Is climatic regionalization in frame of estimated pedologic-ecological system actual in 21st century?

Hana STŘEDOVÁ[1], Filip CHUCHMA[2]

[1] Department of Applied and Landscape Ecology, Mendel University in Brno
Zemědělská 1, 613 00 Brno, Czech Republic; e-mail: hana.stredova@mendelu.cz

[2] Czech Hydrometeorological Institute, branch office Brno
Kroftova 43, 616 67 Brno, Czech Republic; e-mail: filip.chuchma@chmi.cz

Abstract: Climatic variables defining climatic regions of estimated pedologic-ecological system (EPEU) were calculated based on fifty-year climatic data from 1961 to 2010. Obtained results were subsequently compared to intervals determining individual climatic regions defined by previous climatic data (1901–1950). In many agricultural intense areas sum of air temperature and mean air temperature exceeded upper limit. In terms of precipitation it is especially noticeable in the wet (higher) altitudes. Significant volatility was found for probability of dry periods from April to September. The values of the moisture certainty from April to September for the period 1961–2010 reached to several tens. In the final analysis, the only safe prediction is that the present and future are likely to be very different from the past. It is necessary to take it into account for actualization of EPEU methodology. Among the strongest arguments justifying the need of this actualization is in particular climate development since 1901, technological progress and improved measurement technology as well as automation and development of climate models coupled with simulations of complex characteristics and estimates of future climate. It is evident that the development of climate and other factors have an enormous impact on soil fertility. This should be also taken into consideration when fixing the official price. It is necessary to consider the possible replacement of the existing characteristics by more suitable (for example soil moisture balance). The findings might be summarized in few words: old climatic regions do not reflect actual climatic conditions.

Key words: air temperature sum, drought, precipitation, climate development

1. Introduction

Abiotic stress is a main cause of reduced yield in case of healthy plants. The main current problem is the lack of soil water or soil drought along with high

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air temperatures. It has also been proved the prolongation of the growing season by 15 to 25 days in last twenty years. It is attended by an increasing risk of vegetation frost. Production potential of agriculture land fund in the Czech Republic and Slovakia is evaluated by "estimated pedologic-ecological units" (EPEU). EPEU was carried out in the years 1973–1980 by *Mašát et al. (1974)*. The first or first and second positions of five or seven numerical code labeled 0–9 or 0–10 are occupied by climatic region in the Czech Republic and Slovakia respectively. Climatic regions were estimated on the basis of climatic data for the period 1901–1950. Czech climatic regions were defined by the sum of mean daily temperatures above 10 °C, mean annual air temperature and precipitation and climatic variables of growing season such as probability of its dry occurrence and moisture certainty. Similarly in neighboring countries such as Austria and Germany climatic conditions play one of the most important roles when official land prices are determined (*Voltr, 2011*).

EPEU system is an integral part of the Czech national legislation as Regulation of Ministry of agriculture no 327/1998 Coll., Assessment of EPEU characteristics and method of their actualization. EPEU system is used for land appraisement, assessment of payment on land exemption from agricultural land fund and for proposal of new plots in frame of land adjustment to judge a homogeneity of proposed plots. Climatic region combined with pedological data is also important for potential risk of wind erosion assessment (*Podhrázská and Novotný, 2007*).

As was stated above EPEU climatic regions dealt with climatic elements from the first half of 20^{th} century. Recently, approximately 60 years later a question of their validity has arisen. The issue of EPEU and climatic regions actualization was addressed by *Středová et al. (2011).*

Gradual global temperature rise and change of precipitation distribution have been recorded from about the beginning of 19^{th} century. Climatic scenarios and models predict this trend to be continuing even in the future. *Mužíková et al. (2011)* employed A1B scenario to predict climatic changes in the Czech Republic till the end of 21^{st} century. Their climate-diagrams showed possible rising drought hazard towards the future. Similar impact of climate change on Central Europe and Central and North Europe was reported by *Heino et al. (1999)* and *Pongrácz and Bartholy (2006)*, respectively.

2. Materials and methods

Climatic variables defining climatic regions of EPEU were calculated based on fifty-year climatic data from 1961 to 2010 represented by homogenous and fully completed technical series in 10 km grid based on data of Czech Hydrometeorological Institute (*Štěpánek, 2007; Štěpánek et al., 2013*) – see Fig. 1. Obtained results were subsequently compared to intervals determining individual climatic regions defined by *Mašát et al. (1974)* – see Table 1. If the results from 1961 – 2010 fitted into the interval from Table 1 the grid point was marked by blue. If the value of 1961–2010 exceeded or did not reach interval from Table 1 the point was marked by red or green respectively. Significance of difference from interval range is detected by point size.

The evaluation dealt with certain level of tolerance. Range of intervals from Table 1 was extended by value of tolerance defined as AVG –

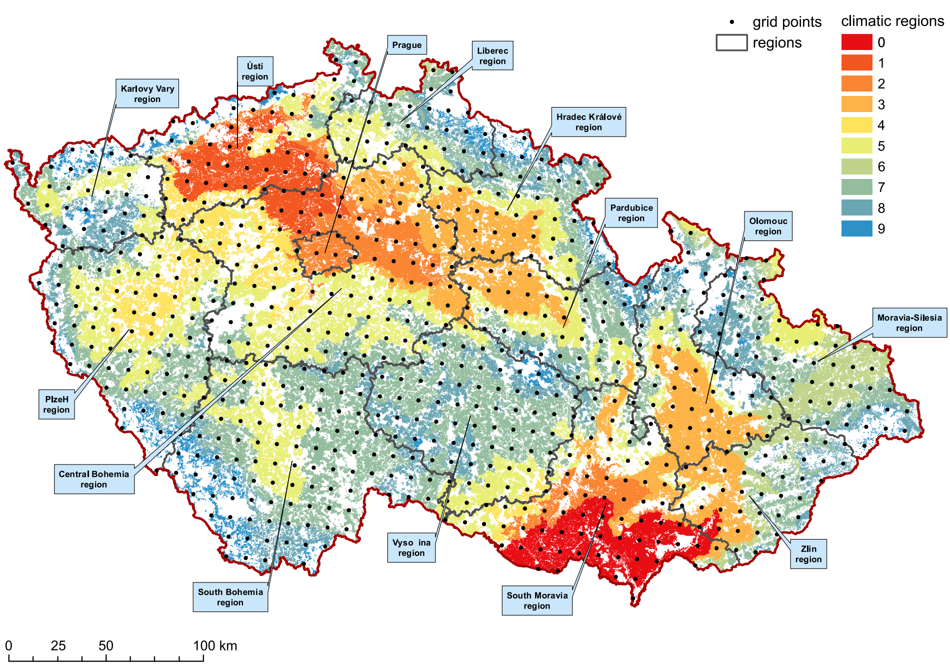

Fig. 1. Map of climatic regions defined by *Mašát et al. (1974)* with individual regions and grid points.

(STDEV/2) – differences equal to zero were not taken into account. All climatic variables were evaluated separately and results were spatially mapped. The results are interpreted on the basis of regions mapped in Fig. 1.

Table 1. Intervals of climatic variables defining individual climatic regions (*Mašát et al., 1974*)

Code	Symbol	Characteristics	TS10		T_{AVG}		P_{AVG}		MC_{IV-IX}		DP_{IV-IX}	
			min	max	min	max	min	max	min	max	min	max
0	VT	very warm, dry	2800	3100	9	10	500	600	30	50	0	3
1	T1	warm, dry	2600	2800	8	9	0	500	40	60	0	2
2	T2	warm, slightly dry	2600	2800	8	9	500	600	20	30	2	4
3	T3	warm, slightly wet	2500	2800	7(8)	9	550	650 (700)	10	20	4	7
4	MT1	slightly warm, dry	2400	2600	7	8.5	450	550	30	40	0	4
5	MT2	slightly warm, slightly dry	2200	2500	7	8	550	650 (700)	15	30	4	10
6	MT3	slightly warm (to warm), wet	2500	2700	7.5	8.5	700	900	0	10	0	10
7	MT4	slightly warm, wet	2200	2400	6	7	650	750	5	15	0	10
8	MCH	slightly cold, wet	2000	2200	5	6	700	800	0	5	0	10
9	CH	cold, wet	–	2000	–	5	0	800	0	0	0	10

Note: abbreviations given by heading are explained below.

Evaluated climatic variables:

TS10 [°C] – *Air temperature sum above 10° C*

T_{AVG} [°C] – *Mean annual air temperature*

P_{AVG} [mm] – *Mean annual precipitation total*

MC_{IV-IX} [mm] – *Moisture certainty from April to September:*

Long-term mean annual MC is defined as a difference between an annual limit of drought and a long-term annual precipitation total divided by a long-term mean annual air temperature. The limit of drought is defined by a formula:

$$p_a = 3\,(t + 7)$$

where p_a – precipitation total characterizing long-term annual limit of drought [cm];

t – long-term mean annual air temperature.

Assessment of limit of drought from April to September according to *Mašát et al. (1974)* is based on the following assumption:

$$\frac{P_\mathrm{a}}{p_\mathrm{a}} = \frac{P_{\mathrm{IV-IX}}}{p_{\mathrm{IV-IX}}}$$

and thus

$$p_{\mathrm{IV-IX}} = \frac{P_{\mathrm{IV-IX}} \cdot p_\mathrm{a}}{P_\mathrm{a}}$$

where $p_{\mathrm{IV-IX}}$ – limit of drought from April to September;
$P_{\mathrm{IV-IX}}$ – long-term mean precipitation total in from April to September;
p_a – long-term annual limit of drought;
P_a – long-term annual precipitation total.

Finally,

$$\mathrm{MC}_{\mathrm{IV-IX}} = \frac{P_{\mathrm{IV-IX}} - p_{\mathrm{IV-IX}}}{t_{\mathrm{IV-IX}}}$$

where $t_{\mathrm{IV-IX}}$ – long-term mean air temperature from April to September.

$\mathrm{DP}_{\mathrm{IV-IX}}$ [%] – *Probability of dry periods from April to September*:
It is defined as percent of years when the precipitation total from April to September is lower than $p_{\mathrm{IV-IX}}$.

3. Results and discussion

In terms of TS10 the most significant excess of upper limit defined by *Mašát et al. (1974)* is more significant in Moravia than Bohemia. These changes were found out in central Bohemia (Středočeský region), central and western parts of South Moravia (Jihomoravský region) and in parts of Zlínský and Moravskoslezský regions. On the contrary, the lower limit of interval was not reached in southern part of Karlovarský region as well as adjacent northern part of Plzeňský region (Fig. 2). *Středová et al. (2011)* carried out a spatial analysis and stated the area with TS10 higher then 3000 °C was

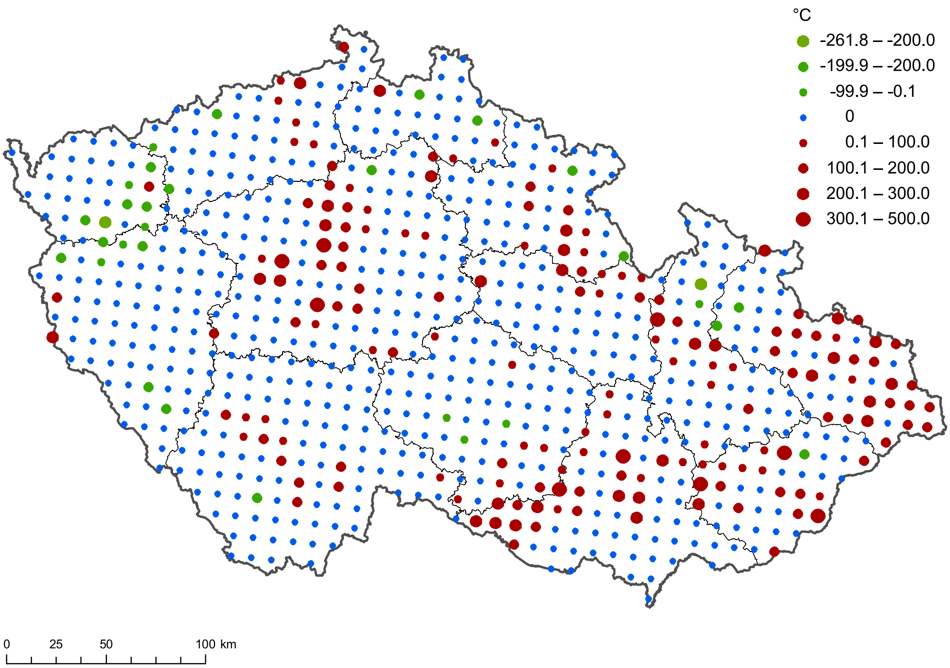

Fig. 2. Significance of $TS10_{(1961-2010)}$ differences from the interval range 1901 – 1950 in Table 1.

twice larger in 1961 – 2010 than in 1961 – 1990.

Except one point in south Moravia all grid points fit to defined interval of T_{AVG} or exceed its upper limit: in Bohemia mainly in south (Jihočeský region), western edge of Plzeňský and Karlovarský region; in Moravia mainly in eastern part of Zlínský and Moravskoslezský region and in south-eastern part of Pardubický region (Fig. 3). *Pretel et al. (2011)* stated 0.8 °C increase of mean annual temperature within the last two decades compared to normal period 1961 – 1990. The most significant changes were recorded in summer whereas the smallest in autumn. A summer temperature increase was a bit faster in Moravia, while the winter one in Bohemia.

In terms of P_{AVG} (Fig. 4) the state is not such unequivocal as in case of T_{AVG}. Defined upper limit was exceeded in eastern part of Zlínský and Moravskoslezský region as well as in northern part of Bohemia (Liberecký and Ústecký region). On the contrary the lower limit of defined interval

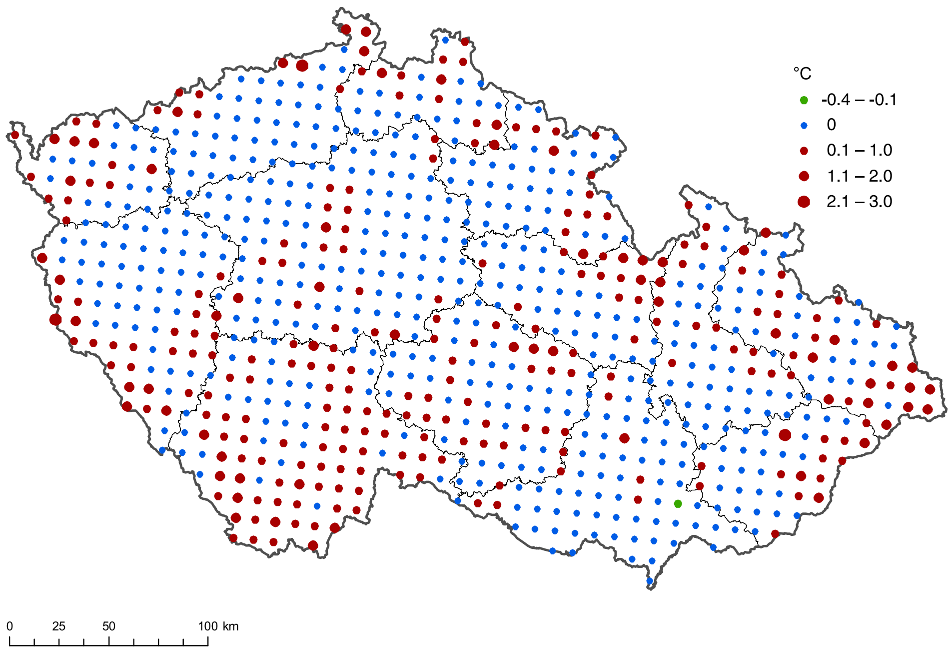

Fig. 3. Significance of $T_{\mathrm{AVG}(1961-2010)}$ differences from interval range 1901 – 1950 in Table 1.

was not reached in region of Vysočina, Jihočeský and part of Karlovarský. *Střeštík et al. (2014)* estimated a long-term change of monthly values of precipitation totals at each of 267 Czech stations for the last 50 years (1961 – 2010). Annual totals for the whole country have slightly increased. The annual variation has slightly changed: maximum precipitation has shifted from June to July and August. Precipitation has risen faster in western part compared to average whereas somewhere in eastern part has even declined. From this point of view precipitation development did not correspond to whole Europe trend stated by (*Kożuchowski and Marciniak, 1990; Räisänen et al., 2004*).

Discrepancy between results of 1960 – 2010 and defined interval in case of $\mathrm{MC}_{\mathrm{IV-IX}}$ is not as significant as in case of other variables. The most significant exceeding of defined upper limit was found for central part of Pardubický region and southern part of Ústecký region. In contrast, values fell bellow lower limit in northern part of Jihočeský region and part of region

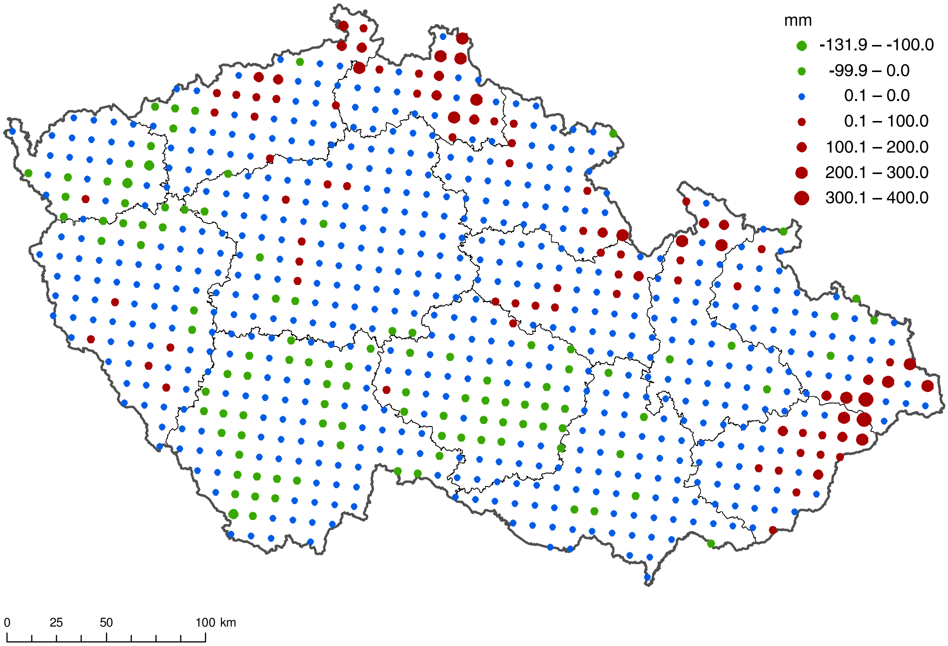

Fig. 4. Significance of $P_{\mathrm{AVG}(1961-2010)}$ differences from interval range 1901 – 1950 in Table 1.

Vysočina and Jihomoravský (Fig. 5).

The most significant decrease of moisture certainty in vegetation period was detected by *Středová et al. (2013)* at higher altitudes. However, due to overall higher precipitation the impact was not as significant as in the case of lower decrease in arid areas.

Kohut et al. (2010) evaluated the moisture conditions in the Czech Republic for the period of 1961 – 2000 based on long-term values of usable soil water expressed as % of AWHC (difference between field water capacity and wilting point). The results generally showed the worsening of the moisture conditions mainly in the last decade 1991 – 2000. The lowest altitude up to 300 m.a.s.l. is characterized by long-term value below 45% of AWHC, the middle altitude to 600 m.a.s.l. by value to 60% of AWHC.

In terms of $\mathrm{DP}_{\mathrm{IV-IX}}$ (Fig. 6) the area of south Moravia (Jihomoravský region) and central Bohemia (Středočeský region) are most interesting due to significant excess of defined upper limit. Values from 1961 – 2010 did

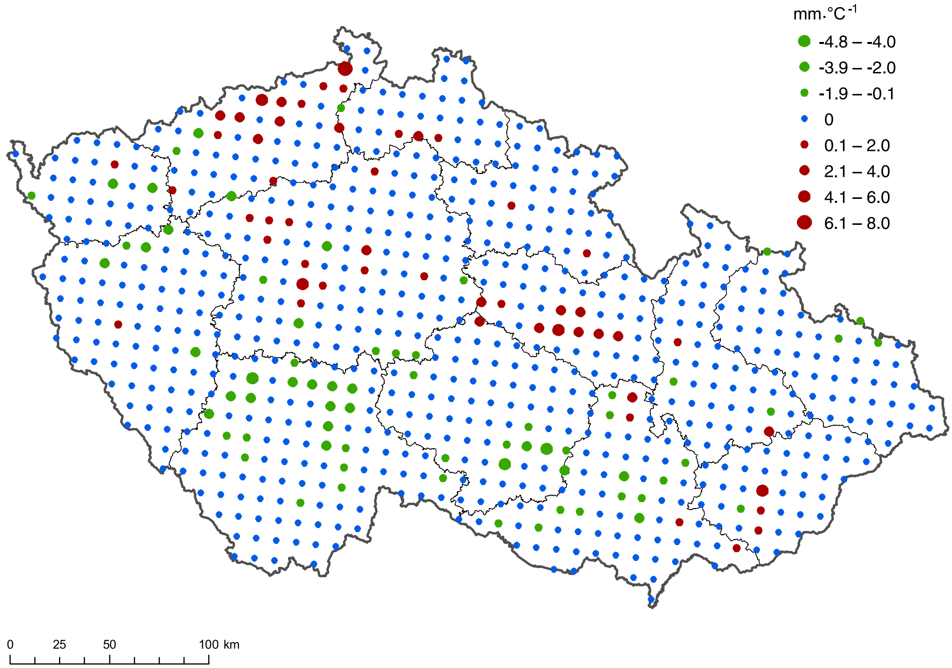

Fig. 5. Significance of $MC_{\mathrm{IV-IX}(1961-2010)}$ differences from interval range 1901 – 1950 in Table 1.

not reach the defined lower limit in many cases – especially in Pardubický, Liberecký, Ústecký and Karlovarský regions. *Van der Schrier et al. (2006)* found out that over the Europe as a whole, the mid-1940s to early 1950s stand out as a persistent and exceptionally dry period, whereas the mid-1910s and late 1970s to early 1980s were very wet. The driest and wettest summers on record, in terms of the amplitude of the index averaged over Europe, were 1947 and 1915, respectively, while the years 1921 and 1981 saw over 11% and over 7% of Europe suffering from extreme dry or wet conditions, respectively. The similar trend is also observed in the Czech Republic.

Higher temperature of air and soil influences many agroclimatic conditions. Along with higher temperature the beginning and end of vegetation season will probably shift from March 31 to March 1 and from October 30 to November 10, respectively (*Pretel et al., 2011*).

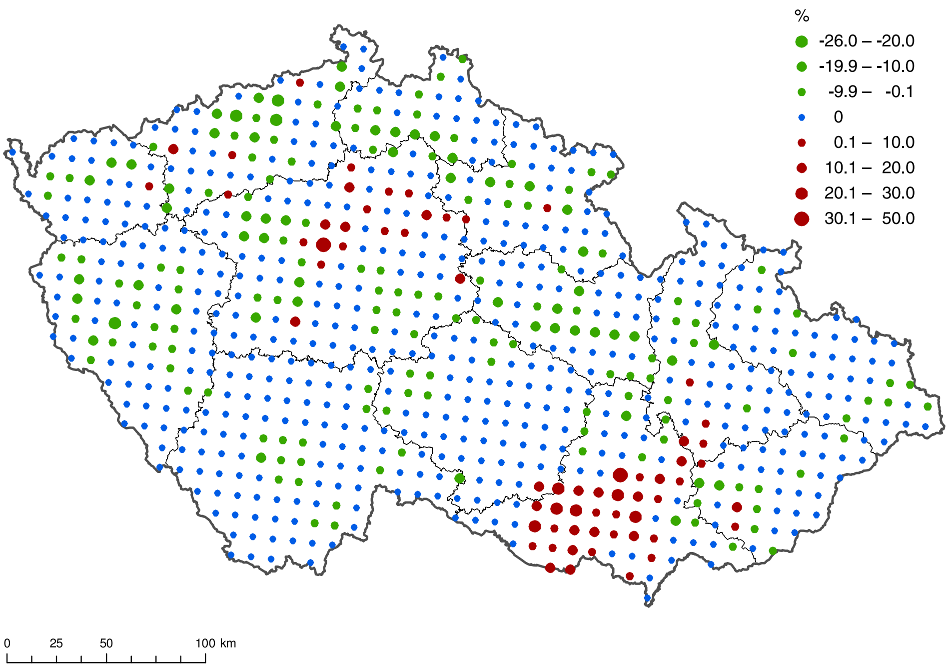

Fig. 6. Significance of $DP_{IV-IX(1961-2010)}$ differences from interval range 1901 – 1950 in Table 1.

4. Conclusions

The maps in Figs. 1 to 5 do not present the absolute decrease or increase of evaluated climatic characteristics values but just their deviation from previously defined intervals. Based on these maps the areas with the most significant deviation from *Mašát et al. (1974)* methodology were specified.

– Středočeský and Jihomoravský region: significant exceeding of TS10 and DP_{IV-IX} upper limit. In addition to these values of MC_{IV-IX} fell bellow lower limit in Jihomoravský region.

– Zlínský and Moravskoslezský region: significant exceeding of TS10, T_{AVG} as well as P_{AVG} upper limit.

– Karlovarský and Plzeňský region: TS10 lower limit was not reached while T_{AVG} in western edge exceeded upper limit, Apart from this P_{AVG} and DP_{IV-IX} did not reach defined lower limit at the same time in Karlovarský region.

- Pardubický region: T_{AVG} and MC_{IV-IX} exceeded upper limit whereas DP_{IV-IX} did not reach to defined lower limit.
- Liberecký and Ústecký region: defined upper limit of P_{AVG} exceeded whereas DP_{IV-IX} did not reach to defined lower limit. DP_{IV-IX} fell bellow lower limit just in Ústecký region.
- Vysočina region: lower limit of P_{AVG} and MC_{IV-IX} was not reached.
- Jihočeský region: T_{AVG} exceeding upper limit while P_{AVG} lower limit was not reached.

Comparison of results of climatic variables used for climatic regionalization in frame of estimated pedological ecological system for the period 1961 – 2010 with range of their interval defined by *Mašát et al. (1974)* drawing conclusion that previously defined methodology do not refer to present climatic condition at all.

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