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RELATIONSHIPS BETWEEN PRECEDING PACIFIC SEA SURFACE TEMPERATURES AND SUBTROPICAL HIGH INDEXES OF MAIN RAINING SEASONS

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Abstract: With correlation analysis and factor analysis methods, the effects of preceding Pacific SSTs on subtropical high indexes of main raining seasons are discussed. The results of correlation analysis show that the effects of SSTs on five subtropical high indexes differ in seasons and regions. The variation of SSTs mostly affects the area and intensity indexes of the subtropical high, followed by the western ridge index, and the effect on the ridge line index is more remarkable than on the north boundary index. The results of factor analysis reveals that the first common factor of SST of each season reflected mainly the inverse relation of SSTs variation between the central and eastern part of equatorial Pacific and the western Pacific, which correlates better with the subtropical high indexes in the main raining seasons than other common factors of SST. The analysis of interdecadal variation indicated that the variation of SSTs was conducive to the emergence of the La Niña event before the end of 1970s, such that in the summer the subtropical high is likely to be weaker and smaller and located eastward and northward. After the 1980s, the opposite characteristics prevailed.

Key words: climatology; relationship; correlation analysis; factor analysis; sea surface temperature; subtropical high index

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1 INTRODUCTION

Western Pacific subtropical high is a synoptic system which affects the summer rainfall of China directly. Many researches [1 - 5] have shown that there are close relationships between the characteristics of the subtropical high, such as the shape, intensity and location, and the tendency of drought or flood in most areas of China in main raining seasons. In recent years, many scholars have realized that it is greatly beneficial for the improvement of the ability of short-term climate prediction to strengthen the research of the key factors affecting the rainfall, analyze the mutual relation between factors having remarkable effect on rainfall and to learn of the future variation tendency of all factors. A lot of researches have shown that preceding Pacific SST, which has a great impact on the shape, location and intensity of subtropical high in summer, is a precursory predicting signal. On the location of the subtropical high affected by preceding SST, Zhao et al.[1] discovered that there is a negative correlation between the ridge line of the subtropical high in June and the SST in the eastern equatorial Pacific during the preceding autumn or winter, whereas the correlation gets weaker in July and August. Huang et al. [6] noted that when the SST of the western Pacific gets higher, the convective activities from the Philippines to South China Sea to Indo-China Peninsula become stronger and the subtropical high will be located more northward, and vice versa. As shown in Li [7], the subtropical high in the summer of El Niño years is more to the south in location and extends more westward than in normal years. In La Niña years, the location of the subtropical high is more to the north. On the intensity of the subtropical high influenced by preceding SSTs, Chen [8] discovered that the SST of the eastern equatorial Pacific and westerly wind drift belt in winter

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(January and February) has a significant effect on the intensity and area of the subtropical high at a later time. According to Zhang et al.[9] , the decadal climate shift of more summer precipitation in South China after the 1980s is closely accompanied with the increase of SST in the western North Pacific and the subtropical high's farther westward stretching with a larger south-north extend. Li et al.[10] discovered that SST of the west wind drift area in June can be considered as the signal of the intensity of the subtropical high in the subsequent July, i.e., the lower SST of the west wind drift area in June presages a stronger subtropical high in the subsequent July, and vice versa. In the opinion of Yan et al.[11], in the El Niño year the subtropical high is stronger and stretches westward obviously, increasing the rainfall in eastern China but decreasing it in South China and Yunnan province. In La Niña years, it is jut the opposite. However, the research of Li [7] has shown that the subtropical high in summer is weaker in El Niño years; it is stronger after a persisting El Niño event in the previous year. Other researches [12, 13] also indicated that preceding SST has a significant effect on the location and intensity of subtropical high in summer.

As shown in the research above, the precedent SST of North Pacific greatly affects the characteristics of the subtropical high in summer. Having defects, these studies also differ from each other in findings. It has two-fold suggestion. On the one hand, the sea has great thermal inertia. The SSTA is marked by features on large spatial scales and long-term time scales. Preceding SSTs of different seasons and zones have different effect on the subtropical high in the raining season. On the other hand, the change in the subtropical high itself is very complicated. Different indexes should be used to describe the diverse characteristics of the subtropical high as a whole, such as intensity, area, location, and shape. It is difficult to demonstrate the impact of SSTs on the subtropical high by considering the relation between SSTs and only one of the indexes for the subtropical high. Only if the relations between SSTs of the whole Pacific and all five indexes of the subtropical high are considered can an integrated understanding of them be achieved.

All data, including the average values of the five subtropical high indexes in summer (ridge line, north boundary, western ridge point, area and intensity), and SSTs of North Pacific ranging from 1951 to 2005 come from National Climate Center. In order to understand the impact of preceding SSTs on the summertime subtropical high, reveal the mutual relations among the main factors which have effect on the rainfall in summer, and to provide arguments for the prediction of rainfall, this paper discusses the effects of preceding Pacific SSTs on the subtropical high indexes for main raining seasons, based on the methods of correlation analysis and factor analysis.

2 DISTRIBUTION OF CORRELATION COEFFICIENT FOR PRECEDING SSTS AND SUBTROPICAL HIGH INDEXES IN SUMMER

The SSTs for October, January and April, representing autumn, winter and spring respectively, were used to study the correlation coefficient between the SSTs in each of above months and the subtropical high indexes in summer (Figures omitted), the result shows:

(1) While the SST in each of the preceding seasons is little correlated with the north boundary index, it has more remarkable effect on the ridge line index. The highly-correlated area is mainly located in central Pacific on the eastern and western sides of Hawaii Islands.

(2) For the western ridge index, the equatorial central-eastern Pacific is an area of steadily and highly negative correlation from autumn to spring. The correlation gets weaker in spring. The northwest Pacific is a positively correlated area in autumn and it moves towards the east in winter and spring.

(3) As far as the area and intensity indexes of the subtropical high are concerned, the equatorial central-eastern Pacific is a steady center for a highly positive correlation area from autumn to spring. The Northwest Pacific is a negatively correlated area in autumn and it moves towards the east in winter and spring.

(4) Judged from the number of SST grids whose correlation coefficients between the preceding SSTs and the five subtropical high indexes have passed the t test with a 0.01 significant level in every previous month, the effect of SSTs in autumn on the area and intensity indexes is the most significant as the number of grids whose correlation coefficients have passed the check is the most. The effect of SSTs in winter on the western ridge index and the effect of SSTS in spring on the ridge line index are the most significant.

3 EFFECT OF SST COMMON FACTORS IN EVERY PREVIOUS SEASON ON SUBTROPICAL HIGH INDEXES IN SUMMER

Based on the EOF method, the common factors are extracted from SSTs in the preceding autumn, winter and spring season respectively. The first five common factors of each season can denote 60% of the SST variance approximately, while the first common factor can denote the variance varying between 20% and 30%.

3.1 *Correlation coefficient between common factors of each season and subtropical high indexes in summer*

Table 1 displays the correlation coefficients of the first five common factors of SSTS in each preceding seasons and five indexes of subtropical high in summer. From Table 1 it can be concluded that:

Table 1 Correlation coefficients between the first five common factors of SSTS of each previous seasons and the five subtropical high indexes.

	Common factors	North boundary index	Ridge line index	Western ridge index	Area index	Intensity index
Autumn	First	-0.03	-0.25	-0.43	0.70	0.66
	Second	-0.16	-0.05	0.15	0.13	0.08
	Third	-0.12	-0.23	0.00	-0.17	-0.16
	Fourth	0.12	0.09	-0.18	0.13	0.24
	Fifth	0.06	0.06	0.17	-0.07	-0.08
Winter	First	0.00	-0.32	-0.53	0.71	0.69
	Second	-0.22	-0.21	0.13	0.02	-0.04
	Third	0.09	-0.11	-0.07	-0.06	0.03
	Fourth	0.01	-0.05	-0.03	-0.11	-0.13
	Fifth	-0.04	0.01	0.25	-0.12	-0.14
Spring	First	-0.11	-0.45	-0.47	0.75	0.73
	Second	0.28	0.23	-0.17	0.15	0.20
	Third	-0.13	-0.03	0.17	-0.05	-0.08
	Fourth	0.03	0.19	0.05	0.11	0.07
	Fifth	-0.14	-0.15	-0.04	0.03	0.02

(1) The first common factor of SSTs is significantly correlated with subtropical high indexes, while the correlation is less between other common factors and the subtropical high indexes. Therefore a conclusion can be drawn that the effect of preceding SSTs on the indexes in summer mainly depends on the change of SSTs as reflected by the first common factor. Through the factor analysis, the ingredients of SST variation having the most significant effect on the subtropical high in summer can be extracted from the preceding SST field.

(2) The first common factor of SSTS in each preceding season is weakly correlated with the north boundary index while having better correlation with the ridge line of subtropical high. There is remarkable negative correlation between the first common factor of SSTs and the western ridge index, which passes the *t* test with a 0.01 significant level. In winter the negative correlation is the most remarkable. There is positive correlation between the first common factor in each preceding season and the area / intensity indexes, which is always significant and pass *t* test with a 0.01 significance level.

3.2 *Variation of SSTS reflected by the first common factor in each preceding season*

Because the first common factors have the closest relation with the subtropical high indexes in summer, the variation of actual SST change as reflected by the first common factor should be analyzed. Fig.1 displays the distribution of the correlation coefficient between the first common factor of each season and its corresponding SST fields, respectively.

From Fig.1, the characteristics of SST change reflected by the first common factor in each season are very similar, i.e. an area of remarkable positive

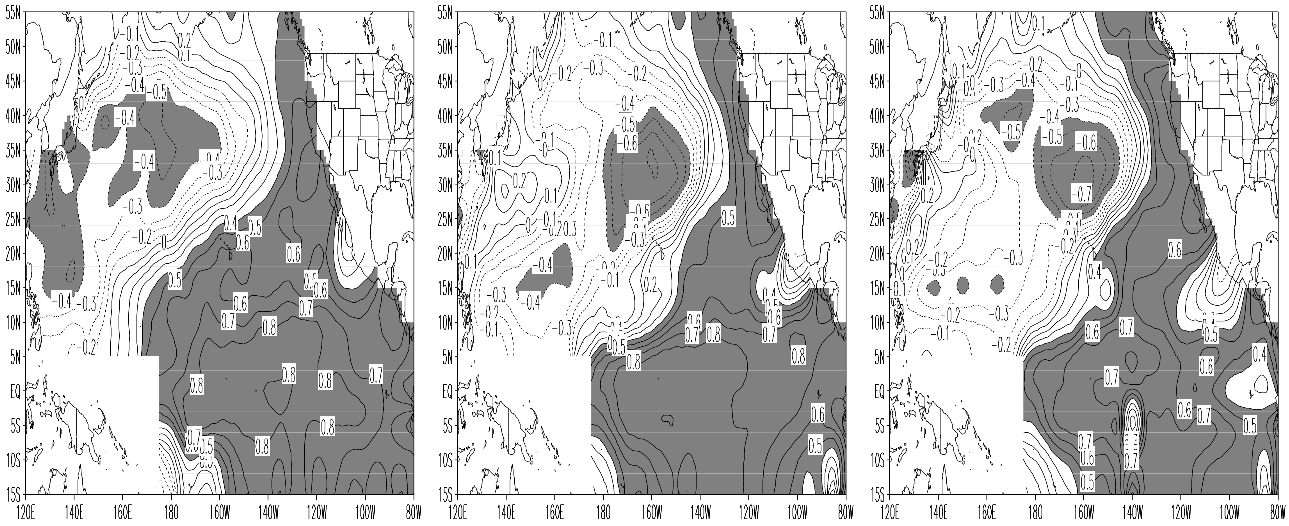

Fig.1 Distributions of correlation coefficient between the first common factor of autumn (left panel), winter (middle panel), and spring (right panel), and its corresponding SST fields. Shaded areas have passed the *t* test with a 0.01 significant level.

correlation locates in the equatorial central-eastern Pacific, while an area of negative correlation lies in the northwest Pacific. It is in accordance with the spatial distribution characteristics of the Pacific-Indian Ocean SST anomaly mode put forward by Ju [14]. The research of Yu [15] also shows that the SST of equatorial eastern and western Pacific is the key factor that influences the long-term change and abnormal activity of the subtropical high. It can be found from the year-to-year variation of the first common factor of SSTs (Figure omitted) that the La Niña event was easier to occur before the end of 1970s as the first common factor for this period was more likely to be negative, such that in summer the subtropical high was more likely to be weaker and smaller and located northward and eastward. After 1980s, the El Niño event occurred more frequently as the first common factor of SSTS tended to be positive, and the subtropical high was more likely to be stronger and larger and located southward and westward.

For analyses of other aspects, refer to the Chinese edition of the journal.

4 RESULTS AND DISCUSSIONS

Based on the above analysis, the results are as follows:

(1) The variations of preceding Pacific SSTs have the most remarkable effect on the area and intensity indexes of the subtropical high and less on the western ridge index, and the effect of SSTs on ridge line index is more remarkable than on the north boundary index. The effects of SSTs on the subtropical high indexes vary in seasons and regions. From the change of the effect of different preceding months of SSTs on the same subtropical high index, the effect of SSTs in autumn on the area and intensity indexes is the most significant. The effect of SSTs in winter on the western ridge index and the effect of SSTs in spring on the ridge line index are the most significant. From the distribution of highly-correlated SSTs area, it is known that the SSTs of central Pacific on the eastern and western sides of Hawaii Islands have the greatest impact on the location of the subtropical high. The SSTs of equatorial central-eastern Pacific in autumn and winter have remarkable correlations with the western ridge, area and intensity indexes. In spring the correlation of this area becomes weak.

(2) From the results of the factor analysis, the first common factor of SSTs in each of the preceding seasons has the most significant correlation with the subtropical high indexes and complies with the results of correlation analysis greatly, while the correlations are less between other common factors and the subtropical high indexes. The first common factor for each of the seasons reflects mainly the inverse relation of SSTs variation between the mid-eastern part of equatorial Pacific and western Pacific. The analysis of interdecadal variations indicates that the variation of SSTs was advantageous to the emergence of La Niña events before the end of 1970s such that in the summer of successive years the subtropical high was likely to be weaker and smaller and located eastward. After 1980s, the El Niño event was more likely to appear and the subtropical high in summer is likely to be stronger and larger, and located southward and westward.

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