Solar Radiometric Data Quality Analysis for ARM Southern Great Plains Site

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The Atmospheric Radiation Measurement (ARM) Program needs the best possible broadband shortwave irradiance information. Atmospheric circulation and climate model development and validation require high quality solar data. The National Renewable Energy Laboratory (NREL) has developed a suite of data quality assessment tools for thorough evaluation of solar irradiance measurements: SERI_QC, QCFIT, and SHADES.

SERI_QC, a mathematical package that assesses the quality of solar radiation data, is the centerpiece of the ARM Southern Great Plains (SGP) data quality analysis process. It progressively tests each of the three broadband shortwave components of solar radiation and flags each data point accordingly. QCFIT is used to create the Gomperz curves that define the acceptable measurement limits for SERI_QC. The SHADES program uses the flags generated by SERI_QC to create shaded "cylinder" plots, a visual tool for diagnosing instrument or maintenance problems.

The SERI_QC software was developed at NREL, formerly the Solar Energy Research Institute (SERI), in 1993. QCFIT, developed that same year, is a stand-alone utility designed to assist users of SERI_QC in selecting the physical limits. SHADES was developed at NREL in 1997 to aid in diagnosing equipment and maintenance problems at remote sites. This paper describes the monthly data analysis process for one ARM SGP site from data aquisition and preprocessing to QCFIT, through SERI_QC and SHADES, to the final visual interpretation of the resulting plots and diurnal profiles.

The flow of data analysis is as follows:

- Data are received at NREL in raw Campbell CR-10 format (see Figure 1) or in NetCDF format.
- Data received in NetCDF format are converted to Campbell format (see Figure 1).
- Data are converted from Greenwich Mean Time (GMT) to the Local Standard Time of the recording station.
- The elements (data fields) are rearranged so that the first three instruments are global horizontal, direct normal, and diffuse horizontal solar irradiance, respectively.
- Data are imported to Augustyn + Company's Data Quality Management System (DQMS). DQMS provides centralized storage and retrieval of all network data, as well as instrument calibration data, station equipment histories, and site history and status information. Augustyn's DataView product produces simple time-series plots of the data stored by DQMS.
- QCFIT is run on 1 month of data in order to set the acceptable two-component limits for SERI_QC (see Figure 2). This step is necessary for the first few years after a new measurement station has been established, and can be discontinued when the limits stabilize at their long-term climatological values.
- SERI_QC uses the curves established by QCFIT and provides a data flag for each of the three major broadband irradiance components (global horizontal, direct normal, and diffuse horizontal) at every time interval (e.g., every minute for 1-minute data). A sample of the flagged broadband is seen in Figure 3, while Table 1 provides a description of the SERI_QC flagging convention.
- Data with SERI_QC flags are used by SHADES to produce a set of four grayscale charts that provide a visual overview of the quality of data for an entire month (see Figure 4). All charts display the time of day on the horizontal scale and the day of the month on the vertical scale. The first chart exhibits the most severe flag from among the three components at each time interval, and the remaining three charts present the relative solar irradiance for each of the three major components.

ID,Year,Day,HrMn,Global,Direct,Diffuse,UpSW,UpLW,DnLW

113,1997,273,924,516.3300,1.9381,526.2800,113.8900,443.33,350.21
113,1997,273,925,519.6100,2.7264,530.9200,114.3000,444.86,350.54
113,1997,273,926,522.5000,2.7527,535.4400,114.5500,447.17,350.96
113,1997,273,927,525.2900,3.4622,540.9600,115.0200,445.37,352.12
113,1997,273,928,528.5900,3.5607,548.9500,115.4600,445.55,350.39
113,1997,273,929,530.7300,3.0745,557.6500,115.7500,445.13,351.26
113,1997,273,930,533.4300,2.1876,567.9300,116.2400,447.70,350.58
113,1997,273,931,536.2500,1.3270,578.2500,116.7600,447.22,350.72
113,1997,273,927,525.2900,3.4622,540.9600,115.0200,445.37,352.12
113,1997,273,928,528.5900,3.5607,548.9500,115.4600,445.55,350.39
113,1997,273,929,530.7300,3.0745,557.6500,115.7500,445.13,351.26
113,1997,273,930,533.4300,2.1876,567.9300,116.2400,447.70,350.58
113,1997,273,931,536.2500,1.3270,578.2500,116.7600,447.22,350.72
113,1997,273,932,538.9800,0.9788,587.2000,117.2800,448.23,350.09
113,1997,273,933,541.4000,0.3679,592.6600,117.6900,447.56,350.70
113,1997,273,934,543.8700,0.5519,594.2400,117.9700,449.55,352.07
113,1997,273,935,546.9100,1.4059,550.1200,118.5100,448.40,347.43
113,1997,273,936,550.0300,240.4500,413.5400,118.9900,449.44,343.59
113,1997,273,937,552.2400,846.9000,67.3200,119.2300,450.61,343.92
113,1997,273,938,554.7500,842.9500,66.4230,119.6200,451.13,345.48
113,1997,273,939,556.7800,840.8700,65.6540,119.9900,449.89,345.68
113,1997,273,940,558.8100,840.7000,65.3090,120.2100,449.87,345.74
113,1997,273,941,562.1500,842.5400,65.3530,120.7600,450.32,344.98
113,1997,273,942,564.2300,843.3800,65.2500,120.9600,450.38,345.98
113,1997,273,943,566.5600,844.9000,65.1410,121.3500,450.84,346.59
113,1997,273,944,568.7300,845.9600,65.0500,121.6000,450.36,346.21
113,1997,273,945,571.1700,847.1100,64.8780,122.1300,451.67,347.40
113,1997,273,946,573.3700,848.1200,64.2750,122.6700,450.14,347.75
113,1997,273,947,575.6200,849.2600,64.0380,122.7600,450.48,347.54
113,1997,273,948,578.5300,851.8100,64.2730,123.2400,451.84,347.25
113,1997,273,949,581.3500,853.6800,64.5830,123.6300,451.90,347.29
113,1997,273,950,583.9400,854.8900,64.9660,124.1000,451.55,347.78

RED: **Suspect Data** GREEN: **Good Data**

Figure 1. This sample from a raw data file was collected on 30 September 1997 at E13, CF1/Lamont, Oklahoma. (For a color version of this figure, please see *http://www.arm.gov/docs/documents/technical/conf_9803/anderberg-98.pdf*.)

- The SHADES flag chart illuminates glaring errors in the data stream. The SHADES data charts may indicate the specific instrument(s) that caused the errors. DataView's diurnal plot of the specific day in question further aids in diagnosing the condition that created the anomaly (see Figure 5). It may be necessary to draw upon the experience of field technicians or meteorologists in order to diagnose the cause of the high error flags.

- Anomalies are logged, and repeated events can lead to a modification of station setup or maintenance procedures.

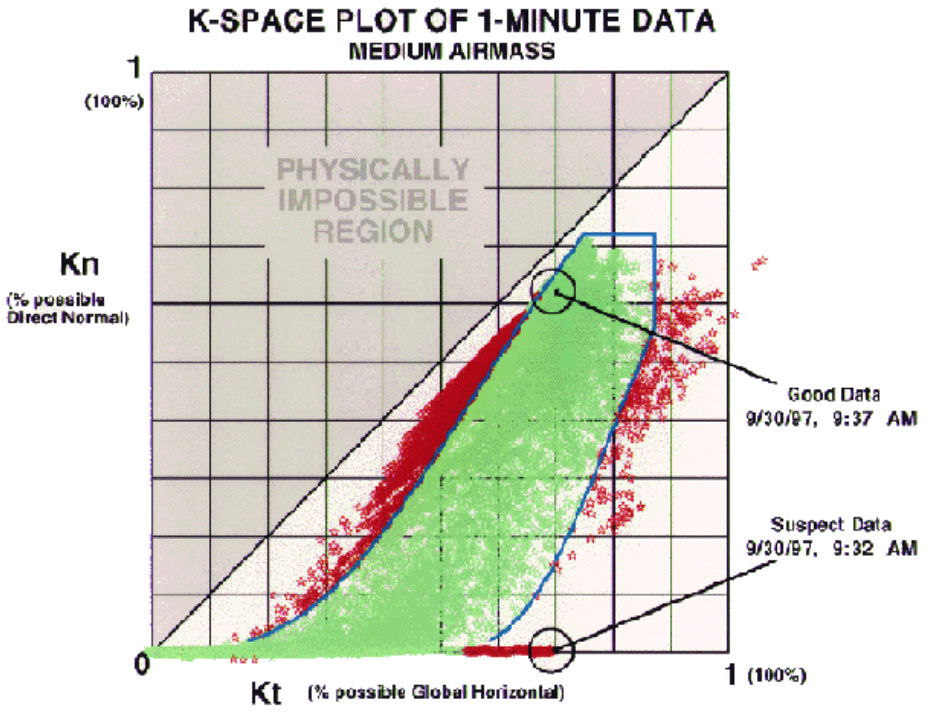

Figure 2. QCFIT is run on 1-month's data to set the limits for the SERI_QC tests. Data fall within acceptable two-component (e.g., global horizontal and direct normal) limits. (For a color version of this figure, please see *http://www.arm.gov/docs/ documents/technical/conf_9803/anderberg-98.pdf*.)

Date	Time	Global	Global Flag	Direct	Direct Flag	Diffuse	Diffuse Flag
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
9/30/97	9:22	510.78	29	2.69	28	518.47	08
9/30/97	9:23	513.57	29	2.02	28	522.41	08
9/30/97	9:24	516.33	29	1.94	28	526.28	08
9/30/97	9:25	519.61	33	2.73	32	530.92	08
9/30/97	9:26	522.50	33	2.75	32	535.44	08
9/30/97	9:27	525.29	33	3.46	32	540.96	08
9/30/97	9:28	528.59	33	3.56	32	548.95	08
9/30/97	9:29	530.73	33	3.07	32	557.65	08
9/30/97	9:30	533.43	33	2.19	32	567.93	08
9/30/97	9:31	536.25	33	1.33	32	578.25	08
9/30/97	9:32	538.98	33	0.98	32	587.20	08
9/30/97	9:33	541.40	33	0.37	32	592.66	08
9/30/97	9:34	543.87	33	0.55	32	594.24	08
9/30/97	9:35	546.91	33	1.41	32	550.12	08
9/30/97	9:36	550.03	03	240.45	03	413.54	03
9/30/97	9:37	552.24	03	846.90	03	67.32	03
9/30/97	9:38	554.75	03	842.95	03	66.42	03
9/30/97	9:39	556.78	03	840.87	03	65.65	03
9/30/97	9:40	558.81	03	840.70	03	65.31	03
9/30/97	9:41	562.15	03	842.54	03	65.35	03
9/30/97	9:42	564.23	03	843.38	03	65.25	03
9/30/97	9:43	566.56	03	844.90	03	65.14	03
9/30/97	9:44	568.73	03	845.96	03	65.05	03
9/30/97	9:45	571.17	03	847.11	03	64.88	03
9/30/97	9:46	573.37	03	848.12	03	64.28	03
9/30/97	9:47	575.62	03	849.26	03	64.04	03
9/30/97	9:48	578.53	03	851.81	03	64.27	03
9/30/97	9:49	581.35	03	853.68	03	64.58	03
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.

Figure 3. Sample of flagged broadband irradiance components. (For a color version of this figure, please see *http://www.arm.gov/docs/documents/technical/conf_9803/anderberg-98.pdf*.)

Table 1. Flagging convention for SERI_QC.

Flag	Description
00	Untested (raw data)
01	Passed one-component test; data fall within max-min limits of Kt, Kn, or Kd
02	Passed two-component test; data fall within 0.03 of the Gompertz boundaries
03	Passed three-component test; data come within +0.03 of satisfying Kt = Kn + Kd
04	Passed visual inspection; *not used* by SERI_QC1
05	Failed visual inspection; *not used* by SERI_QC1
06	Value estimated; passes all pertinent SERI_QCl tests
07	Failed one-component test; lower than allowed minimum
08	Failed one-component test; higher than allowed maximum
09	Passed three-component test but failed two-component test by >0.05
10-93	Failed two- or three-component tests in one of four ways. To determine the test failed and the manner of failure (high or low), examine the remainder of the calculation (flag + 2)/4. **Rem** — **Failure** 0 — Parameter too low by three-component test (Kt = Kn + Kd) 1 — Parameter too high by three-component test (Kt = Kn + d) 2 — Parameter too low by two-component test (Gompertz boundary) 3 — Parameter too high by two-component test (Gompertz boundary) The magnitude of the test failure (distance in K-units) is determined from: d = (INT (flag + 2)/4)/100. Examples and further discussion of the meaning of flags 10-93 are given in the Users Manual for SERI QC Software in Chapter 6 and in Section 9.3, page 153.
94-97	Data fall into a physically impossible region where Kn > Kt by K-space distances of 0.05 to 0.10 (94), 0.10 to 0.15 (95), 0.15 to 0.20 (96), and >0.20 (97).
98	Not used
99	Missing data

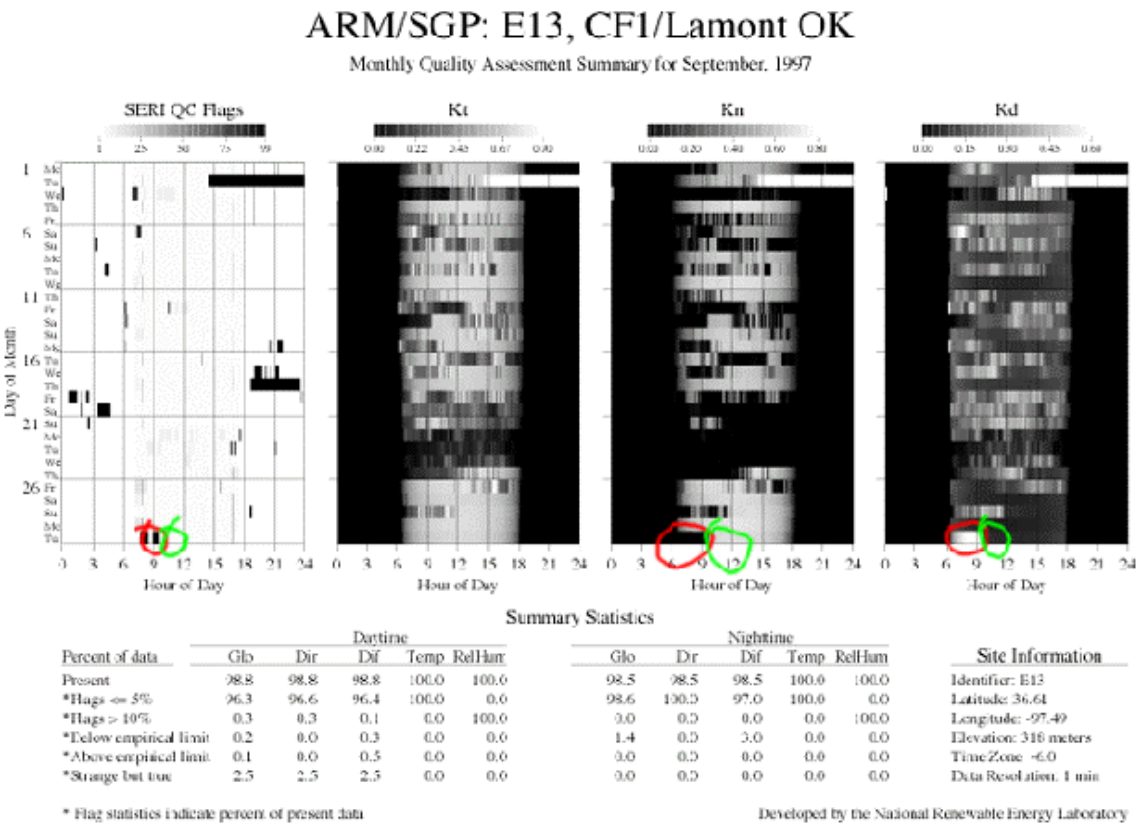

Figure 4. SHADES produces shaded plots of each of the K-space components, and of the worst flags at each point. The leftmost chart displays the most severe SERI_QC flag from among the three components for each point. The remaining three charts display the solar energy level as fractions of possible energy:

Kt for global horizontal solar irradiance
Kn for direct normal solar irradiance
Kd for diffuse horizontal solar irradiance.

Areas circled in red on the charts indicate serious flags and suspect data on the morning of 30 September 1997 at E13. (For a color version of this figure, please see *http://www.arm.gov/docs/documents/technical/conf_9803/anderberg-98.pdf*.)

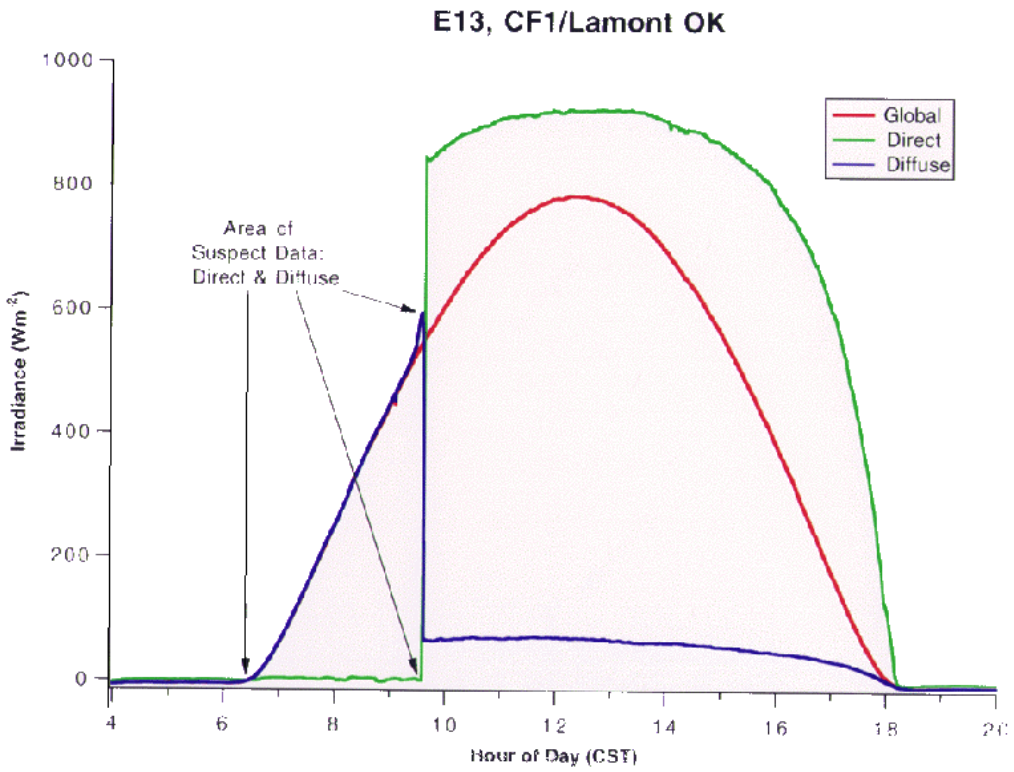

Figure 5. Diurnal plots are used to determine the probable cause of problems seen in the graphs produced by SHADES (Figure 4). In this plot for 30 September 1997 at E13, the global horizontal (red) produces a perfect clear-day curve. The direct normal (green) is absolutely flat until 9:36 a.m. Similarly, the diffuse horizontal tracks the global until 9:36 a.m. (For a color version of this figure, please see *http://www.arm.gov/docs/documents/technical/conf_9803/anderberg-98.pdf*.)