fiducial reference measurements for vegetation

frm4veg

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Overview

NPL National Physical Laboratory

- What is a FRM (**F**iducial **R**eference **M**easurement) project?
- FRM4Veg
- Contribution to CEOS – “supersites”

Data and derived products shall have associated with them a fully traceable indicator of their quality

- Rare for satellite derived data / products to have reliable and fully traceable evidence concerning the quality of the retrieved information
- No regulatory frameworks requiring EO data product producers to be held accountable for ensuring the quality, accuracy and validity of the information (providers + users)

Nightingale *et al*. 2018, 2019

EO Data Quality Status – In situ

- Under-investment in coordinated cal/val infrastructure and methods
  - First budget to be cut → “leveraging”
- Reference networks not primarily designed for, or focussed on, the specific measurement challenges of the satellite data

Doesn’t cut it for quantitative information or climate assessments

- Existing “sites” / in situ campaigns are ah hoc
  - Not maintained – “one off”
  - Consistency of measurements (instruments/measurement techniques)
  - Operator and post-processing
  - Spatial / temporal sampling / representation

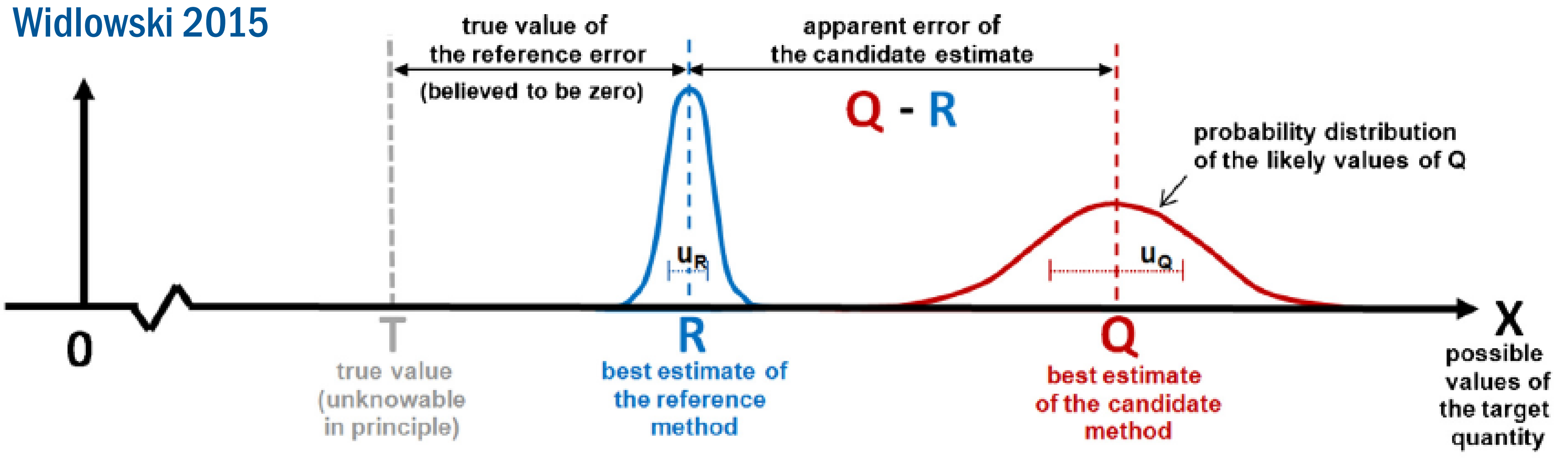
EO Data Quality Status - Satellite

- Many data products created with independent or multiple sources of EO data using different retrieval algorithms and assumptions

- These confounding issues mean that estimating a meaningful bias between the in situ "validation" measurements and the satellite observations is challenging

ECV	# Products
Precipitation (in situ)	53
Surface Air Temp (in situ)	70
LAI	33
fAPAR	30
Wind Speed and Direction	103
Soil Moisture	62
Ozone and Aerosols	180
Ocean Colour	37

Widlowski 2015



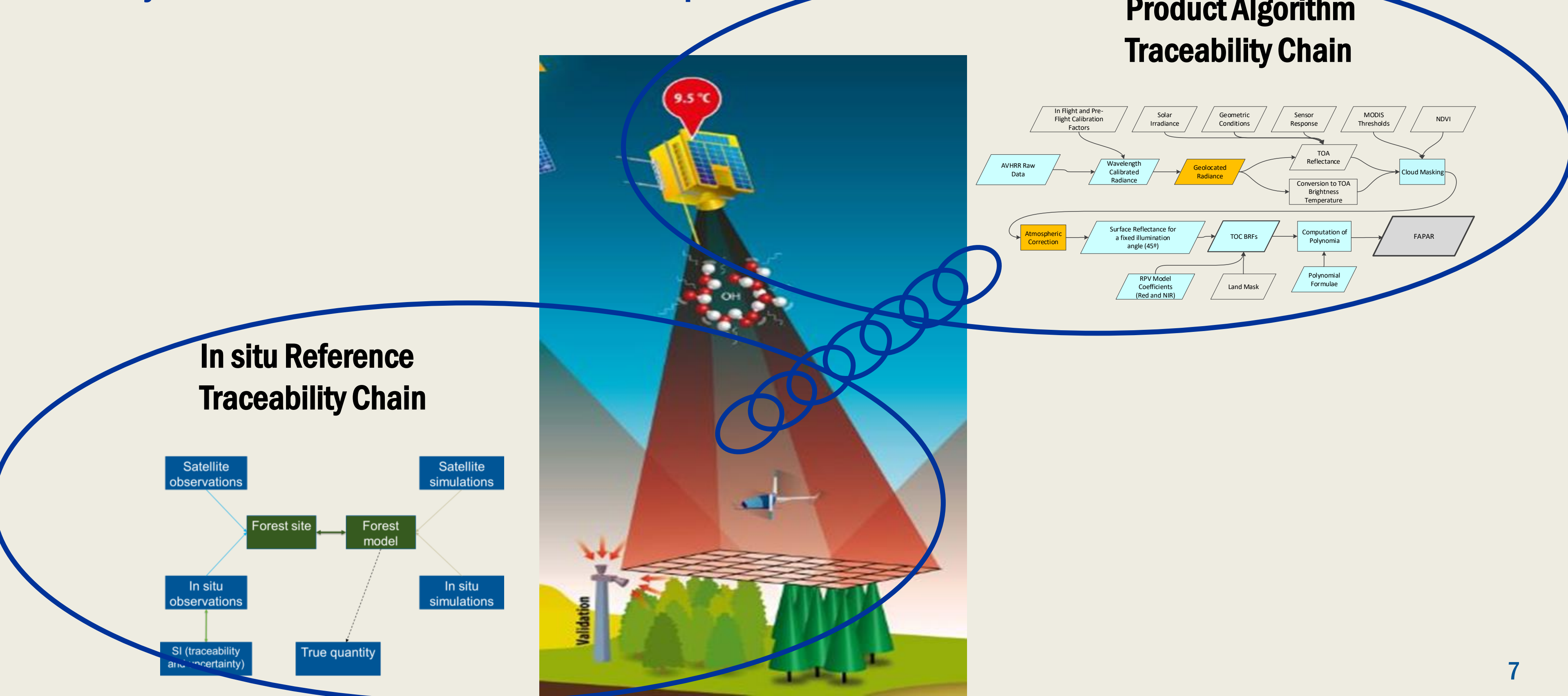
Conformity Testing

The process that determines whether the estimated target quantity (i.e. the satellite estimate) falls within the range of tolerable values (i.e. the reference estimate), or not.

- The conformity of a data product can only be established with respect to permissible deviations from an agreed reference
- Ideally this reference should be SI traceable (or community agreed) and the uncertainty of the reference will be smaller than that of the candidate item
- Reliable compliance information of quantitative EO products will become even more critical as satellite-derived data are increasingly driving the information and knowledge required for decision making
- While these considerations are an integral part of conformity testing in metrology, they are not yet included in validation efforts of satellite-derived quantitative surface information

Ideal Validation Scenario - FRM

- End – to – End Traceability
  - (how the product was produced and how the product was validated)
- Uncertainty characterisation and propagation
  - (sources and extent of error)
- Fully documented with use case examples



FRM Projects MUST…

- Have documented SI traceability (or conform to appropriate international community standards), utilising instruments that have been characterised using metrological standards, both pre-deployment and evaluated regularly post-deployment

- Be independent from the satellite geophysical retrieval process

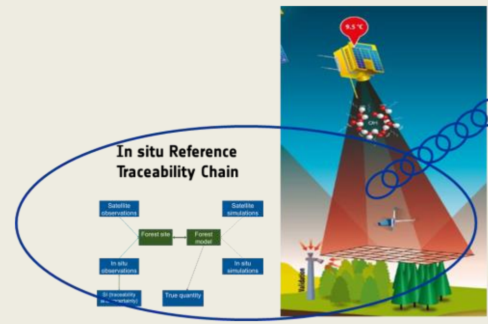
- Be accompanied by an uncertainty budget for all instruments, derived measurements and validation methods

- Adhere to community-agreed, published and openly-available measurement protocols/ procedures and management practices (most still need to be established and written!)

- Be accessible to other researchers allowing independent verification of processing systems

FRM4Veg

FRM4Veg is focused on establishing the protocols required for traceable in-situ measurements of vegetation-related parameters (**surface reflectance, FAPAR, CCC**) to support **Sentinel-2,-3 and PROBA-V product validation.**



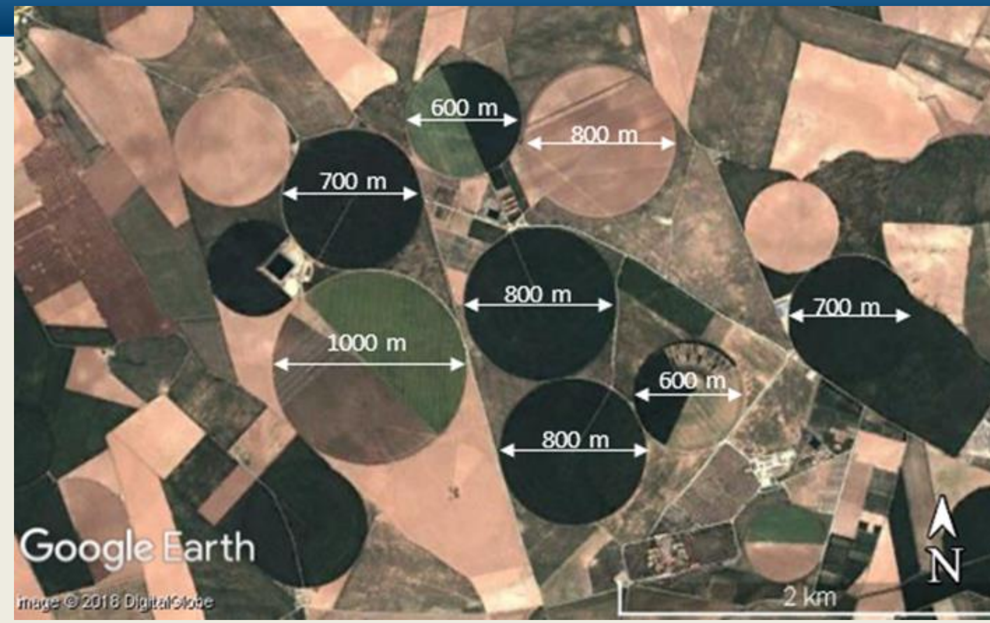
Phase 1 March '18 – March '19

Phase 2 under negotiation expected start Jan '20

fiducial reference measurements for vegetation

Barrax – Las Tiesas

- Experimental farm located close to Barrax
- Irrigated Cereal crops up to 1km diameter
- Flat terrain, generally clear skies

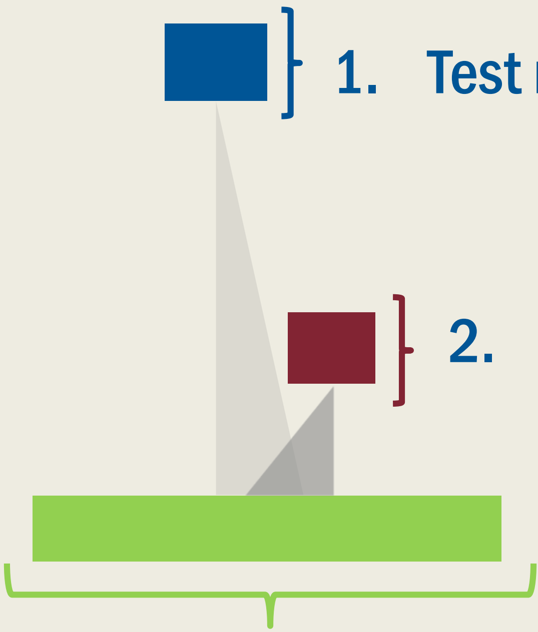


Wytham Woods

- Semi-natural woodland (Oak, Ash, Beech, Hazel, Sycamore)
- Managed research forest with ~75 years of ecological monitoring
- Canopy walkway, Flux tower
- fPAR network

3 Validation Components

Origo et al. In Review.



1. Test measurement
2. Reference measurement
3. Comparison procedure/conditions

Satellite

- Location of site (sensor detector location affectin spectral uniformity)
- Sky conditions (cloud, aerosols, saturation)
- SZA (spectralon panel correction)
- VZA (hot-spot, non-nadir effects)

Reference

- Sampling (area/co-incident with overpass)
- Measurement quantity
- Instrument characteristics
  - FOV, levelling, spectral response

Procedure

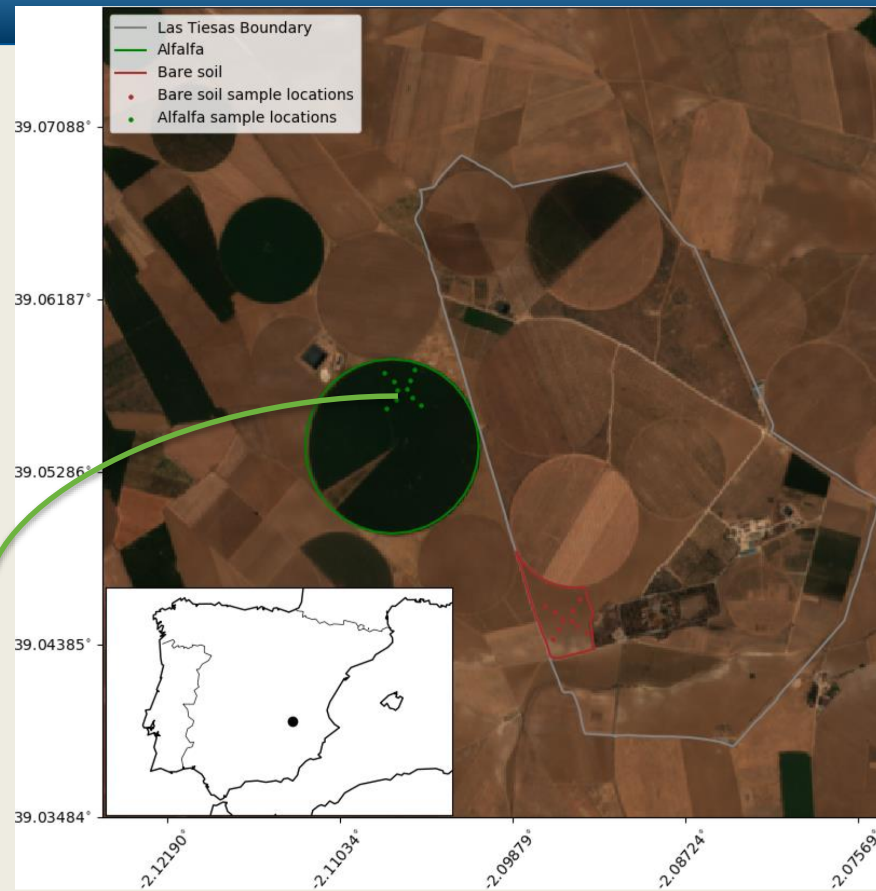
- Point vs area comparison
- Surface BRDF
- Atmosphere
- Solar angle changes
- Homogeneity

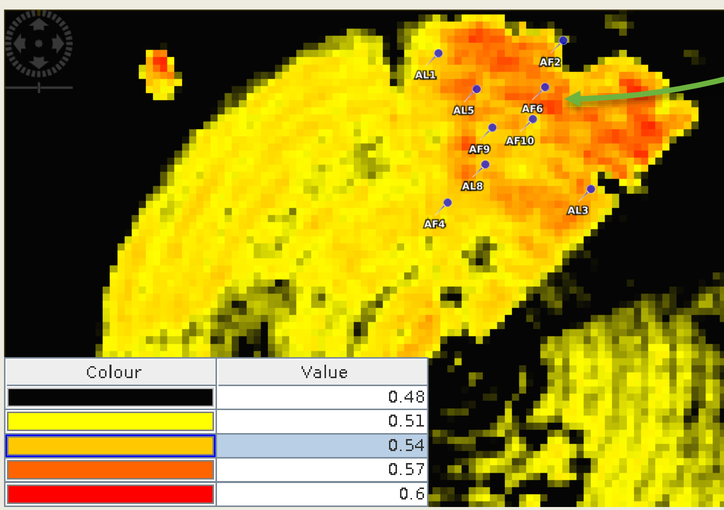
What factors influence each of these values?

Validating Surface Reflectance

Ground measurement

- Trade-off between the size of the area (200x200m) to cover and the time taken to measure.
- 10 sampling location: six individual measurements (one of the reference panel, four of the surface, and another of the reference panel).

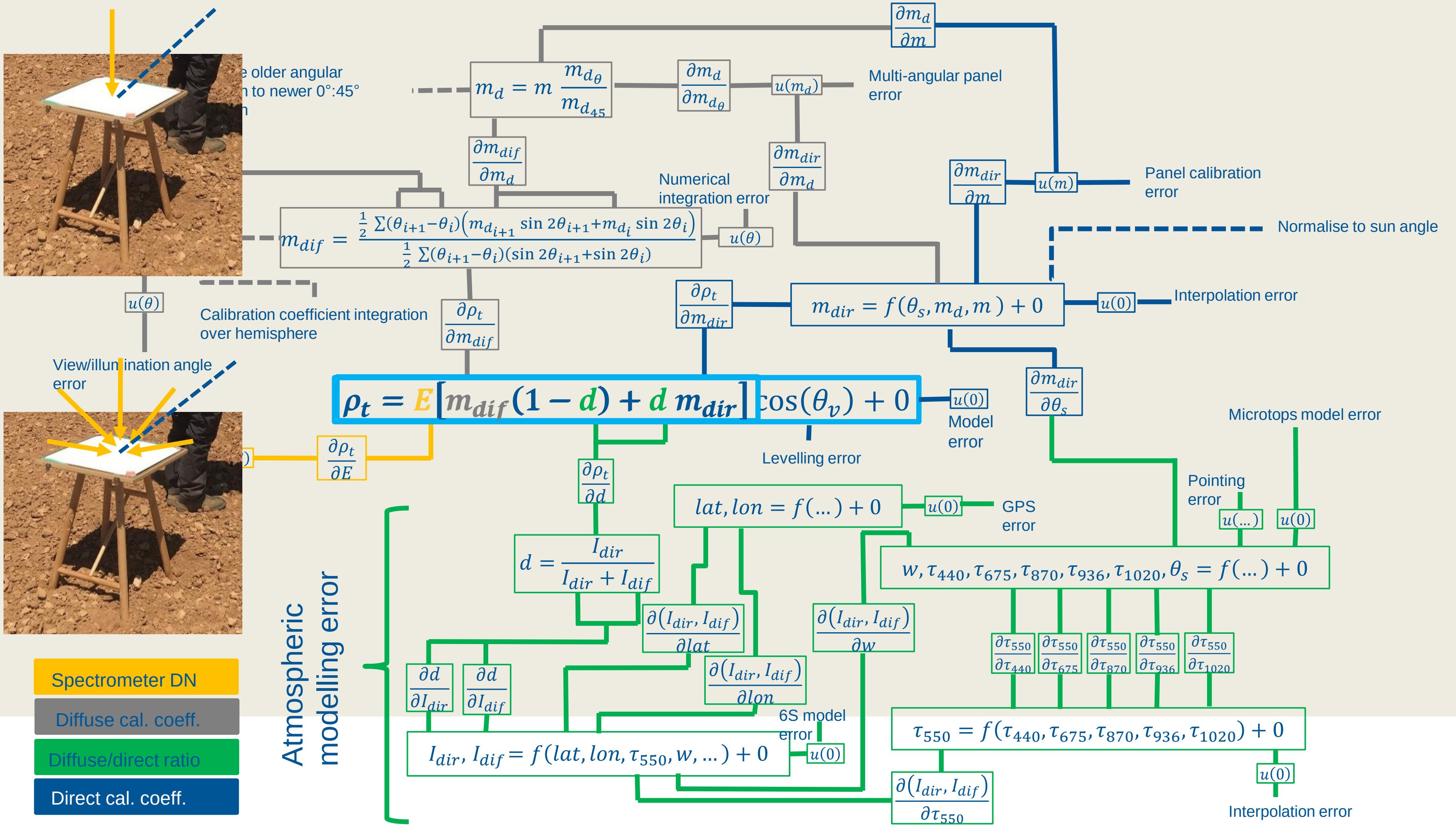




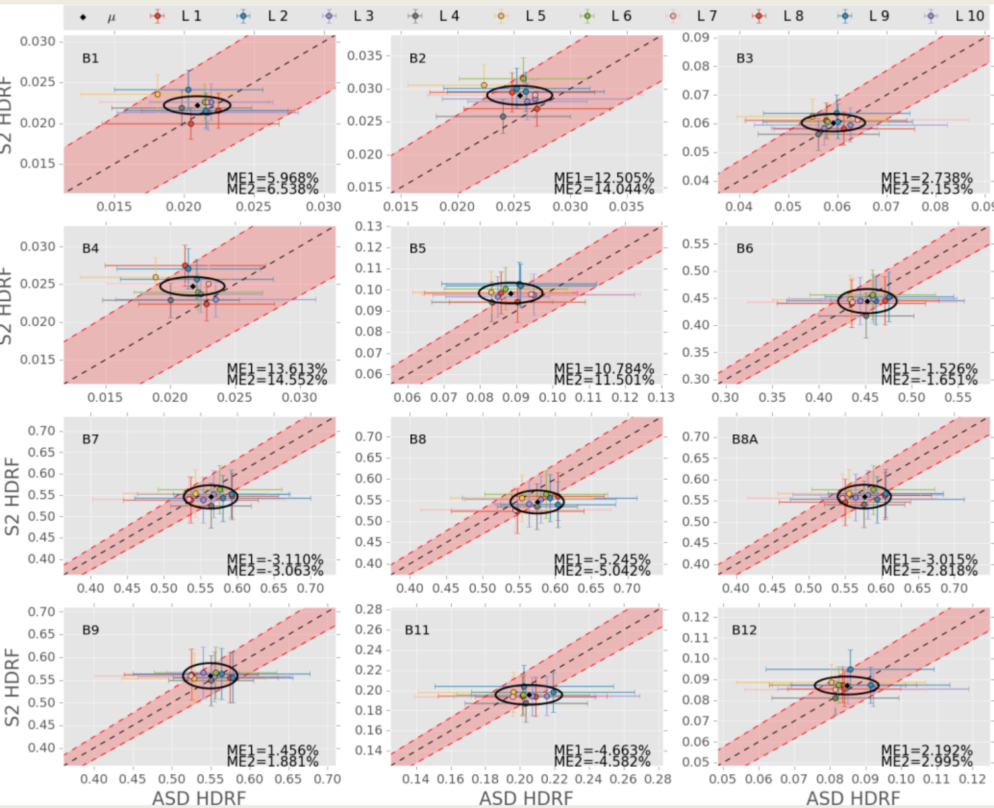
Satellite observation

- 2nd of August 2018 Sentinel 2A overpass with all pixels successfully screened.
- SZA 25°. Spectralon panel correction required
- VZA 6° in forward scattering plane.

FRM: In-situ data uncertainty

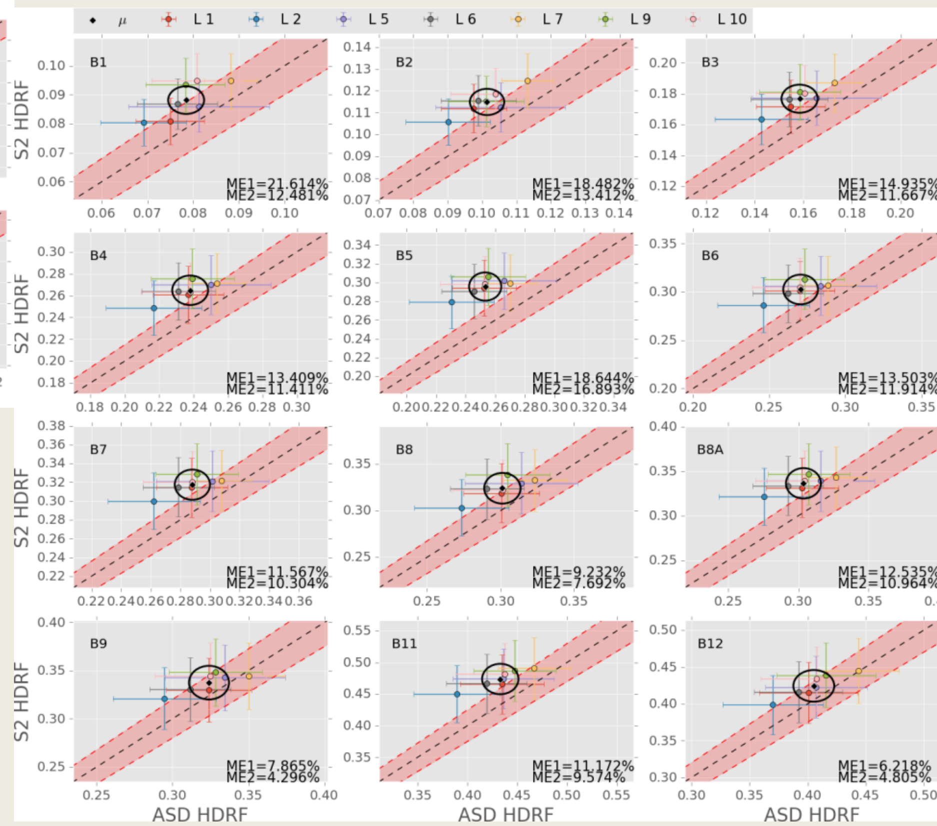


SR Val Results - Barrax



Alfalfa

Sentinel-2 surface reflectance product agreed (within the stated uncertainty) with the ground data collected over the Alfalfa field at both the pixel and area scales



Bare soil

Lower level of agreement due to mismatch in overpass vs. sampling and non-uniformity issues

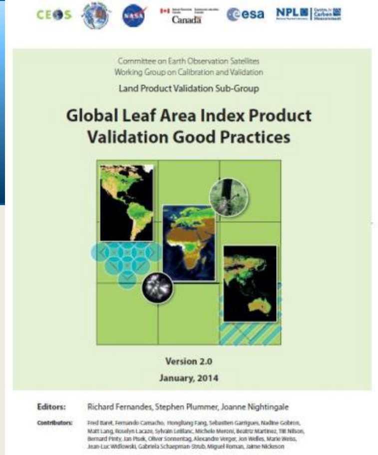
Origo et al. In Review.

Future Improvements

- Hand held spectrometer campaign provides a limited reference
  - Broadness of viewing optics (8° FOV vs <0.1° S2 pixel)
  - Lack of pointing agility ("nadir" operator)
  - Collection time vs. scanned area
  - Trampling of site affecting surface reflectance

- **UAV-based validation** can replicate satellite angular configuration and reduce collection time but system/procedures need to be matured…
  - Particularly important for tall vegetation

Validating fAPAR & CCC



"Community agreed" methods

Measurement Protocol (CIP) → Campaign Execution

Campaign Execution → Processing & Quality Control

Processing & Quality Control ↓

Uncertainty propagation → FRM data

S2

Upscaling of FRM with uncertainty ← FRM data

Upscaling of FRM with uncertainty ↓

FRM-based HR maps → FRM –based HR maps

FRM4Veg dataset

S3

Validation process ← FRM –based HR maps

Validation process ↓

Uncertainty estimate

FRM4Veg outcomes

FPAR measurements

Quantum sensors (Apogee SQ110)
PAR network of Wytham

AccuPAR DeCagon
ceptometer

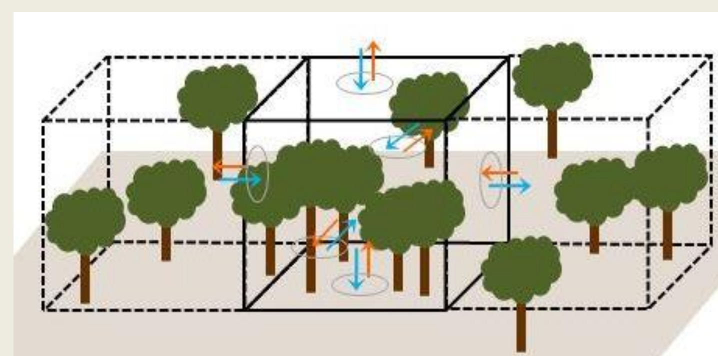
CANON EOS 6D
+ Sigma 8mm F3.5
fisheye lens

Radiometric, Spectral and Angular
Calibration performed at NPL

Radiometric Calibration performed
at NPL.

Angular Calibration
(optical center &
projection function) at
EOLAB & NPL

Reference sensors   PAR sensors



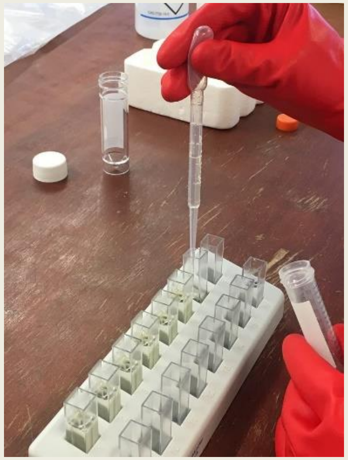
CCC measurements

CCC = Leaf CC x LAI

Chlorophyll meter values = relative (SPAD)

Require calibration to absolute units (g m-2)

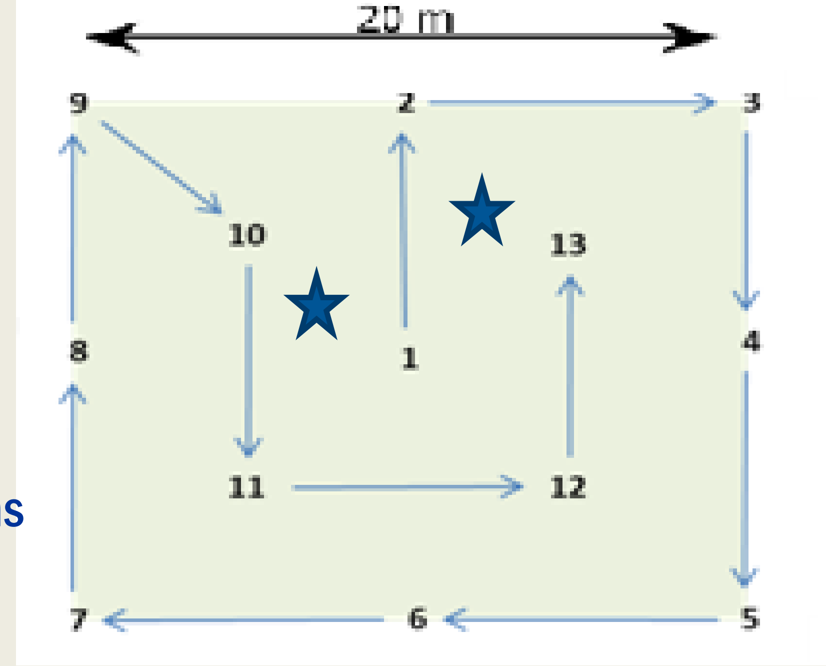
- 60 samples/species with a range of pigmentation
- SPAD related to extracted chlorophyll



Sampling

- A systematic sampling scheme was followed (VALERI, CEOS LPV).
- 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

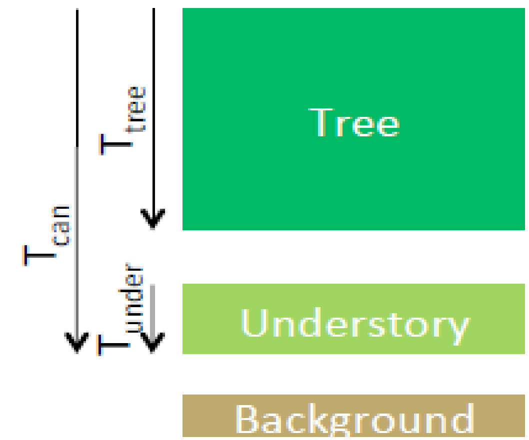
- DHP – 15 photos
- LAI-2200 – 3 up x 5 down
- SPAD – 18 samples x 13 locations
  (3 leaves – top, middle and bottom
  6 replicates per leaf)
- All ESUs were flagged
- fAPAR, LAI and Chl were taken over same locations
- In forest, overstory and understory characterized



fPAR / LAI Uncertainties

- **Propagation** of uncertainties due to **within-ESU variability** of gap fraction (within and between images)

- Experiments to define 'representative' relative uncertainties due **to levelling** and during **the classification process**



T_{can}=1-FIPAR$_{can}$

T_{tree}=1-FIPAR$_{tree}$

T_{under}=1-FIPAR$_{under}$

T_{can}=T_{tree} T_{under}

$$u(LAI_{DHP}) = \sqrt{u(lev)^2 + u(class)^2 + u(meth)^2 + u(samp)^2}$$

DHP		
Angle/Levelling (σ_{lev})	According to Origo et al. (2017), no important differences (~1%) with hand-levelling techniques.	1 %
Sampling (σ_{sam})	Uncertainty due to deviation in the GAP fraction value per image	6%
Operator Class. (σ_{op})	Uncertainty due to Operator decision on the class. CAN-EYE software	4%

Upscaling approach - TF

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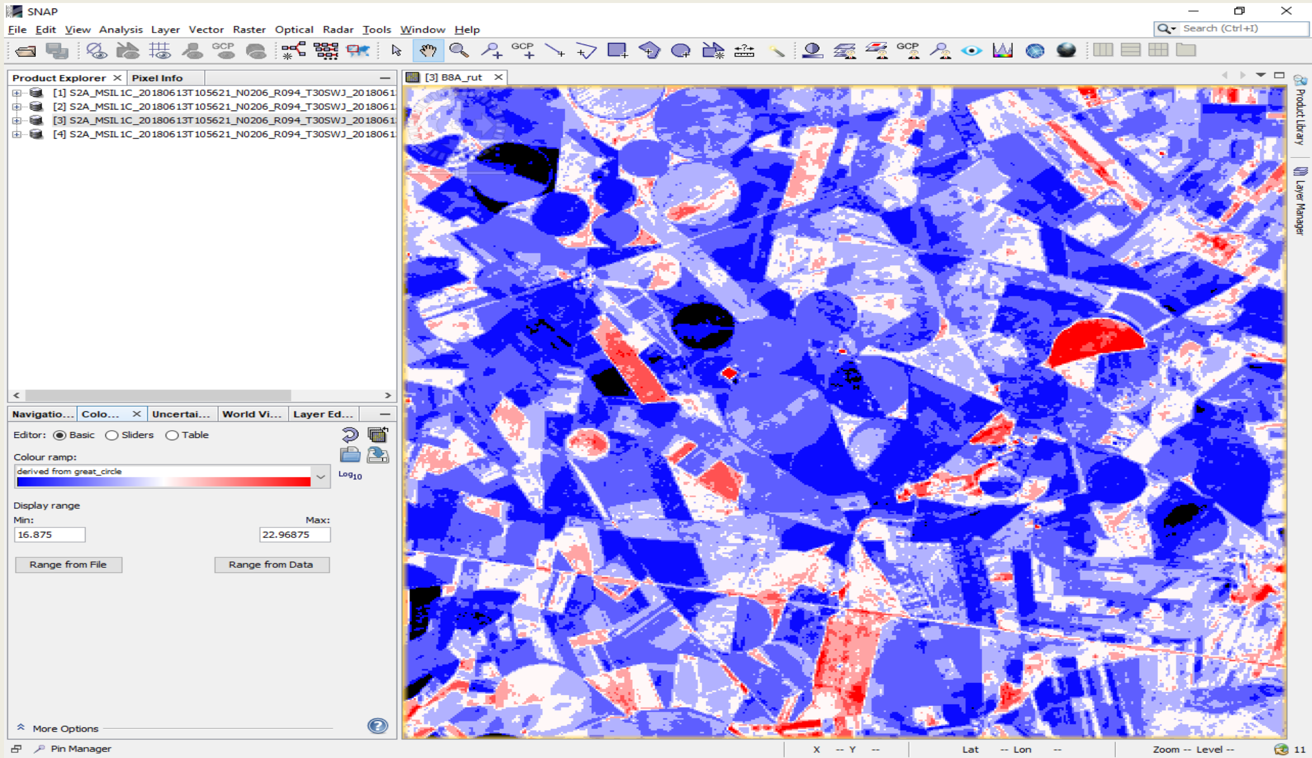
Transfer function established between ESUs and vegetation indices

- LAI = a*exp(NDVI*b)
- FAPAR = a*NDVI+b

Orthogonal Distance Regression (ODR) selected to account for uncertainties

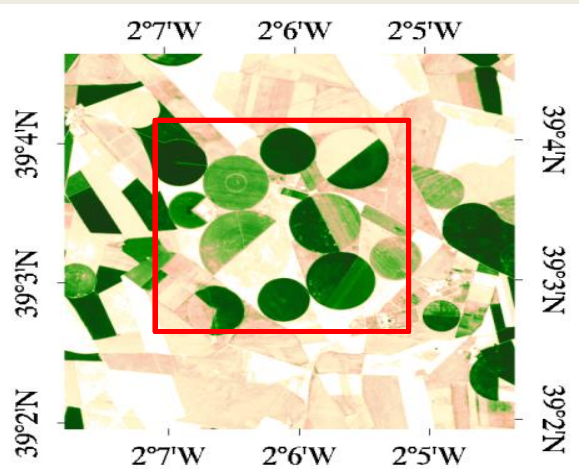
- Uncertainty in vegetation index → S-2 Radiometric Uncertainty Tool (RUT)

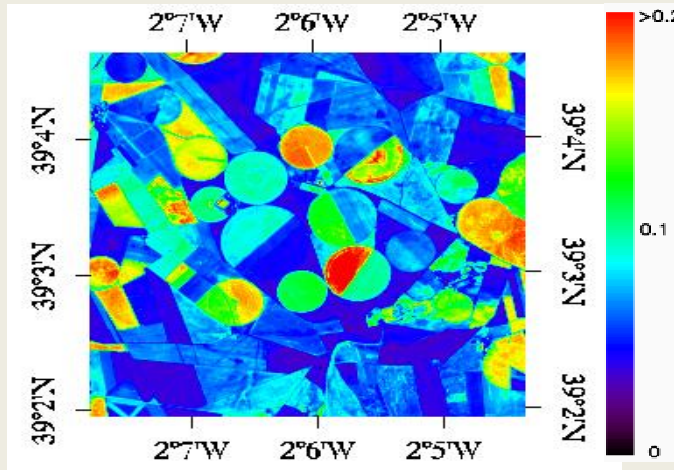
Gorrono et al. 2017

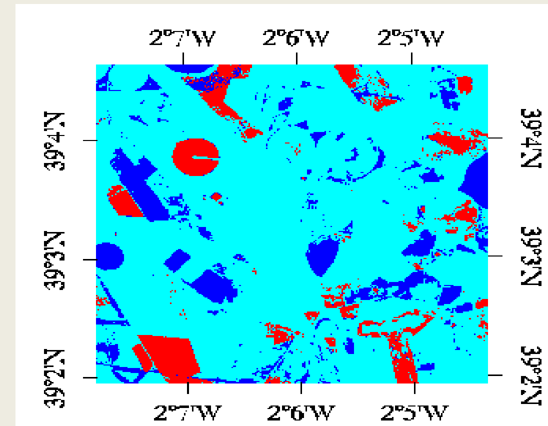


FRM HR maps

Barrax



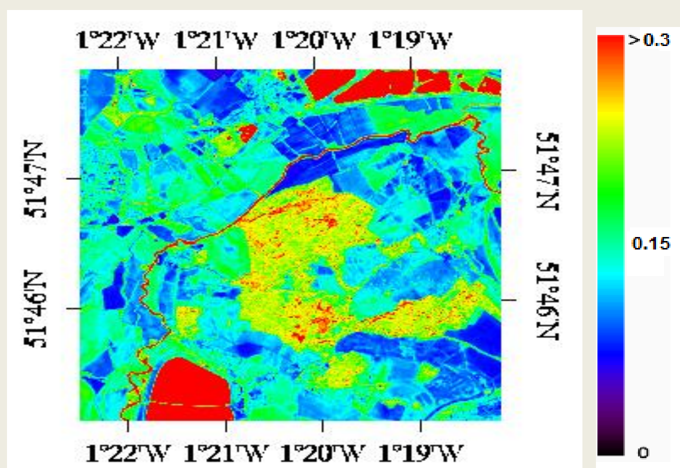


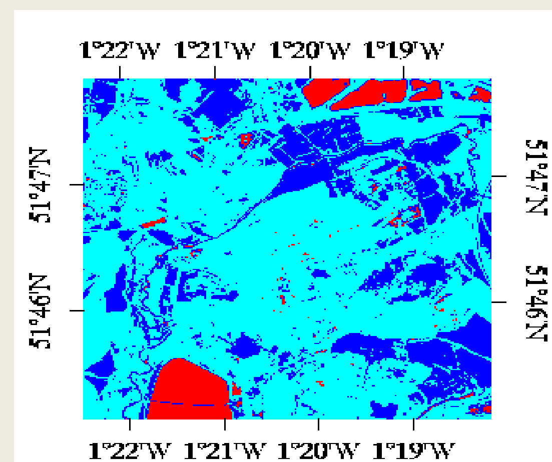


FAPAR S2 (5x5 km^2)

Uncertainty

Quality Flag





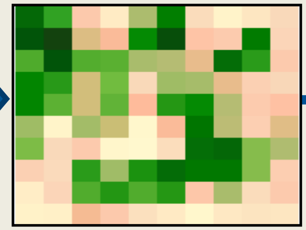
Wytham

Validation

S2 ground reference

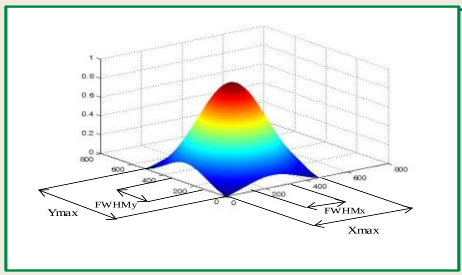
Aggregation

Aggregated (S3)



Qflag >75% Good

Apparent PSF



Optimization of FWHM and pixel extension (max ½ S)

Correlation Analysis

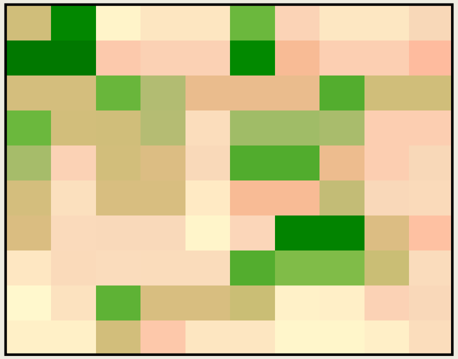
S3 Product

Metrics

- Scatter-plots
- Correlation coefficient (R) – indicates linear association
- Root mean square difference (RMSD) – indicates overall accuracy
- Mean error (B) – indicates bias
- Standard deviation of residuals (S) – indicates precision
- Number of samples (N)
- Slope and intercept of Major Axis Regression (MAR)

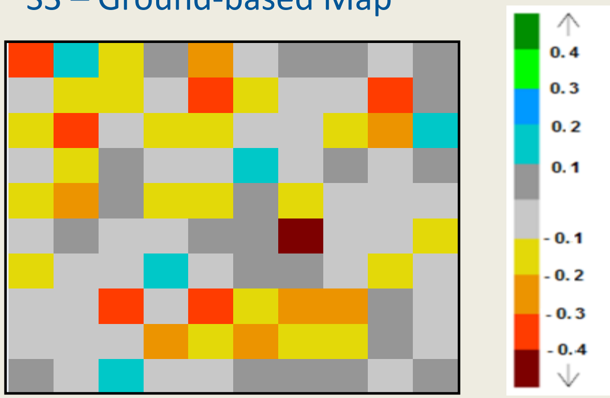
Validation S3 OGVI

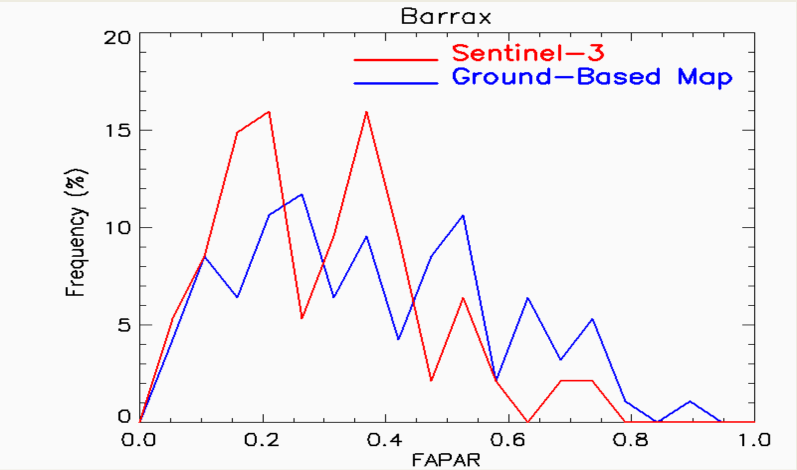
OGVI S3

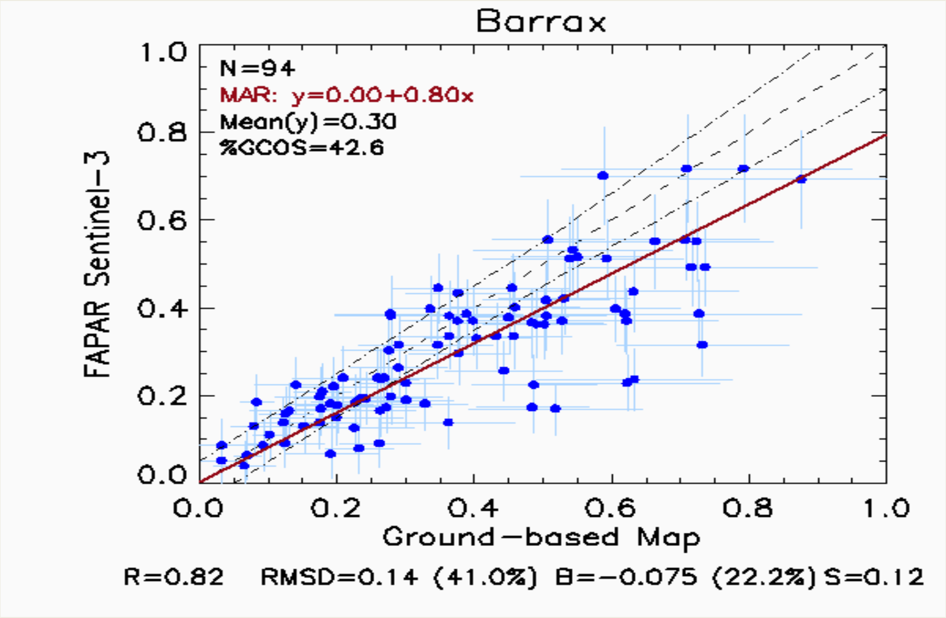


Ground-based (PSF)

S3 – Ground-based Map







The Sentinel-3 OGVI (daily) **uncertainty budget** is:

Barrax crops: **RMSD=0.14** (41%), B= -0.075 (22%)

Wytham forest : **RMSD=0.08** (12%) , B=-0.02 (3%)

Phase 2 and beyond…

- Field campaigns at 2 additional sites in Europe to test and develop FRM methodology / protocols

- Hosting a SR, FPAR and CCC **round-robin exercise** at 1 site ~ summer of 2021

- *Defining* the framework for both Campaign and Permanent FRMs
  - Defining measurements and frequency of measurements (i.e. 5 year TLS repeats, daily PAR…?)
  - Converting existing sites to "FRM compliant" sites
  - International collaboration

Defining what really makes a vegetation supersite "**super**"…

fiducial reference
measurements
for vegetation

Thank you

frm4veg.org/