THE DECREASE OF SNOW COVER DUE TO THE GLOBAL WARMING AND IT'S CONSEQUENCES

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The air temperature in central Europe is ever increasing. This increase is faster than the increase of the global temperature. Due to higher temperature in the winter months more precipitation in these months falls in the form of rain instead of snow, and the respective snow cover, at least partially, melts. If the snow cover disappears totally and then a strong cooling follows, the harvest is threatened by black frosts. More serious is that the water from rains or melting snow drains into the rivers and into the sea, and in the following months it may be absent. Observation of water flows in the river Vltava confirms the increase of flow in winter (January) and decrease in spring (March). Cold winter with snow is for nature favourable, on the contrary, a warm winter with rain indicates a deficit of humidity in the coming year, and predicts a bad harvest. This is one of significant factors contributing to the risk of drought, together with higher evaporation due to higher air temperature and with decreasing precipitation totals. These regularities have been noticed even by our ancestors, they recorded them in folk weather sayings. In the following decades, with the increasing air temperature, more frequent occurrence of warm winter and therefore more frequent occurrence of droughts in summer can be expected.

Keywords: global warming, warm winter, water flows, drought

INTRODUCTION

Climate change, global warming, is a grateful theme and a lot of climate scientists and also such as journalists, politicians and other laypeople are dealing with it. The global temperature, i.e. the average air temperature calculated from the network of stations evenly distributed across the globe, has been calculated since the year 1850. Since that time it is increasing, at first very slowly, in recent decades its increase is accelerating. While for the 100 years from 1850 increased the average global temperature by 0.2ºC, for the next 60 years has risen already about 0.7°C (Brohan et al., 2006). The temperature increase is not the same everywhere. The most rapid it is in Europe and in North America, even more in the Arctic (where it causes a noticeable retreat of glaciations), for 150 years by up to 2ºC, while in the Southern hemisphere the increase is less than 0.5ºC, with exception of Antarctica.

As the cause of the temperature increase the increase of concentrations of green house gases in the Earth's atmosphere is usually considered, mainly CO_2 (Sun and Wang, 1996), which is done by human activities. This process is irreversible and therefore it is supposed that the global temperature will increase in the future as fast as before, if not faster (Hansen and Sato, 2004).

At the same time, the precipitation totals, unlike air temperatures, are expected to slightly decrease, and in some areas they may cause unwanted dryness. Some time ago Kożuchowski and Marciniak (1990) presented a study according to which precipitation totals in Western and Northern Europe have recently been increasing and will increase even longer, whereas in Southern and Eastern Europe they have been decreasing and this decrease will continue. Czech Republic lies in the area of the expected decrease. This trend was confirmed in later studies (Räisänen et al., 2004).

One may assume that a slight warming might be nice. Frosts and much snow in winter are uncomfortable and cause many difficulties, e. g. in traffic. Warmer climate would save also costs for heating, although it would in turn increase costs for air conditioning. But such optimism is not in place. It has been already mentioned that the temperature increase will most probably be connected with the decrease of precipitation totals. Moreover, the increased air temperature brings increased evaporation and therefore the danger of drought will increase too, independently on the change in precipitation totals.

The increase in the average air temperature brings a number of other consequences that are not favourable. In this contribution we will point out some of them. It is necessary already today to reckon with them, because the observed temperature increase will continue in the next decades with all its consequences.

MATERIALS AND METHODS

The air temperature and atmospheric precipitation have been measured at the observatory Prague-Klementinum. The observatory is located in the historical court of the Charles University in Prague Old town. Its coordinates are φ = 50º 05' 12", λ = 14º 24' 59", h = 191 meter above sea level. The temperature has been measured since 1775; precipitation has been measured since 1805. Both data are available for each day and both series are uninterrupted (Jírovský, 1976, Svoboda et al., 2003, data are also available on the website of the Czech hydrometeorological institute). No major construction work was carried out in the vicinity, so that from this point of view the data are homogeneous. From these data were then compiled monthly and annual averages or totals. The average precipitation totals for the whole Bohemia has been calculated too, but only for a limited time period (Jírovský, 1976).

The average monthly water flows in the Vltava River in Prague are available from 1801 and also this data series is uninterrupted (Novotný, 1963, Svoboda et al., 2003). Similar data series for water flow in Labe (Elbe) in Děčín is available for a limited time period (Horský, 1975).

The course of all these quantities will be presented graphically together with the regression lines and the statistical significance of the respective change will be discussed.

RESULTS

Air temperature at the Prague-Klementinum increases more rapidly than the global air temperature in accordance with the temperature increase in whole Europe. This increase, however, is different in the individual months. If we compare the average monthly temperatures in individual years, then the most rapid increase is observed in winter, the least rapid one in summer. In

Fig. 1 the long-term course of the January and March temperatures is presented. The fluctuation between individual years is considerable; this is for the monthly averages always greater than for the annual averages. Nevertheless, the gradual increase during the two centuries is evident and is statistically significant. This is nearly the same for the two months selected.

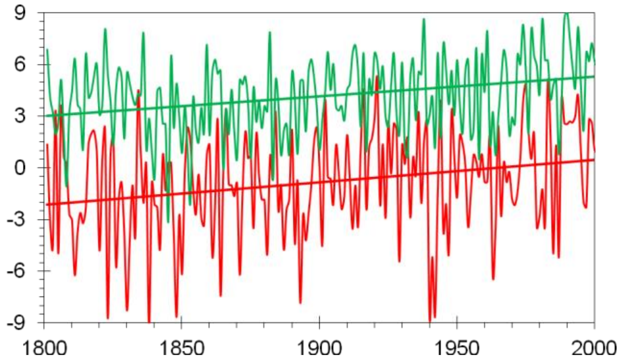

Figure 1. The course of average monthly air temperatures in degrees centigrade at the Prague-Klementinum for January (red) and March (green) with regression lines.

The situation is quite different for precipitation totals. They slightly decrease during the two centuries and this decrease is different in different months. The most apparent decrease occurs in January and December, the slight increase in summer months. In Fig. 2 the course for January and March is shown. Precipitation totals in January evidently decrease, nevertheless, this decrease does not reach the necessary statistical significance. In March the precipitation totals stay nearly on the same level. Long-term change is accompanied by strong fluctuations from year to year, which is greater than in the case of air temperatures.

Monthly precipitation totals expressed in per cent of the annual totals instead of millimetres give a graph different from that in Fig. 2, but the overall long-term trend is the same.

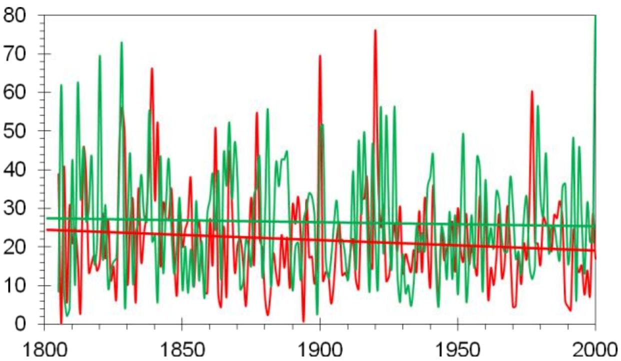

Figure 2. The course of monthly precipitation totals in millimetres at the Prague-Klementinum for January (red) and March (green) with regression lines.

The long-term changes in monthly precipitation totals reflect themselves in water flows in Vltava in Prague. Of course, it would be possible to argue that the precipitation totals at one station cannot be compared with water flow in the river near this station. It is necessary to consider the precipitation totals throughout the whole basin. The necessary data are available. The average precipitation totals for the entire territory of Bohemia have been calculated some time ago (Jírovský, 1976). The territory of Bohemia has a specific property: no river flows into it and all the water drains through only one river, Elbe. Precipitation totals for the whole Bohemia is then possible to compare with water flow on the Elbe in Děčín (Horský, 1975). Unfortunately, precipitation totals for the whole Bohemia have been calculated only for the period 1876-1976. Nevertheless, they display a high correlation with precipitation totals observed in Prague and also the flow rates of water in Děčín shows a high correlation with water flow in Prague (Fig. 3). Therefore, a comparison of precipitation totals in Prague with water flow in the Vltava in Prague is considered to be sufficiently representative.

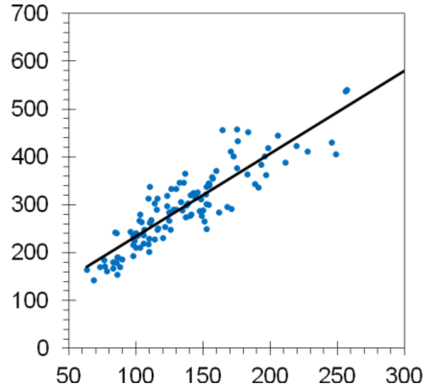

Figure 3. Correlation between the average water flow in Vltava in Prague (horizontal axis) and in Elbe in Děčín (vertical axis), both in cubic meters pro second.

The following figure shows a long-term change of water flows in the Vltava in Prague in the months of January and March. The flow in March is significantly higher than in January. This is due to the melting of the snow on the mountains. The long-term trend is accompanied by significant levels of short-term non-periodical fluctuations, so the long-term change does not reach statistical significance, as in the case of precipitation totals. The exception is the increase of the flow rates in January, which is already slightly above the level for 95% significance. Moreover, this increase does not correspond to the long-term change in precipitation totals in the same month. A similar disagreement is observed also in March, but here the statistical significance does not reach 95%. In other months is a long-term change in flow similar to long-term change in precipitation totals.

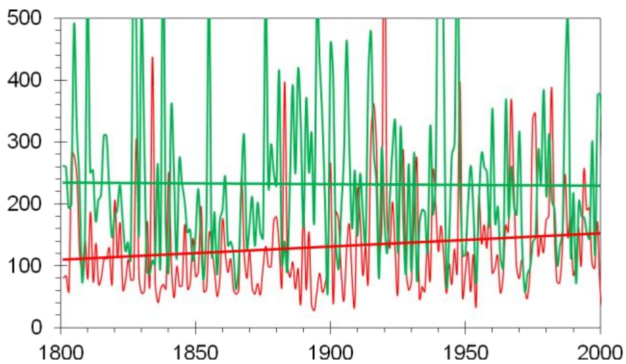

Figure 4. The course of average monthly water flow in cubic meters pro second in Vltava in Prague-Klementinum for January (red) and March (green) with regression lines.

Water flow in Labe in Děčín displays the same pattern, as was found for Vltava in Prague: the increase in flow rates in the winter, mostly in January, and the decrease in the spring, especially in March; of course, this point is valid for shorter time period.

In Figs. 1, 2, and 4, a change in two centuries only for January and March has been presented. Surely it would not be possible and suitable to present all the months, the image would not be legible. Summary information about the other seasons provides the following table. For each season the change of the quantities during two centuries is shown. Numerically this is the difference between the values, where the regression line crosses the vertical axis at 2000 and 1800. As for the air temperature, one can clearly see a faster increase in the winter months, which agrees with the graph for January in Fig. 1. In other seasons the increase is smaller. Precipitation totals show a slight increase with the exception in winter, where the decrease takes place, though the January precipitation totals increase (Fig. 2). But all these changes are small. Water flows in the Vltava show an unexpected strong increase in the winter, although winter precipitation totals slightly decrease. This disagreement will be discussed further in the Conclusion. Summer flow rates show a small increase; this is in accordance with the increase of precipitation in the summer.

Table 1. The change of the values of the individual quantities in different seasons (differences between the values for the regression line in the year 2000 and 1800).

Quantity	Unit	Spring	Summer	Autumn	Winter
Temperature	deg	1.2	0.2	0.4	1.8
Precipitation	mm	4.0	7.6	0.8	-8.0
Water flow	m^3/s	21	48	27	118

CONCLUSION

Logically one can expect a high correlation between the flow rate of water in the river and the precipitation total in the basin over the same period. Significant correlation will be also expected between the water flow rate and the total precipitation at one station in the basin. It is valid in the case of the flow of water in the Labe in Děčín and the average precipitation amount for the whole Bohemia, and only to a little lesser extent between the flow rate of water in Vltava in Prague and the precipitation amount also in Prague. High positive correlation holds for the full-year values, also applies for the seasonal and monthly data. For a shorter period under consideration, however, the correlation decreases. The exception is only the January, as shown in Figs. 2 and 4. Although the precipitation totals for January slightly decrease, or remain at the same level, the water flows in the Vltava and in the Labe increases. The opposite dependence in the far lesser extent is observed in March, when higher increase in flow rates should be expected, but it is not the case.

The increase of the flow of water in rivers in January, although the precipitation totals in this month do not increase, is a direct result of climate change, specifically of a significant air temperature increase in January. In the summer the difference of two degrees, e. g. between 30ºC and 32ºC, is not important and people often do not even distinguish between them. In nature they manifefest only a little increased evaporation, which is a small contribution to the lack of moisture and thus to a threat of drought. In winter, however, the difference between +1ºC and –1ºC is in nature very significant. If the temperature in winter is above zero, then precipitation fall more as rain than snow and a respective snow cover melts. Therefore the landscape may remain without snow cover, and if then strong frosts follow, they may cause serious damages on the crops. A more serious problem is that the water from rainfall and from melting snow is leaving in the final stage into the rivers and into the sea during the winter. At the time of dormancy plants do not need water and soil does not accept it. And because in recent years winter air temperatures are increasing, the most in January, warm periods in the winter appear to be more common, which is manifested by the increasing flow of water in rivers in January. In the next months then the water supply is missing and the year starts with a soil moisture deficit. And this happens at time when the plants after the winter begin to grow and need the water. The March flows in the rivers are not increasing, rather decreasing, because part of the water has already drained off earlier. Warm winter, or more frequent warm episodes in the winter period, is for future harvest unfavourable. This context has been noticed by our ancestors, they expressed it in folk weather sayings. All sayings agree that the warm winter, and especially warm January, as well as a rainy January, is a harbinger of a bad harvest in the year ahead. Cold winter with enough snow, lasting all winter, belongs to Central European nature, and guarantees a good harvest (unless, of course, snow extreme quantity or frosts extremely strong). Unfortunately, long-term change in air temperature (Fig. 1) does not imply that any change would be expected in the next century, and therefore, it is necessary to reckon with further increase, maybe even faster than before. This means that warm winters or warm episodes during the winter will occur in the next decades more often than in the past, together with all the above described consequences. Warm winter without snow will mean more frequent threats to the drought. To prevent this it will be necessary to reduce green house gas emissions, which should slow the increase of the air temperature. And more efficient and surely faster are all the activities leading to retention of water in the landscape and the creation of reserves for the case of drought, before catastrophic scenarios of further increase of the global temperature will be topical.

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