Solar and anthropogenic forcing of late-Holocene vegetation changes in the Czech Giant Mountains
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Abstract

The aim of this research was to identify the factors influencing late Holocene vegetation change in the Giant Mountains (Krkonoše in Czech), using three peat archive sequences. A more specific aim was to evaluate the role of solar forcing on climatic change at ca. 850 cal BC.

The Giant Mountains are located at the border between the Czech Republic and Poland and they occupy the area between 50° and 51° latitude N and 15° and 17° longitude E. The studied sites are the bogs at Pančavská Louka (1320 m), Černá Hora (1190 m) and Úpská Rašelina (1425 m). For the Pančavská Louka site a sequence covering the period between ca. 2200 cal BC and the present time was studied. The analysis of a sequence from Černá Hora was undertaken in order to understand the causes and mechanisms of peat expansion in the area; this sequence covers the period from ca. 96 cal BC to the present. A sequence from Úpská Rašelina was analysed, which covered the period from 180 cal AD to the present time. Special attention was focused on the upper part of the sequence to generate information on human impact.

On the collected material, microfossil (pollen and other microscopic remains) and macrofossil analysis, loss on ignition and C/N ratio determination were carried out. On the Pančavská Louka sequence, geochemical analysis of selected elements was also completed.

Time control was achieved by AMS $^{14}$C dating of selected plant material. Calibration of the dates provided a calendar time control. For the Pančavská Louka sequence, to improve the precision and accuracy of the calendar time control in periods of major changes in $\Delta^{14}$C, the wiggle-match dating strategy (WMD) was applied to the radiocarbon dates between ca. 3200 and 2000 BP, and to those between ca. 800 and 100 BP. The results of simple calibration were then compared to those from different WMD solutions for the dates between ca. 3200 and 2000 BP. The best results of WMD were achieved by modelling the distance in cm between subsequent dates, on the basis of the arboreal pollen concentration. As changes in arboreal pollen concentration in the peat sequence are assumed to be due to changes in accumulation rate (assuming that the arboreal pollen influx is constant in time, in the absence of human impact), a linear accumulation rate was modelled by correcting for the concentration changes. In this way, a solution was found to the problem of non-linearity of stratigraphical depth to time.

The results of the Pančavská Louka high-resolution palaeoecological analysis indicate the occurrence of a climatic deterioration in correspondence with the sharp increase of detrended $\Delta^{14}$C at ca. 850 cal BC. As the sharp increase in $\Delta^{14}$C was induced by a period of low solar activity, the hypothesis was proposed that the low solar activity had also triggered the recorded climatic change. The hypothesis was tested by cross-correlating the curve of detrended $\Delta^{14}$C with selected curves of micro and macrofossil climate proxy-indicators. A significative positive or negative correlation was found for many climate proxies. Particularly high coefficients were found for Ericales pollen (70.5% positive correlation), and for Sphagnum macrofossils (67.5% positive correlation). The increase of Ericales pollen percentages in correspondence with the $\Delta^{14}$C increase may point to the spreading of the subalpine vegetation belt during cool episodes. The increase of Sphagnum macrofossil volume percentages points to the
marked sudden dominance of S. section *Cuspidata* in the sequence and the increased peat preservation, due to increased local humidity. The visual correspondence of changes in curves of regional and local elements with the increase of the solar proxy $\Delta^{14}C$, confirmed by cross-correlation, suggests that low solar activity was the cause of climatic change at ca. 850 cal BC. This finding constitutes new evidence for solar forcing of climatic change.

Evidence of human impact from the three sequences was compared with the available archaeological and historical information. No evidence of human impact was recorded before the seventh century AD, except for scattered grains of Cerealia, most likely coming from the nearby lowlands of Silesia, or from the Bohemian basin. From the seventh to the end of the ninth century AD, a phase of deforestation was recorded in the Černá Hora sequence. A slight decrease in *Abies* and increase in *Artemisia*, Poaceae and Cerealia was found in Pančavská Louka in the eighth century AD, accompanied by an increase of lead, zinc and arsenic. This last feature points to the start of mining activities in the Giant Mountains area. The period from the seventh to the end of the ninth century AD corresponds well with the arrival of Slavic populations in the near area and with the existence of Slavic settlements in the lowlands. In the eleventh – twelfth century AD, a major phase of deforestation is recorded in the three sequences. This phase agrees with historical information, which details the beginning of deforestation for local ore exploitation during the twelfth and thirteenth centuries. In the Černá Hora record, this phase continued until the present time, while in those from Pančavská Louka and Úpská Rašelina it lasted until the fourteenth and fifteenth century AD respectively. At Černá Hora, decreases in the degree of peat decomposition and therefore better preservation of *Sphagnum* remains in the peat occurred in correspondence with the two phases of human impact. A link was hypothesised between deforestation and decreases in evapotranspiration and increased local humidity, which would lead to lower decomposition and more favourable conditions for *Sphagnum* growth. A recovery of forest elements was dated in the sequences of Pančavská Louka and Úpská Rašelina to the fifteenth and sixteenth centuries AD. Possible causes of the decrease of human impact on the environment may have been the onset of a climatic deterioration, possibly the Little Ice Age, or socio-economic causes. The evidence of a climatic deterioration in Pančavská Louka corresponds well with the start of the Spörer minimum of solar activity. A climatic deterioration might have hampered human activities in the mountain area, which in turn would have allowed forest recovery. However, the socio-economic crisis determined by famine and plague epidemics from the fourteenth to the sixteenth century may also have negatively affected human activities in the Giant Mountains. Furthermore, the crisis of the silver mines in Central Bohemia during the sixteenth century also had a negative effect on the economy in the Giant Mountains. In fact, the timber production was mainly directed to Central Bohemian mines, so that a decreased demand for timber would have led to a decrease in forest cutting and a recovery of the forest. In the seventeenth century, a second phase of human impact was recorded both in Pančavská Louka and in Úpská Rašelina. This phase approximately corresponds to the intensive deforestation of the area which resulted in the near total disappearance of *Abies* and *Fagus* forest, and their successive replacement with *Picea* plantations.