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.

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
LCE-1
3 – 7 April 2017
at NPL, Teddington, UK
Comparison of Reference Irradiance Sources

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

To calibrated all participating radiometers prior to each comparison exercise.
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)
Participants measured the targets under controlled laboratory conditions.

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

Similar comparison in outdoor conditions.
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.
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
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 manufacturers and scientists 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: Kevin Rudnick, krudnick@nationalsciences.be

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

FICE AAOT
5 – 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 measurement systems.

The preliminary results show that for Edith, Lambdula, Cylk(Lambdula) and L1(Lambdula) there was generally good agreement with differences of less than 5% between institutes. Differences were greater for Rrs.

Contact: Gavin Tilstone, gth@pmf.ac.uk

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 PMF, RBNS, and UT compared above water radiometer measurements.

See details in TR 6 and TR 5.

TR-6 “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, gth@pmf.ac.uk

WKP-1
21 – 23.02.2017 ESAESRM, 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/D instruments”

Contact: Christophe Lerebourg christophe.lerebourg@aoa-sdt.fr

WKP-2
5 – 6.10.2018 NPL, Teddington, UK
The major recommendations and findings of the FRM4SOC project were presented. See details in SOR and PROC-2.

SOR “FRM4SOC Scientific and Operational Roadmap”


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

LCE-1
3 – 7.04.2017 NPL, Teddington, UK
SI-traceable laboratory comparison experiment for FRM OCR, Verification of reference irradiance and radiance sources.
UK, but international comparison 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 Standard (SPRS) facility and the radiance comparison via an international round robin using transfer radiometers. See details in TR 6. TR 7 and TR 8.

TR-7a “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 Blaèe, agnieszka.blaee@npl.co.uk
Andrew Clive Banks, andrew.banks@npl.co.uk

LCE-2
8 – 13.05.2017 To, Tallinn, 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 intercomparisons. The agreement between all the sensors was good in the indoor intercomparison, but the variability between the sensors increased for radiance (to five times) when natural targets such as sky and water were measured in outdoor conditions. See details in TR 3 and TR-6.

TR-3 “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 Kuula, joelkuulalor@esi.ee

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Contact: Joel Kuula, joelkuulalor@esi.ee
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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