The World Infrared Standard Group

Status report

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Davos Dorf, Switzerland

graubünden Education and Research.

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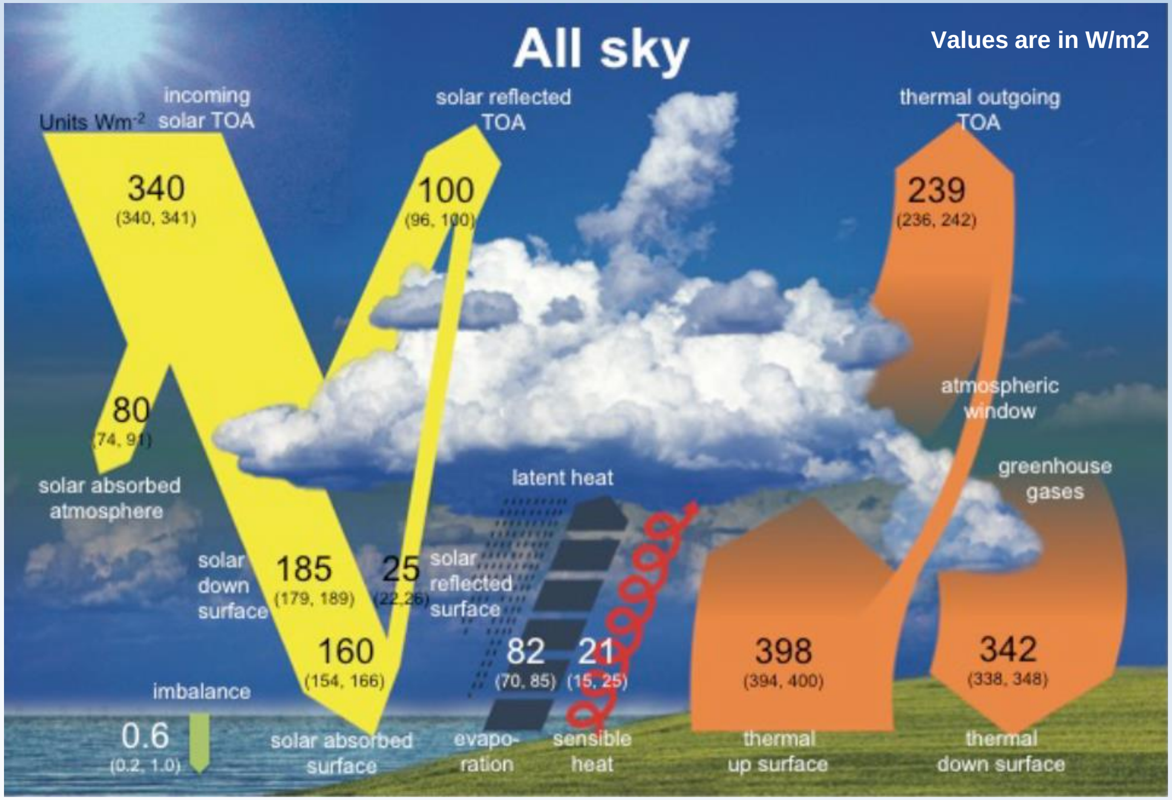
The Earth global radiation balance

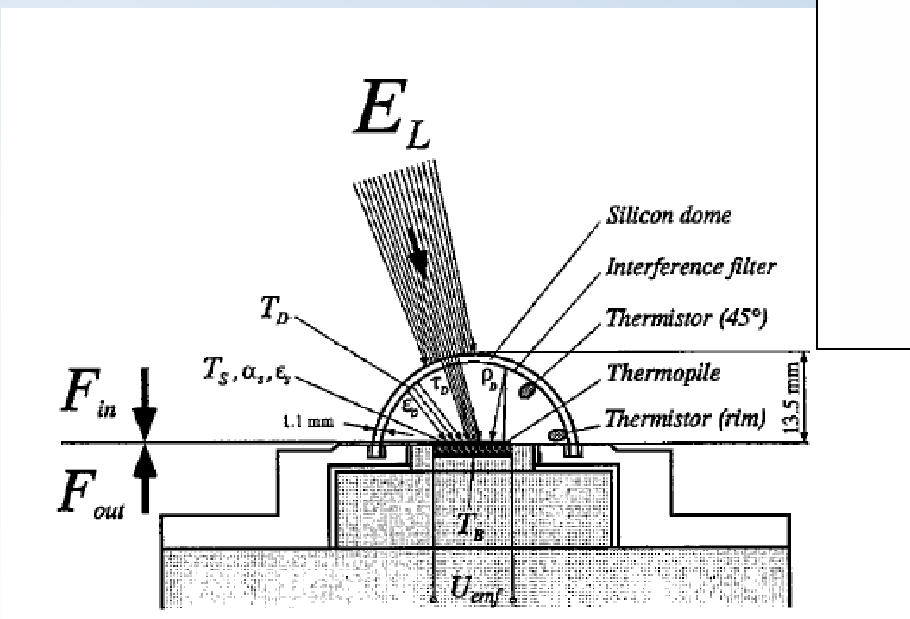
Why we need SI traceable radiation measurements



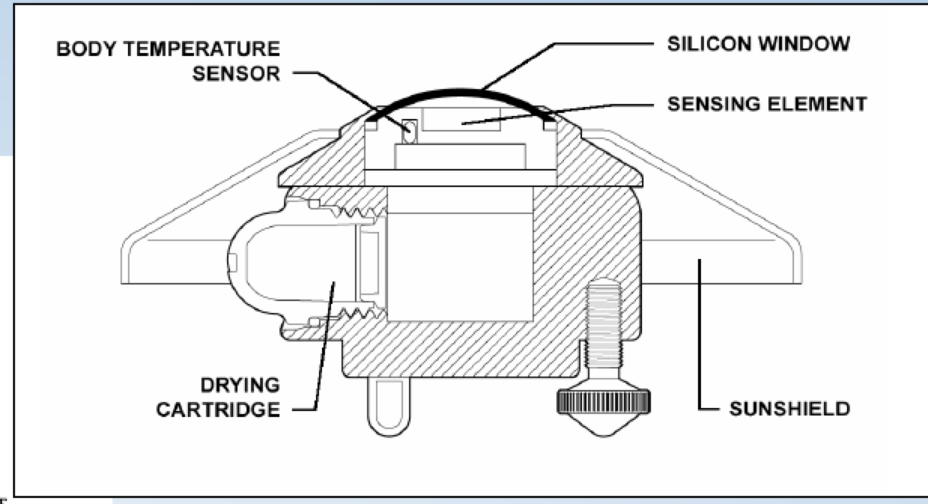
Wild et al., 2015

These global energy balance estimates are part of the newest IPCC AR6 report, published in August 2021.

Pyrgeometer energy balance



Eppley PIR



Kipp&Zonen CG4

Typical values for clear nights:

Net outgoing radiation ~ 100 Wm^{-2}

PIR Dome (ΔT=1K) ~18 Wm^{-2}

Pyrgeometer equations

Several choices for the radiometric model of a pyrgeometer:

Simple Albrecht formula

$$E = \frac{U}{C} + \sigma T_{BODY}^4 - K\sigma (T_{DOME}^4 - T_{BODY}^4)$$

Extended Albrecht (PMOD)

$$E = \frac{U}{C}(1 + k_1 \sigma T_{BODY}^3) + k_2 \sigma T_{BODY}^4 - k_3 \sigma (T_{DOME}^4 - T_{BODY}^4)$$

NREL formula

$$E = K_0 + K_1 U + K_2 \sigma T_{RECEIVER}^4 - K_3 (T_{DOME}^4 - T_{RECEIVER}^4)$$

Fit parameters

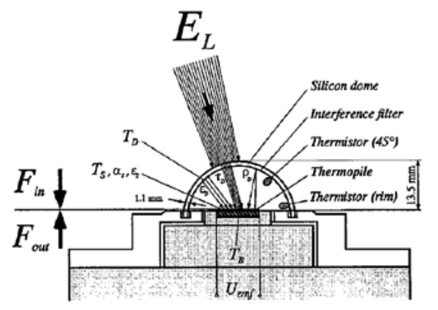


Figure A1: This is a partial copy of Fig 1 from Philipona et al (1995). Note that it does not show the reflection from the sensor surface.

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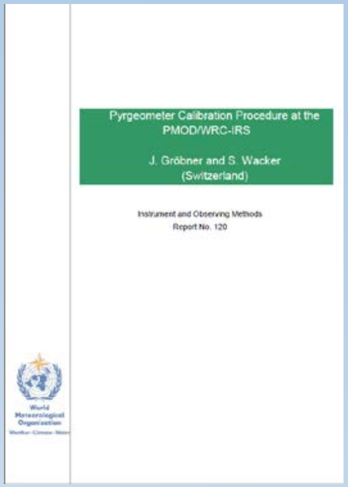
Pyrgeometer calibration procedure


Pyrgeometer Calibration Procedure at the PMOD/WRC-IRS

J. Gröbner and S. Wacker (Switzerland)

Instrument and Observing Methods Report No. 120

Described in IOM 120 (Gröbner and Wacker, 2015)

$$E = \frac{U}{C}\left(1 + k_1 \sigma T_B^3\right) + k_2 \sigma T_B^4 - k_3 \sigma \left(T_D^4 - T_B^4\right)$$

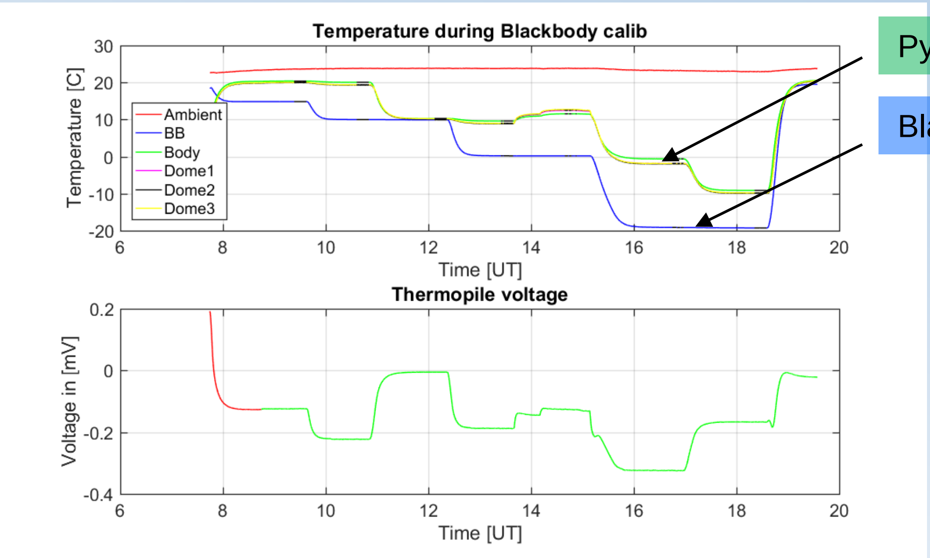
1) Determination of k_1, k_2, k_3 in Blackbody (instrument constants)
2) Outdoor measurements relative to WISG to retrieve responsivity C

$$C = \frac{U(1 + k_1 \sigma T_B^3)}{k_2 \sigma T_B^4 - k_3 \sigma (T_D^4 - T_B^4) - E_{WISG}}$$

Calibration criteria

1. Outliers are removed (U>0.001 V, U<-20 mV, $|T_D|>40$ °C, $|T_B|>40$ °C)
2. Any night containing rain is excluded (limit of 0.2 mm/10 min)
3. Stable atmospheric conditions, defined by the standard deviation of the WISG <2 Wm^{-2}
4. Net radiation measured by the WISG < -70 Wm^{-2}
5. Measurements from one night are used if there are at least 80% valid measurement points
6. Night is defined when the solar zenith angle is larger than 95°
7. Relative standard deviation of the test pyrgeometer signal <3%
8. Integrated water vapour (IWV) greater than 10 mm

Characterisation in the blackbody to retrieve instrument constants k_1, k_2, and k_3



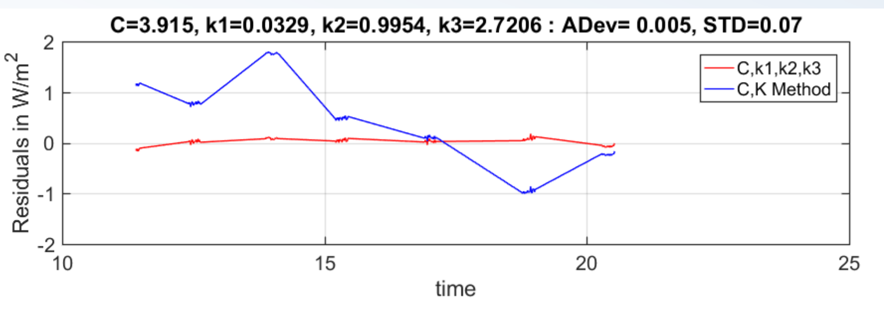
Pyrgeometer temperature range: +20ºC to -10ºC

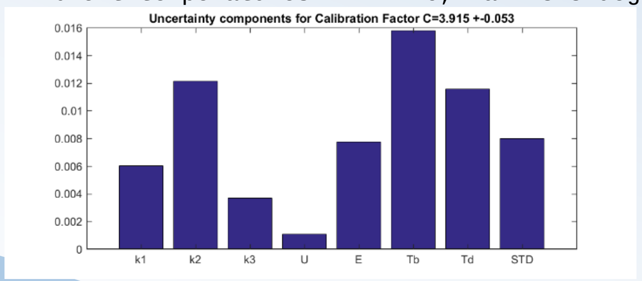
Black Body temperature range:+15ºC to -20ºC

```
bbcalib('31464f3_18122016.dat');
Albrecht Formula:
C=3.651 or using SVD C=3.6510+-0.0067
K(k3)=2.819 or using SVD K=2.819+-0.0381
-------------------------------------------------
Uncertainty of C for k1 (+-0.012000): 0.006000
Uncertainty of C for k2 (+-0.000400): 0.012126
Uncertainty of C for k3 (+-0.015000): 0.003694
Uncertainty of C for U (+-0.000000): 0.001059
Uncertainty of C for E (+-0.090000): 0.007747
Uncertainty of C for Tb (+-0.010000): 0.015791
Uncertainty of C for Td (+-0.010000): 0.011548
Total uncertainty: 0.0253
-------------------------------------------------
SVD: C=3.9154+-0.0494
SVD: k1=0.03291+-0.01338
SVD: k2=0.99544+-0.00038
SVD: k3=2.72064+-0.01000
Expanded Uncertainty (k==2) of C (microV) :0.0531

Blackbody temperatures min=-19.3, max=14.9 degC
PIR Body temperatures min=-9.3, max=20.4 degC
Ambient temperatures min=22.9, max=23.8 degC
```

Results from the regression -> C_{BB}, k_1,k_2,k_3





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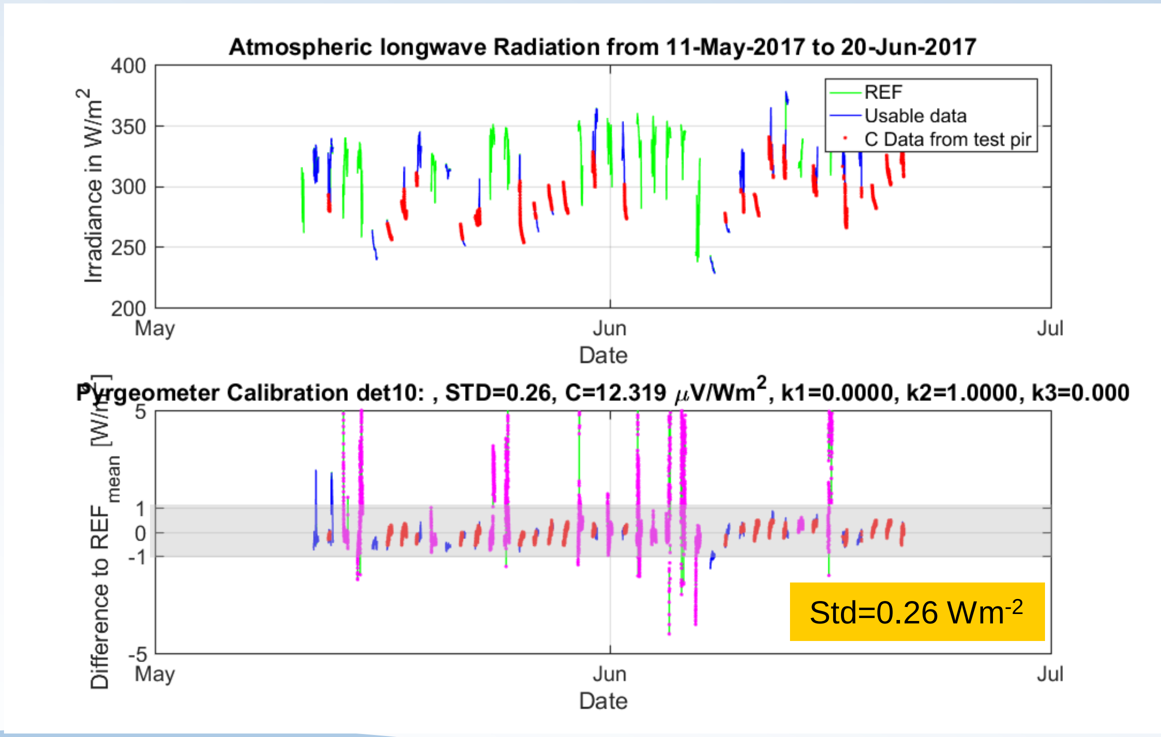
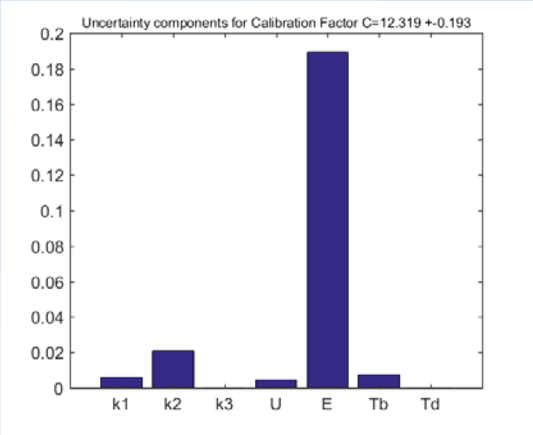
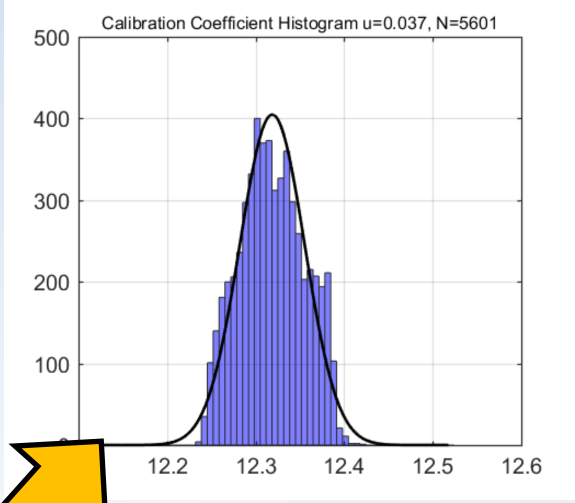
Outdoor calibration relative to the WISG to retrieve the responsivity C

$$C = \frac{U(1+k_1\sigma T_B^3)}{k_2\sigma T_B^4 - k_3\sigma(T_D^4 - T_B^4) - E_{WISG}}$$







C=12.319 ± 0.20 µVW^{-1}m^{2}

u=1.6%

Standard uncertainty relative to WISG 0.3%

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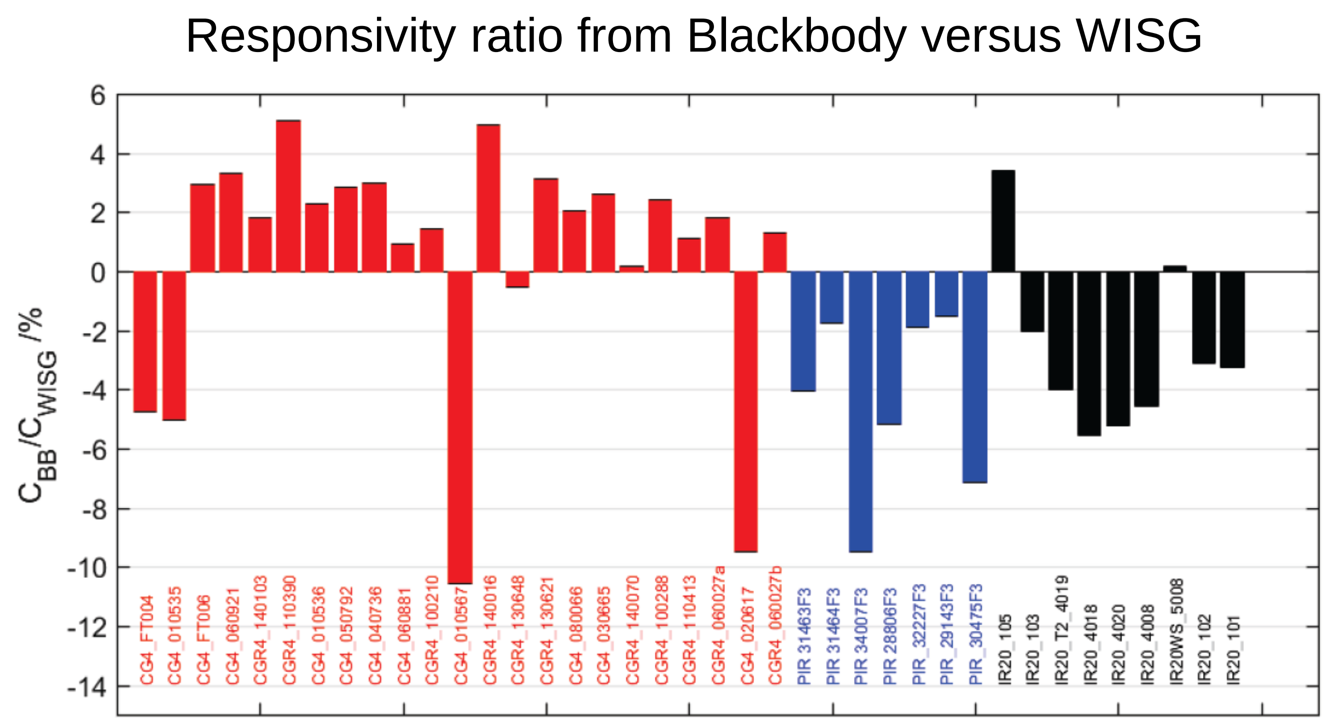
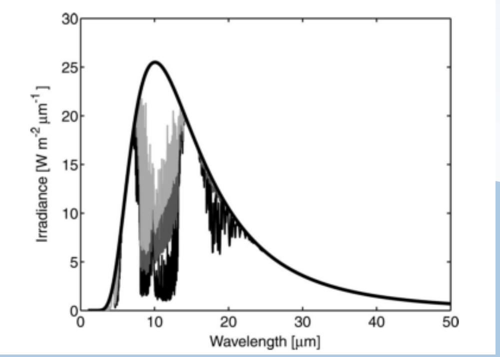
Pyrgeometers calibrated in the blackbody give inconsistent results when measuring atmospheric longwave irradiance



From: IPgC-II report, 2017



Differences between BB & WISG based calibrations are linked to the spectral inhomogeneities of the pyrgeometers (dome transmission & thermopile absorptivity).

Gröbner and Los, 2007

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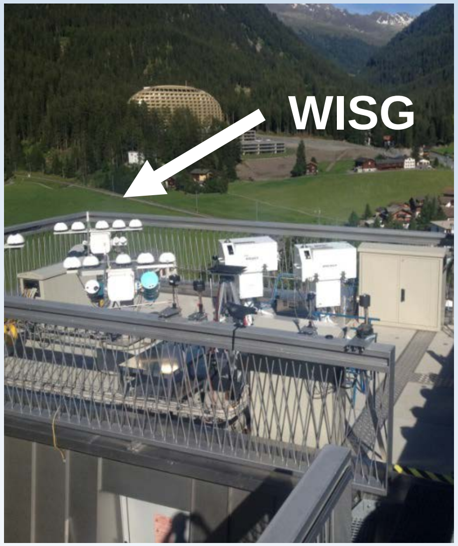
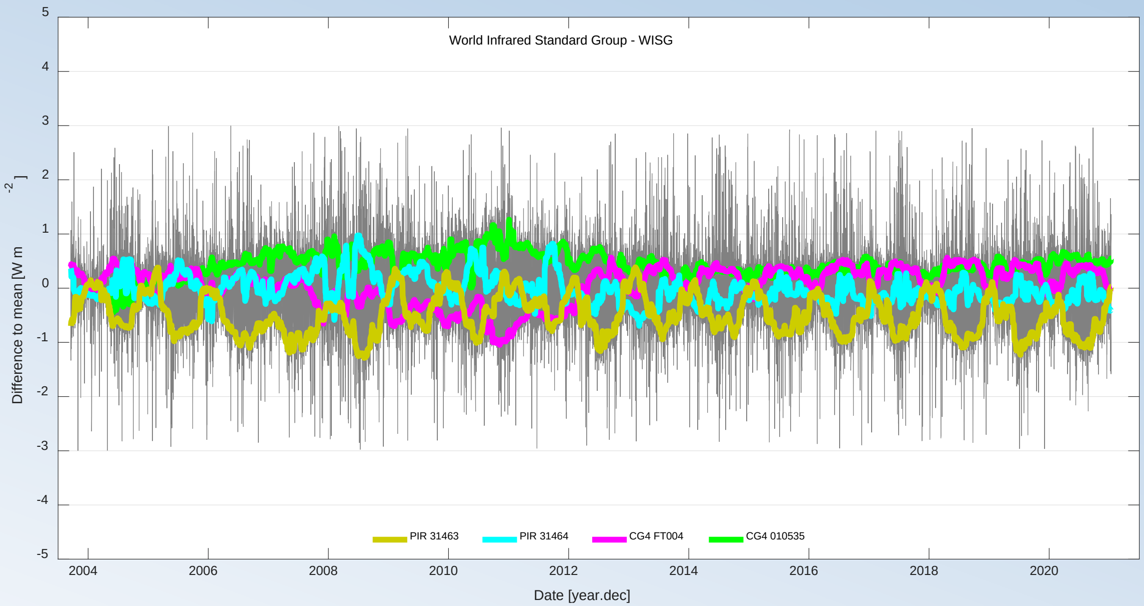
The World Infrared Standard Group (WISG)





±1 Wm^{-2}

Consists of 4 Pyrgeometers:

- 2 modified Eppley PIR, s/n 31463, 31464
- 2 Kipp & Zonen CG4, s/n FT004, 010535 (since 1 June 2004)

The WISG has been stable to ± 1 Wm^{-2} since 2004

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Traceability of atmospheric longwave irradiance to SI

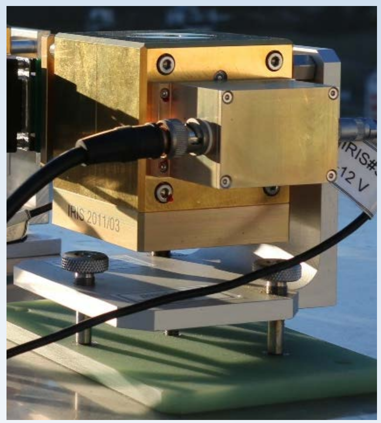
Wm^{-2} realisation (SI traceable) → Transfer standard Radiometer → WISG → Pyrgeometer calibration

BB2007

- Cylindrical cavity
- effective emissivity 0.99993(33)

Gröbner, AO 2008

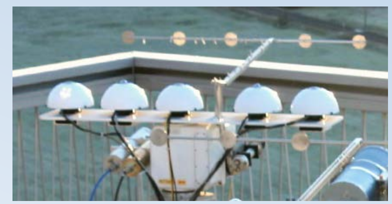
IRIS



- Windowless
- Flat Spectral Response
- Nighttime operation only

Gröbner, Metrologia, 2012

WISG



- PIR31463F3
- PIR31464F3
- CG4 FT004
- CG4 010535

Gröbner et al., JGR, 2014

Pyrgeometer calibration

WMO, IOM 120

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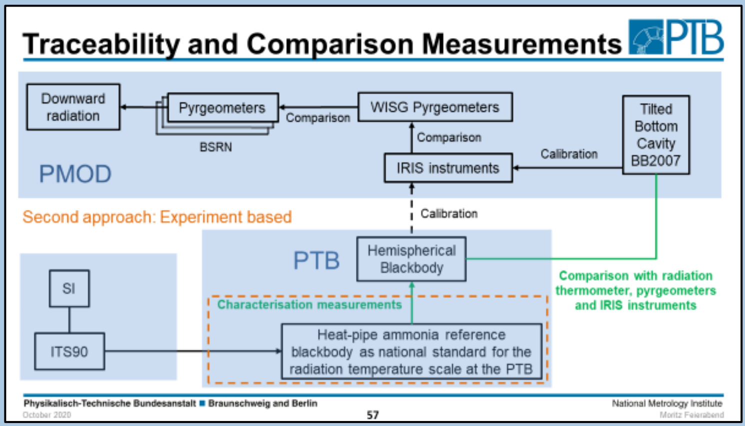
Traceability of atmospheric longwave irradiance to SI

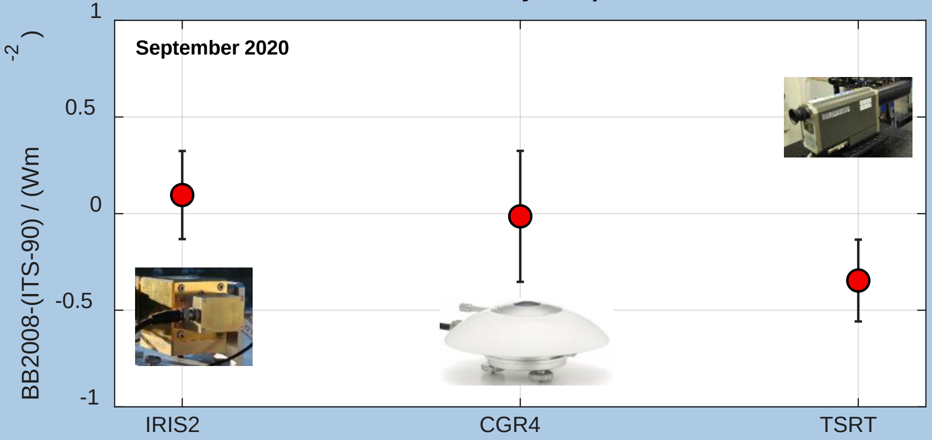
Comparison to the national temperature scale of PTB



September 2020

Radiation thermometer

PMOD/WRC - PTB blackbody comparison



EMPIR METEOC-3 (2017-2020)
EMPIR METEOC-4 (2020-2023)

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Work in collaboration with Moritz Feierabend and Christian Monte, PTB.

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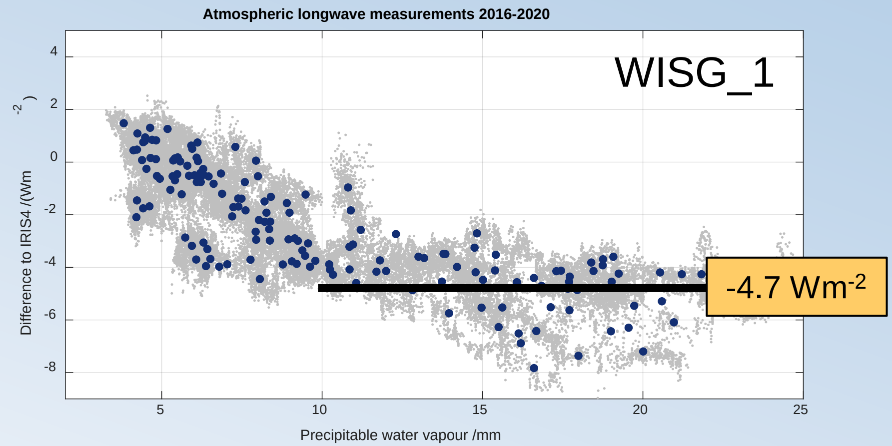
Comparison WISG to IRIS 2016-2020

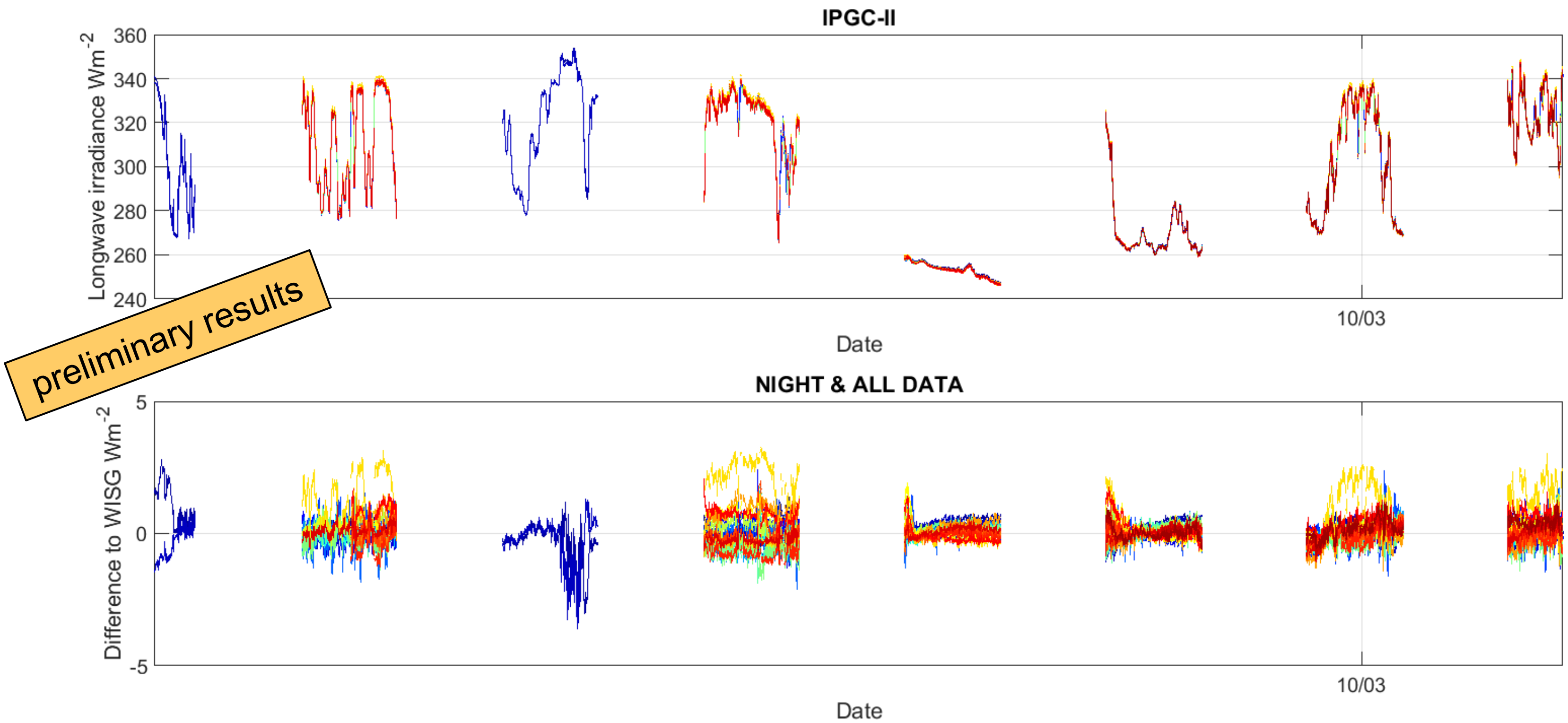
Difference WISG to IRIS 4 in Wm^{-2} for IWV>10 mm

Instrument	Mean	STD	U95	N
WISG1 PIR 31463F3	-4.5	1.3	[-7.4 -1.6]	16495
WISG2 PIR 31464F3	-4.8	1.2	[-7.6 -2.2]	16495
WISG3 CG4 FT004	-4.8	1.2	[-7.5 -1.9]	15375
WISG4 CG4 010535	-4.8	1.2	[-7.4 -1.9]	15375
WISG avg	-4.7			



Confirms results from Gröbner et al., 2014 with IRIS & ACP

IPgC-III



- 37 Pyrgeometer
- 4 IRIS
- 4 ACP

- 3 Eppley PIR
- 24 OTT CG4/CGR4
- 6 Hukseflux IR20/IRxx
- 2 EKO MS-20/MS-21
- 2 EMPIR

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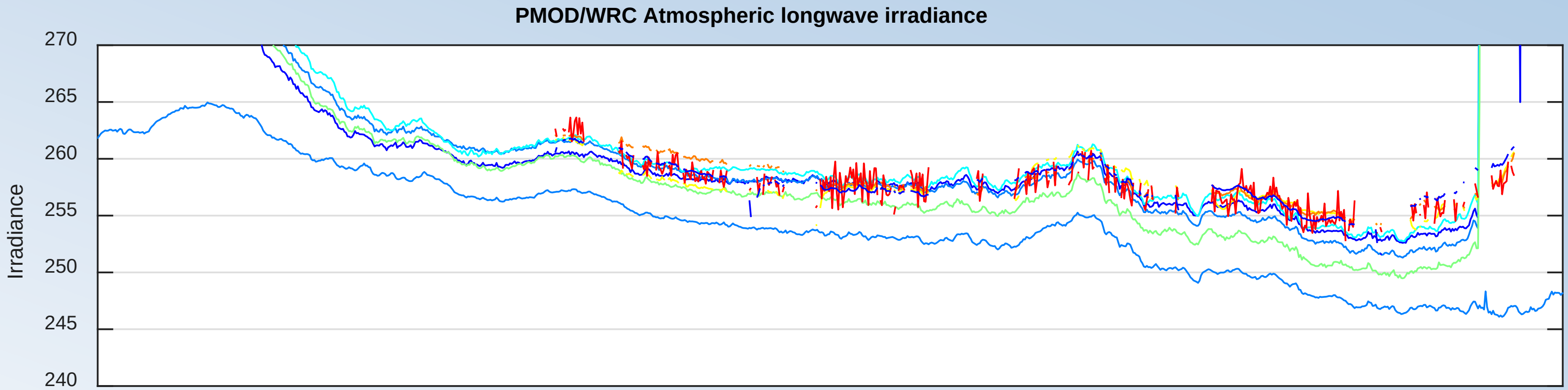
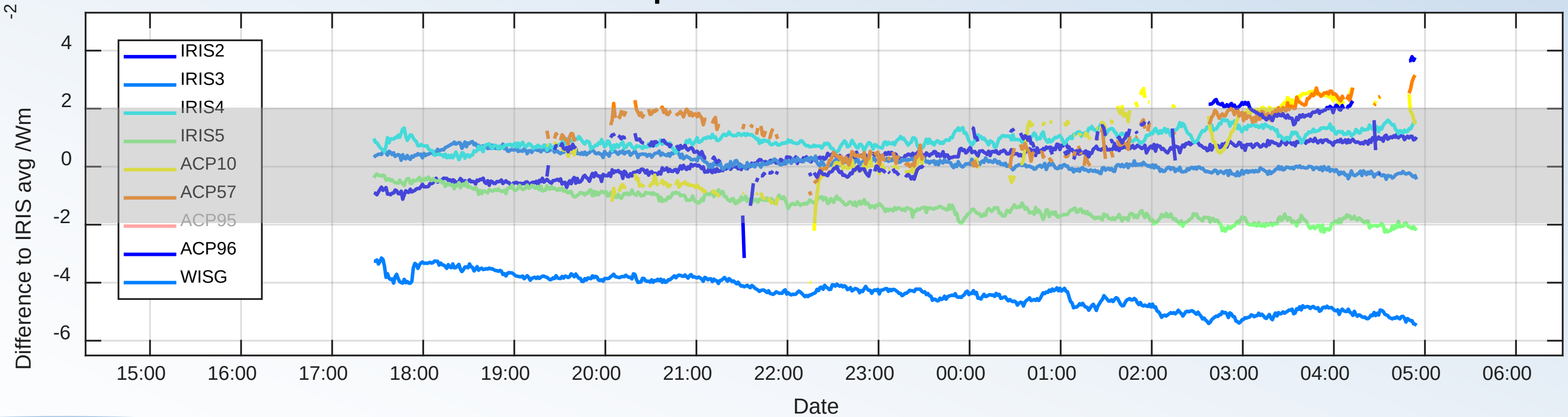
IRIS & ACP



30 September - 1 October



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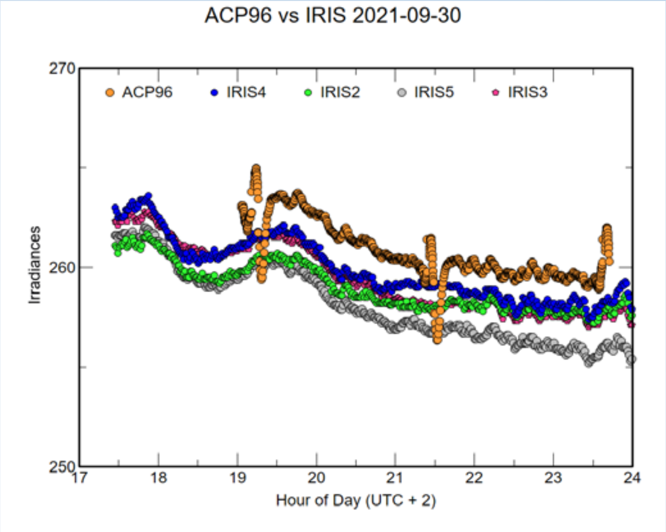
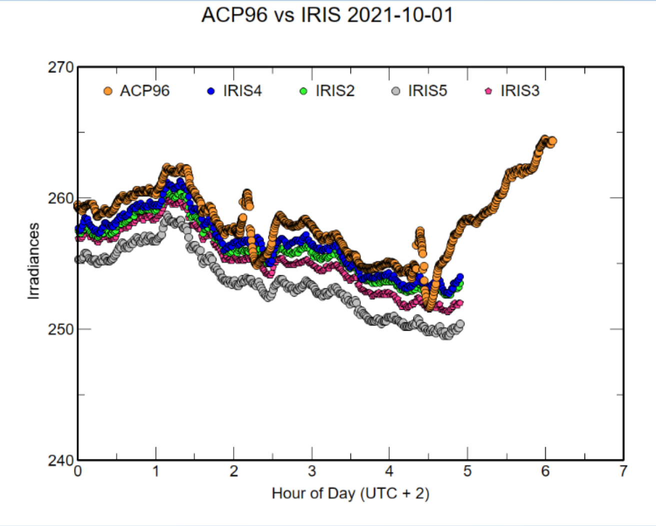
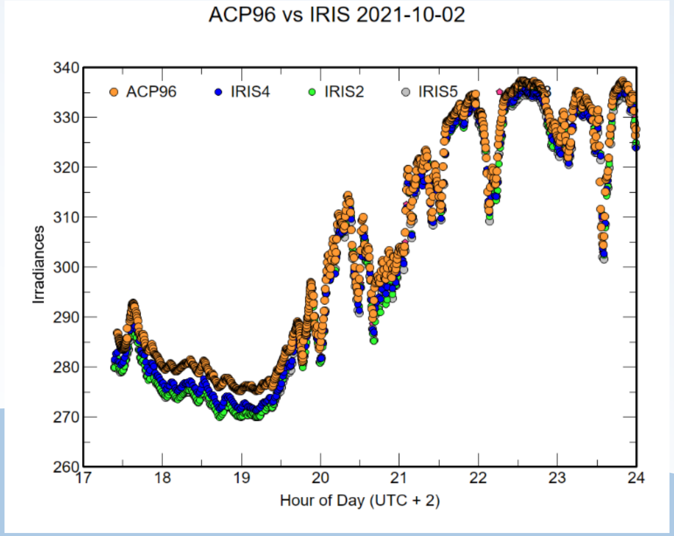
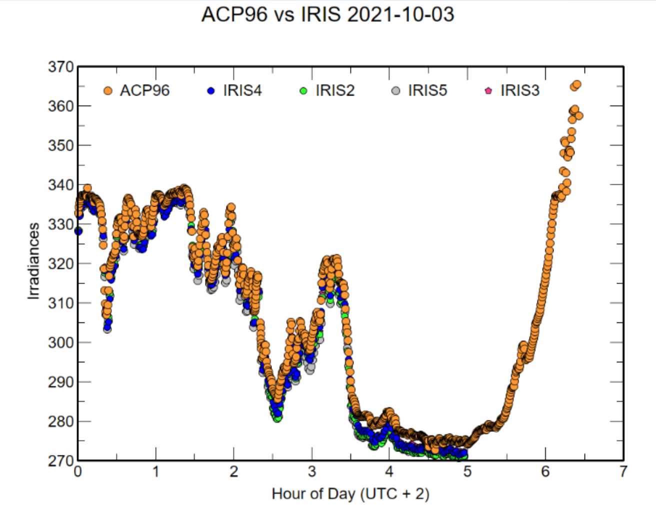
IRIS & ACP96 using Bruce Forgan analysis









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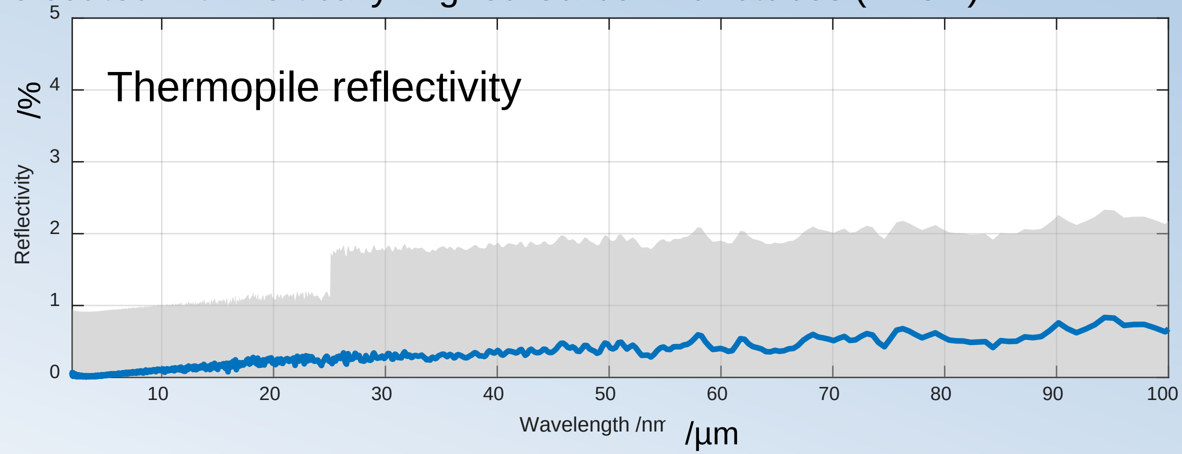
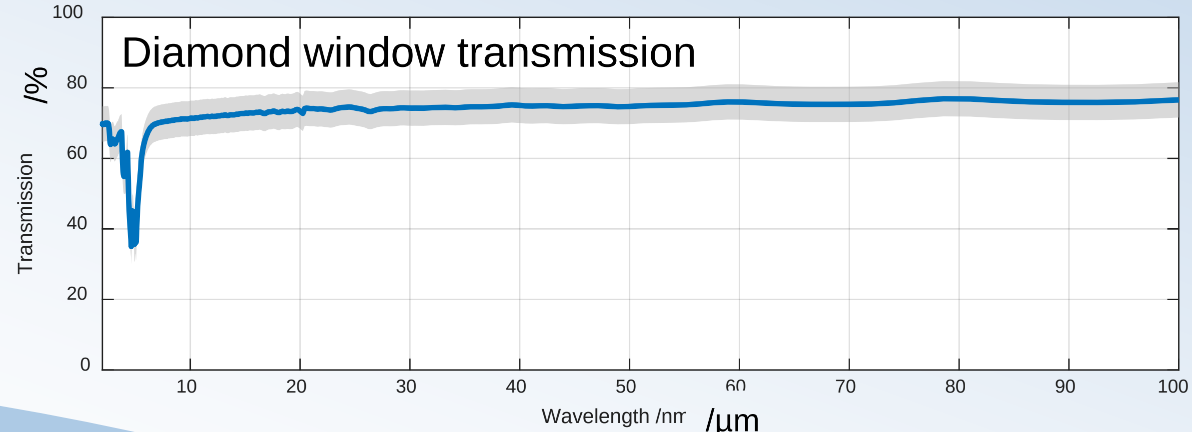
Development of a spectrally flat pyrgeometer

Instrument features:

- Diamond dome
- Thermopile coated with Vertically Aligned Carbon Nanotubes (VACN)





EMPIR METEOC-4 (2020-2023)

EMPIR EURAMET

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

NIST

PTB Physikalisch-Technische Bundesanstalt Braunschweig und Berlin

Hukseflux Thermal Sensors

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IPgC-II report & calibration certificates

Instruments and Observing Methods
Report No. 129

Report on the Second International Pyrgeometer Intercomparison (27 Sept - 15 Oct 2015, PMOD/WRC)

J. Gröbner and C. Thomann (Switzerland)

WEATHER CLIMATE WATER

WORLD METEOROLOGICAL ORGANIZATION

Calibration Certificate

No. 2015-112

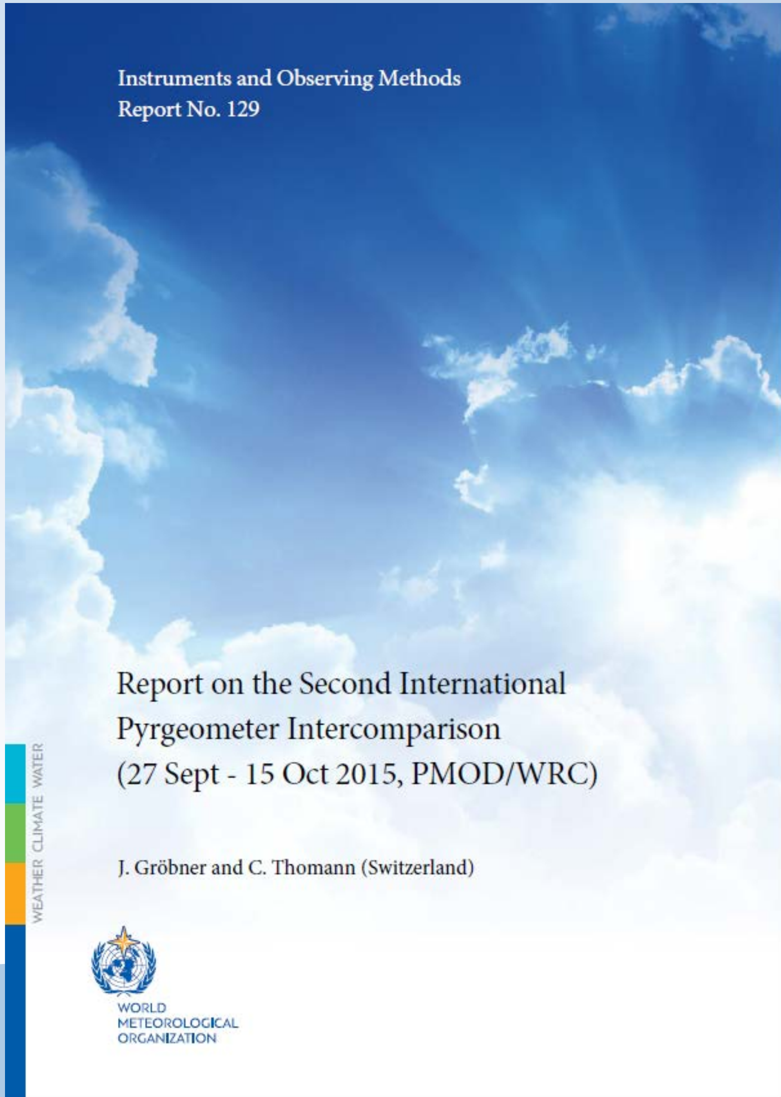
Calibration Item	**Pyrgeometer**	
	Manufacturer	The Eppley Laboratory, Inc.
	Type	Precision Infrared Radiometer, with three dome thermistor
	Serial number	
Customer		
Calibration Mark	2015-1129-01	
Period of Calibration	29-Sep-2015 to 12-Oct-2015	

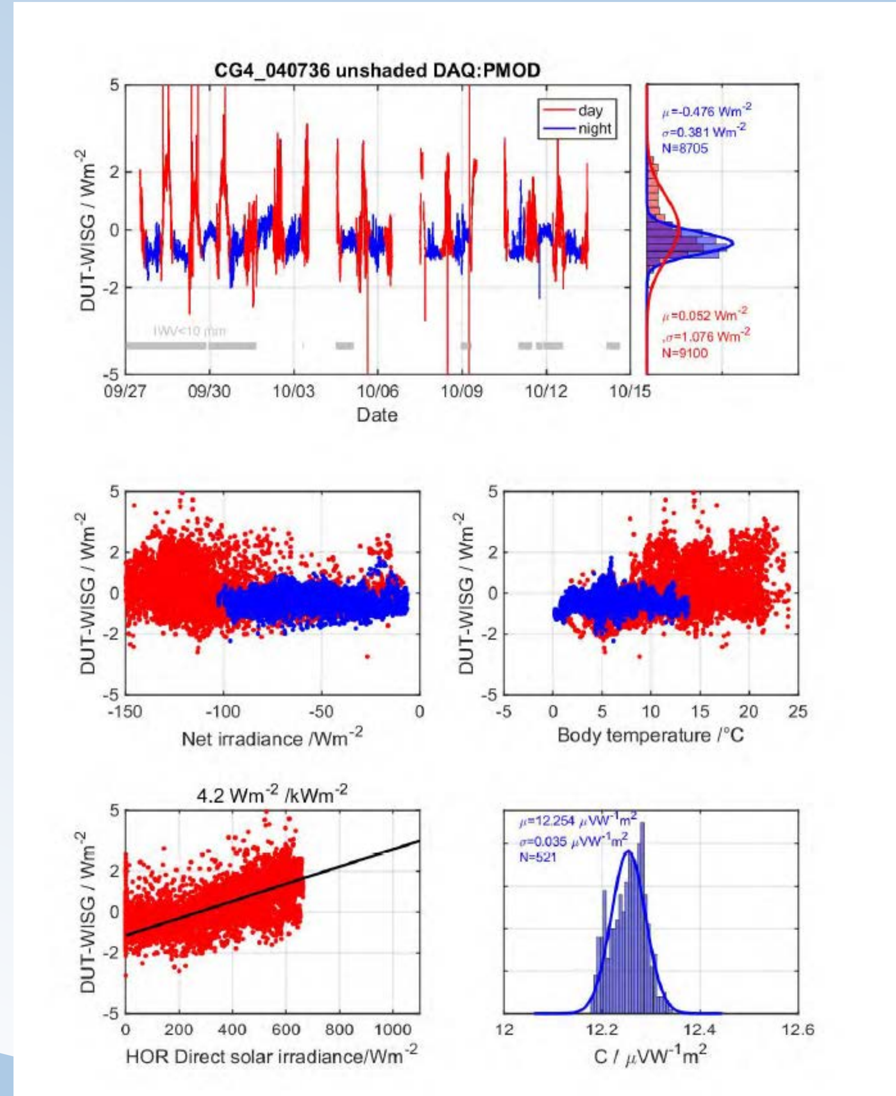
Davos Dorf, 05 November, 2015

C. Thomann
In charge of calibration

Dr. Julian Gröbner
Head IR Radiometry Section

IPgC-II report & calibration certificates





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Governance and traceability of atmospheric longwave irradiance
Annex to Resolution 1 (CIMO 17)

According to its Terms of Reference, in response to the requirement for standardization of atmospheric longwave radiation measurements, the Commission for Instruments and Methods of Observation (CIMO) decides to establish a governance framework for the World Infrared Standard Group (WISG).

The Governance framework comprises an advisory group of at least, five experts in atmospheric longwave radiation measurements, appointed by the president of CIMO for each International Pyrgeometer Comparison, preferably from among the participants in the comparison.

The comparison's leader, appointed by PMOD, will be invited to participate in the group's meeting.

The tasks of the advisory group are, but not limited to:

(a) To review the status and stability of the WISG, and evaluate its role as operational reference standard for providing a stable longwave reference, based on the analysis provided by PMOD/WRC;

(b) To recommend the updating of the calibration factors and changes to the WISG, if necessary;

(c) To ensure the supervision of the International Pyrgeometer Comparison, scheduled to take place every five years in conjunction with the International Pyrheliometer Comparison;

(d) To review progress in and provide advice on maintaining and improving traceability to the SI through the International Pyrgeometer Comparison;

(e) To report their findings and recommendations to the CIMO Management Group.

WMO, No. 1227, 2018