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TAKING THE PULSE OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

Monitoring vegetation structure using automated digital hemispherical photography and wireless quantum sensor networks: results from the Copernicus Ground Based Observations for Validation (GBOV) service

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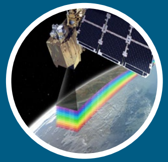
The need for automated in situ measurements

- Periodic field campaigns fail to provide the detailed information on vegetation temporal dynamics needed in many applications:

Modelling carbon storage and exchange

Monitoring vegetation productivity

Simulating the weather and climate systems



Validating satellite products

- To address this, several automated biophysical variable measurement techniques have emerged in recent years…

Automated in situ measurement techniques

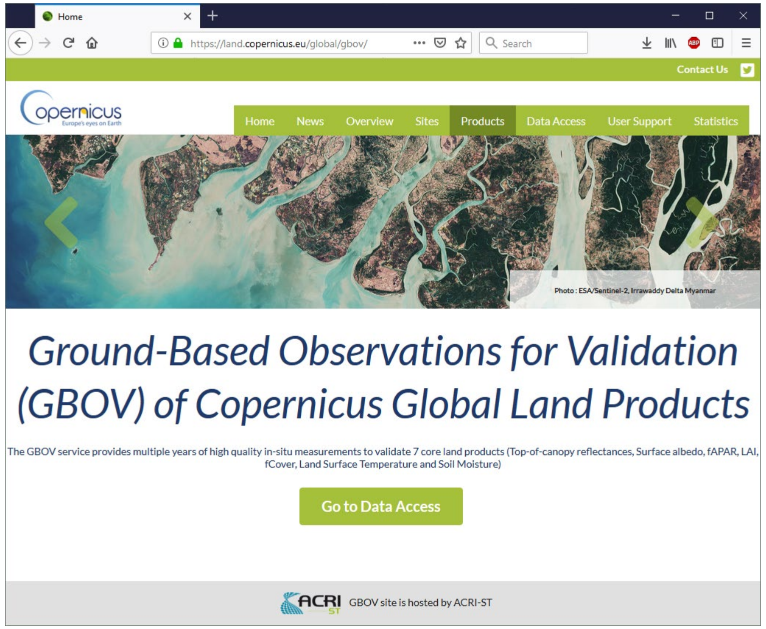
Technique	Image	Advantages	Disadvantages
Radiometric sensors (Qu et al., 2014; Toda and Richardson, 2017; Brede et al., 2018; Fang et al., 2018; Putzenlechner et al., 2019)		Measures a radiometric quantity A network of sensors can provide spatial sampling Can derive FAPAR and LAI_e	Regular calibration needed Variable illumination can cause artefacts (need data screening) Cannot easily derive FCOVER
Automated digital cover photography (Ryu et al., 2012; Toda and Richardson, 2017; Chianucci et al., 2021)		Very inexpensive Can derive LAI_e, LAI, and FCOVER	Leaf angle distribution data needed to derive LAI_e and LAI Limited measurement footprint Cannot easily derive FIPAR
Automated digital hemispherical photography (Brown et al., 2020; Niu et al., 2021; Wilkinson et al., 2021)		Increased measurement footprint Can derive LAI_e, LAI, FIPAR and FCOVER	Sensitive to illumination conditions (need data screening)
Automated terrestrial laser scanning (Culvenor et al., 2014; Portillo-Quintero et al., 2014; Griebel et al., 2015)		Active sensor, so not dependent on illumination conditions Can derive LAI_e, LAI, FIPAR and FCOVER	Expensive Sensitive to wind speed and moist weather (need data screening)

Introduction to GBOV

- Within the Copernicus Land Monitoring Service, the **global component** provides **bio-geophysical products** to monitor the status and evolution of the land surface

- **GBOV** was initiated to **provide in situ data** for calibration and validation activities, and has three components:

1. Collection of **multi-year ground based observations**
2. **Upgrade of existing sites with new instrumentation** or establishment of new sites **to close thematic or geographic gaps**
3. Implementation and maintenance of a **database for distribution of in situ reference measurements** (and upscaled land products for validating moderate spatial resolution EO data)



https://land.copernicus.eu/global/gbov

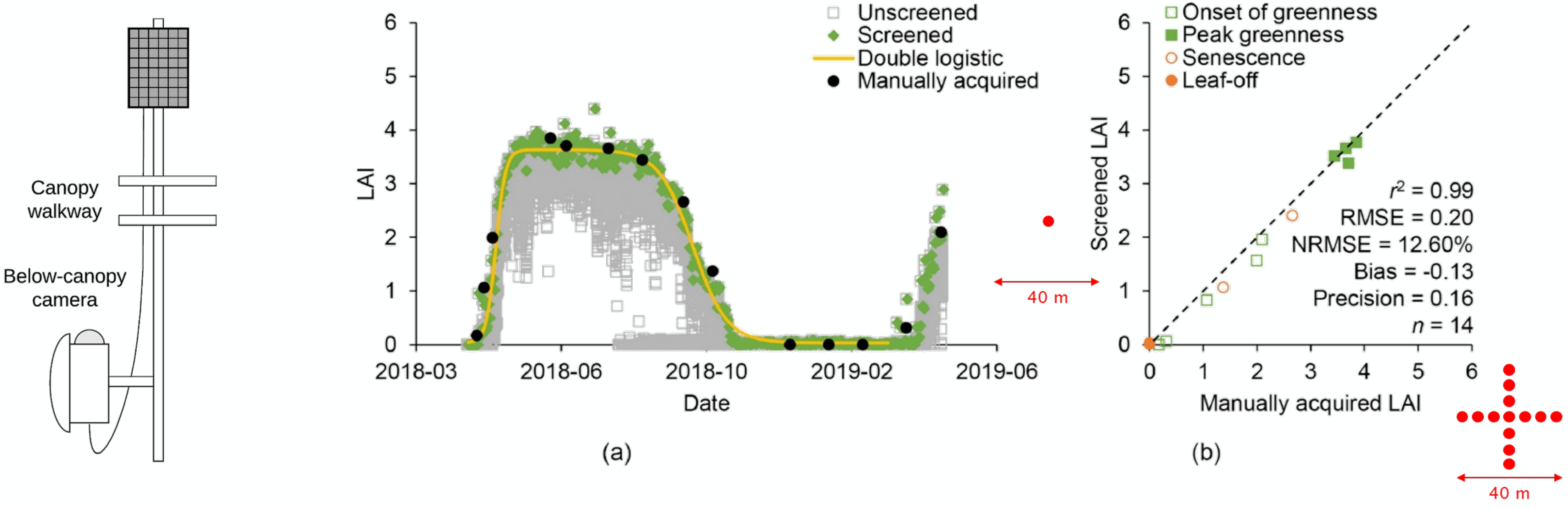
GBOV Component 2 installations in Phase 1 (2017-2021)

Site	Image	Vegetation	Status
Valencia Anchor Station Spain		Vineyard	Wireless quantum sensor network installed
Hainich National Park Germany		Deciduous broadleaf forest	Automated DHP system installed Wireless quantum sensor network installation pending
Tumbarumba Australia		Wet eucalypt forest	Wireless quantum sensor network installed (but lost after 1 month to bushfires!)
Litchfield Australia		Tropical savanna	Automated DHP system installed Wireless quantum sensor network installation pending
Wombat Australia		Dry eucalypt forest	Automated DHP system installed Wireless quantum sensor network installation pending (tower damaged in recent storms)

Automated digital hemispherical photography (1)

Brown et al. (2020)
Agricultural and Forest Meteorology

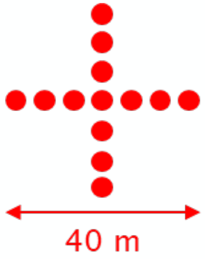
- **Initially investigated at Wytham Woods** (UK)



- **Daily maximum provided most realistic values** (noise was negatively biased)
- Screened data from **automated system agreed well with manually acquired data** (12 points in surrounding 40 m plot under optimal illumination)

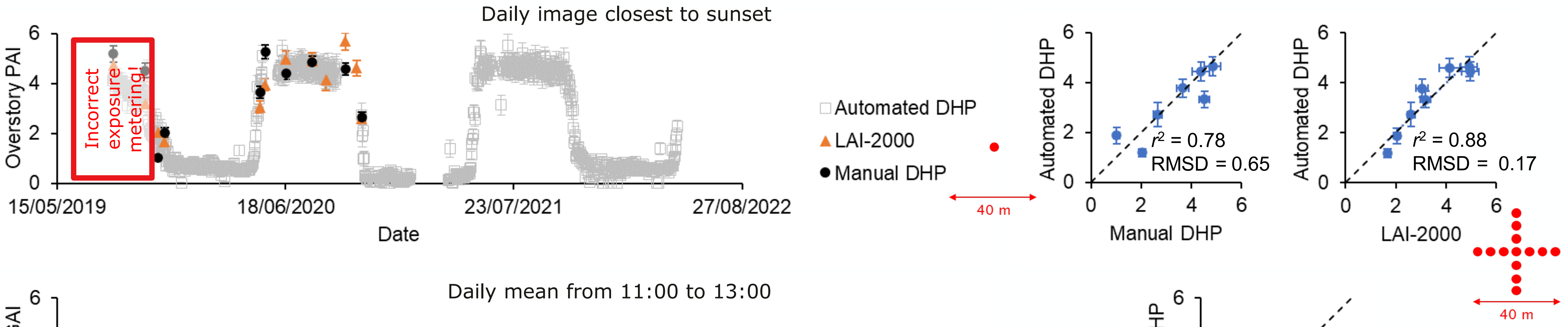
Automated digital hemispherical photography (2)

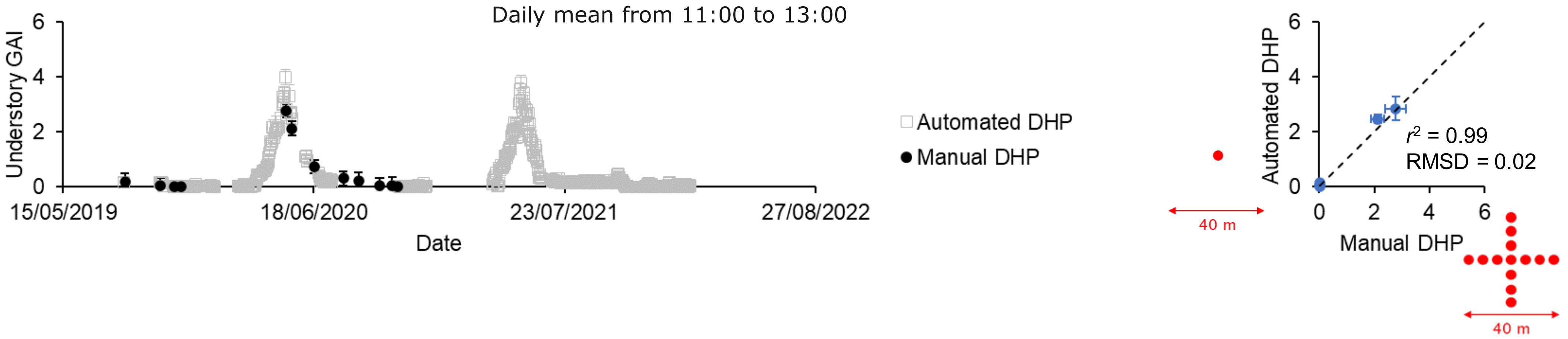
- **First GBOV deployment at Hainich National Park** (2019)
  - Dual camera system (understory & overstory)
  - 1.3 m above ground
- **Second deployment at Litchfield** (2020)
  - Testing a **horizontally mounted** configuration
- **Third deployment at Wombat** (2021)
- **Harbortronics Cyclapse**
  - Waterproof housing
  - Canon EOS 1300D DSLR & Sigma 4.5 mm F2.8 EX DC lens
  - Cellular modem for data transmission
  - Mains or solar power
  - **Images every 30 minutes** during daylight hours
- **Complemented with manual data collection** (DHP, LAI-2000)
  - 13 points within surrounding 40 m plot



Automated digital hemispherical photography (4)

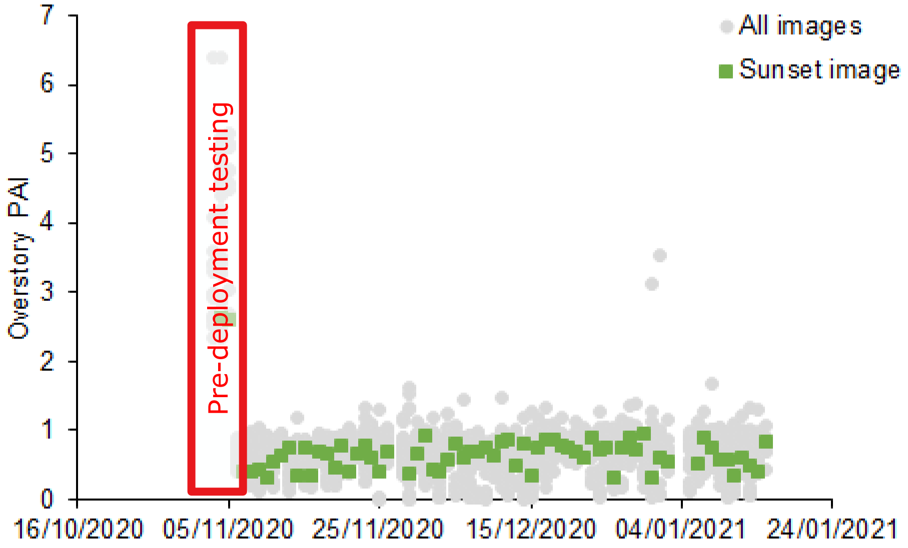
- Screened data show **good agreement with manual DHP & LAI-2000** at Hainich National Park
  - Noise not negatively biased so different data screening required

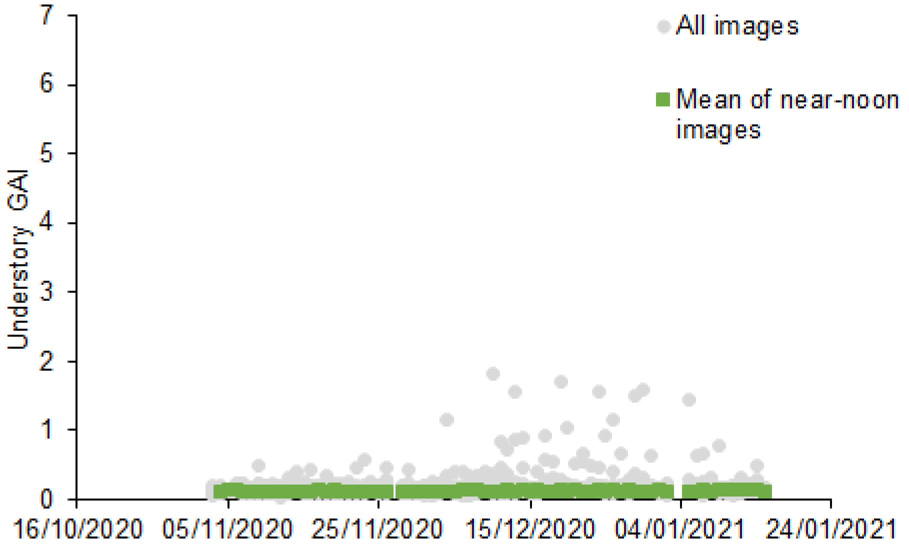




Automated digital hemispherical photography (5)

- Litchfield processing ongoing, but **initial results are in the correct range** for the site (0.6 to 1.0) according to previous studies





- Processing of whole time-series and comparison with manual DHP & LAI-2200 coming soon..!

Wireless quantum sensor networks (1)

- **First GBOV deployment at the Valencia Anchor Station** (2020)
  - **12 nodes** within a 60 m plot (six within and six between rows)
  - **Four sensors per node** (two above and two below)

- **Environmental Sensing Systems**
  - Apogee SQ-110 quantum sensors
  - Data loggers and base station
  - Solar power
  - Cellular modem for data transmission
  - Measurements every 5 minutes

- **Manual data collection throughout the season** (DHP)
  - 21 sampling locations in the 60 m plot




Wireless quantum sensor networks (2)

- **FAPAR derived** at 10:00 local solar time (± 15 minutes)

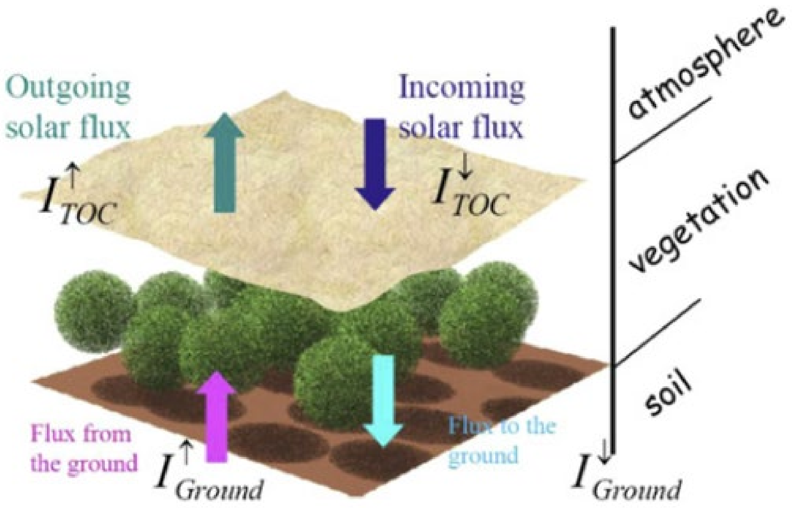
- **Compared with DHP**-derived FIPAR (assumes black leaves)

$$FIPAR = 1 - \overline{P(\theta_{SZA})}$$

- **Two- and four-flux definitions** computed

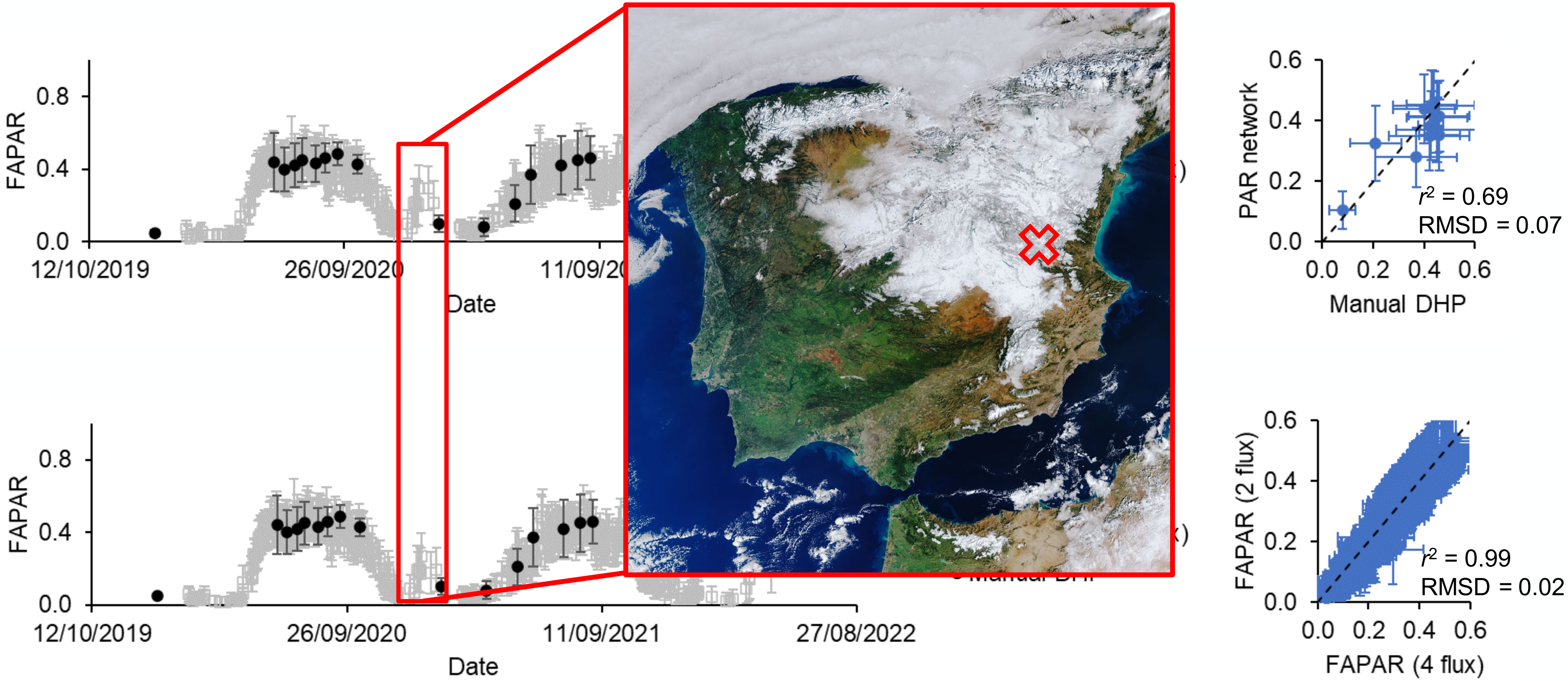
$$FAPAR_{\text{four}-flux} = \frac{I_{TOC}^{\downarrow} - I_{ground}^{\downarrow} + I_{ground}^{\uparrow} - I_{TOC}^{\uparrow}}{I_{TOC}^{\downarrow}}$$

$$FAPAR_{\text{two}-flux} = 1 - \frac{I_{ground}^{\downarrow}}{I_{TOC}^{\downarrow}}$$



Wireless quantum sensor networks (3)

- **Good agreement with manual DHP** at Valencia



Perspectives for satellite product validation

- **Methods to upscale temporally dense but spatially limited in situ data are needed** to validate hectometric satellite products
  - **Multitemporal transfer functions** (Campos-Taberner et al., 2016; Yin et al., 2017)
  - **Radiative transfer model based approaches** (Brown et al., 2021)

- **Product definitions should be considered carefully**
  - Wireless quantum sensors measure total FAPAR
  - Downwards-facing DHP measures green FIPAR and GAI, upwards-facing measures total FIPAR and PAI
  - Corrections for woody area may be needed (e.g. PAI to LAI)

- Even with our bright soil background, **consistency of 2- and 4-flux FAPAR reflects recent work** (Li et al., 2021)
  - Useful for field campaign practicalities

Conclusions and outlook

- **Consistency with manual DHP and LAI-2000 data provides confidence** that the investigated approaches can deliver data of comparable quality

- These approaches are **already useful for validating decametric satellite products** (amongst many other environmental applications)
  - Contemporaneous **in situ data whenever a satellite image is cloud free!**

- Next steps:
  - **Evaluate upscaling approaches** for validating hectometric satellite products
  - Complete the pending deployments at other sites!
  - Explore derivation of **FIPAR and FCOVER time series from the automated DHP systems**
  - Investigate derivation of **PAI_e from the wireless quantum sensor networks** (using measurements when SZA = 57.5° or ancillary data on leaf angle distribution)