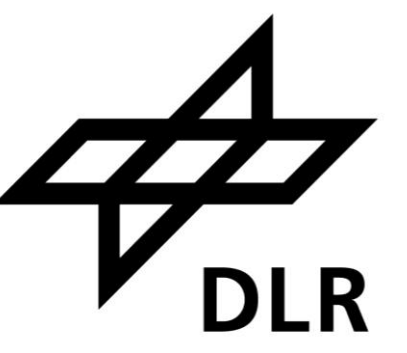


Towards an emulation-based SIF retrieval method for FLEX data



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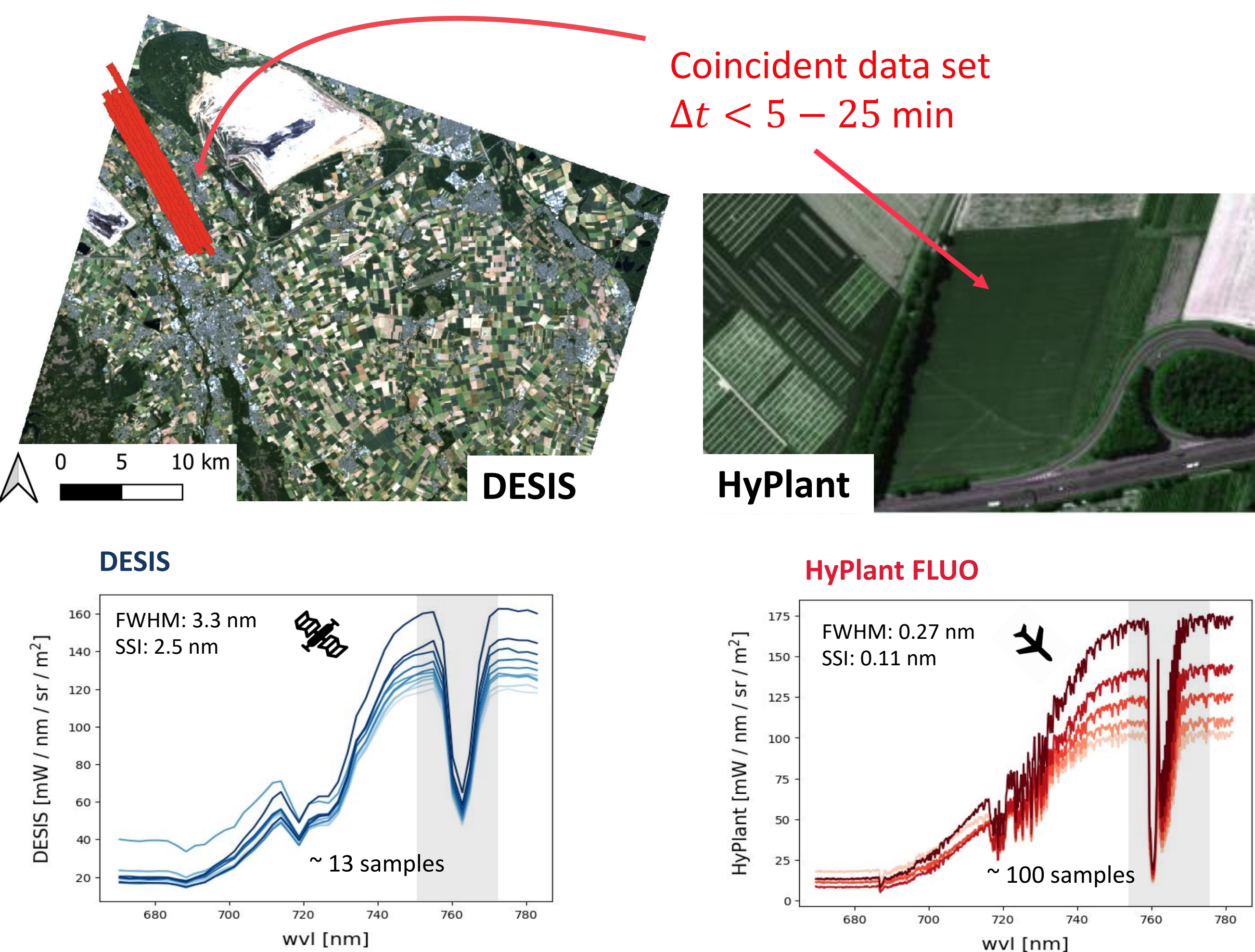
³ Forschungszentrum Jülich, Institute of Bio- and Geosciences, IBG-2: Plant Sciences, Jülich, Germany



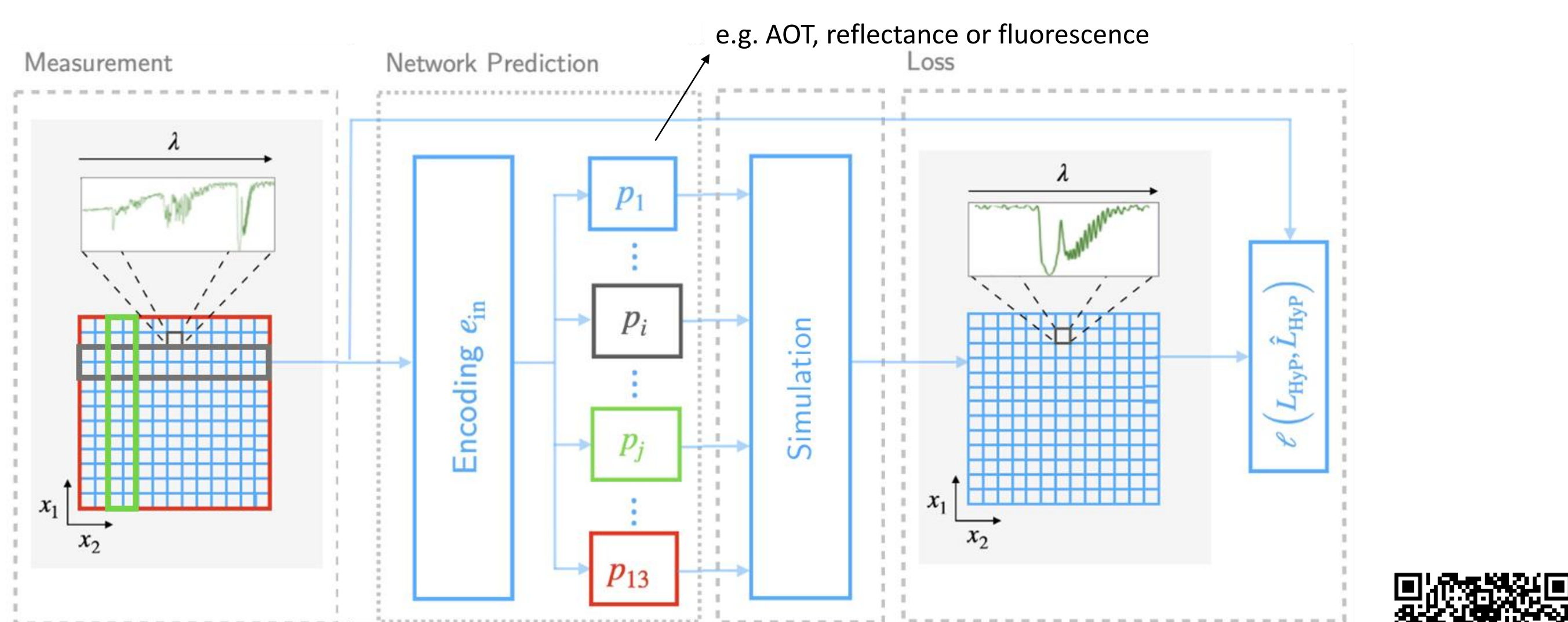
Deep Learning-based SIF retrieval

- 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** (SFMNN).
- This allows **HyPlant** SIF retrieval in generalized conditions and **first SIF maps from DESIS**
- We are currently **generalizing** the methodology to a **sensor-agnostic formulation** allowing the application to **FLEX data**

DESIS and HyPlant match ups provide validation data



Self-supervised spectral reconstruction for SIF retrieval



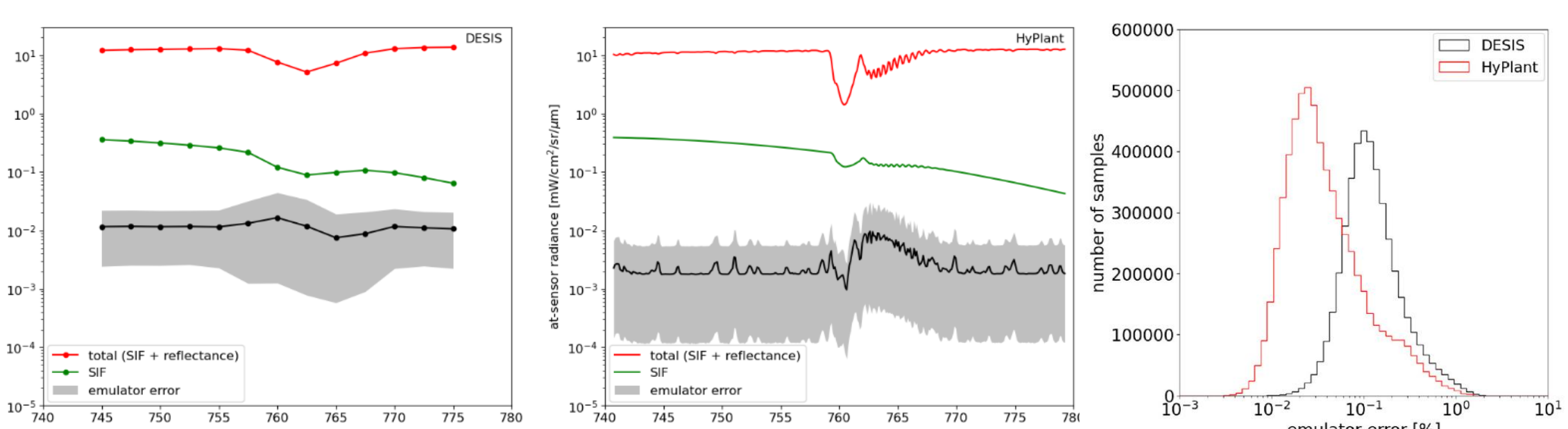
Buffat et al. 2024, A multi-layer perceptron approach for SIF retrieval in the O₂-A absorption band from hyperspectral imagery of the HyPlant airborne sensor system, doi: 10.1016/j.rse.2024.114596

Simulation and emulation allow online use of accurate RTM

- Sampling over observational space
- Simple polynomial surrogate modelling for emulation

Performance parameter	DESIS							
	OLS	P2	P4	P5	N1	N2	KRR	GPR
Test set MAE [mW/cm²/sr/μm]	0.77	0.17	0.011	0.0032	0.040	0.037	0.043	0.039
Total training time	1.6 s	19 s	1.8 min	1.2 min	1.2 h	1.2 h	1.1 min	2.7 s
Prediction time per sample	0.06 μs	1.1 μs	11 μs	28 μs	56 μs	45 μs	0.1 ms	0.2 ms

Performance parameter	HyPlant							
	OLS	P2	P4	P5	N1	N2	KRR	GPR
Test set MAE [mW/cm²/sr/μm]	0.59	0.092	0.0027	0.0013	0.027	0.020	0.018	0.025
Total training time	1.7 min	45 s	1.3 min	1.5 min	2.0 h	2.2 h	6.3 s	13 s
Prediction time per sample	1.3 μs	2.2 μs	17 μs	47 μs	44 μs	43 μs	72 μs	0.7 ms

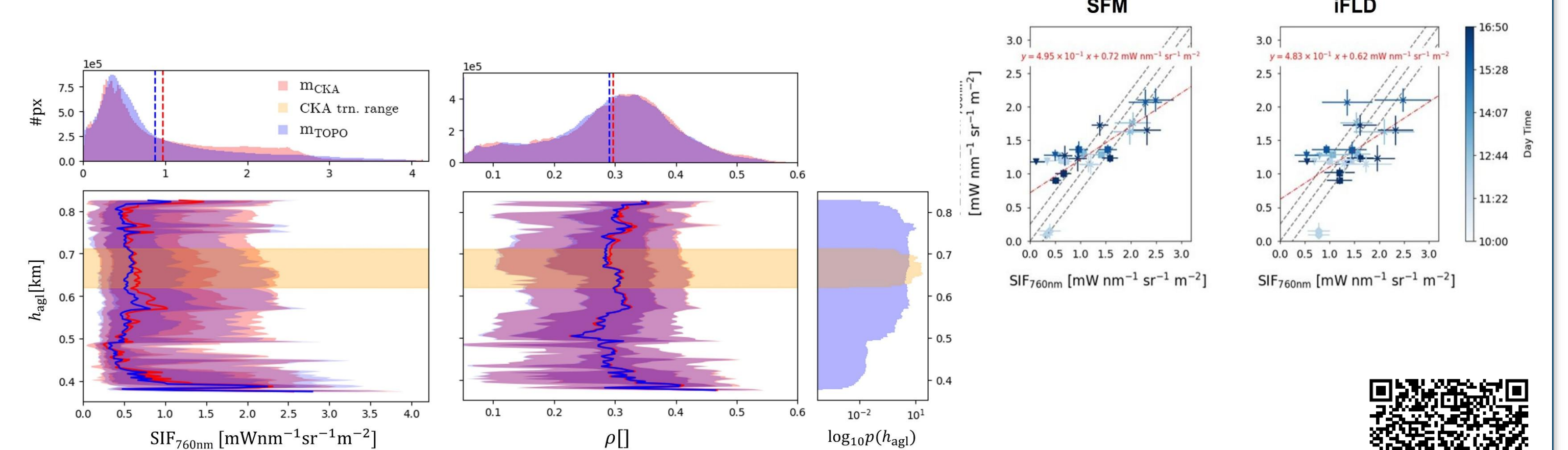


Pato et al. 2025, Simulation Framework for Solar-Induced Fluorescence Retrieval and Application to Desis and Hyplant, doi: 10.1016/j.rse.2025.114944

Pato et al. 2025, Physics-based Machine Learning Emulator of At-sensor Radiances for Solar-Induced Fluorescence Retrieval in the O₂-A Absorption Band, doi: 10.1109/JSTARS.2024.3457231

Emulation-based SIF retrieval in HyPlant

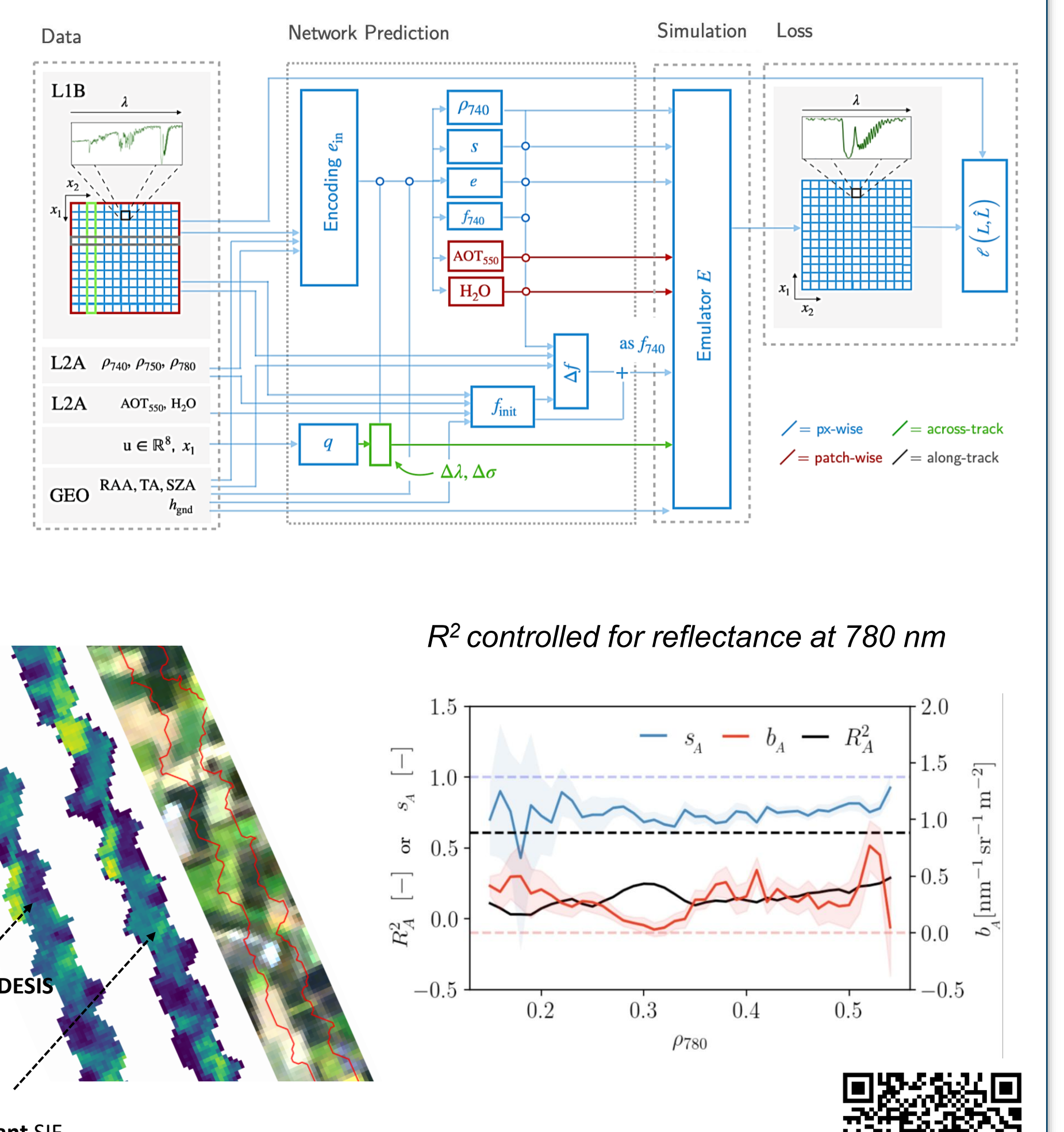
- State-of-the-art in HyPlant FLUO SIF retrieval
- Multi-year FLoX validation data
- Feature **generalization** across terrain and campaigns



Buffat et al. 2026, Emulation-based self-supervised SIF retrieval in the O₂-A absorption band with HyPlant, RSE, doi: 10.1016/j.rse.2025.115203

DESIS: first spaceborne SIF maps at 30m resolution

- Proof-of-concept: **additional regularization** allows DESIS SIF retrieval
- SIF **initialization**
- Supervised training on **L2A** and **atmospheric products**
- Consistency regularization



Buffat et al. 2024, Retrieval of sun-induced plant fluorescence in the O₂-A absorption band from DESIS imagery, CVPPA 2024, doi: 10.1007/978-3-031-91835-3_6

Outlook: Application to FLEX with sensor-agnostic retrieval

- **Aim:** sensor-agnostic retrieval framework
 - improve comparability of SIF products across sensors
 - few-shot training on new sensors: early delivery of FLEX-tuned predictor
- **Approach:** multi-sensor Foundation Modelling
 - Multi-modal (L1/L2) masked image modelling with **sensor-agnostic architecture**
 - Emulation-based SFMNN as downstream task

Dataset	#Rad	Ref.	SIF	Size	Bands	GSD
DESIS	20 × 10 ³	✓	✓	256 × 256	235	30m
EnMAP	20 × 10 ³	✓	✓	256 × 256	202	30m
FLUO	27 × 10 ³	✓	✓	128 × 128	1024	<5m
DUAL	21 × 10 ³	✓	✓	128 × 128	626	<5m
EMIT	65 × 10 ³	✓	✓	256 × 256	240	30m
AvirisNG	8 × 10 ³	✓	✓	256 × 256	220-430	<25m
APEX (*)	10 × 10 ³	✓	✓	128 × 128	312	<10m
Sentinel-3 (*)	27 × 10 ³	✓	✓	256 × 256	11	500 m
Sentinel-5P (*)	22 × 10 ³	✓	✓	256 × 256	200	7 km
E2E FLEX (*)	120	✓	✓	128 × 128	409	300m

