LANDHYPERNET overview and status

Pieter De Vis, Agnieszka Bialek, Joe Riordan, Harry Morris, Morven Sinclair, Kevin Ruddick, Vittorio Brando, Ana Dogliotti, David Doxaran, Philippe Goryl, Joel Kuusk, Mohammadmehdi Saberioon, Quinten Vanhellemont, Astrid Zimmermann

FRM workshop – 19/05/2026

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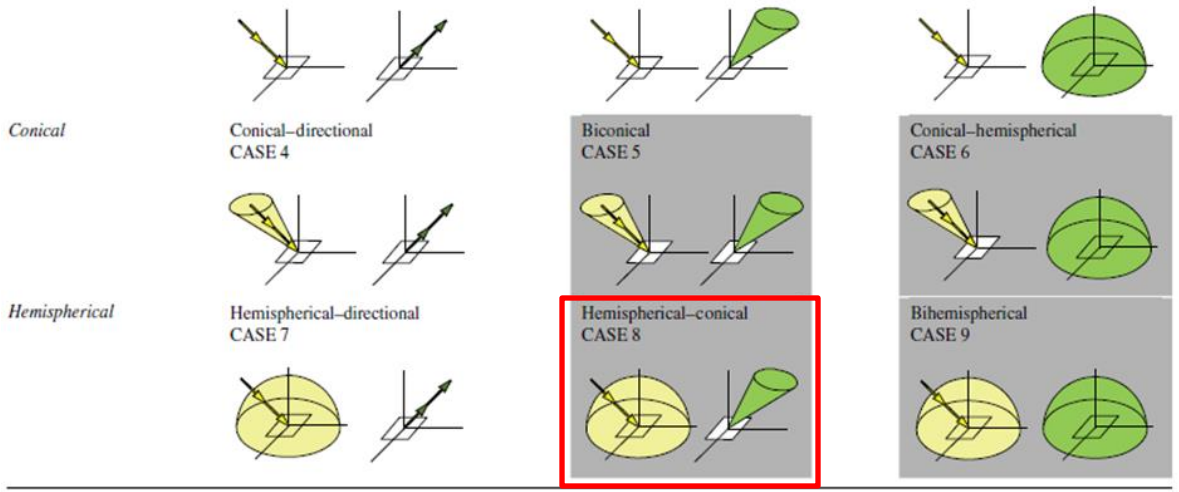
Measurand

The LANDHYPERNET and WATERHYPERNET networks (which together make up the HYPERNETS network) take hyperspectral, pointable HCRF measurements of a range of surfaces to perform L2 BOA surface reflectance satellite products validation

Relation of incoming and reflected radiance terminology used to describe reflectance quantities

Incoming/Reflected	Directional	Conical	Hemispherical
Directional	Bidirectional CASE 1	Directional–conical CASE 2	Directional–hemispherical CASE 3
Conical	Conical–directional CASE 4	Biconical CASE 5	Conical–hemispherical CASE 6
Hemispherical	Hemispherical–directional CASE 7	Hemispherical–conical CASE 8	Bihemispherical CASE 9



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HYPERNETS: a network of automated hyperspectral radiometers to validate water and land surface reflectance (380–1680 nm) from all satellite missions

Kevin G. Ruddick[1]*, Agnieszka Bialek[2], Vittorio E. Brando[3], Pieter De Vis[2], Ana I. Dogliotti[4], David Doxaran[5], Philippe Goryl[6], Clémence Goyens[1], Joel Kuusk[7], Daniel Spengler[8], Kevin R. Turpie[9] and Quinten Vanhellemont[1]

https://doi.org/10.3389/frsen.2024.1372085

HYPSTAR instrument

- A HYperspectral Pointable System for Terrestrial and Aquatic Radiometry (HYPSTAR®) has been designed to provide automated, in situ multiangular reflectance measurements of land and water targets

- The HYPSTAR®-XR (eXtended Range) instruments deployed at each LANDHYPERNET site consist of a VNIR and a SWIR sensor which autonomously measure radiance and irradiance

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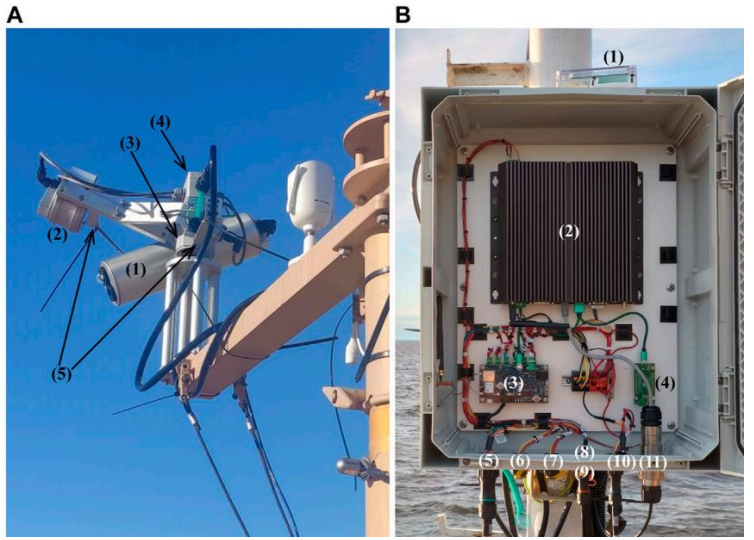
HYPSTAR: a hyperspectral pointable system for terrestrial and aquatic radiometry

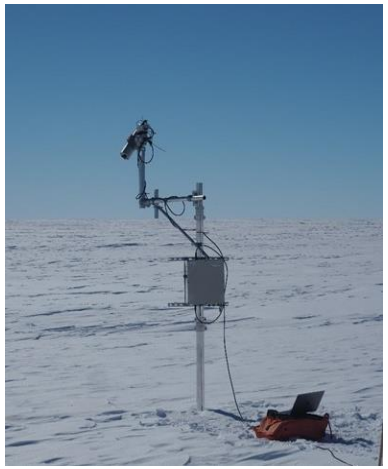
Joel Kuusk[1]*, Alexandre Corizzi[2], David Doxaran[2], Kim Duong[1], Kenneth Flight[1], Joosep Kivastik[1], Kaspars Laizans[1], Edouard Leymarie[2], Silvar Muru[1], Christophe Penkerc'h[2] and Kevin Ruddick[3]

https://doi.org/10.3389/frsen.2024.1347507

Parameter	VNIR water	VNIR land	SWIR land
spectral resolution FWHM	3 nm	3 nm	10 nm
spectral sampling interval	0.5 nm	0.5 nm	3 nm
L2B wavelength range	380–1,020 nm	380–1,000 nm	1,000–1,680 nm
number of L2B channels	1,300	1,260	220
field of view radiance sensor	2°	5°	5°
field of view irradiance sensor	180°	180°	180°

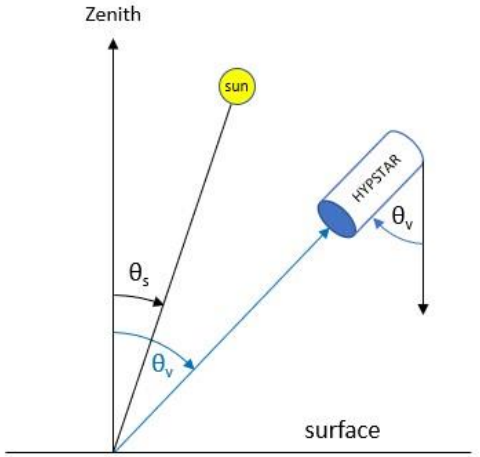


LANDHYPERNET sites

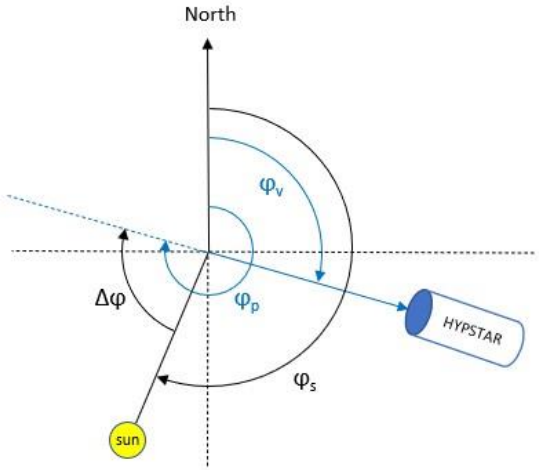


Measurements sequence

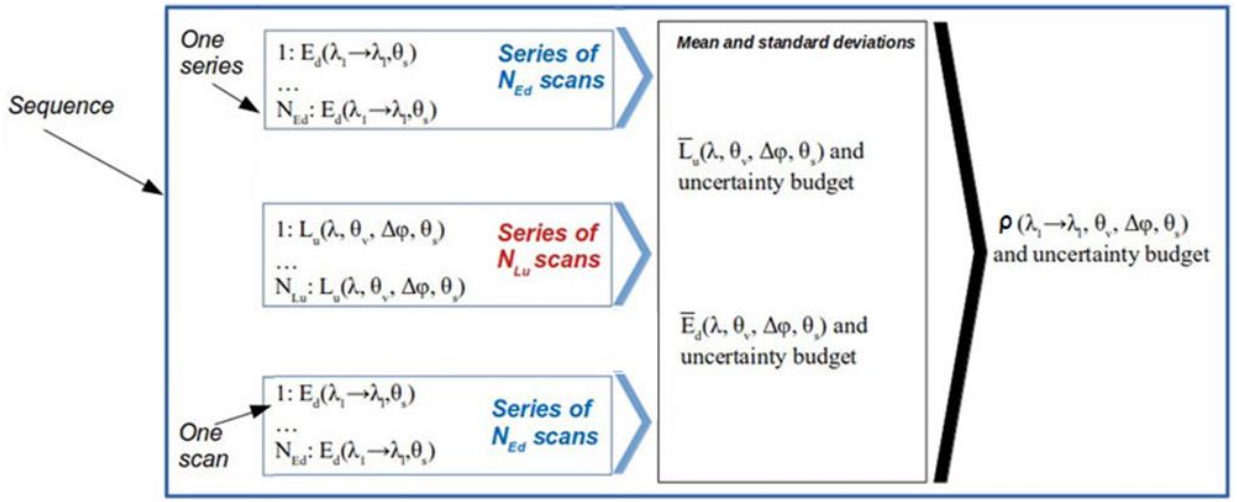
- Sequence is scheduled typically every 30 minutes
- Land sequences start and end with irradiance measurements
- Radiance measurements are performed for a range of viewing geometries
- Viewing geometries are chosen to match typical satellite viewing geometry

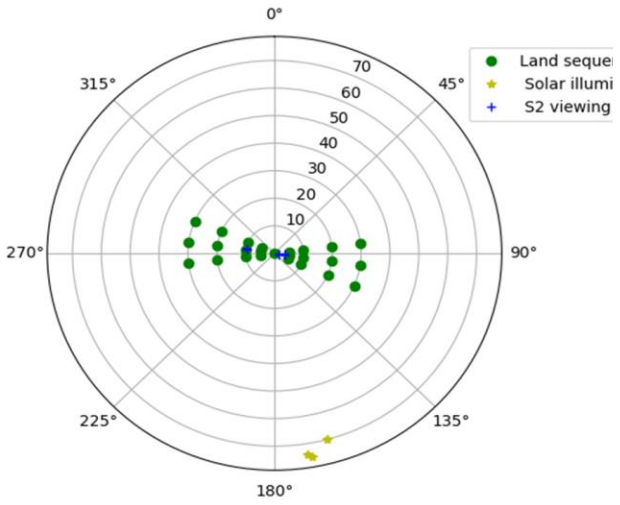


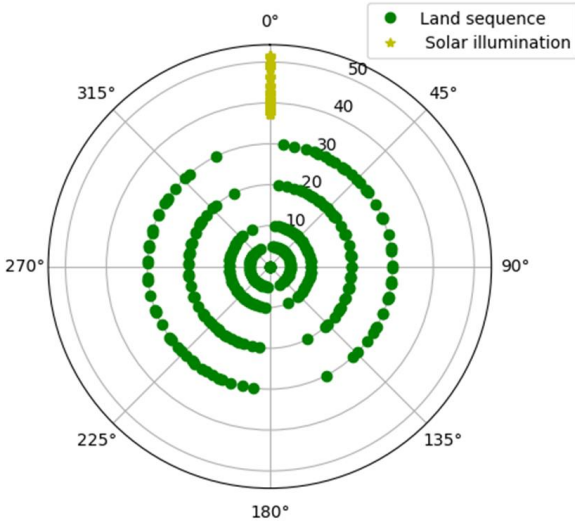
Side view



top view



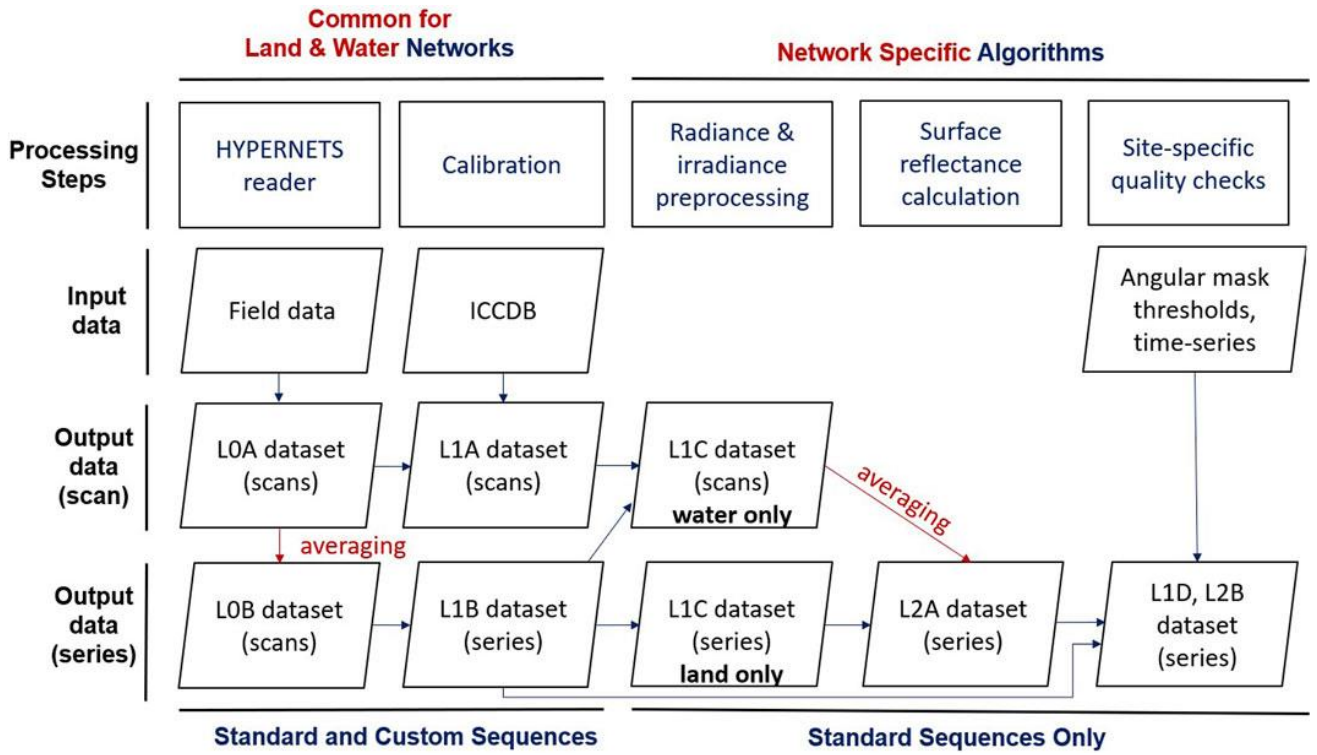


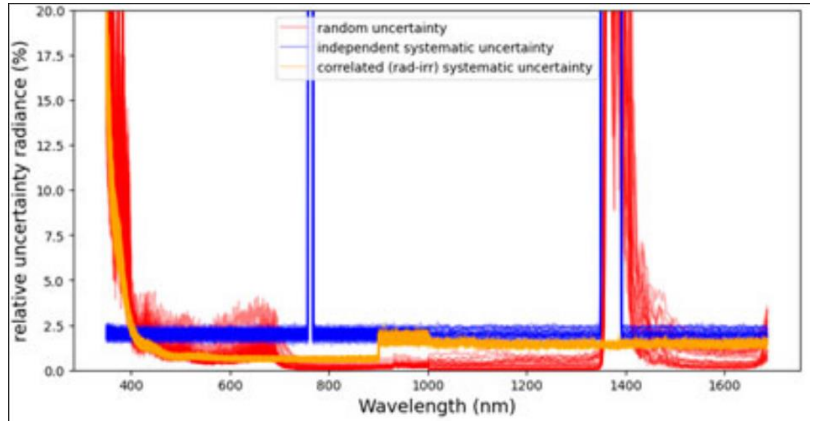


HYPERNETS_PROCESSOR

All measurement data is sent to central server and automatically processed to surface reflectance with associated uncertainty and covariance information

Python code open source on github





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Generating hyperspectral reference measurements for surface reflectance from the LANDHYPERNET and WATERHYPERNET networks

Pieter De Vis[1*†], Clemence Goyens[2†], Samuel Hunt[1], Quinten Vanhellemont[2], Kevin Ruddick[2] and Agnieszka Bialek[1]

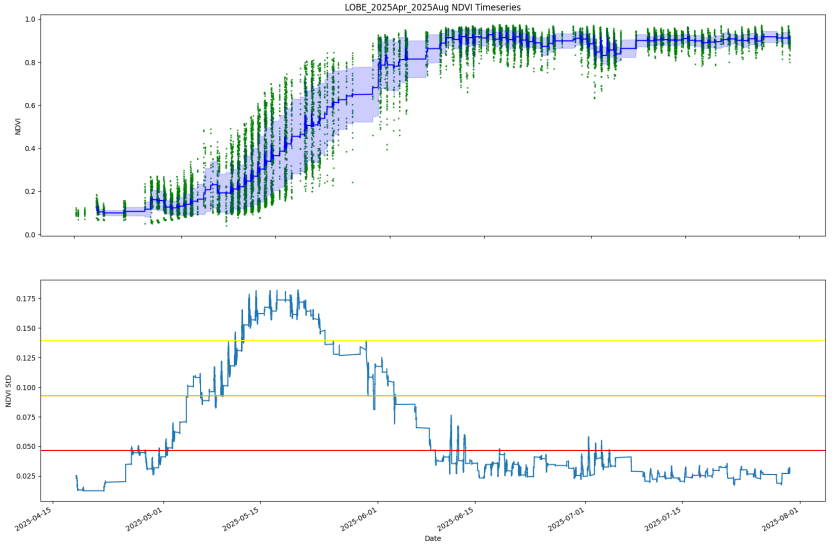
https://doi.org/10.3389/frsen.2024.1347230

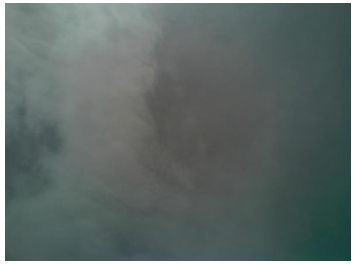
SITE-SPECIFIC QC CHECKS

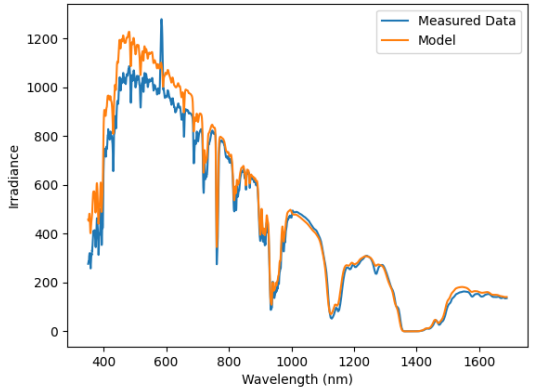
The procedure for site-specific QC checks:

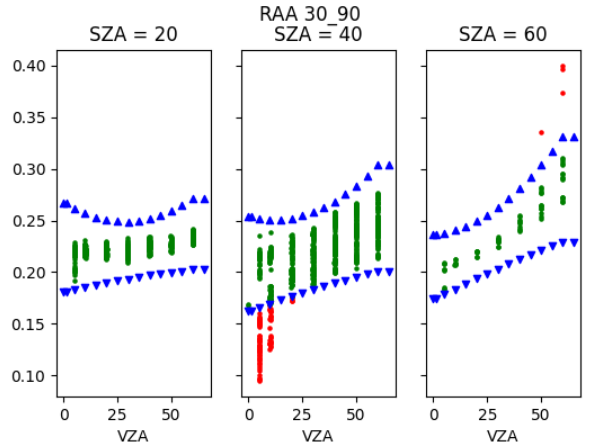
- Offline analysis:
  - Vegetation checks
  - Improved cloud checks
  - Alignment analysis
  - Reflectance plane fits

- L2B/L1D processing by the hypernets_processor:
  - All data which fails any of the QC checks is omitted
  - Alignment is corrected
  - L2B/L1D files produced



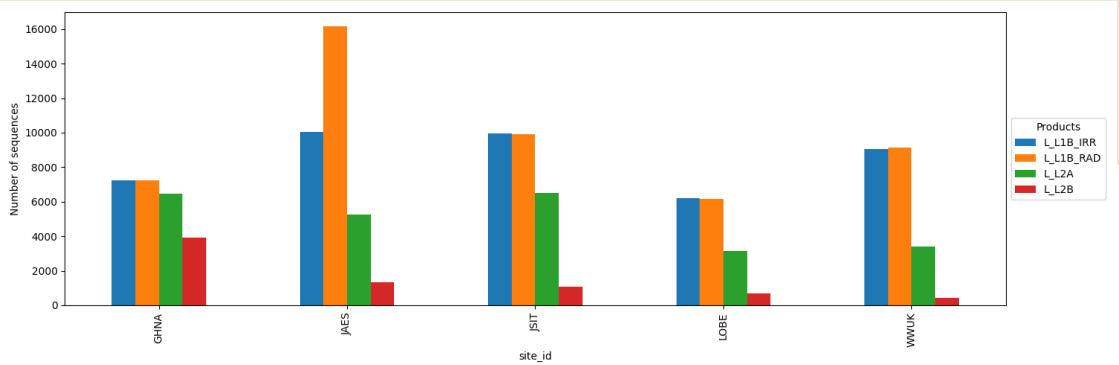




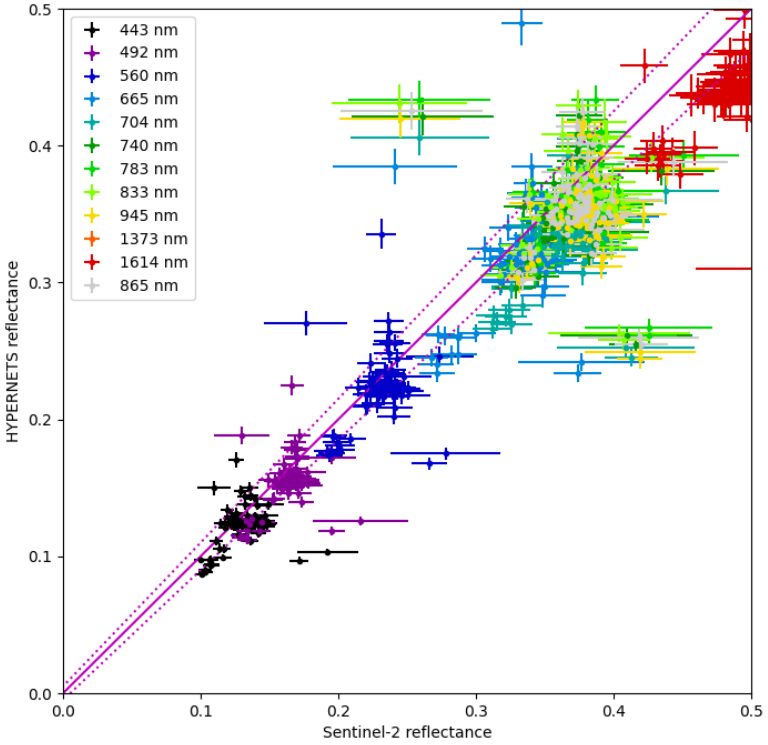


HYPERNETS

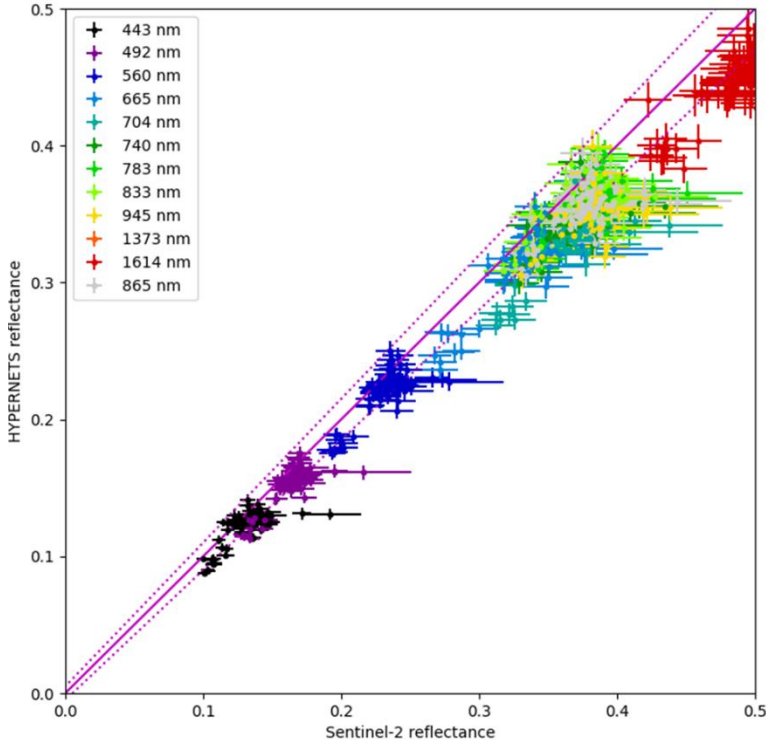
L2B IMPACT



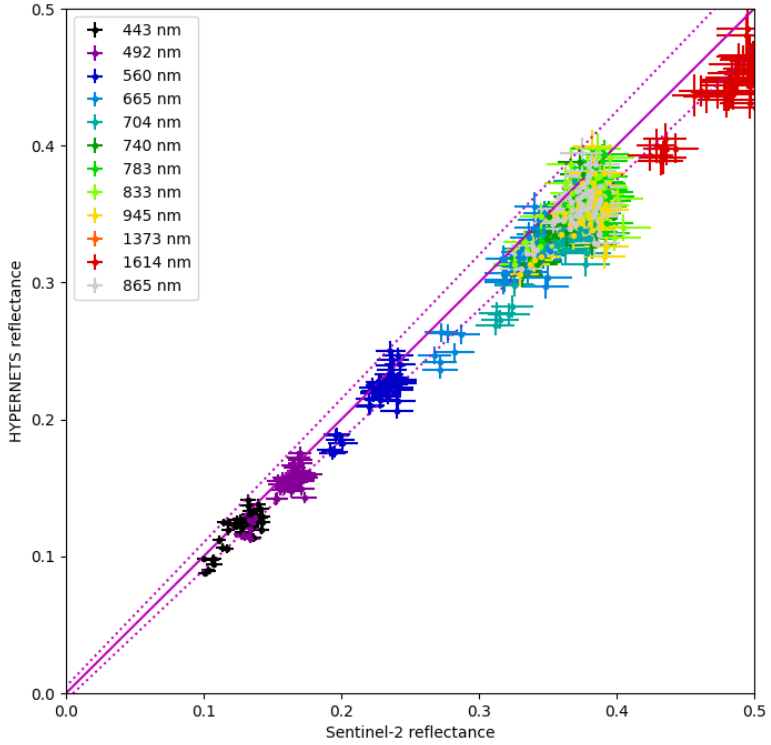
L2A



L2B



L2B
& S2 cloud fraction < 5%

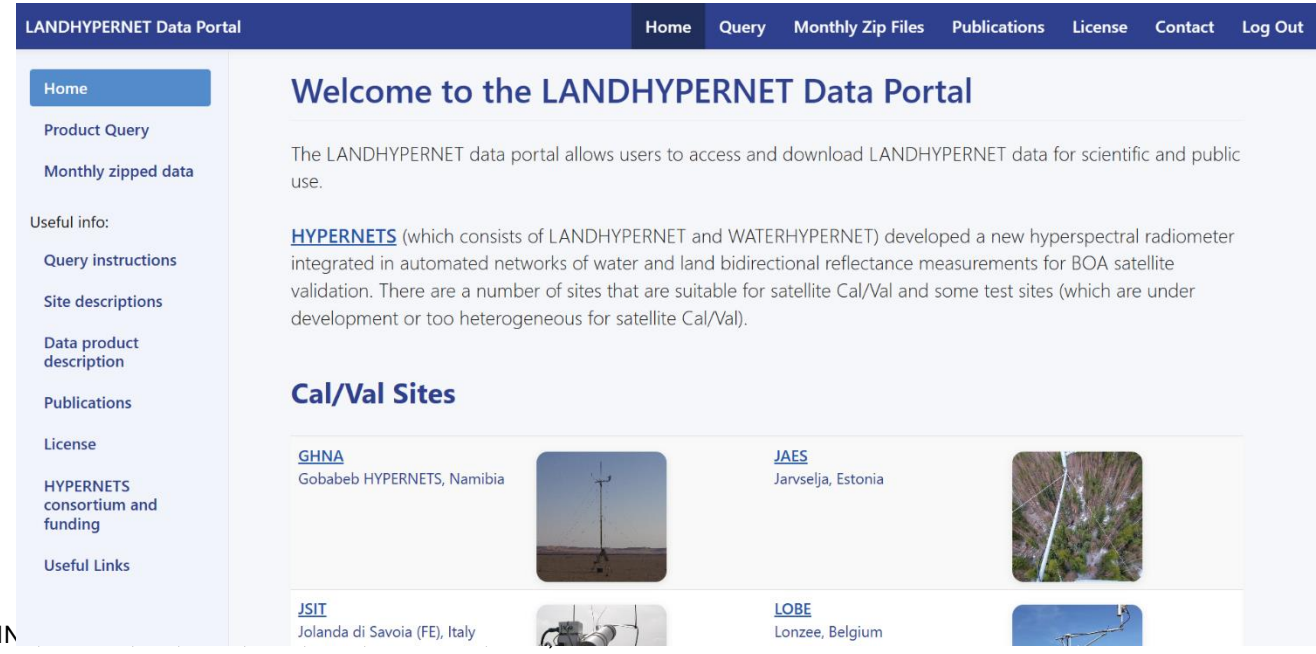


LANDHYPERNET data portal

https://www.landhypernet.org.uk/

- Best place to access LANDHYPERNET products
  - L1D_IRR, L1D_RAD, L2B
  - Additional products available to site_owners or specific expert users
- Query the data or download monthly zip files
- API access being beta-tested
- DOI for each site through Zenodo

GHNA: 10.5281/zenodo.8039302
JAES: 10.5281/zenodo.17619220
JSIT: 10.5281/zenodo.17619560
LOBE: 10.5281/zenodo.17616379
WWUK: 10.5281/zenodo.7962556

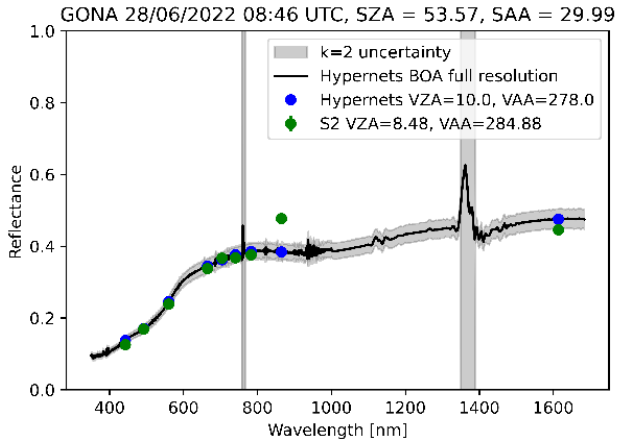


Science results at GHNA (Gobabeb, Namibia)

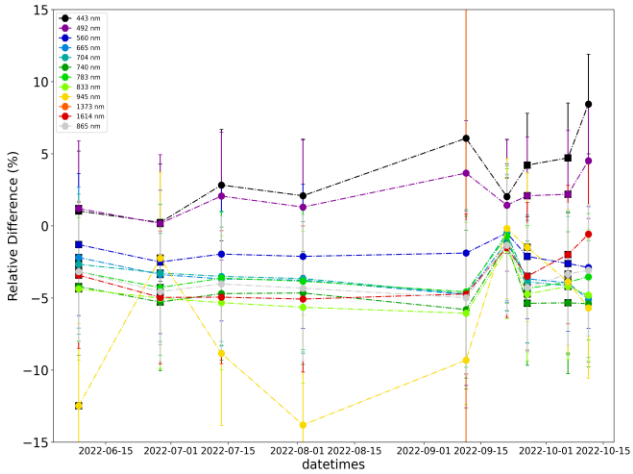
- RadCalNet HYPERNETS BOA validation proceedings paper presented at IGARSS 2023
(Sinclair et al. 2023: DOI: 10.1109/IGARSS52108.2023.10282079)
- Feasibility of Vicarious calibration proven by propagating GHNA data to TOA and comparing to S2, L8 and PRISMA
(De Vis et al. 2024a DOI: 10.3389/frsen.2024.1323998)
- BRDF Model Development Using In-Situ Dataset (Sinclair et al. in prep)
- GHNA used as reference in ACIX-III (Cremer et al. 2025)
- UAV campaign planned for Q3 2026

$$|A_i - B_j| < k\sqrt{u^2(A_i) + u^2(B_j) + u^2(\Delta)}$$

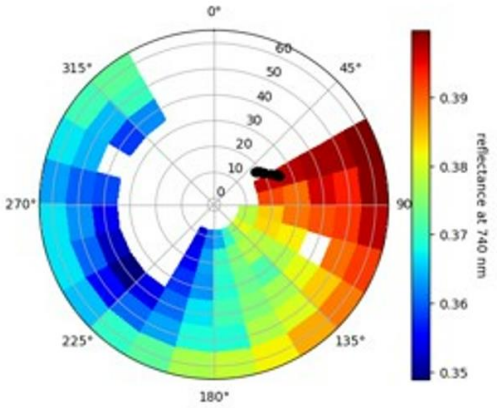
BOA comparison with S2



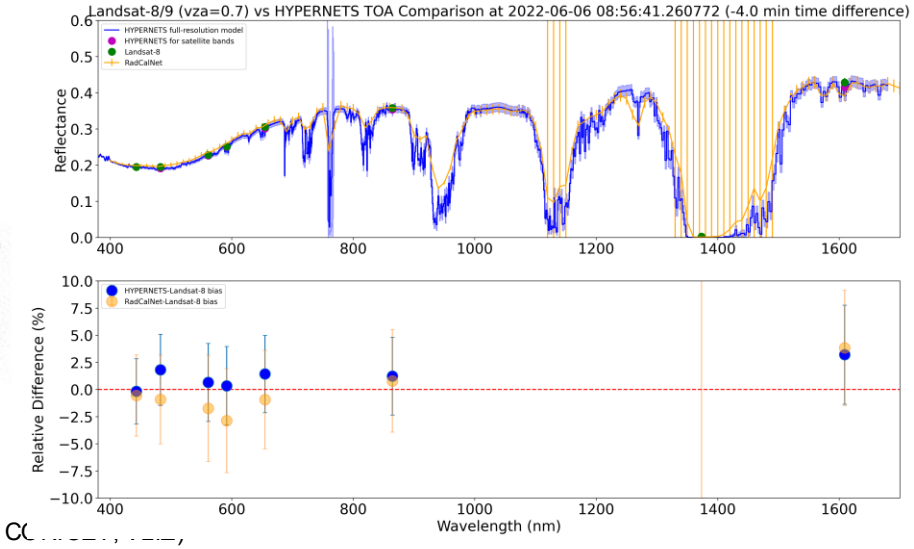
TOA S2 bias time series



Masked BRDF sequence



TOA comparison with L8 and RCN



Science results at WWUK (Wytham Woods, UK)

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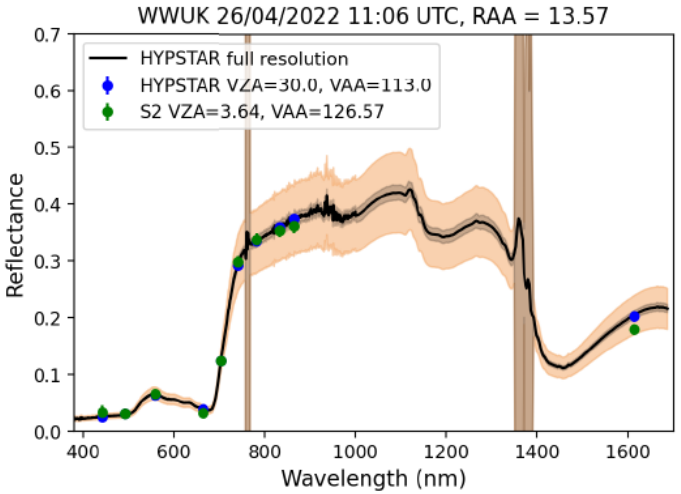
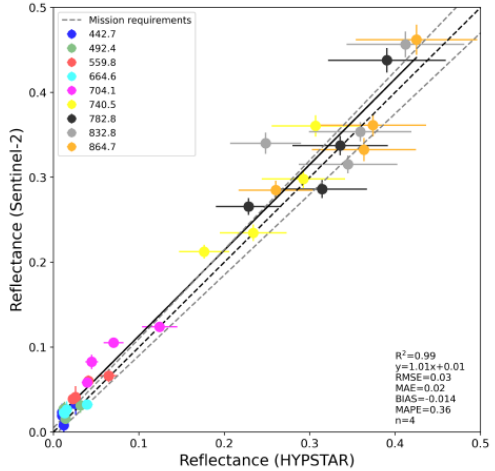
Utilising LANDHYPERNET data products over a deciduous broadleaf forest to validate Sentinel-2 and Landsat surface reflectance products

Harry Morris*, Morven Sinclair, Pieter De Vis and Agnieszka Bialek

https://doi.org/10.3389/frsen.2024.1322760

- Surface reflectance seasonal dynamics paper
  - BOA Validation of multispectral data from Sentinel-2, Landsat-8 and Landsat-9
  - Exploration of the impact of spatial variability and complexities of canopy validation
- Future work on validation potential of vegetation ECVs (CCC/FAPAR) from HYPSTAR data
- 2023 Wytham installation activity:

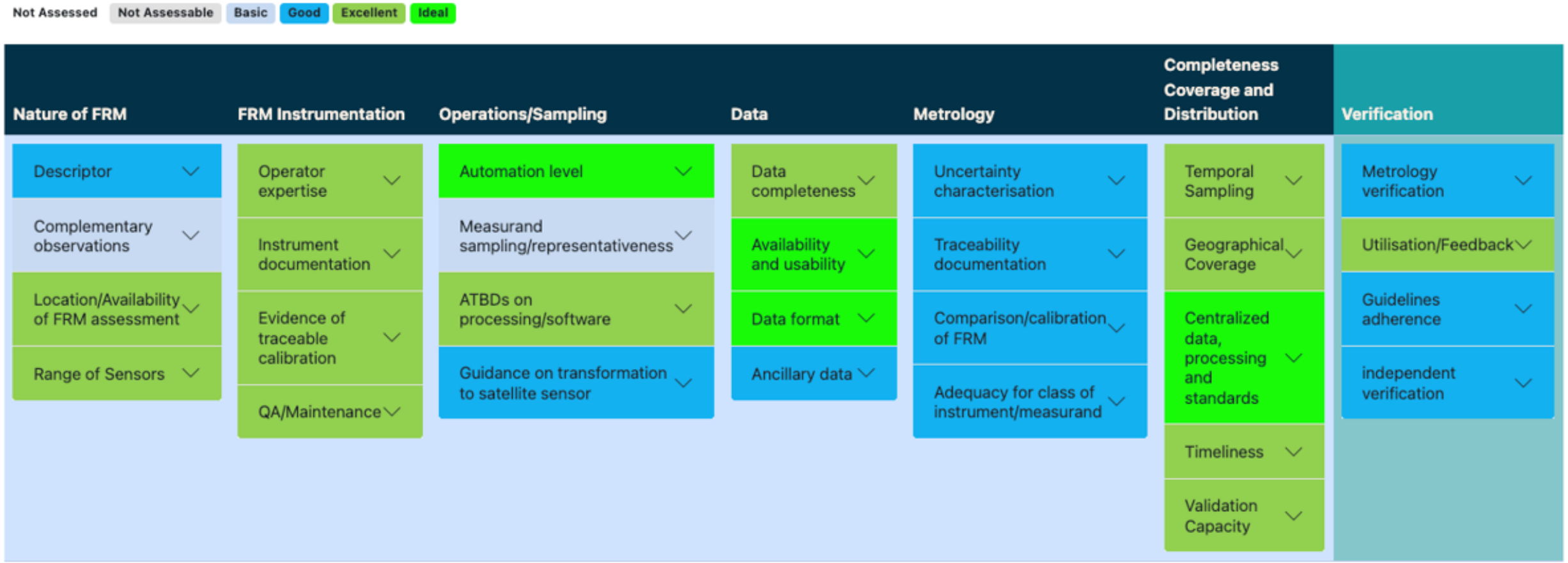




2023	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
January																															
February																															
March																															
April																															
May																															
June																															
July																															
August																															
September																															
October																															
November																															
December																															

Running normally
<3 sequences collected
No data

LANDHYPERNET Maturity Matrix



CEOS-FRM Overall Classification: Class C

FRM comments

- Performing CEOS FRM assessment for LANDHYPERNET network resulted in **Class C** (Good).
  One of the most useful aspects of going through the assessment, is to identify the path to **Class B** (excellent).

- In some cases, the wording of the available answers (e.g. statements such as “The available information is ideal”) resulted in me picking a lower category. I think in multiple places I have been too conservative.
  => Risk for poor inter-consistency between FRMs

- Not all sites in the LANDHYPERNET network have the same maturity.
  Unsure how that should affect the score of the network?

- FRM self-assessment questions cover all the relevant aspects for satellite validation.

- LANDHYPERNET would benefit most from:
  - Quantifying spatial variability
  - Comparisons with independent datasets

Conclusions

- LANDHYPERNET is operationally taking HCRF surface reflectance measurements using HYPSTAR®-XR over a range of different land surfaces (agriculture, forest, desert, snow)
- LANDHYPERNET network provides critical data for the validation of present and upcoming hyperspectral missions (e.g. ENMAP, PRISMA, PACE, SBG, CHIME, FLEX, …)
- Data is being automatically processed and made available on data portal NRT https://www.landhypernet.org.uk/
- Various papers were published in Frontiers special issue https://www.frontiersin.org/research-topics/55073/optical-radiometry-and-satellite-validation/articles

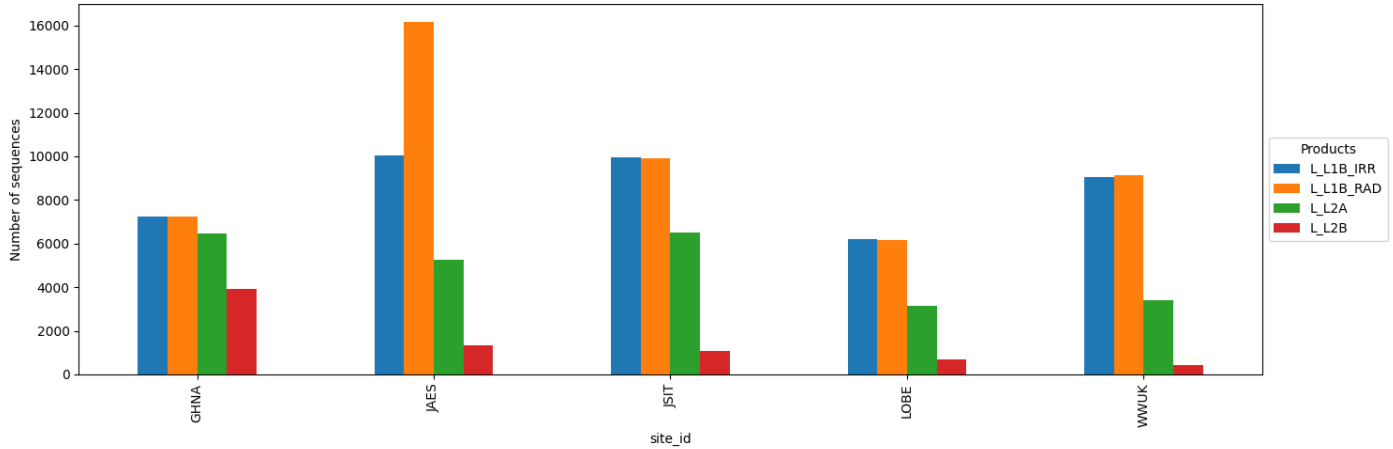
Thank You!

Pieter.de.vis@npl.co.uk

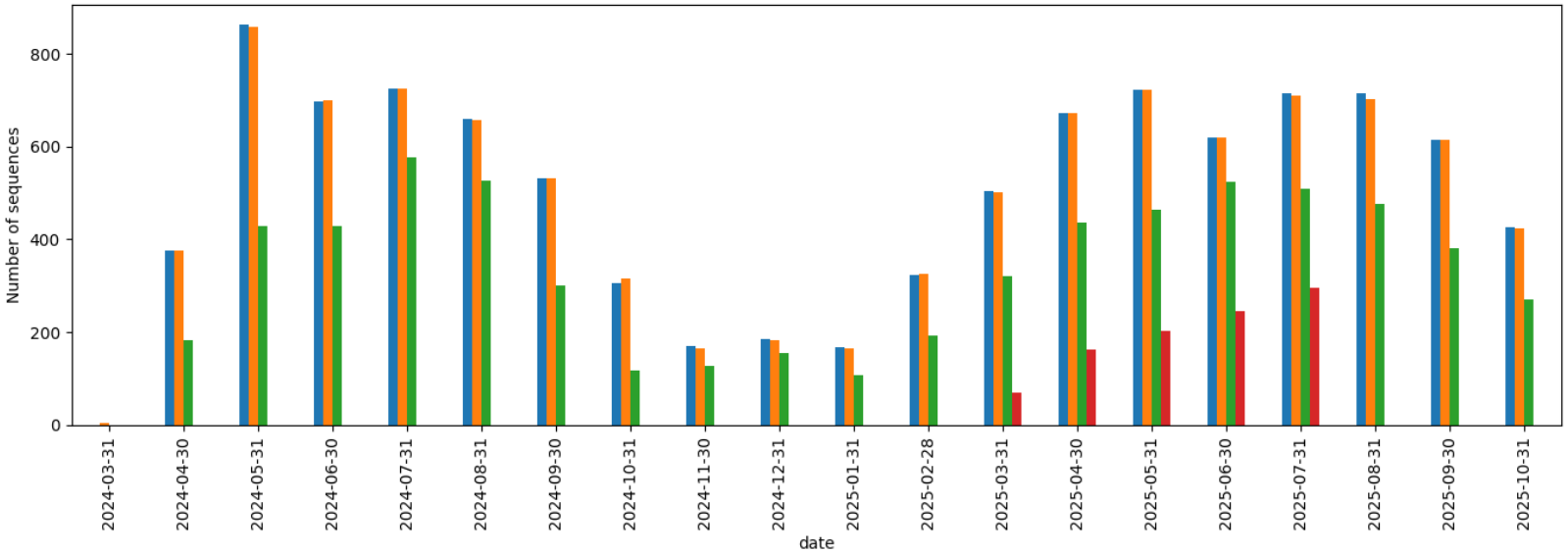
Additional slides

L2B PROCESSING STATISTICS

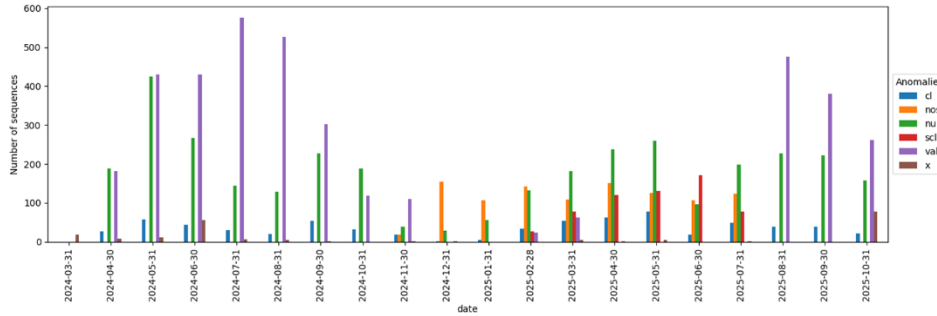
Processing statistics for each site



Processing statistics time series for JSIT



Anomalies time series for JSIT



Using HYPERNETS for Satellite Validation

- Measurand for L2A validation is HCRF at common spectral, spatial, angular and temporal scale
- Metrologically robust validation metric:

$$|x - y| < k\sqrt{u_x^2 + u_y^2 + u_{comp}^2}$$

x: satellite measurand (already processed), with uncertainty u_x
y: reference measurand (already processed), with uncertainty u_y
u_{comp}: uncertainty to account for differences in measurand

- Critical points:
  - Measurand used needs to be clearly described for x and y, and match as closely as possible
  - All uncertainties related to processing to the measurand x and y are included in u_x and u_y.
  - Uncertainties due to differences that cannot be corrected are included in u_{comp}, and mismatch between x and y is clearly described.
  - The results need to be interpreted in the context of a confidence interval.
    If, $k = 2$ is used, this corresponds to 95% confidence interval.

NEW SITE-SPECIFIC QC CHECKS

There is now a new procedure for site-specific QC checks:

- Offline analysis:
  - **Improved cloud checks**
  - Alignment analysis
  - Vegetation checks
  - Reflectance plane fits

- L2B/L1D processing by the hypernets_processor:
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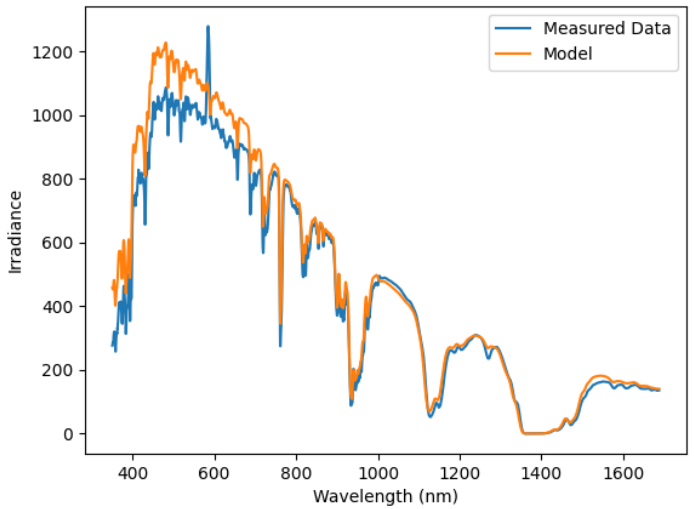

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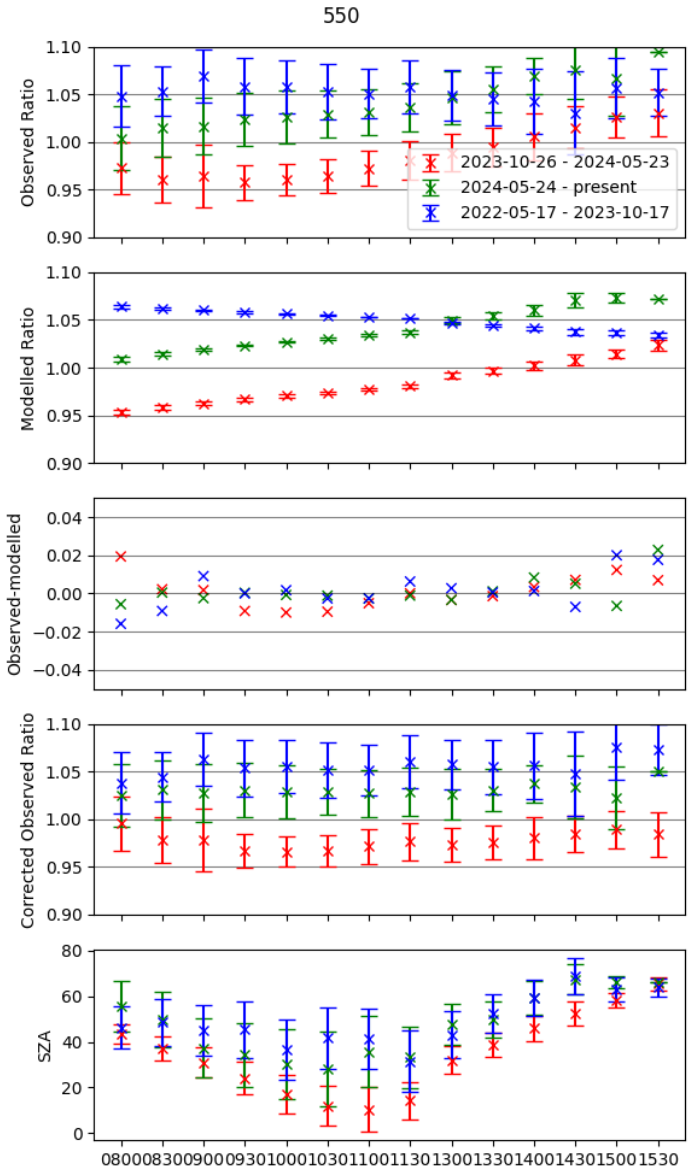

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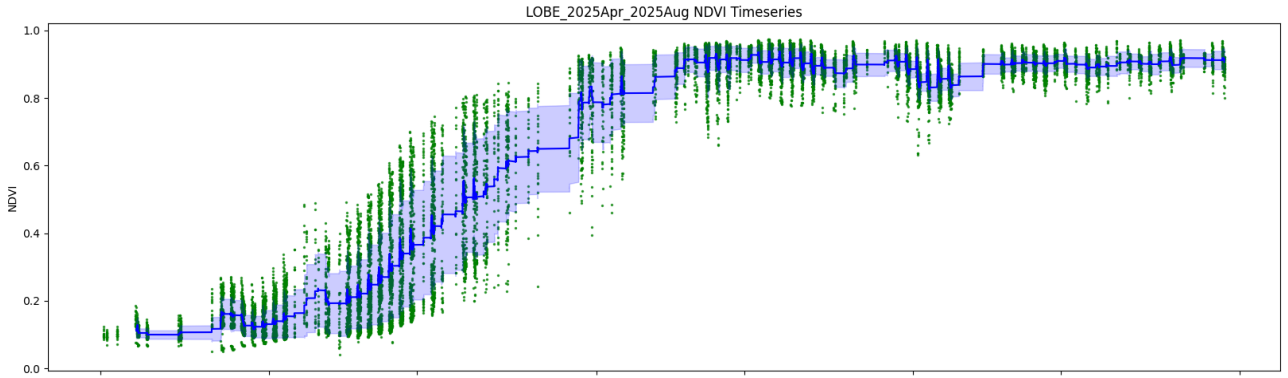

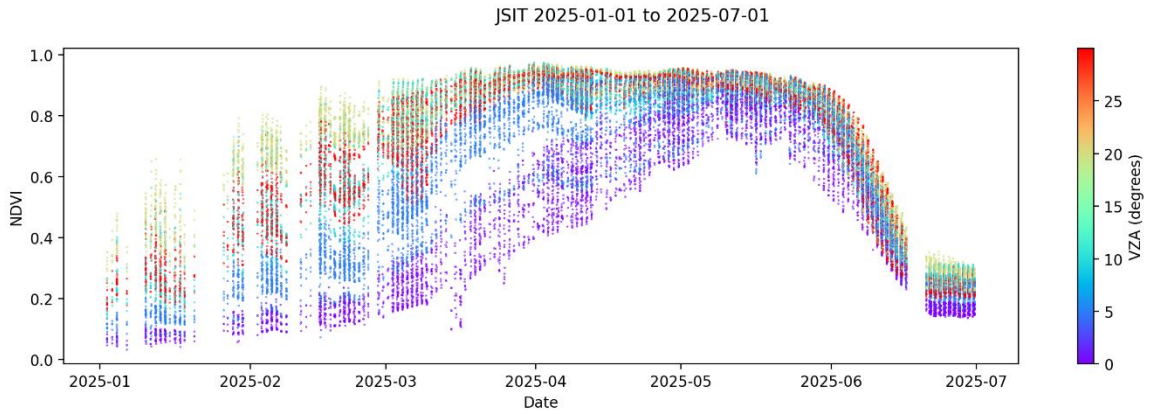

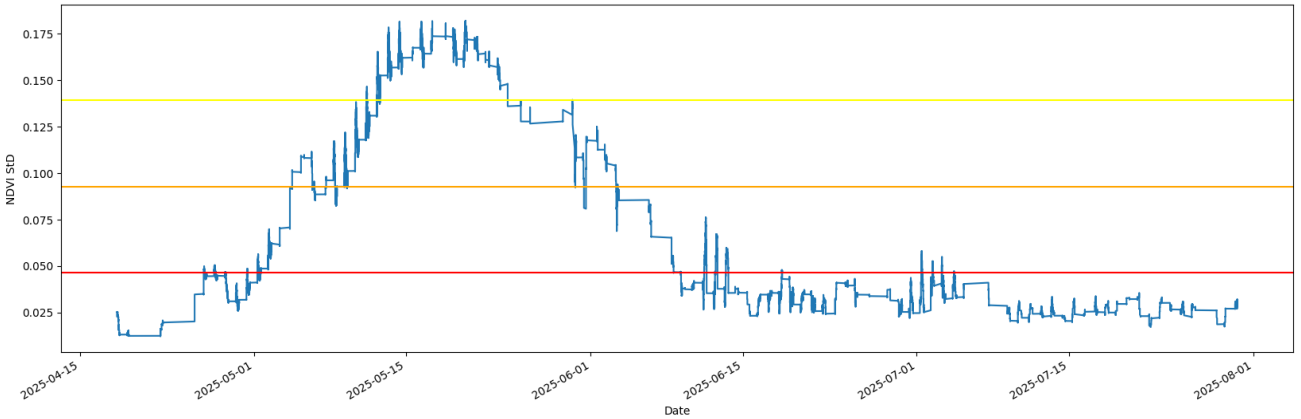

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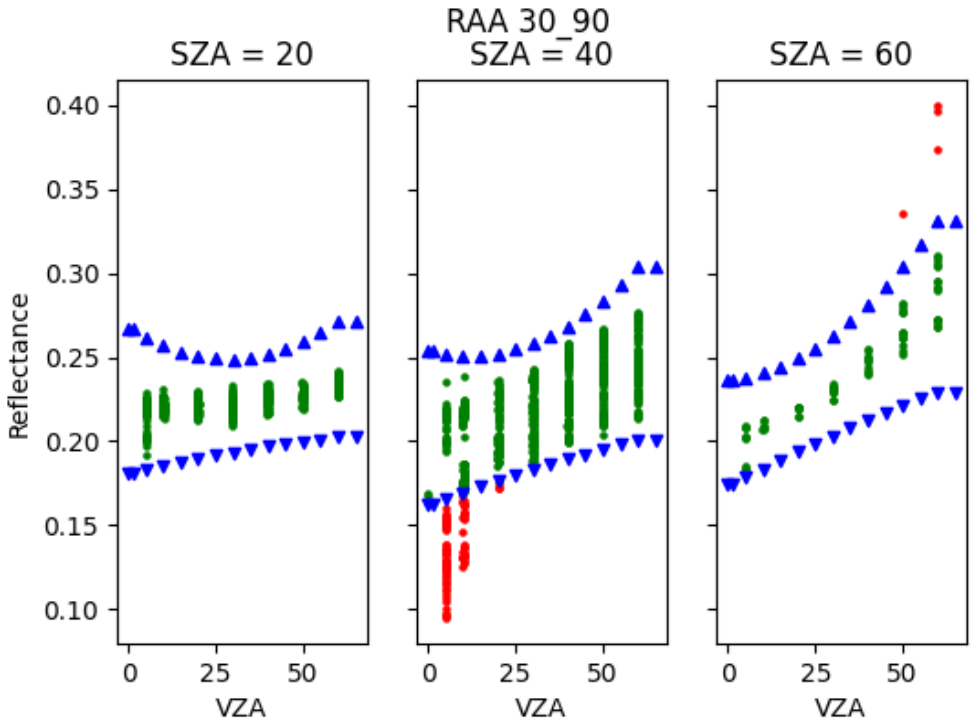
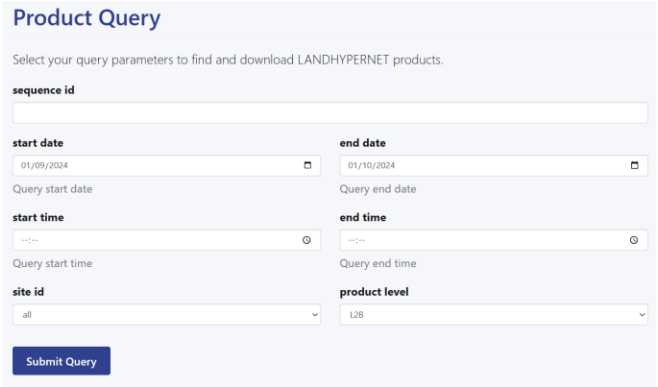


LANDHYPERNET data portal

https://www.landhypernet.org.uk/

- download monthly zip files for each site
- query the data, to select specific time ranges and/or conditions
- Inspect plots of individual sequences



Monthly zip files for JAES

Here is a list of the available monthly zip files with L1D and L2B files. Please click on the link to download the file.

Download JAES_L1DL2B_Sep2025.zip
Download JAES_L1DL2B_Aug2025.zip
Download JAES_L1DL2B_Jul2025.zip
Download JAES_L1DL2B_Jun2025.zip
Download JAES_L1DL2B_May2025.zip
Download JAES_L1DL2B_Apr2025.zip
Download JAES_L1DL2B_Mar2025.zip
Download JAES_L1DL2B_Sep2024.zip
Download JAES_L1DL2B_Aug2024.zip
Download JAES_L1DL2B_Jul2024.zip
Download JAES_L1DL2B_Jun2024.zip
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select	sequence_id	site_id	product_level	datetime	lat	lon	product_name
☐	SEQ20240901T110051	JAES	L_L2B	2024-09-01 11:00:51.000000	58.281975	27.312959	HYPERNETS_L_JAES_L2B_REF_20240901T11
☐	SEQ20240902T110048	JAES	L_L2B	2024-09-02 11:00:48.000000	58.281975	27.312959	HYPERNETS_L_JAES_L2B_REF_20240902T11
☐	SEQ20240902T120047	JAES	L_L2B	2024-09-02 12:00:47.000000	58.281975	27.312959	HYPERNETS_L_JAES_L2B_REF_20240902T12
☐	SEQ20240903T083049	JAES	L_L2B	2024-09-03 08:30:49.000000	58.281975	27.312959	HYPERNETS_L_JAES_L2B_REF_20240903T08
☐	SEQ20240903T100049	JAES	L_L2B	2024-09-03 10:00:49.000000	58.281975	27.312959	HYPERNETS_L_JAES_L2B_REF_20240903T10
☐	SEQ20240903T103049	JAES	L_L2B	2024-09-03 10:30:49.000000	58.281975	27.312959	HYPERNETS_L_JAES_L2B_REF_20240903T10
☐	SEQ20240903T110049	JAES	L_L2B	2024-09-03 11:00:49.000000	58.281975	27.312959	HYPERNETS_L_JAES_L2B_REF_20240903T11
☐	SEQ20240910T083027	GHNA	L_L2B	2024-09-10 08:30:27.000000	-23.60153	15.12589	HYPERNETS_L_GHNA_L2B_REF_20240910T(
☐	SEQ20240910T090033	GHNA	L_L2B	2024-09-10 09:00:33.000000	-23.60153	15.12589	HYPERNETS_L_GHNA_L2B_REF_20240910T(
☐	SEQ20240910T093033	GHNA	L_L2B	2024-09-10 09:30:33.000000	-23.60153	15.12589	HYPERNETS_L_GHNA_L2B_REF_20240910T(
☐	SEQ20240910T100126	GHNA	L_L2B	2024-09-10 10:01:26.000000	-23.60153	15.12589	HYPERNETS_L_GHNA_L2B_REF_20240910T
☐	SEQ20240910T103030	GHNA	L_L2B	2024-09-10 10:30:30.000000	-23.60153	15.12589	HYPERNETS_L_GHNA_L2B_REF_20240910T