Evaluation of Soil Temperatures at Agroclimatological Station Pohořelice

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Abstract: Soil temperatures were analysed for the climatological station Pohořelice during the period of 1961–2000. According to the agroclimatic zoning, this region is a part of warm macroarea, mainly warm area, mainly dry subarea, and a district of mainly cold winter. The average annual air temperature is 9°C and the average year precipitation total is 475 mm. For the characterisation of the soil temperature were used the average monthly soil temperature determined from daily averages, maximal monthly soil temperature determined on the basis of daily maximums, and minimal monthly value determined on the basis of daily minimums. In the Czech Hydrometeorological Institute, the soil temperature was measured in the observation terms at 7:00, 14:00 and 21:00 local mean time. These temperature characteristics were assessed for the depths of 5, 10, 20, 50, and 100 cm. The longterm average annual temperature for the depths measured varies from 10.0°C (at 20 cm) to 10.4°C (at 100 cm). From the longterm viewpoint, the warmest month for the depths of 5, 10, and 20 cm is July, the coldest one is January, and for the depths of 50 and 100 cm the warmest month is August and the coldest one is February. For the classification of single months, the average monthly soil temperature for the respective month was compared with the longterm average soil temperature of 1961–2000. According to the average monthly soil temperature and its standard deviation, the months of the evaluated period were divided into seven categories: thermally normal months, warm months, very warm months, extraordinary warm months, cold months, very cold months, and extraordinary cold months.

Keywords: soil temperature; agroclimatology; soil characteristics

The soil temperature belongs to the outstanding environmental characteristics and is one of main factors of soil climate. From agroecological point of view, it affects the growth and development of the soil organisms and indirectly also the soil fertility; it impacts the water and air regimes, weathering rate, transformation of organic matter, and markedly the cation exchange capacity. The soil temperature also affects seeding, germination, and wintering of crops. Janík (2005) revealed a very close dependence of the biomass production in herbs on the soil temperature by regression analysis.

Pavelka *et al.* (2007) investigated the relationship between the soil CO_2 efflux and soil temperature. The daily dynamics of the soil CO_2 efflux is preferentially affected by the dynamics of the soil temperature near the soil surface.

The sources of soil heat are the Sun energy and biological activity. The soil heat regime is primarily regulated by the seasons and daily air temperature variations. It is also impacted by the radiation balance, exposition, water and air content in the soil, soil type, and canopy. In the moderate climatic zone, temporary subtropical and subarctic climatic zones, and in the areas with vertical

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mountain climate graduate the soil temperature decreases during the winter season. During the periods with the snow cover, the soil temperature is influenced by the heat-insulating feature of snow and possibly of the canopy. Daily amplitude of the soil temperature is given by the season (it is higher in summers), by cloudiness (cloudiness decreases temperature amplitude), soil moisture (the amplitude decreases with the soil moisture), soil colour (dark colour increases the amplitude), and canopy (higher crops decrease the amplitude).

Mellander *et al.* (2007) evaluated the influence of a warmer climate on the snow cover and soil temperature in Scots pine stands of varying ages in northern Sweden. They predict that a warmer climate will shorten the period of the persistent snow pack by 73–93 days, average soil temperature will increase by 0.9–1.5°C at 10 cm depth, advance the soil warming by 15–19 days in springs, and will cause more soil freeze-thaw cycles by 31–38% in the coming century.

The changes in the soil temperature may not be described only as a response to the changes in the air temperature and precipitation. The increasing air temperature has a positive impact on the soil temperature while the impact of the precipitation changes on the soil temperature is more complicated. Heavier snowfalls in early winters will have a strong positive impact on the soil thermal regime, while late snowfalls may have a negative impact due to their high albedo and consumption of latent heat during snow melting. Increased rainfalls in summers may also have a negative impact on the soil temperatures in the seasonally frozen-over regions due to the soil moisture feedback mechanism (Zhang *et al.* 2001).

The first soil temperature measurement results for a territory of the Czech Republic were published in 1873 for Hrušovany nad Jevišovkou locality. From the beginning, the soil temperature was related to other meteorological elements, for instance to the precipitations and air temperature in Hrušovany nad Jevišovkou, solar radiation (insolation), and night emission in Přerov. At first, the measurement of the soil temperature was realized just for a few stations. Regarding the measurement difficulty, the number of stations with the soil temperature measurement is still relatively low. In south Moravia, the soil temperature has been measuring at 23 stations. At nine stations, the soil freezing has been measuring additionally. This phenomenon is important mainly for the building industry (building destruction as the consequence of subsoil rising, freezing of pipelines), agriculture (frost-heaving, agrotechnology planning), forestry, and hydrology (rate of surface and subsurface outflow). The methods of manual and automatic measurements in the frame of the Czech Hydrometeorological Institute (CHMI) agroclimatic stations are described in Instruction for observers. The standard measurement depths are 5, 10, 20, 50, and 100 cm. Past climatological data of the soil temperature from the selected stations of the Czech Republic were published in Climate of ČSSR – Tables (Kolektiv 1961). The average monthly soil temperatures measured for 17 stations at standard depths from 20th to 50th years of 20th century are presented there. Monthly maximum and minimum soil temperatures (based on the observation terms values) are processed for 11 stations. Climate Atlas of ČSR (Kolektiv 1958) contains the diagrams of longterm annual average variations in the air temperature of extraordinary hot summer and extraordinary cold winter. The soil conditions of The Czech Republic are very various and this is also the reason for the spatial soil temperature evaluation difficulty. In the new Climatic Atlas of Czechia (Tolasz *et al.* 2007), the soil temperatures are presented in maps.

MATERIAL AND METHODS

Soil temperatures were analysed for the agroclimatological station Pohořelice in the period

Table 1. Pedological characteristics of argoclimatological station Pohořelice

Depth (cm) and index of genetic horizon	Color (dry/wet)	Sort of soil	Structure	Moisture
0–10 Ad	brown	loamy soil	crumb	fresh wet to dry
10–40 I M	brown	sandy-loam	crumb	fresh wet to dry
40–60 II M	light brown	sandy-loam	polyedric	fresh wet
60–100 D	light rusty	sandy soil	uncohesive	fresh wet

Table 2. Basic physical characteristics of argoclimatological station Pohořelice

Depth (cm)	Particle density (g/cm^3)	Soil porosity (vol. %)	Water retention capacity (vol. %)	Wilting point (vol. %)
10–20	2.65	49.69	36.74	13.38
30–40	2.64	47.31	39.93	12.04
50–60	2.70	41.92	32.01	12.84
70–80	2.63	38.42	15.74	5.84
90–100	2.63	38.42	15.74	5.84

of 1961–2000. Agroclimatic characterisation of Pohořelice is as follows: warm macroarea, mainly warm area, mainly dry subarea, and a district of mainly cold winter. The measurements of the soil temperature were realized in the observed terms at 7, 14, and 21 h of local mean time. The missing data were completed on the basis of correlation analysis of the soil temperatures from different depths and air temperatures (Pokladníková & Rožnovský 2007). The station is located in a plain area in the altitude of 180 m a.s.l. The pedological characteristics are presented in Tables 1 and 2. The soil type at the Pohořelice station is Fluvisol FLi.

For the classification of individual months, the average monthly soil temperature in the given month (for example January 1963) was compared with the longterm average soil temperature for this month (January 1961–2000). According to the average monthly soil temperature and its standard deviation, the months of the evaluated period were divided into the following categories:

$\Delta t_{AVG} \leq \pm S_{\bar{x}}$ month temperature normal

$\Delta t_{AVG} \leq 1.5\ S_{\bar{x}}$ warm month

$\Delta t_{AVG} \leq 2\ S_{\bar{x}}$ very warm month

$\Delta t_{AVG} > 2\ S_{\bar{x}}$ extraordinary warm month

$\Delta t_{AVG} \geq -1.5\ S_{\bar{x}}$ cold month

$\Delta t_{AVG} \geq -2\ S_{\bar{x}}$ very cold month

$\Delta t_{AVG} < -2\ S_{\bar{x}}$ extraordinary cold month

where:

Δt_{AVG} – difference between average monthly soil temperature in the given year and the longterm average (1961–2000)

$S_{\bar{x}}$ – standard deviation (1961–2000)

The temperature categories were assessed for every depth (5, 10, 20, 50, and 100 cm) and every month. Graphical imagination of the methodology used is presented in Figure 2 (processed for 5 cm depth for January).

RESULTS AND DISCUSSION

Absolute maximal soil temperature at depths of 5, 10, and 20 cm occurred in July 1963, at a depth of 50 cm in September 1994, and at a depth of 100 cm in May 1969. Absolute minimal soil temperature at depths of 5 to 50 cm occurred in February 1963 and at a depth of 100 cm in January 1964 and March 1963. There is a noticeable shift of maximal and minimal soil temperature values with the depth. The mean year amplitude decreases with the depth (from 20.7°C at 5 cm to 13.7°C at 100 cm). The average annual temperature is almost constant in the whole soil profile and varies from 10.0°C to 10.4°C (see Table 3).

The annual variation in the average daily temperatures during the years 1961–2000 is shown in Figure 3. In the longterm average, the coldest days are 18th to 21st January when the temperature at 5 cm decreases to –0.9°C, the warmest day is 2nd August when the soil temperature reaches 22.0°C at the depth of 5 cm.

The results of longterm soil temperature measurements were published abroad by Garcia-Suarez and Butler (2006), who evaluated the data from three stations in North Ireland in the period of 1904–2002. They found out (depending on season, locality, and depth) the increase of the soil temperature of about 0.04°C to 0.25°C during ten years using the linear regression method. The influence of global radiation, air temperature, and soil characteristics on the soil temperature at depths of 2, 5, 10, and 50 cm was investigated by Alexandrova and Etropolski (2003). Using regression equations, they characterised the relation between the air temperature and soil

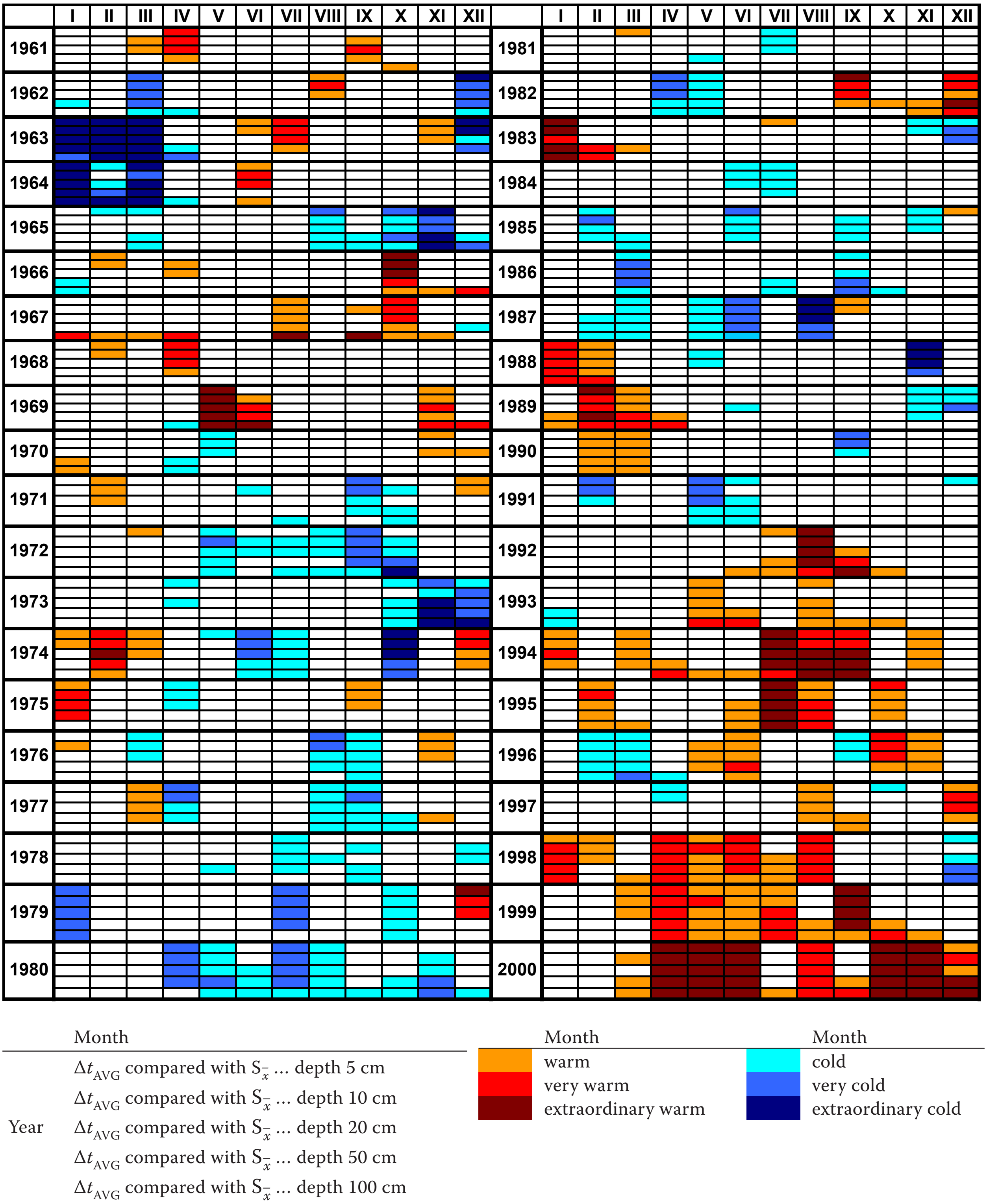

Figure 1. Classification of single months from the soil temperature viewpoint for the period of 1961–2000

temperature at depths up to 50 cm. Also Feng and Cai (2004) studied the soil temperature depending on the air temperature, latitude, and altitude. Plauborg (2002) described possibility of soil temperature modelling at a depth of 10 cm on the basis of meteorological station data. The model was calibrated for various soil types with lawn stand in Denmark. The mentioned methods may be used in such cases when the database of the measured data is not complete.

Table 3. Characteristics of soil temperature, Pohořelice station 1961–2000

Soil depth (cm)			Longterm average 1961–2000												
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
5	AVG	°C	**–0.5**	0.3	4.0	9.9	15.6	19.7	**21.2**	20.4	15.9	10.3	4.8	0.9	10.2
	MAX	°C	6.0	7.9	12.6	19.9	28.2	28.6	**29.1**	28.8	22.6	18.6	12.6	8.1	
		year	1983	1989	1968	2000	1969	2000	**1963**	1963	1994	1994	1997	1979	
	MIN	°C	–9.2	**–9.5**	–8.2	1.5	6.8	10.9	13.5	13.0	8.9	0.5	–1.5	–6.5	
		year	1963	**1963**	1963	1963	1982	1962	1970	1987	1977	1991	1983	1961	
10	AVG	°C	**–0.2**	0.4	3.8	9.6	15.2	19.2	**20.8**	20.1	15.9	10.5	5.1	1.2	10.1
	MAX	°C	5.5	7.5	12.8	18.7	27.7	28.2	**28.7**	28.4	22.6	17.9	11.4	6.47	
		year	1983	1998	1973	1962	1969	2000	**1963**	1963	1997	1994	1989	2000	
	MIN	°C	–7.8	**–8.1**	–7.1	1.9	6.8	11.3	13.9	13.2	8.9	1.4	–1.4	–5.0	
		year	1963	**1963**	1963	1963	1985	1962	1970	1987	1977	1991	1983	1963	
20	AVG	°C	**0.4**	0.7	3.6	9.1	14.3	18.3	**19.9**	19.6	15.8	10.8	5.7	1.9	10.0
	MAX	°C	5.0	7.0	10.7	17.4	26.3	25.4	**26.5**	26.4	21.7	17.6	10.8	6.2	
		year	1983	1998	1968	2000	1969	2000	**1963**	1994	1992	1975	2000	1997	
	MIN	°C	–5.2	**–6.3**	–5.5	1.1	6.9	11.7	14.5	14.2	9.4	3.5	0.5	–3.1	
		year	1964	**1963**	1963	1963	1985	1962	1984	1972	1976	1991	1975	1983	
50	AVG	°C	2.2	**2.0**	3.9	8.4	12.8	16.6	18.5	**18.8**	16.2	12.3	7.7	4.0	10.3
	MAX	°C	6.6	6.9	8.9	15.4	24.1	22.3	23.6	**24.2**	22.2	17.4	12.3	8.0	
		year	1983	1983	1968	2000	1969	2000	1994	**1994**	1992	1999	1977	2000	
	MIN	°C	–2.0	**–2.7**	–2.2	0.0	7.4	11.5	14.8	14.3	11.5	6.8	3.0	0.8	
		year	1964	**1963**	1963	1963	1982	1981	1984	1972	1977	1973	1965	1963	
100	AVG	°C	4.4	**3.6**	4.5	7.4	10.9	14.3	16.4	**17.3**	16.0	13.3	9.7	6.4	10.4
	MAX	°C	6.7	6.3	7.6	12.6	**21.4**	20.4	21.0	21.2	20.5	17.3	13.3	10.3	
		year	1983	1989	1977 1994	2000	**1969**	2000	1967	1967	1992	1994	2000	2000	
	MIN	°C	**1.3**	1.4	**1.3**	**1.7**	7.0	10.2	13.7	14.6	13.0	9.6	6.0	3.9	
		year	**1964**	1963 1964	**1963**	**1963**	1982	1991	1987	1987	1977	1973	1965	1962	

AVG – average monthly soil temperature (°C) computed on the basis of average daily values from the observed term measurements by arithmetic mean method: AVG = $(t_7 + t_{14} + t_{21})/3$
MAX – absolute maximum soil temperature (°C) + year of its occurrence
MIN – absolute minimum soil temperature (°C) + year of its occurrence

From Figure 4, almost regular rotation of multiannual episodes with higher and lower soil temperatures is obvious (for instance 1962–1965 vs. 1966–1971 vs. 1972–1973 vs. 1974–1977 vs. 1978–1990). Since the beginning of 90th years, the average annual soil temperature has persisted at the level of maximal annual values of 1961–1991. The variations in the rotation of lower and higher temperatures are not so significant any more. During the evaluated period of 1961–2000, the absolute higher annual soil temperature was recorded in 2000. In subsequent six years (which are not included in the evaluation), the increasing trend of the average annual soil temperature

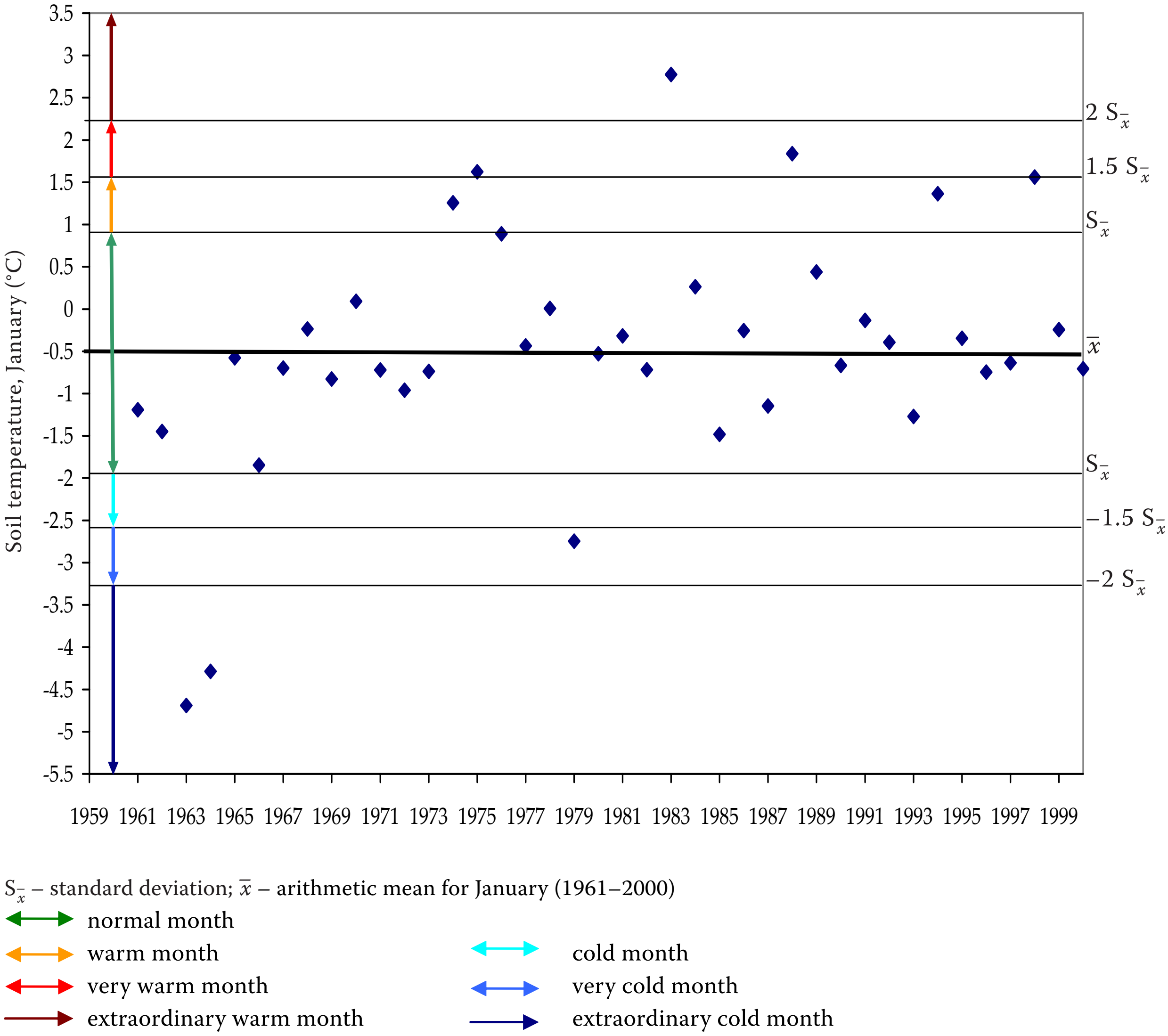

Figure 2. Average monthly soil temperature at the depth of 5 cm (January 1961–2000)

has not been continuing. The values set about 1°C below maximum measured in 2000. Linear regression shows the soil temperature increase of about 1°C from the beginning to the end of the evaluated period. This trend is obvious also in the case if the maximal value of the year 2000 is not included.

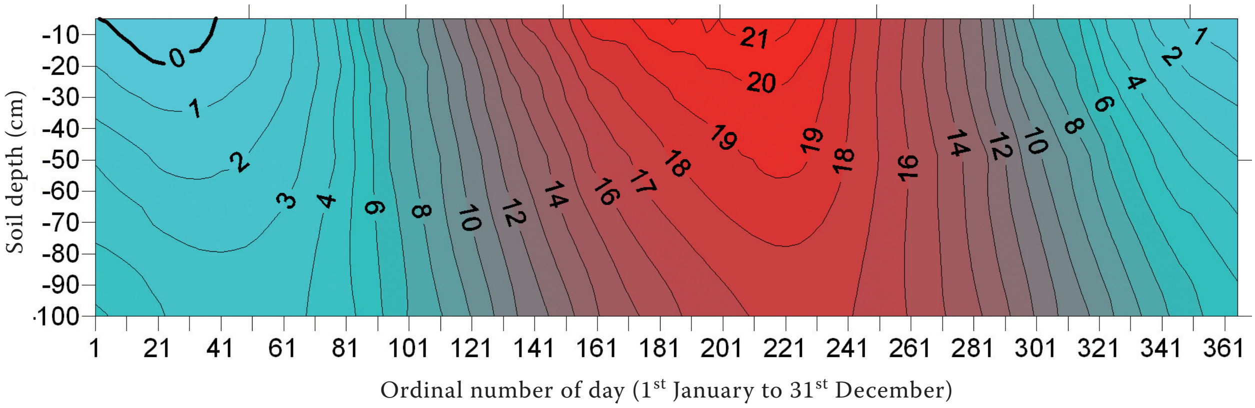

Figure 3. Course of daily average soil temperature, Pohořelice station 1961–2000

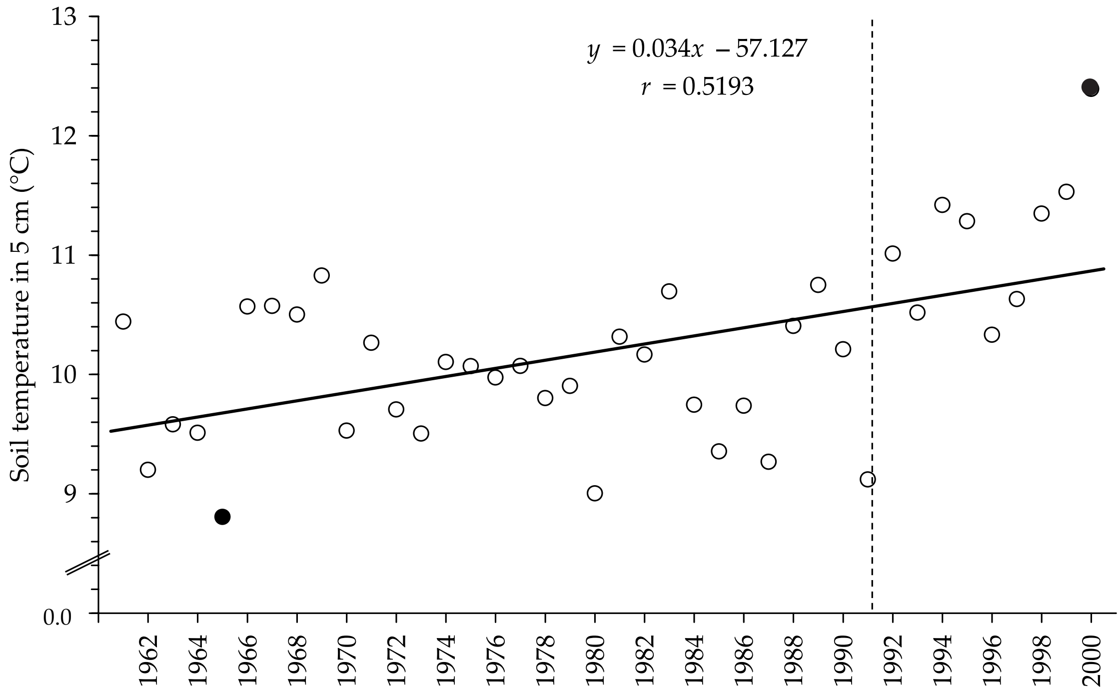

Figure 4. Shift of average monthly soil temperature at 5 cm; 1961–2000

As extraordinary warm in the whole soil profile (to the depth of 100 cm) 7 months can be characterized – May 1969, July 1995, April, May, October and November 2000 and January 1983 except the depth of 20 cm (just very warm), August 1992 except the depth of 100 cm, and July 1994. From the evaluation presented in Figure 1 results that the warmest year was 2000. In this year the temperature was normal in January and February, March was warm at depths of 10, 50, and 100 cm, April to June were extraordinary warm in the whole profile, July was warm at a depth of 100 cm, August was very warm in the whole profile, September was warm at 50 cm and very warm at 100 cm, October and November were extraordinary warm, and December was warm at 5 and 20 cm, very warm at 10 cm, and extraordinary warm at 100 cm.

The months classified as extraordinary cold were January (except 100 cm depth – just very cold), February, March 1963, and January and March 1964 (except 10 cm depth). The coldest year was the year 1980. January, February and March were normal, April was very cold to the depth of 50 cm, May cold respectively very cold, June cold from 20 to 100 cm, July very cold to 50 cm and cold at 100 cm, August cold, September cold just at 100 cm, October cold at 50 and 100 cm, November cold at 10 and 20 cm and very cold at 50 and 100 cm, December was cold only at a depth of 100 cm.

CONCLUSION

Longterm average annual soil temperature at measured depths varies from 10.0°C (at 20 cm) to 10.4°C (at 100 cm).

From the longterm viewpoint, the warmest month considering the depths of 5, 10, and 20 cm is July, the coldest January, and as to the depths of 50 and 100 cm, the warmest month is August and the coldest one is February (Table 3).

The occurrence of maximal and minimal values depends on the depth. The average annual amplitude decreases with the depth (at a depth of 5 cm it was 20.7°C, at 10 cm 20.6°C, at 20 cm 19.5°C, at 50 cm 16.8°C, and at 100 cm 13.7°C).

Extraordinary warm in the whole soil profile in the period of 1961–2000 were 7 months.

Extraordinary cold in the whole soil profile in the period of 1961–2000 were 3 months.

The warmest year was 2000, the coldest year 1980.

In the longterm average, the coldest days are 18th to 21st January, the warmest day is 2nd August (Figure 3).

From Figure 4 almost regular rotation of multi-annual episodes with higher and lower soil temperatures is obvious. Since the beginning of 90^{th} years the average annual soil temperature, has persisted at the level of maximal year values of 1961–1991.

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