Operating procedure at the Infrared Radiation Centre (IRC) of the Physikalisch Meteorologisches Observatorium Davos, World Radiation Centre

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1. Introduction and motivation

The IRC was established in January 2004 at the PMOD/WRC following the recommendation of the Commission for instruments and methods of observation (CIMO) at its thirteenth session in Bratislava, 25 September to 3 October 2002 (Recommendation 1, CIMO-XIII).

The IRC comprises an absolute sky-scanning radiometer (ASR) which provides the absolute longwave irradiance reference to a group of pyrgeometers which form the World Infrared Standard Group (WISG) of pyrgeometers. Comparisons between the ASR and the WISG are performed on a regular basis to maintain the WISG and supervise its long-term stability with reference to the ASR.

The IRC holds the global infrared radiation reference and as such defines the longwave infrared scale to which all longwave infrared radiation measurements should be traced. The role of the IRC is to disseminate this scale to the worldwide community either by individual instrument calibrations at the PMOD/WRC, or preferably through the creation of regional calibration centers which are themselves traceable to the IRC.

2. IRC Instrumentation

a) ASR

The absolute sky-scanning radiometer consists essentially of a pyroelectric detector mounted on a tracking platform which observes the longwave infrared radiance with a five degree field of view entrance optic (Philipona, 2001). The absolute calibration is obtained from measurements of a temperature stabilised black-body before, during, and after the sky radiance measurements. One measurement cycle lasts for about 20 minutes and consists of the measurement of the sky radiance at a total of 32 zenith angles in 4 planes. These 32 measurements are integrated using a gauss-quadrature integration to produce one value for the downwelling longwave infrared irradiance. Since the pyroelectric detector is used without a sun-blocking filter, measurements are only performed during nighttime. Furthermore, since the gauss-quadrature method requires a smooth function of sky radiance versus zenith angle, measurements are only done under stable and clear nighttime conditions without clouds.

b) WISG

Figure 1 World infrared standard group of Pyrgeometers (WISG) at PMOD/WRC

The WISG is currently composed of four pyrgeometers, two precision infrared radiometers (PIR) from Eppley, and two CG4 from Kipp&Zonen. Three instruments were installed in September 2003 on the measurement platform on the roof of PMOD/WRC, while the fourth pyrgeometer was installed in the summer of 2004. All instruments are mounted on a tracker (BRUSAG) which provides shading from the direct solar irradiance using shading disks. Measurements are performed every second and two minute averages and their standard deviation are stored in a daily data file. All pyrgeometers are mounted in ventilation units which also contain a heating ring to heat the air flowing around the dome. The longwave downward irradiance is determined from the thermopile voltage and the dome and body thermistors using the Philipona et al. equation :

$$E = \frac{U_{emf}}{C}(1 + k_1 \sigma T_b^3) + k_2 \sigma T_b^4 - k_3 \sigma (T_d^4 - T_b^4)$$

c) Black-Body

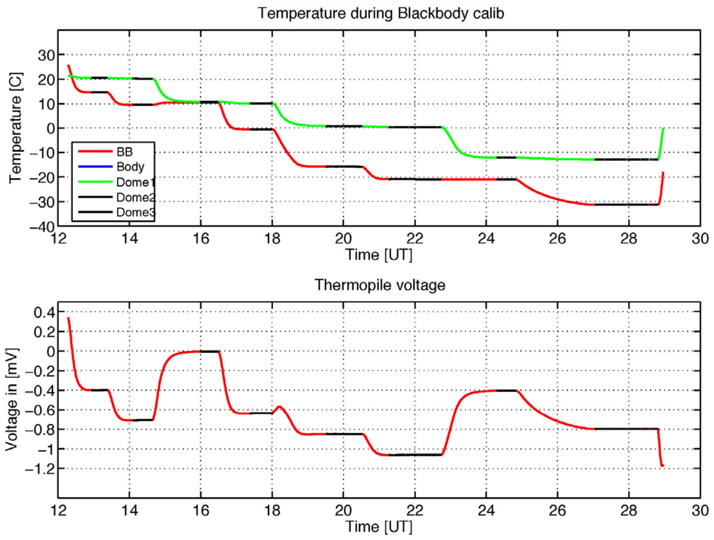

Figure 2 Pyrgeometer characterisation in the black-body. The upper figure shows the temperature of the black-body (red), and the pyrgeometer body (green). The lower figure displays the thermopile voltage in mV.

A black-body is used in the laboratory of IRC to characterise the pyrgeometers, i.e. to determine the calibration constants k1, k2, and k3 used in the equation above. The black-body is described in Philipona et al., 1995. Measurements are done at various equilibrium temperatures of the black-body and of the pyrgeometer to simulate outdoor conditions (see Figure 2). To determine k3 on Eppley pyrgeometers, the dome is heated by a heating ring installed around the rim of the dome so as to reach a temperature difference between dome and body of about 1 degree. The coefficients k1, k2, and k3 can be usually retrieved with an uncertainty of 0.01, 0.0006, and 0.1 respectively.

3. Traceability

The absolute calibration of the WISG is traceable to the International Pyrgeometer and ASR comparison (IPASRC-II) campaign in Barrow, Alaska in March 2001 (Marty, et al., 2003). PIR 31463 and CG4 FT004 of the WISG participated at this campaign and were calibrated relative to the ASR on this occasion. The two other pyrgeometers of the WISG (PIR 31464 and CG4 030669) were calibrated relative to the first two WISG pyrgeometers.

4. Stability of the WISG

The stability of the WISG has been monitored since its inception in September 2003. Figure 3 shows a 30 day running average of nighttime longwave irradiance measured by the WISG pyrgeometers relative to their mean. As can be seen in the figure, inter instrument variabilities are below ±1 W/m^2, which represents a relative variation of typically less than 0.5%.

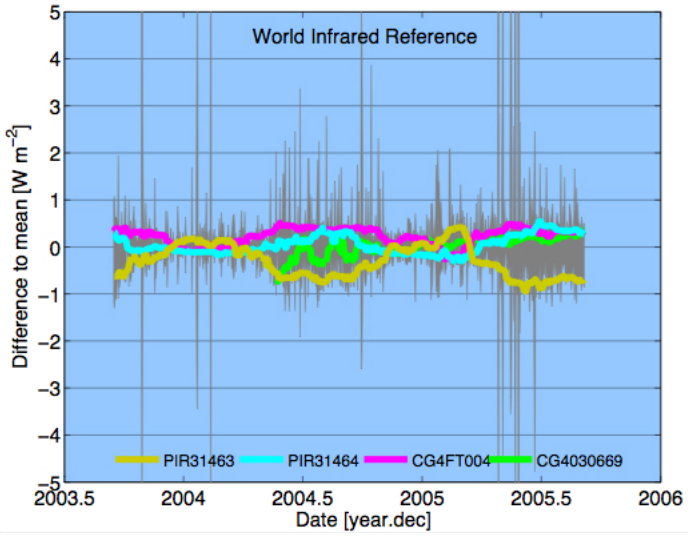

Figure 3 World Infrared Standard Group pyrgeometers. Shown is the 30 day average deviation in nighttime downwelling longwave irradiance relative to the average of the WISG. The gray background are nightly averages of the WISG pyrgeometers.

5. Maintenance and quality control

The pyrgeometers on the measurement platform is inspected daily, and domes cleaned if necessary. Desiccant is checked every three weeks.
Measured data is visually inspected every day to check for instrumental problems.
Time keeping of the data acquisition system is referenced to an internet time server several times a day.
The measured data is stored on the computer controlling the data acquisition, and daily data files are archived every day on the PMOD/WRC server. The server itself has a backup schedule to prevent data loss.

6. Calibration of test pyrgeometers

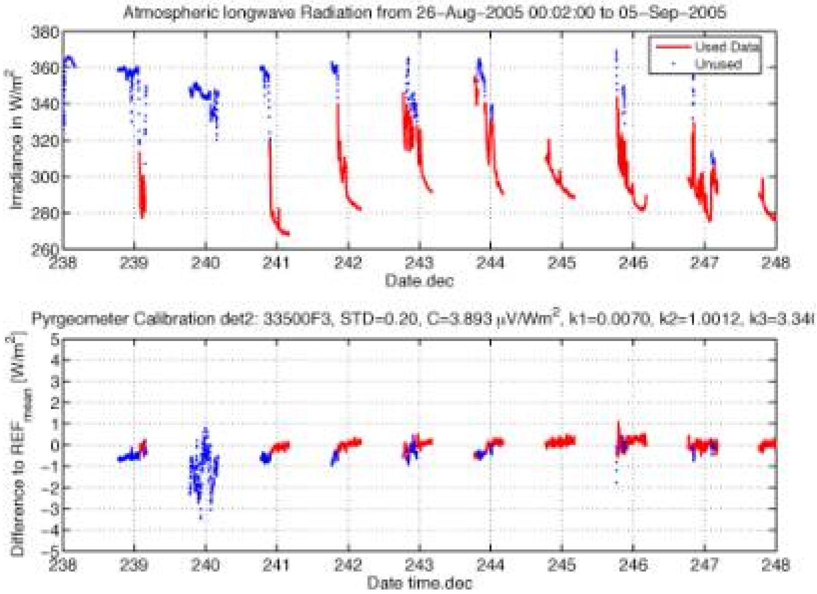

Figure 4 Pyrgeometer comparison to the WISG. The upper figure shows the longwave irradiance during nighttime, while the lower figure shows the residuals between the test pyrgeometer and the WISG. The sensitivity C is determined so as to minimize these residuals.

Test pyrgeometers are inspected on arrival and desiccant changed if necessary. They are first characterised in the black-body to retrieve the characterisation constants as described previously. Then, they are installed on the measurement platform for the determination of the sensitivity by comparison to the WISG. Only nighttime measurements are used so far. A nominal calibration procedure requires about 24 hours for the laboratory characterisation and several days with clear and cloudy skies to determine the sensitivity C and check the stability of the test pyrgeometer. Typical variabilities between the test pyrgeometer and the WISG are less than ±1 W/m^2 during the whole measurement period (see Figure 4).

7. Uncertainties

The determination of a comprehensive uncertainty estimate for the longwave infrared reference is still in progress. A brief overview is presented in the following paragraph. The uncertainties of the WISG are composed of the uncertainty in the ASR absolute longwave irradiance measurements of about 2 W (Philipona, 2001) and the variability of the pyrgeometers within the WISG of 1 W. The combined uncertainty of the WISG is therefore 2.2 W.

The calibration of a test pyrgeometer will thus have an uncertainty which is composed of the WISG uncertainty of 2.2 W, its variability of 1 W, and the variability of the test pyrgeometer relative to the WISG of typically 1 W. This gives a combined uncertainty for a pyrgeometer calibration of 2.6 W.

8. Current developments and future plans

- The ASR black-body has been compared to the IRC laboratory black-body.
- The influence of the horizon on the ASR sky radiance integration was estimated for the PMOD/WRC site. The contribution of the horizon obstructions (mainly mountain slopes) to the longwave irradiance was estimated to be of the order of 1 to 3 W/m^2. Thus, at PMOD/WRC a systematic horizon correction of +2 W , with an associated uncertainty of 1 W seems to be necessary for the ASR measurements.
- A second sky scanning radiometer is under development. The radiometer is based on an electric substitution pyroelectric detector. The aim is to have an automated instrument for unattended measurements of the longwave irradiance during nighttime.
- A second black-body is currently developed. Its design is based on a cylindrical design as described in Metrologia, 2004. The black-body will be purged with nitrogen; the design of the black-body temperature probes will allow routine calibrations relative to calibrated temperature sensors traceable to absolute temperature standards.
- A laboratory facility for the determination of the angular response of pyrgeometers has been developed and is undergoing tests. The source is a quartz-halogen lamp which provides a homogeneous beam at the sensor reference surface.
- The observed differences in the sensitivity C determined either from the black-body or through the WISG (see Figure 5) are investigated to understand their origin.

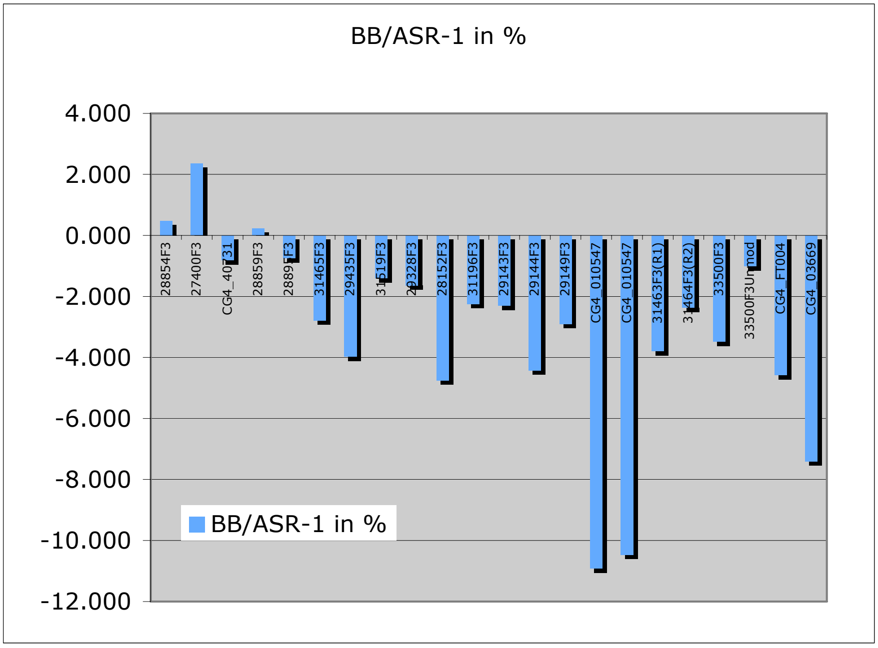

Figure 5 Ratio between the sensitivity C of different pyrgeometers determined in the black-body to the one determined by comparison to the WISG.

9. References

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