Leveraging deep learning for the retrieval of sun-induced fluorescence in the O_2-A absorption band from space

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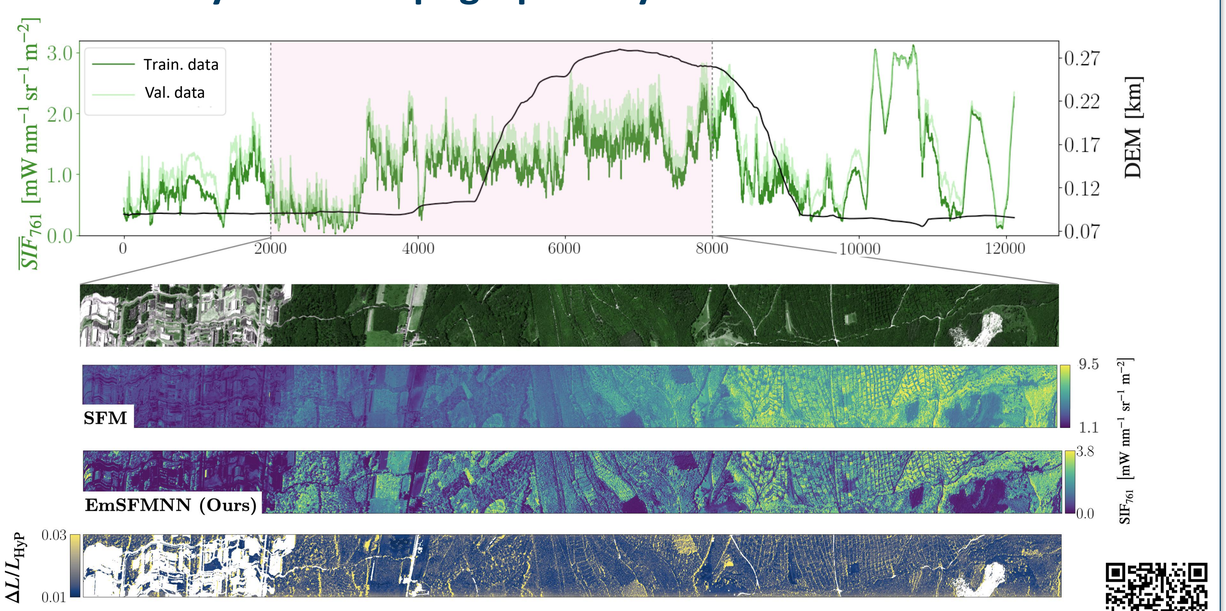
DLR

Deep Learning based SIF retrieval

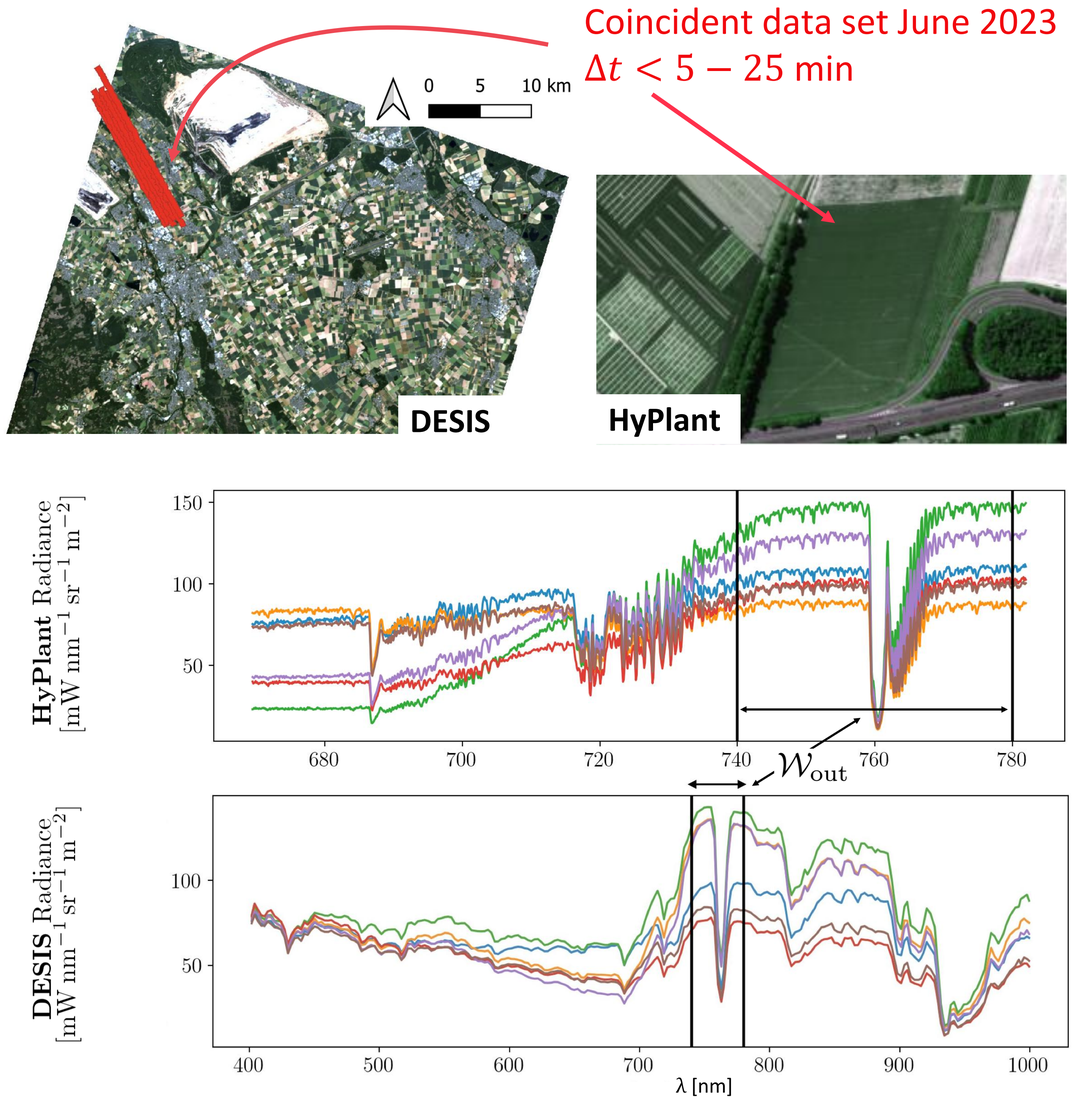
- **Deep Learning** provides a way to combine feature-based **SIF retrieval** with spectral fitting (SFM) approaches.
- We have developed a **reconstruction-based loss** and **training constraints** for self-supervised SIF retrieval in **airborne and spaceborne data.**
- This allows HyPlant SIF retrieval in generalized conditions and **first SIF maps from DESIS**

SIF from HyPlant in topographically variable terrain

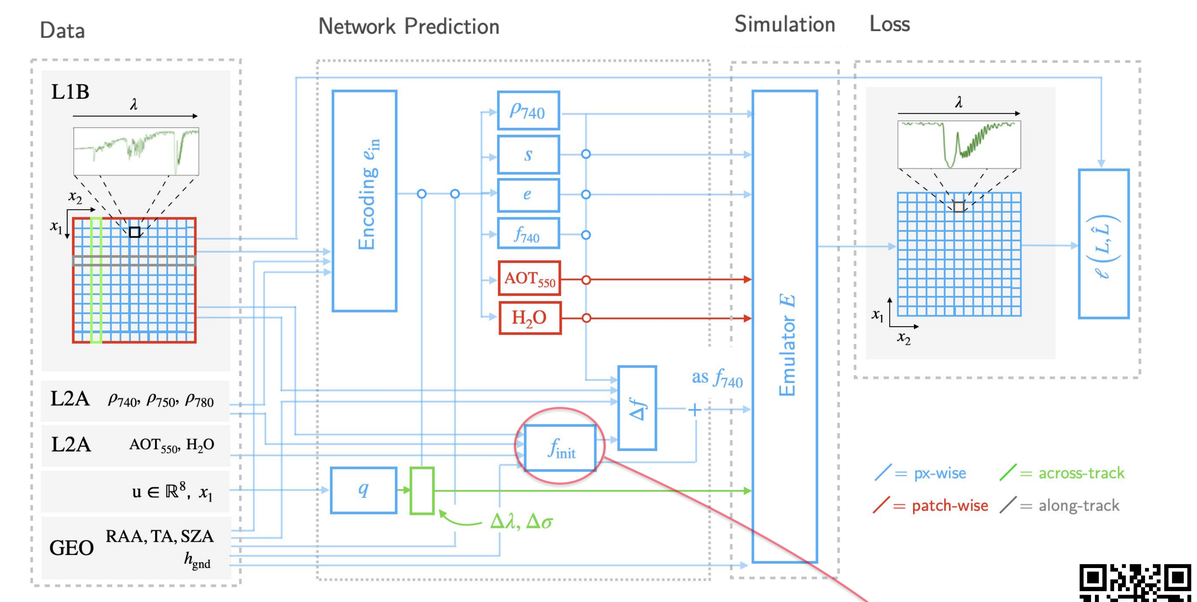


***Buffat J.**, … (2025) Emulation-based self-supervised SIF retrieval in the O2-A absorption band with HyPlant, submitted to RSE, doi: 10.22541/essoar.174000855.50541566/v2*

DESIS and HyPlant coincident data set



DESIS: semi-supervised training and constraints are necessary



Spectral reconstruction

- Polynomial emulator $\hat{L}$ for spectral reconstruction

$$\ell_{\text{res}}\left(L,\hat{L}\right)=\left\langle\left(L-\hat{L}\right)^2\right\rangle_{\lambda,\,x}+\frac{\gamma_f}{|\mathcal{W}_{\text{out}}|}\left\langle\sum_{\lambda\in\mathcal{W}_{\text{out}}}w_\lambda\left(L(\lambda)-\hat{L}(\lambda)\right)^2\right\rangle_x$$

L2A estimates and initial SIF estimate as constraints

- Use atmospheric estimates and simple MLP regressor f_{init}

$$\ell_{\text{m}}=\sum_{k\in\mathcal{K}}\gamma_{p_k}\left(p'_k-\hat{p}_k\right)^2\quad\text{and}\quad\ell_{\Delta f}=\gamma_{\Delta f}\left(\hat{f}-f_{\text{init}}\right)^2$$

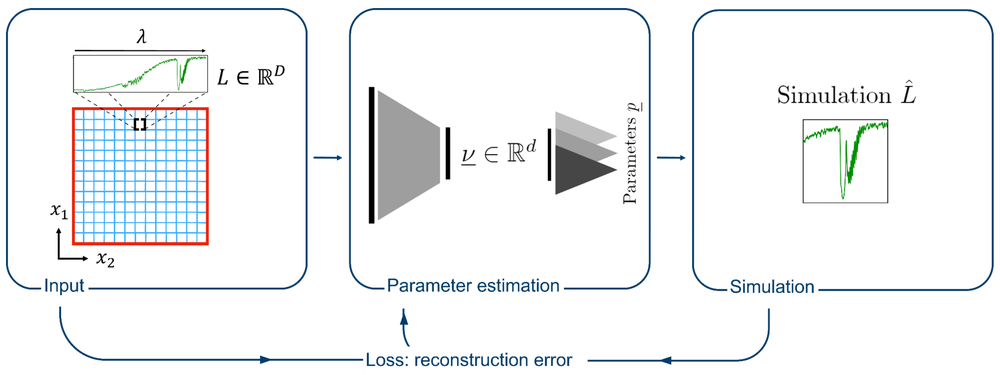
Consistency regularization

- Perturbation in signal $L'_{\delta f}$ must be consistently retrieved

$$\ell_c(L,\hat{f},\hat{p}_j)=\mathbb{E}_{\delta f\sim\mathcal{F}}\left[\left(g_f\left(L'_{\delta f}\right)-\left(\hat{f}+\delta f\right)\right)^2+\left(g_{p_j}\left(L'_{\delta f}\right)-\hat{p}_j\right)^2\right]$$

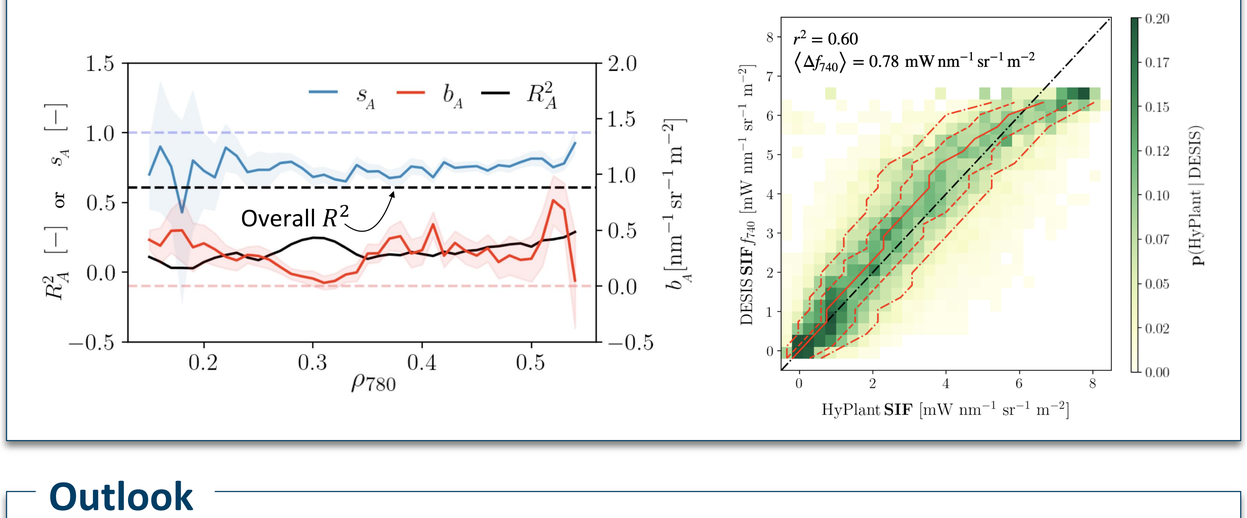
***Buffat J., ….** (2024) Retrieval of sun-induced plant fluorescence in the O2-A absorption band from DESIS imagery, CVPPA 2024, doi: 10.48550/arXiv.2411.08925*

Self-supervised spectral reconstruction task for SIF retrieval



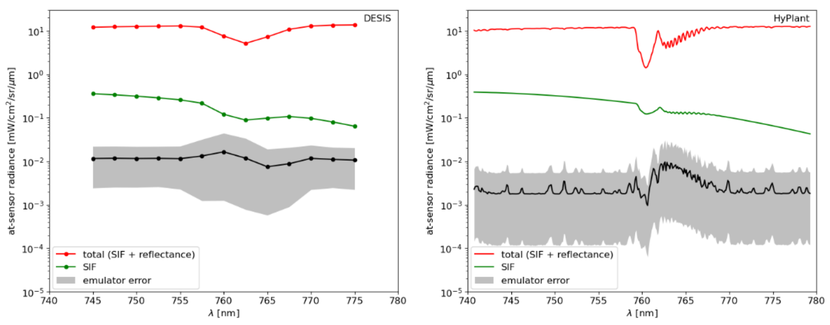
***Buffat J.**, …. (2024) A multi-layer perceptron approach for SIF retrieval in the O2-A absorption band from hyperspectral imagery of the HyPlant airborne sensor system, doi: 10.1016/j.rse.2024.114596*

First spaceborne SIF maps at 30m resolution



Emulate the simulation to allow use of accurate RTM

- Large scale sampling over input space
- Simple polynomial modelling for emulation



*Pato M., **Buffat J.**, …. (2025) Physics-based Machine Learning Emulator of At-sensor Radiances for Solar-induced Fluorescence Retrieval in the O_2-A Absorption Band, doi: 10.1109/JSTARS.2024.3457231*

Outlook

- Suitable to be applied **to FLEX + Sentinel-3 tandem data**
- **Hyperspectral foundation modelling** for simultaneous training in multi-modal data will allow sensor integration

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