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Towards reducing bias in vegetation biophysical variables from Sentinel-2: the GROUNDED EO project

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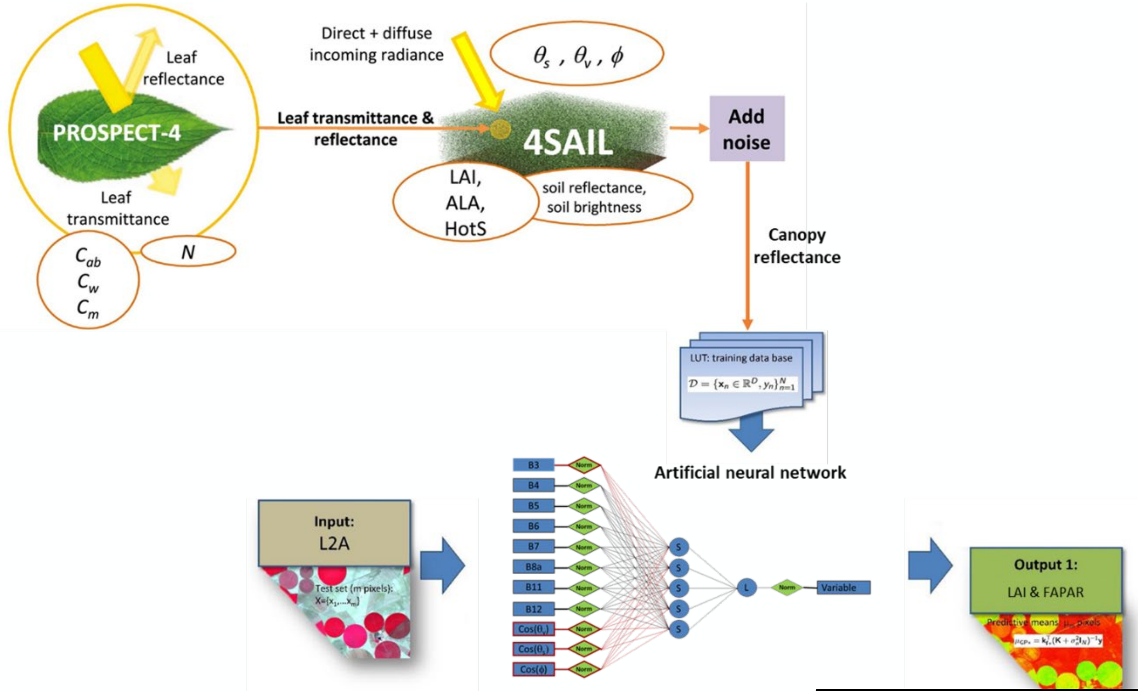
Outline

- Decametric retrieval algorithms, SAIL, & SL2P
- Latest SL2P validation results from GBOV data
- Improving retrieval accuracy with bias correction?
- Swapping SAIL for hybrid radiative transfer models?
- Avoiding the models? – the GROUNDED EO project

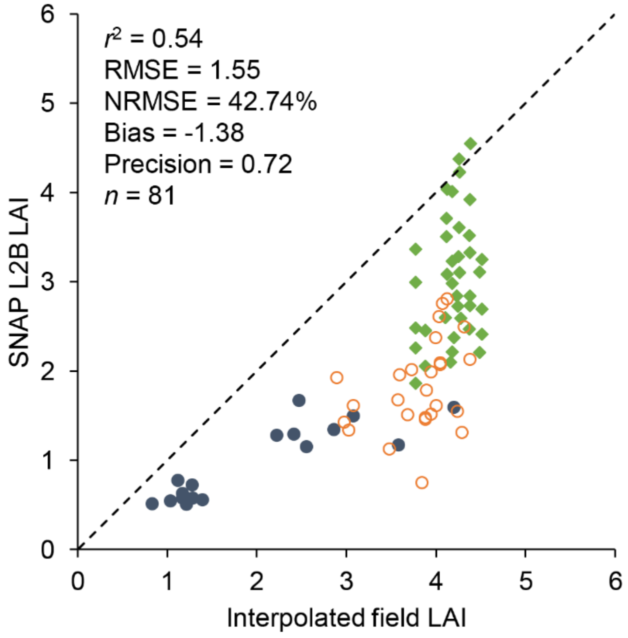
Decametric retrieval algorithms, SAIL, & SL2P

Retrieval algorithms made available to users such as the **Simplified Level 2 Prototype Processor (SL2P)** in SNAP are trained on radiative transfer model simulations

- **Scattering by Arbitrarily Inclined Leaves (SAIL)** assumes a turbid medium



Adapted from Berger et al. (2020), Estévez et al. (2022) & Weiss and Baret (2016)



Brown et al. (2019)
Remote Sensing

Latest SL2P validation results from GBOV data (1)

SL2P validated using GBOV CP1 RM dataset

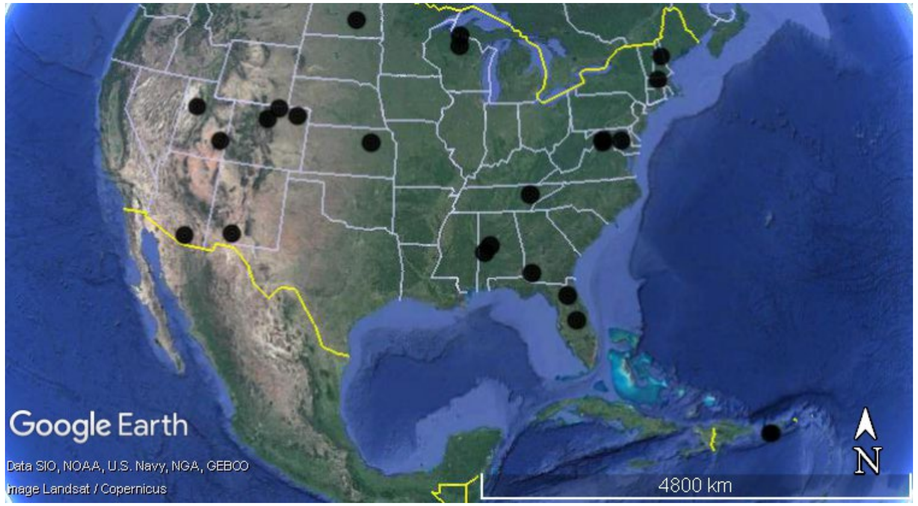
- **24 NEON sites** in the United States, three 20 m elementary sampling units measured every two weeks
- **Understory and overstory** sampling

Automated processing chain to derive **PAI, FIPAR and FCOVER** from digital hemispherical photography

- First-order **correction for woody material convert from PAI** (as provided by GBOV) **to LAI**

Current CP1 dataset = **8,120 ESU-level in situ reference measurements between 2013 and 2022**

- **Provided with quality indicators and uncertainties** according to **FRM** principles



Site	Land cover	Latitude (°)	Longitude (°)
Bartlett Experimental Forest	Deciduous forest	44.0639	-71.2873
Blandy Experimental Farm	Deciduous forest	39.0603	-78.0716
Central Plains Experimental Range	Grassland/herbaceous	40.8155	-104.7460
Disney Wilderness Preserve	Pasture/hay	28.1250	-81.4362
Guanica Forest	Evergreen forest	17.9696	-66.8687
Harvard Forest	Mixed forest	42.5369	-72.1727
Jones Ecological Research Center	Evergreen forest	31.1948	-84.4686
Jornada	Shrub/scrub	32.5907	-106.8430
Moab	Shrub/scrub	38.2483	-109.3880
Niwot Ridge Mountain Research Station	Grassland/herbaceous	40.0543	-105.5820
Onaqui	Shrub/scrub	40.1776	-112.4520
Oak Ridge	Deciduous forest	35.9641	-84.2826
Ordway-Swisher Biological Station	Evergreen forest	29.6893	-81.9934
Smithsonian Conservation Biology Institute	Deciduous forest	38.8929	-78.1395
Smithsonian Environmental Research Center	Deciduous forest	38.8901	-76.5600
Steigerwaldt Land Services	Deciduous forest	45.5089	-89.5864
North Sterling	Cultivated crops	40.4619	-103.0290
Talladega National Forest	Evergreen forest	32.9505	-87.3933
UNDERC	Woody wetlands	46.2339	-89.5373
Woodworth	Grassland/herbaceous	47.1282	-99.2414
Dead Lake	Deciduous forest	32.5417	-87.8039
Lajas Experimental Station	Pasture/hay	18.0213	-67.0769
Konza Prairie Agroecosystem	Cultivated ctops	39.1105	-96.6129
Santa Rita Experimental Range	Shrub/scrub	31.9107	-110.8350

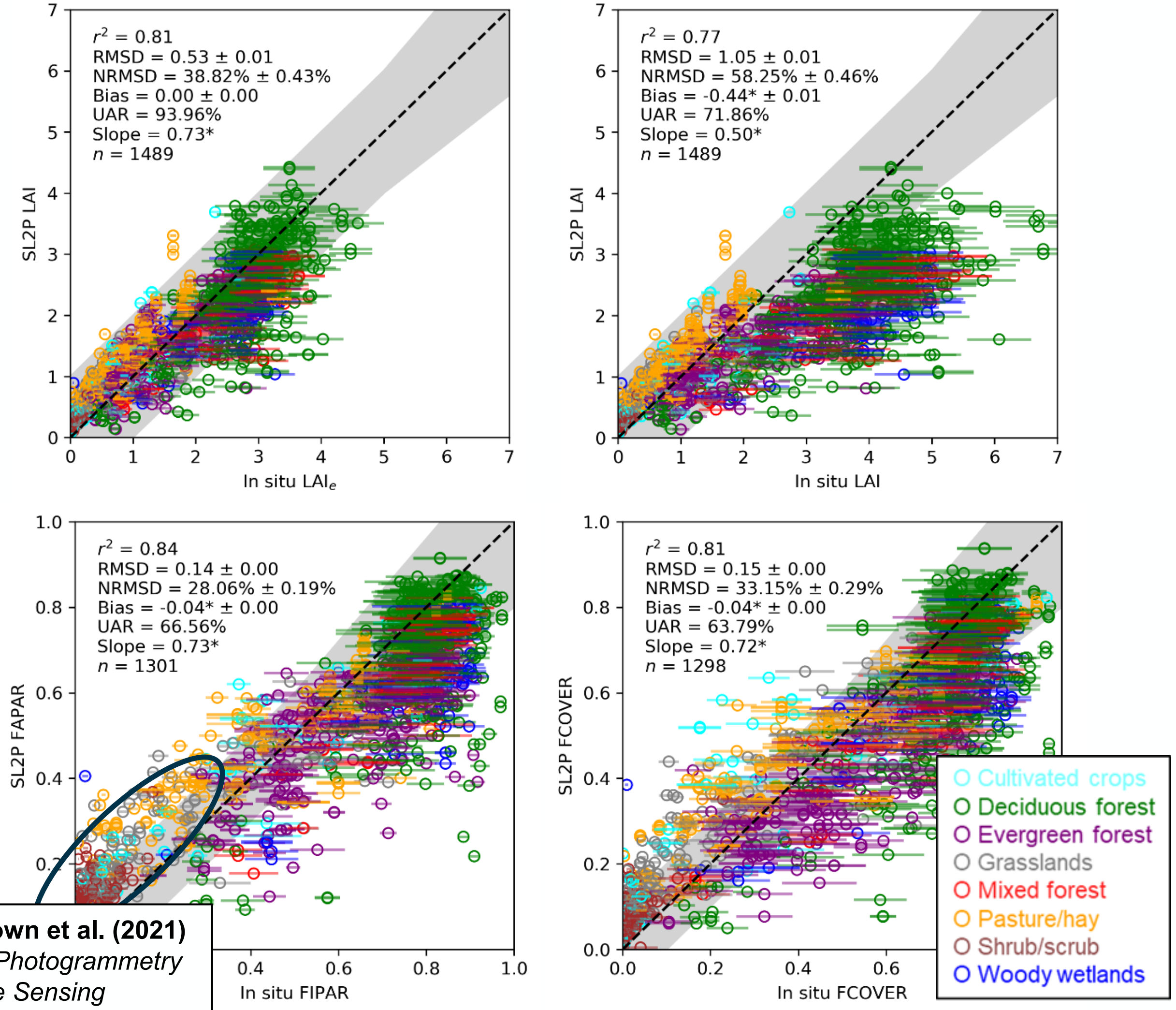
Latest SL2P validation results from GBOV data (2)

Four extra years (2019 to 2022) of data, along with four new sites (**70% increase in matchups with S2**)

Good agreement for LAI_e, biased for LAI > 2

Bias for lower FAPAR values (< 0.2)

- Shrub/pasture = yellow/brown elements that are ‘seen’ by SL2P due to structural-based NIR signal, but not by DHP (sensitive to green elements only when downwards-facing)



Updated from Brown et al. (2021)
ISPRS Journal of Photogrammetry and Remote Sensing

Improving retrieval accuracy with bias correction?

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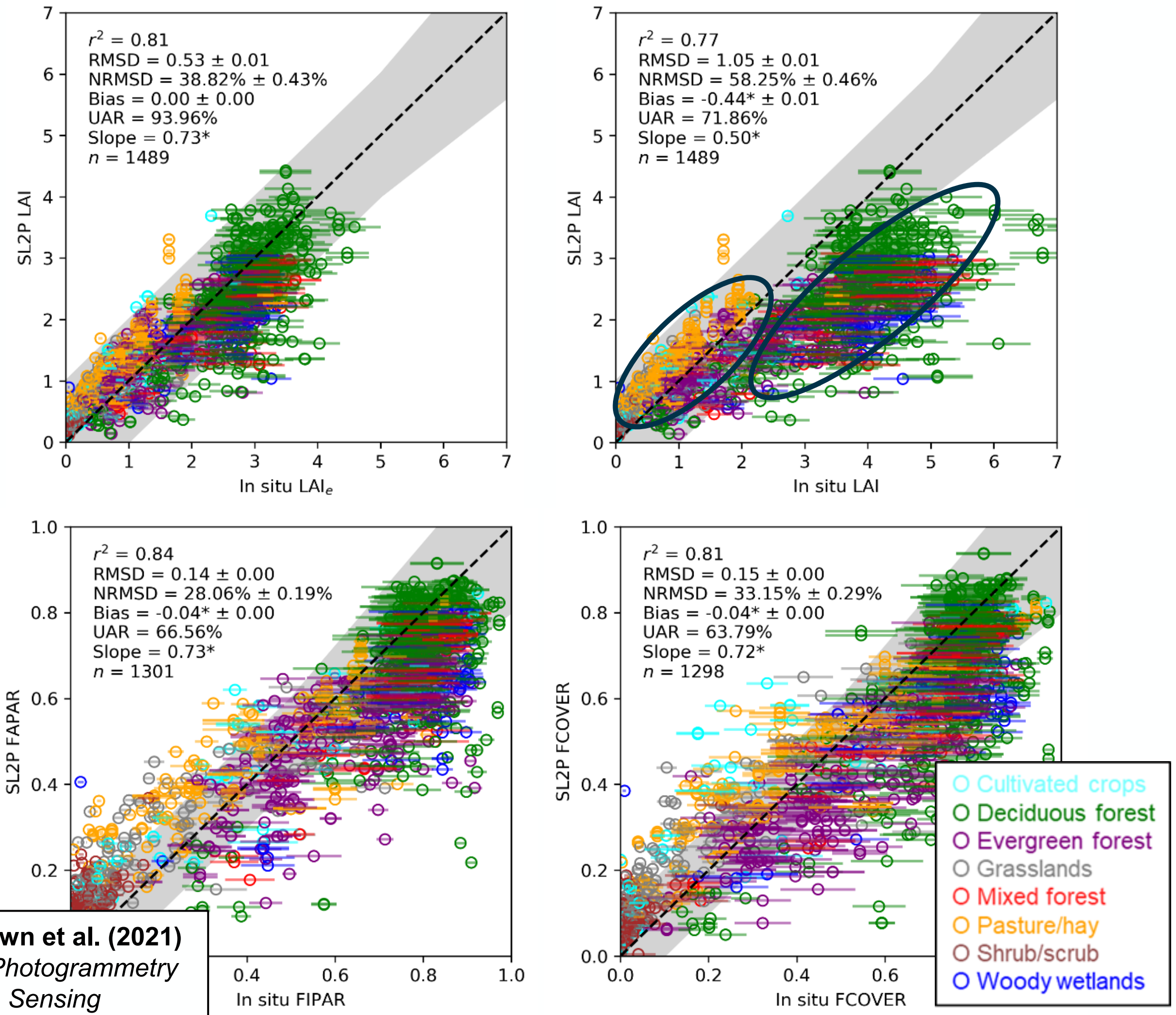
Relatively little bias for homogeneous canopies (turbid medium assumption met)

Biases appear consistent for heterogeneous canopies (turbid medium assumption not met)

- Possibility to apply bias correction for these canopies

Fernandes et al. (2023) applied polynomial bias corrections for North American forests

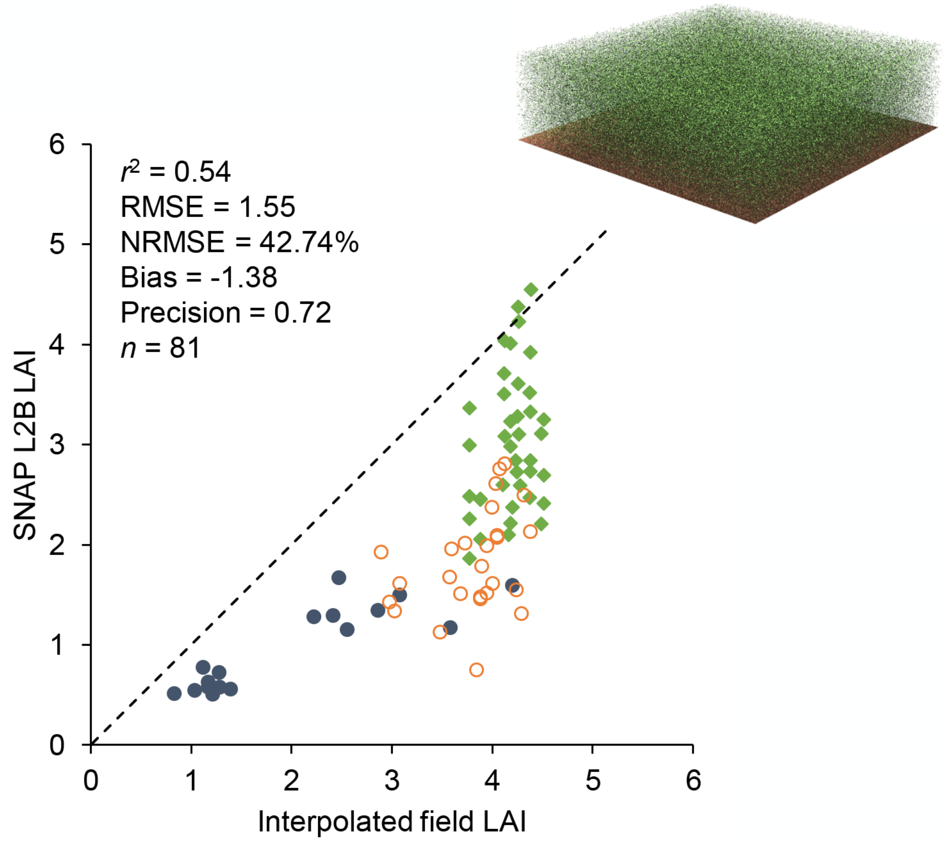
- Accuracy **improved by 57% for FAPAR and 92% for LAI**

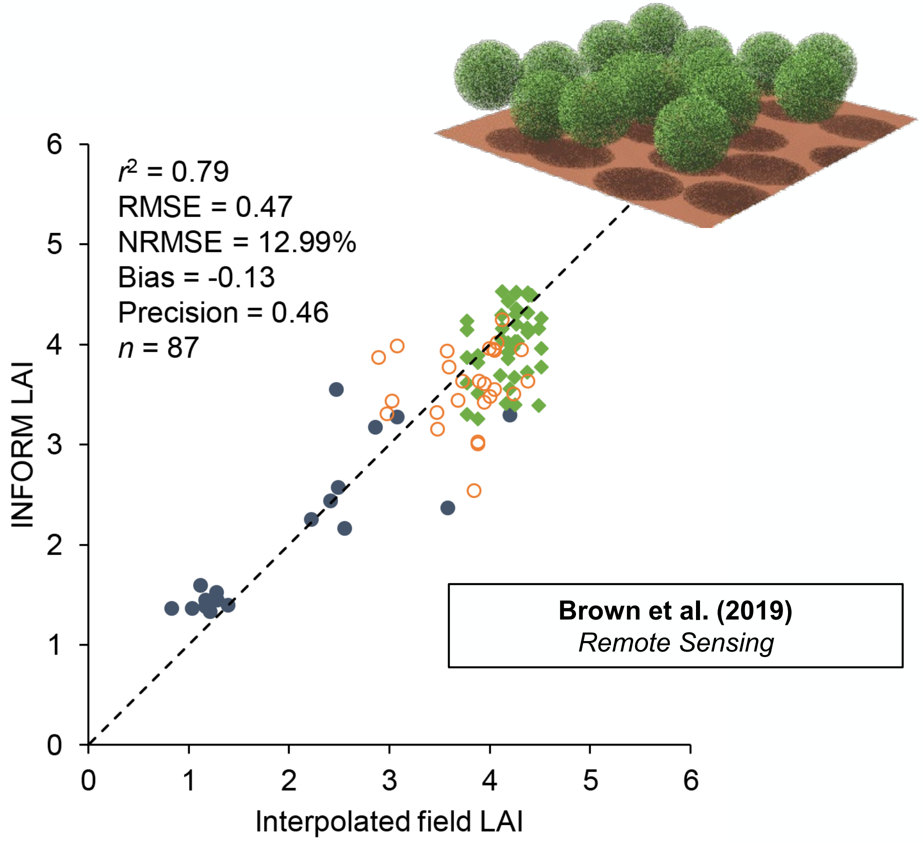


Updated from Brown et al. (2021)
ISPRS Journal of Photogrammetry and Remote Sensing

Swapping SAIL for hybrid radiative transfer models? (1)

Previous study demonstrated **improved Sentinel-2 LAI & CCC retrievals using the hybrid Invertible Forest Reflectance Model (INFORM)** over the New Forest, UK



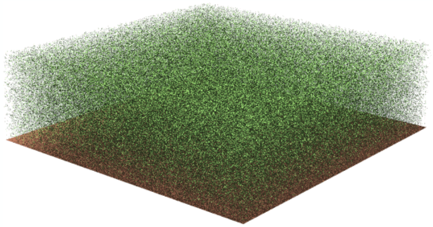


Brown et al. (2019)
Remote Sensing

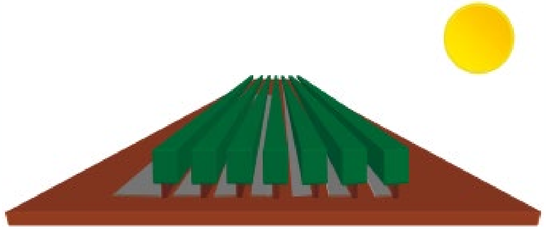
Swapping SAIL for hybrid radiative transfer models? (2)

Similar results for airborne hyperspectral retrieval when applying LUT retrieval using three canopy radiative transfer models:

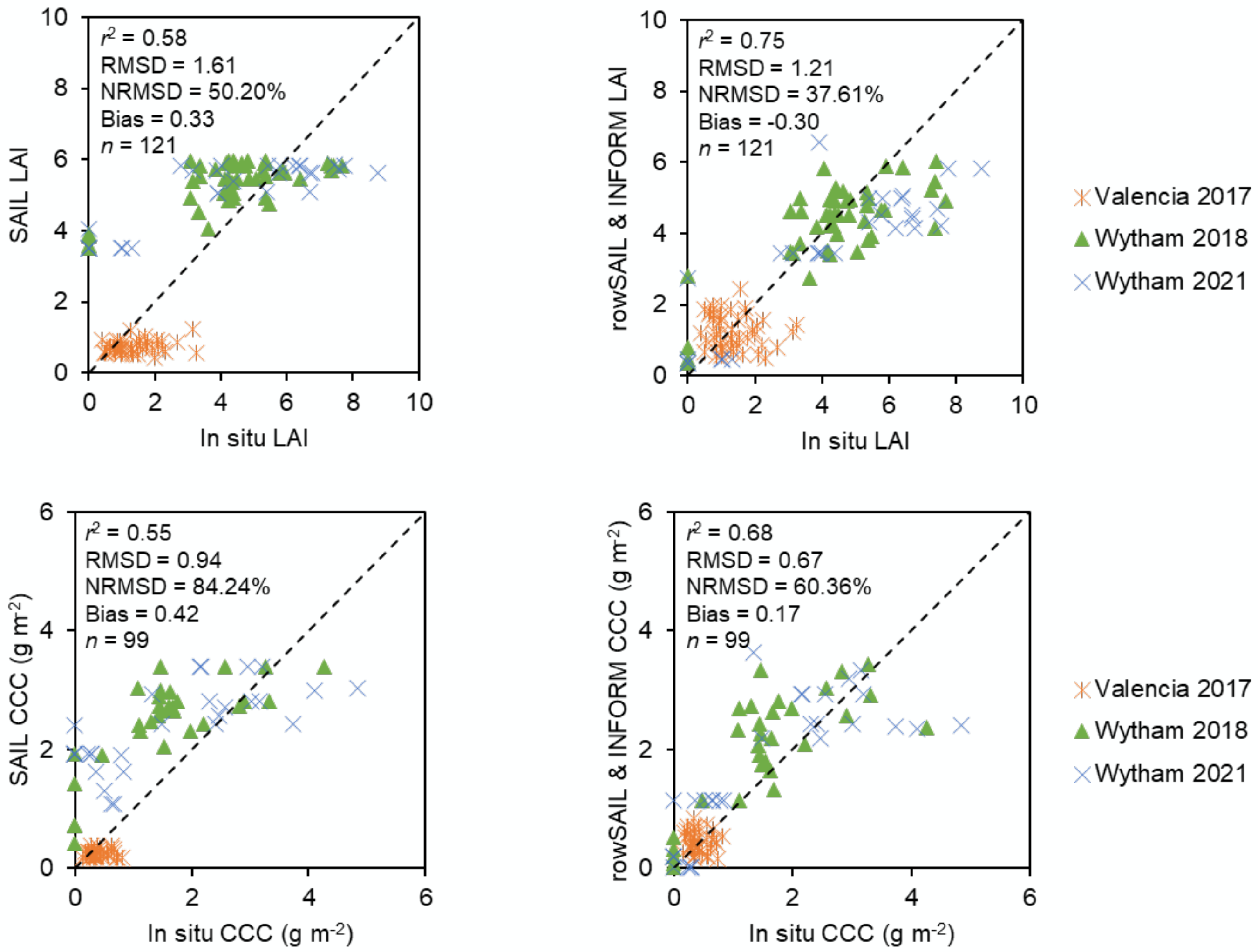
- **SAIL** (Valencia Anchor Station, Spain & Wytham Woods, UK)



- **rowSAIL** (Valencia Anchor Station, Spain)



- **INFORM** (Wytham Woods, UK)



Avoiding the models? – the GROUNDED EO project (1)

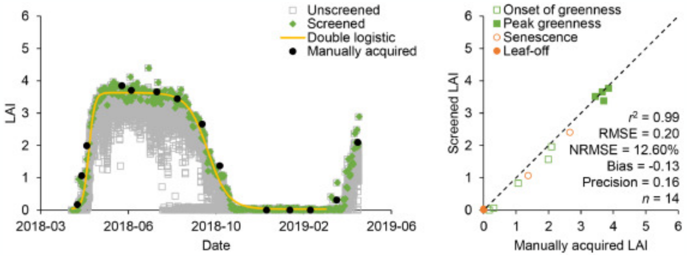
Ground **R**eference **O**bservations **U**nderlying **N**ovel **De**cametric Vegetation **D**ata Products from **E**arth **O**bservation (**GROUNDED EO**)

LIVING PLANET FELLOWSHIP

Project initiated earlier this year to capitalise on several opportunities:

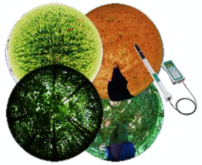
1. **Recent improvements in spatiotemporal coverage & consistency of ground reference data**

- **Automated instruments** to improve temporal characterisation

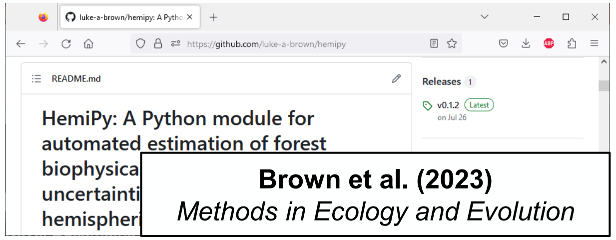


Brown et al. (2020)
Agricultural and Forest Meteorology

- Environmental monitoring networks with **routine & standardised data collection**



- **Consistent, automated processing chains** to derive biophysical variables from raw data



Brown et al. (2023)
Methods in Ecology and Evolution

Avoiding the models? – the GROUNDED EO project (2)

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Ground **R**eference **O**bservations **U**nderlying **N**ovel **De**cametric Vegetation **D**ata Products from **E**arth **O**bservation (**GROUNDED EO**)

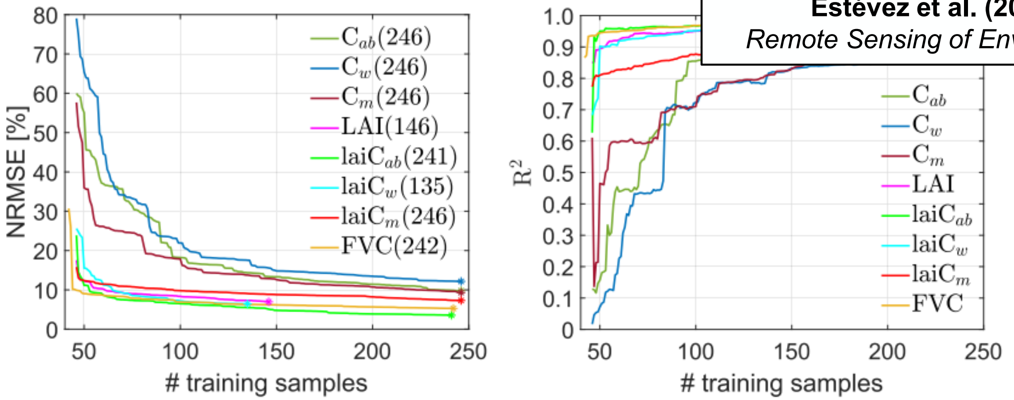
LIVING PLANET FELLOWSHIP

Project initiated earlier this year to capitalise on several opportunities:

2. **Availability of cutting edge machine learning approaches**

- **Substantially reduced number of samples (hundreds/ thousands)** required by GPR than ANNs or LUTs

- **We are already amassing several thousand matchups**



Estévez et al. (2022)
Remote Sensing of Environment

Avoiding the models? – the GROUNDED EO project (3)

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Ground **R**eference **O**bservations **U**nderlying **N**ovel **De**cametric Vegetation **D**ata Products from **E**arth **O**bservation (**GROUNDED EO**)

LIVING PLANET FELLOWSHIP

Project initiated earlier this year to capitalise on several opportunities:

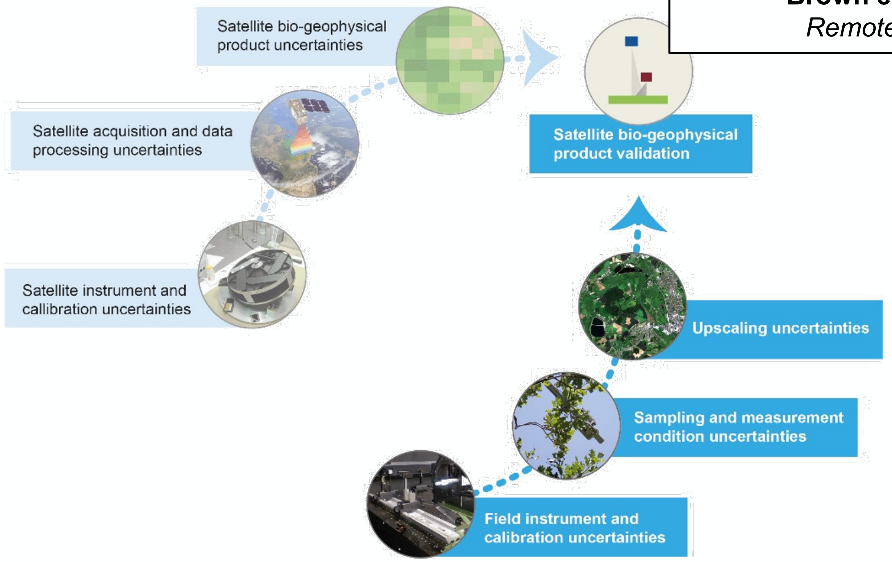
3. **Availability of methods to quantify ground reference measurement uncertainties**

- **Protocols developed** under the FRM4VEG initiative

fiducial reference measurements for vegetation

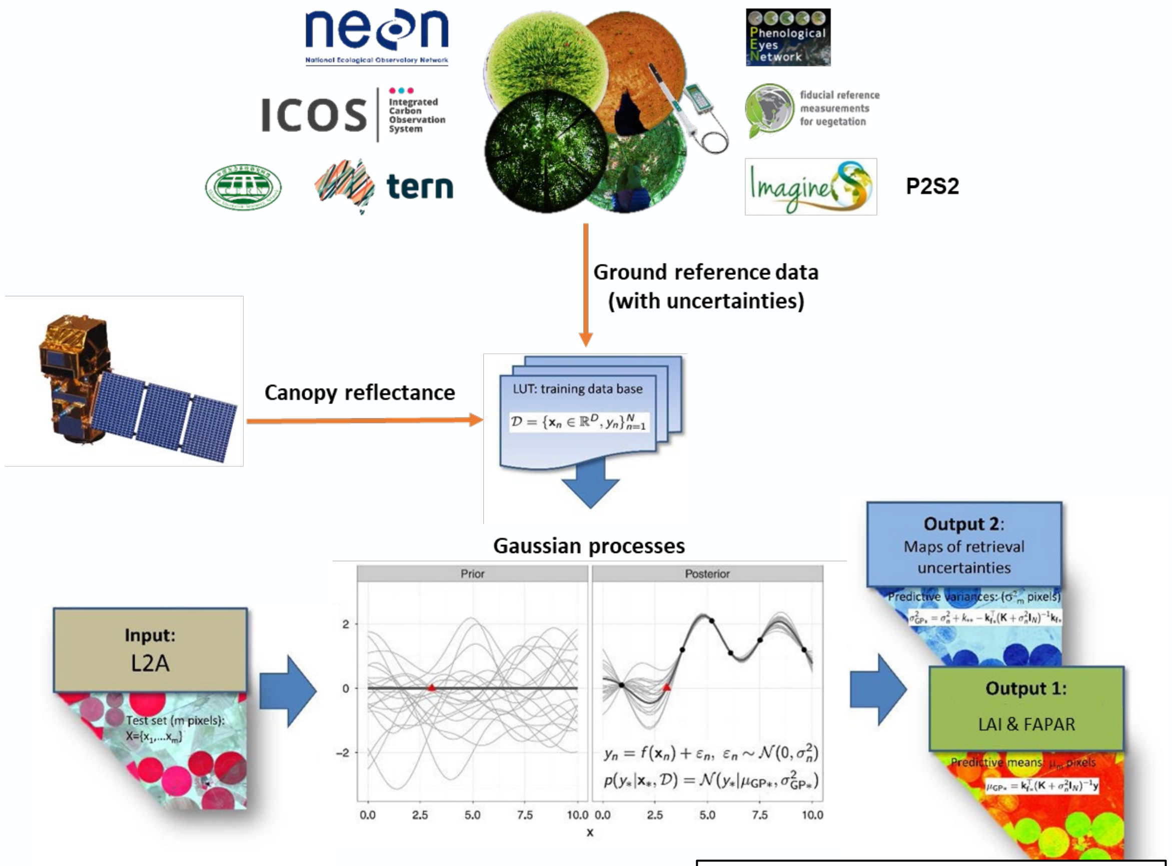
$$u_c^2(y) = \sum_{i=1}^{N} \left(\frac{\partial f}{\partial x_i}\right)^2 u^2(x_i) + 2\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} \frac{\partial f}{\partial x_i}\frac{\partial f}{\partial x_j} u(x_i, x_j) \; .$$

Brown et al. (2021)
Remote Sensing



Avoiding the models? – the GROUNDED EO project (4)

An improved biophysical processor?



Adapted from Berger et al. (2020) & Estévez et al. (2022)

Active learning to optimise training dataset

Samples not used **held back for performance evaluation**

Intercomparison with SL2P, MODIS, VIIRS, & CGLS

GROUNDED EO – database progress (1)

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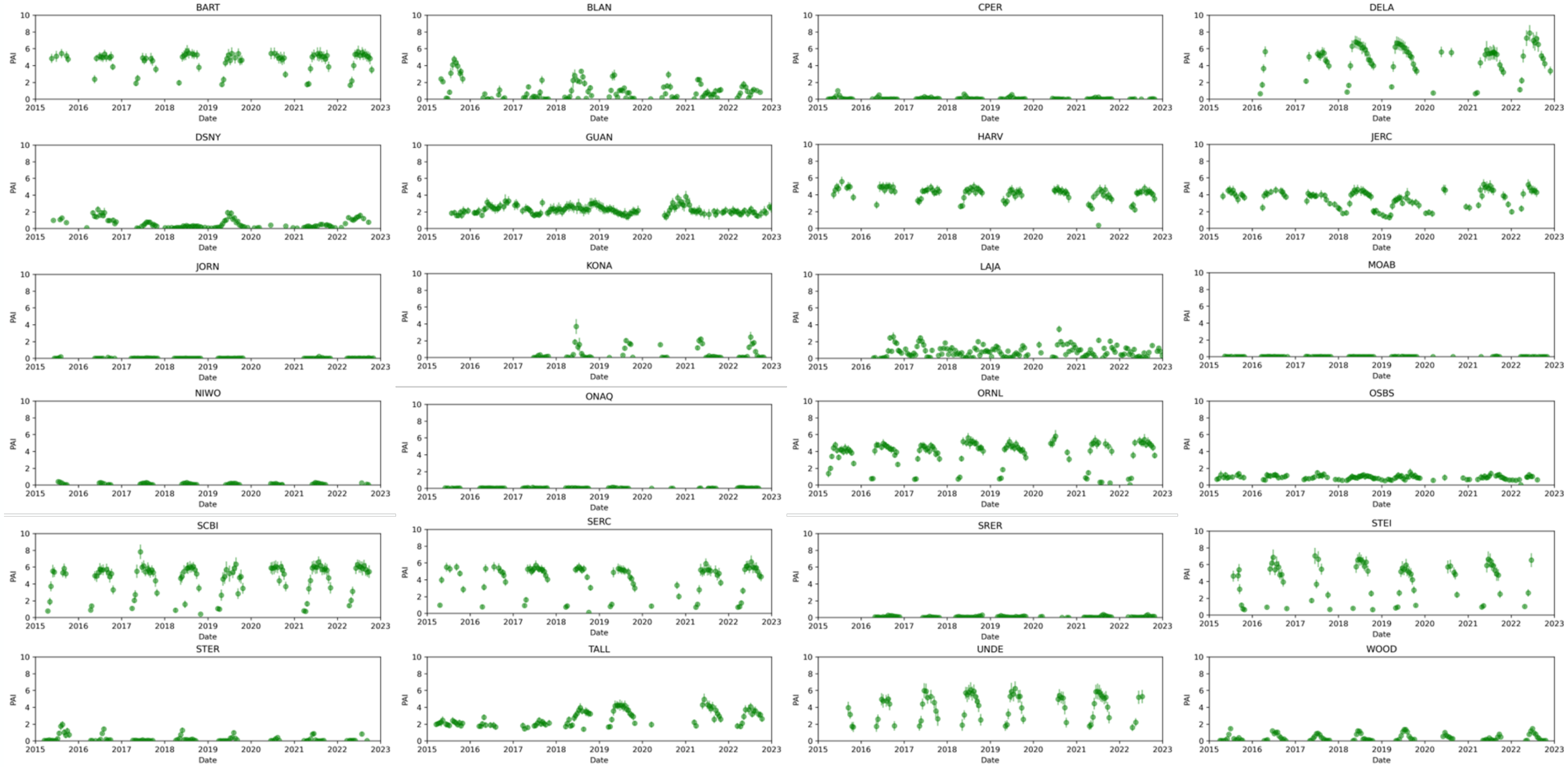
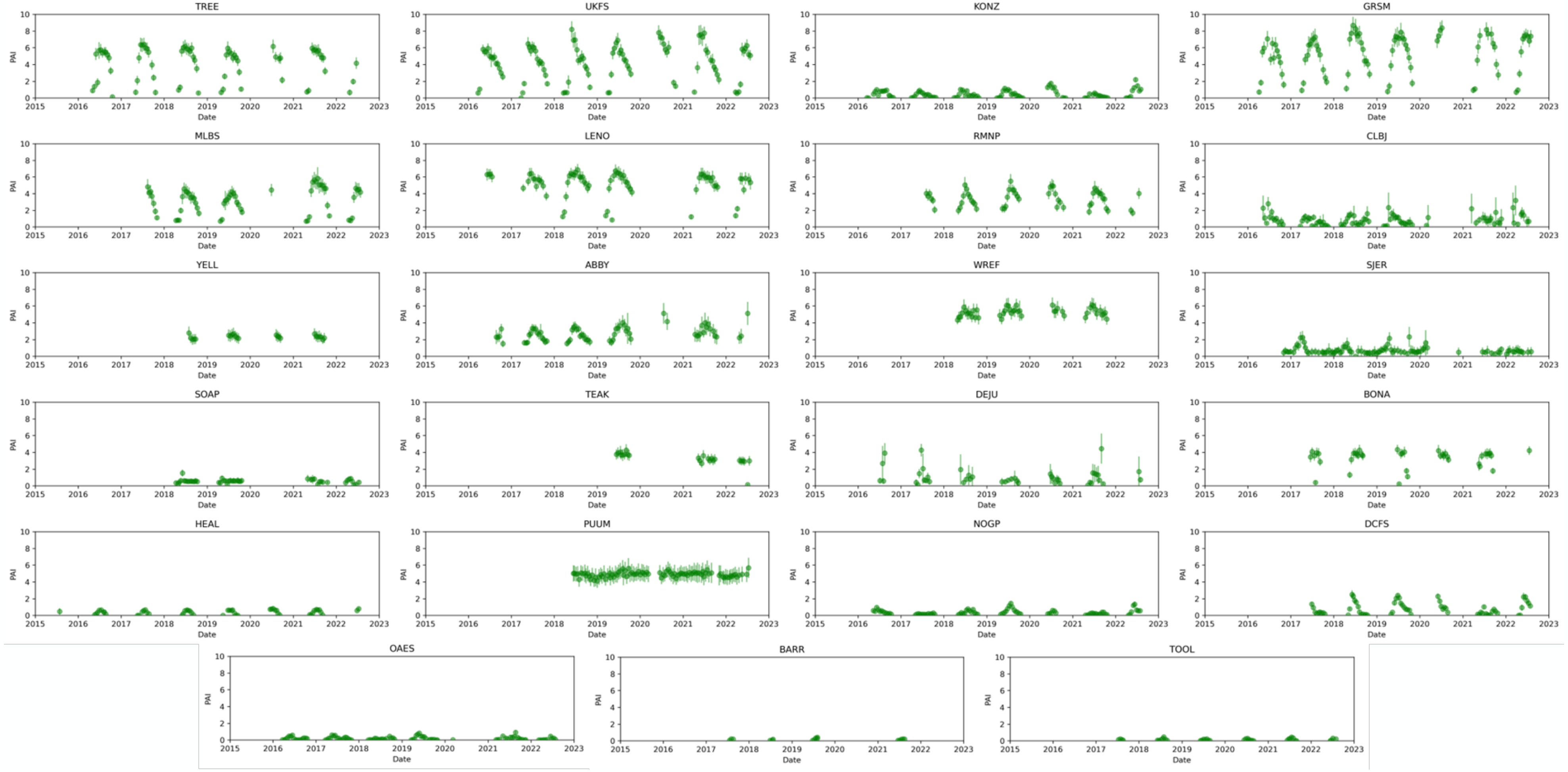
DHP from 24 NEON sites already included in GBOV



GROUNDED EO – database progress (2)

DHP from 23 remaining NEON sites processed under GROUNDED EO



GROUNDED EO – database progress (3)

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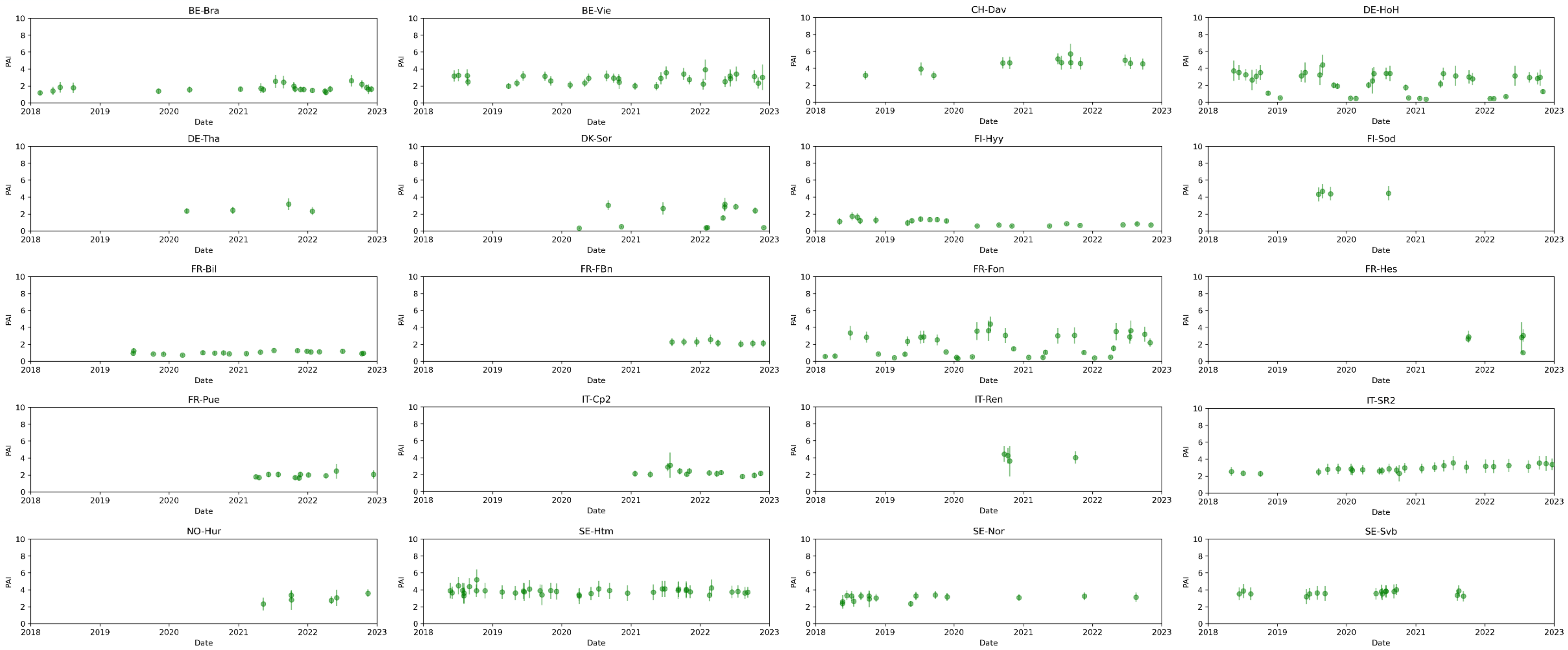
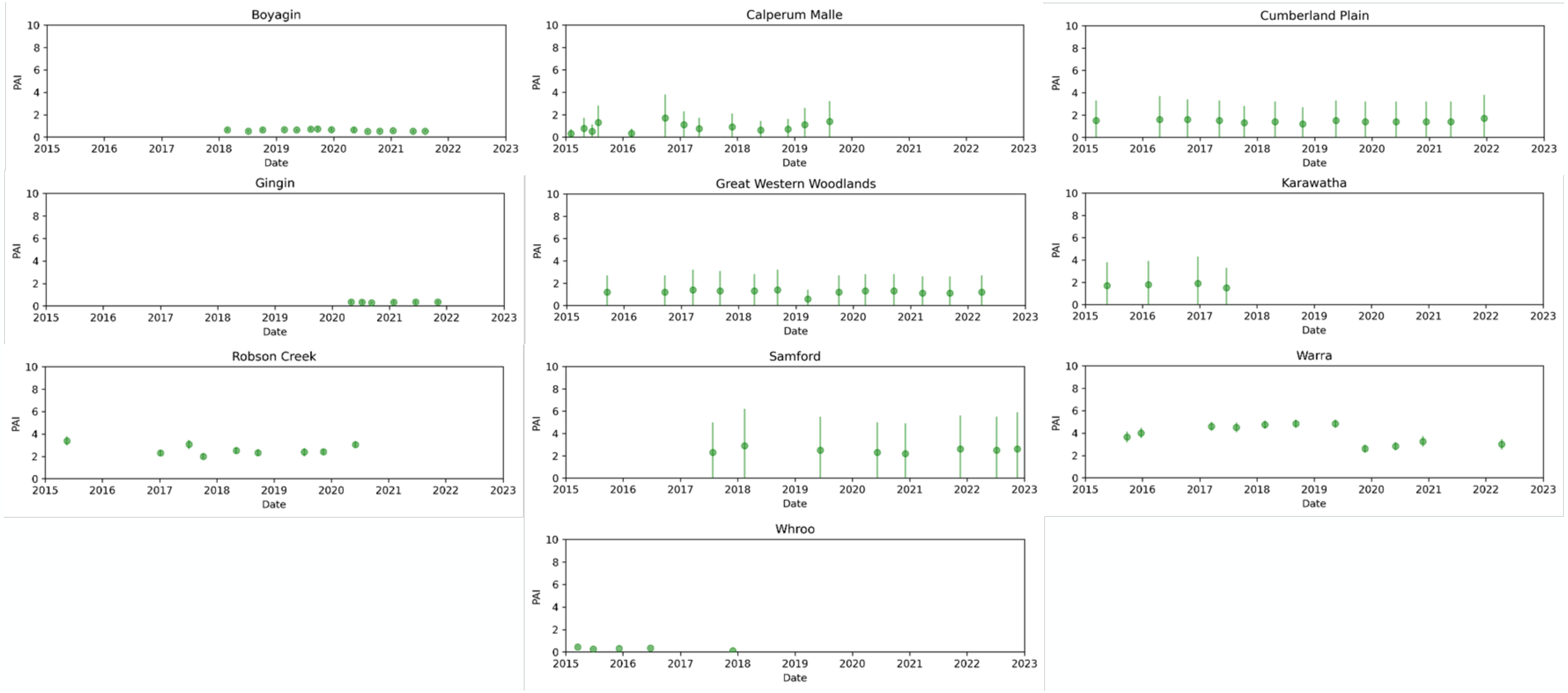
DHP from 20 ICOS sites processed under GROUNDED EO



GROUNDED EO – database progress (4)

Processing of data from TERN DHP and DCP currently in progress



GROUNDED EO – database progress (5)

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LIVING PLANET FELLOWSHIP

The GROUNDED EO database **currently contains 15,464 ESU-scale in situ reference measurements** (20 m x 20 m to 100 m x 100 m) in extent

- **Nearly double the 8,120 available through GBOV**
- Will be made publicly available in near future!

Next steps:

- Complete ground reference database construction
- Development & evaluation of GPR-based biophysical processor