RECONSTRUCTION OF THE FULL SIF SPECTRAL PROFILE FROM HYPERSPECTRAL IMAGERY USING EMULATION

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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 reconstructing the complete spectral SIF emission spectrum from O_2A and O_2B bands by making use of Principal Component Analysis (PCA) dimensionality reduction and SCOPE simulations.

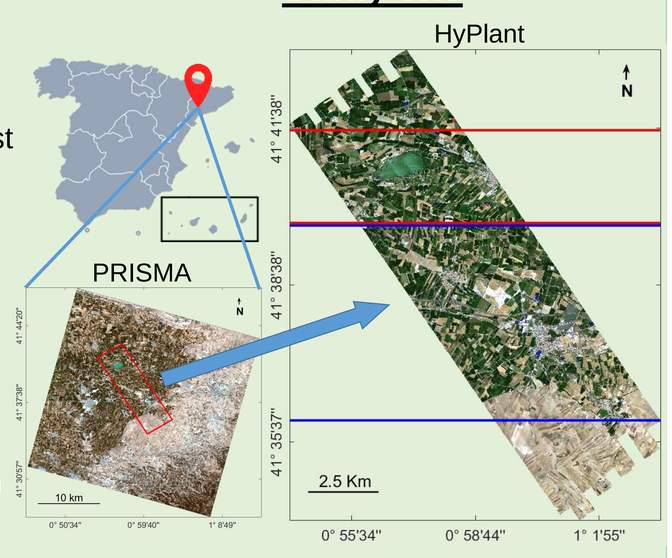
Conclusions

- The results demonstrate the potential of the proposed method to reconstruct a synthetic full-SIF spectrum from the retrieved values in O_2A and O_2B.
- Emulation of the full-SIF emission spectrum from hyperspectral radiance satellite data.
- 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

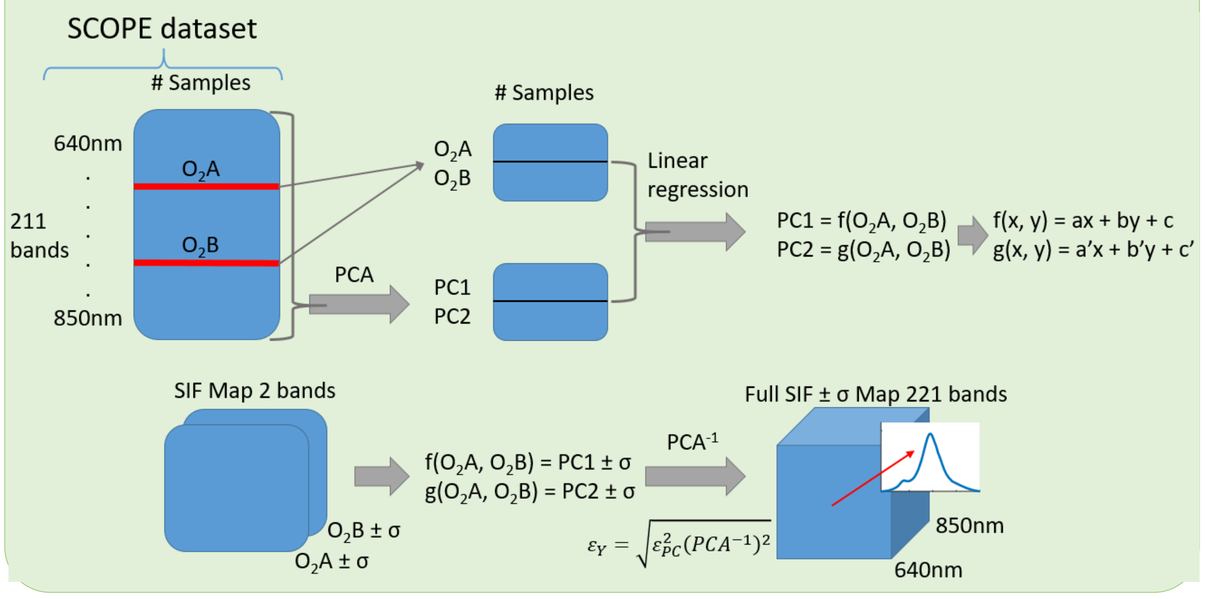
- **Date acquisition:** 17th of July 2021.
- **Study site:** City of Lleida in the northeastern part of Spain. Flight campaign of 9 HyPlant flight lines mosaicked to one image. The image was split in two subsets, Test (red) and Train (blue).
- **Sensors:**
  - **PRISMA:** Radiance data (L1) with 231 bands in the range of 402 to 2497 nm. Spatial resolution of 30m.
  - **HyPlant (FLUO):** SIF-SFM product in O_2A and O_2B with uncertainties. Spatial resolution of 1.7m.

Study site



- **Methods:** SCOPE, Principal Component Analysis (PCA), Neural Networks (NN).
- **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 reduced the hyperspectral SIF data dimensionality to two PCs. We obtained a linear regression between SIF at O_2A and O_2B and the two PCs. This regression model reconstruct PCs from SIF values at O_2A and O_2B. Finally, using the inverse PCA transformation, we reconstruct the full SIF emission spectrum along with uncertainties.

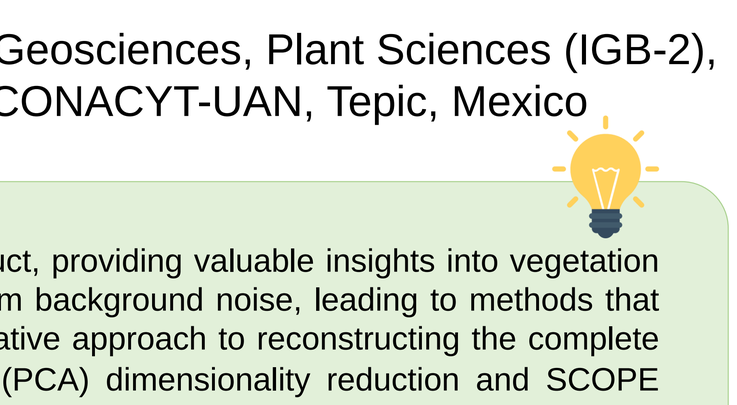
Workflow



Results

- SCOPE LUT of 10,000 samples with LHS distribution.
- Correlation between 211 bands. 687 and 760nm are highly correlated with the rest of the bands.
- Two PCs represent the 99.38% variance.
- R^2 of O_2A vs O_2B = 0,26.
- Linear regression to obtain the $f(O_2A, O_2B)$ and $g(O_2A, O_2B)$.
- After applying PCA^{-1}, we obtained 211 SIF bands covering 640-850nm range.

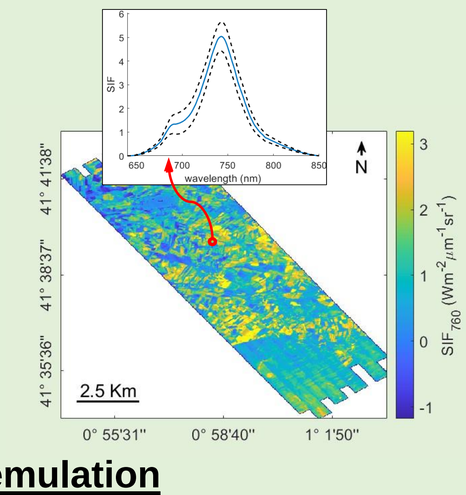
Full-SIF reconstruction



PCs	slopeA ± ε	slopeB ± ε	n ± ε
PC1	7.48 ± 0.02	4.11 ± 0.08	-18.70 ± 0.06
PC2	-1.14 ± 0.02	6.97 ± 0.08	-3.69 ± 0.06

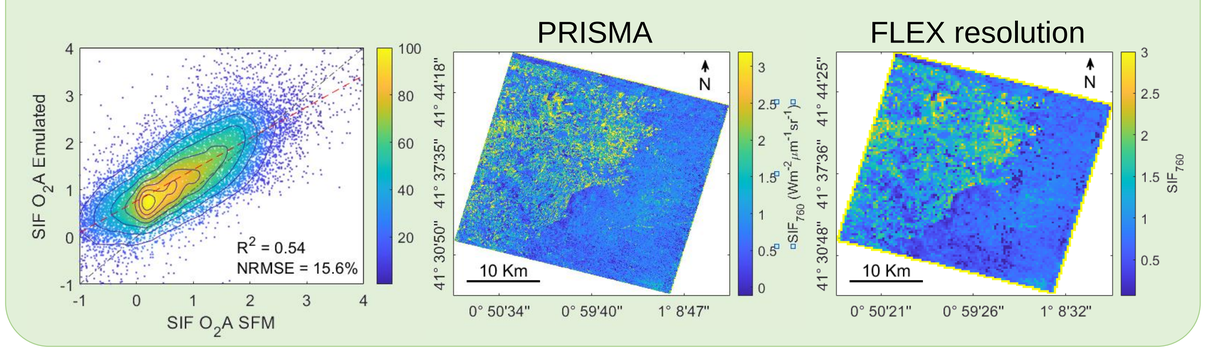
Full-SIF HyPlant Image

Once obtained the two transformation functions, we applied them to the HyPlant image. As the SIF values are obtained with uncertainties from SFM, we propagated it through linear transformation and PCA inversion to obtain uncertainty in the full-SIF synthetic spectrum. The final product is a hyperspectral datacube containing the full-SIF spectra of all image pixels, and the uncertainties of each band.



Full-SIF PRISMA emulation

Finally, we used the PRISMA (L1) hyperspectral spaceborne image as input and synthetic full-SIF spectra from the HyPlant SIF retrieval image as output to train an emulator. We use the Test subset to validate the model in the 760nm band.
211 SIF bands covering from 640nm to 850nm



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