UAV-BASED OBSERVATIONS FOR BRDF ESTIMATION

IDEAS-QA4EO Cal/Val Workshop#3

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SUMMARY

GEO-K is responsible for WP 2175 which focuses on the **estimation of BRDF** by UAS platform.

More in general, this activities aims to establish an UAV flight protocol for collecting **reference in-situ dataset** to assess the quality of BRDF correction algorithms.

- Set-up of a system composed by UAV + Multispectral camera S2 likes
- Design of flight plan on selected test sites
- Elaboration of multiangular dataset
- Evaluation and modelling of BRDF using Ross-Li model

System Set-up

UAV + Multispectral sensor S2 likes

	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

- 9 CMOS sensor with global shutter
- GSD: 4cm at 75m flight altitude
- FOV: 47m x 36 m at 75m flight altitude
- Size and weight 10 x 13 x 4,6 cm, 470 g

- **Hexarotor** MTOM up to **6 kg**
- Up to **20 minutes** of flight time
- Automatic flight capabilities, controlled gimbal for orienting MAIA camera between 0° and 90° respect to surface normal direction

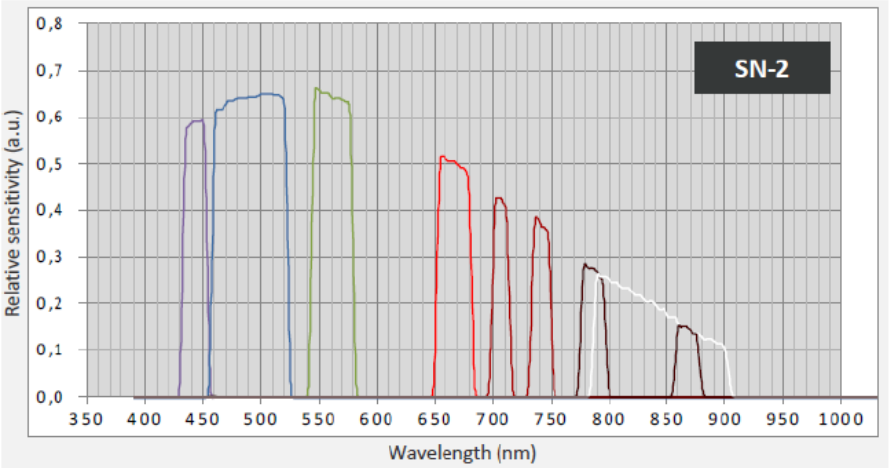
The **Incident Light Sensor (ILS)** measures the level of the down-welling light in each band.

ILS **provides irradiance data at the exact time of shooting for each image and spectral band**, substantially improving the accuracy of radiometric correction.

Multispectral Camera Sentinel-2 likes

Technical Features	
Sensors	9 CMOS sensor 1.2Mpix (1280x960) with global shutter
Acquisition	Single shot or continuous up to 5fps
Image Format	Multi-layer/multi-band RAW 8 - 10 - 12bits per pixel; TIFF
File Size	from 10.7 to 21.2MB depending on the format
Internal Storage	210GB internal storage
Size and weight	99 x 129 x 46 mm³, 470 g

Distanza dal suolo (m)	GSD (mm/pixel)	FOV (m^2)
50	23	30 x 23
75	35	45 x 34
100	47	60 x 45
150	70	90 x 68

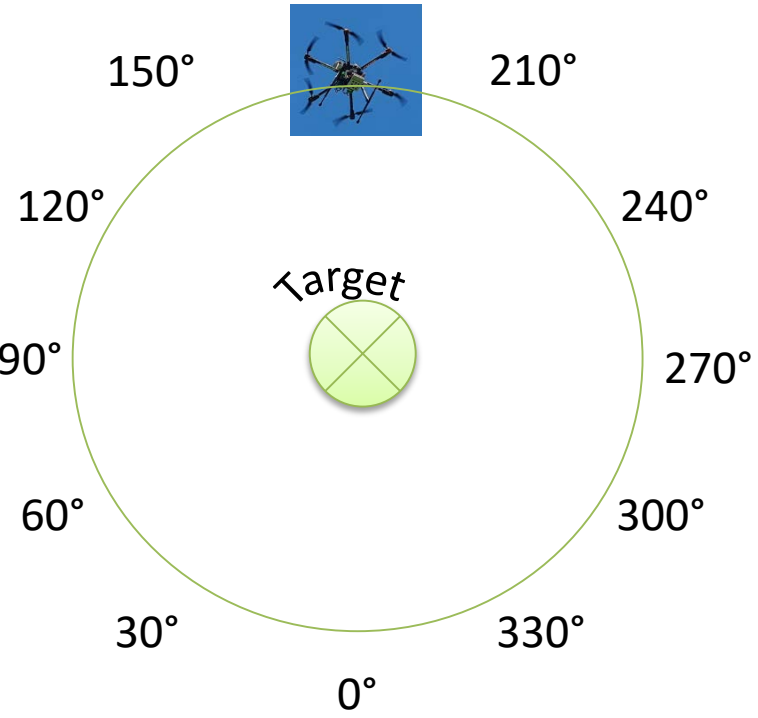


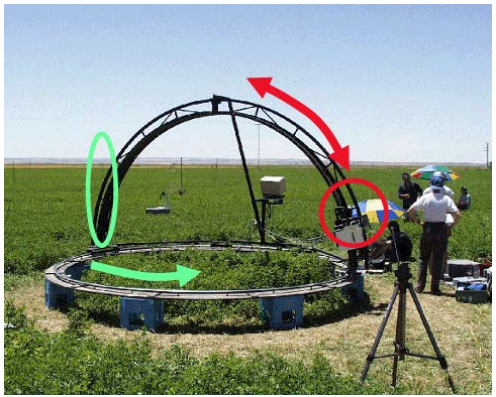
MAIA SN-2 BANDS	
Band (nm)	Name
433-453	Violet (Coastal)
457-523	Blue
542-578	Green
650-680	Red
697-713	Red Edge 1
732-748	Red Edge 2
773-793	NIR1
784-900	NIR2
855-875	NIR3

Sentinel-2 bands	Central wavelength (µm)
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
Band 9 – Water vapour	0.945
Band 10 – SWIR – Cirrius	1.375
Band 11 – SWIR	1.610
Band 12 – SWIR	2.190

Flight Planning

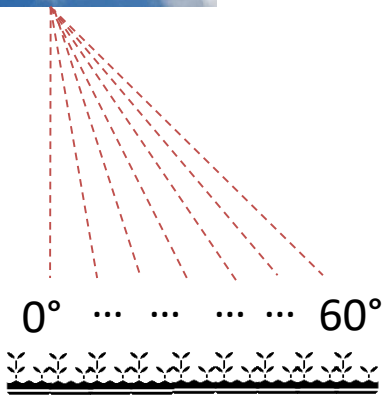
View Azimuth Angle (VAA) variation





On ground Goniometer
Acquisition System
for BRDF measurements

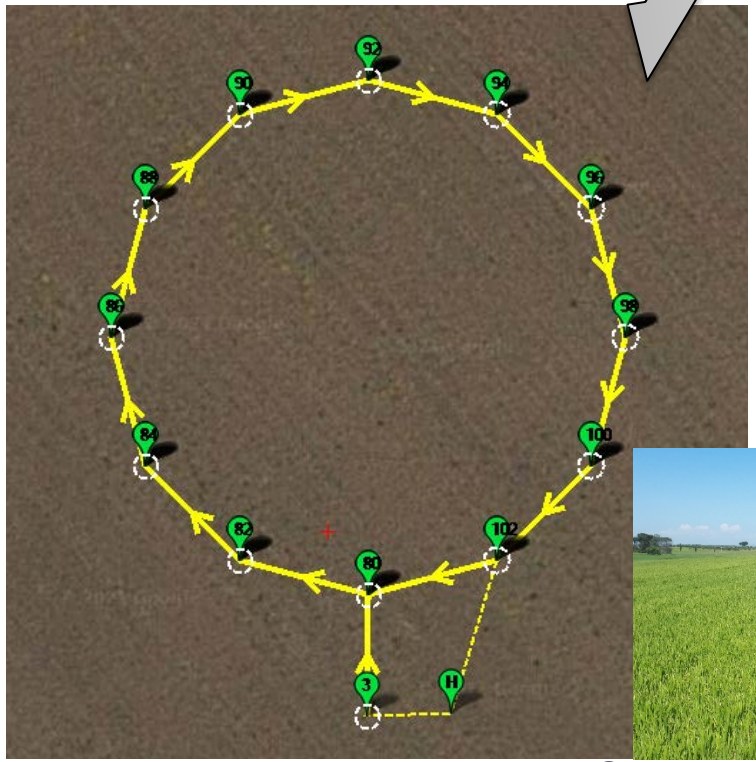
View Zenith Angle (VZA) variation



Flight Planning and Dataset Elaboration: Vegetation Surface

Flight Planning – Veg. Test site

- Acquisition details:
  - **View Azimuth Angles**:
    0° to 360° with 30° steps
  - **View Zenith Angles**:
    0° to 60° with 10° steps
  - **Dataset amount:**
    84 acquisition each survey
  - **More info**:
    - Flight time about 15min
    - Flight altitude: 120m
    - Overlapping Sentinel-2 passage (30/04/2021)

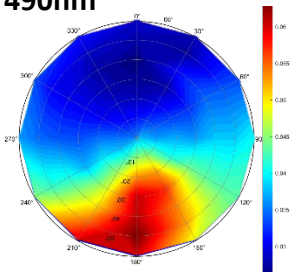


Test site: **Wheat Field**
(Rome, IT, Google Earth imagery)

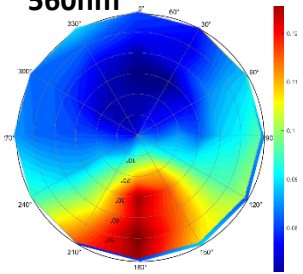
On ground picture: **Wheat Field**

MAIA Field Measurements – Evaluation of BRDF

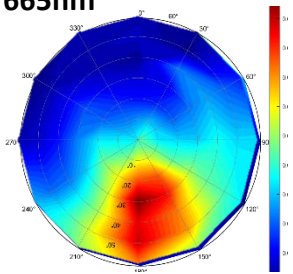
490nm



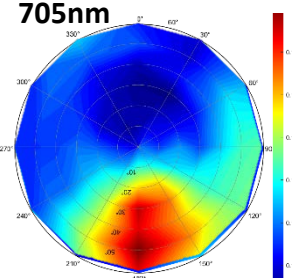
560nm



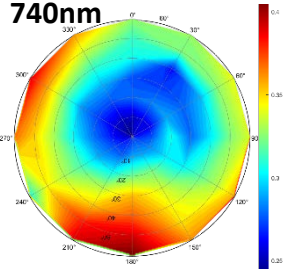
665nm



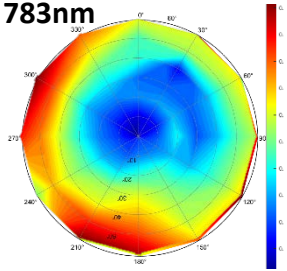
705nm



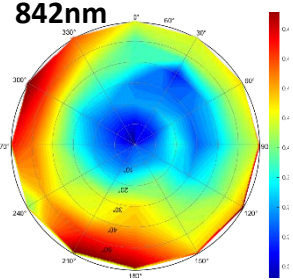
740nm



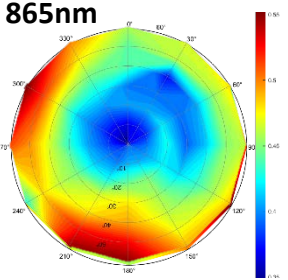
783nm

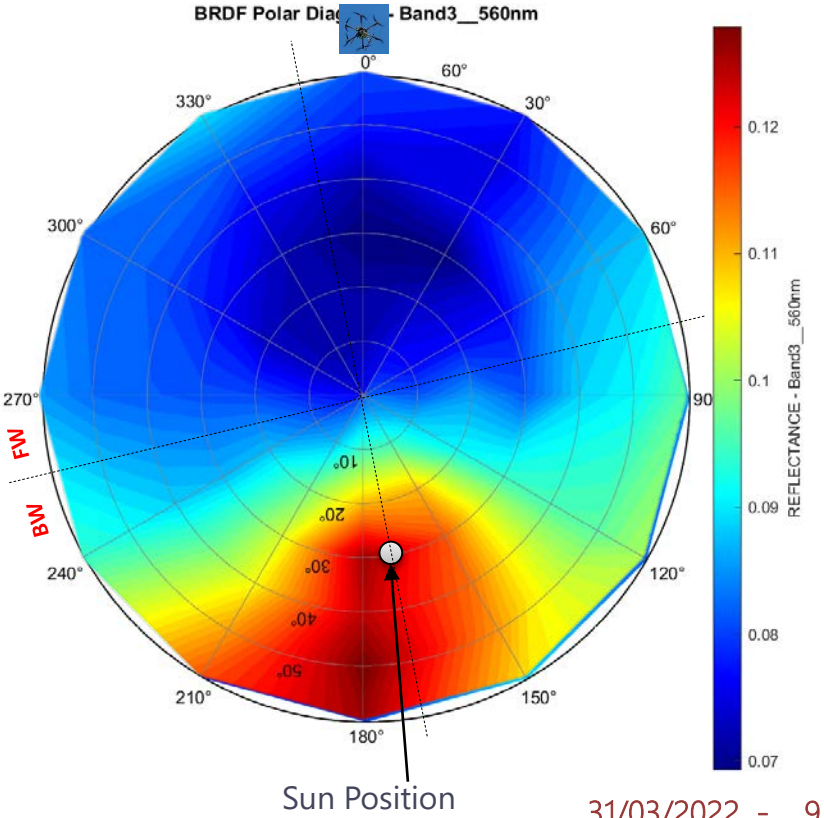


842nm

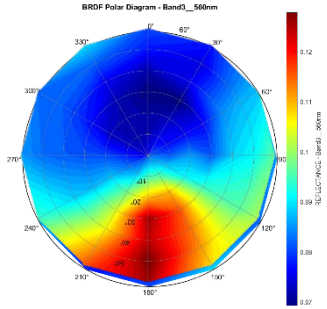


865nm





BRDF Modeling: Ross-Li model



Computing Ross-Li Kernels

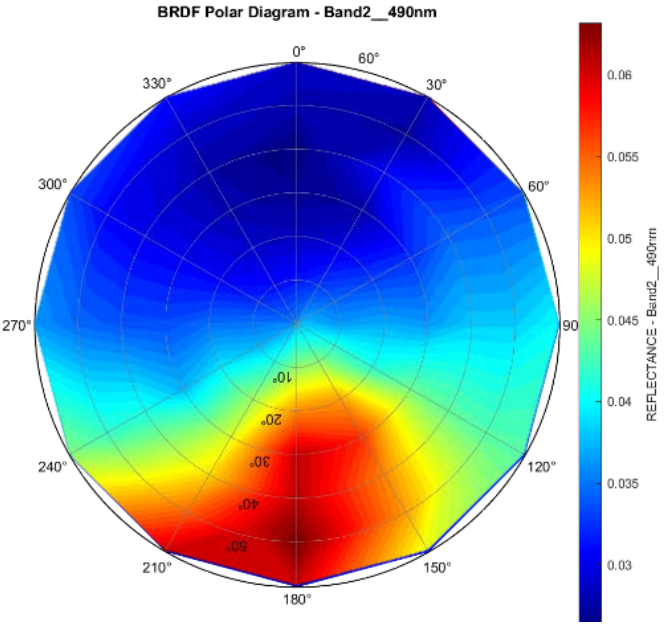
$$K_{RT} = \left[(\pi/2 - \xi)\cos\xi + \sin\xi\right] / \left[\cos\theta_s + \cos\theta_v\right] - \pi/4$$

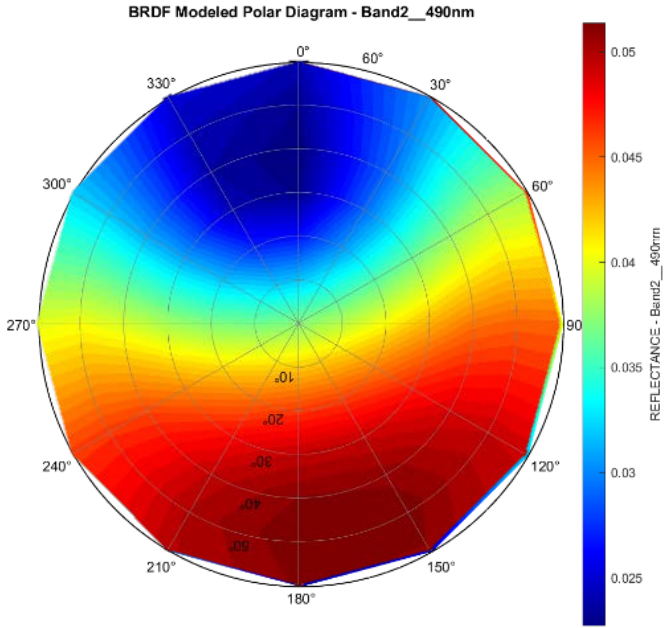
$$K_{LS} = O(\theta_s, \theta_v, \phi) - \sec\theta_s' - \sec\theta_v' + \tfrac{1}{2}(1 + \cos\xi')\sec\theta_s' \sec\theta_v'$$

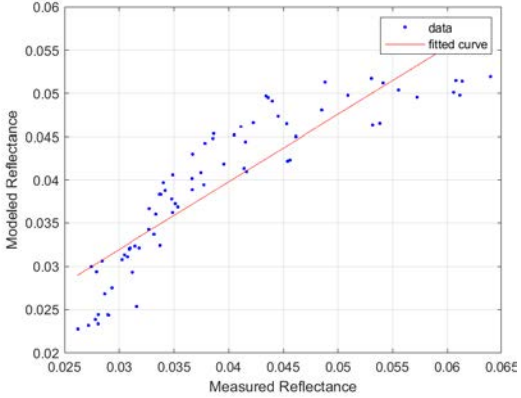
$$R(\theta_s, \theta_v, \phi; \lambda) = f_{iso} + f_{vol} K_{vol}(\theta_s, \theta_v, \phi; \lambda) + f_{geo} K_{geo}(\theta_s, \theta_v, \phi; \lambda)$$

Inversion of the model using least squared method

BRDF Comparison: Measured vs Model



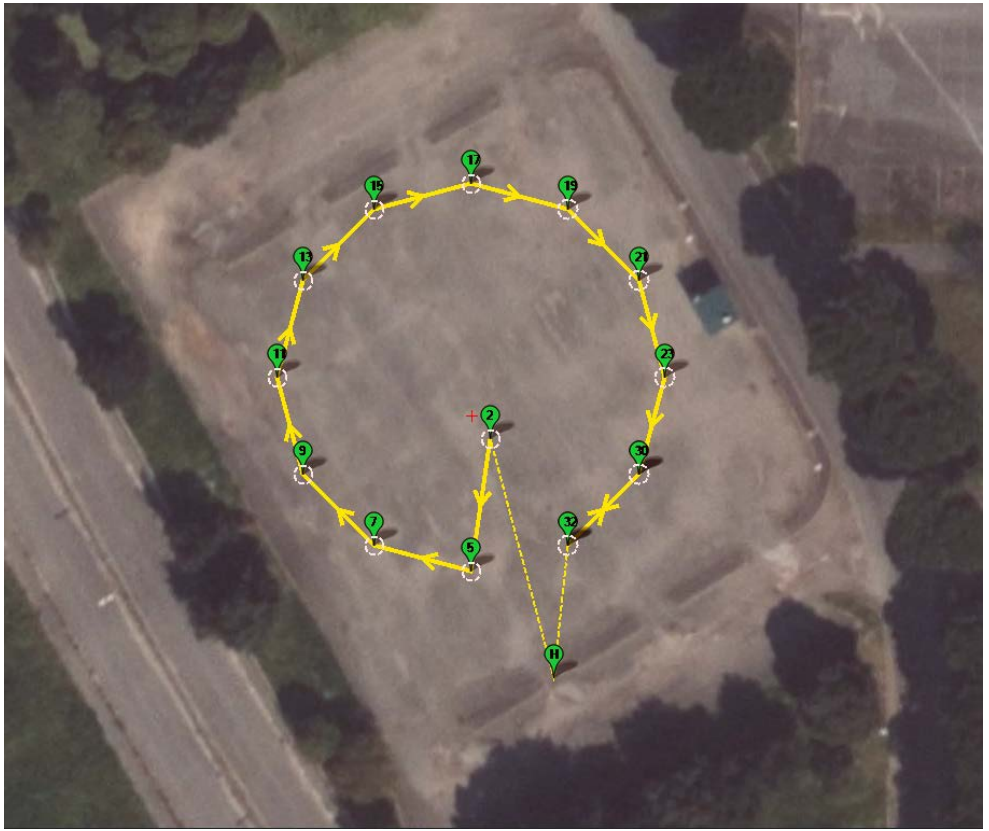




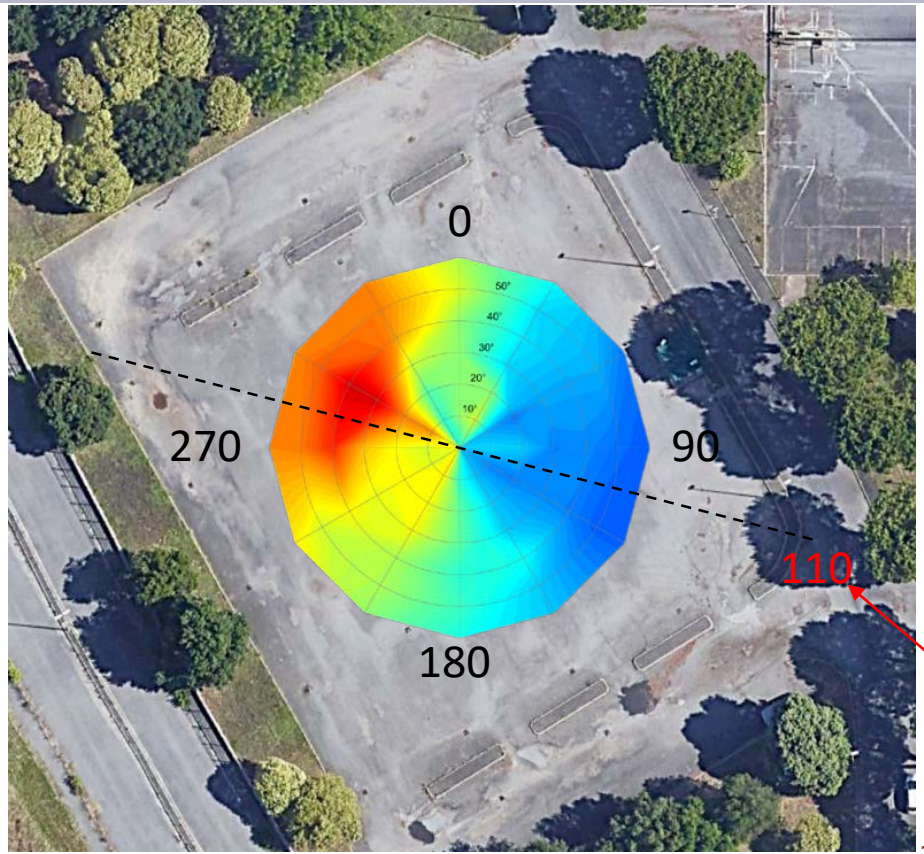
$R^2 > 0.8$

Flight Planning and Dataset Elaboration: Asphalt

Flight Planning – Asphalt Test site

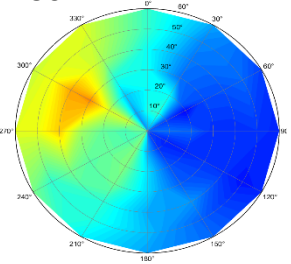


Flight Planning – Asphalt Test site

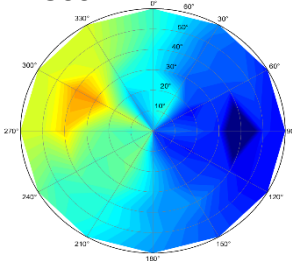


MAIA Field Measurements – Evaluation of BRDF

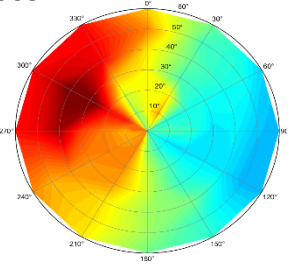
490nm



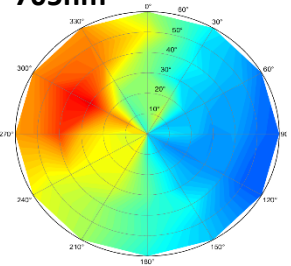
560nm



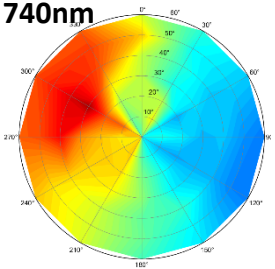
665nm



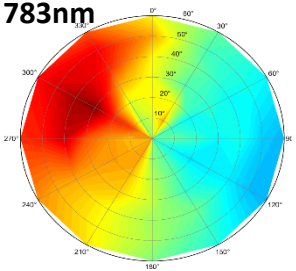
705nm



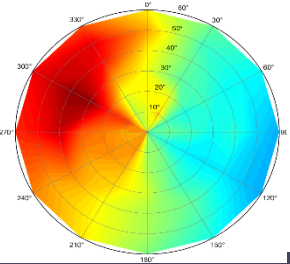
740nm



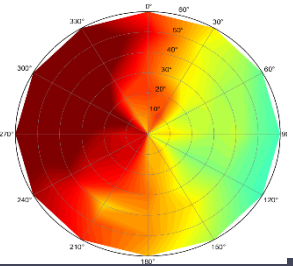
783nm

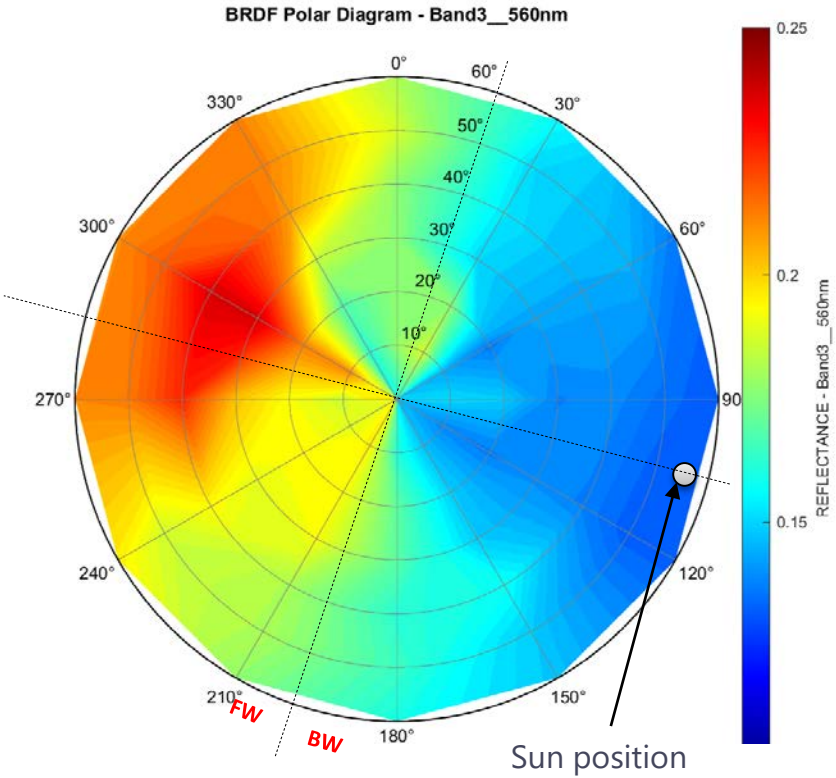


842nm

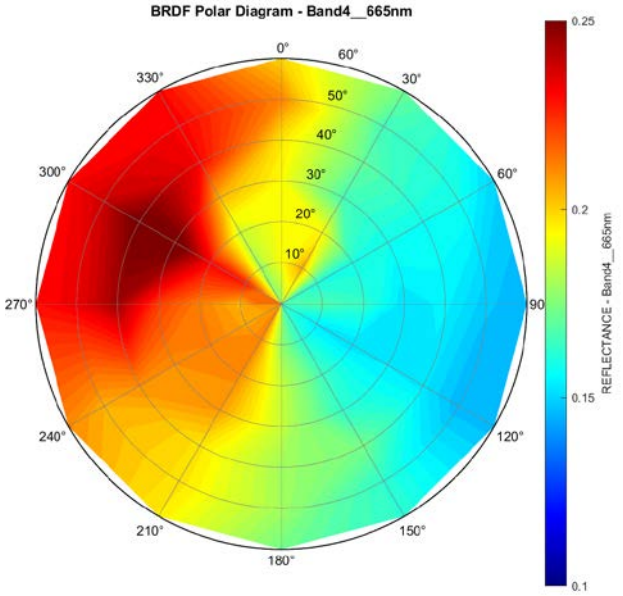


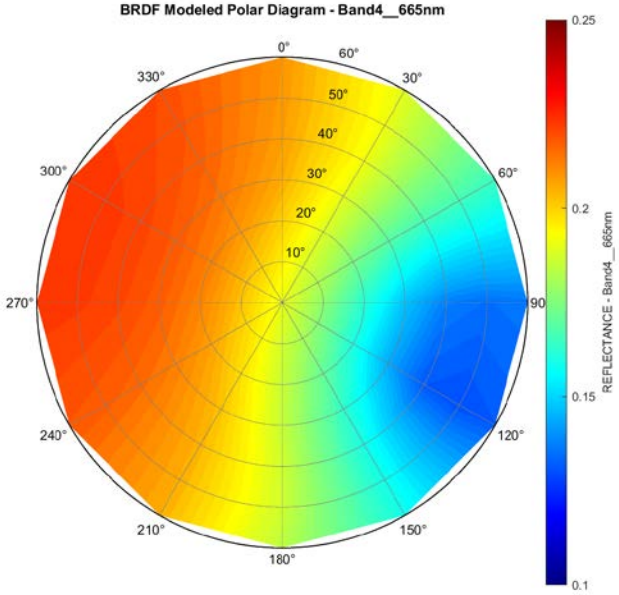
865nm





BRDF Comparison: Measured vs Model





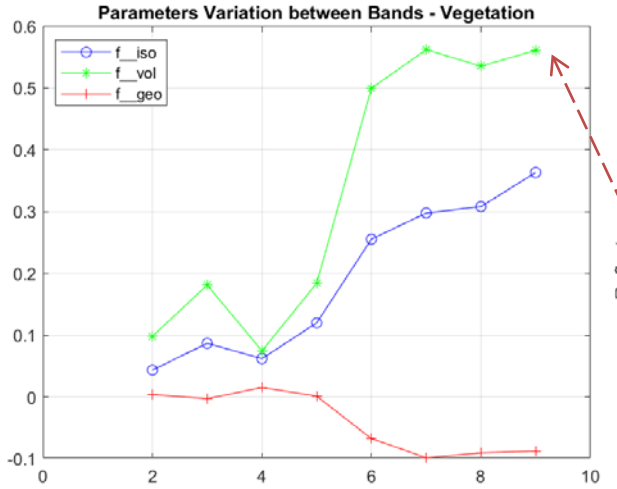
$R^2 > 0.8$

For all modeled bands

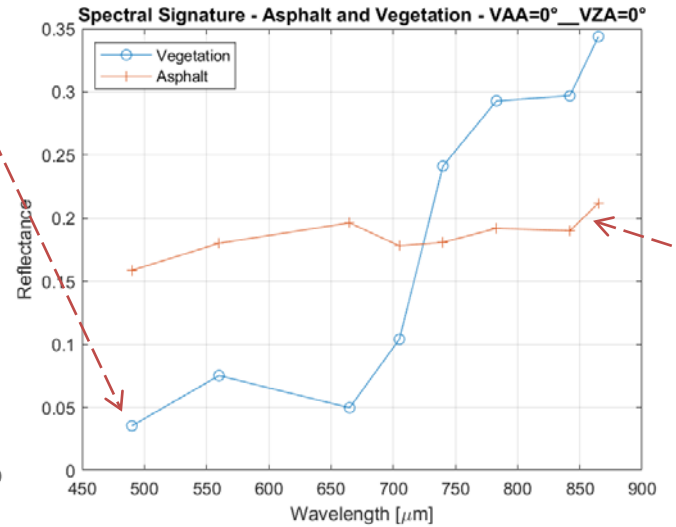
BRDF model parameters: Sensitivity and Statistical analysis

Sensitivity of Ross-Li Parameters to Surfaces and Bands

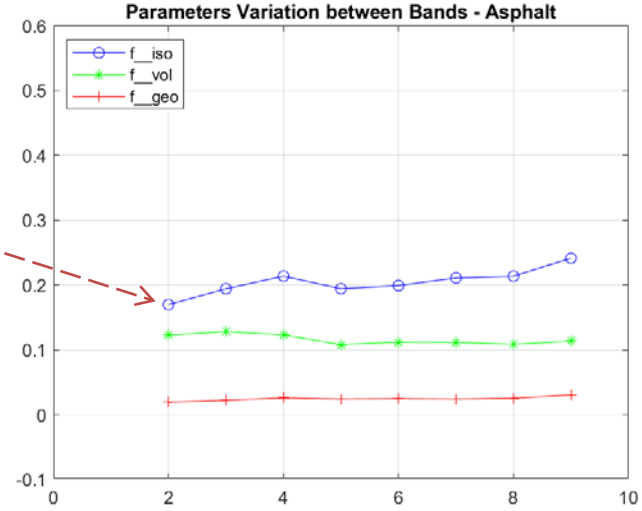
Paramaters on Veg.



Spectral Signature



Paramaters on Asph.



f_iso → predominant in Asph

f_vol → predominant in Veg

f_geo
- Asph → constant values
- Veg → some negative values and variability

$$R(\theta_s, \theta_v, \phi; \lambda) = f_{\text{iso}} + f_{\text{vol}} K_{\text{vol}}(\theta_s, \theta_v, \phi; \lambda) + f_{\text{geo}} K_{\text{geo}}(\theta_s, \theta_v, \phi; \lambda)$$

Random Uncertainty - RossLi

	MAIA Band	RMSE	CORRcoeff	f1 - f_{iso}	Confidence Interval - f1	f2 - f_{vol}	Confidence Interval - f2	f3 - f_{geo}	Confidence Interval - f3
Vegetation	Band2__490nm	0.004	0.933	0.044	0.046 - 0.042	0.098	0.109 - 0.087	0.004	0.006 - 0.002
	Band3__560nm	0.007	0.891	0.087	0.091 - 0.083	0.181	0.204 - 0.159	-0.003	0.001 - -0.007
	Band4__665nm	0.005	0.913	0.062	0.065 - 0.059	0.075	0.091 - 0.059	0.015	0.018 - 0.013
	Band5__705nm	0.009	0.859	0.12	0.125 - 0.115	0.184	0.213 - 0.155	0.002	0.007 - -0.004
	Band6__740nm	0.024	0.829	0.256	0.269 - 0.242	0.5	0.577 - 0.423	-0.067	-0.053 - -0.081
	Band7__783nm	0.032	0.813	0.298	0.315 - 0.28	0.563	0.663 - 0.462	-0.098	-0.08 - -0.116
	Band8__842nm	0.031	0.802	0.308	0.326 - 0.291	0.536	0.634 - 0.438	-0.09	-0.072 - -0.108
	Band9__865nm	0.033	0.787	0.364	0.382 - 0.345	0.561	0.666 - 0.457	-0.087	-0.068 - -0.106
Asphalt	Band1__443nm	0.012	0.848	0.168	0.176 - 0.16	0.114	0.143 - 0.085	0.017	0.024 - 0.01
	Band2__490nm	0.014	0.83	0.17	0.179 - 0.161	0.123	0.157 - 0.088	0.019	0.027 - 0.011
	Band3__560nm	0.014	0.853	0.194	0.203 - 0.185	0.128	0.162 - 0.094	0.022	0.03 - 0.014
	Band4__665nm	0.014	0.863	0.214	0.223 - 0.205	0.123	0.157 - 0.089	0.026	0.034 - 0.018
	Band5__705nm	0.012	0.862	0.194	0.202 - 0.186	0.108	0.139 - 0.077	0.024	0.031 - 0.017
	Band6__740nm	0.012	0.867	0.199	0.207 - 0.191	0.112	0.143 - 0.081	0.025	0.032 - 0.017
	Band7__783nm	0.012	0.874	0.211	0.219 - 0.203	0.112	0.141 - 0.082	0.024	0.031 - 0.017
	Band8__842nm	0.011	0.884	0.214	0.221 - 0.206	0.108	0.137 - 0.08	0.025	0.032 - 0.019
	Band9__865nm	0.013	0.887	0.241	0.25 - 0.233	0.113	0.145 - 0.082	0.03	0.038 - 0.023

Comparison with RossLi Parameters from literature

Table 2 The f_{iso}, f_{vol}, and f_{geo} of the RossThick–LiSparse model for the WFI sensor.

Band	f_{iso}	f_{vol}	f_{geo}
Band1	0.1936	0.1193	0.0199
Band2	0.2323	0.1331	0.0258
Band3	0.2566	0.1373	0.0298
Band4	0.2656	0.1308	0.0322

Pan, Z., Zhang, H., Min, X., & Xu, Z. (2020). Vicarious calibration correction of large FOV sensor using BRDF model based on UAV angular spectrum measurements. Journal of Applied Remote Sensing, 14(2), 027501.

CoverType: Bare soil

RossLi									
Band	CoverType	RMSE	CORRcoeff_RL	f1 - fiso	Confidence Interval - f1	f2 - fvol	Confidence Interval - f2	f3 - fgeo	Confidence Interval - f3
Band2__490nm	Vegetation	0.004	0.933	0.044	0.046 - 0.042	0.098	0.109 - 0.087	0.004	0.006 - 0.002
Band3__560nm	Vegetation	0.007	0.891	0.087	0.091 - 0.083	0.181	0.204 - 0.159	-0.003	0.001 - -0.007
Band4__665nm	Vegetation	0.005	0.913	0.062	0.065 - 0.059	0.075	0.091 - 0.059	0.015	0.018 - 0.013
Band8__842nm	Vegetation	0.031	0.802	0.308	0.326 - 0.291	0.536	0.634 - 0.438	-0.09	-0.072 - -0.108
Band2__490nm	Asphalt	0.014	0.83	0.17	0.179 - 0.161	0.123	0.157 - 0.088	0.019	0.027 - 0.011
Band3__560nm	Asphalt	0.014	0.853	0.194	0.203 - 0.185	0.128	0.162 - 0.094	0.022	0.03 - 0.014
Band4__665nm	Asphalt	0.014	0.863	0.214	0.223 - 0.205	0.123	0.157 - 0.089	0.026	0.034 - 0.018
Band8__842nm	Asphalt	0.011	0.884	0.214	0.221 - 0.206	0.108	0.137 - 0.08	0.025	0.032 - 0.019

Conclusions

- Develop of an automatic and repeatable flight plan for acquiring multi-angular UAV dataset using a multispectral camera Sentinel-2 likes.
- Planning and execution of automatic and repeatable UAV surveys over different landcover types.
- Dataset processed and applied for the estimation of BRDF parameters of Ross-Li linear model.
- Sensitivity and statistical analyses of BRDF parameters have been carried out.
- Participation to SRIX4VEG initiative in Barrax (ES) planned in July 2022.
- Extension of the activities to second phase of QA4EO.

Thanks

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