ABSTRACT BOOK

14th EARSeL

Aalto University, Finland

EARSeL

Aalto University

EARSeL WS IS 2026
Abstract
Corresponding Author: micol.rossini@unimib.it

Validation of FLEX SIF Products Using Multi-scale Observations From Towers, UAS, and Airborne Platforms

Micol Rossini[1], Giulia Tagliabue[1], Roberto Garzonio[1], Tommaso Julitta[2], Andreas Burkart[2], Luigi Vignali[1], Juliane Bendig[3], Uwe Rascher[3], Bastian Siegmann[3], Sergio Cogliati[1], Pietro Chierichetti[1], Falk Pätzold[4], Astrid Lampert[4], Christiaan Van der Tol[5], Pieter De Vis[6], Franco Miglietta[7], Lorenzo Genesio[7], Karolina Sakowska[7], Federico Carotenuto[7], Matthew Haworth[7], Loris Vescovo[8], Alireza Mahmoodi[9], Marco Celesti[10], Dirk Schüttemeyer[10], Marin Tudoroiu[11], Roberto Colombo[1]

[1] Department of Earth and Environmental Sciences (DISAT), University of Milano-Bicocca, Milan, Italy
[2] JB Hyperspectral Devices, Düsseldorf Germany
[3] Forschungszentrum Jülich GmbH
[4] iTUBS
[5] University of Twente
[6] National Physics Laboratory. Teddington, United Kingdom
[7] Italian National Research Council – CNR
[8] Fondazione Edmund Mach, Italy
[9] Magellium, Toulouse, France
[10] European Space Agency, Noordwijk, The Netherland
[11] European Space Agency, Frascati, Italy

Keywords (5): Sun-induced chlorophyll fluorescence (SIF), FLEX mission, Calibration and validation, Unmanned aerial systems (UAS), Multi-scale observations

Challenge

The upcoming ESA FLuorescence EXplorer (FLEX) mission will deliver global, high-resolution observations of sun-induced chlorophyll fluorescence (SIF), enabling improved monitoring of photosynthetic activity. Accurate calibration and validation (Cal/Val) of FLEX Level-2B (L2B) SIF products using independent in situ measurements is essential to ensure reliable and traceable estimates. However, direct validation remains challenging in spatially heterogeneous landscapes: point-based tower measurements are often not representative of the satellite footprint, while airborne imaging systems, despite their spatial coverage, are costly and temporally limited.

To address these challenges, the ESA DISC project investigates alternative Cal/Val strategies based on multi-scale SIF observations. The proposed validation methods have been tested using both simulated datasets and real measurements acquired within the framework of the ESA FRM4FLUO project. This contribution provides an overview of the FLEX Cal/Val strategy and presents initial results from the evaluation of different validation approaches, with a particular focus on unmanned aerial systems (UAS) as a flexible and cost-effective intermediate scale.

Methodology

The validation of FLEX L2B SIF products will primarily rely on in situ–based approaches, complemented by image-based methods and inter-comparisons with other satellite missions. Validation will be performed by comparing satellite-retrieved SIF with independent, collocated, and near-simultaneous ground measurements. Two ground-based validation scenarios will be adopted: single-point validation (L2B 1P) using tower-based observations, and multi-point validation (L2B MP) based on spatial sampling from UAS or mobile platforms.

Single-point validation will use high-spectral-resolution spectrometers installed on fixed towers, providing continuous SIF measurements at well-characterized locations. To mitigate spatial representativeness issues, scale-bridging will be achieved through selected transfer functions derived from high-resolution satellite data. Multi-point validation will address spatial heterogeneity by sampling multiple locations within at least 3×3 FLEX pixels, with measurements synchronized to the satellite overpass to minimize temporal mismatch.

The proposed methods have been tested using both simulated datasets and real measurements acquired within the ESA FRM4FLUO project, demonstrating their robustness under realistic observational conditions.

Study area and data

The experimental dataset was collected during two intensive field campaigns conducted in Tuscany (Italy) in May and June 2025. Multi-scale SIF observations were acquired using ground-based FloX systems and airborne platforms, including UAS-mounted AirFloX and a helicopter-based configuration (HELiPOD). AirFloX is a lightweight (~4 kg) dual-spectrometer system enabling accurate SIF retrievals from UAS platforms, with real-time monitoring and configurable acquisition settings.

The campaigns aimed to evaluate different acquisition strategies for FLEX L2B validation and to assess spatial representativeness across scales. Optimization methods supported flight planning and sampling design by identifying measurement locations that maximize representativeness while minimizing sampling effort.

Discussion and Conclusions

The results demonstrate that the proposed validation strategies for the FLEX mission perform well for both single-point and multi-point approaches. Tower-based measurements provide accurate local validation when supported by scale-bridging techniques, while UAS-based multi-point observations effectively capture spatial heterogeneity within the FLEX footprint, improving representativeness.

Transfer functions play a key role in linking ground observations to satellite-scale SIF. Their performance was evaluated using simulated datasets based on four real-world scenes, including two agricultural sites (US-Lincoln and IT–Jolanda di Savoia) and two forested areas (IT–San Rossore and FR–Mulhouse). Results indicate that NIRv is the most effective transfer function for SIF O_2-A, far-red maximum SIF, and integrated SIF. For SIF O_2-B and red maximum SIF, the Rred × $NIRv^2$ product yielded the best results in simulations, while further analyses are needed to identify transfer functions for red SIF that provide consistent results across both simulated and real measurements.

Overall, the study confirms the robustness of the implemented FLEX Cal/Val approaches and highlights the strong potential of UAS-based SIF observations as a flexible and cost-effective intermediate scale, supporting reliable validation of FLEX L2B products.