fiducial reference measurements for satellite vegetation products

# Fiducial Reference Measurements of land surface parameters for validation of Sentinel 2 y Sentinel 3, FRM4VEG project and CEOS LPV super-sites selection


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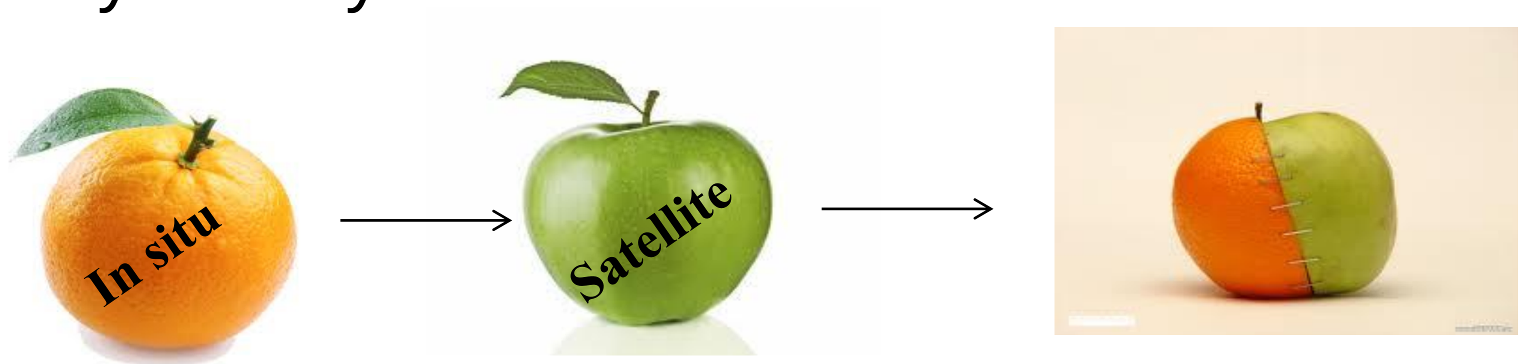
# The Truth about In situ Data

- Most in situ methods do not (can not) measure the target quantity directly




## FRM Projects: Fiducial Reference Measurements

- Concept created out of the S3 mission team for SST
- Direct translation of QA4EO to in situ / reference data
- In situ measurements / campaigns specifically designed for satellite data/product validation:
  - That are rigorous on traceability and uncertainty characterisation
  - May provide a means to bridge potential data gaps
  - Facilitate interoperability between sensors
  - Anchor / establish FDRs
- Largely funded by ESA, but are being adopted more widely by other space agencies in the context of CEOS

# *FRM Projects MUST…*

- Have documented evidence of metrological traceability to SI (or appropriate international community standard) including full uncertainty budget (instrumentation and usage), which must be at a level commensurate with the application
- Consider all spatial/temporal/scaling issues
- Be <u>independent</u> of any satellite geophysical retrieval process
- Provide long-term sustainable mission validation information
- Be carried out following community agreed good practice protocols (some which still need to be written!)

# Current FRM projects

fiducial reference temperature measurements

FRM4ALT
Fiducial Reference Measurements for Altimetry

pandonia
Fiducial Reference Measurements for Atmospheric Composition

fiducial reference measurements for satellite ocean colour

FRM4DOAS

fiducial reference measurements for vegetation

Fiducial Reference Measurements for Greenhouse Gases

FRM4SAR

amt4oceansatflux

Support the initial validation of Copernicus vegetation-related products (fAPAR, LAI, CCC) from:

- Sentinel-3 (L2)
- Sentinel-2 (L2)

As well as proposing the methodologies for the definition of the required Fiducial Reference Measurements (FRM) for vegetated field sites

# Phasing

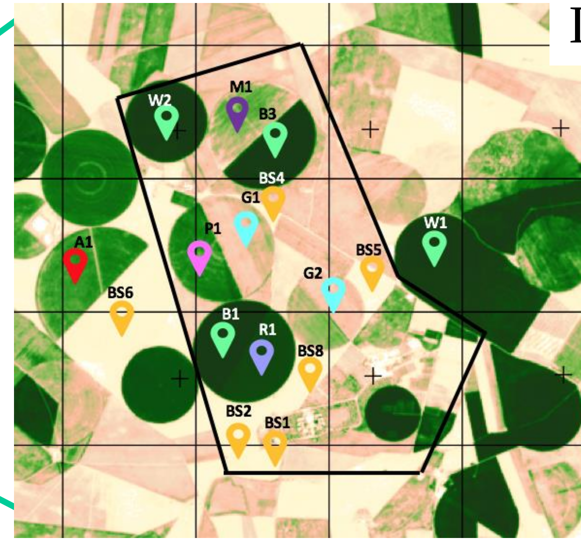
**Phase 1 (2018 -19)**

- Produce FRM protocols and procedures documentation
- Produce FRM validation methodology documentation (uncertainty budgets)
- Pre- and post- field sensor calibrations
- Conduct field campaigns (Barrax, Wytham Woods)

**Phase 2 (2019-20)**

- Repeat phase 1 activities at 2 new field sites
- Define requirements for and set up a FRM supersite

# *Barrax sampling*

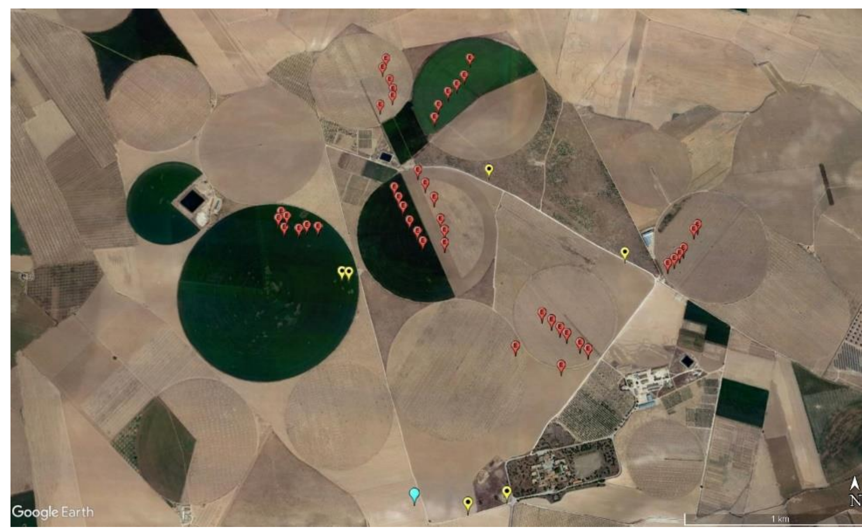

Las Tiesas farm

A –Alfalfa
P –Pappaver
B- Barley
G- Garlic
R- Rapeseed
W-Wheat
BS- Bare soil

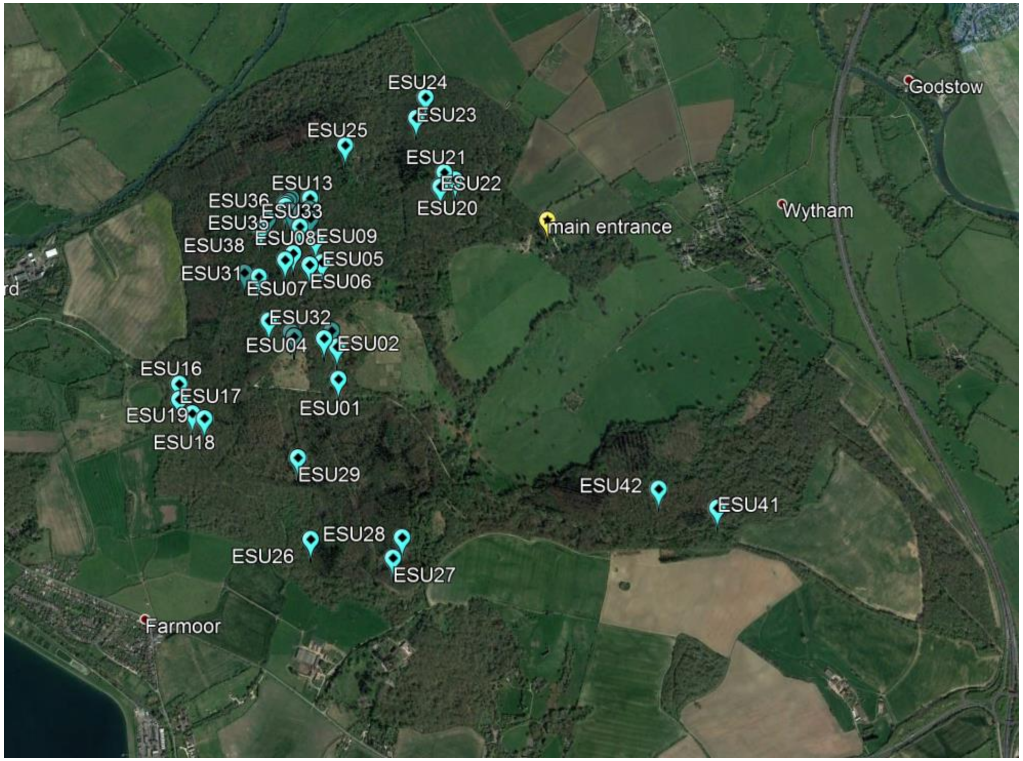
- Dates: **1st -8th June** 2018 + **2nd August** 2018

**52 ESU** were characterized with DHP, LiCor-2200, SPAD

**7 crop types** + barley (senescent)
+ bare soil characterized



# *Wytham sampling*


- Dates: **3rd – 12th July** 2018 + **23rd August** 2018
- 42 ESUs characterized
- 9 ESUs coincident with PAR sensors

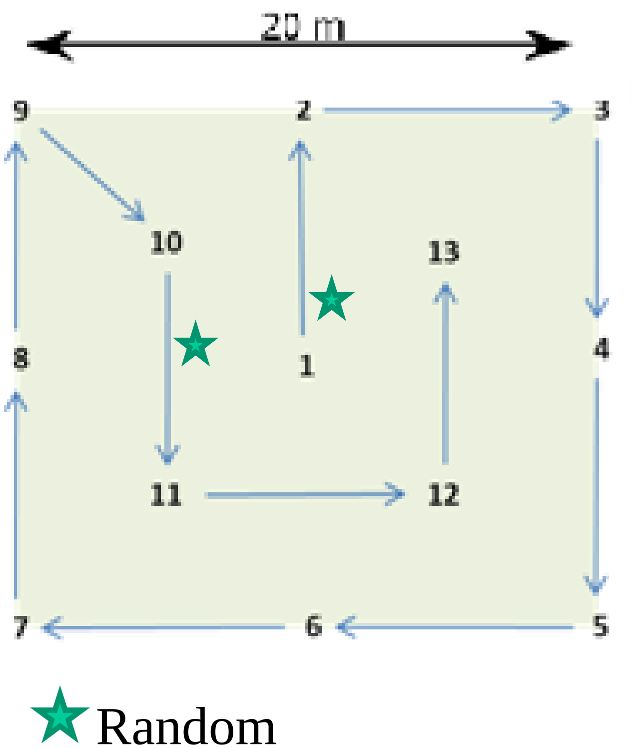
No. PAR sensors used per ESU

| ESU | PAR sensor |
|---|---|
| 10 | 7 |
| 11 | 13 |
| 12 | 20 |
| 33 | 5 |
| 34 | 22 |
| 35 | 27 |
| 36 | 30 |
| 39 | 31 |
| 40 | 28 |

# *Sampling the ESU*


# Sampling the ESU

- ➢A systematic sampling scheme was followed (VALERI).
- ➢The size of the area sampled was around 20 m x 20 m.
- ➢The sampling includes 13-15 individual measurements.
- ➢The GPS coordinates of the centre of the ESU (point 1) taken.




- ➢DHP – 15 photos
- ➢LAI-2200 – 3 up x 5 down
- ➢SPAD – 18 samples x 13 locations
  (3 leaves – top, middle and bottom
  6 replicates per leaf)
- ➢ All ESUs were flagged,
- ➢ **fAPAR, LAI and Chl were taken over same locations !**
- ➢In forest, overstory and understory characterized

# FAPAR uncertainty

| Source | Symbol | Type | Description | Devices |
|---|---|---|---|---|
| Calibration | $u(c)$ | Systematic | Uncertainty in the calibration coefficient | Quantum sensors<br>Ceptometers |
| Spectral | $u(\lambda)$ | Mostly systematic | Error in the spectral range/response not equating to true PAR response | Quantum sensors<br>Ceptometers |
| Radiometric resolution | $u(r_r)$ | Systematic | Resolution of data logger to record voltage | Quantum sensors<br>Ceptometers |
| Angular response | $u(m_\theta)$, $u(m_\varphi)$ | Systematic | May refer to cosine response, lens characterisation, etc. | DHP<br>Quantum sensors<br>Ceptometers |
| Levelling | $u(\theta)$, $u(\varphi)$ | Usually random | Zenith and azimuth errors | DHP<br>Quantum sensors<br>Ceptometers |
| Exposure settings | $u(l)$ | Random | Uncertainty due to exposure settings in the camera | DHP |
| Image classification | $u(class)$ | Random | Uncertainty due to operator decision on the soils/veg classification with CAN-EYE software. | DHP |
| Sampling | $u(samp)$ | Random | Uncertainty due to spatial heterogeneity and the sampling performed (i.e., deviation in the gap fraction value per measurement) | DHP<br>Quantum sensors<br>Ceptometers |
| Sky uniformity | $u(sky)$ | Random | Cloud and sky variations can affect the measurements over the same ESU. | DHP<br>Quantum sensors<br>Ceptometers |
| Definition (assumptions) | $u(def)$ | Systematic | Uncertainty due to the black-leaves assumption (FIPAR vs FAPAR) | DHP<br>Quantum sensors<br>Ceptometers |

Type 1
Manufacture's and calibration

Type 2
Set up and measurements

# Levelling

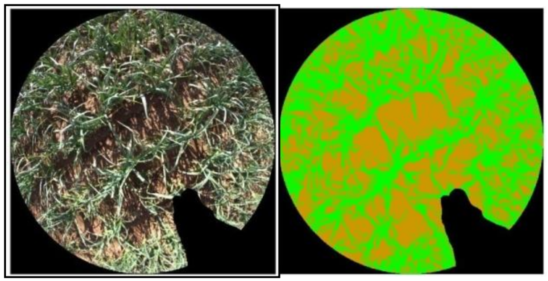
Origo et al. (2017)

***"The results show that the average difference between the two procedures is < 2% for effective plant area index and < 1% for gap fraction"***

$\sigma_{lev}$ = 1% with hand-levelling techniques for FAPAR (2% for PAI).

# *DHP FAPAR uncertainty*

## *Sampling*



Propagation of uncertainties due to within-ESU variability of gap fraction, related to spatial heterogeneity

**$\sigma_{sam}$ = Standard Error from mean gap fractions of all images at the $\theta_s$=10:30 UTC.**

## *Classification*


Experiments conducted in both campaigns. 5 ESUs/site were classified by three different operators

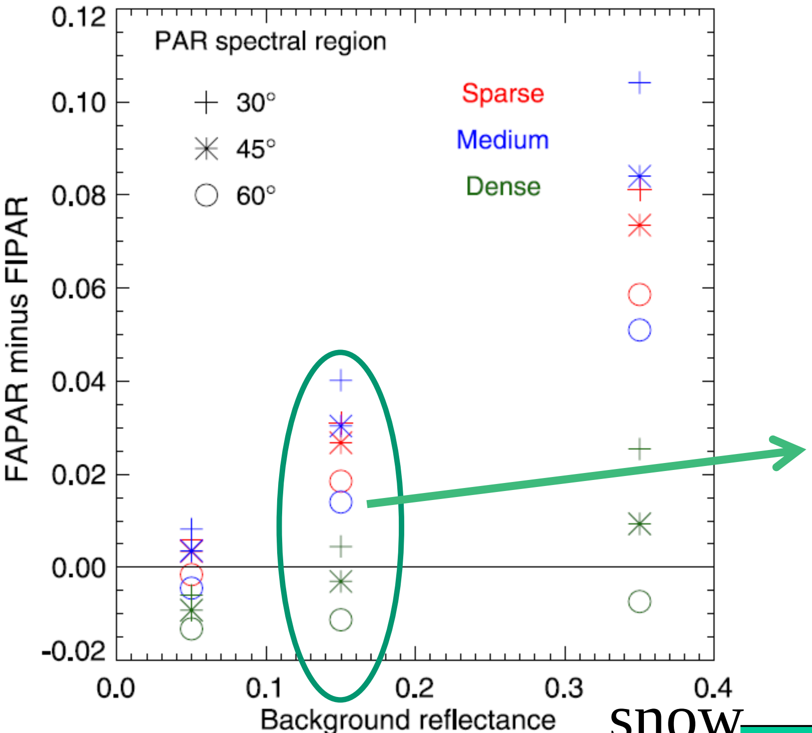
**$\sigma_{clas}$ = Standard Error of FAPAR 10:30**
~ 4 % (no systematic trend detected)

# *DHP FAPAR uncertainty*

## *Definition (assumptions)*

| DHP | | |
|---|---|---|
| Angle/Levelling ($\sigma_{lev}$) | According to Origo et al. (2017), no important differences (~2%) with hand-levelling techniques. | 2 % |
| Sampling ($\sigma_{sam}$) | Uncertainty due to deviation in the GAP fraction value per image | 6% |
| Operator Class. ($\sigma_{class}$) | Uncertainty due to Operator decision on the class. CAN-EYE software | 4 % |
| Definition ($\sigma_{def}$) | due to the black-leaves assumption (FIPAR vs FAPAR) | 5% |

$\sigma_{def}$ =Gobron et al., (2006)




snow

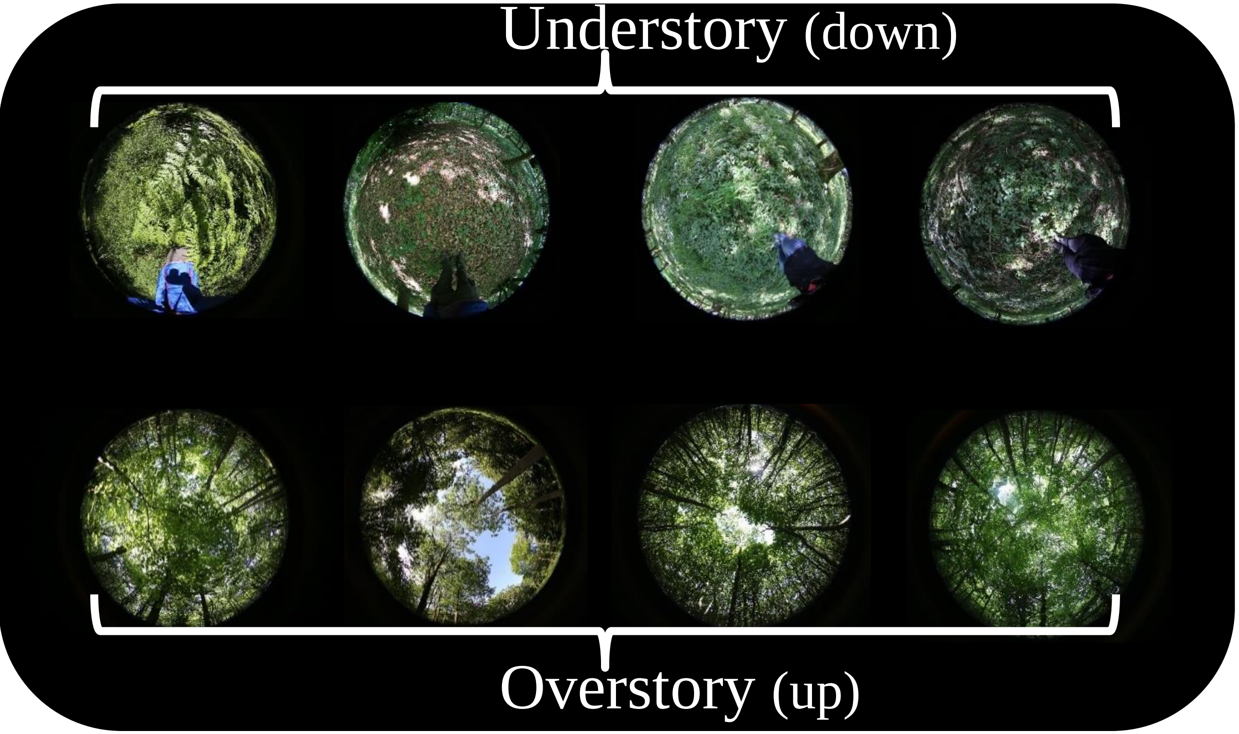
$$\sigma(fAPAR) = \sqrt{\sigma_{lev}^2 + \sigma_{sam}^2 + \sigma_{class}^2}$$

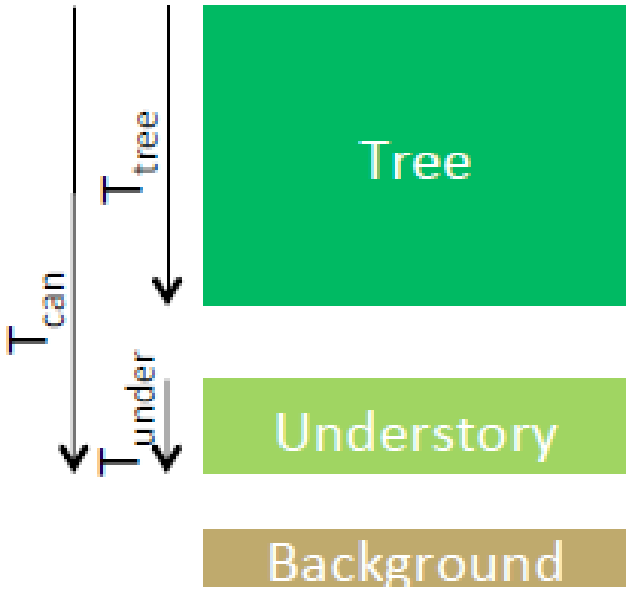
**$\sigma_{def}$ = variable (soil background, LAI, SZA)**

**FIPAR is a good proxy for FAPAR, but somes differences are expected** ~ 5%

# DHP FAPAR uncertainty

## Understory




$T_{can}$=1-$FIPAR_{can}$

$T_{tree}$=1-$FIPAR_{tree}$

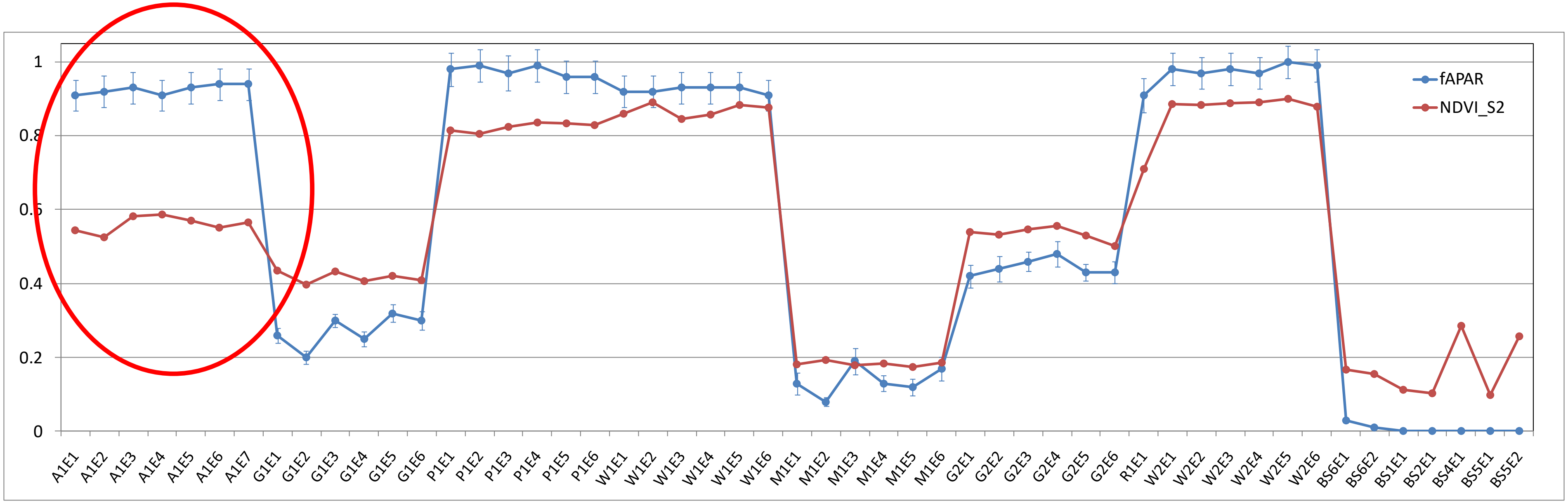
$T_{under}$=1-$FIPAR_{under}$

$T_{can}=T_{tree}\ T_{under}$

$$\mathbf{fAPAR_{combined} = fAPAR_{up} + (1 - fAPAR_{up})\, fAPAR_{down}}$$

$$\sigma(fAPAR_{combined}) = \sqrt{\left[(1 - fAPAR_{up}) fAPAR_{down}\right]^2 + \left[(1 - fAPAR_{down}) fAPAR_{up}\right]^2}$$

# Barrax DHP FAPAR




- Uncertainty values typically within 0.01-0.15 ( average 0.07).

And other sources for upscaling: eg, timing between ground measurements and satellite acquisition can change the status of the vegetation (mainly in crops)

# CCC estimation overview

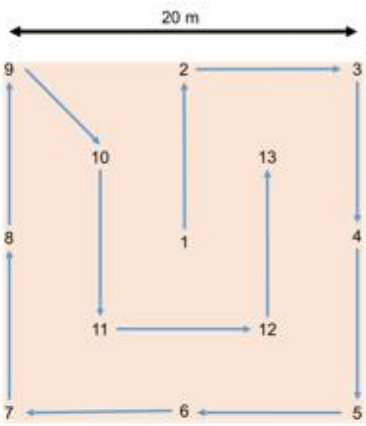
- CCC = LCC x LAI

Digital hemispherical photography

Chlorophyll meter

Sampling

- 13 points/ESU
- 3 leaves/point
- 6 replicates/leaf



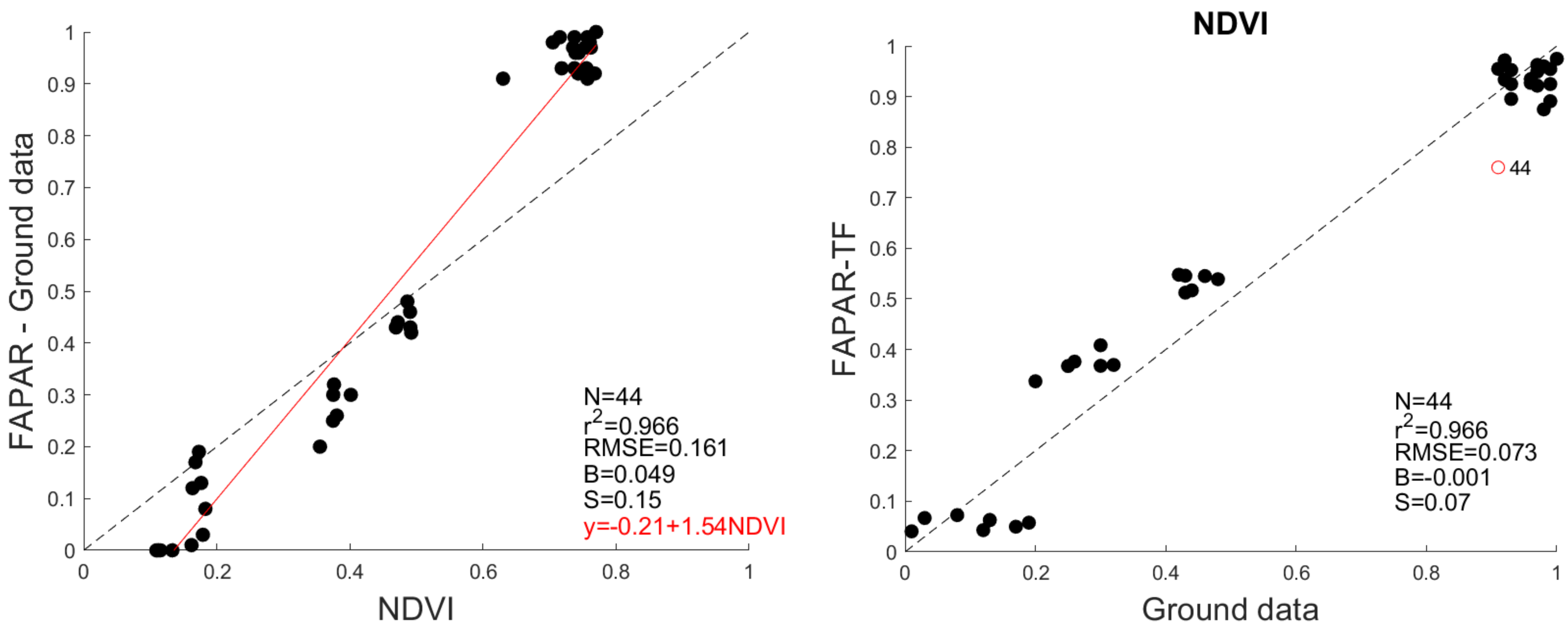
# *LAI uncertainty*

- Propagation of uncertainties due to within-ESU variability of gap fraction and use of different methods
- Experiments to define ‘representative’ relative uncertainties due to levelling and classification

| **DHP** | | |
|---|---|---|
| Angle/levelling ($\sigma_{lev}$) | According to Origo et al. (2017), no important differences (2%) with hand-levelling techniques | 2% |
| Methods ($\sigma_{meth}$) | Standard error of LAI calculated using different methods (CEV6.1, CEV5.1, Miller) | 5% (LAIeff), 7% (LAItrue) |
| Sampling ($\sigma_{sam}$) | Standard error of mean gap fraction over the ESU, propagated though measurement equations | Derived per ESU |
| Operator classification ($\sigma_{op}$) | Uncertainty due to operator decision on the classification in CAN-EYE | 11% (LAIeff), 12% (LAItrue) |

Barrax

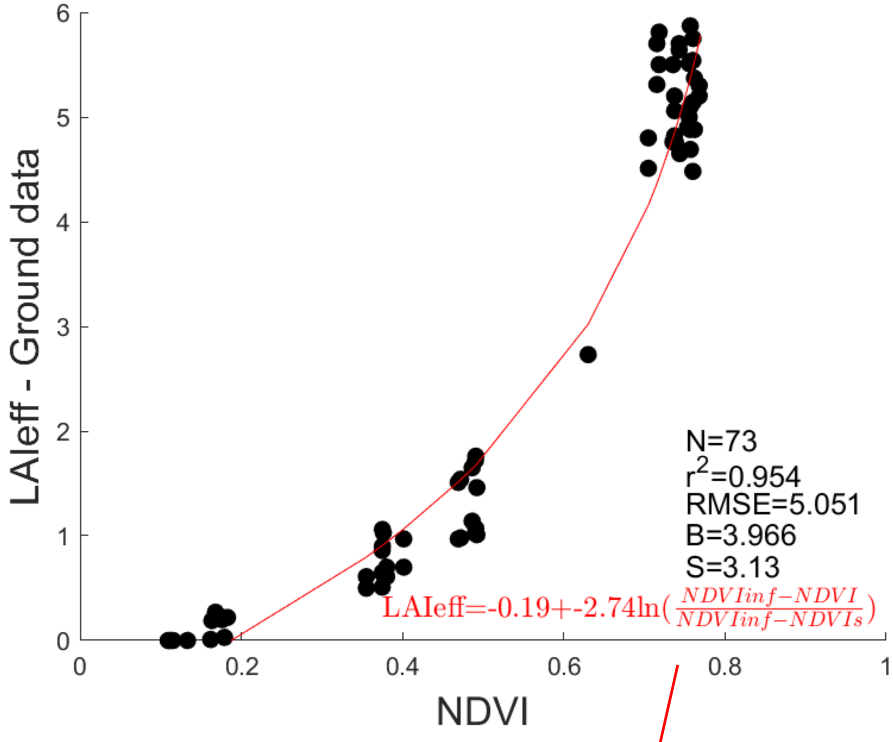
# IRLS (iteratively reweighted least squares) - FAPAR



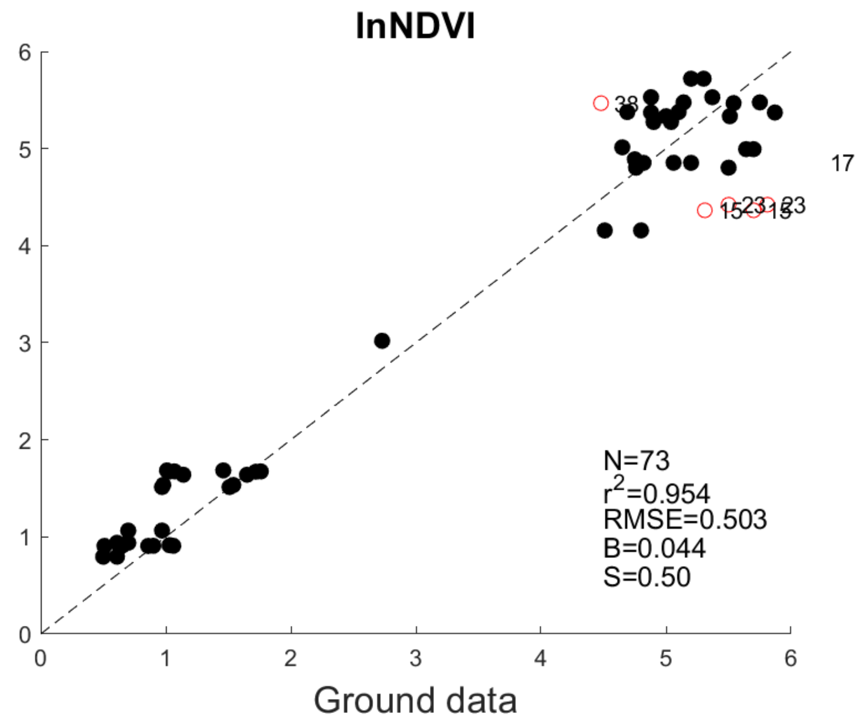

**Discarding:**

- A1E1 to A1E7 (DHP & LICOR)
- P1E5 & P1E6 (LICOR)
- M1E1 to M1E6 (LICOR)
- R1E1 (LICOR)

# IRLS (iteratively reweighted least squares) - LAIeff

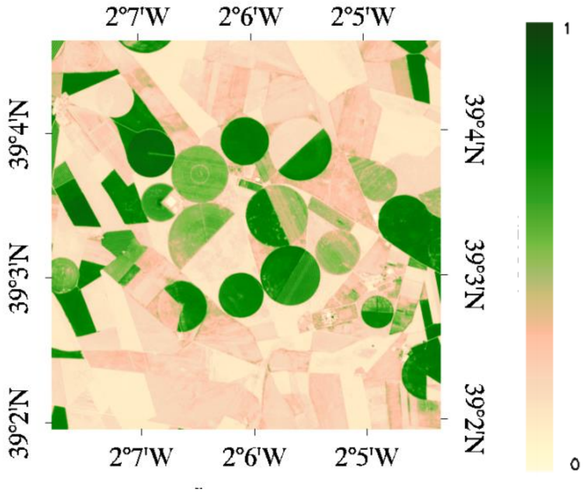



Where NDVIinf=0.85
and NDVIs=0.14

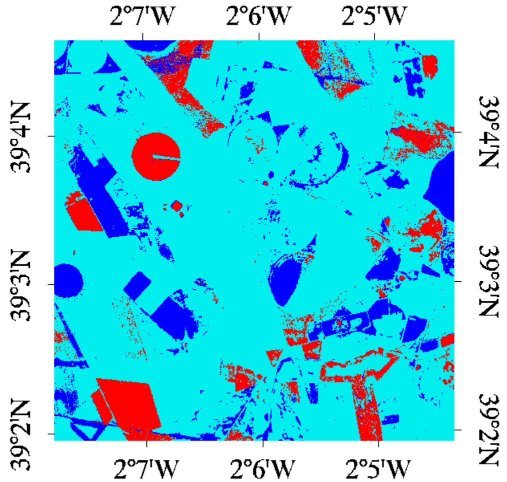


# Maps with IRLS 5x5 km² (NDVI) Barrax

NDVI




QF

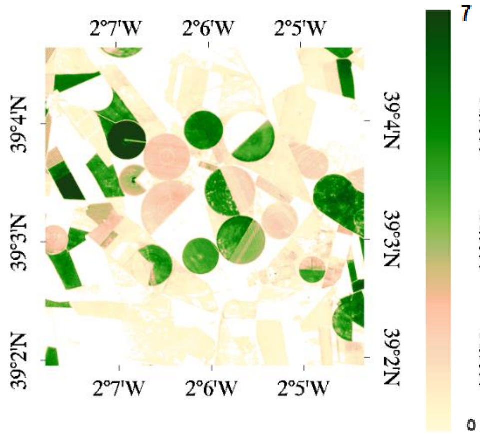



**The function is extrapolating**

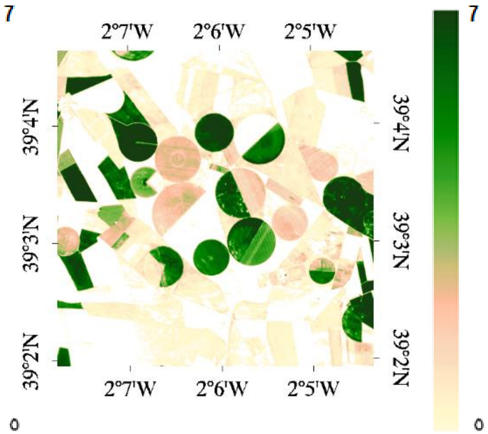
**Good confidence**

**High confidence**

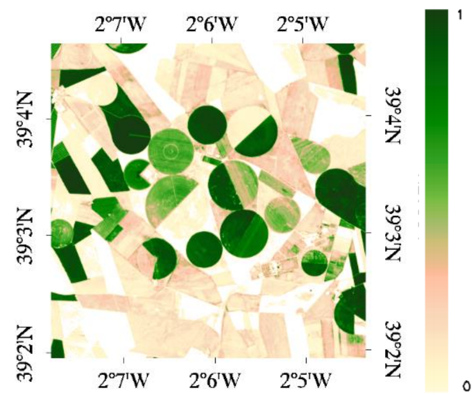
LAIeff



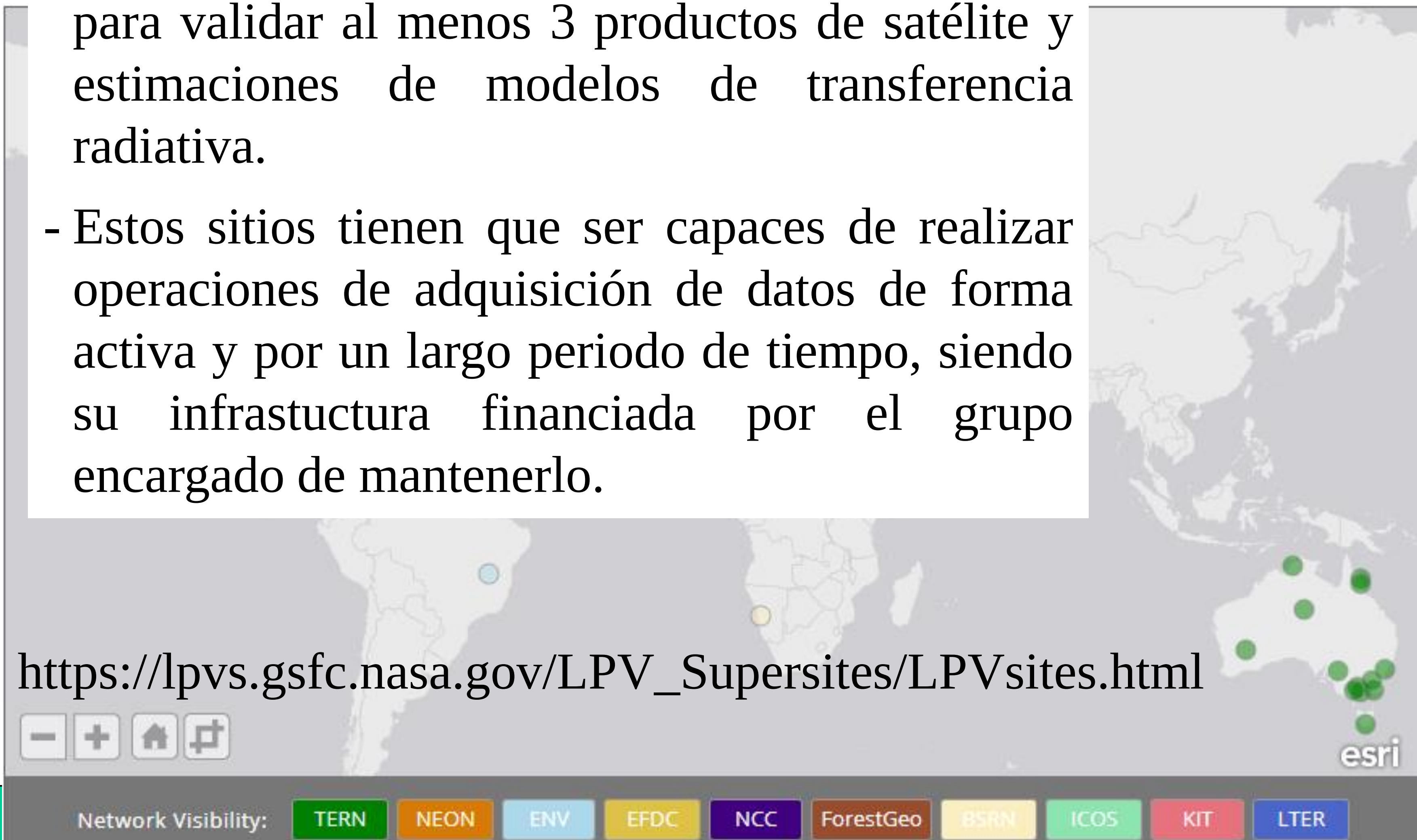

LAI




fAPAR



- Sitios bien caracterizados que siguen un riguroso protocolo de adquisición de medidas para validar al menos 3 productos de satélite y estimaciones de modelos de transferencia radiativa.
- Estos sitios tienen que ser capaces de realizar operaciones de adquisición de datos de forma activa y por un largo periodo de tiempo, siendo su infrastuctura financiada por el grupo encargado de mantenerlo.




https://lpvs.gsfc.nasa.gov/LPV_Supersites/LPVsites.html