

# The World Radiometric Reference and its Quality System

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**Abstract:** The World Radiometric Reference (WRR) has been the basis for meteorological radiation measurements for the last 25 years. It is realized by a group of instruments, the World Standard Group (WSG), which is maintained at the World Radiation Center (WRC) in Davos. In these times of concerns about global warming, it is extremely important to accurately monitor the solar radiation impinging on Earth. Consequently, the proper maintenance of the WRR is crucial.

In order to guarantee the highest accuracy of the WRR and its international recognition, WRC implemented a quality management system satisfying the standard ISO/IEC 17025 and presented it to the EUROMET QS-Forum in February 2005.

The WRC is also in the process of carrying out comparisons between the WRR and cryogenic radiometers to ensure the stability of the WRR and to have a direct link to the SI system of units maintained by metrological institutes.

In this paper, we report on the state of the WRR and on the implementation of the quality management system.

## 1. Introduction

In these times of concerns about global warming, it is more than ever important to accurately characterize and monitor the radiation budget of the Earth. The solar radiation reaching the Earth and its surface is obviously a major issue in this context.

The World Radiometric Reference (WRR) is maintained and operated by the World Radiation Center (WRC) at Physikalisch-Meteorologisches Observatorium Davos (PMOD), Switzerland. The WRR serves as the reference standard used by WMO and other communities for measurements of the direct solar irradiance. Indeed, some ISO standards require traceability to the WRR.

The aim of the WRC is to ensure the best-possible maintenance of the WRR in order to make possible the detection of subtle changes in radiation climates.

In this paper, we present the way chosen by the WRC to ensure the quality of its standard and its international recognition by both the meteorological and metrological communities<sup>1</sup>.

First we will give a brief history of the WRR. Then we will focus on the technical challenges of solar irradiance measurements and explain why there is a need for a dedicated primary standard for this purpose. Finally we will present our efforts to

become a recognized metrology laboratory based on the international standard ISO/IEC 17025.

## 2. The WRR and its maintenance

Radiation measurements in meteorology have to be very homogeneous in space and time in order to yield useful information about the subtle differences of the different radiation climates and their evolution. The achievement of homogeneity in radiation measurements had been of concern since radiation network started to be implemented. At that time the measurement capabilities of metrology institutes were restricted to low intensity levels and consequently, not adapted to solar irradiance. This was the main reason for the development of an independent radiation standard in meteorology. Over the years, several steps were needed to finally define the WRR [1, 2], which has now been in use since January 1, 1981 within the meteorological community [3].

The WRR is basically the result of the intercomparison of 15 absolutely characterized cavity radiometers originating from different manufacturers, each of them being a realization of the unit  $W/m^2$ .

The WRR is realized by a group of absolute cavity pyrheliometers - the World Standard Group (WSG) - and is maintained by the WRC at Davos. Some of the original instruments used to define the WRR are still members of the WSG.

The WSG is made up of different types of instruments in order to enable detection of any

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<sup>1</sup> Throughout this paper, the reader should pay attention to carefully distinguish between the different realms of "meteorology" and "metrology".

aging process or malfunction of an instrument (or an instrument type). All the WSG members had to prove long-term stability in order to be considered as members.

At present all the WSG radiometers are more than 25 years old. Therefore, there is a strong concern, that some of these instruments may fail sooner or later. In order to ensure the future of the WSG, PMOD/WRC currently operates instruments of newer generations on the WSG platform in order to test their long-term stability. After successful performance testing, such instruments could possibly be integrated into the WSG if they are of different types than the WSG instruments or replace faulty instruments.

Another point of concern is that there are presently only two manufacturers of commercial absolute cavity radiometers. In the future, it may consequently become impossible to keep having enough instruments of different types in the WSG. Therefore PMOD/WRC tried to obtain instruments from other manufacturers. Though positive feedback was initially received from various laboratories, only one Chinese laboratory provided instruments on loan.

The stability of the WRR is secured by regular intercomparisons of the WSG instruments. Every 5 years, an International Pyrheliometer Comparison (IPC) is organized and held by PMOD/WRC in Davos. The main goal of the IPC is the dissemination of the WRR to ensure worldwide homogeneity of meteorological irradiance measurements. Since many instruments are regular participants in the IPC, their measurements can be used as an independent check to confirm the stability of the WRR. Should the situation arise that most participating instruments experienced a significant drift relative to the WRR since the last IPC, correcting steps necessitating a deeper analysis would need to be taken, but this has never happened yet.

### **3. Intercomparisons between the WRR and cryogenic radiometers**

Direct intercomparison between the WRR and cryogenic radiometers is not possible since there are presently no cryogenic radiometers, which can measure irradiance and most are restricted to much lower power levels than those used for solar measurements.

Indirect intercomparisons between the WRR and the UK National Physical Laboratory's (NPL) primary standard radiometer (PSR) were carried out in 1990 [4] and 1994 [5], using a laser beam and a trap detector as transfer standard. The results lie well within the absolute uncertainties of the two scales. Such comparisons are primordial in order to independently confirm the stability of the WRR and its consistency with SI units.

It should be noted that, for technical reasons

mentioned above, these comparisons were based on power measurements rather than irradiance measurements, i.e. the diameter of the laser beam was smaller than the precision aperture of the WSG radiometer. The radiometer is consequently not exactly in the same environment as during solar measurements. It cannot be excluded that the estimated uncertainties of the comparisons to the cryogenic radiometer were underestimated. Possible causes of uncertainty which were not taken into account are for example due to the use of the instrument in power-mode instead of irradiance mode, non-complete illumination of the cavity, diffraction correction, stray-light correction, etc.

A new comparison has taken place this year and it is planned to carry out such comparisons on a regular basis to independently check the stability of the WRR.

### **4. The need for a quality system**

As stated above, the WRR was originally designed to meet the needs of the meteorological community. However, since various ISO standards require traceability to the WRR, it is actually used by a much wider community.

Nowadays, the need for certification and traceability is being more and more asked for. This requires a complete traceability chain, where each step from the definition of the unit to the end user is associated with a stated uncertainty.

PMOD/WRC wants to ensure that solar radiation measurements are based on a stable reference and wants to provide this service to the communities relying on the WRR. To achieve these goals, PMOD/WRC decided to implement a quality management system according to ISO/IEC 17025 (General Requirements for the Competence of Calibration and Testing Laboratories).

### **5. BIPM and its relation to WMO**

WMO and the Bureau International des Poids et Mesures (BIPM) decided to co-operate as to ensure that meteorological data are properly traceable to SI units.

Figure 1 shows schematically the structure of the BIPM. It was the Metre Convention, signed in 1875 in order to promote the use of the metric system, which originally led to the foundation of the BIPM. The Comité International des Poids et Mesures (CIPM) supervises the BIPM and Consultative Committees (CC) and co-operates with other international metrological organizations.

In 1999 CIPM issued the so-called Mutual Recognition Arrangement (MRA) based on which National Metrology Laboratories (NMI) mutually recognize each other's standards and calibration certificates. For these purposes metrology laboratories are required to comply with the following regulations:

- Credible participation in key comparisons

- Credible participation in other comparisons
- Declaration of each participant's calibration and measurement capabilities (CMC)
- Quality system for calibration services recognized to be on the level of international best practices.

All quantities (measurables) are subject to approval by the Consultative Committee. In this respect, it should be noted that the quantity "Solar Irradiance" has been proposed to the Consultative Committee on Photometry and Radiometry (CCPR), but the approval process of this quantity is not yet completed. Upon approval of this quantity by CCPR it will be possible for PMOD/WRC (and other metrology laboratories) to announce CMC's on Solar Irradiance to BIPM.

Since the WRR is a conventional primary standard it needs to be included in the international system of standards. To further accentuate this need it should be mentioned that several ISO standards require traceability to the WRR. The WMO Guide to Meteorological Instruments and Methods of Observation also refers to some of these ISO standards.

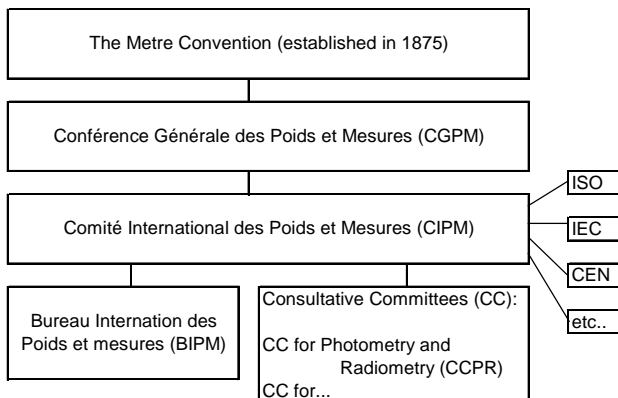


Figure 1: Structure of the BIPM and related bodies.

## 6. National Metrological Institutes and the EUROMET QS-Forum

The formal recognition of the National NMI takes place on a regional basis. The European regional metrology organization is the EUROMET.

The Quality System Forum (QS-Forum) is the EUROMET operational instrument used to share knowledge on ISO/IEC 17025 and its implementation by NMIs. It is a collaborative forum on measurement standards and is the way used by EUROMET to do QS review by peers.

NMIs can also devolve the maintenance of certain measurement standards to external laboratories. Of course, these also have to comply with the same rules.

## 7. The case of the World Radiation Center

The WRR can be considered as a primary standard since it was based on absolutely calibrated radiometers and it is accepted as such throughout the meteorological community (WMO). This situation of a primary standard not being owned by an NMI is rather unique. Therefore the Swiss NMI (METAS) designated it as the institute responsible for Solar Irradiance within CIPM-MRA.

PMOD/WRC consequently opted for self-declaration by implementing a quality system according to ISO/IEC 17025 for parts of its activities – the maintenance of the WRR and the calibrations of pyrhemometers and pyranometers. In these fields PMOD/WRC acts as a metrology laboratory. In the future other activities at PMOD/WRC are planned to be included into the quality system.

ISO/IEC 17025 incorporates all requirements of ISO 9001 and ISO 9002 that are relevant to the scope of testing and calibration services<sup>2</sup>.

The quality system at PMOD/WRC has a two-stage structure. Stage one consists of the *quality management*, which includes the quality policy statement and defines the general rules and range of application for all departments and activities. In each department subject to the quality system a set of documents was compiled to describe all processes and infrastructure within that department (stage two of the quality system). All work procedures, diagrams, schematics of hardware, as well as documents on uncertainty and traceability etc. are part of the stage two quality documentation.

## 8. References

- [1] Fröhlich C.: 1991, *Metrologia* 28, 111
- [2] CIMO VII Session: 1978, Annex IV, WMO No. 490, World Meteorological Organization, Geneva
- [3] Technical Regulations: 1979, No. 49, World Meteorological Organization, Geneva
- [4] Romero J., Fox N. P., Fröhlich C.: 1991, *Metrologia* 28, 125
- [5] Romero J., Fox N. P., Fröhlich C.: 1995/96, *Metrologia* 32, 523

<sup>2</sup> Note that certification against ISO 9001 and ISO 9002 does not of itself demonstrate the competence of the laboratory to produce technically valid data and results.