 doi:10.20944/preprints201806.0312.v1

Tree-ring-based summer temperature minimum reconstruction for Taboshar, Sogd Province, Tajikistan, since AD 1840: linkages to the Oceans

Zulfiyor Bakhtiyorov[1,2], Ruide Yu[1,2,*], Akylai Monoldorova[1,3], Zhijie Ta[1,2], Javhar Aminov[3,4].

[1] State Key Laboratory of Environment Change in Arid Lands, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Chinese Academy of Sciences, 818 South Beijing Road, Urumqi 830011, Xinjiang, China.

[2] University of Chinese Academy of Sciences, 52 Sanlihe Road, Beijing 100864, China.

[3] State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Chinese Academy of Sciences, 818 South Beijing Road, Urumqi 830011, Xinjiang, China.

[4] State key Laboratory of Remote Sensing and GIS, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Chinese Academy of Sciences, 818 South Beijing Road, Urumqi 830011, Xinjiang, China.

*Corresponding Author: Yu Ruide, yuruide@sina.com

Abstract

Despite the ecological importance of forest tree species, our study was motivated by scarce data on dendrochronology studies limited to the northwestern part of Tajikistan due to lack of access to such a part of the country which is difficult to access. Current studies on Junipers in the northwestern part of Tajikistan identified that tree ring-based climate reconstruction is possible. Cores of *Juniperus Turkestanica* from Taboshar area, Sogd province were developed into 176-year tree-ring width chronology. In the current study a summer (June-September) minimum temperature reconstruction spanning AD 1840–2016 was developed, which can explain 30.0% of the instrumental variableness for the period of 1940–2015. Five warmest (1856-1866, 1869-1871, 1907-1916, 1923-1935, 1988-2016) and four coldest time periods (1840-1855, 1872-1906, 1917-1922, 1940-1984) were identified. The developed reconstruction coincides with cold and warm periods with prior investigations from tree-rings in China, Mongolia, Kyrgyzstan, Kazakhstan and Tajikistan. Spatial correlation analysis with the gridded minimum temperature data shows that the temperature reconstruction covers geographical representation over High Asia. Significant correlation was found between temperature reconstruction with summer SST, which suggests strong linkages of regional temperature variability with Indian-Ocean climate system. The obtained spectral peaks from the spectral analysis of the summer temperature reconstruction were significantly at 84.7-year (90%), 2.9-year (99%), 2.6-year (99%), 2.5-year (99%), 2.4-year (99%) and 2.2-year (99%).

Keywords:

Tree-ring width, *Juniperus Turkestanica*, Climate, Temperature minimum, Tajikistan Tian Shan

Introduction

The climatic information in tree-ring chronologies could give a view of the climate condition in the past and thus with the integration of the present climate condition information could help to predict the climate for the future [1]. The population history of many tree species in Europe and North America compared to other continents such as Central Asia is relatively well studied [2, 3]. Focusing on long-term climate changes in the world [4, 5], Central Asia [6] and Tajikistan with suggestions for a rise in a temperature based on a meteorological dataset were presented [7]. As it is mentioned [8], tree-rings are playing an important role in reconstructing past climates in the world.

The Tian Shan mountain system located in Central Asia and extends across five countries including Tajikistan [9]. In Tajikistan, there are a wide variety of climatic conditions associated with high-altitude zone, geography, orography, that is of great interest from the point of view of the study and modeling of climate change at the local and regional scale [10]. Tajikistan is highly vulnerable to global climate change. This is a fact that has been confirmed in recent donor reports [11]. The Qurama range of the Tian Shan mountains situating within Taboshar area is one of the driest regions in the Tian Shan. This range is also rich of Junipers forests[12-14]. Species of this plant family such as *Juniperus sibirica, J. turkestanica, J. seravschanica, J. semiglobosa,* and *J. schugnanica* are endemic to Tajikistan [15]. There are numerous studies on reconstructions temperature, precipitation, drought related by Juniper tree-ring width [16-27], but in Tajikistan, a few studies are conducted [28-31] and the areas in the Qurama range of northern Tajik Tian Shan mountains are extensively missing.

To fill this gap in the knowledge, we developed tree-ring width chronologies using cores of *J. turkestanica* from Taboshar, Sogd Province, northern Tajikistan. This is believed that the current study is going to be the first tree-ring based 1840-2016 reconstruction in the targeted study area. Moreover, the study found out cool and warm periods for north Sogd over the 176 years.

Materials and methods

Physical Settings

The mountains comprising Tajikistan belong to the giant mountain systems of Central Asia - Tian Shan and Pamir-Alay. The Tian Shan mountain system just partly covers the country including the Qurama Range (Tian Shan orogen) and cross Uzbekistan, Kyrgyzstan. Its length is about 170 km from North-West to South-East. The highest point is the Boboiob (In translation means "the father of waters or the grandfather of waters". From the Taj. Bobo - Grandfather and Tajik Ob – Water) which rises up to 3,769 m above sea level [32]. In this part of Tian Shan Mountains middle relief prevails. It is composed of metamorphic schists, sandstone and granitic rocks. At an altitude of 1800 m above sea level, there are coniferous-deciduous forests, *Juniper* forests, on the northern slopes of the walnut, alpine meadows and fescue steppes, and down the slopes there are steppes and xerophilous bushes [33].

Nonferrous metal in the Qurama Range Ridge is available for the big amount metal mines resources in this area that were founded in the early 1950's. The area under investigation lies in a mountainous valley with substantial varieties in both the occasional and day by day air

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 June 2018 doi:10.20944/preprints201806.0312.v1

temperature because of a mainland atmosphere with sweltering and dry summers and short, icy winters and described as parched mainland [34].

The targeted study area (TTT 40°37’ N/69°45’ E) is situated northeast of the town of Taboshar at an elevation rising from 1485 to 1585 m above sea level (als). (Figure 1). It is located in the northern part of Gafurov district in Sogd Province, Tajikistan with temperate climate zone [35-37]. Since in Taboshar the uranium mining industry was set up by USSR in the late 1940s and early 1950s as a part of the nuclear weapon program, the research area under investigation is probably impacted by remnants of nuclear weapons production. [38-41].

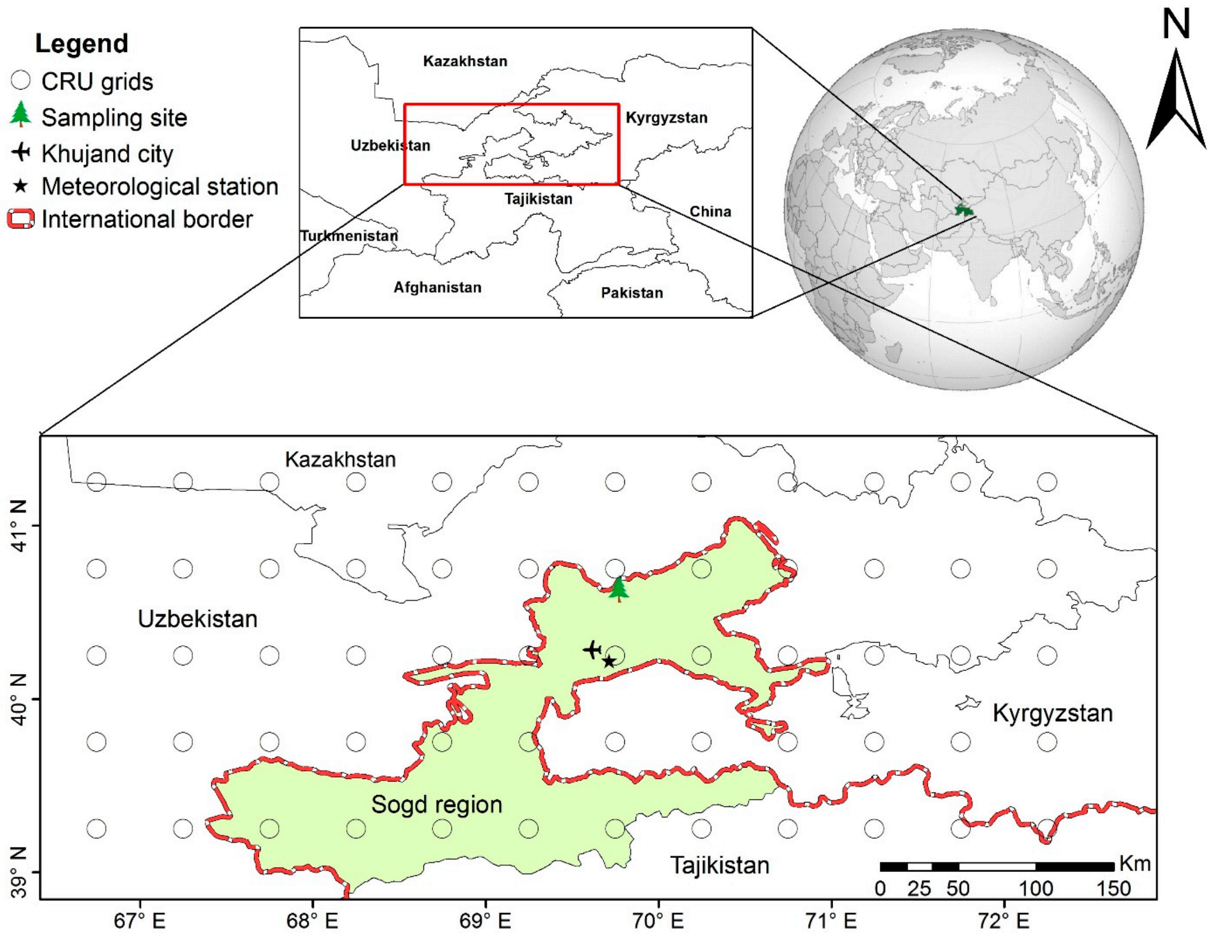

Figure 1. Location map of the sampled sites, meteorological station, CRU and city.

It can be seen that rainfall in this area decreases with rising temperature and is almost absent in the summer. Mean annual precipitation calculated during 1890-2016 is 165 mm in Khujand, with 73 mm in spring March-May period (Figure 2a). Highest temperature period is June-July with mean long-term calculations during 1932-2016 year is 35.1 ºC with highest mean air maximum temperature existent in July at 36.0ºC and coldest month is January with a mean air minimum temperature --3.1ºC (Figure 2b).

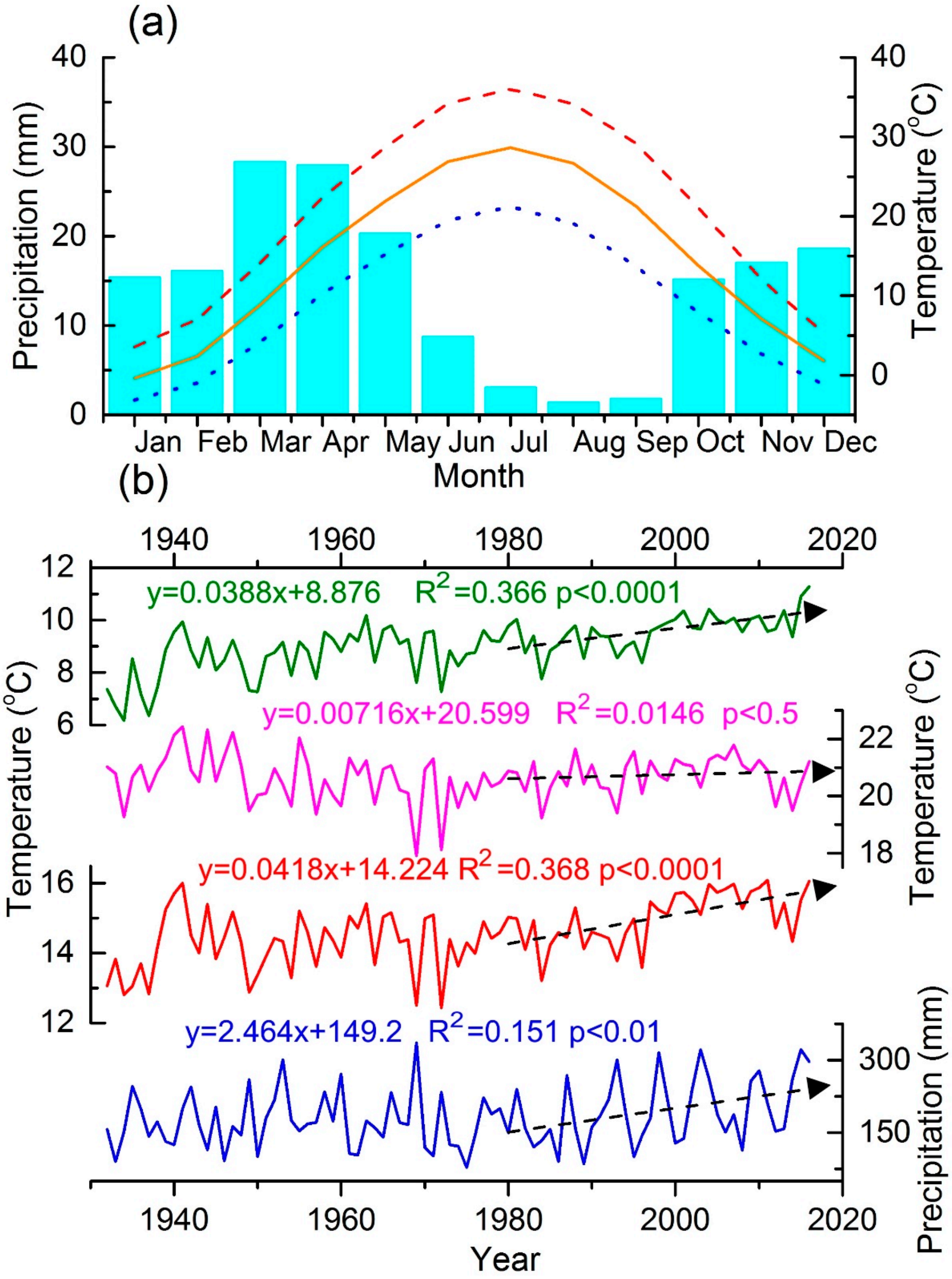

Figure 2. Climate diagrams of the Khujand station: a) total monthly precipitation (filled bar), temperatures maximum (red dash line), minimum (blue dotted line) and mean (orange line); b) the mean annual temperatures minimum (green line), maximum (pink line), mean (red line) and the total annual precipitation (blue line) for their common periods 1932-2016 (Table 1).

Juniperus turkestanica Komarov, var *J. pseudosabina* Fischer and Meyer C. A. (1842) as [42] report could be found throughout of Xinjiang, Mongolia, Kazakhstan, Kyrgyzstan, Tajikistan, Pakistan and Afganistan in various proportion. This range would include the Tian

Shan and Altai, Pamir and Tarbagatay Mountains [43]. In addition, photographer Vladimir Dinets adds: "Var. *J. turkestanica* and *J. semiglobosa* form extensive woodlands or even forests in some areas, from Transcaucasia to Xinjiang. They are logged to extinction for firewood in many areas, but under strict protection in others". Based upon his report, *J. turkestanica* can survive at a lower elevation and on drier sites than the other less adapted plants. As the author [44] emphasizes *Junipers* stands grow on the Qurama Range from 1300 m above sea level (als). Endemics occur at the ecotone zone at elevation of 1400–4000 m above sea level (als), mainly in *Juniper* forests [45]. *Junipers* occupy about 150 thousand ha. *Juniper* forests are good regulators of surface runoff preventing soils from erosion in mountains and valleys, as well as CO_2 sinks. *Junipers* can be as old as more than five centuries [10].

Sampling and data from ring growth

In October 2016, during conducted field investigation, 40 *Juniper* trees in the open stands in general were chosen for sampling (**Figure 1**b) and two cores were extracted from cross-slope sides of each tree. In general, at chest height but from some trees whose crown growth was too low to the ground it had to be taken at the height of 0.2-0.5 m using the 5-mm diameter increment borers. Minimizing non-climatic effects on radial growth, only trees with no harm or malady were extracted. The height of the sampled trees ranged from 7 to 12 m depending on site conditions and their diameter ranged from 92 to 320 cm. Since we found false rings connected with dating errors, missing rings and some wood anomalies we kept out the collected samples for further analysis from about 20 trees. However, the amount of sampling trees was 40.

Further, the collected samples were air dried, mounted on a wooden base and the cores were cut and polished with sandpaper (400-800 grit cm^{-2}) for the purpose of examination in laboratory. Before the cross-dating procedure, visual measurement of the samples was done and the tree-ring widths were pre-marked. This technique is proved to be very helpful for quickly finding the right ring on the sample and verification of correctness of recorded and measured rings [46]. The cores were cross-dated using standard dendrochronology methods [47]. Width measurements of rings were performed using LINTAB VI system with 0.01 mm accuracy. The individual sequences positions, correlation and decision were done with use of the TSAP-Win [48] and COFECHA software [49].

For detrending, indexing and standard chronology, the series produced using the ARSTAN software were chosen for further analysis. The exponential or linear regression curve was used to standardized ring-width [50]. A bi-weighted robust estimation was applied to remove the effects of endogenous stand disturbances. The reliability of chronology period was estimated in the 50-year window with a 25-year lag by threshold of expressed population signal (EPS≥0.85). [51].

Meteorological data and climate response analysis

To measure the effectiveness and guidance of linear relationships, we run Pearson Correlation produces a sample correlation coefficient between the climatic data and the ring chronology, for this, we used the SPSS program. Monthly mean/maximum/minimum temperature, total precipitation data were computed from daily records for the stations which vicinity of the sampling site and were obtained from the Hydrometeorological climate records station. We also used sources such as [52, 53], to complete breaks in the meteorological data (Table 1). To find a good correlation between tree-ring width chronology and climate data we use grid temperature dataset, included precipitation, temperature minimum/maximum/mean covering the period of 1940-2015 at grid point (38º75-41º75' N / 66º75'-72º25' E) and interpolated to our sampling site (Figure 1). Received from the Climatic Research Unit (CRU TS 4.00), East England, UK database, [54, 55], which was calculated by using an automated interface program developed in MATLAB [56]. Such kind of testing statistics were calculated to demonstrate the stability of our reconstruction, like Reduction of error (RE), coefficient of efficiency (CE) statistics, the Sign Test, the Durbin-Watson value and Pearson's correlation coefficient [47].

Table 1. Description of the meteorological station Khujand from the vicinity of the study area (40°13'N, 69°44'E, Altitude = 414 (m a.s.l.))

	Temperature			Precipitation
	Mean	Minimum	Maximum	
First year	1881	1932	1932	1891
Last year	2016	2016	2016	2016
Missing year	1918-1926	-	-	1918-1919 & 1922-1926
Duration	127	84	84	120

In order to show the geographical representation of the reconstructed summer temperature, a spatial correlations performance between reconstruction of temperature and the grid-based data set CRU TS 4.0 [57] for the period from 1940 to 2015 was done using the KNMI climate researcher web-page [58].

The spectral multitaper method was applied for analysis of reconstruction signal to detect characteristics of local climate variability in the frequency domain [59]. The analysis of reconstruction over the period of AD 1840-2016 was executed. Our analysis used 5×3π in a red noise background which provides more strong and significant signals.

Results

Tree-ring width chronologies and climatic signals

The mean sensitivity (0.495) show high correlation by 33.3% of variance, with significant standard deviation (0.335) that reflect good responses to the variation of climate [47]. Mean correlation with master series is 0.507 (Table 2). Reliable ring-width chronology spanning 1840-2016 was developed based on an EPS value ≥0.85 (Figure 3). The reason of why conditions may have very less effect a ring to be narrow (or wide) in one year on the growth of the following year we can understand from the value of first autocorrelation, which is negative value (-0.106). In general, our results on the variation of growth ring through time showed the same patterns as [60] noted: narrow one followed where broad with the width of growth rings showing periodicity; in the young ages width emerged narrow and became wider as trees grew older.

Table 2. Summary of statistics for tree-ring width chronologies of *J. turkestanica*.

Chronology	TTT
Period	1840-2016
No of trees (tree/core)	20/38
AGR (cm)	1.69
MC	0.507
Length (year)	176
MSL	101.8
R	0.353
MS	0.495
SD	0.335
SNR	4.91
AC1	-0.106
VFE (%)	33.3
EPS	0.831
PC#1 (%)	46
Year (EPS≥0.85, series≥5)	1861

**AGR average growth rate; MC mean correlation with master series; MSL mean segment length; R is the all-series Rbar; MS mean sensitivity; SD standard deviation; SNR signal-to-noise ratio; First order autocorrelation; EPS expressed population signal; PC#1 is the variance explained by the first principal component.*

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 June 2018 doi:10.20944/preprints201806.0312.v1

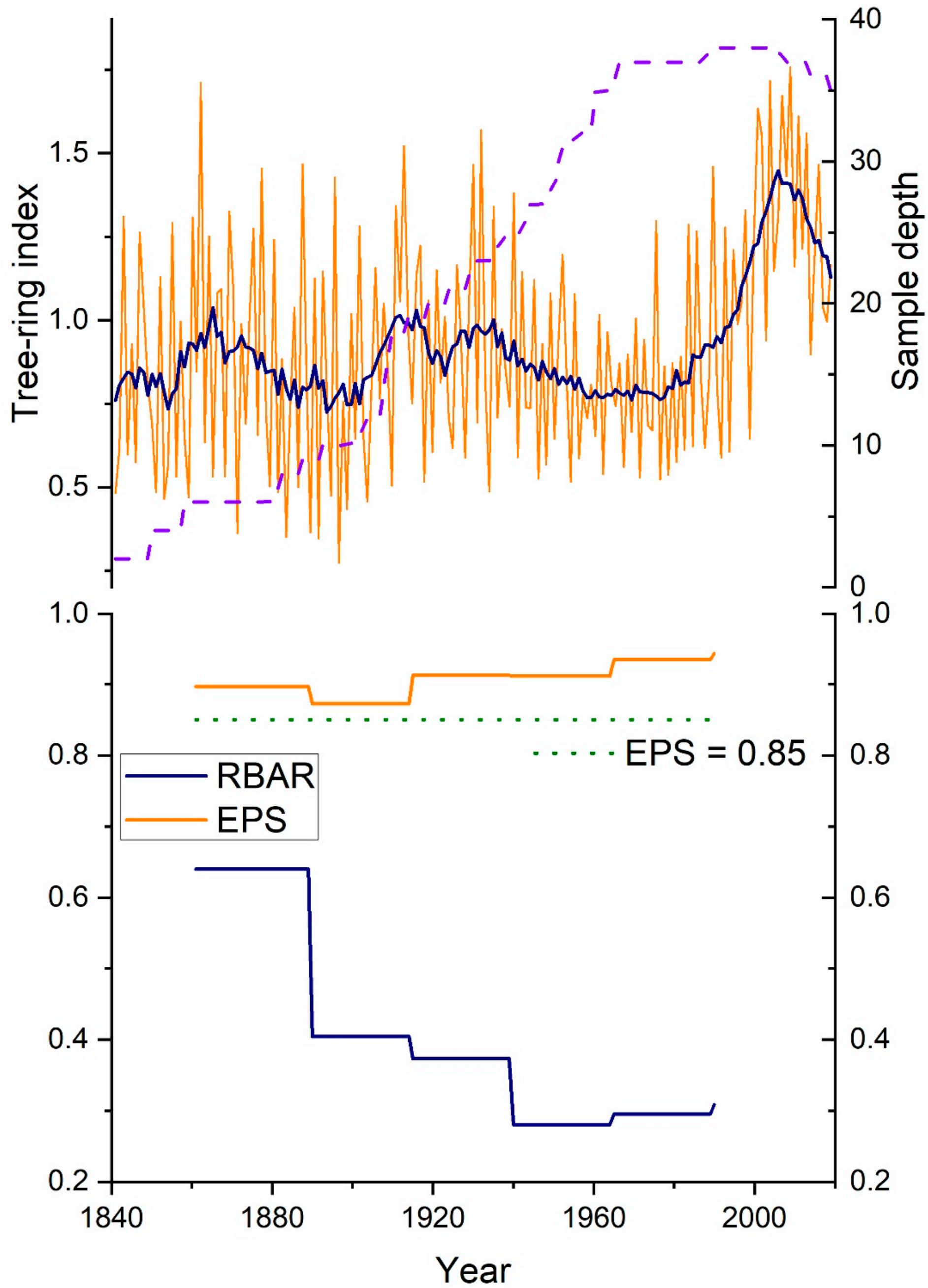

Figure 3. Plot of the standard chronology with 11-year simple smoothing, its running EPS, sample depth and Rbar.

Climate response analysis

Figure 4 describes the significant coefficients for correlation functions. Coefficient correlation between standard chronology and climate reveal significant $p<0.001$ in the gridded temperature minimum CRU grid from the prior June-November period as well as from current January-September period. With precipitation we find correlation ($p<0.05$) in the prior November-December period (Khujand station) or prior December and this February (CRU grid). Correlation positive between tree-ring and temperature maximum in the periods: prior August-

September current March, August-September (CRU grid). In addition, we have found positive significant correlation with temperature mean, which has been shown in Figure 4. We detected significant positive correlations (r=0.548, p<0.001) between radial growth and gridded temperature minimum dataset from current June to September, which indicate strong correlation and that is why we use it as the temperature reconstruction season.

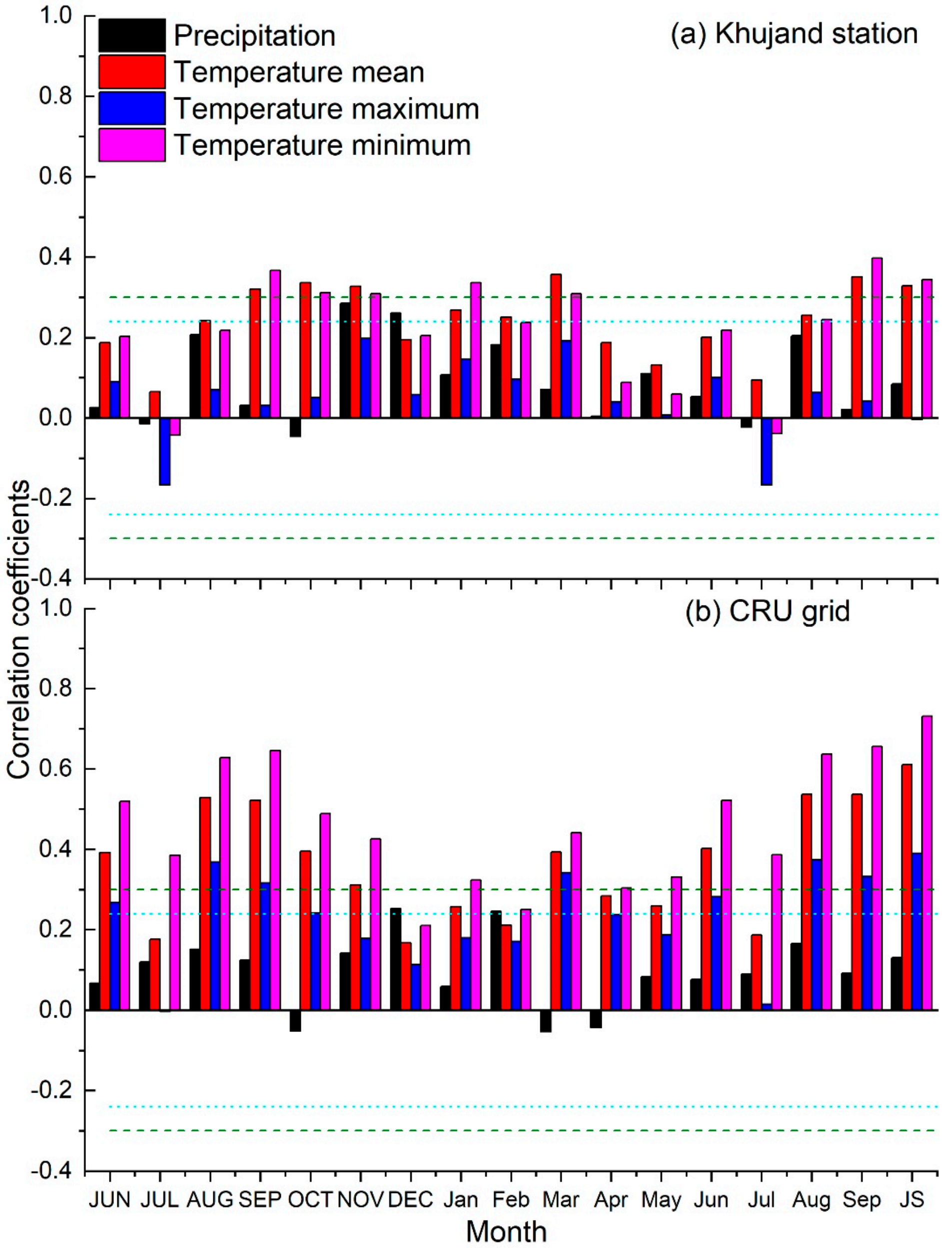

Figure 4. Correlation coefficients of tree-ring width chronologies of *Juniperus Turkestanica*. The horizontal lines indicate the p<0.01 and p<0.05 significance level.

Characteristics of summer temperature reconstruction

Based on the above correlation analysis results, minimum summer temperature (June-September) is the most suitable seasonal forecasting reconstructions. A linear regression model between standards chronology and minimum summer temperature (June-September) of original-summer reconstructed climate in verification period was (F=31.805, 95% confidence level, r=0.548):

$$Y=14.024\times X+1.191,$$

where Y is mean June-September minimum summer temperature and X is the standard chronology.

The comparison of the original-summer reconstructed minimum temperature has been shown in Figure 5a. The leave-one-out cross-validation statistics was also calculated and the results are shown in Table 3.

Table 3. Leave-one-out cross-validation statistics for reconstruction of summer (June-September) CRU minimum temperature reconstruction in the Taboshar

R	r^2	SD	RE/CE	PMT	ST	F	Durbin-Watson
0.548	0.300	0.616	0.271/0.271	5.299	$48^+/27^-$	31.805	1.007

Based on the respective tests RE and CE were positive, which demonstrate that the model has significant merit [1]. The reconstruction correlation coefficient with instrumental actual temperature variance during the time period of 1940-2015 was 0.548 ($p<0.001$) which is statistically significant. In general, the test results sufficiently confirm and demonstrate the validity of our regression model. The results of the sign-test show 95% significant confidence level, which describes how good the predicted value tracks the direction of actual data. Based on the linear regression model, summer (June-September) CRU minimum temperature in the study area has been summer reconstructed for the period 1840–2016 (Series>4, EPS≥0.85) [51].

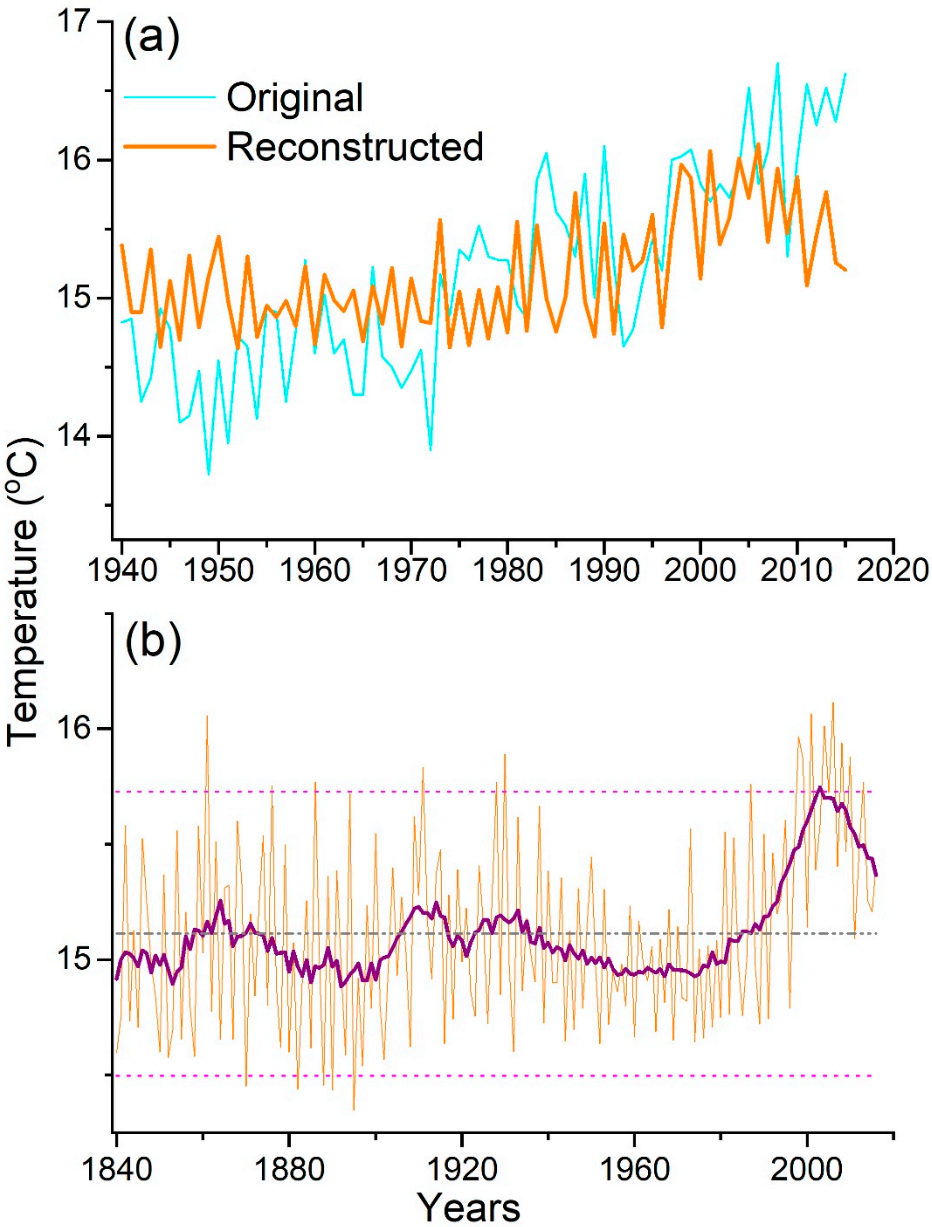

Figure 5. Comparisons of summer temperature reconstructed (June-September) a) with instrumental data for common period 1940–2015; b) 11-year simple smoothed (thick line) over the period 1840-2016. Central horizontal line show the mean reconstructed values; inner round point horizontal lines show the border of ±1SD.

Figure 5b shows the original and 11-year simple smoothing summer (June-September) CRU minimum temperature since AD 1840. The mean of summer (June-September) CRU minimum temperature over the time period of 1840-2016 is 15.11ºC. The most extremes years in the summer reconstruction were 1895 (14.35ºC) and 2006 (16.11ºC). As we know in recent times, increase in temperature can be observed, that leads to call it a global warming and our reconstruction confirms it. The values inside horizontal lines (±1 SD) indicate cool and warm years. The comparative analysis between reconstructions of the average summer (June-September) CRU minimum temperature for two periods: 1) 1840-1940 (15.07ºC) and 2) 1940-2016 (15.18ºC) shows that the second period is increased in 0.11ºC than the first period (Table 4). After 11-year simple smoothing, the temperature reconstruction showed four coldest periods (1840-1855, 1872-1906, 1917-1922, 1940-1984) and the coldest decades (1850s, 1860s, 1880s, 1890s, 1900s, 1910s, 1950s, 1960s, 1970s and 1980s) with temperatures lower than the mean. Five warmest periods (1856-1866, 1869-1871, 1907-1916, 1923-1935, 1988-2016) and warmest decades (1870s, 1920s, 1930s, 1940s, 2000s and 2010s) with temperatures higher than the mean (Table 4).

Table 4. Summary characteristics of unfiltered summer (June-September) CRU minimum temperature reconstruction

5 Most extreme years				5 Warmest and coldest decades				Long-term means	
Years	Coldest (ºC)	Years	Warmest (ºC)	Years	Coldest (ºC)	Years	Warmest (ºC)	Years	Values (ºC)
1895	14.35	2006	16.11	1890	14.90	2010	15.70	1840-1899	15.02
1882	14.44	2001	16.07	1900	14.95	2000	15.37	1900-1949	15.09
1890	14.44	1861	16.06	1970	14.94	1920	15.19	1950-1999	15.17
1888	14.45	2004	16.01	1980	14.94	1930	15.17	2000-2016	15.56
1870	14.46	1998	15.97	1960	14.96	1940	15.17	1840-2016	15.11

Further, in the current study a spectral analysis was implemented [59]. This analysis was performed over the time period AD 1840-2016 reconstruction summer (June-September) CRU minimum temperature. Figure 6 shows peaks low-frequency power, which were found at 84.7-year (at 99% level). High-frequency power peaks were found at 2.9-year (99%), 2.6-year (99%), 2.5-year (99%), 2.4-year (99%) and 2.2-year (99%).

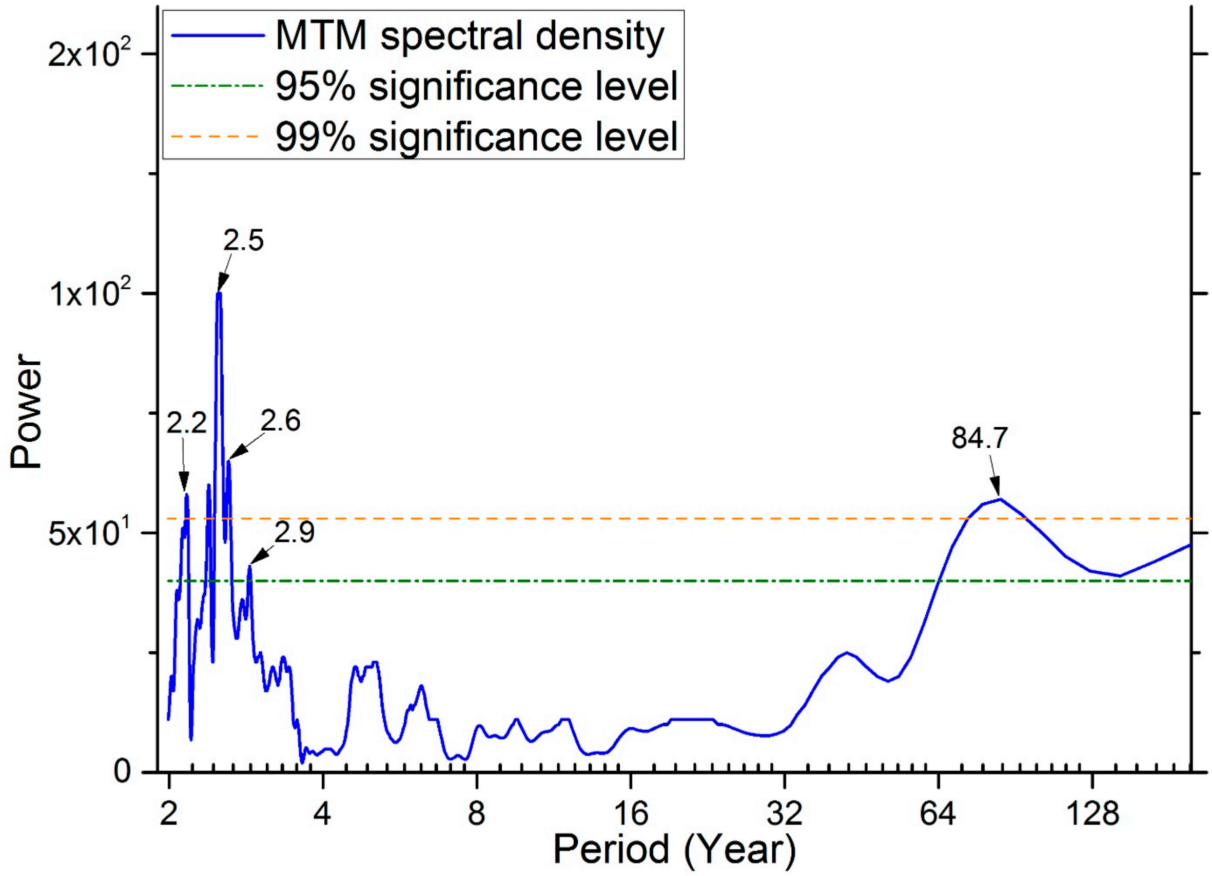

Figure 6. Results of MTM spectral analysis of the summer temperature reconstruction. The dash-dotted dashed and dotted lines indicate the 90 and 95% significance levels, respectively.

Discussion

Tree-ring growth and climate

We believe that a strong correlation between the tree-ring and the summer climate is probably related to the moisture limitation occurring in the middle of the current growth season. Although October-April is the most plentiful season of rain, we did not find any strong and significant correlations. The recorded precipitation value of Taboshar area is low and varying extremely. It was concluded [61] that in warm regions with low altitude and a large interannual change in precipitation leads to decrease in both temperature and soil moisture leading to a sharp growth of the tree during the heavy rainy season. Give such an explanation to the phenomenon, the climate and the field of study, which are close to ours, could not find its confirmation in the current study. This is possible, because we have not so thoroughly studied the cell and the development of cambium for individual periods of time.

From the results of this study, it can be concluded that optimal growth at the Taboshar site depends on cool summer months (i.e. July (**Figure 2**a) which are the hottest months in the year.

From the summer months, the most reiteration can be observed in July rather than June, August and September (**Figure 4**)) and even with the minimum temperature, the correlation with this month is lower. Based on our correlation, estimates is scarce with precipitation in both points of meteorological data. Correlation significant positive just in prior November-December (Khujand station) and prior December and this February (CRU grid) which determines drought area in this part of Tajikistan. We believe that the correlation is high in the winter due to precipitation in the form of snow, thereby retaining soil moisture, when a large amount of moisture is needed for photosynthesis at an early stages of the growing season as declare [62, 63] in the Karakorum, Pakistan and in the Western Tian Shan, China respectively. As it was mentioned earlier, in the Kongtong Mountains temperature takes significant role on drought stress cause it is demonstrated by higher correlation coefficients with temperature than precipitation [64].

Deficiency of water in the growing season inhibits the expansion of tracheids. Moreover, with the increasing temperature, evaporation increases in May-September due to low precipitation, which rev up water stress (**Figure 2**a). When the tracheids become narrower, the dimension of the cell wall in the yearly ring growths due to a reduction in the size of the lumen [65]. Our observations coincide with earlier studies that can explain the high value of early density in narrow rings (dry years) [61]. In fact, this connection reflects short and acute interactions (high frequency signals) between temperature and monsoon deposition. These determinations suggest that persistence of climate variations in radial growth has increased during the latter half of the 20th century due to global warming.

The comparison of regional records

Spatial correlations performed between the reconstruction and temperature minimum dataset of CRU TS 4.0 [57] reveal our record's geographical representation (Figure 7a). Significant positive correlations are found north of approximately 30º- 50º latitude with a 50º - 90º east-west extension. The highest positive correlation suggested that the study area is closely linked with synoptic processes of south Asian monsoon in the High Asia.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 June 2018 doi:10.20944/preprints201806.0312.v1

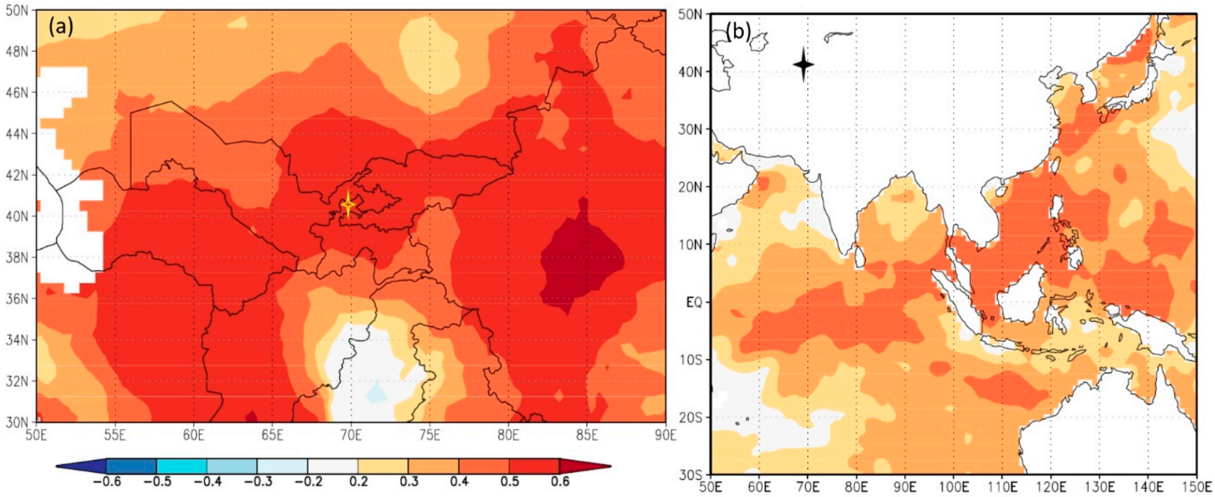

Figure 7. (a) Spatial correlation between the summer temperature reconstructed (June-September) in Taboshar with regional gridded 0.5° × 0.5° CRU TS 4.0 summer (June-September) temperatures for the period 1940–2015. The yellow and black star denote the tree ring site. (b) The summer temperature reconstructed with the gridded sea-surface temperature (SST) data set of HadISST1 over the period from 1940 to 2015.

Further, to investigate the common scale temperature signals with China, Mongolia, Kyrgyzstan and India, we used such source as was described [66]. Summer reconstructed May-June maximum temperature for the Shimen Mountains, Tianshui in the north central China (CSM) [61]. Authors of a study [67] presented the investigations of relationships between climate and tree-ring data on a global scale, from where we choose (study name: “asia_mong001B – Hovsgol Nuur – Breitenmoser Tree-Ring Chronology Data”) for our further comparisons (BMH). Another study [68] developed a long term for rapid warming over Central Asia (DMA). For more respectable visual comparison, all reconstructions have been rescaled to an average zero and 21-year simple smoothed to highlight climate signals in the low-frequency (Figure 8). All the correlation coefficients between our minimum temperature reconstruction and other proxy records are generally in lower agreement for the unfiltered data, but increasing coherence after 21-year low-pass filtering and significant at p>0.01 level, i.e. BMH=0.515; CSM=0.658; SCH=0.386; SCW=0.420; SCE=0.281; DMA=0.529.

In the current study, the temperature reconstruction of the Taboshar area indicates generally similar warm/cold periods to other proxy records. The cold temperature periods in AD 1840-1862, 1870-1907 and 1939-1986 as well as the warm temperature periods in AD 1863-1869, 1908-1938 and 1986-2016. The cold periods from our reconstruction were also reported by other various studies [28, 67-69] and confirmations for the warm period were obtained in several investigations [61, 70, 71] from the China Luya Mountains, Shimen Mountains (CSM) and Kyrgyzstan Tian Shan Mountains.

The tree-ring data from Tajikistan, Kyrgyzstan, Kazakhstan, Mongolia and China revealed the increase of temperature in the 20th century [18, 28, 61, 67-69, 71-74]. The study area under investigation, as we mentioned before belongs western Tian Shan and located in the central Asian mountain system, which is under the influence of the southwestern branch of the Siberia anticyclone circulation and cyclonic activity from the west.

The authors of the study [75], that have investigated the features of Tajikistan's past and future climate condition, concluded that the periods 1999-2002, 2008-2009 and 2011-2012 were drought and warm which was confirmed by the results of the current study. The authors of another study [76], show growing trend in yearly average standardized precipitation-evapotranspiration index (SPEI) with a meaning change in 1986 and after, was justified by the current work.

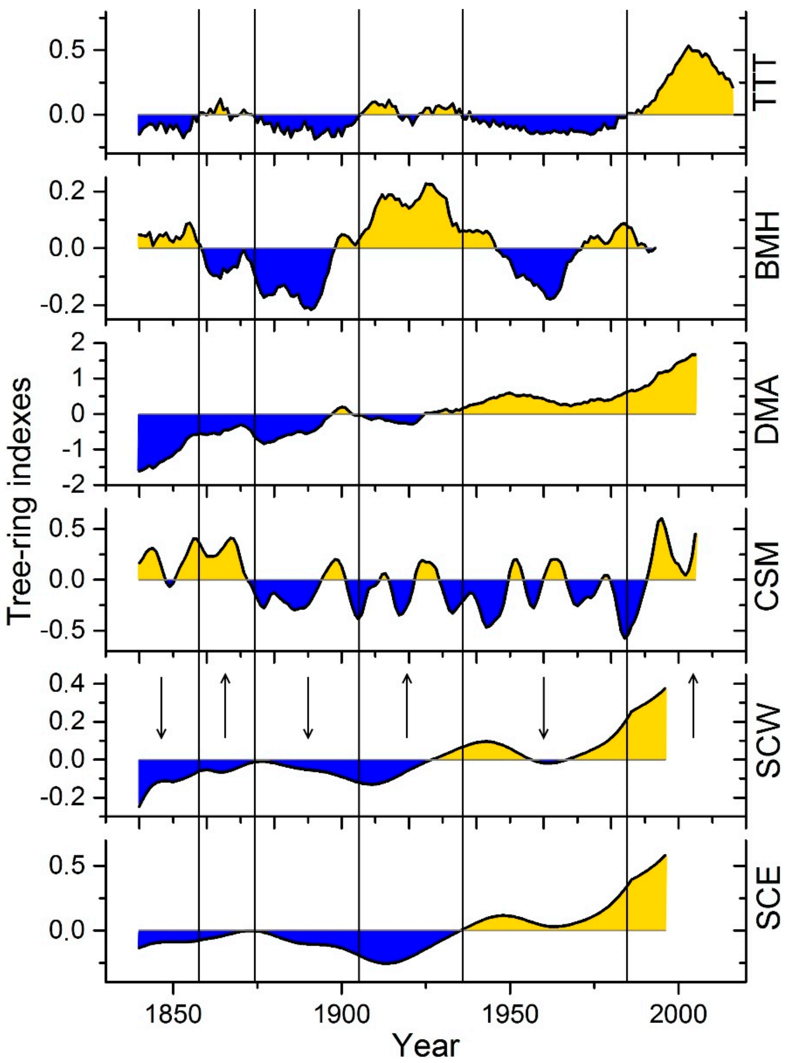

Figure 8. Comparisons between the summer temperature reconstructed of Taboshar and other proxy records after 21-year low-pass filtered (TTT = this study, CSM (Chen Shimen Mountains) = [61], BMH (Breitenmoser Mongolia Hovsgol) = [67], DMA (Davi Mongolia) = [68], SCH (Shi China), SCE (Shi China East), SCW = (Shi China West) = [69]

Linkages to the Ocean climate variability

Spatial correlation between our temperature reconstruction and the sea surface temperature (SST) gridded dataset of HadlSST1 [77] for the period 1940-2015 was conducted. The significant positive correlations of the summer temperature reconstructed related to the SST and show close connections between the temperature in the western Tian Shan Mountains and the remote ocean area. As it is shown in Figure 7b, the most significant area of correlation was found in the Indian Ocean [63, 78], suggesting that SST of this ocean is an important factor affecting the growth of *J. Turkestanica* in Taboshar. Indian Ocean is the moisture source to our study area which fall into the Indian Monsoon domain as reported by a study [79]. Cycles peak fall at 2—3-years in the scope of variability of the El Niño–Southern Oscillation (ENSO) [80, 81]. These low frequency cycles and multidecadal cycle 84.7-year fall inside the overall band-width of the winter North Atlantic Oscillation (NAO) [82] which may suggest influencing NAO on the Climate of Central Asia. However, the mechanism of influence of these circulation systems and how they control the temperature variability of Tajikistan at different times, awaits further study.

Conclusion

This study has presented the summer minimum temperature reconstructed (June-September) from *J. Turkestanica* chronologies. We believe that this is the first proxy record that indicate the possibility of reconstruction over 176 years and explanation the temperature over 19th – 20th century. The sensibility of latest tree-growth to temperature minimum in the Taboshar area was significantly diminished under the climate warming. This record can show different ways of look onto temperature variations, despite mountain terrain and spatial temperature differences. Geographical representation of the conducted reconstruction have been confirmed by spatial correlations. A comparison with various temperature-sensitive ring series in Central and East Asia show a high correlation in the timing of warm and cold periods, i.e. warm periods (1856-1866, 1869-1871, 1907-1916, 1923-1935, 1988-2016) and cold periods (1840-1855, 1872-1906, 1917-1922, 1940-1984). The correlation between our summer temperature reconstruction with summer SST suggest strong linkages of regional temperature variability with Indian-Ocean climate system. This is the first work in the studied area and we hope to continue the scientific investigations in this area, that would help us to better understand the change in the growth of juniper trees to conditions of World Global Warming and the past climate variability in Asia.

Acknowledgment

This study was supported by NSFC-UNEP (project No. 41361140361), Chinese Academy of Sciences (project No. 134111KYSB20160010) and High-level Talent Recruitment Program of Xinjiang Uygur Autonomous Region (Y642091). We thank Samuel B.D. Grace whose comments greatly benefitted this manuscript. The kind help of my colleagues during preliminary works and writing manuscript was highly appreciated. We also thank Abduvali Hamitov for provided data of Khujand station. Also, the author would like to sincerely thank the University of Chinese Academy of Science for the provision of scholarship. Furthermore, the author expresses deep gratitude to his family and all who at least somehow helped with the word or deed.

Author Contributions: Yu Ruide and Bakhtiyorov Zulfiyor designed the research; Bakhtiyorov Zulfiyor, Ta Zhijie, Monoldorova Akylai and Javhar Aminov processed the data. Bakhtiyorov Zulfiyor analyzed the results and wrote the manuscript. Yu Ruide, Ta Zhijie and Bakhtiyorov Zulfiyor provided the analysis tools and technical assistance. All authors contributed to the final version of the manuscript by proofreading and bringing in constructive ideas.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Fritts, H., *Tree rings and climate, 567 pp.* Academic, London, New-York, San-Francisco, 1976.
2. Petit, R.J., et al., *Glacial refugia: hotspots but not melting pots of genetic diversity.* science, 2003. **300**(5625): p. 1563-1565.
3. Soltis, D.E., et al., *Comparative phylogeography of unglaciated eastern North America.* Molecular ecology, 2006. **15**(14): p. 4261-4293.
4. Dai, A., K.E. Trenberth, and T. Qian, *A global dataset of Palmer Drought Severity Index for 1870–2002: relationship with soil moisture and effects of surface warming.* Journal of Hydrometeorology, 2004. **5**(6): p. 1117-1130.
5. IPCC, *Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC*. Vol. 4. 2007: Cambridge University Press.
6. Giese, E., et al., *Long-Term Analysis of Air Temperature Trends in Central Asia (Analyse langjähriger Zeitreihen der Lufttemperatur in Zentralasien).* Erdkunde, 2007: p. 186-202.
7. Makhmadaliev, B., et al., *The second national communication of the Republic of Tajikistan under the United Nations framework convention on climate change.* State Agency for Hydrometeorology, Dushanbe, 2008.
8. Jones, P.D., et al., *High-resolution palaeoclimatology of the last millennium: a review of current status and future prospects.* The Holocene, 2009. **19**(1): p. 3-49.
9. Burtman, V., *Tien Shan and High Asia: Tectonics and Geodynamics in the Paleozoic (Geos, Moscow, 2006)*, in *Google Scholar*, A.A. Mossakovsky, Editor. 2006.
10. Makhmadaliev, B., *First National Communication of the Republic of Tajikistan under the UN Framework Convention on Climate Change. 2002*. 2002: Dushanbe.
11. GB, O., *Joint Mission Report Pilot Program for Climate Resilience Tajikistan,*. 2009, The Centre for Climate Change and Disaster Reduction, Tajikistan.: The World Bank.
12. Kirchhoff, J. and A. Fabian, *Forestry sector analysis of the republic of Tajikistan.* Eschborn: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), 2010.

 doi:10.20944/preprints201806.0312.v1

13. Squires, V.R. and N. Safarov, *High-altitude ecosystems and Biodiversity of Tajikistan: Conservation and Management.* High-Altitude Rangelands and their Interfaces in the Hindu Kush Himalayas, 2010: p. 78.
14. Akhmadov, K., *Forest and forest products country profile: Tajikistan*. 2008: UN.
15. Squires, V.R. and N. Safarov, *Diversity of Plants and Animals in Mountain Ecosystems in Tajikistan.* Journal of Rangeland Science, 2013. **4**(1): p. 43-61.
16. Esper, J., et al., *Ranking of tree-ring based temperature reconstructions of the past millennium.* Quaternary Science Reviews, 2016. **145**: p. 134-151.
17. Chen, F., Y.-j. Yuan, and W.-s. Wei, *Climatic response of Picea crassifolia tree-ring parameters and precipitation reconstruction in the western Qilian Mountains, China.* Journal of Arid Environments, 2011. **75**(11): p. 1121-1128.
18. Chen, F., et al., *Tree ring-based winter temperature reconstruction for Changting, Fujian, subtropical region of Southeast China, since 1850: linkages to the Pacific Ocean.* Theoretical and Applied Climatology, 2012. **109**(1-2): p. 141-151.
19. Chen, F., et al., *Climatic signals in tree rings of Juniperus turkestanica in the Gulcha River Basin (Kyrgyzstan), reveals the recent wetting trend of high Asia.* Dendrobiology, 2015. **74**.
20. Briffa, K.R., *Annual climate variability in the Holocene: interpreting the message of ancient trees.* Quaternary Science Reviews, 2000. **19**(1): p. 87-105.
21. Liphschitz, N., Y. Waisel, and S. Lev-Yadun, *Dendrochronological investigations in Iran.* Tree-Ring Bulletin, 1979.
22. Esper, J., *Long-term tree-ring variations in Juniperus at the upper timber-line in the Karakorum (Pakistan).* The Holocene, 2000. **10**(2): p. 253-260.
23. Ahmed, M., et al., *Dendroclimatic and dendrohydrological response of two tree species from Gilgit valleys.* Pak J Botany, 2013. **45**: p. 987-992.
24. Zhu, H., et al., *Millennial temperature reconstruction based on tree-ring widths of Qilian juniper from Wulan, Qinghai Province, China.* Chinese Science Bulletin, 2008. **53**(24): p. 3914-3920.
25. Wils, T.H.G., et al., *Periodicity of growth rings in Juniperus procera from Ethiopia inferred from crossdating and radiocarbon dating.* Dendrochronologia, 2009. **27**(1): p. 45-58.
26. He, M., B. Yang, and N.M. Datsenko, *A six hundred-year annual minimum temperature history for the central Tibetan Plateau derived from tree-ring width series.* Climate dynamics, 2014. **43**(3-4): p. 641-655.
27. He, M., B. Yang, and A. Bräuning, *Tree growth–climate relationships of Juniperus tibetica along an altitudinal gradient on the southern Tibetan Plateau.* Trees, 2013. **27**(2): p. 429-439.
28. Opała, M., et al., *Towards improving the Central Asian dendrochronological network—New data from Tajikistan, Pamir-Alay.* Dendrochronologia, 2017. **41**: p. 10-23.
29. Mukhamedshin, K., *Dendrochronological scale of a tree form of Turkestan Juniper.* Dendrochronological Scales of the Soviet Union, Laboratory of Dendroclimatology. Institute of Botany, Academy of Sciences of the Lithuanian SSR, Kaunas, 1978: p. 113-115.
30. Chen, F., et al., *Comparison of drought signals in tree-ring width records of juniper trees from Central and West Asia during the last four centuries.* Arabian Journal of Geosciences, 2016. **9**(4): p. 1-10.

31. Maksimov, E. and A. Grebenyuk, *Variability of natural environment of high-altitude zone of Zeravshan Range for the last 800 years.* Izvestiya USSR Academy of Sciences Geographic series, 1972. **2**: p. 105.
32. HPH, *USSR Climate Handbook Wind*. Saint-Petersburg, Moscow, Russia: Hydrometeorological publishing house
33. TGSE, *The Great Soviet Encyclopedia*. 1969, The Soviet Encyclopedia: Moscow. p. 164.
34. Shukurov, N., et al., *Coupling geochemical, mineralogical and microbiological approaches to assess the health of contaminated soil around the Almalyk mining and smelter complex, Uzbekistan.* Science of the Total Environment, 2014. **476**: p. 447-459.
35. Narzikulov, I. and K. Stanjukovich, *Atlas Tajikskoi SSR.* Akademia Nauk Tajikskoi SSR, Dushanbe-Moskva, 1968.
36. Nowak, A., et al., *Vegetation of screes of the montane and colline zones in the Pamir-Alai Mts in Tajikistan (Middle Asia).* Tüxenia, 2015. **36**: p. 223-248.
37. Campelo, F., et al., *Vessel features of Quercus ilex L. growing under Mediterranean climate have a better climatic signal than tree-ring width.* Trees, 2010. **24**(3): p. 463-470.
38. Salbu, B., et al., *Legacy of uranium mining activitites in central Asia–contamination, impact and risks*, in *UMB report*. 2011.
39. Skipperud, L., et al., *Po-210 and Pb-210 in water and fish from Taboshar uranium mining Pit Lake, Tajikistan.* Journal of environmental radioactivity, 2013. **123**: p. 82-89.
40. Silwal, N.S., *Assessment of radon and gamma in Taboshar mining site, Tajikistan*. 2012, Norwegian University of Life Sciences, Ås.
41. Abraham, M., et al., *Geoecological investigation and environmental impact assessment of mining complexes in Kyrgyzstan.* Final Report of the Czech Ministry of Environmental Protection for the Republic of Kyrgyzstan, 2007.
42. Adams, R.P. and Y. Turuspekov, *Taxonomic reassessment of some Central Asian and Himalayan scale-leaved taxa of Juniperus (Cupressaceae) supported by random amplification of polymorphic DNA.* Taxon, 1998: p. 75-83.
43. Vidaković, M., *Conifers: morphology and variation*. 1991: Grafičko Zavod Hrvatske.
44. Davlatov, S.K. and E. Baikova, *Altitudinal limits of Berberis L. in Tajikistan.* Contemporary Problems of Ecology, 2011. **4**(2): p. 164-166.
45. Rahmonov, O., et al., *The consequences of vegetation degradation under the influence of anthropogenic activity in the territory of the Zarafshan Range (Western Tajikistan).* Geography and Natural Resources, 2014. **35**(2): p. 193-197.
46. Stokes, M. and T. Smiley, *An introduction to tree-ring dating. University of Chicago, Chicago, Reprinted 1996*. 1968: University of Arizona Press, Tucson.
47. Cook, E.R. and L.A. Kairiukstis, *Methods of dendrochronology*. 1990, Kluwer, Dordrecht.
48. Rinn, F., *TSAP-Win: time series analysis and presentation for dendrochronology and related applications.* Frank Rinn, Heidelberg, Germany, 2003.
49. Holmes, R.L., *Computer-assisted quality control in tree-ring dating and measurement.* Tree-ring bulletin, 1983. **43**(1): p. 69-78.

50. Cook, E. and P. Krusic, *A tree-ring standardization program based on detrending and autoregressive time series modeling, with interactive graphics (ARSTAN).* Tree-Ring Laboratory, Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY, 2008.
51. Wigley, T.M., K.R. Briffa, and P.D. Jones, *On the average value of correlated time series, with applications in dendroclimatology and hydrometeorology.* Journal of climate and Applied Meteorology, 1984. **23**(2): p. 201-213.
52. Williams, M. and V. Konovalov, *Central Asia temperature and precipitation data, 1879–2003.* Boulder, Colorado: USA National Snow and Ice Data Center, 2008.
53. Bulygina, O.N., et al., *An array of average monthly air temperature data at Russian stations*. 2014, Obninsk: VNIIGMI-WDC. .
54. Harris, I., et al., *Updated high‐resolution grids of monthly climatic observations–the CRU TS3. 10 Dataset.* International Journal of Climatology, 2014. **34**(3): p. 623-642.
55. CRU. *Climatic Research Unit* CRU TS 4.00]. Available from: http://www.cru.uea.ac.uk.
56. Palmer, W., *Meteorological drought. Research Paper Number 45. US Department of Commerce.* Weather Bureau, Washington, DC, USA, 1965.
57. Mitchell, T.D. and P.D. Jones, *An improved method of constructing a database of monthly climate observations and associated high‐resolution grids.* International journal of climatology, 2005. **25**(6): p. 693-712.
58. KNMI. Available from: http://www.knmi.nl.
59. Mann, M.E. and J.M. Lees, *Robust estimation of background noise and signal detection in climatic time series.* Climatic change, 1996. **33**(3): p. 409-445.
60. Susatya, A. and Y. YANSEN, *Dendrochronology of young Swietenia macrophylla and the variation of its growth response to the past wet climate in Bengkulu, Indonesia.* Biodiversitas, 2016. **17**(2).
61. Chen, F. and Y. Yuan, *May–June maximum temperature reconstruction from mean earlywood density in north central China and its linkages to the summer monsoon activities.* PloS one, 2014. **9**(9): p. e107501.
62. Treydte, K., et al., *The climatic signal in oxygen isotopes of junipers at the lower timberline in the Karakorum, Pakistan.* Tree Rings Archaeol, 2004. **2**: p. 100-106.
63. Chen, F., et al., *A 426-year drought history for Western Tian Shan, Central Asia, inferred from tree rings and linkages to the North Atlantic and Indo–West Pacific Oceans.* The Holocene, 2013. **23**(8): p. 1095-1104.
64. Fang, K., et al., *Tree-ring based reconstruction of drought variability (1615–2009) in the Kongtong Mountain area, northern China.* Global and Planetary Change, 2012. **80**: p. 190-197.
65. Pant, G., et al., *Climatic response of Cedrus deodara tree-ring parameters from two sites in the western Himalaya.* Canadian Journal of Forest Research, 2000. **30**(7): p. 1127-1135.
66. ITRDB, *International Tree-Ring Data Bank*. 2015.
67. Breitenmoser, P., S. Brönnimann, and D. Frank, *Forward modelling of tree-ring width and comparison with a global network of tree-ring chronologies.* Climate of the Past, 2014. **10**(2): p. 437-449.
68. Davi, N.K., et al., *A long-term context (931–2005 CE) for rapid warming over Central Asia.* Quaternary Science Reviews, 2015. **121**: p. 89-97.

69. Shi, F., B. Yang, and L. Von Gunten, *Preliminary multiproxy surface air temperature field reconstruction for China over the past millennium.* Science China. Earth Sciences, 2012. **55**(12): p. 2058.
70. Yi, L., et al., *Reconstructions of annual summer precipitation and temperature in north-central China since 1470 AD based on drought/flood index and tree-ring records.* Climatic Change, 2012. **110**(1): p. 469-498.
71. Ahmed, M., et al., *Continental-scale temperature variability during the past two millennia.* Nature Geoscience, 2013. **6**(5): p. 339.
72. Chen, F., et al., *Temperature reconstruction from tree-ring maximum latewood density of Qinghai spruce in middle Hexi Corridor, China.* Theoretical and Applied Climatology, 2012. **107**(3-4): p. 633-643.
73. Chen, F., et al., *Reconstructed temperature for Yong'an, Fujian, Southeast China: linkages to the Pacific Ocean climate variability.* Global and Planetary Change, 2012. **86**: p. 11-19.
74. Chen, F., et al., *Tree ring density ‐based summer temperature reconstruction for Zajsan Lake area, East Kazakhstan.* International Journal of Climatology, 2012. **32**(7): p. 1089-1097.
75. Juha Aalto, et al., *Features of Tajikistan's past and future climate.* INTERNATIONAL JOURNAL OF CLIMATOLOGY, 2017.
76. Tao, H., et al., *Drought and wetness variability in the Tarim River Basin and connection to large-scale atmospheric circulation.* International Journal of Climatology, 2014. **34**(8): p. 2678-2684.
77. Rayner, N., et al., *Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century.* J. Geophys. Res, 2003. **108**(D14): p. 4407.
78. Chen, F., et al., *Tree ‐ring ‐based annual precipitation reconstruction for the Hexi Corridor, NW China: consequences for climate history on and beyond the mid ‐latitude Asian continent.* Boreas, 2013. **42**(4): p. 1008-1021.
79. Li, J. and Q. Zeng, *A unified monsoon index.* Geophysical Research Letters, 2002. **29**(8).
80. Allan, R., J. Lindesay, and D. Parker, *El Niño southern oscillation & climatic variability*. 1996: CSIRO publishing.
81. Liu, N., et al., *A tree-ring based reconstruction of summer relative humidity variability in eastern Mongolian Plateau and its associations with the Pacific and Indian Oceans.* Palaeogeography, Palaeoclimatology, Palaeoecology, 2015. **438**: p. 113-123.
82. Glueck, M.F. and C.W. Stockton, *Reconstruction of the North Atlantic oscillation, 1429–1983.* International Journal of climatology, 2001. **21**(12): p. 1453-1465.