# BOUSSOLE UNCERTAINTY

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> Uncertainty evaluation method

> Field data Quality Control

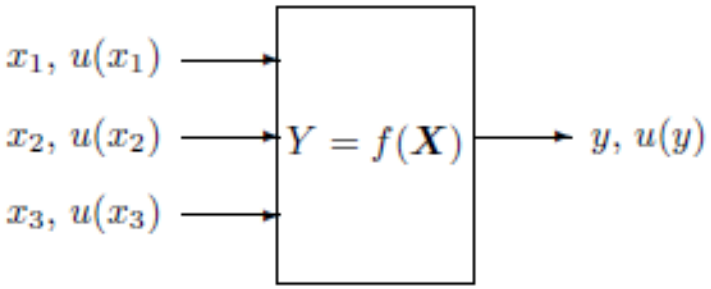
> Uncertainty evaluation

> Conclusion

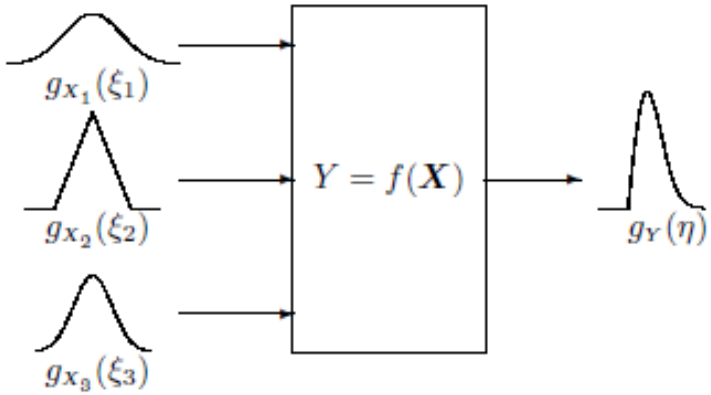
## UNCERTAINTY EVALUATION

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

### GUM




### MCM



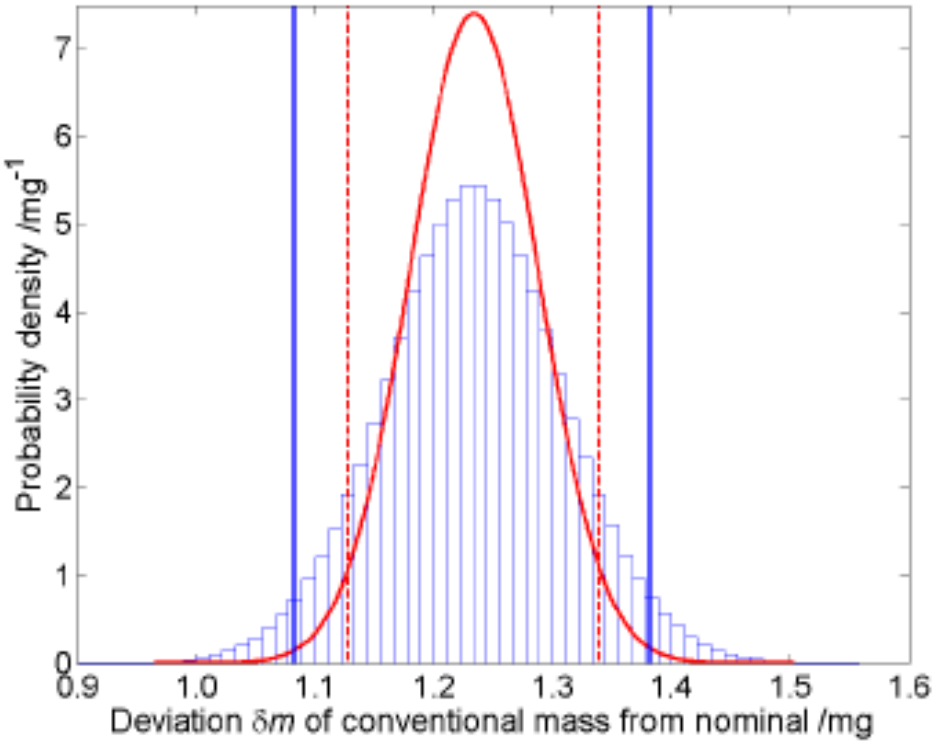

## GUM ASSUMPTIONS AND RESTRICTIONS

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

# GUM AND MCM COMMONALITIES

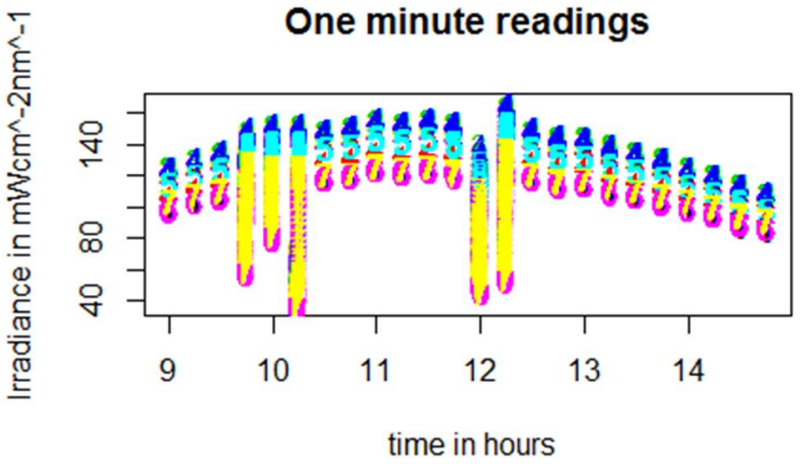
- Traceability Chain ✓
- Calculation Equation ✓
- Sources of Uncertainty ✓
- Measurements Equation ✓
- Sensitivity Coefficients ✗
- Assigning Uncertainties → PDF's
- Combining Uncertainties → Running the model

| Method | $\widehat{\delta m}$ /mg | $u(\widehat{\delta m})$ /mg | Shortest 95 % coverage interval /mg | $d_{\text{low}}$ /mg | $d_{\text{high}}$ /mg | GUF validate ($\delta = 0.005$)? |
|---|---|---|---|---|---|---|
| $\text{GUF}_1$ | 1.234 0 | 0.053 9 | [1.128 5, 1.339 5] | 0.045 1 | 0.043 0 | No |
| MCM | 1.234 1 | 0.075 4 | [1.083 4, 1.382 5] | | | |
| $\text{GUF}_2$ | 1.234 0 | 0.075 0 | [1.087 0, 1.381 0] | 0.003 6 | 0.001 5 | Yes |

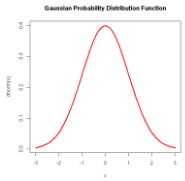


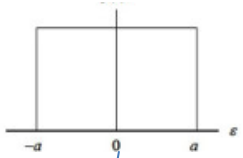

JCGM 101:2008 p 41

| SELECTION CRITERIA | THRESHOLD |
|---|---|
| σ.Es(443)<br>One minute readings stability | < 2 % |
| i.es(443)<br>Clear sky test | 0.9 < & > 1.1 |
| Tilt | < 10 ° |
| SZA | < 70 ° |
| Depth | < 11 m |
| Shading | < 5 % |
| Bio fouling | N |
| DCI – Screening for inter calibration issue | N |



| | |
|---|---|
| **SIGNAL** | $\overline{L_{u4}}$ ,$\overline{L_{u9}}$, $\overline{E_s}$ are median values of 1 minute measurements of two OCR (upwelling radiance at 4 m, $L_{u4}$, and 9 m, $L_{u9}$) and one OCI (surface irradiance, $E_s$) Satlantic 200 series radiometers with 7 VIS spectral bands. |
| **INSTRUMENT RELATED** | absolute radiometric calibration ($f_{cal}$)<br>diffuser cosine response ($f_{cos}$) |
| **ENVIRONMENTAL** | shading ($f_s$)<br>buoy tilt ($f_{tilt}$)<br>$z_4$ and $z_9$ are the actual instruments depths corrected for buoy tilt |
| **MODELLING** | extrapolation to surface correction using *Hydrolight* simulation ($f_H$)<br>the constant for water-air interface<br>fraction of the direct to total solar irradiance ($f_{dir}$) |

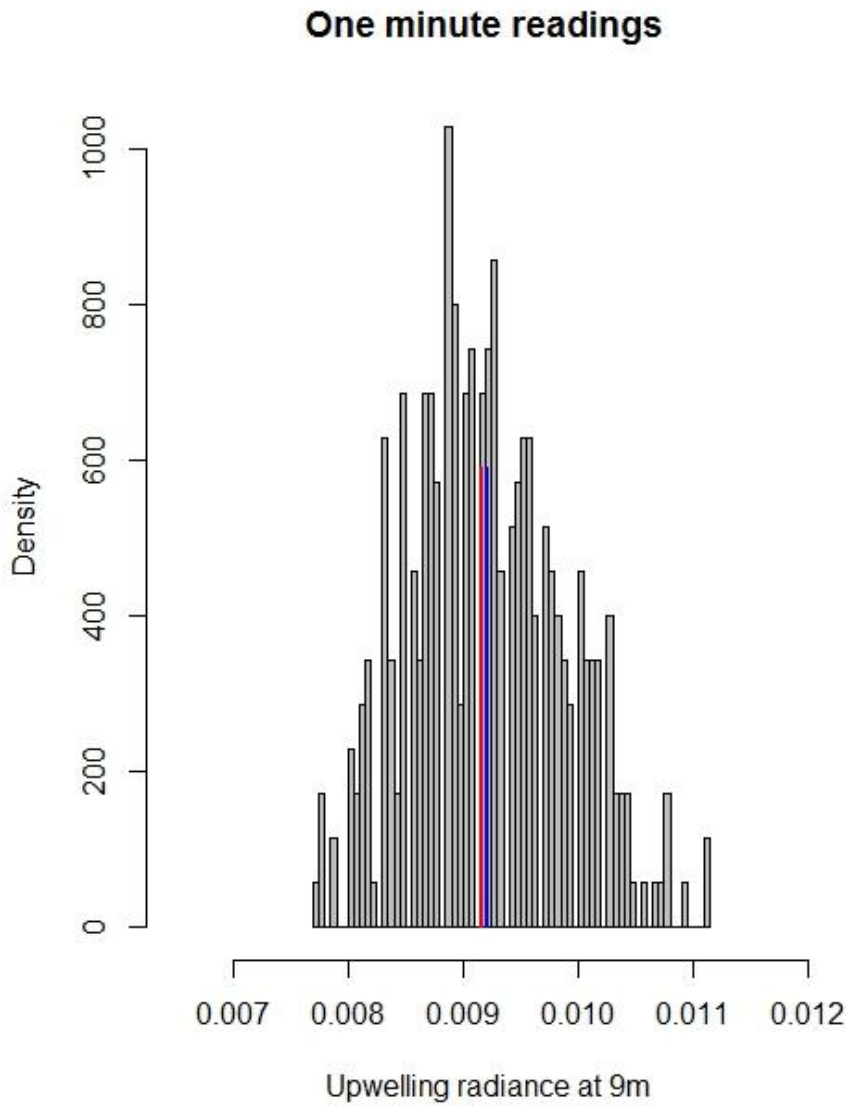



$$R_{rs} = \frac{\overline{L_{u4}} f_{cal} f_{s4} exp\left[z_4 \left(\frac{-\ln\left(\overline{L_{u9}} f_{cal} f_{s9} / \overline{L_{u4}} f_{cal} f_{s4}\right)}{z_9 - z_4}\right)\right] f_H f_{\rho n}}{\overline{E_s} f_{cal} f_{cos} f_{tilt} f_{dir} + (1 - f_{dir}) \overline{E_s} f_{cal}}$$

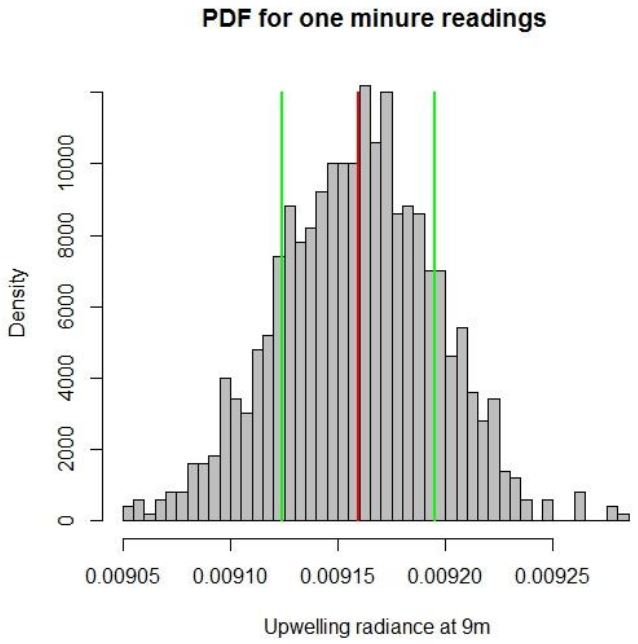
## SIMULTANEOUS 1 MINUTE READINGS (~360 MEASUREMENTS)

$\overline{L_{u4}}$ ,$\overline{L_{u9}}$, $\overline{E_s}$




PDF

- Median value of one minute readings is used as a best estimate
- Standard deviation of the mean is the expectation of the standard uncertainty
- PDF is Gaussian

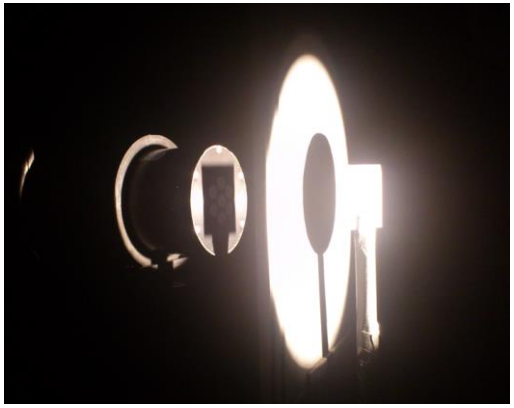


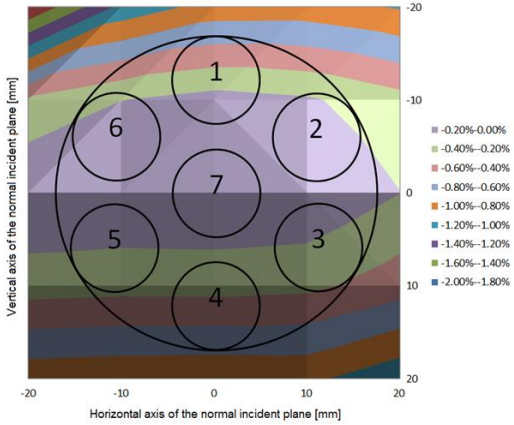
## INSTRUMENTAL

> Derived from laboratory tests with uncertainties defined in the traditional way.

> Gaussian PDFs with standard uncertainty equal standard deviation.

| Source of uncertainty | B1<br>411.96 nm | B1<br>442.03 nm | B3<br>488.86 nm | B4<br>508.93 nm | B5<br>559.12 nm | B6<br>669.4 nm | B7<br>682.74 nm |
|---|---|---|---|---|---|---|---|
| Light Short-term effect; | 0.042% | 0.029% | 0.017% | 0.014% | 0.010% | 0.006% | 0.006% |
| Dark Short-term effect; | 0.045% | 0.033% | 0.018% | 0.016% | 0.010% | 0.006% | 0.006% |
| Stability; | 0.06% | 0.06% | 0.06% | 0.06% | 0.06% | 0.06% | 0.06% |
| Signal related | 0.083% | 0.073% | 0.064% | 0.063% | 0.061% | 0.061% | 0.061% |
| FEL calibration; | 0.54% | 0.48% | 0.40% | 0.39% | 0.38% | 0.36% | 0.36% |
| Calibration distance; | 0.052% | 0.052% | 0.052% | 0.052% | 0.052% | 0.052% | 0.052% |
| Realignment; | 0.157% | 0.157% | 0.157% | 0.157% | 0.157% | 0.157% | 0.157% |
| Current; | 0.030% | 0.029% | 0.026% | 0.025% | 0.022% | 0.019% | 0.018% |
| Aging; | 0.289% | 0.289% | 0.289% | 0.289% | 0.289% | 0.289% | 0.289% |
| Off-centre error | 0.546% | 0.059% | 0.127% | 0.516% | 0.211% | 0.177% | 0.000% |
| Multi-centre Irradiance related | 0.635% | 0.585% | 0.521% | 0.513% | 0.506% | 0.491% | 0.491% |
| Single-centre Irradiance related | 0.837% | 0.588% | 0.536% | 0.728% | 0.548% | 0.522% | 0.491% |
| Multi-centre Combined standard uncertainty ($k$=1) | 0.64% | 0.59% | 0.52% | 0.52% | 0.51% | 0.49% | 0.49% |
| Multi-centre Expanded uncertainty ($k$=2) | 1.28% | 1.18% | 1.05% | 1.03% | 1.02% | 0.99% | 0.99% |
| Single-centre Combined standard uncertainty ($k$=1) | 0.84% | 0.59% | 0.54% | 0.73% | 0.55% | 0.53% | 0.49% |
| Single- centre Expanded uncertainty ($k$=2) | 1.68% | 1.18% | 1.08% | 1.46% | 1.10% | 1.05% | 0.99% |



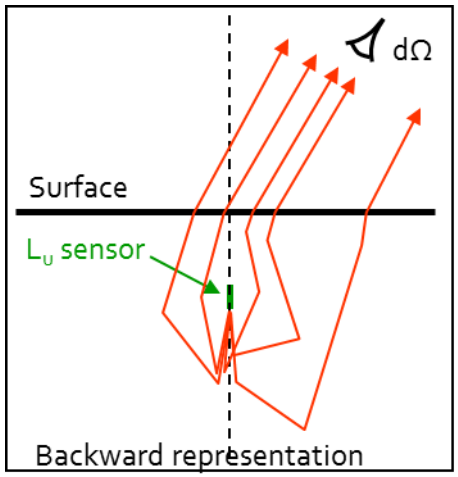


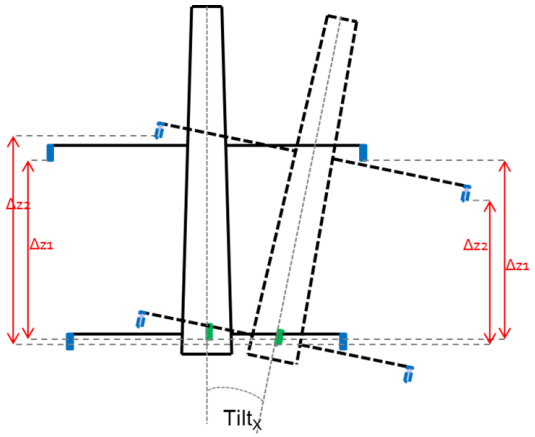
| INSTRUMENTAL | UNCERTAINTY ($k$ = 1) | SOURCE |
|---|---|---|
| Absolute radiometric calibration (Irradiance) | 1.6% - 1.1% (1.5%) | NPL calibration and comparison to Satlantic coefficients |
| Cosine diffuser (Irradiance) | 3% below 60°, 10% above | Satlantic specifications |
| Absolute radiometric calibration (Radiance) | 2.5% - 2.0% (2.2%) | NPL calibrations and comparison to Satlantic coefficients |
| Radiometric stability | 1% (Not included) | From repeated calibrations, if no instruments issues |
| Immersion coefficient | Bias of 0.4 % with 0.19 % uncertainty, currently not included | Literature, Zibordi 2006 |
| Temperature dependence | Negligible | NPL test in 2013 ( for the observed at the site range) |
| Detector linearity | Negligible | NPL test in 2013 |

## ENVIRONMENTAL

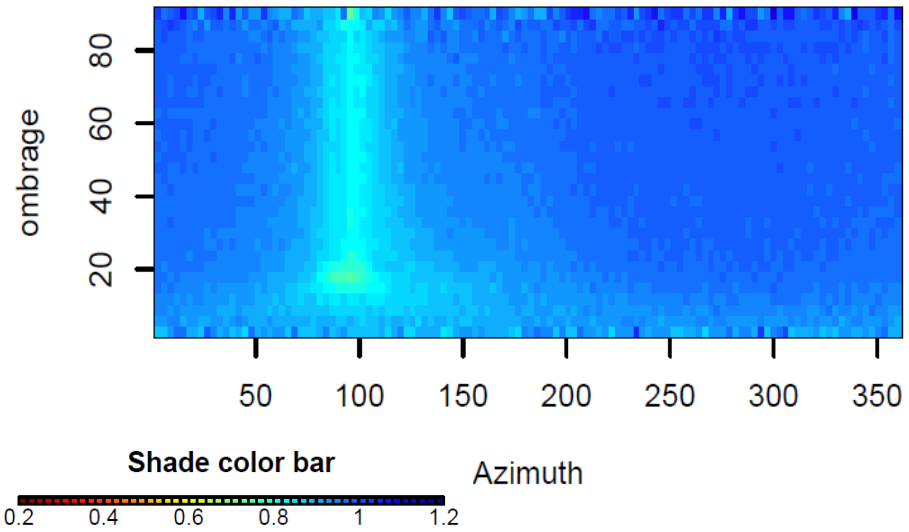
> Evaluated from ancillary buoy data e.g. the buoy tilt, actual depth and MC shading modelling

> Uncertainties have rectangular PDFs or actual derived form MCM




Shading coefficient matrix $L_u$(443,4m) Chl = 0.1 µg/l

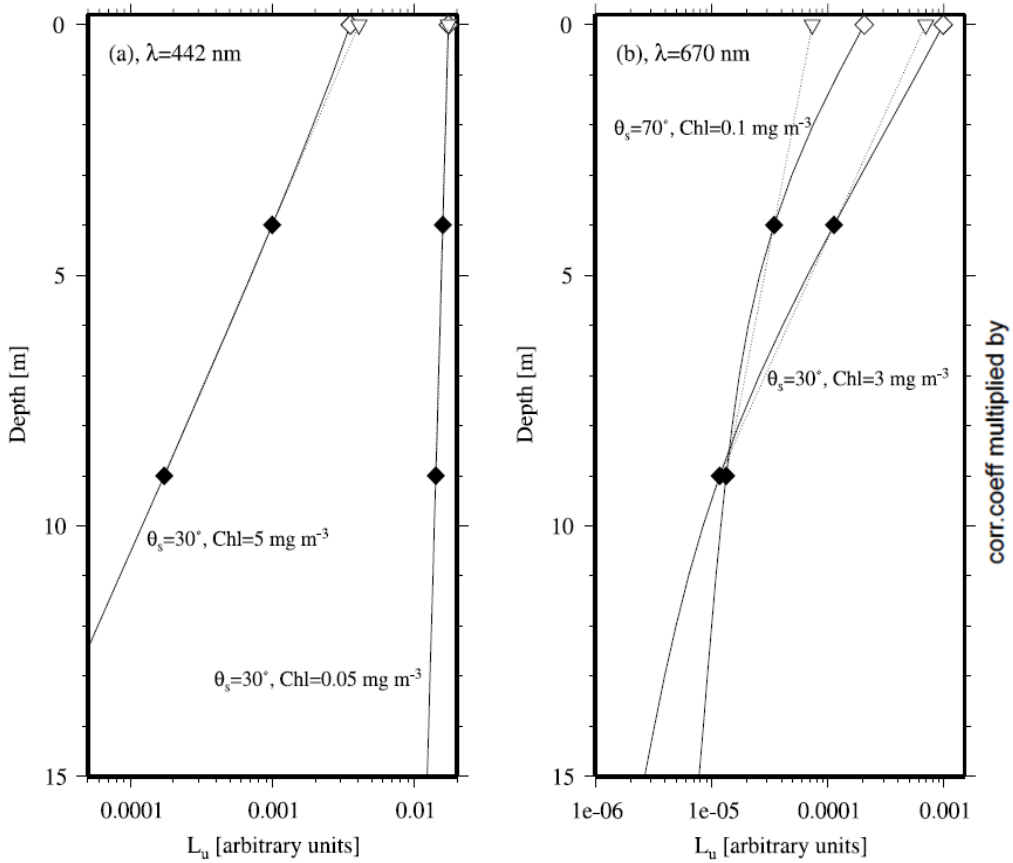


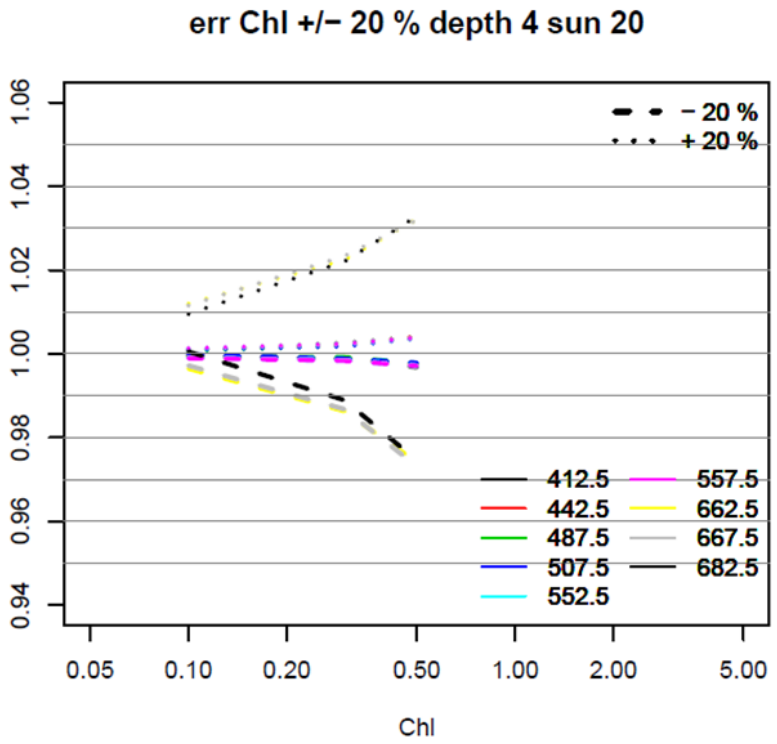
| ENVIRONMENTAL | UNCERTAINTY ($k$ = 1) converted to normal distribution | SOURCE |
|---|---|---|
| Depth | 1% | To be refined by a mini MCM model |
| Tilt ($E_s$) | 2% | To be refined by a mini MCM model |
| Shading | 1.2% | Comparison of LOV MC photon tracking model with others corrections |
| BRDF (effect of the tilt under water) | | Currently being estimated |

## MODELLING

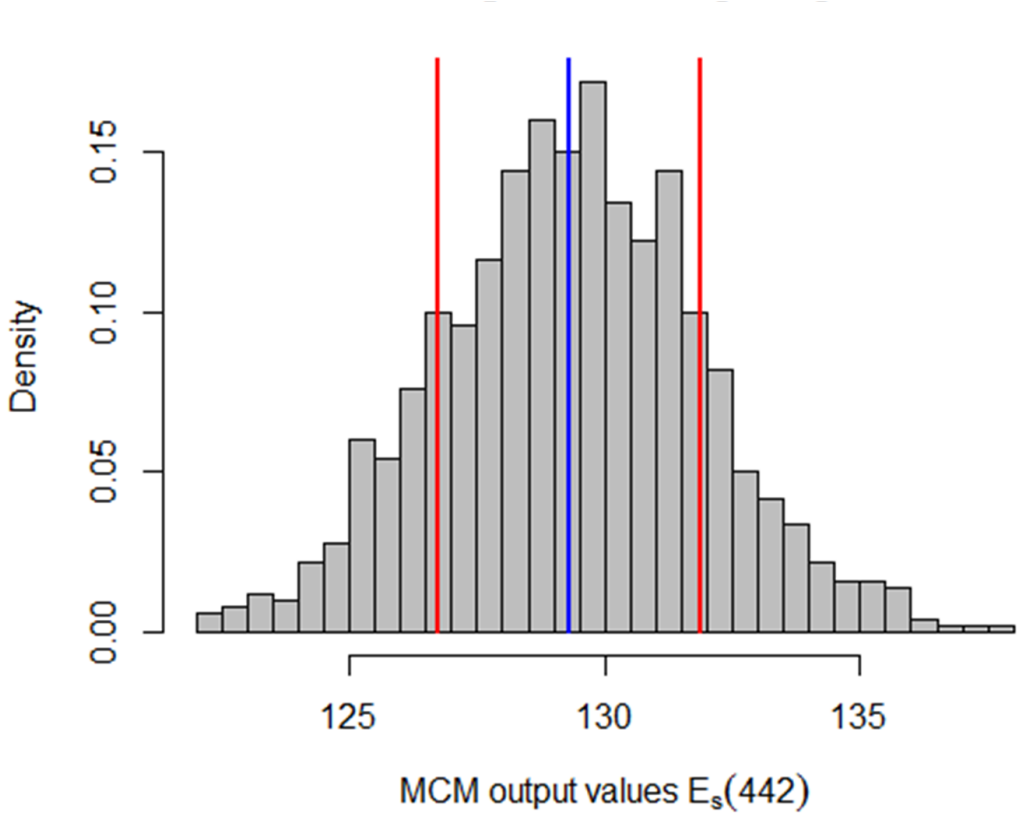
> Defined by theory derived from available models, uncertainty estimated from literature, or sensitivity study on the model.

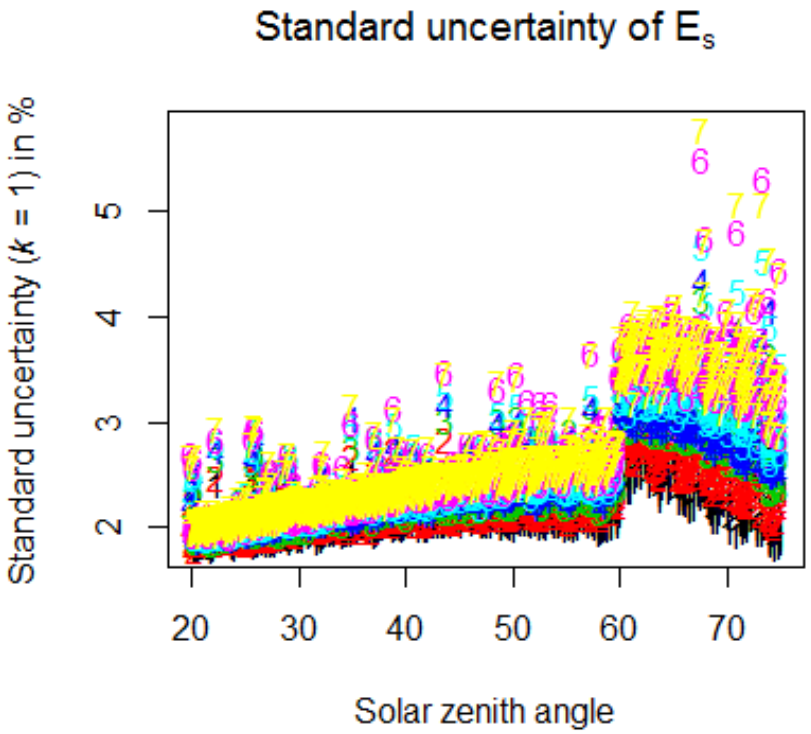
> PDF's rectangular or Gaussian.

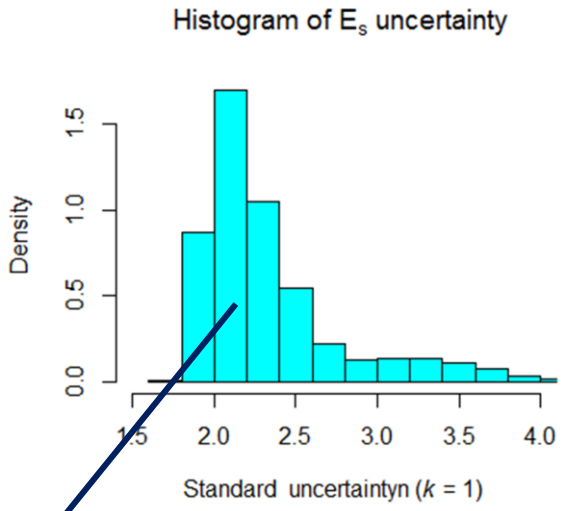


| MODELLING | UNCERTAINTY ($k$ = 1) converted to Normal distribution | SOURCE |
|---|---|---|
| Hydrolight correction | 0.5% below 600 nm<br>2% - 3% above 600nm (Chla dependent)<br>(1.5%) | Sensitivity study by modelling |
| Water – air constant | 0.5% | Literature Austin 1976, Austin and Halikas 1976, Wei et al. 2015 plus modelling |
| Direct to total fraction | 3.5% | Literature |


Density
0.00
0.05
0.10
0.15
125
130
135
MCM output values $E_s(442)$

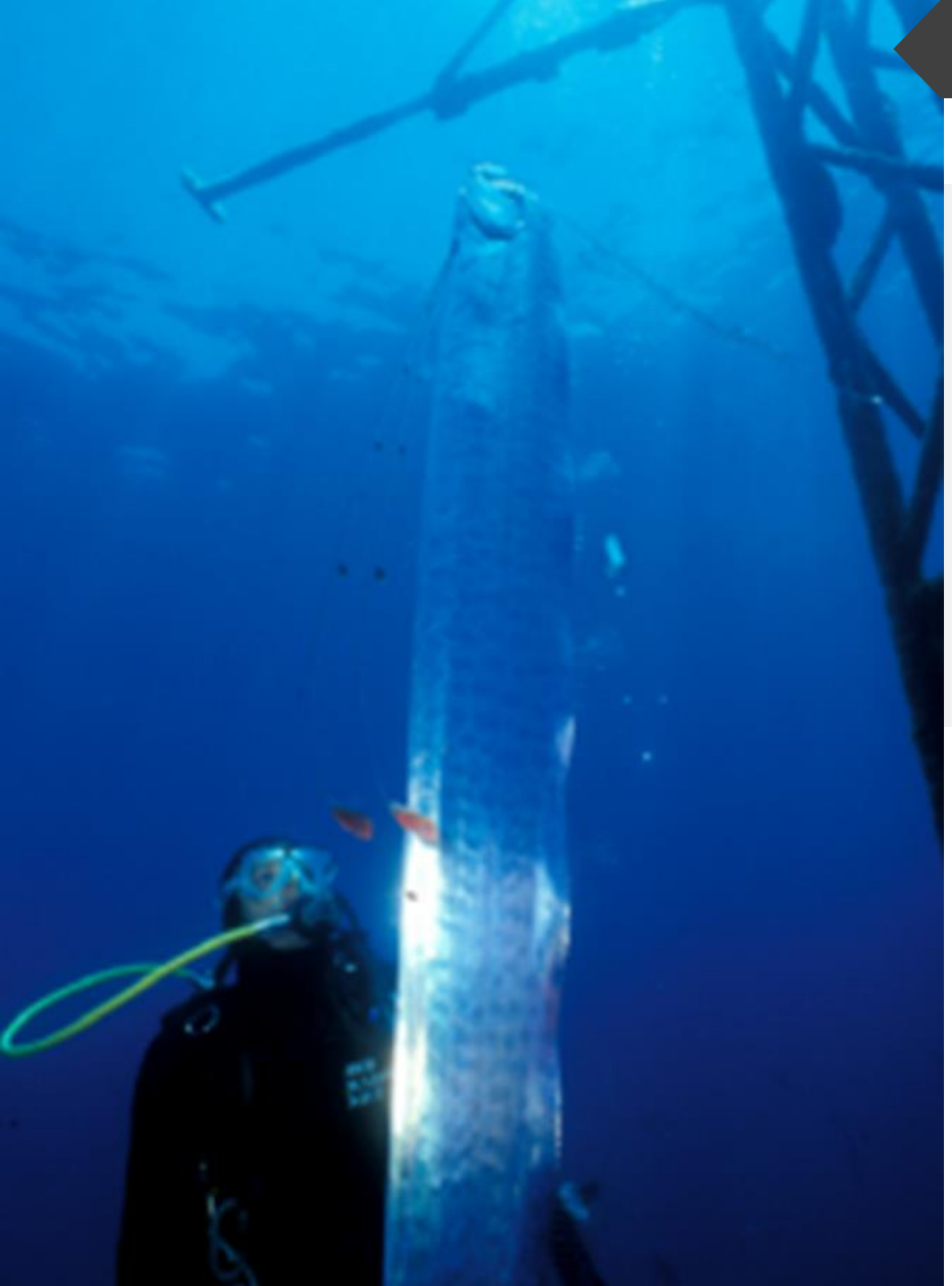



| $u$ in % / $\lambda$ in nm | $E_s$ | $L_{u4}$ | $L_W$ | $R_{rs}$ | $u_{abs}(R_{rs})$ |
|---|---|---|---|---|---|
| 412 | 2.1 | 2.6 | 3.1 | 3.7 | 0.000215 |
| 443 | 2.0 | 2.6 | 3.1 | 3.7 | 0.000225 |
| 490 | 2.0 | 2.6 | 3.0 | 3.7 | 0.000175 |
| 510 | 2.0 | 2.6 | 3.0 | 3.7 | 0.000155 |
| 560 | 2.0 | 2.6 | 3.1 | 3.7 | 0.0000725 |
| 665 | 2.1 | 3.9 | 5.9 | 6.3 | 0.00000410 |
| 681 | 2.1 | 4.0 | 5.9 | 6.3 | 0.00000195 |

## CONCLUSIONS

- "Dynamic" uncertainty value per observation, thus per match-up point rather then one generic value
- Generic available as well as the most probable uncertainty value from all data uncertainties
- MCM deals with nonlinear functions and not normal probability distributions
- The set up framework can be easily used to model and estimate the effect of additional efforts to reduce individual uncertainty components on the overall budget



# Thanks for Attention

D. Antoine – PI
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