Copernicus FICE 2024

Training on
In situ Ocean Colour Above-Water Radiometry towards Satellite Validation

Uncertainty recap

Agnieszka Bialek
National Physical Laboratory
agnieszka.bialek@npl.co.uk,

6-17 May 2024
Venice, Italy

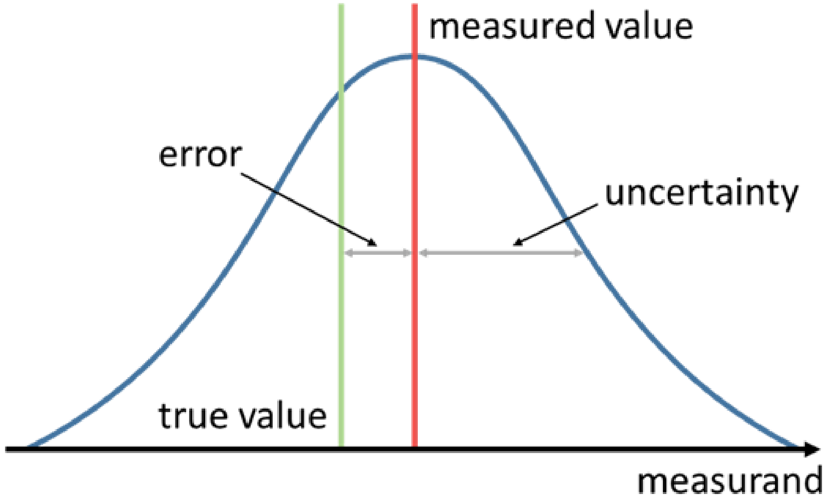
PROGRAMME OF THE EUROPEAN UNION | Copernicus Europe's eyes on Earth | IMPLEMENTED BY EUMETSAT
FRM4SOC Phase-2 | fiducial reference measurements for satellite ocean colour
CNR ISMAR ISTITUTO DI SCIENZE MARINE
NPL National Physical Laboratory

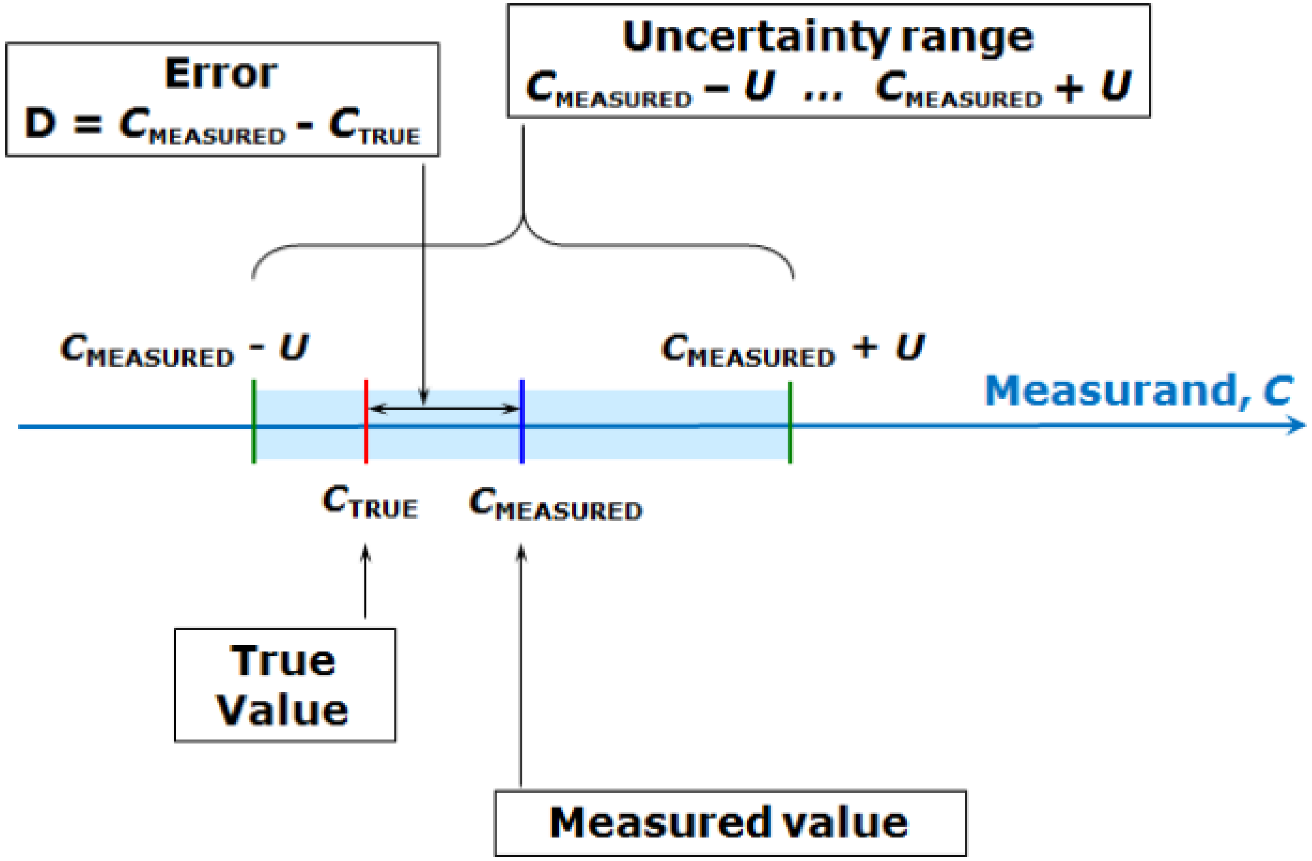
Basic uncertainty concepts

Error

is **NOT** the same as

Uncertainty





https://sisu-vana.ut.ee/measurement/introduction-concept-measurement-uncertainty

ESTIMATION OF MEASUREMENT UNCERTAINTY IN CHEMICAL ANALYSIS

NPL

Search

2. THE ORIGIN OF MEASUREMENT UNCERTAINTY

Brief summary: Explanation, on the example of pipetting, where measurement uncertainty comes from. The concept of **uncertainty sources** – effects that cause the deviation of the measured value from the true value – is introduced. The main uncertainty sources of pipetting are introduced and explained: repeatability, calibration, temperature effect. Explanation of random and systematic effects is given. The concept of **repeatability** is introduced.

The first video demonstrates how pipetting with a classical volumetric pipette is done and explains where the uncertainty of the pipetted volume comes from.

https://sisu-vana.ut.ee/measurement/origin-measurement-uncertainty

Uncertainty vs. error

Uncertainty:

- Describes the spread of a probability distribution i.e. standard deviation

Error:

- The result of measurement imperfections
- From random and systematic effects

Correction

- Where an error is known, it can be corrected by applying a correction
- There will always be an unknown residual error

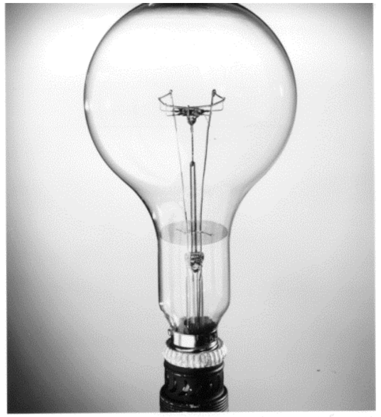
Consistency in terminology is important!

Systematic and random effects:

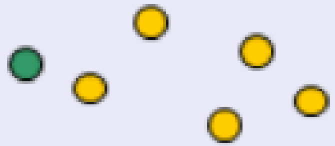
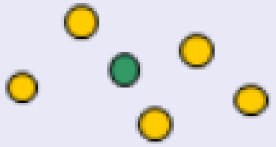
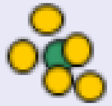
NPL

EFFECT	SYSTEMATIC
Calibration of reference	Yes
Alignment	If not realigned
Noise	No
Lamp current setting	Probably – if constant
Lamp current stability	Probably not
Temperature sensitivity	Depends on how much temperature is changing

lamp measured 5 times



Effects are random or systematic depending on the measurement process itself

Situation	Random effects	Systematic effects	Uncertainty
1. 	Strong	Strong	High
2. 	Strong	Weak (or absent)	Medium
3. 	Weak	Strong	Medium
4. 	Weak	Weak (or absent)	Low

Scheme 2.1. The influence of random and systematic effects on measurement uncertainty.

https://sisu-vana.ut.ee/measurement/origin-measurement-uncertainty

Standard deviation

NPL

- Describes the spread of the sample values about the mean
- A measure of the precision of the sample values
- The standard deviation is formalised as: $\sigma =$

$$\pm\sqrt{\frac{(x_1-\bar{x})^2+(x_2-\bar{x})^2+(x_3-\bar{x})^2+(x_4-\bar{x})^2\ldots+(x_n-\bar{x})^2}{n-1}} =$$

$$\pm\sum_{i=1}^{n}\sqrt{\frac{(x_{i-}\bar{x})^2}{n-1}}$$

Sigma (lowercase) – used to denote the standard deviation

Standard uncertainty associated with the mean

NPL

- Tells us about the uncertainty associated with an average
- Expressed as *u(y)*: uncertainty associated with variable ‘y’
- Standard uncertainty is a margin whose size can be thought of as $\pm$ one standard deviation

$$u = \frac{\sigma}{\sqrt{n}}$$

Standard uncertainty associated with the mean

Standard deviation or spread of the results: Uncertainty associated with a single value

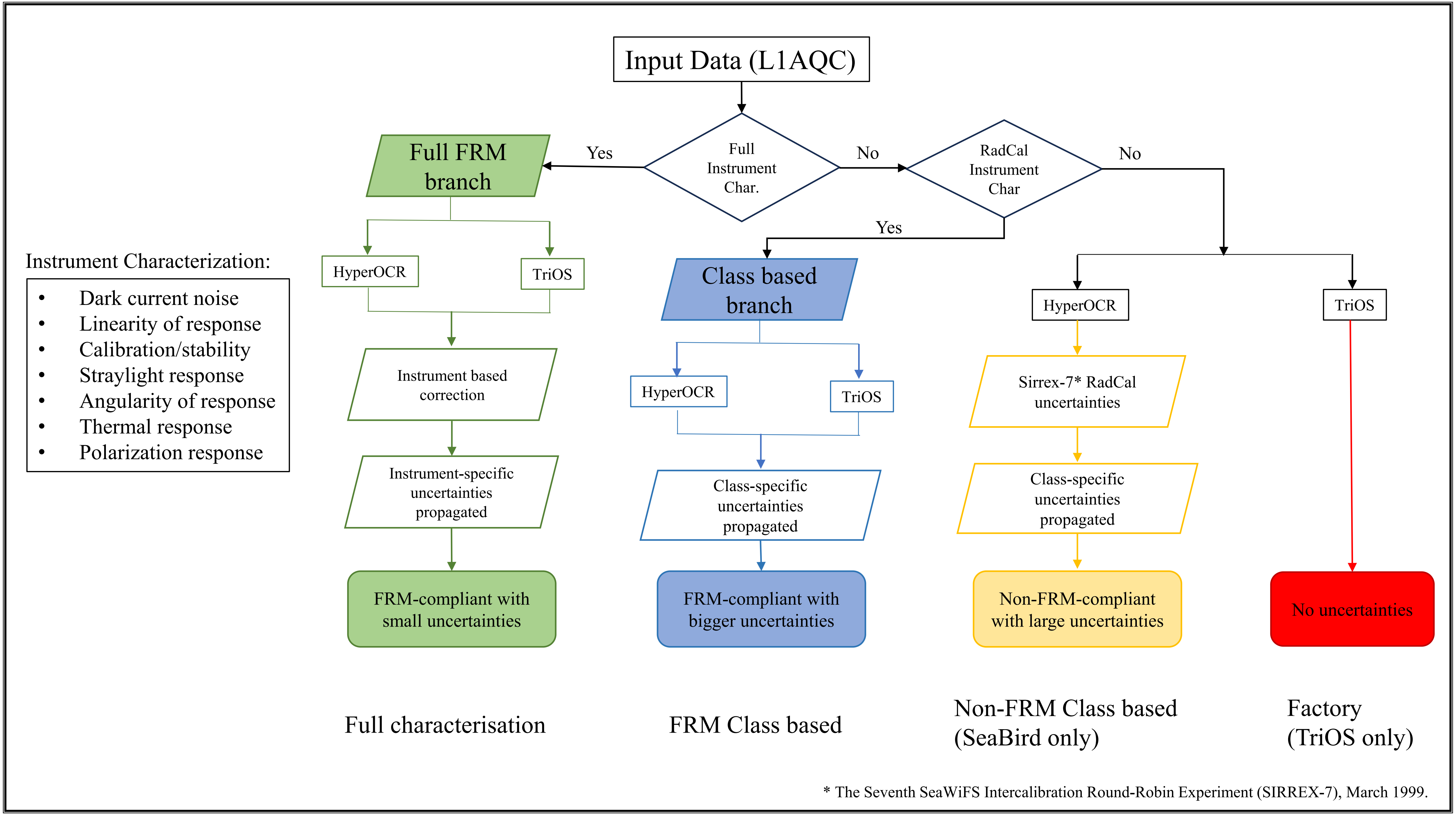
Number of samples

Standard uncertainty associated with the mean for small number of repeats

$$u_{\text{light,mean}}^2 = \frac{N-1}{N-3}\left(\frac{s_{\text{light}}}{\sqrt{N}}\right)^2 .$$

N=5 , s*1.41
N=10, s*1.13
N=25, S*1,04

Uncertainty propagation in HyperCP

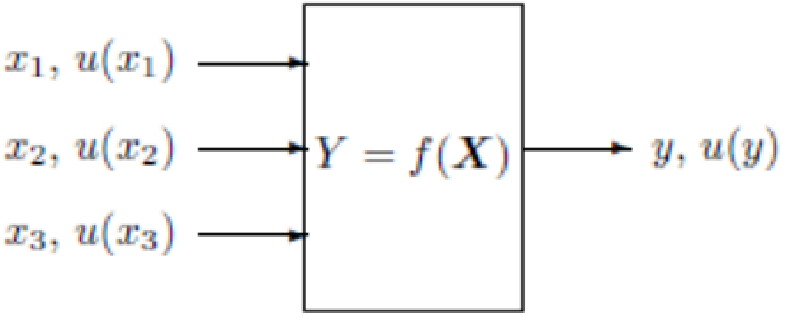

Input Data (L1AQC)
Full Instrument Char.
Yes
No
RadCal Instrument Char
No
Yes
Full FRM branch
HyperOCR
TriOS
Instrument based correction
Instrument-specific uncertainties propagated
FRM-compliant with small uncertainties
Class based branch
HyperOCR
TriOS
Class-specific uncertainties propagated
FRM-compliant with bigger uncertainties
HyperOCR
Sirrex-7* RadCal uncertainties
Class-specific uncertainties propagated
Non-FRM-compliant with large uncertainties
TriOS
No uncertainties
Instrument Characterization:
Dark current noise
Linearity of response
Calibration/stability
Straylight response
Angularity of response
Thermal response
Polarization response
Full characterisation
FRM Class based
Non-FRM Class based (SeaBird only)
Factory (TriOS only)
* The Seventh SeaWiFS Intercalibration Round-Robin Experiment (SIRREX-7), March 1999.

Uncertainty Evaluation

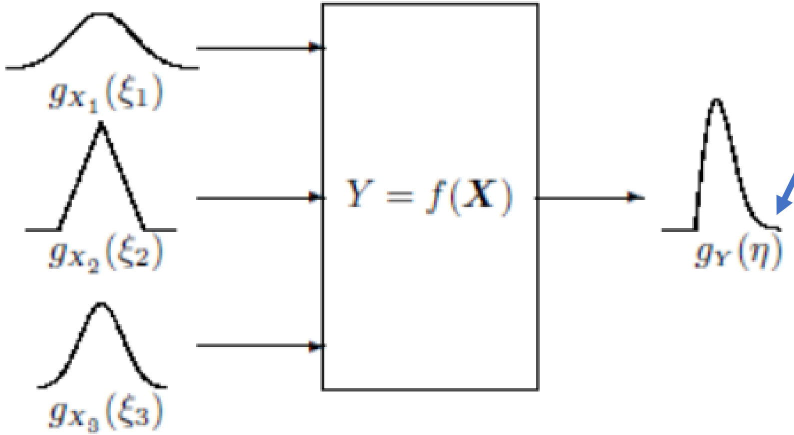
- GUM – Law of propagation of uncertainty
- GUM supplement 1 – Monte Carlo Methods

HyperCP

GUM



MCM



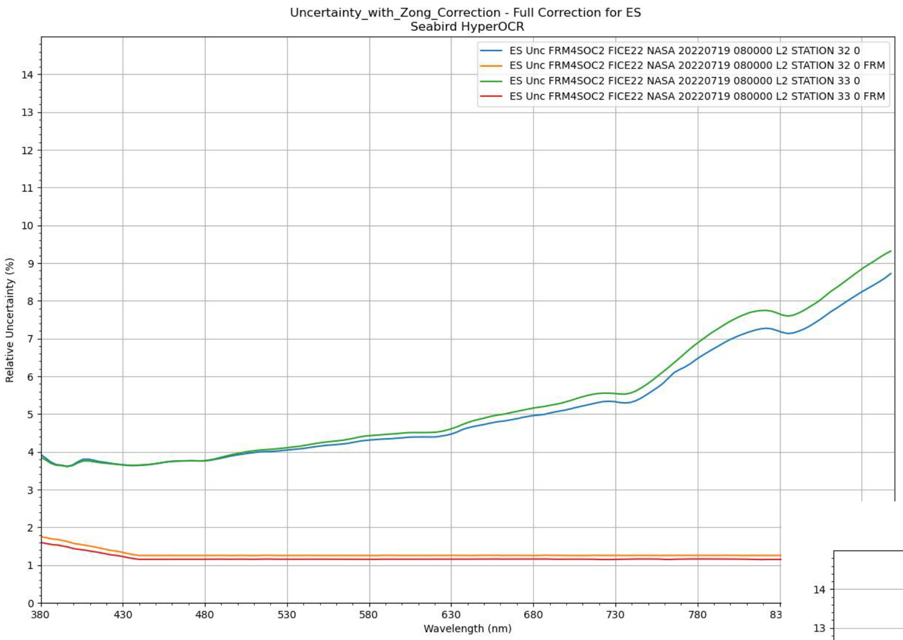
GUM Assumptions and Restrictions

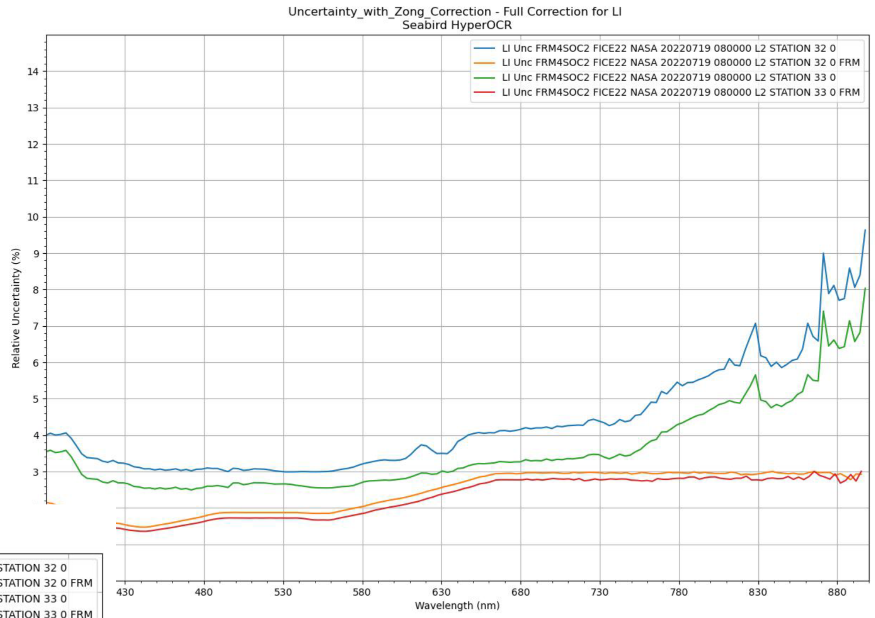
- Output value has Normal distribution
- First order approximation applies to linear models
- Symmetric distribution of inputs

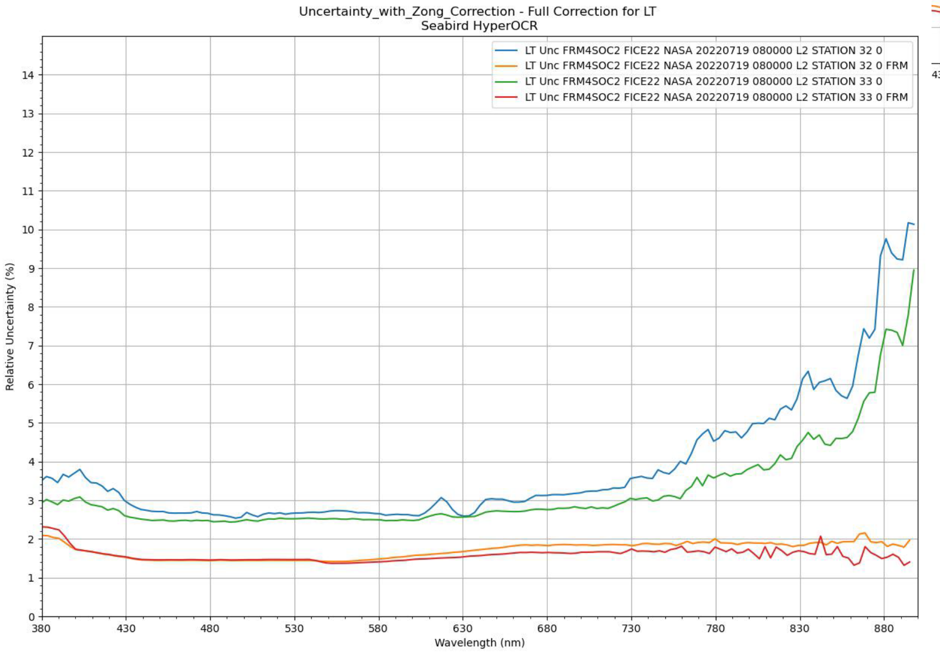
http://www.bipm.org/en/publications/guides/

Bureau International des Poids et Mesures – the intergovernmental organization through which Member States act together on matters related to measurement science and measurement standards.

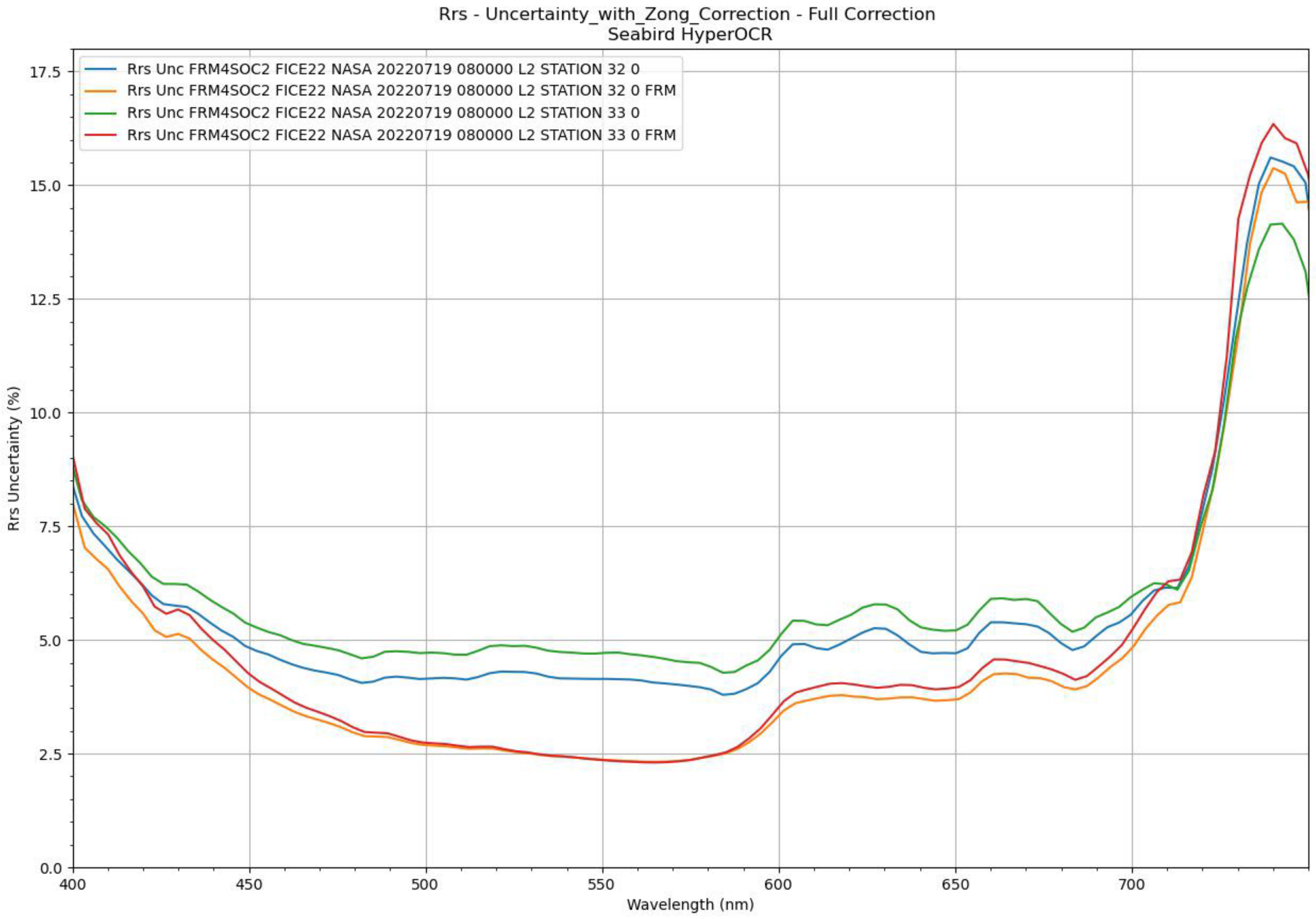
Uncertainty Results – PySAS sample data

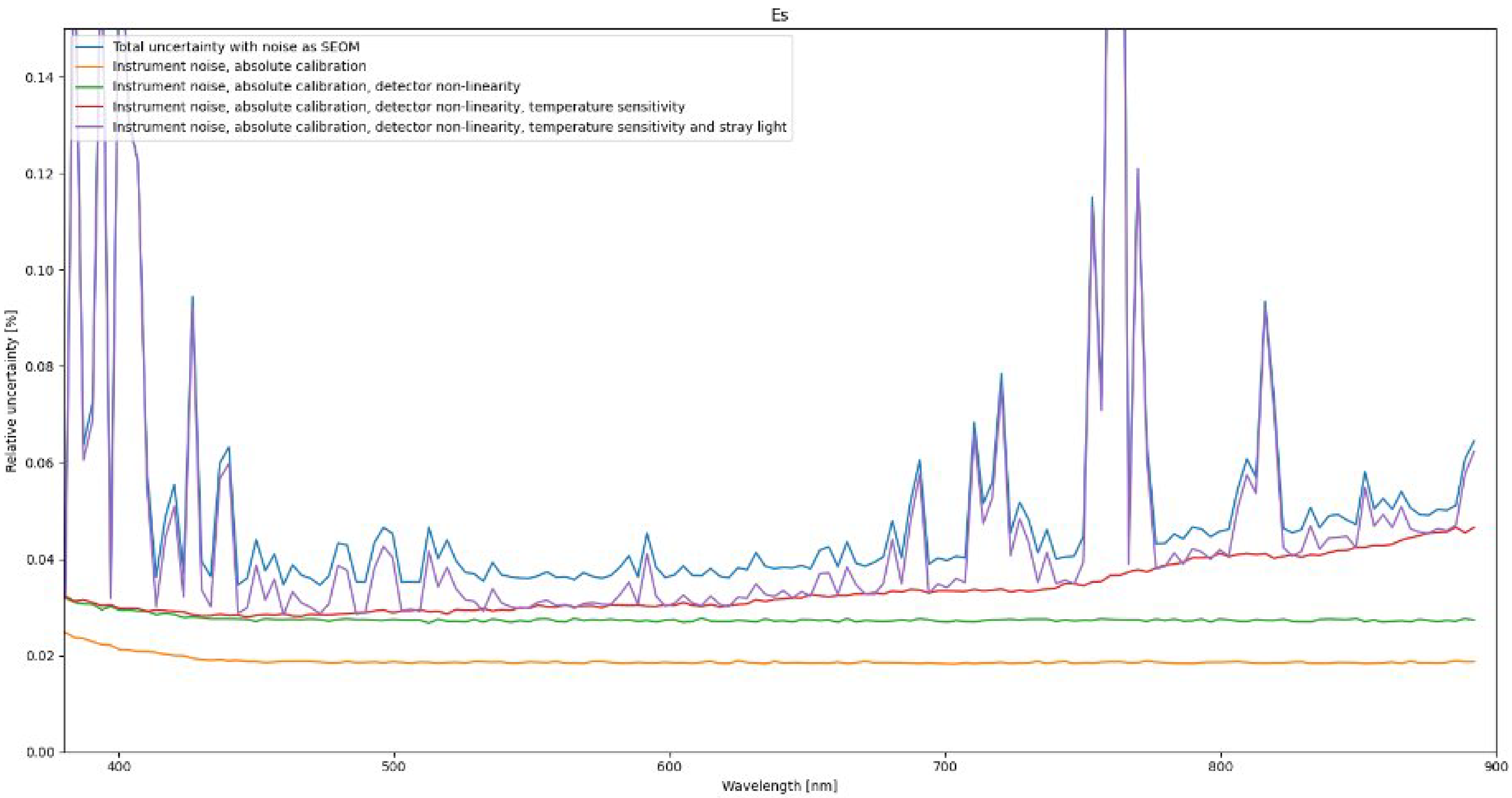






Uncertainty Results – PySAS sample data




Es
Total uncertainty with noise as SEOM
Instrument noise, absolute calibration
Instrument noise, absolute calibration, detector non-linearity
Instrument noise, absolute calibration, detector non-linearity, temperature sensitivity
Instrument noise, absolute calibration, detector non-linearity, temperature sensitivity and stray light
Relative uncertainty [%]
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
400
500
600
700
800
900
Wavelength [nm]

Congratulation!

I finished and you survived ;-)