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Radial Increment Dynamics of Scots Pine (*Pinus sylvestris* L.) as an Indicator of Hydrothermal Regime of the Western Transbaikalia Forest Steppe

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Abstract—The radial increment of Scots pine growing in the forest-steppe zone of Western Transbaikalia at five sites is studied. For each site, additional samples are collected, which allows us to increase reliability and build two regional chronologies. An analysis of chronology correlations with monthly temperatures, precipitation, and Selyaninov hydrothermal coefficient is carried out. The analysis of 10-day moving climatic series makes it possible to clarify the periods of climate impact on the increment: the main limitation of pine increment in the region is observed by moisture supply, including conditions during previous (from late July to late September) and current (May to mid-July) vegetative seasons. Fluctuations of 23–35 years in the dynamics of climatic factors and radial increment of the pine are found.

Keywords: radial increment, Scots pine (*Pinus sylvestris*), temperature, precipitation, Selyaninov hydrothermal coefficient, Western Transbaikalia, forest steppe

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INTRODUCTION

The continental temperate zone of Central Asia is influenced by rather harsh climatic conditions, a lack of moisture during the vegetative season, and low temperatures (Dulamsuren et al., 2009, 2014). Low temperatures limit tree growth in the highlands and determine position of the upper tree line (Jacoby et al., 1996). At the same time, the high annual variability in precipitation leads to an alternation of relatively wet periods and droughts, limiting the dispersal of woody plants and their growth in valleys and plains of Central Asia, i.e., in the forest-steppe ecotone (Dulamsuren et al., 2009; Fang et al., 2010). This leads to the vulnerability of forest-steppe ecosystems to fluctuations in the moisture regime during the vegetative season as a result of reduced rainfall, as wel as raised evaporation and transpiration due to increasing temperature. An increase in the frequency and intensity of drought is recorded in many regions of Asia within current climatic changes, which explains the migration of the forest-steppe ecotone in latitudinal and altitudinal directions (Yatagai and Yasunari, 1995; Dai and Trenberth, 1998; Gunin et al., 1999; Tarasov et al., 2006, 2007; Dulamsuren et al., 2014).

In contrast to the global positive trend of temperature, rainfall displays significant spatial variability, especially in regions with complex terrains (e.g., Pederson et al., 2001; Batima et al., 2005; Dulamsuren et al., 2010). In these conditions, studies of climate and its influence on forest ecosystems of Central Asia at the regional scale are of high significance. One such region is Western Transbaikalia. It is characterized by a developed forest-steppe ecotone and a low extent of dendroecological study. In 1999, in this region data on radial increment of the Scots pine (*Pinus sylvestris* L.) and the analysis of its responce to regional climatic and hydrological fluctuations were obtained (Andreev et al., 1999, 2001a, 2001b; Andreev, 2000). We used generalized chronology of the radial increment in pine trees reflecting regional variability of growth for broad basin of the river Selenga, but a detailed analysis of influence of local natural and climatic conditions on local chronologies remained beyond the scope of the work.

In this regard, we set following goals: improve the statistical reliability of the results and increase the comparison period of the chronologies of radial increment with instrumental climatic data by increasing the sample size (number of measured series of the radial increment per plot), evaluate peculiarities of the increment response to climate factors in the last 20 years by a new sample, examine the spatial response of the combined chronologies on driving climatic factors with monthly and 10-day resolution, and assess the capabilities of these chronologies for detect-

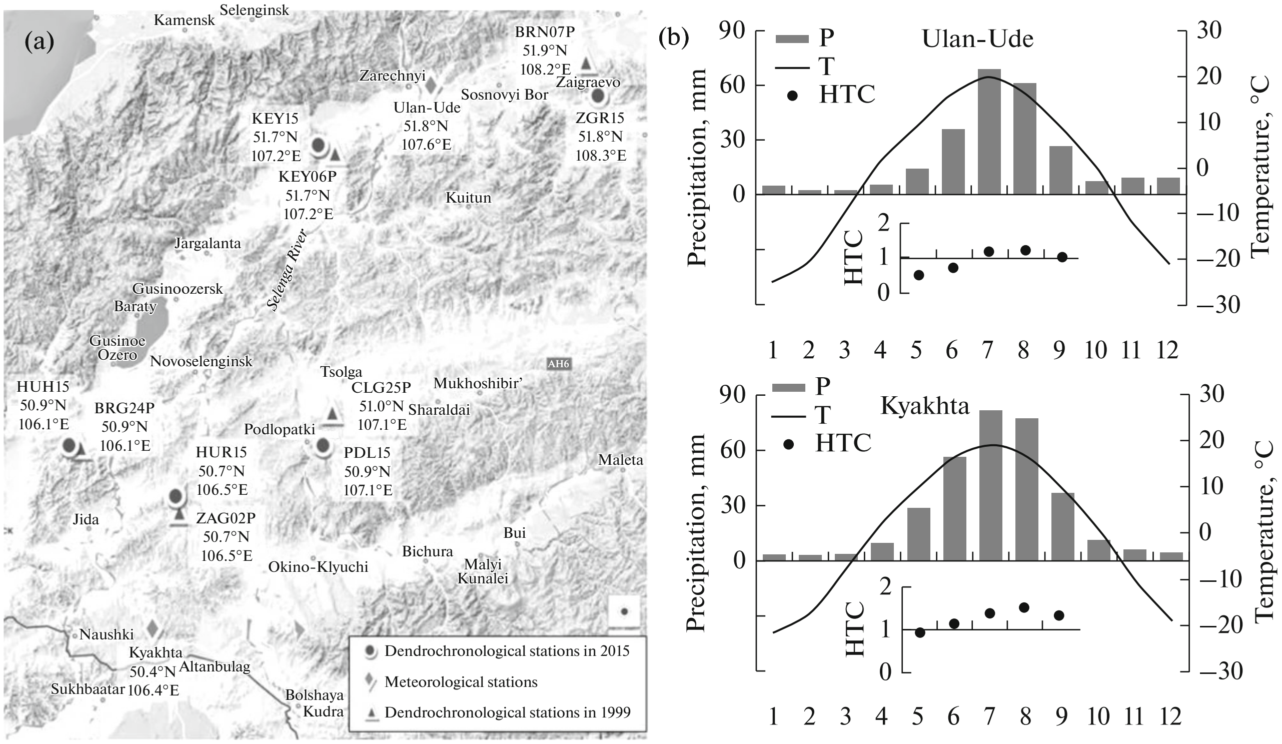

Fig. 1. Study area (a) and climatograms of meteostations Ulan-Ude and Kyakhta (b). Diamonds are climatic stations, triangles are dendrochronological stations in 1999, and circles are dendrochronological stations in 2015.

ing long-term fluctuations of moistening in the studied region.

MATERIALS AND METHODS

Materials for dendroecological studies were collected in the forest steppe of the Selenga middle mountains of Western Transbaikalia (Fig. 1a). According to climatic zonation, the study area is in the temperate continental forest belt of the southwestern subarea of the East Siberian area (Alisov, 1956; Suvorova et al., 2005). The continental character of the climate is characterized by large daily and annual amplitudes of temperatures with severe winters and fairly hot summers and a small amount and uneven spatiotemporal distribution of precipitation (Zhukov, 1960; Fadeeva, 1963). The mean annual air temperature is negative everywhere. The region is characterized by long (5.5 months) and dry winters, with a mean January temperature of –25.4°C. Winter starts from the middle of October, with steady snow cover in hollows appearing after the onset of soil freezing. The amount of winter precipitation falling into hollows from December to February is small (from 10 to 12 mm), and the snow falls mainly in the first half of winter. Some open flat areas and slopes remain snowless during the winter due to the blowing snow by wind and, in general, even taking into account the accumulation of snow on the bottoms of hollows, the height of the snow cover does not exceed 10–15 cm. This leads to the deep freezing of soil and grounds. The study area is in the zone of insular distribution of the permafrost.

To assess the influence of climate on the dynamics of tree growth, we used monthly and daily climatic data on the surface air temperature and precipitation from meteorological stations Ulan-Ude (1886–2015) and Kyakhta (1895–2015) (Fig. 1b), as well as moving decadal series calculated by them. Values of the Selyaninov hydrothermal coefficient (HTC) were calculated from May to September by decades and by months and were averaged to obtain seasonal values (Selyaninov, 1937). The dynamics of the HTC was compared with the SPEI index of dryness for the period from August to July, averaged by geographic coordinates 51.5–52° N 107–108.5° E and 50.5–51° N 106–107.5° E (covering the areas of material collecting) for Ulan-Ude and Kyakhta, respectively (https://climexp. knmi.nl, Trouet and Oldenborgh, 2013).

Monthly temperature data of Ulan-Ude and Kyakhta stations show a high correlation among themselves: during the warm period (April–October) r = 0.78–0.92; in winter (November–March) r = 0.83–0.91. Correlations of monthly data for precipitation are much lower: in the warm season r = 0.21–0.45; in winter r = 0.02–0.24; and for decadal precipitation amounts correlation between stations is r = 0.20–0.60 and r = –0.08–0.36 in warm and cold periods, respectively. Therefore, the temperature field in the study

Table 1. Localization and description of dendroclimatic stations

No.	Code of the site	Geographic coordinates, elevation above sea level, m, localization	Brief characterization of vegetation and growing site
1	ZGR	51.8° N 108.3° E, 600 m Western slope of Khudanskiy Ridge, Ilka River valley, eastern part of village Zaigraevo	Western gentle slope: 1°–2°. Pine forest on sands. Different-aged. *h* ~ 20 m, Ø ~ 50–60 cm. Dwarf shrubs: 5%, herbaceous cover: 5%. Traces of numerous fires.
2	KEY	51.7° N 107.2° E, 700 m. Ivolginskii Raion, 1.5 km south of village Klyuchi	Western slope: 20°. Dead cover–lichen pine forest. Different-aged. *h* ~ 22–24 m, Ø ~ up to 40 cm. No dwarf shrubs, herbaceous cover: 15% (dry cereals), moss and lichen cover: 5% (to 40% in the depression of dry discharge). Soil is primitive with beats of rocks.
3	PDL	51.0° N 107.1°E, 600 m. Mukhoshibirskii raion, southern border of village Podlopatka, Khilok River	Bottom of Tugnuiskaya Hollow: 0°. Steppefied pine forest on sands of mounds. Coverage: 0.1 (open stands). Single-aged. *h* ~ to 20 m, Ø ~ 60–80 cm. Herbaceous and shrub cover is absent. Sandy soil on alluvial deposits.
4	HUH	50.9° N 106.1° E, 700 m. Selenga Hills, 9 km to the west from village Selenduma	Hill top and its northern slope: 15°–20°. Sedge and dead cover pine forest. Cover: 0.3–0.4. Good reproduction. *h* ~ 22 m, Ø ~ 48–52 cm. Dwarf shrubs: 5%, herbaceous cover: 40%, litter: 30%. Sandy loam with large pebbles and beats of rocks.
5	HUR	50.7° N 106.5° E, 850 m. Kyakhtinskii raion, Khurai Ridge	Western slope of the depression of dry discharge: 5°. Cereal–forbs dead cover pine forest. *h* ~ 15 m, Ø ~ up to 60 cm. Herbaceous and dwarf shrub cover is absent. Undershrub is pine. Soil is sandy loamy on carbonate rocks. Traces of numerous fires. Oldest trees retained in the depression of dry discharge.

area is relatively homogeneous, and precipitation in the north and south of the region are different considerably. The values of HTC in the north and south of the study area are significantly correlated, but to a lesser extent than temperature: $r = 0.25–0.65$; correlation between the annual series of the SPEI index for the north and south of the area is 0.69.

On the territory of the Selenga middle mountains in the intermountain depressions and slopes of broad valleys, pine–larch forest landscapes are formed, penetrating deep into steppes. The collection of samples (cores) of pine was performed on five plots located close to places of material collecting in 1998–1999 (Fig. 1a). The network covered central and southern parts of the Selenga middle mountains. These are areas of the Selenga tributaries: Chikoi and Khilok; floodplain of Ilka River; and Khilokskii, Tugnuiskii and Gusinoozerskaya basins, located between spurs of the ridges Tsagan–Daban, Borgoiskiy, Zaganskiy, and Khudanskiy (Table 1).

The collection, transportation, and primary processing of the cores were carried out using standard methods of dendrochronology (Shiyatov et al., 2000), and measurements of radial increment were done with the LINTAB 5 measuring system with specialized TSAP Win package with an accuracy of 0.01 mm (Rinn, 2011). Dating of samples (determination of the calendar year for each ring) was confirmed by cross-correlation analysis in the specialized COFECHA program (Holmes, 1999). Further procedure of standardization (indexing) was performed with the ARSTAN program (Cook and Krusic, 2005). Upon the standardization of individual series, in the first stage, we removed the age trend, for a description of which we had used negative exponential and linear functions. At the second stage, we removed the first-order autocorrelation dependence. After each stage, individual indexed series of increment were averaged to obtain local and regional standard and residual chronologies (Shiyatov et al., 2000). A combining of the local chronologies into groups with maximum similarity of the dynamics of radial increment was conducted by their hierarchical classification (method of full connection; the similarity measure was correlation coefficients between the chronologies over the common period of 1807–2015) taking into account geographical locations of collection sites and meteostations, performed with the STATISTICA program (Statsoft, 2013). The local chronologies were integrated into regional ones using the method of the first principal component (Jolliffe, 2002; Touchan et al., 2011).

We used the following statistical characteristics of the chronologies: arithmetic mean, standard deviation, mean sensitivity coefficient (ratio of the difference between two adjacent values of a variable to their arithmetic mean, averaged by the entire series), and autocorrelation coefficient of the first order (Fritts, 1976; Wigley et al., 1984). The sensitivity coefficient allows us to assess the variability of the radial increment due to rapidly changing external factors, primarily climatic ones.

The relationship of the radial increment of trees with climatic factors was estimated by correlation coefficients between the indexed tree-ring chronologies and temperature, precipitation, and HTC in different periods (10-day, monthly, and for several months) from July of the previous year to August of the current year (Fritts, 1976; Schweingruber, 1996). For an analysis of longer fluctuations of the pine growth and climate variables, relevant series were smoothed using cubic smoothing trends with a fixed-length window of 11 years in the ARSTAN program (Cook and Krusic, 2005); then we carried out a correlation analysis of the smoothed series. For this step we used standard chronologies of radial increment because they retain a greater share of the low-frequency variability than the residual variability (*Methods*..., 1990).

RESULTS

Initially, for each site, local chronologies of the radial increment of pine trees were constructed separately for the samples taken in 1999 and 2015. Correlation coefficients between local chronologies of territorially close samples collected in different years were 0.63–0.95, which allows us to build more generalized local chronologies for each site from combined sample in 1999 and 2015 (Fig. 2). With regard to the period of comparison added after the recollection of materials (1996–2015) on chronologies of radial increment with instrumental climate data in standard chronologies of two northern plots (ZGR and KEY), indices of the increment displayed a negative trend: an average decrease by 0.04 per year ($R^2 = 0.32–0.54$). This is consistent with the trend of annual precipitation at the Ulan-Ude meteostation during the same period, displaying reduction on average by 4.3 mm/year ($R^2 = 0.23$). There are no significant trends in radial increment of the pine (PDL, HUH and HUR) and in the annual sum of precipitation in the southern part of the study area.

Table 2. Correlation coefficients between local standardized tree-ring chronologies (after combination of territorially close samples in 1999 and 2015)

	KEY	PDL	HUH	HUR
ZGR	$\frac{0.65}{0.51}$	$\frac{0.61}{0.52}$	$\frac{0.45}{0.41}$	$\frac{0.48}{0.46}$
KEY		$\frac{0.55}{0.52}$	$\frac{0.60}{0.58}$	$\frac{0.52}{0.50}$
PDL			$\frac{0.60}{0.59}$	$\frac{0.70}{0.72}$
HUH				$\frac{0.77}{0.76}$

* Numerator contains correlation coefficients for standard chronologies; denominator contains those for residual ones. All correlation coefficients are significant at $p < 0.05$.

Taking into consideration the trends in the dynamics of radial increment, values of correlation coefficients between local chronologies, and the location of sampling sites and meteorological stations on the map, all local chronologies were split into two groups (Table 2, Fig. 3). As a result of the generalization, we obtained two regional chronologies: northern BUR-N and southern BUR-S, having high correlation between each other—$r = 0.77$ for standard and $r = 0.66$ for residual chronologies (Fig. 2). The dispersion percentage of the variance of pine radial increment, explained by the first principal component, in the north of the study area is 51.5% and, in the south is 72.7%.

Statistical characteristics of generalized chronologies are shown in Table 3. Interserial correlation coefficients display the presence of a strong common external signal on local and regional levels in the increment dynamics of the pine. This is also confirmed by high values of standard deviation and coefficient of sensitivity. An increase in the sample size (number of series) led to higher values of expressed population signal along the entire length of chronologies. Their excess above the threshold value of 0.85 for the northern and southern regional chronologies was observed from 1733 and 1786, respectively, which is about 80 years earlier than in the sample of 1999. Standard chronologies, especially in the north of the study area, are characterized by a high autocorrelation of the first-order reflecting dependence of the increment of the current year from tree growth and external conditions of the previous year. In addition, all chronologies have practically the same pointer years: maximum values of the increment indices fall on 1782–1783, 1820, 1886, 1891, 1908–1909, 1911–1912, 1918, 1927, and 1933 and minimal ones fall on 1794, 1823, 1863, 1874, 1956, and 1980–1982. In general, statistical characteristics of the chronologies indicate their suitability for dendroecological research.

Dendroclimatic correlation analysis showed a weak cumulative negative effect on the pine increment of the temperatures of vegetative season, which is more

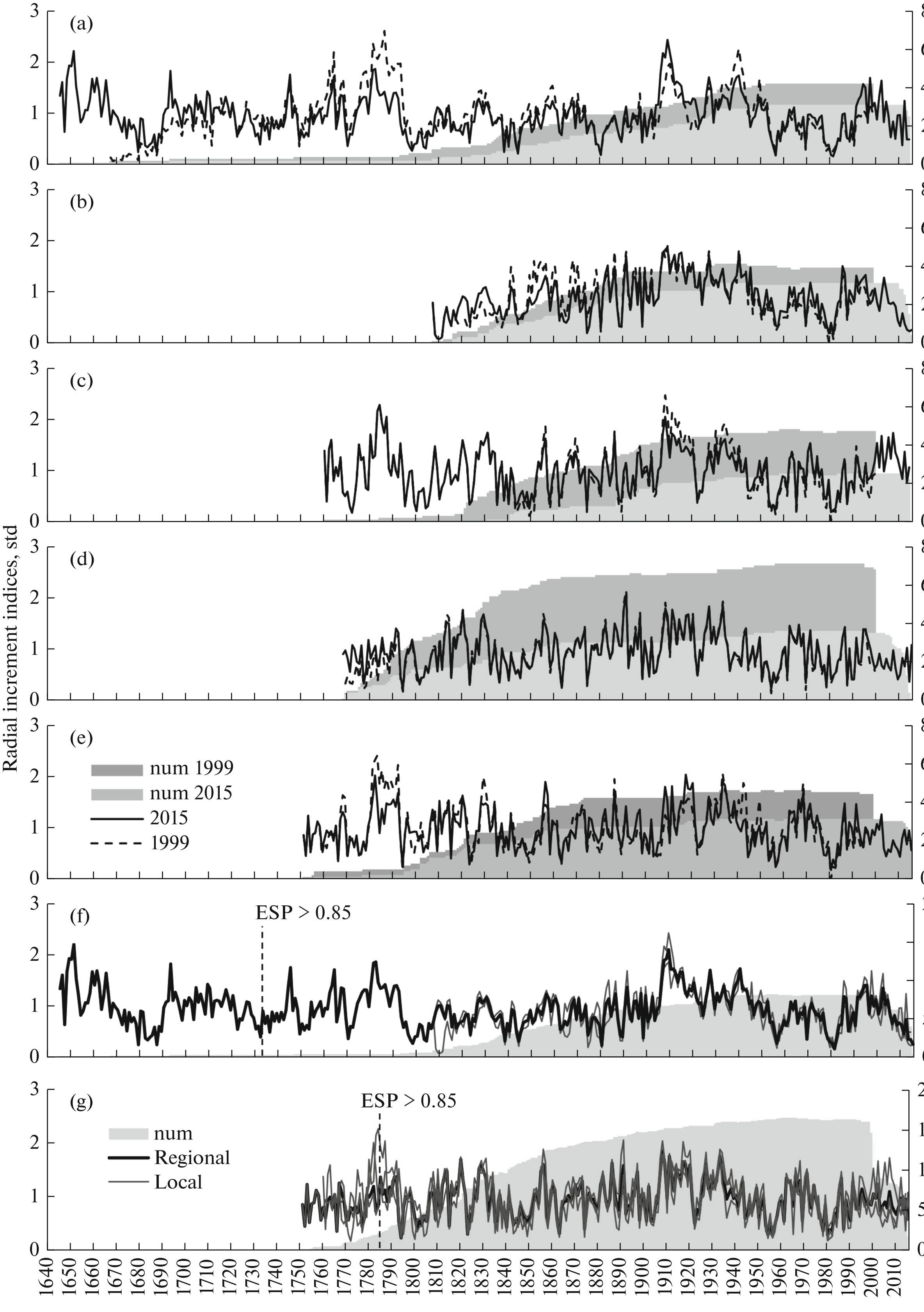

Fig. 2. Dynamics of the pine radial increment: local (collection in 1999 and 2015) and regional standard chronologies with indication of sample size for each year: (a) ZGR, (b) KEY, (c) PDL, (d) HUH, (e) HUR, (f) BUR-N, and (g) BUR-S.

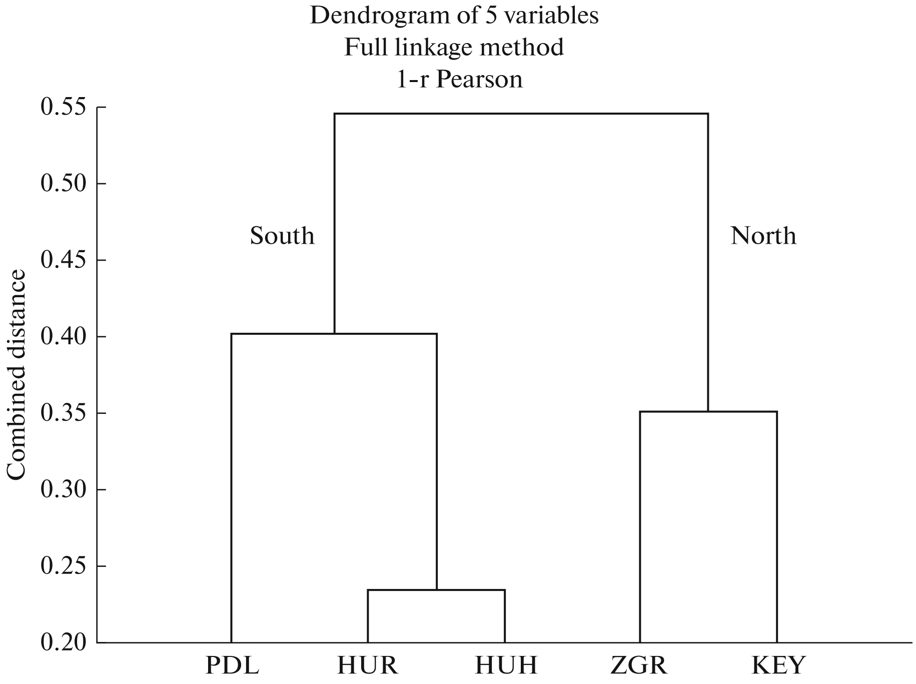

Fig. 3. Hierarchical classification of standard local chronologies of the pine radial increment.

pronounced in the northern part of the study area (Figs. 4a, 4b). In the first half of the season (May–July), temperature fluctuations are reflected in the current annual ring and, in the second half (August–September) in the ring of the next year. In the north, the negative influence on the increment was observed for winter temperatures of November, December, and March. In the southern area, winter temperature does not significantly affect the increment. The response to precipitation from May–June to September is positive

Table 3. Statistical characteristics of indexed tree-ring chronologies

Characteristic	ZGR	KEY	PDL	HUH	HUR	BUR-N	BUR-S
General characteristics							
Duration, years	370	209	255	248	265	370	265
Period, years	1645–2014	1807–2015	1760–2014	1768–2015	1751–2015	1645–2014	1751–2015
Number of trees	42	42	51	73	48	84	172
Total number of annual rings	6573	6110	6956	13250	8130	12683	28336
Characteristics of indexed chronologies*							
Mean interserial correlation coefficient	0.56/0.49	0.47/0.53	0.51/0.56	0.59/0.64	0.57/0.61	0.48/0.44	0.48/0.51
Expressed population signal	0.89/0.88	0.97/0.97	0.96/0.97	0.99/0.99	0.98/0.98	0.90/0.89	0.99/0.99
Standard deviation	0.39/0.27	0.39/0.28	0.42/0.34	0.37/0.33	0.39/0.32	0.36/0.26	0.33/0.30
Coefficient of sensitivity	0.28/0.32	0.32/0.32	0.37/0.42	0.38/0.42	0.35/0.40	0.27/0.30	0.33/0.39
1st order autocorrelation coefficient	0.69/−0.11	0.63/−0.02	0.55/0.01	0.39/−0.08	0.47/−0.08	0.69/−0.09	0.42/−0.15
Correlation coefficients between standard and residual chronologies	0.66	0.79	0.80	0.91	0.86	0.68	0.90

* Numerator shows coefficients for standard chronologies; denominator shows coefficients for residual ones.

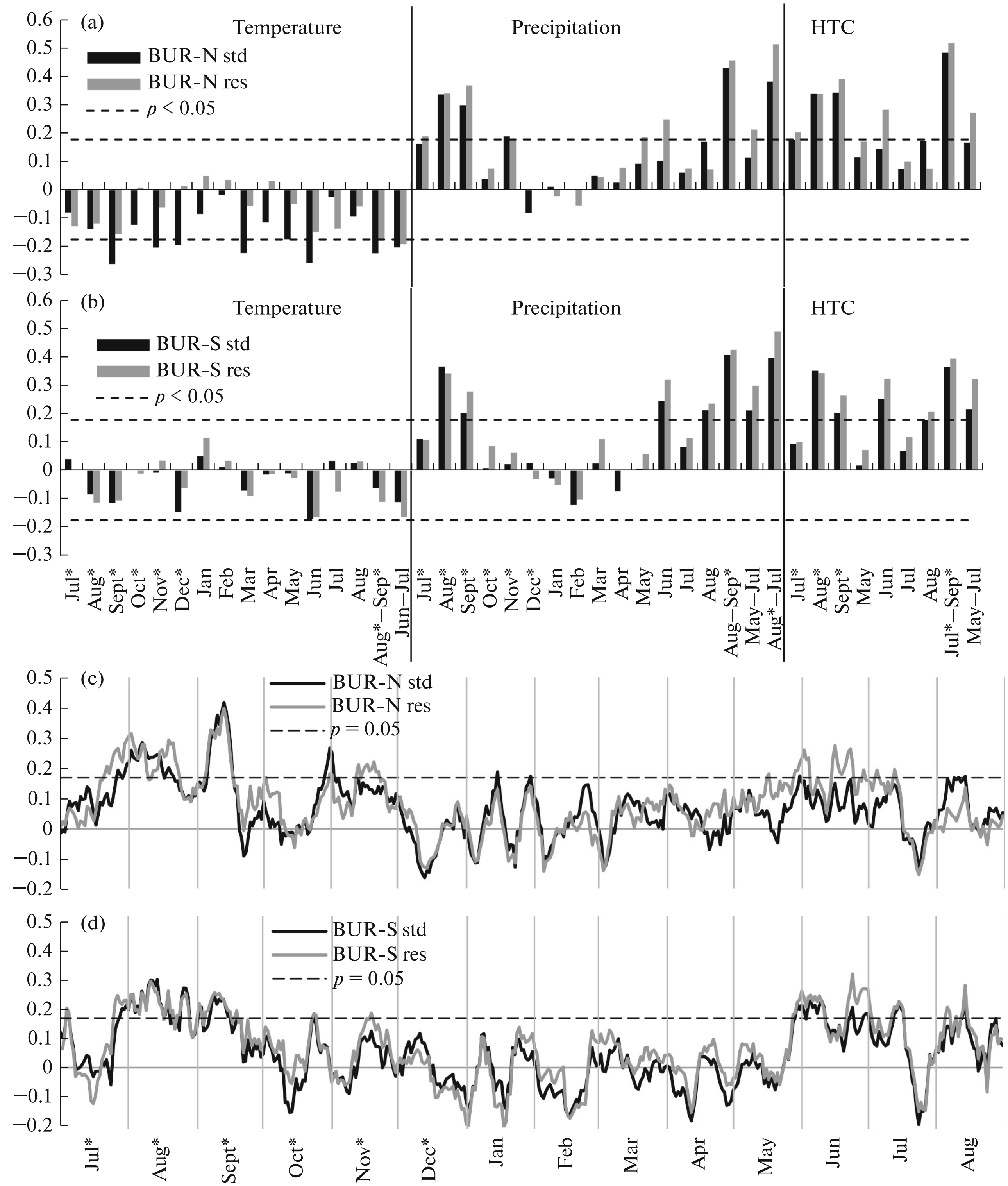

Fig. 4. Correlation coefficients of the indexed regional chronologies with climatic factors: (a) chronologies BUR-N and monthly temperatures, precipitation, and HTC; (b) chronologies BUR-S and monthly temperatures, precipitation, and HTC; (c) chronologies BUR-N and 10-day sums of precipitation by data from the Ulan-Ude climatic station; and (d) chronologies BUR-S and 10-day sums of precipitation by data from the Kyakhta climatic station.

and more pronounced than that to temperature. Precipitation in the second half of the previous vegetative season most strongly affects radial increment. Precipitation in May–June of the current season influences the increment to a weaker extent, and the response is more pronounced in residual chronologies. In the winter period, precipitation is inconsiderable, and its positive impact is significant only in November for the north of the study area. Annual amount of precipitation is reflected maximally in the radial increment during the period from August to July. The hydrothermal coefficient combines temperature and precipitation, so the response of radial increment of the pine on its fluctuations is slightly higher than on precipitation, but has the same regularities. Checking the possibility of using SPEI as an integral indicator of moisture displayed that its correlation with the radial increment of pine trees is lower than the HTC of the same months by 0.05–0.1, with the same pattern.

An analysis of 10-day series of climatic factors allowed us to determine the periods of climate influence on the increment during vegetative season; the radial increment is most sensitive to precipitation of the third decade of May to the first decade of June. The influence on current increase is observed until the second decade of July inclusively (Figs. 4c, 4d). Starting from the third decade of July to the end of September, the climatic factor influences the increment of the next year. Thus, in each annual ring, the maximum influence of the annual sum of precipitation should be observed in the period from the third decade of July of the previous year to the second decade of July of the current year. Indeed, correlations of precipitation in this period with chronologies of the increment in the pine are r = 0.43–0.61, whereas in the period from August to July r = 0.38–0.51. With regard to temperatures and HTC, the maximum correlation with the increase display values of these variables averaged for the sum period from the third decade of July to the third decade of September of the previous year and from the third decade of May to the second decade of July of the current year, which is actually for the same annual period, except for its cold part. The values of correlations are r = 0.42–0.64 for HTC and r = –0.27 to –0.19 for temperatures.

To evaluate the reflection of long-term climate fluctuations in the increment of the pine, we analyzed series of climatic factors for identified periods of maximum response, smoothed with an 11-year window, and compared them with corresponding smoothed standard increment chronologies (Fig. 5). For the entire study area, a long period of increment decrease in hot and dry periods is typical. Climatically determined depressions of the increment in 1951–1961 and 1975–1985 were observed in both chronologies (cf. 1956 and 1980–1982 pointer years). After 2000, a pronounced decrease in the increment in the north, synchronous with the abovementioned negative trend in precipitation, was observed. This is confirmed by correlation coefficients of the smoothed series of climate variables and increment: r = 0.37–0.72, 0.45–0.77 and –0.11 to –0.30 for the HTC, precipitation, and temperature, respectively.

DISCUSSION

The high consistency of dendrochronological data in 1999 and 2015 allowed us to obtain local and regional chronologies with a higher expressed population signal, which means that they more reliably reflect the common external signal. Enhancement of the sample by resampling led to the identification of differences in the dynamics of increment within the region during the last decades linked to differing trends of the climatic dynamics in the north and the south. This is connected with a decrease in annual precipitation by the data from the Ulan-Ude meteostation. However, the uniformity of temperature conditions and significant correlations between precipitation on the north and south of the area cause a high similarity of the increment dynamics within the entire study region, allowing the use of two regional chronologies (reflecting climatic dynamics on the north and south, respectively) and one common chronology used in previous studies of environmental change at a larger spatial scale (Andreev et al., 1999, 2000, 2001a, 2001b).

General patterns of climate response in the pine increment are typical of arid regions of the continental temperate belt of Central Asia they are conditioned by a small amount of precipitation falling mostly during the warm season, a high seasonal amplitude of temperatures, and a combination of hot summers and frosty winters (Suvorova et al., 2005; Magda and Vaganov, 2006; Babushkina and Belokopytova, 2014; Bocharov and Savchuk, 2015; Mukhanov et al., 2015; Lu et al., 2013; Shi et al., 2016; Gradel et al., 2017). The north of the region is characterized by more severe climatic conditions due to frostier winters and less precipitation, which leads to a greater intensity of climatic response.

Defined by decadal climate data, temporal response boundaries indicate the end of July as the approximate time of the end of active radial increment in the pine there. By this time, processes of cell division and their growth by elongation are completed. The formation of secondary cell walls in the latewood, ongoing until the end of September, does not contribute to the width of the current ring (Babushkina et al., 2010; Cuny and Rathgeber, 2014; Babushkina and Belokopytova, 2015). However, in this period, assimilates obtained by the plant are used not only for the construction of cell walls in the wood, but they are also stored by a plant for use in the next growth season (Sudachkova, 1977).

However, due to differences between individual trees in the timing of stages of wood formation (for example, dominant trees have a longer activity period

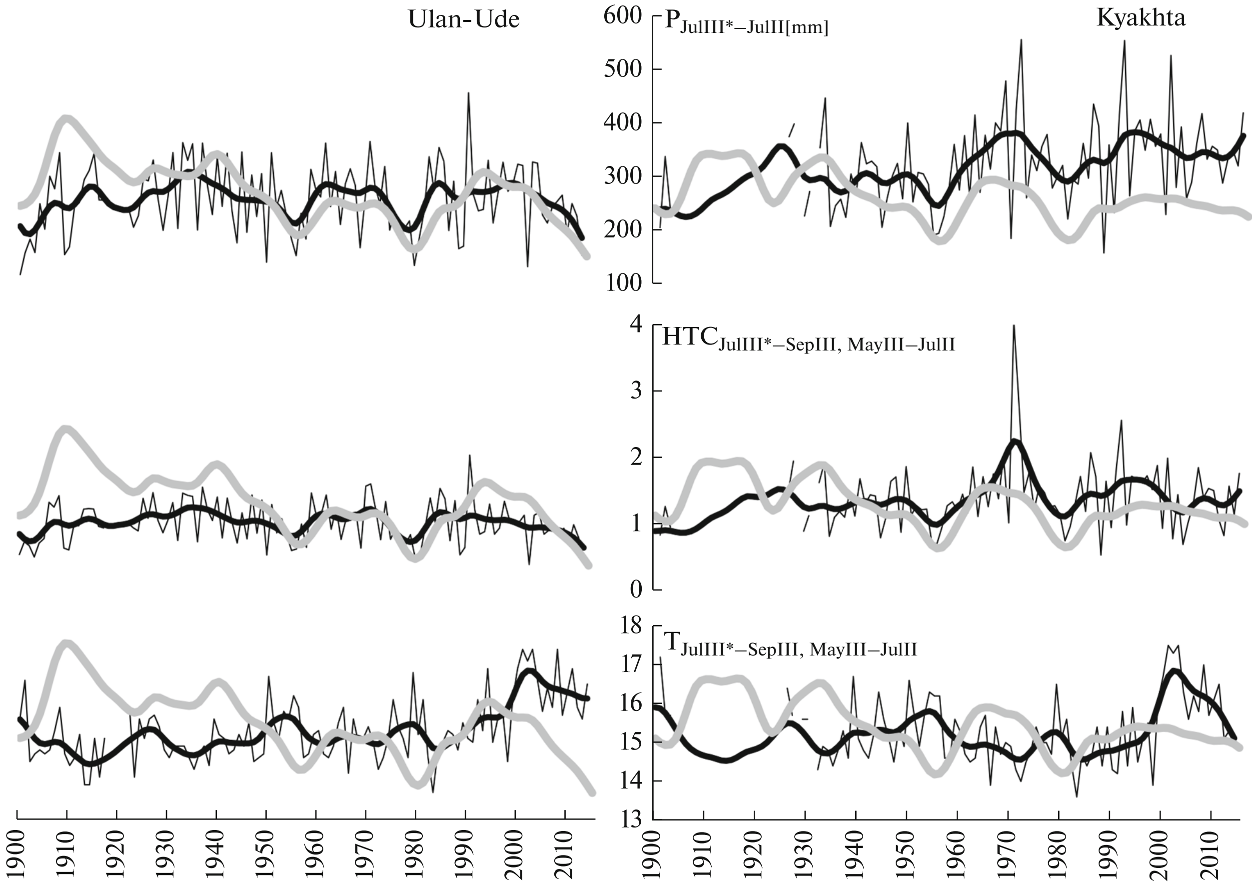

Fig. 5. Interannual and smoothed by 11-year splines fluctuations of the climatic factors which are most significant for the pine increment. Grey lines designate corresponding smoothed standard tree-ring chronologies given for comparison

of cambium than oppressed ones (cf. Babushkina et al., 2015)) and climate-dependent interannual variations of this timing, in the first half of August a weak response of pine increment to precipitation is also observed.

Starting at the end of July, air temperature is gradually reduced; even with declining precipitation this leads to a gradual increase in moisture supply in the soil until its freezing moment. There are the following data on assessing the efficiency of precipitation moisture accumulation in the soil: 9% in the second half of summer and up to 66% in the end of autumn (upon the saving of plant mass in fields) for agricultural arid regions of the United States (Farahani, 1998; Nielsen, 2006). In the natural forest-steppe landscape of Transbaikalia on sandy and stony soils and upon herbaceous vegetation coverage of 10–15% typical for sites of sample collection, the storage of moisture is less effective, but the abovementioned regularities take place (cf. Lampurlanes et al., 2002; Kargas et al., 2012). At the beginning of winter, temperatures fall very sharply, which at low snow cover leads to rapid freezing of the root-inhabiting layer of the soil and the conservation of the water contained there until thawing at the beginning of the vegetative season (Rode, 1965; Schillinger et al., 2010). A small amount of winter precipitation in the conditions of foothills leads to the formation of small snow cover and its blowing into depressions of the relief. As a result, snow does not make a significant contribution to the spring soil-moisture supply. On the other hand, in November–December and March, temperatures may regulate the soil moisture supply (Dulamsuren et al., 2011; Khishigjargal et al., 2014; Gradel et al., 2017). It should be noted that pine, as an evergreen conifer plant, in the study region starts its growth in April–May (Sudachkova, 1977; Suvorov, 2005). Therefore, precipitation stored in the soil from the second half of the previous warm season is a significant source of moisture from the beginning of vegetation until the third decade of May. By this time, soil moisture reserves are exhausted due to their use by vegetation and evaporation upon an increase in temperature, and current precipitation becomes the main source of water. As a result, the annual radial increment of the pine integrates the influence of climatic factors during the period from the third decade of the previous July to the second decade of this July, with a predominance of the impact of the climate of the warm season.

The variability of the pine increment has a pronounced low-frequency component conditioned by long-term fluctuations of precipitation and temperature. Due to harsher climatic conditions in the north of the study area, the amplitude of low-frequency fluctuations of increment is significantly higher there than in the south. Despite regional differences, in both chronologies we observed almost synchronous cycles of 23–35 years that are typical for the cyclicity of fluctuations in the moisture regime (precipitation, moisture indices, and hydrological variables) and were observed earlier in tree-ring chronologies (Shnitnikov, 1969; Balybina, 2006; Mukhanova et al., 2015). However, due to the spatial irregularity of precipitation, the obtained cycles, pointer years, and longer dry/wet periods do not coincide with those observed for other regions of Siberia, Mongolia, and Northern China (Balybina, 2006; Lu et al., 2013; Mukhanova et al., 2015; Shi et al., 2016).

CONCLUSIONS

An analysis of relationships between radial increments of the Scots pine in the forest steppe of Western Transbaikalia with climatic variables, conducted using a large amount of data, allowed us to determine the most significant periods for the formation of annual rings. The main limitation of the pine increment in the region is observed with regard to water supply, including the conditions during previous (from July 20 to September 30) and current (from May 20 to July 20) vegetative seasons. In this case, the conductor of the influence of the conditions of the previous warm season is the soil as a reservoir retaining moisture during winter. Heterogeneity in the variability of precipitation within the study area led to differences between its northern and southern parts in the pine increment dynamics and its climatic response. Upon a large spatial scale, this caused a discrepancy between the pointer years and long-term fluctuations in the increment with chronologies from other regions.

Mechanisms of influence of climate variables on the formation of conifer wood, suggested in this work, need further verification. Therefore, the following areas of research are most interesting: a comparative analysis of different regions within the forest-steppe ecotone and an analysis of relationships of variability of tree-ring chronologies with global climatic oscillations. Highlighting peculiarities of physiological reactions of wood may be useful for simulating its formation in these climatic conditions at the cellular level using the Vaganov–Shashkin simulation model (Vaganov et al., 2006, 2011).

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