Uncertainty in Calibration and Characterisation of Pyranometers

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AIM

1) To propose a new, faster, sequential indoor calibration of pyranometers

2) To assess the impact of different pyranometer calibration procedures on solar resource assessment

MOTIVATION

True field uncertainties can be twice the datasheet minimum values of 2% (hourly) and 3% (daily)

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Better understanding of benefits and constraints of high quality calibrations

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Time-intensive single indoor calibration and/or unsuitable conditions for outdoor calibration

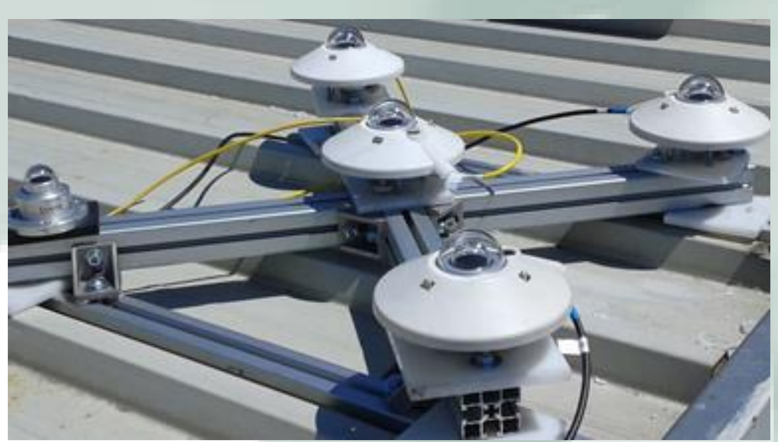
METHODOLOGY

1) **Data handling** procedures comparison for outdoor calibrations.
2) ***New sequential calibration*** indoors and comparison with existing methods.
3) **Scenarios evaluation** with real data from a solar farm.

TEST SUBJECTS (pyranometers)

EURAC: three Secondary Standard (SS, high quality) from manufacturer m1 and one Second Class (2C, moderate quality) from m2.

CREST: three Secondary Standard from m1, one with a temperature sensor (t2) and two without (t1).



Outdoor calibration of pyranometers [image kindly provided by EURAC]

METHODOLOGY (1): Data handling

Filter short description	Beam irradiance, min [W/m²]	Diffuse irradiance, max [W/m²]	Diffuse fraction (diffuse / global irradiance), max [%]	Number of series
All clear sky series	700	150	15 (clear sky series)	32
One clear sky series per group of angles of incidence				15 (one per group of angles of incidence)
One series per group of angles of incidence	0	1000	100	

Overview of adopted filters during mostly sunny days (daily diffuse fraction lower than 15%). Clear sky series correspond to a diffuse fraction not higher than 15%

METHODOLOGY (2): New sequential calibration

Sensor positions during each shade-unshade-shade sequence of measurement, m

position one	position two	position three	position four
t1 refer.	t2 n18	t1 n13	t1 n12
t2 n18	t1 refer.	t1 n13	t1 n12
t2 n18	t1 n13	t1 refer.	t1 n12
t2 n18	t1 n13	t1 n12	t1 refer.

Manual position swapping

21 measurements (42 s) after 30 s of stabilisation per series.

One third of time required compared to traditional calibration !!

Swapping end — No → *Manual position swapping*; Yes → Solving equation system → calibration factors f

3x equations (ISO 9847:1992)

$$f_T = F_R \times \frac{(V_{R(p,m)} + V_{R(p+1,m+1)})}{(V_{T(p+1,m)} + V_{T(p,m+1)})}$$

$V_{T(p+1,m+1)}$: calculated voltage (unshaded minus shaded measurement) of the test sensor T at the position p+1 during measurement sequence m+1.

4x equations

$$\bar{\iota}_p = \frac{\sum_{m=1}^{M} f_m \times V_{pm}}{M}$$

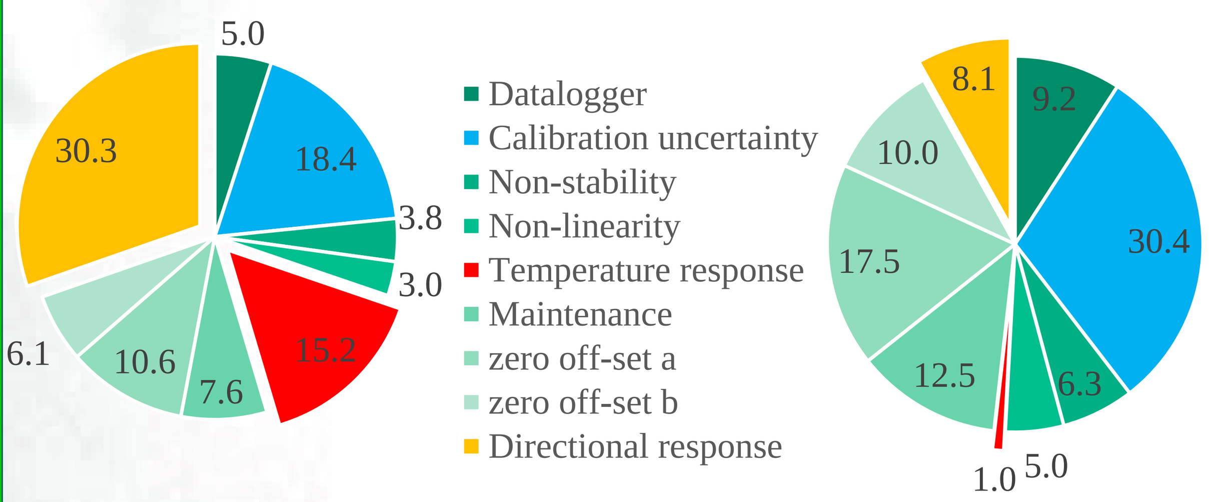
$\bar{\iota}_p$: average measured irradiance at position p based on calculated voltage V and related calibration factor f.

METHODOLOGY (3): Scenarios evaluation

Previous scenario results: -40% irradiance uncertainty by applying a few characterisation-based factors (temperature and directional response).

Relative uncertainty importance Ki in case of datasheet-based (left pie) and characterisation-based (right pie) information for a Secondary Standard. [Francesco Mariottini, Jiang Zhu, Thomas R. Betts, Ralph Gottschalg]

$$K_i = \frac{c_X * u(X)}{\sum_l c_l u(l)} * \frac{u_i}{\sum_m u_m}$$



NEW SCENARIOS

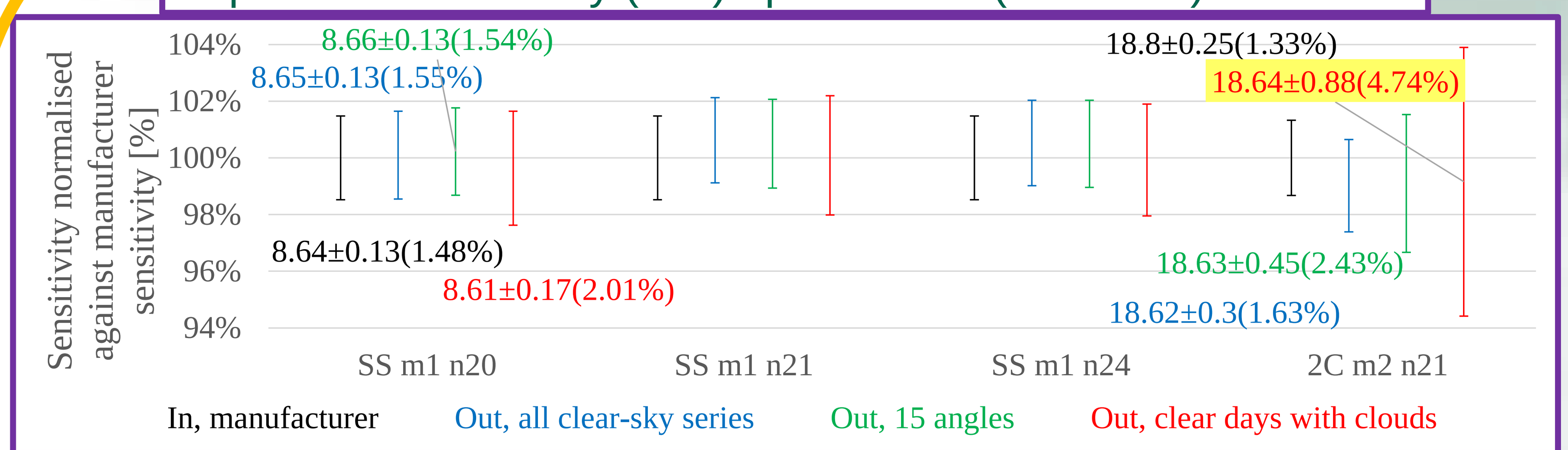
Indoor VS outdoor with clouds, Secondary Standard VS Second Class.

With previous scenario datasheet VS characterization

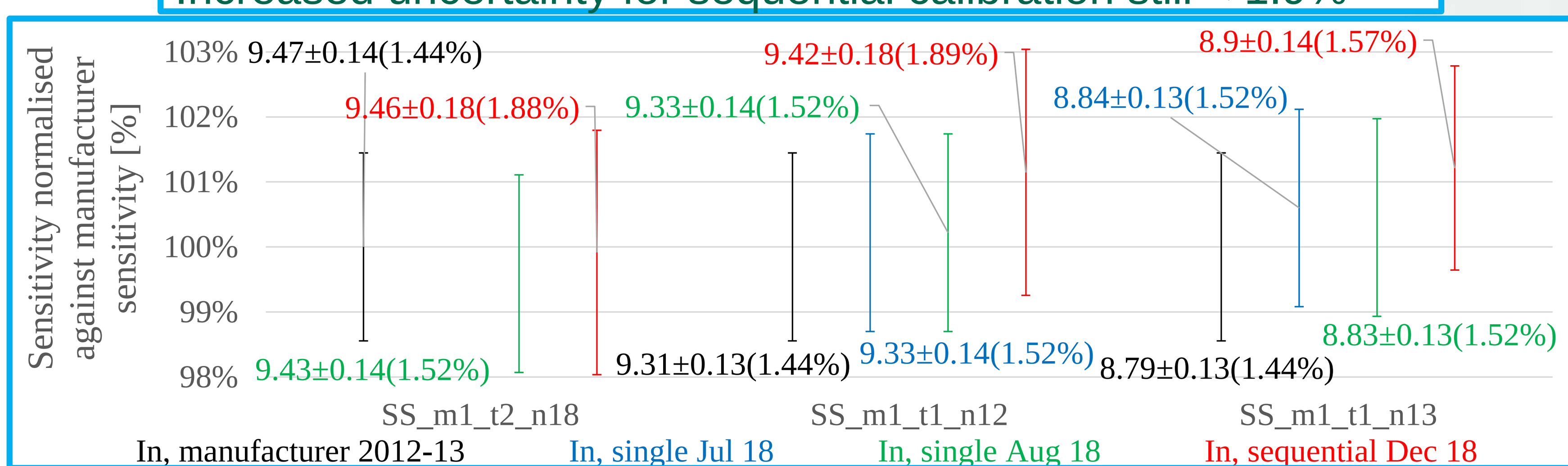
RESULTS

Median deviations from manufacturer calibration values ≤ 1%

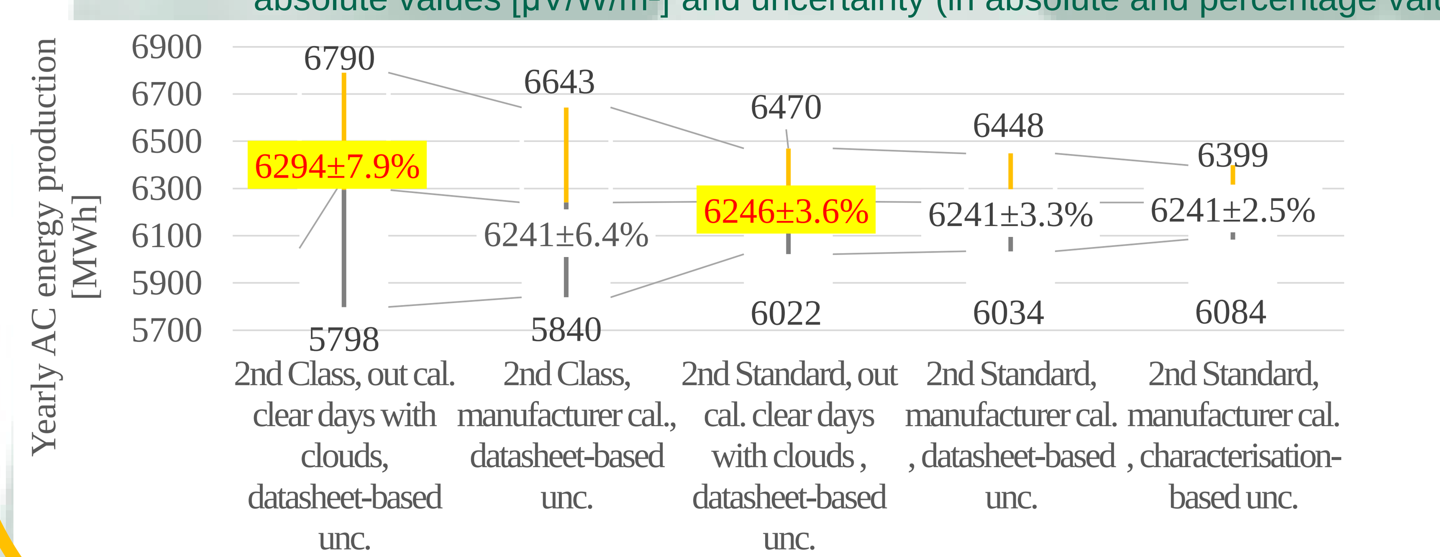
Expanded uncertainty (k=2) up to 4.73% (2nd Class)



Increased uncertainty for sequential calibration still < 1.9%



Normalised sensitivities. Extremes were determined assuming a symmetrical uncertainty. Data labels show absolute values [μV/W/m²] and uncertainty (in absolute and percentage values)



Up to 7.9% and 3.6% uncertainty for 2nd Class and Secondary Standard

Effects of calibration and characterisation uncertainty, based on hourly averaged values, on the yearly yield assessment of a PV solar farm of 7.4 MWp

MAIN CONCLUSIONS

Rigorous calibration and characterisation information may reduce yield assessment uncertainty by 30%

Sequential calibrations are a 3 times faster alternative.

FUTURE STEPS

Uncertainty dependency on installation and maintenance.

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