

Network Quiz!



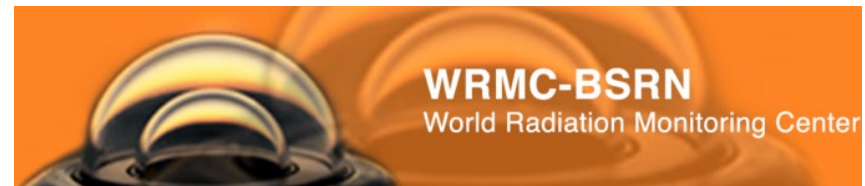
aerosol properties ... water reflectance (multispectral)



surface ... TOA reflectance (vicarious cal)



surface flux of CO_2 , CH_4 , H_2O ...



BSRN: surface radiation flux

A network of **autonomous hyperspectral radiometers**
measuring **water and land surface reflectance** for
satellite validation ... and more ...

Coordinated by Kevin Ruddick,
Royal Belgian Institute for Natural Sciences (RBINS)

HYPERNETS



(c) HYPERNETS Consortium, 2022 (RBINS, TARTU, SU, CNR, NPL, GFZ, CONICET)



Intense near-shore bloom observed by Sentinel-2/MSI in Belgian waters
(red-edge Chl-a absorption – see Vanhellemont & Ruddick 2017)

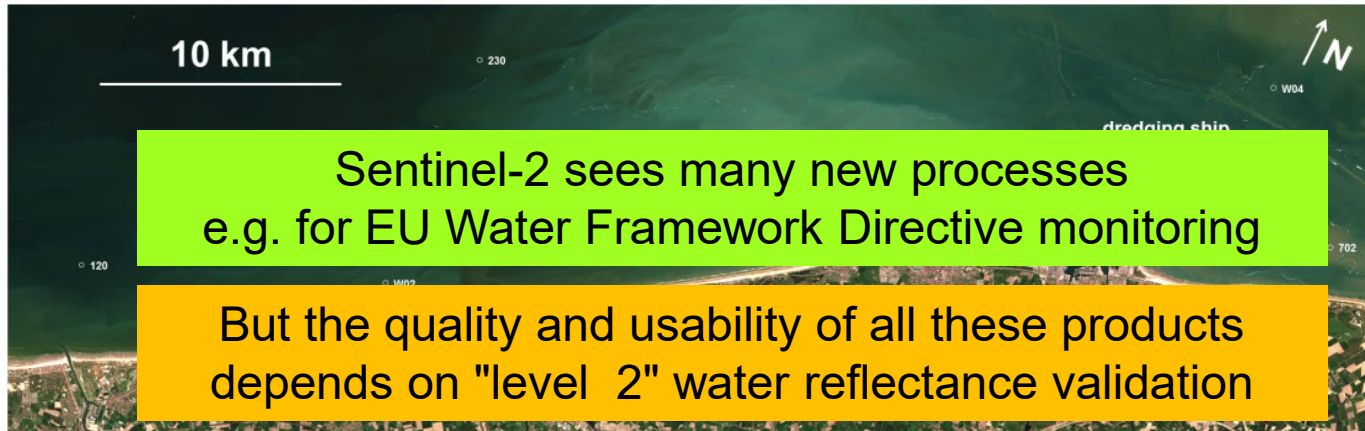


Figure 1 Sentinel-2/MSI Rayleigh-corrected RGB composite of the Belgian coastal zone on 2016-05-01 (10:53 UTC). Common sampling stations are annotated.

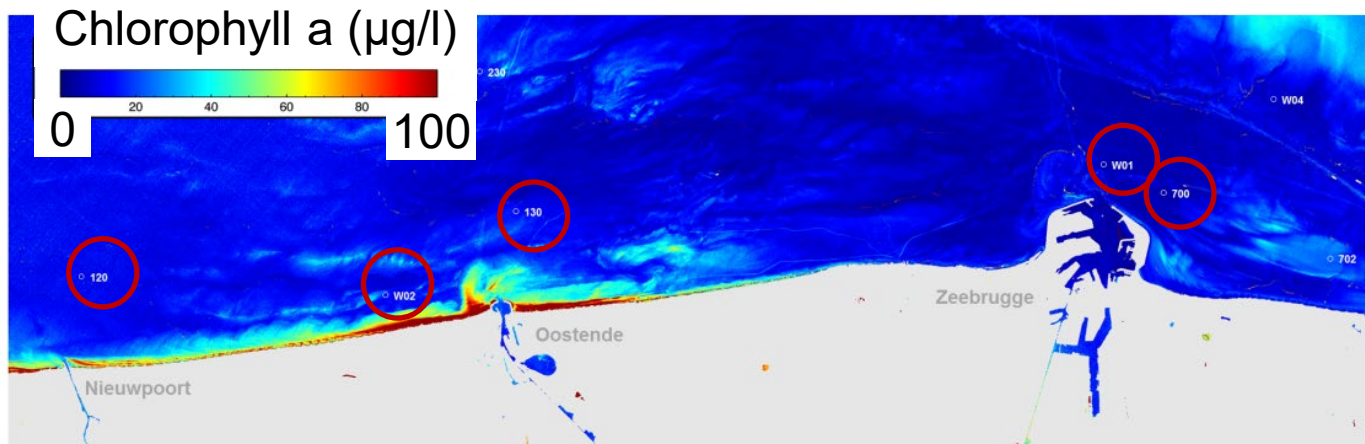
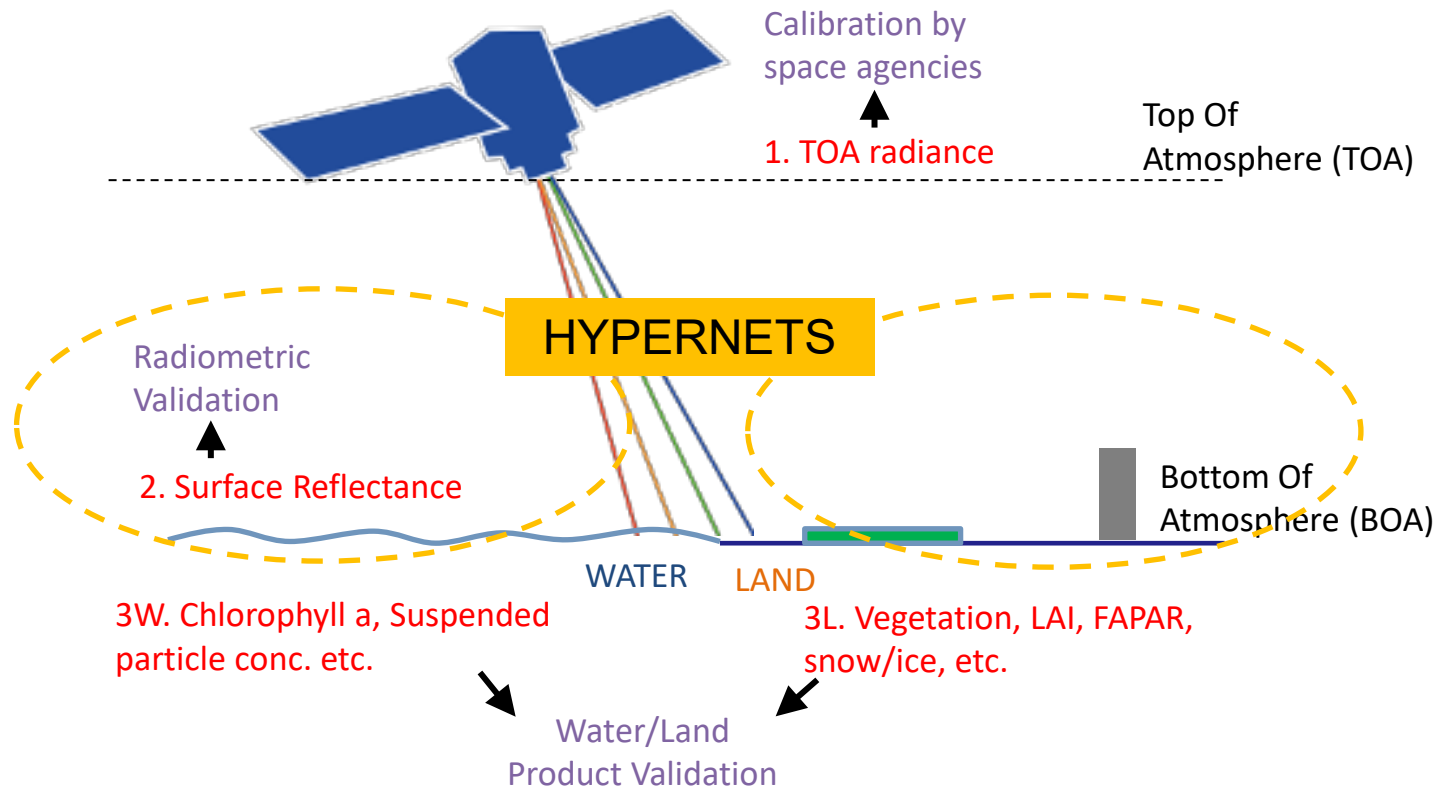


Figure 2 Chlorophyll a concentration derived using the algorithm of Gons (2005), showing an intense bloom between Nieuwpoort and Oostende

MOTIVATION =

Automated measurements for validation of water and land surface reflectance at all VIS/NIR spectral bands (400-1700nm, @3nm FWHM)



HYPERNETS in a single slide

★ STEREO inside!!!

INSTRUMENTS

Automated hyperspectral measurements



PANTHYR system

HYPSTAR® system

[Vansteenkoven et al, 2019]

[<https://hypstar.eu/>]

400-900nm, 10nm FWHM

380-1700nm, 3-10nm

FWHM

NETWORK

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

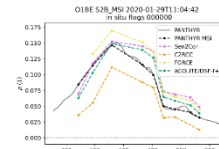


8 water and 4 land sites currently operating

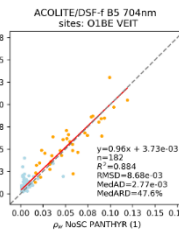
+7 water +3 land by April 2023

Many international requests to join in 2023 ...

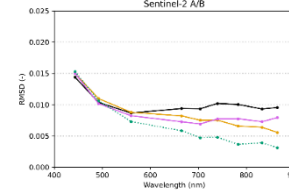
DATA PROCESSING and ANALYSIS



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, @3nm 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, ...)

Water sites currently running

VLIZ: Oostende



RBINS: Blankaart



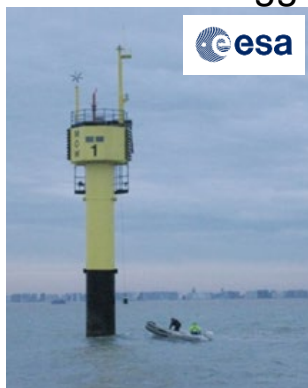
CNR: Lake Garda



CNR: Acqua Alta



RBINS: Zeebrugge



CONICET: La Plata



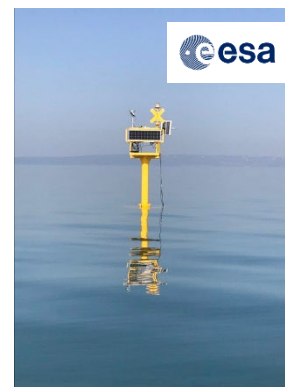
RBINS: Thornton (soon)



LOV: Gironde



LOV: Etang Berre



+ USA trial
co-locating
AERONET-OC
June 2023

Land sites currently running

NPL: Wytham



GFZ: ATB



RBINS: PEAntarctica
(Dec-Jan)



GFZ: DEMMIN



NPL: Gobabeb



NPL/RBINS: Barrax
(Jul 2022)



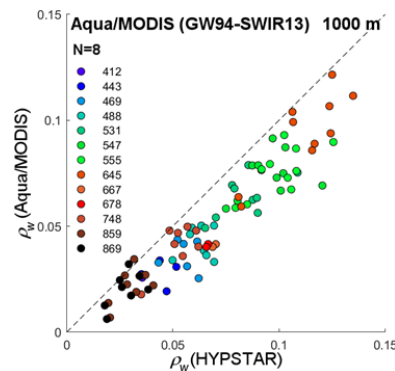
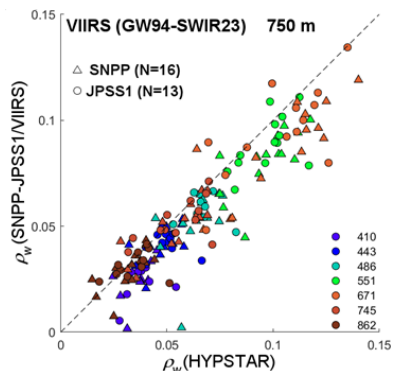
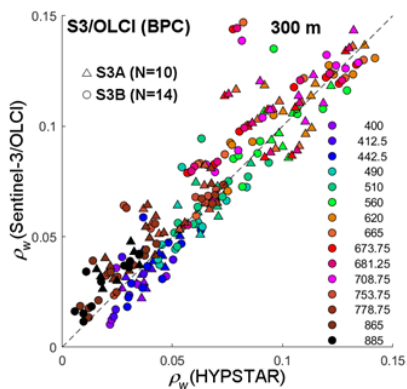
One site validating 9 missions (S2VT/Mar 2022) ...

S3/OLCI-A&B

VIIRS-S&J

MODIS-A

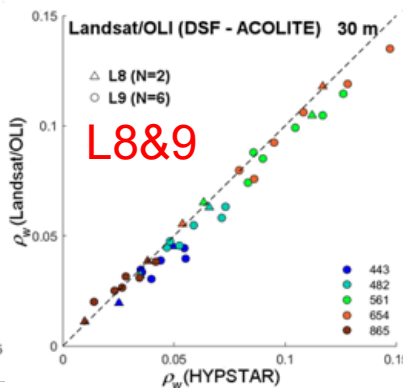
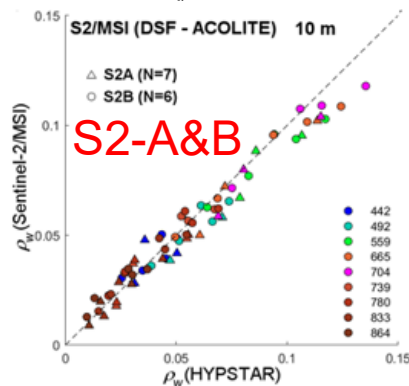
satellite



in situ



La Plata
[CONICET/A.Dogliotti]



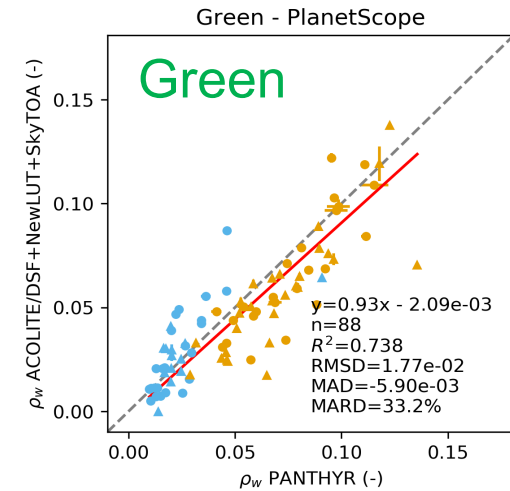
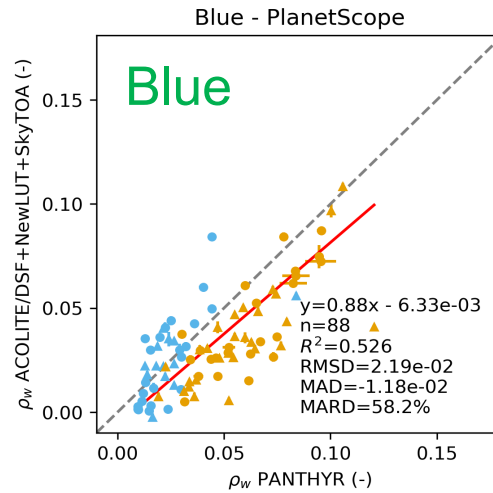
"One month of automated HYPSTAR® = 5 years of shipborne matchups"

Validation of
Planetscope/Doves
 with 2019-2020
 HYPERNETS/
 PANTHYR data from two
 sites

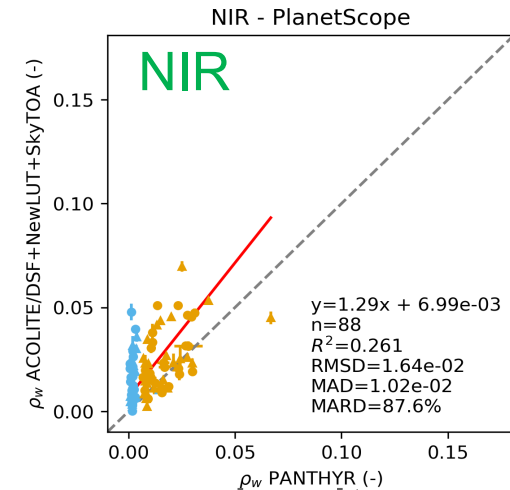
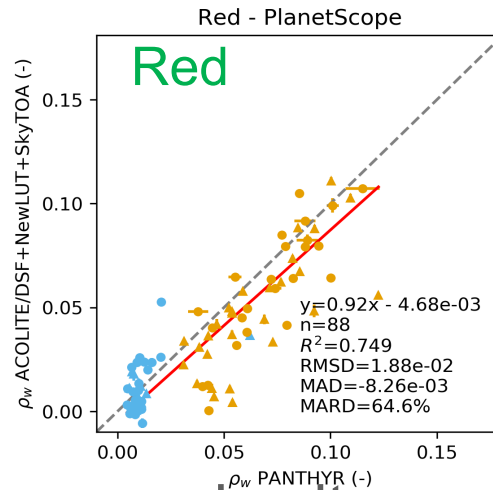
RT1 Oostende, Belgium
 (VLIZ)
 AAOT Venice, Italy
 (CNR)



satellite



satellite



in situ

in situ

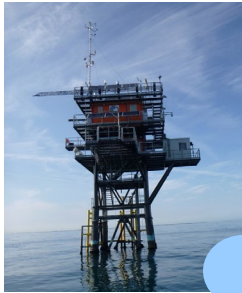
Interoperability?
 Red+Green usable for turbidity! (but not NIR)

88 matchups
 52 different
 satellites

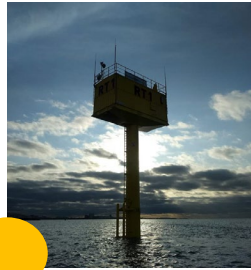
[Vanhellemont (2020) <https://doi.org/10.1364/OE.397456>

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

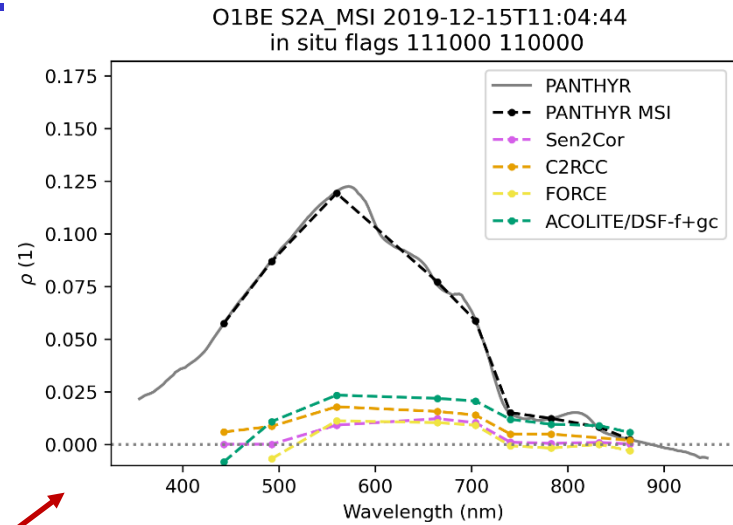
Outliers are interesting too..



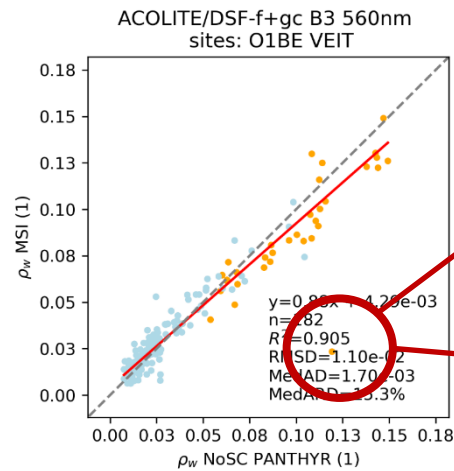
Aqua Alta,
Adriatic Sea
[V. Brando, CNR]



Oostende
[D. Vansteenwegen, VLIZ]



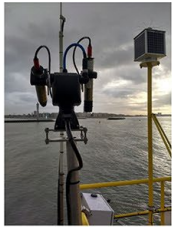
S2A/MSI 2019-12-15 11:04:44
 ρ_s RGB



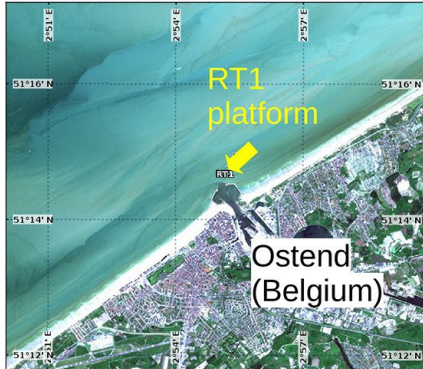
=> cloud shadow detection
needs to be improved (difficult)

[Sentinel-2 data processing and analysis by
Q. Vanhellemont, RBINS; presented at S2VT/Apr2022]

BONUS: hyperspectral radiometry is not just sat val

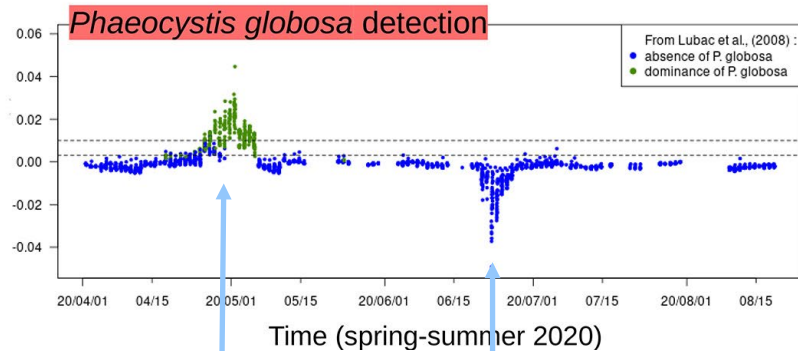
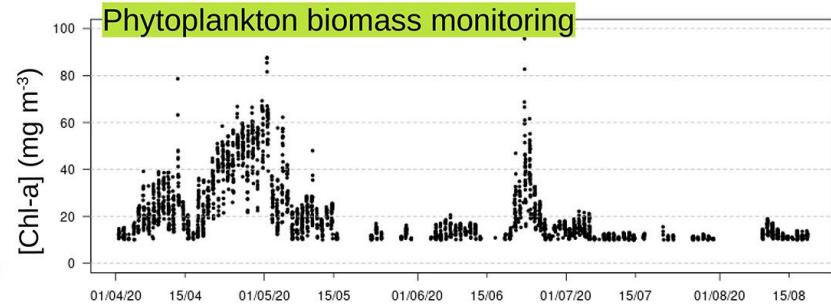


Hyperspectral autonomous radiometer system (PANTHYR) on RT1 platform



Water reflectance from PANTHYR

Modified Astoreca Line Height (m⁻¹)



Spring bloom (*Phaeocystis globosa*) Summer bloom (not *Phaeocystis*)

Phytoplankton pigments could also be seen from spaceborne hyperspectral missions BUT second derivative algos have interband cal reqt, e.g. 0.1% for 470-490nm



Remote Sensing of Environment

Volume 282, 1 December 2022, 113270



Monitoring of high biomass *Phaeocystis globosa* blooms in the Southern North Sea by in situ and future spaceborne hyperspectral radiometry

Héloïse Lavigne, Kevin Ruddick, Quinten Vanhellemont

[Lavigne et al, 2022;
<https://doi.org/10.1016/j.rse.2022.113270>]

HYPERNETS in a single slide

INSTRUMENTS

Automated hyperspectral measurements



PANTHYR system

[Vansteenkoven et al, 2019]

400-900nm, 10nm FWHM

HYPSTAR® system

[<https://hypstar.eu/>]

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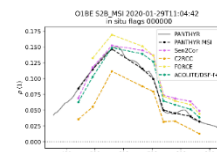


8 water and 4 land sites currently operating

+7 water +3 land by April 2023

Many international requests to join in 2023 ...

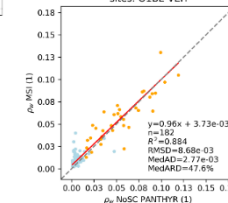
DATA PROCESSING and ANALYSIS



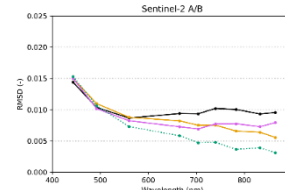
e.g. one matchup

ACOLITE/DSF-1 B5 704nm

sites: O1BE VEIT



one band (S2/704nm), many matchups



spectral stats, many matchups

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Acknowledgements

- Project funding:

- PRODEX...ESA/HYPERNET-VN&POP
- BELSPO/HYPERMAQ+AQUALOOKS
- EU/H2020/HYPERNETS



- Partners:

- RBINS (K. Ruddick, M. Beck, A. Gammaru, C. Goyens, F. Ortenzio, Q. Vanhellemont) + CPOWER+AfKust+IPF+Watergroep
- VLIZ (D. Vansteenwegen, A. Cattrijsse) + POM (Oostende site)
- CNR (V. Brando, L. Gonzales Vilas, C. Giardino)
- +
- TARTU (J. Kuusk, K. Flight, K. Laizans, R. Vendt)
- NPL (A. Bialek, S. Hunt, P. De Vis, M. Sinclair)
- LOV (D. Doxaran, A. Corrizi)
- IAFE/CONICET (A. Dogliotti, E. Piegari, P.Perna, L. Rubinstein)
- GFZ (D. Spengler, M. Saberioon)

THE END

Spare Slides

The Radiometers

Parameter	TRIOS/RAMSES	HYPSTAR®-SR	HYPSTAR®-XR
Measured quantity	Radiance or Irradiance (separate instruments)	Radiance and irradiance (multiplexed)	Radiance and irradiance (multiplexed)
Field of view	7° (radiance) 180° (irradiance)	2° (radiance) 180° (irradiance)	5° (radiance) 180° (irradiance)
Detector array	256 px Si	2048 px Si	2048 px Si + 256 px InGaAs
Spectral range	320-950nm theoretical 400-900nm confirmed	380 ... 1020 nm	380 ... 1700 nm
Spectral sampling interval	3.3nm	0.5 nm	0.5 nm (380-1000nm) 3 nm (1000-1700nm)
Spectral resolution	10 nm	3 nm	3 nm (380-1000nm) 10 nm (1000-1700nm)
ADC resolution	16 bit	16 bit	16 bit
Integration time	4-8000 ms	1-65535 ms	1-65535 ms
Shutter	No: dark pixels	Internal	Internal
Target camera	RGB (external)	5 Mpx, RGB	5 Mpx, RGB
Housing material	Stainless steel (1.4571/1.4404)	Anodised marine grade aluminium	Anodised marine grade aluminium
Dimensions (DxL)	∅48 mm x Irradiance 260 mm Radiance 300 mm	∅110.3 x 267 mm	∅110.3 x 434 mm
Weight	0.9 kg	1.5 kg	3 kg
Power supply	8-12 V DC 0.1 A	8-18 V DC 0.5 A	8-18 V DC 2 A
Environmental protection	IP67	IP67	IP67
Operating temperature	2 ... 40 °C	-25 ... +45 °C	-25 ... +45 °C

Land!

PACE!

Although this may seem a paradox, all exact science is dominated by the idea of approximation. When a man tells you that he knows the exact truth about anything, you are safe in inferring that he is an inexact man. **Every careful measurement in science is always given with the probable error** ... every observer admits that he is likely wrong, and knows about how much wrong he is likely to be.

— Bertrand Russell

In *The Scientific Outlook* (1931), 42.

(For “man/he” read “scientist/s/he”. For “error” read “uncertainty”)

No person will deny that the highest degree of attainable accuracy is an object to be desired, and **it is generally found that the last advances towards precision require a greater devotion of time, labour, and expense, than those which precede them.**

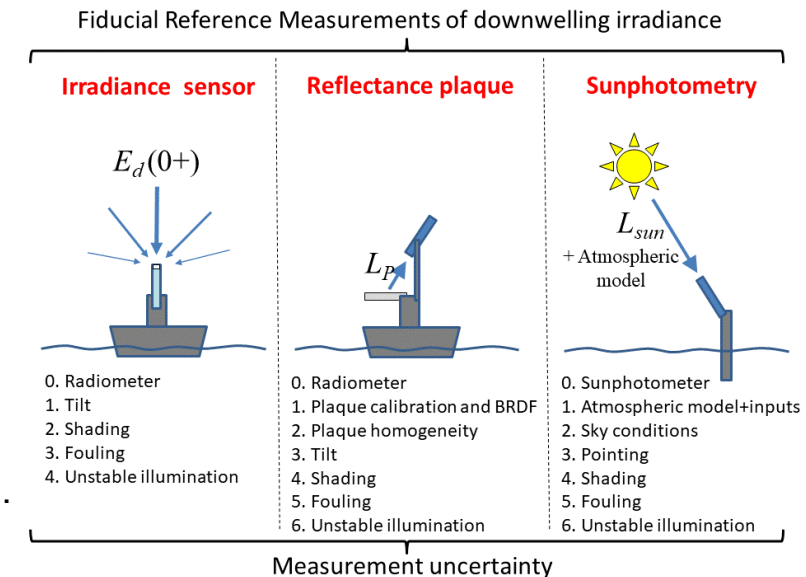
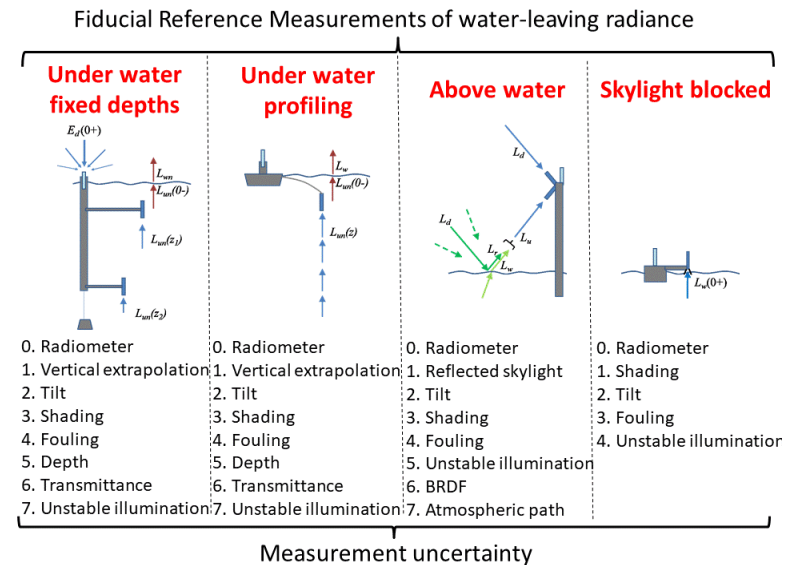
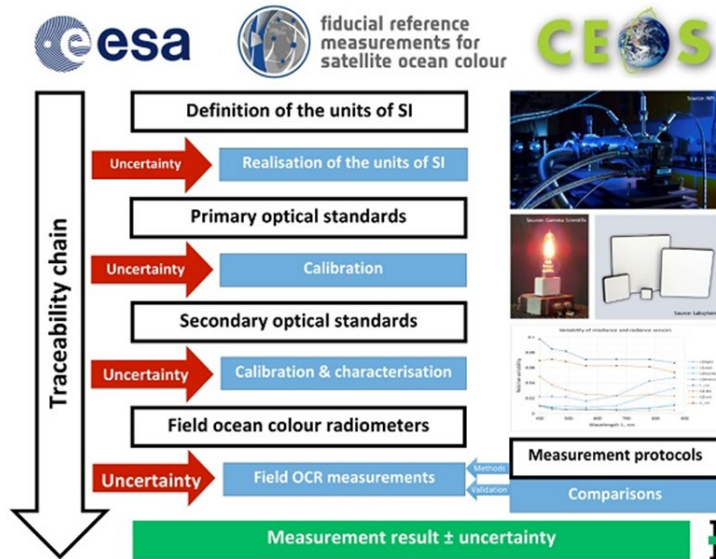
— Charles Babbage

Reflections on the Decline of Science in England (1830), 167.

A measurement result is complete only when it is accompanied by a statement of the associated uncertainty [Wikipedia, Measurement Uncertainty, 2017]

Fiducial Reference Measurements and uncertainties

[Ruddick et al. "A Review of **Protocols** for ... **Water-Leaving Radiance**". Remote Sens. 2019, 11, 2198. <https://doi.org/10.3390/rs11192198>]



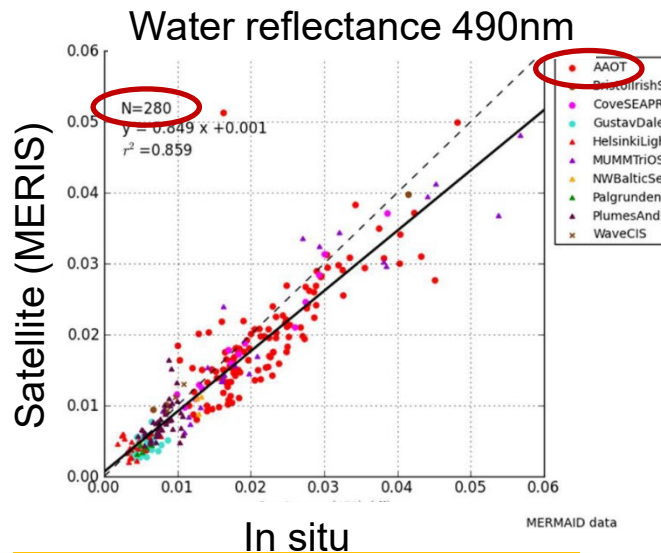
[Banks et al. "Fiducial Reference Measurements for Satellite Ocean Colour (FRM4SOC)". Remote Sens. 2020, 12, 1322. <https://doi.org/10.3390/rs12081322> and <https://frm4soc.org>]

[Ruddick et al. A Review of **Protocols** for ... **Downwelling Irradiance**. Remote Sens. 2019, 11, 1742. <https://doi.org/10.3390/rs11151742>]

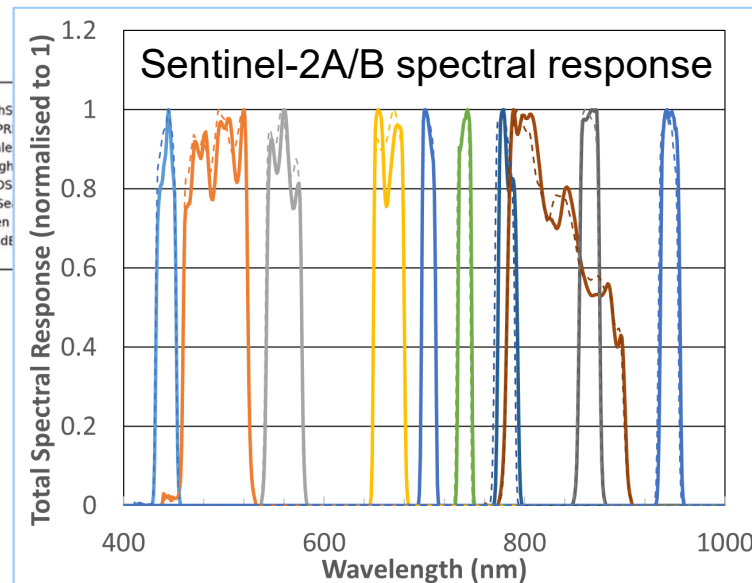
(also relevant for land)

The Motivation for automated hyperspectral

10 years of MERIS water validation, including a few years of AERONET-OC...



Data acquisition must be
AUTOMATED



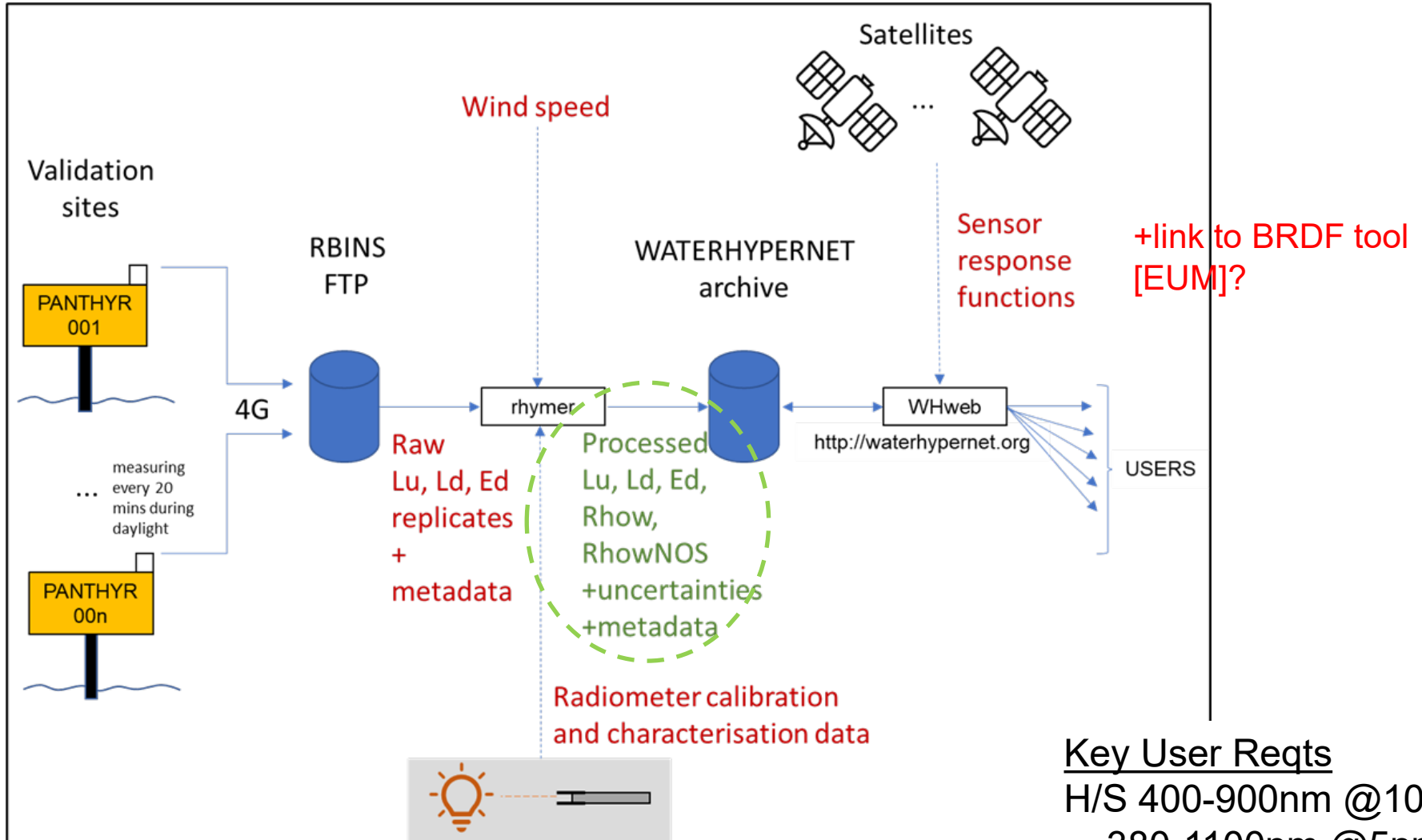
Instrument must be
HYPER SPECTRAL

[MERIS 3rd reprocessing data validation report, ACRI, 2012]

Data courtesy of PIs (D. McKee, K. Ruddick, D. Siegel, S. Kratzer) and AERONET-OC PIs (G. Zibordi, G. Schuster, S. Kratzer, B. Gibson), matchup using MERMAID

Sites preferably
NETWORKED

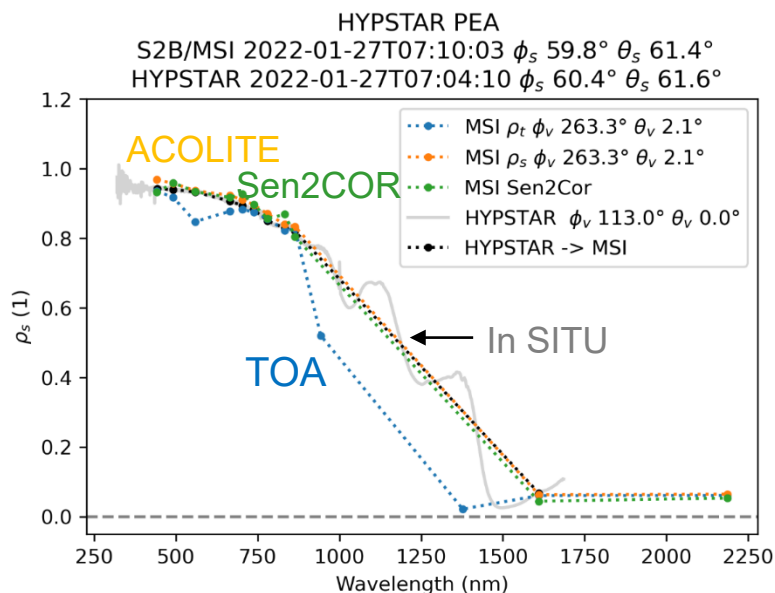
Overview of data flow



Key User Reqts
H/S 400-900nm @10nm
... 380-1100nm @5nm
High data quantity
"High" data quality
Easy mass download

BE Antarctica base (IPF) - example matchup, HYPSTAR® prototype

RBINS HYPSTAR® deployment and S2 processing
 Also to be used for validation of L8, L9, OLCI, ...
 Jan-Feb 2022 (and redeployed Dec2022-Jan2023)



S2B/MSI 2022-01-27 07:10:03
 ρ_s RGB



~3km

Good site for snow properties, HDRF, cloud detection over snow, vcal?, user interest ...

Collaboration with U.Maryland skycams ...