BRIDGING GROUND AND SPACE WITH UAV HYPERSPECTRAL IMAGING FOR CALIBRATION AND VALIDATION OF SATELLITE DATA AT A MEDITERRANEAN SALTY POND

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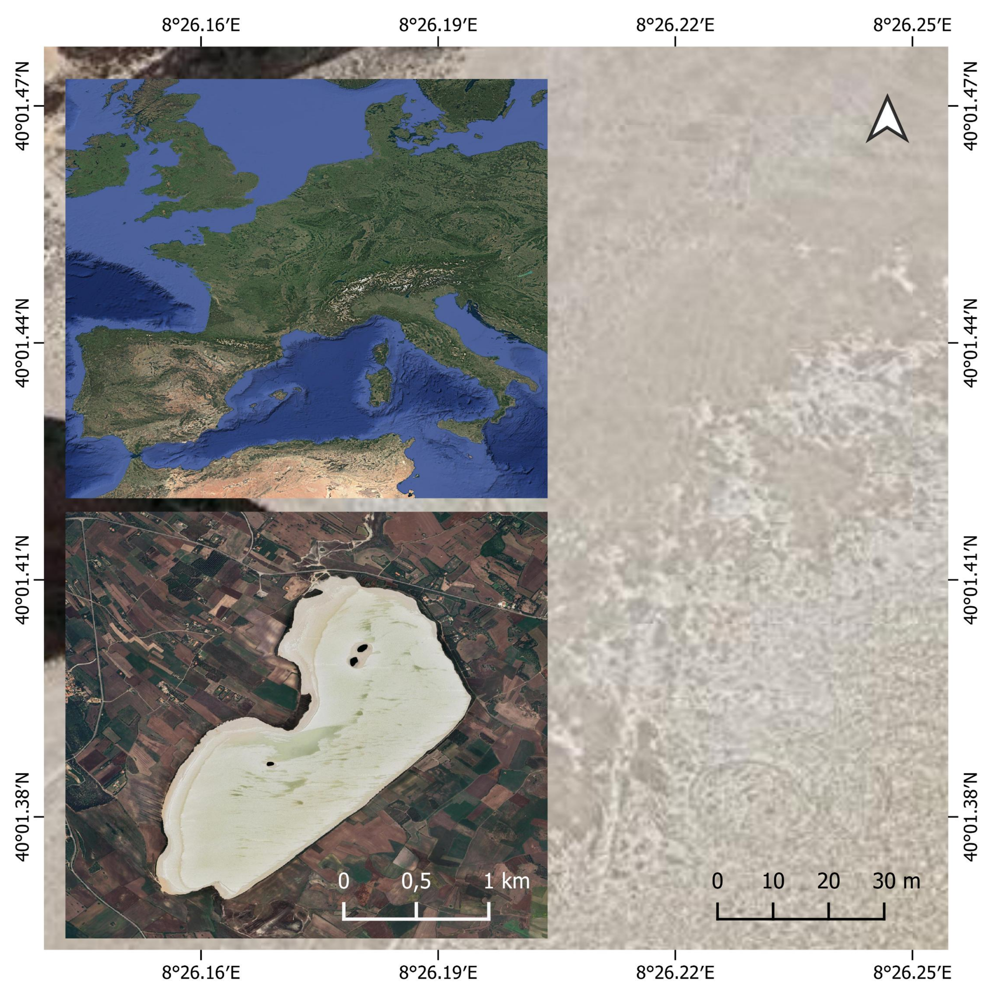
Motivation

New hyperspectral satellite missions such as ASI-PRISMA and DLR-EnMAP, together with the forthcoming ESA-CHIME mission and emerging commercial hyperspectral systems including Planet-Tanager, Airbus' planned hyperspectral constellation, and Maxar's commercial hyperspectral imaging program under development, are rapidly expanding access to detailed spectral observations. Ensuring cross-sensor consistency and interoperability across these platforms requires robust calibration and validation (CAL/VAL) approaches grounded in traceable multi-scale measurements. UAV-based hyperspectral imaging provides an effective intermediate link between ground spectrometry and orbital observations, offering high spatial detail and flexible acquisition conditions for controlled reflectance comparison. The goal of this study is to assess the suitability of Sal 'e Porcus as a CAL/VAL reference site by evaluating whether UAV-based hyperspectral data, calibrated with in-situ spectrometry, can provide reliable reflectance measurements for cross-sensor comparison with ASI-PRISMA and DLR-EnMAP.

Research area



The Sal'e Porcus pond (~3.2 km²), located on the Sinis Peninsula in western Sardinia (Italy), is a temporary saline basin formed in a flat interdunal depression that seasonally accumulates rainwater up to ~1 m deep. With no tributaries or outlets, it behaves as an isolated hydrological system. During summer, evaporation exposes a broad salt crust over impermeable greyish-white clay, promoting seasonal salt deposition and producing spatially extensive, spectrally homogeneous surfaces suitable for multi-scale reflectance measurements and CAL/VAL activities.

Methods and data

Platform	Sensor	Spectral Range	Number of Spectral Bands	Spectral Resolution	Spatial Resolution
Ground	ASD FieldSpec	~350–2500 nm	Continuous (1–3 nm sampling)	n/a	Point measurement
UAV	AISA Kestrel 10	400–1000 nm	~324 bands	~10 nm	~10 cm GSD
Satellite	ASI — PRISMA	400–2500 nm (VNIR+SWIR)	~240 bands (66 VNIR + 174 SWIR)	~12–16 nm	~30 m
Satellite	DLR — EnMAP	420–2450 nm (VNIR+SWIR)	224 bands 102 (VNIR) + 122 (SWIR)	~6.5 nm (VNIR), ~10 nm (SWIR)	~30 m

Spectral Resampling to PRISMA/EnMAP SRFs
$$R_{sensor}(b) = \frac{\sum_{\lambda} R_{UAV}(\lambda) SRF_b(\lambda)}{\sum_{\lambda} SRF_b(\lambda)}$$

Linear Cross-Sensor Comparison
$$R_{sat} = \alpha R_{ref} + b$$

Pearson Correlation
$$r = \frac{cov(R_{sat}, R_{ref})}{\sigma(R_{sat})\sigma(R_{ref})}$$

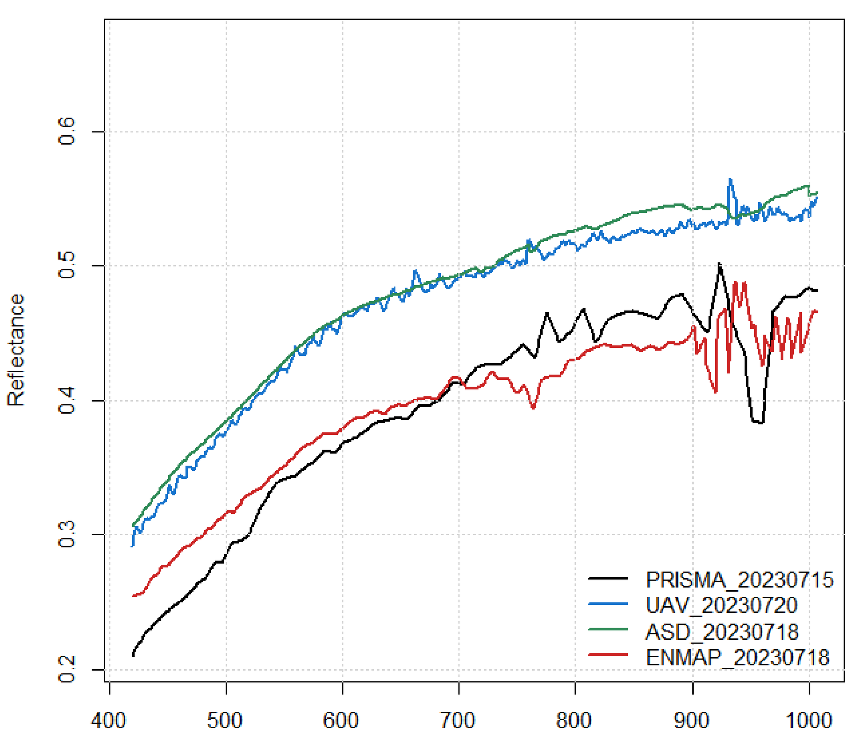
Coefficient of Determination
$$R^2 = 1 - \frac{\sum (R_{sat} - R_{ref})^2}{\sum (R_{ref} - \bar{R}_{ref})^2}$$

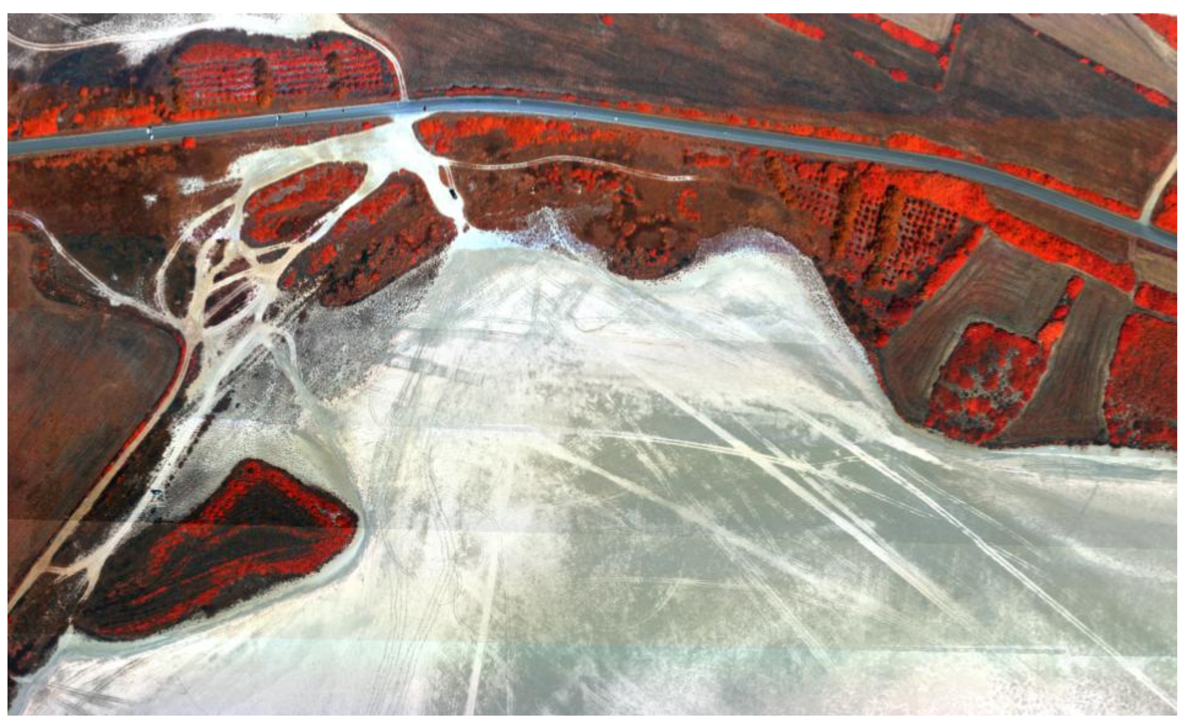
Root Mean Square Error
$$RMSE = \sqrt{\frac{1}{n}\sum (R_{sat} - R_{ref})^2}$$

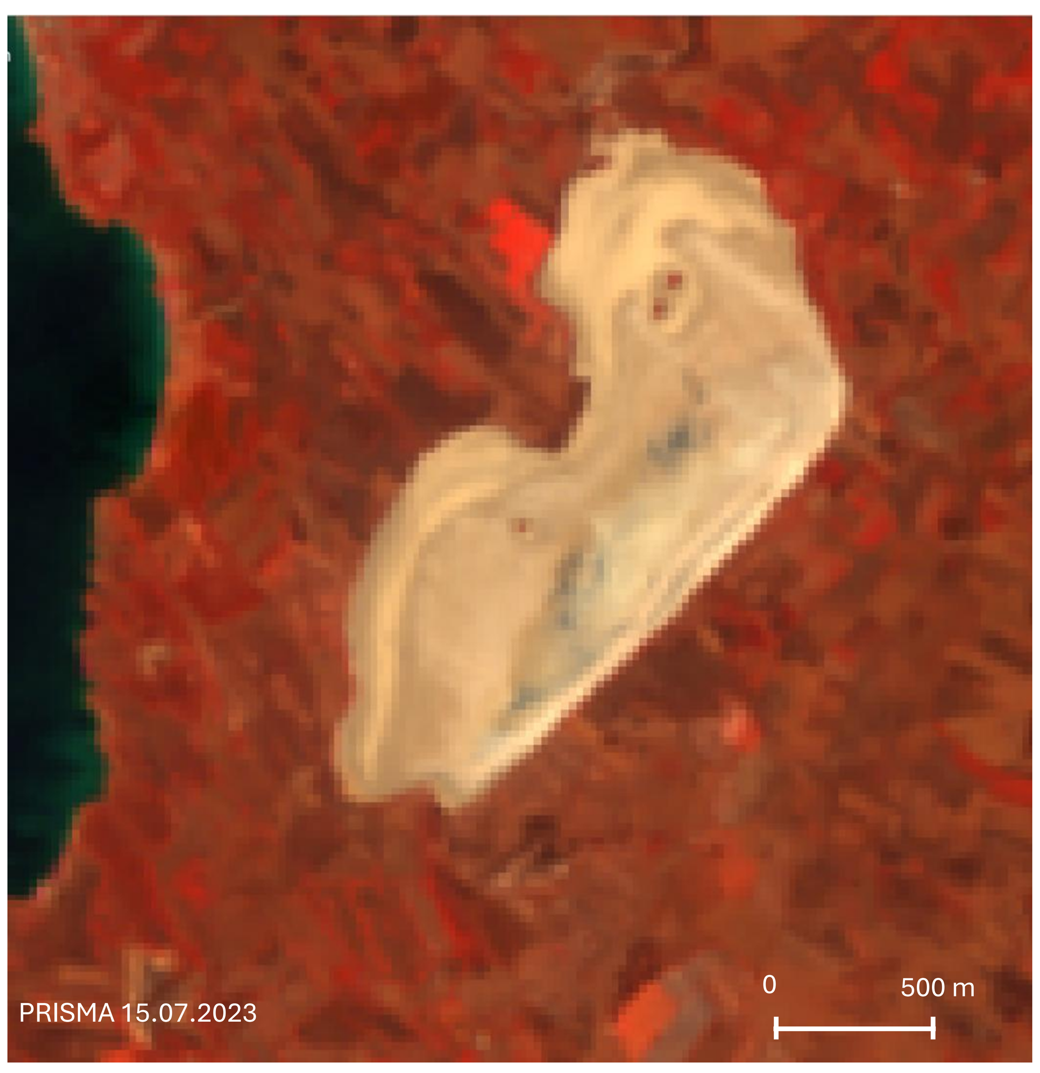
Results

Linear regression between spectral bands 400-1000 nm (interpolated per 1 nm)

pair			N of interpolated spec. bands	PEARS. COR	REGRES. SLOPE	R2	BIAS = MEAN RESID.	RMSE	MAE	SD_RES
PRISMA	vs	UAV	589	0.970	0.863	0.942	0.000	0.016	0.011	0.016
PRISMA	vs	ASD	589	0.981	0.877	0.962	0.000	0.013	0.008	0.013
PRISMA	vs	ENM	589	0.961	0.714	0.924	0.000	0.015	0.010	0.015
UAV	vs	ASD	589	0.995	1.001	0.990	0.000	0.007	0.005	0.007
UAV	vs	ENM	589	0.986	0.824	0.972	0.000	0.009	0.006	0.009
ASD	vs	ENM	589	0.984	0.817	0.969	0.000	0.010	0.006	0.010







Conclusion

Spectral comparisons across ASD, UAV, PRISMA, and EnMAP show consistently high agreement over the 400–1000 nm range. UAV and ASD spectra match most closely (Pearson r = 0.995, slope = 1.001, R^2 = 0.990), indicating that the UAV empirical line calibration preserves in-situ reflectance characteristics. PRISMA exhibits strong correlation with both UAV (r = 0.970, R^2 = 0.942, slope = 0.863) and ASD (r = 0.981, R^2 = 0.962, slope = 0.877), while EnMAP also shows high agreement with UAV (r = 0.986, R^2 = 0.972, slope = 0.824) and ASD (r = 0.984, R^2 = 0.969, slope = 0.817). Residuals are low and unbiased across all comparisons (RMSE < 0.016 reflectance), confirming internally consistent reflectance scaling among sensors.

- UAV spectra match ASD closely ⟶ calibration robust
- PRISMA/EnMAP show high cross-sensor consistency with UAV/ASD
- Residuals low and unbiased (RMSE < 0.016)
- Sal'e Porcus is supported as a candidate CAL/VAL reference site
- UAV imaging is a practical bridge between ground and satellite data

Acknowledgement

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References

[1] MUSACCHIO, M., SILVESTRI, M., ROMANIELLO, V., CASU, M., BUONGIORNO, M. F., MELIS, M. T., 2024: Comparison of ASI-PRISMA Data, DLR-EnMAP Data, and Field Spectrometer Measurements on "Sale 'e Porcus", a Salty Pond (Sardinia, Italy). Remote Sensing, 16(6), 1092.

[2] NIYOGI, D., JAMSHIDI, S., SMITH, D., KELLNER, O., 2020: Evapotranspiration Climatology of Indiana, USA Using In-Situ and Remotely Sensed Products. Journal of Applied Meteorology and Climatology, 59, 2093–2111.

[3] COGLIATI, S., SARTI, F., CHIARANTINI, L., COSI, M., LORUSSO, R., LOPINTO, E., MIGLIETTA, F., GENESIO, L., GUANTER, L., DAMM, A., et al., 2021: The PRISMA imaging spectroscopy mission: Overview and first performance analysis. Remote Sensing of Environment, 262, 112499.

[4] HELLER PEARLSHTIEN, D., PIGNATTI, S., GREISMAN-RAN, U., BEN-DOR, E., 2021: PRISMA sensor evaluation: A case study of mineral mapping performance over Makhtesh Ramon, Israel. International Journal of Remote Sensing, 42, 5882–5914.