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TYPICAL STRONG AND WEAK SOUTH ASIAN SUMMER MONSOON YEARS AND SEA SURFACE TEMPERATURE OF ARABIAN SEA

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1 INTRODUCTION

The South Asian Summer Monsoon (SASM) is an important member of the monsoon system for Asia. It is made up of low-level subsystems of the Mascarene high in the Southern Hemisphere, cross-equatorial Somali jet stream, 850-hPa westerly jet over the Arabian Sea, Indian monsoon trough north of the Bay of Bengal through west India and upper-level tropical easterly jet centered at 5°N and South Asia high centered at 30°N[1]. During the summer monsoon, convection is intense in South Asia, with large scale and in association with abundant amount of latent heat release from condensation[2]. Its anomalies affect not only the industrial and agricultural production and people’s life in South Asia, but also the southwestern part of China. SASM is therefore drawing attention from quite a number of meteorologists from home and abroad. For instance, in their search for indicators of the summer monsoon in the region, Parthasarathy et al.[3], Webster et al.[4] and Goswami et al.[5] defined a number of indexes based on precipitation and circulation. Wang et al.[6] studied existing, widely-used indexes and came up with different regional indexes for the circulation and convection of SASM. Hahn et al.[7] worked on the effect of topography on SASM. With wind field data, Wang et al.[8] divided the years by the intensity of SASM and analyzed the characteristics of interannual variation and circulation for strong and weak years of monsoon. They found that the SASM intensified and weakened as a whole and there were four types of monsoon, being wholly strong and weak, stronger in the west than in the east and weaker in the west than in the east. Yan et al.[9] discovered sharp differences in individual members of the SASM at upper and lower levels over middle and lower latitudes in both strong and weak years of the monsoon. Using the dynamics method, Zhu et al.[10] took the South Asia winter and summer monsoons as two stable equilibrium states and discussed the formation mechanism from the viewpoint of non-linear equilibrium theory. Their result further shows that in addition to thermal difference between land and sea, the topographic effect of South Asia also has significant restraints and influence on the formation and activity of the monsoon[11-14].

Being an inevitable path for the SASM, the Arabian Sea has a low-level westerly jet stream above that is one of the main features of the SASM. Also because of the coupling effect of the ocean and atmosphere, the monsoon is closely linked with the Arabian Sea. The precipitation in the raining season of China is closely associated with the SASM, while the air-sea interactions in the Arabian Sea affect the monsoon in such a way that it becomes an essential factor in governing the changes in weather and climate in China. At present, not much work has been done on the links between the Arabian Sea and SASM. For the purpose, this paper will analyze the circulation with the monsoon and characteristics of preceding and concurrent SST relative to monsoon development and make preliminary attempts to probe into the oceanic precursory in the Arabian Sea for the anomalous years of SASM.

2 SOURCES OF DATA

The NCEP/NCAR 1958-1997 reanalysis wind

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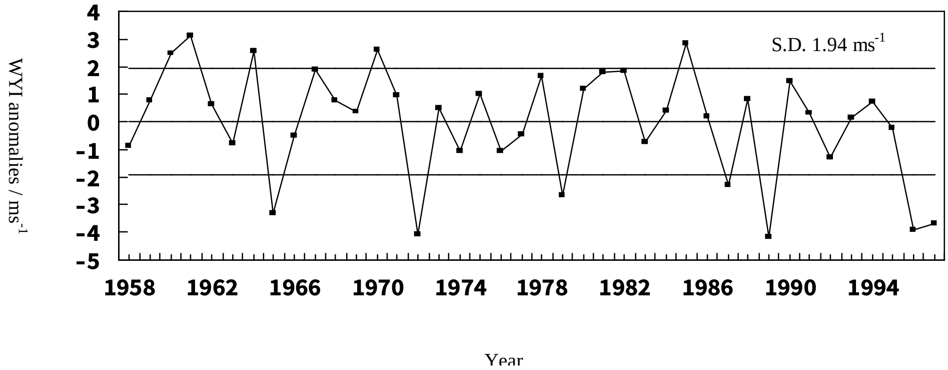


Fig.1 The variation of the anomalies SASM index for 1958 – 1997.

field data for global SST, 850 hPa and 200 hPa and 1958-1997 all Indian rainfall index dataset downloaded from the website at http://grads.iges.org/india/allindia.html are used in this paper. With the methods of composite and correlation analyses, typical characteristics of SST and wind fields of the Arabian Sea prior to and concurrent of strong and weak years of SASM are analyzed to reveal the relationships between the SST in the Arabian Sea and the monsoon. The SST anomalies used in this paper refer to the mean values for the period from 1961 to 1990.

Tab.1 AIRI values (mm) for strong WYI years

Years	1960	**1961**	1964	**1970**	1985
AIRI	839.9	**1 020.5**	922.8	**940.0**	760.0
AIRI-A	-5.2	**175.4**	77.7	**94.9**	-85.1

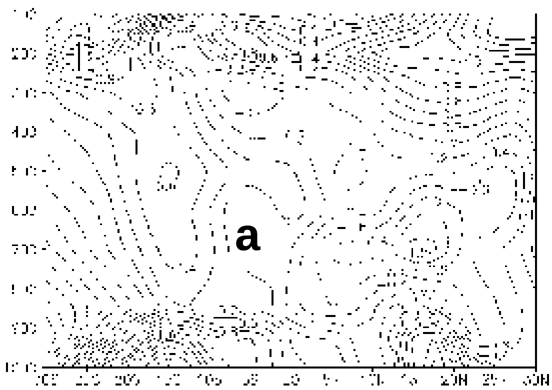
Tab.2 AIRI values (mm) for weak WYI years

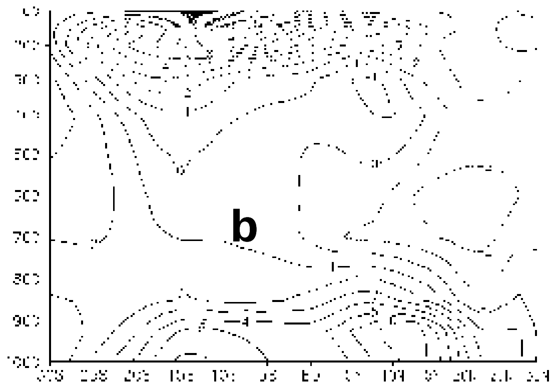
Years	**1965**	1972	**1979**	**1987**	1989	1996	1997
AIRI	**709.6**	653.1	**708.0**	**697.4**	866.9	857.3	870.5
AIRI-A	**-135.5**	-19.2	**-137.1**	**-147.7**	21.8	12.2	25.4

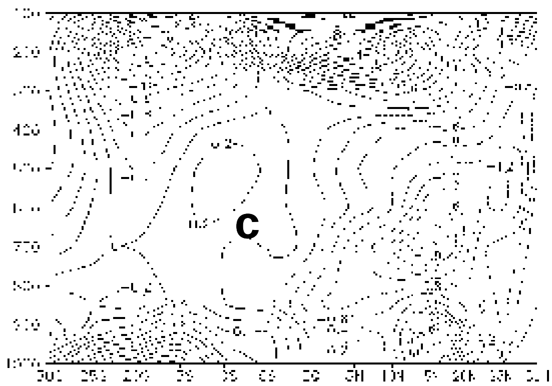
Note: AIRI-A stands for the anomalies of AIRI.

3 DEFINITION AND ANALYSIS

At present, there are quite a number of indexes to define the SASM. The most commonly used is the All Indian Rainfall Index (AIRI)[6], which uses the rainfall in the Indian region for June – September. Webster and Yang [4] used the shear of zonal winds between 850 hPa







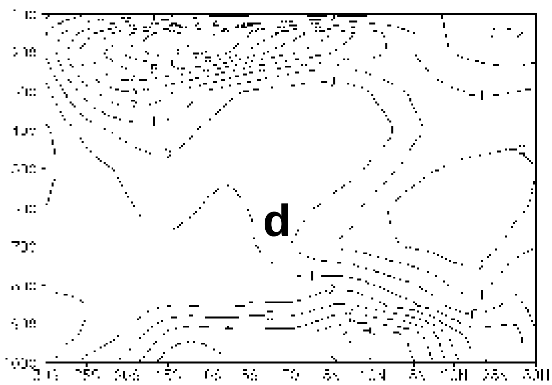


Fig.2 Distribution of composite meridional wind fields in strong and weak years of SASM. The composition is for the region 50 – 100°E, 30°S – 30°N every 5°Long. (a) April in typical strong years; (b) July in typical strong years; (c) April in typical weak years; (d) July in typical weak years.

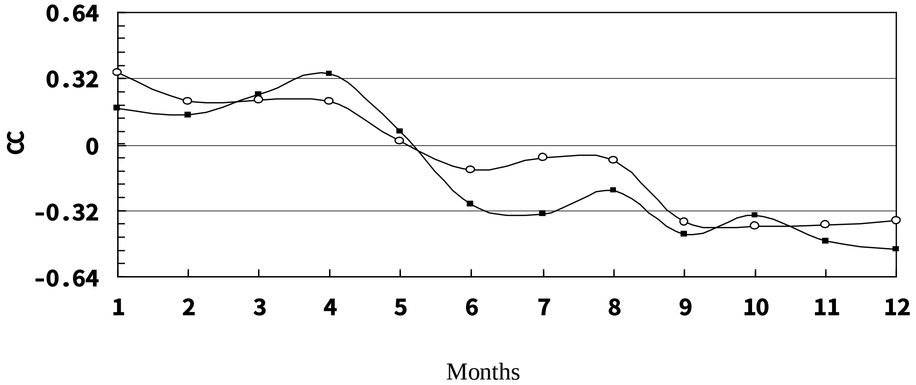


Fig.3 Variation of correlation between the Arabian Sea SST and WYI (the line with ■) and between the former and AIRI (the line with ○) for individual months.

200 hPa within the region of 0° – 20°N and 40°E – 110°E (or the WYI) to define the SASM. To further verify the reliability of the WYI, the current work compares it with AIRI for correlation, which has a coefficient of 0.44 and over the 99% confidence level. The indexes of WYI and AIRI are then used here to study the representative period of SASM (from June to September).

$$\mathrm{WYI} = U_{850} - U_{200} \tag{1}$$

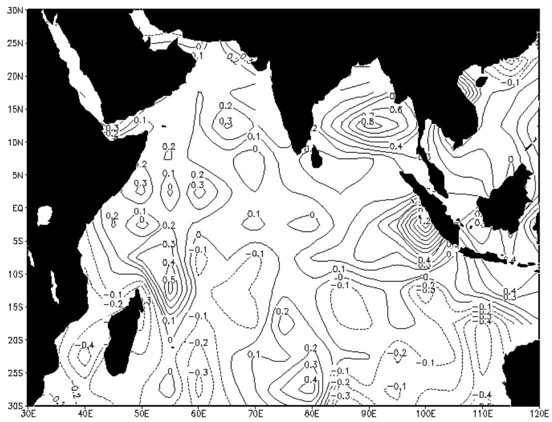
Fig.1 gives the anomalies of WYI for 1958 – 1997, whose series has standard deviation of 1.94 m/s. AIRI is used to select typical years of strong and weak monsoon. Tab.1 and Tab.2 give the variations of AIRI in the strong and weak years of summer monsoon that have been identified with WYI.

The summer monsoon system in South Asia is a meridional circulation cell composed of an updraft from the Indian Monsoon trough and a downdraft from the Southern Hemisphere, which are maintained by the heat sources of the Bay of Bengal and Tibetan Plateau and the cold source over Mascarene in the Southern Hemisphere[1]. As the meridional cell of circulation is not on the same meridional cross section, the region of typical strong and weak monsoon years selected here is compose of cross sections every 5° longitudes within 50°E – 100°E, 30°S – 30°N. Fig.2 gives the composite result. Fig.3 gives the variation of correlation between the Arabian Sea SST and WYI/AIRI for individual months.

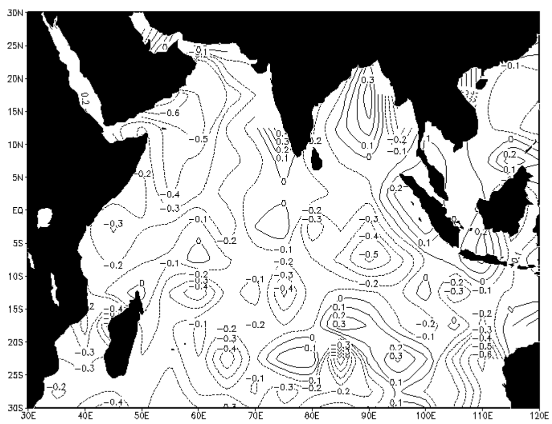
Focusing on the conditions of SST in the periods prior to and concurrent of the strong and weak years of monsoon, the paper attempts to identify oceanic precursory for anomalous monsoon years by running composite analysis with April as the precedent period and July as the concurrent period. Fig.4 gives the distribution of composite SSTA. For analyses on other aspects, refer to the Chinese edition of the journal.

4 CONCLUSIONS

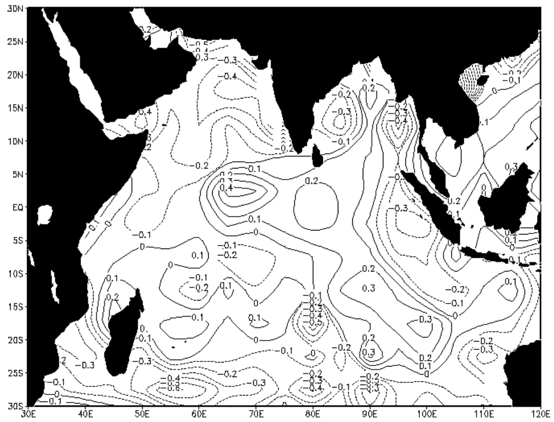
(1) In April, a precedent time before the years of strong SASM, the upper levels of the Southern Hemisphere are dominated by the southerly and the Hadley cell begins to weaken while in the years of weak monsoon, the upper levels are predominant with the northerly and the Hadley cell is as strong as ever. In July, tropical Indian Ocean is mainly of the



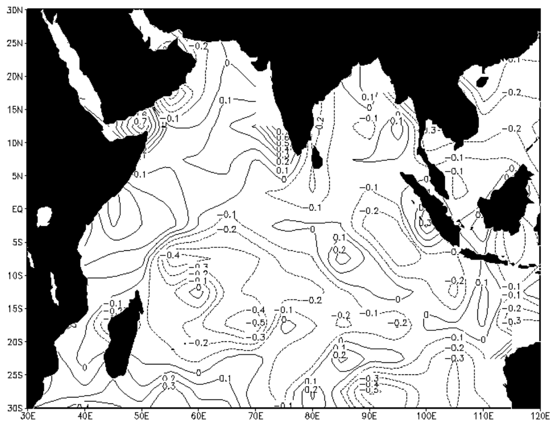
(a) Aprils in typical years of strong SASM.



(b) Julys in typical years of strong SASM.



(c) Aprils in typical years of weak SASM.



(d) Julys in typical years of weak SASM.

Fig.4 Distribution of composite SSTA for typical years of typical strong and weak SASM.

meridional circulation. A southerly center formally in 50°E – 100°E, 15°N – 20°N shifts to 15°S – 20°S and 15°N – 20°N, respectively. Whether it is the precedent or concurrent period for the monsoon, the wind speed is always larger in strong years than in weak years.

(2) As the variation of Arabian Sea SST is ahead of that of the index for SASM, the former is useful in the forecasting of the latter. It is also known from the composite and correlation analyses that the higher (lower) the SST in April, the stronger (weaker) the SASM; the higher (lower) the SST in July, in contrast, the weaker (stronger) the SASM, as the thermal energy of the ocean decays earlier than that of the monsoon.

(3) The Yoshida-Wyrtki Jet along the equator is stronger in the years of strong SASM than in the years of weak SASM.

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