

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

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21<sup>st</sup> November 2019

\*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)

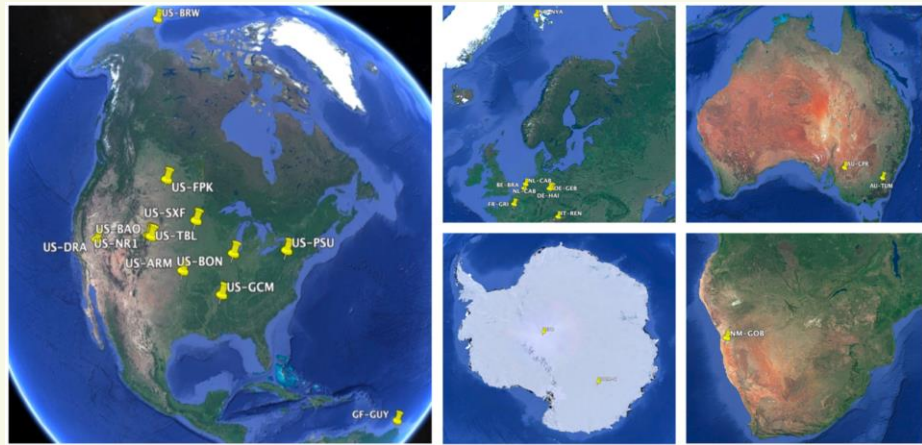
- Quality assured radiance & irradiance

### REFERENCE MEASUREMENTS

(RM1) for 24 tower sites of existing networks (SURFRAD, FLUXNET, BSRN)

- RM1 processed over FoV  $\leq 500m$  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  
**North America:** 11 sites  
**South America:** 1 site

**Africa:** 1 site  
**Australia:** 2 sites  
**Antarctica:** 2 sites

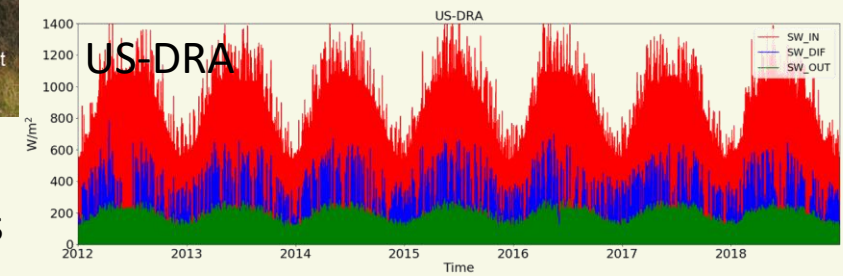
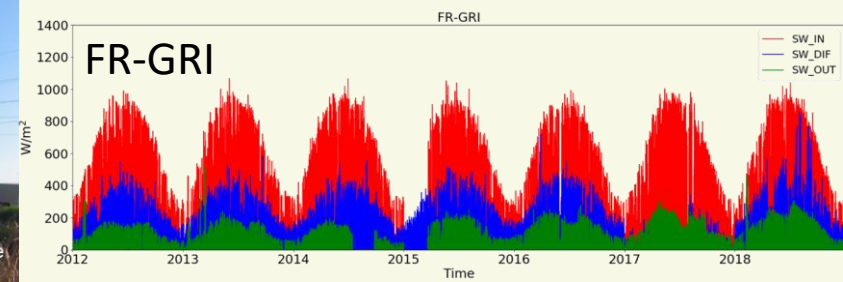
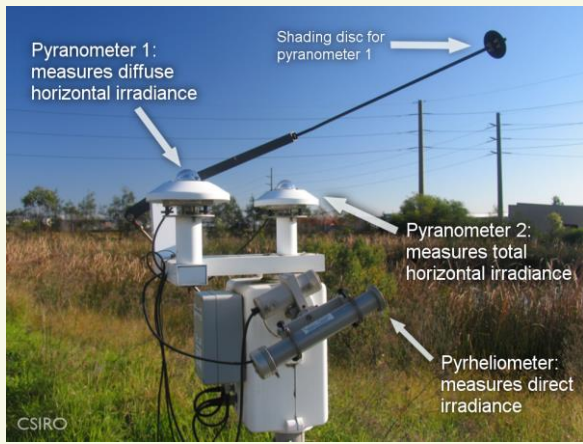
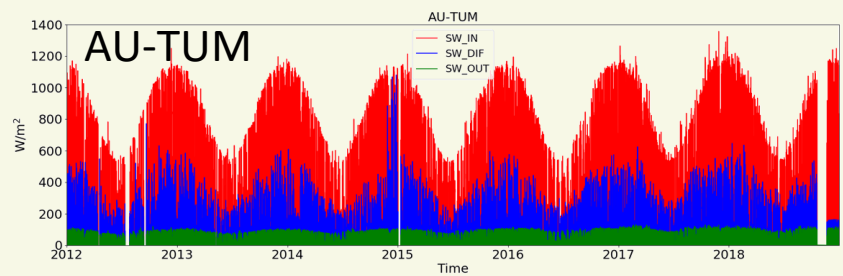
# Tower albedometer example



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

## 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:

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

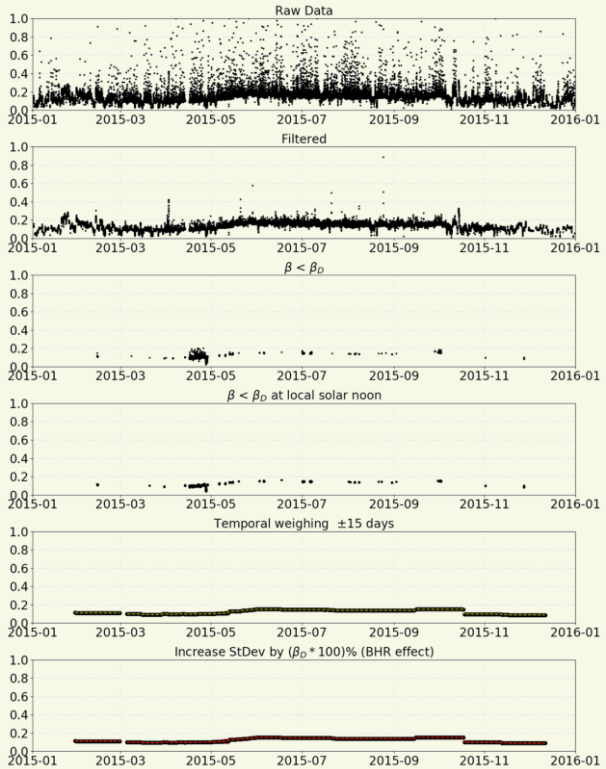
To derive the kernel parameters ( $k_0$ ,  $k_1$ ,  $k_2$ ) of the BRDF model, tower measurements from different solar geometries and downwelling sky diffuse radiation are combined.

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

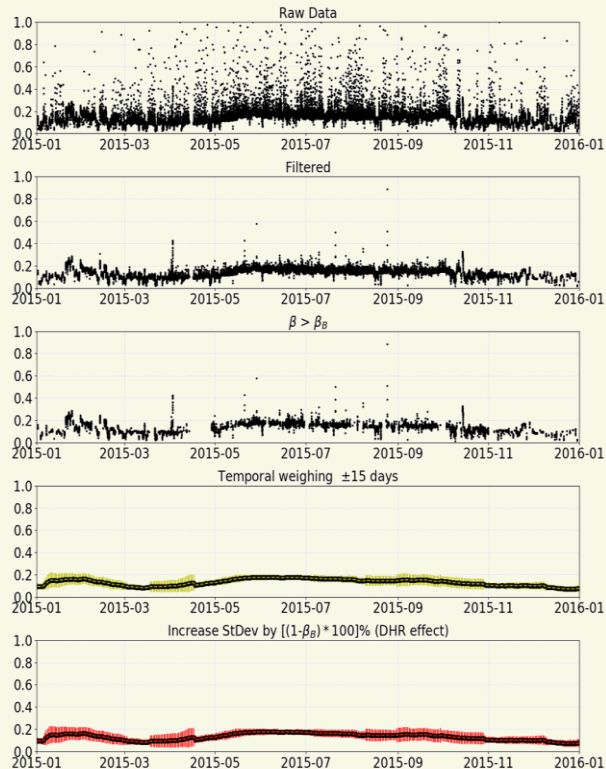
$$\frac{SW\_OUT}{SW\_IN} \approx BHR, \text{ if } \frac{SW\_DIF}{SW\_IN} > 0.99$$

$\theta_{in}$	$I_0^{dhr}$	$I_1^{dhr}$	$I_2^{dhr}$
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



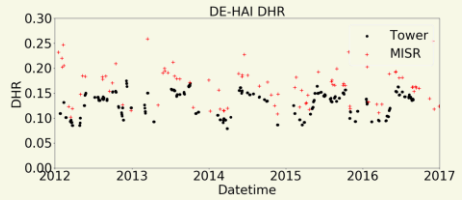
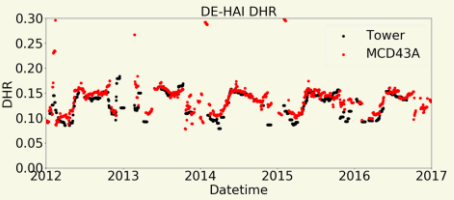
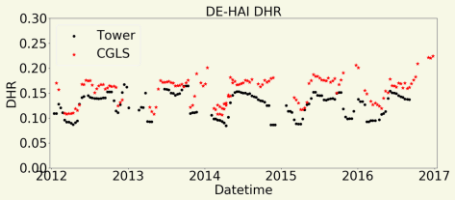
in-situ tower DHR at FLUXNET Hainich



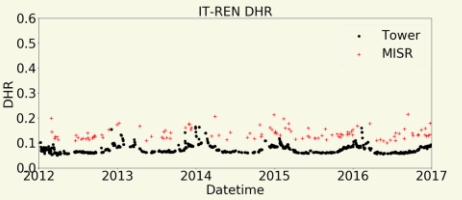
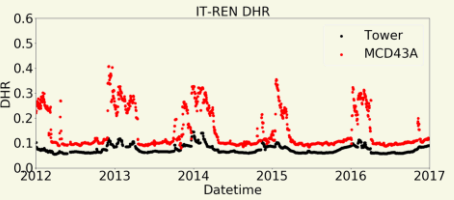
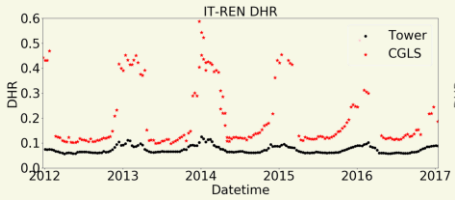
in-situ tower BHR at FLUXNET Hainich

# Albedo DHR: tower vs. CGLS, MODIS, MISR

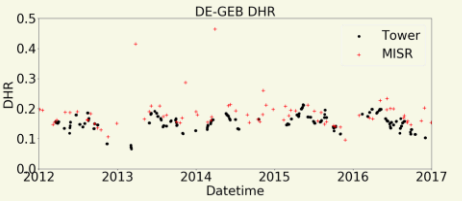
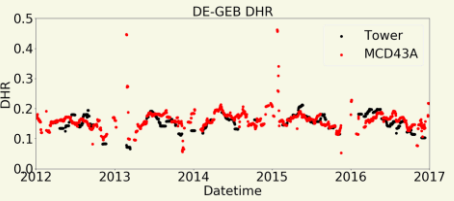
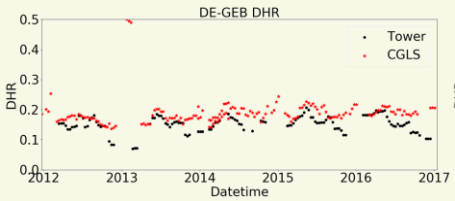
## DE-Hainich



## IT-Renon



## DE-Gebesse



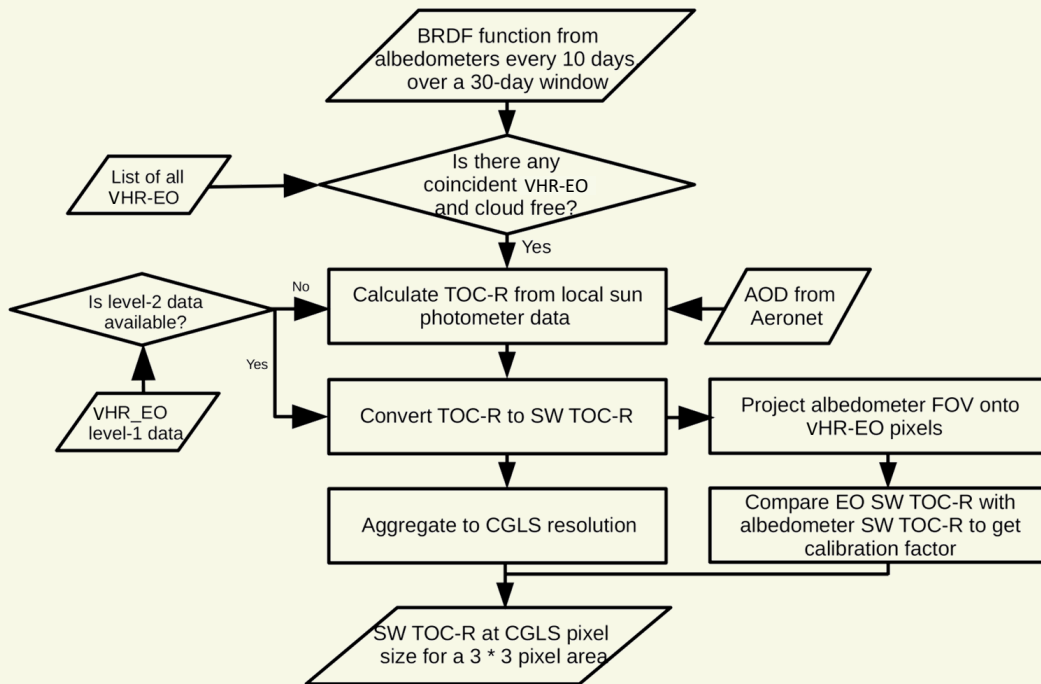
CGLS

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>

A sensor invariant Atmospheric Correction (SIAC) <http://www2.geog.ucl.ac.uk/~ucfafyi/A...>

sentinel-2 landsat-8 atmospheric-correction siac sensor-fusion

125 commits 1 branch 5 releases 1 contributor AGPL-3.0

Branch: master New pull request Find File Clone or download

Feng Yin fix for lost of angle gmi files Latest commit d5e631 20 days ago

SIAC	fix for lost of angle gmi files	20 days ago
docs	adapt the docs	4 months ago
gltignore	support jasmim	2 months ago
.readthedocs.yml	docs debug	7 months ago
travis.yml	build it very time	4 months ago
AUTHORS.rst	adapt the docs	4 months ago
CHANGES.md	adapt the docs	4 months ago
LICENSE.md	update to Version 2	9 months ago
MANIFEST.in	version file has to be in SIAC package	4 months ago
README.md	jasmim adaption	23 days ago
environment.yml	fix docs	5 months ago
requirements.txt	add gdal	4 months ago
setup.py	version file has to be in SIAC package	4 months ago

README.md

### A sensor invariant Atmospheric Correction (SIAC)

Feng Yin

Department of Geography, UCL

[ucfafyi@ucl.ac.uk](http://ucfafyi@ucl.ac.uk)

Python 3.7.13 Build failing docs passed coverage 62%

License: OSI Approved: General Public License v3.0 DOI: 10.5281/zenodo.2548153

This atmospheric correction method uses MODIS MCD43 BRDF product to get a coarse resolution simulation of earth surface. A model based on MODIS PSF is built to deal with the scale differences between MODIS and Sentinel 2 / Landsat 8. We uses the ECMWF CAMS prediction as a prior for the atmospheric states, coupling with 6S model to solve for the atmospheric parameters. We do not have topography correction and homogeneous surface is used without considering the BRDF effects.

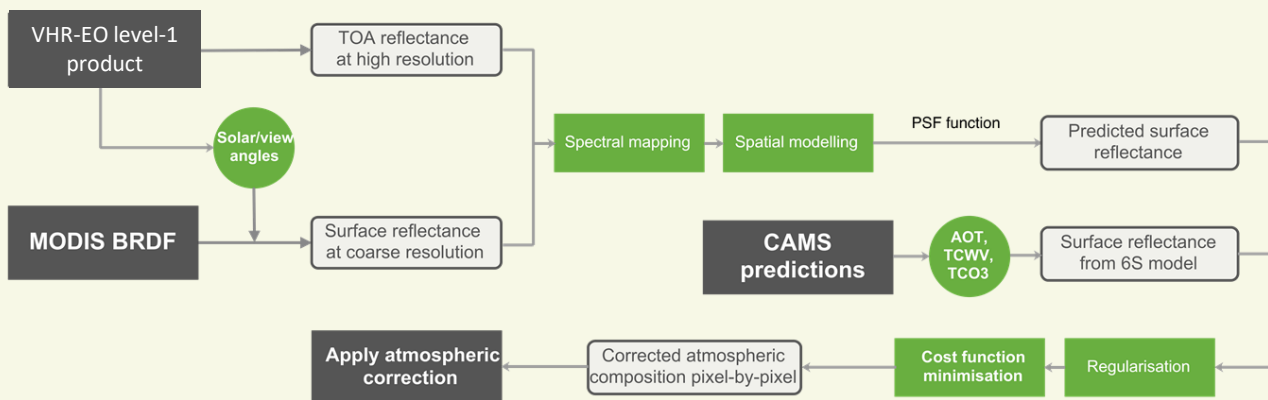
#### Data needed:

- MCD43 : 16 days before and 16 days after the Sentinel 2 / Landsat 8 sensing date
- ECMWF CAMS Near Real Time prediction: a time step of 3 hours with the start time of 00:00:00 over the date, and data from 01/04/2015 are mirrored in UCL server at: <http://www2.geog.ucl.ac.uk/~ucfafyi/cams/>
- Global DEM: Global DEM VRT file built from ASTGTM2 DEM, and most of the DEM over land are mirrored in UCL server at: <http://www2.geog.ucl.ac.uk/~ucfafyi/eles/>
- Emulators: emulators for atmospheric path reflectance, total transmittance and single scattering Albedo, and the emulators for Sentinel 2, Landsat 8 and MODIS trained with 6S V2 can be found at: <http://www2.geog.ucl.ac.uk/~ucfafyi/emus/>

## 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:

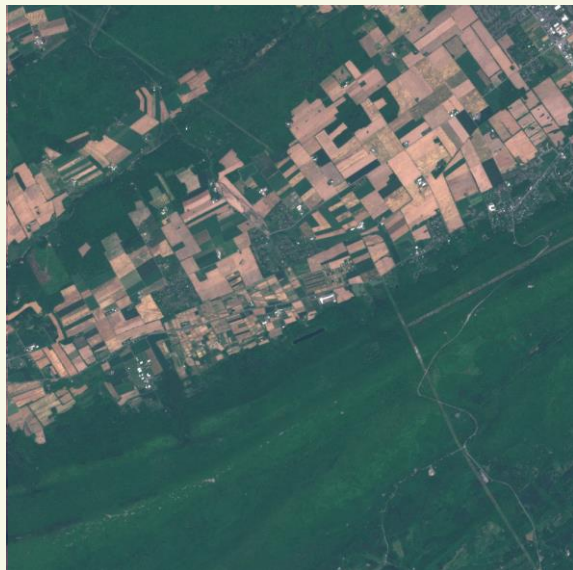
- VHR-EO level-1 data (10m/20m)
- MODIS BRDF (MCD43) 500m
- CAMS (ECMWF) 2.5 km

### 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**

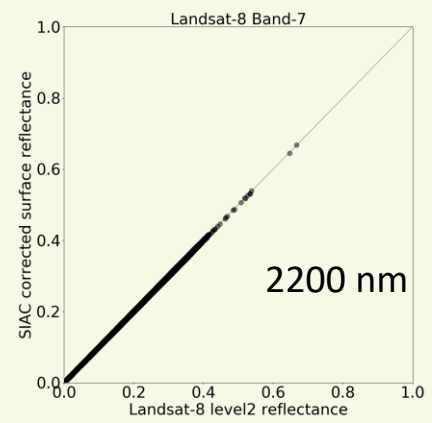
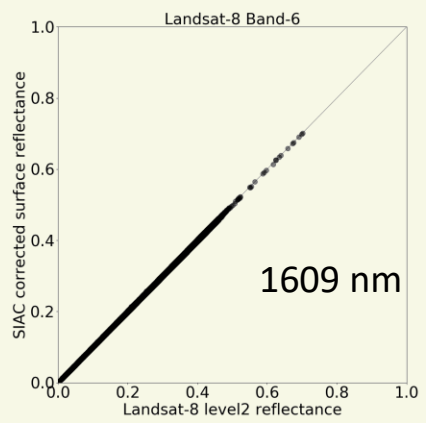
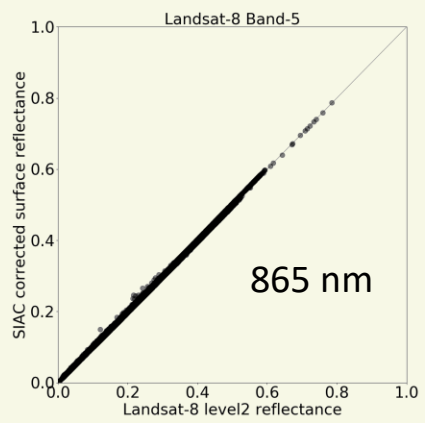
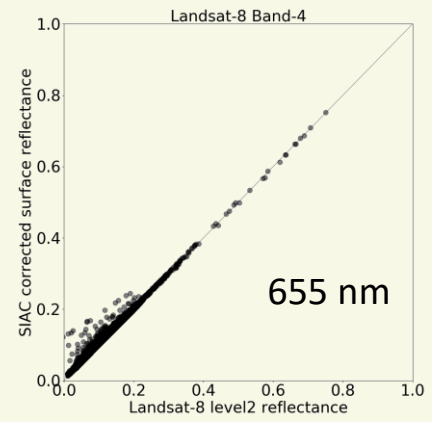
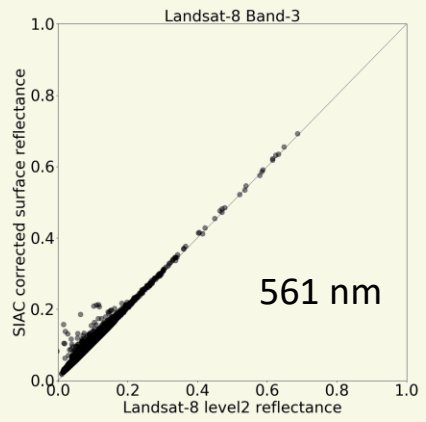
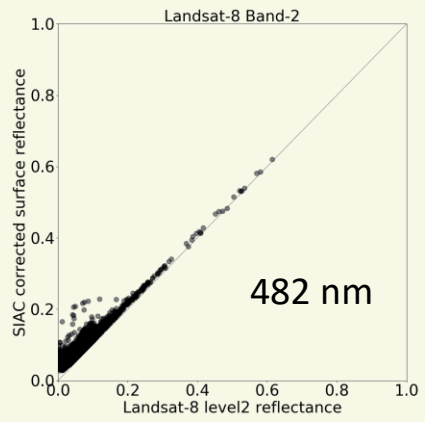


TOA (Top-of-Atmosphere)



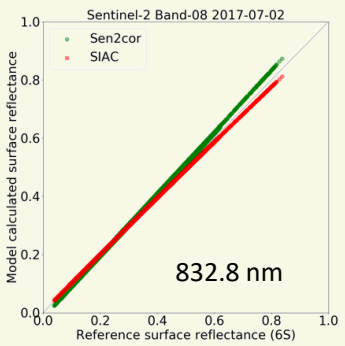
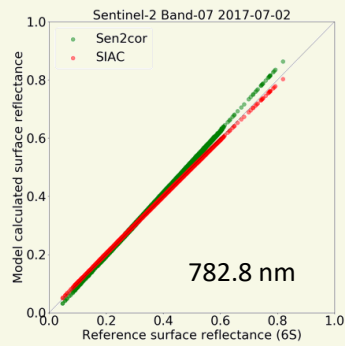
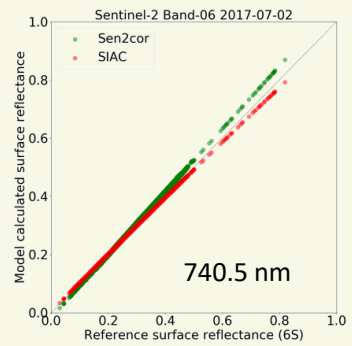
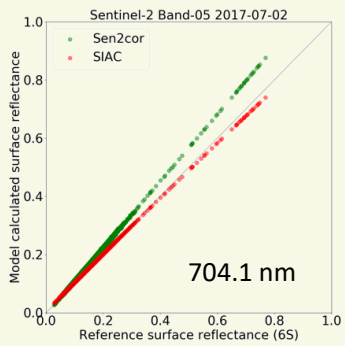
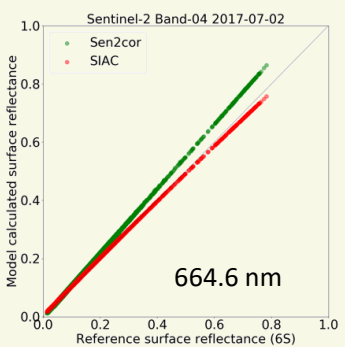
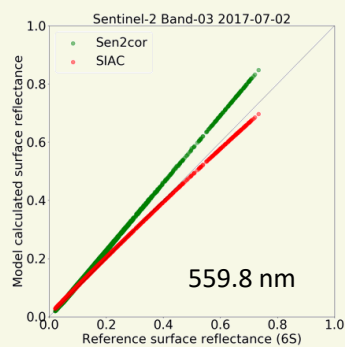
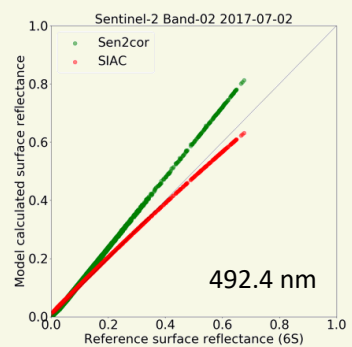
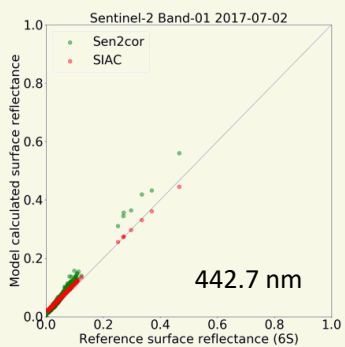
ToC (Bottom-of-Atmosphere)

# Streamlined SIAC vs Landsat-8 level-2

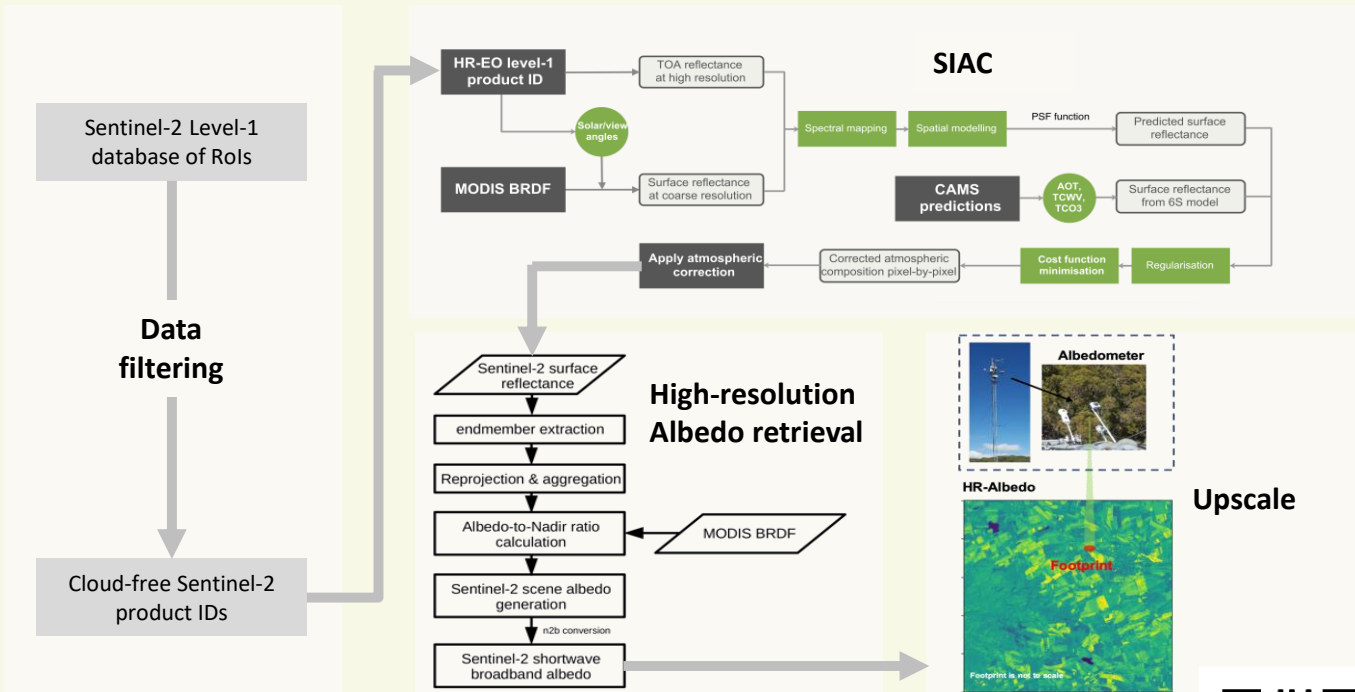




## Streamlined SIAC vs Sen2cor vs 6S (with AERONET)



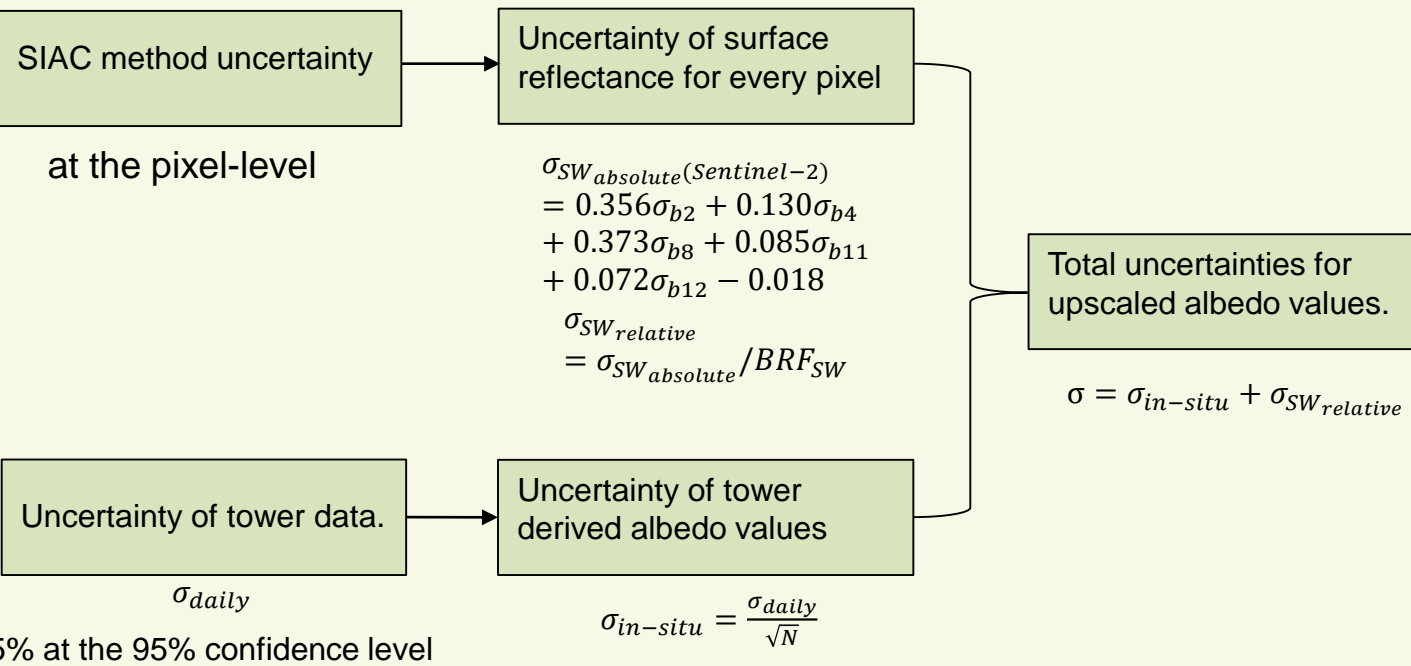
LP1 & LP2 processing chain



[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.

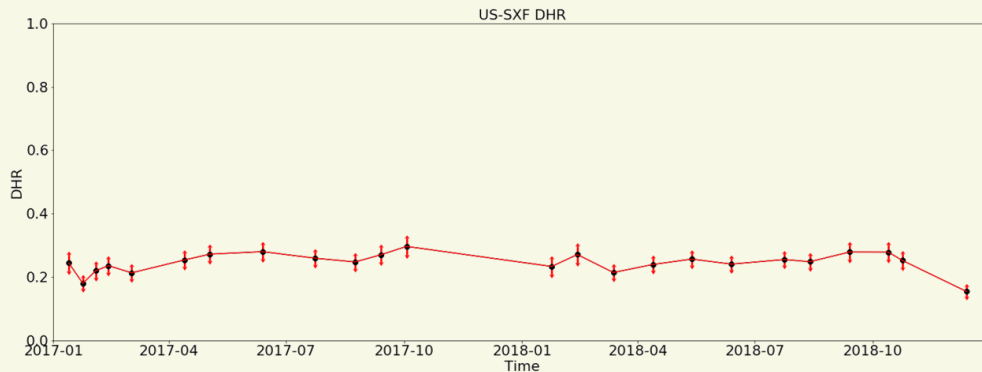
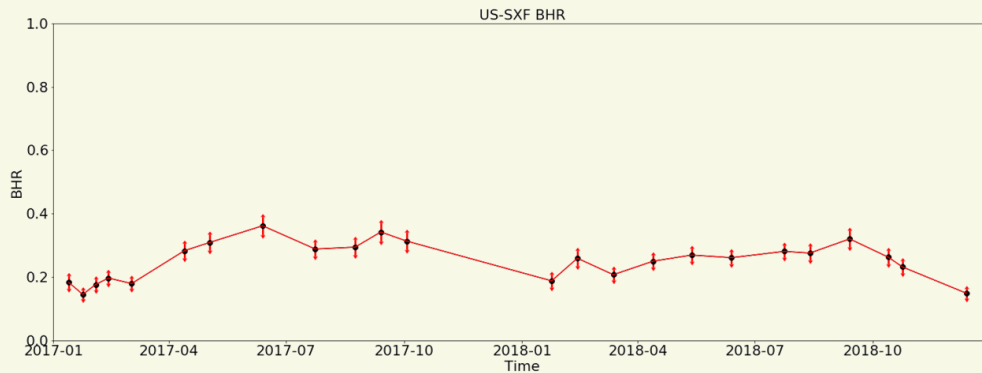


# Uncertainty estimation of LP1/LP2 products

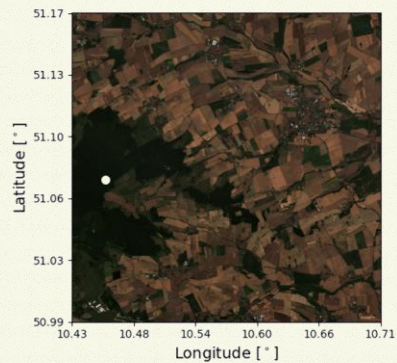




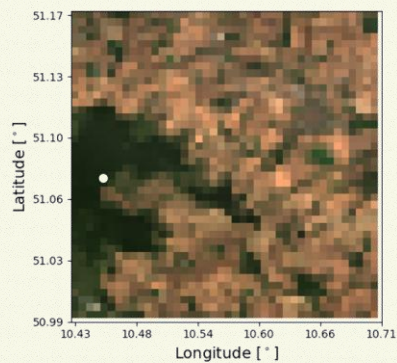
# Example of upscaled albedo with uncertainties



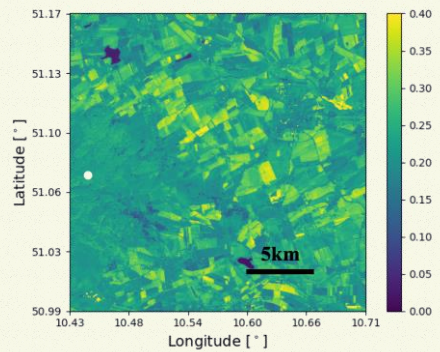
Preliminary example of VHR-albedo generation



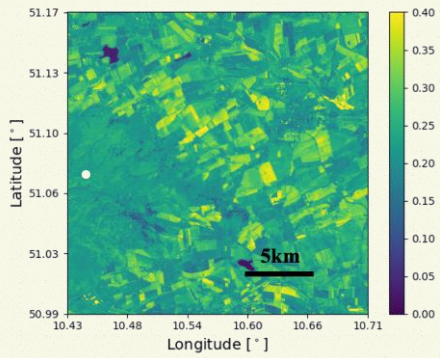
RGB composite of surface reflectance over the Hainich site at Sentinel-2 resolution (20m)



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.