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IMPACTS OF THE ONSET OF THE SOUTHEAST ASIAN SUMMER MONSOON ON THE BEGINNING OF THE RAINY SEASON IN YUNNAN

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1 INTRODUCTION

Summer monsoon in Southeast Asia can cause large-scale precipitation in the region in early summer, which is featured by prevailing low-level southwesterly from the Bay of Bengal to South China Sea (SCS). It has characteristics of its own as well as those of Asian monsoons in general. As found in studies over recent years on East Asian monsoons[1], the earliest onset of the Southeast Asian summer monsoon occurs in early summer over the SCS, among all members of the monsoon system. It then advances westward to India and northward to eastern China, Japan and Korean Peninsula. As pointed out by Lau and Yang[2], the end of April is the earliest time when the Asian monsoon sets up at the southern tip of Indo-china Peninsula. Being the earliest signal for the whole summer monsoon system in Asia, it may be of some predictive value for the establishment of Asian summer monsoon (ASM).

The Southeast Asian summer monsoon influences the rainy season of Yunnan directly, which is located in Southeast Asia. On average, the province's rainy season begins in the 5th pentad of May, though with clear interannual variation and the largest difference being about 50 – 60 days between the earliest and latest dates of rainy season onset[3]. The onset time of ASM system is essential for the precipitation during early summer in Yunnan. Varying much from year to year, the early summer rainfall in the province can, in a large extent, foretell the onset time of monsoon and the annual rainfall expected to occur in Yunnan[3]. It is difficult to forecast early summer rainfall as the province is located at low latitudes over a plateau. Ju et al.[4] studied the relationship between the early summer precipitation in Yunnan and precedent general circulation. Yan et al.[5] probed into the links between the precipitation and tropical SSTA / variation of Asian monsoon. Discussing the weather and climatic causation governing the wetness of this time of the year, Yan et al.[6] suggested that the South Asian high, western Pacific subtropical high, ITCZ and East Asian Trough be the major factors. Attempts have also been made to study the effects of cross-equatorial flows on the beginning of rainy seasons in Yunnan and early summer rainfall, like Huang et al.[7] and Duan et al.[3].

2 DATA

The data used in this work include the near-surface winds from 1951 to 2003 derived from NCEP/NCAR reanalysis dataset with horizontal resolution at 2.5° × 2.5°[8], global SSTA by Reynolds for 1950 – 1999[9], OLR derived from NOAA for 1979 – 2003[10] and monthly precipitation records for 18 stations in Yunnan for 1961 – 2000.

3 ANALYSES

The moisture transported by southerlies increases gradually in low latitude, along with the change of season from spring to summer. The earliest onset of the ASM occurs around the Indochina Peninsula by the end

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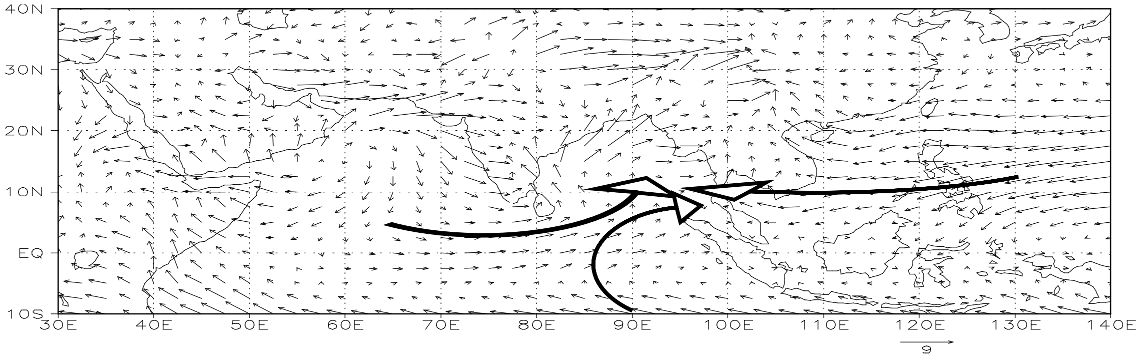

Fig.1 Monthly climatology of near-surface wind for April. Unit: m/s; the area indicated by three arrows are where the cross-equatorial airflows meet.

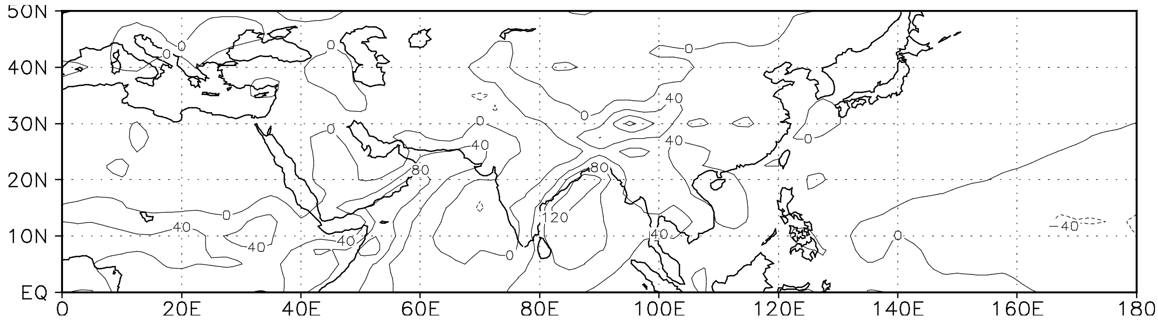

Fig.2 Monthly climatology of near-surface moisture flux for April. Unit: kg/(m s).

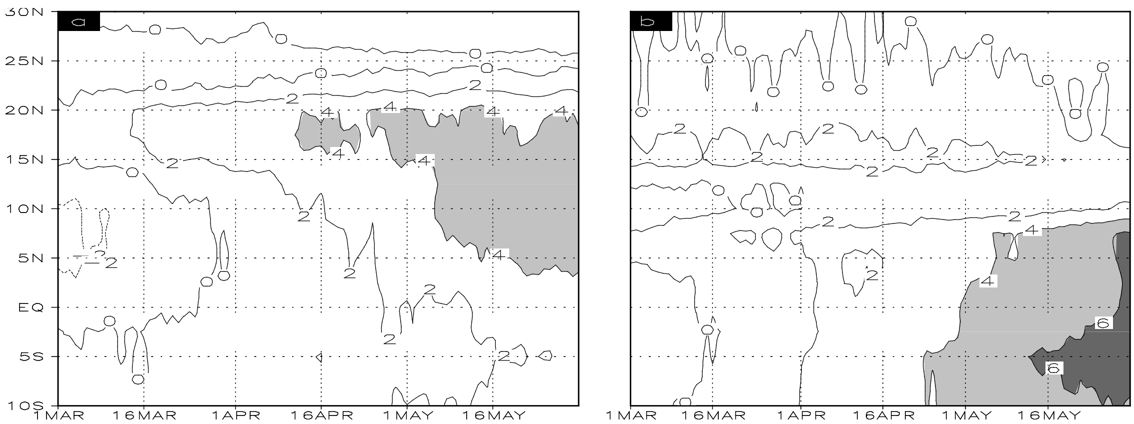

Fig.3 Day-to-day evolution of meridional winds near the surface at 80°E – 90°E (a) and 40°E - 50°E (b) for March – May. Unit: m/s. The areas of wind speed larger than 4m/s are shaded.

of April. Meantime, the winter circulation pattern transforms to the summer one in Northern Hemisphere with summer monsoon beginning to be active in the Indochina Peninsula and the southern part of SCS. When summer monsoon is about to start on full scale over the Asian continent, the intensity of moisture transported via the tropical ocean is closely related with the ASM. The climatological mean distribution of winds at near-surface layers is discussed first. Fig.1 gives the climatological mean of surface wind in April for the period 1951 - 2003.

It is shown in the figure that the most dominant channel of transporting moisture over low-latitude Asian regions in April appears in the Bay of Bengal near 80° – 90°E, which is mainly contributed by the three branches of airflow as indicated by the arrows in Fig.1. The zonal westerlies from low-latitude Indian Ocean within the same hemisphere turn into southerlies when they are blocked by topographic features and SCS high. Airflows turning from the easterlies south of the subtropical high in southern SCS join the westerlies near 100°E. Weak cross-equatorial airflows migrate into the Bay of Bengal from low latitudes. The three airflows combine to form a meridional channel of transporting moisture from the bay.

Fig.2 shows the climatological mean of meridional moisture flux near the surface over Asia in May (1951 – 2003). It can be seen that there are two main southerly channels of moisture from tropical Indian Ocean to central Pacific Ocean in May. They are located in the Somalia area near 45°E and the Bay of Bengal near 80°E - 90°E, respectively. The two moisture channels correspond to the South Asian monsoon subsystem and the Bay of Bengal monsoon subsystem[11].

Fig.3 shows the day-to-day evolution of meridional winds near the surface in the 80°E – 90°E and 40°E – 50°E regions in March – May from 1951 to 2003. It is shown that the southerly appears near 15°N – 20°N in the Bay of Bengal as early as in mid-March. By mid-April, the cross-equatorial airflow from the Southern Hemisphere joins it in the region of 80°E – 90°E to increase the core speed of the southerly to 4 m/s over the Bay of Bengal.

To further discuss the relationship between moisture transportation and Yunnan rainy season, analysis of the correlation between an index of monsoon precipitation in early summer in Yunnan and near-surface meridional winds is performed. The result is shown in Fig.4. It is found that Fig.4 is the correlation between the index for monsoon precipitation in early summer in Yunnan and near-surface meridional winds. It shows that the two are positively correlated (higher than 95% significance level) in regions corresponding to the meridional channel of moisture over the Bay of Bengal.

To explore the effect of low-latitude convection prior to the Yunnan rainy season on early summer rainfall in the province, the index for the latter is used for its correlation with the OLR during the preceding time in April (Fig.5). It shows that the confidence level for the region of Indo-china Peninsula is above 95%, suggesting that convection over the peninsula in April begin to affect the rainfall in successive early summer in Yunnan. For analyses on other aspects, refer to the Chinese edition of the journal.

4 CONCLUSIONS

(1) Prior to the beginning of Yunnan rainy season, the southerly airflow in the meridional moisture channel in the Bay of Bengal plays a more important role than the meridional moisture channel in Somali in the beginning of the rainy season and early summer

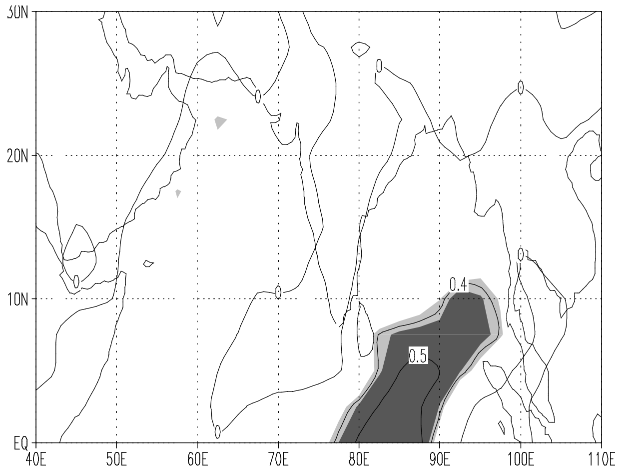

Fig.4 Correlation between the index of early-summer precipitation in Yunnan and meridional winds for precedent April near the surface. Slight shading represents that the meridional wind satisfies the 95% significance level and heavy shading indicates that it passes the 99% significance level test.

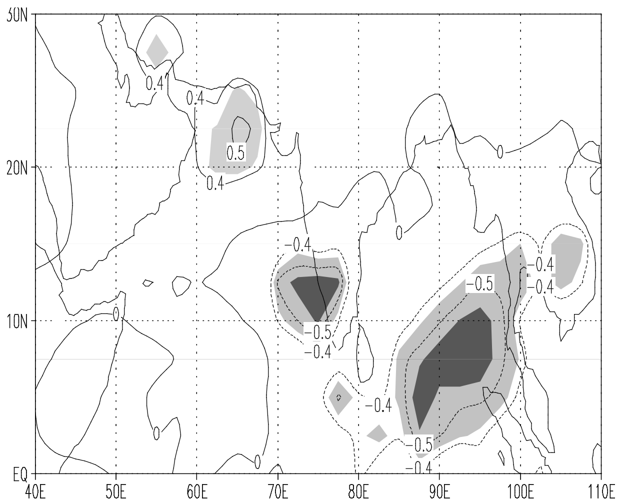

Fig.5 Correlation between the index of early-summer precipitation in Yunnan and outgoing longwave radiation (OLR) for precedent April. Captions are the same as Fig.4.

rainfall in the province. The stronger (weaker) the standardized index of the meridional moisture flux in the bay is, the stronger (weaker) the northward transportation of the bay moisture will be. It usually corresponds to early (late) beginning of the rainy season and more (less) early summer rainfall in the province.

(2) Prior to the beginning of the rainy season, the intensity of convection over Indo-china Peninsula basically agrees with that of the southerly airflow that carries moisture from the bay. When the southerly is strong in the meridional channel, convection will also

be strong in the region of Indo-china Peninsula. It is favorable for earlier-than-normal onset of the summer monsoon in Southeast Asia and eventually results in the early beginning of the rainy season and more rainfall in Yunnan via the changes in wind and convection fields.

(3) Cool SST in the equatorial eastern and central Pacific Ocean in preceding autumn and winter is favorable for enhanced transportation of meridional moisture over the Bay of Bengal, which causes the summer monsoon to break out earlier than usual in Southeast Asia. It finally affects the beginning of the rainy season and early summer rainfall in Yunnan.

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