fiducial reference measurements for satellite ocean colour

→ FRM4SOC 2016 - 2018

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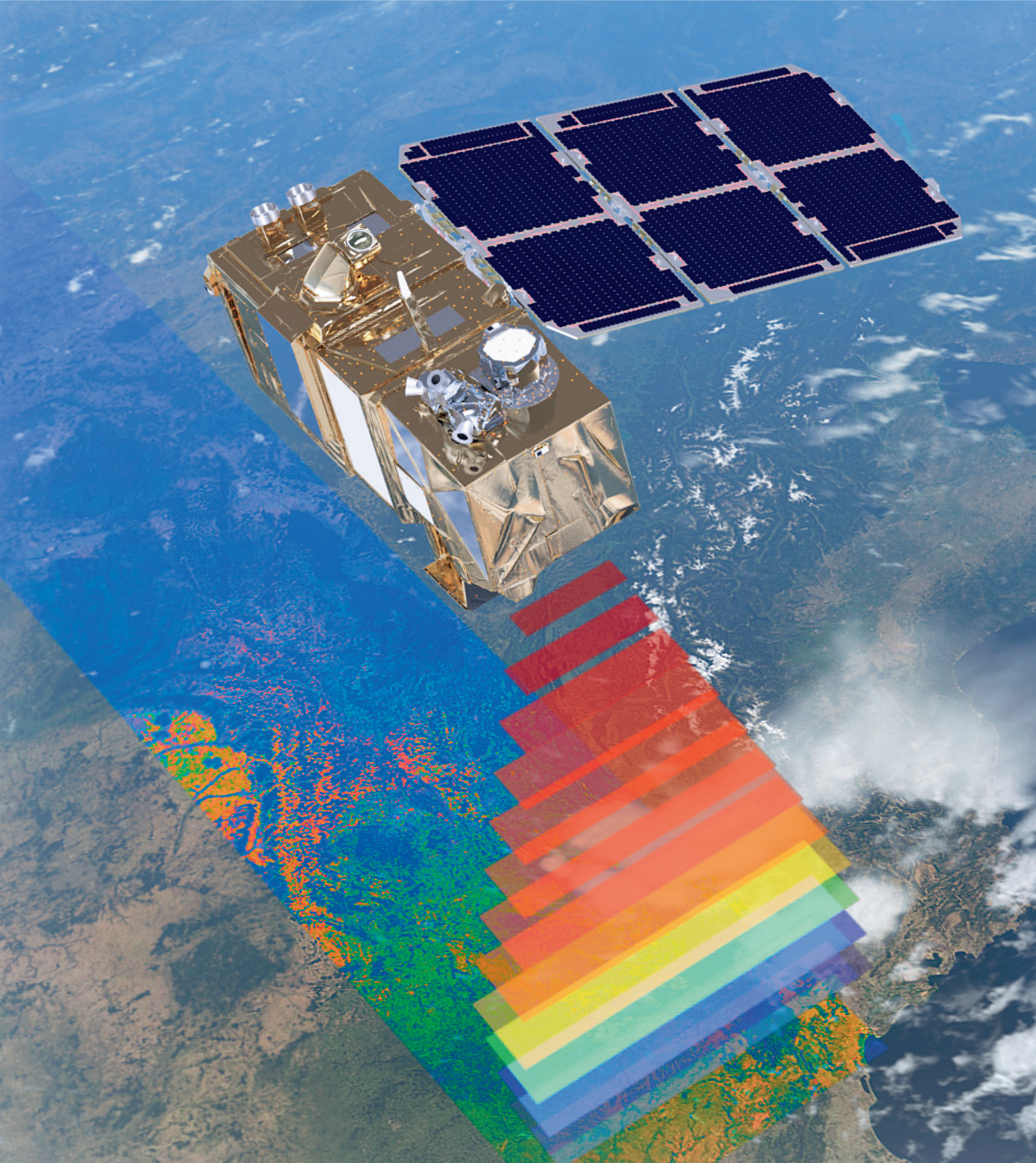
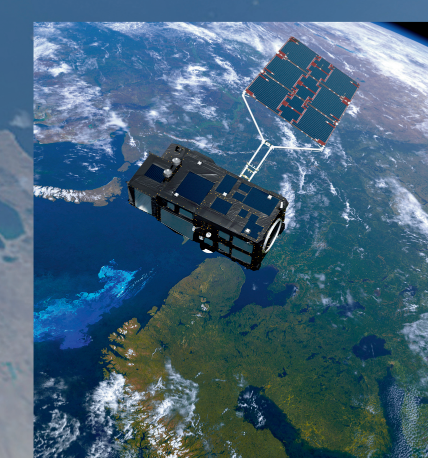


The FRM4SOC project, with funding from ESA, has been structured to provide support for evaluating and improving the state of the art in ocean colour validation through a series of comparisons under the auspices of the Committee on Earth Observation Satellites (CEOS) Working Group on Calibration & Validation and in support of the CEOS ocean colour virtual constellation. FRM4SOC also strives to help fulfil the International Ocean Colour Coordinating Group (IOCCG) in situ ocean colour radiometry white paper objectives and contribute to the relevant IOCCG working groups and task forces (e.g. the working group on uncertainties in ocean colour remote sensing and the ocean colour satellite sensor calibration task force).

The aim of the FRM4SOC project is to establish and maintain SI traceability of Fiducial Reference Measurements (FRM) for satellite Ocean Colour Radiometry (OCR) with accompanying uncertainty budgets.



Revealing the colour of ocean life.
Released 13/01/2016 10:49 am. © ESA/ATG medialab

Colour vision for Copernicus.
Released 11/02/2015 2:42 pm. © ESA/ATG medialab

→ SCIENTIFIC BACKGROUND

"Those responsible for studies of Earth resources, the environment, human wellbeing and related issues ensure that measurements made within their programs are in terms of well-characterized SI units so that they are reliable in the long term, are comparable world-wide and are linked to other areas of science and technology through the world's measurement system established and maintained under the Convention du Mètre."

Resolution 1 of the 20th Conférence Générale des Poids et Mesures (1995).

The Committee for Earth Observation Satellites (CEOS) define

Calibration as "the process of quantitatively defining a system's responses to known, controlled signal inputs".

Validation, on the other hand, is "the process of assessing, by independent means, the quality [uncertainty] of the data products derived from those system outputs".

Validation is a core component of a satellite mission and should be planned for accordingly starting at the moment satellite instrument data begin to flow until the end of the mission.

VIM: International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM) states

Adjustment is "set of operations carried out on a measuring system so that it provides prescribed indications corresponding to given values of a quantity to be measured".

Adjustment of a measuring system should not be confused with calibration, which is a prerequisite for adjustment.

Calibration and Validation of Satellite Ocean Colour Sensors

Accurate radiometric calibration and characterization of the individual satellite sensors is the most critical component toward achieving the goal of consistent, long-term multi-mission Ocean Colour products. Once on-orbit, the uncertainty characteristics of the satellite instruments established during pre-launch laboratory calibration and characterization activities and the end-to-end geophysical measurement retrieval process can only be assessed via independent calibration and validation activities.

Ground Measurements

Ground measurements are essential to Ocean Colour remote sensing for:

- Vicarious adjustment of L2 products;
- Continuous assessment of OCR quality (i.e., validation of normalized water leaving radiance or the equivalent remote sensing reflectance);
- Validation of derived satellite ocean colour products (e.g., chlorophyll-a concentration);
- Development and verification of the bio-optical algorithms required for generating derived products (independent of any specific satellite mission).

Fiducial Reference Measurements

The concept of Fiducial Reference Measurements (FRM) has been established by the Sentinel-3 Validation Team (S3VT) as: "The suite of independent ground measurements that provide the maximum Return On Investment (ROI) 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 entire end-to-end duration of a satellite mission." *https://earth.esa.int/web/sppa/activities*

The defining mandatory characteristics for FRM are:

- FRM measurements have documented SI traceability (eg. via round-robin intercalibration of instruments) using metrology standards.
- FRM measurements are independent from the satellite geophysical retrieval process, noting the exception of L2 product vicarious adjustment that fundamentally depends on FRM ground based measurements.
- An uncertainty budget for all FRM instruments and derived measurements is available and maintained.
- FRM measurement protocols and community-wide management practices (measurement, processing, archive, documents etc.) are defined, published openly and adhered to by FRM instrument deployments.
- FRM measurements are openly and freely available for independent scrutiny.

BOUSSOLE mooring. BOUSSOLE is funded by the European Space Agency (ESA), the French Space Agency (CNES), the Institut National des Sciences de l'Univers (INSU), and benefits from logistical and staff support from the Laboratoire d'Océanographie de Villefranche (LOV), and the Observatoire Océanologique de Villefranche (OOV). 2015. Photos: Courtesy of the LOV, David Antoine and Vincenzo Vellucci.

→ TRACEABILITY TO SI

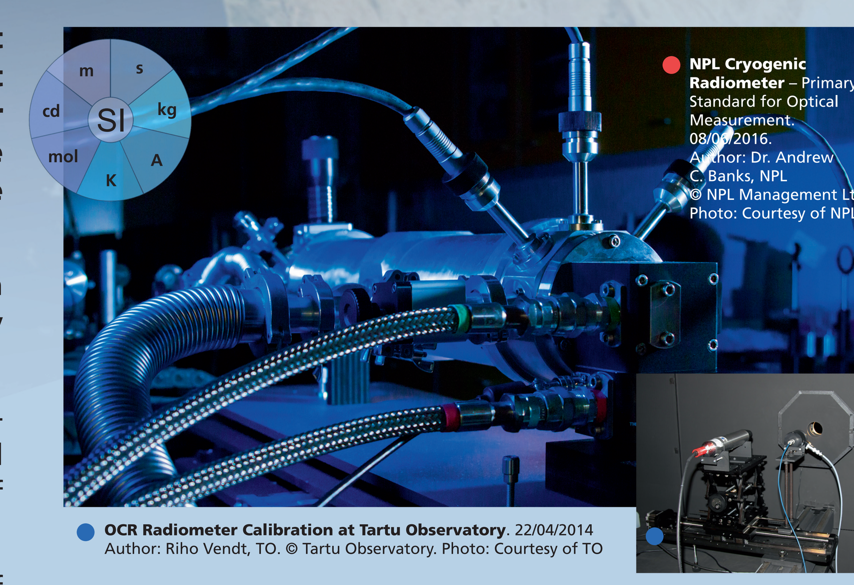
SI provides the foundation for measurement around seven base units and a system of coherent derived units. The SI units must be stable over centuries. They must also be uniform worldwide and independent of the method used to realise the unit.

The metrological community achieves this through three technical concepts: traceability, uncertainty analysis and comparison.

Metrological traceability is a property of a measurement that relates the measured value to a stated metrological reference through an unbroken chain of calibrations or comparisons.

Uncertainty analysis is the review of all sources of uncertainty and the propagation of that uncertainty through the traceability chain.

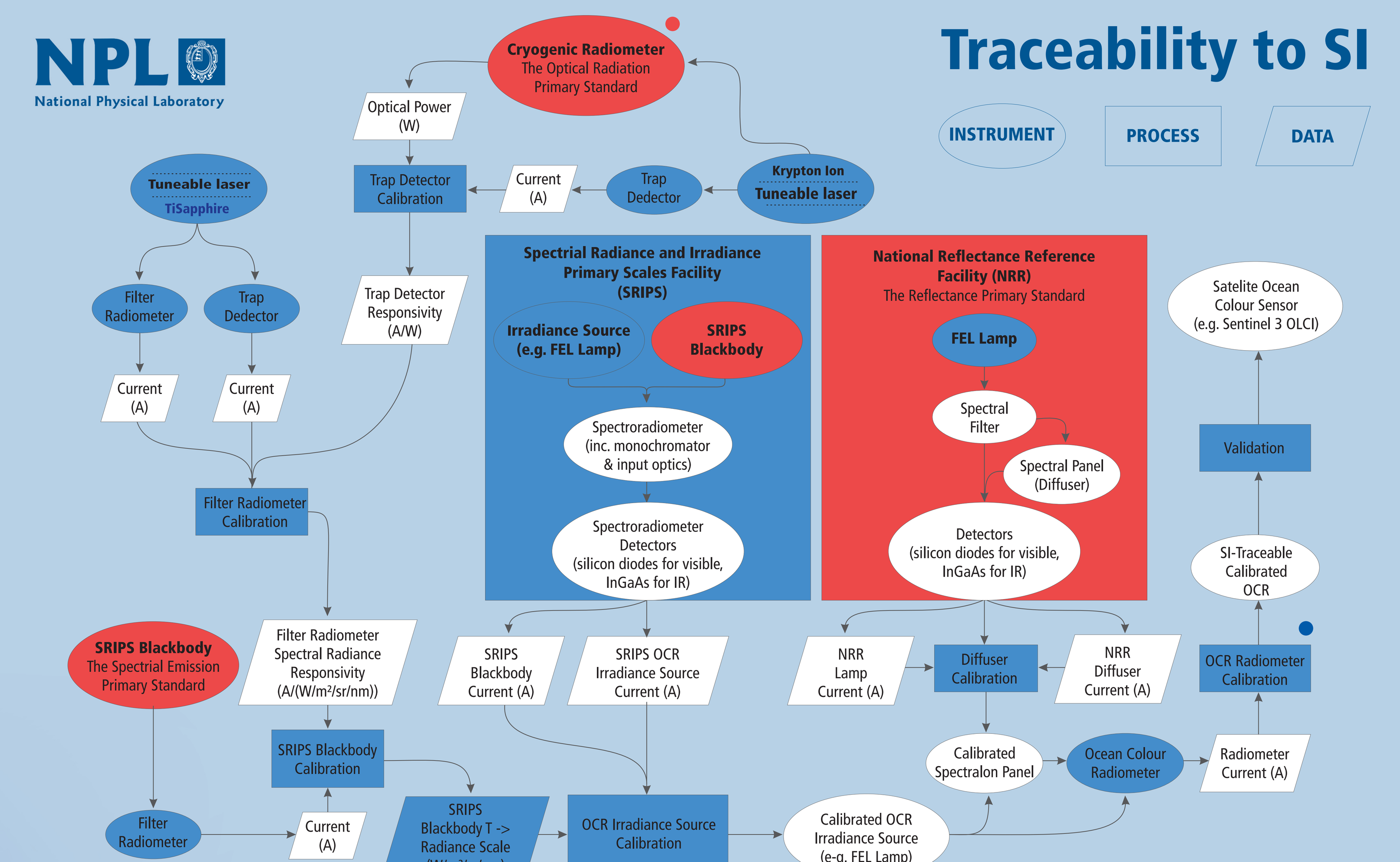
The traceability and uncertainty analysis at the NMIs is rigorously audited through the Mutual Recognition Arrangement, which also involves regular formal international comparisons (Woolliams et al., 2016).



NPL Cryogenic Radiometer – Primary Standard for Optical Measurement. 08/06/2016. Author: Dr. Andrew C. Banks, NPL © NPL Management Ltd. Photo: Courtesy of NPL

OCR Radiometer Calibration at Tartu Observatory. 22/04/2014 Author: Riho Vendt, TO. © Tartu Observatory. Photo: Courtesy of TO

For ocean colour measurements, whether they are made by satellite or in situ ocean colour radiometers, traceability to SI is achieved through an unbroken series of calibrations back to the primary standard for optical radiation: the NPL cryogenic radiometer *(photo above)*. This traceability chain is visualized for FRM4SOC in the figure below.



→ THE IMPORTANCE OF UNCERTAINTY BUDGETS

All measurements are imperfect and have errors that can be of a random nature (i.e. noise on charge coupled device detectors) or of a systematic nature.

Uncertainties arise due to many aspects that can be generally grouped into the following primary categories:

- Instrument measurement uncertainty: those relating to instrument hardware,
- Retrieval/algorithm uncertainty: those relating to derived quantities,
- Application uncertainty: those relating to a specific application,
- Unknown: those uncertainties that are "unknown".

UNCERTAINITY COMPONENTS	SELECTED SPECTRAL BANDS OF THE SENTINEL 3 OLCI SENSOR			
	400 nm	442.5 nm	490 nm	560 nm
FEL standard lamp irradiance	0.78 %	0.61 %	0.61 %	0.61 %
Interpolation of irradiance	0.2 %	0.2 %	0.2 %	0.2 %
Lamp ageing	0.28 %	0.28 %	0.28 %	0.28 %
Shunt	0.002 %	0.002 %	0.002 %	0.002 %
Lamp current	0.15 %	0.15 %	0.15 %	[illegible]
Distance lamp - sensor	0.08 %	0.08 %	0.08 %	[illegible]
Alignment of lamp position	0.1 %	0.1 %	0.1 %	[illegible]
Alignment of radiometer	0.1 %	0.1 %	[illegible]	[illegible]
Temperature variability	0.03 %	0.02 %	[illegible]	0.02 %
Expanded uncertainity, k=2	1.8 %	1.5 %	[illegible]	1.5 %

Wavelength λ [nm]

Establishing an uncertainty budget for FRM is a fundamental step that drives a better understanding of the various error sources. Reliable and well defined uncertainty budgets ensure traceability of measurement results obtained with FRM field radiometers to the units of SI when matched to satellite measurements.

The project contributes to the European system for monitoring the Earth (Copernicus) to ensure that the ground based measurements of ocean colour parameters are traceable to SI. This supports the high quality of Copernicus satellite mission data, in particular Sentinel-2 MSI and Sentinel-3 OLCI ocean colour products, and contributes to the work of ESA and EUMETSAT to ensure that these instruments are validated in orbit.

https://frm4soc.org

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