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DENDROCLIMATIC NET OF NORTHERN HEMISPHERE: RESULTS AND APPLICATION TO FOREST PRODUCTIVITY CHANGES

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Abstract

The comparative analysis of the near-earth air temperature variations in subarctic regions of North America and Asian continent for the last 600 years has been made according to different sources of palaeoclimatic information. The integral assessment of climatic variations is based on the information recorded in tree rings, lake sediments, isotopes of glacier layers and oceanic sediments. A good agreement in temperature variations and especially for the industrial period (the years 1800–1990) has been revealed according to data obtained in North America and Siberian Subarctic. Climate reconstruction throughout the net of Siberian dendrochronological data bank shows a good agreement with the curves of coming solar radiation and volcanic activity. It is preferable to use the net of tree ring chronologies of subarctic region for calibration and verification of global climatic models than the other indirect sources of natural and climatic information. It is caused by their evident advantages: by a high temporal resolution, large correlation with leading mechanisms of global climate changes, duration and availability of a good spatial net.

Introduction

In the last years the attention of researchers of some countries was paid to global climatic changes. As an example, the publication in the journal "Science" in 1997 could be that had an integral assessment of climatic changes (temperature) in arctic regions of the northern hemisphere based on information recorded in tree rings, lake sediments, isotopes, in glacier layers as well as oceanic sediments [1]. The information from subarctic regions of North America has been used in the paper the most fully. Only three sites, and correspondingly, three temporal series of palaeoclimatic indicators presented the Asian part of Eurasia. The authors noted the need of data volume increase in the future, especially for Eurasia. By the moment of paper publication the materials needed for generalizing the Asian part of the subarctic region were already obtained but owing to publication the book in Russian they turned to be not used [2]. The given paper compensates this gap using the mass evidences for the comparative analysis of continuous temporal temperature variations in the arctic region of the northern hemisphere in temporal series of palaeoclimatic data both from North America and the Asian Subarctic. The sites of sampling dendrochronological information in Asia which were used as the main information sources are marked.

Material and Methods

Data of the Siberian dendrochronological net in dendroclimatic stations located evenly in the spatial plane: 65–155 E and 66–72 N have been used in the paper. Different sources of palaeoclimatic information from North America and from, mainly, the western sector of Eurasia were used as well. Palaeoclimatic stations of Siberian dendrochronological net evenly cover the spatial plane of Siberian subarctic region within geographical boundaries from the Urals to Chukotka peninsula. Dendrochronological data are statistically processed. Study methods include both a set of traditional for dendroclimatology, also experimental measuring and statistical approaches (sampling, measuring tree ring parameters in automatized installations, cross dating, standardizing measurements and isolating climatic signal, calculating climatic response functions and regression models to reconstruct the main climatic functions etc.) which are wide used in the

leading laboratories of the world and original methods as well as computer programs of temporal series processing.

Results and Discussion

The series of works has proved that variability of radial tree growth in Subarctic of the Asian continent is explained by summer temperature variations in 60–70% [2, 3, 4]. Tree ring chronologies can be considered as the long-term temporal series of summer temperature variability. To compare the averaged temperature variations in the arctic region obtained in the cited paper [1] we have got similar information on the tree ring chronology net fixed, as also in the paper mentioned above, at the mid-quadratic deviation of every series.

It can be surely stated that the both curves are similar, it means the temperature variations for the last 400 years in the arctic region of Asia correspond to those ones being observed, mainly, in North America. A good synchrony in coming warmings which are short in time and falls of temperature at the general light positive trend of temperature is noted before the year 1800. Rising temperature since the first decades of 19^{th} century to the mid of 20^{th} one is the most clearly shown in both curves. The most temperature minimum in the arctic region of Asia falls on the second decade of the 19^{th} century while the series published earlier shows the most temperature fall for the last 400 years in (18)40s. Interesting results are shown by correlation between the curves compared for the separate time intervals and also for the whole period of time. So, the correlation is large at $p< 0,05$ for the periods since the year 1600 to 1750 and since the year 1750 to 1900 but it is small (R=0,38). The correlation greatly increases (R=0,65, $p<0,001$) for the industrial period (since the year 1800 to 1900) owing to the clearly expressed temperature rise which surely shows itself in both curves. It is interesting to note that the correlation between two integrated curves decreases for the period since 1900 to 1990 (R=0,43). The correlation between two curves of temperature variation in the arctic region of the northern hemisphere made 0,54 at $p< 0,001$for the whole studied period of time (since 1600 to 1990).

Such potential sources of the continuous temperature variations as an increase of carbon dioxide, methane, sulfates (as of an indicator of volcanic activity) in the atmosphere as well as also solar radiation the long series of which have been registrated and published [1, 5, 6, 7] were considered in the paper mentioned earlier. It was stressed that the warming after the year 1920 was caused most probably by increasing green house gases in the atmosphere. This conclusion is made based on a good agreement of temperature increase in arctic regions of the northern hemisphere with increasing carbon dioxide in the atmosphere. However, as the warming began since the mid- 19^{th} century then also the solar radiation increase, volcanic activity decrease as well as back links in the climatic system itself played a very important role [1]. Calculations of correlation between the listed characteristics and the averaged curve of temperature variation have shown that for the whole analyzed period of time the very significant link is noted only between temperature variation and solar radiation coming (R=0,59). This relation increases for the period since the year 1900 to 1990 (R=0,65). The curve built according to the long tree ring chronology for the subarctic Asia shows the large correlation to the solar radiation (for the whole period R=0,32, and for the industrial period since the year 1800 to 1990 R=0,68) and to volcanic activity (for the whole period R=-0,41, and for the industrial one R=-0,59). The negative impact of increasing volcanic activity on summer temperature variations in the arctic region can be especially visually seen from comparing the averaged tree ring curve with sulfate content for the last 600 years. It is extremely important to note that the local minimums of temperature fall on the curve obtained from the subarctic region of Asia correspond to the local splashes of volcanic activity (for instance, the years 1450–1470, (15)50s, (15)80s, 1600–1610, (16)40s, 1690–1700, 1810–1820, 1880–1890, (19)70s). The curve of temperature with prevailing data on North America does not reveal such a clear reverse synchrony what is corroborated by small correlation between these characteristics (R= - 0,01) as well. The last one can be caused both by the real situation and by different quality of palaeoclimatic sources used for temperature reconstruction. Temperature variation dynamics in Subarctic of the Asian continent shows the better agreement with decrease of the coming solar radiation and increase of volcanic activity in the period since the early of (18)00s to (18)40s than it can be observed in the integral curve of temperature variation obtained, mainly, throughout the arctic region of North America. The agreement of cold years with the most large volcanic eruptions was noted earlier when using tree ring chronologies of Eurasia with high (annual) resolution [8, 9].

Conclusion

When analysing continuous temperature variations in the subarctic region of Siberia it was noted, first, the amplitude of the current warming is for the moment within the reconstructed temperature variations in the subarctic region in the Holocene period and, second, the present-day warming is characterized by increase of frequency of the years with anomalously warm summer throughout the entire area of Siberia (the latitudinal transect is circa 5000 km in length) [2, 10]. In other words, the present-day warming "synchronizes" more

often temperature rise in different sectors of Subarctic of northern hemisphere. Therefore, the warming effect, even within the forecast, can have global consequences, especially for productivity change of vegetation in subarctic regions and its status as of an carbon dioxide accumulator or for release of it into the atmosphere. No doubt, the presented integrated data will make a good base for calibrating and verifying global climatic models. The application of the net of tree ring chronologies of the subarctic region of Siberia in the models seems to be preferable in comparison with other indirect sources owing to some their evident advantages: high temporal resolution, large correlation with leading mechanisms of global climatic changes, duration, and good spatial net.

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