Estimation of Mean Evaporation Patterns with Respect to Elevation

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Abstract

The monthly sums of potential evapotranspiration were calculated using the Penman method for the 25-year period from 1956-1980. Ten stations were selected covering the whole vertical range of Slovakia (Hurbanovo 115masl, Lomnicky stit 2,635masl). Mean courses of evapotranspiration in absolute terms were transformed to relative annual courses expressed in percentages of the annual sum. This transformation allows a comparison of the annual distribution in individual stations. The mean relative annual courses of potential evapotranspiration were approximated by a normal distribution curve. The parameters of the distribution x_m and σ were found to be linearly elevation-dependent. Linear regression equations were derived for their evaluation on a monthly basis. Modelled monthly values were compared to published data on potential evapotranspiration and evaporation from water surfaces. The same procedure was used for estimating long-term mean, daily potential evapotranspiration.

Introduction

Evaporation data are essential for many hydrological studies. The measuring of evaporation is included in the routines of some meteorological network stations, but typically these data are observed only in a few selected stations and only during vegetation season. Direct measurements of transpiration are carried out in experimental and research stations only (Molnar and Meszaros 1990). Therefore, the availability of evaporation and/or evapotranspiration data is very low, and other approaches to determine them have to be used.

In some case studies the annual distribution, i.e., the mean monthly values, of evaporation is needed in places where these data are not available (Mendel and Pekarova 1995). As the mean annual values are relatively easier to obtain (calculated or determined from maps), a simple method for approximating the annual patterns is needed, based on some easily available differentiating criterion. This study represents an attempt to find such a distribution with parameters dependent on elevation above sea level.

Monthly Evapotranspiration

The study is based on calculated monthly totals of potential evapotranspiration in ten stations of Slovakia for the 25-year period from 1956-1980. Ten stations were selected at different elevations to cover the whole vertical range of Slovakia. Results from the following three stations are used in this paper: the lowest station, Hurbanovo, at 115masl, Strbske Pleso at 1,330masl, and the highest one, Lomnicky stit, at 2,635masl.

The monthly values of potential evapotranspiration were calculated using the Penman equation (Novak 1989). Three selected stations are plotted in Figure 1. Mean courses of evapotranspiration in absolute terms were transformed to relative annual courses expressed in percentages of the annual sum. This transformation allows a comparison of the annual distribution in individual stations despite the great variation in absolute values. The relative courses in selected stations are given in Figure 2.

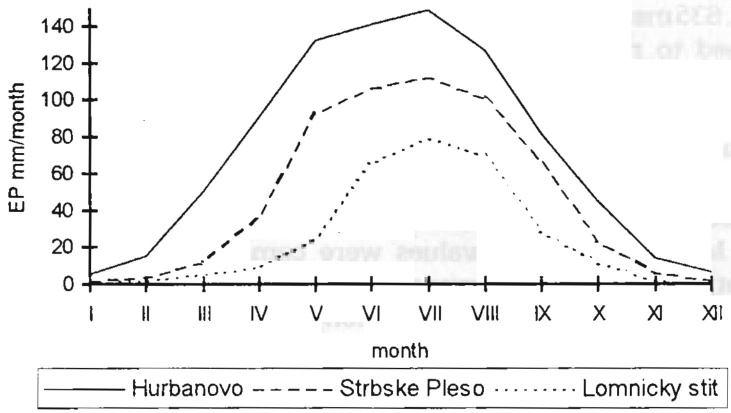

Figure 1: Annual Course of the Absolute Monthly Values of Potential Evapotranspiration in Selected Stations

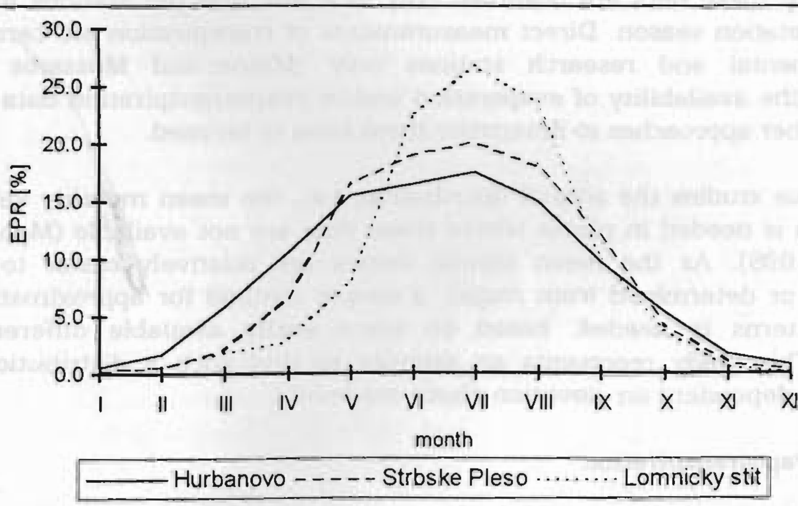

Figure 2: Annual Course of the Relative Monthly Values of Potential evapotranspiration in Selected Stations

For the approximation of the relative annual courses of long-term mean potential evapotranspiration, the equation, formally the same as that of the normal (Gauss-Laplace) distribution, has been chosen in the form:

$$EPR(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{\left(\frac{-(x-x_m)^2}{2\sigma^2}\right)} \qquad (1)$$

where,

EPR = relative potential evapotranspiration in %,

x = number of the month (x = 1, 2, ..., 12),

x_m = time of maximum EPR expressed in months (decimals allowed), and

σ = parameter controlling the shape of the curve (excess).

The best-fit values of x_m and σ have been found for all ten stations. Plotted on a graph, they proved to be elevation-dependent. This is shown in Figures 3 and 4 for both parameters. The dependence of these parameters on elevation is linear and can be exactly enough described by linear regression equations. The formulas found are as follows:

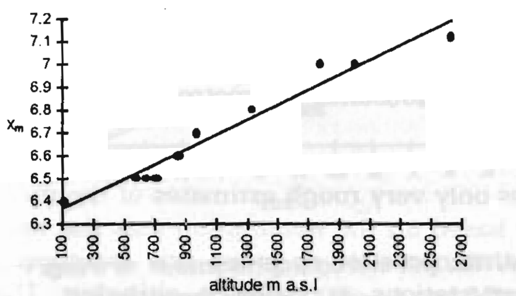

Figure 3: Altitudinal Dependence of the Parameter x_m for Ten Station

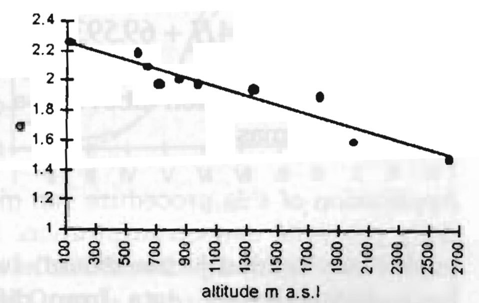

Figure 4: Altitudinal Dependence of the Parameter σ for Ten Stations

$$x_m = 0.324H + 6.336 \qquad (2)$$

$$\sigma = -0.298H + 2.288 \qquad (3)$$

where,

H = elevation above sea level in thousands of metres (H = 1 for 1,000masl).

Knowing the elevation of the station, and using formulas (2) and (3), one can obtain the seasonal variations of evaporation in relative terms by applying equation (1). The absolute values of evaporation in individual months can be obtained if the annual total or its estimate is known. In such a case, the following equation can be used:

$$EPM(x) = EPR(x)EP \quad (4)$$

where,
EPM = modelled monthly evaporation in mm/month, and
EP= Total annual evaporation in mm/year.

The presented method was developed as a simple tool for modelling or approximation of the long-term average monthly potential evapotranspiration at different elevations. The only input data are the elevation of the station and the estimate of the total annual potential evapotranspiration or evaporation for the station.

Daily Evapotranspiration

The same procedure and adopted equations (1) and (4) can be used for estimation of long-term mean daily potential evapotranspiration or evaporation with different values of parameters x_m and σ. Then the regression equations for estimation of the parameters at different altitudes will be in the following form:

$$x_m = 10H + 183 \quad (5)$$

$$\sigma = -9.064H + 69.593 \quad (6)$$

where,
H = elevation above sea level in thousands of metres (H = 1 for 1,000masl).

Application of this procedure can give us only very rough estimates of the mean daily potential evapotranspiration. It is based on the assumption that the daily values are normally distributed. It was not possible to prove this assumption because of lack of data from different stations at different altitudes. This approach can be useful in some hydrological studies, e.g., in mathematical modelling when estimating the input long-term mean daily potential evapotranspiration and/or evaporation. The type of result we can expect is illustrated in Figure 5, showing the estimated daily potential evapotranspiration in a station with the mean annual potential evapotranspiration EP equal to 700mm.

Conclusions

Comparison of the computed monthly evaporation and the modelled one using equations (1) to (4) confirmed the applicability of the method on data used for the study (Fig. 6). The comparison with data published by other authors allows one to conclude that the method is suitable for approximation of the mean monthly potential evapotranspiration or evaporation (Fig. 7) from water surfaces at various altitudes, in Slovakia, in relative terms and also in absolute terms with the assumption that the annual total is determined independently.

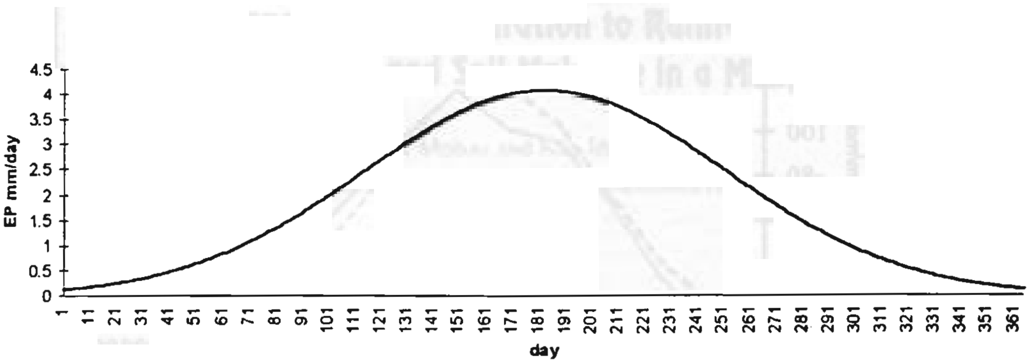

Figure 5: The Estimated Mean Long-term Daily Potential Evapotranspiration in a Station with the Mean Annual Potential Evapotranspiration (EP) Equal to 700mm

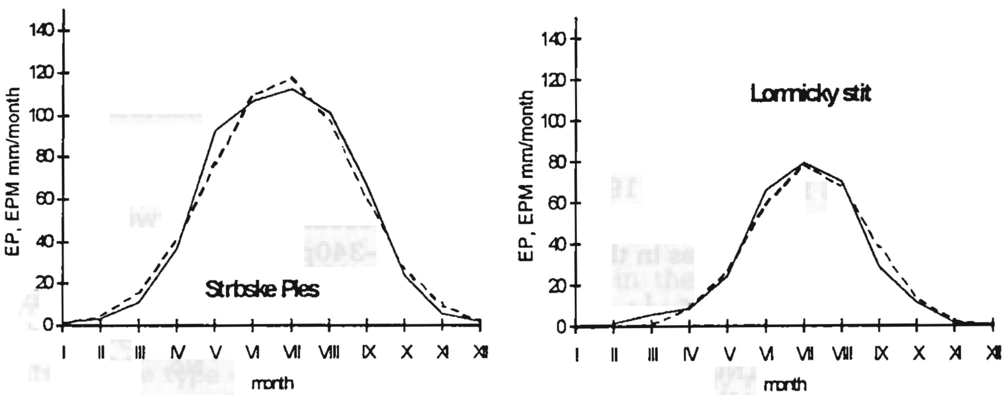

Figure 6: Comparison of the Actual Values of the Mean Monthly Potential Evapotranspiration (———) and Modelled Ones (- - - - -) for Selected Stations

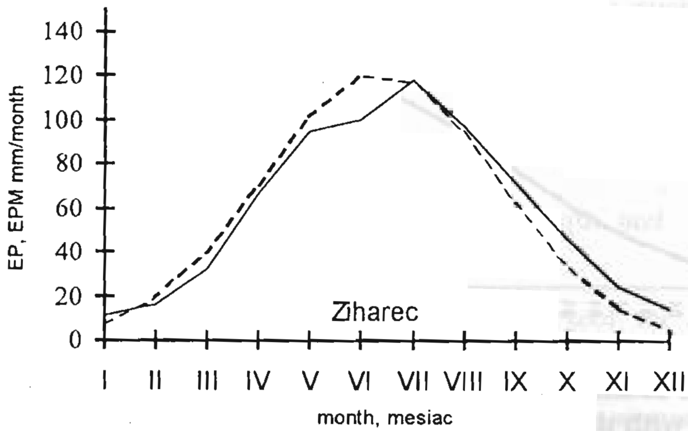

Figure7: Comparison of the Value of the Mean Monthly Evaporation Taken from the Water Table Published by Gavenciak (1970) (——) and Modelled Ones in Ziharec (- - - - -)

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