Near Real Time Data Quality Processing for SGP/C1 GRAMS Radiometer

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Introduction

Mission Research Corporation (MRC) has developed an automated data quality enhancement and outlier detection program as part of the Atmospheric Radiation Measurement (ARM) Program's ongoing efforts to monitor total broadband solar radiometers. The program, called *Data Quality – GRAMS Automated Procedure*, or DQGAP, is designed to analyze the Ground Radiation Measurement System (GRAMS) (Valero et al. 1997) *a0* data stream in a totally automated fashion. The DQGAP analysis suite retrieves GRAMS data, performs a preliminary calibration based upon Broadband Outdoor Radiometer CALibration (BORCAL) (Nelson et al. 1998) data, processes approximately 40,000 data points collected daily, and produces an output netcdf file with calibrated data having outliers flagged. It also produces 60-second and 10-minute averages of non-flagged data.

To be useful, the program must flag enough invalid data points along with so few valid data points that almost any subsequent processing algorithm used by the scientific community will yield results negligibly influenced by either invalid or missing valid data. We attempt to accomplish this by subjecting the data to a number of tests, some rather general statistical tests and some specific to the instrument. Finally, we cross compare to a similar instrument if possible (a collocated second GRAMS instrument, or a Multifilter Rotating Shadowband Radiometer (MFRSR) (Michalsky et al. 1997) broadband channel if available).

Testing of DQGAP has been under way for approximately one year; hence, GRAMS data for the entirety of 1998 has been collected and processed. Via our web page at *http://arm.mrcsb.com/dq/*, we offer output netcdf files for download and plots of processed data to the community for it's judgment of utility.

The DQGAP code is being delivered to the ARM Experiment Center for inclusion in their data processing circuit.

Application

The DQGAP analysis consists of five sequential tests, ordered as follows: 1) min/max test, flagging data outside of physical irradiance limits; 2) dead signal test; 3) time gap test, flagging transient GRAMS data outages; 4) outlier point density test, flagging 2σ and 3δ outliers; and 5) instrument cross-comparison tests. Each test is exemplified below.

The min/max test is probably the most fundamental. We choose lower and upper limits such that all physically valid data should fall in between. For calibrated GRAMS and GRAMSCAL, we use 0 W/m^2 and 1500 W/m^2 as the limits, respectively. In Figure 1, the black cross indicates the point at about 18.25 hours Greenwich Mean Time (GMT), which just exceeds the 1500 W/m^2 level. These physical limits are based upon observation of one year's GRAMS data.

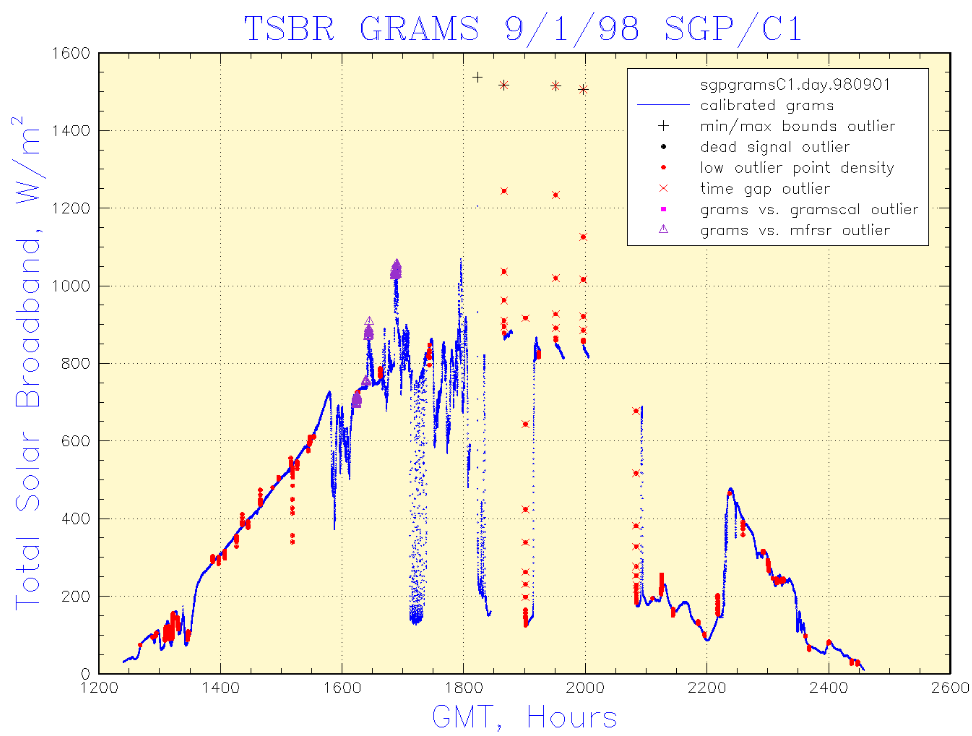

Figure 1. Example of plotted DQGAP output that shows a point failing the min/max test. The black cross at about 18.25 hours GMT exceeds the 1500 W/m^2 level.

Just as the min/max test flags physically unrealistic data, the dead signal test attempts to identify sequences of points having an insignificant variance with time. A peculiarity of the GRAMS instrument is that, on rare occasions, its readout freezes at a constant value for an extended period of time. The best way to detect this is before calibration, when a simple test for a very accurate horizontal line will suffice. An example is shown in Figure 2. The black points show a slight curvature with time because the constant dead signal value has been multiplied by a time dependent calibration constant.

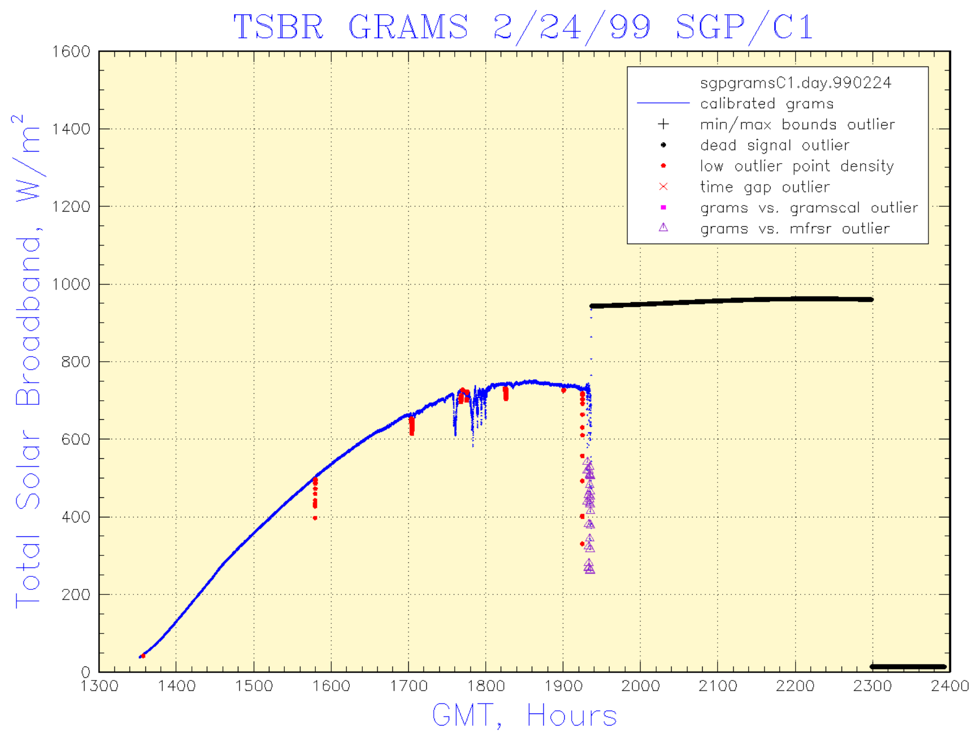

Figure 2. Example of a dead signal. The sequence of black points on the right of the figure that appears to be near horizontal lines, one high and one low, indicate dead signal points.

The third sequential test, the time gap test, is peculiar to the GRAMS instrument. Whenever this instrument resumes measurement after a hiatus, it tends to produce a series of 10 or 20 data points rapidly falling from some undetermined very high value toward the true flux value. This behavior is common because transient outages are common. It is easy to detect and screen. The red x symbols in Figure 3 are examples of outliers flagged by this test.

The outlier point density test was invented to distinguish between climatically interesting and uninteresting rapid signal excursions. Conceivable examples of climatically uninteresting cases include a temporary short due to an insect, or a passerby shadowing the instrument. A case that is climatically interesting is that of rapid variation in signal due to complex cloud structure passing overhead. It is impossible, using only the instrument's data stream, to reliably distinguish between all such cases, due to known and unknown causes. However, we observe that cloud motion, or development, is slower than a short-circuit or than most passing shadows of people. On this basis, we developed a two-tiered test. First, points that are either farther from a sliding mean than two sigma, or are farther from their neighbors than three $<\delta>$ are identified. (By $<\delta>$, we mean the sliding window's mean of absolute point-to-point irradiance changes.) Call these set A. Set A includes the points we want, those due to uninteresting causes, and unfortunately it also includes a good many points due to rapidly changing cloud shadows, frequently a great many. Therefore, we further subject these points to a test based upon point density. That is, for every point in set A, we ask how many set A points lie within a given time period centered at the point. If there are fewer points than a threshold, then the points are rare and therefore probably bad data. If there are more points than the threshold, then the points are

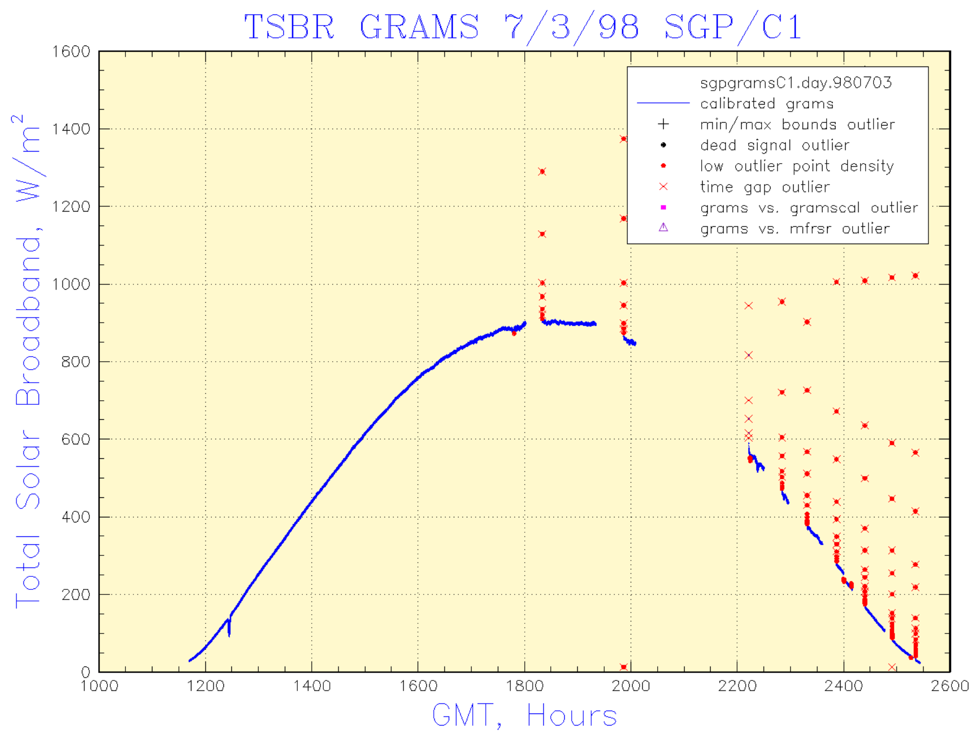

Figure 3. Example of time gap outliers, indicated by the red vertical sequences of points falling from some high value.

dense and are probably due to some persistent phenomenon, such as passing clouds. The value of the sliding time interval we use is presently 10 minutes and the point density threshold is 0.2, but results appear to be insensitive to the particular values of either quantity. The red points in Figure 4 were identified by this test.

One can see that for this clear day, 9/10/98, most points flagged (shown in red) are indeed either above or below the main curve. The nearly vertical set of points around 1430 GMT is called an exponential glitch, a fairly common occurrence with total time span of only a few seconds. This phenomenon is of unknown cause. The dip toward the right, at about 2330 hours is more interesting. Presumably it is due to a passing cloud, a common occurrence. Our algorithm, however, has flagged portions of it as outliers. This is best displayed when irradiance is plotted against air mass rather than time, as in Figure 5. In this presentation, the small dip is accentuated.

It seems that a few points, appearing to the eye as part of the probable cloud-induced dip, have been flagged as low point density outliers. Occasionally, our algorithm thus seems to improperly flag legitimate data points. It is apparent that any algorithm will do so, since natural events can occur on any time scale. We hope ours does it rarely so no serious miscalculation in a research project will result.

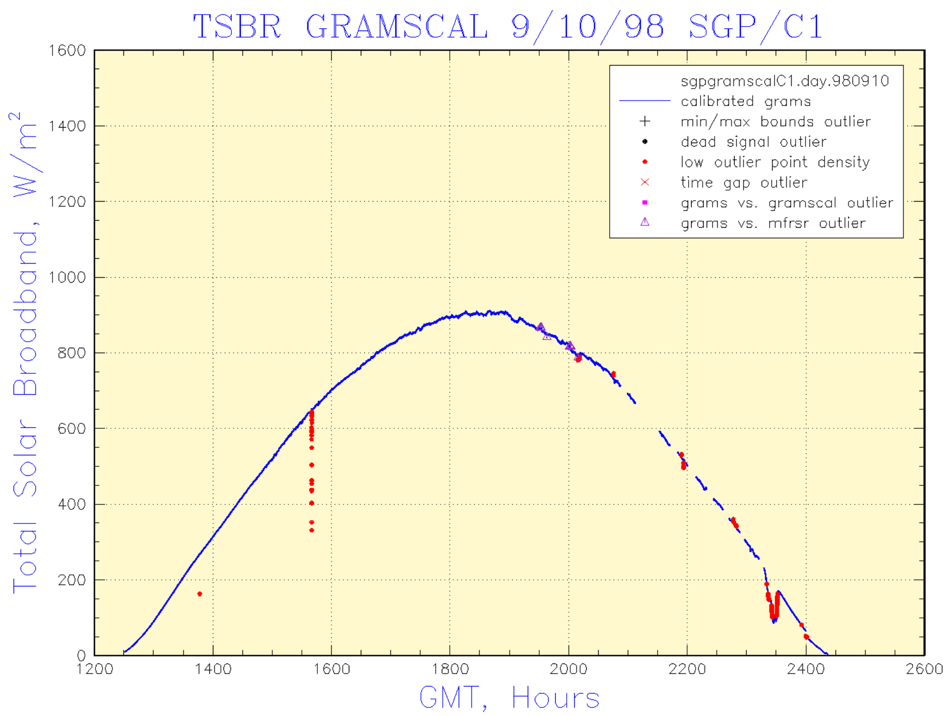

Figure 4. Low point density outliers. Those outliers with temporal density low enough to be considered as due to climatically uninteresting causes are shown in red.

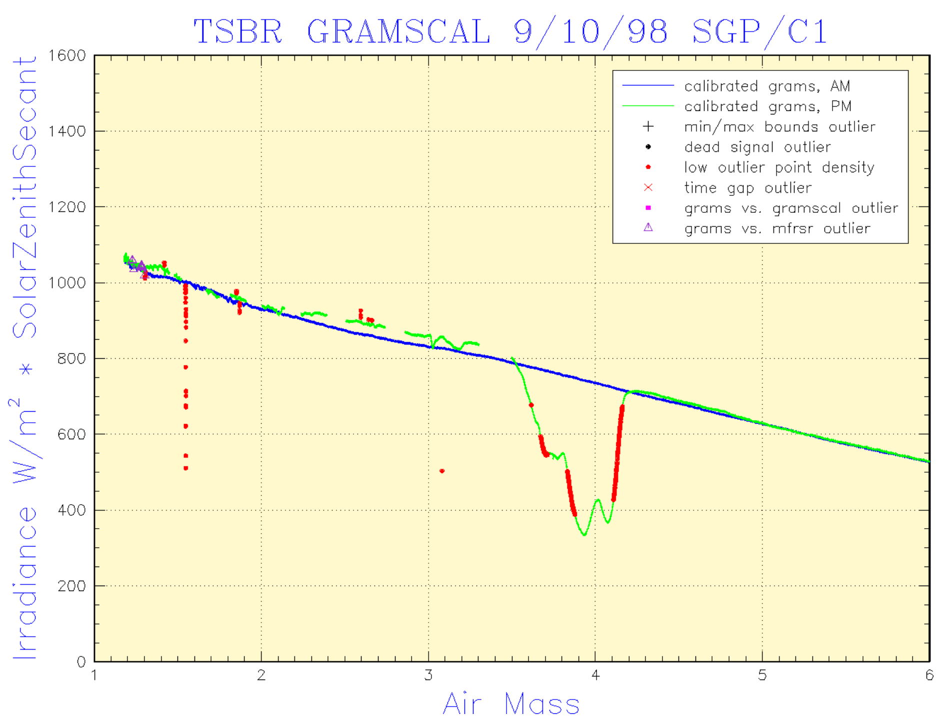

Figure 5. Calibrated GRAMS irradiance for 9/10/98, scaled by solar zenith secant and plotted versus air mass.

A second case further illustrates the combination of obvious data quality issues with probable cloud-induced irregularities. Figure 6 shows the GRAMS calibrated total solar broadband irradiance for 3/1/99 plotted versus time, and Figure 7 shows the same data plotted versus air mass. By comparison it is obvious that the prominent vertical outlier sequences shown in red at 1500 GMT, air mass 2.7, and at 1545 GMT, air mass 2.0, are examples of the exponential glitch described above. The dozen or so flagged data above air mass 3.5 are clearly intertwined with late afternoon variable obscuration, and are most likely false alarms. The two instances near zenith, however, do not obviously belong to either class. In particular, the outlier at 1845 GMT does appear anomalous on the time domain plot. These subjective and non-obvious outliers make tolerance of a small percentage of false alarms necessary.

The final test is a cross comparison to another nearby instrument. This test is made when either GRAMSCAL data are available, or MFRSR broadband data is available. GRAMSCAL is best since that instrument is essentially identical to GRAMS except for location perhaps a hundred yards away. It is frequently the case, however, that GRAMSCAL data is unavailable. MFRSR is usually up, is located close by and, while a different instrument design and uncalibrated, also measures the same physical quantity as GRAMS. Consequently, when both GRAMS and GRAMSCAL data are simultaneously unavailable, we can cross compare with MFRSR.

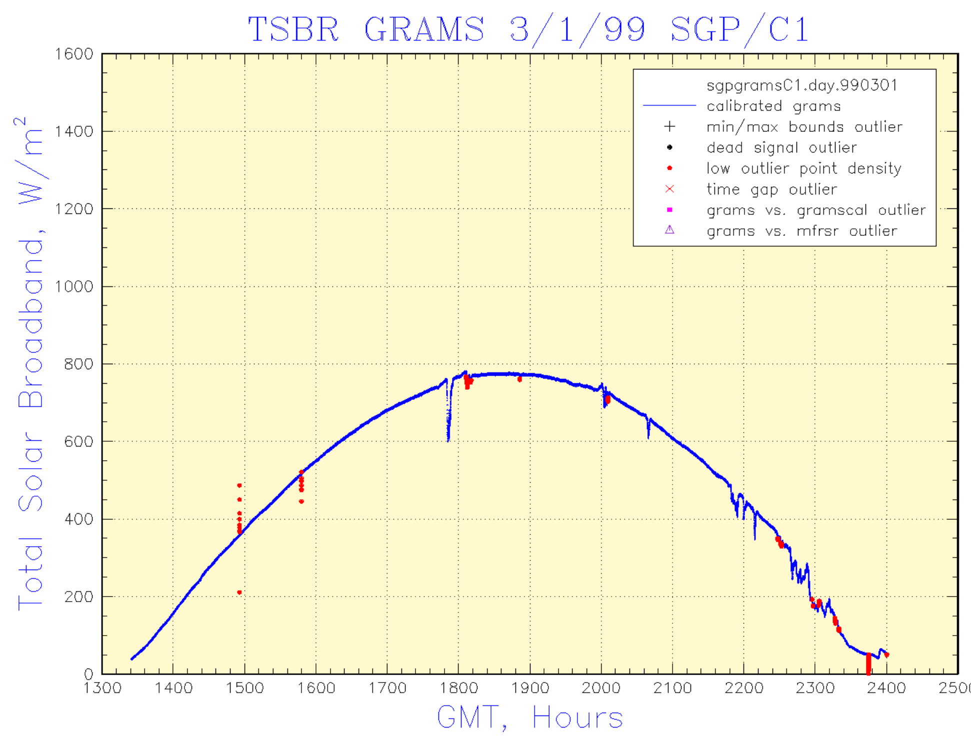

Figure 6. Low density GRAMS outliers for 3/1/99 plotted versus time.

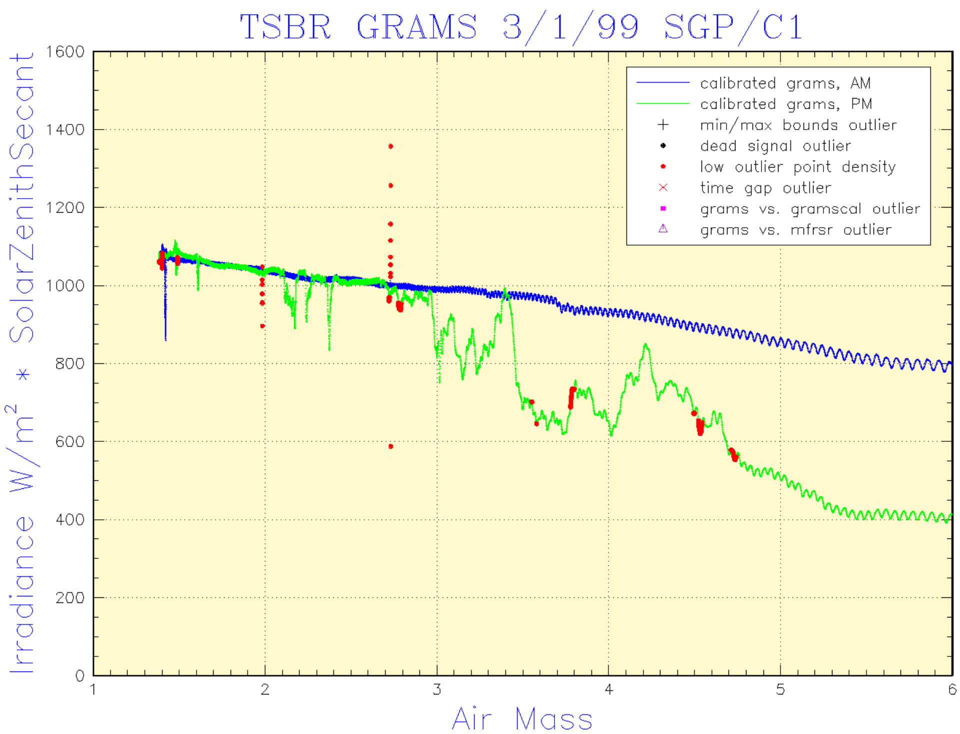

Figure 7. Low density GRAMS outliers for 3/1/99 plotted versus air mass. By comparison with the previous figure, the exponential glitch anomalies are rather obvious.

Figures 8 and 9 show GRAMS and GRAMSCAL data, respectively, for 7/14/98. There is some structure within a few hours of solar transit, both before and after, presumably due to scattered clouds. Just before 1600 GMT, the GRAMSCAL instrument records structure that is not seen by the GRAMS. Similarly, the GRAMS records depressed irradiance values before 1700 GMT and immediately after 1900 GMT that do not coincide with the collocated GRAMSCAL readings. These data are indicated by magenta ■ symbols in the plots.

The MFRSR instrument data, when cross compared with GRAMS or GRAMSCAL data covering the same time period, produce the sequence of purple ∆ symbols seen near 1900 GMT in both figures. In this particular case, given the similar structure seen in both GRAMS and GRAMSCAL, it is likely that these purple triangles are false alarms, perhaps due to the mismatched temporal sampling rate of the MFRSR and GRAMS instruments. For this reason, the GRAMS-MFRSR and GRAMSCAL-MFRSR cross comparisons are by default not implemented whenever the GRAMS-GRAMSCAL cross comparison is available.

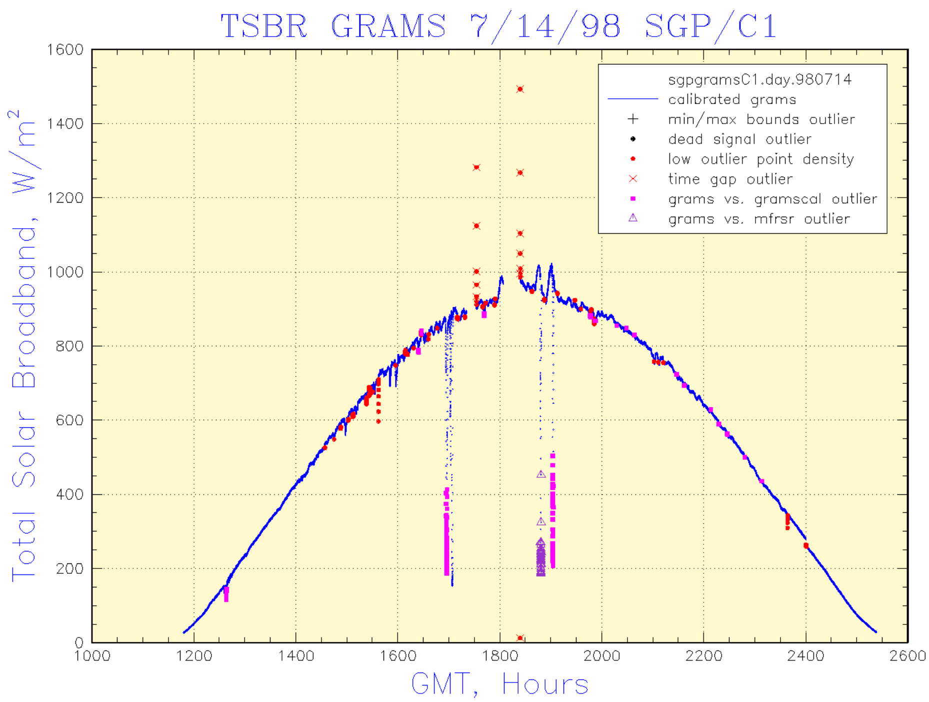

Figure 8. GRAMS total solar broadband versus time for 7/14/98. Some structure near 1700 GMT and 1900 GMT is flagged, having been seen by the GRAMS instrument but not the GRAMSCAL.

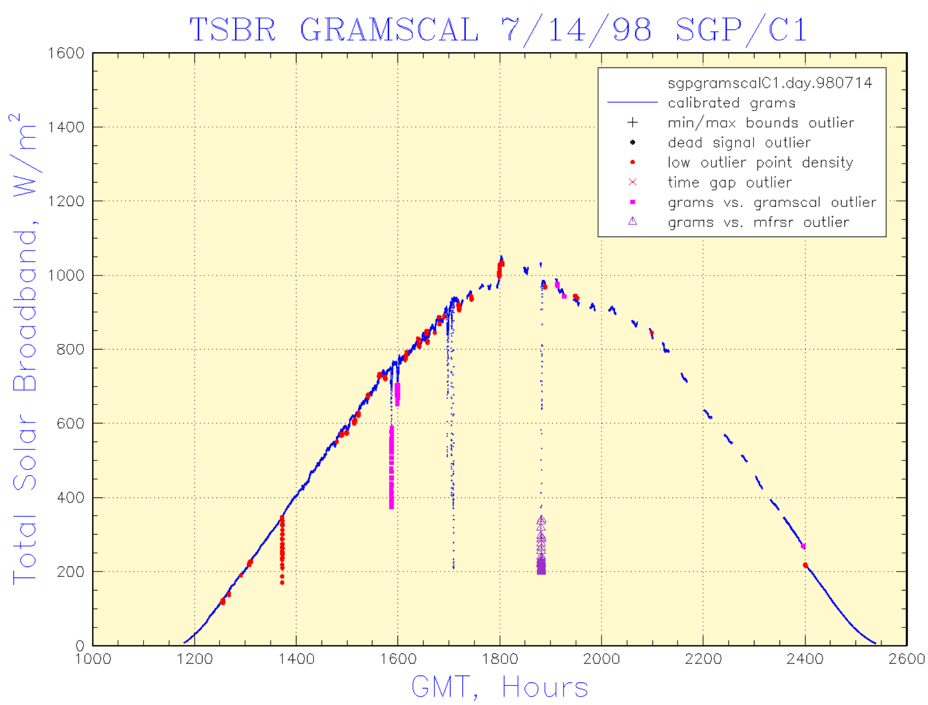

Figure 9. GRAMSCAL total solar broadband versus time for 7/14/98. The magenta symbols indicate readings that differ with GRAMS data of the previous figure.

Conclusions

The DQGAP analysis suite is an automated implementation of tests designed to enhance the data quality of the GRAMS radiometer. Because the ARM Program collects, monitors, and archives vast amounts of solar broadband data, high quality 60-second and 10-minute averages of GRAMS data can now be provided to the scientific user community. In DQGAP, we have balanced the false alarm rate with the frequency of GRAMS data quality anomalies.

The DQGAP program has been delivered to the ARM Experiment Center for inclusion in their automated processing environment. The algorithms employed by DQGAP should be extendable to other radiometer data as well. Future extensions to this work include cross comparisons of Shortwave Spectroradiometer and Rotating Shadowband Spectroradiometer multispectral instruments, for example.

References

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