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# Report of the 13th Baseline Surface Radiation Network (BSRN) Scientific Review and Workshop

Institute of Atmospheric Sciences and Climate
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# 13th BSRN Scientific Review and Workshop

## 1. Overview of Meeting

Christian Lanconelli and Vito Vitale of the Institute of Atmospheric Sciences and Climate (ISAC) in Bologna, Italy hosted the 13th Baseline Surface Radiation Network (BSRN-13) Scientific Review and Workshop. The workshop followed the general form and intent of previous workshops and was intended to provide a forum for BSRN participants and user communities to share progress and experiences in the acquisition and application of surface radiation data for climate and related interests. In attendance were many of the current active BSRN site scientists and station managers, BSRN associates who have a long history of cooperative interaction with BSRN, data users from both the satellite and climate modeling communities, and several local visitors with overlapping interests with BSRN. In addition, several representatives from commercial instrument manufacturers attended as non-promotional observers.

The workshop provided a forum for evaluating the progress and successes of the BSRN network and addressed issues related to the network's activities. The site scientists were reminded of the obligations and requirements for participating in the program, and the BSRN oversight organizations and management were reminded of the valuable and voluntary contributions of each of the field sites and their host sponsors. BSRN continues striving to address its primary goal of providing high quality, broadband surface solar and infrared irradiances on a continuous and long-term basis at a wide climatic variety of sites. The workshop consisted of three and a half days of oral presentations of scientific results, as well as proposals for new stations, updates, and status reports on network activities.

Below are summaries of the oral presentations made at the meeting in the order listed on the agenda. After the summaries of the oral presentations there are summaries of the poster presentations. Electronic versions of many of the presentations, including posters, are available for a limited time at: *http://www.isac.cnr.it/~radiclim/bsrn2014/userfiles/downloads/BSRN_meeting_talks_long.pdf*.

## 2. Opening Session

Joseph Michalsky, the Acting BSRN Project Manager, opened the workshop and welcomed the 63 attendees, briefly reviewing the purpose of the meeting. Dr. Cristina Sabbioni, the Director of ISAC, gave an overview of radiation research performed within ISAC, including activities at Arctic and Antarctic sites, stations in Italy focused on aerosol and cloud radiative forcing issues, and a program on solar energy research.

Tim Oakley, the Implementation Manager for the World Meteorological (WMO) Organization Global Climate Observing System (GCOS), spoke on the efforts of GCOS to coordinate observations, records, and metadata that are useful for climate research. BSRN has been an official surface radiation network for GCOS since 2004. Nozomu Ohkawara reported on the 19$^{th}$ GCOS/World Climate Research Programme (WCRP) Atmospheric Observation Panel for Climate Meeting held in April 2014 and noted that the main focus of GCOS is now to increase the number and spatial distribution of stations measuring surface radiation using BSRN standards.

The final presentation of the opening session was by Joseph Michalsky, who presented the state of BSRN. Ellsworth (Ells) Dutton was remembered for his long service to the BSRN community, having served as its project manager since its inception in the early 1990s until his passing in 2012. The Data and Assessments Panel of GEWEX, which is part of WCRP, governs BSRN. It serves as the baseline surface radiation network for GCOS, and it contributes to both the Global Atmospheric Watch and the

Network for the Detection of Atmospheric Composition Change. Stations that have been closed include Nauru, Papua New Guinea, Darwin, and Regina. Ilorin is currently unfunded for operation, and Eureka and Alert may be reopened. Revived stations include de Aar and Florianopolis with the promise of Budapest delivering data soon. New candidates include Platforma de Solar de Almeria, Graciosa Island, Azores, Summit Greenland, Costa Rica, Peru, and Zvenigrod, with interest from Saudi Arabia, India, and Hanimaadhoo in the Maldives. Citations to BSRN now exceed 1400 with continued growth each year. Two books have been published that focus on radiation measurements: *A Guide to Solar Radiation Measurement* by Rösemann and *Solar and Infrared Radiation Measurements* by Vignola, Michalsky, and Stoffel. Two recent examples of the use of BSRN data were cited, including the use of Tamanrasset data for a *Solar Energy* article by Gueymard. The other example was the use of Japanese data from five stations showing the dimming and brightening pattern reported for other parts of the world; a surprising decrease in long-term aerosol optical depth and increase in single scattering albedo was also demonstrated for the five-station average. In summary, BSRN, despite some station closures, is healthy with a net gain in the number of stations and continuing widespread use of the data.

## Session 2. Proposals for New BSRN Sites

**St. Petersburg—Arctic and Antarctic Research Institute—New Russian Polar Station at Severnaya Zemlya** (Alexander Makshtas)
The main goal for the establishment of the Observatory "Ice Base Cape Baranova" is to identify the causes and consequences of climate change in the Arctic with special attention to the comprehensive studies of interrelated components of the Arctic climate system, specifically:

- Surface heat and radiation balance;
- Cloudiness and aerosol components of the atmosphere;
- Processes of gas and mass transfer;
- Chemical composition of the atmosphere and hydrosphere;
- Melting of permafrost;
- Study of drifting, fast, and lake ice;
- Characteristics of hydrological regime of the Shokalski Strait and western Laptev Sea; and
- Dynamics of glaciers.

Observations and studies began in May 2014 including standard meteorological observations, standard actinometric observations; radiation monitoring in the framework of BSRN; route surveys of spectral albedo; upper-air observations, monitoring of greenhouse gases; heat balance observations; studies of physical-mechanical properties of fast ice; testing of new devices for measurements of freshwater and sea ice thickness; oceanographic investigations in the Shokalski Strait; organization of polygon for glaciological investigations at the Mushketov glacier; and hydrological studies.

**Candidate for New BSRN Station in Costa Rica** (Antonio Paz)
Antonio Paz described three potential sites for BSRN stations in Costa Rica that need more instrumentation to complete the suite of radiometers necessary to become an active BSRN station. Studies and publications about solar radiation in Costa Rica show a direct normal irradiance (DNI) potential of 3.2-6.0 $kWhm^{-2}$ per day (range of maximum values). To obtain reliable information about solar radiation in a typical year and its evolution in time, two methods are required: satellite-based measurements and ground-based measurements. As a result, since 2012 there have been efforts to install ground stations that allow the collection of information using high quality instrumentation.

BSRN documentation has been used to deploy some of the stations, and the accumulated experience has led to an improvement in the design and installation of the local stations. An important step is to set one of the stations to the same level of quality provided by the BSRN guidelines. Adhering closely to those guidelines (sensors, maintenance work, and data quality control algorithms), at least for one station, is a must for two reasons: detecting important changes related to climate change that may affect the country, and ensuring a reference station for ground and satellite observations.

The most advanced stations have instrumentation for downwelling radiation mounted on a tracker (SOLYS1) consisting of one pyrheliometer (CHP1), a shaded pyranometer (CMP22), an unshaded pyranometer (CMP22), all ventilated except CHP1. Meteorological measurements are performed close to the stations (temperature, relative humidity, wind speed, wind direction, and precipitation).

The measurements provided by a Costa Rican station would help to close a wide gap in the global network of BSRN stations, share deployment experience with other countries in zone A, optimize the location of the equipment, and generate quality data for cross referencing with satellite data.

The Status of the De Aar BSRN Station in South Africa **(Katlego Ncongwane)**
**Plans were described to restart the long-dormant South African station at De Aar. Centrally located in the heart of South Africa in the semi-arid Upper Karoo, the De Aar (30.66°S, 23.99°E, 1287 m) station has resumed operations after 5 years of non-operation. Established in 1999, the station, one of the four on the African continent and number 40 in the global network of BSRN stations, monitors shortwave and longwave radiation to detect long-term changes within the South African region. During the 9 years of its operation, the station functioned optimally with regular instrument calibration and traceability to the World Standard Radiation Group (WSG) at the World Radiation Centre in Davos, Switzerland. Quality controlled data since 2000 was submitted to the ETH (German: Eidgenössische Technische Hochschule, Zürich) Institute in Zürich, where the BSRN archive was situated. In 2008 the station ceased operation due to technical difficulties. Through the Solar Resource Mapping for South Africa (SRMSA) Project, funded by the South African government Department of Science and Technology, the De Aar station has been equipped with state-of-the-art solar radiation monitoring technology and is measuring global horizontal irradiance (GHI); diffuse horizontal irradiance (DHI) and direct normal irradiance (DIN); longwave, ultraviolet radiation-A (UVA) and ultraviolet radiation-B (UVB) are also measured. In addition, Automatic Weather Stations (AWS) provide basic observable weather parameters such as temperature, relative humidity, wind speed, and wind direction. The De Aar unique environment makes the De Aar BSRN station an important contributor to the global network of precision surface radiometric flux measurements.**

**Brazil – INPE Status of Four SONDRA BSRN Stations in Brazil** (Enio B. Pereira)
The Brazilian Institute for Space Research (INPE) has implemented the Brazilian Environmental Data Organization System (SONDA) network to provide site-specific solar and meteorological data to support climate research and the Brazilian energy sector regarding information on solar energy resources. A description of the procedures adopted was presented, including new thresholds based on BSRN criteria, to ensure data quality before free public access is granted.

**Arctic Radiation Activities Coordinated through the International Arctic Systems for Observing the Atmosphere** (IASOA, Taneil Uttal)
IASOA (*www.iasoa.org*) is a legacy program from the International Polar Year that coordinates pan-Arctic atmospheric science. The mission of IASOA is to advance coordinated research objectives from independent pan-Arctic atmospheric observatories through (1) strategically developing comprehensive observational capacity, (2) facilitating data access and usability through a single gateway, and (3) mobilizing contributions to synergistic science and socially-relevant services derived from IASOA assets and expertise. IASOA has a strong interest in radiation observations and science, as there are five BSRN stations and two candidate BSRN stations in the network of ten IASOA stations. Consequently, IASOA has a Radiation Working Group that meets primarily through teleconferencing on a regular basis. Activities of the IASOA Radiation Working Group can be viewed at *http://www.esrl.noaa.gov/psd/iasoa/node/103*.

Currently, IASOA Radiation WG areas of interest include:

- Implementation of the Department of Energy's Radiative Fluxes (RadFlux) value-added products, such as cloud forcing with meteorological checks and balances;
- Comparing a new BSRN-compliant set of radiometers with a longer time series of radiometers operated by ETH at the Summit, Greenland station;
- Assimilation of IASOA radiation and rawinsonde data into the European Centre for Medium-Range Weather Forecasts (ECMWF);
- Study of snow melt onset and snow accumulation dates as a metric of Arctic climate change;
- Studies of operational issues of operating radiometers in the Arctic environment;
- Building informal linkages between early-career and mid-, late-, and retired-career scientists; and
- Pursuit of funding opportunities that support IASOA WG radiation activities.

Sandy Starkweather (Sandy.Starkweather@noaa.gov) was identified as the IASOA implementation scientist.

## Session 3. Observations and Analyses

**Solar Absorption and Cloud Radiative Effects Observed at BSRN Sites** (Maria Hakuba)
Making extensive use of direct measurements from both space and the surface, the mean-state (2000-2010) disposition of solar energy and corresponding uncertainties over Europe were quantified in order to establish a key reference for the validation of model integrations and satellite retrievals. Combining ground-based measurements of surface solar radiation (Global Energy Balance Archive, GEBA) with collocated satellite-derived surface albedo (Moderate Resolution Imaging Spectroradiometer, MODIS) and top-of-atmosphere net solar irradiance (Clouds and the Earth's Radiant Energy System Energy Balanced And Filled product, CERES EBAF), estimates of solar absorption at the surface ($ASR_{surf}$) and in the atmosphere ($ASR_{atm}$) of 117±6 $Wm^{-2}$ (42±2% of TOA incident irradiance) and 65±3 $Wm^{-2}$ (23±1%) representative for Europe were obtained. The fractional $ASR_{atm}$ of 23% is largely unaffected by variations in season and latitude. The station average over 19 BSRN sites distributed worldwide yields estimates of $ASR_{surf}$ and $ASR_{atm}$ at 142 $Wm^{-2}$ (45%) and 66 $Wm^{-2}$ (21%), respectively, under all-sky conditions. At these sites, we estimated the surface solar radiation under cloud-free conditions using the clear-sky detection and interpolation algorithm by Long & Ackerman (2000) and found that the presence of clouds enhances atmospheric solar absorption by on average 11 $Wm^{-2}$ (5%) at the BSRN sites, while the CERES EBAF data product suggests cloud absorption three times smaller than that. This discrepancy originates from a strong underestimate in clear-sky surface solar radiation (SSR) and is the subject of further investigation. Furthermore, the satellite product was used to study spatial variations in fractional atmospheric absorption and associated cloud effects, and it was found that cloud absorption acts with greater strength in the extra tropics than in regions governed by the Intertropical Convergence Zone (ITCZ), which leads to a more uniform zonal distribution in fractional $ASR_{atm}$ under all-sky conditions than in the cloud-free case. As expected, the magnitude of cloud absorption strongly depends on cloud type and surface properties as suggested by a distinct land-sea contrast.

**Shortwave Radiation Balance of Northern Yakutia According to the Data from the Tiksi BSRN Station and Russian Standard Stations** (Vasilii Kustov)
Vasilii Kustov presented the solar record from four Arctic sites in Russia that began collecting measurements in the 1960s. Previous comparative analysis of radiation data obtained with solar radiation sensors of the old and modern generations, based on the data sets of measurements executed at the hydrometeorological observatory Tiksi, has shown good agreement between measured values. It is possible to combine the data obtained with the old Russian radiation sensors and modern observational data to create a relatively homogeneous series of data, suitable for analysis of the radiation regime of the Northern Yakutia. Because of this, the results of long-term variability of short-wave radiation fluxes are studied for four stations of the Northern Yakutia: the Tiksi BSRN station and polar stations Verhoyansk, Srednekolymsk, and Olenek.

**BSRN Products and the New Zealand Climate Network** (J. Ben Liley)
Ben Liley described his efforts to rehabilitate solar data for New Zealand using the BSRN station at Lauder to guide his adjustments. The National Institute of Water and Atmospheric Research (NIWA) Climate Database holds solar radiant energy data for 150 stations around New Zealand and the southwest Pacific, for varying periods, largely from LI-COR photodiode sensors, and from Eppley Precision Spectral Pyranometers (PSPs) at some sites. There are good multi-year data for about 70 sites, including all major population centers. There are also hourly measurements of global, diffuse, and direct radiation with Eppley sensors at Kaitaia, Paraparaumu, and Invercargill since 1988, but the best solar radiation data for New Zealand are from the BSRN station at Lauder, in Central Otago. From an error when the climate database was established, radiation data were stored at degraded precision. There are also questions about the calibration stability, as apparent in these data from the Climate Network (not BSRN) station at Lauder.

Radiation sensors have been calibrated regularly by MetService NZ at Paraparaumu, but now NIWA's instruments are calibrated at Lauder. Instruments that remain in statistical control are redeployed to the next vacant site, but the practice of using the new calibration directly has led to unphysical steps in the data. Records of calibrations and deployments are incomplete, and somewhat error-prone, but they show that dividing out the applied calibration actually reduces the variance in (near to) clear sky values. For the Lauder site, agreement with BSRN data has improved.

Regular calibration needs to be combined with statistical control theory, so that instrument response regarded as constant or slowly trending does not become an additional source of error in measurement time series.

**Seasonality in Long-Term Temperature and Radiation Changes in Ny-Ålesund, Svalbard** (Marion Maturilli)
Marion Maturilli showed that the atmosphere around the Ny-Ålesund site has warmed, brightened, and become more moisture-laden in the past 20 years. The Arctic is considered to be most sensitive to climate change, with warming in the Arctic occurring considerably faster than the global average. Several positive feedback mechanisms contribute to the "Arctic amplification", including, for example, the snow/sea ice–albedo feedback. Moreover, clouds, water vapor, and their radiative feedbacks are recognized as important issues in the Arctic climate, and atmospheric circulation changes augment the meridional transport of water vapor to the Arctic. All of these processes having an impact on Arctic climate are important not only concerning local feedbacks with the underlying surface, but also concerning global feedbacks on the energy balance of the planet. Altogether, radiative fluxes play a key role in the complex Arctic region. At Ny-Ålesund (78.9°N, 11.9°E), Svalbard, surface radiation measurements of up- and downward short- and longwave radiation have operated since August 1992 in the framework of BSRN, complemented with surface and upper air meteorology since August 1993. Ongoing changes in the Arctic climate system are reflected over the 21-year observation period. In particular, the observations indicate a strong seasonality of surface warming and related changes in different radiation parameters. The annual mean temperature at Ny-Ålesund has risen by +1.3 ±0.7 K per decade, with a maximum seasonal increase during the winter months of +3.1 ±2.6 K per decade. In the recent warmer winters, precipitation has often occurred in the form of rain rather than snow. At the same time, winter is also the season with the largest long-term changes in radiation, featuring an increase of +15.6 ±11.6 $Wm^{-2}$ per decade in downward longwave radiation. Furthermore, changes in the reflected solar radiation during the months of snowmelt indicate an earlier onset of the warm season by about one week compared to the beginning of the observations.

**Combining BSRN Surface Observations with MODIS Data to Compute Radiative Forcing of a Small Smoke Plume at the Surface, TOA, and within the Atmosphere** (John Augustine)
On 6 September 2010, the smoke plume of a small-scale forest fire over north eastern Colorado drifted over two BSRN surface radiation budget sites where the radiative forcing efficiency of the smoke at the surface was computed in the shortwave (SW), longwave (LW), and all-wave throughout the day. Clouds and the Earth's Radiant Energy System (CERES) broadband imager data could not be

used to compute the radiative forcing of the smoke at the top of atmosphere (TOA) because the plume was only 10 km wide, and the CERES broadband imagers' resolution is 20 km at best. Instead, narrow-to-broadband conversion methods, one for SW and another for LW, were applied to high spatial resolution spectral MODIS imagery for two satellite passes around solar noon that were one hour and 40 minutes apart. Results showed negative SW forcing by the smoke at both TOA and the surface, indicating cooling at both levels, but the magnitude of the cooling was two to four times greater at the surface. LW forcing warmed both TOA and the surface, but the magnitude of the LW warming was 4 to 10 times less than the SW cooling at both levels. This differential between the surface and TOA resulted in instantaneous atmospheric warming rates of 3° to 9° C per day in the SW corresponding to aerosol optical depth (AOD) values of 1.23 and 3.37, respectively, and atmospheric cooling of -2° C per day in the LW for both levels of AOD. These results indicate a strong direct effect of the smoke on the atmosphere in the SW, but smaller and enigmatic effects in the LW, with respect to AOD. MODIS water vapor imagery clearly demonstrated that the burning biomass injected measureable water vapor into the atmosphere. Integrated water vapor within the plume area increased by 20 to 40% due to combustion alone during the period between the two satellite passes, and absolute increases were on the order of 0.1 to 0.2 cm.

**Variations in Solar UV Irradiance and Ozone Column at the Concordia and Mendel Antarctic Stations** (Boyan H. Petkov)
The features of erythemaly weighted (EW) and downwelling shortwave (SWD) solar irradiances, observed at the Antarctic Plateau station Dome Concordia (75°06'S, 123°21'E, 3233 m a. s. l.), have been compared with those measured at the coastal Mendel station (63°48'S, 57°53'W, 7 m a. s. l.) positioned on the opposite part of the continent. Since the solar elevation at Mendel is higher than at Concordia by 20 to 60% during the polar day, due to the geographical position of the two sites, a similar relationship between the radiation levels cannot be assumed. However, the model evaluations and the measurements show that the solar irradiance at both stations is almost equal and moreover, within a short period around maximum solar elevation, the irradiance at Concordia exceeds that observed at Mendel station. Such an occurrence is due to the large difference in the station altitudes and completely different environments (including surface reflectivity) surrounding the two sites that contribute to the irradiances in different ways. It was also found that irradiance pertaining to both EW and SWD spectral ranges shows much lower variability at Concordia than at the Mendel station that can be accounted for by the different cloud conditions typical of the two continental regions. Assuming a similar impact of the clouds on EW and SWD solar radiances, a correction of the EW variations due to this parameter was made and, as a result, at both stations' EW irradiance showed strong correlation with the ozone column time patterns presenting a relationship defined by a power function, which is used to define the radiation amplification factor. Such a relationship between corrected EW irradiance and ozone column can be used for observations of the relative ozone variations at measurement sites where only broadband irradiance is recorded.

## Session 4. Albedo

**Spectral and Broadband Snow Albedo Measurements at Dome-C and Ny-Ålesund** (Christian Lanconelli)
Broadband and spectral albedo measurements of tundra and snow covered surfaces have been performed in the framework of the polar activities that the Italian National Research Council (CNR) carries out at Ny-Ålesund (Svalbard, 79°N) and Dome-C (Antarctica, 75°S). The Climate Change Tower Integrated Project, developed at Ny-Ålesund (*www.isac.cnr.it/~radiclim/CCTower/*) counts, among its infrastructure, a 32-meter high tower operational since September 2009, hosting meteorological instruments at four different levels (nominally at 2, 5, 10, and 32 m), two fixed sonic anemometers, a KH20, a snow height sonic range sensor, a skin temperature IR-camera, and a four-component net radiometer (CNR-1) at the top. Ventilated CM-11 pyranometers and CG4 pyrgeometers have been installed at 25 meters for upwelling component determination following the BSRN standards.

In the period between May and July 2013, a first attempt to automatically determine the spectral albedo variations during the melting season was approached by installing a turn-table at 8 meters, hosting the remote cosine receiver (RCR) of a 350-2500 nm range ASD-FieldSpec 3 spectroradiometer and a commercial fish eye web-camera (D-Link) useful to monitor both the cloud cover index and the snow cover. A continuous recording of downwelling and upwelling spectral irradiance and sky/ground status has been scheduled every 30 minutes for the period between May 20 and July 31, 2013. Spectral and broadband quantities were compared with model calculations performed using Santa Barbara DISORT Atmospheric Radiative Transfer (SBDART) radiative transfer codes (RTC) parameterized with climatology for water vapor, ozone, and aerosol contents.

Albedos from the last four years (2010-2013) varied from 0.75-0.83 (20 to 50 cm) in mid-May to typical values for tundra (below 0.20) encountered in late June. Due to exceptional snow falls occurring in 2014, the snow depth exceeded 100 cm, yielding a delay of the complete melting by about 25 days. The ongoing analysis of the complete data set is oriented to distinguish between cloudy and clear sky albedo behavior, spectral to broadband irradiance matching, and quality-check of the correctness of leveling. First results demonstrate that both intra-day and seasonal variability have been captured. The experiment will be repeated in 2015 by fixing some aspects that arose because of a failure of the electro-mechanical system during the crucial part of the melting period.

For what concerns Antarctic activities, the “STudy of Radiative Regimes over the Antactic Plateau and beyond” (STRRAP-b) Project aims to perform continuous monitoring of the spectral reflectance/albedo between September and April in the 350-1700 nm spectral regions, to extend the broadband characterization already active in the frame of BSRN (dom) site. A first summer campaign was established (Dec 2013-Jan 2014) and more than five thousand spectra were collected, including irradiance, nadir reflectance, and albedo measured around the station of Concordia (Dome-C).

**Validating Satellite Albedo Products Using BSRN Data** (Crystal Schaaf)
BSRN continues to serve as the “gold standard” of land surface albedo measures. It has been designated as such in the Committee on Earth Observation Satellites (CEOS) *Systematic Observation Requirements for Satellite Based Data Products Observations for Climate* (2011). Requests have been made to declare it the designated reference network for the satellite-derived surface albedo, Essential Climate Variable (ECV), and anisotropy (thus designating it for terrestrial data as well as atmospheric data) in the next Requirements document. The CEOS Working Group on Calibration and Validation (WGCV) Land Product Validation (LPV) team is recommending BSRN data (and BSRN standards) in its upcoming Albedo Product Evaluation Protocol where satellite measurements are generally required to 5% accuracy. Requirements include that the greater site location be spatially representative of a moderate resolution satellite field of view (generally 500-1000 m). A larger diversity of surface types (primarily grasslands or crop areas are currently provided) is desirable (especially forest and shrub canopies), but this necessitates larger towers for the downward pointing radiometers (capturing the upwelling radiation) with 10-30 m being ideal depending on the surface cover. Spectral measurements are also of great interest to the satellite and modeling communities and are to be encouraged wherever possible in the future. A large number of photosynthetically active radiation (PAR) sensors are being deployed at BSRN and Fluxnet sites, but little cross calibration is being performed. Additional (primarily silicon) radiometers are being deployed to gather albedo information for the solar industry, but these are usually located in arid or grassland locations as well. Presentations by the various individual sites indicate the high quality of the available BSRN albedo data and a recent improvement in data submission rates to the archive. Evaluations (using BSRN tower data) of MODIS, Visible/Infrared Imager Radiometer Suite (VIIRS), and Landsat albedo products were presented to illustrate the importance of BSRN data to efforts to provide high quality satellite-derived products for climate studies.

## Session 5. Radiometer Improvement

**Towards a New Infrared Standard** (Julian Gröbner)
Two independently designed and calibrated absolute radiometers measuring downwelling longwave irradiance were compared during two field campaigns in February and October 2013 at the Davos Physical Meteorological Observatory/World Radiation Center (PMOD/WRC). One absolute cavity pyrgeometer (ACP) developed by the National Renewable Energy Laboratory (NREL) and up to four Integrating Sphere Infrared Radiometers (IRIS) developed by PMOD/WRC took part in these intercomparisons.

The internal consistency of the IRIS radiometers, as well as the agreement with the ACP, were within ±1 $Wm^{-2}$, providing traceability of atmospheric longwave irradiance to the international system of units with unprecedented accuracy.

Measurements performed during the two field campaigns and over the past four years have shown that the World Infrared Standard Group of pyrgeometers (WISG) is underestimating clear sky atmospheric longwave irradiance of 2-6 $Wm^{-2}$, depending on the amount of integrated water vapor (IWV). This behavior is an instrument-dependent feature and requires an individual sensitivity calibration of each pyrgeometer with respect to an absolute reference such as IRIS or ACP. For IWV larger than 10 mm, an average sensitivity correction of +6.5% should be applied to the WISG in order to be consistent with the longwave reference represented by the ACP and IRIS radiometers.

A concerted effort at the international level will need to be implemented in order to correct measurements of atmospheric downwelling longwave irradiance traceable to the WISG.

**Comparison of Different Types of Pyrgeometers with the IRIS Radiometer in Lindenberg** (Klaus Behrens)
Since May 2011, the Lindenberg Meteorological Observatory has operated an Infrared Integrating Sphere Radiometer (IRIS), which was manufactured at PMOD/WRC. Between June in 2013 and August in 2014, we compared the IRIS on 29 nights during cloudless conditions to five different types of pyrgeometers (PIR, CG4, CGR4, IR20, and IR20WS). While the IRIS is windowless, the domes are transparent in the following regions:

| | |
|---|---|
| PIR | 3.5 – 50 µm |
| CG4/CGR4 | 4.5 – 42 µm |
| IR20 | 4.5 – 40 µm |
| IR20WS | 1.0 – 50 µm |

In this period, the Longwave Downward Radiation (LDR) covered a span from about 220 to 360 W/m² while the integrated water vapour (IWV) varied between 0.5 and 2.6 cm.

In the meantime, the PIR, CG4, and IR20 were about 5 W/m² lower than the IRIS. This is in good agreement with other results, because they are related to the WISG. Furthermore, these instruments show no dependence on IWV. The CGR4 and the IR20WS are closer to the results of the IRIS. In the case of the CGR4, which was produced after 2003, there is no dependence on IWV. The results of the IR20WS have to be analyzed in more detail.

**Longwave Radiation Data Acquired in the SONDA Network: Measurements and Quality Control Procedures** (José Celso Thomaz Jr.)
A series of systematic experiments and calculations of correction factors k (the non-thermopile constants) for longwave irradiance measurements are reported here. Pyrgeometers are the instruments to measure longwave irradiance in climatological networks. Investigations on instrument characterization and measurement techniques are presented and discussed for the Brazilian Environmental Data Organization System (SONDA)/BSRN network. The aim of the SONDA

network is to acquire, store, and deliver free access to high quality ground solar and meteorological data, which can be used to benchmark modeled data sets in solar and wind resource assessments. The pyrgeometer used in the SONDA/BSRN network is the Eppley Precision Infrared Pyrgeometer (PIR). New instruments like the CG4 pyrgeometer from Kipp & Zonen are nowadays used as spares in the SONDA/BSRN network. The CG4s show very promising advantages with respect to dome heating and spectral transmission. We have developed a self-consistent methodology based on the application of Ordinary Least Squares to evaluate the correction factor (k) on pyrgeometer measures. Experiments were performed in the laboratory to compare performance of the PIR (Eppley) and CG4 (Kipp & Zonen) compared to a standard pyrgeometer (CG4) calibrated by PMOD/WRC.

**Evaluation of Radiometers Deployed at the National Renewable Energy Laboratory's Solar Radiation Research Laboratory** (Aron Habte)
Solar radiation resource measurements from radiometers are used to predict and evaluate the performance of photovoltaic and concentrating solar power systems, validate satellite-based models for estimating solar resources, and advance research in solar forecasting and climate change. This study analyzes the performance of various commercially available radiometers used for measuring global horizontal irradiances (GHI) and direct normal irradiances (DNI). These include pyranometers, pyrheliometers, rotating shadowband radiometers, and a pyranometer with a shading ring deployed at the National Renewable Energy Laboratory's Solar Radiation Research Laboratory (SRRL). The radiometers in this study were deployed for one year (from April 1, 2011 through March 31, 2012) and compared to measurements from radiometers with the lowest values of estimated measurement uncertainties for producing reference GHI and DNI. The differences among radiometer measurements were calculated using the mean bias error and root mean square error methods, in which the GHI and DNI values from individual instruments were compared to concurrent computed GHI reference and measured reference DNI. The differences were calculated as a percent of reading for solar zenith angles ranging from 17.5° to 85°. Under clear-sky conditions when the solar zenith angle was less than 60°, differences of less than 5% were observed for both GHI and DNI measurements when they were compared to the reference radiometers. These normalized differences increased during partly cloudy sky conditions and when the solar zenith angle was greater than 60°. The intent of this presentation is to give a general overview of each radiometer's performance. The National Renewable Energy Laboratory made no effort to ensure that the radiometers presented here were representative units; therefore, this paper does not guarantee the same results for all radiometers from the same manufacturer or model.

**Multi-Filter Rotating Shadowband Radiometer Derived Aerosol Optical Depths at the Clouds and the Earth's Radiant Energy Systems Ocean Validation Experiment Site** (Fred M. Denn)
The goal is to determine aerosol optical depth (AOD). The first step is to determine top of atmosphere values of irradiance, also known as $V_0$, using Langley analysis. Three methods of selecting the $V_0$ are presented. The first uses all points for which the root mean square of the data points with respect to the fit line must be less than 0.006, the number of points in the Langley fit must be greater than 200, and the range of points used for the Langley fit must cover 1.5 air mass units. The second imposes the additional requirement that total optical depth remain relatively constant during the Langley event. The third method is to use a $V_0$ derived at Mauna Loa Hawaii (MLO). The first two methods have similar standard errors of the estimate, although the standard deviation is greater for the first. The first two methods also provide slightly better AOD agreement with the Aerosol Robotic Network (AERONET) Cimel sun photometer. The conclusion is that AOD can be determined with as good as, if not better, accuracy using in situ derived $V_0$s than using MLO $V_0$. The in situ case requires a much longer data collection period, months versus days at MLO.

## Session 6. Instrument Evaluations

**Pyranometer Calibration Verification – With Examples from the Australian Stations in the BSRN** (Nicole Hyett)
In situ pyranometer calibration verification can be performed by alternating the placement of pyranometers between global and diffuse on a yearly basis. This method has advantages over other pyranometer calibrations in that it causes little disruption to the data record and a long and consistent data record can be obtained. Any clear or cloudy period can be used to verify the pyranometer calibration by use of the composite sum method (for clear periods) or a simple comparison between pyranometer irradiances (for cloudy periods).

A brief description of the BSRN sites Alice Springs and Darwin (Bureau of Meteorology, Australia) was presented. The traceability of the Bureau network was explained and the data set used in this analysis was described. The algorithm for identification of clear and cloudy days was detailed, with the clear-sky identification being a pared down version of the algorithm by Long and Ackerman. Results for both Alice Springs and Darwin for the period 2008 until end of August 2014 were shown. The verification demonstrated that there had been no significant change in the instrument sensitivities over the six-year period. It was deemed that the BSRN uncertainty requirement of 2% for global and diffuse measurements was attainable.

**Performance Evaluation of Radiation Sensors for the Solar Energy Sector** (Laurent Vuilleumier)
Instruments have been developed that allow inferring the diffuse and direct component of solar radiation separately, and operate in a robust and cost effective way without sun trackers. They can be deployed for continuous field operation with limited maintenance. Typically they are used in the solar energy sector, because measuring the global horizontal irradiance is not optimal for assessing the solar energy input onto collection devices of different shapes or tilt. The tested instruments included two basic designs: the rotating shadowband irradiometers (RSI) and the SPN1 radiometers from Δ-T. Three RSI models were tested with two instruments of each model. RSIs have one or two LI-COR photodiode sensors and a rotating shadowband that briefly shades the sensor once a minute for estimating the diffuse irradiance while the global irradiance is measured when the instrument is not shaded. Three SPN1 radiometers were tested, which include 7 thermopile sensors in a hexagonal pattern (one in the center) and an elaborate fixed shading pattern. The shading pattern is designed so that for every position of the sun in the sky there is at least one sensor that is completely exposed to the direct sun and one sensor that is completely shaded from it. In addition, the shading pattern blocks half of the upper hemisphere.

Evaluating their performances against reference instruments and understanding their operational uncertainty is necessary when using these to monitor solar energy device yields, nowcast local radiation, or when combining such ground data with satellite information. The necessity of such an evaluation was emphasized within the European Cooperation in Science and Technology (COST) Action ES1002 Weather Intelligence for Renewable Energies (WIRE) program and Task 46 of the International Energy Agency Solar Heating and Cooling Programme. An evaluation was conducted at the Payerne BSRN station from June 2012 to September 2013. The tested instruments were compared to the high accuracy BSRN sensors. The reference instruments are traceable to the World Radiometric Reference. For global horizontal irradiance (GHI) when analyzing all data together, the instruments exhibit an accuracy of about ±30 $Wm^{-2}$ (relative error ±10%, covering typically >95% of errors with respect to BSRN reference). For such an analysis, there is no notable difference between the RSIs and the SPN1s. In order to differentiate the performances according to the conditions, the data sets were divided in subsets of low direct normal irradiance (DNI) variability (sunny and no clouds in the vicinity of the sun) and high DNI variability. The data sets were also split in subsets with the sun at high elevation [solar zenith angle (SZA) of $\leq 60°$] and low elevation ($60° < SZA \leq 86°$). When looking at GHI data when DNI is stable and sun elevation is high (large GHI), errors on the order of [-50,+30] $Wm^{-2}$ (-7%,+5%) are found, while for variable DNI at low solar elevation (small GHI), errors are about [-15,+10] $Wm^{-2}$ (-15%,+10%). Errors in DNI, when it is stable at high solar elevation, are about [-60,+90] $Wm^{-2}$ (-7%,+10%), but only the SPN1 radiometers have large positive errors. For RSI instruments alone the range is [-60,+30] $Wm^{-2}$. For GHI, the errors found with the RSIs have strong SZA dependencies when the sky is clear. The smallest cloud cover results in the strongest SZA dependencies, while the heaviest cloud cover results in only small SZA dependencies. Similar behaviors are also found for DNI and diffuse irradiance, but the relationship between the error, SZA dependency, and the cloud cover is less clear. For SPN1, SZA dependencies are smaller, but the spread (range) is larger. These instruments exhibit a strong underestimation of diffuse irradiance that is generally stronger for sunny situations, except at high solar elevation.

**Balloon Measurements of Light Profiles in Cloudy Atmospheres** (Ping Wang)
A green light sensor has been developed at the Royal Netherlands Meteorological Institute (KNMI) to measure actinic flux profiles using an ozone sonde balloon. In total, 63 launches with ascending and descending profiles were performed between 2006 and 2010. The measured uncalibrated actinic flux profiles are analyzed using the Doubling Adding KNMI (DAK) radiative transfer model. Values of the cloud optical thickness (COT) along the flight track were taken from the Spinning Enhanced Visible and Infrared Imager (SEVIRI) Cloud Physical Properties (CPP) product. The impact of clouds on the actinic flux profile is evaluated on the basis of the cloud modification factor (CMF) at the cloud top and cloud base, which is the ratio between the actinic fluxes for cloudy and clear-sky scenes. The impact of clouds on the actinic flux is clearly detected: the largest enhancement occurs at the cloud top due to multiple scattering. The actinic flux decreases almost linearly from cloud top to cloud base. Above the cloud top the actinic flux also increases. We find that clouds can increase the actinic flux to 2.3 times of the clear-sky value at cloud top and decrease it to about 0.05 at cloud base. The relationship between CMF and COT agrees well with DAK simulations, except for a few outliers. Good agreement is found between the DAK simulated actinic flux profiles and the observations for single layer clouds in fully overcast scenes. The instrument is suitable for operational balloon measurements because of its consistency and low cost. It is planned to further develop the instrument and launch it together with atmospheric chemistry composition sensors.

**Qualitative Aspects of Cameras Systems Used on Synoptic Observations Systems (SOS)** (Sylvio Luiz Mantelli Neto)
In this work, the analysis of a surface image set obtained at Sao Martinho da Serra RS, Brazil is described. The images taken from a sky imager will be used to establish criteria to define clear sky and clouds for validation of satellite images. The Bayesian method is used for that purpose in two steps: supervised learning and analysis. Supervised learning will be performed using statistical tools and multivariate exploratory data analysis (EDA). The analysis is based on hierarchic priority and multivariate statistics discrimination. In this way, pixel values present in the images will be mapped into atmospheric patterns. Only patterns identifiable in the visible spectrum and defined by optical and atmospheric physics will be analyzed. To reduce the massive amount of data, they will be split in monthly reports. The current one is from January 2005, with nearly 1600 images.

**A New Spectroradiometer for High-Resolution Aerosol Optical Depth** (Julian Gröbner)
A new generation of solar spectroradiometers, the Precision Solar Spectroradiometer (PSR), has been developed at PMOD/WRC to eventually replace current filter based sunphotometers. It is based on a temperature-stabilized grating spectroradiometer with a 1024 pixel Hamamatsu diode-array detector, operated in a hermetically sealed nitrogen flushed enclosure. The spectroradiometer is designed to measure the solar spectrum in the 300-1020 nm wavelength range with a spectral resolution varying between 1.5 and 5 nm (full width at half maximum). The optical bench made of a carbon alloy is optimized to minimize the temperature dependence of the solar measurements to less than $0.1\%K^{-1}$ for ambient temperatures ranging between -20°C to +40 °C. A Peltier temperature regulation system stabilizes the detector to better than 1K while the overall structure is kept above a pre-defined temperature using a heating system to prevent cold temperatures. The PSR design benefits from the experience gained from successive generations of the successful Precision Filter Radiometers (PFR), which includes: an built-in solar pointing sensor, an ambient pressure sensor, and several temperature sensors to provide routine quality control information, which will allow autonomous operation at remote sites using an internal web-based server interface for instrument control and data retrieval.

## Session 7. Models, Satellites, and Radiative Forcing

**Surface Fluxes, Hydrologic Cycle, and Climate (**V. Ramaswamy)
The importance of surface radiative flux in climate cannot be overemphasized. BSRN measurements are proving to be significant metrics in the evaluation of climate model simulations of direct, diffuse, and global solar radiative fluxes. The successive versions of the Geophysical Fluid Dynamics Laboratory (GFDL) climate models used in the fourth and fifth Intergovernmental Panel on Climate Change (IPCC) climate change science assessments (2007 and 2013, respectively) have been extensively compared against the BSRN measurements (Freidenreich and Ramaswamy, *Journal of Geophysical Research*, 2011). The models compare reasonably well with the observational estimates, but there exist regional biases. Analysis of the biases yields information on the cause of the deficiencies, e.g., deficiency in the parameterization of the aerosol growth with humidity introduced a bias in the clear-sky solar surface flux and biases in cloud amounts over continental regions. Inclusion of other observations (from the International Satellite Cloud Climatology Project, ISCCP) and the reanalyses product (from the European Centre for Medium-Range Weather Forecasts, ECMWF) leads to the finding that the bias in the model's summertime land surface temperature simulation is partially attributable to the bias in the shortwave radiative flux, which in turn is attributable to the bias in the simulated cloud amounts.

Perturbations caused in the surface solar radiative flux due to anthropogenic aerosol emissions leads to significant changes in climate, as revealed by the GFDL climate model (CM2.1) simulation of the $20^{th}$ century. One region most prominently experiencing the impact of aerosols is the Indian monsoon region, especially the north-central portion of India. This region has seen a reduction of the summer rainfall over the last half of the $20^{th}$ century. The GFDL climate model CM2 simulates this rainfall decrease, but only when the effects of anthropogenic aerosol emissions are taken into account. Well-mixed greenhouse gas increases alone; in contrast, serve to increase the rainfall in this region, contrary to the observed change. The rainfall decrease accompanies a significant reduction in surface radiative flux caused by the presence of the anthropogenic aerosol emissions. The reduction in the net surface flux is accompanied by a decrease in the evaporation over the entire region, which in effect slows the hydrologic cycle. There is thus a tight linkage between the surface shortwave flux reduction and the decrease in evaporation and precipitation over the Indian summer monsoon region for the last few decades of the $20^{th}$ century.

**Surface Radiative Fluxes as Observed in BSRN and Simulated in Climate Models** (Martin Wild)
While the radiative fluxes in and out of the climate system at the top of atmosphere can be accurately measured from satellites, the energy fluxes within the climate system and at the Earth's surface are less well determined. Accordingly, the magnitudes of the components of the surface energy balance largely vary in climate models already on a global mean basis. Complementary to the approaches using satellite-derived products as references, we make use of the growing number of surface observations to constrain the radiation budget at the Earth's surface. We combine these observations with the latest modeling efforts performed for IPCC's Fifth Assessment Report (using the phase five of the Coupled Model Intercomparison Project, CMIP5) to infer best estimates for the global mean surface radiative components. A regression between the model-calculated global mean fluxes and their respective biases compared to surface observations suggests global mean values of downward surface solar and thermal radiation near 185 and 342 $Wm^{-2}$, respectively, to be most compatible with surface observations. These estimates coincide within 2 $W^{-2}$ with the latest satellite-derived estimates from CERES EBAF (Kato et al., 2013), which are completely independently determined. Combined with an estimated global mean surface absorbed solar radiation and thermal emission of 161 $Wm^{-2}$ and 398 $Wm^{-2}$, respectively, this leaves 105 $Wm^{-2}$ of surface net radiation globally available for distribution amongst the non-radiative surface energy balance components. We further apply this approach to estimate the land and ocean mean surface radiation balance separately. Over land, where most direct observations are available to constrain the surface fluxes, we obtain 185 and 305 $Wm^{-2}$ for

solar and thermal downward radiation, respectively. Over oceans, with weaker observational constraints, corresponding estimates are around 185 and 356 $Wm^{-2}$. These estimates again closely agree, mostly within 3 $Wm^{-2}$, with the respective quantities independently determined from recent state-of-the-art reanalyses (ECMWF reanalysis, ERA Interim) and satellite-derived products (CERES EBAF). This notable consistency in independent approaches enhances confidence in the determined flux magnitudes, which have traditionally introduced large discrepancies in the surface energy budget estimates and often hampered an accurate representation of surface climates in models. Considering additionally surface albedo and emission, we infer an absorbed solar and net thermal radiation of 137 and -67 $Wm^{-2}$ over land, and 170 and -53 $Wm^{-2}$ over oceans, respectively. The surface net radiation is thus estimated to be around 70 $Wm^{-2}$ over land and 117 $Wm^{-2}$ over oceans, which may impose additional constraints on the respective sensible and latent heat fluxes.

There is further increasing evidence from the direct observations that the surface radiative fluxes undergo significant changes on decadal timescales, not only in their longwave components as expected from the increasing greenhouse effect, but also in the amount of shortwave radiation that reaches the Earth's surface. In the longwave, observations from BSRN updated to 2013 suggest an overall increase of downward longwave radiation at the surface of 1.7 $Wm^{-2}$ per decade when averaged over the 28 stations with the longest records (more than 10 years). This is in line with the latest projections from the CMIP5 models and expectations from an increasing greenhouse effect. On the other hand, the strong decadal changes in surface downward shortwave radiation seen in the observations ("dimming/brightening") are not adequately represented in current climate models. The 26 BSRN stations with the longest records (more than 10 years) show an overall increase of 2-3 $Wm^{-2}$ per decade.

Related recent references:
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Wild, M., Folini, D., Hakuba, M., Schär, C., Seneviratne, S., Loeb, N.G., Rutan, D., Kato, S., and König-Langlo, G., 2014. The energy balance over land and sea: An assessment based on direct observations and CMIP5 models (submitted).

**A Climatology of Surface Radiation, Cloud Cover, and Cloud Radiative Effects for the ARM Tropical Western Pacific Sites** (Charles N. Long)
Results from analyses of the long-term observations gathered at the Atmospheric Radiation Measurement (ARM) tropical western Pacific (TWP) sites (all BSRN stations) were presented. The Manus, Papua New Guinea site is located along the equator and deep within the TWP warm pool area, with the equatorial island nation of Nauru site at the eastern edge of the warm pool. The Darwin, Australia site experiences a tropical summer monsoon, with a stark contrast between the dry and wet season regimes. Thus Manus, Nauru, and Darwin exhibit differing intra-seasonal and inter-annual variability in the surface radiation budget, cloud amounts, and cloud distributions due to differences in influence of climactic factors such as the El Niño Southern Oscillation (ENSO) and the Australian monsoon. Manus shows the least variability, with little change in cloud amounts or surface radiation budget between El Niño and La Niña occurrences. Conversely, Nauru exhibits significantly different cloudiness, cloud radiative effects, and cloud type distributions between El Niño and La Niña occurrences. Darwin exhibits the largest differences, which are between the wet and dry seasons.

The study also includes simple cloud type classification using vertically pointing cloud radar and lidar, and the study of cloud radiative effects by these cloud types. All three sites experience the same general cloud types, though with some differences in frequency of occurrence by type. These basic cloud types exhibit similar cloud radiative effects with no significant differences between sites for a given type. Thus differences in the cloud radiative effects are caused by differences in the occurrence of cloud amount and the mix of cloud type.

Ongoing research includes analysis of the diurnal signature of the various cloud types and their radiative effects. These analyses include not only the aggregate bulk values, but also the differences in diurnal distributions with ENSO phase for the equatorial sites and wet/dry seasonality at Darwin. “Quantifying Diurnal Cloud Radiative Effects by Cloud Type in the Tropical Western Pacific” by Casey D. Burleyson, Charles N. Long, and Jennifer Comstock will be submitted to the *Journal of Applied Meteorology and Climatology* in October 2014.

**Quality-Control and Processing of the BSRN Data and Its Application in Validating the NASA GEWEX SRB GHI, Model-Derived DNI, and Empirically Derived GTI** (Taiping Zhang)
As of November 2013, there were 59 BSRN sites with 7333 site-months of data archived at the Alfred Wegener Institute in Bremerhaven, Germany. These data include records of shortwave and longwave radiative fluxes at 1-, 2-, 3-, or 5-minute intervals. We systematically performed quality control on the original data and then processed the data to generate 3-hourly, daily, and monthly means. The results are then used to validate the satellite-based NASA GEWEX Surface Radiation Budget (SRB) shortwave fluxes at the Earth's surface (GHI). To extend the NASA Prediction of Worldwide Energy Resource Project (POWER) Surface meteorology and Solar Energy (SSE) data set, we applied a global-to-beam model, the DirIndex model, to the GEWEX SRB data to produce global fields of direct normal fluxes (DNI) at the same spatio-temporal resolution as that of the GEWEX SRB, and the results are validated against the direct normal component of the BSRN data. The POWER SSE also provides monthly mean global fluxes on tilted surfaces (GTI) empirically derived using the RETScreen methodology, one of the tilt angles being the same as the latitude of the location and tilted toward the Equator. The BSRN direct component on the tilted surface is obtained by multiplying the BSRN DNI by the cosine of the solar zenith angle relative to the tilted surface, and as a first approach, the BSRN diffuse component on the tilted surface is assumed to be the same as that on the horizontal surface. The BSRN GTI on the tilted surface is thus obtained by summing up the direct and diffuse components on the tilted surface. The monthly validation statistics, bias/root mean square error (RMSE)/N, are 5.2/23.3/4557, 3.6/41.3/2236, and -3.4/44.1/4643 respectively for GHI, DNI, and GTI, where bias and RMSE are in the unit of $Wm^{-2}$ and N is the number of comparable pairs of data points.

References

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Zhang, T., Stackhouse Jr., P.W., Chandler, W.S., and Westberg, D.J., 2014. Application of a Global-to-Beam Irradiance Model to the NASA GEWEX SRB Dataset: An Extension of the NASA Surface meteorology and Solar Energy Datasets, *Sol Energy*, 110, 117-131.

**Evidence of Clear-Sky Daylight Whitening: Are We Already Conducting Geoengineering?** (Charles N. Long)
A paper by Long et al. (2009, *JGR*, doi:10.1029/2008JD011263) analyzed surface radiation data spanning 1995 through 2007 from several ARM and six Surface Radiation Budget Network (SURFRAD) sites across the continental USA, and showed an average 8 $Wm^{-2}$/decade brightening in all-sky downwelling shortwave radiation (SW) that is highly correlated with changes in cloud amounts. The study also showed a 5 $Wm^{-2}$/decade increase in the clear-sky downwelling SW, an expected result of decreasing aerosol optical depths during the same time period (Augustine et al., 2008, *JGR*, doi:10.1029/2007JD009504). However, the unexpected result of the Long et al. study is

that the 5 $Wm^{-2}$/decade increase is all in the diffuse SW, while the direct SW remained virtually unchanged—opposite to what is expected for an aerosol direct effect due to decreases in aerosols. With detailed radiative transfer modeling and correlation with US FAA commercial flight hours through the same years, Long et al. (2009) speculated that while the decreased aerosols did increase the total SW, an increase in high, sub-visual contrail-generated ice haze repartitioned the increase into the diffuse SW component through large-particle scattering.

Using a discussion of the wavelength dependence of molecular scattering versus the scattering of all visible wavelengths equally by clouds, and the differences in scattering phase function between molecular, small (dry aerosols), and large (ice crystals) particles with respect to forward scattering, it was explained how the increased direct SW due to decreased dry aerosols is scattered out of the beam but in the forward direction into the diffuse SW component, producing the observed results. A long-term analysis of the ratio of diffuse over direct SW suggests an increase in atmospheric turbidity consistent with the jet-generated ice haze hypothesis. A corresponding analysis of the ratio of 870 nm over 415 nm spectral diffuse irradiance from the Multi-filter Rotating Shadowband Radiometers is consistent with the expected clear-sky "whitening" from the proposed increased ice haze. Thus evidence suggests that increased air traffic over the continental US has likely modified the partitioning of direct and diffuse SW under what is classified as "cloud free" skies…in effect, an inadvertent form of "geoengineering."

## Session 8. Data Issues

**BSRN Archive Status and the Neumayer BSRN Station** (Gert König-Langlo)
Since July 2008, the World Radiation Monitoring Center (WRMC) has been hosted at the Alfred Wegener Institute (AWI) of Polar and Marine Research at Bremerhaven, Germany (see *http://www.bsrn.awi.de*). In mid-2014, 58 BSRN stations had submitted their data to the WRMC. The data import is organized in so-called "station-to-archive files" which contain all the data from one station collected during one month. There have been a total of 7825 station-month data sets from 58 stations collected in the WRMC by September 2014.

All submitted station-to-archive files are read-accessible from any user who accepts the BSRN data release guidelines (see *http://www.bsrn.awi.de/en/data/conditions_of_data_release/*). The files can be obtained via *ftp://ftp.bsrn.awi.de/* by using a web browser or any ftp tool. The access to the public file archive is password-restricted. Read accounts can be obtained from the WRMC (email Gert.Koenig-Langlo@awi.de). An alternative to the ftp access is data access via the Publishing Network for Geoscientific and Environmental Data, PANGAEA (see *http://www.pangaea.de/*), which offers much more user-friendly services.

Since December 2011, WRMC has also checked the quality of all incoming data. The station scientists are encouraged to test their data prior to submission using, e.g., the BSRN-Toolbox (*http://wiki.pangaea.de/wiki/BSRN_Toolbox*). An updated Technical Plan for BSRN Data Management is now available via the BSRN webpage or *www.wmo.int/pages/prog/gcos/Publications/gcos-174.p*df.

The BSRN measurements at Neumayer are ongoing. They are part of a much bigger observatory program, which includes synoptic observations, upper air soundings, ozone soundings, and surface air chemistry measurements. Radiation data from an automatic weather station (AWS), which ran for one year directly besides the BSRN measurements, were analyzed to quantify typical errors of unmanned systems in Antarctica.

**New BSRN Data Quality Control Developed and Applied at SIRTA Observatory** (Jordi Badosa)
The Site Instrumental de Recherche par Télédétection Atmosphérique (SIRTA) observatory (48.714N, 2.208 E, France) has contributed to BSRN since 2003 with shortwave (SW) and longwave (LW)

downward (DN) irradiances. Recently, a new treatment chain together with a rethought quality control (QC) procedure has been developed. For the latter, a five-step method is applied:
1) Flag all the data not passing the BSRN recommended QC v2.
2) Further flag the minutes with Glo/Sum inconsistencies with the likely reasons.
3) Test and flag for tracker failure periods from using two-step empirically developed criteria.
4) Manually check all flagged data and decide to keep or delete.
5) Reprocess the data with the BSRN Toolbox for final checks.

Steps 1 to 3 are automatic and operationally done every hour. Steps 4 to 5 are to be done every 2 months. The current decision for removing data before submitting to BSRN is for the following cases:

- All data falls outside the physically possible limits
- All diffuse and direct data comes from detected tracker failure periods. All minutes in one day are removed if more than 15 minutes have been detected with tracker failure problems for this day.
- All global, diffuse, and direct isolated (1 minute of duration) data points with Glo/Sum inconsistencies (usually related to cleaning).
- Other particular days with inconsistencies detected from visual inspection of the daily plots.

It is known that every site has different criteria about what data should be removed before submitting to BSRN. For example, our current decision is that the Glo/Sum inconsistencies due to droplets on the pyrheliometer early in the morning or on the instruments after rain are not removed, which is not the case for all BSRN stations.

Also, a “BSRN recommended QC v3” with other tests and recommendations, such as for tracker failure detection, would be very useful for the BSRN community and all sites willing to follow standard procedures. A discussion about these issues is being undertaken as a task in the Long-term Analyses Working Group.

**BSRN Station Cabauw: Workflow from Measurement to Archive** (Wouter Knap)
In this presentation, we explain our workflow from radiation measurement at BSRN Cabauw to the station-to-archive file. The focus is on the software in which administration and quality control are handled. The core of our system consists of a web server and a database. The advantage of a web server is that certain steps in the processing chain can be handled by means of http requests and are operating system independent. We have developed a browser plug-in to handle exceptions, caused by, for example, cleaning events. The administration of calibrations and instrument changes is also handled in a graphical environment, which is connected to the database. Quality control is performed on a daily basis by means of visual inspection of the data and by applying flagging according to Long and Dutton. The generation of the station-to-archive file proceeds fully automatically; only the handling of exceptions is done manually. Since this is done on a semi-daily basis, the station-to-archive file is ready for submission on the first days of the new month.

Cabauw data status: 1.

- Cabauw now has 115 files in the archive (February 2005 to August 2014).
- As of January 2013, the upward shortwave radiation (USR) and upward longwave radiation (ULR) fluxes were added to LR0300.
- Downwelling longwave radiative fluxes (DLR) have yet to be corrected for the period 2005-2011.

**Clear Sky BSRN and GAW Global Data Peculiarities** (Anatoly Tsvetkov)
The term “clear sky” is used as an important characteristic of the atmosphere’s transparency defined by the observer at the Earth’s surface. Global radiation measured with the pyranometer for many years represents the seasonal distribution of the daily data points if all of them are combined on a one-year scale (366/365 days) with maximum values forming an upper limit that can define the clear sky seasonal behavior. On the graphs the maximum values can be estimated in case of the homogeneous time series of global radiation.

In this presentation, definition of the clear sky level is shown for the Global Atmosphere Watch (GAW) and BSRN stations available at the World Radiation Data Centre (WRDC). The 95% probability level for the relative maximum values of daily global radiation Gmax (i) selected from all available years of observations of daily data (i=1,366) is estimated after normalization to the astronomical solar radiation without the atmosphere r (i) = Gmax(i)/G0(i). The procedure of getting the 95% probability level of normalized r(i) allows the elimination of the seasonal effect and the comparison of the results depending on the height and the geographical location of the stations. This defines the 95% probability level for the clear sky of global radiation for the summer period. During winter when the sun height is low, these 95% levels are difficult to estimate. The method of the 95% estimate will be developed for the winter season in the future.

Based on a selection of 27 stations with long time series located in the latitude range 12S - 60N with elevations between 3-3100 m above sea level, the estimated values of 95% probability for clear sky level in global radiation lies between 0.72 and 0.93 of radiation at TOA.

**Measurement Uncertainty of Radiometers from ASTM International's Perspective** (Jörgen Konings)
The Guide to the Expression of Uncertainty in Measurement (GUM) provides a standard method for the determination of uncertainty in measurement. BSRN recommends that all uncertainty calculations follow the procedures of the guide. Within the ASTM International G03.09 on Radiometry, work is being done to publish a standard that is specifically written for the calibration of pyranometers and pyrheliometers and the measurements made using these instruments. The technical contact is Aron Habte at NREL (aron.habte@nrel.gov).

Spreadsheets are available that allow users to input their own data and uncertainty sources. The spreadsheet gives uncertainties per data point. Contributions to the final uncertainty are also broken down by source. Secondary output includes integrated results for hourly and daily totals. A PDF file is available that gives a walkthrough for working with the spreadsheet. Adopting a standardized method allows comparison of quoted uncertainties, based on documented methods of derivation. This work is in no way finished, and there are many open questions. Input is very much welcomed.

**Accuracy of Ground Surface Broadband Shortwave Radiation Monitoring** (L. Vuilleumier)
The uncertainty of broadband shortwave radiation monitoring is determined for direct, diffuse, and global irradiance with data measured at the Payerne (Switzerland) BSRN station. The uncertainty estimates include sources that reflect realistic long-term operating conditions. The uncertainties are derived from the measurement equations following the Guide to the Expression of Uncertainty in Measurement (GUM). Then, the differences between redundant determinations of direct, diffuse, and global irradiance are checked to verify that they are compatible with the uncertainties. In addition, the signatures of some uncertainty sources are sought within the error statistics to find out if corrections can be applied and what their effect is. The global and diffuse irradiance uncertainties range from 1.8% to 2.4% without correction, and are better than 1.8% with corrections. They satisfy or are close to the BSRN uncertainty targets for large signals (global: 1000 $Wm^{-2}$, diffuse: 500 $Wm^{-2}$). For small signals (50 $Wm^{-2}$), the targets are not achieved, mainly because of the data acquisition electronics (DAQ) uncertainty. The direct irradiance uncertainty is about 1.5%, three times higher than the BSRN uncertainty target. Here also an accuracy gain could be achieved at the DAQ level, but even without considering the DAQ uncertainty, the target is exceeded by a factor of about two. Even using an absolute cavity radiometer as transfer standard does not allow the reduction of the uncertainty of the instrument sensitivity below about 1%. The direct irradiance accuracy target of 0.5% is probably not achievable with the current best available technology.

## Session 9. Working Group Reports

**Infrared Working Group** (Julian Gröbner)
The Infrared WG is working on an improved worldwide standard for infrared measurements. The Eppley Precision Infrared Radiometers (PIRs) are very stable and the blackbody calibration technique used by BSRN is very stable. PIRs can be used to detect long-term changes in downwelling infrared to about 0.5 $Wm^{-2}$, even if the scale changes.

The Japan Meteorological Agency calibrates operational pyrgeometers regularly with traceability to the World Infrared Standard Group (WISG). The sensitivity and coefficients of each instrument can be recalculated with traceability with the new scale when the scale changes. The characteristics of pyrgeometers under moist atmosphere [i.e., integrated atmospheric water vapour (IWV) is more than 50 mm] should be confirmed so that the longwave irradiance observation within BSRN could have the same accuracy all over the world when the scale changes.

**Long-Term Data Sets Working Group** (Martial Haeffelin)
The Long-Term Data Sets WG is focused on improving quality control for BSRN data and is seeking new users outside the network for the 20-plus years data sets that have been acquired.

**Archive Working Group** (Gert König-Langlo, Anatoly Tsvetkov, Mohamed Mimouni, Taneil Uttal, Jonathan Tamlyn)
The only topic of discussion was the pros and cons of an automated account system as Taneil Uttal asked for the International Arctic Systems for Observing the Atmosphere. Within the BSRN community, a majority asked to hand out the BSRN account manually as before to get into better contact with the data user. The WG is looking for a successor to the current archive manager, who will retire in a few years.

**Cold Climate Issues Working Group** (Chuck Long, Chair)
A number of issues of particular concern in attempting to make accurate surface radiation measurements in cold climates were listed and examples shown. These concerns include not only adverse weather effects such as riming, frost, and snow deposition, but also such issues as the decrease in thermopile sensitivity at extremely cold temperatures, hazardous conditions for personnel operating the sites, and the shifting surface effects on instrument level. Also of note is the pyrgeometer low water content offset issue noted by Julian Gröbner.

A consortium of Arctic surface sites has been formed, with a Radiation Working Group dedicated to surface radiation observations, named the International Arctic Systems for Observing the Atmosphere (IASOA). The IASOA Radiation Group desires to collaborate with BSRN, as several of the Arctic sites are BSRN sites, in addressing the production of accurate Arctic observations and subsequent analyses documenting the climate changes occurring there.

Discussions covered several topics, including planning for possible participation in a field testing of various ventilator air flow and heating designs at Storm Peak Laboratory in Colorado, USA. It was noted that other participants should be encouraged, and a set of standard configured radiometers be fielded as a comparison control. It was suggested that the Working Group should become involved with the “Year of Polar Prediction” activities planned for the 2017-2018 time period. Part of the discussion included the possible formation of Antarctic sites into a Radiation Working Group consortium similar to the IASOA group, and planning and implementation of a set of travelling comparison standard radiometers to visit each Arctic and Antarctic site during the summer in order to tie the radiation measurements to a common standard for relative comparison and normalization. A final discussion involved the issue of surface albedo observations and their relevance to area representativeness given the shifting and morphing nature of the snowy surface and shadowing. Several ideas for area survey and greater coverage were mentioned. This would be another area where efforts could be organized as part of the Year of Polar Prediction activities, given the likely interest and participation of satellite and modeling groups to whom the larger area albedo is of particular interest.

Working Members: Chuck Long (Chair), Gert Koenig-Langlo, Vasilii Kustov, Stephan Nyeki, Marc Olefs, Taneil Uttal, Vito Vitale, and Laurent Vuilleumier, with vendor representatives Jörgen Konings and Tom Kirk (also attending)

**Oceanic Working Group**
This Working Group is researching suitable platforms for ocean observations.

**Uncertainties Working Group**
The main task of this WG is to develop a report based on the Guide to the Expression of Uncertainty in Measurement (GUM) for uncertainties in BSRN measurements.

**Broadband Pyranometry, Pyrheliometry, Albedo, and Aerosol Optical Depth (AOD) Working Groups** (Joseph Michalsky)
There are currently no chairs for these working groups. There was a discussion of what tasks should be considered by these working groups, such as a comparison of the first-class type of pyranometers used in BSRN measurement systems. The focus could be on the measurement of global irradiance. Possible venues discussed were Deutscher Wetterdienst (DWD), the Atmospheric Radiation Measurement (ARM) program Southern Great Plains (SGP) site, and the National Oceanic and Atmospheric Administration (NOAA) Boulder site. Other possibilities are welcomed.

Another comparison of pyrheliometers that includes the newer instruments developed since the 2008/2009 variable conditions pyrheliometer comparison (VCPC) (Michalsky et al., JAOT 2011) is also necessary. An option would be to limit the comparisons to the International Pyrheliometer Comparison three-week period or the US National Renewable Energy Laboratory (NREL) Pyrheliometer Comparison two-week period.

The AOD Working Group disbanded, but it was suggested that the 2010 (and maybe 2005) AOD comparison(s) conducted during the IPCs in those years be reported in a refereed journal to demonstrate the capability of AOD instruments used in the BSRN program.

Broadband albedo was not discussed, but see the slides and summary by Crystal Schaaf.

**Spectral Working Group**
No summary.

# 3. Poster Summaries

**SIRTA Observatory: Site Description and BSRN Operations** (Jordi Badosa, Marc-Antoine Drouin, Martial Haeffelin, Jean-Charles Dupont, Christophe Boitel, Florian Lapouge, Marie-Christine Gonthier)

The SIRTA observatory (48.714N, 2.208 E, France) has contributed to BSRN since 2003 (Station: PAL). Data submitted to date to BSRN covers the period June 2003-December 2013. Current available parameters are:

(i) Downwelling shortwave radiation ($SW_{Dn}$), [diffuse (DIF), direct (DIR), and global (GLO) components], and downwelling longwave radiation ($LW_{Dn}$)
(ii) Air temperature, relative humidity, pressure

In 2012, a 10-m mast was installed at SIRTA's Zone 1 (700 m) with $SW_{Dn}$, $SW_{Up}$, $LW_{Dn}$ and $LW_{Up}$ measurements.

In 2014, the $SW_{Dn}$ (DIF, DIR, GLO) and $LW_{Dn}$ measurements were duplicated to replace the existing ones in order to ensure the quality (due a crane installation nearby).

As a main development, we have redefined the data treatment chain and the quality control procedures (QC) for the whole data set (see details in our oral presentation).

For 2014, two main actions about BSRN data treatment remain:

- Processing the data of the duplicated station and data submission to BSRN archive.
- QC development for the 10-m mast data and submission to BSRN archive.

As for the ongoing research, the following points are worth mentioning:

- Solar irradiances measured using SPN1 radiometers: uncertainties and clues for development [Badosa et al., paper in revision in (*Atmospheric Measurement Techniques Discussions,* AMTD)]
- Impact of surface radiative forcing anomalies on European heat waves (Chiriaco et al., *Geophysical Research Letters* 2014, see poster)
- Radiative effects during the pollution peak in Paris region (March 2014)
- Clear-sky irradiance modeling (comparison and validation)
- Radiative effects of clouds (10-year study)
- Photovoltaic module efficiency under outdoor conditions.

**Boundary Layer Observations of Irradiation Quantities** (Ralf Becker, Klaus Behrens)
Results of radiation balance components profiled in the atmospheric boundary layer were presented and discussed. Using a tethered balloon as a carrier system for Kipp & Zonen CM11 and CG4 sensors, several in-situ soundings up to 1000 m above ground throughout the year could be performed. Added measurement uncertainty, especially in the shortwave range, is introduced by fast movements of the sensor due to turbulent air streams, as well as possible permanent tilting of the sonde. The effect of rapid changes of sensor position can be quantified by about a doubled RMSE compared to collocated BSRN ground-based measurements, both with respect to a linear fit of shortwave downward (3.5 vs. 8.1 $W/m^2$). Permanent tilting may result in a bias that usually matters more. A correction scheme based on evaluation of data of a 2-axis inclinometer and $2^{nd}$ order polynomial fit of surface data is proposed. Case studies for all-season conditions draw a consistent picture of the evolution of the boundary layer. A further focus was set on determining land surface characteristics. Temporal behavior of surface albedo obtained at 300 m above ground of the measuring site close to Lindenberg (vegetation mosaic) corresponds well to results from the 98 m mast as well as near surface, but deviates up to – 4% during a one-day, high summer campaign. Seasonal and diurnal variability need to be further investigated.

**Validation of Downward Solar Radiation from Meteosat Second Generation by Ground-Based Observations of BSRN Network over Europe and North Africa** (Monica Campanelli, Christian Lanconelli, Teresa Lofeudo, S. Vergari, Paolo Sanò, Claudia Calidonna, Stefano Dietrich)

Interest has risen in the topic of research and development of advanced methodologies for studying non-programmable renewable energy sources, as it will strongly impact the electrical system both in terms of storage/integration into electricity grids, and economic outcomes of the produced energy.

Among these sources, solar energy is being commonly used for the generation of electricity for both grid-connected and stand-alone power systems. For proper economic development and efficient utilization of solar energy, an accurate knowledge of the availability and variability of solar radiation intensity both in time and space is very critical.

Methodologies for solar radiation nowcasting (i.e., weather forecasting for the coming 6-hour period, covering a specific area) need accurate observational datasets. Usually, the global solar radiation measurements are made by instruments such as solar radiometers, pyrheliometers, or sky cameras at only a few locations in a country, which may not be enough for building a healthy solar radiation map for use in the early prediction of the solar radiation at the site of interest. The use of downward solar radiation estimates derived by geostationary satellites measurements can provide the necessary time and space resolution, but the local accuracy of the products has to be specifically assessed.

To this aim, the hourly Downwelling Surface Short-Wave Radiation Flux (DSSF) products, estimated over Europe by the Land Surface Analysis Satellite Application Facility (LSA SAF) from the Meteosat Second Generation/Seviri, were validated using measurements of global radiation taken from pyranometers of the BSRN and of the Italian Air Force Meteorological service networks in 2013.

The impact of atmospheric aerosols on solar radiation measured at the surface was also evaluated using simultaneous measurements of aerosol load and its optical-physical characteristics, retrieved by co-located Cimel-Aeronet or Prede-ESR (European Skyradiometer network: *www.euroskyrad.net*) sun-sky radiometers, in order to assess the errors affecting the satellite products during days with a high aerosol load due, for example, to Saharan dust events. The concurrent analysis of surface solar irradiance and aerosol load underlines the importance of having their estimations available for an observing station.

**Status of the Izaña BSRN Station** (Emilio Cuevas)
Since 2009, the BSRN basic set of parameters has been continuously measured at the Izaña station (IZA). Other parameters, including shortwave and longwave upward radiation and UV-A and UV-B radiation, are also measured, in addition to total ozone column, the vertical distribution of pressure, air temperature, relative humidity, and wind speed and direction obtained with radiosondes (WMO, station #60018). The radiation measurements are tested against physically possible (Gilgen et al., 1995) and globally extremely rare limits as defined and used in the BSRN-recommended data quality control (QC). Also daily comparisons between measurements and simulations are performed for global, direct, diffuse, UV-A, and UV-B radiation under clear-sky conditions (*http://www.bsrn.aemet.es/*). Currently, the instrumentation at Izaña station includes a PMO6 open absolute cavity radiometer as a reference instrument. This instrument has been used to calibrate the pyranometers and pyrheliometers, using as a reference the ISO 9059:1990(E) and ISO 9846:1993.

Apart from the BSRN Network, IZA actively contributes to several international radiation networks as an absolute calibration site, such as the World Radiation Center Physikalish-Meteorologisches Observatorium in Davos, Switzerland (WRC/PMOD) since 2001 and the Aerosol Robotic Network (AERONET) since 2004.

**Status and Operations of the Chesapeake Light (CLH) BSRN Station** (Bryan Fabbri, Greg Schuster, Fred Denn, Robert Arduini, Jay Madigan, Dave Rutan)
Chesapeake Lighthouse (CLH), located approximately 25 miles East of Virginia (coordinates: 36.90N, 75.71W), was established in 1999 as a surface validation site for the Clouds and the Earth's Radiant Energy System (CERES) satellite and other satellites. For this reason, Chesapeake Lighthouse is also known as the CERES Ocean Validation Experiment (COVE). Data collection for BSRN covers May 1, 2000 to the present. Pictures of our upwelling and downwelling instruments were shown. A table was provided with information about our measurements at CLH. The table includes: current measurements, instruments with model number, units, wavelengths measured in nanometers, and additional remarks (please see the poster presentation which provides the information on measurements collected at CLH).

Chesapeake Lighthouse is off the grid. Solar panels, batteries, and a diesel generator provide all the power needs at CLH.

A new calibration site has been created at NASA Langley. This "land location" allows for more opportunities to collect data on clear sky days since it is only 5 km from our office. Travel to CLH requires a helicopter trip and forecasting weather a few days in advance. Instruments calibrated at our "land location" are swapped with instruments at CLH. Pictures display the land location site and the instrument locations when installed at CLH after they are calibrated. The newly calibrated instruments are directly traceable to the World Radiation Group in Davos, Switzerland.

A comparison between modeled (CERES SYN1deg-3hour Edition 3A) and downwelling shortwave and longwave measurements collected at CLH from 2000-2013 with associated statistics is presented. Four plots show the comparisons between downwelling shortwave global, downwelling shortwave global by component summation, downwelling shortwave diffuse, and downwelling longwave.

CLH is now owned by the Department of Energy (DOE). Although the DOE's plans frequently change, we have a good relationship, and it has not affected our research. More information about the CLH BSRN site can be found via *http://cove.larc.nasa.gov/*.

**Long-term Global Solar Radiation at Izaña Atmospheric Observatory from 1933-2013** (Rosa Delia García-Cabrera)
Results from reconstruction of 80 years of global solar radiation (GHI) (1933-2013) at the subtropical high-mountain Izaña Atmospheric Observatory (IZO, Spain) are presented in this poster. For this purpose, we combined estimates from sunshine duration (SD) data using the Ångström–Prescott method over the 1933-1991 period, and GHI observations directly performed by pyranometers between 1992 and 2013. Since GHI measurements have been used as a reference, a strict quality control has been applied; when it was not possible, data have been re-calibrated by using the LibRadtran model. By comparing to high quality GHI measurements, the precision and consistency over time of GHI estimations from SD data have successfully been documented. We obtain an overall root mean square error (RMSE) of 9.2% and an agreement between the variances of GHI estimations and GHI measurements within 92% (correlation coefficient of 0.96). Nonetheless, this agreement significantly increases when the SD estimation is done considering different daily fractions of clear sky (FCS). In that case, RMSE is reduced by half, up to about 4.5%, when considering percentages of FCS > 40% (90 % of days in the testing period). Furthermore, we prove that the GHI estimations can monitor the GHI anomalies in consistency with GHI measurements and can then be suitable for re-constructing solar radiation time series. The re-constructed GHI time series between 1933 and 2013 at IZO confirms discontinuities and periods of increases/decreases of solar radiation at Earth's surface observed at a global scale, such as the early brightening, dimming and brightening. This fact supports the consistency of the IZO GHI time series presented in this work, which may be a reference for solar radiation studies in the subtropical North Atlantic region.

**Overview of the Atmospheric Radiation Measurement (ARM) Program BSRN Sites** (Gary Hodges)
The three Atmospheric Radiation Measurement Program (ARM) Tropical Western Pacific (TWP) sites are ceasing operations. ARM is redirecting the TWP funding for the expansion of the Oklahoma, USA and North Slope of Alaska, USA "super sites." Manus Island operated 199708 – 201407, Nauru Island operated 199810 – 201309, and Darwin operated 200203 – 201412.

ARM has recently established a new site about 1600 km west of Portugal. It is located on Graciosa Island, which is part of the Azores. The Azores are composed of nine major islands that stretch for about 600 km in a northwest-southeast direction. It is a region characterized by marine stratocumulus clouds. ARM operated a mobile facility on Graciosa for 18 months in 2009–2010.

The loss of the three TWP sites is unfortunate, but two ARM sites will continue to be submitted to the archive. Billings (BIL) and E13 are co-located sites within the ARM Central Facility (CF). The CF is a robustly instrumented research site located in north central Oklahoma, USA. These co-located sites are unique in the archive in that they offer the ability to assess how well two sites identically maintained compare with each other.

**Overview of the US Surface Radiation (SURFRAD) BSRN Sites** (Gary Hodges)

Significant station improvements have been made over the past year. We are converting data collection from copper phone lines to broadband cellular. This has reduced the number of missed collections due to noisy phone lines. It will also allow us to provide data in near real-time for renewable energy research. The discontinued Campbell Scientific CR10X data loggers are being replaced with the newer CR1000 model. The Total Sky Imagers (TSI) have been upgraded with an improved mirror controller board and GPS for time and location setting.

Citations of SURFRAD data in the formal published literature are increasing exponentially. The annual average anomalies of incoming solar over the seven SURFRAD sites show a statistically significant increasing trend over 16 years. A documented decrease in aerosols at the SURFRAD sites can only account for 0.8 Wm2 of this approximate 10 $Wm^{-2}$ of brightening. The change is thought to be the result of fewer and/or thinner clouds. Although we do not yet understand this change in cloud cover, a recent publication by NASA (Herman et al., *Atmospheric Chemistry and Physics*, 12, 31991-32038, 2012), which analyzed 33 years of Solar Backscatter Ultraviolet Instrument (SBUV) data, supports our result.

Two mobile SURFRAD stations have been deployed at six locations over the past two years in support of air quality and renewable energy research projects.

**Measuring Reflected Shortwave Radiation with a Horizontally Mounted Instrument** (Gary Hodges)
We needed to measure reflected shortwave over water using land-based instrumentation. An Eppley PSP and a Yankee Multi-Filter Rotating Shadowband Radiometer (MFRSR) sensor were mounted on a tower positioned at the water-shore interface, both instruments oriented vertically with the faces of the detectors pointed at the water's horizon, and each housed in an enclosure designed to obscure the sky. The raw data had calibrations applied as usual, with a multiplier of two since only half the surface was in view of the sensors.

Initial field tests were performed at our Table Mountain research site (this is also the location of the Table Mountain SURFRAD BSRN site). The shortwave narrowband analysis was done a bit differently than the broadband. In this case, ratios of albedo were used rather than reflected shortwave. This was due to calibration issues and slightly different models of MFRSRs that were used. The horizontal pointing data were multiplied by two as with the broadband, and then the albedo was calculated with its corresponding MFRSR. In general we see similar results as the broadband; that is, the horizontal pointing instrument is measuring a bit higher than the traditional (down-pointing) instrument. The 3-D radiation field coupled with the cosine response may explain some of the difference. The results are intriguing and may provide alternatives in unique situations.

**Status of Tartu-Toravere (TOR) BSRN Station** (Ain Kallis)
The Tartu-Toravere (TOR) station is located in the eastern part of Estonia and was established in January 1950. The Tartu-Tõravere Station became a BSRN candidate in 1993, and since 1999 it has operated as a BSRN station. It belongs to the Estonian Environment Agency (former Estonian Meteorological and Hydrological Institute).

In addition to the basic measurements (LR0100), long-wave measurements (LR 0300) and ultraviolet measurements (LR 0500) are transmitted to the BSRN archive on a monthly basis. The basic quantities measured are global, diffuse, direct, and reflected radiation. The instrumentation of the station includes the following sensors: direct irradiance (PMO6 absolute radiometer, pyrheliometers AT-50, NIP); global, diffuse, and reflected irradiance (CM-21); net radiation (GB-1); downward and upward long-wave irradiance (Eppley PIR); UVA, UVB, UV erythemal radiation (CUV3, CUVB1, UV-SET); photosynthetically active radiation; and global and direct (LI-COR 190SA) and total ozone measurements (MICROTOPS II).

New instruments obtained in 2014 include a spectral radiometer PFR, pyrgeometer CGR4 with CVF4 ventilation unit, and a sun tracker 2AP.

All instruments are calibrated yearly. The condition of sensors is checked several times a day.

**Direct Far Infrared Radiometers: The Measurement of Direct Longwave Radiation** (Jörgen Konings)
Pyrheliometers fitted with solar blind-coated silicon windows are pointed at the sun to measure longwave radiation coming directly from the sun. The difference between shaded and unshaded longwave measurements is relevant to daytime data in network operation. The goal of this experiment is to separate the pyrgeometer offset due to dome heating from radiation passing through the pyrgeometer window. Test instruments were installed at DWD, Lindenberg, Germany; at NREL, Golden, Colorado, USA; at PMOD/WRC, Davos, Switzerland; and at Hukseflux, Delft, The Netherlands. The measured effect is significant and on the order of 4 to 6 W/m$^2$ at all four sites. Improved calibration methods and better characterization of the instruments are needed to make definitive statements on the relevance of this measurement.

**Status of the Dome-C Antarctic BSRN Station** (C. Lanconelli, A. Lupi, M. Mazzola, B. Petkov, V. Vitale)
Dome-C (3233 m.a.s.l, 75°S, 123°E) is a joint Italian-French facility on the East Antarctic Plateau, operating throughout the whole year since the winter-over 2005. It is characterized by an extremely dry (precipitable water less than 1mm) and cold temperature that ranges between -80°C and -20°C. A strong surface temperature inversion occurs in particular during winter. The Basic Measurements (LR 0100) were implemented in January 2006 using mostly Kipp and Zonen secondary standards CM22, CH1, and CG4 radiometers, along with a couple of Eppley normal incident pyrheliometers (NIP). A set of radiometers is calibrated every two years with respect to the World Radiometric Reference (WRR) (SW) and the World Infrared Standard Group (WISG) (LW). Since April 2007, a set of ventilated secondary standard radiometers (CM22) and a CGR4 operate on a 3 meter height "T" shaped albedo rack, to measure the upwelling shortwave and longwave components of surface energy budget (LR 0300), while a secondary standard CM11 pair of pyranometers were installed during the 2009-2010 summer campaign at the level of 32 m on the Dome-C scientific tower (45 m) to obtain an albedo representative of a wider area with the aim to provide valuable data for satellite validation. During the summer campaign 2013-2014, basic measurements were moved to a new dedicated platform.

An overview of the corrections applied to the raw measurements was presented as monthly statistics for the period 2006-2014: i) temperature correction has to be performed down to -70°C. This requires extrapolation of the sensitivity correction table S (T) provided by the instrument constructor down to -20°C. We used a third order polynomial fit yielding for some instruments, a -10% variation of S (T) at -70°C. This approach produces temperature compensation absolute corrections of the g2 component lying between 0 and +10 W/m$^2$ on average. ii) Offsets were determined during the winter over periods for SZA>108°. Offset corrections were considered to be proportional to absolute value of |NetIR| as measured by the pyrgeometer ranging on average (monthly) between -75 W/m$^2$ (summer) and –35 W/m$^2$ (winter), producing corrections lying between 0 and +2.5 W/m$^2$. iii) Monthly averaged cosine corrections applied to g2 ranged between 0 and -5 W/m$^2$ on average for the whole period 2006-2013.

The daily behaviors of downwelling and upwelling irradiance, and of the albedo, were presented for the months November to February. Albedos present an asymmetric U-Shape feature with afternoon values greater than those recorded at the corresponding sun elevation in the morning, being in general larger than 0.8 at local noon.

**The New ISAC-MPP Automatized Spectroradiometer** (U. Bonafé, C. Lanconelli, A. Lupi, M. Mazzola, B. Petkov, V. Vitale, F. Zardi)
Atmospheric aerosols play a crucial role in the Earth's radiation balance and may hold the key to assessing climate variability. However, more knowledge is needed about aerosol sources, distributions, and properties. This requires continuous observations from satellites, networks of ground-based instruments, and dedicated field experiments. The Institute of Atmospheric Sciences

Climate National Research Council-Mobile Platform sun-Photometer (ISAC-MPP) combines mobile (including ship-borne and airborne) sun tracking with diffraction spectroscopy to improve knowledge of atmospheric constituents. Hyper-spectral measurements of direct solar radiation improve retrievals of aerosol burdens and properties and gas constituents.

Essentially, the instrument is based upon a two-channel spectrometer model SL40-2 manufactured by Solar TII (www.solartii.com), with a spectral range from 210 nm - 1130 nm. Up to now, the readiness level is set to a ground-based prototype, except for an experimental setup developed with a previous ISAC-MPP model during the Arctic Study of Tropospheric Aerosols, Clouds, and Radiation (ASTAR) 2007, installing it on the AWI Polar5 Aircraft. The next improvement will be measurements of scattered sunlight as a function of angular distance from the sun, in order to retrieve more information of aerosol properties (i.e., absorption and scattering properties, size distribution, effective radius).

During May 2014, in order to verify the instrumental quality, the ISAC-MPP participated in an intercomparison campaign in the framework of 4$^{th}$ International Spectroradiometer and Broadband Intercomparison 2014 in Madrid. Various all-sky instruments have taken synchronous measurements and preliminary results appear to be really encouraging.

**Moon-Photometric Aerosol Optical Depth Measurements during Polar Night** (M. Mazzola, V. Vitale, A. Lupi, R.S. Stone, C. Wehrli, N. Kouremeti, K. Stebel)
Aerosol particles emitted at mid-latitudes can be transported to the Arctic. Their monitoring in these areas is important both for studying the transport process itself, and for observing the effects they may have on the energy balance. Unfortunately, during the polar night their monitoring by remote sensing techniques from the ground is limited to the use of LIDAR and stellar photometry, two techniques expensive in terms of money and manpower. A new possibility is to use the technique of photometry where the radiation source is the moon. This is made possible by the knowledge of the lunar reflectivity in any geometric configuration of the Sun-Moon-Earth system and of the moon phase. This problem was studied and solved by the US Geological Survey (USGS) with the RObotic Lunar Observatory (ROLO) model.

In this contribution we will show the results of the first measurements made at Arctic stations, i.e. Barrow (Alaska) and Ny-Ålesund (Svalbard). The measurements started in November 2012 using a Carter-Scott SP02 sun photometer at Barrow, while in Ny-Ålesund first tests were made in February 2014 using a PFR sun photometer. Both instruments were modified in order to be able to effectively measure the weak radiation signals reflected from the moon. Tests carried out in periods of alternating day and night have shown that this technique allows one to obtain results consistent with those obtained using the solar photometry. Measurements in Ny-Ålesund will continue during the winter 2014/2015.

Other research groups around the world are gearing up to perform this type of measurement, and then monitoring of the columnar aerosol optical properties will be possible during the night in different places on the planet, both polar and not.

**Twenty Years of Radiation Measure at the Tamanrasset, Algeria Station** (Mohamed Mimouni)
In September 1994, solar radiation instruments were installed at Tamanrasset (meteorology service) in collaboration with CMDL/NOAA (Boulder). For the first time, the parameters of direct, global, diffuse, and RG8 filtered solar irradiance were measured with a three-minute time step. In March 2000, the station was upgraded in the BSRN network with new instruments (pyrgeometer PIR downward) and one-minute time step. The measure of diffuse was changed also with disk shade in place of shadowband.

The data are sent regularly to the BSRN archive at AWI (Bremerhaven, Germany), with the last data of 171 file months sent in May 2014. The analysis of daily average shows stable annual values with an important seasonal variation. The minimum of global and diffuse are observed in the winter when the sun is very low and the maximum in the summer. The mean annual values are 23.07 MJ for global, 6.68 MJ for diffuse, and 28.4 MJ for PIR (longwave downward). The diffuse is more important in the summer because this region is influenced by monsoon flux with significant cloud and haze. The pyranometers have a significant offset in the night of about 8-10 W/m$^2$.

In last 3 years, we have also installed an albedometer to measure the value of albedo. The results show that the mean value of albedo in this desert region varies between 0.33 and 0.35 with a small season variation.

The calibration of solar instruments is done in situ with a reference cavity AHF. The results of calibration show a linear decrease of calibration coefficient of about 1 to 2% per year.

**Satellite-Based Ultraviolet and Shortwave Direct-Diffuse Solar Radiation Data Validated through Ground-Measured BSRN Data in Support of Downstream Services Dedicated to Health Prevention and Solar Energy** (Marco Morelli)
All the satellite-based downstream services concerned with solar radiation strongly need accurate ground-based measurements in order to perform a good validation. The Baseline Solar Radiation Network (BSRN) is currently the best possible way to freely retrieve such high quality measurements as needed, providing data acquired with instruments of the highest available accuracy and with high time resolution.

Flyby is involved in solar energy and the healthcare sectors, providing solutions for the near real-time monitoring of solar energy plants (SolarSAT) and an innovative system providing real-time personalized recommendations for a safe sun exposure (HappySun App, currently freely available both for Android and iOS platforms).

So far the GHI, BHI (beam horizontal), and DHI satellite-based data have been validated exploiting BSRN's Carpentras (CAR) station data, while the UVA and UVB data have been validated thanks to BSRN's Izaña (IZA) station measurements. The validation resulted in a good agreement between ground-based and satellite-based data, and it's the starting point for further developments of Flyby's elaboration processes.

Flyby is interested in collaborating with BSRN station scientists (or users) for possible joint scientific research and development activities (e.g., aerosol's impact on solar energy production or UV exposure) or in the frame of EC/ESA funded projects. We may also be interested in ground-based solar radiation data sharing, since Flyby has a (little) proprietary meteorological station in Livorno on its headquarters' roof (with UV sensors and pyranometers installed).

**Time-Series of Downward Long-Wave Radiation using Modified CGR3 Pyrgeometers in Switzerland** (Stephan Nyeki, Stefan Wacker, Julian Gröbner, Laurent Vuilleumier)
In this study, we present down-welling long-wave radiation data for the 8-14 μm window from modified CGR3 measurements at four Swiss stations (Payerne, Jungfraujoch, Davos, and Locarno) for the 2008-2014 period. These sites have instruments belonging to the MeteoSwiss SACRaM (Swiss Alpine Climate Radiation Monitoring) network, and to the PMOD/WRC, Davos. Measurements of a number of radiation and aerosol parameters have been conducted for periods longer than 10 years in some cases. A set of standard CGR3 pyrgeometers (K&Z) instruments were modified by K&Z to have an additional Germanium band-pass filter, which changed the spectral range from 4.5-42 □m to 8-14 □m (i.e., "narrowband" measurements of the main atmospheric window). This range was chosen as the absorption and emittance of long-wave radiation by greenhouse gases is less effective, hence making the atmosphere more transparent. Down-welling longwave (DLR) radiation is therefore reduced in this range, making it mainly dependent on the atmospheric water content. Time-series data since 2008 were analyzed using the seasonal Kendall test, a generalization of the Mann-Kendall test, and Sen's slope method. Narrowband and broadband DLR time-series suggest that a decrease in the

all-sky trend may be due to a decrease in cloudiness while an increase in the cloud-free trend may be due to increasing temperature and/or IWV.

**Quality Control of Radiation Data at High Alpine BSRN Station Sonnblick** (Marc Olefs, Martin Mair)
We present a best practice example of data quality control (DQC) from measurement to data submission for the extreme BSRN site Sonnblick (Austria) with harsh weather conditions and frequent hoar frost formation. Automatic and manual checks are used to combine the best information available to achieve high data quality. DQC follows and extends BSRN guidelines and is also applied at three more radiation monitoring sites in Austria using a comparable measurement setup. The usage of a web interface and a central database for daily quantitative and qualitative maintenance reports, the quality flags resulting from the automatic checks, and additional manual corrections ensure a strict, consistent, and comprehensible DQC at the highest possible level. The automatic algorithms are an extended version of the QCrad checks (Long and Shi, 2008) and are performed on a daily and hourly (most critical ones) basis. The most important extensions are the monitoring of the current of the heating/ventilation devices, the cross check between the sunshine duration sensor and direct solar radiation (tracker alignment), and an outlier check of the difference in instrument body temperatures minus air temperature as well as the connection of the heating and ventilation circuit in order to automatically shut down the heating when the ventilator is blocked due to hoar frost, eliminating an additional zero offset. Manual DQC includes the daily maintenance work by the on-site observer team (frost removal, cleaning of domes, etc.), the regular visual inspection of a 10 minute updated high resolution SLR webcam during day and night by the station scientist and the check of a daily graph summarizing the results of the daily automatic DQC. Occasional, long-term DQC consists of a statistical analysis of the automatic daily DQC results and the cumulative sum of the difference global minus component sum over a, e.g., 3-month period. A python script is finally used to merge all quality flags from the database, to perform a last visual inspection and manual correction of the data, followed by station-to-archive file formatting and submission to the BSRN archive. Future improvements of DQC concern the webcam to better monitor individual sensors in more detail and to upgrade the tracker alignment check towards a direct radiation independent check through a target-performance comparison between internal azimuth and zenith data showing the position of the tracker vs. calculated sun position.

**Effect of the 2011 Arctic Ozone Depletion Event on the Ozone Column over Europe According to Ground-Based Observations** (Boyan H. Petkov, Vito Vitale, Christian Lanconelli, Mauro Mazzola, Angelo Lupi)
The strong ozone depletion event that occurred in the Arctic during spring 2011 was found to cause appreciable reduction in the ozone column in Europe, even at lower latitudes. The features of this episode have been analyzed using the data recorded at 34 ground-based stations located in the European area and compared with similar events in 2000 and 2005. The results provided evidence that ozone column as far south as 40°N latitude was considerably influenced by the Arctic ozone loss in spring 2011. The reduction of ozone column at the northernmost sites was about 40% with respect to the mean value, while at the southern extreme the loss ranged between 12 and 18%.

**Implementing a BSRN Station at the Observatory of Huancayo, Peru** (Luis Suarez)
The Observatory of Huancayo (lat. 12.05° S, long. 75.32° and an altitude of 3,314 m.a.s.l.) has a long tradition of atmospheric monitoring. It belongs to the Unit of Variability and Climate Change of the Geophysical Institute of Peru. It was built over a relatively flat area about 10 km northeast of the city of Huancayo, which has about 350,000 inhabitants. It was started with a generous contribution from Carnegie Institution of Washington, USA, as a research station for geomagnetism, and it has meteorological records from 1922. It is a part of the Ministry of Environment of Peru. During the last few years, it has been increasing its research capabilities based on national funds and international cooperation.

Basic meteorological measurements are performed continuously. A 6-m tower was built to start solar radiation measurements. It consists of a CMP11 pyranometer and a CG3 pyrgeometer, both from

Kipp & Zonen (Netherlands) that are connected to a CR100 data logger from Campbell Scientific (USA). It samples data each 10 minutes. Also, spectral UV radiation measurements are performed by a GUV-511 radiometer from Biospherical Inc. (USA) since 2003. Complementary measurements like temperature, relative humidity, and pressure are also recorded.

During previous years, in cooperation with the Antarctic Research Institute of Peru, we coordinated the monitoring of aerosols with a sunphotometer SP02-L from Middleton Solar (Australia) with four sensors centered at 412, 500, 675 and 862 nm. It also has a solar tracker and a net radiometer CNR1 from Kipp & Zonen.

It is expected that with this basic experience and the local and international interest we will be able to coordinate and complement the efforts to implement a BSRN station at this location that will provide very valuable information on a region with scarce data and increase the coverage over South America.

**Status of the Payerne BSRN Station (2014)** (L.Vuilleumier)
The Payerne station has measured the BSRN basic set of parameters since November 1992. In addition, other parameters including LW and SW irradiance at 10 and 30 m 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 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 that allowed integrating it in the general MeteoSwiss automated network infrastructure. This included completely removing and renewing the old infrastructure including supporting benches as well as signal and power cabling. This was achieved between 15/08/2011 to 30/09/2011. During this period only partial data were available at Payerne BSRN.

Beyond quality control that is performed daily, thorough verification (quality analysis) of the Payerne BSRN data accuracy or reproducibility was performed for shortwave (SW) global, direct, and diffuse as well as longwave (LW) downward irradiance. This revealed that the level of reproducibility and stability reached before the upgrade of the station was maintained in general. However, some discrepancies between redundant measurements seemed to approach and eventually exceed the extremely tight BSRN accuracy targets.

In particular, the discrepancies for the SW direct irradiance and the LW downward irradiance seem to indicate that some problems affected the measurement of these parameters. Increasing differences appeared between DNI measurements by the absolute cavity radiometer and a CHP1 pyrheliometer, even after exchanging the pyrheliometer against a newly calibrated one. This situation was finally diagnosed as a problem of sun tracking, and the sun tracking system was inspected, which showed that the four-quadrant photoelectric sensor designed to correct the alignment of the sun tracker was faulty. The front window of the device suffered some inhomogeneous loss of transparency with time. This resulted in an erroneous correction that still had the sun within the opening angle of the CHP1 and PMO6 radiometer, but not at the center. As a consequence, the uncertainty increased but the DNI measurements were not obviously wrong, which resulted in a long delay before the problem was identified and solved. Similarly, differences larger than expected appeared between measurements of the LW downward irradiance by a K&Z CG4 and an Eppley PIR pyrgeometer. In-depth analysis revealed that an offset affected one of the data acquisition (DAQ) channels used to measure the Eppley PIR pyrgeometer (affecting the logger ADC). Currently the logger does not satisfy the requirements for precision measurements with thermopile-based instruments, and a solution is under investigation at MeteoSwiss for all loggers connected to such instruments.

**CEOS/WGCV/LPV protocol for validation of moderate resolution satellite derived surface radiation measurements** (Zhuosen Wang, Miguel Román, Crystal B. Schaaf, Qingsong Sun, Yan Liu)

The Land Product Validation (LPV) sub-group of the Committee on Earth Observation Satellites (CEOS) Working Group on Calibration and Validation (WGCV) plays a key coordination role and aims to address the challenges associated with the validation of remotely sensed global land products. One of the LPV subgroup activities is the validation of global surface radiation/albedo products. Surface albedo quantifies the radiation interaction between the atmosphere and the land surface. This essential climate variable controls the surface radiation energy budget. Climate models for global surface albedo require an absolute accuracy of 0.02-0.05. The MODerate resolution Imaging Spectroradiometer (MODIS) Bidirectional Reflectance Distribution Function (BRDF)/albedo product has provided measures of surface albedo for more than 14 years. The standard albedo product makes use of a linear "kernel-driven" RossThick-LiSparse Reciprocal (RTLSR) BRDF model to describe the reflectance anisotropy of each pixel at a 500-m gridded resolution. The Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi- National Polar-orbiting Partnership (NPP) satellite (launched on October 28, 2011) has the ability to continue providing BRDF, albedo, and nadir reflectance products for research and operational users through use of the MODIS heritage algorithms. The Baseline Surface Radiation Network (BSRN) provides in situ long-term observed surface albedo measurements for validation from a network of more than 50 globally diverse sites. The footprint of the ground tower measurements is often considerably different than that available with the satellite spatial resolution, however. In this study, spatially representative analysis is applied to detect the surface heterogeneity and spatially representative BSRN sites were selected to validate the VIIRS and MODIS albedo product. The results indicated that VIIRS and MODIS albedo match well with ground measurements over spatially representative BSRN sites. Fine scale satellite albedos are needed to link moderate spatial resolution albedo and ground measurements over non-spatially representative sites.

**ARES Project: Access to Solar Measurements Network** (L. Ramírez, R. Bojo, J. Valero, S. Wilbert L.F. Zarzalejo, A. Paz, G. García, W. Reinalter R.X. Valenzuela, G. Díaz-Herrero, A. Campos, F. Wolfertstetter
The objective of the ARES Project is to provide access to the solar radiation data recorded in distributed meteorological stations, using a web platform and through the definition of standards for solar radiation data management. Thus, the homogenization of procedures such as data acquisition, quality control, storage, and treatment are included in the objectives.

The starting point of this initiative is a collaboration between several CIEMAT Divisions (CETA-Centro Extremeño de Tecnologías Avanzadas, Renewable Energies, and PSA-Plataforma Solar de Almería) and the Qualification Department of the DLR-Deutsches Zentrum für Luft-und Raumfahrt. This collaboration is being developed in the context of the DNICast Project, a EU Project with the objective of improving solar radiation forecasting in high resolution and time frequency.

Beyond the developments in the context of the DNICast, the ARES Project will try to set up a tool that could be extended to similar measurements stations focused on solar radiation. ARES will aim to provide solar radiation data with the guarantee that all the data will have similar data acquisition procedures (in those cases that are possible), metadata, storage structure, quality control procedures, time stamp checks, and validation treatments. For this purpose, software for the management and operation of measurement networks developed by CETA is being adopted for the ARES needs.

**METAS: Meteorological Station for Solar Technologies** (L.F. Zarzalejo, L. Ramírez, R.X. Valenzuela, J. Polo, S. Wilbert, F. Wolfertstetter, N. Hanrieder, B. Nouri, G. García, J. Liria, A. Campos)
METAS (Meteorological Station for Solar Technologies) is the result of a collaboration between Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT) and the German Aerospace Center (DLR). It is a joint facility that develops activities related to the measurement and characterization of solar radiation for energy applications. The complementarity between the CIEMAT- Plataforma Solar de Almería (PSA)-BSRN radiometric station and DLR-AERONET station improves existing capabilities and enables a better understanding of atmospheric attenuation and evolution of cloud cover, crucial for the management, operation, and efficiency of solar power plants.

METAS is located at the Plataforma Solar de Almería (PSA-CIEMAT, *www.psa.es*), the largest European research, development, and test center devoted to solar concentration technologies (South-East of the Iberian Peninsula, 37.09ºN, 2.36 ºW).

**Two years of BSRN measurements in Gobabeb, Namibia** (Roland Vogt)
In May 2012, the Meteorology, Climatology, Remote Sensing (MCR) group from the University of Basel together with the Gobabeb Research and Training Centre and Karlsruhe Institute of Technology installed a BSRN compatible station in Gobabeb, Namibia (*www.gobabeb.org*), on the prominent "radiation rock" (S23.5614, E15.04198) where in former times global radiation was measured with an analog Fuess-Robitzsch bimetal radiation recorder. In a memorandum of understanding it was agreed to maintain these measurements at least for six years (end 2018). Since November 2012, measurements of upwelling shortwave and measurements of upwelling longwave ($LW_{up}$) completed the set-up. Downwelling shortwave ($SW_{dn}$), downwelling longwave ($LW_{dn}$), and DN are measured with redundant instrumentation (CMP22, CGR4, CHP1) while each remaining radiation flux (diffuse downwelling, CMP22; upwelling CMP22 and CGR4) is sampled with one instrument only. In July 2013, the so-called reference instruments were replaced by instruments of the same type. The exchanged reference instruments still need to be calibrated. The maintenance of the instruments is done on a daily basis typically between 6 and 7 UTC. The redundant instruments are used for quality control by inspecting the courses of the differences. Erroneous values are flagged in the monthly data files. A striking feature of the site is the frequent occurrence of fog/high fog during the second half of the night. The fog usually disappears during the first half of the morning. During fog events, the $LW_{dn}$ measurements are especially affected by fog water deposition. Latest data are displayed at *https://mcr.unibas.ch/dolueg/bsrn/*. Acknowledgements: The daily maintenance work of the Gobabeb team is greatly appreciated.

# 4. Participants

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# 5. Agenda

## 13th BSRN Scientific Review and Workshop
## Bologna, Italy
## 9-12 September 2014

### Tuesday, September 9, 2014

| | |
|---|---|
| | **OPENING** |
| 9:00 AM | **Cristina Sabbioni** (Director) - Institute of Atmospheric Sciences and Climate - Welcome |
| 9:20 AM | Lanconelli and Vitale - Meeting logistics |
| 9:40 AM | **Tim Oakley** - WMO/GCOS - (1) Status/Plans for GCOS; (2) The GCOS Implementation Manager and the GCOS Cooperation Mechanism |
| 10:00 AM | **Nozomu Ohkawara** - Japan Met Agency - Report on GCOS AOPC meeting |
| 10:20 AM | **Joseph Michalsky** - NOAA - State of BSRN |
| | **NEW SITES** |
| 11:10 AM | **Alexander Makshtas** - St. Petersburg - AARI - New Russian polar station at Severnaya Zemlya – Potential member of BSRN network |
| 11:40 AM | **Antonio Paz** - Costa Rica - Instituto Costarricense de Electricidad - Installation of solar direct radiation measurement equipment in Costa Rica |
| 12:00 PM | **Katlego Ncongwane** - WEATHERSA - Status of the South African De Aar station |
| 12:20 PM | **Enio Pereira** - INPE - Status of four SONDA BSRN stations in Brazil |
| 12:40 PM | **Taniel Uttal** - NOAA - Arctic radiation activities coordinated through the International Arctic Systems for Observing the Atmosphere (IASOA) |
| | **OBSERVATIONS AND ANALYSIS** |
| 2:30 PM | **Maria Hakuba** - ETH - Solar absorption and cloud radiative effects observed at BSRN sites |
| 2:50 PM | **Vasilii Kustov** - Arctic and Ant. Res. Inst. - Shortwave radiation balance of Northern Yakutia according the data from the Tiksi BSRN station and Russian standard stations |
| 3:10 PM | **Ben Liley** - NIWA - Use of BSRN to enhance the value of radiation data from the New Zealand climate network |
| 3:30 PM | **Marion Maturilli** - AWI Germany - Seasonality in long-term temperature and radiation changes in Ny-Ålesund |
| 4:10 PM | **John Augustine** - NOAA - Combining BSRN surface observations with MODIS data to compute radiative forcing of a small smoke plume at the surface, TOA, and within the atmosphere |
| 4:30 PM | **Boyan Petkov** - ISAC CNR - Variations in solar UV irradiance and ozone column at Concordia and Mendel Antarctic stations |
| | **ALBEDO** |
| 4:50 PM | **Christian Lanconelli** - ISAC CNR - Spectral and broadband snow albedo measurements at Dome-C and Ny-Ålesund |

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| 5:10 PM | **Crystal Schaaf** - U. Mass Boston - Evaluation of MODIS, VIIRS, and Landsat albedos at BSRN sites and development of CEOS/WGCV/LPV albedo ECV protocols |

## Wednesday, September 10, 2014

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|---|---|
| | **RADIOMETER IMPROVEMENT** |
| 9:00 AM | **Julian Groebner** - PMOD WRC - IR reference |
| 9:20 AM | **Klaus Behrens** - DWD - Comparison of different types of pyrgeometers with the IRIS radiometer in Lindenberg |
| 9:40 AM | **Jose Celso Thomaz** - INPE - An application of ordinary least squares to evaluate the correction factor (k) on pyrgeometer measurements at the National Organization Environmental Data System for the Energy Sector (SONDA Network – Measurements) |
| 10:00 AM | **Aron Habte** - NREL - Evaluating solar resource data obtained from multiple radiometers deployed at NREL |
| 10:20 AM | **Fred Denn** - NASA - Comparison of top of atmosphere voltages at Mauna Loa, Hawaii, and at the Clouds and the Chesapeake Lighthouse BSRN site |
| | **EVALUATION** |
| 11:10 AM | **Nicole Hyett** - BoM - Pyranometer Calibrations with examples from the Australian stations in the BSRN |
| 11:40 AM | **Laurent Vuilleumier** - MeteoSwiss - Performance evaluation of radiation sensors for the solar energy sector |
| 12:00 PM | **Ping Wang** - KNMI - Balloon measurements of light profiles in cloudy atmospheres |
| 12:20 PM | **Sylvio Luiz Mantelli Neto** - INPE - LEPTEN -Qualitative aspects of cameras systems used on synoptic observations systems (SOS) |
| 12:40 PM | **Julian Groebner** - PMOD WRC - A new spectroradiometer for high resolution aerosol optical depth |
| | **WORKING GROUPS** |
| 2:00 PM | Working groups meet |
| 2:20 PM | Working groups meet |

## Thursday, September 11, 2014

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|---|---|
| | **MODELS, SATELLITES, AND RADIATION FORCING** |
| 9:00 AM | **V. Ramaswamy** - NOAA - Surface radiative fluxes, hydrological cycle, and climate |
| 9:20 AM | **Martin Wild** - ETH - Surface radiative fluxes in BSRN and in climate models |
| 9:40 AM | **Chuck Long** - PNNL - Climatology of surface radiation, clouds, and cloud radiative effects for the ARM TWP sites |
| 10:00 AM | **Taiping Zhang** - NASA Langley - Quality-control and processing of the BSRN data and its application in validating the NASA GEWEX SRB global horizontal irradiance and model derived direct normal irradiance |
| 10:20 AM | **Chuck Long** - PNNL - Evidence of clear sky daylight whitening: Are we already conducting geoengineering? |

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| 11:00 AM | **POSTER SESSION** |
| | **DATA ISSUES** |
| 2:30 PM | **Gert Koenig-Langlo** - AWI - Archive status and Neumayer, Antarctica |
| 2:50 PM | **Jordi Badosa** - LMD/IPSL - New BSRN data quality control developed and applied at SIRTA Observatory |
| 3:10 PM | **Wouter Knap** - KNMI - BSRN Station Cabauw: Work flow from measurement to archive |
| 3:30 PM | **Anatoly Tsvetkov** - WRDC/MGO - Clear sky BSRN and GAW global data peculiarities |
| 4:10 PM | **Joergen Koenigs** - HukseFlux - Calibration and measurement uncertainty estimation of radiometric data (from ASTM International Standard |
| 4:30 PM | **Laurent Vuilleumier** - MeteoSwiss - Accuracy of ground surface broadband shortwave radiation monitoring |
| | **WORKING GROUPS** |
| 4:50 PM | Hyett - Uncertainties WG report |
| 5:10 PM | Michalsky - Pyranometry, pyrheliometry, albedo WG report |

## Friday, September 12, 2014

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|---|---|
| | **REPORTS OF THE WORKING GROUPS** |
| 9:00 AM | **Julian Groebner** - PMOD WRC - IR WG report |
| 9:20 AM | **Martial Haeffelin** - LMD/IPSL - Long term data sets WG report |
| 9:40 AM | **Gert Koenig-Langlo** - AWI - Archive WG report |
| 10:00 AM | **Chuck Long** - PNNL - Cold climate WG report |
| | **ADJOURN** |
| 11:00 AM | BSRN Business Meeting*<br>*WRR and WISG<br>*Next meeting venue<br>*Next project manager<br>*Other items |

# 6. Listing of Posters

| POSTER SESSION | | | | |
|---|---|---|---|---|
| P02 | BADOSA | Jordi | LMD/IPSL | New BSRN data quality control developed and applied at SIRTA Observatory |
| P03 | BECKER | Ralf | DWD | Status of Lindenburg BSRN site |
| P04 | CAMPANELLI | Monica | ISAC CNR | MSG and BSRN surface observation for global radiation |
| P05 | CUEVAS | Emilio | AEMET | Status of the Izaña BSRN Station and future activities |
| P07 | FABBRI | Bryan | SSAI/NASA Langley | Status and Operations of the Chesapeake Light (CLH) BSRN Station |
| P08 | GARCÍA CABRERA | Rosa Delia | AEMET | Long-term in global solar radiation at Izaña Atmospheric Observatory from 1933-2013 |
| P12 | KALLIS | Ain | EWS | Status of Tartu-Toravere BSRN Station |
| P13 | KONINGS | Jörgen | Hukseflux | Direct Far Infra-Red Radiometers, the measurement of direct longwave radiation |
| P14 | LANCONELLI | Christian | ISAC CNR | Status of the Dome-C BSRN station |
| P15 | LUPI | Angelo | ISAC CNR | The new ISAC-MPP automatized spectroradiometer: First results |
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