II.5-CALB-EVAP CALIBRATION SYSTEM EVAPORATION AND EVAPOTRANSPIRATION ESTIMATES

Introduction

Evapotranspiration (ET) is the process through which water is lost to the atmosphere by evaporation from water, snow, plant and soil surfaces, and from vegetation by transpiration of water through plants. The two processes, evaporation and transpiration, are difficult to separate, so their effects are grouped together under the title evapotranspiration. However the consideration of the similarities and differences of the two processes is useful to better estimate representative values of potential evaporation (PE) for use in model calibrations.

Both evaporation and transpiration depend on vapor pressure differences between the air and the surfaces losing water. In calm air, vapor blankets form near air surface interfaces, suppressing water loss. Wind turbulence mixes the air of different levels, breaking up stratified moisture blankets causing evaporation to proceed at a rate that would be expected from shelter or station measurements of dew point depression. Thus evaporation and transpiration are similarly proportional to vapor pressure gradients and wind.

Both evaporation and transpiration require a source of moisture. Evaporation from dry concrete or dry soil is negligible, even though a large vapor pressure difference exists. Similarly transpiration from vegetation decreases as the soil in the root zone dries.

Moisture loss from open water is exclusively evaporation. The evaporation from a free water surface such as a very shallow lake is called potential evaporation (PE). The term, shallow lake, is used to avoid the problems connected with energy that goes into heat storage. Water is heated by absorbing energy, this energy is subtracted from the incoming energy that would otherwise be available for evaporation. PE and potential evapotranspiration (PET) are used almost interchangeably and both are often referenced by the abbreviation PE. To avoid confusion let PE in this discussion be limited to potential evaporation. Potential evaporation is considered to be the maximum rate at which water is expected to be lost from natural water surfaces (when heat storage effects can be ignored or when water temperature cycles are such that the net changes in temperature are negligible). This evaporation is very similar to the water loss from wet soils or from most adequately watered vegetation.

Transpiration differs from evaporation in that it is done by living plants and is therefore influenced by leaves which transfer moisture to the air and by root systems that extract soil moisture over a much deeper layer of soil than is involved in evaporation alone. Transpiration, however, tends to change as vegetation grows in size or maturity and is therefore influenced by seasonal changes in vegetation. Since it extracts moisture from a thicker layer of soil the transpiration process is affected by differences in the soil.

Because potential evapotranspiration is conceptually such a convenient term, workers in the field of soil water relations have tried to set a standard definition for potential evapotranspiration. For example there are some definitions of potential evapotranspiration which are given in terms of well-watered turf grass maintained at a specified height.

A basin covered by many lakes and marshes would primarily lose water by evaporation, whereas a basin that consists primarily of cultivated fields or orchards would lose water mainly by transpiration and water loss would tend to follow dormancy cycles of the vegetation. Deserts, on the other hand lose very little water by either method since evaporation from soil is confined to the upper few inches and desert vegetation, when it exists, generally transpires very slowly.

Conceptual Treatment of Evapotranspiration Losses

The primary input to water loss computations is PE which has been described in the preceding section. PE is largely independent of the influences of soils and vegetation. It usually computed from pan data using program DLYTRAN which is available at the Internet address http://dipper.nws.noaa.gov/hdsb/data/archived/index.html. When air and water temperatures information is available the pan evaporation is converted to potential evaporation (PE). This conversion is required because evaporation from a pan follows a somewhat different energy exchange process than does evaporation from lakes and vegetation. The Class A pan, which sits above the ground, exchanges energy through its sides and bottom as well as at the pan water surface.

Normal warm season evaporation can dry out soil surfaces very quickly, causing evaporation from bare soil to drop to a low value. The principal loss process then becomes the transpiration from plants which continues at a fairly high level so long as soil moisture is available in the root zone. To include this effect in our hydrologic model, a vegetative demand or transpirational demand curve is used. This curve is used to approximate mathematically the annual cycles of the dominant species of trees and plants on a basin where they actively transpire during the growing season and enter into a dormant cycle during the winter. In the dormant cycle plants transpire very little, even though weather and soil moisture conditions dictate a significant amount. During the period of dormancy, values on the demand curve may be as low as 0.1. During the spring values increase to 1.0 or more as trees leaf out and crops grow and develop. Some studies have suggested that when the leaf area index (area of leaves/horizontal soil surface) exceeds 3, the evapotranspiration can also rise above potential evaporation estimated using pan methods (Kristensen, 1974). The vegetative demand values are multiplied by the daily PE values to get a quantity, which is referred to as evapotranspiration demand (ED). The effect of soil moisture is taken into account in the soil moisture accounting model where actual evapotranspiration is computed.

Potential Transpiration Data Sources

Potential evaporation (PE) estimates used for input to the rainfall-runoff model are derived from observations obtained through use of the National Weather Service Class A pan or when pan data are not available from estimates derived from measurements of air temperature, humidity, wind and radiation, combined in an equation to give values similar to the pan measurements. These observations should conform to specifications described in National Weather Service Observing Handbook Number 2 'Substation Observations'.

Sources of PE estimates for calibrations are:

1. (a) Class A pan data is available from program DLYTRAN. These pan values are modified to PE by a method described by Kohler et al. (1955). This method requires a mean of daily air and pan water temperatures. The maximum and minimum temperatures required to compute these means are also available from program DLYTRAN.

   (b) If pan water temperature is not available PE can be generated from pan evaporation by a coefficient taken from NOAA Technical Report 'Evaporation Atlas of the Contiguous 48 States'.

   (c) If no other data are available rough estimates of PE values can be obtained by multiplying the pan data by a constant coefficient of 0.7.

2. Estimated Class A pan data and PE can be derived from observations of air temperature, dew point, wind speed and solar radiation (or an estimate of solar radiation based on percent sunshine or percent cloud cover). This data is available from the program SYNTRAN which is available at the Internet address http://dipper.nws.noaa.gov/hdsb/data/archived/index.html.

3. Long term monthly means tabulated in Climatological Data or the NOAA Technical Report 'Mean Monthly, Seasonal and Annual Pan Evaporation in the United States' (Farnsworth and Thompson, 1982).

4. A middle-of-the-month long term mean value can be generated from time series of pan data. The network of evaporation stations is adequate for determining mean basin PE in most non-mountainous areas. Reference to maps 2 and 3 in the previously mentioned NOAA Technical Report show the spatial variability of PE on a May-to-October and an annual basis. Reference to these maps should assist a user in relating the degree to which available data represent the area of a given basin. Peculiarities of mountainous areas such as canyons with northeastern aspects or drainage winds must be considered in choosing adjustment factors for PE values.

Note that PE is a daily estimate and techniques have not been developed to develop PE on any shorter time scales.

References

Kristensen, K. J., 1974: 'Actual Evaporation in Relation to Leaf Area', Nordic Hydrology 5, pp 173-182.

Kohler, M. A., T. J. Nordenson and W. E. Fox: 'Evaporation from Pans and Lakes', USWB Research Paper No. 38, May 1955.