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8^{TH} BSRN WORKSHOP AND SCIENTIFIC REVIEW MEETING

I. OPENING SESSION

The 8^{th} Baseline Surface Radiation Network (BSRN) Workshop and Scientific Review Meeting was hosted by the UK Met Office in Exeter, England, from 26-30 July 2004. Dr Ellsworth Dutton, the BSRN Project Manager and Dr Patrick Fishwick, UK Met Office, provided opening comments, introductions, and general logistics information. It was noted that the format of the meeting is different from the previous ones in that it was more results-oriented and the working group discussions were held on the last day of the meeting.

Dr Gilles Sommeria of the Joint Planning Staff (JPS) for the World Climate Research Programme (WCRP) welcomed the participants on behalf of WCRP and expressed his thanks to the UK Met Office for hosting the meeting. He gave a brief overview of recent developments in the Global Energy and Water Cycle Experiment (GEWEX) and WCRP of interest to the audience, including the Coordinated Observation and Prediction of the Earth System (COPES), a new WCRP strategy recently approved by the Joint Scientific Committee (JSC). The JSC has also endorsed BSRN as the GCOS global surface radiation network. Upcoming conferences of notable interest include the 5^{th} International Scientific Conference on the Global Energy and Water Cycle in Orange County, California on June 20-24, 2005 and the 25^{th} WCRP Anniversary Climate Conference to be held in Geneva in early 2006.

The Importance of BSRN Observations to the Validation of Global Surface Radiation Budget Data Sets (Paul Stackhouse, Jr., NASA/Langley Research Center, USA)

This talk focused upon the use of BSRN data for the validation of satellite-derived algorithms to estimate the surface radiation budget through the use of the GEWEX Surface Radiation Budget (SRB) Project. This project estimates the top-of-atmosphere and surface radiation as a time history, every 3 hours since July 1983. The derived surface radiation budget requires reliable long-term measurements for evaluation of the data set. The 1983-1995 average global annual radiation budget was presented at the meeting. Differences relative to other satellite/model/observation based data sets show an uncertainty range of nearly 10-20 Wm^{-2} for several of these parameters. Thus, BSRN surface measurements with quantitative quality and operational uncertainty information are critical for evaluation and assessment.

To evaluate data sets like GEWEX SRB for various time averages, the measurements are averaged and compared to SRB products at intervals of 3-hourly instantaneous, monthly averaged 3-hourly, daily, and monthly averaged time averages. RMS differences vary from 83 W m^{-2} to 23 W m^{-2} for SW 3-hourly to monthly and 33 W m^{-2} to 15 W m^{-2} for LW. Biases range from +/- 5 Wm^{-2}. Clouds and the Earth's Radiant Energy System (CERES) instantaneous fluxes were also compared to more modern BSRN measurements and a first inter-comparison between BSRN, GEWEX SRB and CERES algorithms was completed in 1998. This demonstrates that BSRN links older algorithms estimating the solar flux with new data from projects like CERES.

Examples of time series analysis at various sites were shown noting that meteorological data together with the radiative flux measurement is very beneficial to the analysis of errors and variability. A long-term time series using older SW measurements from WRDC was also presented. It was emphasized that BSRN can act to anchor such networks and help establish the uncertainties of those data. WRDC measurements were analyzed from 1983-1995 by grouping into regions with similar climate types. Deseasonalized anomalies of these measured fluxes were compared with the satellite observations demonstrating the ability of the satellite to correctly account for these anomalies. The 11-year least squares changes were computed for every 1x1 grid in the GEWEX SRB data set. The data from the various regions revealed both positive and negative changes. These locations are many times meteorologically coupled. Lastly, it was noted where BSRN measurements fall in comparison to the WRDC measurement sites, showing that several sites occur near regions of changes but that many regions were still not represented. WRDC data and other network data past 1993, however, would help supplement the BSRN data giving valuable variability information. The correlation of the monthly anomalies from each 1x1 grid box surrounding the BSRN sites was shown at two sites to demonstrate the spatial continuity of the anomalies. It was shown that the correlation region is limited to the region surrounding the site and that sometimes there were anti-correlated regions in proximity.

In summary, the necessity of BSRN measurements was demonstrated in the GEWEX SRB Project. It was noted that BSRN measurements provide a vital role in assessment of the surface radiation budget parameters. The measurements act to link EOS era surface radiation estimates with those from the EOS-era, link to the multitude of past solar measurements, and provides the opportunity to produce measurements with accuracies approaching 1 Wm^{-2} per decade, identified as a crucial sensitivity for climate change.

BSRN: The first 15 Years (Atsumu Ohmura, World Radiation Monitoring Centre, Switzerland)

BSRN started in January 1992 with three objectives to provide irradiances with clearly defined accuracies: 1) to validate surface products from satellite radiometry; 2) to evaluate GCMs and other models; and 3) to detect important changes in radiation in the climate system. The network was initiated first with seven stations, and soon substantiated with increasing number of stations presently counting 37.

The network has a sufficient number of stations for the objectives, but with biased density of distribution. In terms of representation of climatic zones, most major climates are represented, except high altitudes (H) and Mediterranean climate (Cs). There are a certain number of stations which are too long pending (observations are done but without reporting data). There are a fixed group of stations which have remained as candidate stations for a very long period. The project has reached the stage at which we must proceed selectively to choose the sites of future stations, instead of accepting all proposed locations. It is necessary to form a small working group to identify urgently needed geographic sites, and to evaluate the suitability of the sites with respect to available financial, technological, and personnel conditions.

The data centre is responsible for evaluating the quality of the incoming minute data, advising station scientists of possible errors, placing the data for scientific access, and safeguarding the original data for the future use. At the initial stage a difficulty was seen because observations had to be formatted in accordance with the proposed scheme, but most stations solved this problem. The majority of pending stations, however, remained in this category, because the stations could not overcome this initial hurdle to format data in the BSRN scheme. The file system was adopted in 2002 to ease the data sending and access.

The number of users both in satellite and modeling groups increased rapidly, especially in the last 5 years. During the last 2 years, the issue of the variability of radiation, both in short and long wavelength ranges propelled the use of the BSRN radiation and ancillary data. The problem of radiation variability is only possible with the data of the BSRN quality, and simultaneously observed atmospheric characteristics, especially clouds, temperature, and water vapor. Aerosols are another very important characteristic to influence shortwave radiation and clouds.

BSRN made an unexpected but vitally important contribution for improving radiometers and their installation methods. This was not foreseen at the start but turned out to be a very unique and necessary development to fulfill the objectives. The progress in long-wave and diffuse sky radiation should especially be noted. The further progress and adoption of the window-less measurement of direct solar radiation was slow. There should be more progress in the quest for the BSRN relevant albedometry. Further progresses are awaited in spectral observations, including UV, PAR and AOD. The association of BSRN with GCOS received a very positive acceptance both for future development of the network and the data centre.

State of BSRN (Ellsworth Dutton, NOAA/CMDL, USA)

A summary of the current status of the BSRN program was given. The main areas covered were highlights of the past 2 years, new observing sites to be proposed at the meeting, activities of the BSRN working groups, status of the data archive and network site operations, and the need for expansion of the network and improvements in the extent and understanding of the network site representativeness. The highlights included the recent launch of the EU Meteosat II and the expressed interest of the onboard experiment Geostationary Earth Radiation Budget (GERB) Project in the utilization of BSRN data. Other highlights included the invitation from the GCOS program for BSRN to participate in GCOS as the GCOS global baseline radiation network; the completion of a second international diffuse solar inter-comparison; a recent careful comparison between BSRN and ISCCP results showing very good mean agreement; the mailing of letters from GEWEX SSG to the BSRN site scientists and funding organizations; reports of widespread reductions in surface solar irradiance followed by a reversal of that tendency in a number of surface radiation measuring sites; and finally, the presence of the BSRN representative at the GEWEX SSG meeting in the past year. Some additional information was given on the GERB program, which will produce 15-minute surface radiation estimates over a fixed footprint centered on Europe and Africa. Several details of the BSRN/GCOS agreement were given along with the list of 10 monitoring principles that GCOS sites are expected to follow. Preliminary results from the second solar diffuse comparison that was held under the direction of Joe Michalsky were shown. A brief history and summary of the phenomena that has become known as Solar or Global Dimming was presented along with the suggestion that the most recent data and analysis from the same type of sites showed that the dimming up until the late 1980s, was now no longer showing this decreasing trend and possibly was even showing an increase, which has been called by some “solar brightening.” The extent of good agreement between ISCCP derived surface irradiances and BSRN, as to soon be published in the Journal of Geophysical Research, was shown with mean biases between both downwelling surface solar and longwave irradiance near 2 Wm^{-2} for monthly averages for all available BSRN data between 1992 and 2000.

Several newly proposed sites were presented with more detailed descriptions and further discussion on their merits followed in subsequent discussions during the meeting (see Section XI for the list of the newly proposed sites or regions). The status of new sites proposed at the previous meeting (2002) was given with further activity being shown at Cabauw, Palaiseau, Dome C, and in Sweden, all of which were represented at the present meeting. Previously proposed sites in Cuba, India, and Zambia, have not demonstrated significant progress and were not represented at the meeting. Previously approved sites near Budapest and Ilorin were designated as “Suspended” until further demonstration of capabilities to fulfill BSRN requirements. A global map of the current and newly proposed sites was shown with the graphic explanation of the obvious apparent geographical and climatological gaps in the network coverage.

The current status and recent activities of the BSRN archive in Zurich were presented with further discussion of the archive to be presented later in the meeting. Of particular note were the research activities conducted by the archive staff, and the recent changes in accessibility of the archive data through FTP access, and the newly implemented quality control procedures of that FTP accessible data. A table showing the current data residing in the archive by year and station was presented, which is routinely displayed and updated on the BSRN web site (bsrn.ethz.ch), with a total of over 2800 station-months of data. The results of a recent inventory of sub-Rayleigh clear-sky solar diffuse observation resident in the archive were shown. Corrective measures by the few affected sites, which had previously been informed of this problem, have been implemented and corrected data are expected to be submitted in most all identified cases.

It was suggested that the working group structure and productivity needed to be further examined in view of past participation and performance of some of the working groups. The working group on clouds was given special note because of its new and innovative ideas for extracting and supplementing cloud information in the component irradiance measurements. The scope and importance of the cloud information in surface irradiance measurements appears to be much greater than originally anticipated by BSRN.

The representativeness of individual sites and the current and planned BSRN network was shown the cross-correlation of annual averages from a few surface sites and the 17-year record of satellite estimated surface irradiances from the ISCCP project. On the interannual basis, the cross correlation of individual surface sites appears to be rather spatially extensive, sometimes extending to 5 to 10% of the entire globe. The potentially representativeness of the current 34 station BSRN network and a potential 55-station network, based only on the current and proposed sites, was shown to have some representativeness over nearly 80% of the Earths surface, including the oceans, which is more representative than previously realized but still not as representative as observations specific to each location such as satellite derived values.

Areas of current and expected future emphasis for BSRN:

1. Further development of IR and diffuse solar reference standards
2. Studies of pyranometer thermal offsets
3. Supplying aerosol optical depth data to the archive
4. Further specification of the accuracy of pyrheliometer observations
5. Extend BSRN global coverage and addressing issues of ocean observations
6. Assuring maintenance of the long-term observational and data archive efforts
7. Extracting and supplementing cloud information at BSRN sites.

Participants were encouraged to think about additional activities that should be stressed or expanded in the future.

GCOS and BSRN (Hans Teunissen, GCOS Secretariat, Switzerland)

An overview of the Global Climate Observing System (GCOS) Programme was presented that included the GCOS mission and strategy; a broad review of the GCOS networks; the interactions between GCOS and the UN Framework Convention on Climate Change; the development of the *Second Report on the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC* and current development of an Implementation Plan in response to its findings; and the new relationship between GCOS and BSRN through the formal acceptance by WCRP and GCOS of BSRN as the GCOS global surface radiation network. GCOS welcomed the contributions of BSRN to developing the global surface radiation products identified among the Essential Climate Variables defined in the Second Adequacy Report, while noting the importance of expanding the network to full global coverage and participation of dedicated analysis centres to ensure generation of the needed climate products on a continuing basis. It was hoped that participation of BSRN in the GCOS Programme would provide enhanced visibility of the contributions and importance of BSRN to global climate system observation and thereby strengthen efforts to ensure the long-term support and sustainability of the network, as required for all GCOS system.

US GCOS Program Overview: The Atmospheric Domain (Howard Diamond, NOAA/NCDC, USA)

In his role as the U.S. GCOS Program Manager, Dr Diamond provided a background of the U.S. GCOS Program, particularly in reviewing GCOS Atmospheric domain activities not necessarily covered by the global GCOS program (e.g., Atmospheric Brown Cloud, and the U.S. SURFX Program). SURFX is a network of 10 sites in the U.S. for high quality measurements of the air-surface exchange of CO_2 and energy, including water. Some other internationally supported activities include site support for the GCOS Upper Air Network (GUAN), support of the Global Atmosphere Watch Quality Assurance/Science Applications Center for the Americas for Precipitation Chemistry, as well as possible support for the Central UV Calibration Facility in Boulder, Colorado. Some key bi-lateral climate agreements that the U.S. has with countries such as New Zealand, Australia, South Africa, and China were mentioned. In particular, two new bi-lateral activities being supported as part of the U.S./New Zealand Climate Change Partnership were described. These include exciting new trace gas measurements on a new ship route between New Zealand and Japan that crosses the South Pacific and Inter-Tropical Convergence Zones, as well as the establishment of a new stratospheric water vapor measurement site in Lauder, New Zealand to complement the current one global site in Boulder, Colorado.

The US GCOS Program Office is basing the priorities of the $4.0M annual GCOS program on priorities from the GCOS Atmospheric Observations Panel for Climate (AOPC), NOAA Climate Monitoring Working Group, the GCOS Secretariat, as well as from regional workshops and inputs from bi-lateral climate partners. The NOAA Office of Climate Observations which is a NOAA planning activity for both atmospheric and oceanographic observations located on the web at http://oco.noaa.gov was also discussed. A question on overall participation of other US agencies (e.g., US Geological Survey) was brought up and it was noted that the contributions of agencies to GCOS climate activities such as what USGS provides can be found in the US National GCOS report of 2001 which is available on-line at http://www.eis.noaa.gov/gcos/soc_long.pdf. The US Strategic Plan for the Climate Change Science Program *Final Report, July 2003* with input from 17 U.S. federal agencies can also be found at http://www.climatescience/gov.

BSRN and AERONET Initiatives in China (Zhanging Li, Dept. of Meteorology, University of Maryland)

While there are an increasing number of BSRN stations around the globe, there currently are no sites over the vast territory of China. As a part of the US-China joint research project named the East Asian study of Tropospheric Aerosols: an International Regional Experiment (EAST-AIRE), a team of scientists from the University of Maryland, NASA, NOAA, the Chinese Academy of Sciences, and the China Meteorological Administration are working together to establish several BSRN stations. Tentatively, three stations were selected that represent major emission regions in North, South, and Southeast China. An extensive array of instruments listed below will be deployed, which make the sites of the function of not only BSRN but also AERONET. The instruments will be calibrated regularly to meet the requirements of the two networks.

Instruments	**Manufacture**	**Model**	**Observations**
Pyranometer	Kipp & Zonen	CM21	Total and diffuse radiation
Pyranometer	Eppley	8-48	Total and diffuse radiation
Pyrheliometer	Epply	NIP	Normal incident radiation
Pyrgeometer	Epply	PIR	Infrared radiation
PAR radiometer	Kipp & Zonen	LITE	Photosynthetically active Radiation
UV Radiometer	Eppley	TUV	Ultraviolet radiation
Solar Tracker	EKO	STR-22	Tracking the sun
Spectrometer	YES	MFR-7	Direct and total spectral radiation at 7 bands
Spectrometer	Cimel	CE-318	Direct spectral radiation
Sky imager	YES	TSI-4400	Sky true color images

II. REPORTS ON NEW OR PROSPECTIVE FIELD STATIONS

Alert, Nunavut, Canada: Proposed BSRN/SEARCH Radiation Monitoring Site (L.J. Bruce McArthur, Meteorological Service of Canada, Toronto, Canada)

Alert is the northernmost permanent settlement on the globe (82°28' N, 62°30' W) and particularly suited to observe radiative fluxes in the Arctic. In a collaborative effort between the US National Oceanographic and Atmospheric Administration (NOAA) and the Meteorological Service of Canada (MSC), a surface radiation monitoring station is being installed at the Global Atmospheric Watch Baseline Observatory approximately 8 km inland from the Canadian Forces Base (CFB) Alert.

While Canada has made radiation observations at Alert for over 20 years, NOAA's interest in the Arctic through the Study of Environmental Arctic Change (SEARCH) program (http://www.etl.noaa.gov/programs/search/) has provided the opportunity to develop a high quality program to support the scientific needs of both SEARCH and the BSRN. During August 2004, a complete radiation monitoring site funded by the NOAA SEARCH program will be established (see table below) with the data being transmitted to NOAA on a daily basis for quality assurance and provided to both Canadian and U.S. researchers associated with the SEARCH and BSRN programs. Canadian technicians will support the daily operations at the GAW Laboratory and perform the instrument calibrations. It is anticipated that these observations will enhance significantly the knowledge of the radiation budget of the high arctic over the life of the station.

Instruments to be Deployed at the Alert SEARCH/BSRN Site

Alert search/BSRN instrumentation	
Downwelling Fluxes	
Solar Tracking	Kipp & Zonen 2AP Tracker
Direct Beam	2 Eppley Normal Incidence Pyrheliometers (NIP)
Diffuse	Shaded Kipp & Zonen CM22 pyranometer Shaded Eppley B&W pyranometer

Instruments to be Deployed at the Alert SEARCH/BSRN Site (Continued)

Global	Kipp & Zonen CM22 pyranometer
Aerosol Optical Depth	Carter-Scott SP02s 8 – channel sunphotometer
Longwave	Shaded Eppley Precision Infrared Pyrgeometer (PIR)
Data Acquisition	Campbell Scientific CR23X
Upwelling Fluxes	
Support Structure	3 m tipping tower albedo stand
Reflected	Kipp & Zonen CM22
Emitted	Eppley Precision Infrared Pyrgeometer (PIR)
'Albedo'	Up and down facing LiCor LI-200SA Pyranometers
Data Acquisition	Campbell Scientific CR23X
Ancillary Measurements	
Wind Speed and Direction	
Pressure	
Temperature	
Humidity	
Snow Depth	Campbell Scientific SR50
Snow Amount	Nipher Snow Gauge

SIRTA: A Cloud and Radiation Observatory Near Paris (Martial Haeffelin, Institut Pierre Simon Laplace, France)

SIRTA is a cloud and radiation observatory located 25 km south of Paris. The research objectives of SIRTA are threefold: (1) to study dynamic and radiative processes in clouds from the ground to the top of the troposphere; (2) to evaluate and improve representation of cloud processes in NWP and GCM models; and (3) to prepare future and validate current satellite observations.

Tropospheric profiling is obtained by combining active (radar + lidar) and passive (sunphotometer, IR and microwave radiometers) remote sensing instruments. The SIRTA observatory includes a radiative flux station monitoring direct and diffuse solar radiation, and downwelling longwave radiation, using Kipp & Zonen CH1, shaded CM22, and shaded CG4, respectively. Measurements started in April 2003. The CH1 and CM22 were re-calibrated on-site in June 2004 using a PMO6 on loan from Kipp & Zonen. On-site calibration of the CG4 is planned for fall 2004 using a reference CG4 from WRC.

Radar-lidar and lidar-IR synergies are used to derive macrophysical (vertical distribution, optical depth) and microphysical (particle size and shape, ice water content) properties of cloud layers throughout the column. Lidar and sunphotometer measurements are used to characterize aerosolsproperties. Current studies include the evaluation of ice cloud properties and formation of boundary layer clouds in weather prediction models, cloud layer overlap assumptions in global climate models, and aerosol vertical distribution in chemistry transport models. Combination of cloud, aerosol, and surface radiation data will allow us to investigate SW and LW cloud and aerosol forcings as a function of cloud and aerosol type and their distribution in the column.

Cabauw Experimental Site for Atmospheric Research (CESAR), the Netherlands (Wouter Knap, Royal Netherlands Meteorological Institute)

In this presentation a description is given of the Cabauw site with its new radiation set-up, which is currently being constructed according to the standards of BSRN. It is intended that the set-up will be operational by the end of 2004. Several concrete bases with vertical poles and an aluminum framework have been placed at about 250 m from the base of the 200 m high tower. At this place, where there is little horizon obstruction, we will measure the basic radiation fluxes (direct, diffuse, global, and downward longwave). Furthermore, expanded radiation measurements will be made such as direct beam measurements at different wavelengths (for aerosol optical thickness retrievals) and UV radiation. Synoptic meteorological observations are made at different levels of the tower. In Cabauw, no human synoptic observations are made, but standard synoptic, upper-air, and ozone observations are made in De Bilt (20 km from Cabauw). In Cabauw, supporting measurements consist of total cloud amount (total sky imager), cloud-base height (lidar), cloud liquid water path (µwave radiometer), and ice-cloud microphysics (radar/lidar).

The data-acquisition system to be used for the BSRN-type measurements consists of Sensor Intelligent Adaptation Modules (SIAM), a comserver, and several PCs configured in a local area network. The basic unit of the system, the SIAM, is an independently functioning data-acquisition unit which forms the interface between the sensors and the data processing system. The SIAM is standard KNMI equipment which has been adjusted and improved to meet the requirements of BSRN.

This presentation is concluded by a brief overview of sunphotometer calibration activities by KNMI and Kipp & Zonen performed at the High Altitude Research Station, Jungfraujoch, Switzerland during the autumn of 2003. Examples of Langley calibrations are shown together with comparisons of aerosol optical thickness for different instruments operated by KNMI, Kipp & Zonen, MeteoSwiss, and PMOD. Differences are generally less than 0.01 and frequently less than 0.005. Comparisons of the different algorithms used are planned for the near future.

Update on the Brazilian BSRN Sites (Sergio Colle, Federal University of Santa Catarina, Brazil)

The data collected in the period 2000-2002 for FLO have been qualified and sent to WMRC. Data collected in 2003 have been qualified and are being formatted and prepared to be sent to the archive. Data collected in 2004 are being qualified. The data is available up to June 2004. The BAL station was upgraded in the frame of project SONDA. Problems were found in the data acquisition software. After the technical problems were solved, the station re-started operation in May 2004. Data have been collected since May. The station is operated and supervised by a technician that works at the electricity company, Manaus Energia S/A, in Manaus. This dedicated man is paid monthly from funds of research projects of LABSOLAR. The data collected in the period of May-August is available at the LABSOLAR BSRN archive for qualification. Both stations, FLO and BAL, have been upgraded with new CM21 and CM22 pyranometers, datalloger, and Kipp & Zonen four-quadrant solar tracker (only for BAL). The laboratory has been deeply involved with project SONDA. The project is coordinated by Dr Enio B. Pereira from CPTEC/INPE. In the framework of this project, five new BSRN compatible stations have been deployed. All stations are provided with all-sky camera, sunphotometer SIMEL, PAR and Light radiometers, Kipp & Zonen solar tracker with pyrheliometer Eppley NIP, pyrgeometer Eppley, and pyranometers CM21 and CM22 (for diffuse). These new stations are believed to be candidates for the extension of BSRN sites. Before proposing these new sites for BSRN network extension, all pending problems of BAL should be satisfactorily addressed. Efforts have been exercised to minimize the logistics problems of BAL. All travels demanded for supervision and repairing equipments have been supported by LABSOLAR or SONDA project funds.

The SW radiometers have been calibrated at the LABSOLAR calibration facility by using both the summation method and the comparison method with a reference CM22 pyranometer. Station FLO is going to be changed to the new building of LABSOLAR, which is 10 meters higher and a 50 meters distance from the present FLO site.

The laboratory has actively been involved with project SWERA – Solar Wind Energy Resource Assessment, which is funded by UNEP / GEF. In the framework of this project, three satellite based models to derive solar irradiance on the Brazilian territory are being cross-checked, in order to provide a database and maps of incoming solar radiation, with spatial resolution of 10 x 10 km an time resolution of one hour.

100 Years of Solar Radiation Measurements in Estonia (Ain Kallis, Estonian Meteorological and Hydrological Institute)

About 1000 actinometric stations operate presently all over the world. In Estonia episodic measurements of solar radiation started in Tartu in 1904. The first instruments used for recording solar radiation were the Khvolson actinometer, the Callendar's actinograph, and the Ångström pyrheliometer Å-197. Continuous recording of radiation started in the Tartu Actinometric Station (now Tartu-Töravere Meteorological Station) in January 1950. The station has been included in BSRN since 1999.

The radiation network in Estonia consists of four stations:

1. **Tartu-Töravere Meteorological Station** (measuring since 1950)
2. **Tiirikoja Lake Station** (since 1956)
3. **Tallinn Aerological Station** (since 2001)
4. **Jõesuu Meteorological Station** (since 2003)

Systematic changes in the radiation budget and its components have become evident in Estonia during the latest decades. Please see the full report in Appendix B.

The BSRN Station at Ilorin, Nigeria (Clement O. Akoshile, University of Ilorin)

The site is located on the campus of the University of Ilorin, Nigeria in a climatically important desert-region transition zone between the Sahara and the savanna (08°32'N; 04°34' E). Observational capabilities have been enhanced under the NASA-EOS program at this sub-Sahel location to obtain information on aerosols and radiative fluxes. This region is influenced by the dusty Harmattan wind, which persists for long periods of time and is characterized by steady dust conditions with high aerosol loading, which significantly affects the interpretation of satellite observations.

This activity is a collaborative effort between the University of Ilorin, the University of Maryland, NASA Goddard Space Flight Center (AERONET), and NOAA/ERL/CMDL. The Zurich archive personnel and the World Meteorological Organization (WMO) support the participation by scientists from this site in BSRN meetings.

History of Measurements at the Ilorin Site

Year	Measurements
1992	Total global, PAR global, LW down
1995	Add total direct, PAR diffuse, Air temperature, Relative Humidity, Wetness, Pressure
1998	Sun photometer Cimel, Solar tracker, Rain gauge, PAR direct, CR10 Data logger, +PC, Microtops for water vapor, aerosols and ozone
1999	Reconfiguration and addition wind speed and direction

The difficult local conditions under which the Ilorin station operates were described. Presently, this station is operating at a reduced capacity of instruments due to the requirements of instrument maintenance and the limited financial support from the University of Maryland, which is ending in September 2004. Local sources of funding are not yet available. An action plan was discussed at this meeting on how to continue this activity and return to full capacity.

III. DATA APPLICATIONS AND SCIENTIFIC RESULTS

Radiative Forcing Measured at the Earth's Surface and an Increasing Greenhouse Effect Over Europe (Rolf Philipona, World Radiation Center, Switzerland)

The Intergovernmental Panel of Climate Change (IPCC) confirmed that concentrations of atmospheric greenhouse gases and radiative forcing are expected to increase as a result of human activities. Nevertheless, thus far, changes in radiative forcing related to increasing greenhouse gas concentrations have not been detected with instrument measurements at the Earth's surface. Here we show that atmospheric longwave downward radiation significantly increased (+5.2 Wm^{-2}) partly due to increased cloud amount (+1.0 Wm^{-2}), while solar shortwave radiation decreased (-2.0 Wm^{-2}) over 8 years of measurements at eight radiation stations distributed over the central Alps. With cloud effects subtracted, GCM model calculations show the cloud-free longwave flux increase (+4.2 Wm^{-2}) to be in due proportion to the increase of temperature (+ 0.82 °C) and absolute humidity (+0.21 g m^{-3}), but to be three times larger than expected from anthropogenic greenhouse gases. The unexpected large increase of temperature and radiation fluxes was first thought to be related to rising warm air advection under strengthened NAO conditions. However, recent investigations, which include measurements in 2003, show increased warming during the summer time and no correlation with NAO. High correlation, instead is found between temperature increases and the steady increase of total surface absorbed radiation, which seems to indicate that the fast temperature increase in central Europe is driven by increased radiative forcings over land.

Determination of Greenhouse Effect by Surface Longwave Measurements (Bruno Dürr, World Radiation Center, Switzerland)

The radiation balance and the cloud and greenhouse effect at the Earth's surface were investigated at two stations of the Alpine Surface Radiation Budget (ASRB) network in Switzerland from 1995 to 2003. The cloud-free greenhouse effect (G_{cfr}) is defined as the cloud-free longwave upward radiation (LUR) at the surface minus the cloud-free longwave outgoing radiation (LOR) at the top of the atmosphere. LOR was computed with the help of the radiative transfer model MODTRAN v4.0 using Payerne upper air soundings. G_{cfr} and LUR are highly correlated with $r > 0.97$ both for day- and nighttime. LUR and the other radiation quantities like global shortwave and longwave downward radiation are measured at the lowland station Payerne (490 m a.s.l.) and the alpine station SLF-Versuchsfeld (2540 m a.s.l.) near Davos.

Eight years of measurements indicate that the sum of shortwave and longwave radiation absorbed at the surface and the longwave upward radiation and cloud-free greenhouse effect have strongly increased. The net cloud effect, total net radiation, and shortwave downward radiation, however, remained more or less stable. Thus, the strong temperature and absolute humidity increase at both locations over 8 years is predominantly caused by an increase of longwave downward radiation due to enhanced greenhouse gas concentrations (i.e., mainly water vapor).

Use of BSRN Observations to Advance Studies of the African Monsoon (Rachel Pinker, University of Maryland, USA)

BSRN observations are to be used to address outstanding scientific issues, serve as a “link” and an extension of information that is being collected during short-term experiments, and are instrumental in evaluating current scientific methodologies for a better understanding of future needs and directions. In this presentation an attempt was been made to synthesize results from observations made under a BSRN activity in the sub-Sahel and independent relevant projects to estimate errors in current retrievals of surface radiative fluxes from satellite observations in regions affected by persistent dust outbreaks that cover large areas of Africa, as well as the adjacent Atlantic Ocean.

Since the late 1960s, West Africa has been experiencing persistent droughts. The rainfall deficit reached 50% over parts of Sahel, the West African region that is the world’s largest source of aerosols. There is a need to understand the variability and impact of the West African monsoon on the hydrological cycle. Accurate information on Surface Radiation Budgets (SRBs) is required, including mesoscale-convective systems, local scale-links to applications for agriculture, and regional scale interactions.

An example of the climatic effect in the region requires accurate computations of radiative fluxes at the top-of-the-atmosphere (TOA). Such information is needed both at the surface, in the atmosphere and at the TOA. For example, strong differences in outgoing longwave radiation between June 1982 (El Niño) and June 1984 (La Niña) were found, showing positive versus negative anomaly over the same region. Dust will strongly affect such fluxes in the SW region. Under independent projects of the PATHFINDER type, long-term information on radiative fluxes was accumulated, to address some of the above issues. Available data includes:

Global scale – low-resolution data:

- About 20 years of low spatial resolution (2.5 degree) shortwave radiative fluxes (total shortwave), upwelling and down welling, Photosynthetically Active Radiation (PAR), upwelling and down welling, Near-Infrared (NIR) radiation) based on ISCCP D1 satellite observations at the 3-hourly time scale.

Regional scale - higher resolution data:

- About 10 years (1989-2000) of 0.5° resolution satellite data based on ISCCP DX over a large domain covered by two geostationary satellites. Both GOES and METEOSAT data have been used. An EOF analysis was developed and applied to the entire region to achieve homogeneity. The data are available at 3-hourly intervals as instantaneous, hourly averaged, daily and monthly means.

The satellite fluxes are estimated with the GEWEX/SRB model where aerosols are only nominally treated due to lack of information at such scales for long term time periods. The objective of the study was to evaluate the impact of aerosols on surface radiative fluxes over the extended source region and the affected Atlantic.

Observational capabilities have been developed under the NASA-EOS program at a sub-Sahel location to obtain information on aerosols and radiative fluxes. This activity is a collaborative effort between the University of Ilorin, the Department of Meteorology, University of Maryland, NASA Goddard Space Flight Center (AERONET) and the NOAA/ERL/CMDL via the Baseline Surface Radiation Network (BSRN) activity.

To study the impact of aerosols on the surface radiation budget, there was a need to estimate large-scale distribution of the aerosol optical depth (AOD) for input into SRB model. Realistic distribution of AOD was obtained using an empirical method which keeps the large-scale spatial and temporal variation patterns derived from satellite and model results, and simultaneously regulates the magnitude using ground measurements as described in Liu, Pinker and Holben, JGR 2004 (revised). In addition to improved aerosol optical depth, other aerosol parameters (e.g., single scattering albedo) need to be known. Such inputs are as yet not available. Additional capabilities of inference scheme were demonstrated, such as the derivation of PAR. The strong effect of water vapor on PAR was shown. PAR is also affected by aerosols. Such effects as yet have not been evaluated.

In summary, large-scale information on important input parameters to radiative inference schemes (e.g., aerosols) is becoming available and provides an opportunity to improve the inference schemes at least, on regional scales. Presented here was an effort to do such improvements in a climatically important region frequented by persistent outbreaks of dust outbreaks.

Evolution of Shortwave and Longwave Radiation as Observed at BSRN Sites and Simulated in Global Climate Models (Martin Wild, Institute for Atmospheric and Climate Science ETH, Swiss Federal Institute of Technology, Switzerland)

We use BSRN measurements for model validation in the context of the Atmospheric Inter-comparison Project (AMIP II). AMIP is a framework to analyze Global Climate Models (GCM) in a systematic manner, since it provides a standard experimental design followed by all major modeling centres. In AMIP we are responsible for the diagnostic project No. 32, “surface and atmospheric radiative forcing” (Principal Investigator: Martin Wild). This project may serve as interface between the global modeling community on one side and the BSRN community on the other side. In this context, at selected BSRN sites, clear-sky climatologies of surface insolation have been constructed based on composites of cloud-free episodes determined by the Long and Ackerman (2001) algorithm. This allows a separate assessment of the GCM simulated clear sky and all sky climatologies and related surface cloud radiative forcing. An investigation of the surface fluxes in the model series of the Hadley Centre for Climate Prediction and the Max Planck Institute for Meteorology reveal that their older ("AMP II") model versions (HAdAM2, ECHAM3) tend to overestimate the clear sky insolation at the surface. Their newer ("AMIP II") versions (HadAM3 and ECHAM4/5) show a reduced clear sky insolation, due to a higher water vapor and aerosol absorption in the cloud free atmosphere, in better agreement with observations. A comparison with the clear-sky insolation of the other models participating in AMIP II suggests that a significant overestimation of this quantity is still present in many models. This indicates that a lack of absorption of solar radiation in the cloud free atmosphere contributes to the excessive insolation at the surface typically found in GCMs.

The most direct effect expected at the surface from increased concentrations of greenhouse gases in the atmosphere is an increased flux of longwave downward radiation (i.e. the greenhouse forcing at the surface). The longwave downward radiation is, therefore, a potential candidate for an early detection of the greenhouse signal and its evolution of particular interest in the context of greenhouse gas-induced climate change. The monitoring of the longwave downward radiation is a central objective of BSRN. In this study, projections of the evolution of LWD as simulated in transient climate change scenarios with the coupled atmosphere-ocean General Circulation model ECHAM4/ OPYC are analyzed. These projections are related to the natural variability of LWD in unforced control simulations and in observational records at the BSRN sites. A statistically significant greenhouse signal at individual BSRN stations should become detectable in observational records of less than 20 years. The longest available time series of longwave downward radiation at 12 sites from BSRN show already today an overall increase of 0.26 Wm^{-2} per year. This increase is in line with an 0.25 Wm^{-2} increase per year found in transient GCM simulations of the current decades. This gives support for a correct representation of the greenhouse forcing and associated feedbacks in current GCMs.

Longwave Radiation Data Homogenization and Analyses for Arctic Stations (Marcel Sutter, World Radiation Center, Switzerland)

Longwave upward and downward radiation measurements from the Arctic stations BAR, GVN, NYA and SPO evince inhomogeneities up to 20 W/m^2 due to changes in instrumentation (installation of PIRs with 3 dome-thermistors) or other reasons. By analyzing the overcast situations and comparing the clear sky situations with MODTRAN4 Radiation Transfer Model calculated values, the inhomogeneities can be discovered.

Validation of the MODIS Albedo Products from Terra and Aqua (Crystal Schaaf, Boston University, USA)

The standard MODIS BRDF/Albedo product includes measures of albedo, nadir surface reflectance, and surface anisotropy (BRDF) every 16 days at a 1km spatial resolution globally. The data have been reprocessed (V004) and are now available from March 2000 to present. MODIS data from both Terra and Aqua have been combined from mid-2002 in order to increase the number of high quality retrievals possible worldwide. Satisfactory initial validation has been performed with data from the SURFRAD (BSRN) sites and these results were presented. To aid this validation effort and expand it globally, the Oak Ridge National Laboratory Data Active Archive Center (ORNL-DAAC) has begun hosting small spatial subsets of MODIS data for those BSRN stations that archive albedo information. Field data providers are able to download the data directly (in ascii), compute actual (blue-sky) albedos with user-provided solar zenith angles and optical depths, view imagery, and compute multi-year times series. Examples of these tools were presented and the BSRN community was encouraged to participate further in this effort.

Comparisons of MODIS and BSRN Products (Andreas Roesch, ETH, Switzerland)

MODIS surface albedo at high spatial and spectral resolution is compared with other remote-sensed climatologies, ground-based data and albedos simulated with the ECHAM4 global climate model at T42 resolution. The study demonstrates that MODIS data provide a valuable database for assessing and improving albedo parameterizations in weather forecast and climate models.

0.05 degree MODIS surface albedo agree quite well with *in-situ* field measurements collected at BSRN sites during snow-free periods while significant positive biases are found under snow-covered conditions mainly due to differences in the vegetation cover at the BSRN site (short grass) and the vegetation within the MODIS grid box. The remote-sensed PINKER surface albedo climatology follows the MODIS estimates fairly well in both the visible and near-infrared spectrum whereas ECHAM4 simulates high positive albedo biases over snow-covered boreal forests and the Himalayas. In contrast, ECHAM4 is probably too low over the Sahara sand desert and adjacent steppes. Black-sky (direct beam) albedo from the MODIS BRDF model capture the diurnal albedo cycle at BSRN sites with sufficient accuracy. The greatest negative biases are generally found when the sun is low. A realistic approach for relating albedo and zenith angle has been proposed. Detailed evaluations have demonstrated that ignoring the zenith angle dependence may lead to significant errors in the surface energy balance.

The study clearly depicts that neglecting albedo variations within T42 grid boxes possibly leads to significant errors in the simulated regional climate and horizontal fluxes, mainly in mountainous and/or snow-covered regions. Further, the comparison between ECHAM4 and the latest version ECHAM5 shows that the surface albedo over the Himalayas is closer to the observations whereas the positive albedo bias over the boreal forests in winter is even more pronounced in ECHAM5 than in ECHAM4.

Natural Variability and Sampling Errors in Surface Radiation Measurements (Zhanqing Li, University of Maryland, USA)

Radiation measurements have often been employed for evaluating cloud parameterization schemes and general model simulation results. An important question is raised as to how well the measurements represent mean values over the model grids. In contrast to the coarse-resolution GCMs, fine-resolution Cloud System Models (CSM) are playing an increasing role in revealing the fundamentals of cloud-radiation interactions. Another question is thus raised: on what scale does modeling need to occur in order to capture the physical properties that drive the system. This study addresses both questions by examining the spatial and temporal variation of surface radiation data from satellite simulated surface measurements, and characterizes the inherent sampling errors in real surface measurements. The results provide an objective guidance in determining the density of ground stations deployed either permanently or through a mobile facility. Taking advantage of the high spatial and temporal-resolution of the Geostationary Operational Environmental Satellites (GOES) data, we mimic measurements of varying density and temporal frequency and characterizes observation uncertainties caused by cloud variability at different scales in different seasons. Such scale-dependent statistics of observational uncertainties provide critical constraints on model-observation comparisons, and are thus valuable for improving and validating cloud parameterization schemes.

Intercomparison and Validation of Satellite-Derived Albedo Data Sets (Crystal Schaaf, Boston University, USA)

The CEOS/WGCV/Land Product Validation sub-group (LPV) is in the process of initiating an inter-comparison of satellite-derived albedo products. The effort was described and the BSRN community was solicited to participate by assisting in the identification of several field locations appropriate for this inter-comparison and by contributing to the evaluation by ensuring that the ground-collected albedo data are being interpreted correctly. An LPV planning meeting will be held in spring 2005 (tentatively hosted by Fred Baret in Avignon).

Evaluation of Long-Term Shortwave Surface Radiation over China (Tadahiro Hayasaka, Research Institute for Humanity and Nature, Kyoto, Japan)

Downward shortwave radiative flux on the surface around China were evaluated for 1971-2000 by using pyranometer data and calculated results by parameterization with ground-based meteorological data, such as sunshine duration and water vapor. The results were also compared with the NASA/Langley Surface Radiation Budget (SRB) data set for 1984-1994. These radiation data, in general, are consistent with each other for monthly average values, although SRB has a positive bias for big city areas, whereas there is a negative bias for the desert area in the west part of China. One of the reasons for these biases is ascribed to inappropriate assumption of aerosols in the SRB. As for long-term monitoring of radiation, a synthetic analysis should be discussed because the satellite data are limited after 1980s and pyranometer measurements have some difficulties in keeping quality of data due to the calibration and operation.

Automated Retrieval Algorithm for Ground-Based Spectral Radiometer Data (Mikhail Alexandrov, NASA/GISS, USA

A substantial upgrade of our previously developed MFRSR data analysis algorithm is presented. The new version of the algorithm features an automated cloud screening procedure based on optical thickness variability analysis. This technique is objective, computationally efficient, and is able to detect short clear-sky intervals under broken cloud conditions. The performance of the method has been compared with that of the AERONET cloud screening algorithm. Another new feature is the adoption of a bimodal gamma distribution as the aerosol particle size model. The size of the fine mode particles and a ratio between optical thicknesses of the two modes are retrievable. The algorithm has been tested on a multi-year data set from the MFRSR network at the Department of Energy's (DOE) Atmospheric Radiation Measurement (ARM) Program site in the Southern Great Plains (SGP). The aerosol optical thicknesses (total, fine, and coarse) obtained from our analysis were successfully compared with the corresponding

AERONET almucantar retrievals from a CIMEL sun photometer co-located with the MFRSR at the SGP Central Facility. Geographical and seasonal variability of aerosol properties have been observed in the multi-instrument data set from all SGP Extended Facilities for the year 2000. The geographical trends in the fine mode particle size appear to reflect differences in the PM2.5 to PM10 ratios obtained from the EPA monitoring data and nitrate to sulfate ion concentration ratios from NADP/NTN. Long-term temporal variability has been studied on the 1992-1997 dataset from the SGP Central Facility. A significant trend has been detected in coarse mode aerosol optical thickness following the Mt. Pinatubo eruption in 1991, while the fine mode optical thickness exhibits only seasonal variations during that period.

Solar Dimming and Brightening: Decadal Scale Variations in Surface Solar Irradiance: Multiple Perspectives (A. Ohmura/M. Wild/A. Roesch/R. Pinker/E. Dutton)

A review of the history of the expected and occasionally observed long-term stability of surface solar irradiance on local, regional, and global scales was given by A. Ohmura. He reported there had been larger observed interannual trends and variations than expected and that there tended to be a general decrease in many of the reported records. This unexpected result serves as a reminder to keep an open mind about our physical world.

The updated result of variability analysis of the GEBA (Global Energy Budget Archive) and BSRN data bases was given by M. Wild who showed that at most sites there was a suggestion for a decreasing tendency in irradiances until the late 1980s and the reversing to a increasing tendency through the 2000s.

A. Roesch showed comparisons between observed and GCM modeled long-term surface solar irradiances. These comparisons show several matches between the model and observed regional trends and a few cases of mismatches.

Global mean observations from satellite-based sensors were presented by R. Pinker. These observations derived from the ISCCP program and are analyzed to estimate surface solar irradiances from 1983 until 2000. These data show consistency, with statistical significance, in temporal trends with sample surface-based observations. The satellite data also indicated global mean variations similar to that suggested by the new analysis of GEBA and BSRN data as presented by Wild. Zonal means of the satellite data show varying strengths of the trend tendencies.

E. Dutton concluded the discussion with a review of some of the strengths and weaknesses of the early published literature that had been used to establish a suggestion of a widespread decrease in surface solar irradiance leading up to about 1990. He then examined and extended record of surface solar irradiance from a 5-stite globally remote network that has shown high autocorrelation with globally large surrounding and teleconnected regions sometimes composing 5 to 10% of the Earth's surface. These records supported the previously presented summaries leading to a general conclusion that much of the available observation data suggests an overall decreasing surface solar irradiance tendency from the 1960s until about 1990 with leveling to reversal of the tendency into the 2000s.

Sunshine Duration Uncertainty from BSRN Minute Statistics (Bruce Forgan, Bureau of Meteorology, Australia)

The Australian radiation network is operated with the same data collection protocols as used for BSRN. The direct irradiance minute statistics data were examined to determine if it could be used to generate sunshine duration data within the CIMO uncertainty requirement of 0.1 h. An initial study found that there was insufficient data to determine the uncertainty, while only 7% of all data in 2002 was difficult to determine if it was sunshine, on average over 70% of days had more than 0.1 h of uncertain minutes. The Australian network data acquisition was altered to monitor sunshine seconds within each minute. Data from September 2003-June 2004 were examined to compare to the BSRN statistics. The results indicate that using BSRN minute statistics, if the known sunshine periods (S_{ks}) and those periods where the maximum and minimum irradiance straddled 120 Wm^{-2} but the mean was greater than 120 Wm^{-2} (S_{us}) then the relationship $S' = S_{ks} + 0.76\ S_{us}$ produced sunshine duration with an uncertainty approaching 0.1h. When compared to Campbell-Stokes sunshine recorder data in the Australian network, it was evident that in intermittent clouds, the sunshine recorder data overestimated sunshine duration by about 1 h and the uncertainty for daily sunshine duration was about 0.5 h.

Sunshine Duration in the UK (Aidan Green, UK Met Office)

The definition of sunshine duration is the length of time that direct solar irradiance exceeds a certain threshold. The Campbell-Stokes Sunshine recorder was first used in 1853. This recorder has two problems: 1) variation in the level of irradiance required to produce a burn, and 2) over-burning of the card in periods of intermittent sun and cloudiness. In 1982 WMO removed the Campbell-Stokes Sunshine recorder for its inaccuracies in measuring sunshine. Three instruments were tested and all of them met the required accuracy for daily total values. CSD1 was chosen as the best instrument to measure sunshine. It is constructed using 3 photodiodes.

IV. UV AND PAR MEASUREMENT

On the Calibration and Measurement Accuracy of UV Broad Band Filter Radiometers (Alexander Los, Kipp & Zonen B.V., The Netherlands)

Measurements of an ongoing inter-comparison between different UV broadband filter radiometers and a well-calibrated UV spectroradiometer at the JRC (Italy) corroborate the current best-practice results. Although spectral mismatch errors, cosine response imperfections, and sensitivity drifts downgrade the measurement quality, it is possible to reduce the measurement uncertainty by using dedicated correction methods. Therefore, critical broadband radiometer properties, such as the spectral response function, have to be determined accurately (Opt. L., 29, 13, 2004). Two spectral mismatch error correction methods were applied in this study, a model derived correction method and a correction method using spectral measurements. While the spectral measurement based correction yields slightly better results, the model-derived correction is independent of the measurement location.

Results were shown for 5 radiometers (two YES UVB-1, two K&Z SET and one K&Z SBT) which measure global UV irradiance next to a Brewer MK III spectroradiometer since July 2003. It was found that for some radiometers sensitivity drifts tend to reach normal values (less than 3% per year) only after the instruments have been used for a couple of years. Differences between all broadband radiometers using model derived corrections and the spectroradiometer were within 5% (2σ) for Erythema (CIE-1987) weighted UV irradiances greater than 0.1 W/m^2 (or UV indexes greater than 4).

Reconstruction of Past UV Doses (1926-2003) at Davos, Switzerland (Laurent Vuilleumier, MeteoSwiss)

A method previously developed for reconstructing daily erythemal UV doses at Sodankylä, northern Finland, was adjusted to the local conditions at Davos, Switzerland, and used for estimating the erythemal UV doses there over the period 1926–2003. The method uses total ozone, sunshine duration, and snow depth as input, and is based on an empirical relationship between relative sunshine duration and relative UV doses. In order to examine how the method behaves in different environments, the relationships found for Davos and Sodankylä were compared. This revealed that the relationships are very similar in these different environments and that surface albedo and the cloud climate have a comparable influence on the relationship found. Although the method is fairly simple, it accounts for the most important factors affecting the amount of UV radiation reaching the Earth's surface. A comparison between estimated UV doses and the corresponding observations with a broadband biometer at Davos demonstrated the good performance of the method. The correlation coefficient and the root mean square error were found to be 0.98 and 22%, respectively, for daily values, and 0.997 and 4%, for monthly mean values; in addition a small bias on the order of 3% was found. The time series of estimated UV shows that the UV level at Davos has varied considerably throughout the period of this study, with high values in the middle of the 1940s, in the early 1960s, and in the 1990s. Variations in the estimated UV doses prior to 1980, e.g. a steady decrease from the early 1960s to the late 1970s, were found to be caused primarily by changes in sunshine duration. Since 1980, on the other hand, there has been a distinct increase in the UV level caused mainly by the diminution of total ozone. This increase is most clearly seen during winter and spring while the decrease from the early 1960s to the late 1970s is most pronounced during summer. This study also revealed that the performance of the radiative transfer model used performed remarkably well for clear-sky condition. This suggests it could be used as a tool for quality control and monitoring of the biometers.

Report on the BSRN UVB Sub-Group (Alex Manes, Israel Meteorological Service)

The UVB Sub-Group was established at the 5th BSRN meeting in Budapest, Hungary, 18-22 May 1998. The rationale for its establishment was the recognition by the majority of participants that broadband UVB measurements should be part of the measurement suite of BSRN stations. It was also recognized, at that time, that conditions were not yet suitable for matching the accuracy requirements of BSRN stations. Particularly, the calibration instability of existing commercial broadband UVB radiometers, and the lack of a central calibration facility, capable of providing the necessary calibration hierarchy were hampering such efforts within BSRN. The main task of the UVB SG was to monitor the progress made in the field of broadband UVB radiometry, and report to the BSRN Scientific and Review Workshops. In the group's report that was submitted at the BSRN Meeting in Regina, Canada, in 2002, it was indicated that considerable progress was achieved in the accuracy and stability of broadband UVB measurements, especially by the US networks (i.e., SURFRAD and USDA), in close cooperation with the Interagency Central UV Calibration Facility (CUCF) of SRRB, NOAA. It was recommended that BSRN stations carry out broadband UVB measurements routinely, and that the BSRN Archive make provisions for inclusion of UV data in the archive. See Appendix C for the full report of the UVB Sub-Group.

2002 BSRN PAR Sensor Comparison: Bratt's Lake, Saskatchewan (L.J. Bruce McArthur, Meteorological Service of Canada)

Between May 23 and June 3, 2002 a selection of instruments of different manufacture used by various agencies were compared against two spectrometers–an Optronics OL754 double monochromator UV/VIS/NIR grating spectroradiometer and an in-house MSC photodiode array spectrometer. The table below presents the instrument types, serial numbers and owners. While these are not the only sensors on the market, they do represent the most commonly used.

PAR Sensors Used in the 2002 BSRN PAR Instrument Comparison

Manufacturer	**Model** **Serial Number**	**Owner**
Apogee Instruments Incorporated, Logan, UT, U.S.A.	QSO-SUN QSO1005S	Meteorological Service of Canada (MSC)
	QSO-SUN QSO01003S	MSC
Kipp and Zonen Delft, Netherlands	PAR Lite 990026	University of Maryland
	PAR Lite 010134	MSC
	PAR Lite 010135	MSC
LiCor Lincoln, NB, USA	LI-190SA Q13182	University of Maryland
	LI-190SA Q20357	University of Maryland
	LI-190SA Q20554	National Oceanic and Atmospheric Administration (NOAA), Boulder, CO
	LI-190SA Q20556	NOAA
	LI-190SA Q20557	NOAA
	LI-190SA Q23438	Deutscher Wetterdienst (DWD), Potsdam, Germany
	LI-190SA Q23439	DWD

PAR Sensors Used in the 2002 BSRN PAR Instrument Comparison (Continued)

	LI-190SA Q26803	MSC
	LI-190SA Q26804	MSC
	LI-190SA Q26807	MSC
	LI-190SA Q29168	NOAA
Middleton Solar Instruments Carter-Scott Design, Victoria, Australia	SK01-DP 1231251	Carter-Scott Design
Skye Instruments Ltd. Llandrindod Wells, Powys. UK	Quantum Sensor SKP 215 0501 22617	MSC
	Quantum Sensor SKP 215 0501 22618	MSC

The results of the comparison found that the LiCor sensors, in general, measured up to 15% greater amounts of PAR than those of the other manufacturers. Because of the relatively large number of LiCor sensors it was found that there was a significant spread (-15 - +20%) about the mean of the group. The Kipp & Zonen sensors were found to be between 0 to 5% below the average LiCor value, with the Skye instruments ranging between 5 to 10% lower than the mean of the LiCors. The Apogee and Middleton instruments were found to provide the lowest PAR values.

When compared with the two spectrometers employed in the study, the LiCor instruments agreed reasonably well with the photodiode spectrometer, while the remaining instruments had better agreement with the OL754. The difference between the two spectrometers was found to be between 5 and 10%, the photodiode array instrument reporting higher values. The expected difference between the two spectrometers was in the order of 5% RMS. This difference is being investigated, but until such time as the reason for the bias is found, the comparison cannot be used to assess the absolute accuracy of the each of the instruments.

The comparison also performed tests on the directional responsivity, the temperature response, and a test on the out-of-band light leakage of each type of instrument. The results indicate that:

- The Kipp & Zonen PAR-Lite instrument tested had the best directional responsivity. Four LiCor sensors of differing ages were tested, three having similar directional responses, with the fourth being opposite in direction. The Skye instrument that was tested had the worst directional response.

- Each instrument's responsivity changed as temperatures were varied from -50 to 50° C. The PAR-Lite, LiCor and Skye instruments behaved similarly, changing responsivity by approximately 10% over the temperature range, while the Apogee sensor changed by approximately 25%.

- The out-of-band tests showed that most of the sensors had little or no leakage from wavelengths shorter than 300 nm. The Middleton sensor had a significant leak at wavelengths longer than the PAR 700 nm cut-off, while the LiCor sensors tested had an average of 3% of their signal come from wavelengths greater than 700 nm. The data confirmed that the Apogee sensor cuts off at wavelengths less than 700 nm.

A second comparison using a greater variety of spectrometers to determine the absolute quality of the various sensors is being considered for the summer of 2005.

V. DATA HANDLING AND ARCHIVING

Data Homogenization: How does BSRN manage it? (Laurent Vuilleumier, MeteoSwiss)

Thanks to guidelines and operating procedures required for BSRN stations, the irradiance time series measured within BSRN are fulfilling the high accuracy requirements set when the network was initiated. Furthermore, in many cases, technical advances often initiated by BSRN requirements, allow the reproducibility of given instruments to go well beyond the required accuracy. Hence, it is possible that if a single instrument is used for a given time series, and the instrument does not drift, trends significantly smaller than the accuracy required for BSRN can be detected, thanks to such reproducibility and proper averaging procedures. On the other hand, instrument replacements, changes in instrument technology or data processing, re-calibration and other factors, may introduce discontinuities in the time series. In case these discontinuities are not properly addressed and resolved, they will introduce spurious trends. At the BSRN station of Payerne, redundancy in the measurements of main parameters is sought. A redundancy is already built-in the BSRN requirement of measuring global short-wave irradiance both as a single measurement and the sum of direct and diffuse irradiance. In addition, given parameters such as global and direct short-wave irradiance, as well as long-wave downward irradiance, are measured with two or more instruments at Payerne. This redundancy allows checking bias between instruments and random variability. For instance, the differences measured over a period of more than 5 years between two Eppley PIR pyrgeometers modified with three dome thermistors is remarkably stable: average bias on the order of 1-2 W/m^2 and 80% of the difference distribution within ±3 W/m^2 with no detectable seasonal cycle. In case instruments are replaced, long time overlaps between redundant instruments allow estimating inter-instrument bias and correcting for them. Such redundancy, as well as other techniques (e.g., comparison to models) allows homogenization of time series in case discontinuities are introduced by factors mentioned above. The influence of discontinuities can be on the order of decadal trends, thus such homogenization is necessary if irradiance time series trends shall be detected after two decades of BSRN operation as GCMs suggest the possibility. In most cases, homogenization can be achieved relatively simply and correctly by adjusting calibration constants. In other cases, such as long-wave irradiance, it may be advisable that BSRN issues guidelines on proper procedures and statistical techniques to homogenize time series.

Revisions and Additions to BSRN QC (Chuck Long, Pacific Northwest National Laboratories, USA)

New data QC limits/tests developed for the BSRN Archive were described. At the 7th BSRN Meeting, a Working Group consisting of Ells Dutton, Chuck Long, and Atsumu Ohmura was formed and charged with a review of the QC testing then in place, after it was noted there were some problems. New tests were developed using sample data from several high-, mid- and low-latitude BSRN sites. These tests generally set "physically possible" and "extremely rare" limits that apply to the entire range of climate extremes experienced at the BSRN sites. These new tests are now applied to all BSRN data as it goes into the Archive ftp area.

Additionally, QC testing based on on-site climatological limits was presented, since the global limits do not generally address much of a specific site's data quality except for extreme failures. Thus, it was shown that using limits based on the actual climate an individual site experiences affords much better quality assessment. Given knowledge about the behavior of BSRN-type instruments in the field, gained from recent research and analyses, more sophisticated cross comparison methodology has also been developed. It was noted that the BSRN members would need to discuss how much (if any) of these new tests would be appropriate for the Archive to institute. But it was also noted that Dr Long is willing to work with any site scientist individually to institute the current version of the QCRad code at their site.

BSRN Data Archive—Improvements and Status (A. Roesch)

There are currently 34 operational BSRN stations. NOAA, ARM and Surfrad stations are the only stations that are up-to-date in the archive. There are 150 files at the archive that have not been inserted into the database. The preferred procedure for submitting files to the archive is to first send a few files to see if they are formatted correctly, then send the rest. Not all stations with synoptic measurements are being submitted to the archive. Only 18 stations submitted radiosonde data. There are not many stations submitting radiation measurements at 10 and 30 km. Currently, no stations are providing aerosol optical depth (AOD). Plans for future to insert computed AOD for 3 wavelengths after passing consistency checks. No change in the database schema is required. A FTP file archive feature has been added. Only basic measurements can be obtained via the web interface.

VI. DIFFUSE SOLAR

Comparisons of Measurements of Diffuse Radiation – First Results (Klaus Behrens, DWD, Germany)

During the Regina Meeting (2002) G. Major and M. Pusztay (2002) proposed optimal radii and arm length for the shading devices corresponding to the different opening angles of pyrheliometers, respectively. From September 2003 to April 2004, an experiment was carried out investigating the possibility of the proposed optimization. Therefore, two CM21 pyranometers were mounted on a BRUSAG tracker, shaded by a reference disk (r = 30 mm, d =687 mm) and a moving disk (r = 25.4 mm, d = 505, 581, 603 and 630 mm), respectively. The reference disk corresponds to an opening angle of 5.0° while the moving disk corresponds to opening angles of 5.85 (NIP), 5.0 (ref), 4.82 (CH1) and 4.63° (AHF), respectively. The moving disk was driven by a computer controlled step motor. It moved up and down stopping at every mentioned distance for 5 minutes between sunrise and sunset.

During overcast sky conditions, both pyranometers showed positive agreement (between –0.21 and – 0.04 W/m^{-2} – standard deviation 0.16 W/m^{-2}). The ratios Dm/Dr, calculated every minute and arranged to the corresponding distances, show that the median is in every case near zero. The percentiles have a yearly course with small deviations in winter and larger deviations at a higher declination of the Sun. Furthermore, the percentiles are shifted to a distance of 505 mm from lower values with ascending distance to higher values respectively, indicating qualitatively the expected tendency. During clear days the percentiles are closer to the median, which is closer to zero, which was expected. The percentiles on clear days display the same tendency for all of the data observed.

The calculated global radiation of the total from the vertical component of NIP, CH1 and AHF plus the diffuse of the moving disk was subtracted from the global radiation measured by a CM22. The medians of these differences are within 1 W/ m^{-2}, showing no tendency. Furthermore, the percentiles do not indicate any tendency, as in the case of the diffuse radiation observed. This means, that the investigated data do not show the expected optimization. Further investigations involving more parameters (e.g. turbidity) should bring clarity.

Diffuse Radiation Variability Based on Conventional WRDC Data Archive for GAW and BSRN Sites (Anatoly Tsvekov, World Radiation Data Centre, Voeikov Main Geophysical Observatory, Sankt-Petersburg)

Diffuse radiation is considered as one of the main components of radiation balance measured at the Earth surface. It influences global radiation, the sum of direct and diffuse components, which is used for climatic trend estimates. Because of changes in the spectra of diffuse radiation during a day, in particular, when clear sky becomes cloudy, it is important to measure spectra changes at the BSRN stations.

Diffuse radiation data submitted to WRDC archive is mainly daily totals. The list of stations registered in this archive has 277 sites for 40 years (since 1964) when the WRDC was organized. But at the present time only 145 stations continue to provide diffuse radiation data to the WRDC. This data is uploaded on the WRDC server with the address: http://wrdc.mgo.rssi.ru.

The statistical estimates of diffuse radiation variability included as one of the branches in quality control, has been made supplementary in the WRDC, while processing the data received from the national meteorological services. This QC is based on the procedures developed at the WRDC, for example out lies above or below critical levels. One of the tests developed and effectively used in the WRDC is the so called the 95 and 10% probability limits for all the data at a particular station are used to check questionable data values. These probability limits show considerable changes from season to season at sites and also latitude dependent. A combination of parametric and non-parametric tests is also used in search for disruption of the homogeneity in diffuse radiation time series. This is mainly t – test, Wilcoxon and Series tests.

Online processing procedures of data series with useful interface demonstrated during this meeting in particular for daily data of diffuse radiation from WRDC archive, from the database of GAW and BSRN stations, developed recently at the WRDC, showed its applicability in the different aspects of getting climatic estimates and, in particular, for modeling smooth curve of climatic seasonal component even in cases with missing data in time series for a few years available.

Pyranometer Thermal Offsets Under Different Ventilation Regimes (David Halliwell, Experimental Studies Division, Meteorological Service of Canada)

This study looked at the effect of five different ventilation systems on the nocturnal thermal offsets of a group of Kipp & Zonen CM21 pyranometers, using data collected over a period of 50 days at the Regina BSRN station. The offsets were examined by comparing the pyranometer flux to the net IR signal from the thermopile of a pyrgeometer (either an Eppley PIR or a Kipp & Zonen CG4). The study found that the different ventilation systems had only minor effects on offsets, and that the variation amongst instruments was larger than the variation amongst ventilations systems. The offsets were generally in the 0 to -3 Wm^{-2} range for net IR values of 0 to -120 Wm^{-2}. Some instruments showed significantly greater scatter for unknown reasons. Both increased ventilation and heating of the air stream, which helped in reducing frost accumulation on the instrument domes.

Toward the Development of a Diffuse Horizontal Shortwave Irradiance Working Standard (Joseph Michalsky, Air Resources Laboratory, NOAA, USA)

There is a need for an improvement in the accuracy with which diffuse horizontal irradiance is measured. Models of clear-sky diffuse irradiance show a clear tendency to over predict measurements. It is incumbent on experimentalists to ensure that the measurements are not at fault. The second diffuse intensive observation period included 15 pyranometers that measured diffuse irradiance simultaneously using the same geometrical configuration of the shadowing disks. There was a near equal mix of clear, partly cloudy, and overcast days. Eight of the pyranometers agreed to within +/-2% for both clear and overcast conditions. Four of the pyranometers were eliminated because they were unstable, under or over predicted these eight instruments, or were deemed un-correctable for offsets. Three instruments read higher than these eight, but otherwise performed well so could not be easily eliminated from consideration as part of the standard set. Attempts to explain the three high differences that occurred only on clear days included consideration of the shadowing geometry, the cosine response of the instruments for the spatial distributions of skylight under clear and overcast conditions, and the spectral response of pyranometers to a clear sky diffuse given a calibration using total or direct sunlight. A final subtle effect considered was the additional offset that might be caused by additional heating when the sensor is irradiated since the corrections for offset were derived from dark instruments at night and tested with capped (dark) instruments during the day. Some of the difference can be explained by these effects, but not all. Work continues to try to reconcile these diffuse differences for clear-sky conditions.

The Need to Absorb the Global Energy Balance Archive (GEBA) in WRMC (Atsumu Ohmura, WRMC, Switzerland)

The BSRN data centre had an increasing number of inquiries concerning the availability of non-radiative heat fluxes, such as sensible heat flux, latent heat flux, sub-surface heat flux, and heat of melt. This is a natural development of radiation and model studies, as the climate system is maintained with total heat balance where radiation plays an important role. The World Radiation Monitoring Centre (WRMC) has been developing a database, the Global Energy Balance Archive (GEBA), which contains the monthly mean instrumentally measured values of sensible heat flux, latent heat flux, sub-surface heat flux, and latent heat of melt, in addition to all radiative fluxes. The important conditions for accepting data are: 1) the fluxes must be measured by instruments and not just computed; and 2) the observation must last at least for a month over the land and 2 weeks over oceans. The data are accompanied with descriptions of methods of observations, deployed instruments, names, and addresses of authors or workers. The source of fluxes are mostly: 1) scientific journals, 2) data report, 3) unpublished data, and 4) from expeditionary campaigns. Presently, GEBA harbors about 250,000 station-month-data for about 1,600 sites globally including some ocean sites and glaciers. The question of whether this effort, together with WRDC, should officially be endorsed as a part of the activities at WRMC was asked at the meeting. The meeting recommended a motion of request to JSC.

VII. MEASUREMENT IMPROVEMENTS AND IDEAS

Investigations into Direct Solar Beam Measurements (Donald Nelson, NOAA/CMDL, USA)

Implementation of unwindowed cavity direct beam measurements at BSRN sites has been problematic for most sites for a variety of reasons. Hence, direct beam measurements continue to be collected using traditional pyrheliometers at most sites. Therefore investigations of traditional pyrheliometer and cavity performance have been conducted to assess the compromises present when unwindowed cavity measurements are not available. To date, pyrheliometers with different window material and field of view (FOV) modifications (which match cavity FOV) have been compared and results presented at BSRN 2004 meeting. These comparisons are ongoing at NOAA/CMDL in Boulder, Colorado and represent one component of the plan to investigate direct beam measurement capability via side-by-side redundant measurement using multiple sensors with different configurations. Concurrent with these activities there is an ongoing effort at NOAA/CMDL to develop an unwindowed cavity system suitable for unattended operation at remote sites such as those operated by NOAA/CMDL. Such systems have been operational at European sites that are essentially “backyard” sites with sufficient daily attention to prevent possible damage to an expensive measurement system unlike other BSRN broadband radiometers. Features of these systems are being investigated for potential incorporation in systems suitable for remote sites typically operated by NOAA/CMDL. It is probable that BSRN direct beam data collected using conventional pyrheliometers will continue indefinitely and some BSRN sites and the installations of unwindowed cavity systems will be infrequent due to environmental, economic and site support issues.

Thermal Offsets in Unshaded Pyranometers (C. Long/R. Philipona/I. Reda/E. Dutton)

A demonstration of the impact of failing to account for thermal offsets in unshaded pyranometers on the calibration of pyranometers by the summation calibration method when the diffuse component has been properly corrected, was given by C. Long. These offset errors occur in some instruments more prevalently than others due to IR induced temperature differences between the domes and detector surfaces. Long showed that unaccounted for offsets could be misinterpreted as an amplified cosine response error of the instrument, as well as a slight shift in the mean value of the resulting instrument responsivity. R. Philipona reviewed a related investigation he had conducted and presented at the previous BSRN meeting (Philipona, 2002). In this investigation he showed the likely existence of the thermal offsets in unshaded and shaded (diffuse) pyranometers of roughly equal magnitude. He presented graphic examples of the occurrence of the thermal offset errors in total (unshaded) solar irradiance, which can be corrected by instrument ventilation modifications he had previously described. E. Dutton gave a summary of a study conducted by I. Reda and coworkers of the U.S. National Renewable Energy Lab in Golden, Colorado and coworkers, which has been submitted to the *Journal of Oceanic and Atmospheric Technology*. In this work a method is described whereby the offsets that exist in pyranometers can be corrected once the instrument’s response to controlled laboratory IR forcing is determined experimentally. Further demonstration is given in the Reda et al. work that accounts for these offsets in the pyranometer calibration process results in general agreement between the summation and shade/unshade calibration methods. The developed summation method modification also removes site dependencies that were introduced into the calibration due to thermal offset errors that are dependent on local conditions, principally atmospheric moisture. Without the derived corrections, the calibration results contain local biases rendering errors of up to 1.5% depending on water vapor amount over the location where the calibration is performed.

Reference: Philipona, R., 2002: Underestimation of the solar global and diffuse radiation measured at Earth’s surface. *J. Geophys. Res.* 107(D22), 4654, DOI: 10.1029/2002JD002396

Spectral Transmission Data Archive (Bruce Forgan, Bureau of Meteorology, Australia)

The activities since the Melbourne meeting included discussions on the method of ingesting the transmission data with the BSRN Archive and the development of a data protocol for the submission of data. The proposed data format was described and based on an amalgamation of various data formats (GAWPFR, BSRN ftp, XML) but ensured that all the information required to generate the data were available. However, before data can be submitted to the BSRN it was clear that code would have to be written to generate aerosol optical depth and QC and QA information and a method to ingest data that does not have a locator in the BSRN relational database.

VIII. IR AND CLOUDS

Advances in Pyrgeometer Measurements and the WIRCC at PMOD/WRC (R. Philipona, World Radiation Center, Switzerland)

Over the past 10 years pyrgeometer characterization and calibration has been largely improved. Uncertainty on precision of longwave downward and upward radiation measurement has decreased from 10 to 20 Wm^{-2} (early 1990s) down to plus or minus 1 Wm^{-2} for nighttime measurements and plus or minus 2.5 Wm^{-2} for daytime measurements. Comparisons between pyrgeometers, Absolute Sky-scanning Radiometer (ASR) measurements, Atmospheric Emitted Radiance Interferometer (AERI) measurements, and radiative transfer model calculations (LBLRTM and MODTRAN) resulted in an absolute uncertainty of longwave downward radiation of plus or minus 2 Wm^{-2} for nighttime observations.

In 1993 a new blackbody radiation source was built at PMOD/WRC for the characterization and calibration of pyrgeometers. This apparatus allowed investigation of the Eppley PIR pyrgeometer, and it was found that additional thermistors had to be mounted into the dome in order to correctly compensate for the dome heating/cooling effect [*Philipona et al., 1995*]. Pyrgeometer calibration was then internationally compared by the BSRN pyrgeometer round-robin calibration experiment. Five pyrgeometers were individually calibrated at eleven calibration labs in the world. The results were analyzed at PMOD/WRC at Davos and six laboratories found sensitivity values within 2% of the median value for the five pyrgeometers [*Philipona et al., 1998*]. In the following an absolute instrument, the ASR was built at PMOD/WRC to determine absolute uncertainty of longwave measurements. This instrument, 15 pyrgeometers, the AERI interferometer and radiative transfer models were then used during two International Pyrgeometer and Absolute Sky-scanning Radiometer Comparisons (IPASRC-I at the ARM site in Oklahoma with summer conditions [*Philipona et al., 2001*] and IPASRC-II at the ARM site at Barrow, Alaska with winter conditions [*Marty et al., 2003*]) to determine uncertainty on precision and absolute measurements of downward longwave radiation.

During the years 2002 and 2003, preparations were made to host a World Infrared Radiometer Calibration Center (WIRCC) at PMOD/WRC. In 2003 the CIMO commission of WMO confirmed the need for such an international calibration of instruments measuring infrared radiation, welcomed the offer of Switzerland, and recommended that a WIRCC be established at PMOD/WRC at Davos, Switzerland. The calibration of pyrgeometers at the WIRCC has since been based on the World Pyrgeometer Standard Group (WPSG), which consists of two modified Eppley PIR and two Kipp & Zonen CG4 pyrgeometers. Two of these pyrgeometers are traceable to IPASRC I and II and regularly compared to ASR nighttime measurements.

Automatic Cloud Amount Detection by APCADA (Bruno Dürr, World Radiation Centre, Switzerland)

Naked-eye observation of sky cloud cover widely resisted automation. Automatic cloud cover detection systems suitable also for nighttime operation are often demanding large equipment investments and expensive data processing. An automatic partial cloud amount detection algorithm (APCADA) is presented based only on accurate measurements of longwave downward radiation, temperature and relative humidity at screen level height. APCADA provides cloud cover estimates every 10 minutes during day- and nighttime and is applicable to radiation stations without knowledge of synoptic cloud observations. Naked-eye observations from seven radiation sites spanning from arctic to tropical climate have been compared to APCADA estimates. Results show that about 86% of all cases agree within ± 1 octa cloud amount difference for sites with moderate climate, 82% for sites with arctic climate and 78% for the site with tropical climate. For maximum ± 2 octa cloud amount difference average site percentages range from 90% up to 95%.

IX. CLOUDS, ALBEDO, AND AEROSOLS

Comparison of two Radiation Algorithms for Surface-based Cloud Free Sky Detection (Marcel Sutter, World Radiation Centre, Switzerland)

Two methods to automatically detect cloud free skies from the Earth's surface, which are based on algorithms using surface radiation measurements, are compared with weather service ground observations and each other. One algorithm uses total and diffuse shortwave downward radiation (Long (2000), referred to as SWRA) and the other uses longwave downward radiation in combination with surface temperature and humidity referred to as LWRA). The data used for the comparison originates from the BSRN stations GVN, NYA, PAY, BER and KWA and covers time periods of 2 to 6 years.

With Weather Service ground observations as reference, LWRA detects cloud free skies with a percentage of around 80%. Significant overestimation of cloud cover happens during strong inversions. Thin high clouds on the one hand and dry haze (in an otherwise cloud free sky) on the other hand can lead to underestimation of cloud cover by LWRA.

The percentage of detected missed cloud free skies by SWRA is depending on the parameterization (i.e., the definition of cloud free) but comparable to LWRA. Compared to Weather Service ground observations, lower rates of detected cloud free skies were noticed at stations with frequent events with increased turbidity, and underestimation of cloud cover occasionally during periods with only thin high clouds, especially if they are accompanied by increased turbidity.

Flux Analysis for Clouds and Forcing Applied to BSRN Sites (Chuck Long, Pacific Northwest National Laboratories, USA)

The analysis methods described in the Cloud Parameters Working Group report were applied to sample data sets of BSRN sites. Preliminary examples were shown to illustrate the potential to derive cloud parameters using the recommended BSRN measurements. One point stressed during the talk is the importance of surface meteorological measurements, as well as the full radiative energy budget components in order to apply many of the techniques that have been developed for deriving information about clouds at present.

Report of the Albedo Working Group (L.J. Bruce McArthur, Meteorological Service of Canada)

The Albedo Working Group reported on the development of two new short-tower albedo stands and work within the group with respect to seasonal changes in albedo related to plant physiology, soil moisture and sky conditions.

Two groups, NOAA/CMDL and the Meteorological Service of Canada have developed short-tower albedo stands for the measurement of reflectance from uniform surfaces that are free of vegetation or the vegetation is short and uniform. The CMDL tower is a guyed tower of 3 m height that has a cross-arm that extends perpendicularly from the upright in an east-west direction. The tower is able to easily tip to lower the instruments to the surface. The MSC tower is a free-standing tower based on the MSC tipping mast wind-tower design. The mast is angled from the perpendicular with a horizontal beam extending equatorward from the top of the upright. The mast can be made any length, but 4 m above the surface is standard. The mast is counter-balanced so that it can be easily lowered in the direction opposite the instrumentation to allow for cleaning. The angled upright allows greater distance away from the surface and out from the upright to allow for easy ground-access to the instruments.

Two albedo studies were completed and presented. K. Behrens compared albedo observations from 2 m and 98 m from Lindenberg, Germany with soil moisture observations. The work indicated that while the correlation to soil moisture was higher from the 2 m observations, a soil moisture signal could still be identified from observations at 98 m. The highest correlation between albedo and soil moisture was found during April.

The second study, which was conducted at the Bratt's Lake Observatory in Canada, by R. Dexter, compared changes in albedo throughout the growing season with soil moisture, plant physiology (height, dry/fresh weight ratios, leaf area index (LAI)) and cloud conditions. Variations in the albedo could be related to each of these variables. The data showed that soil moisture was most important during bare soil and early growth conditions, while for daily changes in albedo the solar transmissivity was most significant. Longer-term variations in albedo were directly related to crop physiology.

Based on these efforts and the need by the satellite community to obtain reflectance or albedo values from more BSRN sites than presently reporting, the working group recommends that short-tower (3 -7m) albedo measurements be included in the archive when the following conditions are met:

(1) The surface being considered is homogenous in nature or that the surface pattern is multiply repeated within the field of view of the down-facing sensor. Overall, the area under consideration must be representative of what would be viewed by a satellite.

(2) The maximum height of the surface vegetation must not exceed 0.25 times the height from which the observation is made and that any pattern of the vegetated surface must be multiply repeated within the field of view of the down-facing sensor at this maximum height.

(3) That a detailed description of the surface be provided in the site meta-data.

Report on the WMO/GAW Experts Workshop on "A Global Surface-Based Network for Long-Term Observations of Column Aerosol Optical Properties and the GAW SAG Aerosol Meeting (L.J. Bruce McArthur, Meteorological Service of Canada)

The WMO/GAW Experts Workshop on "A Global Surface-based Network for Long-Term Observations of Column Aerosol Optical Properties" was held in Davos, Switzerland, 8-10 March 2004, followed by the GAW Scientific Advisory Group (SAG) Aerosol meeting on 11-12 March 2004. The primary purpose of the experts' workshop was to bring together scientists from various countries to discuss ways and means of collaborating to enhance the present aerosol optical properties measurement programs throughout the globe. Representatives from the major sun photometer networks, AERONET, SKYNET, WMO/PFR, BSRN were present along with scientists from a large number of countries that had national sun photometer networks.

Over the course of the three days, the WMO/GAW secretariat described the importance of aerosol optical observations to the Global Atmosphere Watch program and the fulfillment of the Integrated Global Atmospheric Chemistry Observations (IGACO), whose purpose is to establish a comprehensive globally-integrated system of ground-based, airborne and satellite observations of atmospheric composition involving atmospheric models for selected target gases and aerosols that is freely accessible to a large variety of users. This meeting was to both inform and to encourage the development of a global cooperative integrated optical depth network.

Two working groups were struck to develop plans for such a cooperative network. The first was to look at the strategies for global coverage and applications and the second was to help define the technical coordination necessary to provide consistent, high-quality aerosol optical property observations from a variety of international and national networks that use various instruments. The key findings of these two groups were:

- The need for long-term trends, from regionally-representative sites and the addition of stations to cover different aerosol regimes presently underrepresented. These would be used for climate trend studies and satellite validation.

- The areas requiring increased observations included: Russian Arctic, south China, Africa, India, Middle East, SE Asia and the oceans.

- Overlapping sites (a site where two or more networks intersected) were necessary to ensure the overall comparability of the data from one network to the next.

- That before a federated global network could be established data policy agreements and technical quality agreements would be required.

- Integration of various networks involved in aerosol optical depth (AOD) determination will be difficult without some form of standardization and coordination.

- Every network should have a set of reference instruments at the top of the network's traceability hierarchy or be confident that any instrument can represent best measurement practice for that network.

- The GAW AOD database should provide high frequency products close to the sampling rate of the observation sets. This would include all data for solar zenith angles less that 85° and most importantly allow for a careful examination of the variability of the data over the users preferred time period.

The GAW SAG Aerosol met following the meeting to discuss the outcomes of the experts' meeting and other SAG business. The primary discussion surrounding the meeting was the recognition that the World Data Centre for Aerosols was designed for chemical, not optical data. This difference is significant in the number of observations per day the data centre has ingested. Nevertheless, following considerable discussion, it was agreed that for aerosol optical property data the highest frequency data produced by a given network be archived and used to determine derived optical properties. The data centre will be required to develop data protocols following the acceptance of any recommendations made by the technical working group with respect to data collection. The present aerosol optical measurement protocol can be found in the WMO/GAW Aerosol measurement procedures: www.wmo.ch/web/arep/gaw/publications.html.

X. STATUS AND MEMBERSHIP OF WORKING GROUPS AND COMMITTEES

Direct Solar Beam Working Group

In coordination with the Uncertainties Working Group (WG), this WG assesses the absolute accuracy of an optimal operational pyrheliometer, including window cleanliness and required corrections and adjustments.

Members: D. Nelson, T. Stoffel, J. Michalsky, D. Halliewell, F. Denn

Working Group on Pyranometers

This WG is a combination of the old Diffuse Solar and Pyranometer WGs.

Tasks include:

- Investigate cosine error of utilized instruments
- Specifications for offset corrections
- Help support Diffuse Reference Standard IOP
- Address thermal offsets in upwelling solar with Albedo WG

Members: J. Michalsky (Chair), R. Phillipona (Chair), K. Behrens, C. Long, M. Haeffelin, L. Vuilleumier

Uncertainties Working Group

The Uncertainties Working Group was reinstated from the former Uncertainty WG. This WG in conjunction with the Pyranometer WG will look at operational vs specified uncertainties in all instruments and on different timescales. Their role is to review other WG uncertainty calculations.

After a discussion on data homogeneity, it was decided that this WG would address issues affecting the consistency of data over the length of the record, such as discontinuities, changes in field of view, shifts, and develop guidelines for site scientists.

Members: B. Forgan (Chair), K. Behrens, F. Denn, D. Halliwell, T. Carlund, C. Long, L. Vuillemier, E. Dutton, Darrell Myers

Upwelling Radiative Fluxes Working Group *(name changed from Albedo WG)*

This WG provides guidelines for the quantitative assessment of towers, including tower height, instrument configuration, site assessments and new instruments. The WG will coordinate with the Pyranometer WG to implement shortwave offset corrections.

WG Recommendations:

BSRN will accept the use of low towers (3-7m) for the observation of surface upwelling fluxes in areas where:

(a) the natural surface has no vegetation or the maximum height of the vegetation is not greater than 0.25x the height of the tower; and

(b) the natural surface is spatially homogenous or the “repeatability” of the surface pattern is such that the FOV of the down-facing sensors integrates over this repeating pattern.

The WG recommended that whenever possible, a multiple number of low towers be used over sites to ensure that the upwelling fluxes are representative.

Members: B. McArthur (chair), K. Behrens, R. Pinker, R. Stone, J. Michalsky, K. Rutledge, C. Schaaf, G. Hodges, R. Andreas

PAR Working Group

The full report of this WG is in Appendix E.

The PAR WG has the following tasks:
- Define what is being measured
- Required accuracy
- Available accuracy
- How to achieved required accuracy
- Establish a direct beam equivalent for spectral irradiance that could be a reference for PAR.
- Investigate including PAR in archive.

Members: R. Pinker (chair), A. Kallis, B. McArthur, K. Rutledge, B. Forgan

Cloud Parameters Working Group

Tasks include:
- Assess potential cloud information in BSRN data
- Pursue potential measurements to increase cloud information from site measurements
- Develop cloud properties repository from BSRN and other available data sets
  (Recommendation accepted at this meeting)

Members: C. Long (chair), M. Haefflelin, D. Nowak, B. Forgan, R. Philipona, B. Dürr, G. Hodges

Aerosol Optical Depth Working Group

Tasks include:
- Collecting data from field sites
- Establishing central processing
- Integrating the final product into the archive

It was agreed that this WG will use one algorithm for aerosol optical depth calculations at all BSRN stations. Aeronet is willing to submit spectral transmissions to the BSRN archive. It was noted that Aeronet is required to submit pressure measurements with their transmissions.

Members: B. Forgan (chair), J. Michalsky, C. Wehri

Spectral Measurements Working Group (New)

This new WG will guide BSRN on potential important and feasible measurements and develop standards, methodologies, etc. for spectral irradiances.

Members: B. Forgan (Chair), Fred Denn, A. Los, B. McArthur, J. Michalsky

Working Group on Pyrgeometers

This group was congratulated for the excellent work they have done and will now be placed into hibernation with their only task left being to implement the WMO World Standard Pyrgeometer Reference.

Members: R. Philipona (Chair)

New Working Group on Oceanic Observations

It was agreed that oceanic observations for BSRN should be investigated and a new working group was formed to determine the feasibility and contribution of these observations (e.g., small islands, platforms, ships, buoys) and how these would affect BSRN operating procedures.

Members: K. Rutledge (chair), C. Long, H. Diamond, G. Hodges

UV-B Subgroup

The full report and recommendations of this Subgroup are in Appendix C.

Members: A. Manes (Chair), B. Forgan, B. McArthur, R. McKenzie, J. Olivieri, L. Vuilleumier

Committee on New Sites

A new committee was formed to perform the following tasks.

- Gather information on new sites (physical, financial, logistics, sponsor, scientist, etc.)
- Assess representativeness and climate regime
- Assess extent of global data gap filling
- Identify other desirable site locations (high altitude, ocean, etc)

The committee will determine the locations for optimal sites and will interact with the GEWEX Radiation Panel and GCOS. The WG Chair and mode of operation is to be determined.

Members: B. McArthur, H. Diamond, C. Long, M. Haeffelin, R. Philipona, B. Forgan, A. Ohmura

XI. DISCUSSION TOPICS AND PROPOSALS

New and Proposed BSRN Sites

The following sites were accepted at the meeting as candidate sites:

- Alert, Canada
- American Somoa
- Cabauuw, Netherlands
- Dome C., Antarctica
- Plataforma solar de Almeria, Spain
- Sioux Falls, S. Dakota
- Trinidad Head, CA
- Vindelin, Sweden

The progress of the following proposed sites will continue to be assessed at future BSRN meetings.

- Bukit Tingi Tabang, Indonesia
- Canadian boreal
- China (2-3)
- Sonda (Brazil up to 5 sites)
- Tiksi, Siberia

Third Diffuse IOP

This IOP, which will help in the development of reference standards, was endorsed at the meeting. J. Michalsky accepted the charge to do this and asked for assistance in characterizing candidate instruments. The IOP is planned for the fall of 2005 with place and participants to be determined.

GCOS/BSRN Agreement

The GCOS/BSRN agreement is included in Appendix E. E. Dutton agreed to be the BSRN liaison to GCOS.

Need to Absorb GEBA in WRMC

The BSRN Data Centre has had an increasing number of inquiries concerning the availability of non-radiative heat fluxes, such as sensible heat flux, latent heat flux, sub-surface heat flux and heat of melt. This is a natural development of radiation and model studies, as the climate system is maintained with total heat balance where radiation plays an important role. The World Radiation Monitoring Centre (WRMC) has been developing a database, the Global Energy Balance Archive (GEBA) which contains the monthly mean instrumentally measured values of sensible heat flux, latent heat flux, sub-surface heat flux and latent heat of melt, in addition to all radiative fluxes.

The important conditions for accepting data are:

1) fluxes must be measured by instruments and not only computed, and

2) observations must continue for at least for a month over the land and 2 weeks over oceans. The data are accompanied with descriptions of methods of observations, deployed instruments, name and address of authors or workers.

The source of fluxes are mostly 1) scientific journals, 2) data report, 3) unpublished data, and 4) from expeditionary campaigns. Presently, GEBA harbors about 250,000 station-month data for about 1,600 sites globally, including some ocean sites and glaciers. It was requested that this effort, together with WRDC, be officially a part of the activities at WRMC. This request will be presented to the WCRP JSC.

BSRN Operations Manual (B. McArthur)

This WG needs guidance on additions and modifications. Beginning August 5th, the manual will be available via FTP at: Exp_studies.tor.ec.gc.ca/pub/solar. It was agreed to use the GEWEX BSRN website and group emails for updating the operations manual.

Surface Energy Fluxes (Heat and Moisture) in BSRN Measurements

This would be an obvious climatological extension of BSRN activities. It was recommended that someone from Fluxnet (possibly C. Fairall, NOAA) attend the next BSRN meeting to give a presentation. *Action: E. Dutton to contact Fluxnet.*

Automatic Instrument Cleaning

There is a need for a study on periodically shooting a liquid (distilled water or other substance) on the instruments to clean them. It was recommended that the BSRN sites try different cleaning methods and provide summaries of the pros and cons of different methods, which would then be posted on the GEWEX BSRN website.

Interpolated Upper Air Soundings for BSRN Sites

Is there merit in encouraging BSRN sites that are located far away from sounding sites to acquire upper air soundings? Should operational procedures be modified to allow interpolated soundings in the archives? Can the best sources for upper air data be identified and a link added to the archive to where these data can be obtained? *Action: A. Roasch and M. Wild to address these issues and present a report at the next meeting.*

Ilorin and Budapest Status

Normally, if a station does not meet some archival status, it is dropped from BSRN. Due primarily to funding problems, the Ilorin site did not meet the minimum archival requirements and was dropped. How this could be remedied was discussed and various options were put on the table including contacting John Davies at the World Bank regarding possible funding for Ilorin or establishing a high level contact in Nigeria to increase visibility of this activity with the university. The AMMA project, which is based in this area, may provide interest in re-establishing this site. *Action: R. Pinker, E. Dutton and H. Diamond to develop a plan for addressing the Ilorin issue.*

Budapest was very involved in BSRN for a while, went to meetings (hosted one), but never submitted any data to the archive. The person who was involved retired and did not provide a new contact for Budapest.

WG Mid-Term Reports Between BSRN Meetings

For the committee and working groups to be more productive, it was recommended that more interaction with these groups be conducted in the time between BSRN meetings. This could include having electronic meetings and more contact via e-mail.

Redundant Parameter Archiving

It was recommended that site scientists also submit their data to other UV, ozone and AOD archives.

World Radiation Data Center (WRDC)

Andreas Roesch and Martin Wild were commended for their work at WRDC. Methods for more easily inserting corrected data into the existing archived data should be sought by the archive staff. The long-term status of the archive is under review and discussion by the BSRN and Archive management, with the realization that the archive has exceeded its original expected lifetime, but with the urgent ongoing need for the archive function.

Next Meeting (in 2 years)

Offers under consideration for the next meeting include Australia, New Zealand, Brazil, and Israel. Cape Town, S. Africa has an outstanding offer to host the meeting in 2010. Please contact E. Dutton if you are interested in hosting the next meeting.

Appendix A

LIST OF PARTICIPANTS

Clement Akoshile
University of Ilorin
Physics Department
Ilorin
NIGERIA
Phone: 234-8055902692
E-mail: bsrnclem@yahoo.com.uk

Mikhail Alexandrov
NASA GISS
2880 Broadway
New York, NY 10025
USA
Phone: 1-212-678-5548
E-mail: malexandrov@giss.nasa.gov

Roesch Andreas
IAC ETHZ
Zurich
SWITZERLAND
Phone: 41-1-635-5222
E-mail: andreas.roesch@env.ethz.ch

Klaus Behrens
DWD
OT Lindenberg
Am Observatorium 12
D-15848 Tauche
GERMANY
Phone: 49-331-88893-20
Fax: 49-331-88893-36
E-mail: klaus.behrens@dwd.de

Thomas Carlund
SMHI
Folkborgsv. 1
60176 Norrkoeping
SWEDEN
Phone: 46-11-495-8229
Fax: 46-11-495-8001
E-mail: thomas.carlund@smhi.se

Marc Chiacchio
Analytical Services and Materials, Inc.
1 Enterprise Parkway, Suite 300
Hampton, VA 23666
USA
Phone: 1-757-827-4893
Fax: 1-757-825-8659
E-mail: m.chiacchio@larc.nasa.gov

Holly Coleman
The Met Office
Beaufort Park
Exeter RG403DN
UNITED KINGDOM
Phone: 44-1392-886120
E-mail: holly.coleman@metoffice.gov.uk

Sergio Colle
Federal University of Santa Catarina
Dept. of Mechanical Engineering
PO Box 476
Florianopolis 88040-900-SC
BRAZIL
Phone: 55-(48)-2340408/2342161
E-mail: colle@emc.ufsc.br

Fred Denn
Analytical Services and Materials
1 Enterprise Parkway, Suite 300
Hampton, VA 23666
USA
Phone: 1-757-827-4622
E-mail: f.m.Denn@Larc.nasa.gov

Howard Diamond
NOAA/NCDC
1335 East-West Hwy., #7214
Silver Spring, MD 20910
USA
Phone: 1-301-713-1283+229
E-mail: howard.diamond@noaa.gov

Robert Dolce
Kipp & Zonen
125 Wilbur Place
Bohemia, NY 11716
USA
Phone: 1-800-645-1025
E-mail: robert.dolce@kippzonen.com

Bruno Dürr
PMOD/WRC
Dorfstr. 33
CH-7260 Davis Dorf
SWITZERLAND
Phone: 41-81-417-5130
E-mail: b.duerr@pmodwrc.ch

Ellsworth Dutton
NOAA/CMDL
R/CMDL1
325 Broadway Street
Boulder, CO 80305
USA
Phone: 1-303-497-6660
E-mail: ellsworth.g.dutton@noaa.gov

Dawn Erlich
International GEWEX Project Office
1010 Wayne Avenue, Suite 450
Silver Spring, MD 20910-5641
USA
Phone: 1-301-565-8345
Fax: 1-301-565-8279
E-mail: gewex@gewex.org

Patrick Fishwick
Met Office
FitzRoy Road
Exeter EX I3PB
UNITED KINGDOM
Phone: 44-1392-885534
E-mail: fishwick@metoffice.com

Bruce Forgan
Bureau of Meteorology
Regional Institute Centre
GPO Box 1289K
Melbourne, Victoria 3001
AUSTRALIA
Phone: 61-39-669-4508
E-mail: b.forgan@bon.gov.au

Bella Espinar Frias
Plataforma Solar DeAlmeria
Carretera Senes, KM4
04200 Tabernas
SPAIN
Phone: 34-950387909
E-mail: bella.espinar@psa.es

Aidan Green
Met Office
FitzRoy Road
Exeter EX13PB
UNITED KINGDOM
E-mail: aidan.green@metoffice.com

Martial Haeffelin
Ecole Polytechnique,
LMD/IPSL
91128 Palaiseau Cedex
FRANCE
Phone: 33-1-69-33-45-19
E-mail: martial.haefelin@lmd.polytechnique.fr

David Halliwell
Meteorological Service of Canada
PO Box 160
Wilcox, SK SOG5EO
CANADA
Phone: 1-306-352-3818
Fax: 1-306-546-6400
E-mail: David.Halliwell@ec.gc.ca

Tadahiro Hayasaka
Research Institute for Humanity and Nature
335 Takashima-cho
Kamigyo-Ku
Kyoto 602-0878
JAPAN
Phone: 81-75-229-6161
Fax: 81-75-229-6150
E-mail: hayasaka@chikyu.ac.jp

Gary Hodges
NOAA/OAR/ARL/SRRB
325 Broadway Street
Boulder, CO 80305
USA
Phone: 1-303-497-6460
E-mail: gary.hodges@noaa.gov

Ain Kallis
Estonian Meteorological & Hydrological Institute
Tartu-Toravere Meteorological Station
Toravere 61602
ESTONIA
Phone: 372-7-410-136
E-mail: kallis@aai.ee

Wouter Knap
KNMI
PO Box 201
NL-3730AE De Bilt
THE NETHERLANDS
Phone: 31-30-220-6469
E-mail: knap@knmi.nl

Christian Lanconelli
ISAC-CHR
Gobetti 101
90125 Bologna
ITALY
Phone: 39-051-633-3588
E-mail: c.lanconelli@isac.chr.it

Zhanging Li
University of Maryland, Dept. of Meteorology
2207 CSS Bldg.
College Park, MD 20742-2425
USA
Phone: 1-301-405-6699
Fax: 1-301-314-2782
E-mail: zli@atmos.umd.edu

Chuck Long
Pacific Northwest National Labs
PO Box 999, MSIN: K9-38
Richland, WA 99352
USA
Phone: 1-509-372-4917
E-mail: Chuck.Long@arm.gov

Alexander Los
Kipp & Zonen B.V.
Roentgenweg 1
NL-2624BD Delft
THE NETHERLANDS
Phone: 31-15-269-8013
Fax: 31-15-262-0351
E-mail: alexander.los@kippzonen.com

Angelo Lupi
ISAC-CHR
Gobetti 101
Bologna, 90125
ITALY
Phone: 39-05-6333588
Fax: 39-05-16333532
E-mail: A.LUPI@ISAC.CHR.IT

Alex Manes
Israel Meteorological Service
P.O. Box 25
Bet Dagan 50250
ISRAEL
Phone: 972-3-9682187
Fax: 972-3-9604854
E-mail: alexander@ims.gov.il

Bruce McArthur
Meteorological Service of Canada
Experimental Studies Division
4905 Dufferin Street
Downsview, ON M3H15T4
CANADA
Phone: 1-416-739-4464
E-mail: bruce.mcarthur@cc.gc.ca

Joseph Michalsky
325 Broadway R/ARL
Boulder, CO 80305
USA
Phone: 1-303-497-6360
E-mail: joseph.michalsky@noaa.gov

Mohamed Mimouni
Meteorology Service
P.O. Box 31
Tamanrasset 11000
ALGERIA
Phone: 213-29344673
Fax: 213-29344226
E-mail: m-mimouni-dz@yahoo.fr

David Moore
Met Office
Exeter EZW077
UNITED KINGDOM
Phone: 44-1392-885804
E-mail: david.moore@metoffice.gov.uk

Jean-Philippe Morel
Météo-France
785 Chemin de l'Hermitage
F-84200 Carpentras
FRANCE
Phone: 33-4-90-63-69-67
E-mail: Jean_philippe.morel@meteo.fr

James Morley
Simon Fraser University
Department of Geography
8888 University Drive
Burnaby, BC V5A 156
CANADA
Phone: 1-604-630-6000 ext.11101
E-mail: jum@sfu.ca

Hiroshi Naganuma
Aerological Observatory
1-2, Nagamine, Tsukuba
Ibaraki
JAPAN
Phone: 81-29-851-4424
E-mail: naganuma@met.kishou.go.jp

Donald Nelson
NOAA/CMDL
R/CMDL1
325 Broadway St.
Boulder, CO 80305
USA
Phone: 1-303-497-6662
Fax: 1-303-497-5590
E-mail: donald.w.nelson@noaa.gov

Daniela Nowak
Meteo Swiss
Les Invuardes
CH-1530 Payerne
SWITZERLAND
Phone: 41-26-662-6329
E-mail: daniela.nowak@meteoswiss.ch

Atsumu Ohmura
Division of Climate Research
Department of Georgraphy
ETH Zurich, Winterhurerstrasse 190
CH-8057 Zurich
SWITZERLAND
Phone: 41-1-635-5231
Fax: 41-1-362-5197
E-mail: ohmura@env.ethz.ch

Andy Pearson
Laser & Optical Radiation Dosimetry Group
National Radiological Protection Board
Chillon Didcot
Oxon OX11ORQ
UNITED KINGDOM
Phone: 44-1235-822814
E-mail: andy.pearson@nrpb.org

Rolf Philipona
PMOD/WRC
Observatory Davos
Dorfstrasse 33
CH-7260 Davos-Dorf
SWITZERLAND
Phone: 41-81-417-5131
Fax: 41-81-417-5100
E-mail: rphilipona@pmodwrc.ch

Rachel Pinker
University of Maryland, Dept. of Meteorology
Space Science Building
College Park, MD 20742-0001
USA
Phone: 1-301-405-5380
Fax: 1-301-314-9482
E-mail: pinker@atmos.umd.edu

Andreas Roesch
ETH Zurich
Institute for Atmosphere and Climate
Winterthurestrasse 190
CH-8057 Zurich
SWITZERLAND
Tel: 41-1-635-5206
Fax: 41-1-362-5197
E-mail: aroesch@geo.umnw.ethz.ch

Ken Rutledge
NASA Langley Research Center
MS 936
Hampton, VA 23666
USA
Phone: 1-757-827-4643
E-mail: e.k.Rutledge@larc.nasa.gov

Crystal Schaaf
Boston University
Dept. of Geography
725 Commonwealth Avenue
Boston, MA 02215-1401
USA
Phone: 1-617-358-0503
Fax: 1-617-353-3200
E-mail: schaaf@bu.edu

Gilles Sommeria
WMO/World Climate Research Programme
7bis, avenue de la Paix
Case Postale No. 2300
CH-1211 Geneva 2
SWITZERLAND
Phone: 41-22-730-8247
Fax: 41-22-730-8036
E-mail: GSommeria@wmo.int

Paul Stackhouse
NASA/Langley Research Center
Mail Stop 420
Hampton, VA 23681-2199
USA
Phone: 1-757-864-5368
Fax: 1-757-864-7996
E-mail: p.w.stackhouse@larc.nasa.gov

Marcel Sutter
PMOD/WRC
Dorfstrasse 33
CH-7260 Davis Dorf
SWIZERLAND
Phone: 41-81-417-5131
E-mail: m.sutter@pmodwrc.ch

Hans Teunissen
WMO/GCOS Secretariat
7 bis, avenue de la Paix
Case Postale No. 2300
CH-1211 Geneva 2
SWITZERLAND
Phone: 41-22-730-8086
E-mail: HTeunissen@wmo.int

Jean-Claude Thelon
Met Office
FitzRoy Road
Exeter EXI 3PB
UNITED KINGDOM
Phone: 44-1928-84776
E-mail: jean-claude.thelon@metoffice.gov.uk

Anatoly Tsvetkov
World Radiation Data Center
Main Geophysical Observatory
Karbyshev Str., 7
St. Petersburg 194021
RUSSIA
Phone: 7-812-947-4390
E-mail: tsvetkov@main.mgo.rssi.ru

Cor Von Ort
KNMI
PO Box 201
NL-3730 AE De Bilt
THE NETHERLANDS
Phone: 31-30-220-6417
E-mail: ortvon@knmi.nl

Laurent Vuilleumier
Meteo Swiss
Les Invuardes
CH-1530 Payerne
SWITZERLAND
Phone: 41-26-662-6306
E-mail: laurent.vuilleumier@meteoswiss.ch

Martin Wild
Institute for Atmospheric and Climate Science
Winterhurestrasse 190
CH-8057 Zurich
SWITZERLAND
Phone: 41-1-635-5236
Fax: 41-1-1362-5197
E-mail: wild@env.ethz.ch

Zheng Xiangdong
Chinese Academy of Meteorological Sciences
No. 46 Zhong Guancun Nan
Dajie, Beijing 100081
CHINA
Phone: 86-10-681109574
E-mail: zhengxd@cams.cma.gov.cn

Appendix B

The 8th BSRN Workshop and Scientific Review Meeting

Agenda

Monday, 26 July

08:30 – 08:50 Registration
09:00 – 10:30 Opening Session

Opening comments, introductions, and logistics	E. Dutton/P. Fishwick
Welcome and comments from WCRP/GEWEX	G. Sommeria
The Importance of BSRN Data to the GEWEX Surface Radiation Budget Project	P. Stackhouse
BSRN: The first 15 years	A. Ohmura

10:30 – 11:00 Break (set up Posters)

11:00 – 12:30 Opening Session (continued)

State of BSRN	E. Dutton
Global Climate Observing System (GCOS) and BSRN	H. Teunissen
U.S. GCOS – Atmospheric Component	H. Diamond
A Perspective on Establishing BSRN Sites in China	Z. Li /Z. Xiangdong

12:30 – 14:00 Lunch

14:00 – 15:30 Reports on New or Prospective Field Stations (Chair C. Long)

Alert: A New BSRN Site in the Canadian Arctic	B. McArthur
SIRTA: Cloud and Radiation Observatory Near Paris	M. Haeffelin
Embedding a BSRN Station in the Cabauw Experimental Site for Atmospheric Research (CESAR), the Netherlands	W. Knap
Updates on the Brazilian BSRN sites	S. Colle

15:30 - 16:00 Break

16:00 - 17:00 Reports from field sites (continued)

100 Years of Solar Radiation Measurements in Estonia	A. Kallis
Annual Shortwave Radiation Flux and Seasonal Changes at Ilorin	C. Akoshile
Discussion on new and needed sites	

17:00 - Poster Session

Tuesday, 27 July

08:30 -10:30 Data Applications and Scientific Results (Chair B. McArthur)

Radiative Forcing Measured at the Earth's Surface and an Increasing Greenhouse Effect Over Europe	R. Philipona
Determination of Greenhouse Effect by Surface Longwave Measurements	B. Duerr
Use of BSRN Observations to Advance Studies of the African Monsoon	R. Pinker
Evolution of Shortwave and Longwave Radiation as Observed at BSRN Sites And Simulated in Global Climate Models	M. Wild
Radiation Budget and Greenhouse Effect Calculations for the Arctic	M. Sutter
Validation of MODIS BRDF Products from Terra and Aqua	C. Schaaf

10:30 -11:00 Break

11:00 – 12:30   Data applications and scientific results (continued)

Comparisons of MODIS and BSRN Products — A. Roesch
Sampling Error of Surface Radiation Measurements in the Context of Model and Satellite Validation — Z. Li
Intercomparisons and Validation of Satellite-derived Albedo Data Sets — C. Schaaf
Long Term Variation of Shortwave Surface Radiation over China — T. Hayasaka
Automated Retrieval Algorithm for Ground-Based Spectral Radiometer Data — M. Alexandrov

12:30 – 14:00 Lunch

14:00 - 15:30   Data applications and scientific results continued (Chair R. Philipona)

Solar Dimming and Brightening: Decadal Scale Variations in Surface Solar Irradiance: Multiple Perspectives — Wild/Ohmura/Roesch/Pinker/Dutton
Sunshine Duration Uncertainty — B. Forgan
Sunshine Duration in the UK — A. Green

15:30 – 16:00 Break

16:00 – 17:30 Posters   Data Applications and Field Site Reviews (please be by your poster)

Wednesday , 28 July

08:30 – 10:00   UV and PAR Measurement (Chair M. Wild)

On the Calibration and Measurement Accuracy of UV Broad Band Filter Radiometers — A. Los
Reconstruction of Past UV Doses at Davos — L. Vuilleumier
Report on the Working group for UV — A. Manes
Results of the 2002 BSRN PAR Intercomparison — B. McArthur

10:00 – 10:30 Break

10:30 – 11:30 Data Handling and Archiving

Data Homogenization: How Does BSRN manage it? — L. Vuilleumier
Revisions and Additions to BSRN QC — C. Long
BSRN Data Archive – Improvements and Status — A. Roesch

Wednesday Afternoon /Eve   Field excursion

Thursday, 29 July

08:30 - 10:30   Diffuse Solar (Chair B. Forgan)

Investigations of Measurements of Diffuse Solar Radiation — K. Behrens
Diffuse Radiation Variability Based on Conventional Data Archive and WRDC at the GAW and BSR N Sites — A. Tsvetkov
Pyranometer Thermal Offsets Under Different Ventilation Regimes — D. Halliwell
Towards a Diffuse Reference Standard — J. Michalsky

10:30 – 11:00 Break

11:00 – 12:30 Measurement Improvements and Ideas

Thermal Offsets in Unshaded Pyranometers	C. Long/R. Philipona/E. Dutton
Investigations into Direct Solar Beam Measurements	D. Nelson
Discussion	

12:30 – 14:00 Lunch

14:00 – 15:30 IR and Clouds (Chair J. Michalsky)

Advances in Pyrgeometer Measurements and the IR-Center at PMOD/WRC	R. Philipona
Automatic Cloud Amount Detection by APCADA	B. Duerr
Cloud WG Multiple Reports	C. Long

15:30 – 16:00 Break

16:00 – 17:50 Clouds, Albedo, and Aerosols

Validation and Comparison of Two Radiation Algorithms for Surface-based Cloud Free Sky Detection	M. Sutter
Flux Analysis for Clouds and Forcing Applied to BSRN Sites	C. Long
Review of Albedo Measurement Activities	B. McArthur
WMO/GAW Aerosol Optical Depth Experts Meeting/Davos ’04	B. McArthur
Review of Aerosol Optical Depth Activities	B. Forgan
Working Groups review	

Friday, 30 July

08:30 – 15:30 Special session for Site Scientists (current and prospective) and Other Participants active in the measurements and data flow.

a) Working Groups - Discussions and assignments
b) Review of new recommendations and proposals
c) Operations Manual changes and additions
d) Discussion of proposed and prospective stations
e) General discussion on a better BSRN
f) Plans for next two years
g) Workshop wrap up

Posters

- Status of Regina BSRN station	D. Halliwell
- Status of Payerne BSRN station	L. Vuilleumier
- Status of BSRN station Lindenberg, Germany	K. Behrens
- SurfRad: The continental US contribution to BSRN	G. Hodges/J. Augustine
- Approach for CG4 (pyrgeometer) calibration	H. Naganuma
- Measure of incoming short and long wave radiation at	
- Tamanrasset BSRN station	M. Mimouni
- The Plataforma Solar de Almeria Radiometrical and Meteorological Station (Spain)	B. Frias
- Summertime Spectral Observations at Bratt's Lake	J. Morley
- Modernization of the Swedish Radiation Network with the Aim to Establish a BSRN Station	T. Carlund
- Grounding a BSRN Station to Protect Against Lightening Damage	G. Hodges
- Investigations about the Relationship of Surface Albedo and Soil Moisture	K. Behrens
- Platform Effects at the Chesapeake Ocean Validation Experiment (COVE) BSRN Site	F. Denn

- Observations of Multi-Year Radiation and Aerosols Made on an Ocean Platform — K. Rutledge et al.
- The influence of Clouds on the Radiation Budget at the Coastal Italian Station Mario Zucchelli — A. Lupi/C. Lanconelli
- First Activities and Future Improvements Implementation of a BSRN station at Dome (Antarctica) — C. Lanconelli, M. Nardino, V. Vitale, T. Georgiadis (*), A. Lupi

Pristine Data from Two Partial Solar Eclipses Over the South African BSRN Site at De Aar — D. Esterhuyse

Contribution of the BSRN Station of Carpentras on the Calibration of Broadband and Narrowband UV Instruments" — J. Olivieri and J. Morel

Appendix C

100 YEARS OF SOLAR RADIATION MEASUREMENTS IN ESTONIA

Ain Kallis, Estonian Meteorological and Hydrological Institute
Viivi Russak, Tartu Observatory;
Hanno Ohvril, Tartu University

Historical Background

About 1000 actinometric stations operate presently all over the world. In Estonia episodic measurements of solar radiation started in Tartu in 1904. The first instruments used for the recording of solar radiation were Khvolson actinometer, Callendar's actinograph and Ångström pyrheliometer Å-197. Continuous recording of radiation started in the Tartu Actinometric Station (now Tartu-Töravere Meteorological Station) in January 1950. Since 1999 the station has been included in the Baseline Surface Radiation Network (BSRN).

Configuration of the Radiation Network in Estonia

The radiation network in Estonia consists of four stations:

1. **Tartu-Töravere Meteorological Station** (measuring since 1950):
   - direct irradiance (PMO6 absolute radiometer, pyrheliometers AT-50, NIP)
   - global, diffuse, reflected irradiance (CM-21, CM-11, M-115)
   - net radiation (MB-1, M-10)
   - downward longwave irradiance (Eppley PIR)
   - UVA, UVB, UV erythemal radiation (CUVB1, UVSB2, UV-SET)
   - photosynthetically active radiation, global and direct (LI-COR 190SA)
   - total ozone measurements (MICROTOPS II)
   - aerosol optical depth (sun photometer CE 318-1)
2. **Tiirikoja Lake Station** (since 1956):
   - direct, global, diffuse, reflected irradiance (CM-11, AT-50, M-115)
3. **Tallinn Aerological Station** (since 2001):
   - global irradiance (CM-11)
   - UVB irradiance (CUVB1)
4. **Narva-Jõesuu Meteorological Station** (since 2003):
   - global irradiance (CM-11)

Systematic changes in the radiation budget and its components have become evident in Estonia in the most recent decades. Apart from usual dispersion, a certain decreasing tendency has been established in the time series of global radiation at Toravere since 1955 up to the beginning of the 1990s (Fig. 3). It is likely that the cause is due to the following factors:

1. Annual amount of low clouds have increased by 0.4 in 1955-1995, significance level $p < 0.05$ mostly in March - by 2.5 ($p < 0.01$). Changes in cloudiness are statistically related to the changes in atmospheric circulation.

2. Decreasing tendency in transparency of the atmosphere.
   The Bouguer's atmospheric transparency coefficient P_2 has decreased in the same period (Fig. 4). Besides relatively short-time variations in the time series of P_2 caused by powerful

volcanic eruptions, a linear decreasing trend has been found. At the beginning of the 1990s, the decreasing atmospheric transparency was replaced with an increase. Since atmospheric transparency in Estonia is mainly determined by the transport of aerosols from distant sources (at Toravere and Tiirikoja local sources of air pollution are absent), it is likely that the clearing of the atmosphere during the last decade has been caused by industrial and agricultural decline in the former socialist countries (in Estonia, from 1990 to 1994, industrial production decreased by about 50%), as well as by nature protection measures applied.

3. Lower values of the ground surface albedo, resulting from the shortening of the duration of permanent snow cover (during the period 1962-2000 by 20-30 days).

An increasing tendency has been established in the annual totals of net radiation, $p < 0.01$ (Fig. 5). There was no significant trend in its short-wave component (the trends of global and reflected radiation balanced), while a significant increase ($p < 0.01$) was found in the time series of the net long-wave component. Rather, similar gains in net radiation and its long-wave component (by 194 and 220 MJm^{-2}, accordingly) are probably enhanced by the greenhouse effect.

In order to eliminate the role of increased cloudiness in the observed changes of the greenhouse effect, the cloudless midnight hourly totals of net long-wave radiation have been analyzed separately (Fig. 6). A rather similar temporal course of B_L of all days and cloudless cases indicates the essential role of greenhouse gases in the formation of the long-wave radiation field in Estonia.

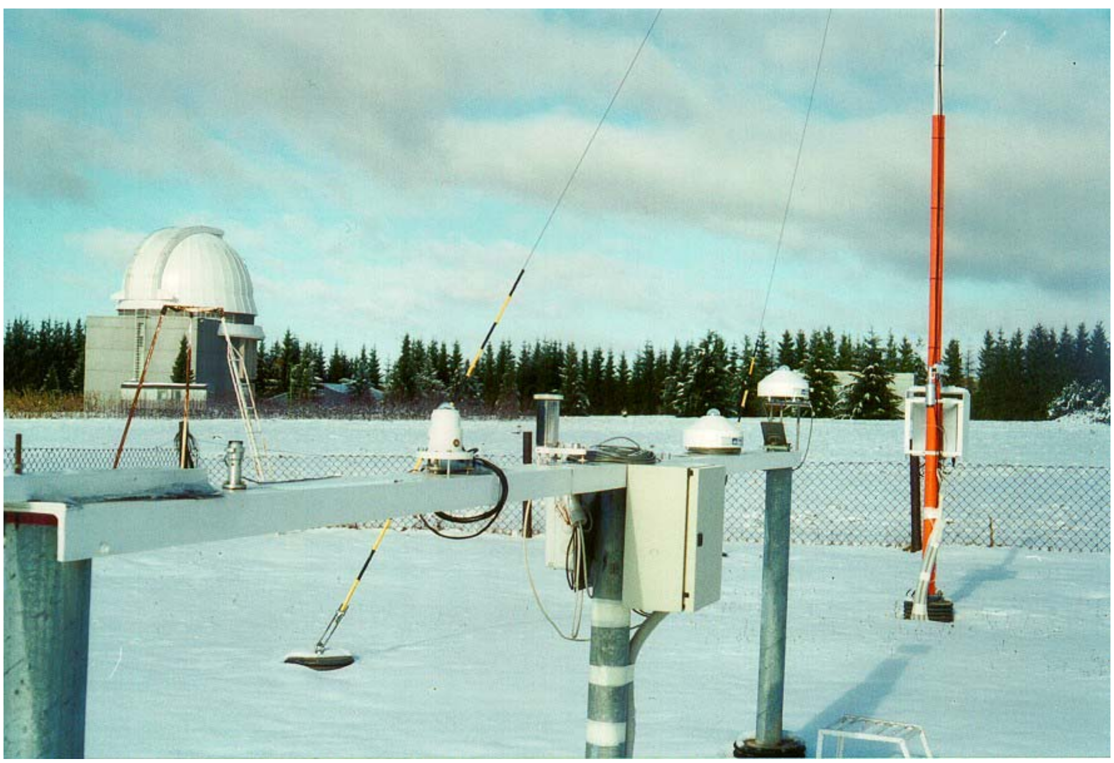

Figure 1. *Radiometric Sensors at Tartu (Töravere) Meteorological Station.*

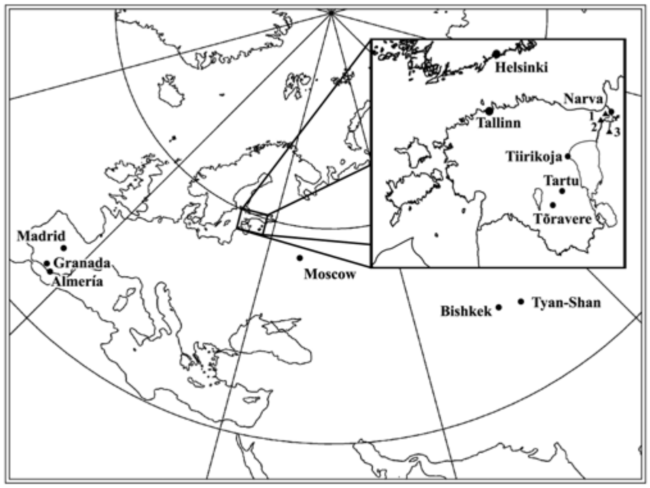

Figure 2. *Map of locations of actinometric stations.*

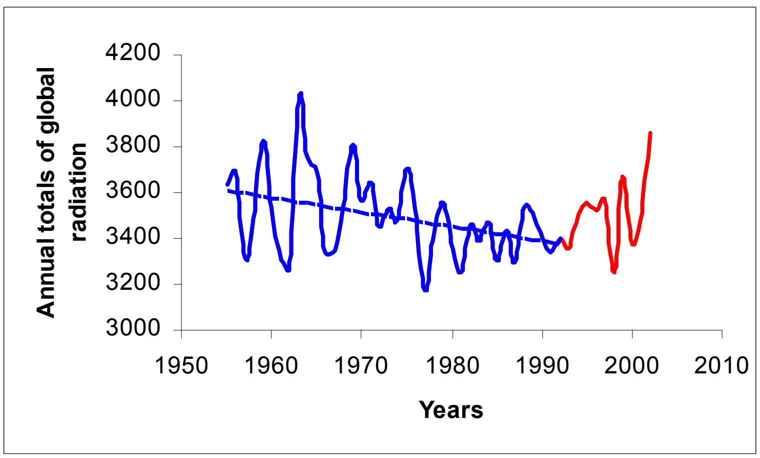

Figure 3. *Annual totals of global radiation at Töravere (MJm^{-2}).*

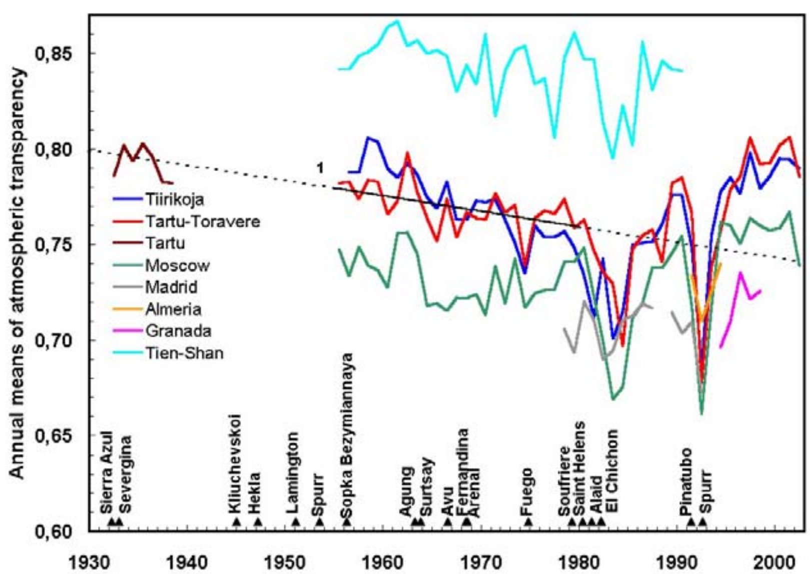

Figure 4. *Annual means of atmospheric transparency: Tiirikoja, 1956–2001; Tartu, 1932–1938; Tartu-Töravere, 1955–2001; Moscow, 1955–2001; Madrid, 1978–1992; Almería, 1991–1994; Granada, 1994–1998; Tien-Shan, 1955–1990; ▲– dates of the great volcanic eruptions.*

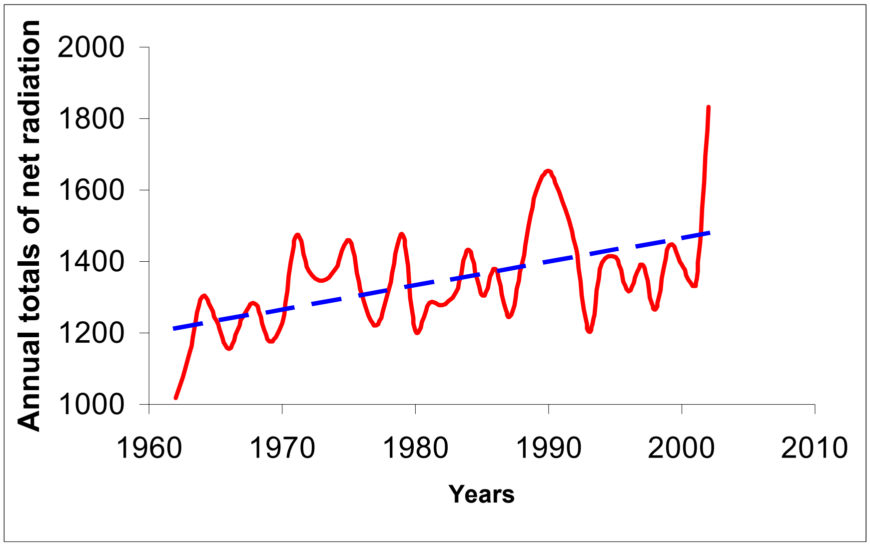

Figure 5. *Annual totals of net radiation at Töravere (MJm*$^{-2}$*)*

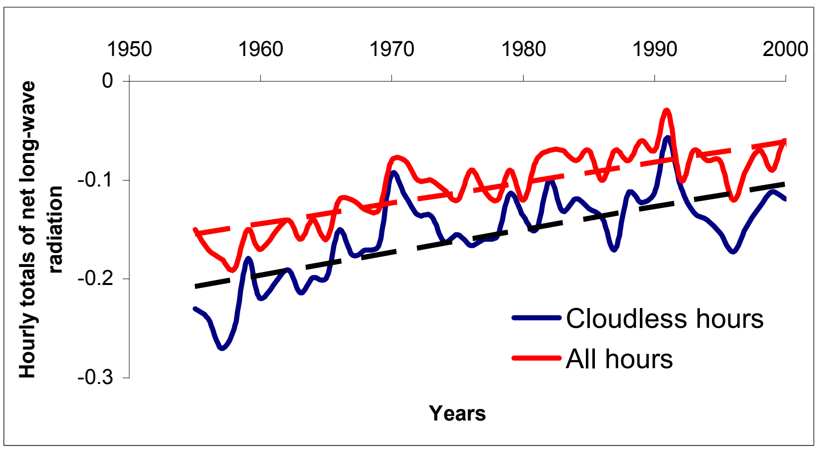

Figure 6. *Midnight hourly totals of net long-wave radiation at Töravere in June (MJm*$^{-2}$*). Both direct and global PAR have been recorded in Tartu station since 2000. The ratio of global PAR to global integral radiation is about 0.436. The ratio of direct PAR to direct integral radiation is somewhat lower – 0.339.*

Report of the BSRN UV-B Sub-Group (A. Manes)
(Submitted to the 8th BSRN Meeting, Exeter, 2004)

Members of the UV-B SG: B. Forgan, A. Los, B. McArthur, R. McKenzie, A. Manes (Chair), J. Olivieri, R. Philipona, L. Vuilleumier

1. History

The UVB Sub-Group was established at the 5th BSRN meeting in Budapest, Hungary, 18-22 May 1998. The rationale for its establishment was the recognition by the majority of participants that broadband UVB measurements should be part of the measurement suite of BSRN stations. It was, however, also recognized at that time, that conditions were not yet suitable for matching the accuracy requirements of BSRN stations. The calibration instability of existing commercial broadband UVB radiometers and the lack of a central calibration facility, in particular, both of which were capable of providing the necessary calibration hierarchy, were hampering such efforts within BSRN. Most of the participants thought that BSRN should not engage in active research activities to solve the above problems, as a number of other agencies are involved in such activities, primarily WMO/GAW. The main task of the UVB SG was, thus, to monitor the progress made in the field of broadband UVB radiometry, and report to the BSRN Scientific and Review Workshops. In our Report submitted to the BSRN Meeting in Regina, Canada, in 2002, we have indicated that considerable progress was achieved in the accuracy and stability of broadband UVB measurements, especially by the US networks, i.e. SURFRAD and USDA, in close cooperation with the Interagency Central UV Calibration Facility (CUCF) of SRRB, NOAA. It was recommended to BSRN stations to carry out broadband UVB measurements routinely, and the BSRN Archive administration was requested to make provisions for inclusion of UV data in the archive.

2. Terms of Reference, Redefined at the Regina Meeting, 2002

Following discussion of the UV SG's report submitted to the 7th BSRN Scientific and Review Workshop, held in Regina, Canada, in 2002, and considering some progress made with all-weather UV spectral instruments, i.e. shadowband and multifilter radiometers, as well as with broadband UVB instruments, most participants were in favor of carrying out UV measurements at BSRN stations. Station managers/site scientists of BSRN stations were advised to submit UV data to the archive. The archive administration will make the necessary provision for the inclusion of UVR data in the archive. It was recommended that:

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

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

3. Present Status of BSRN Stations Measuring and Submitting UV Data to the Archive

Ten stations, out of 35 operational BSRN stations, are measuring and sending UVB data to the archive. The BSRN archive's administration has made the necessary provision for inclusion of UVR data in the archive; the database already allows the insertion of UV data under logical record 500. Most of the stations submitting UV data to the archive are BSRN stations from the USA, the SURFRAD and ARM (Atmospheric Radiation Measurement Program) networks. A list of stations, and periods of operation is given in table 1a. Following a request by Prof. Atsumu Ohmura, the BSRN Archive administration has inquired the BSRN Station Managers/Site Scientists whether they carry out UV and PAR measurement, or intend to do so in the future (Andreas Roesch, personal communication). The results of the inquiry are given in tables 1b and 1c, respectively.

Table 1a. BSRN Stations Reporting UVB to the Archive

Station	State/Country	Acronym	Organization	Period of Record
Boulder	CO, USA	BOS	SURFRAD	1995 - 2003
Goodwin Creek	MS, USA	GCR	SURFRAD	1995 - 2003
Fort Peck	MT, USA	GCR	SURFRAD	1995 - 2003
Bondville	IL, USA	BON	SURFRAD	1995 - 2003
Rock Springs	PA, USA	PSU	SURFRAD	1998 - 2003
Desert Rock	NV, USA	DRA	SURFRAD	1998 - 2003
Momote, Manus Is.	Papua New Guinea	MAN	ARM	1996 - 2004
Nauru Island	Tropical Western Pacific	NAU	ARM	1998 - 2002
Payerne	Switzerland	PAY	MeteoSwiss	1998 - 2002
Toravere	Estonia	TOR	EMHI	2000

Table 1b. BSRN Stations Measuring UV Radiation, Not Reporting to the Archive

Station	State/Country	Acronym	Organization	Period of Record
Tateno	Japan	TAT		From 1990
Syova	Japan	SYO		From 1991
Alice Springs	Australia	ASP	BoM	From 2003
Bratt's Lake	Canada			
Chesapeake	Virginia, USA	CHL	NASA	
Tamanasset	Algeria			From 1997
Neumayer	Germany	GVN		From 1992
Lauder	New Zealand	LAU	NIWA	From 1991

Table 1c. BSRN Stations Planning to Measure UV Radiation

Station	State/Country	Acronym	Organization	
Camborne	UK	CAM	Met Office	
Lervick	UK	LER	Met Office	

4. Activities Relevant to Precision UV Radiometry: 2003-2004

4.1 2003 UV Radiometer Intercomparison, Table Mountain, Boulder, Colorado

The 2003 NOAA/NIST North American UV Radiometer Intercomparison was held from June 13th to 21st at Table Mountain, located 8 km north of Boulder, Colorado. The intercomparison is a quasi-annual campaign organized by the Central UV Calibration Facility (CUCF) of NOAA's Air Resources Laboratory. The primary purpose of the intercomparison is to assess the basic level of agreement of ultraviolet measuring instruments that are representative of the UV monitoring networks in North America and internationally. The participating agencies included the following:

- NOAA's Air Resources Laboratory
- NOAA's Climate Monitoring and Diagnostics Laboratory
- Colorado State University's Natural Resources Ecology Laboratory (NREL)
- Biospherical Instruments (BSI)
- University of Georgia's National UV Monitoring Center
- National Institute of Water & Atmospheric Research of New Zealand (NIWA)
- University of Hanover's Institute of Meteorology and Climatology (IMUK)
- Smithsonian Environmental Research Center (SERC)

- Atmospheric Sciences Research Center at the State University of New York (ASRC)

The UV measuring instruments participating in the intercomparison are given in Table 2:

Table 2. Instruments Participating at the 2003 North American Interagency Intercomparison of Ultraviolet Monitoring Spectroradiometers

Agency	Label	Participating instruments
ASRC	ASRC_RSS	UV-RSS Spectrograph
EPA	EPA_BRW	Sci-Tec Brewer MKIV
CMDL	CMDL	Bentham
IMUK	IMUK_BEN	Bentham
NSF	NSF_GUV	BSI GUV 511
NSF	NSF_SUV	BSI SUV-150
SERC	SERC	SR-18 and SR-19
USDA	USDA_U1K	U111 Spectroradiometer
USDA	USDA_MF1	UV-MFRSR
USDA	USDA_MF2	UV-MFRSR
USDA	USDA_MF3	UV-MFRSR
NOAA-ARL	SL501s (3)	UVB Broadband
NOAA-ARL	YES (3)	UVB Broadband
NOAA-ARL	EKO	UVB Broadband
NOAA-ARL	Scintek	UVB Broadband

Preliminary results of the 2003 Intercomparison Campaign
(Kathleen Lantz, Personal Communication)

The results for the comparison of the spectral solar irradiance from scanning spectroradiometers and the pseudo-scan spectrograph at high sun using the CUCF calibrated lamps are very comparable to previous years. The comparison of spectral solar irradiance from the scanning spectroradiometers and pseudo-scan spectrograph using the participants' calibration (the blind comparison) has shown significant improvement from previous North American UV Spectroradiometer Intercomparisons. In addition, the agreement between solar irradiance from the instruments has improved as a function of SZA from previous years. The preliminary results are very promising and show that recent improvements in instrumentation (e.g. angular response, stray-light rejection), data processing (e.g. temperature corrections), and calibration procedures has had a positive impact on the agreement of solar irradiance between the instruments from the participating agencies. Additional data products from the intercomparison include total ozone and erythemally-weighted irradiance. Final results and details of the intercomparison protocol will be published in two separate forthcoming papers. In these papers, results from the filter radiometers and other data products will be discussed.

4.2 SURFRAD BSRN Station's Experience in Broadband UVB Measurements
(John Augustine, Personal Communication)

The existence of the US Interagency UV Central Calibration Facility (CUCF), and the good practices of station keeping and QA/QC, as undertaken by the SURFRAD and ARM BSRN stations, ensure a relatively high accuracy of broadband UV measurements, with a precision estimated to be within +/-5%, which is near the lower accuracy limit of a PSP pyranometer (see Table 3 below)

Table 3. Data Quality of SURFRAD Monitoring Instruments (John A. Augustine, John J. DeLuisi, Charles N. Long; BAMS, Vol. 81, No. 10, Oct. 2000)

Instrument	Manufacturer	Model	Measurements	Accuracy
Pyranometer	Spectrolab and Eppley	SR-75 (Spectrolab) PSP Eppley	global, diffuse, upwelling solar irradiance	**+/- 2% to +/- 5%**
Pyrgeometer	Eppley	PIR	downwelling and upwelling infrared irradiance	**+/- 9 Wm^{-2}**
Pyrheliometer	Eppley	NIP	direct solar irradiance	**+/- 2% to +/- 3%**
UVB radiometer	YES	UVB-1	global ultraviolet B erythemal iradiance	**+/- 5%**
Quantum sensor	LI-COR	Quantum	PAR -Global photosynthetically active irradiance	**+/- 5%**

The basis of the calibration of SURFRAD UVB broadband instruments is the collective calibration of the CUCF YES UVB1 REFERENCE TRIAD at the Table Mountain Test Facility (TMTF). This UVB reference triad is calibrated absolutely by comparing their output to the output of a collocated UV spectroradiometer. The ozone corrected, erythemal calibration factors (OECF) for the reference triad are provided by the CUCF, as described in section 4.3. To ensure the high accuracy of measurements, as well as shortening the down periods, a cycling procedure is practiced at the SURFRAD network, at least once per year. Before deploying a UVB instrument at a SURFRAD station, it is taken to the TMTF, and run along side the three reference instruments. The ratio of the mean daily-integrated output voltage of the reference triad to the daily-integrated output voltage of the test instrument for a particular day is the scale factor (SF) that relates the test instrument to the standards. No absolute calibrations are applied here, only the relative differences between the test instrument and the reference triad are computed. Any deviation of the scale factor from 1.0 is an indication of the difference of sensitivity of the test instrument with respect to the reference triad. Once the scale factor (SF) has been determined, and knowing the absolute calibration of the reference triad as a function of time, divide the output voltage of the SURFRAD UVB instrument (when it is deployed at the SURFRAD station) by its scale factor, and then multiplying by the reference triad's calibration value appropriate to the SZA and ozone at the time of the measurement, yields an accurate value of UVB erythemal irradiance: **Erythema [sza, ozone] = Voltage*OECF [sza, ozone]/SF**

The methodology of SZA and total ozone correction of the OECF values is described in detail by Kathy Lantz et al. (1999). An indication of the stability of a particular test instrument is given by the change in OECF/SF over time; the actual value of the SF does not describe the stability of the instrument. The scale factors for the UVB instruments, deployed in a number of SURFRAD BSRN stations, are shown in Table 4. The cycling of the instruments is shown by the change of the serial numbers of the instruments.

Table 4. Changes of the broadband UVB radiometers' relative calibrations (SF), with respect to the CUCF's reference group.

Bold serial numbers - the same instrument exposed after recalibration

Bondville, IL			Fort Peck, MT			Goodwin Creek, MS			Table Mt., CO		
Date of Change	Cal (scale factor, unitless)	Serial No.	Date of Change	Cal (scale factor, unitless)	Serial No.	Date of Change	Cal (scale factor, unitless)	Serial No.	Date of Change	Cal (scale factor, unitless)	Serial No.
8 JUN 2004	1.0935	**970818**				4 MAY 2004	1.073	30502	18 SEP 2003	1.0705	10927
21 MAY 2003	1.045	970812	4 SEP 2003	1.109	940301	14 JUL 2003	1.067	930502	16 SEP 2002	1.056	930820
15 OCT 2002	1.06	990509	17 AUG 2003	1.1	**970818**	23 APR 2003	1.021	950207	1 AUG 2002	1.056	930820
20 MAY 2002	1.022	940301	12 SEP 2002	1.1	970818	10 AUG 2002	1	941212	6 SEP 2001	1.048	970812
20 MAY 2001	1.059	990509	2 OCT 2001	1.0435	970819	23 APR 2002	1	941212	28 AUG 2000	1.036	940301
20 JUN 2000	1.006	930701	23 JUL 2001	0.963	930812	17 APR 2001	1.054	930820	14 APR 2000	1.018	950207
20 JUL 1999	1.0365	**970818**	7 OCT 2000	1.044	**970818**	17 JUL 2000	0.955	**930812**	2 SEP 1999	1.018	950207
19 JUN 1998	1.028	950207	13 OCT 1999	0.995	941212	5 APR 2000	0.955	930812	17 AUG 1998	1.08	**930502**
14 NOV 1997	1.052	970819	22 SEP 1998	1.063	970812	22 JUN 1999	0.998	930701	26 AUG 1997	1.06	930820
21 MAY 1997	1.025	930502	23 SEP 1997	1.01	941212	2 JUN 1998	0.97	930812	25 JUL 1996	1.01	930812
27 AUG 1996	1.04	930820	11 OCT 1996	1.02	950207	10 JUL 1997	1.047	940301	26 JUL 1995	1.03	**930502**
7 AUG 1995	1.04	950207	18 OCT 1995	1.01	930805	10 APR 1996	1.006	941212	17 JUL 1995	1.03	930502
24 APR 1994	0.992	930806	11 NOV 1994	1.01	930701	1 DEC 1994	1	**930812**	12 JUN 1995	1.03	**930502**

4.3 UCF BSRN YES-UVB1 Reference Triad (Kathleen Lantz, Personal Communication)

The Ozone-Corrected Erythema Calibration Factors (OECF) for the CUCF YES UVB1 triad at TMTF were calibrated for June 2003. The UVB triad is calibrated by comparing to a collocated spectroradiometer that has been calibrated using the CUCF field calibrator and NIST-traceable lamps. The calibration factor at a solar zenith angle of 40 degrees and total ozone of 300 DU has increased by 11%+/-3% since 1994. This is approximately 1.2% per year. In addition, characterization tests on the YES triad are performed once per year. This includes an absolute test, a spectral response test, and a cosine response test. The spectral response has been measured in December 1997, May 2000, October 2001, October 2002, and May 2004. No significant change in the shape of the spectral response has occurred within the uncertainties of the measurements. The cosine response has been measured in December 1997, May 2000, August 2000, September 2001, November 2002, and May 2004 with no significant change within the measurement uncertainties for the six characterizations.

4.3 European Reference Centre for UV Radiation Measurements (ECUV) (Julian Gröbner, JRC, Personal Communication)

At the European Reference Centre for UV Radiation measurements (ECUV) of the Joint Research Centre (JRC) of the European Commission a UV filter radiometer calibration facility is under development. UV filter radiometers are calibrated in the laboratory for their spectral sensitivity. Then, the absolute calibration is obtained by co-located solar measurements with the reference spectroradiometers of ECUV.

A parallel development has been the installation of a permanent broadband UV radiometer reference group at ECUV. The reference group is intended to be composed of instruments from institutions, who may benefit from a uniform and well maintained UV irradiance scale that will be traceable to the high class UV spectroradiometer standard established at the European Reference Centre for Ultraviolet Radiation Measurements (ECUV) at the JRC. From July 2003 on, several UV filter radiometers have been operating routinely next to the UV spectroradiometer standard. All UV filter radiometers together will form part of the reference group, which will be calibrated according to a common procedure. A subset of 3 units in a component summation measurement configuration has been used for a closure study that allows to assess the measurement accuracy for UV filter radiometers (A. Los and J. Gröbner, 8th IOS, 7.4, AMS-GA, Seattle, *2004*).

A travelling spectroradiometer system has been developed and validated within the frame of the EU-founded project Quality Assurance of Spectral Ultraviolet Measurements in Europe through the development of a transportable unit (QASUME). The aim of the project is to establish a reliable unit, which can be transported to any UV monitoring site in Europe to provide an assessment of the UV measurements performed by the local site instrument. This on-site quality assurance exercise should be viewed as an alternative to the intercomparisons performed previously, where spectroradiometers from different parts in Europe were gathered at one location to assess their performance during simultaneous measurements. The advantages of the proposed approach are that local monitoring instruments do not need to be transported and are used in their natural environment during the intercomparison; furthermore, a site can be visited at regular intervals to check its stability over extended time periods. While this is a more realistic evaluation of a monitoring site, it places strict criteria on the performance and operation of the traveling instrument that must be proven to be stable at a level against which all other instruments will be judged.

The validation phase of the QASUME traveling unit was scheduled for the first year of the project (2002), and consisted of an intercomparison with six qualified spectroradiometers followed by site visits to each of the home sites of these instruments. Based on these measurements and on a comprehensive uncertainty estimate of all relevant parameters affecting the measurements, the conclusion is that the traveling unit is able to provide quality assurance of spectral ultraviolet measurements in the range 300 to 500 nm with an uncertainty of about 5% and an irradiance scale traceable to six independent solar UV monitoring laboratories in Europe.

A total of 13 UV monitoring sites were visited in 2002 and 2003, of which two were visited twice. The results of each site visit are reported in individual reports, which are available from the project WEB-page (http://lap.physics.auth.gr/qasume/) and also as separately published documents:

Gröbner, et al., Quality Assurance of Spectral Ultraviolet Measurements in Europe through the development of a transportable unit (QASUME); Report of visits Round *2002*, EUR 20991 EN, European Commission, 2003;
Gröbner, et al., Quality Assurance of Spectral Ultraviolet Measurements in Europe through the development of a transportable unit (QASUME); Report of visits Round *2003*, EUR 20992 EN, European Commission, 2003.

After the end of the project in late 2004, the unit will be maintained at the JRC and be available to institutions for future QA/QC intercomparisons.

4.4 GAW Activities Relevant to Precision UV Radiometry – Present Status of Establishment of a World UV Central Calibration Facility

The necessity to establish a *UV World Calibration Centre* was stated clearly in the GAW's Strategic Plan 2001-2007. This requirement is reiterated in the WMO/GAW Technical Note No. 142, entitled "Strategy for the Implementation of the GAW Programme (2001-2007)". Under Implementation Strategy, Task 5 (page 43) it is said (quote): "*To establish a UV World Calibration Centre and Regional Calibration Centers in order to initiate regular instrument calibrations and intercomparison campaigns. This task should be implemented by the Scientific Advisory Group on UV radiation (SAG UV) towards July 2003".*

From two recently published WMO/GAW reports (GAW Report No. 142: Addendum for the Period 2005 - 2007 to the Strategy for the Implementation of the Global Atmospheric Watch Programme (2001–2007), April 2004, and Report No. 146: Quality Assurance in Monitoring Solar Ultraviolet Radiation: the State of the Art, 2003) one should, unfortunately, deduce that the establishment of a UV World Calibration Center is no longer part of GAW's Strategic Plan. The effort seems to be shifted towards the establishment of Regional Calibration Facilities, i.e. the European Union's UV Central Calibration Centre (see chapter 4.3 above). While the authors of the GAW Report 146 pay a great deal of credit to SRRB's CUCF, it is recognized as a WMO/GAW Regional Calibration Center for North America, only.

In addition to the above, a WMO/GAW Regional Calibration Center is being established in Buenos Aires, Argentina, by the Servicio Meteorologico Nacional. While the authors of the above report recognize the importance of a central calibration facility, they justify the "diffuse" approach towards regional centers by two reasons: budgetary limitations, and (quote) "two different approaches to a central facility being established, one in North America and the other in Europe". Different approaches are obviously legitimate, it is not clear, however, how the establishment of a multitude of central regional calibration facilities will be less costly than a world central calibration facility. The long-term experience and success of the WMO World Radiation Center (PMOD/WRC) in Davos, Switzerland, is a good proof that a World UV Central Calibration Facility could be a workable solution, providing the necessary calibration hierarchy.

5. Summary Statements and Recommendations

5.1. There is an increasing number of BSRN stations measuring and reporting broadband UVB radiation, and reporting the data to the archive (10 stations measuring and reporting, 8 stations measuring – not reporting, 2 stations - planning measurements).

5.2. The accuracy of broadband YES-UVB1 measurements, as achieved by the SURFRAD BSRN stations, in close cooperation with SRRB CUCF, is remarkable, with a claimed accuracy of +/-5%, which seems to be close to the reported lower limit of accuracy of PSP Eppley pyranometers at SURFRAD BSRN stations (see table 3).

5.3. The +/-5% uncertainty limit of erythema UVB measurements is doubted by a number of UVB SG's members, i.e. B. Forgan, L. Vuilleumier and A. Los. According to Kathy Lantz, the +/-5% is achievable if we are looking at the instrumentally weighted irradiance. The total uncertainty of erythema determined by broadband UV measurements will probably be larger then +/-5%.

5.4. A number of factors may lead to higher uncertainty, i.e. inaccuracies in total ozone measurement; atmospheric variables affecting the application of the erythemal calibration factors due to the disparity of the instrument's spectral response from the erythema action spectrum; environmental conditions may affect the sensitivity of broadband UV radiometers, i.e. temperature and humidity.

5.5. The present policy of WMO/GAW gives priority to the establishment of regional UV calibration centers. Two Regional UV Calibration Centers are active presently, and recognized by WMO/GAW – the SSRB's CUCF and ECUV, The third one will be established in South America (Buenos Aires, Argentina). The establishment of a World UV Calibration Center is thus postponed indefinitely.

5.6. A consolidating effort should be undertaken by BSRN station managers, aimed to unify the characterization and calibration procedures of broadband UVB radiometers, cycling of instruments and maintenance practices.

5.7. BSRN station managers are advised to find the necessary arrangements with the existing regional UV calibration centers, SRRB/CUCF and ECUV, to get their good services in providing characterization and calibration of the broadband UVB radiometers, to be deployed at their stations.

5.8. In the absence of a recognized UV World Calibration Center, it will be in the best interests of the BSRN network, as well as other networks, if SSRB/CUCF and ECUV will establish a framework of cooperation, including joint intercomparison campaigns, and a common reference group of broadband UVB radiometers.

The recommended specifications of broadband UVB radiometers, calibration and maintenance procedures are brought in some detail in Appendix.

References:

1. Kathy Lantz et al. (1999): Methodology for Deriving Clear-Sky Erythemal Calibration Factors for UV Broadband Radiometers of the US Central UV Calibration Facility. Journal of Atmospheric and Oceanic Technology. Vol. 16, Nov 1999, pp. 1736-1752.

2. John A. Augustine, John J. DeLuisi, Charles N. Long (2000): SURFRAD – A National Surface Radiation Budget Network for Atmospheric Research. BAMS, Vol. 81, No. 10, October 2000.

3 Addendum for the Period 2005 – 2007 to the Strategy for the Implementation of the Global Atmosphere Watch Programme (2001 – 2007), GAW Report No. 142. April 2004

4. Ann R. Webb et al. (2003): Quality Assurance in Monitoring Solar Ultraviolet Radiation: The State of the Art. WMO/GAW Report No. 146

Appendix

A.1. Recommended Specifications for Broadband UV Radiometers
(Proposed by the WMO/GAW Scientific Advisory Group [SAG] for UV Measurements, Dr G. Seckmeyer, personal communication, report in preparation for publication)

The 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].

Broadband instruments are used for the measurement of erythemally weighted global UV irradiance. The following instrument specifications (see in table below) are based on the objectives given above, taking into account the limitations of the technology currently available. For instruments to be used within a network, it is recommended to acquire instruments with the least possible variability in their spectral response functions.

Further comments to the values in table:

A.1.1. Remarks to specifications:

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

(1) differences in the instrument-weighted radiation amplification factor (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.

	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 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.

A.1.2. Recommended Characterization and Calibration Procedures for broadband 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 are currently limited, especially for cloudy skies. Therefore the conversion function remains uncertain.

A.2. Instructions for BSRN Station Managers and Site Scientists willing to carry out broadband UVB radiation measurements with utmost, presently achievable, accuracy

BSRN Station Managers/Site Scientists taking a decision to measure UV-B broadband radiation at the station are recommended to follow the procedures as follows:

1. Acquire at least two UV-B instruments of a well-recognized and experienced manufacture. At least, two instruments are recommended to ensure the cycling capability, and replacement in case of malfunction of the field instrument, to decrease down time.

2. The instruments should be calibrated on an annual basis by comparison to reference instruments, traceable (ultimately) to the World Group of Reference Instruments. It is recommended to establish the following calibration hierarchy:

   (a) World UV calibration Center
   (b) Regional Calibration Centers
   (c) National Calibration Centers

Regional Calibration Centers should be equipped with a group of Reference Instruments (of each manufacture), to provide a “traveling reference”. Such procedure may reduce considerably the cost of calibration.

Appendix E

PAR Working Group Report

Members:
Ain Kallis, Tartu Actinometric Station
Bruce McArthur (co-chair) AES Canada
Rachel Pinker (Chair), U of MD
Kevin Rutledge, NASA LaRC

<u>History</u>

First Working Group was established at the 5th BSRN Science and Review Workshop, Budapest, Hungary, 18-22 May 1998: WG updated at the 6th BSRN Meeting, Melbourne, Australia, 2000 and at Regina, 2002.

Highlights of Previous Reports:

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
5. Australia:Middleton
6. Skye-Probetech SKE-510 PAR sensors

Original Charge to Working Group

- What instruments are available to measure PAR
- How accurate are they
- Should PAR be included in BSRN archive

Action Items

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

Early evaluations:

- In Estonia, at the Tartu Observatory, Toravere,a comparison between Li-Cor and Par Lite conducted (Ross and Sulev, 1999)
- At NASA/Langley, calibration of the Li-Cor instrument was undertaken using spectral measurements. Results were presented at the 6th BSRN Meeting at Melbourne, Australia.
- The most systematic evaluation of several instruments started during the Regina Meeting; results presented at Exeter (Bruce McArthur)

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. Middleton
5. Skye-Probetech

Working Group Recommendations at Regina

- need to evaluate results from first experiment; if necessary, comparison should be repeated and results published

- in view of demand for PAR, measurements should continue with available instruments

- premature to formulate archiving guidelines

- dialogue among working group members should continue to deal with original mandate to committee

The following spectroradiometers were used for evaluation:

A diode array instruments “home made” by McArtur’s group to be used in the 380-780 nm interval, at 1 nm resolution.

An Optronics OL754 instrument, which is a grating spectrometer, used in same spectral intervals.

Preliminary results shown at the 7th BSRN meeting and at Exeter indicated that instruments of same kind tended to give similar results, however, there was a distinct difference between instruments.

Due to the lack of absolute calibration of the spectroradiometers used, it was not possible to evaluate the absolute quality of the various instruments.

The results of the intercomparison will be prepared for publication.

Recommendations:

The working group should be in frequent contact during the following two years to come up with new recommendations how to proceed with the intercomparison and charge to the committee.

New Items:

1. New instruments-preliminary status (collaborative effort: EKO Co. and Chiba University)

2. New measurements-to evaluate water vapor effects on PAR at the Sede Boqer BSRN site

To answer following scientific questions:

- Effect of water vapor on PAR/SW relationship
- Optimal conversion between quantum sensors output to W/m**2

Rationale

Large-scale observations form satellites show distinct correlation between precipitable water and the PAR/SW ratio

Measurements being made:

1. Several PAR sensors
2. Spectral measurements with Li-Cor spectroradiometer
3. Total SW fluxes
4. Aerosol properties (CIMEL AERONET site)

Radiative transfer models are used for evaluation.

Appendix F

AGREEMENT BETWEEN
THE GLOBAL CLIMATE OBSERVING SYSTEM
AND THE WORLD CLIMATE RESEARCH PROGRAMME
REGARDING THE BASELINE SURFACE RADIATION NETWORK

This agreement presents the terms and conditions by which the World Climate Research Programme (WCRP) Baseline Surface Radiation Network (BSRN) proposes to satisfy the requirements for being identified as the Global Climate Observing System (GCOS) global baseline surface radiation network. With mutual agreement to these terms, BSRN will henceforth be designated as the GCOS global baseline surface radiation network.

1. The BSRN will remain institutionally and organizationally as it currently is within the domain of the Global Energy and Water Cycle Experiment (GEWEX) of WCRP and will be identified in all GCOS documentation and distributions as the WCRP/GEWEX BSRN, or spelled out as necessary.

2. Both BSRN and GCOS principals will agree to the items set forth in this document.

3. To avoid potential confusion and dilution of the integrity of the BSRN programme, GCOS will not endorse, sanction, or otherwise identify any other surface radiation measurement programme or effort as part of the GCOS global baseline radiation network.

4. New sites will be accepted into the BSRN programme only as discussed below under Principle #7.

5. BSRN will adhere to the GCOS Climate Monitoring Principles as presented and discussed below. While most of the principles are already being followed in BSRN because of their inherent merit for long-term research-quality observations, BSRN documentation (Operations Manual, or OM) does not specifically address some of the points and will be modified accordingly.

The following describes how BSRN relates to each of the ten basic GCOS Climate Monitoring Principles, the full set of which were adopted by the World Meteorological Organization Congress at its fourteenth session through Resolution 9 (Cg-XIV).

Principle #1: The impact of new systems or changes to existing systems should be assessed prior to implementation.

- Such an assessment was completed before BSRN began operations. However, a major goal of BSRN is the improvement of measurement capability. Therefore, as those improvements have been made, they have been implemented *after being assessed as to the merit of, and gain due to, the improvement*. Although this requirement is not explicitly stated in the OM, it has been generally followed to date and a formalization of such a policy will be included in the OM.

Principle #2: A suitable period of overlap for new and old observing systems is required.

- This is inherent in the BSRN mode of operation but is not specifically identified as a requirement in the OM. It is assumed that this principle applies to the exchange of sensors for routine calibration and maintenance as well as the integration of new systems replacing older ones. Overlap in BSRN is achieved by the pre- and post- characterization, calibration, and traceability of instruments and systems prior to deployment and removal from service so as to be consistently inter-compared with the new and old systems or instruments. Traceability may be achieved either in the field or at a suitable characterization and calibration facility. The OM will be modified to reflect this principle but will not significantly change the current mode of operations.

Principle #3: The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e., metadata) should be documented and treated with the same care as the data themselves.

- This is already an integral part of the data reporting and data archival procedures within BSRN. BSRN will review the required metadata currently being acquired to identify any missing information.

Principle #4: The quality and homogeneity of data should be regularly assessed as a part of routine operations.

- This is currently being done in at least two places during BSRN data collection and archival. By basic programme design, BSRN site scientists are responsible for maintaining quality control and data homogeneity at their individual sites before submitting the data to the archive. Also, the central BSRN archive performs data quality flagging as well as data completeness assessments.

Principle #5: Consideration of the needs for environmental and climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.

- BSRN's primary goal is to address climate-related research issues. The placement and design of the BSRN is to provide information for climate analysis and research assessment. The complete data product is freely available for applications in additional disciplines.

- The BSRN archive will not necessarily develop any new products to satisfy this principle given that its resources are currently fully committed.

Principle #6: Operation of historically-uninterrupted stations and observing systems should be maintained.

- BSRN was the beginning of the system now recognized as the BSRN surface radiation measurement methodology. It is the intention of the BSRN and most of its participants to operate these programmes indefinitely as long as they can be practically maintained. Predecessor radiation measuring capabilities existed at several of the current and prospective BSRN sites and the BSRN programme extends a subset of those earlier measurements. However, BSRN does not give preference to an existing measurement record at a candidate site based solely on the existence of those records, although long records are one of the goals of BSRN. BSRN asserts that sites with long BSRN records are of particular value and additional funding consideration should be given to those sites.

Principle #7: High priority for additional observations should be focused on data-poor regions, poorly-observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution.

- BSRN will continue to pursue additional observations in data-poor and under-represented regions. BSRN will add stations to the network only by its current set of standards which require application to, and review by, BSRN management. This is meant to be exclusive to the extent to assure that the proper measurement capabilities exist and are likely to be maintained, preferably at globally under-represented but regionally representative sites pursuant to this Principle. GCOS and others are encouraged to recommend potential sites with consideration to be given to those sites as outlined above. Co-location with other climate related observations is desirable.

- BSRN will determine if under-sampled or poorly-observed parameters are appropriately represented within the realm of the programme and will address them accordingly. BSRN is currently pursuing some such cases, e.g. aerosol optical depth, UVB, and cloud-base temperature/height.

- Temporal representativeness was given high priority in the design of BSRN. Current measurement programmes meet or exceed all currently known or anticipated needs for this requirement.

- While efforts to extend the representativeness of the BSRN are underway and will continue, it has always been recognized that surface-based radiation observations will never be able to completely represent the climatologically significant variation on the planet. It is only through combined satellite and modeling programmes, such as Surface Radiation Budget (SRB) and various GCMs, can this complete representativeness be obtained.

Principle #8: Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of system design and implementation.

- Each BSRN station is intended to be long-term and the data sampling and collection continuous and durable. This was emphasized in the original design of the BSRN as indicated in the letters of invitation that were extended to member nations. In those agreements there was the implicit expectation that the commitment was long-term. While the specific duration of the BSRN is not identified in current institutional documentation, it has always been intended by the participants that it be an indefinitely long programme. Additional emphasis on this aspect of the network will be added to the OM.

- Given the funding realities for scientific exploration and the lack a definitive description from GCOS as to what constitutes adequate institutional structure for adequate longevity, it is felt that BSRN more than adequately fulfills this requirement.

Principle #9: The conversion of research observing systems to long-term operations in a carefully-planned manner should be promoted.

- There is no distinction between research and long-term observations relative to BSRN surface radiation observations. The intent of all the BSRN observations is for research applications. An observational method that would be considered developmental would need to be further developed into an operational state before ever being deployed in the BSRN routine system. BSRN will continue to be a research network in that the purpose of the observations is for research applications. BSRN will continue to ensure that newly-developed observational systems will be suitable for long-term, remote deployment before being a required measurement of the programme. This should satisfy the letter and intent of this monitoring principle.

- GCOS confirms that this principle is primarily intended to encourage establishment of strong, continuing institutional support for all aspect of the ongoing network activities.

Principle #10: Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.

- This is already the case for BSRN. The BSRN archive is an integral part of the network in that it includes personnel intimately familiar with the field collection of the data and its scientific applications. The archive maintains BSRN web site and contributes greatly to the overall management and operation of the network. Organizational investigations are currently underway to ensure the integrity of the archive for the long-term and the eventual turnover of personnel involved.

- The longevity of the BSRN archive is an important aspect of the network and there are current efforts to insure that the archive will be sustainable indefinitely into the future.

Appendix G

POSTERS

Status of the Regina BSRN station: Bratt's Lake Observatory, Saskatchewan, Canada (Ormanda J. Niebergall, Ihab Abboud, David H. Halliwell, L.J. Bruce McArthur, Edmund K. Wu, Meteorological Service of Canada)

This poster displays several graphs of radiation data (direct, diffuse, global, longwave) collected at the Regina BSRN station since 1995. The station has grown since hosting the 2002 BSRN meetings, and the list of collaborative agencies has increased. Weekly ozonesonde flights were introduced in late 2003. The poster displayed graphs of temperature, wind speed and direction, and ozone profiles collected in winter, spring, and summer. The poster also displayed a series of graphs showing radiation and albedo data collected from the 30m tower at the site. Albedo changes were seen in response to seeding of the cropland at the tower, and due to rain and snow events and snow melting.

Status of the Payerne BSRN Station (Laurent Vuilleumier, MeteoSwiss)

The Payerne station measures the BSRN basic set of parameters since November 1992. In addition, other parameters including LW and SW irradiance at 10 and 30m a.g.l., spectral direct irradiance and UV erythemal irradiance are measured. New equipments allowing estimation of cloud parameters have been installed at Payerne. In particular, a Total Sky Imager YES TSI-880 has been operating since 13/11/2003 at Payerne and will remain under the responsibility of the BSRN station. The TSI takes an image of the sky every 30 sec. and an algorithm based on the color (RGB pixels) of the sky allows estimation of the percentage of cloud cover. In addition, a Vaisala CT25K ceilometer has been operating since 2/11/2003 at Payerne. However, this is not an instrument under BSRN responsibility and may be moved to a different MeteoSwiss station in the future. The ceilometer allows detection of cloud base up to an altitude of about 8000 m every 30 sec. The Clear-Sky Detection algorithm of C. Long has been implemented at Payerne. The new station tunable QC checks that are included in the latest version of the program will soon be included in the standard QC procedures. In addition, quality analysis based on measurement redundancy has been developed and is now applied. Errors in data processing affecting data transmitted to WRMC have been identified and are being solved. Correction of old incorrect values in WRMC DB is still pending.

BSRN Station Lindenberg, Germany (Klaus Behrens, DWD, Germany)

As already mentioned in the status report 2002 (Regina Meeting), because of the erection of a new laboratory building, the measurements had to carry out at an interim platform 50 m northern of the old site. This interim period (15.10.2001 – 15.06.2003) was finished. Since 15.06.2003 the measurements have been carried out on the roof of the new laboratory that is equal to the old site (φ= 52,21° N, λ= 14,12° E, h = 121 m).

Now, the measurements of all quantities (global, diffuse, direct, and atmospheric downward radiation) are duplicated to ensure data quality. Two CM22 and CM21 are used for measuring global and diffuse radiation, respectively. Furthermore, atmospheric downward radiation is recorded using shaded PIR and CG4 pyrgeometers. Two CH1 and an AHF are measuring direct radiation. The shaded pyranometers and pyrgeometers as well as the pyrheliometers are mounted on two 2AP Kipp and Zonen trackers. All 2□ instruments are ventilated by a heated air stream as before. The data are recorded by COMBILOG data logger of Friederichs, Hamburg.

A Measurement of the Shadow Effect on Upwelling Shortwave Radiation at the COVE Site (Fred M. Denn, C. Ken Rutledge, Zhonghai Jin, Bryan E. Fabbri; Analytical Services & Materials, Inc. and Gregory L. Schuster; NASA Langley Research Center)

The Clouds and the Earth's Radiant Energy System (CERES) Ocean Validation Experiment (COVE) site is located on the Chesapeake Lighthouse which is a United States Coast Guard facility located in the Atlantic Ocean approximately 25 kilometers east of the mouth of the Chesapeake Bay. The lighthouse structure is an approximately 25 meter by 25 meter square flight deck, about 20 meters above the water surface, with a 13 meter high tower at the southeast corner. Additionally a hoist sticks out about 8 meters from the middle of the west side. Our downlooking instruments are located at the end of this hoist. Consequently our upwelling irradiance measurements are adversely affected by the platform shadow during the forenoon period. This study was an attempt to develop a method to quantify the shadow effect to account for the differences between modeled and measured upwelling irradiance fields. The first step was to place an additional pyranometer next to the standard downlooking pyranometer and compare their measurements, both pyranometers being Kipp & Zonen CM31s. The second pyranometer was then mounted on a helicopter. The helicopter then hovered as close as possible to the standard downlooking pyranometer, and moved slowly away to a distance of about 500 meters. Comparisons of the standard downlooking pyranometer and the helicopter mounted pyranometer measurements were made. These comparisons produced no meaningful results, as either the helicopter induced airflow around pyranometer or the helicopter's effect on the water surface greatly influenced the measurements. Relative comparisons of measurements made with the helicopter mounted radiometer during the flight were then performed. The measured irradiance fields near the lighthouse and 500 meters from it were found to be nearly the same. This is the expected result at the time of day of the measurements (13:33 to 13:51 local standard time). Future studies would include using a non-thermopile device, such as a silicone photodiode, to minimize the air flow induced temperature effects, and to make measurements at a time of day when the modeled and measured irradiance fields are expected to be different. The goal of this study was to account for the difference between the measured and modeled irradiance fields.

The COVE web site can be found at 'http://cove.larc.nasa.gov."

The Plataforma Solar de Almeria (Spain) Meteorological and Radiometrical Station. (Bella Espinar Frias, Plataforma Solar de Almeria, Ciemat)

The Plataforma Solar de Almería is setting up a radiometrical and meteorological station that would be incorporated in the BSRN. With this poster, we would like to introduce the station to all of the participants of the workshop, and recover information that permits us to accomplish all the requirements to become a BSRN station.

The station has measurement sensors for all the most important radiometrical variables. Most of these sensors have recently been acquired, according to the corresponding BSRN requirements. The instrumentation is complete. The station has recorded measurements of shortwave and longwave upward from a 30m height tower along with longwave downward. The station also has three components of the solar radiation and the most important meteorological variable devices will be installed. In addition, a spectroradiometer, which measures the spectral distribution of the three components of the solar radiation, is already running.

Grounding a BSRN Station for Protection from Lightning Induced Surges (Gary Hodges, CIRES/NOAA

During the summer of 2003 the Surface Radiation Research Branch (SRRB) installed a new Surface Radiation (SURFRAD) station near Sioux Falls, South Dakota, USA. As part of this installation, an extensive grounding system was incorporated in order to mitigate equipment damage resulting from cloud-to-ground lightning strikes. In addition to the Sioux Falls installation, a grounding system was also installed at the existing Goodwin Creek, Mississippi, USA SURFRAD site. Both sites required a similar amount of materials, the major components consisting of: approximately 200 meters of 4/0 stranded copper cable; approximately 50 meters of 1/0 stranded copper cable; and approximately twenty-five 3-meter copper clad ground rods. All underground connections were completed using an exothermic welding process. In addition to the cable and ground rods, surge suppression devices were installed on the phone and AC power lines that run to the site. All components of the SURFRAD stations were then bonded to the grounding system using a variety of mechanical clamps. The cost of materials and equipment rental combined was less than $5,000 USD for each site. Installing the system at Goodwin Creek took ten man-days (e.g., two experienced people could have installed the system in 5 days). The Sioux Falls installation was a bit easier since the work was combined with the site installation. Hiring an electrical contractor is an option, but would increase the cost significantly.

The influence of Clouds on the Radiation Budget at the Coastal Italian station "Mario Zucchelli" (75° S) (C. Lanconelli, A. Lupi, M. Nardino, V. Vitale and T. Geogiadis).

Since Antarctic summer 1999-2000, accurate surface measurements of the four radiation balance terms were carried out at the italian coastal base "Mario Zucchelli " (MZS - 74°43' S, 164° 07' E) by using a CNR-1 Kipp & Zonen net radiometer. Simultaneous measurements of the diffuse and direct components of the incoming solar radiation flux were carried out by using a MFR-7 shadowband radiometer (YES). SYNOP observations were regularly carried out by MZS meteo-office together with radiosounding profiles of temperature, pressure, and humidity.

The whole set of data was examined in order to evaluate cloud coverage and cloud type characteristics at this site during the summer season, and to obtain information about their interannual variability. The Long and Ackerman (2000) approach was used in order to obtain clear sky identification and to evaluate cloud effects on global and diffuse components of incoming solar radiation at the surface (SWCE). Average SWCE were found to range between -73 W/m^2 and -96 W/m^2. The differences with evaluations obtained at other polar stations mainly related to low values of surface albedo, usually ranging between 0.4-0.5 during summer to the high frequency, in the Terra Nova Bay area, of cloud with high liquid water content.

Cloud type was estimated following the Duchon and O'Malley (1999) procedure, so that clouds were classified in six classes (Ci, Cu, Ci+Cu, St, Clear and Undefined). The annual average occurrences was found to be *11%, 8%, 6%, 12% 29%, 33%,* respectively. Pyranometer results and simultaneous human observations (SYNOP) agree about *40%* of the time, a result not far from the limit given by authors in their paper (*45%*). By using synop information over a larger period (1993-2002), we obtained annual average occurrences of *10%, 10%, 20%, 14%, 22%* and *23%* for the six Duchon O'Malley's cloud classes. These results appear to indicate that differences between automatic and human classification are mainly related to the misclassification of the Ci+Cu class. Moreover, it is important to note that the unclassified situation presents often a complex multi-level structure with high cover index and optical depth.

A rough estimation of the mean seasonal cloud radiative forcing on the surface radiative balance was achieved by implementing the simple method proposed by Bintanja and Van den Broeke (1996) where cloud radiative forcings are defined by the equations:

$$CRF_{SW} = N\,(S_{ov}-S_{cl})$$
$$CRF_{LW} = N\,(L_{ov}-L_{cl})$$

$S_{ov/cl}$ and $L_{ov/cl}$, shortwave and longwave net fluxes for overcast (N=1) and clear (N=0) conditions were evaluated through a linear best-fit procedure of daily averages vs. daily average cloud amount N (Bintanja and Van den Broeke, 1996). The results (in Wm^{-2}) are summarized below. Campaign 1999/2000 evaluations are not included since only MFR-7 measurements were carried out.

YEAR	S_{cl}	dS/dN	L_{cl}	dL/dN	<N>	CRF_{SW}	CFR_{LW}	CFR
2000/2001	331	-224	-149	+119	0.59	-132	+70	-62
2001/2002	334	-234	-149	+110	0.44	-103	+48	-55
2002/2003	413	-301	-190	+160	0.68	-205	+109	-96

First activities and future improvements implementation of a BSRN station at Dome C (Antarctica) (A. Lupi, M. Nardino, C. Lanconelli, V. Vitale, T. Georgiadis and F. Calzolari)

Dome C (75° 06' S, 123° 24' E) is located at 3233 m height on the polar Plateau at equal distance (1100 km) from the coastal bases of Dumont D'Urville (France) and Terra Nova Bay (now Mario Zucchelli station – Italy) and is in the middle of the East Antarctic Plateau. Dome C presents many differences from the South-Pole, the most important being in cloud and wind regime: snow precipitations range from 2 to 10 cm/yr, while wind maximum speed range around 10 m/sec. Measurements carried out at Concordia station will improve considerably our knowledge on the radiation balance over the Antarctic Plateau and its spatial variability.

A summer camp, made up of dormitory and service tents and containers was built in 1996-1997 by Italians and French, to provide logistic support to Epica Project and the beginning of the construction of the permanent Base of "Concordia". The permanent base, consisting of two cylinders with a diameter of 18 meters and three levels, should start to operate at the end of the next austral summer season. The site for radiation measurements will be fixed N-W the permanent base in the sector dedicated to clean activities. The distance will be obviously fixed by the operational constraints and is now under discussion. The possible horizon for a distance from Concordia station of 700 m will present a maximum obstruction of 2.5 degree in the E-SE direction (azimuth 105 degree).

In summer 1997, a field campaign with a CNR-1 Kipp & Zonen radiometer was carried out to investigate cloud influence on the surface radiation balance at Dome C. Cloud detection was obtained through visual observations. Results from January 21, 1997 to February 2, 1997 indicate a total transmission varying between 0.75 and 0.9. During the Antarctic summer of 1999/2000 a micrometeorological tower was installed with the main aim to study technical solutions for a permanent station measuring surface fluxes in a so extreme an environment. The tower was equipped with several sensors placed at different heights (temperature: 1.25m; temperature-wind speed-RH: 2.5 m, 5 m, 10 m; net radiometer: 12m; wind direction: 13m). The power supply was provided by six-2V-1000A/h accumulators with a special high density acid for low temperature. The measurements were recorded by a Campbell CR-23X data-logger every minute and averaged every 30 minutes. Results of the first measurement campaign showed a net radiation ranging between -100 Wm^{-2} and +50 Wm^{-2} with a negative mean, a snow heat flux at 5 cm depth ranged between –20 Wm^{-2} and 20 Wm^{-2}, and a delay of about 5 hours in the maximum at 15 cm depth. During the last campaign (2003-2004) several tests were performed with Schenk and Kipp & Zonen radiometers to verify operational conditions.

The working plan was heavily delayed as a consequence of the Italian Antarctic Programme reorganization. As a consequence the test campaign planned for 2003-2004 was very preliminary and the full implementation is postponed to the 2005-2006 campaign. In the foreseeable future we should receive the whole set of instruments listed below, so as to be able to start the BSRN basic programme:

- 1 2AP-GD Tracker Gear Drive complete of accessories and shadow assembly
- 1 Pyrheliometer CH 1
- 2 Pyranometer CM 22
- 1 Pyrgeometer CG 4
- 1 NIP Eppley pyrheliometer complete of filter wheel e Schott Glass Filters

Another 2AP-GD Solar tracker, a CM22 pyranometer, a CG4 pyrgeometer and an Eppley absolute cavity radio-meter model AHF-AWX w/408 including Control Unit for any time operations, will allow us to create a first calibration facility in Bologna at the ISAC-CNR Institute.

Cloudless Sky Global Spectral Irradiance in Southern Saskatchewan, Canada (J.U. Morley[1], L.J. B. McArthur[2] and W.G. Bailey[1])

1. Department of Geography, Simon Fraser University, Burnaby, British Columbia, Canada
2. Experimental Studies Division, Meteorological Service of Canada, Toronto, Ontario, Canada

Global spectral irradiance at the Earth's surface is recognized for its importance in many physical, chemical, and biological systems. Although it is most accurately determined through field measurement, there is a paucity of routine and quality observations within Canada and many other countries. Research was conducted in Southern Saskatchewan at the Bratt's Lake BSRN Observatory in 2003 to address this concern. A measurement program for global spectral irradiance over diurnal and seasonal timescales was undertaken for a host of atmospheric conditions. During the summer of 2003, extensive forest fires occurred in the interior of British Columbia and massive plumes of pyroginic aerosols were injected into the atmosphere. Prevailing winds carried these aerosols eastward into Saskatchewan. In late July and August, data collected under cloudless conditions show enhanced attenuation during periods when pyrogenic aerosols were present. Additionally, data demonstrates that morning and afternoon attenuation is dissimilar, with lower transmission present in most post-midday periods. While the pyrogenic aerosols reduced global spectral irradiance over all wavelengths between 0.28 – 0.8 m, the attenuation was found to be greater at shorter wavelengths.

Cloudless Sky Broadband Global Radiation at the Bratt's Lake BSRN Observatory, Saskatchewan, Canada During 2003

J. U. Morley[1], W. G. Bailey[1] and L. J. B. McArthur[2]
1. Department of Geography, Simon Fraser University, Burnaby, British Columbia, Canada
2. Experimental Studies Division, Meteorological Service of Canada, Toronto, Ontario, Canada

Measurements and models of broadband direct, diffuse and global solar radiation were employed in the study of cloudless sky atmospheric attenuation at the Bratt's Lake Observatory in Southern Saskatchewan, Canada. During the summer of 2003, the forested regions of British Columbia in western Canada experienced one of their worst fire seasons on record. Prevailing westerly winds carried pyrogenic aerosols generated from the fires across western Canada. The location of the Observatory permitted broadband monitoring of these aerosol influences. Pyrogenic aerosols arising from the forest fire plumes were found to significantly decrease the transmissivity and increase the diffuse ratio. Overall, global radiation during these conditions was reduced when compared to that from usual cloudless conditions. Furthermore, the cloudless sky radiation model initially proposed by Houghton (1954) was also used to assess the influence of atmospheric attenuants on broadband irradiance. This simple yet robust modelling approach for direct, diffuse and global radiation generates satisfactory results for both one-minute and daily time scales. Model results for the winter season indicate the need for revised parameters to account for the very clean atmosphere found during the cold winter period. The lack of agreement between model and pyrogenic conditions indicate that the aerosols decrease global solar radiation by an additional 5 – 6%.

Observations of Multi-Year Radiation and Aerosols Made from the CHL Ocean Platform

Ken Rutledge[1], Greg Schuster[2], Jay Madigan[1], Bill Smith Jr.[3]
NASA Langley Research Center
1 Analytical Services and Materials, Inc.
2 Radiation and Aerosols Branch
3 University of Wisconsin-Madison, CIMSS/SSEC

Ocean albedo was determined from the 3.5-year radiation dataset contributed to the BSRN archive by the Chesapeake Lighthouse (CLH) site. The Long/Ackerman cloud coverage algorithm (LAA) was used to partition the dataset into different cloud regimes (LAA < 0.1: clear, LAA >0.9: overcast). Clear and overcast albedo over the ocean were presented with attention to wind and solar zenith angle effects. A comparison to the oft-referenced work of Payne (1970) was performed. The clear-sky ocean albedo showed both a strong dependence for solar zenith angle and wind speed. For high sun altitudes, lower winds produced lower albedo. For low sun altitudes, lower winds produced higher albedo. For overcast sky conditions, no obvious dependence on albedo was observed for either wind speed or solar zenith angle. CLH albedo was universally lower compared to comparable data from Payne's work. A review of monthly averaged aerosol extinction optical depth spectra for the AERONET archive was also performed. By comparing these observations to the six-year satellite based ocean color archive from Sea Viewing Wide Field of View Sensor (SeaWIFS) a marked difference in retrieved spectra was observed. An analysis of the ocean color data suggests that the CLH site is "transitional" with respect to case 1 and case 2 optical quality. This "transitional" classification was hypothesized to be the reason for the poor aerosol retrieval results since the algorithms were developed for case 1 regimes.

Status of the BSRN Tateno, Japan (H. Naganuma, Japan Meteorological Agency)

Aerological Observatory Tateno started data submission to the BSRN archive in 1996. It has been done regularly on a monthly basis and the data up to May 2004 have been already reported to the archive. In October 2003, a Kipp & Zonen CM22 pyranometer was installed as replacement of a CM21 on diffuse radiation with the installation of an improved shading sun tracker with shading geometry meeting the BSRN recommendation. The thermal offset error was reduced to less than half that of before by adopting this basically low offset instrument and enhancing ventilation. Two CG4 pyrgeometers were newly installed and they are now under an investigation comparing them against PIR as a reference. The latest BSRN data processing software developed at Tateno for possible use at other stations is presented in this workshop. It's a minor version-up of which was distributed in CD-ROM at the 7th BSRN Workshop in 2002.

Status of the BSRN Syowa, Japan (H. Naganuma, Japan Meteorological Agency)

As a part of the Japanese Antarctica Research Expedition Program by the National Institute of Polar Research, radiation measurement at Syowa Antarctica has been operated substantially by the Japan Meteorological Agency. Data have been submitted to the archive since 1994 on a yearly basis and the data up to December 2002 have been submitted. Downward longwave radiation data have been recalculated through 1994. Kipp & Zonen CG4 pyrgeometers were installed for longwave radiation measurements, replacing the Eppley PIRs; for downward in February 2001 and for upward in February 2002. Syowa Antarctica has enhanced communication lines using satellite transmission.

Status of Tamanrasset-Algeria Station (Mohamed Mimouni, Meteorology Service of Algeria)

The station is located at the limit of the Tropic of Cancer in the south of Algeria (22^{o} 47'N; 05^{o}37'E, 1377 mas), at the "hoggour" mountain. The measure of radiation began in September 1994 in the GAW Program with measuring the global, diffuse (shadow band), and RG8. The site was upgraded in March 2000 to the BSRN program and included the downward longwave radiation in collaboration with the STAR group of radiation (STAR/CMDL-Boulder). The data are sent regularly to the BSRN archive in Zurich, Switzerland and to the World Data Center (WRDC) in St. Petersburg, Russia.

Pristine Data from Two Partial Solar Eclipses Over the South African BSRN Site at De Aar (Danie Esterhuyse, South African Weather Service)

Southern Africa experienced two total solar eclipses within a year and a half, the path of totality covering roughly the same area. The first eclipse occurred on a winter afternoon (21 June 2001), while the second occurred on a summer morning (4 December 2002). Both eclipses manifested partial phases at the South African BSRN site at De Aar (maximum phases respectively 61% and 73%) in comparable solar altitudes (26° and 40°). At the BSRN site, on both occasions, the sky was almost perfectly cloudless for the entire eclipse day, resulting in perfect smooth curves for global, direct, and diffuse radiation, indented only by the eclipse. The diffuse radiation curve reveals that the indentation was caused by a non-atmospheric source (the moon). The loss of global radiation as a result of the eclipse, is 1.06 MJ/m² in 2001 (7.8 % of the possible radiation for that day) compared to 2.02 MJ/m² in 2002 (6.2 % of the daily radiation).

Modernization of the Swedish Radiation Network with the Aim to Establish a Swedish BSRN Station (Thomas Carlund, Swedish Meteorological and Hydrological Institute)

Since 1983 the present Swedish meteorological radiation network has been in operation without any significant upgrades. Being more than 20 years old all the instruments and measurement equipment have become very worn and/or out-of-date. Therefore, planning for the modernization of the radiation network is now occurring and the work will begin in 2005.

According to the current plan the main part of the modernization will be to renew the twelve existing stations. Two or three new stations will probably be established. The number of direct irradiance measurements will be reduced from twelve to three or four. Instead, monitoring of longwave (5-6 stations) and diffuse irradiance as well as aerosol optical depth (3-4 stations) will be introduced in the new network. The aim is also to establish a new station of BSRN standard in the network of SMHI. The research station at Vindeln Experimental Forest Svartberget, run by the Swedish University of Agricultural Sciences (SLU), has been identified as the currently most suitable BSRN candidate site in Sweden. The Vindeln station is located at 64.24ºN, 19.77 ºE, 225m alt, in the boreal forest zone. The idea is to try to establish continuous radiation measurements in the forest at maximum tree top level, around 25 m above the ground. While such measurements have been identified as very interesting and useful, they require a measurement tower to be built which is associated with a very high initial cost. If and when the Swedish BSRN plans will be realized is still unknown. Thus far, discussions have only begun between SMHI and SLU at the decision-maker level.

Contribution of the BSRN Station of Carpentras on the Calibration of Broadband and Narrowband UV Instruments (J. Morel, Météo-France)

This poster summarized the studies done at Carpentras during the past 10 years concerning the calibration and the use of UV-B broadband and narrow-band radiometers. The YES UVB-1 Broadband Radiometer, Serial Number 930702, was installed at Carpentras in July 1994, only 2 or 3 weeks after it was calibrated by its manufacturer on July 1, 1994. During the last 10 years the temporal stability of this instrument has showed no defects. The relative spectral response provided on the reverse of the YES Certificate of Calibration recently offered proof of this assertion.

Using the SMARTS2 Model, and the standardized erythema action spectrum, the real spectral response of the Carpentras' instrument, the standard cosine response of the UVB-1 radiometer functions, we were able to calculate some "factors of calibration." These "factors" *K* are not the true calibration factors of the radiometer, of course, but they are proportional to the modeled "*clear-sky erythemal Calibration Factors*" *k* of Kathleen O. Lantz, et al (study done from 1994 to 1995 or 1996 - results published in a famous article in November 1999).

For Solar Zenith Angle (SZA) less than 50° and for total atmospheric ozone [O_3] between 200 and 350 DU, the mean value of the ratios *K/k* is remarkably constant and equal to 1.9054 (std deviation 0.00976). The constancy of these ratios was established with about 10-year old data. Ten years later, spectroradiometric measurements used as a reference showed that it is always possible to use the first Kathleen's Calibration Factors *k* (that are about 8 to 10 years old).

The constancy of the ratios *K/k* may also be used to determine the *k* Factors for [O_3] superior to 350 DU (Don't forget that [O_3] may reach 500 DU in North Canada, for example). The tests done at Carpentras also confirmed that the erythemal calibration factors of the YES UVB-1 broadband radiometer are mainly dependent on SZA and [O_3]. The variations in air pressure (or altitude) or in air turbidity (or aerosol amounts) are practically negligible. It is the same thing for NO_2.

There are two methods in calibrating and using this Kipp & Zonen CUVB1 306 nm narrow-band radiometer.

Method 1. The spectral Irradiance *UVB* is obtained in dividing the output voltage of the instrument by the corrected sensitivity of the instrument. The sensitivity must be corrected in order to shift the Maximum position of the filter to the ideal 306 nm position, and to take into account the fact that the width (FWHM) of the filter is not constant and is different to the "ideal" 1 nm wide rectangular response.

The correction factors are also SZA and [O_3] dependent. Unfortunately, the user of the instrument is not supposed to know total ozone. We can add that the knowledge of the 306 nm Irradiance does not yet give us information about the erythemally weighted irradiance.

Method 2. Using a model, it was possible to show that there is a linear function that fits the output voltage (or reading) "x" of the instrument and the erythemally weighted irradiance (or UV Index, or MED – Minimal Erythemal Dose) "y".

$y = ax + b$ ($R^2 = 0.9924$ for SZA less than 60°, and [O_3] between 200 and 500 DU)
the parameters a and b are independent of SZA and [O_3], but they are dependent of the instrument we bought. It is the duty of the manufacturer to supply these parameters with the instrument.

Investigations of the Surface Albedo on the Boundary Layer Field Site GM Falkenberg (K. Behrens and W. Adam, Germany)

The surface albedo plays an important role in the heat balance of the atmosphere. Since September 1999 short wave downward and upward irradiance have been measured in parallel in 2 and 98 m height above the surface at the boundary layer measuring field of the Meteorological Observatory Lindenberg of the German Weather Service in Falkenberg, Germany. From these quantities the surface albedo was calculated in 2 and 98m above the ground. Furthermore, values of the soil moisture are available. All data are recorded as 10 minutes averages. The radiation measurements are made with Kipp & Zonen pyranometers CM21 and the soil moisture was determined by the means of TRIME-sondes. The short wave upward radiation measured in 2m above the ground is the reflection from a natural surface of grass, which is changing with the seasons, while the upward radiation in 98m height is also influenced by the surrounding area.

In this paper the daily and yearly course of the albedo in both levels is analysed. Furthermore, the investigations of the albedo show a dependence on the soil moisture especially after rain. This is visible mainly in the albedo at the 2m level.