Tropical Convective Activities Related to Summer Rainfall Anomaly in China①

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ABSTRACT

The paper presents the SVD–revealed relation of the tropical convection anomaly patterns to the summer rainfall counterparts of China, indicating that a) the ENSO–associated tropical convection anomaly is highly advantageous but the corresponding rainfall anomaly can only account for 10.3% of total variance, the rainfall anomaly related to tropical monsoon variation with the northern South China Sea as the center of convection abnormality for 18.8% and to the variation inside the tropical monsoon for 11.2%; b) the ENSO–related summer precipitation anomaly displays a pattern of excessive rainfall in the south and deficit in the north, the anomaly relative to the tropical monsoon variation a pattern of more precipitation in the Yangtze River valleys and less in North, Northeast and South China, and that in relation to the variation within the tropical monsoon a pattern of two rainbands, one in the Yangtze River valleys and the other in North China.

Key words: Tropical convection, Singular value decomposition (SVD), Rainfall pattern

1. Introduction

Tropics serves as the predominant zone of thermal source for driving atmospheric circulations that is linked to latent heat released by the convection. The anomaly of tropical air–sea interaction represented by ENSO is such as to cause severe abnormality of convection therein, which will affect atmospheric circulations and climate on a global basis (Bjerknes, 1969). Therefore, the air–sea interaction anomaly, and especially the ENSO–associated global climate anomaly have been a subject of much interest. Chinese meteorologists have made enormous effort at the relationship of the interaction anomaly to the climate abnormality in China, reaching noteworthy fruits. As early as 1970s, Fu et al. (1977) and Chen (1977) documented the relation of the eastern Pacific SSTA to the western Pacific subtropical highs and summer rainfall anomaly in China (CSRA). In their study of 7 droughts and as many of flood events over the middle and lower reaches of the Yangtze River, Li et al. (1987) showed that the SSTA pattern for the drought (flood) year falls into the El Nino (La Nina) type. Chen, et al.(1991) asserted on a statistical basis that the equatorial eastern Pacific SSTA bears no correlation with the rainfall departures of the middle and lower reaches of the Yangtze River in the context of population sample. Fu et al. (1985) held that effects of ENSO on the

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CSRA depend on the former's category in contrast to the dependence on its phase, as argued by Huang et al. (1989). Besides, Chinese investigators indicated an intimate relation between CSRA and the SSTA in the Indian Ocean and South China Sea (Luo et al., 1985; Chen, 1991; Chen et al., 1996). In fact, tropical SSTA exerts its impact on atmospheric circulations and then the climate of China through tropical convection. Accordingly, Nitta (1987) and Huang et al. (1988) stated that the western Pacific " warm pool" convection anomaly is such as to excite a wavetrain that propagates northeastward into China and North America. Huang et al. made further study on the CSRA influence of the thermal condition of the warm pool, arriving at the conclusion that as the warm pool is warmer(colder), the Philippines convective activities are vigorous (feeble), responsible for the western Pacific subtropical high positioned northward (southward) of normal, leading to rainfall deficit (plenty) over the Changjiang–Huaihe River valleys and abundant (insufficient) precipitation for the Yellow–River basins and South China. However, this explains just one pattern of the CSRA whose multiplicity needs to be explored further. With this motivation in mind we attempt to investigate the relationships of the patterns of tropical convection anomaly to those of the CSRA.

2. Data

The data used consist of

1) global monthly NOAA satellite OLR at 2.5° × 2.5° resolution from January 1979 to December 1997, from which the June–August means for each of the years are taken at 5° × 5° resolution over the tropical band to investigate summer convection;

2) rainfall averaged over June–August, 1979–1997 from 160 stations in China, compiled by the China Meteorological Administration on a monthly basis;

3) SST in the same period from NCEP / NCAR monthly re–analysis.

3. Relationship between the pattern of tropical convection anomaly to that of the CSRA

To make approach to the relationship, singular value decomposition (SVD) is adopted, with 160–station CSRA as the left field and tropical 637–gridpoint OLR anomaly (30°N,S; 40–280°E) as the right counterpart. To eliminate the imbalance of total variance of the two fields, the left(right) field is multiplied by total variance of the right(left) field before SVD is undertaken and then each of the obtained singular vectors is divided by the total variance that has been applied for multiplication after SVD is employed. The sequence of time coefficients for each singular vector (SV) is kept normalized so that the SV distribution will denote the strength of actual anomaly. To illustrate the anomaly relation we prepared the following table, wherefrom we see that a) for the left field, a considerable part of total variance falls onto the first three SVs, indicative of the multiplicity of the SCRA patterns (totaling in 40.3%, each in excess of 10% and the second (SV2) reaching 18.8%); b) for the right field, SV1 accounts for 25.3% of total variance and the others each explain < 10%, suggestive that the tropical convection anomaly (TCA) has a greatly preferred pattern (the first three have the sum of 41.7% of total variance); c) the TCA SV1 (25.3%) is absolutely predominant but the corresponding CSRA SV1 only accounts for 10.3%. The TCA SV2 and SV3 (each smaller than 10%) relate to 18.8% and 11.2% of the corresponding CSRA singular vectors, respectively, indicating that the TCA preferred pattern is not so closely related to CSRA. As we shall see from the following analysis, though ENSO events are the strongest signal for

TCA but nevertheless, other TCA patterns seem to be more intimately linked to the CSRA. Accordingly, it is necessary to examine the relation between the CSRA and TCA (which is however related to other than ENSO).

Table 1. Percentage of total variance explained by each of the first 10 SVD–produced singular vectors of the left (LF) and right field (RF) with their correlation coefficients (CC) given

	Singular Vector									
	1	2	3	4	5	6	7	8	9	10
LF	0.103	0.188	0.112	0.075	0.053	0.051	0.052	0.040	0.048	0.040
RF	0.253	0.098	0.066	0.082	0.079	0.058	0.050	0.053	0.040	0.042
CC	0.83	0.84	0.88	0.85	0.93	0.91	0.90	0.94	0.87	0.92

3.1 *ENSO – CSRA relationship*

The SV1 field of summer OLR anomaly (Fig.1a) explains 25.3% of total variance and is hence the most preferred pattern, almost symmetric about the equator, with pronounced TCA oscillation from the eastern Indian Ocean to the maritime continent / equatorial Pacific, whose centers are located, one in Indonesia (central vigor of >50 W m^{-2}) and the other in the equatorial central–western Pacific to the west of the dateline (central vigor of <50 W m^{-2}); the bands on the north and south side of the centers are marked by opposite TCA, indicating the convective anomaly connection between the equatorial and subtropical belt; another negative OLR anomaly area (central vigor of <30 W m^{-2}) is in the western Indian Ocean, suggesting the air–sea interplay relation between the Pacific and Indian Ocean.

The synchronous correlation of time coefficients of SV1 with summer SSTA (refer to Fig.4) shows the related SST field is similar to the ENSO pattern with maximum positive correlativity in the equatorial central / eastern Pacific whose center (>0.9) is on the east side of the dateline and another (>0.6) centered in the western Indian Ocean in contrast to a negative correlation region in the western Pacific with the central value of –0.7. It is seen from the plot of the temporal coefficients of SV1 (see Fig. 3a) that the ENSO events in 1982 / 1983, 1986 / 1987, 1991 / 1992 and 1997 are in a positive phase so that the ENSO–related TCA pattern is uncovered by this singular vector (SV1).

Figure 2a displays the CSRA distribution (left–field SV1) which is correlated with the above TCA pattern (right–field SV1), reaching the correlation of 0.83, suggestive of a close relation to ENSO events. We also see therefrom that the singular vector reveals the anti–correlative feature of east China summer precipitation in the north and south, i.e., when TCA falls into an ENSO–related pattern, excessive rainfall occurs to the south of the Yellow River in such a way that two rainfall anomaly cores emerge in the upper and middle reaches of the Yangtze River and the band south of its lower basins in particular (80 mm $month^{-1}$) while rainfall deficit happens north of the Yellow River, with maximum of –80 mm $month^{-1}$ in NW and NE China. Reversal takes place with TCA in an anti–ENSO pattern.

From the foregoing analysis we come to the conclusion that the ENSO–associated TCA gives rise to the pattern of southern wetness and northern dryness in China.

3.2 *Relation of variation in tropical summer monsoon to the CSRA*

Although the TCA SV2 (Fig.1b) accounts for < 10% of total variance, the related CSRA

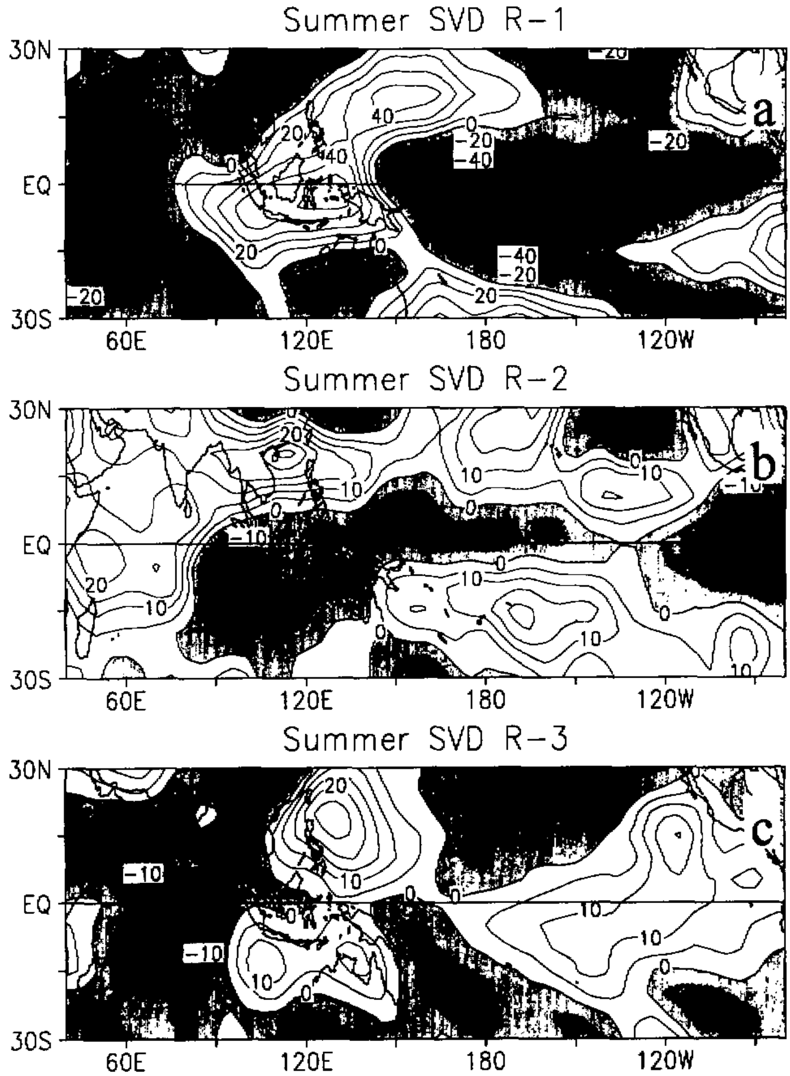

Fig. 1. SVD−produced SV1 (a), SV2 (b) and SV3 (c) based on OLR anomaly averaged over June−August. Units: W m^{-2}.

SV2 explains 18.8%, showing its closest relation to the rainfall anomaly. It is seen therefrom that the Asian tropical monsoon region as a whole is under the control of positive OLR anomaly, suggestive of weaker convection therein, with maximum positive OLR anomaly (>40 W m^{-2}) in the northern South China Sea. An anomalous convection band in the near−equatorial South China Sea and the Southern Hemisphere, centered on the SH side. Therefore, the singular vector displays the variation in the Asian tropical summer monsoon as

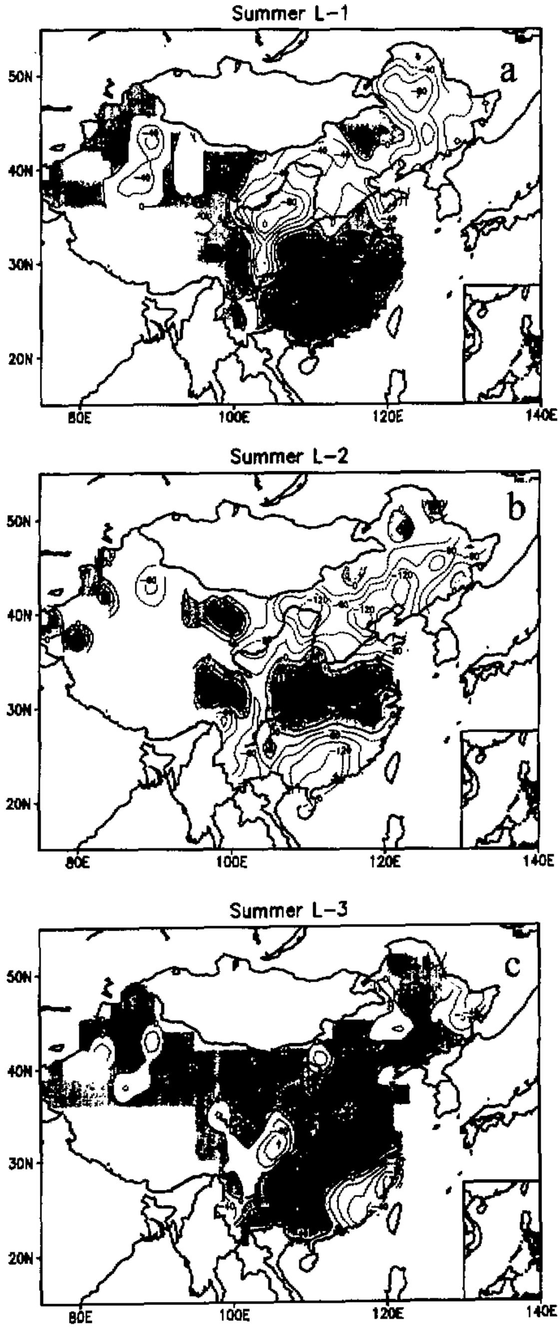

Fig. 2. SVD-produced SV1 (a), SV2 (b) and SV3 (c) based on rainfall anomaly averaged over June–August from 160 stations. Units: mm $month^{-1}$.

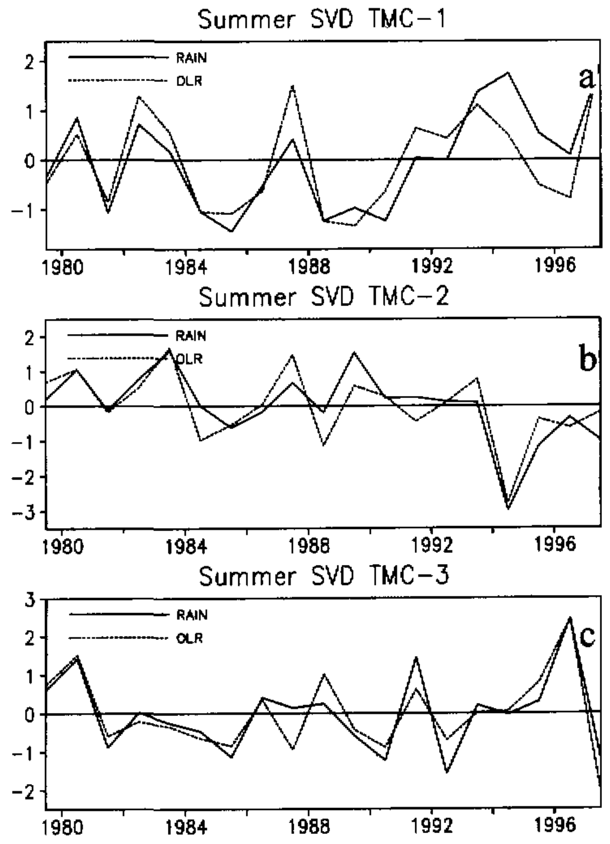

Fig. 3. Time coefficients of SV1 (a), SV2 (b) and SV3 (c). Dashed (solid) line denotes the OLR anomaly (CSRA).

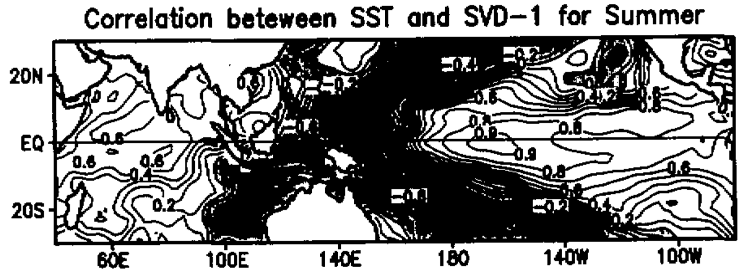

Fig. 4. SV1 temporal coefficients of OLR anomaly correlated to SST on a synchronous basis.

a whole, especially its East Asian subsystem with the South China Sea as the anomaly center.

The time coefficients of SV2 of OLR anomaly and CSRA (Fig.3b) arrive at the correlation of 0.84 and the CSRA pattern associated with summer monsoon variation takes the form of excessive precipitation in the Yangtze River catchments and insufficient in North, NE and South China.

3.3 *Relationship between variation inside summer monsoon and CSRA*

The TCA SV3 (Fig.1c) illustrates the East Asian monsoon region east of 100°E is under the control of positive OLR anomaly, centered on the tropical NW Pacific (>30 W m^{-2}) and the South Asian monsoon west of the longitude is under the effect of negative OLR anomaly. Consequently, this singular vector indicates an opposite pattern of TCA in the East Asian to that in the South Asian monsoon region, revealing the variation inside tropical monsoon, with the tropical NW Pacific as the anomaly center.

The time coefficients of SV3 of the left and right field (Fig. 3c) reach the correlation of 0.88. The left–field SV3 (Fig. 2c) shows that the CSRA associated with the intra–monsoon variation has a pattern of excessive precipitation over most of the country except South China seaboard hit by drought, with the maximum rainfall anomaly belt (central value of 80 mm $month^{-1}$) stretching from the Yangtze River basins to SW China, and another anomaly band (60 mm $month^{-1}$) lies in North China, thus constituting a bi–band rainfall pattern of CSRA.

From the foregoing investigation, we see a close relation of TCA to CSRA patterns. It awaits further research into the physical mechanisms for their connections.

4. Concluding remarks

The following are worthy of note based on the above analysis.

While the ENSO events–associated TCA are greatly advantageous (SV1 explaining 25.3% of total variance), the corresponding CSRA has its SV1 of 10.3% only. Instead, the tropical monsoon variation (SV2, 9.8%) with the northern South China Sea as the TCA core is linked most closely to CSRA (SV2, 18.8%) and the CSRA relating to the variation inside tropical monsoon (SV3, 6.6%) accounts for 11.2% of total variance.

The CSRA in relation to ENSO events displays a pattern of southern flood and northern drought; to tropical summer monsoon variation of excessive precipitation over the Yangtze River valleys and deficient in North, Northeast and South China; to intra–tropical monsoon variation of two hyetal bands, one in the Yangtze River catchments and the other in North China.

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