Evaluation of the monthly air temperature extremity for the 1961-2007 period

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Abstract: For the evaluation of monthly temperature extremity of the 1961–2007 period three stations in south Moravia (Brod nad Dyjí, Lednice and Velké Pavlovice) were chosen. The elevation of the stations is about 200 m a.s.l. and their relative distance is 11–17 km. The mean monthly air temperature based on daily means was compared with the mean monthly air temperature of the normal-period (1961–1990) concrete month. According to the standard deviation of the normal-period included in this difference, the extremity categories were defined. Every month was included to the defined category of extremity (extraordinary above normal, far above normal, above normal, normal, below normal, far below normal and extraordinary below normal). As extraordinary above normal 79 months, as far above normal 115 months, as above normal 175 were classified. As extraordinary below normal 32 months, as far below normal 86 and as below normal 129 were classified. Periods of 1961–1970 and 1971–1980 contain more cold months than the last two periods (with the prevailing warm month). This trend of warming during last 17 years is perceptible at all stations. From this study, the spatial temperature diversity is obvious even in a small area considered.

Key words: air temperature, normal period, extreme temperature

1. Introduction

The weather and its valuation within the year, vegetation seasons, winter, individual months etc. is an internal part of many scientific works, research designs, vegetation experiments, testing of chemicals and creating of growing models (*Kožnarová and Klabzuba, 2002*).

Longterm trends, interannual and intraseasonal variabilities in the mass-balance record are related to the local climate change, synoptic and large

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scale anomalies in the atmospheric circulation (*Shahgedanova, 2007*). For the longterm climate analyses – particularly the climate variability and change analyses – to be specific, the climate data used must be homogeneous (*Peterson et al., 1998*).

Easterling et al. (2000) gives an overview of the literature related to temporal variations in temperature extremes. In the context of climate change under consideration, accompanied by an increase in natural disasters or glacier retreat, especially the mean temperatures have been compared with the longterm means in the last decades. Seasonal analyses show that the greatest temperature increase in the 1975–2004 period occurred during spring and summer whereas they were particularly weak in spring during the 20^{th} century. Recent temperature increases are much more related to increases in the maximum temperature as to increases in the minimum temperature, a trend that was not apparent in the 1901–2000 period (*Rebetez and Reinhard, 2008*). The monthly mean temperatures showed significant warming of winter months. Over the last four decades, the minimum, maximum and mean temperatures had warmed by 0.40, 0.43 and 0.40°C per decade, respectively, and if this trend continues, they will be warmer by 4°C by the end of the 21^{st} century (*Kumar, 2005*).

Alexandrov et al. (2004) found no significant warming trend in Bulgaria during the last century inspite of the warming observed during the last two decades. Summer tends to be warmer from the beginning of the 1980s.

Mean monthly air temperature data from West Greenland reveal the longterm interannual changes of air temperature anomalies. The warming trend which was observed during November and December 1995 was maintained into 1996 for about five months (*Stein, 1998*).

The comparison of actual weather with normal or longterm average is possible in many ways. For the elements with non-negative values (for instance the precipitation totals) the percentages of normal or longterm average can be used. For the characteristics with negative and positive values (temperature) it is possible to use the standard deviation of normal or longterm means. For both types of these climatological elements, the qualitative evaluation is suitable. It means a definition of categories in which the values are included. As an optimal way of assessment of the categories the percentiles (for example 1, 5, 10, 90, 95 and 99%) of the theoretical distribution of given climatological element are considered. The

critical values depend on the chosen theoretical distribution so that results can differ from each other (*Brázdil and Štěpánek, 2002*). Trends in the occurrence of maximum and minimum temperatures greater than the 90^{th}, 95^{th}, and 99^{th} percentile across the United States are strongly influenced by urbanization (*DeGaetano and Allen, 2002*).

Zhang et al. (2008) defined an extreme temperature event by exceeding or falling below various threshold values of daily maximum and daily minimum air temperature: 90^{th} percentile, 95^{th} percentile for the high-temperature events; 10^{th} percentile and 5^{th} percentile for the low-temperature events. Trends in warm extremes have tended to be more pronounced than for cold extremes, but still it has proven difficult to characterize the behavior of these trends on a national or regional level (*Bonsal et al., 2001*).

"Normal" is a statistical climatic characteristic computed for long enough time series of meteorological measurement and observation within climatic stable period for climate representation of a given place. The standard climatic normal is the 1961–1990 period. As a "longterm average" the other period than "normal" is considered.

2. Material and methods

For the evaluation of air temperature three stations in south Moravia were chosen: Brod nad Dyjí, Lednice and Velké Pavlovice. All of those localities lie at altitudes less than 200 m a.s.l. (see Table 1) and the relative distance of the stations 11 to 17 km ranges from. According to agroclimatic regionalization the stations are included in the warm macroarea, very warm area, mainly dry subarea and district of mainly moderate winter (*Kurpelová et al., 1975*).

Table 1. Altitude of chosen stations

Climatological station	Altitude (m a. s. l.)
Brod nad Dyjí	175
Lednice	176
Velké Pavlovice	196

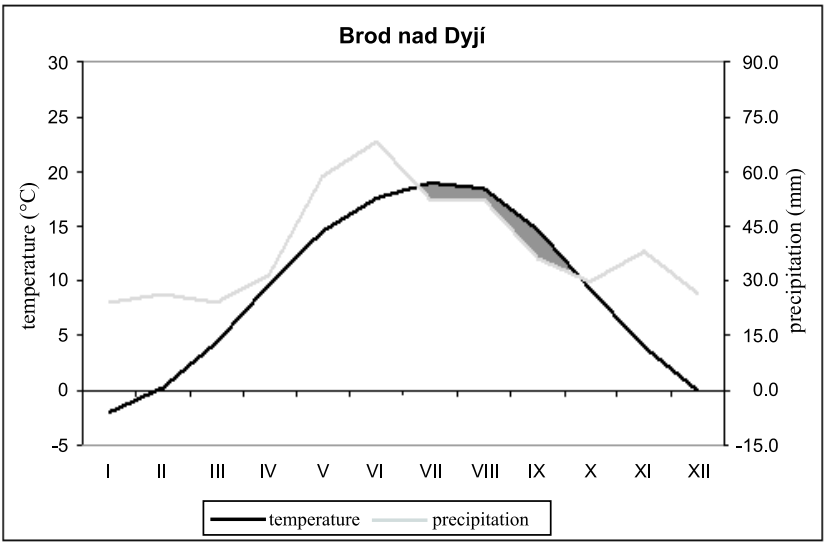

Fig. 1. Yearly course of air temperature and precipitations at Brod nad Dyjí station (1961–1990).

The figures show the yearly course of air temperature and precipitation distribution (Figs. 1 to 3). The grey areas (the overlap of temperature and precipitation curves) represent a season with lack of precipitation. The mean annual air temperature of normal period (1961–1990) is 9.2°C at all stations. The mean annual precipitation total is 468 mm in Brod nad Dyjí, 481 mm in Lednice and 489 mm in Velké Pavlovice.

The data series result from the net station of Czech Hydrometeorological Institute (CHMI). By the use of geostatistical methods and linear regression the station from the neighbourhood of chosen locality were standardized to the same altitude and by Inverse Distance Weighted (IDW) methods the values of climatological elements for chosen pot were given. The data of technical series were compared with the standard deviation of the normal period.

Assessment of air temperature extremity categories

On the basis of mean daily air temperature (1961–2007), the monthly means were computed. The extents of single categories were assessed for every month from January to December according to the mean monthly

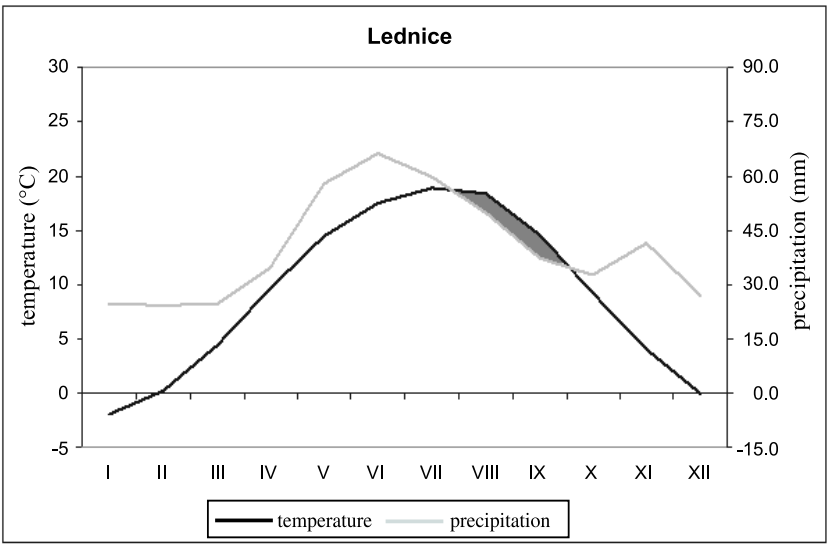

Fig. 2. Yearly course of air temperature and precipitations at Lednice station (1961–1990).

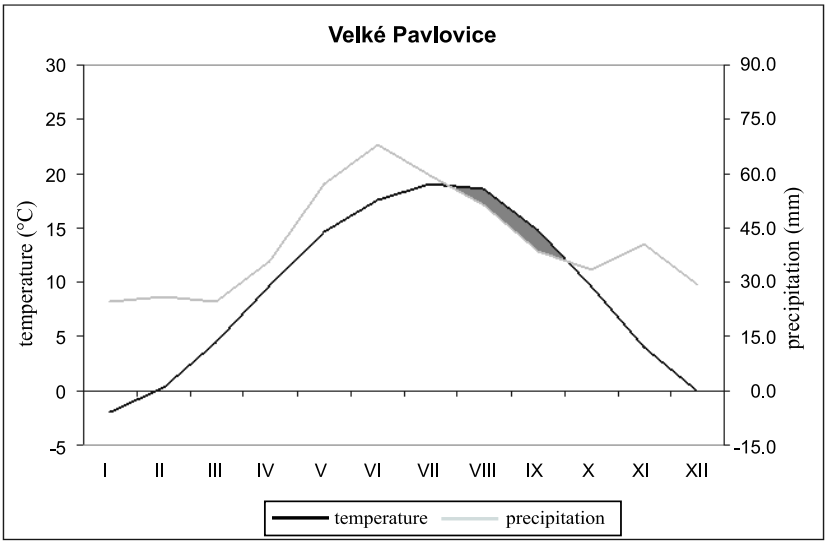

Fig. 3. Yearly course of air temperature and precipitations at Velké Pavlovice station (1961–1990).

air temperature of the normal period (1961–1990) and its standard deviation for every month (January to December). This method of evaluation supposes the normal distribution of air temperature data. Then the difference of monthly mean of particular month (for instance January 1970) and monthly mean of the normal period of given month (January 1961–1990) were assessed. According to the standard deviation of the normal period included in this difference, the mentioned categories were defined. In the case of difference less than the normal standard deviation the month was classified as the temperature normal. The months with difference less (more) than ±1 multiple of the normal standard deviation were classified as temperature below (above) normal, less (more) than ±1.5 multiple as far below (above) normal and less (more) than 2 multiple as extraordinary below (above) normal.

The following categories were defined (Note to Tables 2–4):

●●● extraordinary above normal
●● far above normal
● above normal
○ below normal
○○ far below normal
○○○ extraordinary below normal

Empty cells mean months classified as temperature normal.

3. Results and discussion

Brod nad Dyjí

At the Brod nad Dyjí station, 30 months were classified as extraordinary above normal (7 of them within years 1961–1990 and 23 within years 1991–2007). In 2000 there have been 6 extraordinary above normal months. As far above normal 35 months, and as above normal 57 (half of this value occurred from 1991 to 2007) were classified. Extraordinary - below - normal months occurred 10× (2 within 1991–2007), far below normal 30× and below normal 45× (Table 2).

Table 2. Evaluation of monthly temperature extremity, Brod nad Dyjí (1961–2007)

Brod nad Dyjí												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1961			●	●●●	○		○		●	●		
1962			○○	●	○○	○	○		○			○○
1963	○○	○○○	○								●●●	○○○
1964	○		○			●●		○				
1965		○			○○		○	○○		○○	○○	
1966		●●		●						●●●		
1967							●			●		
1968				●		●					●	○
1969			○		●●							○○○
1970											●	
1971					●	○		●●	○○			●●
1972									○○	○		
1973				○						○	○	
1974	●●	●	●			○○	○	●●		○○○		●●
1975	●								●●●			
1976			○				●	○○			●	
1977			●	○					○○			
1978				○	○		○○	○			○	
1979	○					●●●	○○					●●
1980				○○	○○						○	
1981			●			●						
1982	○			○					●●●			
1983	●●			●			●●●	●●			○	
1984						○	○					
1985	○○○	○○			●	○○○					○○	●
1986		○○○		●	●●							
1987	○○		○○		○			○	●●	●		
1988	●				●						○○○	●
1989		●	●			○						
1990		●	●●					●●	○			
1991		○○			○○○		●●		●			
1992	●					●	●●	●●●				
1993					●●●						○○	
1994	●●		●			●	●●●	●●●	●●	○	●	
1995		●●					●●●			●	○	
1996		○○	○						○○○		●	○○
1997				○○				●		○○		●
1998	●	●		●●		●●	●	●			○○	
1999				●			●		●●●			
2000				●●●	●●●	●●●		●●●		●●●	●●●	
2001					●●		●	●●●	○	●●●		○○
2002		●●			●●●	●●	●●	●			●●	○
2003					●●●	●●●	●	●●●		○○	●	
2004				●				●●				
2005				●					●			
2006	○			●		●	●●●	○	●●	●●	●●	●●
2007	●●●	●●	●	●●●	●●	●●●	●●	●●●	○	○		

Table 3. Evaluation of monthly temperature extremity, Lednice (1961–2007)

Lednice												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1961			●	●●●	○	●	○		●	●		
1962			○○	●	○○	○	○					○○
1963	○○	○○○	○				●				●●●	○○○
1964	○		○			●●		○				
1965		○			○○			○○		○○	○○	
1966		●●		●						●●●		
1967							●●			●		
1968				●		●					●	○○
1969			○		●●●						●	○○○
1970											●●	
1971					●			●●	○			●●
1972		●							○○	○		
1973				○						○	○	
1974	●	●	●			○○		●●		○○○		●●
1975	●●								●●●			
1976			○				●	○○		●	●	
1977			●	○		●			○○			
1978				○	○		○○	○			○	
1979						●●	○○					●●
1980				○○	○○		○				○	
1981			●									
1982	○			○○					●●●			
1983	●●			●			●●●	●			○	
1984						○	○					
1985	○○○	○○			●	○○○					○○	●
1986		○○○		●	●●							
1987	○○		○○○		○			○	●			
1988	●				●						○○○	●
1989		●	●			○						
1990		●	●					●●	○			
1991		○○			○○○		●●		●			
1992						●	●●	●●●				
1993					●●●						○○	
1994	●●		●			●	●●●	●●●	●●		●	
1995		●●					●●●			●	○	
1996		○○	○						○○○		●	○○
1997				○○				●		○○		●
1998	●	●		●●		●●	●	●			○○	
1999				●			●●		●●●			
2000		●		●●●	●●●	●●●		●●		●●●	●●●	
2001					●●		●	●●	○	●●		○○
2002		●●			●●●	●●	●●	●			●●	○
2003					●●●	●●●	●	●●●		○	●	
2004				●				●●		●		
2005												
2006	○		○			●	●●●	○	●●	●	●●	●●
2007	●●●	●●	●	●●	●●	●●●	●●	●●	○			

Table 4. Evaluation of monthly temperature extremity, Velké Pavlovice (1961–2007)

Velké Pavlovice												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1961			●	●●●	○				●●	●		
1962			○	●	○○	○	○	●				○○
1963	○○	○○○	○				●				●●●	○○○
1964	○		○	●		●●						
1965		○			○○			○○		○	○○	
1966		●●		●						●●●		
1967							●●			●		
1968				●		●					●	○
1969			○		●●						●	○○○
1970											●●	
1971					●●			●●	○			●●
1972									○○	○		
1973				○				●		○	○	
1974	●	●	●			○○		●●		○○○		●●
1975	●●								●●			
1976			○				●	○			●	
1977			●	○					○○			
1978				○	○		○○	○			○	
1979				○		●●	○○					●●
1980			●	○○	○○		○				○	
1981			●									
1982	○			○					●●●			
1983	●●			●			●●●	●●			○	
1984						○	○					
1985	○○○	○○				○○○					○○	●
1986		○○○		●	●●							
1987	○○		○○○		○			○○	●			
1988	●				●						○○○	●
1989		●	●			○						
1990		●	●●					●	○			
1991		○			○○○		●●		●			
1992	●					●	●●	●●●		○		
1993					●●●						○○	
1994	●●		●				●●●	●●●	●	○○	●	
1995		●●					●●●			●	○	
1996		○○	○○						○○○		●	○○
1997				○○				●●		○○		●
1998	●	●		●●		●●		●			○○	
1999				●			●		●●●			
2000		●		●●●	●●●	●●●		●●●		●●●	●●●	
2001					●●		●	●●	○	●●		○○
2002		●●			●●●	●●	●●	●●			●●	○
2003					●●●	●●●	●	●●●		○○	●	
2004				●				●●		●		
2005				●								
2006	○		○	●		●	●●●	○	●●	●	●●	●
2007	●●●	●	●	●●	●●	●●●	●●	●●	○	○		

Lednice

At the Lednice station, 25 months were classified as extraordinary above normal (7 of them within years 1961–1990 and 18 within years 1991–2007). In 2000 there occurred 5 as extraordinary above normal months. 39 months were classified as far above normal and 60 as above normal (half of this value occurred from 1991 to 2007). Extraordinary - below - normal months occurred 11 (just 2 within 1991–2007), far below normal 29 and below normal 40 in number (Table 3).

Velké Pavlovice

At the Velké Pavlovice station, 24 months were classified as extraordinary above normal (5 of them within years 1961–1990 and 19 within years 1991–2007). In 2000 there occurred 6 as extraordinary above normal months. 41 months were classified as far above normal and 59 as above normal (half of this value occurred from 1991 to 2007). Extraordinary - below - normal months occurred 11 (2 within 1991–2007), far below - normal 27 and below normal 44 in number (Table 4).

Figs. 4 to 6 present the abundance of months divided to categories of extremity for five partial 10 (7) years long period (1961–1970, 1971–1980, 1981–1990, 1991–2000, 2001–2007) for each station. The months classified as normal are not included. It is obvious that the first two periods (1961–1970 and 1971–1980) contain more cold months than last two (with prevailing warm month). This trend of warming during the last 17 years is perceptible in all stations.

Note to Figs. 4 to 6:
EAN – extraordinary above normal
VAN – very above normal
AN – above normal
BN – below normal
VBN – very below normal
EBN – extraordinary below normal

4. Conclusion

The coldest year in terms of mean annual temperature was 1965 at the Brod nad Dyjí station with the mean annual temperature of 8.0°C, which is

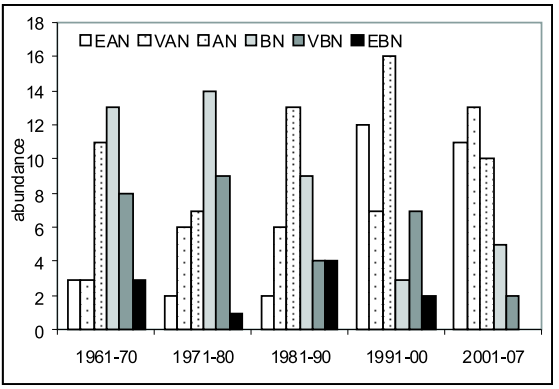

Fig. 4. Abundance of months divided to extremity categories, Brod nad Dyjí.

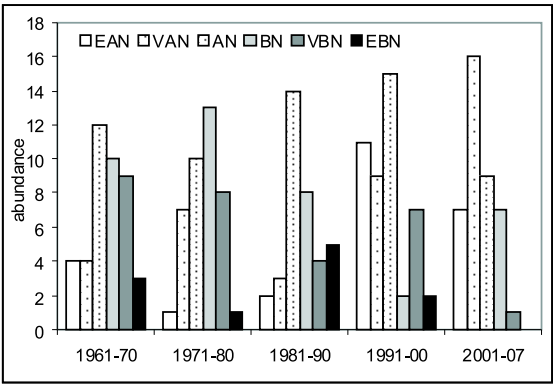

Fig. 5. Abundance of months divided to extremity categories, Lednice.

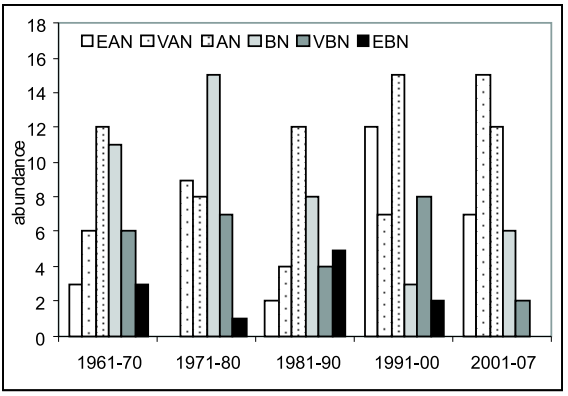

Fig. 6. Abundance of months divided to extremity categories, Velké Pavlovice.

1.2°C lower than normal, and 1985 with mean annual temperature of 8.1°C. At the stations Lednice (8.0°C) and Velké Pavlovice (8.0°C) the coldest year was 1985 (1.0°C and 1.1°C below normal).

The warmest year at all stations was 2000 with the mean annual temperature of 11.1°C, i.e. almost 2°C above normal. The years classified as extraordinary above normal occurred 5 times at the Brod nad Dyjí station, 4 at the Lednice station and 3 at the Velké Pavlovice station. At all stations it includes the years 1994, 2000 and 2007. Also the year 1985 was comparable – Lednice 8.1°C, Velké Pavlovice 8.2°C.

At all stations 32 months were classified as extraordinary below normal, 86 as far below normal and 129 as below normal. Above normal months there occurred 175 stations, very above normal months 115 and extraordinary above normal months 79 in the 1961–2000 period.

The 1961–1970 and 1971–1980 periods contain more cold months than last two (1991–2000 and 2000–2007) with prevailing warm months. This trend of warming during the last 17 years is perceptible at all stations.

It is evident that there is variability also among the neighbouring stations. Therefore the extremity should be evaluated for every station. The use of unified categories for large areas (e.g. whole country) is not suitable.

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