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STATISTICAL ANALYSIS OF TEMPERATURES ON BOTH THE UPPER AND LOWER BOUNDARIES OF SUB-ALPINE DARK CONIFER FORESTS IN CHINA

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ABSTRACT: Temperature of every month on both the upper and lower boundaries of sub-alpine dark conifer forests at various sites in China are estimated in terms of their distributions and temperature records. Based on these estimated data, the heat factors to influence and control the distribution and growth of sub-alpine dark conifer forests in China are discussed. It is found that the most important heat index to influence and control the distribution and growth of sub-alpine dark conifer forests is neither the mean temperature in the warmest month, nor the maximum or minimum temperatures, but monthly accumulated temperature of >0 C or monthly effective accumulated temperature of >5℃. When monthly accumulated temperature of >0℃ is more than 40℃, or monthly effective accumulated temperature of >5℃ is over 50℃, sub-alpine dark conifer forests cannot grow well. When monthly accumulated temperature of >5℃ is less than 60 C, sub-alpine dark conifer forests can not grow at all. When monthly effective accumulated temperature of >5 C is in the range 15℃—45℃, sub-alpine dark conifer forests in China can grow well. The ecological significance of temperature in May and September, and in summer half year are discussed.
KEY WORDS: sub-alpine dark conifer forests, temperature, statistical analysis

I. INTRODUCTION

The distribution and growth of sub-alpine dark conifer forests are strictly controlled by heat condition. When people discuss climate and geographical environment, they usually regard it as a temperature or heat index. But up to now, people know little about the range of temperature in which sub-alpine dark conifer forests can grow. From the ecological point of view, it is also

worth further discussing what the most important heat index to influence and control the distribution and growth of sub-alpine dark conifer forests is. For these reasons, according to the distribution of sub-alpine dark conifer forests and records of temperature from meteorological stations, the authors estimated and analysed the temperature of every month on both the upper and lower boundaries of sub-alpine dark conifer forests at over twenty sites which are less influenced by non-heat factors. Based on these estimated data, the heat factor and the heat index to influence and control the distribution and growth of modern sub-alpine dark conifer forests in China are discussed.

II. METHOD AND DATA SOURCE

1. Sub-alpine Dark Conifer Forests

Not every species of *Abies* and *Picea* has the entire same requirement of heat. Chen Xiqing (1987) ever wrote article to emphasize that *Abies beshanzuensis*, *Abies yuanbaoshanensis* and *Abies ziyuanensis* are different in the taxon of sub-alpine dark conifer forests[1]. They belong to the sorts that can endure warm climate. *Picea wilsonii*, *Picea potaninii* var. *macrocarpa*, *Picea meyeri*, *Picea brachytyla* and *Picea brachytyla* var. *complanata* are distributed in the lower zone and probably can endure warmer climate than other species of *Picea* and *Abies*. The species of *Picea* and *Abies* discussed in this artical are the species excluding the above and they can be called "sub-alpine dark conifer species". The forest composed of these species can be called "sub-alpine dark conifer forest".

2. Selection of Sites

Besides the heat factors, the non-heat factor such as precipitation, topography, soil and human activity also have unignore influence on the distribution and growth of dark conifer forests. Therefore, we must count out the sites where precipitation is too little or altitude is too low or human activities are too heavy, in order to eliminate or weaken the disturbance of the non-heat factor. In Mt. Da Hinggan, for example, drought limits the distribution and growth of *Picea koraiensis* and *Picea jezoensis* (they are only distributed on west banks of rivers or in moist zone of dark and gentle slope). On the south slope of Mt. Tianshan or west Kunlun Mountains forests of *Picea tianshan* (*Picea schrenkiana*) are distributed only in the zone above the elevation of 2,300 or 2,900 metres, because of the influencee of dry climate of desert. But on the

north slope of Mt. Tianshan, they can extend down to altitude of 1,400 meters. The altitude of Mt. Shennongjia in Hubei Province is too low (only 3,053 meters), it doesn't reach the upper boundary of dark conifer forests. In Cangshan, Dali, Yunnan Province, the lower boundary of *Abies delavayi* is about 3,100 meters high before 1937. Because large-scale cutting from 1937 to 1945, *Abies delavayi* can only be seen above the elevation of 3,400 meters at present. The elevation of the upper or lower boundary of dark conifer forests in these sites is greatly influenced by non-heat factor. So when we calculate temperature of the lower or upper boundary of dark conifer forests, the elevation of the upper or lower boundary in these sites must be corrected.

3. Determination of Elevation

The elevation of the upper and lower boundaries of dark conifer forests is determined according to "Chinese Vegetation", "Sichuan Vegetation", "Chinese Trees", "Chinese Plants" and other literatures[2-11].

Table 1 Range of temperatures in January and July between upper and lower boundaries of sub-alpine dark conifer forests in China

Sites	Temperature in January (℃)			Temperature in July (℃)		
	Lower boundary	Upper boundary	Range	Lower boundary	Upper boundary	Range
South slope of Mt. Altay	−12.0	−13.9	1.9	19.5	11.9	7.6
North slope of Mt. Tianshan	−7.5	−10.4	2.9	19.3	10.6	8.7
North slope of Mt. Changbai	−19.8	−21.2	1.4	17.1	13.7	3.4
Eastern sector of Mt. Taibai of Mt. Qinling	06.3	−9.3	3.0	15.5	11.4	4.1
Mt. Xueshan, Yulong, Yunnan Province	3.7	−1.8	5.5	13.4	9.2	4.2
Mt. Cangshan, Dali, Yunnan Province	3.2	−1.4	4.6	12.6	8.9	3.7
Mean value			3.2			5.4

4. Calculation of Temperatures

The temperature records at both ground stations and sky stations are used

to calculate the temperatures of the upper and lower boundaries of dark conifer forests. When one station is lack of temperature records, the nearer station's records are used to calculate. We do our best to avoid using vertical temperature gradient to calculate, because different stations, different altitudes or different months have different vertical temperature gradients.

III. CONCLUSION AND DISCUSSION

1. The Most Important Heat Index

Толмачев А. И. (1954) considered that temperature of the warmest month is the most important heat index that control the distribution of dark conifer forests, because it has the smallest change in the zone of dark conifer forests. This view has been cited so far[2]. Wu Xihao (1983) ever doubted it[9]. The authors think that the view is really worthy of discussing again. First, it is well known, the same temperature of the warmest month may coincide with quite different quantity of heat, because of the difference of yearly temperature range. At Changchun of Jilin Province and Dali of Yunnan Province, for example, mean temperatures of warmest month (July) are both 20.2℃. Monthly effective accumulated temperature of >5℃ is 53.9℃ in Changchun, but that is 122.1℃ at Dali, the difference between them is more than one time. So, it isn't proper to regard temperature of the warmest month as heat index. Second, in most parts of Russia, dark conifer forests appear horizontal distribution. Known to all, the least difference of monthly temperature between south and north is the temperature of the warmest month. No wonder does Толмачев А. И. came to the conclusion that the heat index changing least in dark conifer forest zone is temperature of the warmest month. This conclusion is suitable for Russia, but it isn't applicable in China. Dark conifer forests in China is one part of mountainous vertical spectrum of vegetation. In mountainous area it isn't temperature of the warmest month that change least with the changes of altitude. According to Table 1, the variation range of the coldest month temperature between the upper and lower boundaries is smaller than that of the warmest month temperature. So, the variation range of the warmest month temperature in the dark conifer forest zones reflects the climatic zonation, but not reflect the heat requirement of dark conifer forests. Consequently, the conclusion that heat index, with the least change in the zone of dark conifer forests is the warmest month temperature, and the warmest month temperature is the most important heat index is hardly feasible.

What is the most important heat index or temperature index to influence

and control the distribution and growth of dark conifer forests? We might do a crosswise comparison: the temperature indexes (or heat indexes) on both the upper and lower boundaries of dark conifer forests all over the country are compared with each other. They come from different zones and different altitudes, so the influence of climatic zonation is wakened. Under these circumstances, if some one of temperature indexes is rather stable, and has little change with the site change, we can believe that the temperature index plays an important role in controlling the distribution and growth of dark conifer forests.

According to Table 2—5, it isn't difficult to find out that not only on the upper boundary but also on the lower boundary, the monthly temperatures in summer half year in various parts of China are much more stable than those in winter half year. Average summer temperatures and summer half year's temperature are more stable than winter temperature and winter half year's temperature. This suggests that influence of temperature on the distribution and growth of dark conifer forests in summer half year far exceeds that in winter half year.

People usually use daily accumulated temperature stablly passing one finger to indicate heat condition. For convenience sake, we use monthly accumulated temperature to indicate heat condition in this article. In fact, there is intimate relationship between daily accumulated temperature and monthly accumulated temperature . The regression analysis of 51 sites in various parts of China shows that relevant coefficient can reach 0. 98. Therefore, it is feasible to use monthly accumulated temperature to indicate heat condition. We have calculated various monthly effective accumulated temperatures on both the upper and lower boundaries of sub-alpine dark conifer forests in various parts of China (Table 3 and Table 5). After comparing them, we find out, on the upper boundary of sub-alpine dark conifer forests, monthly accumulated temperature of >0℃ has the least difference between various sites (difference of average between south and north is the smallest) and is the most stable index (average relative deviation is the smallest). On the lower boundary of sub-alpine dark conifer forests, monthly effective accumulated temperature of >5℃ has the least differnce between sites and is the most stable index. So monthly accumulated temperature of >0℃ and monthly effective accumulated temperature of >5℃ are the most important heat index to influence and control the distribution and growth of sub-alpine dark conifer forests in China.

From the physiological and ecological point of view, when temperature is over 0℃, soil unfreezes, soil organisms begin to move and water begins to migrate, the sub-alpine plants such as *Picea* and *Abies* begin to grow[10]. In this

sense, monthly accumulated temperature of > 0℃ indicates the effective quantity of heat making sense to the distribution and growth of sub-alpine dark conifer forests, which directly influences and controls whether dark conifer forests can normally grow or not. So it is the most important heat index to influence and control the upper boundary of sub-alpine dark conifer forests in China.

When temperature is over 5℃, most temperate plants begin to grow, and the sub-alpine plants such as *Picea* and *Abies* enter the best growing period. The fact that the average temperature on the upper boundary of sub-alpine *Picea* and *Abies* forests is 5.5℃ when they are blooming proves that the inference is reliable. But it isn't said that so long as temperature is over 5℃ it can fit for *Picea* and *Abies* growing. When climate is too warm, it may also destroy the normal metabolism of *Picea* and *abies*, make them unable grow well. Temporary high temperature can't exert enormous effects on the normal growth of dark conifer forests. The average of the extreme warmest month temperature varies from 20.7℃ to 31.7℃ (the variation range reaches 11℃) (Table 5). Therefore, only when accumulated temperature exceeds the needs of the dark conifer forests, dark conifer forests can't grow well.

When temperature is in the range 0℃ to 5℃, dark conifer forests can grow, but can't grow well. In this period, the quantity of heat can't meet the needs of the normal growth of dark conifer forests and thus has no influence on lower boundary of dark conifer forests. Only when temperature is above 5℃, the quantity of heat might exceed the needs and affect the normal growth of dark conifer forests. In other words, only when monthly effective accumulated temperature of > 5℃ exceed certain amount, sub-alpine dark conifer forests can't grow well. So, monthly effective accumulated temperature of > 5℃ is one of the most important heat indexes to influence and control the lower boundary of sub-alpine dark conifer forests.

2. Limitations of Heat Conditions for Sub-alpine Dark Conifer Forests

The discussions above indicate that monthly accumulated temperature of > 0℃ and monthly effective accumulated temperature of > 5℃ are two important heat indexes to influence and control the distribution and growth of sub-alpine dark conifer forests. Now we use the two heat indexes to discuss the limitations of heat conditions for sub-alpine dark conifer forests.

According to Table 3. the average of monthly accumulated temperature of > 0℃ is 43.2℃ on the upper boundary of sub-alpine dark conifer forests in China. At most of the sites(75 percent) it's over 40℃, and at none of sites it's

Table 2 Monthyly temperature on the upper boundary of sub-alpine dark conifer forests in various parts of China

Sites	Forests	Elevation(m)	Monthly average temperature (℃)											
			Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
North slope of Mt. Changbai	*Picea jezonesis Abies nephrolepis*	1700	−21.2	−18.6	−11.6	−2.3	4.6	9.2	13.7	12.8	6.1	−1.6	−10.1	−18.0
Southwest slope of Mt. Altay	*A. sibirica*	2350	−13.9	−13.6	−7.4	−2.8	4.6	8.8	11.9	10.3	4.8	−2.8	−9.1	−12.4
North slope of Mt. Tianshan	*P. schrenkiana*	2800	−10.4	−10.2	−4.7	−0.7	4.5	8.6	10.6	10.1	5.7	−0.1	−5.8	−8.6
South slope of Mt. Tianshan	*P. schrenkiana*	3000	−10.2	−10.0	−3.6	−0.9	6.2	10.6	11.7	11.6	7.2	0.9	−5.5	−7.9
West Kunlun Mt.	*P. schrenkiana*	3600	−8.8	−8.6	−2.7	1.7	5.3	8.9	11.0	10.9	6.8	0.9	−5.1	−6.9
Eastern sector of Mt. Qilian	*P. crassifolia*	3400	−13.0	−12.0	−6.2	−1.4	3.7	7.6	9.7	9.6	4.7	−0.5	−8.2	−11.3
Mt. Taibai of Mt. Qinling	*A. chensiensis*, *A. fargesii*	3200	−9.3	−8.4	−3.8	1.1	5.5	8.7	11.4	10.6	6.4	1.9	−3.8	−7.3
Mt. Minshan	*A. fargesis*	3600	−9.3	−8.0	−4.1	−0.8	3.4	6.3	9.5	8.6	5.1	0.6	−4.3	−7.6
Songpan in north Sichuan	*P. purpures*	3800	−7.8	−6.1	−2.7	1.3	4.9	7.0	10.4	8.9	6.2	1.9	−3.2	−6.6
Garze in west Sichuan	*P. likiangensis* var. *bacfouriana*	4000	−5.7	−3.9	−1.2	2.6	6.0	7.6	9.9	9.0	7.3	3.6	−1.6	−4.7
Litang in west Sichuan	*A. squamata*	4000	−5.6	−4.0	−1.3	2.4	6.3	7.7	9.7	8.9	7.2	3.6	−1.5	−4.5
Muli in southwest Sichuan	*A. forrestii*	3900	−3.5	−2.9	0.4	3.4	5.9	7.0	9.4	8.4	6.8	4.0	−0.9	−2.2

(Table 2 continued)

Sites	Forests	Elevation(m)	Monthly average temperature (℃)											
			Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Xiangcheng in southwest Sichuan	*A. georgei*	4300	−6.3	−5.2	−3.1	0.5	4.2	5.5	7.5	6.7	5.1	1.6	−2.9	−5.0
Daocheng in southwest Sichuan	*P. likiangensis*	4000	−4.8	−3.7	−1.1	2.4	6.1	7.5	9.2	8.4	6.8	3.5	−1.1	−36
Mianning in southwest Sichuan	*A. fabri*	3900	−3.3	−2.7	1.0	4.0	6.2	7.0	9.4	8.5	7.0	4.0	−0.2	−2.0
Mt. Cangshan, Dali in Yunnan	*A. delavayi*	3800	−1.4	−1.5	0.8	3.4	6.4	8.0	8.9	8.6	7.3	4.8	1.4	−0.3
Mt. Yulong, Lijiang in Yunnan	*A. forrestii*	3800	−1.8	−1.7	0.8	3.7	7.1	8.1	9.2	8.7	7.2	4.6	1.0	−0.6
Zhongdian in Yunnan	*A. zhongdianensis*	3800	−2.6	−2.0	1.5	4.5	6.7	7.6	9.8	9.0	7.4	4.6	0.4	−1.5
Mean value			−7.3	−6.8	−2.7	1.3	5.3	7.8	10.1	9.8	6.4	1.9	−3.4	−6.2
Average deviation			3.6	3.6	2.4	1.7	0.9	0.9	1.1	0.8	1.8	2.6	3.3	
Mean of north(Qinling and its north)			−12.4	−11.6	−5.6	4.9	8.9	11.4	10.8	6.0	−0.2	−6.8	−10.3	
Mean of south(to the south of Qinling)			05.0	−4.0	−1.0	2.3	5.6	7.1	9.3	8.5	6.6	3.3	−1.4	−3.8
Difference of mean between south and north			7.4	7.6	4.6	2.8	0.7	1.8	2.1	2.3	0.6	3.4	5.4	6.5

Table 3 Temperatures and heat indexes on the upper boundary of sub-alpine dark conifer forests in various parts of China (℃)

Sites	Forests	Elevation (m)	Average yearly temperature	Average temperature in winter	Average temperature in winter half year	Average temperature in summer	Average temperature in summer half year	Average temperature of extreme warmest-month	Monthly effective accumulated temperature				
									>0	>3	>5	<0	<5
North slope of Mt. Changbai	*Picea jezonesis* *Abies nephrolepis*	1700	−3.0	−19.3	−13.5	11.9	7.4	−32.4	46.4	31.4	21.8	83.4	118.8
Southwest slope of Mt. Altay	*A. sibirica*	2350	−1.8	−13.8	−9.9	10.3	6.3	−29.7	40.0	25.4	16.0	62.0	97.6
North slope of Mt. Tianshan	*P. schrenkiana*	2800	−0.1	−9.7	−6.6	9.8	6.5	−25.8	39.7	24.7	15.2	40.5	76.0
South slope of Mt. Tianshan	*P. schrenkiana*	3000	1.0	−9.4	−6.1	11.3	8.1	−22.5	49.1	32.3	22.3	37.2	70.4
West Kunlun Mt.	*P. schrenkiana*	3600	1.1	−8.1	−5.2	10.3	7.5	−23.2	45.5	27.9	17.9	32.1	64.5
Eastern sector of Mt. Qilian	*P. crassifolia*	3400	−1.4	−12.1	−8.5	9.0	5.7	−25.7	35.3	20.3	11.9	52.6	89.2
Mt. Taibai of Mt. Qinling	*A. chensiensis* *A. fargesii*	3200	1.1	−8.3	5.0	10.3	7.3	−21.5	45.6	27.6	17.6	32.1	64.1
Mt. Minshan	*A. fargesis*	3600	0.0	−8.3	−5.5	8.1	5.5		33.5	17.9	9.5	33.6	69.6
Songpan in north Sichuan	*P. purpures*	3800	1.2	−6.8	−4.1	8.8	6.4		40.4	22.2	12.3	26.4	58.3
Barkam in north Sichuan	*A. faxoniana*	4000	0.4	−7.0	−4.5	7.4	5.3		33.1	16.6	7.7	28.1	61.6
Garze in west Sichuan	*P. likiangensis* var. *bacfouriana*	4000	2.4	−4.8	−2.2	8.8	7.1	−21.0	46.0	25.4	14.8	17.0	45.8
Litang in west Sichuan	*A. squamata*	4000	2.4	−4.7	−2.2	8.8	7.1		45.8	25.4	14.8	16.9	45.9

(Table 3 continued)

Sites	Forests	Elevation (m)	Average yearly temperature	Average temperature in winter	Average temperature in winter half year	Average temperature in summer	Average temperature in summer half year	Average temperature of extreme warmest-month	Monthly effective accumulated temperature				
									>0	>3	>5	<0	<5
Muli in southwest Sichan	*A. forrestii*	3900	3.0	−2.9	−0.9	8.3	6.8		45.2	23.8	12.4	9.5	36.7
Xiangcheng in southwest Sichuan	*A. georgei*	4300	1.6	−5.5	−3.5	6.6	4.9	−18.0	31.1	14.0	4.8	22.5	56.2
Daocheng in southwest Sichuan	*P. likiangensis*	4000	2.5	−4.0	−1.8	8.4	6.7		43.9	23.5	13.0	14.3	43.4
Mianning in southwest Sichuan	*A. fabri*	3900	3.2	−2.7	−0.5	8.3	7.2	−11.8	47.1	26.0	14.0	8.2	34.2
Mt. Cangshan, Dali in Yunnan	*A. delavayi*	3800	3.9	−1.1	0.6	8.5	7.1	−9.1	49.6	26.4	14.2	3.2	27.8
Mt. Yulong, Lijiang in Yunnan	*A. forrestii*	3800	3.9	−1.4	0.4	8.7	7.4	−9.8	50.4	27.6	15.3	4.1	29.0
Zhongdian in Yunnan	*A. zhongdianensis*	3800	3.8	−2.0	0.1	8.8	7.5		51.5	28.6	15.5	6.1	30.1
Mean value			1.3	−6.9	−4.1	9.1	6.7		43.1	24.6	14.3	27.9	58.9
Average deviation									14.4	21.0	26.8	32.5	
Average deviation (℃)			1.6	3.5	2.9	1.0	0.7						
Mean of north (Qinling and its north)			−0.4	−11.5	−7.8	10.4	8.9		43.2	27.1	17.5	48.6	82.9
Mean of south(to the south of Qinling)			2.4	−4.3	−2.0	8.3	6.6		43.1	23.1	12.4	15.8	45.0
Difference of mean between south and north			2.8	7.2	5.8	2.1	0.3		0.1	4.0	5.1	32.8	37.9

Table 4 Monthly temperatures on the lower boundary of sub-alpine dark conifer forests in various parts of China

Sites	Forests	Elevation(m)	Monthly average temperature (℃)											
			Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mt. Hinggan	*Picea jezonesis* *Abies nephrolepis*	800	−18.8	−15.8	−7.7	2.5	10.7	16.2	19.0	17.4	11.4	2.8	−9.4	−17.6
Mt. Zhangguangchai	*P. jezoensis* *A. nephrolepis*	1100	−17.4	−14.9	−7.6	1.7	9.7	14.1	17.4	16.8	10.6	3.0	−7.4	−15.5
North slope of Mt. Changbai	*P. jezoensis* *A. nephrolepis*	1100	−19.8	−16.7	−8.2	1.4	8.4	12.7	17.1	15.9	9.0	1.2	−7.7	−16.2
Southwest of Mt. Altay	*P. Xinjiang*	1300	−12.0	−10.7	−2.6	4.0	12.2	17.5	19.5	17.9	12.4	4.0	−4.8	−10.4
North slope of Mt. Tianshan	*P. schrenkiana*	1500	−7.5	−7.2	0.4	6.9	13.0	17.4	19.3	18.8	13.7	6.1	−1.3	−5.6
Eastern sector of Mt. Qilian	*P. crassifolia*	2400	−9.7	−7.7	−0.7	4.8	10.3	14.2	16.1	15.8	10.9	5.2	−3.5	−7.7
Mt. Qilian	*A. fargesii*	2500	−6.3	−5.2	0.1	4.6	9.4	13.2	15.5	14.7	10.1	5.3	−0.5	−4.4
Mt. Daba	*A. chensiensis* *A. fargesii*	2400	−4.4	−3.6	1.6	6.2	10.3	13.1	15.7	15.2	11.2	6.6	1.5	−2.5
Mt. Shennongjia in Hubei	*A. fargesii*	2700	−5.2	−4.3	0.3	4.6	8.8	11.8	14.6	13.7	9.8	5.3	0.2	−3.4
Pingwu in Sichuan	*A. fabri*	2600	−3.7	−1.0	3.5	7.6	10.9	13.2	15.6	15.0	11.9	7.3	1.9	−2.6
Songpan in Sichuan	*P. purpures*	3000	−6.3	−3.4	1.3	5.9	9.3	11.6	14.0	13.0	10.1	5.4	−0.5	−5.3
Barkam in Sichuan	*A. faxoniana*	3000	−2.4	0.4	4.3	8.2	11.0	12.4	14.5	13.8	11.2	7.0	1.9	−2.1
Litang in west Sichuan	*A. squamata*	3200	−2.2	−0.2	3.4	7.2	10.9	12.5	14.0	13.3	11.1	7.1	2.0	−1.6
Garze in west Sichuan	*P. likiangensis* var. *balfouriana*	3400	−3.4	−1.3	2.8	6.9	10.3	11.8	13.7	12.9	10.7	6.8	1.3	−2.8

(Table 4 continued)

Sites	Forests	Elevation(m)	Monthly average temperature (℃)											
			Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mainling in southwest Xizang	*A. spectabilis*	3200	−0.7	1.9	4.9	8.4	12.0	14.6	15.3	14.8	13.2	9.2	3.8	0.2
Nyingchi in southwest Xizang	*A. likiangensis* var. *lintziensis*	3000	0.1	2.4	5.2	8.4	11.7	14.3	15.5	15.1	13.4	9.7	4.7	1.2
Yuexi in southwest Sichuan	*A. forrestii*	3000	1.7	2.2	7.0	10.1	11.7	11.9	14.4	13.6	11.8	8.9	4.7	2.4
Jiulong in west Sichuan	*A. georgei*	3000	0.6	2.9	6.5	9.8	13.0	13.9	15.3	14.7	13.0	9.4	4.6	1.2
Mt. Xueshan, Yulong in Yunnan	*P. likiangensis*	3100	3.7	3.5	6.0	8.5	12.1	12.7	13.4	12.8	11.3	9.1	5.7	3.9
Mt. Cangshan, Dali in Yunnan	*A. delavayi*	3100	3.2	3.1	5.7	8.1	10.9	11.9	12.6	12.3	11.1	8.7	5.2	3.3
Central Mounts in Taiwan	*A. kawakamii* *P. morrisonicola*	2800	2.9	3.4	6.2	8.8	10.8	11.7	12.6	12.3	11.7	9.2	7.8	4.6
Mean value			−5.1	−3.8	1.5	7.1	10.9	13.4	15.5	14.8	11.4	6.5	−0.1	−3.9
Average deviation			5.4	5.5	3.7	1.5	0.98	1.4	1.51	1.4	0.93	1.9	3.9	4.9
Mean of north(Qinling and its north)			−13.1	−11.2	−3.8	3.7	10.5	15.0	17.7	16.8	11.2	3.9	−4.9	−11.1
Mean of south(to the south of Qinling)			−1.1	0.5	4.2	9.1	11.0	12.7	14.4	13.8	11.5	7.8	2.3	−0.2
Difference of mean between south and north			12.0	11.7	8.0	5.4	0.5	2.3	3.3	3.0	0.3	3.9	7.2	10.9

Table 5 Monthly temperatures on the lower boundary of sub-alpine dark conifer forests in various parts of China (%)

Sites	Forests	Elevation (m)	Average yearly temperature	Average temperature in summer	Average temperature in summer half year	Average temperature of extreme warmest-month	Monthly effective accumulated temperature				
							>0	>5	>8	>10	>12
Mt. Hinggan	*Picea jezonesis* *Abies nephrolepis*	800	0.9	17.5	12.9	28.9	80.0	49.7	34.7	24.7	16.6
Mt. Zhangguangchai	*P. jezoensis* *A. nephrolepis*	1100	0.9	16.1	11.7	27.0	73.3	43.6	28.6	18.9	12.3
North slope of Mt. Changbai	*P. jezoensis* *A. nephrolepis*	1100	−0.2	15.2	10.8	25.5	65.7	38.1	23.1	15.7	9.7
Southwest of Mt. Altaly	*P. Xinjiang*	1300	3.9	18.3	13.9	31.7	87.5	54.5	39.5	29.5	19.9
North of Mt. Tianshan	*P. schrenkiana*	1500	6.2	18.5	14.9	30.7	95.6	60.2	42.2	32.2	22.2
Eastern sector of Mt. Qilian	*P. crassifolia*	2400	4.0	15.4	12.0	26.5	77.3	42.5	27.3	17.3	10.1
Mt. Qilian	*A. fargesii*	2500	4.7	14.5	11.3	22.0	72.9	38.2	22.9	13.5	7.4
Mt. Daba	*A. chensiensis* *A. fargesii*	2400	5.9	14.7	12.0	21.0	81.4	43.3	25.5	15.5	8.0
Mt. Shennongjia in Hubei	*A. fargesii*	2700	4.7	13.4	10.6	20.7	69.1	34.0	18.7	10.1	4.3
Pingwu in Sichuan	*A. fabri*	2600	6.6	14.6	12.4		86.9	46.5	26.6	16.6	7.8
Songpan in Sichuan	*P. purpures*	3000	4.7	12.9	10.7		70.6	34.3	18.0	8.7	3.0
Barkam in Sichuan	*A. faxoniana*	3000	6.7	13.6	11.9		84.7	43.1	23.1	12.9	4.7
Litang in west Sichuan	*A. squamata*	3200	6.5	13.3	11.5		81.5	41.1	21.8	11.8	3.8
Garze in west Sichuan	*P. likiangensis* var. *balfouriana*	3400	5.8	12.8	11.1		77.2	38.1	19.4	9.4	2.6

(Table 5 continued)

Sites	Forests	Elevation (m)	Average yearly temperature	Average temperature in summer	Average temperature in summer half year	Average temperature of extreme warmest-month	Monthly effective accumulated temperature				
							>0	>5	>8	>10	>12
Mainling in southwest Xizang	*A. spectabilis*	3200	8.1	14.9	13.1		98.3	52.5	31.5	19.9	9.9
Nyingchi in southwest Xizang	*A. likiangensis* var. *lintziensis*	3000	8.5	15.0	13.1		101.7	53.3	32.1	20.0	10.3
Yuexi in southwest Sichuan	*A. forrestii*	3000	8.4	13.8	12.3	23.3	100.4	49.4	26.4	13.5	4.0
Jiulong in west Sichuan	*A. georgei*	3000	8.7	14.6	13.3		104.9	55.6	33.1	19.9	6.9
Mt. Xueshan, Yulong in Yunnan	*P. likiangensis*	3100	8.6	13.0	11.8	22.3	102.7	46.6	23.9	12.3	3.0
Mt. Cangshan, Dali in Yunnan	*A. delavayi*	3100	8.0	12.3	11.2		96.1	41.5	19.6	8.8	0.9
Central Mounts in Taiwan	*A. kawakamii* *P. morrisonicola*	2800	8.5	12.2	11.3	22.0	102.0	46.1	21.1	9.1	0.9
Mean value			5.7	14.6	12.1		86.2	45.3	26.6	16.3	7.7
Average relative deviation (%)							12.6	12.8	20.0	31.1	58.1
Average deviation (℃)			2.1	1.4	0.83						
Mean of north (Qinling and to the north of it)			2.9	16.5	12.5	27.5	78.9	46.7	31.2	21.7	14.0
Mean of south (to the south of Qinling)			7.1	13.6	11.8	21.9	89.8	44.6	24.3	13.5	4.6
Difference of mean between south and north			4.2	2.9	0.7	5.6	10.9	2.1	6.9	8.2	9.4

less than 30℃. So, we can believe that when monthly accumulated temperature of $>$ 0℃ is less than 40℃, sub-alpine dark conifer forests can't grow well, when monthly accumulated temperature of $>$ 0℃ is less than 30℃, sub-alpine dark conifer forests can't grow at all.

According to Table 5, the average of monthly effective accumulated temperature of $>$ 5℃ on the lower boundary of sub-alpine dark conifer forests in various parts of China is 45.3℃. At most of sites (76 percent) it is less than 50℃, and at none sites it is more than 60℃. So, we can believe that, when monthly effective accumulated temperature of $>$ 5℃ is more than 50℃, sub-alpine dark conifer forests can't grow well, when monthly effective accumulated temperature of $>$ 5℃ is more than 60℃, sub-alpine dark conifer forests can't grow at all.

3. Sign Temperatures and Their Significance

Not only on the upper boundary, but also on the lower boundary of sub-alpine dark conifer forests, the average temperatures of May, September and summer half year are the stablest temperature indexes. Their difference between south and north, and the average deviation are both less than 1℃ (Table 2—5).

Through looking up "Chinese Trees" and "Chinese Plants"[4-5], the authors find that most species of *Picea* and *Abies* in China come to bloom from April to May and their fruits are ripe in September and October. So, the average temperature of May reflects the heat condition in *Picea* and *Abies* florescence, and the average temperature of September reflects the heat condition when *Picea* and *Abies* fruits are ripening, and average temperature of summer half year reflects the average heat conditon of growth period. Because the average temperatures of May, September and summer half year have special implication to the growth of dark conifer forests, we call them "sign temperature".

It is probably because most of sub-alpine *Picea* and *Abies* have the rather same requirement of heat in blossoming period, fruits-bearing period and growing period, the average temperatures of May, September and summer half year are all rather stable on the both upper and lower boundaries, they don't change violently with changes of site and species. So, if the three sign temperatures at both the upper and lower boundaries are combined, we can obtain suitable temperature range for blossoming and fruiting of sub-alpine dark conifer forests, and we also obtain suitable average temperature range of growing period in China.

According to Table 2—5, the average temperature is 5.5℃ on the upper boundary in May, 6.4℃ in September, and 6.8℃ in summer half year. The average temperature on the lower boundary is 10.9℃ in May, and 11.4℃ in September, and 12.1℃ in summer half year. So we obtain that suitable temperature (average monthly temperature) range is about 5.5℃ to 11.0℃ during the blossoming period sub-alpine dark conifer trees , and it is about 6.5℃ to 11.5℃ during fruiting period and the average temperature in growing period is suitable to change from 7.0℃ to 12.0℃ in China.

4. Influence of Extreme Temperature on the Distribution and Growth of Sub-Alpine Dark Conifer Forests

For discussing the influence of extreme temperature on the distribution and growth of sub-alpine dark conifer forests, we estimated the extreme lowest everage monthly temperature on the upper boundary and the extreme highest average monthly temperature on the lower boundary of sub-alpine dark conifer forests. From the results estimated (Table 3 and Table 5), it is found that regional differences are obvious, change range is also enormous. The extreme lowest average monthly temperature varies from −32.4℃ to −9.1℃ on the upper boundary, and the biggest range is 23.3℃. The extreme highest average monthly temperature varies from 31.7℃ to 20.7℃ on the lower boundary, and the biggest range is 11.0℃ . So, we can conclude that the extreme highest monthly temperature and the extreme lowest monthly temperature probably have some influences on the distribution and growth of sub-alpine dark conifer forests in some places, but they have little influences in most parts of China.

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