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Cloud-free global maps of four essential vegetation traits retrieved with Gaussian Processes from S3-OLCI catalogue

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SENTIflex

IPL

FLEX - Sentinel 3 tandem mission

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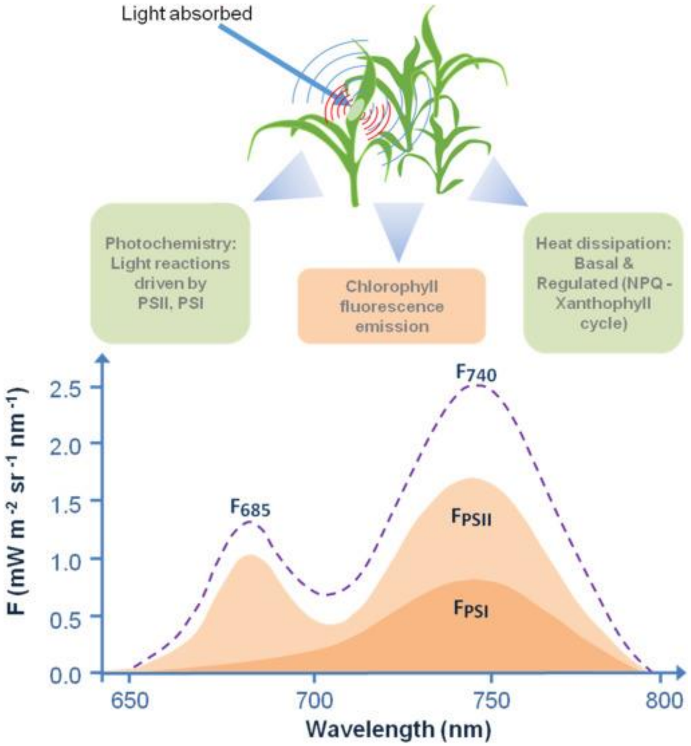
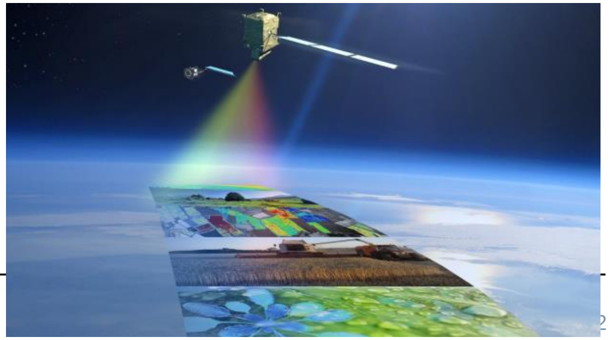
- Goal: Measure Solar Induced Chlorophyll fluorescence and to quantify photosynthetic activity
- Currently **NO** sensors in orbit specified for capturing SIF
- ESA Earth Explorer 8 - Fluorescent Explorer (FLEX) will measure Solar Induced Fluorescence (SIF) at 300m res.
- To be launched in 2025
- Will fly in tandem with Sentinel-3 and benefit from the synergy of OLCI and SLSTR

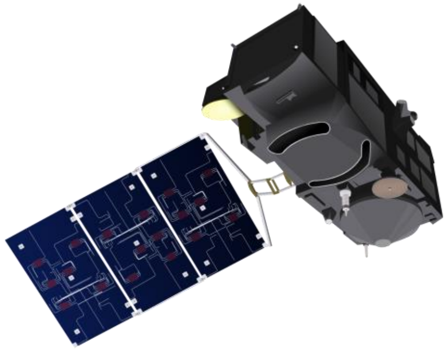


Credit to: Mohammed et al 2019

Our aim: To prepare the workflow and processing chains for future SIF data



Main objectives



To retrieve **temporally reconstructed global maps** of:

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

To utilize S3 OLCI Top Of Atmosphere (TOA) data and hybrid models trained with:

Gaussian Process Regression (GPR)

To implement these models into Cloud computing (Google Earth Engine GEE)

Reconstruct with **Whittaker's smoother** to achieve cloud free data (WS)

Correlate against Copernicus & MODIS products

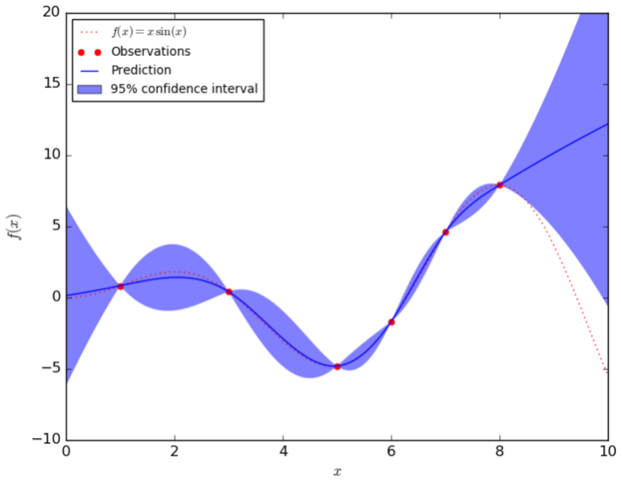
Method of Retrieval

1. Retrieval started with canopy state simulation using the **SCOPE** v.1.7
2. SCOPE **Top Of Canopy** (TOC) were upscaled to →**TOA** using **6SV** RTM[1]
3. Coupling process realized by: Atmospheric Lookup table Generator (**ALG**)[2] and Automated Radiative Transfer Models Operator (**ARTMO**)[3]
4. **GPR** models were trained using TOA radiances and mapped in GEE
5. Spatiotemporally continuous dataset were obtained by using the **WS**

↓

LCC LAI FAPAR FVC

S3-TOA-GPR-1.0-WS models



[1]: Vermote et al. (1997)
[2]: Vicent et al. (2020)
[3]: Verrelst et al. (2012)

Processing S3-TOA-GPR-1.0-WS models

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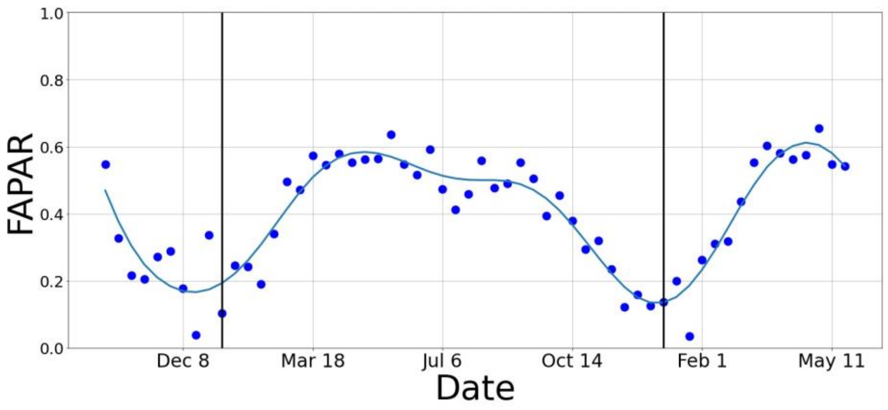
Whittaker's smoother for temporal reconstruction:

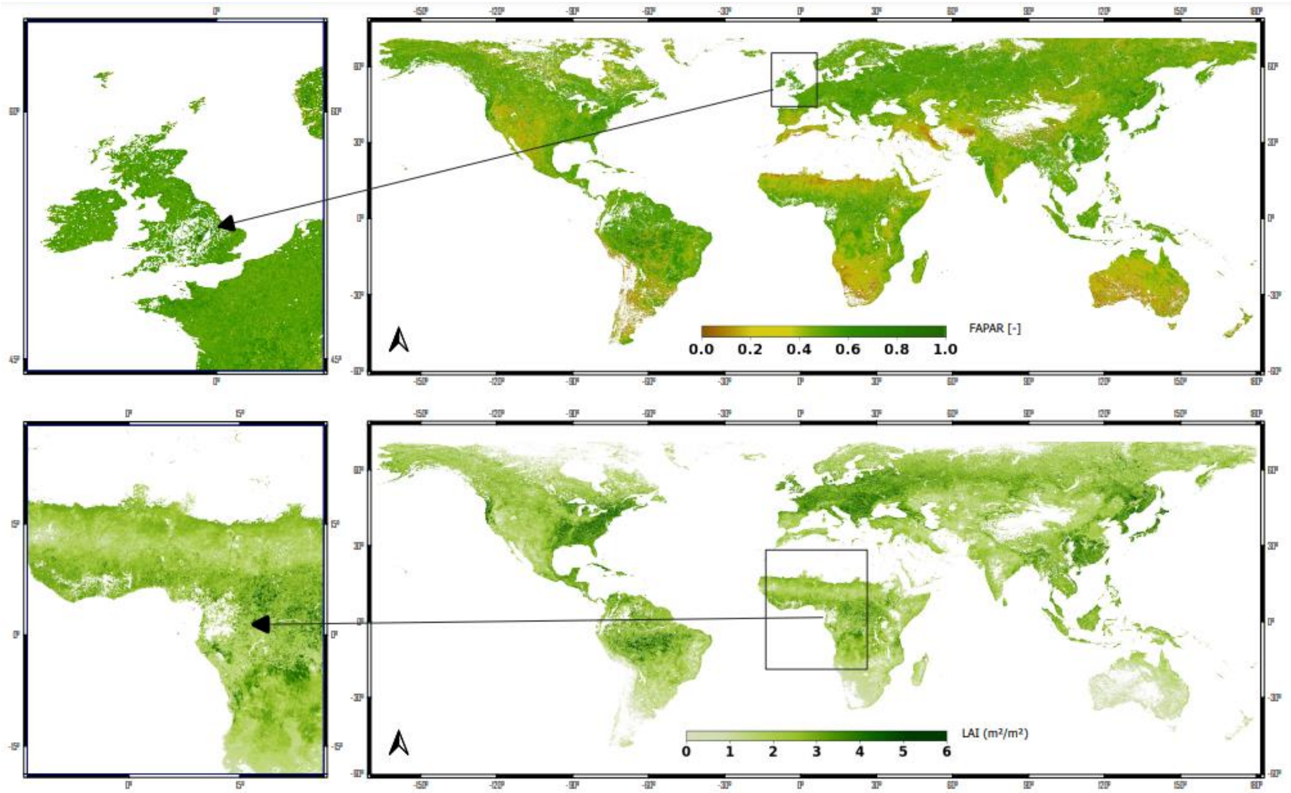
- Penalty weight (λ) = 100, quickly adjustable
- Gaps around low latitudes and polar regions
- Algorithm directly implemented into GEE
- λ can be adjusted quickly

$$(\mathbf{I} + \lambda \mathbf{D}'\mathbf{D})\mathbf{z} = \mathbf{y}$$

Whittaker's governing linear system of equations. Penalty weight: **λ=100**



FAPAR interpolated with Whittaker`s algorithm. 6-6 months extensions for 2019



Global maps

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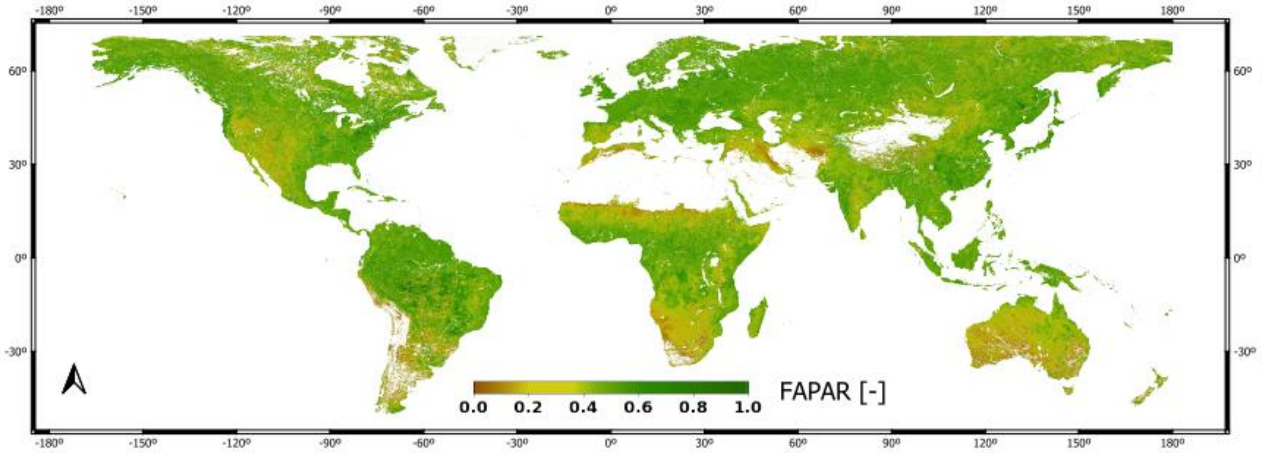
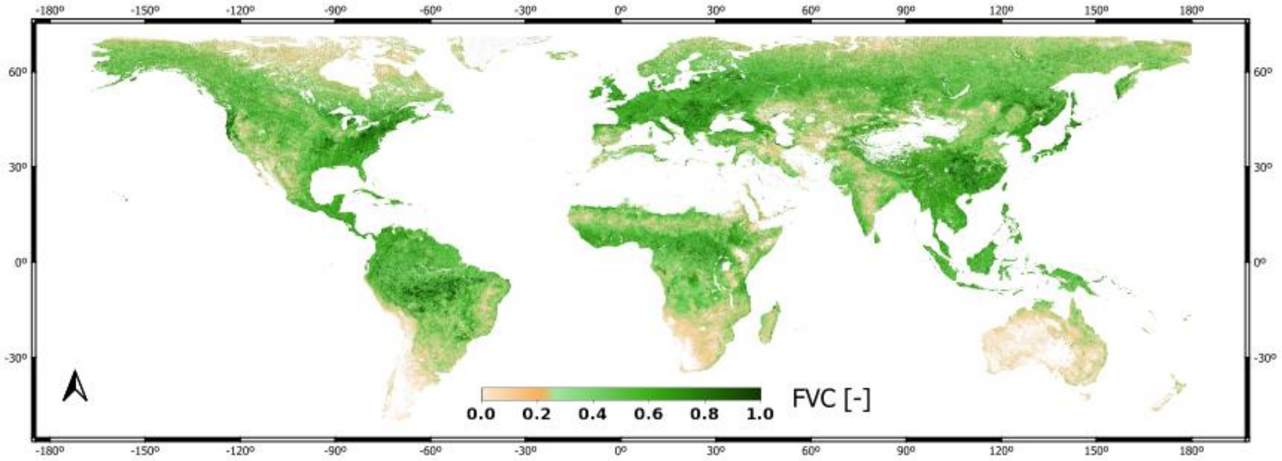
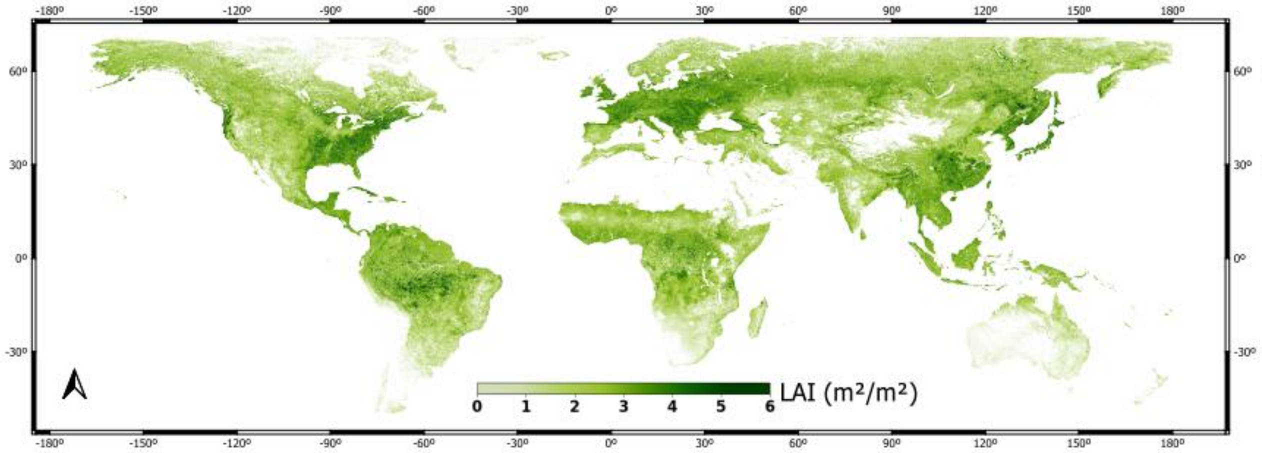
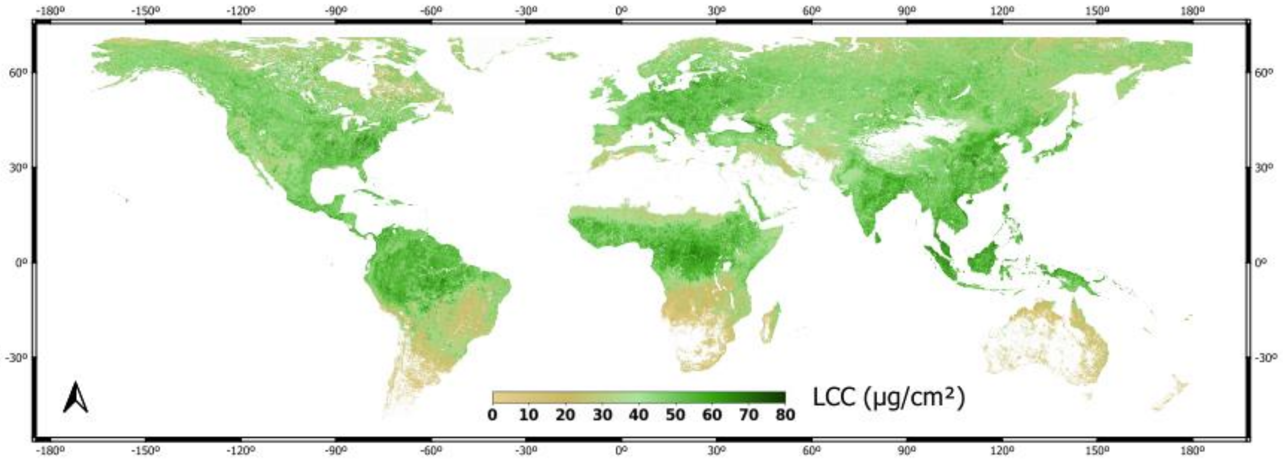
Temporally reconstructed gap-free maps. 10th July 2019 (5km resolution)







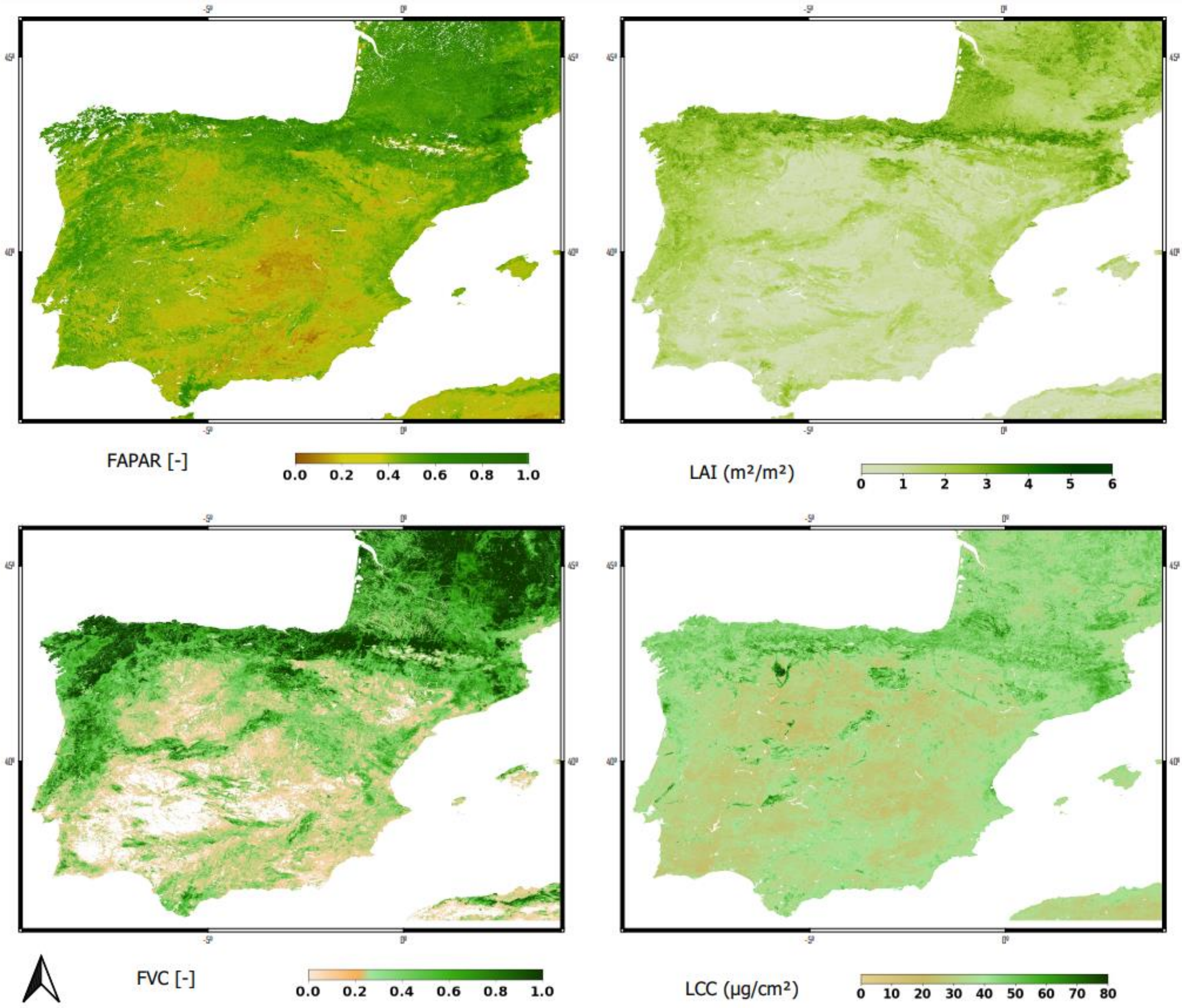


Regional maps at 300m resolution

- 300m (nominal OLCI) resolution results higher memory usage

- Can be used for regional analysis
- 5km is perfectly fine for global applications

10th July 2019 (300 m resolution)

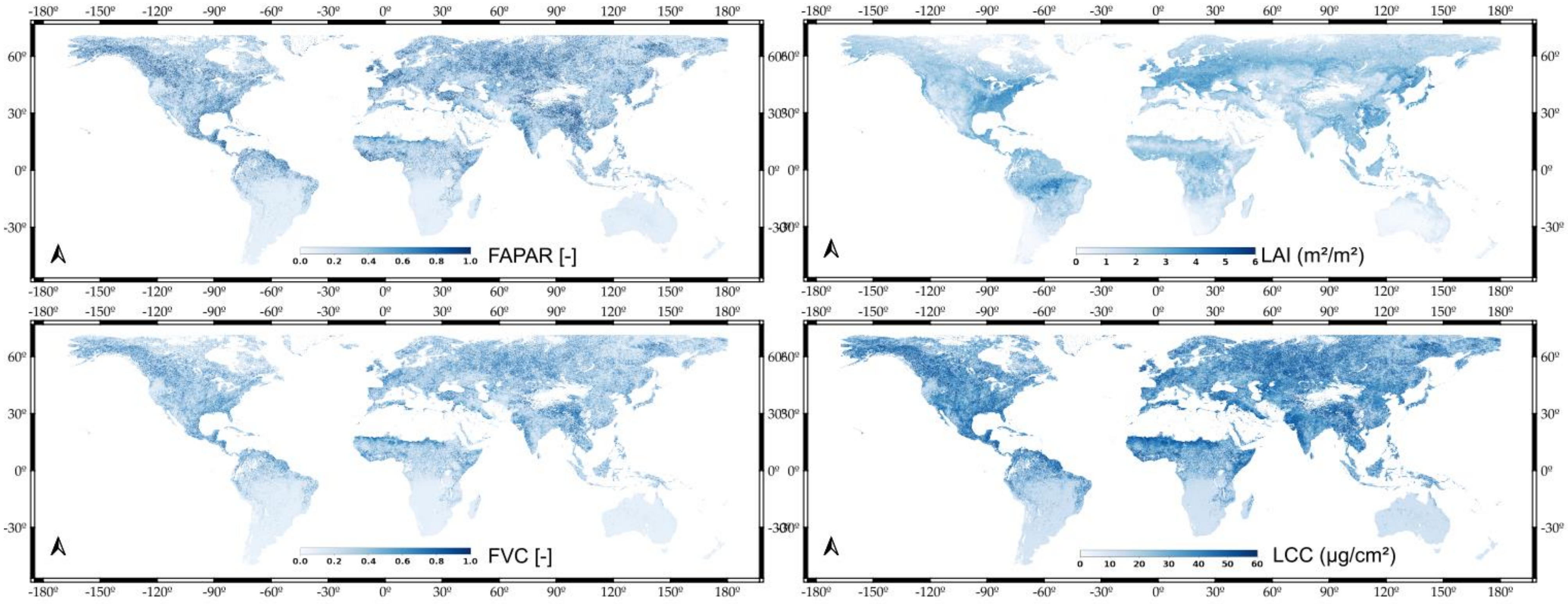


Uncertainty maps

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)



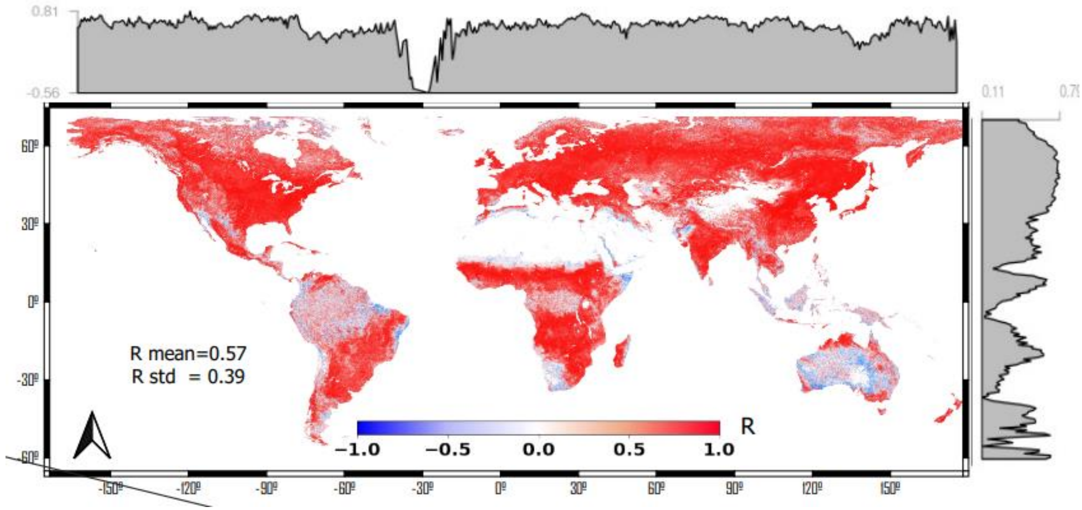
Intra-annual comparison

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

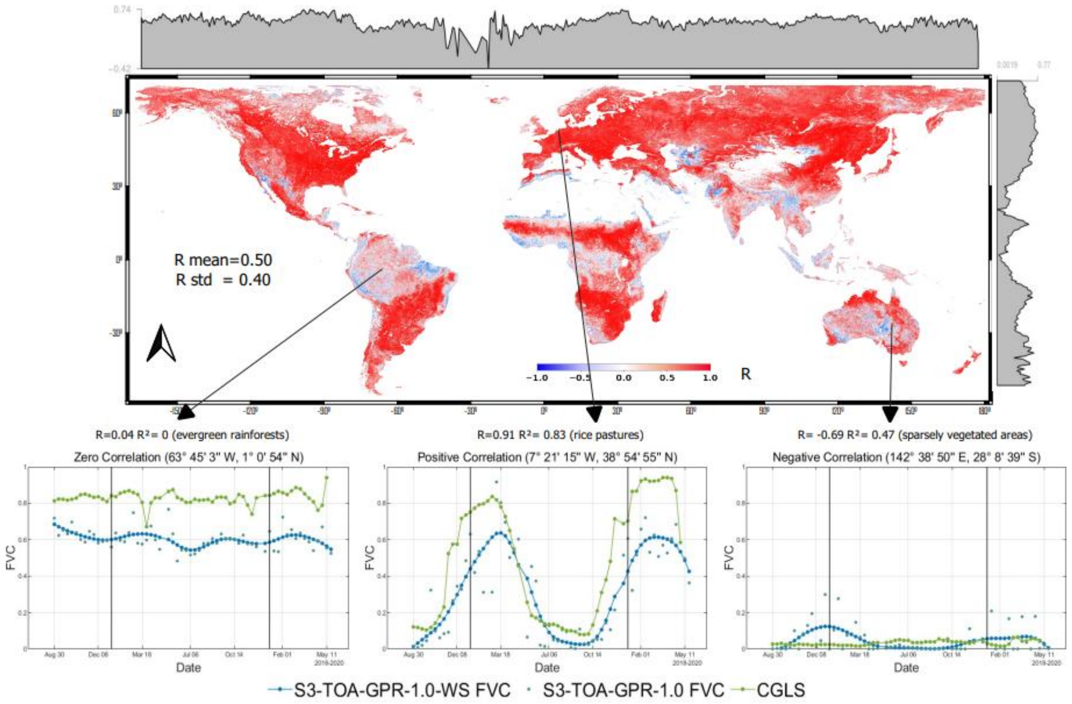
- Against Copernicus (CGLS) and MODIS reference products
- High consistency over 30-60° latitudes

- Lower consistency over latitudes lower than 20°
- Pronounced yearly phenology yielded **superior** GPR retrievals

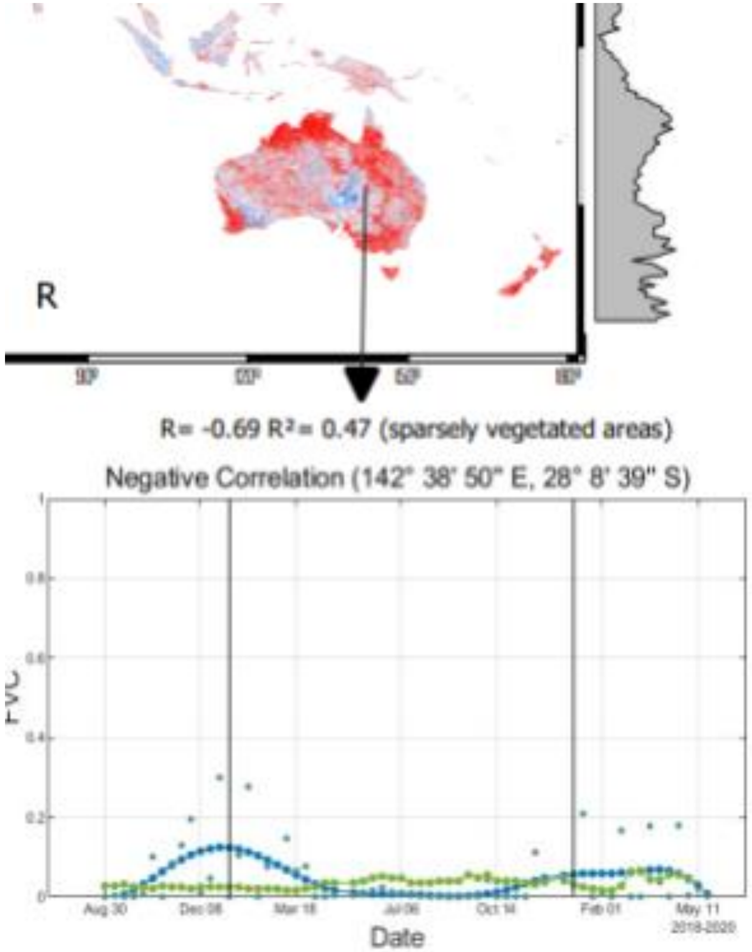
LAI R correlation against CGLS



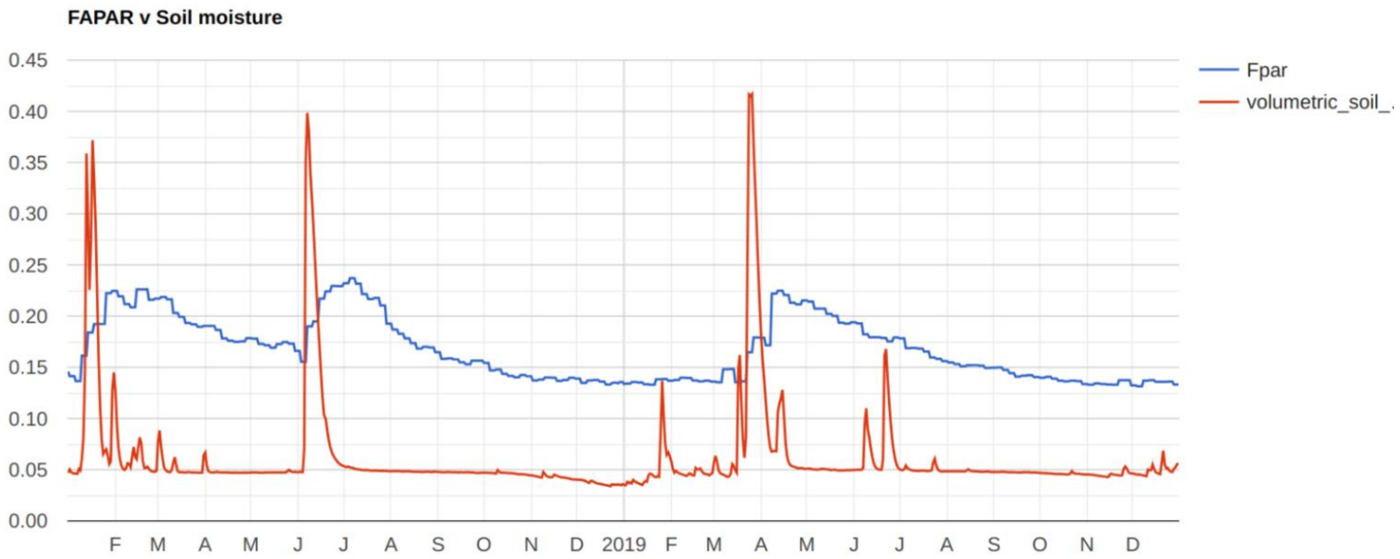
FVC R correlation against CGLS



Environmental causality



- Important remark for models:
  - Soil moisture and precipitation
- Shrublands are much more “sensitive” to precipitation and soil moisture increments
- Interesting vegetation dynamics - highly caused by soil moisture



Validation

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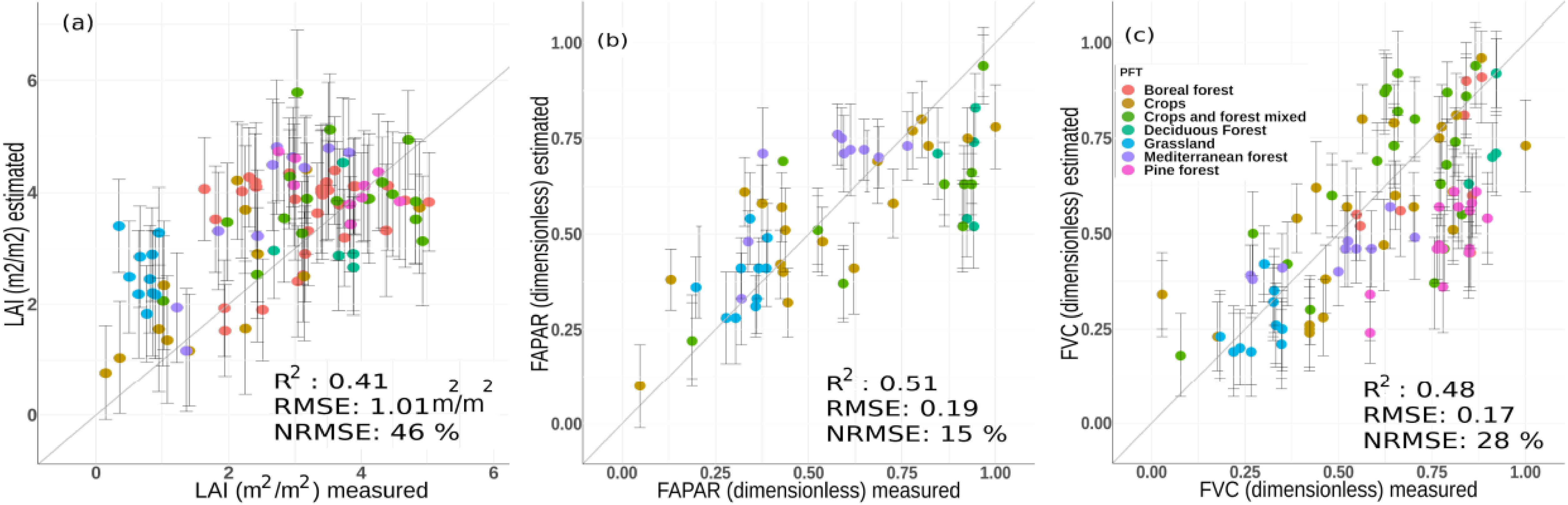
- Against VALERI ground measurements
- FAPAR and FVC best performer followed by LAI
- Overestimation of LAI (grassland and crops)
- FAPAR class samples more "compactly" distributed
- FVC underestimations over pine forests

Validation by Reyes-Muñoz, et al 2022



Land cover specific analysis

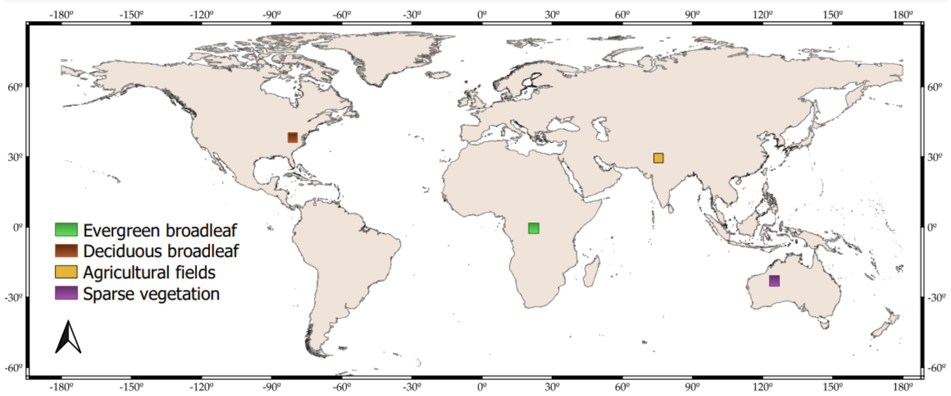
Variables correlated on over

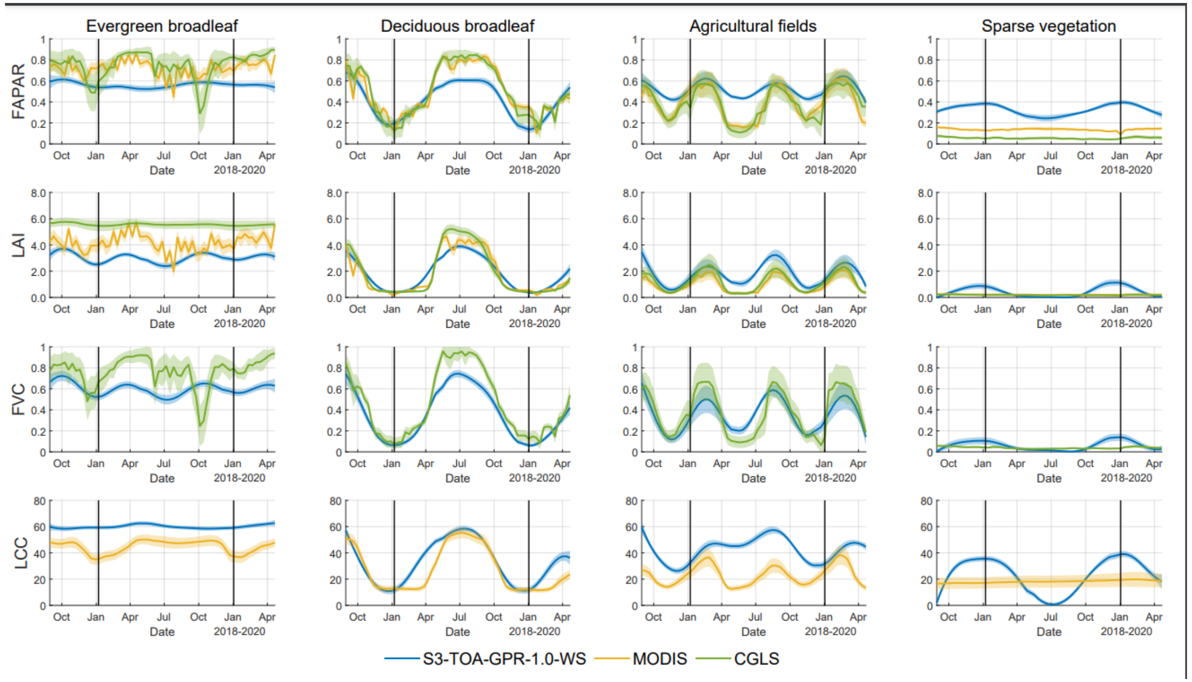
- Evergreen broadleaf (EB)
- Deciduous broadleaf (DB)
- Agricultural (rice and wheat) (AG)
- and Sparse land covers (SP)

Highest correlations, all over DB, yielded by:

1. FVC **R=0.98** vs. CGLS
2. LAI **R=0.95** vs. CGLS
3. LAI **R=0.95** vs. MODIS

Sites for Land cover specific analysis





Advantages of Cloud computing

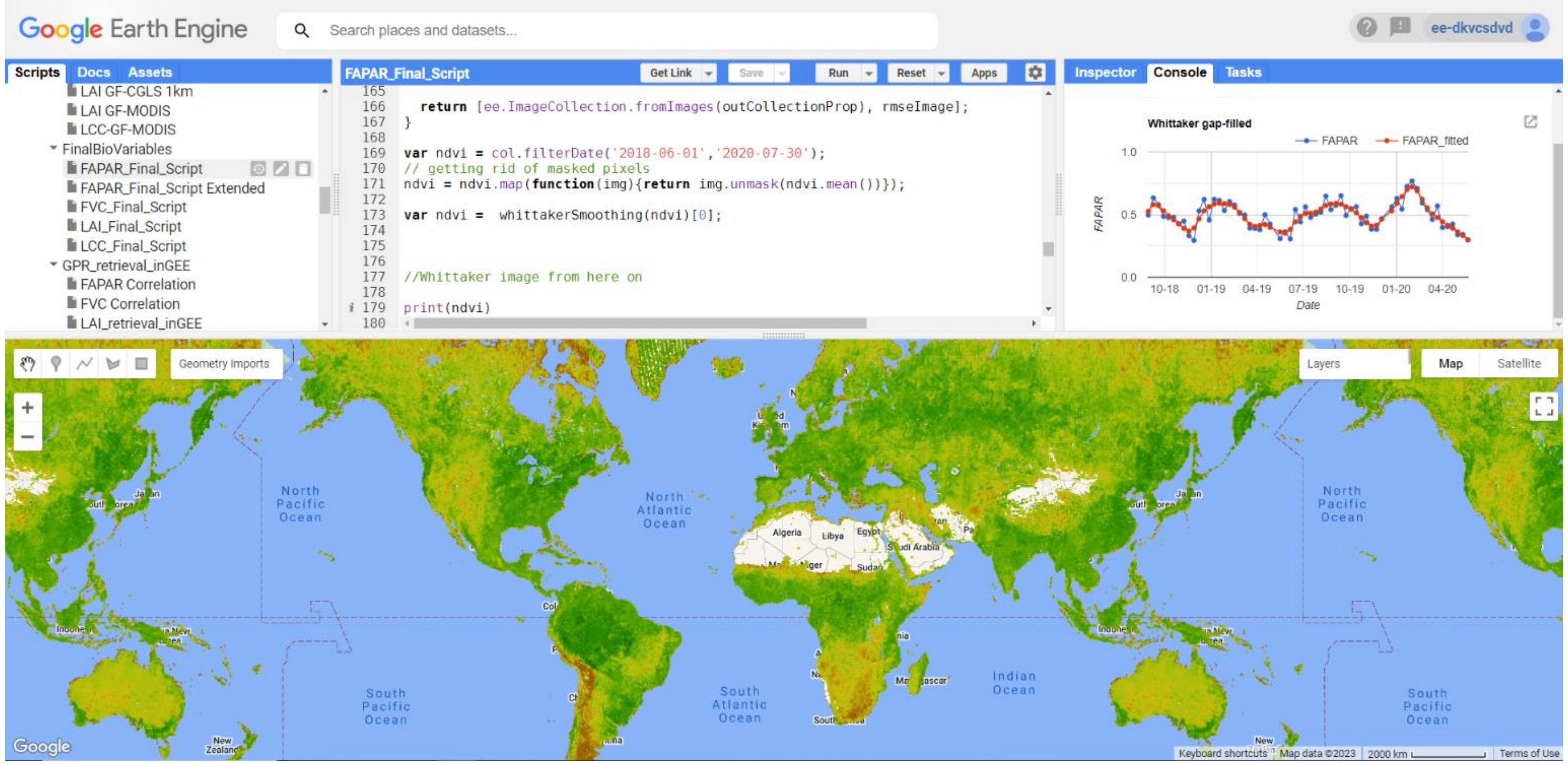
Retrieval can be customized by the user

Processes run on servers, the retrieval can be run on any user's device

Retrieved maps can be downloaded as ".tiffs" and used for further processing

Retrieval widely customisable by freely adjusting:

- Region of interest
- Temporal composites
- Whittaker's lambda can be adjusted freely
- Dates of retrieval: 2016 onwards (S3's launch)
- Spatial resolution



Conclusions

- Cloud based GPR models: can be easily implemented operationally
- Methodology spatially and temporally scalable
- General consistency with MODIS and CGLS products
- Validity is correlated to vegetation seasonality
- Further validation will provide more information about consistencies
- Easily implemented by public users

Any questions?

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Link to GitHub repo:

daviddkovacs/Global-EVT-maps