7.1 THE DEVELOPMENT OF AN OPERATIONAL QUALITY ASSURANCE SYSTEM FOR OASIS SUPER SITE DATA AT THE OKLAHOMA MESONET

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1. INTRODUCTION

In the past, networks that utilized eddy covariance systems to measure the components of the surface energy budget were generally limited to short-term field experiments. However, more recent long-term networks, such as FLUXNET (Baldocchi et al. 2001), have begun to highlight the challenges of maintaining high-quality eddy covariance measurements over longer periods (e.g., Falge et al. 2001; Wilson et al. 2002). Currently, the operators of the Oklahoma Mesonet face similar challenges with measurements from the Oklahoma Atmospheric Surface-layer Instrumentation System (OASIS) Super Sites.

In 1999, 10 Oklahoma Mesonet sites, designated OASIS Super Sites, were instrumented to measure the components of the surface energy balance. While select short-term case studies have utilized OASIS Super Site data, long-term real-time quality assurance (QA) methods have never been incorporated into the collection of OASIS observations. This study details ongoing efforts to update the operational QA database of the Oklahoma Mesonet while highlighting specific QA methodologies for OASIS Super Site data. These methodologies focus on measurements of the surface energy and radiation budgets, particularly those which utilize the eddy covariance approach.

2. OBSERVATIONS

2.1 *Oklahoma Mesonet*

The Oklahoma Mesonet is an automated network of 116 remote, hydrometeorological stations across Oklahoma (Fig. 1; Brock et al. 1995; Shafer et al. 2000). Each station measures 10 core variables which include: air temperature and relative humidity at 1.5 m, wind speed and direction at 10 m, barometric pressure, rainfall, incoming solar radiation, bare and vegetated soil temperatures at 5, 10, and 30 cm below ground level, and soil moisture at 5, 25, 60, and 75 cm. The data are collected every 5 minutes as a 5-minute average value, with the exception of soil temperature (15 min) and soil moisture (30 min) data. The Mesonet was installed in 1993 and became operational on 1 January 1994. Since that time, over 3 billion observations have been archived at an archiving frequency that exceeds 99% of the possible observations. Core Mesonet data are collected and transmitted to a central processing facility every 5 minutes where they are quality assured, archived, and distributed (Shafer et al. 2000).

2.2 *OASIS Project*

In 1999, the OASIS Project upgraded 89 sites with a suite of instruments capable of estimating the surface energy balance (Brotzge et al. 1999; Brotzge 2000; Basara and Crawford 2002). In addition, OASIS Super Sites, a subset of 10 OASIS sites, were instrumented to measure the components of the surface energy balance with enhanced accuracy. The 10 OASIS Super Sites measure latent, sensible, and ground heat fluxes, the four components of net radiation, and surface skin temperature. Each Super Site is located in a different climate region of Oklahoma and, as a permanent installation, permits the investigation of a wide range of atmospheric conditions over extended periods of time.

2.3 *Instrumentation*

The OASIS Super Sites measure net radiation at 1.5 m using a 4-component CNR1 radiometer. As such, incoming and outgoing shortwave and longwave radiation are measured explicitly. Ground heat flux is estimated using a combination method (Tanner 1960) that uses measurements of soil heat flux and soil heat storage. The sensible and latent heat fluxes are measured directly via an eddy correlation approach using a CSI CSAT3 sonic anemometer and Krypton hygrometer installed

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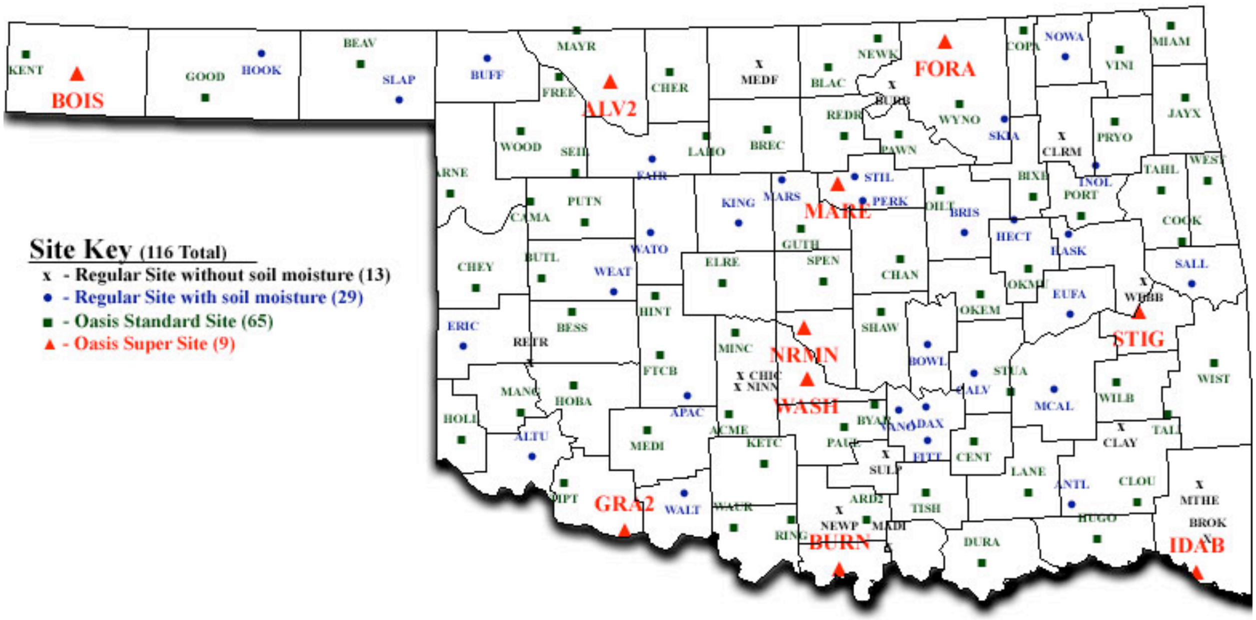

Figure 1: Location of Oklahoma Mesonet Sites in June 2005.

at 4.5 m above ground. Surface skin temperature is measured at 2 m using an infrared thermocouple temperature sensor manufactured by Apogee (Fiebrich et al. 2003).

3. METHODOLOGY

Initial QA procedures for the OASIS Super Site data consisted of visually inspecting the radiation and heat flux time-series plots for each site while scanning the data one observation at a time to assign QA flags. These QA procedures were tedious and time consuming. As a result, only short-term Super Site data sets have been utilized. Current activities aim to efficiently produce long-term Super Site data sets.

Reliable, automated procedures based on inspection of time series can reduce QA efforts and provide a consistent product (Lee et al. 2004). Thus, to utilize any automated QA procedures, periods of bad or missing data needed to be documented and entered into the Mesonet's operational QA database. The CSAT3 sonic anemometer cannot accurately measure the winds when the transducers are wet. Thus, all periods of active precipitation were documented. To avoid the exclusion of research quality data, the periods of active precipitation were documented via graphical inspection of precipitation, net radiation, and sensible heat flux time series (Fig. 2). The quality assurance flags for each datum during active precipitation were: 2 = warning, 3 = sensor failure. Sensor failure was defined as the lack of a sensor response, or consecutive observations of sensible heat flux with values of 0.00 W m^{-2} (Fig. 2, left).

4. QUALITY ASSURANCE CHALLENGES

While documenting periods of active precipitation, it was found that periods of questionable data and sensor failure occurred in the absence of precipitation.

4.1 *Isolated Spikes*

The data logger-derived values of sensible heat flux assume a constant air density of 1.2 kg m^{-3}. To account for natural variations in air density, the corrected sensible heat flux at OASIS Super Sites includes the calculation of the air density via the equation of state with observed values of air temperature and pressure. While documenting active precipitation periods, isolated spikes in corrected sensible heat flux with magnitudes greater than 1000 W m^{-2} were noted. However, there were no coincident spikes in the logger-derived values (Fig. 3). Air temperature and pressure data were analyzed and excluded as causes of the spikes.

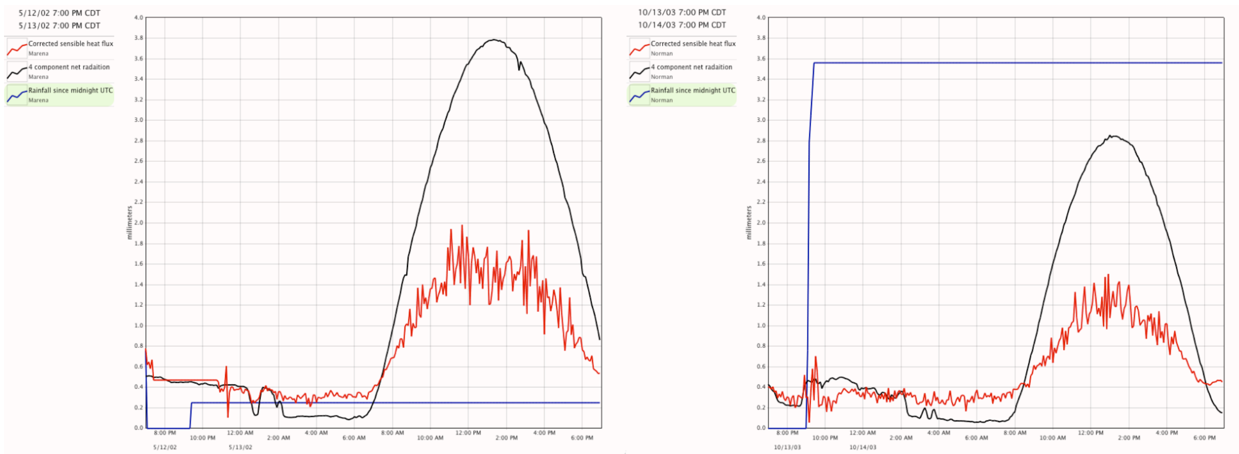

Figure 2. Time series plots of net radiation (W m^{-2}; black), corrected sensible heat flux (W m^{-2}; red), and precipitation (mm; blue) at the Marena Super Site on 13 May 2002 (left) and the Norman Super Site on 14 Oct 2003 (right).

Upon inspection of the data files, it was discovered that covariance values measured by the sonic anemometer with very small magnitudes were expressed in scientific notation. In addition, the ingest software did not support scientific notation. Thus, covariance values listed as 4E-6 were ingested as 4.0 instead of 0.000004. As a result, the calculated values of corrected sensible heat flux were 1-2 orders of magnitude larger than typical peak daytime values.

Now that the cause of the isolated spikes has been identified, the ingest software will be modified to allow for scientific notation and the data will be reprocessed.

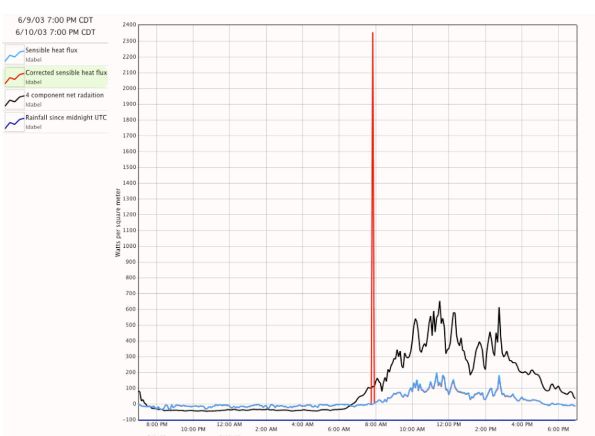

Figure 3. Time series plots of logger-derived sensible heat flux (W m^{-2}; light blue), corrected sensible heat flux (W m^{-2}; red), net radiation (W m^{-2}; black), and precipitation (mm; blue) at the Idabel Super Site on 10 Jun 2003.

4.2 *Condensation*

Conditions favorable for the condensation of water vapor near the surface include clear skies, high relative humidity, and low wind speed. To determine whether sensor failure during periods without precipitation was the result of condensation on the sonic transducers, relative humidity and wind speed data were analyzed.

Figure 4 illustrates a case of water vapor condensing on the transducers of the sonic anemometer. The relative humidity was greater than or equal to 95% for approximately six hours prior to and during the period of sensor failure. In addition, the wind speeds during this period were less than 2.5 m s^{-1} (not shown).

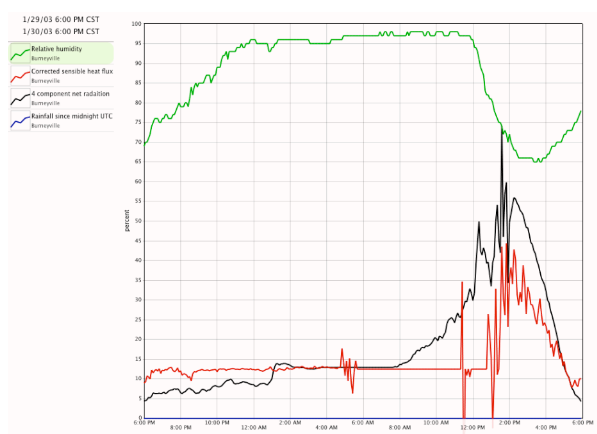

Figure 4. Time series plots of relative humidity (%; green), corrected sensible heat flux (W m^{-2}; red), net radiation (W m^{-2}; black), and precipitation (mm; blue) at the Burneyville Super Site on 30 Jan 2003.

To verify that sensor failure was the result of condensation, surface observations from the Ardmore Municipal Airport (KADM; Ardmore, OK) were examined. KADM, as well as other surrounding surface observation stations, reported relative humidity values near 100%, overcast cloud cover, and either fog or haze for several hours before and during the time period of interest. In order to establish criteria for automated QA, other cases such as this must be studied in more detail.

5. CONCLUSIONS

Although accurate measurement of the components of the surface energy budget remains a challenge, significant progress has been made. Initial manual QA procedures have enabled the identification of sensor behaviors related to specific atmospheric conditions at each OASIS Super Site. This preliminary investigation ensures that obviously flawed measurements are noted in the Oklahoma Mesonet's operational QA database. This process will eventually lead to specific documented criteria for real-time manual QA of these variables, as well as partial automation through computerized algorithms.

Future tasks in the QA process will include the examination of several value-added corrections to the data. Corrections of interest include sonic temperature corrections as outlined by Schotanus (1983) and Liu et al. (2001), coordinate tilt via the planar-fit method described by Wilczak et al. (2001), as well as considerations for averaging times and coordinate systems as discussed by Finnigan et al. (2003) and Finnigan (2004).

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