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THE EAST ASIAN SUBTROPICAL SUMMER MONSOON INDEX AND ITS RELATION WITH THE CLIMATE ANOMALIES IN CHINA

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Abstract: A new East Asian subtropical summer monsoon circulation index is defined, where the barotropic and baroclinic components of circulation are included. Results show that this index can well indicate the interannual variability of summer precipitation and temperature anomalies in China. A strong monsoon is characterized by more rainfall in the Yellow River basin and northern China, less rainfall in the Yangtze River basin, and more rainfall in south and southeast China, in association with higher temperature in most areas of China. Furthermore, comparison is made between the index proposed in this paper and other monsoon indexes in representing climate anomalies in China.

Key words: East Asian subtropical summer monsoon; monsoon index; climate anomalies in China

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1 INTRODUCTION

The defining of an index for the circulation of summer monsoon circulation in subtropical East Asia is the basis for the research into its interannual variation and causation. Due to the complexity of the summer monsoon itself, there has not been any method for defining the index that is widely accepted. One of the indexes has been defined based on the view that the summer monsoon in continental East Asia is mainly resulted from zonal thermal differences between land and sea [1]. Improvements are made on it [2]. Meridional temperature differences between land and sea are also taken into account [3]. Respective monsoon indexes are proposed from the viewpoint of vertical shear of meridional winds and atmospheric teleconnection patterns [4, 5].

It is pointed out that the definition of the index may not be complete if only the dynamic or thermal factor is focused on, as the subtropical East Asian summer monsoon is under both barotropic and baroclinic actions and the eastern part of the Chinese mainland is in the transitional zone between two planetary-scale circulation systems, a baroclinic (thermal) cyclonic circulation with a westward center and a barotropic (dynamic) anti-cyclonic circulation with a eastward center.

Naturally, the follow questions arise. (1) How are the barotropic and baroclinic characteristics of the East Asian summer monsoon considered in constructing the index for monsoonal circulation? (2) Does the index so defined better reflect the anomalous features of the summer weather and climate in China? They are to be discussed in this work.

2 DATA AND METHODS

Global monthly wind field from the NCEP / NCAR reanalysis data for 1961 — 1995, with 12 vertical layers between 1000 hPa and 100 hPa and horizontal resolution at 2.5°×2.5°, and precipitation and air temperature data from 160 weather stations across China were used in the work.

The wind field for a given isobaric surface $\vec{V}$ is decomposed into the sum of $\vec{V}_T$ and $\vec{V}_C$, i.e.

$$\vec{V} = \vec{V}_T + \vec{V}_C \qquad (1)$$

where

$$\vec{V}_T = (P_S - P_T)^{-1} \int_{P_T}^{P_S} \vec{V}\, dp \qquad (2)$$

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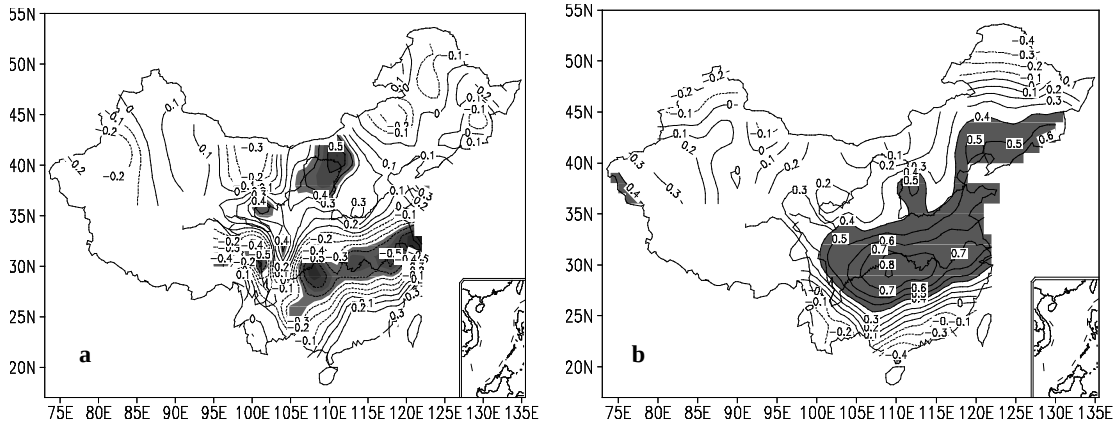

Fig.1 Distribution of simultaneous correlation between SMI and precipitation (a) and air temperature (b)in the summer months of June, July and August in China for 1961 – 1995. Shaded areas have passed the *t* test with confidence level at 95% and the contour is at the interval of 0.1.

Then,

$$\vec{V}_C = \vec{V} - \vec{V}_T \qquad (3)$$

Specifically, P_s denotes the surface pressure and P_T the isobaric surface for the upper boundary (taken to be 100 hPa). $\vec{V}_T$ indicates a mass-weighted mean wind field between P_s and P_T, which represents the part of the actual tropospheric wind that does not change with height. Hereafter, $\vec{V}_T$ is called the "barotropic component" and $\vec{V}_C$ the "baroclinic component".

3 DEFINITION OF SUMMER MONSOON CIRCULATION INDEX FOR SUBTROPICAL EAST ASIA

As the summer monsoon in subtropical East Asia is subject to both the barotropic and baroclinic action, the index for defining its intensity has to reflect the characteristics of both aspects. Therefore, the index is defined as follows:

$$\mathrm{SMI} = (VT_A - VT_B) + (VC_C - VC_D) \qquad (4)$$

Specifically, SMI (Summer Monsoon Index) is the one for summer monsoon circulation in subtropical East Asia, VT_A(VT_B) the vorticity of the flow field of the barotropic component averaged over Region A (B), and VC_C(VC_D) the vorticity of the flow field of the baroclinic component averaged over Region C (D). Regions A, B, C and D cover the areas of (110°E – 130°E, 20°N – 30°N), (110°E – 130°E, 35°N – 45°N), (100°E – 130°E, 30°N – 50°N) and (140°E – 170°E, 20°N – 40°N), respectively.

The first term of the monsoon circulation index above indicates the cyclonic or anticyclonic anomalies of barotropic component in the north – south direction and the second term shows the thermal difference between land and sea in East Asia, which is mainly in the east – west direction and slightly in the north – south direction as well. It agrees with the NNE – SSW orientation of the coastline of the East Asian region.

4 RELATIONSHIPS BETWEEN THE INDEX AND SUMMER CLIMATIC ANOMALIES IN CHINA

As shown in Fig.1a, the southern part and southeastern coast of China are positive with a maximum correlation coefficient of 0.3; the Yangtze River valley is a NE – SW strip that is generally negative with a negative correlation center of -0.5 while the Yellow River valley centered around the Great Bend is positively distributed with the correlation center at 0.5. Therefore, with strong summer monsoon, the Yellow River valley centered around the Great Bend and northern China are with more rain but the Yangtze River valley is with less rain, with anomalous precipitation is recorded in the southern part and southeastern coast of China. With weak summer monsoon, however, the opposite is true. It is mainly in the north – south position of summer rain band that the intensity of the summer monsoon in subtropical East Asia is associated with Chinese precipitation in summer. A stronger summer monsoon is associated with northward rain band.

Fig.1b shows consistently positive distribution of correlation coefficient in most of China, with the maximum of positive correlation in the middle reach of the Yangtze River (coefficient as high as 0.8). It shows that a strong summer monsoon is accompanied with high air temperature in summer over many parts of China, with the valley of Yangtze River the most predominant.

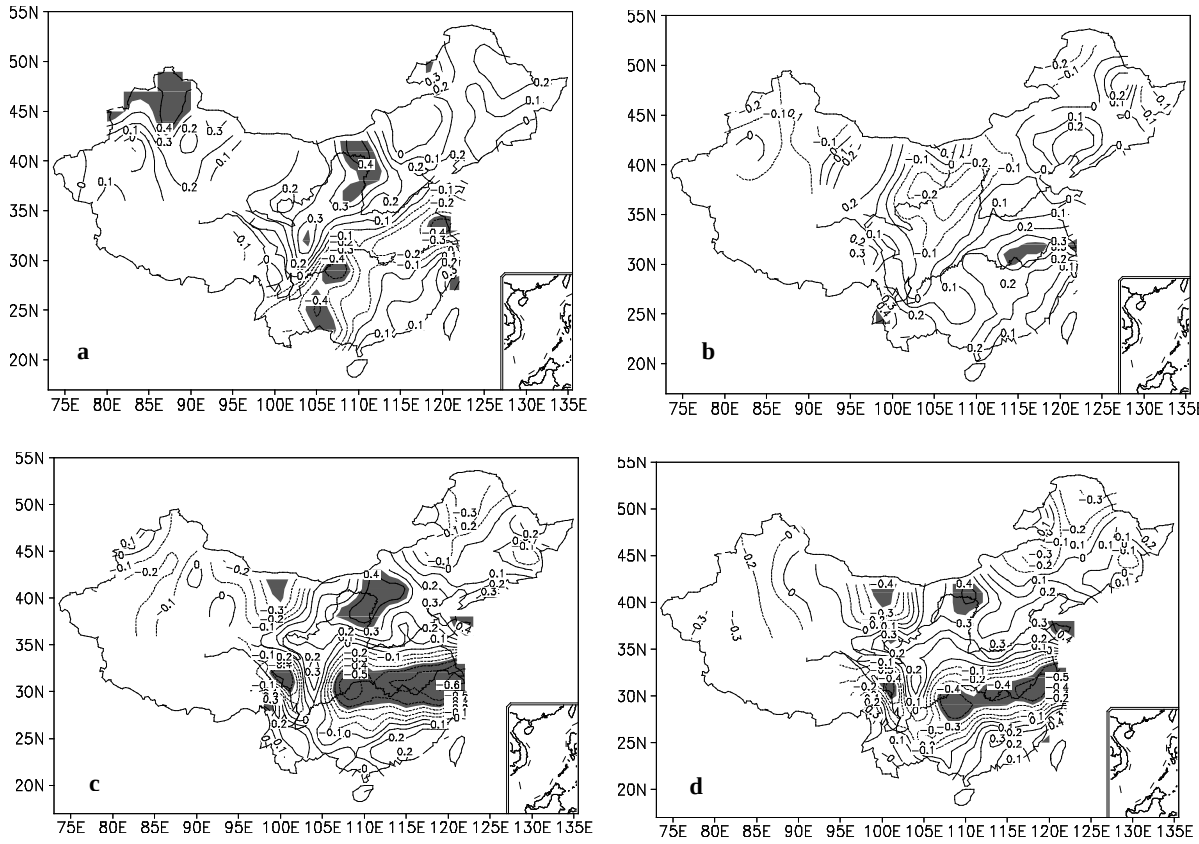

Fig.2 Distribution of simultaneous correlation between four monsoon indexes and precipitation in the summer months of June, July and August for 1961 – 1995. (a) SLP index; (b) IES index; (c) LSTD index; (d) EAP index. Shaded areas have passed the *t* test with confidence level at 95% and the contour is at the interval of 0.1.

5 COMPARISONS OF SMI WITH FOUR OTHER INDEXES

The four other monsoon indexes for East Asia to be compared are the SLP index, which is constructed using zonal sea level pressure difference [2], IES index, which is made from the vertical shear of meridional wind[4], LSTD index, which is determined using zonal and meridional land-sea temperature difference, and EAP index , which shows the atmospheric teleconnection pattern [5].

Fig.2 gives the distribution of simultaneous correlation of the four monsoon indexes with the summer precipitation in China. The patterns of correlation coefficients show that the anomalous distribution of summer precipitation in eastern China as seen in Fig.2 (a, c and d) are all similar to that in Fig.1a, i.e. strong monsoon years are associated with less rain in the Yangtze River valley but more rain in northern China while the anomalous distribution of precipitation shown in Fig.2b is just the reversed. It may be attributed to the mainly tropical latitudes (10°N – 25°N) taken for the IES index, which results in different reflection of Chinese precipitation in summer from the other indexes. With comprehensive consideration, it is the authors' view that the SMI index does a good job in reflecting the location of the summer rain band in China, which is mainly in the areas of the Great Bend and northern China in strong monsoon years, with less precipitation in the middle and lower reaches of the Yangtze River. It is shown from the magnitude of the numerals in Figs. (1a, 2a, 2c and 2d) that the SMI index is the best in reflecting the precipitation in the Great Bend with the correlation coefficient being as high as 0.5; the SLP and LSTD have comparable reflection with the correlation coefficient being 0.4; the LSTD index is the best in indicating the precipitation in the middle and lower reaches of the Yangtze River, with the correlation coefficient being –0.6, followed by the SMI and EAP indexes (both being –0.5) and further away by the SLP index (-0.4) and with smaller area of significant correlation.

It is known from the above comparisons that the methods for determining the SMI, LSTD and EAP indexes, which are different in the aspect they focus on, may indicate the common nature of the summer monsoon in subtropical East Asia from different points of view, for they show high consistence in reflecting

the summer precipitation in China.

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

6 CONCLUSIONS

Based on the observation that the summer monsoon in subtropical East Asia is a mixed process involving both barotropic and baroclinic action, an index (SMI) has been put forward for it and its relationships with climatic anomalies in China are discussed. It is shown in the analysis that:

(1) The SMI index successively describes the anomalies of summer climate in China. In the years of strong summer monsoon, the rain band is more northward than usual with more rain in northern China centered around the Great Bend of the Yellow River but less rain in the Yangtze River; air temperature is anomalously higher in most parts of China, especially so in the Yangtze River valley.

(2) As shown in the comparison with four other indexes, the SMI index, like the LSTD and EAP indexes, is successive in reflecting the summer precipitation in China.

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