JP1.5 EVALUATING NARR SURFACE VARIABLES AND NLDAS USING OBSERVATIONS FROM THE OKLAHOMA MESONET

Justin W. Monroe[1]*, Jeffrey B. Basara[1], David L. Toll[2]
[1]Oklahoma Climatological Survey, University of Oklahoma, Norman, OK
[2]Hydrological Sciences Branch, NASA/GSFC, Greenbelt, MD

1. INTRODUCTION

Land surface characteristics heavily impact the partitioning of available energy in the surface energy balance (SEB). In addition, it is difficult to accurately measure and simulate the surface energy and water budgets. Even so, advances in technology have improved the accuracy and reliability of these measurements. Likewise, computational resources have increased in conjunction with a new focus on simulating the complex processes at the surface-atmosphere interface. These land surface models (LSMs) have now become a key component of numerical weather prediction models, and play a large role in accurate weather forecasts.

The National Centers for Environmental Prediction (NCEP) North American Regional Reanalysis (NARR) is a long-term (1979-2003) atmospheric and land surface hydrology dataset over North America created via enhanced data assimilation techniques (Mesinger et al. 2006). The North American Land Data Assimilation System (NLDAS; Mitchell et al. 2004a) was developed from a multi-institutional collaboration that involved several Universities and government agencies. Within these frameworks, simulations from two LSMs were obtained for the study period 2002-2003.

A key component of any model evaluation is quality in-situ observations. The Oklahoma Mesonet is a modern automated network of over 100 meteorological stations across Oklahoma (McPherson et al. 2007). In 1999, 10 Mesonet sites were upgraded with instrumentation capable of measuring the components of the SEB with enhanced accuracy. These sites were known as the Oklahoma Atmospheric Surface-layer Instrumentation System (OASIS) Super Sites (Brotzge 2000).

This study seeks to detect biases in surface-layer variables simulated by NARR and NLDAS using in-situ observations from the Oklahoma Mesonet. The biases in the simulated turbulent heat fluxes are then related to variations in the values of observed and modeled soil moisture.

*Corresponding author address:
Justin W. Monroe, 120 David L. Boren Blvd, Suite 2900, Norman, OK, 73072. E-mail: jwmonroe@ou.edu

2. DATA

2.1 NARR

The NARR system offers a dataset that benefits from several improvements over both the NCEP National Centers for Atmospheric Research (NCAR) Global Reanalysis (Kalnay et al. 1996), and the NCEP Department of Energy Global Reanalysis (Kanamitsu et al. 2002). Some of the improvements include: increased temporal (3 hour) and spatial (32 km, 45 layer) resolution, the use of the NCEP's mesoscale Eta forecast model and its Eta Data Assimilation System (EDAS, Rogers et al. 2001), the assimilation of observed precipitation, and the use of a recent version (2.6) of the Noah LSM (Ek et al. 2003; Mitchell et al. 2004b).

2.2 NLDAS

The NLDAS includes four LSMs executed in uncoupled mode with common hourly surface forcing using a 1/8° grid over the continental United States. The four LSMs include Noah, Mosaic (Koster and Suarez 1996), VIC (Liang et al. 1996), and Sacramento (Burnash et al. 1973). In this framework, NLDAS works as the "driver" for each LSM by providing all required forcing and fixed surface fields.

NLDAS provides nine primary forcing fields for each LSM (Cosgrove et al. 2003). Of these nine forcing fields, six are provided entirely by EDAS. Two primary differences between forcing within NLDAS and NARR include the use of GOES-based solar radiation in NLDAS (Pinker et al. 2003), as well as precipitation analyses derived from gauge-based observations and radar.

2.3 Observations

The Oklahoma Mesonet is a modern automated network of over 100 meteorological stations across Oklahoma. Each station measures

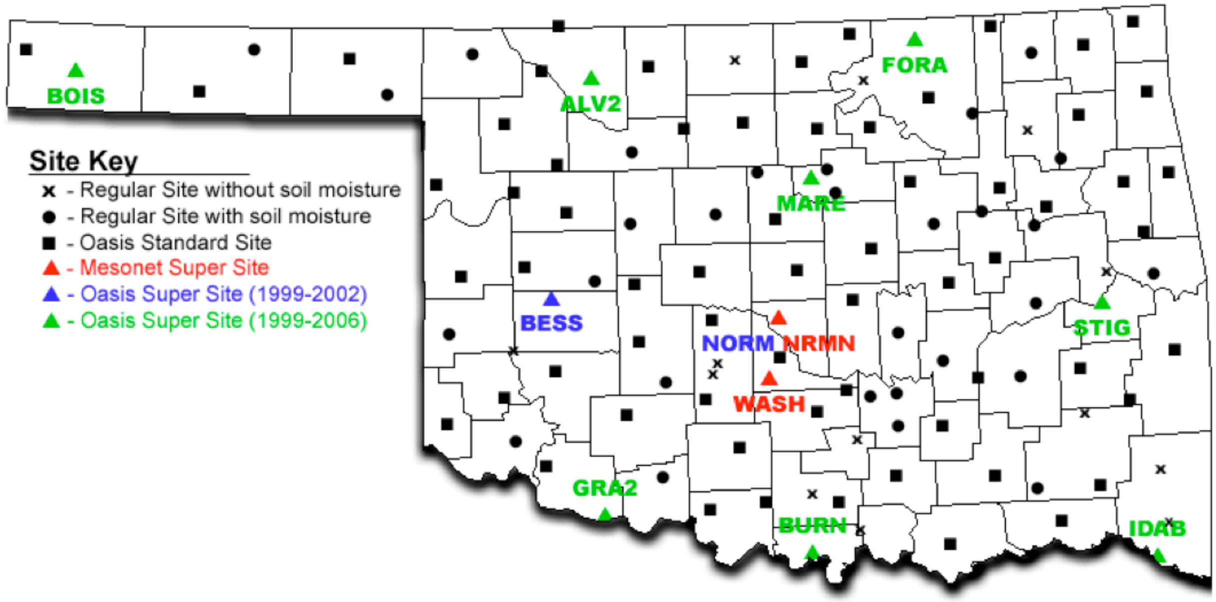

Figure 1: Map of 12 OASIS Super sites during the period 1999-2006.

10 core variables, including air temperature and relative humidity at 1.5 m above ground, wind speed and direction at 10 m above ground, barometric pressure, rainfall, downwelling solar radiation, and soil temperatures at 10 cm below ground under both natural vegetation and bare soil, and soil moisture at 5, 25, and 60 cm below ground. All observations from the Oklahoma Mesonet are collected every 5 minutes, with the exception of soil temperature (15 min) and soil moisture (30 min).

In 1999, 10 Mesonet sites were upgraded with instrumentation capable of measuring the components of the SEB with enhanced accuracy. These sites were known as the OASIS Super Sites (Fig. 1).

3. METHODOLOGY

3.1 Study Domains

The gradients of annual precipitation and vegetation type across Oklahoma are generally northwest to southeast. As such, three study domains were selected to represent these climatological differences.

Each study domain consisted of three Mesonet sites, with each site located within or in close proximity to the selected model grid cells. The ALV2, MARE, and STIG Super Sites were used as the anchor sites for each study domain; the ALV2 Super Site served as the basis of the northwest (NW) study domain, the MARE Super site was the basis of the central (C) study domain, and the STIG Super Site was the basis for the southeast (SE) study domain.

Six NARR grid cells were selected for the model evaluations. The grid cells in the NW study domain were labeled NARR-NW1 and NARR-NW2, the grid cells in the C study domain were labeled NARR-C1 and NARR-C2, and the grid cells in the SE study domain were labeled NARR-SE1 and NARR-SE2.

The NLDAS grid cells were selected to closely match the spatial coverage of the larger NARR grid cells. A total of 12 NLDAS grid cells were selected per study domain. The NLDAS grid cells were labeled individually for each domain using the domain location (NW, C, or SE) as the prefix, and a number (1-12) as the suffix (e.g., NW1). A map of the C study domain is demonstrated in Figure 2.

3.2 Evaluation Methods

The Noah and Mosaic LSMs within NLDAS

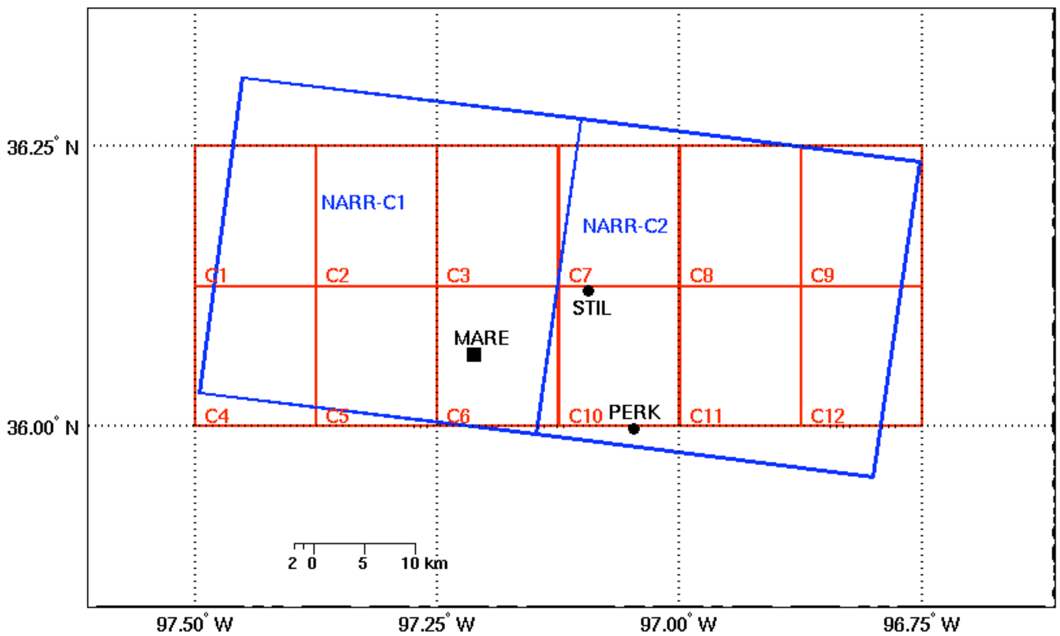

Figure 2: Map of C study domain. The NARR grid cells are outlined in blue boxes. The NLDAS grid cells are outlined by red boxes. The Oklahoma Mesonet sites are shown in black text and symbols, with the MARE Super Site designated with a square.

provided the components of the SEB as one-hour averaged values, while the Noah LSM within NARR provided three-hour averages. The SEB components observed at the ALV2, MARE, and STIG OASIS Super Sites were averaged to one-hour and three-hour values for direct comparison with the modeled values. For comparisons with NARR, the output from the NLDAS LSMs was also averaged to three-hour values. To detect systematic biases in the model output, plots of the mean diurnal cycle were created.

Due to the slowly varying nature of the of soil moisture, volumetric water content values were analyzed using daily-averaged values. Time series plots of volumetric soil moisture anomalies were created over the two-year study period similar to by subtracting the two-year mean from each daily-averaged value.

4. RESULTS

4.1 Volumetric Soil Moisture Anomalies

Soil moisture anomalies were investigated to identify periods where either observed or modeled volumetric water content diverged or remained near mean quantities over the two-year study period. A cursory glance at each domain revealed periods when the soil moisture values modeled by NARR dried out and reached the wilting point for extended periods of time. Dry-down periods were evident as significantly larger negative anomalies than the NLDAS and observed curves (e.g., the C study domain in Figure 3 after July 2002 and July 2003). Further, the NARR soil moisture values displayed this tendency to dry more than NLDAS and observed values at all three study domains. In addition, the Mesonet observations from the C and NW study domains did not compare as well to the models during the winter months, as the observed values remained nearly uniform and did not vary much over time as the models did.

A comparison with the two-year time series of sensible and latent heat fluxes from NARR over the C study domain demonstrated very sharp decreases in latent heat flux values that even reached values of 0 W m^{-2} over a period of a few

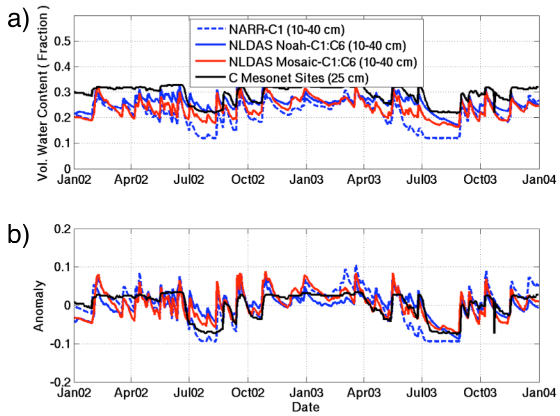

Figure 3: a) Time-series plot of volumetric water content for 2002-2003 at the C study domain with 25-cm observed values compared to those modeled at the 10-40 cm depth. b) Anomalies for each variable.

days (Fig. 4). These days are coincident with the relatively large negative anomalies in NARR 10-40 cm volumetric soil moisture. The decrease in latent heat flux values to 0 W m^{-2} by NARR were not produced by NLDAS Mosaic, NLDAS Noah, or noted in the observations.

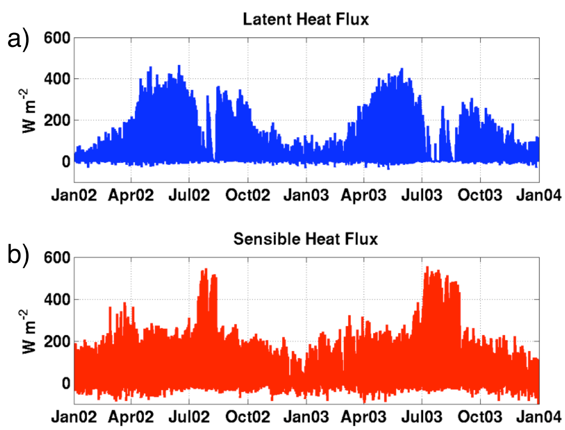

Figure 4: a) Time-series plot of NARR latent heat fluxes for 2002-2003 at the C study domain. b) NARR sensible heat fluxes over the same period.

4.2 Net Radiation

The modeled net radiation matched observations well when averaged over the 2-year period (Fig. 5). Overall, there was a slight positive bias in values from NARR during peak daylight hours, as well as a slight positive bias in values from the NLDAS models early in the day.

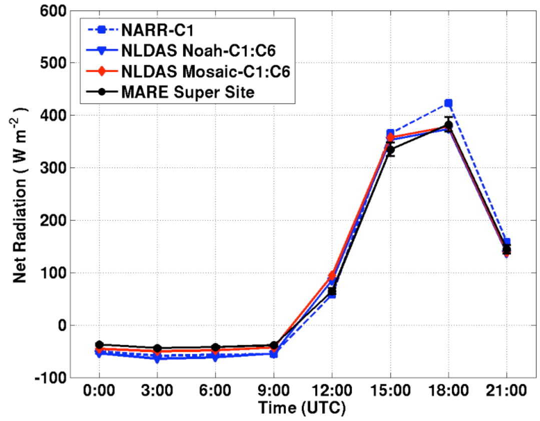

Figure 5: Mean 2-year diurnal cycle (2002-2003) of net radiation (W m^{-2}) for NARR, NLDAS, and the MARE Super Site in the C Study Domain. Error bars represent 95% confidence intervals for the MARE observations.

These biases were most likely related to the positive biases in the downwelling shortwave radiation provided by the model forcing, which were more evident early in the day for the NLDAS values. For NARR, the low biases in values of downwelling longwave radiation, as well as the high biases in values of upwelling shortwave and longwave radiation counteracted the significant high biases of downwelling shortwave radiation (not shown).

4.3 Turbulent Heat Fluxes

Sensible heat flux values from NARR and NLDAS Noah demonstrated a daytime positive bias when compared to observations from the Super Sites at all three domains. The values of sensible heat flux from NLDAS Mosaic compared better to observations from the northwest and C study domains, but revealed positive biases comparable to values from NLDAS Noah in the Southeast. The biases from NARR and NLDAS Noah sensible heat fluxes also increased slightly in the southeast domain. The results from the C study domain are visible in Figure 6, which demonstrates the positive bias in values from NARR and NLDAS Noah during daylight hours, and a much smaller positive bias for values from NLDAS Mosaic in early afternoon.

Modeled latent heat flux values displayed significant daytime negative biases in all three study domains when averaged over the 2-year period. These biases were fairly consistent across

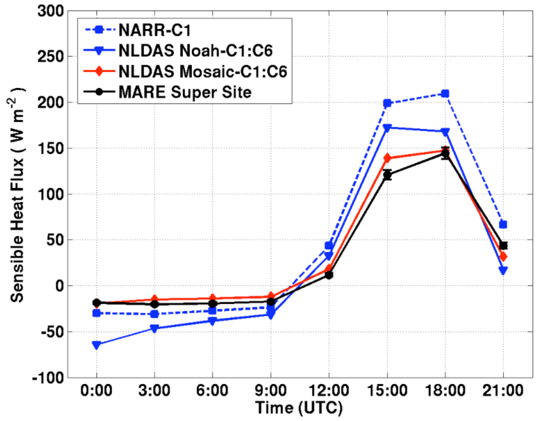

Figure 6: Mean 2-year diurnal cycle (2002-2003) of sensible heat flux (W m^{-2}) for NARR, NLDAS, and the MARE Super Site in the C Study Domain. Error bars represent 95% confidence intervals for the MARE observations.

all three domains, as the modeled and observed latent heat fluxes increased from west to east. All three LSMs output very similar averaged quantities in the C study domain, with the largest magnitude negative bias produced by NLDAS Noah during peak daytime hours (Fig. 7).

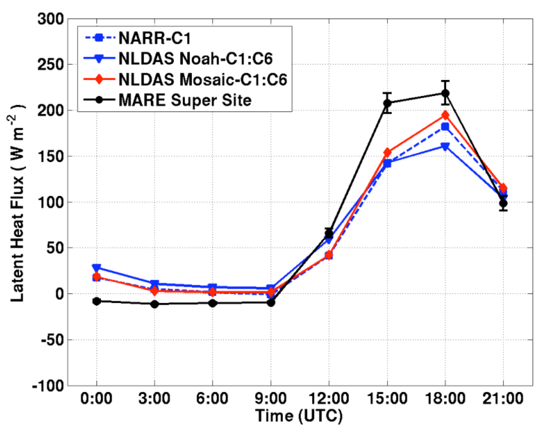

Figure 7: Mean 2-year diurnal cycle (2002-2003) of latent heat flux (W m^{-2}) for NARR, NLDAS, and the MARE Super Site in the C Study Domain. Error bars represent 95% confidence intervals for the MARE observations.

A comparison of sensible and latent heat fluxes for days in June and July 2003 demonstrated a large increase in the magnitudes of the model biases during the July period as the soils transitioned from wet to dry (Fig. 8).

4.4 Ground Heat Fluxes

The modeled ground heat fluxes demonstrated a consistent high bias in each domain, with the bias decreasing slightly from west to east. NARR and NLDAS Noah values were very similar, while values from NLDAS Mosaic consistently had the largest high bias of the models. There appeared to be a temporal displacement in peak values of the fluxes from NLDAS Mosaic during the diurnal cycle, with peak values occurring earlier in the day when compared to values from NARR, NLDAS Noah, and observations. The results from the C study domain are demonstrated in Figure 9.

5. CONCLUSIONS

The modeled soil moisture anomalies from NARR and NLDAS Noah and Mosaic generally agreed well with the observed anomalies, despite the difference in spatial scales between the modeled and observed quantities. While the performance of NARR was good overall, its soil moisture dried too much during extended periods of dry weather.

The modeled soil moisture values also varied more than the observed quantities during the winter months. This lack of variation in the observed soil moisture over Oklahoma during the winter months was consistent with the ”moist plateau phase” described by Illston et al. (2004): a period dominated by low sun angles, mostly cloudy skies, and dormant vegetation that results in very little evaporation or evapotranspiration from the surface.

Modeled values of net radiation agreed well with observations over the period, as biases in the four components of radiation nearly canceled each other out. This was an important result because it ensured that an approximately correct amount of energy was available for partitioning into the turbulent and soil heat fluxes.

The change in the sign of the systematic biases in the turbulent heat fluxes was not surprising due to the partitioning of energy in the SEB equation. The trend in the model biases was exacerbated during dry conditions, as the magnitudes increased. NARR had the most problems in this regard, with latent and sensible heat fluxes approaching unrealistic daytime values when soil

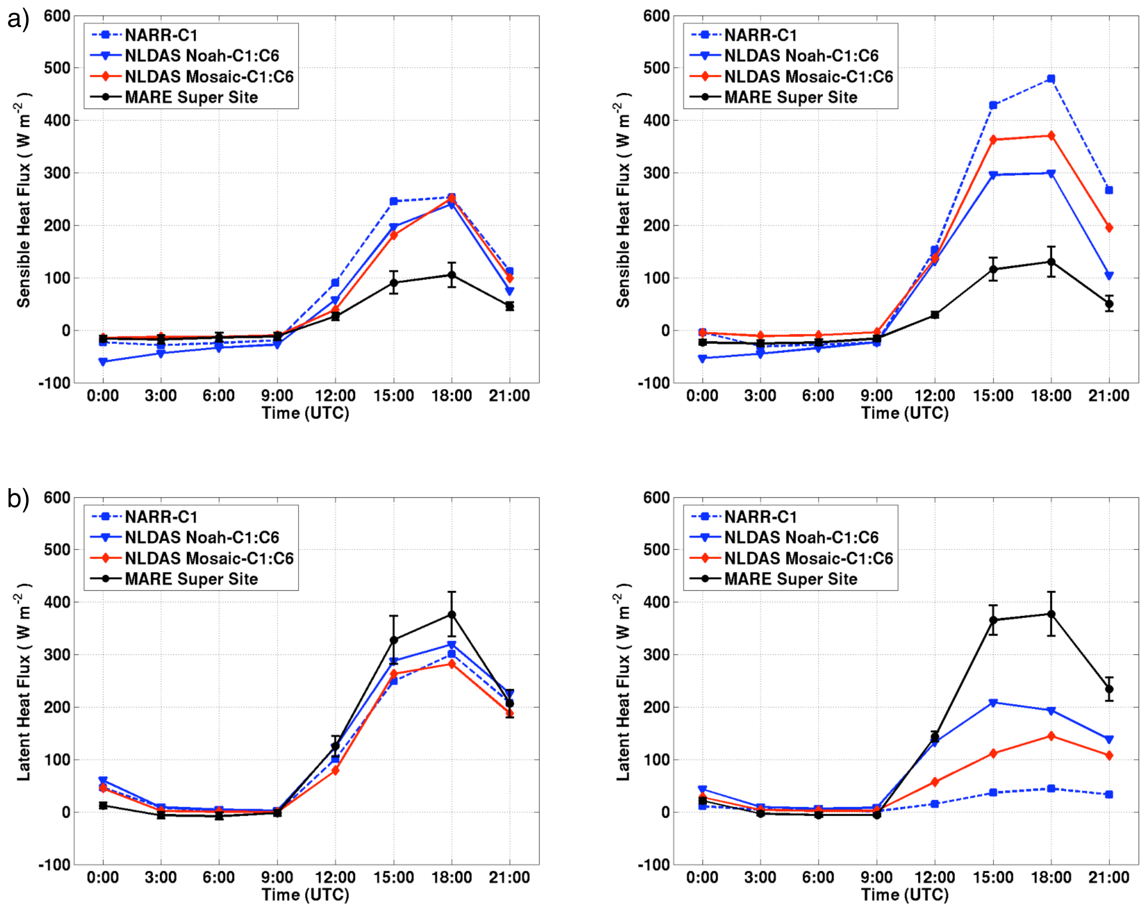

Figure 8: Mean monthly diurnal cycle of a) sensible and (b) latent heat fluxes (W m^{-2}), for NARR, NLDAS, and the MARE Super Site in the C Study Domain. Relatively wet soils in June 2003 (left), and dry soils in July 2003 (right). Error bars represent 95% confidence intervals for the MARE observations.

moisture decreased to low levels during the warm season.

Finally, ground heat flux values from NLDAS Noah, NLDAS Mosaic, and NARR all demonstrated a high bias over the period. The peak values of ground heat flux from the NLDAS models occurred earlier in the day when compared to observations on an hourly time scale. Results from other studies have indicated that values of ground heat flux should peak prior to solar noon (Santanello and Friedl 2003; Liebethal and Foken 2007). Thus, the method of computation for observed ground heat fluxes from the Oklahoma Mesonet should be investigated.

Overall, the models generally performed well in reproducing variables in the atmospheric surface-layer. The NLDAS models outperformed NARR as expected due to their higher temporal and spatial resolution and more advanced land surface

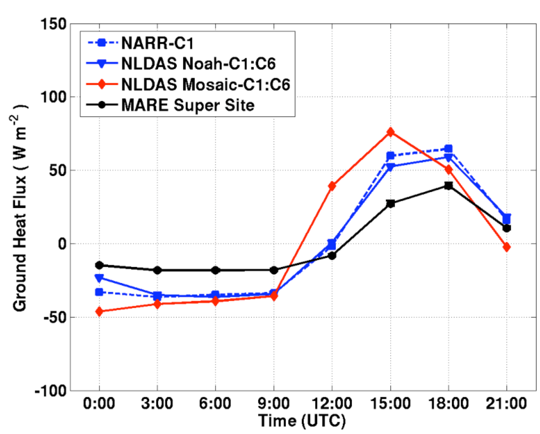

Figure 9: Mean 2-year diurnal cycle (2002-2003) of ground heat flux (W m^{-2}) for NARR, NLDAS, and the MARE Super Site in the C Study Domain. Error bars represent 95% confidence intervals for the MARE observations.

parameter datasets. Despite these results, NARR provides a good alternative for climatic land-surface datasets in most weather conditions.

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