Notes from Brutsaert: Hydrology – An Introduction

Page 123

Energy Balance Equation

The energy balance equation is given as:

$$L_e E + H = Q_n \tag{4.13}$$

where:

- E = evaporation,
- H = sensible heat flux into the air,
- L_e = latent heat of evaporation (*refer to Table 2.4,* 2.466×10^6 *J/kg*),
- Q_n = available energy flux density.

From this equation:

$$Q_n e = \frac{Q_n}{L_e} \quad (\text{“equivalent” fluxes}),$$
$$H_e = \frac{H}{L_e}.$$

Thus, the energy equation can also be written as:

$$E + H_e = Q_n e.$$

Components of Q_n

The available energy flux density, Q_n, can be expanded as:

$$Q_n = R_n - G + L_p f + A_h + \frac{\partial W}{\partial t} \tag{4.14}$$

where:

- R_n = net radiation flux density,
- G = heat flux density into the ground,
- $L_p f$ = thermal energy flux related to the transpiration of CO_2,
- A_h = energy absorption by the canopy,
- $\frac{\partial W}{\partial t}$ = change in heat storage over time.

The terms of this equation represent:

- $R_n - G$: net radiation minus the heat flux into the ground,
- $L_p f$: contribution of CO_2 flux,
- A_h: atmospheric heating,
- $\frac{\partial W}{\partial t}$: heat storage in the system.

Bowen Ratio

The Bowen ratio, B_o, is defined as:

$$B_o = \frac{\gamma}{\Delta} \left[1 - \frac{e_a^* - \bar{e_a}}{e_s^* - \bar{e_a}} \right] \tag{4.21}$$

where:

- $\gamma = \frac{C_p p}{0.622 L_e}$: the psychrometric constant,
- $\Delta = \frac{de_s^*}{dT}$: slope of the saturation water vapor pressure curve at T_a,
- e_s^* = saturation water vapor pressure,
- $\bar{e_a}$ = mean vapor pressure,
- e_a^* = actual water vapor pressure at air temperature.

The Bowen ratio describes the ratio of sensible heat flux to latent heat flux and plays a critical role in energy balance studies.

Key Definitions and Constants

- e_s^*: saturation water vapor pressure at the surface,
- $\bar{e_a}$: mean vapor pressure in the atmosphere,
- e_a^*: saturation water vapor pressure at air temperature,
- $\gamma = \frac{C_p p}{0.622 L_e}$: psychrometric constant (specific heat capacity of air, C_p, at constant pressure p),
- $\Delta = \frac{e_s^* - e_a^*}{T_s - T_a}$: slope of the saturation water vapor pressure curve.

Saturation Water Vapor Pressure Curve

The curve of saturation water vapor pressure as a function of temperature is critical for hydrological studies. Refer to Page 28 (Equation 2.14) and Figure 2.1 for details:

$$e^*(T) \quad \text{versus temperature.}$$

The slope of this curve, Δ, is defined as:

$$\Delta = \frac{de_s^*}{dT}.$$

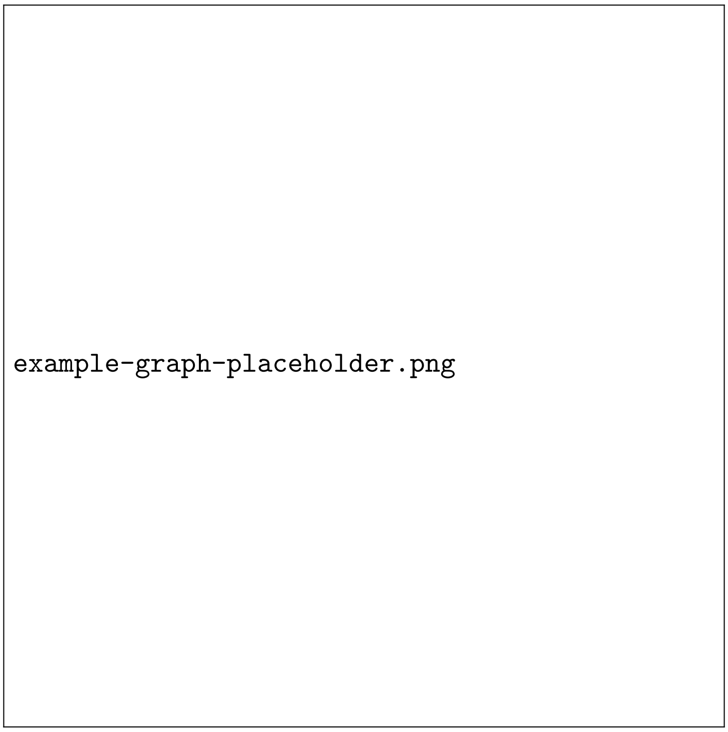

Figure 1: Saturation water vapor pressure curve (Figure 2.1).