

Fiducial Reference Measurements for Satellite Ocean Colour Phase-2

Requirements for Instrument Manufacturers Towards FRM Compliance

Appendix 1. Concise list of FRM requirements for OCR manufacturers

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Acronyms and Abbreviations

Acronym	Description
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FRM	Fiducial Reference Measurements
FRM4SOC	Fiducial Reference Measurements for Satellite Ocean Colour
GEO	Group on Earth Observations
IOCCG	International Ocean-Colour Coordinating Group
IOCCG JiAR	Addendum (June 2024) to IOCCG Protocol Series (2019) Volume 3
ISO	International Standards Organisation
NMI	National Metrology Institute
OC	Ocean Colour
OCDB	Ocean Colour Database
OCR	Ocean Colour Radiometer
RMANU	FRM Requirements Document for Instrument Manufacturers
QA4EO	Quality Assurance framework for Earth Observation

1 Introduction

1.1 Scope of the document

The document is an appendix to the FRM4SOC Phase 2 Technical Guide D-27 and includes a concise summary of the main document with amendments from the conclusions of the Second FRM4SOC Phase 2 Workshop on Calibration and Characterisation of Ocean Colour Radiometers (OCR) held at the University of Tartu, Estonia, from 20 to 22 May 2025.

The objective of the document is to specify the minimum instrument-related requirements under the responsibility of the manufacturer in laying the foundation for Fiducial Reference Measurements (FRM) and clarify the requirements listed in the main part of D-27.

While the FRM4SOC-2 project focuses primarily on the two models of TriOS-Ramses and SeaBird-HyperOCR, the present document is generic enough to cover both these two models and probably all present and future OCR models. The process for the inclusion of any new OCR models as FRM is simply to satisfy these requirements.

The document's target public is an OCR instrument manufacturer whose customers may be interested in making Fiducial Reference Measurements.

2 Applicable documents

- [1] IOCCG Protocol Series (2019). Protocols for Satellite Ocean Colour Data Validation: In Situ Optical Radiometry. Zibordi, G., Voss, K. J., Johnson, B. C. and Mueller, J. L. IOCCG Ocean Optics and Biogeochemistry Protocols for Satellite Ocean Colour Sensor Validation, Volume 3.0, IOCCG, Dartmouth, NS, Canada. <http://dx.doi.org/10.25607/OBP-691>
- [2] Addendum (June 2024) to IOCCG Protocol Series (2019) Volume 3: Request to manufacturers of in situ and above-water spectral imaging radiometers in the UV, VIS and NIR range, (IOCCG JiAR)
- [3] P. Goryl, N. Fox, C. Donlon, and P. Castracane, Fiducial Reference Measurements (FRMs): What Are They?, Remote Sensing, vol. 15, no. 20, Art. no. 20, Jan. 2023, doi: 10.3390/rs15205017.
- [4] FRM4SOC-2, Reflectance Measurement Requirements Document (RMRD), Deliverable D-2, April 2023, <https://frm4soc2.eumetsat.int>
- [5] FRM4SOC-2, FRM Requirements Document for Instrument Manufacturers (RMANU), Deliverable D-27, May 2023, <https://frm4soc2.eumetsat.int>
- [6] Nigel, Fox, Ed. Marie-Claire Greening QA4EO guide: QA4EO-QAEO-GEN-DQK-007, A guide to establishing quantitative evidence of traceability to underpin the Quality Assurance requirements of GEO, QA4EO, V4.0. 27.03.2010.

3 Minimum requirements for the manufacturers of OCR

The IOCCG JiAR [2] defines the essential set of requirements for the manufacturers of OCR:

- i. Provide absolute calibration coefficients with associated **uncertainties**.
- ii. Participate in **comparison experiments** with national metrology institutes and/or secondary calibration laboratories.
- iii. Help to **propagate FRM guidelines, procedures and tools**.

4 Guidelines and recommendations for the manufacturers of OCR to achieve FRM

To ensure compliance with the FRM requirements, continuous and effective communication must be maintained between the manufacturers of OCR and the OC community.

4.1 Providing uncertainties

The IOCCG JiAR [2] request addresses providing uncertainties for OCR calibration coefficients. However, it does not require manufacturers of OCR to perform a full characterisation of each instrument [4], [5].

Very few instrument manufacturers can provide the required detailed characterisations listed in [4], although some may be available on request. The provided calibration certificates and test protocols shall include the statement of uncertainties from the laboratory performing the calibration or characterisation.

These characterisations often require very specialised laboratory facilities and staff, and the implementation can be extremely time-consuming and hence costly per instrument. If not ordered by customers, they will obviously not be performed. If not required by sufficient customers (in this very low-volume market), they will not even be available on request. Therefore, full characterisation of OCR with extensive uncertainty analysis of the results is not expected from manufacturers. However, it is still encouraged to develop characterisation capabilities for some of the most significant uncertainty sources, such as angular response and non-linearity of OCR. Manufacturers of OCR systems must be able to demonstrate their ability to provide high-quality angular diffusers. The choice of a suitable material, such as fused silica, is of great importance. Such ability involves maintaining a laboratory for the characterisation of angular diffusers, and also publishing papers and reports on results.

Manufacturers of OCR must be able to address a maximum uncertainty level that a user would consider when buying the instrument. For example, having the capability to evaluate uncertainty contributions, giving the largest contribution (~3%...10%) to the overall uncertainty budget.

4.2 Maintaining a quality management system

While all instrument manufacturers have an associated calibration laboratory, either in-house or at a nearby dedicated subcontractor facility, such laboratories are not always ISO 17025 compliant. It is noted that to comply with the FRM requirements, the formal accreditation of such a laboratory to ISO 17025 is not strictly required. However, the laboratory must follow the requirements of ISO 17025 and must be ready to provide proof of that at all times [3], [5], [6]. Regular participation in comparison experiments is an essential tool to achieve this.

4.3 Recommendations on instrument design

Whereas the main part of the D-27 lists the *requirements* that must be met for achieving FRM quality, this appendix provides some *recommendations* for manufacturers of OCR, particularly for the case of the design of new radiometers. These recommendations are based largely on lessons learned from the detailed analysis that has been made of the performance of the current generation of commercially available OCR.

The following recommendations for manufacturers on the instrument design are proposed as listed in the main part of the D-27:

- Materials used for the construction of the principal parts of OCRs shall be optically and thermally stable in the full range of the operating conditions.
- The internal optical, mechanical and electronic components shall continuously withstand the specified temperature limits.
- Recommended operating conditions: from 0 °C up to 50 °C
- Internal heat load of OCRs shall be as small as possible and shall not significantly depend on operating mode
- OCRs shall contain all construction elements needed for the effective use of instruments:

- Temperature control of the optical sensor (stabilised to a certain temperature in the range of 5 °C to 10 °C) or
 - Internal thermal sensor in the vicinity of the optical sensor (for OCRs without temperature control)
 - Reliable method for the measurement of the dark signal; for example, the entrance optics shall be occulted via a shutter or a cap
- Maximum permissible errors of some parameters of OCRs shall meet the principal requirements of IOCCG Recommendations or equivalent, especially:
 - For the angular response (cosine collector)
 - For the accuracy of integration times
 - For the polarisation sensitivity
- The OCR specification shall include a description of the complex effect of operating conditions in case inter-dependence of parameters is present - e.g. dark signal shall be presented as a function of temperature and integration time. For long integration times, the applicable upper temperature limit is lower than for the short times.
- Raw data from the sensor shall be available (all pixels, temperature, etc.) for instrument users
- The instrument communication protocol shall be fully described
- Teflon (PFTE) diffusers shall be avoided (because of temperature-dependent optical properties).

The following recommendations were also noted at the Second Workshop on Calibration and Characterisation of OCR.¹

- Ensuring the quality of the OCR components that define the radiometric and metrological performance of the instruments (such as the input optics, spectrometer module, image sensor, signal amplifier & conditioner, analogue-to-digital converter and voltage references) should be the top priority in product development. Enhanced communication means (such as web servers) do not improve the achievement of FRM quality, but add complexity and power consumption.
- Manufacturers of OCR systems should be able to demonstrate their ability to provide high-quality angular diffusers. The choice of a suitable material, such as fused silica, is of great importance.
- Such ability involves maintaining a laboratory for the characterisation of angular diffusers, and also publishing the results.
- Full characterisation of OCR, with extensive analysis of the results, is not typically expected from manufacturers; however, it is still encouraged.
- Manufacturers of OCR could address a maximum uncertainty level that a user would consider acceptable when purchasing the instrument. For example, having the capability to evaluate uncertainty contributions, giving the largest contribution (~3...10%) to the overall uncertainty budget.
- The maximum permitted working temperature for an OCR should be higher than +40 °C. The radiometers may have higher temperatures in field conditions.
- The communication protocol with instruments should be kept simple and straightforward (e.g., a single command to start the acquisition with a defined integration time, gain, etc., and after completion of the measurement, to return the raw data from all available pixels, temperature sensors, etc.).
- Internal automatic application of calibration coefficients and corrections should be avoided.
- Maintaining the 12 V operating voltage (supported by a wider range) is preferred.
- Simple shape form factor (e.g. cylindrical) is favoured for adjustment accuracy and repeatability.

¹ FRM4SOC-2, Proceedings of the Second Workshop on Calibration and Characterisation of Ocean Colour Radiometers, 20 - 22 May 2025, Tartu Observatory, University of Tartu, Tõravere, Estonia, Deliverable D-23b, 2025, <https://frm4soc2.eumetsat.int>