Twenty Years of WCRP/GEWEX Baseline Surface Radiation Network (BSRN) Activities, Operations, Data, and Results

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(With contributions from more than 70 BSRN Site-Scientists and Associates)

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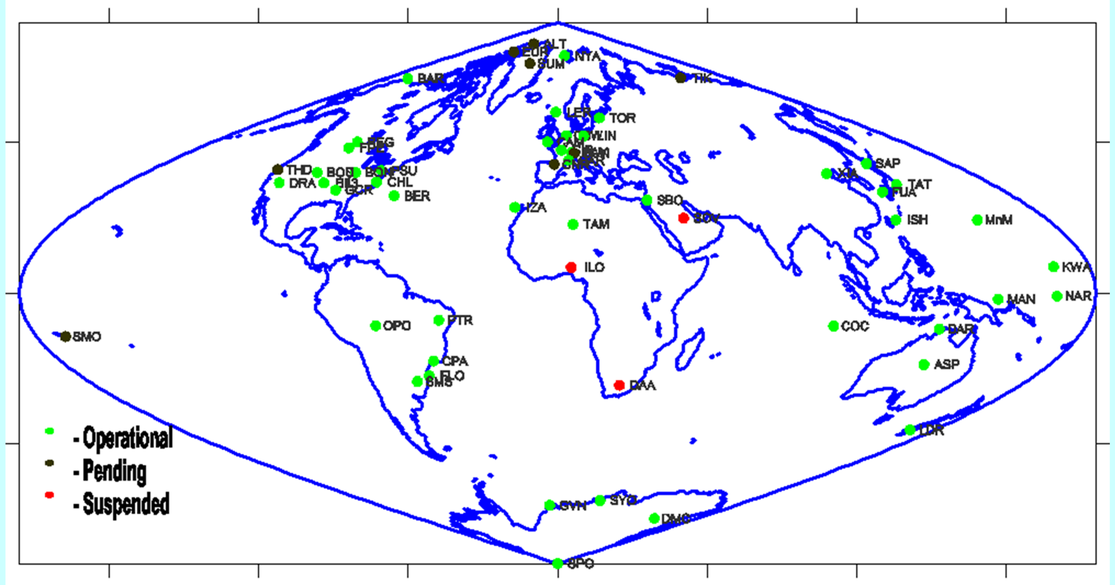
http://www.bsrn.awi.de/ (BSRN archive)

Operations and Network Logistics

Summary Background: The BSRN project was conceived by the WCRP Working Group on Radiative Fluxes in 1988 to address extensive concerns about the overall lack of high-quality, globally-remote and diverse, in-situ, surface irradiance observations. After four years of preparation within WCRP for an on-going continuous observational program, the BSRN began operations in 1992. Nine qualified observing sites submitted solar and infrared surface irradiance data for that year. The program continues today and has grown in size and reach, having now received data from 56 stations and is serving as an affiliated global surface radiation network for multiple additional organizations as indicated by the logos above.

BSRN Station Status, Sept. 2011



BSRN Field Observations

Spectrally integrated irradiances

PRIMARY (required)
- Direct-beam solar
- Diffuse-sky solar
- Downwelling thermal IR
- Total (global) downwelling solar

SECONDARY (but highly recommend)
- Upwelling (reflected) solar
- Upwelling thermal IR

Ancillary (highly desirable)
- Spectral aerosol optical depth
- Surface meteorological variables
- Upper-air soundings (nearby)
- Std. synoptic observations
- Cloud base height

Data Acquisition, Processing and Archival

- BSRN established and provided standardized specifications and recommendations for field data collection.
- Individual Site Scientists are responsible for the acquisition, processing, and quality assurance of the data.
- Irradiances and most other observations are sampled at near 1-hz with 1-minute averages recorded and scaled.
- The scaled data calibrated relative to international calibration reference standards, some developed as a direct result of the needs of BSRN.
- Data are submitted to the central BSRN archive (was at ETHZ , now AWI) for review and distribution.
- The Archive-applied QC has proven to be useful. Nonetheless, users are urged to review the retrieved data for suitability to their applications, and establish contact with the Site Scientist responsible for the data.
- Archived data are typically available with a latency of one month to a few years.

Data Availability and Quality

Below are station-months (by year) of 1- to 3-minute avg. downwelling irradiances available from archive as of 4 Oct 2011 (www.bsrn.awi.de)

Station	Abrev.	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Alice Springs	ASP				12	12	12	12	12	12	11	12	12	12	12	12	12	12			
Barrow	BAR	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	2	
Bermuda	BER	12	12	12	12	12	12	12	12	12	12	12	10	12	12	12	12	12	12	2	
Billings	BIL		4	12	12	12	12	12	12	12	11	12	12	12	12	12	12	12	6		
Boncville	BON				12	12	12	12	12	12	12	12	12	12	12	12	12	12	6		
Boulder, SURFRAD	BOS				5	12	12	12	12	12	12	12	12	12	12	12	12	12	6		
Boulder, BAO	BOU	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	2	
Brasilia	BRB															8	10				
Cabauw	CAB														11	12	12	12	12	12	8
Camborne	CAM										12	12	12	12	12	12	4				
Carpentras	CAR					4	12	12	12	12	12	12	12	12	12	12	12	12	12	12	6
Chesapeake Light	CLH									8	12	11	12	12	12	12	12	12	12	12	8
Cener	CNR																		6	12	8
Cocos Island	COC													3	10	8	12	12			
De Aar	DAA										7	6	12	11	12	1					
Darwin	DAR											10	12	12	12	12	12				
Desert Rock	DRA							10	12	12	12	12	12	12	12	12	12	12	6		
Concordia Station	DOM															12	12	12	12	2	
S. Great Plains	E13			12	7	12	12	12	12	12	12	12	12	12	12	12	12	12	5		
Florianopolis	FLO			6	12	12	10	12	12	9	12	12	12	12							
Fort Peck	FPE				12	12	12	12	12	12	12	12	12	12	12	12	12	12	6		
Fukuoka	FUA																			9	7
Goodwin Creek	GCR				12	12	12	12	12	12	12	12	12	12	12	12	12	12	6		
Neumayer Station	GVN	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	1
Ilorin	ILO	4	12	8	7	12	12	6	12	12	12	7	12	12	7						
Ishigakijima	ISH																			9	7
Izana	IZA																		10	12	8
Kwajalein	KWA	9	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	2	
Lauder	LAU								5	12	12	12	12	12	12	12	12				
Lerwick	LER										12	12	12	12	11	11	4				
Lindenberg	LIN			3	12	12	12	12	12	12	12	12	12	12	12	12					
Momote	MAN					3	12	12	12	12	12	12	12	12	12	12	12	12	6		
Minamitorishima	MNM																			9	7
Nauru Island	NAU							2	12	12	12	12	12	12	12	12	12				
Ny-Ålesund	NYA	5	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	3
Palaiseau Cedex	PAL												7	12	12	12	8				
Payerne	PAY	3	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12		
Rock Springs	PSU							7	12	12	12	12	12	12	12	12	12	12	6		
Petrolina	PTR															1	7				
Regina	REG				12	12	12	12	11	12	12	12	12	12	12	12	9				
Rolim de Moura	RLM																2				
Sapporo	SAP																			9	7
Sede Boqer	SBO															12	12	12	12	12	6
São Martinho da Serra	SMS															9	12	3			
Solar Village	SOV							3	12	12	12	12									
South Pole	SPO	12	12	10	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	2	
Syowa	SYO			12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	3
Sioux Falls	SXF												7	12	12	12	12	12	6		
Tamanrasset	TAM									10	12	12	12	12	12	12	12	12	12	12	5
Tateno	TAT					11	12	12	12	12	12	12	12	12	12	12	12	12	12	12	6
Toravere	TOR								12	12	12	12	12	12	12	12	12	12	12	12	8
Xianghe	XIA															12	12	12	8		
		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011

* Primary reference for the establishment and specifications of BSRN is:
Ohmura et al ., *Bull. Amer . Met. Soc.* , 1998.

** All BSRN solar measurements are based on the WRR calibration scale. Recent indications from the SORCE satellite absolute solar irradiance observations suggest that the WRR scale maybe high by about 0.34%, in which cased all BSRN solar observations would be reduced by 0.34%,or about 0.6 W m^{-2} on a global annual mean.

Accuracy estimates**

BSRN began by assessing WCRP requirements and then identifying commercial instrumentation that was most suitable to achieve the data accuracy goals. The accepted achieved accuracies at the time were considered insufficient, thus requiring development of improved observing methodologies and calibration references.

Original goals*, W m^{-2} :

Total solar	Direct solar	Diffuse solar	Therm. IR
5	2	5	10

These goals turned out to be too optimistic for solar and somewhat conservative for the IR depending on observing conditions. The GEWEX Radiation Panel (GRP) has recently undertaken an extensive assessment of observed irradiance products and will be providing the results in the WCRP/GEWEX Radiative Flux Assessment (RFA, see P. Stackhouse WCRP-OSC2011) The RFA provides extensive review and evaluation of the multiple sources of errors in routine in-situ observations made by the BSRN. The 95% uncertainties in the BSRN downwelling data over multiple time averaging intervals was prepared for the RFA and are presented as summarized below.

Quantity	1-3 min	1 Hr	1 Day	1 month	1 year
SW Direct	±16	±14	±8	±5	±4
SW Diffuse	±14	±13	±8	±5	±4
SW Global	±25	±24	±11	±8	±6
SW Total	±21	±19	±11	±7	±6
LW	±6			±4*	

These uncertainty estimates do no include potential gross errors that can and do occur. Uncertainties for the upwelling quantities were not assessed in the RFA due to the lack of representativeness relative to satellite or modeled values, although the instrumental errors are similar to the downwelling.

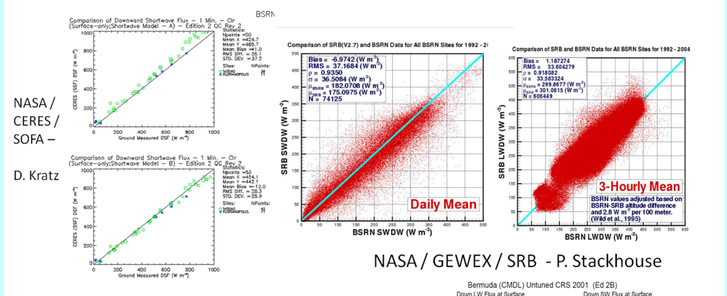
Applications and Results

Example BSRN Data Applications

- Satellite product validation/comparison
- Radiative transfer model comparisons
- Surface energy budget studies
- Local and regional climatologies
- Climate model evaluation
- Various interests, e.g., renewable energy, agriculture, and etc.

Satellite Product Validation and Comparisons

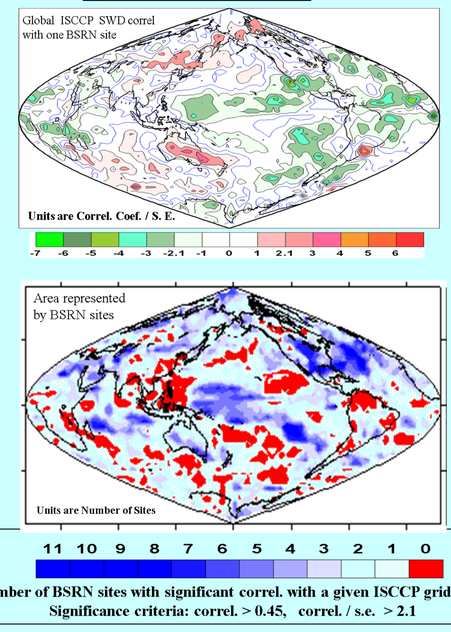
Satellite Surface Irradiance Validated vs BSRN Data



NASA / GEWEX / SRB - P. Stackhouse

Above are examples of comparisons between satellite surface irradiance products and BSRN observations as indicated.

Spatial correlations

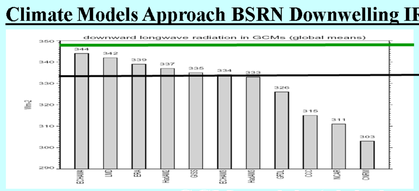


Number of BSRN sites with significant correl. with a given ISCCP grid point
Significance criteria: correl. > 0.45, correl. / s.e. > 2.1

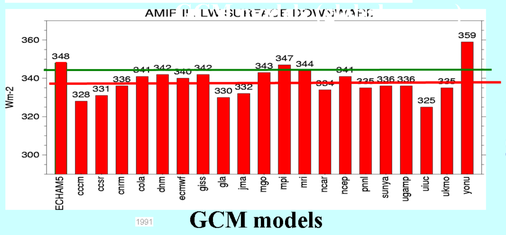
The above two figures show the annual spatial correlations, 1986 – 2003, of individual BSRN sites downward surface solar irradiance (SWD) with the ISCCP/FD data for the globe. The top figure gives the cross correlation coefficient divided by its standard error for Barrow, Alaska, Dutton et al., JGR 2006. The second figure shows the number of ISCCP grid cells containing BSRN sites (out of the 35 as of 2005) that have significant cross-correlation with the ISCCP SWD at that grid point.

Climate Model comparisons

Climate Models Approach BSRN Downwelling IR Results (global means)



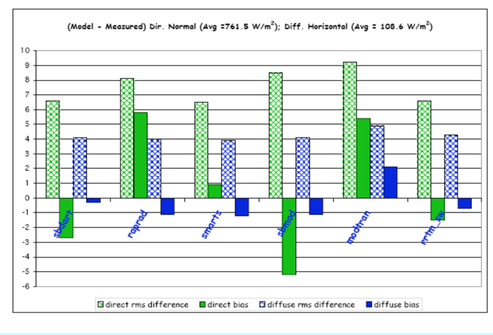
Circa 1998



Circa 2006

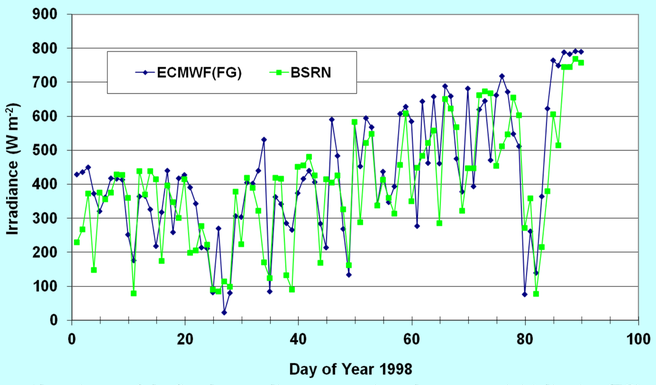
The above two graphs show global mean downwelling surface IR irradiance from numerous GCMs as indicated. The top plot shows results for the models from the mid 1990s whereas on the bottom plot are results about a decade later with the differences due to model changes and improvements. The green horizontal line is the global mean value deduced from BSRN data from site-by-site comparisons to a GCM, M. Wild, *J. Clim.* 2001 & *Tellus* 2008.

Radiative transfer model studies



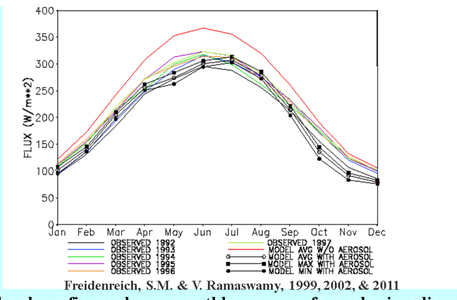
The above shows the biases (solid color) and RMS (cross-hatch) differences between various model calculations (as indicated) and observations for a multi-day period where the observed atmospheric states and composition were incorporated into the models. Michalsky et al. 2005.

Comparison of GCM (ECMWF) and BSRN Radiation Obs.
Bermuda Daily Solar Radiation (18Z -- 00Z)



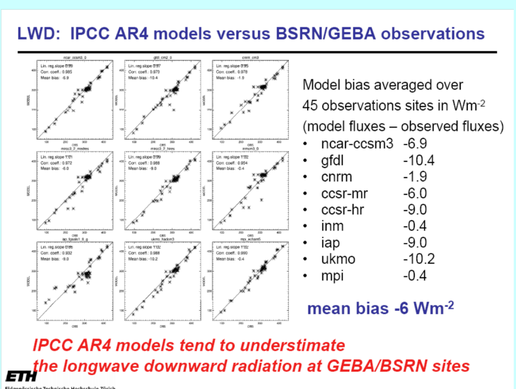
Above is one of the first known direct comparisons between an initialization (FG) of a global cloud-resolving GCM and BSRN-observed surface solar irradiance. Daily averages are for a single daily 6-hour period, 18Z-00Z. ECMWF results provided by J.J. Morcrette

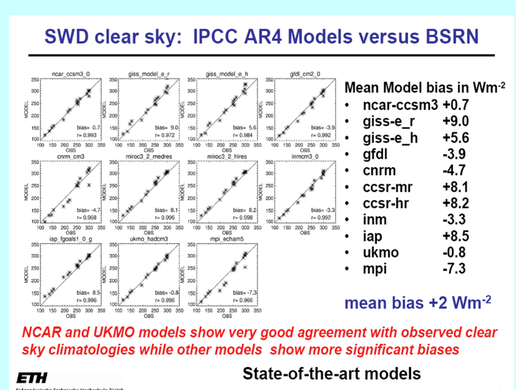
Comparison between NOAA/GFDL GCM and BSRN downwelling solar (shows aerosol effects in the model)



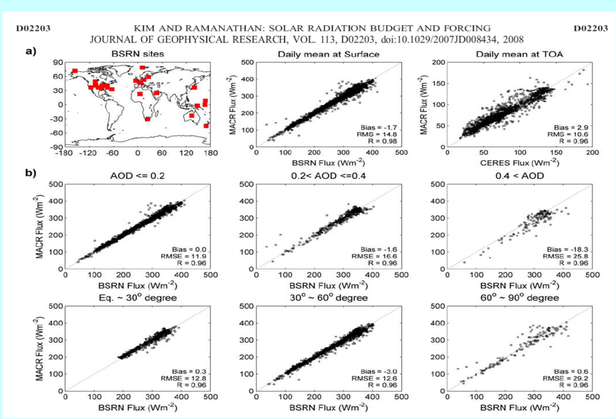
Freidenreich, S.M. & V. Ramaswamy, 1999, 2002, & 2011

The above figure shows monthly mean surface solar irradiances modeled by a NOAA/GFDLGCM for various aerosol loadings and BSRN observations over several years for a site near Boulder, Colorado. This work was begun as GFDL was first introducing aerosols to their GCM.





The above two panels give model-by-model comparisons, scatter plots and mean bias, between several IPCC-AR4 GCM models and BSRN observations at 44 BSRN sites and corresponding model grid boxes, M. Wild, *Tellus* 2008.



To the right is an extended comparison between a Monte Carlo Aerosol-Cloud Radiation Model, Kim & Ramanathan (2008). Shown are the sites used and the scatter diagrams for daily total solar, a), as well as comparisons for different aerosol optical depths (Aeronet) and latitude ranges, b).

References and bibliography:

See: www.bsrn.awi.de/en/other/publications/ for a reasonably complete list of 123 publications and reports.