GeoStudio Example File
Evaporation from the Wilson Soil Column

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Introduction

The example illustrates the simulation of actual evaporation from a one-dimensional soil column. Actual evaporation rates are calculated based on the relative humidity within the soil, which is controlled by temperature and matric suction, and the climate conditions as defined by the Land-Climate Interaction (LCI) boundary condition. The simulated results are compared to measurements from a laboratory experiment (Wilson et al., 1993).

Background

Wilson (1990) carried out a laboratory experiment involving the evaporation of water from a column of sandy soil that was situated within a climate controlled environmental chamber (Figure 1). The entire chamber was subjected to a constant temperature of 38°C and a constant relative humidity of 10%. The base of the column was sealed to prevent water drainage and exposed to evaporation for 42 days. The soil column was weighed frequently during this test period to determine the actual evaporation rates and compared with the evaporative rates from a container of free water. The soil column simulated in this example was 300 mm high with an outside diameter of 169 mm (Wilson et al., 1993).

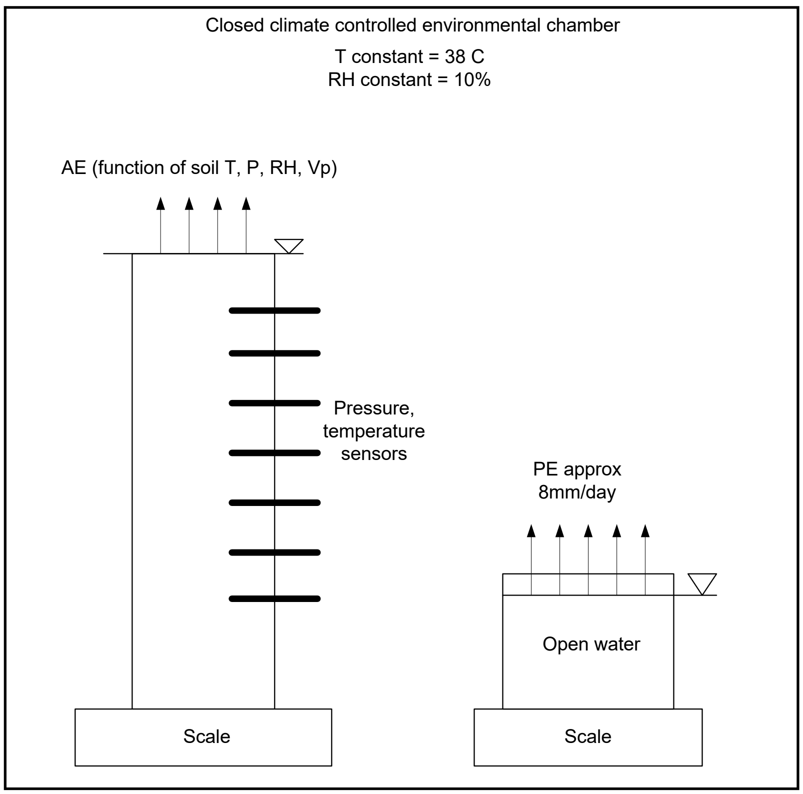

Figure 1. Schematic of the laboratory experiment.

Numerical Simulation

The numerical representation of the laboratory experiment comprises a one-dimensional line with an increased mesh density in the vertical direction (Figure 2). The Physics Tab for this analysis requires both the water transfer and heat transfer processes activated. In order to account for evaporation processes, both the isothermal and thermal vapor transfer options are also activated (Figure 3).

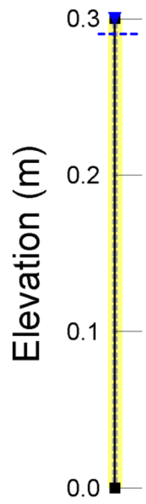

Figure 2. Finite element domain and climate boundary condition.

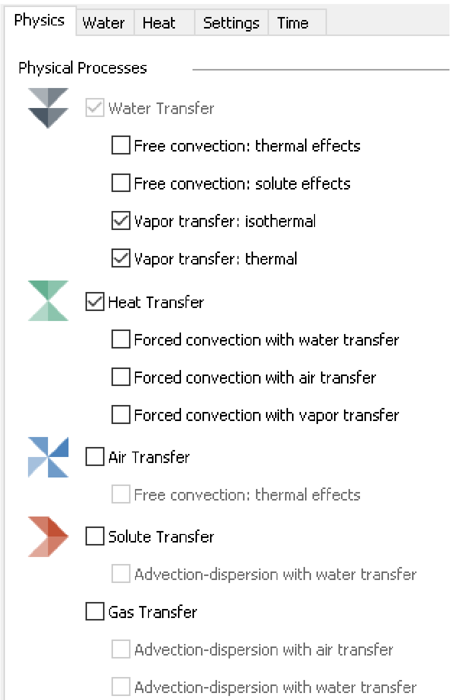

Figure 3. Physics tab for the analysis.

The initial conditions for the temperature and pore-water pressure conditions of the environmental chamber were defined by means of an activation temperature of 38°C and by drawing an initial water table at an elevation of 0.29 m, respectively.

The Land-Climate Interaction (LCI) boundary condition was defined using the measured potential evaporation rates estimated for the pan of water. The temperature and relative humidity functions were set constant values of 38°C and 10%, respectively. The minimum pore-water pressure limiting function was set to a constant of -300,000 kPa.

The material properties used in this example are based on laboratory measurements. The volumetric water content function has been curve fit using the Fredlund and Xing technique (Figure 4). The hydraulic conductivity function is shown in Figure 5. The simplified thermal model was used to represent the sand because the temperature within the chamber was maintained at 38°C (Figure 6).

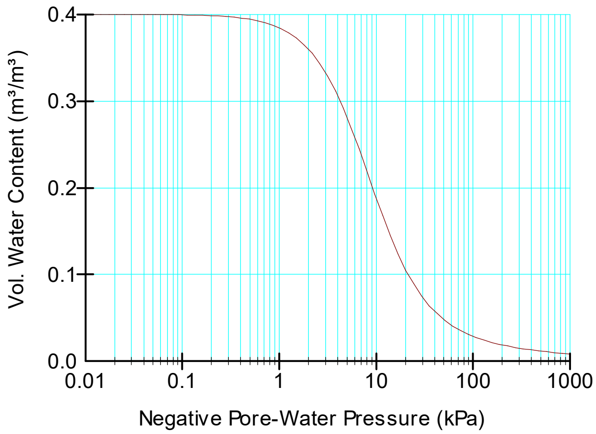

Figure 4. Volumetric water content function for the Beaver Creek Sand.

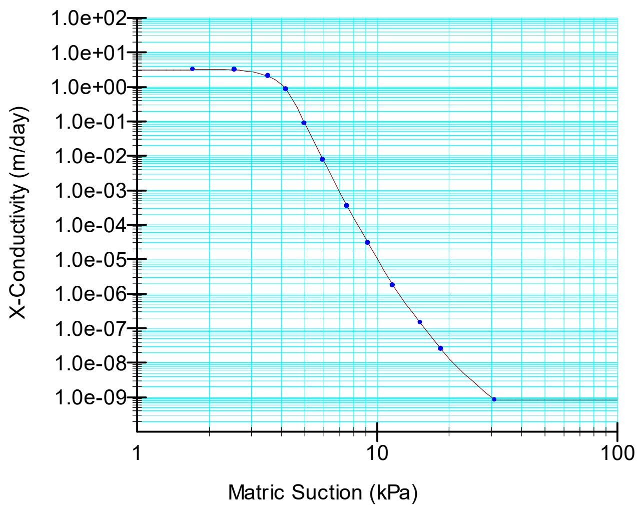

Figure 5. Hydraulic conductivity function of the Beaver Creek Sand.

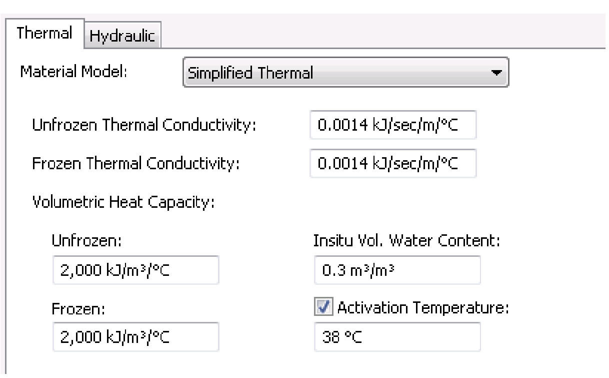

Figure 6. Simplified thermal model material parameters for the Beaver Creek Sand.

The simulated duration of 40 days was completed in 80 linear steps of 12 hours. The global element size of the mesh is set to 5 mm for the entire one-dimensional mesh.

Results and Discussion

Figure 7 shows the measured potential and actual evaporation rates based on the laboratory experiment (Wilson et al., 1993). Figure 8 shows the simulated actual evaporation (AE) as compared to the input potential evaporation (PE), which compares well at all times to the measured values. The AE matches the PE at early times when water is freely available near the surface of the column, then decreases rapidly as the soil begins to dry near the surface.

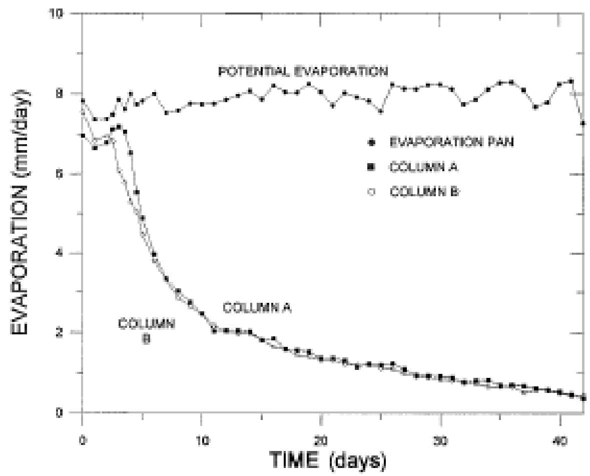

Figure 7. Measured potential and actual evaporation rates (Wilson et al., 1993).

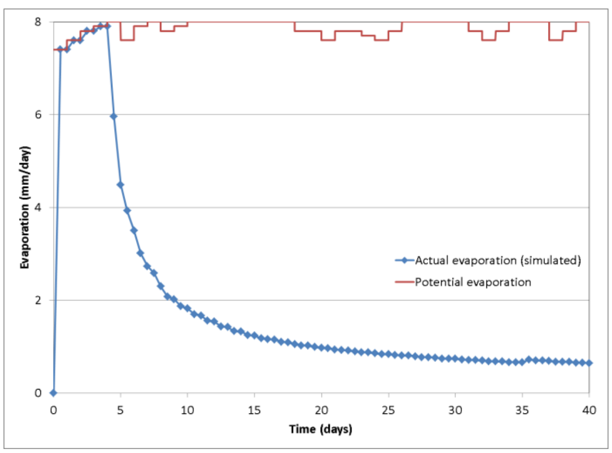

Figure 8. Simulated actual evaporation compared with input potential evaporation.

Figure 9 shows the pore-water pressure at the top nodes as a function of time. The matric suction at the ground surface starts to increase after day 4, which results in a rapid reduction in the evaporative flux. Wilson et al. (1993) describes the physical processes that are responsible for the decrease in the evaporative fluxes.

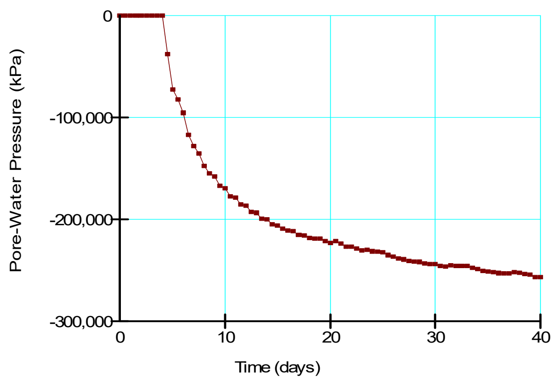

Figure 9. Pore-water pressure versus time at the top nodes.

Figure 10 shows the key water balance data. The cumulative surface evaporation volume is essentially equal to the cumulative change in soil water storage within the entire domain.

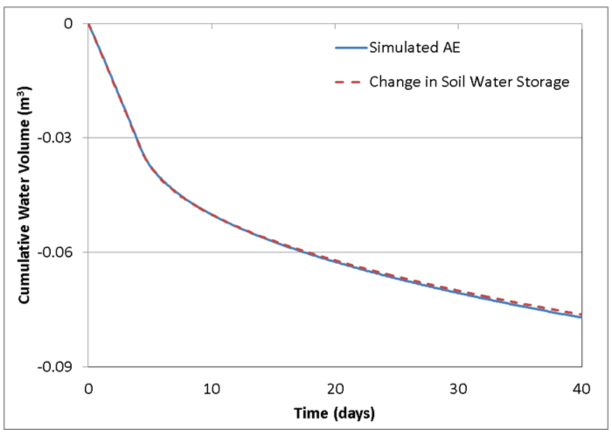

Figure 10. Cumulative change in water storage and actual evaporation.

The cumulative volume of water being removed from the domain at a depth of 10 cm is shown in Figure 11. This graph was created by using a subdomain that extends from the surface of the domain to a depth of 10 cm (Figure 12). The positive values in this case indicate upward movement of water into the bottom of the subdomain. The values of this graph would be negative if the node location was set to the surface, indicating water leaving the subdomain. The figure shows that the water volume passing the 10 cm depth is slightly less than that past the ground surface, indicating that the upper 10 cm of the column dried out more than the rest of the column. The use of the subdomain graphs can be useful in measuring net percolation rates at various depths within the model domain, for example, at the base of a soil cover.

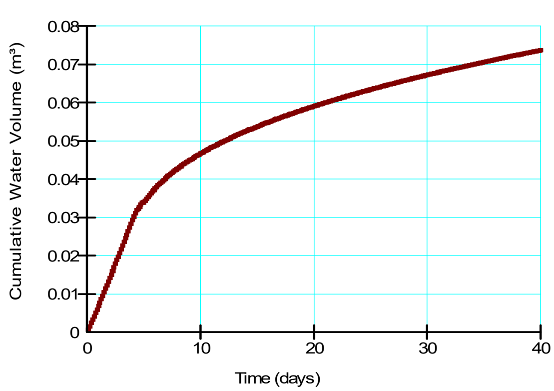

Figure 11. Cumulative volume passing 10 cm depth in the column.

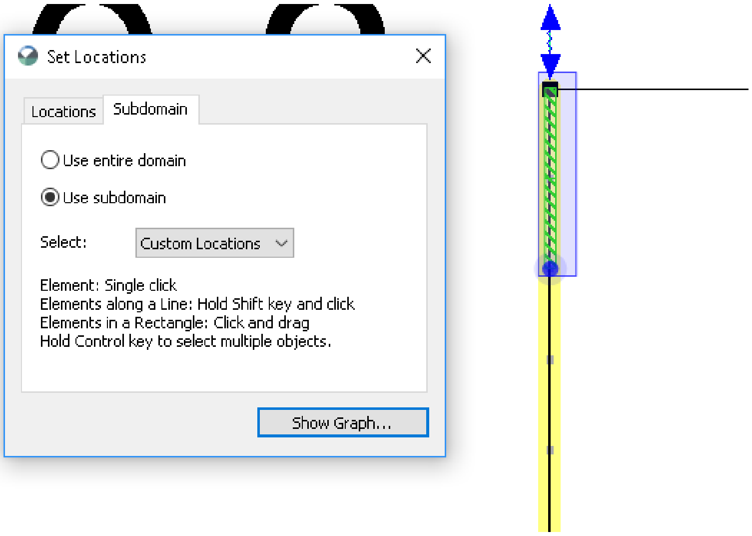

Figure 12. Subdomain and node location for the cumulative water volume passing the 10 cm depth.

Summary and Conclusions

The calculation of actual evaporation rates at the ground surface is based on both the soil and climate conditions. The column was placed in a constant climatic condition; consequently, the decrease in the evaporative rate was controlled entirely by the reduced availability of water at the ground surface. Wilson et al. (1993) provides a detailed description of the physical processes that are operating within the column and summarize the physics by which these processes are described.

References

Wilson, G.W. 1990. Soil evaporative fluxes for geotechnical engineering problems. Ph.D. dissertation. University of Saskatchewan, Saskatoon, Canada.

Wilson, G.W., Fredlund, D.G., and Barbour, S.L. 1993. Coupled soil-atmosphere modeling for soil evaporation. Canadian Geotechnical Journal. Volume 31, pg. 151 – 161.