J9.10 THE VALIDATION OF A LAND DATA ASSIMILATION SYSTEM (LDAS) USING OKLAHOMA MESONET DATA

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1. INTRODUCTION

Land surface variability is important in many hydrologic and land-atmosphere interactions. Anomalous land surface conditions on a large-scale can lead to droughts or floods, while regional variations can enhance dryline formation and initiate convection. Furthermore, the relative partitioning between latent and sensible heat fluxes at all spatial and temporal scales is controlled largely by variations in land surface conditions. Thus, understanding the spatial and temporal variability in the land surface is vital to determine the influence that land surface processes have upon the atmosphere. Due to its importance in Numerical Weather Prediction (NWP), land surface-atmosphere interactions have been incorporated into forecast models. However, errors in the NWP forcing accumulate in the soil moisture and energy stores, resulting in the incorrect partitioning of latent and sensible heat fluxes.

Currently, a Land Data Assimilation System (LDAS) is being developed at both the North American and global scales. It consists of uncoupled models forced with observations, output from NWP models, satellite data, and radar precipitation estimates. LDAS is currently being developed in partnership between federal and university organizations, seeking to improve the simulation of land surface states and energy fluxes in land-atmosphere numerical models. This project will reduce forecast errors and lead to more accurate reanalysis simulations by NWP and climate models.

The Oklahoma Mesonet is an automated network of 114 remote, meteorological stations across Oklahoma (Brock et al. 1995). It has integrated sensing devices to compliment the standard suite of meteorological and hydrological sensors. In addition to providing observations such as air temperature, relative humidity, station pressure, and wind speed and direction, nearly 100 stations measure the components of the surface energy budget and soil moisture.

This study seeks to validate the LDAS surface energy budget simulated by the Mosaic land surface model (LSM) using the independent observations from the Oklahoma Mesonet. The goal is to investigate the response of the flux variables to spatial variability in forcing data. By utilizing the unique land surface observations collected by the Oklahoma Mesonet, improvements can be made to NWP models affecting Oklahoma, North America, and the globe.

2. DATA

2.1 The Oklahoma Mesonet

The Oklahoma Mesonet was designed and implemented jointly by the University of Oklahoma and Oklahoma State University. It is a network of 114 automated, hydrometeorological stations evenly spaced across the state of Oklahoma (Fig. 1). Each station measures air temperature and relative humidity at 1.5 m, wind speed and direction at 10 m, barometric pressure, rainfall, incoming solar radiation, and bare and vegetated soil temperatures at 10 cm below ground level. Approximately one-half of the sites measure supplemental parameters: temperature at 5 cm under bare and vegetated soil, and at 30 cm under vegetated soil. Between 1996 and 1999, soil moisture sensors were installed at 101 Oklahoma Mesonet sites at depths of 5, 25, 60, and 75 cm. Observations are collected at intervals between 5 and 30 minutes, and are subjected to rigorous quality assurance (Shafer et al. 2000).

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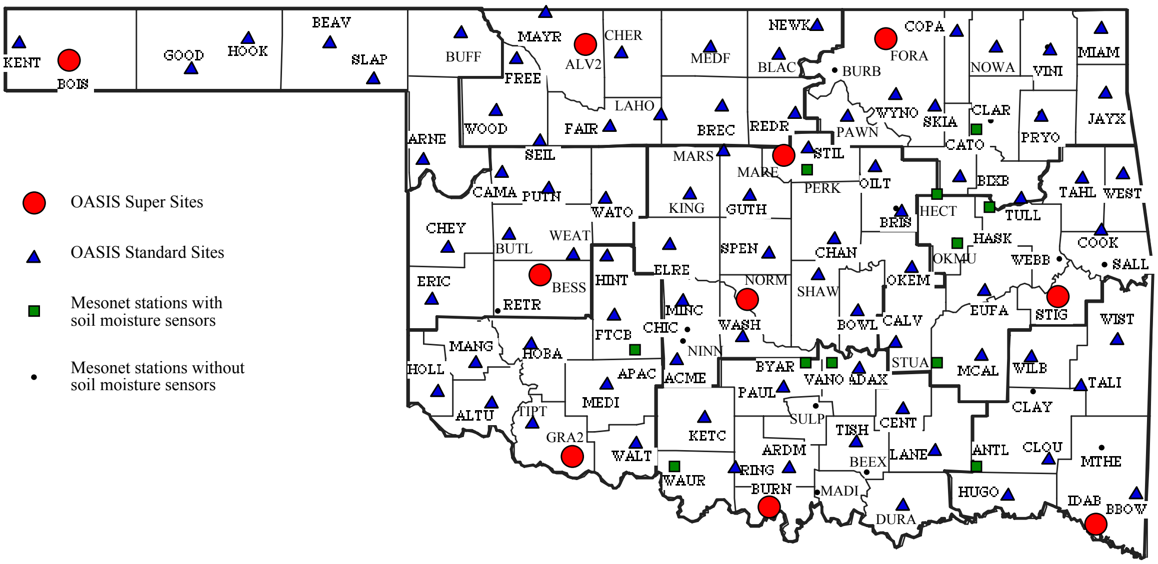

Fig 1: Map of the Oklahoma Mesonet site locations

2.2 The OASIS Project

In 1999, the Oklahoma Atmospheric Surface-layer Instrumentation System (OASIS) Project upgraded 89 sites with a suite of instruments capable of measuring the surface energy budget (Basara and Crawford 2002). In addition, a subset of 10 OASIS sites, designated OASIS Super Sites, were instrumented with sensors that are capable of measuring the components of the surface energy budget with enhanced accuracy. The components of the surface energy budget measured include net radiation, sensible heat flux, ground heat flux and latent heat flux. These Super Sites are each located in a different climate region of Oklahoma and are permanent installations, to allow an investigation of a wide range of atmospheric conditions over an extended period of time.

2.3 OASIS Observations

Net radiation at the 89 standard OASIS sites is measured using the Kipp & Zonen NR-Lite (Brotzge et al. 1999) at 1.5 m. This measures the sum of incoming and outgoing shortwave and longwave radiation. Sensible heat flux is estimated using a profile technique. Sensors mounted at 1.5 m and anemometers at 2 m and 10 m measure 9 m above the ground measure vertical temperature gradients and the vertical wind speed gradient. The Monin-Obukov similarity theory is then applied to the temperature and wind gradients. Ground heat flux is estimated using a combination method (Tanner 1960), which includes estimates of ground heat flux and ground heat storage. Because net radiation, sensible heat flux, and ground heat flux are measured explicitly at each site, latent heat flux is estimated as the residual of the surface energy balance equation:

$$Rn = SH + GH + LH \qquad (1)$$

Surface skin temperature is also measured at each site using an infrared thermocouple temperature sensor manufactured by Apogee mounted at 2 m.

In addition to the standard measurements of the surface energy balance, each Super Site also measures net radiation using the 4-component CNR1 radiometer 1.5 m above ground. Incoming and outgoing shortwave and longwave radiation are measured explicitly. The sensible and latent heat fluxes are estimated using an eddy correlation using the CSI CSAT3 sonic anemometer 4.5 m above ground. The latent heat flux is measured directly using the co-located Krypton KH20 hygrometer. These values are then used in the estimate of sensible heat flux.

Net radiation, sensible heat flux, latent heat flux, and ground heat flux observations are collected at 15-minute intervals.

3. LDAS

The goal of land surface data assimilation is to provide accurate land surface initial conditions to NWP and climate models to improve predictions of surface states estimated by LSMs. Traditional data assimilation systems have errors in the forcing, which accumulate in the soil moisture and energy stores. This results in the incorrect partitioning of sensible and latent heat fluxes. As a result, ad hoc corrections have been imposed to data assimilation schemes to prevent these errors.

The NASA Goddard Space Flight Center (GSFC) is currently developing a Land Data Assimilation System (LDAS) at both the North American (N-LDAS) and global (GLDAS) scales at 1/8 and 1/4 degree resolution, respectively. It consists of uncoupled models forced with in-situ observations, NWP model output, remotely sensed observations, and radar precipitation estimates, leaving it unaffected by the NWP forcing errors. The LDAS project is a research effort between NASA/GSFC, NOAA, Princeton University, Rutgers University, the University of Washington, and the University of Maryland. LDAS is currently running in near real-time mode as well as retrospective mode.

The goals of the LDAS project are to improve the understanding of the land surface-atmosphere interactions, create high quality forcing data to be used by various LSMs, reduce the errors in stores of soil moisture and energy fluxes created by the NWP forcing, and to provide accurate land surface states globally and over North America.

The N-LDAS domain covers the continental United States between 125˚W and 67˚W, and between 25˚N and 53˚N. It has 1/8 degree resolution, which is approximately 14 km.

Model and observation-based data are used to create high quality forcing used by the LSMs. Sources of the forcing data include GOES-based products, gauge-based data, Stage IV precipitation data, and the NCEP EDAS analyses.

The three LSMs included in the LDAS design are the Mosaic (Koster and Suarez 1996), NOAH (Chen et al. 1996), and VIC (Liang et al. 1996) models. These models are running in tandem on a common grid and driven by common forcing. The primary model of interest for this study is the Mosaic model.

The Mosaic model is a soil-vegetation-atmosphere transfer model originally derived from Simple Biosphere (Koster and Suarez 1996). This model allows explicit vegetation control over the computed surface energy and water balances. It computes areally-averaged energy and water fluxes from the land surface in response to meteorological forcing. It is named the Mosaic model for its account of subgrid heterogeneity in surface parameters through the use of tiles.

4. ANALYSIS AND RESULTS

4.1 Ideal Conditions for Study

The ideal conditions for this study are days dominated by strong radiative forcing (no cloud cover) and weak wind shear in the lower troposphere. This study focuses on these days because they are also days in which synoptic-scale forcing was weak. The components of the surface energy budget are more easily interpreted during these conditions. Ideal days were manually selected through visual inspection of the diurnal cycles in incoming shortwave radiation from the year 2000. This process yielded 65 ideal days for each OASIS Super Site. Overall, this presents 650 cases in which there were clear skies and minimal wind shear.

An example of an ideal data set occurred on 4 April 2000 at the Marena Super Site, shown in Figure 2.

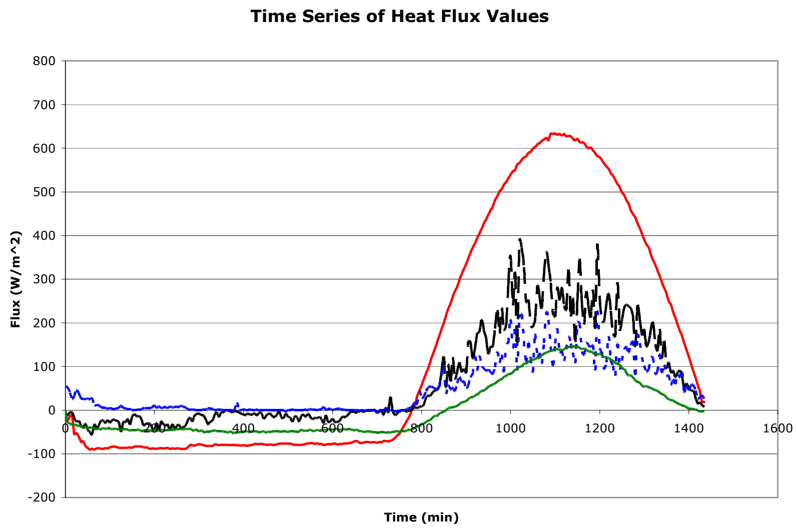

Fig. 2: Time series of net radiation (solid red line), sensible heat flux (large black dash), latent heat flux (small blue dash), and ground heat flux (green dot-dash) at the Marena Mesonet site (4 April 2000).

A second example of ideal conditions occurred at the Alva site on 8 June 2000 (Fig. 3).

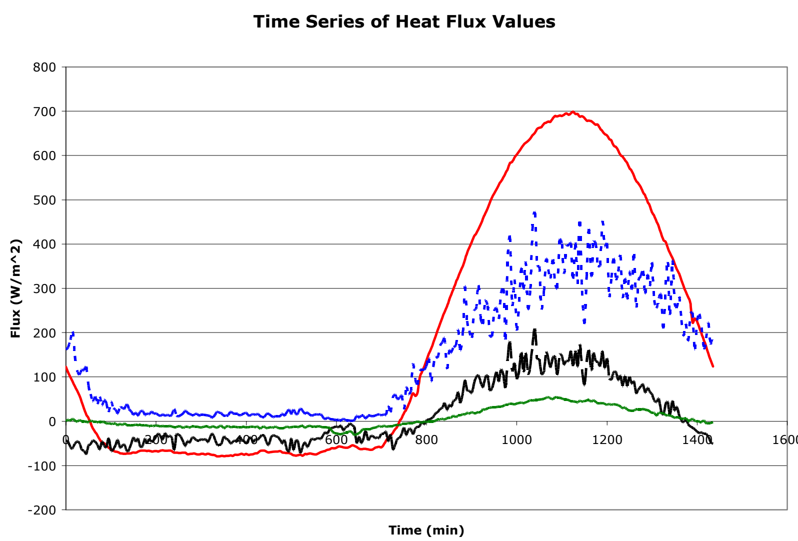

Fig. 3: Time series of net radiation (solid red line), sensible heat flux (large black dash), latent heat flux (small blue dash), and ground heat flux (green dot-dash) at the Alva Mesonet site (8 June 2000).

4.2 Methodology

A 3-year retrospective forcing data set (1996 – 1999) was produced by the NASA/GSFC group for the N-LDAS project, and is being validated with the independent observations of the Oklahoma Mesonet. The domain covers the state of Oklahoma, concentrating on the grid boxes containing the 10 OASIS Super Sites. Energy fluxes are simulated using the Mosaic LSM for the 1999 – 2000 time periods. The standard NASA forcing data is used from 1996 – 1999.

A control run has been produced with this standard NASA forcing through the end of the year 2000. The second simulation replaces the standard forcing data with Oklahoma Mesonet observations from January 1999 through the year 2000. Additional model simulations are conducted using the locally observed forcing at three different spatial scales. The three spatial scales include the 10 individual Super Sites, the average of the 10 Super Sites, and partial averages of the 10 Super Sites based on geographical location and climate classification. Overall, the ultimate goal of this research is to investigate the response of the flux variables to spatial variability in forcing.

5. CONCLUSIONS

By conducting such analyses using the observations collected by the Oklahoma Mesonet, it is possible to determine the biases within the LDAS system. Once the biases are discovered, improvements can be made. Thus, numerical weather prediction models which impact weather and climate forecasts can be improved.

Acknowledgements
This research was made possible, in part, by a NASA-EPSCOR Research Initiation Grant. An NSF MRI grant (125-5645) provided funds to measure components of the energy balance equation.

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