Update of PET module documentation:

January 19, 2018

potet_jh

Equation 1-51 had used the average air temperature in degrees Fahrenheit ($tavgf_{HRU}$) when it should have been degrees Celsius ($tavgc_{HRU}$). The algorithm in the code is correct.

$$\lambda_{HRU} = 597.3 - (0.5653 \times tavgc_{HRU}), \tag{1-51}$$

where

λ_{HRU} is the latent heat of vaporization for each HRU in calories/gram.

potet_hs

Equation 1-56 was modified to take the absolute value of $tmaxc_{HRU} - tminc_{HRU}$ to account for rare cases when the computed minimum temperature was greater than the computed maximum temperature. This can happen when these temperature values are very close to each other and the difference is essentially zero and a small negative number makes the value of the square root undefined when it should be close to zero. The conversion factor (0.000673) for Langleys/day (units of $swrad_{HRU}$) to inches/day was not included in the equation. Equation 1-56 is now updated to:

$$\begin{aligned} potet_{HRU} = {} & \mathbf{hs}_{\mathbf{krs}_{HRU,month}} \times swrad_{HRU} \times 0.000673 \\ & \times \sqrt{ABS(tmaxc_{HRU} - tminc_{HRU})} \times (tavgc_{HRU} + 17.8) \end{aligned} \tag{1-56}$$

potet_pt

The fourth option (module `potet_pt`) uses the Priestley-Taylor formulation, in which PET is computed as a function of daily air temperature, atmospheric pressure, relative humidity, and solar radiation according to Priestly and Taylor (1972). The psychrometric constant ($psycnst_{HRU}$), in kilopascals per degrees C, for each HRU is computed as:

$$psycnst_{HRU} = 1.005 \times \frac{101.3 \times \left((293 - 0.0065 \times hru\_elev\_meters_{HRU})/293\right)^{5.26}}{0.622 \times \lambda_{HRU} \times 4.184}, \tag{1-57}$$

where

101.3 is the specific heat of moist air in kilopascals;

1.005 is the specific heat capacity of air in megajoules per kilogram per degrees Celsius;

0.622 is the molecular weight of water in megajoules per kilogram per degrees Celsius;
4.184 is the conversion from calories to Joules; and
$hru\_elev\_meters_{HRU}$ is the HRU elevation in meters.

The slope of saturation vapor pressure versus air temperature curve (vp_slope_{HRU}), in kilopascals per degrees C, according to Irmak and others (2012), for each HRU is computed as:

$$vp\_slope_{HRU} = \frac{4098 \times 0.61078 \times e^{\frac{tavgc_{HRU} \times 17.26939}{tavgc_{HRU}+237.3}}}{(tavgc_{HRU}+237.3)^2}. \quad (1\text{-}58)$$

Accounting for net long-wave radiation on the basis of the vapor pressure at dew point was added to the potential evapotranspiration equation and is computed identically as in the Penman-Monteith formulation. This change requires that humidity information be specified.

Equation 1-61 has been modified. The temperature at dew point ($tempc\_dewpt_{HRU}$), in degrees Celsius, according to Lawrence (2005), for each HRU is computed as:

$$tempc\_dewpt_{HRU} = \frac{243.0 \times \left[ln\left(\frac{humidity}{100}\right) + \left(\frac{tavgc_{HRU} \times 17.625}{tavgc_{HRU}+243}\right)\right]}{17.625 - \left[ln\left(\frac{humidity}{100}\right) + \left(\frac{tavgc_{HRU} \times 17.625}{tavgc_{HRU}+243}\right)\right]}, \quad (1\text{-}61)$$

where

$humidity$ is the relative humidity as percent. For modules `potet_pt` and `potet_pm` $humidity$ can be specified in a humidity CBH File or using new parameter **humidity_percent** (maximum dimension **nhru** by **nmonths**) as specified in a Parameter File. If a humidity CBH File is not specified, *humidity* is set to parameter **humidity_percent**. For module `potet_pm_sta` $humidity$ is set to the associated $humidity$ value as specified in the Data File on the basis of parameter **hru_humidity_sta** specified in a Parameter File.

The actual vapor pressure (vp_actual_{HRU}), in kilopascals, as shown in Irmak and others (2012) for each HRU is computed as:

$$vp\_actual_{HRU} = 0.61078 \times e^{\frac{tempc\_dewpt_{HRU} \times 17.26939}{tempc\_dewpt_{HRU}+237.3}}. \quad (1\text{-}62)$$

The net long-wave radiation ($lwrad\_net_{HRU}$), in megajoules per square meter per day, is the difference between outgoing and incoming long-wave radiation, as shown in Irmak and others (2012) for each HRU is computed:

$$lwrad\_net_{HRU} = (4.903 \times 10^{-9}) \times \left(\frac{((tmaxc_{HRU}+273.16)^4 + (tminc_{HRU}+273.16)^4)}{2}\right) \times \left(0.34 - 0.14 \times \sqrt{vp\_actual_{HRU}}\right) \times \left(1.35 \times \frac{MIN(10.5, swrad_{HRU})}{MIN(10, soltab\_potsw_{HRU})} - 0.35\right), \quad (1\text{-}65)$$

where

$soltab\_potsw_{HRU}$	is the potential radiation for a horizontal surface (equation 1-6) with a minimum value of 10 to ensure the equation is stable for small values of solar radiation that might occur in Northern Latitudes, high slope, and/or North facing HRUs.
$swrad_{HRU}$	is the incoming shortwave radiation with a minimum value of 10.5 to ensure the equation is stable for small values of solar radiation that might occur in Northern Latitudes, high slope, and/or North facing HRUs.

The heat flux density to the ground (G), in megajoules per square meter per day, according to Lu and others (2005) for each HRU was originally computed as:

$$G = -4.2 \times (tavgc_{HRU}^{m-1} - tavgc_{HRU}). \qquad (1\text{-}59a)$$

However, according to Irmak and others (2012), G can be considered to be equal to 0.0 for daily time steps, which is the value used for G in equation 1-60,

$$G = 0.0. \qquad (1\text{-}59b)$$

PET is computed for each HRU according to Priestley and Taylor (1972, equation 8):

$$potet_{HRU} = \mathbf{pt\_alpha}_{HRU,month} \times \left(\frac{1}{2.54 \times \lambda_{HRU}}\right) \times \left(\frac{vp\_slope_{HRU}}{vp\_slope_{HRU} + psycnst_{HRU}}\right) \times (swrad_{HRU} \times 0.04184 - lwrad\_net_{HRU} - G). \qquad (1\text{-}60)$$

where

0.04184 converts Langleys per day to megajoules per square meter per day; and
2.54 converts the units of centimeters to inches.

`potet_pm` or `potet_pm_sta`

The fifth option (modules `potet_pm` or `potet_pm_sta`) uses a Penman-Monteith formulation in which PET is computed as a function of air temperature, atmospheric pressure, relative humidity, wind speed, and solar radiation.

Saturated vapor pressure (vp_sat_{HRU}) in kilopascals for each HRU is calculated according to Irmak and others (2012):

$$vp\_sat_{HRU} = 0.61078 \times e^{\frac{tavgc_{HRU} \times 17.26939}{tavgc_{HRU} + 237.3}}. \qquad (1\text{-}63)$$

The vapor pressure deficit ($vp\_deficit_{HRU}$), in kilopascals, is computed as:

$$vp\_deficit_{HRU} = vp\_sat_{HRU} - vp\_actual_{HRU}. \qquad (1\text{-}64)$$

Finally, $\mathbf{crop\_coef}_{HRU}$ parameter (ASCE-EWRI, 2005) has been added to the Penman-

Monteith equation, which can be solved for a daily time step for each HRU according to Irmak and others (2012):

$$potet_{HRU} = \mathbf{crop\_coef}_{HRU} \times \left[\frac{0.408 \times vp\_slope_{HRU} \times \left(\left(\frac{swrad_{HRU} \times 0.04184 - lwrad\_net_{HRU}}{0.2389} \right) - G \right)}{vp\_slope_{HRU} + \left(\lambda_{HRU} \times \left(1 + \mathbf{pn\_d\_coef}_{HRU,month} \times wind\_speed \right) \right)} + \frac{\lambda_{HRU} \times \left(\frac{\mathbf{pn\_n\_coef}_{HRU,month}}{tavgc_{HRU} + 273.16} \right) \times wind\_speed_{HRU} \times vp\_deficit_{HRU}}{vp\_slope_{HRU} + \left(\lambda_{HRU} \times \left(1 + \mathbf{pn\_d\_coef}_{HRU,month} \times wind\_speed \right) \right)} \right], \tag{1-66}$$

where

wind_speed is set to the associated HRU *windspeed_hru* value specified in the wind speed CBH File for module `potet_pm` and to the associated *wind_speed* value as specified in the Data File on the basis of parameter **hru_windspeed_sta** specified in the Parameter File for module `potet_pm_sta`.

New References

ASCE-EWRI, 2005, The ASCE standardized reference evapotranspiration equation, Environmental and Water Resources Institute (EWRI) of ASCE, Standardization of Reference Evapotranspiration Task Committee Final Rep. http://www.kimberly.uidaho.edu/water/asceewri/ascestzdetmain2005.pdf.

Lawrence, M.G., 2005, The relationship between relative humidity and the dewpoint temperature in moist air: a simple conversion and applications, Bulletin of the American Meteorological Society, 86, pp. 225–233.