VALIDATING SURFACE REFLECTANCE MEASUREMENTS FROM MULTI- AND HYPERSPECTRAL AIR- AND SPACEBORNE SENSORS IN AGRICULTURAL FIELDS IN GERMANY

David Marshall Ingram, Tobias Eckert, Uta Heiden, Claas Köhler, Kevin Kühl, Raquel de los Reyes, Gabriel Scheib, Konstantin Torgasin

German Aerospace Center (DLR), Earth Observation Center (EOC), Weßling, Germany

INTRODUCTION

HySpex, Puch, Germany. Source: DLR

Surface Reflectance Validation

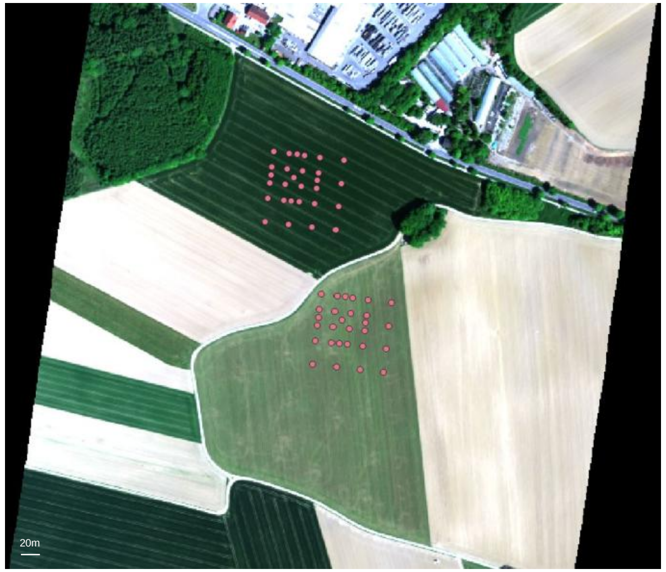
- Validation is important to assess the **accuracy of the products** to the mission requirements
- Reference data is required with (low) uncertainties. For L2A products, typical sources include:
  - **dedicated networks** (AERONET, RadCalNet, Hypernets)
  - **field campaigns**
- The CARMA field campaign gives the opportunity to perform validation activities in an **application setting** (non-ideal atmospheric conditions, heterogeneous targets)

HySpex TOA

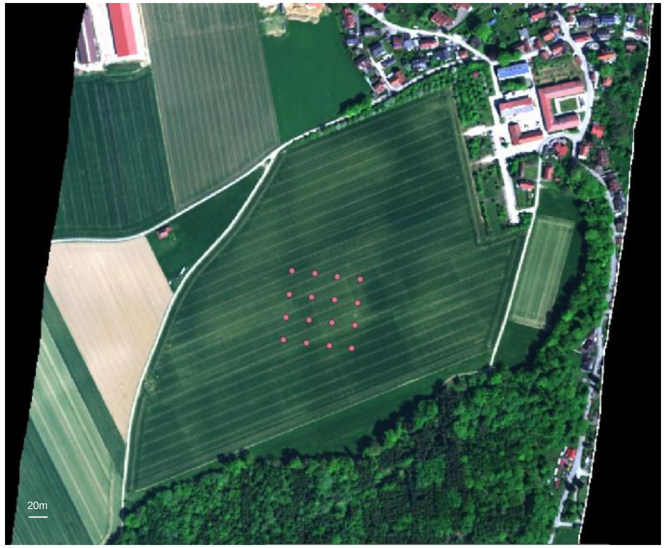
HySpex BOA

Measurement Protocol

- Select large fields
- Measure in centre to minimise adjacency effects
- Make 3x3 pixel grid with at least measurement 16 points
- Use appropriate spacing
  - 30m (for EnMAP, PRISMA, DESIS) 20m (Sentinel-2) or 2m (HySpex) spacing
- Align to overflight path
- Take multiple measurements at each grid point



Source: DLR



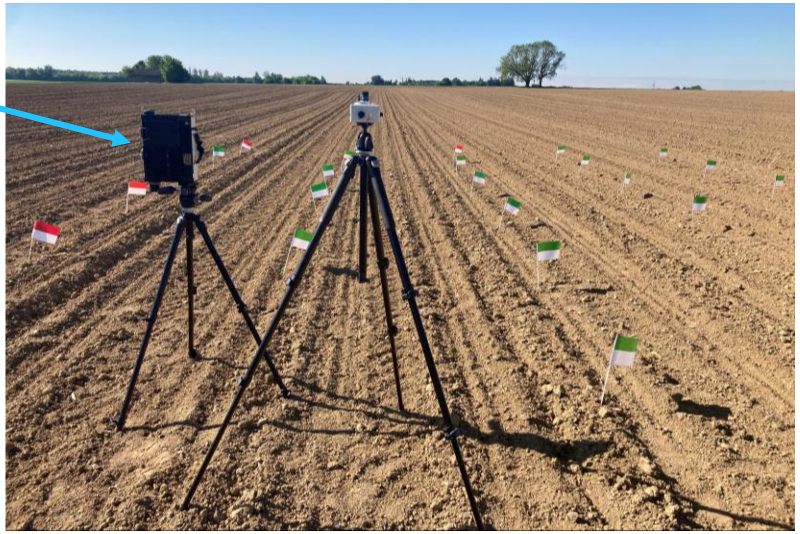
Source: DLR

Equipment

- Spectra Vista Corporation Spectrometer (SVC HR-1024i)
  - Ground measurements in raw digital numbers
  - Calibrated in lab

	SVC HR-1024i
Spectral channels	1024
Spectral resolution (FWHM) for 350 – 1000 nm	4.5 nm
Spectral resolution (FWHM) for 1000 – 1890 nm	13 nm
Spectral resolution (FWHM) for 1890 – 2500 nm	10 nm
Field of View	4° (lens)
Radiometric uncertainty (k = 2)	< 3 % (VNIR), < 4 % (SWIR)

- Wireless External Data Interface (WEDI) sensor
  - Monitor downwelling irradiance
- Spectralon® reflectance panel
  - 50% reflectance for reference
  - Calibrated in lab
- Microtops sun photometers
  - AOT and Ozone measurements


Source: DLR


Source: DLR

HySpex

- Airborne imaging spectrometer with 2 HySpex pushbroom cameras (produced by NEO) operated by DLR

Source: DLR

Source: DLR

HySpex	VNIR-3000N	SWIR-384
Spectral channels	700	288
Spectral resolution	3.5–6.0 nm	5.6–7 nm
Wavelength range	400–994 nm	952–2516 nm
Geometric resolution at 2.1 km above ground	0.2 m	1.6 m
Geometric pixels	3408	384
Radiometric Uncertainty	<3%	<4%

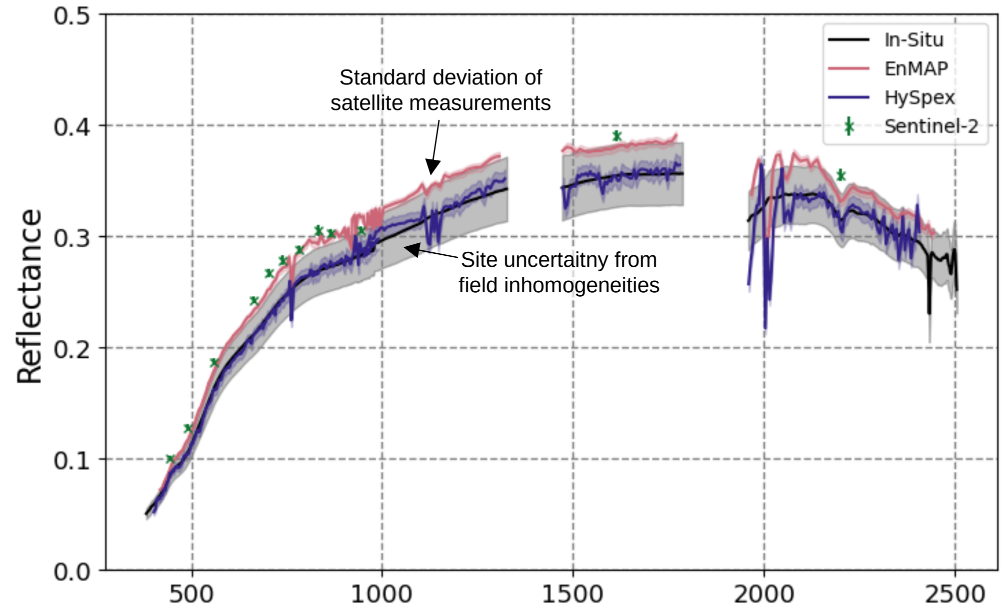
Campaigns

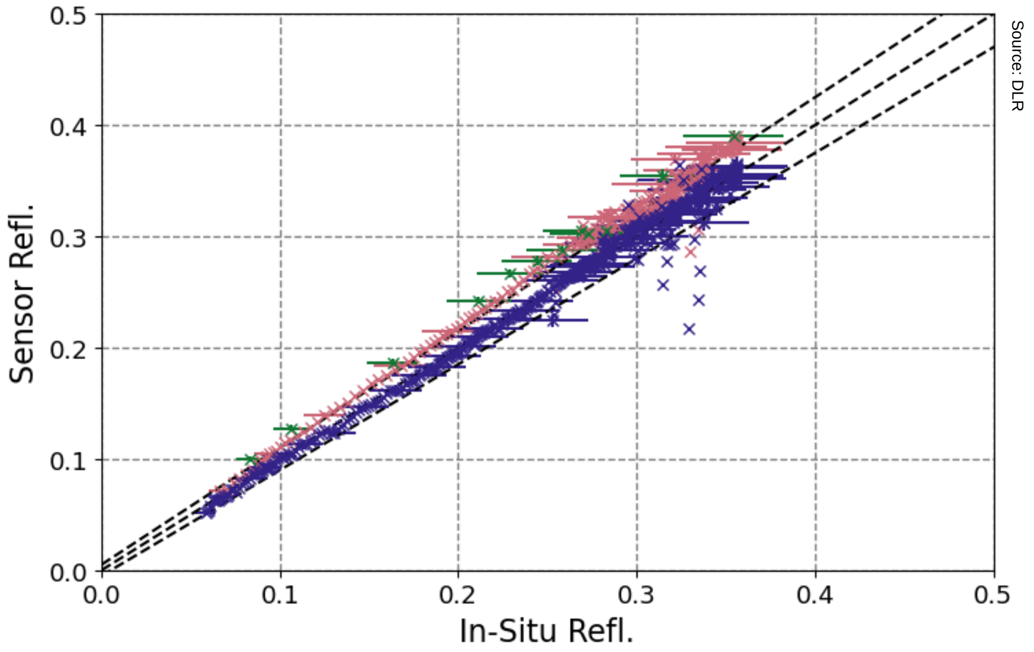
Campaign	Date	Field	Overpasses	Notes
1	16.04.2025	Wheat		Campaign start, no overpass
2	30.04.2025	Wheat	HySpex, Sentinel-2A	Sentinel-2A cloudy
3	12.05.2025	Maize (soil)	HySpex, Sentinel-2C, PRISMA	
4	13.05.2025	Wheat	HySpex	BRDF airborne campaign
5	19.05.2025	Maize (soil)	HySpex, EnMAP	
6	13.06.2025	Barley, Maize, Wheat, Triticale	Sentinel-2A, DESIS	Many fields measured for spectral library, not intended for SR validation
7	07.08.2025	Barley (harvested)		No overpass
8	08.08.2025	Barley (harvested)	Sentinel-2B, DESIS	
9	12.08.2025	Wheat (harvested)	Sentinel-2A, EnMAP, DESIS	
10	18.09.2025	Wheat (harvested)	EnMAP	

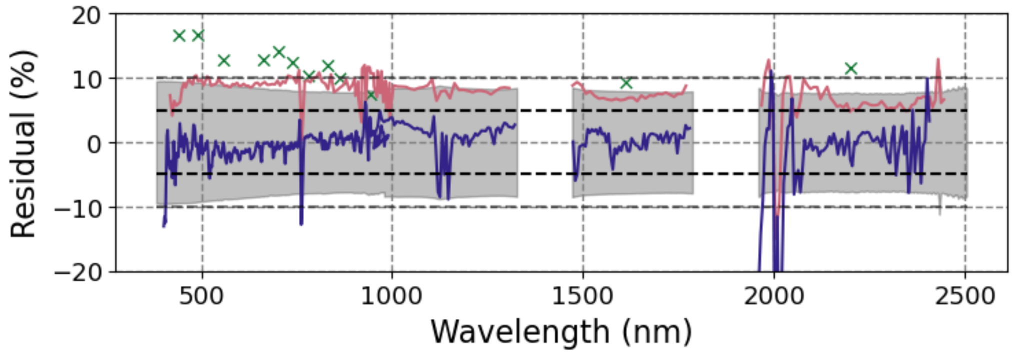
HySpex, Puch, Germany. Source: DLR

VALIDATION WITH IN-SITU

Campaign: 12.05.2025







Overpasses: HySpex, EnMAP, Sentinel-2C

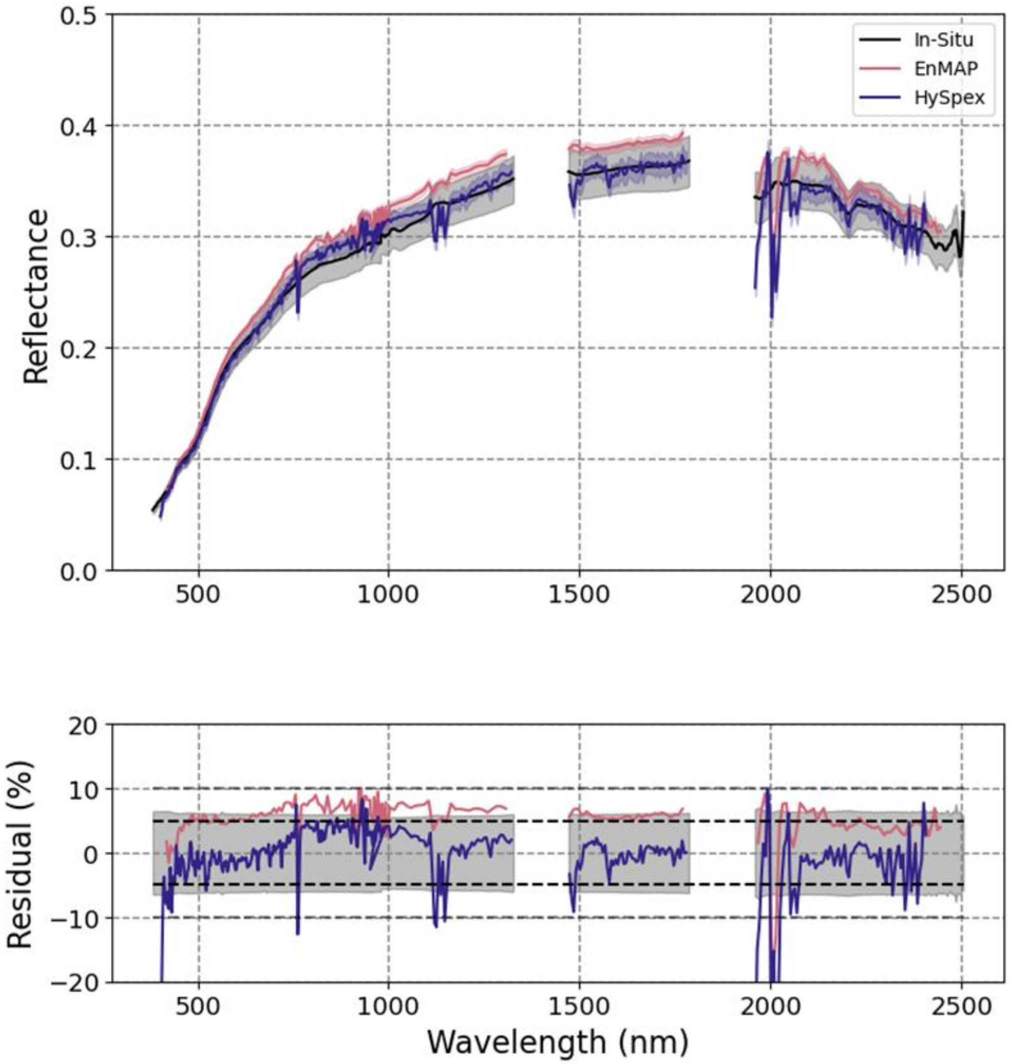
In-Situ uncertainty: 8%

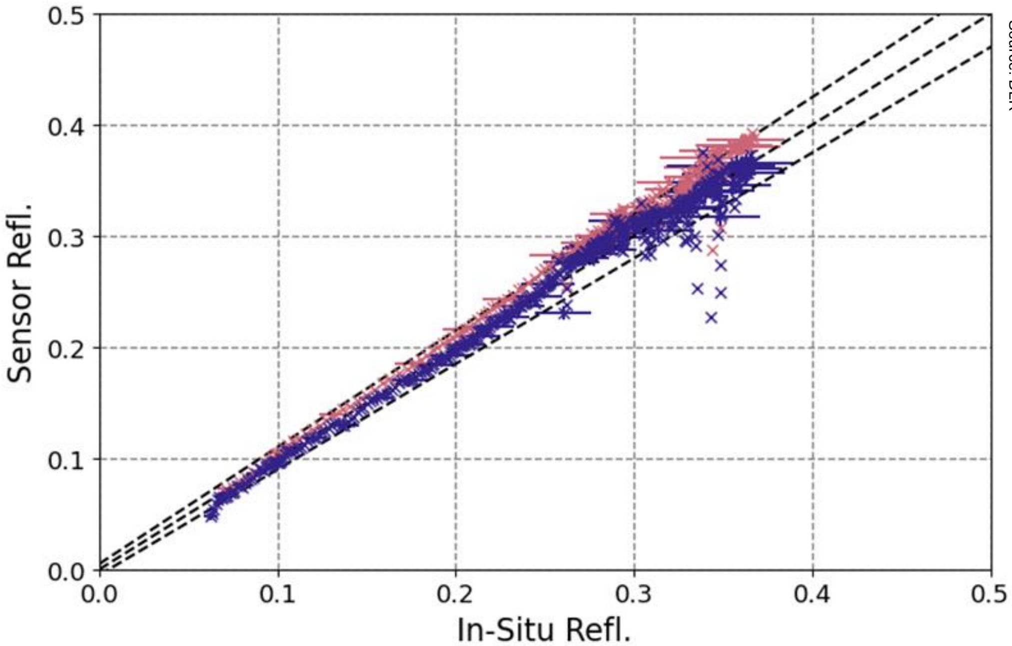
HySpex residual: 2%

EnMAP (19.05) residual: 8%

Sentinel-2C residual: 12%

Campaign: 19.05.2025





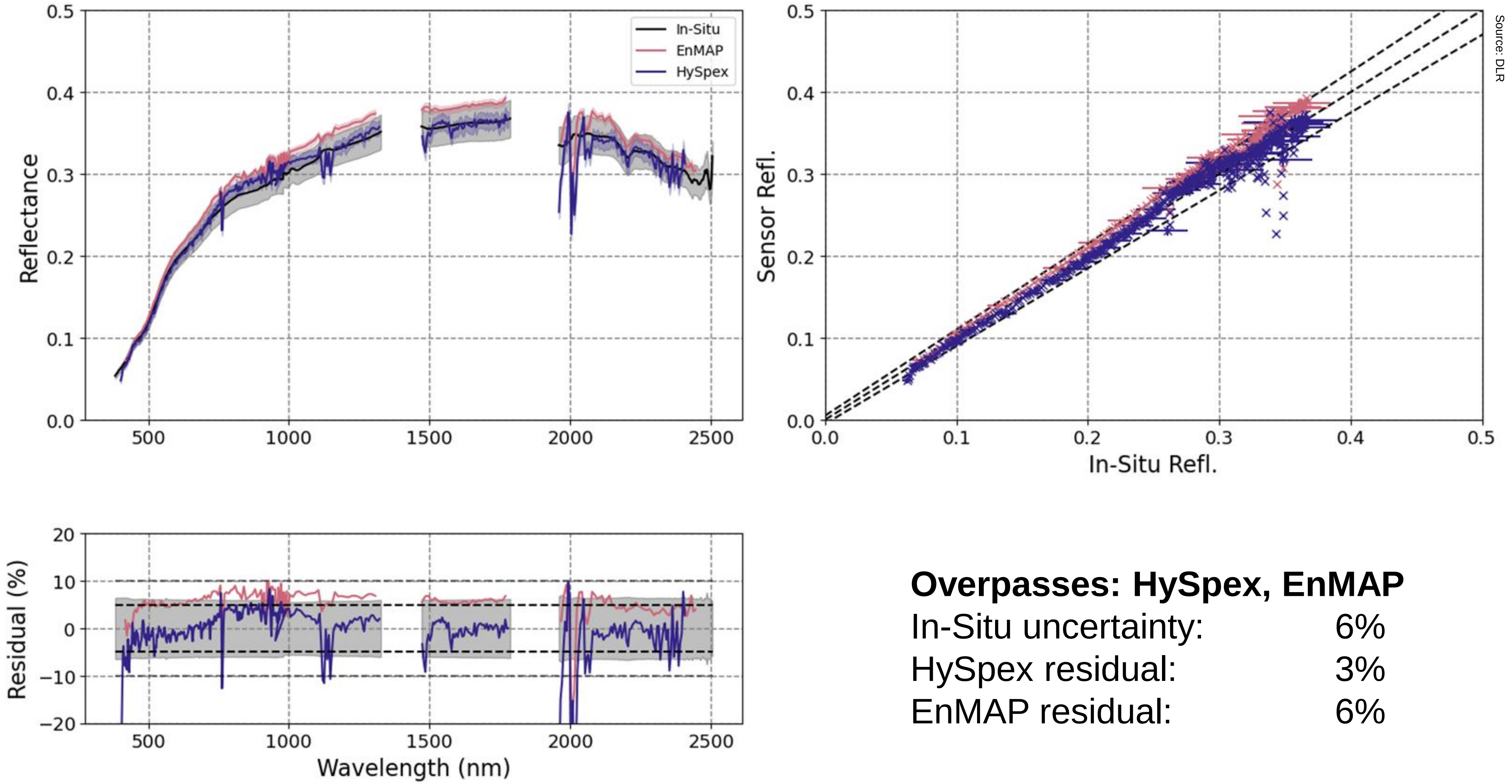
Source: DLR

Overpasses: HySpex, EnMAP

In-Situ uncertainty:	6%
HySpex residual:	3%
EnMAP residual:	6%

Campaign: 19.05.2025

Good agreement between in-situ and HySpex
Why is there a difference to EnMAP/S2?



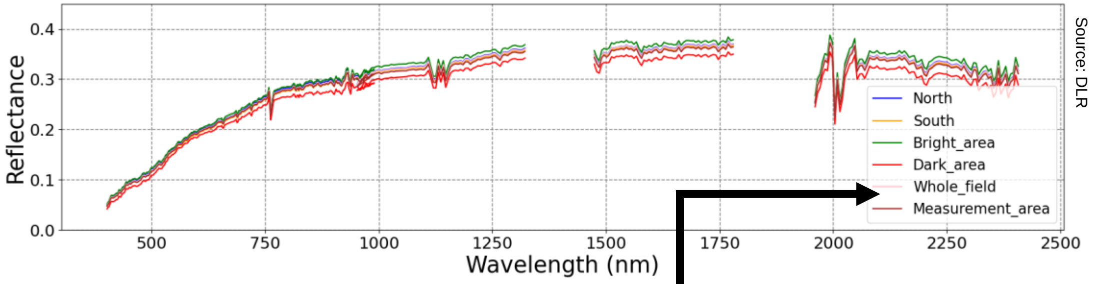
Overpasses: HySpex, EnMAP

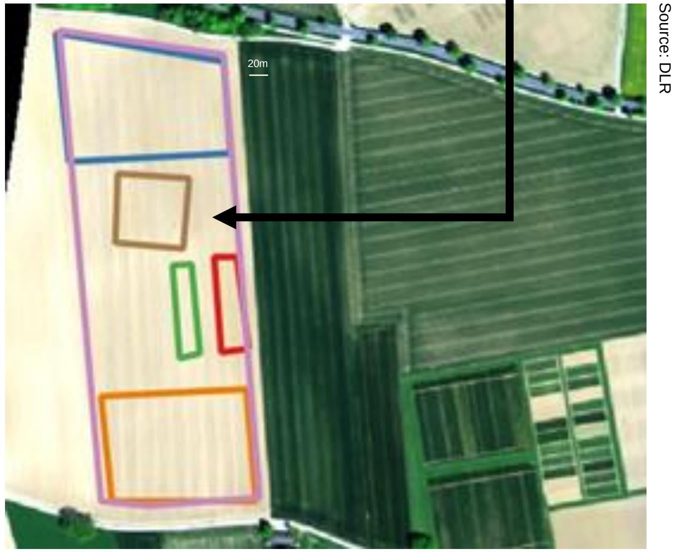
In-Situ uncertainty:	6%
HySpex residual:	3%
EnMAP residual:	6%

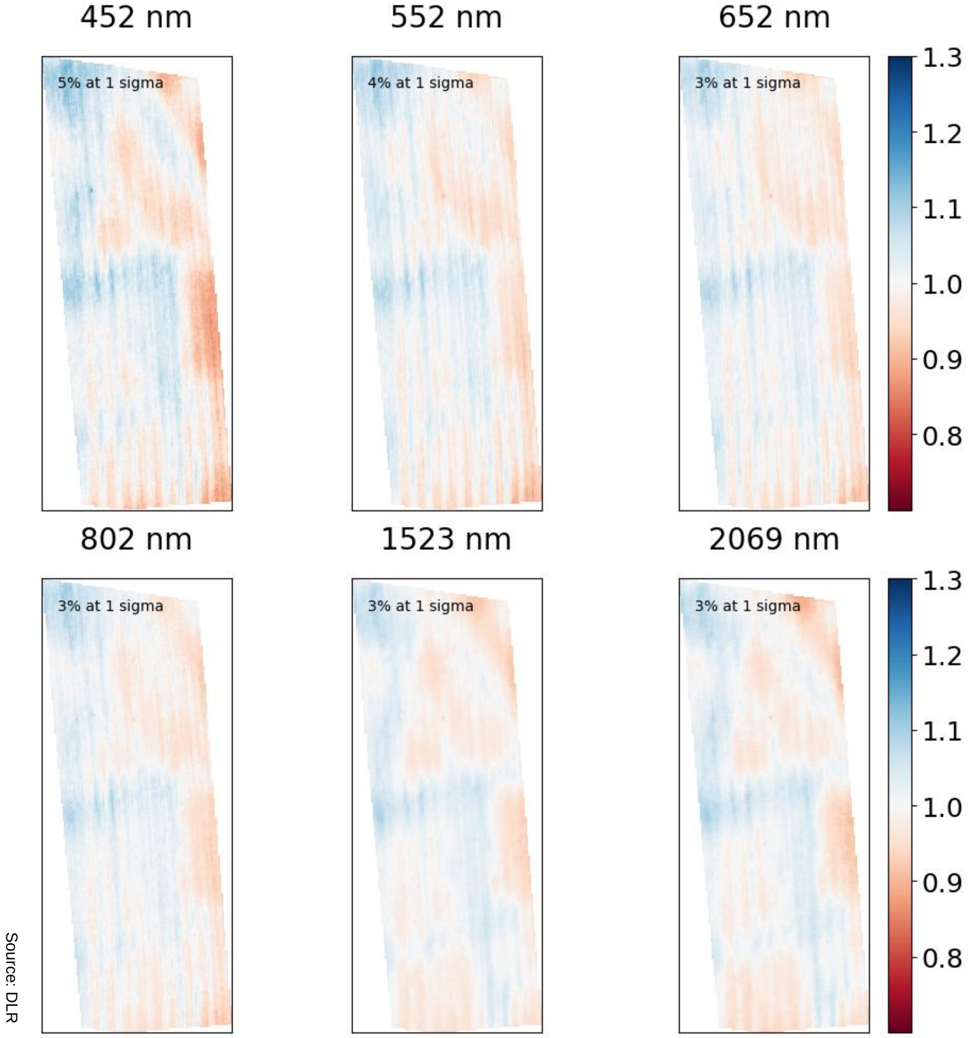
HYSPEX SITE CHARACTERISATION

HySpex, Puch, Germany. Source: DLR

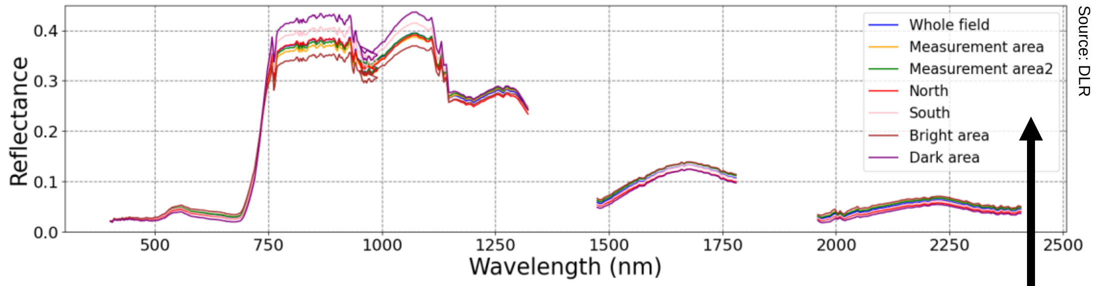
Soil site – spatial non-uniformity

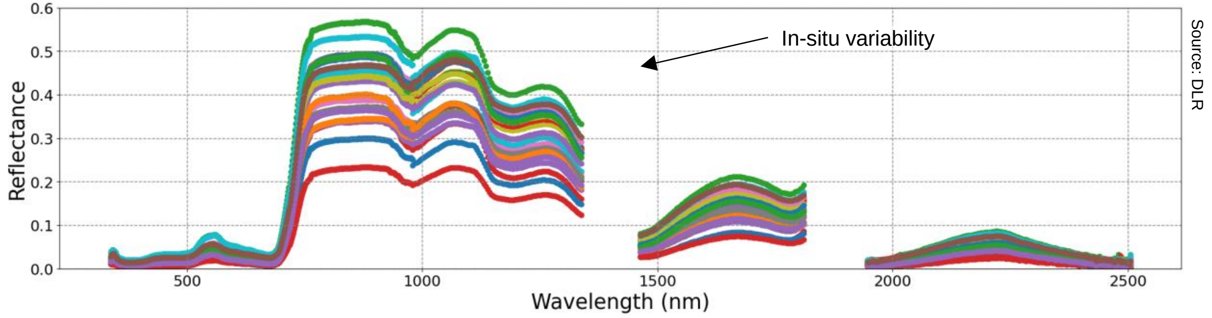


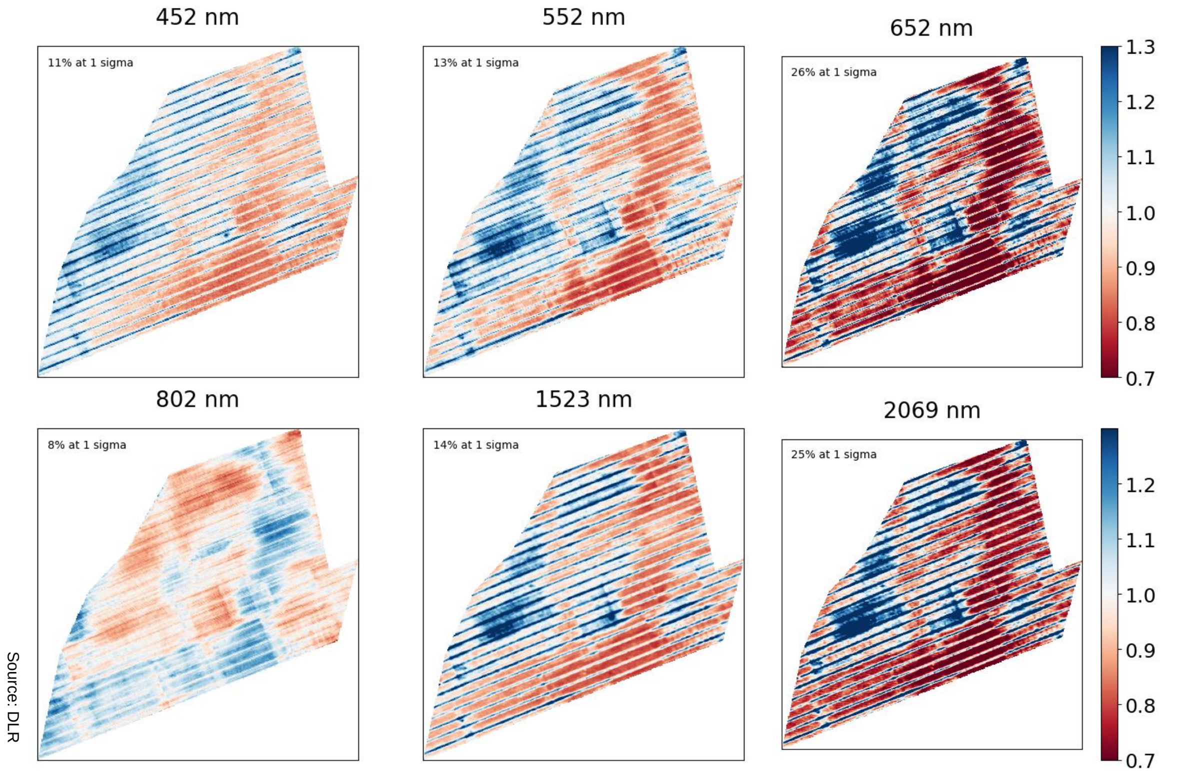




Vegetation site – spatial non-uniformity



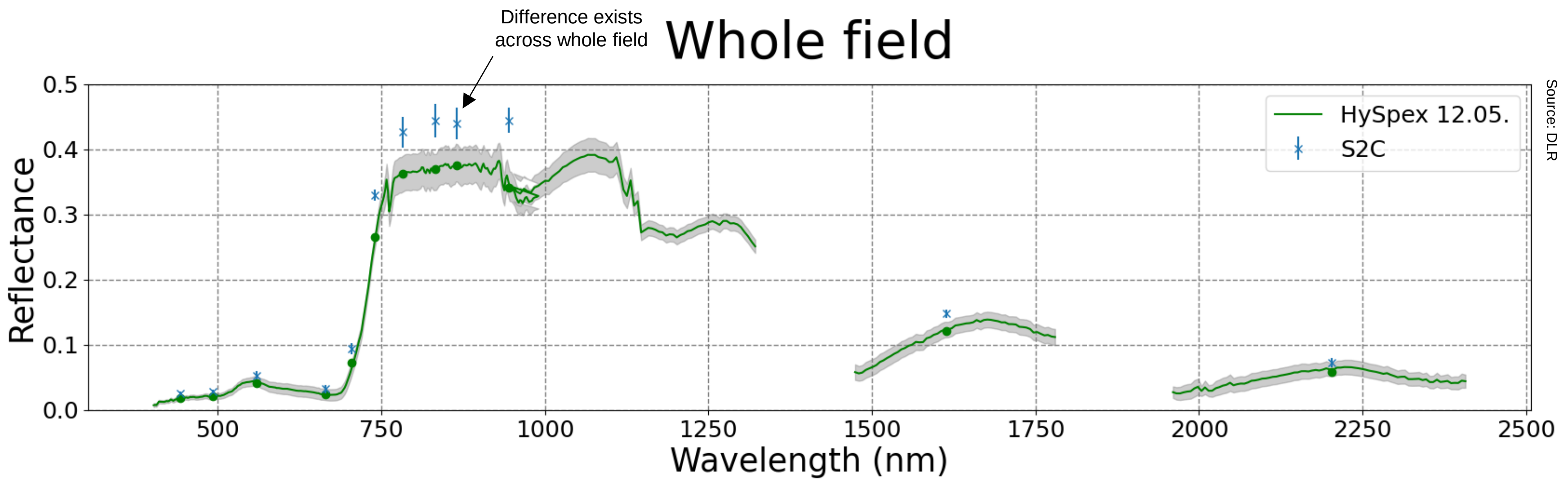


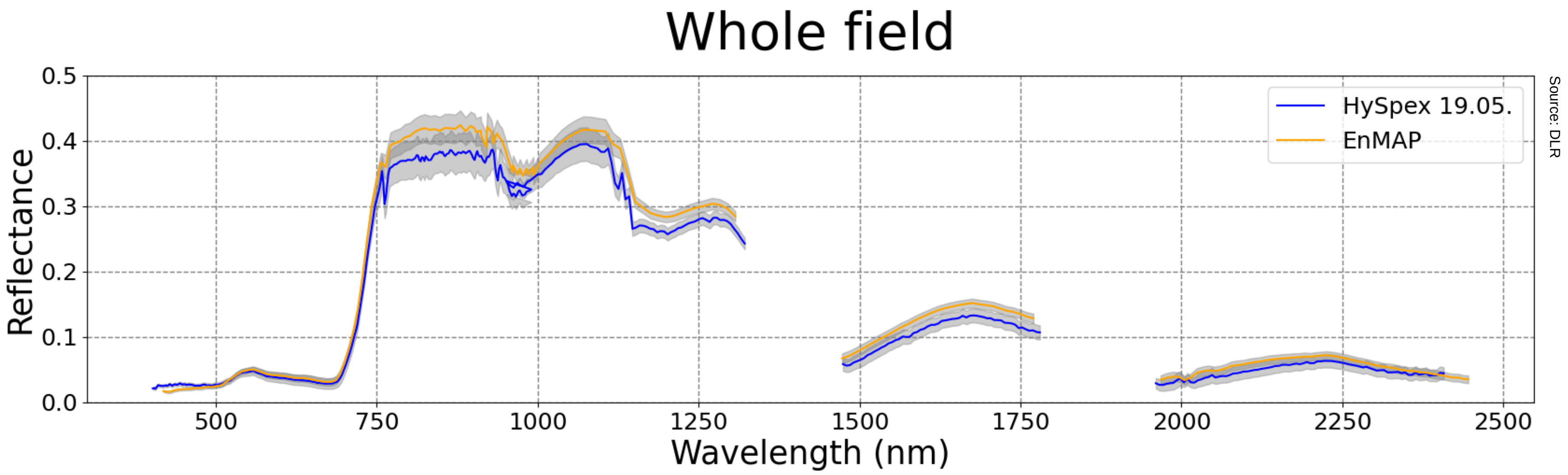


VALIDATION WITH HYSPEX

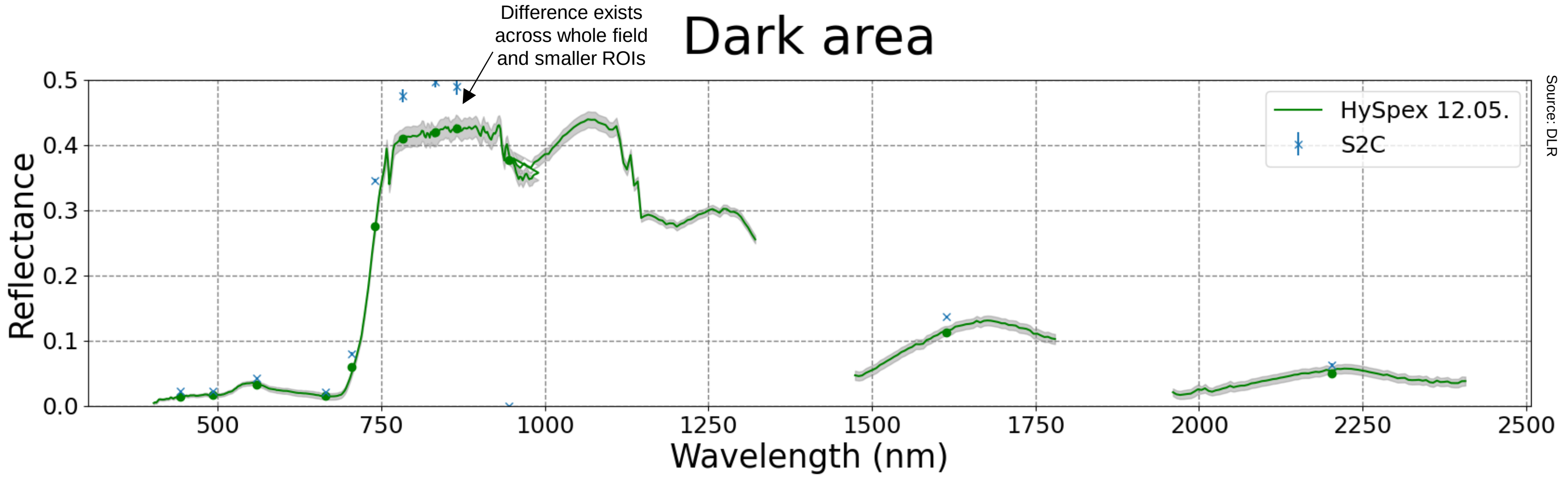
HySpex, Puch, Germany. Source: DLR

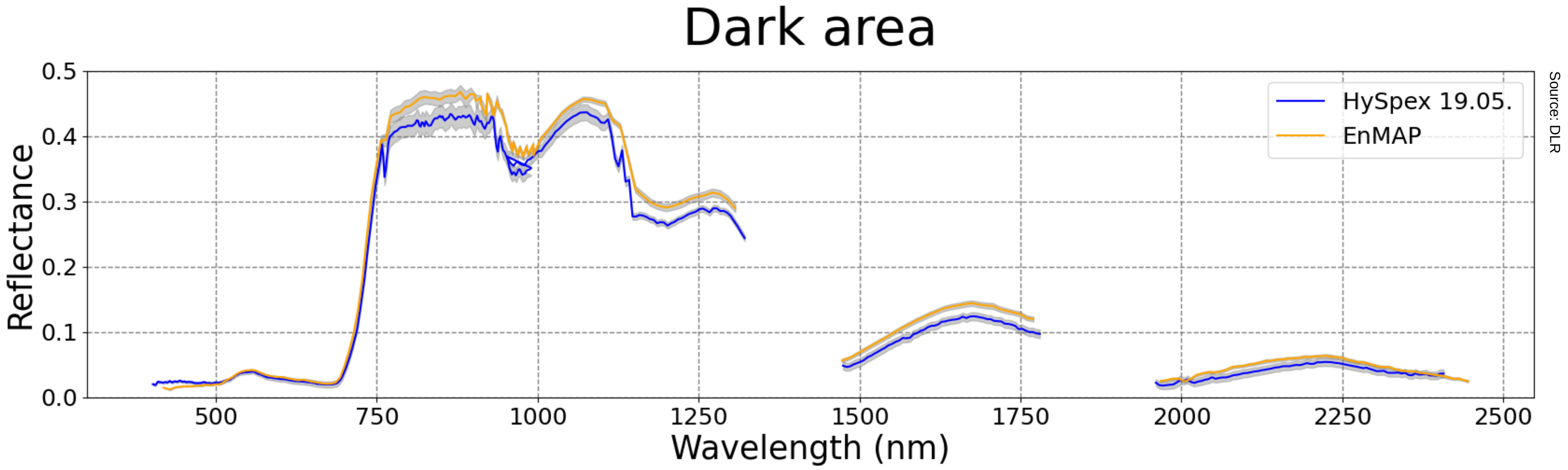
Vegetation site



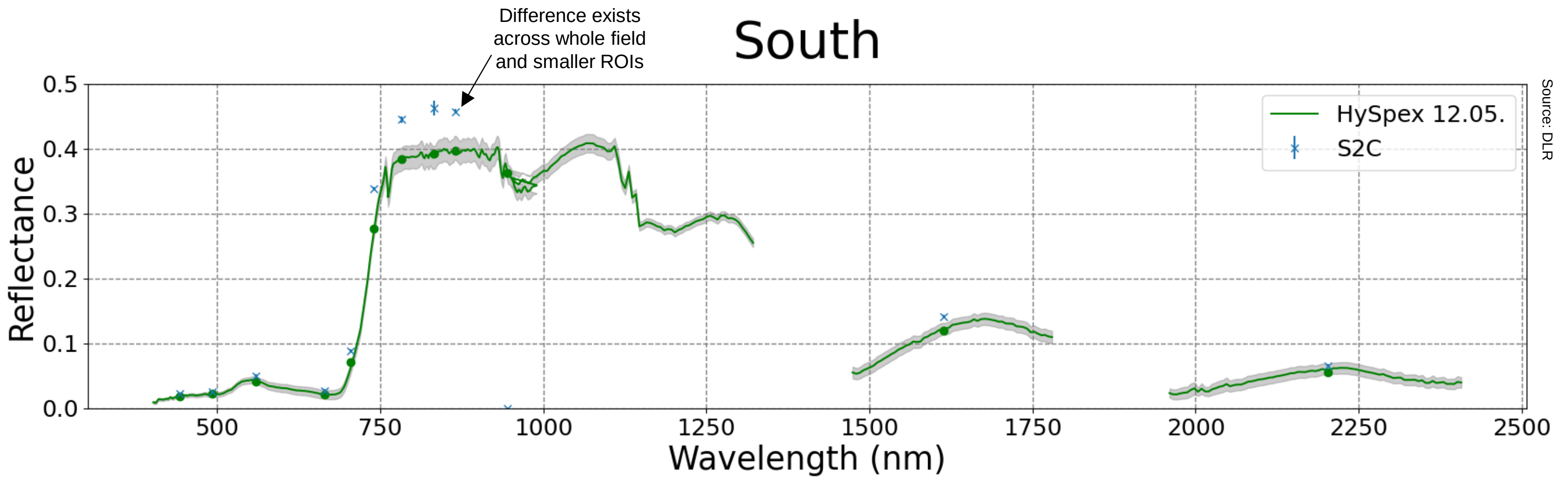


Vegetation site

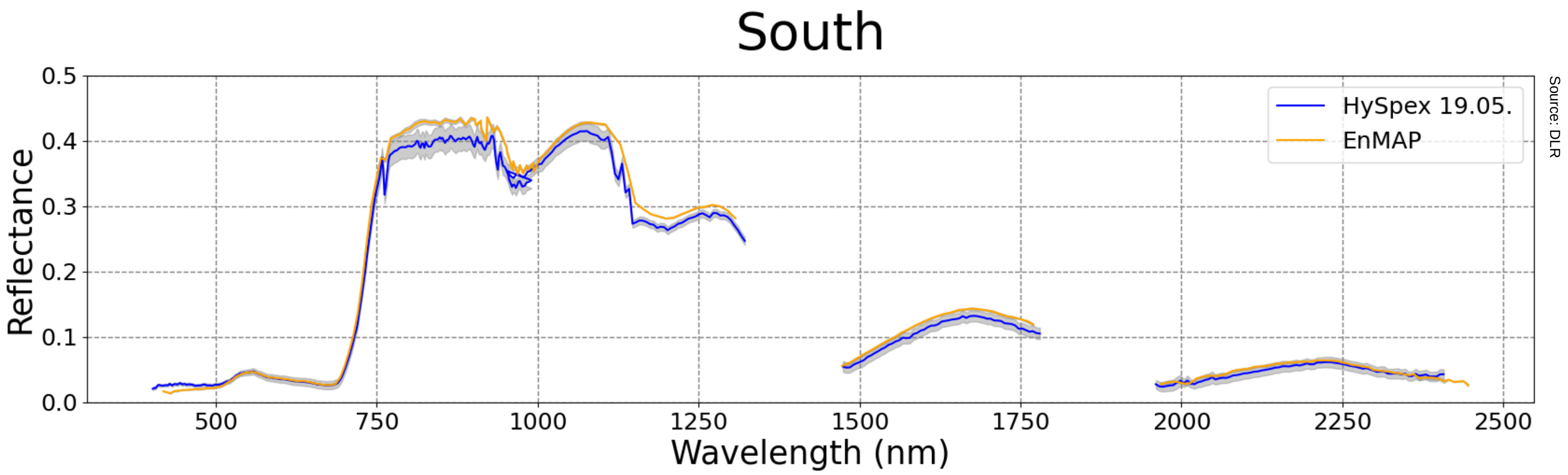




Vegetation site

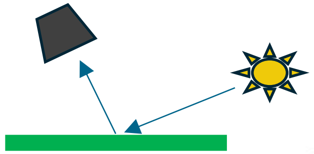


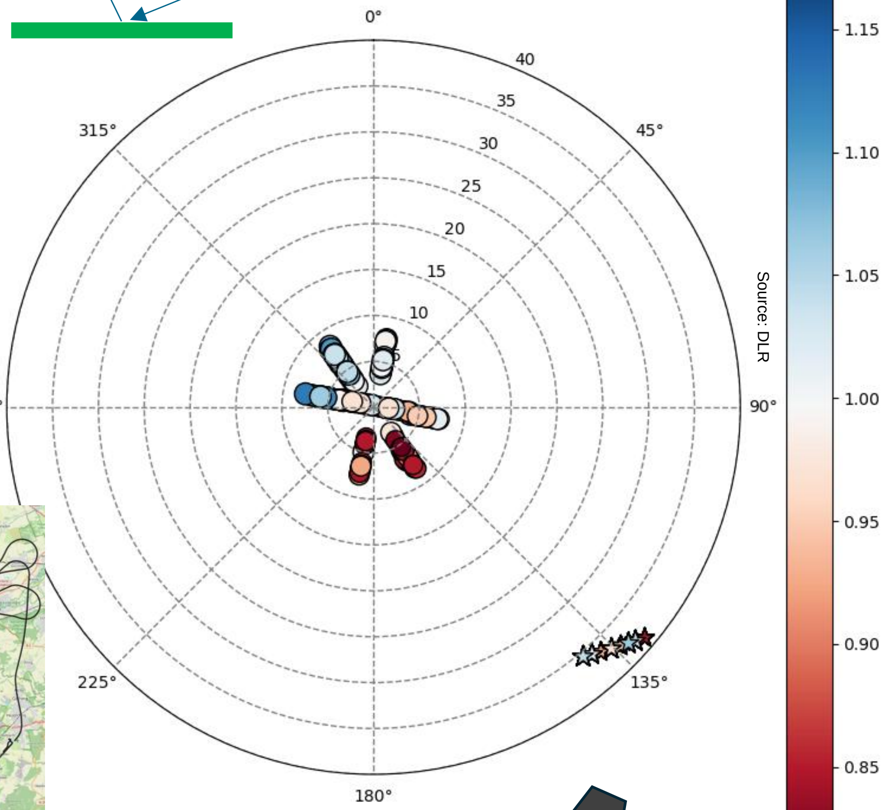
18% average HySpex-S2 difference across ROIs



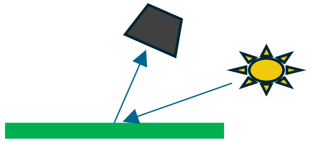
7% average HySpex-EnMAP difference across ROIs

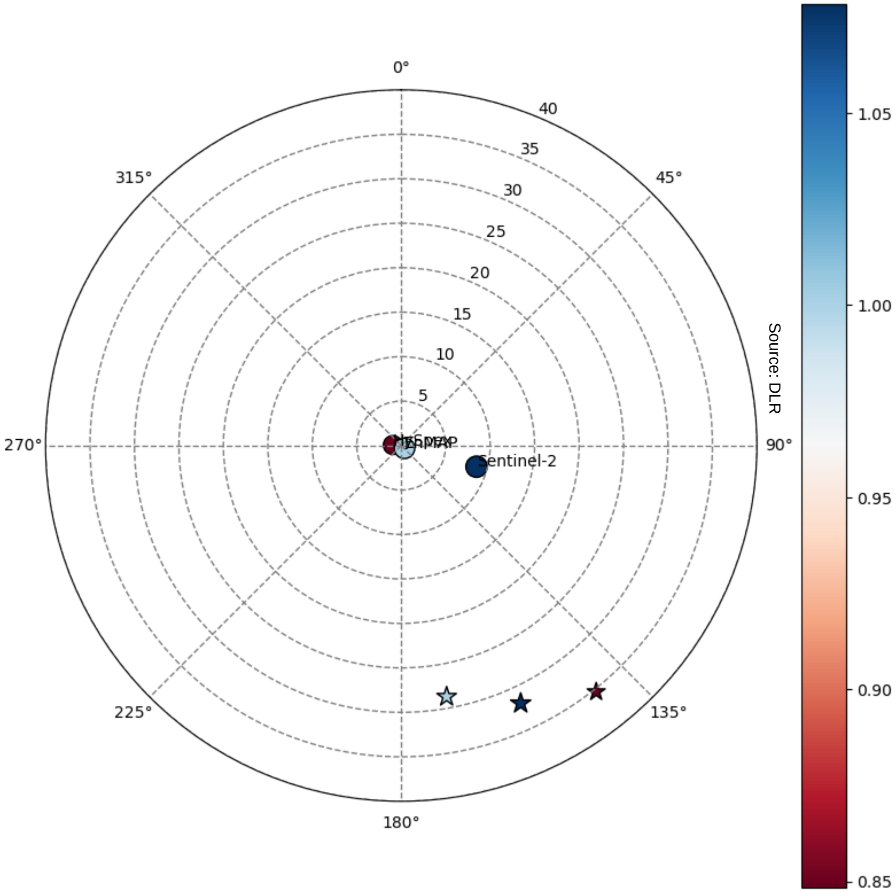
BRDF Correction





BRDF campaign
from 13.09.2025





SUMMARY

HySpex, Puch, Germany. Source: DLR

Summary

- In-situ only suitable for homogeneous sites
- Airborne is necessary for inhomogeneous sites and inhomogeneities assessment
- Good agreement between HySpex and in-situ (2-3%)
- Remaining differences compared to spaceborne (>5%)
- Next steps:
  - Consider illumination geometry
    - Conducted campaign in 2026 at different times of the day
    - Investigate self shadowing and farming tracks
  - Consider effect of atmospheric correction
    - Assess in-situ AOT and ozone measurements
    - Investigate correction algorithms used (PACO/ATCOR/Sen2Cor)

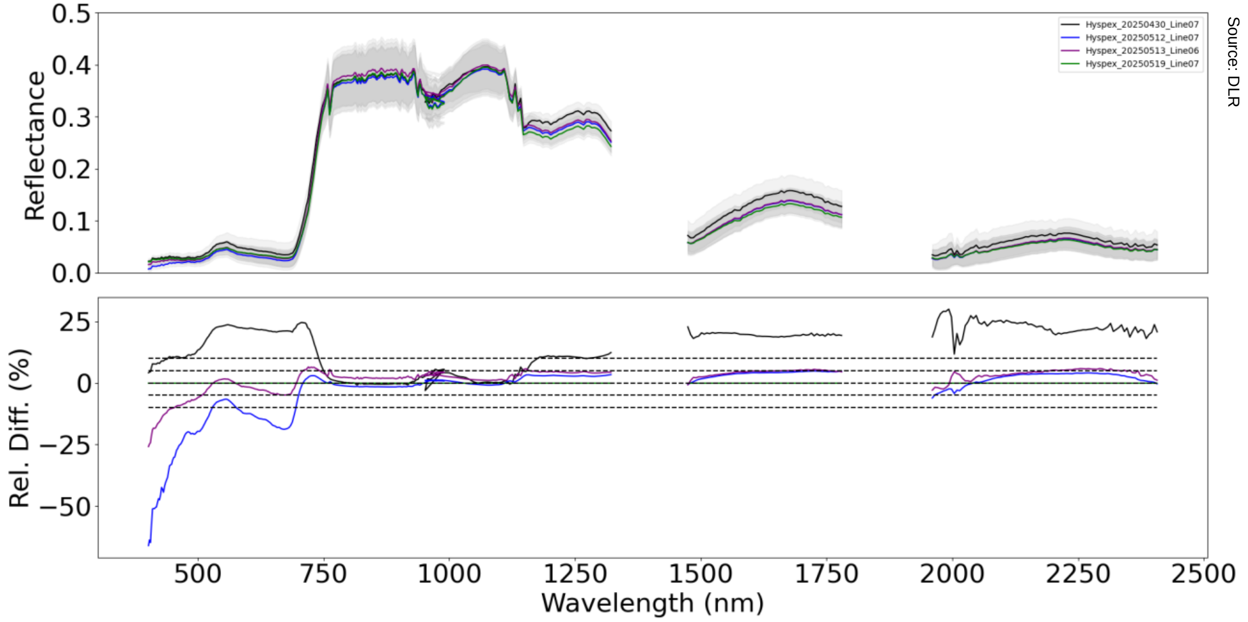
Imprint

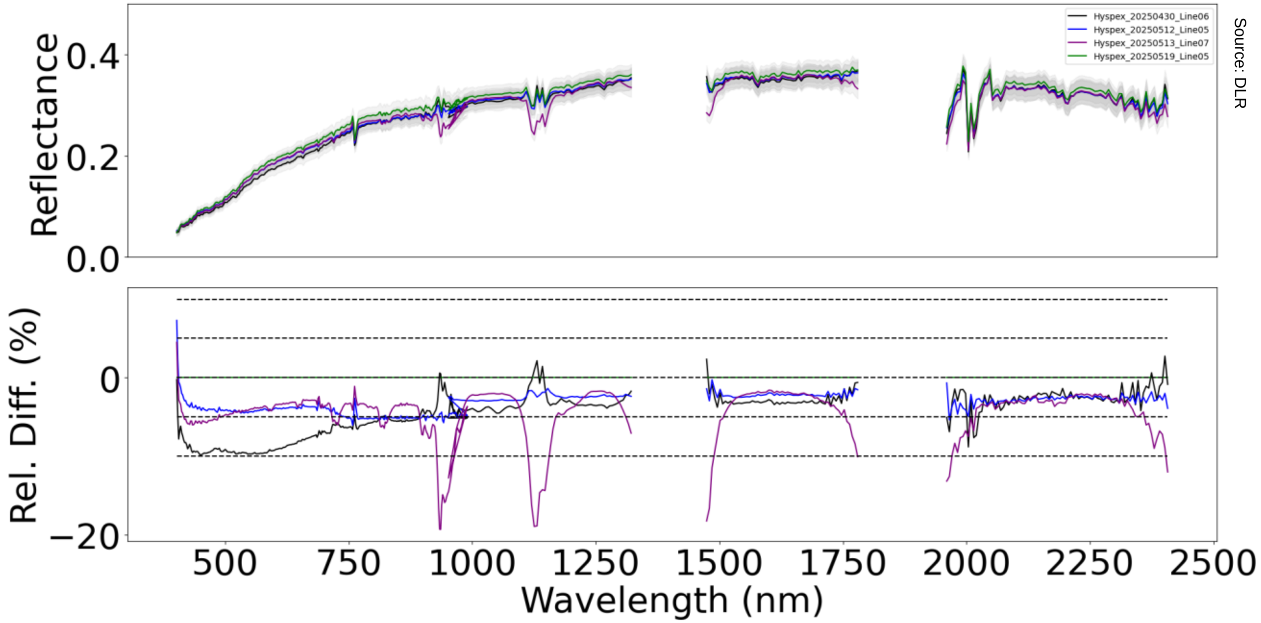
Topic:	**Validating surface reflectance measurements from multi- and hyperspectral air- and spaceborne sensors in agricultural fields in Germany** 14th EARSeL Workshop
Date:	2026-06-04
Author:	David Marshall Ingram
Institute:	DLR, Remote Sensing Technology Institute
Image sources:	All images “DLR (CC BY-NC-ND 3.0)” unless otherwise stated

Vegetation and soil sites

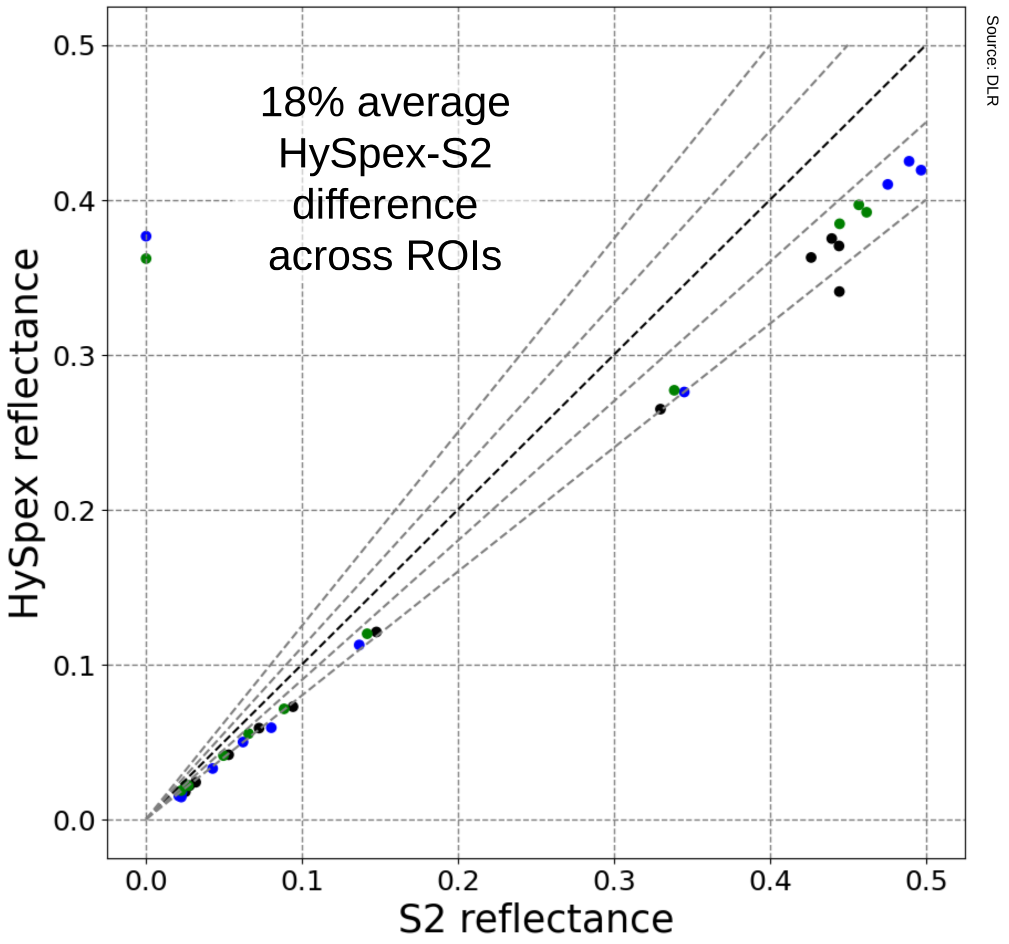
Source: DLR

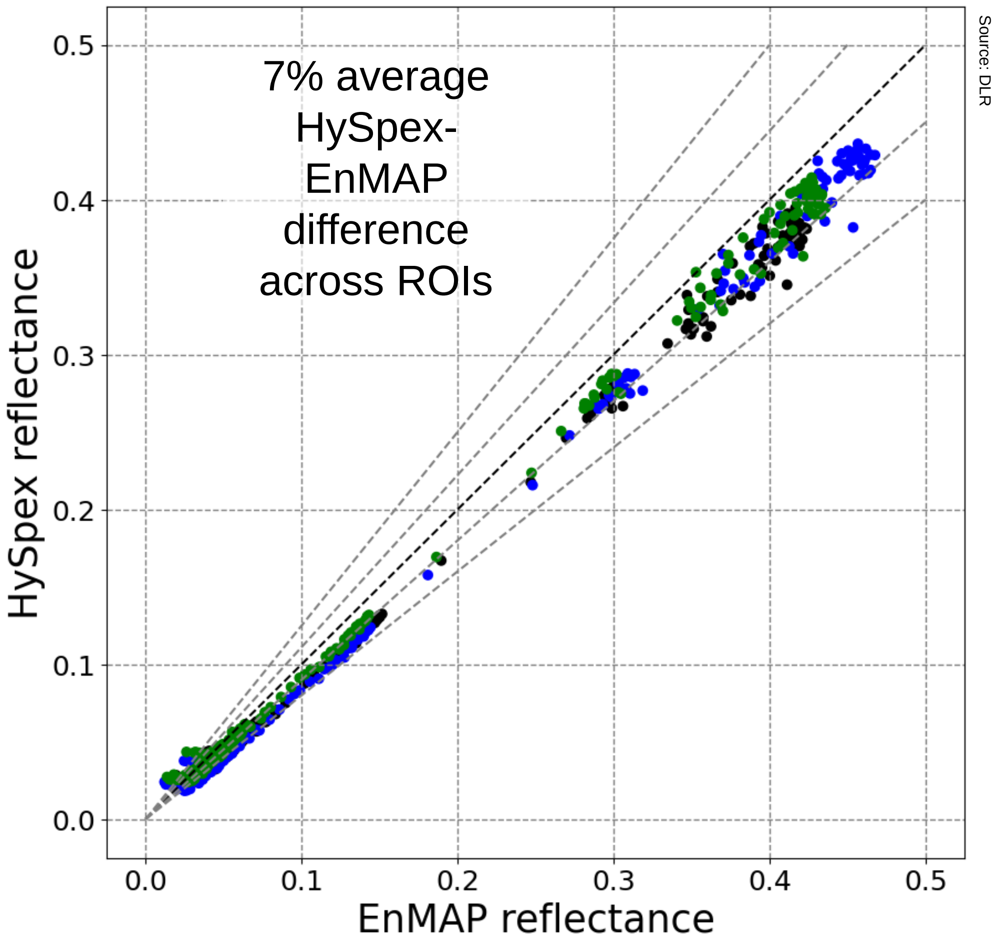
Temporal stability



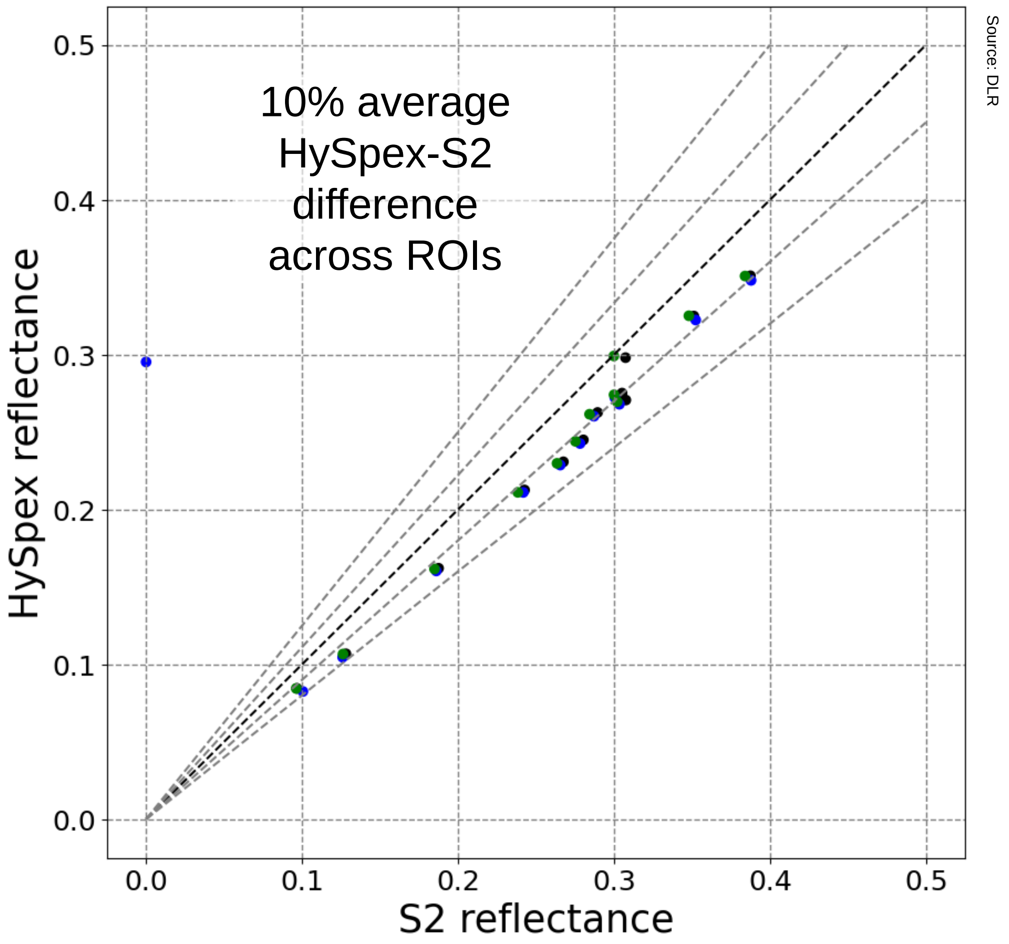


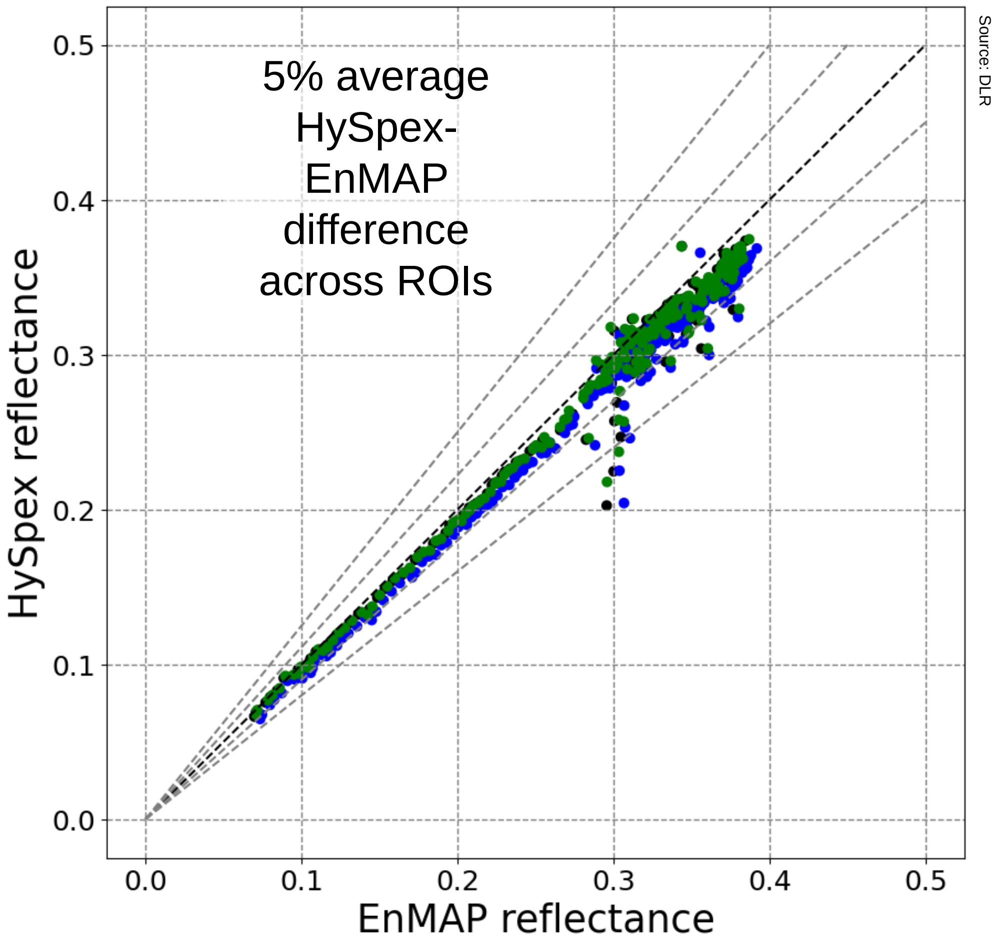
Vegetation site



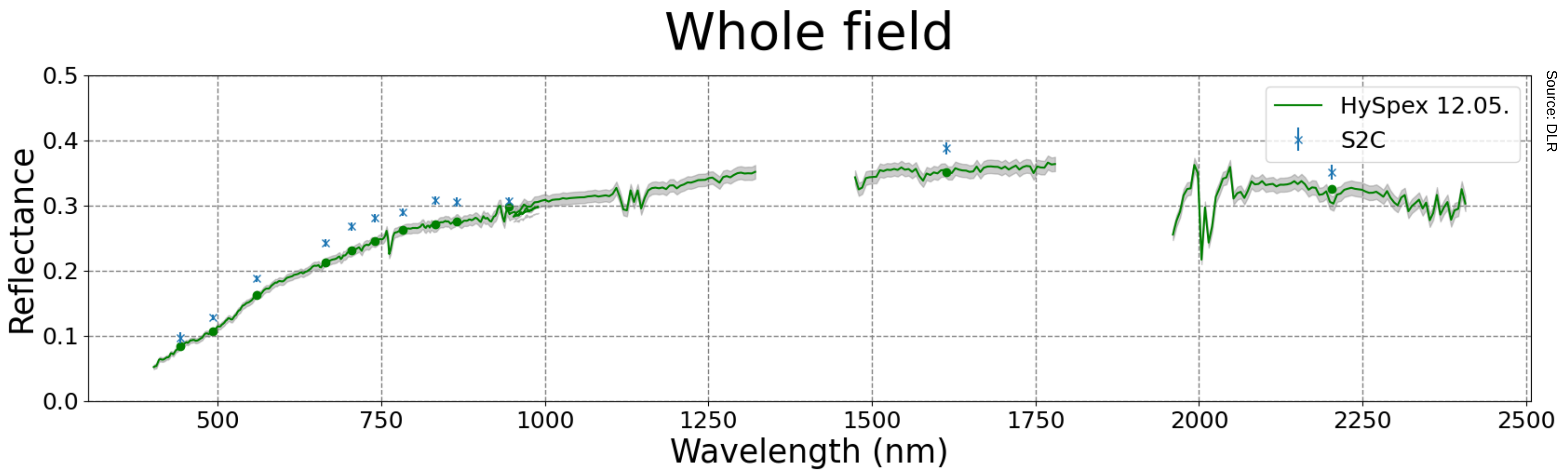


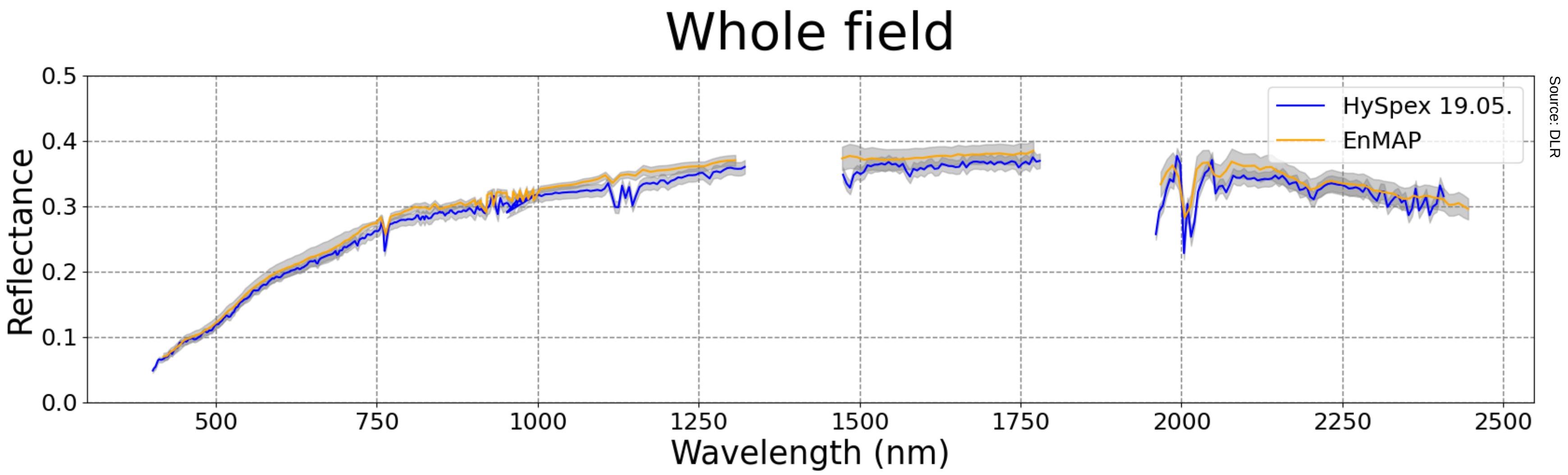
Soil site


10% average
HySpex-S2
difference
across ROIs
HySpex reflectance
S2 reflectance
0.0
0.1
0.2
0.3
0.4
0.5
Source: DLR

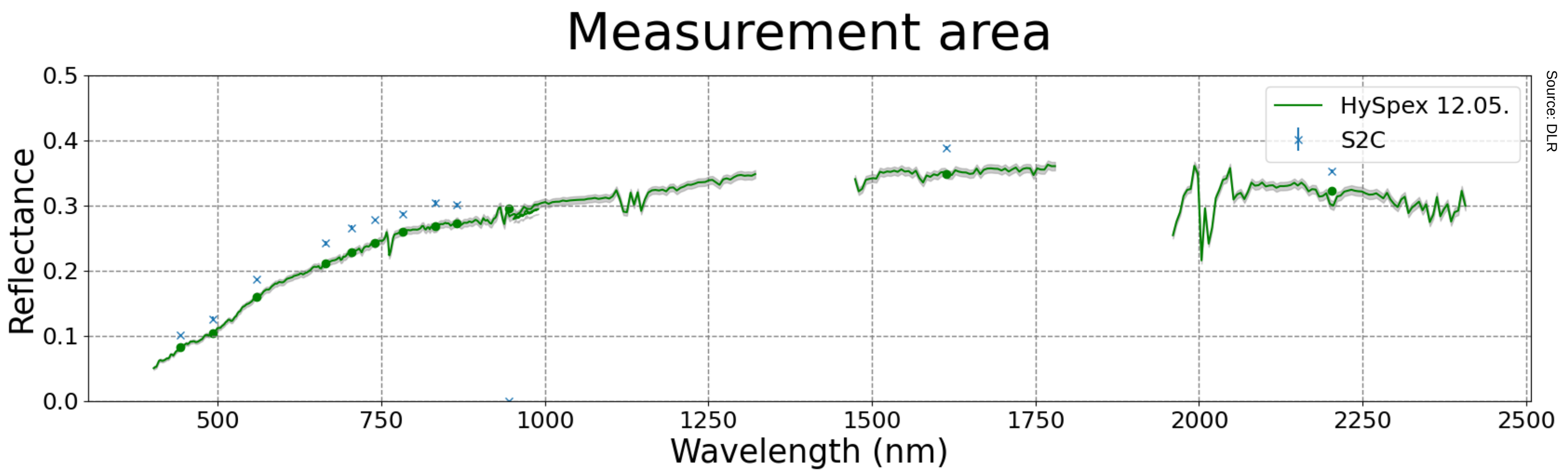

5% average
HySpex-
EnMAP
difference
across ROIs
HySpex reflectance
EnMAP reflectance
0.0
0.1
0.2
0.3
0.4
0.5
Source: DLR

Soil site

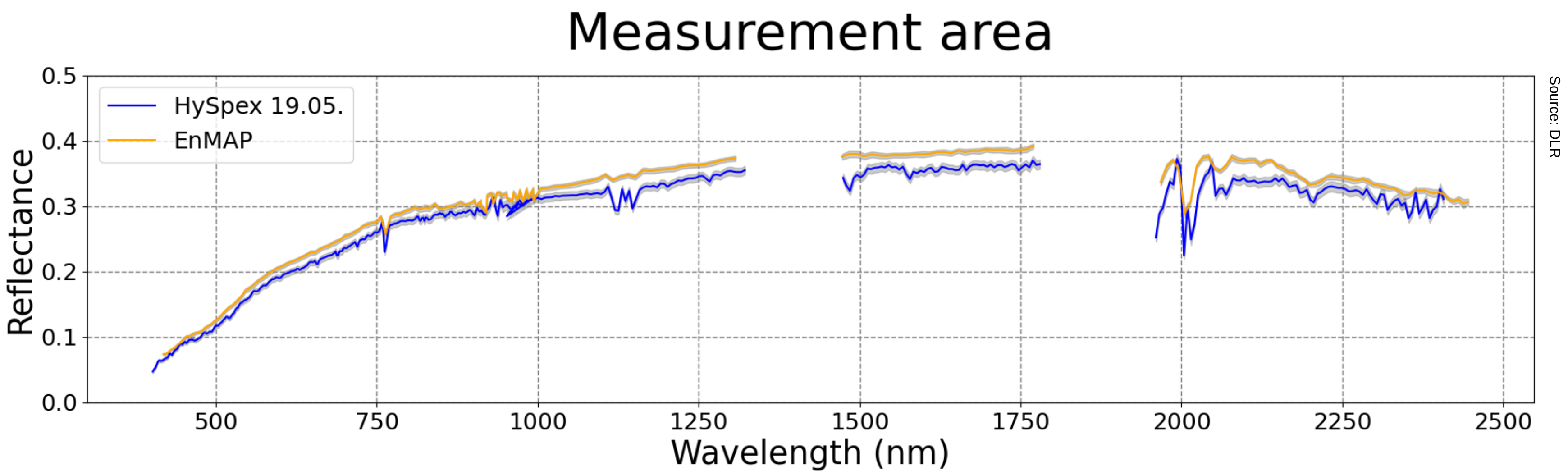

Whole field
Reflectance
Wavelength (nm)
HySpex 12.05.
S2C
Source: DLR
0.0
0.1
0.2
0.3
0.4
0.5
500
750
1000
1250
1500
1750
2000
2250
2500


Whole field
Reflectance
Wavelength (nm)
HySpex 19.05.
EnMAP
Source: DLR
0.0
0.1
0.2
0.3
0.4
0.5
500
750
1000
1250
1500
1750
2000
2250
2500

Soil site

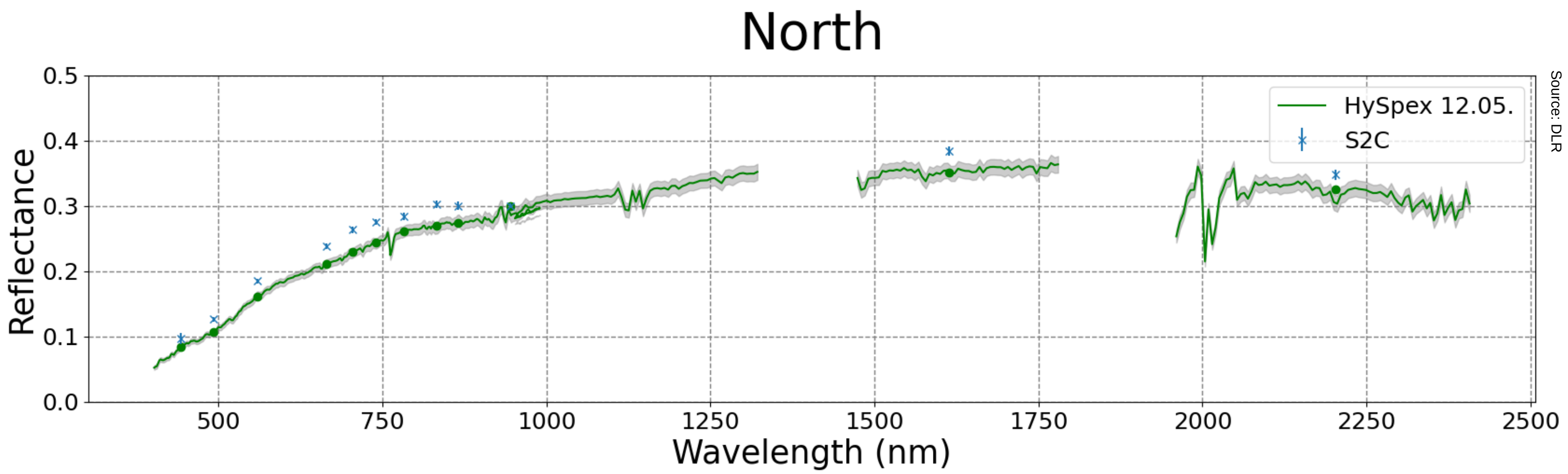


Measurement area
Reflectance
Wavelength (nm)
0.0
0.1
0.2
0.3
0.4
0.5
500
750
1000
1250
1500
1750
2000
2250
2500
HySpex 12.05.
S2C
Source: DLR

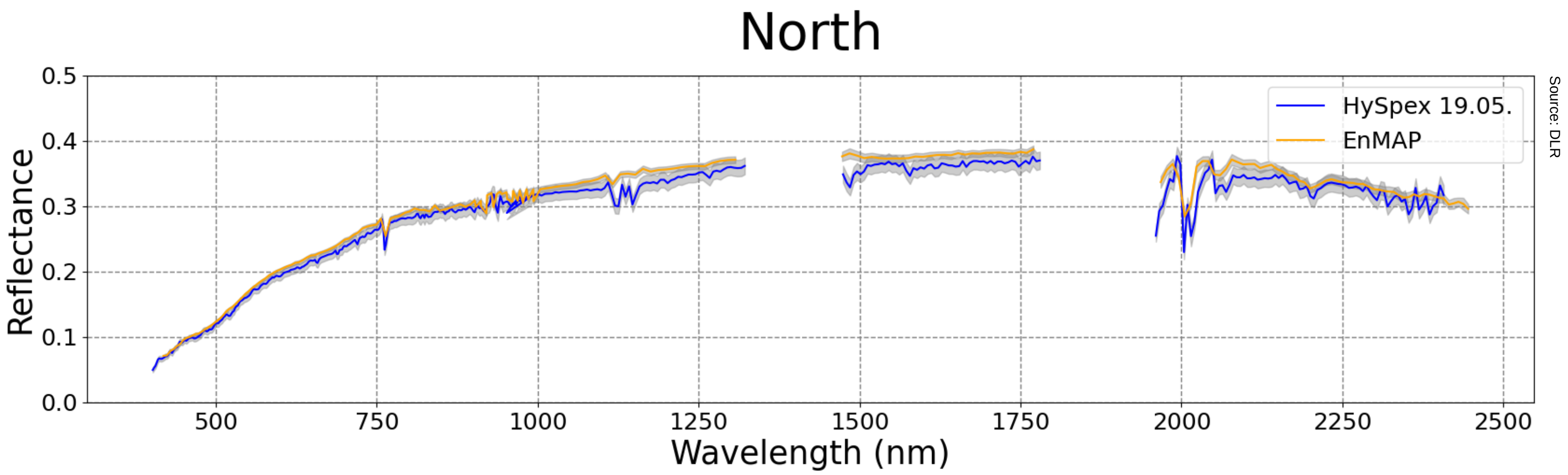


Measurement area
Reflectance
Wavelength (nm)
0.0
0.1
0.2
0.3
0.4
0.5
500
750
1000
1250
1500
1750
2000
2250
2500
HySpex 19.05.
EnMAP
Source: DLR

Soil site



10% average HySpex-S2 difference across ROIs



7% average HySpex-EnMAP difference across ROIs