Our Radiometers and the ISO 9060:2018 AA-class

"Some thoughts about our cavities"

Markus Suter

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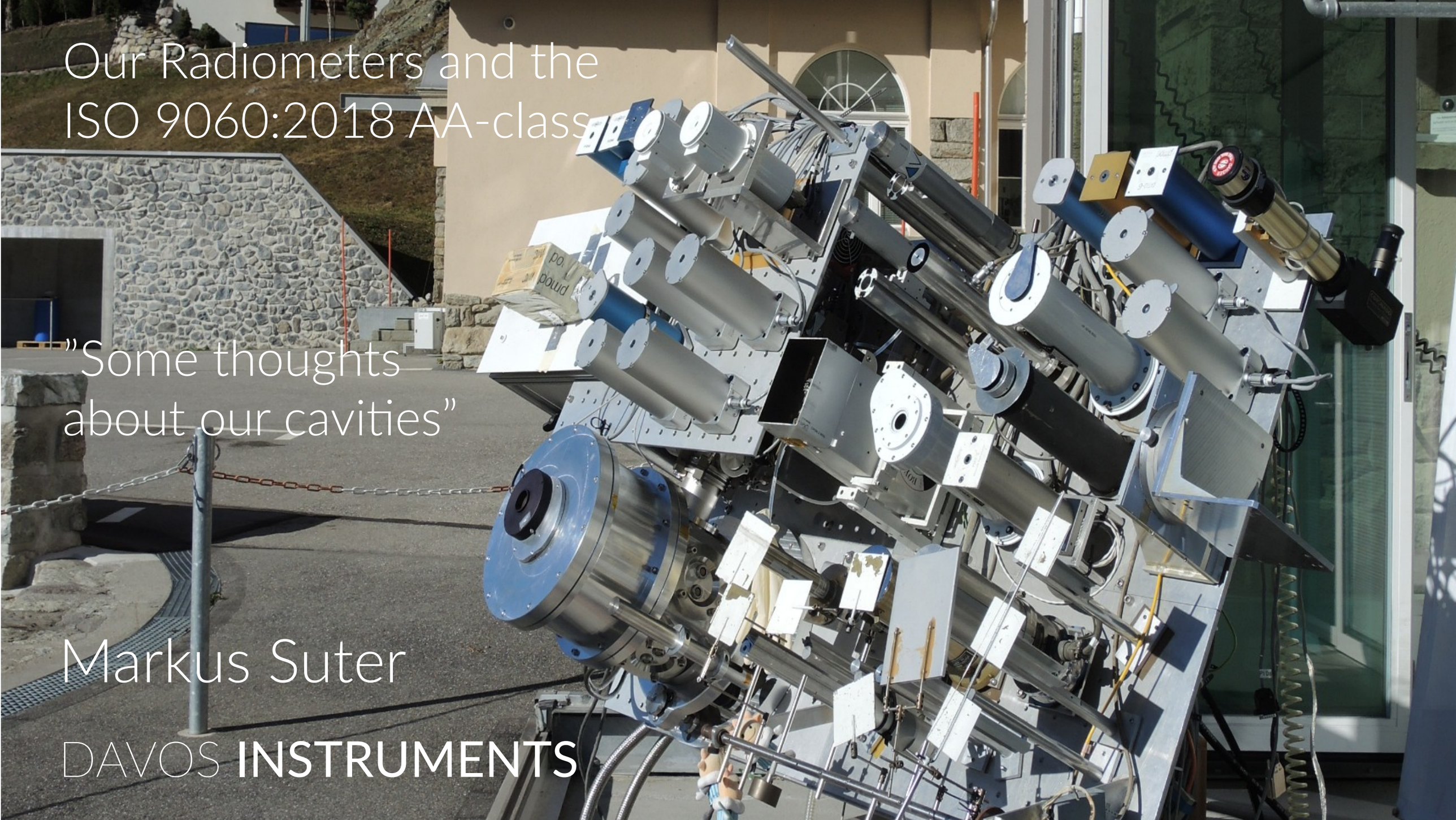
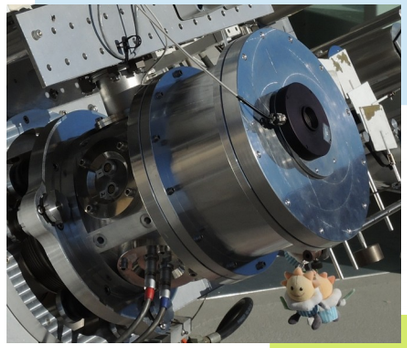


The ISO 9060:2018 Instrument Classes

Pyrheliometer definition
Radiometer designed for measuring the irradiance which results from the solar radiant flux from a well defined solid angle the axis of which is perpendicular to the plane receiver surface.



AA	A	B	C	New
Primary Standard	Secondary Standard	First Class	Second Class	Old

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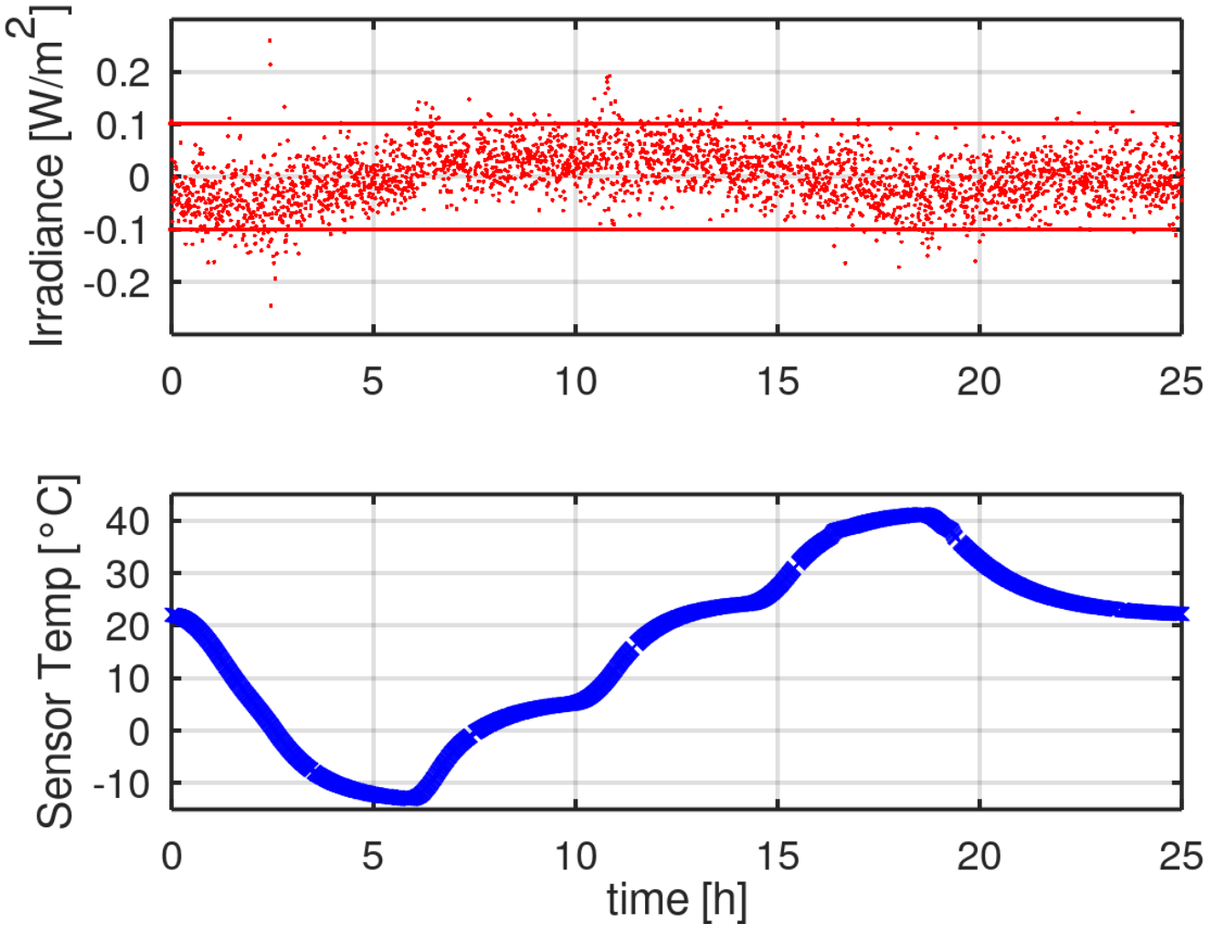
Instrument Classes: Criteria

Criteria	AA-class
Zero off-set a)	±0,1 $W \cdot m^{-2}$
Zero off-set b)	±0,2 $W \cdot m^{-2}$
Non-stability	±100 ppm
Nonlinearity	±100 ppm
Spectral error	±100 ppm
Temperature response	±100 ppm
Tilt response	±100 ppm
Additional signal processing errors	±0,1 $W \cdot m^{-2}$

Zero off-set

a) Response to 5 K·h−1 change in ambient temperature	±0,1 W·m^{-2}
b) Complete zero off-set including the effect a) and other sources	±0,2 W·m^{-2}

Promising results from PMO8 dark measurements
temperature drift up to 10 °C/h



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Temperature response

Percentage deviation due to change in ambient temperature within the interval from −10 °C to 40 °C relative to the signal at 20 °C	±100 ppm

Sources:
Non equivalence of electrical and radiative heating
0.1 - 0.5 %:

- Thermal radiation
- Heat conduction (air)

→ temperature dependency!

Requirement: max 3 ppm/°C

Reality 10 to 30 ppm/°C

- Better receiver design
- Temperature corrections
- How to measure this?
- CSAR as a reference?

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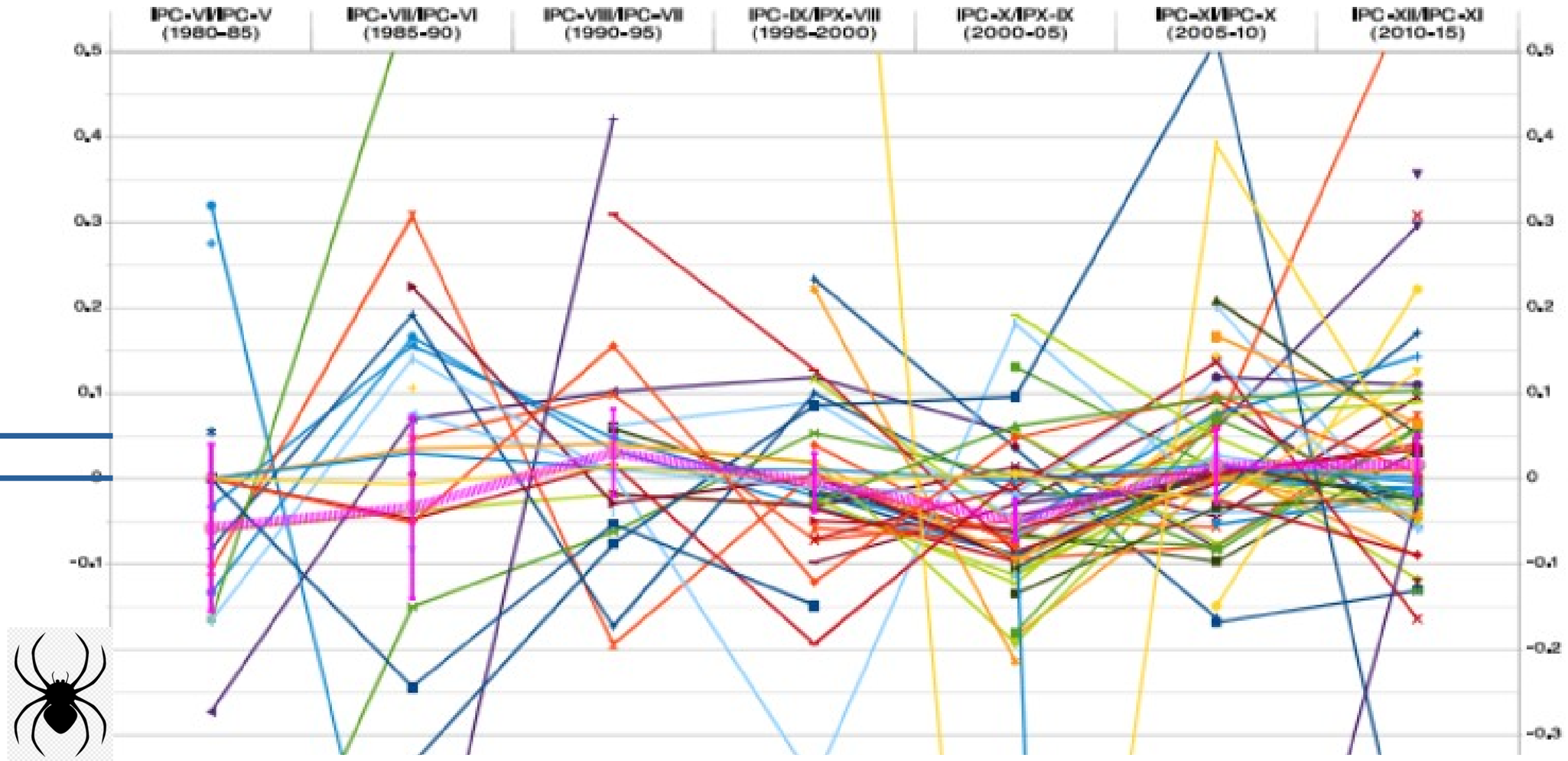
Non stability

Percentage change in responsivity per year

±100 ppm

500 ppm from IPC to IPC

User responsibility & protection



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Nonlinearity

Percentage deviation from the responsivity at 500 $W \cdot m^{-2}$ due to the change in irradiance within 100 $W \cdot m^{-2}$ to 1 000 $W \cdot m^{-2}$	±100 ppm

- Down to 100 $W \cdot m^{-2}$!
- How to measure?
- Correlation with temperature, tilt, or diffraction effects?
- Reference Irradiance / CSAR?

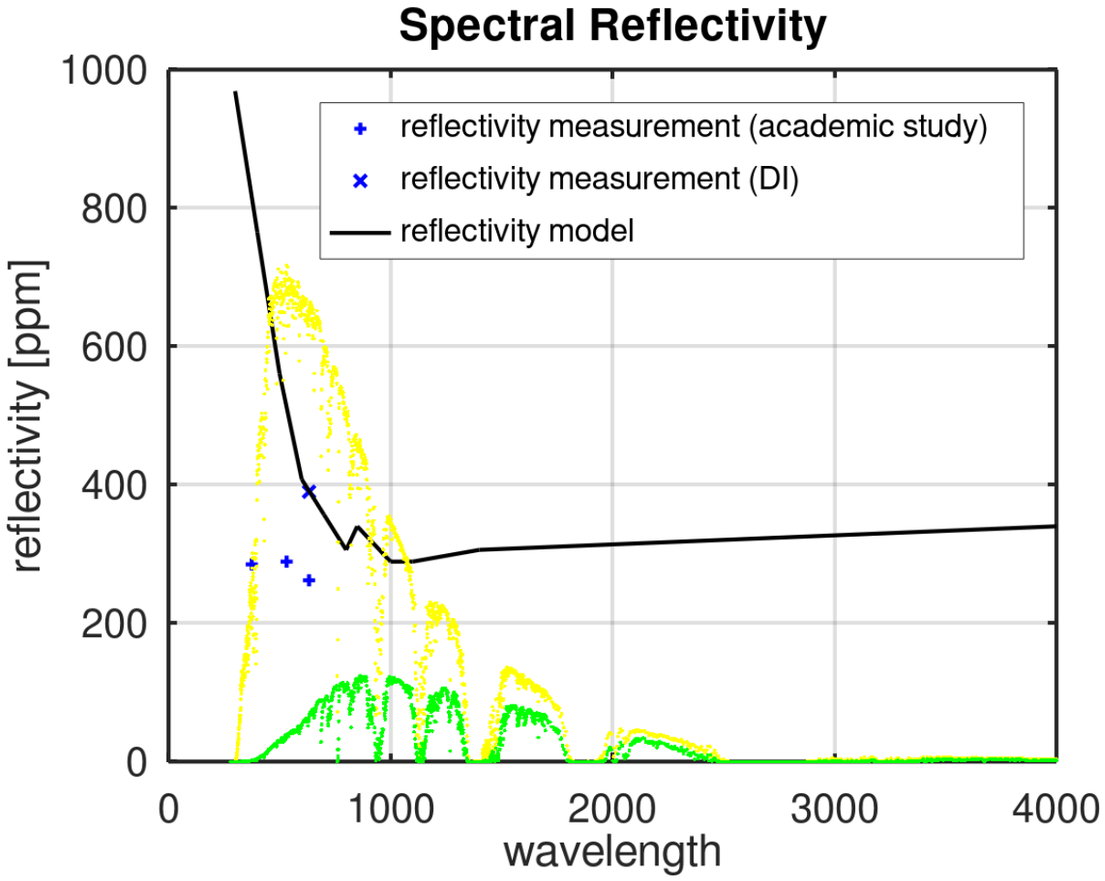
ISO 9059 (Pyrheliometer calibration):
Irradiance for calibrations -> 700 – 1000 $W \cdot m^{-2}$

Spectral error I

Maximum spectral error observed for a set of direct normal irradiance clear sky spectra defined in this document.	±100 ppm

Sources:
- Optical properties of the receiver
- Diffraction of aperture assembly

Optical properties:
< 100 ppm, for CNT example



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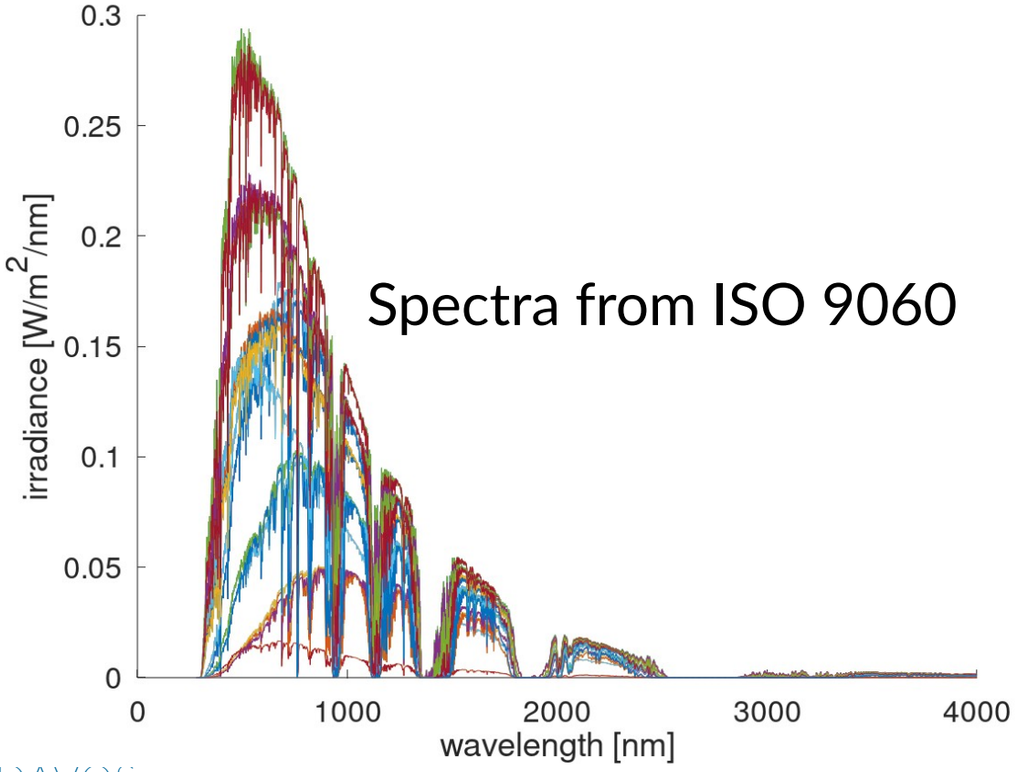
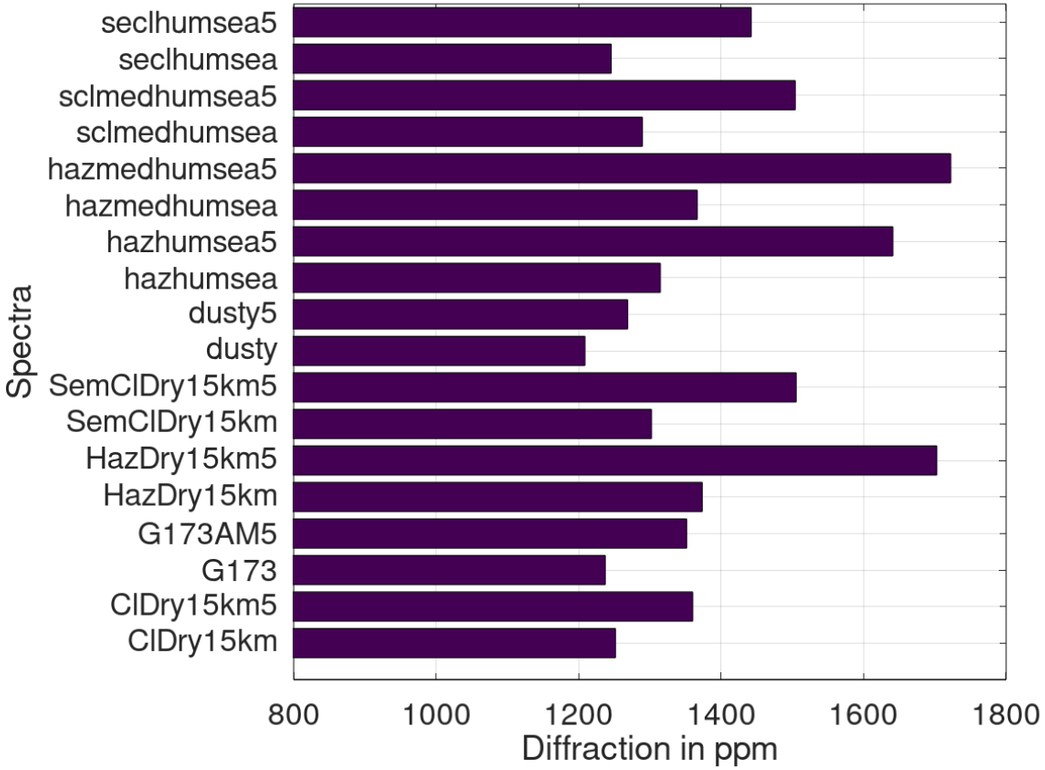
Spectral error II (Diffraction)

- Diffraction at the aperture
- Diffraction is wavelength dependent

Corrections, based on individual spectra
500 ppm !





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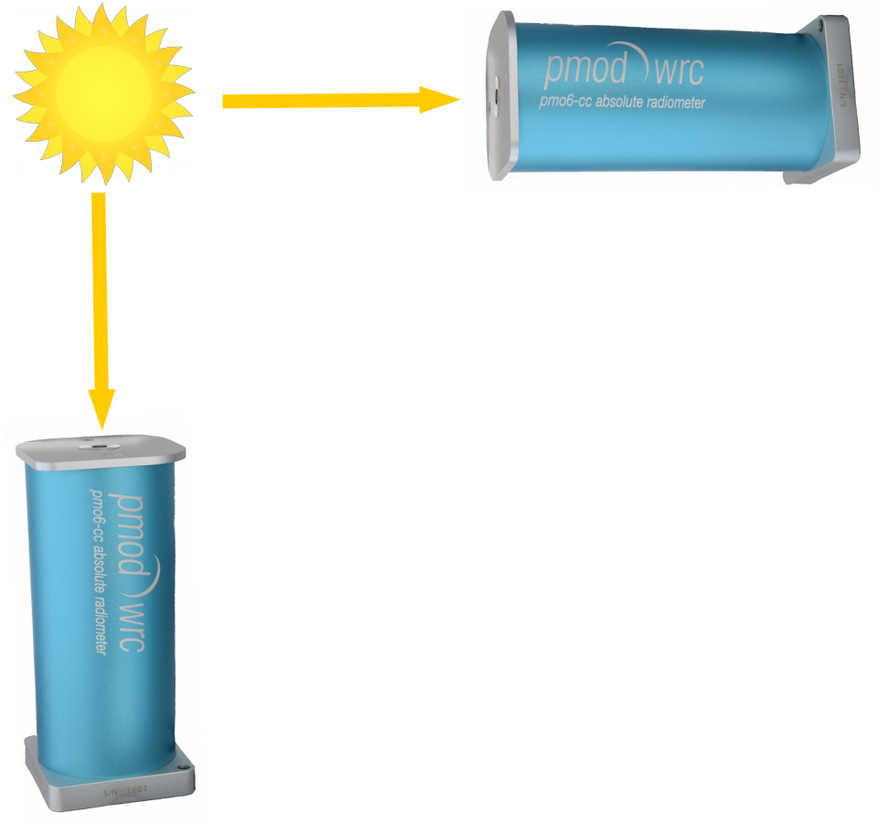
Tilt response

Percentage deviation from the responsivity at 0° tilt (horizontal) due to change in tilt from 0° to 90° at 1000 W·m^{-2} irradiance	±100 ppm (0.1 W·m^{-2})



- Non Equivalence of electrical and radiative heating
- Temperature differences between instrument temperature and ambient temperature.

-> Different air flow within the instrument

Dedicated Lab experiment, artificial source

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Additional signal processing errors

The additional signal processing errors contain data acquisition and analogue to digital conversion that might be carried out in the instrument and all other processing steps carried out within the instrument that are not covered by the criteria.	±0,1 $W \cdot m^{-2}$

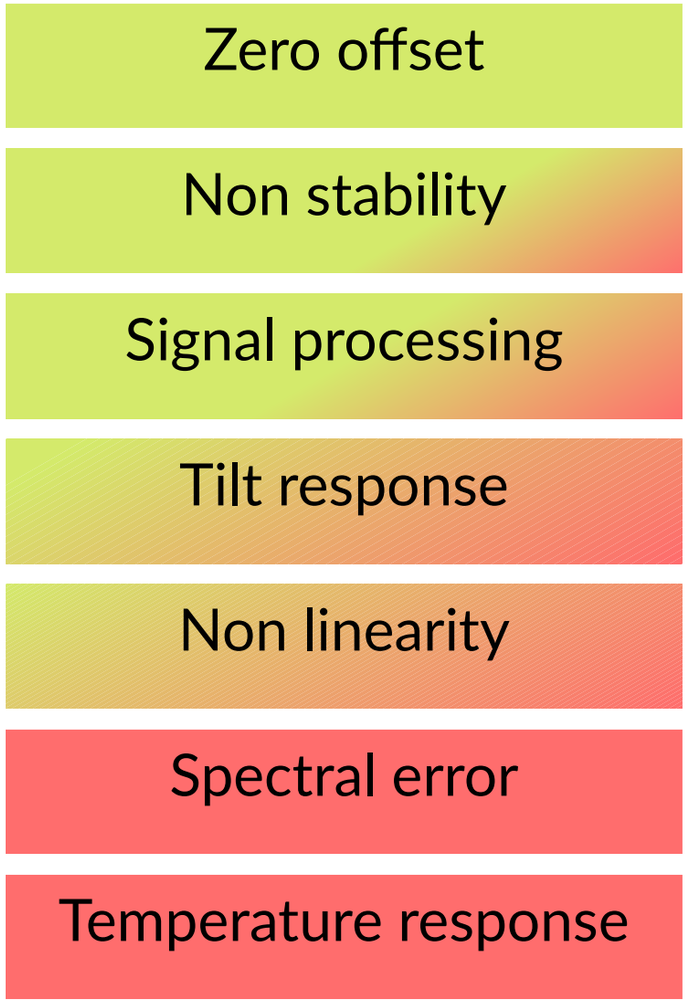
Sources:
Data acquisition

Careful electrical calibration

Correlation with non-linearity criteria

Conclusions

It’s not completely impossible, but it’s very challenging!



- A long way to go
- Dedicated experiments necessary
- Cryogenic reference (CSAR) desirable
- Very carefull operation necessary

Open Questions:

- What is the application of the AA-class?
- Should there be a class in between A and AA?

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Thank you for your attention

Discussion