ACTUAL EVAPOTRANSPIRATION, POTENTIAL EVAPOTRANSPIRATIONAND EVAPORATION FROM THE GGI-3000 AT SELECTED STATIONS OF SLOVAKIA

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The work brings the results of model computation of actual and potential evapotranspiration as well as evaporation measurements from the GGI-3000 pan (evaporimeter) at 4 selected stations of Slovakia for the period 1971-2000. Model computation of monthly totals of actual and potential evapotranspiration was performed by common solution of energy and water balance equations of the top one-meter layer of the soil. The model outputs are compared to the measurement data. Linear regression dependence of the ratio of evaporation from GGI-3000 and actual evapotranspiration totals on relative evapotranspiration with high correlation coefficient was found for the station Bratislava, Koliba.
Key words: monthly totals, evaporation, GGI-3000 pan (evaporimeter), potential evapotranspiration, actual evapotranspiration.

Introduction

Evapotranspiration from arbitrary surface depends on a whole range of factors, from which the total radiation balance of evaporating surface, volume of water in soil and plants and turbulent situation of the atmosphere are the most important ones. Total radiation balance (the difference between global radiation absorbed by evaporating surface and the balance of long-wave radiation) is denoted by the sun altitude, geografic latitude, altitude above sea level, cloudiness, volume of water vapour and solid particles in atmosphere, temperature of air and active surface and surface albedo. Turbulent flow of water vapour from the surface to the atmosphere is denoted by its vertical gradient and wind field above evaporating surface (Tomlain, J., 2000). The submitted work brings results of processing of evaporation measurements by means of the GGI-3000 pan at 4 climatologic stations: Boľkovce, distr. Lučenec (φ= 48°20´ N, λ=19°44´ E, H=214 m a. s. l.), Bratislava, Koliba (φ= 48°10´ N, λ=17°07´ E, H=286 m a. s. l.), Kamenica nad Cirochou (φ= 48°56´ N, λ=22°00´ E, H=178 m a. s. l.) and Somotor (φ= 48°24´ N, λ=21°49´ E, H=100 m a. s. l.) for the period 1971-2000.

Method

The Department of Astronomy, Physics of the Earth and Meteorology, Faculty of Mathematics, Physics and Informatics of Comenius University in Bratislava has developed a mathematic-physical model for estimation of energy balance equation components (total radiation balance and its components, potential and actual evapotranspiration, sensible heat flux). This model is based on a common solution of energy and water balance equations (Budyko, 1978). The input data are: air temperature and humidity, cloudiness, number of days with snow cover and precipitation, i.e. meteorological elements regularly measured in the network of meteorological stations in Slovakia. Because the cloudiness plays an important role in the model calculations, all the cloudiness monthly data have been tested for homogeneity and homogenized using sunshine duration measured data. The time series of the monthly potential evapotranspiration totals (E_o) are denoted by the equation of water vapour diffusion in the atmosphere:

$$E_o = \rho D (q_s - q_2) \quad (1)$$

where ρ is the air density, D - integral diffusion coefficient, q_s - saturated specific humidity at the temperature of evaporating surface and q_2 - specific humidity in meteorological shelter. The actual evapotranspiration is supposed to be proportional to the potential evapotranspiration as follows:

$$E = E_o \frac{\overline{W}}{W_o}, \quad (2)$$

the storage $\overline{W}$ is specified as the moisture stored in the upper soil layer one meter deep, W_o is the critical value above which E equals E_o. The average soil moisture $\overline{W} = (W_1 + W_2)/2$ is determined from the water balance equation by the method of step-by-step approximation (W_1 is the moisture stored in the soil at the beginning of the month and W_2 at the end). The W_o usually represents a layer of 100 to 200 mm water with seasonal and regional variations (Hrvoľ, J., Lapin, M., Tomlain, J., 2001).

Evaporation from a free water surface E_v – is measured by means of GGI-3000 pan daily at 7 o'clock (water temperature is measured 3 times a day) in days without frost (since the 1st of April to 31st of October). Some data of evaporation monthly totals mainly in April, July and October were missing. They had to be completed on the basis of linear regression relation between the ratio of E/Ev and relative evapotranspiration E/E_o. Data with completed values are printed in bold.

Results

The monthly evaporation otals as well as totals of actual and potential evapotranspiration from April to October for the period 1971-2000 are introduced in Tables 1-4. The maximum mean monthly totals of evaporation and potential evapotranspiration occur at all the stations in July, minimum ones in October. The greatest mean monthly value of E_o was computed for Somotor 127.6 mm. Stations Bratislava, Koliba and Boľkovce have nearly the same maximum mean total 126.6 and 126.2 mm, respectively. Actual evapotranspiration at these stations in July differs due to soil moisture. Relative evapotranspiration reaches at station Bratislava, Koliba 56% and at Boľkovce 63%. From these stations, Kamenica nad Cirochou has the greatest value of actual evapotranspiration 86.6 mm in July, Somotor has the smallest one (54,7 mm). The maximum monthly totals of actual evapotranspiration in annual course are computed at stations Boľkovce (83.8 mm) and Kamenica nad Cirochou (87.0 mm) in June, at station Bratislava, Koliba (80.9 mm) and Somotor (82.6 mm) in May. In the period of measurements from April to October, the greatest mean total of actual evapotranspiration was estimated in Kamenica nad Cirochou (452.6 mm), the smallest one in Somotor (392.7 mm). The relative evapotranspiration for the period from April to October at station Kamenica nad Cirochou is expressly higher (78%) than at the other stations where it moves about 62-63%. The greatest mean value of evaporation for the worked out period was measured at station Bratislava, Koliba (537 mm), the smallest one (477 mm) at station Kamenica nad Cirochou, i.e. at the station with the smallest total of potential evapotranspiration. The long-term course of potential and actual avapotranspiration as well as evaporation totals for the period from April to October is in Figures 1, 3, 5 and 7. We can see that the curves of potential evapotranspiration and evaporation totals have similar course. The ratio of evaporation and potential evapotranspiration totals for the whole period moves from 81% at Somotor to 85% in Bratislava, Koliba. The actual evapotranspiration totals are at most smaller than evaporation from the GGI-3000. From Figures 2, 4, 6 and 8 we can determine the value of relative evapotranspiration in % when actual evapotranspiration total for the whole period reaches the evaporation total from the GGI-3000. These values are at stations, Boľkovce, distr. Lučenec 79%, Bratislava, Koliba 79%, Kamenica nad Cirochou 80% and at Somotor 77%. A comparison between

Table 1. Monthly totals of actual (E) and potential evapotranspiration (Eo) as well as evaporation from the GGI-3000 (Ev) in mm at station Boľkovce, distr. Lučenec since April till October for the period 1971-2000 and their ratio in %

Month	4	5	6	7	8	9	10	4-10
Eo [mm]	71.3	101.5	114.2	126.2	110.8	70.3	35.5	629.9
E [mm]	52.4	77.6	83.8	79.1	54.4	33.4	18.5	399.3
Ev [mm]	**52.9**	79.0	89.5	107.8	97.0	61.5	**36.5**	**524.3**
E/Eo [%]	73.5	76.5	73.4	62.7	49.1	47.4	52.2	63.4
Ev/Eo [%]	**74.2**	77.8	78.4	85.4	87.6	87.5	**102.8**	**83.2**
E/Ev [%]	**99.1**	98.3	93.6	73.4	56.0	54.2	**50.7**	**76.2**

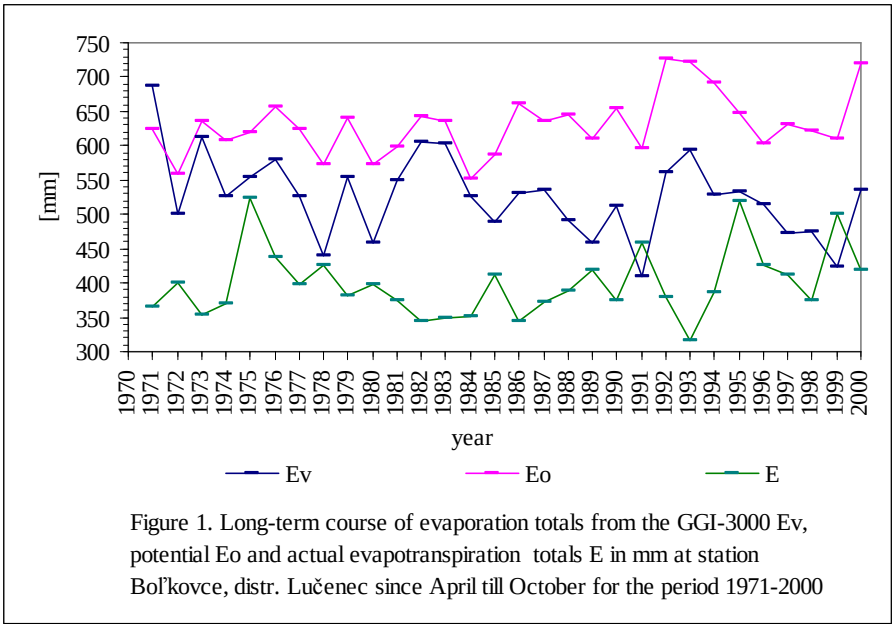

Figure 1. Long-term course of evaporation totals from the GGI-3000 Ev, potential Eo and actual evapotranspiration totals E in mm at station Boľkovce, distr. Lučenec since April till October for the period 1971-2000

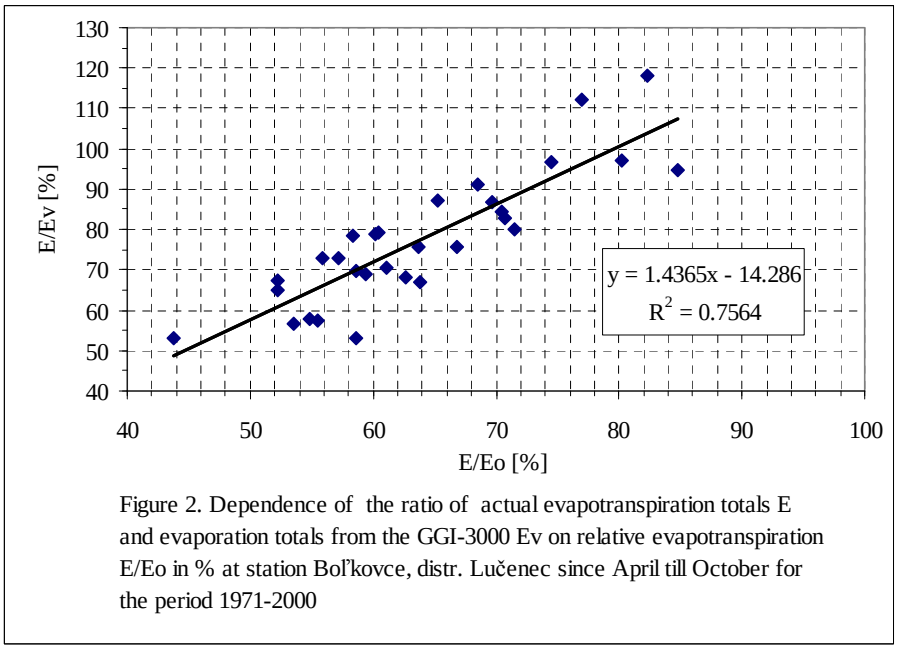

Figure 2. Dependence of the ratio of actual evapotranspiration totals E and evaporation totals from the GGI-3000 Ev on relative evapotranspiration E/Eo in % at station Boľkovce, distr. Lučenec since April till October for the period 1971-2000

Table 2. Monthly totals of actual (E) and potential evapotranspiration (Eo) as well as evaporation totals from the GGI-3000 (Ev) in mm at station Bratislava, Koliba since April till October for the period 1971-2000 and their ratio in %

Month	4	5	6	7	8	9	10	4-10
Eo [mm]	71.3	105.2	112.7	126.6	113.2	70.1	36.3	635.3
E [mm]	58.2	80.9	75.4	71.5	54.9	37.7	22.6	401.2
Ev [mm]	**56.3**	82.3	94.6	107.7	101.5	59.8	**35.0**	**537.2**
E/Eo [%]	81.6	76.9	66.9	56.5	48.5	53.8	62.3	63.1
Ev/Eo [%]	**79.0**	78.2	84.0	85.1	89.7	85.3	**96.3**	**84.6**
E/Ev [%]	**103.3**	98.3	79.7	66.4	54.1	63.0	**64.7**	**74.7**

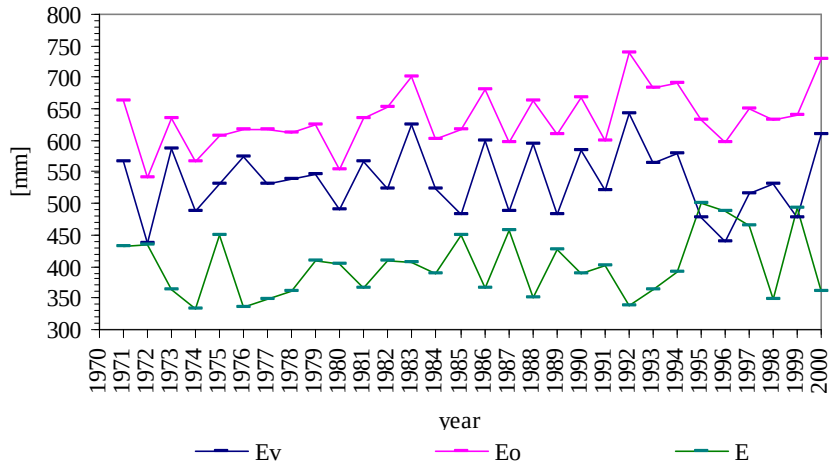

Figure 3. Long-term course of evaporation totals from the GGI-3000 Ev, potential Eo and actual evapotranspiration totals E in mm at station Bratislava, Koliba since April till October for the period 1971-2000

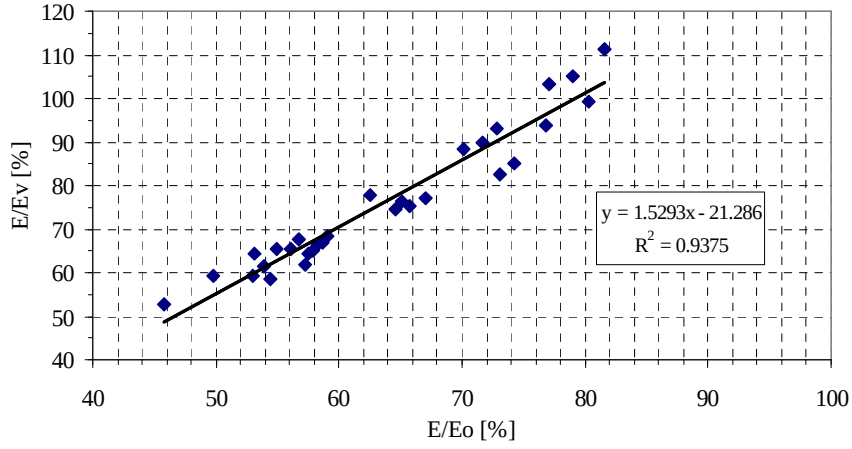

Figure 4. Dependence of the ratio of actual evapotranspiration totals E and evaporation totals from the GGI-3000 Ev on relative evapotranspiration E/Eo in % at station Bratislava, Koliba since April till October for the period 1971-2000

Table 3. Monthly totals of actual (E) and potential (Eo) evapotranspiration as well as evaporation totals from the GGI-3000 (Ev) in mm at station Kamenica nad Cirochou since April till October for the period 1971-2000 and their ratio in %

Month	4	5	6	7	8	9	10	4-10
Eo [mm]	67.0	97.3	106.8	114.0	99.4	60.3	33.6	578.4
E [mm]	54.6	83.1	87.0	86.6	71.7	43.7	26.0	452.6
Ev [mm]	**54.6**	76.5	82.8	90.4	82.4	53.5	36.5	**476.7**
E/Eo [%]	81.4	85.4	81.4	76.0	72.1	72.5	77.3	78.2
Ev/Eo [%]	**81.5**	78.6	77.5	79.3	82.9	88.8	108.6	**82.4**
E/Ev [%]	**99.9**	108.6	105.1	95.8	86.9	81.6	71.1	**94.9**

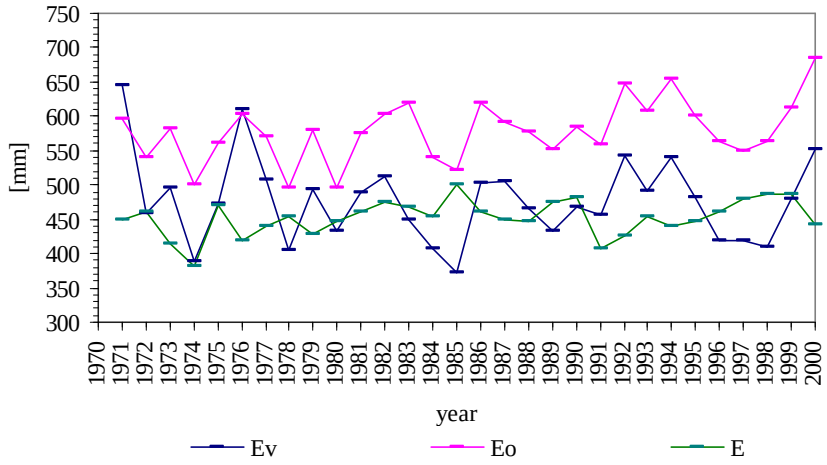

Figure 5. Long-term course of evaporation totals from the GGI-3000 Ev, potential Eo and actual evapotranspiration totals E in mm at station Kamenica nad Cirochou since April till October for the period 1971-2000

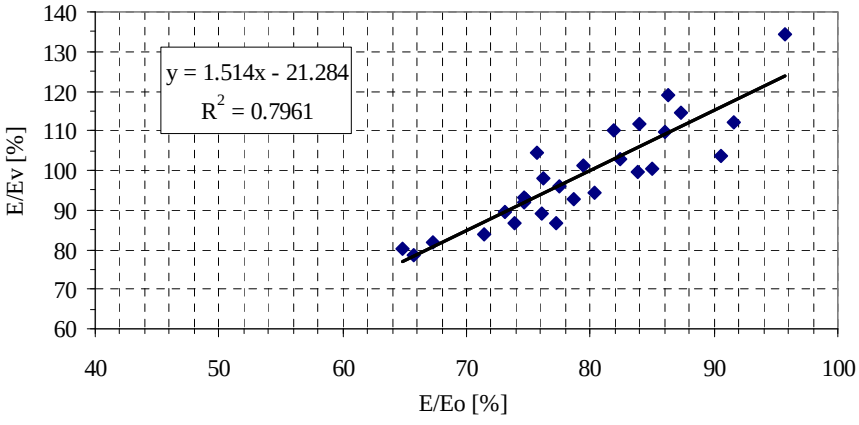

Figure 6. Dependence of the ratio of actual evapotranspiration totals E and the evaporation totals from the GGI-3000 Ev on relative evapotranspiration E/Eo in % at station Kamenica nad Cirochou since April till October for the period 1971-2000

Table 4. Monthly totals of actual (E) and potential evapotranspiration (Eo) as well as evaporation from the GGI-3000 (Ev) in mm at station Somotor since April till October for the period 1971-2000 and their ratio in %

Month	4	5	6	7	8	9	10	4-10
Eo [mm]	71.9	108.6	118.5	127.6	108.7	68.1	33.8	637.3
E [mm]	54.5	82.6	78.0	69.8	52.9	35.6	19.3	392.7
Ev [mm]	**58.7**	80.7	89.5	**100.0**	91.9	59.8	**38.5**	**519.0**
E/Eo [%]	75.8	76.1	65.8	54.7	48.7	52.3	57.0	61.6
Ev/Eo [%]	**81.6**	74.3	75.5	**78.3**	84.6	87.8	**113.8**	**81.4**
E/Ev [%]	**92.9**	102.4	87.1	**69.8**	57.5	59.6	**50.1**	**75.7**

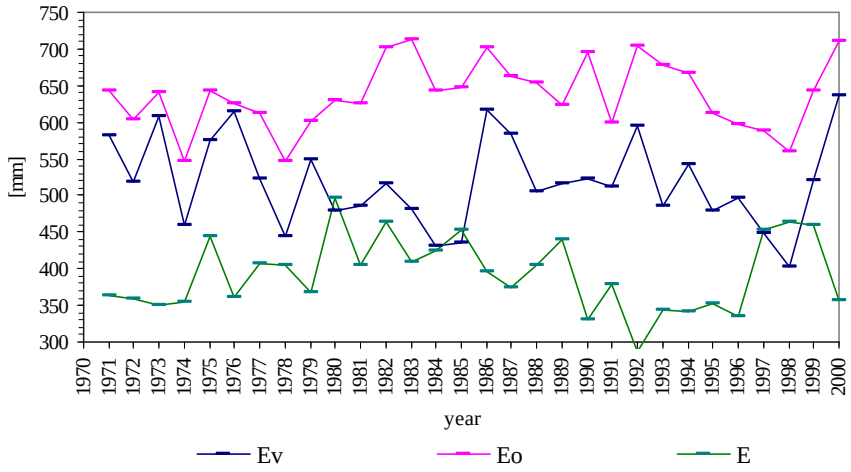

Figure 7. Long-term course.of evaporation totals from the GGI-3000 Ev, potential Eo and actual evapotranspiration totals E in mm at station Somotor since April till October for the period 1971-2000

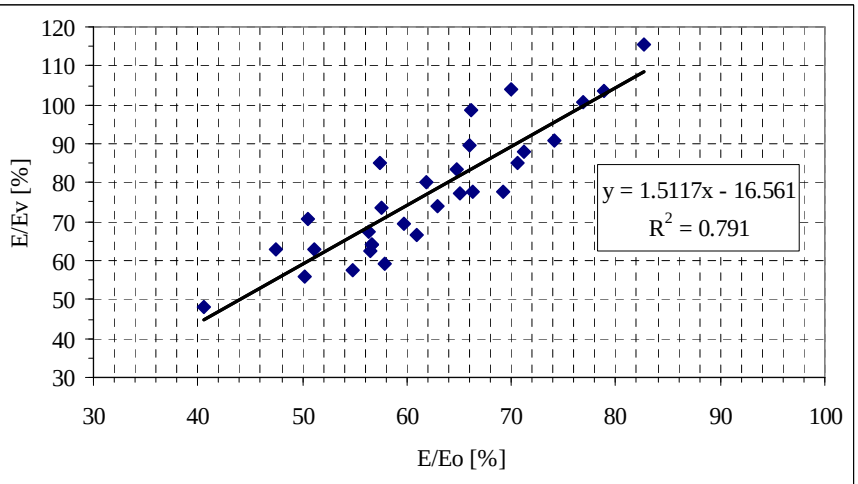

Figure 8. Dependence of ratio of actual evapotranspiration totals E and evaporation totals from the GGI-3000 Ev on relative evapotranspiration E/Eo in % at Somotor since April till October for the period 1971-2000

computed potential evapotranspiration totals and measured higher values of evaporation totals from the GGI-3000 pan at stations Boľkovce, district Lučenec and Kamenica nad Cirochou in year 1971 (Kamenica nad Cirochou also in year 1976) hints at probably incorrect measurements in that year.

Conclusion

1. The linear regression dependence of the ratio of evaporation and actual evapotranspiration totals on relative evapotranspiration for the period 1971-2000 from April till October with the high coefficient of correlation at all the worked out stations, especially at station Bratislava, Koliba was estimated.
2. Values of relative evapotranspiration totals for the whole period (April-October), when actualy evapotranspiration from the earth surface reaches evaporation totals from the GGI-3000, move from 77% at Somotor to 80% at Kamenica nad Cirochou.

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