DEVELOPMENT OF A FULL-SIF RETRIEVAL METHOD BASED ON PRINCIPAL COMPONENT ANALYSIS USING FLOX HYPERSPECTRAL DATA

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Introduction

Photosynthesis, a critical process sustaining life on Earth, releases solar-induced fluorescence (SIF) as a byproduct, providing valuable insights into vegetation health and climate regulation. However, the weak SIF signal poses challenges in its detection and separation from background noise, leading to methods that retrieve SIF only in narrow spectral absorption features with minimal light reflection. This work presents an alternative approach to retrieve the complete spectral SIF emission spectrum by making use of Principal Component Analysis (PCA) dimensionality reduction and SCOPE simulations.

Conclusions

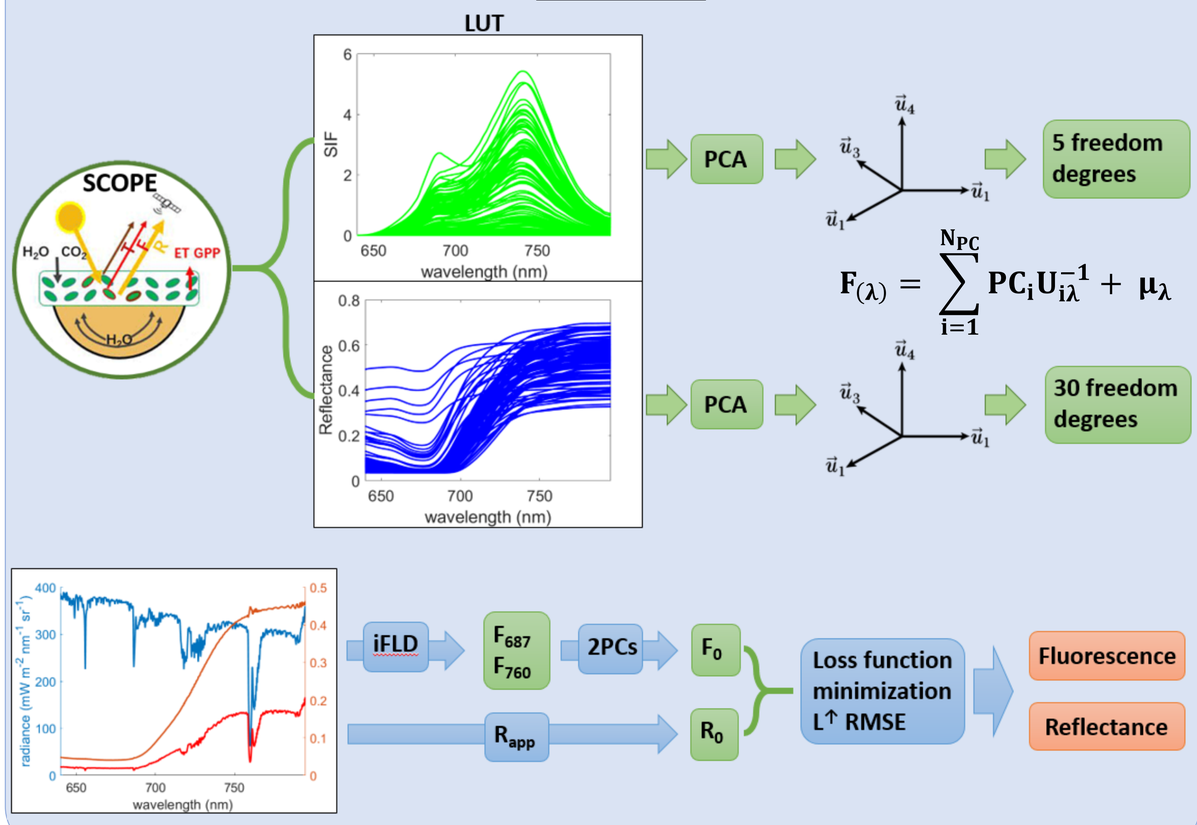
- The results demonstrate the potential of the proposed method to retrieve full-SIF spectrum.
- PCA method is able to fit spectrally with less constrains.
- The proposed method has a high potential to be used to produce FLEX-like SIF data, and thus can be included in preparatory activities in support of the upcoming satellite mission.

Materials & Methods

$$L^{\uparrow}_{(\lambda)} = \frac{R_{(\lambda)} E^{\downarrow}_{(\lambda)}}{\pi} + F_{(\lambda)}$$

- **Study data:**
  - 44 Vegetation and 28 Baresoil spectral data measured by Piccollo. Field 'Las Tiesas' in Barrax, Albacete, (Spain).
  - PhenoRob Central Experiment at the agricultural research station Campus Klein-Altendorf (CKA). Bonn University (Germany).
- **Methods:** SCOPE, Principal Component Analysis (PCA), iFLD, SpecFit.
- **Principal Component Analysis (PCA):** is a linear dimensionality reduction (DR) technique that reduces the number of variables, keeping most of the original information.
- **Workflow:** We obtained a large LUT of 100,000 spectra of SIF and Reflectance from SCOPE. Using PCA, we reduced the dimensionality to 5 and 30 PCs, respectively. Those freedom degrees can produce any spectral curve at a reduced dimensionality. From Radiance and Irradiance measured by the sensor, we can obtain the F_{687} and F_{760} by iFLD. Using only 2PCs from SIF, we can reconstruct the initial F_0. Applying inverse PCA to R_{app}, we obtained the PC values more representative of the R_0 starting point. Using those starting points in the reduced dimensionality, we minimized the loss function of the RMSE for L to obtain the final SIF and R spectral curves.

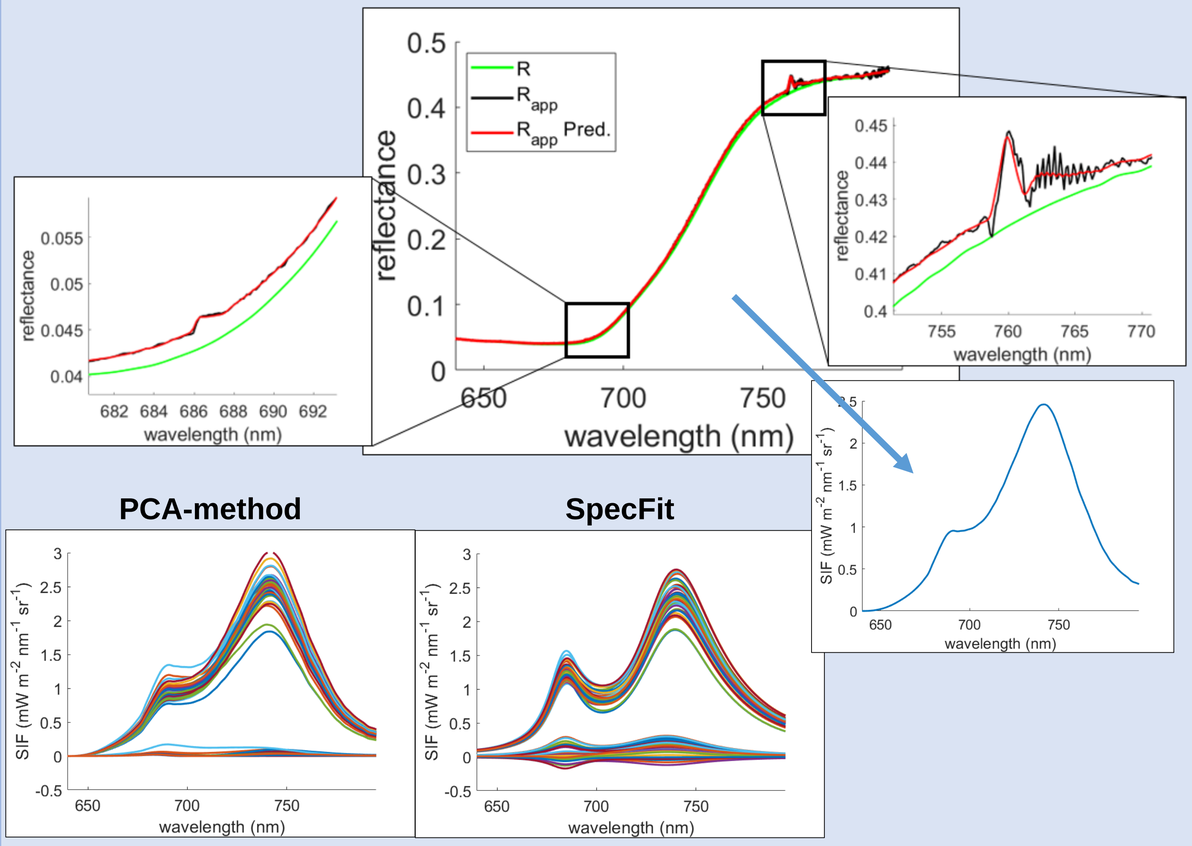
Workflow



Results

PCA Spectral Fitting Method

The PCA Spectral Fitting Method is applied to the sensor signals to obtain the Reflectance and SIF from the measurement. After the minimization search, the PCs for R and F are returned to the original hyperspectral space to obtain the full-SIF spectrum and reflectance. As we can see in the figures, the R_{app} predicted match with the original R_{app}, especially in the O_2A and O_2B regions. The obtained L in comparison with the original L obtained a relRMSE of 0,37%.



Future research

For future research, we aim to evaluate the PCA-SIF retrieval with leaf-level sensor data obtained in the PhenoRob experiment and compare the results with SpecFit. The central spectral region, especially between the red and far-red peaks, is where the largest discrepancies between PCA-SIF and SpecFit were observed. This region is crucial for interpreting physiological changes in vegetation. Future efforts will focus on:

- Investigating the sources of disagreement in this region to refine the PCA fitting strategy.
- Expanding the method to canopy-level and airborne data to assess scalability and robustness under different observation geometries.

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