W O R L D M E T E O R O L O G I C A L O R G A N I Z A T I O N

COMMISSION FOR INSTRUMENTS AND METHODS OF OBSERVATION

CIMO EXPERT TEAM ON METEOROLOGICAL RADIATION AND ATMOSPHERIC COMPOSITION MEASUREMENTS

Second Session

Davos, Switzerland

14-18 September 2009

FINAL REPORT

WMO General Regulations 42 and 43

Regulation 42

Recommendations of working groups shall have no status within the Organization until they have been approved by the responsible constituent body. In the case of joint working groups, the recommendations must be concurred with by the presidents of the constituent bodies concerned before being submitted to the designated constituent body.

Regulation 43

In the case of a recommendation made by a working group between sessions of the responsible constituent body, either in a session of a working group or by correspondence, the president of the body may, as an exceptional measure, approve the recommendation on behalf of the constituent body when the matter is, in his opinion, urgent, and does not appear to imply new obligations for Members. He may then submit this recommendation for adoption by the Executive Council or to the President of the Organization for action in accordance with Regulation 9(5).

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EXECUTIVE SUMMARY

This report provides a summary of the second session of the Expert Team on Meteorological Radiation and Atmospheric Composition Measurements (ET) held in Davos, Switzerland from 14 to 18 September 2009.

In the context of WIGOS, the strengthening of Regional Radiation Centres (RRCs) and the improvement of traceability and quality of radiation measurements is of high importance. Therefore, the meeting decided to undertake a number of activities that would support these purposes and help improve the capabilities in the Regions.

The meeting reviewed and agreed on the plans for holding the Eleventh International Pyrheliometer Intercomparison (IPC-XI) from 27 September to 15 October 2010, conjointly with Regional Pyrheliometer Comparisons (RPCs)[1]. It was decided that the preparation phase of this event would be used to assess the capabilities of RRCs and their needs for training. A specialized training course on radiation measurements, taking into account the information provided by the RRCs will be organized, and given during IPC-XI. It is planned that a certificate of attendance be given to the participants in the course. The ET will be responsible for the development of the syllabus and lectures, which will be distributed to the participants and published as an IOM report to serve as the base of other training on radiation measurements in the Regions.

The meeting reviewed the status of the stability of the instruments of the World Standard Group and provided guidance on their maintenance to PMOD. Comparison between the World Radiometric Reference and the SI showed very good agreement, giving independent confirmation of the procedures used to maintain the WRR over the years. PMOD is developing a Cryogenic Solar Absolute Radiometer (CSAR) that will provide a direct link to SI. In the future, the WRR could possibly be based on the CSAR.

The meeting reviewed the developments made at PMOD and other institutes with respect to infrared radiation measurements. Substantial progress has been made over the last years. The new instruments developed at PMOD show very good agreement with the World Infrared Standard Group (WISG) and therefore provide additional confidence in the values measured by the WISG. Furthermore, the very good agreement between the calibrations obtained using the blackbodies of PMOD and JMA, which have completely different designs, provides additional confidence in the calibration procedure. The meeting provided a number of recommendations related to the further development of infrared measurements and calibrations.

The meeting reviewed relevant chapters of the CIMO Guide and agreed to provide a fully revised version of chapter 7 by the end of 2009 for consideration/approval by CIMO experts. It was noted that a number of ISO standards are relevant to radiation measurements and were originally based on a former version of the CIMO Guide. ISO recently started the review process of those standards. The meeting decided that close cooperation between WMO and ISO was needed to ensure that these standards would continue to meet the needs of WMO in the future and possibly, to develop common ISO-WMO standards when appropriate.

[1] Regional Radiation Comparisons are held during the same period in order to reduce costs. A Regional Radiation Comparison consists of a region's RRCs plus National Radiation Centres.

GENERAL SUMMARY

1. ORGANIZATION OF THE SESSION

1.1 Opening of the session

The second session of the Expert Team on Meteorological Radiation and Atmospheric Composition Measurements (ET) was held at the World Radiation Centre (WRC) in Davos, Switzerland from 14 to 18 September 2009. Mr Bruce Forgan, the Chair of the ET, opened the session. He welcomed the participants in the meeting and thanked PMOD/WRC for hosting this meeting. The list of participants is given in Annex I.

1.2 Adoption of the agenda

The ET adopted the Agenda for the meeting, which is reproduced at the beginning of this report.

1.3 Working arrangements for the session

The tentative timetable for the meeting was agreed upon.

2. REPORT OF THE CHAIR

2.1 Mr Forgan presented a report of ET's activities since its establishment in CIMO-XIV. A number of important results were achieved thanks to the expertise of the ET members and of other co-opted experts.

2.2 He stressed the extremely good agreement that was achieved in the comparison of the World Radiometric Reference (WRR) and the SI, which provides further confidence in the WRR.

2.3 The Regional Radiation Centre of Tsukuba organized a Regional Pyrheliometer Intercomparison (RPC) that was held in Japan in 2007 in which an instrument of the World Standard Group (WSG) took part. A sub-regional pyranometer intercomparison was organized in Croatia for South Eastern Europe. Prior to the ET meeting, the members of the expert team reviewed and endorsed the final report of the intercomparison.

2.4 Advances in infrared[1] irradiance standards and calibration methods were considerable. Topics addressed included the capabilities of blackbodies for pyrgeometer calibration, the derivation method of the calibration coefficients, and the calibration of pyrgeometers with blackbodies and in comparison to the World Infrared Standard Group (WISG). New instrumentation was also developed by PMOD, namely the Infrared Integrating Sphere Radiometer (IRIS), which shows very good agreement with the WISG. This type of instrument could possibly become operational as reference instrument for atmospheric long-wave irradiance.

2.5 Following the recommendation of the previous session of the ET, ISO TC180/SC1 has started the revision of a number of ISO standards. Mr Forgan is chairing that committee. Close cooperation between this ISO sub-committee and the ET is recommended, in particular in view of the recent signing of the ISO-WMO working arrangements.

2.6 Close liaison of the ET with BSRN and GAW continued by having some ET members involved in these communities. BSRN recently finished the observational phase of a pyrheliometer intercomparison that will be highly relevant to the work of the ET.

2.7 Finally, the Chair mentioned that traceability was a topic that has not been given sufficient attention. He stressed that the team must thoroughly review the CIMO Guide chapter relevant to radiation, keeping in mind that the CIMO Guide be relevant to all NMHSs - from developed to developing countries, and covering adequately all the issues that are presently relevant to NMHSs.

[1] The terms "far infra-red", "infra-red", "long-wave" and "terrestrial" radiation are equivalent for the purpose of this document and represent radiation in the interval 3 – 50 μm.

The CIMO Guide should also inform them on the quality of observations that can be achieved with the different systems presented in it.

3. WMO INTEGRATED GLOBAL OBSERVING SYSTEM

3.1 The meeting was informed about the development of the WMO Integrated Global Observing System (WIGOS) and that Pilot Projects and Demonstration Projects had been established to test the concept. The three areas of standardization were presented and it was mentioned that standardization activities would be expected to be carried out in this context.

3.2 The ET recognized that its work was highly relevant to the development of WIGOS. In particular, the maintenance and dissemination of the WRR through the International Pyrheliometer Intercomparison (IPC) and RPCs are crucial in ensuring the traceability of radiation measurements. This situation is unique in that this is the only primary standard for which WMO has responsibility. All other primary standards are maintained by national metrology institutes.

3.3 The ET decided that it would provide a major contribution to WIGOS in the time remaining in this inter-sessional period by reviewing a number of chapters of the CIMO Guide. It was recognized that the meteorological community is putting more emphasis on operational meteorology and investing only very limited resources in climate issues. The ET should consider this when developing guidance and standards for the CIMO Guide. In addition, the ET should have a strong liaison with ISO to ensure that the ISO standards continue to meet the requirements of the meteorological community. Finally, the ET could help in improving further the quality of radiation measurements by investing significant effort in training activities for RRCs.

3.4 The ET expressed concern that the traceability of radiation measurements at the national level has tended to decrease as NMHS were focussing more on applications that require lower quality observations and investing less in the fulfillment of international obligations related to climate monitoring, for example. The ET stressed that the need for traceable data identified in WIGOS requires sustainable networks requiring substantial investments and sustained funding for on-going maintenance. The meeting also noted that there was increasing demand for radiation data by the energy industry.

4. TRACEABILITY OF SOLAR RADIATION MEASUREMENTS AND RELATED MATTERS/ACTIVITIES

4.1 Stability of the WRR and statistical basis for the WRR factors

4.1.1 Mr Finsterle presented the status of the World Standard Group instruments and their stability. Since the last International Pyrheliometer Comparison (IPC-X) in 2005, the WRR appeared to be stable. However, a couple of individual WSG instruments experienced problems. In particular, HF 18748 suffered from sudden drops in its sensitivity twice in late 2006 and early 2007. In case it does not recover or cannot be repaired, the statistical basis for the WRR factors would be reduced in the upcoming IPC-XI (2010).

4.1.2 Following the recommendation of the CIMO-ET meeting in February 2006 the WSG instrument PMO2 was repaired under tightly controlled conditions. After reparation, the PMO2 compared to the WRR exactly as expected. The WRR factor remained valid and the instrument is stable. As PMO-2 was now performing well again, the ET recommended that PMOD investigate in further detail the problems of the HF18748 and suggested that PMOD/WRC contact Eppley Laboratory to assist in this matter.

4.1.3 The WSG instrument PAC3 shows an annual undulation. This instrument is not used as a reference for calibrations but only to calculate the WRR factors during IPCs. Since the IPCs always occur at the same time of the year the annual undulation does not affect the WRR factors. The ET recognized that it was of utmost importance that the IPC always take place at the same time of the year in Davos, rather than at different locations/time with other climatic conditions as had been envisaged some years ago. This would ensure the best possible maintenance and transfer of the WRR over the years.

4.1.4 The ET was informed that the SIAR-type instruments manufactured in China that are future candidates for the WSG showed some bimodal distributions and had experienced shutter problems. The ET recommended that PMOD contact the manufacturers to seek advice on these problems. The ET was very concerned by the small number of manufacturers building absolute cavity radiometers.

4.1.5 PMOD undertook laboratory intercomparisons of the WRR with the cryogenic standard of the National Physical Laboratory (NPL, UK) to verify the compatibility of the WRR with the SI system of units (Metrologia, 2008, Vol. 45, p.377). This showed a very good agreement between the WRR and the SI with lower uncertainty than the results obtained from previous intercomparisons. This provided additional confidence in the process used in maintaining the WRR. The ET complimented PMOD for these excellent results.

4.1.6 A joint project of PMOD/WRC, NPL, and METAS (Bern, Switzerland) was launched to design and build a Cryogenic Solar Absolute Radiometer (CSAR). The main goal of the CSAR project is to fully integrate the Total Solar Irradiance (TSI) measurements in the SI system of units. The CSAR will be able to participate in BIPM key comparisons and thus provide the missing link between the WRR and the SI. In the future, it could be envisaged to base the WRR on the SI through the CSAR, provided it meets its expected capabilities and demonstrates sufficient long-term stability. In such a case, there would be the need to formalize the process on how and how often CSAR would be compared to the WSG.

4.1.7 The meeting was informed that the majority of the calibrations performed at PMOD were made for solar energy industry customers and that this demand had increased strongly in recent years. It was recognized that similar requests might also come to RRCs. However, the meeting was also informed that metrology institutes were apparently interested in entering the business of calibrating pyrheliometers and pyranometers.

4.2 Preparation of IPC-XI

4.2.1 Mr Finsterle presented the plans of PMOD to hold the next IPC from 27 September to 15 October 2010. The ET supported the proposal and stressed that holding the IPCs at regular time intervals was crucial to meeting the needs of clients for traceability of radiation measurements. The ET recognized that this was a unique contribution of CIMO to WIGOS and to the even larger community interested in radiation measurements. The ET noted that the IPC provides the basis for all meteorological radiation measurements and that this cannot be provided by any other institute or by any other means at present. The ET recommended that the cycle of 5 years between each IPC be strictly followed to meet the needs of those communities.

4.2.2 PMOD/WRC is presently developing a new data acquisition system that should be available for IPC-XI. This system would provide a web interface for Angström operators, and probably also for operators of automated data acquisition systems, to ingest their data into the IPC data acquisition computer.

4.2.3 The ET agreed that the 90 s sampling period for radiometers would remain the same as in the past. However, PMOD would investigate the possibility for certain types of instruments to provide intermediate values.

4.2.4 Mr Finsterle indicated the need to have closer interaction with the RRCs and proposed to enforce a report from RRCs on their activities in the last 5 years during the Symposium that is usually held together with the IPC. The ET supported this proposal. In view of training as many people as possible, the ET agreed that the IPC could be combined with RPCs for some or all Regions.

4.2.5 In view of the increased interest for traceability to the WSG by the solar energy industry, the ET was concerned that PMOD might be overstreched with too many groups desiring to participate in IPC-XI. Therefore the ET recommended that the total number of participants should not be above 70 and that priority of participation be as follows:

- RRC
- Manufacturers that contributed to the WSG,
- Instruments that participated in the last IPC (NRC and commercial)
- NRC that did not participate in last IPC
- Commercial that did not participate in last IPC,
- Other participants at discretion of PMOD

4.2.6 Mr Finsterle compiled a new questionnaire for Regional Radiation Centres (RRCs) and National Radiation Centres (NRCs) in order to advertise/check/enforce the updated terms of reference of RRCs and NRCs. The questionnaire would be sent to all RRCs and NRCs together with the first announcement and would have to be returned together with the registration for IPC-XI (see further details in sections 4.4 and 6.2).

4.3 Other plans for intercomparisons of pyrheliometers and pyranometers

4.3.1 A pyrheliometer comparison was conducted between November 2008 and September 2009 at the National Renewable Energy Laboratory in Golden, Colorado, USA, under the auspices of the Baseline Surface Radiation Network (BSRN) Working Group (WG) on Direct Solar Measurements. Participants and manufacturers were asked to contribute three specimens of each unique type of pyrheliometer; however, the study did include one-of-a-kind instruments. Manufacturers included Eppley, Hukseflux, Kipp and Zonen, Matrix, and Middleton. Although EKO was contacted through its U.S. representative, no EKO pyrheliometers were in the study. In total, there were 33 pyrheliometers. One-minute averages of two-second samples were made for all conditions during the 10-month study. Almost every month all pyrheliometers were calibrated using an open cavity that was traceable to the WRR. Ancillary meteorological measurements of temperature, humidity, wind speed, and wind direction were made near the experiment venue. A preliminary sample of two weeks of measurements in the middle of the period was presented to the meeting. Thirty-three unlabeled histograms with overplots of cumulative frequency distributions were shown. The data in these plots were one-minute differences between each instrument and the mean of the four HF windowed cavity radiometers in the study. An independent analysis has been suggested, and the ET provided a number of suggestions for the analysis.

4.3.2 Mr Emanuele Vuerich informed the meeting that the Italian Meteorological Service would be willing to host future intercomparisons of radiation instruments at its site of RESMA, in Vigna di Valle, Italy. He presented in detail the proposed Vigna di Valle site, its staff/observers, and its infrastructure; including its measuring platforms and data acquisition system, which could accommodate up to 100 instruments if needed. A working group was established in Italy to develop a detailed intercomparison proposal. However, at this stage, Italy preferred to offer the site to the meteorological community and let the ET and CIMO decide on the most urgently needed intercomparison rather than make a detailed proposal that may not meet their needs. Mr Vuerich stressed that the present interest of Italy in field measurements were in particular for sunshine duration, pyranometers, pyrheliometers, and UV measuring instruments. The ET welcomed this offer and expressed its thanks to Italy.

4.3.3 Mr Vuerich also informed the meeting that measurements were presently running in Vigna di Valle (Italy) and Carpentras (France) to test and intercompare the results obtained with the pyranometric methods and the sunshine duration measuring instruments, like Campbell-Stokes. The study aims to assess the benefits obtained by performing sunshine duration and global irradiance measurements by means of 2 independent instruments (a pyranometer and a sunshine duration detector) with respect to one radiation instrument (pyranometric method). The ET was very pleased to hear that such a study was taking place as its results are needed by the meteorological community for guidance, as well as by the ET to update the CIMO Guide (see also Chapter 8 of the CIMO Guide), particularly on the uncertainty of sunshine measurements. The ET invited Italy to provide the report of this intercomparison to the ET and encouraged Italy to publish it also as an IOM report.

4.3.4 The ET stressed the need for IPCs to occur regularly, at least every 5 years and that RPCs be organized in the next inter-sessional period, at the latest in 2014.

4.3.5 The ET recognized that not all users will require high-quality observations for their particular needs, but the focus of investigations in recent years has been only on the highest-quality of observations. The ET discussed the possible interpretation of Table 7.5 (Characteristics of operational pyranometers, CIMO Guide) by various users. This discussion resulted in the ET encouraging Members to investigate the characteristics of good and moderate quality instruments using the latest characterization techniques that have been applied to high-quality instrumentation. This may result in NMHSs being able to optimize their networks to their needs.

4.4 Evaluation/auditing of Regional Radiation Centres

4.4.1 Mr Forgan informed the ET that no paper audit of the RRCs had been undertaken because some RRCs indicated confusion on their requirements and interpretation of these requirements after circulation by WMO of the revised Terms of Reference of Regional Radiation Centres (CIMO Guide, Annex 7.C). Discussion ensued and the ET agreed that each of its members would test the revised Terms of Reference of RRCs on his own RRC and inform the Chair on their results by the end of 2009. Following these results, the ET would decide on the need to clarify those terms of reference or whether providing some simple practical example would be sufficient.

4.4.2 Furthermore, the ET decided to distribute a questionnaire to potential participants of IPC-XI that would provide an initial paper audit of the traceability of RRCs by providing information on their status. This would provide the basis for adapting the scope of the training course on radiation measurement that would be held during IPC-XI to the needs of RRCs (see section 6.2). That questionnaire could be followed up after the IPC. The ET endorsed the draft questionnaire provided in Annex II, recommended to the Secretariat that this questionnaire be translated into English, French, Spanish, and Russian, and sent to RRCs together with the invitation to participate in IPC-XI.

4.4.3 The ET recognized that it would be valuable if audits of opportunity could be carried out by competent experts. The ET therefore requested Mr Forgan to inquire at the next BSRN meeting whether some experts would be willing to support CIMO in that respect and to inform him on their plans of travel at locations near RRCs.

5. TRACEABILITY OF ATMOSPHERIC RADIATION MEASUREMENTS AND RELATED MATTERS/ACTIVITIES

5.1 Status of the Infrared Radiometry Section of PMOD/WRC, the WISG and traceability of pyrgeometers, including relevant recommendations on infrared calibration procedures

5.1.1 Mr Gröbner provided an update on the development of infrared (IR) standards at PMOD/WRC, including the development of a second black body whose use clearly demonstrated the stability of the WISG. He also described the development of two new IR pyrgeometers utilizing pyroelectric detectors, IRIS-I and IRIS-II. After calibration in the PMOD blackbody IRIS-I was run against the WISG for close to a year and the agreement was within 4 Wm^{-2}. Initial tests suggest the possibility of a minor seasonal variation in the WISG when compared to the IRIS-I and several other pyrgeometers that have been compared with the WISG in recent time. Mr Gröbner plans to investigate these differences by commencing a measurement series with IRIS-II and by examining the impact of the differences in the IPASRC-1 and IPASRC-2 calibrations, the former being used to assist in the development of the WISG. Mr Gröbner indicated that the estimate of the 95% absolute uncertainty of the WISG was of the order of 5 Wm^{-2} and relative calibrations of the order of 1 Wm^{-2}.

5.1.2 Mr Gröbner asked the ET to consider the possibility of a pyrgeometer comparison concurrent with the IPC-XI, but with participation limited to the RRCs. The ET welcomed this proposal.

5.1.3 The ET expressed its pleasure at the efforts of Mr Gröbner in making significant strides during the last 3 years in confirming the uncertainty of the WISG IR standards, and the development of two new instruments based on different measurement principles that seem likely to improve IR standards and, most importantly, the field transfer of calibrations. The ET was encouraged by the development of pyrgeometers using a measurement principle other than the thermopile, and that this new instrument showed excellent agreement with thermopile-type pyrgeometers. This instrument also offers the potential to measure directly the output irradiance of RRC blackbodies and other key blackbodies without the use of optical filters.

5.1.4 Mr Ohkawara presented a paper about the new Japanese RRC blackbody that was developed to calibrate pyrgeometers for use in the JMA network. Also presented were comparisons between two calibrations by JMA in the new JMA blackbody and one at PMOD of the same pyrgeometer; the agreement between the coefficients from the three calibrations was excellent. He also described the plans for four additional BSRN stations that will be started in the next few months.

5.1.5 The ET expressed great pleasure in the development of the JMA blackbody, its different design to the PMOD systems, and the remarkable agreement between the calibrations, as it increases confidence in blackbody calibrations to provide consistent results of key pyrgeometer equation coefficients.

5.1.6 Mr Forgan gave a short presentation on preliminary work to develop a field calibration method to determine the dome-body coefficient of an Eppley PIR using sun-shade methods and broadband Schott glass filters. Initial results suggested that the method would not succeed if the PIR dome transmits solar irradiance below the nominal IR cut-on, as the impact of transmitted solar radiation is proportional to the dome heating. Other results presented by Mr Forgan suggested that Kipp & Zonen CG4 thermopile output gives anomalous transients of the order of 2 Wm^{-2} and last for about 40 s when the dome is subjected to rapid changes in solar exposure. Mr Forgan also presented some preliminary results of a study with Mr Gröbner and Mr Reda on the reanalysis of data used to calibrate 5 pyrgeometers both at NREL and PMOD. The preliminary results indicated that the process at PMOD to perturb the pyrgeometer dome directly and independently of the body temperature allowed better repeatability in deriving the dome-body coefficient.

5.1.7 The viability of restoring the ASR to working order was discussed during the IR sessions, and the possibility of comparing the IRIS with the ASR. Mr Gröbner indicated that restoring the ASR would require external interest and assistance. Also discussed was the significance of the T^3 term in the Philipona pyrgeometer equation and whether in practice it represented the multiple scattering between the dome and sensor surface or a representation of the temperature response of the thermopile.

5.1.8 As a result of the discussions on IR the ET:

- Congratulated PMOD and Mr Gröbner on the success of the IR developments over the last 3 years.
- Encouraged PMOD to continue doing the developments on the new pyrgeometer designs;
- Encouraged other WMO members to build alternate black bodies, instrumentation and absolute radiometers for pyrgeometry
- Encouraged further investigations on the impact of solar exposure on pyrgeometry
- Congratulated the JMA on developing their new blackbody and the excellent results they have achieved in traceability to the WISG.
- Recommended that any blackbody procedure for calibrating pyrgeometers incorporates a phase in the calibration that forces at least a 1 K temperature differential between the dome and body.
- Encouraged Mr Gröbner to set-up an inter-comparison of pyrgeometers from RRCs at IPC-XI.

- Encouraged interested parties to work with PMOD to restore the ASR for atmospheric IR measurements

6. IMPROVEMENT OF RADIATION MEASUREMENTS IN NATIONAL RADIATION NETWORKS

6.1 Review of the quality of radiation measurements in national networks

6.1.1 Mr Behrens reported on the quality of radiation measurements in national networks. NMHSs publish their radiation data in WMO's WRDC (since 1964) in St. Petersburg, Russia, where all incoming data are checked, and in recent time dubious values are flagged in the WRDC issues, which are published quarterly as pdf files.

6.1.2 While WRDC gave presentations about its work at a BSRN session, for example, it seems that the WRDC does not publish an easily accessible written report or survey about the data quality.

6.1.3 A comparison of the WMO Members that participated at IPC-X and the WMO Members that delivered data to WRDC between 2006 and 2008 showed that the majority of the IPC participants sent data to the WRDC, while a minority of IPC participants do not send data. Conversely, many countries/NRCs did not participate at IPC-X but sent data to the WRDC. These facts give an impression about the problems of an unknown quality of radiation data in national networks. However, the ET noted that a number of NMHSs wanted to give high quality data to the WRDC and did not submit the data until after the publication of the quarterly bulletin.

6.1.4 The ET recommended that WRDC provide a written report to the ET about the current status of the radiation data quality in the WRDC archive up to December 2009, in particular, noting any instrument and/or measurement problems they have encountered, so that the ET could provide any needed help to the WRDC and give recommendations to CIMO-XV

6.1.5 The ET also recommended that WRDC publish the QA/QC algorithms it uses so that Members could perform their own data quality check prior to submitting the data to WRDC.

6.2 Training course in radiation measurement

6.2.1 Mr Ohkawara and Mr Forgan presented a report addressing the need for a training course on radiation measurements. The ET supported the recommendations presented in the report and noted that the majority of the recommendations were in line with previous discussions concerning the preparation of the IPC and for the strengthening of RRCs.

6.2.2 The ET recognized that though various documents providing information on radiation measurements existed, the nature of that information was rarely in a form suitable for maintenance of standards, calibration and propagation of traceability in a network. The implicit consequences are that the quality of radiation data still varies considerably from Region to Region and from country to country, and that there is a need for a suitable training methodology on radiation measurement.

6.2.3 The ET agreed that an excellent model for distributing knowledge on radiation metrology is the seminar series held every 5 years in conjunction with the IPC. It was agreed that a training course on radiation measurements focusing primarily on the needs of RRCs would be held in conjunction with IPC-XI. This course would help ensure that uniform standards are used by all RRCs. This training course would be mandatory for RRCs participating in the IPC and each participant would be awarded a certificate of attendance. Space permitting, other IPC participants would be welcomed to attend the course too. The training material developed for the course could later be used to assist the RRCs in conducting training courses in the Regions.

6.2.4 To ensure that the training is relevant, the ET recognized that it is important to gain an understanding of the actual situation in each RRC. It is intended to obtain this information through the questionnaire discussed in section 4.4.

6.2.5 To ensure the success of such training, it is essential that an agreed and uniform set of study notes and support material be provided as part of the training course. Study materials for the training course should be practical so that following the course all of the participants will be able to improve the outputs and quality of operational national networks through a clear focus on propagating WRR and WISG traceability to the operational instruments. The notes should also contain basic information on measurement and uncertainty in measurements, radiation, and descriptions of instrumentation, including maintenance and installation. The course material will translate the information summarized in the CIMO guide and ISO standards into practical guidance.

6.2.6 To assist in the development of the training materials, the ET encouraged its members and their associated colleagues to provide any existing materials on radiation metrology and equipment installation to Mr Finsterle and Mr Forgan by the end of November 2009. ET participants recalled a number of presentations and seminars held at previous IPCs and encouraged PMOD to recover these materials as a means of assisting in the development of this certificate course. Mr Finsterle and Mr Forgan agreed to coordinate the development of the training syllabus and material.

6.2.7 The ET recommended that its members investigate the possibility of the course being recorded so that it could be made available later on a DVD or on the web.

6.2.8 The ET also recommended that the course presentations and syllabus be published as an IOM report following the IPC.

7. OTHER ACTIVITIES RELATED TO METEOROLOGICAL RADIATION MEASUREMENTS AND LIAISON WITH OTHER COMMUNITIES

7.1 Liaison with WCRP on Matters related to Baseline Surface Radiation Network

7.1.1 Mr Behrens reported on the liaison with the World Climate Research Programme (WCRP) on matters related to Baseline Surface Radiation Network (BSRN).

7.1.2 The BSRN community was informed at the BSRN session in June 2006 about the outcome of the first session of the ET-MR&ACM. The radiation networks of the National Meteorological Services profit from the fulfilled objectives within BSRN to improve the uncertainties of broadband radiation measurements, especially in the infrared region. Conversely, BSRN could use the results and experience of the IPCs, which were organized within CIMO.

7.1.3 BSRN is continuing its successful development, in particular by becoming a part of GCOS. Furthermore, the BSRN is recognized as the most important source of surface radiation data, mainly because of its high quality observations. Over the last several years, the activities of the BSRN focused mainly on data collection and on the transition of the data archive from ETH Zurich to AWI Bremerhaven. The ET complimented ETHZ and AWI Bremerhaven for the smooth transition of the archive. Nevertheless, other projects investigating and improving the measurements continued and new projects were started as mentioned above (see section 4.3).

7.1.4 The ET recognized that the collaboration with BSRN was very fruitful. In particular, it provided a welcomed support for including new information in the CIMO Guide. The ET recommended that the fruitful co-operation between CIMO and BSRN be continued.

7.2 Liaison with CAS related to Operational Practices of Total Ozone, UV and Aerosol Optical Depth Measurements

7.2.1 Mr McArthur presented a report on past and on-going activities of the Global Atmosphere Watch (GAW) Scientific Advisory Groups (SAG) for Ozone, UV Radiation and Aerosol Optical Depth. The report recognized the high quality work accomplished in each of these groups.

Further, it indicated that a number of the activities undertaken within the SAGs were of particular importance to observing practices and should be included in an up-date of the CIMO Guide.

7.2.2 Specifically, the work completed by the SAG-UV on observations of UV irradiance by spectrometers and erythemal broadband sensors was recommended to be incorporated in the appropriate sections of the Chapter on "Measurement of Radiation". The report indicated, however, that a similar document on the measurement of UV irradiance using filter-type instruments had yet to be completed so that the ET seek independent expertise in up-dating this section, rather than waiting for the SAG. While reports published by the SAG-UV on quality assurance and the establishment of observation sites were helpful, they were not found to provide significantly more or better information than what was already in the Guide on these topics.

7.2.3 Work by the SAG-Ozone has been extensive and wide-ranging. Along with other working groups within and external to the WMO (e.g., Network for the Detection of Atmospheric Constituent Change (NDACC)), the documentation presently available surpasses the completeness and detail that could be written for inclusion in the CIMO Guide. Therefore, the report recommended that any further amendments made to the Ozone Chapter be such that the available documentation provided by the SAG-Ozone, the Dobson community and the Brewer User Group be referenced and/or included and/or linked electronically as a means of improving surface-based observations of stratospheric ozone. Similarly, it was recommended that the NDACC standard operating procedures developed for ozone sondes be recognized.

7.2.4 The SAG-Aerosol is primarily tasked with work within the domain of atmospheric chemistry, with only a sub-group involved in the measurement of aerosol optical depth (AOD). Therefore, little was reported on the activity of this SAG over the period since the last ET meeting. Nevertheless, the ET strongly supports the SAG-Aerosol activities in ensuring that the various international networks measuring AOD work together to provide comparable data. The ET was pleased to hear during the meeting that the World Optical Depth Research and Calibration Centre (WORCC) was to hold a comparison of instruments measuring aerosol optical depth in conjunction with the next International Pyrheliometer Comparison (IPC-XI) in 2010.

8. REVIEW OF THE CIMO GUIDE AND OTHER STANDARDS

CIMO Guide

8.1 The meeting addressed the revision of the CIMO Guide chapters that were relevant to the ET Terms of Reference.

Chapter 7 "Measurement of Radiation"

8.2 The meeting reviewed Chapter 7 and made a number of corrections. The ET further agreed to continue making improvements and to provide a fully revised version of this chapter to the WMO Secretariat by the end of November 2009. As the Revised Instruction Manual on Radiation Instruments and Measurements (WMO, 1986) was a key reference of this chapter and as this document was not available anymore, the ET recommended that the WMO Secretariat consider making a PDF document available on the WMO website. The ET decided to consider whether additional guidance on inexpensive systems was needed, as such systems are broadly used. Additional guidance on the temporal and climatological environments in which calibrations are performed on these instruments is also needed to ensure that users know the actual quality of the data rather than the best achievable.

Chapter 8 "Measurement of Sunshine Duration"

8.3 The ET expressed some concern about the future of the Chapter 8 "Measurement of Sunshine Duration" and particularly the unavailability of some documents referenced in the chapter. The meeting was informed by Mr Vuerich that Italy and the RRC of Carpentras (France) were presently conducting a study about measurements of sunshine duration by the pyranometric method (see section 4.3). The ET therefore decided to defer any discussion of revision of this chapter until the provision of the report from this study, expected to be ready by June 2010.

Chapter 16 "Measurement of Ozone"

8.4 Mr McArthur was asked by the ET to seek advice from the CAS/GAW Ozone-SAG on possible revisions of the chapter and in particular on the inclusion of advice on ozone sonde measurements and to coordinate the revision and inclusion of new material in this chapter.

Chapter 17 "Measurement of Atmospheric Composition"

8.5 The review of Chapter 17 "Measurement of Atmospheric Composition" is part of the mandate of the ET. This chapter includes very brief descriptions of a variety of variables, including Greenhouse Gases, particulates, ozone, and wet and dry deposition. The ET recognized that this chapter, as written, does not provide enough information on any of the atmospheric variables considered, nor does it provide quality information on how these variables should be measured in a manner that is useful. Furthermore, many atmospheric chemicals of interest to the chemical weather or toxics communities are not addressed within the chapter. The ET recognized that it was beyond its capability to update this chapter. The ET recommended that the future of this chapter with respect to its place within CIMO and in the CIMO Guide be considered. The ET recommended to the CIMO Management Group that CAS GAW be invited to update this chapter in the same spirit as the other chapters or Part I "Measurement of Meteorological Variables" of the Guide or to provide a high-quality overview of air chemistry measurements (e.g. IGACO) that would be published in Part II "Observing Systems" instead of Part I. The ET further recommended that CAS GAW be responsible for ensuring that it be updated as necessary.

9. WORK PLAN

9.1 The meeting reviewed the work plan for this inter-sessional period and agreed on the deadline for delivery of the various contributions as provided in Annex IV.

9.2 The ET took into account the needs of the community in developing a list of topics that should be addressed in the next inter-sessional period as provided in Annex V. The ET agreed that some of the tasks are of a continuous nature and should be included in the plan for the next inter-sessional period. The ET attempted to place them in order of priority.

10. ANY OTHER BUSINESS

Collaboration with BIPM

10.1 Mr Schmutz provided background on the relationship between PMOD/WRC, METAS, and the BIPM. The WRR is a WMO standard and PMOD/WRC is in charge of maintaining the WRR for WMO. PMOD is now a signatory of the BIPM mutual recognition agreement (MRA) as a designated institute of METAS; there are 74 other organizations or institutes that are signatories of the MRA and the majority are national measurement institutes. A process is in place to make WMO a signatory, and hence the WRC would have two pathways to the MRA system. The MRA means that PMOD will participate in periodic comparisons with other similar status organizations to compare the relationship to the Watt through cryogenic radiometry.

10.2 Calibrations of pyranometers and pyrheliometers have been audited at PMOD under ISO 17025 and registered with METAS and hence the MRA with BIPM was possible.

10.3 Mr Schmutz also informed the meeting that a research proposal on "Metrology for Solar Cells and Solar Thermal Conversion" would be submitted to the European Metrology Research Programme. That proposal recognized that European manufacturers were technology leaders for solar thermal technology and considered the following topics as key for improvements: the calibration uncertainty of reference pyrheliometers, as well as the establishment of full SI traceability, and the calibration procedures for pyranometers to reduce uncertainty levels.

10.4 The ET congratulated WRC for these developments and the recent work to confirm the relationship of the WRR to SI. The meeting also recognized that this was extremely important to provide a direct link to other accreditation bodies.

10.5 The Chair of the meeting requested that during future discussions between the BIPM working group and Mr Schmutz, he determine if IEC 60050-845 is still the relevant standard on radiation and lighting vocabulary and report back to the ET.

Collaboration with ISO

10.6 The meeting was informed about the recent signature of the Working Arrangements between WMO and ISO that allowed the development of common ISO-WMO standards.

10.7 Mr Forgan briefed the meeting on the activities of the ISO TC180 sub-committee 1 on solar climate monitoring and its program to revise the 6 solar standards currently active. The six ISO standards are :

- ISO 9488 - Vocabulary
- ISO 9060 – Specification on instruments
- ISO 9050 – Calibration of field pyrheliometers by a reference pyrheliometer
- ISO 9846 – Calibration of pyranometer by pyrheliometer
- ISO 9847 – Calibration of pyranometer by reference pyranometer
- ISO 9845 – Spectral irradiance standard

10.8 Mr Forgan outlined the history of the relationship between the CIMO Guide and the ISO solar standards. The ISO standards were begun in the early 1980s by Mr Dehne of the German Meteorological Service and were developed from the 1970s version of the CIMO Guide and IEA studies and approved by ISO in the early 1990s. Subsequently, the CIMO Guide was revised in the early 1990s, aligning the radiation chapters to the key ISO nomenclature definitions provided in IEC 60050-845 and the ISO Guide to the Expression of Uncertainty in Measurement (GUM). The ISO solar standards have not been revised since being created and do not include GUM processes. It was at the instigation of Mr Schmutz in 2006 at the last ET meeting that a process was begun that resulted in Mr Forgan being appointed as chair of TC180/SC1 and the revision of the ISO solar standards began. A further development was the recent establishment of a MoU between ISO and the WMO. All these developments provide an opportunity to better align the CIMO Guide and the relevant ISO solar standards.

10.9 Mr Forgan indicated that ISO 9488 (vocabulary) will be the focus of a meeting of TC180/SC1 in October 2009 and a working group has been established from members of ISO; Mr Schmutz is a member of this working group. A ballot was also conducted and it has been agreed that ISO 9060 needs to be revised. Mr Finsterle is also assisting in TC180/SC1 with a preliminary investigation into the revision of ISO 9847 and ISO 9846.

10.10 To assist in the revision process Mr Forgan asked the members of the ET to examine ISO 9488 and provide him with feedback.

10.11 The meeting then discussed these activities and concluded that common standards between ISO and WMO were possible. However, there were issues on whether the common documents would be able to have the status of a manual under WIGOS as ISO standards are prescriptive by their nature. Mr Vuerich indicated that there are three levels of documents in ISO: technical reports, technical specifications and standards, and hence, there may be other ways to accommodate common ISO and WMO documents. The ET recommended that WMO give clear guidance to the Technical Commissions on whether all common ISO-WMO standards would necessarily have the status of Manuals or if they could also have the status of Guides in the WMO regulatory document structure.

10.12 The ET agreed that it was very important to continue the linkage between the ISO solar standards and the CIMO Guide. The ET supported the activities in TC180/SC1 and encouraged Mr Forgan to ensure WMO radiation experts continued to participate in the revision of these ISO standards. The ET recommended that the WMO Secretariat took the necessary step for WMO to participate in the revision of these standards and possibly have them as common ISO-WMO standards in the future, if appropriate and to inform the ET members on the procedure.

11. DRAFT REPORT OF THE SESSION

The meeting reviewed the preliminary version of the final report and decided to adopt the final report of the session by correspondence

12. CLOSURE OF THE SESSION

The session was closed on 18 September 2009 at 16:10 h.

List of participants

Mr Bruce FORGAN ***Chair***	Bureau of Meteorology Data Quality and Improvement Section G.P.O. Box 1289 Melbourne, Vic 3001 Australia tel.: +(61 3) 9669 4111 fax: +(61 3) 9669 4736 b.forgan@bom.gov.au
Mr Bruce McARTHUR	Science and Technology Branch Environment Canada 4905 Dufferin Street DOWNSVIEW, Ontario Canada M3H 5T4 tel.: +(1 416) 739 4464 fax: +(1 416) 739 4281 Bruce.McArthur@ec.gc.ca
Mr Klaus BEHRENS	Deutscher Wetterdienst Meteorologisches Observatorium Lindenberg OT Lindenberg Am Observatorium 12 D-15848 Tauche Germany tel.: +(49 33) 677 60 151 fax: +(49 33) 677 60 280 klaus.behrens@dwd.de
Mr Nozomu OHKAWARA	Ozone and Radiation Division Aerological Observatory Tsukuba Japan Meteorological Agency 1-2 Nagamine Tsukuba City Ibaraki 305-0052 Japan tel.: +(81 2) 9851 4424 fax: +(81 2) 9851 5765 ohkawara@met.kishou.go.jp
Mr Wolfgang FINSTERLE	Physikalisch-Meteorologisches Observatorium Davos (PMOD) World Radiation Center (WRC) Dorfstr. 33 CH-7260 Davos Dorf Switzerland tel: +(41 81) 417 5153 fax: +(41 81) 417 5100 wolfgang@pmodwrc.ch
Mr Julian GRÖBNER **Invited expert**	Physikalisch-Meteorologisches Observatorium Davos (PMOD) World Radiation Center (WRC) Dorfstr. 33 CH-7260 Davos Dorf Switzerland tel.: +(41 81) 417 5157 fax: +(41 81) 417 5100

	julian.Groebner@pmodwrc.ch
Mr Joseph MICHALSKY **Invited expert**	NOAA ESRL 325 Broadway R/GMD BOULDER, CO 80305 USA tel.: + (1 303) 497 6360 fax: +(1 303) 497 6546 joseph.michalsky@noaa.gov
Mr Emanuele VUERICH (part-time) **Invited expert**	Italian Meteorological Service ReSMA Centre Via Braccianese Claudia Km 20,100 0062 Vigna di Valle ROME Italy Tel.: +39 06 9988 7701 Fax: +39 06 9987 297 vuerich@meteoam.it
Mr Werner SCHMUTZ (part-time) **Representative of BIPM**	Physikalisch-Meteorologisches Observatorium Davos (PMOD) World Radiation Center (WRC) Dorfstr. 33 CH-7260 Davos Dorf Switzerland tel.: +(41 81) 417 5145 fax: +(41 81) 417 5100 w.schmutz@pmodwrc.ch
Mr Joop MES **Representative of HMEI**	KIPP & ZONEN B.V P.O. Box 507 NL-2600 AM Delft The Netherlands tel.: +(31 15) 2755 244 fax: +(31 15) 262 03 51 joop.mes@kippzonen.com
WMO SECRETARIAT 7 bis, avenue de la Paix CH-1211 Geneva 2 Switzerland	**WWW website** www.wmo.int/web/www/www.html
Ms Isabelle RUEDI	Senior Scientific Officer Observing System Division OBS Department tel.: +(41 22) 730 8278 fax: +(41 22) 730 8021 iruedi@wmo.int

QUESTIONNAIRE FOR REGIONAL RADIATION CENTRES

Regional Radiation Centre:.....
Respondant:.....
Respondants contact details:.....

1) How many pyrheliometers do you have in your standard group (types and S/N)?
2) Do you know the uncertainty of each of these instruments? YES/NO
   a) If yes: How was the uncertainty obtained for each of the instruments?
3) What type of data acquisition system do you use for the standard group?
4) How frequently do you calibrate your data acquisition system for the standard group?
   a) When was it last calibrated?
5) How many people are involved in maintaining and using the standard group?
   a) What are the qualifications of these people?
   b) What metrology training have these people received?
6) Does your RRC have a quality management system (e.g. ISO 17025, ISO 9001, or internal procedures)? YES/NO
   a) If yes: Briefly describe your quality management system.
7) Is the RRC audited in any way (internally or externally)? YES/NO
   a) If yes: When was it last audited?
8) How frequently do you intercompare the radiometers of your standard group?
   a) What are the results of the latest intercomparison?
   b) Did any of the standard radiometers change with respect to the group and by how much?
9) How do you maintain the traceability of your standard group to the WRR?
   a) How many of your standard group have participated in an IPC/RPC?
10) What would you find most useful in a training course on radiation measurement?

PROGRAMME FOR TRAINING COURSE ON RADIATION MEASUREMENTS

Introduction to Radiation and Radiometers (Rolf Philipona 2000)

Basic instrument and equipment setup (incl. hands on demonstration)

1. data acquisition
2. pyranometer setup
3. pyrheliometer setup
4. pyrgeometer setup

Measurements and Calibrations

1. Sources and quantifying errors
2. Calibration hierarchies (incl. maintaining a standard group)
3. Calibration methods against reference instruments (incl. practical work on data sets with excel sheets)
   a. pyrheliometers
   b. pyranometers
   c. pyrgeometers against a reference pyrgeometer
4. Calibration repeatability (calibration conditions)

Quality Management and Quality Assurance

1. Documentation
2. Logbooks/Instrument histories
3. calibration records
4. simple calibration certificates
5. data storage and archival

WORK PLAN (updated: 18 September 2009)
Expert Team on Meteorological Radiation and Atmospheric Composition Measurements
(2007-2010)

No.	Task description	Person responsible	Action	Deadline for action	Deliverables	Deadline for deliverables
1	**Facilitate further activities related to meteorological radiation measurements:**					
1 a)	IPC-XI, 2010, WRC, Switzerland	W. Finsterle	1. Assist in the preparations and participate in the IPC-XI 2. Analyze results of IPC-XI	Dec. 2010	• Guidelines for IPC-XI • Published results of the IPC-XI	Dec. 2010
1 b)	RPCs, 2006-2010, either in conjunction with IPC-XI or at RPCs concerned	W. Finsterle	1. Initiate RPCs 2. Assist in the preparations and participate in the RPCs 3. Analyze results of RPCs		• Guidelines for RPC comparisons • Published results of the RPC comparisons • At least one RPC	Completed
1 c)	Coordinate the dissemination of World Radiometric Reference (WRR) factors to regional and national radiation standards	W. Finsterle	1. Disseminate radiometric factors to regional and national radiation standards		• Instrument and Observing Methods (IOM) Report to Members	Completed
1 d)	Statistical basis for the WRR factors	W. Finsterle	1. Identify the role of the WRR method in developing factors. 2. Devise a more robust statistical method for deriving WRR factors		• Report to Members • Propose update of CIMO-Guide	CIMO-XV Deferred
1 e)	Cryogenic radiometers for solar measurements	W.Finsterle	1. Assist in investigation of cryogenic radiometers for solar measurements.		• Report to Members	CIMO-XV
1 f	Liaise with the World Climate Research Programme on matters related to Baseline Surface Radiation Network and inform Members of developments	B.Forgan K.Behrens	1. Identify the role of CIMO in further development of BSRN 2. Liaise with WCRP on identified matters		• Report to BSRN on ET activities • Report to Members on BSRN •	Completed
1 g)	Liaise with the CAS SAG Ozone on the operational practice associated with total ozone measurements	B.McArthur	1. Collaborate with CAS on matters related to practices associated with total ozone measurements		• Report to Members • Proposal for update of the CIMO-Guide	CIMO-XV Nov. 2009
1 h)	Liaise with the CAS SAG UV on operational practice associated with UV measurements	B.McArthur	1. Promote the need for the intercomparison of UV calibration centers to the CAS SAG UV 2. Collaborate with CAS on matters		• Report to CAS SAG UV • Proposal for update of the CIMO-Guide	Completed Nov. 2009

No.	Task description	Person responsible	Action	Deadline for action	Deliverables	Deadline for deliverables
			related to practices associated with UV measurements			
1 i)	Liaise with the CAS SAG Aerosol Measurements	B.Forgan	1. Collaborate with CAS on matters related to practices associated with aerosol Measurements		• Report to Members • Proposal for update of the CIMO-Guide	CIMO-XV Nov. 2009
1 j)	Update the CIMO Guide	B.Forgan B.McArthur W.Finsterle	1. Develop proposals for update of Chapters 7, 8, 16, 17 of the CIMO Guide		• Updated Ch 7, 8, 16, 17 of the CIMO Guide	Nov. 2009
1 k)	Develop further the establishment of the World Infrared Standard Group (WISG) of radiometers	B.Forgan (J.Gröbner)	1. Collaborate with PMOD/WRC/IRC on the development of the WISG of radiometers		• At least one radiometer of new design traceable to SI developed and operational	Completed
1 l)	Coordinate the dissemination of pyrgeometer calibration coefficients	B.Forgan (J.Gröbner)	1. Calibration of the pyrgeometers at the IRC		• Calibration certificates to users	On-going
1 m)	Provide technical/scientific guidance to the IRC Davos	B.Forgan (I.Reda J. Gorman)	1. Perform the scientific evaluation of the IRC		• Report to IRC and Members	On-going and CIMO-XV
1 n)	Initiate activities so that radiation measurements in all national radiation networks are of a high quality	B.Forgan W.Finsterle	1. Develop methodology for assessing the quality of radiation data 2. Review the quality of radiation measurements in national networks 3. Assist NRC in improving the quality of radiation measurements 4. Develop proposal for training courses in radiation measurements		• Survey on quality of radiation measurements • IOM Report on the quality of radiation measurements • Methods distributed to NRCs on specific radiation issues • Syllabus and lecture notes for training in radiation measurements	IPC-XI Deferred Oct. 2010 Oct. 2010
1 o)	To determine the status of the traceability of radiation measurements to SI	B.Forgan W.Finsterle B.McArthur	1. Assessment of the traceability of radiation measurements to SI		• Report to Members	CIMO-XV
1 p)	To examine the transfer of WISG to network measurements of infrared irradiance	B.Forgan (J.Gröbner, I. Reda, J.Gorman)	1. Survey on how field pyrgeometers are calibrated		• Report to Members	On-going and CIMO-XV

FUTURE WORK PLAN

Expert Team on Meteorological Radiation and Atmospheric Composition Measurements

(2010-2014)

No.	Task description	Person responsible	Action	Deadline for action	Deliverables	Deadline for deliverables
1	IPC-XI, 2010, WRC, Switzerland And IPC-XII, 2015, WRC, Switzerland	W. Finsterle	1. Analyze results of IPC-XI 2. Assist in the preparations for IPC-XII	Dec. 2010 CIMO-XVI	• Published results of the IPC-XI • Guidelines for IPC-XII •	Dec. 2010 CIMO_XVI
2	RPCs, 2010-2014, either in conjunction with IPC-XI or at RPCs concerned	W. Finsterle	1. Initiate RPCs 2. Assist in the preparations and participate in the RPCs 3. Analyze results of RPCs		• Guidelines for RPC comparisons • Published results of the RPC comparisons • At least one RPC	
3	Coordinate the dissemination of World Radiometric Reference (WRR) factors to regional and national radiation standards	W. Finsterle	1. Disseminate radiometric factors to regional and national radiation standards	April 2011	• Instrument and Observing Methods (IOM) Report to Members	
4	Cryogenic radiometers for solar measurements	W.Finsterle	1. Develop cryogenic radiometers for participation in IPCs	CIMO-XVI	• Report to Members	
5	Update the CIMO Guide		1. Develop proposals for update of Chapters 7, 8, 16, 17 of the CIMO Guide 2. Examine report on sunshine intercomparison (Italy/France) 3. Examine response from CAS to recommendation on chapter 17		• Updated Ch 7, 8, 16, 17 of the CIMO Guide	
6	Develop further the establishment of the World Infrared Standard Group (WISG) of radiometers	J.Gröbner	1. Collaborate with PMOD/WRC/IRC on the development of the WISG of radiometers		• Report to Members on IRIS radiometer and WISG	
7	To determine the status of the traceability of radiation measurements to SI		1. Assessment of the traceability of radiation measurements to SI		• Report to Members	
8	To examine the transfer of WISG to network measurements of infrared irradiance		1. Survey on how field pyrgeometers are calibrated		• Report to Members	
9	Liaise with the World Climate		1. Identify the role of CIMO in further		• Report to BSRN on ET	

No.	Task description	Person responsible	Action	Deadline for action	Deliverables	Deadline for deliverables
	Research Programme		development of BSRN 2. Liaise with WCRP on relevant matters (e.g. CEOP)		activities • Report to ET on BSRN activities • Report on pyrheliometer intercomparison to the ET	
10	Liaise with the CAS GAW Programme		1. Collaborate with CAS on matters related to practices associated with ozone, UV, AOD, atmospheric composition measurements and other related matters		• Report to Members • Proposal for update of the CIMO-Guide	
11	Coordinate the dissemination of pyrgeometer calibration coefficients	J.Gröbner	1. Calibration of the pyrgeometers at the IRC		• Calibration certificates to users	
12	Provide technical/scientific guidance to the IRS Davos		1. Perform the scientific evaluation of the IRC		• Report to IRS and Members	
13	Initiate activities so that radiation measurements in all national radiation networks are of a high quality		1. Review the quality of radiation measurements in national networks		• IOM Report on the quality of radiation measurements	
14	Initiate activities to determine the characteristics of good and moderate quality pyranometers		1. Examine past characterizations/calibrations and past studies of pyranometers 2. Perform characterization studies on a small set of instruments considered to be of good and moderate quality		• IOM Report on characterization of good and moderate quality pyranometers	