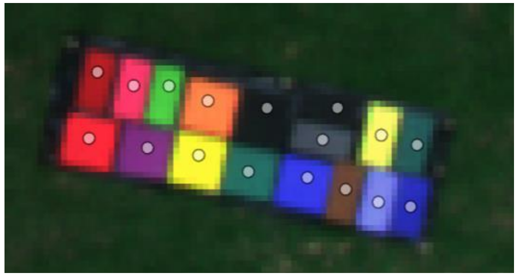
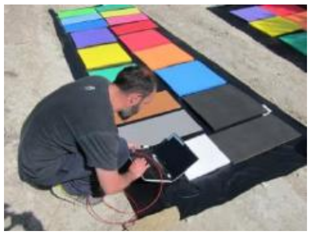
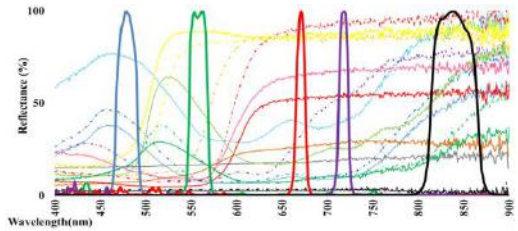
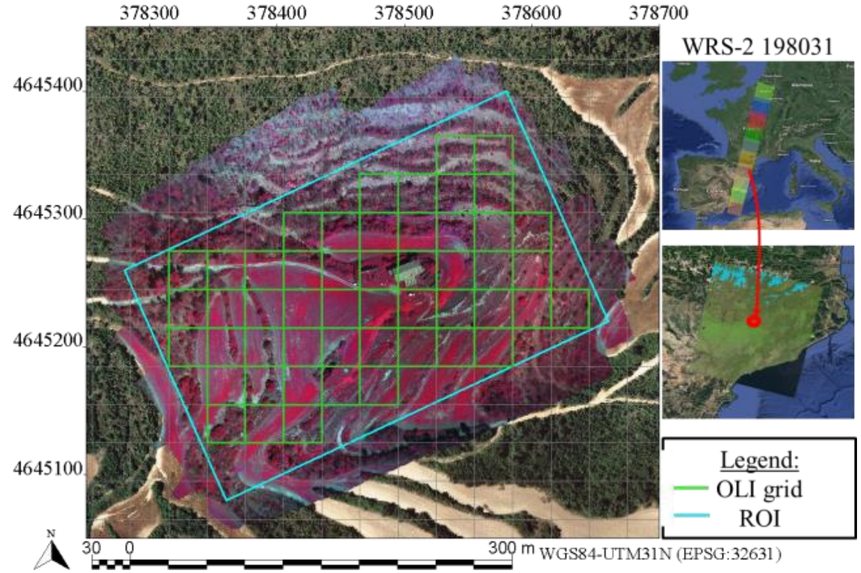
Torrejón de Ardoz 7th March ’19
Instituto Nacional de Técnica Aeroespacial (INTA)



Protocolos y Librerías espectrales en Espectroscopía de campo: de las buenas prácticas a una mayor utilidad de los datos

Synergies between field spectroscopy, sensors onboard drones, and Landsat-8/Sentinel-2 satellite imagery

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Synergies between field spectroscopy, sensors onboard Unmanned Aerial Systems (UAS), and Landsat-8/Sentinel-2 satellite imagery

PREVIOUS WORKS

ETM+ Landsat-7 / OLI Landsat-8

ATCOR3 | SAC-QGIS | LEDAPS LaSRC | PIA-MiraMon

↓

COMPARISON (r^2 and RMSE)

↑

ETM+ / OLI RSRF

MSI Sentinel-2A

ATCOR3 | SAC-QGIS | Sen2Cor-SNAP | PIA-MiraMon

↓

COMPARISON (r^2 and RMSE)

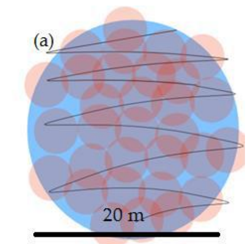
↑

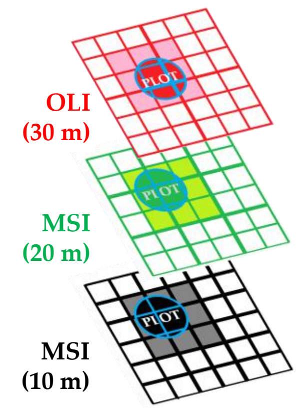
MSI RSRF

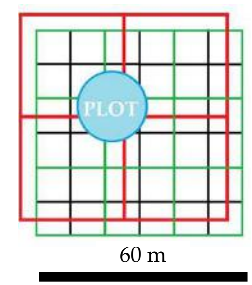
Field spectroscopy (ASD FieldSpec)

↑

20 May 2016 | 04 October 2016 | 22 April 2017 | 01 June 2017







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PREVIOUS WORKS

Complete publication reference:

Padró JC, Pons X, Aragonés D, Díaz-Delgado R, García D, Bustamante J, Pesquer L, Domingo-Marimon C, González-Guerrero O, Cristóbal J, Doktor D, Lange M (2017). **Radiometric Correction of Simultaneously Acquired Landsat-7/Landsat-8 and Sentinel-2A Imagery Using Pseudoinvariant Areas (PIA): Contributing to the Landsat Time Series Legacy.** *Remote Sensing*, 9 (12), 1319-1345. DOI: 10.3390/rs9121319.

https://www.mdpi.com/2072-4292/9/12/1319

(IF: 3.406, Q2: 8/30 (2017) [Remote Sensing])

CONTENTS

¿Is drone data feasible, fits field spectroscopy data?

¿does drone data fit satellite data?

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1: Introduction and objectives | Hypothesis & objectives

HYPOTHESIS

Radiometric correction of satellite imagery can be improved introducing ground-truth measurements obtained from the synergy between conventional field spectroradiometry and sensors embedded in Unmanned Aerial Systems (UAS)

General Objective 1: Improvement of the radiometric treatment of imagery from OLI sensor onboard the L8 satellite and MSI sensor onboard the S2 satellites

General Objective 2: : Improvement of the treatment of UAS imagery, linking it with L8 and S2 imagery, and improvement of land cover mapping using UAS data

Synergies between field spectroscopy, sensors onboard Unmanned Aerial Systems (UAS), and Landsat-8/Sentinel-2 satellite imagery

2: Upscaling| Workflow

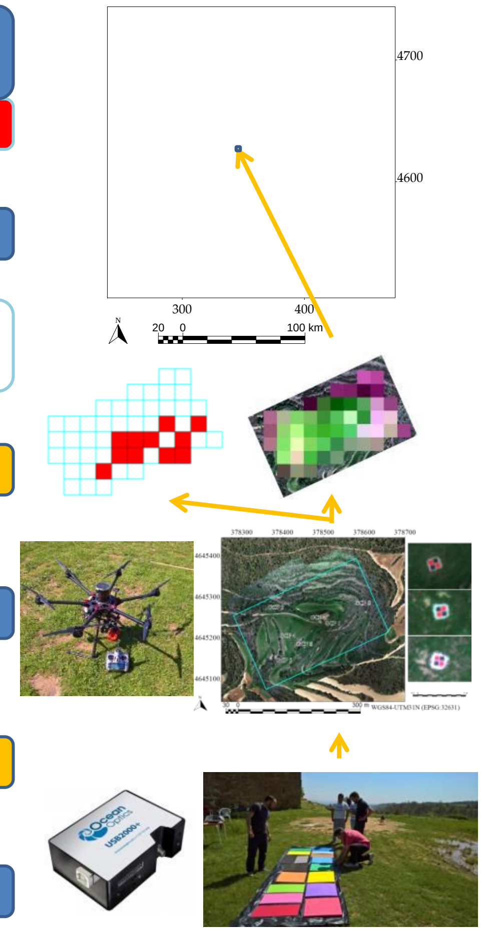
Upscaling from field spectroradiometry to UAV and to satellite

Validation
- Inter-sensor L8 and S2 comparison
- Comparison with L8 and S2 official products
- L8-S2 validation ← 40 % test

Radiometric correction of satellite imagery
- Radiometric correction of L8 and S2 using UAV references
- Global scale
- L8-S2 radiometric correction ← 60 % references

From UAV to satellite
- Spatial resampling
- Local scale
- UAV imagery fitted to field spectroradiometric measurements

From ground to UAV
- UAV Radiometric correction
- Spectral resampling
- *In-situ* scale
- UAV Geometric correction
- Field spectroradiometric measurements



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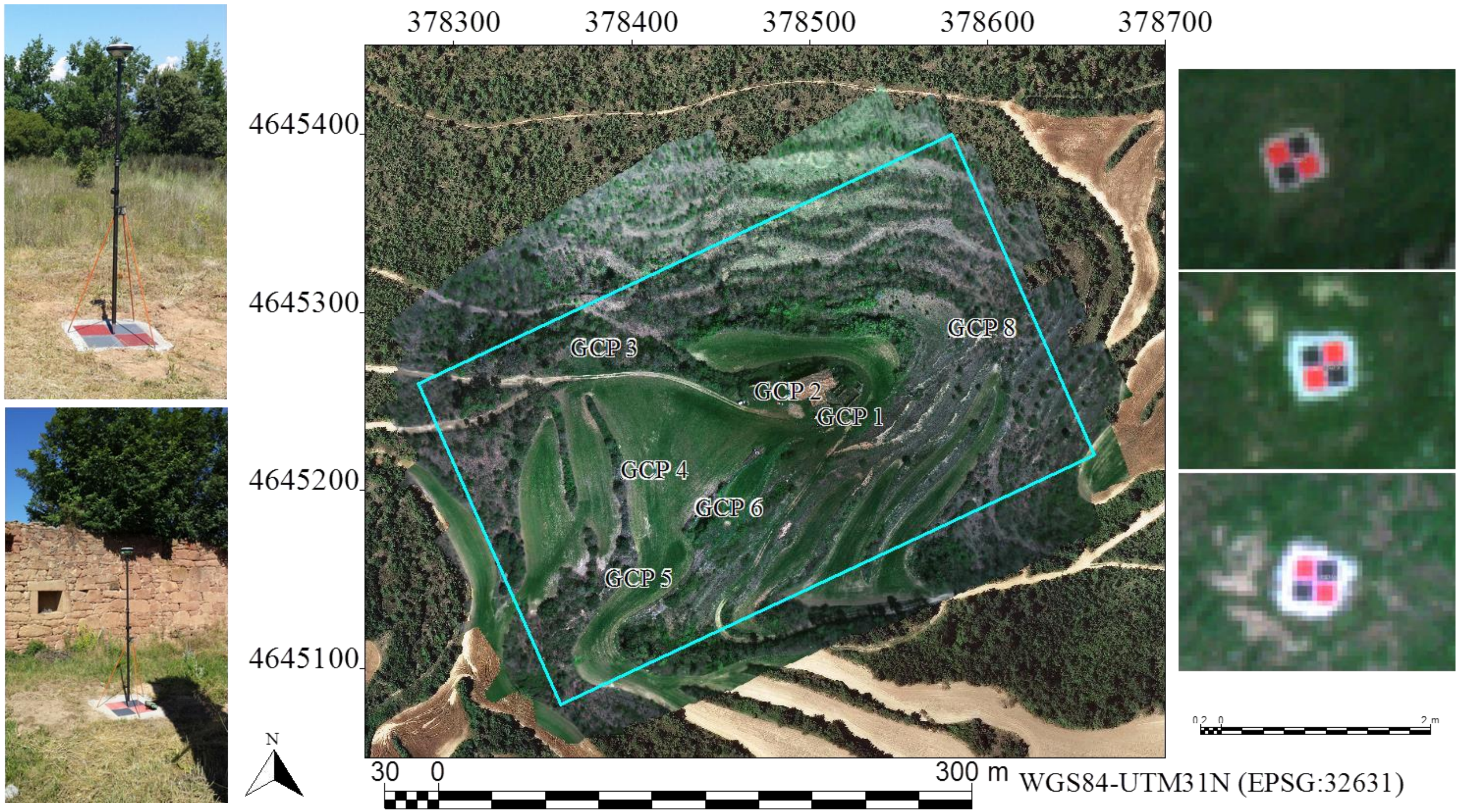
Synergies between field spectroscopy, sensors onboard Unmanned Aerial Systems (UAS), and Landsat-8/Sentinel-2 satellite imagery

2: Upscaling| Linking field data, UAS and satellite imagery



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2: Upscaling| Linking field data, UAS and satellite imagery

Complete publication reference:

Padró JC, Muñoz FJ, Planas J, Pons X (2019). **Comparison of four UAV georeferencing methods for environmental monitoring purposes focusing on the combined use with airborne and satellite remote sensing platforms.** *International Journal of Applied Earth Observation and Geoinformation*, 79, 130-140. DOI: 10.1016/j.jag.2018.10.018.

https://www.sciencedirect.com/science/article/pii/S0303243418306421

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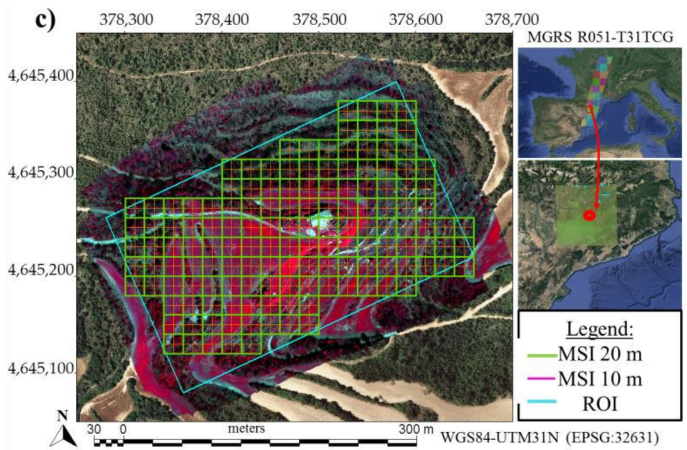
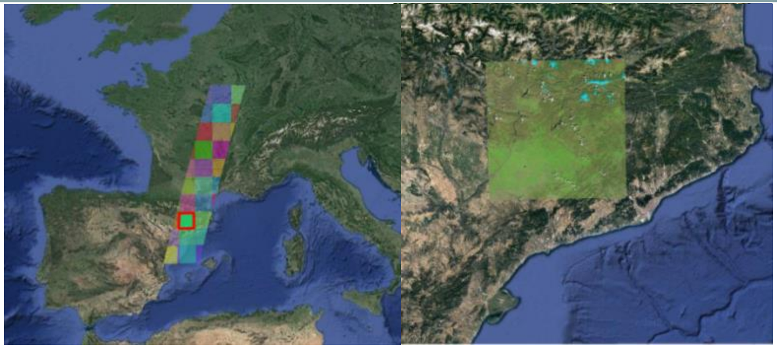
Synergies between field spectroscopy, sensors onboard Unmanned Aerial Systems (UAS), and Landsat-8/Sentinel-2 satellite imagery

2: Upscaling| Linking field data, UAS and satellite imagery

5.24 ha
51 pixels (30 m)
143 pixels (20 m)
517 pixels (10 m)



L8 (OLI): WRS-2 Scene 198-031
S2 (MSI): MGRS Scene R051-T31TCG



FS: Radiometer: Ocean Optics USB2000+
Range (nm): 400-1000. Targets: 17 EVA

UAS Platform DJI S1000. Sensor MicaSense RedEdge
Spatial resolution 6 cm @ 80 m. ρ_λ calibration panel

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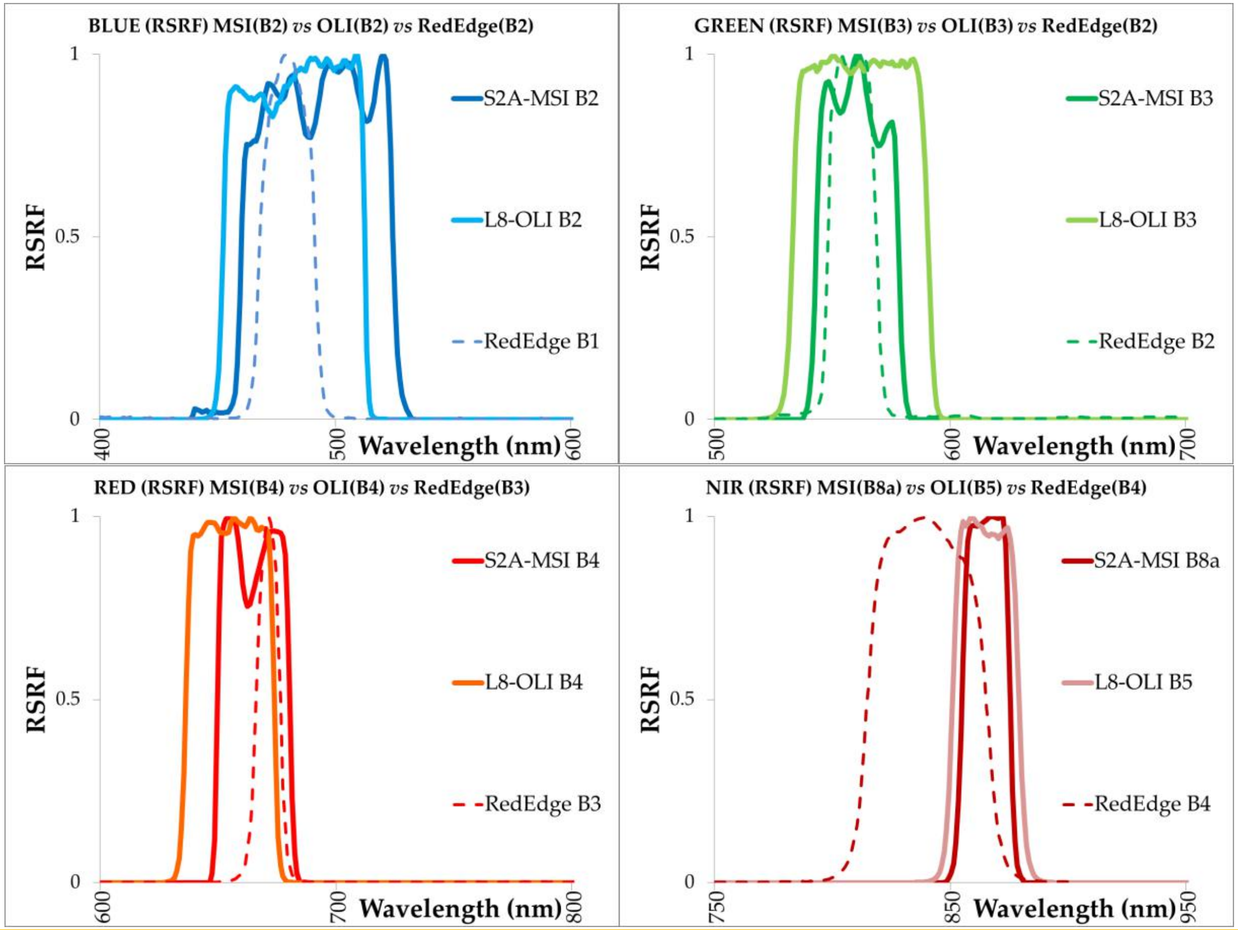
Synergies between field spectroscopy, sensors onboard Unmanned Aerial Systems (UAS), and Landsat-8/Sentinel-2 satellite imagery

2: Upscaling| UAS sensor (MicaSense RedEdge) and satellite sensors (OLI and MSI) matching bands



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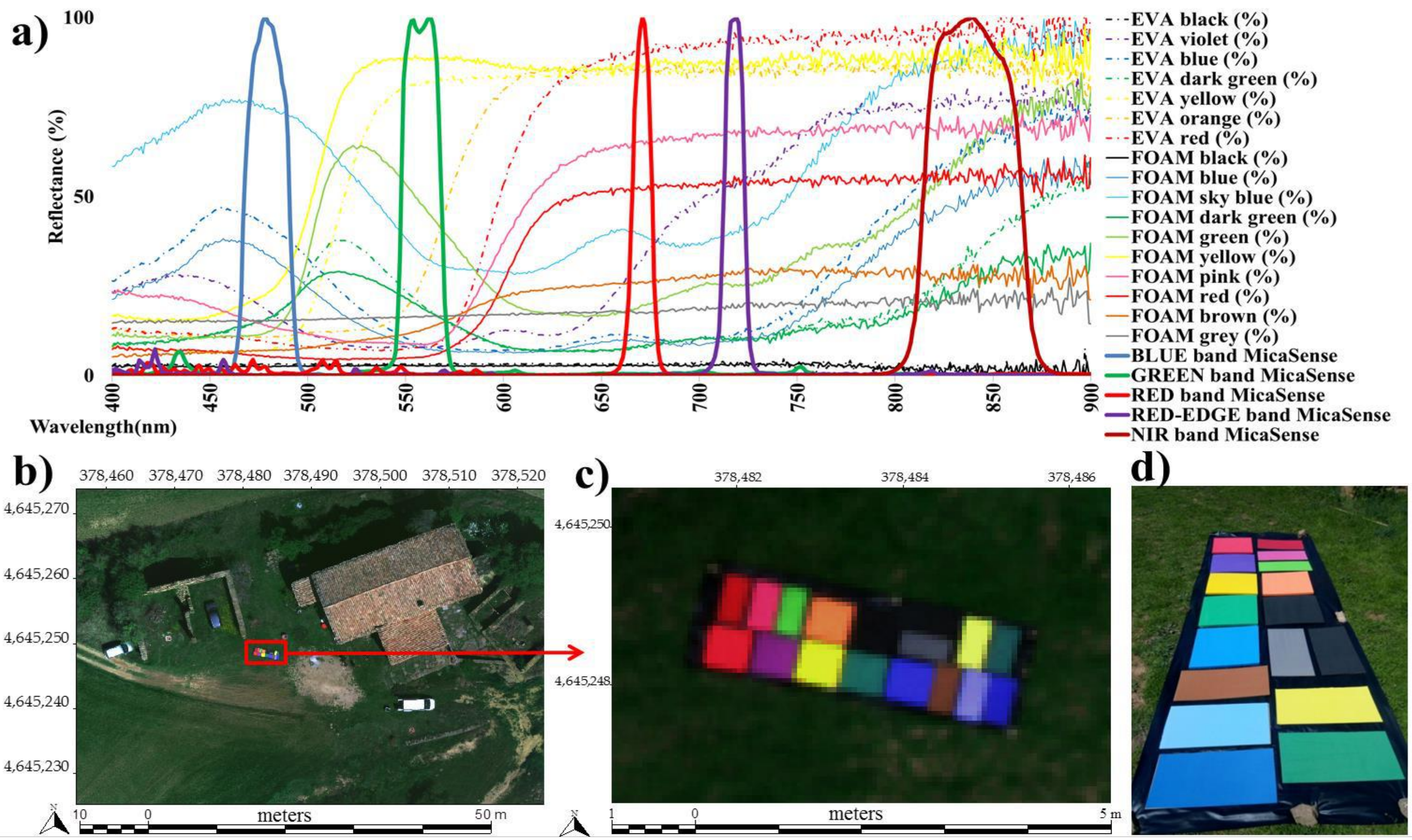
Synergies between field spectroscopy, sensors onboard Unmanned Aerial Systems (UAS), and Landsat-8/Sentinel-2 satellite imagery

2: Upscaling| Linking field data and UAS imagery

Radiometer hyperspectral surface reflectance

UAS multisptectral surface reflectance



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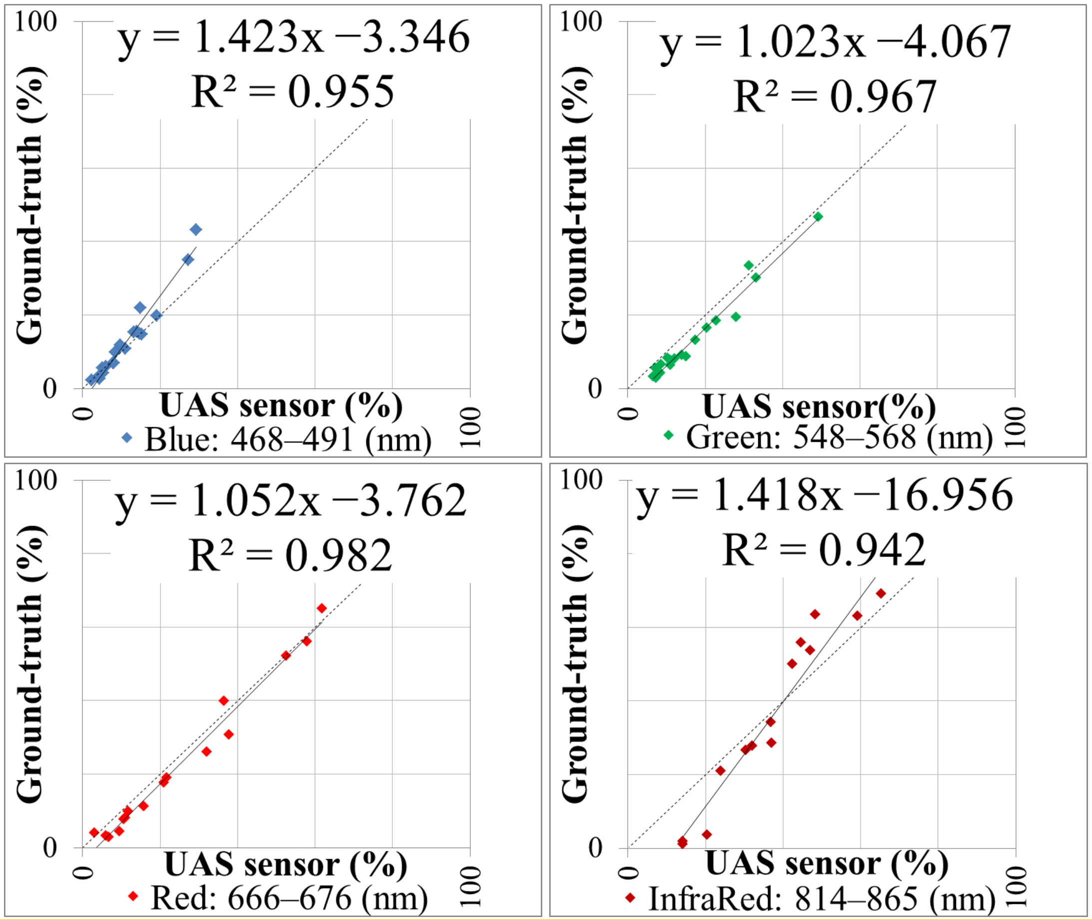
Synergies between field spectroscopy, sensors onboard Unmanned Aerial Systems (UAS), and Landsat-8/Sentinel-2 satellite imagery

Main results

2: Upscaling| Linking field data and UAS imagery

FITTING BETWEEN **FIELD SPECTROSCOPY AND DRONE DATA**



UAS imagery corresponding to OLI sensor bands, sensed **by L8 overpass** **correlated** with **field spectroscopy** measurements over EVA panels

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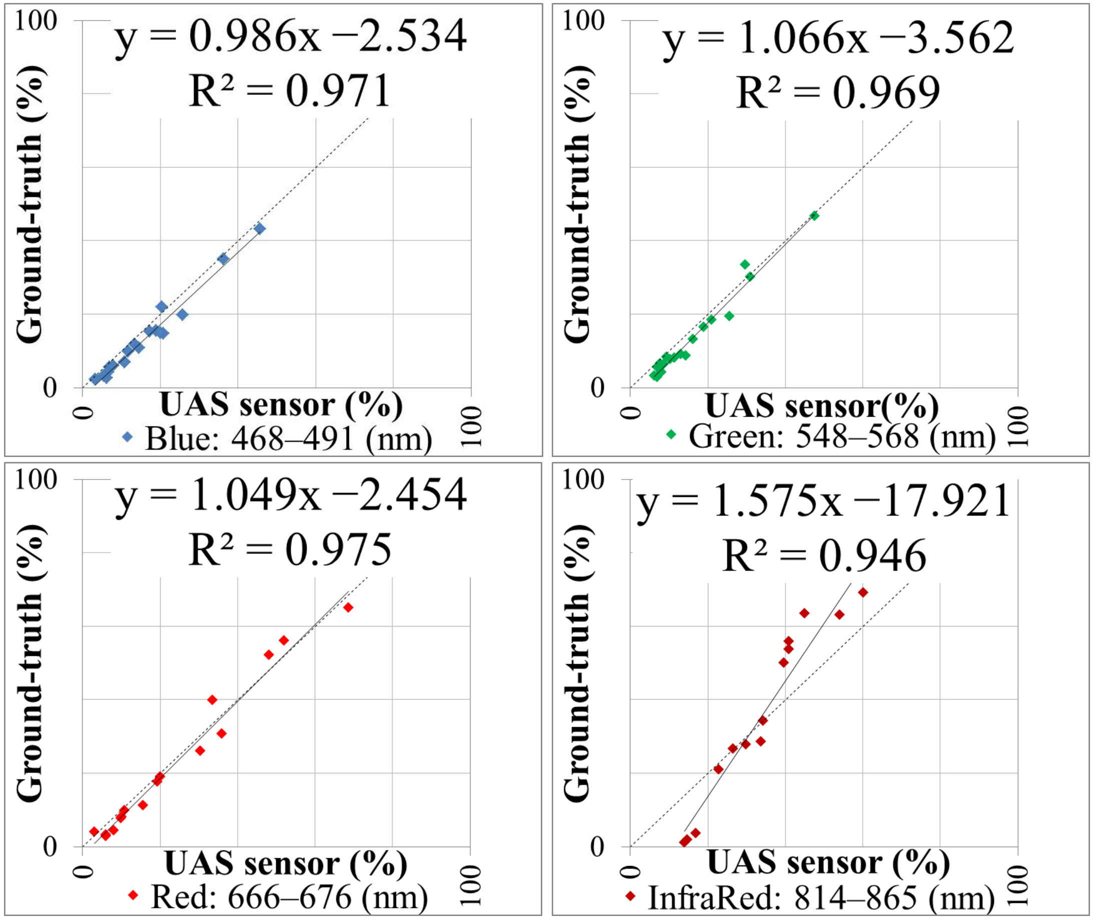
MiraMon

Synergies between field spectroscopy, sensors onboard Unmanned Aerial Systems (UAS), and Landsat-8/Sentinel-2 satellite imagery

2: Upscaling| Linking field data and UAS imagery

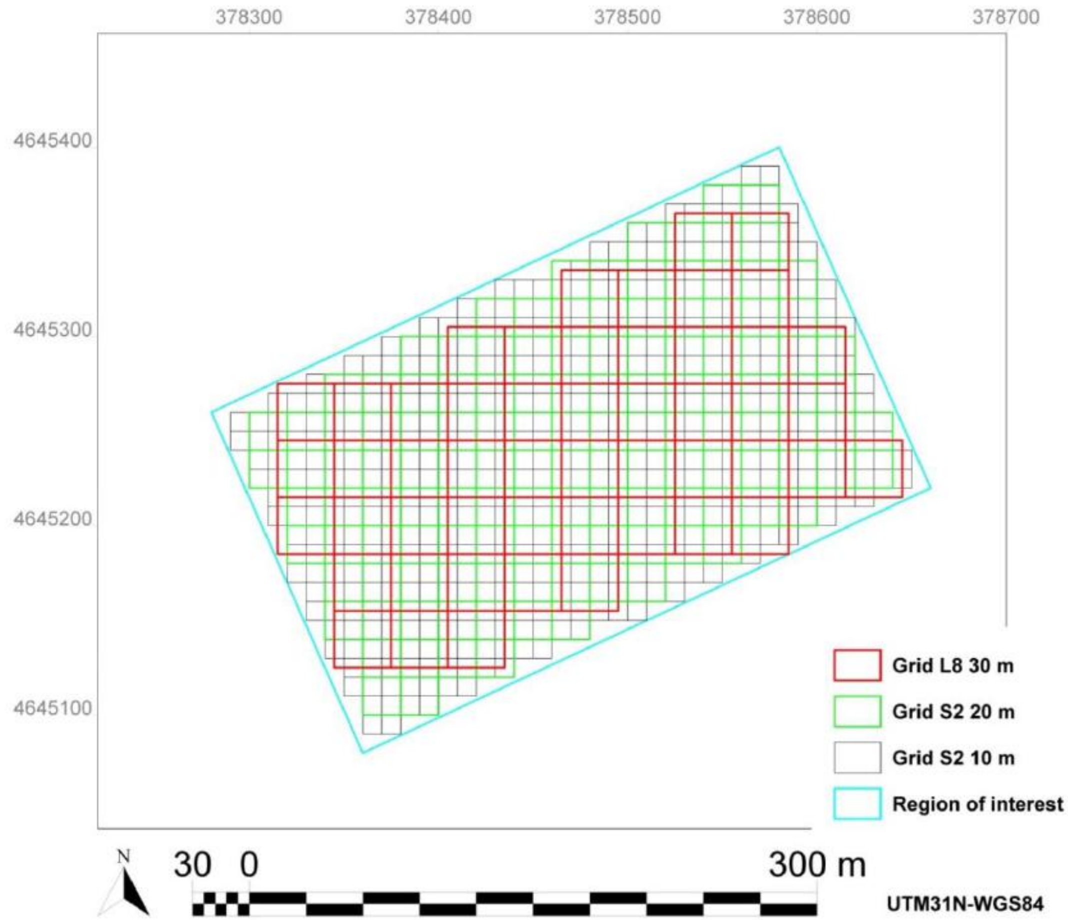
FITTING BETWEEN **FIELD SPECTROSCOPY AND DRONE DATA**

Main results

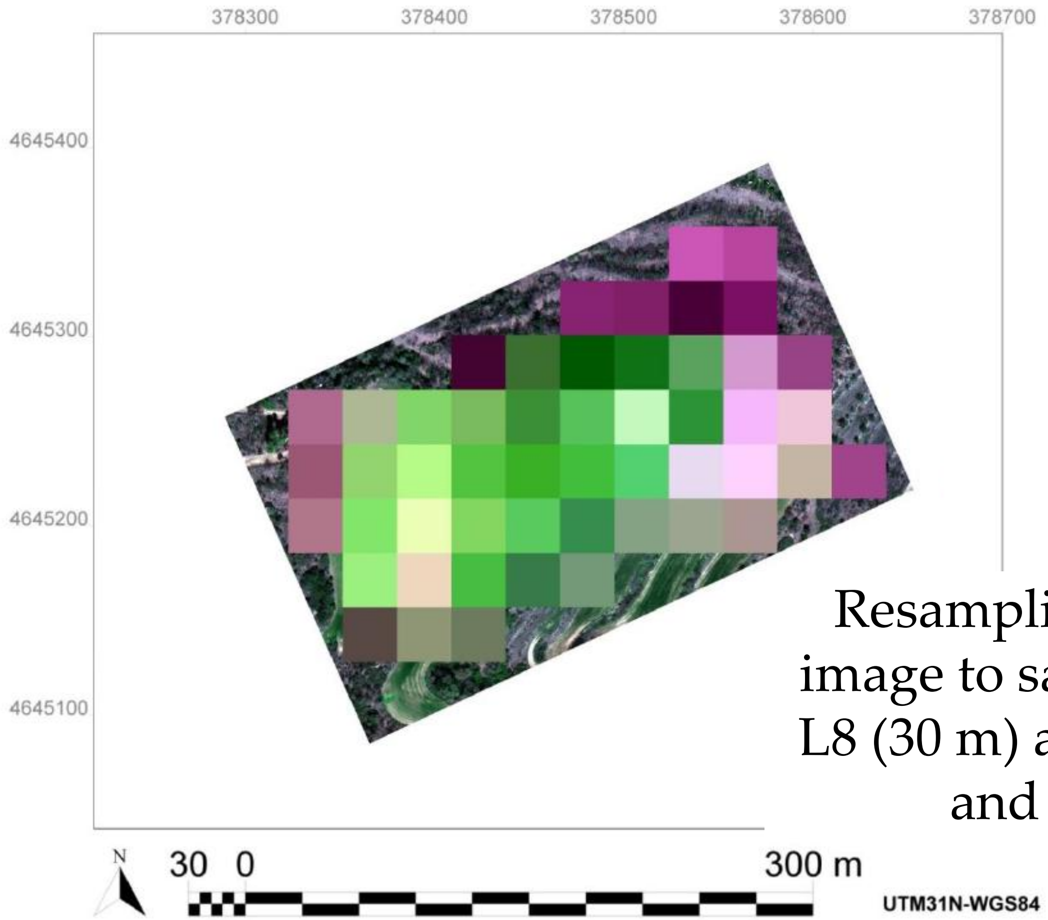


UAS imagery corresponding to MSI sensor bands, sensed **by S2 overpass** **correlated** with **field spectroscopy** measurements over EVA panels

2: Upscaling| Linking UAS and satellite imagery



2: Upscaling| Linking UAS and satellite imagery



Resampling of UAS image to satellite grids L8 (30 m) and S2 (20 m and 10 m)

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2: Upscaling| Linking UAS and satellite imagery

Main results

FITTING BETWEEN **DRONE DATA AND SATELLITE DATA**

RMSE (%) between all the UAS surface reflectance resampled pixels and:
a) L8 and S2 imagery without radiometric correction (TOA reflectance)
b) Official products (LaSRC (L8) y Sen2Cor (S2)) surface reflectance

Band	BLUE		GREEN		RED		NIR	
RMSE UAS *vs.* Satellite	OLI #2 (n=51)	MSI #2 (n=517)	OLI #3 (n=51)	MSI #3 (n=517)	OLI #4 (n=51)	MSI #4 (n=517)	OLI #5 (n=51)	MSI #8a (n=143)
TOA	7.743	6.981	3.684	3.674	3.533	3.101	6.847	8.050
LaSRC or Sen2Cor	2.054	2.192	**1.623**	**2.058**	**2.484**	**2.361**	6.688	8.783

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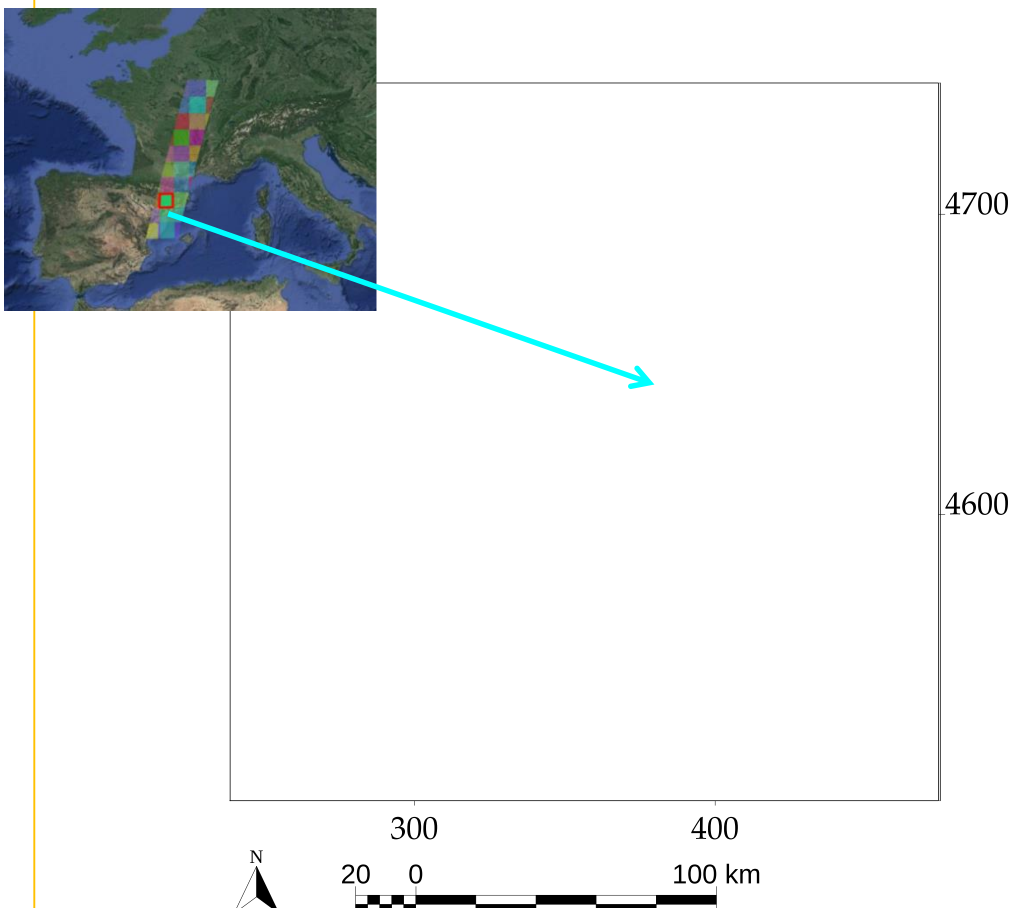
2: Upscaling| Radiometric correction of satellite imagery using drone data in synergy with field spectroscopy



Radiometric correction of 198031 (L8) and T31TCG (S2A) imagery fitting the CorRad-MiraMon algorithm model unknowns to the UAV references (60 %) (UAS-MiraMon):

$$\rho_\lambda = \frac{\pi \cdot [L_\lambda - La_\lambda]}{\cos(\theta) \cdot E_{0\lambda} \cdot \tau\downarrow_\lambda \cdot \tau\uparrow_\lambda} \cdot d^2$$

Validation of the radiometric UAS-MiraMon correction and the official products (LaSRC y Sen2Cor) by means of the band-by-band RMSE in the test pixels (40 %)

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2: Upscaling| Radiometric correction of satellite imagery using drone data in synergy with field spectroscopy

Main results

FITTING BETWEEN **UAS-MIRAMON AND TEST AREAS**

RMSE (%) between test areas and:

a) CorRad-MiraMon with UAS references (UAS-MiraMon) surface reflectance
b) Official products (LaSRC (L8) y Sen2Cor (S2)) surface reflectance

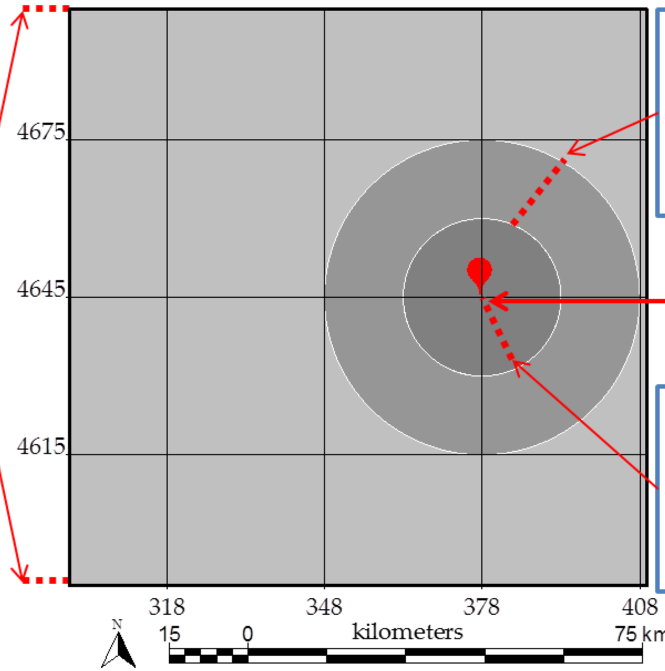
	BLUE		GREEN		RED		NIR	
RMSE Test areas *vs.* Satellite	OLI #2 (n=20)	MSI #2 (n=207)	OLI #3 (n=20)	MSI #3 (n=207)	OLI #4 (n=20)	MSI #4 (n=207)	OLI #5 (n=20)	MSI #8a (n=57)
UAS-MiraMon	**0.712**	**0.745**	**1.000**	**1.230**	**1.871**	**2.018**	7.530	6.760
LaSRC or Sen2Cor	2.197	2.149	1.653	1.806	2.680	2.192	5.841	7.690

2: Upscaling| Radiometric correction of satellite imagery using drone data in synergy with field spectroscopy

Fitting between almost-simultaneous L8 and S2 imagery radiometrically corrected with UAS-MiraMon
(**INTER-SENSOR COMPARISON**)

Common extent L8 tile 198031 and S2 tile R051 TCG.

All S2 bands resampled to 30 m and L8 grid



Radial distance <30 km & >15 km from study area

Study area (center of UAS flight)

Radial distance <15 km from study area

2: Upscaling| Radiometric correction of satellite imagery using drone data in synergy with field spectroscopy

Fitting between almost-simultaneous L8 and S2 imagery radiometrically corrected with UAS-MiraMon
(**INTER-SENSOR COMPARISON**)

Main results

RMSE (%) between L8 and S2 imagery sensed within few minutes and radiometrically corrected with the UAS-MiraMon method

Radial distance from UAV flight area (Number of 30 m L8 and S2 compared pixels)	BLUE	GREEN	RED	NIR
0-15 km (n=681 950)	**0.621**	**0.741**	**0.919**	**1.664**
15-30 km (n=2 203 730)	**0.739**	**0.815**	**0.984**	1.666
TCG scene (n=12 148 700)	**0.852**	**0.940**	**1.147**	1.707

3: Discussion

Conventional field spectroscopy sampling

A) **UAS imagery** has greatly **improved** the **number and speed** of ground **references sampling** (51 OLI plots in ±5 minutes, repeating the flight 20 minutes later for MSI), and **including inaccessible land covers**.

UAS fitting to field spectroscopy data

B) UAS reflectance calibration using sensor manufacturer reference panel obtained high R2 (>0.942) with field measurements, but bias and gain remained (in-situ reflectance values were systematically lower than UAS sensor reflectance values).

Synergies between field spectroscopy, sensors onboard Unmanned Aerial Systems (UAS), and Landsat-8/Sentinel-2 satellite imagery

3: Discussion

From UAV to satellite

C) **UAV MicaSense RedEdge** calibrated data **is**, in general terms, **coherent with L8** and **S2** satellite imagery radiometrically corrected (up to 3% in reflectance in visible bands), in consonance with previous studies.

D) However, **NIR band mismatching** between MicaSense RedEdge and satellite sensors configuration **is too significant to be ignored and reflectance differences are not acceptable in this band**, which was not properly advised in previous studies.

3: Discussion

Radiometric correction of L8-S2 using UAV data

E) CorRad-MiraMon radiometric correction algorithm using UAS references improves the local accuracy over official products, with **accuracies up to 2% in reflectance in visible bands**.

F) **UAS-MiraMon got a RMSEvis<1% inter-sensor coherence** not only in the study area but in all the common L8 and S2 scene.

3: Discussion

Radiometric correction of L8-S2 using UAV data
WEAK POINTS

1) This method should be only used by the simultaneous drone flight and satellite overpass.

2) Currently not all satellite bands are available in low-weight UAV sensors, specially SWIR bands.

3) It is needed ground support to accurately radiometrically correct UAV imagery.

4. Conclusions

This communication shows the increasing possibilities offered by Unmanned Aerial Systems (UAS) or drones, to collect *in-situ* data in order to improve calibration, validation, processing and/or interpretation of satellite data.

4. Conclusions

This drone data, fitted to *in-situ* measurements of multiple reflectance references distributed in the spectral domain and covering a wide range of intensities, is reliable for its use as *in-situ* radiometric reference (or at least to complement conventional measurements).

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4. Conclusions

The sampling method using a drone is more systematic, fast, repeatable and extensive than that obtained with conventional field spectroscopy measurements. The data acquired with drone is carefully georeferenced and, given their raster nature (<10 cm), easily adapted to different satellite sensors grids such as Landsat-8 OLI (30 m) or Sentinel-2 MSI (20 m or 10 m).

4. Conclusions

The result of the radiometric correction of satellite imagery is improved locally. The proposed method provides a good fit for *in-situ* and intersensor data.

It is worth noting that field spectroscopy data is the backbone that supports the full upscaling workflow, and the radiometric feasibility of drone data.

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Complete publication reference:

Padró JC, Muñoz FJ, Avila LA, Pesquer L, Pons X (2018). **Radiometric Correction of Landsat-8 and Sentinel-2A Scenes Using Drone Imagery in Synergy with Field Spectroradiometry.** *Remote Sensing, 10 (11), 1687-1713*. DOI: 10.3390/rs10111687.

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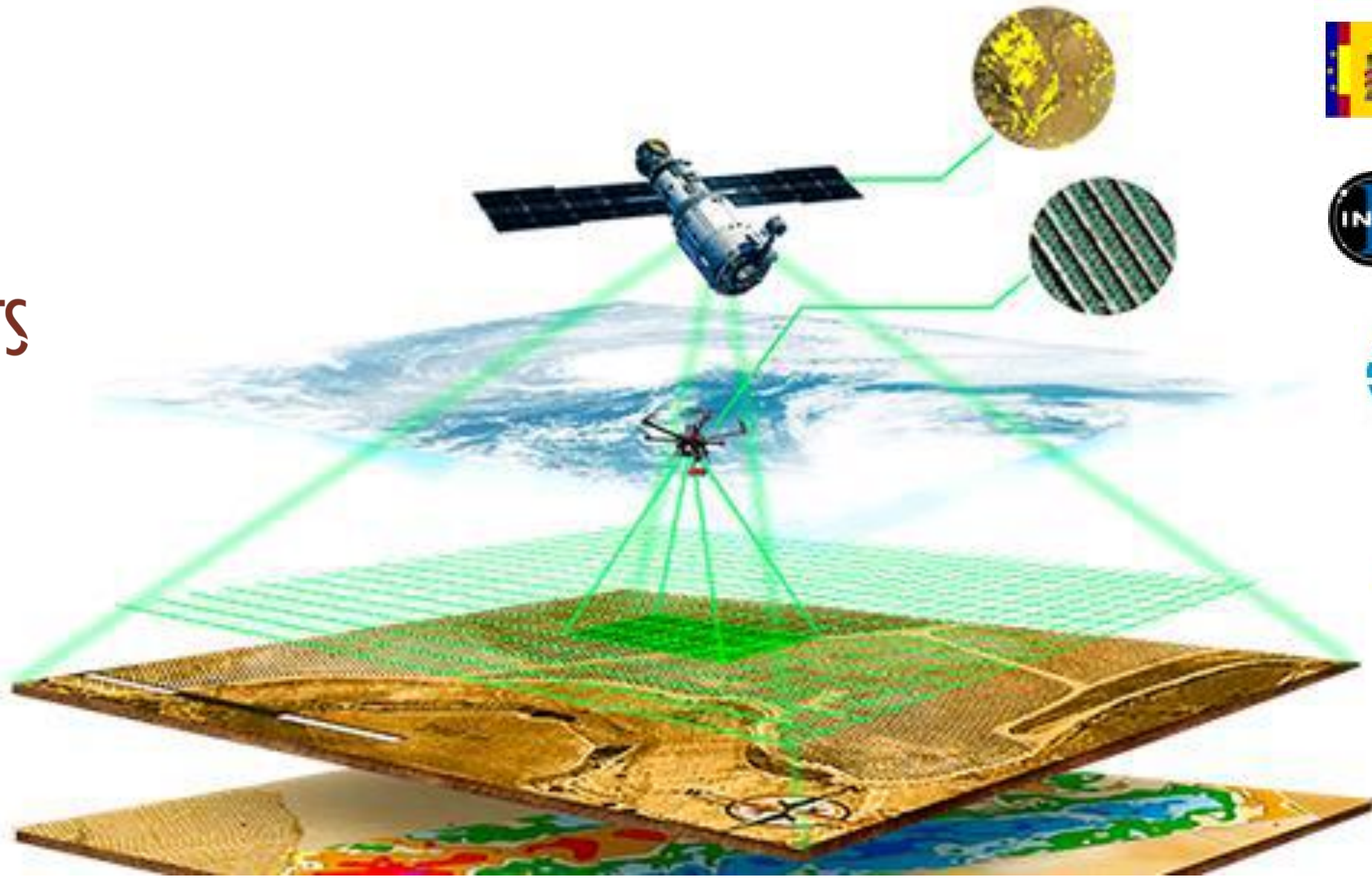
Torrejón de Ardoz 7th March ’19
Instituto Nacional de Técnica Aeroespacial (INTA)

Thanks for your attention

Dr. Joan-Cristian Padró and Dr. Xavier Pons



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