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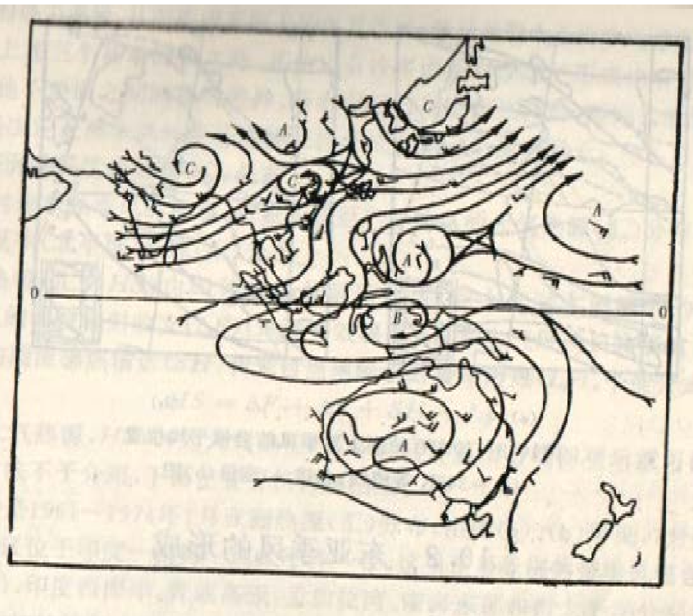
East Asia Summer Monsoon in China

Abstract: The concept and characteristic of East Asia Summer Monsoon (EASM) were introduced in this paper. EASM had clear difference to India summer monsoon (IDSM). EASM had the variation of inter-annual and inter-decadal and had significant relationship to position and strength of precipitation in China.

Key words: EASM, IDSM, inter-annual variation, inter-decadal variation, precipitation, model

Chinese scholars proposed the concept of East Asia monsoon (EAM) and indicated the difference between India monsoon (IDM) in 1980’s formally (Chen et al., 1984). As shown in figure 1, in summer, low level circulation system of East Asia summer monsoon (EASM) were composed with Australian cold anticyclone, cross-equator flow and inter-tropical convergence zone in south china sea, subtropical high, Meiyu belt and cold north wind in mid-high latitudes. On the contrast, India summer monsoon (IDSM) was composed with masklin cold anticyclone in the southern hemisphere, low level cross-equator flow in Somalia and Indian monsoon trough.



(b) 建立后

图10.7　1974～1980年东亚夏季风建立前后850百帕5天的平均合成流场

Fig.1 the EASM circulation system at 850hPa

Scholars implemented many studies to verify EASM and much achievement were acquired. The vertical structure of zonal and meridional wind between EASM and IDSM were analyzed and the clear difference were verified, as shown in figure 2, for the vertical structure of zonal wind, to EASM, west wind existed in lower troposphere but wind direction at upper level was east at the south of 25^0N. West wind appeared in lower troposphere and upper-level were strong west wind at the north of 25^0N. But to IDSM, here were west wind at lower-level and east wind at upper-level. For the meridional wind (figure 3), North wind existed in upper troposphere but south wind was clearly in lower troposphere for the EASM. The vertical structure in meridional wind of EASM was obviously different from IDSM at upper and lower troposphere (Chen and Huang, 2006; Huang et al., 2007).

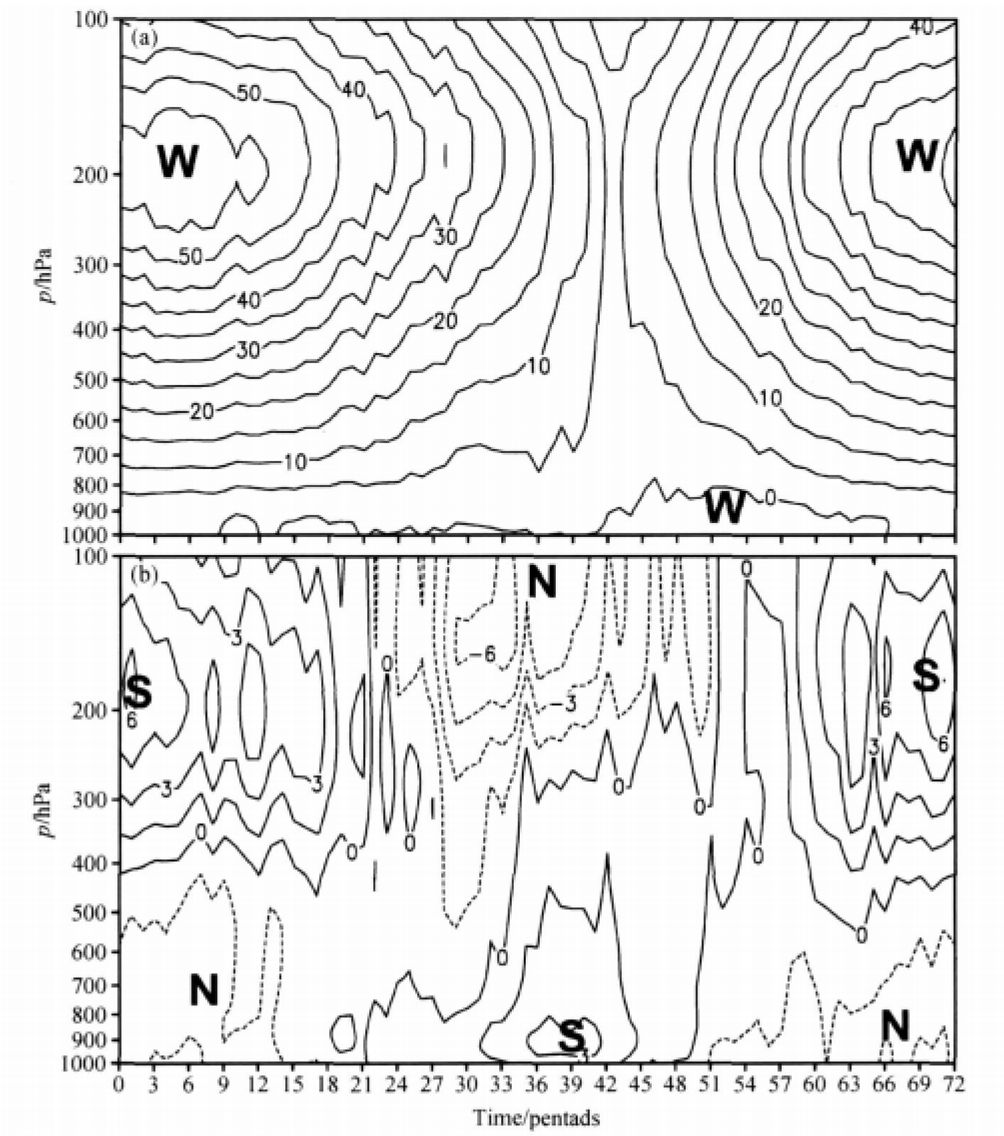


Fig.2 Altitude-time cross sections of (a) zonal and (b) meridional components of wind field (m/s) averaged over East Asia (20^0N-45^0N,100^0E-140^0E) for 1979-2003. The solid (dashed) lines indicate westerly (easterly) in (a), the solid (dashed) lines indicate southerly (northerly) in (b).

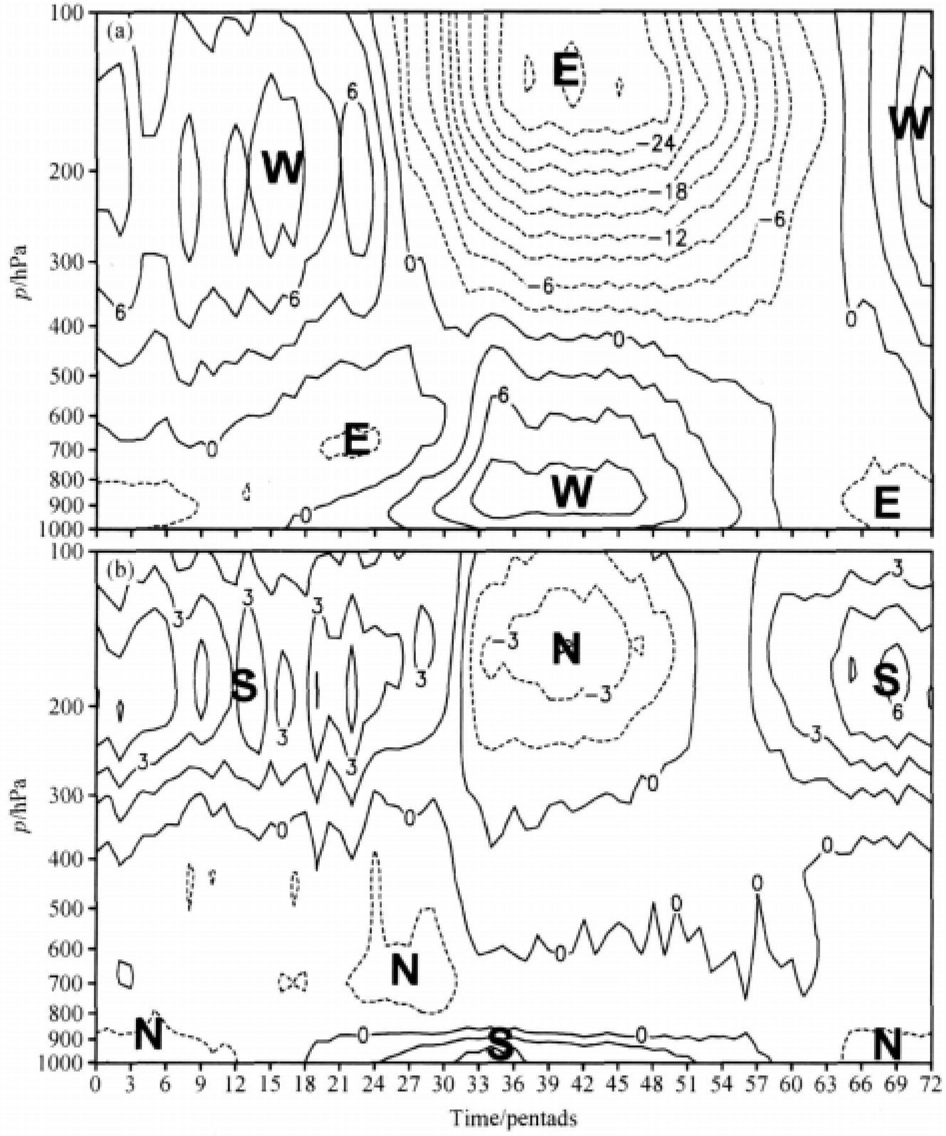


Fig.3 As in Fig.1 except for South Asia (00N-250N, 60^0E-100^0E)

Except for wind, the water vapor transportation and precipitation were different between EASM and IDSM. The transportation of water vapor from south to north was demonstrated to be comparative to zonal for EASM, but the water vapor transportation of IDSM were zonal mostly (Chen and Huang,2007). Precipitation in IDSM was cumulus precipitation mainly while it's mixture of cumulus and stratus in EASM (CHEN et al., 2006) and the conclusion was supported by observation of precipitation classification by tropical rainfall measuring mission (TRMM) in figure 4 (Schumacher and Houze, 2003).

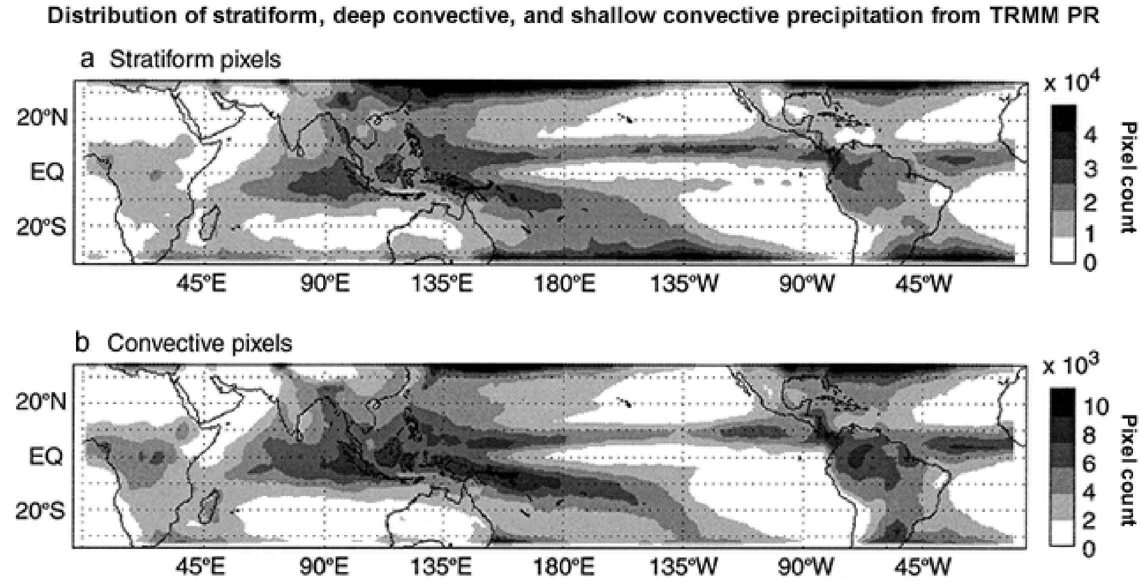


Fig.4 The distribution of (a) stratiform, (b) deep convective precipitation derived from TRMM PR measurements

Synoptic system could be presented by center of total kinetic energy. The zonal propagation of total kinetic energy at 850hPa in equatorial region were discussed based on NCEP/NCAR data from 1980 to 1997 (Chen et al., 2005), result indicated the distribution of total kinetic energy had three center, which were west of arabian sea, bengal bay and the south china sea. To south china sea, most of the total kinetic energy was propagating to east part of bengal bay from west pacific through the south china sea with the manner of from east to west, the propagating of total kinetic energy was from east to west basically and not effected by IDSM at upstream. The propagation of black body temperature in 5-15^{o}N in EASM area were demonstrated from east to west also (Chen et al., 1996).

According to studies in the vertical structure of wind field, water vapor transportation, precipitation, distribution and propagation of total kinetic energy above, it's obviously that the EASM was significantly difference from IDSM.

The temporal variation of EASM was another extensive attention. Scholars implemented many researches and confirmed the EASM had inter-annual and inter-decadal variation. EASM precipitation had a pattern of quasi-biennial oscillation (Miao and Lau, 1990). The inter-annual variation of precipitation, convection, water vapor transportation and circulation anomaly at lower troposphere of EASM had rule of quasi-biennial oscillation, and with a characteristic of meridional tripole pattern distribution (Huang, 2001). Some scholar proposed EASM intensity exhibits quasi 4-year periodic oscillation (Ji et al., 2016). Now many studies had the conclusion that EASM had inter-annual oscillation of quasi 2 and 3-5 year.

To the inter-decadal change of EASM, scholars had the consensus that EASM became weak from the 1970's while the specific time was still debatable. Some scholar suggested EASM system became weak apparently in year 1976 (Huang et al., 1999) while others proposed the variation appeared in middle of 1970's (Lu et al., 2004). A EASM index defined by Wang (Wang, 2002) were adopted in analyzing characteristic of EASM system change and had a conclusion that the weak of EASM system was at the late of 1970's (Han and Wang, 2007). One reason for the inconformity of specific time was the data used by scholars were of little different from each other, A comparison of EASM index calculated by ERA, NCEP/NCAR and observation were shown in figure 5, though weak tendency of index at 1970's appeared clearly in three data, the inflection point of tendency were different from each other.

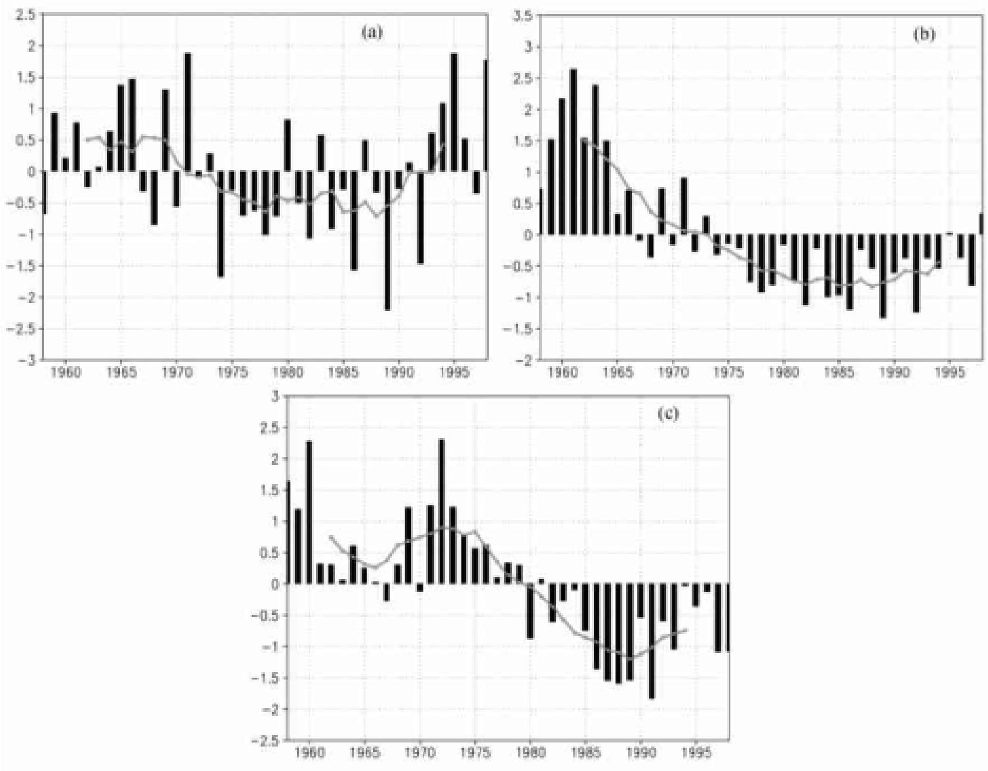


Fig. 5 East Asian summer monsoon indices for (a) ERA (velocity at 850hPa), (b) NCEP/NCAR (velocity at 850 hPa), and (c) observation (surface wind velocity) defined as wind speed ($u^2 + v^2$) averaged over 110^0E-125^0E, 20^0N- 40^0N.

For the reason of inter-annual and inter-decadal variation of EASM, Much researches indicated The ENSO events were the major forcing for the inter-annual variability and ENSO was modulated by the sea surface temperature anomaly (SSTA) in the Indian Ocean and Atlantic Ocean, the Antarctic sea-ice coverage, as well as the anomalous snow and sensible heating over Tibetan Plateau in preceding winter and spring. Furthermore, the inter-decadal variability were determined by the natural changes in climate systems, the tropical SSTA forcing, the anthropogenic aerosols and the long-term changes of surface heating over Tibetan Plateau (Liu and He, 2015). Latest research investigated the effect of aerosol discharge and urbanization, urbanization was indicated beneficial to earlier onset of EASM (Yu et al., 2016) but the increasing in anthropogenic aerosols made EASM weak in southeastern china (Guo et al., 2017).

The intensity of EASM had close relationship to precipitation position and strength in china. Researches indicated EASM had significant effect on the rain belt position that rain belt was northward (southward) when EASM was strong (weak) (Shi et al., 1996). The inter-decadal variation of EASM was responsible for drought in north china and precipitation more than normal in middle and low reaches of yangtze river after 1970's (lu et al., 2004). The relationship between intensity of EASM and precipitation in east china were discussed using black body temperature (Zhang and Tao, 1998), as shown in figure 6, precipitation in Yangtze river and Huaihe river watershed were more (less) than normal when EASM was weak (strong) .

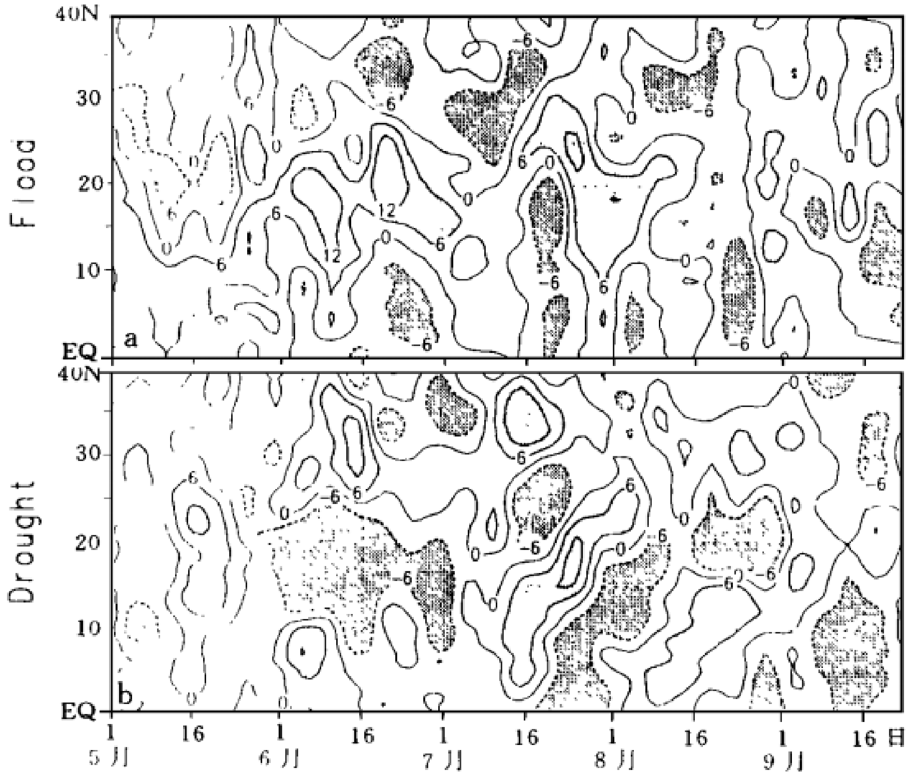


Fig.6 The temporal-zonal profile of averaged TBB over 0-40^{0}N and 115-124^{0}E at situation of precipitation more (a) and less (b) than normal at Yangtze river and Huaihe river watershed.

The influence of EASM on runoff in the east china were evaluated with an index named EASMI, result shown in figure 7 indicated that EASM had positive relationships with runoff in most area between Yangtze River and Songhua River， while negative EASM-runoff relationships in partial area of the South China (Li, 2016).

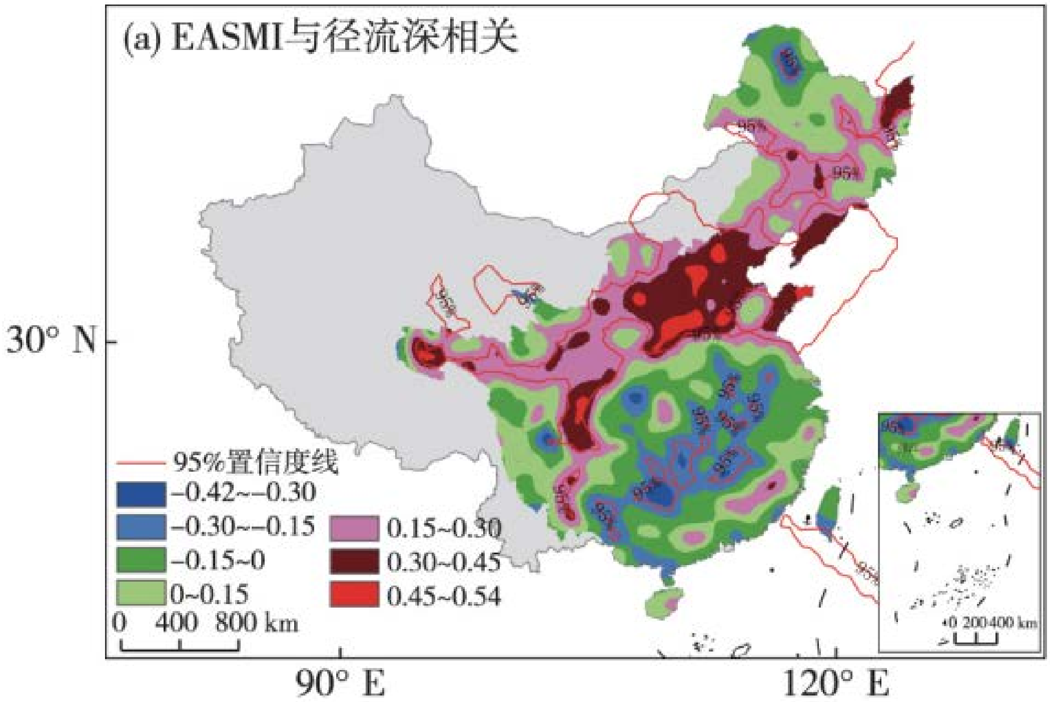


Fig.7 Distribution of correlation coefficients between EASMI and runoff
Read line were confidence coefficient bigger than 95%

Numerical model are wildly used and powerful in forecasting EASM. Models such as the regional climate model (RCM), the atmospheric general circulation models (AGCMs) and weather research and forecasting model (WRF) are comprehensive used in research of formation, influence factor, inter-annual and inter-decadal variation of EASM system. The influences of thermal forcing over the slope/platform of the Tibetan plateau on Asia summer monsoon was evaluated by weather research and forecasting model (WRF) and result indicated that due to himalaya's slope heating, the EASM was also intensified obviously, with characterized both by the enhanced low-level southwesterly wind over east china and the enhanced southward anomalous dry-cold northerly (WANG et al., 2016). Based on simulations of the Community Atmosphere Model Version 3.1 (Cam3) from national center for atmospheric research (NCAR) forced by 1950-1999 monthly global SSTs and reanalysis data, the inter-decadal variations of EASM investigated (ZENG et al., 2007), result indicated that EASM was weaken since the late

1970's, and the inter-decadal variation of weaken were likely to relate to the SST inter-decadal warming in the North Indian Ocean and vicinity of the South China Sea in combination with its effect on the genesis of the anomalous cyclone in the neighborhood of the Japan Sea and South China Sea.

Numerical model were quantitative and reliable in research and forecasting of EASM, while statistic model are helpful still. The early signals of inter-annual and inter-decadal variation of EASM in sea surface temperature at last winter and zonal wind field at 200hPa were investigated and a statistic model about intensity of EASM by method of optimal subset regression was developed, as shown in figure 8, verification indicated the model not only showed better prediction ability for the inter-annual variation of EASM intensity, but also demonstrated certain predictive capability for extreme years (Ji et al., 2016).

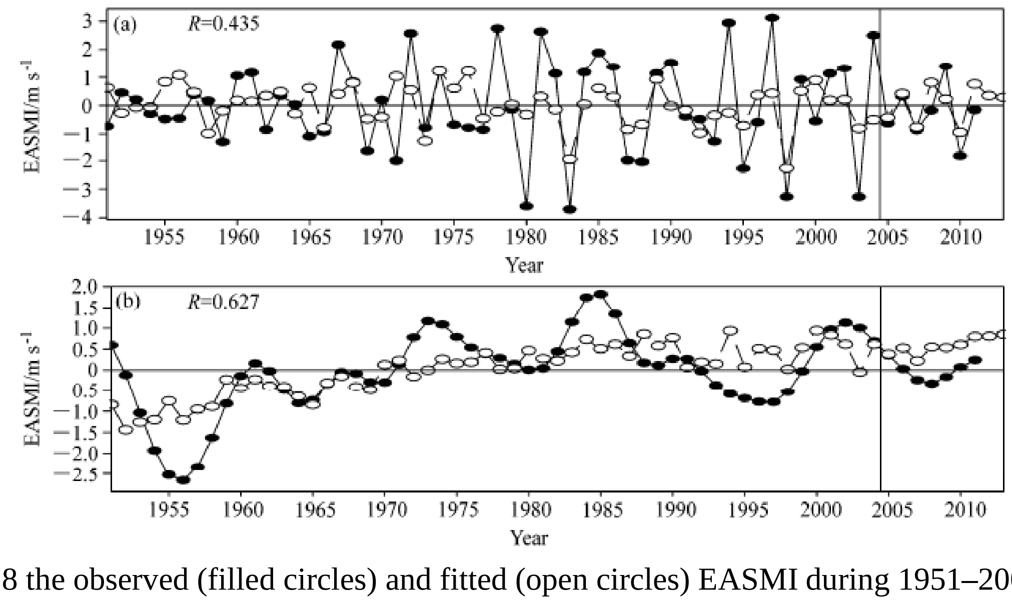


Fig. 8 the observed (filled circles) and fitted (open circles) EASMI during 1951–2004, and the observed (filled circles) and predicted (open circles) EASMI during 2005–2013, at the (a) inter-annual and (b) inter-decadal scales, based on multi-scale optimal subset regression. "R" represents the correlation coefficient

Summary: The concept of East Asia Summer Monsoon (EASM) was proposed formally in 1980's. EASM had significant difference to India summer monsoon (IDSM), which was embodied in circulation system, the vertical structure of zonal and meridional wind, water vapor transportation, precipitation, distribution and propagation of total kinetic energy. EASM had inter-annual variation, with the oscillation of quasi 2 and 3-5 year. EASM had prominent inter-decadal variation, which was weak significantly from 1970's. The ENSO events were the major forcing for the inter-annual variation and the inter-decadal variation were determined by the natural changes in climate systems, the tropical SSTA forcing, the anthropogenic aerosols and the long-term changes of surface heating over Tibetan Plateau. The intensity of EASM had close relationship to position and strength of precipitation, rain belt was northward (southward) when EASM was strong (weak), precipitation in Yangtze river and Huaihe river watershed were more (less) than normal when EASM was weak (strong) . Numerical model such as RCM, AGCMs and WRF were quantitative and reliable in research and forecasting of EASM, while statistic model are helpful still.

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