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Estimation of the Annual and Interannual Variation of Potential Evapotranspiration

Georgeta Bandoc

University of Bucharest, Department of Meteorology and Hydrology
Center for Coastal Research and Environmental Protection
Romania

1. Introduction

Knowledge of ecological factors for all natural systems, including human-modified natural systems, is essential for determining the nature of changes in these systems and to establish interventions that must be achieved to ensure optimal functioning of these systems.

The purpose of this chapter is to identify annual and interannual variations of potential evapotranspiration, in conjunction with climate changes in recent years, on the coastal region of Sfântu Gheorghe – Danube Delta. Under natural conditions, evapotranspiration flows continuously throughout the year, representing a main link in the water cycle and an important heat exchange factor affecting ecosystems. Potential evapotranspiration is the maximum amount of water likely to be produced by a soil evaporation and perspiration of plants in a climate.

Real balance between the amount of precipitation fallen named P and the amount of water taken from the atmosphere as vapour, called potential evapotranspiration PET is of particular importance in characterizing climate, representing an expression of power absorption by the atmosphere and expressing quantity water on soil and vegetation that request (Henning & Henning, 1981).

The difference between precipitation (P) and potential evapotranspiration (PET), i.e. $P - PET$ known as ΔP is denoted by excess precipitation to PET (E) or deficit of precipitation to PET (D) if the difference is positive or, respectively, negative. The intensity of water loss through evaporation from the soil or by transpiration from the leaf surface is largely determined by vapour pressure gradient, i.e. the vapour pressure difference between leaf and soil surface and atmospheric vapour pressure (Berbecel et al, 1970).

The vapour pressure gradient is determined, in turn, by the characteristics of air and soil factors, such as: radiant energy, air temperature, vertical and horizontal movements of the air saturation deficit, the degree of surface water supply evaporation, plant biology and soil characteristics.

Heat factor also has a significant influence on evapotranspiration as temperature, on one hand, intensify of water vapour increases and, on the other hand, increases air capacity to maintain water vapour saturation state, reducing atmosphere's evaporated power (Eagleman, 1967).

2. General issues related to estimate

Potential evapotranspiration evidence and interannual variations of *PET* potential evapotranspiration and water balance, climate charts are used based on measurements from weather stations hydrothermal (Walter & Lieth, 1960; Walter, 1955, 1999; Köppen, 1900, 1936 etc.).

In 2005, Oudin et al. compile lists 25 methods for estimating potential evapotranspiration based on a series of meteorological parameters (Douglas et al, 2009).

Estimation of potential evapotranspiration can be done using the indirect method based on air temperature readings and diagrams and on Thornthwaite's tables (Thorntwaite, 1948; Donciu, 1958; Walter & Lieth, 1960).

Recent studies use Penman's equation for this purpose, Penman (Penman, 1946), Penman - Monteith (Thomas, 2000a, 200b; Choudhury, 1997; Allen et al., 1998; Chen et al, 2005). Also, in determining the potential evapotranspiration, other formulas have been used with results almost similar with the ones of direct measurements, such as formulas of Bouchet (Bouchet, 1964), Turc (Turc, 1954), Hargreaves (Hargreaves & Samani, 1982), Papadakis (1966), Hamon (1963), Priestley – Taylor (1972), Makkink (1957) (Lu et al, 2005) and Blaney-Criddle (1950) (Ponce, 1989).

Potential evapotranspiration *PET* is of great temporal variability and thus an estimation can be done based on heat and water vapour from the atmosphere (Dugas et al, 1991; Celliar and Brunet, 1992; Rana & Katerji, 1996; Droogers at al, 1996; Frangi et al, 1996; Linda et al, 2002 as cited in Chuanyan et al, 2004).

Another model of estimation for *PET* is based on soil moisture and rainfall (model Century) (Metherell et al 1992; Zhou et al, 2008 as cited in Liang et al, 2010). On the interaction of global precipitation and air temperature estimates can be done for potential evapotranspiration (Raich & Schlesinger, 1992; Buchmann, 2000; Andréassian et al, 2004; Li et al, 2008a, 2008b; Casals et al, 2009).

Estimation of potential evapotranspiration can be achieved also based on satellite measurements related to air humidity and wind characteristics, but only in case of high-resolution satellite images (Irmak, 2009).

In the estimation of *PET* remote sensing methods are applied (Chaudhury, 1997; Granger, 1997; Stefano & Ferro, 1997; Caselles et al, 1998; Stewarta et al, 1999). These methods are based using geographic information system using GIS spatial modeling (Baxter et al, 1996; Srinivasan et al 1996; Moore, 1996; Cleugh et al, 2007, Tang et al, 2010).

Other studies use numerical modeling to simulate various weather variables in a particular location, variables used to calculate potential evapotranspiration (Kumar et al, 2002; Smith et al, 2006; Torres et al 2011).

3. Research on characteristics of coastal area of potential evapotranspiration

The location where this study has been made is the south-east of Salt and marine field is bordered by the Black Sea coast in the east, marine low deltaic plain in the west and north-west and the arm of Sfântu Gheorghe –Danube Delta (fig. 1). To the south of arm of Sfântu Gheorghe is the marine plain Dranov , Sfântu Gheorghe secondary delta and Sacalin Island. In the context of global climate change, interannual evolution analysis, annual and multiannual magnitudes that characterize the climate of a region are of particular interest (Palutikov et al, 1994; Chattopadhyay et al, 1997; Kouzmov, 2002; Oguz et al, 2006). This interest increases when it is a coastal region where sea atmosphere - interactions induce very specific issues.
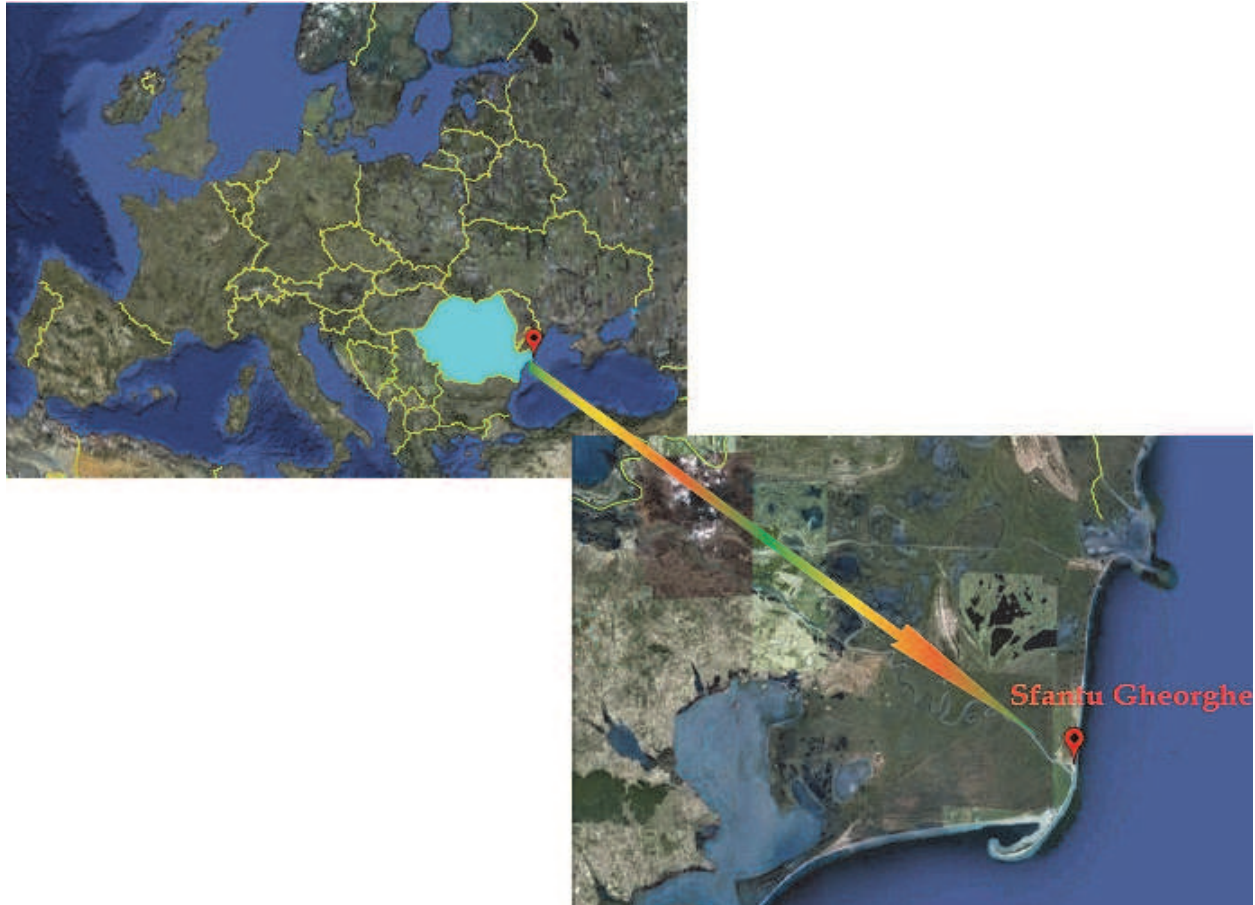
Fig. 1. Study area location

The Danube Delta combines the temperate semi-arid climate space typical for the Pontic steppes. The aquatic very wide plane spaces, differently covered by vegetation and intrerrupted by the sandy islands of the marine fields, make up an active area specific to the delta and to the adjacent lagoons but totally different from that belonging to the Pontic stepps. This active area reacts upon the total radiation intercepted by the general circulation of atmosphere, resulting in a mosaic of microclimates (Vespremeanu, 2000, 2004).

For determining how climate changes affect the interannual potential evapotranspiration in the Sfântu Gheorghe costal area it was started, primarily from the fact that PET potential evapotranspiration has strong fluctuations in time and space as a direct consequence of the variation factors leads. Thus, in order to achieve the intended purpose of this chapter, interannual and annual potential evapotranspiration values were determined according to Thornthwaite's method, both for the period 1961 - 1990, taken as a reference period and analyzed for the studied period 2000 - 2009. Interannual differences $P - PET$ as well as annual amounts of the differences of the same sign, $\sum(P - PET)^{+}$ and $\sum(P - PET)^{-}$ as well as the annual review, are important climatic indicators. The determination of the efficiency of precipitation was done by calculating the difference $P - PET$ taken as reference period 1961 - 1990 and for the period under study from 2000 to 2009. Positive differences indicate excess water from rainfall, water shortages $\sum \Delta P^{+}$ and the negative ones indicate deficit of precipitation, water requirements from the atmosphere $\sum \Delta P^{-}$.

It was also determined the precipitation deficit offset by previously accumulated surpluses and deficits of precipitation uncompensated by previous surpluses.

To identify climate changes in coastal Sfântu Gheorghe area and deviations from the average annual values of air temperature and precipitation, diagrams were drawn, type Walter and Leith, to identify dry periods and also different indices and specific factors were calculated such as: Martonne arid index (I_{ar}), retention index offset (I_{hc}), the amount of rainfall in the period with t ≥ 10 ° C temp ($P_{t \geq 10^0 C}$) rainfall amount of soil loading in the months from November to March (P_{XI-III}), the amount of summer rainfall in July and August ($P_{VII-VIII}$), Lang precipitation index for the period with t ≥ 10 ° C ($L_{t \geq 10^0 C}$), precipitation index for summer Lang ($L_{VI-VIII}$) and Lang precipitation index for spring season (L_{III-V}) and annual and interannual precipitation deficits (D) and excess (E) respectively , comparing to potential evapotranspiration of 10 mm, 20 mm, 30 mm etc. These indices and ratios were calculated based on meteorological measurements for the period 1961 - 1990, taken as a reference period for the 2000 - 2009 period under study. In this chapter, climate charts are playing an important role in the knowledge of the climate changes in the studied area and also helps in determining the precipitation – evapotranspiration, and hence the temperature deficit or surplus in the form of precipitation from evapotranspiration. Dryness site layout is determined in this study. Curve surplus or deficit of precipitation from evapotranspiration is crucial in environmental hydrothermal annual and interannual knowledge of an area.

Climate chart includes curved surfaces and values of temperature, precipitation at the scale 1/5 and 1/3 and potential evapotranspiration after Thornthwaite, interannual, annual and for certain periods (the amount of rainfall during the period from November - March, yet soil load, and the summer period July - August). The diagram also contains interannual surpluses and deficits and total rainfall to *PET*, the deficits in compensated and uncompensated previous surpluses, Walter - Lieth dry period, the annual aridity index, retention index offset, Lang rainfall index, calculated for the period temperature $t \geq 10^0 C$, for summer and spring time.

At the bottom of the chart months of the year and intra-annual valu*es* ΔP are indicated to express the character of moisture or dryness of the climate in different months, the monthly differences in classification categories *E* and *D* for each 10 mm, 20 mm, 30 mm etc. On the diagram, for 1 degree of temperature correspond 5 mm, 3 mm respectively of precipitation. Scale 1/5 was chosen in order to maximally achieve principle of the rainfall curve to be above the temperature when precipitation *PET* outperforms, and below it, when *PET* exceeds precipitation. Scale 1/3 was chosen to determine the dry period after the Walter - Lieth, which lasts as long as the rainfall curve is well below that of temperature.

It is important to know to what extent and interannual deficit of precipitation to *PET* during the growing season is offset by the surplus of precipitation to *PET* during the loading of the soil with water from precipitation (late autumn - winter). In this way deficit or surplus annual and interannual of effective precipitation is obtained comparing to *PET*.

In case of no loss of water through surface runoff and water infiltration or gains, the excess water is retained during loading or accumulated in the soil, and it is called full hydrologic soil (Chiriță et al, 1977).

The entire accumulated surplus of precipitation is the main reserve of soil water in the vegetation is gradually consumed and evapotranspiration together with new fallen rains (Donciu, 1983).

For the studied area, where the climate is characterized by periods of dryness, the water reserve accumulated in the soil is gradually depleted by evapotranspiration and biomass formation. This last amount of water should be considered as an element of water balance, important in the quantitative ratio (Chiriță et al, 1977).

Until finishing the accumulated precipitation of the soil in each month, water loss through evapotranspiration and precipitation is compensated by the previous reserve accumulation. Once this reserve is ended, precipitation deficit starts for the area studied. Evapotranspiration consumes current rainfall, leaving an additional demand of the atmosphere, dissatisfied with the precipitation.

The deficit of precipitation in this period presents the quantitative nature of PET's dry climate and soil and thus the existence of a period of severe water available to vegetation.

4. Results and discussion

The analysis of average monthly PET value as obtained for Sfântu Gheorghe, was a functional correlation of these values with the mean monthly air temperature T (Bandoc & Golumbeanu, 2010). For both analyzed periods, the correlations are straightforward.

From the calculation of correlation coefficient r and determination coefficient r^2 between potential evapotranspiration air temperature values of this coefficient $r = 0,98$, $r = 0,97$ and $r^2 = 96,04\%$, $r^2 = 94,04\%$ resulted, for the reference period 1961 - 1990 and for 2000 - 2009 period under study (fig. 2).

From the climate charts made for coastal Sfântu Gheorghe area (fig. 2, fig. 3, fig. 4, fig. 5, fig. 6, fig. 7, fig. 8 and fig. 9) for the analyzed periods, the result is a series of changes comparing to the duration of dryness reference interval 1961 - 1990.

Analizing the data the drought period for 2000-2009 was found to be 7 months which compared to the reference 1961-1990 (average drought) period of 6 months shows a increase of one month of drought per year.

Arid annual index Martonne calculation to determine the ratio between the amount of rainfall and temperatures $\left(I_{ar} = \dfrac{P}{T + 10} \right)$ showed that for the period 2000 - 2009, there was a decrease in the value of the index with 17,71 % which leads to increased awareness of dryness for the studied area (fig. 10).

Rain index called Lang index or Lang factor of the period with temperatures $\geq 10\ ^0C$ ($L_{t \geq 10^0 C}$), spring (L_{III-V}) and summer ($L_{VI-VIII}$) determined as a ratio of the average monthly precipitation values and P values of monthly average air temperature $T \left(L = \dfrac{P}{T} \right)$.

The results obtained for these intervals revealed that the index $L_{t \geq 10^0 C}$ values decreased by 20,22 % for the period with t $\geq$ 10 ^{0}C, for spring period L_{III-V} rainfall index fell 26,05 %, while during the summer $L_{VI-VIII}$ value of this index was 37,20 % compared to the reference period 1961 - 1990 (fig. 10).

Offset fluid index $\left(I_{hc} = \dfrac{\sum \Delta P^+}{\sum \Delta P^-}\right)$ expresses the extent of precipitation deficits are

compensated by the surpluses. Values lower than the 1 $\left(I_{hc} \leq 1\right)$ expressed precipitation deficits unabated. Following determination of the index for the two periods analyzed, that index values are 0,24 for the reference period 1961 - 1990 and 0,15 for the period 2000 - 2009. From the two values determined using the formula (0,24 and 0,15), for the past 10 years interval, results that the fluid compensation index decreased by 37,5 % compared to the reference period 1961 - 1990.
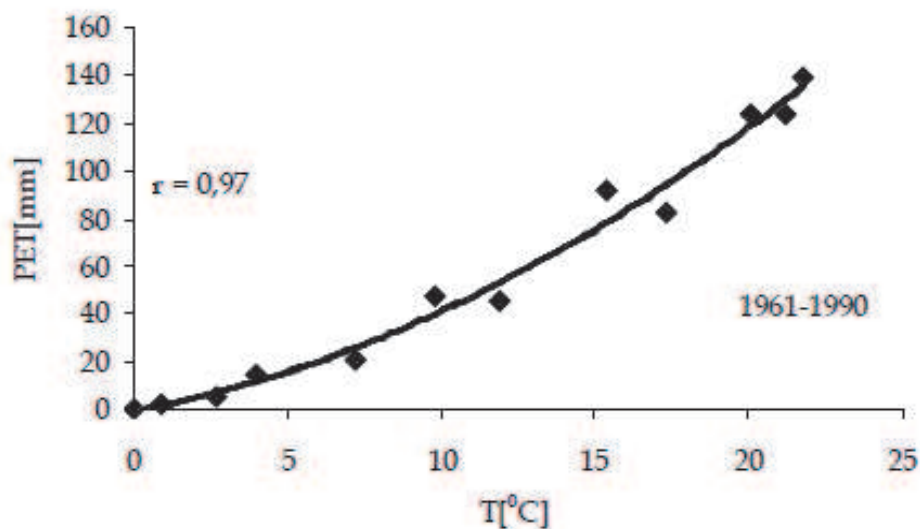

Fig. 2. Correlation between the potential evapotranspiration *PET* and air temperature *T* in the coastal region Sfântu Gheorghe for reference period 1961 - 1990
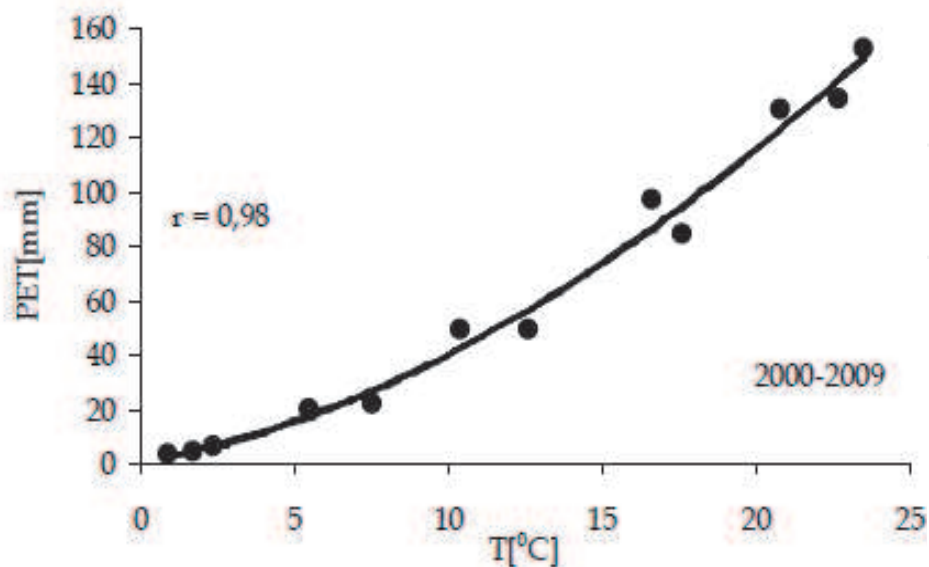

Fig. 3. Correlation between the potential evapotranspiration *PET* and air temperature *T* in the coastal region Sfântu Gheorghe for the period 2000 – 2009
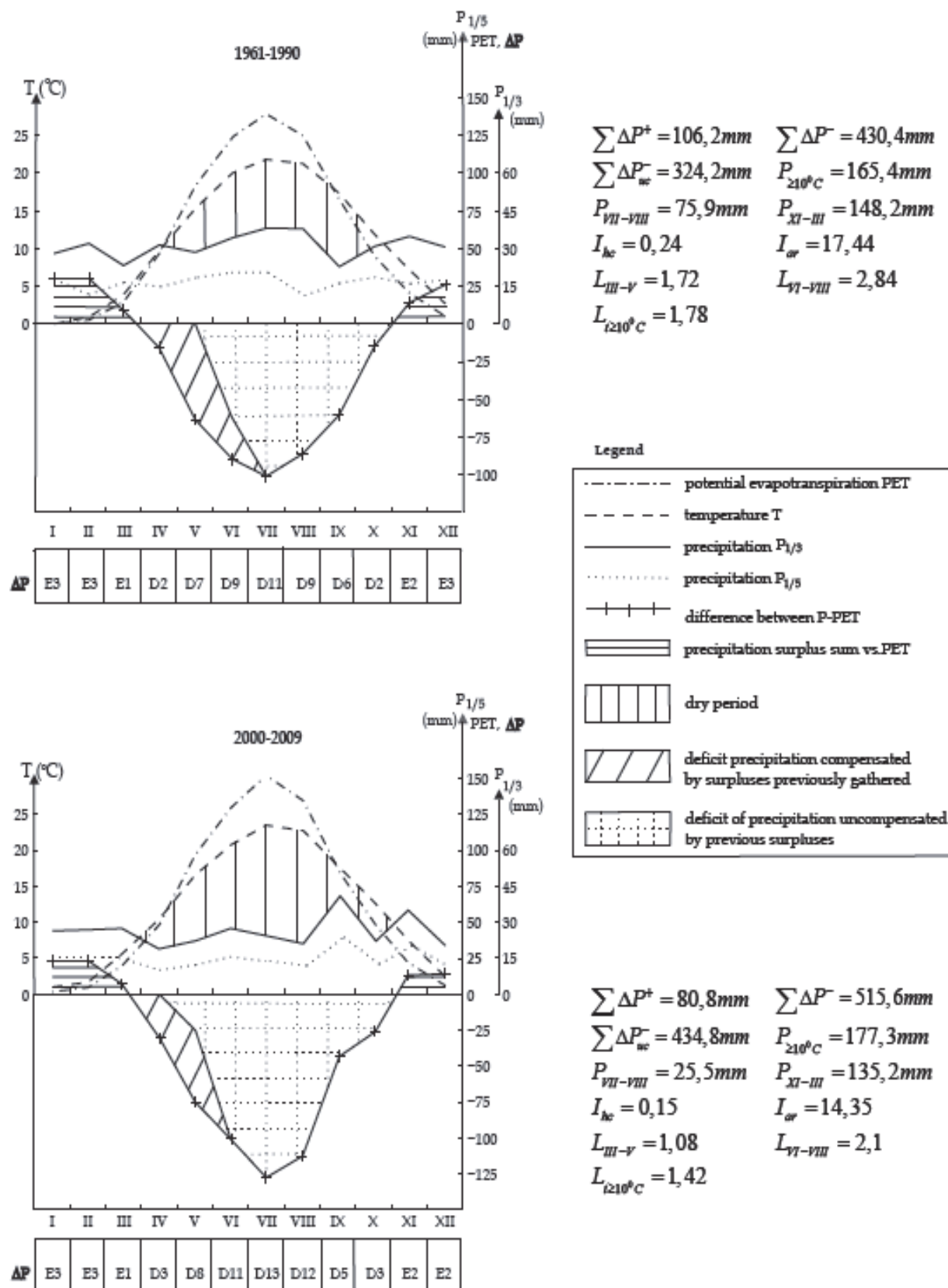
Fig. 4. Climate diagrams for reference interval 1960 – 1990 and interval 2000-2009 with characteristics sizes determined for reviewed site
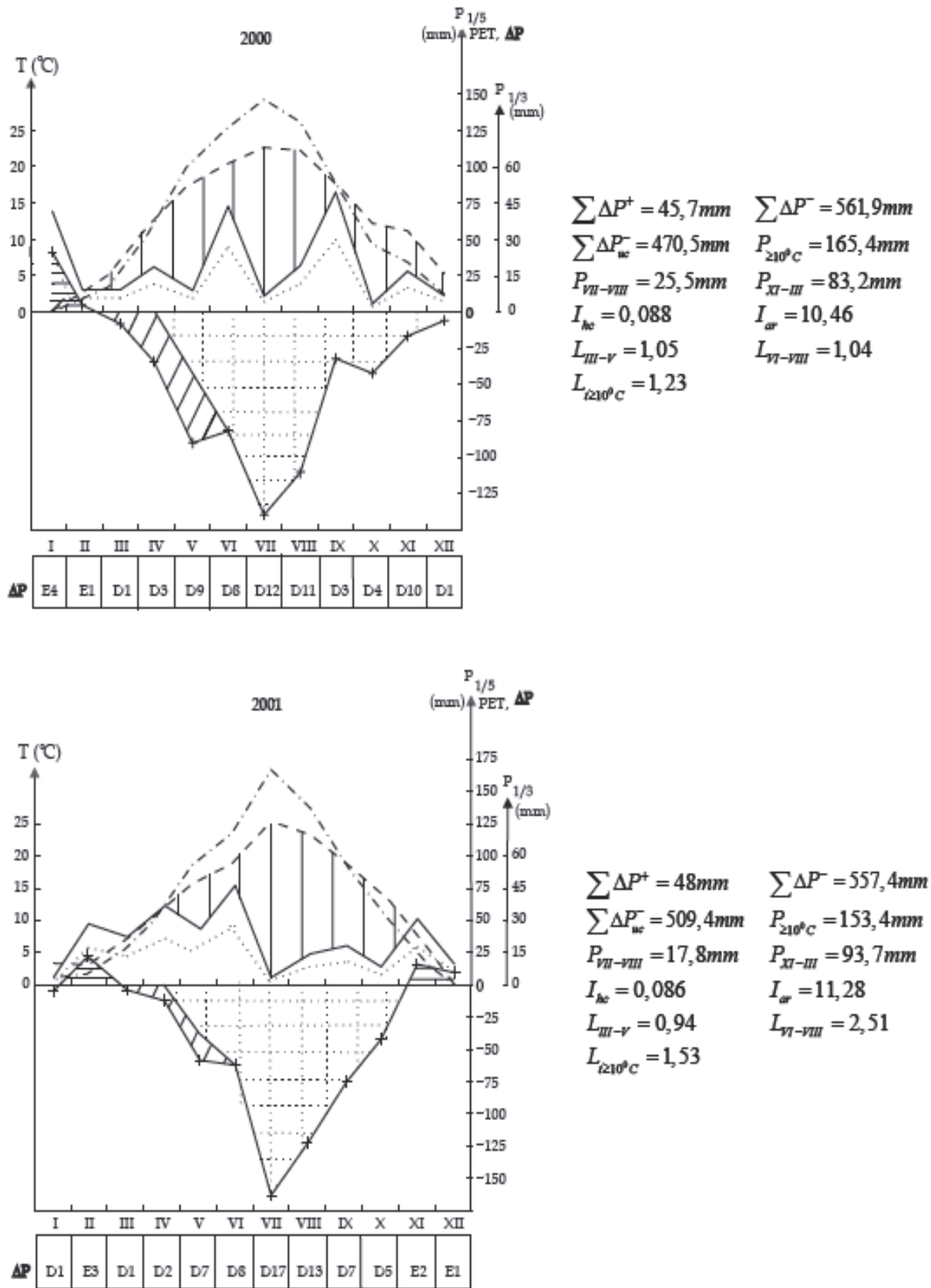
$$\sum \Delta P^+ = 45,7mm \qquad \sum \Delta P^- = 561,9mm$$

$$\sum \Delta P_{uc}^- = 470,5mm \qquad P_{\geq 10^0 C} = 165,4mm$$

$$P_{VII-VIII} = 25,5mm \qquad P_{XI-III} = 83,2mm$$

$$I_{hc} = 0,088 \qquad I_{ar} = 10,46$$

$$L_{III-V} = 1,05 \qquad L_{VI-VIII} = 1,04$$

$$L_{t\geq 10^0 C} = 1,23$$

$$\sum \Delta P^+ = 48mm \qquad \sum \Delta P^- = 557,4mm$$

$$\sum \Delta P_{uc}^- = 509,4mm \qquad P_{\geq 10^0 C} = 153,4mm$$

$$P_{VII-VIII} = 17,8mm \qquad P_{XI-III} = 93,7mm$$

$$I_{hc} = 0,086 \qquad I_{ar} = 11,28$$

$$L_{III-V} = 0,94 \qquad L_{VI-VIII} = 2,51$$

$$L_{t\geq 10^0 C} = 1,53$$

Fig. 5. Climate charts for years 2000 and 2001 and characteristics sizes determined for reviewed site

$$\sum\Delta P^{+}=59,7mm \qquad \sum\Delta P^{-}=626,9mm$$
$$\sum\Delta P^{-}_{we}=509,4mm \qquad P_{\geq10^{0}C}=88,4mm$$
$$P_{VII-VIII}=34mm \qquad P_{XI-III}=19,1mm$$
$$I_{hc}=0,095 \qquad I_{ar}=9,33$$
$$L_{III-V}=0,76 \qquad L_{VI-VIII}=2,26$$
$$L_{t\geq10^{0}C}=0,75$$

$$\sum\Delta P^{+}=86,9mm \qquad \sum\Delta P^{-}=446,6mm$$
$$\sum\Delta P^{-}_{we}=359,7mm \qquad P_{\geq10^{0}C}=207mm$$
$$P_{VII-VIII}=69mm \qquad P_{XI-III}=114,1mm$$
$$I_{hc}=0,241 \qquad I_{ar}=16,75$$
$$L_{III-V}=1,26 \qquad L_{VI-VIII}=1,09$$
$$L_{t\geq10^{0}C}=1,84$$
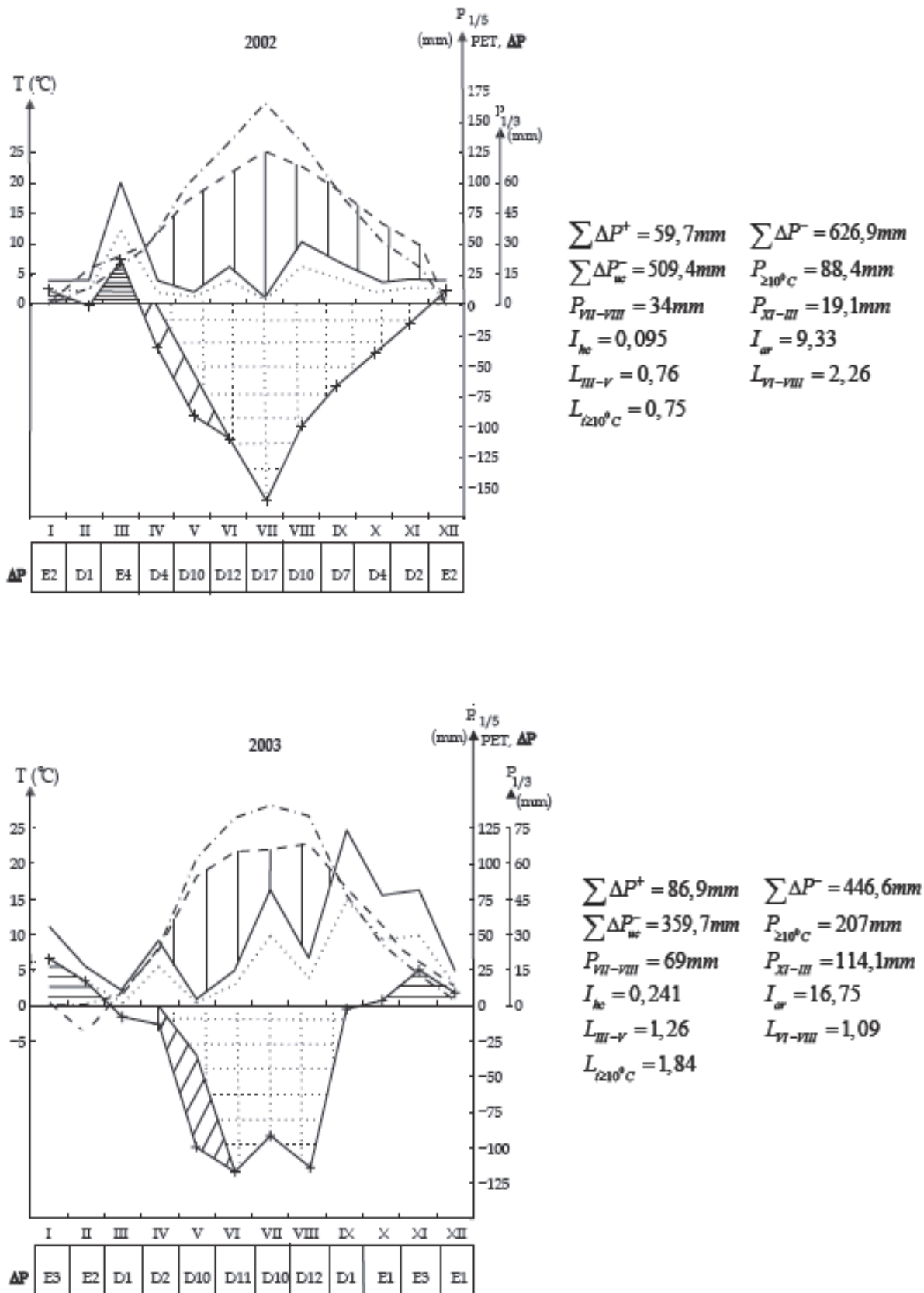
Fig. 6. Climate charts for years 2002 and 2003 and characteristics sizes determined for reviewed site

$$\sum \Delta P^+ = 68mm \qquad \sum \Delta P^- = 472,6mm$$
$$\sum \Delta P^-_{wc} = 404,6mm \qquad P_{\geq 10^0 C} = 225,4mm$$
$$P_{VII-VIII} = 55,1mm \qquad P_{XI-III} = 105,2mm$$
$$I_{hc} = 0,143 \qquad I_{ar} = 15,16$$
$$L_{III-V} = 1,38 \qquad L_{VI-VIII} = 2,82$$
$$L_{t \geq 10^0 C} = 1,83$$

$$\sum \Delta P^+ = 183,8mm \qquad \sum \Delta P^- = 435,1mm$$
$$\sum \Delta P^-_{wc} = 251,3mm \qquad P_{\geq 10^0 C} = 236,4mm$$
$$P_{VII-VIII} = 78,6mm \qquad P_{XI-III} = 229,5mm$$
$$I_{hc} = 0,42 \qquad I_{ar} = 22,23$$
$$L_{III-V} = 1,02 \qquad L_{VI-VIII} = 1,29$$
$$L_{t \geq 10^0 C} = 2,06$$
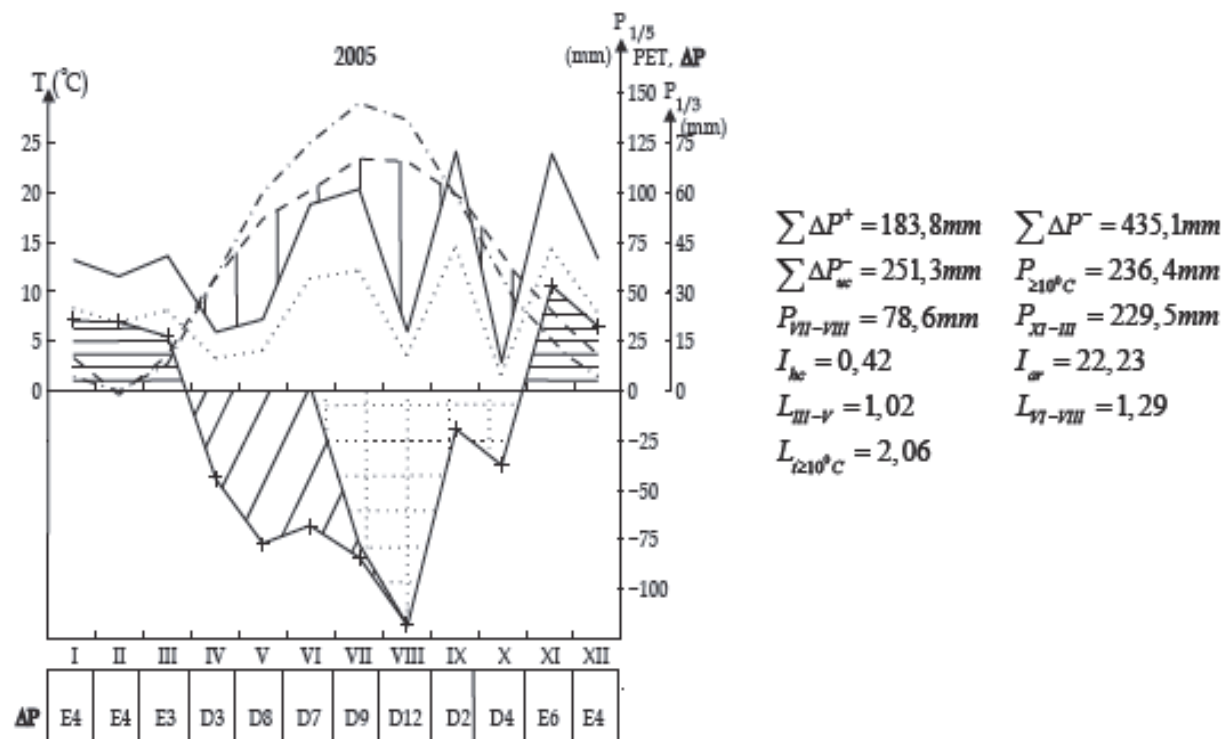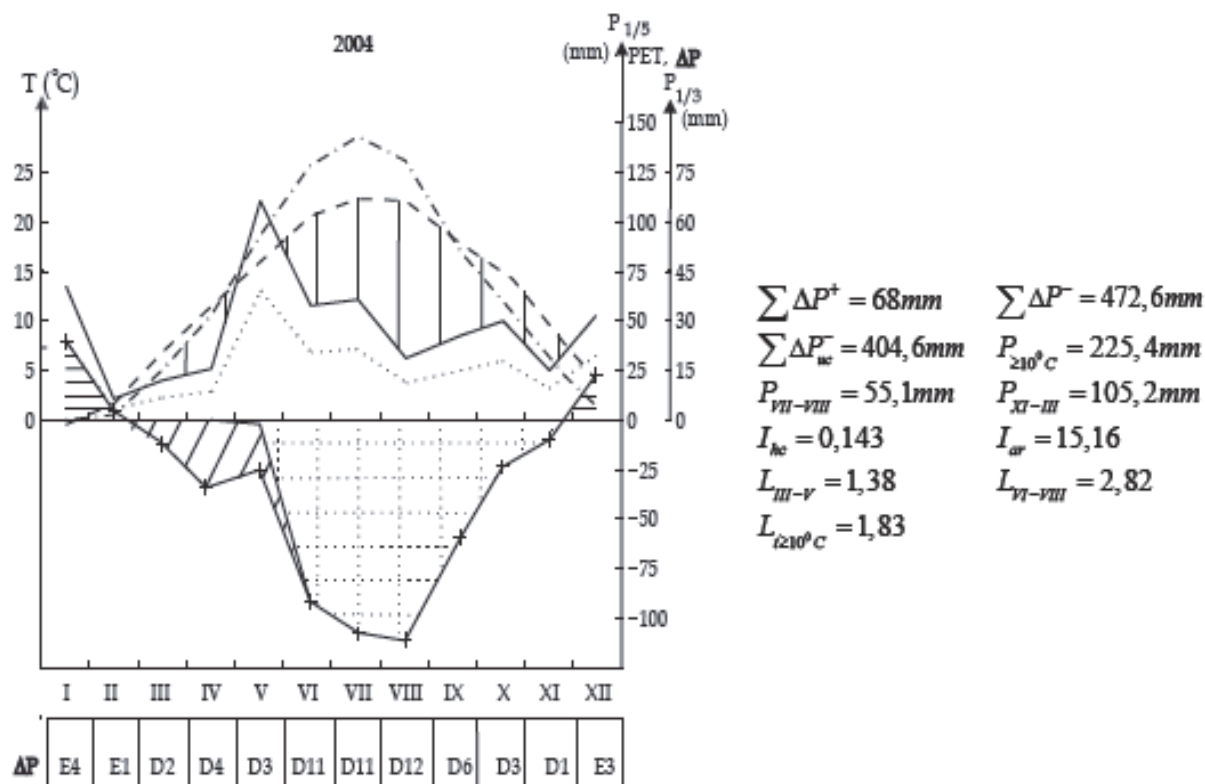
Fig. 7. Climate charts for years 2004 and 2005 and characteristic sizes determined for reviewed site

$\sum \Delta P^+ = 76,5mm \qquad \sum \Delta P^- = 486mm$

$\sum \Delta P^-_{ac} = 409,5mm \qquad P_{210^\circ C} = 187,2mm$

$P_{VII-VIII} = 77,6mm \qquad P_{XI-III} = 114,1mm$

$I_{hc} = 0,15 \qquad I_{ar} = 14,49$

$L_{III-V} = 1,2 \qquad L_{VI-VIII} = 4,35$

$L_{t210^\circ C} = 1,55$

$\sum \Delta P^+ = 218mm \qquad \sum \Delta P^- = 588,2mm$

$\sum \Delta P^-_{ac} = 370,2mm \qquad P_{210^\circ C} = 191,6mm$

$P_{VII-VIII} = 3,6mm \qquad P_{XI-III} = 114,1mm$

$I_{hc} = 0,37 \qquad I_{ar} = 18,01$

$L_{III-V} = 0,38 \qquad L_{VI-VIII} = 1,49$

$L_{t210^\circ C} = 1,54$
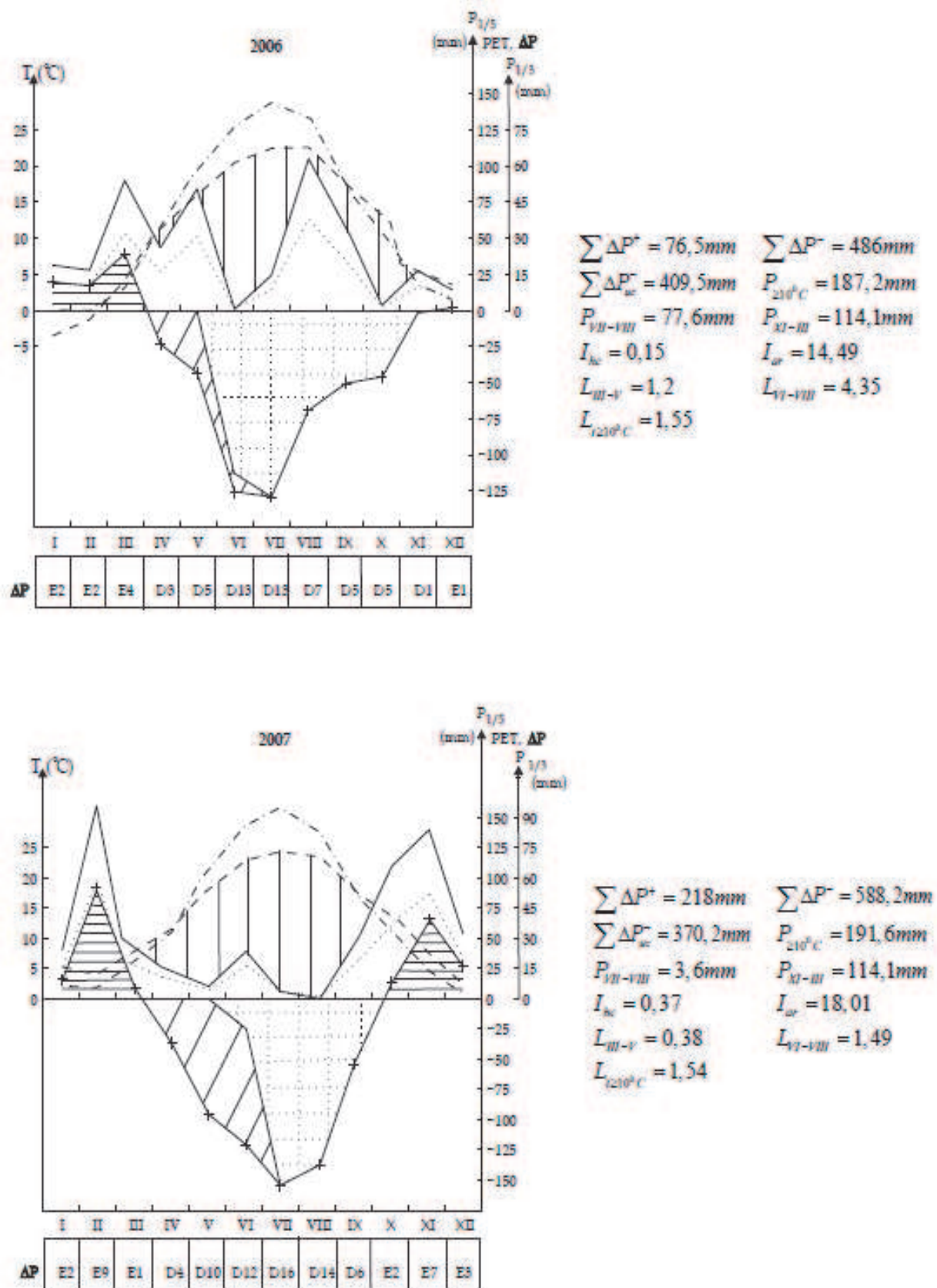
Fig. 8. Climate charts for years 2006 and 2007 and characteristic sizes determined for reviewed site

2008

$$\sum \Delta P^{+} = 70,8mm \qquad \sum \Delta P^{-} = 511,1mm$$
$$\sum \Delta P_{we}^{-} = 440,3mm \qquad P_{\geq 10^{0}C} = 180,4mm$$
$$P_{VII-VIII} = 45,1mm \qquad P_{XI-III} = 138,8mm$$
$$I_{he} = 0,13 \qquad I_{ar} = 23,7$$
$$L_{III-V} = 1,1 \qquad L_{VI-VIII} = 1,35$$
$$L_{t \geq 10^{0}C} = 1,44$$

2009

$$\sum \Delta P^{+} = 59,7mm \qquad \sum \Delta P^{-} = 580mm$$
$$\sum \Delta P_{we}^{-} = 520,3mm \qquad P_{\geq 10^{0}C} = 158,6mm$$
$$P_{VII-VIII} = 49,4mm \qquad P_{XI-III} = 103,3mm$$
$$I_{he} = 0,10 \qquad I_{ar} = 19,01$$
$$L_{III-V} = 0,84 \qquad L_{VI-VIII} = 0,9$$
$$L_{t \geq 10^{0}C} = 1,22$$
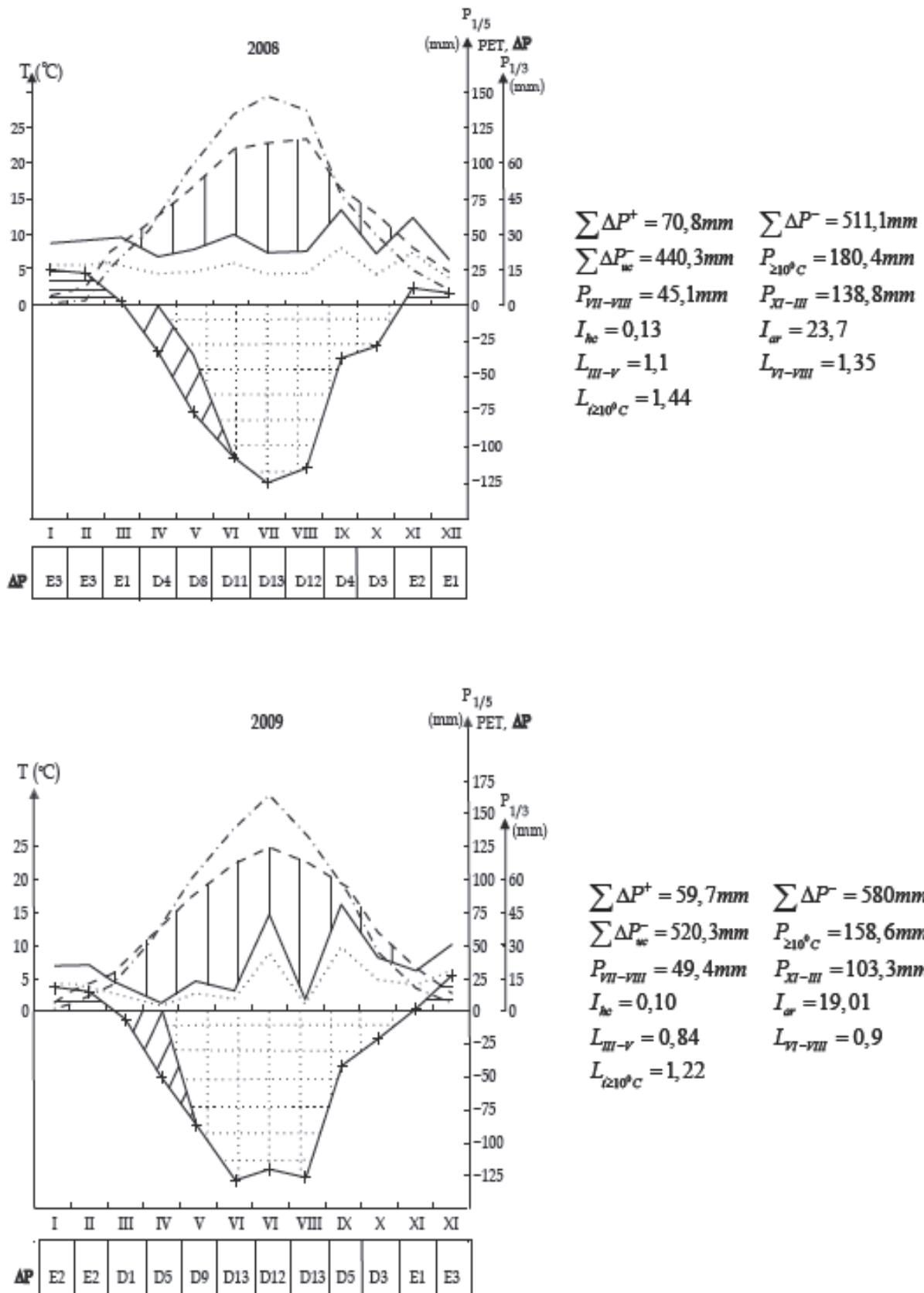
Fig. 9. Climate charts for years 2008 and 2009 and characteristic sizes determined for reviewed site

All the obtained values places the deltaic coast Sfântu Gheorghe in area with a dry climate (Bandoc, 2009).

Regarding the average annual values of the variation of potential evapotranspiration, we can say that, for the period 2000 - 2009 is an increase *PET* value to the annual average of the reference period 1961 - 1990 at a rate of 7 %. Highest increases were registered in 2002, 2007 and 2009, years in which temperatures were recorded over annual average values of the reference period.

The observed values of *PET* in these years are on average 11 % higher than the reference period 1961 - 1990, while during other years the annual increases are in the range 0,07 ... 1 6 % for the period 2000 - 2009 (fig. 11).

Concluding, it can be stated that for Sfântu Gheorghe coastal region there is a significant increase in the potential evapotranspiration *PET* for the last 10 years compared to the reference 1961-1990.

The method used to calculate potential evapotranspiration is Thorntwaite's method, using average monthly air temperature values. Based on the values obtained for *PET* using the method of Thornthwaite (Thornthwaite diagram), one can say that there are significant variations in *PET* for the period under study from 2000 to 2009 compared with the reference period 1961 - 1990, both as annual values and mean interannual values (fig. 12).

The interannual distribution of *PET* in the period 2000 - 2009 shows that these values were, in most months in each year of the analyzed interval over the average interannual values of the reference period 1961 - 1990. It appears that for the months of July and August all *PET* values are over the annual average calculated for the same month of the reference period 1961 - 1990. For instance, for the months of July in 2000-2009 period compared to the the reference values in 1961-1990, PET values are above the multiannual July average (fig.12). Notable years for July values are 2001, 2007 and 2009 where the increase above the multiannual monthly average were 20.14%, 13.66% and 17.98% respectively.

In the same time the following indices were calculated: monthly differences $P - PET$, annual amounts of differences with the same sign $\Sigma (P - PET)^+$ and $\Sigma (P - PET)^-$, as well as the yearly balance $\Sigma (P - PET)_A$, all these being important climatic indices. Calculations for the two analyzed periods led to the following results regarding water deficit and excess from precipitation presented below:
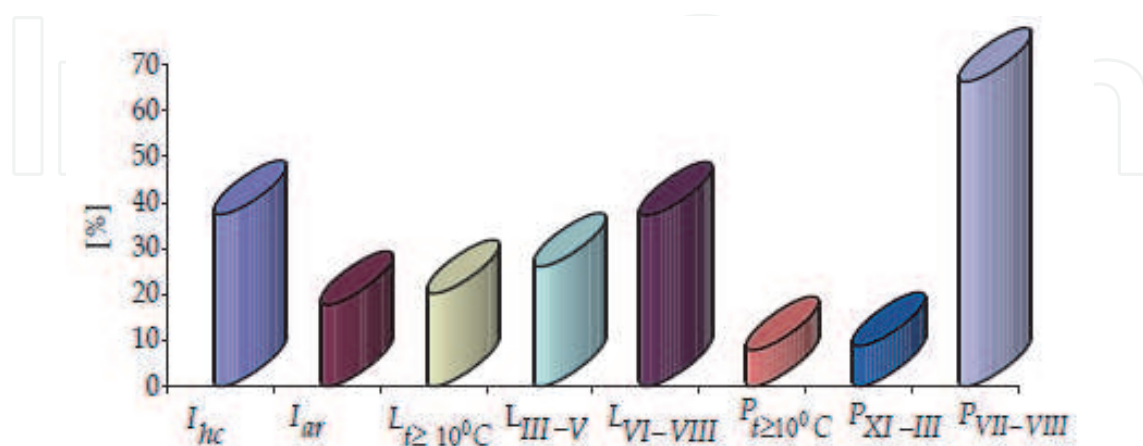

Fig. 10. Increases of the average annual percentage values of main indices for the period 2000 - 2009 for the studied site comparing to the specific values of the reference period 1961 – 1990.
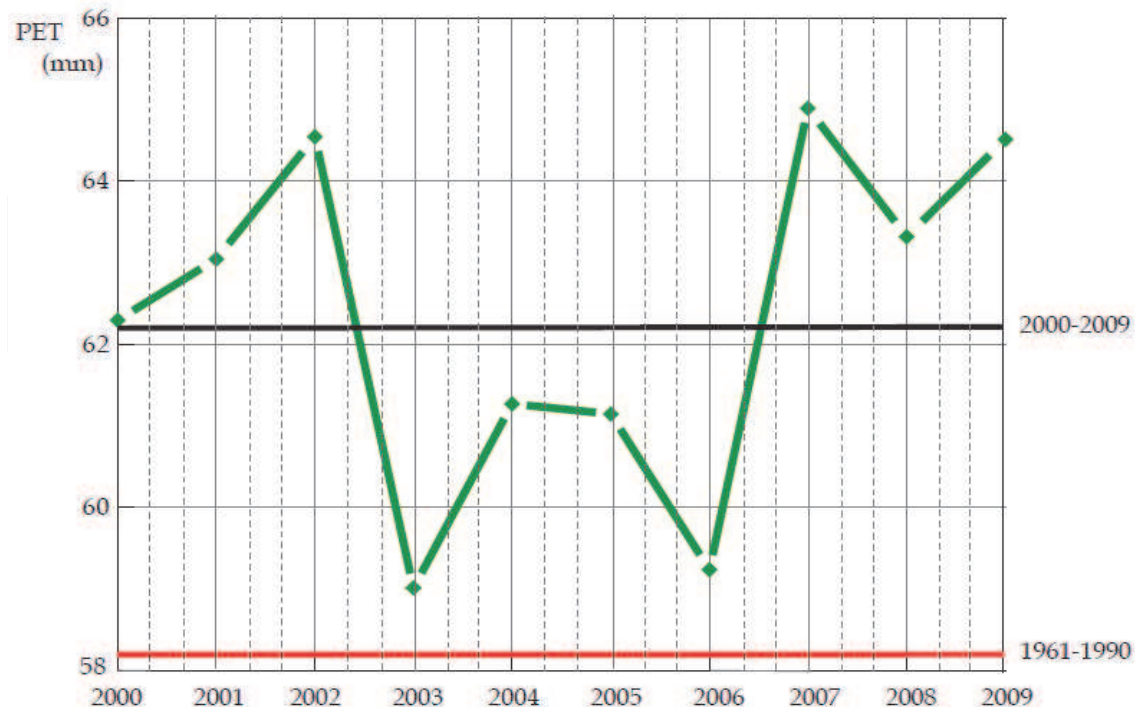
Fig. 11. Changes in annual and multiannual average values of *PET* for the period 2000 - 2009. Comparison with the 1961 - 1990 annual average for the chosen location.

$$\Sigma(P-PET)^{-}_{1961-1990} = 430,4mm \; ; \; \Sigma(P-PET)^{-}_{2000-2009} = 515,2mm \; ;$$

$$\Sigma(P-PET)^{+}_{1961-1990} = 106,2mm \; ; \; \Sigma(P-PET)^{+}_{2000-2009} = 80,8mm$$

The annual balance sheet $\Sigma(P-PET)_{A:2000-2009}$ shows a significant increase, with 31,6 % of the water deficit comparing to the period 1961 - 1990 for which the balance reference value is $\Sigma(P-PET)_{A:1961-1990} = -330,2mm$.

The obtained values show that there is an increase in the deficit for the last 10 years by 19,7 % compared to the reference period and a decrease of 23,9 % in terms of excess rainfall for the period 2000 - 2009 (fig. 13).

For emphasizing very clear each month's character, at the bottom of the chart climate values ΔP were given indicating each month's category in terms of surplus *E* or deficit *D* of precipitation versus potential evapotranspiration. Thus, there are determined the interannual values for the period 2000 - 2009 as well as average multiannual values for the two periods under study.

Based on measurements one could build a mosaic of surpluses *E* and deficits *D* of precipitation variation comparing to potential evapotranspirationfor in the period 2000-2009, comparison with average multianual of *E* and *D* of the periods 2000-2009 and 1961-1990 intervals (fig. 14).

Values for excess precipitation comparing to potential evapotranspiration reached a maximum of *E9* (>80 mm) and *E7* (>60 mm) in February and November 2007 respectively, values much higher than multiannual average of the reference period when the values were *E3* and *E2* (see fig. 14).
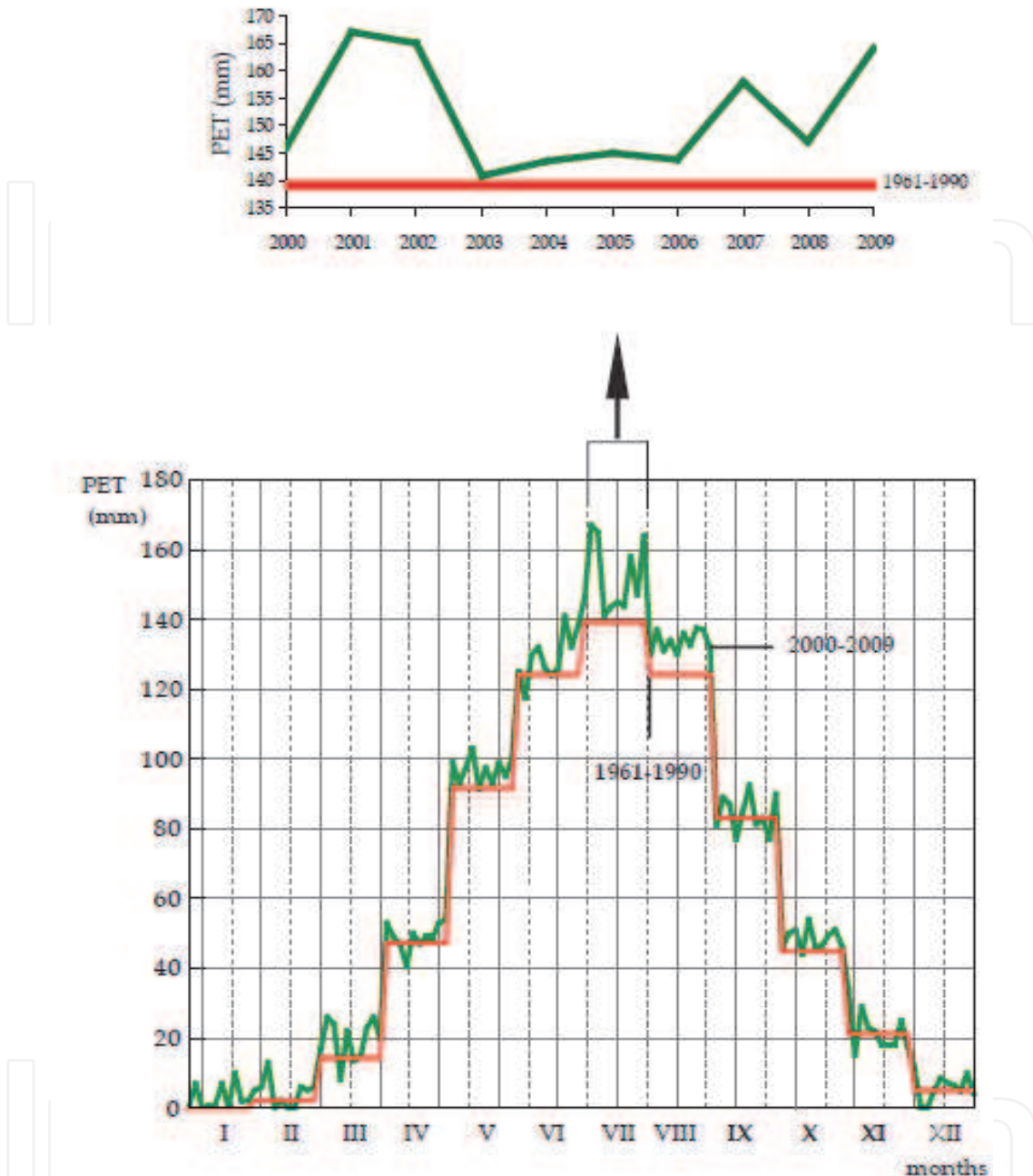
Fig. 12. Interannual distribution of *PET* in the period 2000 - 2009 comparing to the annual average of the reference period 1961 - 1990 for the studied area.

In addition, a reduction of the months with surplus between 2000 - 2009 for the years 2000, 2001, 2003 and 2004 can be seen. Also, there is a reduction in the number of months with a precipitation surplus for 2000, 2001, 2003 and 2004. In these years the precipitation excedent over *PET* period narrowed to 2 months in 2000 and 3 months in 2001, 2002, 2003 compared to 5 months in the reference 1961-1990 period (fig. 14).

As for the precipitation - potential evapotranspiration deficit it can be stated that the deficits suffered a significant increase compared to the reference period. Thus, there can be noticed maximum values of deficits *D17* (>160 mm) to be recorded in 2001 and 2002.
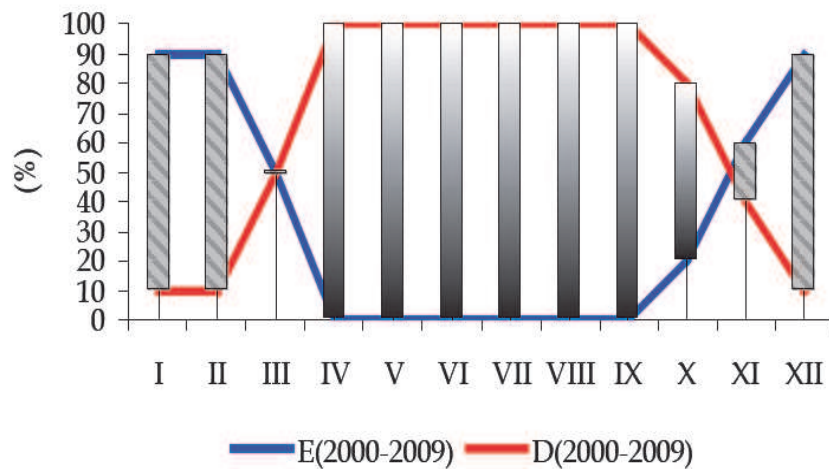
Fig. 13. Percent interannual variations of deficits *D* and surpluses *E* of precipitation to potential evapotranspiration for the period 2000 - 2009.

It appears that while the deficit intervals of the average multiannual values is seven months, the interannual period with deficit intervals is a few months longer between 2000 - 2009. Thus, in 2000, 2001 and 2004 this period has increased by three months and two months respectively compared to that of reference period (fig. 14).

D1		D2		D3		D4		D5		D6		D7		D8		D9
D10		D11		D12		D13		D14		D15		D16		D17		
E1		E2		E3		E4		E5		E6		E7		E8		E9

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
2000	E5	E1	D1	D4	D9	D9	D14	D12	D4	D5	D2	D1
2001	D1	E3	D1	D2	D7	D8	D17	D13	D7	D5	E2	E1
2002	E2	D2	E4	D4	D10	D12	D17	D10	D7	D4	D2	E2
2003	E3	E2	D1	D2	D10	D11	D10	D12	D1	E1	E3	E1
2004	E4	E1	D2	D3	D3	D11	D11	D12	D6	D3	D1	E3
2005	E4	E4	E3	D3	D8	D7	D9	D12	D2	D4	E6	E4
2006	E2	E2	E4	D3	D5	D13	D13	D7	D5	D5	D1	E1
2007	E2	E9	E1	D4	D10	D12	D16	D14	D6	E2	E7	E3
2008	E3	E3	E1	D4	D8	D11	D13	D12	D4	D3	E2	E1
2009	E2	E2	D1	D5	D9	D13	D12	D13	D5	D3	E1	E3
1961-1990	E3	E3	E1	D5	D7	D9	D11	D9	D6	D2	E2	E3
2000-2009	E3	E3	E1	D3	D8	D11	D13	D12	D5	D3	E2	E2

Fig. 14. Distribution of surpluses *E* and deficits *D* of precipitation comparing to potential evapotranspiration in the period 2000 - 2009; comparison with average multiannual of *E* and *D* of the periods 2000 - 2009 and 1961 – 1990.

Analysis of reference period in terms of deficit and surplus, highlights that the studied area is characterized by a lack of *D3* compared to the same period last years when the average value increased to a deficit of *D4*, which means a 17,06 % increase in the deficit.

5. Conclusions

The research results concerning yearly and monthly potential evapotranspiration in the Sfantu Gheorghe coastal area, synthetized in this chapter revealed for years 2001 to 2009 changes in the humidity periods, an increase in air temperature (Busuioc et al, 2010), a diminished atmospheric precipitation amount and also an increase of precipitation to potential evapotranspiration deficit compared to 1961-1990 reference period.

All these changes lead to high vulnerability and low adaptive capacity to adverse impacts from climate change of this area (Liubimtseva & Henebry, 2009).

Thus, by drawing Walter and Leith diagrams, significant increase of dryness periods and decrease of moisture periods were observed with implications upon potential evapotranspiration and upon the shore phytocoenoses.

There are also changes in the length of the periods with precipitation surplus and deficit compared to potential evapotranspiration that means increasing periods of deficit and decreasing periods of surplus.

The following calculated characteristic measurements include the delta coast in Sfântu Gheorghe in arid climate and climatic changes show that the period 2000 - 2009 led to a trend towards increasing aridity: *Martonne arid index (* I_{ar} *), retention index offset (* I_{hc} *), the amount of rainfall in the period with temperature T ≥ 10 ° C (* $P_{t \geq 10^0 C}$ *), the amount of rainfall the soil load in the months from November to March (* P_{XI-III} *), the amount of summer rainfall July and August (* $P_{VII-VIII}$ *), Lang precipitation index for the period with t ≥ 10 °C (* $L_{t \geq 10^0 C}$ *), Lang precipitation index for the summer season (* $L_{VI-VIII}$ *) and Lang precipitation index for the spring season (* L_{III-V} *).*

From the differences in monthly $P - PET$ calculation of amounts $\sum (P - PET)^+$, $\sum (P - PET)^-$ of the precipitation deficit offset by previously accumulated $\sum \Delta P^+$, surpluses and deficits of precipitation uncompensated by previous surpluses $\sum \Delta P_{uc}^-$ and the annual balance $\sum (P - PET)_A$ for the period under study year 2000 - 2009 and for the reference period 1961 - 1990, there was a deficit increase and a decrease of excess water from precipitation, an extension of periods of water shortage against period with excess of water and a significant increase by about 23,9 % for deficit of water that gathers negative differences uncompensated during periods of surplus.

Therefore, the research presented in this article have highlighted significant changes in potential evapotranspiration in relation to climate changes for the 2000 - 2009 studied period, in Sfântu Gheorghe area - Danube Delta, showing an increase of precipitation deficit and an increase of climate aridity .

Indirect method used in this paper work to determine the potential evapotranspiration was based on the values of air temperature and Thornthwaite's diagrams and tables. In this way a general view of a time variation of *PET* for Sfântu Gheorghe area - Danube Delta, has been created.

The advantages of this indirect method results from the fact that it doesn't require a large number of measured meteorological parameters and that it can be easily applied obtaining good estimates.

In the future it is intended that research should continue in order to see whether the growth trend of a interannual and annual potential evaporation is kept over the period 2000 - 2009. No doubt that climate change is underway affecting Earth's biodiversity.

Biggest challenge in this respect is related to the marine area, but it is unclear to what extent these changes in climate will affect ecosystems.

What is known is that the temperatures that rise steadily and increasingly frequent extreme weather events are those that have influence on migrating wildlife and also causes invasive species.

Coastal areas offer considerable benefits to society while human activities are exerting considerable pressure on coastal ecosystems. Therefore, these benefits to society are in danger (Nobre, 2009).

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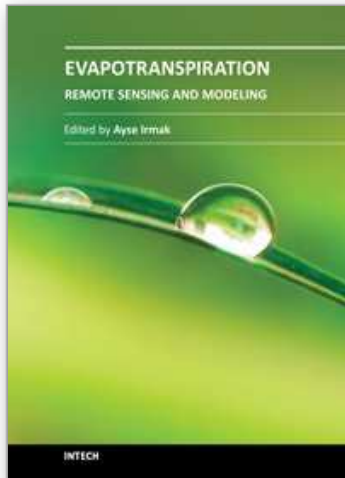
Evapotranspiration - Remote Sensing and Modeling

Edited by Dr. Ayse Irmak

This edition of Evapotranspiration - Remote Sensing and Modeling contains 23 chapters related to the modeling and simulation of evapotranspiration (ET) and remote sensing-based energy balance determination of ET. These areas are at the forefront of technologies that quantify the highly spatial ET from the Earth's surface. The topics describe mechanics of ET simulation from partially vegetated surfaces and stomatal conductance behavior of natural and agricultural ecosystems. Estimation methods that use weather based methods, soil water balance, the Complementary Relationship, the Hargreaves and other temperature-radiation based methods, and Fuzzy-Probabilistic calculations are described. A critical review describes methods used in hydrological models. Applications describe ET patterns in alpine catchments, under water shortage, for irrigated systems, under climate change, and for grasslands and pastures. Remote sensing based approaches include Landsat and MODIS satellite-based energy balance, and the common process models SEBAL, METRIC and S-SEBS. Recommended guidelines for applying operational satellite-based energy balance models and for overcoming common challenges are made.

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