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This report was authored by Dr. Charles N. Long [National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory (ESRL) Global Monitoring Division (GMD)/Cooperative Institute for Research in the Environmental Sciences (CIRES)] on behalf of the Baseline Surface Radiation Network (BSRN).

BSRN, part of the Global Energy and Water cycle Exchanges project (GEWEX) Data and Analysis Panel (GDAP), provides highly accurate worldwide radiative flux measurements to validate satellite-based measurements. It develops instrument requirements, establishes BSRN reference stations worldwide and assembles a database of these measurements.

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Executive Summary

This report details the proceedings of the 15th Baseline Surface Radiation Network (BSRN) Scientific Review and Workshop, held at the Cooperative Institute for Research in the Environmental Sciences (CIRES) in Boulder, Colorado, USA from 16−20 July 2018. BSRN consists of volunteers who operate stations that measure surface solar and infrared (IR) radiation, creating a database of worldwide radiative flux measurements archived at the World Radiation Monitoring Center (WRMC) of the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research. Project scientists and other guests meet biennially to share updates on station operations, instrumentation and the state of the science through oral and poster presentations and by convening Working Groups. The 15th Review and Workshop addressed new station applications, improvements in instrumentation and data reduction methods, data management and quality control issues and ways the data are used by the larger community.

Contents

World Climate Research Programme

1. Introduction and Overview of Meeting

Seventy-six scientists, station managers, and data users from 24 countries representing 49 different organizations presented 37 talks and 31 posters at the 15th Baseline Surface Radiation Network (BSRN) Scientific Review and Workshop held at the Cooperative Institute for Research in the Environmental Sciences (CIRES) in Boulder, Colorado, USA on 16−20 July 2018. The workshop was co-hosted by CIRES and the National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory (ESRL) Global Monitoring Division (GMD), and led by Dr. Charles Long, who was ably assisted by a host of other CIRES and GMD personnel. During the meeting, BSRN observations were reviewed, improvements in instrumentation and data reduction methods discussed, data management and quality control issues considered, and ways the data are used by the larger community were examined. In addition, a total of nine new sites were proposed for consideration to join BSRN.

The GEWEX Data and Analysis Panel (GDAP), co-chaired by Rémy Roca and Tristan L'Ecuyer, oversees and gives general guidance to BSRN. The BSRN project consists of volunteers operating stations that measure surface solar and infrared (IR) radiation. Most stations measure the surface radiation by making broadband solar and infrared downwelling and upwelling irradiances according to a set protocol and using the highest quality radiometers. Many stations also make ancillary measurements, such as ultraviolet radiation (UV), photosynthetically active radiation (PAR), and meteorological parameters. A few stations began operating in 1992, and have accumulated over two decades of high-quality data. Currently, 64 stations have submitted data to the BSRN Archive since 1992, totaling over 10,800 data months, of which 11 have terminated their measurements, two are in the process of restarting their operations after a long hiatus, and the rest are operational. The World Radiation Monitoring Center (WRMC) of the Alfred Wegener Institute of Polar and Marine Research (AWI) in Bremerhaven, Germany archives the data produced by the stations (*http://www.bsrn.awi.de*).

Brief summaries of the oral presentations made at the meeting in the order listed on the agenda, followed by the various Working Group reports and a summary of the business meeting portion of the workshop, can be found in this report. After the summaries of the oral presentations, there are sample summaries of the poster presentations. Electronic versions of many of the presentations, including posters, are available for a limited time at *http://www.esrl.noaa.gov/gmd/grad/meetings/bsrn2018.html*.

2. Meeting Sessions

2.1. Opening Session

Dr. Christine Wiedinmyer, the Associate Director for Science CIRES, opened the meeting on Tuesday, 17 July 2018, giving a welcome address and a brief overview on CIRES. Then Dr. James Butler, Director of the NOAA ESRL GMD, gave a welcome and discussed a brief history of NOAA's Global Monitoring Division, its three research themes and several research applications and its enduring linkage to the Baseline Surface Radiation Network since the inception of BSRN. The presentation underscored the power of partnerships in resolving scientific challenges, most notably in understanding the trends and distributions of surface radiation, clouds and aerosols.

Chuck Long, the meeting host and BSRN Project Manager, chaired the opening session and discussed meeting logistics and gave BSRN greetings and the meeting charge. Items that were noted for discussion during the workshop included the formation of a committee to review the BSRN Manual and requirements, the idea of the formation of an “expertise resource” group to share knowledge and expertise relevant to all aspects of BSRN and the idea to institute a Deputy Project Manager position for succession planning. Finally, Dr. Long announced that he would be retiring at the end of the year, and thus would no longer be able to serve as BSRN Project Manager. Dr. Christian Lanconelli has agreed and been appointed as the new BSRN Project Manager. Christian previously served as the station scientist for the BSRN Dome-C site (Antarctica) and hosted the 2014 13th BSRN Workshop in Bologna, Italy. Christian is currently with the European Commission’s Joint Research Centre working within the “Quality Assurance for Essential Climate Variable” area, where he is involved with satellite related issues. This combination of knowledge of the operational BSRN paradigm plus connection to and experience in the BSRN target communities will serve BSRN well in the coming years.

Dr. Amelie Driemel, Director of the BSRN Archive, gave a status update report. The WRMC currently contains more than 10,800 monthly datasets from 64 stations, which amounts to around 900 years of data. A few stations have closed [Boulder (BOU), Xianghe (XIA), Solar Village (SOV)] or face operational problems [Chesapeake Light (CLH), Eureka (EUR)] and some stations are submitting again [São Martinho da Serra (SMS), Petrolina (PTR), Rolim de Moura (RLM), De Aar (DAA), etc.]. Five of the eight candidate stations from the 14th BSRN Workshop held in 2016 have already submitted data [still missing are Newcastle (NEW), Dongsha Atoll (DON) and Lulin (LLN)]. The archive receives around 140 new data access requests per year, more and more from the renewable energy sector. Current issues within the WRMC are the large amount of station scientists retiring, some of whom do not have a successor yet;, the need for a new BSRN Toolbox developer; and the need to convey to users how to correctly cite BSRN data.

Tim Oakley welcomed the participants on behalf of the Global Climate Observing System (GCOS) Director, Carolin Richter. As there were many new participants at the workshop, he explained the vision of GCOS, how the program gets involved across the whole observing cycle and the key documents that govern its work (Status report, 2015, and Implementation Plan, 2016). He described in more detail the sections of the Implementation Plan that are of direct relevance to the BSRN network and the following two actions:

- Action A11: Ensure continued long-term operation of BSRN and expand the network to obtain globally more representative coverage and improve communications between station operators and the archive centre.

- Action A12: Submit surface radiation data with quality indicators from national networks to the World Radiation Data Centre (WRDC). Expand deployment of surface radiation measurements over ocean.

Tristan L'Ecuyer represented GDAP and gave a status report. The 2017 annual meeting of the GEWEX Data Analysis Panel (GDAP) was held at the National Center for Atmospheric Research (NCAR) Mesa Lab in Boulder in October 2017. The meeting was the first organized by the new co-chairs, Rémy Roca (Laboratoire d'Etudes en Geophysique et Oceanographie Spatiales, LEGOS) and Tristan L'Ecuyer (University of Wisconsin-Madison). GDAP continues to address its primary charge within WCRP of answering the fundamental question "how sensitive is the Earth's climate to changes in radiative and other forcings?" through coordinated global and regional observations of energy and water fluxes. Central to this goal is the vital role that ground-based networks like BSRN play in anchoring satellite-based energy and water cycle datasets. For example, the upcoming release of Version 4 of the GEWEX Surface Radiation Budget (SRB) project includes several modifications to inputs and methods that are currently being assessed against BSRN observations. In addition, BSRN will play a key role in anchoring new GDAP initiatives to promote integrated energy and water cycle assessments and establish a "best practices" guide for scientific data assessments. Toward these goals the panel reiterated strong support for ongoing BSRN efforts to establish absolute IR calibration standards and passed along a user request that BSRN include 2m air temperature and humidity in the standard data stream. It is also recommended that BSRN continue to exhibit leadership in establishing accuracy standards for buoy-based surface radiative flux measurements. GDAP is prepared to support such an effort through a community survey and by hosting a follow-up workshop if warranted.

Tim Oakley gave a second presentation on BSRN in the wider community, primarily that of GCOS and the World Meteorological Organization (WMO). Whilst GCOS is driven primarily through its Implementation Plan, WMO and its Members are the owners and operators of the systems, as given in the technical regulations, in particular the Manual on the Global Observing System (GOS). Here the radiation stations are classified as special stations and this relates more to the instruments at the meteorological surface stations, rather than BSRN. He asked whether the current network was considered suitable for the global monitoring of radiation, and provided his thoughts on the strengths, weaknesses, opportunity and threats. Primarily this was to stimulate further discussion at the workshop on how BSRN might evolve in the future. He concluded with the work of a new GCOS task team that was scoping a potential surface reference network (GCOS Surface Reference Network, GSRN) for which the BSRN could be a potential component. Whilst the "B" in the BSRN is for Baseline, it was suggested that many of the observations were in fact closer to being reference observations.

These talks ended the opening session, which was followed by the new sites proposal session.

2.2. New Site Proposals

Selegua, a proposed new BSRN site in the south of Mexico (Adriana Gonzalez Cabrera)

A new site in southern Mexico was proposed by the Solar Radiation Observatory of the Autonomous Nacional University of Mexico (UNAM). Selegua station belongs to the Mexican solarimetric network (15 stations around the country). Selegua is near the Guatemala border in a flat region and tropical clime located at 15°47'2.46" N and 91°59'24.63" W. In a few months, instruments for longwave radiation upwelling and solar global radiation reflected will be installed. Selegua was selected as provisional BSRN site during the workshop.

A proposed new BSRN site at Paramaribo, Suriname (NE South America) (Ankie Piters)

Suriname resides in a tropical rainforest climate (i.e., > 60mm rain in driest month) over which the Inter-Tropical Convergence Zone (ITCZ) migrates twice per year. Thus the site experiences two rainy seasons and two dry seasons each year. The site is operated by the Meteorological Service of Suriname, in contract with KNMI. The site has collected 16 months of usable data to date. Date submission can start within a few weeks, since the conversion to BSRN format and submission will be through KNMI who already submit the Cabauw station data.

Proposal of a BSRN station at the Observatory of Huancayo, Peru (Luis Suarez Salas)

Measurements of solar radiation at surface stations are critical for verifying climate models and satellite measurements. The World Climate Research Programme (WCRP) Baseline Surface Radiation Network (BSRN) has been operating as a network of surface radiation monitoring observatories for over 10 years. Despite these efforts, western South America is a region with scarce measurements based on BSRN guidelines. This proposal presents the implementation of a BSRN station at the Observatory of Huancayo (lat. 12.05 and long. 75.32 and altitude 3.313 masl), located in the Andes mountain region, which is expected to receive the highest intensity solar radiation. During recent years the Observatory of Huancayo has improved, adding scientific instrumentation for atmospheric sciences. It includes a meteorological station, precipitation radar and a sun photometer from the Aerosol Robotic Network (AERONET)/National Aeronautics and Space Administration (NASA) network, all part of the Laboratory of Atmospheric Microphysics and Radiation (LAMAR) of the Geophysical Institute of Peru. It is expected that this station will have adequate support and will improve the evaluation of aerosols and clouds on the surface radiation budget.

A proposed new BSRN site near Dubai, UAE (Dr. Aaesha Abdulla Alnuaimi)

A site, part of the developing Mohammed Bin Rashid Solar Park of the Dubai Electricity and Water Authority (DEWA), is proposed. The solar park is projected to eventually generate 5000 megawatts (MW) by 2030. The site would represent regions with hot, arid climates (very common for solar plants) in the Middle East. However, the radiation system being proposed would be located within 75 meters of one edge of this massive array of solar photovoltaic (PV) panels, which is expected to have a significant influence on the local surface energy budget and climate. This calls into question whether the observations would really be representative of the hot, arid climates of the region. The suggested personnel that would be associated with the site are obviously knowledgeable and experienced, with apparent organizational support. However, due to delays in permits and such, at present the proposed site development is just now being started with instruments that have yet to be installed.

Granite Island in Lake Superior, a new BSRN water site proposal (Bryan Fabbri)

When Chesapeake Light (BSRN ID: CLH) was deactivated in December 2016 after sixteen years, a rare, long term BSRN water/ocean site left a scene type gap. Granite Island (46.72 N, 87.41 W), privately owned, in Lake Superior, approximately 20 km north of Marquette, Michigan and 10 km to the nearest land point, was discovered. Eighteen months after this discovery, a radiometric and aerosol measurement site was established after agreements were finalized with the owner. The motivating factor for establishing this site was the presence of evaporation measurements already collected for several years. These evaporation measurements are part of the Great Lakes Evaporation Network (GLEN). NASA Langley is interested in using BSRN and Clouds and the Earth’s Radiant Energy System (CERES) measurements with the GLEN evaporation measurements to improve understanding of the Earth’s energy budget. Surface validation of satellites such as CERES and water sites being rare are other motivating factors. Currently, the data being collected are downwelling shortwave direct, diffuse, and global, and downwelling longwave. Also, aerosol data is being collected with a Cimel sun photometer, loaned from the Aerosol Robotic Network (AERONET). The installation is solar powered with communications via serial over Internet Protocol (IP). A few issues still need to be resolved (seagulls and lack of daily cleaning) with plans to mitigate before the end of the year. Data collection commenced June 2018. The GLEN network will provide the meteorology data until a weather station is added.

Assessing surface solar radiation variability and trends in the South-West Indian Ocean from BSRN-like measurements over Reunion Island: Proposal for a new site (Béatrice Morel)

Reunion Island is a small mountainous and volcanic tropical island with very complex terrain and multitudinous microclimates, located in the South West Indian Ocean to the east of Madagascar. The Laboratory of Energy, Electronics and Process (LE2P) of the Université de La Réunion, which has an interest in the smart management of solar energy over the island, has been developing a SPN1 radiometric network since 2008.

In recent years, the lab has improved with scientific instrumentation for downwelling radiation conforming to the standards set out by BSRN: a SOLYS Gear Drive sun tracker, two CMP22 pyranometers (global-diffuse shortwave), a CH1 pyrheliometer (direct shortwave), a CGR4 pyrgeometer (longwave) and a UVS-AE-T radiometer [ultraviolet A (UVA) and erythemally active ultraviolet irradiance (UVE)], located as part of the Faculté des Sciences et Technologies of the Université de La Réunion. A WXT520 Vaïsala weather transmitter near the tracker measures barometric pressure, humidity, precipitation, temperature and wind speed and direction. In addition, the measurement site is collocated with routine upper-air soundings (observations) and basic meteorological instrumentation provided by Météo France and Observatoire de Physique de l'Atmosphère à La Réunion (OPAR)-Maïdo Observatory, which houses a large variety of atmospheric instruments, including light detection and ranging (Lidar) instruments, radiometers and in-situ gas and aerosol sensors.

This site was proposed at the 2016 14th BSRN Workshop where some issues were identified, resulting in the proposers being invited to propose again at the 2018 15th BSRN Workshop. These issues were shown to have been addressed, most importantly that of calibration of the instruments, which was carried out at the Physical Meteorological Observatory in Davos (PMOD) in July−August 2017.

New proposed BSRN stations in the Western Pacific region: Mt. Jude and Orchid Island (Carlo Wang)

After participating in the 2016 BSRN meeting, the Central Weather Bureau (CWB) in Taiwan moves forward with responding to the need for high quality global radiation measurements. In early 2018, the CWB completed the installation of two BSRN standard sites in Yushan (Mt. Jade) and Lanyu (Orchid Island) weather stations. Both sites measure global, direct and diffuse radiation, as well as metrological parameters in one-minute resolution. Yearly calibration procedure, daily maintenance and quality control (QC) procedure are applied to ensure high quality of data. The elevation of Yushan site is 3858 m, making it the highest site in BSRN. At Yushan, aerosol-radiation interaction in the free troposphere, stratospheric volcanic aerosol and climate variability could be studied. The Lanyu site is on a remote island in the Western Pacific. Its potential for scientific study includes the radiation budget, typhoon genesis, and marine clouds and aerosol interaction. The CWB will provide continue funding to support BSRN activities in Taiwan.

Solar and meteorological measurements at Budapest-Lőrinc, Hungary: Proposal for BSRN station (Dénes Fekete)

This Budapest site had been accepted as a provisional BSRN site in the 1990s, but failed to ever successfully submit any data to the BSRN Archive. Thus according to the delinquency rules established at the 2016 14th BSRN Workshop, site representatives were tracked down and informed that the provisional BSRN site invitation was rescinded, and if they desired to they would need to again come and propose the Budapest site as a BSRN candidate site.

Dénes Fekete from the Hungarian Meteorological Service presented the solar and meteorological measurements at Budapest-Lőrinc station in Hungary. The site was founded in 1952, with solar radiation measurements starting 15 years later. The components of the operational measurement program are as follows: global solar radiation, reflected shortwave radiation, longwave downward radiation, longwave upward radiation, direct solar radiation, diffuse solar radiation and aerosol optical depth measurements. Other parameters, including total ozone and spectral UVB and UVA measurements with Brewer spectrophotometer, spectral visible and near-infrared measurements with SolarSIM spectrophotometer, which can determine aerosol optical depth, are also available. Air pressure, air temperature, humidity and ceilometer data are also measured. Automatic data collection and quality checking operated by working instructions of the International Organization for Standardization (ISO) quality control/assurance system are applied.

2.3. Other Site Presentations

The University of Oregon Solar Radiation Monitoring Lab – Where we've been and where we're going (Josh Peterson)

The Solar Radiation Monitoring Laboratory at the University of Oregon (UO SRML) is a solar radiation data center for the Pacific Northwest region of the United States. The lab supplies data to the national solar radiation database and also informs regional utilities and agencies of the solar resource in the area. The Eugene monitoring station located on the University of Oregon campus has been monitoring global horizontal (GHI) and direct normal irradiance (DNI) since 1977. The Eugene station acts as a reference and research station for the other 20 stations in the SRML solar monitoring network. All data being gathered by the SRML are available on the website at *http://solardata.uoregon.edu*. From 1977 through 1997, the annual average DNI had increased by about 10%, but has remained relatively constant since 1998. Calibrations and characteristics of pyrheliometers and pyranometers are studied by the SRML and numerous publications have been based on these findings. The thermal offset of pyranometers, the deviation from the Lambertian cosine response, and the spectral response of the photodiode-based pyranometers are some of the issues that have been studied. Recently the lab has updated and standardized its calibration procedure. The lab is also in the process of updating the data files format to a more comprehensive format that will make it easier to analyze the data. Monitoring the spectral characteristics of the solar resource is now being undertaken to help the solar industry better assess the performance of photovoltaic solar generating facilities.

BSRN Cabauw – Status and applications (Wouter Knap)

A brief demonstration is given on how data exceptions, related to maintenance and, e.g., birds, are handled for the Cabauw BSRN station. Exceptions accompanied by comments are entered into a data base by means of a web interface. On the basis of the to-be-submitted station-to-archive file, another (local) interactive web site is generated that contains a wealth of quality information, mainly based on the BSRN Global Network Recommended QC tests, V2.0 (Long and Dutton, 2002). One of the tests that is discussed in detail is the ratio of global shortwave radiation over the calculated total horizontal radiation (SWD/SumSW). Multi-year time series are shown for the Cabauw station and 13 other BSRN stations. The analysis shows several quality issues, most probably related to global pyranometer cosine response and instrument/calibration changes. The conclusion is that long term monitoring of SWD/SumSW provides a valuable tool for QC of the shortwave components.

Several applications of the use of BSRN data are presented. The first application consists of the evaluation of forecasts of solar irradiance for The Netherlands. Results are shown for short-term (0-2h) forecasts based on the use of atmospheric motion vectors to advect Meteosat Second Generation (MSG) Spinning Enhanced Visible and Infrared Imager (SEVIRI)-derived cloud properties. Longer-term forecasts (0-24h) are generated by the HIgh Resolution Limited Area Model (HIRLAM) Aladin Regional Mesoscale Operational Numerical Weather Prediction In Europe (HARMONIE) model. For daily integrated irradiances, the bias (HARMONIE-BSRN) proves to be -0.15 kWh/m^2 (-4%) and the RMSE is 0.71 kWh/m^2 (20%) for the period April 2017–July 2018. The second application shown is a validation study of an Ozone Monitoring Instrument (OMI)-Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) surface solar radiation product that is validated by means of global irradiances from 15 BSRN stations.

A brief overview of instrumental activities at KNMI is given: the first is the automation of the HF27159 cavity radiometer, now formally known as AHF27159. The instrument was successfully equipped with a shutter and software has been developed to fully automate the measurement protocol that is followed during the International Pyrheliometer Comparisons in Davos. The other activity consists of a field comparison of pyranometers of various manufacturers. The presentation is closed with a pyrgeometer calibration issue related to the BSRN downward longwave irradiance at Cabauw. It is emphasized that such issues can disturb trend analyses.

Solar Radiation Measurement in the Sahara (Algeria) (Sidi Biaka)

The Sahara is the largest desert in the world, spanning 5,000 kilometers from the Atlantic Ocean in the west to the Red Sea in the east. The only measuring BSRN station in all the Sahara desert is Tamanrasset (main city in the Hoggar, also known as Ahaggar Mountains, in South Algeria). The thermal regime is characterized by low temperature compared to the surrounding Sahara because of its rather high altitude of over 1370 to 2700m. In Tamanrasset, the average temperature is 22.0°C with average maximum in summer 35.0 to 36.0°C between June and August, and an absolute maximum of 40.6°C. The temperatures become lower in winter with an average maximum of 20.0°C and the minimum drops to 4.0°C on average in winter (December–January) with an absolute minimum of -3.0°C. Tamanrasset represents an arid climate, and is also influenced by monsoon flux in summer.

The Tamanrasset radiation station was integrated into the BSRN network in March 2000 (with the sponsor and collaboration of NOAA/ESRL/GMD in Boulder). The regional characterization of mineral dust, particularly close to source areas, has become a valuable tool for researchers from different fields. The present work focuses on a detailed characterization of the daily behavior of solar radiation in a desert environment, which shows that in the summer period from May to September, Tamanrasset is influenced by monsoon flux with an important sky and haze cover. During the period 1995 to 2017, the results of a Mann-Kendall Test trend analysis of Direct (Normal Incidence Pyrheliometer) shows the negative slope (-41/year), an overall decrease in Direct (NIP). The aerosols and clouds are responsible (causes) of solar dimming. Also the arid conditions over this region could be causing the atmospheric regime to hold a maximum quantity of dust and sand. The annual mean of diffuse and global shows a positive slope (+40/year and +29/year).

2.4. Satellite and Model Studies

Validation of satellite solar irradiance estimates: Separating clear-sky and cloud effect (Laurent Vuilleumier)

In the framework of the Direct Normal Irradiance Nowcasting methods for optimized operation of concentrating solar technologies (DNICast) project, irradiance estimates from the HelioMont algorithm using MSG/SEVIRI data were validated with ground-based data collected at two sites during the year 2015. One site is the Plataforma Solar de Almeria (PSA), a 1km x 1km solar power research facility in Southern Spain hosting half-a-dozen pyrheliometers. These provide high-quality DNI measurements at a site of the scale of the MSG/SEVIRI pixel resolution. The other site is the Swiss Payerne BSRN station, providing radiation data of the high quality resulting from following BSRN guidelines. The two stations offer a strong contrast in climatic conditions with PSA being located in an arid region with frequent sunshine, while cloudy episodes are much more frequent at Payerne. The study was extended to also include validation of global horizontal irradiance (GHI).

The HelioMont algorithm (Stöckli, 2013) belongs to the Heliosat algorithm family. It first estimates the clear-sky irradiance using look-up tables derived from a radiative transfer model (RTM), then it applies a cloud modification factor (CMF) accounting for the effect of cloudiness using an empirical algorithm and the satellite imagery data. Clear-sky data allowed verifying the RTM. Its most important uncertainty source is the aerosol optical depth (AOD) used as input. With locally-measured AOD, a clear-sky DNI expanded uncertainty of about ±5-6% is found, with negligible bias. Using AOD estimates by the Copernicus Atmosphere Monitoring Service (CAMS, previously MACC), the uncertainty is increased to about ±15% with a negative bias of ~1-3%. An aerosol climatology by Kinne (2008) was also tested, resulting in a significant negative bias of ~15% and a dispersion of ±18% around it. For GHI, using locally-measured AOD allowed reaching a clear-sky expanded uncertainty of about ±3% (2-3 times the measurement uncertainty), while using CAMS AOD resulted in an expanded uncertainty of about 5%.

The CMF estimated by HelioMont was compared with one deduced by dividing the ground-based DNI measurements by the HelioMont clear-sky estimates. For clear-sky situations, the satellite derived CMF is found to be in good agreement with the one deduced from DNI and GHI measurements. On the other hand, the satellite-derived DNI CMF is found to be generally overestimated for cloudy situations, i.e., there are too few very low CMF. An important scatter is found when comparing the satellite and ground-based CMF, but 1-hour temporal averaging or spatial averaging using the multiple pyrheliometer measurements at PSA allows a significant reduction of the scatter. For GHI and cloudy situations, preliminary results indicate that the CMF seem to be somewhat underestimated for low values (i.e., the influence of thick cloud seem to be overestimated) and the opposite for thin cloud.

References:

Stöckli, R., 2013. The HelioMont Surface Solar Radiation Processing. Scientific Report MeteoSwiss, 93.

The critical importance of BSRN to quantify uncertainties and improve NASA/GEWEX SRB fluxes and resulting impacts (Paul Stackhouse)

One of the original intentions for developing the Baseline Surface Radiation Network of globally-distributed, highly calibrated surface measurements was for the validation of long-term satellite-based surface fluxes from projects such as NASA's Global Energy and Water Exchanges (GEWEX) Surface Radiation Budget (SRB) project. During the last several years, the SRB has made improvements in the algorithms and the primary inputs of cloud and meteorology data have been undergoing improvements in quality and spatial and temporal resolution. Now that International Satellite Cloud Climatology Project satellite radiance and cloud products have been reprocessed by NOAA's National Climate and Environmental Information, the GEWEX SRB project is striving to produce its Version 4 using these improved and expanded data products. GEWEX SRB v4 will expand the temporal extent of the Earth's surface radiation budget estimates to over 30 years, with over 20 of those years having at least some measurements of BSRN to validate against. This talk showed how BSRN measurements were used in the past to provide validation against 3-hourly, 3-hourly monthly, daily and monthly averaged SRB data products (mean monthly differences -5.2 and 1.0 W m-2 for SW and LW respectively). Examples of validation analysis include clustering sites by location and climate type. Ensemble monthly averaged anomalies are used to assess temporal variability in time. We showed how BSRN measurements provided a standard to assess improvements from previous versions and will be used to assess long-term variability, showing statistically significant errant trends in SRB SW of -0.25 W m-2/year, but excellent year-to-year variability within a few W m-2. We showed that the new SRB version 4 product is improved, for the years assessed so far, relative to v3 using BSRN. These examples show the need for BSRN to maintain high calibration standards for long periods of time. Additionally, the expansion of BSRN sites to even more locations of the globe and the role BSRN could have in standardizing ocean based measurements of surface fluxes were emphasized. Lastly, we provided a glimpse of the potential impact of the both the science of SRB and its impacts in the realm of applied sciences, which are only possible with standard benchmark measurements like those of BSRN.

Application of the BSRN and RadFlux data in validation and analysis of the GEWEX SRB all-sky and clear-sky shortwave downward fluxes (Taiping Zhang)

- The GEWEX SRB shortwave (GSW) (Rel. 3.0)-BSRN all-sky monthly mean comparison shows a bias/root mean square (RMS)/number (N) of 5.58 (W m-2)/22.72 (W m-2)/4625; GSW (Rel. 3.0)-RadFlux clear-sky monthly mean comparison shows 3.94 (W m-2)/12.99 (W m-2)/3638.
- Compared with CERES version 4A synoptic 1° data product [SYN1deg(Ed4A)] and Energy Balanced and Filled (EBAF) Edition-4.0 data product [EBAF(Ed4.0)], GEWEX SRB GSW(V3.0) has the smallest bias against RadFlux clear-sky fluxes, but EBAF(Ed4.0) has the highest correlation and smallest standard deviation of error.
- The systematic negative bias of clear-sky SW downward fluxes could be partly explained by the systematically lower moisture and aerosol loads as observed at BSRN sites, although the observations are limited. CERES literature also indicates that satellite observations can sometimes miss the presence of clouds and misidentify slightly cloudy sky as clear. More work is needed to address the issue.
- The bootstrapping analyses of the GSW(V3.0)-RadFlux clear-sky monthly mean errors indicate that the resampling by site-month does not cause much variability in the overall bias, but resampling by site causes more variability in the overall bias. This implies that increasing the number of BSRN/RadFlux sites can improve the certainty of the ground-based observation as a global standard of surface-based observation.
- The preliminary GSW(V4.0-IP)-BSRN monthly mean shortwave downward flux comparison over the period from 1998-2007 shows a bias/RMS/N of -1.36 (W m‐ 2)/RMS (W m‐ 2)/2494 as opposed to -3.74 (W m-2)/17.72 (W m‐ 2)/2494 for GSW(V3.0)-BSRN comparison over the same period; the preliminary GSW(V4.0-IP)-Pacific Marine Environmental Laboratory (PMEL) shortwave monthly mean flux comparison shows 0.64 (W m‐ 2)/12.69 (W m‐ 2)/1238 over the period from 2000-2007 as opposed to 9.38 (W m‐ 2)/15.53 (W m‐ 2)/1238.

Use of BSRN data in the validation of NASA's Clouds and the Earth's Radiant Energy System (CERES) EBAF and SYN1deg data products (Dave Rutan)

David Rutan presented an overview of NASA Langley's Clouds and the Earth's Radiant Energy System (CERES) Synoptic 1 degree (SYN1deg) and Energy Balanced and Filled (EBAF-surface) data products. These products provide global, gridded top of atmosphere (TOA), in-atmosphere and surface radiant fluxes for climate studies. He provided a summary of inputs and algorithms to produce these products then described how CERES utilizes the Baseline Surface Radiation Network (BSRN) surface observations of radiative flux to validate the above data product's computed downwelling radiative fluxes. He included a discussion of how the data is presented via a web-based tool where the CERES user community can access the validation data. The web-based tool as well as details on validation results is available at *https://ceres-tool.larc.nasa.gov/cave/jsp/CAVESelection.jsp*. Results show a remarkable agreement between computed and observed fluxes averaged over ocean or land sites. He further separated monthly mean differences between computed and observed fluxes into systematic and random components. He showed that the random component decreases with increasing the number of surface sites used in the validation process. This approach is used to estimate uncertainties at various spatial scales in surface fluxes of the CERES data products.

Evaluation of MODIS/VIIRS/Landsat-8 albedo products over BSRN sites (Zhuosen Wang)

Albedo, defined as the ratio of the hemispheric reflected solar radiation flux to the incident flux upon the surface, is a key climate forcing variable that governs the absorption of incoming solar radiation. Albedo contributes significant uncertainties in the simulation of climate changes; as such, it is defined by the Global Climate Observing System (GCOS) as a terrestrial essential climate variable (ECV) required by global and regional climate and biogeochemical models.

Satellite albedo products (at a gridded 500m or 1km resolution) from the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Visible Infrared Imaging Radiometer Suite (VIIRS) are routinely evaluated using tower-measured albedo from BSRN sites in the United States [as supported by the SURFace RADiation Network (SURFAD)]. These BSRN sites are also used to evaluate higher resolution albedo values derived at 30m or finer by coupling Landsat 8 Operational Land Imager (OLI) values or Sentinel-2A/B MultiSpectral Instrument (MSI) values with the coarser resolution MODIS or VIIRS surface anisotropy products. The BSRN sites are listed as key reference albedo by Land Product Validation (LPV) sub-group albedo validation protocol. The LPV sub-group of the Committee on Earth Observation Satellites (CEOS) Working Group on Calibration and Validation (WGCV) aims to address the challenges associated with the validation of global land products.

NASA's Goddard Space Flight Center's Multi AngLe Imaging Bidirectional Reflectance Distribution Function small-UAS (MALIBU) is part of a series of pathfinder missions to develop enhanced multi-angular remote sensing techniques using small Unmanned Aircraft Systems (sUAS). The MALIBU instrument package includes two multispectral imagers oriented at two different viewing geometries (i.e., port and starboard sides) to capture the intrinsic surface reflectance anisotropy and albedo. The MALIBU serves as an important resource of reference data, in particular over heterogeneous surfaces, to improve global land product validation efforts. MALIBU was deployed at the Table Mountain BSRN site in 2016.

All of the satellite products agree well with the field measurements acquired from spatially representative towers. The daily retrievals from MODIS and VIIRS capture the seasonal variation, ephemeral snow and snow melt effects on surface albedo, as measured by the tower measurements. The airborne MALIBU albedo products also agree very well with the BSRN values.

Use of BSRN data to estimate the Global Energy Balance and its changes (Martin Wild)

In this presentation, it was demonstrated that BSRN data have been instrumental to constrain the surface radiation budget shown in the Global Energy Balance diagram in the 5th Intergovernmental Panel on Climate Change (IPCC) Assessment Report (AR5) (Wild et al., 2013, 2015 *Climate Dynamics*). It has also been shown that clear-sky surface solar radiation flux climatologies can be inferred from minute data of the BSRN records. These novel data have so far been used for the assessment of clear-sky fluxes in the Coupled Model Intercomparison Project Phase 5 (CMIP5) global climate models and for the estimation of the global energy balance under cloud-free condition, as well as the global cloud radiative effects (Wild et al., 2018, under review in *Climate Dynamics*). It has been further pointed out that significant decadal changes can be inferred from both downward longwave and shortwave BSRN records. Specifically, BSRN records show an overall increase in surface solar radiation since the1990s ("brightening") with a recent leveling off, both under clear-sky and all-sky conditions. In addition, BSRN records indicate an overall increase in downward LW radiation of 1.7 Wm-2 per decade, in line with CMIP5 simulations and expectations from an increasing greenhouse effect.

From point to area: Worldwide assessment of the representativeness of monthly surface solar radiation records (Matthias Schwarz)

The spatial-temporal representativeness of surface solar radiation (SSR) point observations for a larger surrounding is a central issue when using these measurements in combination with gridded data, e.g., from satellite observations or numerical models. As previous studies on SSR representativeness focus mainly on individual aspects of representativeness and on small-scale observational networks, a global integrated assessment for the representativeness of SSR point observations is lacking. Consequently, while SSR point observations are broadly used in combination with gridded data as SSR is most accurately determined using ground-based observations, uncertainties arising from the imperfect spatial representativeness of SSR point data are often neglected, which may substantially affect results. Through analyzing high resolution satellite-derived SSR data sets, we for the first time provide an integrated near-global (50°S to 55°N) assessment of the spatial and temporal representativeness of monthly SSR observations with focus on three different aspects of representativeness: decorrelation lengths (δ), spatial sampling biases (β) and spatial sampling errors (ε; defined on the 95%-level). Across the observational domain, we find a median δ larger than 3°, which generally justifies the combination of point and gridded SSR data. For β and ε, which we analyze for a one-degree grid, we find a domain median of 1.4 and 7.6 Wm-2, respectively. These numbers are, however, not uniformly applicable as (a) regional differences are large and (b) they quantify typical (68.2%) sampling biases and errors for all locations within one-degree boxes. Location-specific values can be substantially larger or smaller. Therefore, we recommend using the location-specific errors and biases presented here. Comparing the domain median ε with the uncertainty from SSR measurement devices (i.e., 8 Wm-2) reveals that the sampling error (with respect to a one-degree grid) is of the same magnitude as the measurement uncertainty of state-of-the-art SSR measurement devices. Thus, this study shows that the combination of point observations of monthly mean SSR time series with one-degree gridded data is justified within reasonable uncertainty in most regions, at the price of a combined uncertainty (sampling plus devices uncertainty) that is roughly 40-50% larger than the measurement devices' uncertainty alone.

References:
Schwarz, M., D. Folini, M.Z. Hakuba, and W. Wild, 2017. Spatial representativeness of surface-measured variations of downward solar radiation. *Journal of Geophysical Research: Atmospheres*, (p. 2017JD027261). DOI: 10.1002/2017JD027261

2.5. Observations and Analysis Studies

The uses of the PAL BSRN station: Research, innovation and training (Jordi Badosa)

The BSRN station at Palaisaeau, 15km southeast of Paris, France, was installed in 2003, and since then, its measurements have contributed to research, training and innovation activities. Main research topics are atmospheric processes, climate and renewable energy. The presentation gave some examples through a list of questions addressed: how accurate are downwelling shortwave (SWDn) and downwelling longwave (LWDn) measurements? What are the aerosol effects on solar radiation on pollution peak events? What is the accuracy of solar resource assessment depending on the data available? How can we improve numerical weather predictions? How do radiometers of different quality compare on tilted surfaces? What is the gain of combining photovoltaic panels with reflectors? How do we train on SW and LW radiation? What are the cloud effects on SWDn and LWDn?

Aerosol optical depth, calibration and determination (Fred Denn)

This talk compares the effect of different averaging periods of Langley extrapolations, used to determine top of atmosphere irradiances (V0s), and the effect these different averaged V0s have on Aerosol Optical Depth (AOD). The data used in this study was from a Yankee Environmental Systems Multi Filter Rotating Shadowband Radiometer (MFRSR). V0s were determined at the Filter Radiometer Comparison, which was held In Davos, Switzerland during September and October of 2015, at Mauna Loa Hawaii and at NASA Langley. At NASA Langley three averaging intervals were used and compared, one month, three months, and nine months. The optimal averaging period was determined to be 3 months, which was about 20 Langley extrapolations. This produced average V0s that were acceptable for the determination of AOD. The three month period is also short enough to minimize seasonal effects on the MFRSR. It was also shown that shipping an instrument can have an effect on its sensitivity. The conclusion being that an in place determination of V0s can be optimal.

2017 Pyrgeometer inter-comparison in Darwin, Australia (Nozomu Ohkawara)

A pyrgeometer inter-comparison was conducted in Darwin, Australia in October 2017 as a collaboration campaign between the Australian Bureau of Meteorology (BoM) and the Japan Meteorological Agency (JMA). The main purpose of the inter-comparison is to examine the difference between windowed pyrgeometers calibrated by the World Infrared Standard Group (WISG) and representations of the SI by the windowless infrared integrated sphere radiometer (IRIS) at high total column water vapor. The results are supporting the evidence of a 4-5 Wm-2 offset between the pyrgeometers and the IRIS by the results at the Physical Meteorological Observatory in Davos (PMOD) in Switzerland. The results also indicate that the air temperature in the lower atmosphere largely affects the offset, resulting in a great variation and the cloud does not seem to affect much of the offset at high column water vapor.

Recent updates about the ACP, IRIS and AERI infrared comparisons (Ibrahim Reda)

In recent updates about the Absolute Cavity Pyrgeometer (ACP), InfraRed Integrating Sphere (IRIS) and Atmospheric Emitted Radiance Interferometer (AERI) comparisons, we presented the results of five comparisons between ACPs and IRISes. Two of the five comparisons were held at SGP and included AERI. The results indicate that the irradiance measured by the WISG is lower than the irradiance measured by ACPs, IRISes and AERI; the difference varied from 4.4 W/m^2 to 6.6 W/m^2 depending on the integrated water vapor.

Performance of thermal offset corrections for modern pyranometers (Carlo Wang)

For pyranometers, the thermal offset error is one of the main errors, which is due to the temperature difference between the detector and the domes. It usually results in the underestimation of the measurements. In order to investigate the characteristic of thermal offset for different pyranometers and the performance of different correction methods, we collected 20 pyranometers and carried out an inter-comparison experiment in cooperation with NOAA and pyranometer manufacturers from December 2017 to March 2018. Two thermal offset correction methods (i.e., detector only and full correction method) were applied to daytime irradiance during the experimental period, and the values after correction were compared to the reference units provided by NOAA. Our results show that the three modern pyranometer models (MS-80, SR25-T2 and SR30-D1), which had been designed for improving the thermal offset error, have the magnitudes of nighttime thermal offset (0.01 Wm-2) much lower than that of the other pyranometers (-2.08-0.44 Wm-2). For the pyranometers, which were designed without considering the thermal offset error, a correction for the error is necessary. According to the assessment, the full correction method is suitable for more than half the pyranometers such as CMP11, CMP21, CMP22, MS-80 and ventilated SR-75, SPP and PSP (average correction improvement: 0.17-1.66 Wm-2); however, the better method for unventilated SR20-D2 and PSP, and ventilated SR30-D1, is the detector-only correction (average correction improvement: 0.10-1.04 Wm-2). Overall, the results of the experiment show that the pyranometer measurements are affected by the choice of pyranometers, the on/off of the ventilation and the usage of the thermal offset correction method.

The D-ICE campaign for ice mitigation study (Chris Cox)

In cold climates, ice frequently obscures broadband longwave and shortwave sensors, contaminating measurements. Since icing occurs under particular meteorological conditions, associated data losses constitute a climatological bias. Furthermore, the signal is difficult to distinguish from that of clouds, hampering efforts to identify contamination in post-processing. De-Icing Comparison Experiment (D-ICE) is evaluating systems designed to mitigate the formation of ice using various configurations of ventilation and heating within customized housings, and also aims to characterize any potentially adverse effects of the techniques themselves. Since August 2017, data from a suite of 25 systems has been collected alongside standard units operating with only regularly-scheduled manual cleaning by human operators at the NOAA Baseline Surface Radiation Network (BSRN) station in Utqiagvik (formerly Barrow), Alaska. Icing on the sensors is monitored visually using cameras recording images every 10-15 minutes at the NOAA observatory, as well as the operational stations at the nearby Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Program North Slope of Alaska (NSA) site and the more distant ARM Oliktok Point mobile facility, 250km east of Utqiagvik.

Previous experience within the BSRN community suggests that aspiration of ambient air alone may be sufficient to maintain ice-free radiometers. Initial results based on data collected from November 2017 through February 2018 support this assertion. Most tested systems are observed to significantly reduce icing with several showing markedly little vulnerability (90%+ reduction in the frequency of ice). However, we have also observed large variability in performance between systems, some of which differ in only very minor ways, implying the effectiveness of ventilation is highly sensitive to subtle variations in design. Generally, the systems are more effective at mitigating ice on pyrgeometers than pyranometers, possibly because the former have lower profile domes. For November-February, we compared the raw (pre-quality control) upward-facing BSRN pyrgeometer data to a best-estimate downwelling longwave (LWD) time series constructed from a combination of the data from the D-ICE pyrgeometers when the instruments were ice-free. During brief periods, icing was observed to enhance the BSRN LWD by up to 55 W m-2. However, despite the fact that the ambient air on the D-ICE platform was saturated with respect to ice about 49% of the time, we estimate the operational BSRN data suffered only a small positive bias caused by icing when averaged over time (+1.4 W m-2).

An update on trends in surface radiation over the U.S. as determined from the seven SURFRAD BSRN sites (John Augustine)

The surface radiation budget (SRB) trend analysis for the seven U.S. SURFRAD BSRN sites has been updated through 2017. Trends of the SRB, its components, and ancillary data for the U.S. were first published for the period from 1996 to 2011. A large increase in the SRB of +12 Wm-2 was documented, with most of that signal coming from an increase in downwelling solar at the surface (~ +10 Wm-2), in agreement with brightening globally during that period as documented by Wild (2012). The updated record through 2017 shows the U.S. SRB trend to have leveled off after 2007, but the solar down brightening at the surface to have continued to a peak in 2012. In the five years following 2012, solar down brightening at the surface over the U.S. has dramatically returned to normal (based on the mean over the 22 years of observations), with no obvious trend. The brightening and recent dimming over the U.S. has been attributed to systematic changes in cloud cover. Aerosol optical depth, a proxy for aerosol amount, has steadily decreased over the U.S. over the entire 22-year tenure of the SURFRAD network. That is consistent with brightening, but not the recent dimming. Further, the direct effect of aerosols corresponding to the observed decrease in AOD over the brightening period only explains a small fraction of the decrease in solar at the surface. The change in longwave over the 22 years is highly variable and is governed by surface air temperature, low-level moisture and cloud cover. Nearly 50% of the variance in longwave down over the U.S. is explained by the El Niño Southern Oscillation index. Finally, a noted increase in AOD minima at all SURFRAD sites through the brightening period (ending in 2012) and a decrease of AOD minima in the dimming period thereafter appears to be related to the variability of stratospheric aerosols, as documented by the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP). That same variation is mirrored in clear-sky diffuse solar at the surface as determined by the Radiative Flux Analysis (RadFlux) of SURFRAD data.

Reference:
Wild, M., 2012. Enlightening Global Dimming and Brightening. *Bulletin of the American Meteorological Society*, https://doi.org/10.1175/BAMS-D-11-00074.1.

2.6. Working Group Reports

Infrared Working Group Report (Julian Gröbner)

Members:
J. Gröbner (chair), J. Michalsky (emeritus), S. Wacker (vice-chair), I. Reda, N. Ohkawara, T. Carlund, B. Gorman, B. Forgan, T. Kirk, J. Konings, J. Mes, L. Vuilleumier, J. Celso Thomaz, K. Hoogendijk

Further comparisons between windowless radiometers such as the IRIS, ACP and AERI and common network pyrgeometers were conducted: an IRIS pyrgeometer comparison at high water vapor content [35–55 mm integrated water vapor (IWV)] took place in October 2017 in Darwin, Australia between BoM and JMA. In addition, a comprehensive intercomparison campaign between IRIS, ACP and AERI at ARM SGP was conducted between 16 and 27 October 2017 (phase 1) and between 27 November and 8 December 2017 (phase 2). Results from these three intercomparisons are consistent with previous comparisons and studies which show a good agreement between the windowless radiometers within the uncertainties of the instruments, an underestimation of about 5 Wm-2 of the WISG and network pyrgeometers traceable to the WISG for IWV larger than 10mm and a linear decrease of this offset for IWV contents smaller than 10mm. The Task Team on Radiation References (TT) is now elaborating requirements and timeliness for a future modification of the current longwave world reference WISG based on the results of these comparisons. The guidelines are planned to be released after the 17th Session of the Commission for Instruments and Methods of Observation, which will be held 12–16 October 2018 in Amsterdam. Apart from these inconsistencies, pyrgeometers have shown to be very stable over longer periods. However, an additional source of uncertainty for certain pyrgeometer types may be caused by the sensitivity determined during night time but applied on day time data. Finally, the use of either an outdoor or a Blackbody-based calibration for upwelling longwave irradiance measurements will be studied in more detail.

Cold Climate Issues Working Group Report (Chris Cox)

Participants:
Chris Cox (Chair), Amelie Driemel, Sara Morris, Elke Ludewig, Marion Maturilli, Rich Lataitis, Kai Rosin, Bryan Fabbri, Mark Kutchenreiter, Tristan L'Ecuyer, Stewart Freidenreich, Matt Shupe, Angelo Lupi, Jorgen Konings, Chuck Long, Allison McComiskey, Taiping Zhang, Tom Kirk

During the 2016 meeting, the Cold Climate Issues Working Group (CCIWG) identified three objectives to complete for the Year of Polar Prediction (YOPP) (2017-2019): (1) update the BSRN polar sites in the archive; (2) develop a mobile radiometer intercomparison station; and (3) carry out a campaign to evaluate the state of ice mitigation technology for broadband radiation stations. During the 2018 session, these objectives were reviewed. Objective (1) was determined to be only partially completed and because YOPP is ongoing, this objective was kept as a priority. Objective (2) was not completed, but there was still significant interest from the participants, now including also from representatives of the upcoming Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) drifting observatory (*mosaicobservatory.org*). This interest warranted keeping the mobile intercomparison station project as a CCIWG priority as well, though funding for the project has yet to be identified. Objective (3) was completed: CCIWG and partners carried out the De-Icing Comparison Experiment (D-ICE) from August 2017 through June 2018. Discussion of D-ICE motivations, status, preliminary results and future plans were the focal point of the session and the discussion helped to refine the path forward for the project. Therefore, the third CCIWG objective has been updated to focus on the D-ICE products, including processed data sets and publication of results. It is anticipated that products will include a two-part publication series. The first part will release a "best estimate" data set suitable for YOPP activities, will analyze biases associated with icing and will present recommendations targeting the end-user community. The second part will analyze the performance of the heating and ventilation technologies that were the subjects of the campaign and will present recommendations for broadband radiation station operators.

Spectral Working Group Report (Kathy Lantz)

- The BSRN Spectral Working Group is tasked with three topic areas: UV broadband radiometry, aerosol optical depth and photosynthetically active radiation (PAR).
- We discussed and reviewed tasks that occurred since the last working spectral group session in Canberra, Australia, 2016. These tasks included the findings from the World Radiation Center (WRC) Fourth Filter Radiometer Comparison (FRC-IV) and the WRC Second UV Filter Radiometer Campaign (UVC-II), and future tasks with a PAR radiometer intercomparison, as well as interest in spectral solar irradiance products.
- The UVC-II was held at the PMOD WRC from May 25 – Oct 3, 2017 with an impressive 75 instruments participating from 37 countries. This effort was led by Gregor Hulsen and Julian Grobner. A WMO Global Atmosphere Watch (GAW) 240 report was written and published on the results. This campaign highlighted the importance of calibrations and corrections for deviations in the angular response from an ideal cosine response, and from the desired International Commission on Illumination (CIE) erythema spectral response. The spectral group had a discussion on appropriate maintenance and humidity issues. An actionable item was to include guidance in the BSRN manual for maintenance procedures for UVB radiometers, as well as a description of acceptable calibration methodology and correction for angular and spectral response deviations.
- The Fourth Filter Radiometer Campaign was held at the PMOD WRC in 2015, led by Stelios Kazadzis, Natalia Kouremeti and Julian Gröbner. The WMO GAW Report was written and published and a subsequent paper was published by lead author Stelios Kazadzis. An overview of the results were presented and discussed. Discussions of the group confirmed the findings of a need for a campaign in a location with higher AOD,

such as Taiwan. In addition, it was discussed that it would be desirable to have a longer campaign to represent instruments that use Langley calibrations on site.

- The final task discussed was calibration and characterization of PAR sensors. There were six networks that identified using PAR sensors in an informal count. The group identified the need for a well-calibrated traceable spectroradiometer in the wavelength range of 400-700 nm, preferably three radiometers per manufacturer or type, and characterization of the instruments for spectral and cosine response. Several spectroradiometers were identified. Mark Kutchenreider from the National Renewable Energy Laboratory (NREL) indicated he could possibly provide the calibrated spectroradiometer and a venue for the calibration campaign. The NOAA Central UV Calibration Facility (CUCF) will look into providing the spectral and angular response characterizations. Several BSRN stations identified that they could provide students for the analysis. Actionable items included following up with NREL and the NOAA CUCF and participating of BSRN stations with PAR sensors.

Proposed Use of BSRN in Solar Renewable Energy Working Group (Enio Pereira)

Participants:
Enio Bueno Pereira (Chair), Ansgar Delahage, Baika Sidi, Béatrice Morel, Brighton Mabasa, Frank Vignola, Gary Hodges, Jordi Badosa, Karthik Ramanathan, Kathy Lantz, Marco Steffancich, Matt Perry, Roberto Bonifaz, Taiping Zhang, Will Beuttel

This working group was proposed by Enio Pereira, responsible for the Brasilia (BRB), Petrolina (PTR) and São Martinho da Serra (SMS) stations in Brazil. The rationale for this proposal is that solar energy today is a booming energy market all over the world and there is a growing demand for quality data to support this development. In addition, this market generates high turnover, making it the ideal target to raise funds to maintain BSRN stations and activities. Fifteen colleagues joined the first meeting of this new working group (WG) that convened on Wednesday, 18 July. Several opportunities and barriers were discussed during the meeting, varying from questions about uncertainties in the models for surveying solar energy resources, the bankability of solar energy projects and the intermittence and variability of the solar resource to the short and long term stability of solar energy. The WG recognized the need to develop a deeper analysis of the following specific issues: should BSR modify its data protocol and products to adapt to the renewable energy (RE) sector, and which of the RE sector demands could be attended to with products right off BSRN shelf? There are also issues related to proprietary data in the RE industry and possible use of the BSRN expertise on site-specific data acquisition to help the solar energy survey. Finally, a key question emerged during the meeting: will the RE sector be willing to invest resources to support long-term data acquisition activities typical of BSRN? To address the various issues raised by this WG, It was proposed to use the Strengths, Weaknesses, Opportunities and Threats (SWOT) methodology of strategic analysis to support this WG during the discussions at the next BSRN meeting. An Excel worksheet based on the methodology will be distributed in a timely manner to the members of this WG and other interested parties for this analysis.

BSRN Manual Review Committee (Gary Hodges)

Participants:
Gary Hodges (Lead), Tom Stoffel (Co-Lead), Chuck Long, Kathy Lantz, Jordi Badosa, Joop Mes, Laurent Vuilleumier, Stefan Wacker, Amelie Driemel

A discussion in relation to the BSRN Manual occurred as part of the 2016 BSRN Workshop. The latest version, primary author Bruce McArthur, was published in 2005 as a World Meteorological Organization (WMO) Technical Document (WMO/TD-No. 1274). Given the significant progress and advances in radiometric measurements, understanding and operational and calibration paradigms, an updated version of the manual should be produced. A lunch meeting was held at this year's BSRN Workshop to discuss formation and scope of a

BSRN Manual Review Committee. Gary Hodges has volunteered to lead the effort, along with assistance from Tom Stoffel, and will pursue other volunteers from the BSRN membership to assist. This is recognized as involving a significant effort, and the efforts of any who participate are gratefully recognized.

Along with review of the manual itself, several other areas of concern were mentioned that the committee might look into. One area is to produce a "checklist" of information categories new site proposals must include as part of any new site proposal presentation. It is realized there is a minimum amount of relevant information about any proposed site, its proposed staffing, its proposed instrumentation, its proposed operations and its location, climate and surroundings that must be given in order to actually assess a proposed site's relevance to BSRN. In addition, it was suggested that perhaps some letter of commitment for at least 10 years of operation from the site's sponsor organization be given as a good faith indication of intent for long-term operations. And perhaps the site should be required to already have at least 18 months of BSRN quality data collected at the time of the proposed presentation to demonstrate the proposed site actually meets BSRN specifications. These ideas will be addressed as part of the committee's activities.

Broadband Radiometry Working Group (Allison McComiskey)

A BSRN Broadband Working Group meeting was not held formally this year at the workshop. With limited time for breakouts and important topics to be covered by other working groups, including specific topics of interest to the Broadband Working Group, we decided to forgo a formal meeting. However, the group is still in existence and some relevant topics were discussed in other breakouts and in the plenary sessions at the workshop that are being recorded here so that the group can address and consider meeting at a later time. Major topics involved the recent and ongoing activities to develop new absolute standards for the longwave and in coordination with the effort to address potential offsets of the current WISG. Another is the intercomparison campaigns for a range of pyranometer models widely used by the radiation community to assess their variability under different sky and meteorological conditions and their different IR loss characteristics. The LW standards and WISG topics were covered in the IR breakout and Carlo Wang presented the findings from the pyranometers in a variable condition intercomparison that was performed at the university in Taiwan. This intercomparison was a follow-on to a similar campaign held at NREL in Golden, Colorado. The results from these two campaigns, held in dry and moist environments respectively, will be of interest to the BSRN community, so the Broadband Working Group might play a role in the effort to pull together the data, analysis and reporting of the findings. NCU in Taiwan is currently taking the lead in the analysis and should be the primary point of contact.

Two other subjects were raised at the workshop on note. Wouter Knap (Cabauw) presented long term trends of the ratio of global SW to sum SW (direct+diffuse) for a random selection of BSRN sites. The long-term view of this particular diagnostic is especially useful for detecting measurement anomalies at different sites and may lead to diagnosis, or at least better uncertainty reporting, by site (i.e., providing a characterization of the environmental vs. the instrumental uncertainty). While there is no support at the Alfred Wegener Institute (AWI) for the BSRN archive to do these analyses and make them available online, the BB WG might discuss how to implement such an effort.

A recommended calibration schedule might be developed that would be informed by analysis of long-term calibration data for specific instruments and their change through time. There is likely a large amount of data out there on calibrations stability, especially from NOAA and other organizations that have operated for decades. Several groups have started analyses of these data, so the question is whether or not there is the possibility of getting all interested groups together to provide a coordinated effort. SW calibrations might move to a once-every-two-years schedule and LW to much less frequently, saving resources for site operators, if we invested in this analysis. The Cold Climate Processes group is developing a traveling standard, which might also be useful for this purpose. For groups or sites where short calibration cycles are difficult, doing a field “spot check” might be quite useful to understand whether instruments are drifting or if there is a catastrophic problem. It would also provide more data to support recommendations on cycles. The BB WG might consider working with Cold Climates to develop a suitable unit/units for all sites.

2.7. Business and Discussions

The final session of the Workshop was comprised of BSRN business and discussions. The first item of business was a discussion of the proposed candidate sites.

The candidate sites that were given provisional acceptance were the Selegua, Mexico site (Adriana Gonzalez Cabrera); the Paramaribo, South America site (Ankie Piters); the Huancayo, Peru site (Luis Suarez Salas); Granite Island in Lake Superior, USA site (Bryan Fabbri); the Reunion Island site (Béatrice Morel); the Mt. Jude and Orchid Island sites, Taiwan (Carlo Wang); and the Budapest-Lőrinc, Hungary site (Dénes Fekete). These eight new sites will be marked with white circles as candidate sites on the BSRN Sites map (*http://bsrn.awi.de/stations/maps.html*), and will be designated as full-fledged BSRN sites upon successful acceptance of quality-assessed data files into the BSRN Archive, the final step in becoming a BSRN station.

It was decided that the site near Dubai, UAE not be accepted at this time. Besides the current state of development being only trenching and footers for the intended radiometry platform, serious questions arose about the site being significantly influenced by the nearness to such a large photovoltaic (PV) solar panel field both in the radiation and the ambient meteorology. For instance, Ohmura (2001) and MacFarlane et al. (2013) show that 70% of the clear-sky surface downwelling LW signal comes from the 100m of atmosphere above the instrument, and over 90% from the lowest km of atmosphere above the surface. Given that the vast area of solar PV panels are absorbing solar energy and converting that energy to electricity rather than the ground absorbing that energy, getting heated, and in turn heating the ambient air, it seems intuitively obvious that the air temperature and thus the upwelling and downwelling LW will be affected. This site presentation generated interesting discussion regarding the growth of solar PV farms and the attendant inquiries from the corresponding organizations as to joining BSRN. One idea that was recommended to the Dubai site representatives was a unique opportunity. If they were to also install a surface radiation and met station at least 10km away (the current BSRN distance recommendation for site representativeness) on the more representative desert surface, then a comparison between the two could be used to quantify the influence of the solar PV farm on the local radiation and meteorological fields. Regardless, the Dubai representatives were invited to propose again at a later BSRN Workshop, at least when they actually had their instruments installed and operating.

Once all of the proposed sites discussion was ended, the next item discussed was the idea of having a deputy or assistant BSRN Project Manager. One motivation for this idea stems from a view toward succession for continuity of corporate knowledge and experience now that the BSRN Project Manager position seems to have evolved to a term position. In addition, the duties and tasks of the Project Manager position have grown over the years, including requests from many groups to attend meetings and conferences to represent BSRN. Many of these requests are legitimate collaborations that BSRN should be involved with, but currently the only travel funding associated with the position from WMO is for the Project Manager to attend the biennial BSRN Workshop, and attend the annual GDAP meetings to report on the BSRN status. Perhaps with two persons covering the Project Manager position plus the BSRN Archive

Director, the travel load can be shared and distance from one of the three be minimized for possible travel. A show of hands vote overwhelmingly approved of the idea. Previous discussion with the GDAP Co-Chairs also met with approval. Thus the same methodology for nominating possible candidates will also be pursued by the new Project Manager in collaboration with the GDAP chairs.

In other business, the idea of a used equipment and knowledgeable expertise network was mentioned. The idea of the formation of an “expertise resource” group to share knowledge and expertise relevant to all aspects of BSRN was extended to the idea that perhaps a listing of used and currently unwanted BSRN-related equipment might be gathered to help BSRN members with issues such as repair or even upgrading of their sites to include upwelling irradiance measurements. While no specific action was taken, it is hoped this discussion might serve as a seed for future discussion and action.

Finally, it was mentioned that there is a need for investigation into the quality of BSRN data that actually resides in the Archive. This idea stems from the results that were presented by Wouter Knap during the last Tuesday afternoon session. While BSRN specifications are to be followed, and the quality of each BSRN site's data is the responsibility of the site Station Scientist, it is also recognized that there is a wide range of actual expertise represented across the BSRN membership. Data issues are likely being introduced as the BSRN founding members hand off to newer personnel, and also as new sites come on board. One example is regarding the known issue of IR loss from pyranometers that introduce a negative bias in SW irradiance measurements. A BSRN discussion many years ago agreed that while the physics of the atmosphere preclude negative SW irradiances at night, the physics of our measuring instruments do indeed include IR loss and negative night time offsets that also propagate as a low bias into the daytime data. Thus these negative values need to be included in the data submitted to the BSRN Archive so that users are able to see what the possible negative biases in this site's data might be. In addition, methodologies to correct for IR loss have been published, and station scientists are supposed to be applying these correction methodologies to their data if their particular model instruments fail the BSRN QC -2 W/m^2 lower limit for acceptable SW data at night. But examination of data downloaded from the BSRN Archive show a significant number of site's data are all set to exactly zero at night, which is a physical impossibility for any pyranometer, no matter how good it is. Thus for those sites, a user has no way of knowing what the negative bias of the site's data might be. Again, no specific action was taken on this item, other than encouraging Wouter to continue to look into this as he can and report at the next BSRN Workshop. But it is hoped this discussion again might serve as a seed for future discussion and organized action. Wouter has proposed to start a new “Data Quality Working Group” with himself as chair with Amelie Driemel and Jordi Badosa as first members. The goals of the Data Quality WG will be (1) to identify quality issues in archived and submitted station data and (2) to develop and implement better and new QC methods. Other BSRNers are invited to join.

This brief accounting of the 15th Baseline Surface Radiation Network Scientific Review and Workshop hopefully gives a flavor of the breadth of topic areas of the meeting. Once again the level of expertise and enthusiasm of the participants was especially noteworthy. Most of the presentations and electronic versions of posters are available on the web site: *http://www.esrl.noaa.gov/gmd/grad/meetings/bsrn2018.html*.

References:

Ohmura, A., 2001. Physical basis for the temperature-based meltindex method. *J. Appl. Meteor*., 40, 753–761.

McFarlane, Sally A., Charles N. Long, Julia Flaherty, 2013. A Climatology of Surface Cloud Radiative Effects at the ARM Tropical Western Pacific Sites. *J. Appl. Meteor. Climatol*., 52, 996-1013. doi: http://dx.doi.org/10.1175/JAMC-D-12-0189.1.

3. Example Poster Summaries

Status of the Izana BSRN Station in July 2018 (Rosa Garcia Cabrera)

In 2009, the Izaña Atmospheric Observatory (IZA, BSRN station no: #61) started its process to become a BSRN station. This is a subtropical high-mountain station, located in Tenerife (Canary Islands, Spain, at 28.3°N, 16.5°W, 5 2373 m a.s.l.). It contributes with basic radiation measurements, such as global shortwave radiation (SWD), direct radiation (DIR), diffuse radiation (DIF) and longwave downward radiation (LWD), extended measurements, including ultraviolet ranges (UV-A and UV-B), shortwave upward radiation (SWU) and longwave upward radiation (LWU) and other ancillary information, such as vertical profiles of temperature, humidity and wind obtained from radiosonde (WMO, station #60018) and total column ozone from a Brewer spectrophotometer. The IZA measurements present high quality standards since more than 98% of the data are within the limits recommended by the BSRN. There is an excellent agreement in the comparison between SWD, DIR and DIF (instantaneous and daily) measurements with simulations obtained with the LibRadtran radiative transfer model. The root mean square error (RMSE) for SWD is 2.28% for instantaneous values and 1.58% for daily values, while the RMSE for DIR is 2.00% for instantaneous values and 2.07% for daily values. IZA is a unique station that provides very accurate solar radiation data in very contrasting scenarios: most of the time under pristine sky conditions, and periodically under the effects of the Saharan Air Layer characterized by a high content of mineral dust.

Status of the Payerne BSRN Station (Laurent Vuilleumier)

Federal Office of Meteorology and Climatology, MeteoSwiss, Payerne, Switzerland
The Payerne station has measured the basic BSRN set of parameters since November 1992. In addition, other parameters, including long-wave (LW) and short-wave (SW) 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. These QC checks are applied daily in a first step by an automatic flexible algorithm combining multiple tests. These automatic QC tests single out suspicious data that is afterward assessed visually by human operator. In 2011, an important upgrade of the Payerne BSRN station occurred, which allowed for it to be integrated into the general MeteoSwiss automated network infrastructure. This involved completely removing and renewing the old infrastructure, including supporting benches as well as signal and power cabling. After this renewal, several issues were detected and an important quality analysis effort was launch to understand and solve the issues. In the meantime, data submission was suspended. It took longer than anticipated to solve all the issues, and it is only recently that all corrections could be applied and data submission restarted. The Payerne BSRN station is again active, and submission of the data backlog since 2011 is underway.

Status of Tartu-Tõravere (TOR) BSRN Station (Kai Rosin)

The Tartu-Tõravere station presents the longest time series of radiation measurements in Estonia. The Actinometric station at Tartu, in the eastern part of Estonia, was established in 1950. That was also the beginning of regular measurements of global radiation and direct irradiance. The measurements of diffuse irradiance were added in 1954 and reflected irradiance in 1955. Radiation measurements were moved to Tõravere, 20 km from Tartu, in 1965. The station became a BSRN candidate in 1993, and since 1999 it has operated as a BSRN station with measurement data transmitted to the BSRN archive on a monthly basis. In addition to basic quantities, net radiation, downward and upward long-wave irradiance, UVA, UVB, UV erythemal radiation, photosynthetically active radiation, total ozone and aerosol optical depth measurements are also carried out. All instruments are calibrated yearly, and the condition of sensors is checked several times a day. All sensors will be connected with new data acquisition system in 2018–2019.

Status of the BSRN station PAL at SIRTA Observatory, Paris Region (Jordi Badosa)

The Site Instrumental de Recherche par Télédétection Atmosphérique (SIRTA) observatory has contributed to BSRN since 2003 (Station: PAL). Data submitted to date to BSRN covers the period June 2003–June 2018. Current available parameters are downwelling shortwave (SWDn) irradiance (diffuse, direct and global), downwelling longwave (LWDn) irradiance, air temperature, relative humidity and atmospheric pressure. In 2012, a 10m mast was installed on a field 700m away from the station, equipped with downwelling and upwelling shortwave and longwave irradiance (SWDn, LWDn, SWup, LWup) measurements. In 2014, the SWDn (DIF, DIR, GLO) and LWDn measurements were duplicated (80m away from the initial station) to replace the existing ones in order to ensure the quality (due to a crane installation nearby). Both stations are still maintained (although only data from the recent one are submitted to the BSRN archive), which allows a deeper study on the measurements quality through comparisons. Some examples are given in the poster.

All pyranometers, pyrgeometers and pyrheliometers are regularly sent to PMOD (Davos, Switzerland) for calibration. The poster shows the obtained calibration coefficients over time for all instruments. The rule applied to all the instruments is to keep using the first PMOD coefficient as long as the new ones fall within the calibration uncertainty.

Status of four Indian BSRN Stations (Karthik Ramanathan)

Mr. Karthik R. of the National Institute of Wind Energy presented a poster on the status of the four Indian BSRN stations located at Thiruvallur, Gurgaon, Gandhinagar and Howrah. The four stations were proposed as potential BSRN stations at the BSRN Scientific Review and Workshop in Canberra, Australia during April 2016. Data have been successfully submitted for all four stations starting in August 2014 and are now active stations under BSRN.

The Tiruvallur station, established on 16 April 2014, is located in the southern part of the Indian Peninsula. Its location is in the suburban part of the Indian city of Chennai. The Coromandel Coast of the Bay of Bengal is aerially about 35km to the east of the location. The station is established on a four-story concrete building with altitude around 16m a.g.l.

The Howrah station was established on 14 September 2013 and is located in the eastern part of India. Its location is in the urban part of the Indian city of Kolkata and on the banks of the River Hooghly. The coast (Bay of Bengal) is aerially about 95 km towards south of the location. The station is established on a seven-story concrete building with altitude around 30m a.g.l.

The Gandhinagar station was established on 7 August 2011 and is located in the western part of India. Its location is in the suburban part of the Indian city of Ahmedabad. The station is established on ground level.

The Gurgaon station was established on 20 October 2011 and is located in the northern part of India. The location is in the suburban part of the Indian city of Delhi. The station is established on a three-story concrete building with an altitude of 12m a.g.l.

Status and plans for BSRN stations in the northern Canadian archipelago and Greenland (Chris Cox)

Here we provide an update on BSRN stations at Alert, Canada (82.49ºN, 62.42ºW, 127 m); Eureka, Canada (79.99ºN, 85.94ºW, 85 m); and Summit, Greenland (72.58ºN, 38.48ºW, 3210 m). Of the three, Alert is the only active BSRN station. The Alert station is a collaboration between CIRES/NOAA and Environment and Climate Change Canada (ECCC), represented by Andrew Platt. Recent Alert data (2015-) has not yet been submitted to the BSRN archive. This is because of efforts to update calibrations and assess potential drift in calibration after a period where instruments were deployed beyond their recommended recalibration schedule. Radiometer exchanges were completed in the summer of 2017 and calibrations carried out at NOAA by the Global Monitoring Division (GMD) on schedule with the plans outlined during the 2016 BSRN meeting in Canberra. No instruments were found to have a statistically-detectable drift, and so efforts are currently underway to update Alert within the archive, consolidating the processing procedures with those used by NOAA-GMD.

Eureka was “closed” as a BSRN station in 2012, but measurements continued in collaboration between NOAA and the Canadian Network for the Detection of Atmospheric Change (CANDAC), represented by Pierre Fogal. In summer 2018, the station was refurbished and we anticipate applying to reinstate Eureka as a BSRN station during the 2020 BSRN Scientific Review and Workshop.

Summit, Greenland may be an ideal location for a BSRN station. In addition to the Greenland ice sheet being currently unrepresented within BSRN, the location has many attributes that are well-aligned with BSRN objectives, including homogeneous terrain that is ice covered throughout the year and extreme meteorological conditions, all of which present unique challenges for satellites and models. Unfortunately, despite Summit being formerly a candidate BSRN station, no data has ever been submitted to BSRN. Efforts within NOAA are underway to assemble a new system that could be ready to apply for BSRN status in 2020. NOAA is currently looking for input from the BSRN community about this objective.

Status of the NASA Langley Research Center (LRC) BSRN station (Fred Denn)

Status posters for the two BSRN sites operated by Science Systems and Applications, Inc. for NASA Langley were presented, including the NASA Langley Research Center site (LRC) in Hampton, Virginia, United States. Views of the site were presented. Instrumentation includes up looking radiometeric and standard meteorology. Data is available from December 2014.

New Site Proposal: Granite Island in Lake Superior, a new BSRN water site proposal (Bryan Fabbri)

A semi aquatic BSRN site in Granite Island, Michigan, United States is proposed. Views of the site and instrumentation were presented. Instrumentation includes up looking radiometeric. Meteorology is currently available from the Great Lakes Evaporation Network. Data is expected to be available in October 2018.

Direct spectral irradiance measurements from rotating shadowband EKO grating spectroradiometer (Will Beuttell)

The poster that was presented showcased a rotating shadow band (RSB) configuration for the EKO MS-711 spectroradiometer to measure the global, diffuse and direct components of spectral solar irradiance. An RSB configuration allows lowering the costs associated with the instrumentation and maintenance required to measure the components of spectral irradiance. With only one spectroradiometer, discrepancies associated to sensor calibration are minimized. This work presents a study to validate the EKO RSB spectroradiometer accuracy in measuring the direct normal irradiance (DNI). A comparison is made between the measurements performed with the RSB spectroradiometer and a collimated spectroradiometer at the NOAA Mauna Loa Observatory. The results of the comparison show an agreement within 2% to 5% between the DNI estimated by the RSB and collimation configurations for solar zenith angles smaller than 70°. Larger deviations approximated to 10% are found for larger angles of incidence.

Partitioning of Solar Energy in the Climate System (Matthias Schwarz)

The partitioning of incoming solar energy between absorption in the atmosphere, absorption at the surface and reflection back to space is a key aspect of energy balance studies. Although the partitioning of solar radiation is well understood in terms of long-term climatological means, the temporal variations are not yet well-enough constrained by observations to allow thorough climate change studies. We extend the climatological approach of Hakuba, et al. (2014) to monthly mean time series and combine homogeneous, representative and bias-corrected surface solar radiation station data from BSRN, the Global Energy Balance Archive (GEBA) and data from the Chinese Meteorological Administration (CMA) with top of the atmosphere flux data from the Clouds and Earth's Radiant Energy System (CERES) and Moderate-resolution Imaging Spectroradiometer (MODIS) albedo data to calculate monthly mean time series for the partitioning of solar radiation in the climate system. The combined time series cover a time period from 2000 to 2015. Due to the use of GEBA, BSRN and CMA data, we are able to derive observation-based time series of atmospheric absorption of solar radiation for many regions around the globe including an uncertainty estimate. We use these time series to conduct climatological, seasonal and trend analyses.

Reference:
Hakuba, M.Z., D. Folini, G. Schaepman-Strub, and M. Wild, 2014. Solar absorption over Europe from collocated surface and satellite observations. *Journal of Geophysical Research: Atmospheres*, 119, 3420–3437, DOI: 10.1002/2013JD021421.

Solar radiometric activities at De Aar, South Africa (Brighton Mabasa)

De Aar Baseline Solar Radiation Network (BSRN) station (latitude: -30.67; longitude: 23.99; altitude: 1287m) is located in the cold interior climatic zone in the Northern Cape province of South Africa. The open bare-area De Aar is characterized by insignificant urban development and it is thus a very clean site with an annual average diffuse fraction of 0.2 and an annual clearness index of 0.75. The area has an annual humidity of less than 45%, while mean monthly temperature ranges between 10 to 25°C. The most dominant wind speed velocity is between 3.6–5.7 m/s blowing from South-East direction and the sunshine duration is slightly less than 10 hours in winter and autumn and slightly above 10 hours in summer and spring. The De Aar station undergoes regular maintenance and the data is quality controlled according to (Long and Dutton, 2002) methodology. To date, 40 monthly files have been submitted to the World Radiation Monitoring Center (WRMC), of which 97.8%, 97.68%, 97.72% and 98.38% for Global Horizontal Irradiance (GHI), Diffuse Horizontal Irradiation (DHI), Direct Normal Irradiance (DNI) and Long wave Downward Irradiance (LWD) respectively. These data sets exhibit a flag value of 0 and are therefore of good quality. The available minute dataset can therefore be used with confidence to validate global models and satellites observations. Maintenance of the De Aar BSRN station and 12 other BSRN-like radiometric stations located within all six climatic zones of the country is expected to continue along with the utilization of the solar radiation resource to advance applications research.

Comparison of observed and modelled cloud-free longwave downward radiation (2010–2016) at the high mountain BSRN Izaña station (Rosa Garcia Cabrera)

A seven year (2010–2016) comparison study between measured and simulated longwave downward radiation (LDR) under cloud-free conditions was performed at the Izaña Atmospheric Observatory (IZA, Spain). This analysis encompasses a total of 2062 cases distributed approximately evenly between day and night. Results show an excellent agreement between BSRN measurements and simulations with the library for radiative transfer (LibRadtran) V2.0.1 and MODerate resolution atmospheric TRANsmission model (MODTRAN) V6 radiative transfer models (RTMs). Mean bias (simulated-measured) of <1.1% and root mean square of the bias (RMS) of <1% are within the instrumental error (2%). These results highlight the good agreement between the two RTMs, proving to be useful tools for the quality control of LDR observations and for detecting temporal drifts in field instruments. The standard deviations of the residuals, associated with the RTM input parameters uncertainties, are rather small, 0.47 and 0.49% for LibRadtran and MODTRAN, respectively, at daytime, and 0.49 to 0.51% at night-time. For precipitable water vapor (PWV) >10 mm, the observed night-time difference between models and measurements is +5Wm-2, indicating a scale change of the World Infrared Standard Group of Pyrgeometers (WISG), which serves as reference for atmospheric longwave radiation measurements. Preliminary results suggest a possible impact of dust aerosol on infrared radiation during daytime that might not be correctly parametrized by the models, resulting in a slight underestimation of the modeled LDR of about -3Wm-2 for relatively high aerosol optical depth (AOD>0.20). These results have been recently published in GMD (García et al., 2018).

Reference:
García, R.D., A. Barreto, E. Cuevas, J. Gröbner, O.E. García, A. Gómez-Peláez, P.M. Romero-Campos, A. Redondas, V.E. Cachorro, and R. Ramos. Comparison of observed and modeled cloud-free longwave downward radiation (2010–2016) at the high mountain BSRN Izaña station. *Geosci. Model Dev.*, 11, 2139-2152, https://doi.org/10.5194/gmd-11-2139-2018, 2018.

Inter-comparison of seven solar radiometers on a tilted plane for photovoltaic applications: preliminary results (Jordi Badosa)

Solar radiation measurements (SRM) are needed in photovoltaics (PV) for resource assessment, efficiency evaluation, performance analysis and forecasting. Since 2014, a test bench was installed in the SIRTA Observatory (48.7ºN, 2.2ºE, Paris Region) to study PV modules under real-life conditions. The bench has permanent SRM with RG100 0 and SR01 sensors. A two-week campaign was undertaken to assess the quality and calibration of these radiometers when measuring on a titled plane. Seven radiometers were installed on the plane of the PV modules (27.5º tilt to the South): four silicon quantum sensors (RG100, from Solems), two second class pyranometers (SR01 from Hukseflux and DPA053 from LSI) and one secondary standard pyranometer (CMP22 from Kipp & Zonen). The poster shows comparison results against the CMP22, which is taken as reference. Relative (to the mean) mean absolute error values ranged from 2.0% (SR01) to 5.5% (RG100 2). Some radiometers were suspected to have tilt and orientation deviations from 27.5º and 0º (South), respectively. A method was explored to correct for these deviations; the results are presented for a clear-sky day.

Annex 1 - List of Participants

For a meeting the annexes should include a list of participants and the meeting agenda. All reports should include a list of acronyms or abbreviations.

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Annex 2 - Agenda

Detailed Agenda for the 15th BSRN Scientific Review and Workshop
July 16-20, 2018, Boulder, Colorado, USA

Monday Evening, 16 July 2018

5:00pm – 7:30pm Ice breaker in CIRES Atrium

Tuesday, 17 July 2018

7:30 am – 8:30 am Registration and poster setup
Registration desk in hallway
Registration continues all morning

8:30 am – 10:00 am Plenary

8:30 – 8:35 Opening Welcome (Chuck Long)

8:35 – 8:50 CIRES Welcome and info (Christine Wiedinmyer)
8:50 – 9:05 NOAA GMD Welcome and Info (Jim Butler)
9:05 – 9:15 BSRN Project Manager Greetings and meeting charge (Chuck Long)
9:15 – 9:30 WRMC update - status, challenges, tasks (Amelie Dremel)
9:30 – 9:45 GCOS welcome and status (Tim Oakley)
9:45 – 10:00 GDAP status and BSRN (Tristan L'Ecuyer)

10:00 am – 10:30 am Coffee and poster viewing

10:30 am – 12:05 pm Plenary

10:30 – 10:45 BSRN in the wider WMO/GCOS community (Tim Oakley)

New Site Proposals (20 min each):
10:45 – 11:05 Selegua, a proposed new BSRN site in the south of Mexico. (Adriana Gonzalez Cabrera)
11:05 – 11:25 A proposed new BSRN site at Paramaribo, Suriname (NE South America) (Ankie Piters)
11:25 – 1145 Proposal of a BSRN station at the Observatory of Huancayo, Peru (Luis Suarez Salas)
11:45 – 12:05 A proposed new BSRN site near Dubai, UAE (Dr.Aaesha Abdulla Alnuaimi)

12:05 pm - 1:40 pm Lunch

1:40 pm – 3:00 pm Plenary

New Site Proposals (Cont. 20 minute talks):
1:40 - 2:00 Granite Island in Lake Superior, A new BSRN water site proposal (Bryan Fabbri)
2:00 – 2:20 Assessing surface solar radiation variability and trends in the South-West Indian Ocean from BSRN-like measurements over Reunion island: Proposal for a new site (Béatrice Morel)

2:20 – 2:40 New proposed BSRN stations in the Western Pacific region: Mt. Jude and Orchid Island (Carlo Wang)
2:40 – 3:00 Solar and meteorological measurements at Budapest-Lőrinc, Hungary: Proposal for BSRN station (Dénes Fekete)

3:00 pm – 3:30 pm Coffee and poster viewing

3:30 pm – 5:00 pm Plenary

Other Sites (20 minute talks):
3:30 – 3:50 The UO Solar Radiation Monitoring Lab – Where we've been and where we're going (Josh Peterson)
3:50 – 4:10 BSRN Cabauw – status and applications (Wouter Knap)
4:10 – 4:30 Solar Radiation Measurement in the Sahara (Algeria) (Sidi Biaka)
4:30 – 5:00 Discussion and organization for Wednesday morning WG breakouts
All at once or staggered?
Proposed Use of BSRN in Solar RE WG (Enio Pereira)
Formation of committee to review/amend BSRN Manual and minimum requirements

Wednesday, 18 July 2018

8:30 am – 11:30 am Working Group breakouts
Room locations to be announced

10:00 am – 10:30 am Coffee and poster viewing

11:30 am – Break for lunch

1:30 pm Buses leave for excursion
Please arrive at least 15 minutes early for boarding
Location will be announced
Group dinner starts at 6:30pm
The Med restaurant, 1002 Walnut St., Boulder, CO

Thursday, 19 July 2018

8:30 am – 10:00 am Plenary

Satellite and Model Studies
8:30 – 8:50 Validation of satellite solar irradiance estimates: Separating clear-sky and cloud effect (Laurent Vuilleumier)
8:50 – 9:10 The Critical Importance of BSRN to Quantify Uncertainties and Improve NASA/GEWEX SRB Fluxes and Resulting Impacts (Paul Stackhouse)
9:10 – 9:30 Application of the BSRN and RadFlux Data in Validation and Analysis of the GEWEX SRB All-Sky and Clear-Sky Shortwave Downward Fluxes (Taiping Zhang)
9:30 – 9:50 Use of BSRN data in the validation of NASA's Clouds and the Earth's Radiant Energy System (CERES) EBAF & SYN1deg data products (Dave Rutan)

9:50 am – 10:20 am Coffee and poster viewing

10:20 am – 12:00 pm Plenary

Satellite and Model Studies (Cont.)
10:20 – 10:40 Evaluation of MODIS/VIIRS/Landsat-8 Albedo Products over BSRN Sites (Zhuosen Wang)
10:40 – 11:00 Use of BSRN data to estimate the Global Energy Balance and its changes (Martin Wild)
11:00 – 11:20 From point to area: Worldwide assessment of the representativeness of monthly surface solar radiation records (Matthias Schwarz)

Analysis Studies
11:20 – 11:40 The uses of the PAL BSRN station: Research, innovation and training (Jordi Badosa)
11:40 – 12:00 Aerosol Optical Depth, Calibration and Determination (Fred Denn)

12:00 pm – 1:30 pm Lunch

1:30 pm – 3:00 pm Plenary

Analysis Studies (Cont.)
1:30 – 1:50 2017 Pyrgeometer Inter-comparison in Darwin, Australia (Nozomu Ohkawara)
1:50 – 2:10 Recent Updates about the ACP, IRIS, and AERI Infrared Comparisons (Ibrahim Reda)
2:10 – 2:30 Performance of thermal offset corrections for modern pyranometers (Carlo Wang)
2:30 – 2:50 The D-ICE Campaign for Ice Mitigation Study (Chris Cox)
2:50 – 3:10 An update on trends in surface radiation over the U.S. as determined from the seven SURFRAD BSRN sites (John Augustine)

3:10 pm – 3:40 pm Coffee and poster viewing
Posters need to be removed by the end of the day Thursday

3:40 pm – 5:00 pm Plenary

Working Group Breakout Reports
1) Infrared WG
2) Cold Climate Issues WG
3) Spectral WG
4) Proposed Use of BSRN in Solar RE WG
5) BSRN Manual Committee

Friday, 20 July 2018

8:30 am – 12:00 noon Plenary

Business Meeting
Discussion of new sites proposals
Discussion of new Project Manager and proposed Deputy Project Manager
Other business

10:00 am – 10:30 am Coffee

12 noon Adjourn

Participants at the 15th BSRN Meeting

Annex 3 - Listing of Posters

BSRN Site Posters

1) BSRN station PAL at SIRTA Observatory, Paris Region: Status and news (Jordi Badosa)
2) BSRN Station of Carpentras (France): Status and news (Stephane Mevel)
3) Status of the Payerne BSRN station (2018) (Laurent Vuilleumier)
4) Status of Tartu-Tõravere (TOR) BSRN station (Kai Rosin)
5) The Dome-C Antarctic BSRN Station (Angelo Lupi)
6) Status Of De Aar BSRN And Solar Radiometic Activities at South African Weather Sevices (Saws) (Brighton Mabasa)
7) Status of the active BSRN sites in Brazil (Enio Pereira)
8) Status of Japanese BSRN stations (Nozomu Ohkawara)
9) Radiation measurement at Leodo & Socheongcho Ocean Research Station in South Korea (JEONGPIL JANG)
10) Radiation Measurement on South Korea: In focus on Observation Environment and Quality Control (Il-Sung Zo)
11) Status of the Arctic BSRN Site Ny-Ålesund (Marion Maturilli)
12) U.S. SURFRAD BSRN Station Update (Gary Hodges)
13) ARM BSRN Station Update (Gary Hodges)
14) Status of the Lindenberg BSRN station (Stefan Wacker)
15) Status of Four Indian BSRN Stations (Karthik Ramanathan)
16) Status update of BSRN station Sonnblick (SON)-(Jul 2018) (Elke Ludewig)
17) Status of the NASA Langley Research Center (LRC) BSRN station (Fred Denn)
18) Status of the Izana BSRN Station in July 2018 (Rosa Garcia Cabrera)

Proposed Site Posters

1) New proposed BSRN stations in the Western Pacific region: Mt. Jude and Orchid Island (Carlo Wang)
2) Solar radiation measurements at Budapest-Lőrinc station (Dénes Fekete)
3) Status and plans for BSRN stations in the northern CAA and Greenland (Chris Cox)
4) Granite Island in Lake Superior, a new BSRN water site proposal (Bryan Fabbri)
5) Assessing surface solar radiation variability and trends in the South-West Indian Ocean from BSRN-like measurements over Reunion island: Proposal for a new site (Béatrice Morel)
6) Toward The Implementation Of A New Candidate BSRN Station In The Ross Sea Area, Antarctica (Mauro Mazzola)
7) Preliminary results of the first six months operation of the Selegua Station in Southern Mexico (Roberto Bonifaz)
8) A proposed new BSRN site near Dubai, UAE (Ansgar Delahaye)

Science Posters

1) Validation of CM SAF Satellite-Derived Surface Radiation Data Records Using BSRN Measurements (Stefan Wacker for Jörg Trentmann)
2) Use of BSRN Data to Assess Changes in the Shortwave Surface Flux Simulation for Three Generations of the GFDL Coupled Climate Model (Stuart Freidenreich)
3) Distributed radiation measurements at MOSAiC (Matt Shupe)
4) Intercomparison of seven solar radiometers on a tilted plane for photovoltaic applications: preliminary results (Jordi Badosa)
5) Data analyses of 1.5 year field testing of the Razon+ DNI & diffuse system (Joop Mes)
6) Direct spectral irradiance measurements from rotating shadowband EKO grating spectroradiometer (Will Beuttell)
7) Comparison of observed and modelled cloud-free longwave downward radiation (2010-2016) at the high mountain BSRN Izaña station (Rosa Garcia Cabrera)
8) Partitioning of Solar Energy in the Climate System (Matthias Schwarz)

Annex 4 - Acronyms

ACP	Absolute cavity pyrgeometer
AERI	Atmospheric Emitted Radiance Interferometer
AERONET	Aerosol Robotic Network
AOD	Aerosol optical depth
AR5	5th Intergovernmental Panel on Climate Change (IPCC) Assessment Report
ARM	Atmospheric Radiation Measurement program
AWI	Alfred Wegener Institute of Polar and Marine Research
BoM	Australian Bureau of Meteorology
BOU	Boulder BSRN Station
BRB	Brasilia BSRN station
CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarization
CAMS	Copernicus Atmosphere Monitoring Service
CANDAC	Canadian Network for the Detection of Atmospheric Change
CCIWG	Cold Climate Issues Working Group
CEOS	Committee on Earth Observation Satellites
CERES	Clouds and the Earth's Radiant Energy System
CIE	International Commission on Illumination
CIRES	Cooperative Institute for Research in the Environmental Sciences
CLH	Chesapeake Light BSRN station
CMA	Chinese Meteorological Administration
CMF	Cloud modification factor
CMIP5	Coupled Model Intercomparison Project Phase 5
CUCF	Central UV Calibration Facility
CWB	Central Weather Bureau of Taiwan
DEWA	Dubai Electricity and Water Authority
D-ICE	De-Icing Comparison Experiment
DIF	Diffuse radiation
DIR	Direct radiation
DNI	Direct normal irradiance
DNICast	Direct Normal Irradiance Nowcasting methods
DOE	Department of Energy (United States)
DON	Dongsha Atoll BSRN station
EBAF (Ed.4.0)	Energy Balanced and Filled (EBAF) Edition-4.0 data product
ECCC	Environment and Climate Change Canada
ECV	Essential climate variable
ESRL	NOAA Earth System Research Laboratory
EUR	Eureka BSRN station
FRC-IV	Fourth Filter Radiometer Comparison
GAW	Global Atmosphere Watch
GCOS	Global Climate Observing System
GDAP	GEWEX Data and Assessments Panel
GEBA	Global Energy Balance Archive
GEWEX	Global Energy and Water cycle Exchanges project
GHI	Global horizontal irradiance

GLEN	Great Lakes Evaporation Network
GMD	Global Monitoring Division (NOAA)
GOS	Global Observing System
GSRN	GCOS Surface Reference Network
GSW	GEWEX SRB shortwave
HARMONIE	High Resolution Limited Area Model (HIRLAM) Aladin Regional Mesoscale Operational Numerical Weather Prediction In Europe model
IP	Internet protocol
IPCC	Intergovernmental Panel on Climate Change
IR	Infrared radiation
IRIS	Infrared integrated sphere radiometer
ISO	International Organization for Standardization
ITCZ	Inter-Tropical Convergence Zone
IWV	Integrated water vapor
IZA	Izaña Atmospheric Observatory
JMA	Japan Meteorological Agency
KNMI	Royal Netherlands Meteorological Institute
LAMAR	Laboratory of Atmospheric Microphysics and Radiation (Geophysical Institute of Peru)
LDR	Longwave downward radiation
LE2P	Laboratory of Energy, Electronics and Process
LibRadtran	Library for radiative transfer
Lidar	Light Detection and Ranging
LLN	Lulin BSRN station
LPV	Land Product Validation
LRC	NASA Langley Research Center BSRN site
LW	Longwave
LWD	Longwave downward radiation
LWDn	Downwelling longwave
LWU	Longwave upward radiation
MALIBU	Multi Angle Imaging Bidirectional Reflectance Distribution Function sUAS
MFRSR	Multi Filter Rotating Shadowband Radiometer
MODIS	Moderate Resolution Imaging Spectroradiometer
MODTRAN	Moderate resolution atmospheric Transmission model
MOSAiC	Multidisciplinary drifting Observatory for the Study of Arctic Climate
MSG	Meteosat Second Generation
MSI	Sentinel-2A/B MultiSpectral Instrument
MW	Megawatt
N	Number in a trial or sample
NASA	National Aeronautics and Space Administration (United States)
NCAR	National Center for Atmospheric Research (United States)
NEW	Newcastle BSRN station
NOAA	National Oceanic and Atmospheric Administration (United States)
NREL	National Renewable Energy Laboratory
NSA	North Slope of Alaska BSRN site
OLI	Landsat 8 Operational Land Imager

OMI	Ozone Monitoring Instrument
OPAR-Maïdo	Observatoire de Physique de l'Atmosphère à La Réunion-Maïdo
PAR	Photosynthetically active radiation
PMEL	Pacific Marine Environmental Laboratory
PMOD	Physical Meteorological Observatory of Davos
PSA	Plataforma Solar de Almeria
PTR	Petrolina BSRN station
PV	Photovoltaic
PWV	Precipitable water vapor
QC	Quality control
RadFlux	Radiative Flux Analysis
RE	Renewable energy
RMS	Root mean square
RMSE	Root mean square error
RSB	Rotating shadow band
RTM	Radiative transfer model
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Chartography
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SIRTA	Site Instrumental de Recherche par Télédétection Atmosphérique observatory
SGP	Southern Great Plains atmospheric observatory
SMS	São Martinho da Serra BSRN station
SOV	Solar Village BSRN station
SRB	Surface Radiation Budget
SRM	Solar radiation measurements
SSR	Surface solar radiation
sUAS	small Unmanned Aircraft Systems
SumSW	Calculated total horizontal radiation
SURFAD	Surface Radiation Network
SW	Shortwave
SWD	Global shortwave radiation
SWDn	Downwelling shortwave
SWOT	Strengths, Weaknesses, Opportunities and Threats analysis
SWU	Shortwave upward radiation
SYN1deg	Synoptic 1 degree data product
TOA	Top of atmosphere
TT	Task Team on Radiation References
UNAM	Autonomous National University of Mexico
UO SRML	Solar Radiation Monitoring Laboratory at the University of Oregon
UV	Ultraviolet radiation
UVA	Ultraviolet A
UVB	Ultraviolet B
UVC-II	Second Ultraviolet Filter Radiometer Comparison
UVE	Erythemally active ultraviolet irradiance
V0s	Top of atmosphere irradiances
VIIRS	Visible Infrared Imaging Radiometer Suite

WG	Working group
WGCV	Working Group on Calibration and Validation (CEOS)
WISG	World Infrared Standard Group
WMO	World Meteorological Organization
WRC	World Radiation Center
WRMC	World Radiation Monitoring Center
XIA	Xianghe BSRN station
YOPP	Year of Polar Prediction

The
World Climate Research Programme (WCRP)
facilitates analysis and prediction of Earth system change for use in a range of practical applications of direct relevance, benefit and value to society.

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