RESEARCH ARTICLE

Climate Response of Tree Radial Growth at Different Timescales in the Qinling Mountains

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Abstract

The analysis of the tree radial growth response to climate is crucial for dendroclimatological research. However, the response relationships between tree-ring indices and climatic factors at different timescales are not yet clear. In this study, the tree-ring width of Huashan pine (Pinus armandii) from Huashan in the Qinling Mountains, north-central China, was used to explore the response differences of tree growth to climatic factors at daily, pentad (5 days), dekad (10 days) and monthly timescales. Correlation function and linear regression analysis were applied in this paper. The tree-ring width showed a more sensitive response to daily and pentad climatic factors. With the timescale decreasing, the absolute value of the maximum correlation coefficient between the tree-ring data and precipitation increases as well as temperature (mean, minimum and maximum temperature). Compared to the other three timescales, pentad was more suitable for analysing the response of tree growth to climate. Relative to the monthly climate data, the association between the tree-ring data and the pentad climate data was more remarkable and accurate, and the reconstruction function based on the pentad climate was also more reliable and stable. We found that the major climatic factor limiting Huashan pine growth was the precipitation of pentads 20–35 (from April 6 to June 24) rather than the well-known April–June precipitation. The pentad was also proved to be a better timescale for analysing the climate and tree growth in the western and eastern Qinling Mountains. The formation of the earlywood density of Chinese pine (Pinus tabulaeformis) from Shimenshan in western Qinling was mainly affected by the maximum temperature of pentads 28–32 (from May 16 to June 9). The maximum temperature of pentads 28–33 (from May 16 to June 14) was the major factor affecting the ring width of Chinese pine from Shirenshan in eastern Qinling.

Introduction

Climate studies are very important for obtaining the information on natural and human environments, and the paleoclimate is essential for the overall understanding of climate change.
Due to their wide spread, precise date, high resolution, and high sensitivity to the climate, tree
rings have been widely used in past climate reconstructions across many regions [1–7]. In den-
droclimatological research, monthly climatic factors, such as monthly total precipitation and
mean temperature, are consistently used to study the response relationship between tree-ring
indices and climate. Under such circumstances, the continuous growth process of trees is
mechanically separated, during which some of the climate signal from the tree ring is likely
lost. If the tree response to climate is conducted at an appropriate timescale that corresponds
to tree growth regularity, more accurate climate signals can be obtained from tree rings.

The living environment and climate factors, such as precipitation, temperature and soil mois-
ture, are critical for tree growth [8, 9]. Because of the diurnal variation in climatic elements and
tree physiological properties, the radial growth of trees exhibits small diurnal changes [10, 11].
Studies of tree growth mechanisms usually utilize daily climatic factors [12, 13]. Daily climatic fac-
tors play an important role in the formation of tree-ring width and density, especially the daily
temperature in the pre- and early growing season [14]. In dendroclimatology, Feng et al. [15]
noted that tree radial growth was more sensitive to daily temperature than to monthly tempera-
ture, and tree-ring series could be used to reconstruct daily cumulative temperature [16]. In addi-
tion to daily and monthly timescales, other common scales, such as pentad (5 days), weekly and
dekad (10 days) timescales, have also been used in dendroclimatology. Using correlation coeffi-
cients between the mean temperature of pentads and tree-ring width indices, Vaganov et al. [17]
reported the important interval of the tree growth season at four sites near the northern timber-
line. Naurzbaev and Vaganov [18] reconstructed early summer (June 17–July 11) temperature
variations in east Taymir and Putoran over the last two millennia based on the response relation-
ship between tree-ring width chronology and pentad climatic factors. Utilizing the weekly cambial
activity of Scot pine, Seo et al. [19] analysed the radial growth variation in response to the weekly
climate change during the growing season. Based on Chinese pine (Pinus tabulaeformis) ring-
width chronology, Liu et al. [20] reconstructed February–early July precipitation for the Wu Dang-
hao region and February–mid-July rainfall for the La Madong region, Inner Mongolia, China.
However, all of the above studies were carried out within one timescale. It is necessary to explore
the differences and similarities of the climate-growth relationships of trees at different timescales.

The Qinling Mountains form a significant geographic division line and serve as the most
crucial boundary for climate and vegetation distribution in the middle of China due to their
west-to-east alignment, which separates semi-arid areas from humid regions [21]. Many stud-
ies of past climate and environmental changes based on tree rings have been carried out in the
Qinling Mountains and surrounding areas. In the western Qinling Mountains, Yang et al. [22]
used a modified point-by-point regression method and multi-proxy indices to reconstruct the
annual mean temperature change from 1500 to 1995 in west Qinling, and Chen et al. [23]
reconstructed February–July mean temperature for Zhouqu back to AD 1650 based on Faxon
fir ring-width standard chronology. In the central Qinling Mountains, Liu et al. [21] found that
the climatic conditions of the previous year and the early summer temperatures had a pro-
nounced influence on ring width on the southern and northern slopes, respectively. Based on
the total tree-ring width and maximum latewood density, Garfin et al. [24] reconstructed Feb-
uary–April temperature for Foping and July–August precipitation for Xi’an. In the eastern
Qinling Mountains, the ring widths of Chinese pine and high-elevation Huashan pine (Pinus
armandii) in Funiushan were used to reconstruct the average maximum temperature of May–
July and the winter half-year temperature [25, 26].

Dendroclimatic studies in Huashan along the northern margin of the eastern Qinling
Mountains have provided some results [27–30]. Because there is a meteorological station with
more than 60 years of observed data in Huashan, tree rings in this region can be used for more
specific studies of the tree-ring response to climate.
In this paper, we utilized the tree-ring chronology of Huashan pine and its nearby meteorological data to (1) determine the differences and similarities of the tree growth response to climatic factors at daily, pentad, dekad and monthly timescales; (2) demonstrate that pentad is a more suitable scale for dendroclimatology; and (3) determine the limiting pentad climatic factor of tree radial growth in the Qinling Mountains. We believe that our study will be highly significant for the development of dendroclimatology and climatology.

**Materials and Methods**

**Tree-ring data**

The three tree-ring chronologies used in this study were obtained from the National Centers for Environmental Information, NOAA (http://ncdc.noaa.gov/paleo/study). The sampling sites are located in the Qinling Mountains, north-central China (Fig 1). Huashan is located along the northern margin of eastern Qinling, and Shimenshan and Shirenshan are in western and eastern Qinling, respectively. The Shimenshan tree-ring data are Chinese pine earlywood density standard chronology [31], and the Shirenshan data are Chinese pine tree-ring width standard chronology [32]. The Huashan data are the originally measured tree-ring widths of Huashan pine at three sites [33]. As the three Huashan pine sampling sites were very close to each other and the ring-width series cross-dated very well [27], all of the increment cores were used to construct the tree-ring chronology using the ARSTAN program [34, 35]. Here, we used the standard chronology which preserves both low- and high-frequency information and mainly reflects the variations in climate.

**Climate data**

The observed climate data of Huashan, Tianshui and Luanchuan were obtained from the China National Meteorological Center (http://ncc.cma.gov.cn/). These stations are the nearest meteorological stations to each sampling site (Table 1 and Fig 1). The annual mean temperatures of Huashan, Tianshui and Luanchuan are approximately 6.2°C, 11.1°C and 12.1°C, and the annual precipitation levels are 836 mm, 521 mm and 853 mm, respectively.

**Methods**

Huashan station has a similar altitude and climate environment to the sampling location of Huashan pine and thus reflects the trees’ living climate. Therefore, Huashan chronology and
meteorological data were the major materials used to analyse the different responses of tree growth to climate at daily, pentad, dekad and monthly timescales. All of the climate data from the meteorological stations were processed using the same method. The climatic factors examined were precipitation and temperature (minimum, maximum and mean temperature).

The daily data were used to calculate the pentad, dekad and monthly values. For Huashan, we first generated the daily average of each climatic factor from 1953 to 2010 (Fig 2A). There is an extra day in a leap year: February 29th. The total precipitation of February 28 and 29 was used as the February 28 precipitation, and the average temperature of February 28 and 29 was used as the February 28 temperature. There are 73 pentads in a year. For example, the first pentad is January 1–5, and the 73rd pentad is December 27–31 [36]. The pentad precipitation is the total rainfall over a five-day period, and the temperature is the mean temperature of those five days (Fig 2B). There are three dekads in a month and 36 dekads in a year. The first dekad of a month extends from the first to the 10th day of the month; the following 10 days are the second dekad; and the 21st to the last day of the month is the third dekad. Similar to the pentad, the dekad precipitation is the sum of the daily rainfall, and the temperature is the mean value of the 10 days (Fig 2C).

At the daily, pentad, dekad and monthly timescales, a correlation function analysis method was used to identify the growth response of the trees to climate. A simple linear regression model was used to establish the reconstructed equation, and the split calibration-verification procedure was used to verify the reconstruction function [35, 37].

Results and Discussion

Tree response to climate at four timescales

The main growing season of Huashan pine is from approximately April to September [38, 39], and tree growth is affected by the climate of not only the current year but also the previous year [37]. Therefore, correlation analyses between ring widths and climatic variables were performed from October 1 of the previous year to September 30 of the current year at a daily timescale, from pentad 55 of the previous year to pentad 55 of the current year, from dekad 31 of the previous year to dekad 30 of the current year, and from October of the prior year to September of the current year at the pentad, dekad, and monthly timescales, respectively. According to the dendroclimatology method [35, 37], the response relationships of tree growth to climate were analysed during their common period from 1953 to 2005.

Correlation analysis showed a remarkable relationship between tree growth and precipitation; this relationship was mainly positive, and a significant negative correlation only appeared at the daily and pentad timescales (Fig 3). The striking negative response relationship occurred during almost every period of a year at the daily timescale and only appeared at the end of the previous growing season at the pentad timescale. The high precipitation at the end of the previous growing season may saturate the soil, contributing to low aeration and low root growth [37]. Trees cannot store sufficient nutrients to utilize at the beginning of the next growing

Table 1. Information on tree-ring sites and meteorological stations in the Qinling Mountains.

|                | Huashan | Huashan | Shimenshan | Tianshui | Shirenshan | Luanchuan |
|----------------|---------|---------|------------|----------|------------|-----------|
| Longitude (°E) | 110.08  | 110.08  | 106.15     | 105.75   | 112.23     | 111.60    |
| Latitude (°N)  | 34.47   | 34.48   | 34.45      | 34.58    | 33.73      | 33.78     |
| Altitude (m)   | 1950–2050 | 2065   | 2050–2100  | 1142     | 1675       | 750       |
| Tree species   | P. armandii | P. tabulaeformis | P. tabulaeformis |
| Indices        | Ring width | Earlywood destiny | Ring width |

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season, which does not result in the formation of a larger ring. Fritts [37] pointed out that, at
certain times of one year, extremely high precipitation might influence environmental conditions
which directly or indirectly limit tree growth. There was a remarkable correlation
between chronology and temperature, which was mainly negative (Fig 3). Significant direct
relationships were observed at the end of the previous growing season and the pre-growth
period of the current season at the daily and pentad timescales. The higher temperature at the
end of the previous season may promote the storage of carbohydrates, thus enhancing growth
during the following year [37, 40]. Although cambial activity ceases at the end of the previous
growing season, a higher temperature is beneficial for the trees and helps them to synthesize
organic substances. These organic substances could be used to produce more wood in the next
growing year [41]. A higher pre-growing season temperature may result in an earlier starting
date of the growing season, thereby lengthening the growing season and leading to wider rings
[42, 43]. These results indicate that the tree growth response to climate at the daily and pentad
timescales can clearly reflect the influence of climate on trees to some extent.

In addition, we also calculated the correlation coefficients between tree-ring indices and all
of the combinations of climate variables at each timescale to recognize the key climate factor
influencing tree growth. There were 66,795 precipitation groups at the daily timescale, 2775 at
the pentad timescale, 666 at the dekad timescale and 78 at the monthly timescale. Temperature
(minimum, maximum and mean temperature) was divided into the same groups as precipita-
tion. The maximum correlations between the tree-ring data and climate variables exhibited cer-
tain similar characteristics at the four timescales (Table 2). At all timescales, the tree-ring data
had the strongest correlation with precipitation. Regardless of the precipitation and the three
temperature factors, the absolute value of the maximum correlation coefficient increased as the
timescales decreased. The numbers of days with the maximum correlations between the tree-
ring data and the precipitation and temperature variables were similar for the four timescales,
and the onset/end dates were approximate. The temperature values of the onset dates of the
tree responses to precipitation and temperature were similar for the four timescales (Table 2
and Fig 2). This indicated that the temperature required for the highest speed of xylem cell pro-
duction needed to reach suitable value [44, 45]. The above points indicate that the response of
 tree rings to climate at the four timescales is reasonably credible.

However, the differences in tree response to climate at different timescales are the emphasis
of this study. The highest correlations were observed between the tree-ring data and all of the
climate elements at the daily timescale. The superiority of daily timescale was found in dendro-
climatic models. Dendroclimatic models with daily climate data were more efficient in identify-
ing special climatic events that lasted only a few days but drastically influenced tree growth
compared with dendroclimatic models using monthly climatic factors [46]. It was reported
that the influences of temperature on the radial growth of Quercus ilex L. were more relevant at
shorter time scales and explained the reason why the correlations between tree-ring width and
precipitation were often more significant than those between ring width and temperature at
monthly timescale in Western Mediterranean Basin [47]. The numbers of days and onset/end
dates of the maximum correlations between the tree-ring data and each climate element were
slightly different at the four timescales and were relatively precise at the daily scale. Thus, the
daily timescale should be the best selection for research on tree growth and climate. However,
the calculations at the daily timescale are too large; for example, there were 66,795 groups for
each climate element in this study. In addition, the maximum correlation coefficients between
the tree-ring data and climatic factors as well as their numbers of days and onset/end dates at
the pentad scale were similar to those at the daily timescale, especially with respect to the first
two important factors: precipitation and maximum temperature. This indicated that the pentad
timescale could substitute the daily scale to a certain extent. In addition, the pentad timescale is
also widely used in climate change [36, 48–50], agriculture [51] and tree physiology [17, 52]
research. The response relationship of cambium activity in trees to climate was discovered by
analysing the correlations between tree-ring structure parameter chronologies and pentad tem-
perature in the Siberian Subarctic [52]. Therefore, comparatively speaking, the pentad time-
scale is better for studying the relationships between climate change and tree radial growth in
Qinling Mountains.

The Twenty-four Solar Terms, Chinese traditional terms, precisely describe the climate
change characteristics in the seasonal cycle. They present some meaningful directions for sea-
sonal sequence, phenology change and crop growth, especially for the agriculture and forestry
production [53]. The highest response of radial growth of Huashan pine to precipitation at
pentad timescale (Table 2) happened to be the season from Pure Brightness to the Summer Sol-
stice [53]. During this seasonal interval, precipitation of Huashan remained in a relatively

![Fig 3. Correlation coefficients between ring width and each climate element at daily (a), pentad (b), dekad (c) and monthly (d) timescales.](image-url)
stable level (Fig 2C). When Pure Brightness arrives, trees and grasses begin to bud and everything begins to grow. The Summer Solstice indicates that Northern China enters into midsummer and everything is in the most robust growth time in a year [54]. The seasonal time of the highest pentad temperature response to tree growth was from 10 days after the Beginning of Summer to 5 days after the Summer Solstice. The Beginning of Summer indicates that summer arrives in Northern China and trees and crops turn into the exuberant growth time [54]. Since 10 days after the Beginning of Summer, mean pentad temperature was larger than 11°C (Fig 2C), which made Huashan pine growth be subject to temperature in stress [15]. And we also found that the onset date of pentad 20 was close to the beginning of the trees’ growing season which was from the observed phenological data at Xi’an, the nearest phenological station to Huashan [49, 55].

### Advantages of the pentad timescale compared to the monthly timescale

Monthly climate is not the best choice for the studies on relationships between tree growth and climate change at sometimes. Through collecting micro-cores from five even-aged Chinese pine trees at weekly intervals, Liang et al. [44] discovered cell division in the cambial zone of trees in North China started within the third week of May rather than at the beginning or the end of a month. It was also found that climate had a more accurate response relationship with tree growth at a timescale shorter than one month in the Inner Mongolia and the April 1–July 10 precipitation was reconstructed [56]. The response of tree growth to climate is stronger and more precise at the pentad timescale compared with the monthly timescale in this study (Table 2). The absolute values of the maximum correlation coefficients increased by 0.038 for precipitation, 0.040 for minimum temperature, 0.062 for mean temperature and 0.084 for maximum temperature from the pentad to the monthly timescale. To further explain the superiority of the pentad timescale, we determined the maximum correlation between the tree-ring data and the precipitation for all 18 pentad groups. Although 18 pentads had the same number of days with a 3-month period, their coefficients and dates of maximum correlation were different (Table 3). The maximum coefficient for the 18 pentads (0.766) was higher than that (0.758) for the 3-month period. There were also differences in the maximum correlation

### Table 2. Maximum correlations between tree-ring width and each climate element at different timescales.

| Climate element | Time scale | Correlation coefficient | Onset Date | End Date | Number of days |
|-----------------|------------|-------------------------|------------|----------|----------------|
| Precipitation   | Day        | 0.804                   | April 8    | June 23  | 77(Days 98–174) |
|                 | Pentad     | 0.796                   | April 6    | June 24  | 80(Pentads 20–35) |
|                 | Dekad      | 0.779                   | April 11   | June 20  | 71(Dekads 11–17) |
|                 | Month      | 0.758                   | April 1    | June 30  | 91(April–June)  |
| Mean temperature| Day        | -0.700                  | May 14     | July 7   | 55(Days 134–188) |
|                 | Pentad     | -0.687                  | May 16     | June 29  | 45(Pentads 28–36) |
|                 | Dekad      | -0.671                  | May 11     | June 30  | 51(Dekads 14–18) |
|                 | Month      | -0.625                  | May 1      | June 30  | 61(May–June)    |
| Minimum temperature| Day    | -0.608                  | May 14     | July 7   | 55(Days 134–188) |
|                 | Pentad     | -0.589                  | May 16     | June 29  | 45(Pentads 28–36) |
|                 | Dekad      | -0.567                  | May 11     | June 30  | 51(Dekads 14–18) |
|                 | Month      | -0.549                  | May 1      | June 30  | 61(May–June)    |
| Maximum temperature| Day    | -0.750                  | May 14     | June 30  | 48(Days 134–181) |
|                 | Pentad     | -0.739                  | May 16     | June 29  | 45(Pentads 28–36) |
|                 | Dekad      | -0.716                  | May 11     | June 30  | 51(Dekads 14–18) |
|                 | Month      | -0.655                  | May 1      | June 30  | 61(May–June)    |

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between the tree-ring data and temperature for 12 pentads and 2 months. The correlation coefficients increased from 0.018 to 0.029 (Table 3).

High-quality past climate reconstruction depends on successful calibrations and quantitative relationships between tree-ring indices and instrumental data of climatic factors [57, 58]. According to the principle of dendroclimatology, we established reconstructed functions (omitted in this paper) for precipitation of pentads 20–35 and precipitation from April–June. The functions were examined using a split calibration-verification procedure [35]. Due to its superior test parameters, the reconstruction function of the precipitation of pentads 20–35 was more reliable and stable (Table 4). For example, the correlation coefficient (r), reduction of error test (RE) and coefficient of efficiency (CE) increased, and the sign test (ST) was more significant [35, 37]. These results further indicated that the pentad timescale was superior for dendroclimatic research.

Tree radial growth had a good response to temperature and precipitation at different timescales, but the highest response happened to the relationship between the tree-ring width of Huashan pine and the precipitation of pentads 20–35. Therefore, according to the principle of dendroclimatology [35, 37], the precipitation from pentad 20 to pentad 35 is the major determinant of Huashan pine growth, which can be explained with explicit physiology. Monsoon rainfall plays an important role in the climate change and vegetation condition in northwest China and the pentad precipitation represents the variation of monsoon rains [50]. From pentad 20, the mean temperature is higher than 5°C, above which Huashan pine enters a rapid growth period [39]. Once the temperature reaches a specific suitable value and tree radial growth starts, factors other than temperature generally become limiting [37, 59]. Higher rainfall

### Table 3. Maximum correlations between the tree-ring data and climate factors at pentad and monthly timescales with the same number of days.

| Climate element | Time scale | Correlation coefficient | Onset Date | End Date | Number of days |
|-----------------|------------|-------------------------|------------|----------|----------------|
| Precipitation   | Pentad     | 0.766                   | March 27   | June 24  | 90             |
|                 | Month      | 0.758                   | April 1    | June 30  | 91             |
| Mean temperature| Pentad     | -0.654                  | May 11     | July 9   | 60             |
|                 | Month      | -0.625                  | May 1      | June 30  | 61             |
| Minimum temperature| Pentad | -0.567                  | May 11     | July 9   | 60             |
|                 | Month      | -0.549                  | May 1      | June 30  | 61             |
| Maximum temperature| Pentad | -0.683                  | May 11     | July 9   | 60             |
|                 | Month      | -0.655                  | May 1      | June 30  | 61             |

Table 4. Statistics of the split calibration-verification model for monthly and pentad precipitation reconstruction.

| Time scale       | Calibration | Verification |
|------------------|-------------|--------------|
|                  | Period      | r | ST | t   | Period      | r | RE | CE | ST | t   |
| Pentad (20–35)   | 1953–1979   | 0.772 | 21** | 4.884 | 1980–2005   | 0.821 | 0.653 | 0.592 | 19** | 5.154 |
|                  | 1979–2005   | 0.820 | 21** | 5.503 | 1953–1978   | 0.756 | 0.619 | 0.504 | 23** | 4.232 |
|                  | 1953–2005   | 0.796 | 44** | 7.255 |               |     |     |     |     |     |
| Month (April–June) | 1953–1979 | 0.751 | 21** | 4.765 | 1980–2005   | 0.769 | 0.601 | 0.523 | 18   | 5.329 |
|                  | 1979–2005   | 0.775 | 20*  | 5.776 | 1953–1978   | 0.731 | 0.587 | 0.468 | 22** | 4.150 |
|                  | 1953–2005   | 0.758 | 43** | 7.165 |               |     |     |     |     |     |

*Significant at the 0.05 level
**Significant at the 0.01 level
r, correlation coefficient; RE, reduction of error test; CE, coefficient of efficiency; ST, sign test; t, the product means test.
is better for cambial activity and is conducive to the generation of additional and larger cells, which benefits wider ring formation [27, 28]. With the coming of the rainy season, precipitation increases. From pentad 36, high amounts of rainfall are sufficient to replenish soil moisture and meet the demands of tree growth. The role of precipitation in tree radial growth weakens [37]. This tree growth pattern controlled by precipitation during the growing season was widely found in northwest China, such as the Xiaolong Mountain [60], the north-western Qilian Mountain [61] and the north Helan Mountain [62].

Application of the pentad timescale in western and eastern Qinling

Chen and Yuan [31] indicated that the maximum temperature from May to June was the major climate factor controlling the mean earlywood density (EWD) of Chinese pine trees in Shimenshan in western Qinling. Based on the EWD chronology [31], we analysed the response of tree growth to maximum temperature at the pentad and monthly timescales. The chronology had the strongest correlation with the maximum temperature of pentads 28–32 (May 16–June 9). The coefficient was higher than that between chronology and May–June maximum temperature (Table 5), demonstrating that the major factor affecting the mean earlywood density was the maximum temperature of pentads 28–32, in addition to that from May to June. In eastern Qinling, Shi et al. [32] found that the maximum temperature from May to June was also the main factor limiting the ring width of Chinese pine trees in Shirenshan. Similarly, the maximum temperature of pentads 28–33 (May 16–June 14) was the main limiting factor. The absolute value of the correlation coefficient increased by more than 0.1, demonstrating that the pentad was indeed a better timescale for tree-climate response. However, we should be conscious that these results merely showed a deeper understanding of the response relationship between tree-ring indices and climatic factors at different timescales in the Qinling Mountains.

Conclusions

By utilizing the tree-ring width chronology of Huashan pine from Huashan, north-central China, we found that the response relationship between tree radial growth and climate varied at the daily, pentad, dekad and monthly timescales. As the timescale decreased, the maximum correlations between the tree-ring data and climatic factors increased. The response of tree-growth to climate was stronger and more precise at short timescales. Compared to the other three timescales, the pentad was more suitable for analysing the response of tree growth to climate. When the pentad climate was used to analyse the climate-growth response in the Qinling Mountains, the major climatic factor limiting the growth of Huashan pine from Huashan was the precipitation of pentads 20–35 (from April 6 to June 24) rather than the well-known April–June precipitation. The mean earlywood density of Chinese pine trees in Shimenshan was mainly limited by the maximum temperature of pentads 28–32 (May 16–June 9) and not by the May–June maximum temperature. The major factor limiting the ring-width of Chinese pine trees in Shirenshan was the maximum temperature of pentads 28–33 (May 16–June 14) rather than that of May–June.
In general, because of different physiological properties and living environments, a climate signal sometimes exists in the tree ring that is likely not monthly climate but rather pentad climate. If the response of trees to monthly climate fails to meet the requirements of reconstruction, the pentad climate is a better selection criterion.

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Author Contributions

Conceived and designed the experiments: YL CFS.
Performed the experiments: CFS.
Analyzed the data: CFS.
Contributed reagents/materials/analysis tools: CFS YL.
Wrote the paper: CFS YL.

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