Fiducial Reference Measurements for Satellite Ocean Colour

FRM4SOC
https://frm4soc.org

04. October 2018, NPL, Teddington

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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
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
<table>
<thead>
<tr>
<th>LCE-1</th>
<th>Verification of reference irradiance and radiance sources</th>
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</thead>
<tbody>
<tr>
<td>LCE-2</td>
<td>Verification of OC radiometer performance</td>
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<td>Compilation of end-to-end uncertainty budgets</td>
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<td>FICE</td>
<td>OC Field Inter-comparison experiments</td>
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European Space Agency

organized an international workshop

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

on 21 – 23 February 2017 ESA/ESRIN, Frascati, Italy

Gallery 1 List of participants 1 Presentations you will find under Agenda

D.246 Proceedings of WKP-1 (PROC-1) Report of the international workshop

- Agenda

Workshop will be held from 21 – 23 February 2017 in Magellan room in ESRIN.

DAY 1 – Tue, 21 February 2017

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>9:00</td>
<td>Session 1 – Introduction/Workshop objectives (Chair C. Loresboug &amp; M. Lewis)</td>
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<td>Why this workshop and why at this particular moment. Review of satellite constellation (note: new)</td>
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<td>Definition of the system vicarious calibration requirements for the EC's Copernicus programme</td>
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<td></td>
<td>Review of historical and contemporary approaches for vicarious adjustment, general requirements</td>
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The first round table seminar with manufacturers of Ocean Colour Radiometers was held on 6-th September 2017 at ESTEC.

It would be beneficial to continue this initiative and establish an OCR forum in a form of series of seminars.
Uncertainty Budgets for Fiducial Reference Measurement Ocean Colour Radiometers

- Uncertainty Budgets of FRM4SOC Fiducial Reference Measurement (FRM) Ocean Colour Radiometer (OCR) systems used to Validate Satellite OCR products
  - Follows the Guide to the expression of Uncertainty in Measurement (GUM).
  - Comparison is a validation of evaluated uncertainty budgets
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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<tr>
<td>Satlantic, Canada</td>
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<tr>
<td>Sea Bird Scientific</td>
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<td>Cimel Electronique S.A.S., France</td>
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<tr>
<td>In-situ Marine Optics, Australia</td>
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<td>Commonwealth Scientific and Industrial Research Organisation, Australia</td>
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<tr>
<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 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
FRM4SOC Final Workshop
The Future of Fiducial Reference Measurements for Satellite Ocean Colour
National Physical Laboratory (NPL)
Teddington, London, UK.
4. - 5. October 2018
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 Ruddick, krud@naturalsciences.be

FICE AAOT
9 – 10.07.2018 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 EQioa, Lambda, Lskioa(Lambda) and Lskioa(Lambda) there was generally good agreement with differences of less than 5%. Differences were greater for Rs.
See details in TR-8 and TR-9.
Contact: Gavin Tilstone, gtil@pml.ac.uk

FICE AMT
28.05. – 01.06.2017
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, RBNS, and UEL 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, gtil@pml.ac.uk

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

WKP-1
21 – 23.02.2017 ESAESRIN, 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@esa.int

LCE 1
3 – 7.04.2017 NPL, Teddington, UK
SI-traceable laboratory comparison experiment for FRM OCR. Verification of reference irradiance and radiance sources. WPL led 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 Sources (SPRPS) facility and the radiance comparison was an International Round Robin using transfer radiometers. See details in TR-3a and TR-4.
TR-3a “Protocols and Procedures to Verify the Performance of Radiance (a) and Irradiance (b) Sources used by National 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 Bialk, agnieszka.bialk@pml.ac.uk
Andrew Clive Banks, andrewbanks@pml.ac.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 intercomparisons, but the variability between the sensors increased upon radiometric (radiance) to field (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@tsi.ee
Scientific Operational Roadmap

Panel Discussion Session
Towards FRM for all validation of satellite ocean colour data – a scientific roadmap
Chair: C. Donlon & T. Casal
Contact information and updates

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