

**Simulation evaporation from
soil based on single-crop
FAO-56 model**

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In this example the development of a simple evaporation model based on the single-crop FAO-56 Penman–Monteith (Allen et al., 2005) model will be described.

The FAO-56 single crop model can be expressed as:

$$ET = k_c k_s ET_0 \quad (1)$$

where ET_0 is calculated based on the full Penman-Monteith equation:

$$ET_0 = \frac{\Delta}{\Delta + \gamma} E_r + \frac{\gamma}{\Delta + \gamma} E_a \quad (2)$$

where

Δ [$(Pa^\circ C^{-1})$] is the rate of change of saturation specific humidity with air temperature:

$$\Delta = \frac{de_{as}}{dT} = 4098 \frac{e_s}{(237.3 + T)^2} \quad (3)$$

γ is the psychrometric constant (by default equal to $66.8 Pa/^\circ C$).

e_{as} is the saturated vapor pressure:

$$e_{as} = 611 e^{\frac{17.27T}{T+237.3}} \quad (4)$$

E_r is the radiation induced evaporation rate

$$E_r = k_l \frac{R_n}{l_v \rho_w} \quad (5)$$

k_l is a calibration constant, R_n is the radiation rate [W/m^2], l_v is the latent heat of evaporation and ρ_w is the density of water. E_a is the wind-induced evaporation calculated as:

$$E_a = 9.82^{-10} k_a u e_{as} (1 - R_h) \quad (6)$$

where k_a is a calibration constant (in the standard form $= \ln(z_2/z_0)^{-2}$), u is the wind speed at elevation z_2 , and R_h is the relative humidity.

k_s is the stress coefficient which is calculated as:

$$k_s = \max\left(\min\left(\frac{\theta - \theta_{wp}}{\theta_{fc} - \theta_{wp}}, 1\right), 0\right) \quad (7)$$

where θ_{wp} is the wilting point moisture content and θ_{fc} is the field capacity moisture content.

The value of k_c depends on the growth stage of plants and is provided by the user as a time-series.

The model is composed of a soil layer with a depth of 1.5m that is discretized into three non-equal layers, a surface water layer represented by a pond and groundwater layer that is assumed to have a fixed hydraulic head. The soil is assumed to be recharged solely through precipitation. Below are the step to build the model. Time series data representing light, precipitation, temperature and humidity are provided as comma delimited text files in the example folder. It is assumed that evaporation mainly occurs directly from the top soil layer into the atmosphere and diffusive vapor transfer controls the movement of moisture from lower soil layers to the upper ones.

The steps to construct the model are provided below:

- **Construct the model structure:** Add the three soil layers, a pond layer and a Darcy layers and connect them together as shown in Figure 1.

Assign properties to each layer according to Table 1. Assign the lengths of the connectors according to Table 2.

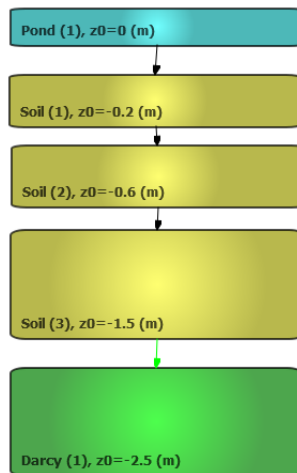


Figure 1: Schematic of the model

- **Setting up the evaporation model:**
 - Right-click on the **Evapotranspirations** item in the **Project Explorer** window and click on **Add Evapotranspiration** from the drop down menu that will appear.

- Choose the **Evapotranspiration** object that was just created and set the following properties:
 - * **Model:** *FAO-56*
 - * **Wind Coefficient:** *0.047*. The value is calculated based on the formula $\ln(z_2/z_0)^{-2}$ assuming the wind is measured at an elevation $z_2 = 2m$ and a surface roughness of *2cm*.
 - * **Solar-radiation coefficient:** *1*
 - * **Wilting point moisture content:** *0.05*
 - * **Field capacity moisture content:** *0.2*
 - * Right-Click on the box in front of **FAO-56 crop coefficient** and choose **Edit time series** from the drop-down menu. In the window that shows up enter values according to figure 2. This specifies the crop coefficient time-series over the year of simulation. Click on the save button and provide a file name (e.g. "k_c.txt"). The crop coefficient time series look like

	1	2
1	names	Value
2	40179.0	0.2
3	40274.0	0.2
4	40304	1.4
5	40414	1.4
6	40444	0.2
7	40544	0.2

Figure 2: Crop coefficient time-series

figure 3.

- **Climate Settings:** We need 5 climate related time series to run the model. These include solar radiation, relative humidity, temperature, wind and precipitation. The time series are provided with the examples and should be including in the downloaded files (figure 4).

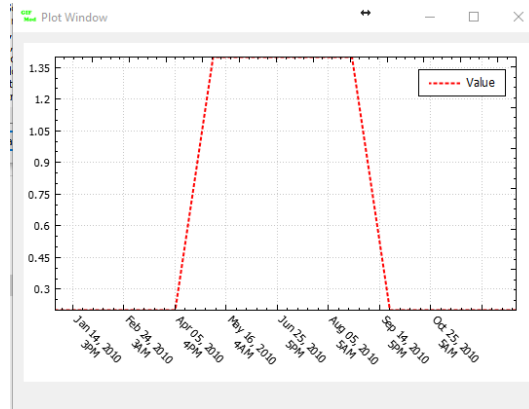



Figure 3: Crop coefficient time-series

- * Click on **Settings**→**Climate Settings** and then from the properties window select the file named "Radiation.txt" for the **Solar-radiation** property.
 - * Select the file named "humidity.txt" for the **humidity** property.
 - * Select the file named "temperature.txt" for the **Temperature** property.
 - * Select the file named "wind.txt" for the **Wind** property.
- **Start and end date of the simulation:** Through **Setting**→**Project Setting** menu set start date to *Jan 01 2010* and end date to *Dec 30 2010*.
 - Turn the **Oscillation control** off through **Setting**→**Project Setting**. This will allow the simulation to be conducted faster.
 - **Applying the evaporation to the top soil layer:** Select *Soil (1)* and select *Evapotranspiration* for the **Evapotranspiration**. This assigns the evapotranspiration model introduced to the top soil layer.
 - **Run the model:** Click on the run  and let the simulation to finish.
 - **Inspecting the results:** To check the evapotranspiration rate from the top soil right click on *Soil (1)* block and choose **Plot Hydraulic Results**→**Evaporation**. The results will look like figure 5. You can similarly check the moisture content as is shown in figure 6.

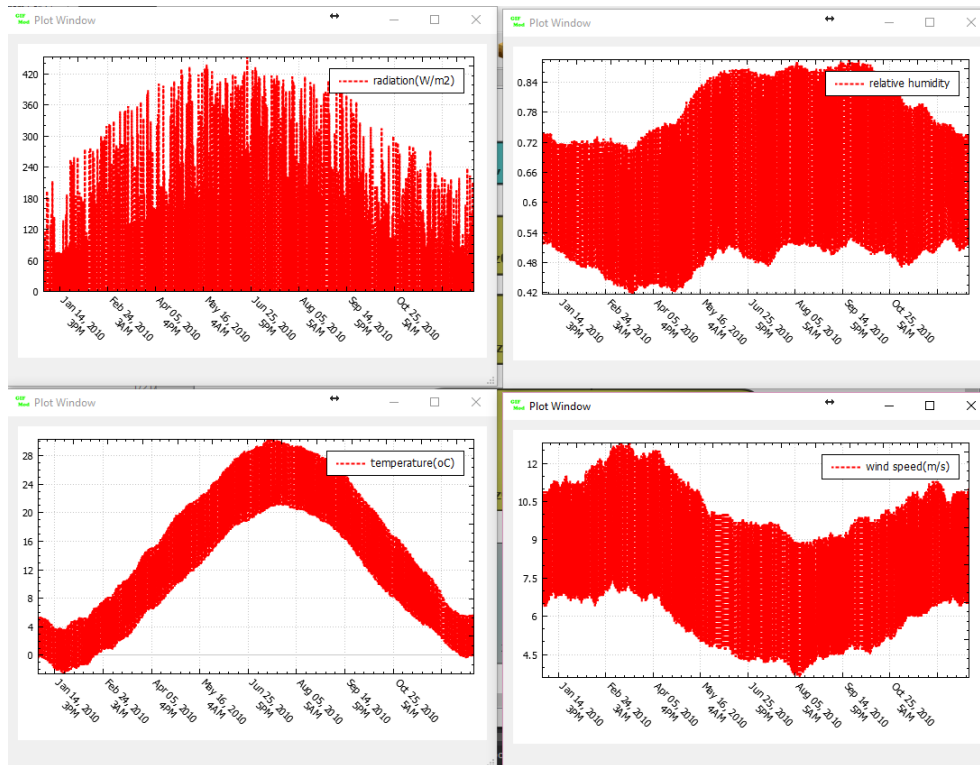


Figure 4: Radiation, Relative Humidity, Temperature, and Wind Speed over the period of simulation

Pond (1)	
Bottom Area	$100m^2$
Vapor Diffusion	$0.01m^2/day$
Soil (1)	
SubType	Sandy Clay
Bottom Area	$100m^2$
Bottom Elevation	$-0.2m$
Depth	$0.2m$
Vapor Diffusion	$0.01m^2/day$
Solar Radiation	Yes
Soil (2)	
SubType	Sandy Clay
Bottom Area	$100m^2$
Bottom Elevation	$-0.6m$
Depth	$0.4m$
Vapor Diffusion	$0.01m^2/day$
Soil (3)	
SubType	Sandy Clay
Bottom Area	$100m^2$
Bottom Elevation	$-1.5m$
Depth	$0.9m$
Vapor Diffusion	$0.01m^2/day$
Darcy (1)	
Bottom Area	$100m^2$
Bottom Elevation	$-2.5m$
Depth	$1m$
Vapor Diffusion	$0.01m^2/day$
Saturated moisture content	0.35
Initial moisture content	0.35
Head-storage relationship	-1.5

Table 1: properties of blocks

Connector	Length (m)
Pond (1) - Soil (1)	0.1
Soil (1) - Soil (2)	0.3
Soil (2) - Soil (3)	0.65
Soil (3) - Darcy (1)	0.95

Table 2: Lengths of connectors

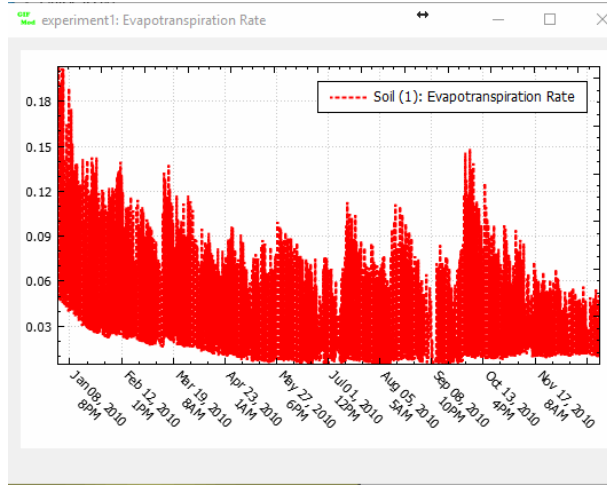


Figure 5: Evaporation rate from the top soil layer

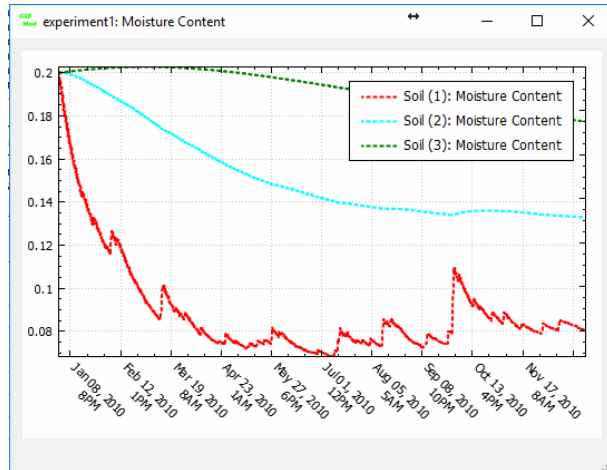


Figure 6: Moisture content in soil layers

Bibliography

Allen, R. G., Pereira, L. S., Smith, M., Raes, D., and Wright, J. L. (2005).
Fao-56 dual crop coefficient method for estimating evaporation from soil
and application extensions. *Journal of irrigation and drainage engineer-
ing*, 131(1):2–13.