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Increase of annual and seasonal air temperatures in the Czech Republic during 1961 - 2010

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Abstract

Using the monthly means of air temperatures at 267 stations in the Czech Republic, the long-term change has been estimated at each station for the last 50 years. Annual mean temperatures for the whole country show a considerable increase, more pronounced than that for global temperature, however, supplemented by strong fluctuations from year to year. Long-term changes in air temperatures at different stations and in different regions vary. Stronger increase in air temperatures can be seen in Bohemia, whereas in Moravia temperature increase is not so significant. This difference is more pronounced in the winter, whereas in the summer, the differences are smaller and perhaps of opposite nature. This means that the continentality of the climate in Moravia increases, while in Bohemia it very slightly decreases. Long-term changes depend only marginally on the absolute values of annual mean temperatures at the respective station. The increase of autumn temperatures is considerably lower than that of other seasons.

Keywords: air temperatures, long-term change, regions, seasons

Introduction

The climate change – global warming – has been the subject of intensive research for many decades. The observed temperature increase started more than a century ago and in the last decades has become more and more rapid. It is believed that the main cause of this increase is the increasing concentration of greenhouse gases in

the atmosphere due to human activity (Smith, 1993). The process is irreversible and so the increase of global temperature is expected to continue in the future (Hansen and Sato, 2004) as well. There are also some natural long-term temperature fluctuations (Pfister, 1992), which may mean some necessary corrections of the supposed increase.

The temperature increase varies in different regions. In general, in the Northern Hemisphere the temperature increases more than in the Southern one. Especially, compared to the tropic region (between 30^{o} N and 30^{o} S), the increase is more pronounced towards North and less pronounced towards South (Brohan et al., 2006). Moreover, some preliminary studies suggest that also within the European territory, even over some small regions, the temperature increase is not equal.

In this paper, data from a network of stations on the territory of the Czech Republic will be processed and the increase at each station will be determined. The differences among the individual stations will be analyzed in order to find possible dependence of this increase on the position of the station.

Materials and methods

As a source material, the monthly mean temperatures observed at 267 stations in the Czech Republic have been used. From these data, the annual and seasonal mean for each station and mean values for the Czech Republic as a whole have been calculated. For comparison, also the global temperatures have been included.

Results

Annual mean temperature for the whole Czech Republic over the entire period analyzed is 7.62 degrees centigrade. During the individual years, however, one can see a large variation in the observed data: in the warmest year 2000 it was 9.07 ^{o}C, in 2007 it was 9.04 ^{o}C, in the coldest ones 1980 and 1996 only 6.27 ^{o}C, in 1962 it was 6.31 ^{o}C. There are very large differences between temperatures observed at the individual stations. In general, the temperature depends on the altitude (corr. coefficient -0.75). Therefore the warmest regions are lowlands, especially South Moravia, and the Elbe lowland. Nevertheless, the highest mean annual temperature (10.36 ^{o}C) has been observed in Prague (197 m above sea level) due to the urban heat island effect. The coldest regions are mountains, the lowest mean annual temperature (1.26 ^{o}C) has been observed at Praděd (1492 m). These numbers are

means for the whole period of 1961-2010. The highest annual mean temperature has been observed in 2007 in Prague (12.1 ^{o}C), the lowest one in 1980 at Praděd (-0.3 ^{o}C). The mean temperature also depends to a smaller extent on the latitude (corr. coefficient -0.20) and longitude (corr. coefficient 0.15), but this dependence is masked by the unequal distribution of mountains and lowlands in the Czech Republic territory and therefore no conclusions can be derived from this dependence. The distribution of annual mean temperatures over the territory of the Czech Republic is presented in Fig. 1.

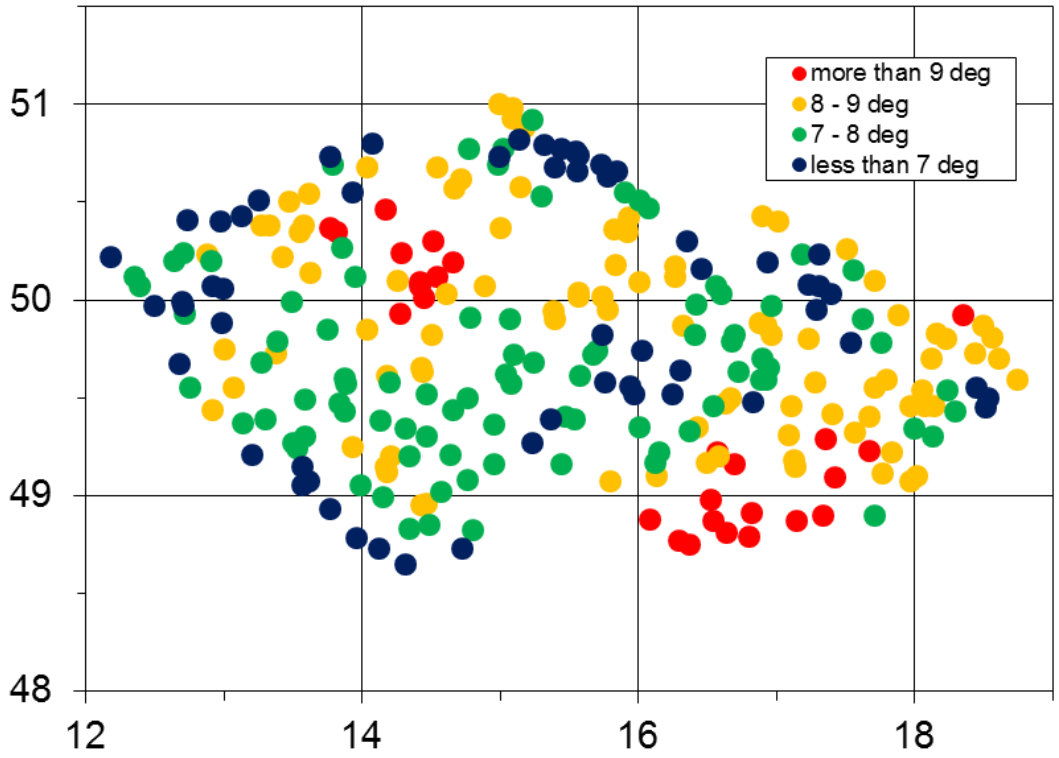

Fig. 1. Distribution of annual mean air temperatures during 1961-2010 over the territory of the Czech Republic.

During the last 50 years, the annual mean temperature has clearly been increasing. This increase is supplemented by considerable fluctuations from year to year. The course of the mean annual temperatures for the Czech Republic as a whole is shown in Fig. 2 together with the course of the global temperature during the same time period. A constant has been added to the global temperature in order to achieve the same mean value as the temperature for the Czech Republic (7.62 ^{o}C.). It is clear that the increase of the temperature in the Czech Republic is more pronounced than that of the global temperature. Based on the regression lines, the increase was

determined to be 1.40 °C for the temperatures in the Czech Republic, whereas for the global temperatures the increase is only 0.70 °C and for the NH region not including the tropics (above 30° N) it is 0.89 °C (Brohan et al., 2006). Regression lines are mathematically expressed as $T = 0.028 * y - 48.36$ for the Czech republic and $T = 0.034 * y - 68.07$ for the global temperature (where T is the temperature and y is the year).

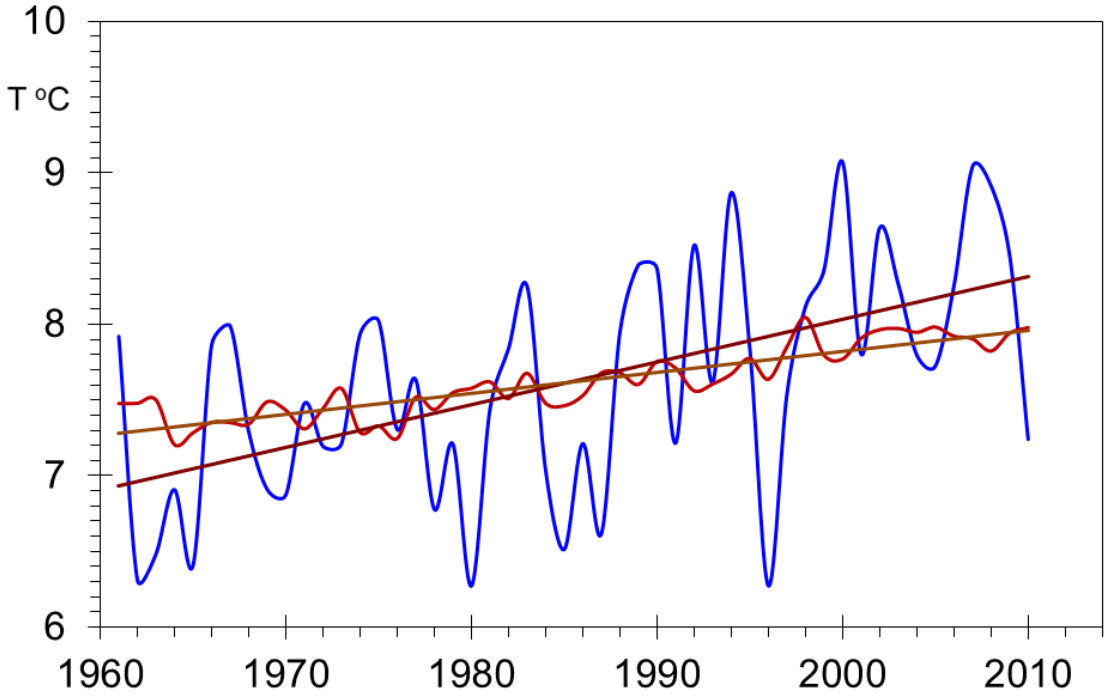

Fig. 2. The course of annual mean air temperatures for the Czech Republic during 1961-2010 (blue) and of the global temperature (red). Approximation by regression lines (brown) is also shown.

In addition, there are many fluctuations, which are quite different for both series. Their amplitude for the data from the Czech Republic is considerable; the temperature sometimes ranges by more than 2 degrees during 1-2 years. Similar fluctuation in the global temperature is much less apparent because these data are smoothed over the whole Earth. There is no evident long-term periodicity (for periods of about 3 – 10 years) which would suggest that warm and cold years alter regularly. The mean air temperature for the first half of the period investigated (1961-1985) is 7.24 ± 0.58 °C, for the second half (1986-2010) 8.00 ± 0.71 °C. Using Student's test of significance, the parameter $\boldsymbol{t}$ = 4.08 and therefore the difference between the

means in the two halves is highly significant (the limit for the 99% significance is ***t*** = 2.79). For the global temperature, the increase itself is not so pronounced, nevertheless, the parameter ***t*** = 9.32 because of a much lower fluctuation.

The same pattern concerning the long-term change can be seen from the mean values for the individual decades, or the individual 20- or 30-year overlapping periods, respectively. These means are presented in Table 1. It should be pointed out that the increase also continued in the last decade (2001-2010), whereas the global air temperature during the same time period stagnated (the highest global temperature was observed in 1998).

Table 1. Mean air temperatures in the individual decades and in 20- a 30-yr periods for the whole Czech Republic.

1961-1970	1971-1980	1981-1990	1991-2000	2001-2010
7.10	7.30	7.56	7.94	8.21
1961-1980	1971-1990	1981-2000	1991-2010	
7.20	7.43	7.75	8.08	
1961-1990	1971-2000	1981-2010		
7.32	7.60	7.91		

The increase of annual mean temperatures at the individual stations differs considerably from the mean increase for the Czech Republic as a whole. Its values range from -0.6 ^{o}C (Horská Kvilda in the Bohemian Forest) to +2.4 ^{o}C (Vítkovice in Giant Mountains) during a period of 50 years.

All 267 stations have been subdivided into five groups based on the observed temperature increase at the respective station. Their distribution in the Czech Republic territory is depicted in Fig. 3 by circles with different colors. One can see that the distribution is not random. There is a substantial difference between Bohemia and Moravia. In Bohemia, larger increase is observed, values higher than 1.5 ^{o}C prevail and an increase of less than 1.0 ^{o}C occurs only occasionally. In Moravia, the temperature increases slowly, values lower than 1.25 ^{o}C prevail and values higher than 1.5 ^{o}C occur only occasionally. This difference leads to the conclusion that the air temperature increase also slightly depends on the longitude, in particular that at stations further from the Atlantic Ocean, the temperature increases more slowly.

Moreover, it seems that in Moravia smaller increases are observed more at stations in mountains (in the Northern part), but this regularity is not unambiguous and is not seen in Bohemia. For the whole Czech territory there is a slight dependence of the temperature increase on the longitude (corr. coefficient -0.19), latitude (corr. coefficient 0.18) and on the altitude (corr. coefficient being -0.23). However, these correlation coefficients are not significant. The dependence of the temperature increase on the mean temperature at a station is also very low and not significant (corr. coefficient 0.23). The ***t*** parameters have also been calculated for temperatures at the individual stations. They show a very high correlation with the temperature increase (shown in Fig. 3) at the same station, correlation coefficient being 0.93. This means that the fluctuations are almost equal at all stations and that the value of ***t*** is determined predominantly by the temperature increase.

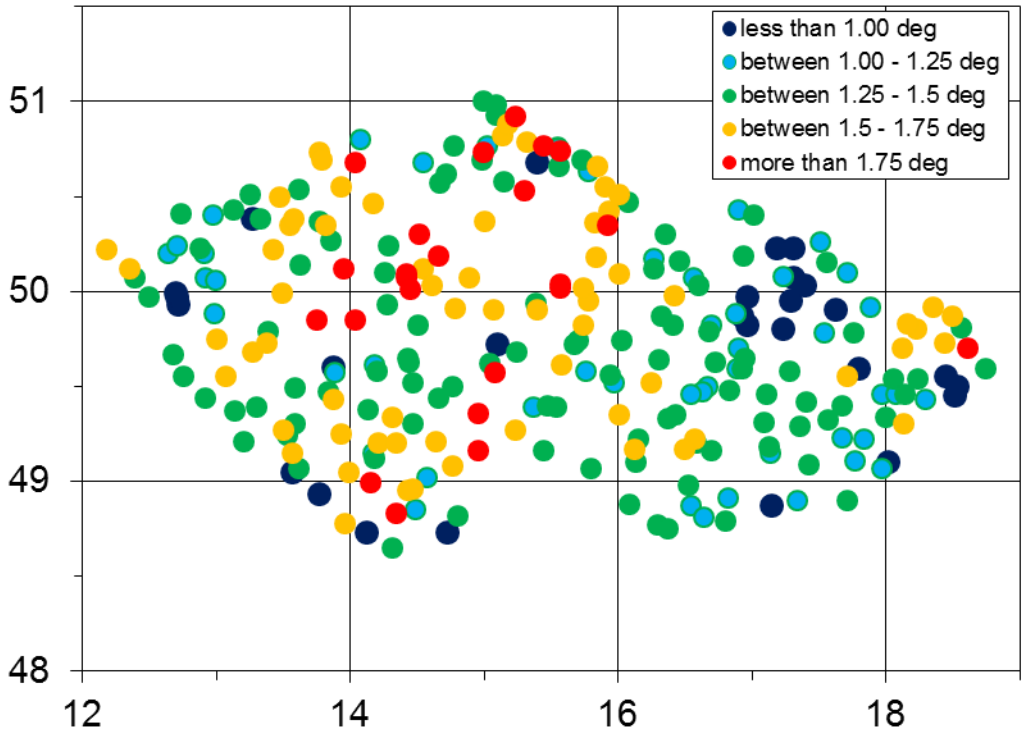

Fig. 3. Distribution of the increases of annual mean air temperatures during 1961-2010 over the territory of the Czech Republic.

Mean spring temperature for the whole Czech Republic is 7.49 ^{o}C, at the individual stations the values range between 0.22 ^{o}C and 10.32 ^{o}C. Mean summer temperature is 16.52 ^{o}C (between 9.23 ^{o}C and 19.47 ^{o}C), mean autumn temperature is 7.80 ^{o}C (between 0.09 ^{o}C and 10.29 ^{o}C) and mean winter temperature is -1.49 ^{o}C (between -

6.55 °C and 1.20 °C). During all seasons, the highest temperature has been observed in Prague, the lowest at Praděd. The distribution of low and high mean temperatures in the individual seasons in the Czech Republic does not differ much from that observed for the whole year, given in Fig. 1.

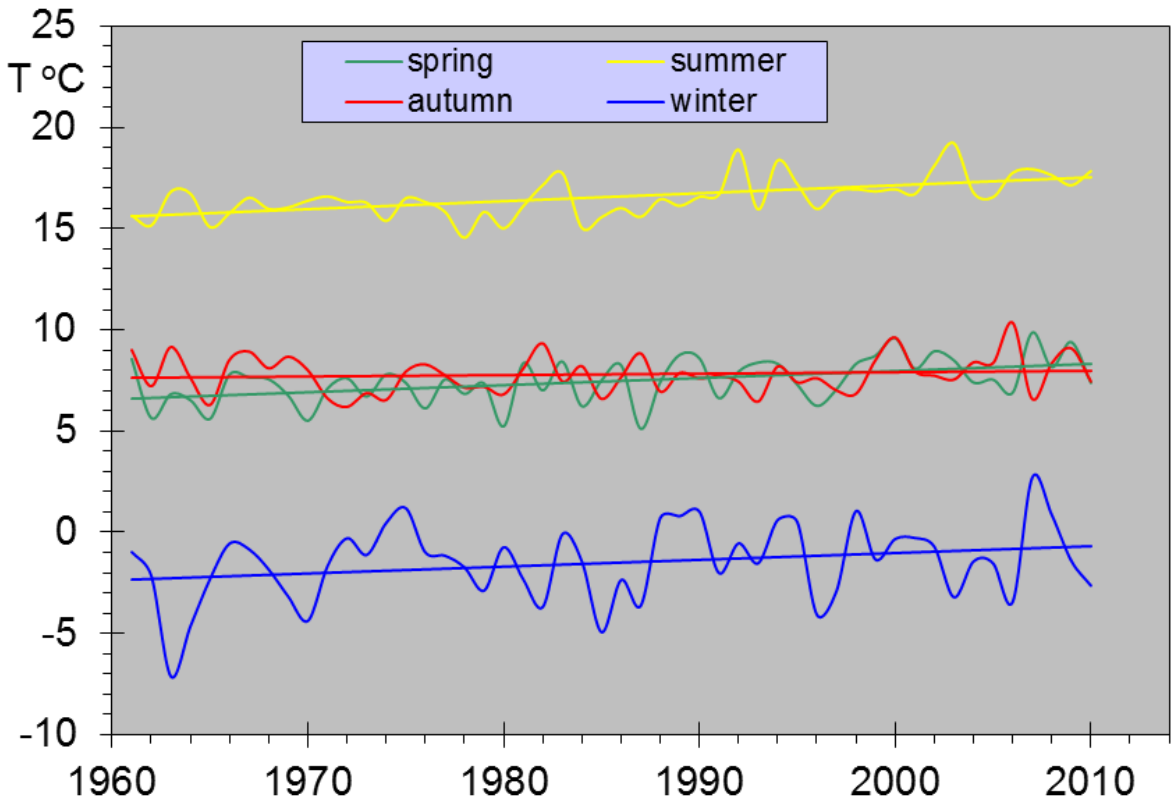

Fig. 4. The course of seasonal mean air temperatures for the Czech Republic during 1961-2010. Approximation by regression line of the same color has been added.

The increase of air temperature in the individual seasons is different from that for the whole year shown in Fig. 2. The course of seasonal temperatures during the period analyzed is presented in Fig. 4. Even though the vertical scale is compressed due to different temperatures in the individual seasons, some important patterns can be seen. A considerably lower increase takes place in autumn – only 0.35 °C. Differences among other seasons are not large: 1.75 °C in spring, 2.00 °C in summer and 1.65 °C in winter, all being a little higher than those for the annual temperatures (1.40 °C). Short-term fluctuations do not differ much from those observed for annual temperatures, only in the winter they are significantly more apparent. Regression lines are expressed by $T = 0.034 * y - 68.07$ for winter, $T = 0.035 * y - 62.22$ for

spring, T = 0.040 * y – 62.33 for summer and T = 0.007 * y - 7.00 for autumn. The Student's parameter (calculated in the same way as for the annual temperatures) ***t*** = 1.88 for winter (so small and not significant due to the larger fluctuations compared to the other seasons), ***t*** = 3.26 for spring, ***t*** = 4.48 for summer and ***t*** = 0.77 for autumn (not significant, due to the very small increase).

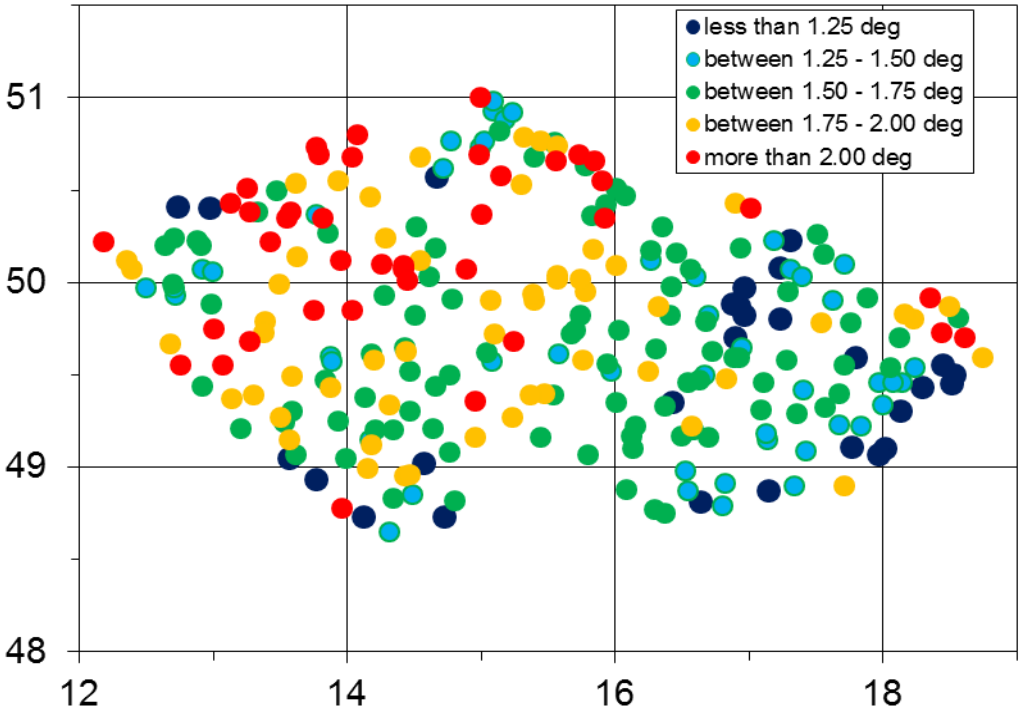

Fig. 5. Distribution of the increases of winter mean air temperatures during 1961-2010 over the territory of the Czech Republic.

The increase of the mean air temperature described above differs at different stations. In general, the increase follows similar distribution as shown in Fig. 3 – the increase is larger in the western regions than in the eastern. However, the difference is larger in the winter (Fig. 5). In Bohemia a strong increase has been observed at more stations than in case of the annual temperatures, whereas in Moravia more stations exhibit a weaker increase, especially in the South. In summer, the situation is opposite. Stations at Moravia, especially in its southern part, exhibit a strong increase, whereas in Bohemia the increase is a little weaker. However, the difference between Bohemia and Moravia is small in summer (Fig. 6). In spring, the distribution is similar to that of the whole year (not shown graphically); during autumn, the increase is very small at all stations.

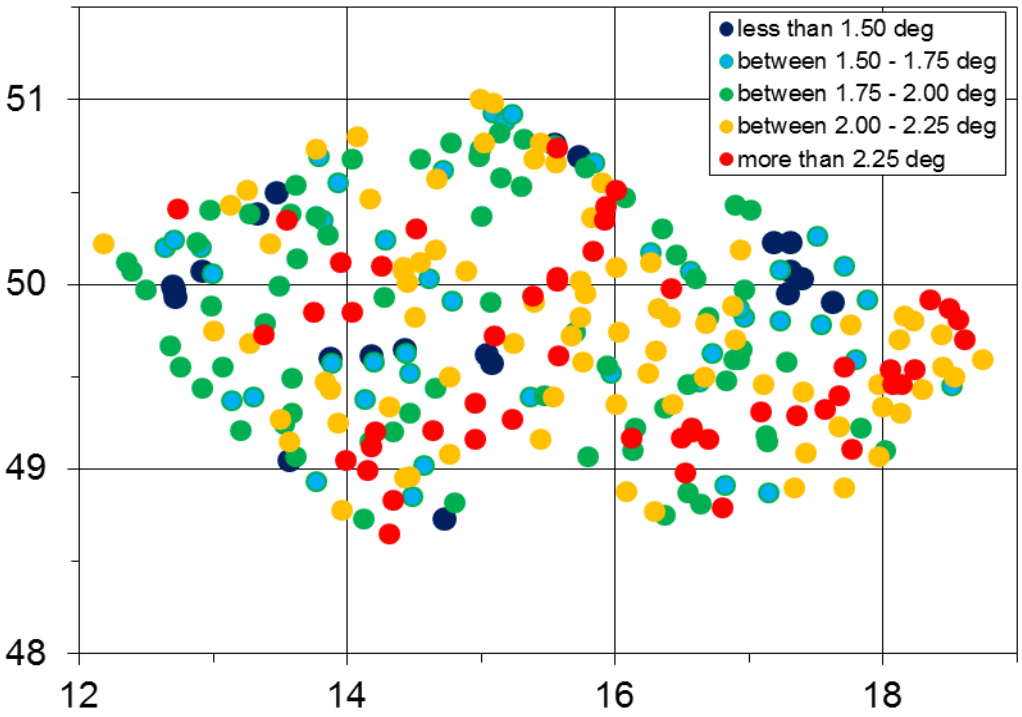

Fig. 6. Distribution of the increases of summer mean air temperatures during 1961-2010 over the territory of the Czech Republic.

The distribution of the temperature increase is different also for the individual months, even within the same season. The differences, however, are not very significant. Showing these courses for all months in one graph (similar to that in Fig. 4) would not be very clear. More convenient is to show the annual variation of the air temperature for different time intervals. This was done for three 30-yr overlapping intervals and the results are given in Fig. 7. For easier interpretation, the winter months are repeated on the right side of the graph. No changes in autumn months or significant increases in summer and in winter are apparent. In summer, there is no difference between June, July and August, whereas in the winter some differences occur. The temperature increases most in January, the increases in February and in December are less pronounced.

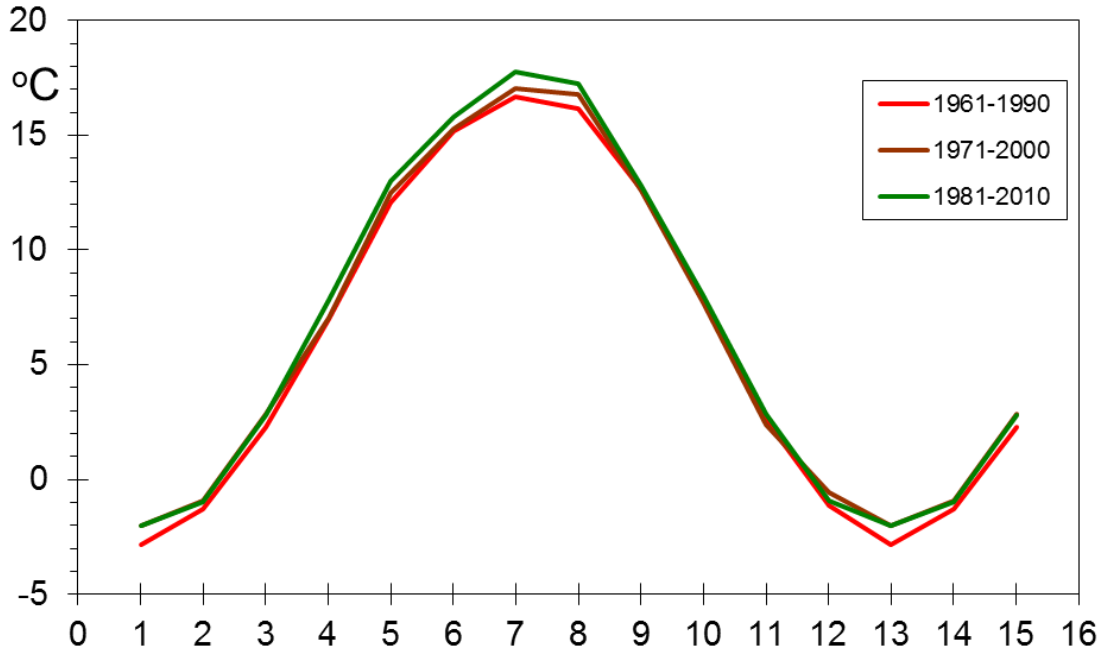

Fig. 7. Mean monthly air temperatures in the territory of the Czech Republic in three 30-yr periods. Months No 1-3 (January-March) have been added at the end labeled as 13-15.

Discussion and conclusion

The above presented results show that the air temperature increases on the territory of the Czech Republic at a higher rate than the global temperature. There is also a clear difference between this increase at stations located in the western part of the Czech Republic (Bohemia) and the eastern part (Moravia). The increase of the temperature is more pronounced in Bohemia than in Moravia. There are also some differences among seasons. The increase in autumn is very weak, in other seasons it is a little stronger than that for the whole year. In the winter, the difference between the increase in Bohemia and Moravia is more apparent, whereas in the summer, the temperature increase is a little stronger in Moravia. The strong increase of mean summer temperatures in Moravia is not favorable for the agriculture because at the same time, a decrease of total precipitation is being observed over the same region (Střeštík et al., 2014). Stronger increase of the temperature in the summer than that in the winter in Moravia means that the difference between summer and winter temperature increases, i.e., a small increase of continentality of the climate takes place. This point is valid only for Moravia, whereas in Bohemia the continentality decreases only very little. Regression lines for the temperature course in all seasons

and for both parts of the Czech Republic do not suggest any change in the last decade, as is the case for global temperatures, and therefore the continuation of the described trend is expected.

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Summary

Na základě měsíčních průměrů teploty vzduchu registrované na 267 stanicích v České republice byla určena dlouhodobá změna průměrné teploty vzduchu na každé stanici za posledních 50 let. Roční průměrná teplota vzduchu vypočtená pro celou zemi vykazuje značný růst, který je mnohem větší než růst globální teploty vzduchu. Je ovšem doprovázen silnými fluktuacemi z roku na rok. Dlouhodobá změna na různých stanicích a v různých regionech je odlišná. Vyšší růst teploty je pozorován na stanicích v Čechách, zatímco na Moravě je růst nižší. Tento rozdíl je výraznější v zimním období, zatímco v létě je velmi malý a snad i opačného smyslu. To znamená, že kontinentalita klimatu na Moravě roste a v Čechách velmi slabě klesá. Dlouhodobá změna závisí jen velmi nepatrně na absolutních hodnotách průměrné teploty na konkrétní stanici. Růst teploty v podzimním období je podstatně nižší než v jiných ročních obdobích.

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