Community guidelines on radiometer cal/char requirements and schedules.

Viktor Vabson, Ilmar Ansko, Riho Vendt, Joel Kuusk
UT

Introduction

Community guidelines on radiometer cal/char requirements and schedules are presented in Document D-8. To support our proposal, data of D-9 are analyzed, including 34 OC radiometers both radiance L and irradiance E sensors of the two most common models (TriOS RAMSES and Satlantic/Sea-Bird HyperOCR).

Absolute radiometric calibration is the most important part in the complete cal/char of OCRs.

Major requirements for the calibration are:

- SI traceability
- uncertainty of calibration coefficients
- regular re-calibration

For the scope of characterisation the central problem is:

- class-specific treatment or strictly individual approach required
- regularity of characterisation

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Problems with preparing cal/char guidelines

Cal/char results contribute to the uncertainty of the OC products (radiance, irradiance, reflectance) but contribution depends on definition of the measurand:

- a number of sensors used
- properties of the measured signal
- environmental conditions
- number of light and dark repetitions
- integration times
- synchronisation, etc.

Therefore, evaluation of risks related with class-specific characterization of OCRs is difficult. In the case of limited information, individual characterization looks more preferable.

D-8: Guidelines for individual OCR cal/char and the re-characterisation schedule.

Parameter	Scope	Before initial use	Re-cal/char	D-2 requirement
1. Absolute calibration for radiometric responsivity	individual	required	1 year	IR1
2. Long term stability	individual	required	after every calibration	IR1
3. Stray light and out of band response	**individual**	required	3 – 5 years	IR2
4. Immersion factor (irradiance)	individual	required for under-water	after fore-optics modification	-
4b.Immersion factor (radiance)	class-specific	recommended	after fore-optics modification	-
5. Angular response of irradiance sensors in air	individual	required	after fore-optics modification	IR3
6. Response angle (FOV) of radiance sensors in air	**individual**	recommended	after fore-optics modification	-
7. Non-linearity	**individual**	recommended	after repair in workshop	IR4
8. Accuracy of integration times	individual	recommended	after repair in workshop	IR4
9. Dark signal	individual	required	1 year	IR7
10. Thermal responsivity	**individual**	recommended	after repair in workshop	IR5
11. Polarisation sensitivity	class-specific	recommended	after repair in workshop	IR6
12. Temporal response	TBD	TBD	TBD	IR8
13. Wavelength scale	class-specific	recommended	after fore-optics modification	IR9
14. Signal-to-noise ratio	individual	recommended	1 year	-
15. Pressure effects	TBD	TBD	TBD	-

Parameters marked red by some of reviewers are suggested as class-specific.

Analysis of D-9 results

Analysis deals mainly with the characterisation data of:

- Thermal coefficients
- Nonlinearity coefficients
- Angle characteristics
- Straylight response

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Radiometric responsivity

Yearly re-calibration of the OC radiometers is required.

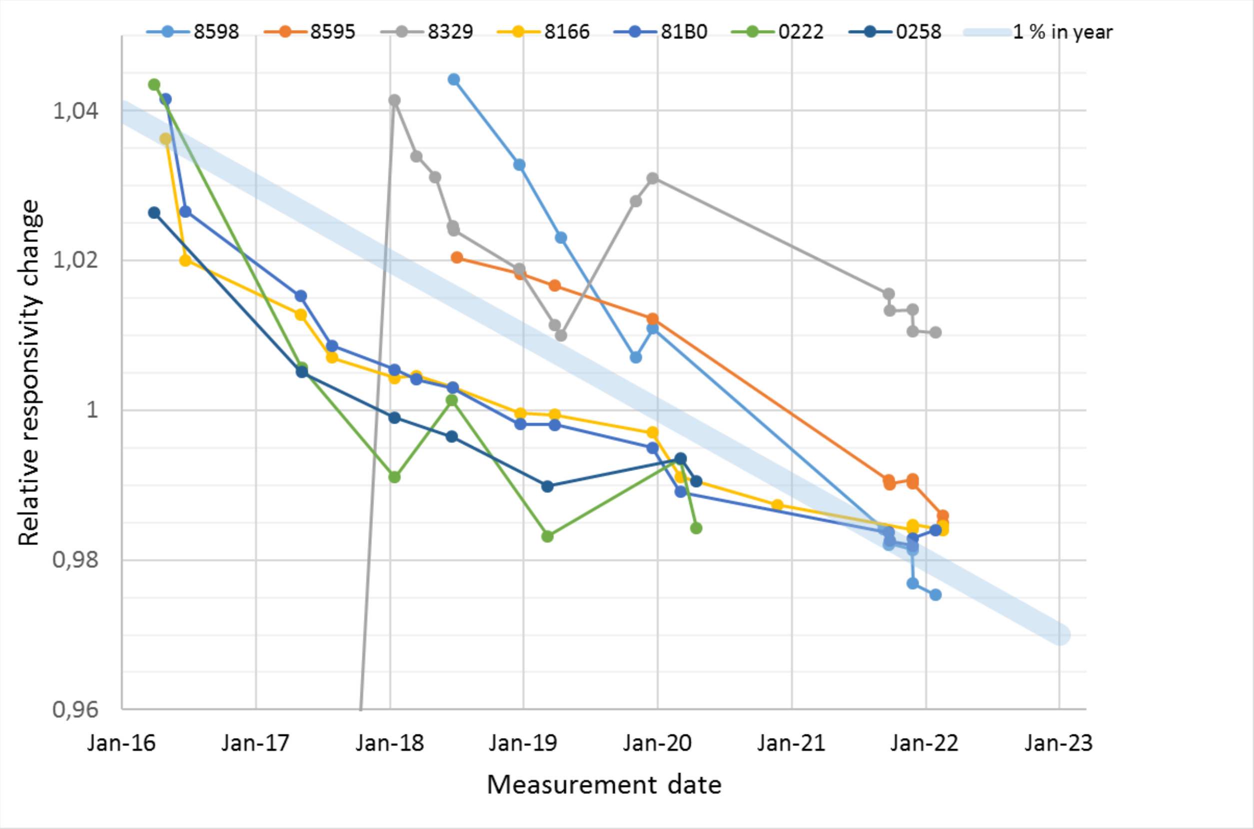
or

Calibration before and after each deployment is required.

Which is preferable?

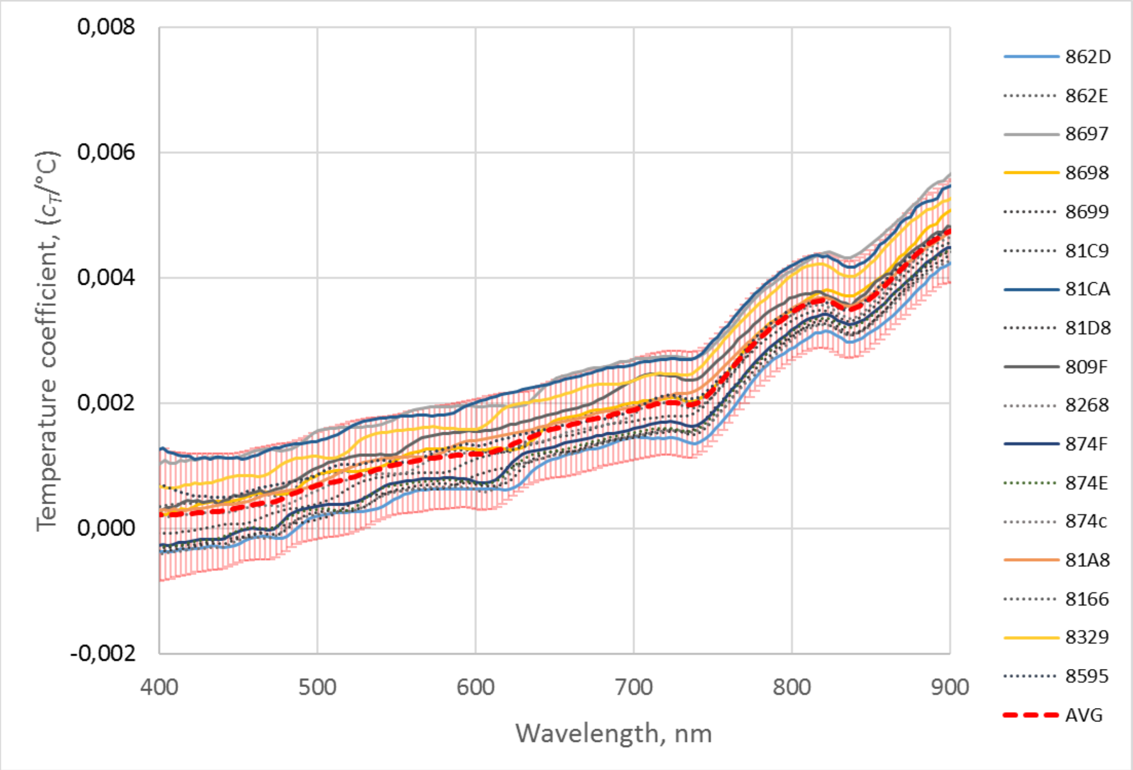
Average drift about -1 % per year is shown with broad blue line.

Drift for selected instruments.

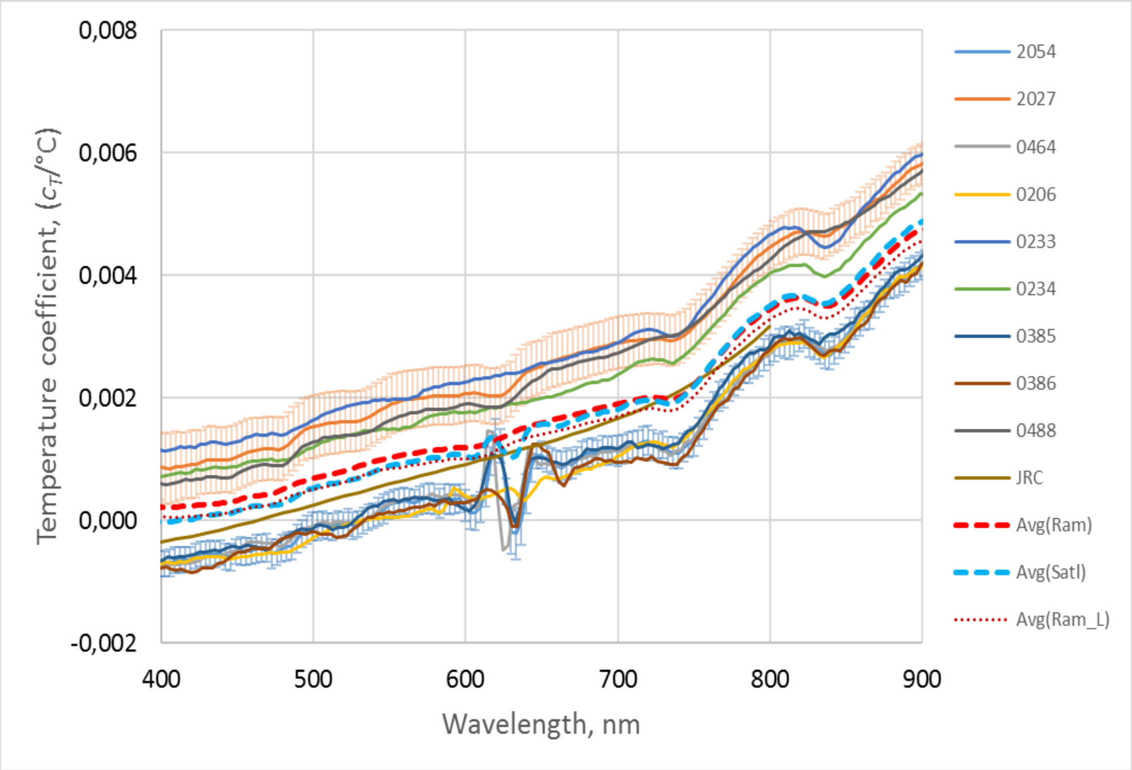


Thermal response (26 radiometers)

Thermal coefficients of 17 RAMSES sensors; uncertainty for class-specific presentation



Thermal coefficients of 9 Satlantic sensors; uncertainties for two individual characteristics



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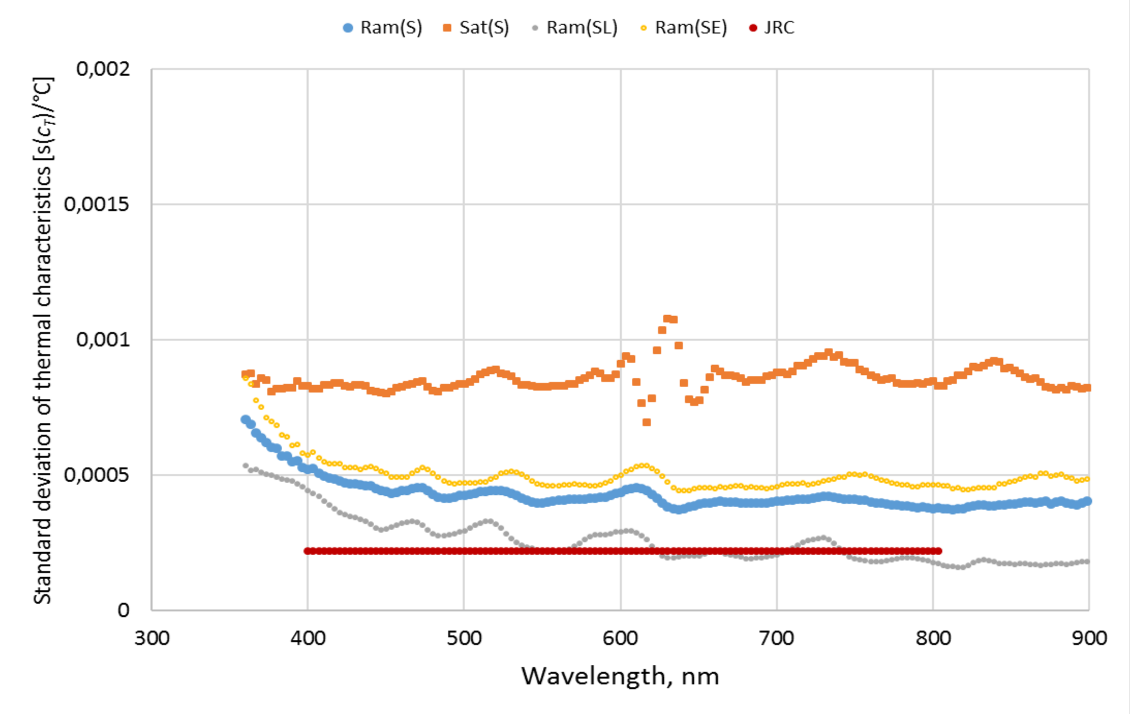
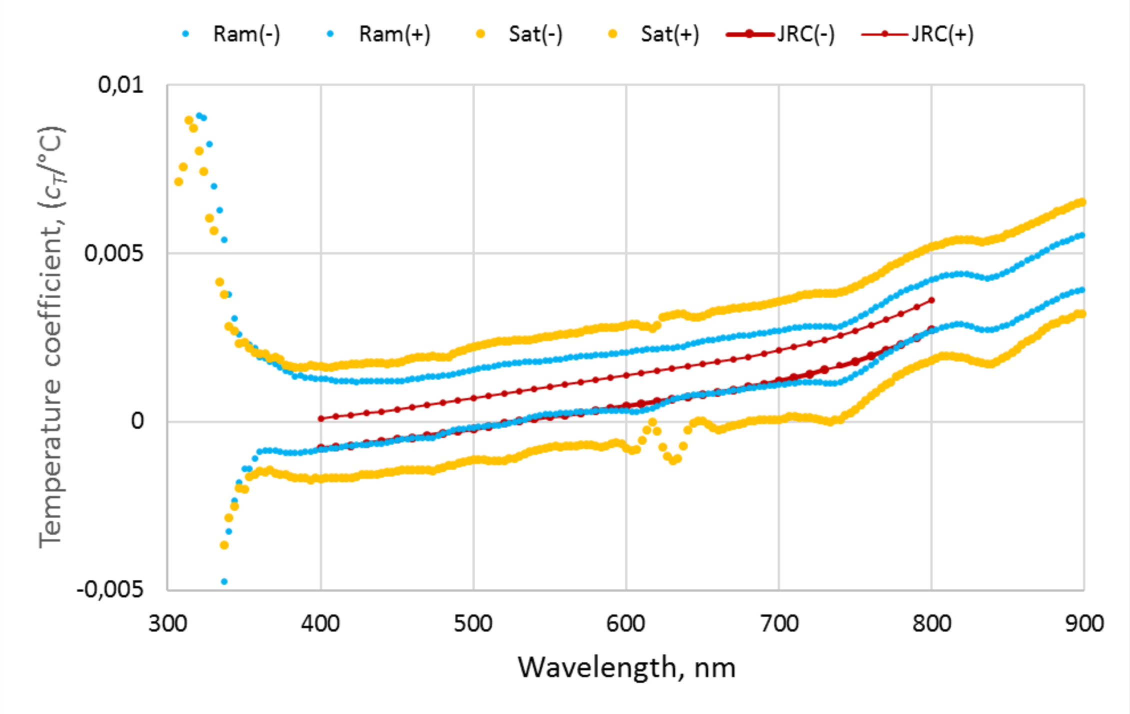
Standard deviation of individual thermal coefficients

Spread of individual thermal coefficients - Standard deviations for class-specific presentation



Regions covering 95 % of individual thermal coefficients indicating uncertainty for class-specific presentation (RAMSES – blue; HyperOCR – yellow)



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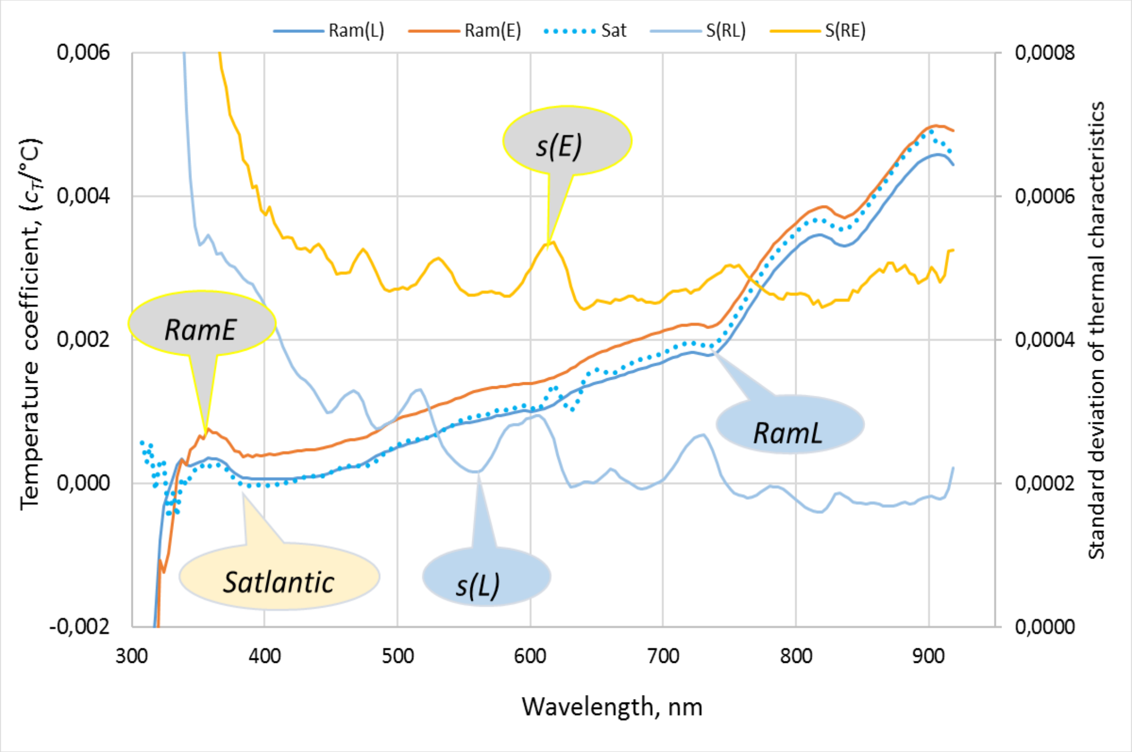
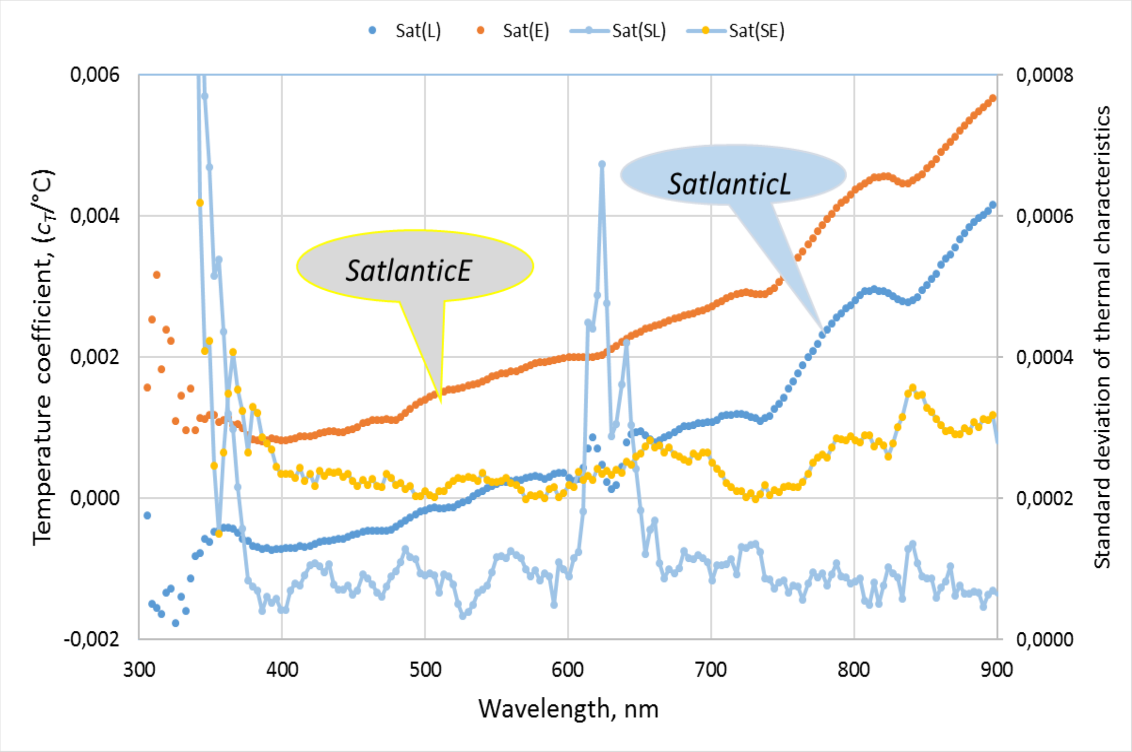
Differences between averaged thermal coefficients

RAMSES: difference is small, spread larger than has HyperOCR

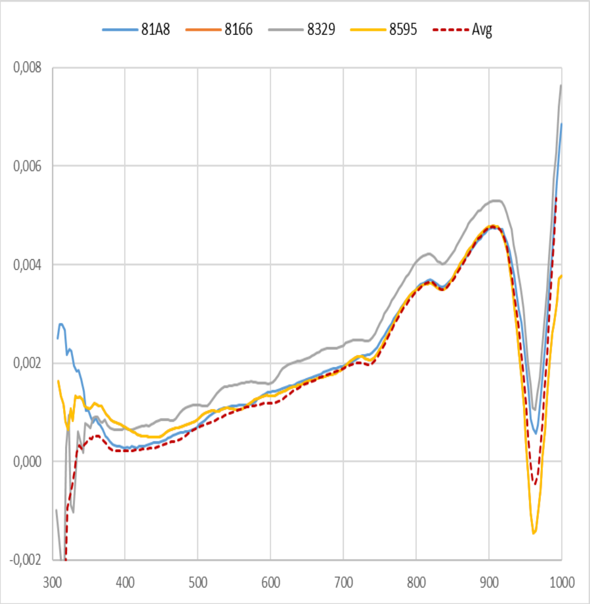


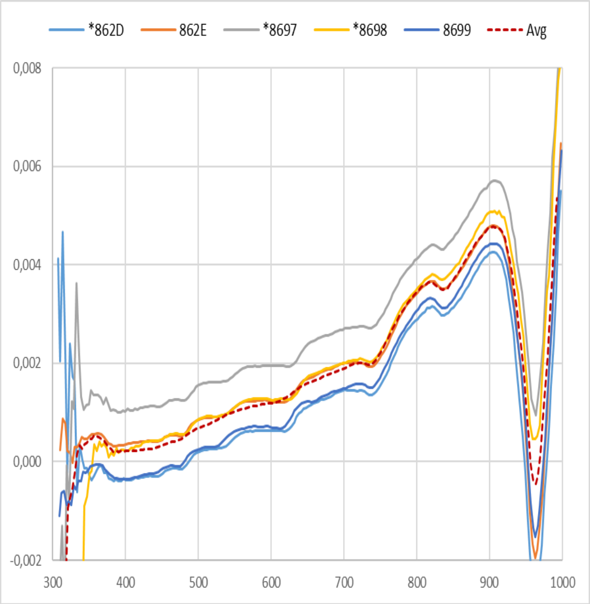
HyperOCR: large difference between E and L

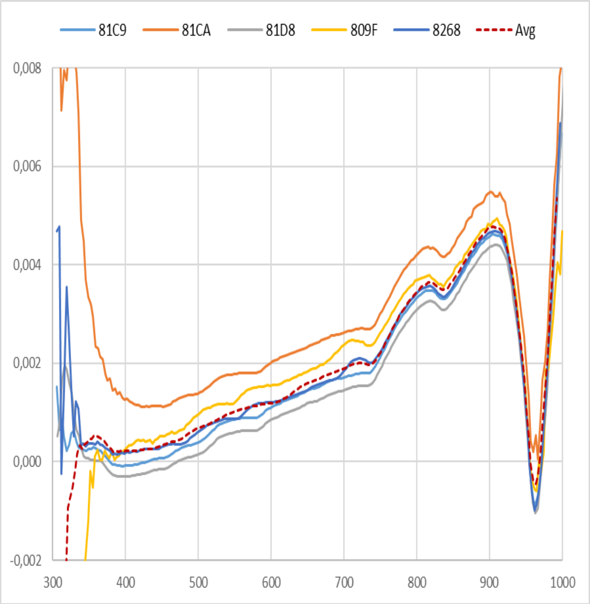


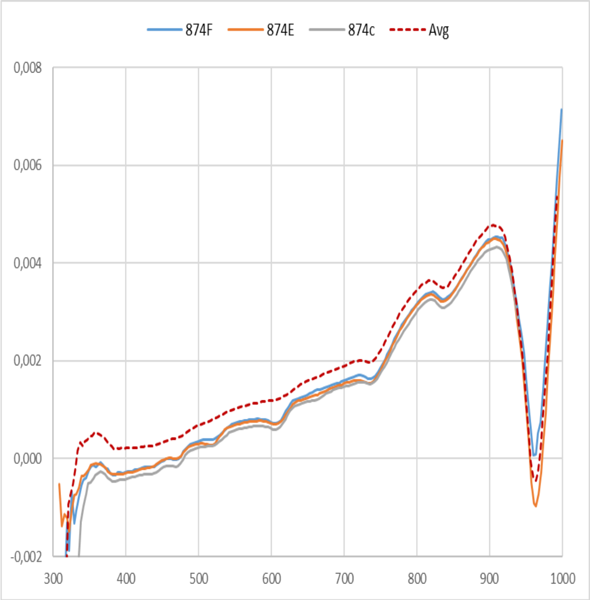
Differences between RAMSES radiometers

Four groups of radiometers belonging to four different institutions; two groups likely are suited for class specific treatment, but two others probably not.









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Thermal response

Average thermal response of the RAMSES irradiance and radiance sensors is close, but spread of irradiance sensors is much larger.

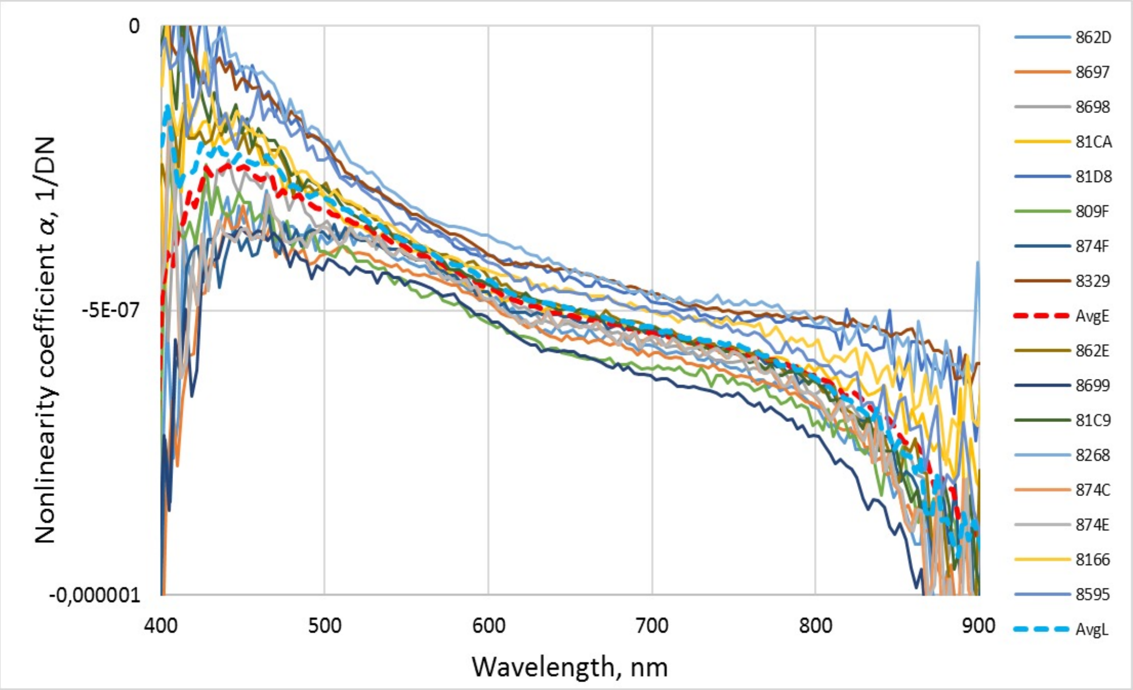
Different response of the HyperOCR irradiance and radiance sensors is likely caused besides the optical sensor also by the cosine collector made of PTFE. This difference is the main cause of much larger spread among all HyperOCR sensors.

Average thermal response of all sensors is close, but large spread among all characteristics makes the class-specific approach questionable.

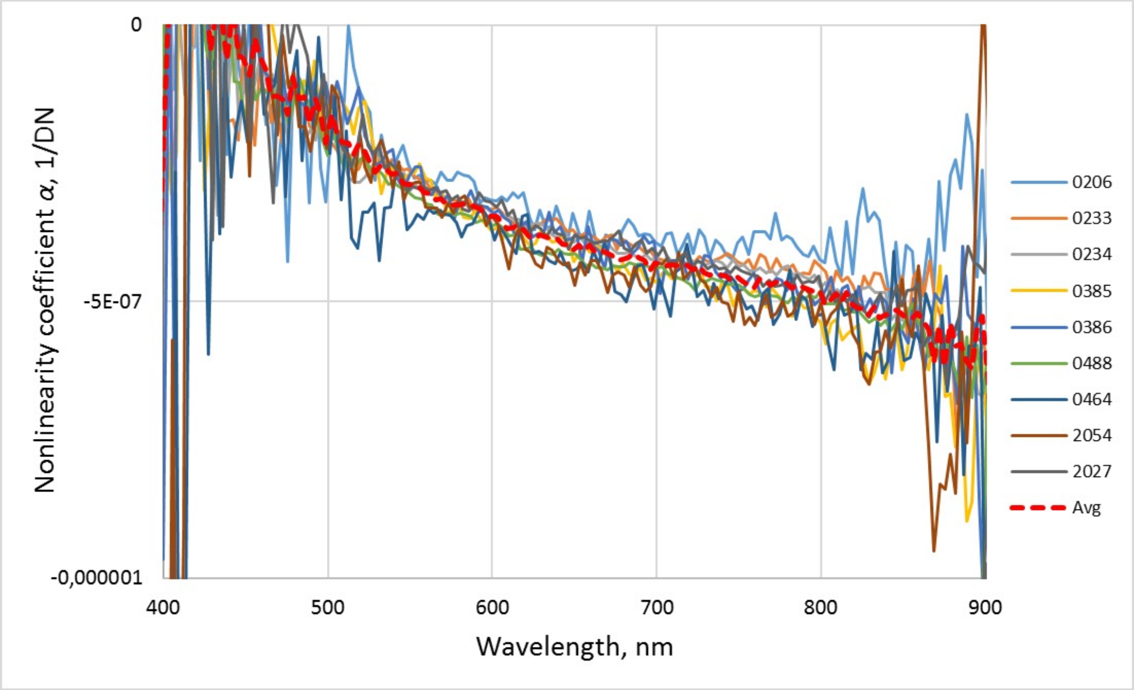
Transmittance of PTFE changes abruptly by 1 - 3 % at around 19 °C due to a phase shift, see for example *L. Ylianttila and J. Schreder, Optical Materials 27, 1811–1814 (2005)*.

The radiometric non-linearity coefficients

Non-linearity coefficients α of 16 RAMSES sensors

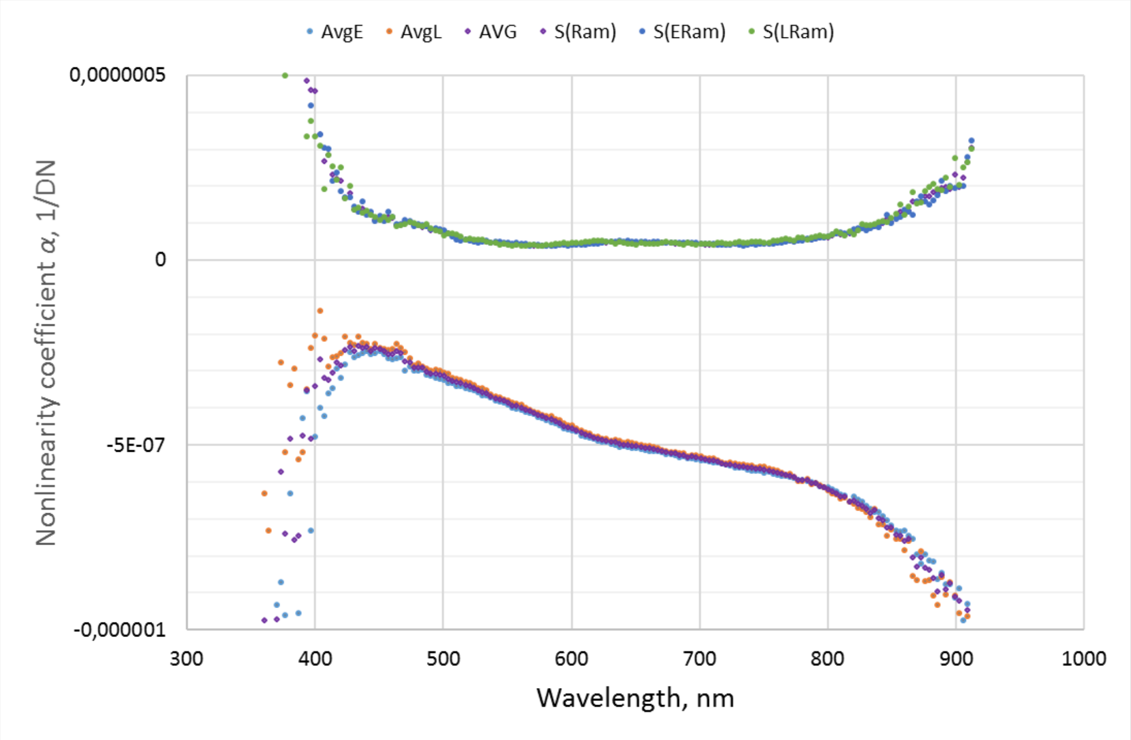


Non-linearity coefficients α of 8 HyperOCR sensors

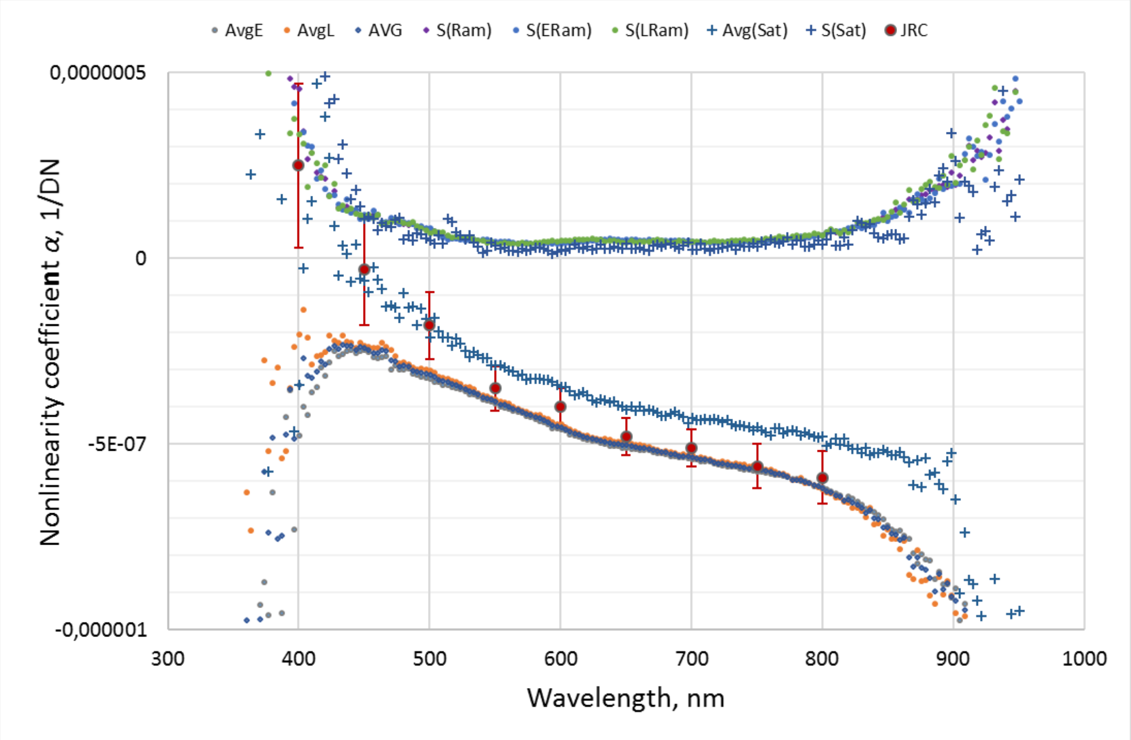


Average non-linearity with standard deviations

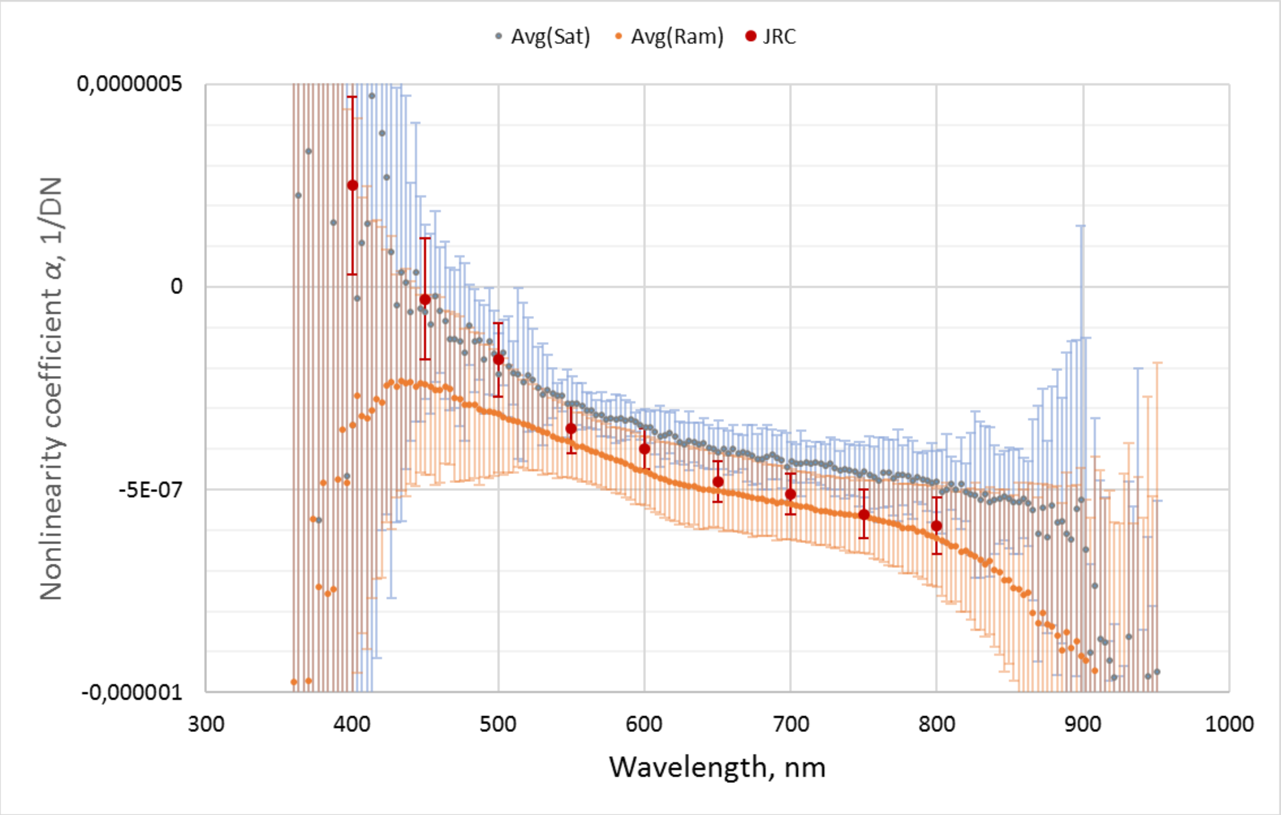
RAMSES: Average of E, L, and all sensors



Additionally average of all HyperOCR sensors, and JRC
Difference between RAMSES and HyperOCR is evident

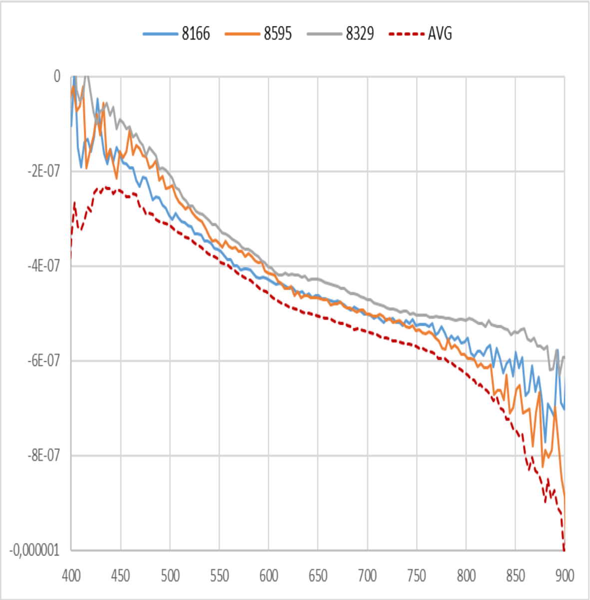


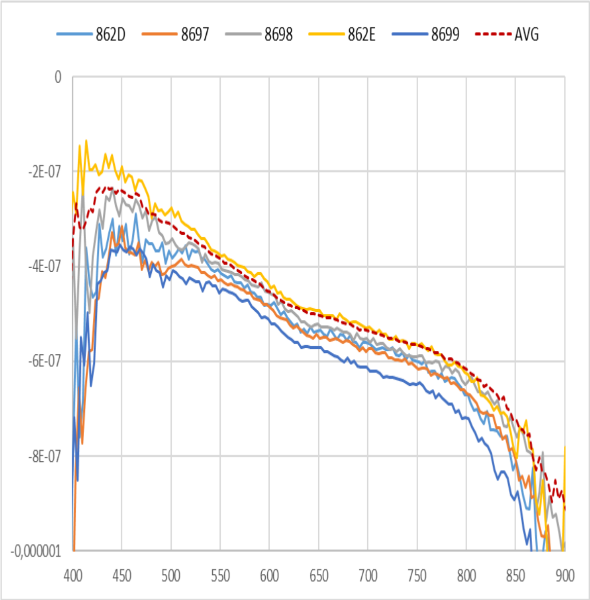
Uncertainty for class-specific presentation

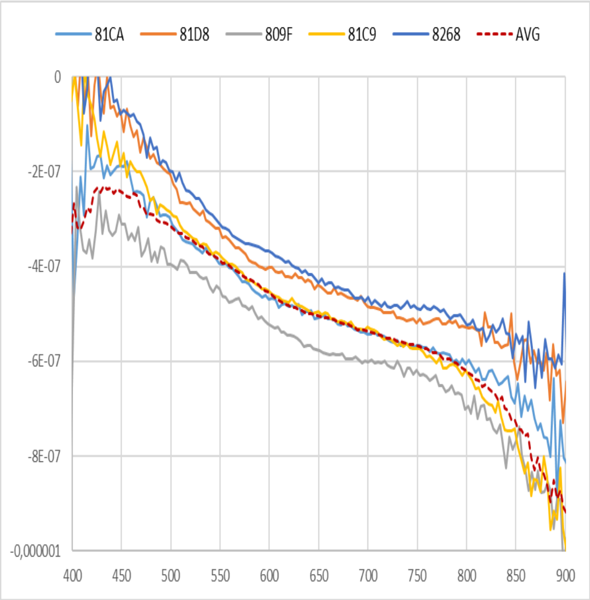


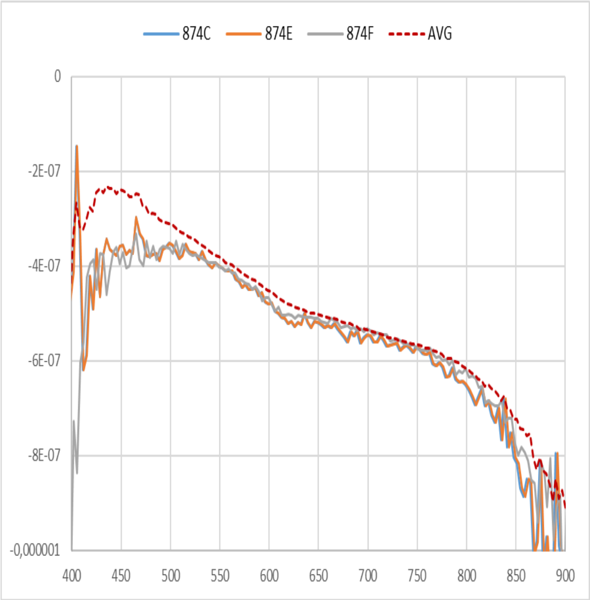
Differences between RAMSES radiometers

Four groups of radiometers belonging to four different institutions; Average non-linearity is shown with red dotted line.









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Non-linearity response

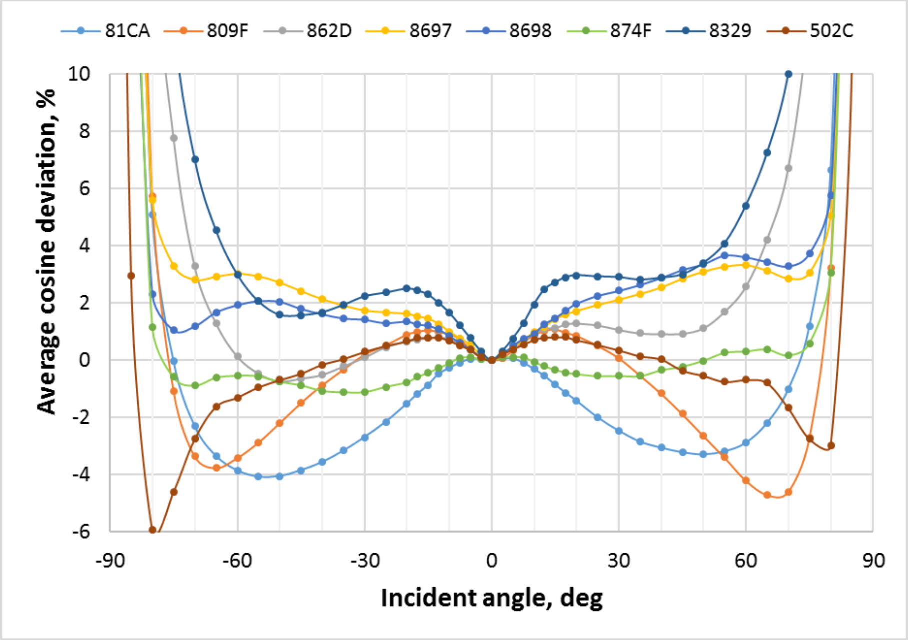
Average non-linearity response of the RAMSES irradiance and radiance sensors is close, and spread of sensors is also similar.

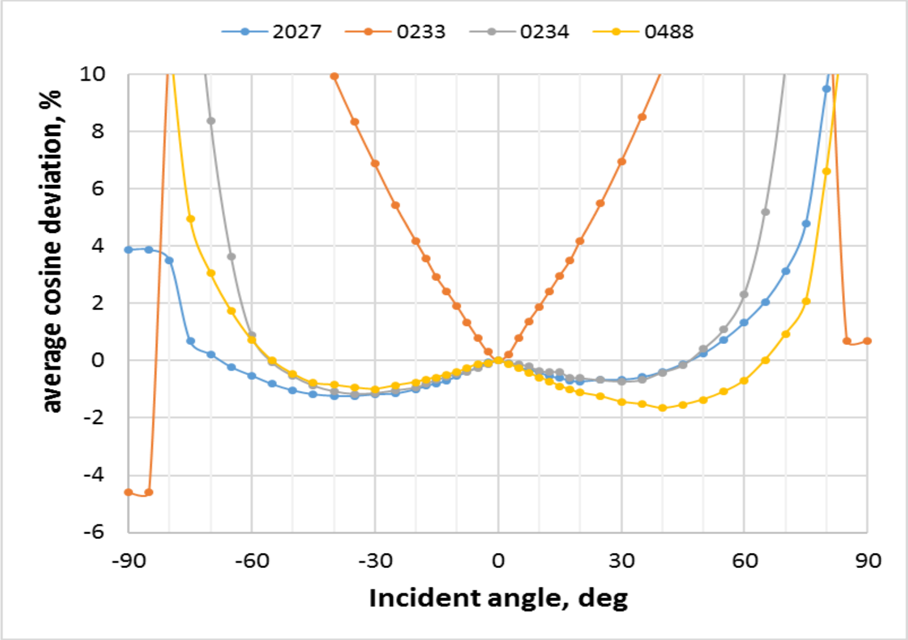
Different non-linearity response of the HyperOCR and RAMSES sensors is clearly evident.

Large spread among all non-linearity characteristics makes the class-specific approach questionable.

Average angle response of 8 RAMSES and 4 HyperOCR sensors

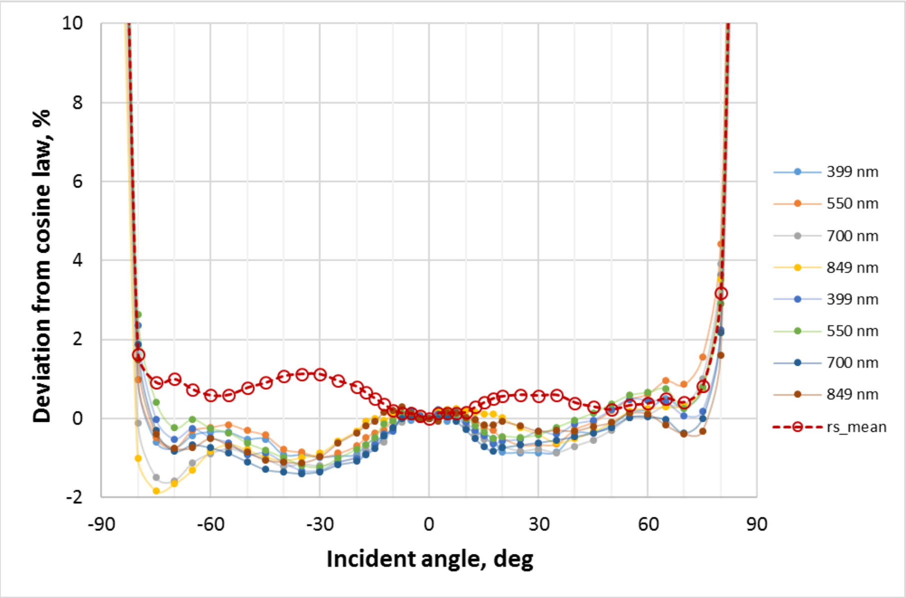
Differences between average angle responses of RAMSES sensors is much larger than among HyperOCR sensors. Nine RAMSES sensors left, four HyperOCR sensors right.

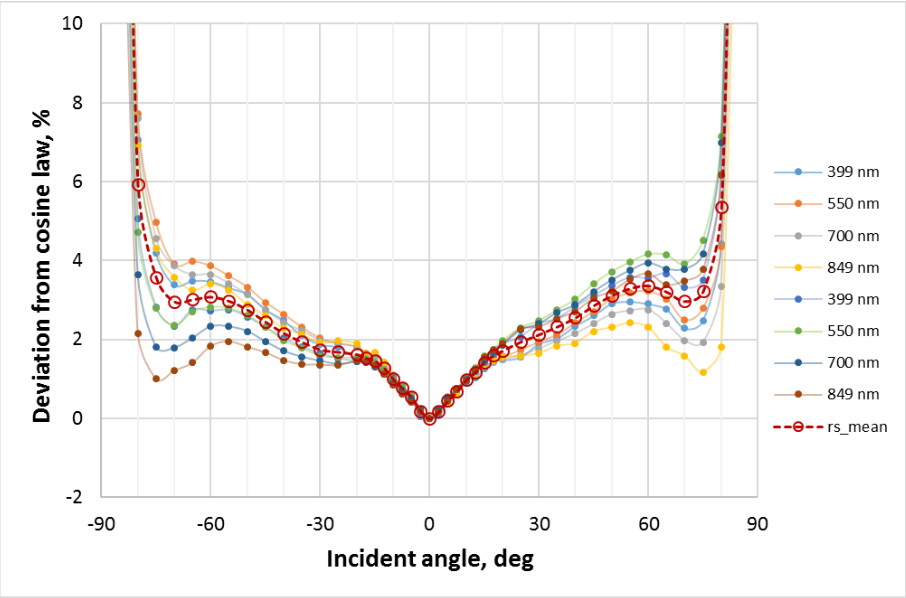




Individual angle response of two RAMSES sensors

For comparison of a number of sensors, the root mean square of cosine deviations of each sensor is calculated (red dotted line with red dots).





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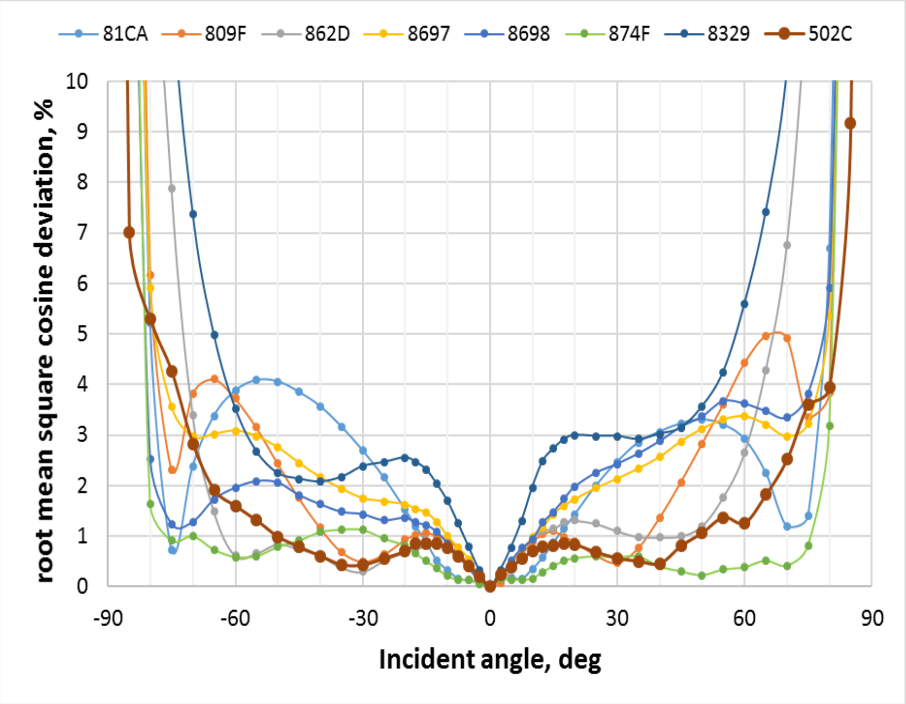
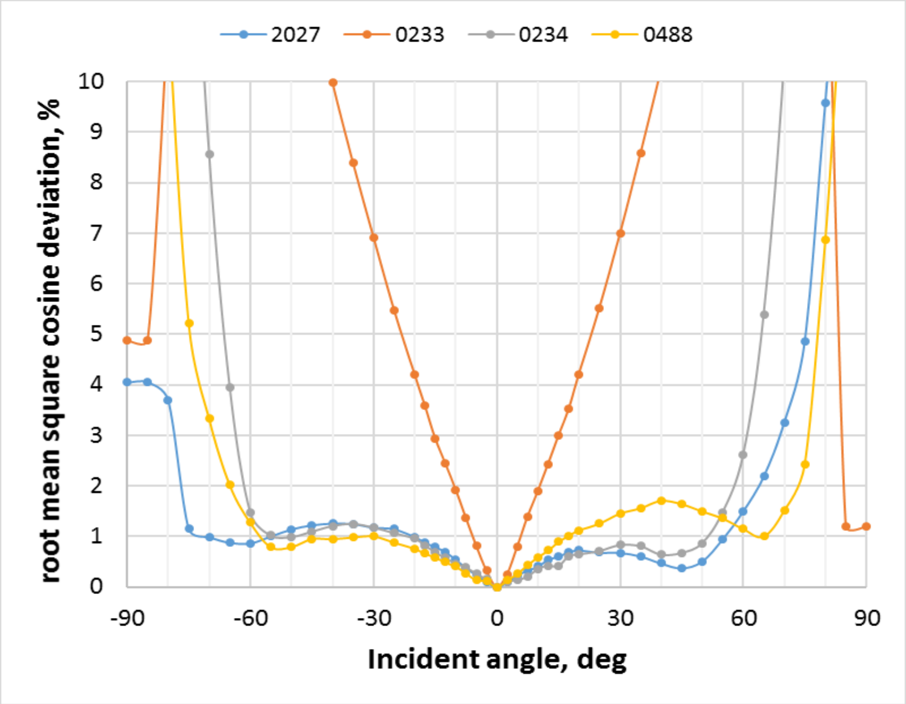
Root mean square angular response of RAMSES and HyperOCR sensors

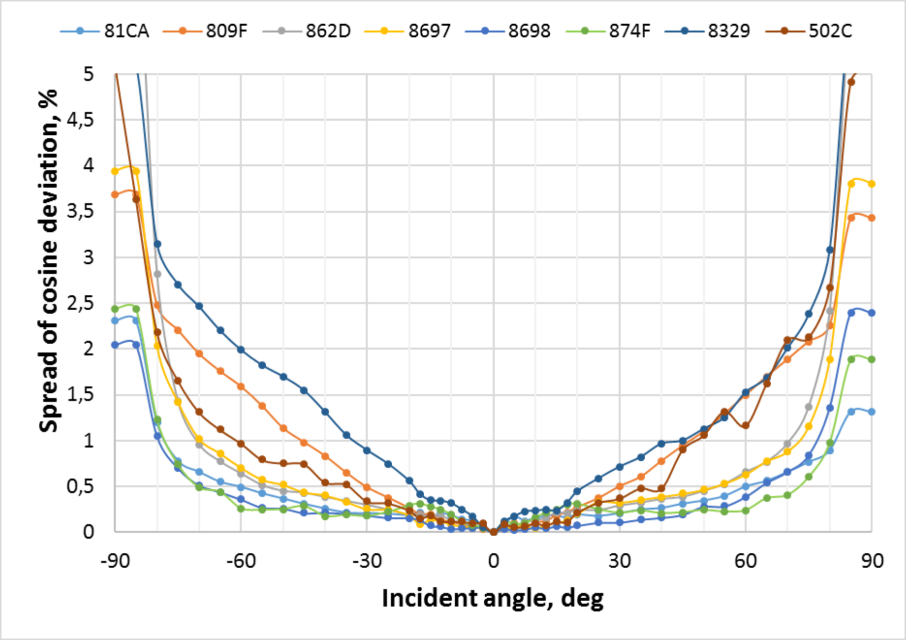
The best cosine response of RAMSES is well comparable with the cosine response error of HyperOCR sensors.

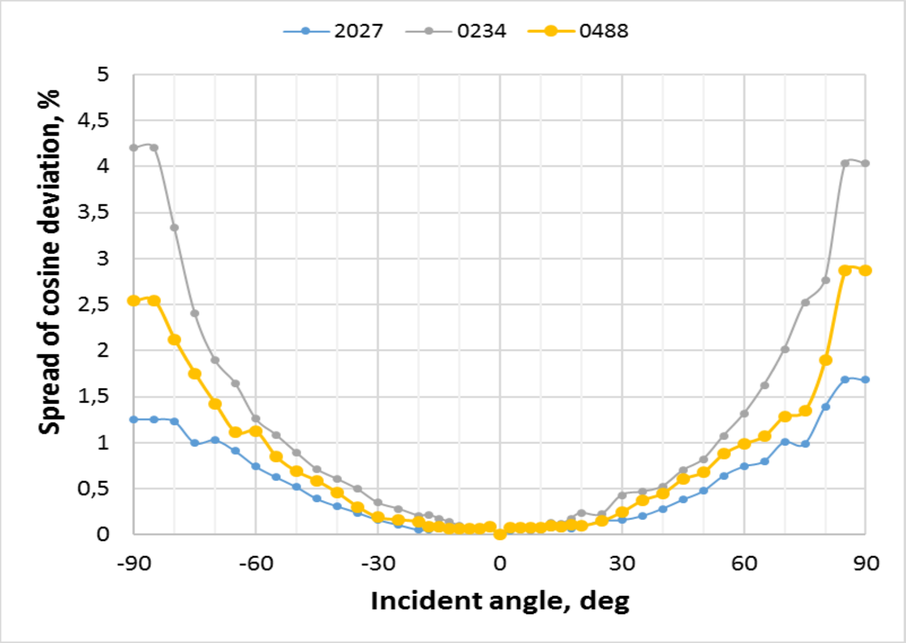




Spread of angle response

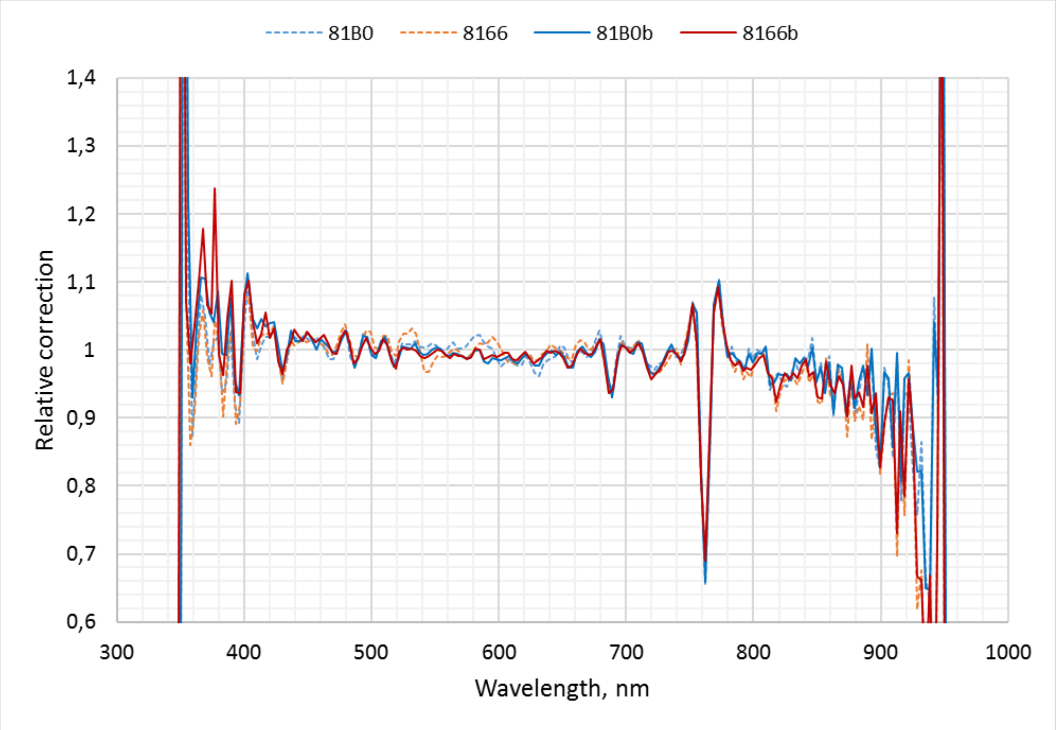
Spread of angle characteristics is evaluated as standard deviation of individual response values.



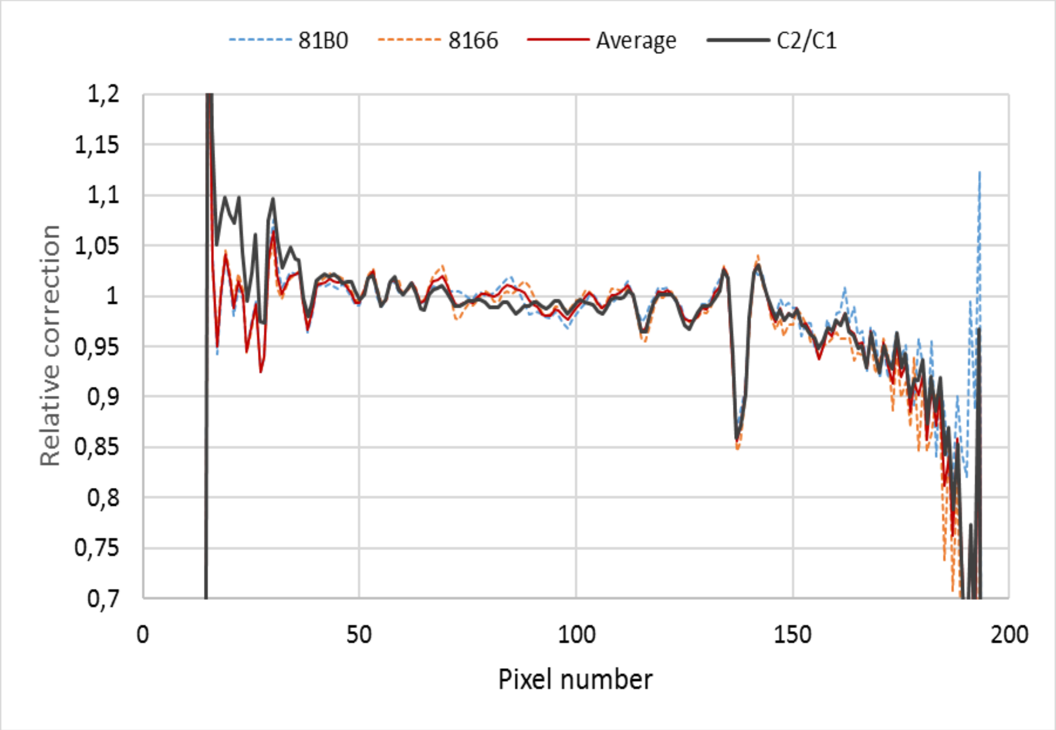


Straylight response

Relative straylight correction for sky spectrum C12 of two RAMSES sensors calculated with the individual SLM.

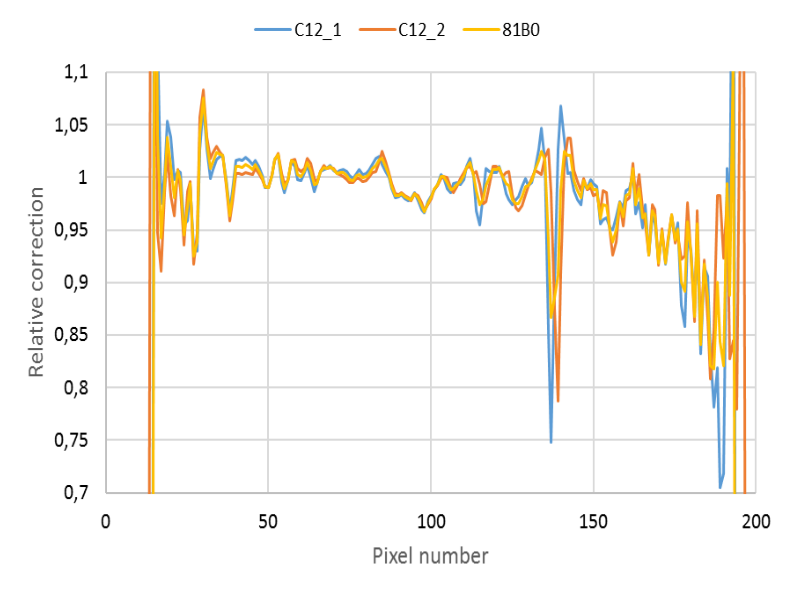


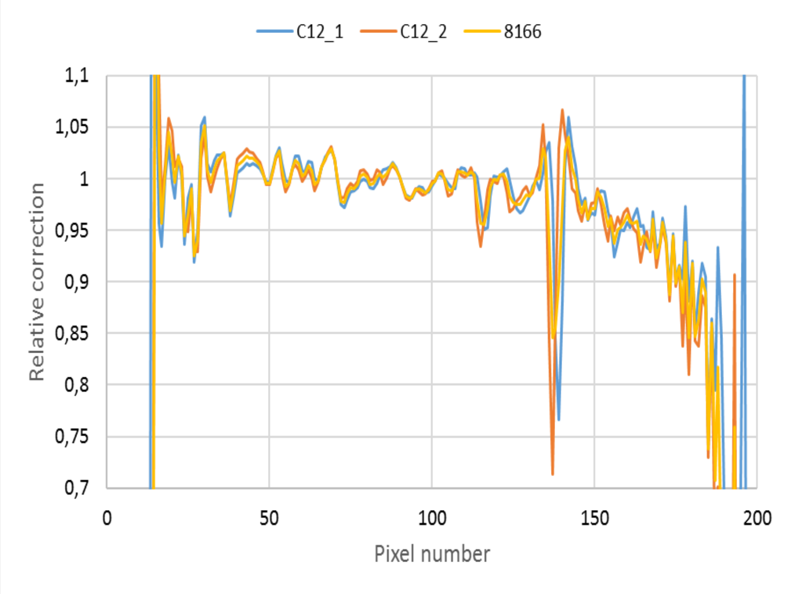
Average straylight correction for C12 of two RAMSES sensors calculated with the SLMs of other sensors.

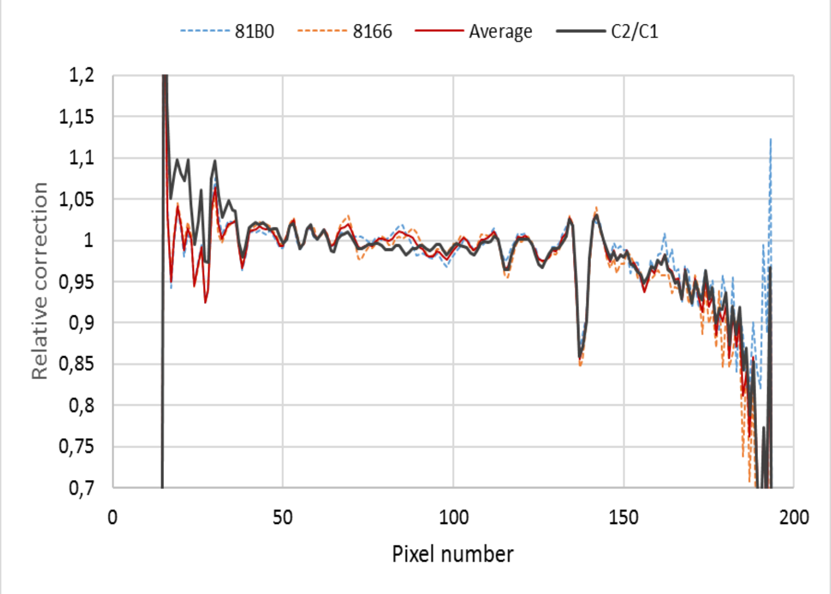


Straylight response with SLM of ohter sensors

Dependence of the general shape of the average straylight correction from the used SLM is rather weak expect the region with sharp spectral features.







Class-specific characterisation

Procedures are needed:

- For preparing class-specific characteristics/related uncertainties
- For individual use of the class-specific characteristics

Contribution of particular characteristics to a value/uncertainty of a OC products/uncertainties should be evaluated, calculating the product:

- without correction
- with correction basing on the individual characteristic
- with correction basing on the class-specific characteristic

D-8: Guidelines for individual OCR cal/char and the re-characterisation schedule.

Parameter	Scope	Before initial use	Re-cal/char	D-2 requirement
1. Absolute calibration for radiometric responsivity	individual	required	1 year	IR1
2. Long term stability	individual	required	after every calibration	IR1
3. Stray light and out of band response	**individual**	required	3 – 5 years	IR2
4. Immersion factor (irradiance)	individual	required for under-water	after fore-optics modification	-
4b.Immersion factor (radiance)	class-specific	recommended	after fore-optics modification	-
5. Angular response of irradiance sensors in air	individual	required	after fore-optics modification	IR3
6. Response angle (FOV) of radiance sensors in air	**individual**	recommended	after fore-optics modification	-
7. Non-linearity	**individual**	recommended	after repair in workshop	IR4
8. Accuracy of integration times	individual	recommended	after repair in workshop	IR4
9. Dark signal	individual	required	1 year	IR7
10. Thermal responsivity	**individual**	recommended	after repair in workshop	IR5
11. Polarisation sensitivity	class-specific	recommended	after repair in workshop	IR6
12. Temporal response	TBD	TBD	TBD	IR8
13. Wavelength scale	class-specific	recommended	after fore-optics modification	IR9
14. Signal-to-noise ratio	individual	recommended	1 year	-
15. Pressure effects	TBD	TBD	TBD	-

For the parameters marked red and suggested as class-specific further discussion is needed.

General notes from reviewers

Requirements for re-calibration and re-characterization shall be related with the uncertainty requirements of OC products.

Class-specific characterizations shall be well identified for the instrument-series, and be accompanied by uncertainties.

Class-specific characterizations shall be applicable without any further action (re-characterizations recommended for different reasons).

The identification of class-specific corrections and their impact on measurements is an extraordinary and commendable effort.

Some references, some illustrating graphs and explanations are missing.

Conclusions

- Full cal/char has been performed on 34 OC radiometers.
- Statistical basis for identification of class-specific characterisation is improved, but large spread makes the approach still questionable.
- Procedures for preparing class-specific characteristics and for individual use of these class-specific characteristics are needed.
- Analysis is needed, how to use cal/char data for different parameters and application schemes.

Themes for discussion

1. Principles of class-specific charaterisation
2. List of characterisations which shall be performed individually
3. Required cal/char regularity
4. Is the specified performance metrics needed for OC radiometers?
   - Manufacturer’s specification
   - User’s specification
   - International standard/recommendation specifying requirements for different parameters
5. Is the uniformity of OC radiometers sufficient?

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