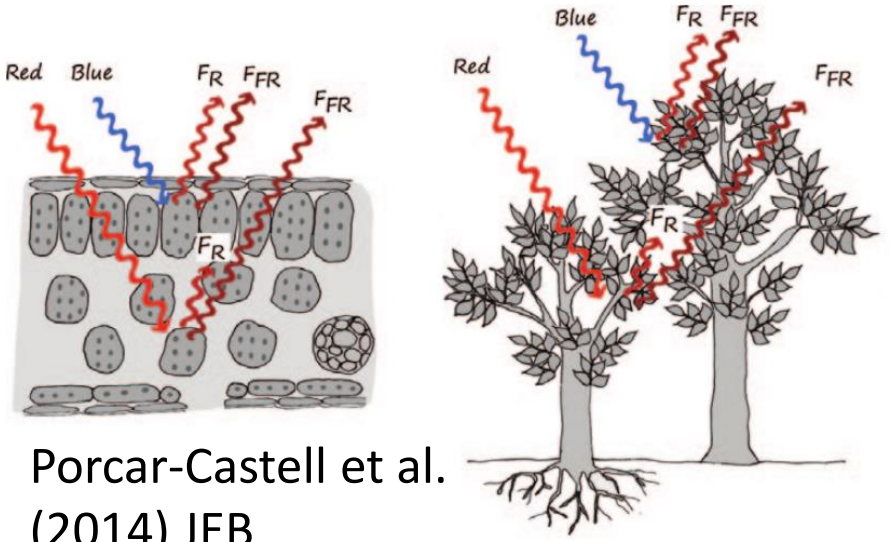
MULTI-FLEX

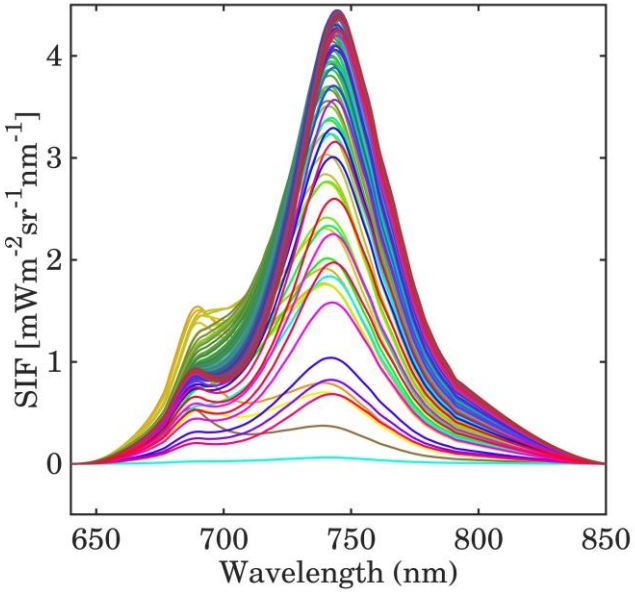
Marco Celesti (University of Milano-Bicocca)

Context of the research

- Solar-induced chlorophyll fluorescence (SIF) is emitted at photosystem level as a function of absorbed excitation energy (APAR) and SIF quantum efficiency (Φ_F)
- Propagates through the leaf and the canopy → top of canopy fluorescence (→ RS measurements)
- Inherently linked to the functioning of the photosynthetic machinery
- Highly dynamic in time and space



Porcar-Castell et al. (2014) JEB



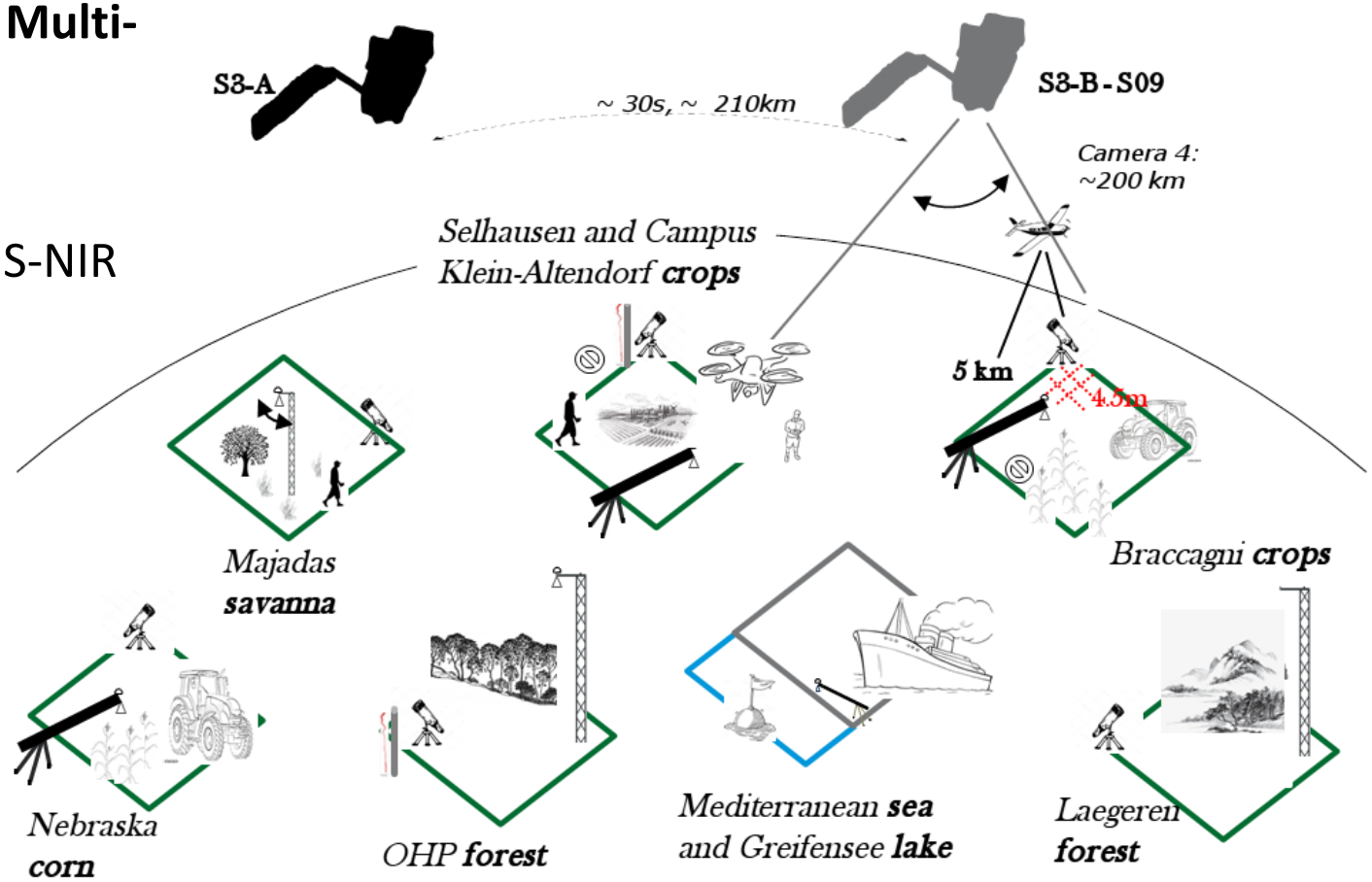
ESA EE8 FLEX mission

First mission conceived for global SIF retrieval at 300m x 300m spatial resolution

Experimental data collection

ESA FLEXSense + **ATMO-FLEX** campaign → **Multi-scale** dataset acquired in Summer 2018

- Long term ground based hyperspectral VIS-NIR measurements (FLOX)
- Atmospheric characterization (e.g., Sunphotometer)
- Airborne overpasses (HyPlant)
- S-3B "FLEX like" acquisitions
- Ancillary data (site specific)



Project overview

MULTI-FLEX: TOWARDS A STRATEGY FOR FLUORESCENCE MONITORING AT MULTIPLE SCALES WITHIN THE CONTEXT OF THE FLEX/S-3 TANDEM MISSION

Duration: 1 Dec 2018 – 30 Nov 2020

Main objective: to explore the spectral, temporal and spatial variability of fluorescence for plant status monitoring exploiting multi-source remote sensing optical data

Specific objectives:

- to develop a processing chain for coupled retrieval of fluorescence and vegetation parameters from continuous ground hyperspectral measurements in FLEX-like spectral configuration;
- to adapt and test this inversion scheme to the spectral resolution of the reconfigured Sentinel-3B OLCI;
- to exploit HyPlant (TOC) products to test reflectance-based metrics capable of tracking the spatial heterogeneity of fluorescence
- to test these approaches on fluorescence products derived from the reconfigured Sentinel-3B OLCI data

Project status

Work Package	Description	Status at mid term
WP1	Development of a processing chain for coupled retrieval of fluorescence and vegetation parameters from continuous ground hyperspectral measurements	Main development completed; Refining and evaluating results
WP2	Adaptation of the inversion scheme to the spectral resolution of the reconfigured Sentinel-3B OLCI	Data prepared and first tests; now adapting retrieval scheme
WP3	Exploiting HyPlant and Sentinel-3A TOC products to test simple fluorescence-derived metrics	Data prepared; now performing geostatistical analysis
WP4	Scaling of the scheme proposed in WP2 to the reconfigured OLCI-B TOC data	Delayed due to missing L-1b data: WP5
WP5	Processing of the reconfigured Sentinel-3B OLCI data to L1b TOA radiances	Added to the original proposal with a CCN; Completed

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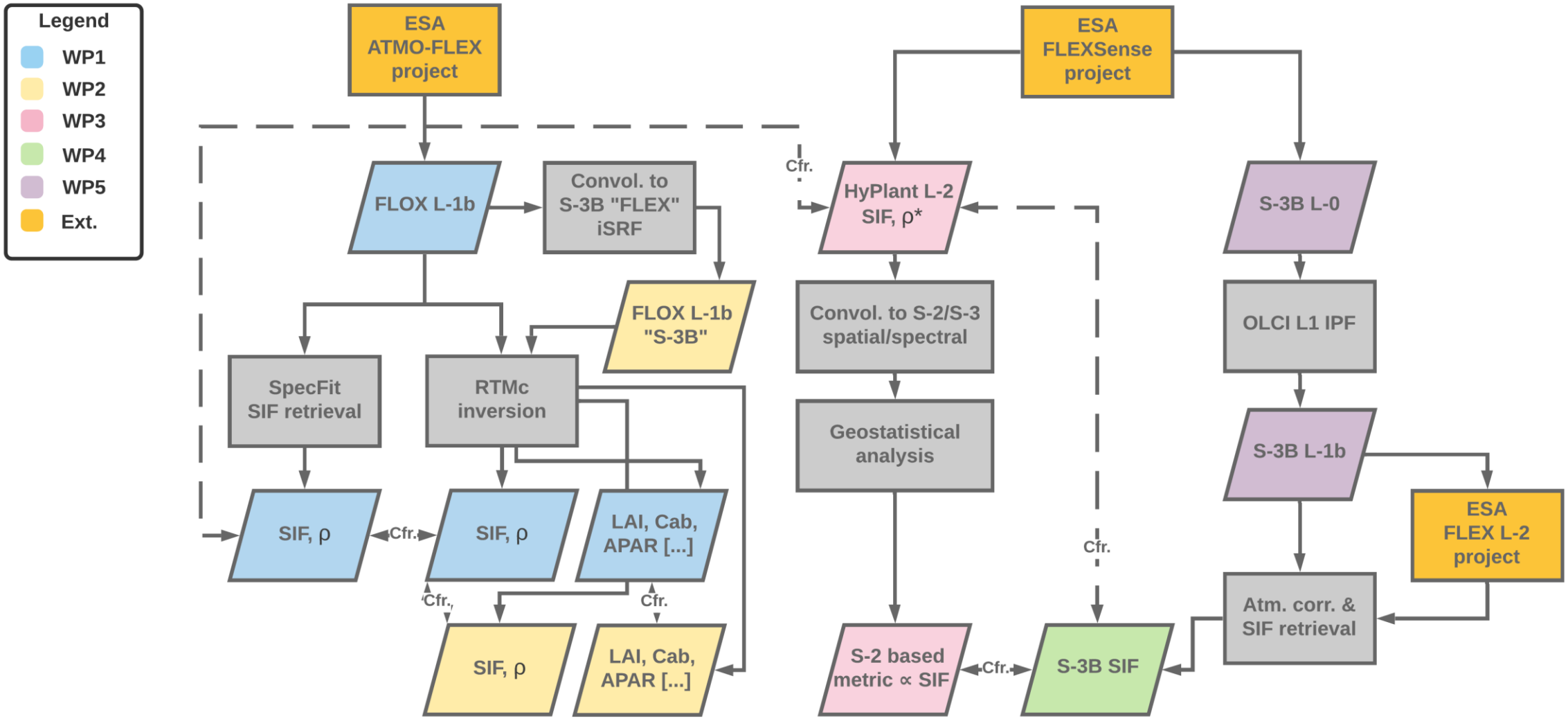
Project workflow



Data & Methods [WP1]

Coupled retrieval of fluorescence and vegetation parameters from continuous ground hyperspectral measurements

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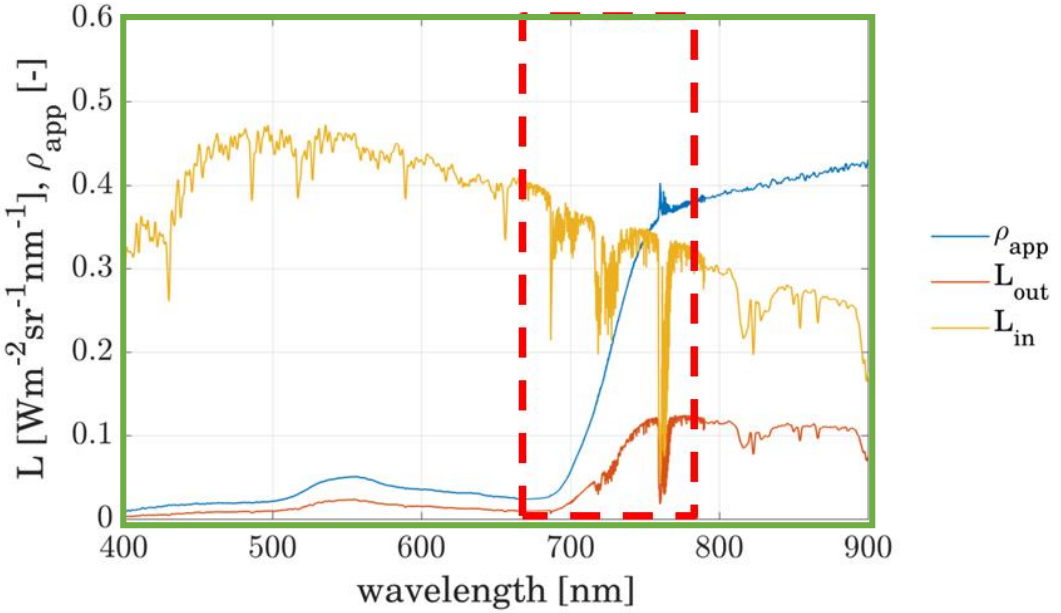

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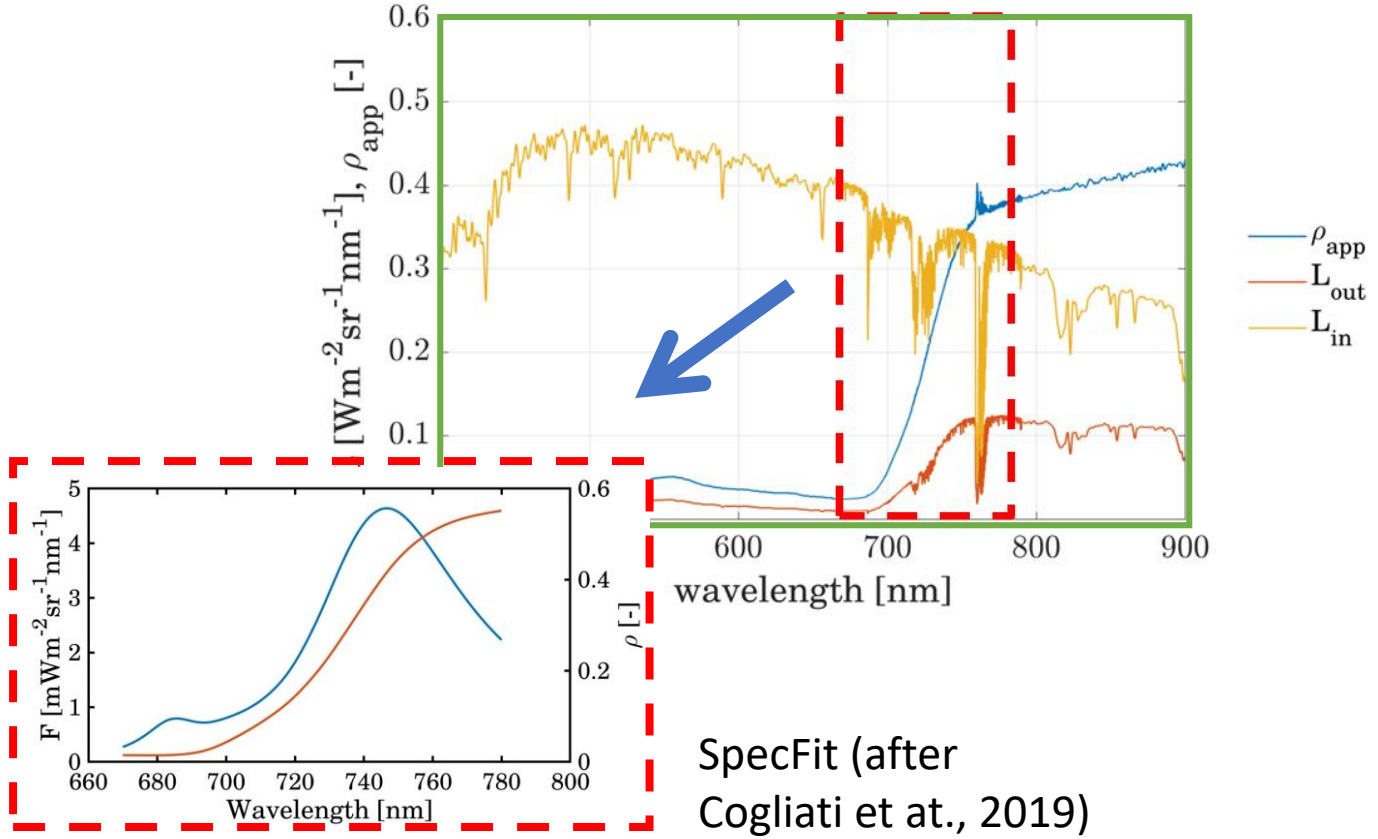

SpecFit (after Cogliati et at., 2019)

Data & Methods [WP1]

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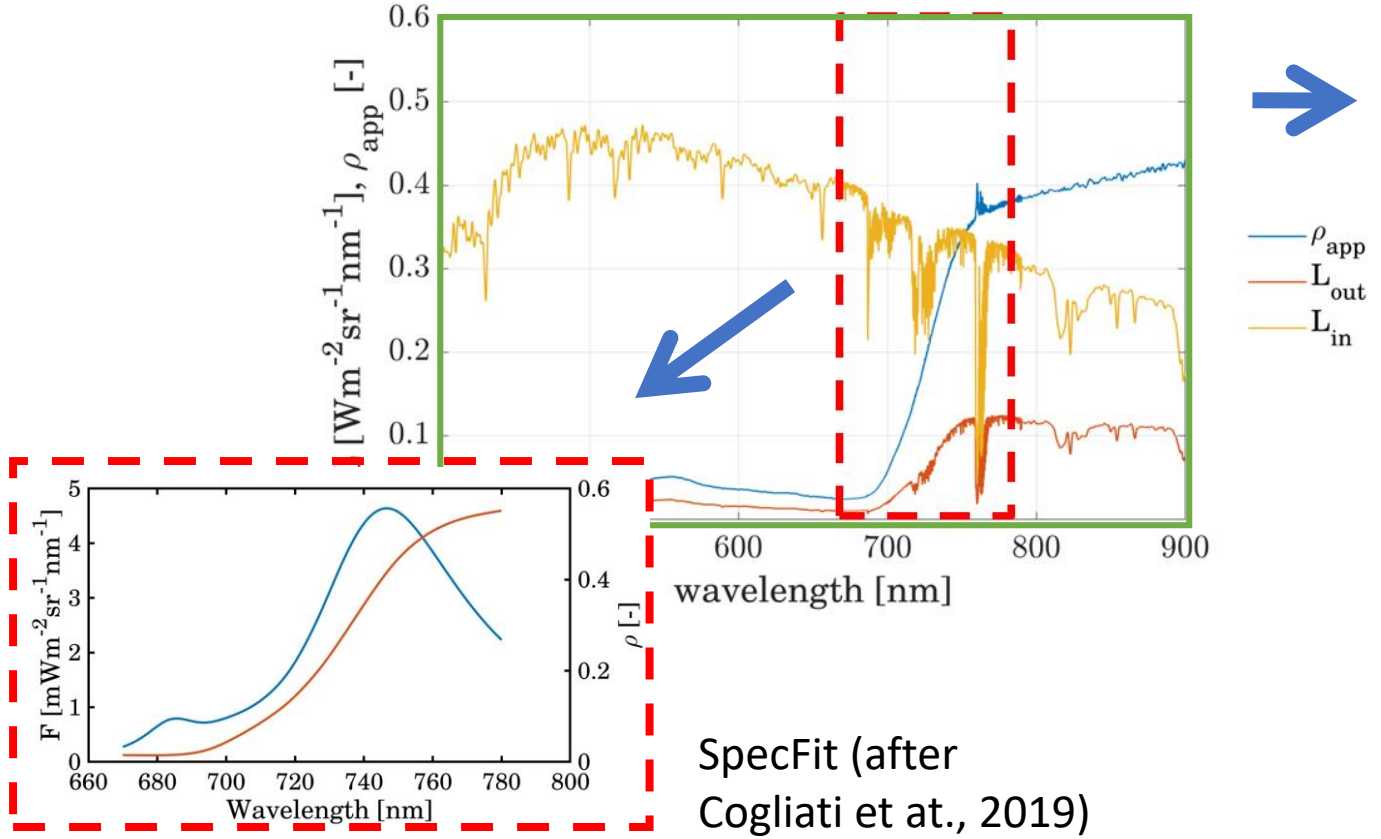
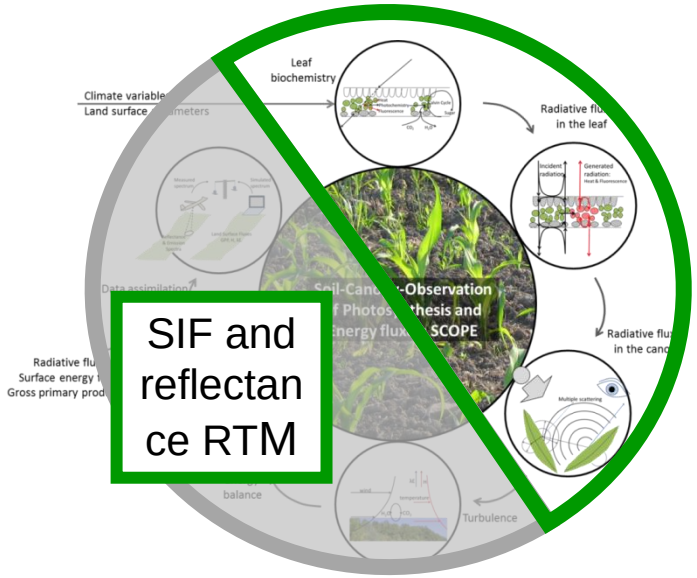


SpecFit (after Cogliati et at., 2019)

SCOPE model (RTM + fluxes)

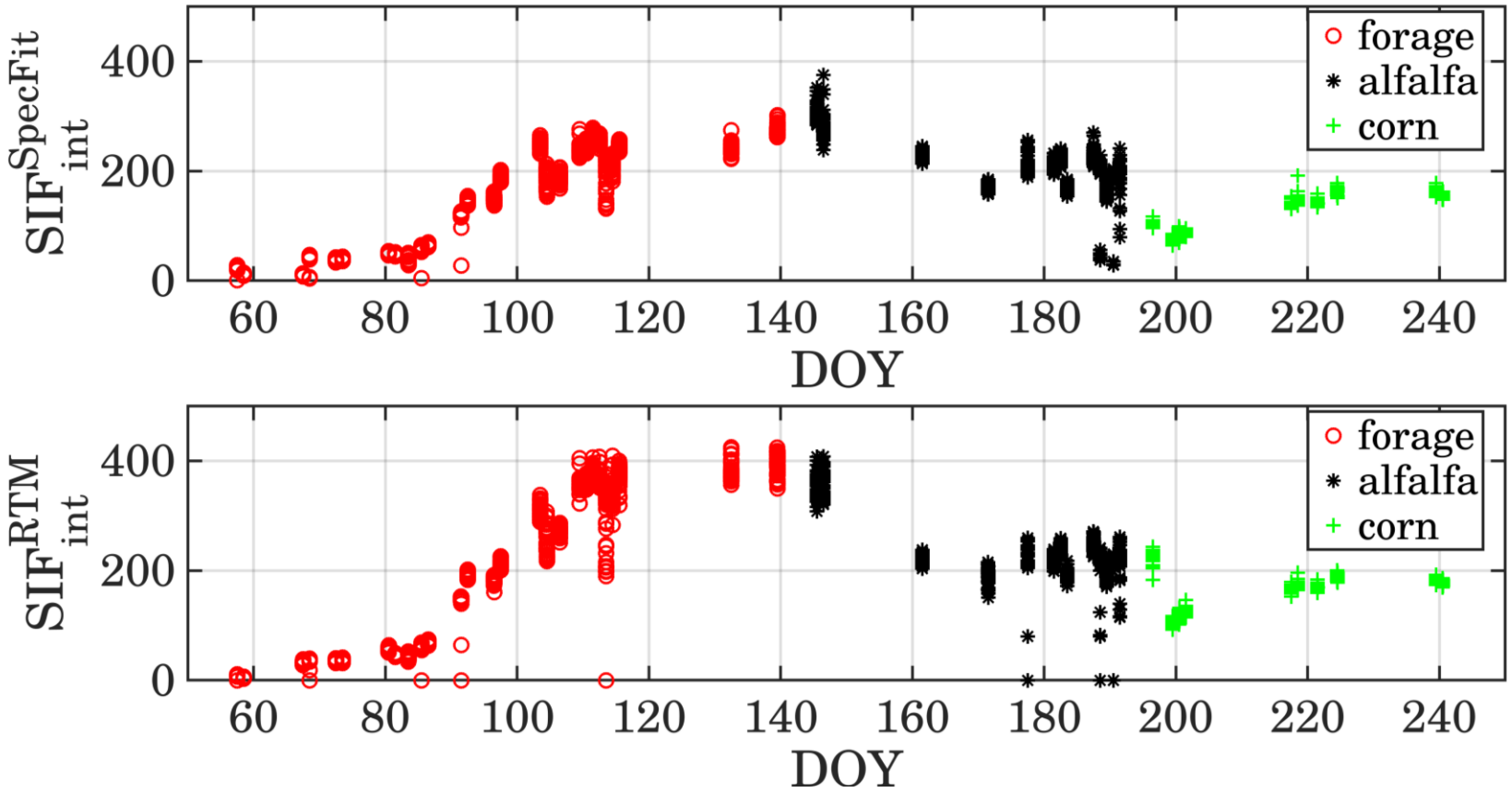


SIF and reflectance RTM

Non-linear Least Square NO:
Cab, Cca, Cdm, Cw …
LAI, APAR …
Φ_F → fluorescence quantum efficiency

Results [WP1]

Time series of full spectrum SIF integral retrieved with SpecFit and with RTM inversion -> an example from the Italian site



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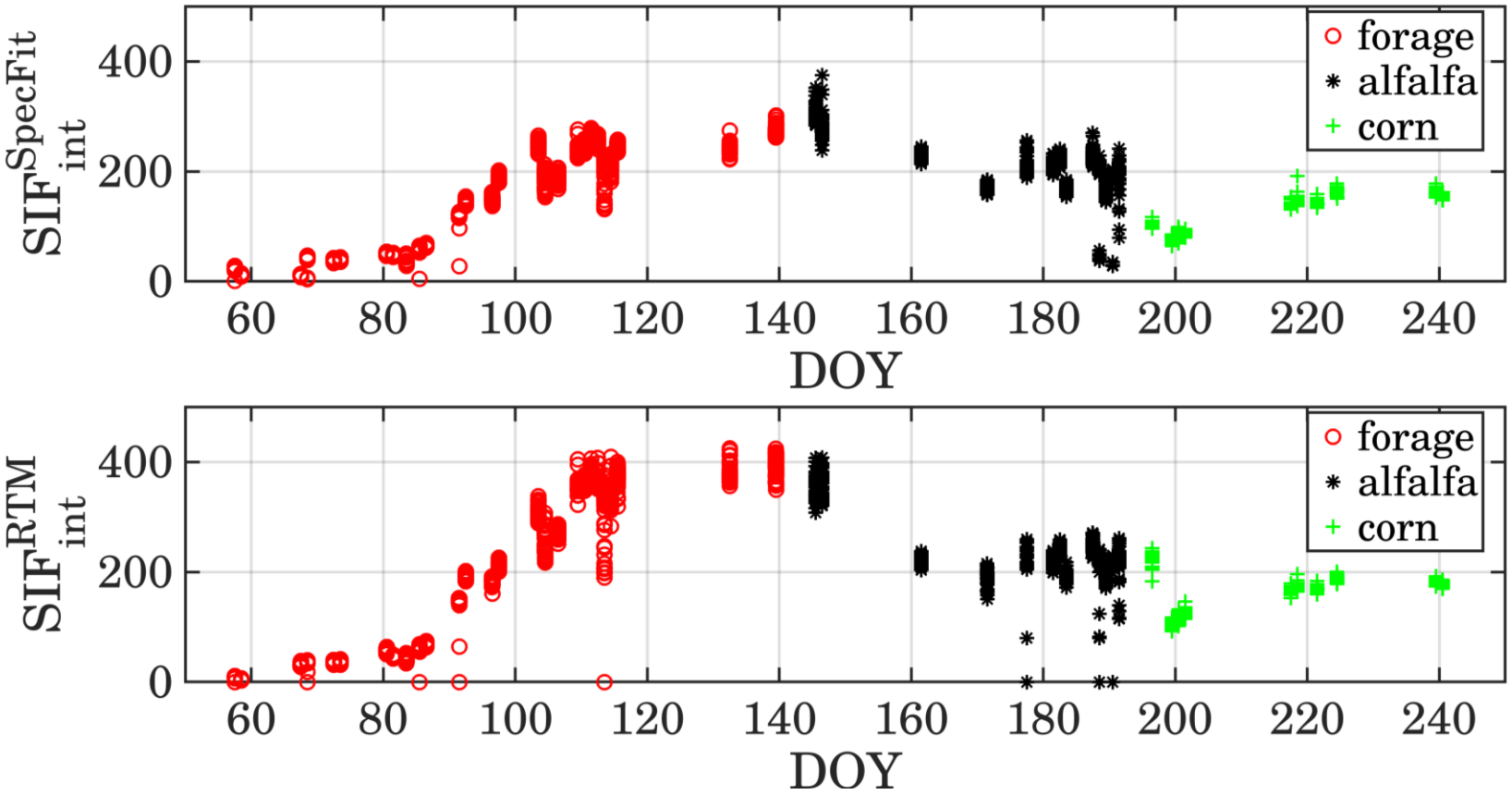

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- Absolute values are overestimated

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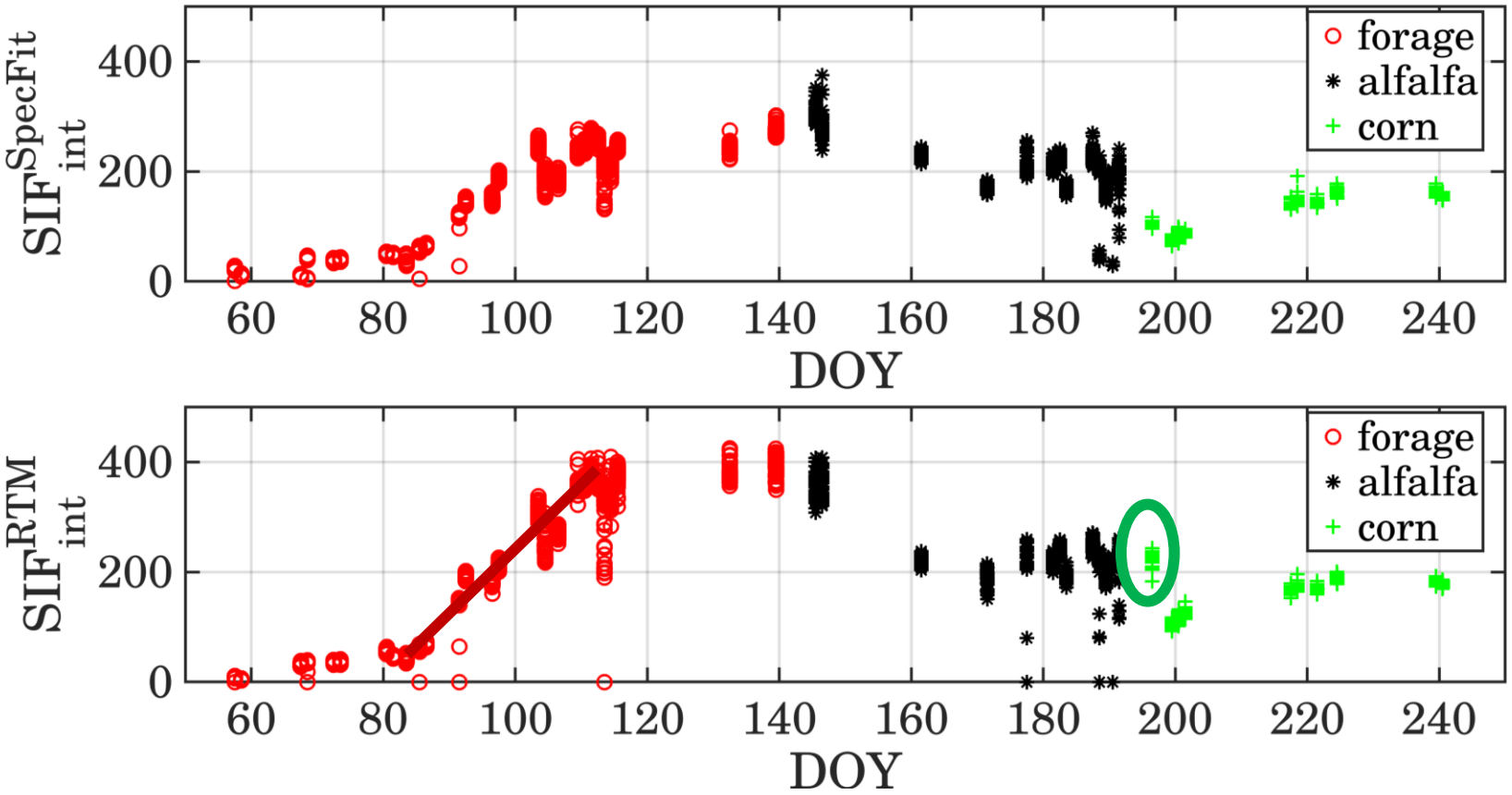

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- Largest discrepancy during forage growing phase and beginning of corn growth (low fractional cover)

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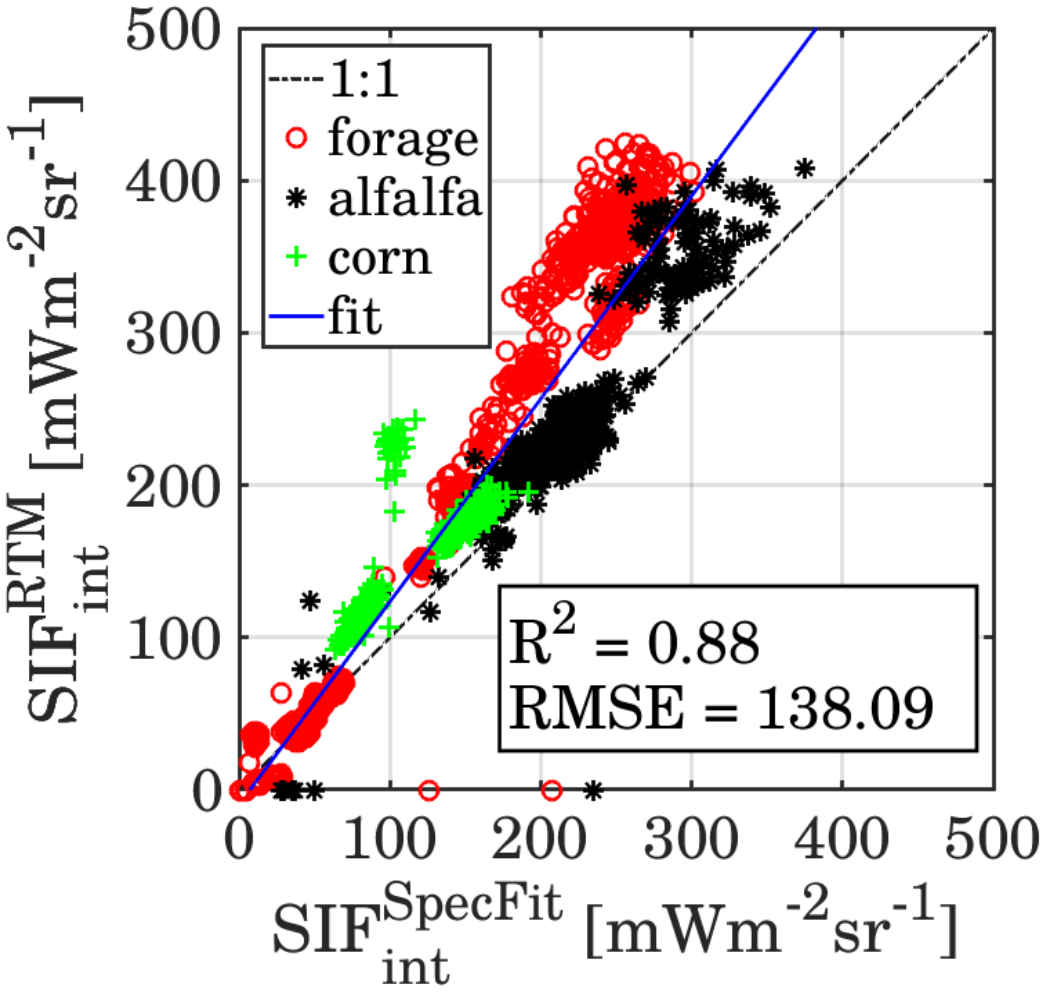

- Overestimation due to uncertain retrieval of SIF-driving parameters (e.g., LAI, Cab)
- Crop specific trends suggest potential incorrect representation of different leaf angle distribution functions (LADf) --> Additional test with more degrees of freedom in the LADf retrieval

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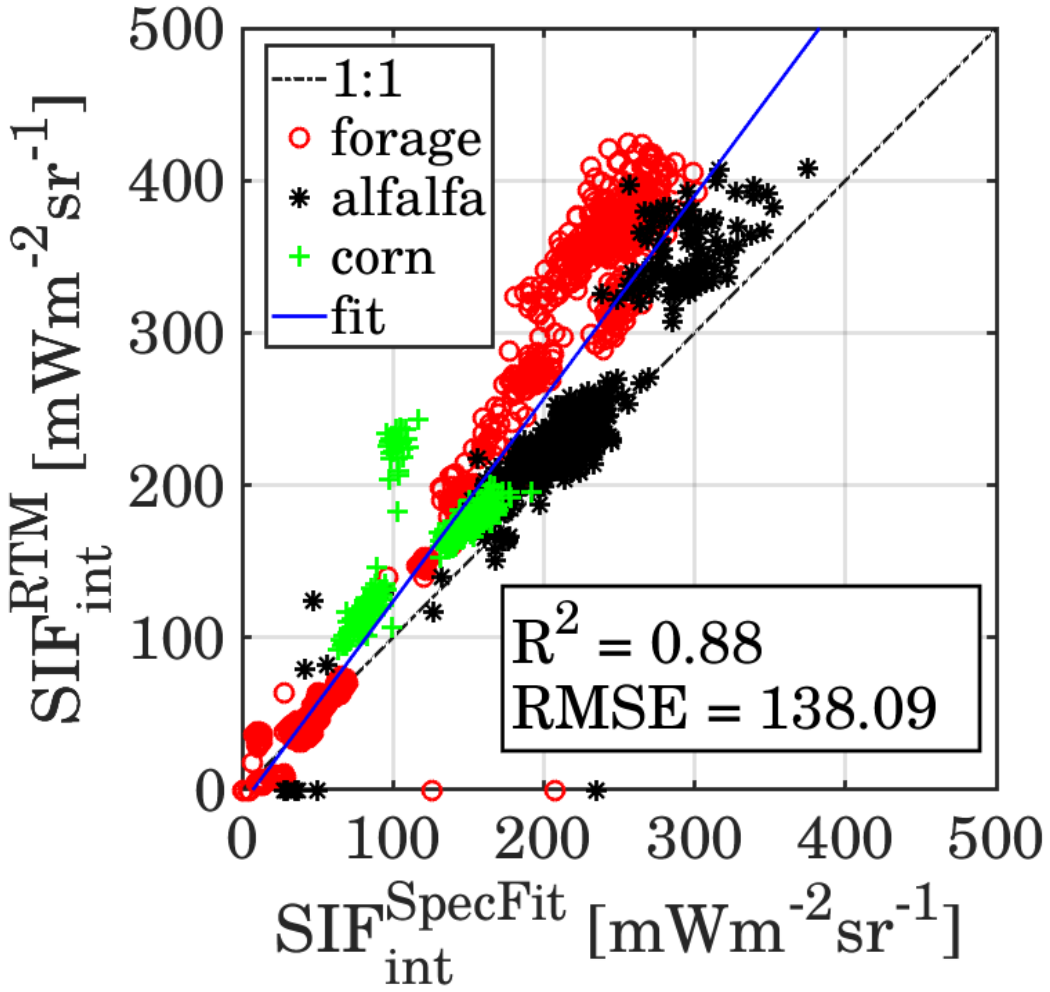

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TODO

- time regolarization (Jacobians)
- $SIF_{SpecFit}$ as a constrain

Data & Methods [WP2]

Testing SIF retrieval on reconfigured S-3B OLCI data (convolved FLOX data)

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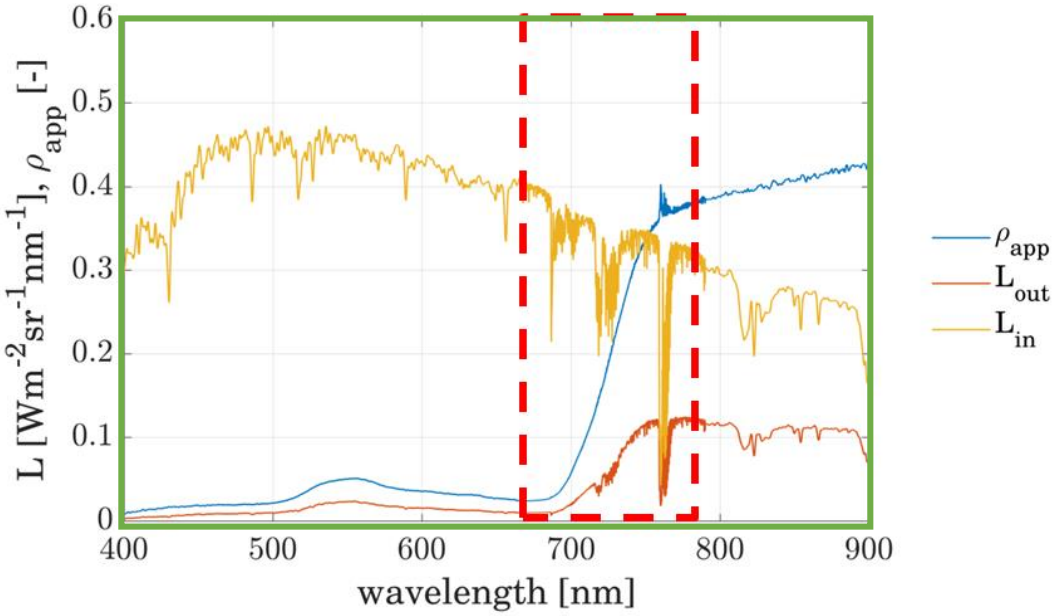

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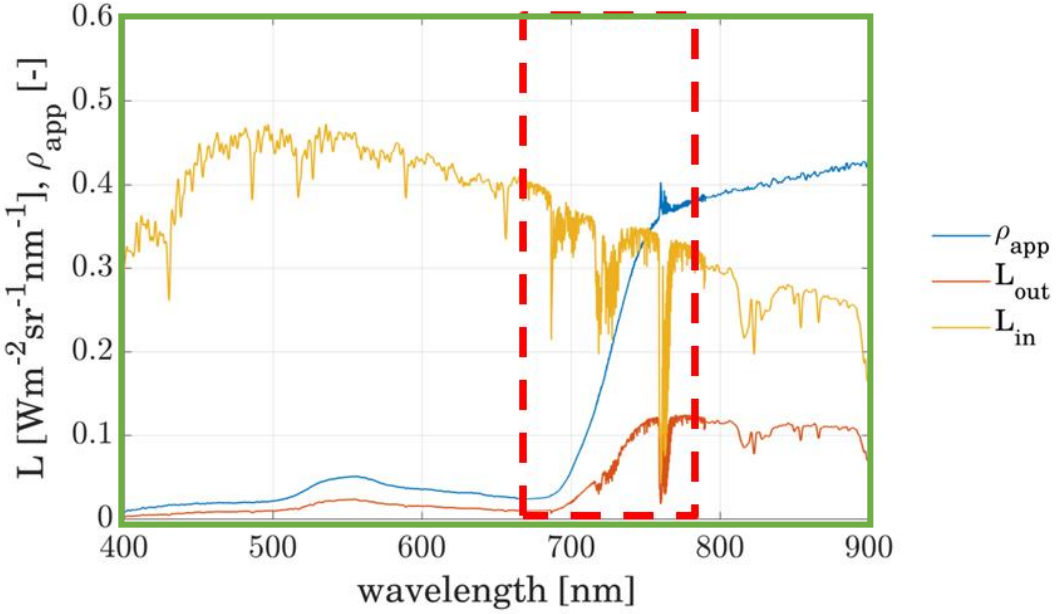

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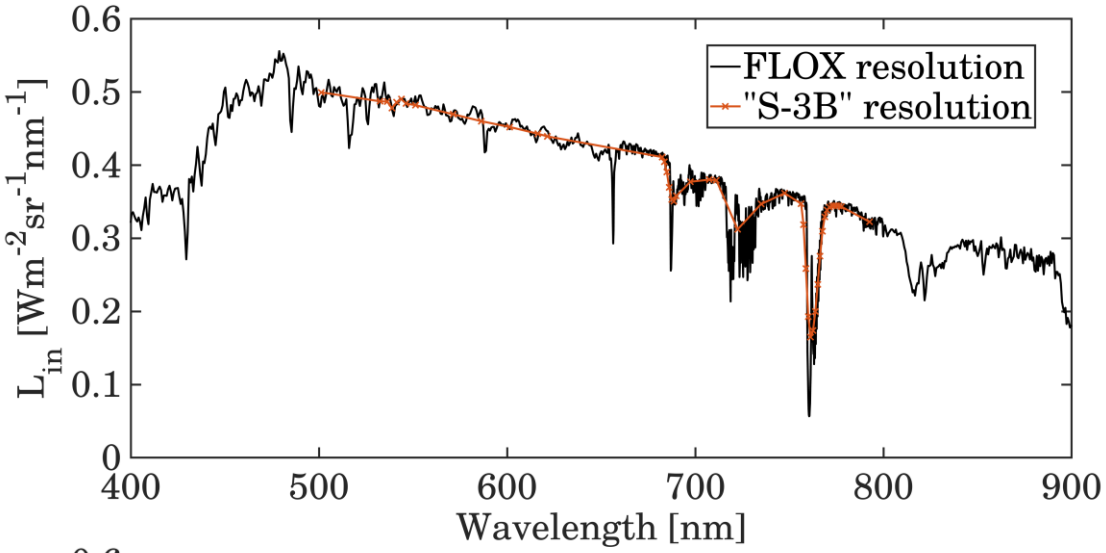

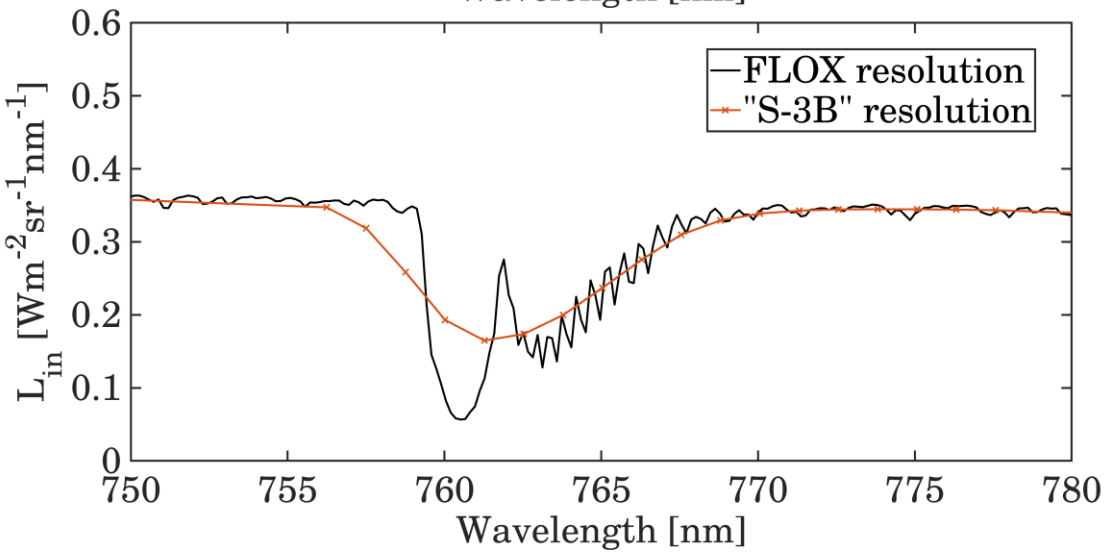

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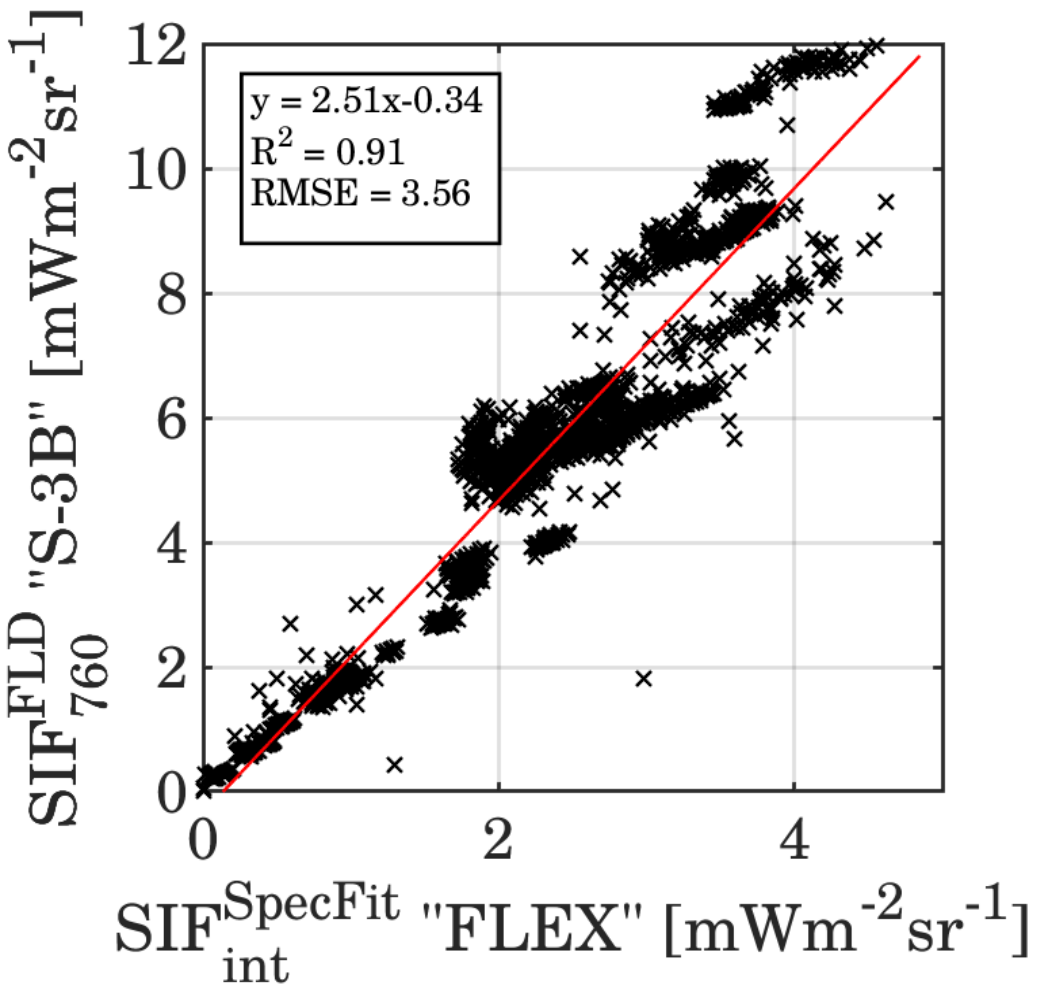

FLD retrieval from "S-3B" data and cf. with state of the art

- Overestimation due to the different spectral resolution (critical in the absorption bands where SIF is retrieved) but good overall relative agreement in the O_2-A band (SIF_{760})
- Simple retrieval approaches (e.g., FLD) do not work well in the O_2-B band while a higher spectral resolution is required for complex methods (e.g., SpecFit) → potential for process-based retrieval (to be evaluated)

Data & Methods [WP5]

Processing of the reconfigured Sentinel-3B OLCI data to L1b TOA radiances

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S-3B OLCI "FLEX-mode" = Modified S09 configuration:

- 45 µbands
- Focus on O_2-A and O_2-B

No ground processor capable of dealing directly with S09 data

- Preparation of Level-0 ISPs + ADFs in order to be processed with EO standard processor (i.e., three 21-bands subsets)

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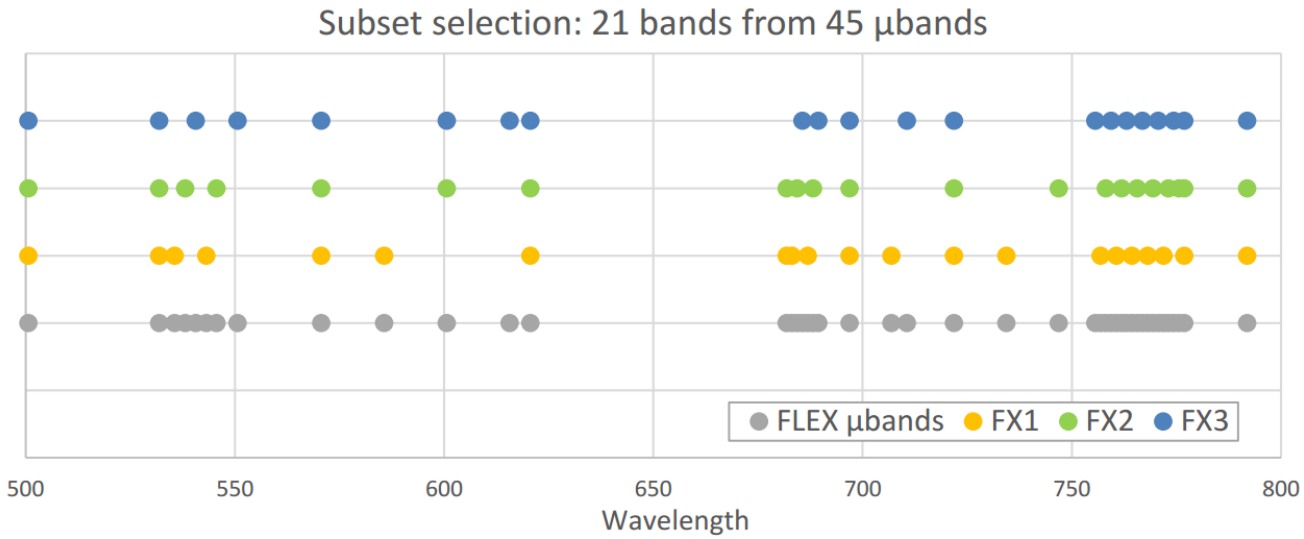
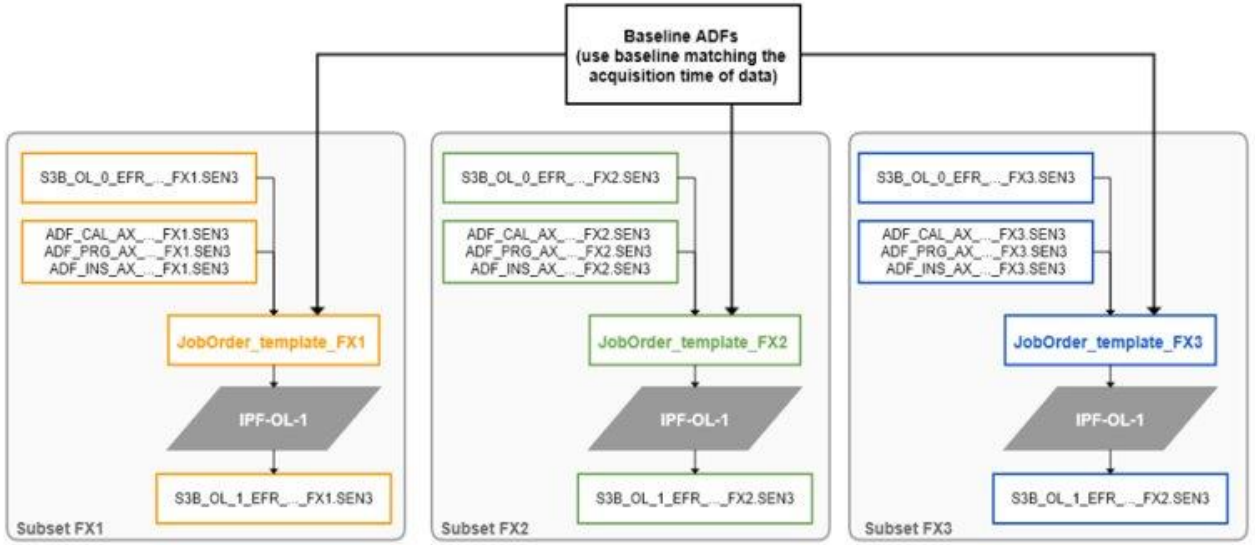
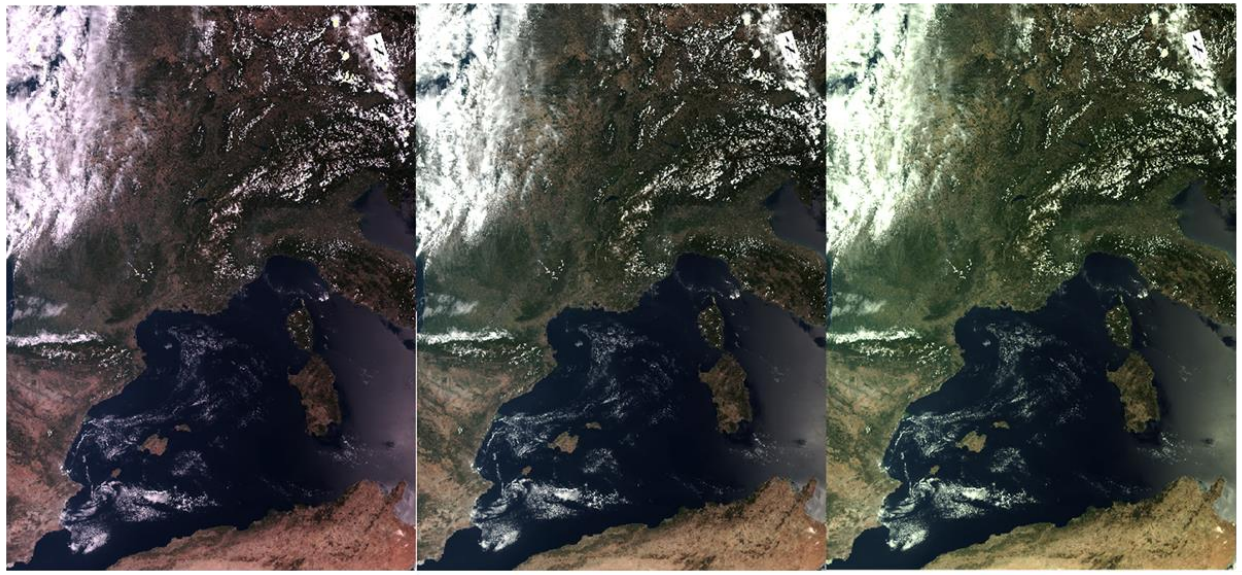
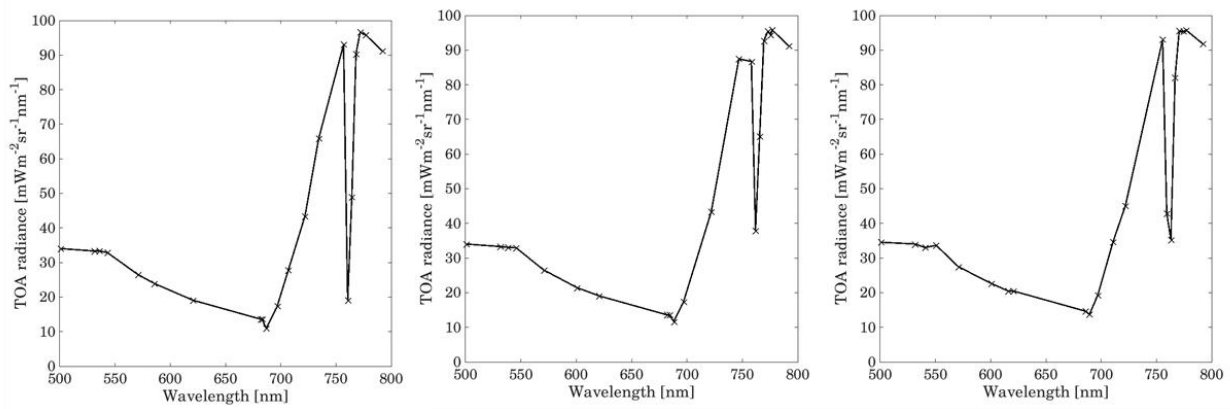




Results [WP5]

FX1 FX2 FX3





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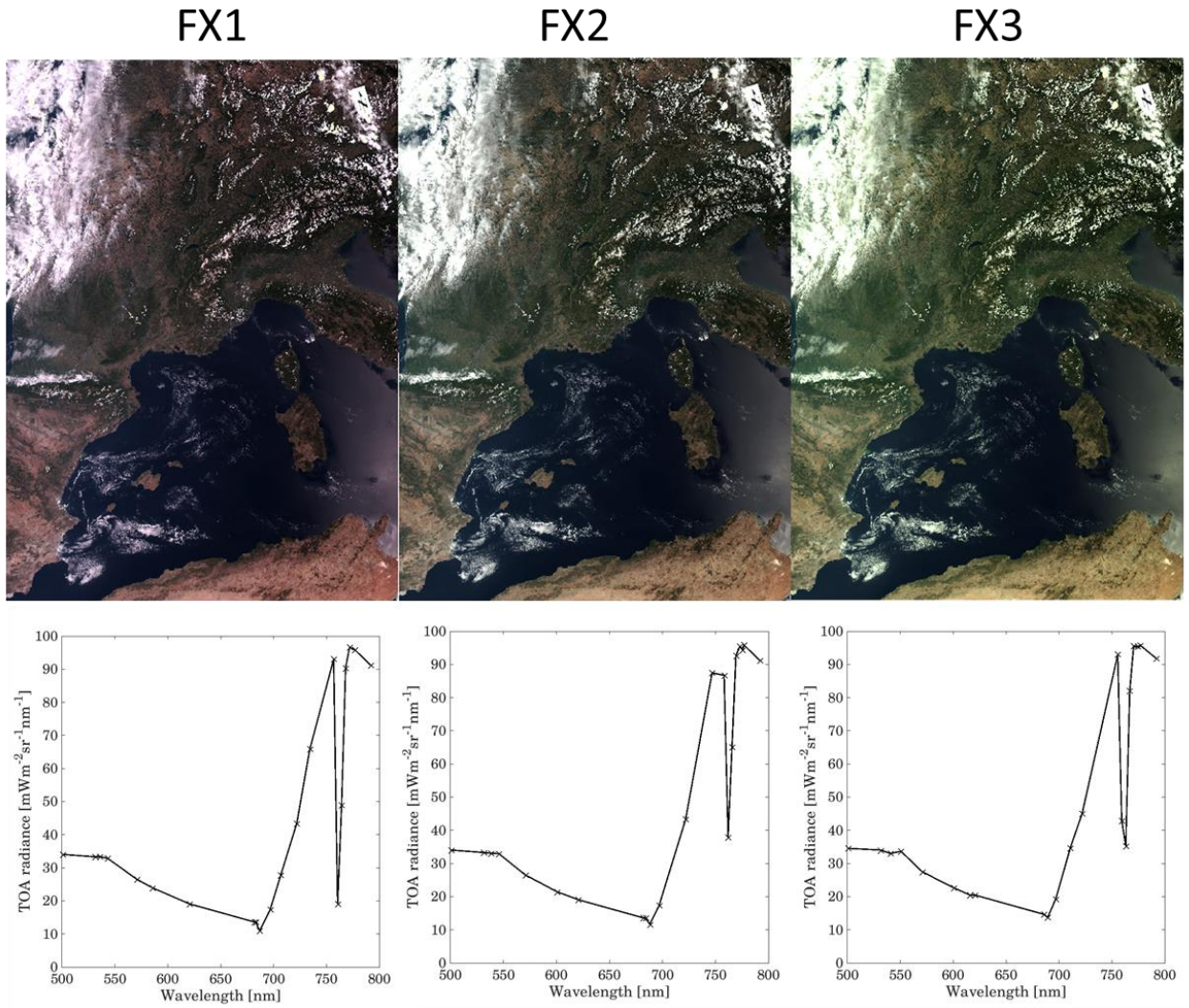
Results [WP5]

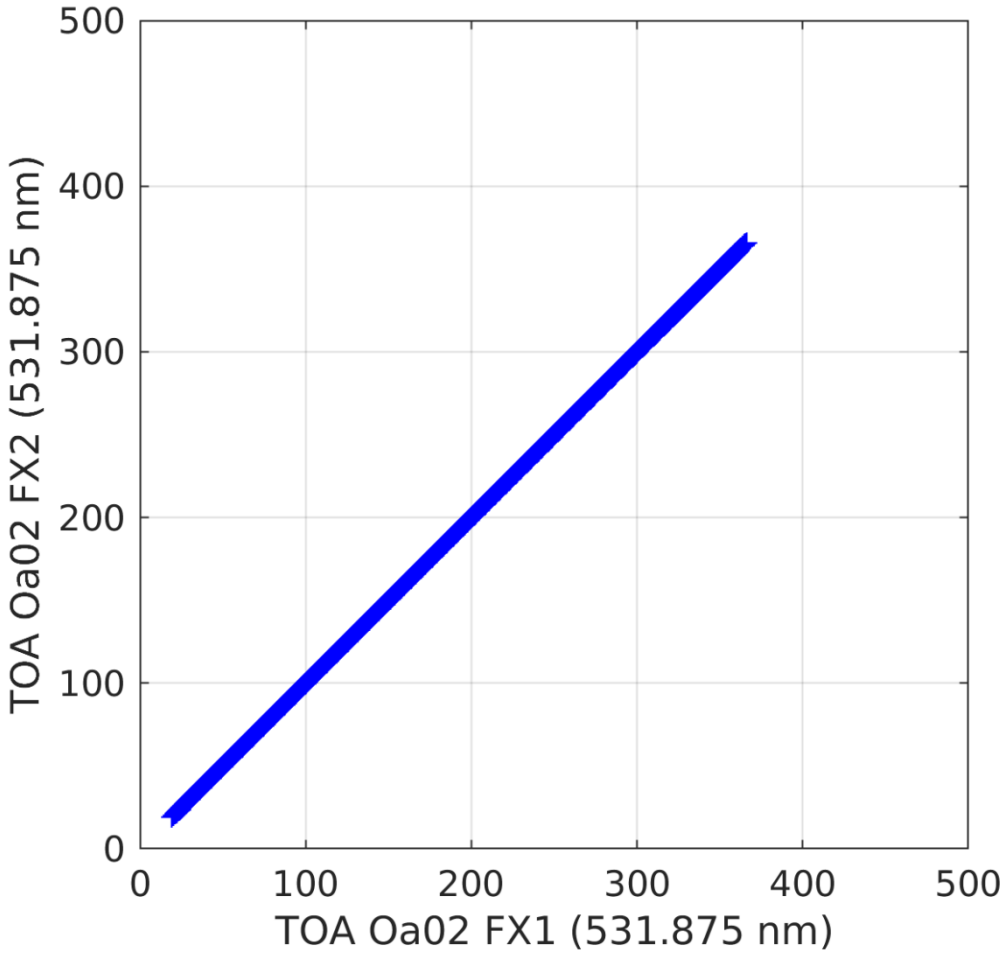


- How to quantitatively evaluate the performance of the processor with non-relaxed bands? Critical part is most likely stray-light correction…

13

Results [WP5]

Q-Q plot between two subsets (same microband)



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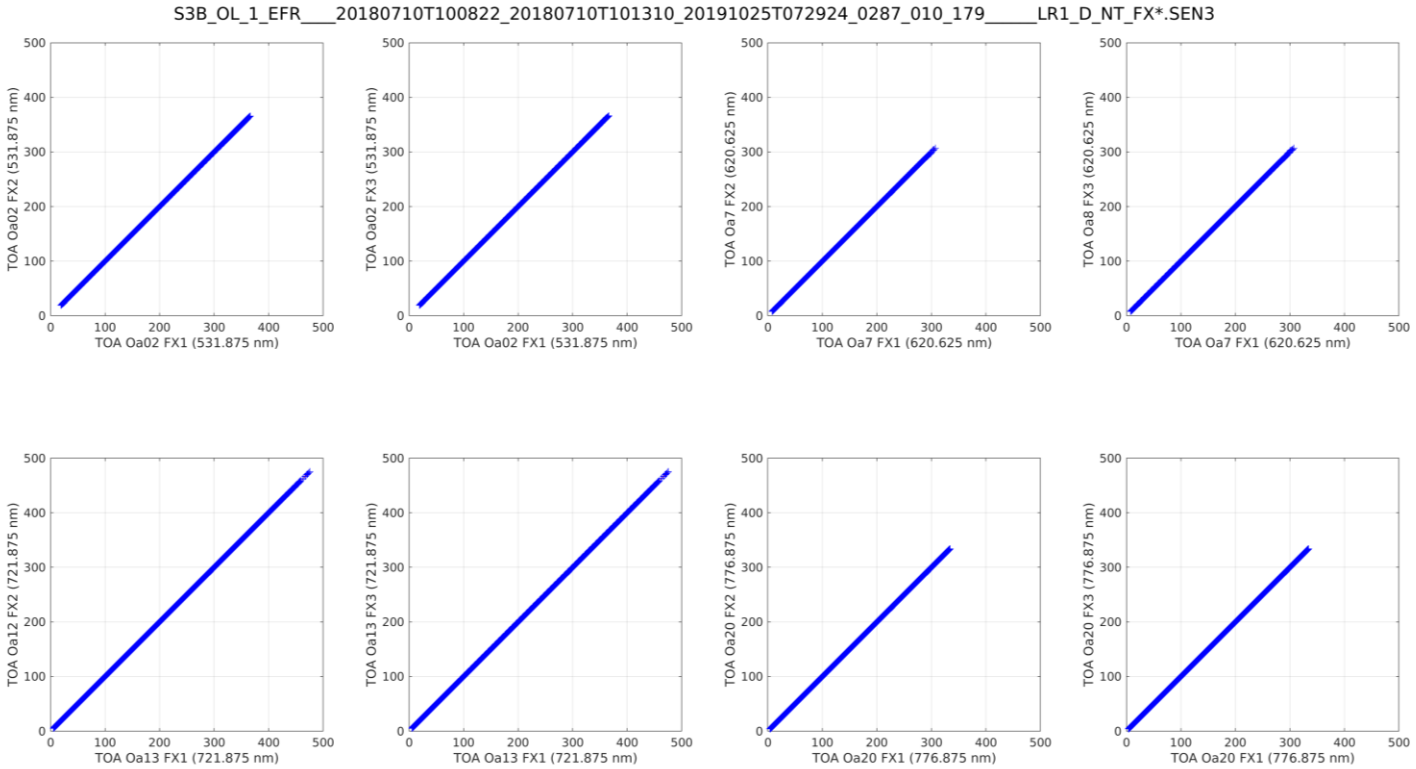
- Cf. of common bands between FX1, FX2 and FX3 (completed) → perfect match after removing saturated pixels

Results [WP5]

Q-Q plots between all common microbands



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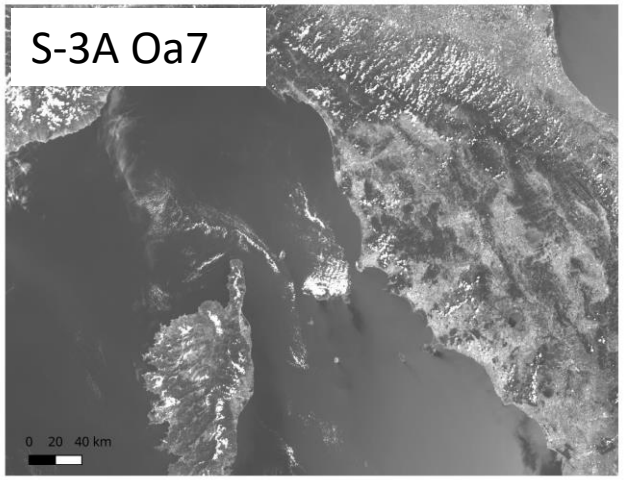

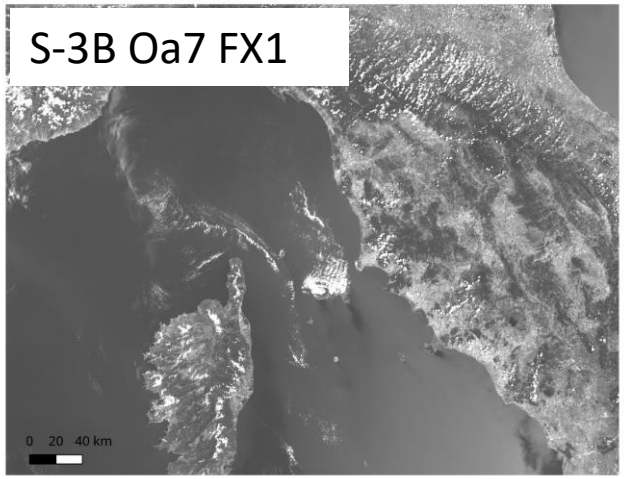

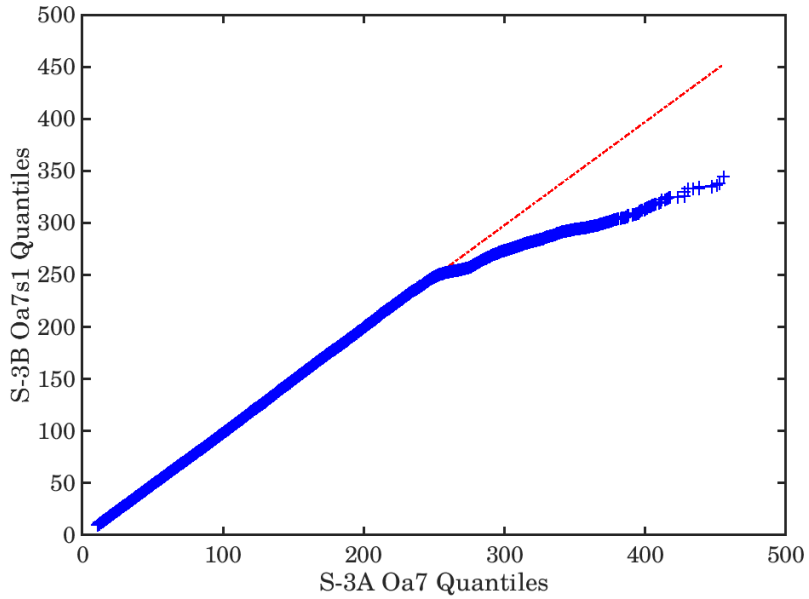

- How to quantitatively evaluate the performance of the processor with non-relaxed bands? Critical part is most likely stray-light correction…
- Cf. of common bands between FX1, FX2 and FX3 (completed) → perfect match after removing saturated pixels
- Cf. with S-3A OLCI (started) → very good agreement apart from high values (sat. pixels not yet removed + spectral mismatch + spatial mismatch)

Workplan for 2nd year

Work Package	Description	Actions to be performed during 2nd year
WP1	Development of a processing chain for coupled retrieval of fluorescence and vegetation parameters from continuous ground hyperspectral measurements	Consolidate the analysis over the different targets (i.e., different sites) in a scientific publication
WP2	Adaptation of the inversion scheme to the spectral resolution of the reconfigured Sentinel-3B OLCI	Finalize the adaptation of the retrieval scheme and evaluate the feasibility of its application to the satellite data
WP3	Exploiting HyPlant and Sentinel-3A TOC products to test simple fluorescence-derived metrics	Evaluate S-2 reflectance-based metrics to track SIF heterogeneity at FLEX spatial resolution
WP4	Scaling of the scheme proposed in WP2 to the reconfigured OLCI-B TOC data	Work in synergy with the FLEX Level-2 study to perform atmospheric correction and SIF retrieval
WP5	Processing of the reconfigured Sentinel-3B OLCI data to L1b TOA radiances	Distribute the data following a scientific publication

Scientific output

1st year - Conferences and workshops

- Celesti, M.,et al.(2019) Exploring the Physiological Information of Solar-Induced Chlorophyll Fluorescence Through Radiative Transfer Model In-version: a Multi-Scale Approach From Ground to Airborne Data. ESALiving Planet Symposium, 13-17 May 2019, Milan, Italy;
- Celesti, M.,et al.(2019) Sentinel-3B OLCI in “FLEX mode” during the tandem phase: a new opportunity for fluorescence retrieval from space. ESA Living Planet Symposium, 13-17 May 2019, Milan, Italy;
- Celesti, M.,et al.(2019) Exploring continuous time series of vegetation hyperspectral reflectance and solar-induced fluorescence through radiative transfer model inversion. AGU Fall meeting, 9-13 December 2019, SanFrancisco, USA;
- Celesti, M. (2019) “MULTI-FLEX” Living Planet Fellowship: Concurrentretrieval of Solar-induced fluorescence and plant traits from multi-scalehyperspectral data. Presented at the ESA FLEX Mission Advisory Groupmeeting, 25 June 2019, ESA-ESTEC, The Netherlands;
- Celesti, M. (2019) Solar-induced fluorescence (SIF) scaling: an issue withmany contributors. Presented at the SENSECO COST action WG1 workshop,26 September 2019, Budapest, Hungary;
- Celesti, M. (2019) Satellite based imagery from the 2018 campaign – overviewon the S-2 and S-3 data and the processing of the S-3B reprogrammeddata. Presented at the ESA ATMO-FLEX/FLEXSense progress meeting, 14-17September 2019, ESA-ESRIN, Italy;
- Hueni, A. and Celesti, M. (2019) FLUOSPECCHIO: a spectral informationsystem in support of the FLEX mission calibration/validation activities. Presented at the SENSECO COST action WG1-WG2-WG3-WG4 joint work-shop, 28-30 October 2019, Lanzarote, Spain;
- Celesti, M. (2019) Overview of the S-3B OLCI data reprogrammed in“FLEX mode”.Presented at the Sentinel-3 Mission Performance Group meet-ing, 5 November 2019.

Scientific output

1st year - Peer reviewed papers (co-author)

- Cogliati, S., Celesti et al. (2019). A Spectral Fitting Algorithm to Re-trieve the Fluorescence Spectrum from Canopy Radiance. Remote Sens-ing, 11(16), 1840.https://doi.org/10.3390/rs11161840;
- Biriukova, K., Celesti, M. et al. (under review). Effects of varying solar-view geometry and canopy structure on solar-induced chlorophyll fluorescence and PRI. ISPRS Journal of Photogrammetry and Remote Sensing. Corr. author;
- Siegmann, B., […], Celesti, M., et al. (accepted) The high-performance airborne imaging spectrometer HyPlant – From raw images to top-of-canopy reflectance and fluorescence products: Introduction of an automatized processing chain. Remote Sensing.

2nd year – Conferences

- European Geophysical Union general assembly (EGU) 2020
- 6th Sentinel-3 Validation Team meeting
- IEEE International Geoscience and Remote Sensing Symposium (IGARSS) 2020
- 6th International Symposium Recent Advances in Quantitative Remote Sensing (RAQRS) 2020

2nd year – Peer reviewed papers

- Celesti, M., et al. Sentinel-3B OLCI in “FLEX mode” during the tandem phase: a new opportunity for fluorescence retrieval from space. To be submitted end of 2019.
- Celesti, M., et al. Exploring continuous time series of vegetation hyperspectral reflectance and solar-induced fluorescence through radiative transfer model inversion. To be submitted in 2020.
- Celesti, M., et al. Using S-2 reflectance-based metrics to track the spatil heterogeneity of solar-induced fluorescence. To be submitted in 2020.

Thanks for your attention!