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PV MODULE LIFE TIME FORECAST AND EVALUATION

Uncertainty in calibration and characterisation of pyranometers

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AIM

- To propose a new, faster, sequential indoor calibration of pyranometers
- To assess the impact of different pyranometer calibration procedures on solar resource assessment.

MOTIVATIONS

- True field uncertainties can be twice the datasheet minimum values of 2% (hourly) and 3% (daily)
- Time-intensive single indoor calibration and/or unsuitable conditions for outdoor calibration

Need better understanding of benefits and constraints of quality calibrations

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)

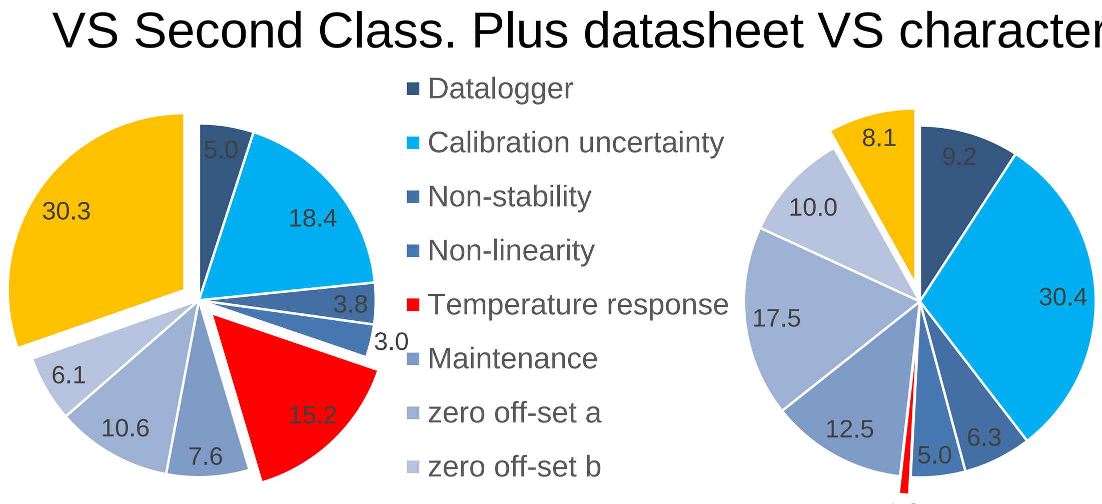
- **EURAC**: three Secondary Standard (SS, high quality) from manufacturer m1 and one Second Class (2C, moderate quality) from m2.
- **CREST**: three Secondary Standard from m1, one with a temperature sensor (t2) and two without (t1).

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)	32
One clear sky series per group of angles of incidence	700	150	15 (clear sky)	15 (one per group of angle of incidence)
One series per group of angles of incidence	0	1000	100	15 (one per group of angle of incidence)

METHODOLOGY (3): Scenarios evaluation

- **Previous study results**: -40% irradiance uncertainty by applying a few characterisation-based factors (temperature and directional response).
- **New scenarios:** Indoor VS outdoor with clouds and Secondary Standard VS Second Class. Plus datasheet VS characterization (previous study).



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

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

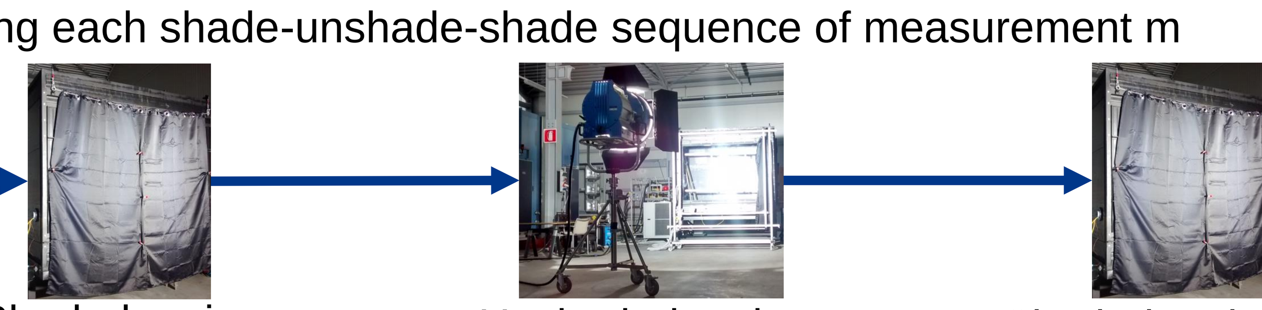
https://solar-train.eu/ @MSCA_SolarTrain

METHODOLOGY (2): New sequential calibration

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.

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

Manual position swapping



Shaded series — Unshaded series — Shaded series

No

21 measurements (42 s) after 30 s of stabilisation per series.
One third of time required compared to traditional calibration !!

Swapping end

Yes

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.

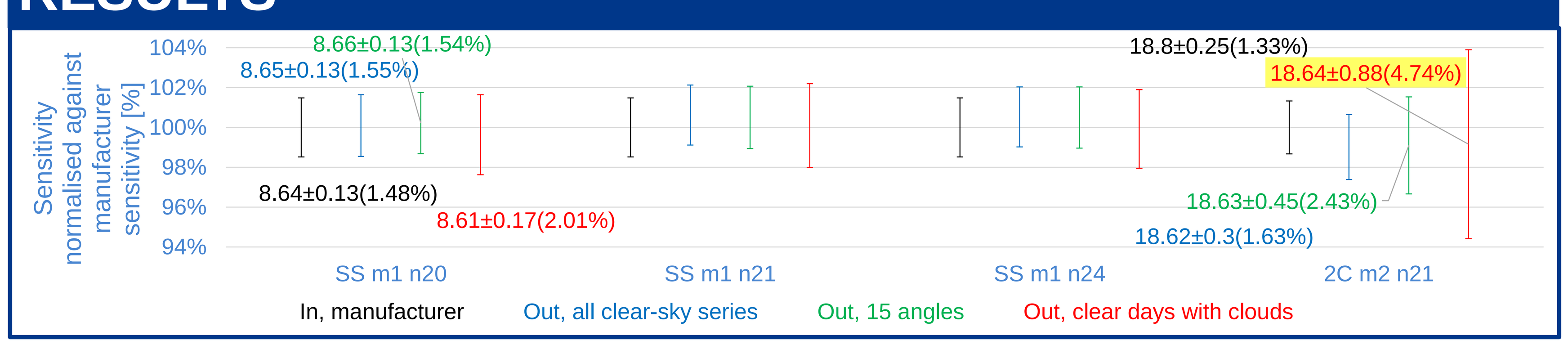
Solving equation system → calibration factors f

4x equations

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

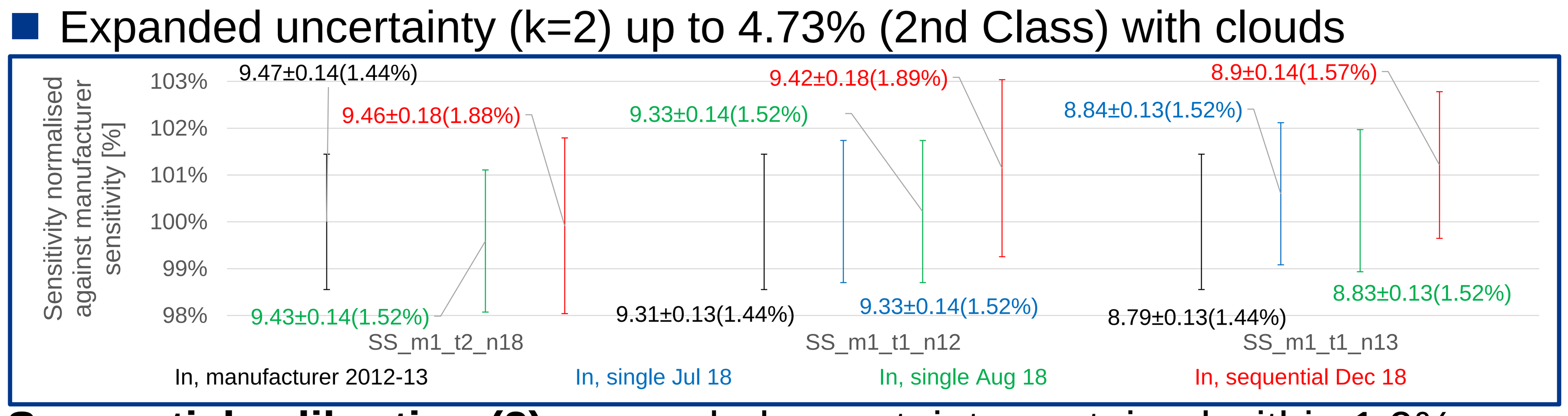
$\bar{\iota}_p$: average measured irradiance at position p based on calculated voltage V and related calibration factor f.

RESULTS

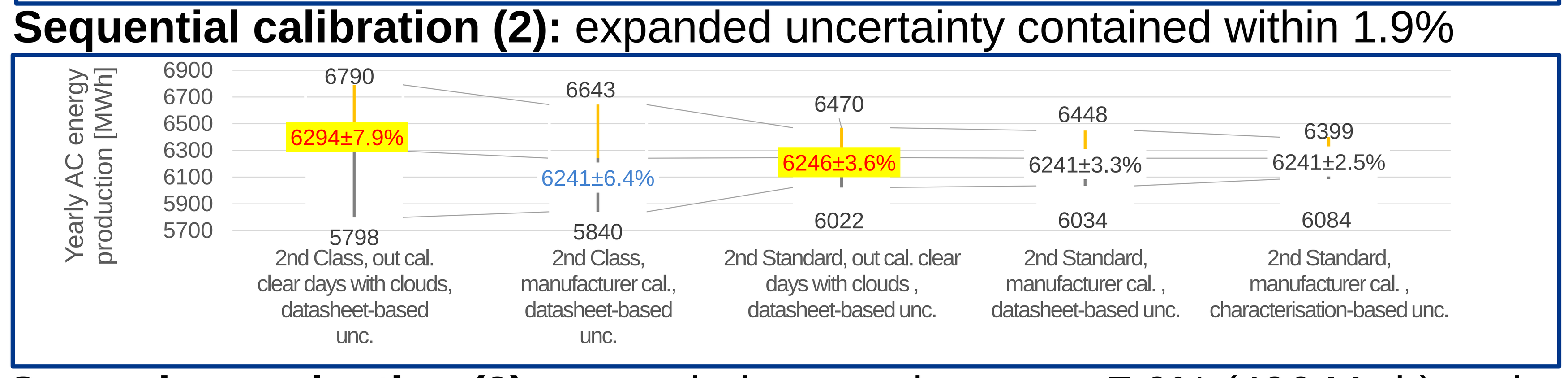


Data handling (1)

- Median deviations from manufacturer calibration values ≤ 1%
- Expanded uncertainty (k=2) up to 4.73% (2nd Class) with clouds



Sequential calibration (2): expanded uncertainty contained within 1.9%



Scenarios evaluation (3): expanded uncertainty up to 7.9% (496 Mwh) and 3.6% (224 Mwh) for 2C and SS in annual yield of 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

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