The 12th International Pyrheliometer Comparison (IPC-XII) was held at the World Radiation Center (PMOD/WRC) in Davos, Switzerland from 28 September through 16 October 2015. Representatives from 15 Regional and 15 National Radiation Centers as well as 25 manufacturers and other institutions took part in the comparison. They were represented by 111 individuals from 33 countries who operated 134 pyrheliometers. The six World Standard Group (WSG) and 18 additional pyrheliometers, including the Cryogenic Solar Absolute Radiometer (CSAR), were operated by the WRC staff. We will present the procedures and results of this IPC.

Status of the WSG and WRR

The WSG consists of six absolute cavity pyrheliometers of different make and model: PMO2, PMO5, CROM2L, PAC3, MK67814, and HF18748. All of them except HF18748 have been part of the WSG since its conception in 1977. HF18748 was added to the group in 1990. The six pyrheliometers are mounted permanently on a large solar tracking platform, which is protected from the weather by a sliding cabin. The control units and data acquisition voltmeters are installed in the data acquisition room in the basement of the PMOD/WRC building. The WSG is operated regularly when the sky is clear, resulting in about 60 days of measurement each year. Regular maintenance consists in checking of the alignment before the measurements and covering of the entrance apertures when the tracking platform is in the parking position. The data from the WSG are regularly analyzed in order to detect deviations in any of the six pyrheliometers. Problems can be caused by insects in the receiver cavity or failing electronics parts, such as amplifiers or capacitors. The identification and correction of such problems involves detailed inspection of the affected pyrheliometer and its control unit and requires careful documentation and characterization of all involved parts before and after they are fixed or replaced. Ideally, the effect of the correction on the sensitivity of the pyrheliometer can be calculated based on the characterization of all involved parts. If this is not possible, the affected pyrheliometer is excluded from the WSG until the next IPC, when a new WRR factor can be determined.

The WRR is calculated by applying the WRR factor to the measurement of any of the WSG pyrheliometers. The WRR factors are re-determined during IPCs by calibrating each WSG pyrheliometer against the average WRR from at least four WSG pyrheliometers. This procedure is prescribed by the CIMO Guide (WMO-No. 8). It assures that each WSG pyrheliometer represents the WRR. The re-determination of the WRR during IPCs can also compensate sensitivity drifts in individual WSG pyrheliometers to some degree. A better statistical assessment of the long-term stability of the WSG (and thus the WRR) is achieved by comparing the WRR to a larger number of pyrheliometers which have participated in multiple IPCs. Based on this assessment it can be shown that the WRR was stable to within ±0.05% between consecutive IPCs and that it has drifted less than 0.1% since the first IPC after it was defined in 1977 (see Figure 1).

The future of the WRR as a conventional irradiance scale

The WRR was defined in 1977 as a conventional scale for ground-based solar irradiance measurements in order to homogenize meteorological radiation data world-wide. The absolute accuracy of the WRR with respect to SI base units was originally stated as ±0.3%, which was adequate for most meteorological and climatological purposes. For solar energy applications on the other hand a better agreement between the WRR and SI scales is desirable. The WRC follows a dual strategy to meet this demand by the solar energy industry. First the WRR-to-SI scale ratio was determined using the latest laboratory equipment available. A scale discrepancy of ~0.3% was found by Fehlmann et al. (2012), with the WRR scale yielding higher irradiance values. Secondly, a new Cryogenic Solar Absolute Radiometer (CSAR) was designed and built in collaboration with the National Physical Laboratory (NPL) in Teddington (UK) and METAS in Wabern (Switzerland). The CSAR enables direct traceability of solar irradiance measurements to SI primary standards through participation in BIPM key comparisons alongside other cryogenic radiometers. The CSAR has already participated in
the past two IPCs (IPC-XI, 2010 and IPC-XII, 2015). The preliminary CSAR data confirm the ~0.3% scale offset found by Fehlmann et al. (2012). The CIMO Task Team on Radiation References is currently working out recommendations on how to re-define the WRR through the CSAR and how to ensure homogeneity of world-wide radiation data throughout this process. The Task Team will publish its recommendations for CIMO-17 (2018).

**Outcome of the IPC-XII**

The IPC-XII confirmed the stability of the WRR, and new WRR factors were assigned to the six WSG and 152 participating pyrheliometers based on the data from nine measurement days during the three-weeks IPC period. According to Resolution 1 of CIMO-XI an Ad-hoc Group was established to discuss the preliminary results of the IPC-XII, based upon criteria defined by the WRC, evaluate the reference and recommend the updating of the WRR factors of the participating instruments. Over 40 talks and several posters were presented to the IPC-XII seminar. The results are published in the IPC-XII final report (WMO IOM Report No. 124, 2016).

*Figure 1: The long-term stability of the WSG (and the WRR) is assessed by comparing the WRR to a large number of pyrheliometers during IPCs. The thick lines show the average inter-IPC change (magenta) and the cumulative drift of the WRR (yellow) since IPC-V (1980).*