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# EFFECTS OF ENSO ON THE RELATIONSHIP BETWEEN IOD AND SUMMER RAINFALL IN CHINA

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**Abstract:** Based on the data of 1950 – 1999 monthly global SST from Hadley Center, NCAR/NCEP reanalysis data and rainfall over 160 weather stations in China, investigation is conducted into the difference of summer rainfall in China (hereafter referred to as the "CS rainfall") between the years with the Indian Ocean Dipole (IOD) occurring independently and those with IOD occurring along with ENSO so as to study the effects of El Niño - Southern Oscillation (ENSO) on the relationship between IOD and the CS rainfall. It is shown that CS rainfall will be more than normal in South China (centered in Hunan province) in the years of positive IOD occurring independently; the CS rainfall will be less (more) than normal in North China (Southeast China) in the years of positive IOD occurring together with ENSO. The effect of ENSO is offsetting (enhancing) the relationship between IOD and summer rainfall in Southwest China, the region joining the Yangtze River basin with the Huaihe River basin (hereafter referred to as the "Yangtze-Huaihe basin") and North China (Southeast China). The circulation field is also examined for preliminary causes of such an influence.

**Key words:** Climatology; summer rainfall in China; partial correlation analysis; Indian Ocean Dipole; ENSO

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## 1 INTRODUCTION

Analyzing the Sea Surface Temperature Anomaly (SSTA) in equatorial Indian Ocean, Saji et al.[1] and Webster et al. [2] revealed a reverse-phase oscillation which acted as signals of a kind of SSTA between the east and west equatorial Indian Ocean, i.e. IOD, and stressed its independence relative to ENSO. Although they seem to be independent from each other in some isolated years, IOD and ENSO are well correlated in general and the physical processes linking them up are mainly the coupled evolution of a pair of reversely rotating Walker cells over the equatorial Pacific and Indian Ocean, as pointed out in more recent studies by Li et al.[3], Chao et al.[4] and Tan et al.[5].

IOD plays an active role in climate change, especially with regard to the climate of East Asia, as confirmed in numerous research findings. IOD has significant impacts on the Asian summer monsoons by influencing the upper tropospheric South Asian high and West Pacific subtropical high as well as the low-level tropospheric flow fields: its positive phase corresponds to strong summer monsoons in the South China Sea (SCS) and India; its negative phase corresponds to weak summer monsoon in SCS but strong summer monsoon in southern India (Li et al., [6]). The CS rainfall could be affected by IOD through the Southwest Monsoon (Yan et al.[7]). As suggested in a statistical survey by Xiao et al.[8], a positive IOD phase brings less rain to northern China but more rain to southern China, having larger impacts on the climate of China than the negative phase: the positive phase may influence the summer rainfall directly via the Southwest Monsoon while the negative phase may affect it through the Pacific-Japan wavetrain. IOD affects the CS rainfall by means of East Asian summer monsoons [9].

Due to the close relationship between IOD and ENSO, the aforementioned conclusions drawn for the effect of IOD on the East Asian summer monsoons and summer climate in China may contain something about that of ENSO [10]. The aim of this study is to determine

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whether an ENSO episode will affect the relationship between IOD and CS rainfall. They will be addressed separately with and without the ENSO effect and from the viewpoint of general circulation the reasons will be examined for the difference existing in them with and without the presence of ENSO episodes.

## 2 DATA AND METHODS

This study uses the following datasets of (i) monthly rainfall for 160 weather stations in China as compiled by China Meteorological Administration, (ii) monthly mean geopotential heights and wind fields from the NCEP / NCAR reanalysis, with horizontal resolution at 2.5°×2.5°, and (iii) monthly mean sea surface temperature (SST) at 1°×1° from the Hadley Center. They all cover a length of 1950 – 1999.

The methods of correlation analysis, composite analysis, *t*-test and partial correlation analysis are used in this study. The last method is one in which the correlation coefficient is determined for any two given signals from three or more signals by removing undesirable contribution. The three variables for this study are IODI, Niño3 and the CS rainfall.

## 3 DETERMINATION OF YEARS OF INDEPENDENT IOD OCCURRENCE AND JOINT OCCURRENCE IOD WITH ENSO

The IOD Index (IODI) as defined by Saji et al.[1], which refers to the difference of mean SSTA between the western equatorial Indian Ocean (10°S – 10°N, 50°E – 70°E) and the eastern part (10°S – 0°, 90°E – 110°E), is used in this study, and the index of Niño3 is used to represent the intensity of the El Niño (La Niña) episodes. They are standardized for the summer months of June – August and graphically depicted in Fig.1. It is shown in the computation that they are correlated by a coefficient of 0.357, which passes the 0.01 significance test. It suggests a relatively robust positive correlation between the two indices in that the positive (negative) phase of IOD is usually accompanied with the El Niño (La Niña) episode.

The years will be classified to be with positive (negative) IOD phase if their normalized IODI is more than 0.8 (less than -0.9) and they will be considered to be with El Niño (La Niña) episode if their normalized Niño3 index is more than 0.5 (less than -0.5). It is based on these criteria that the years for independent occurrence of IOD and those for joint occurrence of IOD and ENSO are determined (See Table 1).

## 4 EFFECT OF ENSO ON RELATIONSHIP BETWEEN IOD AND CS RAINFALL

Fig.2 presents the composite anomaly of CS rainfall for the years of independent occurrence of IOD. Fig.2a is for the positive phase of IOD and Fig.2b for the negative phase. When IOD independently occurs, there is significant increase (decrease) of rainfall in South China, especially in Jiangxi and Hunan provinces, in the years of positive (negative) IOD phase. It is consistent with a study on the relationship between all IOD years and CS rainfall as given in Xiao et al.[8].

To verify the composite results as presented above, the Niño3 index is so controlled that a partial correlation coefficient is determined for IODI and CS rainfall (Fig.3a). It is shown that independent occurrence of IOD affects the summer rainfall of South China significantly: rainfall is relatively large in the years of positive IOD phase but relatively small in those of negative IOD phase. To help in the discussion on the effect of ENSO on the relationship between IOD and CS rainfall, the partial correlation coefficient is sought between the Niño3 index and CS rainfall (Fig.3b). The figure shows that there are vast stretches of significantly negative correlation in

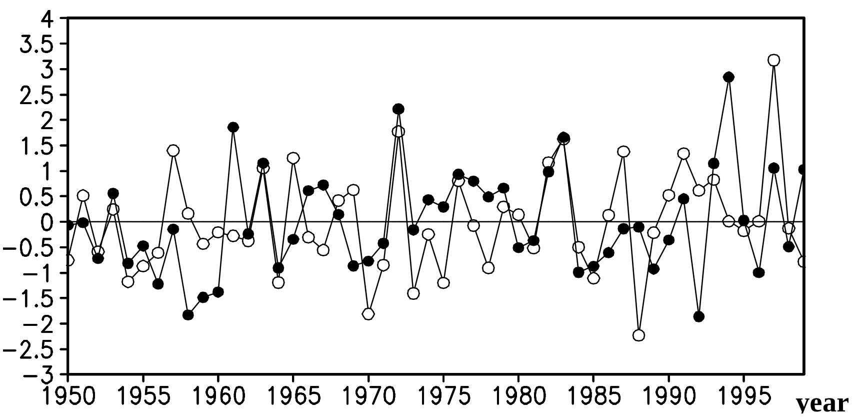


Fig.1 Curves of interannual variations of IODI (line with solid circles) and Niño3 index (line wiht hollow circles) for 1950 – 1999.

the Great Bend of the Yellow River (hereafter referred to as "Great Bend") and North China, highly positive correlation in the Yangtze-Huaihe basin, mildly negative correlation in western South China and mildly positive correlation in the coastal area of Southeast China. It agrees with the conclusion of Shi et al.[11].

Table 1 Years for independent occurrence of IOD and joint occurrence of IOD and ENSO.

| IOD phase | Years of independent IOD occurrence | Years of joint IOD and ENSO occurrence |
|---|---|---|
| positive | 1961, 1977, 1994, 1999 | 1963, 1972, 1976, 1982, 1983, 1993, 1997 |
| negative | 1958, 1959, 1960, 1989, 1992, 1996 | 1956, 1964, 1984, 1985 |

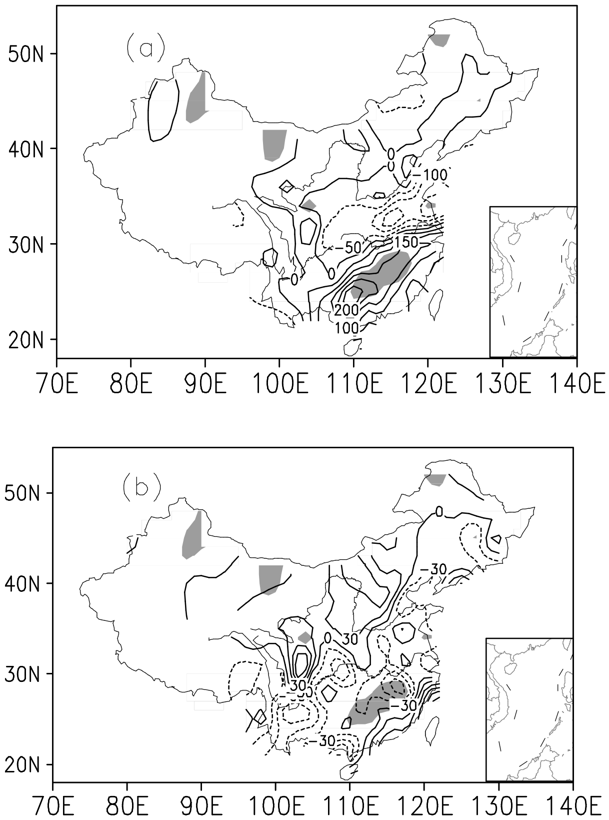


Fig.2 Composite anomalies of CS rainfall for the years of independent occurrence of IOD. a. Positive phase years; b. negative phase years. The shades indicate the areas passing the 0.1 significance *t* test. (unit: mm)

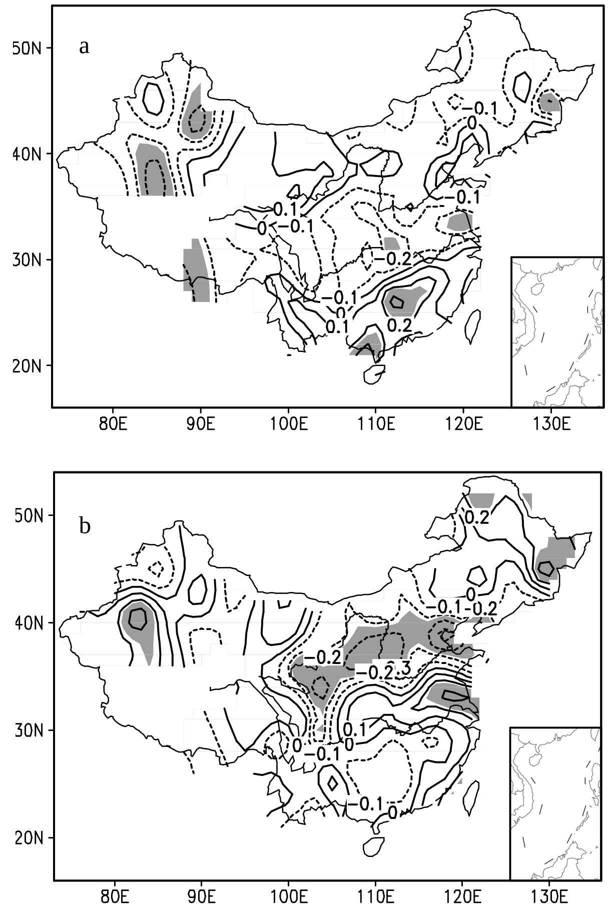


Fig.3 Partial correlation coefficients for IODI (a) and Niño3 index (b) and CS rainfall. The shades indicate the areas passing the 0.05 significance *t* test.

What has been demonstrated above is the anomalous performance of CS rainfall with the independence of IOD. To discuss a so-called "disruption" by ENSO episodes on the effect, composite anomaly will be applied to the CS rainfall for the years when IOD jointly happen with ENSO episodes (Fig.4).

For further understanding of the effect of ENSO onset on the relationship between IOD and CS rainfall, the distribution of partial correlation coefficients is compared between IODI versus the CS rainfall (Fig.3a) and Niño3 versus the CS rainfall (Fig.3b). It is shown that IOD and ENSO have enhancing effect on the rainfall: areas with the same signs are mostly in coastal Southeast China while areas with opposite signs in western South China, the Yangtze-Huaihe basin, Great Bend and North China.

For details of the analysis of circulation difference field for the years of joint occurrence and independent occurrence, see the Chinese edition of the journal.

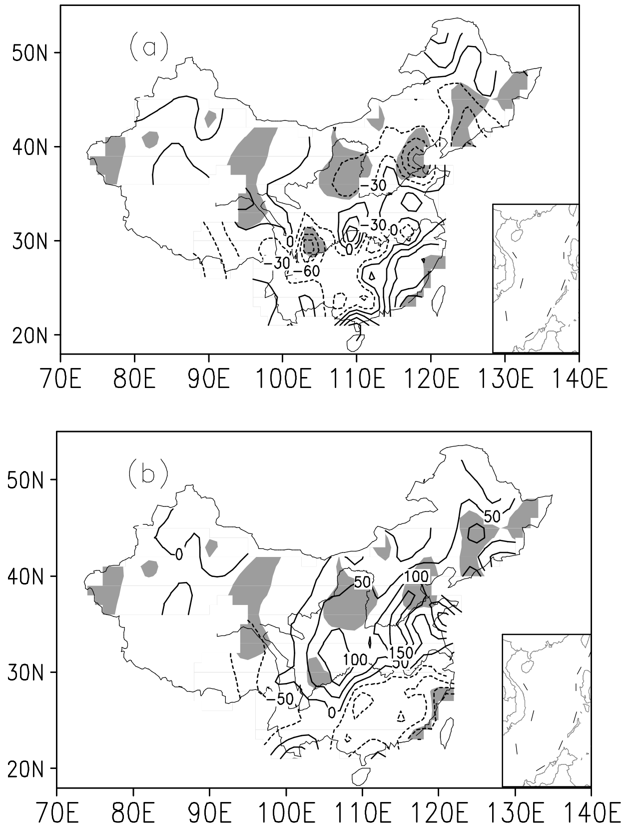


Fig.4 Composite anomalies of CS rainfall for the years of joint IOD occurrence with ENSO episodes. a. Positive phase years; b. negative phase years. The shades indicate the areas passing the 0.1 significance t test. (unit: mm)

## 5 CONCLUSIONS

With the difference of SSTA averaged for the western and eastern parts of the equatorial Indian Ocean (represented by IODI) and ENSO intensity (represented by Niño3 index), the anomalous distribution of CS rainfall is studied for either the years of independent occurrence of IOD or joint occurrence of IOD and ENSO and the effect of ENSO episodes also is discussed on the relationship between IOD and CS rainfall.

(1) In the years of positive (negative) phase of independent IOD occurrence, rainfall increases (decreases) in the area south of the Yangtze River, especially in the provinces of Jiangxi and Hunan. In the years of joint IOD and ENSO occurrence, areas of significant difference shift to northern China and rainfall decreases (increases) there corresponding to positive (negative) phase.

(2) It is shown from comparisons of the difference in CS rainfall between the years of independent IOD occurrence and those of joint IOD and ENSO occurrence that the episode of ENSO is offsetting the relationship between IOD and summer rainfall in western South China, the Yangtze-Huaihe basin, Great Bend and North China while intensifying that for the coastal area of Southeast China.

(3) Weakening (intensifying) the Asian summer monsoons and pushing the subtropical high more to the south (north), the episode of El Niño (La Niña) is the general circulation responsible for the difference in CS rainfall between the years of independent IOD occurrence and those of joint IOD and ENSO occurrence.

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