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THE RELATIONSHIP BETWEEN SCS SUMMER MONSOON INTENSITY AND OCEANIC THERMODYNAMIC VARIABLES AT DIFFERENT TIME SCALE

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Abstract: The oscillation characteristics of 1948 – 2003 South China Sea (SCS) summer monsoon intensity (SCSSMI) is analyzed by wavelet transform and the relationship between SCSSMI filtered by Lanczos filter at different time scale and oceanic thermal conditions is studied. The results show that SCSSMI exhibits dominant interannual (about 4 a), decadal (about 9 a) and interdecadal (about 38 a) oscillation periods. The interannual variation is the strongest and the interdecadal variation the weakest. The region of significant correlation between SCS summer monsoon intensity and oceanic thermodynamic variables at different time scale is greatly different. Significant correlation area of interannual variation of SCSSMI is concentrated in near equatorial region. Corresponding correlation displays quasi-biannual variability. If positive anomalies of SST and the depth of thermocline happen in eastern equatorial Indian Ocean and western equatorial Pacific, and negative anomalies of SST and the depth of thermocline happen in western equatorial Indian Ocean and eastern equatorial Pacific in previous autumn and winter, the interannual variation of SCSSMI will enhance. If the condition is contrary, interannual variation of SCSSMI will weaken. The interannual variation of SCSSMI will influence SST. The region surrounding SCS and east of Australia shows significantly negative correlation in autumn, and significantly positive correlation exhibits in west equatorial Indian Ocean, eastern equatorial Pacific and equatorial Atlantic in winter. The decadal variation of SCSSMI is modulated by PDO. Interdecadal variation of SCSSMI is relevant to the global warming and PDO.

Key words: SCS summer monsoon intensity; different time scale; oceanic thermodynamic variables; precursory signal

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1 INTRODUCTION

The outbreak of the SCS summer monsoon signifies the arrival of the summer monsoon in East Asia and the onset of rainy season in China It has significant effect on the circulation and weather in the Northern Hemisphere as well as the monsoonal system in Asia[1]. The SCSSMI usually has close relationship with severe drought and flood and precipitation in rainy season in China[2 - 4]. If precursory signals can be identified to predict the SCSSMI, it will have important practical implication for the forecast of the precipitation in rainy seasons and severe drought and flood in China.

It is shown that SST plays an important role in the variation of SCSSMI[5 - 12]. It varies on the interannual and interdecadal scales[13, 14]. It is noted, however, the above studies do not decompose SCSSMI to various scales while studying the effect of SST on the SCS

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summer monsoon and most of the areas of interest concentrate on tropical Indian Ocean and Pacific Ocean, and they do not address the effect of the monsoon on thermal factors of the ocean. It is then necessary to study the relationship between the variation of SCSSMI and oceanic thermal field for a broader domain and on more scales.

The index in [13] is used here to define the SCSSMI. First, wavelet analysis is done of the series of SCSSMI on the yearly basis from 1948 to 2003. Then, primary periods are put through the Lanczos filter[15] for the variation of SCSSMI on various time scales. In the last part of our work, the relationship between SCSSMI and oceanic thermal fields of global SST, depth of the thermocline, thermal capacity at 125 m and 500 m, which is provided in SODA (simple ocean data assimilation, available at http://dods.atmos.umd.edu/SODA)[16], is studied.

2 VARIATION CHARACTERISTICS OF SCSSMI

It is known from the wavelet coefficient (Fig.1a) that the series is marked by significant interannual, decadal and interdecadal variations. The interannual variation was stronger from the late 1960's to early 1970's and over the time after the 1970's than the rest of the interest period. The decadal variation was stronger before the 1960's and over the time from the early 1970's to the end of 1980's than the rest of the interested period. On the interdecadal scale, the index experiences shifts of becoming stronger in 1960 but becoming weaker in 1981. For the time of occurrence, the shift in 1981 was close to the abrupt climatic change at the end of 1970's[17]. Periodic changes of 8 – 10 a were mainly seen in the time from the 1950's to early 1960's and from the 1970's to 1980's while periods of quasi-2- to 3- a were predominant in the time from the 1990's to the present. It is known from the variance of wavelets that the SCSSMI mainly varies at periods of significant 4 a, 9 a and 38 a.

It is also known from wavelet variance that periodic oscillations of 5 a and 19 a are corresponding to the bandgaps of SCSSMI change. Taking them as the periods of truncation, the Lanczos filter naturally decomposes the time series of SCSSMI into changes on the interannual (less than 5 a), decadal (between 5 a and 19 a) and interdecadal (more than 19 a) scales (figure omitted). The standard deviation of the SCSSMI variation is 0.91 m/s and that of the interannual, decadal and interdecadal changes are 0.68, 0.45 and 0.22 m/s, respectively. The interannual variation is the strongest while the interdecadal variation is the weakest.

3 RELATIONSHIP BETWEEN THE CHANGE OF SCSSMI AND OCEANIC THERMAL FILED ON DIFFERENT TIME SCALES

3.1 The interannual scale

The area in which SCSSMI is significantly correlated with SST on the interannual scale is mainly

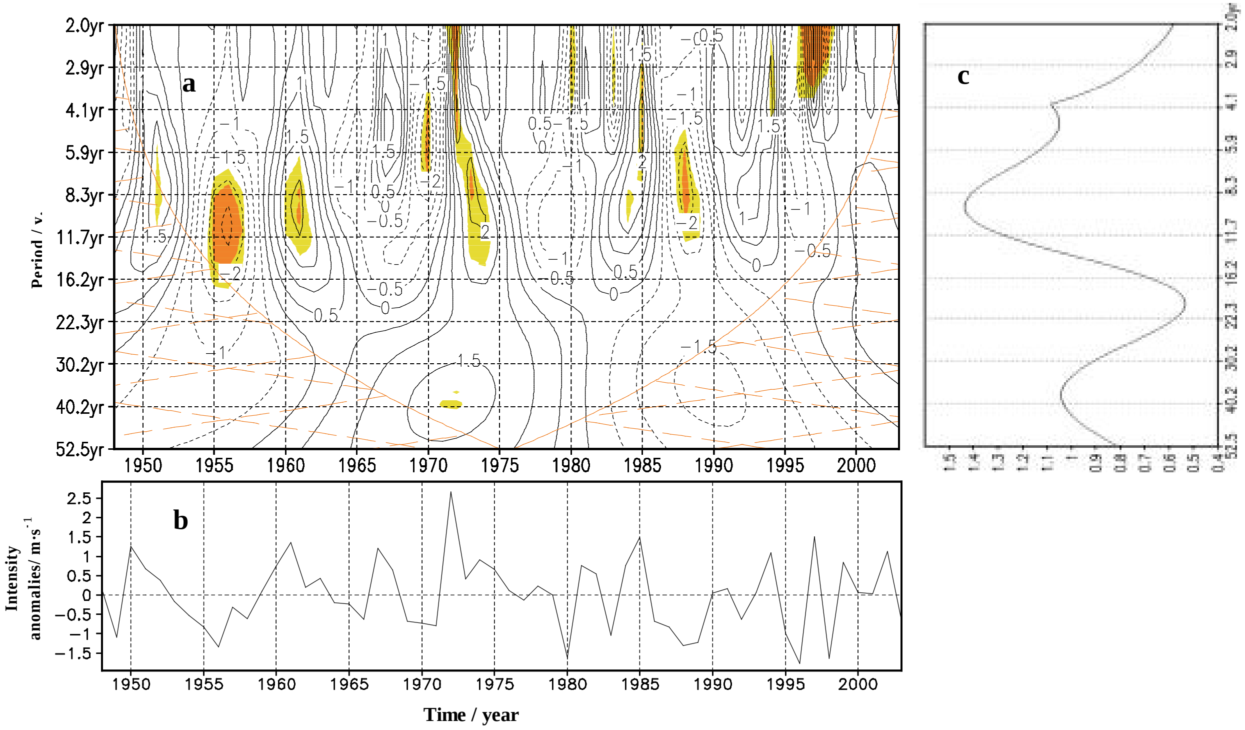

Fig.1 wavelet coefficient (a), intensity anomalies (m/s, b) and wavelet variance (c) of the SCSSMI on the yearly basis.

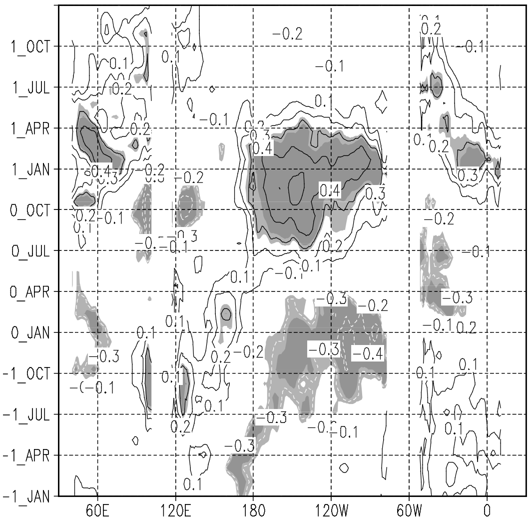

Fig.2 The variation of the correlation coefficient on the latitude (averaged over 5°S – 5°N) in terms of SCSSMI and SST on the interannual scale and its lead and lag.

near the equator. It is seen from the coefficient for the correlation with the SST in the preceding November (figure omitted) that the SCSSMI is in significant negative correlation with the SST in the equatorial western Indian Ocean but in significant positive correlation with the SST in waters near Sumatra. In other words, the distribution is similar to that of negative IOD (Indian Ocean dipole) in the Indian Ocean. The SCSSMI is in significant negative correlation with the SST in the equatorial central and eastern Pacific, similar to the La Niña type. It is known from the coefficient of the correlation with the SST in February of the current year that the significant negative correlation still exists between the equatorial western Indian Ocean and equatorial central and eastern Pacific Ocean, in addition to positive correlation in the equatorial western Pacific, significant negative correlation over the ocean east of Australia, significant positive correlation east of the dateline and significant negative correlation in the equatorial north Atlantic.

It is shown in the distribution of correlation between the interannual variation of SCS summer monsoon and SST in the current August that significant negative correlation appears extensively over the adjacent areas of the SCS and significant positive correlation occurs over the equatorial central Pacific Ocean. With the intensification of the monsoon, the total wind speed will increase, fluxes of sensible and latent heat lost from sea surface will be greater and SST will be lower. It indicates that the SCSSMI affects the SST in the adjacent areas of the SCS via air-sea thermal interactions.

Fig.2 gives the variation of correlation coefficient with latitude (averaged over 5°S – 5°N) and time for SCSSMI versus SST to depict the temporal and spatial evolution of the correlation. It shows that the correlation pattern of the Indian Ocean for the autumn preceding to the outbreak of SCSSM is similar to the negative dipole in the Indian Ocean; with the set-in of winter, the positive anomalies west of Sumatra disappears rapidly while the negative anomalies over the equatorial western Indian Ocean does not disappear until spring. In the preceding autumn, the area of significant negative correlation has expanded to the whole of equatorial eastern Pacific after crossing the dateline earlier, showing the La Niña-type distribution. In the current spring, the SST in the equatorial Indian Ocean and Pacific Ocean is poorly correlated with the SCSSMI, possibly due to the spring barrier for forecasting SST in the equatorial Indian Ocean and Pacific. With the onset of SCS summer monsoon, the equatorial central and eastern Pacific soon becomes an area of significant positive correlation, the equatorial western Pacific and eastern Indian Ocean become negatively anomalous and equatorial western Indian Ocean also changes to positive anomalies at the end of the current autumn.

3.2 The interdecadal scale

Fig.3 gives the coefficient of the correlation between the interdecadal SCSSMI and SST, which shows that negative correlation prevails in all but the central part of North Pacific, in which there is significant positive correlation, indicating that the interdecadal variation is linked with both global warming and the abrupt change of PDO. Specifically speaking, with SST 5 years ahead in phase, significant negative correlation appears in the southern Indian Ocean, the warm pool in North Pacific (including the SCS) and tropical eastern Pacific while significant positive correlation occurs in the central part of North Pacific; with SST 3 to 1 year ahead in phase, there is no substantial change in the area of correlation in the Pacific Ocean while the negative correlation spreads to cover almost the whole basin in the Indian Ocean and significant negative correlation also appears in North Atlantic.

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

4 CONCLUSIONS

The following conclusions can be drawn from the analysis above:

(1) As shown in wavelet analysis, the variation of SCSSMI is marked by dominant interannual (about 4 years), decadal (about 9 years) and interdecadal (about

38 years) oscillation periods.

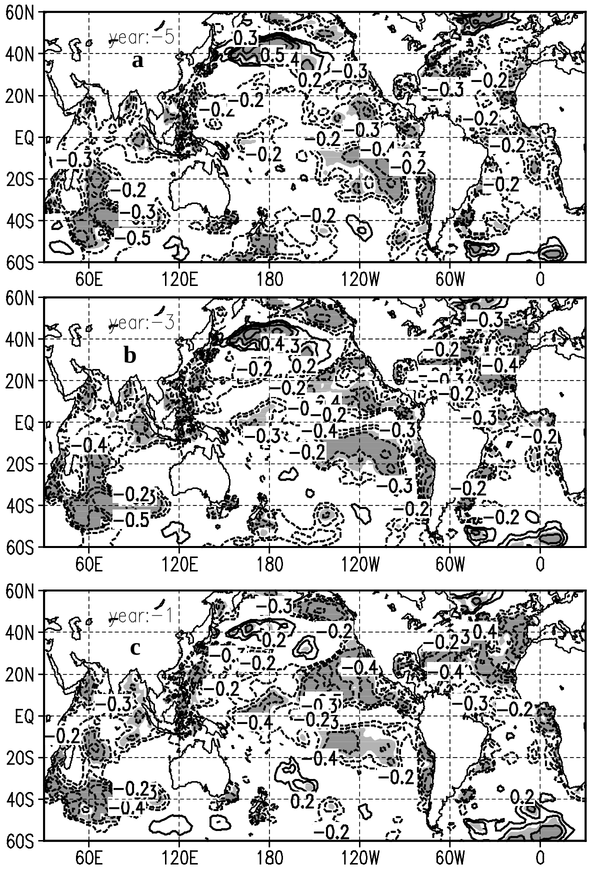

Fig.3 Correlation coefficient for the variation of SCSSMI and SST on the interdecadal scale. The SST is leading by 3 years. The SST is 5 years ahead (a), 3 years ahead (b) and 1 year (c).

(2) On a quasi-2-year basis, the interannual variation of SCSSMI is chiefly associated with the change of tropical ocean near the equator. If there is positive SST anomalies over the equatorial eastern Indian Ocean and equatorial western Pacific in the preceding autumn and winter and negative SST anomalies in the equatorial western Indian Ocean and equatorial central and eastern Pacific, summer monsoon in the SCS will strengthen on the interannual scale. It will weaken otherwise. The SCS summer monsoon affects successive SST in the following ways. In autumn, SST is in significant negative correlation for waters adjacent to the SCS and off the eastern coast of Australia; in winter, SST is in significant positive correlation for waters in the tropical western Indian Ocean, equatorial central and eastern Pacific and equatorial Atlantic.

(3) The interdecadal variation of SCSSMI is associated with both global warming and the abrupt change of PDO.

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