Journal of Earth Science & Climatic Change

Zulfiyor et al., J Earth Sci Clim Change 2017, 8:12
DOI: 10.4172/2157-7617.1000432

Research Article Open Access

Reconstructed Precipitation for the Eastern Tian Shan (China), based on *Picea Shrenkiana* Tree-Ring Width

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Received: Oct 12, 2017; **Accepted:** Dec 12, 2017; **Published:** Dec 16, 2017

Abstract

Our recent study introduces the reconstruction of May-June precipitation based on *Picea Shrenkiana* tree-ring growth, spanned AD 1892-2015. We used three monthly climatic gridded data parameters of China which covers with a 0.25° spatial resolution over 1952-2012 (temperature mean (°C), total precipitation (kg m^{-2} s^{-1}) and total snow-water equivalent (kg m^{-2})) interpolated to our sampling site for highlight correlations coefficients. Snow-water equivalent with ring-width gives us a significant positive correlation (approximately in p<0.05 level) in April-May period (0.411) and September (0.263). With precipitation, correlation is higher in May-June period (0.468) which leads us that limiting factor in this area is water, which is felt during the initial growth of the tree. Results of negative correlation in March-October period (-0.478) with mean temperature, suggest that increase of temperature leads to increase of evaporation and water transpiration. Our reconstruction indicated 6 dry decades (1920, 1930, 1970, 1980, 2000, 2010) and five wet decades (1910, 1940, 1950, 1960, 1990). Our reconstruction confirms to global change, which suggest decreasing precipitation from 1991 until now. To represent our reconstruction geographical meaning, we conducted spatial correlation between our May-June precipitation reconstruction, instrumental gridded interpolated May-June precipitation and gridded CRU TS 4.0 May-June precipitation, which significant in Xinjiang Tian Shan Mountains and goes through Mongolia, Kazakhstan, Kyrgyzstan and Tajikistan. In addition, we are running Multi-taper spectral analysis and after getting results try to connect our study to ENSO variability, with high-frequency cycles 6.1-year (99%), 5.1-4.8-year (90%), 2.7-2.9-years (90%).

Keywords: Tree-ring; *Picea shrenkiana;* Reconstruction; Tian Shan

Introduction

Dendroclimatology in Tian Shan Mountains has been studied on the characterization of the growth and development of trees, reconstructions of the past millennia for that or region [1-6]. There are numerous papers has shown that the growth of trees is controlled by a set of climate conditions, for example [7] reconstructed spring precipitation in Western Nepal Himalaya since AD 1840. [8] reconstructed from maximum tree-ring latewood density a 382-year August mean minimum temperature for southeastern Tibetan Plateau (China). Growing season relative humidity variations and possible impacts on Hulunbuir grassland observed these authors [9,10] for central Inner Mongolia (China) reconstructed PDSI based on tree-ring-width. Stream flow reconstruction of the upper Fenhe River basin in the North China, since 1799 made by sun [11]. Regeneration and protection desert Riparian Populus euphratica Forest in Arid Areas is represented by our colleagues [12]. Multi-millennial reconstruction of a 1436-year soil moisture and vegetation water use history based on tree-ring width from Qilian junipers in northeastern Qaidam Basin (China) has been shown in this work [13]. Another reconstruction from Western Himalaya (India) of heat index derived from Pinus roxburghii tree-ring growth presented by Ram and Borgaonkar [14]. To give clearly description of climate of past could be use a several parameters of tree-ring, include width, density, cell, radioactive, stable isotope ratios and others [15].

The *Picea schrenkiana* or Schrenk spruce (Fisch. et Mey) is a unique tree species in Tian Shan Mountains, which is very convenient for dendroclimatological analysis and gives very good results, which has already been confirm by [16-21], since this we choose Picea Shrenkiana to further investigation and developing tree-ring chronologies in Tacheng Prefecture, Shawan County, Xinjiang Autonomous Region, China. This study explains some driest and wettest period during 1892-2015, and also important because it confirms with other proxy records of other regions of Tian Shan Mountains, spatial correlation and spectral analysis.

Materials and Methods

Characteristics of the study area

The Tian Shan Mountains one of the largest mountain ranges in the world located in Central Asia. The eastern portion of Tian Shan Mountains in western China's Xinjiang Region was listed as a World Heritage Site where also situated our sampling site. Xinjiang Tianshan presents exceptional physical geographic highlights and grandly delightful ranges including fabulous snow and cold mountains ice

Citation: Zulfiyor B, Ruide Y, Meilin Y, Akylai M, Javhar A (2017) Reconstructed Precipitation for the Eastern Tian Shan (China), based on *Picea Shrenkiana* Tree-Ring Width. J Earth Sci Clim Change 8: 432. doi:10.4172/2157-7617.1000432

sheet topped pinnacles, undisturbed woods and knolls, clear streams and lakes and red bed gorge. These scenes stand out from the tremendous adjoining desert scenes, making a striking visual difference amongst hot and icy conditions, dry and wet, devastate and rich. The landforms and environments of the site have been safeguarded since the Pliocene age and present a remarkable case of progressing organic and biological transformative procedures [22].

The east gate of the Tacheng Prefecture is Shawan County area of 13.900 km^2, located in the middle of the northern foot of the Tian Shan Mountains in Xinjiang. Shawan County is a continental temperate arid climate with an average temperature of 6.3°C to 6.9°C. The total number of suns is 2800 hours to 2870 hours, ≥10°C accumulated temperature 3400°C to 3600°C, frost-free period 170 to 190 days. Annual precipitation of 140 mm to 350 mm, annual evaporation of 1500 mm to 2000 mm. The sampling site was >>50 km from Shawan County Figure 1, but from the human living area (e.g. Kalaba Sitaocun and Akeje Yekecun) closer to about 10 km and may be subject to human interference is relatively large, because this piece of forest grazing. Climate conditions in this area are almost completely different for example; a mean temperature is 1.4°C and annual precipitation 645 mm (Figure 2).

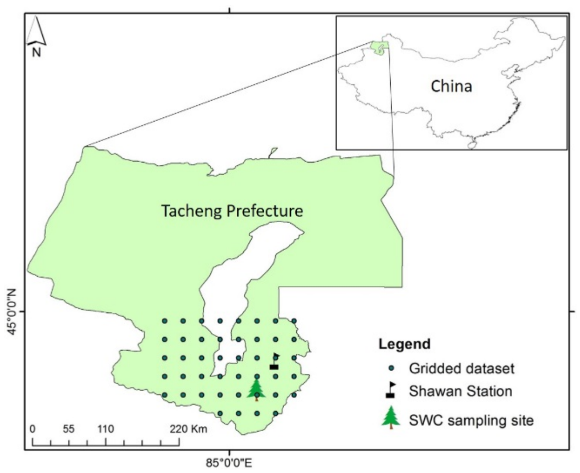

Figure 1: Location map of the sampled site, Shawan meteorological station and the gridded dataset.

Picea schrenkiana is high trees growth up to 60 m tall, diameter of trunks can be reach up to 2 m has a dull-brown bark, which is densely flaky; its crown is cylindrical or narrowly pyramidal. Can be grown on N-facing slopes, cool ravines in the altitude 1200-3500m, could be find in Xinjiang, Kazakhstan and Kyrgyzstan. The timber is used for construction, aircraft, machines, poles, and wood pulp, and tannin is extracted from the bark. The species is also cultivated for afforestation and as an ornamental. In the towering depths of the Tian Shan Mountains, it is vigorous tall and straight, four seasons green, climbing, full of endless, like a green building along the mountains and built the Great Wall. The wind, snow, sound, waves are almost all kept by these majestic trees. Tian Shan Mountains Snow pines, is said to be more than 4000 years ago, migrated from the Qinghai-Tibet Plateau, evolved into the northwest unique and the most spectacular trees [23].

Collection samples and data from tree-ring width

In August 2015, from Shawan County from 4 points covered 43°56'-58'N, 85°20'-22'E, 1650-1800m a.s.l., of Tacheng Prefecture the samples from Snow Spruce (Picea schrenkiana), totally 64 from 32 trees was collected, since the distance between points was >>10 km we codded as SWC and merge into one place, (Figure 1). Shawan County collection sites, may be relatively large interference by human factors, because this piece of forest grazing. The diameter of Picea Shrenkiana tree ranged from 60 to 150 cm depending on site conditions. Generally sampling were at breast height (1.3 m) and 2-3 cores were extracted with advantageously borax age using 5 mm diameter increment borers, (Sweden) from various directions for further dendrochronological dating. To limit non-climatic impacts on tree growth, just trees with no damage and malady were inspected.

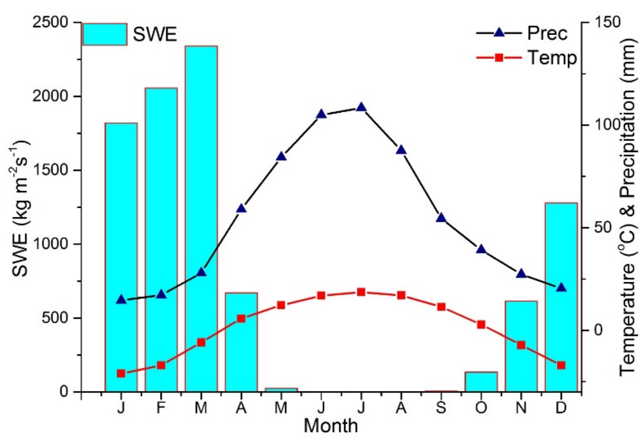

Figure 2: Climate diagram interpolated to sampling site from gridded dataset (1952-2012).

After arrived at the tree-ring laboratory, samples were clearly air-dried, polished, mounted and cross-dated according to standard International Tree Ring Data Bank [24] procedures. To measure growth characteristics was applied a measurement system LINTAB VI (0.001 mm), and in order to identify outliers and false rings is very convenient program TSAP-Win Scientific 4.8 [25]. To assess a measurement accuracy and detect "outlier" ring we used COFECHA software [26]. To apply a robust estimation of the mean value function to remove effect of endogenous stand disturbances and produce residual chronology series we run ARSTAN program [27]. Reliable of estimation of the tree-ring chronology, were calculated such kind of parameters as inter-series correlation (RBAR), expressed population signal (EPS) and signal-to-noise ratio (SNR; [28]) over 50 years lagged by 25 years.

Statistical data

To measure the strength and direction of linear relationships, we are running the bivariate Pearson Correlation produces a sample correlation coefficient between the climatic data and the ring chronology, for this, we used the SPSS program. Meteorological data were monthly parameters such as temperature mean (°C), total precipitation (kgm^{-2}s^{-1}) and total snow-water equivalent (SWE) (kg m^{-2}) data, were interpolated to our sampling site, by using MATLAB [29], from developing a consistent and comprehensive land surface dataset of China which covers with a 0.25° spatial resolution and a daily time step for 1952–2012 obtained from [30] (Figure 1). We use such kind of data because our sampling site was far from nearest meteorological data and cannot provide good signals, so interpolated data gives more regional connections.

To analyses climate statistically data and find El Niño–Southern Oscillation (ENSO) tele-connections we run a spatial correlation in the KNMI Climate Explorer web application [31], between our reconstructed precipitation May-June and the grid-data precipitation CRU TS 4.0 [32] for the period 1952-2015 (over 30-60°N, 60-120°E). To analyze short, noisy time series and calculating spectral estimates and closely link with local and geographical representations, we used multi taper method (MTM) of spectral analysis [33] and produce it in 5×3π tapers and in a red noise background.

Results and Discussion

Ring chronology and climate response

Statistical cross-dating and residual chronology produced by COFECHA and ARSTAN has been shown in Table 1. Average Pearson's correlation (within 99%) were high 0.689, the same as mean sensitivity (0.568), standard deviation (0.447) and variance of eigenvalue by 46%, which has significant reflect to the variation of climate [27]. Tree-ring width chronology spanned 1888-2015 AD (Figure 3) and show high EPS (0.927) and SNR (12.784), it is possible to characterize the close links with environmental information. Since our first-order autocorrelation (AC1) is negative (-0.113) which can implies that the following year have great effect on the growth by the conditions in prior year rings [34].

Chronology	SWC
No of trees (tree/core)	32/64
Chronology period	1888-2015
Length (year)	128
AGR (cm)	0.167
R	0.169
MC	0.689
MS	0.568
SD	0.447
AC1	-0.113
SNR	12.784
VFE	0.46
EPS	0.927
Year (EPS>0.85, series>6)	1940
MSL	71.8

*AGR average growth rate; R is the all-series Rbar; MC mean correlation with master series; MS mean sensitivity; SD standard deviation; AC1 first autocorrelation; SNR signal-to-noise ratio; VFE Variance explained by the first principal component; EPS expressed population signal; MSL mean segment length;

Table 1: Statistical cross-dating for the residual chronology.

Figure 4 depicts the simple correlation coefficients for the 1952-2012 period between residual chronology and gridded dataset. As it happens usually at such kind of regions and the same type of trees in this case with Picea Shrenkiana, the results of analysis related that growth of rings mainly response to summer precipitation May-June (0.468 at p<0.001). Negative correlation coefficient with mean temperature was significant with March (-0.307, at p<0.01), May-July (-0.454, at p<0.001) and October (-0.253, at p<0.05). In addition, we evaluated also positive correlations with SWE in April-May (0.411, at p<0.001) and September (0.263, at p<0.05).

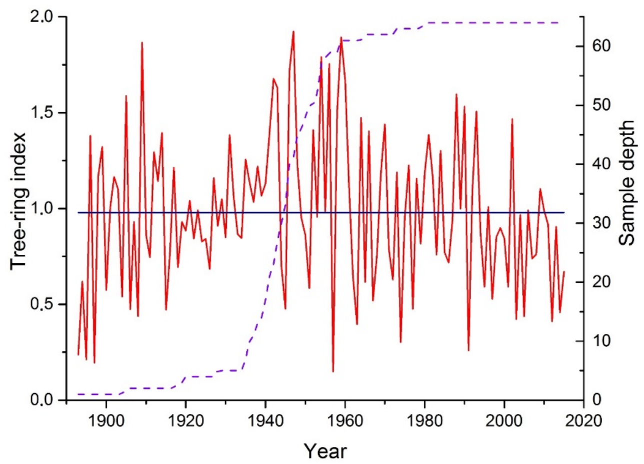

Figure 3: Tree-ring width of residual chronology from 1888 to 2015 AD, with changing sample depth over time.

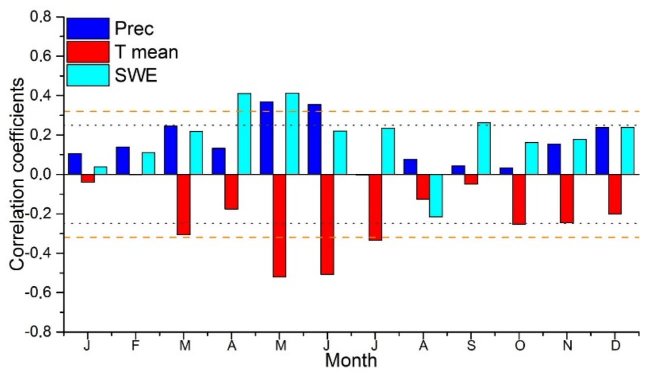

Figure 4: Correlation coefficients of the residual chronology of the Tacheng County with the monthly sum of precipitation, monthly sum of snow-water equivalent and monthly mean temperature (1952-2012). The dotted (p<0.05) and dashed (p<0.001) lines indicate significant variables.

Characteristics of summer precipitation reconstruction

Basing on the above climate responses, May-June precipitation was selected to reconstruct using the regression analysis [27]. A linear regression model for the 1952-2012 calibration period (Figure 5) was strong (F=16.51, p<0.05, r=0.468). We have presented reconstruction of May-June precipitation and 7-year simple smoother moving average for Tacheng Prefecture Shawan County (Figure 6).

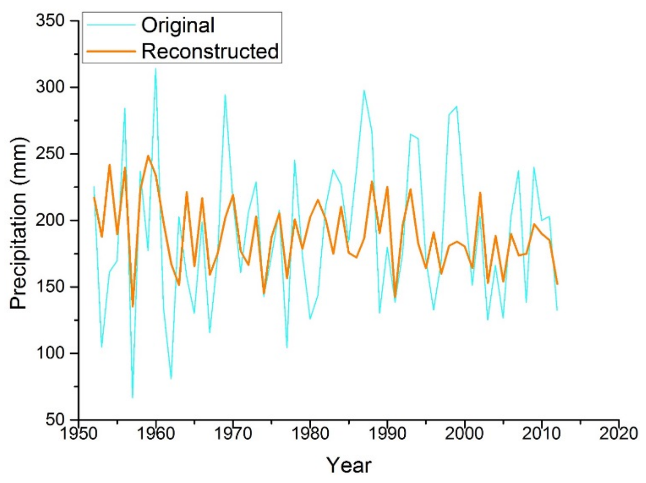

Figure 5: Comparison between original and reconstructed May-June precipitation over 1952-2012.

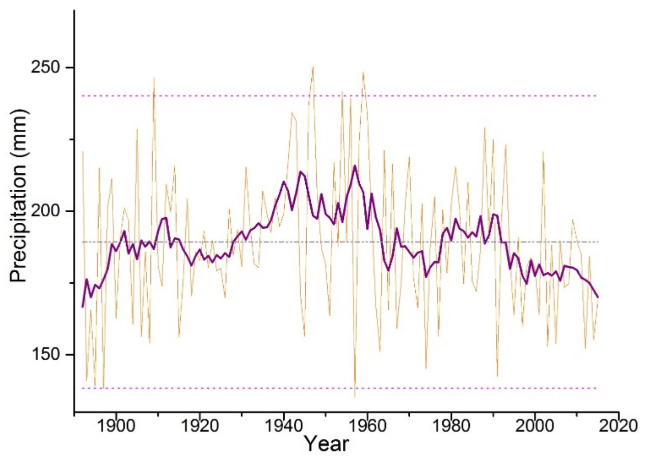

Figure 6: Reconstruction of May-June precipitation and 7-year simple smoother moving average. Central horizontal line shows the mean of the estimated values, dotted line show the border of ±1 SD.

The model obtained was:

Y=64.849×X+125.695

where Y is total May-June precipitation and X is the residual chronology.

R	r^2	SD	RE/CE	PMT	ST	F	Durbin-Watson
0.468	0.219	50.9	0.163/0.163	2.84	39+/21-	16.51	1.682

Table 2: Results of regression model statistics.

Statistical parameters (Table 2) such as the reduction of error (RE) and coefficient of efficiency (CE), the sign test (ST), the product mean test (PMT), regression Equation test (F) and the Pearson's correlation coefficient was used for reliability of the reconstruction models [27,34].

The mean value of total May-June precipitation over the 1952-2012 period is around 189.3 mm and SD is 50.9. Based on Akkemik [35] the inner horizontal lines (±1 SD) indicate dry and wet years, dry periods with below average precipitation were found in AD 1892-1898, 1916-1927, 1964-1967, 1969-1977 and 1994-2015. These periods AD 1910-1913, 1929-1963, 1978-1991 are indicating most wet years. The 1947 (250.3 mm) and 1957 (135.1 mm) as the most extreme years. During the reconstruction, we found six dry decades (1920, 1930, 1970, 1980, 2000, and 2010) and five wet decades (1910, 1940, 1950, 1960, and 1990). Our reconstruction confirms to global change which suggest decreasing precipitation from 1991 until now. More detailed characteristics has been shown in Table 3.

5 Most extreme years				5 Driest and wettest decades				Long-term means	
Years	Driest (mm)	Years	Wettest (mm)	Years	Driest (mm)	Years	Wettest (mm)	Years	Values (mm)
1957	135.1	1947	250.3	2000	180.3	1960	207.9	1950	192.9
1895	138.4	1959	248.4	2010	180.4	1950	207.1	2000	191.2
1897	138.4	1909	246.6	1980	182.1	1990	197.9	1892-1992	191.6
1893	140.8	1954	241.7	1930	185.1	1930	196.9	1892-2015	189.3
1991	142.3	1956	240.2	1920	187.3	1910	190.2		

Table 3: Summary characteristics of unfiltered summer (May-June) precipitation reconstruction.

Tree-ring growth and climate trends

Positive correlation with April-May snow-water equivalent and May-June precipitation implied great influence to the growth rings of Picea Shrenkiana, and this may possibly be due only to hydrological control and water deficit at early stages of the growing season which leads to suppression of extensions of tracheids and division of cambium cells in trees [34]. Scarce water can lead to narrowing tracheids and the rings, which also affects the change in density, decrease the size of the lumen and increase the proportion of the cell wall in the annual ring [36]. Strong negative correlation with mean temperature from March-October, suggests a possible increase in temperature and an increase in evaporation in this region, so it confirm our hypothesis about water availability as the main factor limiting growth.

To find the connection between our reconstruction and the geographical representation (Figure 7). We used spatial correlation between instrumental data spanned 1952-2012 May-June precipitation and CRU TS 4.0, and May-June precipitation reconstruction spanned 1952-2015, suggest that reconstruction represents broad-scale regional climatic variations, which begins and embraces moving along the great mountain chain of the Tian Shan Mountains from Mongolia, Xinjiang, Kazakhstan, Kyrgyzstan and Tajikistan.

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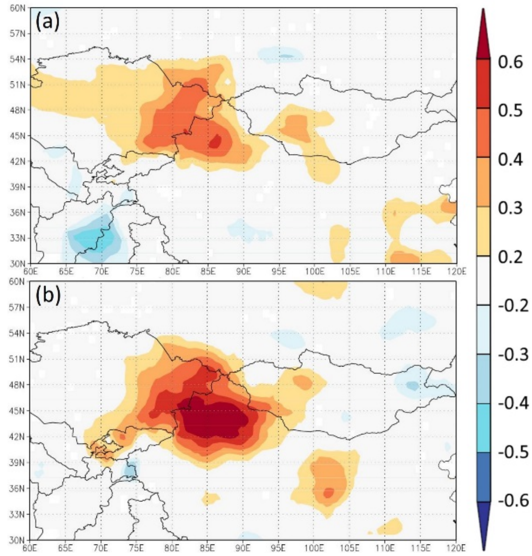

Figure 7: Spatial correlation fields of (a) reconstructed and (b) instrumental May-June precipitation with gridded CRU TS 4.0 May-June precipitation over 1952-2012.

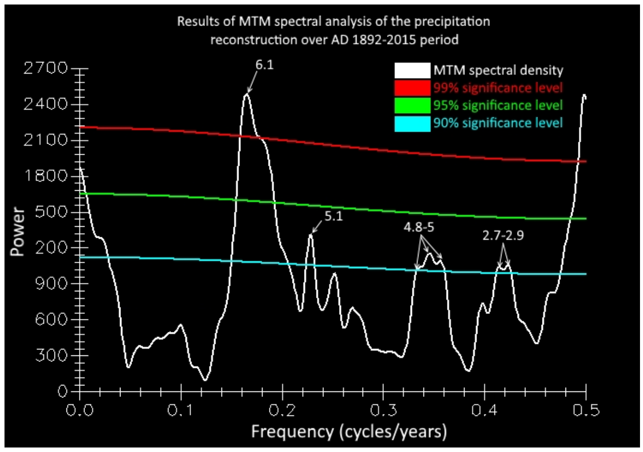

Figure 8: Multi-taper spectral analysis using 5×3π tapers and in a red noise background for the whole reconstruction of the May-June precipitation (1892-2015).

As shown in Figure 8 significant high-frequency peaks from MTM spectral analysis were found 6.1-year (99%), 5.1-year (90%), 5-year (90%), 4.9-year (90%), 2.9-year (90%), which can link to variability of the ENSO [37]. In order to study in more detail, the influencing factors and how certain cyclones affect our research area, we need other meteorological parameters (sunshine, wind speed and direction, carbon composition, etc.), and we need other analyzes (radiocarbon determination of density and others).

Conclusion

In this study, we have presented the summer May-June precipitation reconstruction from Snow Spruce (Picea Shrenkiana) chronologies. April-May snow-water equivalent and May-June precipitation shows significant positive correlation, suggest to water deficit at early stages of the growing season. Negative correlation was indicated from March-October mean temperature, which explains as increase in evaporation and water transpiration. Reconstruction was built over 1892-2015 period and explain driest and wettest periods over XIX – XXI century. In the course of the study, two extreme years with values 1947 (250.3 mm) and 1957 (135.1 mm) and also six dry decades (1920, 1930, 1970, 1980, 2000, 2010) and five wet decades (1910, 1940, 1950, 1960, 1990) were employed. From 1991 we observed decrease in precipitation which can be up to Global Climate Change Variability. Spatial correlation with gridded CRU TS 4.0 was significant suggest of possibility of our reconstruction. Strong linkages were found with Xinjiang Tian Shan Mountains and some parts of Mongolia, Kazakhstan, Kyrgyzstan and Tajikistan. MTM spectral analysis results connect our study area to ENSO variability with such high-frequency cycles 6.1-year (99%), 5.1-year (90%), 5-4.8-year (90%), 2.7-2.9-year (90%).

Acknowledgment

This study was supported by NSFC-UNEP, project (No. 41361140361) and Chinese Academy of Sciences (No. 134111KYSB20160010), High-level Talent Recruitment Program of Xinjiang Uygur Autonomous Region (Y642091) and CAS "Light of West China" Program (2015-XBQN-B-22). The kind help of Tao Hui, Zhang Yanjing, Shi Bingbing and Guo Yanfei during preliminary works was highly appreciated. We also thank Xue-Jun Zhang for his kindly replying for all our misunderstanding parts and for using his data [30]. Also, the author sincerely thanks to Chinese Academy of Science to get such kind of scholarship and chance to get knowledge in China. In addition, the author expresses deep gratitude to his family and all who at least somehow helped with the word or deed.

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