The Impact of Climate Change on *Betula tortuosa* Ledeb. Radial Increment on the Eastern Macroslope of Kuznetsk Alatau

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Abstract. The climatic response of birch in eastern Kuznetzky Alatau Mountains (Siberia) were analysed based on dendrochronology data. Studied climate variables included temperature, precipitation and root zone moisture (RZM). Periods with maximal correlations for each variable were found. It was established that radial increment was limited by June temperature and July RZM. Correlations of radial increment and eco-climatic factors were higher when a negative anomalies of respective factor occurred. To estimate the advancement rate of birch trees along elevation gradient, three elevational transects were laid in mountain forest-tundra ecotone. Estimated advancement rate is about 0.5 m per year. Although temperature have a stimulating effect on birch's radial increment and advancement on elevation gradient in Kuznetzky Alatau Mountains, some depressions in radial increment corresponds to years with soil moisture decrease.

1 Introduction

Climate change has a multidirectional effect on forest ecosystems. At treeline, the observed temperature increase mainly has a stimulating effect on the radial increment and the advancement of trees along the elevation gradient [1, 2, 3]. At the same time, aridization of the climate at lower elevations, caused by an increase in temperature, leads to a massive decline of dark coniferous forests [4]. Under such conditions, ecotones (transition zones between different types of vegetation) are the most sensitive areas to climatic impacts. Trees growing in ecotones especially strongly react to changes in the temperature and moisture regime [5]. The reaction of birch (*Betula tortuosa* Ledeb.) trees to climatic changes in the mountain forest-tundra ecotone of the Kuznetsk Alatau Mountains is also of great interest because in the Altai-Sayan region communities with birch are unique objects [6]. Our work aimed to analyse the effects of recent climate change on the birch (*Betula tortuosa* Ledeb.) trees.

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2 Materials and methods

Studied birch trees grew on eastern macroslope of Kuznetsk Alatau Mountains at elevations from 1100 to 1500 m above sea level (fig. 1). Samples for dendrochronological analysis (N = 111) were collected at four main sites. To estimate the rate of advancement, three transects were laid from timberline to treeline. On each transect temporary test plots (3X3 or 5X5 m) with an interval of 10 m along the elevation gradient were laid to describe morphometric parameters of trees, some soil and vegetation features. Sampled trees were selected throughout each transect. For each sampled tree, coordinates and elevation were fixed.

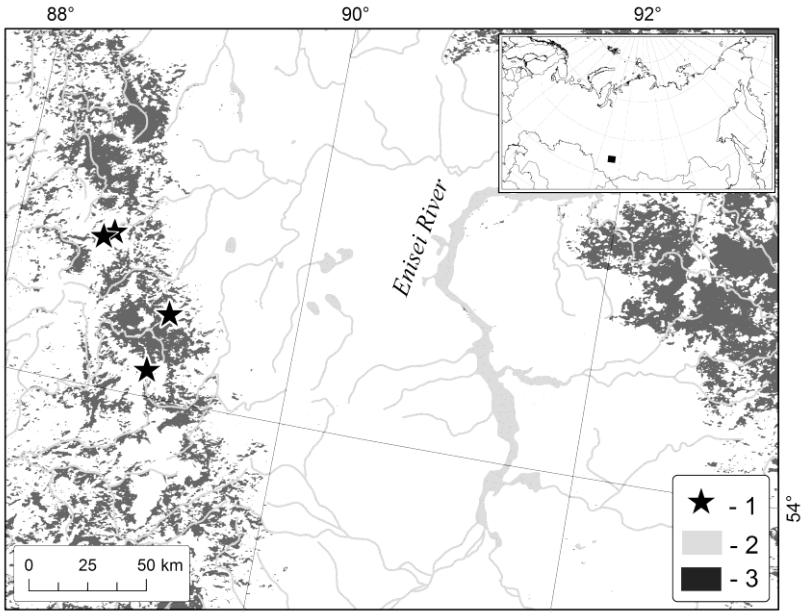

Fig. 1. Geographical location of the studied sites (1 – test plots, 2 – rivers and lakes, 3 – dark needle conifer stands).

Dendrochronological analysis was performed according to generally accepted methods [7]. Measurement of tree-ring width was carried out on the platform LINTAB-6. The quality of cross-dating was tested in the COFECHA program [8]. Tree-ring chronologies were indexed in the ARSTAN program using the negative exponent or linear regression with a negative slope methods [9]. Radial increment in final chronology is presented in dimensionless growth indexes (GI) with an average of 1.0 and a relatively constant variance. The average interserial correlation coefficient of the chronologies is 0.61; average sensitivity coefficient is 0.44. The series of eco-climatic parameters were obtained from the "Nenastnaya" weather station (WMO 29752; about 10-60 km from test sites) and the database of the MERRA-2 project. Pearson's correlation coefficients (including running 11-yr correlation) were used in dendroclimatic analysis.

3 Results

Tree-ring chronology of *Betula tortuosa* trees have an increasing (r^2 = 0.78) trend in the period 1968-1977 and a negative trend (r^2 = 0.64) in 1994–2000 (fig. 2). Similar dynamics in radial increment was recorded earlier in *Larix sibirica* Ledeb. trees growing in the study

area [3]. Between the chronologies of these species, a significant correlation coefficient was found (0.55; period 1940-2012).

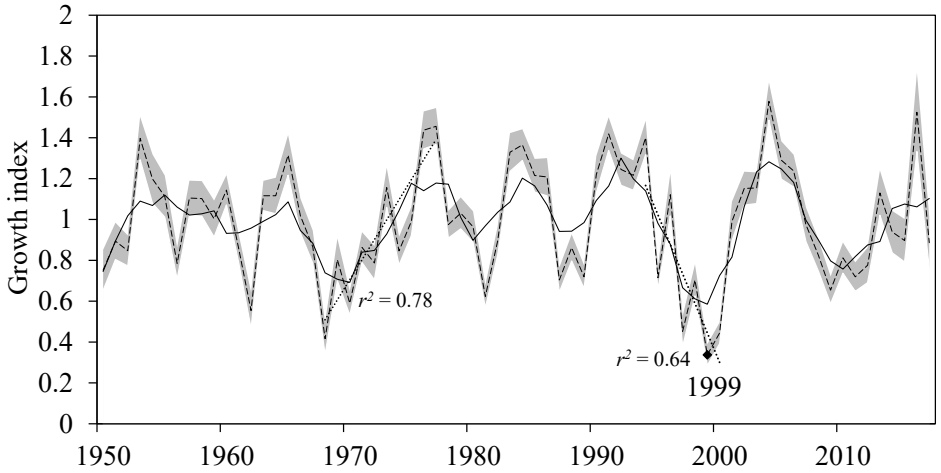

Fig. 2. Tree-ring chronology of *Betula tortuosa* trees (dot indicated absolute minimum of radial increment; grey background indicated confidence level ($p < 0.05$); solid line indicated 5-yr running average).

The radial increment of birch correlates with the temperature of June, however, the climatic signal is unstable (fig. 3a), achieved in some periods r = 0.8. Significant correlations coincide with periods of June temperature negative anomalies. For example, the decrease in June temperature explains the fluctuations of the radial increment in the period from the early 1980s to the early 1990s (June temperature was 1.4 °C lower than average). However, correlation between radial increment and June temperatures is insignificant in the period of a GI decrease in 1990s (with minimum in 1999).

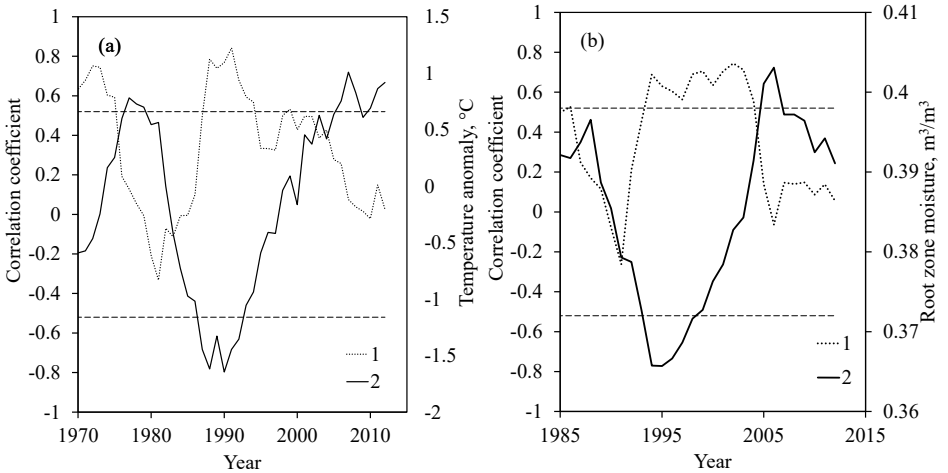

Fig. 3. Dynamics of 11-yr running correlation between GI and eco-climatic parameters (1) and 11-yr running average of eco-climatic parameters (2): a – June temperature anomaly; b – July root zone moisture (dashed line - $p < 0.05$).

Period about 1995 characterized by low root zone moisture (RZM; fig. 3b). GI decrease in late 1990s corresponds to soil drought (in 1999 both GI and RZM reached the

minimum). Correlations of July RZM and GI become stable significant during soil moisture decrease (r = 0.65; fig. 3b).

Based on data of tree's age and coordinates, rate of birch advancement estimated about 0.25-0.5 m per year. Field data confirm that birch trees have appeared at elevations not previously occupied by woody plants.

During the period of climatic changes (1970-2018), radial increment of *Betula tortuosa*, growing in the Kuznetsk Alatau Mountains, is mainly correlated with air temperature in June and root zone moisture in July. Correlations increase in a period of lowering the parameters of corresponding eco-climatic factor. Temperature increase also stimulating advancement of birch trees along elevation gradient.

4 Findings

• The rate of *Betula tortuosa* advancement along the elevation gradient is estimated ~ 0.25-0.5 m / year.
• Radial increment of *Betula tortuosa* trees is influenced by June temperature and July root zone moisture.
• The magnitude of *Betula tortuosa* climatic response increases in a period of lowering the parameters of the corresponding eco-climatic factor.

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