J1.3 ANALYSIS OF SURFACE ENERGY BUDGET DATA OVER VARYING LAND-COVER CONDITIONS

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1. INTRODUCTION

A major area of study in boundary-layer meteorology concerns the surface energy budget (SEB) and quantifying the spatial and temporal variability of the SEB is vital in large agricultural areas. For example, a 2400-kilometer stretch of the Great Plains region is utilized to grow wheat, which behaves unlike the region's native vegetation.

This paper presents the results of the analysis of surface energy budget data collected from two different land-cover types across the Little Washita watershed in southwestern Oklahoma: rangeland and winter wheat fields.

2. METHODOLOGY

Four eddy covariance flux towers were deployed in the Little Washita watershed in late April 2007 as a part of the Cloud and Land Surface Interaction Campaign field experiment (CLASIC). Two of the towers were placed in winter wheat fields and the other two towers were placed in rangeland with native vegetation. The sites continually measured a number of variables from April - September 2007, including those of the surface energy budget, and averaged them over fifteen minute intervals.

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Figure 1 – Eddy covariance flux tower in a wheat field

The diurnal cycle of the SEB was analyzed for ideal days with those of little cloud cover. Long-term trends of the SEB for each site were also analyzed whereby the sensible and latent heat flux data from 1900 to 2200 UTC were normalized to a single value for each day (i.e., each heat flux value was divided by the net radiation and the subsequent values in the time block were averaged). The normalization of data made it possible to quantify the relative partitioning of the net radiation to sensible and latent heating over each terrain type.

3. DATA

The energy budget can be expressed as:

Net Radiation = Sensible Heat Flux + Latent Heat Flux + Ground Heat Flux

Net radiation is defined as the total amount of downwelling shortwave and longwave radiation minus the upwelling shortwave and longwave radiation (Arya 1988). Sensible heat flux is the amount of energy in a system that is utilized in heating the air within it. Latent heat flux is the amount of energy that is used for heating the water within the system. The effects of evapotranspiration generally dominate latent heat flux. Lastly, ground heat flux is defined as the amount of energy in a system that is utilized in heating the ground within the system. An example of ideal type conditions for analysis of the SEB in the Little Washita watershed during CLASIC is shown in Figure 2.

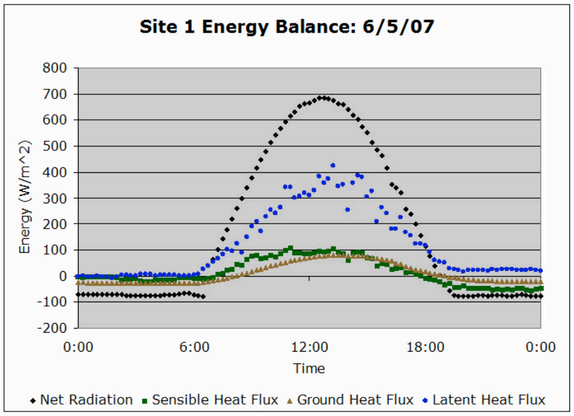

Figure 2 - A depiction of the surface energy budget over a twenty-four hour period at a site deployed in the Little Washita watershed during the CLASIC field experiment.

4. RESULTS

Significant differences in the sensible and latent heat flux trends between each of the sites occurred during the project. However, the variability of long-term ground heat flux values at the sites was minimal during the period, and is not included in this paper.

Figure 3 depicts the normalized sensible heat flux trends for Site 1, one of the rangeland sites. In late April and early May, the vegetation at the site was green and lush which is reflected in the data whereby the majority of available energy that was used for evapotranspiration. Hay was baled at this site between May 18 and May 25, which resulted in a spike in the normalized sensible heat fluxes due to the removal of the vegetation at the site. Thus, the loss of vegetation removed decreased the evapotranspiration at the site and a greater partitioning of energy to sensible heating. During the month of June, the normalized sensible heat flux trend decreased to a range between 0.1 and 0.3 as a result of a large portion of the energy received at the site was partitioned to latent heating due to historic rainfall totals across central Oklahoma. By early July much of the rainfall subsided and this site began to dry resulting in a general increase in sensible heating.

In early August, hay was baled once again at the site. As in May, a sharp increase in the sensible heat flux occurred. However, the magnitude of the increase was larger than it was in May due to the lack of rainfall in July combined with the sudden removal of plant life.

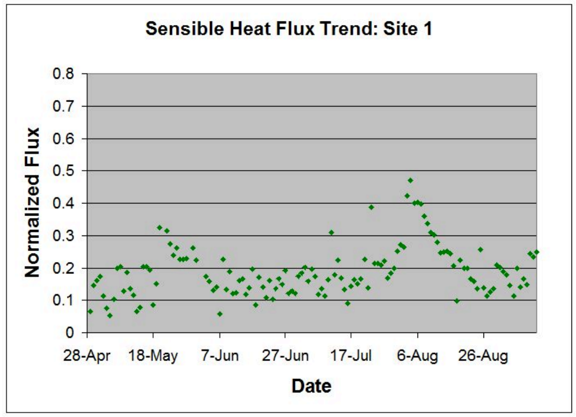

Figure 3 - Normalized sensible heat flux values for Site 1

The normalized latent heat flux trend is depicted in Figure 4 for Site 1. Compared to the sensible heat flux trend for this site, the overall latent heat flux values were higher for the period. However, a downward spike in the data occurs between May 18 through May 25 as a result of the hay baling efforts. Latent heat flux values shortly after this event were slightly reduced as a result of the lessened transpiration in the area. Beginning in June, the overall trend of the calculated values increased as a result of the large amounts of rainfall that occurred during that month combined with the steady re-growth of the vegetation in the area. Even after most of the rainfall stopped in early July, the amount of vegetation that had re-grown in the area provided enough moisture to increase the latent heat flux values back to the original levels before the vegetation was baled as hay.

The latent heat flux response to the hay baling in August is very apparent on the graph; average values sharply dropped from the 0.5-0.6 range to between 0.1-0.2. This further demonstrates that the dry period combined with the removal of vegetation was the major contributor to this shift.

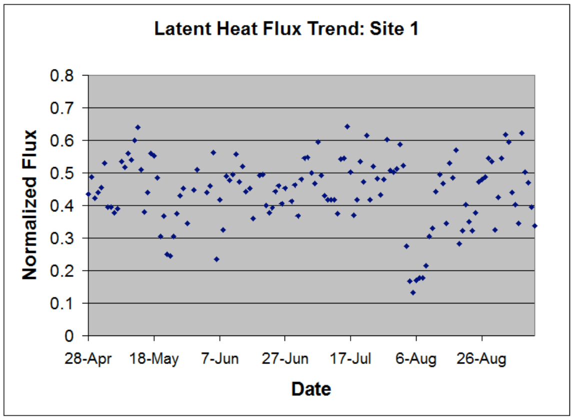

Figure 4 – Normalized latent heat flux values for Site 1

In Figure 5, the normalized sensible heat flux trend for Site 2 is shown. The vast majority of the data points from late April to mid-July in this graph lie between values of 0.1 and 0.3, indicating that overall, much of the energy in this area was partitioned to latent heat flux. After mid-July, the majority of data point values slowly increased and remained in the range between 0.2 and 0.3, indicating a trend towards increased drying at the site. The land at this site was utilized in a different way than the other rangeland site. The vegetation at Site 1 was used for hay production, while the vegetation at Site 2 was not. Site 2 incorporated grazing cattle in the area, while Site 1 did not. The cattle at Site 2 were able to keep most of the vegetation at a consistent density throughout the study period, which allowed the sensible heat flux trend to remain fairly constant for much of the study period.

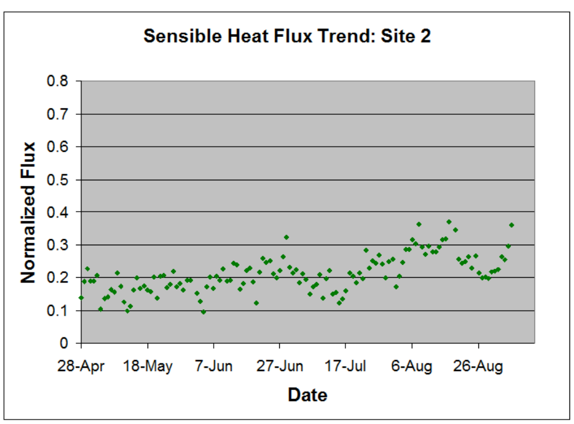

Figure 5 - Normalized sensible heat flux values for Site 2

Figure 6 shows normalized latent heat flux values for Site 2. The values on this graph show the latent heat fluxes were within a range of 0.3 to 0.5 until late-July. After this point, values of the latent heat flux generally decreased to values between 0.3 and 0.4. Once again, the reason for the decrease in values for the latent heat fluxes is due to the dry period that enveloped region.

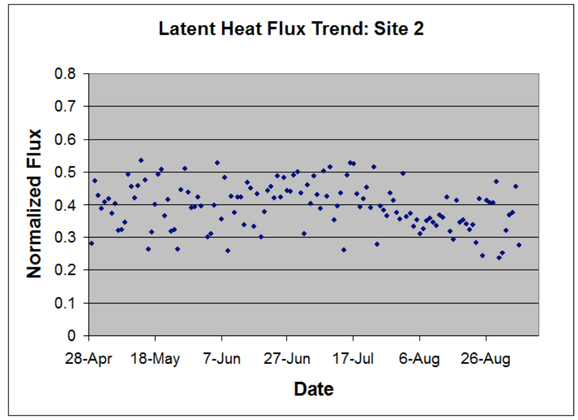

Figure 6 - Normalized latent heat flux values for Site 2

Site 3, underwent major changes over the course of the study period. At the beginning of the study period in late April, the site was a green winter wheat field. However, by mid-May, the wheat turned golden brown, and became ready for harvest. On June 1st, severe weather damaged much of the wheat crop in the area but by mid-June, the crop had been harvested, leaving only wheat stubble and bare soil at the site. Over the course of the next month, native vegetation intruded on the wheat field site, and by Mid August the location was used for cattle grazing.

Figure 7 displays the normalized sensible heat flux trends for Site 3. Unfortunately, data was lost for periods in May and June. Even so, the values collected revealed a minimum in late April/early May, as the wheat in this area was green and the majority of available energy was partitioned to evapotranspiration. As May passed, the wheat died, and became ready for harvest. The data reveals an increase in the values of normalized sensible heat flux due to the rapid decrease in photosynthetic activity. In early June, the wheat crop was harvested, which would normally cause an increase in sensible heat flux, significant rainfall at the site resulted in a decrease of sensible heat flux. When the rains subsided in early July, the sensible heat flux values remained somewhat low due to standing water in the area and very moist soils. Eventually, the conditions dried and sensible heat flux values increased through mid August.

On August 18, 2007, the remnants of Tropical Storm Erin passed over Oklahoma and up to 10" of rainfall occurred in some areas of central Oklahoma. The excessive precipitation yielded increased evaporation and decreased sensible heat flux.

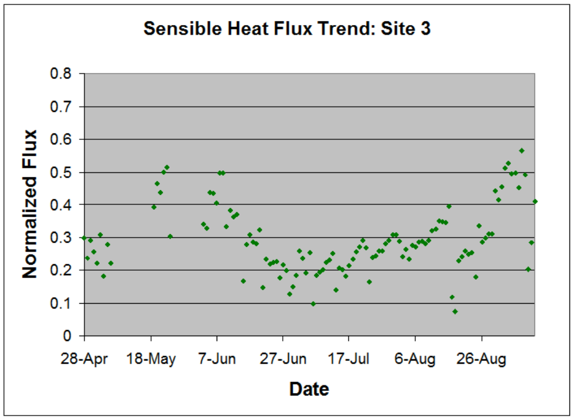

Figure 7 - Normalized sensible heat flux values for Site 3

Site 3 normalized latent heat flux values are shown in Figure 8 and the latent heat flux values at this site are a virtual mirror image of the normalized sensible heat flux values. In the beginning phase of the field experiment, latent heat flux values are fairly high, due to the large amount of green wheat and increased transpiration. As the wheat browned and became suitable for harvest, photosynthesis and transpiration decreased beginning in May. The values remained low until the effects of the rainfall combined with the intrusion of native vegetation in the area became a major source of latent heat flux. Throughout the remainder of June through mid August, the latent heat flux values decreased as the conditions at the site dried. However, the influx of water from Tropical Storm Erin caused a significant increase in the latent heat flux trend after August 18th. Thereafter, the water evaporated, and values once again decreased.

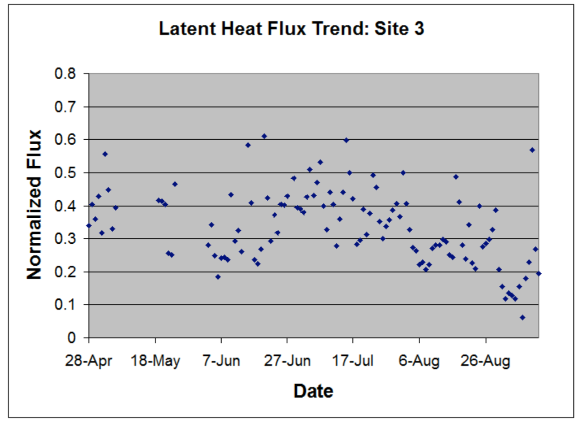

Figure 8 - Normalized latent heat flux values for Site 3

Figure 9 is a comparison of sensible heat flux values at all four sites. The top left plot displays sensible heat flux data on June 5th and shows that Sites 1 and 2 behave in a similar fashion, while Sites 3 and 4 both act similarly. By June 13th, the sensible heat fluxes of both pairs of sites were still distinct, but slowly becoming similar to each other. The bottom left graph shows sensible heat flux data for July 1st. In this plot, all of the curves are very similar due mostly to the rain that had occurred at the sites. The last graph shows the same data for July 17th. In this example the sensible heat fluxes for Sites 1, 2, and 3 are very similar and quite different than Site 4. The SEB at Site 3 had transitioned to conditions that were consistent with the rangeland sites.

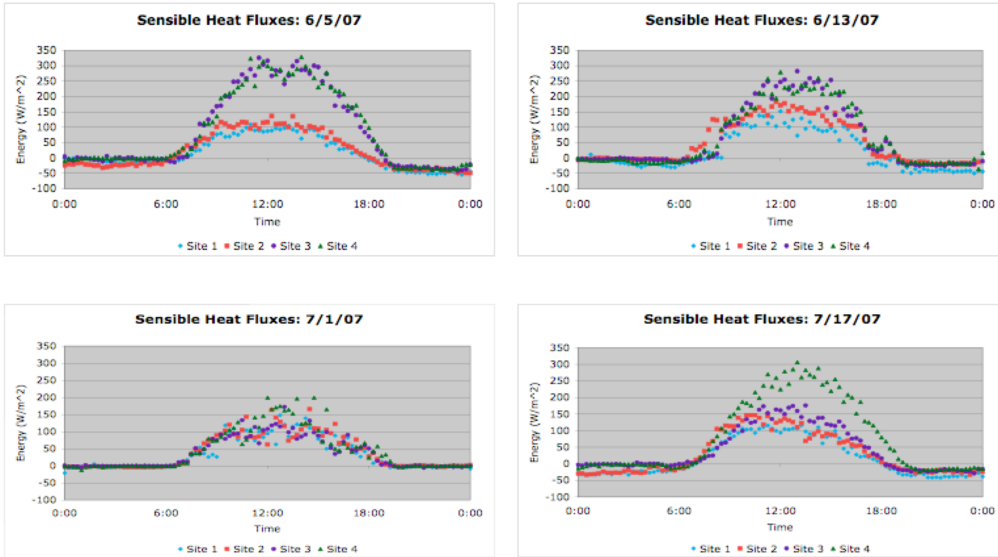

Figure 9 - A comparison of sensible heat flux data over a 24-hour period for all four sites on differing days.

The second winter wheat field site, Site 4, behaved very differently than Site 3. Unlike Site 3, Site 4 did not incur an intrusion of native vegetation after the wheat harvest. Thus, the post-harvest Site 4 remained as bare soil and wheat stubble for the remainder of the study period. As such, the normalized sensible and latent heat flux trends were different than at Site 3.

Figure 10 displays the normalized sensible heat flux trend for Site 4. In the May-June timeframe of the experiment, the trend acts in a somewhat similar manner to Site 3, the values increased in late spring as the wheat turned from green to brown, and decreased with the onset of the June rains. When June ended, and the rains stopped, the behavior of the site diverged from that of Site 3. Thus when the water had sufficiently evaporated, the majority of energy partitioning favored sensible heating. Further, sensible heat flux increased at a faster rate at Site 4 and earlier in the study period than at Site 3.

The effects of the passing of Tropical Storm Erin were also apparent at this site. In mid-August, sensible heat flux values dropped from 0.5 to 0.1. The site had essentially dried from a lack of rainfall combined with little remaining vegetation from the wheat harvest. However, the large amounts of water that fell on the site as a result of the Erin's movement yielded significant evaporation following the event.

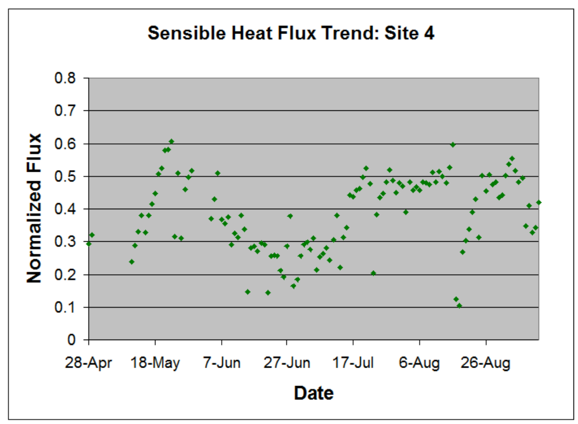

Figure 10 - Normalized sensible heat flux values for Site 4

Lastly, the normalized latent heat flux trend for Site 4 for is shown in Figure 11. Site 4 follows a similar pattern to that of Site 3. Values were high in early May, and steadily decreased as the wheat became ready for harvest. After the wheat was harvested and the rains began, the latent heat flux values increased for the duration of June. After the rains subsided, much of the water in the soil quickly evaporated in early July. Due to the lack of rainfall and plant life at Site 4, the latent heat flux trend decreased rapidly. Overall values remained low with the exception of July 23rd, when rain fell at the site. The amount of energy being partitioned to latent heat flux quickly declined again through July 25th, and remained very low until August 18th. After Tropical Storm Erin passed through the area, a response to latent heat flux occurred similar to that noticed at Site 3 whereby values sharply increased from roughly 0.1 to 0.5, and decreased afterwards.

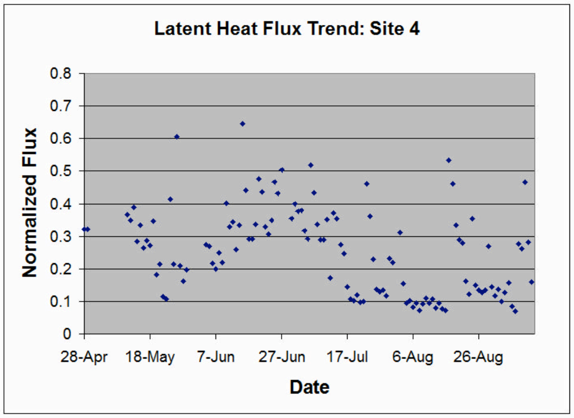

Figure 11 - Normalized latent heat flux values for Site 4

5. Acknowledgements

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6. References

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