

DESCRIPTION OF SOLRAD DAILY DATA FILES

Contact:

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Use the following reference in any publications that use SOLRAD data (Note that SOLRAD was formerly called ISIS):

Hicks, B. B., J. J. DeLuisi, D. R. Matt, 1996: The NOAA Integrated Surface Irradiance Study (ISIS)--a new surface radiation monitoring program. Bull. Amer. Meteor. Soc., 77, 2857-2864

DATA DISTRIBUTION:

Daily SOLRAD text data files for each station may be downloaded from GML at the following location:

<https://gml.noaa.gov/aftp/data/radiation/solrad/>

To get to a specific file, advance to the appropriate station directory, and then to the specific year directory, e.g., for Albuquerque 2003 data:
<https://gml.noaa.gov/aftp/data/radiation/solrad/abq/2003/>

SOLRAD data are actually processed in near-real-time every 15 minutes. These real-time data files build during the day and have the same names and structure as the daily quality-controlled files on the GML FTP site, but they are not checked for quality, so use at your own risk. The real-time data files are available at:

<https://gml.noaa.gov/aftp/data/radiation/solrad/realtime/>

FILENAME INFORMATION:

SOLRAD data files distributed by GML contain one day of data for one station. The FTP directories from which SOLRAD data are distributed are organized by station and year. The naming convention for SOLRAD 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.

"abq" is the station identifier for Albuquerque, New Mexico
"bis" is the station identifier for Bismarck, North Dakota

"hnx" is the station identifier for Hanford, California
"sea" is the station identifier for Seattle, Washington
"tlh" is the station identifier for Tallahassee, Florida
"slc" is the station identifier for Salt Lake City, Utah
"ste" is the station identifier for Sterling, Virginia
"msn" is the station identifier for Madison, Wisconsin
"ort" is the station identifier for Oak Ridge, Tennessee

For example, the file " abq95099.dat " contains data for Albuquerque for day 99 of 1995 (9-Apr-1995).

SOLRAD data processing software is year 2000 compliant. The year within the data files is written unambiguously with 4 digits on each line.

The extension ".dat" is used because both radiation and meteorological data are included. The file " abq02099.dat " contains all of the radiation data for Albuquerque on day 99 of 2002 (9-apr-2002).

DATA STRUCTURE:

SOLRAD data are organized into daily files of one- or three-minute data, and are written in ASCII text. Before 1-jan. 2015 the data were reported as 3-min averages; on and after 1-Jan. 2015, SOLRAD data are reported as 1-min. averages of 1-sec. samples.

The format was specified in such a way to ensure that all entries are separated by at least one space so that the files may be read with free format.

SOLRAD 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. The data files are written in ASCII. They may be read with the FORTRAN code shown below. The format was specified in such a way to ensure that all entries are separated by at least one space so that the files may be read with free format. Quality control parameters follow each measurement or calculated value. SOLRAD follows the quality control (QC) philosophy of the BSRN. Instead of deleting questionable data, they are flagged. 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 could mean that the recorded value is beyond the physically possible range for that measurement. A value of 2 usually means 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.

It is not unusual that thermopile-based solar pyranometers register a small negative signal at night. Most of this error is attributed to the thermopile cooling to space.

This generally affects the global and diffuse solar measurements, if thermopile-based instruments are used for those measurements. This error

is also present in daytime data, but its magnitude is difficult to determine. Nighttime errors between 0 and -10 Wm^{-2} are typical. Because this behavior is common, only nighttime signals that drop below the common range are flagged.

Daytime diffuse measurements made by thermopile-based pyranometers are also adversely affected as much as the global measurements. Because they are shaded, the cosine error caused by the solar beam is precluded, and thus Eppley model 8-48 pyranometer (notorious for its cosine error) can be used for the diffuse measurement. The Eppley model 8-48 pyranometer, which has been used for the diffuse measurement since the 2001 instrument exchanges, does not have this problem. The model 8-48 pyranometer relies on a differential signal between a black and a white surface on the detector. Since these two surfaces emit the same in the infrared, the differential signal owing to infrared cooling of the sensor's surface is zero. Thus, there is little or no offset owing to radiative cooling of the 8-48.

The global solar sensor has the same infrared cooling problem, but solar heating inside of the dome during the day prevents development of a simple relationship using nighttime data that is applicable during the day. Direct solar heating is not a problem with the diffuse pyranometer because it is, by practice, shaded. Therefore, the global solar measurement is not yet correctable, and should only be used in cases when the direct-normal and diffuse solar measurements are not available

On June 18, 2009, a pyrgeometer was added to the Madison complement of instruments and the UVB instrument was removed. After that date, Madison's file format changed.

The following FORTRAN code may be used to read daily SOLRAD files EXCEPT for Madison after 18 June 2009:

```
parameter (nlines=1440)
character*80 station_name
c
integer year,month,day,jday,elevation,hr_to_LST,version
integer min(nlines),hour(nlines)
c
real latitude,longitude,dt(nlines),zen(nlines)
real direct(nlines)
real dw_psp(nlines)
real diffuse(nlines)
real uvb(nlines),uvb_temp_v(nlines)
c
integer qc_direct(nlines)
integer qc_dwpsp(nlines)
integer qc_diffuse(nlines)
integer qc_uvbnlines)
integer qc_uvbnlines)
c
c
lun_in = 20
open(unit=lun_in,file=[filename.dat],status='old',readonly)
```

```

c.
c.
c.
  read (lun_in,10) station_name
10  format(1x,a)
  read(lun_in,*) latitude, longitude, elevation, hr_to_LST
c
  icount = 0
  do i = 1,nlines
c
  read(lun_in,30,end=40) year,jday,month,day,hour(i),min(i),dt(i),
1  zen(i),dw_psp(i),qc_dwpsp(i),direct(i),qc_direct(i),
2  diffuse(i),qc_diffuse(i),uvb(i),qc_uv(b)(i),uvb_temp(i),
3  qc_uv(b)_temp(i),std_dw_psp(j),std_direct(j),std_diffuse(j),
4  std_uv(b)(j)
c
  icount = icount + 1
c
30  format(1x,i4,1x,i3,4(1x,i2),1x,f6.3,1x,f6.2,5(1x,f7.1,1x,i1),
1  4(1x,f9.3))
c
  enddo
40  type *,'end of file reached, ',icount,' records read'
.
.
.
c
c
c
c
c The following code can be used to read MADISON files AFTER 18 June 2009
c
  parameter (nlines=1440)
  character*80 station_name
c
  integer year,month,day,jday,elevation,hr_to_LST,version
  integer min(nlines),hour(nlines)
c
  real latitude,longitude,dt(nlines),zen(nlines)
  real direct(nlines)
  real dw_psp(nlines)
  real diffuse(nlines)
  real uvb(nlines)
  real uvb_temp_v(nlines)
  real dpir(nlines) !Downwelling IR in Wm^-2
  real dpirc(nlines)!PIR case temperature (K)
  real dpird(nlines)!PIR dome temperature (K)
c
  integer qc_direct(nlines)
  integer qc_dwpsp(nlines)
  integer qc_diffuse(nlines)
  integer qc_uv(b)(nlines)
  integer qc_uv(b)_temp(nlines)

```

```

integer qc_dpir(nlines)
integer qc_dpirc(nlines)
integer qc_dpird(nlines)
c
c
  lun_in = 20
  open(unit=lun_in,file=[filename.dat],status='old',readonly)
c.
c.
c.
  read (lun_in,10) station_name
10 format(1x,a)
  read(lun_in,*) latitude, longitude, elevation, hr_to_LST
c
  icount = 0
  do i = 1,nlines
c
  read(lun_in,30,end=40) year,jday,month,day,hour(i),min(i),dt(i),
1 zen(i),dw_psp(i),qc_dwpsp(i),direct(i),qc_direct(i),
2 diffuse(i),qc_diffuse(i),uvb(i),qc_uv(b(i),uvb_temp(i),
3 qc_uv(b_temp(i),dpir(i),qc_dpir(i),dpirc(i),qc_dpirc(i),dpird(i),
4 qc_dpird(i),std_dw_psp(i),std_direct(i),std_diffuse(i),
5 std_uv(b(i),std_dpir(i),std_dpirc(i),std_dpird(i)
c
  icount = icount + 1
c
30 format(1x,i4,1x,i3,4(1x,i2),1x,f6.3,1x,f6.2,8(1x,f7.1,1x,i1),
1 7(1x,f9.3))
c
  enddo
40 type *,'end of file reached, ',icount,' records read'
.
.
.

```

The SOLRRAD data 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 displacement in hours from local standard time. The files are organized in Universal Coordinated Time (UTC). These are followed by at most, 480 lines of data for 3-min. data and 1440 lines for 1-min. data (from 2015 on).

The date and time parameters and solar zenith angle are given on every line. Data are reported as 1-minute or 3-minute averages of one-second samples. Reported times are the end times of the 3-min. averaging periods, i.e., the data given for 0000 UTC are averaged over the period from 2357 or 2359 (of the previous UTC day) to 0000. 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, i.e., 1.5 minutes before the reported time on the line. Missing-data periods within the files are not filled in with missing values, therefore, a file with missing periods will have fewer than 480 data records.

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. Also, if the accuracies of the instruments improve to a fraction of a Wm^{-2} , the data format will not have to be changed.

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

```

station_name      character  station name, e. g., Goodwin Creek
latitude          real      latitude in decimal degrees (e. g., 40.80)
longitude         real      longitude in decimal degrees (e. g., 105.12)
elevation         integer    elevation above sea level in meters
h_to_lst          integer    hours displaced from local standard time
year              integer    year, i.e., 2002
jday              integer    Julian day (1 through 365 [or 366])
month             integer    number of the month (1-12)
day               integer    day of the month(1-31)
hour              integer    hour of the day (0-23)
min               integer    minute of the hour (0-59)
dt                real      decimal time (hour.decimalminutes),e. g., 23.5 = 2330
zen               real      solar zenith angle (degrees)
dw_psp            real      downwelling global solar (Watts m-2)
direct            real      direct solar (Watts m-2)
diffuse           real      downwelling diffuse solar (Watts m-2)
uvb               real      global UVB (milliWatts m-2)
uvb_temp          real      UVB temperature (C) - 40-45 deg. C is normal
qc_dwpsp          integer    quality control parameter for downwelling global
solar (0=good)
qc_direct         integer    quality control parameter for direct solar (0=good)
qc_diffuse        integer    quality control parameter for diffuse solar (0=good)
qc_uv             integer    quality control parameter for UVB irradiance (0=good)
qc_uv_temp        integer    quality control parameter for the UVB instrument
temperature (0=good)
std_dw_psp        real      standard deviation of the 1-sec. samples for global
solar (dw_psp)
std_direct        real      standard deviation of the 1-sec. samples for direct
solar
std_diffuse       real      standard deviation of the 1-sec. samples for diffuse
solar
std_uv            real      standard deviation of the 1-sec. samples for uvb

```

for MADISON AFTER 18 June 2009:

```

dpir              real      downwelling thermal IR (Watts m-2)
dpirc             real      downwelling PIR case temperature (K)
dpird             real      downwelling PIR dome temperature (K)
std_dpir          real      standard deviation of the 1-sec. samples for downwelling
IR
std_dpirc         real      standard deviation of the 1-sec. samples for PIR case
temp
std_dpird         real      standard deviation of the 1-sec. samples for PIR dome
temp

```

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

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 sunburns 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.

Erythemal UVB irradiance reported in SOLRAD 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 SOLRAD 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

QUALITY CONTROL AND QUALITY ASSURANCE

These data are provisional. 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 data quality control. The data are subjected to automatic procedures as the daily files are processed. At present, they are subjected only to a 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 or biannual basis. Calibrations are performed by world-recognized organizations. Pyranometers and pyrhemometers have been calibrated at the National Renewable Energy Laboratory (NREL) in Golden, Colorado, or the World Meteorological Organization's (WMO) Region 4 Regional Solar Calibration Center at NOAA in Boulder, Colo., which is maintained by GML. Calibration factors for the UVB instrument are transferred from three standards maintained by GML's National UV Calibration Facility in Boulder. In general, all of the standards the GML and NREL are traceable to NIST, WMO, or their equivalent.

INSTRUMENTS:

1. The Yankee UVB Broadband Radiometer

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.

2. The Normal Incidence Pyrheliometer (NIP)

The NIP measures direct solar radiation in the broadband spectral range from 280 to 3000 nm. Those used at SOLRAD stations are calibrated nominally on a biennial basis at the NOAA calibration facility in Boulder, CO

3. Precision Spectral Pyranometer (PSP)

A PSP measures downwelling global irradiance at SOLRAD stations. These instruments are sensitive to the same broadband spectral range as the NIP, 280 to 3000 nm. They are calibrated on a biennial basis at the NOAA calibration facility in Boulder, CO

An inherent problem with the PSP, or any radiometer with a single-black thermopile detector, is that its sensor cools to space (if it is directed upward) and this causes a negative signal. This is apparent at night where it shows up as an erroneous negative irradiance that can be as high as -30 Wm^{-2} . Daytime data also contain this error but it is overwhelmed by the large solar signal. This error especially affects the diffuse measurement made by a PSP because the sensor is shaded. Therefore, the PSP is not used for the diffuse measurement.

4. Eppley 8-48 "black and white" pyranometer

This pyranometer has been used for the diffuse solar measurement since 2001. The 8-48 has been found to have desirable properties for this measurement because it does not use a solid black surface for the detector and thus does not have the "nighttime" offset problem. These instruments are sensitive to the same spectral range as the other broadband solar radiometers, 280 to 3000 nm. They are also calibrated on a yearly basis.

5. Precision Infrared Radiometer (PIR)

The PIR measures and downwelling thermal infrared irradiance at Madison only. It is sensitive to the spectral range from 3000 to 50,000 nm. NOAA maintains three standard PIRs that are calibrated biennially by PMOD in Davos, Switzerland, and are used to calibrate field PIRs.

Fair use policy, license, etc.:

Findable and Accessible:

SOLRAD data are freely available to users from the GML web-site (e.g. [GML web-site](#), GRAD ftp data access).

Fair Use:

These data are made freely available to the public and the scientific community in the belief that their wide dissemination will lead to greater understanding and new scientific insights. To ensure that GML receives fair credit for their work please include relevant citation text in publications (see below). We

encourage users to contact the data providers, who can provide detailed information about the measurements and scientific insight. In cases where the data are central to a publication, co-authorship for data providers may be appropriate.

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