3rd WORKSHOP ON INTERNATIONAL COOPERATION IN SPACEBORNE IMAGING SPECTROSCOPY
13-15 November 2024 | ESA-ESTEC | Noordwijk | The Netherland

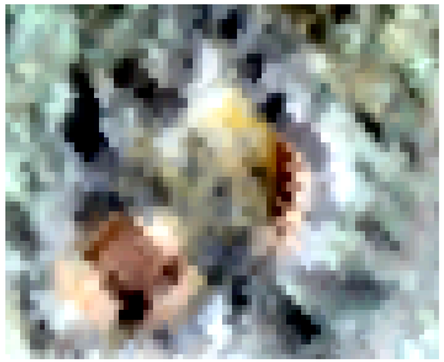
A Hyperparameter Optimization Algorithm for Efficient Unmixing of Multi-scale Hyperspectral Remote Sensing Data

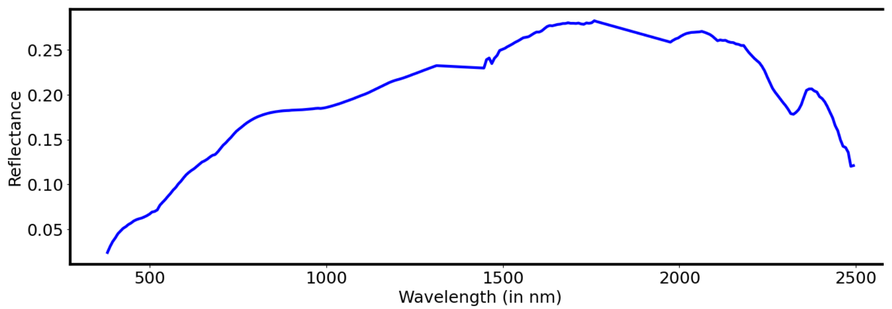
Presenter - Dr. Parth Naik (Scientific Employee, Helmholtz-Zentrum Dresden-Rossendorf),

Dr. Rupsa Chakraborty, Dr. Sharad Gupta, Dr. Sam Thiele, Dr. Moritz Kirsch, Dr. Richard Gloaguen

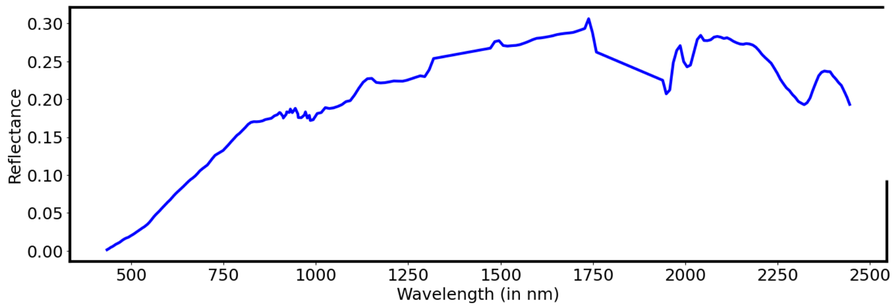
Multi-scale Hyperspectral data

60 m

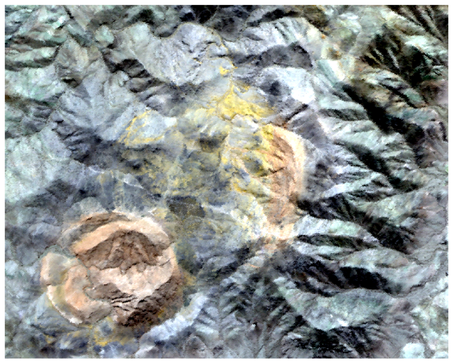


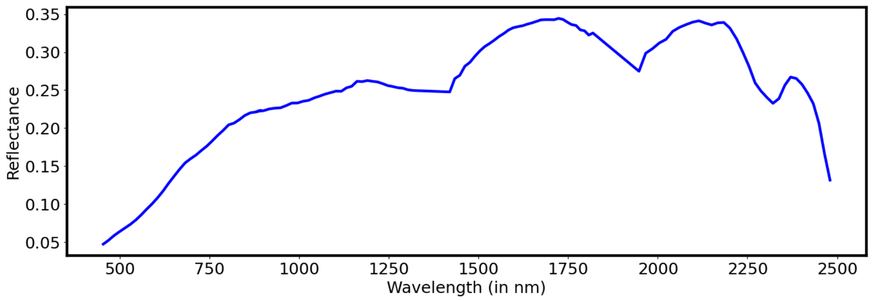


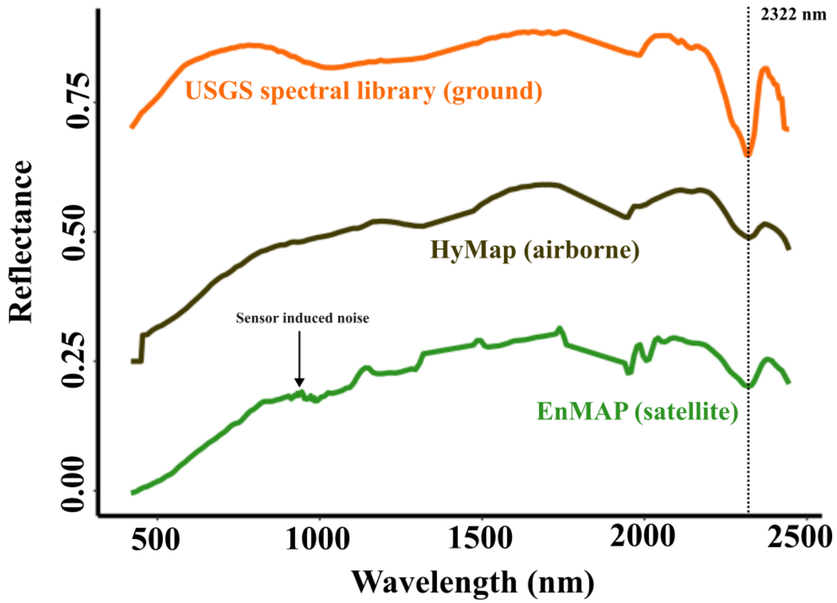
30 m



5 m



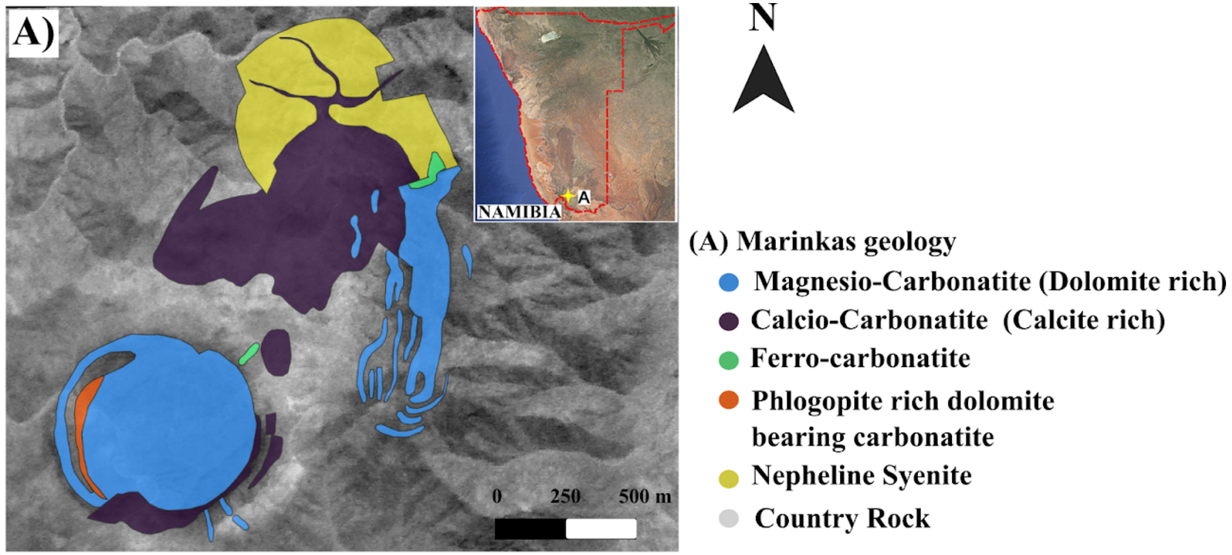


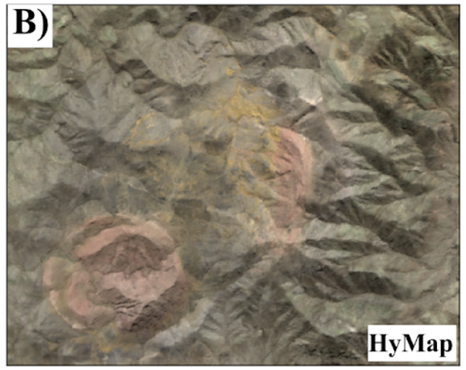


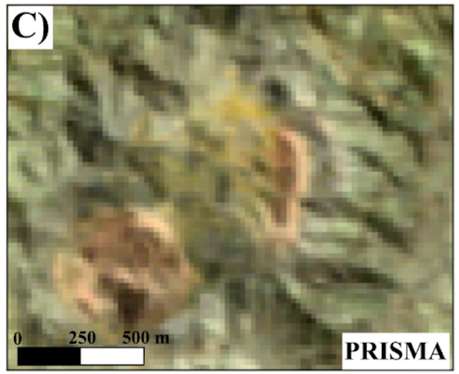
- Endmembers detected at one scale not a representative at other scales.
- Small feature identifiable at high resolution blend into neighbourhood at low-resolution.
- Harmonisation in-terms of end-product delivery and feature transfer from HR to LR?

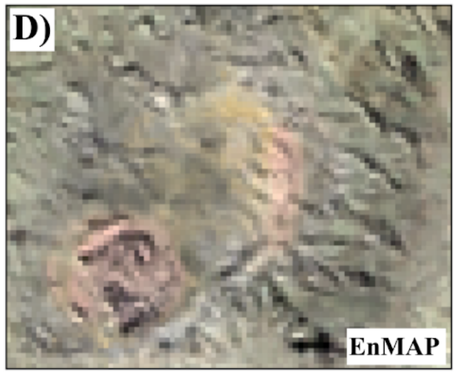
Datasets and Study Site

Location: Marinkas-Quellen, Namibia







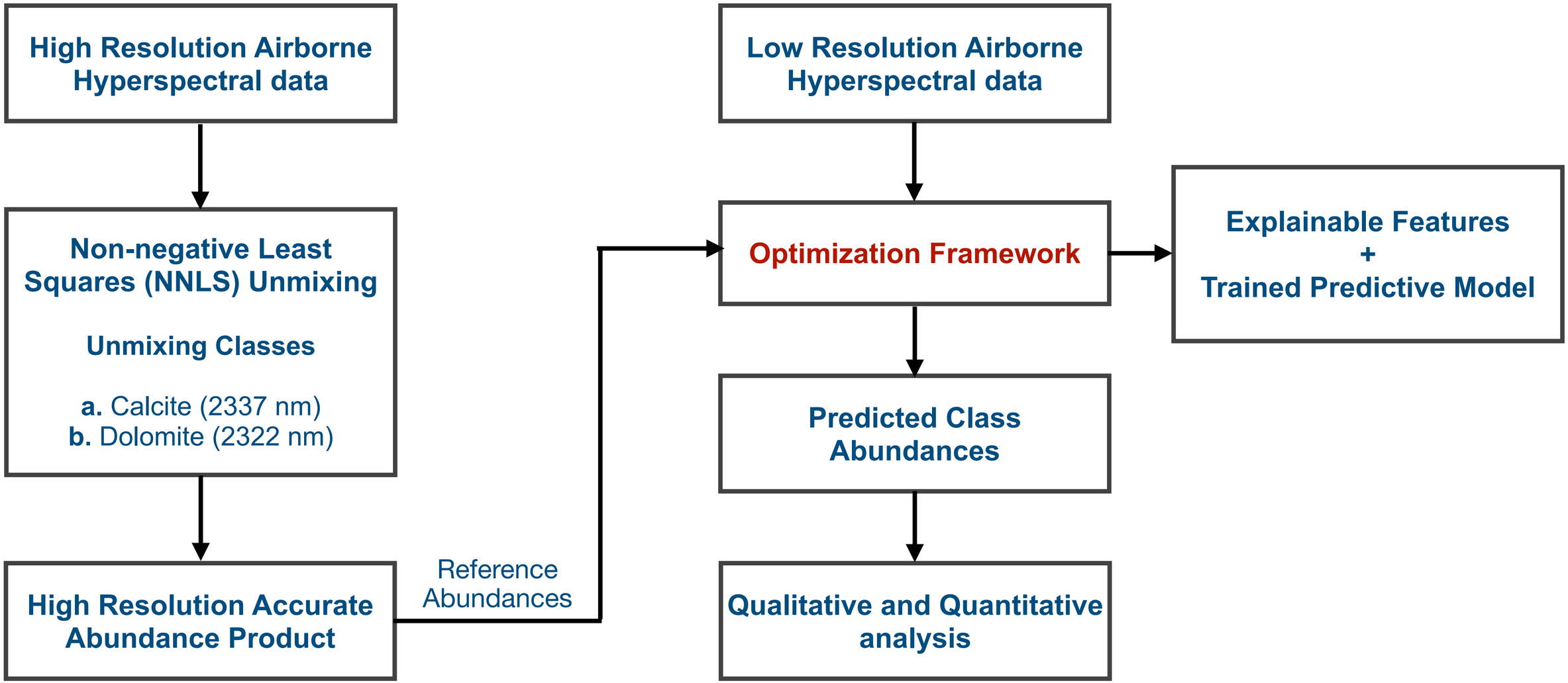


HyMap (airborne)
Spatial resolution :- 5 m
VNIR :- 450-1350 nm
SWIR :- 1400-2480 nm
No. of bands :- 125 bands

EnMAP (satellite)
Spatial resolution :- 30 m
VNIR :- 400-1010 nm
SWIR :- 920-2505 nm
No. of bands :- 237 bands

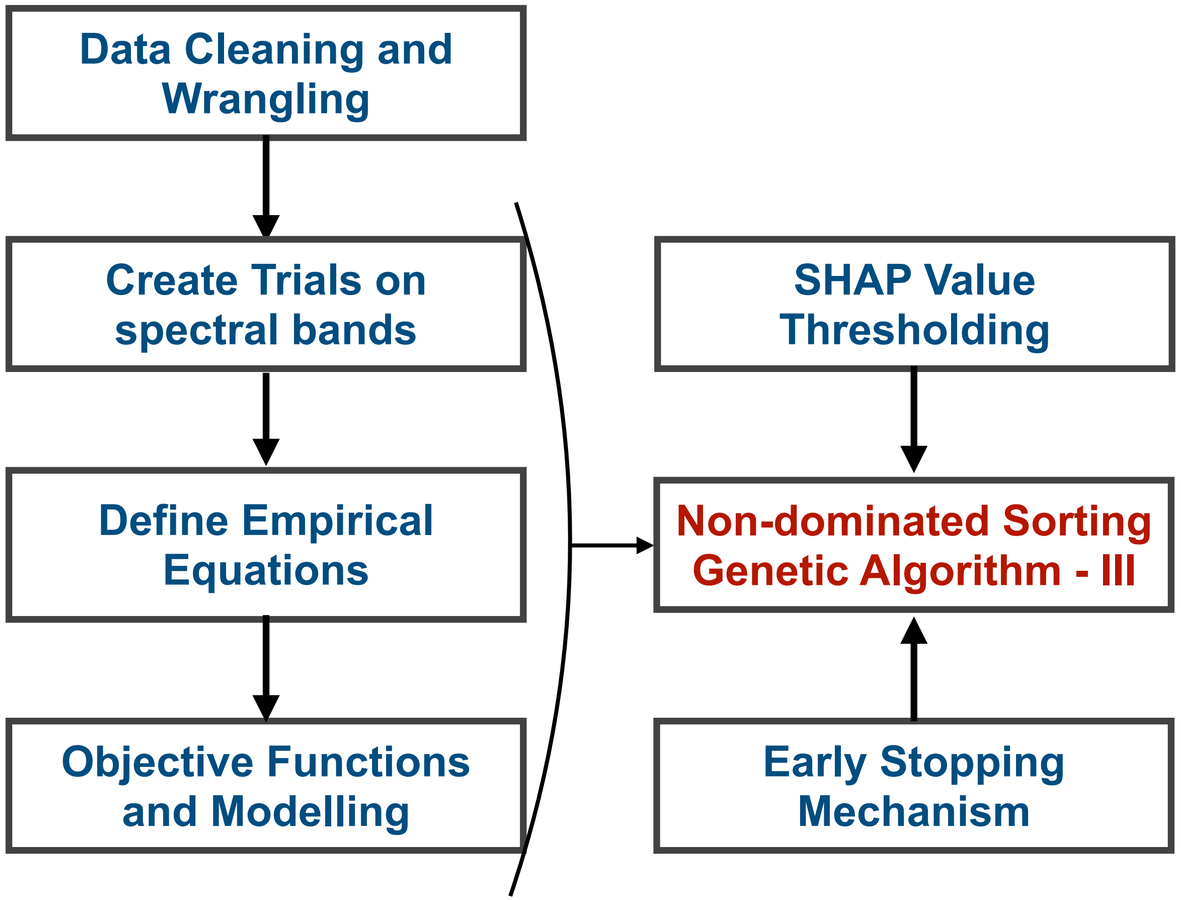
PRISMA (satellite)
Spatial resolution :- 30 m
VNIR :- 420-1000 nm
SWIR :- 900-2450 nm
No. of bands :- 224 bands

Proposed Framework



Optimization Framework

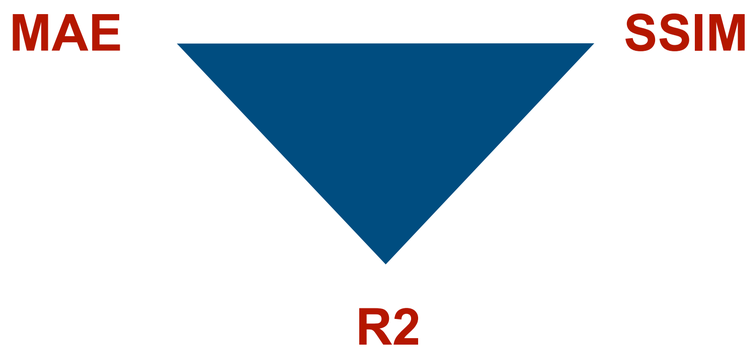
Solving the feature engineering problem



Empirical indices for optimization process

Index No.	Empirical Indices		Index No.	Empirical Indices
1	B1 - B2		7	(B15 - B16) / B17
2	B3 + B4		8	(B18 + B19) / B20
3	B5 - B6 / B5 + B6		9	(B21 - B22) / (B23 - B24)
4	B7 / B8		10	(B25 - B26) / (B27 + B28)
5	B9 / (B10 - B11)		11	(B29 + B30) / (B31 - B32)
6	B12 / (B13 + B14)		12	(B33+B34) / (B35+B36)

Multi-objective Optimization



Non-dominated Sorting Genetic Algorithm

- **Evolutionary:** Mechanism inspired by biological evolution (mutation, recombination, selection etc.)

- **Non-dominated sorting:** Solutions are ranked based on Pareto dominance

- **Pareto Front:** Should be better in at least one objective and no worse in all others, considered non-dominated and form the Pareto front (best solution).

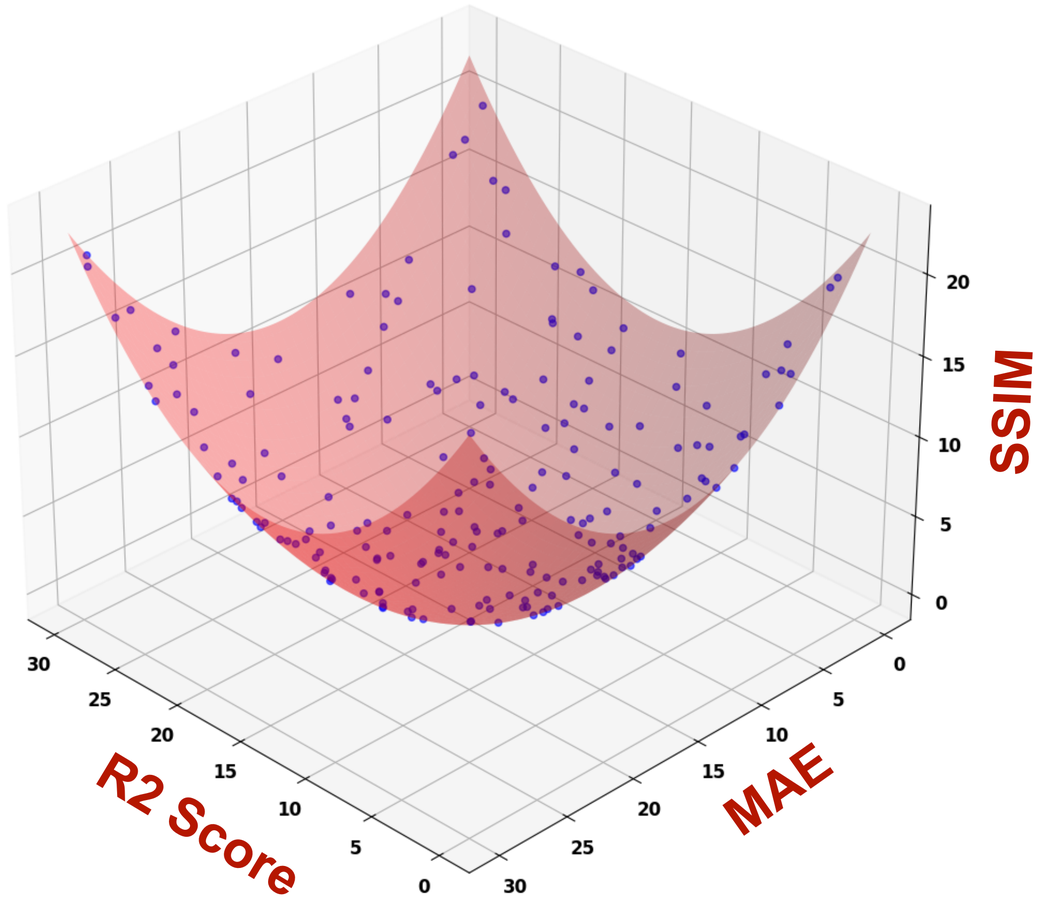
- **Crowding distance** - maintain diversity.

- Iterative process with **Mutation** (swap one / two bands randomly) and **Crossover** (combine parts of two solutions).

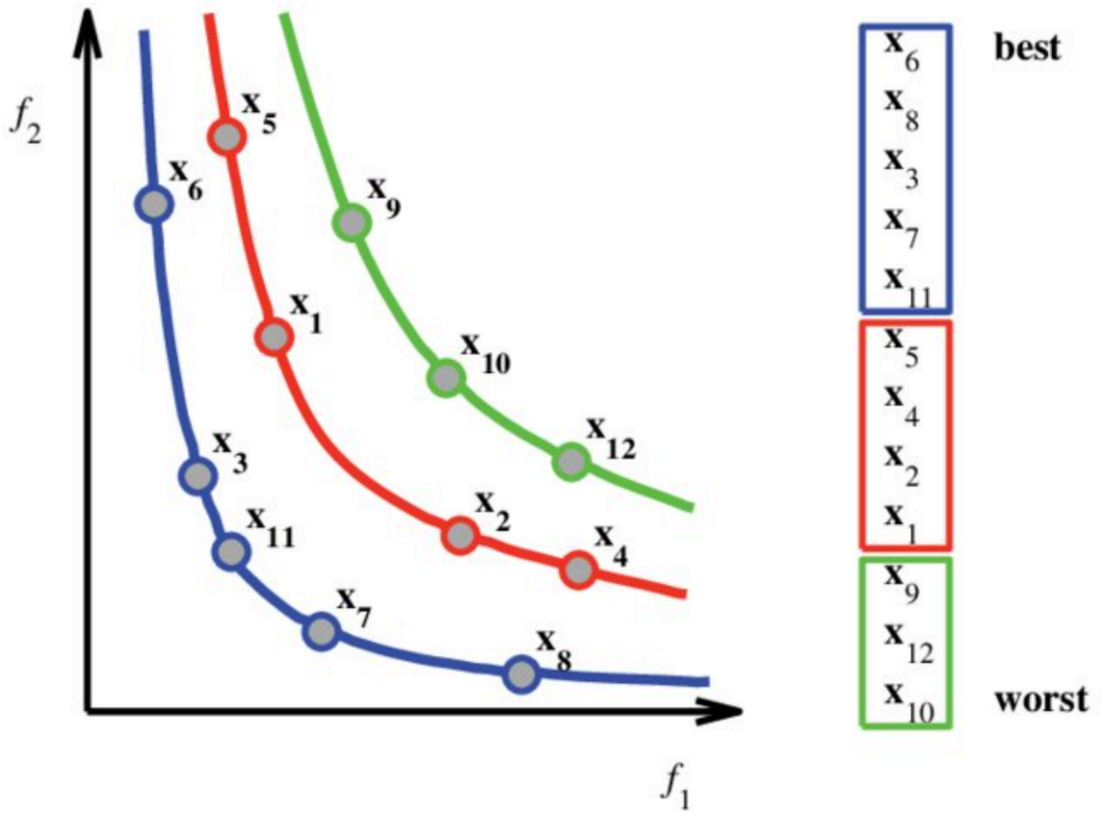
- **Multi-objective handling** - Can optimize more than one objective functions simultaneously.

Non-dominated Sorting Genetic Algorithm

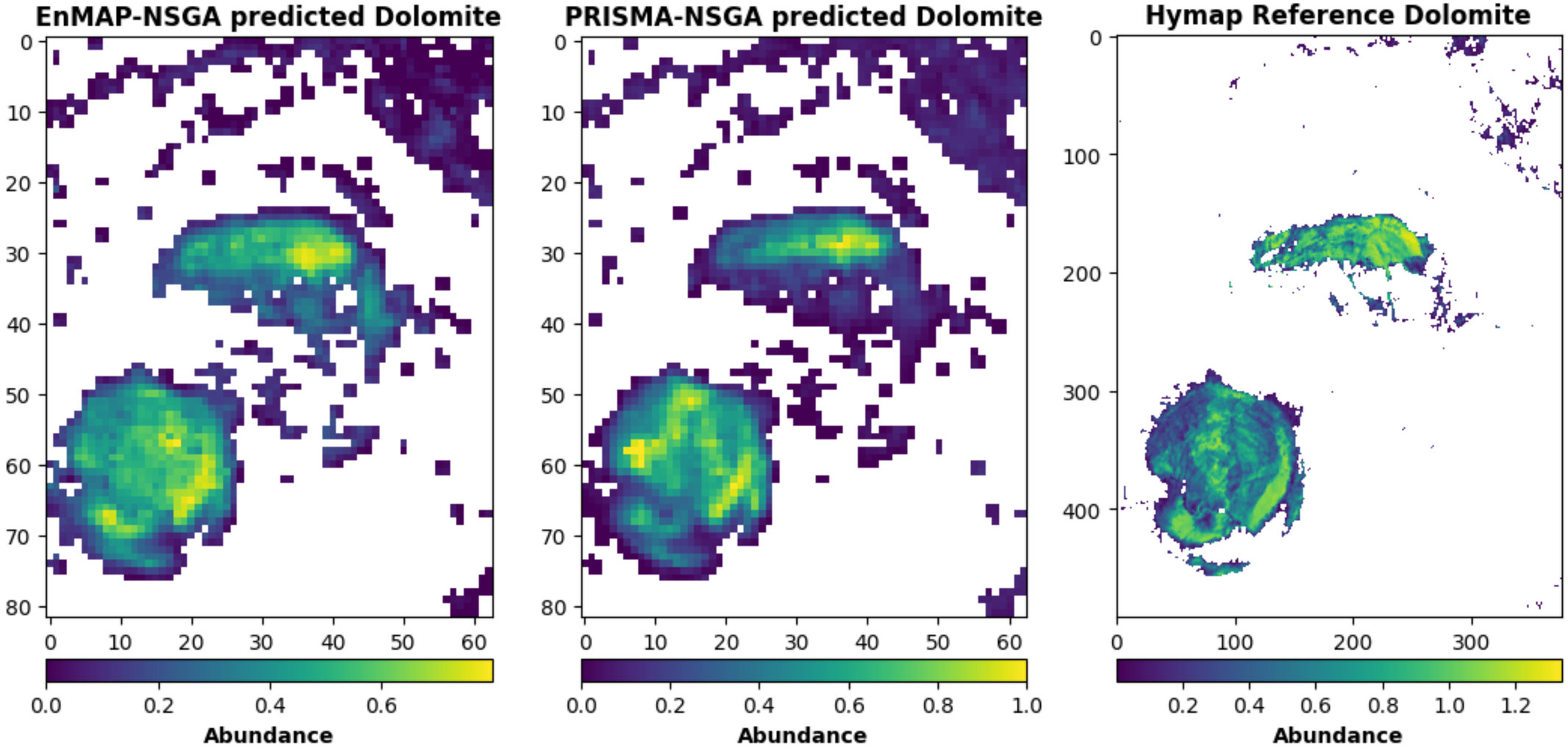
Pareto Front



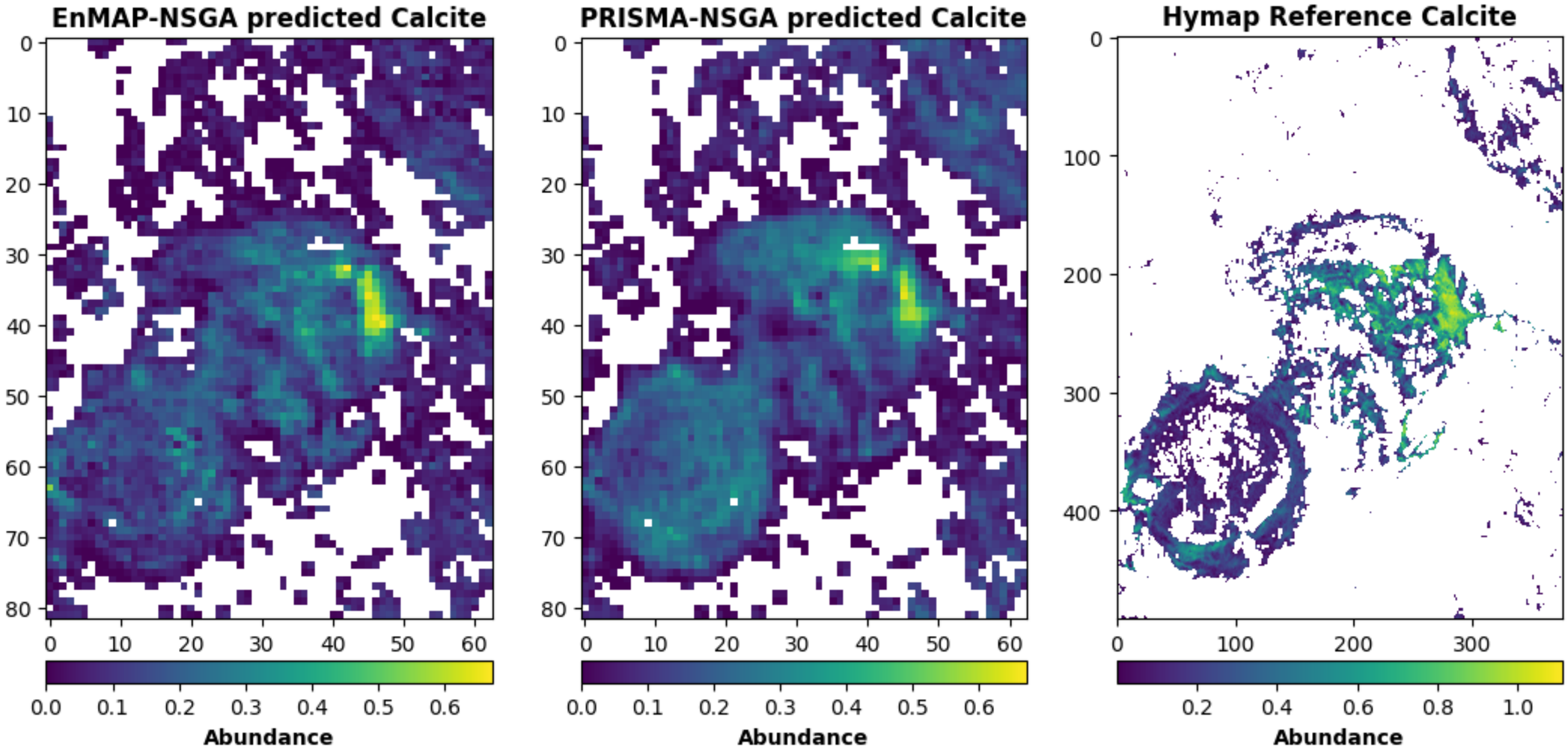
Selection of band combinations



Results


EnMAP-NSGA predicted Dolomite
PRISMA-NSGA predicted Dolomite
Hymap Reference Dolomite
Abundance
Abundance
Abundance

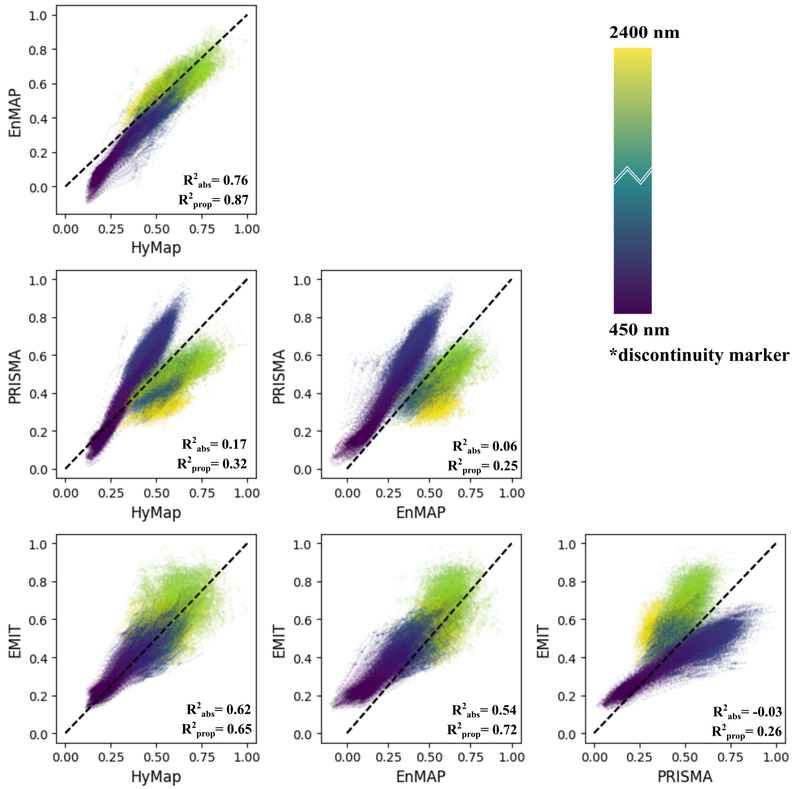
Results


EnMAP-NSGA predicted Calcite
PRISMA-NSGA predicted Calcite
Hymap Reference Calcite
Abundance
Abundance
Abundance

Results

Selected empirical indices and wavelengths

Sensor	2337 Calcite **Index:** Wavelengths(nm)	2332 Dolomite **Index:** Wavelengths(nm)
EnMAP	**1:** 2353, 2392	**12:** 2191, 2345, 2306, 2306
PRISMA	**10:** 2191, 1394, 2349, 1914	**7:** 2298, 2036, 535



Chakraborty et al., 2024

- Primary signature spectral range (SWIR) identified by the genetic optimizer.
- Effective separation and identification of two very similar carbonate minerals.
- A small fraction of the available spectral bandwidth used for delivering accurate predictions.
- A very sparse solution: tuneable and multi-objective optimized.

Qualitative and Quantitative assessment indicators

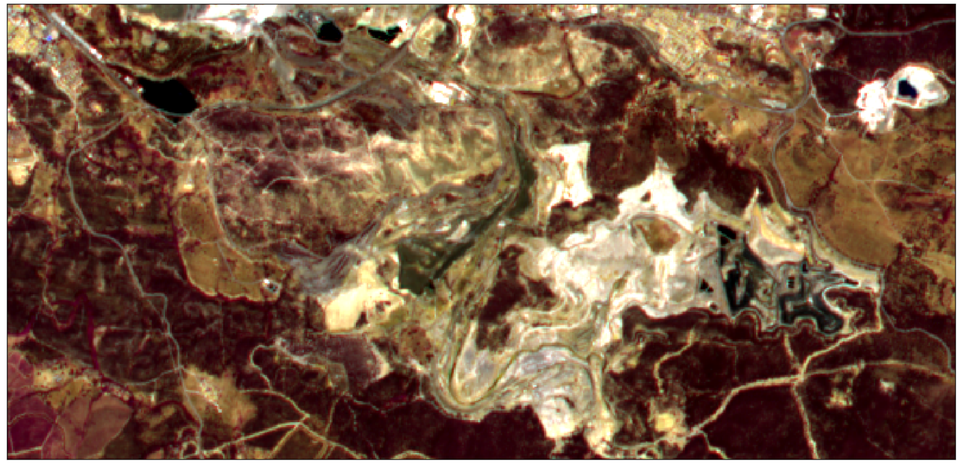
Sensor	Class	R^2	RMSE	SSIM	Max. Trials
EnMAP	Calcite	0.48	0.09	0.50	13
	Dolomite	0.72	0.11	0.60	648
PRISMA	Calcite	0.54	0.08	0.58	764
	Dolomite	0.75	0.10	0.62	1976

Achievements

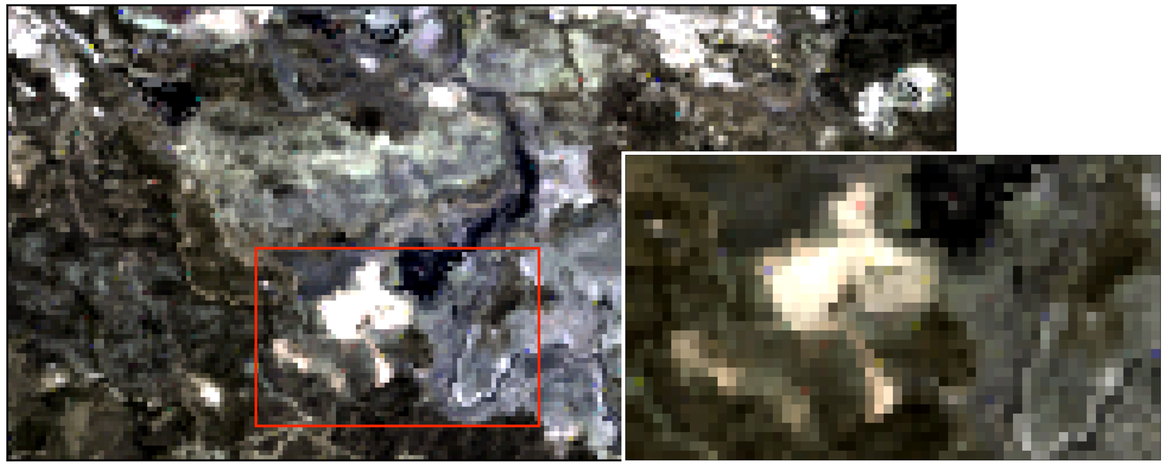
- Efficient predictive and automated feature engineering approach for abundance mapping.
- Unlike unmixing algorithms, facilitates explainability and tunability (contribution and selection of specific wavelengths in a multi-sensor scenario).
- Accurate performance with materials with close spectral signatures and overlapping range of primary absorption features.
- Management of redundant / trivial information in hyperspectral data.
- Optimized with multiple objectives to ensure reliability and accuracy of results across multiple hyperspectral spaceborne sensors.
- Diverse and wide-ranging applications (sensor selection, resolution enhancement etc.).

Applications - Resolution Enhancement

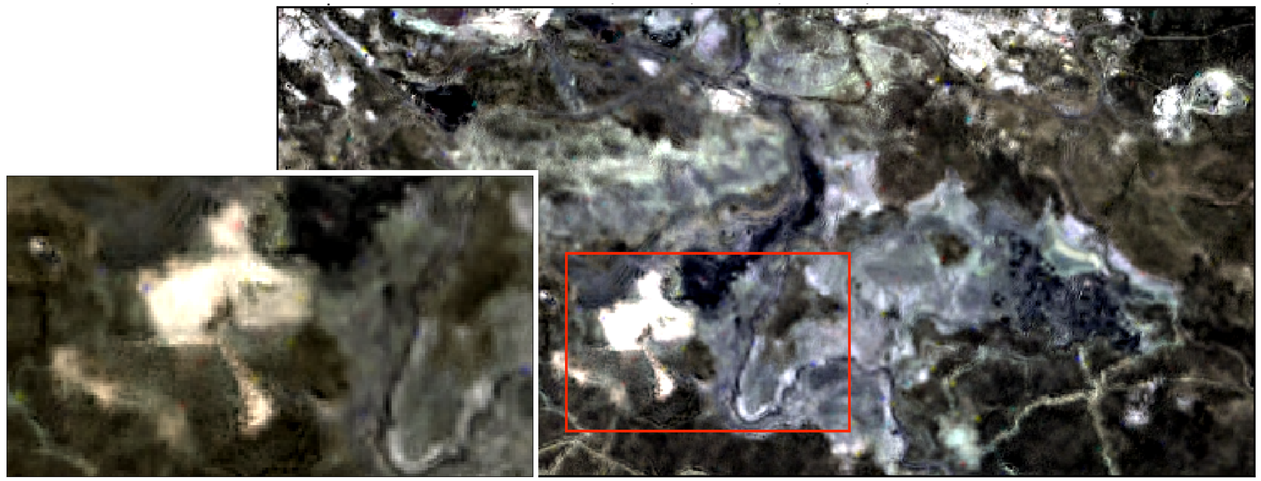
Sentinel (10 m)

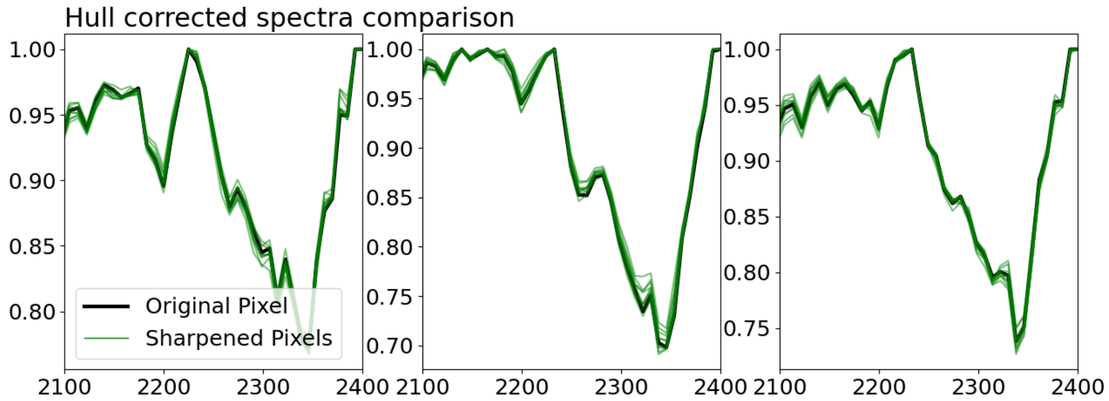


EnMAP (30 m)



Enhanced EnMAP (10 m)





Discussion

- **Contribution in improving harmonisation ?**

  Inducing features in low-resolution hyperspectral data using high resolution product through a feature-level harmonization framework.

- **Aspect of harmonisation that benefits the user ?**

  Explainable features and pin-pointing informative spectral bands in low-resolution based on a high resolution hyperspectral product.

- **Harmonisation of formats or information content ?**

  Harmonization of formats - processing, integration and pipelining (best for all practical reasons!)
  Harmonization of information - Information = Insights, Comprehensive datasets, Product accuracy and better time-series analysis.

Connect with us !

CASUS
CENTER FOR ADVANCED
SYSTEMS UNDERSTANDING

HiF

Connect with us !

HyperUAV

Funded by CASUS Open Projects

HZDR
HELMHOLTZ ZENTRUM
DRESDEN ROSSENDORF

HELMHOLTZ