Standards, Specifications and Characteristics of Global Irradiance Sensors

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Introduction

- User perspective
- PV system performance

- Want to achieve greater accuracy and quantified uncertainty in conclusions about PV system performance

- Need to better understand the accuracy/uncertainty of irradiance measurements and data sets

- Need to better understand instrument characteristics

Some years ago…

1981 - IEA Conference on Pyranometer Measurements

Goal 2: Determine ways to improve the measurement accuracies of pyranometers currently available by developing a more complete understanding of the instruments' performance characteristics.

1996 - IEA Solar Heating and Cooling Programme Task 9

Improved Measurements of Solar Irradiance by Means of Detailed Pyranometer Characterisation

Information Sources

- Manufacturer specifications
  - classification standards
  - testing standards

Characteristics

- Response time
- Zero offsets/thermal offsets
- Non-stability (long-term)
- Non-linearity
- Directional response
- Spectral selectivity
- Temperature response
- Tilt response

Non-Linearity

- Pyranometer: (WMO/ISO)
  - deviation from responsivity at 500 W/m²
  - irradiance range 100-1000 W/m²
  - 10/10 specified a maximum deviation
  - 1/4 manufacturer specified a broader irradiance range

- Photodiode:
  - 4/5 specified a maximum deviation
  - no indication how deviation was calculated
  - all chose different irradiance ranges

Non-Linearity

- Reference cell: (IEC 60904-10)
  - maximum deviation from a linear fit on output vs. G
  - irradiance range not specified ("range of interest")
  - 1/7 specified a maximum deviation
  - no indication how deviation was calculated or over what range

Non-Linearity Correction ?

- Many sensors for other phenomena are non-linear, and linearity corrections are common

- Need a reliable linearity curve for the instrument or instrument type

Temperature Response

- Pyranometers (WMO/ISO)
  - maximum deviation over (floating) 50C range
  - 1-3% over 50C range
  - 1/10 products provided with graph, 1/10 with numerical data
  - 1/4 manufacturer chooses a wider temperature range

- Photodiode pyranometers
  - 5/5 provide % deviation per C
  - makes 2-10% over 50C range

Temperature Response

- Reference cells
  - 6/7 provide % or mV deviation per C
  - applicable over full operating range
  - makes 1-4% over 50C range

Temperature Response Correction ?

- Need instrument temperature
  - 2/10 pyranometers have built-in sensors
  - many (most?) reference cells have built-in sensors

- Need reliable temperature response curve or slope coefficient
  - 1/10 pyranometers provided with correction instructions
  - temperature correction for reference cells is common

Directional Response

- Thermopiles: (WMO/ISO)
  - maximum deviation in W/m^2 in any direction when normal irradiance is 1000 W/m^2
  - 10/10 datasheets provide maximum errors
  - 1/4 manufacturers specifies angle limit
  - measurements at different instrument rotations are needed as well to assess non-symmetry

Directional Response

- Photodiodes:
  - 1/5 datasheets provides maximum error in W/m^2
  - 4/5 datasheets provide maximum error in %
  - all datasheets specify angle limits
  - several datasheets provide graphs

- Reference cells:
  - 1/7 datasheets mentions angle limit
  - 0/7 datasheets provide maximum error

Directional Response Correction ?

- Need sun position and diffuse fraction

- Need reliable directional response curve

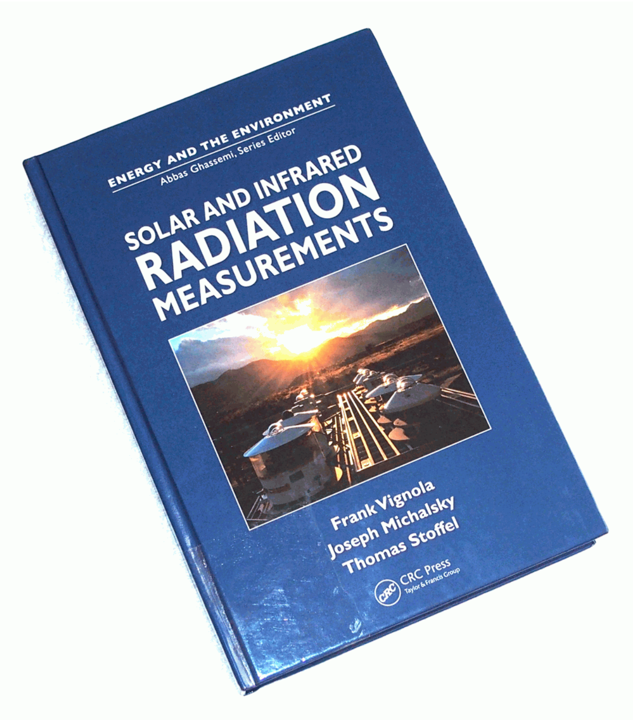
More Corrections ?

- Pyranometer thermal offsets
  - correction based on IR measurements

- Photodiode or reference cell spectral response
  - correction using models based on air mass

Information Sources

- Manufacturer specifications
  - Classification standards
  - Testing standards
- Books
- Independent studies



Photon 2010

Solarstrahlungssensoren: Tageseinstrahlungssummen

Hersteller	Typenbezeichnung	Bauart	Abweichung zur Referenzmessung in %
Apogee Instruments Inc.	SP-215	Pyranometer mit Photodiode	15,15
EKO Instruments Co. Ltd.	MS-602	Thermosäulenpyranometer	4,26
Hukseflux Thermal Sensors BV	LP02	Thermosäulenpyranometer	2,88
IKS Photovoltaik GmbH	Iset Sensor (amorph)	Solarzelle (amorphes Silizium)	-1,08
	Iset Sensor (monokristallin)	Solarzelle (monokristallin)	-4,89
	Iset Sensor (polykristallin)	Solarzelle (polykristallin)	-3,19
Kipp & Zonen BV	CMP3	Thermosäulenpyranometer	-0,28
	SP Lite2	Pyranometer mit Photodiode	8,60
LI-COR Biosciences	LI-200SA	Pyranometer mit Photodiode	7,86
Mencke & Tegtmeyer GmbH	Si-02-Pt100-K	Solarzelle (monokristallin)	-3,75
	Si-10TC-K	Solarzelle (monokristallin)	-6,66
	Si-420TC-T-K	Solarzelle (monokristallin)	-4,26
NES Mess- und Meldesysteme, Lothar Viel	SOZ-03	Solarzelle (monokristallin)	-3,54
	SOZ-03 mit Verstärker	Solarzelle (monokristallin)	-2,61
Reinhardt System- und Messelectronic GmbH	Globalstrahlungssensor	Thermosäulenpyranometer	4,60
Skye Instruments Ltd.	SKS 1110	Pyranometer mit Photodiode	7,27
Soluzione Solare	Sunmeter	Solarzelle (monokristallin)	-7,56
Technische Alternative GmbH	GBS01	Photodiode (monokristallin)	-10,55
Tritec International AG	Spektron 200*	Solarzelle (monokristallin)	-8,38
	Spektron 210	Solarzelle (monokristallin)	-5,47
	Spektron 300*	Solarzelle (monokristallin)	-14,05
	Spektron 310	Solarzelle (monokristallin)	-1,16

-15 -10 -5 0 5 10 15 20

* wird nicht mehr hergestellt,
Referenzwert gemessen mit »Secondary Standard«-Pyranometer (Kipp & Zonen CM 21)

Messungen von November 2009 bis September 2010

Schultz et al 2010

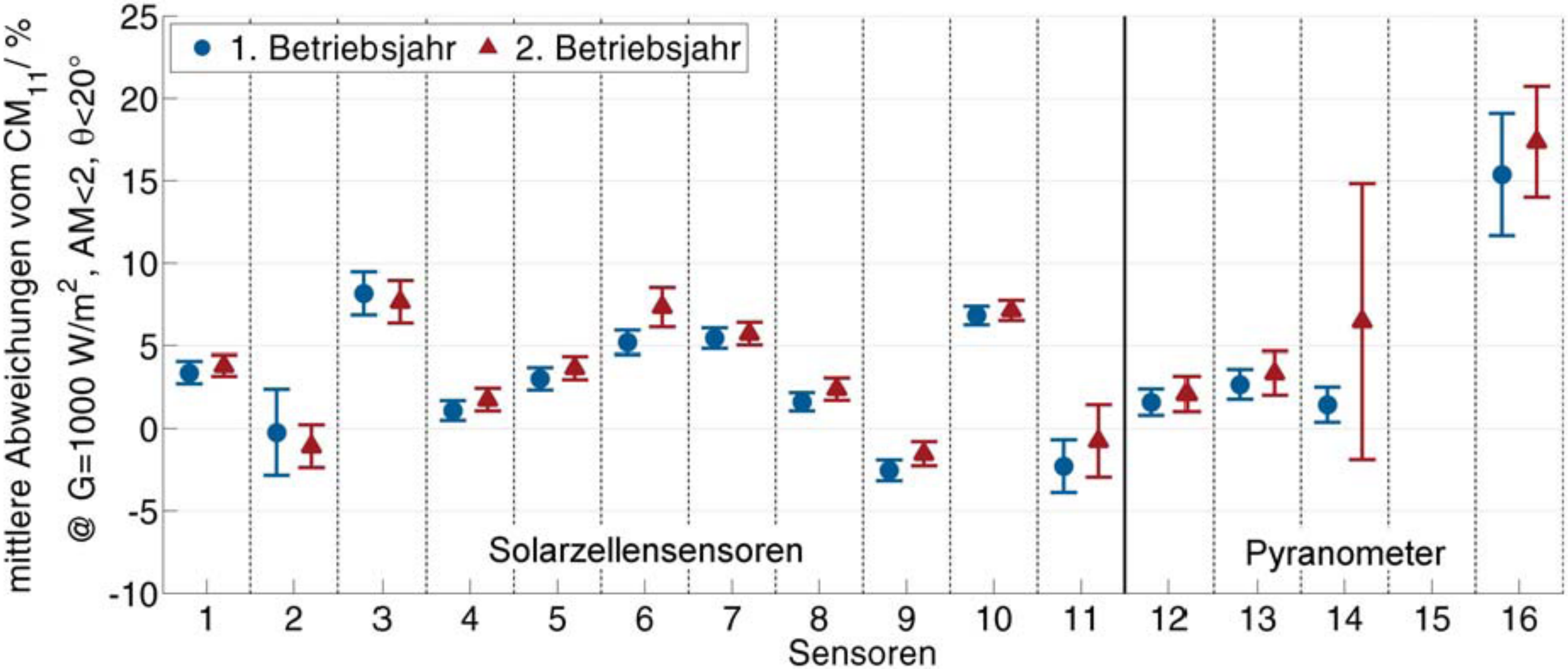


Abbildung 1: mittlere Abweichungen vom Thermosäulen-Pyranometer.

Schultz et al 2010

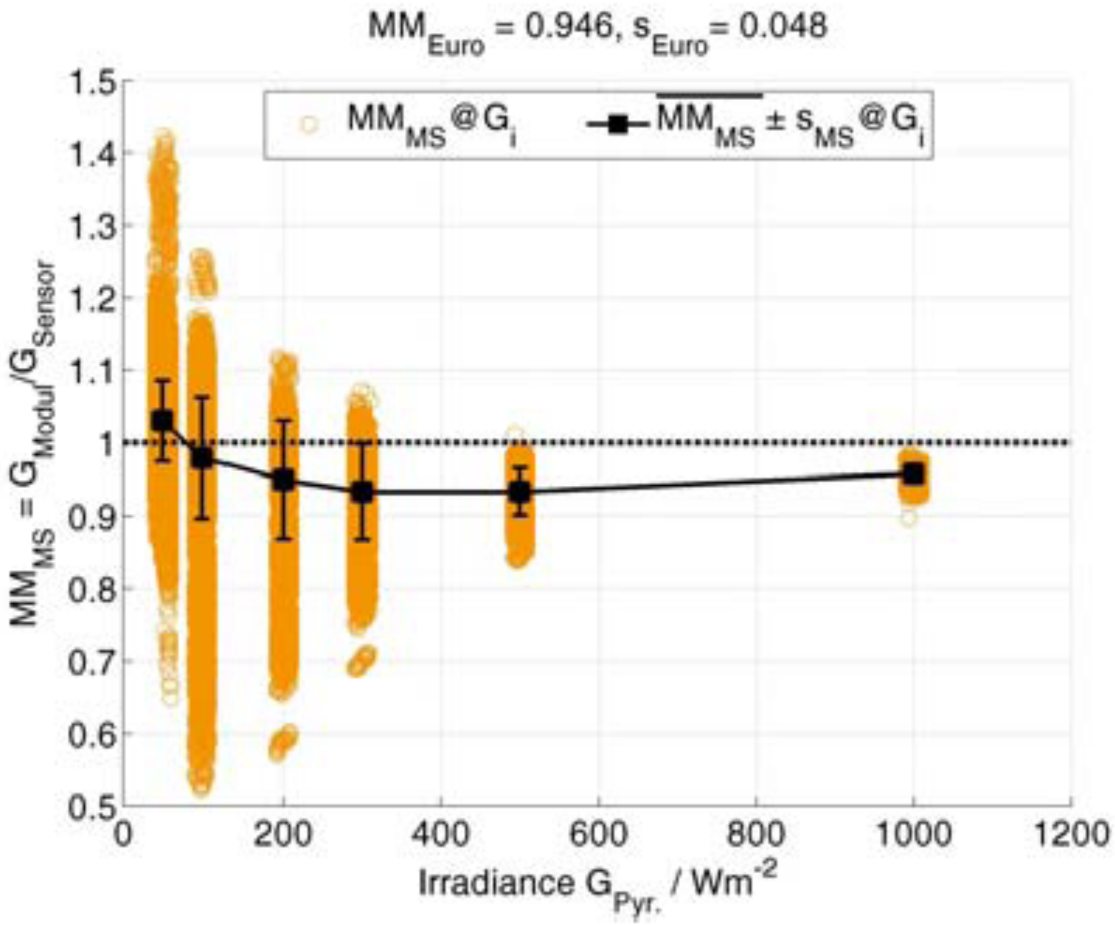


Figure 5: Mismatch between a monocrystalline PV module and a thermopile pyranometer (sensor 15)

EU PV Performance Project 2007

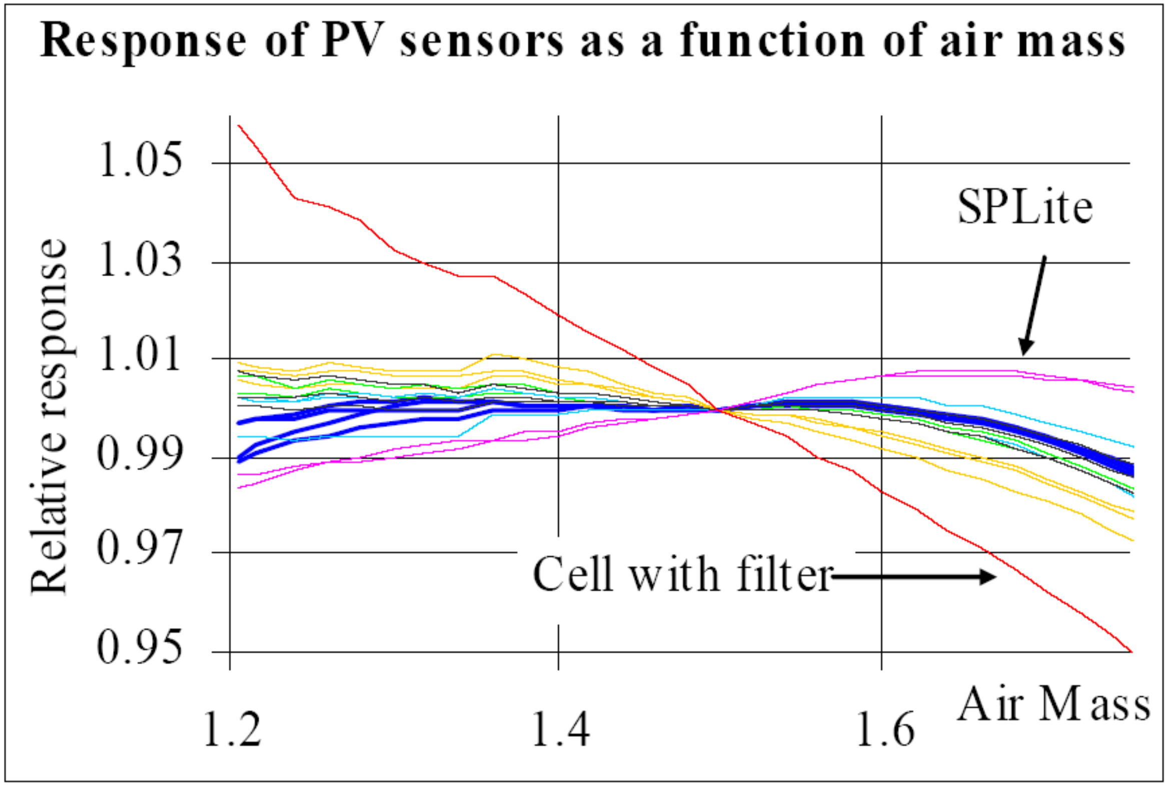


Figure 5: Relative response of reference cells as a function of air mass.

Wilcox and Meyers 2008

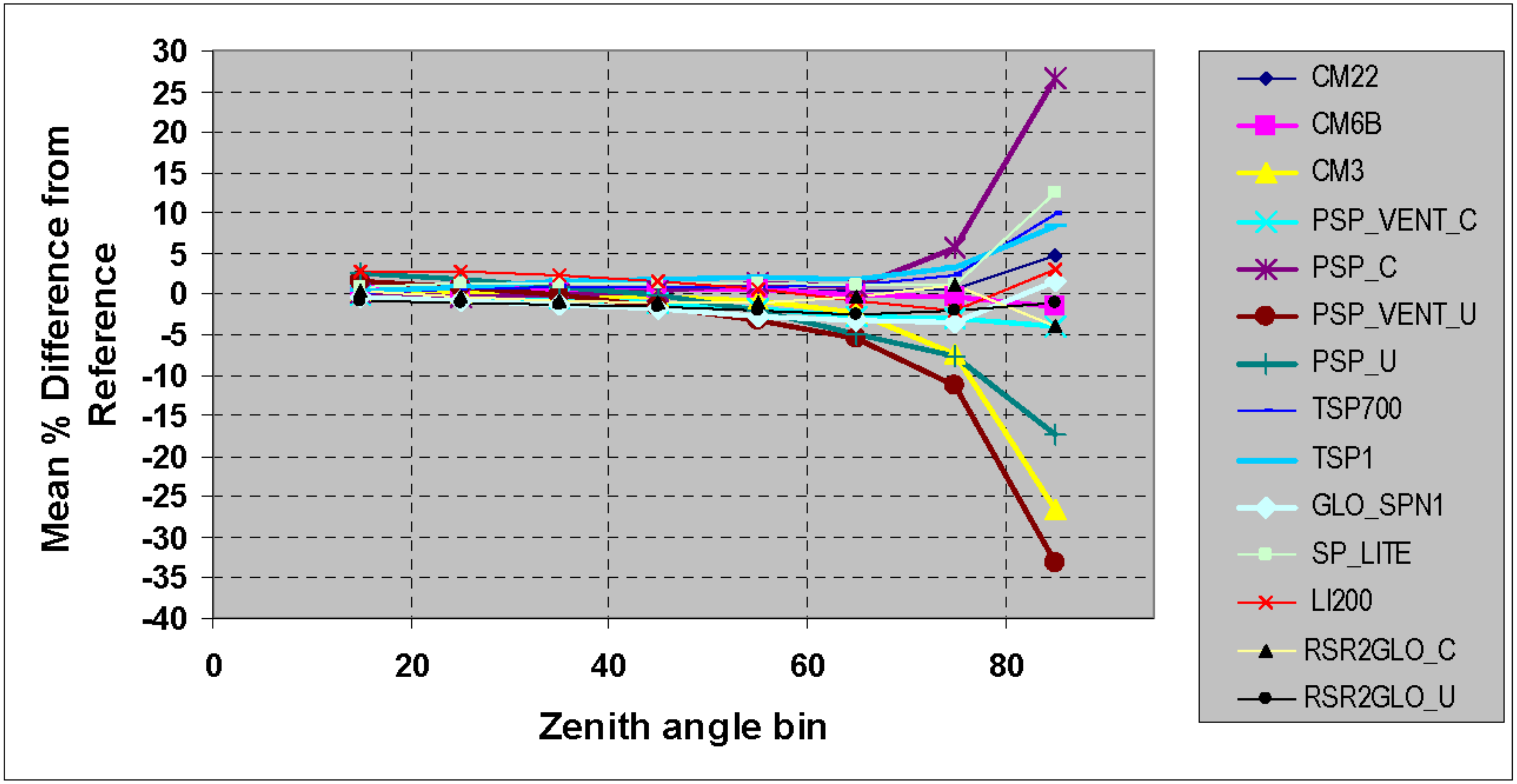


Figure 3-1. Mean percent differences from reference global irradiance for pyranometers as function of zenith angle. See Appendix A, Table A-1 for instrument list.

IEA Conf. Pyranometer Measurements 1981

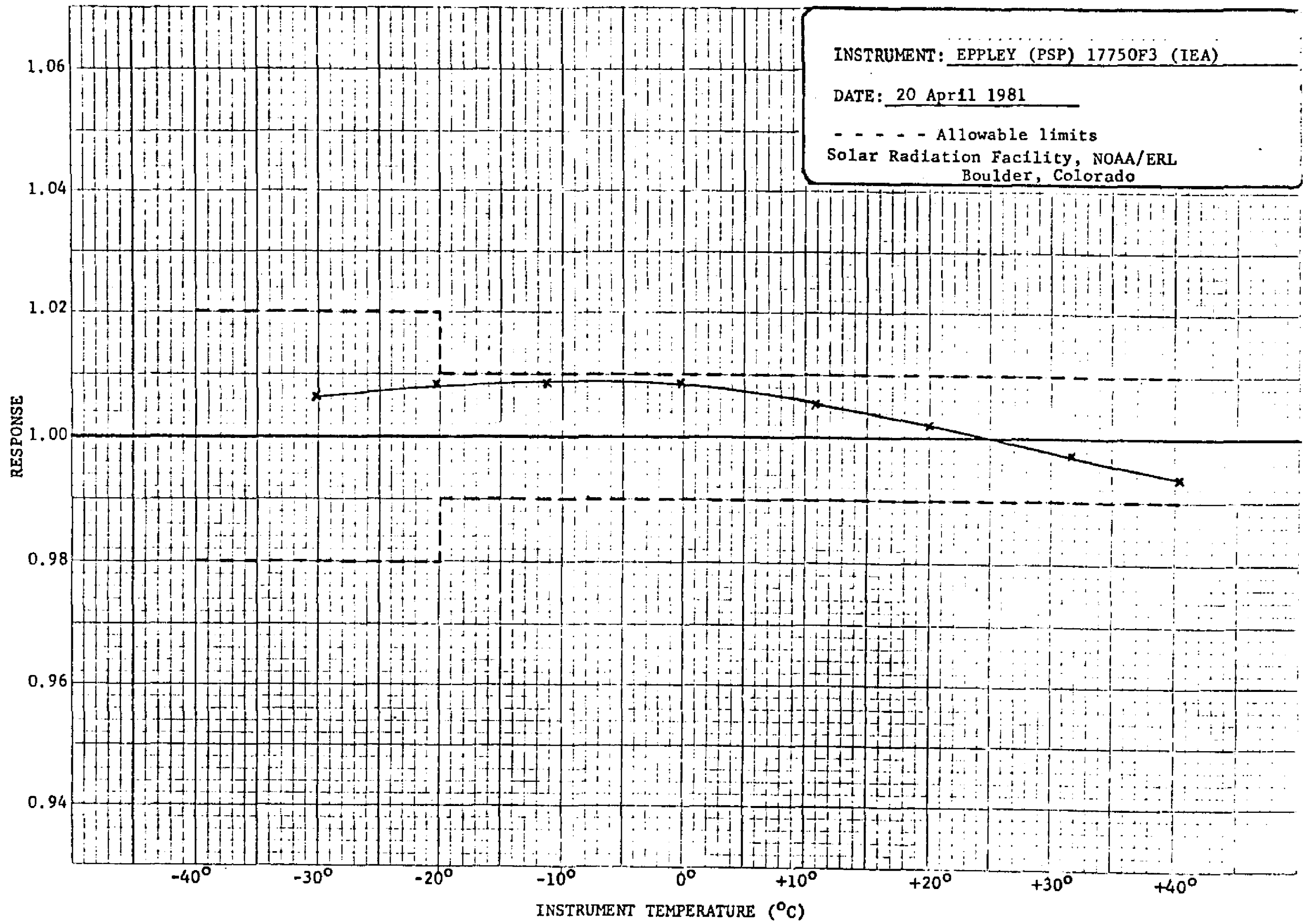
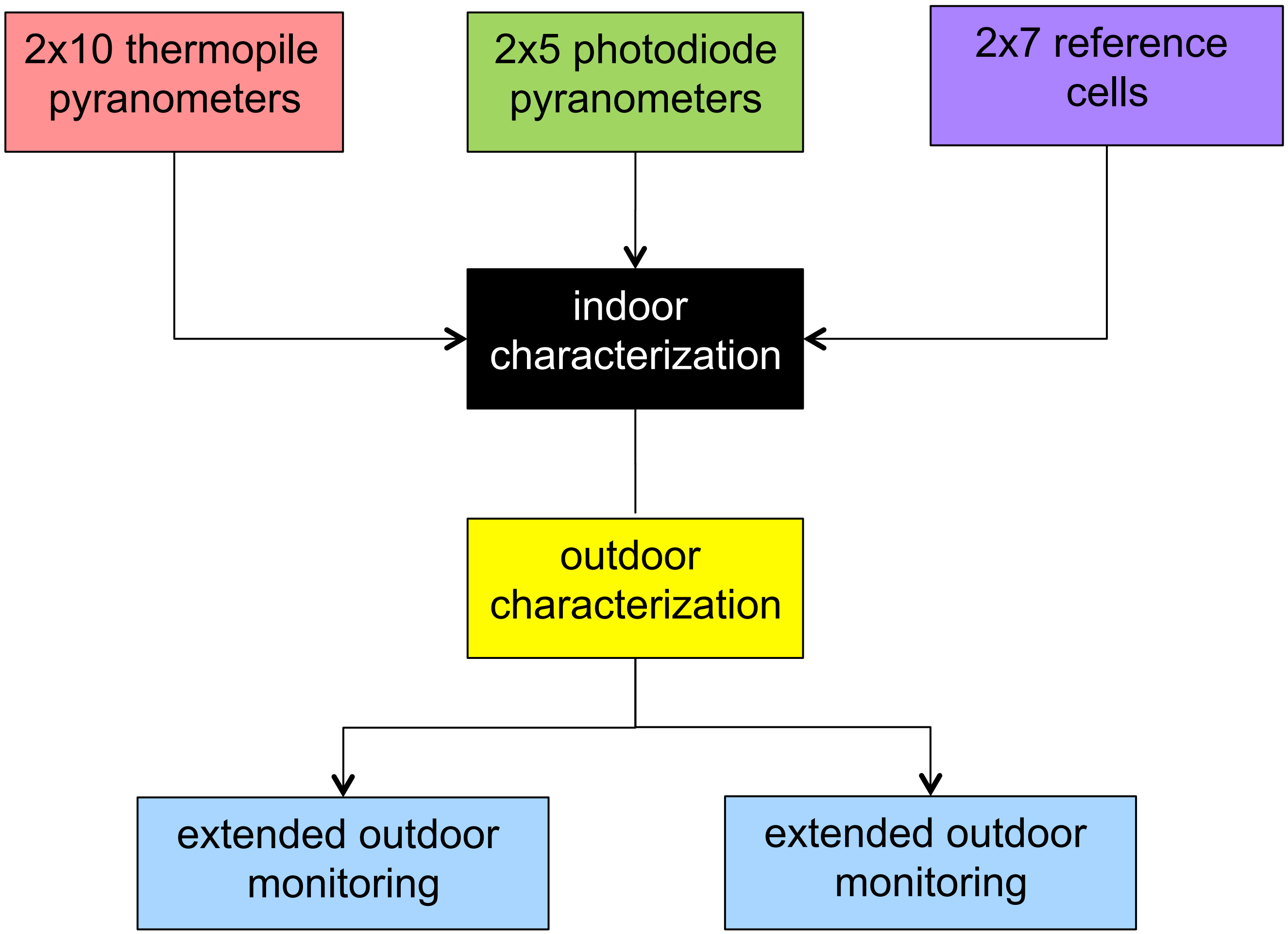


Figure 22: Temperature chamber test data for Eppley PSP 17750F3.

PVSENSOR 2014+



Expected Outcomes

- Detailed curves describing each instrument's response to the most important external influences
- Ability to apply corrections to and/or calculate uncertainties for individual irradiance measurements
- Ability to assess the suitability of instruments for different purposes
- Insights and recommendations for instrument test methods

Opportunities for Further Exploration

- Variability with instruments of the same type
- Additional characteristics: long-term stability, …
- Survey PV industry to find out what products have been and are currently being installed
- Identify potential instrument improvements to better meet the needs of the PV industry

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