An Analysis of Soil Temperatures to Determine Thermal Diffusivity

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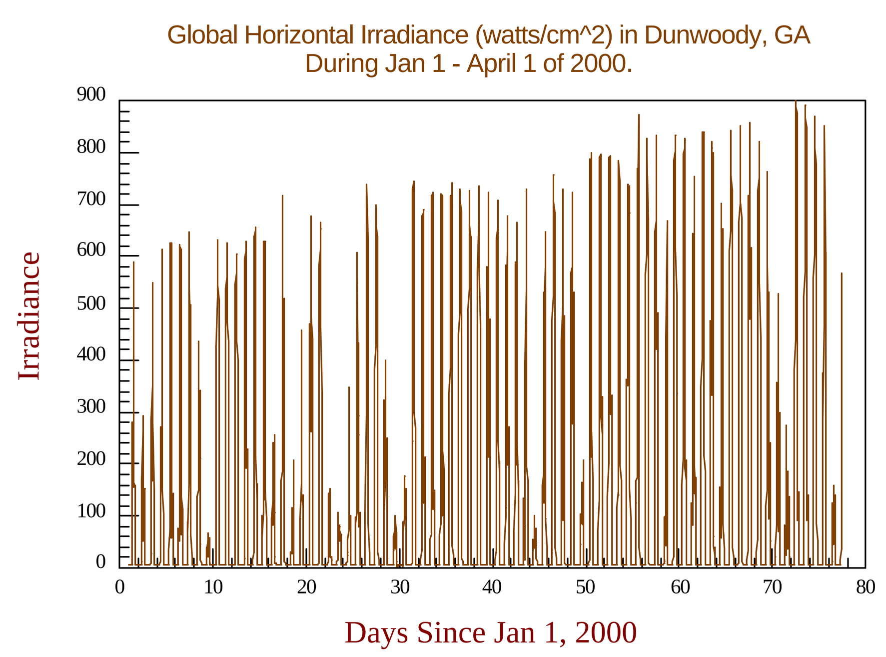
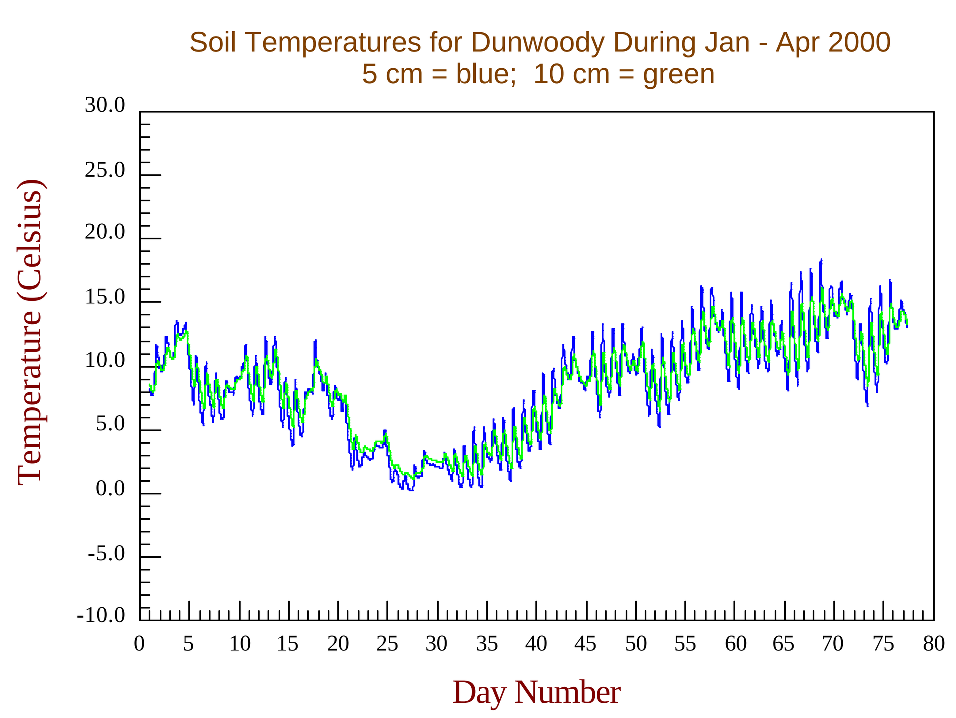
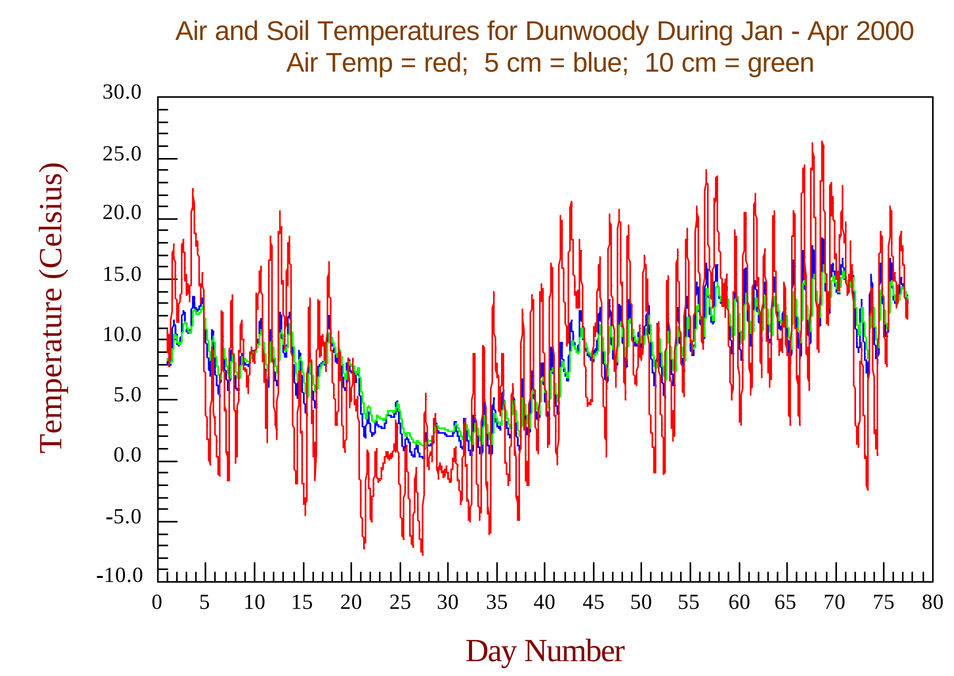
Introduction

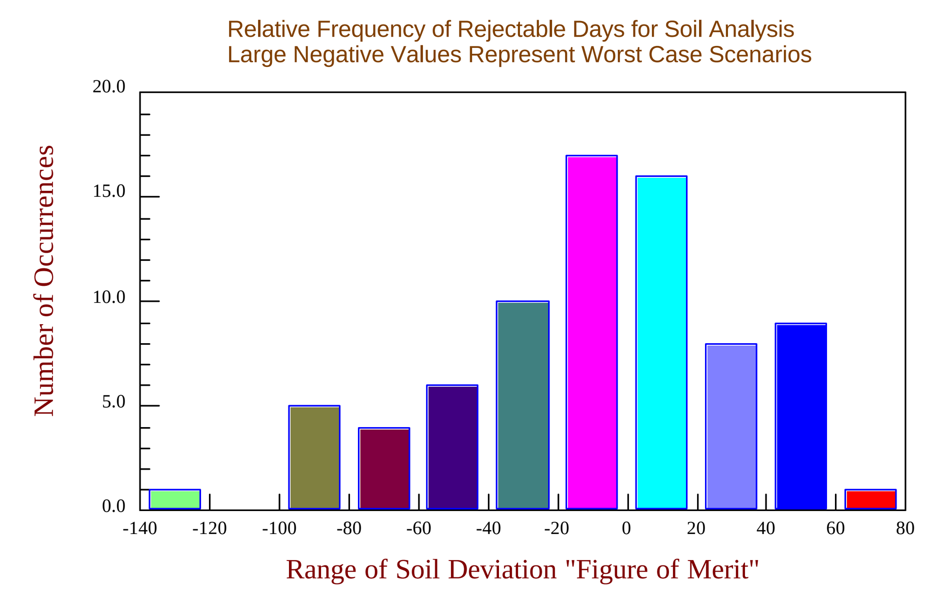
Thermal diffusivity is a measure of heat transfer in a solid. The thermal diffusivity of soil is known to be a strong function of soil moisture content. CAU plans to estimate and map the thermal diffusivity of grass-covered soils across the state of Georgia as an indication of how soil moisture content changes day by day. This information can be of use to agricultural and aquatic farmers who are interested in rates of evaporation and soil moisture recharge.

Data









Purpose

In our study, soil temperature gradient data is examined to estimate the thermal diffusivity for 24-hour periods. Data from the Georgia Automated Environmental Monitoring Network (AEMN) is used to show how thermal diffusivity is affected by air temperature and atmospheric radiation.

The rate of heat transfer in the soil is called the heat flux, H. At any depth z, the value of H is related to the mass density, ?, the heat capacity of the soil, c, the thermal diffusivity, $?_H$, and the temperature gradient, ?T/?z, by the equation

$$H = ?\ c\ ?_h\ ?T/?z.$$

Theory

For a twenty-four hour temperature wave specified by a sinusoidal function, an equation for the soil temperature, T, can be developed for the temperature as a function of depth and time.

$$T= T_m + A_s \exp (-z / d) \sin [(2? / P) (t - t_m) - z / d],$$

where T_m is the mean temperature of the surface or the submedium, A_s and P are the amplitude and period of the surface wave, t_m is the time when $T = T_m$ at the surface, and d is called the damping depth. By examining the temperature records at two levels, 5 cm and 10 cm below the surface, one can show that the value of d is the ratio

$$d = (z_2 - z_1) / \ln (A_1 / A_2)$$

where z_2 is 10 cm, z_1 is 5 cm, A_1 is the amplitude of the wave at 5 cm and A_2 is the amplitude at 10 cm. The value of d is determined by the above equations and used in a formula relating d and the thermal diffusivity.

$$?_h = d^2\ ?/ P.$$

The above formula was used to determine the thermal diffusivity value for a 4-month series of daily soil temperature values at 5 and 10 cm depths.

Conclusions

Thermal diffusivity is a parameter that will be used to determine soil moisture variations in Georgia. This data will be studied further and displayed on the AEMN. Dr. Gerrit Hoogenboom provided the 15-minute soil temperature data from AEMN stations in Georgia. This data will be displayed on state-wide maps and will inform farmers about changes in soil moisture content. In addition, the classical problem of transmission of heat to deeper layers of the soil will be analyzed by methods employed in this study.