Fiducial Reference Measurements for Satellite Ocean Colour

FRM4SOC

https://frm4soc.org

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Fiducial Reference Measurements

- the suite of independent ground measurements
- that provide the maximum scientific utility/return on investment for a satellite mission
- by delivering, to users, the required confidence in data products,
- in the form of independent validation results and satellite measurement uncertainty estimation,
- over the duration of the mission.

C. J. Donlon, P. J. Minnett, N. Fox, W. Wimmer, "Chapter 5.2 - Strategies for the Laboratory and Field Deployment of Ship-Borne Fiducial Reference Thermal Infrared Radiometers in Support of Satellite-Derived Sea Surface Temperature Climate Data Records," in *Optical Radiometry for Ocean Climate Measurements*, vol. 47, Academic Press, 2014, pp. 557–604.

The FR Measurements must

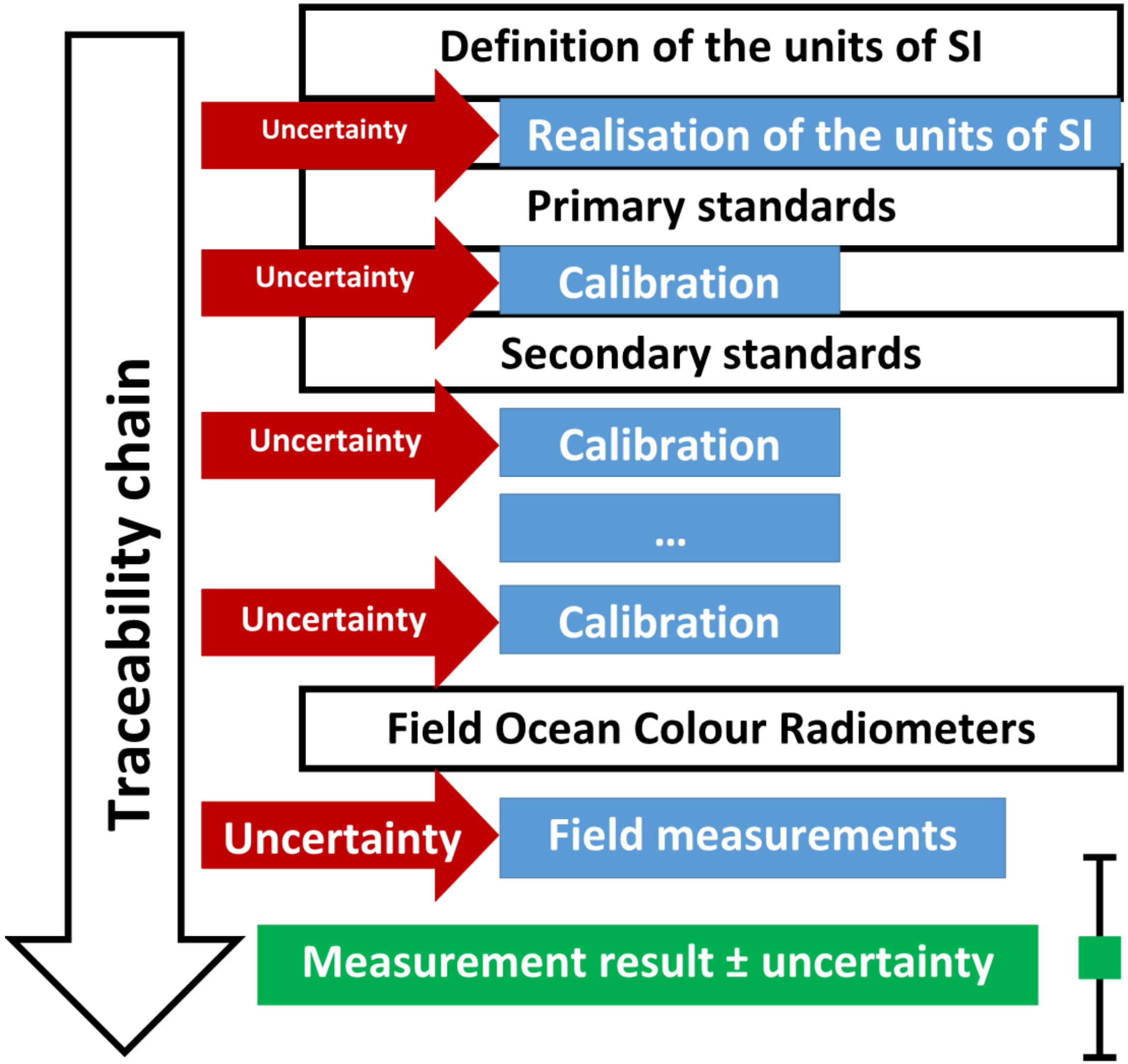
- have documented **traceability to SI** (calibration, comparison);
- be **independent from the satellite retrieval process**;
- have evaluated **uncertainty budgets** for all FRM instruments and measurements procedures available and maintained;
- defined and adhered **protocols/community-wide management practices** (measurement, processing, archive, documents etc.);
- be openly and freely available for independent scrutiny.

Objectives of FRM4SOC

- Establish and maintain **SI traceability** of ground-based FRM for satellite Ocean Colour Radiometry with relevant **uncertainty budgets**

- Set up the **protocols** for an international ongoing reference measurement system for the validation of satellite ocean colour.

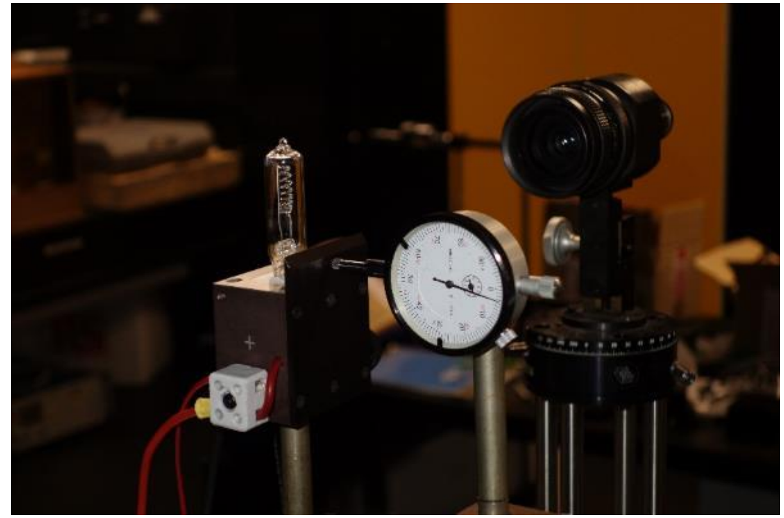
- Support that the ESA Sentinel satellite measurements of ocean colour (MSI on Sentinel 2 and OLCI on Sentinel 3) are of the highest quality possible


Traceability chain
Definition of the units of SI
Uncertainty
Realisation of the units of SI
Primary standards
Uncertainty
Calibration
Secondary standards
Uncertainty
Calibration
...
Uncertainty
Calibration
Field Ocean Colour Radiometers
Uncertainty
Field measurements
Measurement result ± uncertainty

esa fiducial reference measurements for satellite ocean colour CEOS

LCE-1

3 – 7 April 2017
at NPL, Teddington, UK
Comparison of Reference Irradiance Sources

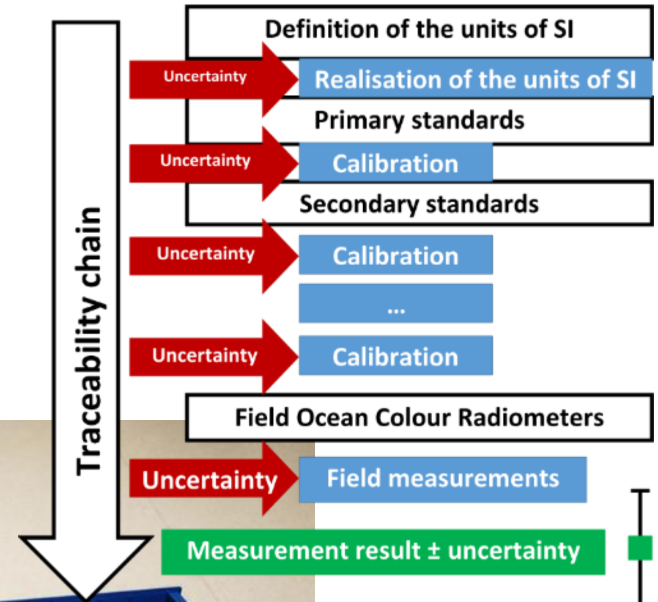


Participants
National Physical Laboratory, UK
Tartu Observatory, Estonia
European Commission – DG Joint Research Centre
Laboratoire d’Océanographie de Villefranche, France
Satlantic, Canada Sea Bird Scientific
Cimel Electronique S.A.S., France
In-situ Marine Optics, Australia
Commonwealth Scientific and Industrial Research Organisation, Australia
Norsk Institutt for Vannforskning, Norway
Natural Environment Research Council’s Field Spectroscopy Facility, UK
National Oceanic and Atmospheric Administration, USA
Remote Sensing Technology Institute, Deutsches Zentrum für Luft und Raumfahrt, Germany

University of Tartu Tartu Observatory · ACRI ST · PML Plymouth Marine Laboratory · NPL National Physical Laboratory · museum fiducial reference measurements for satellite ocean colour

Calibration of radiometers

TO calibrated all participating radiometers prior to each comparison exercise.



UNIVERSITY OF TARTU Tartu Observatory · ACRI ST · PML Plymouth Marine Laboratory · NPL National Physical Laboratory · museum

LCE-2, 8 – 13 May 2017 at TO, Tõravere, Estonia

13 organisations from 8 countries

ESA
TO (EE), pilot
AWI (DE)
CIMA (PT)
Cimel (FR)
CNR (IT)
HZG (DE)
NPL (UK)
PML (UK)
RBINS (BE)
Satlantic (CA)
UT (EE)
UVIC (CA)

esa

fiducial reference measurements for satellite ocean colour

CEOS

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Participants measured the targets under controlled laboratory conditions

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ACRI ST

PML | Plymouth Marine Laboratory

NPL National Physical Laboratory

museum

LCE-2, 8 – 13 May 2017 at Lake Kääriku, Estonia

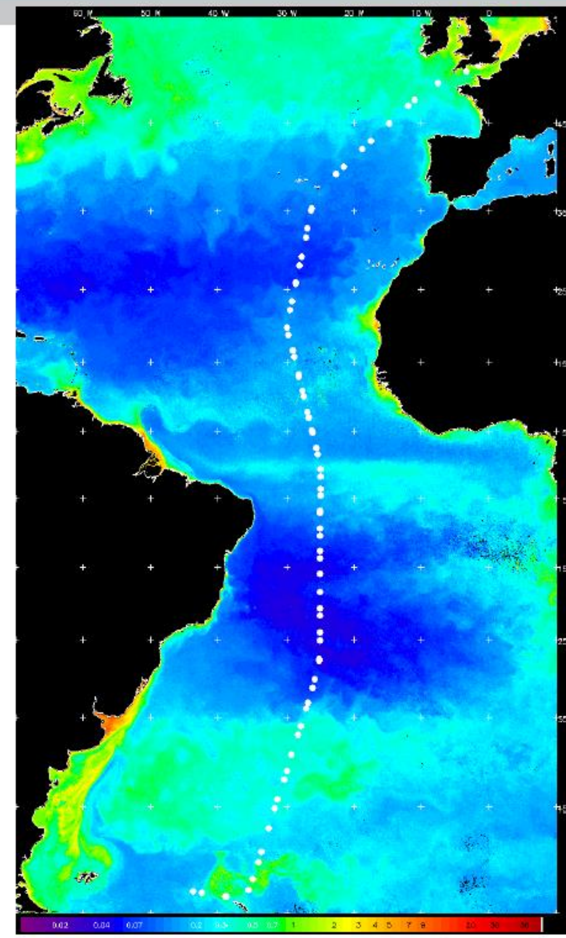
Similar comparison in outdoor conditions.

fiducial reference measurements for satellite ocean colour

PML | Plymouth Marine Laboratory

FICE-AMT: Update.

Personnel joined ship: **18 Sept 2017.**
Sailed from Southampton: **23 Sept 17.**
RBINS & TO Azores: **29 Sept 17.**
Disembark Falkland Islands: **5 Nov.**
Equipment return to UK: **Jan 2018.**



VIIRS CI composite 19 Sept – 9 Nov 2017.

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NPL National Physical Laboratory
museum

FICE Acqua Alta Oceanographic Tower (AAOT)

Gulf of Venice, Italy.

8-18 July 2018.

1.	Martin Ligi	University of Tartu, Tartu Observatory, Estonia
2.	Martin Hieronymi	Institute for Coastal Research (HZG), Germany
3.	Davide D'Alimonte	Institute - CIMA U. Algarve, Portugal
4.	Astrid Bracher	Alfred-Wegener-Institute Helmholtz Center for Polar and Marine Research, Germany
5.	Maycira Costa	University of Victoria, Canada
6.	Kevin Ruddick	RBINS, Belgium
7.	Matthew Beck	RBINS, Belgium
8.	Giorgio Dall'Olmo	Plymouth Marine Laboratory, UK
9.	Gavin Tilstone	Plymouth Marine Laboratory, UK
10.	Vincenzo Vellucci	LOV, France
11.	Tania Casal	ESA
12.	Dieter Vansteenwegen	Flemish Marine Institute (VLIZ), Belgium

➔ ACHIEVEMENTS

The FRM4SOC consortium organized a set of events to establish and maintain SI traceability of Fiducial Reference Measurements for satellite ocean colour radiometry.
The results and findings of these activities were formulated in technical reports (TR), proceedings (PROC) and a roadmap (SOR) available at the webpage
https://frm4soc.org

MEASUREMENT REQUIREMENTS AND PROTOCOLS

The FRM4SOC consortium reviewed common fiducial reference measurement (FRM) ocean colour radiometers (OCR) used for Satellite OCR validation and worked out requirements and protocols for operating these measurements. The reports were discussed with instrument manufactures and scientist users to arrive at final consensus. See details in TR-1 and TR-2.

TR-1 "Measurement Requirements and Protocols when Operating Fiducial Reference Measurement (FRM) Ocean Colour Radiometers (OCR) for Satellite Validation"

TR-2 "A Review of Commonly used Fiducial Reference Measurement (FRM) Ocean Colour Radiometers (OCR) used for Satellite OCR Validation"

Contact:
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WKP-1

21.–23.02.2017 ESA/ESRIN, Frascati, Italy

Workshop "Options for future European satellite OCR vicarious adjustment infrastructure for the Sentinel-3 OLCI and Sentinel-2 MSI series"

Consensus on the way forward to ensure the highest Copernicus Ocean Colour products quality through System Vicarious Calibration was reached. See details in PROC-1 and TR-10.

PROC-1 "Proceedings of the international workshop on system vicarious calibration"

TR 10 "Requirements and recommendations for infrastructure required for the long-term vicarious adjustment of the Sentinel-3 OLCI and Sentinel-2 MSI A/B/C and D instruments"

Contact:
Christophe Lerebourg
christophe.lerebourg@acri-st.fr

LCE-1

3.–7.04.2017 NPL, Teddington, UK

SI-traceable laboratory comparison experiment for FRM OCR. Verification of reference irradiance and radiance sources.

NPL led international comparisons of (a) irradiance sources and (b) the radiance measurement capability of laboratories that calibrate ocean colour radiometers. The irradiance comparison was held at NPL using the Spectral Radiance and Irradiance Primary Scales (SRIPS) facility and the radiance comparison via am international round robin using transfer radiometers. See details in TR-3a, TR-3b and TR-4.

TR-3a,b "Protocols and Procedures to Verify the Performance of Reference Irradiance (a) and Radiance (b) Sources used by Fiducial Reference Measurement Ocean Colour Radiometers for Satellite Validation"

TR-4 "Results from the First FRM4SOC Reference Radiance and Irradiance Source Verification Laboratory Calibration Experiment Campaign"

Contact:
Agnieszka Bialek, agnieszka.bialek@npl.co.uk
Andrew Clive Banks, andrew.banks@npl.co.uk

LCE-2

8.–13.05.2017 TO, Tõravere, Estonia

SI-traceable Laboratory Intercomparison Experiment to verify the performance of FRM field OCR

The LCE-2 exercise consisted SI-traceable radiometric calibration of participating radiance and irradiance spectroradiometers followed by indoor and outdoor intercomparison. The agreement between all the sensors was good in the indoor intercomparison, but the variability between the sensors increased two (radiance) to five (irradiance) times when natural targets such as sky and water were measured in outdoor conditions. See details in TR-5 and TR-6.

TR-5 "Protocols and Procedures to Verify the Performance of Fiducial Reference Measurement (FRM) Field Ocean Colour Radiometers (OCR) used for Satellite Validation"

TR-6 "Results from the First FRM4SOC Field Ocean Colour Radiometer Verification Round Robin Campaign"

Contact:
Joel Kuusk, joel.kuusk@ut.ee

FICE AMT

20.09.–04.11.2017
Atlantic Meridional Transect 27

Fiducial Inter-Comparison Experiment at the Atlantic Meridional Transect (AMT)
FICE AMT was conducted on the Atlantic Meridional Transect 27 during which PML, RBINS, and UT compared above water radiometer measurements. See details in TR-8 and TR-9.

TR-8 "Protocols and Procedures for Field Inter-Comparisons of Fiducial Reference Measurement (FRM) Field Ocean Colour Radiometers (OCR) used for Satellite Validation"

TR-9 "Results from the First FRM4SOC Field Inter-Comparison Experiment (FICE) of Ocean Colour Radiometers"

Contact:
Gavin Tilstone, ghti@pml.ac.uk

FICE AAOT

9.–19.07.2018 Gulf of Venice, Italy

Fiducial Inter-Comparison Experiment for Sentinel-3 at the Acqua Alta Oceanographic Tower (AAOT)

An inter-comparison was conducted at the AAOT to assess differences between eight measurement systems.
The preliminary results show that for Ed(0+, lambda), Lsky(Lambda) and Lt(Lambda) there was generally good agreement with differences of <5% between institutes. Differences were greater for Rrs.
See details in TR-8 and TR-9.

Contact: Gavin Tilstone, ghti@pml.ac.uk

WKP-2

5.–6.10.2018 NPL, Teddington, UK

Workshop "The Fiducial Reference Measurement Network for Satellite Ocean Colour"

The major recommendations and findings of the FRM4SOC project were presented.
The Scientific and Operational Roadmap for future FRM activities was formulated. See details in SOR and PROC-2.

SOR "FRM4SOC Scientific and Operational Roadmap"

PROC-2 "Special issue of MDPI journal Remote Sensing (ISSN 2072-4292) "Fiducial Reference Measurements for Satellite Ocean Colour"

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Andrew Clive Banks, andrew.banks@npl.co.uk

FRM4SOC Final Workshop

The Future of Fiducial Reference Measurements for Satellite Ocean Colour

National Physical Laboratory (NPL)
Teddington, London, UK.
4. - 5. October 2018

Conclusions – 1. Implementing FRM

1. Measurement results collected for EO data validation shall have metrological **traceability to the units of SI with related uncertainty evaluation**.

2. Space agencies should:

   i. in the medium term, **encourage and stimulate the adoption of FRM** requirements, and

   ii. in the **long term**, when sufficient progress and consensus is achieved, **use only FRM** for the routine validation of satellite ocean colour data.

3. Space agencies and National Metrology Institutes should consider forming a **symbiotic relationship** in order to **harmonise approaches, methodologies** and **implement** the principles of **FRM worldwide**.

4. **Financial support** from ESA and other space agencies or entities shall be ensured for implementing the principles of FRM.

Conclusions – 2. Methods, protocols, procedures, and uncertainty budgets.

1. **International worldwide cooperation on all levels** (e.g. agencies, research institutes, experts, etc.) is imperative in order to ensure high quality global climate data. Different protocols existing for OCR data validation all over the world shall be harmonised, understood and applied uniformly.
2. **Data and expertise collected over years** by the international community shall be **acknowledged**, preserved and **passed to next generations**.
3. Principles of **best practice** in performing measurements **shall be documented** and encouraged for application.
4. Practical consolidated **examples on compiling uncertainty budgets** shall be provided.
5. **Established methods**, principles of best practice, and uncertainty budgets and **shall be validated in comparison measurements**.
6. Definition, adoption and validation of the principles of best practice and uncertainty budgets shall be supported with **appropriate funding** from ESA and other space agencies or entities.

Conclusions – 3a. Properties of OCR

1. **Properties of OC radiometers** must **reflect the needed accuracy** for Satellite OCR data validation and **correspond to requirements** as identified and established by the international community in the field. Community **consensus on practically feasible requirements** is aimed however, the principles of metrology – traceability and acceptable uncertainty limits – must be followed.
2. **A document setting minimum requirements** for most important properties of **radiometric instruments used for satellite OCR** validation is needed. Preparation of such document should be encouraged and funded by ESA and other space agencies or entities.
3. **Vital components and specifications for new generation** (e.g. hyperspectral) **instruments** shall be identified and characterisation capabilities of required metrology infrastructure shall be developed accordingly.

Conclusions – 3b. Properties of OCR

4. ESA and other **space agencies** or entities should **encourage further development of OCR instruments**, including a requirement that such developments provide FRM-compatible information on radiometer characterisation.

5. Characterisation and regular calibration of OCR is needed in order to ensure traceability to the units of SI and evaluate the instrument related uncertainty contributions.

6. ESA and other **space agencies or entities should fund and encourage activities** to test radiometers from all manufacturers according to standardised methodology.

Conclusions 4. – Comparison experiments

1. **Periodic comparison experiments** are essentially needed for validation of established methods and uncertainty budgets on **all levels of the traceability chain**.
2. Comparison experiments also serve the purpose of **training, sharing experience**, and support achievement of **common** understanding and interpretation of the measurement protocols.
3. Application of **unified data handling or a community processor** will reduce overall uncertainty and improve agreement between individual datasets.
4. **Worldwide international participation** of agencies and research organisations in comparison exercises should be aimed.
5. ESA and other **space agencies or entities shall encourage and support implementing of comparison experiments with appropriate funding**.

Conclusions – 5. SVC infrastructures

1. **Operational SVC infrastructures are mandatory.** SVC infrastructure shall be redundant in order to ensure steady and sufficient data provision.

2. **Two SVC sites should be operated in Europe** to ensure the long-term quality of Copernicus products.

3. European SVC site BOUSSOLE should be maintained and upgraded to full operational status while a second site should be implemented.

Contact information and updates

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European Union Regional Development Fund

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