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# The QCRad Value Added Product: Surface Radiation Measurement Quality Control Testing, Including Climatology Configurable Limits

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## 1. Introduction

This document describes the QCRad methodology, which uses climatological analyses of the surface radiation measurements to define reasonable limits for testing the data for unusual data values. The main assumption is that the majority of the climatological data are "good" data, which for field sites operated with care such as those of the Atmospheric Radiation Measurement (ARM) Program is a reasonable assumption. Data that fall outside the normal range of occurrences are labeled either "indeterminate" (meaning that the measurements are possible, but rarely occurring, and thus the values cannot be identified as good) or "bad" depending on how far outside the normal range the particular data reside. The methodology not only sets fairly standard maximum and minimum value limits, but also compares what we have learned about the behavior of these instruments in the field to other value-added products (VAPs), such as the Diffuse infrared (IR) Loss Correction VAP (Younkin and Long 2004) and the Best Estimate Flux VAP (Shi and Long 2002).

## 2. Definitions

In this document, we refer to various quantities related to the measurements and tests. Although many are discussed more fully in the text, we provide here a brief listing for reference.

SZA = solar zenith angle
$\mu_0$ = Cos(SZA)
Note: In the formulas used for QCRad testing, if SZA > 90°, $\mu_0$ is set to 0.0 in the formula
$S_0$ = solar constant at mean Earth-Sun distance, QCRad uses a value of 1368 $Wm^{-2}$
AU = Earth – Sun distance in Astronomical Units [1 AU = mean E-S distance]
$S_a = S_0/AU^2$ = solar constant adjusted for Earth – Sun distance
Sum SW = [Diffuse SW + (Direct Normal SW) x $\mu_0$]
$\sigma$ = Stephan-Boltzman constant = 5.67 x 10-8 $Wm^{-2}$ $K^{-4}$
$T_a$ = air temperature in Kelvin [must be in range 170 K < $T_a$ < 350 K]
$T_d$ = pyrgeometer dome temperature
$T_c$ = pyrgeometer case temperature
$T_{snw}$ = temperature limit for albedo limit test, temp at which "snow" limit is allowed
Global SWdn: SW measured by unshaded pyranometer
Diffuse SW: SW measured by shaded pyranometer
Direct Normal SW: direct normal component of SW
Direct SW: direct normal component of SW times the cosine of SZA
[(Direct Normal SW) x $\mu_0$]
$LW_{dn}$: downwelling LW measured by a pyrgeometer
$LW_{up}$: upwelling LW measured by a pyrgeometer
Prs: surface station pressure in millibars (not adjusted to sea level)

## 3. Data Tests Applied

In many cases, three levels of testing are applied for the QCRad methodology. These levels are defined in order of their severity as far as data falling outside the limits. A data Quality Control (QC) flag value of "0" indicates that the data have not failed any of the tests applied and, as far as we can tell, represent "good" data. The greater the QC flag value, the more the data fall outside the normal range of values typically seen for the quantity represented. The QCRad code applies testing using the largest limits first and, if the data passes that testing, applies the next smaller limits testing. Thus, the flag value represents the level of severity at which the tested data failed. The larger the QC flag integer value, the more severe the testing failure. In general, an odd QC flag value indicates a measurement that falls below the corresponding minimum limit, while an even value indicates a measurement that falls above the corresponding maximum test limit. The one exception is when a specific test is not possible, usually because some value needed to perform the test is not available. In this case, a QC flag value of "-1" is assigned, which means that the data could not be tested in that way. For example, if the ambient air temperature measurements are missing or deemed "bad," then the tests based on using the air temperature cannot be performed, and the corresponding flags are set to "-1." A flag of "-1" does not mean the data are "bad," merely that the particular test could not be applied; therefore, we do not know if it would have passed or failed if it had been tested that way.

For the QCRad VAP, we set the smallest testing limits to reflect the range within which the majority of data typically fall. We then set the next largest limits to include data that have been recorded at the site and have shown to be possible, but rarely occur so they may also be "bad" data. In this latter case, the QC flags are set to a value of either 1 or 2 as appropriate, but the data value itself is left in the output files. The intent is to flag these values as "possible, but rarely occurring," and it is left to the user to determine whether or not to use these data. Any data that fall outside the second level of testing are deemed to be "bad;" the QC flag value is set to either 3 or 4; and the corresponding data are set to a "bad" value of "-9999.0" (i.e., the data value is not given to the user).

For the shortwave (SW) variables, limits typically are set using the cosine of the solar zenith angle as the independent variable. For the longwave (LW), some tests apply simple maximum and minimum limits on acceptable values. Other tests use the high degree of correlation known to exist between the surface 2-meter ambient air temperature and typical ranges of measured LW for the particular climate.

## 3.1 Temperatures

The QCRad code uses air temperature measurements, if available, to help determine limits and tests for reasonable data. The availability of air temperature measurements is especially beneficial for testing LW data. However, before using any air temperature measurements, we need to test them for reasonable values to avoid using "bad" data to test other related data. Thus, if the input data includes pyrgeometer case and dome temperatures, and/or air temperature, then these temperatures are tested by:

$$T_{min} < T_x < T_{max}$$

Where $T_{min}$ and $T_{max}$ are user-defined minimum and maximum limits, respectively, determined using analysis of climatological data, and $T_x$ is the temperature value being tested. Then if each $T_c$-$T_d$ pair is within +/- 10 K of each other, they are included in producing an average of all $T_c$ and $T_d$ values that pass the testing. $T_a$ must then fall within +/- 20 K of this average, and each individual $T_c$ and $T_d$ must fall within +/- 15 K of this average, else the value is set to -9999.

### 3.2 Physically Possible Limits (based on global analyses) per Baseline Surface Radiation Network (Quality Control Flags set to 5 or 6)

The Baseline Surface Radiation Network (BSRN) is comprised of groups of researchers from around the world dedicated to the long-term, accurate measurement of the surface radiation budget for climate and climate change research purposes, under the auspices of the World Meteorological Organization (WMO) World Climate Research Program (WCRP). The BSRN is also charged with setting the standards by which accurate surface radiation measurements might be accomplished (Ohmura et al. 1998; WMO 1996), including testing for physically reasonable values given the wide range of conditions found over the entire globe. (The Data Archive for BSRN is hosted at ETH in Zurich, Switzerland, under the guidance of Dr. Atsumu Ohmura. For more information on BSRN, see http://bsrn.ethz.ch/.) The BSRN has established "globally physically possible" limits for surface radiation measurements (Long and Dutton 2002), which we include in the QCRad testing. For these "globally physically possible" tests, any measurement that falls outside the limit is given a QC flag value of 5 (if it falls below the minimum limit) or 6 (if it falls above the maximum limit), and the corresponding data value is set to "-9999.0."

The formulas used for these tests for each tested variable are as follows:

Global SWdn
- Min: -4 $Wm^{-2}$
- Max: $S_a$ x 1.5 x $\mu_0^{1.2}$ + 100 $Wm^{-2}$

Diffuse SW
- Min: -4 $Wm^{-2}$
- Max: $S_a$ x 0.95 x $\mu_0^{1.2}$ + 50 $Wm^{-2}$

Direct Normal SW
- Min: -4 $Wm^{-2}$
- Max: $S_a$
- [for Direct SW, Max: $S_a$ x $\mu_0$]

SWup
- Min: -4 $Wm^{-2}$
- Max: $S_a$ x 1.2 x $\mu_0^{1.2}$ + 50 $Wm^{-2}$

LWdn
- Min: 40 $Wm^{-2}$
- Max: 700 $Wm^{-2}$

LWup
- Min: 40 $Wm^{-2}$
- Max: 900 $Wm^{-2}$

### 3.3 Extremely Rare Minimum Limits (based on global analyses) per Baseline Surface Radiation Network (Qality Control Flags set to 3)

Additionally, the QCRad code uses the BSRN defined second-level testing limits for minimum acceptable values for SW measurements as follows:

Global SWdn
Min: -2 $Wm^{-2}$

Diffuse SW
Min: -2 $Wm^{-2}$

Direct Normal SW
Min: -2 $Wm^{-2}$

SWup
Min: -2 $Wm^{-2}$

### 3.4 Comparison Tests (based on global analyses) per Baseline Surface Radiation Network

Finally, the BSRN has defined the following comparison tests, which are included:

Ratio of Global over Sum SW:
(Global)/(Sum SW) should be within +/- 8% of 1.0 for SZA < 75°, Sum > 50 $Wm^{-2}$
(Global)/(Sum SW) should be within +/- 15% of 1.0 for 93° > SZA > 75°, Sum > 50 $Wm^{-2}$
For Sum SW < 50 $Wm^{-2}$, test not possible

Diffuse Ratio:
(Dif SW)/(Global SW) < 1.05 for SZA < 75°, GSW > 50 $Wm^{-2}$
(Dif SW)/(Global SW) < 1.10 for 93° > SZA > 75°, GSW > 50 $Wm^{-2}$
For Global SW < 50 $Wm^{-2}$, test not possible

SWup Comparison:
SWup < (Sum SW) [or Global SW if Sum SW missing or "bad"]
For Sum SW [or Global SW] > 50 $Wm^{-2}$
For Sum SW [or Global SW] < 50 $Wm^{-2}$, test not possible
If SWup > (Sum SW) AND SWup > (Global SW), Swup = "bad"

Note: the first two tests are "non-definitive;" (i.e., while data may fail the tests, it is unknown which of the data used to calculate the ratio are problematic. In these cases, the corresponding QC flags are set to values of 1 or 2, and no corresponding data values are set to "-9999.0." For the SWup test, failure results in QC flag values of 5 or 6, and the SWup data set to "-9999.0."

### 3.5 Climatological (Configurable) Limits

All of the previous limits discussed so far are "hard wired" into the QCRad code. What follows are limits that are configured for each site based on analyses of several years of the site data. Those limits labeled "1st level" are the "smallest" testing limits described previously, while those labeled "2nd level" are the second set of limits where failure causes the data value being tested to be set to "-9999.0." The specific formulas for these tests are as follows:

<u>Global SWdn</u>:

Max: $S_a \times D_1 \times \mu_0^{1.2} + 55\ Wm^{-2}$ (2nd level)
Max: $S_a \times C_1 \times \mu_0^{1.2} + 50\ Wm^{-2}$ (1st level)

<u>Diffuse SW</u>:

Max: $S_a \times D_2 \times \mu_0^{1.2} + 35\ Wm^{-2}$ (2nd level)
Max: $S_a \times C_2 \times \mu_0^{1.2} + 30\ Wm^{-2}$ (1st level)

<u>Direct Normal SW</u>:

Max: $S_a \times D_3 \times \mu_0^{0.2} + 15\ Wm^{-2}$ (2nd level)
[for Direct, Max: $S_a \times D_3 \times \mu_0^{1.2} + 15\ Wm^{-2}$] (2nd level)
Max: $S_a \times C_3 \times \mu_0^{0.2} + 10\ Wm^{-2}$ (1st level)
[for Direct, Max: $S_a \times C_3 \times \mu^0_{1.2} + 10\ Wm^{-2}$] (1st level)

<u>SWup</u>:

Max: $S_a \times D_4 \times \mu_0^{1.2} + 55\ Wm^{-2}$ (2nd level)
Max: $S_a \times C_4 \times \mu_0^{1.2} + 50\ Wm^{-2}$ (1st level)

<u>LWdn</u>:

Min: $D_5\ Wm^{-2}$ (2nd level)
Max: $D_6\ Wm^{-2}$ (2nd level)
Min: $C_5\ Wm^{-2}$ (1st level)
Max: $C_6\ Wm^{-2}$ (1st level)

<u>LWup</u>:

Min: $D_7\ Wm^{-2}$ (2nd level)
Max: $D_8\ Wm^{-2}$ (2nd level)
Min: $C_7\ Wm^{-2}$ (1st level)
Max: $C_8\ Wm^{-2}$ (1st level)

### 3.6 Climatological (Configurable) Comparisons

The QCRad code makes use of cross-comparisons between measured and calculated variables. One calculated variable is a generic estimate of the expected clear-sky downwelling SW as a product from a power law formula where the user specifies the "a" and "b" coefficients (see below), and again the cosine of the solar zenith angle ($\mu_0$) is used as the independent variable. The use of a power law formulation has been shown to well represent downwelling SW for clear skies (Long and Ackerman 2000; Long and Gaustad 2004). The clear-sky SW estimate is used in the first test listed below, which tests for whether or not the solar tracker was properly tracking the sun. If the ratio of the measured over clear-sky SWdn is greater than 0.85, this indicates that most of the possible SWdn is reaching the unshaded pyranometer; i.e., there is no significant cloudiness between the sun and the instrument. At the same time, if the corresponding ratio of the shaded pyranometer (supposedly measuring the diffuse SW) over the unshaded pyranometer is also greater than 0.85, then the "shaded pyranometer" has become unshaded because these are mutually exclusive conditions. For times when there is a cloud between the sun and the unshaded pyranometer, this test does not work; however, the "sum of direct plus diffuse" is valid because there is no significant direct component.

Another calculated variable is an estimate of the expected clear-sky diffuse SW produced by Rayleigh (molecular) scattering only. A non-overcast diffuse measurement, which occurs with at least some additional scattering due to the presence of aerosols or haze in the atmospheric column, should never fall below the Rayleigh limit. If the measured station pressure (not adjusted to equivalent sea-level pressure) is available, then it is used in the formula given below, else a generic station pressure set by the user is used in the calculation. This formula was produced as part of the development of the ARM Diffuse IR Loss Correction VAP, and details are presented in Younkin and Long (2004).

For testing the upwelling SW, we use the air temperature, if available, to refine the limits for whether snow-covered ground (with attendant high surface albedo) is possible. When the ground is completely covered with snow, virtually all the net radiative energy input into the surface goes toward changing the snow from solid to liquid (i.e., changing the phase). Thus, snow-covered ground cannot be more than zero degrees Centigrade in temperature (although it can be lower in temperature). Thus, in turn, the snow-covered ground cannot drive the air above it (through conduction and convection) to air temperatures greater than freezing until significant portions of the ground become uncovered through snow melt. Even blowing air over snow-covered ground (over the surrounding domain) will usually remain near freezing due to low-level turbulent mixing. Thus, we set an air temperature limit above which the allowable albedo limits are much more restrictive. This air temperature setting must account for the possibility that, during snow melt as the ground becomes more and more uncovered, the air temperature can climb significantly above freezing. How much above freezing depends to large extent on the nature of the surface roughness present. For example, at the Southern Great Plains (SGP) Central Facility, tall dried stalks usually stand in the area where the radiometer systems are located, while at the same time deep snow-fall events are not usual. Thus for the SGP, we use an air temperature limit of 8°C. For data that occur when temperatures are above 8°C, the allowable albedo is more restricted than when the air temperatures fall below 8°C. Using air temperature to help determine the albedo limit does not guarantee that the colder data are well tested, because lower air temperatures can and often do occur in winter months with no snow present. However, using air temperature as an aid improves the testing of data during warmer conditions more than just using an albedo limit all year that allows for snow-covered ground.

The air temperature measurements are also used to test the pyrgeometer case and dome temperatures directly. Given that the case and dome temperatures are used to the $4^{th}$ power in the formulations that calculate the LW irradiance, even a few degrees error can produce significant error in the LW calculations. Since all ARM downwelling radiometers are ventilated, and the upwelling radiometers are protected by sun shields, the case and dome temperatures should always be within some small range of the ambient air temperatures.

Finally, the downwelling LW is compared to the corresponding upwelling LW to test for consistency. Similar to the air temperature, the upwelling and downwelling LW over land surfaces is physically correlated, and thus should fall within certain values in relation to one another.

The specific formulas for the above cross-comparison tests are as follows:

<u>"Tracker off" test</u>:
Using ClrSW = $[a/AU^2] \times \mu_0^b$, where "a" and "b" are configured by user
Then for dif > 50 $Wm^{-2}$,
if (Sum SW)/ClrSW > 0.85 [or Global SW if Sum SW missing or "bad"]
AND if Dif/(Sum SW) > 0.85 [or Global SW if Sum SW missing or "bad"]
Then the tracker is not properly following the sun

<u>Rayleigh Limit Diffuse Comparison</u>:

Rayleigh ($R_L$) diffuse SW is estimated using:

$$R_L = a\mu_0 + b\mu_0^2 + c\mu_0^3 + d\mu_0^4 + e\mu_0^5 + f\mu_0 Prs$$

Where:

a = 209.3
b = -708.3
c = 1128.7
d = -911.2
e = 287.85
f = 0.046725
$\mu_0$ = cosine of the solar zenith angle
Prs = station surface pressure in millibars

If Global SW is greater than 50 $Wm^{-2}$, and (Diffuse SW)/(Global SW) is less than 0.8, and diffuse SW is less than ($R_L$-1.0), then diffuse is set to "bad," QC2 is set to "8"

<u>SWup comparison</u>:
SWup < $C_x$ x (Sum SW) + 25 $Wm^{-2}$ [or Global SW if Sum SW missing or "bad"]
For Sum SW [or Global SW] > 50 $Wm^{-2}$
For Sum SW [or Global SW] < 50 $Wm^{-2}$, test not possible
$D_9$ and $C_9$ if $T_a > T_{snw}$ limit ("normal" ground cover)
$D_{10}$ and $C_{10}$ if $T_a < T_{snw}$ limit (ground may be "snow covered")
NOTE: if limit greater than Sum SW+25, set equal to Sum SW +25
[or Global SW if Sum SW missing or "bad"]
$T_{snw}$ = Temperature limit for test, degrees C, > 0°C

If SWup is greater than the 1st level limit, but less than the 2nd level limit, then the QC flag is set to "1" for $T_a > T_{snw}$ or "2" for $T_a < T_{snw}$, else if SWup is greater than the 2nd level limit, SWup is set to "bad," QC flag is set to "3" or "4" as appropriate.

LWdn to Air Temperature comparison
$D_{11} \times \sigma T_a^4 < LWdn < \sigma T_a^4 + D_{12}$ (2nd level)
$C_{11} \times \sigma T_a^4 < LWdn < \sigma T_a^4 + C_{12}$ (1st level)

LWup to Air Temperature comparison
$\sigma(T_a - D_{13}\ K)^4 < LWup < \sigma(T_a + D_{14}\ K)^4$ (2nd level)
$\sigma(T_a - C_{13}\ K)^4 < LWup < \sigma(T_a + C_{14}\ K)^4$ (1st level)

For the above two tests, if the value of the variable being tested (LWdn or LWup) falls outside the limits, the QC flag is set to "1" if less than the 1st level limit, but greater than the 2nd level limit; "2" if greater than the 1st level limit, but less than the 2nd level limit; "3" if less than the 2nd level limit, or "4" if greater than the 2nd level limit. For QC flags greater than a value of "2," the data value is set to "bad" (i.e. -9999.0).

LWdn to Lwup comparison
$LWup - D_{15}\ Wm^{-2} < LWdn < LWup + D_{16}\ Wm^{-2}$ (2nd level)
$LWup - C_{15}\ Wm^{-2} < LWdn < LWup + C_{16}\ Wm^{-2}$ (1st level)

For the above test, if the value of the LWdn falls outside the limits, the QC flag is set to "1" if less than the 1st level limit, but greater than the 2nd level limit; "2" if greater than the 1st level limit, but less than the 2nd level limit; "3" if less than the 2nd level limit, or "4" if greater than the 2nd level limit. Since this is a non-definitive test (i.e., for failure beyond the 2nd level limits, we do not know which radiometer was "bad"), no data values themselves are set to "bad," only the QC flags are set.

Test/Compare $T_a$, $T_c$, $T_d$

$T_a - C_{17} < T_x < T_a + C_{17}$ (1st level)
(for both $LW_{dn}$ and $LW_{up}$ instruments. If have all 3, can determine "bad" one)
If $T_a$ not available, test not possible.

$C_{18} <= (T_c - T_d) < C_{19}$
If $T_c$ and/or $T_d$ "bad," test not possible.

### 3.7 Standard Deviation Testing for the Precision Infrared Radiometer Case and Dome Temperatures

There have been instances where for some period of time the pyrgeometer case and/or dome temperature exhibits significantly noisy behavior. Since these temperatures are taken to the 4th power in the equation to calculate the LW irradiances, this "noisy" behavior results in an extremely noisy time series of LW measurements. Whether this "noisy" behavior is caused by problems with the thermistor, or the system data logger channels, or some other cause is unknown; however, our investigations have shown that during these "noisy" occurrences the accuracy of the LW data are invariably negatively impacted. We include testing for this "noisy" behavior by calculating the running standard deviation over an 11-minute time period, and then comparing that standard deviation to a standard deviation calculated over the same 11-minute time period, but using running 11-minute averages calculated from the data, instead of the data themselves. In this way, the standard deviation calculated from the "smoothed" data captures the real variability of the LW time series due to physical causes, which are naturally somewhat slowly evolving. A comparison of the "smoothed" standard deviation to a standard deviation calculated from the 1-minute measurements easily detects times when the case/dome temperature "noise" problem is occurring. The formulation of these tests are as follows:

$$Tc(d)\_sdev - Tc(d)\_avg\_sdev > 0.1 \text{ data is BAD}$$

Where:

Tc(d)_stdev = 11-minute running standard deviation of the Case (Dome) precision infrared radiometer (PIR) Temperature (K)
Tc(d)_avg_stdev = 11-minute running standard deviation of the 11-minute running average of the Case (Dome) PIR Temperature (K)

For a more detailed description of the running standard deviation comparison test and its development, see ARMTR-009 "Improved Correction of IR Loss in Diffuse Shortwave Measurements: An ARM Value-Added Product" (Younkin and Long 2004) Section 3.1.2.1.5.

### 3.8 Global Shortwave Corrections

Studies have shown (Shi and Long 2003 and 2006) that unshaded pyranometer measurements suffer IR loss similar to the precision spectral pyranometer (PSP) diffuse SW measurements. A VAP has been developed (Younkin and Long 2004) to correct the diffuse IR loss. Another VAP is currently being developed to deal with the IR loss in the unshaded pyranometer measurements. In the QCRad VAP, a generic correction coefficient, which is obtained through historical data analyses at each site, is applied to the unshaded pyranometer measurements.

ARM radiometers are typically replaced each year with newly calibrated units, though at different dates. To nominally correct for IR loss in global SW (GSW) data, we examined all the data from the different radiometer pairs, separated as moist and dry modes as determined by the relative humidity and the differences between the pyrgeometer case temperature and the effective sky brightness temperature per Younkin and Long (2004). The nighttime GSW data are then compared to the detector flux, and generic correction coefficients are obtained for each site and facility (Section 9.2). The generic correction coefficients are then used to nominally correct for IR loss in the unshaded pyranometer measurements for data testing (see discussion and figures in Section 4.1).

## 4. Example Plots of Testing Limits

### 4.1 Shortwave Examples

Three years of radiation measurement data (1997, 1999, and 2002) from the twenty Extended Facilities of the ARM SGP network were examined to determine the appropriate climatological limits for all SGP network facilities. The following plots illustrate the various tests outlined above, using examples from the SGP Central Facility. The data from the ARM Diffuse Correction VAP (Younkin and Long 2004) were used as input. Figure 1 shows the maximum limits used for downwelling total (global) SW testing, as well as 15-minute averages of the unshaded pyranometer data from 1997. Most data fall below the 1st level limit (green) as expected, with only a few data falling above the 2nd level (blue) and BSRN Physically Possible (red) limits. The "thickness" of these limit lines on the plot are caused by the changes in Earth-Sun distance throughout the year. The yellow line is the estimated clear-sky SW used in the solar tracker alignment testing described previously. Note the points from a SZA of about 65 degrees upward that reside above the limits and increase as the SZA increases. These data have the wrong date/time stamp associated with them.

Figure 2 shows similar results as Figure 1, but for diffuse SW. Here also is evidence of the same date/time stamp problem as with the unshaded pyranometer data. In this plot, the pink dots represent the data that have failed the solar tracker alignment testing. Note that no data have failed the Rayleigh limit testing, indicating that these data have been corrected for IR loss. Figure 3 shows the results for direct SW. In the case of the direct SW, the maximum limits are comparatively easier to set, since generally a problem such as debris on the window or loss of solar tracking results in a decrease in direct SW, and the narrow field-of-view precludes the instrument being subjected to positive cloud effect (irradiance greater than the corresponding clear-sky amount), which affect the total and diffuse SW.

Figures 4 and 5 show cross-comparison tests in the form of ratios. The ratio of the GSW measured by the unshaded pyranometer over the sum of the direct plus diffuse SW is shown in Figure 4. Ideally this ratio should be 1.0, but instrument characteristics such as cosine response error often produce values away from unity. Additionally, IR loss from the unshaded pyranometer values (numerator), when there is no significant IR loss in the sum (denominator) as in this case where the diffuse SW has been corrected for IR loss, produces decreasing ratio values with increasing SZA that looks like cosine response error. Recent research (Reda et al. 2005) has indicated that unshaded pyranometers suffer about the same magnitude of IR loss as the same units operated in shaded mode. We determined an average generic set of moist and dry-mode nighttime offset coefficients from examination of many years of data, and applied the same type of detector only correction methodology as the Diffuse Correction VAP, but in this case, we applied it to the unshaded pyranometer data (see Younkin and Long 2004 for details). In Figure 4, the red data use uncorrected GSW, while the black data use GSW that has been corrected for IR loss using the same methodology as was used to correct the diffuse SW. Note that a significant number of the uncorrected data fail this ratio test because of the lower values at higher SZA, whereas the IR loss-corrected GSW ratios pass the testing. Figure 5 shows the ratio of Diffuse SW over GSW, again with red data using uncorrected GSW, and black using corrected GSW. With IR loss in this case in the denominator, many of the uncorrected points fall above the maximum limit and fail the test, where with corrected GSW these points pass.

It must be noted that the testing represented in Figures 4 and 5 are non-definitive; i.e., a test failure gives no indication which of the measurements involved caused the failure. Thus, for these non-definitive test failures none of the corresponding measurements are ever set to "-9999.0," rather only the corresponding QC flag is set to the appropriate value.

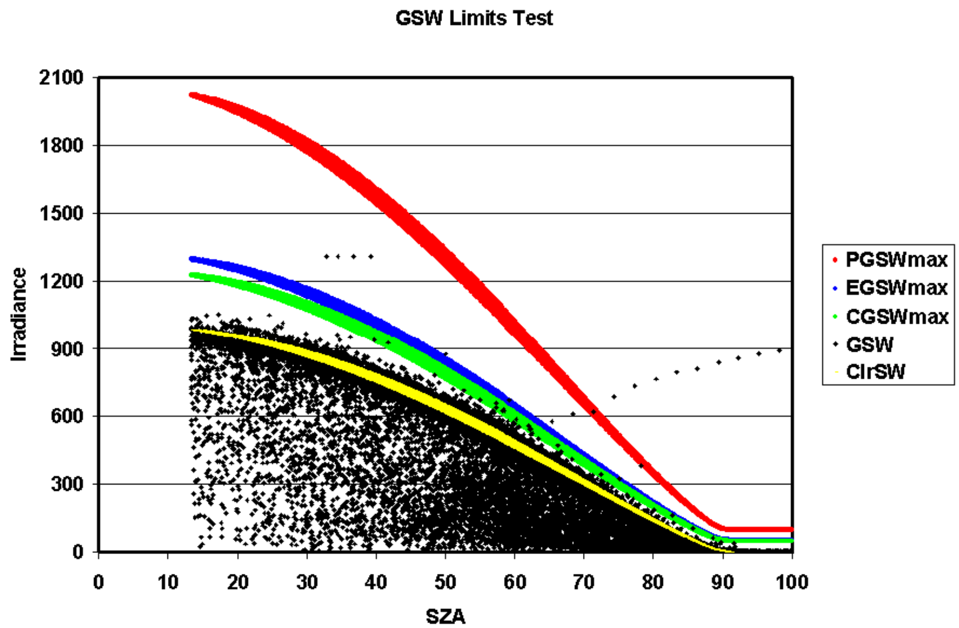


**Figure 1**: Fifteen-minute averages of downwelling total (global) SW (black), the 1st (green), 2nd (blue) and BSRN Physically Possible (red) maximum limits used in testing. Yellow is the estimated clear-sky downwelling SW.

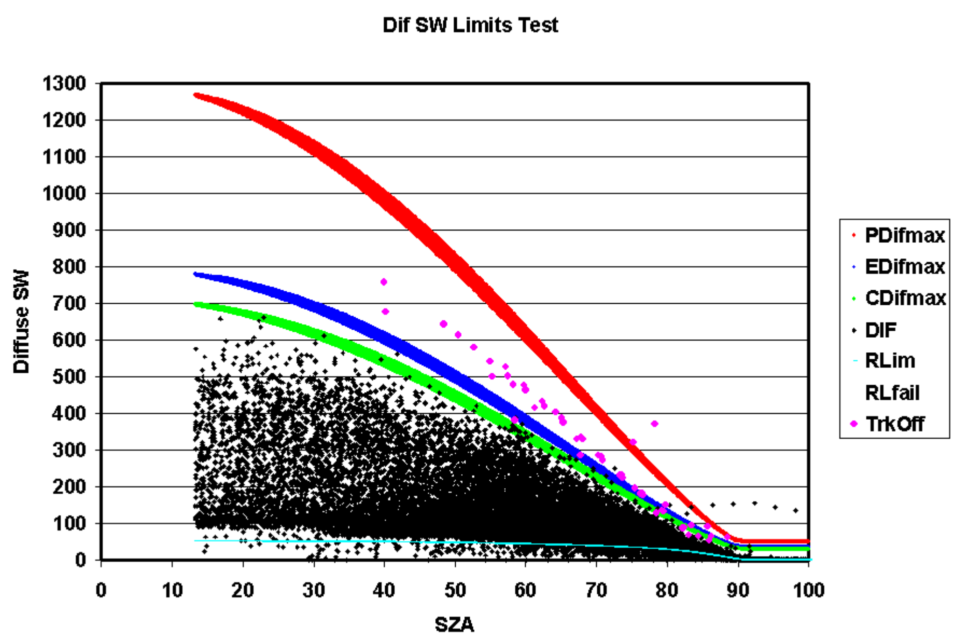


**Figure 2**: Same as Figure 1, but for diffuse SW. Light blue is the estimated Rayleigh diffuse limit and pink are the data that failed the solar tracker alignment testing.

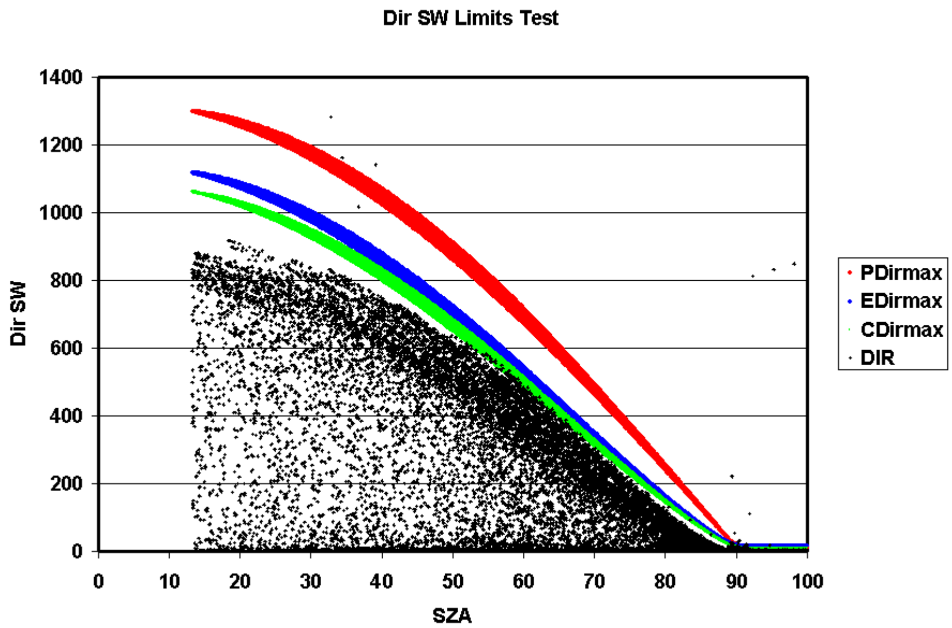


**Figure 3**: Same as Figure 1, but for direct SW.

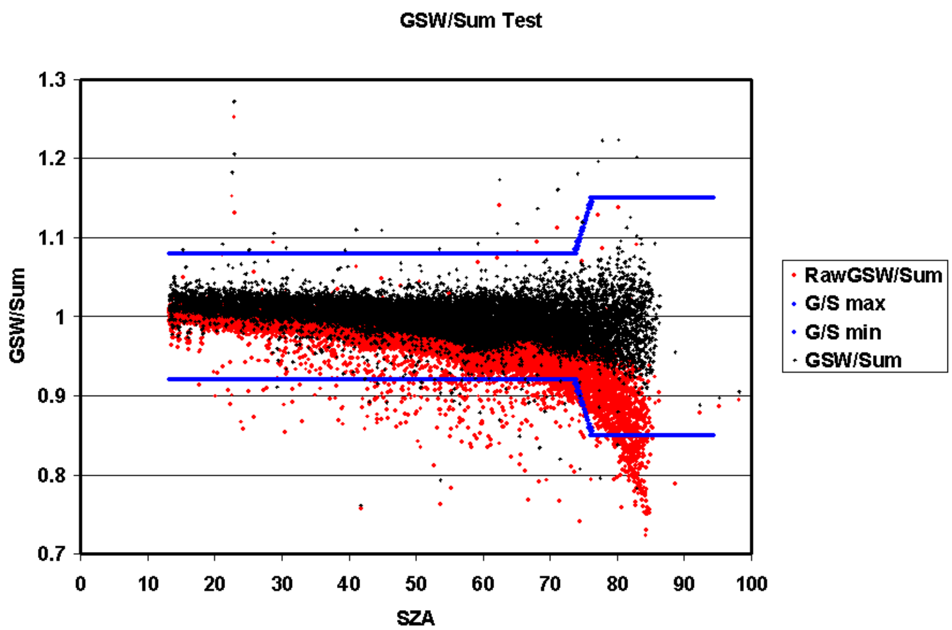


**Figure 4:** Ratio of global SW over the sum of direct plus diffuse SW. Red is original GSW uncorrected for IR loss, black is corrected data. Blue lines denote testing maximum and minimum limits.

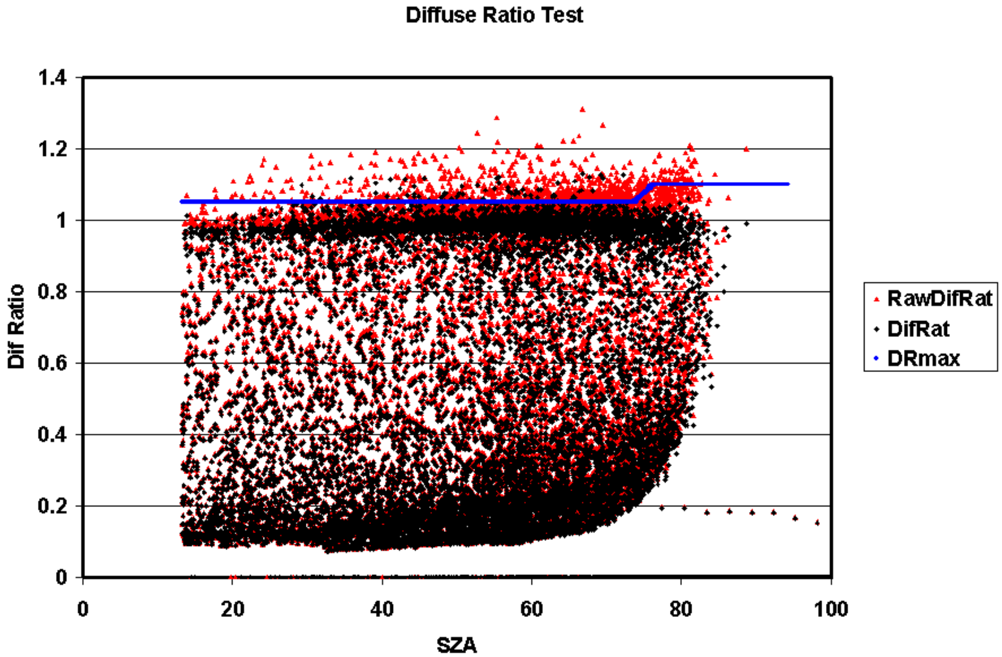


**Figure 5:** Ratio of diffuse SW over GSW. Red is original GSW uncorrected for IR loss, black is corrected data. Blue line denotes testing maximum limit.

For the upwelling SW, we first apply testing similar to that for the GSW, as shown in Figure 6. In this case, however, we must allow limits that include the possibility of snow-covered ground, here with occurrences indicated by the greater SWup values at SZA greater than 55°. As previously described, we also use the ambient air temperature to screen for when snow-covered ground is highly unlikely, and thus can better test the data for air temperatures above the set discrimination limit. Figure 7 shows the results for our example data using an air temperature limit of 8°C for SGP. As can be seen, there are occurrences of data when the air temperature was at or below 8°C that would have passed the more stringent limit testing, but the snow-covered ground data would have failed the more stringent test limits. Using the air temperature to discriminate which limits should be used allowed the snow-covered data to pass, but does a much better job of testing the SWup data for warmer times than using the snow-covered ground limits at all times.

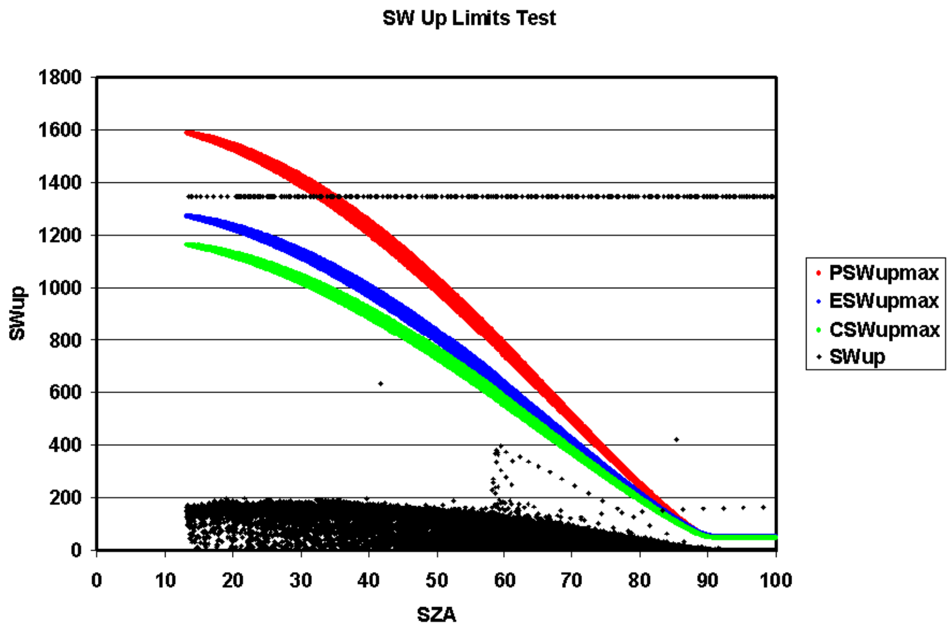


**Figure 6:** Same as Figure 2, but for upwelling SW.

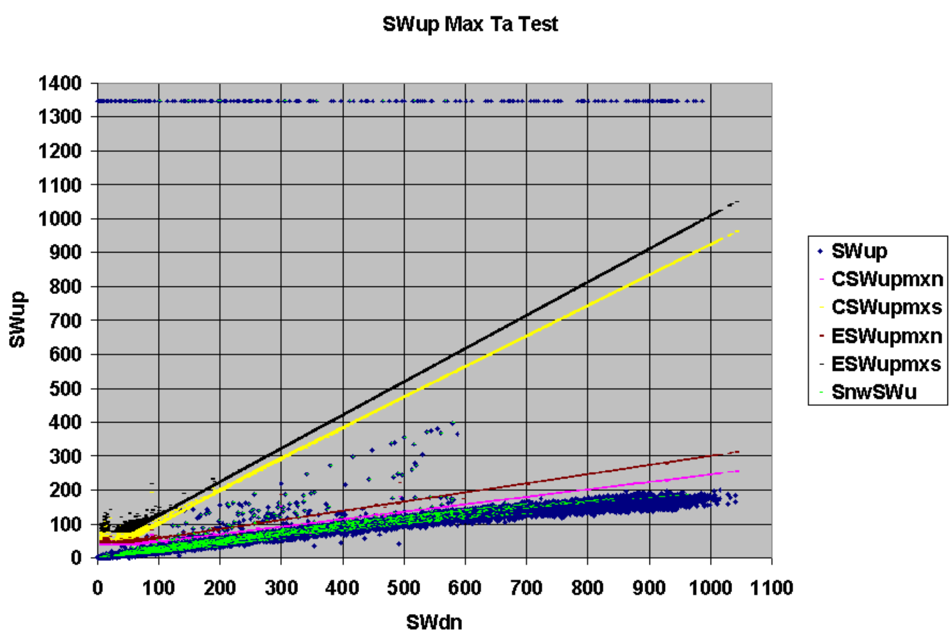


**Figure 7:** Upwelling SW testing using air temperature as a limit discriminator. Yellow and black lines represent the 1st and 2nd level limits for when the air temperature is below the set limit, and snow-covered ground is possible. Pink and brown lines are the 1st and 2nd level limits for warmer temperatures when snow-covered ground is far less likely. Blue is the measured SWup, green is the SWup when the air temperature is below the discrimination limit.

## 4.2 Longwave Examples

For the downwelling and upwelling LW, we first use simple maximum and minimum limits as shown in Figure 8. Figure 9 illustrates using ambient air temperature for testing the LW data, based on the previously noted high degree of correlation between the two as seen here. The 1st and 2nd level maximum and minimum limits are calculated using the formulas previously given, and provide a nominal shape to the limit curves that approximate the nature of the air temperature—LW relationships. Because of the demonstrated correlation of LW to air temperature, the downwelling and upwelling LW measurements themselves are also correlated, as shown in Figure 10. Thus we also test and compare these measured values as well, as an additional constraint and for those times when air temperature measurements might not be available.

With only a few exceptions for the upwelling LW shown in the bottom part of Figure 8 near 40° SZA, all the LW data passed the testing illustrated in Figures 8 and 9. However, the fairly broad range of allowable values between the limits can still allow data with significant error to pass. To test for more subtle problems, our experience has shown that testing the pyrgeometer case and dome temperatures can be used. Since the case and dome temperatures are used to calculate the LW in a non-linear fashion (using the 4th power of the temperatures), a few degrees error in the case or dome temperatures can result in the LW calculations being in error by up to 10 $Wm^{-2}$ or more. Yet since the ARM radiometers are operated with forced-air ventilators, both the case and dome temperatures should not be too different from the ambient air temperature surrounding the radiometers. Figure 11 shows comparisons of the case and dome temperatures for the upwelling and downwelling pyrgeometers. As in this example, the upwelling LW instrument's case and dome temperatures tend to have a closer relationship with the air temperature than does the downwelling LW instrument. Nevertheless, in both cases fairly close relationships exist between the two. As can be seen, some data for both the upwelling and downwelling instruments failed these tests, and are identified as problematic data not caught by the limits testing shown in Figures 8 and 9.

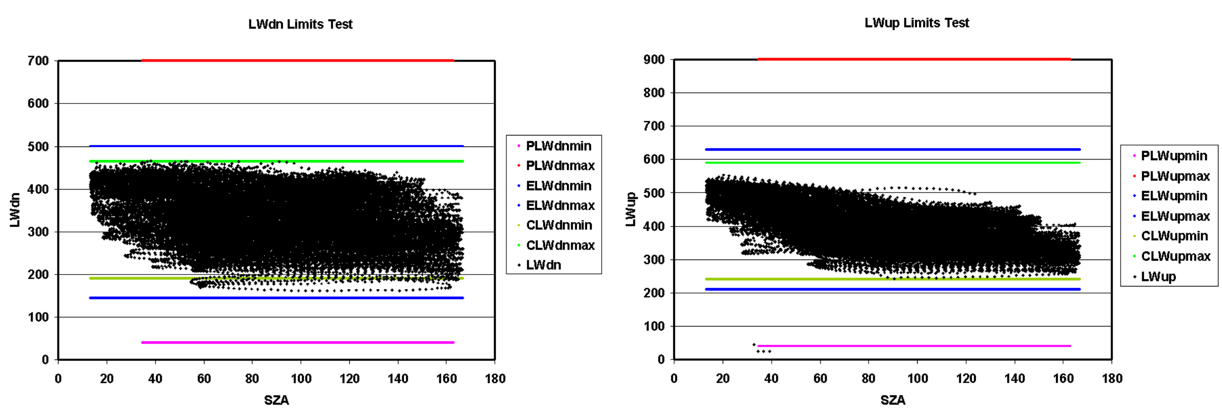


**Figure 8:** Simple maximum and minimum limits for testing the downwelling (left) and upwelling (right) LW. Red and pink are the BSRN physically possible limits, green and blue are the 1st and 2nd level testing limits, respectively.

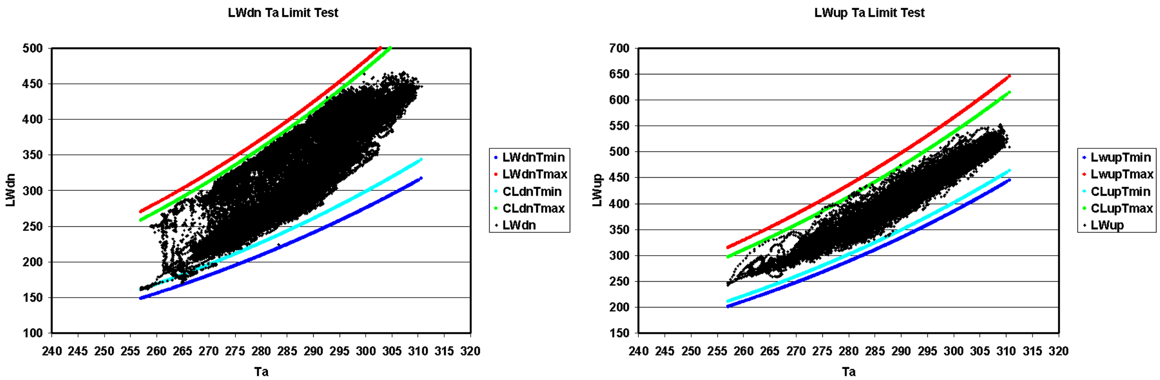


**Figure 9:** Downwelling (left) and upwelling (right) testing versus air temperature. Green and red represent the 1st and 2nd level maximum, while light and dark blue represent the 1st and 2nd level minimum limits.

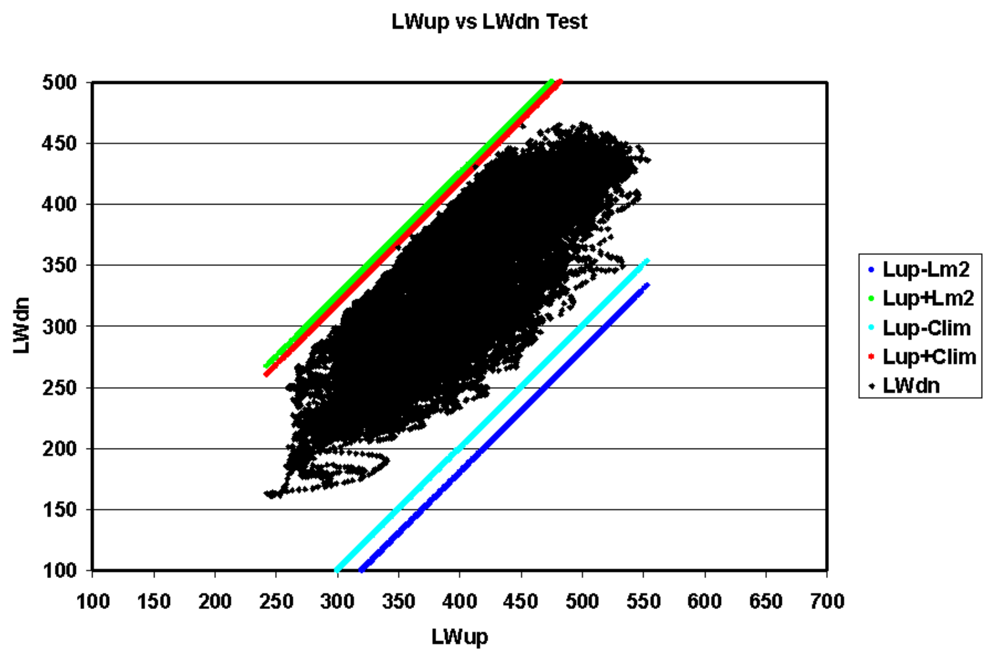


**Figure 10:** Comparison of downwelling and upwelling LW measurements.

We also monitor the difference between an individual instrument's case and dome temperatures. Our analyses have shown that generally, with ventilated systems, only a relatively small range of difference should be exhibited between these two temperatures under normal conditions. Figure 12 shows the case minus dome temperature differences for our example data. Note that the dome is generally cooler than the case for the downwelling instrument, although there are times when the dome is slightly warmer. The opposite is generally true for the upwelling instrument. In both cases, if the dome is warmer than the case, it is normally only warmer by no more than half a degree C. If the dome of the upwelling instrument is cooler that the case, it is also generally only cooler by about half a degree C. For the downwelling instrument, the dome generally is not cooler than the case by more than 2°C.

For the pyrgeometer testing illustrated in Figures 11 and 12, our analyses have shown that test failures are likely to be associated with erroneous data. These test failures indicate that the instrument is not in normal thermal balance, for example, under thermal shock conditions such as the start of heavy cold rainfall on a warm summer day, or that the temperature sensors have a problem that precludes accurate measurements. Thus, failure of any of these tests causes the associated QC flag to be set to a value of 4 or higher and the associated data to be set to a value of "-9999.0" in the output files.

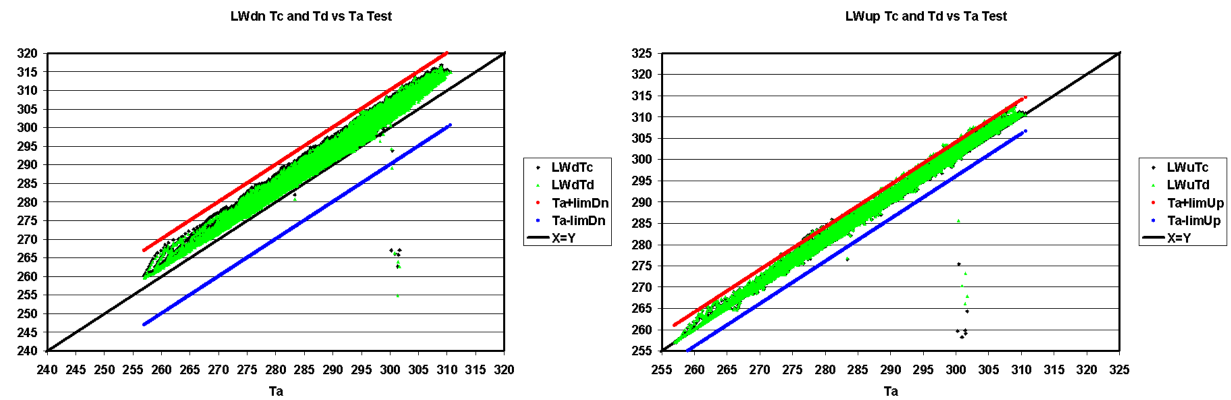


**Figure 11:** Comparison of pyrgeometer case (black) and dome (green) temperatures versus air temperature for downwelling (left) and upwelling (right) pyrgeometers. Red and blue lines represent the maximum and minimum limits, respectively.

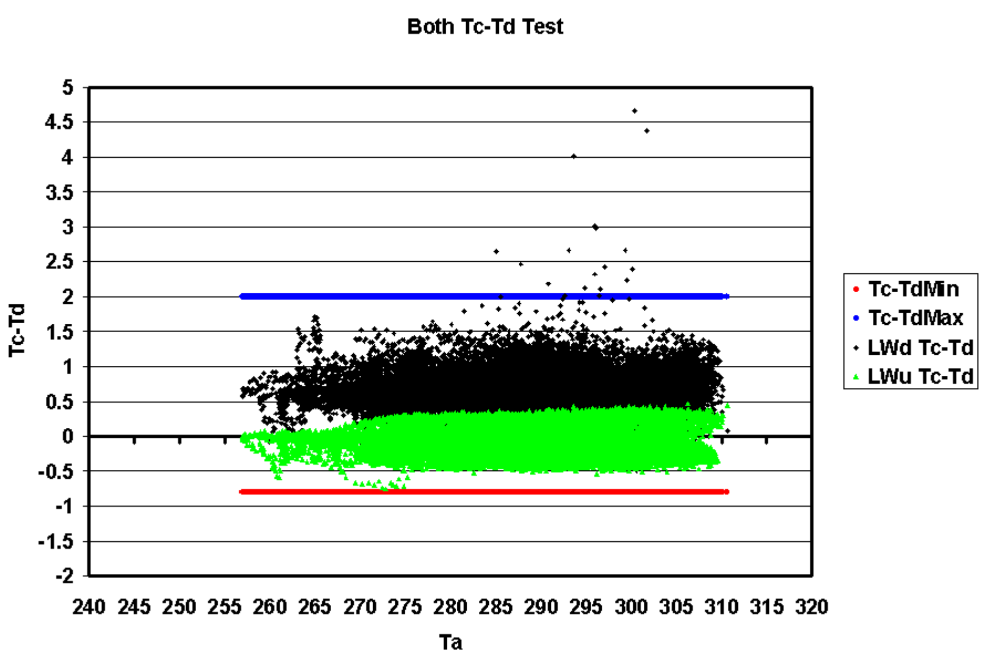


**Figure 12:** Plot of case minus dome temperature differences versus air temperature for the downwelling (black) and upwelling (green) pyrgeometers.

Figure 13 shows an example of the testing for "noisy" case and/or dome temperatures in the pyrgeometer data. In this example, taken from Younkin and Long (2004), the noise problem manifested itself starting at about 0330 and lasting through about 1630. As this plot illustrates, the 11-minute running standard deviation of the 1-minute data is much larger than the corresponding standard deviation of the 11-minute running average "smoothed" data. We use this obvious difference, as illustrated in the bottom plot, to detect the occurrence of this problem. Figure 14 shows an example of the screening results for June 10th, 2000, for the SGP Extended Facility (E1). On this day, some amount of noisy data were detected from about 1500 through 2400 Universal Time Coordinates.

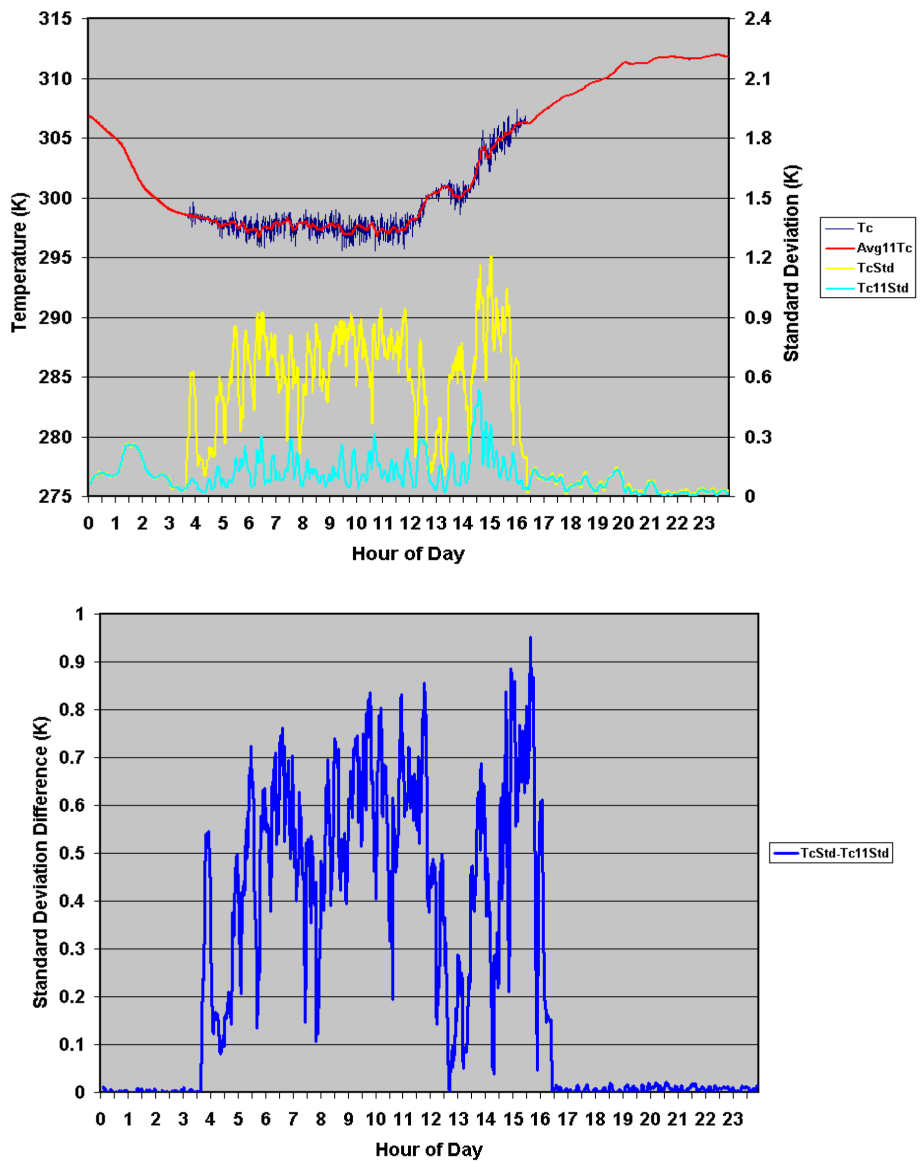


**Figure 13:** An example of the downwelling case temperature "noise" problem (from Younkin and Long 2004) showing standard deviations used for testing data. The measured (dark blue, top plot) case temperature exhibits the noise problem compared to the corresponding 11-minute running average (red, top plot). The running standard deviation of the measured temperature (yellow) is very nearly equal to the running standard deviation of the 11-minute average (light blue), except for when the noise problem occurs. The difference in these two standard deviations is shown in the bottom plot (blue line).

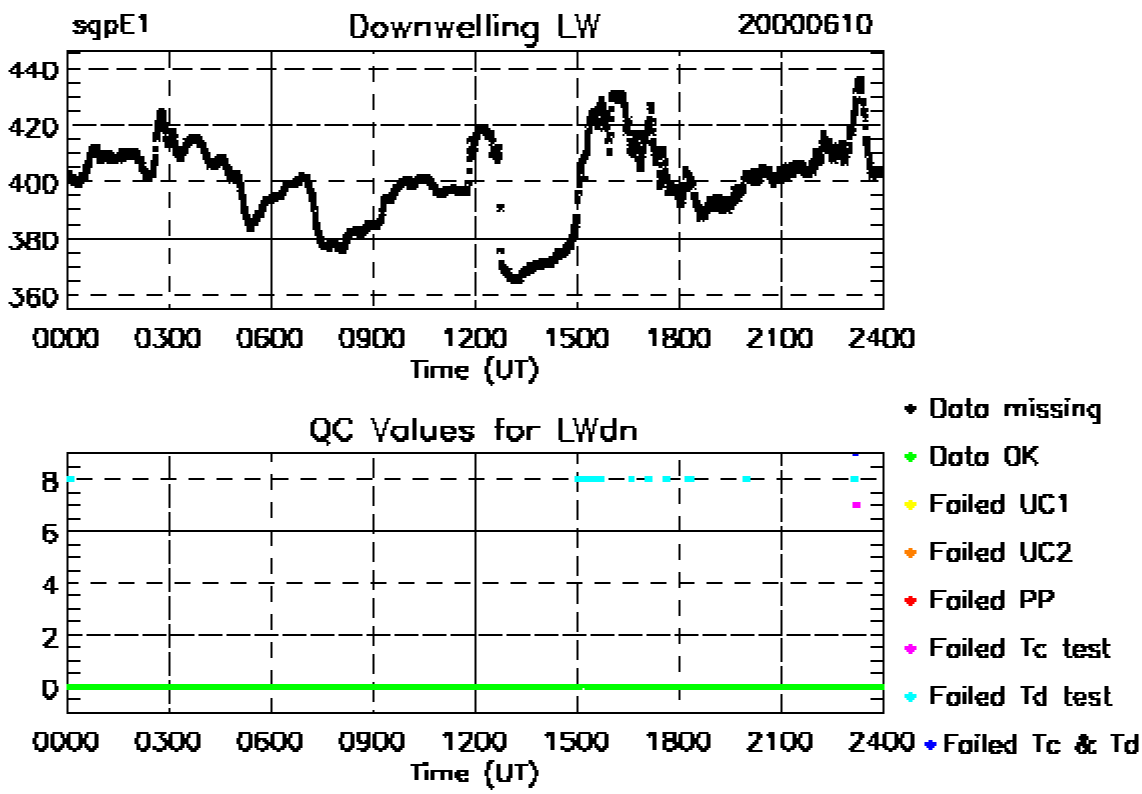


**Figure 14:** An example of the downwelling case and dome temperatures failing standard deviation tests, marked as pink, cyan, and blue in the lower plot.

## 5. Daily Summaries of Test Failures

### 5.1 Shortwave Results

The QCRad code is designed to run each day to test the previous day's data. However, there are more subtle tendencies and problems that are more likely revealed by studying results over longer time periods, such as monthly and yearly. Therefore, the code also produces a file that lists a summary of the amount of data failing the various tests for each day. These results can then be used to study the persistence of problems or abrupt shifts that might not be evident on a day-to-day basis. In the following plots, all definitive testing results are only counted once at the greatest level of failure. For example, if downwelling LW data fail the simple limits testing at the level of the BSRN Physically Possible limit, then subsequent 2$^{nd}$ and 1$^{st}$ level testing is not applied nor failures counted in the daily summaries, nor are the testing versus air temperature counted or applied.

Figure 15 shows a summary of the daily test results for the downwelling unshaded pyranometer for the example year data. As can be seen, the generic correction for IR loss in the unshaded pyranometer still leaves some data failing the physically possible (blue) and 2$^{nd}$ level (green) too-low limits. These low failures are all nighttime data. Additionally a few days failed the Global/Sum ratio test, notably near the beginning of May and again in the beginning of September. These data were previously shown in Figure 4.

Figure 16 shows the daily test results summary for the Diffuse SW (shaded pyranometer) for the example year data. In this plot, as illustrated in Figure 5, it is shown that the diffuse over global SW ratio test failures mostly occurred in the latter part of 1997. For these data, the diffuse has been better corrected for IR loss through the ARM DiffCorr VAP, as evidenced by very few too-low failures. Note that some failures of the 2nd level maximum tests occur early in October (light blue). These failures correspond to the tracker not properly tracking the sun, as shown in Figure 17. Figure 17 also shows only a few cases where the direct SW falls below the 2nd level too-low limit.

Figure 18 shows the daily summary results for upwelling SW testing. We note here brief periods of anomalously large upwelling SW during April, early July, August, and September of 1997. These months are not typified by snowfall events at the SGP, thus these results cannot be attributed to a high albedo surface, but rather to other causes (Figures 6 and 7) that preclude these data being accurate measurements of upwelling SW. Note also that a brief period occurs in August, where the upwelling SW measurements were anomalously low during nighttime hours, likely indicating an IR loss offset.

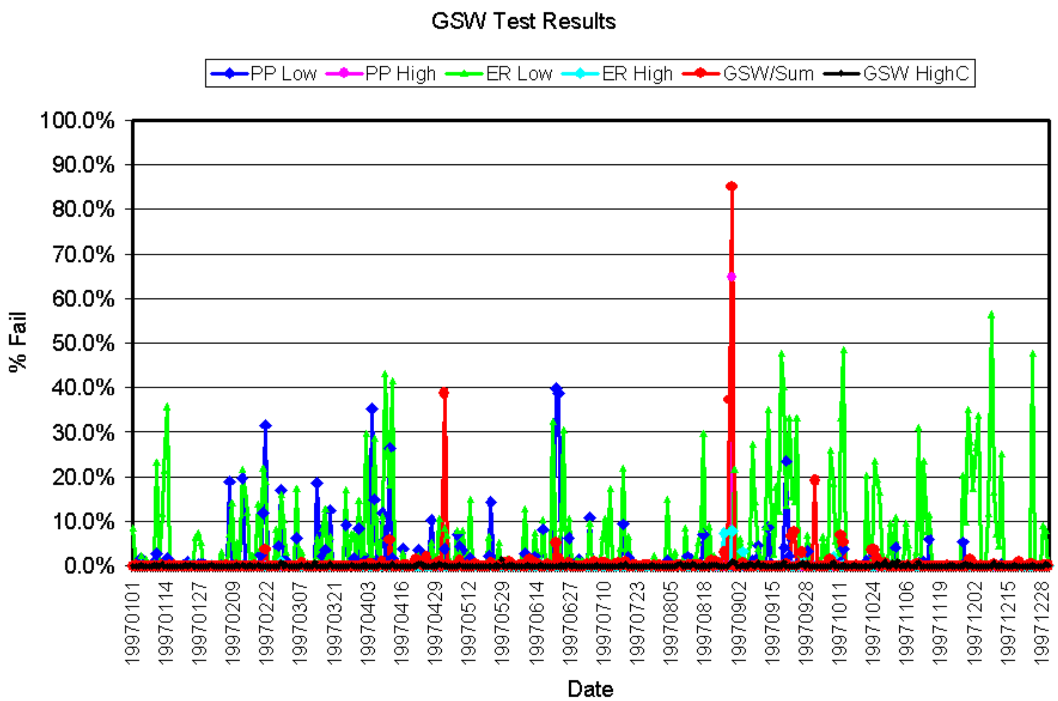


**Figure 15:** Daily summary of the percentage of various testing failures compared to amount of possible data for the global (unshaded) pyranometer measurements. Blue and pink represent the low and high BSRN Physically Possible test failures, respectively. Green represents 2nd level lower limit, light blue the upper level 2nd level limit, black the upper 1st level limit. Red denotes the global over sum SW ratio testing as illustrated in Figure 4.

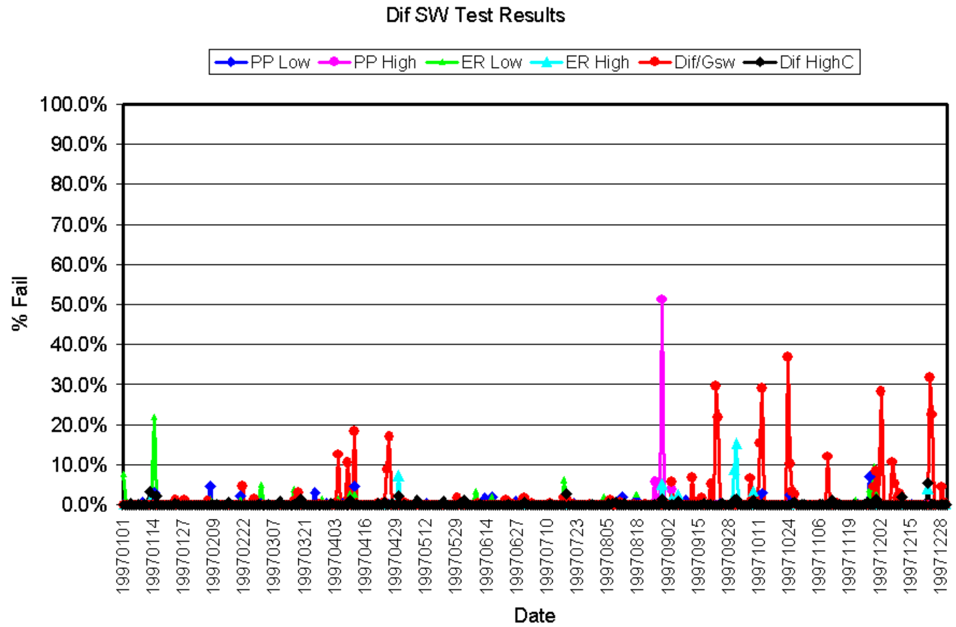


**Figure 16:** Same as Figure 13, but for diffuse SW tests. Note that, in this plot, red denotes diffuse over total SW ratio testing results as illustrated in Figure 5.

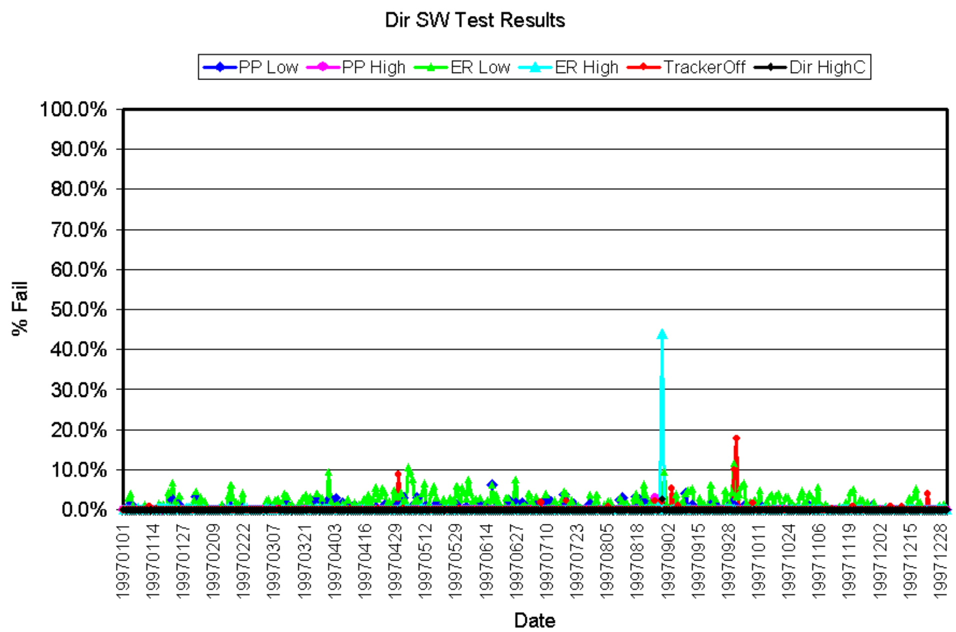


**Figure 17:** Same as Figure 13, but for direct SW tests. Note that, in this plot, red denotes solar tracker alignment testing results as illustrated in Figure 2.

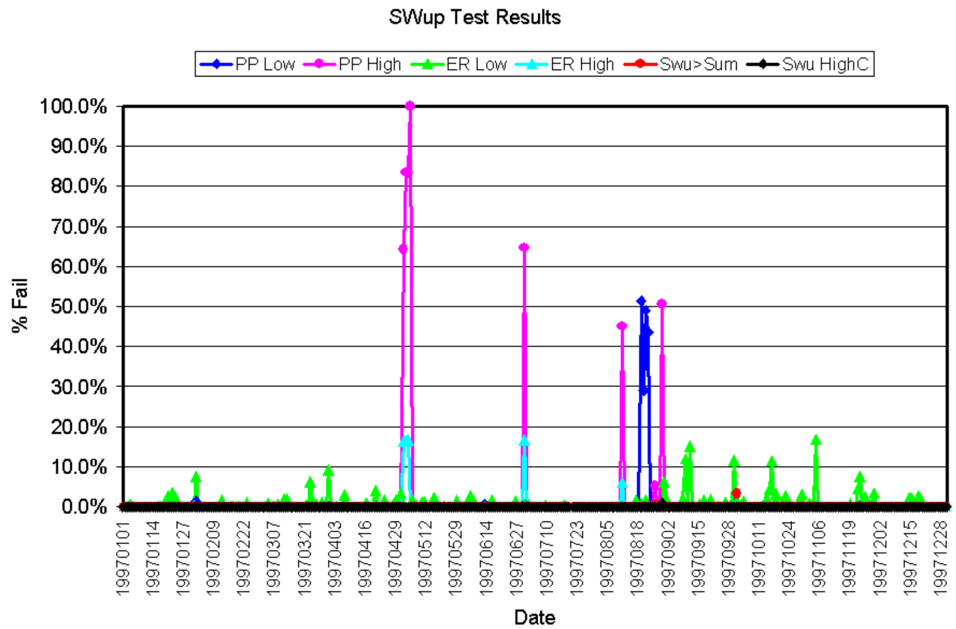


**Figure 18:** Same as Figure 13, but for upwelling SW tests. Note that, in this plot, red denotes upwelling SW is greater than the downwelling SW plus 25 $Wm^{-2}$.

## 5.2 Longwave Results

For the LW, Figures 19 and 20 show the summary results of the simple limits testing illustrated in Figure 8 for the downwelling and upwelling LW, respectively. For the downwelling LW (Figure 19), the problem data (too low) occurred in January of 1997, whereas for the upwelling LW (Figure 20) problems (too high) occurred primarily in late July. Additional downwelling LW anomalously low data during the January period were caught by the comparison to air temperature testing shown in Figure 21. For the upwelling LW, some data were shown to be anomalously high versus air temperature (Figure 22) in March and April of 1997.

Figure 23 shows the results of the testing of the pyrgeometer case and dome temperatures versus air temperature, and the testing of the air temperatures themselves. In this plot, the results for both the upwelling and downwelling pyrgeometers are summed together. This plot shows some of the case and/or dome temperatures differing from the air temperatures more than the set limits (Figure 11) primarily through the first two-thirds of 1997. Similarly, for a few times, the difference between the pyrgeometer case and dome temperatures fell outside expected limits. The only time that the air temperature data itself failed to agree within 15°C of the average of the pyrgeometer case and dome temperatures occurred on one day near the beginning of September.

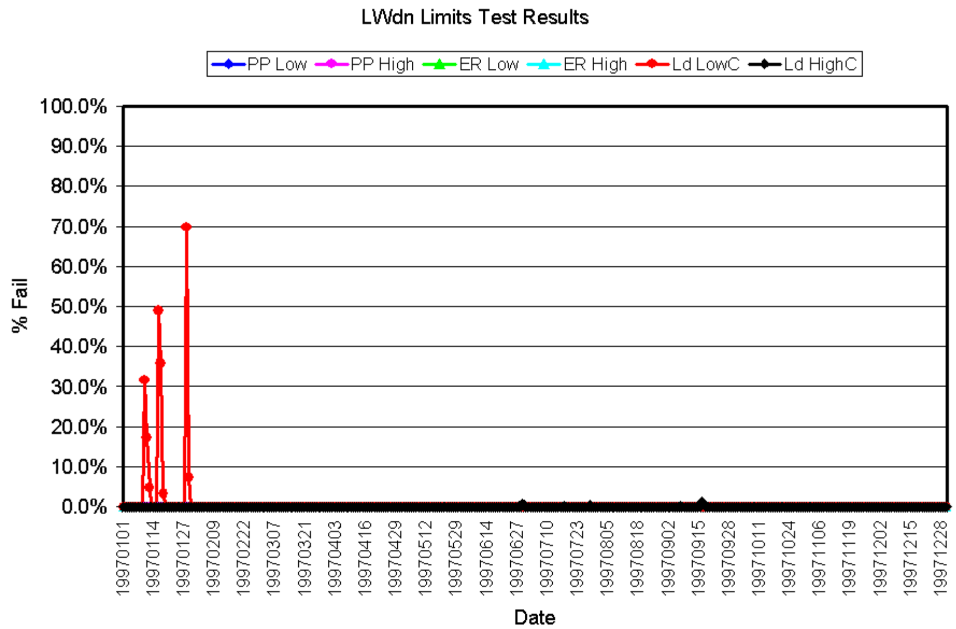


**Figure 19:** Results for downwelling LW simple limits tests, where PP denotes the BSRN Physically Possible limits, ER denotes the 2nd level configurable Extremely Rare limits, and C denotes the 1st level configurable limits.

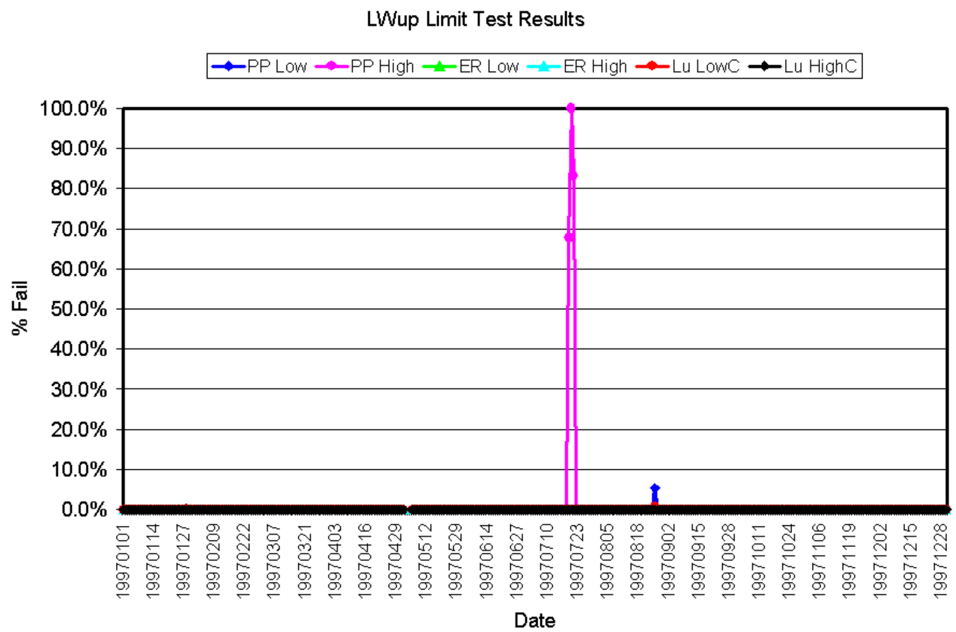


**Figure 20:** Same as Figure 19, but for upwelling LW.

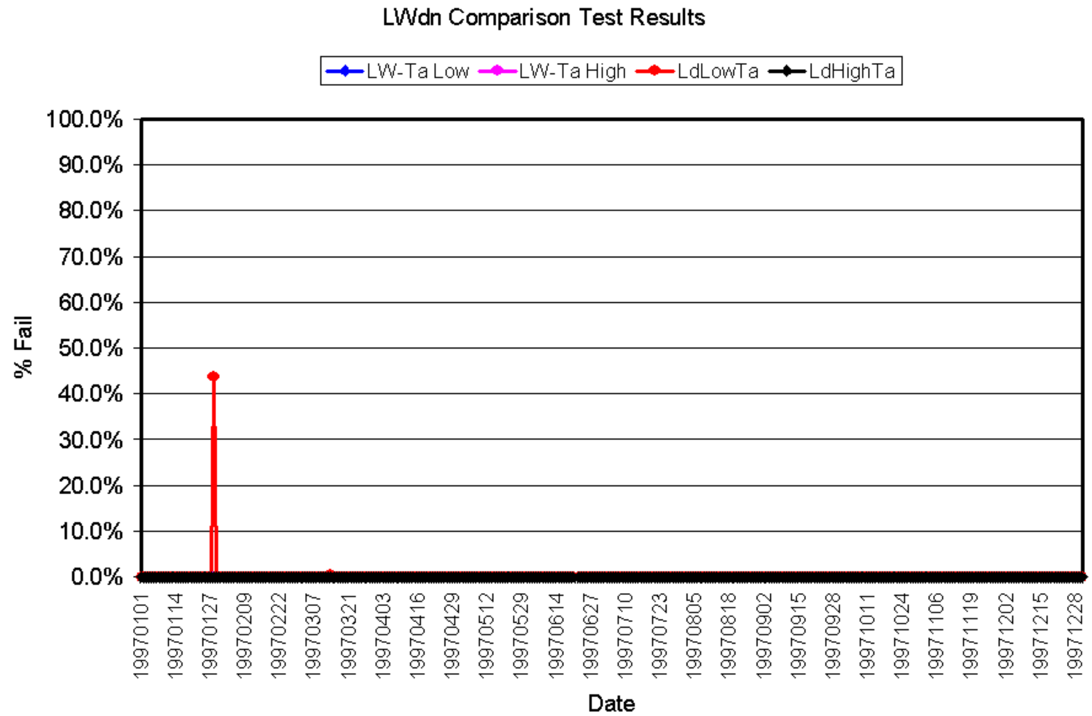


**Figure 21:** Limits test results using air temperature measurements for downwelling LW. Blue and pink represent the minimum and maximum 2nd level test limits, respectively; red and black represent the minimum and maximum 1st level test limits, respectively.

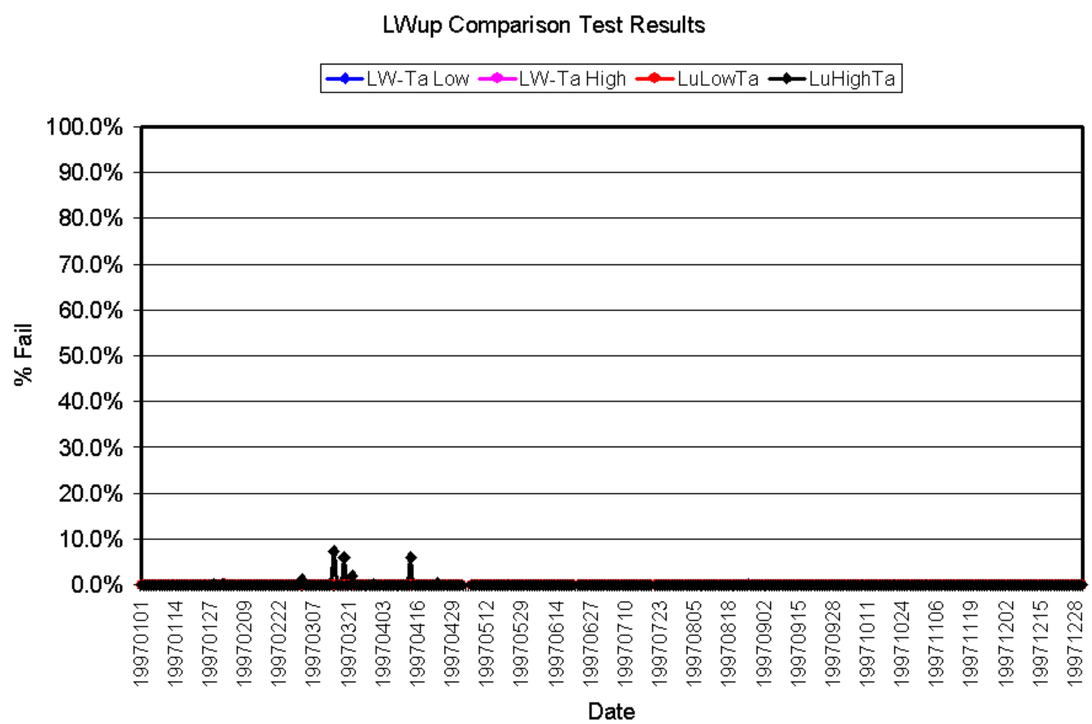


**Figure 22:** Same as Figure 21, but for upwelling LW.

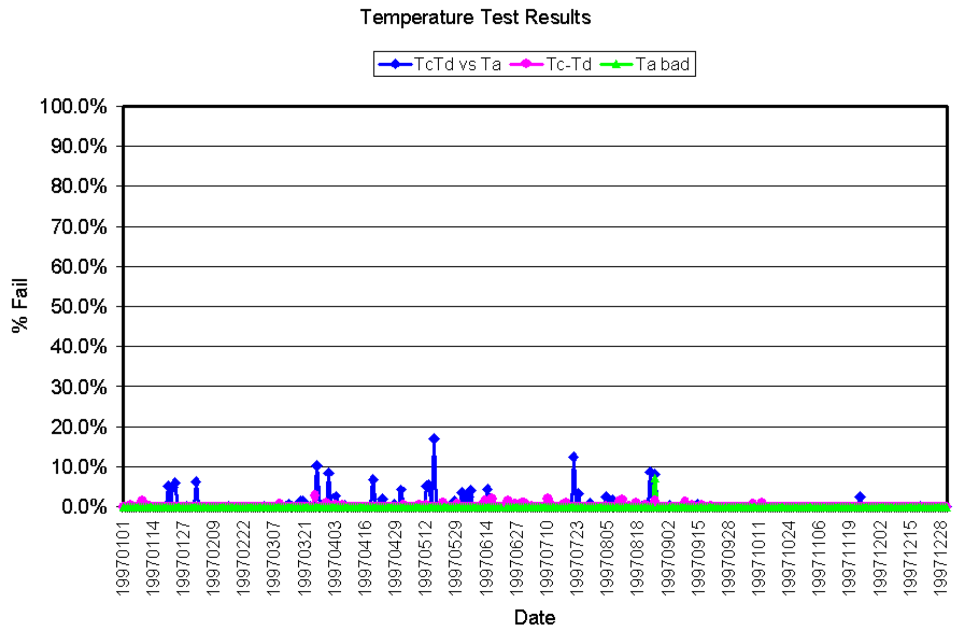


**Figure 23:** Results of the pyrgeometer case and dome temperatures testing and the air temperatures. Blue represents a summary of all failures of both the upwelling and downwelling pyrgeometer case and dome temperatures compared to both the average of all temperatures as explained in Section 3.1, and to the minimum and maximum testing limits shown in Figure 11. Red represents a summary of all failures of both the upwelling and downwelling pyrgeometer case-dome difference testing shown in Figure 12. Green represents failures of the air temperature measurements themselves.

## 5.3 Summary of Test Failure Results

Figure 24 shows a summary of all test failures by measurement. For example, all the failures of the various testing of the total SW are added up and displayed in blue on the plot. Most of the problems with the downwelling LW measurements occurred early in the study year, while most of the upwelling SW problems occurred in the middle of the year. One day in the beginning of September exhibits significant test failures for the total, diffuse, and upwelling SW, indicative of a system problem rather than individual instrument problems.

In summary, the QCRad VAP provides useful quality analysis results for both the daily and the longer-term runs of the code. Each of these run-modes can be used to examine different aspects of data quality management and monitoring of the various ARM radiometer systems.

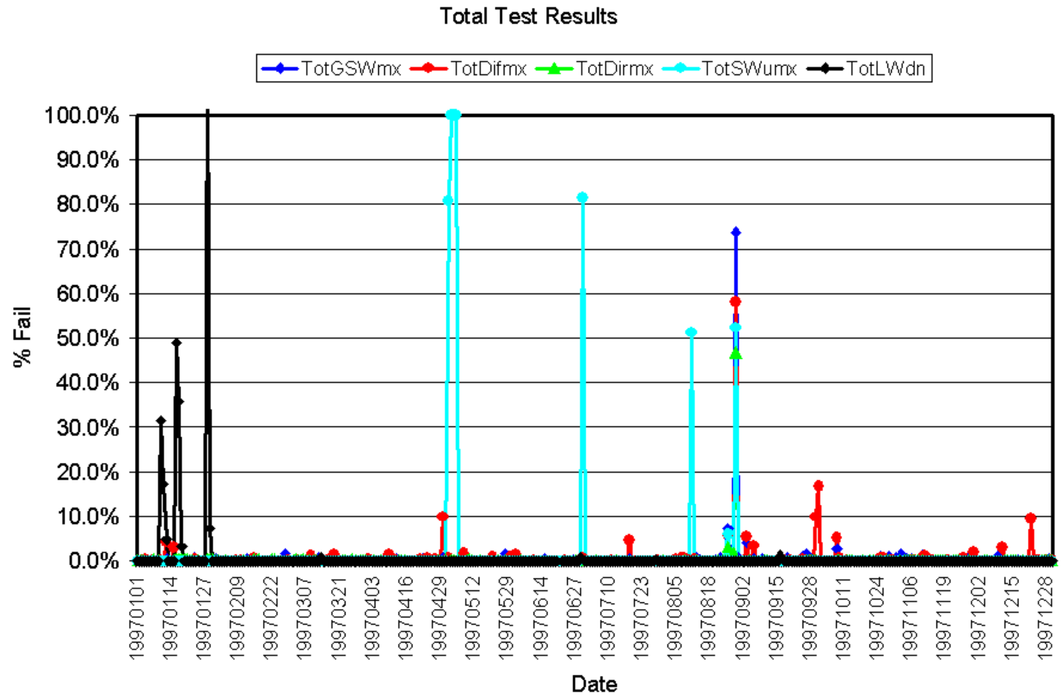


**Figure 24:** Summary of all testing results for the total SW (blue), diffuse SW (red), direct SW (green) upwelling SW (light blue), and downwelling LW for the example year of 1997 for the SGP Central Facility.

## 6. Best Estimate of Global Shortwave

In the QCRad VAP, the best estimate of total downwelling shortwave radiation is derived using the sum of direct and diffuse components where possible, with any gaps in the sum time series filled using a fitted relationship between the sum and unshaded pyranometer measurements. If the unshaded pyranometer measurements are missing or "bad," then the open channel data from a collocated multi-filter rotating shadowband radiometer (MFRSR) are used to derive a fitted relationship to fill the gaps. The methodology uses the following form:

1. For any given time, if Direct Normal SW and Diffuse SW data are good and the ratio of Global SWdn vs. Sum SW and Diffuse SW vs. Global SWdn pass the quality tests, and the absolute difference between Sum SW and Global SWdn is less than limits obtained through historical analysis of known good data, then Best Estimate GSW = Sum SW. The agreement limits used here are:

$$\text{Abs(sumSW-GSW)} <= 20\ \text{Wm}^{-2} \text{ or abs(sumSW-GSW)/sumSW} <= 0.05.$$

2. If the above condition is not met, then MFRSR measurements are used as a cross examination of the data quality. Since the sampling rates of the SIRS and the MFRSR instruments are different, it is necessary to average the data over time before we can compare the two measurements.

3. If the MFRSR GSW is within the 1st level configurable limits used to test the global SW (see "Climatological [Configurable] Limits" section), both Direct Normal SW and Diffuse SW QC flags are 2 or less, and the ratio of the averaged values of MFRSR GSW over Sum SW or their absolute

differences are within limits obtained through historical analysis of known good data, then again Best Estimate GSW = Sum SW. The agreement limits used here are:

(MFRSRGSW/sumSW <=1.14 and MFRSRGSW/sumSW > 0.92)
or abs(MFRSR-sumSW) < 20 $Wm^{-2}$.

4. If the above condition is not satisfied, but the GSW data are good and the ratio of the averaged values of MFRSR GSW over GSW or their absolute differences are within the same agreement limits as in #3 above, then the GSW data are deemed good and can be used to get the best estimate of the GSW.

5. To use the GSW, we first check the time to see whether this measurement occurs in the morning or in the afternoon. If it occurs in the morning, then GSW is linearly fitted to Sum SW using all the "good" (i.e., QC flags equal to 0) morning data. If there are no at least 30 "good" data points available in the current day, we add the previous day's and next day's (if the previous day's data are not enough) morning data and do the fitting. We check up to one week of data either before or after the current day to find enough data for fitting. If enough data are not available (an extremely rare occurrence, if ever) within this time period, then the fitting cannot be done. The same procedure applies to missing afternoon data, except that afternoon data are used for fitting.

6. If none of the above conditions are met, and if GSW is good (i.e., QC flag of 2 or less), then the GSW itself is used as the best estimate. If the GSW is missing, then the MFRSR GSW is fit to the sum similar to the method in #5 above, and the result is used as the best estimate.

## 7. Example Atmospheric Radiation Measurement Data Analysis Results

### 7.1 Global Shortwave

Figure 25a shows GSW versus SZA in year 2000 at SGP E2. The red curve is the maximum physically possible limits (PGSWmax), the blue curve is the maximum extremely rare limits (EGSWmax), the green curve is the maximum configurable limits (CGSWmax), and the cyan curve is the estimated clear-sky SW envelope (ClrSW). The minimum test limits are not shown in this figure. Figure 26b shows the percent of data that failed each of these tests. Figure 25b shows 40% to 60% of the data failed the minimum GSW Physically Possible limit tests; this is due to the IR loss of the unshaded pyranometer causing negative values at night. The seasonal trend is also shown here since the site experiences longer nights in winter and shorter nights in summer. This IR loss is also shown in the GSW/Sum SW test (Figure 25c). Here the Sum SW is calculated using the shaded PSP diffuse SW data that were corrected for IR loss. Figure 25d shows the same ratio, but with GSW data that has also been corrected for IR loss to the same amount that the diffuse SW data were corrected. Note that correcting both the global and sum SW, as shown in Figure 25d, decreases what might otherwise be interpreted as "cosine response error" in the unshaded PSP in Figure 25c.

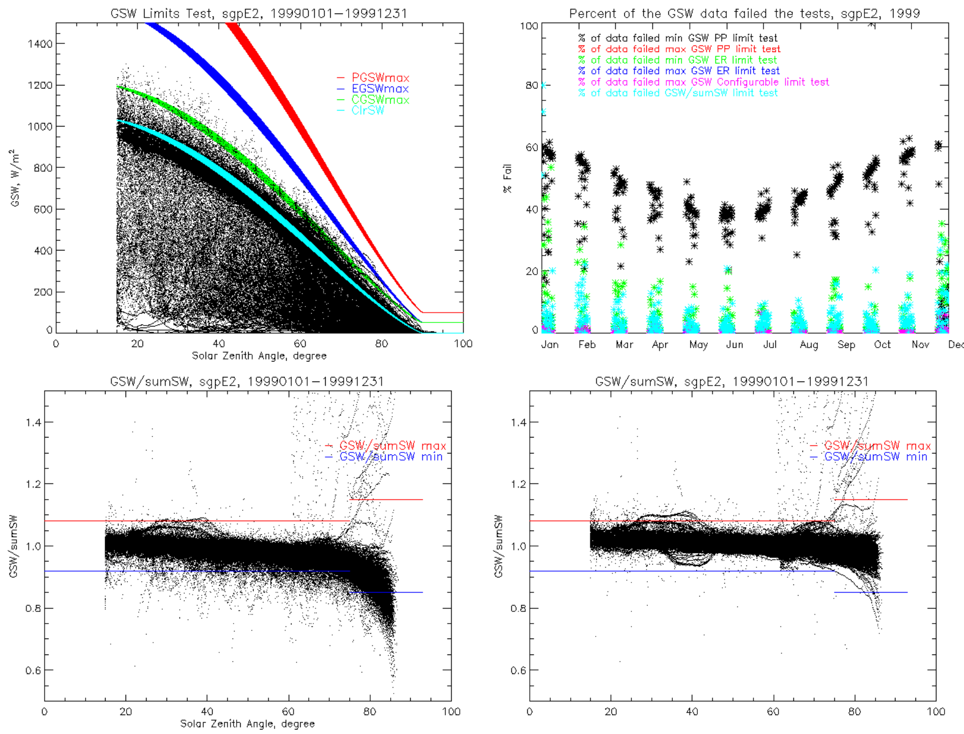


**Figure 25:** GSW tests for 1999 SGP E2 data. a) Top left: GSW vs. SZA showing limits; b) Top right: daily percent of data that failed GSW testing; c) Bottom left: ratio of GSW/Sum SW using diffuse SW corrected for IR loss in Sum; d) Bottom right: ratio of GSW/Sum SW using both IR loss corrected diffuse SW and corrected GSW.

Table 1 shows that about 2% of the 1999 Nauru data fails the GSW/SumSW test, represented as light blue dots in Figure 26a. These cases mostly occurred from January to April, and then from August to October. The erroneous data can also be seen in Figure 26b as the data lower than the minimum (blue line) or greater than the maximum (red line) limits. This disagreement between the sum and unshaded pyranometer SW is exhibited to some extent at all sites, as the results in Section 9.2 for the Tropical Western Pacific (TWP) and North Slope of Alaska (NSA) sites imply.

**Table 1:** Percent of data failing the GSW/sumSW tests.

| Site | Facility | Year | GSW/sumSw |
|---|---|---|---|
| TWP | C1 | 1997 | 19% |
| TWP | C1 | 1998 | 27% |
| TWP | C1 | 1999 | 17% |
| TWP | C1 | 2000 | 7% |
| TWP | C2 | 1999 | 2% |
| TWP | C2 | 2000 | 2% |
| NSA | C1 | 1999 | 7% |
| NSA | C1 | 2000 | 17% |
| NSA | C2 | 1999 | 1% |
| NSA | C2 | 2000 | 12% |

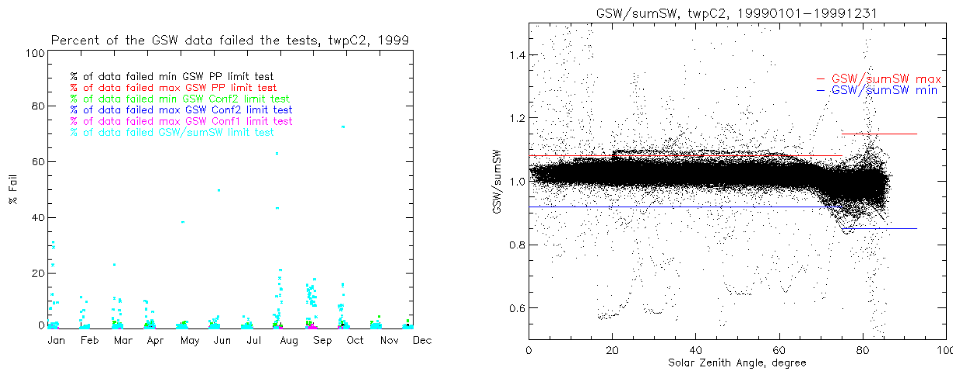


**Figure 26:** Daily summaries (a, left) of percent of test failures for 1999 Nauru data. Right plot (b) shows the 1999 Nauru global over sum SW ratio test by SZA.

## 7.2 Diffuse and Direct Shortwave

Similar to Figure 25, Figure 27a shows the Diffuse SW limits tests, while Figure 27b shows the percent of data failing these tests. The IR loss in uncorrected GSW can also be seen from the DiffSW/GSW test, as shown in Figures 27c using uncorrected GSW and in 27d using IR loss corrected GSW. Similar limits tests are done to Direct SW, as shown in Figure 28a and 28b. Most direct SW data are well within the defined limits, except for less than 5% of the data that failed minimum extremely rare limit tests.

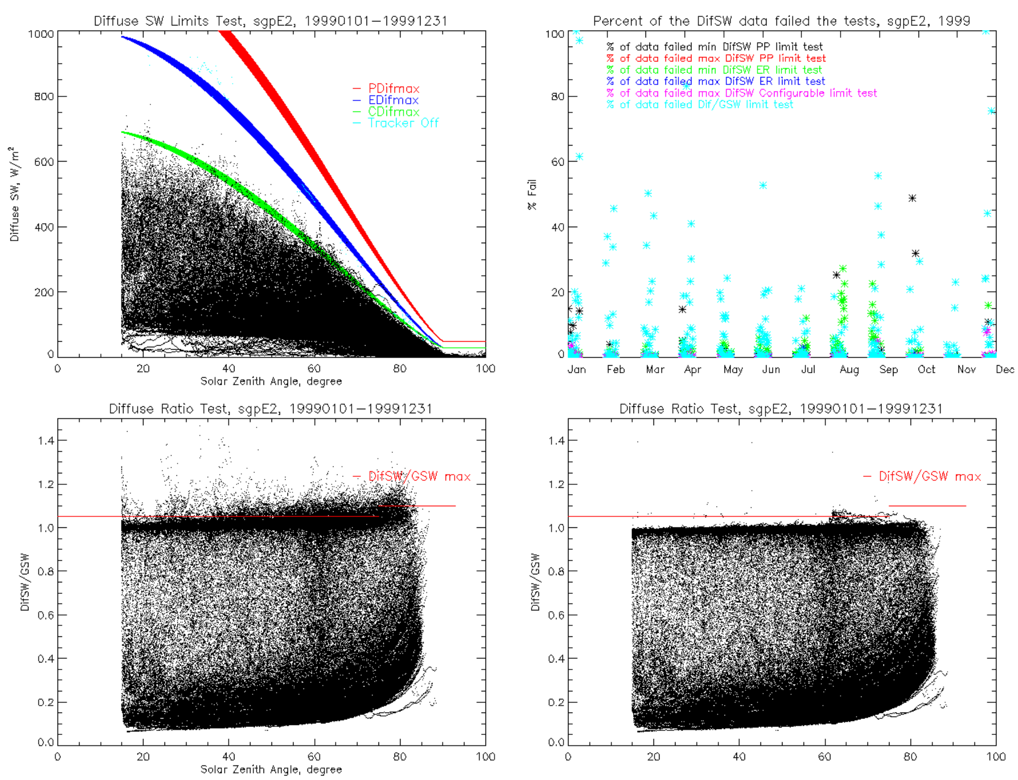


**Figure 27:** Diffuse SW tests for 1999 SGP E2 data. a) Top left: DiffSW vs. SZA showing limits; b) Top right: daily percent of data that failed DiffSW testing; c) Bottom left: ratio of DiffSW/GSW using DiffSW corrected for IR loss; d) Bottom right: ratio of DiffSW/GSW using both corrected DiffSW and corrected GSW.

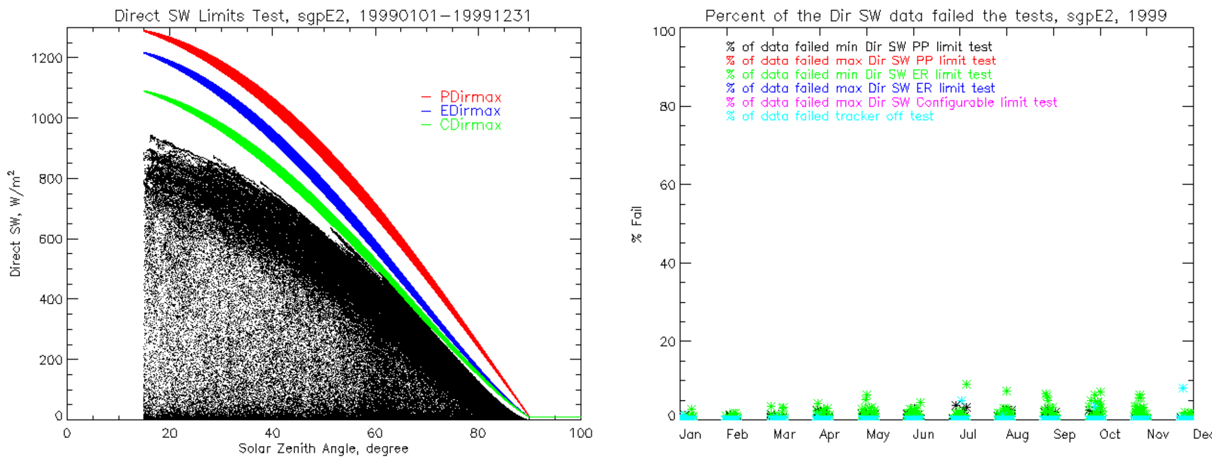


**Figure 28:** Direct SW tests for 1999 SGP E2 data. a) Left: DirSW versus SZA showing limits; b) Right: daily percent of data that failed DirSW testing.

Figure 29a (upper left) shows the 1999 diffuse SW data for Nauru. All the data above the extremely rare limit (blue curve) are known to be bad, while the data above the normal limits (green curve) but below the extremely rare limits are indeterminate, meaning the data are feasible but occur rarely in this climate. The pink dots in this plot mark the data corresponding to times when the solar tracker was deemed to be off tracking alignment. Table 2 shows that 9% of these 1999 data failed the tracker-off test. To further investigate these data, we plot the time series of diffuse SW, as shown in Figure 29c (middle left). The tracker-off alignment data occurred from August to October (pink dots). Figure 29b (top right) shows the corresponding direct SW data, illustrating that most direct SW data fall within the maximum user configurable limits, except for some obviously problematic data. Figure 29d shows the tracker-off period as in 29c. Figures 29e (diffuse SW) and 29f (direct SW) summarize the percentage of daily test failing data, which also shows the August to October tracker problems. Table 2 summarizes the tracker testing results for various sites.

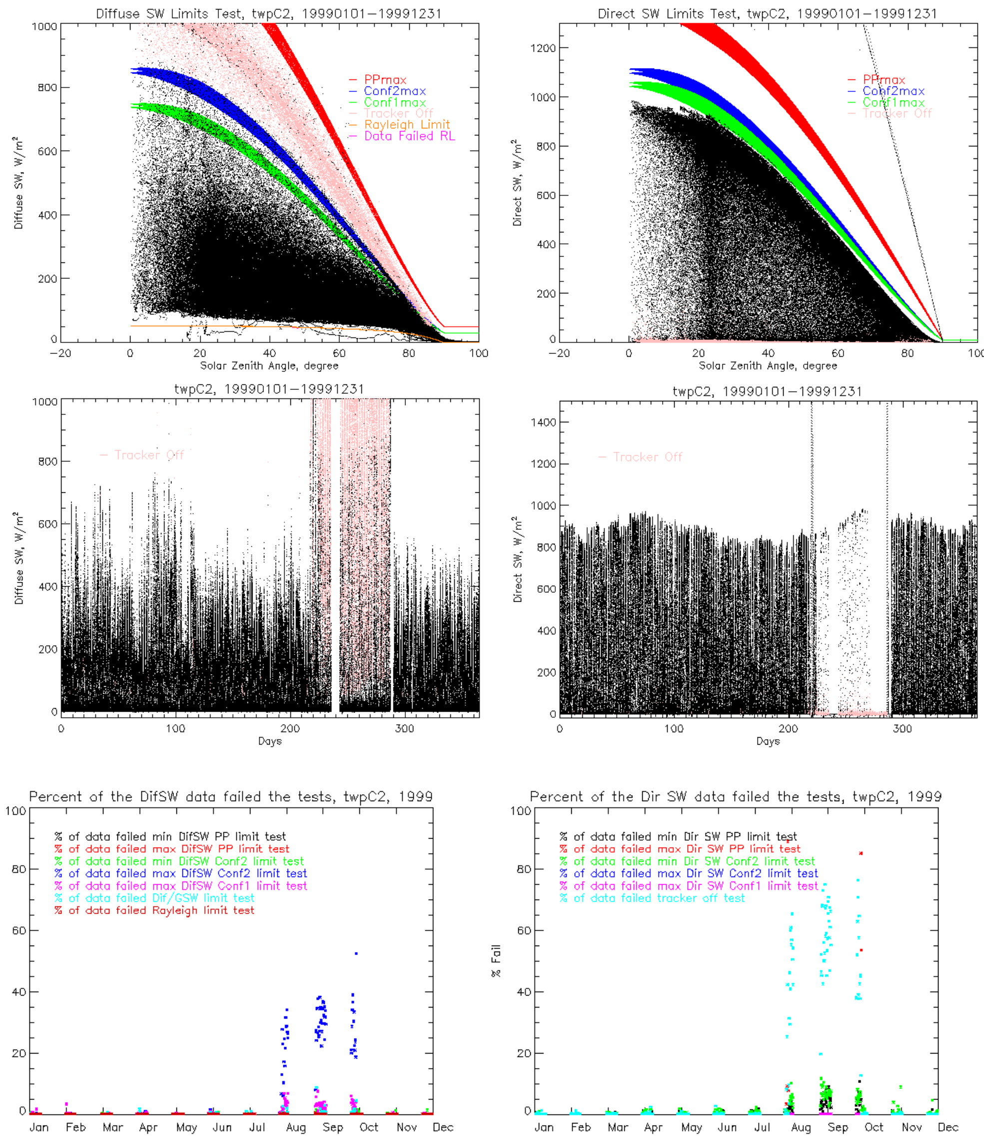


**Figure 29:** Diffuse (left plots) and Direct (right plots) SW testing results for 1999 Nauru data.

**Table 2:** Percent of data failing solar tracking tests.

| Site | Facility | Year | Tracker Off |
|---|---|---|---|
| TWP | C1 | 1997 | 0% |
| TWP | C1 | 1998 | 1% |
| TWP | C1 | 1999 | 3% |
| TWP | C1 | 2000 | 0% |
| TWP | C2 | 1999 | 9% |
| TWP | C2 | 2000 | 0% |
| NSA | C1 | 1999 | 0% |
| NSA | C1 | 2000 | 0% |
| NSA | C2 | 1999 | 7% |
| NSA | C2 | 2000 | 0% |

## 7.3 Upwelling Shortwave

Figure 30 shows example upwelling SW test results for SGP Extended Facility E2 for 1999. The data between the green (configurable 1st level SWup limits) and blue (2nd level maximum SWup limits) curves in Figure 30a occur during snow events. In Figure 30b these data lie between the red and the blue curves, showing that the air temperature was below the Tsnw limit similar to Figure 7. Figure 30c shows the daily percent of data that failed the testing. Some data in December and January exceed the SWup 1st level configurable limits but are below the 2nd level limits, again indicating possible snow events. This graph also shows some data in May exceeded the maximum configurable limits or maximum physically possible limits, these data are shown both in Figure 30a and 30b as the scattered black dots, indicating something is wrong with the instrument.

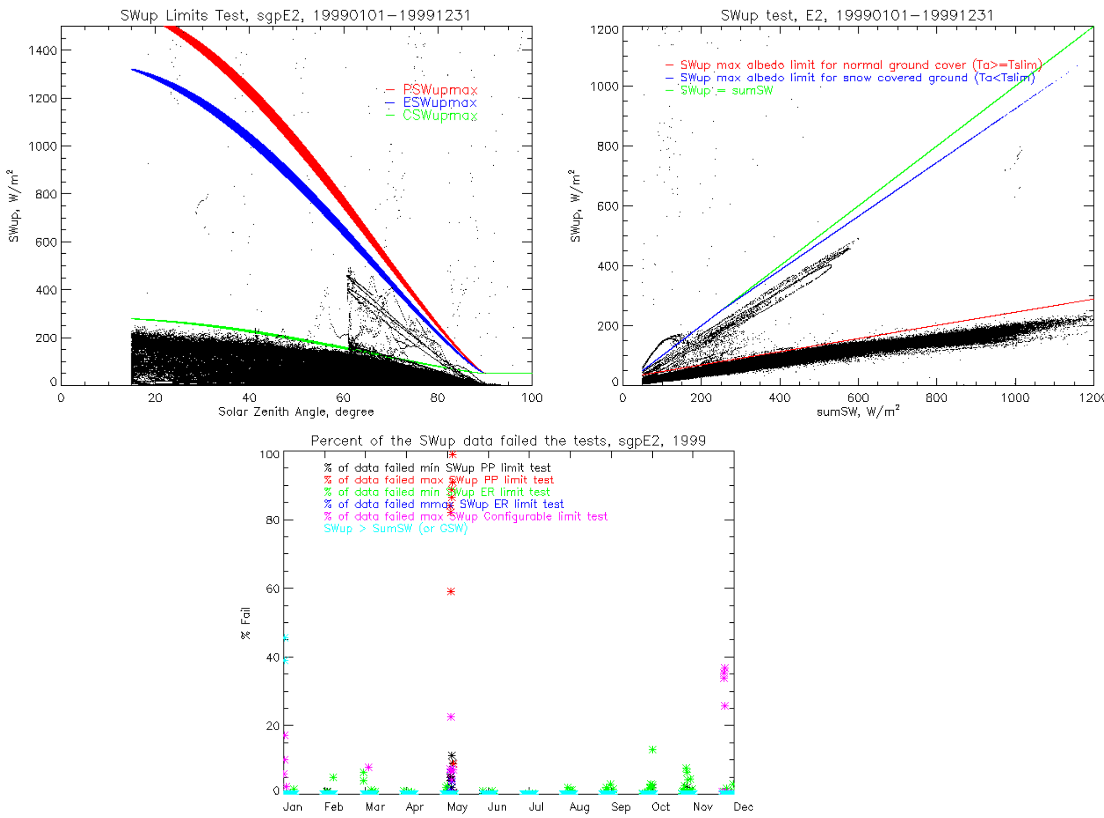


**Figure 30:** Upwelling SW tests for 1999 SGP E2 data. a) Top left: SWup vs. SZA showing limits; b) Top right: SWup vs. SumSW showing limits; c) Bottom: daily percent of data failing SWup testing.

Figure 31a (upper left) shows the time series of upwelling SW for the 1999 Nauru data. Note that, near day 220, the upwelling SW data exhibit unrealistically high values. This also shows in the temperature-screened SWup test shown in Figure 31b (upper right), where these data exceed even the max albedo limit for near freezing temperatures which never occur at Nauru (blue line). Unrealistically high values were also found in Manus 1999 [lower left plot] and Nauru 2000 data [lower right plot]. At the NSA Barrow site all the SWup data drop sharply after a certain date, associated with the spring snow melt, as shown in Figure 32.

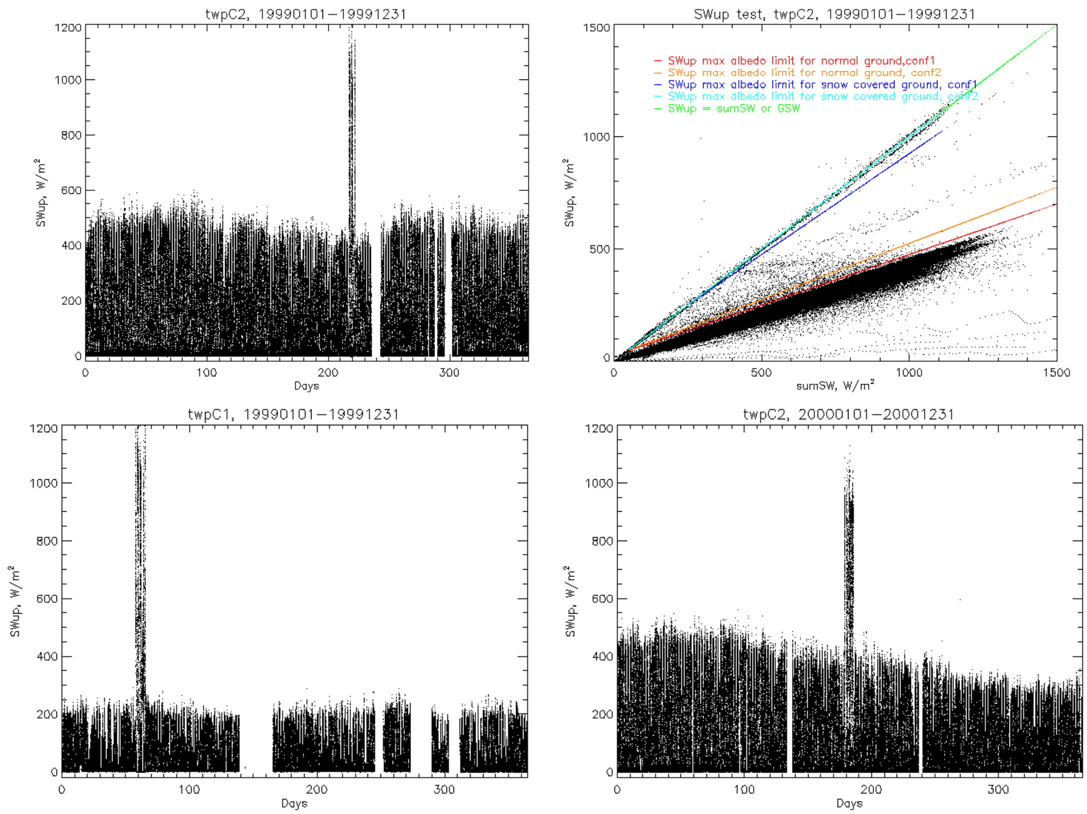


**Figure 31:** Upwelling SW time series from Nauru (both left plots, and lower right plot) and temperature-screened test for the 1999 data (upper right).

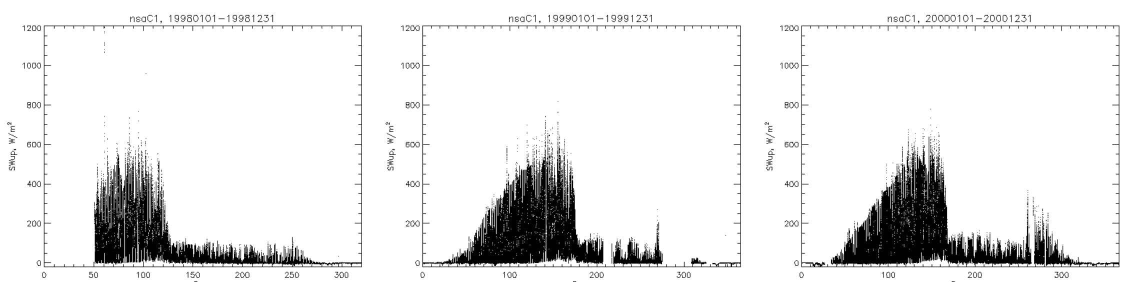


**Figure 32:** Upwelling SW time series from Barrow for 1998 (left), 1999 (middle), and 2000 (right).

## 7.4 Downwelling and Upwelling Longwave

Figures 33 and Figure 34 show the downwelling and upwelling LW tests, respectively, for the SGP E2 1999 data. For this year, most data are well within the defined limits and pass the testing. A few downwelling LW data do fall outside the set limits for the case-to-dome temperature comparison (Figure 33d, lower right plot) indicating when the instrument likely suffered thermal shock conditions, such as at the outset of cold rain events. Note also that the upwelling LW is more tightly related to air temperature (Figure 34b) than is the downwelling LW (Figure 33b).

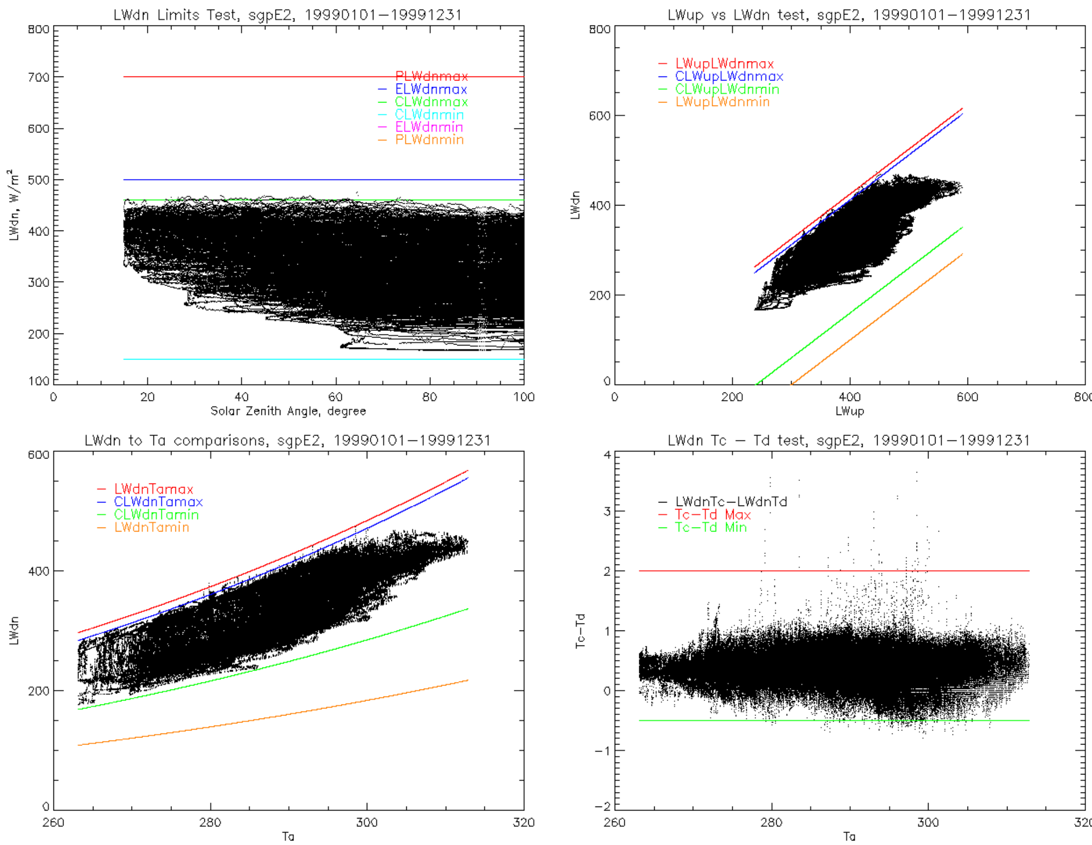


**Figure 33:** Downwelling LW tests for 1999 SGP E2 data, with limits shown in each graph. a) Top left: LWdn vs. SZA; b) Top right: LWdn vs. LWup; c) Bottom left: LWdn to Ta comparisons; d) Bottom right: $T_c - T_d$ tests.

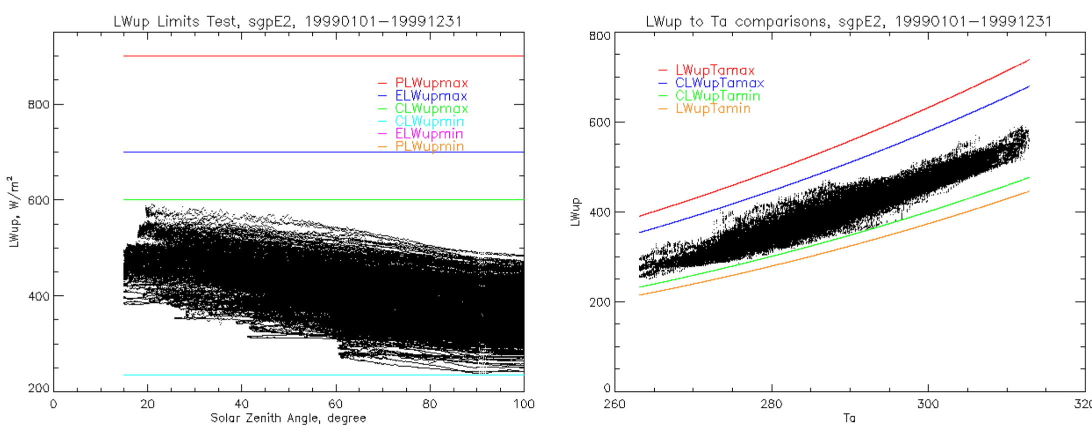


**Figure 34:** Upwelling LW tests for 1999 SGP E2 data. a) Left: LWup vs. SZA showing limits; b) Right: LWup to $T_a$ comparisons showing limits.

Figure 35 shows the time series of upwelling LW for Nauru for the years 1998 (upper left, data collection starts on October 29), 1999 (upper right), and 2000 (lower left). In all three years, the upwelling LW data occasionally exhibit anomalously low values for the same periods that the upwelling SW data exhibit unrealistically high values (Figure 31). These periods are correlated with TWP RESET visits where the downward facing instruments are faced upward for comparison to the normally upward facing

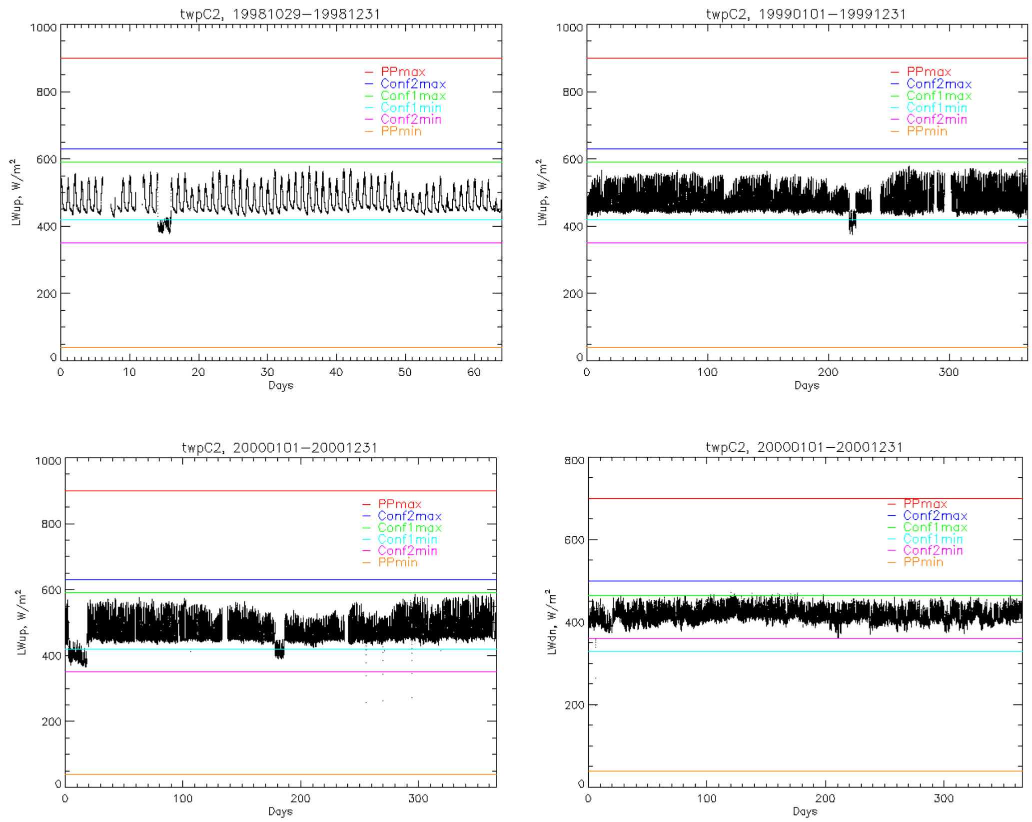


**Figure 35:** Upwelling LW time series from Nauru (both top plots, and lower left plot) and downwelling LW for 2000 (lower right).

instruments. The LWup-SWup anomaly correlation is not always reversely true though. At the beginning of 2000, the upwelling LW data are anomalously low (Figure 35 lower left) but the upwelling SW seems acceptable (Figure 31d). The downwelling LW data tend to behave fairly well at Nauru, as the example plot of 2000 downwelling LW data (lower right) shows.

## 7.5 Summary

The QCRad VAP is intended to provide an automated assessment of the quality of surface broadband radiation measurements. The VAP will process data on a daily basis as a tool to identify problems in operation of the instruments so that appropriate measures can be taken quickly. However, as shown in the previous sections, perhaps more subtle problems can be identified through knowledgeable analyses of longer-term assessments. Combining this latter idea with the current development of an IR Loss correction VAP for unshaded pyranometer measurements, we intend to pursue yearly evaluations of ARM surface radiation measurements. This effort will then provide information such as presented in Table 3, which summarizes the QCRad testing results for several years of data from the SGP EF2 facility. Additionally, information on measurement or data problems is primarily distributed through ARM Data Quality Reports, which are included with all data orders placed and retrieved through the ARM Archive. The longer-term analyses will afford the opportunity to provide overall reporting of problematic data, such as those presented in Table 4 for the TWP Manus and Nauru facilities.

**Table 3:** Percent of data failing QC testing in 1997, 1999, and 2002 at SGP E2.

| | | | Global SW | | | Diffuse SW | | | Direct SW | | | SWup | | | LWdn | | | LWup | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Year | | 1997 | 1999 | 2002 | 1997 | 1999 | 2002 | 1997 | 1999 | 2002 | 1997 | 1999 | 2002 | 1997 | 1999 | 2002 | 1997 | 1999 | 2002 |
| Physically Possible | Min | | 42 | 42 | 42 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 |
| | Max | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Extremely Rare | Min | | 6 | 5 | 7 | 3 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Max | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| User Defined | Min | | | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | Max | | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GSW/SumSW | | | 23 | 5 | 5 | | | | | | | | | | | | | | | |
| DiffSW/GSW | | | | | | 3 | 5 | 0 | | | | | | | | | | | | |
| Tracker Off | | | | | | | | | 1 | 0 | 0 | | | | | | | | | |
| SWup > SumSW | | | | | | | | | | | | 1 | 0 | 0 | | | | | | |
| LWdn & LWup to Ta tests | Global | Min | | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Max | | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | User Defined | Min | | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Max | | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| LWdn to LWup tests | Global | Min | | | | | | | | | | | | | 0 | 0 | 0 | | | |
| | | Max | | | | | | | | | | | | | 0 | 0 | 0 | | | |
| | User Defined | Min | | | | | | | | | | | | | 0 | 0 | 0 | | | |
| | | Max | | | | | | | | | | | | | 0 | 0 | 0 | | | |
| Tc &Td vs Ta | | | | | | | | | | | | | | | 0 | 0 | 0 | | | |
| Tc - Td | | | | | | | | | | | | | | | 0 | 0 | 0 | | | |
| Ta tests | | | | | | | | | | | | | | | 0 | 1 | 1 | | | |

**Table 4:** Example Summary of problematic TWP data.

| | |
|---|---|
| TWP C1 1997 | 1. July 20 ~ August 20, GSW/sumSW ratio too high=> direct normal low |
| | 2. January 1 ~ February 27, LWupTd exceptionally high (from 350 to over 600 K) |
| TWP C1 1998 | 1. April 23 – May 2, SWup, LWup, & LWupTc data are bad |
| | 2. August 22 – 26, No data |
| | 3. August 12 – 14, Tracker off |
| TWP C1 1999 | 1. October 28 – September 11, Tracker off |
| | 2. 19990525-0614, 1002-1017, 0904-0909, No data |
| | 3. February 28 – March 7, SWup & LWup data bad |
| TWP C1 2000 | 1. March 28 – April 2, SWup, LWup, & LWupTc&Td data bad |
| TWP C2 1999 | 1. August 25 – 31, No data |
| | 2. August 6 – October 15, Tracker off |
| | 3. August 6 – 11, Swup, LW up, & LWupTc data bad |
| | 4. March 6 – 7, Ta data noisy |
| TWP C2 2000 | 1. January 4 – 20, Lwup data not normal |
| | 2. 20000104 – 0120 & 0627 – 0705, Swup, & LWupTc data bad |

# 8. Details of the Atmospheric Radiation Measurement Quality Control Radiation Value-Added Products Files

## 8.1 Input Files

The input data for this VAP includes broadband radiation and surface meteorology measurements. The data streams are standard ARM NetCDF files, with different data files being used depending on the specific site and facility, as well as the date of the measurements with respect to programmatic changes that occurred through the years.

The input files involved in this VAP are as follows, where: XX stands for the facility name (C1, C2, E1, E2, etc); and YY stands for the data level (a0, a1, a2, or b1).

SGP Site

sgpsirs1duttXX.c1, or sgpsiros1duttXX.c1, or sgpsirsXX.YY, or sgpbrs1duttXX.c1, or sgpbrsXX.YY, or sgpbeflux1longC1.c1
sgp1smosXX.YY or sgp5ebbrXX.YY
sgpmfrsrXX.YY

TWP site

twpskyrad1duttXX.c1 or twpskyrad60sXX.b1
twpgndrad1duttXX.c1 or twpgndrad60sXX.b1
twp1smet60sXX.b1
twpmfrsrXX.a1

NSA Site

nsasirs1duttXX.c1, nsasiros1duttXX.c1, or nsaskyrad60sXX.b1
nsagndrad1duttXX.c1 or nsagndrad60sXX.b1
nsa1smet60sXX.b1
nsamfrsrXX.a1

All the above listed files can be ordered online from the ARM Data Archive Center (http://www.archive.arm.gov). For more details on the input variables, please refer to Appendix A.

## 8.2 Test Configuration Limits per Site

The configuration limits are derived from historical data analyses at each site. Table 5 shows two sets of values for each site, representing the $1^{st}$ and $2^{nd}$ level configurable limits where appropriate, respectively.

**Table 5:** Configurable limits at each ARM site.

| | SGP | | TWP | | NSA | | |
|---|---|---|---|---|---|---|---|
| Tsnw | 9.0 | | 0.0 | | 5.0 | | * snow covered ground Ta limit for albedo tests (real, degrees C > 0.0) |
| C1, D1 | 0.92 | 0.97 | 0.96 | 1.02 | 0.92 | 1.06 | * Max GSW climatological mult. limit factor (real < 1.2) |
| C2, D2 | 0.52 | 0.58 | 0.52 | 0.6 | 0.8 | 0.92 | * Max Diffuse SW climatological mult. limit factor (real < 0.75) |
| C3, D3 | 0.82 | 0.86 | 0.76 | 0.8 | 0.8 | 0.92 | * Max Direct Normal SW climatological mult. limit factor (real < 0.95) |
| C4, D4 | 0.87 | 0.95 | 0.18 | 0.22 | 0.8 | 0.85 | * Max SWup climatological albedo limit factor (real < 1.0) |
| C5, D5 | 190 | 145 | 330 | 360 | 100 | 80 | * Min LWdn climatological limit factor (real > 60.0) |
| C6, D6 | 465 | 500 | 465 | 500 | 380 | 400 | * Max LWdn climatological limit factor (real < 500.0) |
| C7, D7 | 240 | 210 | 410 | 380 | 120 | 100 | * Min LWup climatological limit factor (real > 60.0) |
| C7, D8 | 590 | 630 | 610 | 630 | 450 | 470 | * Max LWup climatological limit factor (real < 700.0) |
| C9, D9 | 0.22 | 0.27 | 0.3 | 0.34 | 0.2 | 0.25 | * SWup max albedo limit for normal ground cover (Ta>Tslim, real<1.0) |
| C10, D10 | 0.9 | 0.98 | 0.9 | 0.98 | 0.87 | 0.9 | * SWup max albedo limit for snow covered ground (Ta<Tslim, real<1.0) |
| C11, D11 | 0.65 | 0.6 | 0.76 | 0.8 | 0.58 | 0.62 | * Min LWdn climatological Ta mult. limit factor (real > 0.4) |
| C12, D12 | 11 | 23 | 11 | 23 | 11 | 23 | * Max LWdn climatological Ta additive limit factor (real < 25.0) |
| C13, D13 | 10 | 13 | 16 | 14 | 14 | 12 | * Min LWup climatological Ta subtractive limit factor (real < 15.0) |
| C14, D14 | 12 | 16 | 16 | 14 | 18 | 16 | * Max LWup climatological Ta additive limit factor (real < 25.0) |
| C15, D15 | 200 | 220 | 200 | 180 | 180 | 160 | * Climatological LWdn > LWup - limit Factor (min, real < 300.0) |
| C16, D16 | 18 | 25 | 27 | 20 | 27 | 20 | * Climatological LWdn < LWup + limit Factor (min, real < 25.0) |
| C17, D17 | 10 | 4 | 10 | 12 | 10 | 20 | * Tc & Td within +/- limit of Ta for LWdn, LWup (real, degrees C) |
| C18 | -0.8 | | -1.3 | | -0.8 | | * Td < (Tc - limit) (real, degrees C) |
| C19 | 2 | | 1 | | 3.5 | | * Td > (Tc - limit) (real, degrees C) |
| Tmin | -20 | | 7 | | -103 | | * Min climatological allowable Ta,Td,Tc (degrees C, real > -103.0) |
| Tmax | 42 | | 40 | | 75 | | * Max climatological allowable Ta,Td,Tc (degrees C, real < 75.0) |
| | 1050.5 | | 1050.5 | | 1150 | | * Clear sky shortwave a coefficient for SumSW |
| | 1.095 | | 1.095 | | 1.095 | | * Clear sky shortwave b coefficient for SumSW |
| | 1050.3 | | 1050 | | 1150 | | * Clear sky shortwave a coefficient for GSW |
| | 1.148 | | 1.1 | | 1.1 | | * Clear sky shortwave b coefficient for GSW |
| | 0.07 | 0.17 | 0.03 | 0.2 | 0.05 | 0.36 | * dry mode coeff. & wet mode coeff. |
| | 0.9 | | 0.85 | | 0.95 | | * Tracker off limit; 0.9 for sgp & nsa |

## 8.3 Output Files

The QCRad VAP produces two NetCDF files daily, both files containing 1-minute resolution data of radiation and meteorological measurements including direct and diffuse SW, upwelling SW, downwelling and upwelling LW irradiances, the best estimate of downwelling SW, and the corresponding QC flag for each field. The first output file contains all the detailed bit-packed QC information, while the second "summary" file summarizes and simplifies the QC information as follows:

QC flag = -1; Data missing
QC flag = 0; Data good
QC flag = 1; Data extremely rare but possible, quality indeterminate
QC flag = 2; Data bad

The QCRad VAP output files follow the ARM naming convention:

[site]qcrad1long[facility].LL.YYYYMMDD.hhmmss.cdf

where

[site] is the ARM site name (SGP, NSA, TWP); [facility] is the facility name (C1, C2, E1, E2, etc); LL is the Level of the data stream, LL = c1 for the NetCDF file with the bit-packed QC information and LL = s1 for the summary file; YYYY is the year; MM is the month of the year; DD is the day of the month; hh is the hour of the day of data start; mm is the minutes of the hour; and ss is the seconds of the minute. The output fields, and their units and descriptions, are listed in Appendix B. The data files can be ordered through the ARM Data Archive at http://www.archive.arm.gov/. See Appendix B for a detailed description of the output fields in both the c1 and s1 level NetCDF files.

## 8.4 Description of Quality Control Flags

The QCRAD VAP output files are composed of three parts: the measured or calculated fields, the standard QC fields associated with these fields, and the ancillary QC fields. Each output field has a standard QC field, which contains bit-packed information about the field. In general, the purpose of the bit-packed type of QC field is to standardize the ARM VAP QC flagging for machine readability. The ancillary QC fields in the output file are designed according to the scientific needs of the VAP. They include most of the standard QC fields, but expressed as ASCII numbers rather than bit-packed information. They also include other QC checks that are not directly associated with a specific output field.

The following describes the ancillary QC flags included in the output file. The standard QC fields are combinations of these flags, see Appendix B for details.

Flag Value: Related to Type test:
5-6 Global Physical Limits (PP)
3-4 User configurable (UC2) 2$^{nd}$ level tests, also LW Tc and Td tests
1-2 User configurable (UC1) 1$^{st}$ level tests and non-definitive tests

(Non-definitive means that while a comparison test may fail, it is unknown which of the values compared might be the "bad" one.)

The tests and flags are set restrictively in descending order. In other words, if a value fails a PP limit, then the ER and UC tests are not performed, as the data will always fail these tests as well. Thus, the QC flag reflects the largest test failure value.

Daily Files and All File:

QC1 – QC6
-1 - missing data or test not possible
0 - No test failures
1 - too low (UC1)
2 - too high (UC1)
3 - too low (UC2)
4 - too high (UC2)
5 - too low (PP)
6 - too high (PP)
9 - "tracker off" (QC2 and QC3)

QC7 – GSW/Sum test [non-definitive]
-1= test not possible
0 = No test failures
1 = Z < 75°; GSW/Sum < 0.92, or GSW/Sum > 1.08, Sum > 50 $Wm^{-2}$
2 = $93^{O}$ > Z > 75°; GSW/Sum < 0.85, or GSW/Sum > 1.15, Sum > 50 $Wm^{-2}$

QC8 – Dif/GSW test [non-definitive]
-1= test not possible
0 = No test failures
1 = Z < 75°; Dif/GSW > 1.05, GSW > 50 $Wm^{-2}$
2 = 93° > Z > $75^{O}$; Dif/GSW > 1.10, GSW > 50 $Wm^{-2}$

QC9 – SWup vs Sum SW test
-1= test not possible
0 = No test failures
1 = Sum or GSW > 50 $Wm^{-2}$; SWup > C9 * Sum+25 $Wm^{-2}$, Ta >= Tsnw
2 = Sum or GSW > 50 $Wm^{-2}$; SWup > C10 * Sum+25 $Wm^{-2}$, Ta < Tsnw
3 = Sum > 50 $Wm^{-2}$; SWup > Sum
4 = Sum not avail, GSW > 50 $Wm^{-2}$; SWup > GSW
5 = Sum AND GSW > 50 $Wm^{-2}$; SWup > Sum AND SWup > GSW; Swup "bad"

QC10 – LWdn to Ta test
-1= test not possible
0 = No test failures
1 = Ta OK; LWdn < (C11 *sigma*$Ta^4$)
2 = Ta OK; LWdn > (sigma*$Ta^4$+C12)

3 = Ta OK; LWdn < (D11*sigma*$Ta^4$)
4 = Ta OK; LWdn > (sigma*$Ta^4$+D12)

QC11 – LWup to Ta test
-1= test not possible
0 = No test failures
1 = Ta OK; LWup < (sigma*$(Ta-C13)^4$)
2 = Ta OK; LWup > (sigma*$(Ta+C14)^4$)
3 = Ta OK; LWup < (sigma*$(Ta-D13)^4$)
4 = Ta OK; LWup > (sigma*$(Ta+D14)^4$)

QC12 – LWdn to LWup test
-1= test not possible
0 = No test failures
1 = lwdn < lwup-C15
2 = lwdn > lwup+C16
3 = lwdn < lwup-D15
4 = lwdn > lwup+D16

QC13 – LWdn Tc vs Ta
-1= test not possible
0= No test failures
3= Tc < Ta - C17
4 = Tc > Ta + C17

QC14 – LWdn Td vs Ta
-1= test not possible
0= No test failures
3= Td < Ta - C17
4 = Td > Ta + C17

QC15 – LWup Tc vs Ta
-1= test not possible
0= No test failures
3= Tc < Ta - C17
4 = Tc > Ta + C17

QC16 – LWup Td vs Ta
-1= test not possible
0= No test failures
3= Td < Ta - C17
4 = Td > Ta + C17

QC17 – LWdn Tc vs Td
-1= test not possible
0= No test failures

3= (Tc - Td) < C18
4= (Tc - Td) > C19

QC18 – LWup Tc vs Td
-1= test not possible
0= No test failures
3= (Tc - Td) < C18
4= (Tc - Td) > C19

QC19 – Ta testing
-1= test not possible, (no Ta)
0= No test failures
1 = Ta > 350K or Ta < 170K
2 = Ta more than Tavg +/- 20K

## 8.5 References

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# Appendix A: Input Data

Table A.1 lists the data streams used in the QCRad VAP and the fields involved in each input data file, where XX represents facility names (C1, C2, C3, E1, E2, …) and YY indicates data levels (a0, a1, a2, b1, etc.) of the input datastream.

**Table A.1:** Input data streams and fields

| | |
|---|---|
| sgpsirs1duttXX.c1<br>sgpsiros1duttXX.c1<br>twpskyrad1duttXX.c1<br>nsaskyradduttXX.c1<br>sgpbrs1duttC1.c1 | down_short_hemisp_uncorrected |
| | up_short_hemisp |
| | up_long_hemisp |
| | down_long_hemisp |
| | short_direct_normal |
| | dsdh_best_estimate |
| | down_long_case_temperature |
| | down_long_dome_temperature |
| | up_long_case_temperature |
| | up_long_dome_temperature |
| | rh |
| | air_temperature |
| | bar_pres |
| | detector_flux |
| | wind_speed_1 |
| | wind_speed_2 |
| | wind_direction_1 |
| | wind_direction_2 |
| | precip |
| sgpsirsXX.YY<br>sgpbrsXX.YY | down_short_hemisp |
| | short_direct_normal |
| | down_short_diffuse_hemisp |
| | up_short_hemisp |
| | up_long_hemisp |
| | down_long_hemisp |
| | down_long_hemisp_shaded |
| | inst_down_long_shaded_case_temp |
| | inst_down_long_shaded_dome_temp |
| | inst_up_long_case_temp |
| | inst_up_long_dome_temp |
| sgpmfrsrXX.YY | hemisp_broadband |
| | diffuse_hemisp_broadband |
| | direct_norm_broadband |
| | direct_normal_broadband |
| sgp1smosXX.YY | temp |
| | rh |
| | bar_pres |
| | wspd |
| | wdir |
| | precip |

**Table A.1:** (contd)

| | |
|---|---|
| sgp5ebbrXX.YY | tair_top |
| | hum_top |
| | pres |
| | wind_s |
| | wind_d |
| sgpbeflux1longC1.c1 | down_short_hemisp |
| | short_direct_normal |
| | down_short_diffuse_hemisp |
| | up_short_hemisp |
| | up_long_hemisp |
| | down_long_hemisp |
| twpskyrad60sXX.YY<br>nsaskyrad60sXX.YY | down_short_hemisp |
| | short_direct_normal |
| | down_short_diffuse_hemisp |
| | down_long_hemisp |
| | down_long_hemisp_shaded1 |
| | down_long_hemisp_shaded2 |
| | inst_down_long_shaded1_case_temp |
| | inst_down_long_shaded2_case_temp |
| | inst_down_long_shaded1_dome_temp |
| | inst_down_long_shaded2_dome_temp |
| twpgndrad60sXX.YY<br>nsagndrad60sXX.YY | up_short_hemisp |
| | up_long_hemisp |
| | inst_up_long_case_temp |
| | inst_up_long_dome_temp |
| twpsmet60sXX.YY<br>nsasmet60sXX.YY | temp_mean |
| | relh_mean |
| | atmos_pressure |
| | up_wind_spd_arith_avg |
| | up_wind_dir_arith_avg |
| | precip_mean |

## Appendix B: Output Fields

Below is a sample output Data Object Design for the QCRad VAP, which includes all the output field definitions, units, and their corresponding QC fields. Here qc_XX represent standard QC fields and aqc_YY represent ancillary QC fields. See Section 9.4 for details of the QC field definitions.

```
netcdf sgpqcrad1longE1.c1.20000101.000000 {
dimensions:
    time = UNLIMITED ; // (1440 currently)
variables:
    int base_time ;
        base_time:string = "1-Jan-2000,0:00:00 GMT" ;
        base_time:long_name = "Base time in Epoch" ;
        base_time:units = "seconds since 1970-1-1 0:00:00 0:00" ;
    double time_offset(time) ;
        time_offset:long_name = "Time offset from base_time" ;
        time_offset:units = "seconds since 2000-01-01 00:00:00 0:00" ;
    double time(time) ;
        time:long_name = "Time offset from midnight" ;
        time:units = "seconds since 2000-01-01 00:00:00 0:00" ;
    float BestEstimate_down_short_hemisp(time) ;
        BestEstimate_down_short_hemisp:long_name = "Best Estimate Global Downwelling Shortwave
Hemispheric Irradiance" ;
        BestEstimate_down_short_hemisp:units = "W/m^2" ;
        BestEstimate_down_short_hemisp:missing_value = -9999.f ;
    int qc_BestEstimate_down_short_hemisp(time) ;
        qc_BestEstimate_down_short_hemisp:long_name = "Data Quality Check for
Best_Estimate_down_short_hemisp" ;
        qc_BestEstimate_down_short_hemisp:units = "unitless" ;
        qc_BestEstimate_down_short_hemisp:description = "This field contains bit packed values which
should be interpreted as listed; no bits set (zero) represents good data" ;
        qc_BestEstimate_down_short_hemisp:bit_1_description = "Valid data value not available, data
value in output file set to -9999" ;
        qc_BestEstimate_down_short_hemisp:bit_1_assessment = "Bad" ;
    int source_BestEstimate_down_short_hemisp(time) ;
        source_BestEstimate_down_short_hemisp:long_name = "Flag indicating how the
BestEstimate_down_short_hemisp was derived" ;
        source_BestEstimate_down_short_hemisp:units = "unitless" ;
        source_BestEstimate_down_short_hemisp:description = "This field contains flag values which
should be interpreted as follows:" ;
        source_BestEstimate_down_short_hemisp:-3 = "missing data" ;
        source_BestEstimate_down_short_hemisp:-2 = "BEGSW=MFRSRGSW" ;
        source_BestEstimate_down_short_hemisp:-1 = "BEGSW=GSW" ;
        source_BestEstimate_down_short_hemisp:0 = "BEGSW=SumSW" ;
        source_BestEstimate_down_short_hemisp:1 = "BEGSW=Morning fitting" ;
        source_BestEstimate_down_short_hemisp:2 = "BEGSW=Afternoon fitting" ;
```

float down_short_hemisp(time) ;
down_short_hemisp:long_name = "IR corrected Global Downwelling Shortwave Hemispheric Irradiance" ;
down_short_hemisp:units = "W/m^2" ;
down_short_hemisp:missing_value = -9999.f ;
int qc_down_short_hemisp(time) ;
qc_down_short_hemisp:long_name = "Data Quality Check for down_short_hemisp" ;
qc_down_short_hemisp:units = "unitless" ;
qc_down_short_hemisp:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
qc_down_short_hemisp:bit_1_description = "Valid data value not available in input file, data value in output file set to -9999" ;
qc_down_short_hemisp:bit_1_assessment = "Bad" ;
qc_down_short_hemisp:bit_2_description = "data too low (UC1)" ;
qc_down_short_hemisp:bit_2_assessment = "Indeterminate" ;
qc_down_short_hemisp:bit_3_description = "data too high (UC1)" ;
qc_down_short_hemisp:bit_3_assessment = "Indeterminate" ;
qc_down_short_hemisp:bit_4_description = "data too low (UC2), data value set to -9999" ;
qc_down_short_hemisp:bit_4_assessment = "Bad" ;
qc_down_short_hemisp:bit_5_description = "data too high (UC2), data value set to -9999" ;
qc_down_short_hemisp:bit_5_assessment = "Bad" ;
qc_down_short_hemisp:bit_6_description = "data too low (PP), data value set to -9999" ;
qc_down_short_hemisp:bit_6_assessment = "Bad" ;
qc_down_short_hemisp:bit_7_description = "data too high (PP), data value set to -9999" ;
qc_down_short_hemisp:bit_7_assessment = "Bad" ;
qc_down_short_hemisp:bit_8_description = "GSW2SumSW (SZA <= 75 and SumSW > 50 W/m^2; GSW/SumSW < 0.92 or GSW/SumSW > 1.08)" ;
qc_down_short_hemisp:bit_8_assessment = "Indeterminate" ;
qc_down_short_hemisp:bit_9_description = "GSW2SumSW (93 > SZA > 75 and SumSW > 50; GSW/SumSW < 0.85 or GSW/SumSW > 1.15)" ;
qc_down_short_hemisp:bit_9_assessment = "Indeterminate" ;
qc_down_short_hemisp:bit_10_description = "DifSW2GSW (SZA < 75; DifSW/GSW >1.05, GSW > 50 W/m^2)" ;
qc_down_short_hemisp:bit_10_assessment = "Indeterminate" ;
qc_down_short_hemisp:bit_11_description = "DifSW2GSW (93 > SZA > 75; DifSW/GSW > 1.10, GSW > 50 W/m^2)" ;
qc_down_short_hemisp:bit_11_assessment = "Indeterminate" ;
int aqc_down_short_hemisp(time) ;
aqc_down_short_hemisp:long_name = "Data Quality Check for down_short_hemisp" ;
aqc_down_short_hemisp:units = "unitless" ;
aqc_down_short_hemisp:description = "This field contains integer values which should be interpreted as follows:" ;
aqc_down_short_hemisp:-1 = "missing data" ;
aqc_down_short_hemisp:0 = "data ok" ;
aqc_down_short_hemisp:1 = "data too low (UC1)" ;
aqc_down_short_hemisp:2 = "data too high (UC1)" ;

```
        aqc_down_short_hemisp:3 = "data too low (UC2), data value set to -9999" ;
        aqc_down_short_hemisp:4 = "data too high (UC2), data value set to -9999" ;
        aqc_down_short_hemisp:5 = "data too low (PP), data value set to -9999" ;
        aqc_down_short_hemisp:6 = "data too high (PP), data value set to -9999" ;
    int aqc_GSW2SumSW(time) ;
        aqc_GSW2SumSW:long_name = "GSW/SumSW test" ;
        aqc_GSW2SumSW:units = "unitless" ;
        aqc_GSW2SumSW:-1 = "test not possible" ;
        aqc_GSW2SumSW:0 = "data ok" ;
        aqc_GSW2SumSW:1 = "SZA <= 75 and  SumSW > 50 W/m^2; GSW/SumSW < 0.92 or GSW/SumSW > 1.08" ;
        aqc_GSW2SumSW:2 = "93 > SZA > 75 and SumSW > 50; GSW/SumSW < 0.85 or GSW/SumSW > 1.15" ;
    int aqc_DifSW2GSW(time) ;
        aqc_DifSW2GSW:long_name = "DifSW/GSW test" ;
        aqc_DifSW2GSW:units = "unitless" ;
        aqc_DifSW2GSW:-1 = "test not possible" ;
        aqc_DifSW2GSW:0 = "data ok" ;
        aqc_DifSW2GSW:1 = "SZA < 75; DifSW/GSW >1.05, GSW > 50 W/m^2" ;
        aqc_DifSW2GSW:2 = "93 > SZA > 75; DifSW/GSW > 1.10, GSW > 50 W/m^2" ;
    float down_short_diffuse_hemisp(time) ;
        down_short_diffuse_hemisp:long_name = "Downwelling Shortwave Diffuse Hemispheric Irradiance" ;
        down_short_diffuse_hemisp:units = "W/m^2" ;
        down_short_diffuse_hemisp:missing_value = -9999.f ;
    int qc_down_short_diffuse_hemisp(time) ;
        qc_down_short_diffuse_hemisp:long_name = "Data Quality Check for down_short_diffuse_hemisp" ;
        qc_down_short_diffuse_hemisp:units = "unitless" ;
        qc_down_short_diffuse_hemisp:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
        qc_down_short_diffuse_hemisp:bit_1_description = "Valid data value not available in input file, data value in output file set to -9999" ;
        qc_down_short_diffuse_hemisp:bit_1_assessment = "Bad" ;
        qc_down_short_diffuse_hemisp:bit_2_description = "data too low (UC1)" ;
        qc_down_short_diffuse_hemisp:bit_2_assessment = "Indeterminate" ;
        qc_down_short_diffuse_hemisp:bit_3_description = "data too high (UC1)" ;
        qc_down_short_diffuse_hemisp:bit_3_assessment = "Indeterminate" ;
        qc_down_short_diffuse_hemisp:bit_4_description = "data too low (UC2), data value set to -9999" ;
        qc_down_short_diffuse_hemisp:bit_4_assessment = "Bad" ;
        qc_down_short_diffuse_hemisp:bit_5_description = "data too high (UC2), data value set to -9999" ;
        qc_down_short_diffuse_hemisp:bit_5_assessment = "Bad" ;
        qc_down_short_diffuse_hemisp:bit_6_description = "data too low (PP), data value set to -9999" ;
        qc_down_short_diffuse_hemisp:bit_6_assessment = "Bad" ;
```

qc_down_short_diffuse_hemisp:bit_7_description = "data too high (PP), data value set to -9999" ;
qc_down_short_diffuse_hemisp:bit_7_assessment = "Bad" ;
qc_down_short_diffuse_hemisp:bit_8_description = "GSW2SumSW (SZA <= 75 and SumSW > 50 W/m^2; GSW/SumSW < 0.92 or GSW/SumSW > 1.08)" ;
qc_down_short_diffuse_hemisp:bit_8_assessment = "Indeterminate" ;
qc_down_short_diffuse_hemisp:bit_9_description = "GSW2SumSW (93 > SZA > 75 and SumSW > 50; GSW/SumSW < 0.85 or GSW/SumSW > 1.15)" ;
qc_down_short_diffuse_hemisp:bit_9_assessment = "Indeterminate" ;
qc_down_short_diffuse_hemisp:bit_10_description = "DifSW2GSW (SZA < 75; DifSW/GSW 1.05, GSW > 50 W/m^2)" ;
qc_down_short_diffuse_hemisp:bit_10_assessment = "Indeterminate" ;
qc_down_short_diffuse_hemisp:bit_11_description = "DifSW2GSW (93 > SZA > 75; DifSW/GSW > 1.10, GSW > 50 W/m^2)" ;
qc_down_short_diffuse_hemisp:bit_11_assessment = "Indeterminate" ;
qc_down_short_diffuse_hemisp:bit_12_description = "data failed Rayleigh limit test" ;
qc_down_short_diffuse_hemisp:bit_12_assessment = "Bad" ;
qc_down_short_diffuse_hemisp:bit_13_description = "data failed tracker off test" ;
qc_down_short_diffuse_hemisp:bit_13_assessment = "Bad" ;
int aqc_down_short_diffuse_hemisp(time) ;
aqc_down_short_diffuse_hemisp:long_name = "Data Quality Check for down_short_diffuse_hemisp" ;
aqc_down_short_diffuse_hemisp:units = "unitless" ;
aqc_down_short_diffuse_hemisp:description = "This field contains integer values which should be interpreted as follows:" ;
aqc_down_short_diffuse_hemisp:-1 = "missing data" ;
aqc_down_short_diffuse_hemisp:0 = "data ok" ;
aqc_down_short_diffuse_hemisp:1 = "data too low (UC1)" ;
aqc_down_short_diffuse_hemisp:2 = "data too high (UC1)" ;
aqc_down_short_diffuse_hemisp:3 = "data too low (UC2), data value set to -9999" ;
aqc_down_short_diffuse_hemisp:4 = "data too high (UC2), data value set to -9999" ;
aqc_down_short_diffuse_hemisp:5 = "data too low (PP), data value set to -9999" ;
aqc_down_short_diffuse_hemisp:6 = "data too high (PP), data value set to -9999" ;
aqc_down_short_diffuse_hemisp:8 = "data failed Rayleigh limit test" ;
aqc_down_short_diffuse_hemisp:9 = "data failed tracker off test" ;
float short_direct_normal(time) ;
short_direct_normal:long_name = "Shortwave Direct Normal Irradiance" ;
short_direct_normal:units = "W/m^2" ;
short_direct_normal:missing_value = -9999.f ;
int qc_short_direct_normal(time) ;
qc_short_direct_normal:long_name = "Data Quality Check for short_direct_normal" ;
qc_short_direct_normal:units = "unitless" ;
qc_short_direct_normal:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
qc_short_direct_normal:bit_1_description = "Valid data value not available in input file, data value in output file set to -9999" ;

qc_short_direct_normal:bit_1_assessment = "Bad" ;
qc_short_direct_normal:bit_2_description = "data too low (UC1)" ;
qc_short_direct_normal:bit_2_assessment = "Indeterminate" ;
qc_short_direct_normal:bit_3_description = "data too high (UC1)" ;
qc_short_direct_normal:bit_3_assessment = "Indeterminate" ;
qc_short_direct_normal:bit_4_description = "data too low (UC2), data value set to -9999" ;
qc_short_direct_normal:bit_4_assessment = "Bad" ;
qc_short_direct_normal:bit_5_description = "data too high (UC2), data value set to -9999" ;
qc_short_direct_normal:bit_5_assessment = "Bad" ;
qc_short_direct_normal:bit_6_description = "data too low (PP), data value set to -9999" ;
qc_short_direct_normal:bit_6_assessment = "Bad" ;
qc_short_direct_normal:bit_7_description = "data too high (PP), data value set to -9999" ;
qc_short_direct_normal:bit_7_assessment = "Bad" ;
qc_short_direct_normal:bit_8_description = "GSW2SumSW (SZA <= 75 and SumSW > 50 W/m^2; GSW/ SumSW < 0.92 or GSW/SumSW > 1.08)" ;
qc_short_direct_normal:bit_8_assessment = "Indeterminate" ;
qc_short_direct_normal:bit_9_description = "GSW2SumSW (93 > SZA > 75 and SumSW > 50; GSW/ SumSW < 0.85 or GSW/SumSW > 1.15)" ;
qc_short_direct_normal:bit_9_assessment = "Indeterminate" ;
qc_short_direct_normal:bit_10_description = "data failed tracker off test" ;
qc_short_direct_normal:bit_10_assessment = "Bad" ;
int aqc_short_direct_normal(time) ;
aqc_short_direct_normal:long_name = "Data Quality Check for short_direct_normal" ;
aqc_short_direct_normal:units = "unitless" ;
aqc_short_direct_normal:description = "This field contains integer values which should be interpreted as follows:" ;
aqc_short_direct_normal:-1 = "missing data" ;
aqc_short_direct_normal:0 = "data ok" ;
aqc_short_direct_normal:1 = "data too low (UC1)" ;
aqc_short_direct_normal:2 = "data too high (UC1)" ;
aqc_short_direct_normal:3 = "data too low (UC2), data value set to -9999" ;
aqc_short_direct_normal:4 = "data too high (UC2), data value set to -9999" ;
aqc_short_direct_normal:5 = "data too low (PP), data value set to -9999" ;
aqc_short_direct_normal:6 = "data too high (PP), data value set to -9999" ;
aqc_short_direct_normal:9 = "data failed tracker off test" ;
float up_short_hemisp(time) ;
up_short_hemisp:long_name = "Upwelling Shortwave Hemispheric Irradiance" ;
up_short_hemisp:units = "W/m^2" ;
up_short_hemisp:missing_value = -9999.f ;
int qc_up_short_hemisp(time) ;
qc_up_short_hemisp:long_name = "Data Quality Check for up_short_hemisp" ;
qc_up_short_hemisp:units = "unitless" ;
qc_up_short_hemisp:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
qc_up_short_hemisp:bit_1_description = "Valid data value not available in input file, data value in output file set to -9999" ;

qc_up_short_hemisp:bit_1_assessment = "Bad" ;
qc_up_short_hemisp:bit_2_description = "data too low (UC1)" ;
qc_up_short_hemisp:bit_2_assessment = "Indeterminate" ;
qc_up_short_hemisp:bit_3_description = "data too high (UC1)" ;
qc_up_short_hemisp:bit_3_assessment = "Indeterminate" ;
qc_up_short_hemisp:bit_4_description = "data too low (UC2), data value set to -9999" ;
qc_up_short_hemisp:bit_4_assessment = "Bad" ;
qc_up_short_hemisp:bit_5_description = "data too high (UC2), data value set to -9999" ;
qc_up_short_hemisp:bit_5_assessment = "Bad" ;
qc_up_short_hemisp:bit_6_description = "data too low (PP), data value set to -9999" ;
qc_up_short_hemisp:bit_6_assessment = "Bad" ;
qc_up_short_hemisp:bit_7_description = "data too high (PP), data value set to -9999" ;
qc_up_short_hemisp:bit_7_assessment = "Bad" ;
qc_up_short_hemisp:bit_8_description = "SWupTest test (SumSW or GSW > 50; SWup > C9*SumSW+25, Ta >= Tsnow)" ;
qc_up_short_hemisp:bit_8_assessment = "Indeterminate" ;
qc_up_short_hemisp:bit_9_description = "SWupTest test (SumSW or GSW > 50; SWup > C10*SumSW+25, Ta < Tsnow)" ;
qc_up_short_hemisp:bit_9_assessment = "Indeterminate" ;
qc_up_short_hemisp:bit_10_description = "SWupTest test (SumSW or GSW > 50; SWup > D9*SumSW+30, Ta >= Tsnow)" ;
qc_up_short_hemisp:bit_10_assessment = "Bad" ;
qc_up_short_hemisp:bit_11_description = "SWupTest test (SumSW or GSW > 50; SWup > D10*SumSW+30, Ta < Tsnow)" ;
qc_up_short_hemisp:bit_11_assessment = "Bad" ;
qc_up_short_hemisp:bit_12_description = "SWupTest test (SumSW and GSW > 50; SWup > SumSW or SWup > GSW; SWup bad)" ;
qc_up_short_hemisp:bit_12_assessment = "Bad" ;
qc_up_short_hemisp:bit_13_description = "SWupTest test (SumSW and GSW > 50; SWup > SumSW and SWup > GSW; SWup bad)" ;
qc_up_short_hemisp:bit_13_assessment = "Bad" ;
int aqc_up_short_hemisp(time) ;
aqc_up_short_hemisp:long_name = "Data Quality Check for up_short_hemisp" ;
aqc_up_short_hemisp:units = "unitless" ;
aqc_up_short_hemisp:description = "This field contains integer values which should be interpreted as follows:" ;
aqc_up_short_hemisp:-1 = "missing data" ;
aqc_up_short_hemisp:0 = "data ok" ;
aqc_up_short_hemisp:1 = "data too low (UC1)" ;
aqc_up_short_hemisp:2 = "data too high (UC1)" ;
aqc_up_short_hemisp:3 = "data too low (UC2), data value set to -9999" ;
aqc_up_short_hemisp:4 = "data too high (UC2), data value set to -9999" ;
aqc_up_short_hemisp:5 = "data too low (PP), data value set to -9999" ;
aqc_up_short_hemisp:6 = "data too high (PP), data value set to -9999" ;
int aqc_SWupTest(time) ;
aqc_SWupTest:long_name = "SWup test" ;

aqc_SWupTest:units = "unitless" ;
aqc_SWupTest:-1 = "test not possible" ;
aqc_SWupTest:0 = "data ok" ;
aqc_SWupTest:1 = "SumSW or GSW > 50; SWup > C9*SumSW+25, Ta >= Tsnow" ;
aqc_SWupTest:2 = "SumSW or GSW > 50; SWup > C10*SumSW+25, Ta < Tsnow" ;
aqc_SWupTest:3 = "SumSW or GSW > 50; SWup > D9*SumSW+30, Ta >= Tsnow" ;
aqc_SWupTest:4 = "SumSW or GSW > 50; SWup > D10*SumSW+30, Ta < Tsnow" ;
aqc_SWupTest:5 = "SumSW and GSW > 50; SWup > SumSW or SWup > GSW; SWup bad" ;
aqc_SWupTest:6 = "SumSW and GSW > 50; SWup > SumSW and SWup > GSW; SWup bad" ;
float down_long_hemisp(time) ;
down_long_hemisp:long_name = "Downwelling Longwave Hemispheric Irradiance" ;
down_long_hemisp:units = "W/m^2" ;
down_long_hemisp:missing_value = -9999.f ;
int qc_down_long_hemisp(time) ;
qc_down_long_hemisp:long_name = "Data Quality Check for down_long_hemisp" ;
qc_down_long_hemisp:units = "unitless" ;
qc_down_long_hemisp:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
qc_down_long_hemisp:bit_1_description = "Valid data value not available in input file, data value in output file set to -9999" ;
qc_down_long_hemisp:bit_1_assessment = "Bad" ;
qc_down_long_hemisp:bit_2_description = "data too low (UC1)" ;
qc_down_long_hemisp:bit_2_assessment = "Indeterminate" ;
qc_down_long_hemisp:bit_3_description = "data too high (UC1)" ;
qc_down_long_hemisp:bit_3_assessment = "Indeterminate" ;
qc_down_long_hemisp:bit_4_description = "data too low (UC2), data value set to -9999" ;
qc_down_long_hemisp:bit_4_assessment = "Bad" ;
qc_down_long_hemisp:bit_5_description = "data too high (UC2), data value set to -9999" ;
qc_down_long_hemisp:bit_5_assessment = "Bad" ;
qc_down_long_hemisp:bit_6_description = "data too low (PP), data value set to -9999" ;
qc_down_long_hemisp:bit_6_assessment = "Bad" ;
qc_down_long_hemisp:bit_7_description = "data too high (PP), data value set to -9999" ;
qc_down_long_hemisp:bit_7_assessment = "Bad" ;
qc_down_long_hemisp:bit_8_description = "data failed case temperature standard deviation testing (Tc_sdev - Tc_avg_sdev > 0.1)" ;
qc_down_long_hemisp:bit_8_assessment = "Bad" ;
qc_down_long_hemisp:bit_9_description = "data failed dome temperature standard deviation testing (Td_sdev - Td_avg_sdev > 0.1)" ;
qc_down_long_hemisp:bit_9_assessment = "Bad" ;
qc_down_long_hemisp:bit_10_description = "data failed both case and dome temperature standard deviation testing" ;
qc_down_long_hemisp:bit_10_assessment = "Bad" ;
qc_down_long_hemisp:bit_11_description = "LWdn2Ta test (Ta OK; LWdn < C11*sigma*Ta^4)" ;
qc_down_long_hemisp:bit_11_assessment = "Indeterminate" ;

```
        qc_down_long_hemisp:bit_12_description = "LWdn2Ta test (Ta OK; LWdn >
sigma*Ta^4+C12)" ;
        qc_down_long_hemisp:bit_12_assessment = "Indeterminate" ;
        qc_down_long_hemisp:bit_13_description = "LWdn2Ta test (Ta OK; LWdn <
D11*sigma*Ta^4)" ;
        qc_down_long_hemisp:bit_13_assessment = "Bad" ;
        qc_down_long_hemisp:bit_14_description = "LWdn2Ta test (Ta OK; LWdn >
sigma*Ta^4+D12)" ;
        qc_down_long_hemisp:bit_14_assessment = "Bad" ;
        qc_down_long_hemisp:bit_15_description = "LWdn2LWup test (LWdn < LWup - C15)" ;
        qc_down_long_hemisp:bit_15_assessment = "Indeterminate" ;
        qc_down_long_hemisp:bit_16_description = "LWdn2LWup test (LWdn > LWup + C16)" ;
        qc_down_long_hemisp:bit_16_assessment = "Indeterminate" ;
        qc_down_long_hemisp:bit_17_description = "LWdn2LWup test (LWdn < LWup - D15)" ;
        qc_down_long_hemisp:bit_17_assessment = "Bad" ;
        qc_down_long_hemisp:bit_18_description = "LWdn2LWup test (LWdn > LWup + D16)" ;
        qc_down_long_hemisp:bit_18_assessment = "Bad" ;
    int aqc_down_long_hemisp(time) ;
        aqc_down_long_hemisp:long_name = "Data Quality Check for down_long_hemisp" ;
        aqc_down_long_hemisp:units = "unitless" ;
        aqc_down_long_hemisp:description = "This field contains integer values which should be
interpreted as follows:" ;
        aqc_down_long_hemisp:-1 = "missing data" ;
        aqc_down_long_hemisp:0 = "data ok" ;
        aqc_down_long_hemisp:1 = "data too low (UC1)" ;
        aqc_down_long_hemisp:2 = "data too high (UC1)" ;
        aqc_down_long_hemisp:3 = "data too low (UC2), data value set to -9999" ;
        aqc_down_long_hemisp:4 = "data too high (UC2), data value set to -9999" ;
        aqc_down_long_hemisp:5 = "data too low (PP), data value set to -9999" ;
        aqc_down_long_hemisp:6 = "data too high (PP), data value set to -9999" ;
        aqc_down_long_hemisp:7 = "data failed case temperature standard deviation testing (Tc_sdev -
Tc_avg_sdev > 0.1)" ;
        aqc_down_long_hemisp:8 = "data failed dome temperature standard deviation testing (Td_sdev -
Td_avg_sdev > 0.1)" ;
        aqc_down_long_hemisp:9 = "data failed both case and dome temperature standard deviation
testing" ;
    int aqc_LWdn2Ta(time) ;
        aqc_LWdn2Ta:long_name = "down_long_hemisp (LWdn) to Ta test" ;
        aqc_LWdn2Ta:units = "unitless" ;
        aqc_LWdn2Ta:description = "This field contains integer values which should be interpreted as
follows:" ;
        aqc_LWdn2Ta:-1 = "test not possible" ;
        aqc_LWdn2Ta:0 = "data ok" ;
        aqc_LWdn2Ta:1 = "Ta OK; LWdn < C11*sigma*Ta^4" ;
        aqc_LWdn2Ta:2 = "Ta OK; LWdn > sigma*Ta^4+C12" ;
        aqc_LWdn2Ta:3 = "Ta OK; LWdn < D11*sigma*Ta^4" ;
```

aqc_LWdn2Ta:4 = "Ta OK; LWdn > sigma*Ta^4+D12" ;
int aqc_LWdn2LWup(time) ;
aqc_LWdn2LWup:long_name = "down_long_hemisp (LWdn) to up_long_hemisp (LWup) test" ;
aqc_LWdn2LWup:units = "unitless" ;
aqc_LWdn2LWup:description = "This field contains integer values which should be interpreted as follows:" ;
aqc_LWdn2LWup:-1 = "test not possible" ;
aqc_LWdn2LWup:0 = "data ok" ;
aqc_LWdn2LWup:1 = "LWdn < LWup - C15" ;
aqc_LWdn2LWup:2 = "LWdn > LWup + C16" ;
aqc_LWdn2LWup:3 = "LWdn < LWup - D15" ;
aqc_LWdn2LWup:4 = "LWdn > LWup + D16" ;
float up_long_hemisp(time) ;
up_long_hemisp:long_name = "Upwelling (10 meter) Longwave Hemispheric Irradiance" ;
up_long_hemisp:units = "W/m^2" ;
up_long_hemisp:missing_value = -9999.f ;
int qc_up_long_hemisp(time) ;
qc_up_long_hemisp:long_name = "Data Quality Check for up_long_hemisp" ;
qc_up_long_hemisp:units = "unitless" ;
qc_up_long_hemisp:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
qc_up_long_hemisp:bit_1_description = "Valid data value not available in input file, data value in output file set to -9999" ;
qc_up_long_hemisp:bit_1_assessment = "Bad" ;
qc_up_long_hemisp:bit_2_description = "data too low (UC1)" ;
qc_up_long_hemisp:bit_2_assessment = "Indeterminate" ;
qc_up_long_hemisp:bit_3_description = "data too high (UC1)" ;
qc_up_long_hemisp:bit_3_assessment = "Indeterminate" ;
qc_up_long_hemisp:bit_4_description = "data too low (UC2), data value set to -9999" ;
qc_up_long_hemisp:bit_4_assessment = "Bad" ;
qc_up_long_hemisp:bit_5_description = "data too high (UC2), data value set to -9999" ;
qc_up_long_hemisp:bit_5_assessment = "Bad" ;
qc_up_long_hemisp:bit_6_description = "data too low (PP), data value set to -9999" ;
qc_up_long_hemisp:bit_6_assessment = "Bad" ;
qc_up_long_hemisp:bit_7_description = "data too high (PP), data value set to -9999" ;
qc_up_long_hemisp:bit_7_assessment = "Bad" ;
qc_up_long_hemisp:bit_8_description = "data failed case temperature standard deviation testing (Tc_sdev - Tc_avg_sdev > 0.1)" ;
qc_up_long_hemisp:bit_8_assessment = "Bad" ;
qc_up_long_hemisp:bit_9_description = "data failed dome temperature standard deviation testing (Td_sdev - Td_avg_sdev > 0.1)" ;
qc_up_long_hemisp:bit_9_assessment = "Bad" ;
qc_up_long_hemisp:bit_10_description = "data failed both case and dome temperature standard deviation testing" ;
qc_up_long_hemisp:bit_10_assessment = "Bad" ;
qc_up_long_hemisp:bit_11_description = "LWup2Ta test (Ta OK; LWup < C13*sigma*Ta^4)" ;

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        qc_up_long_hemisp:bit_11_assessment = "Indeterminate" ;
        qc_up_long_hemisp:bit_12_description = "LWup2Ta test (Ta OK; LWup > sigma*Ta^4+C14)" ;
        qc_up_long_hemisp:bit_12_assessment = "Indeterminate" ;
        qc_up_long_hemisp:bit_13_description = "LWup2Ta test (Ta OK; LWup < D13*sigma*Ta^4)" ;
        qc_up_long_hemisp:bit_13_assessment = "Bad" ;
        qc_up_long_hemisp:bit_14_description = "LWup2Ta test (Ta OK; LWup > sigma*Ta^4+D14)" ;
        qc_up_long_hemisp:bit_14_assessment = "Bad" ;
        qc_up_long_hemisp:bit_15_description = "LWdn2LWup test (LWdn < LWup - C15)" ;
        qc_up_long_hemisp:bit_15_assessment = "Indeterminate" ;
        qc_up_long_hemisp:bit_16_description = "LWdn2LWup test (LWdn > LWup + C16)" ;
        qc_up_long_hemisp:bit_16_assessment = "Indeterminate" ;
        qc_up_long_hemisp:bit_17_description = "LWdn2LWup test (LWdn < LWup - D15)" ;
        qc_up_long_hemisp:bit_17_assessment = "Bad" ;
        qc_up_long_hemisp:bit_18_description = "LWdn2LWup test (LWdn > LWup + D16)" ;
        qc_up_long_hemisp:bit_18_assessment = "Bad" ;
    int aqc_up_long_hemisp(time) ;
        aqc_up_long_hemisp:long_name = "Data Quality Check for up_long_hemisp" ;
        aqc_up_long_hemisp:units = "unitless" ;
        aqc_up_long_hemisp:description = "This field contains integer values which should be
interpreted as follows:" ;
        aqc_up_long_hemisp:-1 = "missing data" ;
        aqc_up_long_hemisp:0 = "data ok" ;
        aqc_up_long_hemisp:1 = "data too low (UC1)" ;
        aqc_up_long_hemisp:2 = "data too high (UC1)" ;
        aqc_up_long_hemisp:3 = "data too low (UC2), data value set to -9999" ;
        aqc_up_long_hemisp:4 = "data too high (UC2), data value set to -9999" ;
        aqc_up_long_hemisp:5 = "data too low (PP), data value set to -9999" ;
        aqc_up_long_hemisp:6 = "data too high (PP), data value set to -9999" ;
        aqc_up_long_hemisp:7 = "data failed case temperature standard deviation testing (Tc_sdev -
Tc_avg_sdev > 0.1)" ;
        aqc_up_long_hemisp:8 = "data failed dome temperature standard deviation testing (Td_sdev -
Td_avg_sdev > 0.1)" ;
        aqc_up_long_hemisp:9 = "data failed both case and dome temperature standard deviation testing"
;
    int aqc_LWup2Ta(time) ;
        aqc_LWup2Ta:long_name = "up_long_hemisp (LWup) to Ta test" ;
        aqc_LWup2Ta:units = "unitless" ;
        aqc_LWup2Ta:description = "This field contains integer values which should be interpreted as
follows:" ;
        aqc_LWup2Ta:-1 = "test not possible" ;
        aqc_LWup2Ta:0 = "data ok" ;
        aqc_LWup2Ta:1 = "Ta OK; LWup < sigma*(Ta-C13)^4" ;
        aqc_LWup2Ta:2 = "Ta OK; LWup > sigma*(Ta+C14)^4" ;
        aqc_LWup2Ta:3 = "Ta OK; LWup < sigma*(Ta-D13)^4" ;
        aqc_LWup2Ta:4 = "Ta OK; LWup > sigma*(Ta+D14)^4" ;
    float Temp_Air(time) ;
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```
        Temp_Air:long_name = "Air Temperature" ;
        Temp_Air:units = "C" ;
    int qc_Temp_Air(time) ;
        qc_Temp_Air:long_name = "Data Quality Check for Temp_Air" ;
        qc_Temp_Air:units = "unitless" ;
        qc_Temp_Air:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
        qc_Temp_Air:bit_1_description = "Valid data value not available in input file, data value in output file set to -9999" ;
        qc_Temp_Air:bit_1_assessment = "Bad" ;
        qc_Temp_Air:bit_2_description = "Ta > Tmax or Ta < Tmin" ;
        qc_Temp_Air:bit_2_assessment = "Bad" ;
        qc_Temp_Air:bit_3_description = "Ta more than Tave +/- 20K" ;
        qc_Temp_Air:bit_3_assessment = "Bad" ;
    int aqc_Temp_Air(time) ;
        aqc_Temp_Air:long_name = "Temp_Air testing" ;
        aqc_Temp_Air:units = "unitless" ;
        aqc_Temp_Air:description = "This field contains integer values which should be interpreted as follows:" ;
        aqc_Temp_Air:-1 = "test not possible" ;
        aqc_Temp_Air:0 = "data ok" ;
        aqc_Temp_Air:3 = "Ta > Tmax or Ta < Tmin" ;
        aqc_Temp_Air:4 = "Ta more than Tave +/- 20K" ;
    float LWdnTc(time) ;
        LWdnTc:long_name = "Downwelling LW Case Temperature" ;
        LWdnTc:units = "C" ;
    int qc_LWdnTc(time) ;
        qc_LWdnTc:long_name = "Data Quality Check for Downwelling LW Case Temperature" ;
        qc_LWdnTc:units = "unitless" ;
        qc_LWdnTc:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
        qc_LWdnTc:bit_1_description = "Valid data value not available in input file, data value in output file set to -9999" ;
        qc_LWdnTc:bit_1_assessment = "Bad" ;
        qc_LWdnTc:bit_2_description = "LWdnTc2Ta test (Tc < (Ta - C17))" ;
        qc_LWdnTc:bit_2_assessment = "Bad" ;
        qc_LWdnTc:bit_3_description = "LWdnTc2Ta test (Tc > (Ta + C17))" ;
        qc_LWdnTc:bit_3_assessment = "Bad" ;
        qc_LWdnTc:bit_4_description = "LWdnTc2Td test ((Tc - Td) < C18)" ;
        qc_LWdnTc:bit_4_assessment = "Bad" ;
        qc_LWdnTc:bit_5_description = "LWdnTc2Td test ((Tc - Td) > C19)" ;
        qc_LWdnTc:bit_5_assessment = "Bad" ;
    int aqc_LWdnTc2Ta(time) ;
        aqc_LWdnTc2Ta:long_name = "LWdn Tc vs Ta" ;
        aqc_LWdnTc2Ta:units = "unitless" ;
```

aqc_LWdnTc2Ta:description = "This field contains integer values which should be interpreted as follows:" ;
aqc_LWdnTc2Ta:-1 = "test not possible" ;
aqc_LWdnTc2Ta:0 = "data ok" ;
aqc_LWdnTc2Ta:3 = "Tc < Ta - C17" ;
aqc_LWdnTc2Ta:4 = "Tc > Ta + C17" ;
int aqc_LWdnTc2Td(time) ;
aqc_LWdnTc2Td:long_name = "LWdn Tc vs Td" ;
aqc_LWdnTc2Td:units = "unitless" ;
aqc_LWdnTc2Td:description = "This field contains integer values which should be interpreted as follows:" ;
aqc_LWdnTc2Td:-1 = "test not possible" ;
aqc_LWdnTc2Td:0 = "data ok" ;
aqc_LWdnTc2Td:3 = "(Tc - Td) < C18" ;
aqc_LWdnTc2Td:4 = "(Tc - Td) > C19" ;
float LWdnTd(time) ;
LWdnTd:long_name = "Downwelling LW Dome Temperature" ;
LWdnTd:units = "C" ;
int qc_LWdnTd(time) ;
qc_LWdnTd:long_name = "Data Quality Check for Downwelling LW Dome Temperature" ;
qc_LWdnTd:units = "unitless" ;
qc_LWdnTd:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
qc_LWdnTd:bit_1_description = "Valid data value not available in input file, data value in output file set to -9999" ;
qc_LWdnTd:bit_1_assessment = "Bad" ;
qc_LWdnTd:bit_2_description = "LWdnTd2Ta test (Td < (Ta - C17))" ;
qc_LWdnTd:bit_2_assessment = "Bad" ;
qc_LWdnTd:bit_3_description = "LWdnTd2Ta test (Td > (Ta + C17))" ;
qc_LWdnTd:bit_3_assessment = "Bad" ;
qc_LWdnTd:bit_4_description = "LWdnTc2Td test ((Tc - Td) < C18)" ;
qc_LWdnTd:bit_4_assessment = "Bad" ;
qc_LWdnTd:bit_5_description = "LWdnTc2Td test ((Tc - Td) > C19)" ;
qc_LWdnTd:bit_5_assessment = "Bad" ;
int aqc_LWdnTd2Ta(time) ;
aqc_LWdnTd2Ta:long_name = "LWdn Td vs Ta" ;
aqc_LWdnTd2Ta:units = "unitless" ;
aqc_LWdnTd2Ta:description = "This field contains integer values which should be interpreted as follows:" ;
aqc_LWdnTd2Ta:-1 = "test not possible" ;
aqc_LWdnTd2Ta:0 = "data ok" ;
aqc_LWdnTd2Ta:3 = "Td < Ta - C17" ;
aqc_LWdnTd2Ta:4 = "Td > Ta + C17" ;
float LWupTc(time) ;
LWupTc:long_name = "Upwelling LW Case Temperature" ;
LWupTc:units = "C" ;

int qc_LWupTc(time) ;
qc_LWupTc:long_name = "Data Quality Check for Downwelling LW Case Temperature" ;
qc_LWupTc:units = "unitless" ;
qc_LWupTc:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
qc_LWupTc:bit_1_description = "Valid data value not available in input file, data value in output file set to -9999" ;
qc_LWupTc:bit_1_assessment = "Bad" ;
qc_LWupTc:bit_2_description = "LWupTc2Ta test (Tc < (Ta - C17))" ;
qc_LWupTc:bit_2_assessment = "Bad" ;
qc_LWupTc:bit_3_description = "LWupTc2Ta test (Tc > (Ta + C17))" ;
qc_LWupTc:bit_3_assessment = "Bad" ;
qc_LWupTc:bit_4_description = "LWupTc2Td test ((Tc - Td) < C18)" ;
qc_LWupTc:bit_4_assessment = "Bad" ;
qc_LWupTc:bit_5_description = "LWupTc2Td test ((Tc - Td) > C19)" ;
qc_LWupTc:bit_5_assessment = "Bad" ;
int aqc_LWupTc2Ta(time) ;
aqc_LWupTc2Ta:long_name = "LWup Tc vs Ta" ;
aqc_LWupTc2Ta:units = "unitless" ;
aqc_LWupTc2Ta:description = "This field contains integer values which should be interpreted as follows:" ;
aqc_LWupTc2Ta:-1 = "test not possible" ;
aqc_LWupTc2Ta:0 = "data ok" ;
aqc_LWupTc2Ta:3 = "Tc < Ta -C17" ;
aqc_LWupTc2Ta:4 = "Tc > Ta + C17" ;
int aqc_LWupTc2Td(time) ;
aqc_LWupTc2Td:long_name = "LWup Tc vs Td" ;
aqc_LWupTc2Td:units = "unitless" ;
aqc_LWupTc2Td:description = "This field contains integer values which should be interpreted as follows:" ;
aqc_LWupTc2Td:-1 = "test not possible" ;
aqc_LWupTc2Td:0 = "data ok" ;
aqc_LWupTc2Td:3 = "(Tc - Td) < C18" ;
aqc_LWupTc2Td:4 = "(Tc - Td) > C19" ;
float LWupTd(time) ;
LWupTd:long_name = "Upwelling LW Dome Temperature" ;
LWupTd:units = "C" ;
int qc_LWupTd(time) ;
qc_LWupTd:long_name = "Data Quality Check for Downwelling LW Dome Temperature" ;
qc_LWupTd:units = "unitless" ;
qc_LWupTd:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
qc_LWupTd:bit_1_description = "Valid data value not available in input file, data value in output file set to -9999" ;
qc_LWupTd:bit_1_assessment = "Bad" ;
qc_LWupTd:bit_2_description = "LWupTd2Ta test (Td < (Ta - C17))" ;

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        qc_LWupTd:bit_2_assessment = "Bad" ;
        qc_LWupTd:bit_3_description = "LWupTd2Ta test (Td > (Ta + C17))" ;
        qc_LWupTd:bit_3_assessment = "Bad" ;
        qc_LWupTd:bit_4_description = "LWupTd2Td test ((Tc - Td) < C18)" ;
        qc_LWupTd:bit_4_assessment = "Bad" ;
        qc_LWupTd:bit_5_description = "LWupTd2Td test ((Tc - Td) > C19)" ;
        qc_LWupTd:bit_5_assessment = "Bad" ;
    int aqc_LWupTd2Ta(time) ;
        aqc_LWupTd2Ta:long_name = "LWup Td vs Ta" ;
        aqc_LWupTd2Ta:units = "unitless" ;
        aqc_LWupTd2Ta:description = "This field contains integer values which should be interpreted as follows:" ;
        aqc_LWupTd2Ta:-1 = "test not possible" ;
        aqc_LWupTd2Ta:0 = "data ok" ;
        aqc_LWupTd2Ta:3 = "Td < Ta - C17" ;
        aqc_LWupTd2Ta:4 = "Td > Ta + C17" ;
    float rh(time) ;
        rh:long_name = "Relative Humidity" ;
        rh:units = "%" ;
        rh:valid_min = "-2.f" ;
        rh:valid_max = "104.f" ;
        rh:resolution = "0.1f" ;
        rh:missing_value = "-9999.f" ;
        rh:uncertainty = "+/- 2.06 % RH for 0 to 90 % RH +/- 3.04 % RH for 90 to 100 % RH Errors included in uncertainty are calibration uncertainty, repeatability, temperature dependence, long term (1 yr) stability, and A/D conversion accuracy.  Wind speed dependence and radiation dependence have not been considered and may increase the uncertainty." ;
    int qc_rh(time) ;
        qc_rh:long_name = "Data Quality Check for Relative Humidity (rh)" ;
        qc_rh:units = "unitless" ;
        qc_rh:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
        qc_rh:bit_1_description = "Valid data value not available, data value in output file set to -9999" ;
        qc_rh:bit_1_assessment = "Bad" ;
        qc_rh:bit_2_description = "Field failed min test" ;
        qc_rh:bit_2_assessment = "Bad" ;
        qc_rh:bit_3_description = "Field failed max test" ;
        qc_rh:bit_3_assessment = "Bad" ;
        qc_rh:bit_4_description = "Field failed delta test" ;
        qc_rh:bit_4_assessment = "Bad" ;
    float press(time) ;
        press:long_name = "Atmospheric Pressure" ;
        press:units = "kPa" ;
        press:valid_min = "80.f" ;
        press:valid_max = "110.f" ;
        press:resolution = "0.01f" ;
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            press:missing_value = "-9999.f" ;
            press:uncertainty = "+/- 0.035 kPa Errors included in uncertainty are linearity, hysteresis, repeatability, calibration uncertainty, temperature dependence, and long-term (1 yr) stability.  Wind speed dependence has not been considered and may increase the uncertainty." ;
      int qc_press(time) ;
            qc_press:long_name = "Data Quality Check for Atmospheric Pressure (press)" ;
            qc_press:units = "unitless" ;
            qc_press:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
            qc_press:bit_1_description = "Valid data value not available, data value in output file set to -9999" ;
            qc_press:bit_1_assessment = "Bad" ;
            qc_press:bit_2_description = "Field failed min test" ;
            qc_press:bit_2_assessment = "Bad" ;
            qc_press:bit_3_description = "Field failed max test" ;
            qc_press:bit_3_assessment = "Bad" ;
      float wind_speed(time) ;
            wind_speed:long_name = "Wind Speed" ;
            wind_speed:units = "m/s" ;
            wind_speed:valid_min = "0.f" ;
            wind_speed:valid_max = "60.f" ;
            wind_speed:resolution = "0.01f" ;
            wind_speed:missing_value = "-9999.f" ;
            wind_speed:threshold = "1.00 m/s" ;
            wind_speed:uncertainty = "+/- 1% for 2.5 to 30 m/s - 0.12 to +0.02 m/s at 2.0 m/s - 0.22 to +0.00 m/s at 1.5 m/s - 0.31 to -0.20 m/s at 1.0 m/s - 0.51 to -0.49 m/s at 0.5 m/s Error included in uncertainty are calibration accuracy, data logger timebase accuracy, and bias by underestimation due to threshold.  The latter assumes normal distribution of winds about the mean with standard deviations ranging between 0.25 and 1.00 m/s." ;
      int qc_wind_speed(time) ;
            qc_wind_speed:long_name = "Data Quality Check for wind_speed" ;
            qc_wind_speed:units = "unitless" ;
            qc_wind_speed:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
            qc_wind_speed:bit_1_description = "Valid data value not available, data value in output file set to -9999" ;
            qc_wind_speed:bit_1_assessment = "Bad" ;
            qc_wind_speed:bit_2_description = "Field failed min test" ;
            qc_wind_speed:bit_2_assessment = "Bad" ;
            qc_wind_speed:bit_3_description = "Field failed max test" ;
            qc_wind_speed:bit_3_assessment = "Bad" ;
      float wind_direction(time) ;
            wind_direction:long_name = "Wind Direction" ;
            wind_direction:units = "degrees" ;
            wind_direction:valid_min = "0.f" ;
            wind_direction:valid_max = "360.f" ;
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wind_direction:resolution = "0.1f" ;
wind_direction:missing_value = "-9999.f" ;
wind_direction:threshold = "Wind speed </= 1.00 m/s" ;
wind_direction:uncertainty = "+/- 5.0 deg for wind speed > 1.0 m/s +/- 180.0 deg for wind speed </= 1.0 m/s Errors included in uncertainty are sensor accuracy, alignment accuracy, and A/D conversion accuracy." ;
int qc_wind_direction(time) ;
qc_wind_direction:long_name = "Data Quality Check for wind_direction" ;
qc_wind_direction:units = "unitless" ;
qc_wind_direction:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
qc_wind_direction:bit_1_description = "Valid data value not available, data value in output file set to -9999" ;
qc_wind_direction:bit_1_assessment = "Bad" ;
qc_wind_direction:bit_2_description = "Field failed min test" ;
qc_wind_direction:bit_2_assessment = "Bad" ;
qc_wind_direction:bit_3_description = "Field failed max test" ;
qc_wind_direction:bit_3_assessment = "Bad" ;
float precip(time) ;
precip:long_name = "Precipitation" ;
precip:units = "mm" ;
precip:valid_min = "0.f" ;
precip:valid_max = "10.f" ;
precip:resolution = "0.001f" ;
precip:missing_value = "-9999.f" ;
precip:uncertainty = "Under normal conditions, uncertainty for rain is +/- 0.254 mm (one bucket). Uncertainty increases to an unknown value during strong winds or very heavy rains (in excess of 75 mm per hour). The instrument is not considered reliable for snow amounts." ;
int qc_precip(time) ;
qc_precip:long_name = "Data Quality Check for precip" ;
qc_precip:units = "unitless" ;
qc_precip:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
qc_precip:bit_1_description = "Valid data value not available, data value in output file set to -9999" ;
qc_precip:bit_1_assessment = "Bad" ;
qc_precip:bit_2_description = "Field failed min test" ;
qc_precip:bit_2_assessment = "Bad" ;
qc_precip:bit_3_description = "Field failed max test" ;
qc_precip:bit_3_assessment = "Bad" ;
float detector_flux(time) ;
detector_flux:long_name = "Detector flux (Downwelling pyrgeometer thermopile voltage * PIR-DIR calib-coef) Calculated value from 20s data" ;
detector_flux:units = "W/m^2" ;
detector_flux:missing_value = "-9999" ;
int qc_detector_flux(time) ;

qc_detector_flux:long_name = "Data Quality Check for detector_flux" ;
qc_detector_flux:units = "unitless" ;
qc_detector_flux:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
qc_detector_flux:bit_1_description = "Valid data value not available, data value in output file set to -9999" ;
qc_detector_flux:bit_1_assessment = "Bad" ;
float MFRSR_hemisp_broadband(time) ;
MFRSR_hemisp_broadband:long_name = "MFRSR Broadband Global SW" ;
MFRSR_hemisp_broadband:units = "counts" ;
MFRSR_hemisp_broadband:valid_min = "0.f" ;
MFRSR_hemisp_broadband:valid_max = "5000.f" ;
MFRSR_hemisp_broadband:resolution = "1.f" ;
MFRSR_hemisp_broadband:explanation_of_broadband_channel = "Unfiltered Silicon, nominally from 320 to 1200nm" ;
MFRSR_hemisp_broadband:Notes_on_units = "Raw counts have been linearly scaled to be roughly equivalent to W/m^2 at solar noon" ;
int qc_MFRSR_hemisp_broadband(time) ;
qc_MFRSR_hemisp_broadband:long_name = "Data Quality Check for MFRSR_hemisp_broadband" ;
qc_MFRSR_hemisp_broadband:units = "unitless" ;
qc_MFRSR_hemisp_broadband:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
qc_MFRSR_hemisp_broadband:bit_1_description = "Valid data value not available, data value in output file set to -9999" ;
qc_MFRSR_hemisp_broadband:bit_1_assessment = "Bad" ;
qc_MFRSR_hemisp_broadband:bit_2_description = "Field failed min test" ;
qc_MFRSR_hemisp_broadband:bit_2_assessment = "Bad" ;
qc_MFRSR_hemisp_broadband:bit_3_description = "Field failed max test" ;
qc_MFRSR_hemisp_broadband:bit_3_assessment = "Bad" ;
float MFRSR_diffuse_hemisp_broadband(time) ;
MFRSR_diffuse_hemisp_broadband:long_name = "MFRSR Broadband Diffuse SW" ;
MFRSR_diffuse_hemisp_broadband:units = "counts" ;
MFRSR_diffuse_hemisp_broadband:valid_min = "0.f" ;
MFRSR_diffuse_hemisp_broadband:valid_max = "5000.f" ;
MFRSR_diffuse_hemisp_broadband:resolution = "1.f" ;
MFRSR_diffuse_hemisp_broadband:explanation_of_broadband_channel = "Unfiltered Silicon, nominally from 320 to 1200nm" ;
MFRSR_diffuse_hemisp_broadband:Notes_on_units = "Raw counts have been linearly scaled to be roughly equivalent to W/m^2 at solar noon" ;
int qc_MFRSR_diffuse_hemisp_broadband(time) ;
qc_MFRSR_diffuse_hemisp_broadband:long_name = "Data Quality Check for MFRSR_diffuse_hemisp_broadband" ;
qc_MFRSR_diffuse_hemisp_broadband:units = "unitless" ;
qc_MFRSR_diffuse_hemisp_broadband:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;

qc_MFRSR_diffuse_hemisp_broadband:bit_1_description = "Valid data value not available, data value in output file set to -9999" ;
qc_MFRSR_diffuse_hemisp_broadband:bit_1_assessment = "Bad" ;
qc_MFRSR_diffuse_hemisp_broadband:bit_2_description = "Field failed min test" ;
qc_MFRSR_diffuse_hemisp_broadband:bit_2_assessment = "Bad" ;
qc_MFRSR_diffuse_hemisp_broadband:bit_3_description = "Field failed max test" ;
qc_MFRSR_diffuse_hemisp_broadband:bit_3_assessment = "Bad" ;
float MFRSR_direct_normal_broadband(time) ;
MFRSR_direct_normal_broadband:long_name = "MFRSR Broadband Direct Normal SW" ;
MFRSR_direct_normal_broadband:units = "counts" ;
MFRSR_direct_normal_broadband:valid_min = "0.f" ;
MFRSR_direct_normal_broadband:valid_max = "5000.f" ;
MFRSR_direct_normal_broadband:resolution = "1.f" ;
MFRSR_direct_normal_broadband:explanation_of_broadband_channel = "Unfiltered Silicon, nominally from 320 to 1200nm" ;
MFRSR_direct_normal_broadband:Notes_on_units = "Raw counts have been linearly scaled to be roughly equivalent to W/m^2 at solar noon" ;
int qc_MFRSR_direct_normal_broadband(time) ;
qc_MFRSR_direct_normal_broadband:long_name = "Data Quality Check for MFRSR_direct_normal_broadband" ;
qc_MFRSR_direct_normal_broadband:units = "unitless" ;
qc_MFRSR_direct_normal_broadband:description = "This field contains bit packed values which should be interpreted as listed; no bits set (zero) represents good data" ;
qc_MFRSR_direct_normal_broadband:bit_1_description = "Valid data value not available, data value in output file set to -9999" ;
qc_MFRSR_direct_normal_broadband:bit_1_assessment = "Bad" ;
qc_MFRSR_direct_normal_broadband:bit_2_description = "Field failed min test" ;
qc_MFRSR_direct_normal_broadband:bit_2_assessment = "Bad" ;
qc_MFRSR_direct_normal_broadband:bit_3_description = "Field failed max test" ;
qc_MFRSR_direct_normal_broadband:bit_3_assessment = "Bad" ;
int MFRSR_flag(time) ;
MFRSR_flag:long_name = "MFRSR Data Usage Flag" ;
MFRSR_flag:units = "unitless" ;
MFRSR_flag:0 = "MFRSR data not used" ;
MFRSR_flag:1 = "MFRSR data are good but not agree with SumSW or GSW" ;
MFRSR_flag:2 = "MFRSRGSW agree with SumSW" ;
MFRSR_flag:3 = "MFRSRGSW agree with GSW" ;
float zenith(time) ;
zenith:long_name = "Solar Zenith Angle" ;
zenith:units = "degrees" ;
zenith:comment = "Calculated using solarposition() function, by Nels Larson, PNNL" ;
float sun_earth_distance(time) ;
sun_earth_distance:long_name = "Distance from the Earth to the Sun (AU)" ;
sun_earth_distance:units = "Astronomical Units" ;
float lat ;
lat:long_name = "north latitude" ;

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		lat:units = "degrees" ;
		lat:valid_min = -90.f ;
		lat:valid_max = 90.f ;
	float lon ;
		lon:long_name = "east longitude" ;
		lon:units = "degrees" ;
		lon:valid_min = -180.f ;
		lon:valid_max = 180.f ;
	float alt ;
		alt:long_name = "altitude" ;
		alt:units = "meters above Mean Sea Level" ;

// global attributes:
		:Date = "Wed Aug  2 23:21:29 2006" ;
		:Version = "$State: Exp $" ;
		:Command_Line = "qcrad1long -d 20000101 -f sgpE1 -N" ;
		:Input_Platforms = "sgpsirs1duttE1.c1, sgpsiros1duttE1.c1, sgpsirsE1.a1, sgpsirsE1.a2,
sgpsirsE1.b1, sgpmfrsrE1.a1, sgpmfrsrE1.b1, sgp1smosE1.a0, sgp1smosE1.a1, sgp1smosE1.b1,
NULLplatform, NULLplatform, NULLplatform, NULLplatform, NULLplatform, NULLplatform,
NULLplatform, NULLplatform, NULLplatform, NULLplatform, NULLplatform" ;
		:BW_Version = "$State: ds-dsutil-bw-4.6-0 $" ;
		:qc_standards_version = "0.1" ;
		:Title = "Data Quality Assessment of ARM Radiation DATA" ;
		:BEGSW = "BestEstimate_down_short_hemisp" ;
		:MFRSRGSW = "MFRSR_hemisp_broadband" ;
		:UC1 = "First user configurable limits" ;
		:UC2 = "Second user configurable (extremely rare) limits" ;
		:PP = "BSRN physically possible limits" ;
		:DirN = "short_direct_normal" ;
		:DifSW = "down_short_diffuse_hemisp" ;
		:SumSW = "DirN * cos(SZA)+ DifSW" ;
		:GSW = "down_short_hemisp" ;
		:LWdn = "down_long_hemisp" ;
		:LWup = "up_long_hemisp" ;
		:SWup = "up_short_hemisp" ;
		:sigma = "Stephan-Boltzmann constant = 5.67 * 10 ^ 8" ;
		:SZA = "Solar Zenith Angle" ;
		:Ta = "Air temperature" ;
		:Tmin = "User defined minimum air temperature" ;
		:Tmax = "User defined maximum air temperature" ;
		:Tsnow = "Temperature limit for albedo limit test, temperature at which snow limit is allowed" ;
		:Tc(d)_stdev = "11-minute running standard deviation of the Case (Dome) PIR Temperature (K)";
		:Tc(d)_avg_stdev = "11-minute running standard deviation of the 11-minute running average of
the Case (Dome) PIR Temperature (K)" ;
		:cnf0 = "9.0		* snow covered ground Ta limit for albedo tests (real, degrees C > 0.0)" ;
		:cnf1 = "0.92   0.97		* Max GSW climatological mult. limit factor (real < 1.2)" ;
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        :cnf2 = "0.52   0.58         * Max DifSW climatological mult. limit factor (real < 0.75)" ;
        :cnf3 = "0.82   0.86         * Max DirNSW climatological mult. limit factor (real < 0.95)" ;
        :cnf4 = "0.87   0.95         * Max SWup climatological albedo limit factor (real < 1.0)" ;
        :cnf5 = "190.0  145.0        * Min LWdn climatological limit factor (real > 60.0)" ;
        :cnf6 = "465.0  500.0        * Max LWdn climatological limit factor (real < 500.0)" ;
        :cnf7 = "240.0  210.0        * Min LWup climatological limit factor (real > 60.0)" ;
        :cnf8 = "590.0  630.0        * Max LWup climatological limit factor (real < 700.0)" ;
        :cnf9 = "0.22   0.27         * SWup max albedo limit for normal ground cover (Ta>Tslim,
real<1.0)" ;
        :cnf10 = "0.90   0.98        * SWup max albedo limit for snow covered ground (Ta<Tslim,
real<1.0)" ;
        :cnf11 = "0.65   0.60        * Min LWdn climatological Ta mult. limit factor (real > 0.4)" ;
        :cnf12 = "11.0   23.0        * Max LWdn climatological Ta additive limit factor (real < 25.0)" ;
        :cnf13 = "10.0   13.0        * Min LWup climatological Ta subtractive limit factor (real < 15.0)" ;
        :cnf14 = "12.0   16.0        * Max LWup climatological Ta additive limit factor (real < 25.0)" ;
        :cnf15 = "200.0  220.        * Climatological LWdn > LWup - limit Factor (min, real < 300.0)" ;
        :cnf16 = "18.0   25.0        * Climatological LWdn < LWup + limit Factor (min, real < 25.0)" ;
        :cnf17 = "10.0   4.0         * Tc & Td within +/- limit of Ta for LWdn, LWup (real, degrees C)" ;
        :cnf18 = "-0.8               * Td < (Tc - limit) (real, degrees C)" ;
        :cnf19 = "2.0                * Td > (Tc - limit) (real, degrees C)" ;
        :cnf20 = "-20.0              * Min climatological allowable Ta,Td,Tc (degrees C, real > -103.0)" ;
        :cnf21 = "42.0               * Max climatological allowable Ta,Td,Tc (degrees C, real < 75.0)" ;
        :cnf22 = "1050.5             * Clear sky shortwave a coefficient for sumSW" ;
        :cnf23 = "1.095              * Clear sky shortwave b coefficient for sumSW" ;
        :cnf24 = "1050.3             * Clear sky shortwave a coefficient for GSW" ;
        :cnf25 = "1.148              * Clear sky shortwave b coefficient for GSW" ;
        :cnf26 = "1.0                * 1 = Correct GSW for IR loss; 0 = Do not correct GSW" ;
        :cnf27 = "0.07   0.17        * dry mode coeff.= 0.07; wet mode coeff. = 0.17" ;
        :cnf28 = "0.0                * 0 = load in sirsC1 data; 1 = load in beflux data; 2 = load in brs1dutt
data; " ;
        :cnf29 = "6.0                * Tc and Te differences for separating wet and dry modes" ;
        :cnf30 = "0.9                * Tracker off limit; 0.9 for sgp & nsa; 0.85 for twp" ;
        :Input_Datastream_Descriptions = "A string consisting of the datastream(s), datastream
version(s), and datastream date (range)" ;
        :Input_Datastreams_Num = "25" ;
        :Input_Datastreams = "sgpsirs1duttE1.c1 : $State: process-vap-diffcor1dutt-2.1-2 $ :
19991225.000000-20000101.000000 ;\n",
            "sgpsirsE1.a1 : 6.000000 : 20000101.000000 ;\n",
            "sgpmfrsrE1.a1 : 6.000000 : 19991225.000000-20000101.000000 ;\n",
            "sgp1smosE1.a0 : 6.000000 : 19991225.000000-20000101.000000 ;" ;
        :zeb_platform = "sgpqcrad1longE1.c1" ;
        :history = "created by user shi on machine jade at 2-Aug-2006,23:21:31, using $State: ds-zebra-
zeblib-4.15-0 $" ;
}
```