**P4.3** QUALITY OF ATMOSPHERIC RADIATION MEASUREMENT (ARM) PROGRAM DATA

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## 1. INTRODUCTION

The U.S. Department of Energy-sponsored Atmospheric Radiation Measurement (ARM) Program collects data at three locales around the globe. Its Southern Great Plains (SGP) site encompasses a good portion of Oklahoma and Kansas and approximates the size of one General Circulation Model (GCM) grid box. The North Slope of Alaska (NSA) site is comprised of facilities in Barrow and Atqasuk, and the Tropical Western Pacific (TWP) site has instrumentation on Manus and Nauru Islands and in Darwin, Australia. The main goal of ARM is to collect data of the highest research quality possible to allow scientists to improve and test parameterizations of clouds and atmospheric radiation in GCMs and climate models. To this end, the quality of data being collected is crucial for the current research and for future data users.

The ARM Program has collected data since 1992 from the SGP, 1996 from the TWP, and 1997 from the NSA. There are numerous instrument platforms at each site, including radiometers that measure solar and terrestrial radiation, tower-mounted instruments that measure wind, temperature, and humidity, buried sensors that measure soil temperature and moisture properties, and a host of cloud observing instruments such as millimeter cloud radars and micropulse lidars.

The ARM Data Quality Office (DQO) was formed in July 2000 to coordinate the process of inspecting, assessing, and reporting on the quality of ARM data. Since its inception, automated and manual examination of data from all three sites has taken place on a daily to weekly basis. This "real-time" analysis allows problems to be identified and rectified quickly, and limits the amount of incorrect data collected. Cross-instrument and like-instrument comparisons are also made on a real time basis. In addition to supporting site operations, the DQO develops and performs long-term data checks for detection of events such as calibration drift and instrument degradation. These techniques and results can be seen at http://dq.arm.gov/, which includes color translations of automated flags, static plots, reporting mechanisms, and an interactive plotting tool (NCVweb) that allows analysts to selectively extract and view data. ARM Program data are freely available to the research and education communities. They can be accessed via the ARM Data Archive (http://www.archive.arm.gov), where quicklook graphics are available. ARM data are stored in Netcdf data format.

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## 2. NEAR REAL-TIME DATA ANALYSIS

Since the inception of the DQO, coordination between ARM's operations and research communities on data quality issues has been greatly enhanced. Prior to that time, instrument mentors and site scientists were responsible for ordering data from the ARM Archive and reviewing them after receipt. After reviewing these data, the mentor or site scientist contacted site operations when a problem was detected. From there, a work order was issued and the problem was addressed within one to two weeks. The time it took to run through this process potentially meant that the data user was not informed about data quality problems as quickly as one would hope. With the new system at http://dq.arm.gov, data are inspected more quickly and information about their quality conveyed in a more timely fashion.

Within the new system, once an analyst has viewed data from an instrument, using color metrics tables, diagnostic plots, and other supporting information such as maintenance reports, he/she issues a weekly status report that is distributed to that site's operations staff, the instrument mentor, and the ARM Data Management Facility (DMF). New tools, such as the Data Quality Problem Report (DQPR) have been created to improve the quality reporting process by documenting the problem resolution process from identification to resolution. Before the DQPR, each site (SGP, NSA, and TWP) had its own recording and tracking mechanisms. This made it difficult to standardize problem reporting to data users, identify common problems between sites, and perform statistical analyses. It is now possible to determine the average time it takes to fix instrument problems at each site. This may point out deficiencies or efficiencies with issues such as maintenance protocols and calibration techniques.

The DQO analyzes ARM data from all sites on a daily and weekly basis. During Intensive Observation Periods (IOP), data quality analysts monitor the data on an hourly basis as needed. Not only does this timely analysis identify problems quickly, but it also limits the amount of incorrect data collected and distributed to users. An example of how http://dq.arm.gov is used to inspect, assess, and report on data is presented in this section. Please also see Sonntag et al. (2003).

Figure 1 shows the color translation of automated flagging results for broadband radiometers at SGP Extended Facility 9 (Ashton, KS) on 21-22 October 2003. The downwelling shortwave hemispheric pyranometer was malfunctioning, failing a three-component sum test wherein the measured hemispheric irradiance, compared to a computed value composed of corresponding direct normal and diffuse measurements, was consistently 30-50 W/m$^2$ too low. Failing values are denoted as red hourly squares in the table. At 1550

UTC on 21 October, a maintenance crew replaced the downwelling hemispheric pyranometer, and values returned to normal (green).

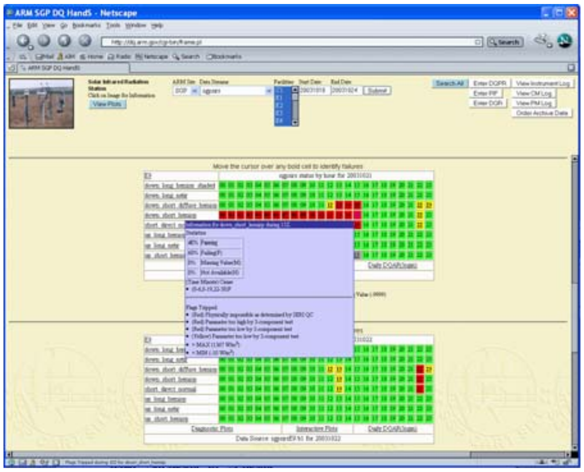

*Fig. 1. Color flag translation tables for 21-22 October.*

During the maintenance action, values of the direct normal and diffuse measurements were also affected, as denoted by yellow and red squares. The blue popup displays the flag information for the downwelling hemispheric measurement during hour 1500 UTC. A diagnostic plot for 20 October (Figure 2 top) reveals the hemispheric measurement (black line) riding below the component sum line (gold line), but a return to coincident values after sensor replacement on 22 October (Figure 2 bottom).

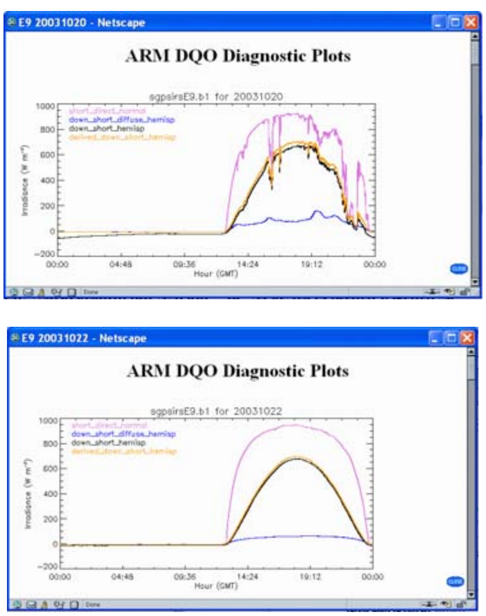


*Fig. 2. Top: Comparison plot on 20 October before maintenance action, showing the discrepancy in measured and computed hemispheric irradiance at E9. Bottom: same on 22 October after maintenance, showing better agreement.*

A data quality problem report (DQPR; Figure 3) had been issued by the DQO to the instrument mentor and site operator regarding this problem on 20 October, with the first degradation in data noticed on 14 October. The regularly scheduled maintenance visit for E9 was 21 October, and the sensor swapout was made then. Subsequent checking of the data on 27 October indicated that they had improved, changing the status of the DQPR from "open" to "pending "data quality report" (DQR), to be written either by the originator of the DQPR or the instrument mentor. A DQR in the ARM Program is a written statement of problem description and resolution intended for a user of the data. Whenever these data are then ordered from the Data Archive, this DQR will be attached to the data order. It is written through a new Data Quality Reporter system that pulls information from reports such as a DQPR from a database and populates a form. The DQR writer then fills in the rest.

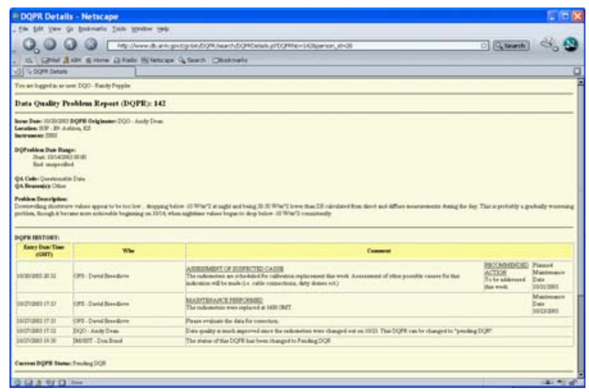

*Fig. 3. DQPR form 142 for the discrepancy problem in measured and computed hemispheric irradiance at E9.*

## 3. INTERACTIVE PLOTTING CAPABILITY

A key component of our data quality inspection and assessment system is called NCVweb (Moore and Bottone, 2003), an interactive plotting tool developed by our collaborators Sean Moore and Steven Bottone of Mission Research Corporation. It is accessible from http://dq.arm.gov. This tool allows one to formulate plots to his/her liking, including the ability to zoom in on a particular time period to view finer scale resolution and combine traces from multiple data gathering sites. Figure 4 below show plots of barometric pressure at E9 on 24 October 2003, a day in which a cold frontal passage occurred. The frontal passage is evident between 2000 and 2100 UTC in the regular view (top panel). Hours 1600-2400 UTC are "blown up" in the bottom panel to allow one to see finer-scale detail. This tool is particularly good for viewing such detail in data suspected to be in error, and for comparing like measurements from multiple collection sites. NCVweb has been enhanced to provide the ability to look at data streams that are produced in three dimensions.

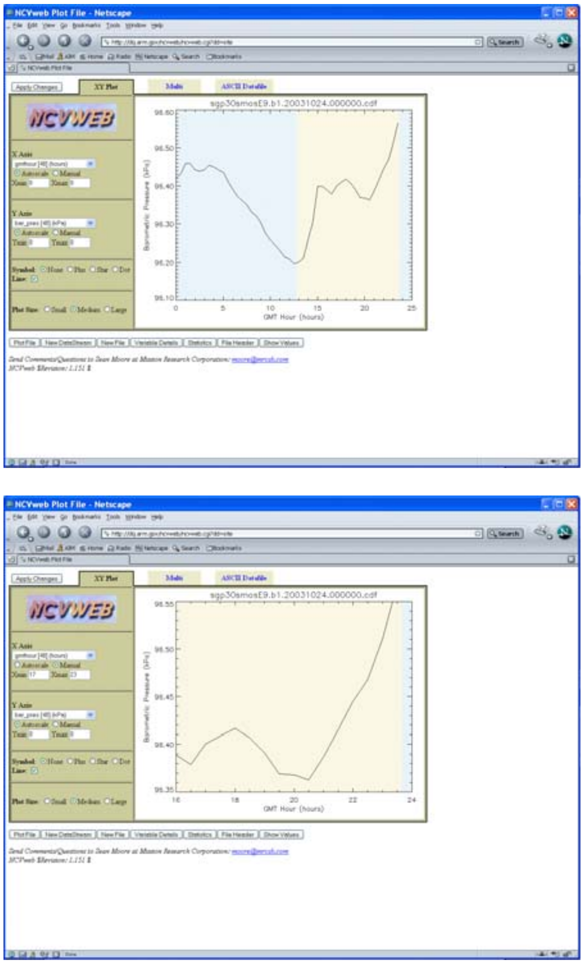


*Fig. 4. Top: Barometric pressure trace from NCVweb at E9 on 24 October 2003 showing cold frontal passage between 2000 and 2100 UTC. Bottom: same trace during the hours 1600-2400 UTC only showing a closer view of a cold frontal passage.*

## 4. EXAMPLES OF SYSTEM EFFECTIVENESS

The biggest influence the DQO's new data quality inspection and assessment system has had on ARM Program data quality during the past year is the speed with which DQPRs have been issued and the resulting speed with which the instrument mentors and site scientists have responded to them to solve problems. A big part of the improvement has involved better interaction between these groups and the DQO.

In summer 2003, the DQO was given permission by a number of mentors to issue DQPRs for their particular instruments, owing to the fact that the DQO has as its central mission to inspect and assess the data. Since this time, DQPRs have been issued more quickly, with the resultant mentor and site operations troubleshooting and maintenance activity occurring more quickly to address problems. Most mentors in fact have encouraged this extra set of eyes being cast on the data. The result has been faster problem resolution, usually within two weeks of problem diagnosis. There have been several examples of shadowband misalignments involving multifilter rotating shadowband radiometers (MFRSR) and humidity sensor malfunctions with surface meteorological observing systems (SMOS) that have been detected more quickly than in the past with this new process.

The MFRSRs have seen a dramatic rise in attention in the past year. A new mentor assumed responsibilities and immediately made contact with the DQO to provide her synopses of instrument performance and pointers on how to inspect the data. Subsequently, routine data quality assessments have improved drastically, and DQPRs have been issued for such problems as the shadowband misalignments, along with for datalogger malfunction and data ingest problems. ARM Program problem identification reports (PIF), requiring programmatic evaluation, were issued for several of the MFRSR instruments regarding chronic calibration problems, likely resulting in some level of re-engineering. Thus, the DQO has been able to better report on the data quality of the MFRSRs thanks to better communication with the instrument mentor and co-use of the new inspection and assessment system.

Another example of data quality improvement has involved the energy balance Bowen ratio system (EBBR). The DQO now has weekly contact with the EBBR mentor, and issues "pre-reports" to him asking for confirmation of what has been seen and guidance on how to move forward. The result of this effort has been more thorough data inspection and assessment by both the mentor and the DQO. Furthermore, the mentor's frequency of issuance and updating of DQPRs has increased over the past year, in no small part due to the DQPR system set in place.

The DQO was also able to use the new system to catch an error in the infrared temperature (IRT) upwelling shortwave hemispheric readings, wherein an incorrect calibration coefficient was being applied to the raw readings. This caused values to be opposite in sign of what they should have been. When the DQO issued a PIF on this problem, site operations maintenance occurred within two weeks and the problem was solved.

Another example involves the ARM Program's relatively new total sky imager (TSI). The mentor approached the DQO during summer 2003 at a mentor-wide meeting and expressed appreciation for reporting on chronic missing data gaps within the TSI data record. This has led to subsequent correspondence with the respective site scientists to work on a solution.

Other instances of the positive value of the new data quality inspection and assessment system are listed below:

- Close monitoring of NSA data allowed recognition of the need to reboot the met tower datalogger and subsequent issuance of a DQPR. This problem was solved quickly.
- Daily monitoring of SGP broadband radiometers revealed chronic suntracking problems, which previously went unnoticed for

periods of up to a month. These are now rectified within two weeks.

- Daily monitoring of data has allowed the DQO to alert on-site technicians as to whether or not the changes they have made are producing good data.
- Once TWP data collection and dissemination became near real-time in 2003, the DQO was able to apply its system to those data and allow the site scientist there to have quicker access to visual aides.
- Previous to the DQO's automated system, the mentor for the microwave radiometer (MWR) ordered data from the ARM Archive, ran his own plotting routines, and analyzed the data himself from all three ARM sites. He indicated that this process caused him to run 1-2 months behind in his analyses. Now, with the automated system, the mentor allows the DQO to perform the routine data inspection and assessment activity, allowing him to focus on more serious performance problems such as calibration.

Overall, the new system has improved data quality reporting, scope, and speed through (1) more frequent assessment reporting, (2) quicker and more meaningful communication and interaction with instrument mentors, (3) providing of a comprehensive DQPR system that allows more flexibility in reporting, documenting, and solving problems; and (4) better communication with the site scientists. A more coordinated reporting system will be completed in late 2003 that will tie together a number of programmatic databases to allow comprehensive inclusion of disparate metadata for a specific problem.

## 5. REFERENCES

Moore, S.T., and S. Bottone, 2003: NCVweb: An interactive web-based tool for viewing Atmospheric Radiation Measurement (ARM) data. *Preprints, 19th Conference on IIPS*, Amer. Meteor. Soc., 9-13 February 2003, Long Beach, California, manuscript P1.45, CD-ROM.

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