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DETERMINATION OF SOUTH CHINA SEA MONSOON ONSET AND EAST ASIAN SUMMER MONSOON INDEX

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ABSTRACT: Results of the definition of South China Sea summer monsoon onset date and East Asian summer monsoon index in recent years are summarized in this paper. And more questions to be resolved are introduced later.

Key words: South China Sea summer monsoon; onset date; East Asian summer monsoon index

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1 INTRODUCTION

China locates in the Asian monsoon region. Monsoon anomaly brings significant impacts on weather and climate related disaster and living environment in China. Monsoon has become an everlasting topic for the Chinese atmospheric scientists. Being an important division and the tie between South Asia and East Asia monsoon systems, the activities of South China Sea Summer Monsoon (hereafter SCSSM) are not only regionally meaningful, but also influencing the large scale and even global weather and climate by the circulation of energy and water vapor. Although it is still controversial if SCSSM is the earliest one in Asia, it is no doubt that the onset and evolution of SCSSM is an important signal for the seasonal transition and the approaching of rainy seasons in East Asia. The SCSSM anomaly directly affects the precipitation of South China, Yangtze River and Huaihe River valleys, Taiwan and Japan in rainy seasons. It has been of scientific and practical importance to study the SCSSM onset date and the intensity of the East Asia Summer Monsoon (hereafter EASM). Since the 1980's, significant progresses have been made in these two areas. This article will review the relevant research findings.

2 INDICES FOR DETERMINING ONSET OF SCS SUMMER MONSOON

As an important component of the EASM, SCSSM onset announces the EASM onset. Since South China Sea Monsoon Experiment (SCSMEX) that was carried out in 1998, a lot of researches have been conducted to discuss the indices to determine SCSSM onset, and great achievements have been made. Thermodynamic and dynamic factors are usually taken into consideration for the definition of the onset date of SCSSM, and feature parameters over the South China Sea (hereafter SCS), which can characterize the onset of SCSSM, are used as indices. Then certain threshold values are set for those parameters to determine the onset date of SCSSM. These indices are categorized into three types as followed.

2.1 Precipitation indices over monsoon area

From the climatological point of view, the onset of monsoon is usually accompanied by significant precipitation events. So Tao and Chen[1] defined the mean onset date of Indian and East Asia summer monsoon by the seasonal variation of precipitation. Chen et al.[2] used more reliable precipitation data to give the start date for the subtropical monsoon rainy season, which spans from spring to summer, and the tropical summer monsoon rainy season, which follows

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the onset of tropical summer monsoon in Asia. Jiang and Qian[3] applied the wavelet analysis to time series of precipitation data over the South China Sea and found that the average SCSSM onset date is mid-May and the outbreak of the monsoon is actually the transition from small-scale precipitation to large scale one. Once the relatively heavy and large-scale precipitation reaches the South China Sea, the SCSSM breaks out. Qiao et al.[4] made a zone division for the SCS precipitation using clustering and correlation analysis. Results show that the precipitation in the region 10-20 °N and 110-120 °E can better represent the abruptness of the precipitation change before and after SCSSM onset. And in that area, the average outbreak date of the summer monsoon precipitation is the 4th pentad of May. However, we would like to point out that because of the scarcity of marine stations, the lack of observational precipitation data over SCS region, the locality of the precipitation in this area, and the influence by non-monsoon weather systems (e.g. westerly trough/ridge), even before the onset of summer monsoon, there has already been obvious frontal rainfall in the north of SCS and South China. So it has its own disadvantage to use precipitation in determining the SCSSM onset date.

2.2 Circulation index at lower and upper levels

An important signature for the onset of EASM is the shift of lower level prevailing wind from northerly to southwesterly. Yan[5] took regional varieties into consideration, and selected different indices for different regions of the South China Sea. For the coastal region of northern SCS, southwest wind at lower levels (850 hPa or 925 hPa) shall sustain for 5 days with the maximum wind speed exceeding 10 m/s, meanwhile the southwest wind at 850 hPa over Indo-China Peninsula shall sustain with the maximum wind speed above 8 m/s; for Xiasha Waters, similar indices were adopted; for Nansha waters and the coastal region of southern SCS, low-level southwest wind shall sustain for 5 days. The average onset date for northern SCS is the 3rd pentad of May, and it is the 4th pentad of May for southern part.

He et al.[6] proposed an index (IWH) combining wind and height field according to two well-known characteristics of the circulation after the Asian tropical monsoon onset: first, prevailing southwest wind at lower levels and easterly wind at upper levels; second, the high pressures over SCS and Arabian Peninsula (usually called “SCS High” and “Arabian High”) in spring and winter retreating to the east and west respectively. If the IWH switches from negative to positive values and the break (negative IWH) from the first positive pentad is less than 3 pentads, then the first positive pentad is the onset date of the South China Sea tropical monsoon. If the break is more than 3 pentads, the same principal is applied to the next positive-value pentad. Here, the East Asia monsoon region is within 5-20 °N and 90-120 °E. Since the definition of IWH is complicated, the detail equation is not listed here.

Li and Long[7] used the divergence departure between lower and upper troposphere to define the onset date of the SCSSM as the divergence departure can represent the vertical motion of the atmosphere to some extent. The date, when the index I_d switches from positive to negative, is defined as the SCSSM onset date. Here $I_d = \Delta D / \sqrt{\sum (\Delta D_i)^2 / n}$, $\Delta D = \overline{(D_{850} - D_{200})_i}$, and I_d is the average divergence difference between lower and upper levels over the SCS (5-17.5 °N，105-120 °E). Yao and Qian[8] pointed out that horizontal divergence is actually a small value subtracted by two relatively large values, so its precision is poor, which may cause uncertainty in the sign of the value. Compared to that, vorticities at lower and upper levels are more representative in terms of either precision or circulation prior to and after the SCSSM onset. So they suggested that the date when moisture potential vorticity (MPV) at 850 hPa shifted from negative to positive, be the SCSSM onset date. The index has taken the temperature into consideration.

Linag and Wu[9] proposed two criteria to mark the SCSSM onset date. One is that the average zonal wind at 850 hPa over SCS should be westerly, and the other is that the westerly wind should originate from tropical areas. If both of the criteria are met and sustained for over 5 days, the first day is defined as the SCSSM onset date. The way of determining the source region of southwest wind over SCS is depicted as follows: Locate the strongest westerly wind over SCS, then trace back to the west, in the area of 80-95 °E to find out the position of the axis of the maximum westerly wind speed. If its average position is lower than 15 °N, the source region of the southwest wind over SCS is determined to be in low-latitude tropical area. Wang et al.[10] also used the zonal wind at 850 hPa over the area (5-15 °N, 110-120 °E) as the criterion for the outbreak of monsoon. Xie and Dai[11] defined the date as the SCSSM onset date when average zonal wind over middle and southern SCS (5-15 °N，105-120 °E) switched from negative to positive value and sustained for 2 pentads or more.

2.3 Combined index by circulation and thermal characteristics

Lots of researches have revealed that the outbreak of the SCSSM is an abrupt change not only in circulation, but in temperature and moisture fields. Some other indices to define the onset of SCSSM integrate the circulation with convection features. As for the thermodynamic (convective) indices, they are usually OLR, TBB or θ_{se} (pseudo-equivalent temperature).

Liang and Wu[12] adopted a combined method that uses the OLR data and the southwest wind component. When $I_{SCSMS}=(V_{SW}-1.0)/a+(235-V_{OLR})/b$ changes from positive to negative, the SCSSM breaks out. Specifically, V_{SW} is the average southwest component of the wind speed over the region within 5-20 °N and 105-120 °E, and V_{OLR} is the average OLR in the same region. Coefficients a and b are empirical and preset as 1 m/s and 10 W/m^2 respectively. Liu et al.[13] defined the date as the SCSSM onset date when the pentad average OLR over the SCS drops to 235 W/m^2, and in the meantime, the regional average zonal wind shifts from easterly to westerly. Liu et al.[14] used the pentad average OLR over northern SCS (12.5-22.5 °N, 112.5-120 °E) as the index with the threshold of 235 W/m^2, so when the pentad average OLR is less than 235 W/m^2 for the first time, the SCSSM was said to break out. Zhang[15] defined the onset date of the SCSSM by the following criteria: 1) At 850 hPa, subtropical high has retreated from SCS which is dominated by west-southwest wind (wind speed ≥3.0 m/s). Meanwhile, there exist the cross-equatorial flows near Somali or (and) the areas of 70-95 °E, which represents the establishment of summer circulation; 2) At 200 hPa, high pressure circulation dominates the Indo-China Peninsula with its center above 17 °N, while the northeast wind prevails over the SCS, with velocity over 4.5 m/s; 3) Large-scale deep convections begin to appear with OLR less than 230 W/m^2. Xu[16] described the outbreak of SCSSM as a situation where regional (5-20 °N, 105-120 °E) mean daily OLR drops to 235 W/m^2, in the mean time, the regional zonal wind direction at 850 hPa changes from easterly to westerly and sustains for at least one week.

As for the use of TBB data, Wang[17] studied the two characteristics accompanying with the SCSSM outbreak: zonal wind over SCS shifting from easterly to westerly and the explosive increase of the deep convection over SCS, then defined a SCSSM outbreak index $I_{ms}=\frac{u}{|\bar{u}|}-\frac{TBB-275}{|\overline{TBB}-275|}$. Specifically, u is the pentad-mean zonal wind over SCS (5-20 °N, 110-120 °E), $\bar{u}$ is the mean zonal wind of years, and so is with TBB. If I_{ms} of any pentad changes from negative to positive and the positive index maintains for 2 pentads, then the first pentad is the onset pentad of the SCSSM. Jin[18] adopted the criteria that TBB maintains below 274K for at least 3 days. Kuo[19] applied "Sliding t Test" to the regional (6-18 °N, 112-120 °E) pentad mean TBB data to determine the SCSSM onset date. Lan et al.[20] defined a new SCSSM onset index that regional (10-20 °N, 110-120 °E) mean heat source Q1 shall be greater than 38.4 W/m^2, which is the statistical mean of Q1 from 1979 to 1993.

He and Tan[1] discussed the SCSSM onset date from the aspects of thermohygro characteristics in the lower troposphere and the abrupt changes of circulation in the upper air. They inferred that the first day, when regional (7.5-20 °N, 110-120 °E) mean $\theta_{se}|_{850\,hPa}\geq 336$ K and regional (10-22.5 °N, 100-120 °E) mean $u_{200\,hPa}|\leq 0$ m/s, is the SCSSM onset date. FONG et al.[21] defined the SCSSM onset date using a similar method: at 850 hPa over SCS (5-20 °N, 105-120 °E), when warm and moist southwest wind prevails with wind speed above 2 m/s, the θ_{se} is greater than 335 K, and half of the SCS region is dominated by the summer monsoon, SCSSM breaks out. Gao[22] analyzed the abrupt change of the wind direction and potential temperature (PT) by applying Yamamoto signal/noise ratio testing to the grid data over SCS and found that better indication for SCSSM can be identified in the region (10-20 °N, 110-120 °E), which was just the same as the abrupt change region obtained by Qiao et al.[4] based on precipitation data. In that region, the date, when mean zonal wind at 850 hPa shifts steadily from easterly to westerly, with θ_{se} at the same level being steadily greater than 335K, is defined as the SCSSM onset date. They described the so called "steadiness" as being that (1) the status sustains for 3 pentads and the following interrupted period is not more than 2 pentads, or (2) the status sustains for 2 pentads followed by 1 interrupted pentad, then turns back to the previous status.

Due to the lack of early OLR or TBB data, the pre-mid-1970's monsoon onset dates mentioned above are based on the NCEP/NCAR reanalysis data. Concerning the reliability of the reanalysis before 1958, most of the authors only gave the SCSSM onset date after 1958. He et al.[23] summarized the representative definitions of SCSSM onset date and made some amendments.

2.4 Determination of the SCSSM in 2004

Based on the status review mentioned above, the general characteristics of the onset of the SCSSM can be depicted as followed: At upper levels, South Asian

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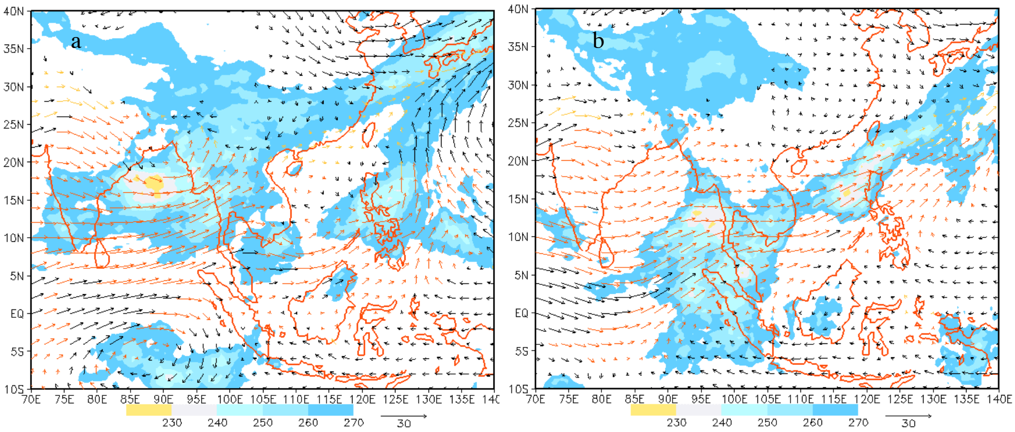

Fig.1 Wind vector at 850 hPa and the cloud top temperature (CTT) distribution in 4th (a) and the 5th (b) pentad of May 2004. Shading depicts the region where CTT<270K; Red vector denotes the southwesterly wind areas where the potential temperature (PT)>340, with easterly wind at 100 hPa; Orange vector indicates the southwesterly wind areas where PT>340, with westerly at 100 hPa.

High moves to the northern Indo-China Peninsula with SCS dominated by northeast wind, while at lower levels, West Pacific Subtropical High retreats continuously to the east with SCS dominated by the southwest wind. Correspondingly, cross-equatorial flows appear at 105 °E, and a SCS monsoon trough develops accompanying with convective precipitation, abrupt change of the temperature and moisture, the reversion of the meridional temperature gradient, and the establishment of summer meridional circulation over SCS. Taking the year 2004 as example and based on the characteristics and the indices of the SCSSM onset, this paper discusses on the onset date of SCSSM in 2004.

Pentad-mean data show that West Pacific Subtropical High dominates the SCS before the 4th pentad of May. In the 4th pentad of May (Fig.1a), at lower level (850 hPa), a westerly flow from the Bay of Bengal merged with the cross-equatorial flow near 105 °E into a warm and moist westerly air stream over southern SCS, while at the upper levels, the leading wind direction was easterly. And at that time, convective systems began to develop in this region. Though the main body of subtropical high had retreated out of SCS, weak anti-cyclone circulation still dominated the mid-northern SCS where it was clear sky. In the 5th pentad (Fig.1b), the anti-cyclone over mid-northern SCS was replaced by the southwesterly wind. Meanwhile the ridge of the South Asia High at upper levels shifted northward, and the convective systems became active. By then, the atmospheric circulation at either lower or upper levels completely met the criteria for SCSSM onset. Therefore, the SCSSM had already broken out in the 5th pentad of May. Examination of the observational data twice a day (Fig.2) before May 19 shows that westerly wind was prevailing over southern SCS (5-10 °N), while mid-northern SCS was dominated by easterly wind. Convective systems were active only in southern SCS. There was a precipitation belt relating to a South China quasi-stationary front to the north of 20 °N. On May 19, an abrupt northward shift occurred to the westerly current, which occupied the whole SCS region and caused south and north cloud belts to merge as one. The situation continued for more than 1 week. So it can be determined that the day, May 19, was the onset date

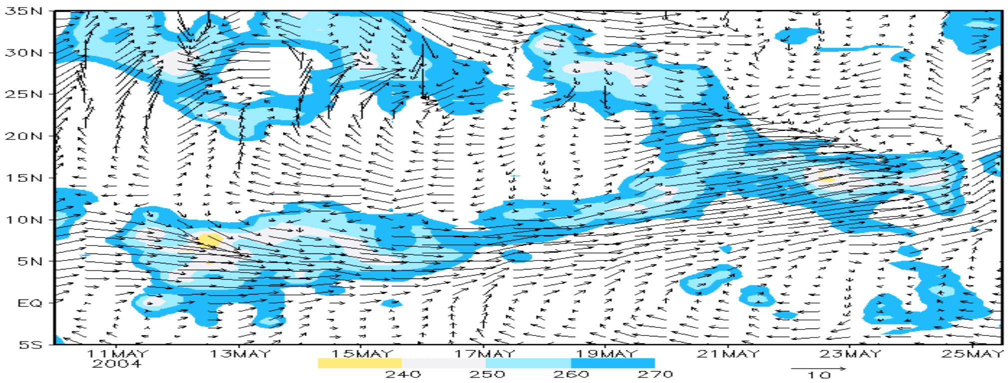

Fig.2 Zonal (105-120 °E) mean time-longitude cross section plotted twice a day from 10- 25, May 2004. Shading depicts the region where CTT <270; black arrows are the wind vectors at 850 hPa.

of the South China Sea southwest monsoon.

As for 2004, because of the lack of surface observational precipitation data since May and θ_{se} maintained above 335 K, it is difficult to determine the summer monsoon onset date based on precipitation related indices solely.

Among the indices of regional mean, meridional wind at 850 hPa, divergence departure between lower and upper levels, and convective indices (e.g. cloud top brightness temperature) can help determine the SCSSM onset date. It needs to be pointed out that the selection of the area for regional mean calculation affects the onset date significantly. The region within 10-20 °N and 105-120 °N is recommended. If 5-20 °N is chosen, an earlier onset date will be determined.

3 DETERMINATION OF THE STRENGTH OF EAST ASIA SUMMER MONSOON (EASM)

Asian Monsoon has an obvious annual variation, whose abnormity often results in large-scale flood/drought in this region. To investigate the annual variation and the relationship between monsoon and other circulation as well as the climatic variability, to find out the correlation between internal/external forcing and the monsoon variability, a set of indices for monsoon intensity are indispensable. In India, countrywide rainfall is used to measure the monsoon intensity. In South Asia, the vertical zonal wind shear between lower and upper levels is a good index (Webster and Yang[24]). EASM, however, contains both tropical monsoon and subtropical monsoon, with the zonal extent reaching up to 40-50 degrees of latitude, and it is easily influenced by mid-high latitude atmospheric circulation systems. So it is far more difficult to determine East Asian monsoon index than to choose one for Indian monsoon or South Asian monsoon.

At present, quite a few EASM indices have been put forward, which can be categorized to three groups: by monsoon circulation, by monsoon thermodynamic features and by sea-land temperature difference.

As an important component of EASM, the South China Sea summer monsoon and its intensity change are the major concerns. Two types of indices are used to reflect the SCSSM intensity. One is dynamics indices, such as the one proposed by Xie and Dai[11]: from the monsoon onset date till the end of August, the velocity data on each grid point over SCS (5-20 °N, 105-120 °E), where the zonal wind speed is greater than zero, are summed up as the SCSSM intensity index. Li and Long[7] used divergence difference, while Yao and Qian[8] used vorticity difference between lower and upper levels, to represent the monsoon intensity. The other is a kind of combined index of dynamics and thermodynamics such as the one used by Liang and Wu. They used above-mentioned I_{SCSMS} as the monsoon intensity index. In a similar way Zhang et al.[15] proposed their own. Studies have revealed good correlation among these dynamical and thermodynamic indices. But the dynamical indices are recommended with regard to relatively short period of data archives for thermodynamic indices like OLR and TBB, which is available only from the 1970's.

Most indices tend to treat East Asian monsoon as a whole to determine its intensity. Some indices use zonal or meridional wind at lower level (850 hPa). For example, Wu and Ni[25] used the regional (20-30 °N, 110-130 °E) mean meridional wind anomaly at 850 hPa as the EASM index. Based on the fact that, among the EASM systems, Intertropical convergence zone (tropical monsoon trough) exhibits a reverse tendency in intensity against subtropical convergence zone (Meiyu front), Zhang et al.[26] used subtraction of the regional mean zonal wind at 850 hPa between East Asian tropical monsoon trough area (10-20 °N, 100-150 °E) and East Asian subtropical area (25-30 °N，100-150 °E) as the East Asian monsoon intensity index. Vertical wind shear between lower and upper layers is also used to depict the East Asian monsoon intensity. Zhou et al.[27] used the vertical shear of zonal or meridional wind between lower and upper in different regions to formulate the East Asian subtropical westerly circulation index (I_{ew}), East Asian subtropical southerly circulation index (I_{es}), SCS westerly circulation index (I_{sw}) and SCS southerly circulation index (I_{ss}). I_{es} and I_s have good correlation with the precipitation in SCS and East Asian subtropical area respectively. Similar definitions of monsoon intensity come from He[28] and Wang[29].

Huang and Yan[30] proposed a monsoon index to reflect the teleconnection pattern of the East Asian atmospheric circulation. It is $(Z'_{s(40°N, 125°E)}/2-Z'_{s(20°N, 125°E)}/4-Z'_{s(60°N, 125°E)}/4)^{*}$. Specifically, $Z'=Z-\bar{Z}$, Z is the potential height at 500 hPa at one point in one summer, Z is the multi-year mean of potential height, $Z'_s= Z'\sin45°/\sin\varphi$, φ is latitude, the asterisk * denotes a normalization processing.

Wang and Fan[31] chose specific thermodynamic parameters to denote the intensity of monsoon by giving separate definitions of convection indices for South Asia and East Asia, which can be indicated by OLR anomalies averaged over two regions of (0-25 °N, 70-100 °E) and (10-20 °N, 115-140 °E).

In East Asia, the land-water heating difference results in the heat low over the continent and cold high over the waters. The land-water pressure gradient is an important driving force for East Asian monsoon. Guo[32] chose the sum of the sea level pressure difference, which is less than -5 hPa and calculated every 10 degrees zonally within 10-50 °N, 110-160 °E to represent the summer monsoon intensity. Shi et al.[33] improved on it to eliminate the influence by uneven mean square deviation at different grid points. The index was modified as the normalization of the sum of normalized zonal sea level pressure difference calculated every 5 degrees within 20-50 °N, 110 °E-160 °E. There are not only west-east-oriented land-water temperature differences, but also north-south ones. So Sun et al.[34] used the soil temperature (T_{EC}) within East Asian monsoon region (27-35 °N, continent to the east of 105 °E) subtracted by the sea surface temperature within subtropical West Pacific Ocean region (15-30 °N, 120-150 °E) to represent the west-east-oriented land-water heating difference; and the soil temperature (T_{EC}) within the SCS region (south of 27°N, continent to the east of 105 °E) subtracted by the sea surface temperature within the subtropical West Pacific Ocean region (5-18 °N, 105-120 °E) to represent the north-south-oriented land-water heating difference. Thus the East Asian thermodynamic difference index, $LSTD = (T_{EC} - SST_{STNWP}) \times 4/5 + (T_{SC} - SST_{SCS}) \times 1/5$, is defined. The index discerns quite well the flood/drought over Yangtze River valley during summer monsoon period and it is significantly correlated to the West Pacific Subtropical High index and the circulation characteristics in East Asian region.

Besides, concerning the complexity of the choice of monsoon indices, some scientists put forward a combined index. Zhu et al.[35] normalized the zonal wind shear (U_{850}-U_{200}) in the region 0-10 °N, 100-130 °E and the zonal monthly mean sea level pressure of 160 °E subtracted by that of 110 °E respectively. Then the addition of the two normalized value forms a new East Asian monsoon index. The index greater than 0 indicates that summer monsoon (southwest wind) is prevailing, and otherwise, winter monsoon (northeast wind) prevails.

Gao et al.[36] compared 4 representative monsoon indices defined in different ways by Huang and Yan[30], Zhang et al.[26], Shi et al.[33] and Sun et al.[34] respectively. Analysis shows that the 4 indices are positively correlated with each other, which indicates that the sea level pressure field, potential height field, low level wind field and temperature field have significant correlation with each other. What's more, the 4 indices follow similar annual variations (figure omitted) and demonstrate quit well in some widely recognized strong monsoon years (e.g. 1972, 1978 and 1994) and weak monsoon years (e.g. 1980, 1983 and 1991), which also indicates the good representation of the 4 indices for monsoon anomaly. In reflecting the temperature and precipitation anomaly, the 4 indices have good discerning capability and their own characteristics. In strong summer monsoon years, it is hot in most of China during summer, wet in North China and South China, and dry in Yangtze and Huaihe River valley; in weak summer monsoon year, the contrary. And in this aspect, the land-water thermodynamic difference LSTD defined by Sun et al.[34] seems to be better as compared to other indices.

However, the EASM indices mentioned above are generally used to depict the interannual variation of monsoon intensity. As for the EASM intensity at a certain time, more studies are still needed to follow up.

4 FURTHER DISCUSSIONS

He et al.[23] made a comparison on the monsoon onset dates calculated using the methods proposed by different authors, and found that for most of the years, SCSSM onset dates are consistent, which is the 4th pentad of May on the average. But because of the intentional choice of the parameters, the concerning regions and the threshold values by different authors, the onset dates determined by different methods will certainly have evident difference in some of the years. The reasons that cause the difference are of the following 4 aspects: (1) Summer monsoon is relatively weak or a process of gradual change, so there is no abrupt change in the observational data. (2) Different methods have their own regions of interest, indices and threshold values. (3) The repeated establishment of summer monsoon atmospheric circulation makes it difficult to determine the monsoon onset date. (4) It is still controversial as to the source for strengthened southwest wind over SCS. In terms of the years with larger diversity, Gao et al.[37] made a comparison analysis on SCSSM onset dates determined by different methods, and gave a reasonable time series of SCSSM onset date, which combines three aspects of summer monsoon circulation, source of air stream, and the abrupt change of weather elements, with the "date priority pentad".

Regardless the methods used to define the monsoon intensity indices, if they have good ability to distinguish drought/flood in East China during summer monsoon period, have significant correlation with feature parameters of west Pacific Subtropical High and the features of atmospheric circulation over East Asia, and persistently have good performance mentioned above with the data increase, then they can be properly used as EASM indices. But it should be pointed out that researchers tend to define monsoon index according to their own need, resulting in the artificiality of the monsoon index. So far, many investigations on EASM index have been conducted inside or outside China, but none of them is widely accepted. More studies in this area are needed.

In practice, monsoon intensity at a certain time and the areas affected by summer monsoon also draw much attention. In terms of SCS monsoon, the southwest wind intensity over SCS has good correlation with convection activities (precipitation). That is to say, strong (weak) southwest wind is correlated with active (inactive) convection. Therefore, southwest component of wind speed can represent the SCSSM intensity at a certain time. In terms of EASM, it has the well-known feature of north-south swaying, and the EASM-induced precipitation belt moves correspondingly, so it is not easy to depict EASM intensity by precipitation. As is mentioned in this paper, Intertropical convergence zone (tropical monsoon trough) exhibits a reverse tendency in intensity against subtropical convergence zone (Meiyu front), so it is feasible to use the departure of the regional mean zonal wind at 850 hPa between East Asian tropical monsoon trough area (10-20 °N, 100-150 °E) and East Asian subtropical area (25-30 °N, 100-150 °E) as the East Asian monsoon intensity index. Taking into account that EASM consists of southwest air stream, an EASM-dominated region is defined as the area where equivalent potential temperature is greater than 335 K and southwest wind speed component is greater than 0 (applicable in the region to the east of 110°E).

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