LABORATORY CHARACTERIZATION OF OCEAN COLOR RADIOMETERS

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INTRODUCTION

Comprehensive characterization of the most widely used Ocean Color (OC) hyperspectral radiometers took place in the framework of the FRM4SOC Phase 2 project at the Tartu Observatory (TO), University of Tartu in spring-summer 2022. The following parameters were determined for ~40 devices:

- radiometric responsivity
- wavelength scale
- radiometric linearity
- spectral straylight
- angular response
- polarization sensitivity (radiance sensors only)
- thermal response
- signal-to-noise ratio

Additionally, the immersion coefficients were measured for 10 radiometers at the Joint Reasearch Centre (JRC), Ispra, Italy. Some findings, most relevant to the uncertainty evaluation, are shown here. The characterization methods, data and analysis will be available in the FRM4SOC Phase 2 reports.

RADIOMETRIC RESPONSIVITY

Change of the radiometric responsivity at 550 nm is shown in Figure 1 (the change in the UV spectral region is even more evident). This information is collected over many years for selected instruments. Average drift of characterized radiometer is quite similar and close to-1% per year. In rare occasions, the radiometer might show responsivity jumps as shown with the red line. Therefore, pre- and post-deployment calibrations are strongly recommended while the minimum requirement is yearly re-calibration.

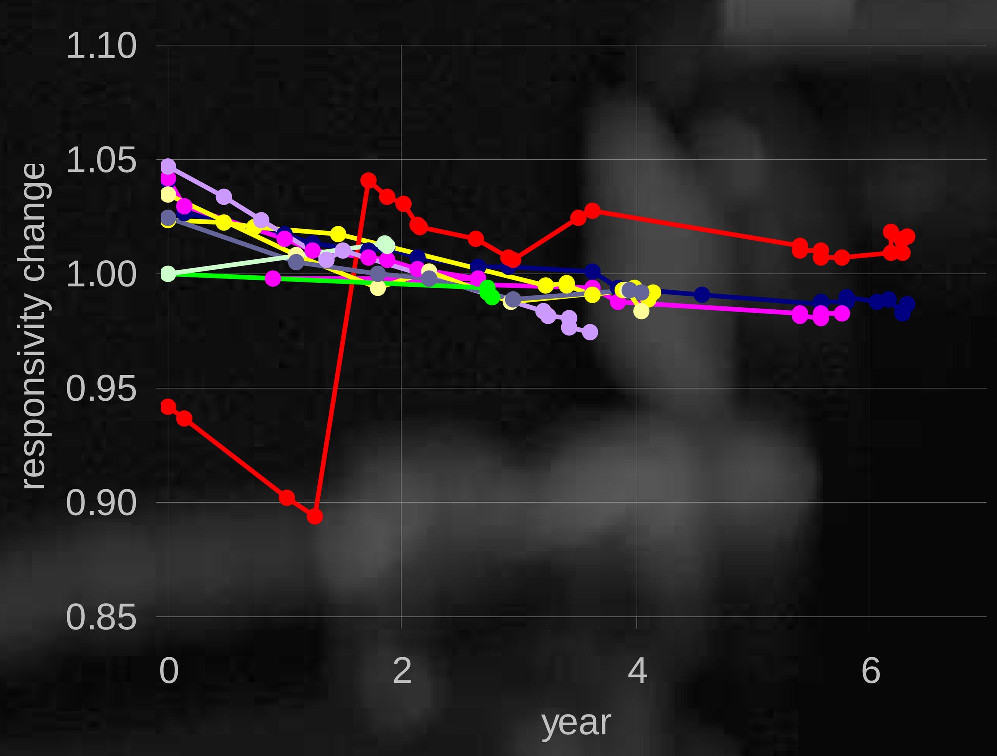

Figure 1. Change of radiometric responsivity

RADIOMETRIC LINEARITY

was measured by varying the devices's integration time while measuring stable broad-band source. This method is easy to implement even for the end-users without the optical lab resources. The method was compared with the varied distance method [1]. Additionally, the varied integration time method was used with tunable monochromatic source to improve uncertainty in the spectral regions with low radiometric responsivity (Figure 2).

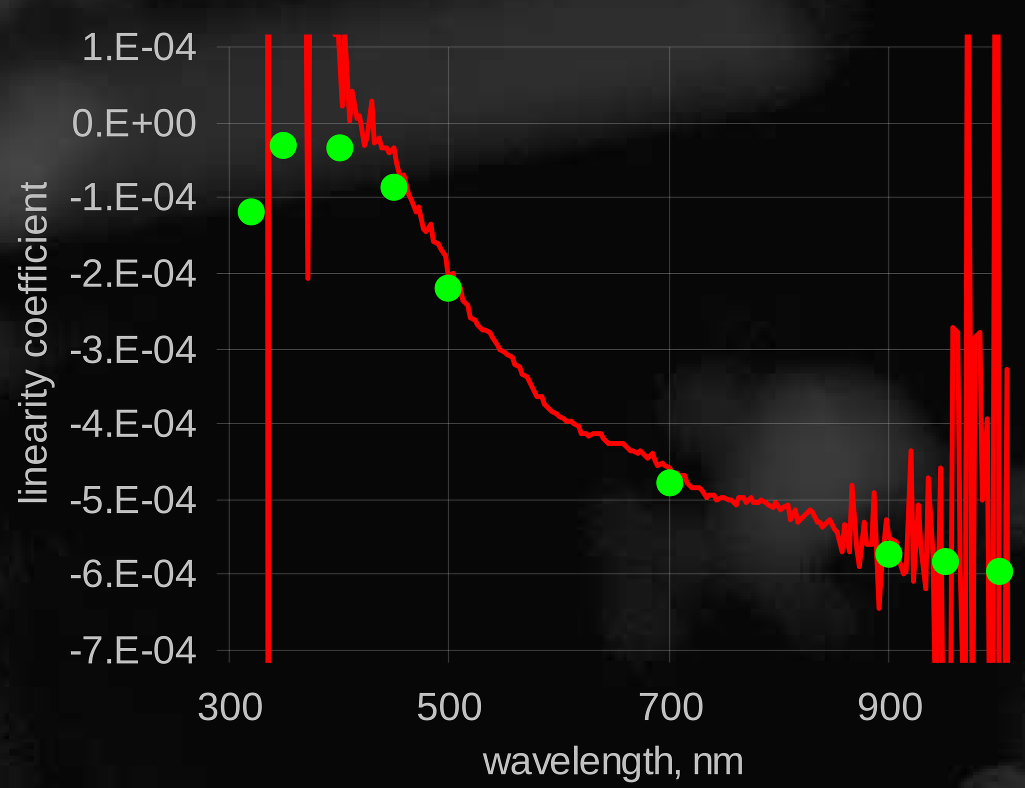

Figure 2. Radiometric linearity: integration time method with broad-band (line) and monochromatic (dots) source

ANGULAR RESPONSE

of the irradiance sensor depends on the measurement geometry, i.e. the angular response, in general, has no circular symmetry (Figure 3). Determination of angular response with small uncertainty is a demanding task as it depends critically on alignment, selection of the light source, temporal and thermal drifts. Comparison of the angular measurements between TO and JRC are shown in Figure 4.

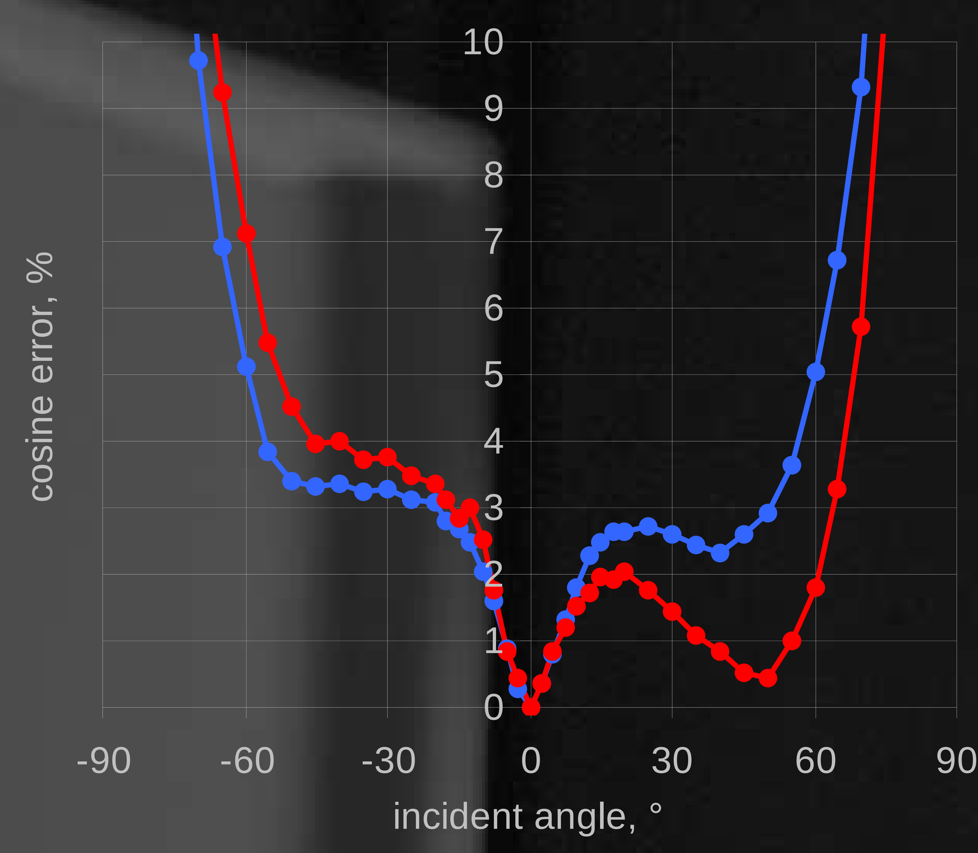

Figure 3. Cosine error at two azimuth angles

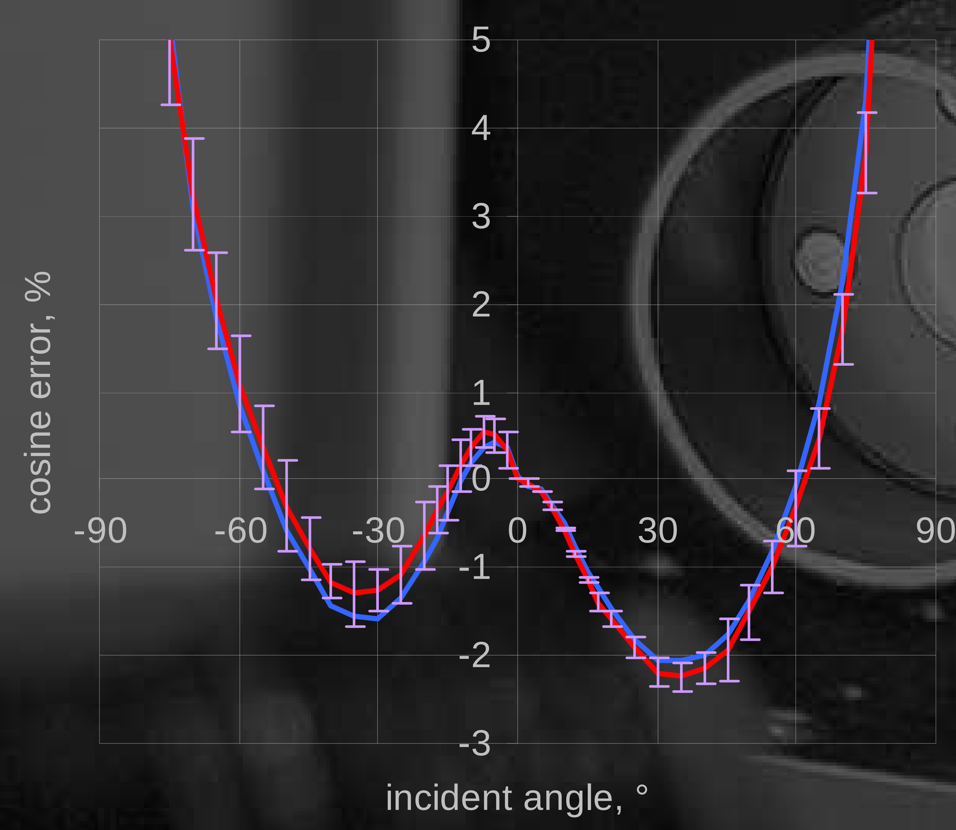

Figure 4. Agreement between the angular measurements at JRC (red) and TO (blue)

THERMAL CHARACTERIZATION

Temperature is the main influence factor for the OC radiometers which may affect the measurement uncertainties. Both the dark signal and radiometric responsivity vary significantly with temperature while other parameters, such as the wavelength scale, show minor drifts. In general, thermal behaviour of the optical sensor is well predictable while various components of the front-end electronics tend to have individual nature.

Thermal coefficients from different sources (TO, JRC [2], Satlantic/Seabird [3]) were compared (Figure 5). In spite of some individual spectral features, deviating from the polynomial approximation, the agreement is satisfactory.

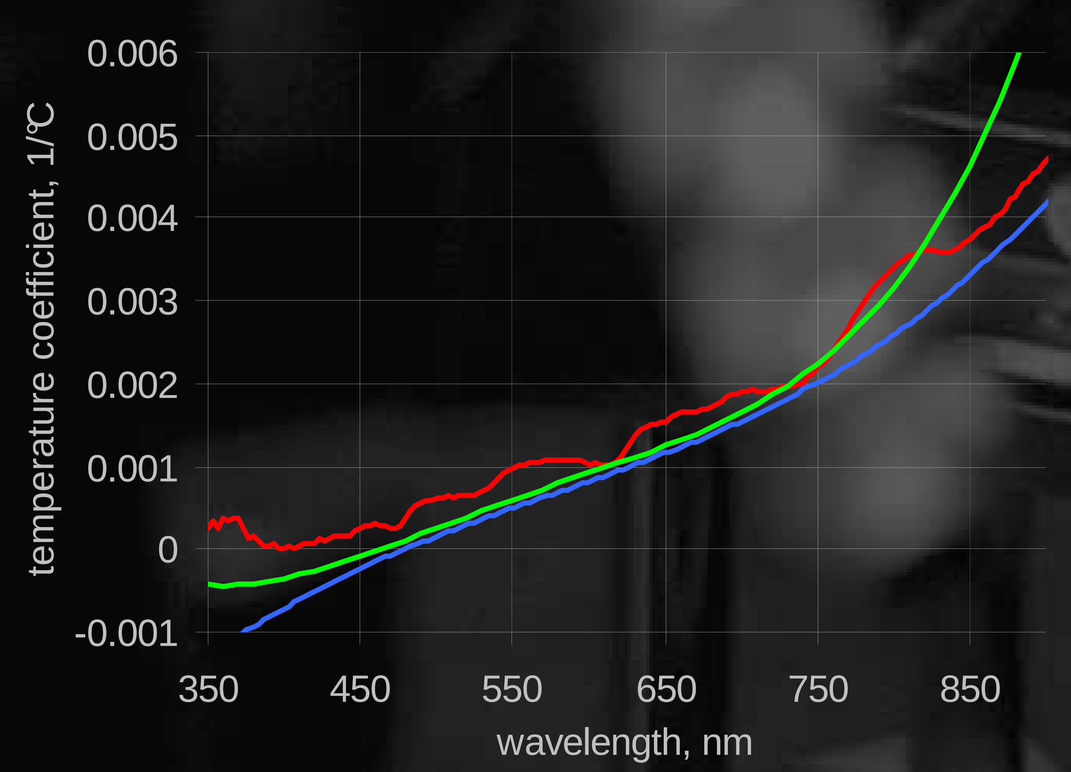

Figure 5. Agreement between the thermal characterizations: TO (red), JRC (green), Satlantic/Seabird (blue)

Strong internal thermal loads, gradients inside the radiometers, lack of internal temperature sensors but also the placement of such sensors cause problems during the instrument characterization. Attempts were made to use the dark signal as a proxy to the sensor effective temperature. The ability to adequately represent the effective temperature is related to the signal-vs-temperature hysteresis during rapid temperature ramps. Changes of the ambient temperature during the field measurements are unavoidable. Figure 6 shows that the dark signal can represent the responsivity changes even better than the embedded temperature sensor. The residual uncertainty can be as low as 0.3 °C. However, using the dark signal implies using the longest available integration times and mechanical shutters, which cannot be easily realized in the field practices.

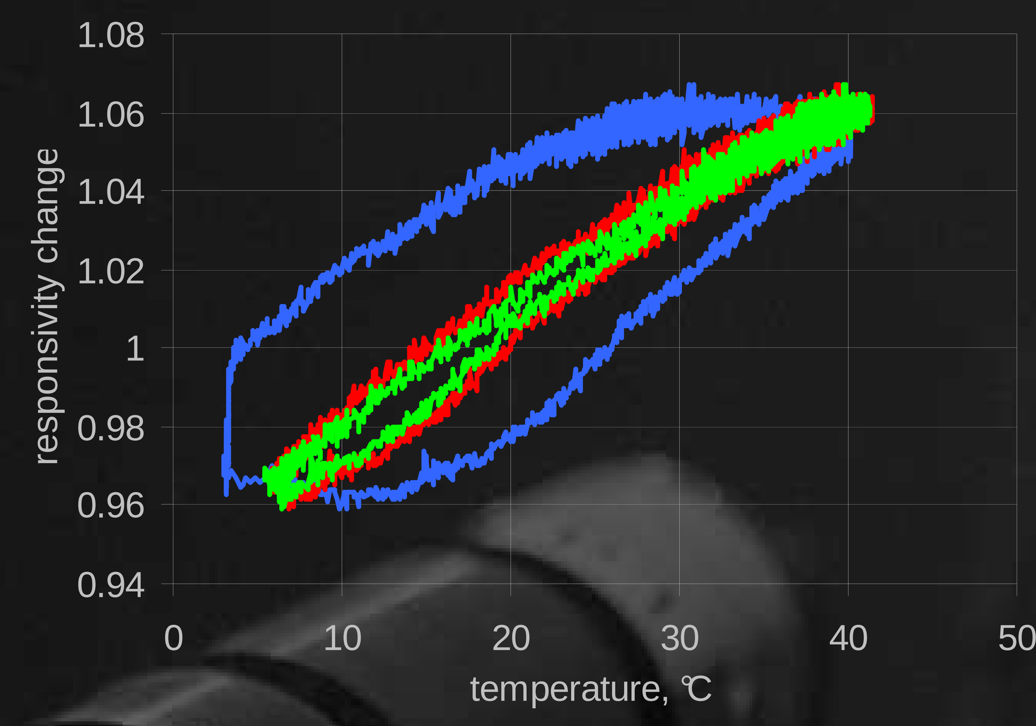

Figure 6. Radiometric signal change vs the internal (red), ambient (blue) and dark-derived (green) temperatures

The well known phase transition around +19 °C, related to the PTFE, often used for the irradiance diffusers, implies additional difficulties, as the diffuser is thermally detached from the optical sensor and follows the ambient temperature rather than the internal one. The corresponding jumps in thermal hysteresis, clearly visible in Figure 7, can significantly increase the measurement uncertainty.

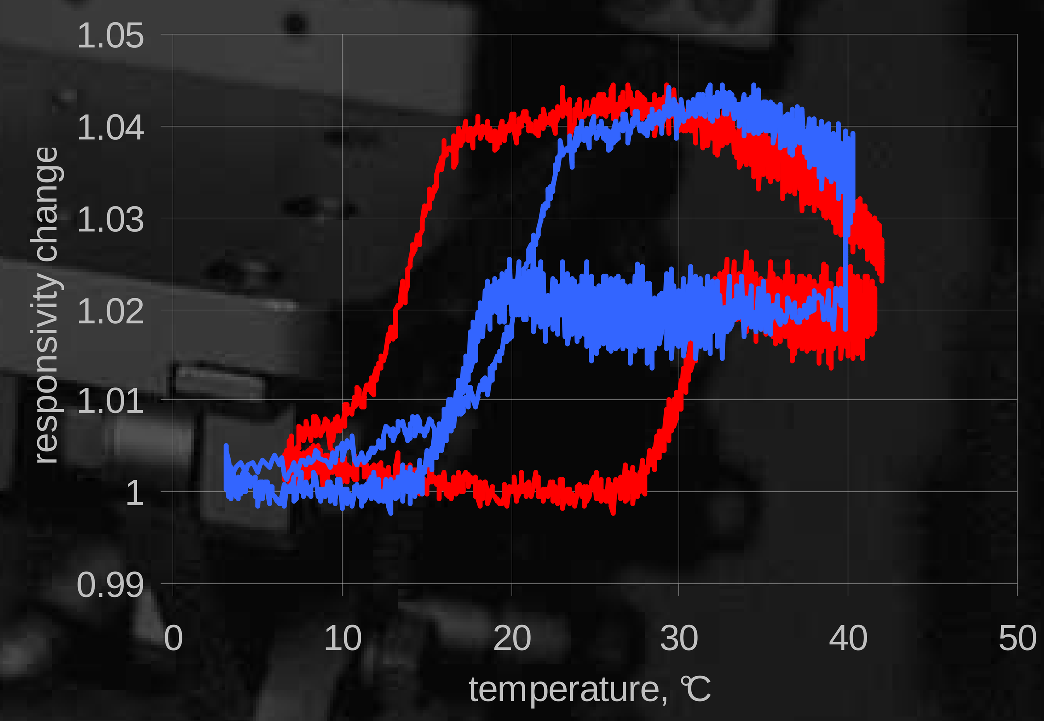

Figure 7. PTFE-related responsivity jump of the irradiance sensor vs the internal (red) and ambient (blue) temperature

CONCLUSIONS

- The instrument characterization results cannot be directly converted into the uncertainty of the OC products (radiance, irradiance, reflectance) as the measurement conditions (e.g. geometry) and properties of the measurand (e.g. spectral shape) affect the result.
- As with exception of the radiometric calibration, which is a well established procedure, the rest of the opto-electronical characterizations are only occasionally covered by detailed instructions; the availability and the readiness of the labs is insufficient for smooth intercomparisons.
- Determination of many parameters is affected by the self-heating of the instruments, as the responsivity change due to temperature is comparable to the expected characterization result. Careful definition of the measurement sequence can help in many cases.
- A major problem when using characterization results is the limited spectral range due to large difference between the spectral shapes of the natural and the calibration sources.
- Cooperation with developers is needed in order to help to improve the instrument parameters, most contributing to the OC uncertainty.

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