Global cloud-free maps of four essential vegetation traits retrieved with hybrid models from the S3-OLCI L1B catalogue

Dávid D.Kovács[1]***,*** *Pablo Reyes Muñoz*[1]*, Matías Salinero Delgado*[1]*, Mészáros Ixion Viktor*[1]*, Katja Berger*[1]*,* [2] *and Jochem Verrelst*[1]

[1] *Image Processing Laboratory (IPL), University of Valencia, Spain*
[2] *Mantle Labs GmbH, Vienna, Austria*

david.kovacs@uv.es

Agenda

1.Retrieval of biophysical variables

Retrieved gap-free FAPAR, FVC ,LAI ,LCC with S3-OLCI TOA data and hybrid models

2. Validation on GBOV sites

Validated over ten sites (FAPAR,FVC,LAI)

LCC compared to OLCI Terrestrial Chlorophyll Index

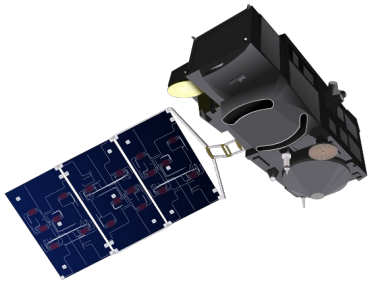
3. Long-term temporal reconstruction 2002-2022

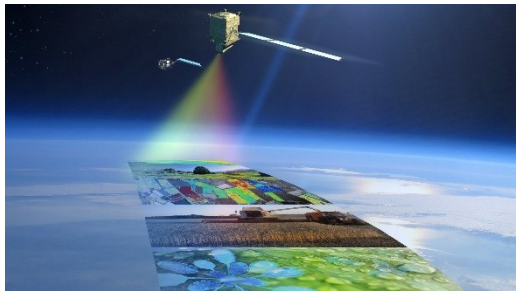
Used MODIS data as predictor variables to reconstruct past S3 OLCI based variables

Main objectives: global S3-OLCI EVTs retrieval

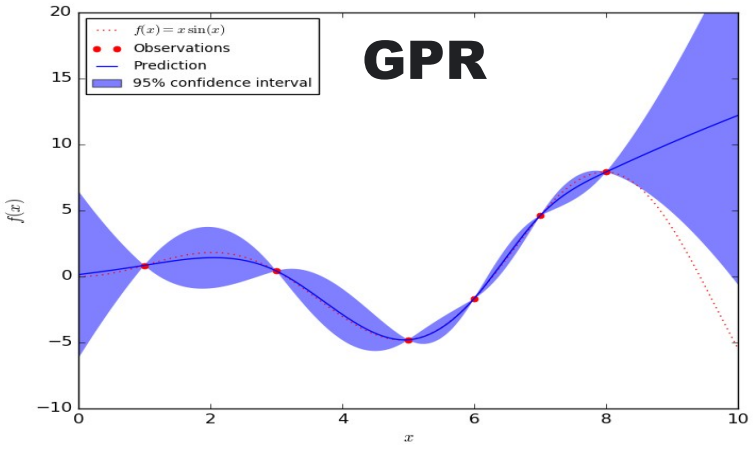
To generate **temporally reconstructed global Essential Vegetation Trait (EVT) products** of:

- **leaf area index (LAI)**
- **leaf chlorophyll content (LCC)**
- **fraction of absorbed photosynthetically active radiation (FAPAR)**
- **fractional vegetation cover (FVC)**





To use **S3 OLCI Top Of Atmosphere (TOA)** data and hybrid models trained with: **Gaussian Process Regression (GPR)**

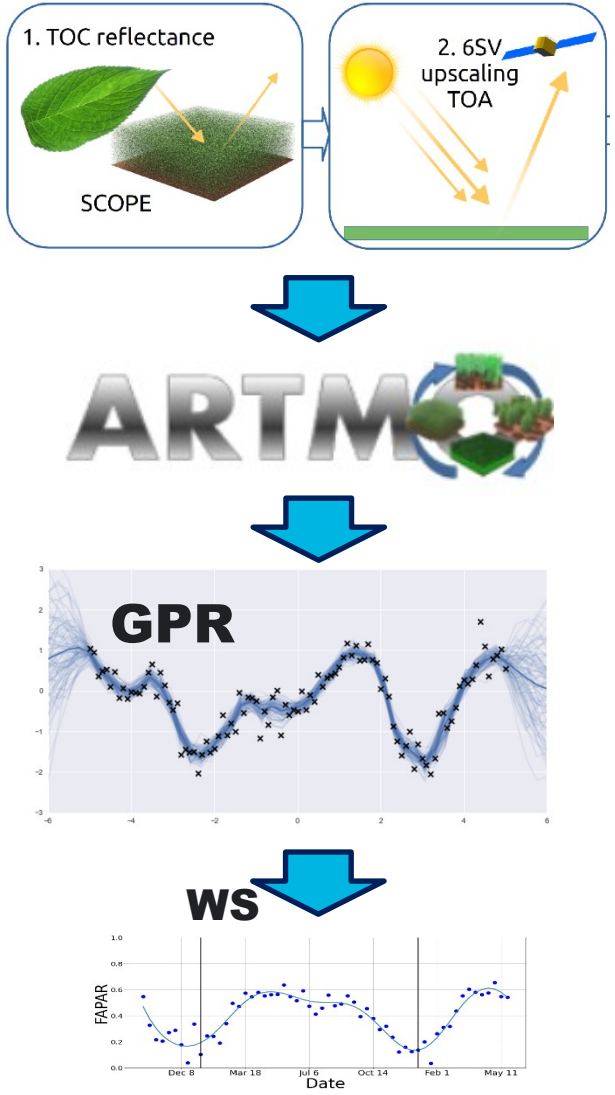


Temporally reconstruct with **Whittaker's smoother** (WS) to achieve cloud-free (gap-filled) data

Cross-correlate against **Copernicus (CGLS) & MODIS** products

Workflow

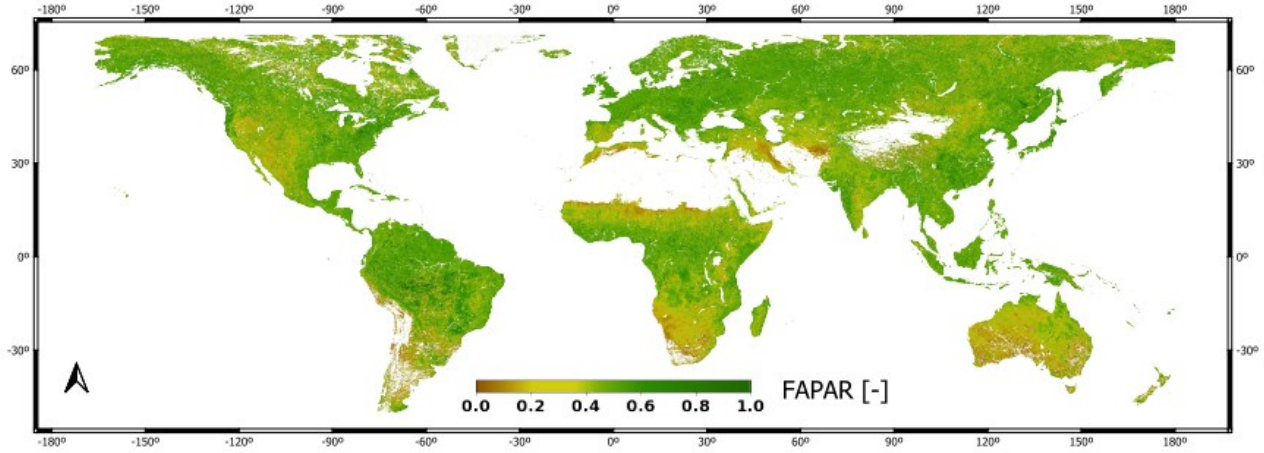
1. Retrieval started with **canopy simulations using SCOPE**[1]
2. SCOPE **Top Of Canopy (TOC) reflectance were** upscaled to →**TOA** radiance simulations using **6SV** RTM[2]
3. Coupling process by: Atmospheric Lookup table Generator (**ALG**)[3] and Automated Radiative Transfer Models Operator (**ARTMO**)[4]
4. **GPR models were trained using simulated TOA radiance data**
5. **Spatiotemporally continuous dataset were obtained by using Whittaker Smoother (WS): S3-TOA-GPR-1.0-WS** models
6. Past time series reconstruction with ancillary MODIS time series: **2002-2022**

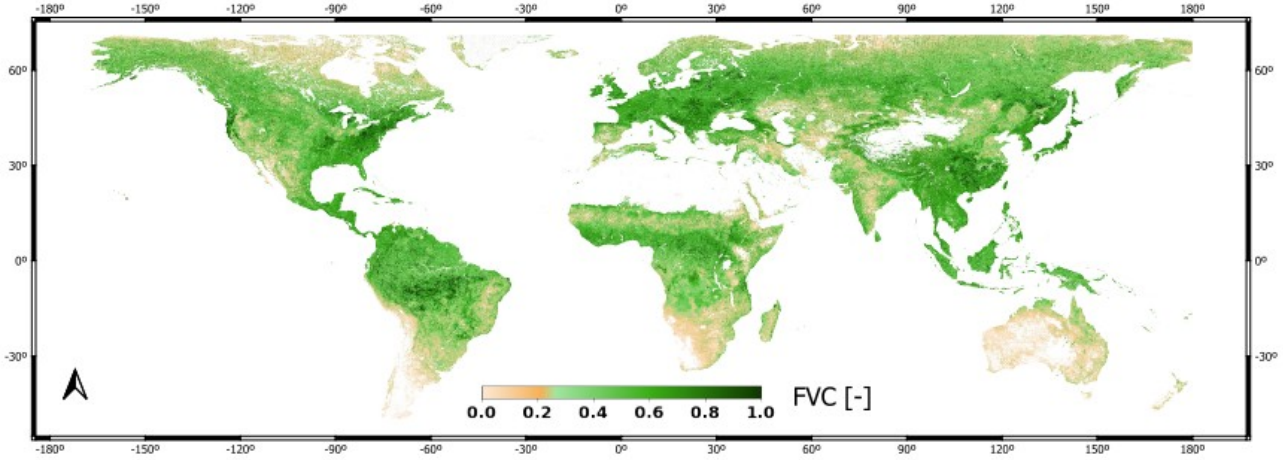


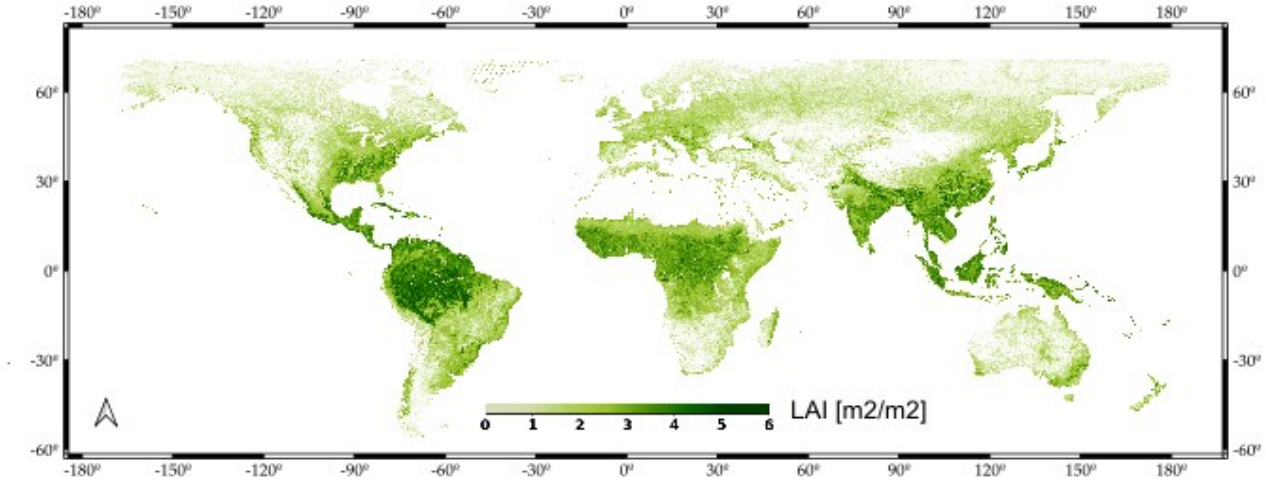
[1]: Van Der Tol et al. (2009)
[2]: Vermote et al. (1997)
[3]: Vicent et al. (2020)
[4]: Verrelst et al. (2012):

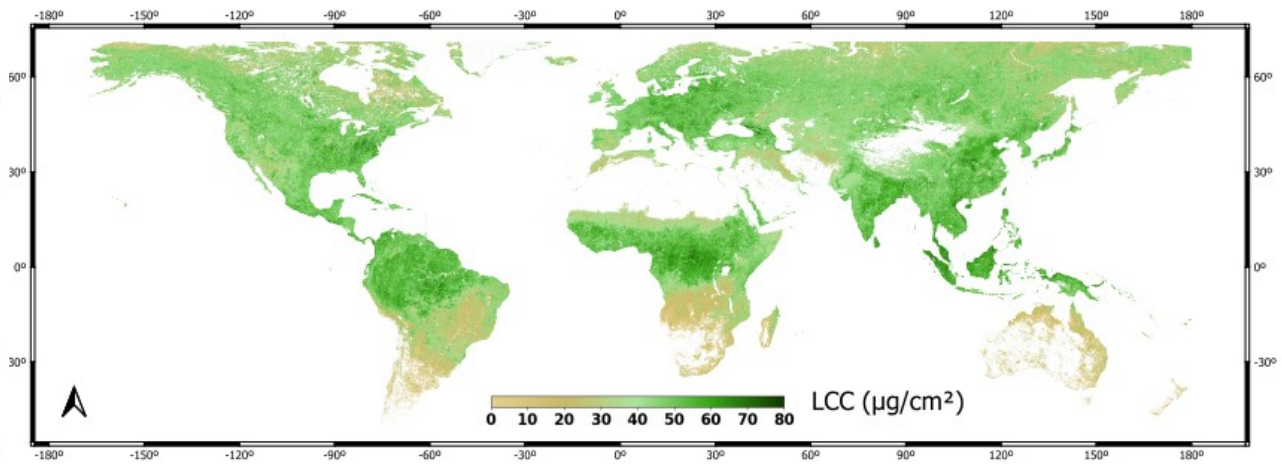
Cloud-Free Global maps

Temporally reconstructed cloud-free maps. 10th July 2019 (5km resolution)







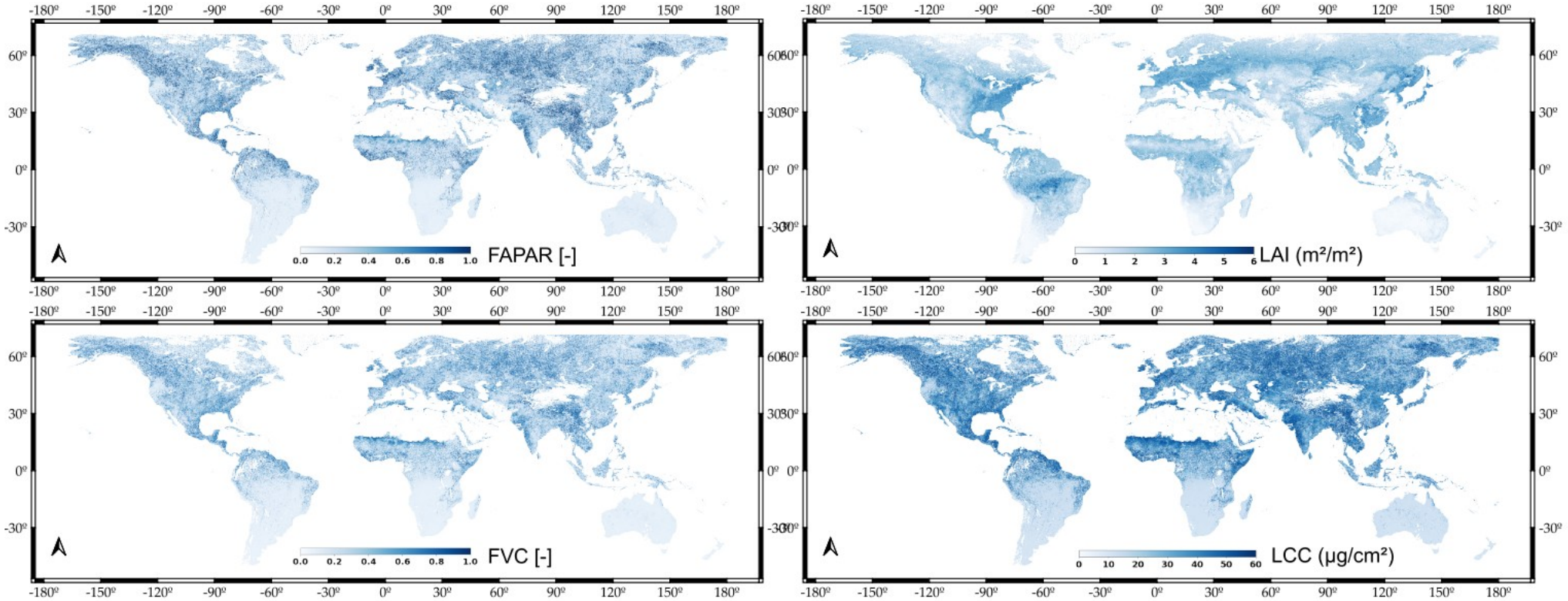


Uncertainty maps

The Bayesian GPR algorithm also provides associated uncertainties (σ)

Each σ relates to the absolute value of the estimate

Uncertainty maps 2019, monthly averaged (5km resolution)

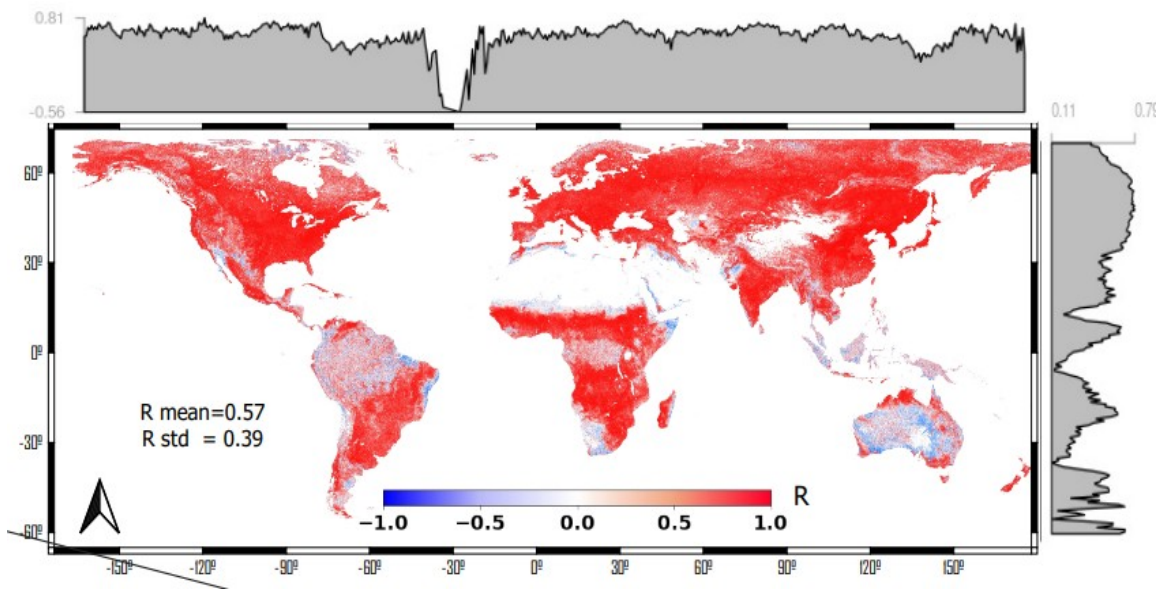


Intra-annual cross-comparison vs reference

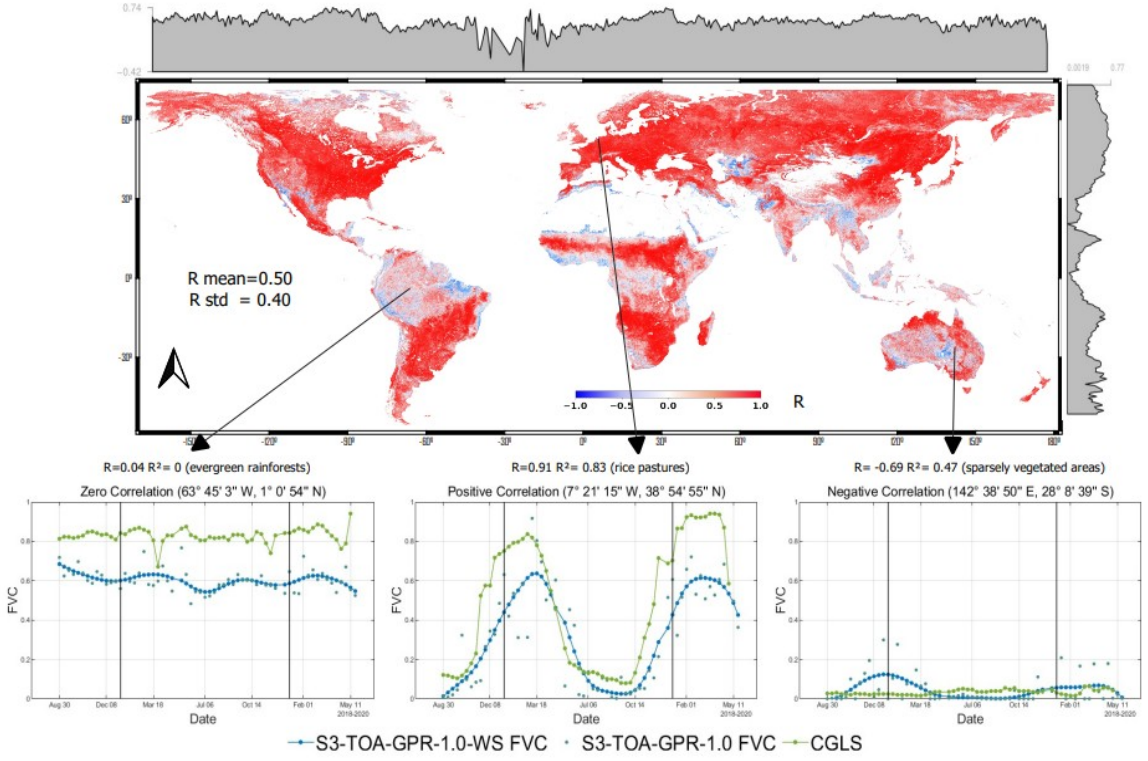
Per-pixel intra-annual cross-comparison for 2019 of the 4 EVTs:

- **Copernicus (CGLS) and MODIS reference products**
- **High consistency over 30-60° latitudes**
- **Lower consistency over latitudes lower than 20°**
- **Pronounced yearly phenology yielded superior GPR retrievals**

LAI correlation against CGLS



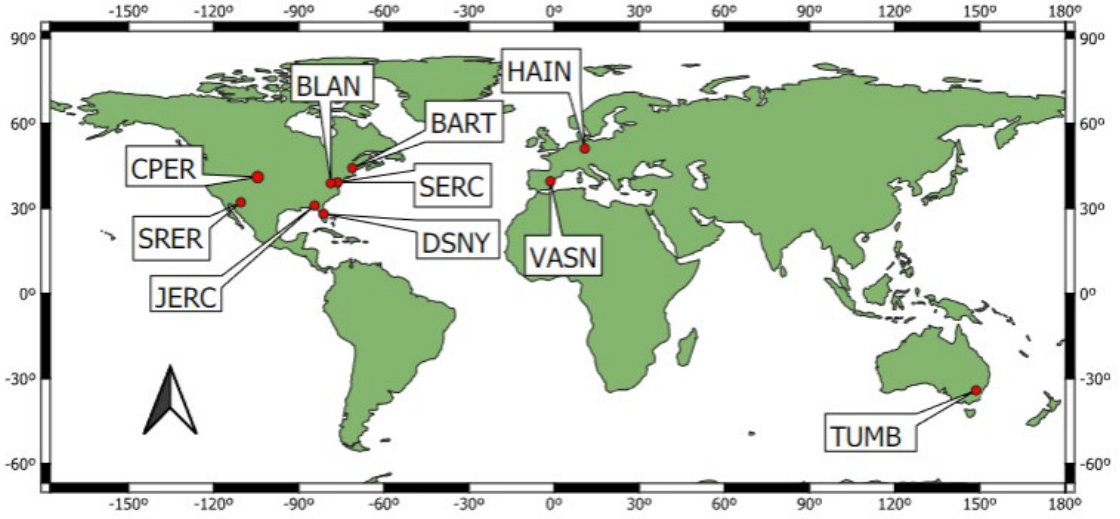
FVC correlation against CGLS



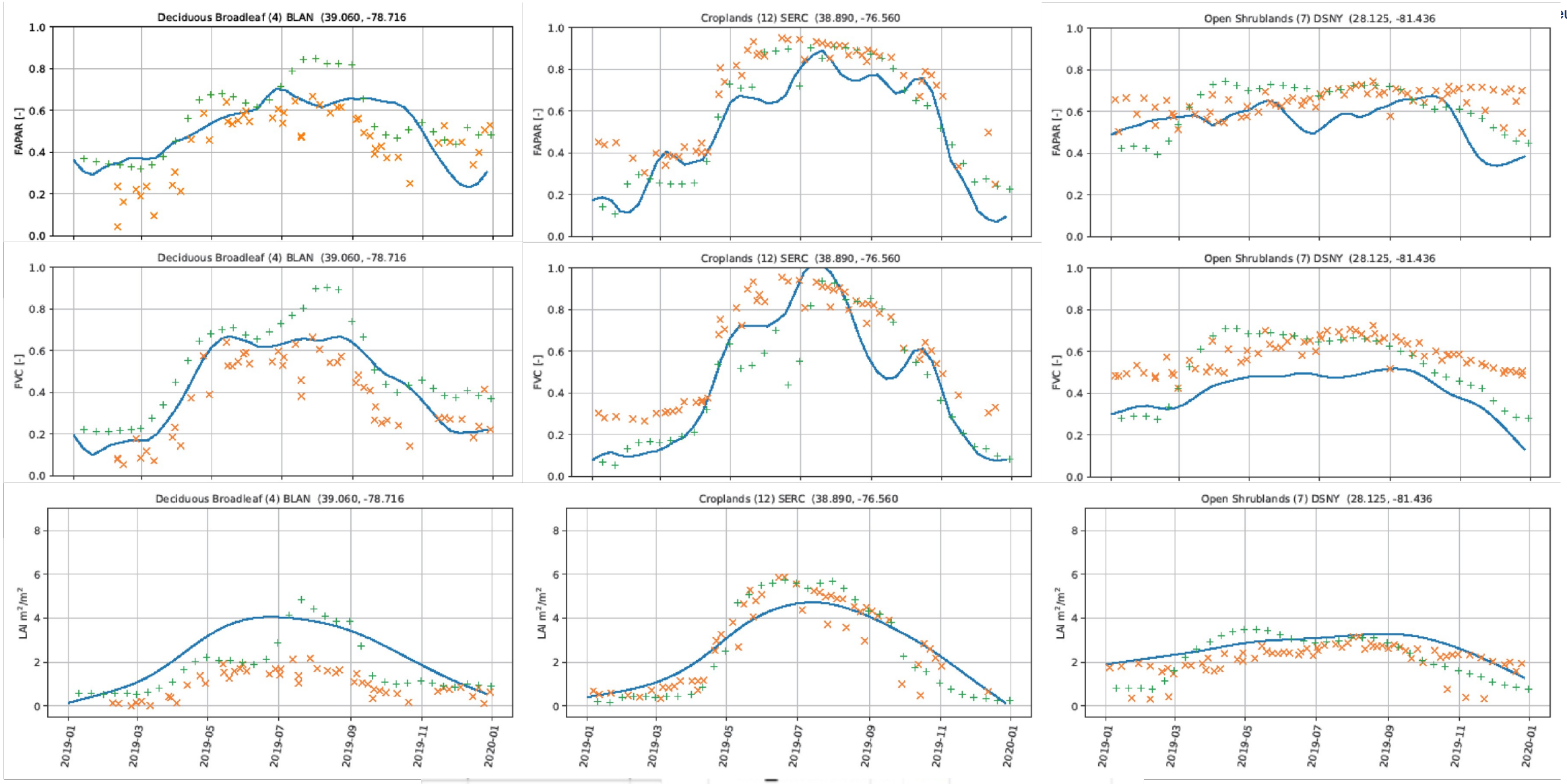
Validation to GBOV reference measurements

- 10 GBOV sites
- Again, consistency closely related to seasonality
- FAPAR,FVC and LAI validated
- LCC in-situ data absent (work in progress to compare to OTCI)
- Issues around TUMB and VASN
- Pixel heterogeneity over VASN

GBOV site name		Dominant land cover (1.5x1.5km)
Blandy Experimental Farm	BLAN	Deciduous Broadleaf
Bartlett Experimental Forest	BART	Mixed Forest
Central Plains Experimental Range	CPER	Grassland
Disney Wilderness Preserve	DSNY	Open Shrublands
Jones Ecological Research Center	JERC	Evergreen Needleleaf
Smithsonian Environmental Research Center	SERC	Croplands
Santa Rita	SRER	Shrublands
Tumbarumba	TUMB	Evergreen Broadleaf
Hainich	HAIN	Mixed Forest
Valencia Anchor Station	VASN	Cropland Mosaics

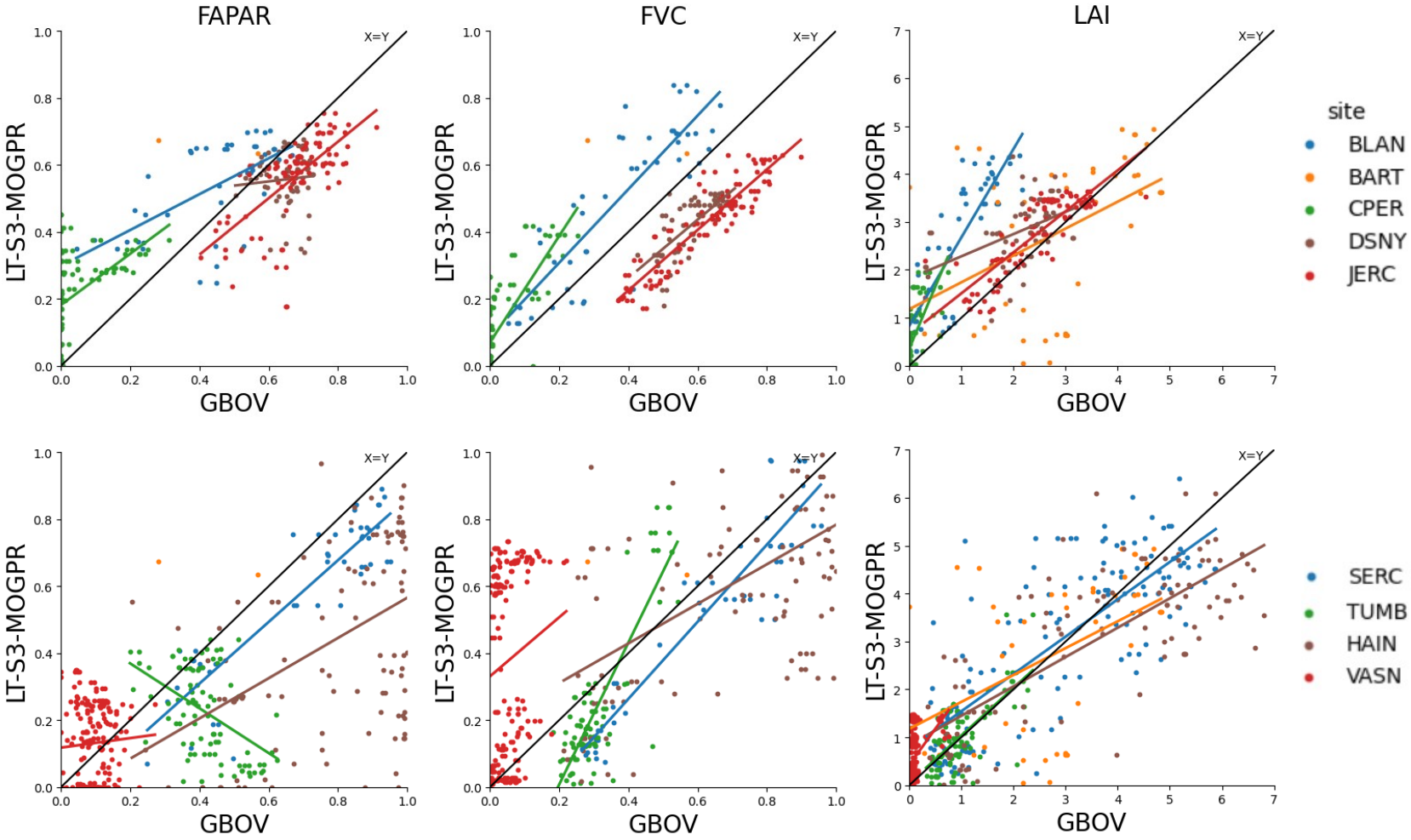


Exemplary time series to GBOV / Copernicus data



Scatterplots S3 validation

	FAPAR		FVC		LAI	
	R	NRMSE	R	NRMSE	R	NRMSE
BLAN	0.63	0.17	**0.89**	0.14	**0.83**	0.19
BART	0.24	0.22	0.52	0.33	0.46	0.15
CPER	0.46	0.2	**0.78**	0.14	0.65	0.71
DSNY	**0.09**	0.12	**0.74**	0.17	0.47	0.98
JERC	0.66	0.14	**0.92**	0.2	**0.85**	0.53
SERC	**0.9**	0.14	**0.93**	0.17	**0.8**	1.11
TUMB	-0.49	0.26	**0.86**	0.17	**0.7**	0.52
HAIN	0.44	0.45	0.53	0.28	**0.76**	1.4
VASN	0.06	0.14	0.13	0.42	0.36	0.69



Long-Term OLCI based vegetation products

Goal:

To reconstruct non-existent past data, back until 2002 **way before S3's launch (2002-2022)**

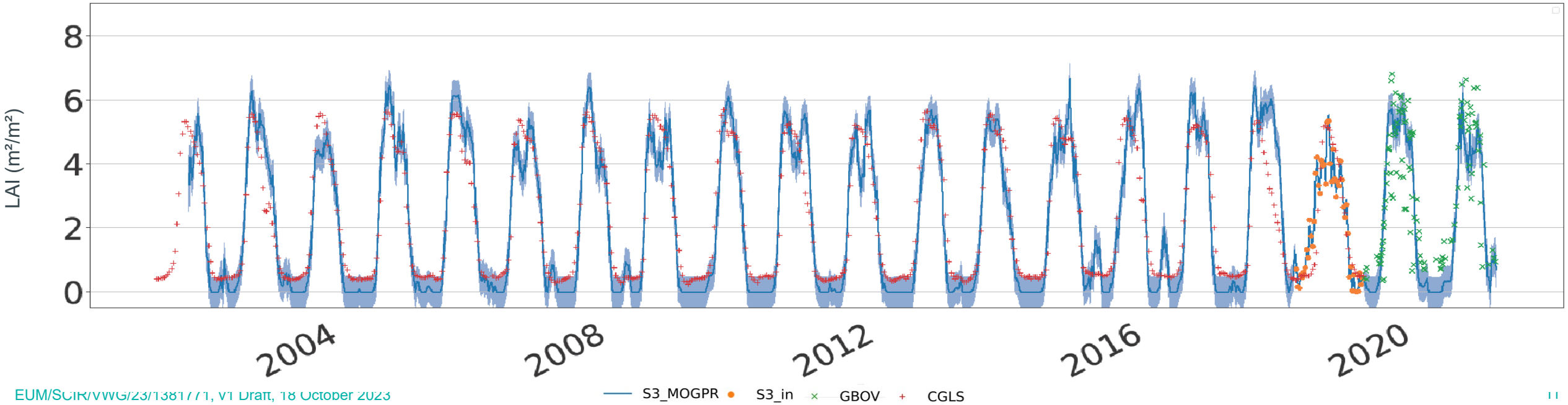
Methodology:

Vegetation products on **existing** 2019 S3 imagery retrieved as explained

Used MODIS time series (LAI, FAPAR, NDVI) (since 2002) as **predictor** variables

Trained a Multi-Output Gaussian Process over the year 2019

Reconstructed 2002-2022 time frame of FAPAR, FVC, LAI, LCC → Over 10 GBOV sites



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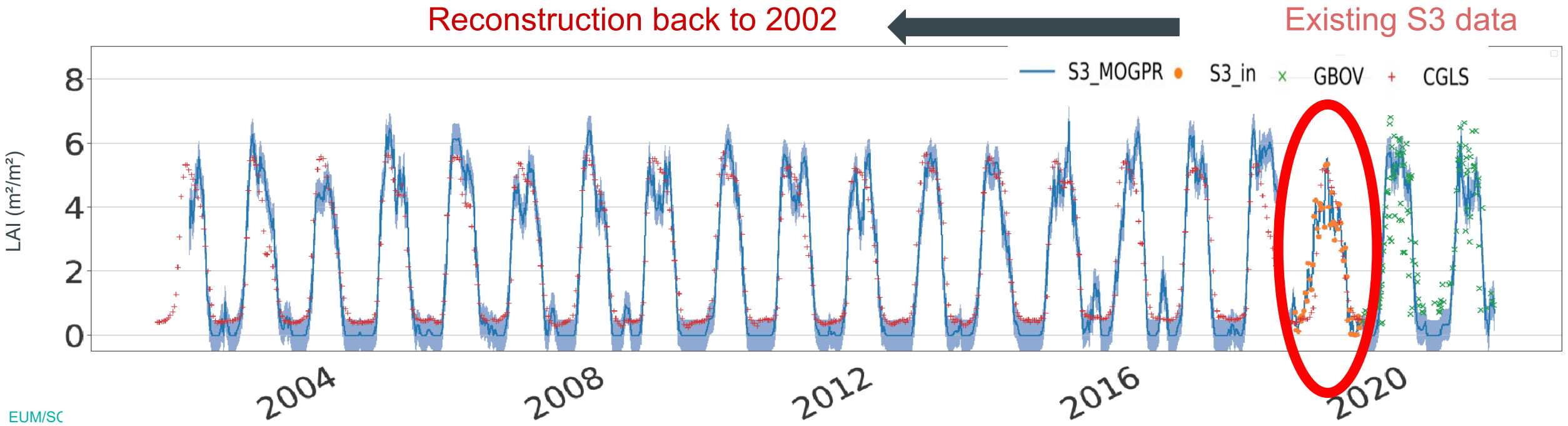

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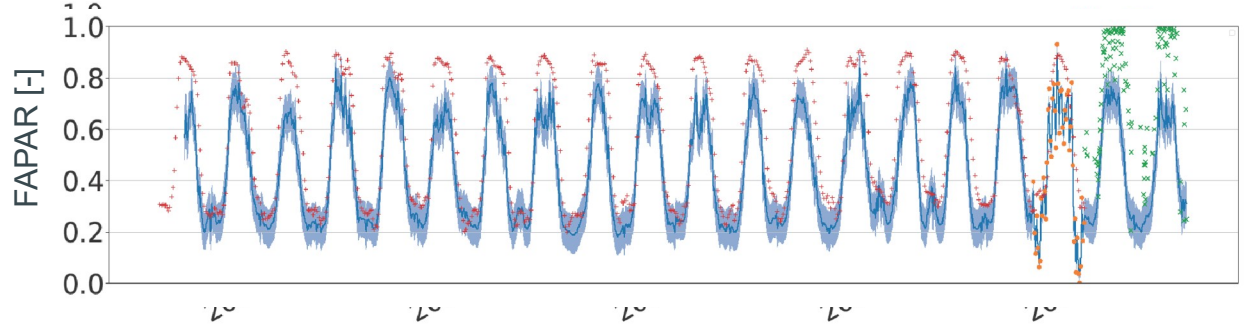
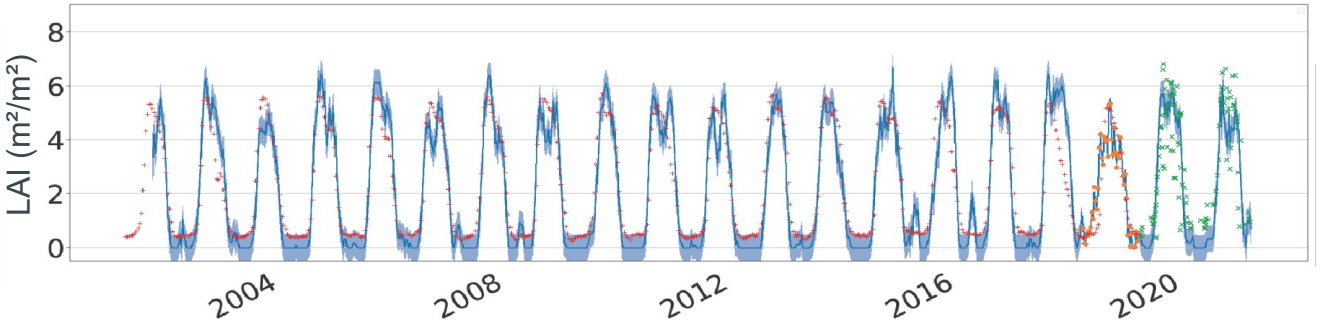
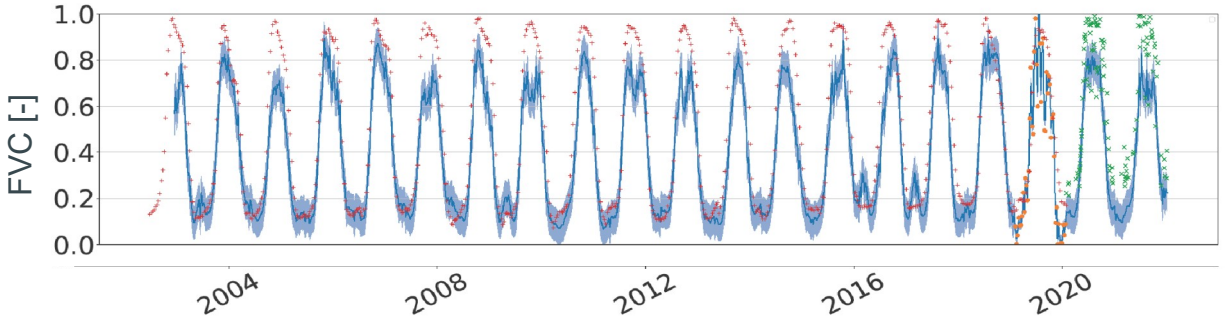
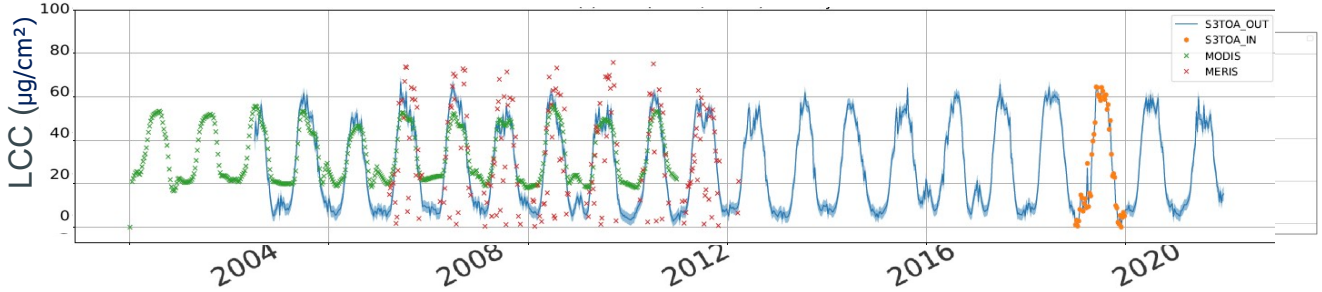








S3_MOGPR S3_in GBOV CGLS

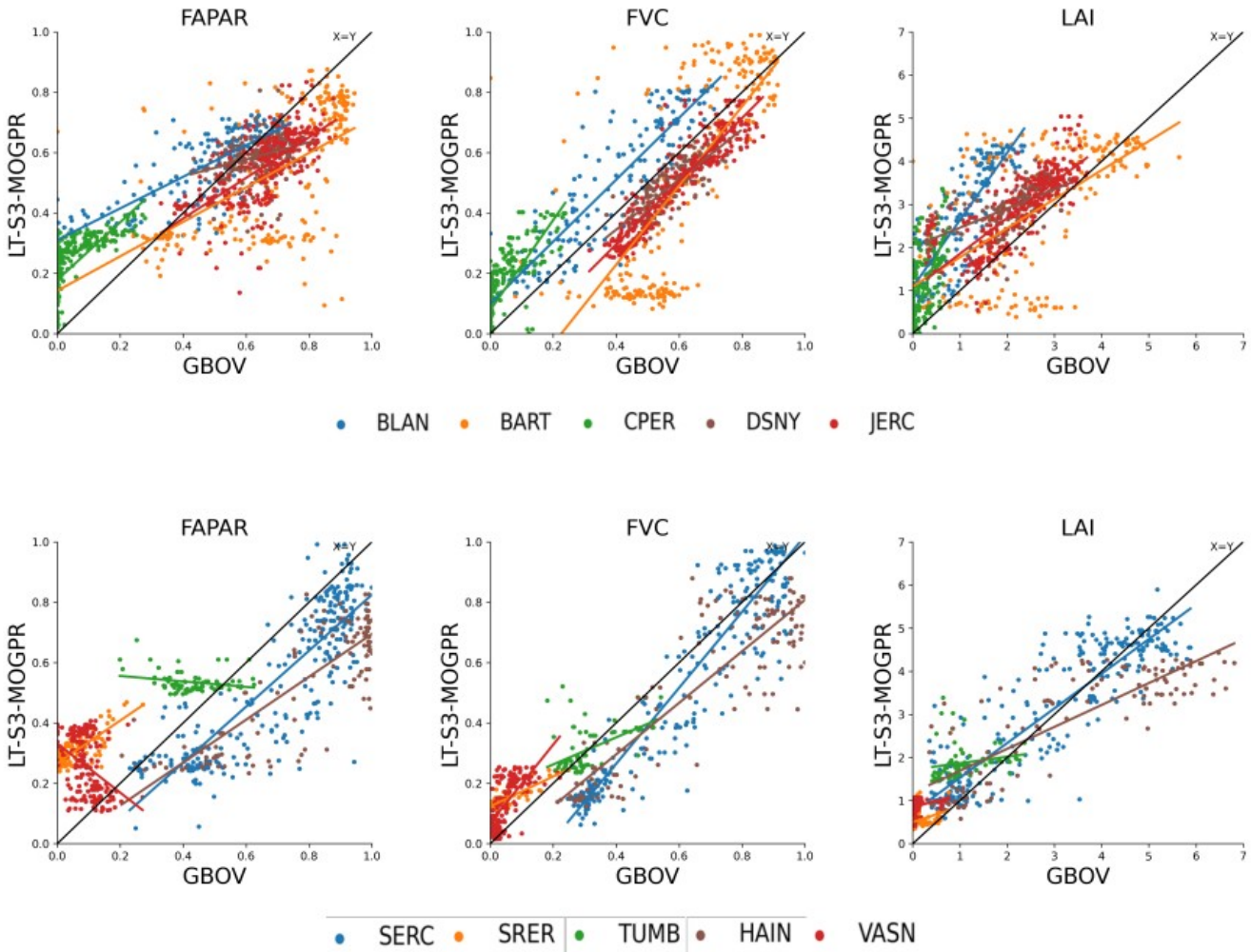
Long-term S3 reconstructed validation results

Reconstructed S3 variables validated on same 10 sites

- Best performing reconstructed variable: **FVC**
- Over 6 sites R>0.9

- Important factors: seasonality, heterogeneity
- Issues with reconstruction over TUMB, VASN

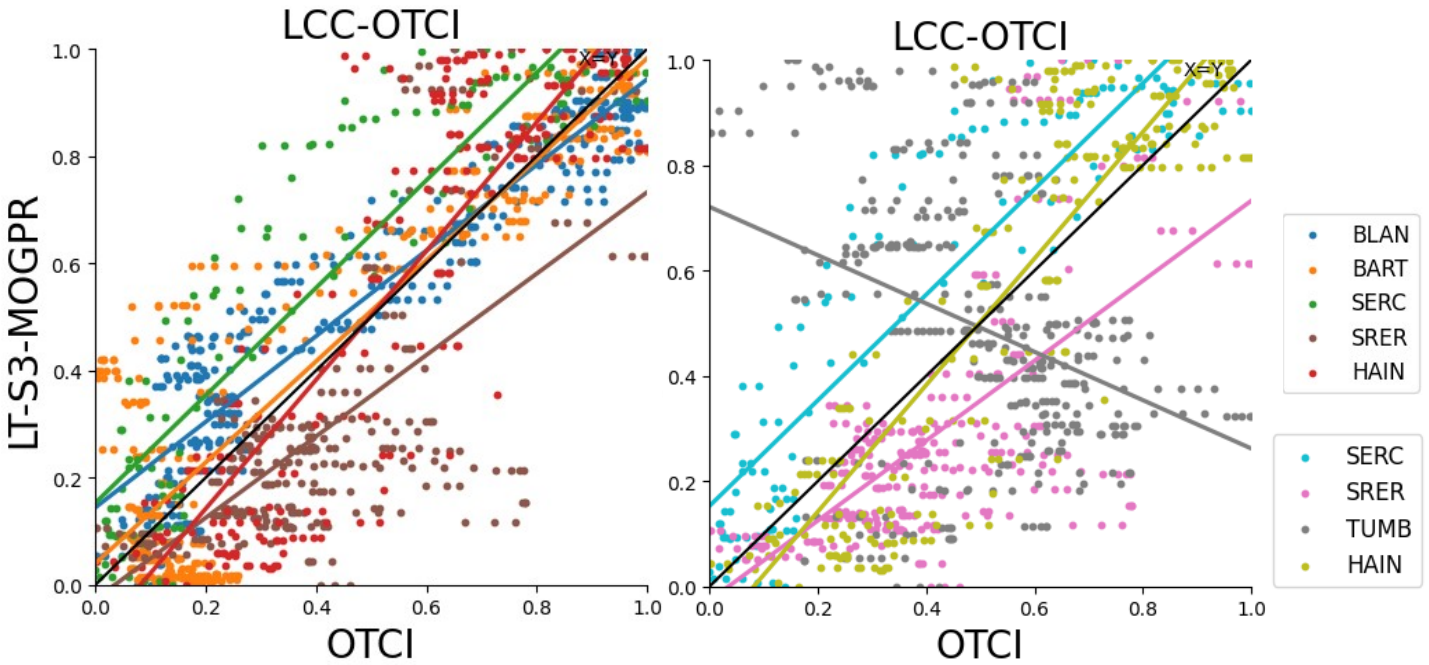
	FAPAR		*FVC*		*LAI*	
	R	NRMSE	R	NRMSE	R	NRMSE
BLAN	0.75	0.14	**0.88**	0.14	**0.82**	0.19
BART	0.6	0.24	0.74	0.26	0.61	0.14
CPER	0.68	0.2	0.78	0.1	0.69	0.09
DSNY	0.34	0.1	0.83	0.1	0.64	0.11
JERC	0.68	0.14	**0.93**	0.1	0.79	0.09
SERC	**0.86**	0.2	**0.93**	0.14	**0.9**	0.08
SRER	0.81	0.26	**0.84**	0.1	0.36	0.05
TUMB	-0.25	0.14	0.56	0.1	0.2	0.1
HAIN	**0.83**	0.26	**0.88**	0.2	**0.82**	0.13
VASN	-0.4	0.2	0.69	0.1	0.23	0.08



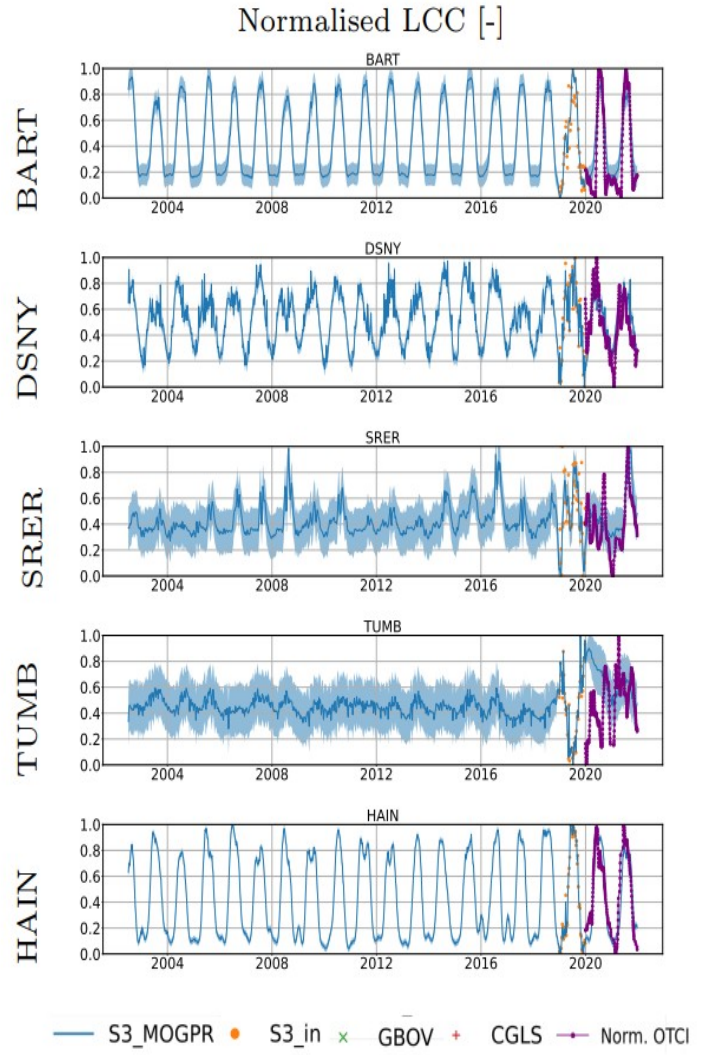
LCC - OTCI comparison

Due to lack of LCC reference products:

- Chose **OLCI Terrestrial Chlorophyll Index** (OTCI) as reference
- Normalised both data between 0-1, needed to smooth OTCI (Whittaker)

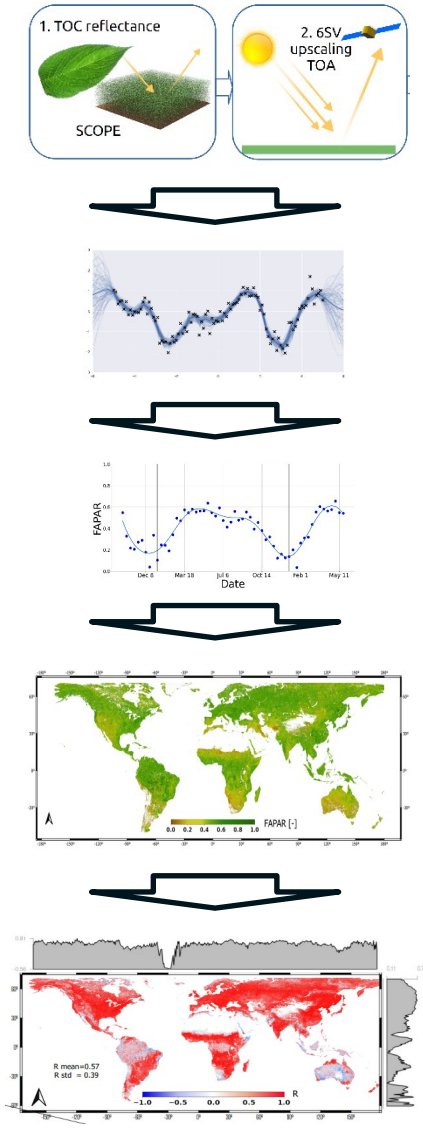


	R
BLAN	0.94
BART	0.90
CPER	0.56
DSNY	0.76
JERC	0.83
SERC	0.91
SRER	0.68
TUMB	-0.38
HAIN	0.90



Conclusions

- **Cloud-based GPR models**: can be easily implemented in **GEE for global mapping**
- **General intra-annual consistency with corresponding MODIS and CGLS products**
- **Efficient reconstruction of past time series 2002-22**
- Intra-annual consistency strongly correlated to **vegetation seasonality**
- Validation against in-situ data is promising, and will be continued
- High consistency to OTCI products
- Easily shareable and applicable: https://github.com/SentiFLEXinel



VNIVERSITAT DE VALÈNCIA

GitHub repo:
daviddkovacs/Global-EVT-maps

david.kovacs@uv.es

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