End-to-end uncertainty budget

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Whole team inputs

Funded by the European Union

Introduction

Objectives:

- Provide end-to-end uncertainty budget calculation for Ocean Colour Radiometry
- Finalise the uncertainty budget evaluation started in FRM4SOC project (Bialek et al. 2020)
- Apply uncertainty evaluation in community processor
- Provide an easy to follow user guide, so everybody can propagate their own uncertainty.

Contents

[VIM3] 2.26 measurement uncertainty
uncertainty of measurement, uncertainty

Options

non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used

Notes

NOTE 1 Measurement uncertainty includes components arising from systematic effects, such as components associated with corrections and the assigned quantity values of measurement standards, as well as the definitional uncertainty. Sometimes estimated systematic effects are not corrected for but, instead, associated measurement uncertainty components are incorporated.

NOTE 2 The parameter may be, for example, a standard deviation called standard measurement uncertainty (or a specified multiple of it), or the half-width of an interval, having a stated coverage probability.

NOTE 3 Measurement uncertainty comprises, in general, many components. Some of these may be evaluated by Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from series of measurements and can be characterized by standard deviations. The other components, which may be evaluated by Type B evaluation of measurement uncertainty, can also be characterized by standard deviations, evaluated from probability density functions based on experience or other information.

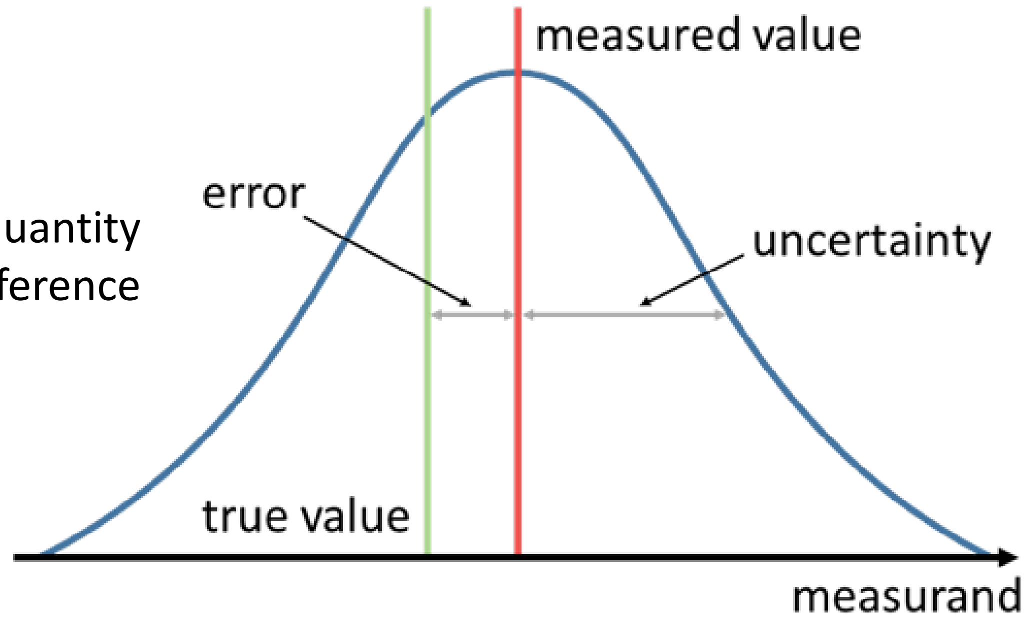
NOTE 4 In general, for a given set of information, it is understood that the measurement uncertainty is associated with a stated quantity value attributed to the measurand. A modification of this value results in a modification of the associated uncertainty.

https://jcgm.bipm.org/vim/en/2.26.html

Methodology and resources

- The International Vocabulary of Metrology (VIM)

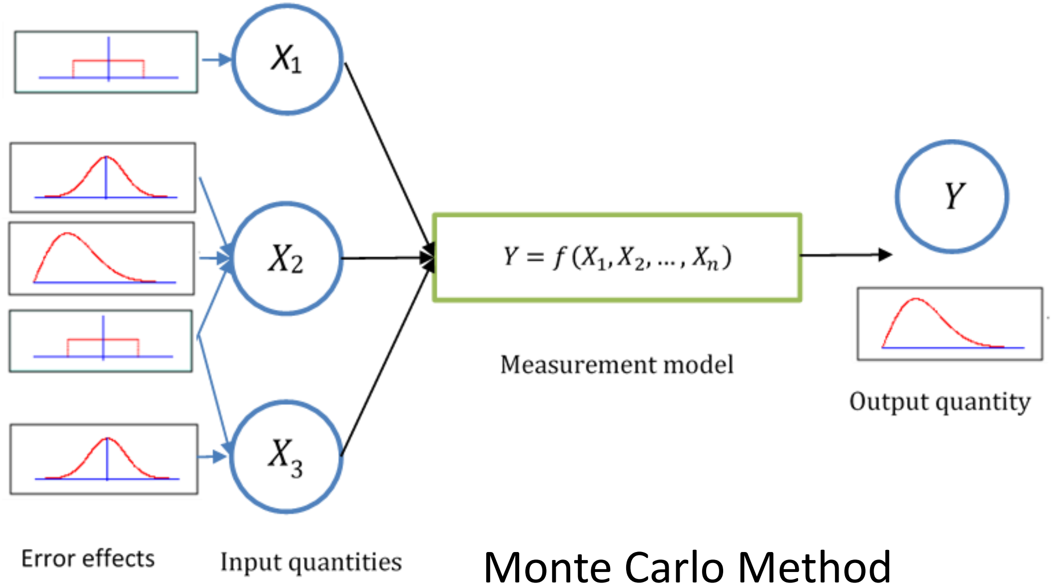
"the measured quantity value minus a reference quantity value."



"a non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used."

Methodology and resources

- the Guide to the expression of Uncertainty in Measurement (GUM) and its supplements



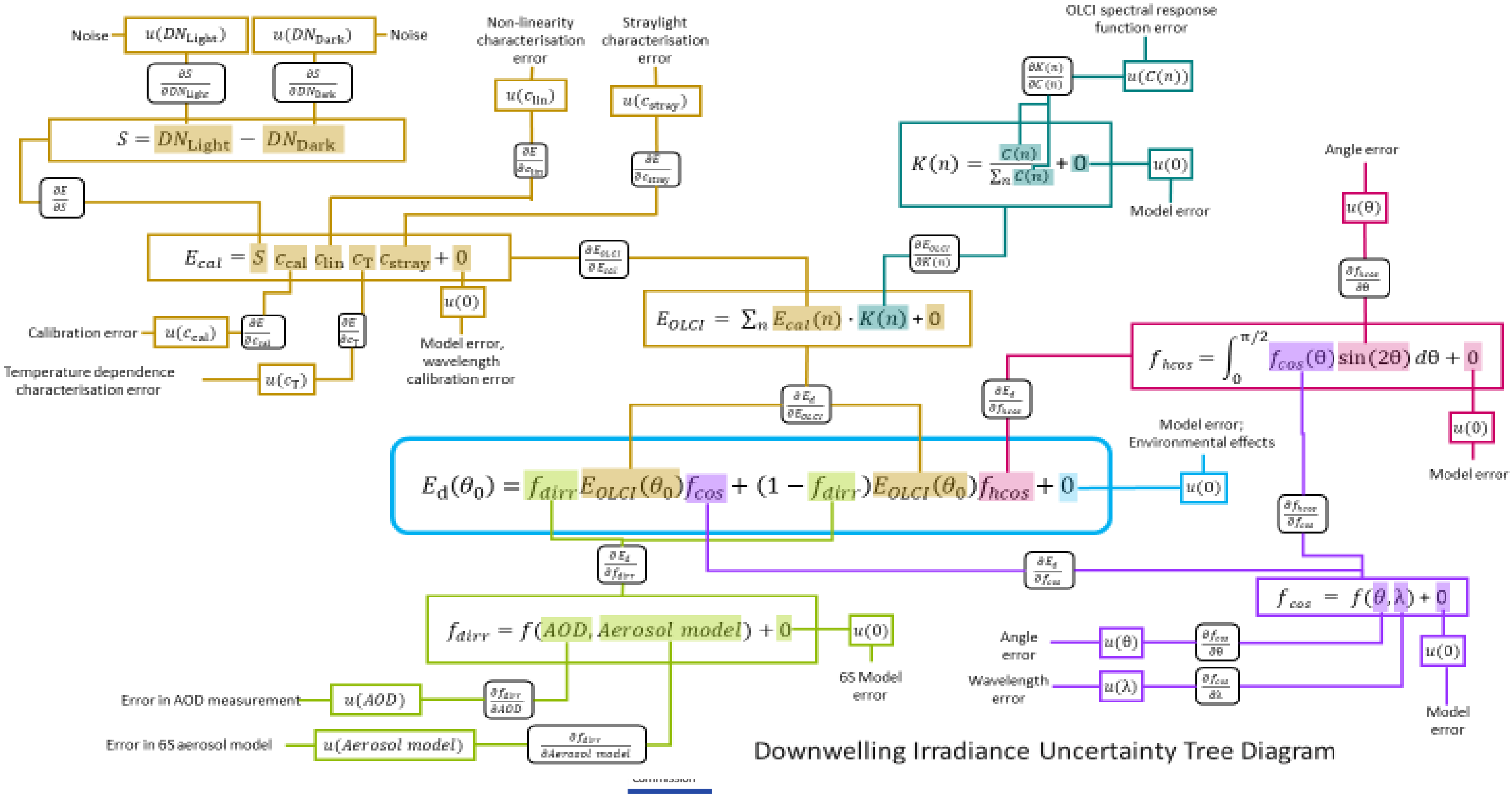
Monte Carlo Method

$$u^2(y) = \sum_{i=1}^{N} c_i^2 u^2(x_i) + 2 \sum_{i=1}^{N-1} \sum_{j=i}^{N} c_i c_j u(x_i, x_j),$$

The Law of Propagation of Uncertainties

Resources – Uncertainty tree diagrams

FIDUCEO (FIDelity and Uncertainty in Climate data records from Earth Observations)



Downwelling Irradiance Uncertainty Tree Diagram

Resources – Effects tables

FIDUCEO (FIDelity and Uncertainty in Climate data records from Earth Observations)

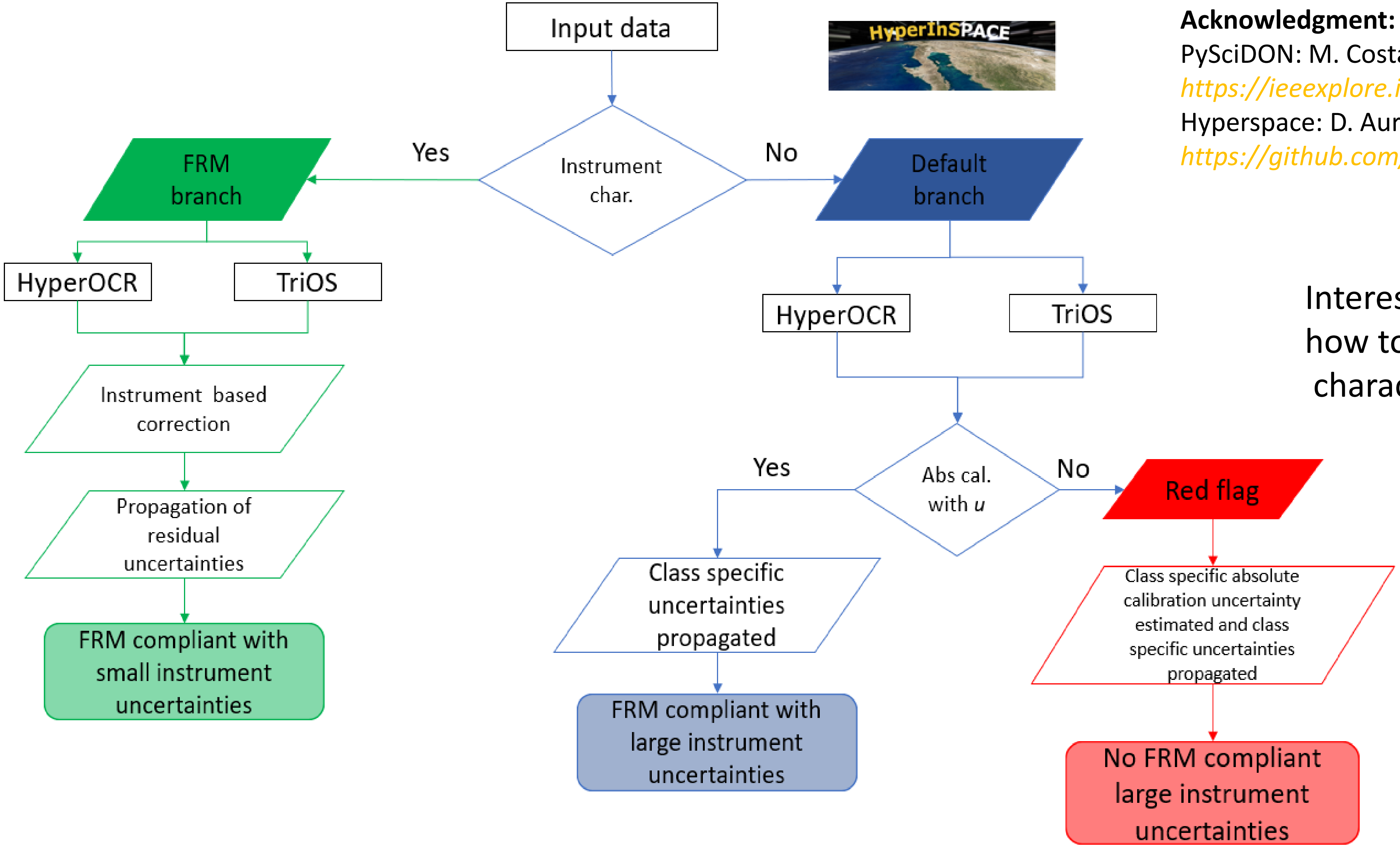
Not considered yet

Correlation between effects, added

Table descriptor			
Name of effect		Noise in light counts	Night in dark counts
Affected term in measurement function		DN_{Light}	DN_{Dark}
Instruments in the series affected		All	All
Correlation type and form	Temporal within deployment	Random	Random
	Temporal between deployments	Random	Random
	Spectral (hyperspectral in-situ)	Random	Random
Correlation scale	Temporal within deployment	0	0
	Temporal between deployments	0	0
	Spectral (hyperspectral in-situ)	0	0
Channels/bands	List of channels / bands affected	All	All
	Error correlation coefficient matrix	Identity – No correlation	Identity – No correlation
Uncertainty	PDF shape	Gaussian	Gaussian
	units	Counts	Counts
	magnitude	Less than 0.1%	Less than 0.1%
Sensitivity coefficient		$\frac{\partial f}{\partial DN_{\mathrm{Light1}}}, \frac{\partial f}{\partial DN_{\mathrm{Light2}}}$	$\frac{\partial f}{\partial DN_{\mathrm{Dark1}}}, \frac{\partial f}{\partial DN_{\mathrm{Dark2}}}$

Antoine at al, ROSACE, 2020

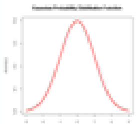
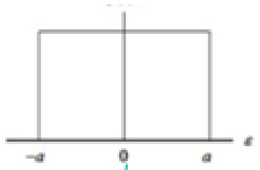
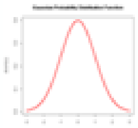
Uncertainty processing instrument aspect



Acknowledgment:
PySciDON: M. Costa, N. Vanderberg (U. Victoria)
https://ieeexplore.ieee.org/abstract/document/8121926
Hyperspace: D. Aurin (NASA)
https://github.com/nasa/HyperInSPACE

Interesting point raised at S3VT, how to deal with patrial instrument characterisation cases.

GUM Methodology applied in CoMET tool

$$R_{rs} = (L_t c_{cal0222} - (\rho * L_i c_{cal0223})/E_s c_{cal0258}$$

random

systematic

L_t	c_{c2}	ρ	L_i	c_{c3}	E_s	c_{c8}
1	0	0	0	0	0	0
0	1	0	0	1	0	1
0	0	1	0	0	0	0
0	0	0	1	0	0	0
0	1	0	0	1	0	1
0	0	0	0	0	1	0
0	1	0	0	1	0	1

JCGM100:2008. Evaluation of measurement data - *Guide to the expression of uncertainty in measurement*
JCGM101:2008. Evaluation of measurement data - *Supplement 1 to the Guide to the expression of uncertainty in measurement - Propagation of distributions using a Monte Carlo method.*

Default branch measurements equations

- Irradiance

$$E_d(\lambda) = \overline{E_d(\lambda)} \cdot c_{cal}(\lambda) c_{stab}(\lambda) c_{lin}(\lambda) c_{stray}(\lambda) c_T(\lambda) f_{cos}$$

- Radiance

$$L_t(\lambda) = \overline{L_t(\lambda)} \cdot c_{cal}(\lambda) c_{stab}(\lambda) c_{lin}(\lambda) c_{stray}(\lambda) c_T(\lambda) c_{pol}(\lambda)$$

Default processing (branch) contains class based instrument characterisation files

Variable symbol	Variable name/description	Uncertainty	
		TRIOS	HyperOCR
$\overline{L_t}, \overline{L_i}, \overline{E_d}$	Mean value of radiometric quantity measured by a single instrument	Random noise calculated from the cast statistics	
c_{cal}	Absolute radiometric calibration	Uncertainty values from calibration certificate divided by 2 to convert them back into standard uncertainty, *k*=1	
c_{stab}	Absolute calibration stability	1%	
c_{lin}	Detector non-linearity	2%	
c_{stray}	Spectral stray light	Vary spectrally and per instrument due to difference in spectral shape of the signal, should come from the class-based stray light file	
c_T	Temperature sensitivity	Vary spectrally should come from the class-based temperature sensitivity file,	
c_{pol}	Polarisation sensitivity (Radiance only)	Vary spectrally and per instrument to use published data from (Talone and Zibordi, 2016)	Vary spectrally and per instrument triple values for TRIOS , as shown by Tartu
f_{cos}	Cosine response (Irradiance only)	Directional 3.5%	Directional 2%

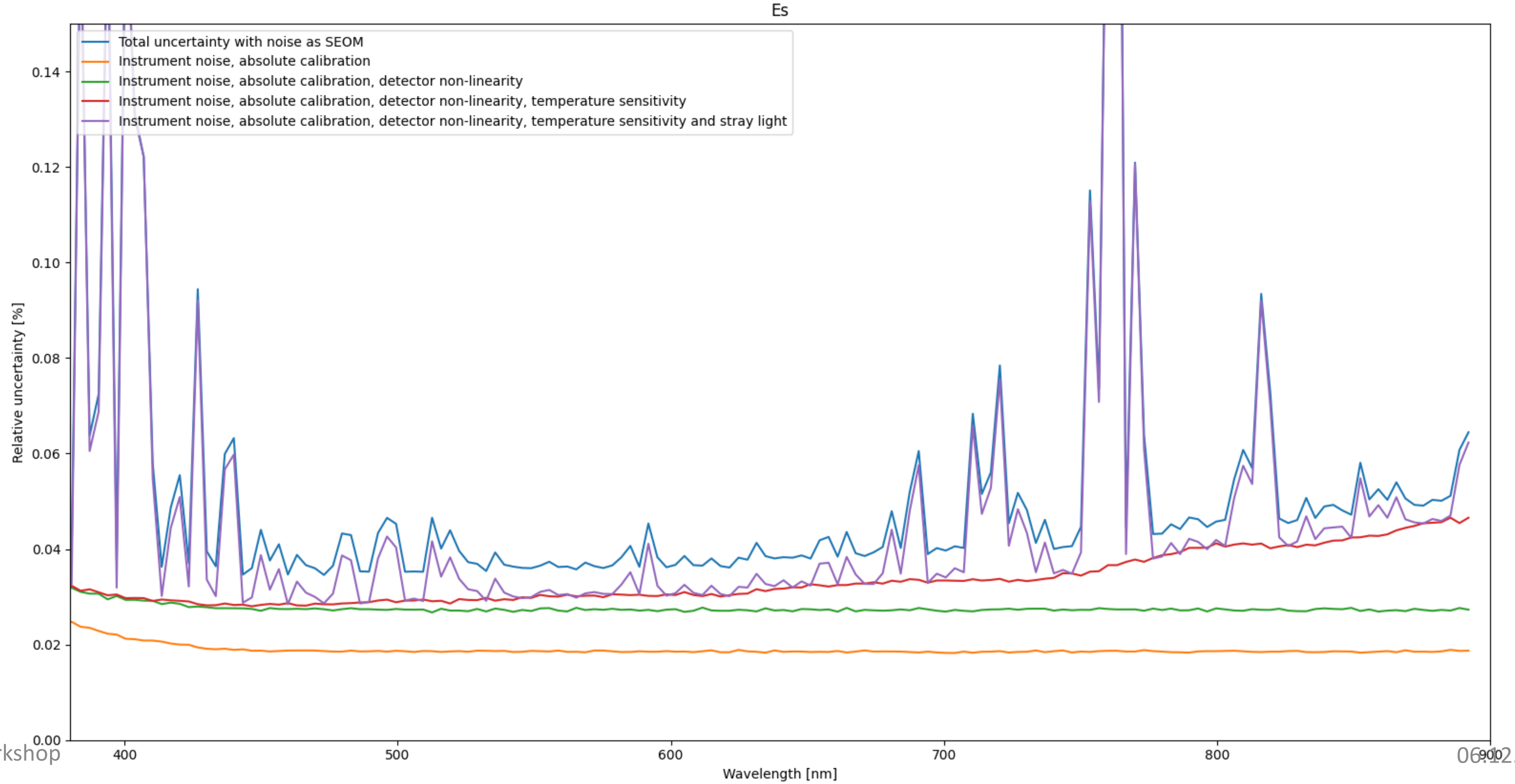
Default Branch CP Implementation Example

Source of Uncertainty	Input Uncertainty
DN_{light}	Std (k=1)
DN_{dark}	Std (k=1)
c_{cal}	Tartu file
c_{stab}	1%
c_{lin}	2%
c_{stray}	FRM4SOC-1
c_{temp}	Tartu file
c_{cos}	2%

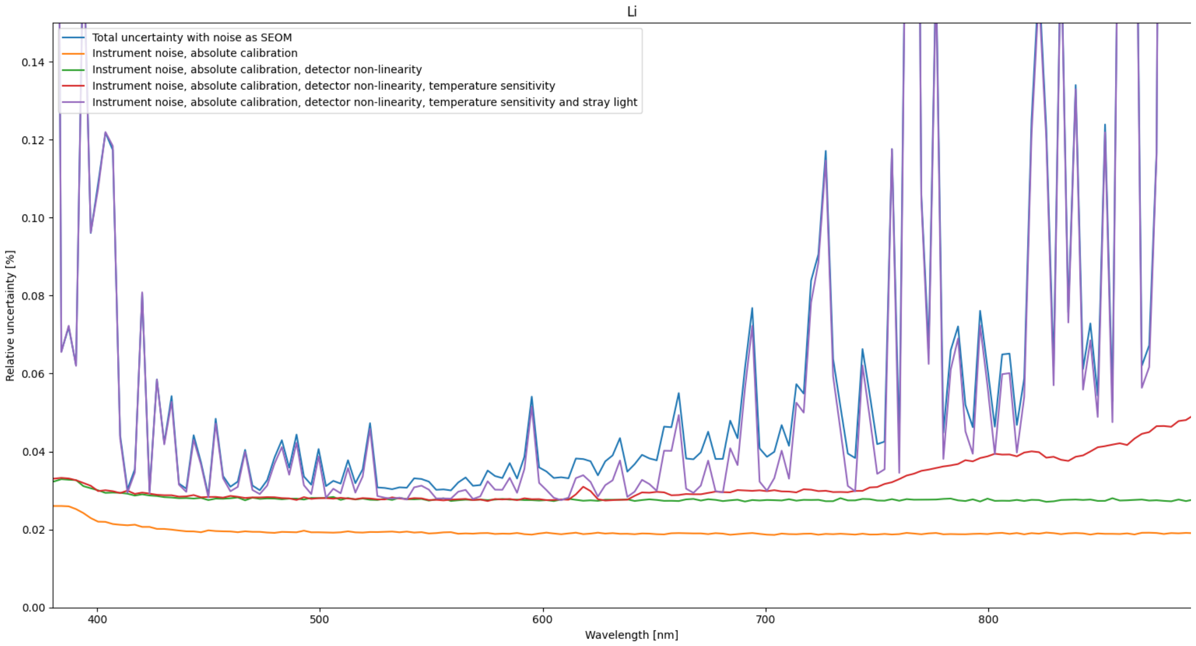
```python
    @staticmethod
    def Es(DNLight, DNDark, Ccal, Cstab, Clin, Cstray, Ct, Ccos):
        """(DNLIGHT-DNDARK).Ccal.Cstab.Clin.Cstray.Ct.Ccos"""
        return (DNLight - DNDark) * Ccal * Cstab * Clin * Cstray * Ct * Ccos
```

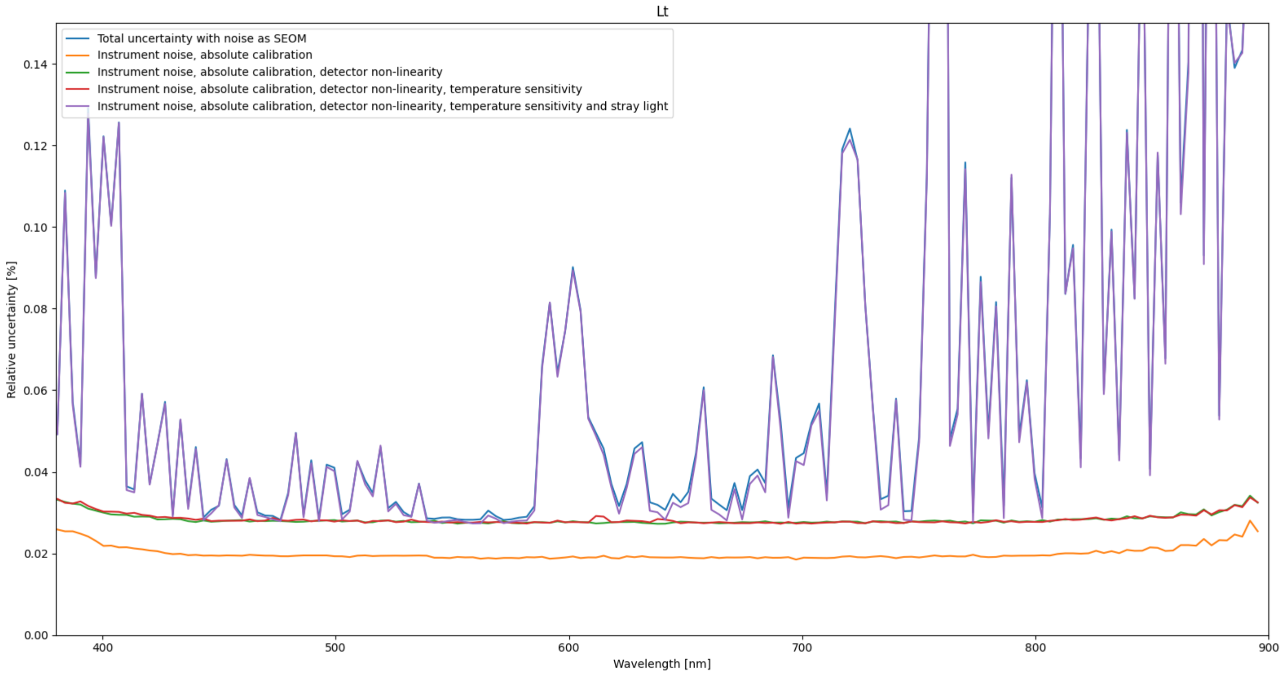
- Occurs at L1B during dark correction, c_{cal} is taken from Tartu file.
- Time average DN_{light} & DN_{dark}.
- Remaining coefficients are set to 1.
- Measurement function is defined in python.
- Punpy generates samples from inputs and uncertainties.
- Runs M=10000 Monte Carlo uncertainty propagation according to the GUM.
- Output is divided by signal to generate relative uncertainty.
- Saved in the uncertainty budget group.

Example results per pixel



Example results per pixel Li and Lt





S3 band integrated values

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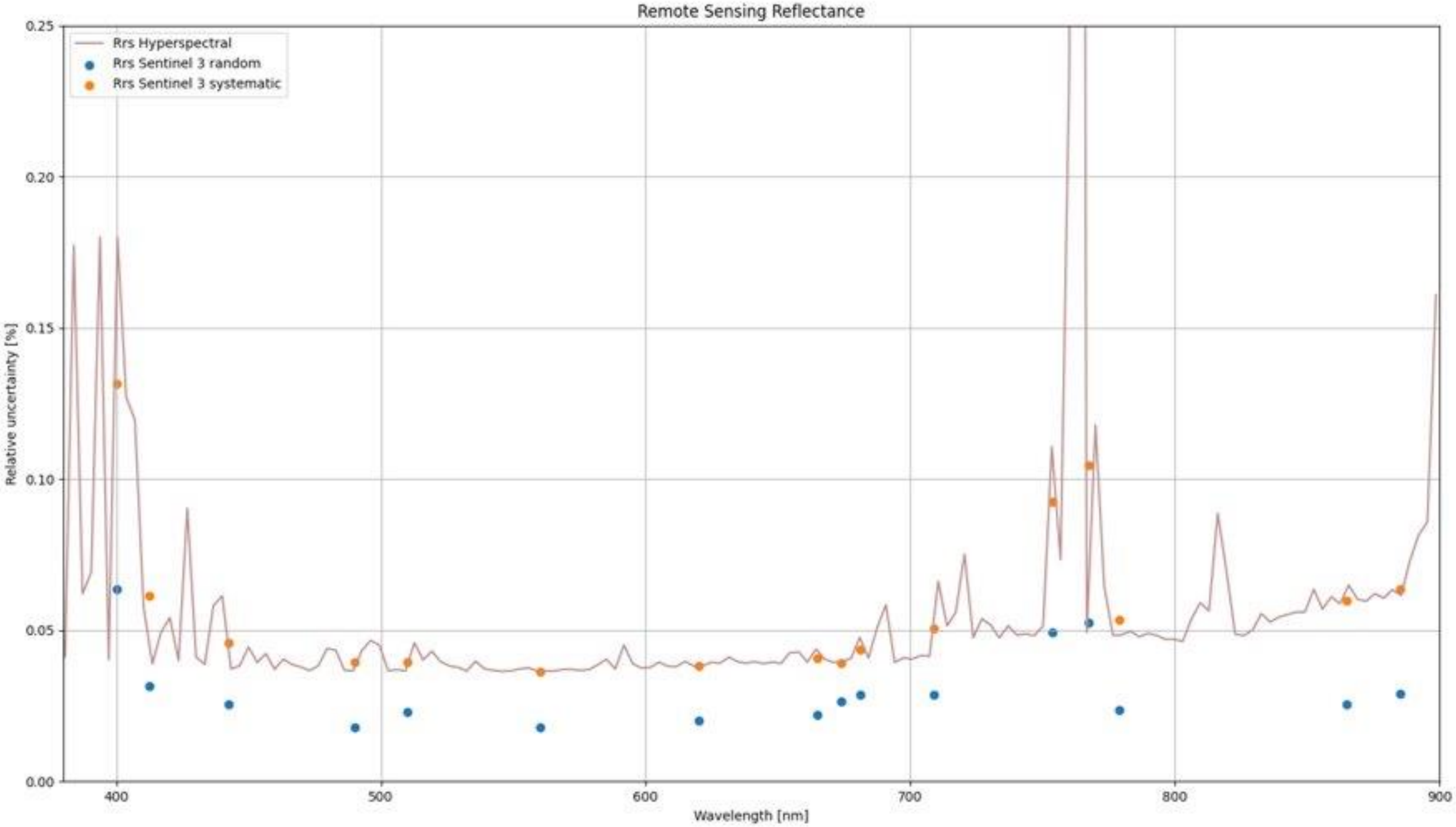
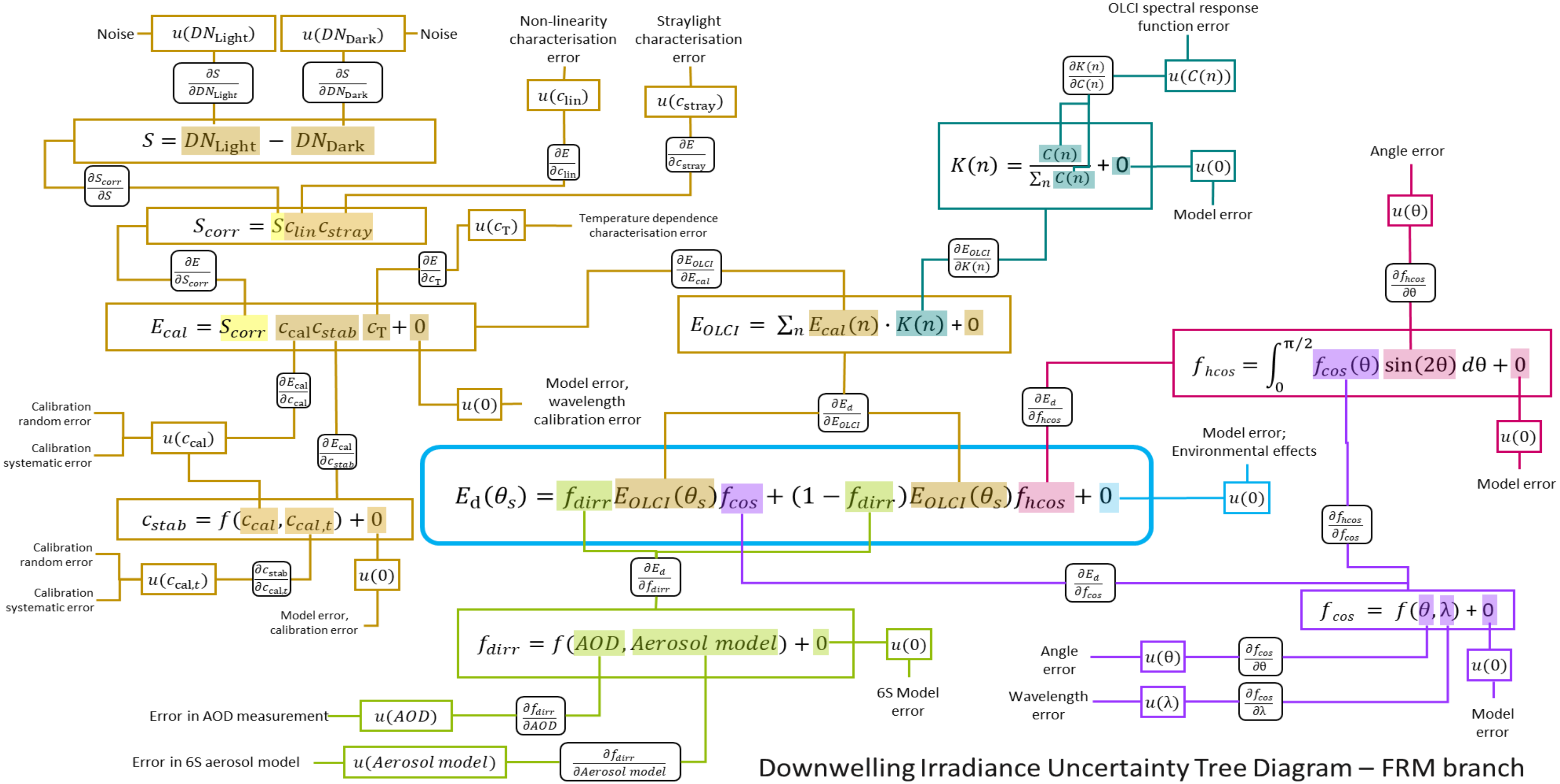


FRM processing (branch)

Under construction

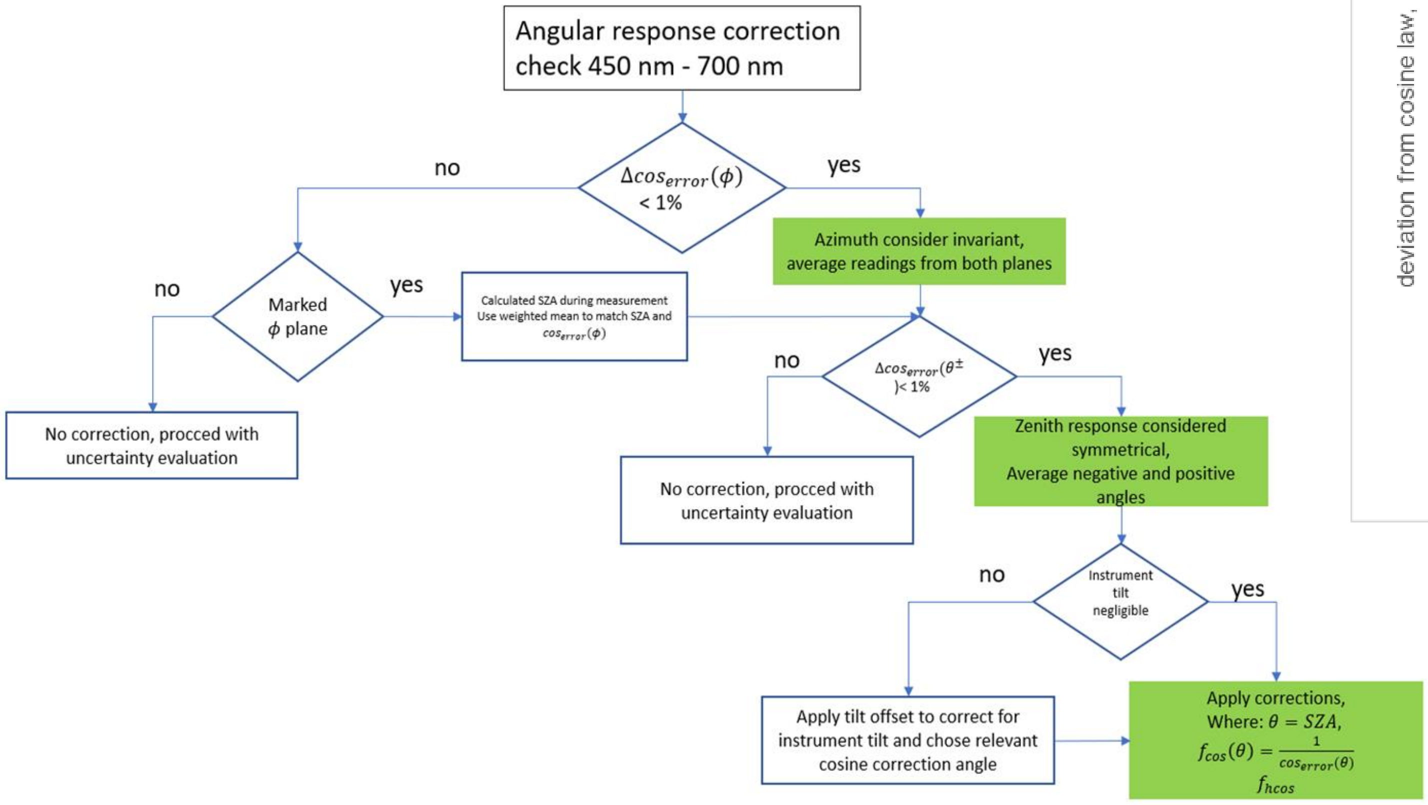
New calibration files

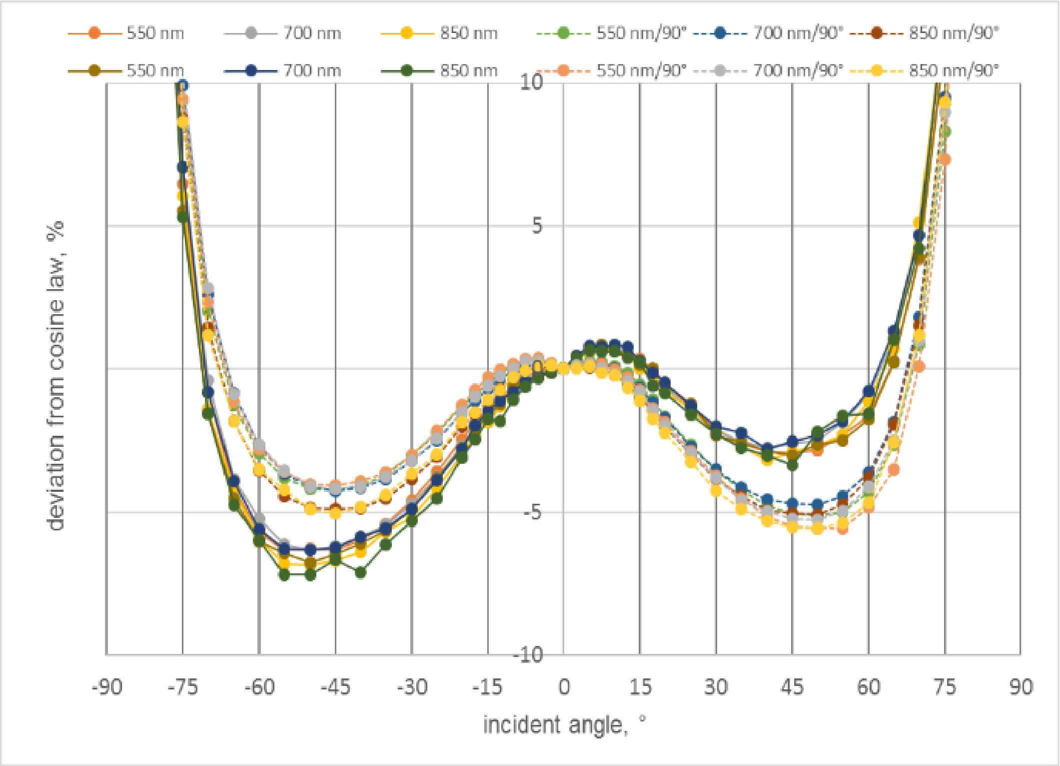
- Include lamp irradiance and reflectance standard data
- Dark corrected DNs at two international times for - non-linearity correction



Downwelling Irradiance Uncertainty Tree Diagram – FRM branch

Cosine correction



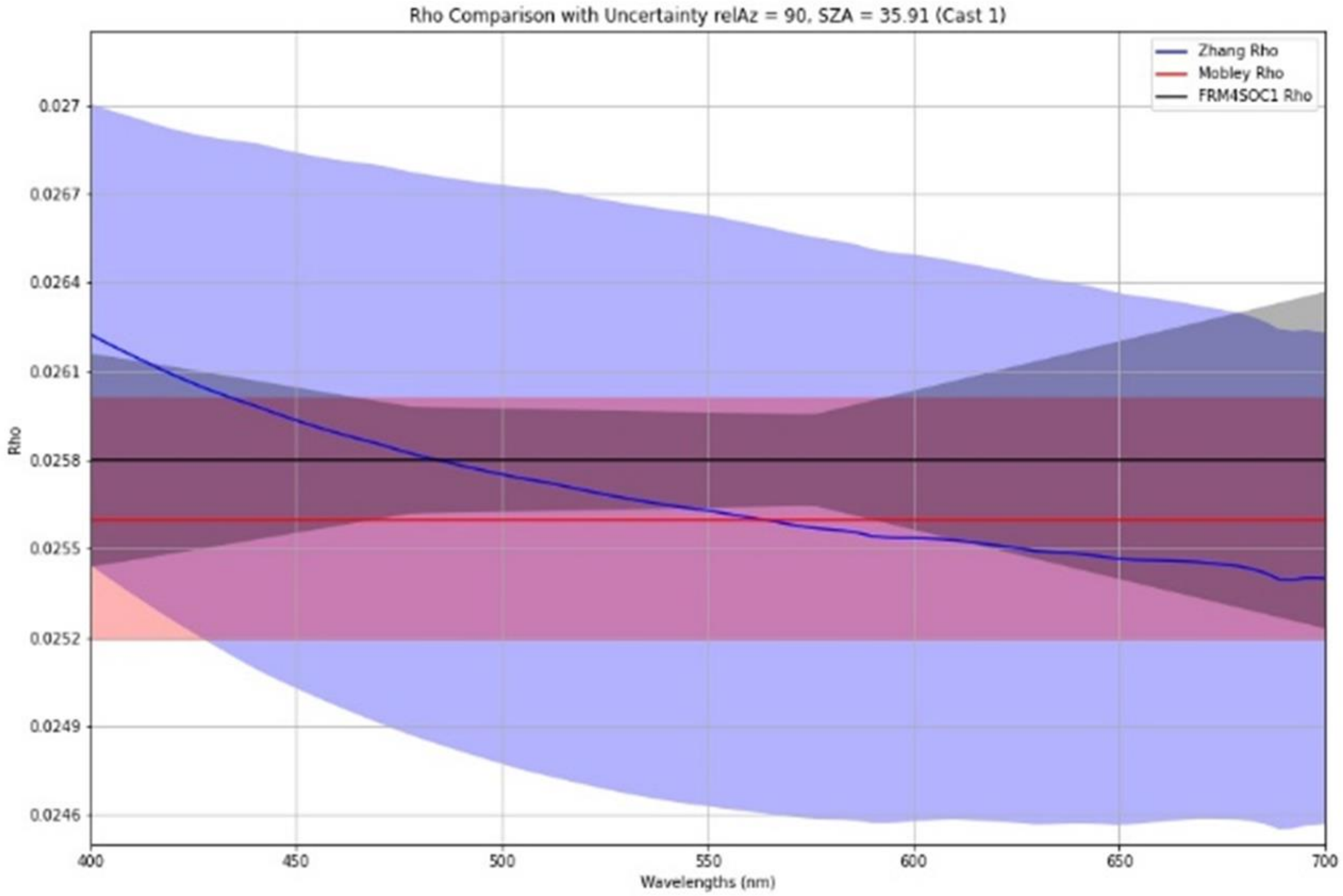


For bad cosine diffuser maybe recommend modelling Ed

Sun and sky glint removal

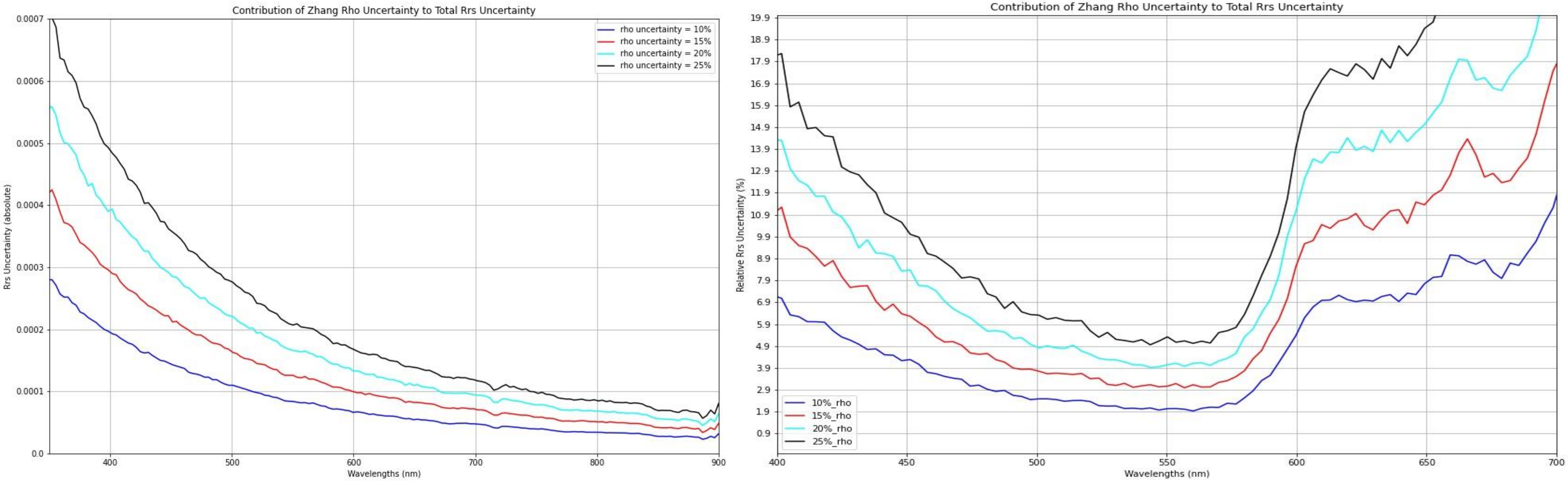
uncertainty effects of ρ

Comparisons of three ρ models



Wind speed 0.5 m/s

Zhang models uncertainty only as input to Rrs



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Next steps

- Focus on FRM processing and application of correction for individual instrument characteristics
- Run CP thought various data sets and perform “Magnitude of error study” for example of the impact Temperature effects for a wide range 0-40 degrees
- Implement BRDF correction in to CP

Conclusions

- We have a tool to propagate uncertainties that is incorporated into a community processor we still working on uncertainty estimation for some contributors
- We have a growing knowledge base and test results of instrument characterisation tests, that are use to robustly estimate instrument related errors
- We work on developing an instrument based corrections for majority of instrument related effects (FRM branch in community processor), sometimes we have to change our approach due to test results
- We did some simulation on inputs components of ρ factor and comparison of different models Mobley and Zhang to try to estimate uncertainty associate with ρ
- We work toward a practical guide for the user community. Please talk to me, if you have any suggestions on how to make easier for you.

Thank you

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