Analyzing the Thermophysical Properties of Soils with Respect to the Physical Properties of Soils

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Introduction

The thermophysical properties of soils, namely thermal diffusivity and moisture diffusivity, are of great importance to understanding the earth system. The data was gathered just outside central Atlanta, Georgia on the grounds of Aiken's home. Measuring stations were set up at high ground, approximately 40 feet above the water table and at low ground, 3 feet above the water table.

Objectives

To measure thermal diffusivity and moisture diffusivity at varying depths while also analyzing the soils physical profile at the measured depths to understand the diffusion of heat and water in heterogeneous soil.

Instrumentation

An AMS Soil Sampler for soil corings, Delta-T Theta Probes for surface moisture ratios, Delta-T Soil Profilers for moisture ratios at different depths, Type T Thermocouples for temperature, and the Campbell CR10X and CR5000 Data loggers.

Method

Thermal diffusion of heat energy originating at the surface was measured by horizontally burying a thermocouple array of five thermocouples at varying depths, thereby measuring the change in temperature at those depths over a 24-hour period. When a soil profiler was used, the thermocouples were buried at the same depths as the moisture sensors on the profiler.

Moisture diffusion was measured by placing a theta probe at the surface to analyze the change in surface moisture over time as it is lost to diffusion, runoff, and evaporation. A soil profiler was also used to analyze the change in soil moisture at the depths of 5, 9, 13, and 16 inches.

Results

At the high ground control site the soil consisted of a layer of organic material followed by several inches of inorganic soil and then dense red clay which makes up an aquatard at around 14-16 inches.

At the control site at high ground the thermocouple array was buried to match the profiler as shown in figure 1. Each peak is recognized to be one diurnal cycle. In the troughs of the peaks, the staggered nature of the peaks can be seen, caused by the diffusion of heat through the soil layers.

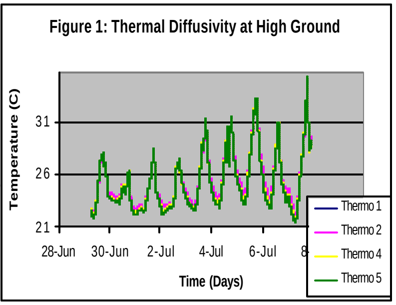


Figure 1: Thermal Diffusivity at High Ground

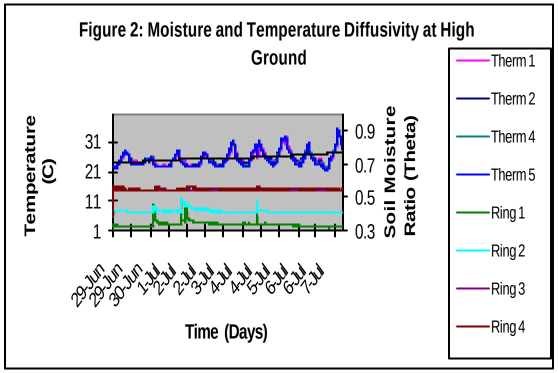


Figure 2: Moisture and Temperature Diffusivity at High Ground

Figure 2 shows the ratio of water volume to total soil volume ($m^3 m^{-3}$) in conjunction with the temperature (C). Notice that when looking at the soil moisture content at the bottom ring on the profiler, there is little change in moisture content. This is due to its having reached its field capacity and also its density thereby forming an aquatard. This could lead to the possibility of lateral water flow.

At the low ground site figure 3 shows the measured soil moisture ratio with respect to the sample taken. The soil is more porous and has a thicker layer of organic material, followed by thick layer of sandy inorganic material, unlike the clay mix at the control site. At around 14-16 inches there is a thick layer of sandy clay.

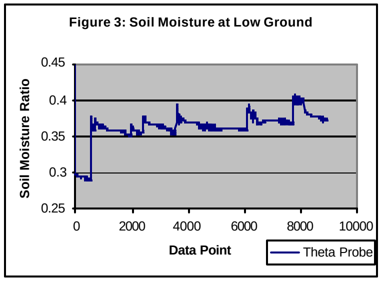


Figure 3: Soil Moisture at Low Ground

Discussion

Differential equations are required to analyze the actual diffusivity constants for heat and moisture. Temperature data for the low ground site is still being compile and thus could not be presented. Analyzing the diffusion of moisture and temperature while looking at the subsurface layers yields a more accurate model of subsurface environment.

Graphs in Detail

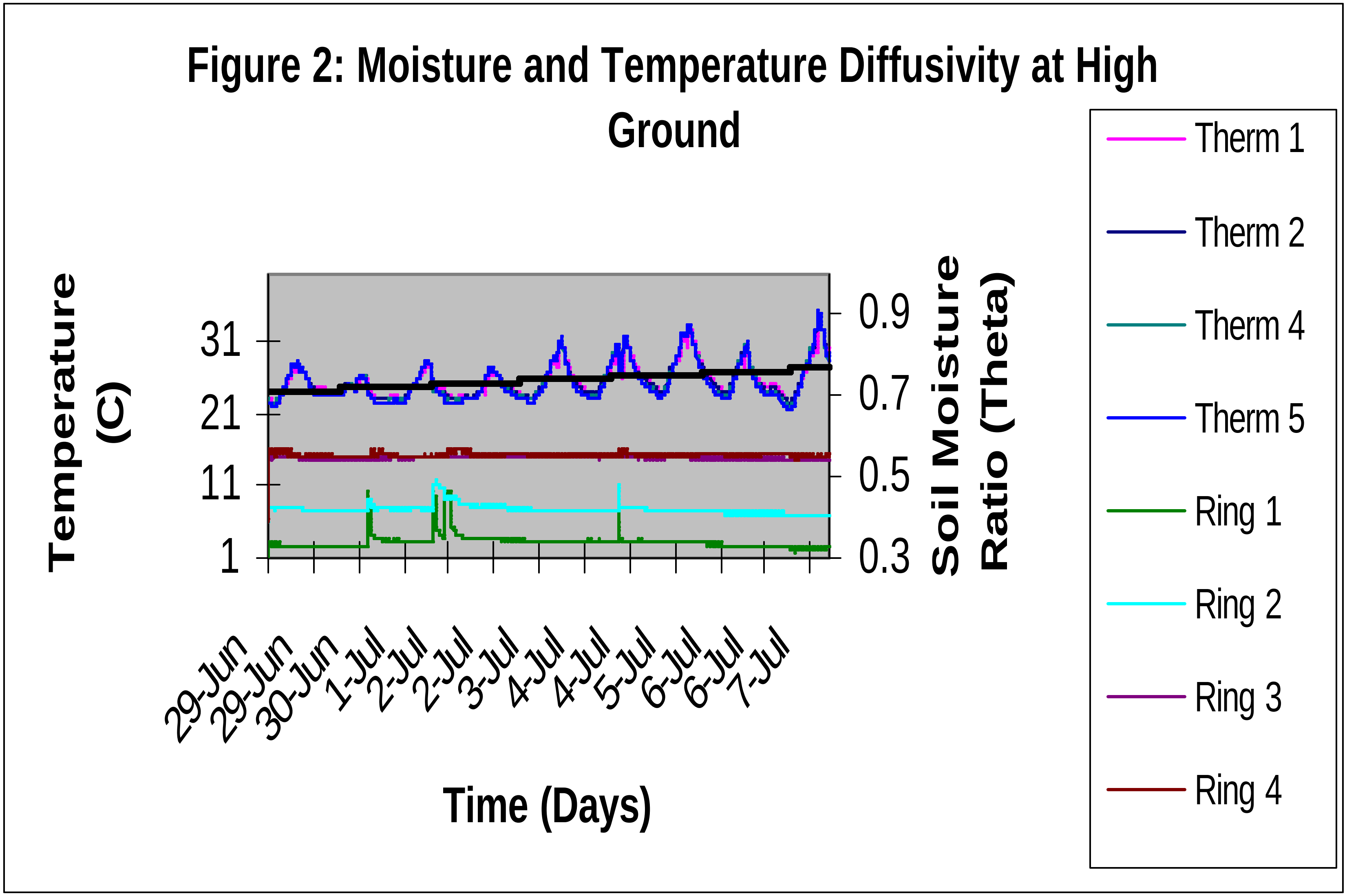


Figure 2: Moisture and Temperature Diffusivity at High Ground

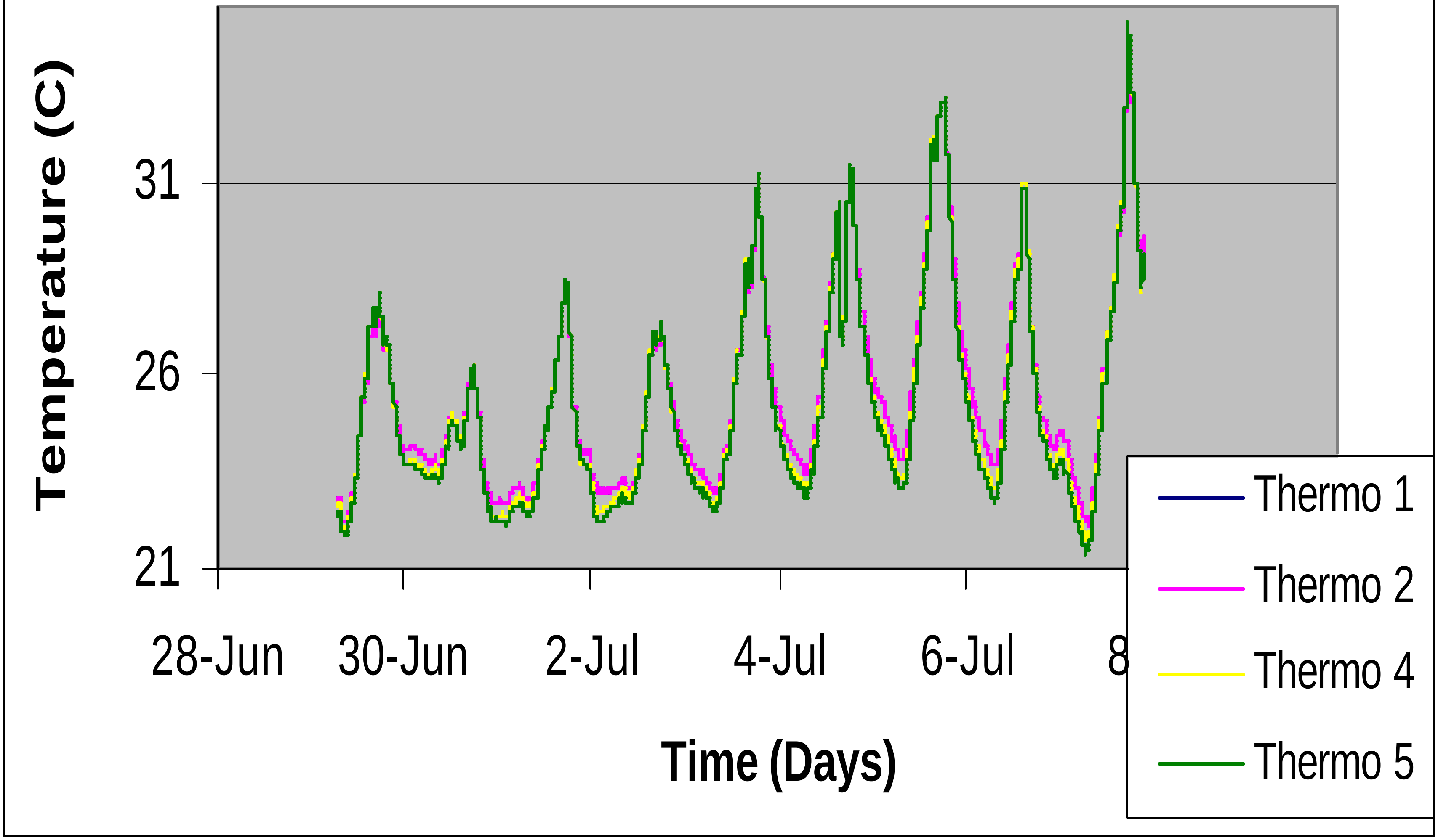
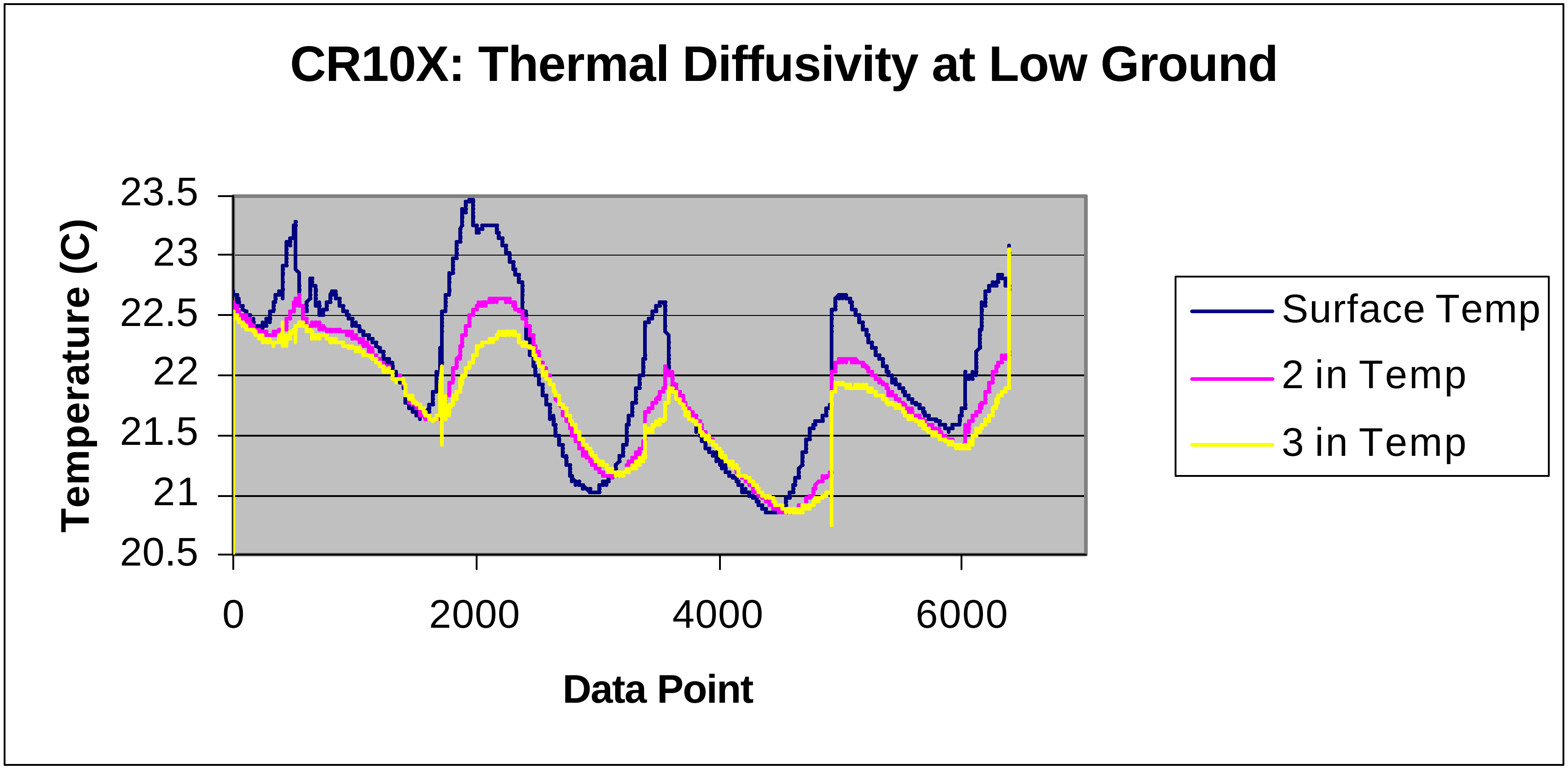
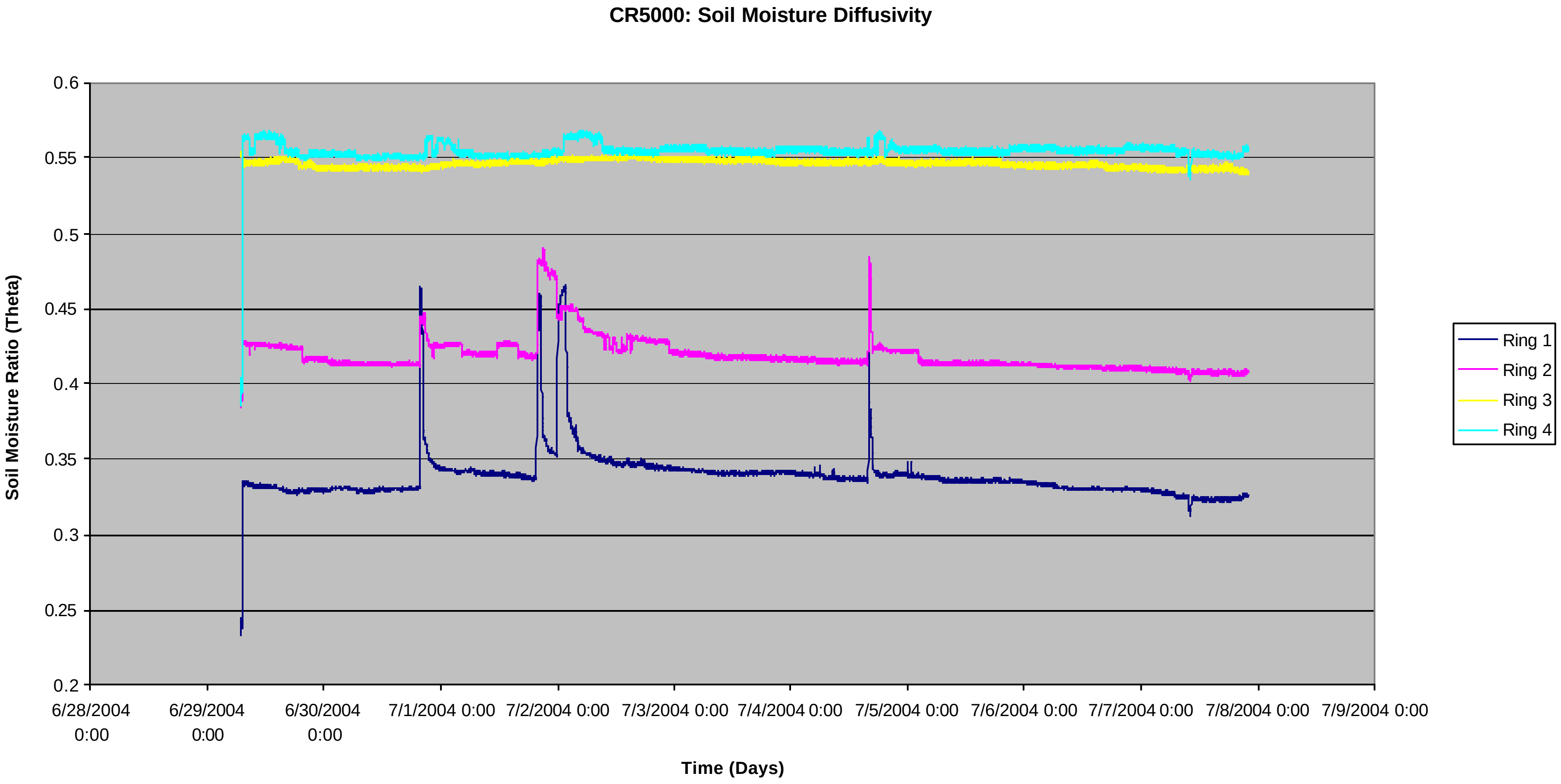
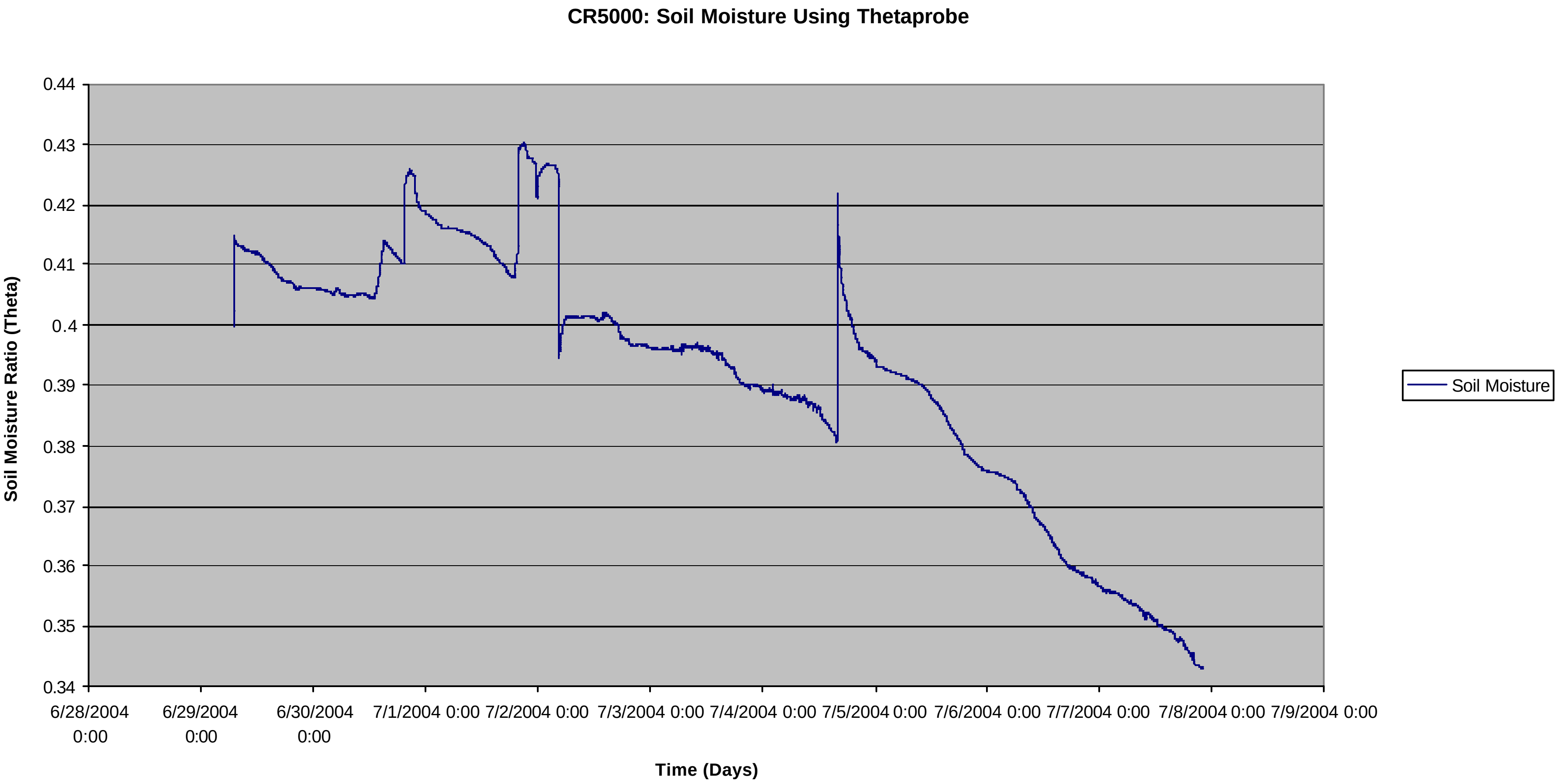


Figure 1: Thermal Diffusivity at High Ground


CR10X: Thermal Diffusivity at Low Ground
Temperature (C)
23.5
23
22.5
22
21.5
21
20.5
0
2000
4000
6000
Data Point
Surface Temp
2 in Temp
3 in Temp


CR5000: Soil Moisture Diffusivity
Soil Moisture Ratio (Theta)
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
6/28/2004 0:00
6/29/2004 0:00
6/30/2004 0:00
7/1/2004 0:00
7/2/2004 0:00
7/3/2004 0:00
7/4/2004 0:00
7/5/2004 0:00
7/6/2004 0:00
7/7/2004 0:00
7/8/2004 0:00
7/9/2004 0:00
Time (Days)
Ring 1
Ring 2
Ring 3
Ring 4


CR5000: Soil Moisture Using Thetaprobe
Soil Moisture Ratio (Theta)
0.44
0.43
0.42
0.41
0.4
0.39
0.38
0.37
0.36
0.35
0.34
6/28/2004 0:00
6/29/2004 0:00
6/30/2004 0:00
7/1/2004 0:00
7/2/2004 0:00
7/3/2004 0:00
7/4/2004 0:00
7/5/2004 0:00
7/6/2004 0:00
7/7/2004 0:00
7/8/2004 0:00
7/9/2004 0:00
Time (Days)
Soil Moisture

Temperature and Moisture Diffusion (Detail)

Thermal Diffusivity

i. Differential equation needed to understand the length of time required for solar radiation, turned into heat energy at the surface, to pass through layers of soil.
ii. Dependent on heat capacity, surface moisture, and cooling due to evaporation (loss of heat).

Moisture Diffusivity

i. Differential equation needed to understand the length of time required for moisture from a rain event or surface anomaly to travel through different soil layers. Depending on soil composition at each layer.
ii. This includes soil anomalies such as aquatards, roots, stones, and locations with abnormally high soil density.
iii. Moisture traveling down after a rainfall event or surface anomaly is initially prone to evaporation before diffusing.

Informal Conclusion

- **Continued testing and comparison to rainfall data to determine how much moisture is being absorbed and how much is being evaporated and running off after the soil has reached its field capacity.**

- **Models to be developed to determine the capacity for moisture to reach the water table or layer of saturation.**

- **Moisture diffusivity depending on distance of soil from water table.**

- **Determination of "wick" effect during dry periods, where water rises from layer of saturation or water table to dryer layers.**

- **Heat capacity of soil and its ability to adsorb solar radiation and the amount of energy absorbed conducted relative to the amount emitted by the surface and energy used in evaporation.**

- **Difference in soil conductance based on the composition of different soil layers and soil anomalies.**

- **Connection between humidity, evaporation, and the amount of heat energy passing through the surface soil layer and downward.**

h. I have a new diagram to put into the paper that I think better describes a realistic soil profile rather than the model they were working off of last year. I have to draw it on my computer but I just haven't had the time yet. But I do have it in my notebook.