Copernicus FICE 2025

Training on
In situ Ocean Colour Above-Water Radiometry towards Satellite Validation

Automated above water hyperspectral radiometry at Acqua Alta: review of recent results and perspectives

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fiducial reference measurements for satellite ocean colour
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Automated above water hyperspectral radiometry at Acqua Alta: review of recent results and perspectives

V. E. Brando, L. Gonzalez Vilas, J. A. Concha, M. Bastianini, F. Braga

Quinten Vanhellemont, Kevin Ruddick, Matthew Beck

Mariana Altenburg Soppa

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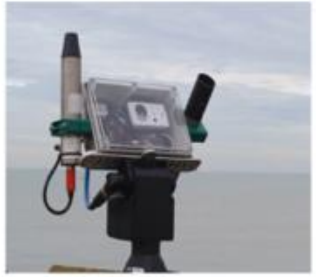
AWI

HYPERNETS

HYPERNETS in a single slide

INSTRUMENTS

Automated hyperspectral measurements



PANTHYR system
[Vansteenwegen et al, 2019]
400-900nm, 10nm FWHM

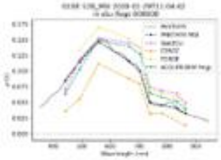
HYPSTAR® system
[https://hypstar.eu/]
380-1700nm, 3-10nm FWHM

NETWORK

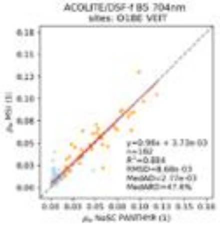
RBINS (BE, coordinator)
+ VLIZ (BE), CNR (IT), LOV (FR), NPL (UK), GFZ (D), TARTU (ES), CONICET (ARG), UMBC (USA)

11 water and 7 land sites currently operating
Many international requests to join in 2024 ...

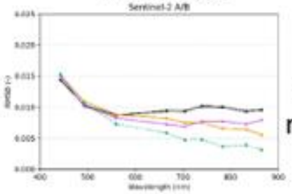
DATA PROCESSING and ANALYSIS



e.g. one matchup



one band (S2/704nm), many matchups



spectral stats, many matchups

Prototype network has provided validation data and information to:

Sentinel-2A&B, Sentinel-3A&B/OLCI, Landsat-8&9, Planetscope Doves and Superdoves, PRISMA, Pléiades, ENMAP, MODIS-A&T, VIIRS-1&2,...

OBJECTIVE: To validate **all** VIS/NIR spectral bands (400-1700nm, @3-10nm FWHM) for **all** satellite missions measuring water or land surface reflectance

and preparing for:

ACIX, DESIS, MTG and SEVIRI, EMIT, CHIME, LSTM, PACE, GLIMR, SBG, PROBAV-CC, GOCI, SABIAMAR, various Newspace, ... (national hyperspectral imagers from Canada, Norway, Australia, ...)

HYPERNETS

Research Topic
Frontiers in Remote Sensing

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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]

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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]

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Validation of satellite water products based on HYPERNETS *in situ* data using a Match-up Database (MDB) file structure

Luis González Vilas[1]*, Vittorio E. Brando[1], Javier A. Concha[1,2], Clèmence Goyens[3], Ana I. Dogliotti[4,5], David Doxaran[6], Antoine Dille[3] and Dimitry Van der Zande[3]

[1]CNR-ISMAR, Istituto di Scienze Marine, Consiglio Nazionale delle Ricerche, Rome, Italy, [2]Serco S.p.A. c/

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ces (CAS),

United States

Validation of satellite-derived water-leaving reflectance in contrasted French coastal waters based on HYPERNETS field measurements

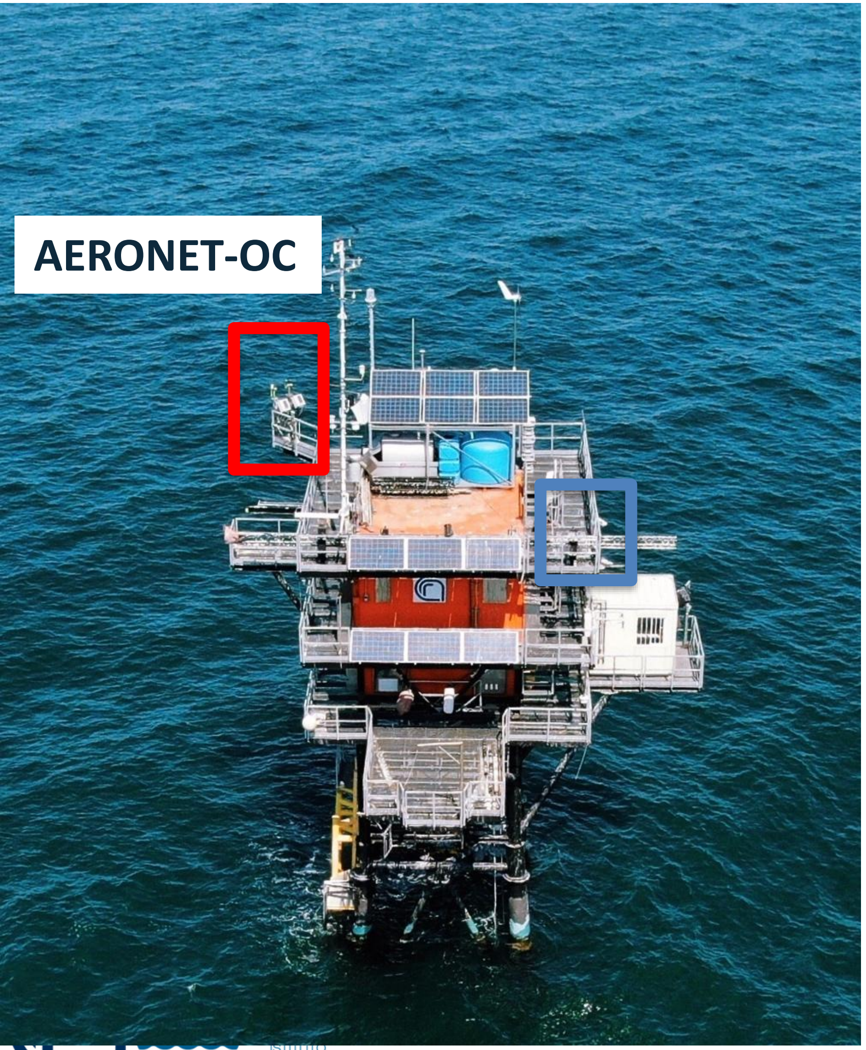
David Doxaran[1]*, Boubaker ElKilani[1], Alexandre Corizzi[1] and Clémence Goyens[2]

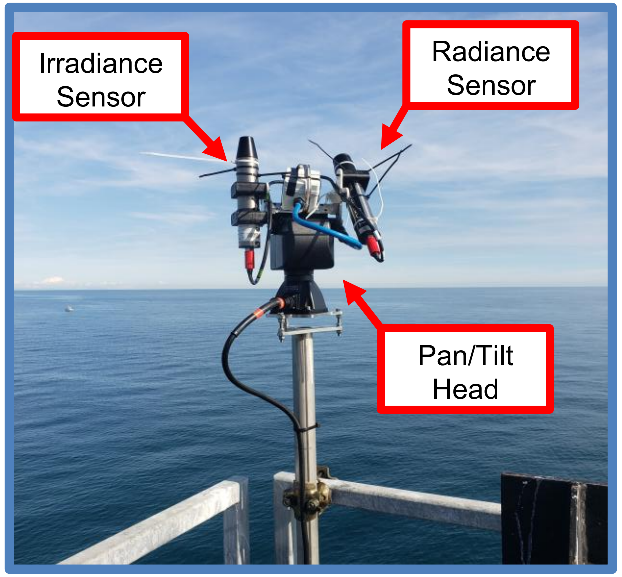
Using the automated HYPERNETS hyperspectral system for multi-mission satellite ocean colour validation in the Río de la Plata, accounting for different spatial resolutions

Ana I. Dogliotti[1,2]*, Estefanía Piegari[1,3], Lucas Rubinstein[1,4], Pablo Perna[1] and Kevin G. Ruddick[5]

HYPERNETS

Aqua Alta Oceanographic Tower





PANTHYR (Pan-and-Tilt HYperspectral Radiometer System, Vansteenwegen et al., 2019) **:**

- 2 TRIOS/RAMSES COTS hyperspectral radiometers
- Installed on 27-09-2019

Data for Oct. 2019—Mar. 2022 is publicly available on: https://zenodo.org/records/10024445

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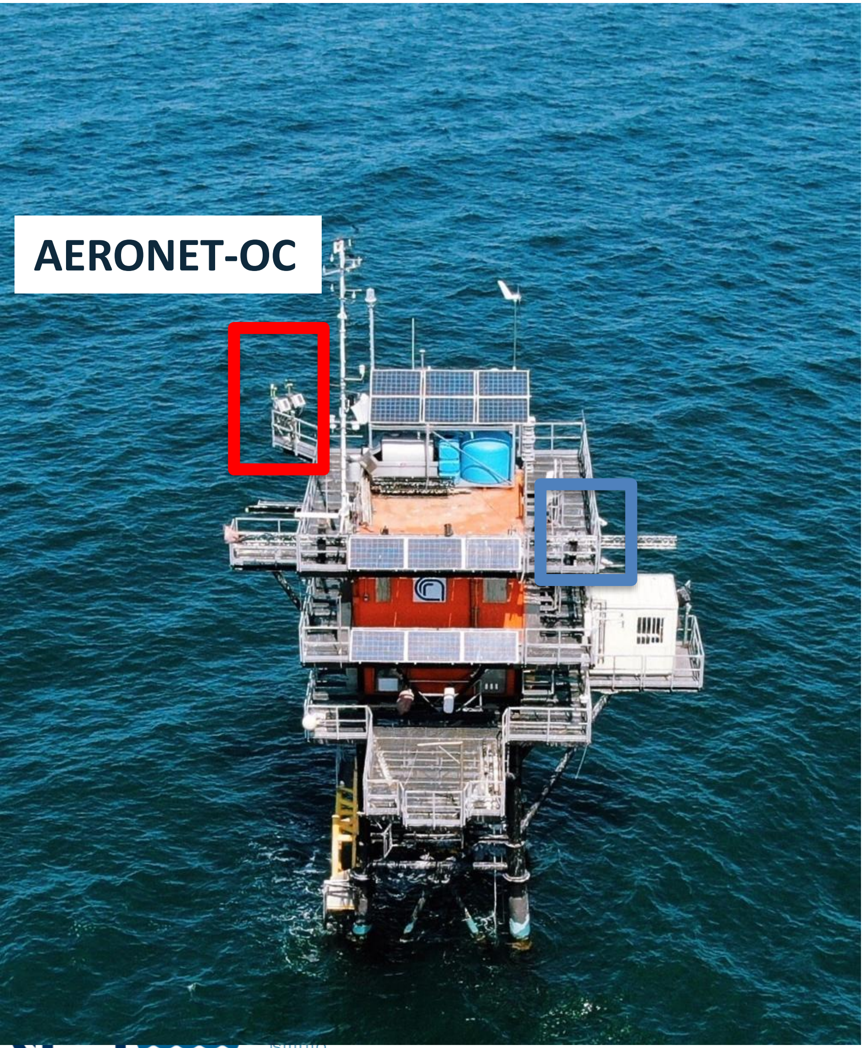
Aqua Alta Oceanographic Tower



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spectral sampling interval	0.5 nm
L2B wavelength range	380–1,020 nm
number of L2B channels	1,300
field of view radiance sensor	2°
field of view irradiance sensor	180°

HYPSTAR® (**HY**perspectral **P**ointable **S**ystem for **T**errestrial and **A**quatic **R**adiometry, https://hypstar.eu)

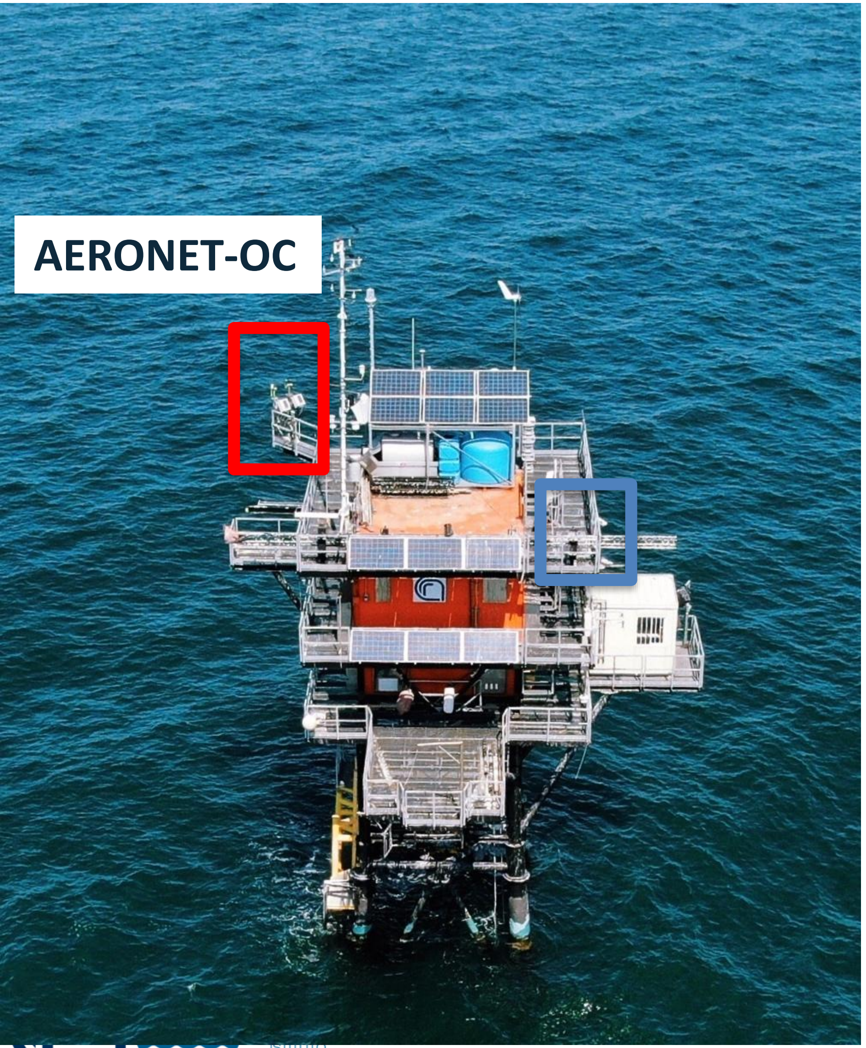
- **V1 sensor** First deployment 15-04-2020 : 08-05-2022
- Calibration at Tartu
- Second deployment 13-07-2022 : 13-03-2023

Data available at:

https://zenodo.org/records/8057531

HYPERNETS

Aqua Alta Oceanographic Tower



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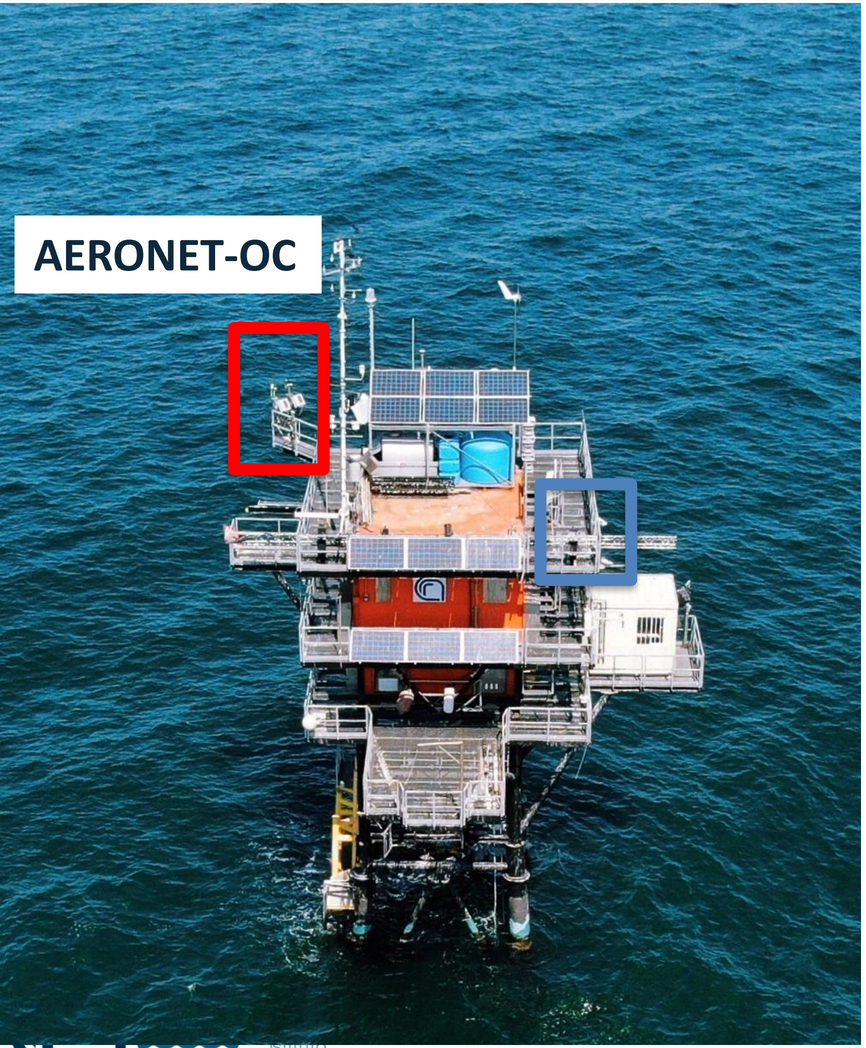
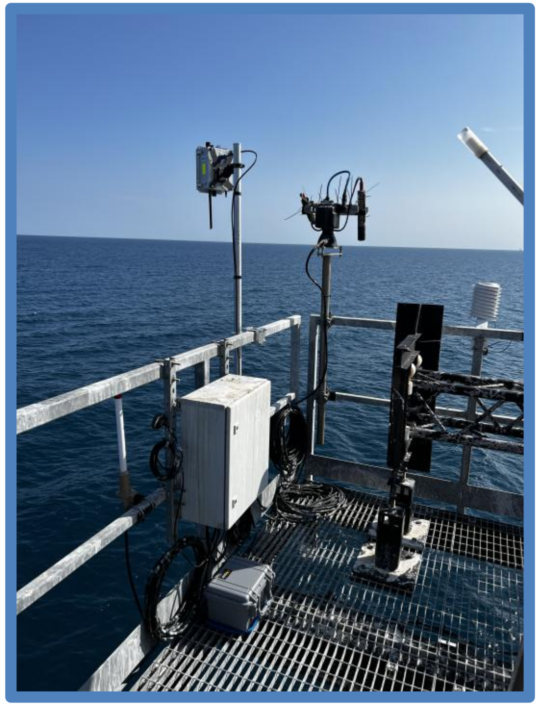
- Second deployment 13-07-2022 : 13-03-2023
- **V3 sensor** installed in AERONET-OC corner on 17-03-2023

Aqua Alta Oceanographic Tower





HydraSpectra

a low-cost optical system for field-deployed water quality monitoring of water bodies based on spectral reflectance developed by the CSIRO.

- installed in PANTHYR corner
- First deployment 6/10/2023

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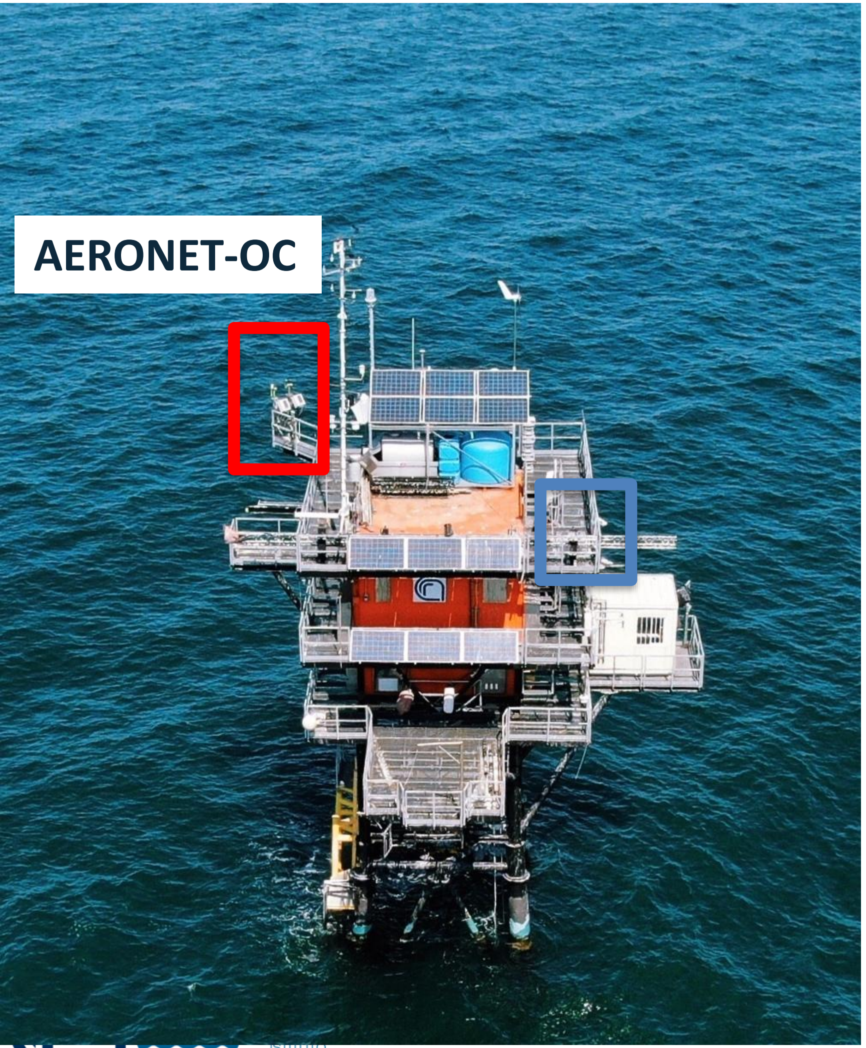
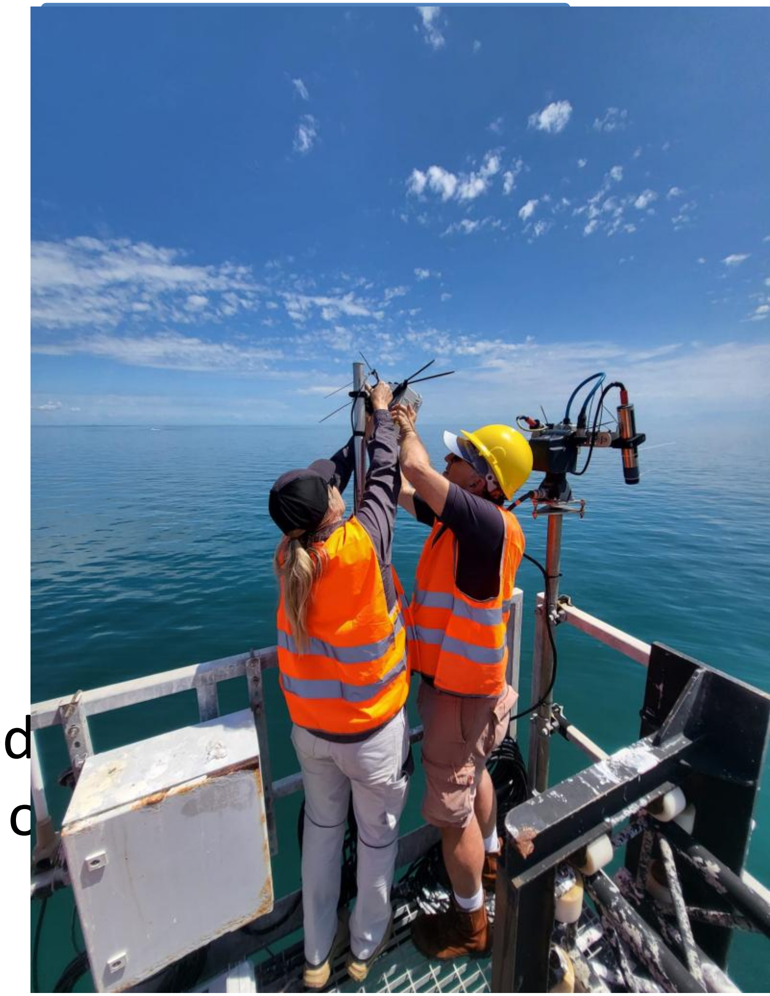
CSIRO

Aqua Alta Oceanographic Tower





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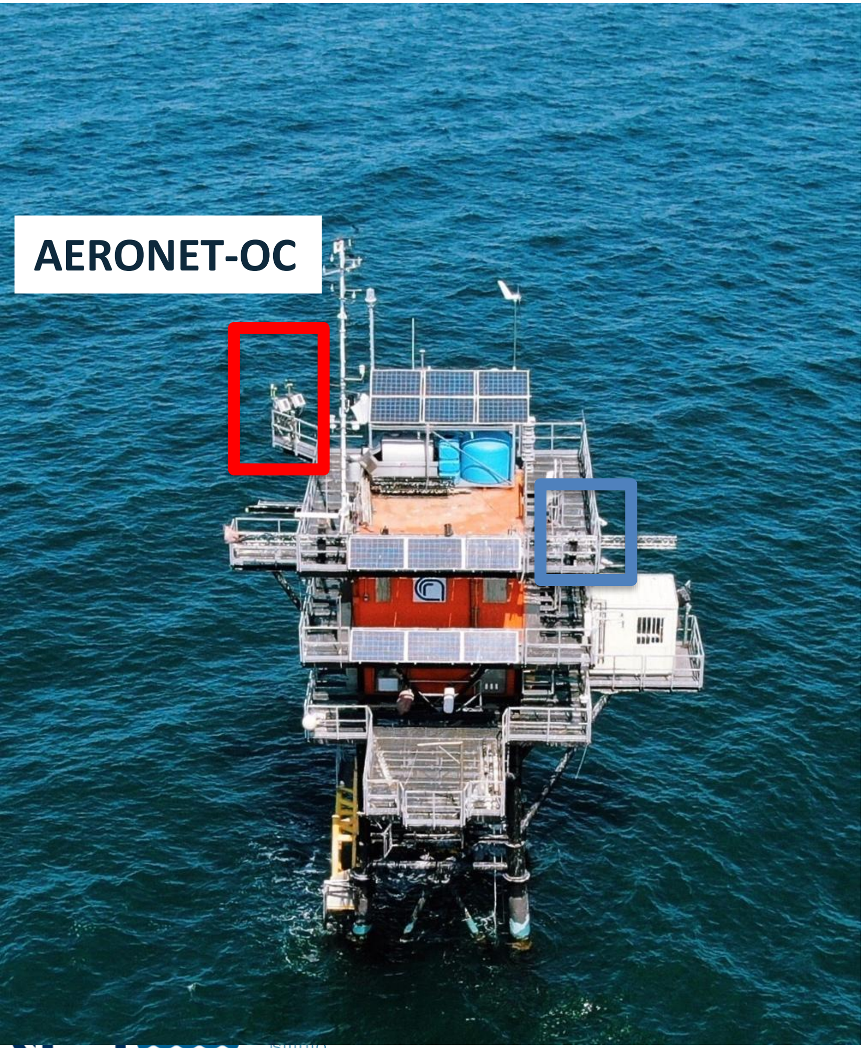
Aqua Alta Oceanographic Tower



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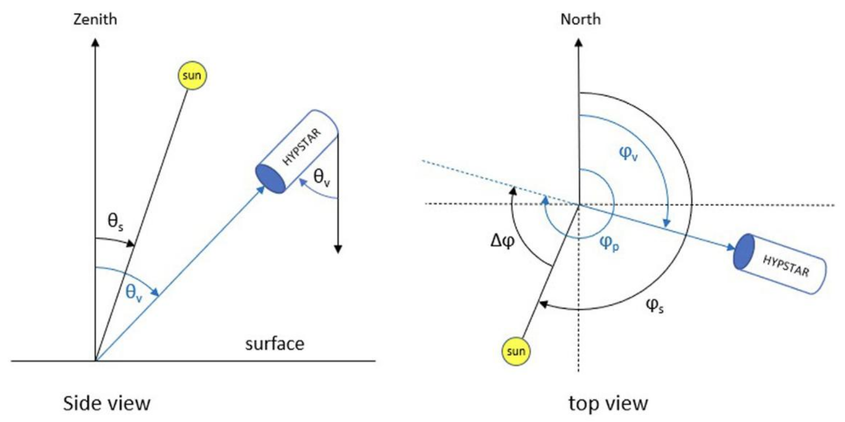

FIGURE 2
Left: Side-view diagram defining viewing zenith angles θ_v and solar zenith angles θ_s. Right: Top-view diagram defining the viewing azimuth angles φ_v, 'pointing-to' azimuth angle φ_p and solar azimuth angles φ_s, measured clockwise from North. The relative azimuth angle $\Delta\varphi$ is defined as the difference between φ_p and φ_s. All angles are defined in the reference frame centred on the measurement location on the surface.

Parameter	VNIR water
spectral resolution FWHM	3 nm
spectral sampling interval	0.5 nm
L2B wavelength range	380–1,020 nm
number of L2B channels	1,300
field of view radiance sensor	2°
field of view irradiance sensor	180°

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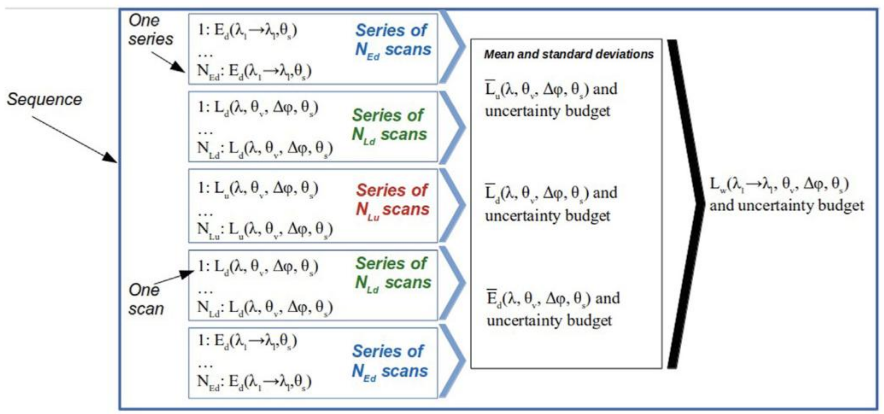

FIGURE 3
Diagram illustrating the measurement protocol for the WATERHYPERNET network with a sequence being a series of scans of upwelling radiance L_u preceded and followed by a series of scans of downwelling irradiance, E_d, and a series of scans of downwelling radiance L_d. In the figure N_x, λ, θ_v, θ_s, and, $\Delta\phi$ stand for number of scans, wavelength, viewing zenith angle, solar zenith angle and relative azimuth angle, respectively.

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Quality checks

TABLE 4 HYPERNETS_PROCESSOR flags applied during L1C processing.

Name	Network	Level (C)	Description	Flag triggered	Anomaly raised	Processing halted
check_valid_irradiance	L, W	L1	Halt processing if 'variable_irradiance' flag was triggered at previous level		'nu'	✓
check_valid_sequence	L, W	L1	Halt processing if there are no valid series (flagged by 'not_enough_dark_scans', 'not_enough_irr_scans', 'not_enough_rad_scans' or 'vza_irradiance')		'in'	✓
single_irradiance_used	L, W	L1	If only one series of irradiance is used for the computation of the reflectance	✓		
no_clear_sky_sequence	L, W	L1	If all irradiance series are flagged with the 'no_clear_sky_irradiance' flag	✓	'cl'	
variable_radiance	W	L1	More than 10% difference between start and end L_d at 550 nm		'nd'	✓
single_skyradiance_used	W	L1	If only one series of downwelling radiance is used for the computation of the reflectance	✓		
lu_eq_missing	W	L1	If there is no upwelling and downwelling radiance pair with similar pointing azimuth angles (within 1° tolerance)	✓	'l'	✓
rhof_angle_missing	W	L1	If there are no downwelling radiance scans at the appropriate viewing zenith angle (i.e., 180°-θ_v) (within 1° tolerance)	✓	'l'	✓
rhof_default	W	L1	If the viewing geometry of the upwelling and downwelling radiance measurements are outside the viewing geometry range of the selected LUT for the 'rhof_option' (e.g., $\Delta\phi > 180°$ when using the LUT from Mobley (1999)), a default ρ_F is used for the air-water interface correction factor (default: $\rho_F = 0.0256$)	✓		
temp_variability_irr	W	L1	If the difference in $E_d(\lambda)$ scans exceeds a given threshold between two neighbouring scans (default: threshold = 25% and λ = 550, see also Ruddick et al. (2006))	✓		
temp_variability_rad	W	L1	If the difference in $L_d(\lambda)$ or $L_u(\lambda)$ scans exceeds a given threshold between two neighbouring scans (default: threshold = 25% and λ = 550, see also Ruddick et al. (2006))	✓		
min_nbred/lu/lsky	W	L1	If the total number of scans not flagged by either 'L0_threshold', 'bad_pointing' or 'outliers', is less than a given threshold (default: 3)	✓	'ned' 'nlu' 'nld'	✓
def_wind_flag	W	L1	If a default wind speed is used (by default: wind speed = 2 m^{-1})	✓		
simil_fail	W	L1	If the quality check applied on the NIR similarity spectrum is not verified as suggested by Ruddick et al. (2005) (see Section 3.2 and Figure 4 in Ruddick et al. (2005)) with default values for the computation of the NIR Similarity being 780 and 870 nm, the reference wavelength 670 nm and the threshold 5%	✓		

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spectral sampling interval	0.5 nm
L2B wavelength range	380–1,020 nm
number of L2B channels	1,300
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Quality checks

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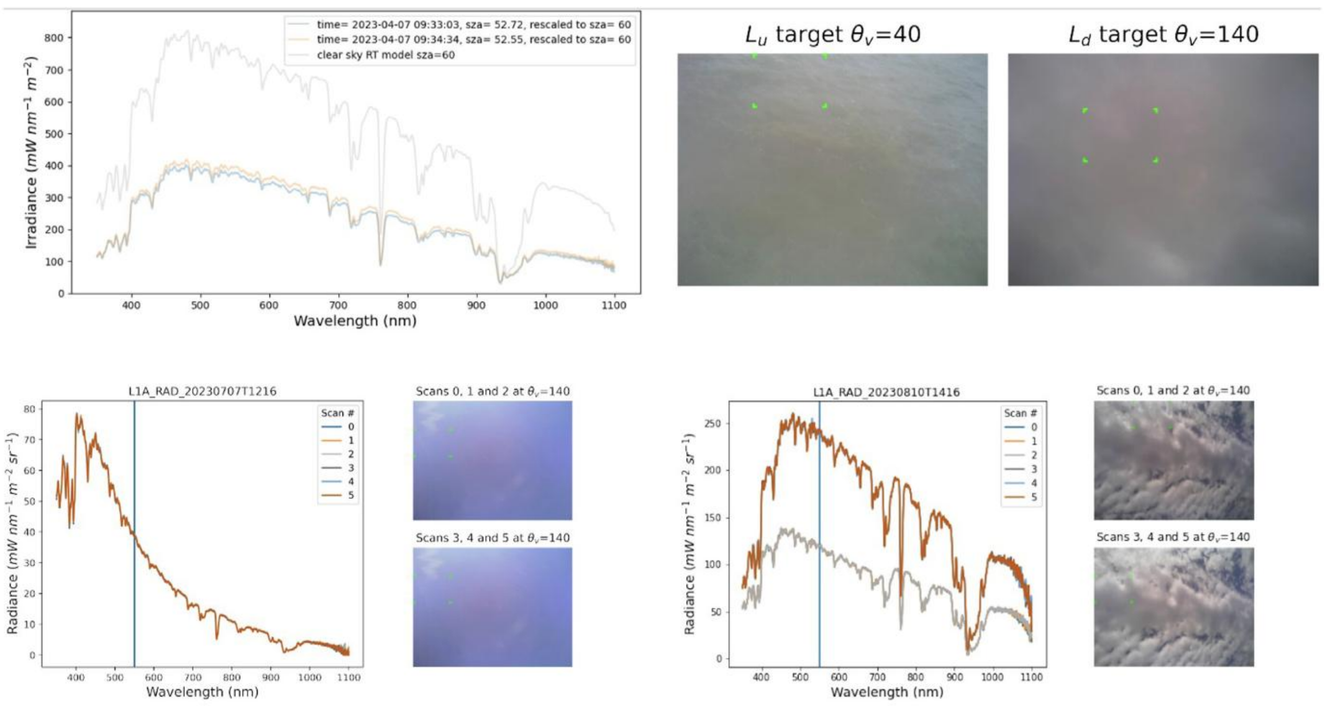
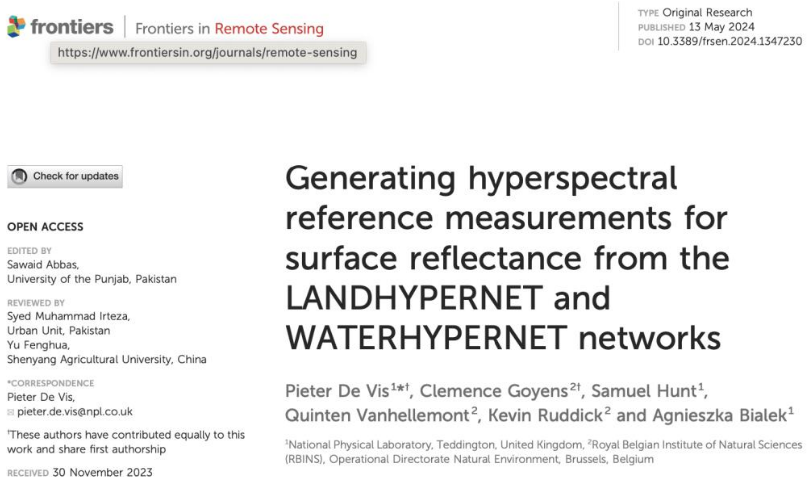


FIGURE 11
Example of the quality checks on the illumination applied in the L1B and L1C data processing for the downwelling irradiance and radiance, respectively. The top row shows the irradiance measurements not passing the 'no_clear_sky_irradiance' check taken at Zeebrugge MOW-1 Belgium (M1BE) site on the 2023–04–07 at 09:32 together with the simulated clear sky (for the same illumination geometries). Images of the sky (θ_v = 140°) and the water (θ_v = 40°) for this sequence are also shown. Bottom row shows (1) an example of downwelling radiance scans passing the quality criteria for constant downwelling radiance taken at WRUK on 2023–07–07 and the images taken with the camera during the measurements (bottom left panels), and, (2) an example of downwelling radiance scans not passing this quality check (variable_radiance flag is raised), and, the images taken with the camera during the measurements taken on 2023–08–10 at WRUK (bottom right panels).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Quality checks at AAOT

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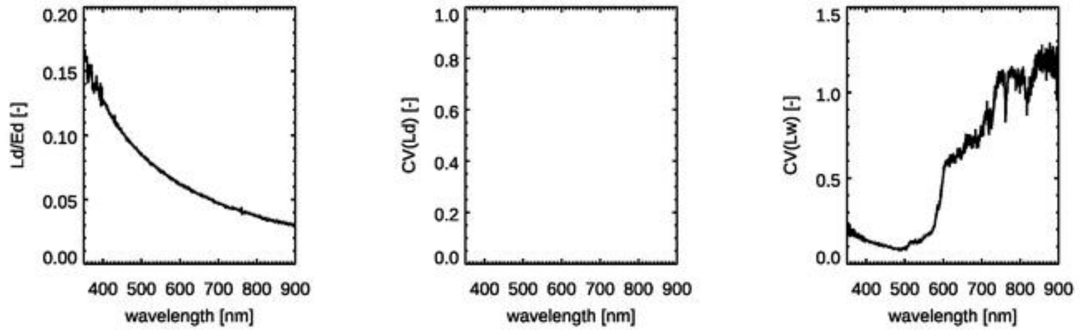
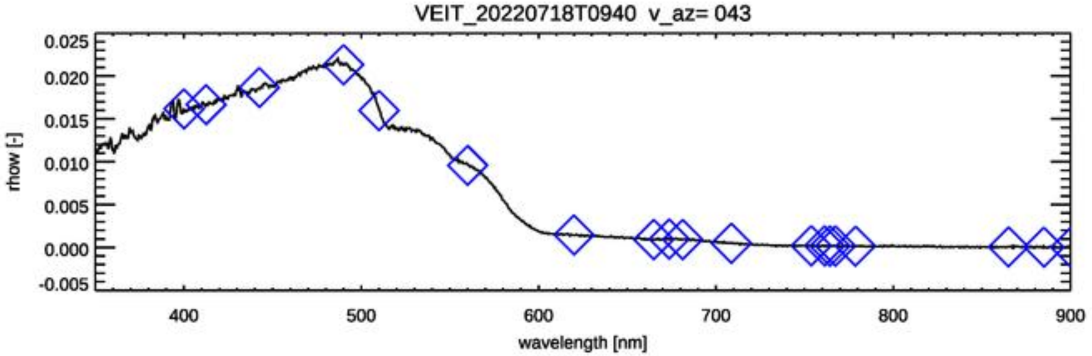
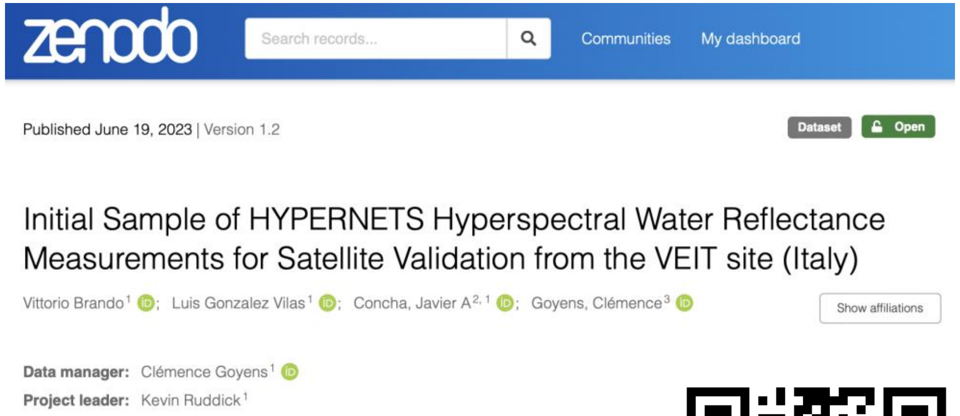


Rhow max 0.025





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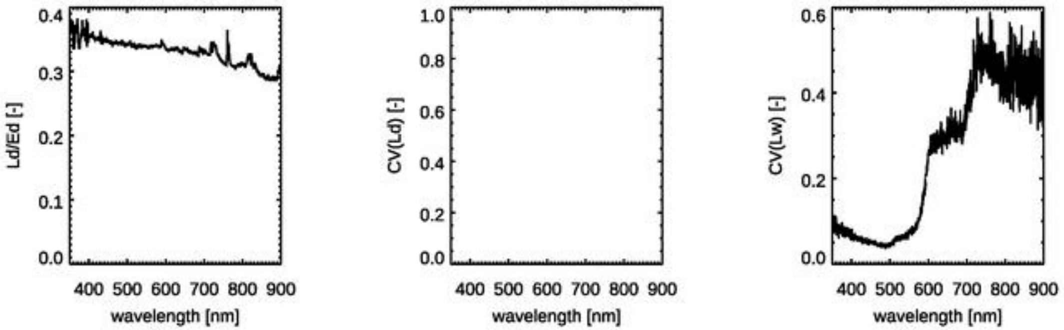
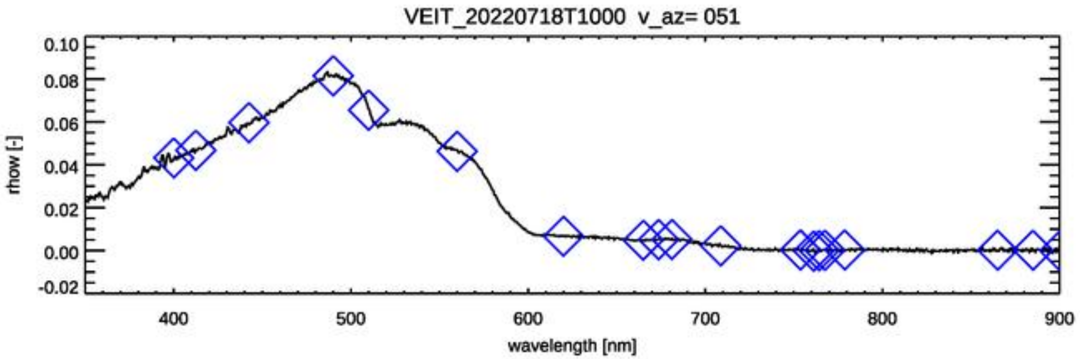


Rhow max 0.010



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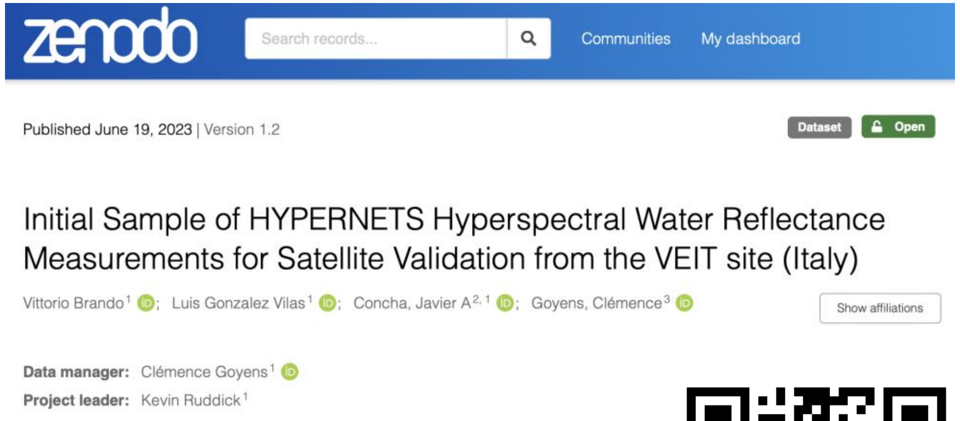

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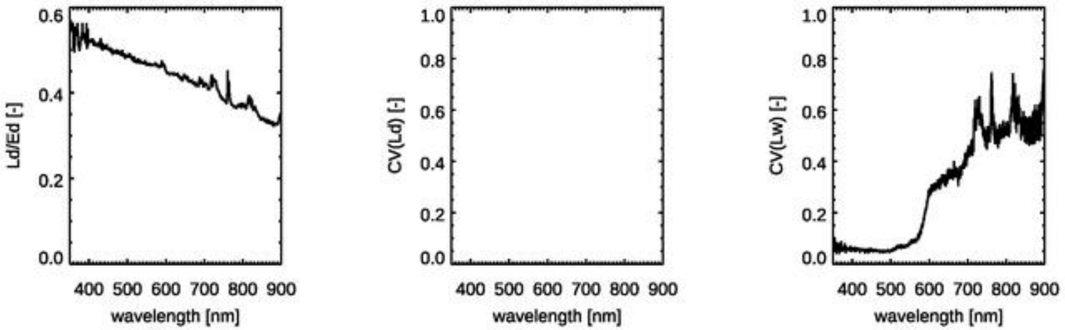
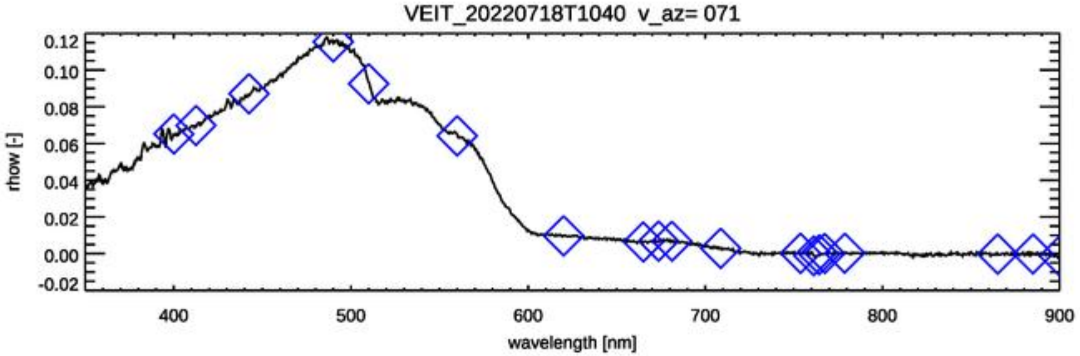
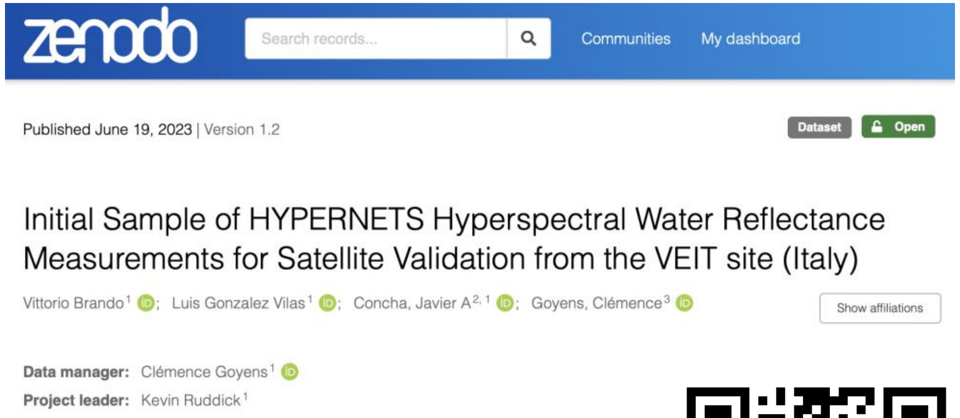
Parameter	VNIR water
spectral resolution FWHM	3 nm
spectral sampling interval	0.5 nm
L2B wavelength range	380–1,020 nm
number of L2B channels	1,300
field of view radiance sensor	2°
field of view irradiance sensor	180°



Rhow max 0.012





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Aqua Alta Oceanographic Tower

Sentinel 3 A&B OLCI vs **PANTHYR®**

27 September 2019 to 23 September 2020

S3A match-ups: 79

S3B match-ups: 76

OLCI IPF V7.0

Normalized water-leaving radiance from OLCI FR L2 data:

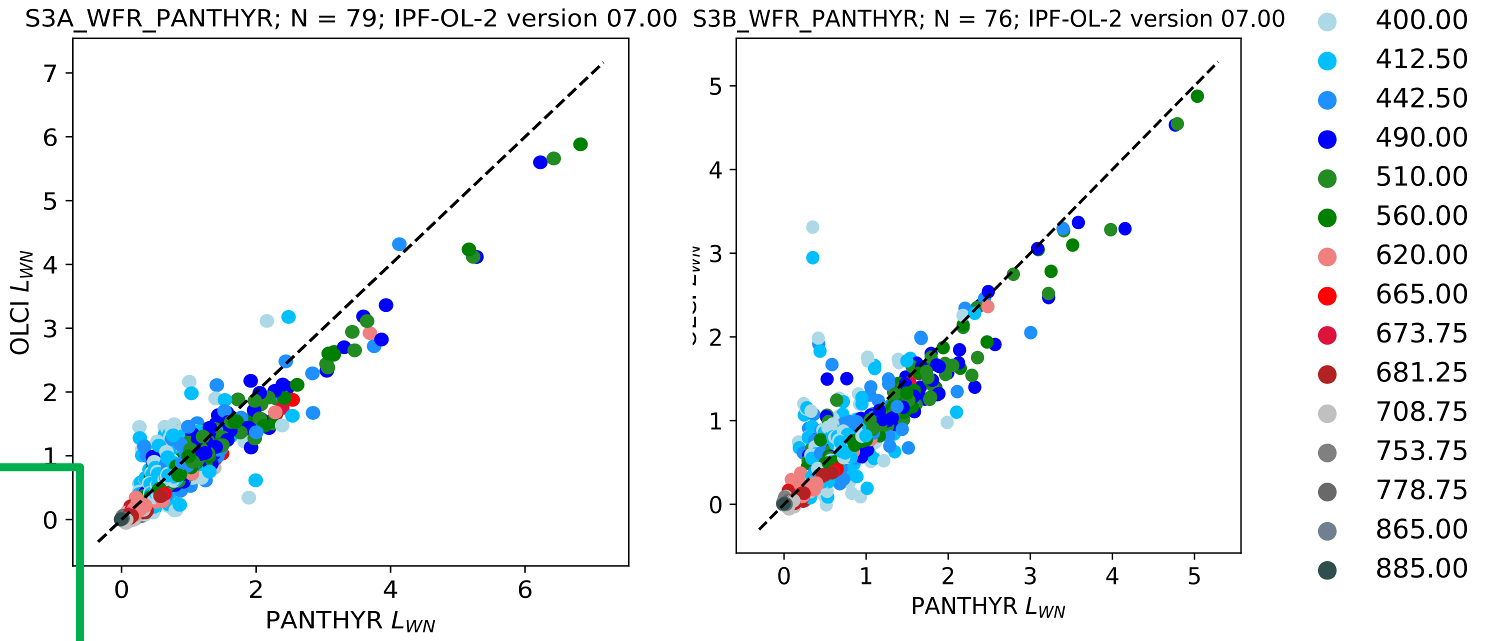
$$L_{WN}^{OLCI}(\lambda) = \rho^{OLCI}(\lambda)\frac{F0(\lambda)}{\pi}C_{f/Q}(\lambda)$$

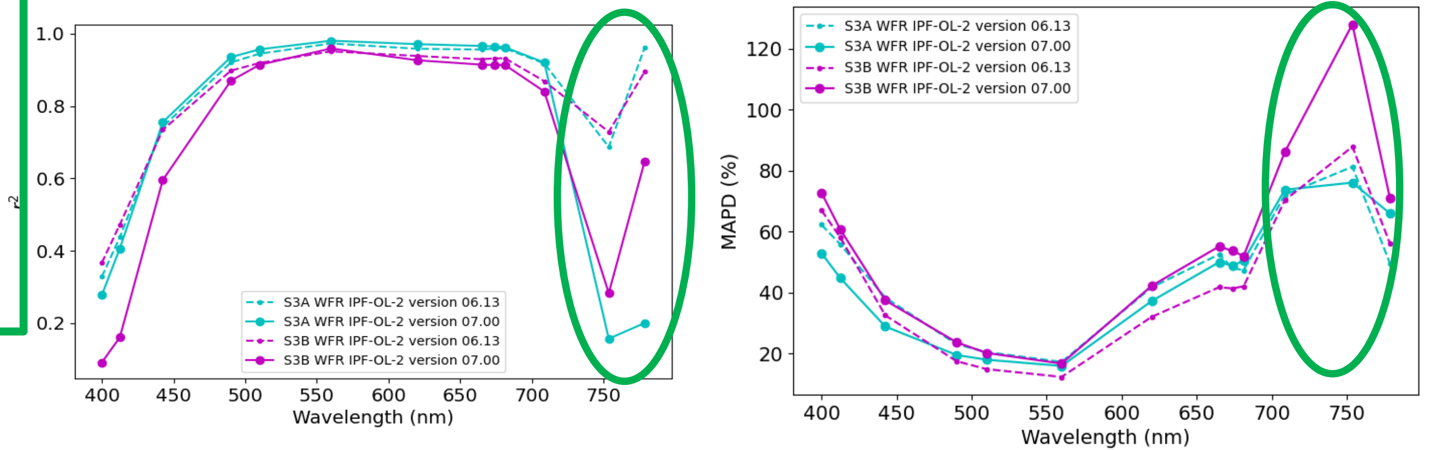
ρ^{OLCI}: OLCI FR L2 reflectance

$F0$: mean extraterrestrial solar irradiance

$C_{f/Q}$: BRDF correction factor (Morel, Antoine, and Gentili 2002).

PANTHYR hyperspectral data used to identify a degradation of 753 and 778nm with IPF V7.0 processor that was addressed by EUMETSAT in V3.0.1





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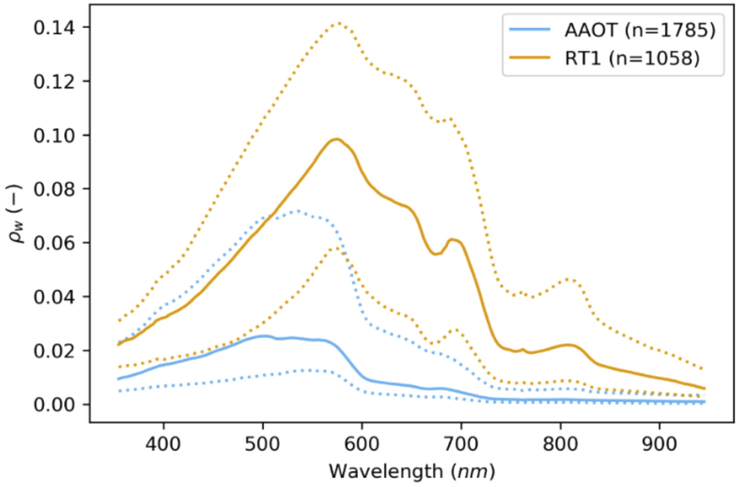
Sentinel 2 A&B MSI

vs **PANTHYR®**

26 September to 28 December 2019

Hyperspectral data resampled to match broad S2/MSI spectral bands



Research Article Vol. 28, No. 20 / 28 September 2020 / Optics Express 29955
Optics EXPRESS

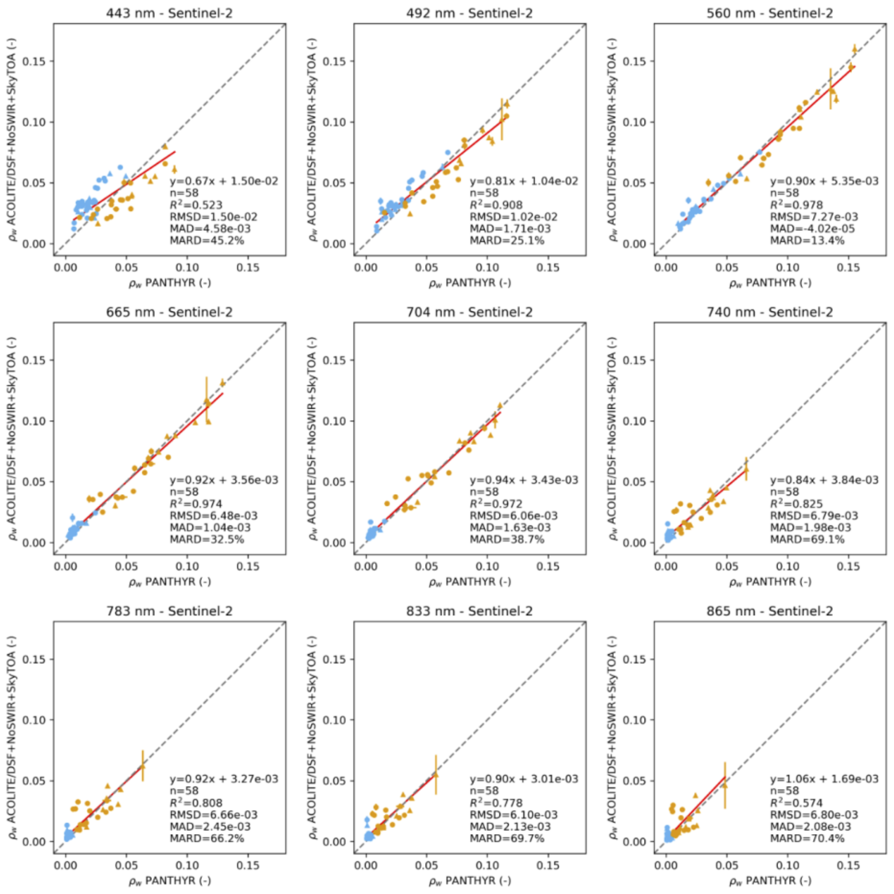


Fig. 5. Scatterplots for the matchups between PANTHYR and the nine visible and near-infrared bands Sentinel-2 A/B for DSF+NoSWIR+SkyTOA. Orange and blue dots are measurements from RT1 and AAOT respectively. Circles represent matchups with bounding and interpolated in situ data, triangles show matchups with only the closest in situ measurement.

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Research Article Vol. 28, No. 20 / 28 September 2020 / Optics Express 29948
Optics EXPRESS

Sensitivity analysis of the dark spectrum fitting atmospheric correction for metre- and decametre-scale satellite imagery using autonomous hyperspectral radiometry

QUINTEN VANHELLEMONT*

Royal Belgian Institute of Natural Sciences, Operational Directorate Natural Environments, Vautierstraat 29, 1000 Brussels, Belgium
*quinten.vanhellemont@naturalsciences.be

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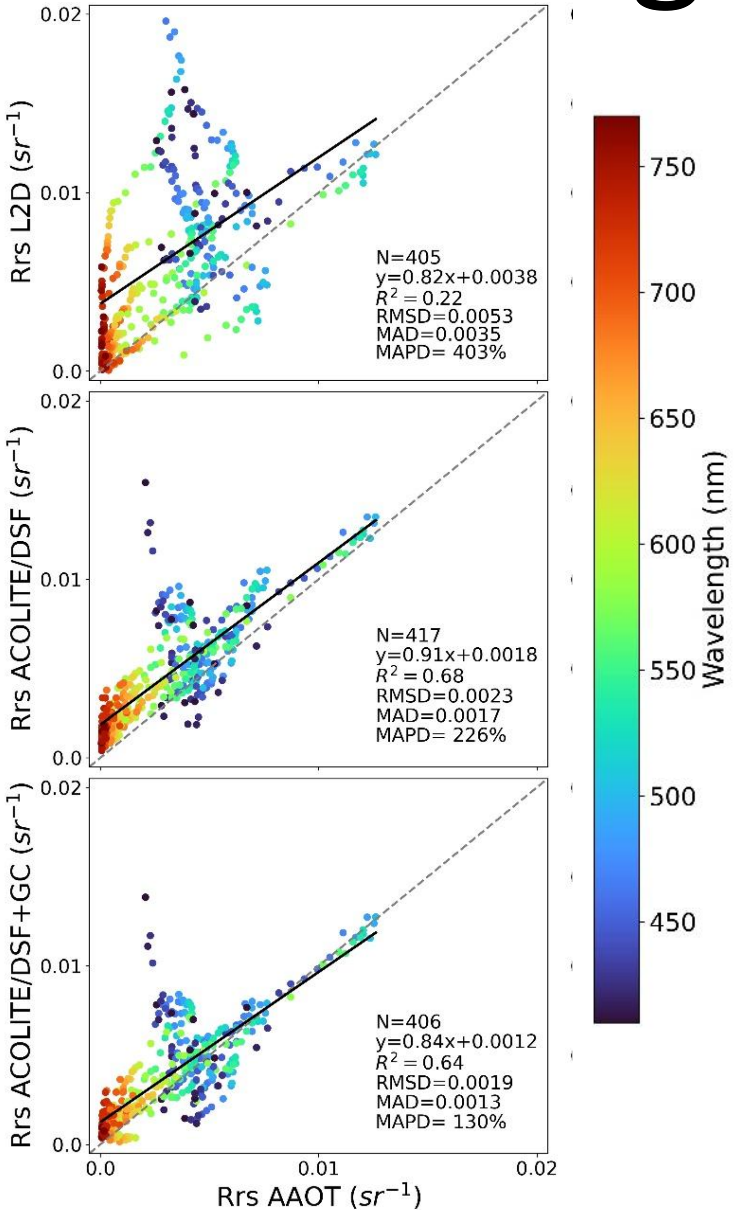
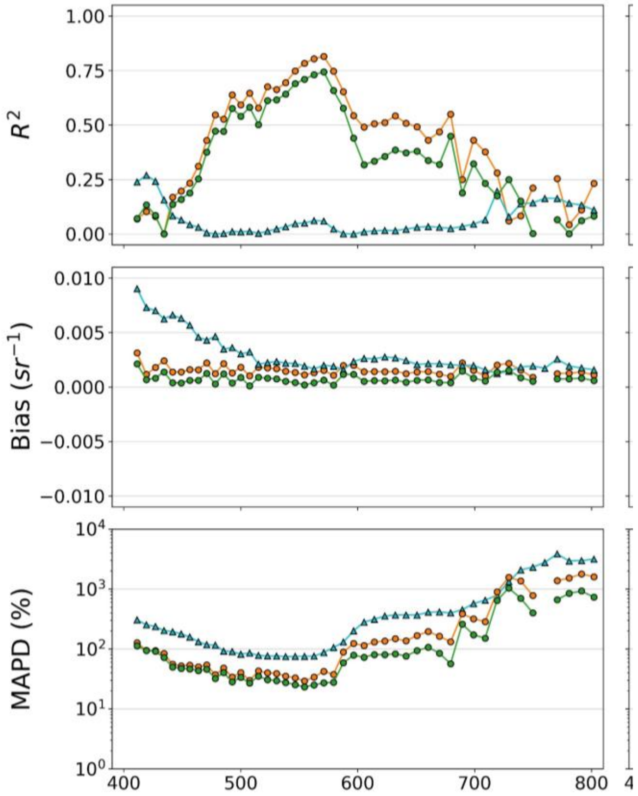
ASI/PRISMA vs **PANTHYR®**

11 match-ups in 2019-2021

Qualitative comparison of Rrs at their original spectral resolutions.

PRISMA - Level 2 standard atmospheric correction processor and ACOLITE atmospheric correction tool






ISPRS Journal of Photogrammetry and Remote Sensing 192 (2022) 99–114

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journal homepage: www.elsevier.com/locate/isprsjprs

Assessment of PRISMA water reflectance using autonomous hyperspectral radiometry

Federica Braga [a,*], Alice Fabbretto [b,c], Quinten Vanhellemont [d], Mariano Bresciani [b], Claudia Giardino [b], Gian Marco Scarpa [a], Giorgia Manfè [a], Javier Alonso Concha [e,f], Vittorio Ernesto Brando [g]

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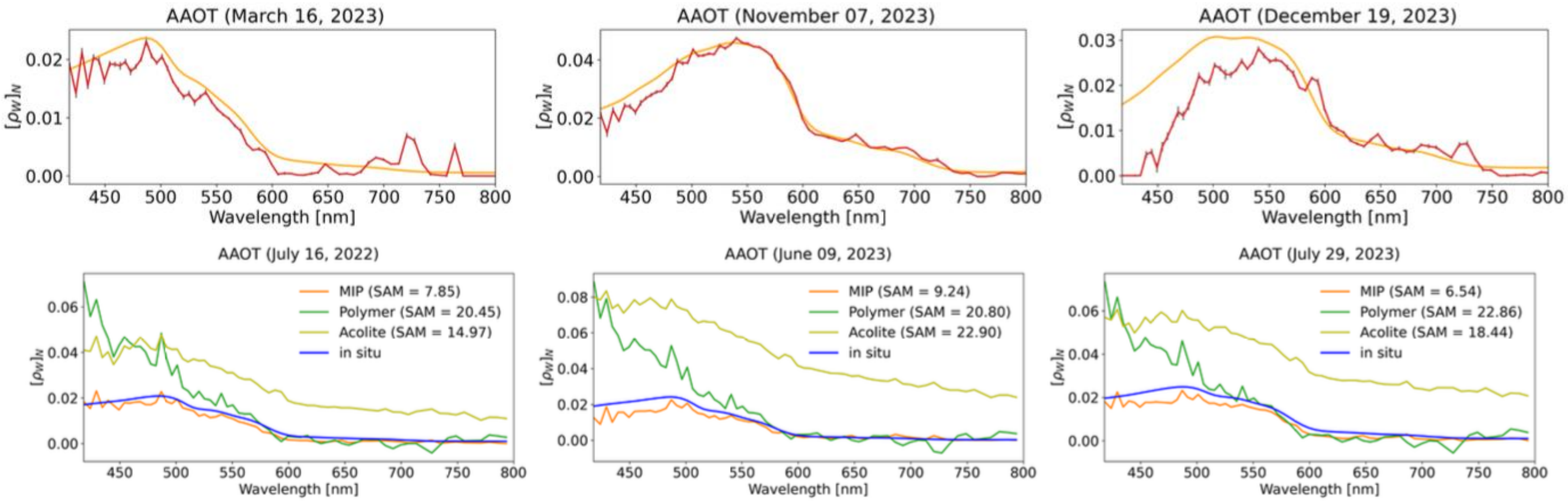
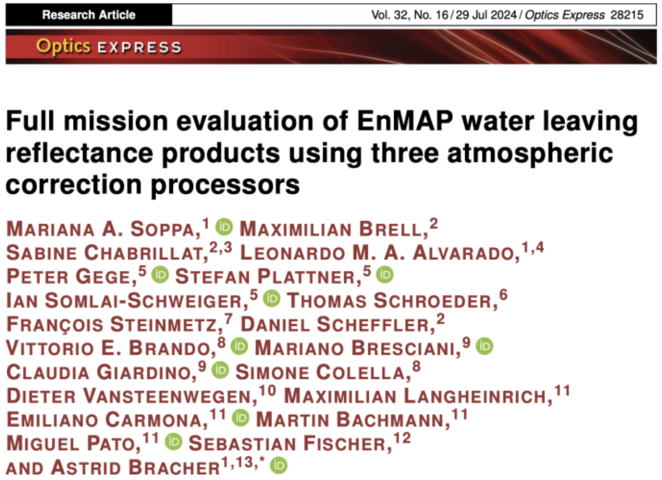
DLR/EnMAP vs **PANTHYR®**

Qualitative comparison of Rrs at their original spectral resolutions.

EnMAP - Level 2 standard and alternative atmospheric correction processors

Single examples and contribution to overall assessment over water targets





Research Article Vol. 32, No. 16 / 29 Jul 2024 / *Optics Express* 28215

Optics EXPRESS

Full mission evaluation of EnMAP water leaving reflectance products using three atmospheric correction processors

MARIANA A. SOPPA,[1] MAXIMILIAN BRELL,[2] SABINE CHABRILLAT,[2,3] LEONARDO M. A. ALVARADO,[1,4] PETER GEGE,[5] STEFAN PLATTNER,[5] IAN SOMLAI-SCHWEIGER,[5] THOMAS SCHROEDER,[6] FRANÇOIS STEINMETZ,[7] DANIEL SCHEFFLER,[2] VITTORIO E. BRANDO,[8] MARIANO BRESCIANI,[9] CLAUDIA GIARDINO,[9] SIMONE COLELLA,[8] DIETER VANSTEENWEGEN,[10] MAXIMILIAN LANGHEINRICH,[11] EMILIANO CARMONA,[11] MARTIN BACHMANN,[11] MIGUEL PATO,[11] SEBASTIAN FISCHER,[12] AND ASTRID BRACHER[1,13,*]

EnMAP

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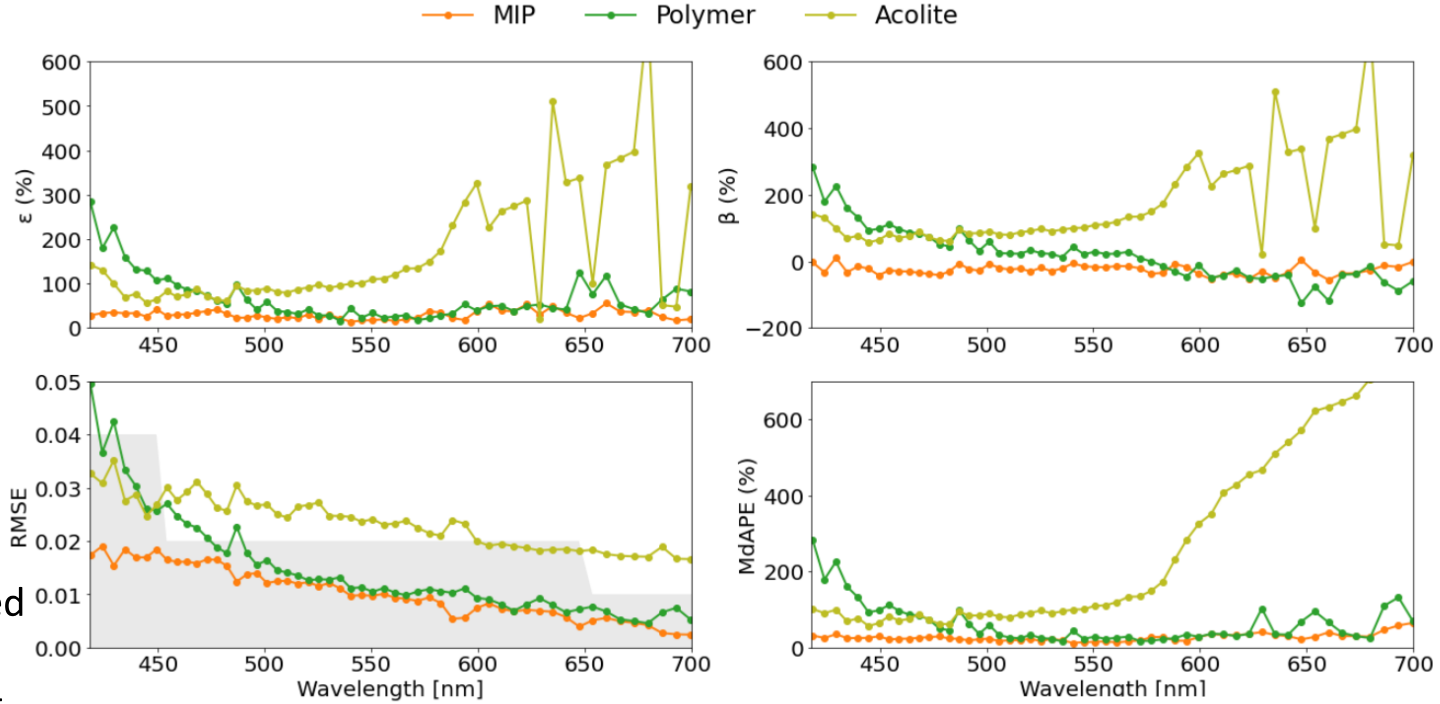
DLR/EnMAP vs **PANTHYR®**

Qualitative comparison of Rrs at their original spectral resolutions.

EnMAP - Level 2 standard and alternative atmospheric correction processors

Single examples and contribution to overall assessment over water targets



The grey shaded area represents the required uncertainty (RMSE) as defined by the EnMAP Ground Segment

The required uncertainty as defined by EnMAP ground segment was only achieved by MIP water reflectance product.
The uncertainty requirements by dedicated ocean colour missions in not-optically complex waters of 5% in the blue was not achieved by any of the AC processors.

Research Article Vol. 32, No. 16 / 29 Jul 2024 / Optics Express 28215
Optics EXPRESS

Full mission evaluation of EnMAP water leaving reflectance products using three atmospheric correction processors

Mariana A. Soppa,[1] Maximilian Brell,[2] Sabine Chabrillat,[2,3] Leonardo M. A. Alvarado,[1,4] Peter Gege,[5] Stefan Plattner,[5] Ian Somlai-Schweiger,[5] Thomas Schroeder,[6] François Steinmetz,[7] Daniel Scheffler,[2] Vittorio E. Brando,[8] Mariano Bresciani,[9] Claudia Giardino,[9] Simone Colella,[8] Dieter Vansteenwegen,[10] Maximilian Langheinrich,[11] Emiliano Carmona,[11] Martin Bachmann,[11] Miguel Pato,[11] Sebastian Fischer,[12] and Astrid Bracher[1,13,*]

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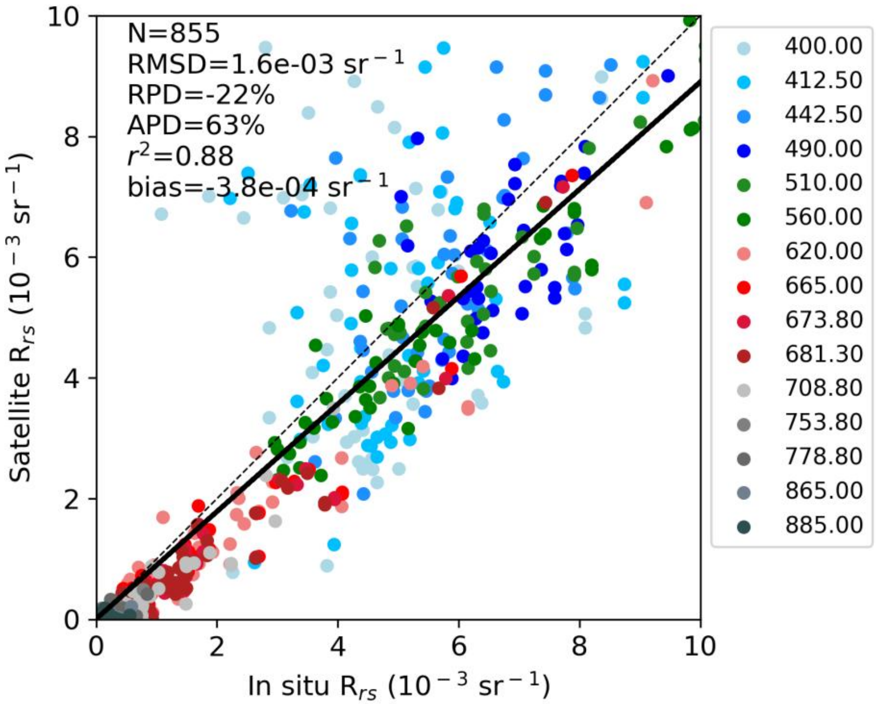
Sentinel 3 A&B OLCI

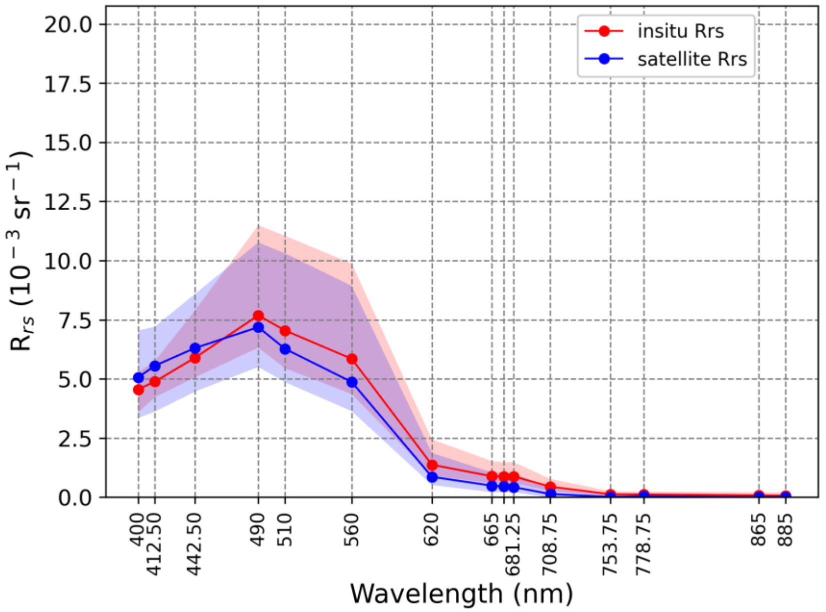
vs **HYPSTAR® V1 sensor**

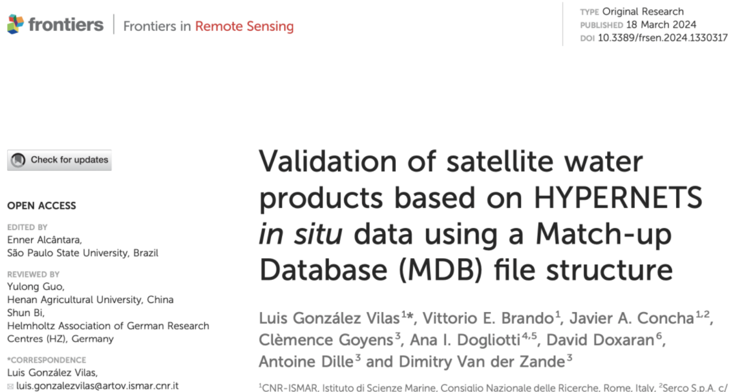
15 April 2021 to 31 December 2022

S3A match-ups: 100

S3B match-ups: 94



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PUBLISHED 18 March 2024
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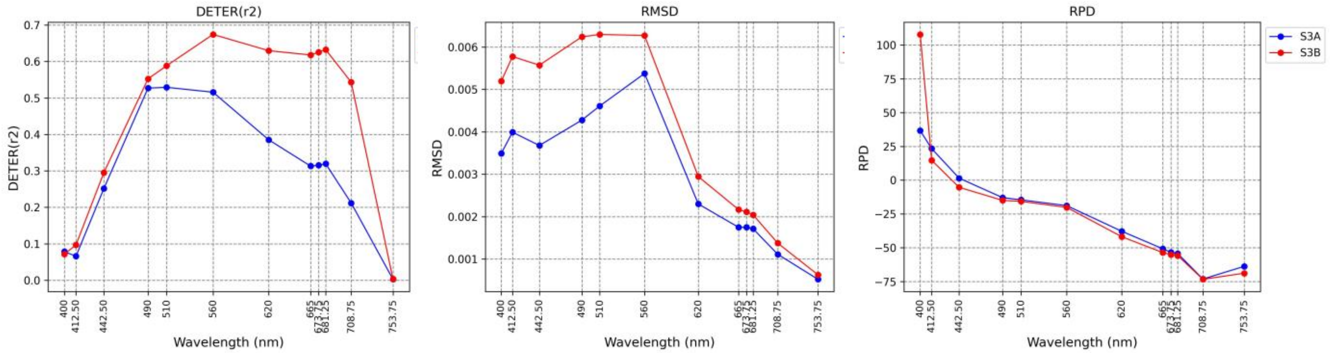
Luis González Vilas,
luis.gonzalezvilas@artov.ismar.cnr.it

Validation of satellite water products based on HYPERNETS *in situ* data using a Match-up Database (MDB) file structure

Luis González Vilas[1]*, Vittorio E. Brando[1], Javier A. Concha[1,2], Clémence Goyens[3], Ana I. Dogliotti[4,5], David Doxaran[6], Antoine Dille[3] and Dimitry Van der Zande[3]

[1]CNR-ISMAR, Istituto di Scienze Marine, Consiglio Nazionale delle Ricerche, Rome, Italy, [2]Serco S.p.A. c/



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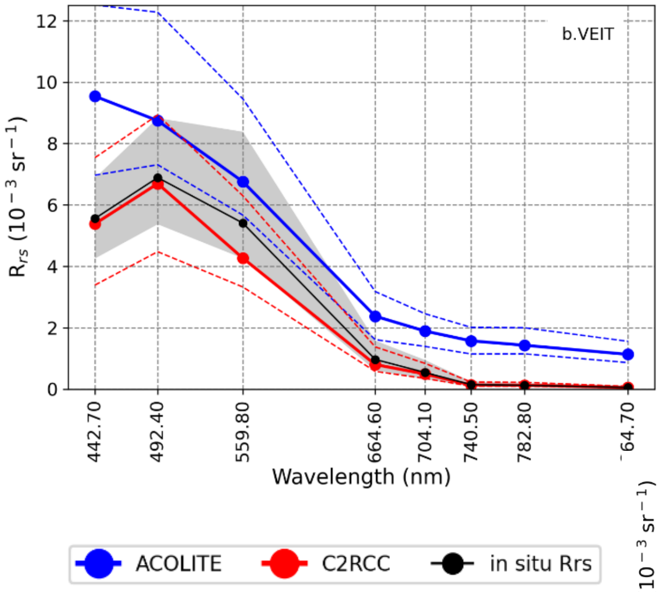
Sentinel 2 A&B MSI

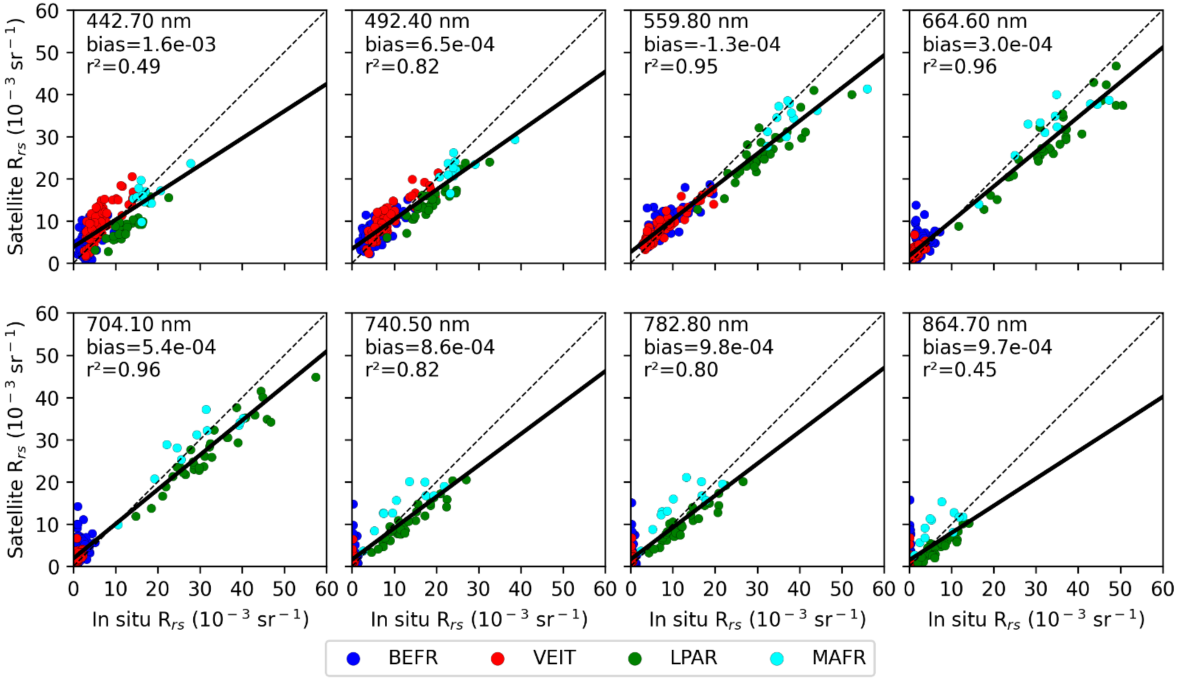
vs **HYPSTAR®** **V1 sensor**

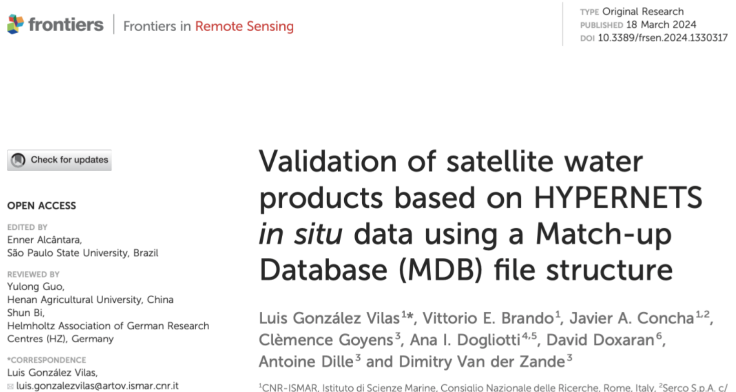
15 April 2021 to 28 February 2023

S2A + S2B match-ups: 77

Hyperspectral data resampled to match broad S2/MSI spectral bands







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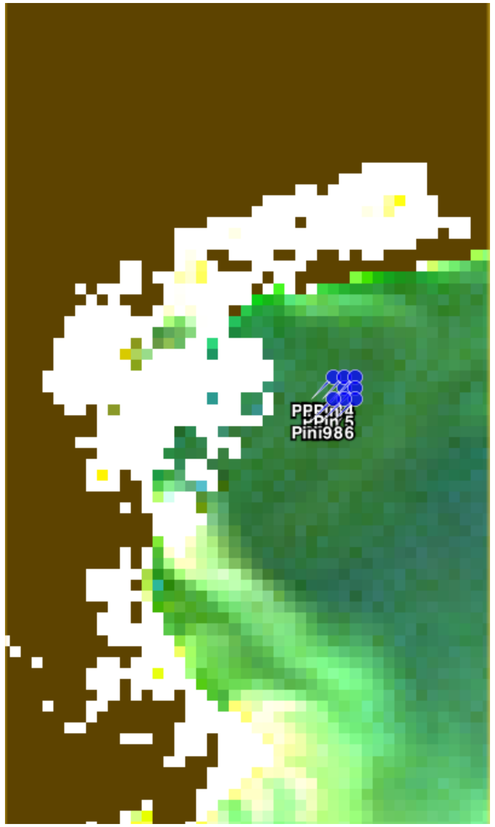
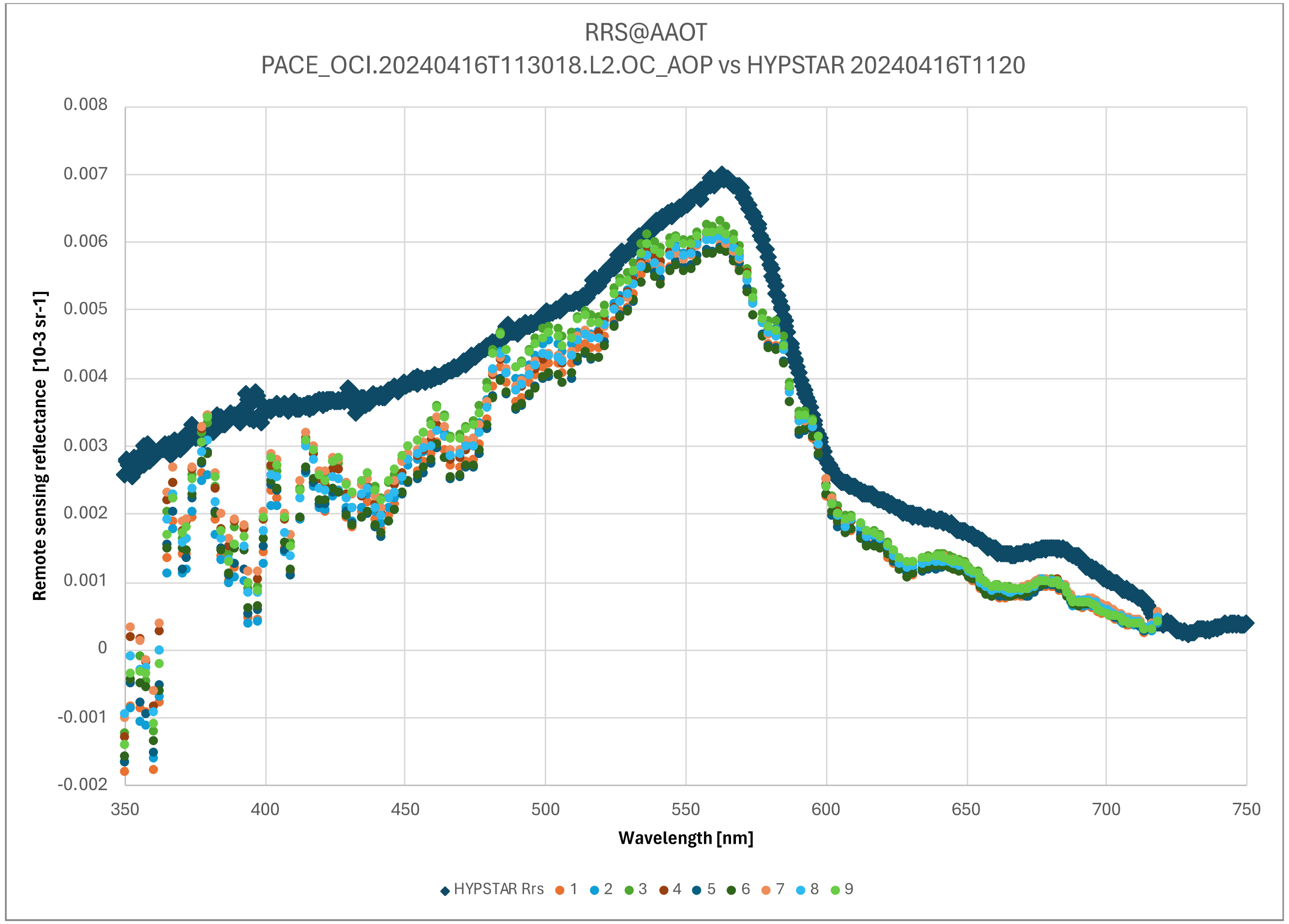
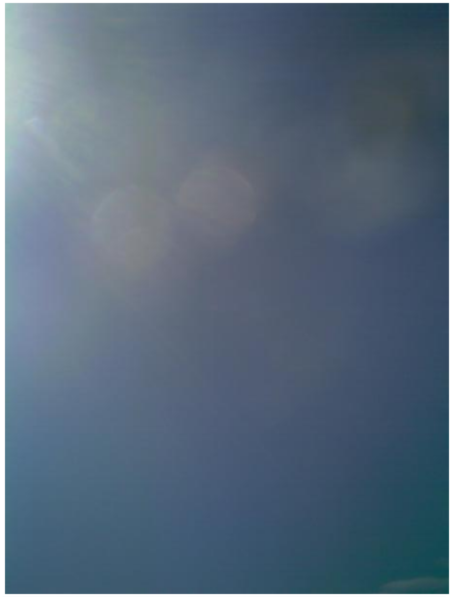
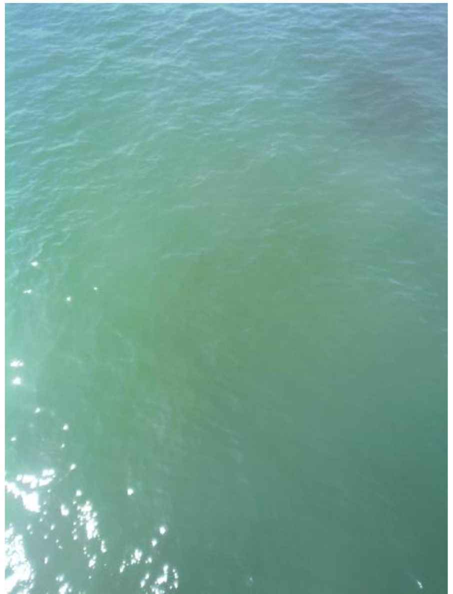
First match-up for PACE OCI 16 April 2024 (V1)









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HYPSTAR spectra acquired 10 minute before the PACE OCI image the similarity corrected reflectance was used for the comparison

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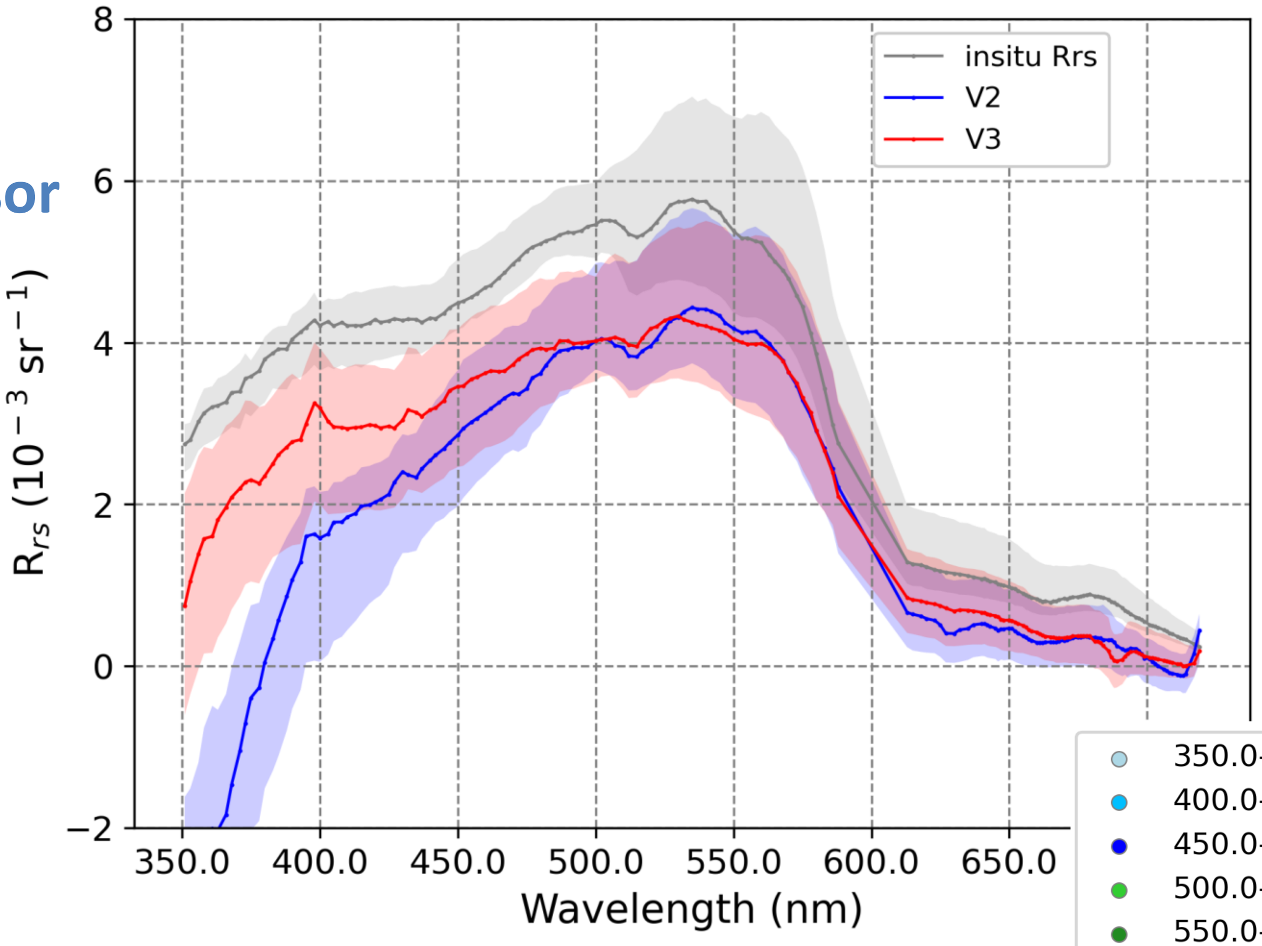
Validation of PACE OCI V2 and V3

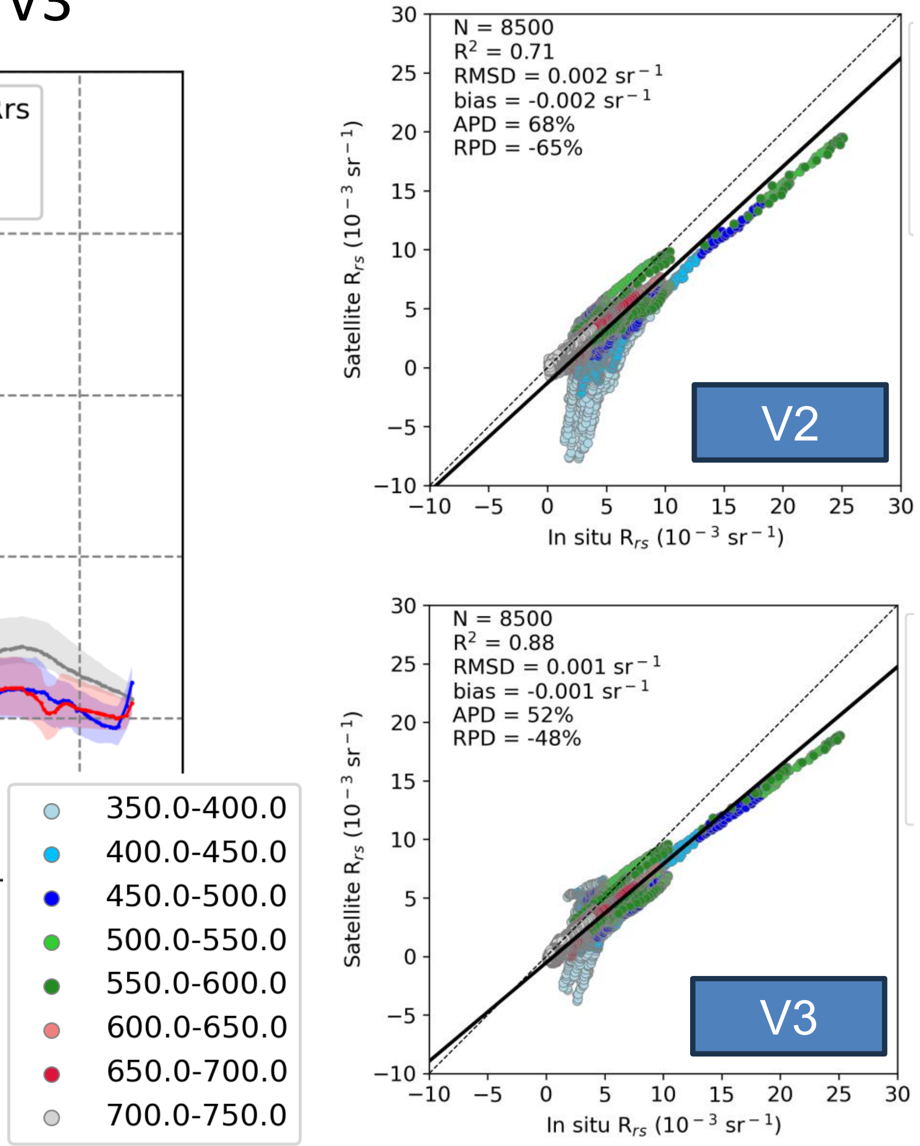
PACE/OCI (V2 & V3)

vs **HYPSTAR®** **V3 sensor**

2024-03-15 to 2024-04-01
2024-05-17 to 2024-10-20

Potential match-ups: **132**
V2 match-ups: **51**
V3 match-ups: **56**
common match-ups: **51**





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full presentation by Luis

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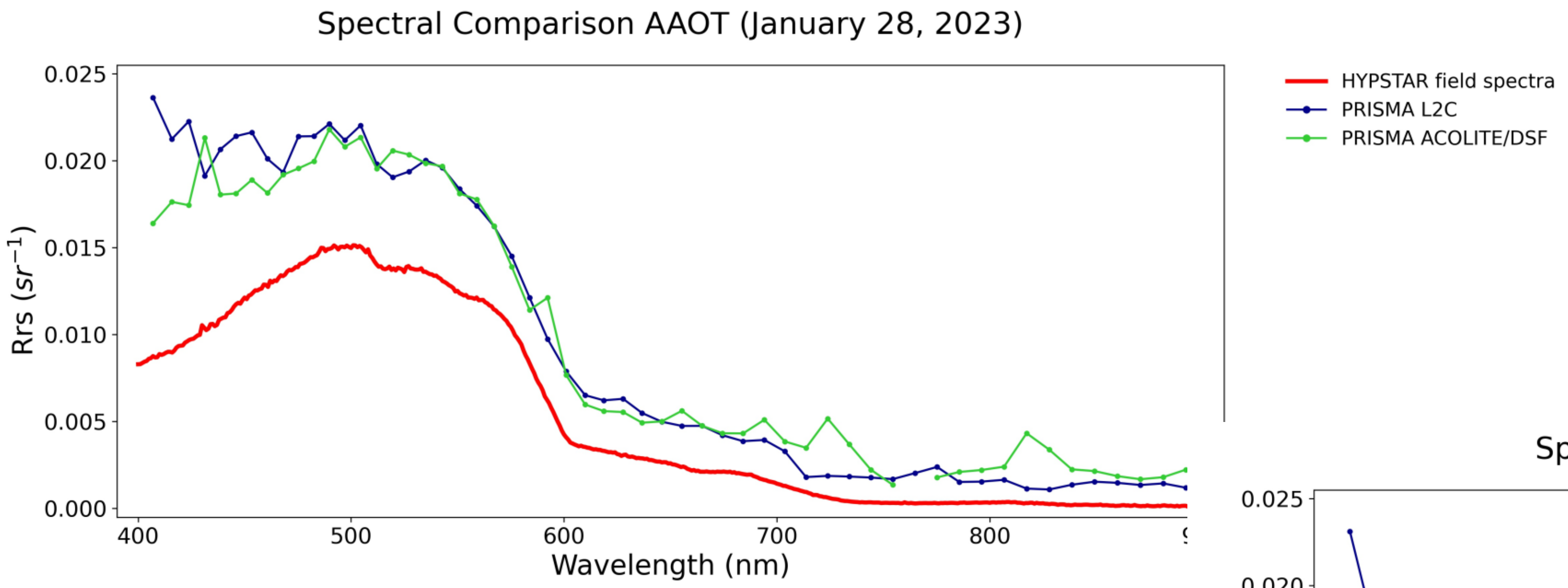
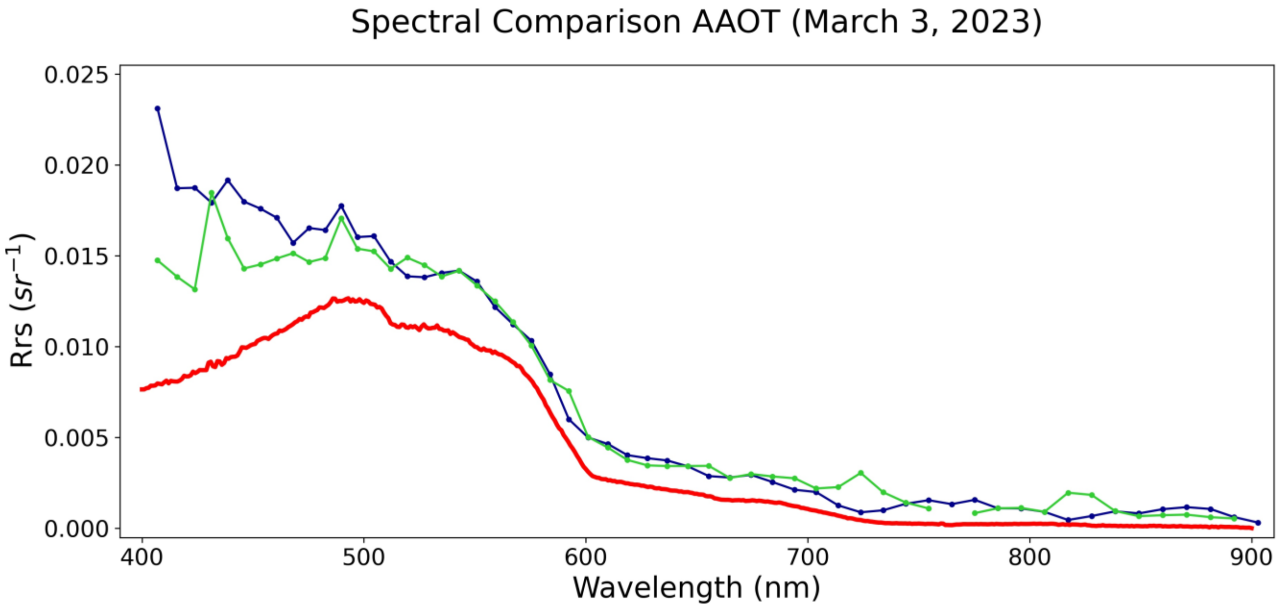
PRISMA vs **HYPSTAR® : 2** match-ups in 2023



New PRISMA LTOA calibration

Perfomance degraded



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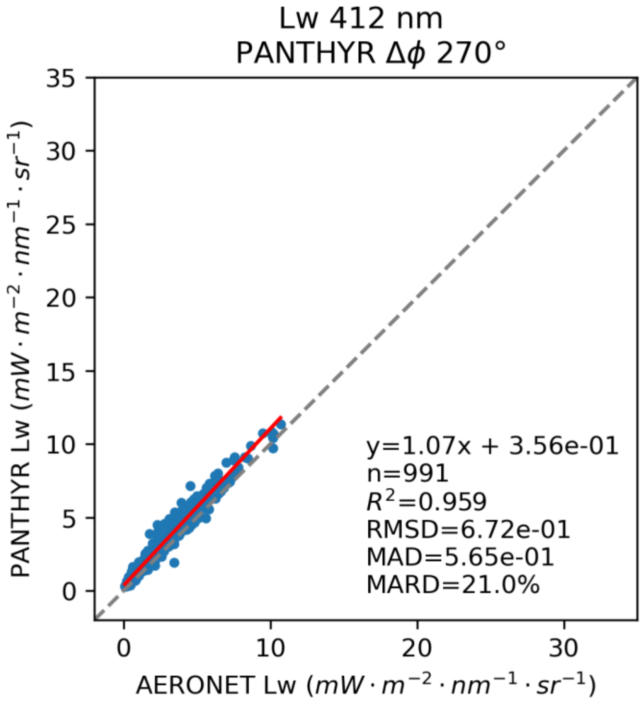
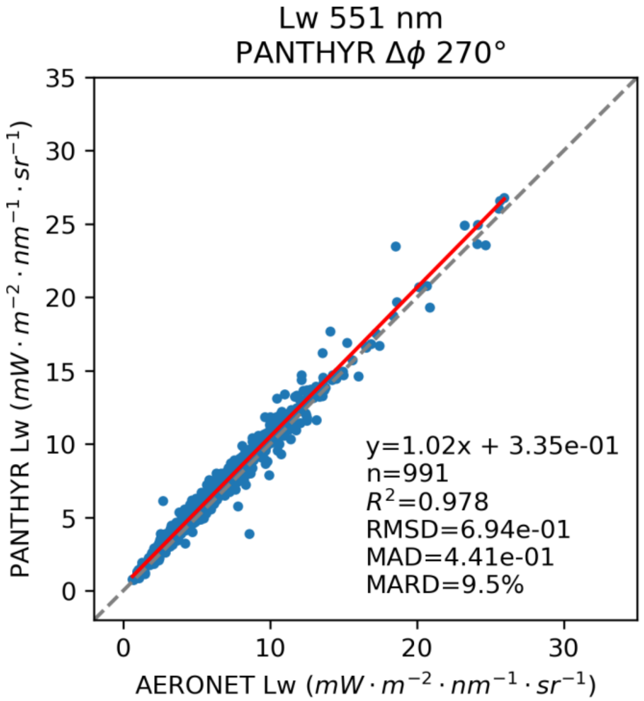
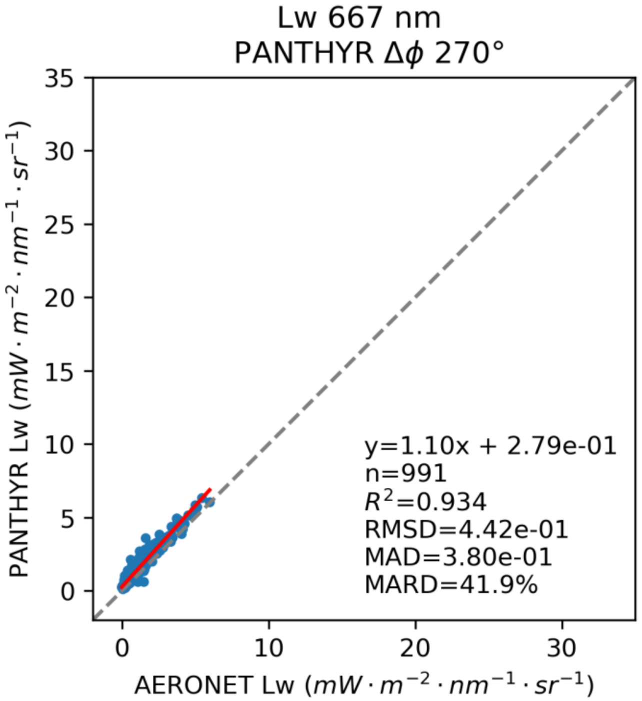
Comparison PANTHYR vs Aeronet-OC: radiometry from opposite corners



412 nm



551 nm



667 nm

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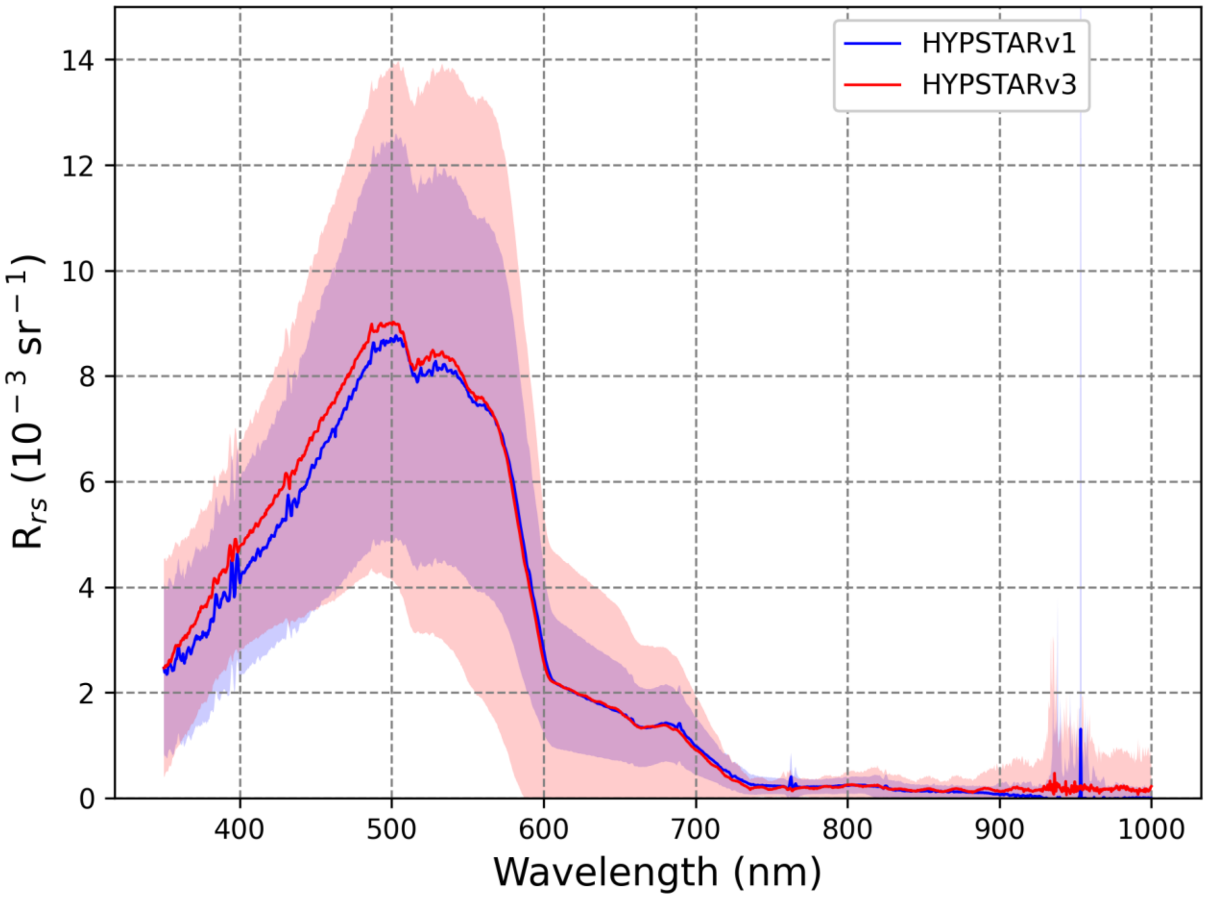
effect of HYPSTAR® relocation

V1 sensor : 15-04-2020 - 13-03-2023

V3 sensor in AERONET-OC corner: 17-03-2023 ->



Similar dynamic range for V1 and V3 even for measurements in different periods

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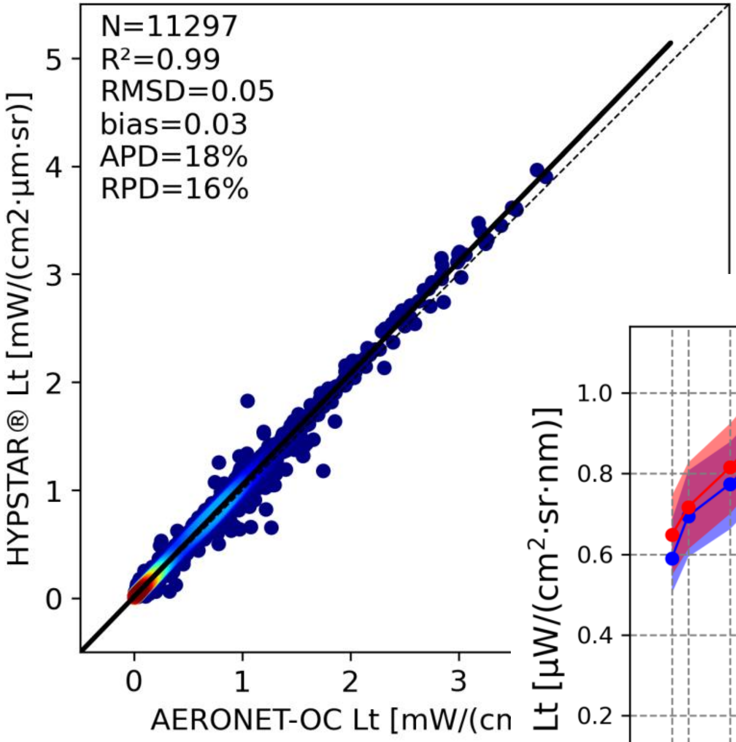
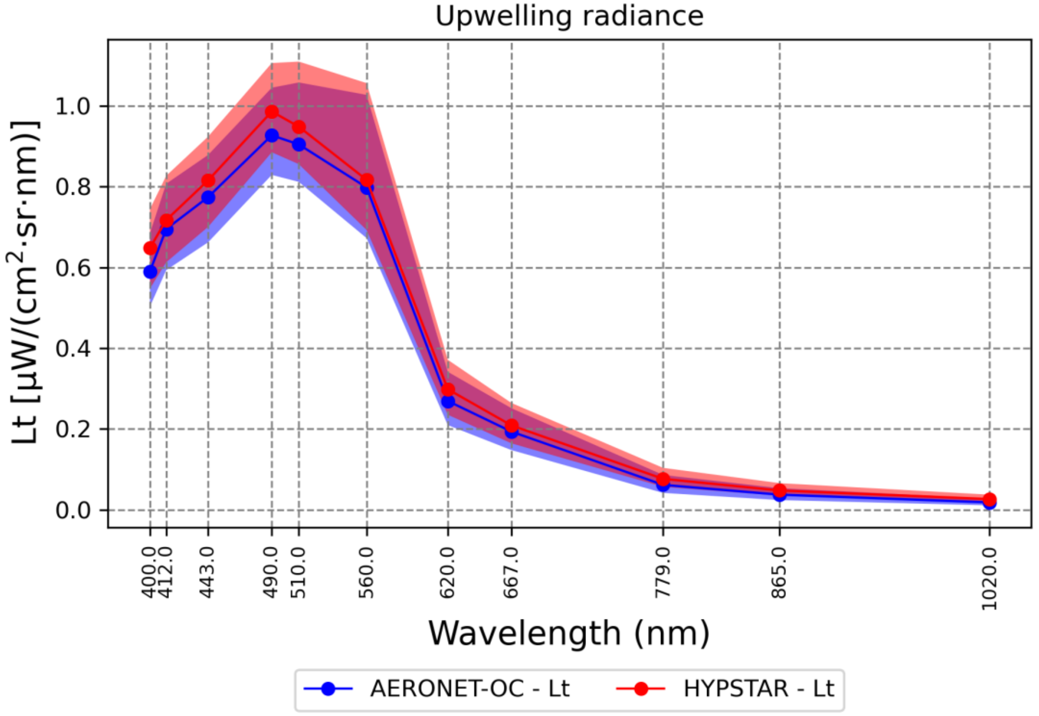
Comparison HYPSTAR ® vs Aeronet-OC: radiometry from the same location and with the same geometry Lt – Total radiance from the sea surface.

Analysis in progress to assess the impact of the differences in the sensor characteristics, and in the data acquisition and data reduction methods

V3 sensor in AERONET-OC corner: 17-03-2023 ->



AERONET-OC data based on Lt_mean



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2024-01-01 … 2024-09-30
1027 matches withinn 10 minutes across 121 days

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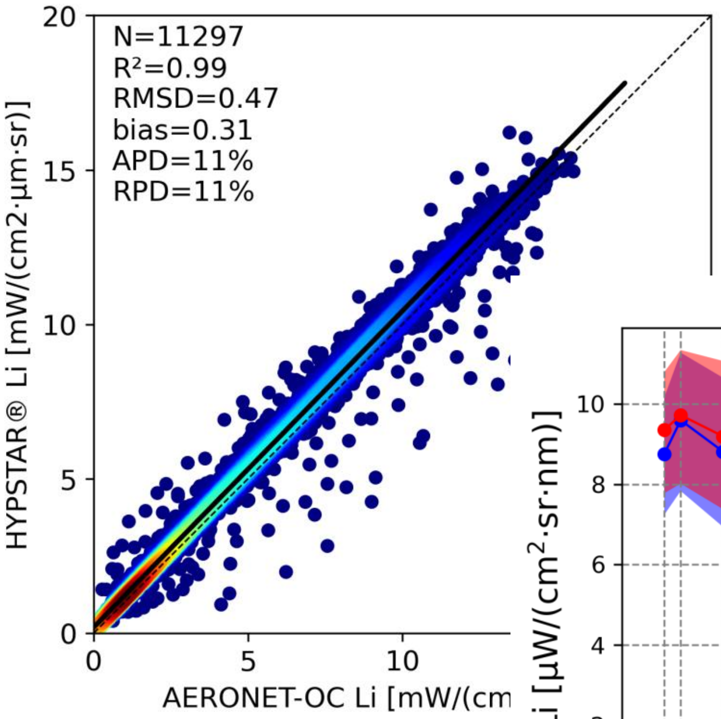
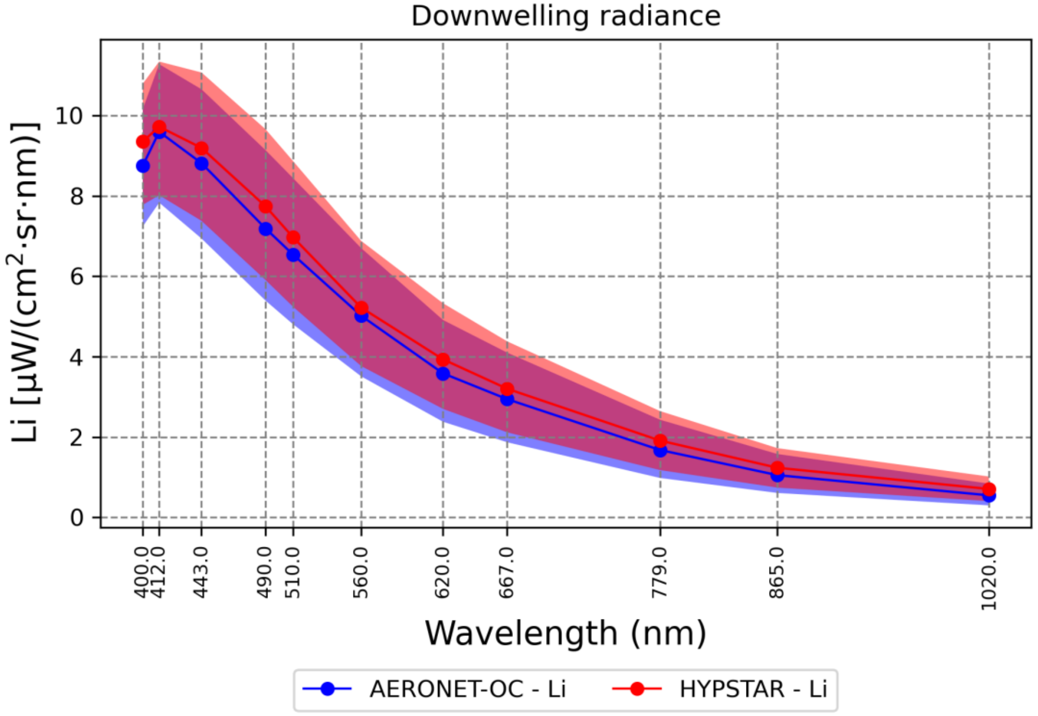
Comparison HYPSTAR ® vs Aeronet-OC: radiometry from the same location and with the same geometry Li – Sky radiance

Analysis in progress to assess the impact of the differences in the sensor characteristics, and in the data acquisition and data reduction methods

V3 sensor in AERONET-OC corner: 17-03-2023 ->





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2024-01-01 … 2024-09-30
1027 matches withinn 10 minutes across 121 days

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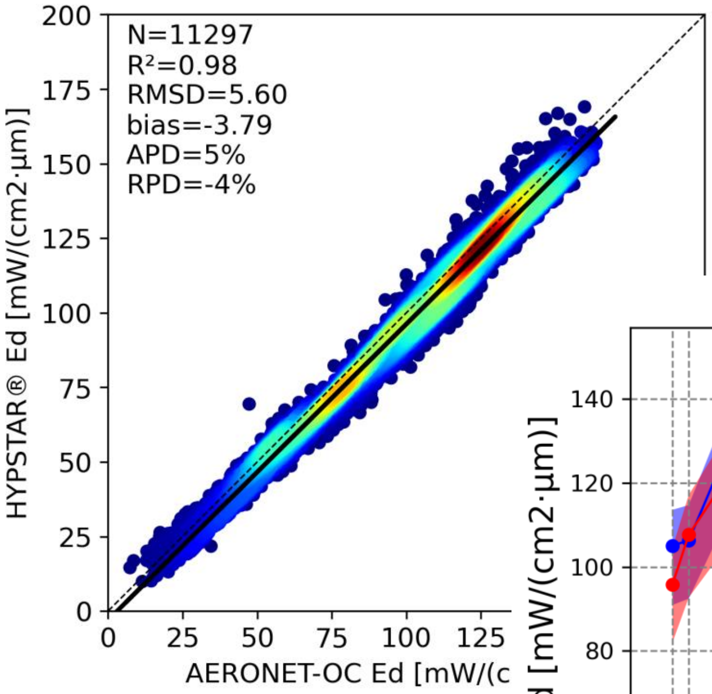
Comparison HYPSTAR ® vs Aeronet-OC: radiometry from the same location and with the same geometry Ed – Downwelling irradiance

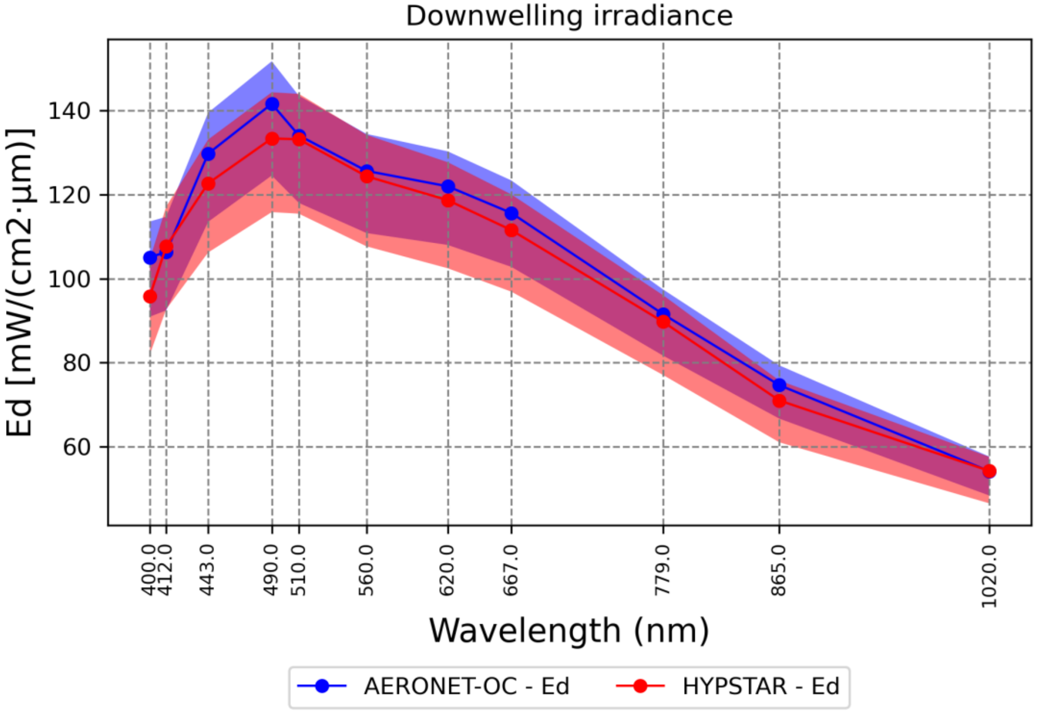
Analysis in progress to assess the impact of the differences in the sensor characteristics, and in the data acquisition and data reduction methods

V3 sensor in AERONET-OC corner: 17-03-2023 ->



AERONET-OC Ed

$$E_d = \frac{F_0 \, L_w}{L_{wn}}$$



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2024-01-01 … 2024-09-30
1027 matches withinn 10 minutes across 121 days

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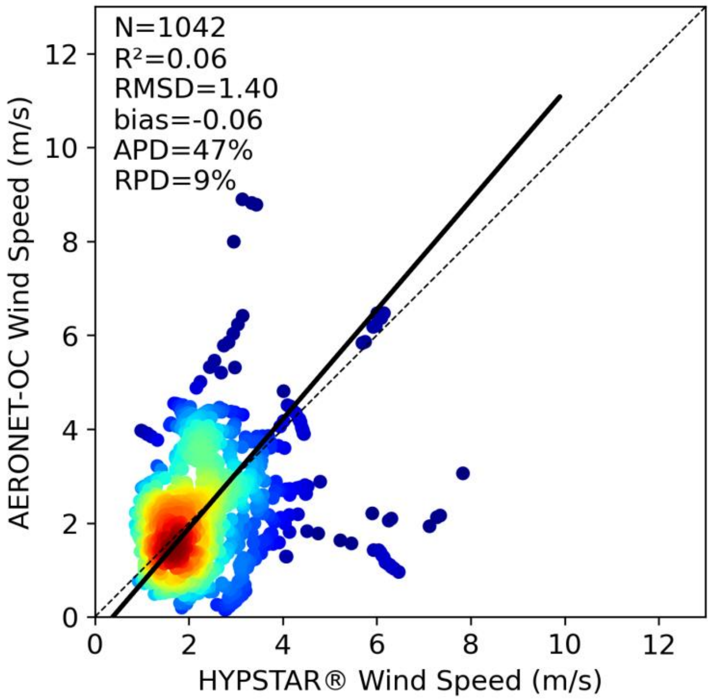
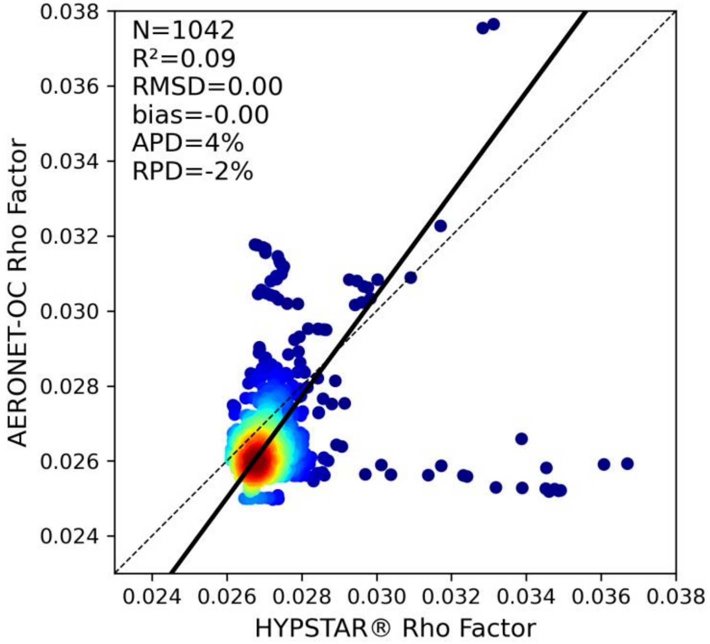
Comparison HYPSTAR ® vs Aeronet-OC: radiometry from the same location and with the same geometry

Analysis in progress to assess the impact of the differences in the sensor characteristics, and in the data acquisition and data reduction methods



Data reduction methods: different source for wind speed leads to significant differences in Rho values



V3 sensor in AERONET-OC corner: 17-03-2023 ->

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2024-01-01 … 2024-09-30
1027 matches withinn 10 minutes across 121 days

Summary

- Automated radiometry leads to high number of matchups (~70-80 per year at AAOT)
- Automated hyperspectral radiometry enabled qualification for all 15 OLCI bands with HYPSTAR and PANTHYR
- PANTHYR at VEIT used for PRISMA, EnMAP and PACE Hyperspectral L2 qualification
- PANTHYR and HYPSTAR at VEIT used for Sentinel 2 MSI multispectral
- Intercomparisons between time series from radiometers is on-going

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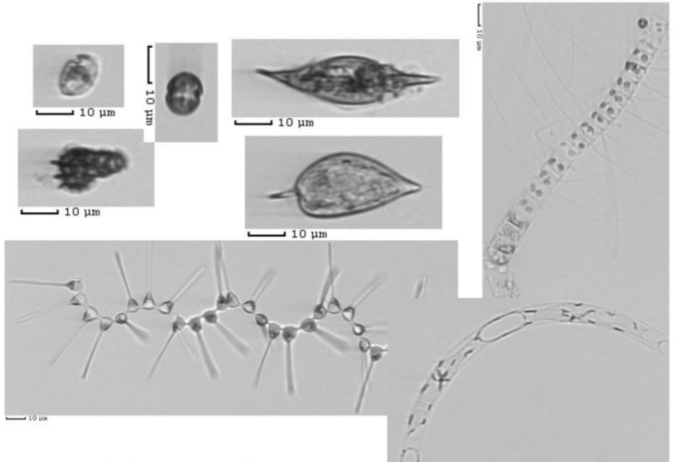
> WORKSHOP REPORT

74 *Oceanography* | Vol.33, No.1

DATA NEEDS FOR HYPERSPECTRAL DETECTION OF ALGAL DIVERSITY ACROSS THE GLOBE

By Heidi Dierssen, Astrid Bracher, Vittorio Brando, Hubert Loisel, and Kevin Ruddick



5-m Sample from 18 October 2022

- Hyperspectral Water-leaving Reflectance (Rrs)
  - Field data from ships, moorings, etc…
  - Algal culture data
  - Satellite or airborne data (e.g., HICO, CHRIS-PROBA, AVIRIS, PRISM) after atmospheric correction
  - Simulated data
- Hyperspectral optical properties (IOPs) when available, absorption by phytoplankton (aphyt) most useful
- Phytoplankton Dominant Taxa (WORMS classification)
- Phytoplankton Dominant Taxa Method
- Concentration metric (carbon/L, cells/L, etc..)
- Fractional composition of major Phytoplankton Groups (PGs)
- PG method
- Relevant metadata (location, date, time)
- Relevant ancillary data (temperature, salinity, nutrients, etc…)

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Research Topic
Frontiers in Remote Sensing

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TYPE Perspective
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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

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

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Validation of satellite water products based on HYPERNETS *in situ* data using a Match-up Database (MDB) file structure

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Validation of satellite-derived water-leaving reflectance in contrasted French coastal waters based on HYPERNETS field measurements

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Using the automated HYPERNETS hyperspectral system for multi-mission satellite ocean colour validation in the Río de la Plata, accounting for different spatial resolutions

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HYPERNETS

Publicly available datasets on zenodo

VEIT PANTHYR L2 data for Oct. 2019—Mar. 2022	**VEIT HYPSTAR® L2** data for Apr. 2021—Apr. 2023	**GAIT HYPSTAR® L2** data for June 2022—Nov. 2022

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Automated above water hyperspectral radiometry at Acqua Alta: review of recent results and perspectives

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