DESCRIPTION OF RADSYS DAILY DATA FILES

FILENAME INFORMATION:

RADSYS data files contain one day of data for one station. The FTP directories from which RADSYS data are distributed are organized by station. The naming convention for RADSYS data filenames is "stayyjjj.dat", where sta is a three-letter station identifier, yy represents the last two digits of the year (i.e., 95 for 1995, 00 for 2000), and jjj is the day of year. A "day of year" in a filename that is less than 100 would be preceded by one or two zeros, e.g., day 75 would appear as 075, day 2 would appear as 002 in the filename. The SURFRAD processing software is year 2000 compliant. The year within the data files is written unambiguously with 4 digits on each line.

Station Identifier List
"ckp" is the station identifier for the Kettle Ponds site from the SPLASH field campaign in Crested Butte, Colorado

The extension ".dat" is used because both radiation and meteorological data are included. The file "ckp21289.dat" contains all of the radiation and meteorological data for Kettle Ponds on day 289 of 2021.

Daily RADSYS data files for each station may be downloaded from the following location:

https://gml.noaa.gov/aftp/data/radiation/campaigns/Format/

Or using ftp at
ftp://aftp.cmdl.noaa.gov/data/radiation/campaigns/Format/

To get to a specific file, advance to the appropriate station directory, e.g.,
ftp://aftp.cmdl.noaa.gov/data/radiation/campaigns/Format/ckp/ for Kettle Ponds data

DEPLOYMENT SPECIFIC INFORMATION:

Campaign	Site	Identifier	Pyranometer Deployed
SPLASH	Kettle Ponds (Crested Butte, CO)	CKP	K&Z CMP11

DATA STRUCTURE:

RADSYS data are organized into daily files of one minute data, and are written in ASCII text.

RADSYS data follows the quality control (QC) philosophy of the BSRN. Bad data are deleted, but questionable data are only flagged. Integer QC flags follow each data point.

A QC flag of zero indicates that the corresponding data point is good, having passed all QC checks. A value greater than 0 indicates that the data failed one level of QC. For example, a QC value of 1 means that the recorded value is beyond a physically possible range, or it has been affected adversely in some manner to produce a knowingly bad value. A value of 2 indicates that the data value failed the second level QC check, indicating that the data value may be physically possible but should be used with scrutiny, and so on. Missing values are indicated by -9999.9 and should always have a QC flag of 1.

The file structure includes two header records; the first has the name of the station, and the second gives the station's latitude, longitude, elevation above mean sea level in meters, and the version number of the file. These are followed by at most, 1440 lines of 1-min. data.
Files are organized in Universal Coordinated Time (UTC). The date and time are given on every line. Data are reported as 1-minute averages of one-second samples. Reported times are the end times of the 1-min. averaging periods, i.e., the data given for 0000 UTC are averaged over the period from 2359 (or 2357) of the previous UTC day, to 0000 UTC. The solar zenith angle is reported in degrees on each line of data. It is computed for the central time of the averaging period of the sampled data. Missing-data periods within the files are not filled in with missing values, therefore, a file with missing periods will have fewer than 1440 lines.

Radiation values are reported to the tenths place. Although this is beyond the accuracy of the instruments, data are reported in this manner in order to maintain the capability of backing out the raw voltages at the accuracy that they were originally reported.

The variables, their data type, and description are given below:

RADSYS Output File Columns

Output Column	Column Title	Description	Units	Data Type	Notes
1	yyyy	year, i.e., 1995	year	int	
2	jday	Julian day (1 through 365 [or 366])		int	

3	month	number of the month (1-12)	month	int	
4	day	day of the month(1-31)	day	int	
5	hour	hour of the day (0-23)	hr	int	
6	min	minute of the hour (0-59)	minute	int	
7	dt	decimal time (hour.decimalminutes, e.g., 23.5 = 2330)	hr	Float	
8	SZA	solar zenith angle	Degrees	Float	Calc From Timestamp and Lat/Lon
9	dw_solar	downwelling global solar	W/m^2	Float	QC = Col 10
11	uw_solar	upwelling global solar	W/m^2	Float	QC = Col 12
13	Direct horizontal	Direct horizontal solar	W/m^2	Float	QC = Col 14, calculated as described below
15	Diffuse	Downwelling diffuse solar	W/m^2	Float	QC = Col 16, calculated as described below
17	dw_ir	downwelling thermal infrared	W/m^2	Float	QC = Col 18
19	DwCaseTemp	downwelling IR case temp.	Kelvin	Float	QC = Col 20
21	DwDomeTemp	downwelling IR dome temp.	Kelvin	Float	QC = Col 22
23	uw_ir	upwelling thermal infrared	W/m^2	Float	QC = Col 24
25	UwCaseTemp	upwelling IR case temp.	Kelvin	Float	QC = Col 26
27	UwDomeTemp	upwelling IR dome temp.	Kelvin	Float	QC = Col 28
29	UVB	global UVB	W/m^2	Float	QC = Col 30, not usually measured with RADSYS
31	PAR	photosynthetically active radiation	W/m^2	Float	QC = Col 32, not usually measured with RADSYS

33	NetSolar	net solar (dw_solar - uw_solar)	W/m^2	Float	QC = Col 34
35	NetIR	net infrared (dw_ir - uw_ir)	W/m^2	Float	QC = Col 36
37	TotalNet	net radiation (netsolar+netir)	W/m^2	Float	QC = Col 38
39	AirTemp	10-meter air temperature	Celcius	Float	QC = Col 40
41	RH	relative humidity	%	Float	QC = Col 42
43	WindSpd	wind speed	m/s	Float	QC = Col 44
45	WindDir	wind direction	Degrees	Float	QC = Col 46
47	Baro	station pressure	mBar	Float	QC = Col 48
49	SPN1_total_Avg	Total irradiance as measured by SPN1	W/m^2	Float	QC = Col 50
51	SPN1_diffuse_Avg	Diffuse irradiance as measured by SPN1	W/m^2	Float	QC = Col 52

INSTRUMENTS:

1. The Kipp & Zonen CMP11 or Eppley PSP pyranometer

Pyranometers measure global downwelling and upwelling solar irradiance on RADSYS systems. These instruments are sensitive to the shortwave broadband spectral range of 280 to 3000 nm. They are calibrated on a yearly basis.

RADSYS systems use either K&Z CMP11 or Eppley PSP pyranometers to measure the SW broadband irradiance depending on the deployment and instrument availability. Which is used is documented in the table in the section DEPLOYMENT SPECIFIC INFORMATION.

An inherent problem with solid black thermopile pyrometers is that their sensor cools to space (if it is directed upward) and that causes a negative signal. This is apparent at night where it shows up as an erroneous negative irradiance that can be as great as -30 Wm^-2. The nighttime offset in the PSP has a larger magnitude. An offset still exists for the CMP11, but is much smaller than the PSP because of engineering designs which improve the thermal conduction between the body and dome.

2. The SPN1 pyranometer

The SPN1 pyranometer measures total and diffuse downwelling shortwave irradiance using seven thermopile sensors with a unique shading pattern that always keeps at least one sensor in direct sun and one fully shaded. The SPN1 pyranometer has a heater which mitigates frost and dew on the dome. This heater also compensates for the IR loss problem so that is not seen in SPN1 data.

These instruments currently need to be calibrated by sending to the factory and removing the shading pattern. Calibration is not done annually, but instead basic comparison checks are done against reference instrumentation. An in house calibration methodology is under development.

These instruments are used in RADSYS systems because they allow deployment with no moving parts, are a less expensive and more flexible way to measure shortwave components than a full tracking system, particularly in remote deployments. However, SPN1 measurements are not as high quality as those from a tracking system (e.g. Badosa et al. 2014). The measurements from the SPN1 are thus considered supplementary to the higher quality pyranometer measurement and diffuse and direct irradiances are calculated by scaling the diffuse ratio to the pyranometer measurements as described below.

Badosa, J., Wood, J., Blanc, P., Long, C. N., Vuilleumier, L., Demengel, D., and Haeffelin, M., 2014: Solar irradiances measured using SPN1 radiometers: uncertainties and clues for development, Atmos. Meas. Tech., 7, 4267–4283, https://doi.org/10.5194/amt-7-4267-2014.

3. Precision Infrared Radiometer (PIR)

Two PIRs measure upwelling and downwelling thermal infrared irradiance. They are sensitive to the spectral range from 3000 to 50,000 nm. NOAA maintains three standard PIRs that are calibrated annually by a world-reputable organization. These standards are used to calibrate field PIRs.

4. The Yankee UVB Broadband Radiometer (*Note: UVB not generally measured in RADSYS systems*)

The UVB radiometer measures erythemally weighted UVB irradiance in the range from 280 to 320 nm. Field UVB instruments are calibrated by referencing them to three standard instruments that are rigorously maintained by NOAA's Central UV Calibration Facility. Calibrations for these instruments are applied as a function of solar zenith angle.

5. The LI-COR Quantum (PAR) Sensor (*Note: UVB not generally measured in RADSYS systems*)

The LI-COR Quantum (Photosynthetically Active Radiation, or PAR) sensor measures radiation in the band from 400 to 700 nm, which is the part of the solar spectrum that activates photosynthesis in plants. The PAR sensor sits on the main platform at SURFRAD stations and collects downwelling global radiation in the PAR band. These instruments are sent to the manufacturer annually for calibration.

DATA PROCESSING:

1. Processing SW data for IR loss correction:

It is not unusual that thermopile-based solar instruments register a small negative signal at night. Most of this error is attributed to the thermopile cooling to space. These erroneous offsets are minor in the instruments used in the RADSYS systems, and are not corrected in these files. The downwelling shortwave measurement is applied The SPN1 instrument that is used to measure diffuse and global manifested in the global measurements from the and diffuse solar measurements, but not in the pyrheliometer that measures direct-normal solar irradiance. Erroneous nighttime offsets in the diffuse and global solar measurements of between 0 and -10 Wm^-2 are typical, but can be as great as 30 Wm^-2. Because this behavior is common, only nighttime signals that drop below -30 are flagged. The erroneous offset is also present in daytime data, but is masked by the solar signal. A way to correct this error in the daytime diffuse measurements has been developed. It is described in Dutton et al, 2001 (J. Atmos. and Ocean Tech., 18, 297-314). Their method involves the development of a relationship between the thermopile output of a collocated pyrgeometer and the negative diffuse signals for nighttime periods. That relationship is then applied to all diffuse data (night and day).

2. Calculating Diffuse and Direct SW components

Because the PSP or CMP11 pyranometer measurements are of higher quality than the SPN1, diffuse and direct irradiance are scaled to the primary pyranometer measurements in order to maintain consistency between measurements.

$$Diffuse \;=\; Primary\ Pyranometer\ Total\left(\frac{SPN1\ Diffuse}{SPN1\ Total}\right)$$
$$Direct\ Horizontal\ Irradiance \;=\; Primary\ Pyranometer\ Total \;-\; Diffuse$$

3. Net radiation processing:

Net radiation, net solar, net infrared, and total net (net solar + net infrared) are computed and reported in the daily processed files. In computing net solar (downwelling solar - upwelling solar) the best measure of downwelling solar is used. Whenever any of the solar measurements are negative (owing to cooling of the thermopile near dusk and dawn), they are set to 0 before computing the net radiation.

Net solar is computed for solar zenith angles between 0 and 96 degrees. The net solar calculation is extended beyond 90, to 96 degrees to account for civil twilight.

All radiation parameters, except UVB, are reported in units of Watts m^-2;
UVB is reported in milliWatts m^-2.

QUALITY CONTROL AND QUALITY ASSURANCE

NOAA has attempted to produce the best data set possible, however the data quality is constrained by measurement accuracies of the instruments and the quality of the calibrations. Regardless, NOAA attempts to ensure the best quality possible through quality assurance and quality control. The data are subjected to automatic procedures as the daily files are processed. At present, they are subjected only to this first-level check, and a daily "eye" check before being released, however, as quality control procedures become more refined, they will be applied, and new versions of the data files will be generated.

Quality assurance methods are in place to ensure against premature equipment failure in the field and post deployment data problems. For example, all instruments at each station are exchanged for newly calibrated instruments on an annual basis. Calibrations are performed by world-recognized organizations. Pyranometers have been calibrated at the World Meteorological Organization's (WMO) Region 4 Regional Solar Calibration Center at NOAA in Boulder, CO or at the Delta-T Devices factory in the case of the SPN1.

RADSYS pyrgeometers are calibrated using three standards maintained at NOAA's Field Test and Calibration Facility at Table Mountain near Boulder, CO. RADSYS pyrgeometer standards' calibrations are traceable to the WISG world standard device in Davos, Switzerland, where they are calibrated annually. In general, all of the standards at NOAA/Boulder are traceable to world standards or an equivalent. Calibration factors for the UVB instrument are transferred from three standards maintained by NOAA's National UV Calibration Facility in Boulder. Finally, in order to maintain continuity between the returned instruments and their replacements, all instruments are gauged against three standard instruments before and after field deployment.

UVB processing: (*Note: UVB not usually measured with RADSYS*)

The UVB flux is given as the total measured surface UVB flux convoluted with the erythemal action spectrum, i.e., that part of the UVB spectrum responsible for sun burns on human skin (erythema) and DNA damage. It is reported in this way because the response function of the UVB instrument approximates the erythemal action spectrum; thus the reported value is most representative of what the instrument is actually measuring.

The erythemal UVB irradiance reported in SURFRAD data files is computed for

300 Dobson units of ozone. This is done because the ozone value over the stations is unknown during the near real-time processing. If the ozone for a particular day is less than 300 Dobson units, then the reported UVB irradiance would be less than it should be. If the user would like to correct reported SURFRAD UVB measurements for the actual ozone, correction tables are available. Contact the webmaster for these tables.

The field UVB instruments are calibrated against a triad of "standard" UVB instruments that are maintained by NOAA's Central UV Calibration Facility. The standard instruments are periodically calibrated in the sun by comparing their broadband measurements to the integrated output of UV spectroradiometers. These calibrations are transferred to the field instruments just before they are deployed in the network by operating them side-by-side for a few days. To accomplish this transfer, a scale factor, which is simply a ratio of the test instrument's daily integral to that of the mean of the standards, is computed for each day that the test UVB instrument is run alongside the standards. The mean of the daily scale factors is used to transfer the standards' well maintained calibrations to the test instruments when they are deployed in the field.

Mean calibration factors for the UVB standards are computed as a function of solar zenith angle, and are applied to the field instrument as such in the daily processing. For example, to compute the UVB irradiance, the output voltage, is multiplied times the Standards' calibration factor for the solar zenith angle that the measurement was made, then that result is divided by the scale factor for that field instrument.

The following table lists the UVB Standards' calibration information computed using the September 23, 1997 UV Spectroradiometer intercomparison data.

erythemal conversion factor (W m^-2 / V)	solar zenith angle
0.136	0.0 extrapolated
0.136	5.0
0.136	10.0
0.135	15.0
0.134	20.0
0.133	25.0
0.132	30.0
0.131	35.0
0.130	40.0
0.129	45.0

0.128	50.0	
0.128	55.0	
0.129	60.0	
0.132	65.0	
0.138	70.0	
0.147	75.0	
0.164	80.0	
0.191	85.0	
0.220	90.0	extrapolated

Similar calibration tables for the three UVB standards were computed for June 22, 2003, they are:

erythemal conversion factor (W m^-2 / V)	solar zenith angle	
0.150	0.0	extrapolated
0.150	5.0	
0.150	10.0	
0.149	15.0	
0.148	20.0	
0.147	25.0	
0.145	30.0	
0.144	35.0	
0.143	40.0	
0.141	45.0	
0.140	50.0	
0.140	55.0	
0.141	60.0	
0.144	65.0	
0.149	70.0	
0.159	75.0	
0.177	80.0	
0.206	85.0	
0.240	90.0	extrapolated

There is evidence that the standards calibration changed linearly between these benchmark years. Therefore, code that applies them in the SURFRAD processing algorithm has been written to linearly interpolate the standards calibration to the day being processed. As of 2 Sept. 2004, all SURFRAD data has been reprocessed to include these improved UVB calibrations.

PAR processing: (*Note PAR not usually measured with RADSYS*)

To be consistent with other reported radiometric data in the file, values of photosynthetically active radiation (PAR) are reported in units of Wm^-2. The factory calibration for our Quantum sensors that measure PAR does not transform raw output from the instrument to these units; rather, it converts the sensor output to umoles (of photons) m^-2 s^-1. These units are converted to Wm^-2 by dividing umoles m^-2 s^-1 by 4.6, which is the conversion factor derived for the solar spectrum. To convert the reported value back to the original units, simply multiply our reported values times 4.6. The theoretical basis for converting umoles (of photons) m^-2 s^-1 to Wm^-2 for various light sources (including the sun) is described in Proceedings of the NATO Advanced Study Institute on Advanced Agricultural Instrumentation, 1984. W. G. Gensler (ed.), Martinus Nijnoff Publishers, Dordrect, The Netherlands.