JP1.5 SOIL MOISTURE CONTROLS ON CARBON AND WATER CYCLING

Tyler L. Buck and Nathaniel A. Brunsell
University of Kansas

1. Introduction

Soil moisture affects land-atmosphere interactions at multiple temporal and spatial scales; including boundary layer convection and energy balance partitioning. A study of soil moisture control on carbon and water cycling was conducted in a brome grass field experiencing woody-encroachment at the Nelson Environmental Research Area (NESA) near Lawrence, KS. Data from an eddy covariance station was used to examine the impact of soil moisture variability on the surface energy balance, as well as the impact of water limitation on carbon and water fluxes. Special emphasis is placed on examining dry down periods and the responses of energy balance partitioning and closure as a function of time from precipitation events. Understanding the relative control of soil moisture in such ecosystems is important for assessing regional scale water and carbon cycling in areas impacted by altered land cover.

2. Field Measurements and Methods

The NESA research area is located north of Lawrence, KS. The site was a formerly used for agriculture and now consists of a combination of C3 and C4 grasses. Currently, the site is experiencing woody-encroachment due to a lack of natural prairie fires that once occurred in these areas. Flux measurements were conducted by an eddy covariance tower, main components being a CSAT3 3D Sonic Anemometer, a LI-COR 7500 Open-Path Gas Analyzer, and a REBS Q7 Net Radiometer. Soil moisture measurements were taken with a Delta-T ML2x soil moisture probe.

Data from the soil moisture probe and the eddy covariance tower was collected by a Campbell Scientific CR 3000 Datalogger. Turbulence data is collected at 20Hz, while ancillary data is stored at 30 min averages. Data is processed in both MATLAB and the University of Edinburgh's EdiRe. Data began being collected from the tower on June 15, 2007 and has been collected continuously. This study specifically focuses on DOY 166-266.

One of the primary goals of this study was to show how variations in soil moisture effect energy balance partitioning. The energy balance equation can be expressed as (Twine, et. al., 2000):

$$Rn = H + LE + G \quad (1)$$

where Rn is net radiation (Wm^{-2}), H is sensible heat (Wm^{-2}), LE is latent heat flux (Wm^{-2}), and G is the soil heat flux (Wm^{-2}). Eddy covariance systems have been found to have problems with energy balance closure (Wilson et. al., 2002). Energy balance closure is defined as:

$$C = (H + LE) / (Rn – G) \quad (2)$$

3. Results

First, we examined the effect that soil moisture has on water and carbon fluxes. Variations in soil moisture have direct control on the magnitude of these fluxes. Figure 1 shows a time series of soil moisture values during the measurement period. High soil moisture levels are correlated with higher latent heat fluxes, generally due to the fact that there is more moisture available and plants are not water stressed. Because plants are not water stressed, they leave their stomata open, releasing water vapor and assimilating carbon (Figure 2). As soil moisture decreases plants become water stressed and close their stomata resulting in less assimilation.

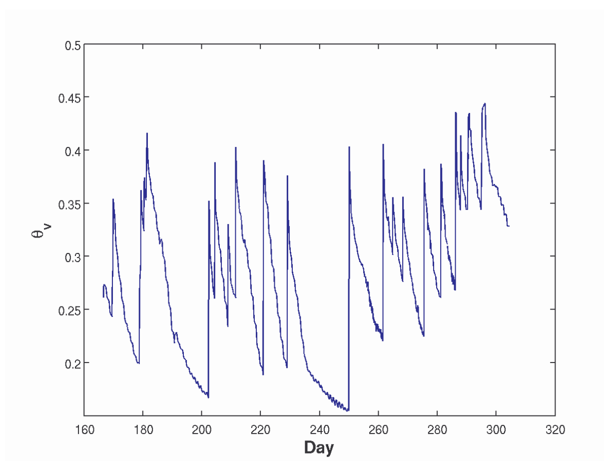

Figure 1. Soil moisture measurements at NESA Eddy covariance site (DOY 166-304, 2007).

A specific example to help examine soil moisture effects on energy partitioning occurred during DOY 230-250. The site experienced a dry-down period which affected the partitioning of available energy into LE and H fluxes (Figure 3). As the number of days since the last precipitation event increased, there was a significant decrease in the water flux. There was a correspondingly large increase in the percentage of energy going to sensible heat flux. As soil moisture decreases, H increases and therefore more convection occurs.

Another issue that we examined was soil moisture effects on closure (Figure 4). As soil moisture levels increase, closure values tend to worsen (slope = -0.44, r^2 = 0.36). This implies that this is a function of stomatal control, which is also exhibited in the carbon vs. closure (slope = -0.01, r^2 = 0.40) relationship (Figure 5). More carbon assimilation correlates with higher closure values. This can also be related to the carbon flux and soil moisture relationship.

The above results imply that accurate determination of soil moisture is necessary for understanding the surface energy balance. Remote sensing offers the only feasible opportunity to do this over large regions, therefore we examined the relationship between soil moisture and radiometric surface temperature determined from Moderate Resolution Imaging Spectroradiometer (MODIS) data (Figure 6). Higher levels of soil moisture are accompanied with lower radiometric surface temperatures, while lower soil moisture levels show higher radiometric surface temperatures.

Using MODIS imagery for radiometric surface temperatures can be a useful tool to examine temporal variability in soil moisture. By using radiometric surface temperature as a

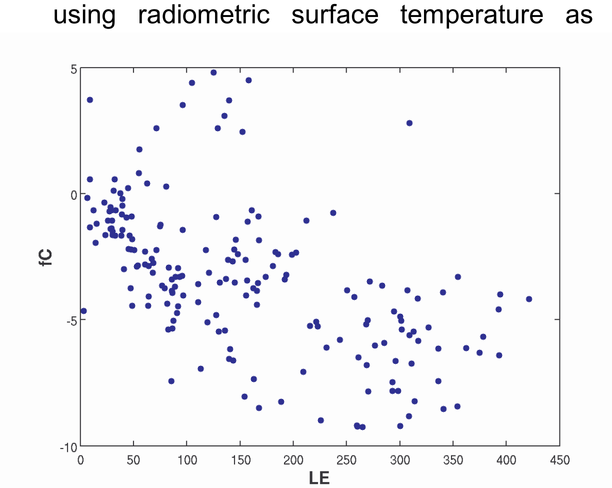

Figure 2. Carbon flux plotted as a function of latent heat flux.

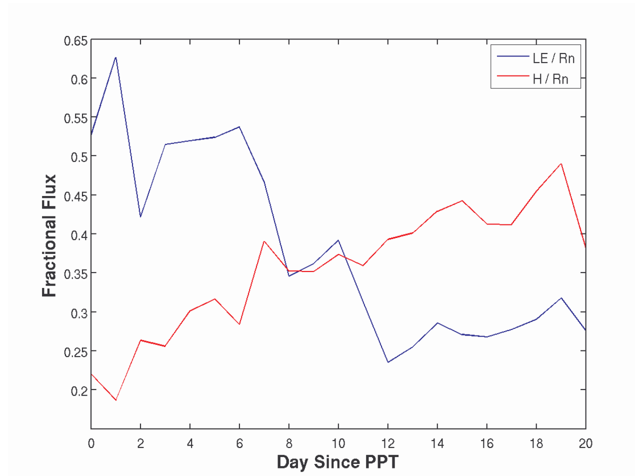

Figure 3. Fractional fluxes of LE/Rn and H/Rn during dry-down event (DOY 230-250).

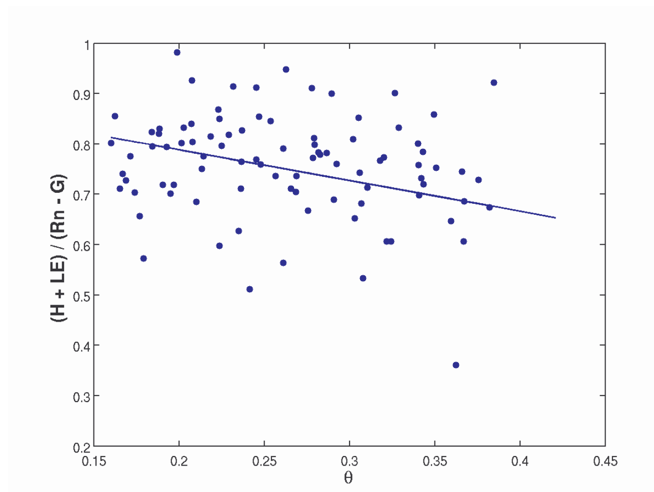

Figure 4. Closure plotted as a function of soil moisture.

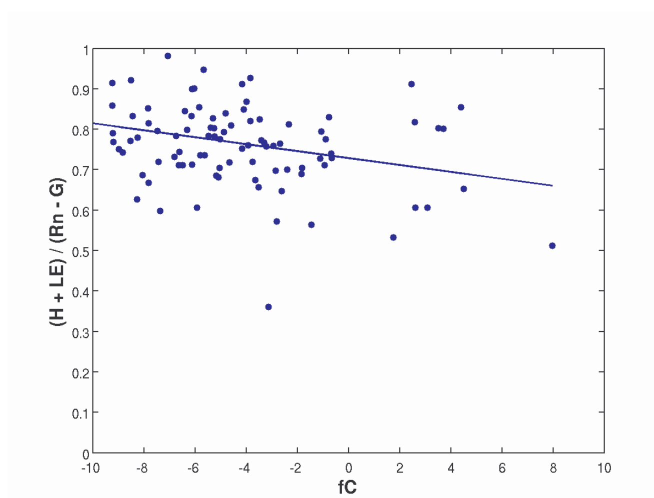

Figure 5. Closure plotted as a function of carbon flux.

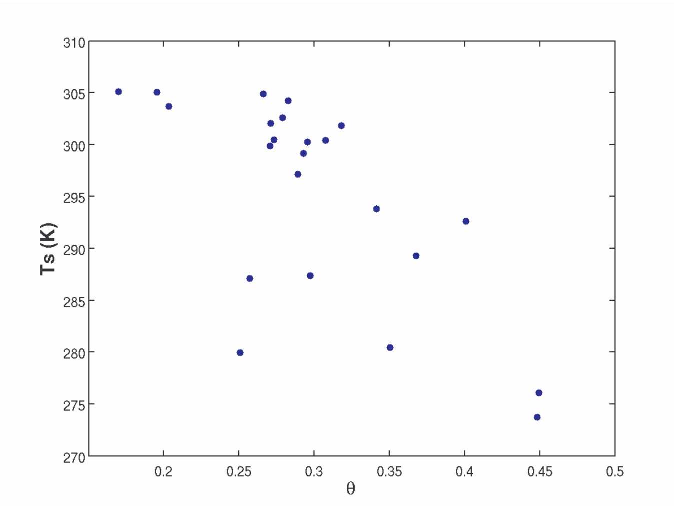

Figure 6. Radiometric temperature plotted as a function of soil moisture.

proxy for soil moisture, larger scale studies of soil moisture variability can be performed (Brunsell, 2006).

4. Conclusions

Using surface measurements from an eddy covariance tower and a soil moisture probe we were able to examine the effect that soil moisture variability has on water and carbon cycling. In addition, we showed that soil moisture levels are correlated with energy balance closure. It appears that as soil moisture levels increase, the closure values worsen. If this holds as a generality, this implies that as a scientific community we are either underestimating our water flux due to an inability to accurately measure it, or we do not fundamentally understand the role of turbulent transfer of water flux, particularly in the relationship between the sources and sinks of water and heat. However, from the data obtained in this study, it does not appear that closure is an issue associated with net radiation and/or soil heat flux. It appears to be connected to the turbulent transfer of water vapor.

5. References

Brunsell, N.A., 2006: Characterization of land-surface precipitation feedback regimes with remote sensing. *Remote Sensing of Environment*, 100, 200-211.

Twine, T.E., Kustas W., Norman, J, Cook, D., Houser, P., Meyers, T., Prueger, J., Starks, P., Wesely, M., 2000: Correcting eddy-covariance flux underestimates over a grassland. *Agricultural and Forest Meteorology*, 103, 279-300.

Wilson, K. and Co-authors, 2002: Energy balance closure at FLUXNET sites. *Agricultural and Forest Meteorology*, 113, 223-243.