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RESEARCH ARTICLE

# Snow cover as a factor of radial growth of woody plants in different habitats of Altai

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### Abstract
The dependence of the of annual ring width of woody plants in the Altai Mountains on such parameters of snow cover as maximum thickness, water reserve, dates of disappearance, and establishment and duration of occurrence of stable snow cover, is analyzed. The data of the state hydrometeorological stations (HMS) and the authors' own dendrochronological materials were used for the analysis. The features of the response of the radial growth to the snow cover parameters for various trees, fir (*Abies sibirica* L.), Siberian larch (*Larix sibirica* L.), Siberian stone pine (*Pinus sibirica* Du Tour), and pine (*Pinus sylvestris* L.), depending on the geographical location, were established.

### Keywords
Altai, snow cover, tree rings, woody plants

## Introduction

Snow cover in Siberian regions is one of the most important environmental factors for plants. It changes the thermal and water regimes of their habitat, having a mechanical effect on them. In winter it acts as a heat insulator, protecting plants from freezing and drying out by the wind, and also contributes to less soil freezing. In the spring, it delays the warming of the soil and the beginning of vegetation, and sometimes it is the cause of the rotting of plants. Also, in the spring-summer period, it largely determines soil moisture, which in some habitats acts as a limiting factor (Bykov and Popov 2011). The mechanical effect of the snow cover on plants occurs due to the sliding of the snow cover down the slope, avalanches, or the abrasive effects of blizzards.

Many researchers have studied the influence of snow cover indicators on the growth of woody plants of various habitats (Gedalof and Smith 2001; Falarz 2017; Sanmiguel-Vallelado et al. 2019). It was found that the influence of snow cover is largely differentiated by geographical location (Nikolaev and Skachkov 2011). In areas of long-term occurrence of snow cover, the relationship of its indicators with those of annual rings becomes closer (Vaganov et al. 1999; Schmidt et al. 2010; Owczarek and Opała 2016; Watson and Luckman 2016). Some researchers used the results obtained to reconstruct various characteristics of the snow cover: duration of occurrence; maximum thickness for the snow season or a certain date; the time of disappearance (Kirdyanov et al. 2003; Woodhouse 2003; Schmidt et al. 2006; Qin et al. 2016), and the amount of snow reserves in a river basin (Hart et al. 2010).

Rarely have such studies been conducted in the Altai Mountains of southern Siberia (Bykov 1998). This territory is characterized by extremely differentiated, unique conditions: from extremely snowy to sparse snow, and in some years to completely snowless conditions. It should be expected a priori that the reaction of woody plants to changes in snow cover indicators in the Altai will be different. At the upper boundary of the forest (hereafter – treeline), where the productivity of woody plants is controlled by the sum of positive air temperatures, an increase in snow cover indicators is likely to entail a reduction in the growing season and a decrease in the radial growth of trees. By contrast, at the lower boundary of the forest such a change in nival conditions should contribute to an increase in radial growth, since in forest-steppe and steppe areas the main limiting factor is the amount of water (Demina et all. 2017; Rygalova et al. 2022). This determined the purpose of this work – the analysis of the relationship between the values of various characteristics of snow cover and the width of annual rings of woody plants in various habitats of the Altai Mountains.

## Material and methods

The Altai is a vast mountainous region, parts of which differ significantly from each other in physical and geographical terms. The climatic conditions here change not only with the elevation of the terrain but also with the distance from the peripheral areas of the mountainous region to its interior. However, meteorological observations in Altai are limited. Almost all weather stations are located at the bottom of river valleys or mountain basins, which makes it difficult to analyze the dependence of the radial growth of trees on meteorological indicators along the altitude gradient. This determined the selection of sites for dendrochronological sampling in our study (Table 1). Most of the sites were chosen near weather stations in the Altai and nearby territories (Salair Ridge and West Siberian Plain). For comparison, dendrochronological samples were also taken from the treeline. They were obtained from fir (*Abies sibirica* L.), Siberian larch (*Larix sibirica* L.), Siberian stone pine (*Pinus sibirica* Du Tour), and Scots pine (*Pinus sylvestris* L.). Sampling was carried out in accordance with the recommendations of dendroclimatic work (Shiyatov et al. 2000). At each site, 30 cores were obtained from 15 trees of the same species. As the main parameter, the width of the annual rings was chosen, whose measurements were carried out on a semi-automatic Lintab 6 devise with an accuracy of 0.01 mm. Standardization and generalization of the dendrochronological series was carried out with the help of the ARSTAN software.

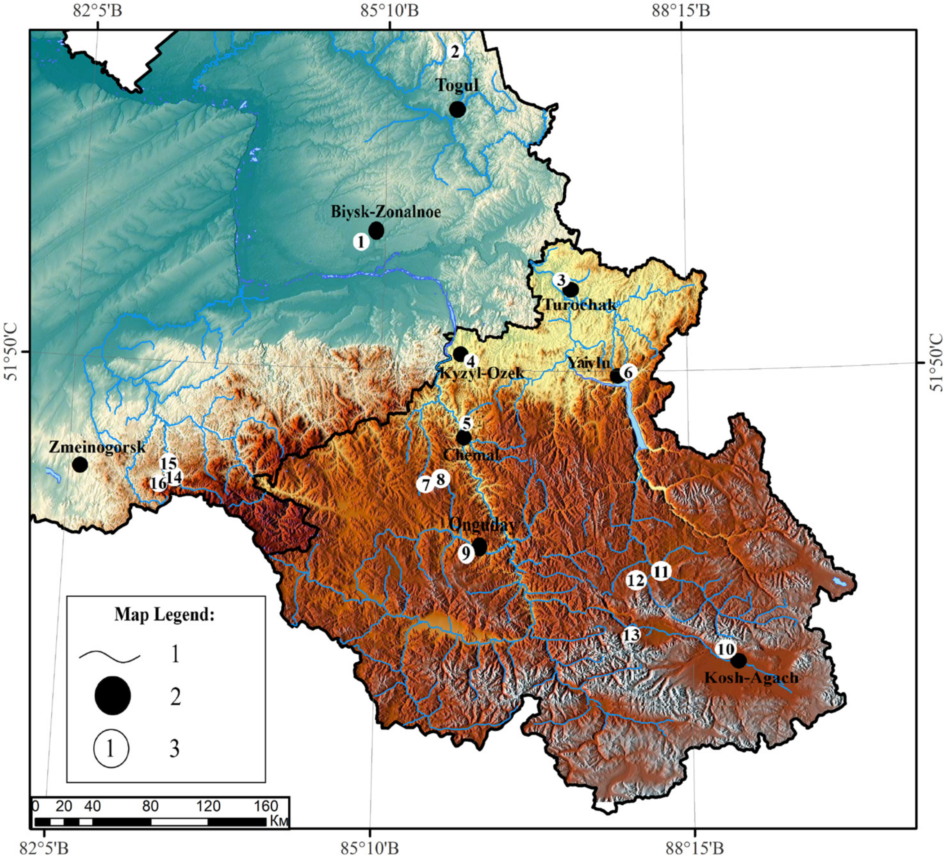


**Figure 1.** Position of sampling sites and weather stations. Map Legend: **1**- administrative and state borders; **2** – weather station; numbers of sampling sites for dendrochronological samples: **1**- chronology of Z; **2** – chronology of ST; **3** – chronology of T; **4** – chronology of KO; **5** – chronology of Che; **6** – chronology of Ya 1–3; **7** – chronology of 2S; **8** – chronology of S; **9** – chronology of On; **10** – chronology of Or; **11** – chronology of K1; **12** – chronology of K4; **13** – chronology of Masch; **14** – chronology of Kh; **15** – chronology of Tig 1–3; **16** – chronology of I.

**Table 1.** Geographical location of dendrochronological sampling sites, studied tree species, and snow-cover characteristics (Hmax – maximum thickness of snow cover in winter; Wmax – maximum water reserve of snow cover; Du – date of establishment of a stable snow cover; Dr – date of disappearance of a stable snow cover; P – duration of occurrence of a stable snow cover)

| Chronology name, tree species, weather station | Coordinates | Absolute elevation of the terrain, m | Forest type | Average snow cover indicators for the period of 1990–2020 years |
|---|---|---|---|---|
| | | West Siberian Plain | | |
| Z, *Pinus sylvestris* L., Biysk-Zonal | 52.5161 84.7912 | 210 | Birch-pine forest | Hmax – 50 cm; Wmax – 130 mm; Du – 10 November; Dr – 10 April; P – 149 days |
| | | Salair Ridge | | |
| ST, *Abies sibirica* L., Togul | 53.6976 85.9939 | 310 | Aspen-fir forest | Hmax – 59 cm; Wmax – 152 mm |
| | | Altai | | |
| T, *Pinus sylvestris* L., Turochak | 52.2951 87.1088 | 330 | Fir-birch-pine forest | Hmax – 69 cm; Wmax – 169 мм; Du– 2 November; Dr – 16 April; P – 166 days |
| KO, *Pinus sylvestris* L., Kysyl-Osek | 51.8680 86.0051 | 370 | Birch-pine forest | Hmax – 56 cm; Du– 5 November; Dr – 7 April; P – 152 days |
| Che, *Pinus sylvestris* L., Chemal | 51.3949 86.0104 | 490 | Birch-pine forest | Hmax – 13 cm; Wmax – 23 mm |
| Ya 1, *Pinus sylvestris* L., Ya 2 *Larix sibirica* L., Ya 3, *Pinus sibirica Du Tour*, Yailyu | 51.7701 87.6190 | 450 | Birch-larch-cedar-spruce forest | Hmax – 53 cm; Wmax – 122 mm; Du– 12 November; Dr – 1 April; P – 139 days |
| S, *Pinus sibirica Du Tour*, Ongudai | 51.0577 85.6561 | 1890 | Pine (*Pinus sibirica*) forest | |
| 2 S, *Pinus sibirica Du Tour*, Ongudai | 51.0447 85.6312 | 1740 | Pine (*Pinus sibirica*) forest | |
| On, *Larix sibirica* L., Ongudai | 50.7350 86.0906 | 1039 | Birch-larch-pine (*Pinus sibirica*)-spruce forest | Hmax – 19 cm; Wmax – 34 mm |
| Or, *Larix sibirica* L., Kosch-Agach | 50.0190 88.4789 | 1760 | Larch forest | Hmax – 8 cm; Wmax – 21 mm; Du– 17 November; Dr – 14 March; P – 121 days |

| Chronology name, tree species, weather station | Coordinates | Absolute elevation of the terrain, m | Forest type | Average snow cover indicators for the period of 1990–2020 years |
|---|---|---|---|---|
| K 1, *Larix sibirica* L., Kosch-Agach | 50.5868 87.8716 | 1330 | Spruce-pine (*Pinus sibirica*) -larch forest | Hmax – 8 cm; Wmax – 21 мм; Du– 17 November; Dr – 14 March; P – 121 days |
| K 4, *Larix sibirica* L., Kosch-Agach | 50.5051 87.6422 | 2120 | (*Pinus sibirica*)-larch forest | |
| Mash, *Larix sibirica* L., Kosch-Agach | 50.1917 87.59925 | 2280 | Pine (*Pinus sibirica*)-larch forest | |
| Kh, *Larix sibirica* L., Zmeinogorsk | 51.0862 83.0078 | 1290 | Larch-pine (*Pinus sibirica*)-aspen-fir forest | |
| Tig 1, *Pinus sylvestris* L., Zmeinogorsk | 51.1380 82.9923 | 500 | Pine plantations | Hmax – 44 cm; Wmax – 116 mm; Du – 9 November; Dr – 9 April; P – 151 days |
| Tig 2, *Larix sibirica* L., Zmeinogorsk | 51.1427 83.0324 | 490 | Larch-aspen-fir forest | |
| Tig 3, *Abies sibirica* L., Zmeinogorsk | 51.1293 83.0313 | 590 | Aspen-fir forest | |
| I, *Abies sibirica* L., Zmeinogorsk | 51.0388 82.9584 | 1430 | Pine (*Pinus sibirica*)-fir forest | |

To analyze the relationship between the width of annual rings and snow cover indicators, data from weather stations of the State Meteorological Network (ARRIHMI-WDC (http://meteo.ru)) were used. The Togul station was the closest to the sampling points on the Salair Ridge, Biysk-Zonal – to the south of the West Siberian Plain, Zmeinogorsk – to the northwestern Altai; Kyzyl-Ozek and Chemal – to northern Altai; Turochak and Yaylu – to the northeastern Altai; Ongudai – to the central Altai; and Kosh-Agach – to the southeastern Altai. As factors of radial growth of woody plants, such indicators of snow cover as the maximum thickness of snow for the winter period (Hmax) at meteorological sites and snow-measuring tracks, the maximum water reserve of snow cover (Wmax) on snow-measuring routes, the dates of establishment (Du) and disappearance (Dr) of a stable snow cover, as well as the duration of its occurrence, were considered (P) (Table 1). The dates of the establishment and disappearance of a stable snow cover in the correlation analysis were determined as the number of days from January 1.

The average annual values of snow cover indicators (for the period 1966–2020) in the study area vary significantly according to the weather stations. The lowest values of all snow cover indicators are noted at the Kosh-Agach station: the maximum thickness is 8 cm; the maximum water reserve is 21 mm; the establishment of a stable snow cover is November 17; the disappearance of a stable snow cover is March

14; and the duration of occurrence is 121 days. The highest values are observed at the Turochak station: the maximum thickness is 69 cm; the maximum water reserve is 169 mm; the establishment of a stable snow cover is November 2; the disappearance of a stable snow cover is April 16; and the duration of occurrence is 166 days. However, it should be borne in mind that the thickness, water reserve, and duration of snow cover increase significantly toward the treeline.

The relationship between tree-ring chronologies and snow cover indicators was determined by calculating Pearson correlation coefficients. The period for comparison of snow cover indicators with the dendrochronological series is determined by the time of core sampling in specific locations. In most cases, it covers the years from 1966 to 2020.

## Results

Analysis of the relationship of snow cover indicators and the width of annual tree rings in the Altai and adjacent areas indicates that the influence of snow cover on the radial growth of woody plants is differentiated by the geographical location and species of trees (Table 2). Radial growth of Scots pine (*Pinus sylvestris* L.) trees located at the bottom of mountain valleys, as a rule, responds positively to an increase in the thickness and water reserve of snow cover. Trees in the most snow-free areas react especially sensitively to this, such as in the Katun River valley near the village of Chemal (chronology Che). This circumstance may be due to the fact that in areas of insufficient moisture snow cover provides a favorable water regime of soils for trees during their growing season. At the same time, the pines of the most snow-covered region of the Altai (chronology T) and the forest-steppe region of the West Siberian Plain (chronology Z) respond to an increase in the thickness and water reserve of the snow cover by decreasing radial growth in the subsequent growing season. Such a reaction is probably due to the fact that in these areas the snow cover contributes to excessive soil moisture. In all habitats Scots pine trees react negatively to the duration of stable snow cover. Such a reaction of trees is probably due to the fact that an increase in the duration of this period entails a reduction in the period of the growing season. The trees of the northern studied areas (chronologies Z and T) react most sensitively to this indicator. An earlier disappearance of a stable snow cover leads to an increase in the growth of Scots pine (*Pinus sylvestris* L.), as well as its later establishment.

Firs (*Abies sibirica* L.) in snow-covered areas – the treeline in the northwestern Altai (chronology I) and the black taiga of the low-elevation Salair Ridge (chronology ST) – react negatively to an increase in the thickness and water reserve of the snow cover. However, in the lower part of the forest belt in the northwestern Altai, their response to the thickness of the snow cover is positive (Tig 3 chronology). It is possible that the thickness of the snow cover here determines the degree of soil freezing. With less soil freezing, earlier thawing occurs, and the beginning of vegetation shifts to an earlier date. The duration of the period of stable snow cover negatively affects the radial growth of fir trees throughout the forest belt, especially in its lower part. At the same time, the date of disappearance of a stable snow cover is of the greatest importance here, and at the treeline it is the date of the establishment of a stable snow cover (Table 2).

The reaction of Siberian stone pine (*Pinus sibirica Du Tour*) to the thickness and water content of the snow cover depends on its altitude. At the treeline (S and 2S chronologies), it responds positively to an increase in these indicators of snow cover. But at the same time, the relationship between the width of the annual rings and the thickness and water reserve of the snow cover decreases rapidly with a drop in the elevation of the terrain (Table 2). For example, on the Seminsky Ridge, stone pines located only 150 m below the treeline (2S chronology) compared to the treeline position (chronology S) demonstrate a less close relationship with snow cover indicators, and on the coast of Lake Teletskoe (chronology Ya 3) this relationship is not manifested at all. At the same time, it is found that the tree-ring chronologies for the stone pine have a closer relationship with the snow cover indicators, not of the nearest Ongudai station but rather of the one located on the plain (Biysk-Zonal station). This circumstance can be explained by the fact that the Ongudai station characterizes the nival conditions of the bottom of the intermountain basins of the central Altai, where the thickness and water reserve of the snow cover are low. The dynamics of these indicators of snow cover on the treeline is probably better reflected in data from the stations located in the snowier northern regions of the studied region. Similarly, stone pines react to the duration of a stable snow cover. At the treeline, the longer this period is, the greater their growth will be. On the coast of Lake Teletskoe (Ya 3 chronology), the long period of snow cover reduces the growing season and the width of the annual rings. Also, in the upper part of the forest belt the later establishment of a stable snow cover contributes to a decrease in the growth of stone pines in the subsequent growing season, and in the lower part, by contrast, an increase. The early disappearance of snow cover in the lower parts of the forest belt has a positive effect on the radial growth of stone pines, and in the upper parts, a negative effect.

The reaction of Siberian larch (*Larix sibirica* L.) to the snow cover indicators is more complicated. Thus, in the northwestern (Tig 2 chronology), northeastern (Ya 2 chronology), and eastern (K1 chronology) Altai at the lower levels of the forest belt, the greater the thickness and water reserve of the snow cover, the greater the width of the annual tree rings in the next growth season. A similar reaction of larches was noted earlier in the middle taiga subzone of central Yakutia (Nikolaev and Skachkov 2011). According to these authors, this kind of reaction of woody plants is due to the heat-insulating properties of the snow cover: with less soil freezing in winter, they warm up more quickly in spring and, accordingly, the growth processes of larches begin earlier. However, there are other opinions on this issue. Some authors express the view that with an increase in the thickness of the snow cover the width of the annual rings should decrease, since it leads to a later disappearance of the snow cover and a later onset of growth processes in larches (Kirdyanov et al. 2003). We noted such a reaction of larches in the northeastern, eastern, and northwestern Altai in the upper parts of the forest belt. However, such a reaction does not manifest itself everywhere in these regions. For example, in the upper part of the forest belt in the northwestern Altai, larch trees (Kh chronology) respond positively to an increase in the water supply of the snow cover.

**Table 2.** Correlation of the thickness of annual rings of forest tundra and northern taiga trees with the maximum thickness of snow cover in winter on the meteorological site (hm), the maximum thickness ($h_f$ – field, $h_w$ – forest) and water reserve ($w_f$, $w_w$) of snow cover in winter on routes, the date of establishment (Du – calendar year; Du-1 – previous year), disappearance (Dr) and duration (P) of occurrence of stable snow cover (correlation coefficients are statistically significant at a value of 0.23 and higher at p<0.05)

| Chronology name, tree species, absolute elevation of the terrain, m | Weather station | Thickness snow cover | | | Water reserve snow cover | | Characteristics of stable snow cover | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $h_m$ | $h_f$ | $h_w$ | $w_f$ | $w_w$ | Du | Du-1 | Dr | P |
| Z, *Pinus sylvestris* L., 210 | Biysk-Zonal | -0.28 | -0.25 | | -0.25 | | 0.19 | 0.32 | -0.37 | -0.42 |
| ST, *Abies sibirica* L., 310 | Togul | | -0.05 | | -0.02 | | | | | |
| T, *Pinus sylvestris* L., 330 | Turochak | -0.12 | | -0.03 | | -0.07 | -0.08 | 0.20 | -0.20 | -0.31 |
| KO, *Pinus sylvestris* L., 370 | Kyzyl-Ozek | 0.18 | | | | | 0.15 | 0.27 | 0.05 | -0.15 |
| Che, *Pinus sylvestris* L., 490 | Chemal | | 0.26 | | 0.28 | | | | | |
| Ya 1, *Pinus sylvestris* L., 450 | Yailu | 0.03 | | 0.14 | | 0.06 | 0.00 | 0.10 | -0.13 | -0.19 |
| Ya 2, *Larix sibirica* L., 450 | Yailu | 0.14 | | 0.41 | | 0.33 | -0.09 | 0.16 | 0.29 | 0.06 |
| Ya 3, *Pinus sibirica* Du Tour, 450 | Yailu | -0.06 | | -0.01 | | -0.03 | 0.19 | 0.16 | -0.23 | -0.21 |
| On, *Larix sibirica* L., 1030 | Ongudai | | -0.10 | | -0.06 | | | | | |
| Or, *Larix sibirica* L., 1760 | Kosh-Agach | -0.02 | -0.08 | | -0.13 | | -0.19 | 0.06 | 0.02 | -0.10 |
| K 1, *Larix sibirica* L., 1330 | Kosh-Agach | 0.05 | 0.15 | | 0.12 | | -0.11 | 0.01 | 0.17 | 0.04 |
| | Yailu | 0.08 | | 0.05 | | 0.14 | 0.11 | -0.11 | 0.29 | 0.26 |
| K 4, *Larix sibirica* L., 2120 | Kosh-Agach | -0.16 | -0.13 | | -0.2 | | -0.11 | 0.06 | -0.15 | -0.05 |
| | Yailu | -0.11 | | -0.36 | | -0.26 | -0.01 | 0.23 | -0.14 | -0.23 |
| Tig 1, *Pinus sylvestris* L., 490 | Zmeinogorsk | 0.21 | 0.02 | | 0.12 | | -0.18 | 0.01 | -0.21 | -0.11 |

| Chronology name, tree species, absolute elevation of the terrain, m | Weather station | Thickness snow cover | | | Water reserve snow cover | | Characteristics of stable snow cover | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $h_m$ | $h_f$ | $h_w$ | $w_f$ | $w_w$ | Du | Du-1 | Dr | P |
| Tig 2, *Larix sibirica* L., 502 | Zmeinogorsk | 0.18 | 0.21 | | 0.16 | | -0.11 | -0.02 | -0.16 | -0.05 |
| Tig 3, *Abies sibirica* L., 590 | Zmeinogorsk | 0.23 | 0.05 | | -0.17 | | -0.03 | 0.02 | -0.34 | -0.24 |
| Kh, *Larix sibirica* L., 1290 | Zmeinogorsk | -0.08 | -0.07 | | 0.14 | | 0.10 | -0.16 | 0.04 | 0.12 |
| I, *Abies sibirica* L., 1430 | Zmeinogorsk | -0.15 | -0.21 | | -0.27 | | 0.03 | 0.18 | -0.01 | -0.18 |
| Masch, *Larix sibirica* L., 2280 | Kosh-Agach | -0.06 | -0.09 | | 0.10 | | 0.14 | 0.00 | -0.08 | -0.04 |
| | Biysk-Zonal | 0.07 | 0.10 | | 0.08 | | -0.14 | -0.17 | 0.24 | 0.22 |
| | Ongudai | | 0.24 | | 0.20 | | | | | |
| S, *Pinus sibirica Du Tour*, 1890 | Biysk-Zonal | 0.29 | 0.30 | | 0.31 | | -0.38 | -0.27 | 0.20 | 0.28 |
| | Ongudai | | 0.14 | | 0.09 | | | | | |
| 2S, *Pinus sibirica Du Tour*, 1740 | Biysk-Zonal | 0.16 | 0.11 | | 0.12 | | -0.37 | -0.11 | 0.06 | 0.13 |
| | Ongudai | | -0.03 | | -0.08 | | | | | |

In Central and Southeastern Altai, *Larix sibirica* L. at the lower limit of the forest belt (On and Or chronologies, respectively) react negatively to the increase in the thickness and water reserve of the snow cover, and at the upper boundary of the forest (Masch chronology), by contrast, positively. At the same time, the correlation of the Masch tree-ring chronology is better with the thickness and water reserve indicators at the Ongudai weather station than at the Kosh-Agach weather station, although the latter is closer.

The studied larches also have an ambiguous reaction to the duration of a stable snow cover. In the eastern (K1 chronology) and northeastern (Ya 2 chronology) Altai, the relationship between the annual ring width and the snow cover duration is either neutral or positive. At the treeline (K 4 chronology), it has a negative character. However, at the lower boundary of the forest in the southeastern (Or chronology) and northwestern (Tig 2 chronology) Altai this relationship is either neutral or negative. At the upper boundary of the forest in the central (Masch chronology) and northwestern (Kh chronology) Altai, this connection has a positive character.

The reaction of larches to the time of disappearance of a stable snow cover is similar. In the lower part of the forest belt in the eastern and northeastern Altai, the late disappearance of the snow cover contributes to a more intensive radial growth of trees. The reason for such a reaction may be a later melting of the snow cover, which provides trees with favorable soil moisture at the time of their intensive growth. An increase in the growth of larches as a reaction to a later date of the disappearance of a stable snow cover was also noted by other researchers (Nikolaev and Skachkov 2012). At the same time, in the same areas (K 4 chronology) on the treeline a later disappearance of the snow cover slows down the radial growth of larches. Similar phenomena were noted by other authors in the forest-tundra zone of the Yenisei River basin (Kirdyanov et al., 2003). It should be noted here that the treeline is somewhat similar to the northern boundary of the forest zone; in both cases, the rate of radial growth is controlled by the sums of summer air temperatures (Bykov et al. 2022; Vaganov et al. 1996). However, in the northwestern (Kh and Tig 2 chronologies) and central (Masch chronology) parts of the Altai the reaction of larches is reversed: an early disappearance of snow cover in the lower part of the forest belt increases the growth of trees, and in the upper part, decreases it.

The late establishment of snow cover contributes to a decrease in the growth of larch on the upper boundary of the forest in the northwestern (Kh chronology) and central (Masch chronology) regions of the Altai. In the eastern Altai, in the upper part of the forest belt (K 4 chronology) the later establishment of snow cover contributes to an increase in the radial growth of larch.

It should also be noted that the deciduous tree-ring chronologies of the treeline zone in the Altai demonstrate a closer relationship with the snow-cover indicators of weather stations in snow-covered areas than in snow-free areas.

## Conclusions

In the course of our research, it was found that snow cover is not the main factor limiting the radial growth of woody plants, even in the upper part of the Altai forest belt, where its values are extreme. Its effect on woody plants depends on a combination of geographical factors and the type of tree.

The maximum thickness and water reserve of the snow cover are important factors for the radial growth of woody plants on the lower and upper boundaries of the Altai forest, as well as in the forest-steppe zone of the West Siberian Plain. In snow-rich areas, fir (*Abies sibirica* L.), Siberian larch (*Larix sibirica* L.), and Scots pine (*Pinus sylvestris* L.), as a rule, respond negatively to an increase in these indicators of snow cover, and positively in low-snow areas. The reaction of stone pine (*Pinus sibirica Du Tour*) is exactly the opposite. At the same time, tree-ring chronologies of snow-covered areas demonstrate a greater connection with the long-term record of snow-cover indicators of snow-covered areas, and not the nearest snow-free areas. Thus, the distance factor here is not decisive for the nature of the correlation.

The dates of disappearance of stable snow cover for fir (*Abies sibirica* L.), Siberian larch (*Larix sibirica* L.), and Scots pine (*Pinus sylvestris* L.) in most cases have a negative impact on growth, that is, the later the snow cover disappears, the slower the growth of these trees. The exception is the larch in dry habitats with cold and low-snow winter, where the late snow cover provides normal moisture during the period of intensive tree growth. A similar positive reaction to the late disappearance of the snow cover is observed in stone pines (*Pinus sibirica Du Tour*) at the treeline.

The dates of the establishment of a stable snow cover, as a rule, are directly proportional to the radial growth of trees. That is, the later a stable snow cover is established the greater the radial growth of trees in the subsequent growing season will be. However, at the treeline and at the lower boundary of the forest in areas with the most severe winters the early establishment of snow cover favorably affects the radial growth of trees after the end of winter.

The duration of the period with stable snow cover in most cases negatively affects the radial growth of trees in the study area. The exceptions are the larch of the lower boundary in areas with the most severe winters, and stone pine (*Pinus sibirica Du Tour*) on the treeline.

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