

Web-based tool for validation of Sentinel-2 and Sentinel-3 derived bio-geophysical products against ICOS terrestrial ecosystems measurement

Noelle Cremer¹, Dario Papale^{2,3}, Giacomo Nicolini³, Simone Sabbatini³, Luke Brown⁴, Erminia De Grandis¹, Fabrizio Niro¹

¹ Serco for ESA/ESRIN ² National Research Council – IRET ³ CMCC Foundation - Euro-Mediterranean Center on Climate Change

⁴ University of Salford

Contents

Project outline

ICOS web services and data

TERRASCOPE cloud platform

Match-up database and web tools

Additional LAI data

Conclusions

Project outline

Project work package

IDEAS-QA4EO WP-2650

Project duration

October 2022 to October 2023

Project aim

demonstrate **Integrated Carbon Observation System (ICOS)** terrestrial ecosystem sites' suitability as a **network for the validation of Earth Observation (EO) products** (Sentinel-2 and Sentinel-3)

Project content

a **web-based tool** for validation of **satellite-derived biophysical products** (faPAR, LAI) against in situ data, while ensuring a **good representativeness** of the validation dataset in terms of spatial and temporal sampling

Project architecture

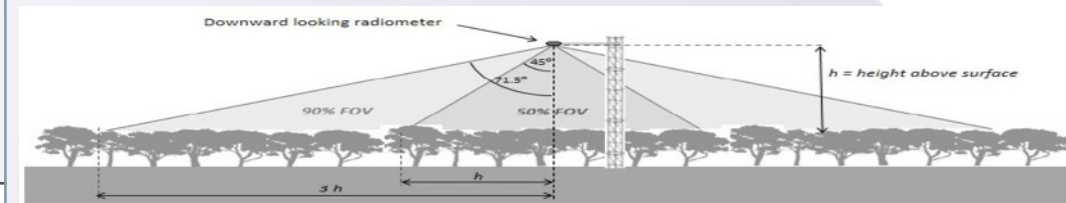
cloud-based data services (**Terrascope platform**) chosen to guarantee an effective EO data access, a good data completeness and an easy interoperability

ICOS web services and data

- **ICOS** is a network of more than 170 measurement stations (with > 100 *Ecosystem Stations*) across 16 European countries, **providing standardised and open data** for greenhouse gas concentrations and carbon fluxes in three domains: *Atmosphere, Ecosystem and Ocean*

Satellite retrieval	ICOS measurement
Fraction of absorbed photosynthetically active radiation (faPAR)	IN/OUT photosynthetic photon flux density (PPFD) sensors on top of towers, some forest sites have below canopy incident PPFD every 30 mins (data not useful without PPFD _{BC_{in}}), no measurement specific uncertainties
Leaf area index (LAI)	plant area index (PAI) measured in campaigns, via DHP or ceptometers (in forests if LAI larger than 6), measured in continuous plots (CP), no measurement specific uncertainties, but standard deviation for the whole plot

$$FAPAR = \frac{PPFD_{IN} - PPFD_{OUT} - PPFD_{BC_{IN}}}{PPFD_{IN}}$$



Carrara, A., Kolari, P., de Beeck, M. O., Arriga, N., Berveiller, D., Dengel, S., Ibrom, A., Merbold, L., Rebmann, C., Sabbatini, S., Serrano-Ortiz, P., & Biraud, S. C. (2018). Radiation measurements at ICOS ecosystem stations. In *International Agrophysics* (Vol. 32, Issue 4, pp. 589–605). Walter de Gruyter GmbH. <https://doi.org/10.1515/intag-2017-0049>

- Data available via **ICOS data portal** and **API** (custom function for LAI), additional data supplied for this project by ICOS Ecosystem Thematic Centre (site target area, measurement per CP)

Terrascope platform and data



- Online platform provided by **VITO** to access **open-source satellite images** (Sentinel-2, Sentinel-3 and corresponding biophysical products)
- Credit system, 1000 credits for free at sign up
- 60 000 additional credits for this project supported through the **Network of Resources**
- Access to data and development of web tools via **Jupyter Notebooks** in Python

Ground measurement	EO product	Resolution	Match up
PPFD at overpass time converted to FAPAR	TERRASCOPE_S2_FAPAR_V2	10 m	Closest 30 minutes
Sporadic PAI measurements	TERRASCOPE_S2_LAI_V2	10 m	Closest date, maximum distance adjustable
10-day aggregated PPFD at overpass time converted to FAPAR	CGLS_FAPAR300_V1_GLOBAL	300 m	Closest 30 minutes, rolling 10 day mean
Sporadic PAI measurements	CGLS_LAI300_V1_GLOBAL	300 m	Closest date, maximum distance adjustable

Match-up database and web tools I – Match-up database

Select ICOS site: Fontainebleau-Barbeau ▼

Select site radius (m): 25 ▼

Select satellite dataset: S-2 ▼

Select biophysical variable: FAPAR ▼

Include dataset Salford? no ▼

Select Salford biophysical variable: ▼

Select max timespan (LAI): 10

Calculate

ICOS site from Ecosystem sites

Area around the site for satellite retrieval (25 – 3000 m)

Sentinel-2 or Sentinel-3

FAPAR or LAI

Include external dataset

PAI, PAIE, PAIE_MILLER

Maximum number of days between ground and satellite match-up

Match-up database and web tools I – Match-up database, faPAR example

Information	Line plot	Scatter plot	Table
-------------	-----------	--------------	-------

Information provided for Fontainebleau-Barbeau and the S-2 FAPAR dataset.
Information is available from 2019-09-30 to 2024-05-15.
The mean standard deviation for the available satellite product is 0.02.

Match-up database and web tools I – Match-up database, faPAR example



Match-up database and web tools I – Match-up database, faPAR example



Match-up database and web tools I – Match-up database, faPAR example

Information | Line plot | Scatter plot | Table

Information | Line plot | Scatter plot | Table

Information | Line plot | Scatter plot | Table

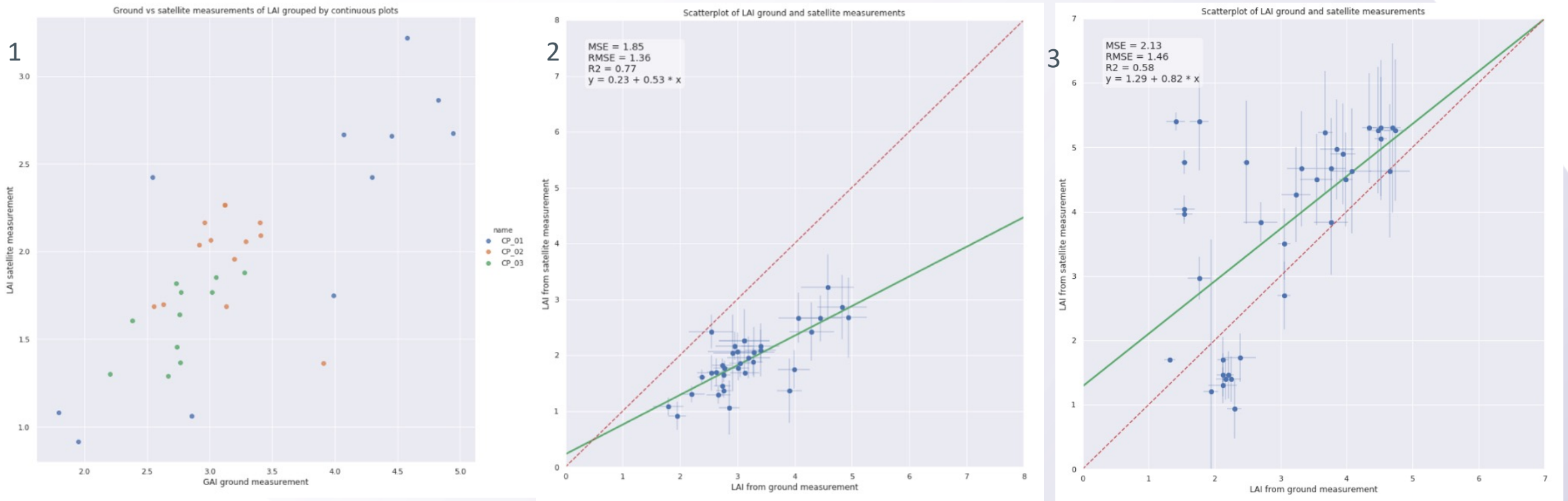
Information | Line plot | Scatter plot | Table

FAPAR

	TIMESTAMP	FAPAR_ground	FAPAR_satellite	FAPAR_ground_uncertainty	FAPAR_satellite_sd
0	2020-03-26 10:46:39	0.646718	0.330	0.129344	0.015964
1	2020-04-05 10:46:19	0.653306	0.385	0.130661	0.029662
2	2020-04-10 10:50:31	0.764058	0.595	0.152812	0.035512
3	2020-04-15 10:46:19	0.871538	0.805	0.174308	0.021230
4	2020-04-20 10:50:31	0.936758	0.880	0.187352	0.013944
6	2020-05-20 10:50:31	0.966085	0.915	0.193217	0.011304
7	2020-05-30 10:50:31	0.965018	0.925	0.193004	0.007265
8	2020-06-24 10:46:29	0.968621	0.915	0.193724	0.011304
9	2020-06-29 10:50:31	0.967902	0.960	0.193580	0.005000
10	2020-07-09 10:50:31	0.966710	0.910	0.193342	0.011577
11	2020-07-29 10:50:31	0.956551	0.880	0.191310	0.017038
12	2020-08-08 10:50:31	0.946828	0.845	0.189366	0.025468
13	2020-08-18 10:50:31	0.955847	0.370	0.191169	0.014142
14	2020-09-07 10:50:31	0.949063	0.870	0.189813	0.023318
15	2020-09-12 10:46:29	0.945644	0.830	0.189129	0.032766
16	2020-09-17 10:50:31	0.948349	0.810	0.189670	0.031203
17	2020-09-22 10:46:49	0.941224	0.815	0.188245	0.026939
18	2020-11-06 10:52:41	0.883755	0.760	0.176751	0.090443

Match-up database and web tools II – Upscaling

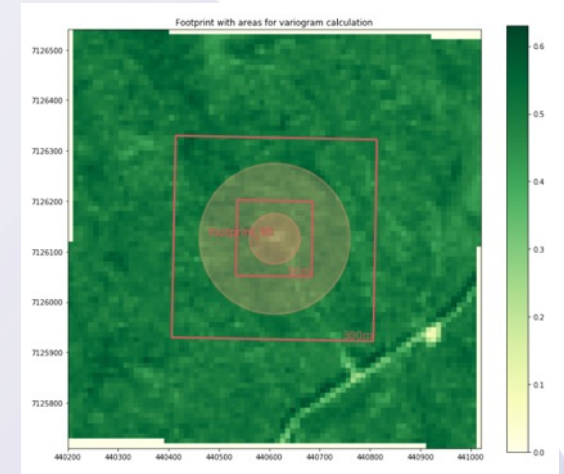
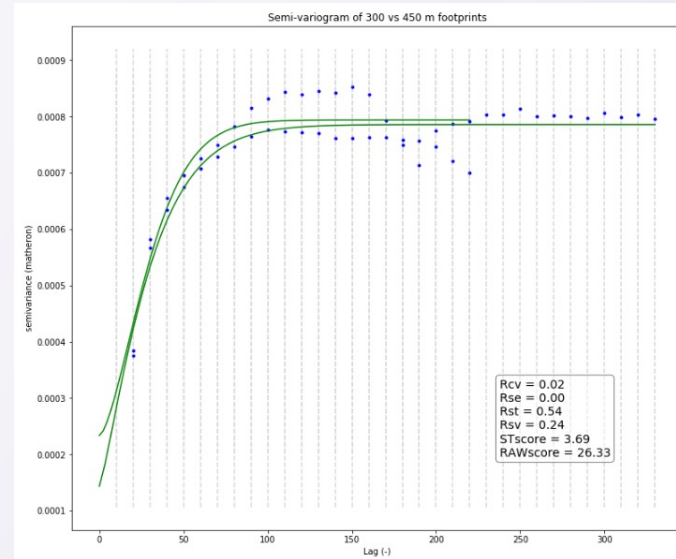
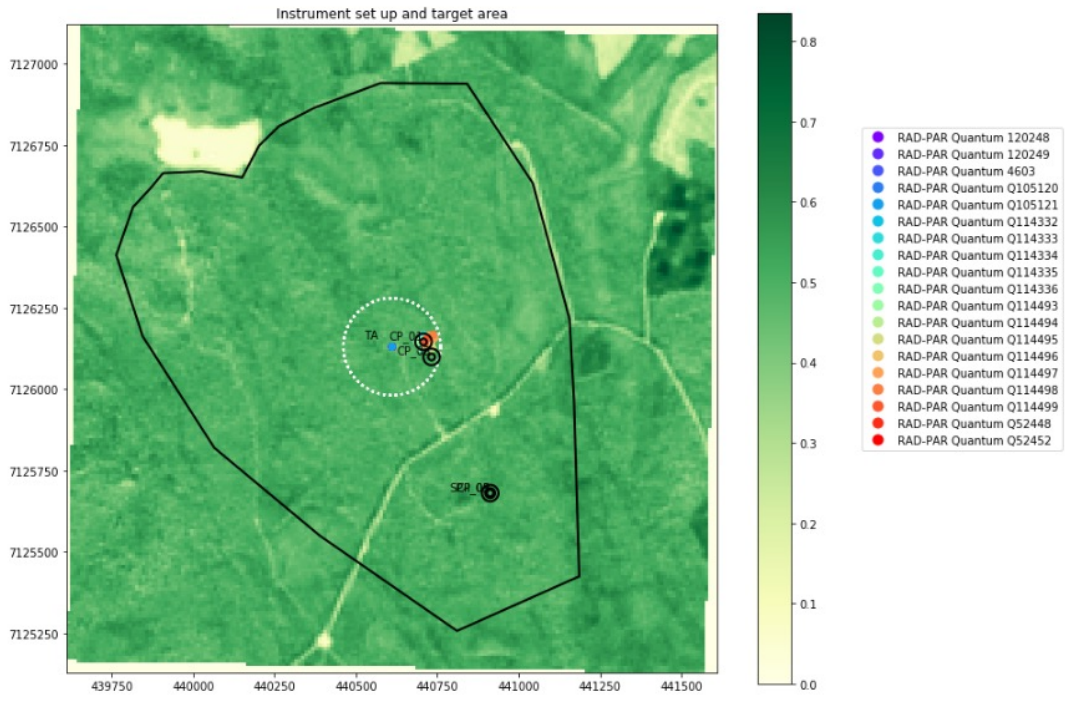
1. Match-up of every possible ground measurement with a Sentinel-2 retrieval within the CP (25 m²)
2. Retrieval of upscaling factor and bias with linear regression
3. Upscaling of ground segments to Sentinel-2 acquisition and match-up with same day Sentinel-3 acquisitions on the site



Match-up database and web tools III – Spatial representativeness

Spatial representativeness is assessed with statistical metrics and semi-variograms to estimate the suitability of the various sites

Select ICOS site: Svartberget Select dataset: FAPAR Select season: Summer



Approach adopted from Román, M. O., Schaaf, C. B., Woodcock, C. E., Strahler, A. H., Yang, X., Braswell, R. H., Curtis, P. S., Davis, K. J., Dragoni, D., & Goulden, M. L. (2009). The MODIS (Collection V005) BRDF/albedo product: Assessment of spatial representativeness over forested landscapes. In *Remote Sensing of Environment* (Vol. 113, Issue 11, pp. 2476–2498). Elsevier BV. <https://doi.org/10.1016/j.rse.2009.07.009>

Additional LAI data – Match-up database

Select ICOS site: Hohes Holz

Select site radius (m): 25

Select satellite dataset: S-2

Select biophysical variable: LAI

Include dataset Salford? yes

Select Salford biophysical variable: paie

Select max timespan (LAI): 10

Calculate

ICOS site from Ecosystem sites

Area around the site for satellite retrieval (25 – 3000 m)

Sentinel-2 or Sentinel-3

FAPAR or LAI

Include external dataset

PAI, PAIE, PAIE_MILLER

Maximum number of days between ground and satellite match-up

Additional LAI data – Match-up database

Information

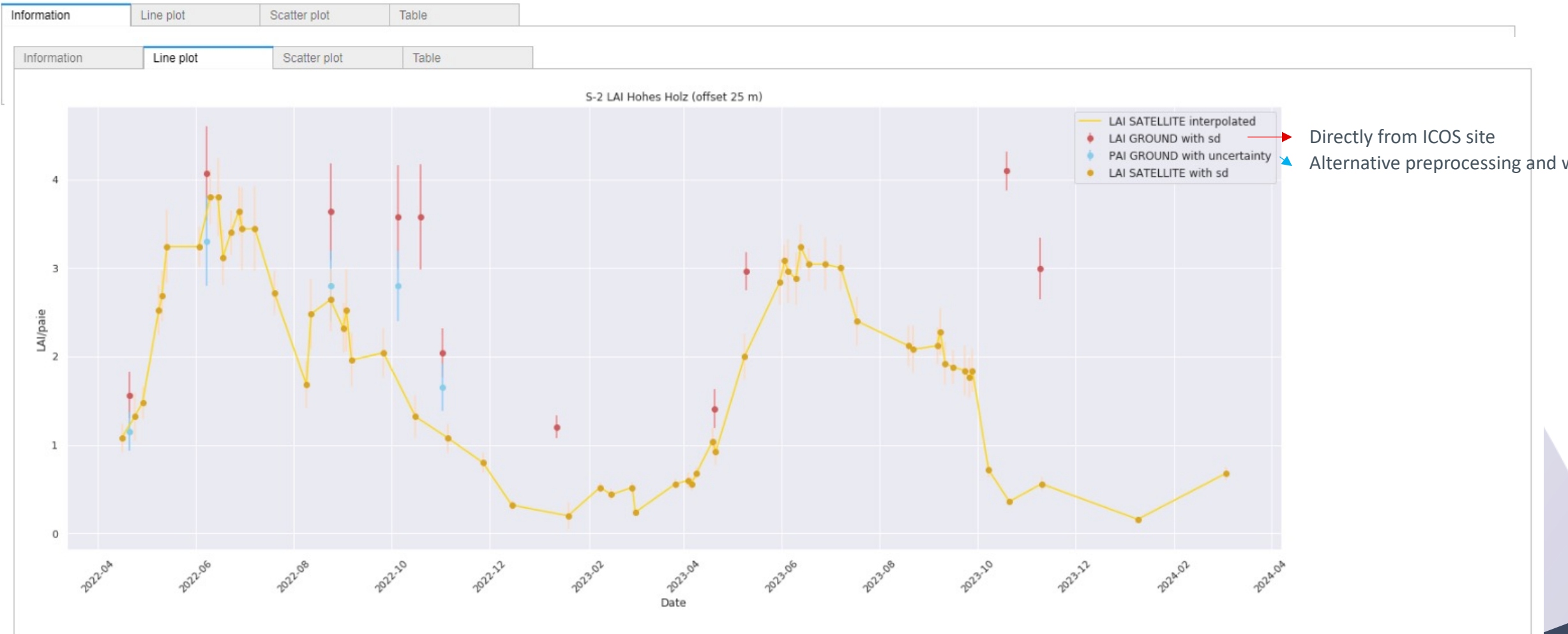
Line plot

Scatter plot

Table

Information provided for Hohes Holz and the S-2 LAI dataset.
Information is available from 2019-04-10 to 2024-03-06.
The mean standard deviation for the available satellite product is 0.22.

Additional LAI data – Match-up database

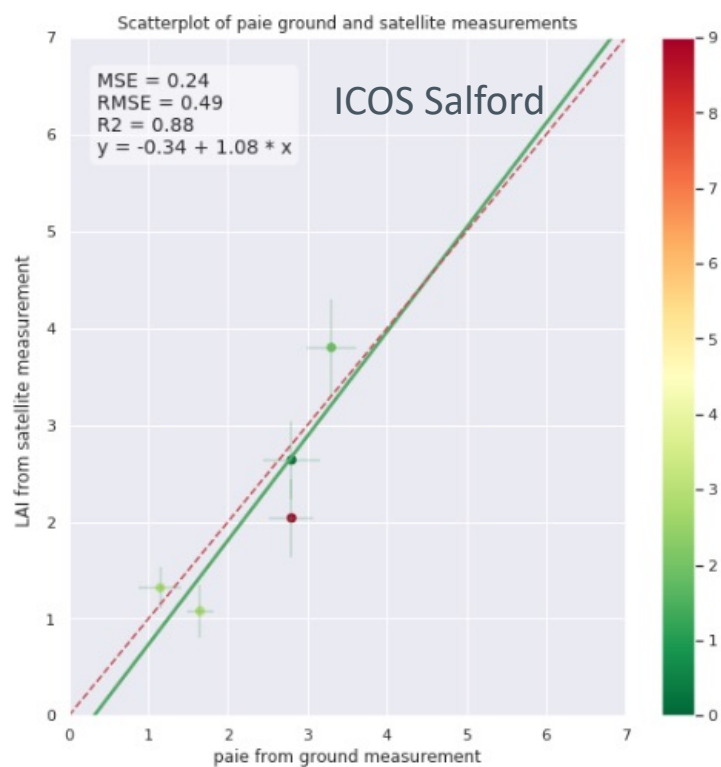
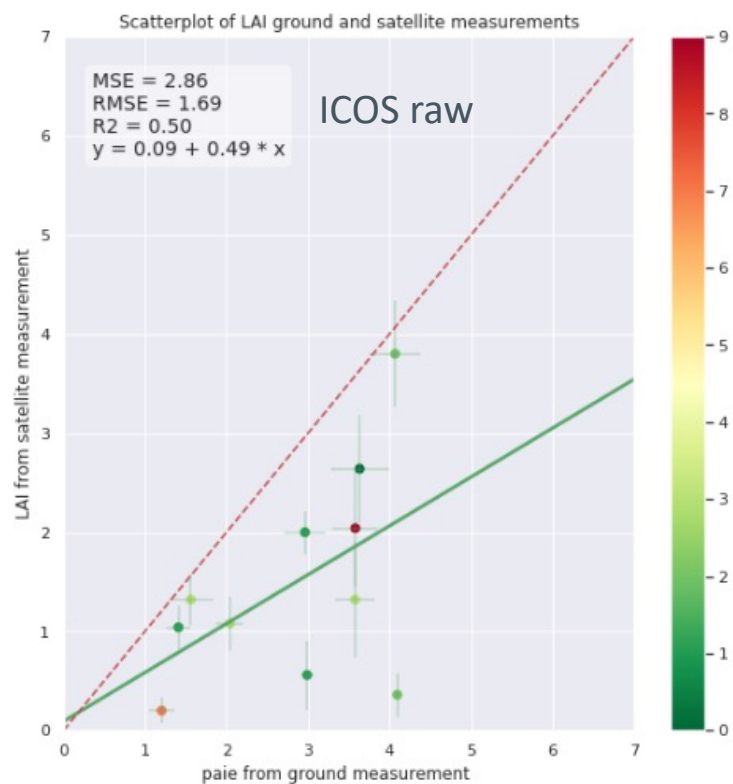


Additional LAI data – Match-up database

Information Line plot Scatter plot Table

Information Line plot Scatter plot Table

Information Line plot Scatter plot Table



Additional LAI data – Match-up database

Information	Line plot	Scatter plot	Table					
Information	Line plot	Scatter plot	Table					
Information	Line plot	Scatter plot	Table					
Information	Line plot	Scatter plot	Table					
TIMESTAMP_GROUND	LAI_ground	LAI_satellite	LAI_ground_sd	TIMESTAMP_SAT	LAI_satellite_sd	interpolated_value	TIMESTAMP_diff	
13	2022-04-21	1.561778	1.32	0.263111	2022-04-24	0.269744	False	3
14	2022-06-08	4.066889	3.80	0.533544	2022-06-10	0.311433	False	2
15	2022-08-24	3.632972	2.64	0.544593	2022-08-24	0.355099	False	0
16	2022-10-05	3.579500	2.04	0.584450	2022-09-26	0.277815	False	9
17	2022-10-19	3.576964	1.32	0.591681	2022-10-16	0.241109	False	3
18	2022-11-02	2.041556	1.08	0.273451	2022-11-05	0.163998	False	3
19	2023-01-12	1.203778	0.20	0.128478	2023-01-19	0.152190	False	7
20	2023-04-20	1.410222	1.04	0.216539	2023-04-19	0.149412	False	1
21	2023-05-10	2.962444	2.00	0.214524	2023-05-09	0.256571	False	1
22	2023-10-19	4.094667	0.36	0.221607	2023-10-21	0.028284	False	2
23	2023-11-09	2.986444	0.56	0.348764	2023-11-10	0.075895	False	1
TIMESTAMP_GROUND	TIMESTAMP_SAT	paie_ground	LAI_satellite	paie_ground_uncertainty	LAI_satellite_sd	interpolated_value	TIMESTAMP_diff	
35	2022-04-21	2022-04-24	1.15	1.32	0.22	0.269744	False	3
36	2022-06-08	2022-06-10	3.30	3.80	0.50	0.311433	False	2
37	2022-08-24	2022-08-24	2.80	2.64	0.40	0.355099	False	0
38	2022-10-05	2022-09-26	2.80	2.04	0.40	0.277815	False	9
39	2022-11-02	2022-11-05	1.65	1.08	0.27	0.163998	False	3

Conclusions

- Functioning match-up database as an initial tool of using ICOS network data for validating biophysical variables from satellite retrievals for faPAR and LAI
 - Available functionalities for upscaling ground measurements, checking spatial representativeness and adding further data sources
-
- Data format updates to minimize preprocessing for satellite validation, open access to CP measurements and TA characterization
 - Inclusion of LAI into API for easier access
 - PPFD below canopy measurements are necessary for realistic FAPAR ground measurements: PPFD below canopy and PAI measurements are being expanded to more sites > more match-ups and denser time-series
 - Denomination of LAI/PAI/GAI variables within ICOS data distribution is not consistent
 - Uncertainty characterization and propagation could be improved for ICOS data and satellite retrieval



Thank you very much for your attention.

serco.com

