Validation of Space-based Global Albedo Products by upscaling from Ground-based Measurements*

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*JRC GbOV project led by ACRI-ST

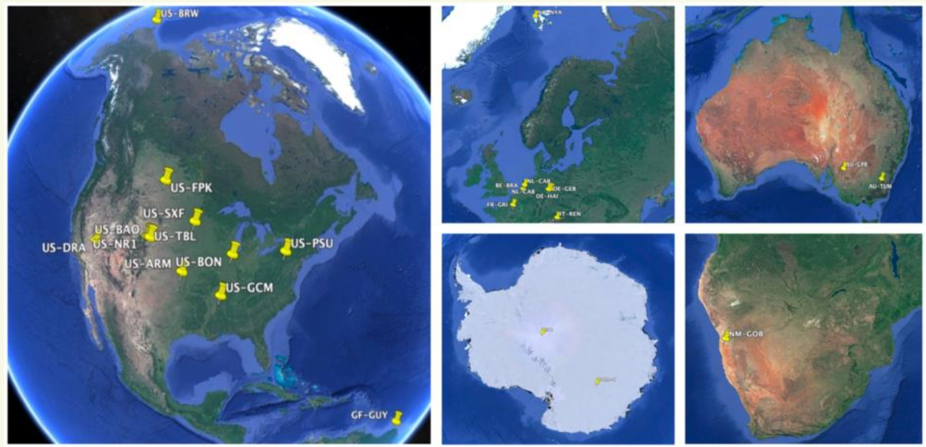
Ground-based Observations for Validation (GbOV)

- GbOV aims to provide tower-based quality-controlled land surface parameter datasets for validation of Copernicus Global Land Surface products (and comparable EO data)

- Quality assured radiance & irradiance **REFERENCE MEASUREMENTS** (**RM1**) for 24 tower sites of existing networks (SURFRAD, FLUXNET, BSRN)

- RM1 processed over FoV ≤ 500m into **Top-of-Canopy Reflectance** (ToC-R, **LP1**) & Shortwave Albedos, **LP2** {DHR (Direct Hemispherical Reflectance) and BHR (Bi-hemispherical diffuse Reflectance)}.

- **LP1** & **LP2** then upscaled to CGLS via VHR-EO BRF/albedos.



Europe:	7 sites	**Africa:**	1 site
North America:	11 sites	**Australia:**	2 sites
South America:	1 site	**Antarctica:**	2 sites

Tower albedometer example

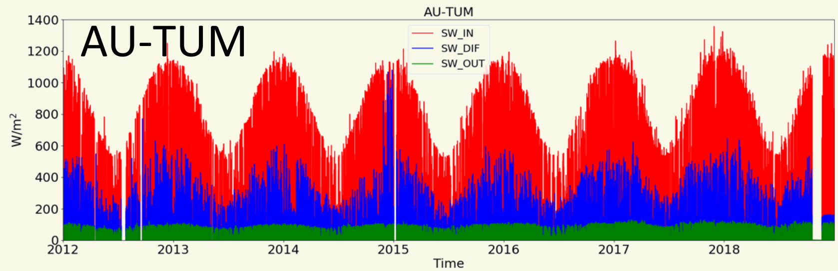
Photos of 70m Tumbarumba Flux tower, and example location and example of CNR4 albedometer (extreme right). Courtesy of Dr William Woodgate, CSIRO Australia

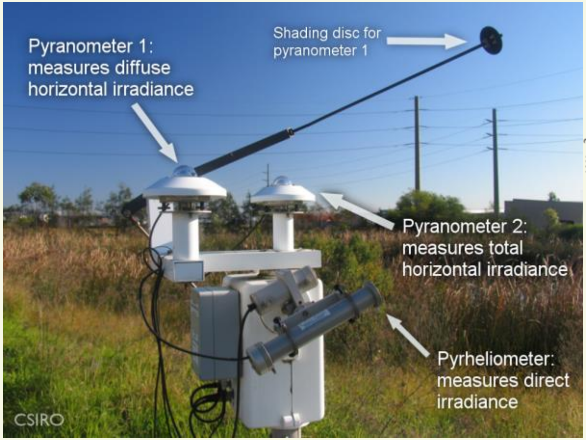
Example of albedometer measurements

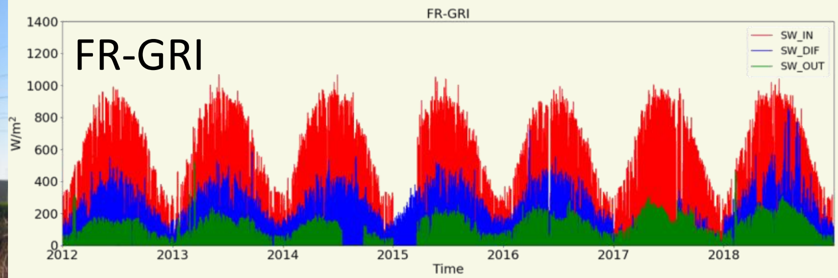
SW_IN

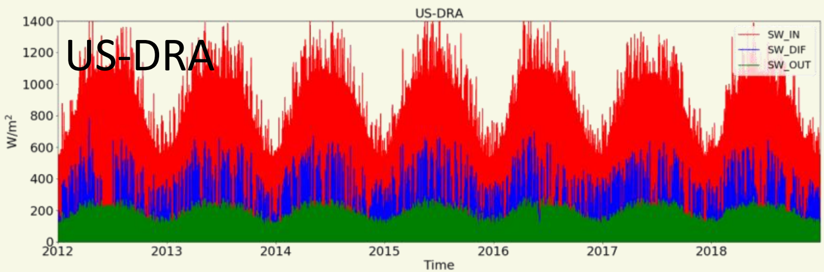
SW_DIF*

SW_OUT









Some sites also have diffuse Pyranometer measurements

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BRDF inversion from albedometer measurements

The bidirectional reflectance distribution function (BRDF)

The BRDF employed here to derive tower measured ToC-R and DHR is the semi-empirical linear model of (Roujean, 1992) where the reflectance is represented as follows:

$$R(\lambda, \theta_{in}, \theta_{out}, \varphi) = k_0(\lambda) + k_1(\lambda) f_1(\theta_{in}, \theta_{out}, \varphi) + k_2(\lambda) f_2(\theta_{in}, \theta_{out}, \varphi)$$

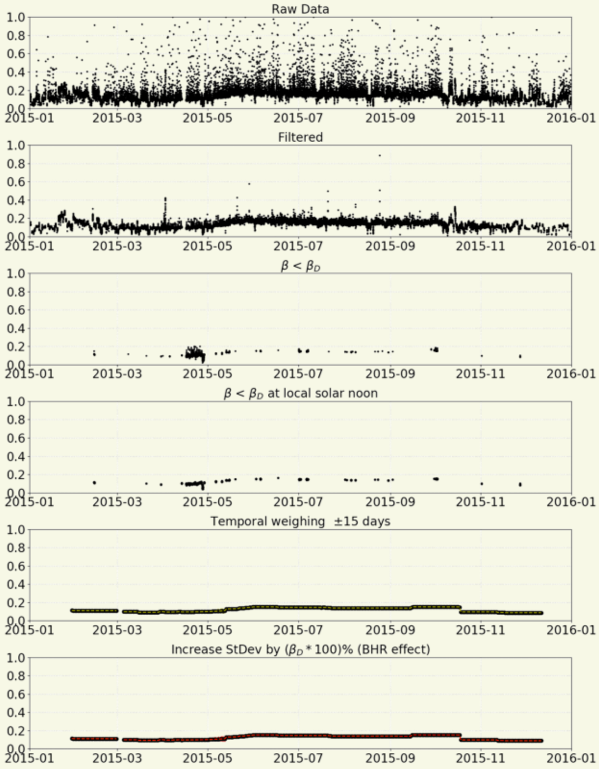
To derive the kernel parameters (k_0, k_1, k_2) of the BRDF model, tower measurements from different solar geometries and downwelling sky diffuse radiation are combined.

$$\frac{SW\_OUT}{SW\_IN} \approx DHR, if \ \frac{SW\_DIF}{SW\_IN} < 0.1$$

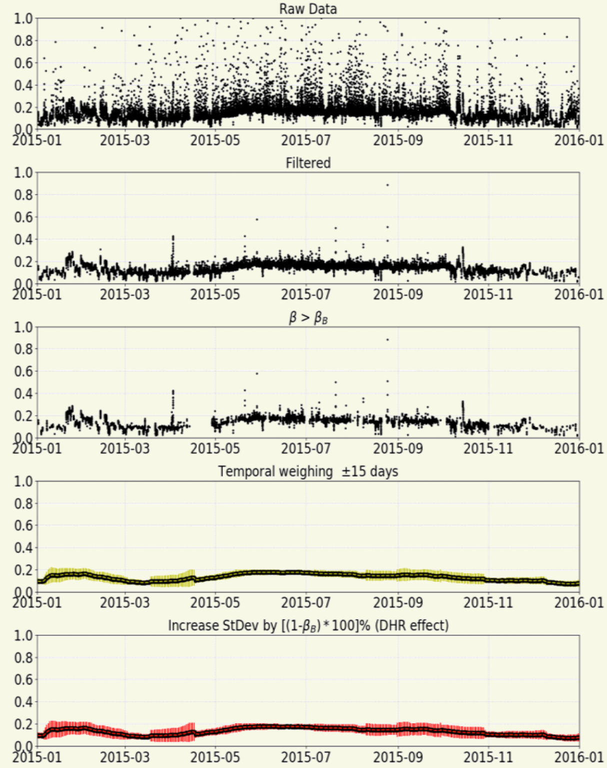
$$\frac{SW\_OUT}{SW\_IN} \approx BHR, if \ \frac{SW\_DIF}{SW\_IN} > 0.99$$

θ_{in}	I_0^{dhr}	I_1^{dhr}	I_2^{dhr}
0°	1.0	-0.997910	-0.00894619
5°	1.0	-0.998980	-0.00837790
10°	1.0	-1.00197	-0.00665391
15°	1.0	-1.00702	-0.00371872
20°	1.0	-1.01438	0.000524714
25°	1.0	-1.02443	0.00621877
30°	1.0	-1.03773	0.0135606
35°	1.0	-1.05501	0.0228129
40°	1.0	-1.07742	0.0343240
45°	1.0	-1.10665	0.0485505
50°	1.0	-1.14526	0.0661051
55°	1.0	-1.19740	0.0878086
60°	1.0	-1.27008	0.114795
65°	1.0	-1.37595	0.148698
70°	1.0	-1.54059	0.191944
75°	1.0	-1.82419	0.248471
80°	1.0	-2.40820	0.325351
85°	1.0	-4.20369	0.438371
--	I_0^{bhr}	I_1^{bhr}	I_2^{bhr}
	1.0	−1.28159	0.0802838

Example of processed in-situ DHR and BHR



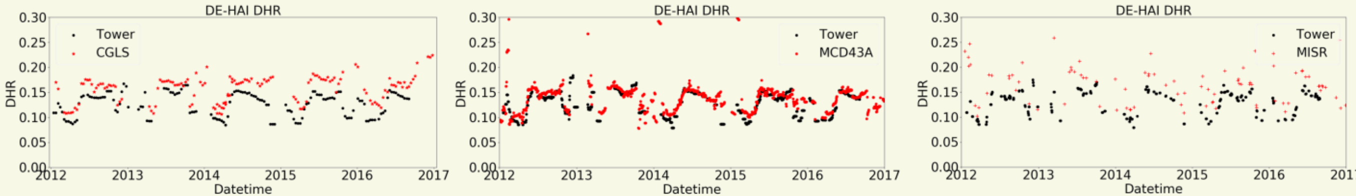
in-situ tower DHR at FLUXNET Hainich



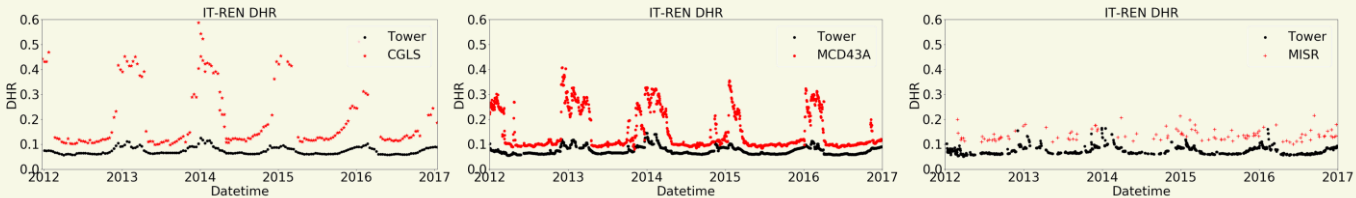
in-situ tower BHR at FLUXNET Hainich

Albedo DHR: tower vs. CGLS, MODIS, MISR

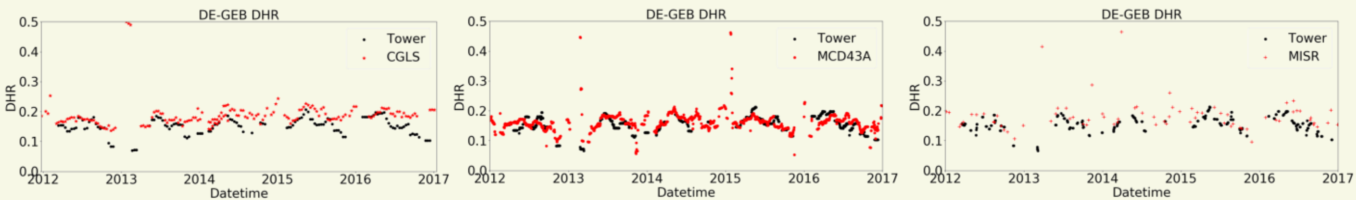
DE-Hainich



IT-Renon



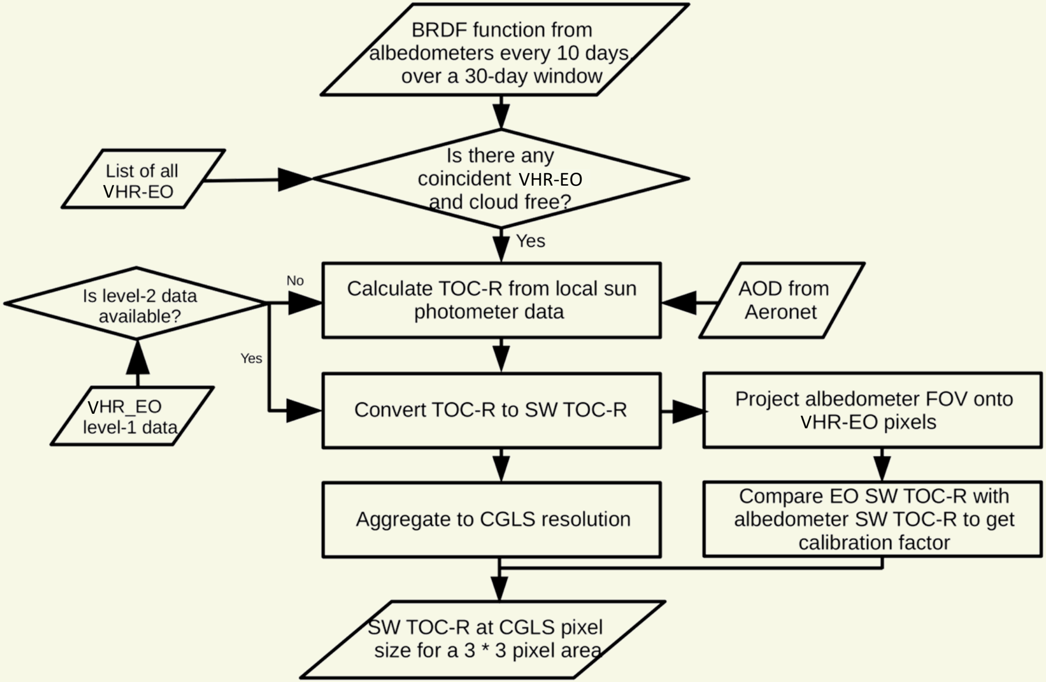
DE-Gebesse



CGLS MODIS MISR

How to use *in situ* DHR/BHR and TOC-R?

Upscale *in situ* DHR and BHR to coarse resolution using VHR-EO data, and compare with coarse-resolution EO products.



SIAC atmospheric correction method

SIAC is an open source sensor invariant Atmospheric Correction method, developed by Feng Yin *et al* from the Department of Geography, UCL.

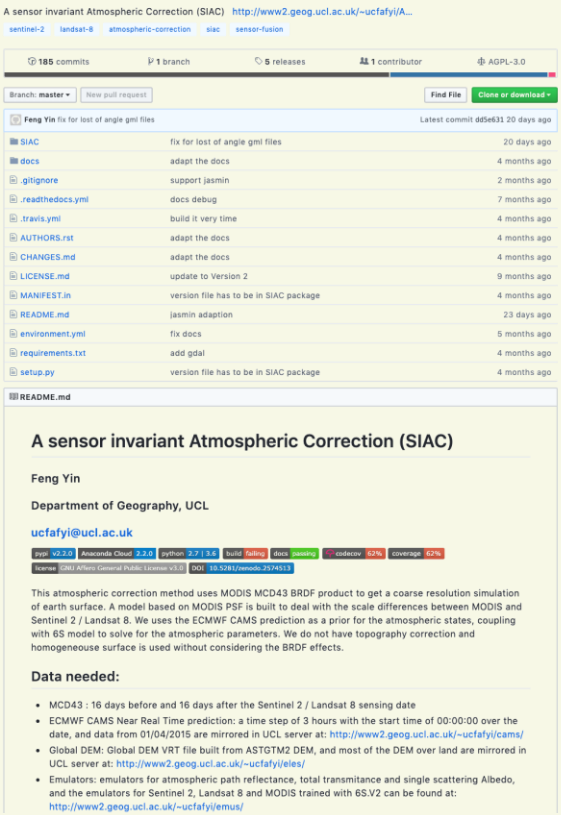
Advantages:

- ➢ It explicitly considers the effect of surface BRDF.
- ➢ It does not rely on AERNOET aerosol measurements.
- ➢ It has uncertainty estimation for every single pixel.

The current version works on:

- Landsat-8 (original implementation)
- Sentinel-2 (new implementation)

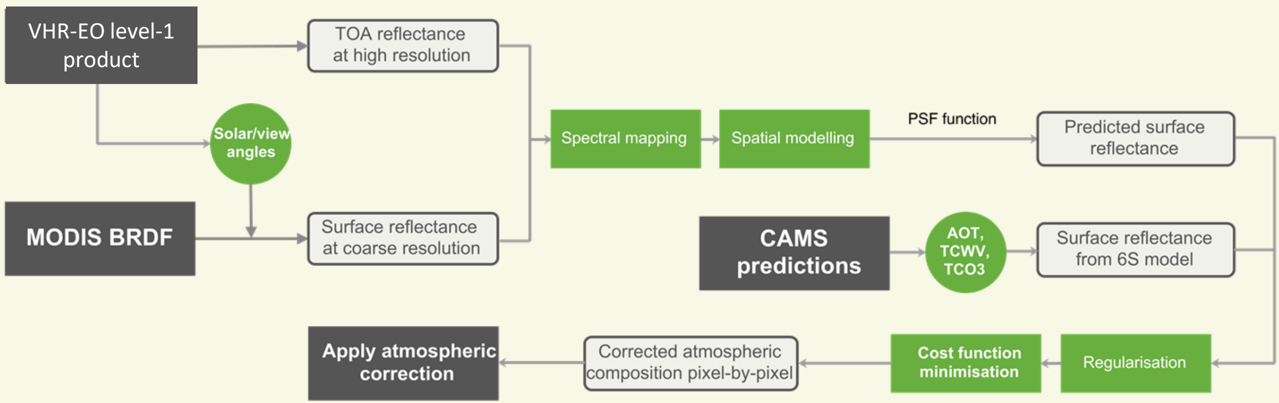
https://github.com/MarcYin/SIAC



SIAC atmospheric correction method

A streamlined version of SIAC has been developed which can automatically:

1) search for cloud-free Sentinel-2 level-1 data;
2) download level-1 data from AWS;
3) calculate surface reflectance and uncertainty values for each pixel using the SIAC method.



Input data:

- VHR-EO level-1 data (10m/20m)
- MODIS BRDF (MCD43) 500m
- CAMS (ECMWF) 2.5 km

Output data:

- VHR-EO surface reflectance data (10m/20m)
- Estimated uncertainty value for every pixel

SIAC atmospheric correction method

US-PSU: 2018-05-24

TOA (Top-of-Atmosphere)

ToC (Bottom-of-Atmosphere)

SIAC atmospheric correction method

US-PSU: 2018-05-09

TOA (Top-of-Atmosphere)

ToC (Bottom-of-Atmosphere)

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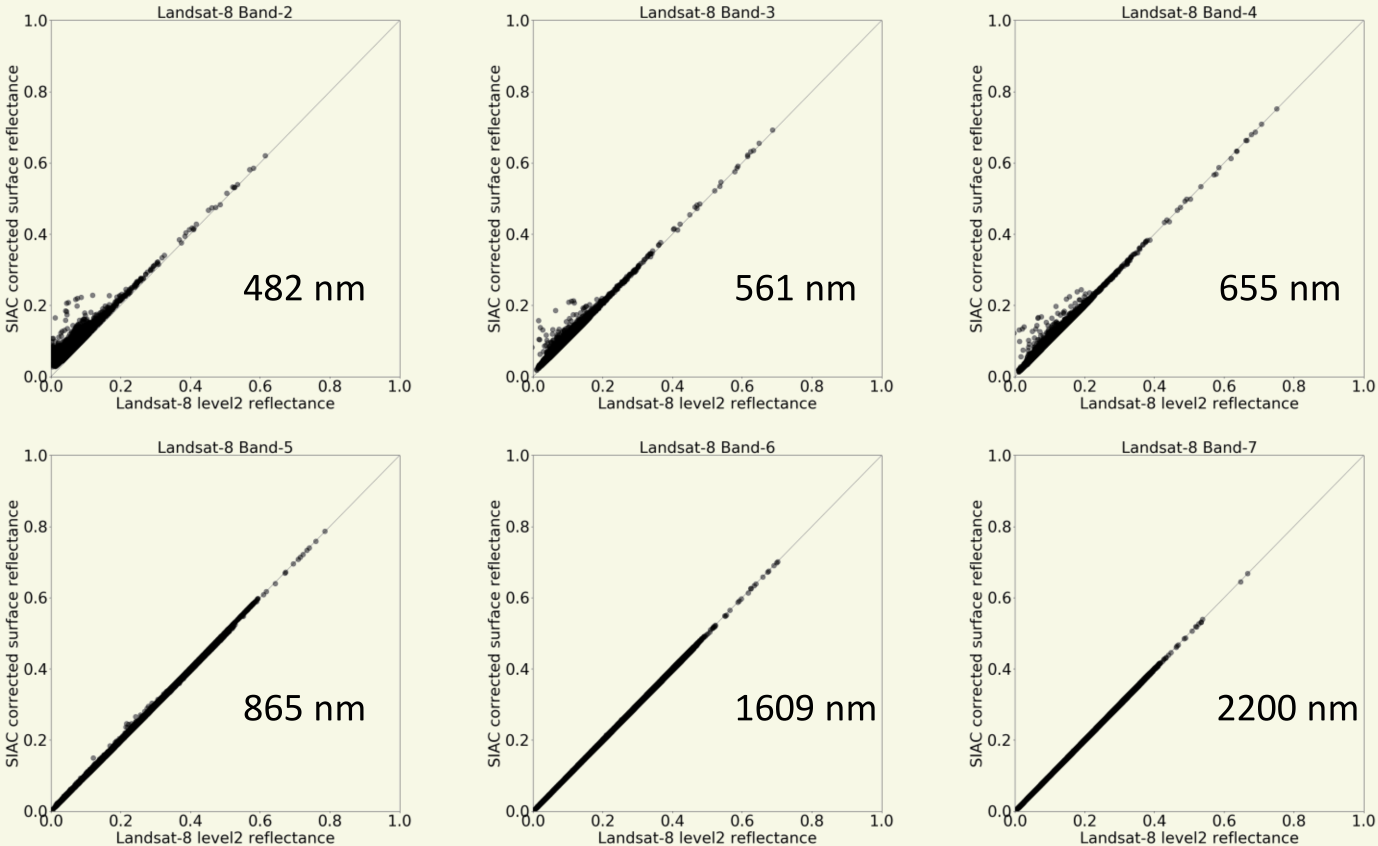
Streamlined SIAC vs Landsat-8 level-2



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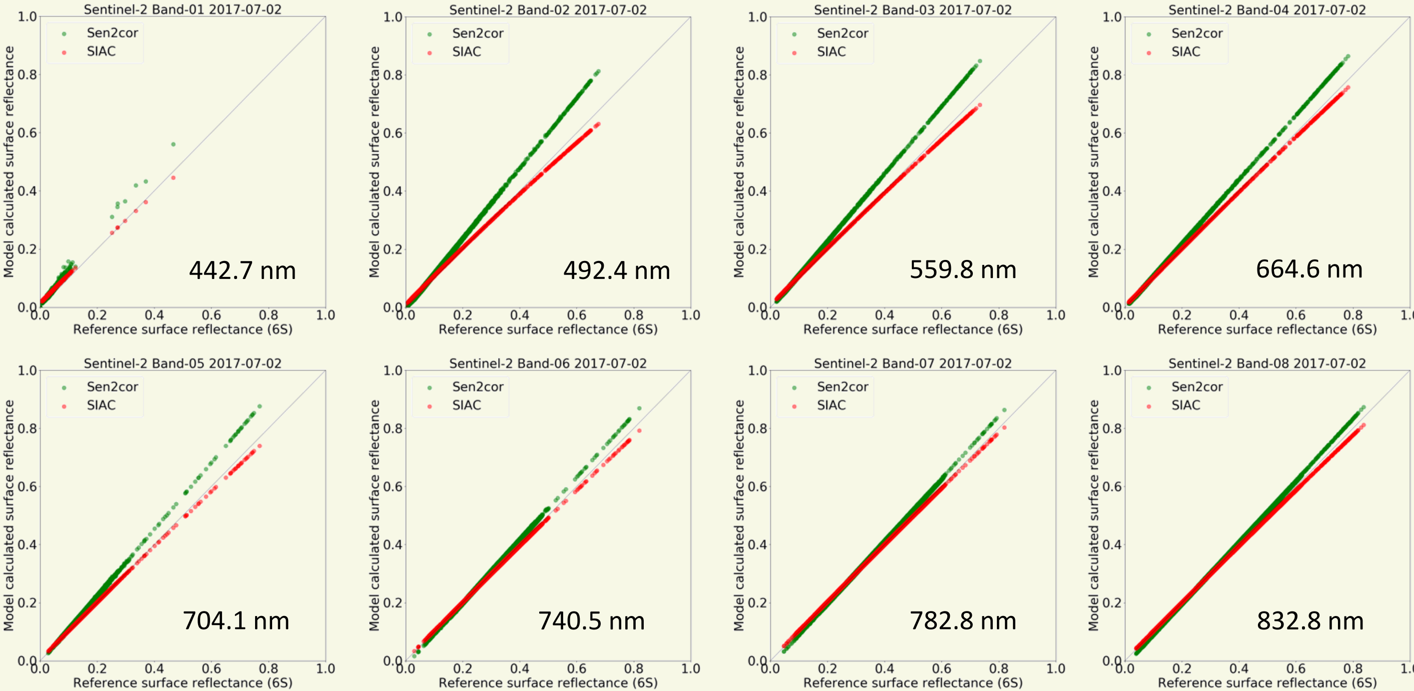
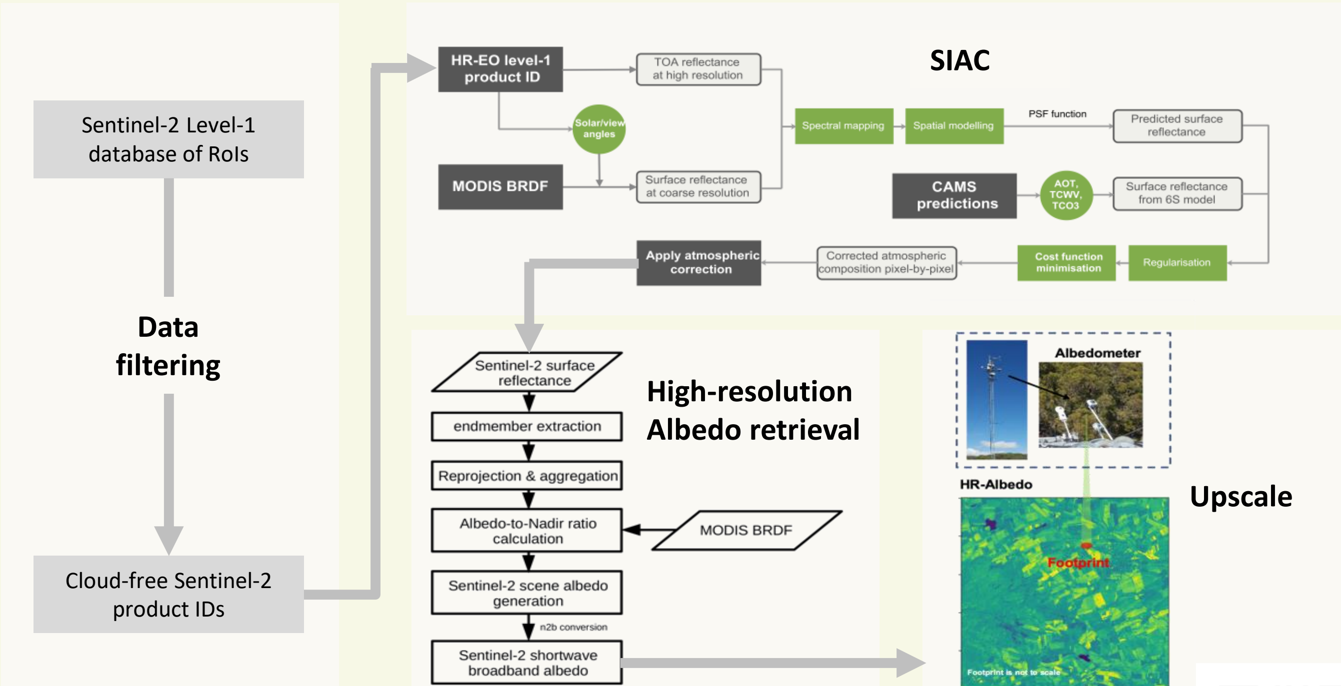
Streamlined SIAC vs Sen2cor vs 6S (with AERONET)



LP1 & LP2 processing chain



[1]: Song, R.; Muller, J.-P.; Kharbouche, S.; Woodgate, W. Intercomparison of Surface Albedo Retrievals from MISR, MODIS, CGLS Using Tower and Upscaled Tower Measurements. *Remote Sens.* **2019**, *11*, 644.

Uncertainty estimation of LP1/LP2 products

SIAC method uncertainty → Uncertainty of surface reflectance for every pixel

at the pixel-level

$$\sigma_{SW_{absolute}(Sentinel-2)} = 0.356\sigma_{b2} + 0.130\sigma_{b4} + 0.373\sigma_{b8} + 0.085\sigma_{b11} + 0.072\sigma_{b12} - 0.018$$

$$\sigma_{SW_{relative}} = \sigma_{SW_{absolute}} / BRF_{SW}$$

Uncertainty of tower data. → Uncertainty of tower derived albedo values

σ_{daily}

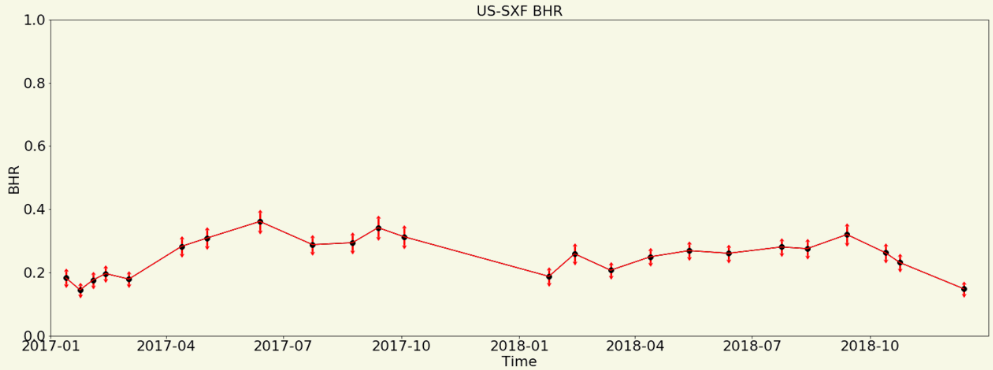
5% at the 95% confidence level

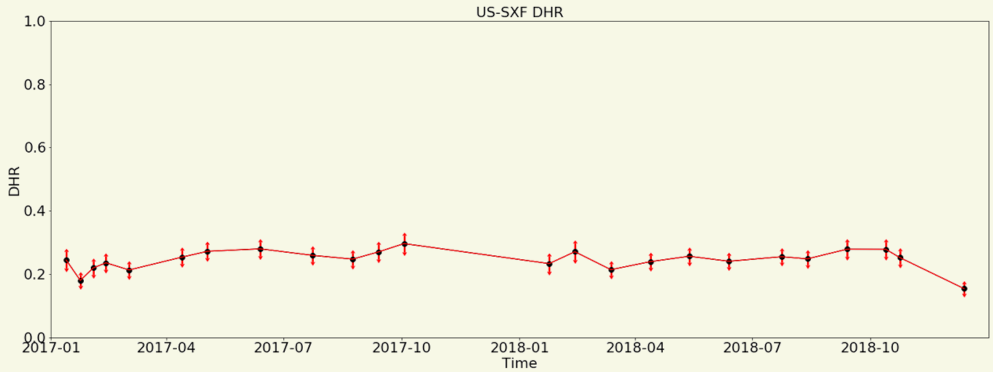
$$\sigma_{in-situ} = \frac{\sigma_{daily}}{\sqrt{N}}$$

Uncertainty of surface reflectance for every pixel + Uncertainty of tower derived albedo values → Total uncertainties for upscaled albedo values.

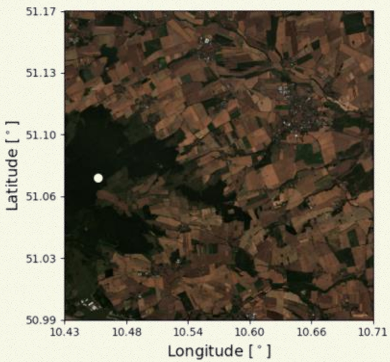
$$\sigma = \sigma_{in-situ} + \sigma_{SW_{relative}}$$

Example of upscaled albedo with uncertainties

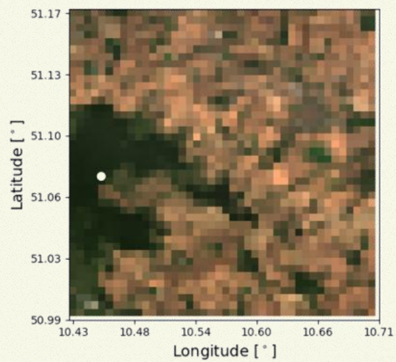




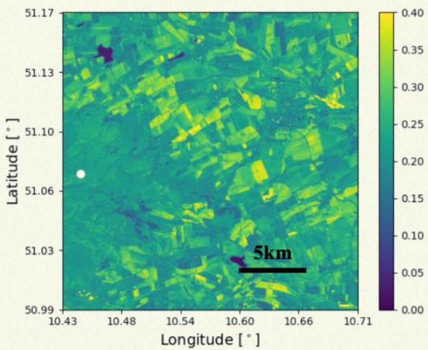
Preliminary example of VHR-albedo generation



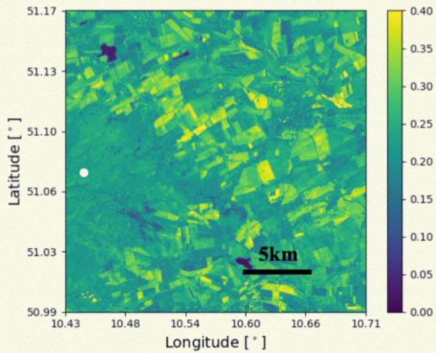
RGB composite of surface reflectance over the Hainich site at Sentinel-2 resolution (20m)



RGB composite of surface reflectance over the Hainich site after aggregation to MODIS resolution (500m)



Calculated 20m high-resolution SW-DHR over the Hainich site on 6th August, 2015



Calculated 20m high-resolution SW-BHR over the Hainich site on 6th August, 2015

Next steps

- Add 7 new sites (5 in Australia and 2 in Europe) with albedometer measurements into the network for CGLS albedo calculation and upscaling.
- Install an albedometer instrument at Skukuza station, Kruger National Park (South Africa) on 23 m height tower and collect data for albedo retrievals.
- Start the VHR-AlbedoMap project (ESA Science for Society programme), which aims to generate 10m global spectral and broadband albedos for precision agriculture.