9.1 TEMPORAL VARIABILITY OF THE CONTROLS ON EVAPOTRANSPIRATION FROM GRAZED PASTURELAND DURING EXTREME DROUGHT

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1. INTRODUCTION

At any given time during the years between 1900 and 2000 approximately 9.7% of the land area of the United States has experienced severe to extreme drought (NCDC 2002). However, there have been several notable exceptions such as the 2002 drought, which at its peak encompassed nearly 39% of the United States, primarily in the western states (Douglas et al. 2003).

Furthermore, these drought events have had significant social and economic impacts. Drought is the most costly of all weather related disasters (Wilhite 2000). For example, it has been estimated that the cost of the 1988 drought exceeded $30 billion (Svoboda et al. 2002) and the total cost of major droughts in the United States since 1980 is thought to be more than $100 billion (Lawrimore et al. 2002).

Given the negative effects of drought, it is important that they be correctly predicted so that appropriate mitigation measures, such as the implementation of water resource management and water conservation policies, may be taken. To develop quality forecasts, it is necessary both to understand the physical processes that link the land surface to the atmosphere and to design climate and weather models that fully incorporate this understanding.

Environmental variables, such as net radiation, humidity, wind speed, soil moisture, and vegetation characteristics, play a key role in controlling the processes involved in evapotranspiration. Each of these variables can vary significantly over time, and, as a result, both evapotranspiration and the relative influences of each of the variables controlling it also change with time. By quantifying this temporal variability, it is possible to develop relationships describing how evapotranspiration varies with changes in the various environmental properties. These relationships can then be compared to those utilized by atmospheric models in order to assess the capability of models to describe both evaporative and transpirative processes.

To carry out this type of analysis for a site experiencing drought, data collected as a part of the International H2O Project 2002 (IHOP) were used. The data, which included vegetation, soil, and micrometeorological measurements, were collected at IHOP Site 10 located in the panhandle of Oklahoma (36.9°N, 100.6°W) during May and June, 2002. This site was chosen not only because it was experiencing extreme drought, but also because it was most representative of both the land use and land conditions of the surrounding area.

IHOP Site 10 was a heavily grazed pastureland dominated by a single species of C4 grass, Big Bluestem (*Andropogon gerardii*), which covered approximately 30% of the land surface and created intricate mosaic with the bare soil. Due to the dry conditions, the vegetation was dormant at the beginning of the study, but it underwent significant greening during the course of the study. Finally, the site had sandy loams soils and very little topographic relief (Figure 1).

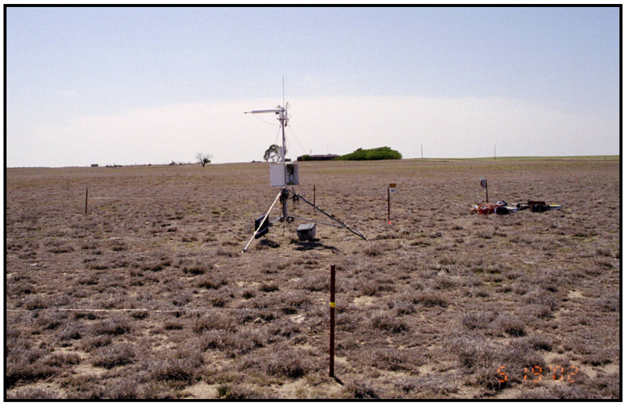

Figure 1. A view of IHOP Site 10 on the day the micrometeorological tower was erected, May 19, 2002. The patchwork of dormant vegetation and bare ground is clearly visible.

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A full complement of data was collected at the site. This data included micrometeorological and eddy covariance energy flux measurements, which were processed with a suite of standard corrections. Soil property data included measures of soil moisture at three levels and soil temperature. Finally, vegetation characteristics including leaf area index, greenness fraction, and NDVI were measured.

2. RESULTS

Using Principle Component Regression analysis (PCR), the relative influence of several environmental controls, including vapor pressure deficit, wind speed, net radiation, surface layer soil moisture, and greenness fraction, on the latent heat flux (λE) was determined. While certain controls, such as net radiation and soil moisture appeared to have a greater influence than others, there was no clear temporal pattern.

However, when the data were sorted by environmental condition and the analysis was repeated, several clear patterns became evident. For example, it was found that the role the vapor pressure deficit increases with increasing soil moisture while the influence of wind speed is most significant when the soil was dry (Figure 2). In the case of the water vapor deficit, it is suggested that this was due to water availability no longer acting as a limiting factor when there is a high soil moisture content. In the case of wind speed, it is suggested that the ability of air movement to maintain a strong vapor gradient between the surface and the air is particularly important when the surface is very dry. To understand these relationships, the total λE was partitioned into evaporation from the bare ground and transpiration from the vegetation using the method described by Shuttleworth and Wallace (1985). By doing so, the influence of the environmental controls on these individual fluxes, as well as the resistances to the transfer of water could be investigated. It was found that the λE from the vegetation and the canopy resistance were primarily controlled by the vapor pressure deficit. In turn, λE from the soil, which constituted approximately 70% of the total λE, was primarily controlled by the vapor pressure deficit and soil moisture. Additionally, the soil resistance to the transfer of moisture to the atmosphere was controlled by soil moisture.

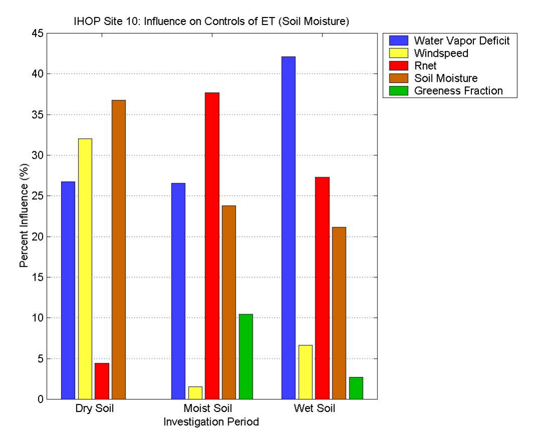

Figure 2. The relative influence of environmental properties on λE for differing groupings of data based on surface layer soil moisture (θ). These groupings are dry soils ($\theta < 8\%$), moist soils ($8\% < \theta < 24\%$), and wet soils ($24\% < \theta$).

Soil hydraulic processes were the focus of the final phase of the study since it was the main pathway for transferring moisture into the atmosphere. A comparison of the relationship of the soil resistance and soil moisture derived from observational data and the relationship used by various atmospheric models was made. It was found that none of the relationships used in the models, which included, among others, the NCAR Community Land Model (NCAR CLM) and Simple Biosphere 2 model (SiB2), corresponded with the observed relationship. Indeed, these relationships often diverged significantly from observation (Figure 3). Because of these discrepancies, both the modeled λE and the partitioning of energy at the earth's surface do not correspond with observation.

3. CONCLUSION

Based on the results of this study, it is clear that λE varies over time in concert with the environmental conditions that control it. While the interrelationships are complex and no property can be considered in isolation, soil moisture, in particular, played a key role in controlling the amount of water transferred into the atmosphere even though the site was experiencing drought. This is because soil moisture is both the chief source of moisture and an important control on soil resistance.

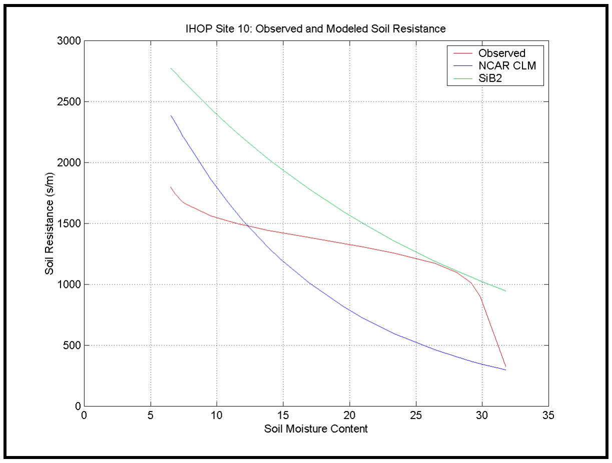

Figure 3. The divergence between observed and modeled relationships between soil resistance and soil moisture is shown for both the NCAR CLM and the SiB2 model.

As a result, it is of great importance to correctly define these processes in atmospheric models. Especially in dry environments such as the one investigated in this study, it is necessary to accurately describe both soil moisture and its effects on soil resistance in order to properly describe λE. To achieve this, and thus improve the ability of scientific community to predict severe weather events such as drought, better descriptions of the relationship between soil moisture and soil resistance must be incorporated into the models. One potential relationship that could be used is the one found in this study

4. REFERENCES

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