CLIMATIC RESPONSE FROM TREE-RING WIDTH OF POPULUS EUPHRATICA, ALTAI, CHINA.

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Abstract

Trees can give clear visions of what parameters influence in this or that period of its growth. Due to lack of the influencing of climatic variables on tree growth in this area, therefore we are faced with the task of what climatic factors affect growth in different periods of development, how different soil moisture layers are related to other parameters and its relationship with the tree. Tree-ring width chronology of *Populus euphratica* was investigated based on dendrochronological standards on the Irtysh river floodplain, Altai Prefecture at an altitude of 500 m a.s.l. and climatic factors influencing the tree-ring width were examined using a Pearson's correlation coefficients. Six parameters of monthly climatic data [mean temperature, total of precipitation, relative humidity, base flow, snow water equivalent and soil moisture <<for 3 vertical layers (0.1-2.5m)>>] were used for the analysis. Ring width related to precipitation and snow water equivalent from the end late growing season prior November until early growing is March, where the April temperature affects negatively, thereby increasing evaporation and including the effect of relative humidity. Soil moisture effected to tree-ring width from prior November to this June, while base flow influence current April-September. Such spectral high frequency cycles were identified at 16.3, 12.5, 8.1, 2.7, 2.6, 2.4 and 2.1-years, which suggest possible linkages with huge scale ocean-atmosphere-land circulation system and an influence of solar activity. Our results suggest that all the connection have possess time to impact, so *Populus euphratica* has a sufficient potential to shed light on climatic factor.

Keywords: Tree-ring; Altai; Soil moisture; *Poplar*; Irtysh River.

Introduction

Human activities are straightforwardly affecting stream water withdrawals for different purposes, in the last our work [1] we have compared growth situation of *Populus* and *Betula* trees, but in this study, we have focused just in *Populus euphratica* tree species and evaluated in detailed tree-ring chronology in the Altai Prefecture Irtysh River. We set ourselves the following goals: 1) to investigate the climatic response of tree *Populus euphratica* ring chronology; 2) detailed characteristic of growth situation in different stages of growing season; 3) how the soil layers get moisture and influence to the ring width and 4) what cyclones determine the climate in our research area based on the results of spectral analysis.

Materials and methods

Physical Settings

The second greatest waterway in Xinjiang is Irtysh River with a length of 633 kilometers, and with a territory of 52.73 million km^2, it likewise the river system which streams into the Arctic Ocean in China. It flows through Fuyun, Fuhai, Burqin, Habahe River and the 185th regiment recovery of the tenth agrarian division. The Irtysh floodplain is blended, in the upper course, it is snowy and cold, in the center and lower achieves, rain, ground, and snow, with the power of the last mentioned. Consequently, the most extreme high water levels in the Irtysh are seen amid the dissolving of snow. It streams to the southeast in the mountain region. Because of the impact of the sea and the encompassing mountains, it has run of the mill semi-bone-dry atmosphere qualities: dry atmosphere, less precipitation and large amounts of evaporation.

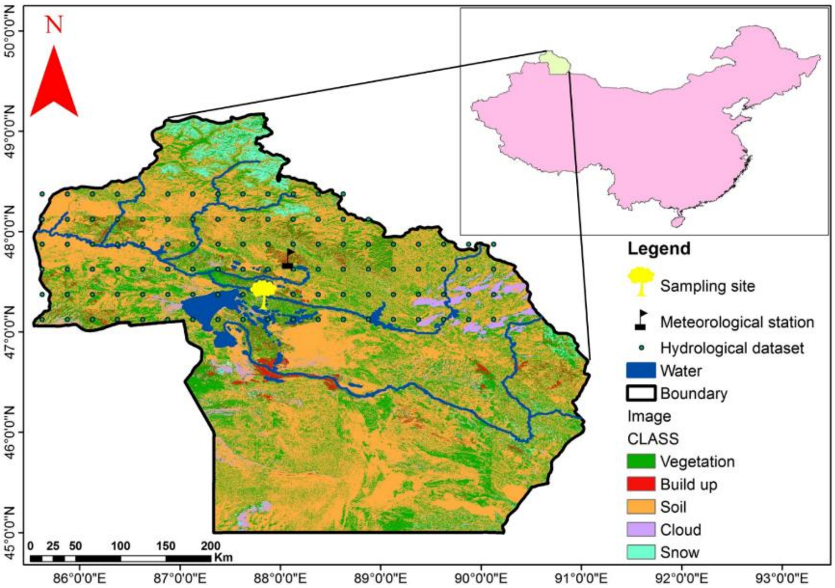

Fig 1. Location of study area in Altai Prefecture, China.

Climate data was acquired from the region of our examining destinations (Fig 2a). Altai has a frosty semi-arid atmosphere, without a solid monsoonal impact on regular precipitation designs that characterizes the atmosphere crosswise over quite a bit of China. Based on instrumental data from a station in Altai over the common period of 1957–2015 the total annual rainfall is 200 mm, and annual mean temperature is 4.5 °C. Winters are long, intensely cool and dry, with the coldest month in January of −16.1 °C; however, the presence of the Altai Mountains to the north helps moderate the severity of winter cold as compared to locations further to the east. Spring and autumn are short but mild. Summers are dry and with the highest mean temperature in July 21.9 °C.

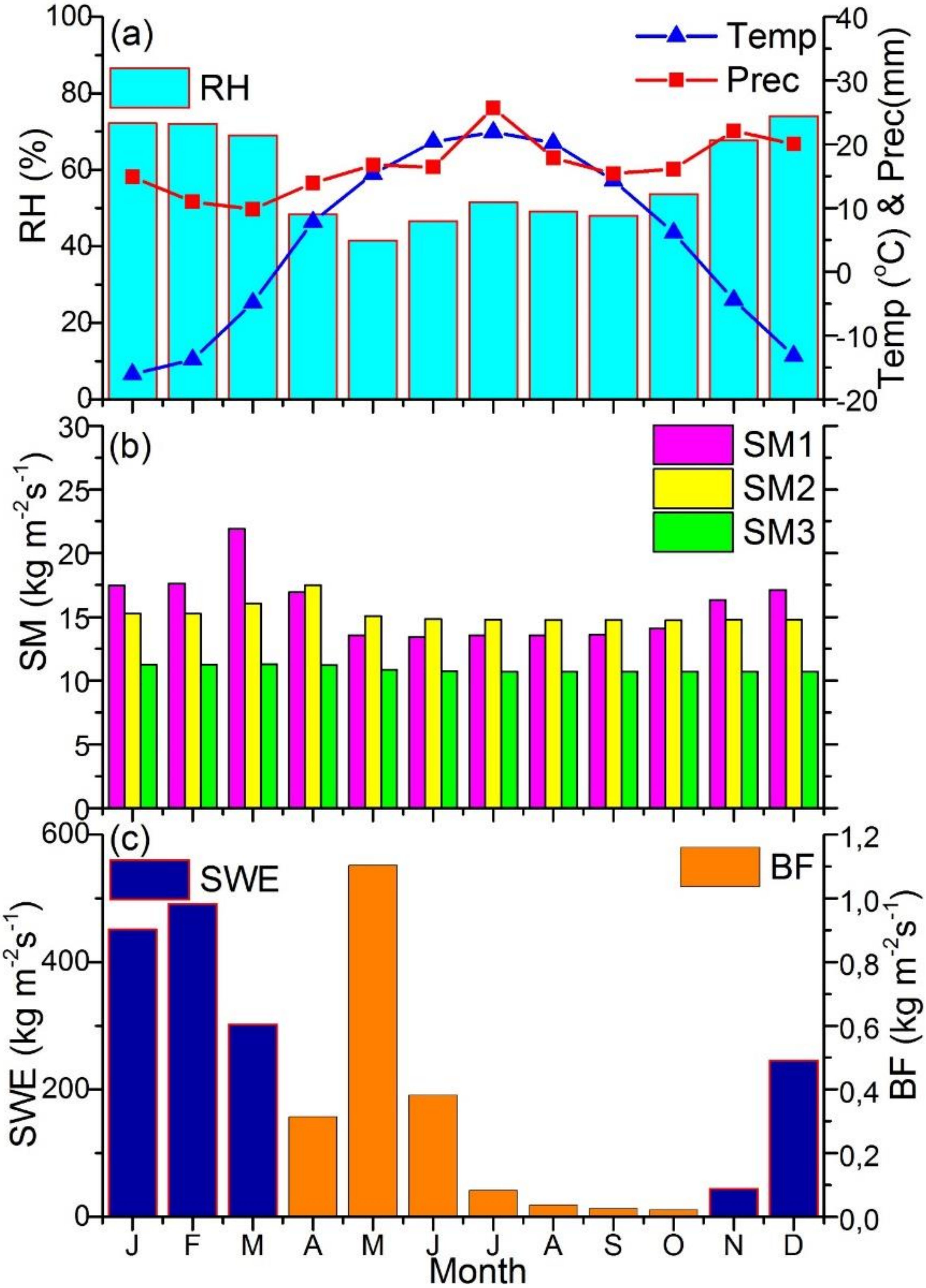

Figure 2. Climate diagram relative humidity (RH), temperature (Temp) and precipitation (Prec) from Altai meteorological stations (1954-2015 AD) and interpolated to our sampling site hydrologic dataset (1952-2012) 3 parameters: soil moisture (SM), snow water equivalent (SWE) and base flow (BF).

Study area and tree species

Xinjiang's wood assets are comprised of numerous types of *Poplar,* (Latin name: *Populus L.*) is a genus of *Populus*. The root system is very wide and powerful; trunk usually straight. It grows on superficial moist soils, and deep on less humid soils. Roots give rich root posterity, regularly at an incredible separation from the mother tree: up to 20 meters from the storage compartment. The fast growth of poplars proceeds to 40–60 years, after which it slows down. Some species live to 120–150 years, but usually, plants are affected early by various fungal diseases. In general, poplars live up to 60–80 years.

We chose *Populus* because it is the most common species in our study area and sampled at Beitun encoded site (BT) located in the Altai County (Fig 1). According to the International Tree-Ring Data Bank standard, one or two increment cores were taken from each tree. Beitun (BT) study area is located in the central part of Beitun city (47°22'N, 87°49'E, 495–520 m a.s.l.). The height of *Populus euphratica* trees ranged from 10 to 21 m depending on site conditions; the diameter ranged from 110 to 210 cm; alluvial (floodplain) soils predominate. Two cores per tree were extracted with an increment borer, and a total of 49 cores were taken from 25 trees.

Tree-ring analysis

In the research facility, the increment core samples were air–dried, mounted on a wooden mounts, ground and polished with sandpaper (400–1200 grit cm^{-2} for better–identified fall rings) until tree–ring boundaries were visible under a microscope The tree–ring width arrangement from two sites were cross-dated visually . Then ring width was measured to 0.001 mm accuracy with a LINTAB TM–6 tree ring analyzer (Germany) with TSAP–Win Professional software. Statistical cross–dating was performed with COFECHA program. The cross–dated tree-ring width were detrended and indexed using ARSTAN software [2]. To evaluate the reliability of the chronology the length in years of segment to examine 30 years lagged by 15 years were calculated: average growth rate (AGR), mean correlation (MC), mean sensitivity (MS), signal–to–noise ratio (SNR), standard deviation (SD), 1st –order autocorrelation, inter-series correlation (Rbar), the subsample signal strength (SSS) and the expressed population signal (EPS). The EPS decides how great an order built upon a limited number of trees approximates the theoretical population chronology and the SSS statistics were utilized to decide the base number of trees that ought to be used as a reliable estimate of the mean chronology [2].

Meteorological data and statistical analysis

Bootstrapped correlation functions between standard chronology and the climate data were computed by SPSS software. Meteorological data as temperature, precipitation, and relative humidity was used from Altai station spanned 1954-2015. Since the climate stations provide local signal, therefore our results showed lowest correlations with the tree–ring data than the gridded records, which represent more geographical representations. The hydrological dataset covers China (Fig 2b,c) with a 0.25° spatial resolution and a daily time step for 1952–2012 monthly soil moisture (SM) kg m^{-2} for 3 vertical layers within 2.5 m soil depth (i.e., 0.1m, the 2nd and 3rd layers vary within the range of 0.1-2.5m); snow water equivalent (SWE) kg m^{-2}; base flow (Q_{sb}) kg m^{-2} s^{-1} were obtained from the http://hydro.igsnrr.ac.cn/ [3] interpolated for the sampling site by using MATLAB .

To explain the characteristics of local climate variability in the frequency domain, we used Multi-taper (MTM) spectral analysis [4]. We use $2\times3\pi$ tapers and in a red noise background instead of $5\times3\pi$ tapers since the peaks were more significant and strong and the analysis was performed over the standard chronologies index.

Results

Width chronologies

Fig 3 shows the tree–ring width chronologies. A summary of the standardized chronologies is given in (Table 1).

Table 1.

Summary of statistics for standardized chronologies of Populus Euphratica.

	Chronology
	BT
No of trees (tree/core)	25/49
Chronology period	1941–2016
Length (year)	76
Mean (1/100) mm	467.4
Mean sensitivity	0.281
Standard deviation	0.222
AC1	– 0.201
MC[a]	0.56
MSL[b]	41.7
R[c]	0.422
PC#1[d]	47.85%
SNR[e]	7.3
EPS[f] [year (n)]	0.88 [1965 (6)]

[a]Mean correlation with master series. [b]Mean segment length.[c]All series Rbar. [d]Variance explained by the first principal component. [e]Signal–to–noise ratio. [f]Expressed population signal. [l] Subsample signal strength.

High mean correlation (0.56) with master series indicates good cross-matching between the sequences and shows the common signal between the series. In contrast, the chronology in BT has the lowest first-order autocorrelation (–0.201), indicating high levels of year–to year variation. The inter-annual measure variation of mean sensitivity (0.281), which suggests that the Poplars are slightly sensitive to environmental variability. The chronologies had high EPS (0.88), high SN (7.3) and high standard deviation (0.222) indicating that the radial growth of trees was responding to common factors and was suitable for dendroclimatic research. Variance explained by the 1st principal component accounted for 48% indicating that rather moderate common signals exist among trees.

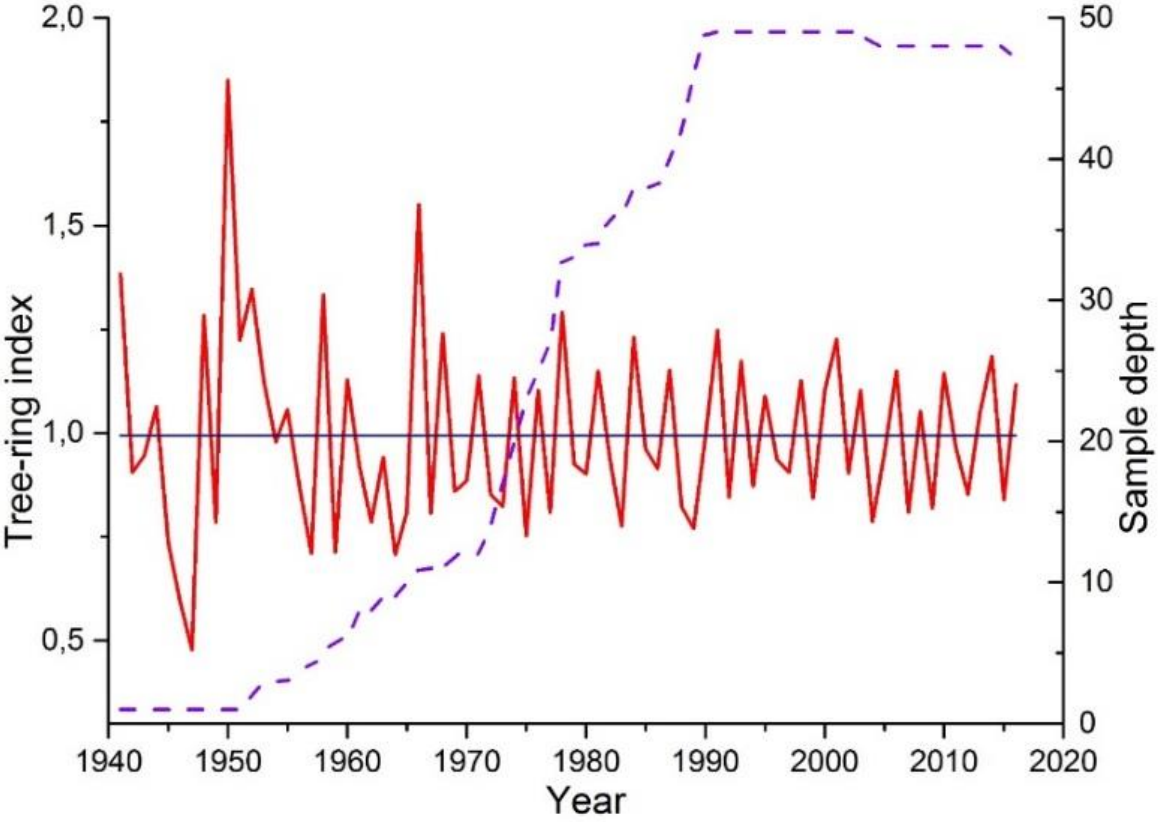

Figure 3. Standardized tree-ring-width chronology and sample depth of Populus Euphratica at the floodplain on Altai Prefecture in Xinjiang, China.

Response to climate

The chronology of the BT site correlates negatively with this April mean temperature (Fig 4a) of the current growing season; significantly positive correlated with this January–March (0.428 at $p<0.001$) precipitation and relative humidity confirm the negative correlation of this April mean temperature, so that's why is positive correlated (0.328 at $p<0.001$).

The results of correlation functions analysis showed that the summer precipitation had positive effects on tree growth, while mean temperature had a negative effect because high temperature will increase water evaporation and transpiration, thereby resulting in water loss in the trees. Based on the correlations mentioned above we believe that on the growth of *Populus euphratica* tree species in addition to the temperature, precipitation, and relative humidity, in this research area there are other climatic factors that also make their own positive or negative contribution to the development of the rings tree. Therefore, to investigate the climate tree–ring relationships, we screened the tree-ring chronologies in correlation analysis with the three layers of soil moisture, base flow and snow water equivalent of gridded data (Fig 4b). We found strong positive correlations between the BT site and soil moisture: 1stlayer from prior November to current May (0.475 at $p<0.001$); 2nd layer from January to May (0.386 at $p<0.001$); 3rd layer January–June (0.275 at $p<0.05$). Snow water equivalent also significantly correlated with the rings, since we have found positive influences with prior November to this March (0.335 at $p<0.001$). Strong positive correlation was found between tree-ring chronology and base flow from current April to September (0.335 at $p<0.001$).

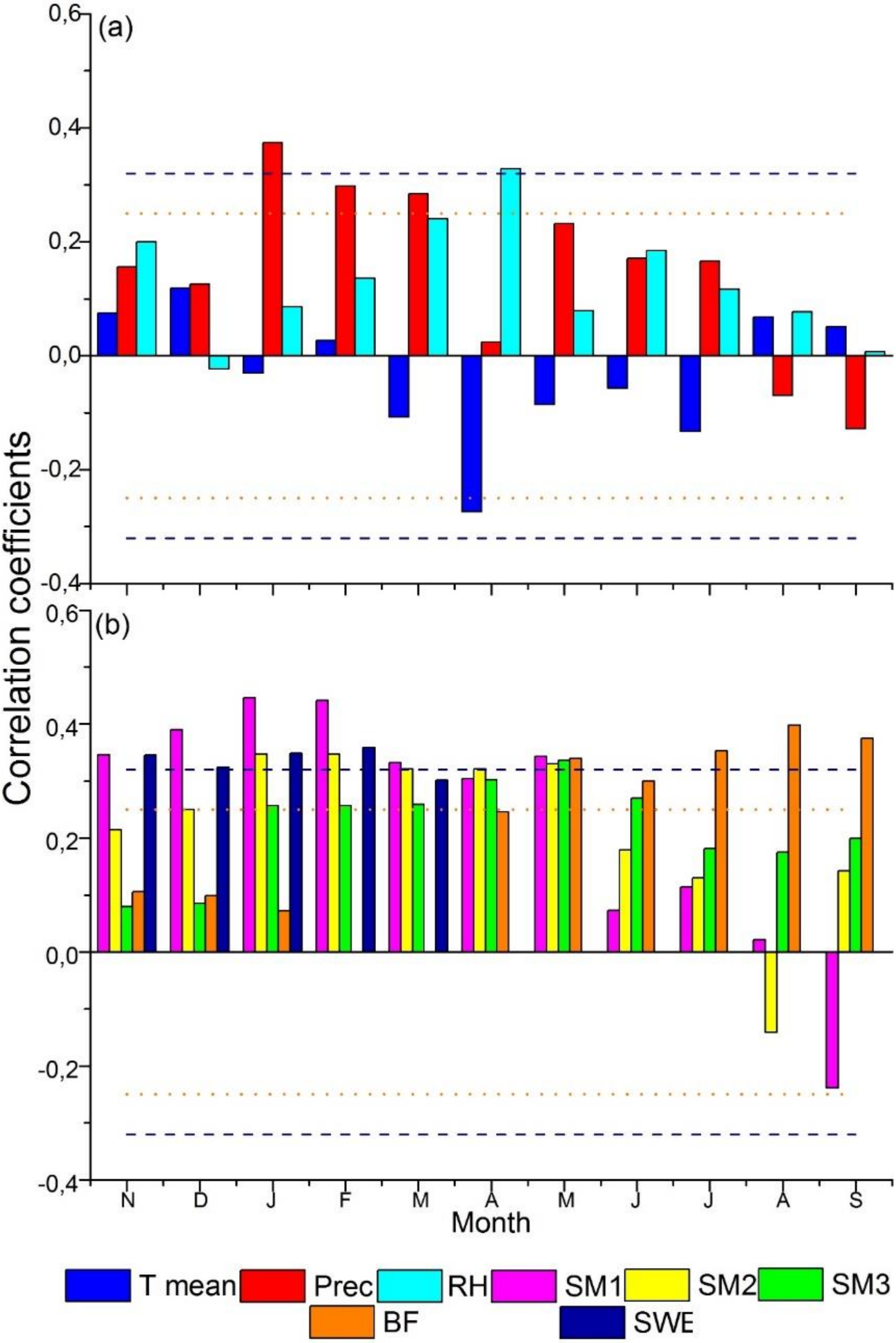

Figure 4. Correlation coefficients (bars) between tree-ring chronology and (a) climatic data (b) hydrological dataset. The horizontal dashed lines indicate the p<0.01 and dotted lines indicate the p<0.05 significance level for the correlation function.

Spectral analysis

To represent our results the geographical importance and to understand which climatic cyclones effect of our research area, we conducted a spectral analysis [4]. Significant high-frequency peaks as shown in (Fig 5) were found at 16.3-year (90%), 12.5-year (90%), 8.1-year (90%), 2.7-year (95%), 2.6-year (99%), 2.4-year (95%) and 2-year (99%). Our high-frequency of short-cycle 2-8-year could likewise be identified with the climatological, physiological or outside unpleasant two-year cycle and suggest possible connections with El Nino-Southern Oscillation (ENSO) [5] and tropospheric biennial oscillation (TBO) which related to the huge scale ocean-atmosphere-land circulation system. Decadal inter-annual (12.5 and 16.3-years) peaks were found during the "Little Ice Age" in the Changling Mountains [6] and in northern Tibet [7], which proposed that there existed dry spell variety notwithstanding happening at bring down temperatures and also an influence of solar activity [8].

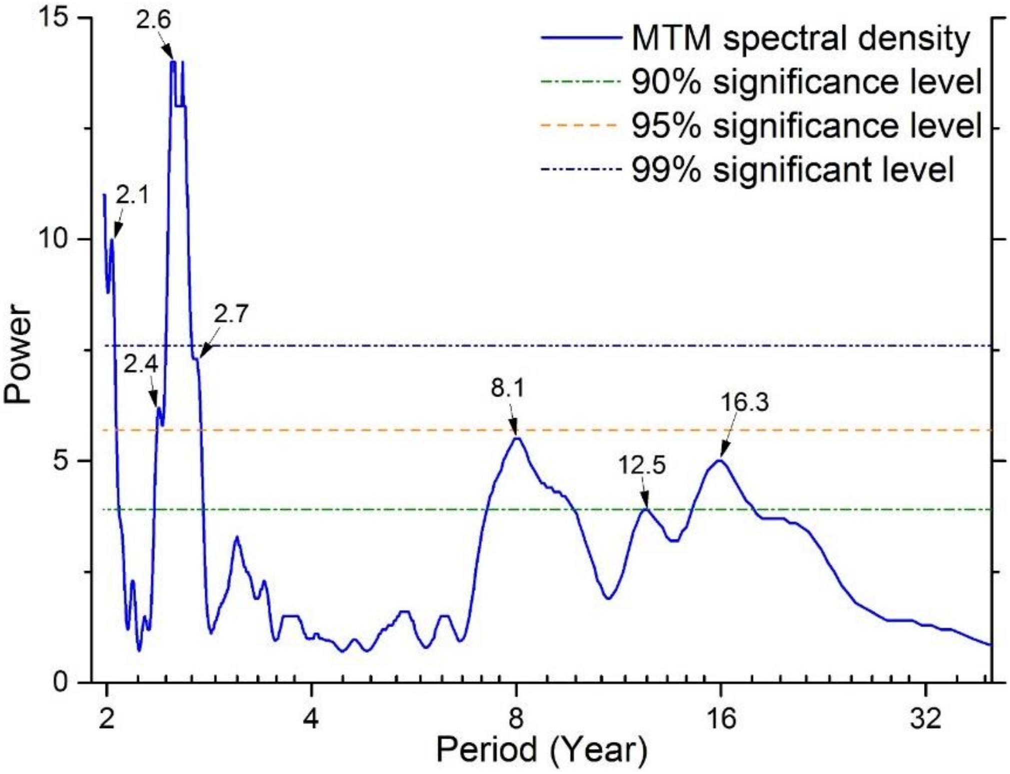

Figure 5. MTM spectral analysis results of standard chronology from Populus euphratica Irtysh river floodplain, Altai, China

Discussion

The strong positive correlation was found at the end of late growing period of prior year, November and December with snow water equivalent, which makes possible to retain moisture in the soil before the beginning of the growing season and to provide a large amount of moisture in the earliest period of photosynthesis . We believe that it is because of the snowpack in the previous November and December we have a significant correlation with the 1st layer of soil moisture. As we can observe in the (Fig 2a) precipitation increase in the November and December, while the temperature is below zero, therefore we can say with confidence that the precipitation at this time is in the form of snow and our results just confirm it.

The negative correlation was found between tree-ring width, and current April mean temperature, which means that at this time the growth of the tree is affected by another factor, in particular, the relative humidity. Along with this, after a long winter, the trees need heat and sun, for the process of photosynthesis, from which we can draw the first good portion of heat trees receives in April, where also a large evaporation begins, which leads to air humidification.

From (Fig 4) we can see that with the beginning of the temperature increase, the temperature in this region above zero is observed from March, and the correlation coefficient with the 1st layer of the soil decreases and increases with the deep layers. As shown in (Fig 2), the maximum temperature relates to the most extreme precipitation, and the minimum temperature to the minimum precipitation, which is to say, the higher temperature is in the growth season, the more intensive the soil evaporation and plant transpiration are. Moreover, this leads to worse conditions for tree growth, which has very little effect on the growth of trees, since it practically does not stay in the soils [9].

Gridded data of base flow data, which was obtained from [3] has been shown in the (Fig 2c), shows that mean base flow is more than 0.026 kg m^{-2} s^{-1} per month spanned from April till September. According to it, we have found strong correlations with the base flow in the current April-September, which suggest increasing moisture in the deepest layers of soil (Fig 4b). Base flow is one of the most important sources of river flow, which in turn depends on melting snow and glaciers in high mountains, as well as precipitation, temperature, and sunshine.

In addition to the role of soil moisture in the collaborations between the land surface and the atmosphere, soil moisture is a capacity of water amongst rainfall and evaporation that acts as a controller to one of the more fundamental hydrologic processes, infiltration and runoff creation from rainfall and which must be represented in any water and energy balances [10].

Fig 4b shows the positive correlation between ring width of *Populus Euphratica* and climatic conditions like snowpack in the prior November-December; current precipitation January-March; relative humidity and mean temperature this April; soil moisture with various layers and base flow from current April to September. Considering all the circumstances and taking into account the fact that the roots of *Poplars* are on the surface of the earth and contribute to the retention of water in the deep layers, as the roots of this kind of tree constantly need moisture, the roots simply pull out moisture and nutrients from anywhere, that is why so few other representatives of the plant kingdom grow around them. Our results suggest that growth of *Populus Euphratica* under control of set climate conditions.

Conclusion

Poplars were successfully cross-dated and dendrochronologically analyzed in Altai Prefecture. During the study, a different manifestation of the growth and development of these trees was studied, in which individual indices for the influence of external climatic influences. Precipitation and SWE positive influence from the beginning non-growing period from prior November to March, which can support preservation and maintenance on the earliest formation and photosynthetic production of the width of the rings. We believe, the correlation coefficients with soil moisture of surface layers decreases are related to mean temperature because it increases evaporation of soil moisture, and relative humidity confirms it. After we found positive correlations with the base flow, our doubts about the impact with the river flow have disappeared, and a response appeared to increase correlations with deep soil layers. Based on results of spectral analysis the study region is under influencing ENSO and TBO land ocean-atmosphere circulation system and an influencing of solar activity. The results show that *Populus euphratica* confirms that it is the best floodplain forest species.

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