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SEVENTH BSRN SCIENCE AND REVIEW WORKSHOP

1. INTRODUCTION AND OBJECTIVES OF THE MEETING

The seventh Science and Review Workshop for the World Climate Research Programme (WCRP) Baseline Surface Radiation Network (BSRN) was held in Regina, Canada, from 28 to 31 May 2002 at the kind invitation of the Meteorological Service of Canada.

The meeting was opened by a welcome from the City of Regina representative, Mr. Bill Hutchinson and from Mr. Tim Goos, Director, Prairie and Northern Region, Meteorological Service of Canada (see Appendix C). It was chaired by Dr. Ellsworth Dutton, BSRN International Programme Manager with major participation of Bruce McArthur, Chairman of the local organizing committee. Dr. Gilles Sommeria of the Joint Planning Staff (JPS) for the WCRP welcomed participants on behalf of the WCRP and expressed his thanks to the Meteorological Service of Canada for their kind hosting of the meeting.

The Draft Agenda was revised and accepted after agreement of a few minor adjustments (see Appendix B).

G. Sommeria stressed the importance of BSRN activities for WCRP and mentioned recent developments in the Global Energy and Water Cycle Experiment (GEWEX) Programme of interest to the audience. Most of the action items from the previous workshop had been completed and/or would be addressed as part of the agenda for this meeting, including reports from the ad hoc Working Group.

Ellsworth Dutton provided an overview of the programme and highlighted major accomplishments of the BSRN, presented recent activities in both BSRN observations and applications, outlined some the work that remained to be done and what tasks had to be addressed during the meeting. A review of the current network status and goals was given as well as the major areas of application of the BSRN datasets. In consideration of the relatively large number of new participants at the meeting, Dutton listed and briefly explained the major components of the BSRN, which demonstrate a fairly extensive and sophisticated international observational project. It was pointed out that BSRN was established to address some rather specific issues in the climate research community, particularly the lack of suitable surface irradiance observations for climate research. Quotes from past leaders of the WCRP and GEWEX Radiation Panel had exclaimed the success of BSRN, in which the organization should be quite pleased. A long list of major accomplishments of the past 10 years was presented. As a sort of a tutorial on the need and application of BSRN data, Dutton presented a diagram explaining the general areas of application of the BSRN data. It shows that there are three broad areas of application related to climate research where relevant atmospheric composition can be determined from optical depth measurements, total energetics for comparison to model and satellite determinations, as well as monitoring the temporal variability of the observed quantities. A number of particularly “hot” topics for related to BSRN interests were presented but time prevented much elaboration on them. Nearly all the introduced subjects came up during the subsequent course of the meeting.

The presentation then turned to the brief summaries of selected highlights of BSRN work of the past two years. The highlighted items included: a) Work on irradiance reference standards, b) Radiative transfer model comparisons and applications, pointing out specifically that 3-dimensional modeling is approaching being able a address the point observations that are, of necessity, the type made at BSRN, c) GCM applications, emphasizing the work of Martin Wild and others, d) Satellite applications, e) The value of aerosol optical depth measurements and brief review of the methods being developed by BSRN, f) The status of work being done to account and adjust for thermal offset errors in pyranometer measurements with special thanks to D. Esterhuyse, Y. Hirose, K. Behrens, and J. Olivieri for sharing some of their results of pyranometer dome capping experiment, g) and finally, a brief introduction to the concept of deriving cloud information from irradiance measurements, a topic presented in greater detail later in the week by Chuck Long.

The next portion of E. Dutton’s presentation had to do with the current status of the observing network and the flow of data into the archive. A current map of the active and candidate observing sites was shown along with tables of the current status of data submission by each station in the network. (29-32). A summary of the process for becoming and remaining a BSRN observing station was given, as evolved from the practical experience of the organization over the years.

Finally a list of items to be addressed during the upcoming week was presented with some explanation and discussion. All the listed topics and more were discussed in the following three days, with the culmination of the weeks work given in the recommendations adopted by the group as given at the end of this report.

2. BSRN STATION STATUS

2.1 State of BSRN network: Table and map of existing stations

2.2 Status reports of existing stations

Station Status at the BSRN Archive
(Site, Number of Months - Last Month)

Alice Springs, Australia	75 - 01/02
Florianopolis, Brazil	61 - 7/99
Regina, Canada	32 - 8/97
Toravere, Estonia	16 - 4/00
Carpentras, France	37 - 9/99
Ny Alesund (Germany)	53 - 12/96
Lindenburg, Germany	51 - 12/98
Georg V Neu. (Germany)	58 - 1/97
Tateno, Japan	77 - 6/02
Syowa, Antarctica (Japan)	24 - 12/95
Payerne, Switzerland	59 - 8/97
Barrow, Alaska	120 - 12/01
Boulder, Colorado (BAO)	120 - 12/01
Bermuda	120 - 12/01
Kwajalein, Marshal Islands	117 - 12/01
South Pole, Antarctica (US)	120 – 12/01
ARM SGP1	102 - 12/01
Manus, New Guinea (ARM)	63 - 12/01
Nauru (ARM)	38 - 12/01
Ft Peck, Montana	86 - 2/02
Bondville, Illinois	86 - 2/02
Goodwin Crk, Mississippi	86 - 2/02
Boulder Surfrad, Colorado	79 - 2/02
Dessert Rock, Nevada	48 - 2/02
Penn State, Pennsylvania	45 - 2/02
Ilorin, Nigeria	35 - 7/95
Tamanrasset, Algeria	21 - 11/01
Lauder, New Zealand	19
Total	1848

ARM and SURFRAD stations as part of the BSRN (G. Hodges, NOAA, USA)

There are currently four Atmospheric Radiation Measurement Program (ARM) sites and six Surface Radiation (SURFRAD) sites being submitted to the BSRN archives by NOAA's Surface Radiation Research Branch (SRRB) located in Boulder, Colorado, USA <http://www.srrb.noaa.gov>. The number of SURFRAD sites will increase to seven when a new SURFRAD station located in West Virginia, USA is installed and comes on-line towards the end of 2002. It is hoped that in the coming years more SURFRAD stations will be established in other climatologically unique areas of the United States. SRRB is also willing to submit other ARM sites as requested by ARM and/or BSRN.

ARM and SURFRAD data are being submitted to the archive on the order of every few months, with SURFRAD submissions typically leading ARM by a couple of months. This is due to the lag time in getting data from the two Tropical Western Pacific sites and the BSRN archive requirement that data for all sites from one agency be submitted simultaneously. Users of these data can expect to have files available for download from the BSRN archive on no more than a six-month delay. At the time of the 2002 biannual BSRN meeting in Regina, Canada, ARM data are available through year 2001 and SURFRAD data are available through February 2002.

Bratt’s Lake, Canada (B. McArthur, Meteorological Service of Canada)

The Bratt’s Lake station continues with the normal BSRN sampling of direct solar, diffuse solar, global solar and longwave irradiances. Temperature, humidity and pressure measurements are made at the main measurement platform. Readings are made every second and the values averaged every minute along with the min, max and standard deviation. Broadband reflectance and emittance measurements are made at 10 m and 30 m as part of the extended measurement program. A fully automatic meteorological station also provides standard observations including present weather and cloud-base height.

Most quantities observed at the platform are duplicated to ensure data quality. Three trackers are used in obtaining direct solar readings with two of these trackers each having instruments for the measurement of diffuse solar and longwave irradiance. Two global solar instruments operate beside each other. On clear days, two Eppley H-F radiometers operate on separate trackers; one inside an all-weather cavity, while the other operates as a fair-weather instrument.

Enhancements to the observation program at the 30-meter tower include new data logger programming, improved hinges on the boom at 30 meters for easier instrument access and a catwalk at 10 meters for safety. Recently developed quality assurance programs allow data to be viewed in real-time in several different graphical modes and ensure datafile integrity.

The list of non-BSRN clients using station facilities continues to increase, with 10 organizations using the site as of summer 2002. The number of instruments has also increased. In April 2001 a Precision Filter Radiometer (PFR, GAW) and a Multi-Filter Rotating Shadow band Radiometer (MFRSR, Yankee Environmental Systems) were added at the platform. A tracker (to measure direct solar, diffuse solar and longwave irradiance) and a single ventilated pyranometer (to measure global irradiance) were installed at the meteorological site.

During the summer of 2001, an aerosol optical depth comparison amongst five instruments was undertaken. In addition, during the summer of 2001 and again in 2002, broadband and spectral reflectance measurements are being made at a constant 2-meter height above the surface as part of a surface cover characterization experiment. Four flights of the tethersonde in mid-April 2002 increased the albedo data with measurements taken between 6 meters and 1.6 km.

De Aar, South Africa and GAW activity (D.J. Esterhuyse, South African Weather Service)

In July 2001, the South African Weather Service (SAWS) became a parastatal organization of the government of South Africa. The BSRN and related monitoring and research activities now form an integral part of the Weather Service's Global Atmosphere Watch (GAW) program under the World Meteorological Organization (WMO).

GAW activities in the SAWS include:

(1) Trace gas monitoring and research at the GAW Cape Point station,

(2) Ozone monitoring (column and umkehr) by means of two Dobson Spectrophotometers, as well as ozonesoundings in collaboration with NASA-SHADOZ, (3) Surface ozone monitoring at the SANAE Antarctic base, (4) The BSRN station and surface solar radiation network of SAWS.

The De Aar BSRN Station is in operation since July 1999, and data since June 2000 up to December 2001 have been submitted to the Zürich WRC database. An extensive set of Fortran programmes for processing the data in required formats have been developed in-house.

Data is transmitted direct daily by a Wide area network (WAN) between two identical computers, one at the site and one at Pretoria HQ.

Regular maintenance at the De Aar instruments are done daily by trained personnel reporting weekly, as well as monthly instrument inspections. The site scientist visits the site every six months for routine cavity radiometer calibration of the instruments, as well as global/diffuse exchange.

The basic set of instruments are: Two Kipp & Zonen CH1 pyrheliometers for useful quality control exercises, Two Kipp & Zonen ventilated CM21 pyranometers, (global and diffuse) and one upfacing Eppley PIR pyrgeometer. They are in operation since primary installation, and the following gradual deterioration in thermopile sensitivity have been observed : pyrheliometers: respectively 2.32% and 1.24%, pyranometers : 1.98% and 2.91%. This calibration factor reduction is taken into account when preparing data for the archive.

Recent developments at the site were :

1. Installation of a 2m-adjustable beam housing one ventilated pyrgeometer and one ventilated pyranometer for measuring upwelling quantities. The instruments can be rotated by 180° for direct intercomparison with operational instruments.

2. Mini-intercomparison of all available SAWS calibration references: PMO-6 radiometer # 850404, Linke-Feussner # 700198, AHF cavity # 31109. Agreement ratios of between 0.9944 and 1.0033 throughout was found to be satisfactory.

Budapest-Lorinc, Hungary (G. Major, Hungarian Meteorological Service)

In the Budapest-Lorinc Observatory of the Hungarian Meteorological Service several meteorological elements are measured. Most of the parameters required for BSRN stations are amongst them.

Global, diffuse, reflected solar and upward longwave radiation values are measured by Kipp&Zonen instruments. The downward longwave radiation are measured by a shaded Eppley pyrgeometer modified by PMOD. Direct solar radiation is registered by CH1 instrument, but continuous cavity measurements are not made. UV-B is measured by Solar Light Co.'s UV-Biometer Model 501. Ozone and UV data are provided by a Brewer MKIII. In cloudless cases spectral direct measurements are made by a LICOR-1800. Rawindsonde data are provided by a Vaisala equipment.

Recently two data acquisition devices are operated to collect radiation data with a 3 seconds sampling rate. In September 2002 the two devices will be replaced by an Agilent 34970A equipment, the sampling rate remaining at 3 seconds.

The formatting and transmission (to the BSRN Archive) of the data collected in the last two years are planned after the installation of the new data collecting device.

Ilorin, Nigeria (O. Aro, University of Ilorin, Nigeria)

Observations at this site were carried out on a regular basis but the funding for continuous operation remains a matter for concern. An arrangement between the University of Ilorin and the Nigerian Meteorological Service is under negotiation but there is still no guarantee of funding in the coming years.

T.O. Aro presented the project of an albedo measuring station at Ilorin with the following characteristics:

Latitute: 8° 29.525'N Altitude:
Longitude: 4° 40.663'E 397.76m
Height of Mast: 10 m above surface

The uniqueness of the site lies in its Savanna Grassland environment. Vegetation grows up to 6 ft during the growing season, March-September, and is burnt during the dry season, November-December. This type of vegetation extends typically from 7°N to 11°N. The annual cycle of such an environment still needs to be documented.

Lindenberg, Germany (K. Behrens, Deutscher Wetterdienst)

Some improvements and upgrading took place during the last two years. The ancillary elements temperature, relative humidity and pressure have been measured since February 2001 directly on the BSRN platform with a frequency of 1 Hz instead of using those values from the nearby weather station. Furthermore, in the same month, with a CG4 a second pyrgeometer of different type was added, measuring atmospheric downwelling radiation.

Because of a planned new building with laboratories and a roof as platform for radiation measurements, it was necessary to built an interim platform at a site about 50 m north of the old one. The interim platform was equipped identically in type and number, but with new instruments. Between 1st and 15th October 2002 the measurements on both platforms were running side by side. Since 16th October 2002 the data have been taken only from the interim platform.

On December 6th 2001 a crane was mounted to build the laboratory, which was within the Sun's path up to 10th of March 2002. The crane influenced direct and global radiation about 7 minutes every day. In the case of clear sky and changing clouds the corresponding data were discarded.

Payerne, Switzerland (L. Vuilleumier, A. Heimo and A. Vernez, Météo Suisse)

The Payerne station measures parameters from the basic set of measurements since November 1992, as well as upward long-wave (LW) and short-wave (SW) irradiance at 10 and 30m above ground and downward SW and LW at 30 m since September 1993. Since May 1993, direct global and spectral (3 wavelengths) irradiance was also measured. An upgraded set of Precision Filter Radiometer (PFR) is being installed and will soon allow measurement of direct irradiance at 16 WMO recommended wavelengths from UV to IR.

LW and SW global irradiance are each measured using two collocated identical instruments. This allows testing some components of the measurement uncertainty by comparison. While this does not allow testing bias due to the instrument configuration or check absolute precision, the random uncertainty and reproducibility of the measurement can be estimated. The Payerne data were divided in monthly samples including several thousands data points each. Differences between simultaneous measurements from collocated instruments were calculated and percentiles of the monthly distributions computed. Percentile time series showed that differences for LW and SW downward irradiance remains within ± 3 W/m^2 (80% of distribution within ± 3 W/m^2) since September 1997. Prior to this date, larger differences (up to ± 10 W/m^2) were found and a strong seasonality could be observed for SW measurements with larger differences in summer. In August 1997, the Payerne site was overhauled. Particularly, a new temperature control system including heating and ventilation was installed on pyranometers and pyrgeometers.

Some remaining seasonality can still be observed for SW irradiance with higher differences (though much smaller than before September 1997) in summer. Computation of correlation between irradiance differences and various ancillary measurements showed that SW differences were relatively strongly correlated with the difference between the temperatures of the body of the pyranometers. Similarly, the LW differences were relatively strongly correlated with the dome-body temperature difference of either one or the other pyrgeometer.

Sedeh Boqer, Israel (A. Manes and I. Setter, Israel Meteorological Service)

The Sede Boqer station is located at the premises of the Desert Research Institute of the Ben Gurion University of the Negev, situated at the central part of the Negev Desert in southern Israel. The suite of radiation measurements includes global, diffuse, and direct components of solar radiation, as well as the longwave atmospheric radiation component. All instruments are of Eppley Lab manufacture, mounted on a SciTec solar tracker. Ancillary meteorological measurements are taken at the automatic meteorological station, collocated with the radiation station. Upper air data are taken from the Bet Dagan Aerological Station, about 70 miles to the north of the Sedeh Boqer station. Unfortunately, some building activity takes place recently at the campus of the institute. At the end of this activity, we shall re-evaluate the siting of the station, with the possibility of moving the station on the top of a flat roof, to improve the exposure of the instruments.

We have noted with satisfaction that three months of Sedeh Boqer data were inserted successfully to the archive, and we appreciate very much the assistance of Andreas. At the beginning of September we shall continue sending formatted data to the archive.

Solar Village, Saudi Arabia (N.M. Al-Abbadi)

In a cooperative project between the Saudi Arabia King Abdulaziz City for Science and Technology (KACST), the U.S. National Renewable Energy Laboratory (NREL), and the U.S. National Aeronautics and Space Administration (NASA), and existing solar radiation measurement stations at the KACST Solar Village research center was upgraded to BSRN specifications in September of 1998.

The Solar Village site was chosen because of its unique desert climate, proximity to an established research infrastructure, and its potential value to the NASA Earth Observing System (EOS) project for ground truth measurements. KACST funded all equipment upgrades. With NASA EOS funding, NREL provided the expertise and training to establish and configure the site. All on-going operations at the site are staffed and funded by KACST.

Syowa, Antarctica (Y. Hirose, Japan Meteorological Agency)

Radiation measurement at Syowa Antarctica is part of the Japanese Antarctica Research Expedition Programme by the National Institute of Polar Research and has been operated substantially by the Japan Meteorological Agency. BSRN data submission began in 1994 based on five-second sampling measurements. In April 1998 upward components with one-second sampling were added by installing a measurement tower on the snow field. In February 1999 all the radiation measurements shifted to one-second sampling as required in BSRN specification. Though serious signal noise in the measurements caused the loss of the radiation data in 1999, it is resolved now by improving the wiring and grounding of single lines. Syowa Antarctica continues the instrumentation upgrade. In February 2001 the latest pyrgeometer Kipp & Zonen CG4 was installed for downward long-wave radiation measurement, which will be extended to upward long-wave radiation measurement in the near future.

The data for submission cover the basic measurements (0100), other measurements (0300) except net radiation, surface SYNOP (1000), and radiosonde measurements (1100). Urgent problem for Syowa Antarctica is the submission of accumulated data up to 2001, including the data of 1996 to 1998 which have already been reported to the archive but not inserted in the data base yet due to partial format mismatch.

Tamanrasset, Algeria (M. Mimouni, Service météorologique algérien)

The site of radiation of Tamanrasset (22°47'N, 05°31'E , 1377 m) is located in the center of the city, in a rocky region (Hoggar) with a dry climate: average of humidity = 20 % , rainfall = 46 mm.

The radiation measurements began at Tamanrasset in September 1994 as part of in the GAW programme with measuring the Direct , Global , Diffuse(shadowband) , RG8 each 3 mn. Since March 2000, the station of Tamanrasset has been included in the BSRN programme with a new measure of long wave downward and diffuse with shade disk each one minute, all these activities were upgraded by the radiation group TAR/CMDL at Boulder.

Until may 2002, 21 files were submitted and accepted in the BSRN archive (March 2000 to November 2001). The BSRN files of Tamanrasset contain the basic measurements, the surface synop and total ozone.

Other files have also been submitted since September 1994 to WRDC (world radiation data center – St Petersburg) with the assistance of NREL (Golden, USA).

Tateno, Japan (Y. Hirose, Japan Meteorological Agency)

Aerological Observatory Tateno (Tsukuba), run by the Japan Meteorological Agency, started its role as BSRN station in 1996. Since then the data submission to the BSRN archive has been done regularly on a monthly basis with a full BSRN-standardized data acquisition system and instrumentation. In June 2001, surface meteorological data, surface SYNOP, and radiosonde data were added to the data submission going back to 1996. A BSRN data processing software developed at Tateno for possible use at other BSRN stations was distributed in CD-ROM at the 6^{th} BSRN Workshop 2000 in Melbourne, the latest version of which is presented in this workshop. For the maintenance of radiation instruments and in order to take part in the long-wave radiation programme of BSRN, a PIR pyrgeometer calibration procedure has been investigated at Tateno. In 2001, a Kipp & Zonen CM22 pyranometer and a CG4 pyrgeometer were purchased for future installation. In January 2002 an improved shading sun tracker was installed to meet the BSRN recommendation regarding the shading geometry for diffuse solar radiation measurement.

Toravere (Tartu), Estonia (A. Kallis, Estonian Meteorological and Hydrological Institute)

The Toravere Station is operated by the Estonian Meteorological and Hydrological Institute. Since 1999 it has been included in the BSRN network (42 files with data have been sent to WRMC).

The implementation of the station enables to compare instruments designed in the former Soviet Union with those meeting BSRN specifications. The present equipment includes a PMO6 cavity pyrheliometer as a reference instrument, an Eppley NIP, a CM-21 and a Yanishevsky M-115M for measurements of global, diffuse and reflected shortwave radiation, LI-COR sensors for direct and global PAR, Kipp&Zonen instruments for registration of UV-A and UV-B radiation, measurement of aerosols with CIMEL CE-318-1 (in cooperation with NASA and Tartu Observatory). In August 2002, downward longwave irradiation measurements will be started with Eppley PIR.

With the use of a new Vaisala automatic station MILOS 520 we will also be able to send synoptic data to WRMC in the near future.

United Kingdom stations (P. Fishwick, and A. Green, UK Met Office)

The UK Met Office has had BSRN stations at Camborne (50.22°N, 5.32°W) and Lerwick (60.13°N, 1.18°W) since 1998. Data have been submitted to the archive since late 2001. Both stations are located at fully manned Met Stations, with 3 radiosonde ascents per day and ozone measurements made by Dobson spectrophotometers. The aim is to have all BSRN data since 1998 added to the archive as soon as possible, and to continue regularly adding future data to the archive.

Spectral measurements are currently being undertaken at Bracknell in the 368, 412, 500 and 778 nm wavelengths. It is planned to relocate these measurements to Camborne, with the possibility of extending these to Lerwick.

Currently these include the basic set of measurements. Instruments are calibrated against the World Radiometre Reference via the Met Office TMI and HF standard cavity radiometers. Quality control is carried out on a weekly basis using a combination of quantitative consistency checking and graphical visualisation. Problems occur through deposition of dirt, especially marine slat, on the windows and domes of the instruments. Other problems are due to tracker malfunction, cable snagging and power failure. Long-term maintenance is made difficult at Lerwick in particular by severe corrosion.

BSRN stations provide data which can also be used to assess the performance of these stations operated by the Met Office. This has been applied particularly with respect to global radiation and sunshine duration.

The Met Office also has around 80 further radiation stations throughout the UK, collecting both synoptic and climatological data. They can be contacted for any further details about these stations or the data they provide.

2.3 New and potential BSRN stations

Possible Swedish BSRN candidate stations (T. Carlund, Swedish Meteorological and Hydrological Institute)

Currently there are already several (≈ 8) BSRN stations in western Europe. However, there is a gap in the areal distributions of stations over Scandinavia and the Baltic Sea. The rationales for a Swedish BSRN station are therefore, among others, from a Swedish point of view

- Researchers, both internal at SMHI and external, from the climate analysis and modelling and remote sensing communities, ask for BSRN data over Sweden and Scandinavia
- A BSRN station would be a very important part of the modernized national radiation network in Sweden
- To gain deeper knowledge in and experience of meteorological radiation observations through work of our own, but not least through a direct dialogue with leading experts
- As most people working with radiation measurements and instrument calibration, we wants to measure as accurate and complete as possible which is also the very goal for BSRN

and from an international/BSRN project point of view

- New climatic region in Europe, within the GEWEX/BALTEX area, will be covered
- Swedish contribution through participation in coming experiments/BSRN working groups
- Contribute in the evaluation of new methods/findings.

Here, a couple of sites are presented from which one could become a candidate station and finally, if accepted, an operational BSRN station. All of the presented sites lie within the GEWEX/BALTEX study (run-off) area. The potential sites are primarily Vindeln (64.24ºN, 19.77 ºE, 225 m alt.), an inland (> 65 km from the coast) site in central/northern Sweden surrounded mainly by coniferous forest in a slightly hilly terrain typical for a large part of the country, and Hoburgen (56.92 ºN, 18.15 ºE, 37 m alt.) on the southern tip of the island of Gotland in the Baltic Sea. Secondary alternatives are Abisko (68°21'N, 18°49'E, 388 m alt.) and Katterjåkk (68 º25'N, 18 º10'E, 520 m alt.) in the northernmost part of the Swedish mountains. All of these sites have their advantages and disadvantages. Within the work of modernizing the national radiation network investigations will continue to find out which one of these site that is the most suitable site to become a future Swedish BSRN station.

Potential new Antarctic station (V. Vitale, ISAC-CNR, Italy)

A new research project, approved and financed at the beginning of this year by the Italian National Commission for Antarctic Researches (CSNA), aiming at carrying out continuously and with high accuracy surface radiation measurements at the new permanent station of Dome Concordia (lat. 75° 06' 06" S, long. 123° 23' 42" E, height 3233 m a.m.s.l.), was presented. In terms of the BSRN measurements categories, this programme will implement a BASIC set of measurements, including direct solar irradiance, diffuse sky irradiance, global irradiance and long-wave downward irradiance. Moreover, in cooperation with other research programmes, upward short-wave and long-wave radiation measurements will be taken from 12 or 30 m of height.

These highly accurate short-wave and long-wave radiation measurements at Concordia station will be very important to: (a) give accurate and representative information on the radiation regime at the surface in the East-Antarctic Plateau region; (b) supply with high accuracy essential input parameters to both mass balance and climatic models for a crucial area; (c) provide surface irradiance measurements for validating satellite measurements as well as climatic models parametrization schemes and results and (d) give useful information for PBL studies and characterizations.

In implementing our measurements, the instrument requirements and quality control strategies (including calibration) adopted by the BSRN network and detailed described in the operations and data management manuals will be carefully followed in order to obtain the highest possible accuracy. The scheduled plan foresees, at the moment, a first test campaign during the 2003/2004 austral summer expedition and a full implementation in the autumn 2004.

The new permanent Concordia station will offer, at the moment, an unique possibility to add a second measurements site on the Antarctic Plateau, where monitor with high accuracy all components of the radiation budget at the surface. Since Dome C present many differences from South-Pole (the other measurement point), the most important being in cloud and wind regimes, measurements carried out routinely and continuously at Concordia station could improve considerably our knowledge on the radiation balance over the Antarctic plateau, its spatial variability, seasonal and interannual cycles. Anyway, combining irradiances measurements with information concerning atmosphere state and composition as vertical profiles of temperature and humidity, turbidity conditions, and, as far as possible, cloud coverage and vertical structure, can enormously improve their usefulness for research in climate and radiative transfer modeling as well as for satellite validation activity. Than, a very big effort will be produced to include as much as possible routinely synoptic upperair and aerological measurements to radiometric measurements.

Cabauw Experimental Site for Atmospheric Research: CESAR initiative for a BSRN site (W. Knap, W. Hovius, and R. Boers, Royal Netherlands Meteorological Institute)

The Cabauw observatory (52 °N, 5°E) of the Royal Netherlands Meteorological Institute (KNMI) has been the centre of experimental atmospheric research of KNMI since the early seventies. The 213 m tower at the site, which is located in a very flat agricultural area, has been providing a wealth of data for boundary layer research. Recently, it has been decided to bring together in Cabauw instruments of different national research institutes and to install new instruments for extensive atmospheric research. The initiative is named CESAR: Cabauw Experimental Site for Atmospheric Research. The aim of CESAR is to research the interaction between radiation and clouds/aerosols, land-atmosphere processes and atmospheric composition. It is our intention to include in CESAR a radiation set-up according to the BSRN standards. Initially, we will operate a basic set of instruments for the measurement of direct, diffuse, and global shortwave radiation, and downward longwave radiation. Synoptic meteorological observations as well as upper-air measurements are available. In the course of time we expect to obtain an integrated dataset of atmospheric measurements which could be of potential use for the BSRN database.

Status of BSRN Brazilian stations and SONDA project (S. Colle (Federal University of Santa Catarina), E. Pereira (Instituto Nacional de Pesquisas Espaciais), Brazil)

The stations of Balbina and Florianópolis are going to have the pyranometers Kipp&Zonen CM11 replaced by pyranometers CM 21 for global radiation and CM 25 for diffuse radiation. The Eppley tracker of the BSRN Balbina is going to be replaced by the tracker Kipp&Zonen 2AP-BD + shading + sun pointer. The data collected at BSRN Florianópolis are already qualified and available for the WMRC archive. The equipments mentioned above are already purchased and are presently being shipped to Brasil. It is expected BSRN Balbina will be in full operation by December this year. The global and LW radiation have been measured in Balbina, and the data have been qualified at LABSOLAR.

SONDA is a project aiming at deploying nine new BSRN-standard radiometric stations in several selected sites of Brazil. In the first stage, four stations will be deployed: Petrolina, Brasilia, Ji-Paraná, Santa Maria. Each of these four stations will contain the following equipments:

- Radiometers (global KIPP&ZONEN CM21;
- Diffuse KIPP&ZONEN CM22;
- Long have downward EPPLEY PIR all ventilated);
- Direct EPPLEY NIP PAR KIPP&ZONEN;

- Lux KIPP&ZONEN;
- Tracker KIPP&ZONEN 2AP-BD + shading + sun pointer;
- Sun photometer (AERONET-CIMEL CE318-1, on 440, 670, 870 (3), 936, 1020 nm);
- Ceilometer VAISALA LD-40 (cloud base and aerosol).
- Sky immager (automatic cloud cover index) YANKEE TSI-440.
- Anemometer at two levels of interest for energy exploitation (30 and 50 m) RM YOUNG 5106MA-LM
- Basic meteorological station (humidity, temperature, precipitation, pressure) RM YOUNG 41372 VC aspirated, HIDROLOGICAL SERVICES TB4-L34, VAISALA CS 105
- Data logger - ethernet link (CAMPBELL CR23X-4M + NL100)

The equipments are now being purchased and the schedule is to start setting up the equipment in the field by the beginning of next year. The target is to have these four stations fully operational by March/2003.

Additional sites will be selected for deployment of five stations with more modest configuration.

These sites have not yet been selected and the target is to have them operational by the second semester of 2003.

Two other stations were proposed during the meeting, one in Lusaka by Dr. Nasitwitwi and one in Palaiseau (south of Paris) by Dr. Haeffelin.

3. BSRN ARCHIVE, QUALITY ASSURANCE AND DATA MANAGEMENT

3.1 <u>Status of the BSRN archive (A. Roesch, ETH Zurich, Switzerland)</u>

Since the last BSRN meeting two years ago BSRN underwent substantial upgrades to both software and hardware. Among other things, all station-to-archive data files had to be reinserted into the database. During this process it turned out that lots of data were erroneous which caused an intense and still on-going correspondence with the station scientists. So far 1808 monthly station-to-archive files have been inserted into the BSRN database.

Presently, the BSRN database contains 36 operational, 4 pending, and 2 candidate stations; 4 and 6 out of the operational stations are ARM and SURFRAD stations, respectively. Most of the stations are situated either in Western Europe or US. Asia, South America and Africa. In order to have a more uniform spatial distribution, installation of new BSRN stations in the previously mentioned countries should be strongly encouraged. Furthermore, BSRN should advocate for at least two stations per surface-type, namely sand, rock, shrub, water, ice-shelf and glacier. Contrary to the BSRN guidelines, only 12 and 16 operational stations include synop and radiosounding measurements, respectively.

The quality check procedure mainly suffers from the still unresolved problem of the night-time offsets. 13.2% and 11.6% of all global and diffuse radiation data are flagged due to negative night-time offsets. As many station scientists perform a sophisticated quality control of their data, it was suggested they send all available data quality algorithms to the WRMC data manager.

In May 2002, 138 external BSRN users were registered, about 75% out of them in USA, UK, Japan, Germany and Switzerland. A more detailed study showed that only 24 users actively retrieved data during the last two years, but they usually download data from numerous years and/ or stations.

Due to a lack of computer staff at the IAC ETHZ, all the duties regarding further software and hardware updates cannot be fulfilled. Main deficiencies remain the poor WWW-interface which only allows the retrieval of data from the basic measurements. Moreover, several changes in the program for data insertion ("instat") should be accomplished. Besides several major drawbacks, the current program version suffers from a too strict consistency control in the metadata part.

In summary, the BSRN database is - again - available and of good quality. However, to fulfil all the archive's duties regarding both software and hardware, BSRN archiving centre needs more human resources in the near future.

The issue of financial resources and staff for the archiving centre has been discussed extensively during the meeting and one of the recommendations deals with it.

3.2 Quality assurance and data management

Quality metrics from an operational BSRN site (C. Long, Pacific Northwest National Laboratory, USA)

Results of a comparison of 3 separate, co-located surface radiometer systems were presented. These sets of radiometers are located within a few 10s of meters of each other, and are operated per BSRN specifications. The purpose of the comparison is to study the uncertainties users can expect in the long-term field measurements distributed by the BSRN Archive. The results suggest that operationally, the “uncertainty” of measurements of direct normal and diffuse SW are about 4-5 times the calibration accuracies presented in Table 3 of Ohmura et al., 1998, BAMS. On the other hand, operational downwelling LW “uncertainty” is about half the Ohmura et al. Table 3 calibration accuracy value.

Selecting the highest quality from among multiple data streams (Easley, Wilcox, Myers (National Renewable Energy Laboratory, USA), and Al-Abbadi)

The BSRN recommends two direct normal measurements, one by a cavity radiometer and the other by a conventional pyrheliometer. However, with two measurements, the BSRN archive accepts only one direct normal field. If it is possible to differentiate the quality of the two-like measurements, we propose a method of delivering to the user the best of the two.

The method described involves a multi-tiered approach to determine the relative quality by comparing the measurements to the related global and diffuse values, and also comparing the two measurements to each other. The ultimate choice of a measurement is documented in the BSRN Station-to-Archive file in records 0008 and 0009.

3.3 BSRN Operations Manual, Version 2.0 (B. McArthur)

Version 1.0 of the Operations Manual, published in 1998 is in need of a significant revision. While the purpose of the BSRN has not changed since its inception, the manners in which some of the measurements are being made have changed significantly. Types of measurements acceptable at the time of writing, no longer should be used. Issues associated with other measurements have arisen and scientific studies developed to determine their significance. At the Scientific and Review Workshop in Melbourne, Australia in 2000 the Working Group on Aerosols proposed, and the meeting accepted, a method of measuring atmospheric transmittance that would lead to the calculation of aerosol optical depth.

The first major revision of the manual is in the final processes of being completed. Those aspects of the manual that had time limitations associated with them, such as observation frequency, have been removed. Updates in areas such as the station list and the accuracy of measurements have been made. A new chapter on the measurement of atmospheric transmittance has been added based on the proposal of the Working Group on Aerosols.

Several of the chapters of the manual have been altered to make them more readable. The overall structure of the manual has also changed somewhat to better reflect the operations associated with a station. Some of the information that was new at the time of the first writing and inserted into appendices has now been woven into the text. References to scientific papers that were used as the foundation of methods of operation, while not extensive have been increased to direct the reader to pertinent background information. Appendices associated with instrument manufacturers have been updated and expanded where necessary. A glossary of uncertainty terms and equations used in uncertainty calculations has been added. Finally, an index will be added to help readers locate areas of interest.

Although it was anticipated that the manual would be ready for review at the 7th BSRN Scientific and Review Workshop, this did not occur. A pdf copy of the revised manual should be released to the meeting delegates before mid-July. Following a one-month period for comments, revisions will be made where appropriate and a request sent to WCRP for publication of version 2.

4. IR RADIATION AND INSTRUMENTATION

A comparison of downward long-wave radiation measured by PIR and CG4 (K. Behrens)

During about 13 month between the beginning of March 2001 and the end of April 2002 the atmospheric downward radiation measured by a PIR and CG4 was compared at BSRN Station Lindenberg, Germany. The differences CG4-PIR and the ratios CG4/PIR of 1 minute values were investigated under various atmospheric conditions: night-time clear sky, night-time cloudy, daytime clear sky and daytime cloudy. The PIR was always shaded, the CG4 was only shaded between mid October 2001 and the beginning of February 2001.

The following conclusions were derived:

- during night-time and if shaded both the PIR and the CG4 are very close together (<1.5 W/m² or <0.5%)
- during daytime, if the CG4 is not shaded, the difference in the monthly means is <3.5 W/m² or <1.1%
- this figures match the demands of 5 W/m² or 10% if the shaded PIR is close to the truth
- it is possible to correct the small dependence on global radiation of the unshaded CG4 by linear regression
- with the CG4 we have a second pyrgeometer that fulfils the demands of BSRN

Discrepancies in pyrgeometer measurements (Y. Hirose)

Some experiments on PIR pyrgeometer calibration were performed using a blackbody cavity apparatus developed in the Japan Meteorological Agency(JMA). Twelve calibration points covering moderate measuring conditions in the fields were selected to complete one cycle of calibration.

It was shown that individual calibration factor in the PIR pyrgeometer formula depended sensitively on the temperature conditions of PIR and blackbody cavity in calibration. Under well-controlled same temperature conditions the reproducibility of the calibration results was satisfactory.

Outdoor comparison of downward long-wave irradiances calculated from twelve different sets of calibration factors obtained from the experiments was carried out. They agreed within 2 $W \cdot m^{-2}$ disregarding the diversity of individual calibration factor. The maximum irradiance difference between the two PIR pyrgeometer did not exceed 2 $W \cdot m^{-2}$. The irradiance difference between the two pyrgeometer formula, i.e. with four factors(BSRN standard formula) and two factors(Albrecht formula), was well under 2 $W \cdot m^{-2}$. These results demonstrate that a relative homogeneity of 3 $W \cdot m^{-2}$ for long-wave radiation measurements in the field could be achieved with the calibration procedure developed in JMA.

Outdoor comparison of downward long-wave irradiances calculated from the calibration factors offered by PMOD, CMDL, and JMA was carried out. The irradiance differences between PMOD, CMDL, and JMA were not negligible. The maximum difference between PMOD and JMA was nearly 7 W m^{-2} while it was under 2 W m^{-2} if Albrecht formula was used. The difference between CMDL and JMA was about 4 W m^{-2}. These difference could be minimized to 2 W m^{-2} by adjusting the C and/or k_1 values by each laboratory.

Pyrgeometer comparisons (IPASRC- I/II) and status of longwave irradiance uncertainty (R. Philipona, World Radiation Center, Switzerland)

The first International Pyrgeometer and Absolute Sky-scanning Radiometer Comparison (IPASRC-I) were held under midlatitude summer conditions at the Southern Great Plain (SGP) site of the U.S. DOE Atmospheric Radiation Measurement (ARM) program in Oklahoma in September 1999. Results of this comparison were reported at the sixth BSRN science and review workshop (WCRP Informal Report No. 17/2001) that was held in Melbourne in May 2000. During that workshop it was decided to make a second pyrgeometer comparison to investigate longwave radiation issues under Arctic winter conditions.

IPASRC-II was held at the North Slope of Alaska (NSA) ARM site at Barrow, Alaska in March 2001. A total of 14 calibration traced pyrgeometers, chosen from a broad international community were compared during IPASRC-II. These pyrgeometers were subdivided into two groups. The first group consisted of seven original Eppley PIR pyrgeometers. Original PIRs are instruments as available from the manufacturer. The second group consisted of five modified Eppley PIR pyrgeometers and two Kipp&Zonen CG4 pyrgeometers. The modified PIRs have three instead of only one dome thermistor in order to provide a more uniform temperature measurement. The CG4 pyrgeometers use a meniscus shaped hemispherical dome, which is designed to minimize temperature effects within the dome by optimizing the thermal contact to the body of the instrument.

As absolute reference instrument we used the Absolute Sky-scanning Radiometer (ASR) that was built at the World Radiation Center (PMOD/WRC) at Davos. ASR measurements were used to field calibrate the pyrgeometers. Pyrgeometer measurements with different calibration sets were then compared to ASR measurements with respect to precision (comparability between individual pyrgeometers) and uncertainty (comparison of mean values of pyrgeometer groups with different calibration sets and the ASR). In order to learn about the absolute uncertainty of surface longwave irradiance determination we compared pyrgeometer and ASR measurements with Atmospheric Emitted Radiance Interferometer (AERI) measurements and radiative transfer model calculations.

As a general result from IPASRC-I and II we found that sensitivity values determined by the common blackbody calibration (performed by CMDL before the comparisons) leads to higher precision between pyrgeometers than sensitivities provided by the owner of the instruments. But field calibrating pyrgeometers during the comparison has achieved an increase of precision by a factor of three over measurements with CMDL sensitivities. However, it was found that sensitivity values determined by field calibration at midlatitude summer conditions are not best performing at an arctic winter site. Hence separate field calibrations for specific climatic regions are required to achieve highest precision.

With regard to absolute uncertainty of longwave irradiance we analyzed several nighttime cases of IPASRC-I and II by comparing ASR-, pyrgeometer- and AERI measurements with model calculations. As a general result we found that for arctic winter and midlatitude summer nighttime longwave downward irradiances determined with pyrgeometers, AERI and models are within 2 Wm^{-2} to measurements of the absolute sky-scanning radiometer. Nighttime longwave downward irradiances can therefore be measured with an absolute uncertainty of ± 1.5 Wm^{-2}. Daytime longwave radiation measurements have a slightly larger uncertainty that is mainly caused by the influence of solar shortwave radiation, even though pyrgeometers were always shaded from direct solar radiation. IPASRC-I results have been published (Philipona et al., JGR, 106, 28129-28141, 2001). A publication on IPASRC-II results is in preparation.

Pyrgenometer characterizations for the ARM Program (T. Stoffel)

The Atmospheric Radiation Measurement (ARM) Program, funded by the U.S. Department of Energy, requires accurate calibration and characterization of pyrgeometers deployed in measurement networks in the Southern Great Plains, Tropical Western Pacific, and the North Slope of Alaska (http://www.arm.gov). The purpose of the presentation is to provide an overview of recent indoor and outdoor pyrgeometer characterizations at NREL's Solar Radiation Research Laboratory (SRRL) and ARM's Radiometer Calibration Facility (RCF).

John Hickey (The Eppley Laboratory, Inc.) and Ibrahim Reda (NREL) have developed a Pyrgeometer Blackbody Calibration System for the ARM Program. The new system was designed to meet the BSRN protocol for pyrgeometer calibration. Two blackbody calibration systems have been built and installed at SRRL in Golden, Colorado and the RCF in Lamont, Oklahoma. A group of three Model PIR and one CG4 pyrgeometers was selected from those calibrated in the blackbody system for use as Transfer References. Outdoor comparisons at SRRL and the RCF were made to assess the PIR performance and evaluate four methods of computing longwave irradiance.

Blackbody calibrations at SRRL and the RCF agree within ± 0.8% (PIR s/n 31236F3). Outdoor comparisons of 12 PIRs calibrated at the RCF agree within ±1% of the mean irradiance. Future plans include blackbody and outdoor comparisons of more PIR and CG4 pyrgeometers at both facilities and the definition of calibration uncertainties.

Reference:

Reda, et al, in-press: Pyrgeometer calibration at the National Renewable Energy Laboratory (NREL), Journal of Atmospheric and Solar-Terrestrial Physics, Vol 64/15, pp 1617-1623. Elsevier, October 2002.

5. UV AND SPECTRAL MEASUREMENTS

5.1 Summary of UV Working Group Report (A. Manes, Israel Meteorological Service)

The members of this working group are:

A. Manes (Chair)
B. Forgan
I. Galindo
A. Heimo
B. McArthur
R. McKenzie
J. Olivieri
R. Philipona

The Summary of recommendations from this group are given here, the full report being available as Appendix D.

Following discussion of the UV WG's report submitted to the 7th BSRN Scientific and Review Workshop, and considering:

- the relatively good experience with commercially available all-weather UV spectral instruments, i.e. shadowband and multifilter radiometers

- progress made with UVB broadband instruments, by achieving higher stability of the calibration factors by correcting for the total ozone and SZA dependencies, as carried out by the Central UV Calibration Facility (CUCF) of NOAA, and at some BSRN stations (e.g. (Carpentras).

and noting that the majority of station managers and site scientists, present at the workshop, have expressed their consent to carry out UV measurements at the BSRN stations, the following resolutions were adopted:

1. UV radiation measurements will be carried out at BSRN stations with the best, available at the station, instruments for the purpose.

2. In case broadband instruments will be used, the station will be provided with the necessary correction algorithm/program, with total ozone derived from TOMS database.

3. UV data will be submitted to the archive. The archive administration will make the necessary provision for inclusion of UV data in the archive.

4. The UV WG will continue to monitor the activities of other agencies, primarily GAW, with regard to precision UV measurements and instrumentation, and report to the 8th Workshop in 2004.

5. The UV WG will seek cooperation with the SAG on UV of WMO/GAW, and encourage the establishment of a World UV Reference Center, to provide the necessary calibration hierarchy.

5.2 Technical and scientific developments

UV measurements at Carpentras - Calibration of the UV sensors (J. Olivieri, Météo France)

The BSRN station of Carpentras owns an **UVB-1** ultraviolet pyranometer - a *Yankee Environmental Systems, Inc.* radiometer - since July 1994. Very recently some *Solar Light Co.* UVA and UVB detectors, which references are respectively **PMA 1111** and **PMA 1102**, were purchased. This last radiometer is a "simplified" and less expensive version of the well known SL 501 A radiometer. All these instruments are broadband sensors.

The best method of calibrating UV broadband instruments is to compare them directly to a *well-calibrated* spectroradiometer and to integrate the resulting spectra, eventually weighted by a biological action spectrum, over the appropriate wavelength bands.

The station of Carpentras owns also a spectroradiometer since 1998. This instrument, made by *Optronic Laboratories, Inc.*, is a microprocessor controlled spectroradiometer, called **OL 754 – O – PMT**. It is optimized for *Global solar spectral irradiance measurements* over the 200 nm to 800 nm wavelength region.
Assuming that the spectroradiometer is correctly calibrated, the spectra measured are *not* usable for comparing broadband UV-B radiometers. Due to several causes: noise, stray light, effect of the blocking filters, *etc*., the spectra are not correct under about 300 nm. The erroneous spectral irradiances *must be* replaced by other ones that are "calculated". For that purpose a simple spectral radiation model called **SMARTS2** is used at Carpentras. *SMARTS2* enables the users to estimate at *a given time*, Direct, Diffuse and then Global, spectral irradiances at the Earth's surface under *cloudless skies*.

The association (OL 754 + *SMARTS2*) permits to obtain corrected spectra. These spectra are possibly weighted and then integrated, or simply integrated, in order to supply the "true values" of the erythemally weighted and/or total UV-B (or UV-A) irradiances.

Aerosol and UV measurements at the BSRN Payerne and other CHARM stations (L. Vuilleumier, A. Lehmann, A. Heimo and A. Vernez)

UV radiation is measured at the Payerne BSRN station and other stations from the Swiss Atmospheric Radiation Monitoring Program (CHARM) by both broadband biometers and spectral direct irradiance photometers. Biometers measure UV-B (with an erythemal response function) and UV-A irradiance, while UV direct spectral irradiance is measured by newly installed sun photometers (at Payerne, UV wavelength spectrophotometer is currently being installed and is due for completion end of summer 2002).

The relatively short time-span of UV measurements at CHARM does not allow the study of long-term climatic trends linked for instance to changes in the ozone layer. On the other hand, it is possible to use the multiple years of data to evaluate the seasonal behavior of UV-B erythemal radiation at Payerne, Davos and Jungfraujoch. Data from a given day of the year for multiple years were averaged together to produce yearly profiles. As expected, the main feature is the large seasonal change due to the changing maximal solar elevation. However, cloud amounts and importance of snow cover are main factors to explain differences between the profiles of the different stations.

Time series of UV-B erythemal global irradiance at Payerne exhibits decreases in average intensity in 2000 and 2001. However, it is questionable whether such decreases reflect real diminution in UV-B irradiance or are produced by sensitivity loss of the instrument. A preliminary study of the uncertainties affecting UV-B measurement was conducted by comparing global irradiance with the sum of direct and diffuse components. Relatively large differences were found, which exhibited a strong seasonality (larger differences in summer), and increased with time. While global was generally higher than the sum of the components, the opposite case occurred a significant number of times during the second half of 2000 and first half of 2001. Such behavior may also reflect a loss of sensitivity from the global UV-B irradiance biometer.

Direct irradiance UV-B measurements may also be compared with results of a relatively simple model that depends on sun elevation, and optical depths due to ozone, aerosols and Rayleigh scattering. Results of comparison emphasized the importance of uncertainties in the model parameters. For instance, model computation agreed relatively well with results from Davos because ozone column was accurately determined from neighboring Arosa station, and conditions allowed relatively precise determination of aerosol Angstrom parameters from collocated direct spectral irradiance measurements. On the other hand difficult conditions for determining aerosol Angstrom parameter at Payerne resulted in a large variability of the model to measurement ratio.

Development and implementation of a UV calibration system (A. Los, Kipp & Zonen BV, The Netherlands)

UV-A, UV-B and UV-E (Erythema weighted) broadband filter radiometers are widely used for routine monitoring of harmful UV radiation intensities. Due to the different measurement principle between such UV filter radiometers and pyranometers the measurement accuracy of the UV radiometers is inferior to that of current state-of-the-art pyranometers. Nevertheless the quality of UV radiometer measurements can be increased by carefully determining individual instrument parameters and by using well-calibrated and maintained UV spectroradiometers for UV spectral irradiance measurements. These parameters allow to correct broadband UV radiometer measurements for various instrument imperfections. Although no standard calibration method is yet defined for broadband UV filter radiometers outdoor calibration methods using the sun as a radiation source are the most widely used. Nevertheless important details in the procedures differ from one method to the other. The oral contribution presents the UV calibration procedure of the 'UV Calibration Service Center' currently developed at Kipp & Zonen BV, Delft, The Netherlands.

6. PYRANOMETRY

Pyranometer characterizations for the ARM Program (T. Stoffel, National Renewable Energy Laboratory, USA)

The Atmospheric Radiation Measurement (ARM) Program, funded by the U.S. Department of Energy, requires accurate calibration and characterization of pyranometers deployed in measurement networks in the Southern Great Plains, Tropical Western Pacific, and the North Slope of Alaska (http://www.arm.gov). An overview was presented of the method for determining the reference diffuse irradiance in Broadband Outdoor Radiometer Calibrations (BORCAL) at NREL's Solar Radiation Research Laboratory (SRRL).

The summation technique is used to calibrate pyranometers in the BORCAL process. The reference irradiance is computed from coincident measurements of the direct normal and diffuse horizontal irradiance components. In the absence of a standard for diffuse irradiance and the desire to eliminate the effects of thermal offset, we have chosen to use two Eppley Laboratory, Inc. Model 8-48 pyranometers as BORCAL references. These *black and white* pyranometers were calculated using a Model AHF absolute cavity radiometer and the shade-unshade method. The shade and unshade intervals are 150 s and 300 s respectively to account for the 5 s time response of the radiometer. Clear-sky responsivities are determined for three azimuthal orientations and averaged for the final measurement of diffuse irradiance.

Results of subsequent outdoor comparisons of six (6) pyranometers suggest a measurement uncertainty of ± 2.8% + 1 W/sq m. Future plans include shade calibrations of other pyranometers with reduced thermal offset characteristics, such as the CM22.

Reference:

Establishing the Clear Sky Diffuse Reference for BORCAL Using EPLAB Model 8-48 Pyranometers at the National Renewable Energy Laboratory Ibrahim Reda, Tom Stoffel, and Daryl Myers, 12th ARM Science Team Meeting April 2002 St. Petersburg, Florida (Abstract available from http://www.arm.gov)

Results of the 2001 ARM Diffuse Intensive Observation Program (J. Michalsky, SUNY Albany, USA)

Motivated by the persistent discrepancy between measurements of clear-sky diffuse horizontal irradiance and models of same, an experiment was undertaken in which diffuse irradiance was measured simultaneously by 14 radiometers over a period of two weeks at the Oklahoma Atmospheric Radiation Measurement (ARM) site during September and October 2001. The goal was to determine whether a consensus within a few W/m^2 could be reached among different types, and independently calibrated, instruments. The measurements revealed a natural division of instruments with a very consistent group of five commercial pyranometers, the remaining five commercial pyranometers, and the four prototypes. The five most consistent measurements agreed within 1-2 W/m^2. Four of the five remaining commercial instruments agreed to within 2-3 W/m^2. The prototypes were much less consistent. Plots of night-time readings of the radiometers versus net infrared measured with a pyrgeometer revealed offsets in several of the radiometers. A capping experiment on a clear afternoon indicated that most of the radiometer offsets measured just after capping could be predicted using the relationships indicated in the night-time data. The main conclusion was that a subset of the radiometers could be selected to establish a working standard for diffuse irradiance until such time as an absolute standard can be developed. A very different measurement of the diffuse spectral irradiance was made using two spectrometers calibrated with standard lamps. The ultraviolet and visible spectra were integrated, and modeled clear-sky diffuse irradiance beyond 1050 nm of 4-5 W/m^2 was added to get total shortwave diffuse irradiance. These independent measurements agreed with the five most consistent broadband measurements to within 1-2 W/m^2.

Severe underestimation of solar global and diffuse radiation caused by pyranometer thermal offsets (R. Philipona)

Reinvestigations of pyranometer calibration and field measurements at the World Radiation Center endorse previous experiments showing diffuse irradiance underestimated due to pyranometer negative thermal offsets. Thermal offsets measured during daytime are considerably larger than night offsets and do not directly scale with net longwave radiation. While other researchers report smaller offsets on global radiation, our experiments show negative offsets of similar magnitude on diffuse as well as on global irradiance measurements. Three calibration methods have been used to investigate the effect of thermal offsets on pyranometer calibration and four different types of prominent pyranometers were used in the tests. Due to the fact that negative offsets on pyranometers are similar during the diffuse and the global measurement phase, the alternating sun/shade calibration method results in correct calibrations even if pyranometers are used in the traditional unconditioned way (no ventilation, no heating). However, the use of an unconditioned reference pyranometer results in a systematic calibration error of 1 to 2 % with the component sum calibration method. Even though with the tracker calibration method (pyranometer normal to the sun with limited sun viewing angle of 5 degrees) pyranometers are not subject to thermal offsets, other pyranometer errors limit the accuracy of such a calibration for most of the tested pyranometers. During field measurements, the use of component sum calibrated unconditioned pyranometers results in 8 to 20 Wm^{-2} underestimations of clear-sky global and diffuse solar radiation. Our experiments show that thermal offsets are of different magnitude for different pyranometer types, and demonstrate that thermal offsets can be suppressed or at least minimized with adequate ventilation and heating systems. However, since in the past pyranometer measurements were often made without ventilation and heating, thermal pyranometer offsets may have caused considerable underestimation of global solar irradiance. Future solar global and diffuse radiation measurements will have to be made with proper conditioning systems and with pyranometers with small or no thermal offsets.

The BSRN Standard Shading Disk for Diffuse Observation: A Proposal (A. Ohmura (ETH Zurich, Switzerland), and G. Major (Hungarian Meteorological Service))

The method of calculation of circumsolar part of irradiance for pyrheliometers and diffusometers developed by A. Ohmura was presented. In this method the irradiation of each point of the receiver is calculated first and later on the average insolation of the whole receiver. According to the numerical evaluation of these forms the circumsolar irradiances for absolute cavity radiometers, the CH-1 pyrheliometer and the most common diffusometers as well are within 3 W/m^2, so they fulfill the 5 W/m^2 requirement prescribed for diffuse measurements.

Ohmura recommends to use Eppley 8-48 pyranometer for BSRN diffuse measurements with shading disk radius of 28 mm and arm length of 641 mm. For the same pyranometer and absolute cavity radiometers G. Major calculated as optimal geometrical parameters 300 mm and 726 mm respectively (see the Solar Diffuse Geometry WG's final report). According to Ohmura's calculation method, these two geometries would result the following circumsolar contribution in W/m^2:

Solar zenith angle, deg	Major's shading	Ohmura's shading
0	12.8	12.9
30	10.6	11.1
60	6.0	6.3

The differences between the respective values are negligible.

The most of the details of the 4 years activity of the Solar Diffuse Geometry Working Group is collected in the Final Report of the WG annexed to this Regina report (see Appendix E).

All-weather cavity measurements at Bratt's Lake (D.H. Halliwell, B. McArthur, I. Abboud, E. Wu, Meteorological Service of Canada)

The presentation reviews the performance of three Eppley HF absolute cavity radiometers in comparisons carried out at Environment Canada’s BSRN Observatory, located near Wilcox, Saskatchewan. The study focuses on the relative performance of HFs situated in an all-weather enclosure, compared to HFs in a normal, naturally-exposed condition. The all-weather enclosure protects the instrument in inclement weather, using an automated hatch cover triggered by a precipitation sensor. This hatch cover is also automatically closed for five minutes every half hour, for calibration of the HF thermopile sensitivity. With the hatch open, the instrument has an unobstructed view of the sun. The enclosure is ventilated via an inlet at the rear, with air escaping through the front during normal operation and through a spring-controlled outlet at the rear when the hatch is fully closed. Two of the three HFs used in the study - numbers 18747 and 20406 - have participated in IPC and NREL comparisons since 1980 and 1995, respectively.

Data collected using the all-weather enclosure covers several periods with varying ventilation settings: no ventilation, low and high ventilation rates, and several air filtration methods. With ventilation off, the HF inside the enclosure compares very well with an HF exposed normally: daily regression of one-minute irradiance values between the two instruments generally yields slopes between 1.00 and 1.01 and r^2 values exceeding 0.999. With ventilation active, results vary widely and are generally poor. By examining the instrument responsivities as a function of temperature (as determined by the calibration cycle every half hour), it could be seen that instrument responsivity is highly dependent on the ventilation regime. Although any single ventilation regime usually provided a tight clustering of points (with a temperature dependency), different regimes displayed different clusters.

It is speculated that the undesirable effects of the ventilation system are related to an asymmetrical heating of the instrument within the enclosure, where temperatures are consistently several degrees warmer than a normally-exposed instrument. Recent comparisons with insulation wrapped around the HF in the enclosure show much improved results, similar to the results with the ventilation shut off. Further data are required to confirm long-term stability of the insulated instrument under a wider range of environmental conditions. The results also suggest that wind effects on the normally-exposed instrument may be a concern, given the frequent high winds observed at this location.

Water Vapor Path Influences on Solar Direct Beam Measurements (D.W. Nelson, NOAA CMDL, USA)

A primary goal of the BSRN (Baseline Surface Radiation Network) is to improve the quality of surface radiation budget monitoring efforts throughout the world. Protocols to achieve this goal have been developed and implemented by BSRN participants. An important protocol that has been adopted is the use of component summation for determination of total solar irradiance (direct beam + diffuse sky), with an unwindowed self-calibrating cavity radiometer used for direct beam determination. Implementation of the direct beam protocol has proved difficult for most participants and to date traditional pyrheliometers are still being used to measure the direct solar beam.

The magnitude of variability in solar direct beam measurement when traditional pyrheliometer performance is examined with respect to effects of atmospheric water vapor is illustrated Three pyrheliometers equipped with window materials exhibiting different spectral ranges were compared with an unwindowed cavity. Results suggest that for measurements here in Boulder at DSRC, under clear sky conditions, the magnitude of variabilities range from less than plus or minus five watts to plus or minus 15 watts. The variabilities are caused by the pyrheliometer window material and the total water vapor path length, with calcium fluoride window material being the least influenced by water vapor effects when compared with an unwindowed cavity traceable to the WRR.

7. SPECIAL MEASUREMENTS, CLOUDS, AEROSOLS, ALBEDO, SPECTRAL BANDS

7.1 Cloud observations

Report of Working Group on cloud issues (C. Long)

Results were presented on the current status of retrieval of cloud properties from broadband radiometer and common meteorological measurements. So far, great success has been achieved in:

1) detection of clear-sky periods during daylight hours
2) continuous estimates of clear-sky global, diffuse, and direct SW
3) fractional sky cover

Preliminary results were presented of work/progress in retrieval of:

1) “effective” cloud optical depth (assumed single layer, plane parallel)
2) continuous estimates of clear-sky downwelling LW
3) estimates of cloud base temperatures
4) rudimentary (low, mid, high) cloud base height
5) sky/cloud classification

It is noted that these “derived quantities” are of great interest as “truth” for model and satellite comparisons. In addition, the Cloud Issues working group forwarded a recommendation that Infrared Thermometers be included on the BSRN “ancillary” recommended instrument list to serve as a cost effective means of estimating cloud base temperatures and heights both day and night. One aspect that this presentation uncovered that needs discussion is the question of what “derived quantities” the BSRN Archive should consider for storage and distribution to the community.

7.2 Aerosols

Comparison of aerosol optical depth measurements at Bratt’s Lake (D.H. Halliwell, B. McArthur, O.J. Neibergall, N.T. O’Neill, J.R. Slusser, and C. Werhli)

The presentation examines the performance of five instruments used for aerosol optical depth measurements at the Bratt’s Lake (BSRN) Observatory, located near Wilcox, Saskatchewan, during the summer of 2001. All instruments measure solar irradiance at several wavelengths in the range 340-1020 nm, using narrowband interference filters (2 – 10 nm FWHM). Three of the instruments - the Cimel CE-318, the Global Atmosphere Watch (GAW) Precision Filter Radiometer (PFR), and the Middleton SPO1-A - are sun-tracking photometers. The remaining two instruments - a pair of Yankee Environmental Systems (YES) Multi-Filter Rotating Shadowband Radiometers (MFRSR) - obtain direct beam irradiance values by subtraction of diffuse irradiance from global irradiance, using measurements obtained by shading the sensor head. Three of the instruments are administered by international networks: the Cimel is part of AEROCAN/AERONET, the GAW PFR is operated as part of the Global Atmosphere Watch program, and one YES MFRSR is operated by the USDA UVB Monitoring program. The remaining instruments (SPO1-A and YES MFRSR) are owned and operated by the Meteorological Service of Canada (MSC). AERONET and the USDA UVB programs performed all calculations of optical depths with their instruments. GAW PFR data was analysed by MSC staff using software and following protocols provided by GAW. The two MSC instruments were analysed using software developed at MSC. There are differences in the handling of ozone, pressure, etc. between the systems, but most differences are minor. Measurement frequencies vary between instruments, ranging from once every 15 seconds for the MSC MFRSR to tens of minutes or more for the AERONET Cimel.

Most networks or instruments provide some sort of method for cloud screening. The data were first reduced to a set where several methods agreed on cloud-free conditions. Aerosol optical depths were calculated and compared, and Ångström alpha and beta coefficients were calculated using both instantaneous measurements and Langley analysis for selected half-day periods. Optical depths were compared using similar (within 10 nm) wavelengths between instruments. Under clear, stable conditions, aerosol optical depths at 500 nm were <0.1. Overall, the sun-tracking instruments generally give aerosol optical depths that agree within 0.01. The MFRSR instruments show poorer agreement, and show diurnal variations that suggest alignment and/or cosine response of the sensor head may not have been correctly accounted for. Ångström coefficients showed much greater variation, suggesting that extreme caution should be exercised in comparing optical properties derived from optical depths. The results of various cloud-screening methods also vary considerably, and should be reviewed. Finally, improvement in comparisons between instruments will result if more detailed information on pressure, ozone, and other absorbers can be incorporated into the analysis methods.

Aerosol optical depth from sky-radiometer measurements (M. Shiobara, National Institute of Polar Research, Japan)

Sky-radiometer is a sky-scanning spectro-photometer to obtain optical properties of aerosols such as the optical depth, phase function, size distribution, refractive index, single scattering albedo, etc., using not only direct solar attenuation but also sky radiance measurements.

A modified Langley method is applied for calibration of sky-radiometers. It is noted that the surface albedo should be given correctly for high quality calibration.

Accurate calculations of Rayleigh scattering optical depth are needed for accurate estimation of AOD particularly in clean area with abnormal atmosphere profiles such as Antarctica.

As a network of sky-radiometers, SKYNET in Asia is introduced. SKYNET actually includes not only sky-radiometers but also flux radiometers and aerosol and cloud related instruments, and is deployed at more than 20 sites in Asia to contribute to national/international research programs such as GAME, APEX, and ACE-Asia and also to the ground validation of satellite retrievals.

Aerosol optical depth from PFR instruments in GAW trial network (C. Wehrli, World Radiation Center, Switzerland)

A world wide trial network of automated sunphotometers is under development at GAW global observatories and alternative sites with the aim to collect quality controlled measurements from which accurate and reliable aerosol optical depths (AOD) can be derived. A World Optical depth Research and Calibration Center (WORCC) was established in 1996 at the Physikalisch-Meteorologisches Observatorium Davos as one of the Swiss contributions to GAW.

A new type of weatherproof precision filter radiometer (PFR) with 4 spectral channels was designed and a limited number of instruments manufactured for deployment in the network. Their calibration is based on a set of reference instruments maintained at Davos, which were calibrated at high altitude observatories on Jungfraujoch or Mauna Loa and verified by a stratospheric balloon flight at a height of 40 km. The radiometric sensitivity of these reference PFRs is routinely monitored by comparison to the spectral irradiance scale maintained at the Physikalisch-Technische Bundesanstalt (PTB) in Berlin via a trap detector used as transfer standard. The stability of the reference instruments is estimated at <±0.5%/year. Calibration of the network PFR is linked to the WORCC reference by traveling standards or exchange of sensors.

On a cooperative base, the stations are contributing sun tracking facility and limited amount of manpower for routine maintenance and data handling while the PFR instruments are funded by Météo Suisse. As of spring 2002, 8 stations of the 12 foreseen are operational and delivering data. While 2 additional stations proposed by the GAW Scientific Advisory Group for aerosols have agreed to host a PFR, the placement of the last two instruments in Africa and South America is still open.

Data are sampled at the BSRN rate of 1 minute and will be archived at WDCA in Ispra, Italy. From a technical aspect, the data could easily be submitted to the WRMC in Zürich, at least from those stations that operate under BSRN rules. Currently they are still collected and processed at WORCC where they are available on request.

An extensive field comparison between a PFR and a Cimel instrument operated by Aeronet at Mauna Loa during 10 months in 2000 has shown excellent agreement in AOD to RMS differences of 0.003 to 0.006. The calibration of the PFR at Mauna Loa was found to be stable within <1%/year. David Halliwell has presented results of another comparison between several sunphotometers, including a PFR, at Bratt's Lake during this workshop.

Aerosol observations at Ilorin, Nigeria (R. Pinker (University of Maryland, USA)

A heavy dust event in the sub-Sahel during January 2000 was documented from observations made at the University of Ilorin, Ilorin (08° 19' N, 04° 20' E), Nigeria, in cooperation with the Aerosol Robotic Network (AERONET) (Holben et al., 1998). Analysis of the observations in seven wavelengths revealed that during the dust outbreak event, the optical properties of the dust aerosols were much different from what is assumed in aerosol climatalogies in desert areas, or from observations preceding the dust event. Aerosol optical depths at all seven wavelengths showed a sharp increase when compared to the average for the season, reaching values up to 3.5 at 500 nm. The daily mean size distributions observed during the dust outbreak of January 29–February 1, when large amounts of coarse and fine particles were transported to the site, were presented, showing an order of magnitude increase in volume size distribution. The Angstrom exponent was reduced from 1.2 to 0.3.

Using a two-year record of continuous ground-based measurements at the Ilorin site, desert aerosol models as presented in the literature are augmented, to better characterize the prolonged dust outbreak season in West Africa, which overlaps with the biomass-burning season. Observed average values of aerosol optical depth are compared with those from other sources and observed average values of single scattering albedos during the Harmattan and non-Harmattan seasons are compared with those from other sources.

These results are an important contribution to the characterization of sub-sahel aerosol properties.

7.3 Albedo

Report of the Albedo Working Group (Working Group Members:K. Behrens, I. Grant, B. McArthur, R. Pinker, R. Stone)

The efforts of the Working Group on albedo have been directed toward obtaining high quality measurements based upon the specifications set out in the original BSRN documents and summarized in the BSRN Operations Manual. Over the last two years, work contributing to the improvement of albedo measurements has been undertaken in three areas.

1. The ability of many to measure albedo over a representative surface is made difficult because of location and expense. In regions that are relatively homogeneous, tower measurements can provide a reasonably representative albedo. However, even measurements from tall towers, beyond their expense, can pose significant problems, even in these locations. In areas where the surface is transported by wind (e.g., sand, snow) the tower can alter the wind patterns to the extent that drifts can form on the leeward side and alter the landscape being measured. This is particularly true of Arctic regions. The second major difficulty associated with tall tower measurements remains the care and maintenance of the instrumentation.

   Two members of the working group have attempted to overcome some of the obstacles associated with tall-tower measurements in areas where the regional footprint can be easily integrated upward from a relatively small area. Ian Grant, working in the Australian Outback, and Robert Stone, attempting to deal with blowing snow issues associated with Arctic work, have each developed methods of obtaining surface reflectance measurements at lower heights above the surface than the tower measurements recommended within the BSRN.

   The Australian work is based on a 'spider' mount that uses three short towers set in a triangle from which wires are used to suspend a downfacing radiometer above the surface. The use of such a triangular system reduces the amount of the towers the pyranometer sees, while increasing the height above the more normal 1.5 m height above the surface. Parts of the Australian outback are a mix of scrub, rock and soil in a 'random' pattern that repeats at a high frequency. This mounting system sets the pyranometer at a height of 2.5 m above the surface (FOV ~ 5 m diameter). To obtain a representative surface reflectivity a number of the 'spider' mounts are used to cover different patches of the same area.

The Arctic work was instigated primarily because of the need to obtain higher quality data than available from either a standard 2 m high rack mounting system or a tall tower. In the former case, the effective field of view of the instrument was too small to be representative of the region, while for the latter, drifting snow about the tower alters the terrain seen by the radiometer and in Arctic conditions, the tower is self-shading because of the solar path during summer months. A potential solution to these problems has been found by reducing the tower height and significantly reducing its cross-sectional area. A 4 m tall, guyed, pivoting mast with a balanced T-boom has been used to obtain reflectance measurements. The field of view is ~ 20 times greater than the 2 m rack mount and the reduced cross-sectional area reduces problems associated with drifting snow and self-shading. A newer design of this system will allow the T-boom to rotate about the vertical axis at a constant rate, further increasing the FOV and reducing some of the difficulties associated with leveling the sensor on the original design. Reduced costs in constructing and maintaining such a system will also increase the probability of using multiple units as a means of integrating the regional albedo.

A third party in the working group, led by Bruce McArthur, has used a tethered balloon to explore reflectance characteristics on the Canadian prairies. The investigations have shown that the surface albedo of prairie farmland near the Bratt's Lake Observatory cannot be adequately sampled even from a 30 m tower. Based on farm practices set out at the start of the 20th Century, field sizes vary between 65 and 260 ha. Observations indicate that during the growing season, this repeated patchwork requires that the reflected irradiance be integrated over an area with a diameter of approximately 7 km (95% FOV) to obtain a regional albedo. With the FOV of satellite instruments becoming smaller, and models using finer grids, knowledge of the variation in reflectance across these various surfaces will become more important than a regional reflectivity. During the summer of 2001, reflectance measurements taken 2.5 m above a growing wheat crop showed significant differences over distances in the order of 100 m because of the history of different farming practices on adjacent fields. These gross and fine scale variations in surface albedo indicate the need for observations at various spatial scales. Measurement systems, as described above, may well meet these requirements in many locations when used as part of a measurement grid.

2. Many albedo measurements are observed with the downwelling sensor some distance from the upwelling sensor because of operational convenience. Experiments at the Bratt's Lake Observatory during 2001 have shown that coincident measurements are essential for one-minute average albedo calculations. Data collected from two different downfacing sensors were used to compute albedo using two common upfacing sensors located approximately 30 m distant. During clear or overcast conditions, the difference in the albedo calculation was insignificant. However, during days of scattered cloud cover, especially during conditions where winds exceeded approximately 25 km hr^{-1}, the albedo calculations were found to differ significantly. The collected data indicate that measurements of upwelling and downwelling fluxes must be co-located if accurate one-minute averages are to be obtained.

3. The measurement of spectral fluxes is becoming increasingly important. Both the modeling and satellite communities require spectral reflectance measurements. Experimental spectral albedo measurements, using a photodiode array spectrometer, were obtained during summer 2001 over a maturing wheat crop. While the overall spectal results are similar to other spectral measurements of similar crops, diurnal and day-to-day variations were greater than expected. Such changes in spectral reflectance are significant when considering many model calculations and satellite algorithms use standard albedos for a variety of different surfaces and only infrequently alter these during the course of a growing season. The preliminary results of this effort indicate that greater knowledge of the spectral nature of the surface is critical.

Based on the efforts over the last two years the Working Group would recommend the following activities for the coming two-year period:

1. That work continues on the development of a low-cost means of measuring representative albedos. The inability of most stations to install a 30 m tower for the measurement of albedo is a significant hindrance to the goals of the BSRN in providing high-quality data to the satellite and model communities. It is also recognized, however, that albedo measurements obtained over a 2 m

well-watered grass surface do not provide the data necessary to meet the needs or either community. As part of this effort, it is hoped that both new tower systems mentioned above (as well as others that may be under development) can be tested in other environments. The working group will attempt to compare these methods in at least two locations during 2003.

2. Closely associated with (1), the working group recommends that more effort be placed on attempting to integrate near-surface reflectance measurements into a regional albedo. The measurement programs above will form the base of this effort, but other regional efforts are encouraged. With the exclusion of the tethersonde observations at the Bratt's Lake Observatory, the determination of an integration factor may be difficult. Aircraft, or even model aircraft flights, may provide the transects necessary to aid in this effort.

3. The increasing need of spectral measurements requires further effort be placed in this area. While not the top priority at present, the future need of both downwelling and upwelling spectral fluxes is such that work should continue on the research level in this area. The goal over the next two years of the working group is to increase the body of knowledge associated with spectral albedo and, if possible, develop, or encourage the development of a spectral albedometer based on the principle of the rotating shadowband radiometer.

4. Most albedo work within the BSRN has been over homogeneous flat surfaces such as snow or ice. A review of the literature indicates that some short-term work has been done over forest canopies. Efforts need to be increased to develop a cost-effective means of obtaining quality albedo measurements over more difficult and diverse surfaces. While the group is limited in time and resources, some effort will be expended on increasing our capability to observe albedo over more complex terrain, but especially for areas such as boreal or rain forests.

5. On the recommendation of the participants at the 7th BSRN Scientific and Review Workshop, the WG Chair will also consider the information available in the BSRN Operations Manual and add detail if and where appropriate.

Over the last two years, the WG has not considered the measurement of upwelling longwave irradiance. This measurement is part of the same extended set of measurements as the reflected shortwave flux. It is a necessary component of the surface radiation balance and therefore requires the attention of the WG. While no specific recommendations have been made to contribute to our knowledge of this observation, the members of the WG recognize that there are issues associated with the measurement of surface emittance. A suggestion at the meeting to use an infrared thermometer to better understand cloud-base temperature was brought forward. Observing the surface using similar instrumentation might also aid in our understanding of surface characteristics and broadband emissions. Those within the BSRN are encouraged to develop this and other ideas that might aid in our understanding of surface emissions.

Simultaneous spectral albedo measurements near the ARM SGP Central Facility (J. Michalsky)

Spectral albedo is a critical variable in models needed to improve the agreement with measurements of downwelling and, especially, upwelling irradiance. During the second ARM Enhanced Shortwave Experiment (ARESE II) upwelling and downwelling irradiance measurements were made on low-altitude (150-350 m) flight legs of the Twin Otter aircraft over ARM instruments on the ground that also measured albedo. The aircraft spectrometer was the NASA Ames Research Center's Solar Spectral Flux Radiometer (SSFR) that measures between 350 and 1650 nm. The routine ARM measurements are made with one six-channel multi-filter radiometer (MFR) over ungrazed pasture and another over wheat. Hand-held spectrometer measurements were also made on one of the flight days with an Analytical Spectral Devices (ASD) spectrometer that covers the spectral range from 350-2650 nm. These were made over wheat and un\grazed pasture. The MFR measurements and the SSFR measurements were parameterized where there were spectral gaps to give continuous spectral coverage between 300 and 3000 nm, or approximately, the complete shortwave range. Calculations were performed for cloud optical depths of 10 and 20 to compare downwelling irradiances using the three different albedo inputs. While the spectra differed by up to about 5% in the worst cases, the integrated broadband irradiances were within 0.1 and 0.2% for the optical depth 10 and 20 cases, respectively. The albedo was measured tens of times in each low altitude flight leg and indicated visible and near-infrared differences of over 100% from their lowest values. Repeated measurements directly over the sight indicated differences of less than about 10% that were probably associated with the somewhat different altitudes of the aircraft on each pass. The cloudy day estimates of aircraft and MFR surface albedoes agreed well in the mean spectrally, and agreed less well on clear days, but the difference in downwelling irradiance for clear-sky calculations amounted to only about 2%. One conclusion is that MFR albedoes are probably sufficient for broadband downwelling shortwave model and measurement comparisons, but not spectrally resolved comparisons. Another is that calculations show that adding spectral albedo information as opposed to a single broadband albedo input to models, decreases the difference between models and measurements by about one-half.

Spectral albedo measurements at the Bratt's Lake Observatory (B. McArthur, I. Abboud, D.H. Halliwell, R. Dexter, C. McLinden, O.J. Niebergall, E. Wu)

Understanding the reflectance from various surface types is crucial for both climate modelers and those inverting reflectance measurements obtained from satellites. Most work on surface reflectance has been:

(1) based on broadband irradiance measurements,
(2) used laboratory samples to obtain spectral information about a particular surface type (soil or vegetation) or
(3) obtained only limited field samples for short periods of time because of the nature of the spectrometer being used to collect the information.

During the 2001 growing season at the Bratt’s Lake Observatory, an intensive study was undertaken to understand the relationships between albedo and the major surface characteristics of a maturing wheat crop. Observations were made, beginning before planting and ending at harvest. As part of this experiment, a miniature spectrometer, designed to use a grating in first and second-order to measure the spectral bandwidth between 300 and 780 nm using a 1024 element photodiode array, was used to measure spectral albedo over from just after the first emergence of the crop until harvest. The instrument was maintained at a distance of 2.5 m above the crop surface throughout the summer.

The spectrometer uses a rotating prism to direct light from either an up-facing or down-facing spectralon diffuser housed beneath a single quartz dome. The observation sequence consisted of instrument functions, including a system dark count and wavelength check and then a series of 10 up-facing and down-facing observations in the UV and VIS/NIR portion of the spectrum. A complete measurement sequence lasted approximately 30 minutes. The length of time required to obtain visible spectra was 0.35 seconds and either 2 or 4 seconds for the UV portion of the spectrum depending upon the instrument measuring sky or surface irradiance.

The results of the experiment show changes in the PAR and NIR portion of the spectrum throughout the growing season. In the spring, immediately following the emergence of the crop, the spectral distribution was a combination of soil and plant materials. Within three weeks of plant emergence the soil signature disappeared giving way to the standard spectral curve associated with grass species. Upon senescence, the overall albedo increased significantly, losing the characteristic ‘green peak’, to increase linearly with wavelength. In all cases, however, the reflectance values of the wheat were less than database values associated with grass.

Daily measurements were also to found to vary considerably more than anticipated. It would appear that changes during the day associated with soil moisture availability and plant stress factors can be seen even in the longer visible wavelengths. Such rapid changes throughout the day may have significance when attempting to invert satellite data obtained at various times during the day.

Comparison of spectral surface albedos and their impact on the GCM simulated surface climate (A. Roesch)

This study investigates the impact of spectrally resolved surface albedo on the total surface albedo. The neglect of albedo variation within the shortwave spectrum may lead to substantial errors as the atmospheric water greatly influences the spectral distribution of the incoming radiation. It is shown that ignoring the spectral dependence of the surface albedo will affect the predicted climate. The study reveals substantial changes in the climate over northern Africa when modifying the surface albedo of the Sahara deserts.

Detailed information is given how the ECHAM4 GCM can be extended to include surface boundary conditions for both the visible and near-infrared incoming radiation. This comprises global climatologies for both the visible and near-infrared albedo for snow-free conditions, as well as the corresponding albedo values over snow, land-/ sea ice and over snow-covered forests.

Comparisons between several available surface albedo climatologies and a newly-compiled albedo dataset show substantial scatter in estimated albedos. The largest albedo differences are found in snow-covered forest regions as well as in arid and semi-arid terrains.

7.4 PAR measurements

Report of PAR Working Group (R. Pinker)

History

The first Working Group was established at the 5th BSRN Science and Review Workshop held in Budapest, Hungary, 18-22 May 1998 with following membership:

D. Cahoon, NASA Langley Research Center
J. Hickey, Eppley Laboratory
R. T. Pinker (Chair), U of MD
C. H. Wehrli, Davos, Switzerland

The Working group was updated during the 6th BSRN Meeting, Melbourne, Australia, 2000:

John Hickey, Eppley Laboratory
Ain Kallis, Tartu Actinometric Station
Kevin Larman, NASA LaRC
Bruce McArthur, AES Canada
Rachel Pinker (Chair), U of MD
Kevin Rutledge, NASA LaRC

Charge to the group:

1. what instruments are available to measure PAR
2. how accurate are they
3. should PAR be included in the list of parameters of the BSRN observations

Highlights of Previous Report:

Several groups are now measuring PAR, on a regular basis.

The most common instruments:

1. Li-Cor quantum sensor
2. Kipp and Zonen Par Lite
3. Colored hemispheres on pyranometers (Schott filters)
4. Spectroradiometers

No systematic evaluation of these instruments is available.

During the last two years, the following work was done on evaluating PAR observations:

1. In Estonia, at the Tartu Observatory, Toravere, a comparison between Li-Cor and Par Lite conducted (Ross and Sulev, 1999).
2. At NASA/Langley, calibration of the Li-Cor instrument was undertaken using spectral measurements. Results were presented in a poster at the 6th BSRN Meeting at Melbourne, Australia.
3. Bruce McArthur is measuring PAR with pyranometers equipped with Schott Filters.

    1. Action Items:

        a. The Working Group will develop a work plan on issues that will lead to the formulation of recommendations regarding the need to archive PAR at Zurich.

        b. The Working Group was charged with the task of initiating the preparation of a draft document related to PAR archival issues, similar to the one developed by Bruce Forgan on "BSRN Specification Related to Aerosol Optical Depth".

c. At the next BSRN meeting a one-week PAR intercomparison campaign will be conducted.

Update

1. Other instrument identified:

   a. Australia: Middleton

   b. Skye-Probetech SKE-510 PAR sensors

Has a silicon detector with a teflon diffuser and interference filters. Calibrated in W/m2, as opposed to photon flux density. Calibration drifts quite rapidly when used for continuous monitoring, probably due to filter degradation. It was calibrated against cloudless model estimates when the AOD was low (<0.1 at 500nm) (see Eck et al., 2001, JGR,106, pp. 3426-3427). Therefore, its use along with the CIMEL measurements in the Amazon was switched to RG695 filter domes on Kipp & Zonen CM21 pyranometers. Together with unfiltered CM21's will give the 300-695 nm flux.

Working Group Recommendations

1. need to evaluate results from first experiment; if necessary, comparison should be repeated and results published
2. in view of demand for PAR, measurements should continue with available instruments
3. premature to formulate archiving guidelines
4. dialogue among working group members should continue to deal with original mandate to committee

First Intercomparison Experiment

Regina, Canada, started in the middle of July, 2002

About 15 instruments are participating in the intercomparison. They are of the following make:

1. Li-cor
2. Kipp and Zonen Par Lite
3. Apogee
4. Missleton
5. Nilu
6. Skye-Probetech

Also, the following spectroradiometers will be used for evaluation:

- 2 diode array instruments “home made” by McArtur’s group. They will be used in the 380-780 nm interval, at 1 nm resolution.
- One Optronics OL754 instrument, which is a grating spectrometer, to be used in same spectral intervals.

Preliminary results shown at the 7th BSRN meeting indicated that instruments of same kind tended to give similar results, however, there was a distinct difference between instruments. The results of the intercomparison will be prepared for publication.

Preliminary results of the BSRN PAR instrument comparison (B. McArthur, E. Wu, D.H. Halliwell, I. Abboud)

The Working Group on PAR Measurements decided at the 6th Scientific and Review Workshop held in Melbourne, Australia, 2000 that a comparison of PAR instruments should take place in conjunction with the 7th Scientific and Review Workshop. The decision was made in late March 2002 to hold this comparison at the Bratt’s Lake Observatory during the week preceding the meeting. Due to difficulties in receiving some of the instruments, the comparison began several days later than anticipated and continued through the meeting.

Overall, the comparison comprised 19 PAR instruments that came from 6 separate groups. The most common instrument was the LiCOR sensor (10 instruments), but Kipp and Zonen (3 instruments), Skye (2 instruments), Apogee (2 instruments), Middleton (1 instrument) and NILU (1 instrument) were also represented. The Meteorological Service of Canada contributed three spectrometers to measure the spectral distribution of the incoming flux. Two of these instruments are portable single-grating photodiode array instruments capable of measuring the PAR band (400 – 700 nm) in less than 0.5 seconds. The third spectrometer used for the comparison is an Optronics OL754 double-monochromator instrument with a PMT as the detector. This instrument requires approximately 15-minutes to complete a single scan, so can only be used during high solar angles on the most stable days. Two Eppley PSP pyranometers using Schott glass filters at 395 and 695 nm were also monitored throughout the period.

The PAR sensors use a filtered silicon photodiode as the detector, having a time constant in the order of 10^{-6} seconds. Therefore, the sampling rate for the comparison was selected to be 60 Hz as a means of matching the spectrometer and sensor outputs. Data for the PAR instruments, with the exception of the NILU instrument, were collected on a Campbell Scientific CR5000 Datalogger. The NILU instrument has its own data acquisition unit.

The first results preliminary results indicate that each of the different types of instruments appear to be internally consistent. The LiCor instruments gave the largest readings, with a variation of about 3.5% across all the instruments. The Kipp & Zonen instruments provided similar readings, while the Apogee and Skye instruments read slightly lower. The Middleton gave the lowest readings of the group. The NILU and spectrophotometer data had not been processed by the end of the meeting.

Following the field comparison, those instruments that did not have to be returned immediately were to be shipped to Toronto to be characterized with respect to temperature and cosine response.

8. APPLICATIONS

Application of BSRN observations to the WCRP Surface Radiation Budget Project at NASA Langley (M. Chiacchio (AS & M, Inc., USA), P.W. Stackhouse, Jr., C. Mikovitz, S. Gupta, and S. Cox)

The NASA/GEWEX SRB Project has the goal to produce a global surface radiation budget dataset on a 1° x 1° grid spanning from July 1983 to October 1995. The global surface radiative budget parameters and relevant input information will be made available on a 3-hourly basis and in averages of 3-hourly monthly, daily, and monthly. As processing continues the key parameters of the data set are being validated with surface measurements from data archives such as from the World Radiation Data Center (WRDC), NOAA Climate Monitoring Diagnostics Laboratory (CMDL), and the Baseline Surface Radiation Network (BSRN). In this talk, we compared measurements of solar and terrestrial radiative fluxes to SRB estimates for monthly, daily, and 3-hourly monthly averages for the years 1992 and 1993.

For the monthly averaged comparisons, we find that monthly averaged downward LW flux for both 1992 and 1993 give a Root Mean Square Difference (RMSD) within 19 Wm^{-2} and a bias of -1 Wm^{-2}. We note that the estimated fluxes for the LW are overestimated for tropical sites. The downward SW flux estimates gave an RMSD within 22 Wm^{-2} and a bias of 3 Wm^{-2}. Monthly averaged time series for 1992 were then presented for sites such as Kwajalein (KWA), Boulder (BOU), and Bermuda (BER) to determine whether the month-to-month variability is properly captured. Comparisons to both 1992 and 1993 measurements of daily averaged downward LW flux gave an RMSD within 26 Wm^{-2} and a bias of -1 Wm^{-2}. The SW flux comparisons gave an RMSD within 40 Wm^{-2} and a bias of 5 Wm^{-2}. Also, daily averaged time series and cumulative flux histograms for individual sites were shown for several months in 1992 to evaluate the agreement in the day-to-day variability. Patterns of disagreement for individual sites will be examined more closely. Finally, the monthly-averaged diurnal cycle (monthly 3-hourly) estimates were compared with SW measurements for the BER site in January, April, July, and October of 1992. The integrated SW fluxes agreed very closely during the equinox months of April and October, and to about 10% for January and July.

Future plans include refining and applying validation procedures for each new year processed. Some of these refinements include applying the Long and Ackerman technique (2000, JGR) for discriminating between clear and cloudy skies. This discrimination will also be important to compare the direct/diffuse SW fluxes and to better discern sources of error in the data sets.

GCM calculations of present and future downward longwave radiation at BSRN stations (M. Wild, ETH Zurich, Switzerland)

Part one of the talk (assessment of GCMs with respect to their performance in the longwave using BSRN data) is missing.

An increase of longwave downward radiation emitted from the atmosphere back to the surface is the most direct manifestation of an increase in atmospheric greenhouse gases. The longwave downward radiation is proposed as a most valuable candidate for an early detection of the greenhouse signal, as it emerges earlier from the background noise than the surface temperature. The expected change in the longwave downward radiation projected by a coupled atmosphere ocean GCM amounts to approximately 2 Wm^{-2} per decade, when averaged overall BSRN sites. The projected changes at these sites exceed twice the corresponding standard deviation in the unforced control run after 20 years. This indicates that within 20 years, the greenhouse gas-induced signal should become discernible in the observational record of longwave downward radiation at the BSRN site.

Comparison of modelled irradiances with tethersonde observations (S. Freidenreich)

The BSRN data is being used to validate the clear-sky surface shortwave radiation in the GFDL General Circulation Model. The temporal variations in the BSRN data have been analyzed in order to isolate "clear-sky" observations. A single observation is considered to be clear-sky if it is the midpoint of a 30 minute time interval where the transmission value of all the observations differ from a calculated clear sky value by < 0.2. From these selected observations, monthly mean climatologies for both the direct and total (direct+ diffuse) transmitted solar flux at the surface have been derived. This analysis is carried out for Boulder and Payerne only. These two stations are interesting to compare due to the large differences in the aerosol amount present.

A 17 year integration (1982-98) of the GFDL GCM with prescribed SST's is made both with and without aerosols included. The aerosol data set, provided by J.M. Haywood, consists of monthly mean climatologies derived from 3d chemistry transport models, and include natural and anthropogenic sulfate and dust, soot, organic carbon and sea-salt. Monthly mean climatologies of the clear-sky transmitted flux at the surface for the grid points closest to Boulder and Payerne are derived.

Comparing the model and observed direct transmitted surface flux at both locations, the GCM consistently overestimates the observed BSRN values when aerosols are excluded from the model with differences exceeding 40 W/m2. For Boulder, the magnitude of the differences between the GCM and observed values are less when the Haywood aerosol climatology is included, except during October to December. For Payerne, the prescribed aerosol climatology results in greater underestimates due to the much larger aerosol optical depths in this region. Also there is a large interannual range in the model values due to the dominance of sulfate aerosols in this region and the dependence of its extinction properties on the relative humidity. For the total transmitted flux at the surface, the agreement with observed is better for both locations when aerosols are included.

Thus, the BSRN data is found to be a valuable tool in pointing out the biases in the GCM clear-sky transmitted solar flux, both in the case when aerosols are excluded, and when they are included with the currently specified climatology.

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Overview of the CCSR In-Situ Sensor Measurement Assimilation Program (G. Fedosejevs, Canada Centre for Remote Sensing)

Significant advancements in Earth observation are expected to come about by developing more systematic capabilities for assimilating remote sensing observations and in situ measurements for use in models, at relevant scales, to generate geophysical and biospheric information products. This presentation on the In Situ Sensor Measurement Assimilation Program (ISSMAP) at the Canada Centre for Remote Sensing (CCRS) provides an overview of the role of in situ sensing in the context of integrated Earth sensing. It also defines a framework for taking advantage of intelligent sensor webs based on the converging technologies of micro-sensors, computers, and wireless telecommunications in support of critical activities such as the monitoring of remote environments, risk assessment and hazard mapping, and renewable resource information management. For selected biospheric applications, ISSMAP's objectives are to collaborate with partners to: (1) design and deploy intelligent sensor networks for in situ data acquisition; (2) develop methods to assimilate in situ and remote sensing data into models that generate validated information products; (3) facilitate the integration of in situ sensor data and/or metadata into on-line geospatial data infrastructures. The knowledge gleaned from integrated Earth sensing has the potential to empower managers and decision makers to act on critical climate, sustainable development, natural resource, and environmental issues.

Preliminary results from the BSRN SW Flux Analysis (C. Long, M. Wild, A. Roesch)

The SW Flux Analysis code has been installed to operate on the BSRN Archive System. Work is progressing on final implementation of the code and related semi-automation for operation, which should be completed in the next 1-2 months. The output of the code includes:

1-minute sampling:
Measured data (GSW, Dif, Dir, Swup, LWdn, Lwup, P, T, RH)
Clear Sky (GSW, Dif, Dir, Sum SW, SW Albedo)
Data QC/Clr flags
Details are available at: http://www.arm.gov

15-minute sampling:
All above, plus average and standard deviation of sky cover

Preliminary climatological analyses of cloud properties such as daily percent of clear-sky occurrence, sky cover frequency histograms, and comparisons of sky cover versus measured/clear SW ratio (as a surrogate for cloud optical depth) were presented for many of the BSRN sites who have submitted data to the Archive.

A description of the CERES Ocean Validation Experiment (COVE), a dedicated EOS validation site (F.M. Denn (NASA Langley, USA), and C.K. Rutledge)

NASA's Clouds and the Earth's Radiant Energy System (CERES) Ocean Validation Experiment (COVE) is a dedicated Earth Observing System (EOS) test site. COVE is located approximately 20 km east of Virginia Beach, Virginia, USA (latitude 36.90 N, longitude 75.71 W). This is near the outlet of the Chesapeake Bay. The optical properties of the water are periodically affected by the discharge of the Bay, and the rivers which flow into it. These effects are the result of the biotic and abiotic processes which take place in the Bay, estuaries, and contributing rivers. The location of COVE in the Atlantic Ocean provides a uniquely homogeneous scene type when viewed by a satellite.

The current Baseline Surface Radiation Network (BSRN) radiation instrumentation deployed at this site consists of a Kipp & Zonen CH1 for direct beam measurements, Kipp & Zonen CM31 radiometers for shortwave diffuse and global measurements, and an Eppley Precision Infrared Radiometer (PIR) for longwave measurements. Meteorological instrumentation measures wind speed and direction, temperature, relative humidity, and atmospheric pressure.

Additional radiative measurements are obtained from a standard Multi-Filter Rotating Shadowband Radiometer (MFRSR), an ultraviolet MFRSR, a Cimel CE 318-1, and a Schulz SP1A sunphotometer. A second standard MFRSR is mounted in the inverted position making spectral albedo measurements possible. A Heitronics KT11 pyrometer is used to measure sea surface temperature. Water vapor is determined with a Trimble 4700 Global Positioning System (GPS) based system.

9. RECOMMENDATIONS FROM THE MEETING (E. Dutton, B. McArthur, G. Sommeria)

1/ Solar Diffuse Geometry - Differences between the shading geometries presented by the WG are minor compared to operational considerations of tracking, wind vibrations, and practical mechanical limitations as well as remaining uncertainty due to forward scattering by clouds and aerosols and as well as potential and likely differences in the detector sizes of future radiometers. The proposed tables of Ohmura and Major *are* accepted and geometries within the ranges of those tables *will* be established as the network recommendations. The work of the WG will be considered complete. A table of these results is included in the meeting proceedings and a complete final report that gives the source of the results will be published by the working group. - Adopted

2/ Aerosol optical depth - It remains to be decided as whether the final step in processing routinely observed spectral transmissions be performed at either the Archive or the by the site scientists, but in either case using a standard algorithm that is being developed by the AOD WG. This algorithm will be completed within six (6) months following this meeting and its final form will be at the discretion of the WG chair. Further assessment of the Archive's current and future ability to handle this activity, considering other pressing demands on the Archive, is required and should be completed within two (2) months from the end of this meeting. Field sites should proceed with developing their AOD (spectral transmission) measurement programs using a recommended instrument (BSRN 2000) and prepare to submit either requested quantity to the archive. *After completion of the AOD reduction algorithm, the AOD working group should evolve to an aerosol working group and move on to assessing the potential for determining other climatically important aerosol optical properties and continue to monitor developments in the area of remote sensing of aerosols from the surface.* Adopted

3/ Thermal offset correction (solar diffuse only) - It has been firmly established that thermally induced offset errors due to dome temperature differentials exist in pyranometers being used by BSRN stations and that in some cases the errors exceed BSRN specifications. Likewise, some instruments have been shown to have small to minimal thermal offsets. Site scientists *should use* the information presented at the recent BSRN meetings ($5^{th,}$ 6^{th}, and 7^{th}) and/or the published or soon-to-be published literature (Rayleigh comparisons, daytime-capping, Dutton et al, Long et al, R. Philipona, Bush et al, Cess et al….) to determine the extent of offset errors in their solar diffuse measurements. The site scientists should then make corrections using demonstrated methods such that errors larger than BSRN specifications can no longer be shown to exist in the final data as determined by Rayleigh comparisons, capping, or comparisons with low-offset instruments. These corrections should be made to past and existing data and resubmitted data to the archive, as possible. The nature of the applied correction should be identified in the archived meta data. In addition, it is recommended that instruments and instrument configurations (ventilation and dome temperature conditioning or dome temperature measurement with corrections (Philipona 2002, Haeffelin et al.) which have been shown or are known to have low thermal offset characteristics (Philipona 2002, Wardle and Barton 1988, Dutton et al 2001, Michalsky et al., 2002) should be deployed at the field sites as soon as practical, possibly overlapping the previous measurements for further evaluation. This recommendation will be considered an "operating guideline" rather than a specification since the exact implementation is being left to the site scientist. - Adopted with concerns from the Archive staff that the available comment line in the meta data will not be large enough to contain all the information. A suggestion has been made that a link to a text page be established at the archive for each field site where further details of specific site related information could be easily stored. - Adopted -The work of the working group is considered completed.

4/ Global pyranometers - *The preliminary evaluation of some global pyranometers used to measure total irradiance suggests that significant daytime thermal offsets may exist. Work should continue on the evaluation of this problem. The BSRN specification for the use of the diffuse plus direct as the primary measurement of total downwelling shortwave will help compensate for this problem in the BSRN and is one way to determine the extent of the offset errors in the global measurement.* This recommendation was added to the charge to the new Pyranometer Working Group, which consists of the remaining members of the "Zero Offset" WG and the Radiometer Accuracy WG, although the work of the Accuracy group was not reported and is not complete. Duties of the former Accuracy WG will be divided, as appropriate, between the Pyranometer and Direct Solar Beam WGs. - Adopted

5/ Night zeroing - Except for extremely unusual phenomena (e.g., nearby super nova), when the sun is more than x (4?) degrees below be horizon the integrated shortwave total radiation is less than 0.5 W m^{-2} *but non-negative*. Data submitted to the archive should not indicate otherwise. For data quality control at the measurement sites, the magnitudes of the nighttime values are very useful for examining several aspects of the data, e.g. noise, extent of night thermal offsets, data logger offsets and etc. These values should be used by the site scientist to evaluate their measurements systems, but only the known best values for all times of the day should be submitted to the archive. – not adopted after extensive debate.

6/ New Stations - Several new BSRN stations have been proposed at this meeting. It has become apparent that measurement sites at locations with more localized characteristics than originally specified by the BSRN program would be useful to the BSRN objectives. However, current limitations of the program capacities (primarily Archive work load) require that sites in the most underrepresented (in the BSRN) climatic *and geographic* regions be given priority consideration. New sites proposed at this meeting:

Brazil (four potential)
Cuba *(specific site to be determined)*
Dome C, Antarctica (Italy)
India (submitted by R. Pinker)

Palaiseau (France)
Netherlands (Cabauw)
Russia (submitted by P. Morozov) *(three potential)*
Sweden *(one of several potential)*
Zambia

are encouraged to continue to develop their sites and will be considered as "Potential Future BSRN Sites." *It is highly recommended that these sites continue to be developed and that funding be identified for those sites listed above that are not currently funded by national resources since they are considered, for the most part, excellent potential BSRN facilities. A letter of support at the WCRP or WMO level may be helpful in some cases.* Further final acceptance of official new BSRN sites will be dependent on further evaluation of the requirements and capabilities of the BSRN and on the potential contribution of the proposed site. Decisions on the acceptance of further official candidate sites will be made at the discretion of the Archive and Project managers with consideration for suggestions and recommendations from BSRN participants. - Adopted

7/ Revision of existing QC limits at Archive - A small working group should be formed to review the current quality control limits prescribed and currently applied at the archive. This should be completed in the next two months and not require any reprogramming at the archive other than changing the limit specifications, which may include simple algebraic expressions using information currently readily available in the database, e.g. solar zenith angle. *The Archive should enhance its quality control procedures by assuring that the results of that Archive QC are passed on the users as well as the site scientists. The site scientists are requested to respond to the QC reports and indicate corrective action taken or give other explanation.* - Adopted – review group will be – E. Dutton, C. Long, A. Ohmura

8/ Value added products produced at the Archive - *The data archive should make a determination of the extent to which "value added" products can or will be derived at the Archive and distributed as part of the BSRN effort. Such products include the derived aerosol optical depths, cloud properties, clear sky periods etc.* Adopted

9/ IR and *Solar Diffuse* - WGs should continue working towards developing international reference standards. T*he ultimate goal*s will be *an evaluat*ion of *the absolute accuracy of the reference and making the standard universally available.* Adopted
(note: The pyranometer Offsets Working Group, which had been working on the diffuse issues, was combined with the Working group on Accuracy Specifications and will address all issues relating to broadband pyranometry and will be known as the Pyranometer Working group. Accuracy issues related to IR will be handled by the IR (Pyrgeometer) Working Group. Membership is as before with the addition of Chuck Long to the Pyranometer group.

10/ Albedo - As recommended from WG Adopted with modifications per McArthur
Adopted recommendations are included in the meeting proceedings. The working group will continue its work on the basis of these recommendations

11/ UV & PAR - As recommended from WGs – Adopted as submitted or as modified by the Chairs - A. Manes will supply report with adopted recommendations for inclusion in meeting proceedings. Recommendation for a reference and calibration centre.

12/ Direct Solar Beam - Work should continue by all sites, where such capabilities exist, to further evaluate operational accuracies of direct beam measurements with considerations for cavity detector temperature drifts and window characteristics. Side-by-side comparisons should consider the effects of physical distance (at the sub 1-meter) between instruments and timing differences on the sub 1-second level. Adopted as a new (revived) Working Group – members given below

13/ Clouds WG -

1. Archive products be developed for cloud information – included and covered in an above recommendation that the Archive perform an internal assessment of its ability to accept "derived" products

2. Vertical looking narrow band IR radiometer for cloud base. The working group will evaluate the potential of such an instrument for applications at BSRN sites. The Chair of this WG suggested that a new IRT with a gold mirror rather than a tubular design would ease operations and maintenance of such an instrument.

3. Additional WG members are requested.

Adopted

<u>14/ Archiving Centre</u> - Bruce McArthur suggested a new WG to reflect previous comments regarding Archive operating in the "university" environment and Ohmura's pending retirement. The goals for the new WG would be (1) To seek increased funding for Archive and (2) To consider localisation issues including the possibility of a New Home for Archive. A. Ohmura gave his full support to the idea. The present organization needs to begin making plans for various potential future archive options. The working group would assist to identify the extent of tasks to be achieved by the archiving centre, number and types of users expected, resources required, give examples of similar archiving centres and see how they are organized and funded, identify potential sponsors (i.e. space agencies). It was not formed pending an assessment report from the current archiving centre including its recommendations for the course of actions in the next several years.

<u>15/ Next Meeting (in about two years):</u>
Gyorgy Major offered a return to Budapest.
UK Met Office offered to host a future meeting corresponding to their move to new facilities in 12 months (near Camborne site).
Previous offers from Manes (Israel) and McKenzie (New Zealand) are also under consideration.
A tentative offer to host a meeting in Cape Town, South Africa in the time frame of 2010 was also received.

<u>16/ Misc</u>.

Alain Heimo announced that his new replacement at Swiss Met Office" is Laurent Vuilleumier.

The local organizing committee and the team in charge of the meeting arrangements was warmly congratulated and thanked.

<u>17/ Current (for at least the next two years) membership of the working groups:</u>
The following working groups will be continued with membership derived primarily from past membership. This takes into account reorganizations discussed above.

(Persons retiring or otherwise departing the group before the next meeting are encourage to recommend replacements for their WG positions)
<u>Pyranometer Working Group</u> (elements of the former Offsets and Accuracy group)
B. Forgan (Chair), K. Behrens, R. Philipona, J. Michalsky, K. Rutledge, and C. Long

<u>Pyrgeometer Working Group</u> (Former Pyrgeometer Calibration Working Group)
R. Philipona (Chair), K. Behrens, and T. Stoffel)

<u>Direct Solar Beam Working Group</u> – D. Nelson, T. Stoffel, J. Michalsky, and D. Halliewell

<u>UVB Sub-Group</u> – A. Manes (Chair) B. Forgan, B. McArthur, R. McKenzie, J. Olivieri and R. Philipona

<u>PAR Working Group</u> R. Pinker (Chair) A. Kallis, B. McArthur and K. Rutledge

<u>Cloud Parameters Working Group</u> - C. Long (Chair), B. Forgan, R. Philipona (additional interested persons should contact the Chairman)

<u>Albedo Working Group</u> - B. McArthur (Chair) K. Behrens, R Pinker, R. Stone, and J. Michalsky

<u>Aerosol Optical Depth Working Group</u> - B. Forgan (Chair) , J. Michalsky, and Christoph Wehrli
As Project Manager, E. Dutton is available and responsive to all of these groups.

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APPENDIX B

WORKSHOP PROGRAMME

P – indicates a poster presentation

TUESDAY, MAY 28

0800	Registration and Continental Breakfast
0900	Welcome and Opening Remarks City of Regina Meteorological Service of Canada
0940	Review of Agenda
0945	WCRP Welcome and Review of Action Items from BSRN Workshop #6 (Sommeria)
1000	**BREAK**
1020	Overview of the state of the BSRN (Dutton)
1120	**Altered, New and Potential BSRN Stations – Part 1 (Dutton)**
1120	BSRN and other radiation measurements in the UK (Fishwick)
1140	Status of BSRN Brazilian Stations and SONDA Project Impacts on the BSRN (Colle and Pereira)
1200	Solar Irradiance at Lusaka, Zambia: A Possible BSRN Station (Nasitwitwi)
1220	**LUNCH**
1320	**Altered, New and Potential BSRN Stations – Part 2**
1320	Possible Swedish BSRN Candidate Stations (Carlund)
1340	Potential new French BSRN Station (TBD)
1400	Potential new Antarctic Station (Vitale)
	P - Status of the UK Met Office BSRN Stations (Green)
	P – Status of the Swiss BSRN Station (Vuillemier)
	P – Status of the German Polar BSRN Stations at Neumayer and Ny Aalesund (König-Langlo)
	P – Results of Radiation Measurements at the BSRN Station at Tamanrasset (Mimouni)
	P – The Brazilian Solar Radiation Network – Project SONDA and its Impacts on BSRN (Colle and Pereira)
	P – Cabauw Experimental Site for Atmospheric Research: CESAR Initiative for a BSRN-like site (Knap)
	P – ARM and SURFRAD – 30% of the BSRN Sites (Hodges)
	P – Solar Radiation Measurements in Havana – A possible BSRN Station (Vigón del Busto)

	Altered, New and Potential BSRN Stations – Part 2 (Continued)
	P – Status of the South African BSRN Station (Esterhuyse)
	P – Setup and Status of the Solar Village Station (Al-Abbadi)
	P – The Lindenberg, Germany BSRN Station (Behrens)
1420	**Cooperative Research and Future Directions**
1420	Necessary Observations in the Future BSRN Project (Ohmura)
1450	Marriage of BSRN and Atmospheric Chemistry Measurements: The Bratt's Lake Example (MacTavish)
1520	**BREAK** (Chance to view Station posters)
1600	**Quality Assurance and Data Management (Colle)**
1600	BSRN – Progress and Developments (Roesch)
1630	Quality Metrics from an Operational BSRN Site (Long)
1650	DQMS3: The Data Quality Management System (Augustyn)
1710	Selecting the Highest Quality from among Multiple Data Streams (Wilcox)
1730	Report on the Working Group on Uncertainty (Forgan)
1750	**Open Discussion on Quality Assurance Issues**
1820	**ADJOURN**

WEDNESDAY, MAY 29

0830	**IR Radiation and Instrumentation (Long)**
0830	Calibration facilities based on the low-temperature blackbody sources developed at VNIIOFI (Morozov)
0850	A Comparison of Downward Longwave Radiation Measured by PIR and CG4 (Behrens)
0910	Discrepancies in Pyrgeometer Measurements (Hirose)
0930	Pyrgeometer Comparisons IPASRC I/II and status of Longwave Irradiance Uncertainty (Philipona)
0950	Pyrgeometer Characterizations for the ARM Program (Stoffel)
	P – Comparison between Measured and Modeled Longwave Irradiance during the Arctic Winter (Philipona)
1010	**BREAK**
1030	**Open Discussion on Longwave Radiation Measurements**
1100	**UV and Spectral Measurements (Manes)**
1100	Establishing a Detector-based Spectral Irradiance Standard (Forgan)

	UV and Spectral Measurements (Manes) (Continued)
1120	Report of UV Working Group (Manes)
	P – UV Measurements at Carpentras (Olivieri)
	P – Aerosol and UV Measurements at the BSRN Payerne and other CHARM Network Stations (Vuillemier)
	P – Characteristics of the Optronics OL754 Spectrometer and Implications for BSRN Spectral Measurements (Wu)
	P – The use of Lamp Standards in Spectral UV Measurements (Wu)
	P – Development and Implementation of a UV Calibration System (Los)
1140	**Open Discussion on UV and Spectral Radiation Measurements**
1210	**Lunch**
1320	**Pyranometry (Behrens)**
1320	Pyranometer Characterization for the ARM Program (Stoffel)
1340	Results of the 2001 ARM Diffuse Intensive Observation Program (Michalsky)
1400	Severe Under-estimation of Solar Global and Diffuse Radiation Caused by Pyranometer Thermal Offsets (Philipona)
1420	The BSRN Standard Shading Disk for Diffuse Observation: A Proposal (Ohmura and Major)
1440	NIP and Cavity Radiometer Transmission Factors (Nelson)
1500	**BREAK**
1520	**Pyranometry (Continued)**
1520	All-weather Cavity Measurements at Bratt's Lake (Halliwell)
1540	Report of Working Group on Zero Irradiance (Forgan)
1600	Report of Working Group on Cloud Issues (Long)
1620	**Open Discussion on Pyranometer Issues**
1720	**DINNER**
1900	**EVENING SESSION – AEROSOLS (Forgan)**
1900	Comparison of Aerosol Optical Depth Measurements at Bratt's Lake (Halliwell)
1920	Aerosol Optical Depth from Sky-radiometer Measurements (Masataka)
1940	Aerosol Optical Depth from PFR Instruments in GAW Trial Network (Wehrli)
2000	Report on Aerosol Working Group (Forgan)
	P – Fully Automated Aerosol Optical Depth Measurements in Polar Regions (König-Langlo)

	EVENING SESSION – AEROSOLS (Forgan) (Continued)
	P – Monitoring Aerosol Optical Depth at CMDL Polar Observatories
2020	**Open Discussion on Aerosol Measurements**
2050	**Adjourn**

THURSDAY, MAY 30

0830	**Applications (Ohmura)**
0830	Application of BSRN Observations to the WCRP Surface Radiation Budget Project at NASA Langley (Chiacchio - invited) (30 min.)
0850	MODIS Albedo Product: Evaluation and Validation (Schaaf)
0910	GCM Calculations of Present and Future Downward Longwave Radiation at BSRN Stations (Wild)
0930	Comparison of the GFDL GCM Surface Radiation with BSRN Data (Freidenreich)
0950	Comparison of Modelled Irradiances with Tethersonde Observations (McLinden)
1010	**BREAK**
1030	**Applications (Continued)**
1030	Satellite and Surface Observations (Tentative Title) (Pinker)
1050	Overview of the CCRS In-Situ Sensor Measurement Assimilation Program (Fedosejevs)
1110	The Solar and Wind Energy Resource Assessment (SWERA) Project in Latin American (Pereira)
1130	Preliminary analysis results from the operational SW Flux Analysis of BSRN data (Long, Wild, Roesch)
	P – Estimation of Radiation Values using Meteorological Parameters in Nigeria (Muyiolu)
	P – Description of the CERES Ocean Validation Experiment (COVE) – A dedicated EOS Validation Site (Denn) [double poster]
1150	**LUNCH**
1310	**Meet at Hotel for Tour**
1315	**Tour begins**
2100	**Return to Regina Inn**

FRIDAY, MAY 31

0800	**PAR Measurements (Pinker)**
0800	Preliminary results of the BSRN PAR instrument comparison (McArthur)
0820	Report of PAR Working Group (Pinker)

0830	**Open discussion on the desirability of PAR measurements**
0900	**Albedo (McArthur)**
0900	Simultaneous Spectral Albedo Measurements near the ARM SGP Central Facility (Michalsky)
0920	Summer Spectral Albedo Measurements at the Bratt's Lake Observatory (McArthur)
0940	Comparison of spectral surface albedos and their impact on the GCM simulated surface climate (Roesch)
1000	The establishment of an albedo site (Aro)
1020	**BREAK**
1040	Report of the Albedo Working Group (McArthur)
	P – Changes in the albedo of a maturing wheat crop (Dexter)
1100	**Open discussion on the future of albedo measurements**
1130	BSRN Operations Manual, Version 2.0 (McArthur)
1200	**LUNCH**
1315	**Where we are and where we are going – open discussion and proposals (Dutton)**
1430	**Debate and passage of written recommendations (McArthur)** New BSRN Stations (Dutton) UV Measurements (Manes) PAR Measurements (Pinker) AOD Measurements (Forgan) Others
1530	Location of next meeting
1545	Unfinished Business
1615	**ADJOURNMENT**

APPENDIX C

Address to the BSRN meeting in Regina
by Mr. Tim Goos, Director, Prairie and Northern Region
Meteorological Service of Canada

I would like to welcome all of you to Regina for the 7th Science and Review Workshop for the Baseline Surface Radiation Network (BSRN)

Thank you for giving me the opportunity to open the session today. The Meteorological Service of Canada is pleased that you chose to hold your session in Canada – near our Bratt's Lake BSRN station.

I find the timing of this session to be auspicious for a couple of reasons.

Yesterday, a number of our national media carried a news report celebrating the 10th anniversary of the introduction of the UV Index in Canada. For the past 10 years, the MSC has provided daily information to Canadians about the relative strength of ultra-violet light at the surface of the earth – using an index from 1 to 10. This new service was begun to equip people with additional information in order to protect themselves from potentially harmful radiation from the sun.

Such an index of radiation substantially increased Canadians interest in the issue of ozone depletion and the resulting impacts on people's health and ecosystems. As the introduction of the index was combined with public education initiatives including specific initiatives for school children, the impact of this index has been far-reaching in Canadian society.

The introduction of the index has developed Canadian's interest in solar radiation. Canadians all still appreciate the return of the sun following our legendary dark, cold winters but we are more aware of the need to protect ourselves while enjoying our environment.

Last week, our federal government released a consultation document concerning Canada's response to the challenge of climate change – proposing 4 options whereby Canada could meet its commitments under the Kyoto protocol. If you had read the media reports in the past week, you would have seen significant discussion about this document. One of the provinces in our federation has expressed considerable unhappiness about all of the options – they view the impacts of any of these options on the economy in that province will be very negative. Similarly, some representatives of industry have expressed reservations and more as they view the potential impact on their business in Canada. Of course, there are also strong supporters for taking action on climate change in government, in industry and also in the general population.

What is clear, however, is that responding to the Kyoto commitments is a significant challenge for Canada – it's governments, it's industries and it's people. As with any challenge, there are both risks and benefits to the response options – and it is important that the best information is available to manage those risks and benefits.

In addressing both of these issues, we are using models of the atmosphere – to forecast surface UV radiation in the short-term; to produce scenarios of long-term climate change in the other. As you are undoubtedly well aware, the General Circulation Models used to produce scenarios of long-term climate change are frequently criticized for being inaccurate –for not appropriately modeling certain atmospheric or oceanographic processes.

At its core, the issue of climate change is a radiation balance issue – will the changes we are making in the composition of the atmosphere significantly change the global balance of radiation thereby warming (or cooling) the earth? Of course, the issue is made complex with elements like the existence of a surface of the earth that has a highly variable (in space and time) albedo and with an atmosphere that contains water – a very powerful radiatively active component that is exceptionally variable in space and time.

To wit, the critical point that all of you are very aware of: the existence of high quality data from a global network of professionally managed observing sites are critical to developing our models of and ultimately our response to climate change.

I expect some of you have noticed that it is not very green in Regina this spring. In fact, this is a common issue across the Prairies and, in many ways, across Canada. We have had a winter that didn't seem to know when to quit – a winter that stretched into spring and beyond. But, in much of the Prairies, we also have significant drought. A late spring combined with dry conditions create a situation that could seriously impact agricultural operations as well as water supplies. Improved atmospheric (and oceanographic) models to improve both seasonal climate predictions as well as long-term climate change scenarios are important to the management and development of society on our Prairies.

As you consider further developments in this important data network, I encourage you always to consider how the data can and will be used – by governments, by industry, by individuals – in not only understanding but also responding to the issues that face our society – issues like climate variability, climate change as well as the direct human and ecosystem effects of solar radiation.

I am pleased to congratulate you on the extremely valuable and important effort you have collectively put forth. I wish you the best of luck in your important discussions this week.

Report of the BSRN UV-B Sub-Group

Members of the BSRN UV SG: A. Manes (Chair), B. Forgan, I. Galindo, A. Heimo,
B. McArthur, R. McKenzie, J. Olivieri, R. Philipona

1. Introduction - Terms of Reference

Terms of reference of the UV-B SG were redefined at the Sixth BSRN Science and Review Workshop, held in Melbourne between 1-5 May 2000, as follows (quote from the relevant resolution of the WCRP Informal Report No. 17/2001, concerning UV measurements, Page 18, Paragraph 4.3.7 of the Report). "*Following discussion of this issue, it was agreed that the BSRN Sub-Group on UV-B Measurements would continue to monitor the activities of various relevant groups and would seek the cooperation of individuals, agencies and manufacturers of precision UV radiometers in its activities. The sub-group was asked to recommend specifications and technical requirements for UV radiometers suitable for measurements at BSRN stations and to report these to the next BSRN Workshop in 2002".*
In the following some of the main activities undertaken by various agencies in the field of precision UV measurements are described.

2. LAP/COST/WMO Intercomparison of Erythemal Radiometers

The results of LAP/COST/WMO Intercomparison of Erythemal Radiometers, held in Thessaloniki, Greece, 13-23 September 1999 were published recently (WMO/GAW Working Paper No. 141). Twenty-nine instruments from 14 countries took part in the campaign, the majority representing the most widely used instrument types for erythemal UV radiation measurements, the SL-501 and YES UVB-1 radiometers. Two UV spectroradiometers were used to provide the reference for the intercomparison, a Bentham DTM-300 was used as the first reference, and a Brewer Mk III was used as a secondary instrument. The results of the Thessaloniki intercomparison seem to be rather discouraging (see tables 2 and 3 below). The comparability of the UVB radiometers, of both the SL 501's and the YES instruments, taking part in the intercomparison, is relatively poor, and the divergence between the calibration factors, as provided by the manufacturers, and those actually measured during the Thessaloniki intercomparison, is considerable.

Table 3: SRF-based calibration factors of the analog-output instruments

Instrument Type	Serial number	Calibration factors			ID
		Certificate	LAP 1999 (327 DU)	Change (%)	
YES UVB-1	930814	0.138	0.127	-8.0	CA1
	970825	0.138	0.121	-12.3	ES1
	970839	0.138	0.121	-12.3	ES2
	920901	0.138	0.132	-4.3	GR2
	921110	0.138	0.162	17.4	GR3
	920602	0.147	0.115	-21.8	RS1
Kipp & Zonen CUV3	990086	N/A	0.412		CA3
Scintec UV-S-A/E-T	010-A-00360	0.174	0.119	-31.6	DE1
Vital BW-100	94041	1.000	1.319	31.9	IT1
EKO MS-210D	S91049.04	N/A	0.991		IT2
MO-MSU		12.400	10.863	-12.4	RS2

3. Effect of Ozone Column and SZA on BB UV Radiometers Calibration

The inconsistencies and lack of calibration stability of BB UV radiometers observed at the Thessaloniki intercomparison were observed also at previous intercomparisons, and they probably stem from the mismatch of the instrument spectral response and the erythemally weighted (CIE) response, depending on the SZA and ozone column. As we know, these dependencies were shown convincingly in a detailed study of the effects of ozone and SZA on the calibration of BB UV sensors, carried out at the Mauna Loa Observatory (MLO) during July 1995-July 1996 time period (Barry A. Bodhaine, Ellsworth G. Dutton, Richard

L. McKenzie and Paul V. Johnston - *Calibrating Broadband UV Instruments: Ozone and Solar Zenith Angle Dependence.* J. Atmos. Oceanic Technology, Vol. 15. 1998, pp.916-925).

Table 2: CIE-based Calibration factors of the instruments that took part in the LAP/COST/WMO intercomparison or erythemal radiometers

Instrument Type	Serial Number	Calibration factors				ID
		Certificate	LAP 1999 (327 DU)	LAP 1999 (270 DU)	Change (%)	
SL 501	0629	1.089	0.999	1.021	-6.3	CA2
	0635	0.98[s]	0.882	0.889	-9.3	FI2
	0922	1.08[s]	0.965	0.990	-8.3	SE1
	0935	1.000	0.952	0.979	-2.1	PL1
	1081	1.26[s]	1.011	1.024	-18.7	GR1
	1098	1.000	0.919	0.933	-6.7	NL1
	1120	1.20[s]	1.227	1.238	3.2	PL2
	1240	1.000	1.159	1.178	17.8	AT4
	1451	1.000	1.018	1.024	2.4	DE2
	1466	1.11[s]	1.065	1.074	-3.3	FI1
	1483	1.000	1.016	1.028	2.8	AT2
	1485	1.000	0.962	0.972	-2.8	AT1
	1875	1.000	0.973	0.982	-1.8	CZ1
	2706	1.000	1.258	1.278	27.8	AT3
	2733	1.114	1.066	1.064	-4.5	CZ2
	3749	1.000	0.828	0.840	-16.0	PT1
SL 501A	1493	0.214	0.220	0.225	5.1	CH1
	4388	0.230	0.209	0.212	-8.0	SE2

[s] Calibration from STUK 1995 (the calibration factor is the average value at solar elevations higher than 35° with no ozone column specified)

The authors actually propose a calibration methodology of BB UV radiometers accounting for the total ozone and SZA dependencies, stating in conclusion: "*a given calibration factor is good only for a particular value of SZA and a particular value of total atmospheric ozone. Errors as high as 10% or more can result if the effects of ozone are not taken into account".* It is rather unfortunate that most manufacturers of BB UV radiometers have hardly considered these findings, as well as a number of other relevant studies pointing to similar results. As far as the SZA dependence is concerned, only the YES Co. provides a calibration sheet with corrections for the various SZAs.

4. National, Regional and World UV Calibration Centers

The need for a World UV Calibration facility, to provide the necessary reference, traceability and calibration hierarchy for a large, and ever growing number of UV networks, seems to be obvious. It is also part of the WMO-GAW Strategic Plan. Its implementation, however, is still far behind. Meanwhile national and regional UV calibration centers are emerging.

4.1 Swiss National UV Network and Calibration Facility (PMOD/WRC web site)

PMOD/WRC in collaboration with the Swiss Meteorological Institute (SMI) maintains the Swiss national UV-network as part of the Swiss Atmospheric Radiation Monitoring program. The four operational stations of the Swiss national UV network provide an interesting vertical profile of the UV radiation field over Switzerland going from 490 to 3580m a.s.l

UV broadband measurements were resumed in 1993 using UV-Biometers from Solar Light Co., which weight the UV radiation to the human skin erythema action spectrum and therefore predominantly measure UV-B radiation. *Long term tests of individually measuring the direct solar - and the diffuse sky component, showed positive results with regard to the accuracy of broadband UV measurements and to the understanding of the radiation field*. Direct radiation is measured with a full view angle of 8 degrees whereas the instrument measuring diffuse radiation has a shading disc covering the sun with a full view angle of 8 degrees. An additional UV-Biometer measuring global radiation is used for redundancy and quality control of the measurement. The UV-A radiation is separately measured with a global Solar Light UV-A bandpass instrument. Measurements are performed every second and the mean, st dev, min and max are recorded every 2 minutes with a datalogger**.** *Calibration is maintained by periodically comparing UV-Biometers to the SWISS reference instrument using the sun as a source. The SWISS reference instrument took part at the WMO/STUK 1995 intercomparison at Helsinki and is periodically compared to spectroradiometers.*

4.2 SRRB CUCF - Regional North-American UV Calibration Facility

The Central UV Calibration Facility (CUCF) of NOAA SRRB has evolved recently as an Interagency UV Calibration Center, in cooperation with the NIST, providing calibration and characterization services for UV instruments used at the various UV networks in the US and Canada, acting thus as a Regional North-American UV Calibration Facility.

According to Kathy Lantz and Peter Disterhoft (personal communication), broadband UVB instruments may show remarkable stability, and can, thus, be a valuable source of information on UV. *The instruments, however, are only as good as the characterizations, calibrations, and maintenance in the field*. The Central UV Calibration Facility (CUCF) performs characterizations and calibrations of a wide range of UV instruments of the various UV networks in the North-American region.

Modes of calibration: The instruments can be calibrated in two modes, converted to irradiance weighted by erythema, or weighted by a typical instrument response. With the former, the benefit is that many instrument types can be intercompared*, but calibration factors as a function of SZA and ozone need to be used.* With the latter only instruments from the same manufacturer can be compared but uncertainties are significantly reduced and no ozone information is needed.

CUCF Facilities: The CUCF has three facilities, the Characterization Laboratory, the Table Mountain Test Facility (TMTF), and the High Altitude Observatory. The Characterization Laboratory provides characterizations of the spectral response, the cosine response, and a stability check with a calibrated lamp. The first two measurements are needed for calibration factors and checking changes over time. Erythemal (CIE) calibration factors are provided for a particular radiometer from field results at the TMTF.

Instrumentation at TMTF: The instrumentation at the TMTF consists of a number of "standard" UVB radiometers, and "reference" spectroradiometers. These include three YES UVB broadband radiometers, three SL501 radiometers, one older Scintec instrument, and one Eko radiometer. The U111 (USDA) and Mark IV Brewer (EPA) spectroradiometers are used as "reference" instruments. Recently a Rotating Shadowband UV Spectroradiometer (UVRSS) was added, as well as UVA instruments and two types of Kipp and Zonen broadband radiometers. Typically for the CUCF standard set, three radiometers are operating continuously at the TMTF. These three provide a check to see how the radiometers are doing with respect to each other on a given day and over time.

The stability of the calibration of the standard UVB sets against a spectroradiometer was evaluated. Calibration of the YES standard triad indicates that from 1997-2001, their sensitivity has decreased by approximately 5%. Continued comparisons of the standard triad against the U111 reference spectroradiometer are ongoing.

Test radiometers – calibration procedure: According to Kathy Lantz and Peter Disterhoft (personal communication), each of the test instruments are calibrated against the standards yielding *scale factors*, while the "standards" are calibrated against a "reference" spectroradiometer yielding a *calibration factor.* To convert from voltage to erythemally weighted irradiance the voltage of a test instrument is taken times its scale factor times the SZA and ozone dependent calibration factor. The above method Is based, however, on the assumption that the spectral response and the cosine response are similar instrument to instrument, which is, according to Kathy Lantz, the case for YES UVB-1 instruments manufactured after 1993. In summary, the calibration factors for a given instrument are a combination of the scale factor and the calibration factor. For the YES UVB instruments from the USDA Network, since 1997 the scale factors on average have changed by approx. 0.6% and the standards by approx. 5%. This works out to little over a 1% per year. The YES UVBs from the SURFRAD network give similar results.

CUCF's Calibration of the USDA UVB Monitoring Network

Dr. James Slusser, Colorado State University, Director of USDA UVB Monitoring Network has provided kindly (personal communication) the following brief analysis of USDA UVB Network's experience with 42 Yankee UVB broadbands. The CUCF performed 65 repeat calibrations in 2001 of 41 UVB broadbands, showing changes in calibration (scale) factors that fell in the 0 - 1.5% range for 85% of the instruments. The egregious 2 outliers were instruments, which suffered soaking water damage. The annualized median change in scale factors for 2001 was 0.5% (see figure below, by courtesy of Dr. Jim Slusser).

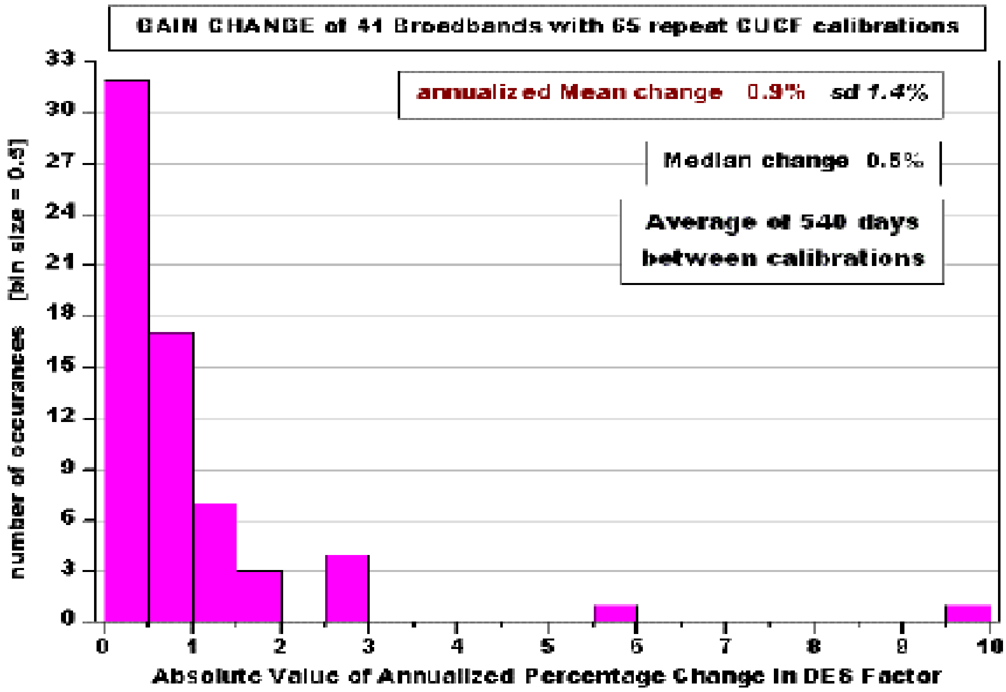

Figure 3: Histogram of gain changes for 41 broadband measured at CUCF. Most gain changes are less than 1% per year.

Carpentras Radiometric Center, Meteo-France (reported by Jean Olivieri)

A series of UV-B measurements using YES BB UV-B radiometers and a spoectroradiometer serving as "reference", was carried out at Carpentras during June-July 2001. Using the method of calibration as applied by CUCF, accounting for the SZA and ozone dependence, the integrated erythemally weighted (CIE) spectroradiometer measured UVB values were found very close to those measured by the BB UV-B radiometer.

4.3 European Regional UV Calibration Center (ECUV)

On the request by several leading research institutions in Europe involved in solar UV monitoring, an European Reference Centre for UV Radiation Measurements (ECUV) will be established by the Joint Research Center (JRC) in Ispra (Italy), with the support of the European Community. At the moment the focus is on spectrally resolved measurements of the solar UV radiation, but the application towards calibration of broadband radiometers has been recognized as an essential activity, as most National Networks in Europe consist of such types of instruments. Facilities will be thus developed also to allow for characterization and calibration of broadband radiometers. The ECUV may be extended regionally, especially towards the Middle East and the North-African countries. According to Dr. Julian Gröbner (personal communication), it is not the intention of ECUV to serve as a WMO-GAW World Calibration Centre.

4.4 World UV Calibration Center – Present Status

The need for such center is well recognized, and it may appear that one of the regional centers may take over the duties of a World Center. According to Liisa Jalkanen of WMO-GAW (personal communication), the CUCF in Boulder would have been excellent for this purpose and some time ago this possibility was explored. However, at least at that time, NOAA SRRB did not have the resources to do this. If and when resources become available, GAW would welcome this possibility to consider again such arrangement for UV calibrations. However, all such calibration facilities need to be considered and approved, as appropriate, by the SAG UV. The World Calibration Centre issue should be discussed after the new chief of GAW, Len Barrie, takes up his post at the end of June 2002.

According to John DeLuisi, SRRB, CUCF (personal communication), WMO's interest in the CUCF as a world calibration facility may be reconsidered positively. Since this is a matter for the upper level management of NOAA, the request should come from the higher levels of WMO through official NOAA channels

5. Recent Activities of WMO-GAW Scientific Advisory Group (SAG) on UV

The WMO/GAW Scientific Advisory Group (SAG) for UV was established in 1995 to develop and implement the Global UV Radiation Monitoring Network in GAW. This includes drafting guidelines for instrument characterization, proposing standards for compatible observations, quality assurance and common calibration systems, data analysis and data archiving. The members of the WMO/GAW SAG on UV are:

P. Simon (chair)	IASB-BIRA	Belgium
A. Kricker	NBCC	Australia
S. Madronich	NCAR	USA
M. Miyauchi	JMA	Japan
G. Seckmeyer	IFU	Germany
P. Taalas	FMI	Finland
D. Wardle	MSC	Canada
B. Weatherhead	NOAA	USA
A. Webb	UMIST	United Kingdom
C. Zerefos	AUTH	Greece
L. Jalkanen	WMO	Switzerland

The SAG for UV has concentrated in recent years in the preparation of Working Papers dealing with *Instruments to Measure Solar Ultraviolet Radiation*. *Part 1: Spectral Instruments* was published recently by WMO/GAW under Working Paper No. 125, with G. Seckmeyer as Leading Author. *Part 2: Broadband Instruments Measuring Erythemally Weighted Solar Irradiance*, is in preparation (Draft Document, personal communication). This is a very important document, which provides clearly stated objectives and specifications of broadband UV radiometers, as well as calibration procedures to account for SZA and ozone column dependencies of the calibration factors. The above document may play an important role in encouraging the manufacturers of spectral and broadband UV instruments to comply with the specifications as outlined in the Working Papers.

5.1 **Part 1: Spectral Instruments** (from WMO/GAW Working Paper N0. 125)

The specifications of UV instrumentation are based on the objectives of UV research. These include:

To establish a UV climatology by long-term monitoring, e.g. within a network of UV spectroradiometers

1. To detect trends, especially spectrally resolved tends, in global UV irradiance
2. To provide datasets for specific process studies and for the validation of radiative transfer models and/or satellite derived UV irradiance at the Earth's surface
3. To understand geographic differences in global spectral UV irradiance
4. To gain information about actual UV levels
5. To allow the determination of a UV index

Some of the objectives (e.g. trend detection) require high accuracy instruments with a superior long-term stability, because the expected magnitude of UV trends is rather small. In contrast, somewhat less demanding specifications are sufficient for instruments employed for the determination of erythemally weighted UV doses and hence the UV indices.

Two types of spectral instruments, type S-1 and type S-2, will be introduced. The specifications of type S-2 instruments are more rigid and consequently, the domain of these instruments is especially those measurements, where the highest accuracy is required. From past experience, it appears that the lowest calibration uncertainty that can be maintained for instruments designed to measure solar UV irradiance is currently limited to a few percent (e.g., ± 5%). Thus, to achieve the above goal, it will be necessary to include measurements at short wavelengths, where small changes in total ozone lead to relatively large changes in UV irradiance.

Uncertainties in the measurements of global spectral irradiance resulting from uncertainties in the wavelength alignment escalate at shorter wavelength.

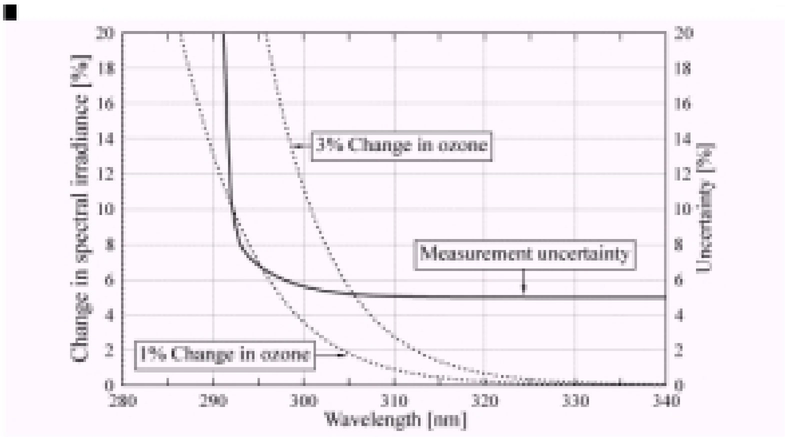

Figure 1: Percentage change in global spectral irradiance caused by a 1% and 3% change of total ozone compared with the uncertainty in spectral measurements arising from a 5% calibration uncertainty, a wavelength error of 0.05 nm, and a detection threshold of 10^{-6} W m^{-2} nm^{-1}. The change in irradiance was calculated for a solar zenith angle of 30° and a total ozone column of 300 DU.

Recommended specifications of Spectral UV Radiometers

A useful but ambitious goal for type S-2 instruments is to attempt to detect a change in spectral UV irradiance resulting from a 1% change in total ozone column. The primary interest is in UV increases resulting from reductions in total ozone column. However, in this context, possible reductions in UV resulting from future recovery of the ozone layer, or from a build up of tropospheric pollution (e.g., aerosols, ozone) or stratospheric particle loading may be relevant as well. These considerations and the objectives listed above were proposed by the Network for the Detection of Stratospheric Change (NDSC) (McKenzie et al., 1997) and form the basis for the desired overall accuracy for type S-2 instruments, and, are also the basis for the following instrument specifications. The instruments should be capable of all-weather, and automated operation.

Quantity	Quality
Cosine error§	(a) < ±5 % for incidence angles <60° (b) < ±5 % to integrated isotropic radiance
Minimum spectral range	290 - 400 nm+
Bandwidth (FWHM)	< 1 nm
Wavelength precision	< ±0.03 nm
Wavelength accuracy	< ±0.05 nm
Slit function	< 10^{-3} of maximum at 2.5·FWHM away from centre < 10^{-5} of maximum at 6.0·FWHM away from centre
Sampling wavelength interval	< 0.5·FWHM
Maximum irradiance	> 2 W m^{-2} nm^{-1} (noon maximum at 400 nm)
Detection threshold	< 10^{-6} W m^{-2} nm^{-1} (for SNR = 1 at 1 nm FWHM)
Stray light	< 10^{-6} W m^{-2} nm^{-1} (for SNR = 1 at 1 nm FWHM) when the instrument is exposed to the sun at minimum SZA
Instrument temperature	Monitored; typical temperature stability < ±2 °C to achieve a sufficient overall instrument stability
Scan time	< 10 minutes, e.g., for ease of comparison with models
Overall calibration uncertainty*	< ±5% (unless limited by threshold)
Scan date and time	Recorded with each spectrum so that timing is known to within 10 seconds at each wavelength

5.2 Part 2: Broadband UV Radiometers (Dr. G. Seckmeyer, personal communication)

An advantage of broadband instruments is their low hardware cost compared with spectroradiometers to measure UV irradiance. Broadband instruments tend to have fewer operational problems in the field compared with spectroradiometers because of their simpler design. It should be noted, however, that considerable efforts in quality control and assurance (QA/QC) are required to produce the greatest yield of scientifically useful information. Therefore, maintenance and QA/QC of these instruments introduce substantial additional cost that can far exceed the hardware investment [WMO, Webb et.al. 1998]

Recommended Specifications for Type B-1 instruments (BB Radiometers)

Type B-1 instruments are defined as broadband instruments used for the measurement of erythemally weighted global irradiance. The following instrument specifications are based on the objectives given above, taking into account the limitations of the technology currently available. Further comments to the values are appended below the table.

	Quantity	Quality
1.1.1	***1.1.2 Spectral response***	a) Radiation amplification factor (RAF) for SZA=30° and 300 DU Desired: 1.21 ± 0.05 Recommended: 1.21 ± 0.2 Currently in use: 1.21 ± 0.4 b) Ratio (CF 75 / CF 30) at 300 DU Desired: 1.0 ± 0.02 Recommended: 1.0 ± 0.15 Currently in use: 1.0 ± 0.3
2	Stability in time	Better than 5%/year desired:
3	Temperature stability	To within ±1°, and temperature preferably recorded
4	Cosine error	(a) <10% for incidence angles <60° (b) <+10% to integrated isotropic radiance (c) < 3% azimuthal error at 60° incidence angle
5	Accuracy of time	Better than ±10s
6	Response time	<5 seconds, and preferably < 1 second
7	Sensitivity to visible and IR solar radiation	< 1%, or below the detection limit
8	Detection threshold	<0.5 mW m^{-2} (CIE Weighted)
9	Leveling	<0.2 °
10	Sample Frequency	<= 1 minute

For instruments to be used within a network, it is recommended to acquire instruments with the least possible variability in their spectral response functions.

Remarks to specifications:

Spectral Response: The importance of mis-matches between the instrument response function and the erythemal response function can be specified in terms of:

(1) differences in the instrument-weighted RAF from the erythemally-weighted RAF, and
(2) sensitivity of the Calibration Factor (CF) (for converting instrument-weighted UV to erythemally-weighted UV) to changing SZA and ozone amount.

For instruments designed to measure erythemally weighted UV, the RAF should match the RAF for erythema (e.g. RAF= 1.21 at 30 SZA and 300 DU) as closely as possible. . The recommended criterion of +/- 0.2 corresponds to state-of-the-art instruments. Few of the currently available instruments meet the recommended specification. RAF factors as low as 0.8 (instead of 1.2) are found in commonly used instruments. Ideally the calibration should be independent of SZA and total ozone column. *Available instruments do not meet this requirement. Few of the currently available instruments meet the recommended specification*. After the application of the correction factors uncertainties in ozone changes and in SZA changes shall lead to additional (to the spectroradiometric calibration) uncertainties in erythemal irradiance of less than 5%. Instruments that meet the "desired" specification are expected to deliver results that need no post-correction.

Recommended Characterization and Calibration Procedures of BB UV Radiometers

For many applications, it is necessary to convert the instrument-weighted signal into CIE-weighted irradiance. It is recognized that in general this conversion depends on the difference between the CIE spectrum and the instrument spectral response, and is therefore a complex function of environmental conditions (solar zenith angle, ozone column, clouds, aerosols etc.). Direct comparisons between the broadband instrument signal and the spectral measurements weighted by the CIE spectrum can provide an estimate of this conversion function [Mayer and Seckmeyer, 1996; Leszczynki et.al., 1997; Bodhaine et al., 1998; Bais et.al., 2001]. It should be remembered that such empirical functions are valid only for the conditions under which they were derived. Extension to general conditions could be based, for example, on an accurate radiative transfer model for the conditions specific to each measurement (zenith angle, ozone column, etc.). However, the possibilities to find the correct input parameters for the radiative transfer models is currently limited, especially for cloudy skies. Therefore the conversion function remains uncertain.

Calibration of Broadband UV Instruments

The calibration of a broadband meter usually requires knowledge of the specific spectral sensitivity of that instrument. The spectral response describes the conversion from the detector output (in any units) at each wavelength to monochromatic input (e.g. in W m^{-2} nm^{-1}). Measurements of one broadband detector can be directly compared with results of other detectors only if all instruments have exactly the same spectral sensitivity. This is usually not the case even for detectors of the same manufacturer. *Therefore, a common reference weighting spectrum is necessary to compare results within a network and globally*. Usually the CIE action spectrum for erythema [McKinlay and Diffey, 1987] is used for the interpretation of the results of commonly used broadband meters. A correction is necessary for each instrument, as no instrument has a spectral sensitivity identical to the erythema action spectrum. This correction is fundamentally dependent on the source spectrum. The better the agreement between the spectral sensitivity of the detector and the erythema action spectrum, the smaller is the correction, and the less is the sensitivity of the correction to slight variations of the source spectrum (generally the sun). There are several methods in use for calibration of broadband meters, which differ in expenditure and accuracy [Lantz et al, 1999]. In the following, two methods are discussed in detail. The first focuses on best accuracy, the second on valuable accuracy with smaller expenditure. Other methods may give similar results, but their broad usage is restricted due to the necessity for additional special equipment in the laboratory.

Suggested calibration method*:* The spectral response and the cosine error of the broadband detector have to be known as a requirement for this calibration procedure. This information should either be supplied by the manufacturer or preferably determined in a calibration laboratory. To avoid significant errors, the steeply sloping instrument response should be determined at a spectral resolution (FWHM) of < 2 nm. An appropriate setup might include the use of a Xenon lamp, a double monochromator, and deconvolution techniques to attain the required resolution.

The basic step for the calibration is to simultaneously measure the spectral irradiance of the sun with a calibrated spectroradiometer (reference) and the broadband meter, under cloudless sky conditions. The measured spectrum is weighted with the spectral sensitivity of the broadband meter and integrated over all wavelengths relevant for the broadband meter. The result is given in the units [detector-weighted Wm^{-2}], relative to a defined wavelength (usually the maximum of the erythema action spectrum at 298 nm or the maximum of the spectral sensitivity of the broadband meter). For different atmospheric conditions (solar elevation, ozone content) the relation of the detector-weighted spectral integral to the output of the detector after cosine correction should be constant within the uncertainty estimate; otherwise spectral sensitivity of the broadband meter or the spectroradiometric measurements were incorrect.

Both the spectroradiometric and the broadband measurements have to be corrected for any cosine error (see Seckmeyer et.al. 2001). To obtain the correct angular response of the broadband instrument, it is desirable to use a lamp/filter combination, which simulates a typical solar spectrum. The conversion of detector-weighted units to erythema-weighted units is done with a radiative transfer model. Such models are now available through the Internet. The analysis should take into account the actual solar elevation and the actual ozone content, whereas for aerosol amount, altitudes above sea level and albedo (mainly snow coverage of the terrain) typical values are usually sufficient [Bernhard and Seckmeyer, 1999]. Total ozone content is very often available from satellite data. It should be noted that there might be difficulties in using those satellite estimates for special weather conditions due to differences in local ozone column and averaged columns provided by the satellites.

The radiative transfer model is used only for the determination of the relative difference between the two weighting functions (detector sensitivity and erythema action spectrum) and not to compare absolute irradiances. Therefore, the uncertainty due to the uncertainty of the estimated input parameters is of minor significance. Furthermore, the same model calculations can be used to apply a cosine correction to the reading of the broadband meter, although a complete cosine correction is not possible under conditions with varying cloudiness. Look-up tables or fit functions can be prepared once for each individual detector, which allow fast and routine conversion from the detector reading to erythemally weighted irradiance for many atmospheric conditions.

Summary of suggested calibration method:

- Measure the spectral response and the cosine error of the broadband detector .
- Measure the spectral irradiance of the sun with a calibrated spectroradiometer and simultaneously with the broadband meter, under clear skies.
- Determine a scale factor to convert the signal of the broadband meter to irradiance units. The scaled broadband measurements should agree to within x% (where x% is determined by the laboratory experts) with the spectroradiometric measurements after weighting with broadband meter's spectral responsivity function.
- Apply cosine corrections to both data sets.
- Weight the measured spectrum with the spectral sensitivity of the broadband meter.
- Use a radiative transfer model to convert from detector-weighted units to erythema-weighted units.

A similar method is outlined in Lantz et al. [1999].

Alternative calibration method: The basic step for the alternative calibration method is to measure the spectral irradiance with a spectroradiometer simultaneously to the broadband meter. The measured spectrum is weighted with the erythema action spectrum and integrated over all wavelengths relevant for the erythema action. The result is given in the units [erythema-weighted W m^{-2}], relative to a defined wavelength (usually the maximum of the erythema action spectrum at 298 nm). The spectroradiometric measurements have to be corrected for any cosine error. The resulting calibration factor relates the spectroradiometrically determined erythemal irradiance with the output of the broadband meter. Due to the difference between the spectral sensitivity of the detector and the erythema action spectrum this calibration factor is valid only for one certain solar spectrum. To take into account the variations of the solar spectrum (dependence on solar elevation, ozone content and to a smaller extent aerosol amount, altitude above see level and albedo), it is necessary to carry out a large number of simultaneous measurements between the spectroradiometer and the broadband meter. From these data the correction factors as a function of solar elevation and other atmospheric variables especially total ozone, can be obtained. Also the cosine error of the broadband meter will have different effects depending on the actual ratio diffuse over global irradiance. An average calibration as a function of solar elevation is derived, which will give good results as long as the atmospheric conditions are close to the conditions defined by the average of the calibration measurements. Additionally the dependence on total ozone can be taken into account if a long-term series of simultaneous spectroradiometric measurements is available. This method does not need additional model calculations.

Summary of alternative calibration method:

- Measure the spectral irradiance simultaneously to the broadband meter measurement.
- Deduce the erythemally-weighted spectral irradiance and apply cosine correction
- Repeat for large number of simultaneous measurements to deduce the correction factor's dependence on SZA and ozone