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LATE AUTUMN AND EARLY SPRING FROSTS IN CONNECTION WITH GLOBAL WARMING

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Abstract: During the last 150 years, an increase of mean air temperatures as well as that of mean daily minimal air temperatures takes place. Due to this warming the last spring frosts occur about two weeks earlier and the first autumn frosts occur about one week later. These shifts mean that the frost-free period becomes longer by about three weeks. Using dates of the last night in spring and of the first night in autumn, both with temperature under −2 °C instead of zero degree, these shifts are a few days longer. This fact may be favourable for farmers and gardeners. However, considerable fluctuations accompany these shifts, which limit the possible expectations of better conditions for the agriculture. Moreover, the date of the first autumn frost cannot be predicted using the date of the last spring frost, and the same is valid for the last spring frost using the date of the first autumn frost.

Key words: global warming, global temperature, last spring frost, first autumn frost, frost-free period

Global air temperature has increased systematically since 1850. Contemporary temperatures are about one degree centigrade higher than those 150 years ago. The increase in the last decades is more rapid – during the last 50 years, it reached 0.6 °C, whereas during the preceding 100 years the increase was only 0.4 °C. In some regions, e.g. in Europe, is the increase more pronounced, especially in the last decades.

The increase of mean annual air temperature observed in Prague-Klementinum (φ = 50° 02', λ = 14° 25', h = 191 m) during the last 150 years reaches 1.8 °C, during the last 50 years 1.2 °C (Fig. 1). These values result from the regression line of second order. This increase, however, is accompanied by considerable fluctuations – the temperature in one year may be often higher or lower by more than two degrees than that in the previous year. Nevertheless, the increase and its acceleration in the last decades, represented by averages in consequent 25-yr intervals, are clear.

The same trend appears for annual means of daily maximal and minimal temperatures (Fig. 2). The increase of annual means of daily minimal air temperature during the last 150 years in Klementinum reaches 1.6 °C, in the last 50 years 1.1 °C. However, considerable fluctuations of the same range as those for the mean annual temperatures accompany this increase. Its representation by 25-yr averages is clear just as that for the mean air temperatures.

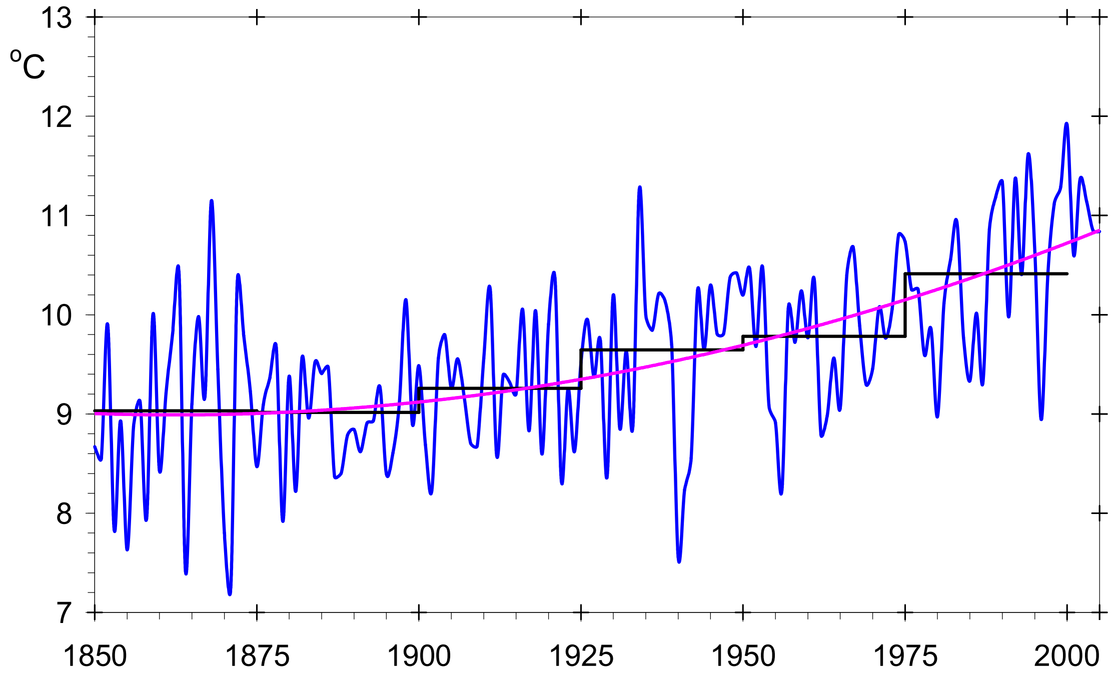

Fig. 1. Mean annual air temperatures between 1850 and 2005 in Prague-Klementinum (blue), with 25-yr averages (black) and approximation by a polynomial of second order (red).

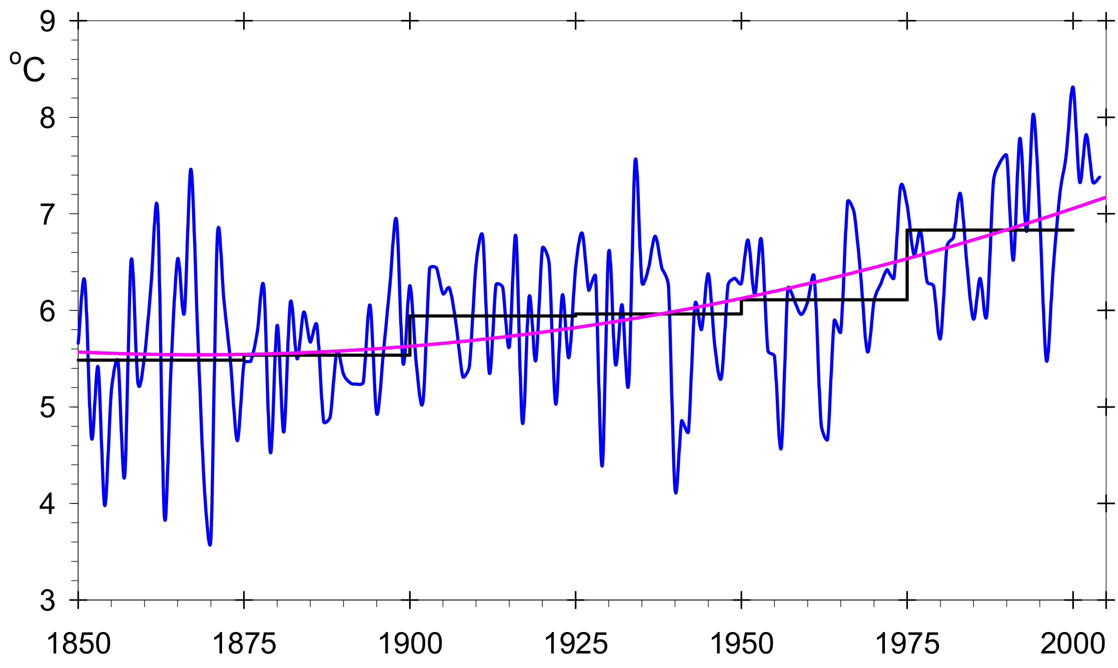

Fig. 2. Annual means of daily minimal temperatures between 1850 and 2005 in Prague-Klementinum (blue) with 25-yr averages (black) and approximation by a polynomial of second order (red).

It seems that higher mean (and higher maximal and minimal) air temperatures will be favourable for farmers and gardeners, because they offer them certain possibilities to grow such kinds of vegetable, which require a little warmer climate. However, the temperature itself is not decisive. Very important are situations when the temperature decreases below zero centigrade, i.e., the occurrence of frosts, especially in late spring as well as in early autumn. Therefore, the date of the last spring frost and of the first autumn frost is important to judge the conditions for the agricultural production. In some occasions, a weak frost, say −1 °C, may not be too dangerous. From this point of view dates of the last night in spring with temperature under −2 °C and dates of the first night in autumn with temperature under −2 °C we shall consider too.

The dates of the last spring frost fluctuate considerably from year to year (Fig. 3). The last frost appeared in some years as early as to the end of February and no frosts came in the following weeks and months, but in other years, some frosts may occur to the end of April. The last night with temperature under −2 °C occurs in early February in some years, in other years as late as in early April. Within these broad limits, a small shift in the mean date has been observed, clearly seen using averages in 25-yr intervals. A straight line approximating the graph (not a polynomial), suggests a shift in the date of the last frost from April 4 to March 23 (12 days). For temperatures under −2 °C this shift appears from March 22 to March 1 (21 days). Using the limit −2 °C instead of zero degree the shift in the date is more pronounced.

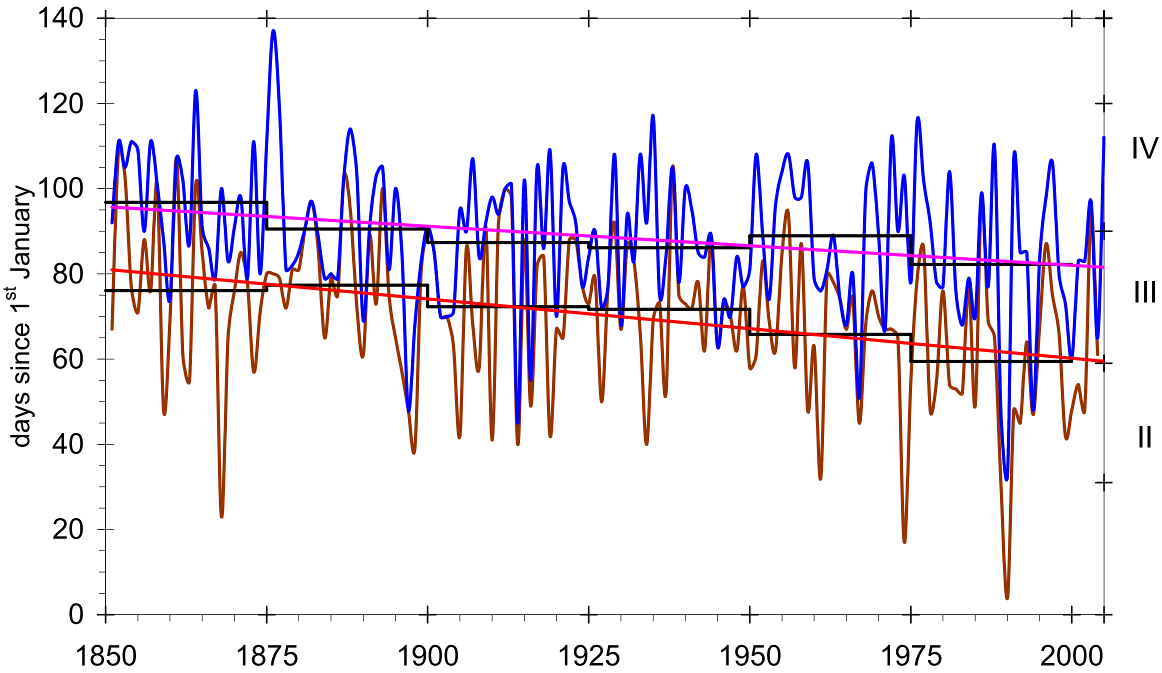

Fig. 3. The date of the last spring frost observed between 1850 and 2005 in Prague-Klementinum (blue) and the date of the last night with temperature under −2 °C in the same time and station (brown), both with 25-yr averages (black) and regression lines (red).

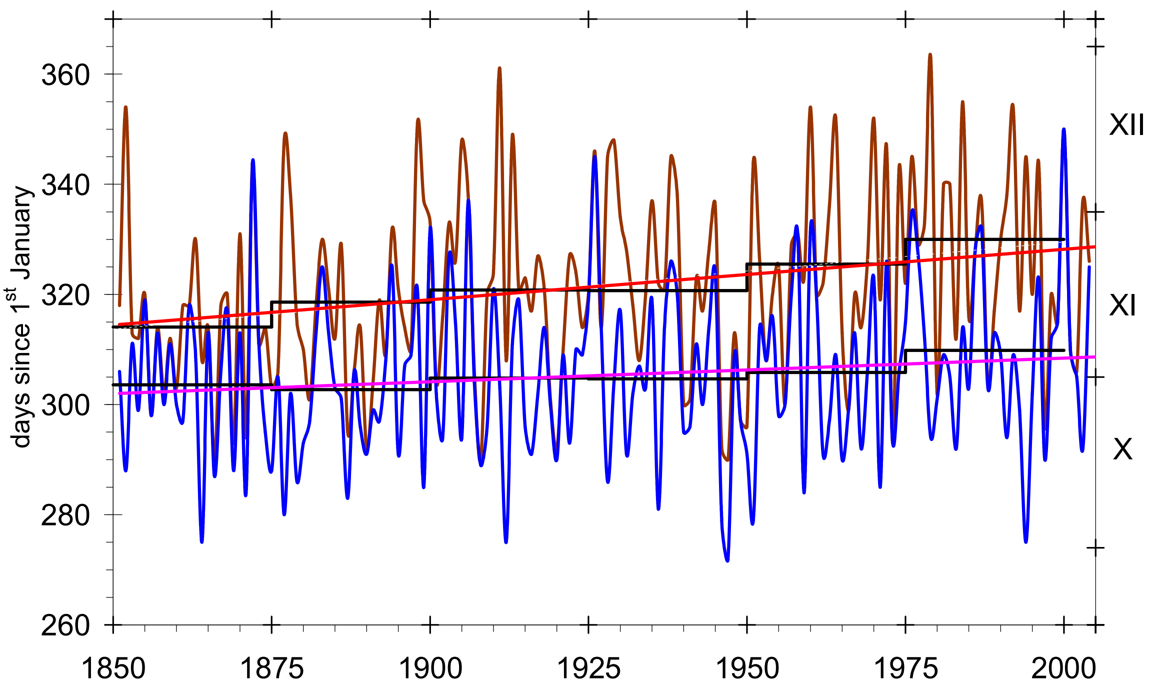

Fig. 4. The date of the first autumn frost observed between 1850 and 2005 in Prague-Klementinum (blue) and the date of the first night with temperature under −2 °C in the same time and station (brown), both with 25-yr averages (black) and regression lines (red).

Similar situation has been observed in dates of the first autumn frost (Fig. 4). The first frost occurs in some years as early as in early October, but in other years the weather without frosts lasts until early December. The first night with temperature under −2 °C occurs to the end of October in some years, in other years as late as to the end of year. Within these broad limits a small shift in the mean date has been observed, clearly seen using averages in 25-yr intervals. This graph can be approximated by a straight line too, not by a polynomial, which suggests a shift in the date of the first frost from October 29 to November 4 (6 days). For temperatures under −2 °C this shift comes from November 10 to November 26 (16 days). The shift is here also more pronounced using limits under −2 °C, nevertheless, for both limits it is less expressive than that in the case of spring frosts.

The frost-free period is defined as the time interval between the last spring frost and the first autumn frost. Similarly, we shall consider a "strong-frost-free" period as the time interval between the last night with temperature under −2 °C in spring and the first night with temperature under −2 °C in autumn. Because the last nights with low temperatures in spring occur a little earlier and the first nights with low temperatures in autumn occur a little later, this period is longer than the frost-free period (Fig. 5). The length of frost-free period increased from 206 days to 228 days, i.e., the prolongation is about 22 days. The length of the period with temperatures above −2 °C increased from 233 to 269 days, i.e., the prolongation is about 36 days.

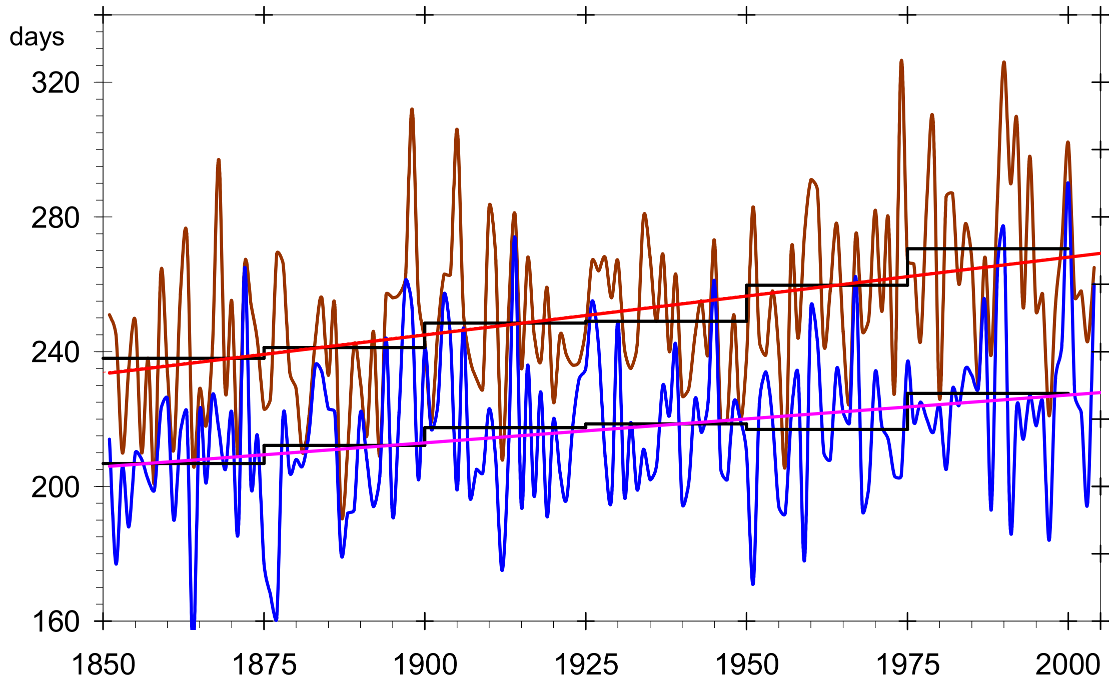

Fig. 5. The length of frost-free period (the interval between the last spring frost and the first autumn frost) observed between 1850 and 2005 in Prague-Klementinum (blue) and the interval between the last and first nights with temperature under −2 °C in the same time and station (brown), both with 25-yr averages (black) and regression lines (red).

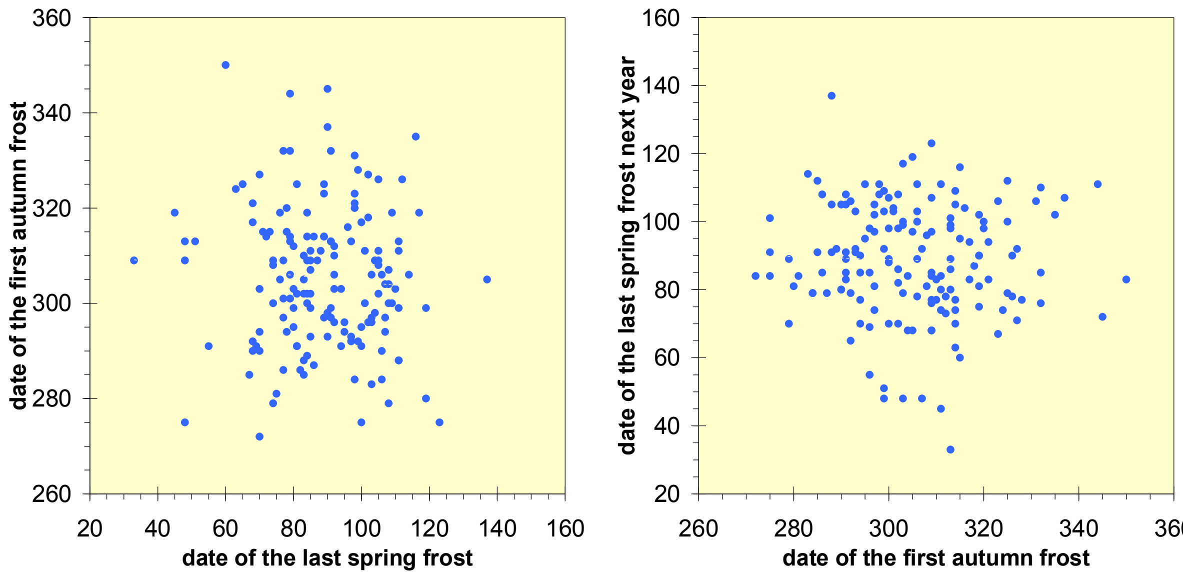

Fig. 6. Correlation between the dates of the last spring frost and the first autumn frost (a) and the dates of the first autumn frost and the first spring frost next year (b).

The correlation between the dates of the last spring frost and the dates of the first autumn frost is negligible. Similarly, there is negligible correlation between the dates of the first autumn frost and the dates of the last spring frost in the next year. Correlations between these dates are represented in Figs. 6a,b. It means that the observed date of the last spring frost cannot be used for prediction of the first autumn frost, and the same is valid for the first autumn frost used for the prediction of the last spring frost next year.

These results agree well with those published by other authors and dealing with the climate changes in different countries, e.g. Easterling (2002), Robeson (2002), Shen et al. (2005). They used data for the 20th century only and therefore they found that the prolongation of frost-free period was a little shorter than that presented here. Cutforth et al. (2004) pointed out that the shift of the first autumn frost is much weaker than the shift of the last spring frost, as shown also here. Menzel et al. (2003) investigated prolongations of frost-free periods in different countries. They considered also the “strong-frost-free” periods using the limits under −3 °C and under −5 °C in spring and in autumn. Their lengths increased more when limits under −3 °C and even under −5 °C instead zero degree were used.

Conclusion: Contemporary climatic change brings higher minimal temperatures as well as higher mean temperatures. Due to this warming the last spring frosts occur a little earlier and the first autumn frosts occur a little later than 100 years ago and therefore the frost-free period becomes longer. This shift makes about two weeks in spring and one week in autumn, therefore the frost-free period becomes longer by about three weeks. Using dates of the last night in spring and of the first night in autumn, both with temperature under −2 °C instead of zero degree, these shifts are a few days longer and therefore the period with temperatures above −2 °C becames longer by nearly five weeks. This fact may be favourable for farmers and gardeners, it could make possible to grow such plants, which require a little warmer climate and longer frost-free period. However, considerable fluctuations accompany these shifts, and this fact limits possible expectations of better conditions for the agriculture. One must still calculate with unexpected late frosts in spring or early frosts in autumn. Moreover, the date of the first autumn frost cannot be predicted using the date of the last spring frost, and the same is valid for the last spring frost using the date of the first autumn frost. Thus we can conclude that though the prolongation of frost-free period is not negligible, due to the above mentioned complications it is not sufficient to bring substantial improvements in agriculture.

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