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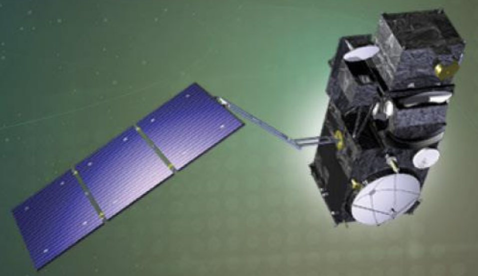

7th Sentinel-3 Validation Team Meeting 2022

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

OLCI L1 radiometric uncertainty validation

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1: ACRI-ST
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OLCI L1 uncertainty status

OLCI uncertainty status

The per pixel uncertainties are now available in L1 products, at ESA production (and in a near future for EUMETSAT production).

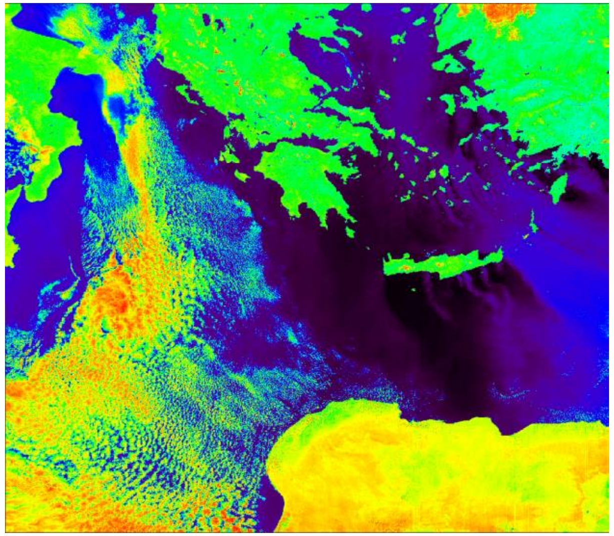
- Encoded over 1 byte with logarithm scale
- Increase of the product size by 35% (uncompressed)

Stored within the same SAFE folder, in a dedicated NetCDF file.

S3A_OL_1_EFR____20210224T084238_20210224T084538_20220518T…
- geo_coordinates.nc
- instrument_data.nc
- Oa01_radiance.nc
- Oa01_radiance_unc.nc
- Oa02_radiance.nc
- Oa02_radiance_unc.nc

Oa17 radiance:

Oa17 unc:



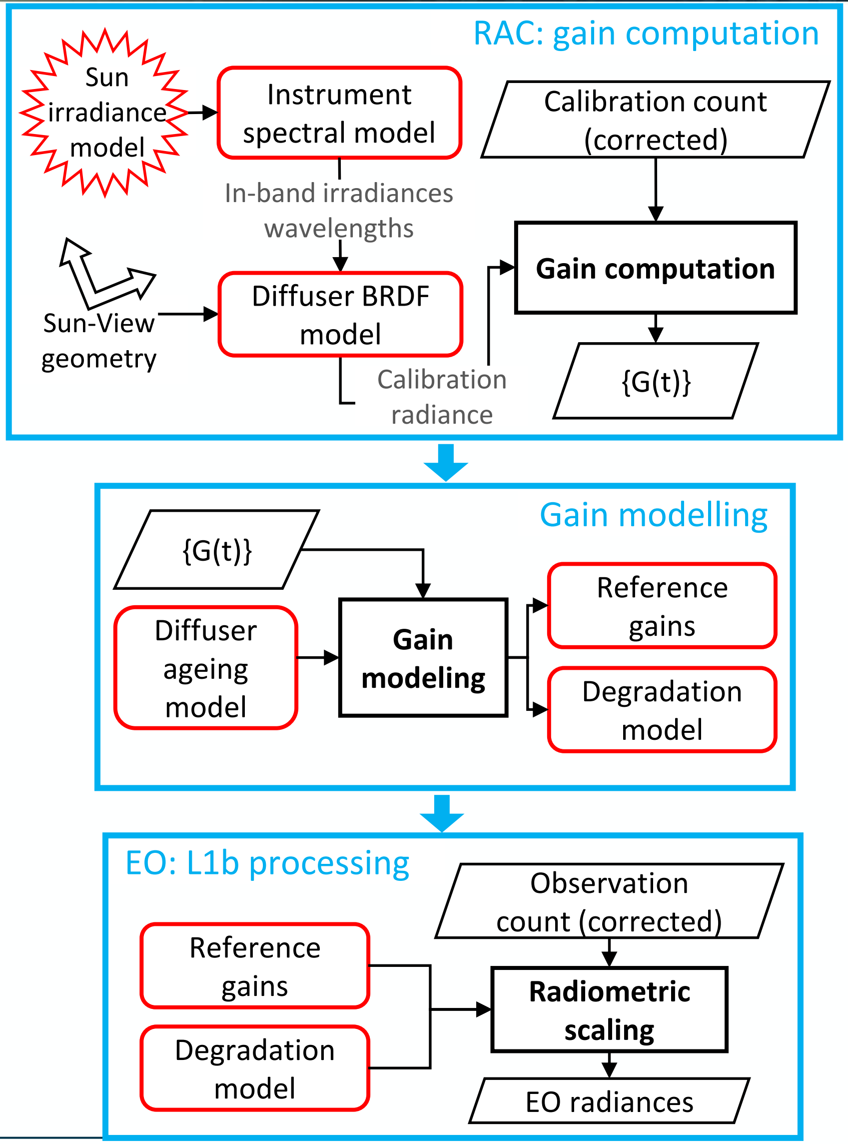
OLCI uncertainty status

OLCI level-1 uncertainties are computed through each step of the radiometric processing, including calibration, following the GUM methodology:
➔ Producing per-pixel uncertainties for TOA radiances, from the L0 data.

Simplifications are used due to lack of inputs or due to complexity of algorithm especially for BRDF and Straylight correction, which are estimated as a simple percentage, based on correction performances.

Analysis is focused on radiometric, uncorrelated, random uncertainties. Meaning that some contributors are not included :

- No georeferencing contributor
- No spectral contributor
- No systematic contributor.



OLCI uncertainty status

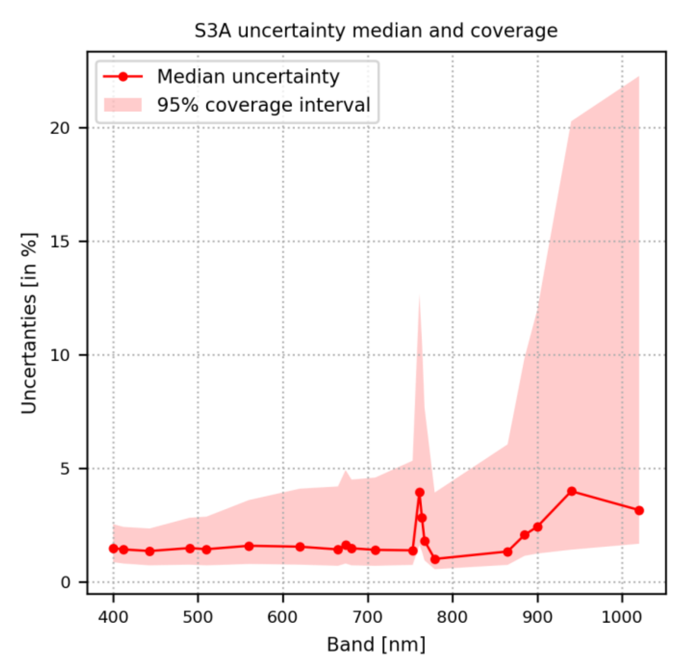
Statistical analysis of the uncertainties over a full day of acquisition.

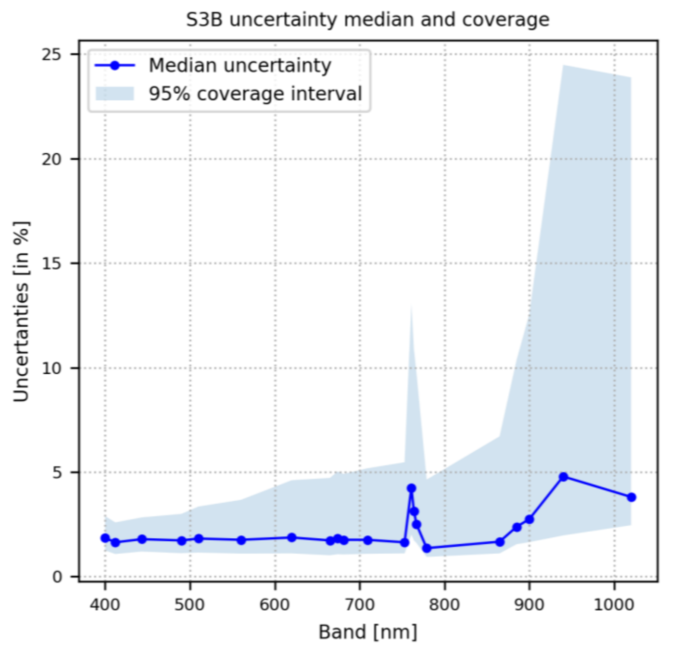
Median uncertainty:

- Expressed in percentage of the radiance.
- Below 2% for all visible bands, Oa01 to Oa12 (excluding absorption band).
- Increase in the NIR, but remaining below 5%.

95% coverage (k=2):

- Interval containing the central 95% of the uncertainty values, the interval defined by the 2.5th and 97.5th percentiles.
- Below and around 5% for visible bands (excluding absorption band).
- Strong augmentation in NIR (expression of uncertainties in percentage for pixel without signal can lead to high percentage for Oa20 and Oa21).
- The wide range of the 95% coverage is not due to “outlier” uncertainty in physical unit.





OLCI L1 uncertainty validation

Validation methodology

"Uncertainties validation" refers to the "Relative inter-comparison of Tandem Level-1 uncertainties" and not to the absolute validation, as usually done for L2 ocean reflectance for example.

Based on SLSTR Methodology published by Samuel Hunt et al., from NPL. Adapted to OLCI specificities.
"Comparison of the Sentinel-3A and B SLSTR Tandem Phase Data Using Metrological Principles", Remote Sens. 2020, 12, 2893.

Metrological approach: Analysis of the distribution of the uncertainty-normalised differences:

$$\varepsilon_i = \frac{\Delta L}{u(\Delta L)}$$

If the variance of differences is well described by the uncertainties, the resulting distribution should follow a standard normal law, (Gaussian centred on 0 with a standard deviation of 1)

Custom reprocessing of tandem OLCI A-B : 4 full days (Each Monday of the 4 weeks of July 2018)

Data filtering

- **"Nearest-neighbour" reprojection on co-registered grid,** common to S3A and S3B, at 300m resolution. Only |Lat| < 70° are kept.

- **L1 flags are filtered : saturated, bright, invalid, cosmetic.**

- **Data are then re-binned into 4x4 macro-pixel:** Macro pixel uncertainty is computed through the propagation of uncorrelated uncertainties

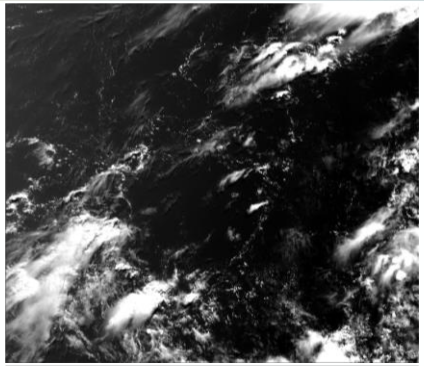
$$u^2(L_{MP}) = \frac{1}{N^2}\sum_{i=1}^{N} u^2(L_i)$$

- **A Coefficient of Variation criteria is applied to select homogenous pixels**

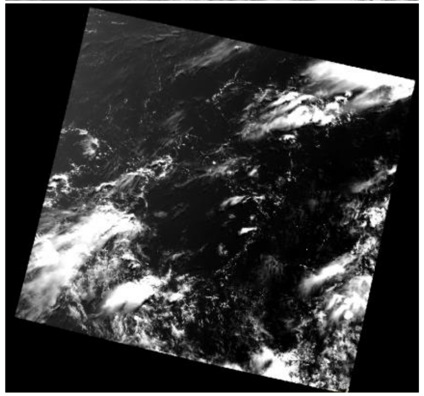
- **Epsilon ratio is computed for each macro pixel :**

$$\varepsilon_i = \frac{\Delta L}{u(\Delta L)} = \frac{L1_{MP}^{S3A} - L1_{MP}^{S3B}}{\sqrt{u^2(L1_{MP}^{S3A}) + u^2(L1_{MP}^{S3B})}}$$

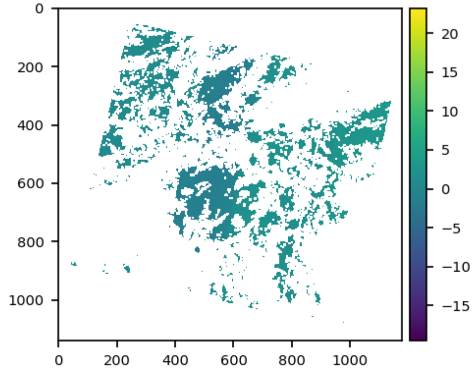
➔ **For OLCI uncertainties, since only uncorrelated uncertainties are considered: uncertainty of the difference become the quadratic sum of the uncertainties.**



Initial granule S3B Oa01



Reprojected data Band Oa01



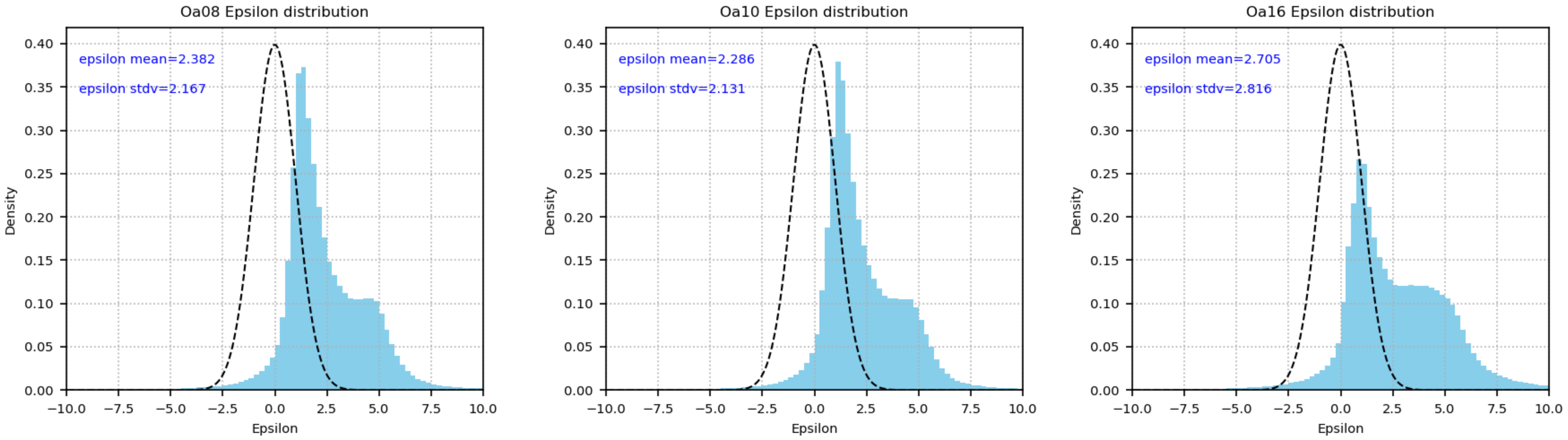
Re-binned and Filtered Epsilon ratio

Raw results

Uncertainty-Normalised difference distribution is computed over composite scene, aggregating ~50 granules.

But direct results from this method are not satisfying :

- Bi-modal distribution instead of a gaussian shape : Difficult to produce any conclusive analysis.
- Strong bias shifting the distribution, mean value above 2.
- Elevated standard deviation, above the expected value of 1.



➔ **Impact of the instrumental differences between OLCI-A and B**

A-B instrumental differences

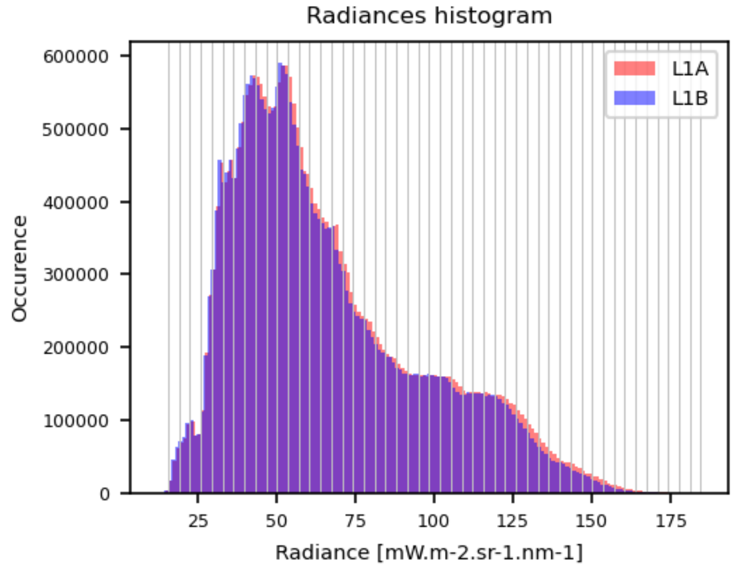
OLCI uncertainty analysis focuses on uncorrelated, random uncertainty
➔ *bias from instrumental differences is not included in the uncertainty budget.*

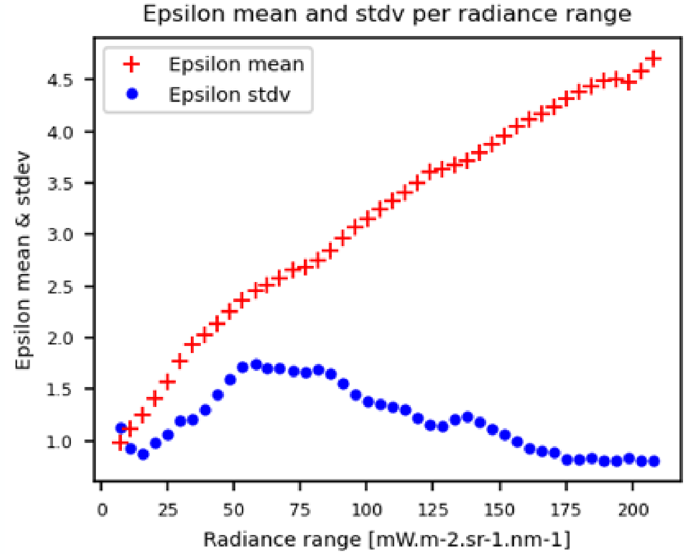
Epsilon distribution is computed from a difference and not from a ratio
➔ *bias impacts differently low and high radiances*

Radiance histograms clearly show the bias between L1A and L1B.

Histogram is divided per bins of radiance on which independent Epsilon distribution are computed.

For each distribution mean and std are evaluated:
➔ *Epsilon mean value have a strong relation with the radiance.*
➔ *While Epsilon standard deviation remains fairly stable.*

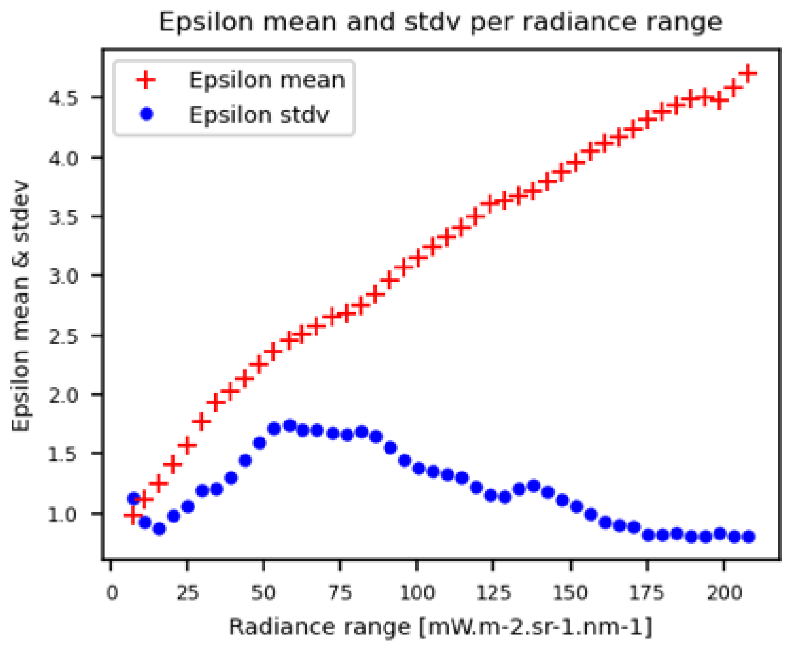




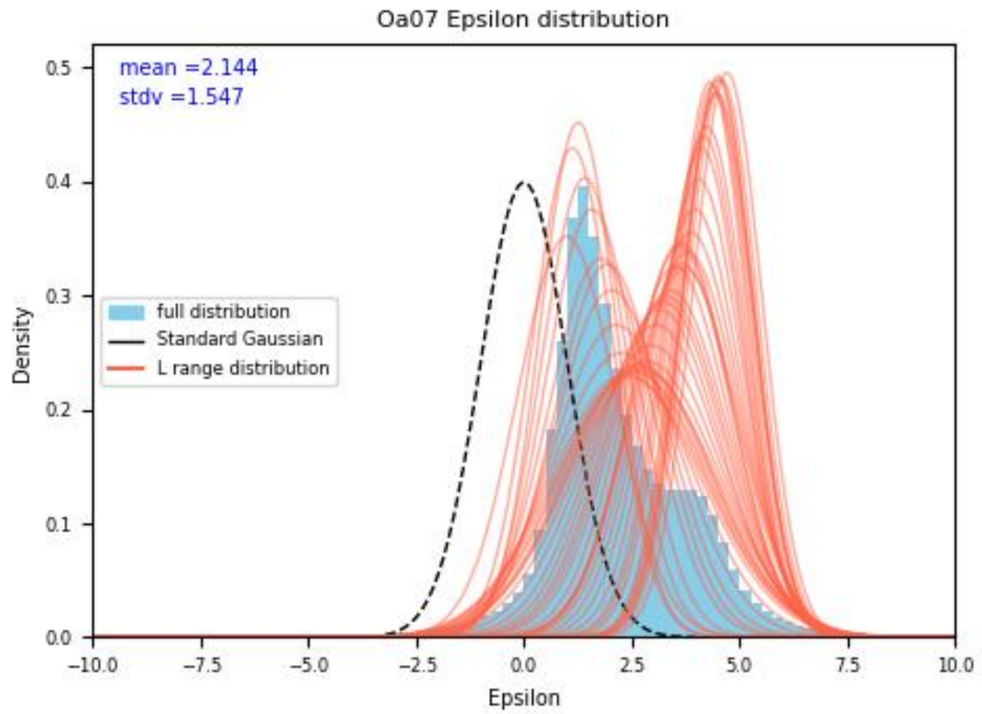
A-B instrumental differences

For each bin, if we represent the individual Epsilon distribution with a Normal law on the global distribution (using individual mean value and standard deviation), impact of bias become clear.

➔ **The bi-modal behaviour is caused by a shift of the mean epsilon value between low and high radiances.**



$$N(\mu, \sigma^2)$$



Mean delta harmonisation

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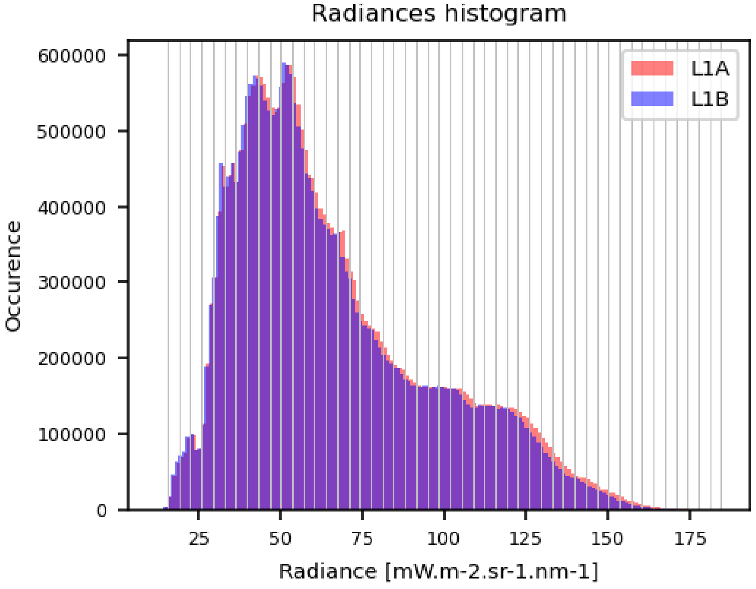
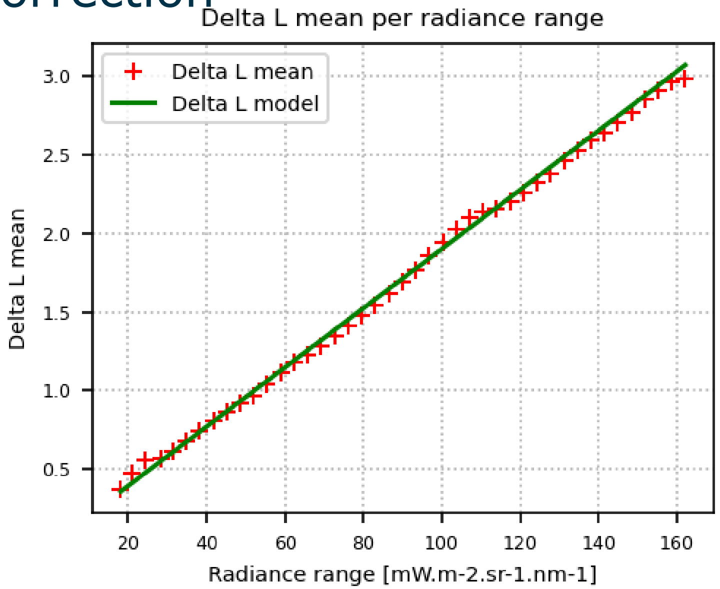
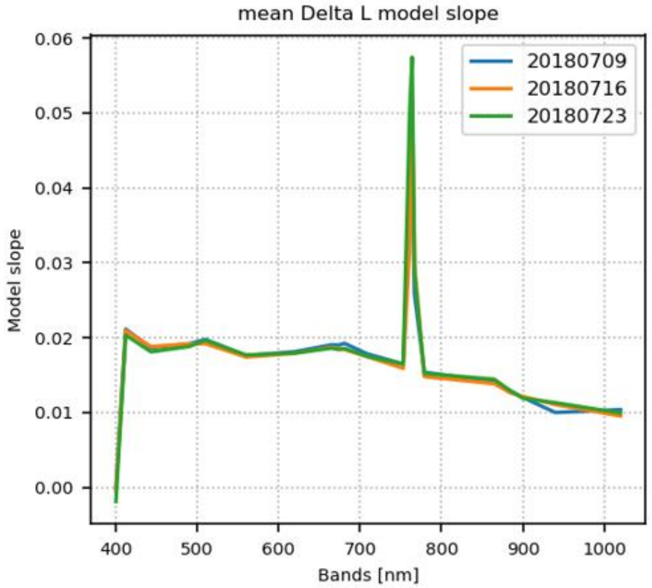
Bias from instrumental differences impact need to be accounted for, as follow:

- The linear relation between the mean difference and the mean radiance over bins is computed.
- For each band, a linear model is fitted as follow: $Mean(\Delta L_{bin}) = a * Mean(L1A_{bin}) + b$
- The linear coefficient is used to roughly harmonise L1A: $L1A_{corr} = L1A * (1 - a)$
- The linear slope computed for each band is consistent with the known radiometric bias.

Mean Delta correction







~2% in the blue and ~1% in the NIR

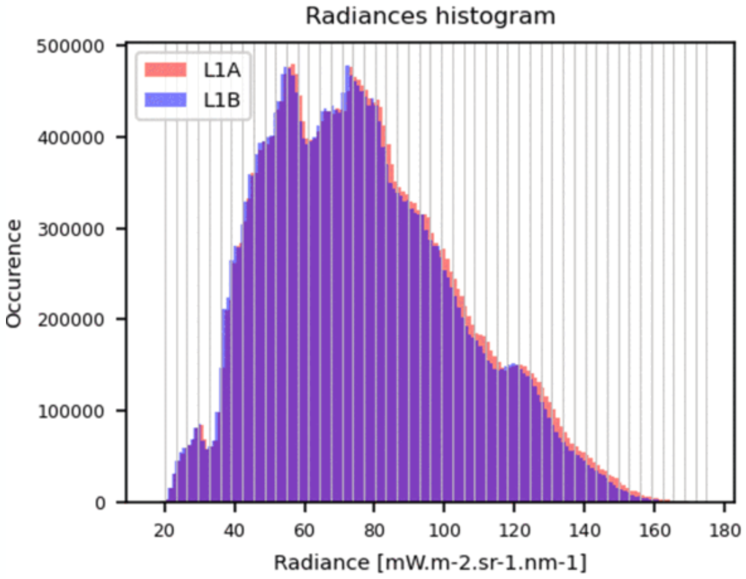
Mean delta harmonisation

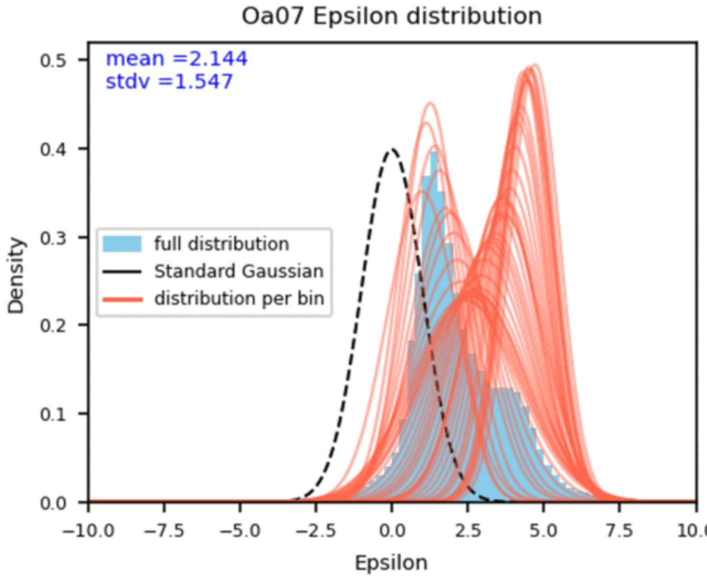
Analyse is done using harmonised data :

- OLCI uncertainties only account for the random error and not the systematics biases.
- No propagation needed on $L1A_{corr}$ uncertainties, the correction of the biases is needed to obtain coherent analysis.

Harmonisation solves the mains issues:

- Individual Epsilon per bin are now centred on 0, no remaining significative bias.
- Bi-modal shape is corrected for global distribution, as the mean epsilon value is not shifted with the radiance anymore.
- Standard deviation is not stretch by the multi-modal distribution.



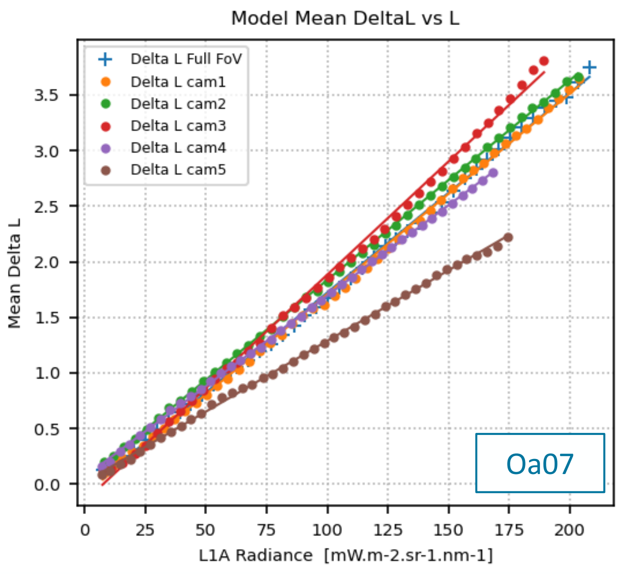


<u>Before/After comparison:</u>
Left : Oa03 Radiance histograms
Right: Oa07 Epsilon distribution

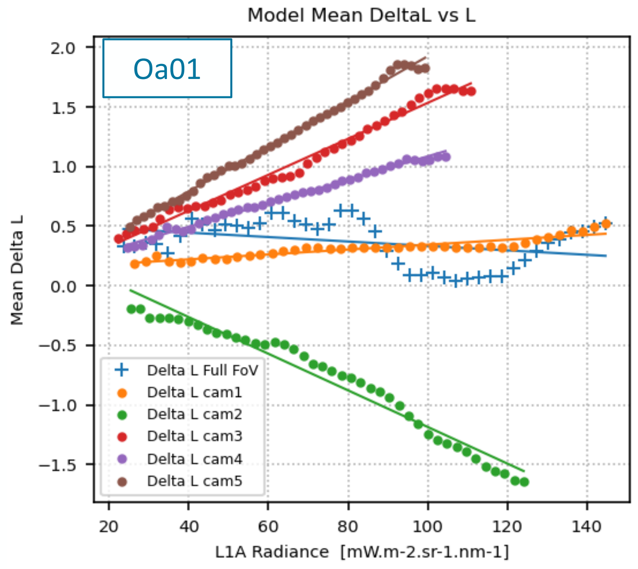
Per camera harmonisation

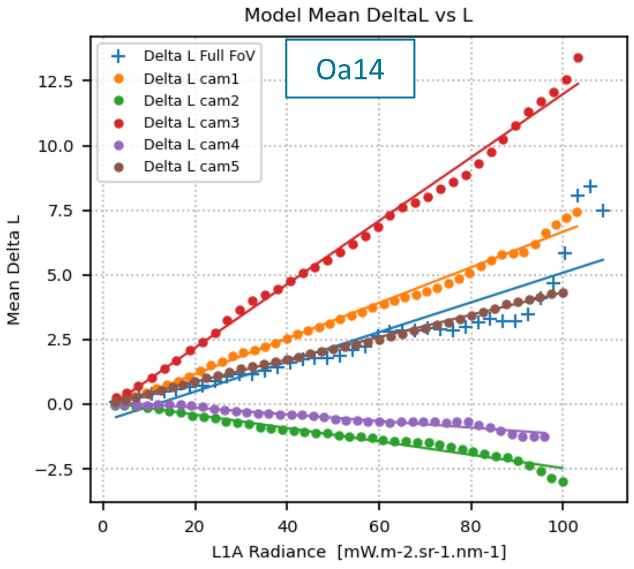
This ad-hoc harmonisation corrects the bias for most of the bands. But for some bands the inter-camera effects dominate the bias :

- The harmonisation process need to be done "per camera" instead of globally.
- One linear model is computed independently for each camera.
- Concerned bands are Oa01, and O_2-A absorption bands, Oa13 to Oa15.



Most of bands : Per camera models behave similarly, and using a global model is enough to correct all cameras.





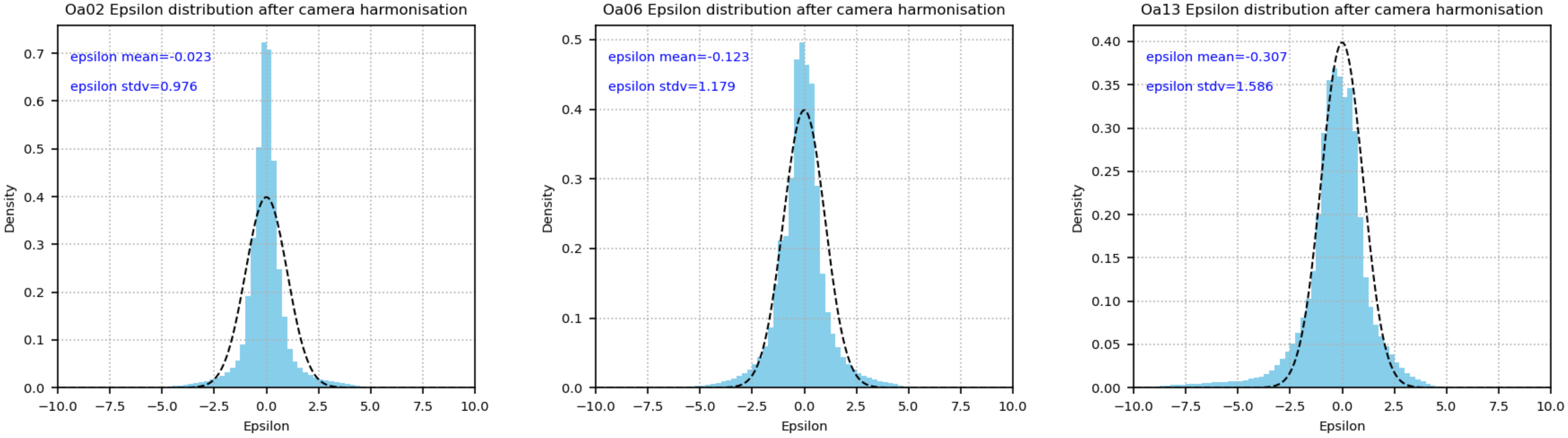
Oa01 and Oa13 to Oa15: Per camera models behave differently, the global model is not a good representant of individual camera.

Per camera harmonisation

This ad-hoc harmonisation corrects the bias for most of the bands. But for some bands the inter-camera effects dominate the bias :

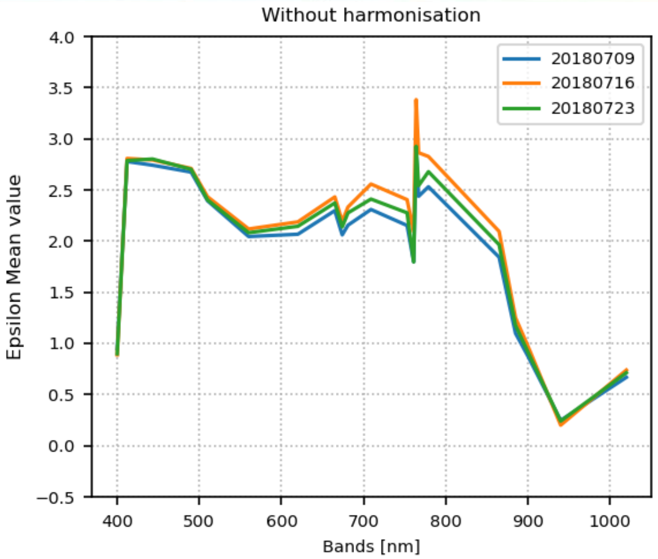
- The harmonisation process need to be done “per camera” instead of globally.
- One linear model is computed independently for each camera.
- Concerned bands are Oa01, and O_2-A absorption bands, Oa13 to Oa15.

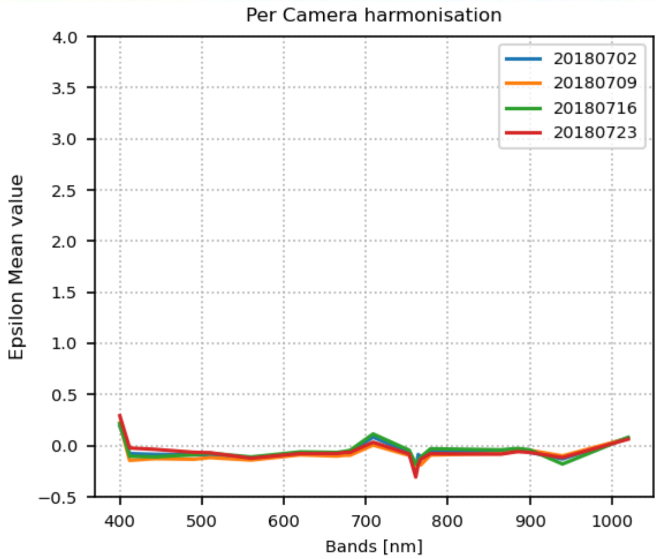
With per camera harmonisation Gaussian shape are obtained for all the bands:



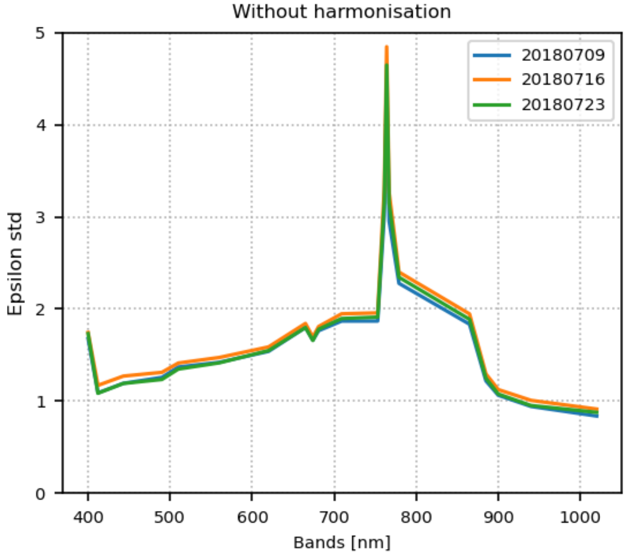
Harmonised results

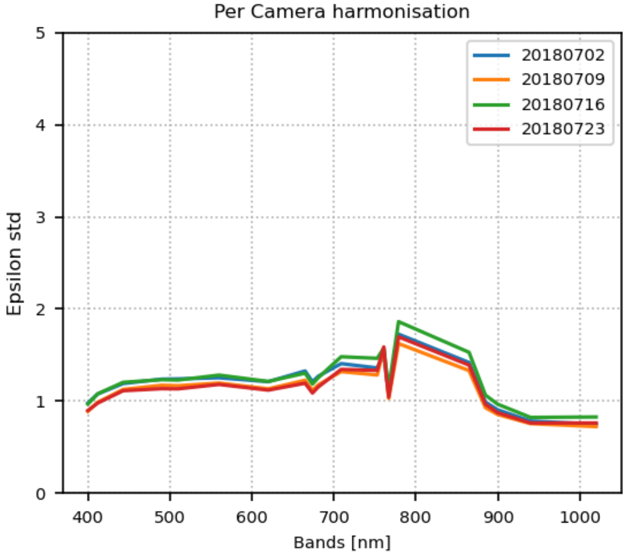
Epsilon mean value:





Epsilon standard deviation:





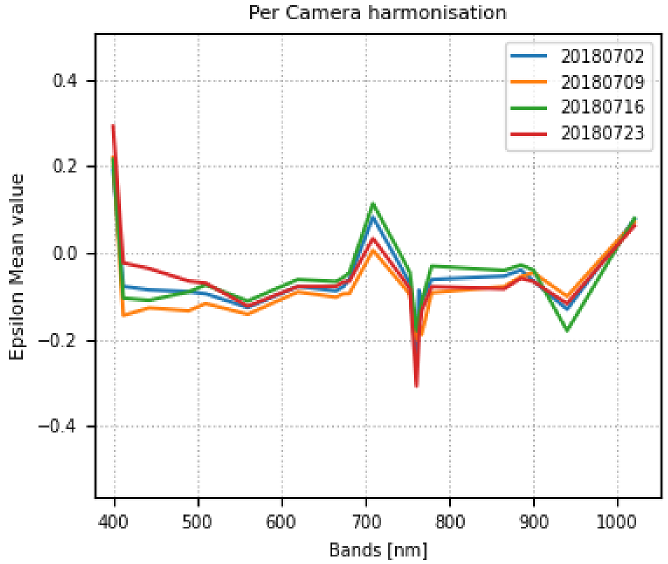
Conclusion

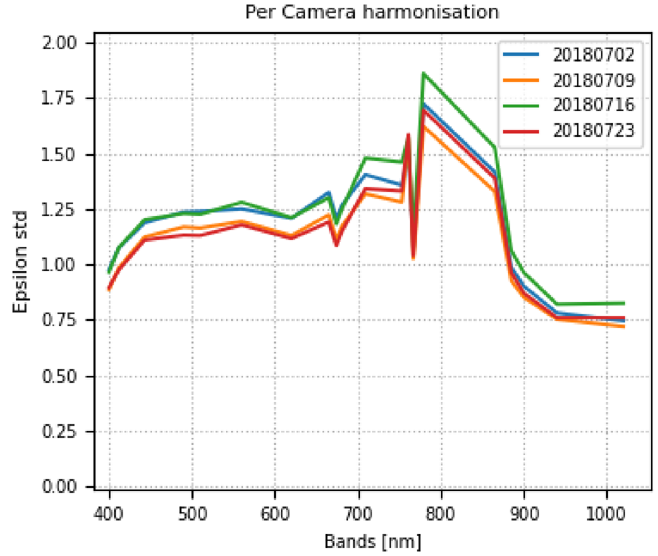
Validation of uncertainties for OLCI requires an L1 harmonisation between the 2 instruments to correct the biases not accounted for in the uncertainties.

With a rough ad-hoc harmonisation process we show that:

- The uncertainty-normalised difference is a Gaussian distribution without any bi-modal shape.
- The mean values are close to 0, meaning that the main sources of biases have been corrected by the per camera harmonisation.
- The standard deviation are around 1:
  - Between [~0.75 , ~1.25] for most of the band ➔ good representativity of the uncertainty.
  - Bands Oa16 and Oa17 : slightly higher standard deviations, indicating a possible small under-estimation of the uncertainties.

Overall results are really satisfying: the uncertainty-normalised difference distribution follows the standard normal gaussian law, validating that the uncertainties correctly describe the variance of the radiometric differences for all the bands.





Thank you for listening.