On the Problem of Monitoring of Hydrological Conditions in the Baikal Region Using Dendrochronological Methods

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ABSTRACT. Peculiarities of radial growth dynamics of pine under arid regime of Baikal Region as well as the possibility of using the tree-ring chronologies are considered in the paper in order to reveal regularities of moistening variations in Baikal Region. All the chronologies have revealed the availability of a strong regional climatic signal caused by precipitation fluctuations for one hydrological year. The correlation analysis has shown that the tree growth dynamics records variations of integral indices of water regime during many years in this region, it means dynamics of the Selenga river and the Baikal Lake level variations. This allowed to obtain reliable statistical models for reconstructing water regime indices according to the tree-ring chronologies as well as to analyze a cyclic structure of moistening variations. The revealed large cyclicities in variations of water regime characteristics allow to build statistical model for predicting the Baikal level dynamics.

KEY WORDS: dendroclimatology, tree-ring chronologies, hydrological regime, global climate changes, the Baikal region.

Introduction

Dendroclimatic studies play a certain role in solving problems of global and regional changes of climate and environment. The most perspective the dendroclimatic studies in the regions with extreme conditions of tree growing are where one of factors (temperature and precipitation) steadily limits the radial tree growth (Fritts, 1976). Under insufficient moistening (steppe zone, semi-desert zone) the variability of radial tree growth is closely related to precipitation variations. In southern steppe regions of Siberia where moistening regime variations determine, mainly, the primary productivity of meadow systems and yielding agricultural cultures practically there are no dendroclimatic papers on reconstructing the long-term changes of moistening. Establishing of a net of stations for dendroclimatic monitoring in the steppe zone of Baikal Region (in Republic Buryatia area) as well as obtaining the long-term tree- ring chronologies allowed to realize this work (Andreev et al., 1999).

Methods and materials studied

Cores of pine (*Pinus sylvestris* L.) became the object for dendrochronological analysis. Sites for sampling were located in intermountain depressions of the Selenga Central mountains. Sampling, processing and analysis of dendrochronological material was realized according to the conventional procedure (Cook and Kairiukstis, 1990; Fritts, 1976) using computer programs TSAP, DPL and STATISTICA.

Results and analyses

The 156 trees were measured and 11 generalized chronologies were built according to 11 dendroclimatic stations. As a result of the correlation analysis of local chronologies the combining them to two generalized ones was (for the south- west – SS and the north- east NN regarding Ulan-Ude) which have shown also a high synchrony, correlation between them and close spectral characteristics (Table 1). Generalized chronologies have high values of sensitivity coefficient (0.30) and of standard deviation what shows, first, a strong climatic signal is contained in them and they are suitable for the quantitative reconstruction of climatic changes and, second, in both chronologies the large regional component is present common for the whole steppe zone.

Chronologies	Amount of series	Length of tree-ring chronology (years)	Sensitivity	Root-mean square deviation (%)	Interserial coefficient of correlation	Autocorrelation of the 1 order	Signal-Noise
NN	75	332	0.30	44	0.76	0.66	66.30
SS	81	280	0.30	34	0.71	0.49	60.31

Tab. 1. The main statistical characteristics of tree-ring generalized chronologies.

The high coefficient of correlation between two generalized chronologies (R = 0,60) points to this. Therefore both generalized chronologies were combined into one chronology which was used for analysis of climatic response functions and searching statistical models of reconstruction.

High values of signal to noise ratio (8.0) and interserial correlation coefficient (0.78) as well as also of sensitivity coefficient and standard deviation show that there is a strong and stable in time climatic signal in generalised chronology. The analysis of the first three principal components (PC analysis) shows that they in the aggregate explain more than 90% of the general dispersion of the series therewith somewhat about 65% fall on the first component. Just it is determined by variability of climatic variables and thus is the main object for dendroclimatic analysis.

The correlation of the distinguished first component with the temperature and precipitation (meteostation of Ulan - Ude) in decades for the observing period since the year 1922 to 1990 was considered for the detailed assessment of temperature and precipitation effect on tree growth variability. It was found that precipitation have the most effect on tree growth variability in the studied region. The direct influence of temperature is not large, it is indirect and, obviously, shows itself through the increase of transpiration and water deficit. Taking into account the peculiarities of seasonal growth of trees under the steady water deficit (in steppe and semi-desert zones) it can be supposed that the soil moisture change which is determined not only by the current precipitation income but by water income for the fall period of the previous year and also from snow melting of winter precipitation will be the most important factor of the year-to-year growth variability. The strong correlation relation of tree growth (the first component) with precipitation for the period September of the previous year - August of the current year confirm this. Precipitation just of this period determines, mainly, the initial and current content of water in soil.

High and significant relations between tree growth variability and precipitation for the period September of the previous - August of the current year allowed to obtain the quantitative model of precipitation reconstruction according to dendrochronological data (Fig. 1). In synchrony (70%), Fisher's criterion ($11.9_{3,63}$, $p < 0.001$) and correlation ($R^2 = 0.36$) the quality of the model of precipitation reconstruction can be considered as satisfactory.

Discussion and conclusions

Registering reliably the annual precipitation variations in the steppe zone the trees reflect the more integral characteristics of water regime (runoff of the rivers and Baikal Lake level) in the long- term growth variations. Large correlation between tree growth and precipitation in the steppe zone as well as between the tree growth and the Selenga river runoff both at level of annual variations and of the long variations allows to suppose that the is a good correlation between precipitation in steppe zone and that in mountain regions which are the part of the catchment basin of the Selenga river. If there were not such a relation in annual and many-year variations of precipitation then there would not be a large relation between the tree growth and the Selenga river runoff since the tree growth registrates really only precipitation variability in steppe zone. The most interesting is the revealed relation between the tree growth variations during many years and variations of the Baikal Lake level. The reconstruction models explain 70–75% of variability of precipitation and the Selenga river runoff and 50% of variability of the Baikal Lake level. It is known that the Selenga river runoff makes 50–60% of water income to the Baikal Lake therefore the relation of tree growth and runoff has predetermined also the large correlation of increment and the level of the Baikal Lake. The data obtained by the author are based on a cause and effect chain of events: precipitation variability (and, as a result, tree growth variability) - runoff variability - the Baikal Lake level variability. It means the trees are the reliable recorder of variability of initial process (precipitation income) which finally results in variations of the Baikal Lake level. The relation of tree growth and variations of the Lake level turns to be sufficient for reliable quantitative reconstruction of level variations in the past and assessing amplitude of these long-term variations.

The Fourier analysis data reconstructed according to the tree-ring chronology dynamics of precipitation and the Lake level allow to conclude that in the last 250 years the structure of cyclic variations of the Lake did not experience any large changes. The variations 27–30 and 10–11 years prevail. This is a good base for building prediction model. If the cyclically 27–30 years remains the main in the amplitude in the near future time then the large level decrease should be expected in the very beginning of the next century.

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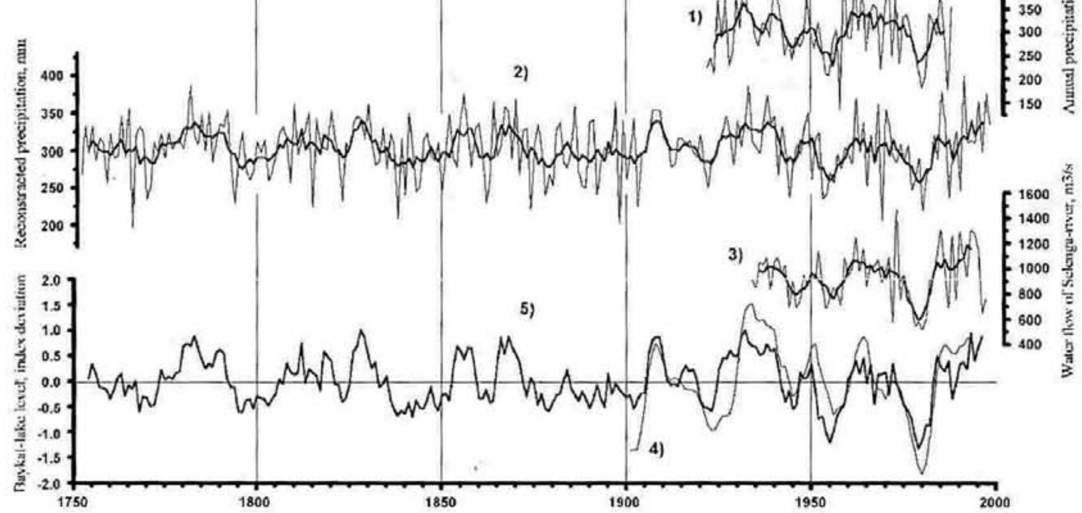

Fig. 1. Dynamics of annual and long changes in hydrological regime of the Baikal region: 1) annual precipitation instrumentally observed; 2) the tree-ring chronology of precipitation; 3) annual runoff of the Selenga river instrumentally observed; 4) the level of Baikal Lake instrumentally observed; 5) the tree-ring chronology of the Baikal Lake level.