WCRP REPORT
World Climate Research Programme

GCOS
GLOBAL CLIMATE OBSERVING SYSTEM

Baseline Surface Radiation Network (BSRN)

Update of the Technical Plan for BSRN Data Management

October 2013

GCOS – 174
WCRP – 24/2013

Chairperson, Publications Board
World Meteorological Organization (WMO)
7 bis, avenue de la Paix
P.O. Box 2300
CH-1211 Geneva 2, Switzerland

Tel.: +41 (0) 22 730 84 03
Fax: +41 (0) 22 730 80 40
E-mail: Publications@wmo.int

Foreword

The Earth's radiation budget is essential for driving the general circulation of the atmosphere and ocean, and for building the main conditions for the Earth's climate system. To detect changes in the Earth's surface radiation field the Baseline Surface Radiation Network (BSRN) and its central archive - the World Radiation Monitoring Center (WRMC) - was created in 1992.

BSRN is a project of the Radiation Panel (now the Data and Assessment Panel) from the Global Energy and Water Cycle Experiment (GEWEX) under the umbrella of the World Climate Research Programme (WCRP). It is the global baseline network for surface radiation for the Global Climate Observing System (GCOS), contributing to the Global Atmospheric Watch (GAW), and forming a cooperative network with the Network for the Detection of Atmospheric Composition Change (NDACC).

The data are of primary importance in supporting the validation and confirmation of satellite and computer model estimates. At a relatively small number of stations (currently 58) in contrasting climatic zones, solar and atmospheric radiation is measured with instruments of the highest available accuracy and with high temporal resolution (mainly 1 minute). A total of about 7000 station-month datasets were available in the WRMC in mid 2013. All data are interactively accessible to external users for bona fide research purposes at no cost.

This report provides information for scientists interested in high quality surface radiation data as well as for scientists running a BSRN station. It offers information about the available data, the data access and describes tools to visualize the data and to check their quality.

(Intentionally Blank)

The Baseline Surface Radiation Network and its World Radiation Monitoring Centre at the Alfred Wegener Institute

Gert König-Langlo[1], Rainer Sieger[1], Holger Schmithüsen[1], Amelie Bücker[1], Friedrich Richter[1], and Ellsworth. G. Dutton[2] †

[1] {Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany}
[2] {NOAA/Global Monitoring Division, Boulder, Colorado, USA}

Correspondence to: G. König-Langlo (Gert.Koenig-Langlo@awi.de)

Table of Contents

1. Introduction

The Earth’s radiation budget is essential for determining the thermal structure of the atmosphere, for driving the general circulation of the atmosphere and ocean, and for building the main conditions for the Earth's climate system. Because the Earth's surface transforms more than 50% of the solar radiation that is absorbed by the planet (Wild et al. 2013), the irradiances at the Earth's surface are especially important for understanding the climate processes. These irradiances also play an important role in the ocean surface energy budget and thus influence the main features of the ocean currents.

A small change in irradiance at the Earth's surface could result in a significant change in climate (Chylek et al. 2007). However, many of the older existing radiometric networks were not capable of arriving at the required accuracy for climate research. At present, our knowledge about the spatial distribution of the radiation is not sufficient for understanding the present climate. This makes the simulation of the past and future climate changes, which could be caused by the changes in radiation, even more uncertain. To help overcome these shortcomings, the radiometric network BSRN was launched in 1992 by WCRP to support the research projects of the WCRP and other scientific programs.

In contrast to the World Radiation Data Center WRDC (http://wrdc-mgo.nrel.gov/), and the Global Energy Balance Archive GEBA (Gilgen et al. 1999), which archive long-time averaged radiation fluxes from more than a thousand sites associated with national weather services, the BSRN/WRMC consists only of a small number of selected research stations, which provide typically 1-minute averaged short- and long-wave surface radiation fluxes of the best possible quality currently available. The surface radiation fluxes are high sampling-rate observations selected from stations within different climate zones of the globe, where collocated surface and upper air meteorological data and other supporting observations are also available. Throughout the BSRN network, the measurements are time-continuous and can be used to:

- monitor the background of the short- and long-wave radiative components as well as changes using the best methods currently available
- provide datasets for validation and evaluation of satellite-based measurements of surface radiative fluxes
- produce high-quality observational datasets for the evaluation of climate model results and for the development of local radiation climatologies

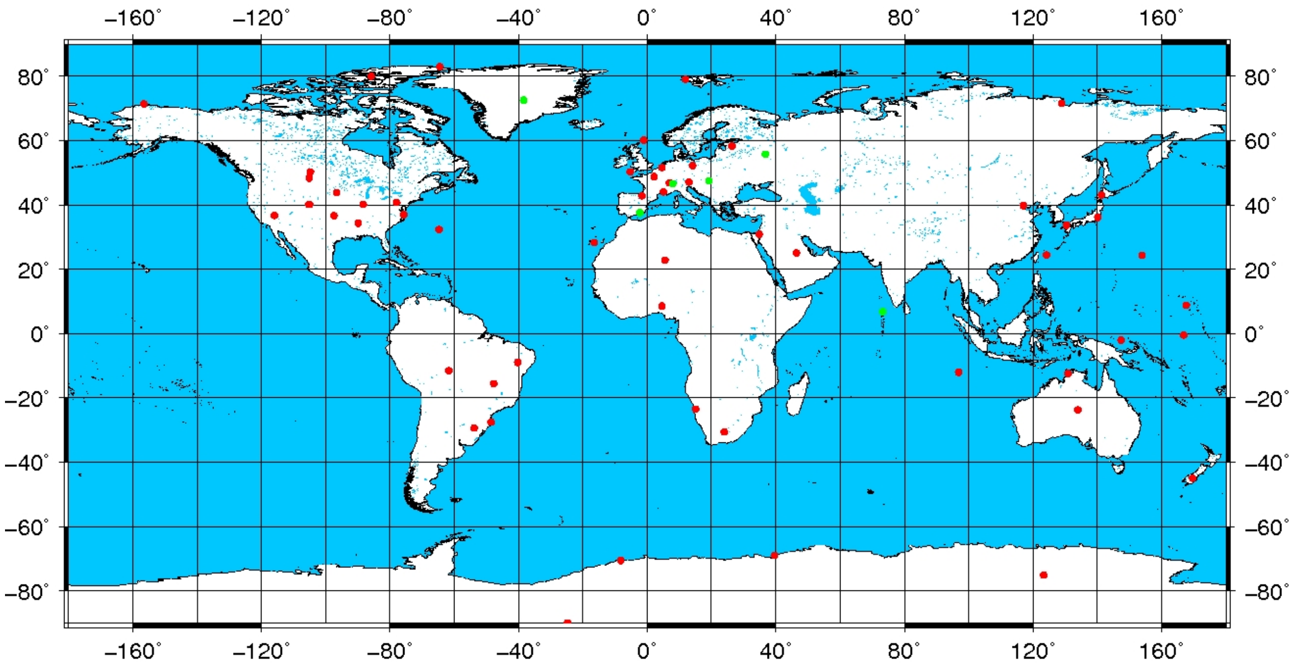


Fig. 1. Active BSRN stations (red) and candidates (green) mid 2013.

The BSRN operations manual (McArthur 2005) offers detailed information on how these BSRN measurements should be made. All the qualified BSRN measurements are centrally archived in the WRMC, which was founded in 1992 at ETH Zurich, Switzerland. In 2008 the WRMC was moved to the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI), Bremerhaven, Germany (http://www.bsrn.awi.de/).

This paper provides information for scientists running a BSRN station and customers of the WRMC. It offers information about the available data, the data access and describes tools to visualize the data and to check their quality. The paper is partly based on papers by Gilgen et al. (1995) and Hegner et al. (1998). For more general information about the BSRN, see Ohmura et al. (1998).

2. Current state of the WRMC

As of mid 2013, 58 BSRN stations have submitted data to the WRMC (Fig. 1). The data import is organized in so-called station-to-archive files, which contain all the data from one station collected during one month. Currently a total of over 7000 station-month datasets from 58 stations are available in the WRMC, although only 9 stations have delivered their data back to 1992. The measurements from BSRN stations are expected to be submitted to the WRMC with no more than about one year delay, however, the most recent data from some stations are being submitted with much longer delays (for an overview of available surface radiation data see http://www.pangaea.de/PHP/BSRN_Status.php?q=LR0100). The utility and desirability of the BSRN data is enhanced when submitted in the timeliest manner, after all quality checks have been made by the station scientists. Several stations are currently submitting their data within one month of collection.

The WRMC archives many parameters observed at the BSRN stations. Because the stations provide different parameters, the station-to-archive files are organized in logical records (LR) according to various groups of measurements. An overview of all supported LRs and the comprising parameters is given in Table 1. The mandatory parameters are included in the logical record LR 0100; these are global, direct, diffuse, downward long-wave radiation, air temperature, relative humidity, and air pressure at instrument height. Other parameters like the upward radiation fluxes and ancillary data such as upper-air soundings and basic meteorological observations are optional.

Logical Record	Stations	Months
LR 0100: (Global, Diffuse, Direct, Long-wave down)	58	7294
LR 0300: (Short-wave up, Long-wave up, net radiation)	11	1905
LR 0500: (UV)	14	1613
LR 1000: (Synoptic observations)	13	1731
LR 1100: (Upper air soundings)	29	3699
LR 1200: (Total ozone)	9	1447
LR 1300: (Ceilometer data)	3	614
LR 3010: (Radiation measurements from 10 m height)	10	1568
LR 3030: (Radiation measurements from 30 m height)	2	259
LR 3300: (Radiation measurements from 300 m height)	1	218

Table 1. The datasets available in the WRMC mid 2013

3. Data input

BSRN stations need to meet several basic requirements. The most important requirement is a long-term involvement of an expert in surface radiation measurements for each measurement site, who is designated as the BSRN station scientist. The BSRN station scientists are responsible for the data quality of their station. All the BSRN station scientists are instructed to readily provide acquired data to the WRMC in a timely manner.

3.1 Producing station-to-archive files

Each BSRN station scientist is responsible creating his own station-to-archive files. Since this process differs significantly from station to station, no special software is offered to create these files. In case help is needed, please contact other station scientists to share ideas, programs, etc.

The format of the station-to-archive files is given in the Appendix Tables A1-A7. A single station-to-archive file is a quite complex ASCII-file. It normally contains many datasets and a variety of metadata necessary for the data interpretation. All BSRN-stations and radiation instruments used in the network are assigned to a WRMC identification number. Please contact the WRMC in case you need new identification numbers.

It is recommended to produce the files in a UNIX environment. This will guarantee that the end-of-line character of the files will automatically be correct (just LF). Files produced in a Windows environment frequently use CR/LF as end-of-line character. These kinds of files are not accepted within the WRMC. They must be converted to UNIX-like files prior to the submission to the WRMC (e.g. using special editors or tools like dos2unix).

3.2 Checking and compressing station-to-archive files

As soon as a station-to-archive file is ready to get submitted to the WRMC the station scientist is strongly recommended to check the correct format of his file using e.g. the program f_check.c provided at: http://www.bsrn.awi.de/en/software/. The program checks for the right station name, line length, illegal characters and several logical record specific line formats. After the compilation of this c-program on the local computer of the station scientist the executable f_check must be started with a station-to-archive file name as input parameter. A well-formatted station-to-archive file will produce the following output:

```
f_check stammyy.dat

File name: stammyy.dat
**********
*Check for line length.......... OK
*Check for illegal characters... OK
*Check for line format.......... OK
```

In all other cases f_check will output a detailed error description. Alternatively, this format-check can be performed using the BSRN-Toolbox, see Chapter 5, which additionally offers the BSRN recommended quality checks V2.0 (Long et al. 2002), see Chapter 6.

To save disk space and to reduce data transmission time all files in the WRMC are compressed (**.gz,* GNU zip). Thus, it is strongly recommended to compress station-to-archive files prior to their submission. In a UNIX environment you may use the free software: http://www.gnu.org/software/gzip/. In a Windows environment you may use the free software: http://7-zip.org/.

3.3 Submitting station-to-archive files

Checked and compressed station-to-archive files must be sent to the ftp-server ftp.bsrn.awi.de from the WRMC. The ftp-server offers a public part with read permission to all station-to-archive file from all station for anybody who accepted the BSRN data release guidelines. The ftp-server also has a private area with read and write permission accounts reserved to the individual station scientists. This means that any station scientist has 2 different accounts for using the ftp-server ftp.bsrn.awi.de. The individual account with write permission must be used to submit new checked and compressed station-to-archive files. Station scientists from new BSRN-stations must contact the WRMC in order to get their individual account.

Many suitable ftp-tools are available. For Windows you may use the free software: http://filezilla-project.org/.Compressed files need to be transferred in binary mode. Make sure that your ftp-tool is using the binary mode and not ASCII mode.

No one except the station scientist and the staff of the WRMC has access to the private parts of the ftp-server. After a station-to-archive file is successfully submitted the WRMC the data curators of the WRMC are notified automatically and will perform additional checks. If these checks fail, the data curators will contact the station scientists for clarification. Otherwise, they will move the file into the public part of the ftp-server, import all data into PANGAEA and send a short e-mail to the station scientists that the submission was successful.

4. Data output

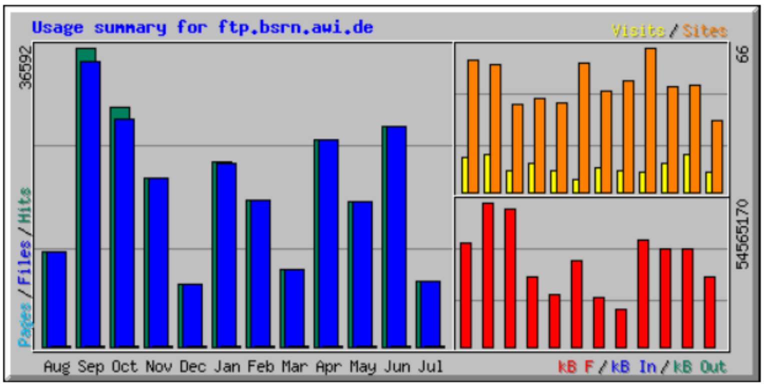
Each individual station-to-archive file contains all the data from one station for one month. All files are named as *stammyy.dat,* with *sta* = station abbreviation (see Table A2 or “event label” in the station listing at http://www.bsrn.awi.de/en/stations) for a list of all contributing stations), *mm* = month (01-12), and *yy* = year (last two digits).

The data in the station-to-archive files are averages, maxima, minima, and standard deviations computed over a time interval. The recommended time interval of the radiation data is one minute. However, longer intervals were accepted in the early phase of the program. All time labels in the station-to-archive files denote the start of a time interval.

4.1. Data output via the ftp-server: ftp.bsrn.awi.de

All station-to-archive files are read-accessible to 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 (http://www.bsrn.awi.de/). Station scientists should note that their individual write accounts for data submission cannot be used as read account.

After logging into ftp://ftp.bsrn.awi.de/ via a read account, the user will be automatically directed into the public part of the server (/pub), which contains one directory for each station, named according to the unique three-letter station abbreviation (see Table A2 or "event label" in the station listing at http://www.bsrn.awi.de/en/stations). These directories contain the original station-to-archive files as submitted by the station scientists. The users who intend to retrieve multiple station-to-archive files or the whole ftp archive may use ftp tools that support wild cards such as ? and *. Approximately 10000 station-to-archive files get downloaded from the archive per month (Fig. 2).



Summary by Month												
Month	Daily Avg				Monthly Totals							
	Hits	Files	Pages	Visits	Sites	kB F	kB In	kB Out	Visits	Pages	Files	Hits
Jul 2013	256	256	0	0	33	26379139	0	0	9	9	7943	7952
Jun 2013	898	897	0	0	49	36760087	0	0	17	25	26937	26951
May 2013	573	572	0	0	48	36771498	0	0	13	20	17735	17790
Apr 2013	846	846	0	0	66	40368445	0	0	9	9	25384	25407
Mar 2013	327	326	0	0	51	14261197	0	0	10	13	9482	9485
Feb 2013	638	638	0	0	46	18809536	0	0	11	14	17878	17880
Jan 2013	778	776	0	0	59	32834236	0	0	6	7	22511	22582
Dec 2012	275	275	0	0	41	19566856	0	0	10	13	7705	7710
Nov 2012	690	689	0	0	43	26311969	0	0	13	15	20682	20710
Oct 2012	947	898	0	0	40	52262398	0	0	10	13	27843	29367
Sep 2012	1219	1160	1	0	58	54565170	0	0	17	36	34808	36592
Aug 2012	373	372	0	0	60	39349498	0	0	16	21	11552	11567
Totals						398240027	0	0	141	195	230460	233993

Fig. 2. Usage statistics for ftp.bsrn.awi.de mid 2013.

4.2 Data output via the PANGAEA search engine

An alternative to ftp access is data access via PANGAEA – Data Publisher for Earth & Environmental Science (http://www.pangaea.de/). The information system PANGAEA is operated as an Open Access library that is used for archiving, publishing, and distributing geo-referenced data from Earth system research. The main features of PANGAEA are as follows:

- PANGAEA offers a Google-like interface for searching and distributing data
- each dataset from PANGAEA has a bibliographic citation including a Digital Object Identifier (DOI)
- PANGAEA metadata are searchable e.g. by Google (high ranking)
- PANGAEA provides free software for any PANGAEA derived datasets

Although a single WRMC dataset can be found by using search engines like Google, PANGAEA, etc., the most direct access is given via pre-compiled PANGAEA search phrases (http://www.bsrn.awi.de/en/data/data_retrieval_via_pangaea/). As an example, Fig. 3 presents the lower part of a list with links to pre-compiled PANGAEA search phrases that lead to all datasets offering data from the logical record LR0100 (http://www.pangaea.de/PHP/BSRN_Status.php?q=LR0100). The numbers given in the table represent the quantity of available monthly-granulated datasets. The lowermost row gives access to comparable tables for other logical records and station information. An “X” in the rightmost column leads to all datasets of a station. An “X” in the bottom row leads to all datasets of a selected year. The “X” in the lower right corner selects all datasets.

Firefox | Baseline Surface Radiation Network - Sta... | www.pangaea.de/PHP/BSRN_Status.php?q=LR0100 | Google

Florianopolis	FLO	Sergio Colle (colle@emc.ufsc.br)				6	12	12	10	12	12	9	12	12	12	12	12									X
Fort Peck	FPE	John Augustine (John.A.Augustine@noaa.gov)					12	12	12	12	12	12	12	12	12	12	12	12	12	12	6					X
Fukuoka	FUA	Hiroshi Tatsumi (h-tatumi@met.kishou.go.jp)																				9	12	12	5	X
Goodwin Creek	GCR	John Augustine (John.A.Augustine@noaa.gov)					12	12	12	12	12	12	12	12	12	12	12	12	12	12	6					X
Gobabeb	GOB	Roland Vogt (roland.vogt@unibas.ch)																						8	6	X
Neumayer Station	GVN	Gert König-Langlo (Gert.Koenig-Langlo@awi.de)	121	9	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	1	X
Ilorin	ILO	T O Aro		4	12	8	7	12	12	6	12	12	12	7	12	12	7									X
Ishigakijima	ISH	Hiroshi Tatsumi (h-tatumi@met.kishou.go.jp)																				9	12	12	5	X
Izana	IZA	Emilio Cuevas-Agulló (ecuevasa@aemet.es)																			10	12	12	12	7	X
Kwajalein	KWA	David Longenecker (David.U.Longenecker@noaa.gov)		9	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	2				X
Lauder	LAU	Bruce Forgan (B.Forgan@bom.gov.au)									5	12	12	12	12	12	12	12	12	12	11	12	12	12	3	X
Lerwick	LER	Patrick Fishwick (patrick.fishwick@metoffice.com)											12	12	12	12	11	11	4							X
Lindenberg	LIN	Klaus Behrens (Klaus.Behrens@dwd.de)				3	12	12	12	12	12	12	12	12	12	12	12	12	2							X
Momote	MAN	Charles Long (chuck.long@pnl.gov)						3	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	3		X
Minamitorishima	MNM	Hiroshi Tatsumi (h-tatumi@met.kishou.go.jp)																				9	12	12	5	X
Nauru Island	NAU	Charles Long (chuck.long@pnl.gov)								2	12	12	12	12	12	12	12	12	12	12						X
Ny-Ålesund	NYA	Marion Maturilli (Marion.Maturilli@awi.de)		5	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	9		X
Palaiseau	PAL	Martial Haeffelin (martial.haeffelin@lmd.polytechnique.fr)													7	12	12	12	8							X
Payerne	PAY	Laurent Vuilleumier (laurent.vuilleumier@meteoswiss.ch)		3	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	5			X
Rock Springs	PSU	John Augustine (John.A.Augustine@noaa.gov)								7	12	12	12	12	12	12	12	12	12	12	6					X
Petrolina	PTR	Enio Bueno Pereira (eniobp@cptec.inpe.br)																1	7	4	12	12	12	1		X
Regina	REG	David Halliwell (David.Halliwell@ec.gc.ca)					12	12	12	12	11	12	12	12	12	12	12	12	12	12	12	12	12			X
Rolim de Moura	RLM	Enio Bueno Pereira (eniobp@cptec.inpe.br)																	2							X
Sapporo	SAP	Hiroshi Tatsumi (h-tatumi@met.kishou.go.jp)																				9	12	12	5	X
Sede Boqer	SBO	Vera Lyubansky (veralub@ims.gov.il)													12	12	12	12	12	12	12	12	12	9		X
São Martinho da Serra	SMS	Enio Bueno Pereira (eniobp@cptec.inpe.br)																9	12	7	12	12	12	5		X
Sonnblick	SON	Marc Olefs (marc.olefs@zamg.ac.at)																							3	X
Solar Village	SOV	Naif Al-Abbadi (nabbadi@kacst.edu.sa)								3	12	12	12	12												X
South Pole	SPO	David Longenecker (David.U.Longenecker@noaa.gov)		12	12	10	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	5	X
Syowa	SYO	Koji Kawashima (antarctic@met.kishou.go.jp)				12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	1		X
Sioux Falls	SXF	John Augustine (John.A.Augustine@noaa.gov)													7	12	12	12	12	12	6					X
Tamanrasset	TAM	Mohamed Mimouni (m_mimouni_dz@yahoo.fr)										10	12	12	12	12	12	12	12	12	12	12	12	12	5	X
Tateno	TAT	Osamu Ijima (ijima@met.kishou.go.jp)						11	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	5	X
Tiksi	TIK	Vasilii Kustov (kustov@aari.ru)																				7	9	12	5	X
Toravere	TOR	Ain Kallis (kallis@aai.ee)									12	12	12	12	12	12	12	12	12	12	12	12	12	12	6	X
Xianghe	XIA	Xiangao Xia (xiangaoxia2000@yahoo.com)															12	12	12	12	12	12				X
Historical station	Eismitte		1																							X
	All			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
			pre BSRN	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**All**

[BSRN homepage] - [Staff | Stations | Parameter | Methods] - [**LR0100** | LR0300 | LR0500 | LR1000 | LR1100 | LR1200 | LR1300 | LR3010 | LR3030 | LR3300 | All | latest datasets]

Fig. 3. The lower part of a list of the BSRN stations and the numbers of the submitted monthly LR0100 datasets per year taken mid 2013. The numbers are links to precompiled PANGAEA search phrases to access the data via the PANGAEA search engine. The lowermost row gives access to comparable tables for other logical records and station information. An “X” in the rightmost column leads to all datasets of a station. An “X” in the bottom row leads to all datasets of a selected year. The “X” in the lower right corner selects to all datasets (http://www.pangaea.de/PHP/BSRN_Status.php?q=LR0100).

Following a link to such a pre-compiled PANGAEA search phrase will open the PANGAEA search engine and present the search results to the user. An example of such a search result is given in Fig. 4, which is a list containing links to the actual datasets. If desired, the search phrase can be manually altered. By selecting the option “Advanced Search”, individual search queries can be generated very specifically. The green button “Show Map” leads to a map showing the location of all selected stations. An example of one dataset is given in Fig. 5. All metadata are shown. Within the metadata, a link to the corresponding station-to-archive file in the ftp-archive is also presented. Several PANGAEA download options of the measurements are offered at the bottom of the metadata page.

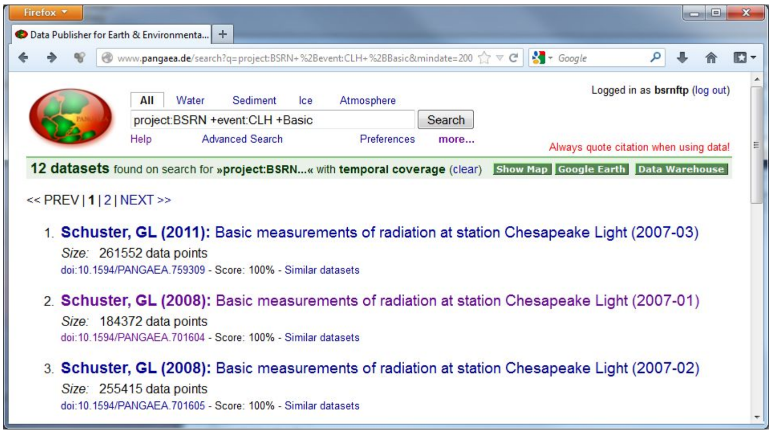


Fig. 4. An example of a query as a result of the PANGAEA search engine. The list contains links to the metadata as well as to the measurements. The green button “Show Map” leads to a map showing the location of all selected stations.

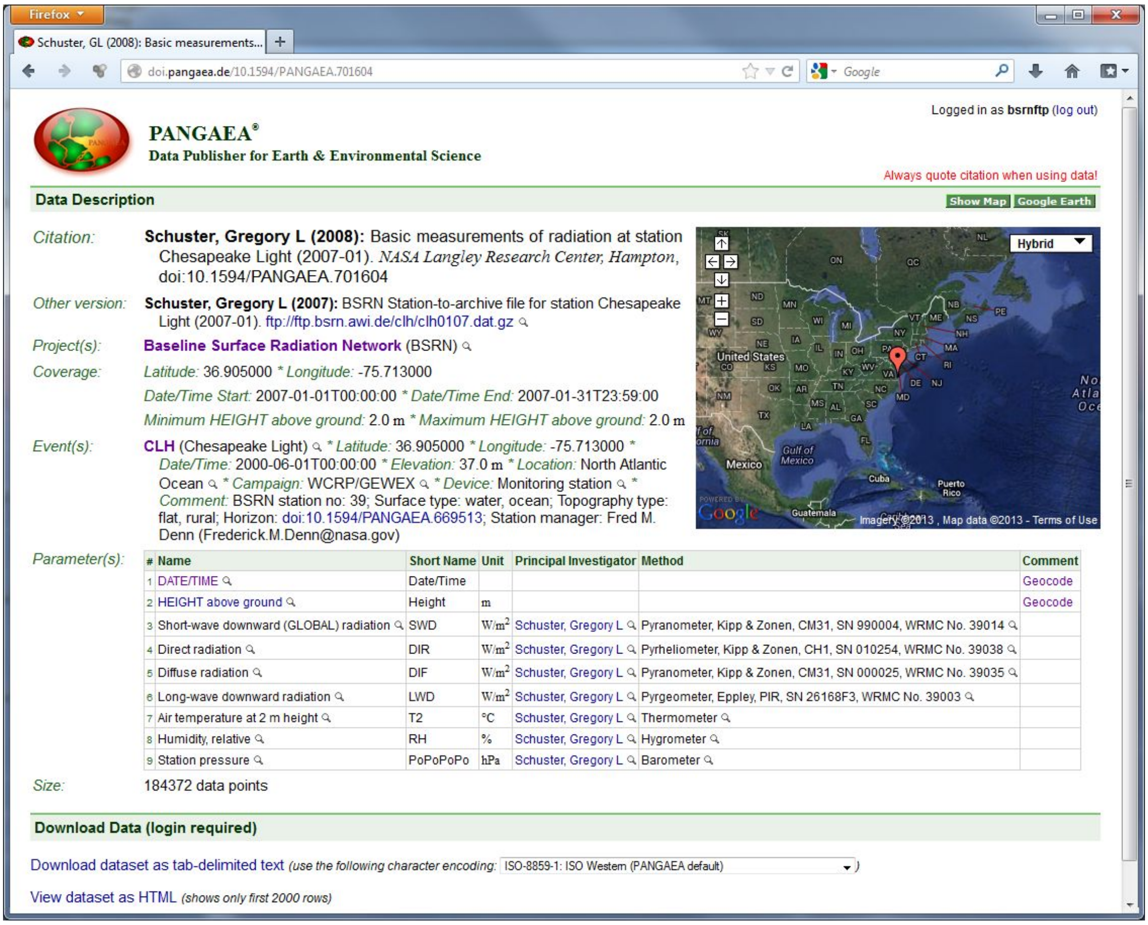


Fig. 5. An example of the metadata of the PANGAEA retrieved dataset http://dx.doi.org/10.1594/PANGAEA.701604. Several download options of the measurements are offered in the last rows.

The download is password restricted. A read account for the data of all stations can be obtained by contacting the WRMC staff (http://www.bsrn.awi.de/). It is valid for ftp as well as PANGAEA access.
Each file downloaded from PANGAEA is a text file which includes all metadata in the file header and a tab-delimited table. The files can be read using any text editor or spreadsheet program. Several format converters are offered in the program Pan2Applic (Sieger et al. 2005). Additional programs tailored to datasets exported from PANGAEA are described in the following chapters.

4.3 Data output via the PANGAEA "Data Warehouse"

All datasets are provided in monthly granularity and at the original time resolution. In case longer time series, simple averages, subsets of offered parameters, or joint datasets from different stations are needed, the so-called "Data Warehouse" is recommended. The "Data Warehouse" is offered only for logged in users (see the right green button in Fig. 4). Once selected, the "Data Warehouse" will present a list of all parameters contained in the search results of the PANGAEA search engine (see Fig. 6).

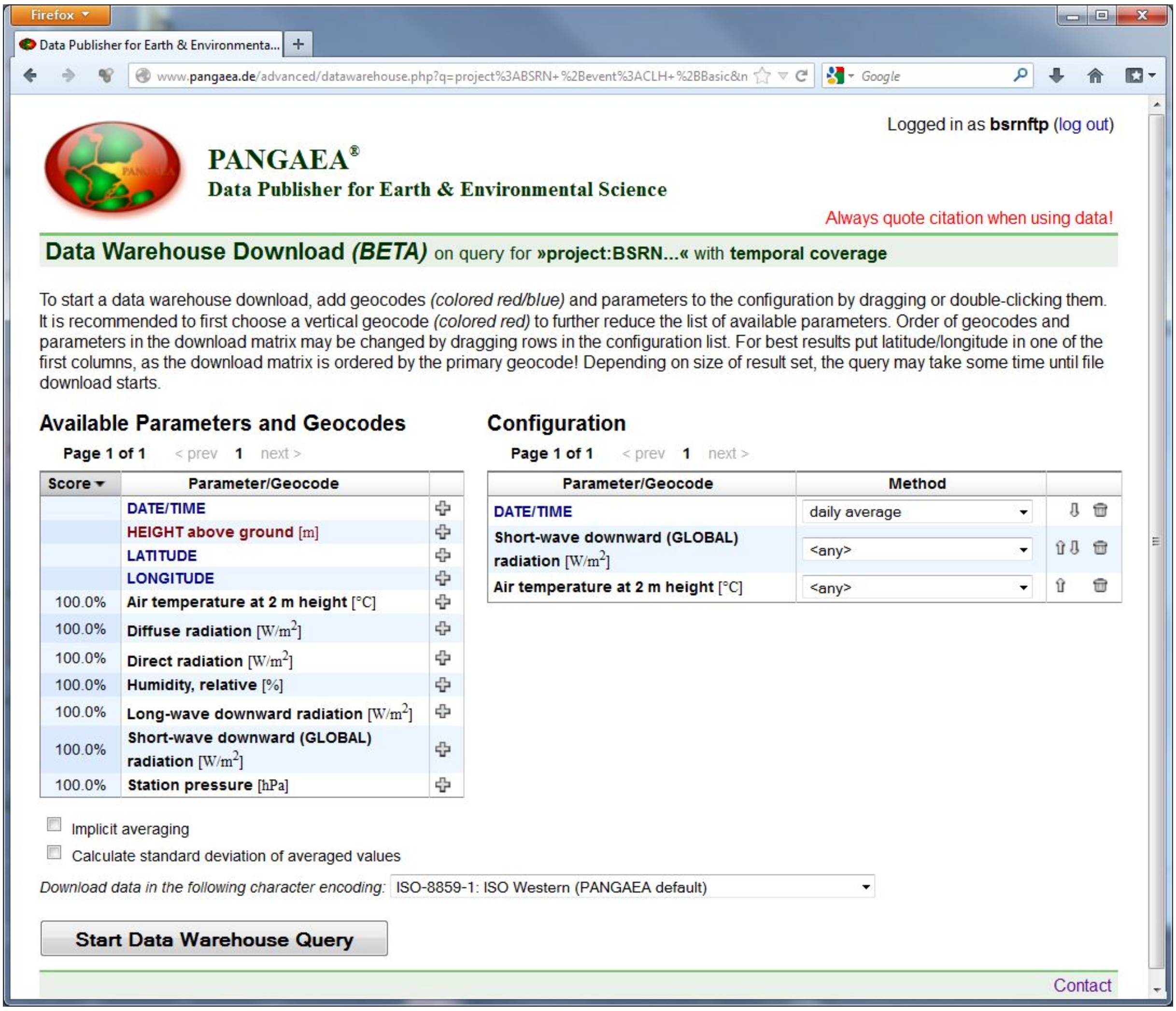


Fig. 6. An example of "Data Warehouse" managing the search results of Fig. 4, where the daily averages of the global radiation and the air temperature for 2007-01 to 2007-12 from the BSRN station Chesapeake Light will be retrieved.

The "Data Warehouse" provides optional simple data averaging (hourly, daily, monthly, and yearly). Most parameters are displayed with a score that shows the percentage of availability of a parameter within the search engine's results. When a "Data Warehouse" query is started, the data will be automatically downloaded as a tab delimited file on the user's computer. Table 2 shows an example. In the output files, there are columns of the selected parameters and links to the origin of the data. The character "ø" is added to averages calculated by the "Data Warehouse".

Date/Time	SWD [W/m^2]	T2 [°C]	Origin of Values
2007-01-01	ø47	ø14.732	http://doi.pangaea.de/10.1594/PANGAEA.701604
2007-01-02	ø134	ø10.744	http://doi.pangaea.de/10.1594/PANGAEA.701604
2007-01-03	ø134	ø10.378	http://doi.pangaea.de/10.1594/PANGAEA.701604
2007-01-04	ø108	ø14.256	http://doi.pangaea.de/10.1594/PANGAEA.701604
2007-01-16	ø16	ø13.971	http://doi.pangaea.de/10.1594/PANGAEA.701604
2007-01-17	ø147	ø1.921	http://doi.pangaea.de/10.1594/PANGAEA.701604
2007-01-18	ø30	ø5.524	http://doi.pangaea.de/10.1594/PANGAEA.701604
2007-01-19	ø125	ø7.665	http://doi.pangaea.de/10.1594/PANGAEA.701604
2007-01-20	ø138	ø4.486	http://doi.pangaea.de/10.1594/PANGAEA.701604
...	...	...	...

Table 2. The result of the "Data Warehouse" query of Fig. 6. Averaged values are marked with the flag "ø"

4.4 Offline data output via a "Local WRMC" on a DVD

A snapshot of the whole content of the WRMC is created about once a year (see http://www.bsrn.awi.de/en/data/data_retrieval_via_pangaea/off_line_access/). This snapshot can be downloaded as an ISO image and burned on DVDs to retrieve BSRN data offline. The snapshot offers all the datasets submitted to the archive up to the date when the snapshot was created. Data submitted or modified on and after the day when the snapshot was created can only be accessed online.

5. Visualization software

Special visualization software useful for any PANGAEA derived radiation/meteorological data file is provided at http://www.pangaea.de/software/. All software is licensed under the General Public License (GPL) and therefore free of charge. Time series can easily be visualized with PanPlot2. For vectorized datasets, such as upper air soundings, Ocean Data View (ODV) is recommended. Station-to archive files can be converted with the BSRN-Toolbox (see Chapter 5) to be used as input files for PanPlot2 and ODV.

5.1 PanPlot2

PanPlot2 (Sieger et al. 2013) enables Windows, Linux as well as Mac OS X users to plot data versus time or space in multivariable graphs. The easiest way to visualize a PANGAEA derived data file is to drag the file icon on the PanPlot2 icon. The default settings of PanPlot2 will display the data immediately. PanPlot2 is a useful tool for data browsing. Fig. 7 gives an example. Users can easily modify the default scales and graphic features. PanPlot2 graphs can be exported as BMP, PDF, PNG, and SVG files.

5.2 Ocean Data View

Ocean Data View (ODV) is a software package for the interactive exploration, analysis and visualization of oceanographic and other geo-referenced profiles or sequence data. ODV runs on Windows, Mac OS X, Linux, and UNIX (Solaris, Irix, AIX) systems. ODV data and configuration files are platform-independent and can be exchanged between different systems.

The ODV software is under development by Prof. Dr. Reiner Schlitzer and can be downloaded free of charge at http://odv.awi.de. Although the development of OVD is aimed at handling oceanographic data, it is also very useful for any other 2-dimensional (e.g. upper air soundings) and 3-dimensional datasets (e.g., time series of upper air soundings). A brief introduction can be found at:
http://www.bsrn.awi.de/en/software/ocean_data_view_r_schlitzer/ .

6. BSRN-Toolbox

The BSRN-Toolbox was primarily developed to be used by the staff of the WRMC to create PANGAEA import files from the rather clumsy station-to-archive files. The BSRN-Toolbox includes a download manager for the ftp-server ftp.bsrn.awi.de, a decompressor, and format checker. It handles single as well as multiple files. Thus, also large amounts of data from one or multiple stations can be executed. The BSRN-Toolbox can be used to extract metadata as well as distinct logical records. Furthermore, it offers tools to convert and compress files.

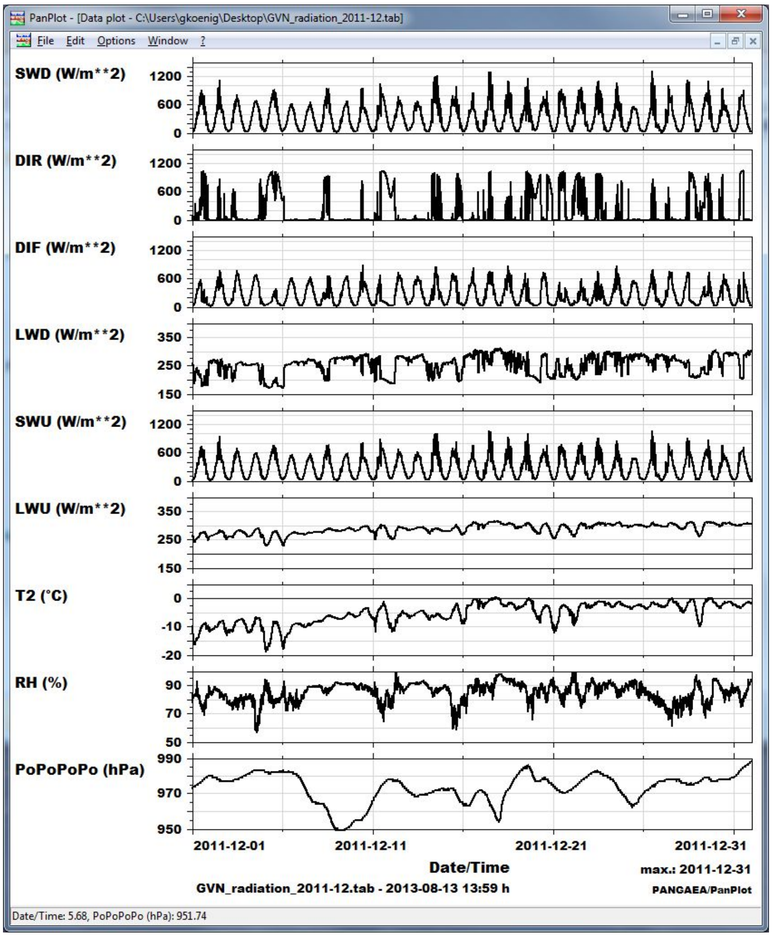


Fig. 7. An example (http://doi.pangaea.de/10.1594/PANGAEA.783623) of a time series produced with PanPlot2.

Meanwhile, the BSRN-Toolbox is used more and more by station scientists to test the quality of their station-to-archive files prior to submission. Furthermore, customers of the WRMC use the BSRN-Toolbox to convert files from the ftp-archive into the more readable PANGAEA-like dataset tables. These files can be opened using any text editor, spreadsheet programs like Microsoft Excel, OpenOffice Calc or can be visualized with PanPlot2.

The most recent version of the BSRN-Toolbox (Schmithüsen et al. 2012) is available free of charge for Windows, Mac OS X, and Linux. It also contains code to check the quality of BSRN data. More information about the BSRN-Toolbox can be found at http://wiki.pangaea.de/wiki/BSRN_Toolbox.

7. Quality control

Data submitted to the WRMC runs through an incoming inspection, which includes format checks, visualizations, and the BSRN recommended quality checks V2.0 (Long et al. 2002). Some of the resultant quality codes of these quality checks are displayed at http://www.bsrn.awi.de/en/products/quality_code/. Files with detected errors are not imported into the archive but are returned to the submitter. Although these procedures ensure the basic integrity of the data set, it is incumbent on all scientists to do their individual quality checks relevant to their application after extracting BSRN-data.

However the WRMC does not remove or replace bad data points, only identifies them wherever it is possible. It is the responsibility of the station scientist to make the final determination of the content of the archive and the responsibility of the archive user to determine whether the data quality of extracted BSRN-data fulfill their demands.

7.1 History of quality control

At ETH Zurich, a central flagging of the data quality was performed. The quality control was made by fixed limits, following the rules published from Gilgen et al. (1995) and Hegner et al. (1998). The flags and the derived global radiation (calculated from direct and diffuse) were included in the station-to-archive files. It was up to the user to follow or to disregard these static flags.

During the transition of the WRMC from ETH Zurich to the AWI (end of 2007) the central flagging of the data quality was terminated. Nowadays, all station-to-archive files in the WRMC have exactly their native format as submitted by the station scientists, who are responsible for the quality of their submitted data.

The quality checks which are now offered by the WRMC at the AWI, are implemented as a flexible post process, which can be adapted to the individual demands of a variety of users with different aims. A strict separation between data and quality code is now realized.

7.2 Quality control via BSRN-Toolbox

The quality of many BSRN data can be checked individually by the BSRN Toolbox version 2.0 (Schmithüsen et al. 2012) or higher. The tool is rather flexible; it handles several input formats:

- station-to-archive files created by a station scientists prior to submission
- station-to-archive files downloaded from the public ftp-archive
- files directly downloaded from PANGAEA
- files downloaded using PANGAEA's "Data Warehouse" (for longer time series)

The quality checks of the BSRN Toolbox offer numerous output datasets, including quality codes and cleaned data. Output files are text files, with the format following that featured by PANGAEA. The original input files are not altered. The quality checks from the BSRN Toolbox can assist:

- the station scientists to test station-to-archive files before they get submitted
- the data curator from the WRMC before archiving submitted data (this gets done routinely since December 2011)
- any customer of the WRMC using data extracted from the WRMC

Currently, the BSRN Toolbox offers the "BSRN Global Network recommended quality check tests, V2.0" (Long et al. 2002). In the future, more quality check options will be developed and implemented. These will include individually adjustable limits to meet the different requirements of the customers and to take into account the characteristics of different instrument types as well as local specialties of the different stations.

7.3 Quality checks recommended for station scientists and data users

Since the station scientists are responsible for the quality of their data, it should be in their own interest to check their data prior to submission to exclude any error and to optimize the data quality. Errors, which are detected after submission to the WRMC, will result in extra work for the archive as well as for the station scientists and should thus be avoided. In general, all data customers of the WRMC are encouraged to do their individual quality checks after exporting data.

The first recommended check is a visual check of the time series plots. By doing this, the outliers (wrong default values, etc.) are usually found immediately. Station-to-archive files can be reformatted by using the BSRN Toolbox (Schmithüsen et al. 2012), which generates output e.g. for PanPlot2 (Sieger et al. 2013) to obtain time series plots like Fig. 7. PANGAEA output files can be directly used in PanPlot2. It is expected that this visual check will be performed by all station scientists before data submission.

Further quality checks are recommended following "BSRN Global Network recommended quality check tests, V2.0" (Long et al. 2002). Again, the BSRN Toolbox (Schmithüsen et al. 2012) is recommended for station scientists as well as for data customers. These tests prove whether the data:

- exceed physically possible limits
- exceed extremely rare limits
- compare to each other

Occasionally, correct measurements exceed the physically possible limits because of severe refraction processes, multiple reflections between broken clouds and bright surfaces, inversions, night-time offsets, temperature jumps, etc. Therefore, the results of all these tests need to be confirmed by visual inspection of the data.

An automatic replacement of the data exceeding the test limits could result in a loss of realistic measurements and is thus not recommended. False data points resulting from a wrongly pointing solar tracker, hoar frost deposition, malfunction of a sensor, etc. are normally replaced with “missing values” (defined in Table A1) by the station scientists prior to submission.

7.4 Error handling in the archive

Any user who finds questionable data should inform the WRMC staff (http://www.bsrn.awi.de/) about the problem; thereby the data can be double checked. If necessary, the WRMC staff contacts the corresponding station scientists and asks to resubmit corrected data carrying a higher version number. The corrected files will then replace the erroneous versions in the ftp-archive. However, a version history is not offered! Also in PANGAEA, only the latest version is available. The DOI-numbers from old versions are kept but redirected to the newest version carrying a different DOI-number.
If the corrected or verified data cannot be submitted from the station scientist to the WRMC within a reasonable period of time, the questionable data will be deleted in PANGAEA. A warning, or restriction, will also be placed in the corresponding station directory of the ftp-archive.

8. Summary

The BSRN/WRMC has provided climate researchers with surface radiation data since 1992. In contrast to the WRDC and GEBA, which archive long-time averaged radiation fluxes from more than a thousand sites associated with national weather services, the BSRN/WRMC consists only of a small number of selected research stations which provide, typically, 1-minute averaged short- and long-wave surface radiation fluxes of the best possible quality currently available.

BSRN is a GEWEX project under the WCRP and as such is aimed at detecting important changes in the Earth's radiation field at the Earth's surface, which may be related to climate changes. BSRN is designated as the global surface radiation network for the GCOS and contributes to the GAW. Since 2011, BSRN and the NDACC have reached a formal agreement to become cooperative networks.

More than 7000 station-month datasets collected from 58 stations covering a latitudinal range from 80°N to 90°S are interactively available at the WRMC in mid 2013 to external users for bona fide research purposes at no cost.

9. Acknowledgements

Special thanks go to all station scientists who provide their data to the BSRN of the highest possible quality free of charge (see http://www.pangaea.de/ddi?request=bsrn/BSRNStaff&format=html&title=BSRN+Staff), and also to the staff at the BSRN stations for their careful maintenance work. Without the help of Chresten Wübber from the AWI Computing and Data Centre and Wolfgang Cohrs from the AWI Polar Meteorology group, the ftp.bsrn.awi.de server would not run. Michael Diepenbroek and Uwe Schindler from MARUM developed and maintain the PANGAEA information system, which brought the WRMC a big step forward. Thanks also to Ana Macario and Dennis Steinhoff from the AWI Computing and Data Centre who set up the BSRN web-server. Last but not least many thanks go to Atsumu Ohmura and his group at ETH Zurich who initiated the WRMC and ran it until 2007.

10. References

Chylek P., U. Lohmann, M. Dubey, M. Mishchenko, R. Kahn, and A. Ohmura, 2007: Limits on climate sensitivity derived from recent satellite and surface observations. JGR, VOL. 112, D24S04, doi:10.1029/2007JD008740.

Gilgen H., C. Whitlock, F. Koch, G. Müller, A. Ohmura, D. Steiger, and R. Wheeler, 1995: Technical plan for BSRN (Baseline Surface Radiation Network) data management, Version 2.1. WMO/TD-No. 443, WCRP/WMO.

Gilgen, H., and A. Ohmura, 1999: The Global Energy Balance Archive. Bull. Amer. Meteor. Soc., 80, 831–850, doi:10.1175/1520-0477(1999)080<0831:TGEBA>2.0.CO;2.

Hegner H., G. Müller, V. Nespor, A. Ohmura, R. Steigrad, and H. Gilgen, 1998: Technical Plan for BSRN Data Management - 1998 Update.
WMO/TD-No. 882, WCRP/WMO, http://hdl.handle.net/10013/epic.39581.d001.

Long, C. N., and E. G. Dutton, 2002: BSRN Global Network recommended QC tests, V2.0. http://hdl.handle.net/10013/epic.38770.d001.

McArthur L. J. B., 2005: Baseline Surface Radiation Network (BSRN). Operations Manual. Version 2.1. WCRP-121, WMO/TD-No. 1274, http://hdl.handle.net/10013/epic.39582.d001.

Ohmura, A. , E. Dutton, B. Forgan, C. Fröhlich , H. Gilgen, H. Hegner, A. Heimo, G. König-Langlo, B. Mcarthur, G. Müller, R. Philipona, R. Pinker, C. H. Whitlock, and M. Wild, 1998: Baseline Surface Radiation Network (BSRN/WRMC), a new precision radiometry for climate research. Bull. Amer. Meteor. Soc., 79, 2115 – 2136, doi:10.1175/1520-0477(1998)079<2115:BSRNBW>2.0.CO;2.

Schmithüsen, H., R. Sieger, and G. König-Langlo, 2012: BSRN Toolbox - a tool to create quality checked output files from BSRN datasets and station-to-archive files. Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, doi:10.1594/PANGAEA.774827.

Sieger, R., and H. Grobe, 2005: Pan2Applic - a tool to convert and compile PANGAEA output files. Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, doi:10.1594/PANGAEA.288115.

Sieger, R., and H. Grobe, 2013: PanPlot 2 - software to visualize profiles and time series. Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, doi:10.1594/PANGAEA.816201.

Wild, M., D. Folini, C. Schär, N. Loeb, E. G. Dutton, and G. König-Langlo, 2013: The global energy balance from a surface perspective. Climate Dynamics, Volume 40, Issue 11-12, pp 3107-3134, doi:10.1007/s00382-012-1569-8.

Annex: Station-to-archive file format description

To avoid conflicts with files already submitted to the ftp archive, the format of the station-to-archive file was changed only insignificantly with respect to the pervious Technical Plan for BSRN Data Management from Hegner et al., 1998 (http://hdl.handle.net/10013/epic.39581.d001). Only minor inconsistencies have been corrected. From the logical record 1300 all information concerning spectral aerosol optical depth has been excluded since it has never been used before. The logical records 4000 and 4nnn were added in order to archive also pyrgeometer temperatures at ground level and nnn meters height above ground.

A single station-to-archive file contains all data from one month and one station. All files are named *stammyy.dat* with *sta* = station abbreviation, see Table A2, but written in small letters, *mm* = month (01-12) and *yy* = year (last two numbers). All station-to-archive files are ASCII coded, see Table A1. The length of the lines in the files is less than or equal to 80 characters. The end-of-line character of the files is LF.

The lines in the file are grouped in logical records. The logical records are headed by a line beginning with *C9999 or *U9999, where 9999 is the logical record number. The second character of the logical record header line is C if data in the logical record has been changed compared to the previous month, U if there are no changes. For the metadata logical record, numbers below 99 are used; for the atmospheric data the logical record 100 is obligatory. All optional logical records carry higher numbers. General messages and information not to be inserted in the BSRN database are given in the logical record 3.

The identification numbers of the quantities measured, of the topography and the surface types, of the stations, and the pyrgeometer compensation codes are given in Tables A3 – A7. The identification numbers of the radiation instruments are assigned by the WRMC. For new numbers please contact the WRMC (http://www.bsrn.awi.de/). The numbers are unique in the BSRN.

The first line of most metadata logical records and of the instrument sub-records contains the date when any change as compared to the previous accumulation period occurred. This date is the start of the period, for which the values given in the following fields of the record apply. The missing value code (-1) indicating that no change has occurred is mandatory if the logical record is flagged as unchanged in the record header line.

The file format also contains flags indicating whether the SYNOP and special surface observations of the extended measurement program (see Table A1, logical record 0007) are operated. There is also an operated/not-operated flag for every radiation instrument (see Table A1, logical record 0008, line 1). These flags are used for recording gaps in the measurement and/or changes of the instruments.

Table A1. BSRN station-to-archive file format.

All logical records are compulsory definitions. The file is identified by the station id no., the year and the month in logical record 0001. The dates of change in logical records 0002, 0004, 0005, 0006, 0007, 0008, and 0009 are given by day, hour, and minute with ranges 1... 31, 0... 23, and 0... 59. The dates of measurement in logical records 0100, 0200, ... are given by day and minute with ranges 1... 31 and 0... 1439 also for quantities measured in hour intervals

Logical record	Line no.	Description of field / format of line	Range of values	Missing code	Format
0001	1	station identification number	1 - 99		I2
		http://www.bsrn.awi.de/en/stations/listings /			
	1	month of measurement	1 - 12		I2
	1	year of measurement	>= 1992		I4
	1	version of data	1 - 99		I2
	1	(X,I2,X,I2,X,I4,X,I2)			
	2	id. no. of 1st, 2nd, ... quantity measured	Table A3		I9
	et seq.	(8(X,I9)); missing values -1 to fill up line	Table A3		
		as many lines as needed			
0002	1	date when scientist changed (day, hour, min.)	0 - 59	-1	3(X,I2)
scientist	2	name of station scientist			A38
	2	telephone no. of station scientist			A20
	3	FAX no. of station scientist			A20
	3	(A38,X,A20,X,A20)			
	3	TCP/IP no.		XXX	A15
	3	e-mail address		XXX	A50
	3	(A15,X,A50)			
	4	address of station scientists			(A80)
	5	date when deputy changed (day, hour, min.)	0 - 59	-1	3(X,I2)
	6	name of station deputy			A38
	6	Telephone no. of station deputy			A20
	6	FAX no. of station deputy			A20
	6	(A38,X,A20,X,A20)			
	7	TCP/IP no. of deputy		XXX	A15
	7	e-mail address of deputy		XXX	A50
	7	(A15,X,A50)			
	8	address of deputy			A80
0003	1	messages not to be inserted in		XXX	A80
	et seq.	the BSRN database		XXX	A80
0004	1	date when station description changed. (day, hour, min.)	0 - 59	-1	3(X,I2)
station	2	surface type	Table A4		I2
descr.	2	topography type	Table A5		I2
horizon	2	(X,I2,X,I2)			
	3	address (A80)			
	4	telephone no. of station		XXX	A20
	4	FAX no. of station		XXX	A20
	4	(A20,X,A20)			
	5	TCP/IP no. of station		XXX	A15
	5	e-mail address of station		XXX	A50
	5	(A15,XA50)			
	6	latitude [degrees, 0 is Southpole, positive is northward]	0 - 179		F7.3
	6	longitude [degrees, 0 is 180 W, positive is eastwards]	0 - 359		F7.3
	6	altitude [m above sea level]			I4
	6	identification of "SYNOP" station		XXXXX	A5
	6	(2(X,F7.3),X,I4,X,A5)			
	7	date when horizon changed. (day, hour, min.)	0 - 59	-1	3(X,I2)
	8	azimuth [degrees from north clockwise]	0 - 359	-1	I3
	et seq.	elevation [degrees]	0 - 89	-1	I2
		(11(X,I3,X,I2)); as many lines with 11 pairs			
		to give horizon, last line filled up with -1			

Table A1. BSRN station-to-archive file format continued.

Logical record	Line no.	Description of field / format of line	Range of values	Missing code	Format of v./l.
0005	1	date when change occurred (day, hour, min.)	0 - 59	-1	3(X,I2)
radiosonde	1	is radiosonde operating?	Y, N		AI
equipment	1	(3(X,I2),X,A1)			
	2	manufacturer			A30
	2	location			A25
	2	distance from radiation site [km]			I3
	2	time of 1st launch [h UTC]	0 - 23	-1	I2
	2	time of 2nd launch [h UTC]	0 - 23	-1	I2
	2	time of 3rd launch [h UTC]	0 - 23	-1	I2
	2	time of 4th launch [h UTC]	0 - 23	-1	I2
	2	identification of radiosonde			A5
	2	(A30,X,A25,X,I3,4(X,I2),X,A5)			
	3	remarks about radiosonde		XXX	A80
0006	1	date when change occurred (day, hour, min.)	0 - 59	-1	3(X,I2)
ozone m.	1	are ozone measurements operated?	Y, N		AI
equipment	1	(3(X,I2),X,A1)			
	2	manufacturer			A30
	2	location			A25
	2	distance from radiation site [km]			I3
	2	identification number of ozone instrument			A5
	2	(A30,X,A25,X,I3,X,I5)			
	3	remarks about ozone measurements		XXX	A80
0007	1	date when change occurred (day, hour, min.)	0 - 59	-1	3(X,I2)
station	2	method est. cloud amount (digital proc.)		XXX	A80
history	3	method est. cloud base height (with instrument)		XXX	A80
	4	method est. cloud liquid water content		XXX	A80
	5	method est. cloud aerosol vertical distribution		XXX	A80
	6	method est. water vapour press. v.d. (A80)		XXX	A80
	7	6 flags indicating if the SYNOP and/or the corresponding quantities of the expanded	Y, N		AI
	7	programme, are measured (A1,X,A1,X,A1,X,A1,X,A1,X,A1)			
0008	1	date when change occurred (day, hour, min.)	0 - 59	-1	3(X,I2)
radiation	1	is instrument measuring	Y, N		AI
instruments	1	(3(X,I2),X,A1)			
	2	manufacturer			A30
	2	model			A15
	2	serial number			A18
	2	date of purchase [MM/DD/YY]		XXX	A8
	2	identification number assigned by the WRMC			I5
	2	(A30,X,A15,X,A18,X,A8,X,I5)			
	3	remarks about the radiation istrument		XXX	A80
	4	pyrgeometer body compensation code	Table A6	-1	I2
	4	pyrgeometer dome compensation code	Table A7	-1	Î2
	4	wavelength of band 1of spectral i. [micron]		-1.000	F7.3
	4	bandwidth of band 1of spectral i. [micron]		-1.000	F7.3
	4	wavelength of band 2		-1.000	F7.3
	4	bandwidth of band 2		-1.000	F7.3
	4	wavelength of band 3		-1.000	F7.3
	4	bandwidth of band 3		-1.000	F7.3
	4	max. ┐ zenith angle [degree] of direct	0 - 90	-1	I2
	4	min. ┘ (spectral) instrument	0 - 90	-1	I2
	4	(2(X,I2),6(X,F7.3),2(X,I2))			
	5	location of calibration			A30
	5	person doing calibration			A40
	5	(A30,X,A40)			

Table A1. BSRN station-to-archive file format continued.

Logical record	Line no.	Description of field / format of line	Range values	Missing code	Format of v./l.
	6	start of calibration period (band 1 of spectr. instr.)			A8
	6	end of ... (both [MM/DD/YY])			A8
	6	number of comparisons (band 1 of spectr. instr.)		-1	I2
	6	mean calibration coefficient (band 1 of spectr. instr.)			F12.4
	6	standard error of cal. coeff. (band 1 of spectr. instr.)		-1.0000	F12.4
	6	(A8,X,A8,X,I2,2(X,F12.4))			
	7	start of calibration period band 2 of spectr. instr.		XXX	A8
	7	end of ... (both [MM/DD/YY])		XXX	A8
	7	number of comparisons band 2 of spectr. instr.		-1	I2
	7	mean calibration coefficient band 2 of spectr. instr.		-1.0000	F12.4
	7	standard error of cal. coeff. band 2 of spectr. instr.		-1.0000	F12.4
	7	(A8,X,A8,X,I2,2(X,F12.4))			
	8	start of calibration period band 3 of spectr. instr.		XXX	A8
	8	end of ... (both [MM/DD/YY])		XXX	A8
	8	number of comparisons band 3 of spectr. instr.		-1	I2
	8	mean calibration coefficient band 3 of spectr. instr.		-1.0000	F12.4
	8	standard error of cal. coeff. band 3 of spectr. instr		-1.0000	F12.4
	8	(A8,X,A8,X,I2,2(X,F12.4))			
	9	remarks on calibration, e.g. units of cal. coeff.		XXX	A80
	10	remarks on calibration (continued)		XXX	A80
	11	date when change occurred	0 - 59	-1	3(X,I2)
	11	…			
		Every radiation instr. at the station is described by 10 lines in the format given above (radiation subrecord)			
0009	1	date when change occurred (day, hour, min.)	0 - 59	-1	3(X,I2)
assignment	1	id. no. of radiation quantity measured			I9
of radiation	1	id. no. of instrument which measured quantity			I5
quantities	1	no. of band (for spectral instruments)		-1	I2
to	1	(3(X,I2),X,I9,X,I5,X,I2)			
instruments	2	date when change occurred (day, hour, min.)	0 - 59	-1	I2

	2	as many lines to list all quantities together with the instruments; e.g.,
		` 1  0  0        101   21013  1`
		` 1  0  0        102   21013  2.`
		` 1  0  0        103   21013  3`
		` 1  0  0          3   21005 -1`
		` 1  0  0          4   21006 -1`
		`15  0  0          3   21007 -1`
		The above lines mean that (i) the short-wave spectral fluxes at bands 1, 2 and 3 are measured with instrument 21013, bands 1, 2, 3, (ii) the direct radiation is measured with instrument 21005 from the 1st day of the month until the 14th day of the month, with instrument 21007 since the 15th day of the month, and (iii) the diffuse radiation is measured with instrument 21006. Legal quantity id. nos. are listed in Tab A3, legal instrument id. nos. are assigned to the instruments at the BSRN stations by the WRMC. If an instrument measures more than one quantity, lines with the same instrument id. no. and the same date, but with different quantity id. nos. are repeated. However, repeating lines with the same date and the same quantity id. no. is not allowed.
		`< 1  0  0          1   21005 -1      not   allowed  >`
		`< 1  0  0          1   21006 -1      not   allowed  >`			

Table A1. BSRN station-to-archive file format continued.

Logical record	Line no.	Description of field / format of line	Range of values	Missing code	Format of v./l.
0100	1	date [day]	1 - 31		I2
basic	1	time [minute]	0 - 1439		I4
meas.	1	global 2 (mean, std. dev., min., max.: columns 12 - 31)		-999 or	I4 or
	1	direct (mean, std. dev., min., max.: columns 35 - 54)		-99.9	F5.1
	2	diffuse (mean, std. dev., min., max.: columns 12-31)			
	2	downward long-wave radiation			
		(mean, std. dev., min., max.: columns 35 - 54)			
	2	air temperature at downward long-wave instrument height		-99.9	F5.1
	2	relative humidity at downward long-wave instrument height		-99.9	F5.1
	2	pressure at downward long-wave instrument height		-999	I4
		(X,I2,X,I4,2(3X,I4,X,F5.1,X,I4,X,I4),/			
		8X,2(3X,I4,X,F5.1,X,I4,X,I4),4X,F5.1,X,F5.1,X,I4)			
	3	date [day]	1 - 31		I2
	3	…			
		2 lines for each time measured			
0200	1	date [day]	1 - 31		I2
expanded	1	time [minute]	0 - 1439		I4
measurem.	1	downward short-wave spectr. at wavel. 1		-999 or	I4 or
	1	(mean, std. dev., min., max.: columns 12 - 31)		-99.9	F5.1
	1	...at wavel. 2 (mean, std. dev., min., max.: col. 35 - 54)			
	1	...at wavel. 3 (mean, std. dev., min., max.: col. 58 - 77)			
		(X,I2,X,I4,3(3X,I4,X,F5.1,X,I4,X,I4))			
	2	…			
		1 line for each time measured			
0300	1	date [day]	1 - 31		I2
other	1	time [minute]	0 - 1439		I4
measurem.	1	upward short-wave reflected		-999 or	I4 or
in		(mean, std. dev., min., max.: columns 12 - 31)		-99.9	F5.1
minutes	1	upward long-wave			
intervals		(mean, std. dev., min., max.: columns 35 - 54)			
	1	net radiation (net radiometer)			
		(mean, std. dev., min., max.: columns 58 - 77)			
	1	(X,I2,X,I4,3(3X,I4,X,F5.1,X,I4,X,I4)			
	2				
		…			
		1 line for each time measured			
0400	1	date [day]	1 - 31		I2
special	1	time [minute]	0 - 1439		I4
spectral	1	downward short-wave spectr. at wavel. 4		-999 or	I4 or
measurem.	1	(mean, std. dev., min., max.: columns 12 - 31)		-99.9	F5.1
	1	...at wavel. 5 (mean, std. dev., min., max.: col. 35 - 54)			
	1	...at wavel. 6 (mean, std. dev., min., max.: col. 58 - 77)			
	2	...at wavel. 7 (mean, std. dev., min., max.: col. 12 - 31)			
	2	...at wavel. 8 (mean, std. dev., min., max.: col. 35 - 54)			
	2	...at wavel. 9 (mean, std. dev., min., max.: col. 58 - 77)			
	3	...at wavel. 10 (mean, std. dev., min., max.: col. 12 - 31)			
	3	...at wavel. 11 (mean, std. dev., min., max.: col. 35 - 54)			
	3	...at wavel. 12 (mean, std. dev., min., max.: col. 58 - 77)			
		(X,I2,X,I4,3(3X,I4,X,F5.1,X,I4,X,I4)/			
		2(8X,3(3X,I4,X,F5.1,X,I4,X,I4)/))			
	4	…			
		3 lines for each time measured			

Table A1. BSRN station-to-archive file format continued.

Logical record	Line no.	Description of field / format of line	Range of values	Missing code	Format of v./l.
0500	1	date [day]	1 - 31		I2
ultra-violet	1	time [minute]	0 - 1439		I4
measurem.	1	uv-a global (mean, std. dev., min., max.: columns 10 - 32)		-99.9	F5.1
	1	uv-b direct (mean, std. dev., min., max.: columns 34 - 56)			
	2	uv-b global (mean, std. dev., min., max.: columns 10 - 32)			
	2	uv-b diffuse (mean, std. dev., min., max.: columns 34 - 56)			
	2	uv-b-reflected			
		(mean, std. dev., min., max.: columns 58 - 80)			
		(X,I2,X,I4,4(X,F5.1),4(X,F5.1),/			
		8X,4(X,F5.1),4(X,F5.1),4(X,F5.1)			
	3	date [day]	1 - 31		I2
	3	…			
		2 lines for each time measured			
1000	1	YYGG9 IIiii Nddff 1SnTTT 2SnTdTdTd 3P0P0P0			<A80
surface		4PPPP 7wwWlWl 8NhClCmCh			
SYNOP		333 8NsChshsh 8NsChshsh 8NsChshsh			
		as many lines as needed in format (A80)			
		The code is part of FM 12–XII Ext. SYNOP report of surface observation from a fixed land station. NsChshsh can be coded up to 3 times. All other groups are compulsory.			
		…			
		Example:			
		`01039 10393 82407 10091 20076 30018 40144 71000 80006 333 85273`			
		`01049 10393 82506 10088 20077 30018 40144 7//// 80007`			
		Alternative codes are welcome but stored only as ACSII-strings.			
1100	1	date [day]	1 - 31		I2
radiosonde	1	time [minute]	0 - 1439		I4
measurem.	1	level number (first level = 1)	1 - 9999		I4
in launch	1	pressure at level		-999	I4
intervals	1	height at level			I5
	1	temperature		-99.9	F5.1
	1	dew point		-999.9	F6.1
	1	wind direction, azimuth	0 - 359	-99	I3
	1	wind speed		-99	I3
	1	ozone concentration		-9.9	F4.1
	1	(X,I2,X,I4,3X,I4,X,I4,X,I5,X,F5.1,X,F6.1,X,I3,X,I3,X,F4.1)			
	2	date [day]	1 - 31		I2
	2	…			
		1 line for each level measured			
1200	1	date [day]	1 - 31		I2
ozone	1	time [minute]	0 - 1439		I4
measurem.	1	total ozone amount		-999	I4
in hours	1	(X,I2,X,I4,3X,I4)			
intervals	2	date [day]	1-31		I2
	2	…			
		1 line for each time measured			
1300	1	date [day]	1 - 31		I2
expanded	1	time [minute]	0 - 1439		I4
measurem.	1	total cloud amount with instrument		-9	I2
in hours	1	cloud base height with instrument in m			
		(no clouds 99999)		-9999	I5
intervals	1	cloud liquid water in mm		-99.9	F5.1
1st part	1	(X,I2,X,I4,3X,I2,X,I5,X,F5.1)		-	
	2	date [day]	1 - 31		I2
	2	…			
		1 line for each time measured			

Table A1. BSRN station-to-archive file format continued.

Logical record	Line no.	Description of field / format of line	Range of values	Missing code	Format of v./l.
1500	1	date [day]	1 - 31		I2
other	1	time [minute]	0 - 1439		I4
measurem	1	thermal spectral at wavelength 1		-9	I4
.					
in hours	1	thermal spectral at wavelength 2		-9	I4
intervals	1	thermal spectral at wavelength 3		-9	I4
	1	hemispheric solar spectral at wavelength 1		-9	I4
	1	hemispheric solar spectral at wavelength 2		-9	I4
	1	hemispheric solar spectral at wavelength 3		-9	I4
	1	(X,I2,X,I4,2(3X,I4,X,I4,X,I4))			
	2	…			
		1 line for each time measured			

The following are two examples of logical records defined for the measurements at heights of 10 and 30m on the Payerne station tower. Such logical records, and the corresponding relations in the BSRN database, are defined according to the configuration of the instruments at the BSRN stations that perform measurements at heights other than the standard height, i.e., for BSRN stations with a tower. The formats of both records are approximately the same as the format for logical record 100; thus the software for writing the records to the station-to-archive file at Payerne and for reading and inserting the data in the BSRN database at the WRMC is more standardized.

Logical record	Line no.	Description of field / format of line	Range of values	Missing code	Format of v./l.
3010	1	date [day]	1 - 31		I2
other	1	time [minute]	0 - 1439		I4
measurem	1	global 2 (mean, std. dev., min., max.: columns 12 - 31)		-999 or	I4 or
.					
at	1	short-wave upward			
10m		(mean, std. dev., min., max.: columns 35 - 54)		-99.9	F5.1
	2	downward long-wave radiation			
		(mean, std. dev., min., max.: columns 12 - 31)			
	2	upward long-wave radiation			
		(mean, std. dev., min., max.: columns 35 - 54)			
	2	air temperature		-99.9	F5.1
	2	relative humidity		-99.9	F5.1
		(X,I2,X,I4,2(3X,I4,X,F5.1,X,I4,X,I4),/			
		8X,2(3X,I4,X,F5.1,X,I4,X,I4),4X,F5.1,X,F5.1)			
	3	date [day]	1 - 31		I2
	3	…			
		2 lines for each time measured			
3030	1	date [day]	1 - 31		I2
other	1	time [minute]	0 - 1439		I4
measurem	1	global 2 (mean, std. dev., min., max.: columns 12 - 31)		-999 or	I4 or
.					
at	1	short-wave upward			
30m		(mean, std. dev., min., max.: columns 35 - 54)		-99.9	F5.1
	2	downward long-wave radiation			
		(mean, std. dev., min., max.: columns 12 - 31)			
	2	upward long-wave radiation			
		(mean, std. dev., min., max.: columns 35 - 54)			
	2	air temperature		-99.9	F5.1
	2	relative humidity		-99.9	F5.1
		(X,I2,X,I4,2(3X,I4,X,F5.1,X,I4,X,I4),/			
		8X,2(3X,I4,X,F5.1,X,I4,X,I4),4X,F5.1,X,F5.1)			
	3	date [day]	1 - 31		I2
	3	…			
		2 lines for each time measured			

Table A1. BSRN station-to-archive file format continued.

Logical record	Line no.	Description of field / format of line	Range of values	Missing code	Format of v./l.
4000	1	date [day]	1 - 31		I2
pyrgeo.	1	time [minute]	0 - 1439		I4
temp.	1	dome temperature 1downward long-wave instrument [°C]		-99.9	F5.1
	1	dome temperature 2 downward long-wave instrument [°C]		-99.9	F5.1
	1	dome temperature 3 downward long-wave instrument [°C]		-99.9	F5.1
	1	body temperature downward long-wave instrument [°C]		-99.9	F5.1
	1	thermopile output downward long-wave instrument [W/m^2]		-999	I4
	1	dome temperature 1upward long-wave instrument [°C]		-99.9	F5.1
	1	dome temperature 2 upward long-wave instrument [°C]		-99.9	F5.1
	1	dome temperature 3 upward long-wave instrument [°C]		-99.9	F5.1
	1	body temperature upward long-wave instrument [°C]		-99.9	F5.1
	1	thermopile output upward long-wave instrument [W/m^2]		-999	I4
		(X,I2,X,I4,4(F5.1,X),I4,3X, 4(F5.1,X),I4			
4nnn pyrgeo. temp. at nnn meter		pyrgeometer temperatures from instruments mounted on towers at a height of nnn meters are coded according to the definitions for pyrgeometers at standard height (~ 2 meters) see LR 4000.			

Table A2. BSRN stations. For more information see: http://www.bsrn.awi.de/en/stations/listings/.

Station abbreviation	Station name	Start date	Latitude	Longitude	Elevation [m]	Station identification number
ALE	Alert	01.08.2004	82.490	-64.420	127	18
ASP	Alice Springs	01.01.1995	-23.798	133.888	547	1
BAR	Barrow	01.01.1992	71.323	-156.607	8	22
BER	Bermuda	01.01.1992	32.267	-64.667	8	24
BIL	Billings	01.06.1993	36.605	-97.516	317	28
BON	Bondville	01.01.1995	40.066	-88.366	213	32
BOS	Boulder	01.07.1995	40.125	-105.237	1689	34
BOU	Boulder	01.01.1992	40.05	-105.007	1577	23
BRB	Brasilia	01.02.2006	-15.601	-47.713	1023	71
BUD	Budapest		47.429	19.182	139	Candidate, 14
CAB	Cabauw	01.12.2005	51.971	4.926		53
CAM	Camborne	01.01.2001	50.216	-5.316	88	50
CAR	Carpentras	01.08.1996	44.083	5.059	100	10
CLH	Chesapeake Light	01.06.2000	36.905	-75.713	37	39
CNR	Cener	01.07.2009	42.816	-1.601	471	45
COC	Cocos Island	14.09.2004	-12.193	96.835		47
DAA	De Aar	01.05.2000	-30.666	23.993	1287	40
DAR	Darwin	01.06.2002	-12.425	130.891	30	2
DOM	Concordia Station, Dome C	01.01.2006	-75.1	123.383	3233	74
DRA	Desert Rock	01.02.1998	36.626	-116.018	1007	35
DWN	Darwin Met Office		-12.424	130.892	32	Candidate, 65
EUR	Eureka	01.09-2007	79.989	-85.9405	85	19
E13	S. Great Plains	01.08.1997	36.605	-97.485	318	27
FLO	Florianopolis	01.06.1994	-27.533	-48.517	11	3
FPE	Fort Peck	01.01.1995	48.316	-105.1	634	31
FUA	Fukuoka	01.04.2010	33.581	130.375	3	6
GCR	Goodwin Creek	01.01.1995	34.25	-89.87	98	33
GOB	Gobabeb	05.15.2012	-23.5614	15.0420	407	20
GRS	Greenland Summit		72.566	-38.483		Candidate
GVN	Georg von Neumayer	01.01.1992	-70.65	-8.25	42	13
HAN	Hanimaadhoo		6.783	73.183		Candidate
ILO	Ilorin	01.08.1992	8.533	4.566	350	38
ISH	Ishigakijima	01.04.2010	24.336	124.163	5	7
IZA	Izaña	01.03.2009	28.309	-16.499	2372	61
JUN	Jungfraujoch		46.55	7.983		Candidate
KWA	Kwajalein	01.03.1992	8.72	167.731	10	25
LAU	Lauder	01.07.1998	-45.045	169.689	350	60
LER	Lerwick	01.01.2001	60.133	-1.183	84	51
LIN	Lindenberg	01.09.1994	52.21	14.122	125	12
MAN	Momote	01.09.1996	-2.058	147.425	6	29
MNM	Minamitorishima	01.04.2010	24.288	153.983	7	8
NAU	Nauru Island	01.11.1998	-0.521	166.916	7	30
NYA	Ny-Ålesund	01.08.1992	78.925	11.93	11	11
PAL	Palaiseau Cedex	01.05.2003	48.713	2.208	156	63
PAY	Payerne	01.09.1992	46.815	6.944	491	21
PSA	Plataforma Solar de Almeria		37.5	-2.2		Candidate
PSU	Rock Springs	01.05.1998	40.72	-77.933	376	36
PTR	Petrolina	01.12.2006	-9.068	-40.319	387	72
REG	Regina	01.01.1995	50.205	-104.713	578	5
RLM	Rolim de Moura	01.01.2007	-11.582	-61.773	252	73
SAP	Sapporo	01.04.2010	43.06	141.328	17	4
SBO	Sede Boqer	01.01.2003	30.905	34.782	500	43
SMS	São Martinho da Serra	01.01.2006	-29.442	-53.823	489	70
SOV	Solar Village	01.08.1998	24.91	46.41	650	41
SON	Sonnblick	01.01.2013	47.054	12.9577	3109	75
SPO	South Pole	01.01.1992	-89.983	-24.799	2800	26
SXF	Sioux Falls	01.06.2003	43.73	-96.62	473	37
SYO	Syowa	01.01.1994	-69.005	39.589	18	17
TAM	Tamanrasset	01.03.2000	22.78	5.51	1385	42
TAT	Tateno	01.02.1996	36.05	140.133	25	16
TIK	Tiksi	08.06.2010	71.586	128.918	48	48
TOR	Toravere	01.01.1999	58.254	26.462	70	9
XIA	Xianghe	01.01.2005	39.754	116.962	32	44
ZVE	Zvenigrod		55.695	36.775	180	Candidate, 46

Table A3. Quantity measured.

Every radiation value is measured by exactly one radiation instrument. If a value in height is missing, the quantity is measured only once at standard height. The id. no. of instruments not measured at standard height consists of the id. no. measured at standard height followed by 6 numericals expressing the height of the instruments above ground in cm.

Id. number	Height in cm	Quantity measured	Unit	Format
2		global 2 (pyranometer)	Wm^{-2}	9999
3		direct	Wm^{-2}	9999
4		diffuse sky	Wm^{-2}	9999
5		long-wave downward	Wm^{-2}	9999
21		air temperature	°C	999.9
22		relative humidity	%	99.9
23		pressure	hPa	9999
121		uv-a-global	Wm^{-2}	9999
122		uv-b-direct	Wm^{-2}	9999
123		uv-b-global	Wm^{-2}	9999
124		uv-b-diffuse	Wm^{-2}	9999
125		uv-b-reflected	Wm^{-2}	9999
131		short-wave reflected	Wm^{-2}	9999
132		long-wave upward	Wm^{-2}	9999
141		net radiation (net radiometer)	Wm^{-2}	9999
2000700	700	global 2 (pyranometer)	Wm^{-2}	9999
131000700	700	short-wave reflected	Wm^{-2}	9999
132000700	700	long-wave upward	$Wm-^{2}$	9999
5000700	700	long-wave downward	Wm^{-2}	9999
21000700	700	air temperature	°C	999.9
22000700	700	relative humidity	%	99.9
131003000	3000	short-wave reflected	Wm^{-2}	9999
104		short-wave spec. bd. 1		99999
104		short-wave spec. bd. 1		99999
112		short-wave spec. bd. 3		99999
301		total cloud amount with instrument	%	99
302		cloud base height with instrument	m	9999
303		cloud liquid water	mm	999.9

Table A4. Types of surface.

Id. number	Surface type	
1	glacier	accumulation area
2	glacier	ablation area
3	iceshelf	-
4	sea ice	-
5	water	river
6	water	lake
7	water	ocean
8	desert	rock
9	desert	sand
10	desert	gravel
11	concrete	-
12	asphalt	-
13	cultivated	-
14	tundra	-
15	grass	-
16	shrub	-
17	forest	evergreen
18	forest	deciduous
19	forest	mixed
20	rock	-
21	sand	-

Table A5. Types of topography.

Id. number	Topography type		
1	flat		urban
2	flat		rural
3	hilly		urban
4	hilly		rural
5	mountain	top	urban
6	mountain	top	rural
7	mountain	valley	urban
8	mountain	valley	rural

Table A6. Pyrgeometer body temperature compensation codes.

Id. number	Body temperature compensation
1	Manufacturer´s battery circuit
2	Corrected manufacturer´s battery circuit
3	Temperature measurement with σT_c^4
4	Other

Table A7. Pyrgeometer dome temperature compensation codes.

Id. number	Dome temperature compensation
1	Dome shaded
2	Instrument ventilated
3	Temperature measurement with σT_c^4
4	shaded & ventilated
5	shaded & σT_c^4
6	ventilated & σT_c^4
7	shaded & ventilated & σT_c^4
8	Other