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Blackbody Comparison Measurements for Improved Traceability of Longwave Downward Radiation Measurements

Objective

Longwave downward radiation refers to the infrared radiation emitted in the atmosphere and received on the surface of the Earth. Pyrgeometers are broadband infrared detectors with a hemispherical acceptance angle and are typically used to measure longwave downward radiation. Such measurements take place at multiple stations globally and are, for example, organised by the Baseline Surface Radiation Network (BSRN) [1]. Within the BSRN, the Tilted Bottom Cavity BB2007 [2] at PMOD/WRC has long served as a reference for tracing longwave downward radiation measurements to the SI.

The objective of this work is to validate the current traceability of the BB2007 within the target irradiance uncertainty of 0.5 W/m². To do so, a new independent traceability path is to be established by means of the new Hemispherical Blackbody (HSBB). The HSBB has been developed in recent years and is specifically designed to calibrate broadband infrared detectors with a hemispherical acceptance angle.

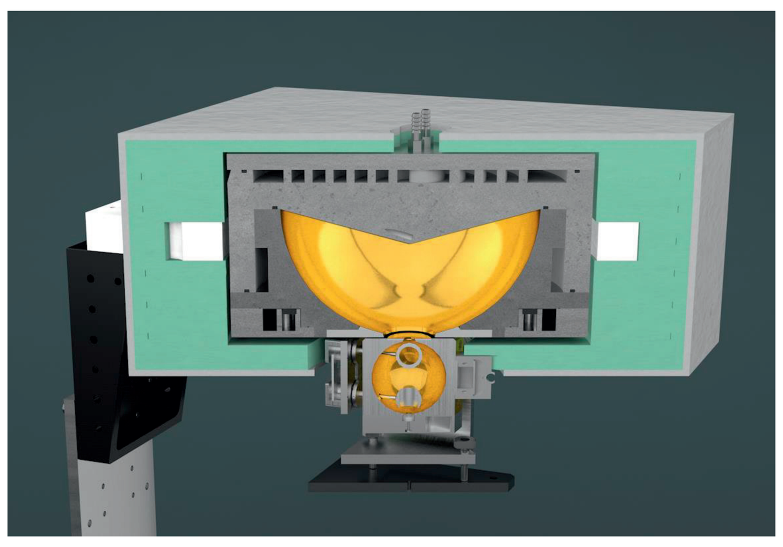

Figure 1: The new Hemispherical Blackbody (HSBB). In the picture, an Infrared Integrating Sphere (IRIS) instrument is placed below the HSBB.

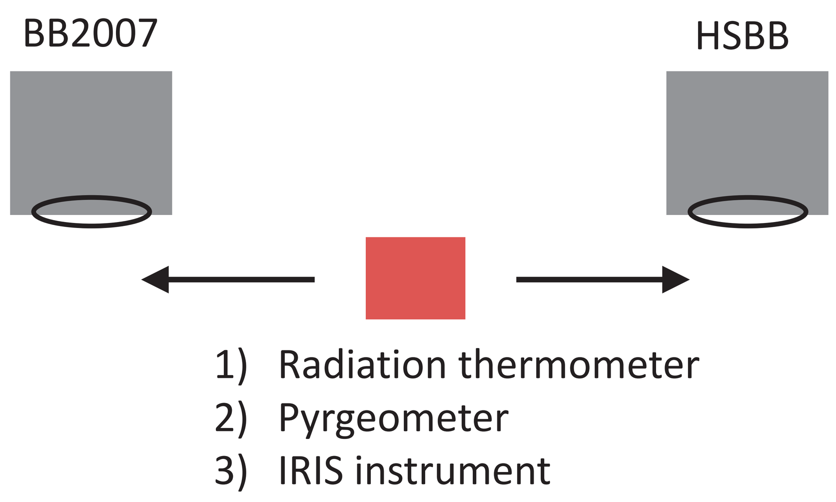

Figure 2: Schematic setup for the comparison measurements between the BB2007 and the HSBB. Different detectors serve as transfer instruments.

Setup

The HSBB, which is shown in a sectional view in figure 1, consists of a black coated cone in combination with a highly specular reflecting golden hemisphere.

The measurements were carried out in two stages. In the first stage, the HSBB was characterised against the ammonia heat-pipe blackbody that serves as a reference for the Radiation Temperature Scale of PTB [3]. Measurements were carried out with a radiation thermometer as a transfer instrument at normal incidence. For the second stage, the HSBB was brought to PMOD/WRC, where comparison measurements took place between the BB2007 and the HSBBBB. These measurements were performed not only with the radiation thermometer, but also with a pyrgeometer and an Infrared Integrating Sphere (IRIS) [4] as transfer instruments with a hemispherical acceptance angle.

The schematic setup corresponding to the second stage of the measurements is demonstrated in figure 2. Because the BB2007 and the HSBB were operated face down, a tilted mirror was placed in front of the radiation thermometer to bend the radiation beam.

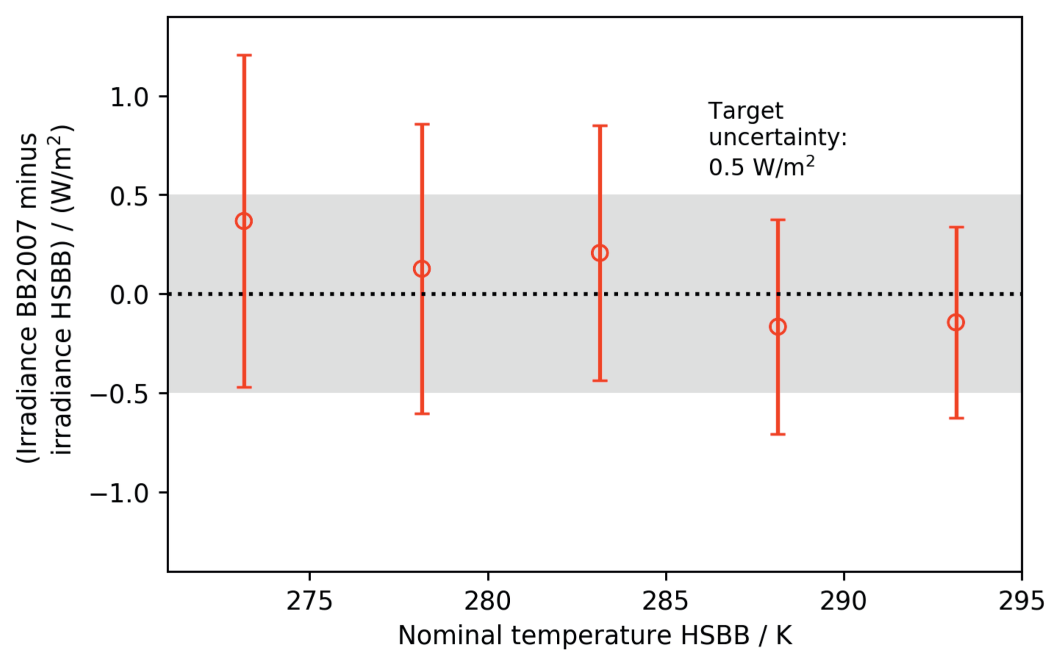

Figure 3: Results for the comparison measurements between the BB2007 and the HSBB. The data correspond to the measurements performed using an IRIS instrument. The uncertainties correspond to combined uncertainties.

Results

For the comparison measurements between the BB2007 and the HSBB, the results are shown in figure 3 as examples of measurements using the IRIS instrument. Very good agreement was found within the target uncertainty. Similar results with small but insignificant trends were obtained from the measurements using the radiation thermometer and the pyrgeometer.

References

[1] A. Driemel et al. „Baseline Surface Radiation Network (BSRN): structure and data description (1992-2017)". In: *Earth System Science Data* 10.3 (2018), pp. 1491-1501.

[2] J. Gröbner. "Operation and Investigation of a Tilted Bottom Cavity for Pyrgeometer Characterizations". In: *Applied Optics* 47.24 (2008), pp. 4441-4447.

[3] I. Müller et al. „Non-contact temperature measurement at the Physikalisch-Technische Bundesanstalt (PTB)". In: *Quantitative InfraRed Thermography Journal* 18.3 (2021), pp. 187-212.

[4] J. Gröbner. "A Transfer Standard Radiometer for Atmospheric Longwave Irradiance Measurements". In: *Metrologia* 49.2 (2012), pp. S105-S111.

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Conclusion

Very good agreement was found within the target uncertainty of 0.5 W/m² between the BB2007 with its current traceability and the HSBB that is traceable via the Radiation Temperature Scale of PTB. The current traceability of the BB2007, which is mainly based on contact thermometry and optical simulations, was validated.

The results are to be considered a major achievement in improving the significance of longwave downward radiation measurements in the realm of climate research and determining the surface energy budget of the Earth. The results will help reduce the measurement uncertainties of longwave downward radiation measurements.

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