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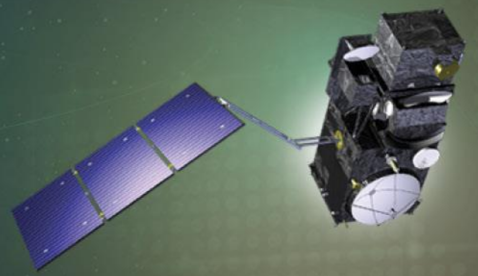


7th Sentinel-3 Validation Team Meeting 2022

18-20 October 2022 | ESA-ESRIN | Frascati (Rm), Italy

Complete characterisation and calibration of Ocean Colour Radiometers for Ocean Colour Validation

Viktor Vabson [1], Ilmar Ansko [1], Riho Vendt [1], Joel Kuusk [1], Kevin Ruddick [2], Agnieszka Bialek [3], Juan Ignacio Gossn [4], Ewa Kwiatkowska [4]

1 Tartu Observatory, University of Tartu, Estonia
2 Royal Belgian Institute of Natural Sciences, Belgium
3 Climate and Earth Observation Group, National Physical Laboratory, UK
4 EUMETSAT, Germany

INTRODUCTION

The EUMETSAT's FRM4SOC phase 2 study includes comprehensive characterisation of the most widely used OC hyperspectral radiometer models performed at Tartu Observatory in spring-summer 2022.

Radiometers used for the validation of satellite OC shall be SI-traceably calibrated and fully characterised, in order to account for:

- Responsivity drifts
- Biases of individual instruments
- Environmental factors affecting the results

The priority of the study was to assess the two most common models:

- TriOS RAMSES
- Satlantic/Sea-Bird HyperOCR

About 40 radiometers, both radiance L and irradiance E sensors were studied.

RADIOMETRIC RESPONSIVITY

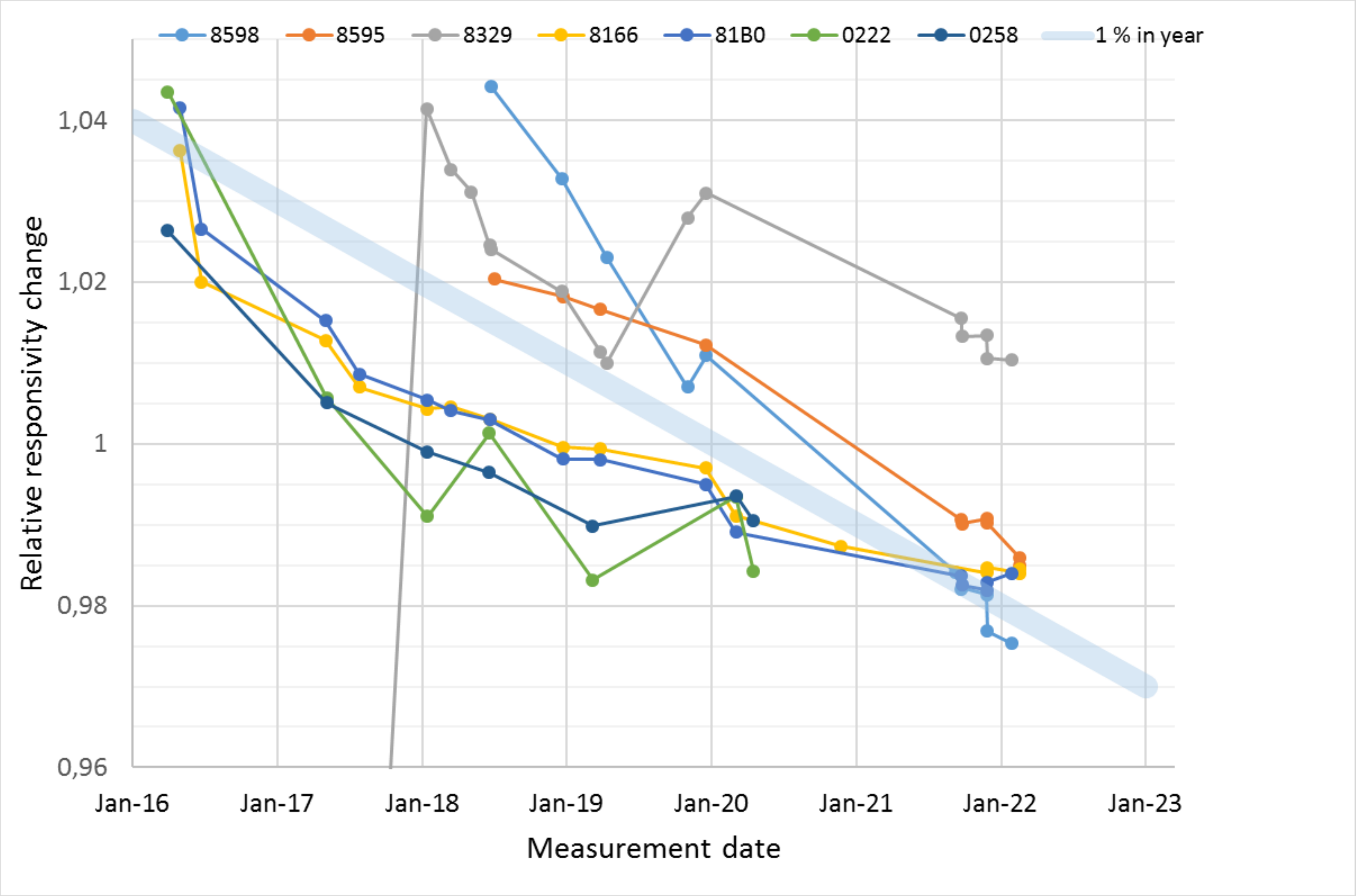
Variation of the radiometric responsivity over many years is shown for selected instruments.

Average drift is close to -1 % per year (shown with broad blue line).

Seldom, the responsivity jumps of several percent may happen.

Calibration of the OC radiometers is strongly recommended before and after each deployment.

Yearly re-calibration is a minimum requirement.



THERMAL CHARACTERISATION

Temperature is the main influence factor of the OC radiometers.

Both the radiometric responsivity and the dark signal vary with temperature significantly.

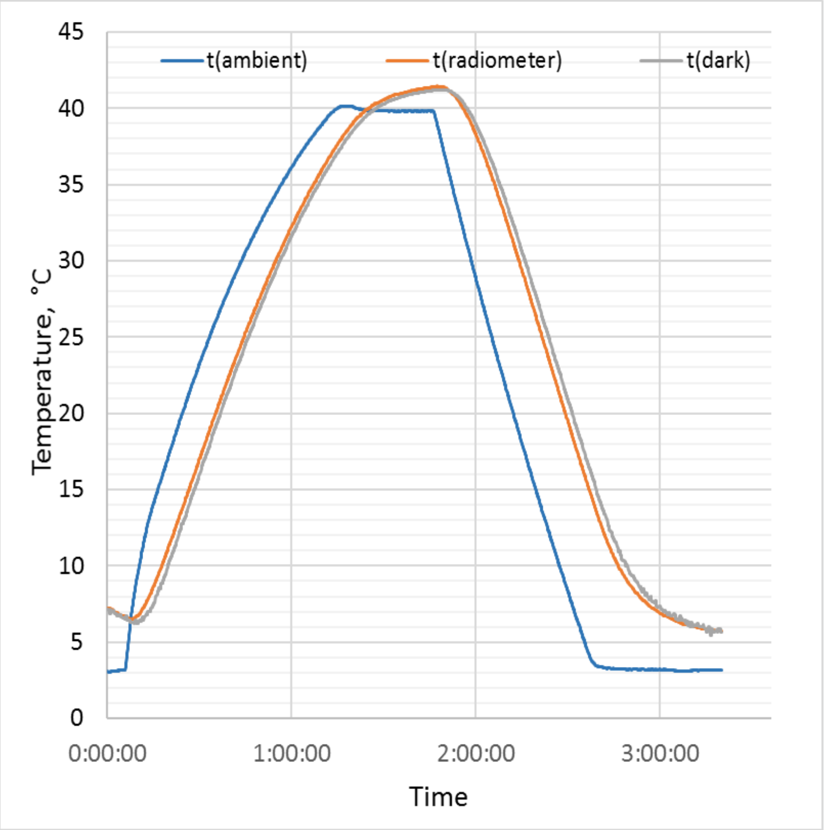
Difference between ambient temperature and internal temperature sensor of HyperOCR is about (2 to 3) °C depending on the mode of data acquisition and on ambient conditions. Temperature time lag depends on speed of variation.

Correcting for thermal effects without internal temperature sensor is less effective due to large uncertainty of the temperature difference during calibration and in-field use.

High internal thermal load is hindering characterisations and increasing uncertainty during in-field use.

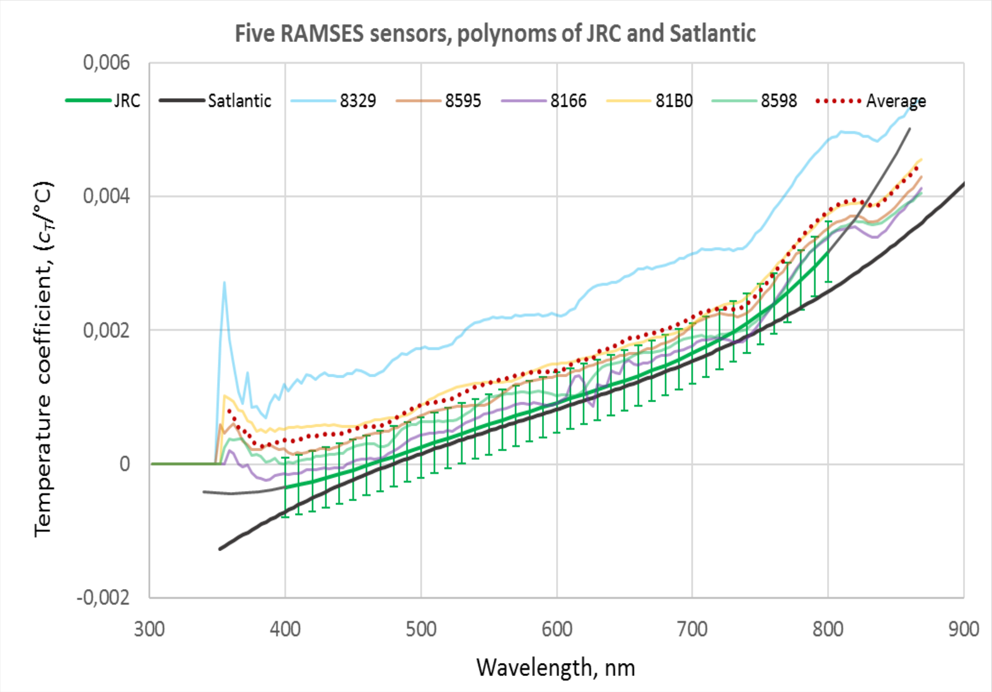
Temperature of the HyperOCR sensor determined by using:

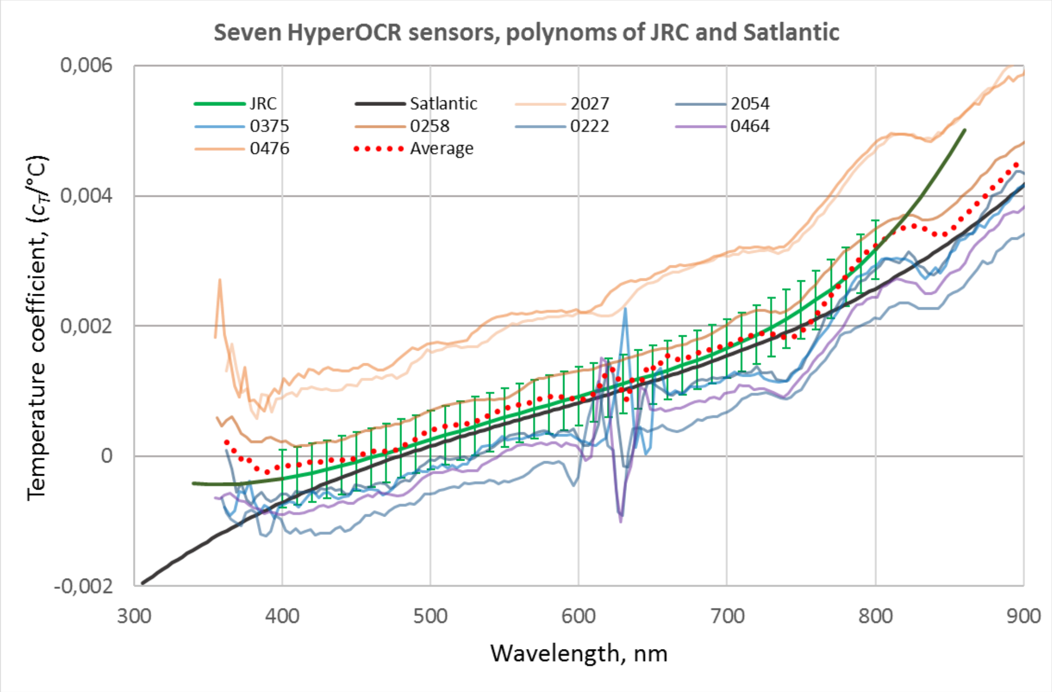
- Outside thermometer
- Internal temperature sensor
- Calculation from the dark signal



THERMAL COEFFICIENTS of 5 RAMSES and 7 HyperOCR sensors

Comparison of Thermal coefficients from different sources (TO, JRC, Satlantic/Seabird). Expanded uncertainty is covering the thermal characteristics determined in [1].





In some cases, class-specific uncertainties may appear unexpectedly large.

G. Zibordi, M. Talone, and L. Jankowski, "Response to Temperature of a Class of In Situ Hyperspectral Radiometers," *J. Atmospheric Ocean. Technol.*, vol. 34, no. 8, pp. 1795–1805.

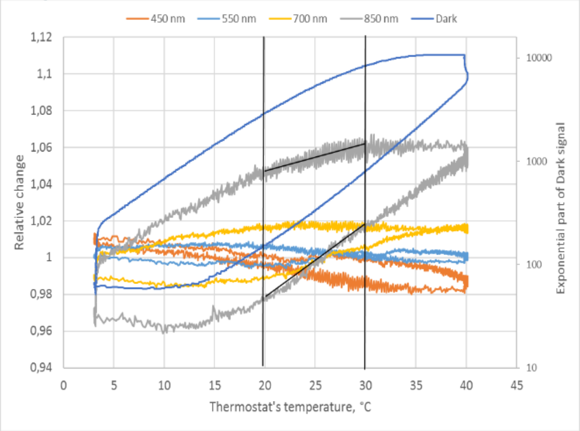
DYNAMIC THERMAL RESPONSE ERROR

Changes of the ambient temperature during field measurements are unavoidable.

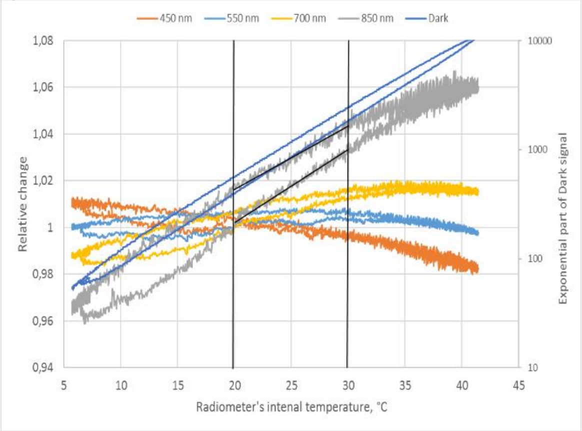
If only ambient temperature is measured then the error due to signal hysteresis can be larger than due to varied thermal responsivity.

Dark signal follows the responsivity changes better than the embedded temperature sensor, but flexible incorporation of long integration times with closed shutter into the field protocols may be difficult.

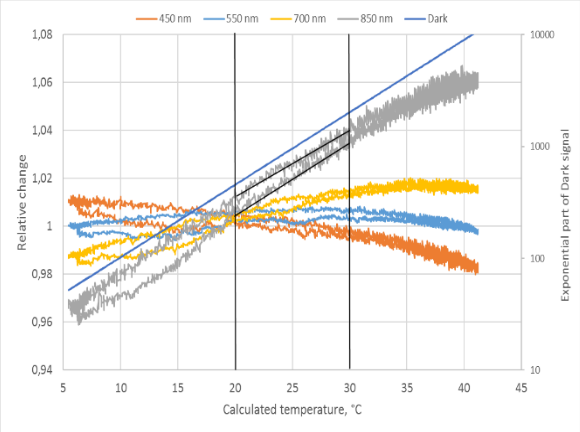
Signal vs ambient temperature



Signal vs internal thermometer



Signal vs temperature calculated from dark signal



HYSTERESIS OF HyperOCR IRRADIANCE SENSORS

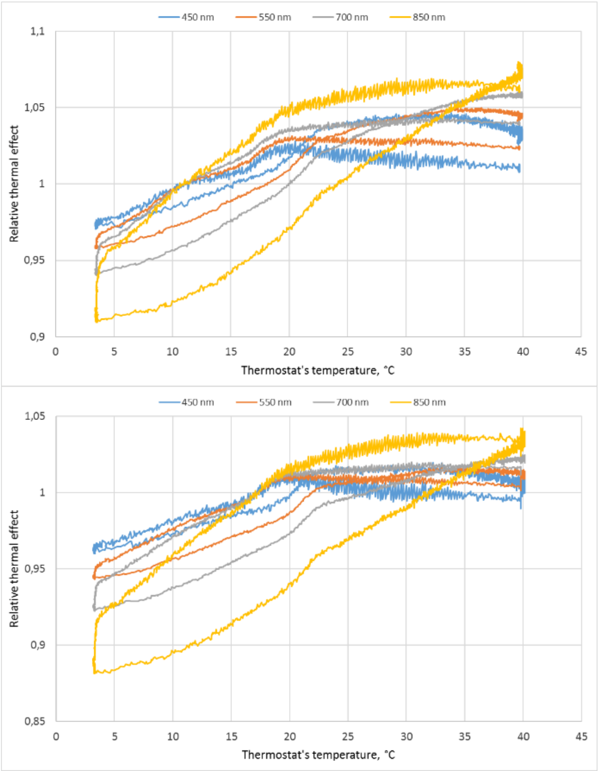
Differently from radiance sensors, hysteresis presented as a function of the internal temperature did not decrease significantly.

Response of the irradiance sensor is caused besides the optical sensor inside also by the cosine collector made of PTFE.

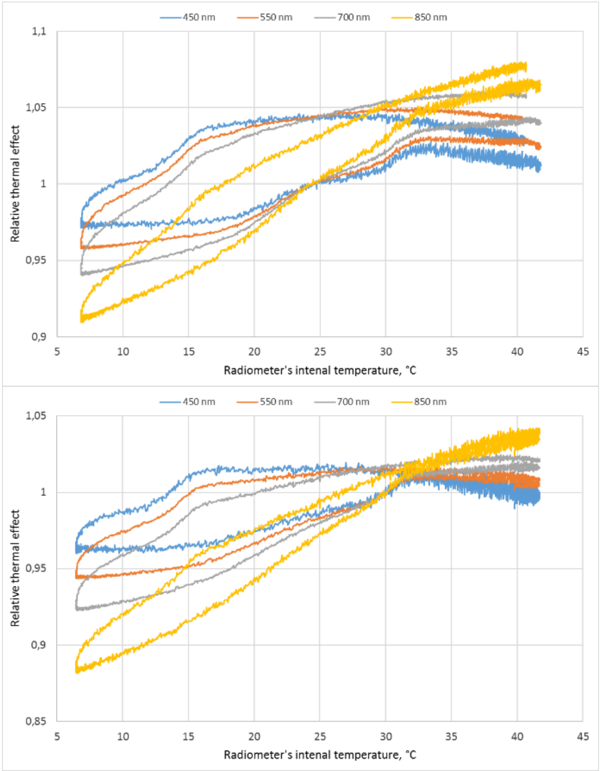
Transmittance of PTFE changes abruptly by 1 - 3 % at around 19 °C due to a phase shift, see for example *L. Ylianttila and J. Schreder, Optical Materials 27, 1811–1814 (2005)*.

Signal jump around 19 °C of HyperOCR irradiance sensors can make its use strongly problematic.

Vs ambient temperature



Vs. internal temperature

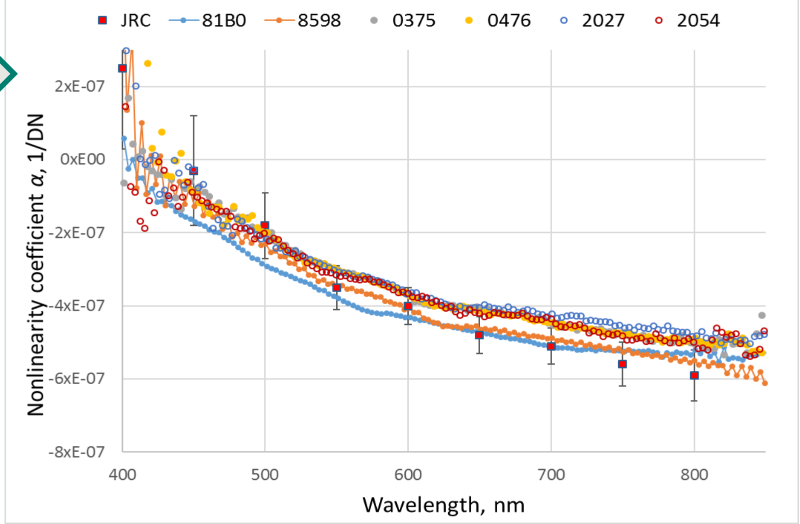


RADIOMETRIC LINEARITY

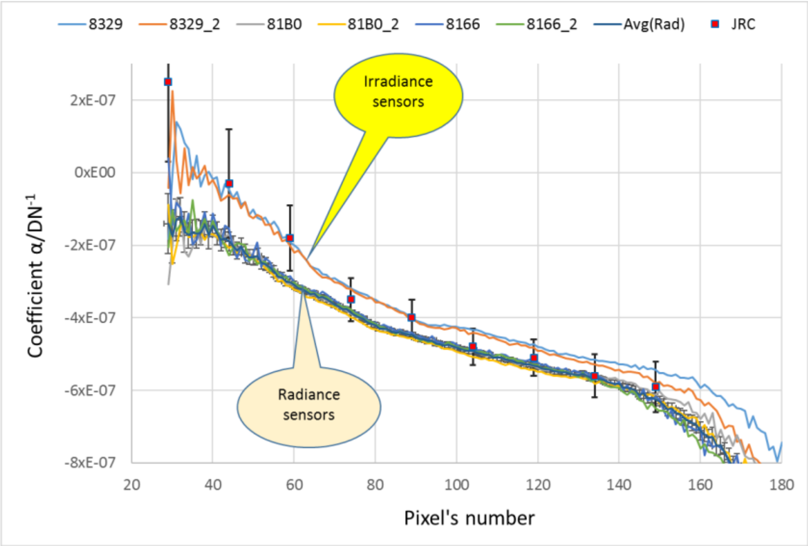
The non-linearity was measured by varying the integration time while measuring a stable broad-band source. The method was compared with the varied distance method [1,2] (JRC – red points).

Additionally, to improve uncertainty in the spectral regions with low radiometric responsivity, the varied integration time method was applied with tunable source measuring non-linearity pixel-by-pixel (blue points).

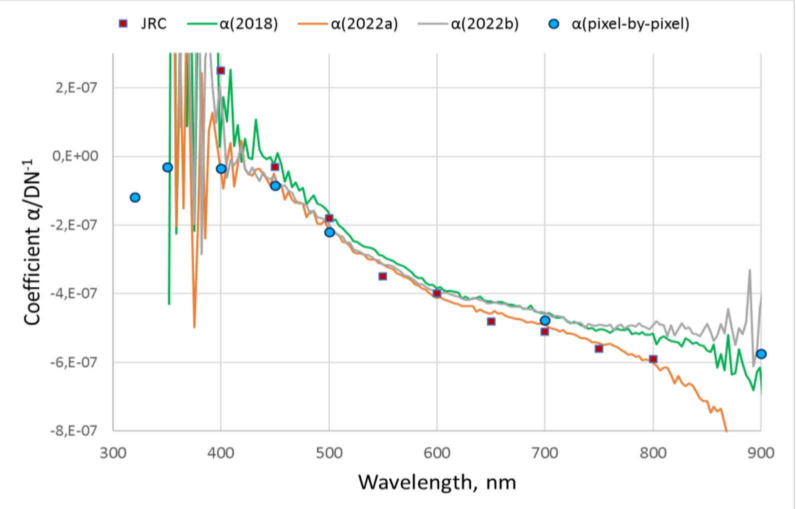
2 RAMSES and 4 HyperOCR



Repeatedly 3 RAMSES sensors



Pixel-by-pixel method, blue points



1. M. Talone and G. Zibordi, "Non-linear response of a class of hyper-spectral radiometers," *Metrologia*, vol. 55, no. 5, pp. 747–758, Sep. 2018.
2. M. Talone, G. Zibordi, and A. Bialek, "Reduction of non-linearity effects for a class of hyper-spectral radiometers," *Metrologia*, vol. 57, no. 2, p. 025008, Mar. 2020.

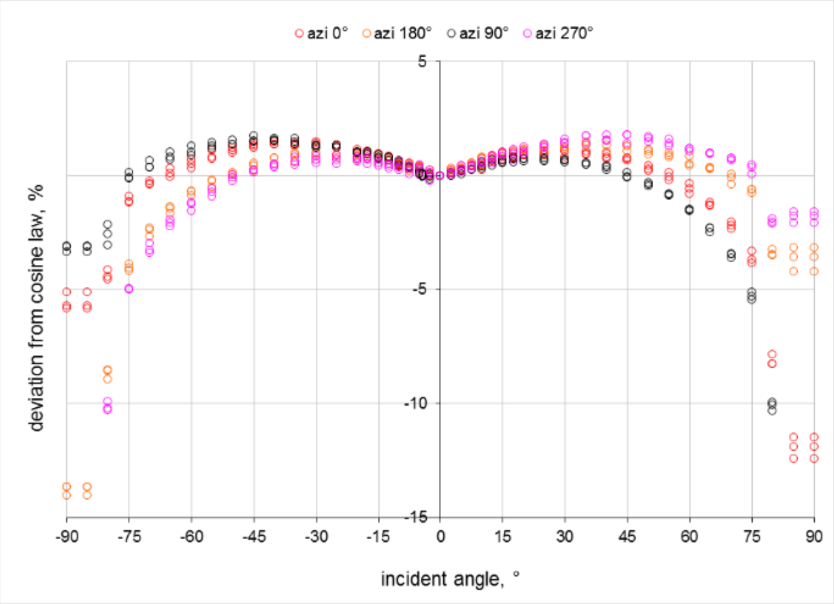
ANGULAR RESPONSE OF IRRADIANCE SENSORS

Cosine error of HyperOCR irradiance sensor is usually smaller than of RAMSES sensors.

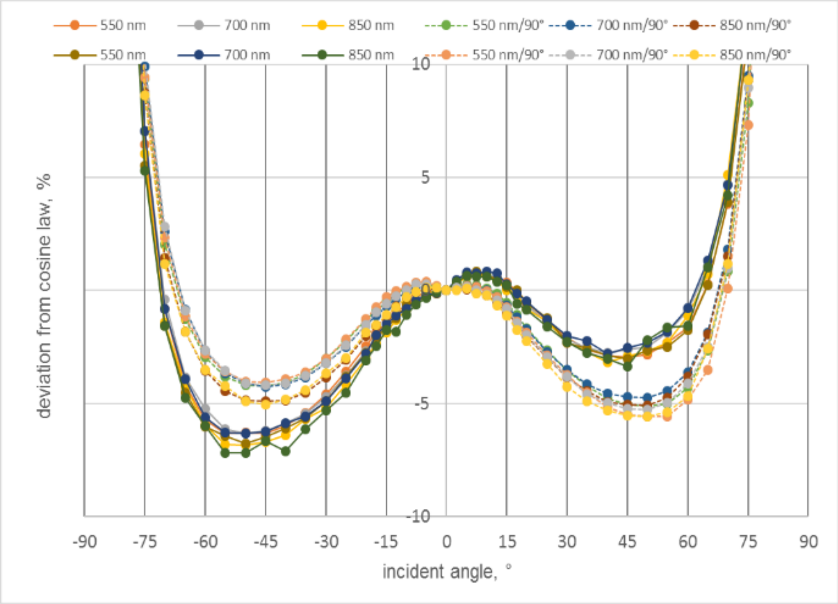
Angle characteristics of TriOS RAMSES irradiance sensors are often strongly non-symmetrical and thus, depend on the azimuth angle used for measurements.

In varying ambient conditions, cosine collector made of PTFE can cause large errors.

HyperOCR irradiance sensor



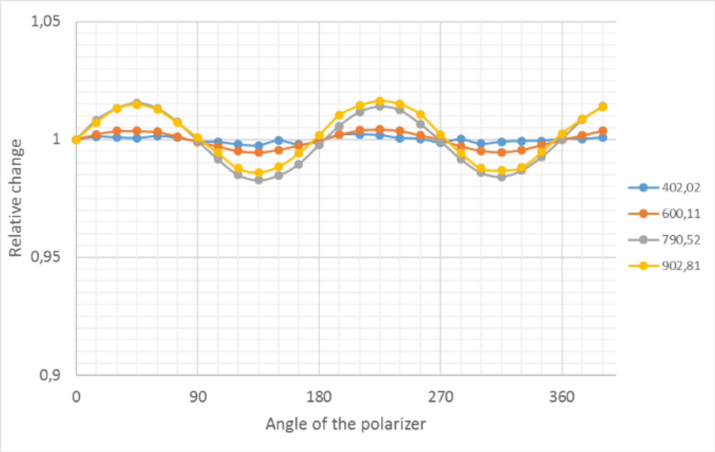
Ramses irradiance sensor

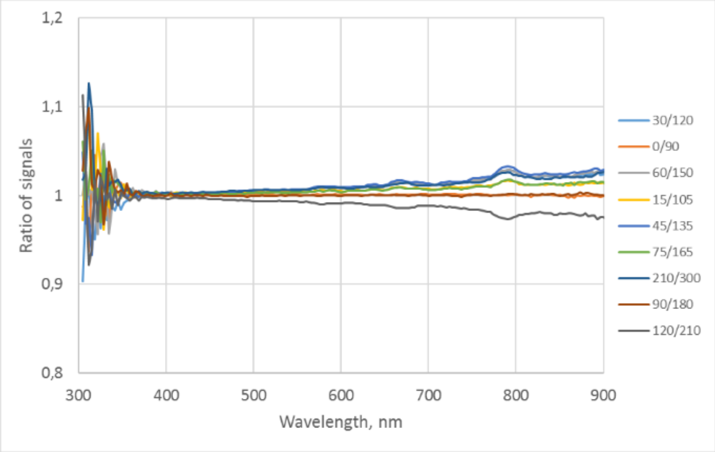


RELATIVE POLARISATION EFFECT

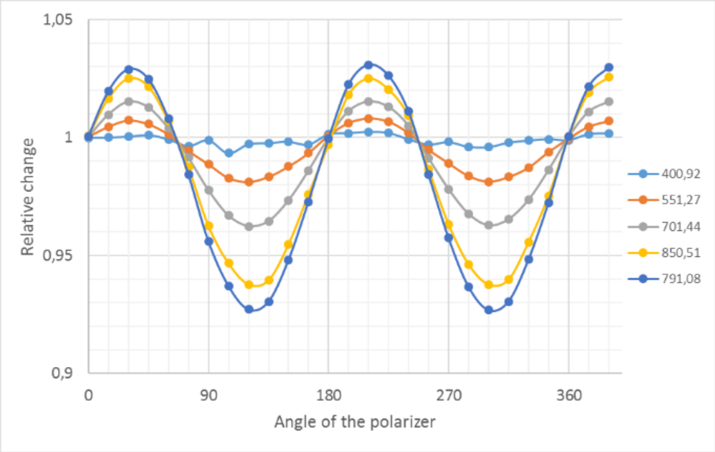
Relative polarisation effect of HyperOCR radiance sensors as a function of angle and wavelength is more than three times larger than of Ramses sensors.

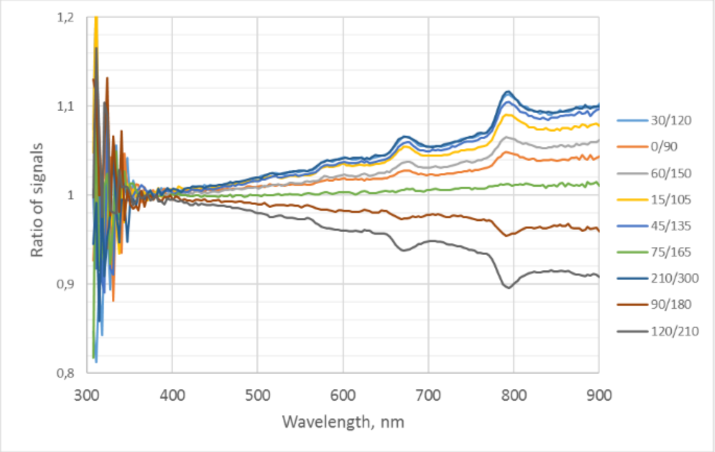
Ramses radiance sensor





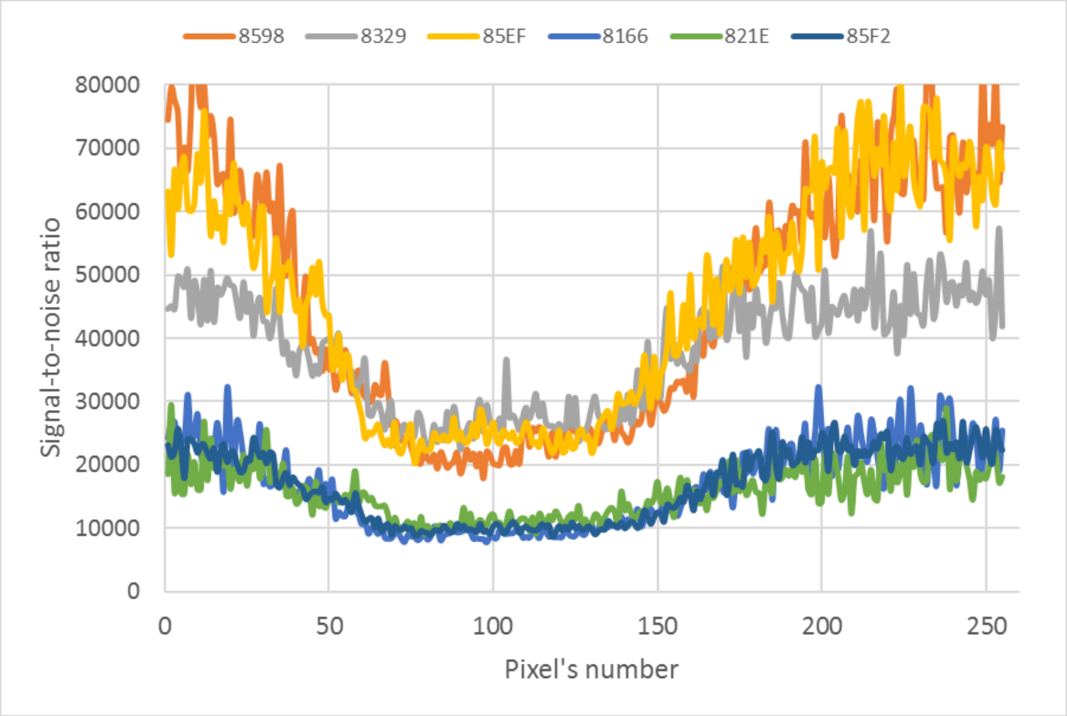
HyperOCR radiance sensor



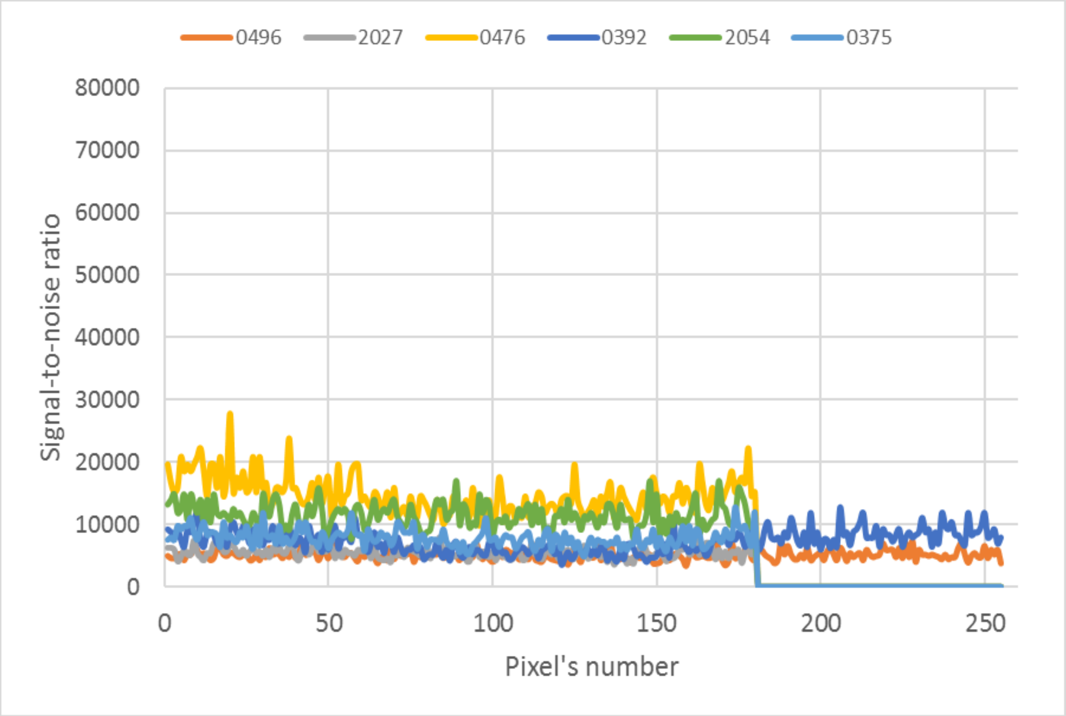


SNR SCALED TO FULL-RANGE VALUE OF RADIOMETERS

Six RAMSES radiometers



Six HyperOCR radiometers



CONCLUSIONS

- Characterisation results cannot be directly converted into the uncertainty of the OC products (radiance, irradiance, reflectance) as the measurand, the conditions, signal's properties and procedure affect the result.
- Characterisation of many parameters is affected by the self-heating of the radiometers, as the responsivity change is comparable with the measured effects. Methods for drift elimination shall be applied.
- Agreement with previous results was satisfactory. However, further validation by comparison measurements is needed for majority of characterisation procedures used for the OC radiometers.
- For specification of the class-specific uncertainty a distribution parameters (center, shape and spread) of individual characteristics must be known.
- Differences in hard- and software of OC radiometers make the cal/char procedures model dependent and impede harmonisation of guidelines. Therefore, cooperation with instrument developers is needed in order to standardise and improve the parameters, contributing to the OC uncertainty at most.