Traceability of Surface Longwave Irradiance Measurements to SI Using the IRIS Radiometers

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Abstract. The traceability of the World Infrared Standard Group of Pyrgeometers (WISG) was established through the comparison to several independently calibrated radiometers (Infrared Integrating Sphere Radiometer (IRIS), Absolute Cavity Pyrgeometer (ACP), Atmospheric Emittance Radiance Interferometer (AERI)). The traceability of the longwave irradiance measurements to SI was validated by a comparison of two independently characterized blackbody cavities.

INTRODUCTION

The World Radiation Center at PMOD/WRC is operated on behalf of the WMO. The Infrared Radiometry Section of the WRC (WRC-IRS) provides traceability of downwelling atmospheric longwave radiation measured with pyrgeometers by comparison to the World Infrared Standard Group (WISG) [1]. As has been discussed previously [2], the current implementation of the WISG measures lower longwave irradiances than the two candidate reference radiometers IRIS (Infrared Integrating Sphere Radiometer) and the ACP (Absolute Cavity Pyrgeometer). To validate the findings reported in [2], additional measurements since that publication in 2014 have been performed and are discussed in this paper. Specifically,

1) Measurements during cloud-free nights at PMOD/WRC between the WISG and IRIS radiometers.
2) A field campaign at the Atmospheric Radiation Monitoring Site (ARM) at Southern Great Plains, Oklahoma with IRIS, ACP, AERI (Atmospheric Emittance Radiance Interferometer) and WISG traceable pyrgeometers.
3) Laboratory comparison between the reference blackbody BB2007 of PMOD/WRC with the Hemispherical Blackbody (HSBB) developed by PTB.

ATMOSPHERIC LONGWAVE RADIATION MEASUREMENTS AT PMOD/WRC

Three IRIS (IRIS#1, IRIS#2, and IRIS#4) radiometers have been placed in operation at PMOD/WRC, Davos, since 2008 and have been measuring atmospheric downwelling longwave irradiance beside the WISG. Due to their windowless design, only nighttime measurements during cloud-free nights are analysed to avoid the influence of the solar radiation affecting the measurements. Figure 1 shows the atmospheric longwave irradiance measurements from WISG and IRIS for this period.

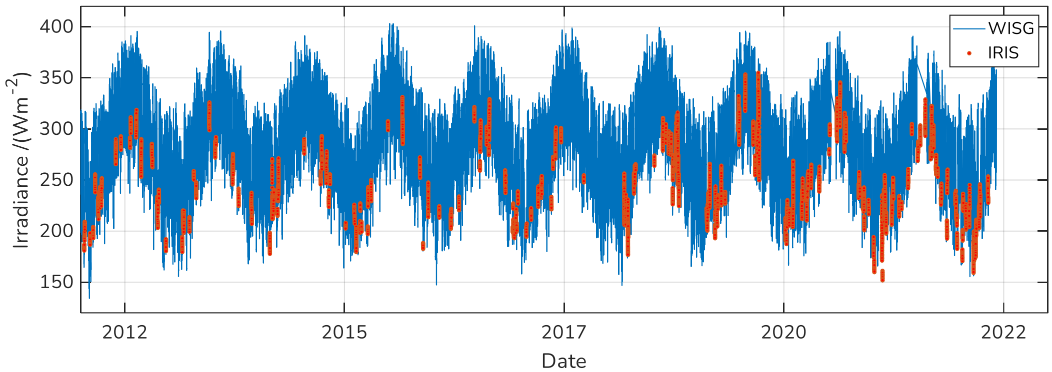

FIGURE 1 Atmospheric longwave irradiance measurements at PMOD/WRC from the WISG (blue), and during cloud-free nights with the IRIS radiometers (red) over the period 2011 to 2022.

The difference between the WISG and the IRIS radiometers shows a clear dependence with atmospheric integrated water vapour (IWV), being on average lower by 4 Wm^{-2} for IWV larger than about 10 mm, and rising to near equal values for lower IWV values, representative for cold and dry atmospheres (Figure 2).

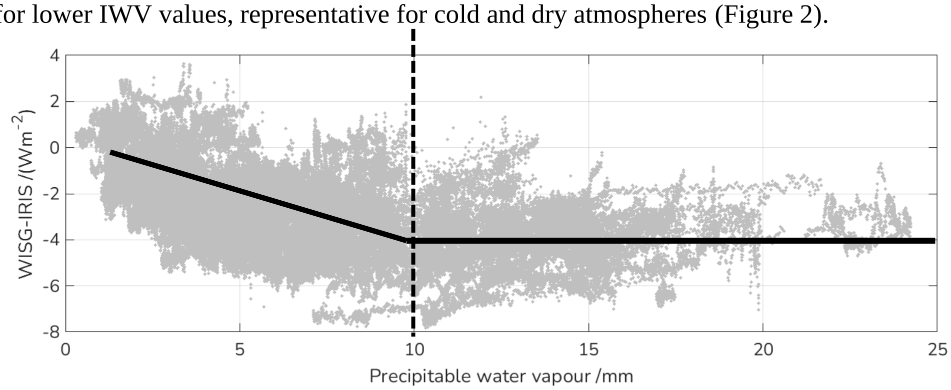

FIGURE 2 Difference between WISG and IRIS with respect to Integrated Water Vapour (IWV) for the simultaneous measurements shown in Figure 1.

These differences confirm the findings already discussed in [2] and show that the WISG systematically underestimates downwelling longwave irradiance. Measurements obtained during the International Pyrgeometer Comparison (IPgC-II) in September 2015 [3], and during IPgC-III in 2021 between WISG, IRIS and ACP (report in preparation) also confirmed these observations.

FIELD CAMPAIGN AT THE ARM SITE, SOUTHERN GREAT PLAINS

During a field campaign organised at the ARM site at Southern Great Plains in Oklahoma, US, two intensive operational periods for 2 weeks each were scheduled in October 2017 and in December 2017. The aim of the campaign was to obtain simultaneous longwave irradiance measurements between IRIS, ACP, AERI, and pyrgeometers traceable to the WISG for two different atmospheric conditions in a different environment than at PMOD/WRC.

The Atmospheric Emittance Radiance Interferometer (AERI)

The AERI measures downwelling spectral radiance from 3.3 to 19 µm. Longwave fluxes are derived by first performing AERIoe retrievals [4] to derive temperature and humidity profiles from the AERI-observed radiance data. These thermodynamic profiles are then used to drive the LBLRTM model to compute downwelling radiance from 3.3 to 100 µm in wavelength. Then the LBLRTM gaseous optical depths were used as input to LBLDIS [5] to compute both downwelling radiance and spectral flux from 3.3 to 100 µm; these were used to get the anisotropy factors needed to convert the AERI radiance to flux. The LBLDIS calculation was used to cover the 19 to 100 µm band that the

AERI does not sample. The spectral flux was then integrated to provide the downwelling longwave flux used for the comparisons shown here.

Figure 3 shows measurements obtained on 18 October 2017 (left figure), and on 6 December 2017 (right figure). The IWV was 11.2 mm on 18 October and 5.3 mm on 6 December.

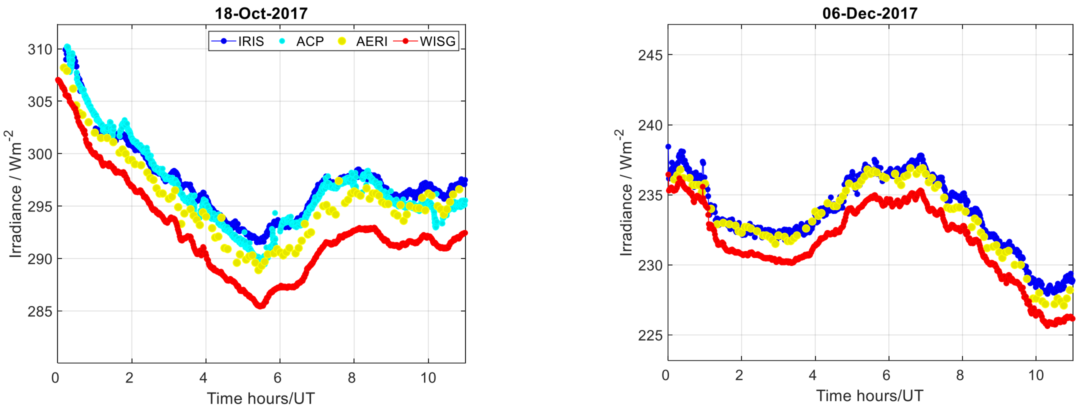

FIGURE 3 Downwelling longwave irradiance measurements from IRIS (blue), ACP (magenta), AERI (yellow), and pyrgeometers traceable to the WISG (red) at SGP for 18 October 2017 (left) and 6 December 2017 (right). The IWV was 11.2 mm on 18 October and 5.3 mm on 6 December.

As can be seen in the figure, the pyrgeometers measured consistently less than the other instruments, with a difference of about 5 Wm^{-2} in October, and 2 Wm^{-2} in December, in accordance with the results also seen at PMOD/WRC. Furthermore, as can be seen in these figures, the measurements between the IRIS radiometer and the AERI agreed extremely well during the two periods, confirming the observed offsets between IRIS and WISG, and confirming also the dependence with the atmospheric precipitable water vapour content.

LABORATORY-BASED BLACKBODY CAVITY COMPARISON AT PMOD/WRC

The blackbody BB2007 is the primary standard for longwave infrared irradiance at PMOD/WRC [6]. In the frame of an international collaboration with PTB, this blackbody was compared to the Hemispherical Blackbody (HSBB), which was developed, built and brought into operation at PTB [7]. Several transfer standard radiometers were used, of which we show in Figure 4 the comparison between BB2007 and HSBB using IRIS#4.

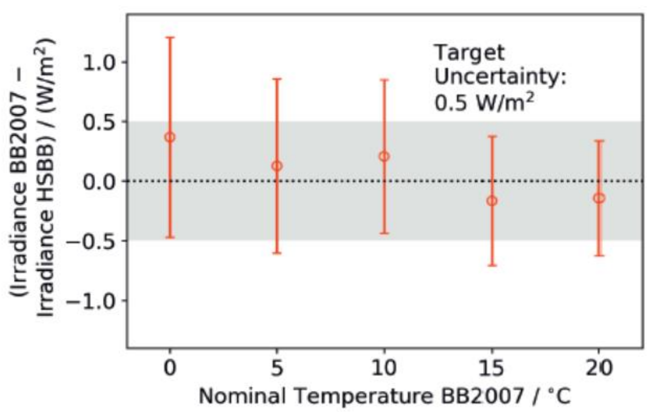

Figure 4 Difference between the irradiances measured by IRIS#4 exiting the BB2007 and the HSBB. The error bars represent the standard combined uncertainties.

As can be seen in this figure, the agreement between BB2007 and the HSBB using the IRIS#4 radiometer is within their combined standard uncertainties and within the target uncertainty of 0.5 Wm^{-2}.

The results show good agreement with respect to the target irradiance uncertainty of 0.5 Wm^{-2} provided by the HSBB. This comparison consequently supports and validates the traceability of atmospheric longwave downward radiation to the SI by linking measurements performed with the World Infrared Standard Group (WISG) of pyrgeometers to the traceability of the reference blackbody BB2007 using the Infrared Integrating Sphere (IRIS) instruments as transfer standard.

CONCLUSION

1) Clear-sky atmospheric longwave irradiance measurements of several IRIS radiometers versus the WISG show consistent higher values of 4 Wm^{-2} to 5 Wm^{-2}.
2) A direct comparison between IRIS, ACP and AERI gave longwave infrared irradiances with differences less than 2 Wm^{-2} between all instruments.
3) Longwave irradiances from the BB2007 and the HSBB of PTB agreed to better than 1 Wm^{-2}.
4) A redefinition of the atmospheric longwave irradiance scale based on the WISG is necessary to account for the observed offset of the WISG with respect to reference instruments such as the IRIS. This is one of the objectives of the WMO expert team on radiation references [8].

5) ACKNOWLEDGMENTS

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