Towards fast and sensor-independent retrieval of sun-induced fluorescence from spaceborne hyperspectral data

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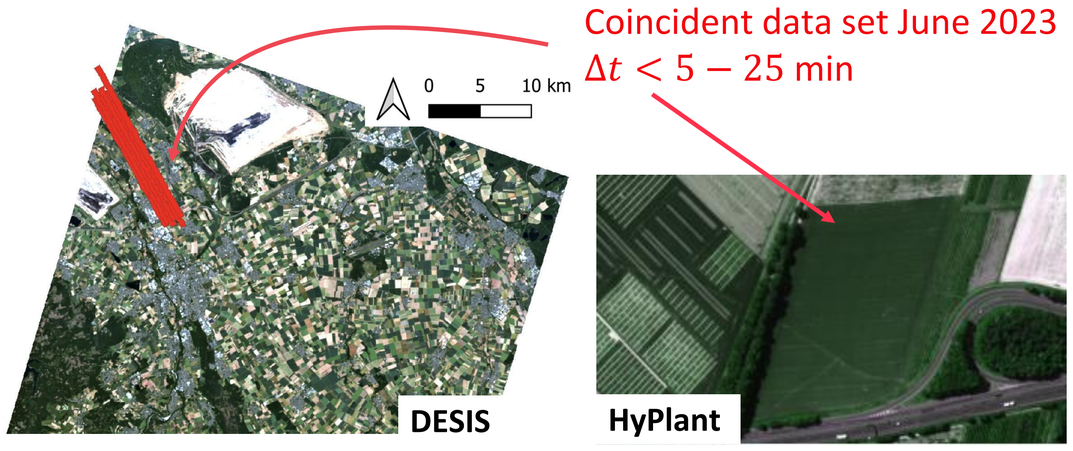
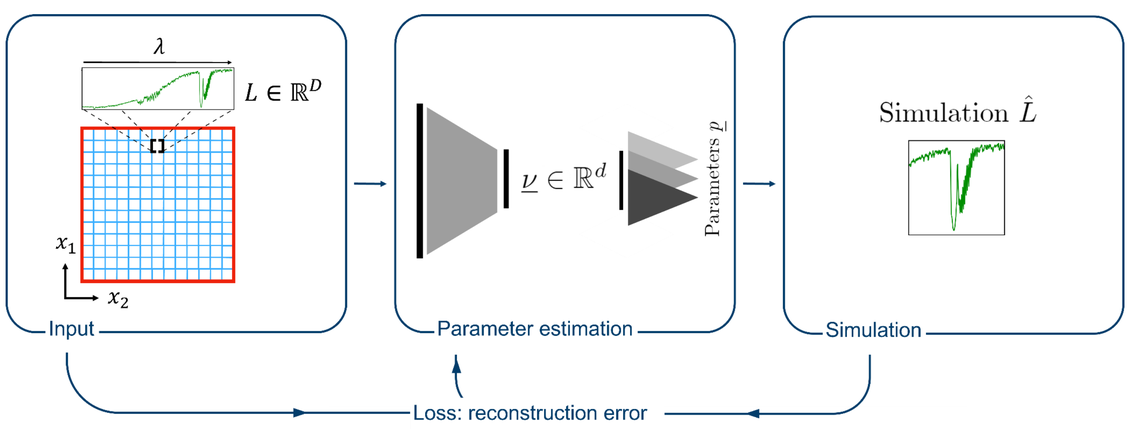
Deep Learning based SIF retrieval

- **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**

DESIS and HyPlant coincident data set



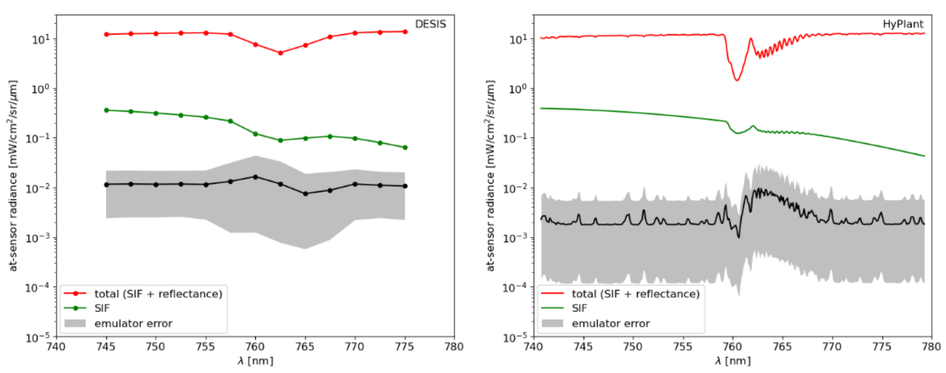
Self-supervised spectral reconstruction task for SIF retrieval



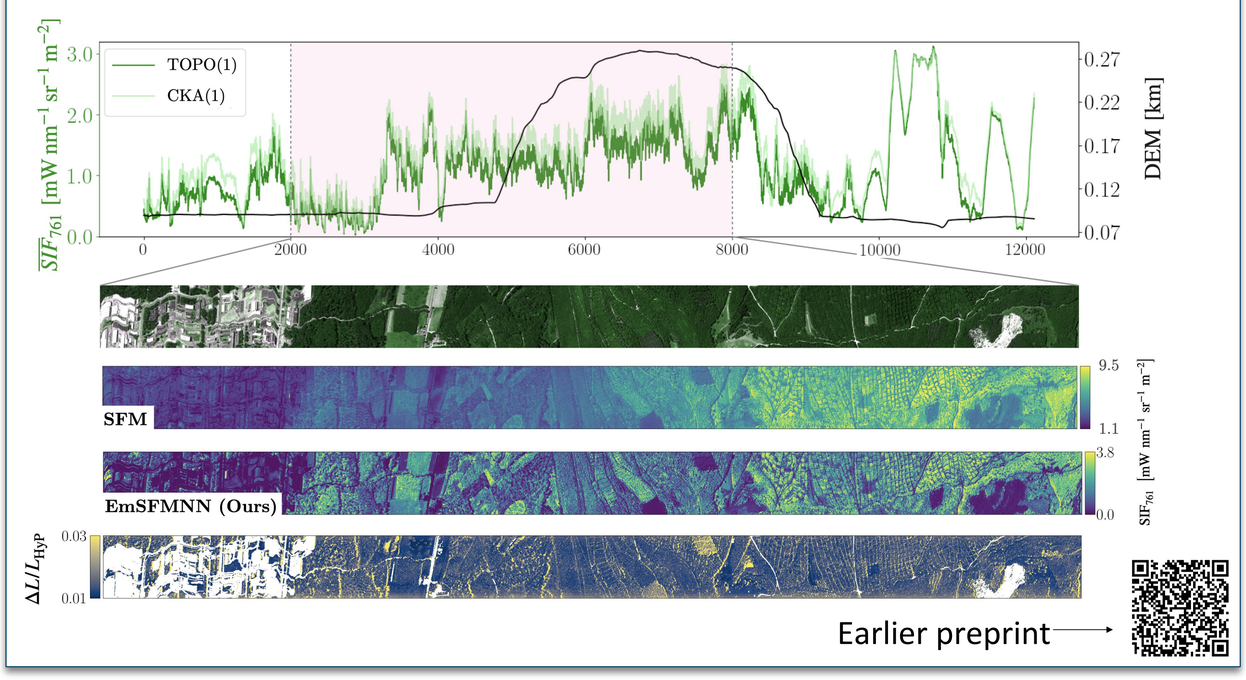
Emulate the simulation to allow use of accurate RTM

- Large scale sampling over input space
- 4th order polynomial is sufficient

Details

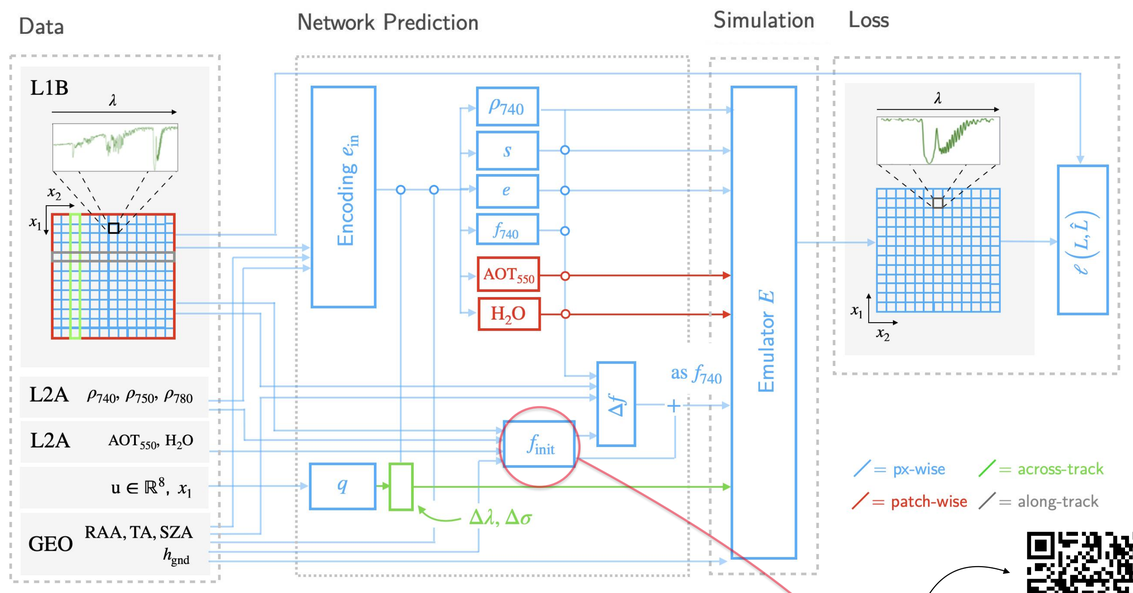


SIF from HyPlant in topographically variable terrain



Earlier preprint

DESIS: semi-supervised training and constraints are necessary



Details

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}

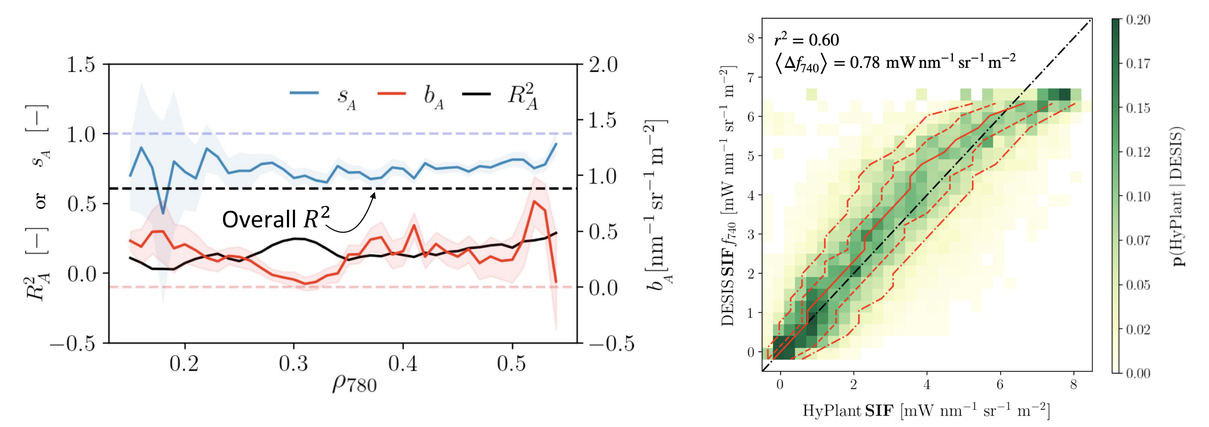
$$\ell_{\text{m}} = \sum_{k \in \mathcal{K}} \gamma_{p_k} \left(p'_k - \hat{p}_k\right)^2 \quad \text{and} \quad \ell_{\Delta f} = \gamma_{\Delta f} \left(\hat{f} - f_{\text{init}}\right)^2$$

Consistency regularization

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

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

First spaceborne SIF maps at 30m resolution



Outlook

- Our method is 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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