

# Fiducial Reference Measurements for Satellite Ocean Colour

FRM4SOC

Project Update for CEOS-WGCV-IVOS

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## Main aim of FRM4SOC:

To establish and maintain SI traceability of ground-based Fiducial Reference Measurements (FRM) for satellite ocean colour radiometry (OCR).

### Specific Objectives:

- Develop, document, implement and report OCR measurement procedures and protocols. It shall design, document and implement both laboratory and field inter-comparison experiments for FRM OCR radiometers to verify their FRM status.
- International coordination activities to define next generation of Ocean Colour vicarious calibration/adjustment infrastructure (FRM4SOC workshop).



## International Context

- The **FRM4SOC** project, with funding from **ESA**, has been structured to provide support for evaluating and improving the state of the art in OC validation through a series of comparisons under the auspices of **CEOS** WGCV and in support of the CEOS OCR virtual constellation.
- FRM4SOC also strives to help fulfil the **IOCCG** in situ OCR white paper objectives and contribute to the relevant IOCCG WGs and Task Forces (e.g. WG on uncertainty, ocean colour satellite sensor calibration task force); the European perspective and the importance of Copernicus and the Sentinel series of satellite sensors in general and in particular for ocean colour.

### Three types of internationally open intercomparison exercises:

1. LCE-1 For OCR Radiance and Irradiance Calibration Sources
2. LCE-2 For OCR Calibration
3. FICE for OCR field measurements

(End-to-end uncertainty evaluation for FRM4SOC carried out by NPL)





fiducial reference  
measurements for  
satellite ocean colour



## FRM4SOC International Workshop on Options and Approaches to the Long-term Vicarious Adjustment of Sentinel- OLCI & MSI A/B/C and D Instruments

- Took place at ESA-ESRIN, Frascati, Italy, 21-23 Feb, 2017
- 30+ participants from Europe, USA, Canada, Australia & S.Korea
- Included many of the world's leading experts in the field





# FRM4SOC International Workshop on Options and Approaches to the Long-term Vicarious Adjustment of Sentinel- OLCI & MSI Instruments

## General outcomes:

- Workshop reviewed and learnt from the experience of the existing reference sites for OC-SVC.

- MOBy (the Marine Optical Buoy) deployed off the Hawaiian coast since 1996;
- BOUSSOLE (Buoy for the acquisition of long-term optical times series) deployed in the Ligurian Sea since 2004.

- Converged toward a consensus for future development of OC-SVC infrastructure in Europe & the CEOS Ocean Colour Radiometry Virtual Constellation that has a Fiducial Reference Measurement (FRM)/metrological foundation.

- Gives ESA the practical evidence (supported by the data provider, data users and world class experts) needed to strongly advocate for the development and long term maintenance of cutting edge FRM systems for OC-SVC to ensure the highest possible Copernicus data quality for the coming decades.





# FRM4SOC International Workshop on Options and Approaches to the Long-term Vicarious Adjustment of Sentinel-OLCI & MSI Instruments

## Workshop consensus for the future of OC-SVC:

A good metrological foundation with 'hands-on' involvement of NMIs at all stages of development and operations is a key component

In situ radiometry needs to be hyperspectral, very high resolution and very high quality, and of an SI-traceable fiducial reference measurement nature with a full uncertainty budget and regular SI-traceable calibration

Europe should strengthen and consolidate the BOUSSOLE activity to full operations & add one new site in the Eastern Mediterranean (likely off the coast of Crete) using a MOBY-NET buoy

In the absence of necessary in-flight radiometric accuracy of a sensor there is a need to have at least 3 well-calibrated reference Buoys to ensure robust long term interoperability and CDRs

- Added to the upgrade of MOBY by the US, 2 buoys in Europe for OC-SVC will help meet the global operational redundancy requirements of the CEOS OCR virtual constellation

Long-term investment is critical – this should be a budget that recognises not only the cost of the initial purchase and installation of the infrastructure but also include adequate funding for ongoing operations in terms of updates/ upgrades, maintenance, and consistent staffing that develops and retains expertise



# Laboratory Calibration Exercise 1 (LCE-1) Update: Reference Irradiance and Radiance Sources

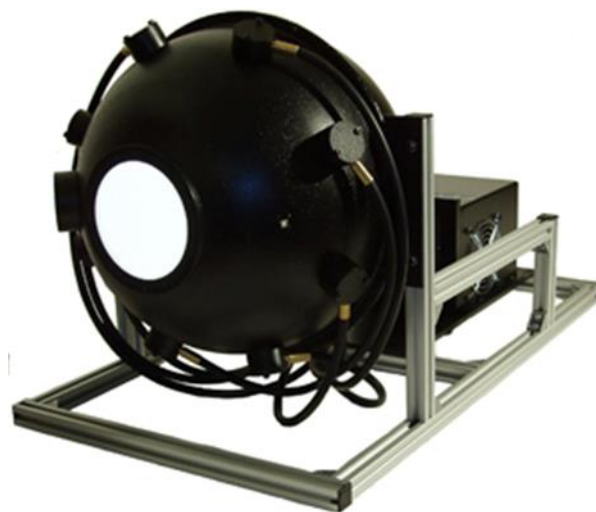
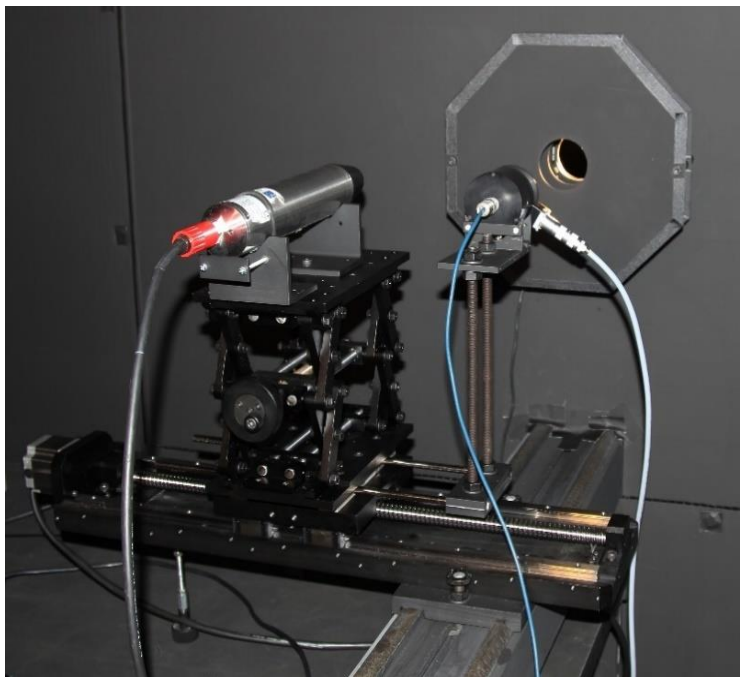
- Taking place 03-07 April 2017 at NPL.
- NPL (UK pilot) with 11 participants from around the world, including:
  - Tartu (Estonia)
  - JRC (EC)
  - NOAA (USA)
  - Satlantic (Canada)
  - CSIRO & IMO (Australia)
  - NIVA (Norway)
  - NERC (UK)
  - LOV & Cimel (France)
  - DLR (Germany)
- LCE-1 is aimed at verifying the performance of irradiance and radiance sources used to calibrate ocean colour radiometers (OCRs)
- Participants will be supplying their irradiance sources to NPL for comparison with the primary standards using the NPL Spectral Radiance and Irradiance Primary Scales (SRIPS) facility & Reference Spectroradiometer System (RefSpec)..
- Transfer radiometers will be sent back and forth to each participant lab between April and December 2017 for radiance source measurements and to compare the participant's in-house radiance sources with the NPL derived radiance scale.

## Laboratory Calibration Exercise 2 (LCE-2): Ocean Colour Radiometers (OCRs) 8 – 13 May 2017 at TO, Tõravere, Estonia

### Main objective:

Establish and document protocols and best practice to practically verify the performance of FRM OCRs through

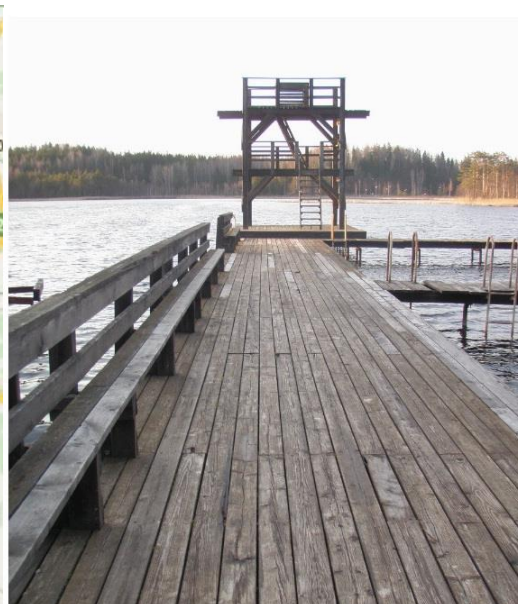
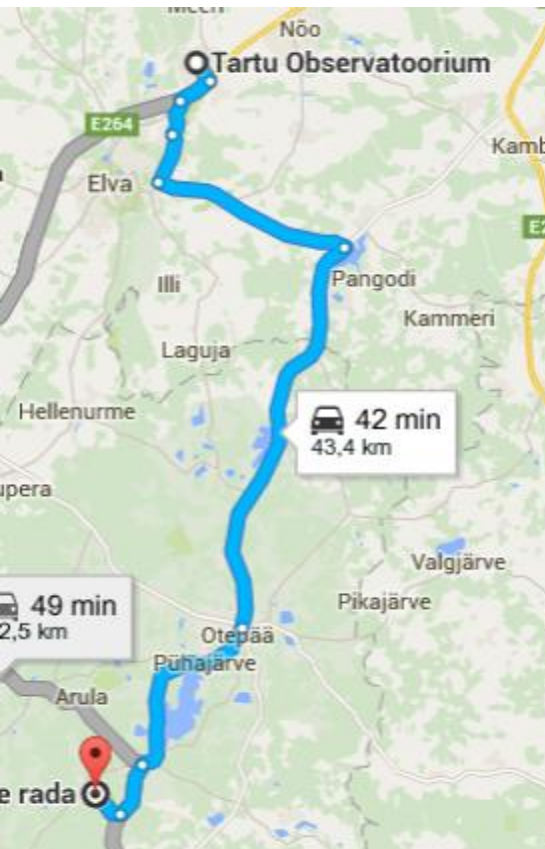
1. TO calibrates all participating radiometers
2. Participants measure the targets under controlled laboratory conditions





# LCE-2 outdoor intercomparison - Lake Kääriku, 08-13 May 2017

- Controlled outdoor environment near Tartu Observatory, Estonia



HIGHROC Oslo workshop,  
NIVA, Feb 2015



TURBINET Buenos Aires  
IAFE/RBINS, Nov 2015

## Uncertainty Budgets

for Fiducial Reference Measurement Ocean Colour Radiometers

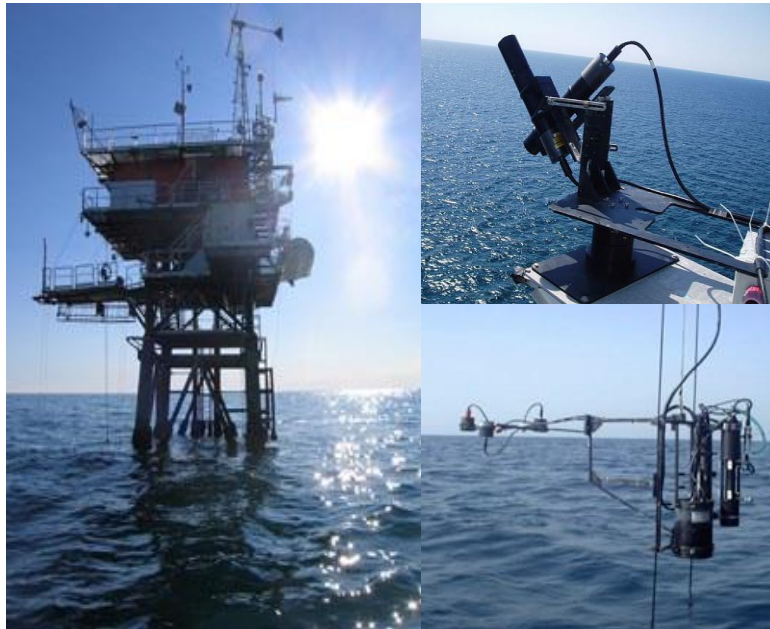
- ✓ The end-to-end uncertainty budget will be incrementally built up during the project following the schedule of the experiments:
  - ✓ NPL will characterise the uncertainty for all steps of LCE-1.
  - ✓ Tartu will characterise the uncertainty for all steps of LCE-2 and the controlled outdoor comparison experiments under the guidance of NPL.
- ✓ Data analysis will be carried out by NPL following the end of the experiments culminating in a key FRM4SOC publication.
- ✓ All uncertainty evaluation and reporting should follow the NPL defined protocols.



## FICE experiments will be conducted on two platforms:

which have a long history of satellite ocean colour validation and development during NASA and ESA missions (O'Reilly et al. 1998; Zibordi et al. 2006).

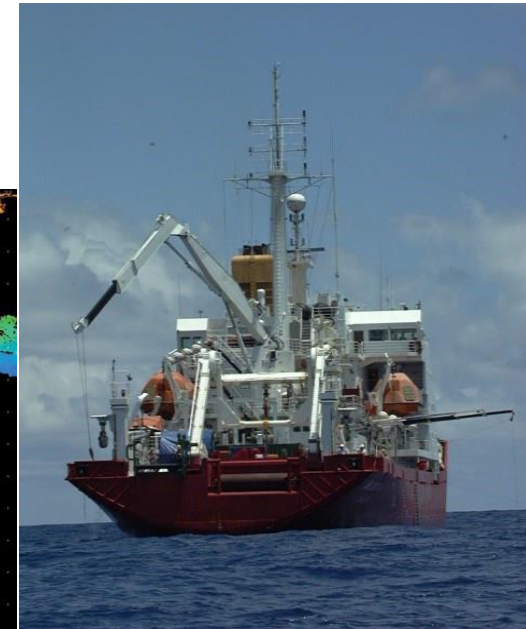
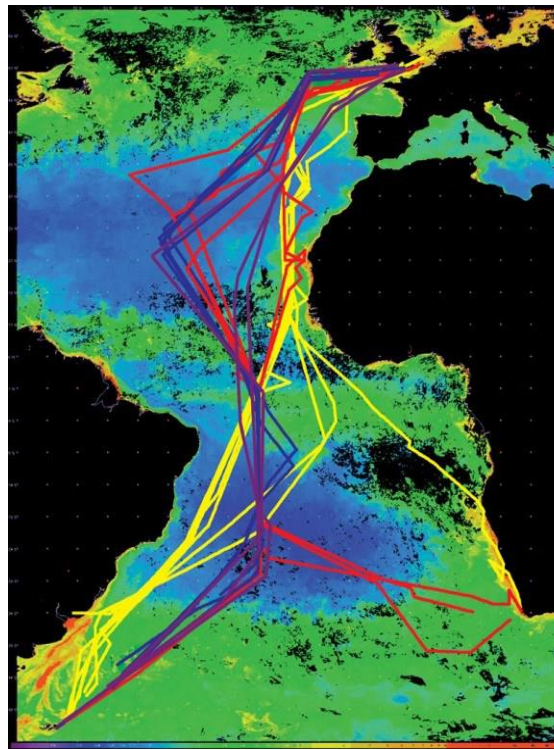
1. The **Acqua Alta Oceanographic Tower (AAOT)**, Gulf of Venice, Italy.  
8 days, in **July 2018** (date tbc).



Purpose built steel tower with instrument house platform to conduct optical measurements under stable conditions to tilt and roll and illumination geometry.

2. The **Atlantic Meridional Transect (AMT)**  
No.27. **Sept-Oct 2017.**

AMT cruises are conducted between UK & South Atlantic on a NERC ship.



AMT passes through a wide range of environmental conditions and biogeochemical provinces.



## Field Inter-Comparison Exercise (FICE)

**WHAT:** The FICE will compare –

### ***Above Water systems:***

e.g. SeaPRISM, SATLANTIC, TRIOS-RAMSES, TACCS using fixed and floating systems.

### ***In water methods:***

AAOT & AMT winch & freefall;

AAOT fixed-depth profiles from buoys; Referenced to JCR WiSPER system.

***Uncertainty budgets*** will be quantified for each system and method. The same calibration sources and methods and data processing schemes will be used.

All optical sensors will be inter-calibrated against the same standards and methods prior to the FICE. Uncertainty budgets will be quantified for each system and method. Data analysis will be conducted on centre wavelengths for Sentinel 2 & 3 (400, 412, 442, 510, 560, 620, 665, 673, 681, 708 nm).

Fiducial Reference Measurement	Abbrev.	Units
Above water Apparent Optical properties	AOPs	
Remote sensing reflectance	Rrs= Lu/Ed	sr <sup>-1</sup>
Normalised water leaving radiance	nLw	mW cm <sup>-1</sup> mm <sup>-1</sup> sr <sup>-1</sup>
In water Apparent Optical properties	AOPs	
Photosynthetically active radiation	PAR	mE m <sup>-2</sup> s <sup>-1</sup>
Attenuation coefficient	Kd	m <sup>-1</sup>
Euphotic depth	Zeu	m
Downwelling Irradiance	Ed	mW cm <sup>-1</sup> mm <sup>-1</sup>
Upwelling radiance	Lu	mW cm <sup>-1</sup> mm <sup>-1</sup>
Upwelling irradiance	Eu	mW cm <sup>-1</sup> mm <sup>-1</sup>

## Update Summary

- FRM4SOC international workshop on “Options and Approaches to the Long-term Vicarious Adjustment of Sentinel- OLCI & MSI A/B/C and D Instruments held at ESA-ESRIN, 21-23 February 2017 successful in:
  - ✓ Reviewing and learning from existing reference sites for OC-SVC
  - ✓ Converging toward a consensus for future development of OC-SVC infrastructure
  - ✓ Giving ESA (and CEOS) the practical evidence needed to strongly advocate for the development and long term maintenance of cutting edge FRM systems for OC-SVC
- Updates on the 3 FRM4SOC international intercomparison exercises:
  - LCE-1 for radiance and irradiance calibration sources will take place April 03-07, 2017 at NPL and a round-robin April-December, 2017. Eleven participants from Europe, USA, Canada and Australia. Implementation plan finalised. Protocols in draft form.
  - LCE-2 for ocean colour radiometers will take place 08-13 May, 2017 at Tartu Observatory. 20+ international participants. Implementation plan finalised. Protocols in draft form.
  - Field intercomparison exercise part 1 (AAOT) pushed back to July 2018, due to installation of new oceanographic tower. Cruise part still scheduled for September-October, 2017 on the AMT .