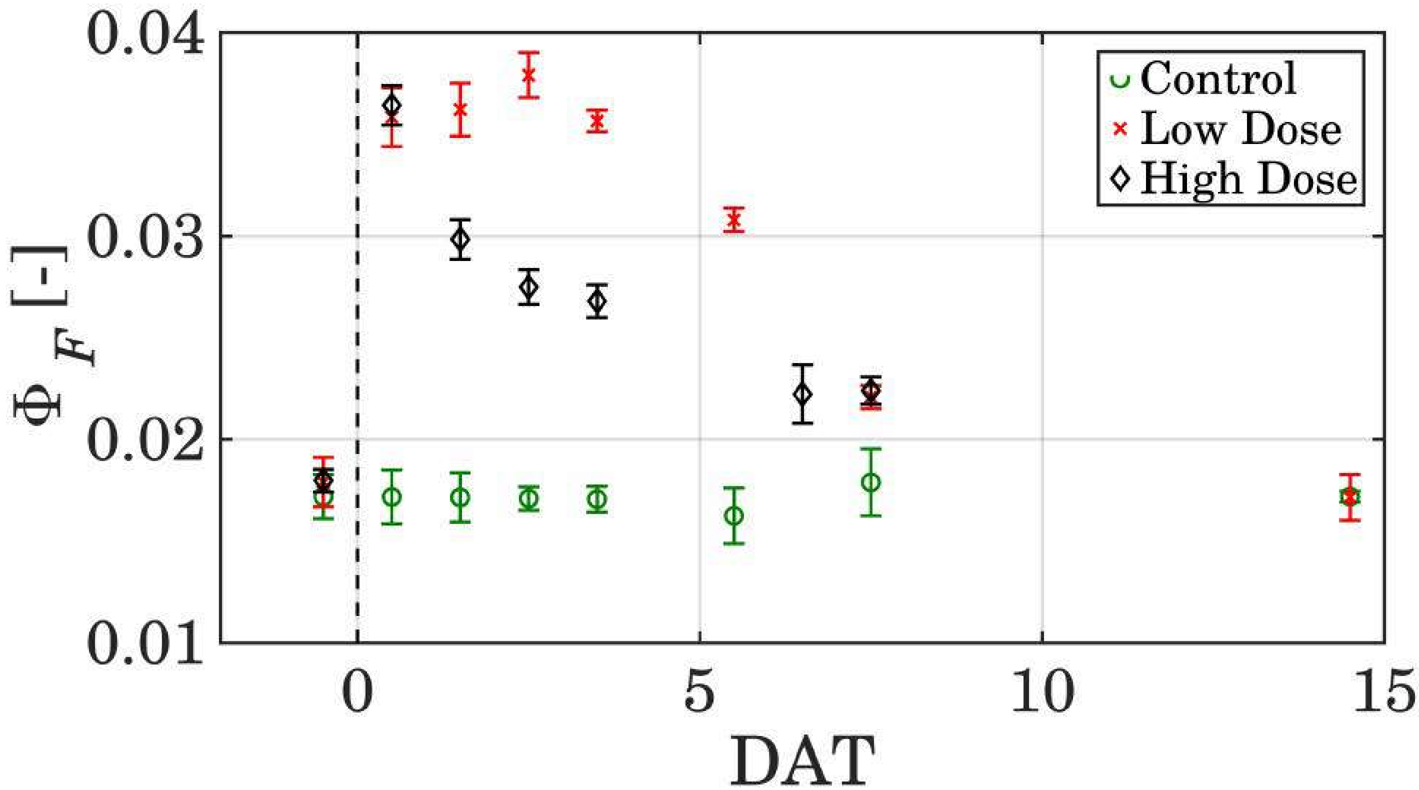
Celesti et al., under review in RSE

Results – time series



Celesti et al., under review in RSE

Results – time series



Maximum theoretical range of Φ_F is [0.01:0.05]

→ almost entirely covered

Very high Φ_F values are in good agreement with the effect of Dicuran on PQ and NPQ

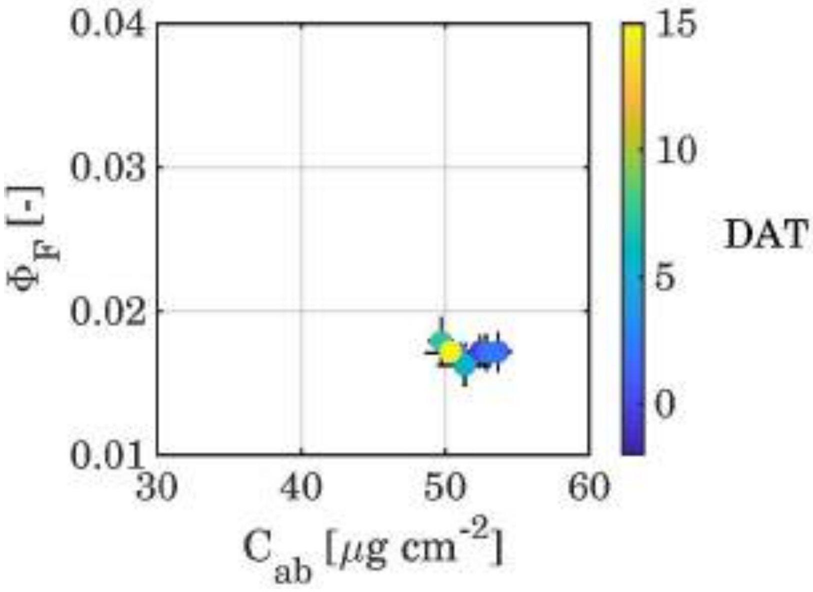
Celesti et al., under review in RSE

Results – temporal evolution

Celesti et al., under review in RSE

Results – temporal evolution

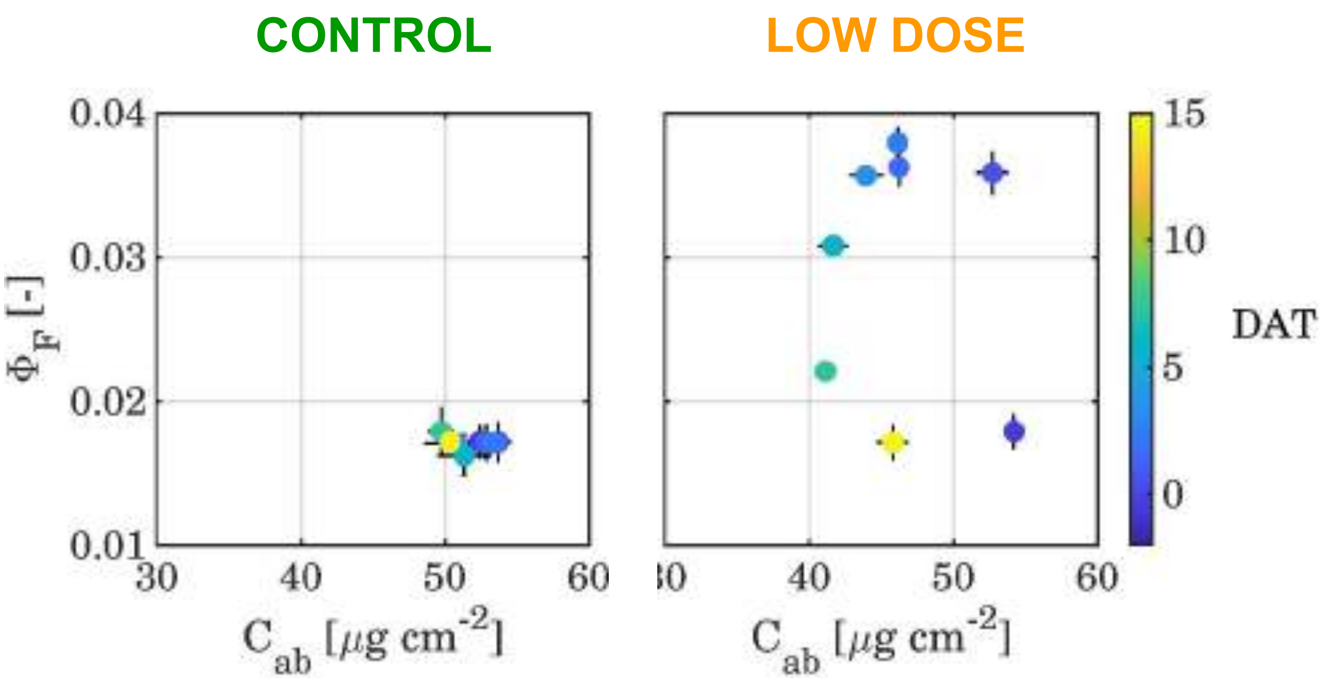
CONTROL



- No variation in the control

Celesti et al., under review in RSE

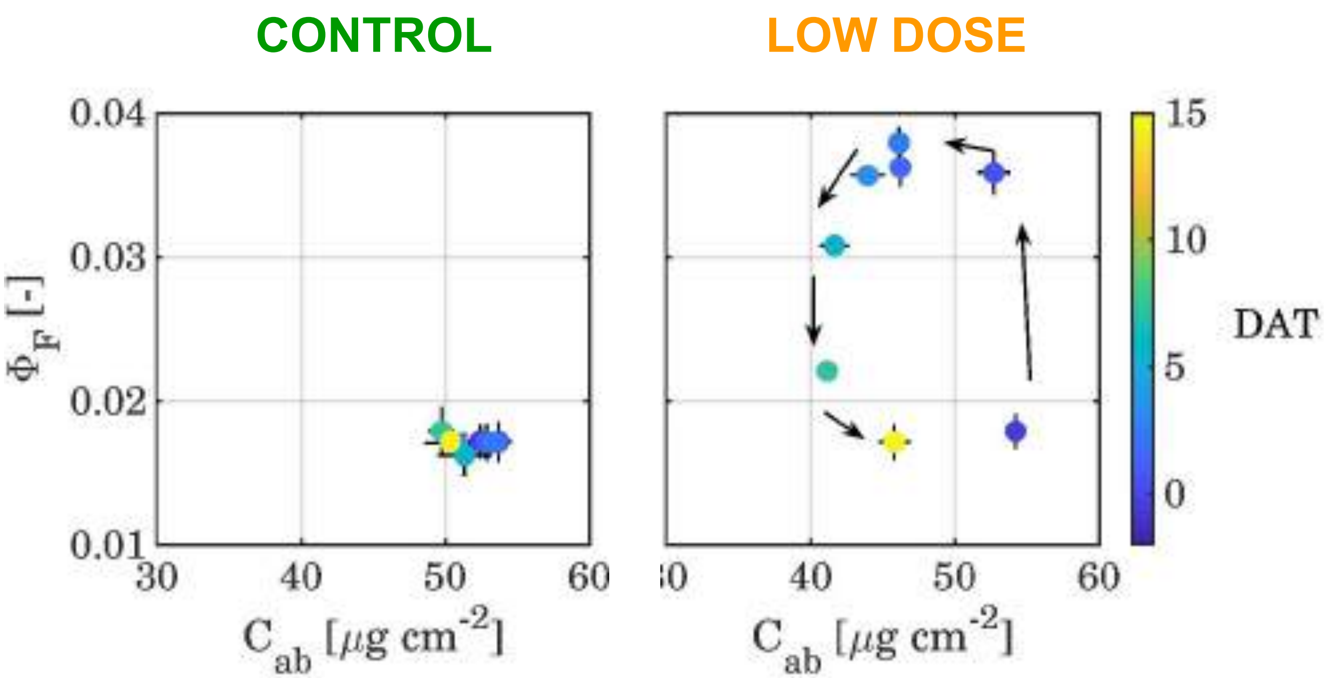
Results – temporal evolution



- No variation in the control
- in the treated plots, Φ_F and pigments respond sequentially to the stress event. After 14 days back to pre-treatment state in lower doses

Celesti et al., under review in RSE

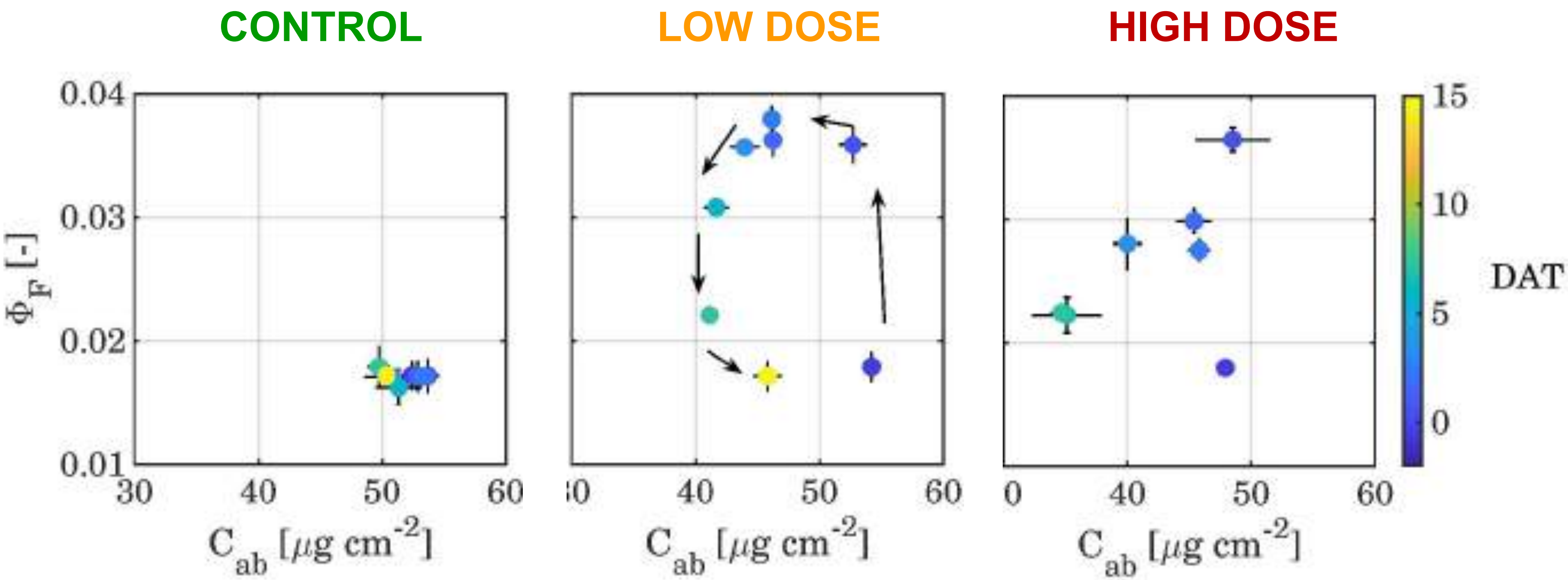
Results – temporal evolution



- No variation in the control
- in the treated plots, Φ_F and pigments respond sequentially to the stress event. After 14 days back to pre-treatment state in lower doses

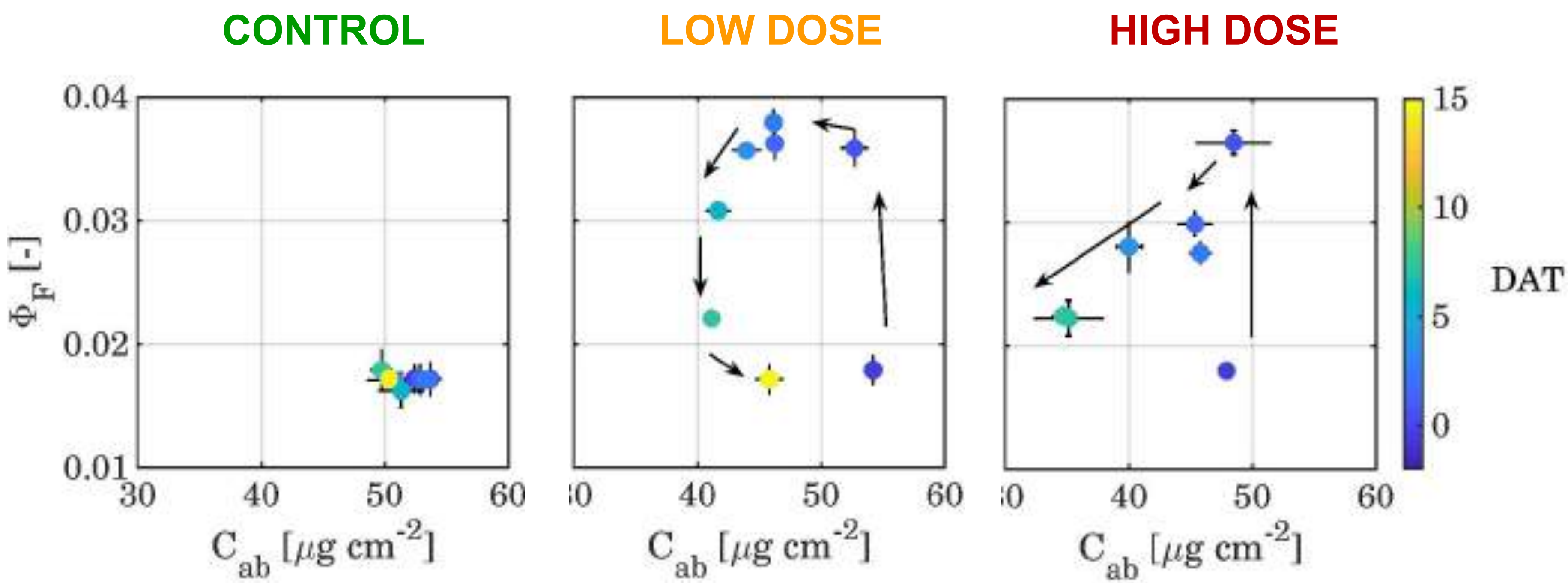
Celesti et al., under review in RSE

Results – temporal evolution



- No variation in the control
- in the treated plots, Φ_F and pigments respond sequentially to the stress event. After 14 days back to pre-treatment state in lower doses

Results – temporal evolution



- No variation in the control
- in the treated plots, Φ_F and pigments respond sequentially to the stress event. After 14 days back to pre-treatment state in lower doses
- in the highest dose plants started brownishing and not recovered anymore

Celesti et al., under review in RSE

Conclusions

- For the first time we inverted SCOPE on very high resolution top of canopy measurements
- The concurrent retrieval of veg. parameters and sun-induced chlorophyll fluorescence provided coherent information on their dynamics. Modeled absolute values of F were in very good agreement with a state of the art retrieval (SFM)
- F can be used as an early warning, Concurrent evaluation of biochem/struct/fluorescence can provide more information on veg. dynamics (stress/recovery)
- With this approach we avoid “contradictory” results (but also missing “surprising” ones), within the domain of applicability of the model

Acknowledgments

OPTIMISE COST action for funding my STSM to ITC (C. van der Tol)

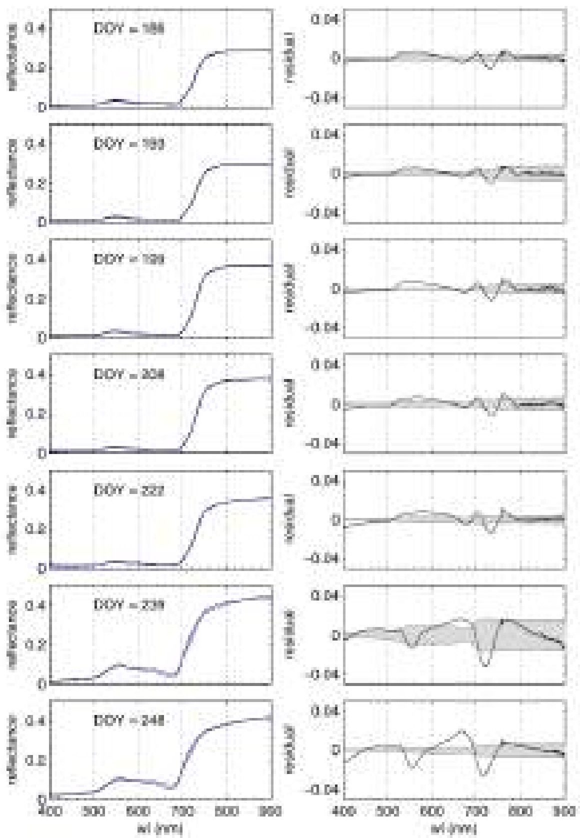
THANKS FOR YOUR ATTENTION

Marco Celesti

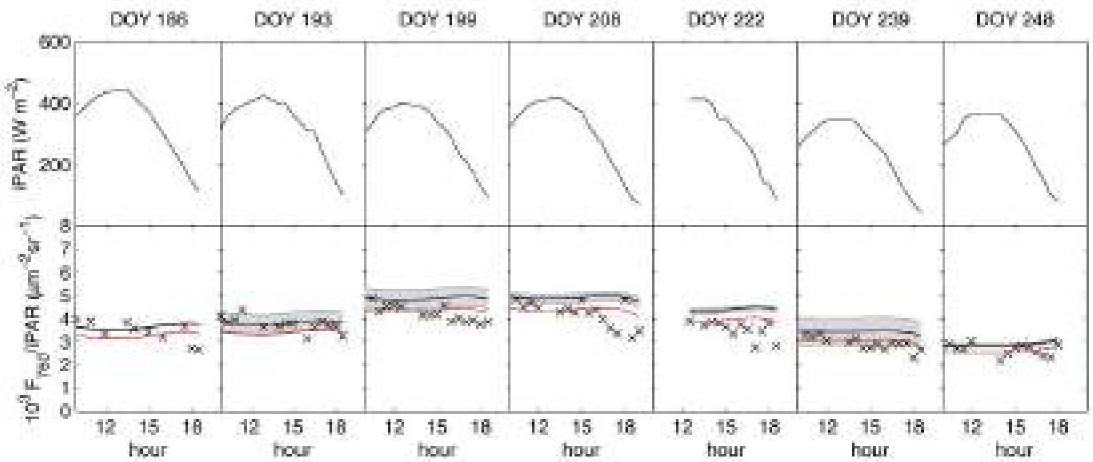
Remote Sensing of Environmental Dynamics Laboratory,
DISAT, University of Milano-Bicocca,
Milano, Italy

marco.celesti@unimib.it

Results - Numerical inversion of reflectance to model F



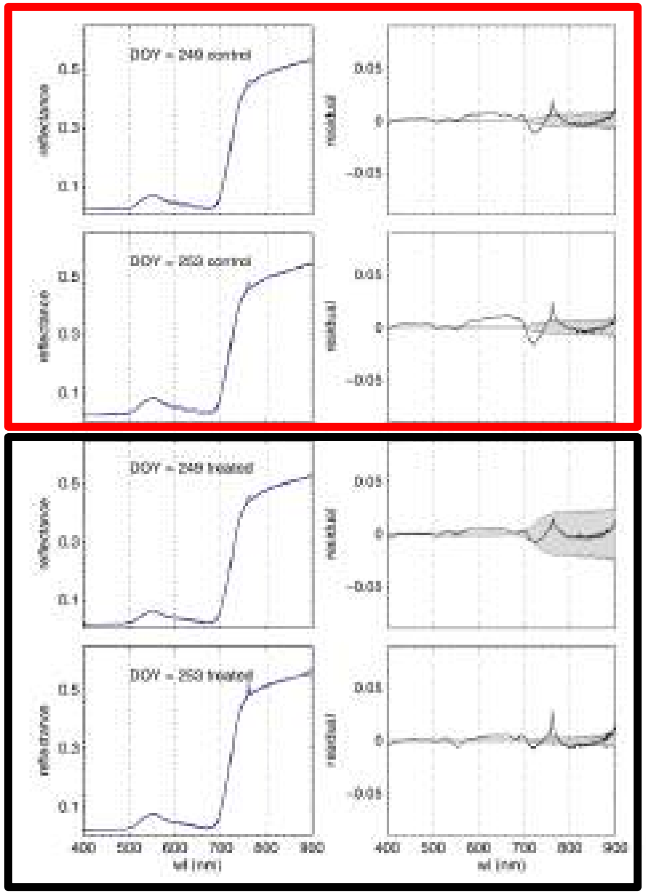
Time series of hyperspectral reflectance data over a rice field along the growing season
-Numerical inversion of RTMo (~1nm)
- Dynamic simulation of Φ_F according to van der Tol et al. (2014) JGR
- Forward modeling of F

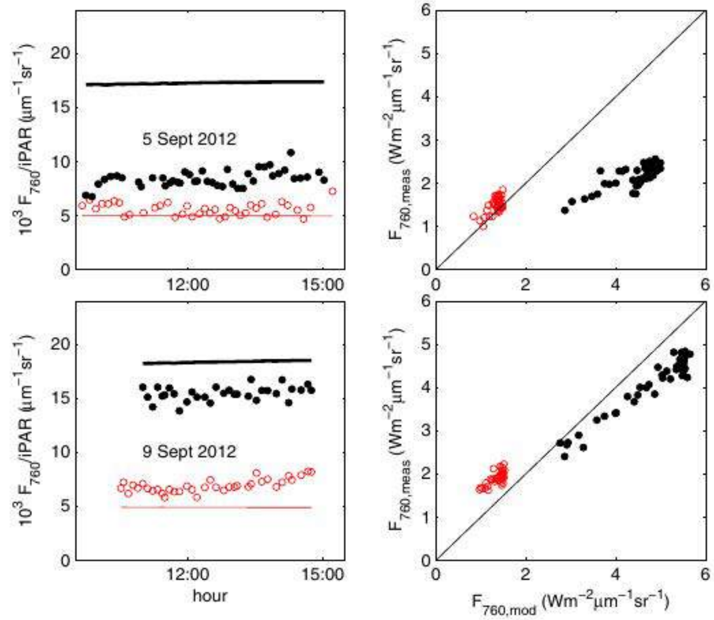


- Relatively small effect of Vcmo and meteo var. on normalized F (F/PAR)
- In unstressed canopies F variablity is driven by biochemical and structural parameters + incoming light

van der Tol et al. (2016) RSE

Results - Numerical inversion of reflectance to model F



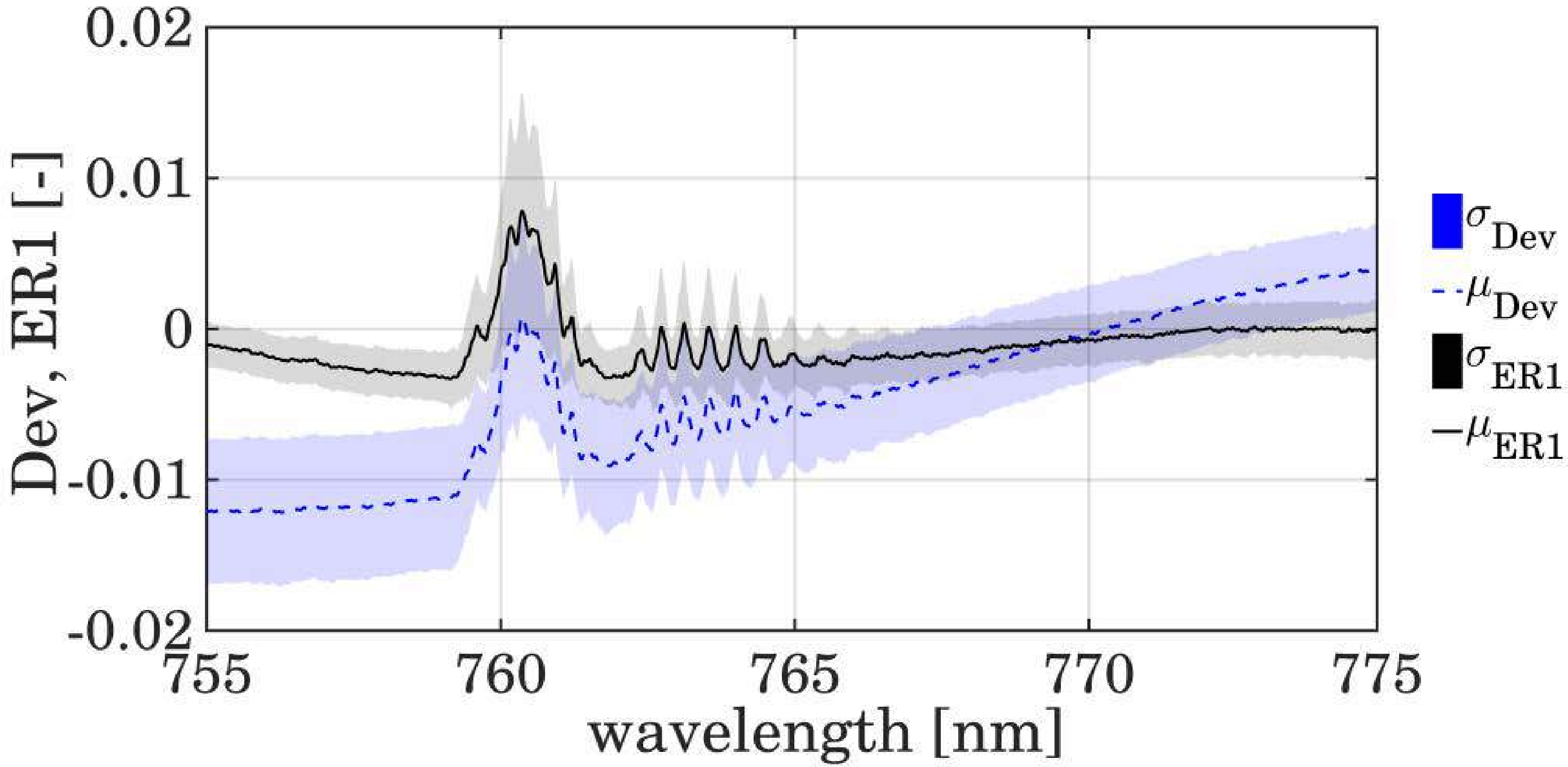


F response to strong reduction of PQ and NPQ

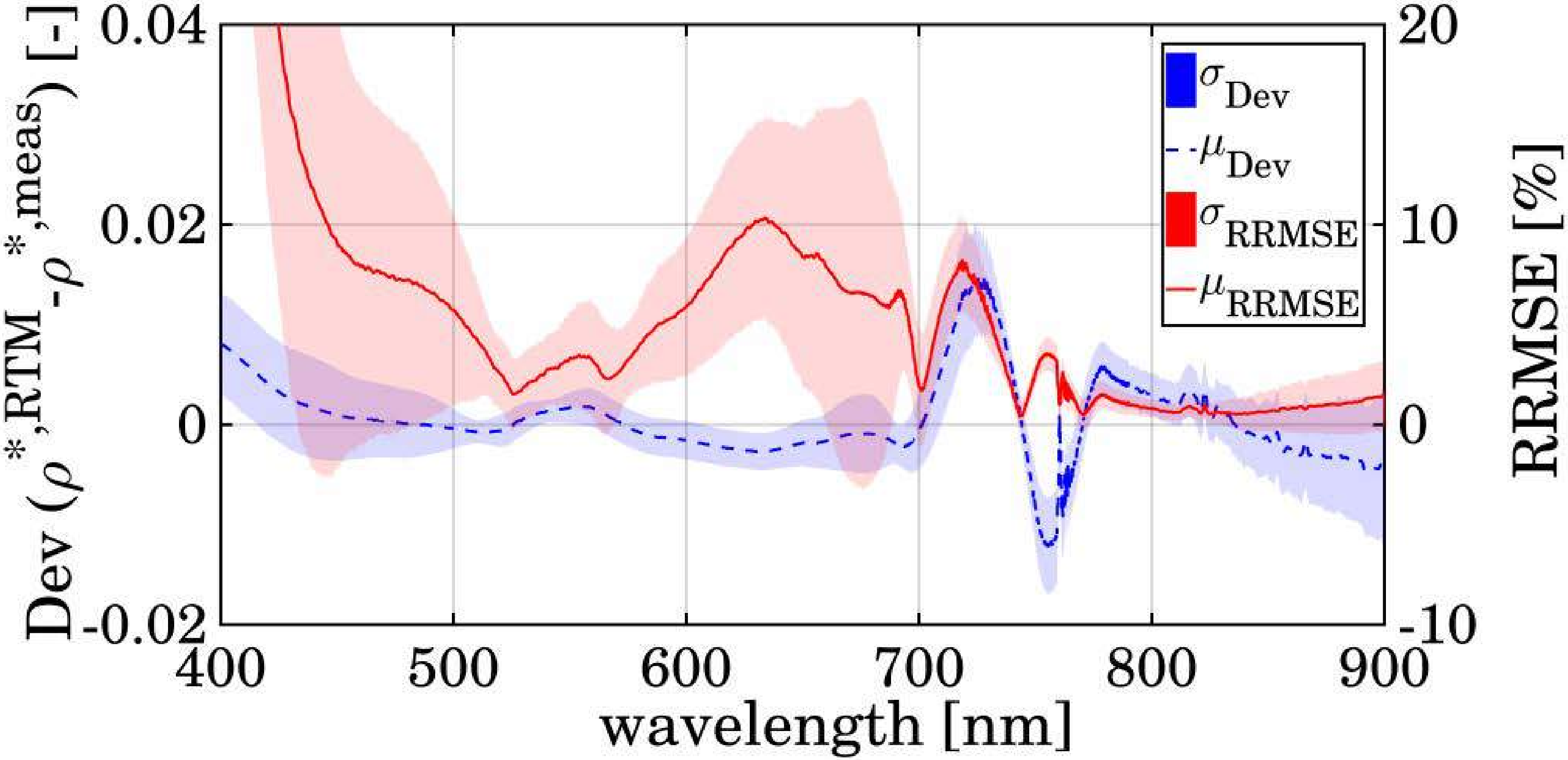
- Treated F values close to theoretical maximum

van der Tol et al. (2016) RSE

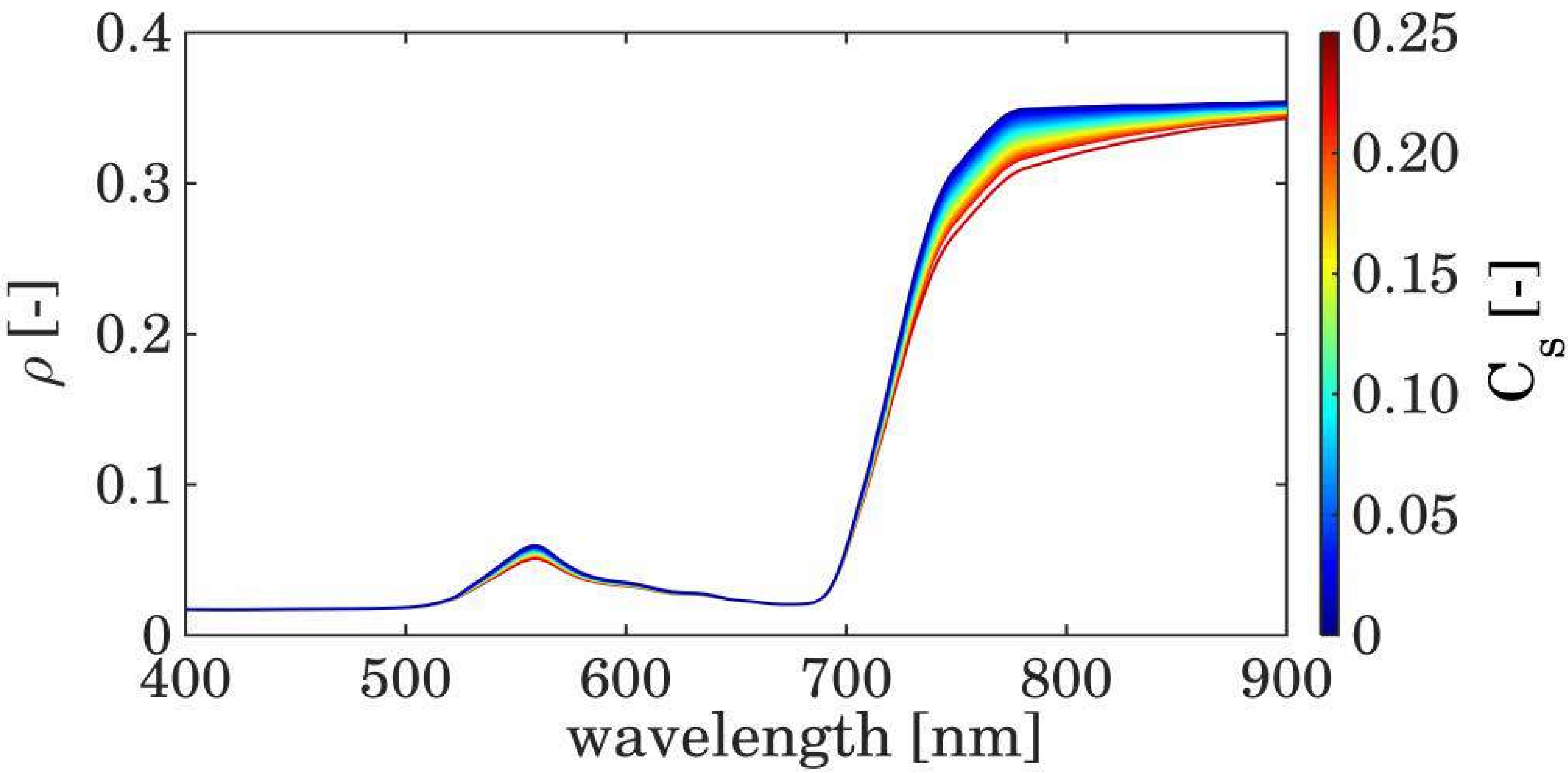
Results



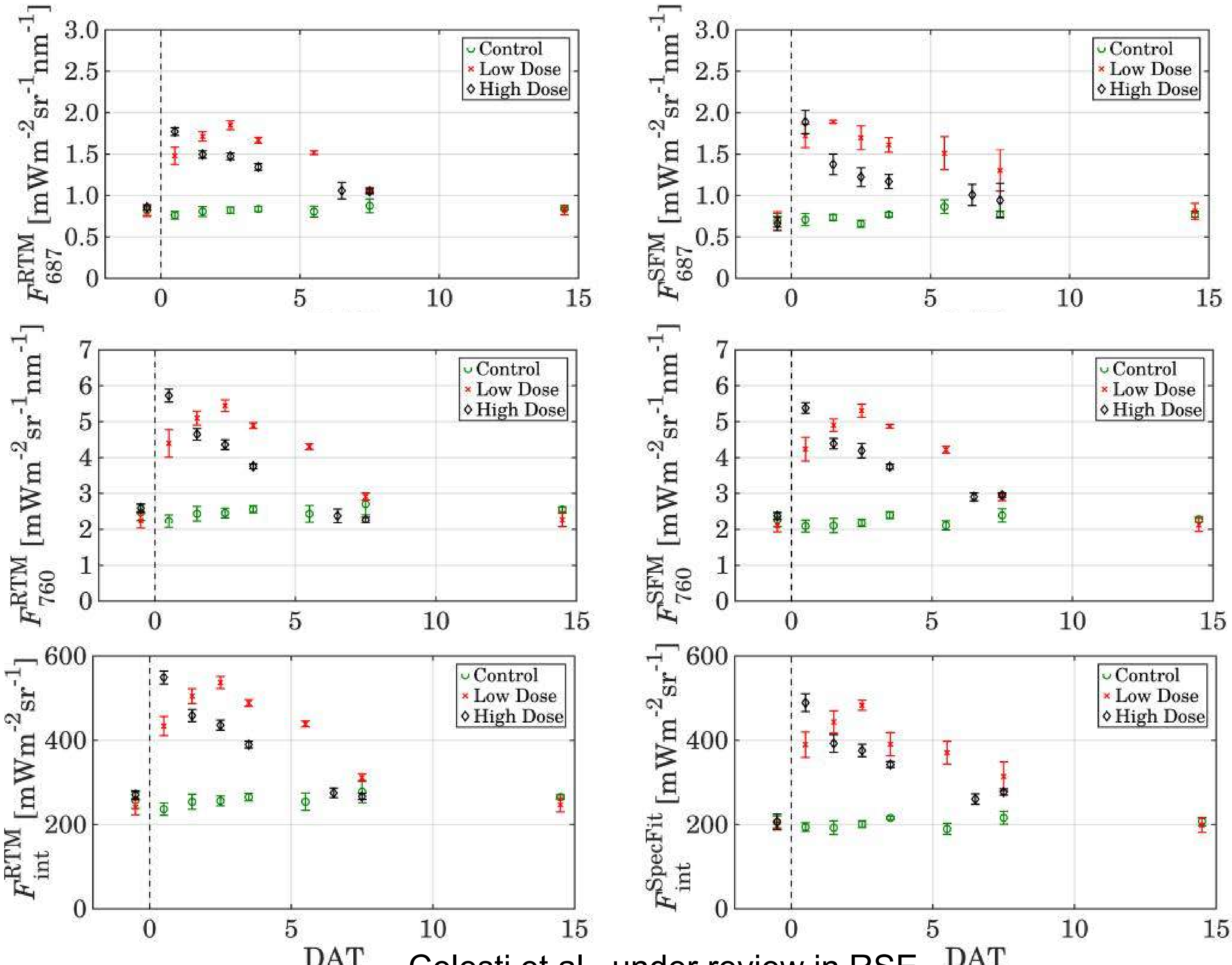
Celesti et al., under review in RSE



Celesti et al., under review in RSE



Celesti et al., under review in RSE



Celesti et al., under review in RSE