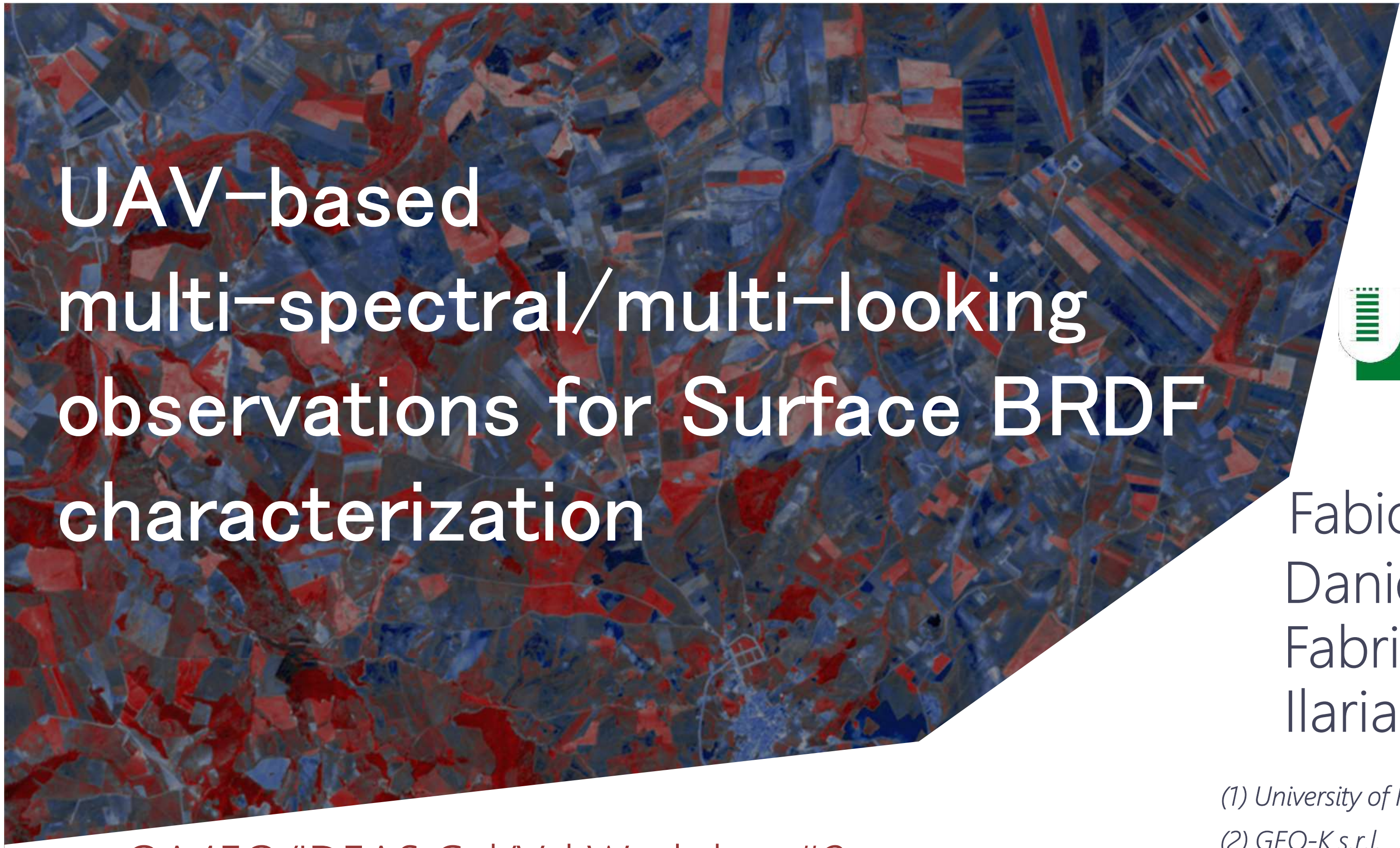

UAV-based multi-spectral/multi-looking observations for Surface BRDF characterization

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Motivations

Natural surfaces reflect light in different ways and different amounts according to the viewing and illumination conditions and the reflective character of the surface

Such behaviour depends on the level of anisotropy of the surface itself, which depends on the optical properties of the surface elements and their geometric and volumetric mutual positioning

The level of surface anisotropy is quantitatively described by the BRDF whose knowledge is important to

- to normalize the observation to a standard angular configuration
- retrieve relevant bio-geophysical variables

Although there is a vast literature on BRDF modelling and its applications for correcting optical remote sensing observations there is currently a lack of extensive in-situ validation data to assess the quality of this correction

Motivations

Recent advances in UAV techniques and on-board acquisition systems offer new opportunities in this context

In particular

- they represent a cost-effective solution to the problem of upscaling the in-situ measurements to the satellite pixel scale
- they operate in a complete automatic way which allows to plan the measurements according to a predefined grid of points selected within a volume
- measurements can be easily reiterated to smooth out possible fluctuations in the acquisition operations

Objectives

- To develop and test a UAV-based platform for performing multi-spectral radiometric measurements of land surfaces using multi-looking strategy
- To design and consolidate measurement protocols for collecting UAV-based optical measurements, which are relevant to retrieve information on surface BRDF over land
- To plan and carry out a UAV-based validation campaign focusing on vegetated homogeneous sites suitable for validation at S2, Proba-V, and S3 products resolution scale.
- To repeat the campaign for different seasonal conditions to study spatio-temporal evolution of surface anisotropy

Maia Multispectral Camera

MAIA is the most advanced multi-spectral imaging camera, specifically designed for use abroad **UAVs**

MAIA is based on an array of imaging sensors, capable to acquire multispectral images in the **same bands Sentinel-2** satellites in the VIS to NIR region (395nm to 950nm)

The imaging sensors features 1.2Mpix resolution, high-sensitivity and **global shutter technology**, allowing the simultaneous acquisition of images free from motion artifacts

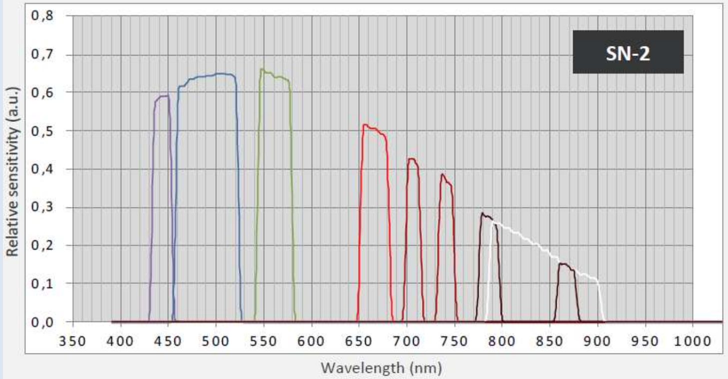
AGL (m)	GSD (mm/pixel)	FOV (m^2)	Maximum UAV speed for 10 ms exposure (m/s) – (km/h)
50	23	30 × 23	2.3 – 8.4
75	35	45 × 34	3.5 – 12.7
100	47	60 × 45	4.7 – 16.9
150	70	90 × 68	7.0 – 25.3
200	94	120 × 90	9.4 – 33.8
300	141	180 × 135	14.1 – 50.6
400	188	240 × 180	18.8 – 67.5

Technical Specification

- 9 CMOS sensor 1.2Mpix (1280x960) with global shutter
- Ground sampling distance (GSD): 4cm at 75m flight altitude
- Field of view (FOV): 47m x 36 m at 75m flight altitude
- Size and weight 10 x 13 x 4,6 cm, 470 g
- Battery: Up to 18h of mission
- Internal storage 210GB (from 10.000 to 20.000 images)

Spectral Bands

SN-2 (Sentinel-2)		
	Band (nm)	Approx. color
1	433-453	Violet (Coastal)
2	457-523	Blue
3	542-578	Green
4	650-680	Red
5	697-713	Red Edge 1
6	732-748	Red Edge 2
7	773-793	NIR 1
8	784-900	NIR 2
9	855-875	NIR 3



Add On

The Incident Light Sensor (ILS) **measures the level of the downwelling light in each band** and allows the correction for light changes during the survey, such as those caused by clouds

ILS provides **irradiance data at the exact time of shooting for each image and in each spectral band**, substantially improving the accuracy of radiometric correction and allowing to conduct multi-temporal multispectral surveys.

The ILS features a **GNSS receiver that provides the geo-referencing information** embedded into each image.

Radiometric Calibration

The radiometric correction is used in post-processing to correct for the component of irradiance light (normally the sun) and **obtain the radiance of the elements** (plants, terrain..) that compose the scene.

Radiometric calibration is implemented by the **MAIA proprietary software** application, adopting a rigorous correction method based on the use of Irradiance Light Sensor (**ILS**).

The method assumes that radiation measured by the ILS is the same that irradiates the scene of interest. The corrected reflectance value of the scene DN' for each Bi spectral band is computed according to:

$$DN'_i = \frac{1}{ILS_i} \cdot DN_i$$

being ILSi the value of the light intensity detected by the ILS for each Bi spectral band.

Mounting on UAV Multirotor

- Hexarotor with maximum **take-off weight up to 6 kg**
- Plug & Play System allows to switch between payloads
- Real-time mission management, **Autonomus Waypoint navigation**, Integrated GPS and IMU sensors, Auto-stabilization of flight in manual mode.
- **Up to 20 minutes** of flight time
- ENAC has given the Certification of Design attesting the **compliance to Italian and European (EASA) laws**
- Remote controlled gimbal for **orienting MAIA camera between 0° and 90°** respect to surface normal direction

Preliminary flights - Test on field

26/11/2020 10:03 UTC overlapping Sentinel-2 acquisition

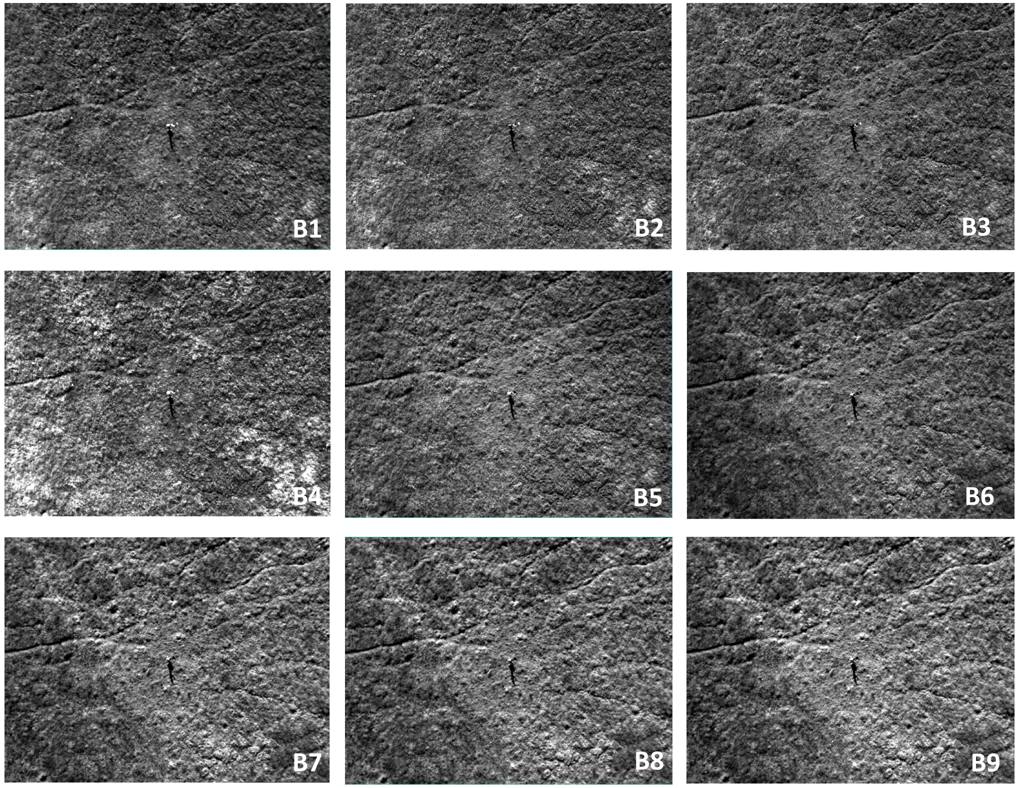
S2 acquisition

Altitude: 90m
GSD: 5cm
FOV: 60mX45m

Pre-Processing step

- **Image from each band are stored as RAW files (12 bit).**
- **Pre-processing consists of the following step:**

Preliminary Flights - Output 9 bands tif



Spectral Bands

Sentinel-2 Bands	Central W
Band 1 - Coastal aerosol	0.443
Band 2 - Blue	0.490
Band 3 - Green	0.560
Band 4 - Red	0.665
Band 5 - Vegetation Red Edge	0.705
Band 6 - Vegetation Red Edge	0.740
Band 7 - Vegetation Red Edge	0.783
Band 8 - NIR	0.842
Band 8A - Vegetation Red Edge	0.865

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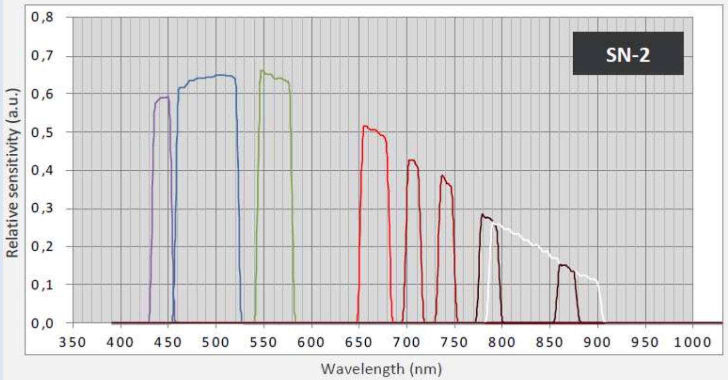
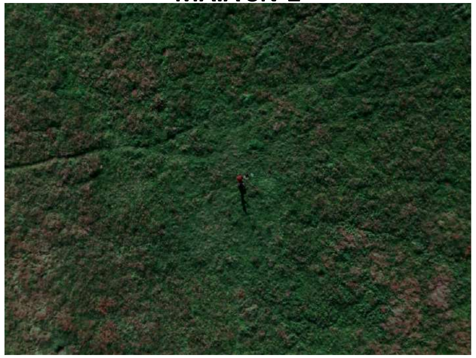
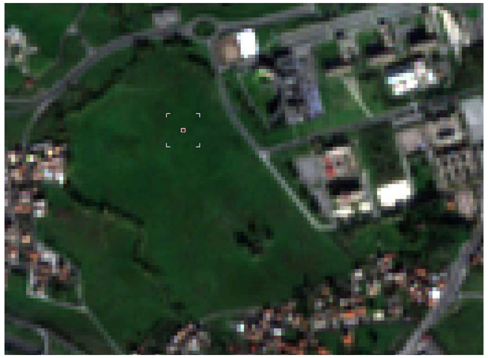


Preliminary Flights - Color composition

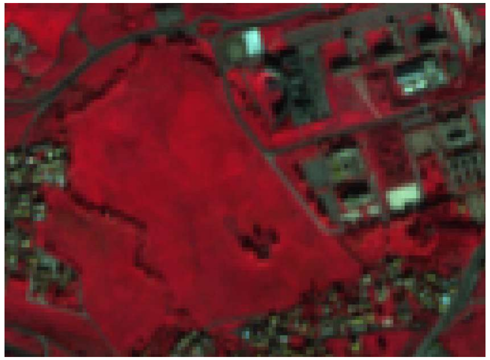
MAIA SN-2 | **Sentinel - 2**

R G B





Nir R G



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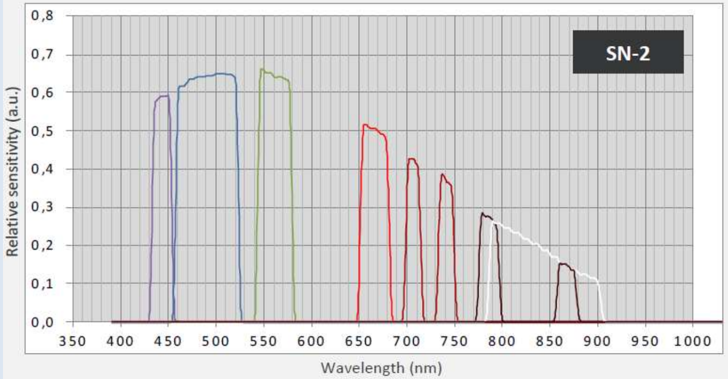
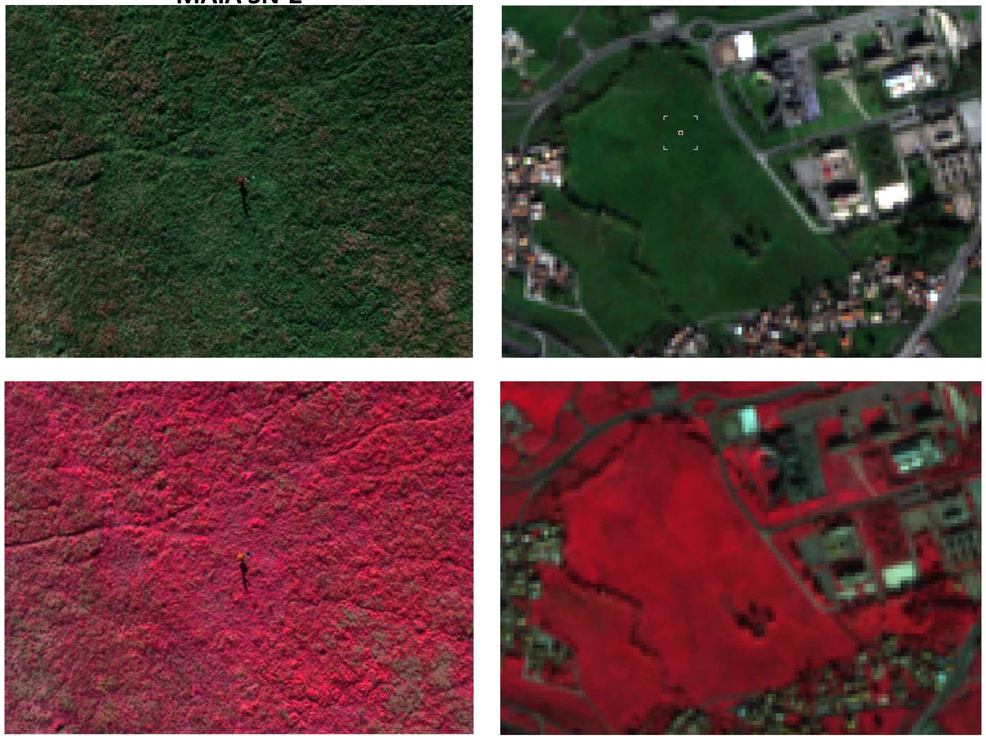


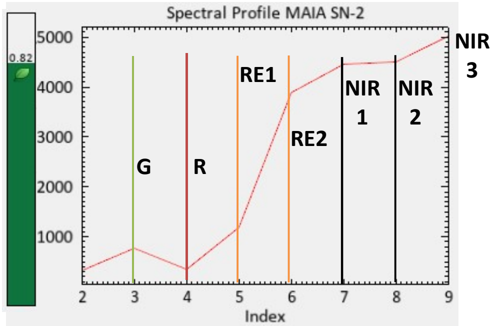
Preliminary flights - Spectral check

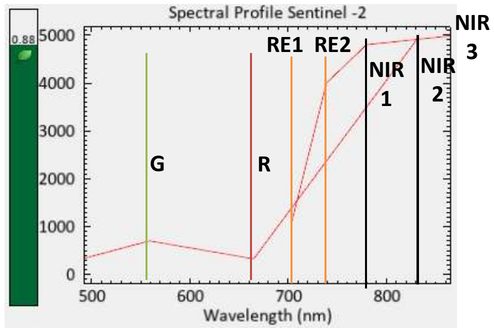
MAIA SN-2 | Sentinel - 2

R G B

Nir R G

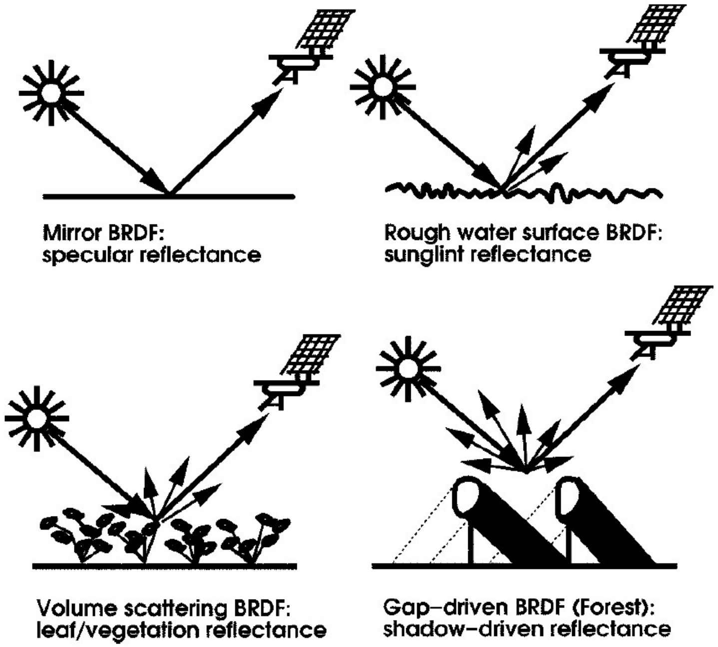






BRDF model analysis

Bidirectional Reflectance Distribution Function describes the REFLECTANCE ANISOTROPY and is useful to determine surface reflectance at any geometry conditions



Causes for land surface reflectance anisotropy

➢ Linear Models

- Walthall (Walthall et al., 1985; Nilson & Kuusk, 1989)
- Roujean/Ross thick (Roujean et al., 1992)
- Ross-Li (Lucht et al., 2000)

➢ Non-Linear Models

- Rahman-Pinty-Verstraete (RPV) (Rahman et al., 1993)

Ongoing and Next Activities

- Complete Model investigations
- Final On-flight system and internal device setup
- Systematic acquisition plan driven by S2 (for time) and models (for geometry)
- First full measurements campaign and data analysis
- Repeated acquisition for different seasonal conditions to study spatio-temporal evolution of surface anisotropy
- Analysis of validation campaign to derive BRDF model parameters covering the different vegetated conditions and to use these results to validate BRDF-estimation from S2
- Repeat for a different type of surface