# IMPACT OF SEA SURFACE TEMPERATURE ANOMALY ON TWO GLOBAL WARMING PERIODS IN THE 20TH CENTURY OVER THE ARID CENTRAL ASIA

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**ABSTRACT**

Based on the gridded monthly air temperature data and the sea surface temperature (SST) data, the influence of SST change on two global warning periods in the 20th century over the arid central Asia is analyzed. The results show that the SST anomaly produces obvious effect on temperature. The winter temperature of the arid central Asia is much warmer (cooler) when high positive (negative) SST anomaly occurs in the equatorial central–eastern Pacific (ECEP) from autumn to winter. The summer temperature of the arid central Asia is much warmer (cooler) when higher (lower) summer SST occurs in the ECEP, the “warm pool”, the Kuroshio area and the westerly drift zone.

The arid central Asia made different responses to the two warming periods from the 1920s to the 1940s and from the 1970s to the 1990s, in close dependence on the anomalies of SST controlling the arid area at the two time intervals. Study shows that the impacts of global warming in the 1920s-1940s and 1970s-1990s differ upon the arid central Asia, resulting in its different responses thereto.

***Keywords*—**Arid central Asia, air temperature, sea surface temperature, two global warming periods, the 20th century

## 1. INTRODUCTION

Arid central Asia is a transition belt between high latitude and low latitude areas. Being the special geographic location, its arid climate has significant impacts on environmental change far beyond its borders [1, 2]. It is well known that global warming has drawn widespread attention in the world and there are two global warming periods in the 20th century [3, 4]. Arid central Asia has also responded obviously to the global warming [5]. But the interesting things are as follows: For the first warming period from the 1920s to the 1940s, there was no single response in the whole arid central Asia, except for the eastern marginal area, where monsoon is dominant. However, for the second warming period after 1970s, the whole arid area has an overall response [6]. Qian et al [7] pointed out that the strongest signal of sea surface temperature anomaly (SSTA) occurred over the Pacific Ocean at the decadal time scale. The SSTA in the eastern equatorial Pacific is still an important reference factor to predict coming short-range climate status not only in China but also in the world. The interaction between the ocean and the atmosphere is a main factor resulting in climate anomaly and oscillation. In order to better understand the role of SSTA in air temperature change of arid central Asia, the relationship between the SST of Pacific and the air temperature of arid central Asia, and the response to the SSTA over the arid central Asia in two global warming periods are analyzed in this paper.

## 2. DATA AND METHODS

The high-resolution gridded (0.5°×0.5°) monthly air temperature data is obtained from the Climate Research Unit (CRU) and the Tyndall Center of the University of East Anglia, UK [8]. The monthly sea surface temperature data (2°×2°) is obtained from the National Oceanic and Atmospheric Administration (NOAA), USA [9]. The data period is from 1901 to 2002. The Singular Value Decomposition (SVD) method is utilized to identify the relationship between the North Pacific SST and the temperature of arid central Asia.

## 3 RELATIONSHIP BETWEEN WINTER AIR TEMPERATURE OF THE ARID CENTRAL ASIA AND SST OF THE NORTH PACIFIC BY SVD ANALYSIS

### 3.1 The SVD Analysis Of The Winter Air temperature And SST at the Corresponding Period

By using the method of SVD, and taking the winter air temperature of the arid central Asia as left field and the winter SST of the North Pacific as right field, the first six pairs singular vectors of the explanation variance and correlation coefficient between winter air temperature and winter SST are obtained. Tab. 1 shows that the accumulated explanation variance of the first six pairs singular vectors can account for up to 97% of the total variance. Especially, the first pair of singular vector can account for 85% of the total variance. This means the first pair of singular vector can reflect correlation of the two series (i.e. the winter air temperature and the SST) well. Also, the first pair of singular vector can discribe the main coupling relationship between winter air temperature of arid central Asia and winter SST of the North Pacific.

Tab.1 The explanation variance and correlation coefficient between winter temperature of arid central Asia and SST of North Pacific by the method of SVD

| singular vectors | the first pair | the second pair | the third pair | the fourth pair | the fifth pair | the sixth pair |
|---|---|---|---|---|---|---|
| explanation variance （%） | 84.91 | 6.31 | 2.28 | 1.84 | 1.36 | 1.03 |
| accumulated explanation variance （%） | 84.91 | 91.22 | 93.50 | 95.34 | 96.70 | 97.73 |
| correlation coefficient | 0.31 | 0.41 | 0.32 | 0.38 | 0.35 | 0.42 |

For spatial distribution of the first pair of singular vector of winter air temperature (Fig. 1a), the correlation coefficient is negative and the greatest value is located at South Xinjiang and western Mongolia. At the corresponding period, for spatial distribution of the winter SST of the North Pacific (Fig. 1b), the area with absolute value of correlation coefficient greater than 0.2 is mainly located at the equatorial central–eastern Pacific (ECEP). These spatial distributions mean that there is obvious positive correlation between winter air temperature of the arid central Asia and winter SST of the North Pacific. The winter air temperature of the arid central Asia is much warmer (cooler) when high positive (negative) SSTA occurs in the ECEP in winter.

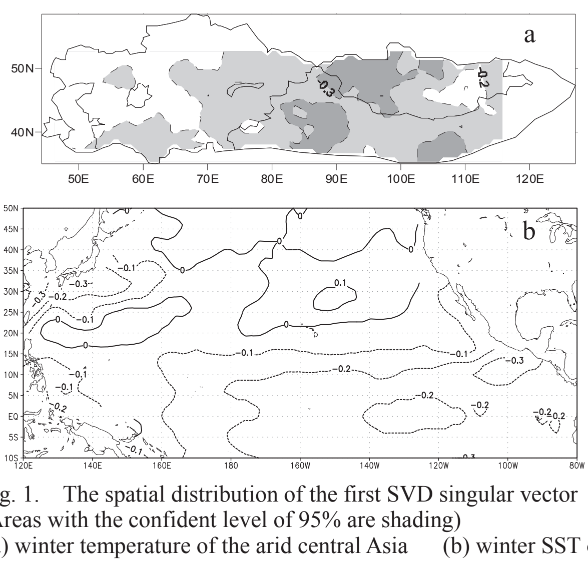


Fig. 1. The spatial distribution of the first SVD singular vector (Areas with the confident level of 95% are shading)
(a) winter temperature of the arid central Asia (b) winter SST of the North Pacific

### 3.2 The SVD Analysis Of The Winter Air temperature And SST at the Former Period

By using the method of SVD, and taking the winter air temperature of the arid central Asia as left field and the autumn SST of the North Pacific as right field, the first six pairs singular vectors of the explanation variance and correlation coefficient between winter air temperature and autumn SST are obtained. The accumulated explanation variance of the first six pairs singular vectors can account for 98% of the total variance. Especially, the first pair of singular vector can account for 87% of the total variance (not shown). Therefore, the coupling relationship between winter air temperature of the arid central Asia and autumn SST of the North Pacific can be discribed by analying the first pair of singular vector.

For spatial distribution of the first pair of singular vector of winter air temperature (not shown), the correlation coefficient is negative in the whole area and the greatest value is located at western Mongolia. At the former period, for spatial distribution of autumn SST of the North Pacific (not shown), it seems that the distribution is likely same as that of winter SST (see Fig.1b). These spatial distributions mean that there is obvious positive correlation between winter air temperature of the arid central Asia and autumn SST of the North Pacific as well. The winter air temperature of the arid central Asia is much warmer (cooler) when high positive (negative) SSTA occurs in the ECEP in autumn.

According to the above analysis, it can be seen that the SSTA produces effects on air temperature change over the arid central Asia. The winter temperature of the arid central Asia is much warmer (cooler) when high positive (negative) SSTA occurs in the ECEP from autumn to winter.

## 4 RELATIONSHIP BETWEEN SUMMER AIR TEMPERATURE OF THE ARID CENTRAL ASIA AND SST OF THE NORTH PACIFIC BY SVD ANALYSIS

### 4.1 The SVD Analysis Of The Summer Air temperature And SST at the Corresponding Period

Taking the summer air temperature of the arid central Asia as left field and the summer SST of the North Pacific as right field by using the method of SVD, the first six pairs singular vectors of the explanation variance and correlation coefficient between summer air temperature and summer SST are obtained. The accumulated explanation variance of the first six pairs singular vectors can account for 96% of the total variance. Especially, the first pair of singular vector can account for 68% of the total variance (not shown). And the correlation coefficient between every pair of singular vectors pass confident level of 99.999%. Therefore, the coupling relationship between summer air temperature of the arid central Asia and summer SST of the North Pacific can be discribed by analying the first pair of singular vector.

For spatial distribution of the first pair of singular vector of summer air temperature (Fig. 2a), the correlation coefficient is negative in the whole area and the greatest value is located at central Xinjiang and western Mongolia. At the corresponding period, for spatial distribution of summer SST of the North Pacific (Fig. 2b), the correlation coefficients exceed 0.2 over the equatorial eastern Pacific, the “warm pool”, the Kuroshio area and the westerly drift zone. These spatial distributions mean that there is obvious positive correlation between summer air temperature of the arid central Asia and summer SST of the North Pacific over above mentioned areas. The summer air temperature of the arid central Asia is much warmer (cooler) when high positive (negative) SSTA occurs in the equatorial eastern Pacific, the “warm pool”, the Kuroshio area and the westerly drift zone in the western North Pacific in summer.

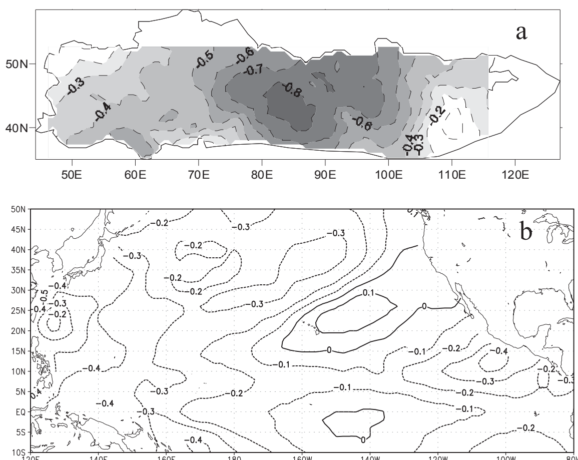


Fig. 2 The spatial distribution of the first SVD singular vector(Areas with the confident level of 95% are shading)
(a) summer temperature of the arid central Asia (b) summer SST of the North Pacific

### 4.2 The SVD Analysis Of The Summer Air temperature And SST at the Former Period

By using the method of SVD, and taking the summer air temperature of the arid central Asia as left field and the spring SST of the North Pacific as right field, the first six pairs singular vectors of the explanation variance and correlation coefficient between summer air temperature and spring SST are obtained. The accumulated explanation variance of the first six pairs singular vectors can account for 97% of the total variance. Especially, the first pair of singular vector can account for 68% of the total variance (not shown). Therefore, the coupling relationship between summer air temperature of the arid central Asia and spring SST of the North Pacific can be discribed by analying the first pair of singular vector.

Fig. 3a and Fig. 3b show the spatial distribution of the first pair of singular vector of summer air temperature and spring SST, respectively.

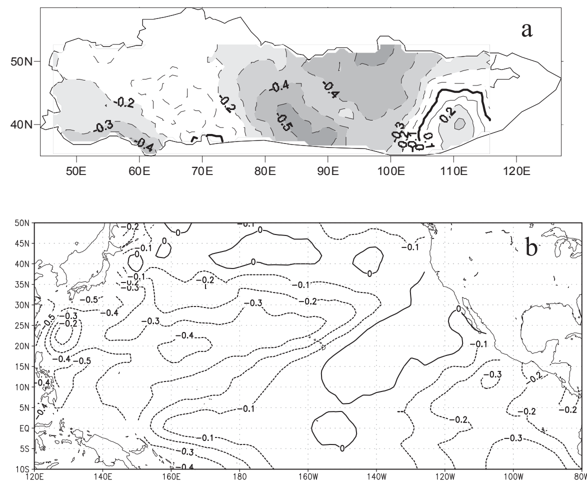


Fig. 3 The spatial distribution of the first SVD singular vector(Areas with the confident level of 95% are shading)
(a) summer temperature of arid central Asia (b) spring SST of the North Pacific

For spatial distribution of the first pair of singular vector of summer air temperature (Fig. 3a), the correlation coefficient is almost negative in the whole area except for the east part. At the former period, for spatial distribution of the spring SST of the North Pacific (Fig. 3b), the correlation coefficients exceed 0.2 over the equatorial eastern Pacific and the Kuroshio area. These spatial distributions mean that there is an opposite change trend of temperature among the east part and the other areas over the arid central Asia. There is obvious positive correlation between summer air temperature of the arid central Asia (except for the east part) and spring SST of the North Pacific over the equatorial eastern Pacific and the Kuroshio area. The summer air temperature of the arid central Asia (except for its east part) is much warmer (cooler) when high positive (negative) SSTA occurs in the equatorial eastern Pacific and the Kuroshio area in spring. For the east part of the arid central Asia, its summer air temperature is much cooler (warmer) when high positive (negative) SSTA occurs in the equatorial eastern Pacific and the Kuroshio area in spring.

## 5. SST ANOMALY DURING TWO GLOBAL WARNING PERIODS IN THE 20TH CENTURY

It is well known that two warming periods exist in the 20th centrury, namely the first warming period from the 1920s to the 1940s and the second warming period from 1970s to 1990s. Fig.4a and Fig.4b show the distribution of the SSTA during the two warming periods, respectively.

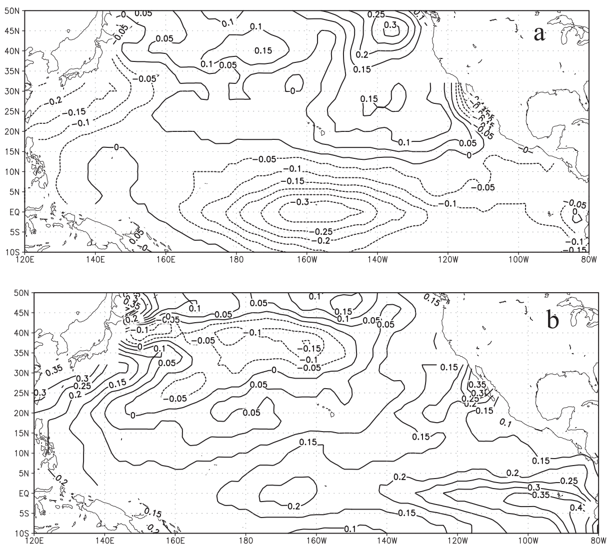


Fig. 4 Average Northern Hemisphere SSTA
(a)1920s-1940s (b)1970s-1990s

It can be seen from Fig.4a and Fig.4b that the SSTA presents opposite change trend during the two warming periods over the ECEP, the "warm pool", the Kuroshio area and the westerly drift zone in the western North Pacific. In section 3, the results had shown that the winter temperature of the arid central Asia is much warmer (cooler) when high positive (negative) SSTA occurs in the ECEP from autumn to winter. The distribution of the SSTA in Fig.4a is just the distribution, which can result in much cooler winter temperature in the arid central Asia. However, the distribution of the SSTA in Fig.4b is just the distribution, which can result in the much warmer winter temperature in the arid central Asia. Namely, comparision between the 1920s-1940s and the 1970s-1990s, winter temperature during the former period is cooler than that during the latter period. Because the annual temperature over the arid central Asia is mainly dominated by the winter temperature [10]. So the cause of winter temperature incresing can explain the cause of annual temperature incresing. Fig.4a shows the SSTA in the ECEP decreases obviously, this is one of the factors to result in air temperature decreases in the arid central Asia during 1920s-1940s. Fig.4b shows the SSTA in the ECEP increases obviously, this is one of the factors to result in air temperature increases in the arid central Asia during 1970s-1990s.

## 6. CONCLUSIONS

The SSTA produces effects on air temperature over the arid central Asia. The winter temperature of the arid central Asia is much warmer (cooler) when high positive (negative) SSTA occurs in the ECEP from autumn to winter. The summer temperature of the arid central Asia is much warmer (cooler) when significantly higher (lower) summer SST occurs in the ECEP, "warm pool", the Kuroshio area and the westerly drift zone in the western North Pacific. Also, the summer temperature is prone to be higher (lower) in the arid central Asia with exclusion of its east when much higher (lower) spring SST occurs in the ECEP and the Kuroshio.

The arid central Asia made different responses to the two warming periods during the 1920s-1940s and 1970s-1990s, in close dependence on the SSTA controlling the arid area at the two time intervals. The highly warm ECEP SST is a factor to result in higher temperature in the arid central Asia. The impacts of global warming during the 1920s-1940s and 1970s-1990s differ upon the arid central Asia, resulting in its different responses thereto.

## ACKNOWLEDGMENT

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