WCRP REPORT
World Climate Research Programme

# SUMMARY REPORT
# FROM THE

# ELEVENTH Baseline Surface Radiation Network (BSRN) Scientific Review and Workshop
## (Queenstown, New Zealand, 13-16 April 2010)

**August 2010**
WCRP Informal Report N° 08/2010

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# 11th BSRN SCIENTIFIC REVIEW AND WORKSHOP

## I. OPENING SESSION

The Eleventh Baseline Surface Radiation Network (BSRN-11) Scientific Review and Workshop was hosted by Dr. Richard McKenzie with the support of Graeme Strang of the National Institute of Water and Atmospheric Research (NIWA) from 13–16 April 2010 In Queenstown, New Zealand. Dr. Ellsworth Dutton, BSRN Project Manager, chaired the workshop that brought together BSRN scientists, station managers, data users, and experts in areas related to BSRN to review the status of BSRN activities, including the latest developments in instrumentation, operational procedures, data management, and quality control; to discuss some of the scientific progress achieved as a result of the availability of the BSRN and its data archive; and to consider future needs and plans for the BSRN.

**Agenda Review, Expectations for the Meeting, and BSRN Overview** (Ells Dutton, National Oceanic and Atmospheric Administration/Global Monitoring Division)

A brief review of the agenda of the agenda was followed by description of the expected outcomes for the meeting. These included a review of the status of network, consideration of newly proposed sites, the advancement of basic observational capabilities, a review of the data archive activities, working group reports and realignment of those groups' charges, an update on the BSRN aerosol optical depth centralized computation activity, the general interactions among the participants, and a spotlight on recent work using BSRN data for long-term variability research. An overview of the status of the BSRN highlighted the following major project accomplishments:

- Satellite product comparisons and validation
- Observational improvements – instruments, techniques, and reference standards
- Climate and radiative transfer model comparisons
- Local/regional radiation climatologies – broad applications
- Substantial data archive accumulated, and archive management is pro-active
- Provides a unique and productive forum for observational radiation scientists

Major challenges facing the network are the needs associated with maintaining existing sites and data accuracy, extending the spatial representativeness of the network, and developing new data quality control measures and products at the data archive. In the area of related research, the major needs identified were further refinement in observational capabilities, evaluation of the various models used to simulate surface radiation quantities, evaluation and understanding of the long-term variability in accumulated data records, and further investigation of the requirements for spectral measurements. All the challenges need to be addressed in the typical environment of poorly- to modestly-funded observational programs, although some opportunities for adequate financial support have been known to appear on occasion. It was noted that the sponsoring international organizations that initially either created or recruited BSRN to fulfill their recognized needs, continue to evolve and focus on their most pressing issues and can sometimes fail to recognize the valuable efforts of existing projects like BSRN. However, BSRN participants can be assured that their efforts continue to serve the needs of the international climate research community. It was also recognized that everyone's contribution to BSRN is a voluntary endeavor and that participants can have other pressing requirements on their time that can prevent them from being as active in BSRN-specific activities as they might prefer. The final point raised in this overview was to review and re-evaluate the pyrgeometer data reduction methodologies as applied within the BSRN program, which was an item that was not on the initial agenda but required some attention. This last issue was addressed by the Pyrgeometer

Working Group and preliminary considerations were covered later in the meeting by that working group's chair.

**Overview of Atmospheric Research in New Zealand** (Richard McKenzie, National Institute for Water and Atmospheric Research - Lauder)

This presentation provided an overview of the organization of science in New Zealand and its history. The focus was on the roles of the National Institute of Water and Atmospheric Research (NIWA). NIWA is organized along the lines of the U.S. National Oceanic and Atmospheric Administration (NOAA), but is more broadly focused. Emphasis was given to the contribution to the work undertaken a NIWA's atmospheric research facility at Lauder, in preparation for the site visit later in the week.

**GEWEX: The Global Water and Energy Cycle Experiment** (Dawn Erlich, International GEWEX Project Office)

An overview of the organization of GEWEX was given and GEWEX Phase I results and Phase II objectives were reviewed. GEWEX is developing a new mission statement and set of imperatives for the post 2013 period, which will be refined at the Second Pan-GEWEX Science Meeting in Seattle, August 23–27, 2010. Also presented were GEWEX data sets and results, including the recent inventory of available global surface latent and sensible heat flux products produced by the LandFlux Project. First results from global, monthly comparisons for the period 1993-1995 indicate that overall geographical patterns are consistent among data sets (dry vs. wet regions), but there exists a large range between data sets in some regions, in particular in tropical rainforest areas.

**An Update from the GCOS Secretariat and Report of Station Renovation Activities** (Richard Thigpen, GCOS Implementation Project Manager)

The new Director of Global Climate Observing System (GCOS), Dr. Carolin Richter, was announced and a brief review was given of recent GCOS activities, such as the Implementation Plan. Some of the activities to improve the operation of the GCOS Surface and Upper Air Networks were described and included direct station renovations, regional technical support projects, and a network of Commission for Basic Systems (CBS) Lead Centers. The GCOS Cooperation Mechanism, the trust fund used by GCOS to fund renovation projects was described and BSRN meeting participants invited to identify potential projects that might improve the operation of some of their stations.

## II. OBSERVATORIES – STATUS AND PROPOSALS

**New BSRN stations in Japan** (Nozumu Ohkawara, Aerological Observatory/Japan Meteorological Agency)

Mr. Nozomu Ohkawara reported that in March 2010, the Japan Meteorological Agency began operation of four new BSRN type stations in Japan (Sapporo, Fukuoka, Ishigakijima and Minamitorishima). The stations are representative of the four climate zones within Japan. Mr. Ohkawara provided an overview of each station, including location, climate, instrumentation, environment and ancillary observations. He requested the approval of the new four stations as official BSRN sites to enrich the coverage by BSRN in Asia and Northwest Pacific.

**Additional BSRN Field Site Reports** (Ells Dutton, NOAA/GMD)

Station reports for several sites' representatives that were unable to attend the meeting were given. Those sites include Izana, Cabauw, Tamanarasset, and the Brazilian Sonda sites. All these sites provided examples of their ongoing BSRN arctivities, which included data analysis and summaries along with model and satellite comparisons. Izana is a new sited added since the last meeting and is providing excellent data from a mountain top in the Canary Islands. Cabauw is a rather unique site with the very tall tower for albedo observations and making extensive radiative model comparisons. The site at Tamanarasset continues to be and outstanding site very advantageously located in the central Sahara and recently added albedo observations. The Brazial Sonda sites nicely fill out the BSRN map in central South America with additional sites proposed as was an additional site in the Canary islands close to Izana but at sea level.

# III. ARCHIVE ACTIVITIES AND DATA QUALITY CONTROL

**Status of the World Radiation Monitoring Center** (Gert König-Langlo, Alfred Wegener Institute)

Since July 2008, the World Radiation Monitoring Center (WRMC) has been hosted at the Alfred Wegener Institute (AWI) of Polar and Marine Research at Bremerhaven, Germany (see *http://www.bsrn.awi.de*). In early 2010, 47 BSRN stations submitted their data to the WRMC. The data import is organized in so-called “station-to-archive files” which contain all the data from one station collected during one month. There have been a total of 5622 station-month data sets from 47 stations available in the WRMC in January 2010 while only nine stations delivered their data in 1992.

All submitted station-to-archive files are read-accessible from any user who accepts the BSRN data release guidelines (see *http://www.bsrn.awi.de/en/data/conditions_of_data_release*/). The files can be obtained via ftp*://ftp.bsrn.awi.de/* by using a web browser or any ftp tool. The access to the public file archive is password-restricted. Read accounts can be obtained from the WRMC (email *Gert.Koenig-Langlo@awi.de*).

An alternative to the ftp access is a data access via the Publishing Network for Geoscientific and Environmental Data, PANGAEA (see *http://www.pangaea.de/*). The information system PANGAEA is operated as an “Open Access” library that is aimed at archiving, publishing, and distributing geo-referenced data from Earth system research. Although individual BSRN data sets can be found by using common search engines (e.g., h*ttp://www.google.com/*) or the specific PANGAEA search engine (*http://www.pangaea.de/*), the most direct access is given via pre-compiled PANGAEA search phrases (see *http://www.bsrn.awi.de/en/data/data_retrieval_via_pangaea/*).

A central quality management system for the WRMC is under construction. The basic idea is altering the data output of the archive but not the data input. A program for data quality flagging will be accessible free of charge and can be used by any WRMC user. The program is supposed to keep the error limits flexible to allow more specific error analysis, depending on the applied instrument, the station environment, and the demand of users.

Atmospheric optical depths (AOD) as well as the corresponding transmission measurements will be included in WRMC PANGAEA-service in the near future. The AOD data will be centrally calculated from submitted transmission data following the proposal from Bruce Forgan.  An updated Technical Plan for BSRN Data Management, including some new parameters such as pyrgeometer temperatures, is under construction.

**WRDC Activities under the GAW Program** (Anatoly Tsvetkov, World Radiation Data Center)

The World Radiation Data Center (WRDC) is one of the World Meteorological Organization (WMO) Global Atmospheric Watch (GAW) data centers for collecting, archiving, and disseminating solar radiation components submitted by national weather and meteorological services. Currently, WRDC operates two databases, one with data archived beginning in 1964 and the other with data from the 227 GAW stations, plus supporting ones. The average resolution for GAW stations is hourly and daily for the conventional stations. Some results of the new QC procedures, based on parametric and non-parametric statistical analysis of time series, were presented. Metadata (station and instruments history) allows more qualified conclusions on the data quality.

**Processing and Analysis of the BSRN Data and Its Application in Validating the GEWEX Surface Radiation Budget Project Release 3.0 Data** (Taiping Zhang, SSAI/NASA Langley Research Center)

As of February 2010, there were 5523 site-months of BSRN data in the archive at *http://www.bsrn.awi.de*. The time intervals of the records are either one-, two-, three- or five-minute. This study focused on the five observed variables: (1) the total shortwave downward flux by the pyranometer (Global 2 flux, G2); (2) direct normal flux; (3) diffuse flux; (4) longwave downward flux; and (5) the sum of direct horizontal and diffuse fluxes (Global 1 flux, G1). The quality-check (based on the methodology of ETH and Long and Shi (2008) was performed on the original BSRN data to remove data points considered in error. Then 3-hourly means were computed that centered on synoptic hours and hours in-between, and daily and monthly means based on local time. The 3-hourly means were computed from hourly means, which, in turn, were computed from 15-minute means. A valid 15-minute mean requires that at least 50% of the records have valid measured values. An hourly mean requires four valid 15-minute means. Daily means were computed from hourly means. Following specified criteria, missing hourly means were interpolated either linearly or based on cosine of solar zenith angle before the daily mean was computed. A daily mean was not computed if there were too many missing hourly means according to the specified criteria. Monthly means were computed from monthly mean diurnal cycles. A valid monthly mean diurnal cycle consists of 24 monthly-hourly means. The minimum number of valid hourly means used to compute the monthly-hourly mean in the monthly mean diurnal cycle can be used as a measure of validity of the concerned monthly mean.

Through the analysis of the BSRN data and the GEWEX SRB-BSRN comparisons, we summarize and conclude:

1.) Up until February 2010, there were 5523 site-months of BSRN data in the archive from 43 of the 47 BSRN sites, the earliest being January 1992 and the latest January 2010;

2.) Quality-flags were produced based on the methodology used at the earlier BSRN site at ETH, and the methodology of Long and Shi (2008), which are then used to determine whether a record is retained or abandoned;

3.) About 20% of the sites show G1-G2 RMS errors above 25 and up to 55 Wm-2. After quality checking, all root mean square (RMS) errors were reduced to below 20 Wm-2. The change in G1-G2 bias errors is not as dramatic except for Llorin, Florianopolis and De Aar;

4.) The site Llorin has problems with Global 1, but its Global 2 and longwave values appear to be with the normal range;

5.) The SRB data shows appreciable disagreement with the Syowa and the Georg von Neumayer site data, in general. However, in the case of daily means without hourly interpolations, their bias and RMS errors become comparable with other sites;

6.) The missing records in the original BSRN observations can considerably increase the uncertainties in both the G1-G2 agreement and the SRB-BSRN agreement. In the case of daily means, as the number of hourly mean interpolations decreases, the SRB-BSRN bias and RMS errors generally decrease as well, which is true for either G1 or G2 or G1-G2 blended;

7.) In the case of monthly means (which are computed from 24 hourly-monthly means), as the percentage of hourly means for computing the hourly-monthly mean increases, the SRB-BSRN bias and RMS errors generally decrease for either G1 or G2 or G1-G2 blended;

8.) SRB-BSRN longwave comparisons show generally very good agreement, and the missing records do not significant effect on the level of agreement.

# IV. BASIC OBSERVATIONS – ANALYSIS AND REVIEW

**Decadal Changes in Surface Radiation Fluxes** (Martin Wild, ETH Zurich)

A recent download of the BSRN archive data (March 2010) showed that there are now already 20 BSRN sites with at least one decade of useful data. An update of trends in surface solar (global) radiation at these BSRN sites to 2009 indicates a slow-down of the brightening after the year 2000 compared to similar earlier analyses published in Wild et al. (2005, *Science*) and Wild et al. (2009, *JGR*).

With the recently available satellite data set Clouds and the Earth's Radiant Energy System (CERES) instrument Energy Balanced And Filled (EBAF) data sets it is now possible to build a "roof" for BSRN data starting from 2000 (i.e. to have observational estimates on the radiative fluxes at the top-of-atmosphere collocated with surface radiation sites). The combination of surface shortwave (SW) absorption [calculated from BSRN data and surface albedo from the (Moderate Resolution Imaging Spectroradiometer-MODIS)] and the CERES top-of-atmosphere (TOA) SW absorption, allows the determination of atmospheric column SW absorption above the BSRN sites, and an estimation of partitioning between surface and atmospheric absorption. The combination of BSRN observations with satellite TOA observations will also allow a better identification of origins of trends in surface solar radiation, so that we can start looking at the full 3-dimensional picture of radiation changes, covering surface, atmospheric and TOA changes. The majority of the longwave BSRN records show an increase, as expected from greenhouse theory, but are seldom significant at individual sites. Yet the overall change of +0.3 Wm-2$y^{-1}$ is surprisingly close to climate model projections.

**Trend Analysis of Down-Welling Long-Wave Radiation from the BSRN Site Payerne and from Four Stations of the Alpine Surface Radiation Budget (ASRB) Network** (Stefan Wacker, PMOD/WRC)

A long-term trend analysis of cloud-free down-welling long-wave radiation calculated from four stations of the Alpine Surface Radiation Budget in Switzerland was performed. Cloud-free situations have been selected applying the partial cloud amount criteria to the individual ten minutes measurement periods. Observations with a partial cloud amount less or equal to one were attributed to cloud-free situations. The cloud-free monthly data set was analyzed using nonparametric statistical methods that take the serial correlation and the interaction between the serial correlation and an existing trend into account. Cloud-free down-welling long-wave radiation has been increasing over Switzerland, on average by about 3 Wm-2 $dec^{-1}$. Monthly trends revealed negative trends in winter, whereas the trends showed for all stations an upward tendency in summer except in August. The longwave trends are consistent with the corresponding temperature and humidity trends. Using a modified cloud-free longwave parameterization of Brutsaert, which parameterizes the longwave radiation with respect to surface temperature and humidity, allowed the estimation of the relevant radiative forcing components. Results indicate that more than 50% of the observed longwave trends are temperature and humidity induced. Less than 10% are caused by rising $CO_2$ concentrations. There is some clear evidence that the remaining longwave trends must be due to changes in the cirrus cloud cover in some single months. The data propose a decrease of cirrus clouds south of the Alps and an increase north of the Alps. Shortwave data are generally consistent with the described changes in the cirrus cloud cover derived from the longwave trends.

**Aerosols and Global Dimming** (Ben Liley, NIWA – Lauder Station)

Aerosol optical depths (AOD) measured over the Lauder BSRN station in Central Otago, New Zealand in 1996-1997, and continuously since 1999, have mean values amongst the lowest observed worldwide. The Lauder measurements show a seasonal cycle in AOD with a winter minimum and summer local maximum, and there is a springtime peak that is more variable. There was an insignificant downward trend in mean AOD over the period 1999-2008.

Global dimming and brightening in the New Zealand region is apparent in pyranometer data from four long-term sites; they show a downward trend up to 1990, with a reversal at three of the sites after that time. Attribution to the direct aerosol effect is uncertain from clear-sky vs. all conditions, but Lauder AOD data are too low for this to be a substantial component. A comparison with much longer records of sunshine hours throughout New Zealand shows that there was a trend of increasing cloudiness to around 1990, and a decline since then, consistent with the global pattern.

LIDAR observations of aerosol backscatter at 532 nm over Lauder from November 1992 to February 2009 provide a uniform data record since the Pinatubo aftermath. The upper tropospheric AOD from LIDAR shows an annual spring maximum that correlates with BSRN data, and supports the inference that the aerosols are of remote origin. From a minimum around 2000, the stratospheric aerosol column has increased at a rate of around 4% per year.

**A Closer Look at Dimming and Brightening in China During 1961-2005** (Xiangao Xia, LAGEO, Chinese Academy of Sciences)

This study investigates dimming and brightening of surface solar radiation (SSR) from 1961-2005 in China as well as its relationships to total cloud cover (TCC). This is inferred from daily ground-based observational records at 45 pyranometer stations. A statistical method is introduced to study contributions of changes in the frequency of TCC categories and their atmospheric transparency to the secular SSR trend. The surface records suggest a renewed dimming beyond 2000 in North China after the stabilization in the 1990s; however, a slight brightening appears beyond 2000 in South China. Interannual variability of SSR is negatively correlated with that of TCC, but there is a positive correlation between decadal variability of SSR and TCC in most cases. The dimming during 1961-1990 is exclusively attributable to decreased atmospheric transparency, a portion of which is offset by TCC frequency changes in Northeast and Southwest China. The dimming during 1961-1990 in Northwest and Southeast China primarily results from decreased atmospheric transparency under all sky conditions and the percentage of dimming stemming from TCC frequency changes is 11% in Northwest and 2% in Southeast China. Decreased atmospheric transparencies during 1991-2005 in North China in most cases lead to the dimming. TCC frequency changes also contribute to the dimming during this period in North China. This feature is more pronounced in summer and winter when TCC frequency changes can account for more than 80% of dimming. In South China, increased atmospheric transparencies lead to the brightening during 1991-2005. A substantial contribution by TCC frequency changes to the brightening is also evident in spring and autumn.

## V. INSTRUMENT SPECIAL REPORTS

**Infrared Irradiance Calibration Activities at the World Radiation Center, PMOD/WRC** (Julian Gröbner, PMOD/WRC)

Two Infrared Integrating Sphere (IRIS) Radiometers have been operating beside the World Infrared Standard Group (WISG) pyrgeometers at the Physikalisch-Meteorologisches Observatorium Davos PMOD/World

Radiation Centre (WRC) since November 2008 and October 2009 respectively. The IRIS radiometers are calibrated for longwave irradiance using the PMOD cavity and serve as transfer standards for atmospheric longwave irradiance.

The stability of the IRIS-1 Radiometer was found to be within ±0.3% over the current measurement period with an estimated uncertainty of 1.6 $Wm^{-2}$ in longwave irradiance measurements. Between October 2009 and March 2010 both IRIS Radiometers have shown an excellent agreement of 1.1 $Wm^{-2}$ and a standard deviation of 0.5 $Wm^{-2}$ during nighttime measurements. Even though the WISG has shown an internal consistency of 1 $Wm^{-2}$ since January 2004, all WISG pyrgeometers show systematic dependencies of up to 6 $Wm^{-2}$ with respect to the IRIS radiometers, with increasing differences occurring in drier atmospheres at a lower integrated column water vapor. These observations are consistent with International Pyrgeometer Comparison (IPASRC-I) and IPASRC-II campaigns that also showed similar differences between humid and dry atmospheres. Investigations of specific pyrgeometers indicate that the spectral transmission functions of the silicon domes protecting the thermopiles are responsible for this behavior. Ongoing work at PMOD/WRC is aimed at securing the IRIS radiometers to become transfer standards for atmospheric longwave irradiance and thereby replacing the conventional WISG reference by a group of IRIS radiometers providing direct traceability to the SI unit $Wm^{-2}$ realized in well-characterized cavities.

**Direct Beam Comparison (Various Conditions Pyrheliometer Comparison-VCPC)** (Joe Michalsky, NOAA/OAR and Tom Stoffel, National Renewable Energy Laboratory)

Thirty-three commercially available or modified pyrheliometers were compared over a 10-month period from November 2008 to September 2009 at the National Renewable Energy Laboratory in Golden, Colorado, USA. Three of these were windowed cavity radiometers whose average was compared to each of the other commercial pyrheliometers in the study. On a monthly basis, all pyrheliometers, including the windowed cavities, were calibrated using four open cavity radiometers. The purpose was to compare the performance of various types of pyrheliometers, represented by a triplet of a given type of instruments, relative to a best possible reference group of measurements under all atmospheric conditions, Differences of each pyrheliometric, 1-minute measurement from the average of the three windowed cavities revealed clear agreements among the pyrheliometer triplets and clear distinctions among the different types. Three types showed similar and larger deviations; four types showed similar and smaller deviations; all prototypes, for which only single instruments were included, fell into one of these two categories except for two clear outliers; and the smallest deviations were among the cavity radiometers. Uncertainties of these three categories are roughly 0.5% absolute for the windowed cavities, 0.7% for commercial pyrheliometers showing the smaller deviations, and a still respectable 1.4% for the largest deviating pyrheliometer types. The outliers are not considered in this estimate of uncertainty.

**Correcting for Tilt in Aircraft and Ocean Shortwave Observations Using the Diffuse to Direct Ratio** (Chuck Long, Pacific Northwest National Laboratory)

Downwelling shortwave (SW) measurements made on moving platforms are negatively impacted due to the continuously changing tilt from horizontal of the measuring instruments. Using a newly available radiometer (SPN-1) that makes reasonable simultaneous measurements of downwelling total, diffuse, and direct SW regardless of azimuthal orientation with no moving parts, a methodology has been developed to correct the data for tilt from horizontal. The methodology corrects 90% of the data to within 10 $W/m^2$ for tilt from horizontal up to +/- 10 degrees. There is a need for long-term accurate surface measurements representing all areas of the globe to document climate change. Yet over two-thirds of the Earth's surface is oceanic, where long-term measurements are most practical using buoys which are highly prone to tilt errors. The development of the new SPN-1 radiometer along with the technique for tilt correction now opens a real possibility for producing the needed long-term accurate measurements over the world's oceans.

## VI. WORKING GROUP REPORTS

**Infrared Working Group** (Julian Gröbner, PMOD/WRC)

The Infrared Working Group was not active as a group during the past two years. However, significant work has been done by individual members of the group in collaboration with other BSRN members. Thus, investigations on Eppley pyrgeometer characterizations in cavities demonstrated the importance of differential heating of the body and dome to retrieve the dome-body factor with low uncertainties. Furthermore, a variety of pyrgeometer equations were applied to the cavity measurements in view of improving the current pyrgeometer radiometric model used by the BSRN community. Comparisons of pyrgeometer characterizations have been carried out between several laboratories (PMOD, JMA, NREL) and have shown very good agreement in retrieving the coefficients of the PMOD equation in some cases. The work topics to be addressed in the coming period within the IR WG will be to propose an improved pyrgeometer equation to be used as BSRN reference and to continue with bi-lateral comparisons of black-body cavities operated by various groups within BSRN. As a third topic, the influence of solar radiation on longwave irradiance derived from shaded and unshaded pyrgeometers will be investigated.

**AOD Working Group Report** (Bruce W. Forgan, WG Chair, Bureau of Meteorology)

Significant progress has been made in the spectral transmission archive since the BSRN Meeting held in July 2008. Since modification of the submission format in September 2008, and the initial submissions received in February 2009, 16 stations have either provided test data or submitted several monthly submissions. To date over 1400 station-months of successful submissions have been made and Aerosol Optical Depth (AOD) products derived.

The initial submissions were very beneficial in establishing the data checking protocols prior to processing for AOD products. Currently, checks on station level pressure, apparent solar zenith distance, and transmission limits have highlighted some differences in station processing methodologies, particularly for zenith distance calculations. As a result, it has been recommended that station managers utilize the solar-position algorithms available in the World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation (CIMO) Guide, Chapter 7, or algorithms similar to that available from US Department of Energy National Renewable Energy Laboratory (NREL) (spa formulation). Regardless of the source it is essential that once implemented, the algorithms are checked against primary verification sources like the Nautical Almanac.

The Alfred Wegener Institute for Polar and Marine Research (AWI) and the AOD WG are developing a methodology so that the transmission and derived 'BSRN' AOD products can be incorporated into the PANGEA information system. It is expected that this will be under trial before the end of 2010. A by-product of BSRN processing will be the ability to produce AOD statistics files in a form suitable for transmitting to the GAW aerosol database. Data submitters to the BSRN transmission archive have been asked to indicate whether they want their data to be submitted by the BSRN into the Global Atmosphere Water (GAW) aerosol database.

**Spectral Working Group Report** (Joseph Michalsky, NOAA/Office of Oceanic and Atmospheric Research)

Members contributing to this report were Alex Manes, Laurent Vuilleumier, Rachel Pinker, and Joseph Michalsky. Alex's report brought our attention to three papers; the first one was "Intercomparison of erythemal broadband radiometers calibrated by seven UV calibration facilities in Europe and the USA" by Hülsen et al. in Atmospheric Chemistry and Physics 2008. The authors showed that the laboratories are able to provide spectral and cosine characterizations, and corrections for ozone column and solar zenith angle for broadband sensors to estimate erythemal to about 5% with one exception. A WMO report (TD-1289) by G. Seckmeyer et al., “Instruments to measure solar ultraviolet radiation: Part 2: Broadband instruments measuring erythemally weighted solar irradiance,” clearly outlines the specifications that should be adhered to for broadband sensors that are used to measure erythemal irradiance. The third is a WMO report (TD-1454) by Johnsen et al., “Intercomparison of global UV index from multiband filter radiometers: Harmonization of global UVI and spectral irradiance,” which describes the results of comparing narrowband UV instruments that are used to estimate the UV index (UVI). The outcome was production of UVIs that are as much as 12% off in the worst case. Using a multivariate regression approach for all of the UVI-sensitive channels, the UVIs can be made to agree within a couple of percentage points. Rachel Pinker presented a plot of Photosynthetically Active Radiation (PAR) as estimated from the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments. One plot showed the PAR product developed at the University of Maryland in collaboration with NASA Langley. The PAR measurements made by SURFRAD at the surface were compared to the satellite estimates in another. While the results were satisfactory, she felt that there were still too few sites measuring PAR for a thorough validation of the satellite data.

**Measurement Uncertainties Working Group** (Bruce W. Forgan, Bureau of Meteorology)

While there has been little activity directly related to the Working Group, several external factors have strengthened the need to increase derivation of uncertainties for BSRN observations. These include:

1. Memorandum of Understanding between the International Organization for Standardization (ISO) and the World Meteorological Organization (WMO) on standards application and dissemination;
2. the Mutual Recognition Arrangement between the International Bureau of Weights and Measures, France (BIPM) signed in April 2010; and
3. the recent BIPM and WMO co-sponsored meeting on meteorological observation traceability; and extensions to the ISO Guide to the Expression of Uncertainty in Measurement on utilization of the law of propagation of distributions (LPD).

Two examples were presented showing the application of the LPD to estimating uncertainties in daily solar exposure estimates from geostationary satellite imagery, and modeling the impact on missing daily exposure data when calculating annual average solar exposure.

Two recommendations were presented:

a) Continue with the Uncertainty Working Group but more with a watching brief; and
b) Invite a meteorologist from a relevant national measurement institute (e.g. NPL, PBT, NIST, etc.) to the next BSRN meeting.

**Cold Climate Issues Working Group** (Chuck Long, Pacific Northwest National Laboratory)

A summary of the progress and description of measurement issues associated with operating in cold climate regimes was given. It was noted that indications of global warming are expected to be most noticeable in the polar regions. Detecting these indications requires accurate long-term radiation measurements, but the cold climate regime is perhaps the most difficult and harsh in which to make these measurements due to difficulties associated with adverse frost, riming, and snow influences on the instruments and measurement systems. Several studies have been or are underway to investigate possible ways to mitigate these adverse effects, but to date there has been no definitive answer. Under the auspices of the BSRN Cold Climate Issues Working Group, work will be continuing in the hopes that in the future perhaps some recommendations can be made to the community on successful methods for dealing with the adverse situations encountered in cold climate regimes.

**Long Term Data Sets Issues and Analysis Working Group** (Martial Haeffelin, LMD/IPSL/CNRS, Ecole Polytechique)

Participants at BSRN 2010: J. Badosa (U. Girona), K. Behrens (DWD, D), J. Gröbner (PMOD, CH), M. Haeffelin (IPSL, F; Chair), C. Long (PNL, USA), R. McKenzie (NIWA, NZ), N. Ohkawara, (Kishou Met), L. Vuilleumier (MeteoSwiss), S. Wacker (PMOD, CH), M. Wild (ETH, CH), T. Zhang (NASA, USA)

Objective: To list what topic the LTWG would like to address in the next 2 years
Discussion topics
1. Quality Control:
- LTWG feels that QC flags must be associated with BSRN data
- Recommend that QC flags be "re-introduced" quickly in the database
- Extensive work on QC already exist (e.g. Taiping Zhang or Chuck Long)

2. Error bars:
- Error bars are missing in many analyses
- Requires in depth uncertainty analysis (e.g. Bruce Forgan)

3. How to?
4. Numerical routines (fortran, C, Matlab)

Series of actions to disseminate know-how: half page reviews + references
1. Recommended methods to compute monthly means (M. Wild)
2. Practical methods for robust linear fitting (C. Long)
3. Procedure to handle non normally distributed radiation data (B. Liley)
4. Steps to remove auto-correlations in trend analysis (S. Wacker, J. Gröbner)
5. Report on techniques developed by B. Weatherhead to help detect trends in radiation data (T. Zhang)
6. Added benefit of using relative values (e.g. measured SW/parametrized clear-sky SW) in long-term analyses (C. Long)
7. Added benefit of using weather regimes in variability and trend analysis (M. Haeffelin, C. Long)
8. Recommendation of Metadata required to analyze historical data (N. Ohkawara)
9. List available useful routines in Matlab (J. Badosa)

## VII. CLOUDS AND AEROSOLS

**GAW-PFR Network and Its Calibration** (Christoph Wehrli, PMOD/WRC)

The World Optical Depth Research and Calibration Centre (WORCC) operates a network of Precision-Filter-Radiometer (PFR) sunphotometers at 12 global stations. Over the last two years nine additional sites in Europe and Antarctica have joined this network as associated stations. Raw measurements from the instruments are collected and processed at WORCC on a daily basis and made available as quick-look plots at *http://www.pmodwrc.ch/worcc*. A total of about 1250 station-months have been collected since 1999. Quality assured data are available from the World Data Center for Aerosols (WDCA) (*http://wdca.jrc.it*), which was moved to *http://ebas.nilu.no* in January 2010. Numerical aerosol optical depth values will become available from Norwegian Institute for Air Research (NILU) for assimilation and validation of weather forecast and chemical transport models.

Instrument calibration within the Global Atmosphere Watch (GAW) Programme - Precision Filter Radiometers (PFR) network is traceable to a Triad of reference instruments maintained at WORCC. Internal monitoring and external validation of the Triad indicate an uncertainty of slightly better than one percent over a period of several years.

**Explaining the Seasonal Variation of Multi-Filter Rotating Shadowband Radiometer In Situ Calibrations** (John Augustine, NOAA Global Monitoring Division)

A recurring seasonal periodicity of about ±4% has become obvious in the Langley calibrations of the visible Multi-Filter Rotating Shadowband Radiometer (MFRSR) used for, among other things, the determination of spectral aerosol optical depth. This effect has been seen in all channels, all MFRSR instruments, and at all stations, which indicates that the phenomenon is inherent in the instrument design. The MFRSR head is supposed to be stabilized at 40°C, but head temperature data show that the MFRSR head is not well stabilized. For example, at the Table Mountain Station environmental temperatures ranged from –10°C to over 30°C over a 4 year period and the measured head temperature ranged from 34°C to 40°C. Based on the relative positions of the electronics (amplifiers and feedback resistors) and detectors inside of the head, it was determined that the electronics are not thermally stabilized, but the temperature of the detectors is well controlled.

A laboratory experiment was set up to investigate the temperature sensitivity of the MFRSR head. Several MFRSR heads were tested in an environmental chamber with heating and cooling capabilities. A stable FEL lamp was used as the light source. The temperature of the chamber was ramped up and down from –10°C to 45°C while channel signals were measured. Dark signals (measurements without the light source) showed signal variations with temperature that were consistent with variations in field in situ calibrations, i.e., low signals at low temperatures and higher signals at higher temperatures. This behavior indicates that the thermal response of the electronics in the MFRSR head is the source of the seasonal variation of Langley calibrations. MFRSR channel signals for the constant FEL light source also show the same temperature dependence. Not accounting for this thermal sensitivity produces AOD errors of about 0.04.

A newly designed MFRSR with better thermal stabilization was used to examine temperature effects on the MFRSR Spectralon diffuser. Those experiments showed that structural changes of Spectralon across 19°C cause a 2% change in transmission for all channels. This transmission change during a Langley calibration can produce a maximum error in AOD of 0.004.

Last, we looked at whether the thermal response of the MFRSR had a “cosine” effect. MFRSR head placement was at normal incidence to the light source for most of the chamber experiments. Measurements for head tilts of 60° and 80° showed no difference compared to results determined at normal incidence, which indicates that our experimental results apply to in situ measurements used for Langley calibrations, which are made between 60° and 80° solar zenith angles.

**The Glory of Radiation: Multi-Angle Polarized Remote Sensing of Clouds, Aerosols, and Surfaces** (Mikhail D. Alexandrov, Department of Applied Physics and Applied Mathematics, Columbia University)

An overview of retrieval capabilities of a space/airborne multi-angle polarimetric sensor based on the data analyses from the Research Scanning Polarimeter (RSP) was presented. This instrument is an airborne prototype for the Aerosol Polarimetry Sensor (APS), which is due to be launched in 2010 as part of the National Aeronautics and Space Administration (NASA) Glory Project. RSP measures both polarized and total reflectance in 9 spectral channels with center wavelengths of 410, 470, 555, 670, 865, 960, 1590, 1880 and 2250 nm. This is a push broom sensor (scans along track) recording 152 scenes within 60 degrees from the normal with 1 degree resolution. The measured Stokes parameters allow for retrievals of a number of cloud and aerosol properties, as well as the ground surface characteristics.

An algorithm for retrieval of cloud droplet size distribution parameters (effective radius and variance) from RSP measurements of the polarized rainbow (in the 140 - 170 degrees scattering angle range) was described. The shape of the rainbow is determined mainly by single scattering properties of the cloud particles. Thus, cloud retrievals from RSP data are just as accurate over land as over ocean (no surface albedo issues), and are independent of the optical depth (i.e., work for common low water path clouds). The algorithm's performance is illustrated by the results from two recent field campaigns: the Coastal Stratocumulus Imposed Perturbation Experiment (CSTRIPE, 2003) and the Routine AVP CLOWD (Clouds with Low Optical Water Depths) Optical Radiative Observations (RACORO, 2009). Our retrievals are consistent with the correlated in situ measurements of cloud droplet sizes made during these campaigns.

Aerosol retrievals from RSP data include optical depth, particle size distribution, and complex refractive index. These retrievals are made jointly with derivation of the surface characteristics, such as chlorophyll concentration in the ocean or bidirectional reflectance of the land. In particular, polarized reflectance of the land is spectrally invariant even over complex natural and urban scenes, thus allowing for accurate retrievals of aerosol properties. Aerosol retrievals over clouds utilize the polarized reflectance at side scattering angles (away from the rainbow). Typical accumulation mode aerosols generate significant polarization at 865/670 nm. These aerosol retrievals also improve cloud top pressure estimates.

**Detection of the Occurrence and Impacts of Island Influence on Nauru ARM/BSRN Measurements** (Chuck Long, Pacific Northwest National Laboratory)

The small island of Nauru hosts a U.S. Department of Energy Atmospheric Radiation Measurement (ARM) measurement site that is intended to represent the larger surrounding oceanic area and is a BSRN contributing site. However during a field campaign there in 1999, it was noted that the island land mass is sometimes producing clouds that, depending on the wind direction, could travel over the ARM site and bias the measurements away from that of the surrounding oceanic area. A subsequent experiment developed the means to identify when a Nauru island influence on the ARM measurements was occurring, and a simple separate downwelling shortwave (SW) site was established on the southern side of the island in September of 2005. Using data from 2005-2009, an analysis of the frequency of an island influence, and the corresponding impact on the ARM site measurements of cloud frequency and downwelling SW, was presented. In summary, an island influence occurred on average during 11% of the daylight hours, increasing the low level cloud occurrence by 15-20% in the 500 to 1000 m height layer, and decreased the downwelling SW amount by 20% compared with non-influenced times. A data set that includes a 1-minute resolution flag whether an island influence is occurring will be made available through the ARM Archive, and could conceivably be included as information given out through the BSRN Archive.

**Cirrus cloud radiative forcing on surface-level shortwave and longwave irradiances in cloudy and quasi clear-sky situations** (M. Haeffelin and J-C. Dupont, Institut Pierre et Simon Laplace, Ecole Polytechnique/UVSQ/CNRS, France; and C. Long, Pacific NW National Laboratory, Richland WA, USA

Data collected at four ground-level sites are analyzed to determine the surface cloud radiative effect (CRE) induced by cirrus clouds at regional scale for shortwave (CRESW) and longwave (CRELW) fluxes. Cloud radiative effects are determined by subtracting parametrized clear-sky fluxes derived from measured all-sky fluxes. Sensitivity of surface CRESW to cloud optical thickness (COT) modulated by solar zenith angle and atmospheric turbidity (noted CRESW*) and sensitivity of surface CRELW to infrared emissive power of cirrus cloud modulated by water vapor content (noted CRELW*) are studied. The average CRESW* is −120 W $m^{-2}$ $COT^{-1}$ but it ranges from −80 to −140 W $m^{-2}$ $COT^{-1}$ depending on the solar illumination with a residual variability ranging from +40 and −40 W $m^{-2}$ $COT^{-1}$ from pristine to turbid conditions, respectively. The CRELW*, that corresponds to the infrared transmissivity of the atmosphere, ranges from 3% to 40% from dry to wet atmospheric conditions, respectively. The subvisible cirrus class (COT<0.03) over mid-latitude sites, that represents 20% of the population, induces a significant increase in surface LW irradiance at the 2–7 W $m^{-2}$ level. The semi-transparent cirrus class (0.03<COT<0.3), that represents 45% of the population, affects the surface SW irradiance by −12 to −25 W $m^{-2}$. Finally, by combining SW, LW and LIDAR measurements, we find that situations typically classified as clear-sky in irradiance analyses, may contain high-altitude cirrus clouds. These cirrus clouds detected by the LIDAR in “quasi” clear-sky situations belong to the semi-transparent (50%) and subvisible (50%) classes.

**Radiation Regime and Cloud Characteristics of the East Antarctic Plateau as Derived from a 4-Year Record from Dome Concordia** (Christian Lanconelli, ISAC-CNR)

The Italian-French station of Dome Concordia (C) located at 75°S and 3200 m on the East Antarctic Plateau has hosted a BSRN basic set of instruments since January 2006. The implementation of measurements of the extended upwelling component was installed during April 2007. An automatic quality control of downwelling longwave (LWD) radiation, based on the BSRN community recommendations, was developed. After an additional manual check of monthly files, the quality checked data were submitted to the network (currently updated to February 2010). The overall amount of data received from Dome C every month is likely to be more that the 90% of the total data, and greater than 95% for all the SW components if daylight time is assumed as a reference. Nevertheless, a long tracker failure period (August 2007 to January 2008) was reported. Data logger failures occurred in April 2008 and 2009, producing a loss of approximately the 40% of the data for those months.

The quality checked data fraction appears to be excellent in respect to the physical possible limits (PPL) and good in respect the extremely rare limits (ERL), the LWD component being the one with the greater failure in lower ERL, which is likely to be related to the extremely cold and dry climate of Dome C. The 4 year period was analyzed in order to continue using the same procedure for the whole dataset (including tracker failure periods), using an algorithm derived from the SW clear identification algorithm (Long and Ackermann, 2000) and the clear sky parameters of the equation $Y=A*\cos Z^b$ from global radiation. Average values for parameter A and B are 1405±51 and 1.15±0.03 respectively, and they appeared to be comparable with those obtained for the Georg yon Neumayer station (GvN) Antarctic Coastal Station using the same algorithm.

Using daily parameters for the definition of the clear sky irradiance curves, the cloud effect SWDE on the downwelling shortwave global component and the cloud apparent transmittance T were calculated and averaged on a monthly base (from October to March for all campaigns). The average of SWDE over the 4-year period is $-9 \pm 7$ W/m$^2$, with monthly values variable between -20 W/m$^2$ and 0; any temporal tendency was observed. The apparent transmittance varies between 0.9 and 1.0 with an average value of 0.96±0.03 for the period considered (October to March), as typical for cirrus clouds.

Upwelling SW and LW components, measured since April 2007, are going to be included in the archive as the L0300 logical record. In this framework the net radiation balance RN, defined by the sum of all the four components SWD + LWD - (SWU+LWU), was calculated. Its monthly averages were observed to vary between -50 W/m$^2$ during winter periods, to some positive but lesser absolute values during the summer months (November-February).

A seasonal behavior of the atmospheric effective emissivity was also reported to vary between 0.4 (summer) and 0.65 (winter) for clear sky cases. Higher values for wintertime are likely related to the strong surface inversion present throughout the year excluding January and December.

## VIII. UV, ALBEDO, AND SPECIAL APPLICATIONS

**Ultraviolet Radiation Index Research in New Zealand** (Richard McKenzie, NIWA – Lauder)

An overview of the wide range of ultraviolet radiation (UV) research activities undertaken by NIWA, especially at Lauder, was given. Included were the science of ozone depletion and its effects, and the effects of other atmospheric and terrestrial variables. Other aspects include quantifying health effects of UV (both positive and negative); outreach such as providing UV information to the public through the media, the Internet, and instrumentation; and finally the provision of policy advice for public health messages. For more details, see *http://www.niwa.co.nz/our-services/online-services/uv-and-ozone*.

**Estimation of Cloud Effect on UV Erythemal Irradiance Using SW Irradiance Data** (Laurent Vuilleumier, Meteo Swiss)

The application of radiative transfer models (RTMs) for estimating ultraviolet radiation (UV) for time periods and locations where no observations are available leads to good results for clear-sky situations, whereas the treatment of cloudy situations is far more difficult. A UV reconstruction method based on modeled clear-sky radiation and cloud modification factors derived from observed total shortwave irradiance (SW) was developed to address this. Relationships between the cloud effects on UV and SW radiation were investigated for their dependencies on different environmental effects and climate conditions using measurements from four stations in Switzerland (Payerne, Davos, Jungfraujoch, and Locarno-Monti). The method captured the short-term variability caused by changing cloud coverage and demonstrated good agreement with observed UV during an approximately 1-year validation period, which confirms that it performs well in different climate regions in Switzerland without further adaptations. Root mean square differences (RMSs) between 4.5 and 7.2 mW/m$^2$ (9.7-12.1%) were found for 10 minutes' data, and for estimated daily doses the RMSs were smaller than 8.5%.

The derived relationship was used for reconstructing UV radiation at the four stations for the time period 1981 and 2007 and establishing a climatology of UV radiation at locations representative of different climate regions in Switzerland. This allowed an analysis of the evolution of the reconstructed UV time-series. Positive decadal trends for the median daily UV values between 5.6-11.5% were found for January to June, with the largest relative changes for March, while in May and June, the absolute increase in the UV-index over the last 27 years was between 0.54 and 0.85 units.

The temporal evolution of observed SW radiation and total ozone was identified as being statistically insignificant for most stations and months. Thus, the significant increase of UV radiation found at most stations in January to June results from the combination of mainly non-significant increases of SW radiation and reductions of ozone. On the other hand, a statistically significant decrease in regional snow cover could somewhat offset the effects from SW and ozone changes.

**UV Measurements in the Centre of the East Antarctic Plateau** (B. Petkov, V. Vitale, C. Lanconelli, M. Mazzola, M. Busetto, A. Lupi, ISAC-CNR)

The results of total ozone and surface UV irradiance variations at Dome Concordia Plateau station registered by the narrow-band filter radiometer UV-RAD during a three-year period has been presented. Developed at the Institute of Atmospheric Sciences and Climate (ISAC-CNR, Bologna, Italy), the radiometer measures the solar global UV irradiance at ground level within seven channels peaked at 300, 306, 310, 314, 325, 338 and 364 nm, respectively. Each channel, containing a narrow-band interference filter and corresponding pass-band components, presents a full width at half maximum (FWHM) varying between 0.7 and 1.0 nm. To evaluate the ratio of irradiance at two wavelengths for which the ozone presents a different extent of absorption, the total ozone amount is extracted, using a look-up table computed by the radiative transfer model. The UV-RAD measurements allow for the reconstruction of the surface UV spectrum, fitting the calculated by means of the radiative model (TUV in the present case) spectrum, where the total ozone is inserted as an input parameter and assuming FWHM=0.8 nm, to the measured irradiance. After that, the biological weighted doses together with the UV-Index can be assessed. Several intercomparison campaigns performed during the past 5 years, after UV-RAD had been calibrated through comparison with the Bentham spectroradiometer, confirmed the good quality of the instrument.

The UV-RAD was based at Concordia station in the austral spring of 2007. The total ozone extracted from the UV-RAD data showed a large variability during the springs of 2007-2009, presenting amplitudes of 100-140 DU. At the same time the comparison with data from the ground-based SAOZ and OMI satellite instruments indicates a difference, reaching about ±20% with respect to the first dataset and an overestimation of no more than 15% with respect to the second. The quite stable values ranging between 280 and 320 DU took place during the summer period, when the comparison with the OMI data showed a good agreement ( $\geq 5\%$).

In some cases, the summer daily erythemal doses evaluated through the UV-RAD data exceeded 6 kJ $m^{-2}$, a higher value than the corresponding one registered at Bologna, Italy by the same type of instrument. A comparison of the erythemal doses assessed at the Concordia station with those evaluated at the Ny-Ålesund Arctic station, where an UV-RAD has operated from 2008, highlights the impact of the clouds, which are able to significantly reduce the erythemal dose. The results show that at the Concordia station the summer level of daily erythemal dose is higher than the corresponding Ny-Ålesund levels by a factor between two and three.

The analysis of UV-B irradiance variations, presented by 306 nm irradiance time-patterns during the 2008 and 2009 austral springs, showed a strong dependence on the total ozone amount behavior within the same period. The UV-A band, represented by 364 nm wavelength irradiance, was found to depend mainly on cloud cover conditions.

**Evaluation of Radiometers in Full-Time Use at the U.S. National Renewable Energy Laboratory** (Tom Stoffel, National Renewable Energy Laboratory)

An evaluation of the relative performance of the complement of pyrheliometers and pyranometers deployed at the National Renewable Energy Research Laboratory (NREL) Solar Radiation Research Laboratory (SRRL) was conducted. The evaluation represents a limited sample of instruments (usually one) from various manufacturers, and thus should not be viewed as a representative of a specific manufacturer or model of instrument, but only of the instruments at hand for the evaluation. Reference irradiances for direct normal, diffuse horizontal, and global horizontal are compared with the data from 12 pyranometers, three pyrheliometers, and two shaded pyranometers in full-time use at SRRL. Data at one-minute intervals were retrieved from the SRRL Baseline Measurement System (*http://www.nrel.gov/midc/srrl_bms*). Data from other radiometers were used to assess the reference data quality prior to the comparisons with the test instruments. Data for 12 months were used for the analysis, except for a few test instruments installed after the beginning of the test period. No explicit conclusion about instrument performance is offered, as the experiment was aimed at a very general array of applications with a wide range of instrumentation and accuracy requirements.

The study shows that for radiometers installed and operated at SRRL, for pyranometer data based on a single calibration factor (sometimes in combination with corrections for cosine response and thermal offsets) there is agreement to better than five percent for solar zenith angles in the range of 30º to 60º on a one-minute basis. Averaging (hourly, daily totals and averages, monthly mean and annual mean daily totals) helps cancel some of the random variability between instruments. There are differences (up to ±2%) in the responsivity of pyrheliometers from the two models under analysis. Thermopile pyrheliometers used in this study exhibited ±2% differences when compared with electrically self-calibrated absolute cavity radiometes traceable to the World Radiometric Reference. A copy of the full NREL report is available at *http://www.nrel.gov/docs/fy09osti/44627.pdf*.

**Solar Resources for Photovoltaic Variability** (Tom Stoffel, National Renewable Energy Laboratory)

A rapidly growing number and the increasing scale of photovoltaic (PV) system deployments has created a commercial need for high-resolution solar radiation data. Existing national solar resource climatologies are limited to about a decade of data representative of hourly variations over 10 km x 10 km regions. Current and future PV designs and operations will benefit from solar radiation data with one to five second temporal resolution and site-specific (microscale) to a few hundred meters spatial resolution.

Preliminary results were provided related to developing a simple measurement system for monitoring the spatial variations of global irradiance over a 1 km x 1 km area in Oahu, Hawaii. Data were collected at one-second intervals from 17 pyranometers and a rotating shadowband radiometer. Such data are planned for developing and validating new solar forecast methods that are needed for electric utilities to operate their mix of generation options that will include PV systems. Forecasts of solar irradiance (PV module plane-of-array, direct normal, global horizontal, etc.) will be used as input to models to simulate PV and concentrating solar power systems electrical power generation.

**Variability of Total, White and Black Sky Spectral Albedo at US-DOE Atmospheric Radiation Measurement Facility** (Gary Hodges, NOAA/ESRL/GMD)

We explore the variability of spectral albedo, including the breakdown of the white and black sky components, using data collected at the Atmospheric Radiation Measurement Program (ARM) facility located in north central Oklahoma. Black sky albedo is the reflectance of the surface from direct beam illumination only, and is a function of solar zenith angle. White sky albedo lacks a direct component and is independent of solar zenith angle. The instruments used for this analysis are lamp calibrated Multi-Filter Rotating Shadowband Radiometers (MFRSR). These instruments measure at six narrowband channels: 415, 500, 615, 673, 870, and 940 nm. At the central facility the ARM program operates two MFRSRs in the usual up-pointing position measuring incoming fluxes. The program also operates two MFRSR heads mounted on towers in a down-pointing position measuring reflected fluxes. The two towers, while close in proximity, are installed in disparate surface-type locations. One tower is located in a natural grass/vegetation field. The instrument on this tower is mounted ~10m above the surface. The other tower is located in an active agricultural field. The second tower is 60m in height but the MFRSR is located at the 25m level. The data we present cover all of 2009. During this period the agricultural field produces two crops, and is plowed twice.

To separate total albedo into its components we first identify day pairs that consist of one overcast day and one clear day. Using the surface albedo measured under overcast conditions we determine the white sky albedo. We then look at the clear day and extract the black sky component with the following equation:

$$\text{Albedo}_{BS} = [\text{Total}\uparrow - (\text{Diffuse}\downarrow * \text{Albedo}_{WS})] / (\text{Direct}\downarrow * \text{Cos}\theta)$$

A primary assumption for this analysis is that diffuse albedo is comparable under both cloudy and clear sky conditions. In this work we focus on the variability of total spectral albedo for the area under the 60m tower as accompanying imagery facilitates the analysis. We then break down selected days to show how the white and black sky albedo varies with different surface states and solar zenith angles.

**Evolution of Surface Reflectivity in Switzerland Between 1980 and 2008** (Laurent Vuilleumier, Meteo Swiss)

The reflectivity of the ground directly affects the downwelling irradiance by multiple reflections at the surface and backscattering in the atmosphere above. Surface reflectivity is thus an important parameter for radiation transfer, and it is strongly determined by the presence and absence of snow. A scheme has been developed for estimating the regional snow distribution in the surrounding of any location in Switzerland on a daily basis. This scheme is based on observed snow depths and is consequently independent of satellite data.

The temporal evolution of the regional snow distribution was studied using the method based on observed snow depth in combination with a digital elevation model. Time series of snow distribution in Switzerland were reconstructed back to 1980 and validated against snow observations and satellite snow masks. In the cross-validation during winter periods (November to April), a probability of detection of 0.96 and a false alarm rate (FAR) of 0.15 were obtained. The validation of modeled snow coverage against satellite observations yielded an agreement between 69% and 97%. A trend analysis of reconstructed time series using Mann-Kendall tests showed a decrease of the snow cover between -10% and -15% in the lowlands north of the Alps. The negative trends in the more elevated alpine regions are smaller (1%–8%) and statistically non-significant ($p > 0.1$).

This confirmed that the regional snow cover can successfully be derived over the last 28 years in Switzerland, providing valuable information for describing the seasonal variability in surface reflectivity on a larger spatial scale. Nevertheless, it is still difficult to achieve good modeling results in the lowlands, since not only the occurrence of snow is infrequent, compared to alpine regions, but also the amount of snow is lower. Therefore, both the occurrence and the persistence of snow at these low altitudes depend stronger on local effects, which are difficult to assess with this method.

**Spectral Closure in the Visible and Near-Infrared** (Joseph Michalsky, NOAA/OAR)

Measurements of spectral irradiance have been made at the U.S. Department of Energy's Atmospheric Radiation Measurement site in northern Oklahoma using the rotating shadow-band spectroradiometer (RSR) for about five years. In this study three models were run using independent (nothing derived from the spectral data itself) and available inputs to the model and compared to the instantaneous measurements of clear-sky direct and diffuse irradiance. The measurements and models were compared in transmission, not in irradiance. The outcome for six cases was discussed. Some shortcomings seem to be the need for a better specification of aerosol optical depth as a function of wavelength, more information on the absorption properties of the aerosols, and an inability to model diffuse in the blue-green region properly.

**The State and Future of BSRN** (Ells Dutton, NOAA/GMD)

BSRN Project Manager, E. Dutton, concluded the formal presentations with an update on the overall status of the BSRN Project taking into account the information provided by the participants during the Workshop. Overall, BSRN has had many successes in achieving its original goals, but faces continuing challenges in improving, extending, and expanding its measurements. There is an ongoing and future scientific need for the data being produced and the perceived actual importance of the products and results produced by BSRN participants continues to grow as the need for global climate understanding becomes more widely recognized. The level of attendance and enthusiasm at the meeting demonstrates the critically needed energy and the participating organizations' support for the continuance of the now nearly 20-year old endeavor. In addition to continuing to fulfill the observational needs addressed by BSRN is the growing interest in the data review and analysis and in particular pursuit of the temporal variability being revealed and many of the data sets.

BSRN is indeed fortunate to have the new generation data archive and its eagerness to support both the archiving and data evaluation requirements. It is anticipated that the archive will adequately support the central processed data collection and dissemination for a number of years to come and will continue to expand the data review and quality assurance procedures. The archive will also begin to ingest centrally processed aerosol optical depths from the BSRN sites.

Considerable issues of mutual interest relative to surface radiation observations in the polar regions have been identified and highlighted by the Polar Regions Working Group. It is expected that this group will continue to work together towards mitigation of the more problematic problems of instrumentation icing, which appears to be the most common and high impact of the concerns addressed.

The longwave, or infrared, measurements working group has highlighted their concerns regarding the inherent difficulty in establishing the temporal stability of pyrgeometer data reduction coefficients when utilizing the more extensive recently derived raw data processing expressions. This, along with several other efforts, has suggested some improvement to data integrity by using these newer (since 1995) expressions. The working group will continue to investigate and report on their progress in recommending the best procedures. Establishing and conveying the uncertainty in BSRN observations has long been a topic of interest to the group. BSRN has conducted multiple demonstrations and field tests to help elucidate the typical expected errors and uncertainty in the networks routine observations. Minimization of those uncertainties remains a major focus of the network with the Uncertainties Working Group taking the lead in promoting and advising on the developments and desired future directions for BSRN. With the report from the Group this year, it is apparent that future focus on properly specified and documented measurement uncertainty will become an important of a part of the data record as the mean or best-estimate quantities reported for each physical variable.

An early if not initial motivation for the formation of BSRN was to provide for data of adequate quality, quantity, temporal resolution, and spatial representativeness to be useful for intercomparison with satellite derived estimates of the similar surface radiation quantities. Much of the initial development of the specifications and requirements for contributing to BSRN were developed about this need. During the meeting we saw several examples of how existing BSRN data have been and are being utilized by the satellite community, and indeed, our GEWEX sponsor's primary interest in BSRN's activities remains focused on this application, particularly for its Surface Radiation Budget (SRB) project, which was ably represented at this meeting by Taiping Zhang. Current and future satellite missions are being conducted and planned and the continued connection between the activities and products from BSRN and the satellite community will continue indefinitely.

Since the beginning of the Project, BSRN has been the focal point between radiometric instrument manufacturers and the needs of the observational climate research community. While the role was born out of necessity of standardization of reasonably cost-effective measurement techniques, there continues to be the need to the evaluation and reevaluation of available instrumentation. Since the last meeting BSRN focused on assessing existing and new commercially available pyrheliometers used for measurement of the direct solar beam. This was in part in recognition that there remains some of the greatest uncertainty in the direct solar beam BSRN measurements and that initial expectations to substantially reduce those uncertainties by the network wide proliferation of all-weather unwindowed cavities had not materialized. Also, further stimulating this interest, some attempts to characterize and explain some non-random error sources in these measurements had showed promise, along with the appearance of new and possibly improved instruments from various manufactures. An extensive comparison of available instrumentation was conducted with preliminary results presented by Joseph Michalsky. Those results suggest that windowed cavities do make a viable and highly accurate routine field measurements and further that some available less expensive, simpler, and perhaps more robust, field pyrheliometers may closely replicate that capability.

The interest of the BSRN participants in the causes and consequences of the magnitude and extent of variability within surface radiation quantities continues as evidenced by several related presentations. Popular topics of investigation continue to be clouds, aerosol, water vapor, and albedo. Albedo is a surface property of considerable influence on the BSRN measurements. Observation of the upwelling broadband reflected solar irradiance to compute albedo at BSRN site are highly desired and encouraged. However, these were not included in the basic set of minimal measurements necessary to participate in BSRN and greater emphasis was placed on the downwelling quantities. It nonetheless remains scientifically important to also have observations of associated upwelling solar and infrared quantities at these sites as well. It is generally more difficult to identify and establish an observational strategy for the upwelling observations because the highly variable nature of surface area surrounding many sites. This is crucial especially for satellite or larger-scale model comparisons but the limited local representativeness of these measurements can provide for local and regional relative changes over time, helping document the effects of things like snow cover, soil moisture, growing season variations and similar. All participants were encouraged to consider establishing or expanding measurements of the upwelling solar and infrared components of the net surface radiation budget. The field trip to the Lauder BSRN site provided a good example where that additional measurement would be desirable.

It was pointed out that BSRN continues to play a unique role in the scientific community, not only in its data production activities, but in that it is the only forum of its kind for its participants. That forum, primarily through these meetings and resulting contacts, provides an international connection for both measurement practitioners and data users. That connection would only be a peripheral component of other organizations and not the end-to-end unified and coordinated endeavor that BSRN is for this globally diverse and dedicated group.

Participation in BSRN as a data provider brings responsibilities, not only to following observing specifications, but also following through the activities associated with the specifically identified Site Scientist. A somewhat lengthy list of those responsibilities was discussed and is given below.

BSRN Site Scientist Responsibilities include, but are not limited to:

- Establishing and maintaining a station to BSRN specs
- Collecting, processing and providing quality control (QC) data
- Submitting the highest quality data to the BSRN archive
- Being responsive and accountable to inquires about the data
- Notifying the archive about known problems in previously submitted data and supplying corrected data if and when possible
- Attending and participating in BSRN meetings and working groups
- Adhering to the GCOS-10 climate monitoring principles
- Forever trying to figure out how to do it better

To expand on one of these responsibilities, adherence to the GCOS-10 monitoring principles, each of the ten was reviewed, and which can be found on the GCOS web site, at: *http://www.wmo.int/pages/prog/gcos/documents/GCOS_Climate_Monitoring_Principles.pdf*.

As an aside to primary intent of the meeting, but of relevance and general interest to the BSRN community, a recent summary of global mean temperatures was shown as was recently presented on an identified web site blog. Presented were five rather well-known, published, and independent analysis of two fundamentally different surface or near-surface air temperature data sources (three analysis of one source (surface meteorological station records) and two or the other source (satellite Microwave Sounding Unit.) It was then demonstrated that the linear fit to each for the last thirty years including data through 2009, are virtually indistinguishable (and were so on the graphic shown.) The point being made that despite what may be some eroding confidence or integrity of any one of either the analysis methods of the data source, there is still multiple evaluations indicating the steady multi-decadal of temperature. Another plot combining that result with a much longer record indicates, but with less confidence because the lack of multiple records, that as we approach the last 30 years of the record the rate of increase to the current point where the five analysis are in substantial agreement.

This presentation concluded with a discussion of the challenges and goals for the future for BSRN:

- Continue to fulfill and update BSRN specifications
- Increase/improve oceanic observations
- Extend network to data poor regions
- Develop, promote, and perpetuate meas. reference standards
- Improved and extend data QC/QA
- Satisfy GCOS monitoring principles
- Identify adequate funding for operations
- Provide data summary products from the archive
- Finalize incorporation of AOD into archive
- Spectrally specific observations - UV, PAR, hi-res
- Complete surface radiation budget measurements (add upwelling where missing)
- Strive to address the GCOS concept for a truly "Global" Reference Network
- Expanding applications to be addressed--renewable energy, agriculture, UV health, carbon flux (providing net PAR)
- Expand participation in important and rewarding analysis and research

## IX. ACTION ITEMS AND DECISIONS (Ells Dutton, NOAA/GMD)

Before the Workshop was concluded, a few items of business were addressed that had not been discussed earlier. Eight new BSRN sites were proposed during the course of the meeting, four in or near Japan, two in Brazil, one in the Canary Islands, and one on the island of Reunion. After review of the characteristics of the proposed sites the voting attendees recommended that the four Japanese sites should be included in the network. The two new sites in Brazil show promise, but it was decided that the archive submission from the existing sites in Brazil need to be brought up-to-date before adding additional sites. The sea level site in the Canary Islands did not appear to address the primary BSRN requirements for a new site since it appeared to be only representative of the local micro to mesoscale climate. The site on Reunion also appears to have extensive local influence and the proposing institution was requested to supply more information as to the characteristics and potential for the site being more widely representative for some percentage of the time. The discussion about these sites and considering similar limitations on previously proposed sites and their spatial representativeness, led to the decision that there needs to be a designation for such sites if they are otherwise producing and providing high quality data. The BSRN archive representative responded that there already is a designation assigned at the archive that gives some indication of the surrounding surface type for the station, although there is not a specific "non-regional representative site" designation that was felt to be necessary if certain of the proposed sites would be encouraged to participate further.

The BSRN Working Groups and current membership were briefly reviewed. All members were asked to indicate if they either wanted to be removed from their current group or if there were any apparent changes that needed to be made within their working group. In addition, all were asked to contact the current working group chairs if they would like to be added to a working group. The current working group membership is given later in this report, as are the primary and most current charges to the each working group as indicated.

The ongoing cooperative efforts of BSRN and the WMO Committee on Instruments and Methods of Observation (CIMO) – Subgroup for Atmosphere Composition and Radiation was briefly discussed by Bruce Forgan, the Chairman of the that committee. There are lots over overlapping interests of these two groups with CIMO, primarily involving specification and standardization. BSRN is actively pursuing related observations and filling in gaps that CIMO has not previously or recently addressed.

The BSRN Archive Director, Gert Konig Langlo indicated that a decision had been during the week on how spectral transmissions can be submitted from each participating BSRN station to the archive. This will allow for the centralized processing of the information into a uniform BSRN aerosol optical depth (AOD) product. Gert will be providing further information to those submitting data.

Workshop attendees were reminded that cloud-base height observations were one of the originally desired BSRN measurements to be archived. While some of the more sophisticated LIDAR capabilities that were initially envisioned for these observations did not materialized, at least in a readily accessible form, there may have been some loss of interest or attention to this measurement. It was pointed out that there are commercial ceilometers being produced and used at some of the BSRN sites. All sites were encouraged to report those measurements, if available, or consider adding the appropriate instrumentation where otherwise no cloud base height information is available. While some of the potential instruments have height detection limits, the observation of lower heights or an expression for "greater than" the limit would also be of value.

The participation in these meetings by representatives from commercial manufactures of instrumentation utilized by BSRN sites was discussed. In the past, their participation had ranged from none to a few, to all known companies being invited to attend in a limited, non-voting capacity. For various reasons, there were no commercial representatives invited to this workshop, although some had expressed an interest in attending. After some discussion, it was overwhelmingly agreed that all relevant instrument manufacturers be invited to send one representative to the next meeting, with the understanding that, as before, they would be essentially observers and that nonpromotional interaction and information exchange from them would be encouraged.

In addition to this summary report copies of many of the presentations given during the week are available on the GEWEX web site at: *http://gewex.org/bsrn.html*. All participants were encouraged to provide their presentations to be displayed in this manner and to submit a summary paragraph for inclusion in this report. All attendees and the meeting host, Richard McKenzie, were thanked for their participation in both this Workshop, as well as for their ongoing contributions to the BSRN Project. The time and location for the next meeting has not yet been determined, but is expected to occur in two years, and activities in the meantime will be through interactions with the data archive and within the Working Groups.

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**Appendix B**

# Agenda

**13 April, Tuesday**

08:00 – 08:30 Registration

**Opening Session**

08:30 – 08:40 Ellsworth Dutton and Graeme Strang – Meeting Opening and Logistics
08:40 – 09:10 Richard McKenzie – Overview of New Zealand/NIWA Atmospheric Science Activities
09:10 – 09:25 Dawn Erlich – Overview of GEWEX Activities
09:25 – 09:40 Richard Thigpen – An Update from the GCOS Secretariat and Report of Station Renovation Activities
09:40 – 10:00 Ellsworth Dutton – BSRN Review and Expectations for the Meeting
10:00 – 10:30 **Break** (poster set-up and viewing)

**Observatories – Status and Proposals (other status reports are in Posters)**

10:30 – 10:50 Nozumu Ohkawara – New BSRN Stations in Japan
10:50 – 11:10 Jordi Badosa – Nine Years (2000-2009) of Radiation Measurements at Lauder, New Zealand
11:10 – 11:50 Ells Dutton – Additional BSRN Field Site Reports
11:50 – 13:30 **Lunch and Poster Viewing**

**Archive Activities and Data Quality Control**

13:30 – 14:00 Gert König-Langlo – Status of the World Radiation Monitoring Center
14:00 -- 14:20 Anatoly Tsvetkov – WRDC Activities under the GAW Program: Recent Updates
14:20 – 14:40 Taiping Zhang – Processing and Analysis of the BSRN Data and Its Application in Validating the GEWEX SRB Release 3.0 Data
14:40 – 15:00 Discussion on BSRN Archiving Procedures and Services
15:00 – 15:30 **Break (Posters)**

**Basic Observations – Analysis and Review**

15:30 – 15:50 Martin Wild – Decadal Changes in Surface Radiation Fluxes
15:50 – 16:10 Stefan Wacker – Trend Analysis of Downwelling Longwave Radiation from Alpine Surface Radiation Budget (ASRB) Network Sites
16:10 – 16:30 Ben Liley – Aerosols and Global Dimming
16:30 – 16:55 Xiangao Xia – Closer Look at Brightening and Dimming in China

**14 April, Wednesday**

**Instrument Special Reports**

08:30 – 09:00 Julian Gröbner – Calibration Activities at the World Radiation Center, PMOD/WRC
09:00 – 09:50 Tom Stoffel and Joe Michalsky – Direct Beam Comparison (Various Conditions Pyrheliometer Comparison)
09:50 – 10:20 **Break (Posters)**
10:20 – 10:30 Chuck Long –Correcting for Tilt in Aircraft and Ocean Shortwave Observations Using the Diffuse to Direct Ratio

**Working Group Reports**

10:30 – 10:50 IR Working Group – Julian Gröbner

10:50 – 11:30 Aerosol Optical Depth Working Group – Bruce Forgan
11:30 – 11:50 Spectral Working Group Report – Joseph Michalsky
11:50 – 13:00 **Lunch**
13:00 – 13:20 Pyranometer Working Group – David Halliwell
13:20 – 13:40 Measurement Uncertainties Working Group – Bruce Forgan
13:40 – 14:00 Cold Climate Issues Working Group (new) – Chuck Long
14:00 – 14:20 Long Term Data Sets Issues and Analysis Working Group (new) – Martial Haeffelin
14:20 – 15:15 Open Discussion on Working Group Needs and Activities
15:15 – 15:45 **Break (Posters)**

**Clouds and Aerosols**

15:45 – 16:05 Christoph Wehrli – The GAW-PFR AOD Network and Its Calibration
16:05 – 16:25 John Augustine – Explaining the Seasonal Variation of Multifilter Rotating Shadowband Radiometer In Situ Calibrations
16:25 – 16:45 Mikhail Alexandrov – The Glory of Radiation: Multi-Angle Polarized Remote Sensing of Clouds, Aerosols, and Surfaces
18:00 – Group Dinner

**15 April, Thursday**

09:00 – 18:00 Field Trip to Lauder BSRN Station

**16 April, Friday**

**Clouds and Aerosols** *(con't)*

08:30 – 08:50 Chuck Long – Detection of the Occurrence and Impacts of Island Influence on Nauru ARM/BSRN Measurements
08:55 – 09:20 Martial Haeffelin – Cirrus cloud radiative forcing on surface-level shortwave and longwave irradiances in cloudy and quasi clear-sky situations
09:20 – 09:50 Christian Lanconelli – Radiation Regime and Cloud Characteristics of the East Antarctic Plateau as Derived from a 4-Year Record from Dome Concordia
09:50 – 10:30 **Break** (next to last chance to view posters)

**UV, Albedo and Special Applications**

10:30 – 11:00 Richard McKenzie – UVI Research in New Zealand
11:00 – 11:30 Laurent Vuilleumier – Estimation of Cloud Effect on UV Erythemal Irradiance Using SW Irradiance Data
11:30 – 11:40 Christian Lanconelli – UV Measurements in the Centre of East Antarctic Plateau
11:40 – 12:00 Tom Stoffel – Evaluation of Radiometers in Full-Time Use at the U.S. National Renewable Energy Laboratory

12:00 – 13:10 **Lunch**

13:10 – 13:30 Tom Stoffel – Solar Resources for Photovoltaic Variability
13:30 – 14:00 Gary Hodges – Variability of Total, White and Black Sky Spectral Albedo at US-DOE Atmospheric Radiation Measurement Facility
14:00 – 14:20 Laurent Vuilleumier – Evolution of Surface Reflectivity in Switzerland Between 1980 and 2008
14:20 – 14:40 Joe Michalsky – Spectral Closure in the Visible and Near-Infrared
14:40 – 15:30 Ellsworth Dutton – The State and Future of BSRN
15:30 – 16:30 Discussion, Recommendations, Wrap-up

**Posters**

Wouter Knap and Ping Wang – Shortwave closure and validation of satellite derived global radiation

Fred Denn – Observations from the Chesapeake Lighthouse

Jean-Phillipe Morel – The Global Dimming and the Brightening Periods at Carpentras

Martial Haeffelin – The Palaiseau BSRN station

Robert Albee – Obtaining energy budget measurements in the Arctic

Tom Stoffel– NREL Pyrheliometer Comparisons

Gary Hodges – Status and Updates of ASR (formerly ARM) BSRN sites

Gary Hodges – Status and Updates of SURFRAD BSRN sites

Klaus Behrens – Status of the Lindenberg BSRN station

David Halliwell – Status of the Regina BSRN station

Ain Kallis – Solar radiation measurements in Estonia

Laurent Vuilleumier – Status of the Payerne BSRN station

Vinod Jena and Sapana Gupta – Assessment of atmospheric aerosol pollution and their adverse effects

# BSRN Working Group Structure (2010)

**Pyranometer**: David Halliwell (chair), Klaus Behrens, Chuck Long, Martial Haeffelin, Wouter Knap, Rakel Gastesi, Lourdes Ramirez

**Pyrgeometer** WG: Julian Gröbner (Chair), Joseph Michalsky, Klaus Behrens, Thomas Stoffel

**Oceanic**: TBD (chair); Gary Hodges, Chuck Long, Martin Wild, Shawn Smith, Fred Denn

**Direct Beam**: Ells Dutton (Chair) Steve Wilcox, Klaus Behrens, Patrick Fishwick, Thomas Stoffel, David Haliwell, Donald Nelson

**IR**: Julian Gröbner (chair), Joseph Michalsky, Tom Stoffel, Alexander Los, Klaus Behrens

**Aerosol Optical Depth**: Bruce Forgan (chair), Joseph Michalsky, Christoph Wehrli, Vito Vitae, Mikhail Alexandrov, John Augustine

**Upwelling Irradiances**: Gary Hodges (Chair), Rachel Pinker, R. Stone, Crystal Schaaf, Joseph Michalsky, Fred Denn

**Spectral Measurements**: Joseph Michalsky (chair), Rachel Pinker, Alexander Manes, Bruce Forgan, Laurent Vuilleumier, Bruce McArthur, Ain Kallis, Richard McKenzie

**Uncertainties**: Bruce Forgan (chair), Klaus Behrens, David Halliwell, Thomas Carlund, Chuck Long, Laurent Vuilleumier, Thomas Stoffel

**Cold Climate Issues** Chuck Long (chair), Laurent Vuilleumier, Bruce Forgan, Vito Vitale, Dave Halliwell, Gert König-Langlo

**Long Term Data Sets Issues and Analysis** : Martial Haeffelin (chair), Chuck Long, Martin Wild, Julian Gröbner, Enio Pereira, Lourdes Ramirez, Taiping Zhang, Klaus Behrens, Rakel Gastesi, Nozomu Ohkawara, Vito Vitale, Stephane Mevel

**Archive Advisory Panel**: Chuck Long, Martin Wild, Ells Dutton, Gary Hodges, Steve Wilcox, Gert König-Langlo, Anatoly Tsvetkov, Lamine Boulkelia, Fernanda Carvalho

**WMO CIMO** – BSRN contact –Bruce Forgan

# Posters

**Global Dimming and Brightening at Carpentras and Trappes (France)** (Jean-Philippe Morel, Radiometric Center, Carpentras)

Global Dimming and brightening refer to the decadal variations in solar radiation received at the Earth's surface. The first phenomenon is relative to the widespread continual decrease in the amount of energy and light reaching the Earth's surface between 1950–1980. Global brightening is related to the increase of ground-level down-welling irradiance partially recovered after 1988–1990 until the present.

Whereas Global Dimming can be related to increased aerosol load caused by pollution, Global Brightening is likely to be rather related to a reduction in pollution. There is now much evidence to show that pollution—or atmospheric turbidity—is one of the main causes behind both Global Dimming and Global Brightening. However some scientists consider that cloud cover might also have played a significant role (a more important role than aerosols?) In fact the causes of global brightening may be more complex than initially thought. Global Dimming and Brightening periods can be clearly identified from graphs showing annual variations of global irradiance at Carpentras and Trappes in France over recent decades.

**Obtaining budget measurements in the Arctic (tech perspective)** (Robert Albee, Dave Longenecker, Jim Wendell, Taneil Uttal)

Faced with many challenges, but driven by the scientific desire for radiation measurements above the Arctic Circle, new arctic stations are being established. The Barrow Alaska station has demonstrated that reliable and useful information is obtainable from such regions. Other stations that show signs of strong potential and success are Alert, Canada, Eureka, Canada, Summit, Greenland, and Tiksi, Russia. Radiation data is being acquired from these locations in an effort to meet BSRN standards for placement into the world archives.

Alert Canada is a Canadian military outpost at 82N 62W established 1950 on the northern part of Ellesmere Island. On August 15th, 2004 a suite of instruments were deployed by NOAA in cooperation with Environment Canada at the 1986 established GAW station 7 km from the military base. These instruments include a K&Z 2AP tracker, two Middleton SP02 sunphotometers, two Eppley NIP pyroheliometers, one shaded Eppley pyranometer, one shaded Eppley pyrgeometer, one shaded K&Z pyranometer, one K&Z global pyranometer, one K&Z upwelling pyranometer, one Eppley upwelling pyrgeometer, and one Yankee total sky imager.

Eureka Canada is a Canadian weather station at 80N 86W established 1947 middle of Ellesmere Island. During August 2007 both NOAA and Environment Canada deployed many instruments. These include an EC deployed 2AP tracker with an Eppley NIP pyroheliometer, a global pyranometer, a diffuse pyranometer, and a shaded pyrgeometer. In addition, NOAA deployed a K&Z downwelling pyranometer, an Eppley downweling pyrgeometer, a K&Z upwelling pyranometer, and an Eppley upwelling pyrgeometer.

Summit Greenland was established in 1989 by the National Science Foundation and is located at 72N 38W and 3216 meters above sea level. In 2000 ETHZ deployed a tracker with a pyrheliometer, global pyranometer, diffuse pyranometer, and downwelling pyrgeometer. In addition upwelling pyranometer and pyrgeometer measurements are also being collected.

The Barrow Alaska NOAA baseline facility, which is 8 km northeast of Barrow at 71N 156W, was established in 1973 and has collected radiation measurements since 1977. This station has a K&Z tracker, two Eppley NIP pyrheliometers, two Middleton SP02 sunphtometers, one Eppley global pyranometer, one up facing RG8 red dome pyranometer, one shaded Eppley 848 B&W pyranometer, one shaded Eppley pyranometer, and one shaded Eppley pyrgeometer. In addition, it has a down facing Eppley pyrgeometer and down-facing Eppley pyranometer on an albedo rack.

Tiksi, Russia is a town at the Lena delta in Siberia at 71N 128E. The Tiksi weather station, which is about 7 km from Tiksi has been in operation since 1932. Until recently, radiation data was collected via a Campbell-Stokes recorder. Momentarily there is a Roshydromet AARI deployed global pyranometer collecting information. Two new buildings were constructed in 2007. As of April 13th 2010, a large suite of instruments have been delivered with intention for deployment in June 2010. These include a K&Z 2AP tracker, one Eppley pyroheliometer, two Eppley pyranometers, one Eppley 848 B&W pyranometer, three Eppley pyrgeometers, and one K&Z CM22 pyranometer.

There are also many instruments at all of the above sites collecting supporting measurements. Information is continually accessible at the IASOA web site, *http://iasoa.org/iasoa*, and the NOAA web site, *http://cmdl1.cmdl.noaa.gov:8000/~star/daily/active_sta.html*.

**NREL Pyrheliometer Comparisons** (Tom Stoffel and Ibrahim Reds, National Renewable Energy Laboratory)

Accurate and continuous long-term measurements of direct-normal solar irradiance from pyrheliometers are important for improving our understanding of the Earth's energy budget, the development of renewable energy conversion systems, and for other applications involving solar radiation flux. Maintaining accurate radiometer calibrations traceable to an international standard is the first step in producing research-quality solar irradiance measurements. In 1977 the World Meteorological Organization (WMO) established the World Radiometric Reference (WRR) as the international standard for the measurement of direct normal solar irradiance. The WRR is a detector-based measurement standard determined by the collective performance of seven electrically self-calibrating absolute cavity radiometers comprising the World Standard Group (WSG) developed and maintained at the Physikalisch- Meteorologisches Observatorium Davos - World Radiation Center (PMOD/WRC). Every 5 years, the PMOD/WRC hosts an International Pyrheliometer Comparison (IPC) for transferring the WRR to participating radiometers. NREL has participated in each IPC since 1980. As a result, NREL has developed and maintained a select group of absolute cavity radiometers with direct calibration traceability to the WRR. These instruments are then used by NREL to transfer WRR calibration to other radiometers participating in the annual NREL Pyrheliometer Comparisons (NPCs) at the Solar Radiation Research Laboratory (SRRL) in Golden, Colorado. This poster discribed the NPC methodology and provided sample results based on our experiences since the first NPC in 1994. The NPC results demonstrate absolute cavity radiometers are very stable with individual uncertainties ranging from 0.15% to 0.25%. The next NPC is scheduled for 26 September through 7 October 2011.

**Status-Report of BSRN Station Lindenberg, Germany** (Klaus Behrens, DWD, Germany)

Since June 2003, measurements have been carried out on the roof of the radiation laboratory ($\varphi$ = 52,21° N, $\lambda$= 14,12° E, h = 121 m) of the Lindenberg Observatory. 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 pyranometers and pyrgeometers are ventilated by a heated air stream as from the start of the measurements in October 1994. The data are recorded by COMBILOG data logger of Friederichs, Hamburg.

In the last weeks additional to the basic measurements (LR0100) the data of LR1000, LR1100, LR1200 and LR1300 (synoptic data, radiosonde data with one ozone profile in every week, daily totals of ozone column and cloud base height) were transmitted into the archive at AWI in Bremerhaven. In the next weeks, beginning with June 2003, the data transmission of all data will be continued.

The data of two shaded and two unshaded PIR and CG4, respectively, were compared with the reference group of pyrgeometers of DWD calibrated by PMOD/WRC between 2004 and 2009. The data of day and night time as well as at clear and cloudy are in good agreement. Detailed investigation will be continued. Furthermore, measured long-wave downward radiation at clear sky (17000 cases between 2000 and 2009), determined by the APCADA algorithm (Dürr, 2004) was compared with data generated by the STREAMER model. Profiles of temperature and humidity from a MicroWaveProfiler as well as measured daily total ozone column were used as input data. The median of the ratio MOD/MEA is 1.0059 and the values for the first and third Quartile are 0.9978 and 1.0137, respectively.

**Status of the Regina BSRN Station** (David Halliwell, Ormanda Niebergall, James Morley, Ihab Abboud and Bruce McArthur, Experimental Studies Section, Atmospheric Science and Technology Directorate, Environment Canada)

Environment Canada continues to operate its BSRN station at Bratt's Lake, Saskatchewan, and the site has seen significant growth in the past 2 years. Construction of a building for calibration of AEROCAN/ AERONET instruments was completed in March 2010, and the laboratory should be operational later this year. The building will also house a new LIDAR. Greenhouse gas measurements (CO2, CH4) were added in the fall of 2009. The site continues to participate in several national and international instrumentation networks, dealing with radiation, air quality, atmospheric gases, and precipitation. Spectral radiation measurements of direct, global, and diffuse radiation began in late 2007, and are now running continuously.

**Tartu-Toravere, Estonia** (Ain Kallis, Estonian Meteorological and Hydrological Institute)

The Tartu-Toravere Station, which was established in 1950 and became a BSRN station in 1999, is operated by the Estonian Meteorological and Hydrological Institute. Station data are provided to the BSRN archive on a monthly basis and a total of 135 files having been submitted since 1999.

The station enables the comparison of instruments designed in the former Soviet Union with those meeting BSRN specifications. Currently, the instrumentation at Tartu-Toravere includes a PMO-6 cavity pyrheliometer as a reference instrument, an Eppley NIP and AT-50 (direct), CM-21 (global, diffuse and reflected shortwave radiation), LI-COR sensors for direct and global PAR, Kipp & Zonen instruments for registration of UV-A and -B, Scintec UV-SET and YES UVB-1 for UV-index estimations, Eppley PIR (upward and downward longwave irradiation), CIMEL CE-318-1 (AOD in cooperation with NASA and Tartu Observatory). All the sun trackers are designed at Toravere Station and Tartu Observatory.

Status of the Payerne, Switzerland BSRN Station **(L. Vuilleumier, Federal Department of Home Affairs FDHA, Federal Office of Meteorology and Climatology MeteoSwiss)**

The Payerne Station has measured the BSRN basic set of parameters since November 1992. In addition, other parameters including longwave and shortwave irradiance at 10 and 30m a.g.l., spectral direct irradiance and UV erythemal irradiance are measured. Many measurements are made with redundant instruments, and there are many opportunities for quality control (QC) checks. However, the multiplicity of parameters measured and possible QC checks make such checking procedure cumbersome. A new flexible automated

QC assessment algorithm taking into account the results of the different QC checks has been developed and implemented at Payerne. It is performed daily and its results are available using a web interface on MeteoSwiss intranet.

Since 2004, all the UV erythemal broadband radiometers (biometers) in operation at MeteoSwiss (including at Payerne) have undergone yearly calibration checks by comparison to a well-calibrated reference. The estimated uncertainty for such a method is a little in excess of 5% for the calibration of the reference and on the order of 4% for inter-instrument reproducibility. This uncertainty is compatible with the observed difference between redundant measurements of UV global erythemal irradiance with several biometers. The total uncertainty of UV measurements is estimated at about 10%.

Errors and inhomogeneities in the old data submitted to WRMC in the long-wave, diffuse SW and UV have been identified and are being analyzed. However, correction of old unhomogenized values in the WRMC database is still pending.