Evaluation Examples

(1) Energy Balance Method

On 24 January 2013, in the Upper Brushy Creek watershed, the net radiation averaged over the day from the National Land Data Assimilation System, is 52 W/m^2. The average air temperature through the day is 17°C. Compute the corresponding potential evaporation rate using the energy balance method.

Solution

The potential evaporation by the Energy Balance method is given by Eq. (3.5.10):

$$E_r = \frac{R_n}{\rho_w \; l_v} = \frac{R_n}{L}$$

Where L = $\rho_w \; l_v$ is the Latent Heat factor given in Table 1. For a temperature of 17°C, the corresponding factor is L = 28.89 (W/m^2)/(mm/day). Hence, the potential evaporation by the energy balance method for a net radiation of 52 W/m^2 is:

$$E_r = \frac{R_n}{L} = \frac{52}{28.89} = \underline{1.80 \; mm/day}$$

Temp (°C)	Water Density (kg/m3)	Latent Heat (J/kg)	L (W/m2) /(mm/day)
0	1000	2500000	28.94
5	1000	2499988	28.94
10	1000	2499976	28.93
15	999	2499965	28.91
20	998	2499953	28.88
25	997	2499941	28.85
30	996	2499929	28.82
35	994	2499917	28.76
40	992	2499906	28.70

Table 1. Latent heat factor, L as a product of water density and latent heat, in units of mm/day.

(2) Aerodynamic Method

On 24 January 2013, the observed climate data at Austin Bergstrom Airport data are: temperature 17°C, relative humidity 83%, and wind speed 0.9 m/s. Determine the potential evaporation by the aerodynamic method.

Solution

The potential evaporation by the aerodynamic method, E_a, is given by Eq. (3.5.17) in which e_s is the saturated vapor pressure corresponding to the air temperature and e is the actual vapor pressure.

$$E_a = B(e_s - e)$$

and the wind function B (mm/day Pa) is given by Eq. (3.6.1)

$$B = 0.0027\left(1 + \frac{u}{100}\right)$$

where u is the 24-hour wind run in km/day.

For these conditions, the average wind velocity is 0.9 m/s, which corresponds to a 24-hour wind run of u = 0.9*24*3600*(1/1000) = 77.8 km/day.   Hence

$$B = 0.0027\left(1 + \frac{77.8}{100}\right) = 0.0048\ (\frac{mm}{day\ Pa})$$

The saturated vapor pressure for a temperature of 17°C is given by Eq. (3.2.9)

$$e_s = 611\ exp\left(\frac{17.27T}{237.3 + T}\right) = \ 611\ exp\left(\frac{17.27 * 17}{237.3 + 17}\right) = 1938\ Pa$$

and the actual vapor pressure is given by the product of the saturated vapor pressure and the relative humidity

$$e = \ e_s R_n = 1938 * 0.83 = 1608\ Pa$$

The vapor pressure deficit is given by the difference between these two vapor pressures:

$$e_s - e = 1938 - 1608 = 330\ Pa$$

The evaporation by the aerodynamic method is then calculated as the product of the wind function and the vapor pressure deficit:

$$E_a = B(e_s - e) = 0.0048 * 330 = \underline{1.58\ mm/day}$$

(3) Combination Method

Determine the potential evaporation using the Combination Method.

Solution

This method balances the values from the Energy Balance and Aerodynamic methods assuming that neither of these is completely governing. The potential evapotranspiration is given by Eq. (3.5.26)

$$E_o = \frac{\Delta}{\Delta + \gamma} E_r + \frac{\gamma}{\Delta + \gamma} E_a$$

Where the term Δ is the gradient of the saturated vapor pressure versus temperature function, given by Eq. (3.2.10):

$$\Delta = \frac{4098 e_s}{(237.3 + T)^2} = \frac{4098 * 1938}{(237.3 + 17)^2} = 122.8 \frac{Pa}{°C}$$

and the psychrometric constant, γ, for a temperature of 17°C is taken from Table 2 as γ = 66.5 Pa/°C. The sum of these two quantities is given by $\Delta + \gamma$ = 122.8 + 66.5 = 189.3 Pa/°C

Hence the evaporation by the Combination Method is given by:

$$E_o = \frac{\Delta}{\Delta + \gamma} E_r + \frac{\gamma}{\Delta + \gamma} E_a = \frac{122.8}{189.3} * 1.80 + \frac{66.5}{189.3} * 1.58 = \underline{1.73\, mm/day}$$

Temp °C	**ϒ(Pa/°C)**
0	65.4
5	65.8
10	66.1
15	66.4
20	66.7
25	67.0
30	67.4
35	67.7

Table 2. Psychrometric constant, taken from Table 4.2.1 Handbook of Hydrology (Maidment, 1993)