

EVAPPNMN:an Excel Add-In to Calculate Potential Evopotranspiration from Open Water

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Abstract

A Microsoft Excel spreadsheet implementation of an energy-budget formula for calculating potential evapotranspiration, based on the Penman method, allows the user to enter weather observations and view resultant evapotranspiration quickly and easily. The use of a spreadsheet provides both easy, powerful input-editing and a wide range of output graphing options, lets the user see results immediately and immediately check for spurious input, and avoids the difficulties of file import/export.

The potential evapotranspiration formula used requires average temperature, average relative humidity, average wind speed, net radiation, pressure, and heat advected into the water body. Pressure can be treated as a constant based on elevation, and heat advected into the water body can be reasonably assumed to be zero. Net radiation absorbed by the water is estimated as 60% of incident short wave radiation. The spreadsheet calculates the resulting depth of potential evapotranspiration on an areal basis, which can then be used to calculate total evaporative loss by multiplying by the surface area of the free water area.

The potential evapotranspiration formula and related formulae have been implemented as functions in a Visual Basic module and converted into an Excel add-in (EVAPPNMN.XLA) for ease of use and improved speed. A sample spreadsheet that uses these formulas to calculate open-water evaporation at Quivira (EVAP0010.XLS) is included.

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How to Use the Add-In

The potential evaporation functions are provided in the form of an Excel Add-In, along with a variety of unit-conversion functions to help the users. The data needed to calculate evaporation rates for open water are

- | | |
|---|---------|
| • temperature in degrees Celsius | Average |
| • pressure in kilopascals | Average |
| • wind speed at 2 meters above land surface in meters per second | Average |
| • water-vapor pressure-deficit in kilopascals | Average |
| • net radiation expressed in millimeters of water evaporated | Total |
| • heat advected into the water in millimeters of water evaporated | Total |

The example spreadsheet Evap0010.XLS shows a typical application. The columns containing daily values, mainly in English units, are on the left part of the spreadsheet. The next set of columns convert the English units to the needed metric units and calculate intermediate values. (EVAPPNMN.XLA includes functions to convert between temperature in degrees-Fahrenheit and degrees-Celsius. One mile per hour is 0.447 meters per second.) The intermediate values are included to make the spreadsheet more readable; these columns can be omitted and the conversions performed directly in the evaporation formula. Because pressure does not vary much, it is assumed constant at the theoretical value for 535 meters above sea level for this example. This could be replaced by measured pressure. Finally, the last two columns show the estimated potential evaporation from an open water body, one using the intermediate values, the other using direct conversions in the formula.

How to Install the Add-In

The evaporation formulas have been compiled into an Excel add-in for ease of use and for increased speed. The formulas should be available in the Insert=>Function menu under User Defined category. If they are not listed (look for PenmanET_Water), you need to install the add-in. Select the Tools=>Add-Ins menu item. If there is an Add-In available listed as "Evaporation using Modified Penman Method", the Add-In has been installed but not activated: check the appropriate box, choose OK, and it's installed. If the Evaporation Calculations Add-In is not listed, click on the Browse... button, find the Add-In as EVAPPNMN.XLA. Click on OK and it's installed and available.

Explanation of the Energy-Balance Formula

The derivation of energy balance formula used herein is described in detail in the Handbook of Hydrology, 1993 (Maidment, 1993) in Chapter 4 and is not repeated here. It is based on an energy balance at the water surface. According to Maidment (1993), the recommended equation for estimating PET is

$$E_p = \frac{\Delta}{\Delta + \gamma} (R_n + A_h) + \frac{\gamma}{\Delta + \gamma} \frac{6.43(1 + 0.536U_2)D}{\lambda} \text{ or, equivalently}$$

$$E_p = \text{Evaporation due to Radiation} + \text{Evaporation due to Dryness}$$

where

E_p is potential evapotranspiration in mm/day —**Function** PenmanET_Water

R_n is net radiation exchange for the free water surface expressed in mm/day (millimeters of water evaporated per day)

A_h energy advected into the water body expressed in mm/day, if significant

U_2 is windspeed measured at 2 meters in m/s

D is vapor pressure deficit in KiloPascals ($e_s - e_{\text{Observed}}$) (Saturated water vapor pressure at T - Observed water vapor pressure)—**Function** WaterVaporDeficit

$\lambda = 2.501 - 0.002361T$ is latent heat of vaporization at temperature T in MegaJoules/kilogram (T is measured in degrees Celsius)—**Function** Lambda

$\Delta = \frac{\partial e_s}{\partial T} \cong \frac{4098e_s}{(237.3 + T)^2}$ is the derivative of saturation vapor pressure of water with respect to temperature in KiloPascals/degree-Celsius (T is measured in degrees Celsius)—**Function** Delta

$e_s \cong 0.6108e^{\left(\frac{17.27T}{237.3+T}\right)}$ is the saturation vapor pressure of water in KiloPascals —**Function** SaturatedVaporPressureOfWater

$\gamma = 0.0016286 \frac{P}{\lambda}$ is the psychrometric “constant” in KiloPascals/degree-Celsius (P is the pressure in KiloPascals)—**Function** Gamma

If pressure is not measured, it should be calculated from altitude. using **Function** PressureFromAltitude

For daily net radiation R_n , use $R_n = 0.65 * R_{\text{Observed}}$ (or about two-thirds of the absorbed radiation.) For this formula, R_n and R_{Observed} are total daily values in any consistent units and. (This is based on empirical measurements reported in Jensen, Burman, and Allen, 1989). To convert energy in MegaJoules/(m² day) into (millimeters of water evaporated per day), divide by λ ($\frac{R[\text{J}/\text{day}]}{\rho_w[\text{kg}/\text{m}^3]\lambda[\text{J}/\text{kg}]}$ has units of meters per day.)

Other empirical relationships could be used for estimating net radiation from observed incident radiation. Users may wish to implement other estimates of net radiation themselves.

References

Maidment, D. R., 1993, Editor in chief of *Handbook of Hydrology*, McGraw-Hill, New York

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