# Evaluating and Unmixing Spaceborne DESIS Solar-Induced Fluorescence: A Comparative Analysis With Airborne HyPlant Observations

Mohammed Hajaldaw, Dainius Masiliūnas, Na Wang, Lammert Kooistra, Carlos Camino, Jim Buffat, Stefan Maier

WAGENINGEN UNIVERSITY & RESEARCH

Living Planet Symposium VIENNA 23-27 June 2025

## Background

Photosynthesis is essential for biomass production as it enables plants to convert sunlight into energy, making its monitoring vital for plant health and agricultural productivity. This process can be better understood using Sun-Induced Fluorescence (SIF), which is a weak electromagnetic radiation emitted by plants during photosynthesis. SIF is mainly estimated around the Oxygen absorption band (O2A) at 760 nm using radiance-based methods such as the three Fraunhofer Line Discrimination (3FLD) and the Spectral Fitting Method (SFM).

## Problem

In recent decades, remote sensing has been used in research to monitor SIF at various scales, with satellite-level research primarily conducted using atmospheric chemistry satellites that have accidental SIF retrieval capabilities. However, the limited spatial resolution of these satellites poses challenges in evaluating and unmixing their SIF products. In contrast, newer missions like the DLR Earth Sensing Imaging Spectrometer (DESIS) offer higher spatial resolution, but their potential for SIF applications has not been fully explored due to their lower spectral resolution.

## Objectives

This study focuses on DESIS aiming to improve large-scale vegetation monitoring by:

- Performing a comparative analysis between multiple SIF retrievals from DESIS and HyPlant (airborne system), with HyPlant data serving as a reference.
- Developing a novel SIF unmixing machine learning framework that generates vegetation-specific SIF maps.

## Methods

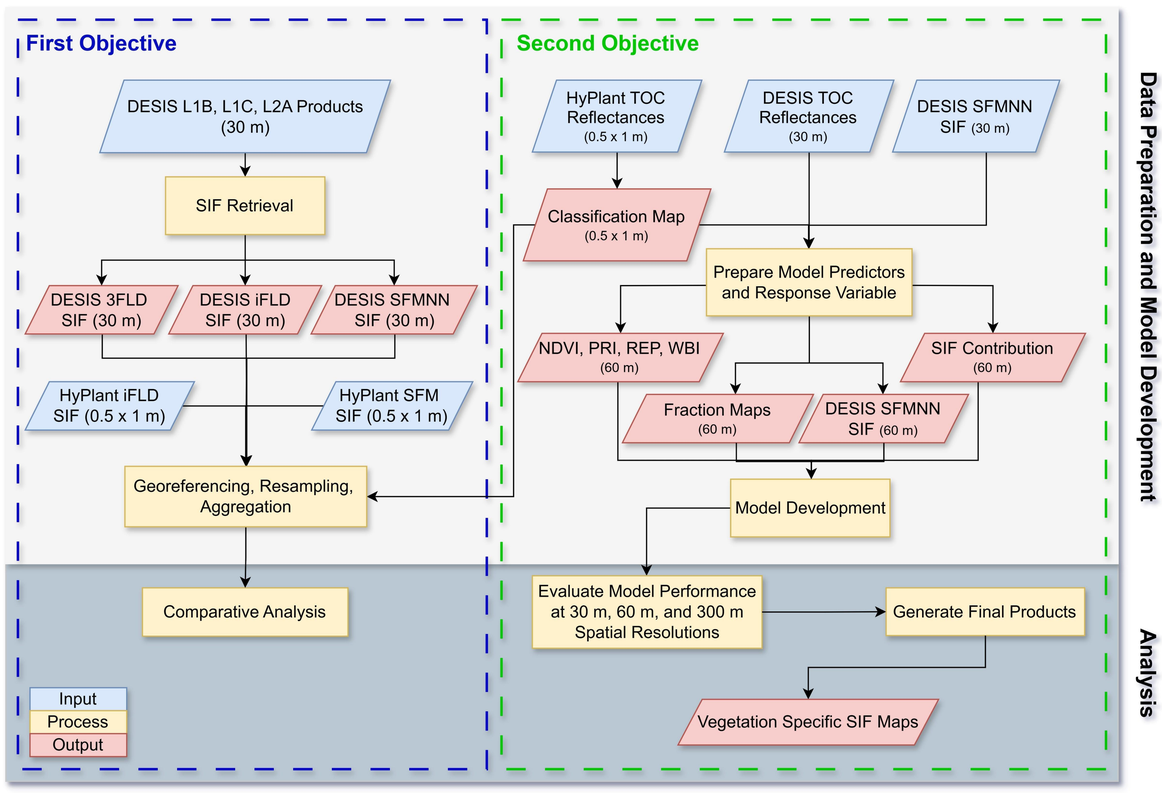


**Figure 1.** Flowchart representing the general workflow. The main elements are illustrated in the legend. The processing part is divided into data preparation and model development (light grey) and the analysis (dark grey) parts. The colored dashed rectangles (blue and green) indicate the main processing steps needed to achieve each of the two objectives.

## Results

### Evaluation of DESIS Retrievals

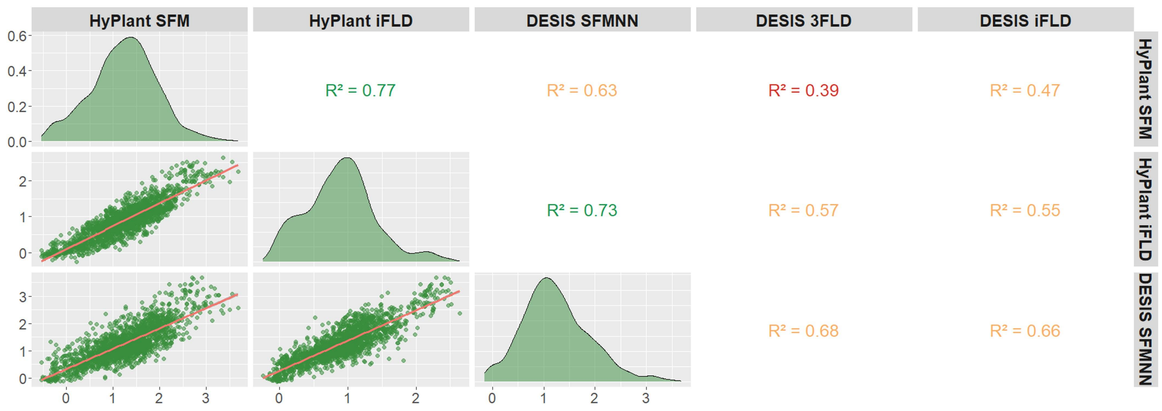


**Figure 2.** Pair plot showing the correlations between different SIF products at 30 m spatial resolution. The SIF products were generated from both DESIS and HyPlant datasets using four different retrieval methods: 3FLD, iFLD, SFM, and SFMNN. The $R^2$ colors indicate the strength of the correlation from weak (red) to strong (green). All SIF values are in $mWm^{-2}nm^{-1}sr^{-1}$.

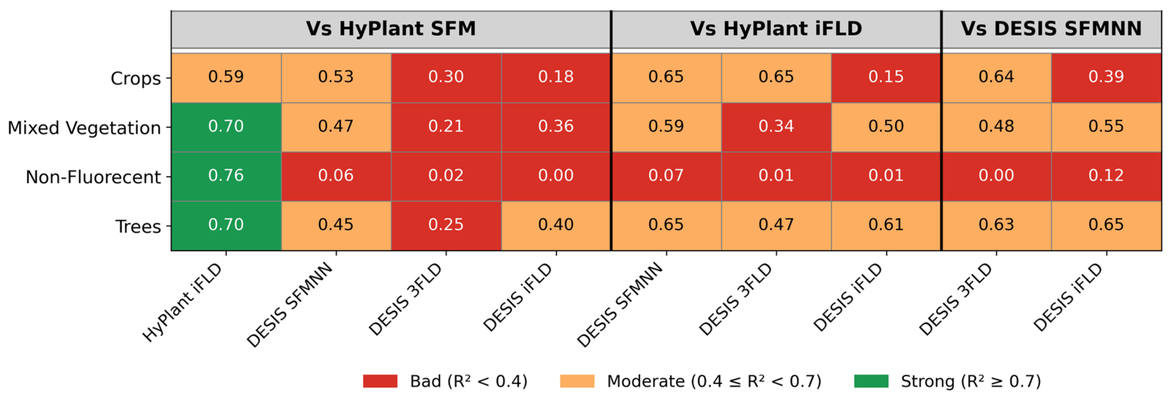


**Figure 3.** Heatmap table showing the correlation between DESIS and HyPlant SIF products across four distinct classes: Crops, Mixed Vegetation, Non-Fluorescent, and Trees. The comparisons were performed at 30 m resolution with HyPlant SFM mainly serving as a reference for all other retrievals. The colors of the $R^2$ values represent the strength of the correlation from weak (red) to strong (green). All SIF values are expressed in mW m−2 nm−1 sr−1.

### Evaluation of Unmixing Model Performance

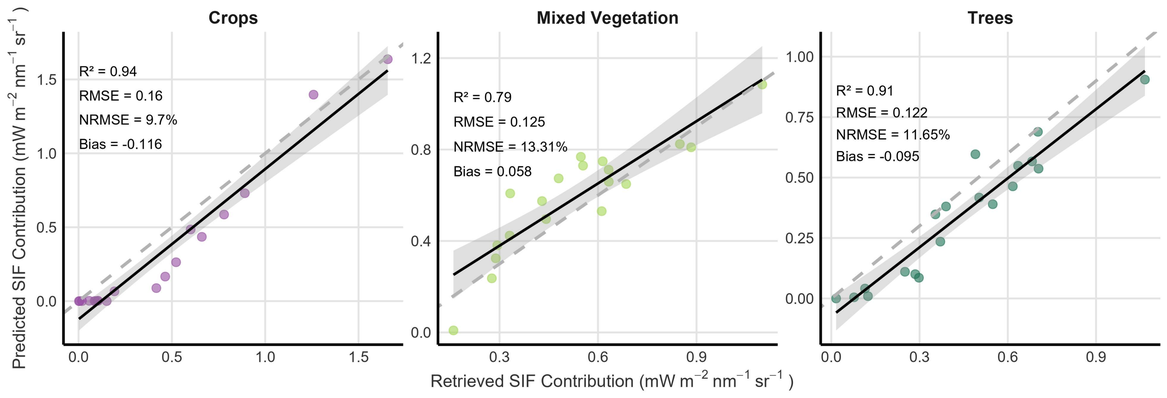


**Figure 4.** Scatter plots illustrate the performance of the developed model across three classes (Crops, Mixed Vegetation, Trees) at 300 m spatial resolution using HyPlant SFM SIF data. For each subplot, grey line is the 1:1 line, while the black line represents the regression line.

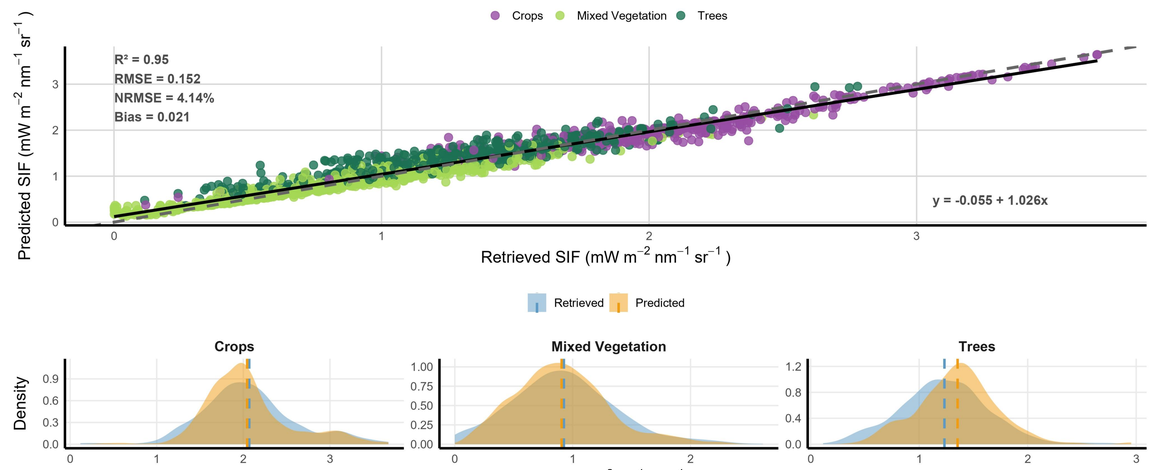


**Figure 5.** Combined scatter and density plots comparing the predicted and retrieved DESIS SIF values at 30 m spatial resolution. The plots show four error metrics (R2, RMSE, NRMSE and Bias) and SIF values distribution across three vegetation classes: Crops, Mixed Vegetation, and Trees.

## Conclusion

- DESIS SFMNN SIF product outperformed DESIS FLD products, showing potential for large-scale vegetation monitoring, though further improvements are needed.
- The proposed unmixing framework demonstrated strong performance in predicting vegetation-based average SIF (R2 = 0.95, NRMSE = 4.14%), highlighting its effectiveness for SIF unmixing applications.
- The study was limited to a small study area (3.4 km²) and a short temporal window (1 hour), so further evaluation is necessary.
- Future work could focus on evaluating and unmixing SIF maps generated by the upcoming FLuorescence EXplorer (FLEX) mission.

## Acknowledgments

We would like to express our gratitude to Bastian Siegmann from the German Research Center Forschungszentrum Jülich (FZJ) for providing both field and airborne data.

## References

Buffat, J., Pato, M., Alonso, K., Auer, S., Carmona, E., Maier, S., ... & Scharr, H. (2025). Retrieval of Sun- Induced Plant Fluorescence in the O $$ _2 $$-A Absorption Band from DESIS Imagery. In European Conference on Computer Vision (pp. 81-100). Springer, Cham.

Kira, O., & Sun, Y. (2020). Extraction of sub-pixel C3/C4 emissions of solar-induced chlorophyll fluorescence (SIF) using artificial neural network. ISPRS journal of photogrammetry and remote sensing, 161, 135-146.

Wageningen University & Research
P.O. Box 243, 6709 PA Wageningen
Contact: mohammed.hajaldaw@wur.nl
M +31 (0)6 57 53 43 99