Global Hydrology Resource Center

Data User Guide

GOES-R PLT Surface Radiance Red Lake

Introduction

The GOES-R PLT Surface Radiance Red Lake dataset consists of surface radiation budget, ultraviolet-B (UVB) and photosynthetically active radiation (PAR) flux, meteorological (temperature, pressure, relative humidity, winds), and spectral aerosol optical thickness data collected by a mobile SURFRAD station at Red Lake, Arizona for the GOES-R Post Launch Test (PLT) field campaign. The campaign took place from March to May of 2017 in support of post-launch L1B and L2+ product validation of the Advanced Baseline Imager (ABI) and the Geostationary Lightning Mapper (GLM). Data files are available in ASCII text format from March 27, 2017 through April 12, 2017. Surface reflectance measurements based on spectroradiometer data are also included in Microsoft Excel format.

Citation

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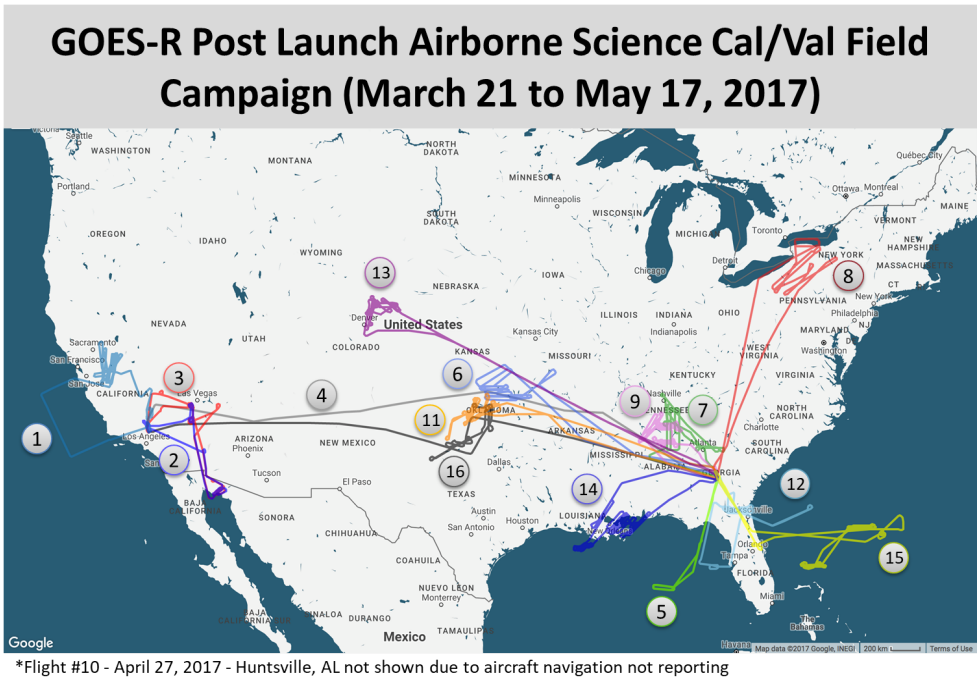
NASA, GHRC, NOAA, GOES-R, GOES-16, ABI, GLM, SURFRAD, electromagnetic radiation, radiance, downwelling, upwelling, SW, LW, UVB, PAR, Red Lake, Arizona

Campaign

The Geostationary Operational Environmental Satellites - R series (GOES-R) is a geostationary satellite program comprised of a four-satellite fleet including GOES-R, GOES-S, GOES-T, and GOES-U. The GOES-R Series Program is a collaborative development and acquisition effort between the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA) to develop, launch and operate the satellites. The first satellite in the GOES-R series, GOES-R, launched on November 19, 2016 and became GOES-16 when it reached geostationary orbit. GOES-16 replaced GOES-13 as NOAA's operational GOES-East satellite at 75.2 degrees west longitude on December 18, 2017. GOES-16 observes North and South America, as well as

the Atlantic Ocean all the way to the west coast of Africa. GOES-16 provides high spatial and temporal resolution imagery of the Earth using its Advanced Baseline Imager (ABI). GOES-16's Geostationary Lightning Mapper (GLM) is the first operational lightning mapper flown in geostationary orbit. GOES-16 also includes four other scientific instruments for monitoring space weather and the Sun. More information about the GOES-R mission can be found at the GOES-R website.

The GOES-R Post Launch Test (PLT) field campaign took place between March 21 and May 17, 2017 in support of the post-launch validation of NOAA's new generation of geostationary Earth-observing instruments: ABI and GLM. The campaign was comprised of two phases: the first centered on the U.S. west coast, providing tests primarily for the ABI instrument, and the second focused on the central and eastern U.S. with tests primarily for the GLM instrument (Figure 1). The validation effort included targeted data collections by the NASA ER-2 high-altitude aircraft coordinated with ground-based and low earth-orbit referenced data from several operational and research satellite missions. Dedicated ABI 30-second mesoscale (MESO) imagery collections were conducted concurrently with the ER-2 high-altitude aircraft based sensors during each GLM mission. The GOES-R PLT field campaign provided critical reference data and new insights into the performance NOAA's new generation of geostationary Earth-observing instrument products. More information about the GOES-R PLT field campaign is available on the GOES-16 Field Campaign webpage and the GOES-R PLT Field Campaign Micro Article. More information about SURFRAD's role in GOES-R ABI product validation is described in this GOES-R ABI Validation Planning document.



*Flight #10 - April 27, 2017 - Huntsville, AL not shown due to aircraft navigation not reporting

Figure 1: The GOES-R PLT Field Campaign study area
(Image source: Frank Padula)

Instrument Description

The Surface Radiation Budget Network (SURFRAD) is a collection of radiation measurement stations positioned in different climatic zones around the U.S. to monitor the country's surface radiation budget. SURFRAD primarily measures downwelling (downward movement toward Earth's surface) and upwelling (upward movement away from Earth's surface) radiation in the solar, or short-wave (SW), and infrared (IR), or long-wave (LW), parts of the electromagnetic spectrum to assess the impacts of the Sun's radiation on Earth's surface-atmosphere system. SURFRAD stations provide high-quality ground-based radiation observations that can be used to validate satellite-based estimates used in weather models and climate studies. Supporting measurements of direct and diffuse radiation, photosynthetically active radiation (PAR), ultraviolet-B (UVB) radiation, spectral solar radiation, and meteorological parameters are also taken. The SURFRAD station used during GOES-R PLT was a mobile system that was stationed at Red Lake, a dry lake bed, in Arizona for approximately 3-weeks (Figure 2). This SURFRAD station was used to validate GOES-R (GOES-16) Advanced Baseline Imager (ABI) satellite measurements.

A SURFRAD station consists of a variety of instruments and equipment mounted on 3 separate platforms (Figure 3). These platforms are arranged in a line from north to south to prevent a platform from casting a shadow on upward-looking instruments. The main platform is located in the center and is comprised of an upward-looking pyranometer, pyrgeometer, UVB radiometer, PAR radiometer, and Multi-Filter Rotating Shadowband Radiometer (MFRSR). Pyranometers measure global (i.e., total) solar radiation, pyrgeometers measure infrared radiation, and pyrheliometers measure direct solar radiation. The data logging, power distribution, and communication equipment are mounted on the central platform which also houses a barometer inside the data logger box. The platform to the south of the main platform includes an automatic sun tracker that moves the platform with the sun. Mounted on this sun tracker platform is a pyrheliometer, shaded pyrgeometer, and shaded pyranometer. The platform to the north of the main platform is a 10-meter tower that holds a downward-looking pyranometer and pyrgeometer, anemometer, and temperature and humidity probe. Each instrument and its function is outlined in Table 1 below.

Figure 2: Mobile SURFRAD station at Red Lake, Arizona
(Image source: NOAA Global Monitoring Division)

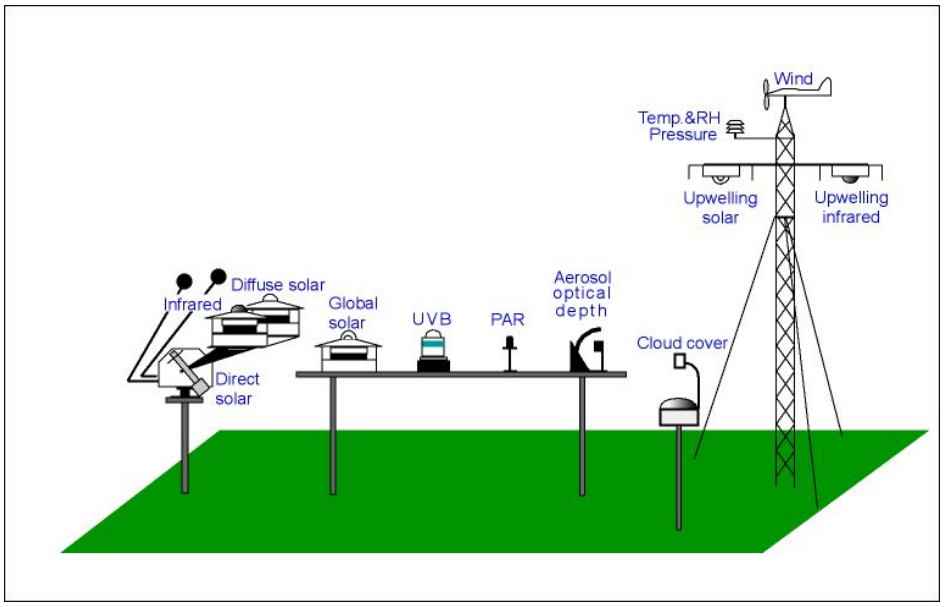


Figure 3: Diagram of the SURFRAD station configuration; the cloud imager denoted by the text "Cloud cover" on the right-hand side of the diagram was not included in the Red Lake SURFRAD station.
(Image source: NOAA SURFRAD Overview webpage)

Table 1: SURFRAD Instrument Descriptions

Platform	Instrument	Function
Central (main)	Upward looking broadband pyranometer	Measures global downwelling solar radiation
	Upward looking pyrgeometer	Measures downwelling infrared radiation

	Upward looking UVB radiometer	Measures the intensity of incoming UVB radiation
	Upward looking PAR radiometer	Measures the intensity of PAR radiation (part of the spectrum driving plant photosynthesis)
	Upward looking MFRSR	Measures global and diffuse solar radiation to obtain aerosol loading information
	Barometer	Measures station pressure
North	Anemometer	Measures wind speed and direction
	Temperature and humidity probe	Measures air temperature and relative humidity
	Downward looking pyranometer	Measures solar radiation reflected from the surface
	Downward looking pyrgeometer	Measures upwelling infrared radiation
South	Pyrheliometer	Measures direct solar radiation
	Shaded pyrgeometer	Measures diffuse infrared radiation
	Shaded pyranometer	Measures diffuse solar radiation

More information about SURFRAD can be found on the NOAA SURFRAD Overview webpage and the NOAA Global Monitoring Division Review document. An overview of the functions and differences between pyranometers, pyrgeometers, pyrheliometers, and radiometers as well as information about global solar radiation in general, is detailed in this Campbell Scientific Pyranometers Article.

Investigators

Kathleen Lantz
NOAA ESRL Global Monitoring Division
Boulder, CO

Joel Mccorkel
NASA GSFC
Greenbelt, MD

Data Characteristics

The GOES-R PLT Surface Radiance Red Lake dataset consists of surface radiation budget, UVB and PAR radiation, aerosol optical thickness, and ancillary meteorological measurements collected by a mobile SURFRAD station at Red Lake, Arizona. These files are in ASCII text and Microsoft Excel format at a Level 1B processing level. More information about the NASA data processing levels is available on the EOSDIS Data Processing Levels webpage. The characteristics of this dataset are listed in Table 2.

Table 2: Data Characteristics

Characteristic	Description
Platform	Surface Radiation Budget Network (SURFRAD) station
Instruments	Pyranometers, pyrgeometers, pyrheliometer, Ultraviolet-B (UVB) radiometer, Photosynthetically Active Radiation (PAR) radiometer, Multi-Filter Rotating Shadowband Radiometer (MFRSR), temperature and humidity probe, barometer
Spatial Coverage	N: 35.670 , S: 35.650 , E: -114.055 , W: -114.075 (Red Lake, Arizona)
Spatial Resolution	Point
Accuracy	Pyranometers & pyrheliometers*: ~15 W/m^2 Pyrgeometers*: ~5 W/m^2 UVB and PAR radiometers: 0.1 W/m^2 MFRSR: ~ 0.15 millivolts Temperature and humidity probe: 0.1 K and 0.1% Barometer: 0.1 mb
Temporal Coverage	March 27, 2017 - April 12, 2017
Temporal Resolution	Daily
Sampling Frequency	1 minute
Parameter	Radiance
Version	1
Processing Level	1B

*Note: These values are a combination of the accuracy and the uncertainty of the transfer.

File Naming Convention

The GOES-R PLT Surface Radiance Red Lake dataset files are named using the following convention:

Data files: GOES-R_SURFRAD-RadFlux_YYYYMMDD_RedLake.txt
Quality Control files: GOES-R_SURFRAD-QCRAD_YYYYMMDD_RedLake.txt

Table 3: File naming convention variables

Variable	Description
RadFlux	Radiation Flux files containing data processed with RadFlux algorithm
QCRAD	Quality-control files with output from QCRAD3 code
YYYY	Four-digit year
MM	Two-digit month
DD	Two-digit day
.txt	ASCII text file

Data Format and Parameters

The GOES-R PLT Surface Radiance Red Lake dataset files are in ASCII text format. Each file begins with a header describing the location of the instrument, latitude and longitude coordinates, PI contact information, and the data column labels and descriptions. There are two main types of files: the *RadFlux* data files and the *QCRAD* data files. Each file type is described below.

RadFlux Data Files

These files include the various measurements collected from the SURFRAD station's surface radiance observations. These data were processed using the *RadFlux* algorithm, described later in the *Algorithm* section. Following the header are the file's data fields in columnar format. These data fields are listed in Table 4 below and in the RadFlux Readme. Note: Not all of the data field labels are included in the header description.

Table 4: RadFlux Data Fields

Field Name	Description	Unit
Zdate	Date in YYYYMMDD format, based on GMT	-
Ztim	Time in hhmm format, based on GMT (Note: hh= two-digit hour; mm= two-digit minute)	-
Ldate	Date in YYYYMMDD format, based on LST	-
Ltime	Time in hhmm format, based on LST	-
CosZ	Cosine of the solar zenith angle	-
AU	Earth-sun distance (in astronomical units)	AU
SWdn	Best estimate downwelling SW from sum or global pyranometer	W m^{-2}
CSWdn	Estimated clear-sky downwelling SW	W m^{-2}
LWdn	Downwelling LW from pyrgeometer	W m^{-2}
CLWdn	Estimated clear-sky downwelling LW	W m^{-2}
SWup	Upwelling SW from pyranometer	W m^{-2}
CSWup	Estimated clear-sky upwelling SW	W m^{-2}
LWup	Upwelling LW from pyrgeometer	W m^{-2}
CLWup	Estimated clear-sky upwelling LW	W m^{-2}
DifSW	Measured downwelling diffuse SW	W m^{-2}
CDifSW	Estimated clear-sky downwelling diffuse SW	W m^{-2}
DirSW	Measured downwelling direct SW	W m^{-2}
CDirSW	Estimated clear-sky downwelling direct SW	W m^{-2}
ClrF	Clear sky flag, 1 if SW detected clear sky, 2 if LW detected, 9 if CLW>LW, 3 if only std and Ta-Te diff OK and ONLY LWup accepted as clear LWup [NOT LWdn!!!], else 0 if cloudy	-
TauF*	Tau flag, 1 if liquid g used, 2 if ice g used, 0 if not calculated	-

TlmF	T limit flag, 1 if SW Scv used, 2 if LW Scv used, 3 if avg Ec used, 4 if lim=0.965*Ta used, 5 if just config limit temp used, 0 if not calculated	-
LWScv	Estimated effective LW fractional sky cover	-
SWScv	Estimated fractional sky cover from SW	-
CldTau	Estimated effective visible cloud optical depth (only for SWScv > 0.95)	-
CldTrn	Estimated effective SW cloud transmissivity (SWdn/CSWdn ratio)	-
TeLim	Ice cloud temp limit	K
LWTe	Sky brightness temp from LWdn	K
CldTmp	Estimated effective cloud radiating temperature	K
CldHgt	Estimated effective cloud radiating height	km
Tair	Air temperature	K
VPrs	Vapor pressure	mb
RH	Relative humidity	%
RHfac	RH adjustment to Ec	%
Ec	Effective clear-sky LW emissivity	-
Wspd	Wind speed (same as input)	m/s
Aprs	Air pressure	mb
LWdTc	Downwelling LW pyrgeometer case temperature	K
LWdTd	Downwelling LW pyrgeometer dome temperature	K
LWuTc	Upwelling LW pyrgeometer case temperature	K
LWuTd	Upwelling LW pyrgeometer dome temperature	K
o_GSW	Total (global) SW from unshaded pyranometer	W m^{-2}
GCorr	IR loss correction applied to global SW measurements	-

Note: Fill value is *-9999*.
*For this field, "g" is the asymmetry parameter used to scale the cloud optical depth.

QCRAD Data Files

These quality control (QC) files contain output from the *QCRAD3* code described later in the *Quality Assessment* section. These files are in the same format as the *RadFlux* files and contain a slightly different set of data fields, 21 of which are QC test fields. The QCRAD Readme lists the *QCRAD* data fields along with relevant references. These data fields are listed in Table 5 below.

Table 5: QCRAD Data Fields

Field Name	Description	Unit
Date	Date in YYYYMMDD format, based on input time (UTC/LST/etc.)	-
Time	Time of day in hhmm format, based on input time (UTC/LST/etc.)	-
BESW	Best estimate SW, sum of direct plus diffuse if both pass QC tests, else global SW if available	W m^{-2}

GSW	Total (global) SW from unshaded pyranometer	W m^{-2}
DIF	Measured downwelling diffuse SW	W m^{-2}
DIR	Measured downwelling direct SW	W m^{-2}
SWup	Upwelling SW from pyranometer	W m^{-2}
LWdn	Downwelling LW from pyrgeometer	W m^{-2}
LWup	Upwelling LW from pyrgeometer	W m^{-2}
Ta	Air temperature	K
RH	Relative humidity	%
Prs	Station pressure (NOT adjusted to sea level)	mb
LWdTc	Downwelling LW pyrgeometer case temperature	K
LWdTd	Downwelling LW pyrgeometer dome temperature	K
LWuTc	Upwelling LW pyrgeometer case temperature	K
LWuTd	Upwelling LW pyrgeometer dome temperature	K
qc1 - qc19	*	-
gflg	Type of IR loss correction applied to global SW *	-
dflg	Type of IR loss correction applied to diffuse SW*	-
Z	Solar zenith angle	degrees
AU	Earth-sun distance (in astronomical units)	AU
ClrSW	Estimated clear-sky total downwelling SW, from user-set power law coefficient settings in configuration file	W m^{-2}
DifCorr	IR loss correction applied to diffuse (shaded) SW measurements	-
GSWCorr	IR loss correction applied to global (unshaded) SW measurements	-
UVB_down	Measured downwelling UVB	W m^{-2}
PAR_dn	Measured downwelling PAR	W m^{-2}
WindSp	Wind speed (same as input)	m/s
WindDr	Wind direction	degrees

Note: fill value -*9999*
*see *Quality Assessment* section

Additional Data Files
The Reflectance Summary File (20170404_redlake-UASsmallsite_refl_summary_NASA.xlsx) is available for 04/05/17 and summarizes reflectance measurements that are based on Analytical Spectral Devices, Inc. (ASD) spectroradiometer data with reference to a Spectralon diffuser. More information about spectroradiometers and how they work can be found on the EOSDIS Remote Sensors webpage.

Algorithm
The SURFRAD data was processed using the *RadFlux* algorithm to produce the derived parameters included in the *RadFlux* data files. This methodology uses radiative flux measurements to detect periods of clear-sky conditions and uses the measurements taken during these periods to derive products such as estimated clear-sky downwelling SW and

fractional sky cover. Additional information about the Radiation Flux Analysis technique and its development is included in the RadFlux Readme. It cites the journal articles that describe the methodologies for producing optical depth, clear-sky downwelling LW, LW effective sky cover, clear-sky LW upwelling, and cloud height estimates as well as the accuracy of these variables.

Quality Assessment

The *QCRAD* files are QC files that contain the output of the *QCRAD3* code. These files include 21 QC test fields: q1, q2, q3, q4, q5, q6, q7, q8, q9, q10, q11, q12, q13, q14, q15, q16, q17, q18, q19, gflg, and dflg. There is one quality testing flag for each test performed. See QC_Rad3_flg_key.pdf for details. The general format of the QC flags is described in Table 6 below.

Table 6: QC Flags General Format

Flag Value	Type
5-6	Global Physical Limits (PP)
3-4	2nd Level User Configurable/Global Extremely Rare (ER) and Global Comparisons. Also LW Tc and Td tests
1-2	1st Level User Configurable tests and non-definitive tests

The quality tests and flags are set in descending order, hence, the QC flag indicated represents the largest test failure value. The QC_Rad_qc_tests.pdf document goes into further detail for each QC test along with its variables, values, and calculations. Each quality test field is described below in Tables 7 - 22.

Note

T_a = air temperature in Kelvin
T_{snw} = temperature limit for albedo limit test (temperature at which snow is allowed)
T_d = pyrgeometer dome temperature
T_c = pyrgeometer case temperature

Table 7: “qc1” - “qc6” Field Descriptions

Field	Description
QC1	Global SW
QC2	Diffuse SW
QC3	Direct SW
QC4	Upwelling SW
QC5	Downwelling LW
QC6	Upwelling LW

Table 8: “qc1” - “qc6” Flag Values

Value	Description

-1	Missing data or test not possible
0	OK
2	Too high (UC)
3	Too low (ER)
4	Too high (ER)
5	Too low (PP)
6	Too high (PP)
8	Fail Rayleigh Limit test (QC2)
9	“Tracker off” (QC2 and QC3)

NOTE: If QC1, QC2, or QC3 flag value is set to "10" or greater, then that SW value was either "missing" or tested "bad" and the value was replaced by adding or subtracting the other two SW components to calculate the value. This calculated value is then tested just as the original value would have been, and might then be set to "bad" if the testing is not passed. The second digit (<10 value) represents the "normal" test flagging as described in QC_Rad3_flg_key.pdf.

Table 9: “qc7” for GSW/Sum test (non-definitive) Flag Values

Value	Description
-1	Test not possible
0	OK
1	Z < 75; GSW/Sum < 0.92, or GSW/Sum > 1.08, Sum > 50 Wm^{-2}
2	93 > Z > 75 and Sum > 50; GSW/Sum < 0.85, or GSW/Sum > 1.15, Sum > 50 Wm^{-2}

Table 10: “qc8” for Dif/GSW test (non-definitive) Flag Values

Value	Description
-1	Test not possible
0	OK
1	Z < 75; Dif/GSW > 1.05, GSW > 50 Wm^{-2}
2	93 > Z > 75; Dif/GSW > 1.10, GSW > 50 Wm^{-2}

Table 11: “qc9” for SWup vs Sum SW test Flag Values

Value	Description
-1	Test not possible
0	OK
1	Sum of GSW > 50; SWup > C_9 * Sum+25 Wm^{-2}, T_a >= T_{snw}
2	Sum of GSW > 50; SWup > C_{10} * Sum+25 Wm^{-2}, T_a < T_{snw}
3	Sum of GSW > 50; SWup > D_9 * Sum+30 Wm^{-2}, T_a >= T_{snw}
4	Sum of GSW > 50; SWup > D_{10} * Sum+30 Wm^{-2}, T_a < T_{snw}
5	Sum of GSW > 50; SWup > Sum or GSW+25; Swup “bad”
6	Sum and GSW > 50; SWup > Both Sum and GSW+25; Swup “bad”

Table 12: “q10” for LWdn to T_a test Flag Values

Value	Description
-1	Test not possible
0	OK
1	LWdn < C_{11} *sigma*T_a^4
2	LWdn > sigma* T_a^4+C_{12}
3	LWdn < D_{11}*sigma*T_a^4
4	LWdn > sigma* T_a^4 + D_{12}

Table 13: “qc11” for LWup to T_a test Flag Values

Value	Description
-1	Test not possible
0	OK
1	LWup < sigma*(T_a-C_{13})^4
2	LWup > sigma*(T_a+C_{14})^4
3	LWup < sigma*(T_a-D_{13})^4
4	LWup > sigma*(T_a+D_{14})^4

Table 14: “qc12” for LWdn to LWup test Flag Values

Value	Description
-1	Test not possible
0	OK
1	lwdn < lwup-C_{15}
2	lwdn > lwup+C_{16}
3	lwdn < lwup-D_{15}
4	lwdn > lwup+D_{16}

Table 15: “qc13” for LWdn T_c vs T_a Flag Values

Value	Description
-1	Test not possible
0	OK
3	T_c < T_a - C_{17}
4	T_c > T_a + C_{17}
5	T_c < T_{avg} - 15
6	T_c > T_{avg} + 15

Table 16: “qc14” for LWdn T_d vs T_a Flag Values

Value	Description
-1	Test not possible
0	OK
3	T_d < T_a - C_{17}
4	T_d > T_a + C_{17}
5	T_d < T_{avg} - 15

6	$T_d > T_{avg} + 15$

Table 17: “qc15” for LWup T_c vs T_a Flag Values

Value	Description
-1	Test not possible
0	OK
3	$T_c < T_a - C_{17}$
4	$T_c > T_a + C_{17}$
5	$T_c < T_{avg} - 15$
6	$T_c > T_{avg} + 15$

Table 18: “qc16” for LWup T_d vs T_a Flag Values

Value	Description
-1	Test not possible
0	OK
3	$T_d < T_a - C_{17}$
4	$T_d > T_a + C_{17}$
5	$T_d < T_{avg} - 15$
6	$T_d > T_{avg} + 15$

Table 19: “qc17” for LWdn T_c vs T_d Flag Values

Value	Description
-1	Test not possible
0	OK
3	$(T_c - T_d) < C_{18}$
4	$(T_c - T_d) > C_{19}$

Table 20: “qc18” for LWup T_c vs T_d Flag Values

Value	Description
-1	Test not possible
0	OK
3	$(T_c - T_d) < C_{18}$
4	$(T_c - T_d) > C_{19}$

Table 21: “qc19” for T_a testing Flag Values

Value	Description
-1	Test not possible (no T_a)
0	OK
3	T_a > Tmax or T_a < Tmin
4	T_a more than T_{avg} +/- 20 K

The *QCRAD3* code can correct for infrared (IR) lost for diffuse and global irradiance. The type of correction that was applied is indicated in the "gflg" and "dflg" fields, described in Table 22 below.

Table 22: "gflg" and "dflg" Field IR Correction Types

Flag Value	Type
0	None
1	Full dry
2	Full moist
3	Detector dry
4	Detector moist

The SURFRAD station's instruments undergo various calibration procedures. In addition, the combined measurements of global, direct, and diffuse radiation provide QC of the data by enabling comparison between each of these radiation measurement types to ensure accuracy.

Software

No special software is needed to view these SURFRAD ASCII data files. These files can be viewed in any text file reader such as Notepad. The Microsoft Excel file can be opened in spreadsheet software.

Known Issues or Missing Data

A fill value of -9999 indicates "bad" or missing data.

References

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Related Data

All data collected by other instruments during GOES-R PLT are considered related datasets. They can be located using the GHRC HyDRO2.0 search tool and entering the term 'GOES-R PLT' in the search box.

Contact Information

To order these data or for further information, please contact:

NASA Global Hydrology Resource Center DAAC
User Services
320 Sparkman Drive
Huntsville, AL 35805
Phone: 256-961-7932
E-mail: support-ghrc@earthdata.nasa.gov
Web: https://ghrc.nsstc.nasa.gov/

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