Intercomparison of indoor and outdoor spectral irradiance measurements between INTI and INMETRO

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National institutes of metrology of Argentina and Brazil perform an intercomparison of spectral irradiance. Each institute developed its own secondary calibration facilities and provided a calibrated lamp. These lamps and a third one are alternately measured using their characterized spectroradiometers in the range from 250 nm to 1100 nm. The spectroradiometers are then taken outdoor to simultaneous solar measurements in UV range. Agreement between the results assess the institute's calibration capability.

INTRODUCTION

Spectral irradiance scale is usually materialized in standard lamps ultimately traced to a high-temperature blackbody [1] and to an electric-substitution cryogenic radiometer [2] as primary standards. Direct comparison using a spectro-radiometer allows the transference of calibration between different artefacts. The *Instituto Nacional de Metrología Industrial* (INTI / Argentina) and the *National Institute of Metrology, Quality and Technology* (INMETRO / Brazil) have developed their own facilities for secondary calibration of lamps based on direct comparison to FEL 1000 W reference standards (traced to the *Physikalisch-Technische Bundesanstalt*, PTB/Germany) using fully-characterized spectroradiometers.

Here we report the results of the intercomparison of indoor and outdoor spectral irradiance measurements performed at INTI's installations in Buenos Aires (Argentina) between May 27th and June 5th, 2019 [3]. Spectral irradiance lamps are measured by the participants against their own secondary standards using their spectroradiometers. The instruments are then taken outdoor for comparative measurements of UV solar spectral irradiance.

EQUIPMENT

INTI uses a double monochromator scanning spectroradiometer with a photomultiplier detector equipped with an integrating sphere and an optical diffuser for solar and indoor measurements, respectively. INMETRO [4] uses a 2048 pixels, Si CCD-based array spectroradiometer with a cosine-response PTFE diffuser. Both devices use optical fibers and are beforehand characterized for intensity and time linearity, spectral straylight, wavelength scale, spectral bandwidth, cosine response and optical plane of incidence. Each participant provides a certified secondary FEL 1000W lamp which has been calibrated in its own facility against their reference standards, according to Table 1, and also a third lamp.

Table 1. Standard lamps used in the intercomparison.

Lamp	A	B	C
Certificate	INTI	INMETRO	Neither

MEASUREMENT PROTOCOL

Each lamp is aligned in the optical bench and measured at a distance of 700 mm with both spectroradiometers. The results for each test lamp are obtained as $L_T(\lambda) = L_S(\lambda)\, M_T(\lambda)/M_S(\lambda)$, where $L_S(\lambda)$ is the certified spectral irradiance of each participant's own standard lamp (A or B) and $M_{T,S}(\lambda)$ are the *in-locus* spectral measurements.

For outdoor measurements, participants calibrate their spectroradiometers against the same reference (lamp A). The instruments are positioned in the rooftop of INTI's installations (34.57º S, 58.52º W) and their input are aligned towards zenith. Total acquisition period is matched between systems and measurements rounds start synchronously. Global measurements include both direct Sun and hemispherical scattering of the sky dome. Diffuse irradiance is obtained by shading the entrance optics. Direct irradiance is computed as their difference.

RESULTS

Figure 1 shows an example (lamp B) of spectral irradiance measurement performed by the participants in the range from 250 nm to 1100 nm. The achieved calibration uncertainty values (k=2) are compared. Relative difference between results obtained by the institutes for lamps A, B and C are shown in Fig. 2.

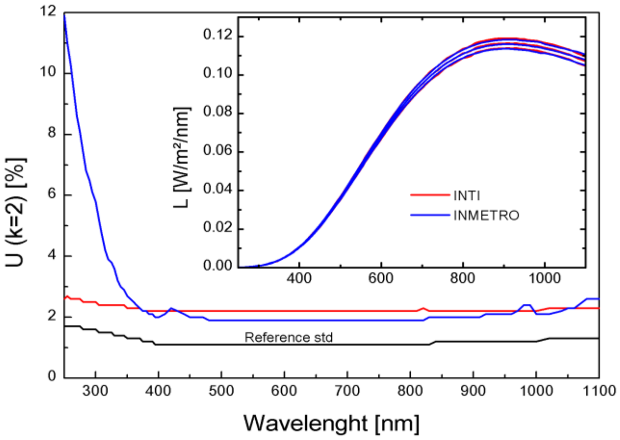

Figure 1. Calibration uncertainty of secondary standards of both institutes (primary lamp uncertainty shown in black). Inset shows spectral irradiance of lamp B.

Region between outer lines in Fig. 2(a-c) indicate combined uncertainty. This range touched the zero line, indicating agreement between data. Normalized error (*En*) between measurements (the absolute difference over their combined uncertainty) in Fig. 2d are within acceptance criterion of $En \leq 1$, except for few data points. INMETRO's higher uncertainty in UV is due to reduced sensitivity of its array spectroradiometer in this spectral region

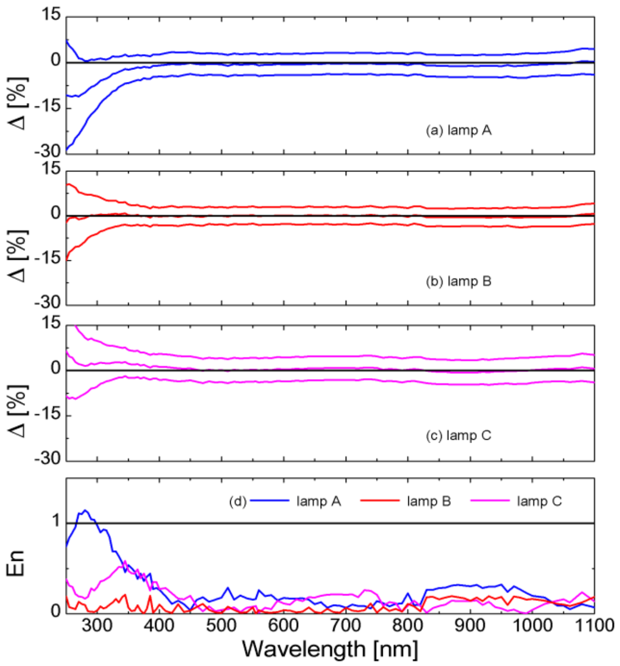

Figure 2. (a, b, c) Relative differences and (d) En computed over measurements of lamps A, B and C.

Five complete rounds of outdoor measurements were performed in June 3rd, between 12:49 and 13:32. Simultaneous results of both institutes obtained with their spectroradiometers in UV range are shown in Fig. 3, and also the normalized error. The observed spectral pattern is due to difference in spectral bandwidth of the instruments. Histograms of *En* (inset in Fig. 3d) reveals the value is mostly below unit, indicating good agreement between data, except for the lowest wavelengths, where INMETRO's instrument is less sensitive.

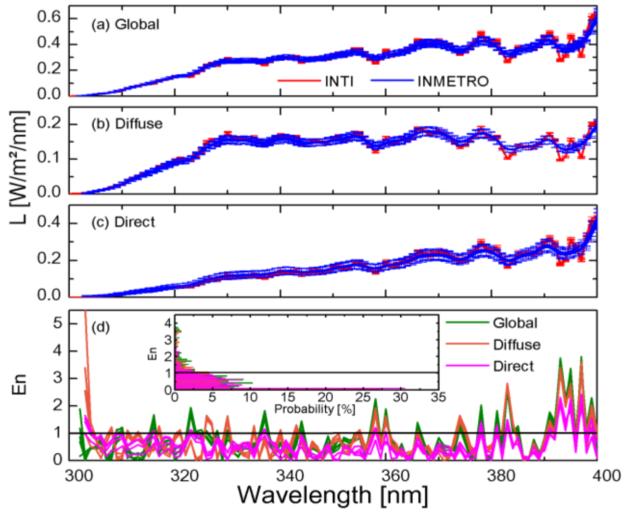

Figure 3. Measurements of (a) global, (b) diffuse and (c) direct UV solar spectral irradiance measured by INTI and INMETRO and (d) normalized error (inset: histogram).

CONCLUSION

Normalized error below unit for three lamps indicate agreement between INTI and INMETRO, assessing their independent secondary spectral irradiance calibration systems. Although solar measurements are performed in a rather experimental purpose, results exhibit good agreement, indicating the spectroradiometers are well characterized.

ACKNOWLEDGEMENTS

Authors thank Dr. Peter Sperfeld and Dr. Saulius Nevas for technical support and enlightening discussions, and the PTB/Germany for financial support under the Regional Fund Quality Infrastructure for Biodiversity and Climate Protection.

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