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FRM4SOC-2 WORKSHOP

on Calibration and Characterisation of Ocean Color Field Radiometers

20 – 22 May 2025

@ Tartu Observatory, University of Tartu, Estonia

FRM4SOC-2 Laboratory Comparison and lessons learned

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PROGRAMME OF THE EUROPEAN UNION

IMPLEMENTED BY EUMETSAT

FRM4SOC-2 Laboratory Comparison Exercise (LCE)

- International comparison of the spectral responsivity of irradiance and radiance OCRs between six participants was performed in 2022-2023.
- The relative expanded uncertainty stated by the participants for the comparison standards was around 2 %.
- Satisfactory metrological consistency was achieved only after correcting for the data handling errors and biases due to varying measurement conditions.

The consistency of results in the spectral range from 450 nm to 800 nm:

- For the irradiance sensors within 2 %, excluding results of one participant.
- For the radiance sensors within 3 %.

Participants of the LCE

Institute/Laboratory	Contact persons
UT / TO (Pilot)	Organization: Viktor Vabson,
	Measurements: Ilmar Ansko
NIVA Norsk Institutt for Vannforskning	Sabine Marty, Thomas Heggem
Sea-Bird Scientific	Christina Orrico, Eric Rehm, Ryan Lamb
MLML Moss Landing Marine Laboratories	Michael Feinholz, Kenneth Voss
NOAA / NESDIS National Oceanic and Atmospheric Administration	Michael Ondrusek
NPL National Physical Laboratory	Agnieszka Bialek, Clemens Rammeloo

Duration of the comparison measurements was 564 days (Jan 2022 – August 2023), the analysis is still going on.

Comparison’s transfer radiometers

Four hyperspectral radiometers were applied as comparison artefacts: TriOS GmbH (Germany) RAMSES radiance and irradiance sensors, and Sea Bird Scientific (US) HyperOCR radiance and irradiance sensors.

No	Serial Number	Manufacture Date	Function	Manufacturer	OCR’s family
1	SAM_81B0	2006	Radiance (L)	TriOS GmbH	RAMSES
2	SAM_8598	2018	Irradiance (E)	TriOS GmbH	RAMSES
3	SAT2073	2021	Radiance (L)	Sea-Bird Scientific	HyperOCR
4	SAT2072	2021	Irradiance (E)	Sea-Bird Scientific	HyperOCR

General measurement conditions

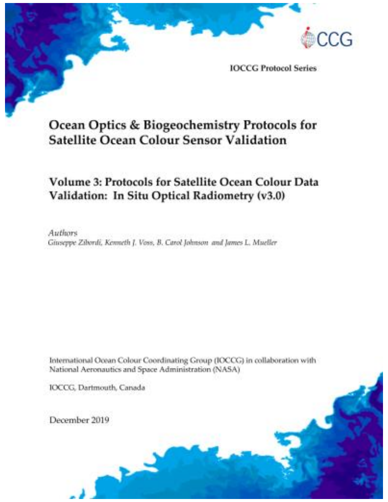
Measurement standards, distances and the number of different integration times reported by participants.

Participant	Standards		Measurement distance, mm			Number of used int. times
	Irradiance	Radiance	Irradiance	Radiance		
			FEL- OCR	Integrating Sphere - OCR		
P1	FEL	Sphere	500	N/A		1
P2	Two FELs	Sphere	500	140		3 - 4
				FEL- Plaque	Plaque - OCR	
P3	FEL	FEL + Plaque	500	500	N/A	3
P4	FEL	FEL + Plaque	500	1300	N/A	3 - 4
P5	FEL	FEL + Plaque	500	1000	N/A	1
P6	FEL	FEL + Plaque	500	500	200; 250	3

Temperatures during calibrations

Laboratory	Measurement location	Temperature, °C			
		SAM_81B0	SAM_8598	SAT2072	SAT2073
P1	Ambient	N/A	N/A	26.0	26.2
	Device internal	26.8	27.7	30.3	30.1
P2	Ambient	N/A	23.8 – 25.1	N/A	N/A
	Device internal	23.3 – 25	24 – 24.3	26.3 – 30.0	26.2 – 26.8
P3	Ambient	21.5	21.5	21.5	21.5
	Device internal	23.5	22.8	24.3 – 24.5	23.5 – 24.5
P4	Ambient	21.9 – 22.4	N/A	22.6 – 23.1	22.9 – 23.1
	Device internal	N/A	N/A	26.3 – 27.2	26.8 – 27.3
P5	Ambient	26	26	26	26
	Device internal	N/A	N/A	N/A	N/A
P6	Ambient	21.5 – 21.8	21.3 – 22.1	21.5 – 22.1	N/A
	Device internal	22 – 22.3	21.3 – 21.7	24.1 – 25.1	N/A

Calibration and characterisation guidelines


IOCCG Protocol Series

Ocean Optics & Biogeochemistry Protocols for Satellite Ocean Colour Sensor Validation

Volume 3: Protocols for Satellite Ocean Colour Data Validation: In Situ Optical Radiometry (v3.0)

Authors
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IOCCG, Dartmouth, Canada

December 2019

- *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
- FRM4SOC2-D12: *Harmonised cal/char lab guidelines, including lab protocols for FRMOCnet OCR models, 2024*
- *Protocol for the laboratory comparison measurement: Calibration of radiometers. Characterization of radiometers. Comparison report, 2021*

Calibration guidelines

More detailed descriptions and recommendation are needed.

All participants did use during the LCE the Quartz Tungsten Halogen (QTH) FEL 1000W lamps as a spectral irradiance standard, but different lamp holders with specific alignment jigs have been used (at least two types).

In lamp calibration certificates different number of spectral points for the absolute irradiance and different uncertainties were reported. One certificate was without explicit uncertainty statement.

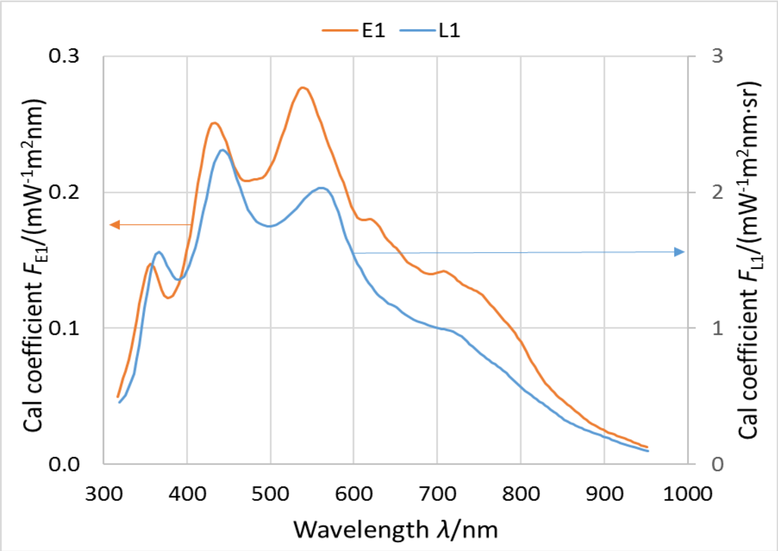
Recalibration interval of radiometric standards more than five years was present.

Responsivity coefficients of RAMSES and HyperOCR radiometers are calculated with different algorithms, and have different units.

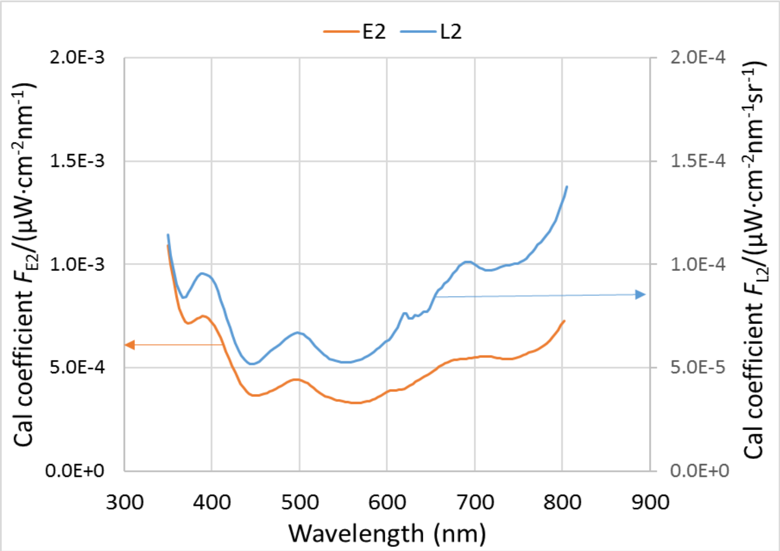
Responsivity coefficients of comparison’s radiometers

The measurement task of the laboratory comparison was the absolute radiometric calibration of OCRs and expected outcome – valid calibration coefficients.

TriOS RAMSES



Seabird HyperOCR



Goals of the Laboratory Comparison

1. Identification of differences between participants
2. Identification of measurement problems and harmonisation of protocols
3. Confirmation of the uncertainty estimates and the measurement capability of participants

Problems with initial data of participants

For the comparison analysis, data submitted by participants were reviewed and data formats unified. Calibration data of the reference standards and interpolations used for each comparison radiometer were reviewed as well.

Initial differences between participant's results were within ±10 %. The stated relative expanded uncertainty for the comparison radiometers was around 2 %.

In the first stage, the reported values were modified by Pilot to have:

1) Suitable units for each comparison radiometer
2) Common integration times for HyperOCR sensors

In the second stage, pilot applied:

1) Unified data handling starting from the raw spectra
2) Corrections for biases due to different measurement conditions

Corrections applied by the pilot

Correcting submitted calibration coefficients was needed to account for the significant differences in measurement conditions during comparison:

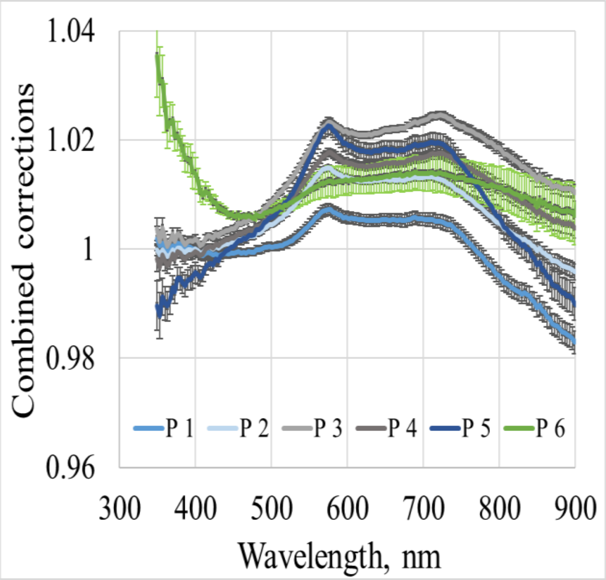
- non-linearity effects due to difference of used sources (FEL lamps and integrating spheres)
- thermal effects due to differences in ambient temperatures and radiometer's internal temperatures
- drift effects of radiometers due to different measurement dates (1.5 years)

Combined corrections with uncertainties

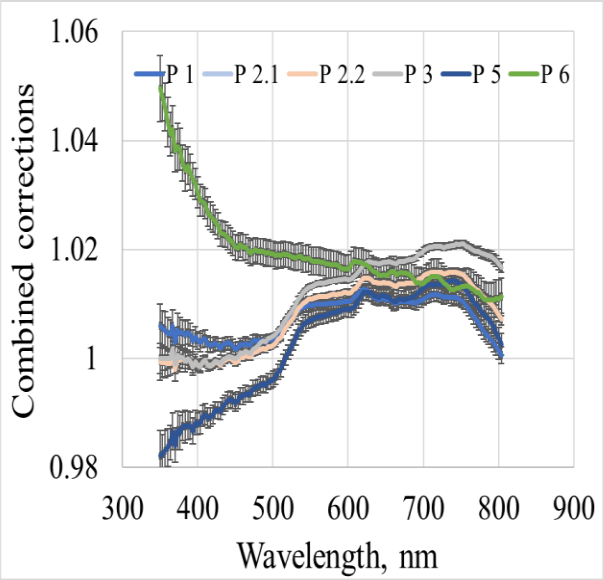
RAMSES sensors left

HyperOCR sensors right

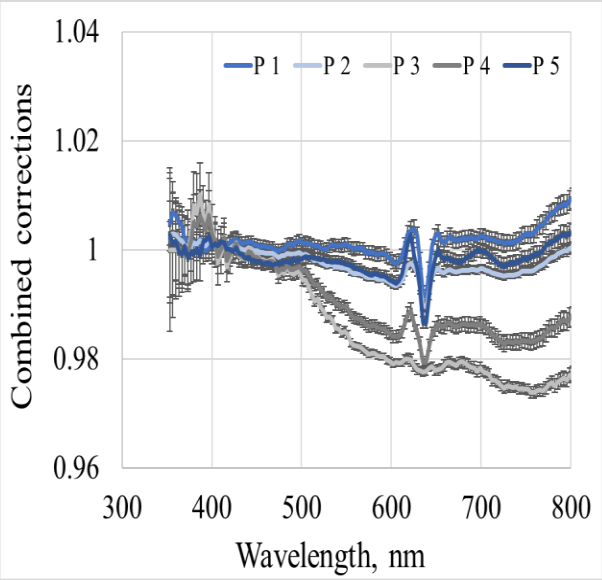
SAM81B0



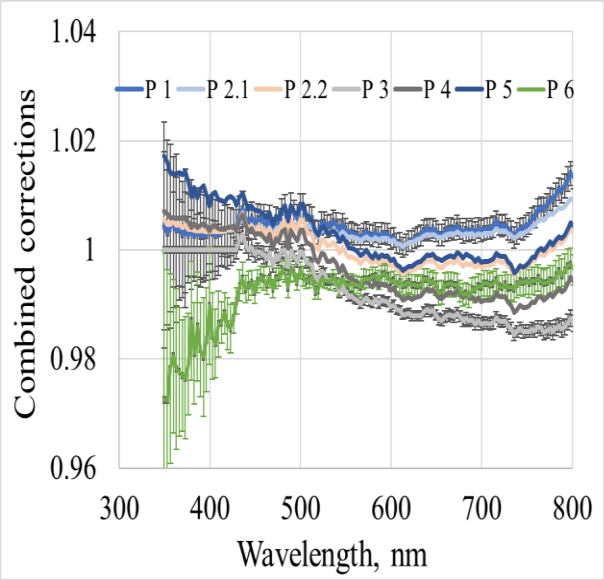
SAM8598



SAT2073



SAT2072



Effect of correcting

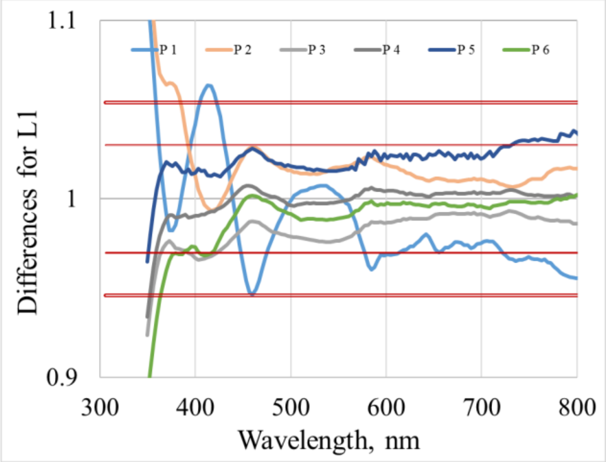
- Changes about ±1 % for RAMSES and up to ±2 % for HyperOCR were evident due to similarity of corrections of different laboratories.
- Consensus values were also changing around ±2 %.
- The initial uncertainties of participants will increase to account for uncertainties of corrections (0.1 …0.4 % combined contribution).
- Without applying corrections, increase of initial uncertainties needed to account for different conditions in labs is significantly larger.

Effect of data handling in case of radiance sensors

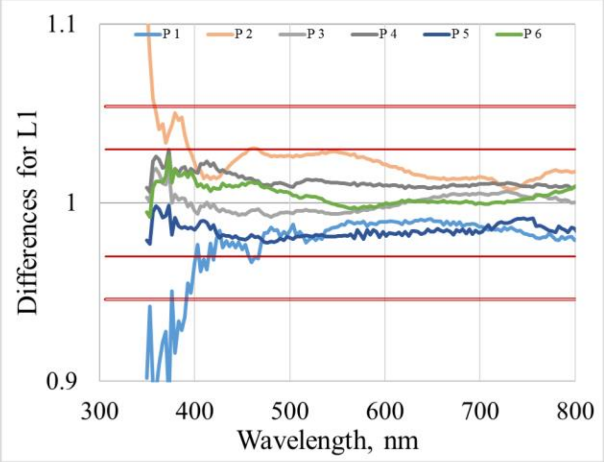
Unified data handling and correcting for different measurement conditions *with rank I and II uncertainty limits* according to SIRREX-7 experiments (red lines).

In the spectral range from 450 to 800 nm, the radiance differences from CCV will decrease to be in the rank-I uncertainty limits.

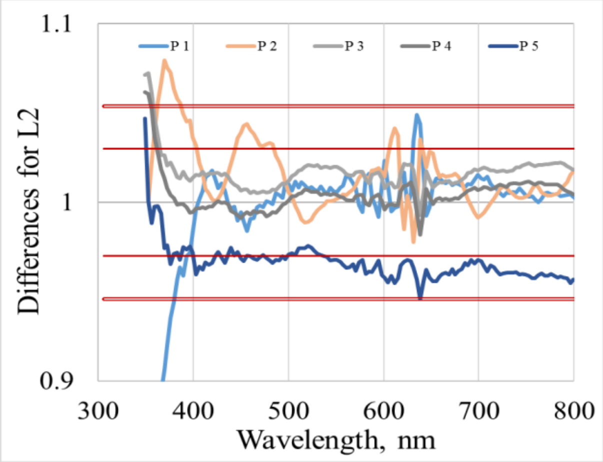
Initial results



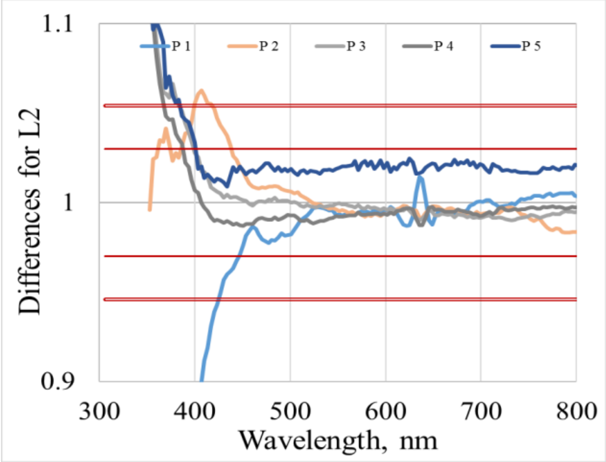
After reprocessing



Initial results



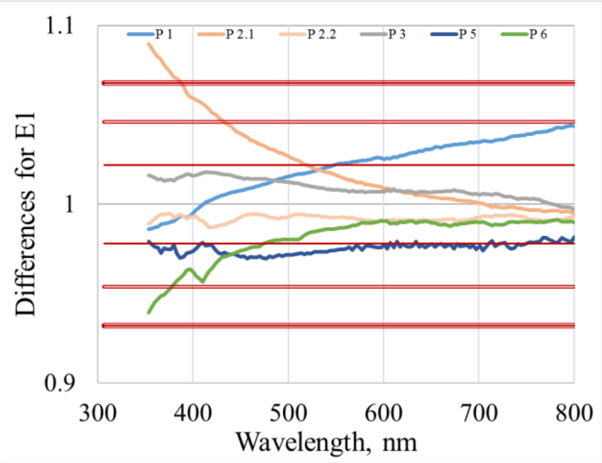
After reprocessing



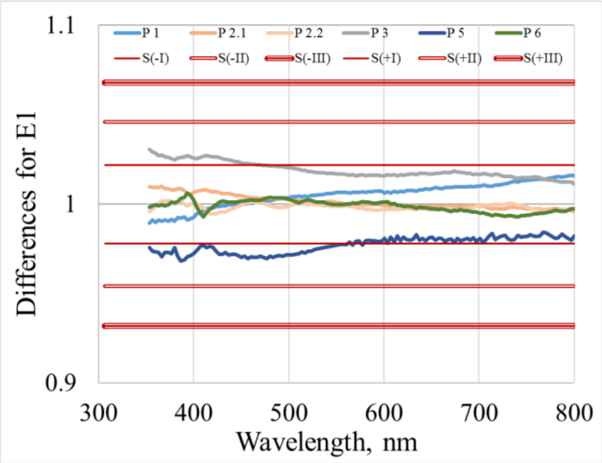
Effect of data handling in case of irradiance sensors

In the spectral range from 450 to 800 nm, the irradiance differences from CCV will significantly decrease, but one result is still outside the SIRREX-7 rank-I uncertainty limits.

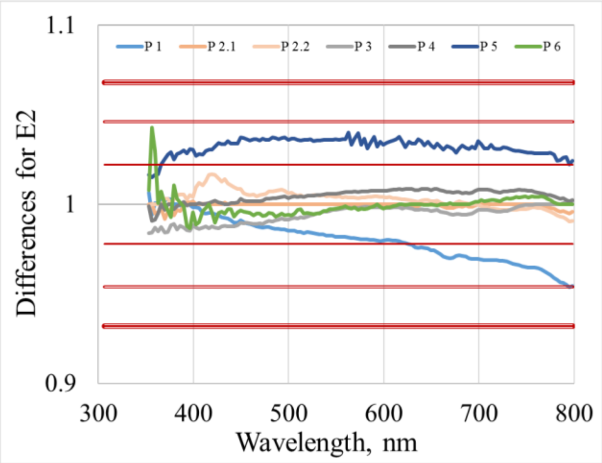
Initial results



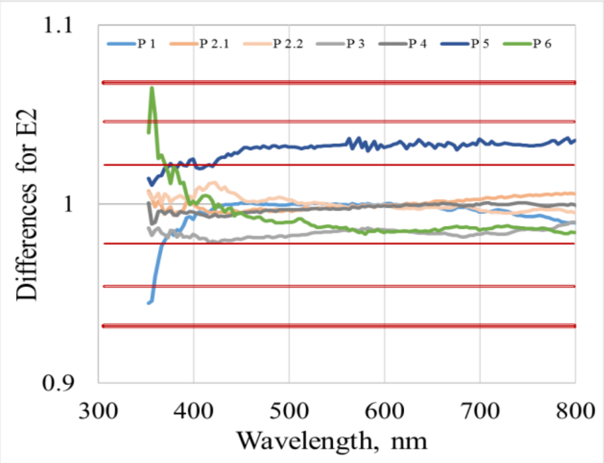
After reprocessing



Initial results



After reprocessing

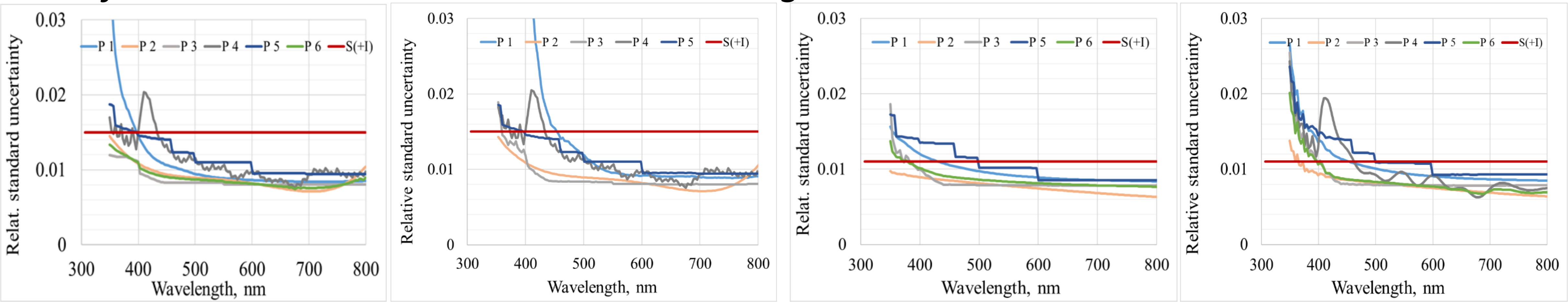


Calibration uncertainties after correcting

Standard uncertainties of responsivity coefficients reported by the participants after the uncertainty due to corrections for nonlinearity, drift and different temperatures was added.

Uncertainty according to SIRREX-7 rank-I is shown with red line.

Left: radiance sensors *Right: irradiance sensors*

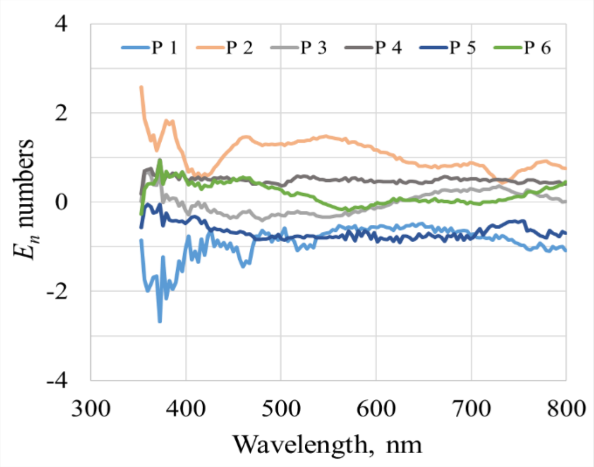


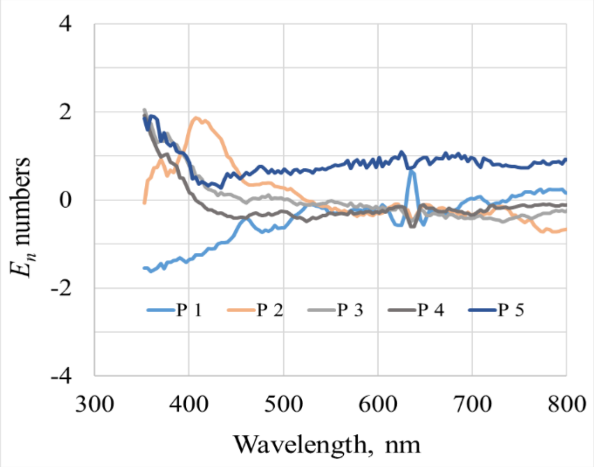
Agreement of participant’s results using En numbers

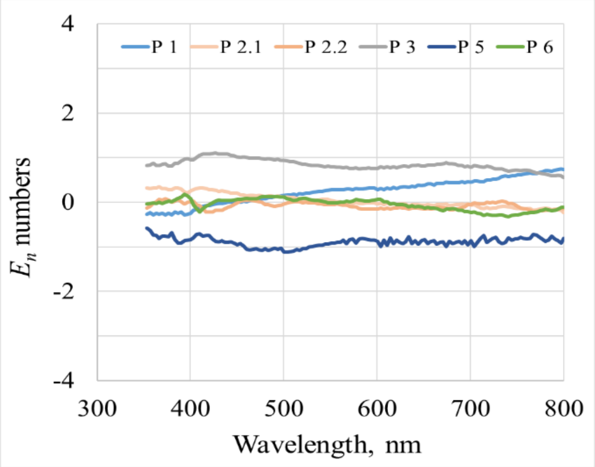
A good agreement between all participants was evident after modifications by Pilot. Only 2 out of 20 results are inconsistent with En numbers around 1.5 … 2, and a few results have En numbers close to ±1.

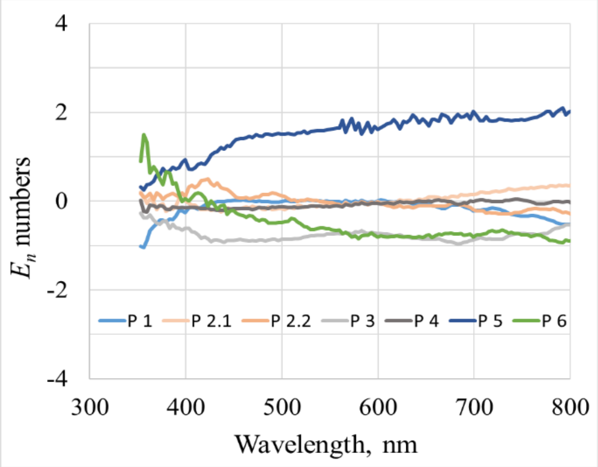
Left: radiance sensors

Right: irradiance sensors









Consistency of results

I. Pilot converted the reported results:

1) to the same units and
2) to the common integration times as by the manufacturer calibration (HperOCR)

II. Substantial improvement was obtained after unified data handling and correcting for different measurement conditions

To get such agreement in submitted reports better documentation of OCR's models is needed and procedures for the measurement and data handling should be validated and contain suitable intermediate checks.

Regular reviewing of the uncertainty budgets and more regular recalibration of radiometric standards is advisable.

Problems of OCRs identified during comparison

- Radiometric response depends on the self-heating and data acquisition process. Thus, level and stability of the internal heat load is significant property.
- Temperature of radiometer’s optical sensor is a key parameter. Correcting for thermal effects without internal temperature sensor is inefficient.
- Missing shutter limits the accuracy of the dark signal recording during field use.
- Teflon diffusers shall be avoided because of thermally instable optical properties.

LCE workshop's Conclusions, December 2024

The Pilot of the comparison (UT) provided guidelines for uncertainty evaluation in January 2025.

The Pilot provided an online folder for sharing the comparison documents.

Some participants updated their measurement and uncertainty data by the end of April 2025.

The Pilot added the calculation algorithms for the calibration coefficients, for corrections applied by pilot and for respective uncertainty contributions.

The Pilot is updating the comparison report D 13 and preparing a draft of a paper for a peer-reviewed publication (June 2025).

Comparison process and analysis

Full duration of the laboratory comparison measurements was 564 days.

The comparison analysis did not follow the rigor as required for formal inter-comparisons to confirm the measurement capability.

Analysis was more like to scientific-technical study demonstrating metrological consistency after extensive reprocessing of reports.

For good SI-traceability, regular recalibration of the radiometric standards with suitably small uncertainty is indispensable.

However, satisfactory metrological consistency between participant's results was obtained only after reprocessing and correcting for different in measurement conditions. Biases due to data handling exceeded the biases due to radiometric standards in majority of cases.

Conclusions

- Confusion in data handling was significant. Errors detected in data handling imply that for the calculation procedures improved protocols are needed
- After reprocessing, the metrological equivalence of the OCR calibrations was satisfactory
- Small number of participants limits the reliability of consensus value (ISO/IEC 17043 and ISO 13528)
- Technical barriers hinder the comparison significantly: shorter time schedule is strongly preferable
- Harmonization of procedures for the measurement and data handling, intermediate checks and training are needed to improve metrological consistency of the spectral responsivity calibrations
- Further inter-comparison measurements are regularly needed to confirm the capabilities of participants