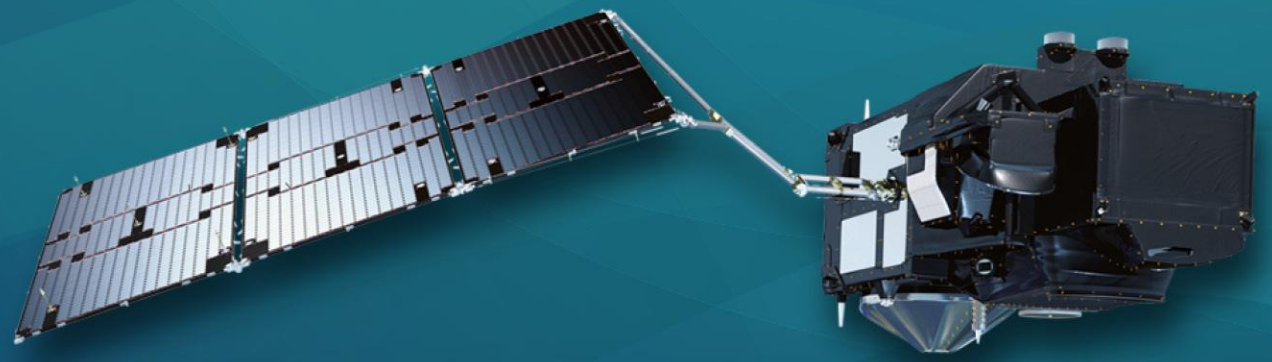
PROGRAMME OF THE EUROPEAN UNION

opernicus Europe's eyes on Earth

EUMETSAT

co-funded with esa



9th Sentinel-3 Validation Team meeting 2026

30 March–01 April 2026 | ESA–ESRIN | Frascati (Rome), Italy

FRMOCnet: Empowering Ocean Colour Data Collection

Presenter: Riho Vendt, University of Tartu
FRM4SOC Team

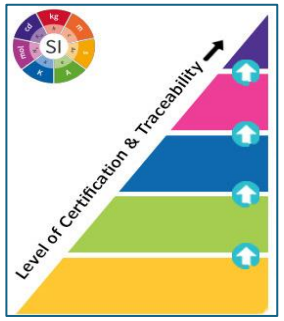
FRM4SOC-2 Team

- *University of Tartu* Riho Vendt, Krista Alikas, Ilmar Ansko, Kim Duong, Joel Kuusk, Martin Ligi, Viktor Vabson,
- *ACRI-ST* Christophe Lerebourg, Alexis Deru, Gabriele Bai, Marine Bretagnon
- *Brockmann Consult GmbH* Carsten Brockmann, Uwe Lange, Sabine Embacher, Benjamin Lutz
- *Consiglio Nazionale delle Ricerche (CNR)* Vittorio Brando
- *EOScience* Giuseppe Zibordi
- *National Physical Laboratory (NPL)* Agnieszka Bialek, Ashley Ramsay
- *Plymouth Marine Laboratory (PML)* Gavin Tilstone, Thomas Jordan
- *Royal Belgian Institute for Natural Sciences (RBINS)* Kevin Ruddick, Heloïse Lavigne
- *Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS)* Giorgio Dall'Olmo
- *NASA* Dirk Aurin
- *EUMETSAT* Juan I. Gossn, Ewa Kwiatkowska

Fiducial Reference Measurements (FRM)

"Earth Observation data without proper calibration and uncertainty assessment has little value for most applications, because if the data cannot be trusted, no reliable information can be derived from them."

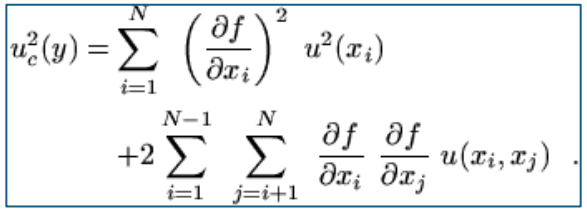
*FRM -- A suite of **independent**, **fully characterised**, and **traceable** (to a **community agreed reference**, ideally **SI**) measurements of a **satellite relevant measurand**, tailored specifically to address the **calibration/validation needs** of a class of satellite borne sensors, and following the guidelines outlined by the **GEO/CEOS Quality Assurance framework for Earth Observation (QA4EO)***



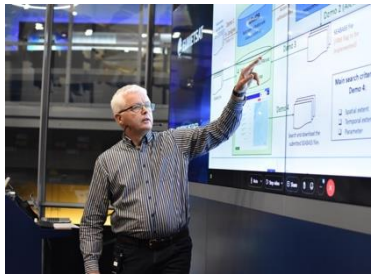
$$u_c^2(y) = \sum_{i=1}^{N} \left(\frac{\partial f}{\partial x_i}\right)^2 u^2(x_i) + 2 \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \frac{\partial f}{\partial x_i} \frac{\partial f}{\partial x_j} u(x_i, x_j)$$

Goryl, P.; Fox, N.; Donlon, C.; Castracane, P. Fiducial Reference Measurements (FRMs): What Are They? Remote Sens. 2023, 15, 5017.

FRM4SOC – Fiducial Reference Measurements for Satellite Ocean Colour



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




fiducial reference measurements for satellite ocean colour


2016 – 2019 FRM4SOC Phase 1

- Funded and coordinated by ESA
- Foundations to achieve FRM quality in the Ocean Colour (OC) domain
- *https://frm4soc.org*

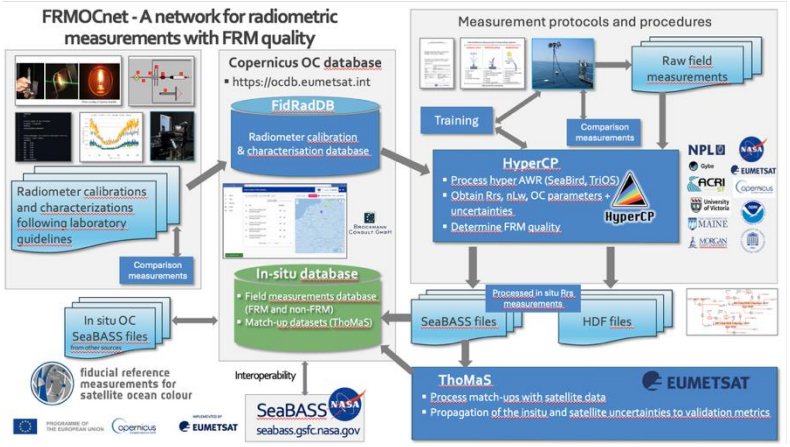
2021 – 2026 FRM4SOC Phase 2

- *Funded by the EU Copernicus Program and coordinated by EUMETSAT*
- *Promote the adoption of FRM principles across the OC community*
- *Develop foundations for operational implementation of the FRM principles by the OC community (in situ hyperspectral radiometry)*
- *Verify and demonstrate the operations of the FRM in the community framework*

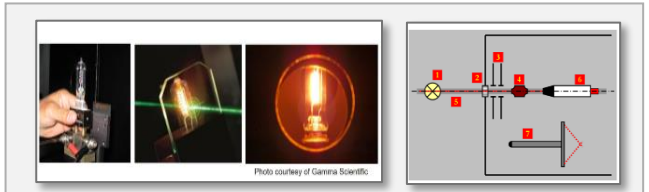
https://frm4soc2.eumetsat.int/

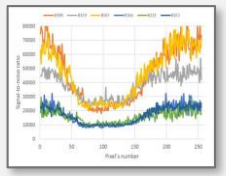
FRMOCnet

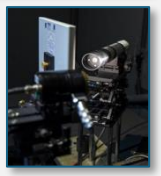
- Joint outcome of the FRM4SOC-2 project tasks.
- Network of FRM quality instruments and measurements.
- Implements the FRM principles in the Ocean Colour domain and empowers collection of quality field data.
- Joins and supports the OC community via training, workshops, instruments, and calibration.



FRMOCnet - A network for radiometric measurements with FRM quality







Radiometer calibrations and characterisations following laboratory guidelines

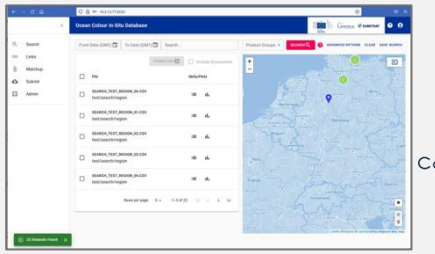
Comparison measurements

Copernicus OC database

- https://ocdb.eumetsat.int

FidRadDB

Radiometer calibration & characterisation database



BROCKMANN CONSULT GMBH

In-situ database

- Field measurements database (FRM and non-FRM)
- Match-up datasets (ThoMaS)

In situ OC SeaBASS files
from other sources

fiducial reference measurements for satellite ocean colour

Interoperability

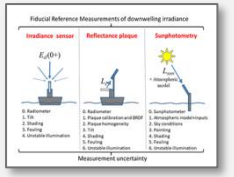
SeaBASS
seabass.gsfc.nasa.gov

PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

IMPLEMENTED BY EUMETSAT

Measurement protocols and procedures



Raw field measurements

Training

Comparison measurements

HyperCP

- Process hyper AWR (SeaBird, TriOS)
- Obtain Rrs, nLw, OC parameters + uncertainties
- Determine FRM quality

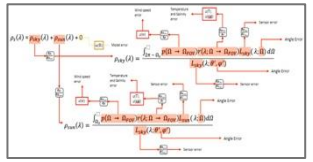
HyperCP

NPL · NASA · Gybe · EUMETSAT · ACRI ST · Copernicus Europe's eyes on Earth · University of Victoria · NOAA · The University of Maine · University of Tartu · Morgan State University

Processed in situ Rrs measurements

SeaBASS files

HDF files



ThoMaS

EUMETSAT

- Process match-ups with satellite data
- Propagation of the insitu and satellite uncertainties to validation metrics

[1] NASA Goddard Space Flight Center

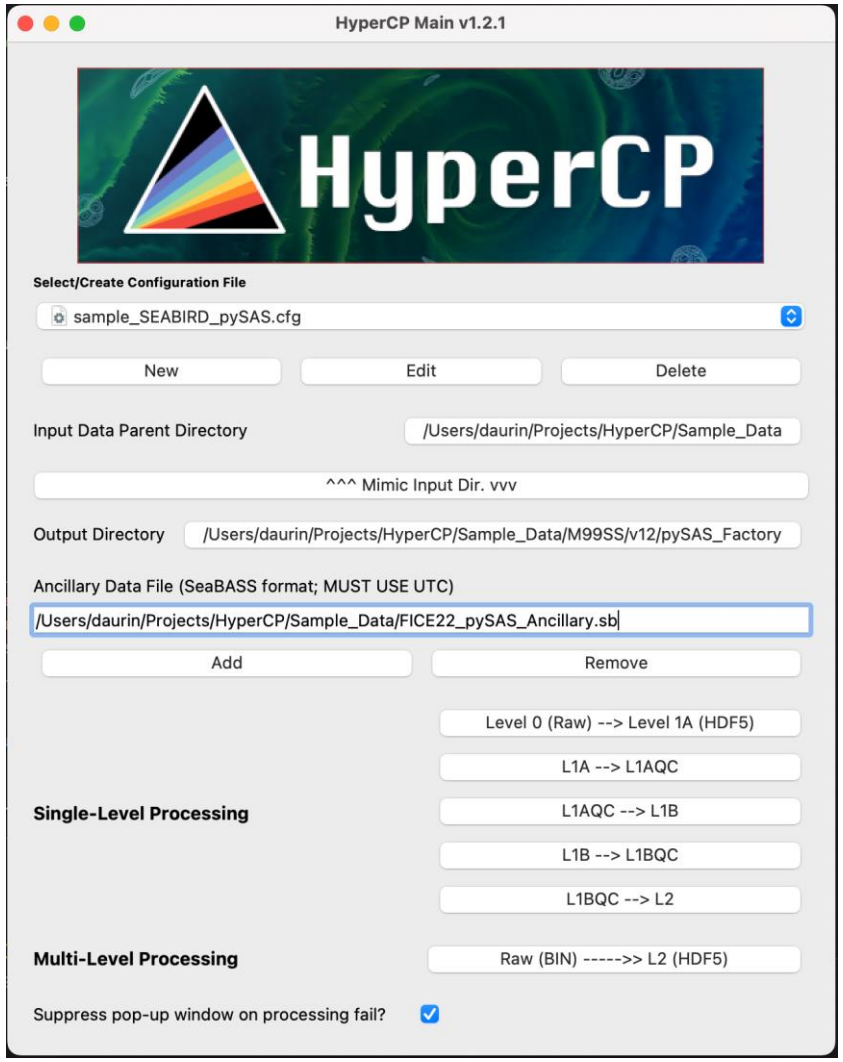
[2] Morgan State University

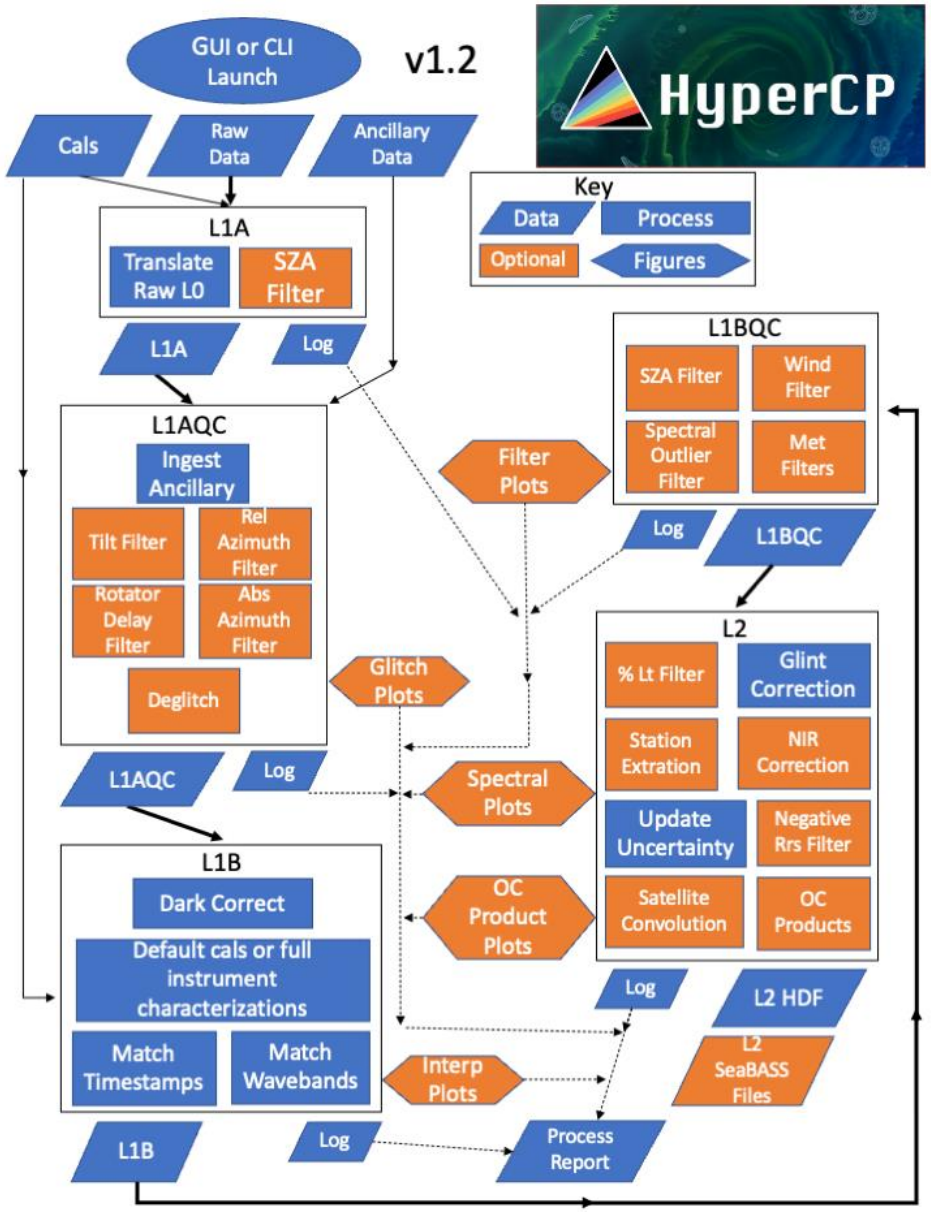
[5] University of Victoria

[7] National Physical Laboratory (UK)

[10] NOAA NMFS

https://github.com/nasa/HyperCP





[3] EUMETSAT

[4] Copernicus Programme of European Commission

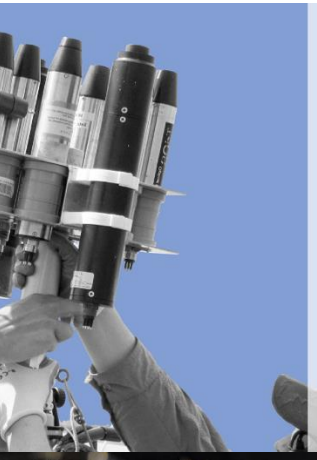
[6] ACRI-ST

[8] University of Maine

[8] University of Tartu

[9] Gybe Inc.

Funding from NASA PACE Mission and Copernicus FRM4SOC-2 Initiative

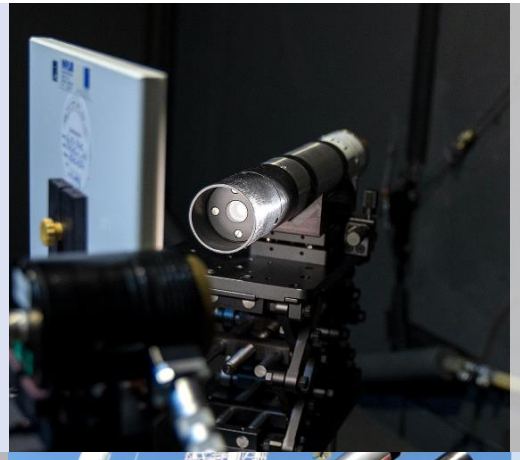


FRM4SOC-2 Project Workshop

04.12.2022

5 – 7 December 2022
EUMETSAT,
Darmstadt, Germany

At this workshop, we present the most important outcomes from the FRM4SOC phase project and seek for agreement in the community through discussions.



FRM4SOC Phase 2 laboratory comparison

14.03.2022

The absolute radiometric calibration comparisons will be implemented through a round-robin comparison of each participant's irradiance and radiance calibration capability using ocean colour transfer radiometers.

Field InterComparison Exercise (FICE)

11-20 July 2022,
at Acqua Alta Oceanographic Tower (AAOT), Venice, Italy.

Comparison of L_i, L_t, L_w, E_d, R_{rs}, L_{wn}

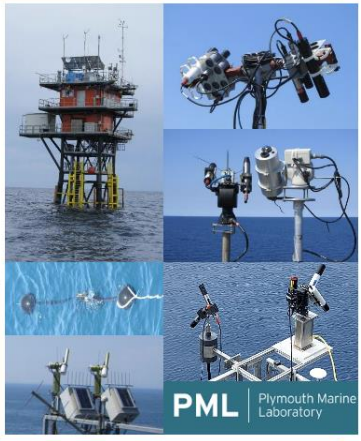
Critical review, testing, and feedback on
- Measurement protocols/procedures
- Community processor
- FRMOCnet
- Application of instrument characterisation

Validation of
- SI traceability;
- Uncertainty budgets;
- Aimed uncertainty levels.

Participants: CNR-ISAC, Helmholtz Center Hereon, NASA, NOAA, PML, RBINS, UT

Instruments:
Above water (7): TRIOS RAMSES, TriOS RAMSES G2 sun tracker (SoRAD), Seabird HyperOCR HyperSAS with PySAS robot, HYPSTAR, PANTHYR.

In-water (2): Sea-Bird HyperPro II, TriOS RAMSES floating buoy.



The second
FRM4SOC-2 WORKSHOP
on Calibration and Characterisation of Ocean Color Field Radiometers

20 – 22 May 2025
@ Tartu Observatory, University of Tartu, Estonia

Second FRM4SOC Workshop on Calibration and Characterisation of Ocean Colour Field Radiometers

30.06.2025

Click here for the details and agenda.

Short-term use of Ocean Colour radiometric system. Free calibration of your own radiometers.

11.04.2024

The application period has ended.

Opprotunity to apply for the

Unlocking the Seas: First Copernicus FRM4SOC-2024 Training

27.08.2024

The training was held at the Italian Research Council's Institute of Marine Sciences and at the Acqua Alta Oceanographic Tower (AAOT) in the Adriatic Sea.

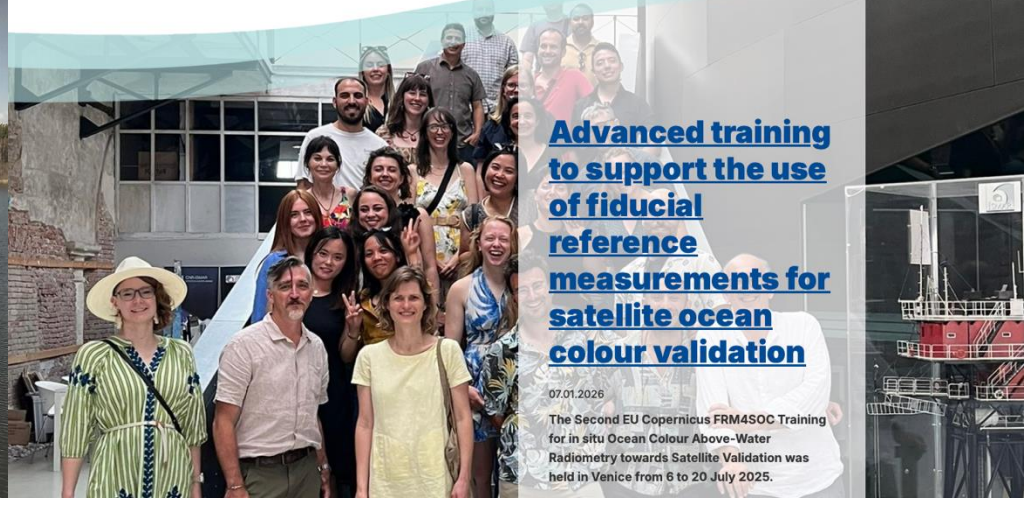
PROGRAMME OF THE EUROPEAN UNION
Copernicus Europe's eyes on Earth
IMPLEMENTED BY EUMETSAT

UNIVERSITY OF TARTU Tartu Observatory 1632
ACRI ST
Brockmann Consult GmbH
Consiglio Nazionale delle Ricerche
EOScience
natural sciences .be
NASA
NPL National Physical Laboratory
PML Plymouth Marine Laboratory

Short-term (free) rental of an Ocean Colour radiometric system. Free calibration of your own radiometers - SECOND CALL

27.01.2025

SECOND CALL (closed)



Advanced training to support the use of fiducial reference measurements for satellite ocean colour validation

07.01.2026

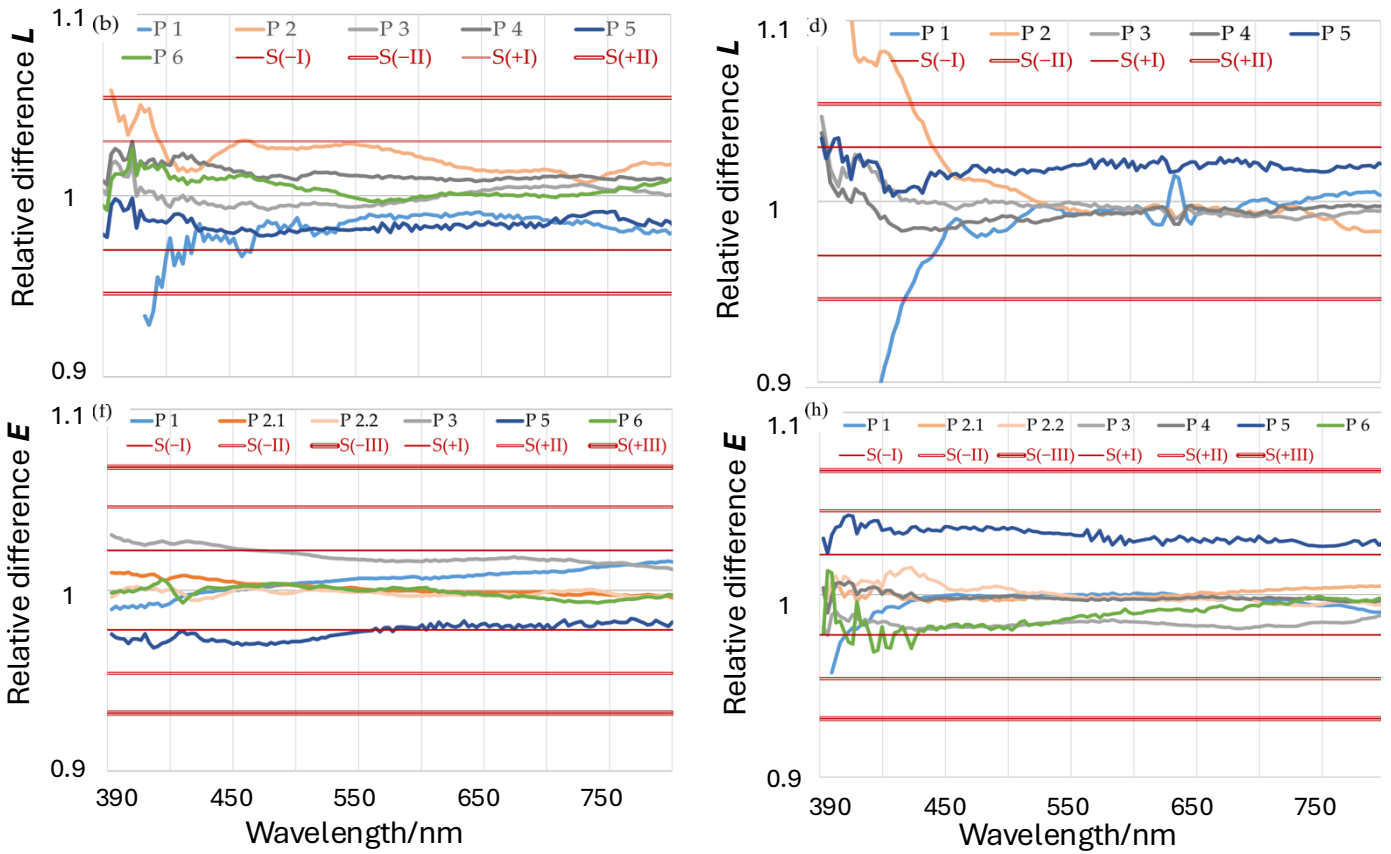
The Second EU Copernicus FRM4SOC Training for in situ Ocean Colour Above-Water Radiometry towards Satellite Validation was held in Venice from 6 to 20 July 2025.

Laboratory comparison of OCR

Vabson, et al. 2025, Remote Sens. MDPI, 17, 3692.

TriOS Ramses

Seabird HyperOCR



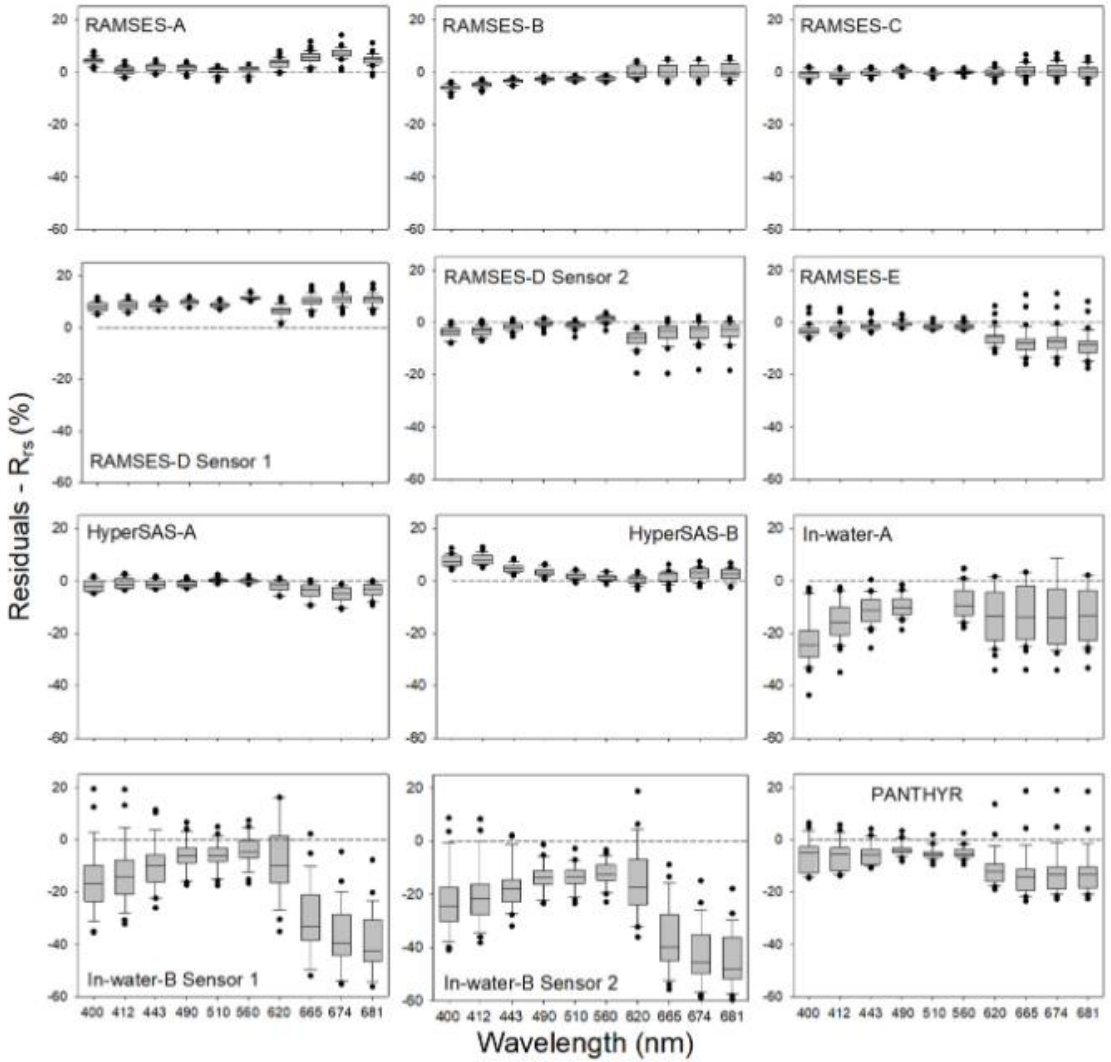
The relative difference from CCV of L and E sensors. Agreement among participants within $\pm 3\%$

FRM4SOC 1 & 2. Field inter-comparison results.

FRM4SOC 1.

Percent residuals of Rrs for above- and in-water systems.

Tilstone et al. 2020, Remote Sens. MDPI, 12, 1587.

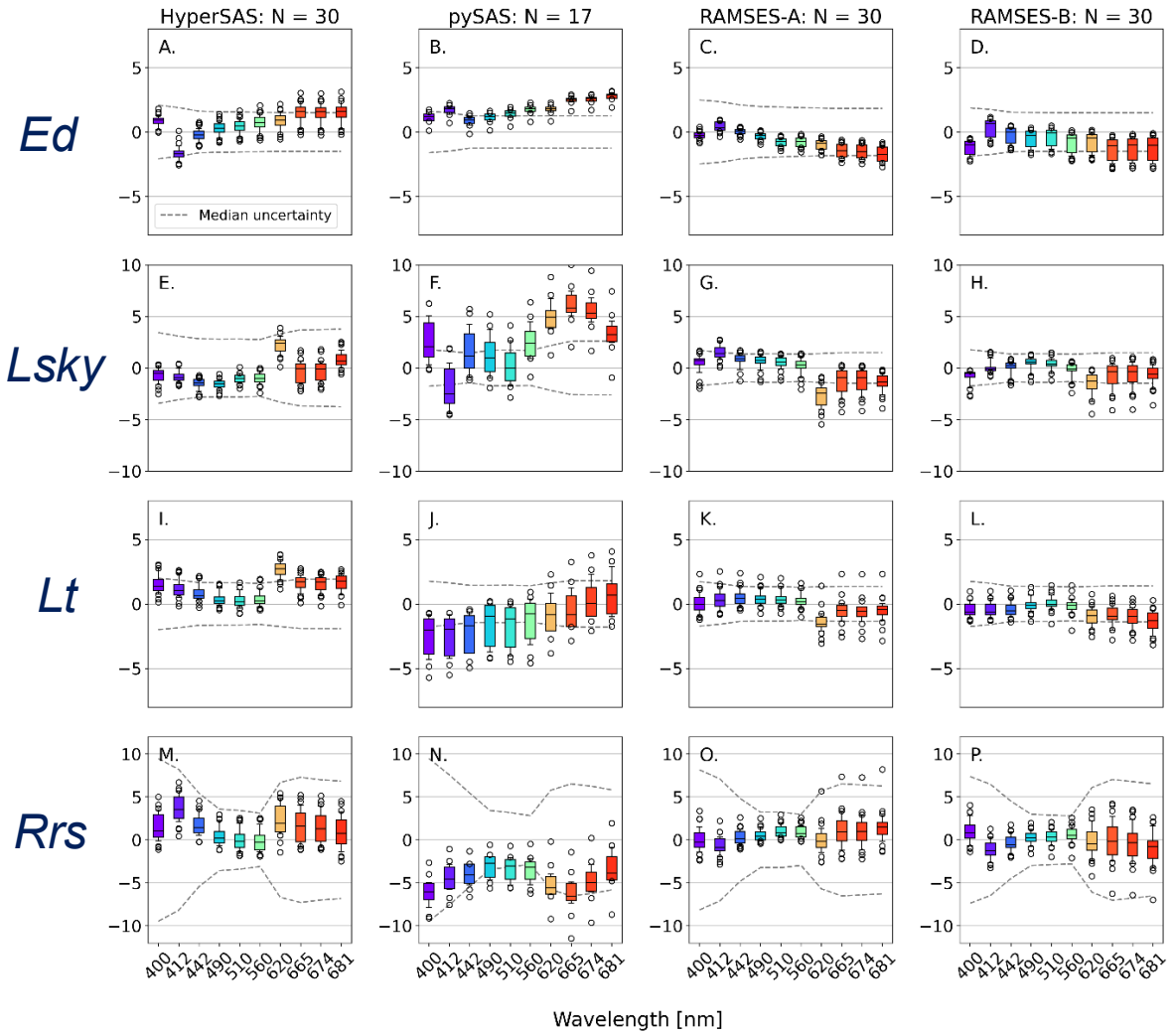


Differences between TriOS RAMSES were <3.5%, <2.5%, <7.5%; for Sea-Bird HyperSAS were 3.5%, 1%, 3% at 443, 560, 665 nm.

FRM4SOC 2.

Percent residuals compared to the mean of all systems.

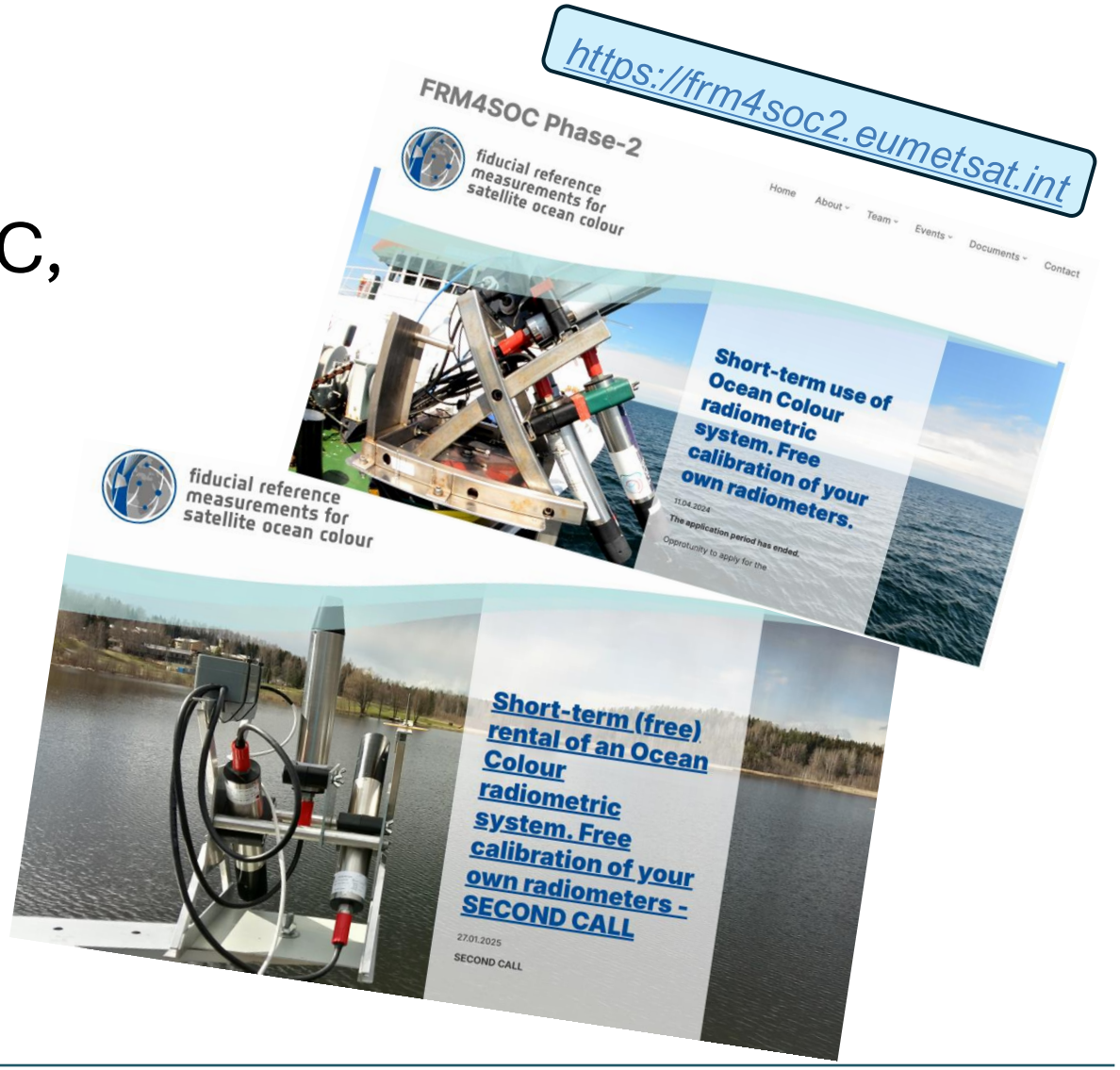
Tilstone et al. 2025, Optics Express, 33, 15756-15781.



Differences in Ed(λ), $Lsky(\lambda)$, $Lt(\lambda)$ & $Rrs(\lambda)$ between instrument systems was **<2.5%** using Sensor-specific characteristics.

Instrument pool – fully operational, calibrated and characterised system (TriOS Ramses) kindly provided by JRC,

- **(Free) short-term rental for**
  - 2 campaigns in 2024.
  - 2 campaigns in 2025
  - New call expected in 2026
- **Project-supported calibrations**
  - 4 sets of radiometers in 2024.
  - 4 sets of radiometers in 2025
  - New call expected in 2026



Acknowledgements

- FRM4SOC Phase-2 – EUMETSAT project no. EUM/CO/21/460002539/JIG
- ESA Estonia research infrastructure funded by the Estonian Research Council grant TARISTU24-TK3.
- Estonian Research Council grant PRG2646 “Methods, Traceability and Validation of the In-Water Ocean Color Measurements”.

Contact: *https://frm4soc2.eumetsat.int/*