TYPE 501: GROUND TEMPERATURE PROFILE

General Description

This subroutine models the vertical temperature distribution of the ground given the mean ground surface temperature for the year, the amplitude of the ground surface temperature for the year, the time difference between the beginning of the calendar year and the occurrence of the minimum surface temperature, and the thermal diffusivity of the soil. These values may be found in a variety of sources including the ASHRAE Handbooks (refer to soil temperature).

Nomenclature

T	[C]	Temperature
T_{mean}	[C]	Mean surface temperature (average air temperature)
T_{amp}	[C]	Amplitude of surface temperature (maximum air temperature minus minimum air temperature)
Depth	[m]	Depth below surface
α	[m^2/hr]	Thermal diffusivity of the ground (soil)
t_{now}	[1..365]	Current day of the year
t_{shift}	[1..365]	Day of the year corresponding to the minimum surface temperature

Detailed Description

Kasuda[1] found that the temperature of the undisturbed ground is a function of the time of year and the depth below the surface and could be described by the following correlation:

$$T = T_{mean} - T_{amp} * \exp\left[- depth * \left(\frac{\pi \alpha}{365} \right)^{0.5} \right] * \cos\left\{ \frac{2\pi}{365} * \left[t_{now} - t_{shift} - \frac{depth}{2} * \left(\frac{365\alpha}{\pi} \right)^{0.5} \right] \right\} \qquad \text{(Eq. 501.1)}$$

In absence of a measured value, T_{mean} (the mean surface temperature) may be taken as the average annual air temperature.

The Kasuda equation results in a distribution of temperature with respect to time for different values of soil depth and for a given climate as shown in Figure 1:

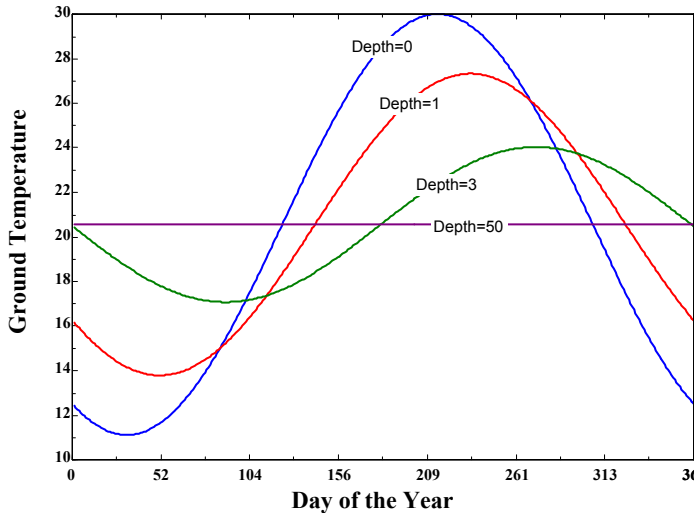


Figure 1: Temperature Profiles as a Function of Depth

The range of temperatures generated by this equation are shown in Figure 2. Line WI shows one extreme that the temperature profile assumes during the winter season. Line SU shows the other extreme that the temperature profile assumes during the summer. In between the summer and winter extremes, the ground temperature profile will lie between the two extremes. In the shoulder seasons (spring (SP) and fall (FA)), the surface is heated and cooled more quickly than the lower depths; resulting in the 'humped' distributions shown in Figure 2.

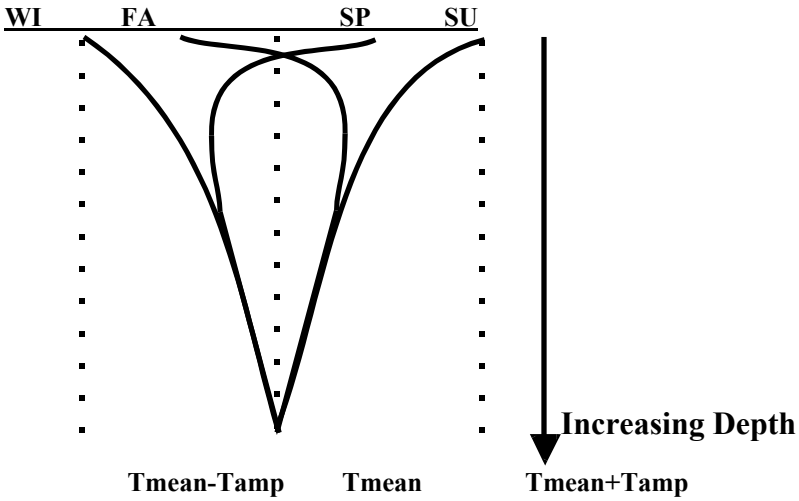


Figure 2: Seasonal Temperature Distributions as a Function of Depth

References

[1] Kasuda, T., and Archenbach, P.R. "Earth Temperature and Thermal Diffusivity at Selected Stations in the United States", ASHRAE Transactions, Vol. 71, Part 1, 1965