The East Asian Monsoon Simulation with IAP AGCMs–A Composite Study[1]

Wang Huijun (王会军) and *Bi Xunqiang* (毕训强)
Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences, Beijing 100029
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ABSTRACT

Preliminary analyses on simulation of East Asian monsoon (EAM) by IAP 9–level and 2–level Atmosphereic General Circulation Models of AMIP run were made. The analyses include the seasonal and interannual variations of EAM circulation, the monsoon index defined with 850 hPa wind, the circulation differences of composite strong and weak monsoon years and the regional precipitation over China monsoon region. Two models can give reasonable simulation on the seasonal variation of the subtropical high over Western Pacific and the middle latitude circulation index, the observed global circulation differences for strong and weak EAM. However, the abilities of the models on reproducing the cross–equatorial wind of EAM system, the interannual variation of EAM and the regional precipitation variability are unsatisfactory. Improvements on EAM simulation should contain both the better representation on the regional surface details (orography, surface albedo and surface water and energy flux) and the improvement of the tropical global circulation modelling.

Key words: East Asian monsoon simulation, Composite study

I. INTRODUCTION

Monsoon, as a significant planetary scale feature of global climate, has been drawing great scientific efforts throughout the world. China, located in the EAM region, suffers seriously from the flood and drought frequently caused by the anomaly of EAM. Therefore, studies on EAM in China began early in the 1930's, e. g. Zhu (1934), Tu and Huang (1944) and Yao (1939). The well–known finding of them is the seasonal migration of summer EAM and abruptness of the establishment and retreatment of EAM in East China.

During the following time until present several major achievements on the EAM study have been made as follows:

—— detailed research on the seasonal abrupt change of general circulation in Eas Asia during June and October (Ye et al., 1959),

—— the seasonal migration of EAM rain belt over East China (Tao et al., 1987),

—— the dynamical and thermal impacts of the Tibetan Plateau on the EAM (Ye et al., 1979; Kuo et al, 1981; Kuo et al, 1982; Hahn et al, 1975),

—— the influence of tropical SST anomaly on the Indian and East Asian monsoons.

—— the possible relations between winter EAM and the global tropical circulation and SSTA (Li, 1988; Li, 1990),

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—— modelling of Asian monsoon with GCMs (Zeng et al, 1988; Yuan, 1990; Shukla et al, 1992; Sperber et al, 1994; Latif et al, 1994).

The motivation of this study is to validate the model in reproducing some of the major features of EAM mentioned above.

II. SEASONAL AND INTERANNUAL VARIATIONS OF EAM CIRCULATION

It is known that the EAM system includes several highly interactive components, namely, the cross–equatorial wind at about 105–110°E, the ITCZ at the South China Sea (SCS), the subtropical high at Western Pacific (WP) and the Meiyu front over Yangtze River valley during summer season. Moreover, the middle and high latitude cold air effect and the extended Indian monsoon which is tightly related to the cross–equatorial wind near Somali play key roles in the EAM system and its variation.

From the analysis on the two IAP models' AMIP runs, we have found that both models can reproduce the seasonal cycle of Australian high (120—150°E, 20—30°N), the SCS high (105—115°E, 14—26°N) and the WP high (130—150°E, 14—26°N) at 500 hPa fairly well. The simulations on the seasonal cycle of middle and high latitude circulation index are realistic as well. However, the 2–L AGCM gives the wrong seasonal cycle as revealed by the ECMWF analysis and the 9–L AGCM's result is also not satisfactory.

Both models have the weak abilities to simulate the interannual variation of the above EAM components. This is possibly the greatest difficulty for all the models in simulating the monsoon systems and forms the biggest uncertainty in the seasonal and extra–seasonal prediction on the East China climate.

III. COMPOSITE ANALYSIS ON THE STRONG AND WEAK EAM

Since in monsoon regions the seasonality of low atmospheric wind is much greater than that of the global average, we define a monsoon index

$$IM = -2V_{ju}V_{ja} \Big/ \left(V_{ju}^2 + V_{ja}^2\right) ,$$

where the V_{ju} and V_{ja} are July and January meridional wind at 850 hPa.

One may easily find that positive value means greater seasonality of meridional wind (July and January meridional wind directions are opposite). Through computing the observed global distribution of IM, almost all the positive IM regions are the known monsoon regions. Furthermore the modelled distributions of IM by the two models are very qualitatively satisfactory (figures not shown).

We also note that the model simulated IM in Indian monsoon region (60—90°E, 6—22°N) and the EAM region (110—125°E, 12—22°N) seems to be negatively correlated. For EAM, strong IM years are 1981, 1985, 1986 and 1987 and weak IM years are 1980, 1983, 1984 and 1988. We therefore compared the circulation and SST difference for the strong and weak IM year and found some interesting results.

In the observed 500 hPa geopotential height field, positive and negative differences (strong –weak IM composites) are at the middle latitudes in the Northern Hemisphere in spring and summer seasons respectively. At high latitudes the differences are negative and positive respectively for spring and summer while in the tropics the difference is small for both seasons. This means that higher and lower circulation indices appear in East middle latitudes in spring and summer respectively in strong EAM years than in weak EAM years. Hence for the strong EAM case the East Asia trough deepens in summer. As for the simulation the results agree qualitatively well with the observation despite some detailed discrepancies. It seems that the 2–L model givs the more resonable results in Asia for summer than the 9–L model.

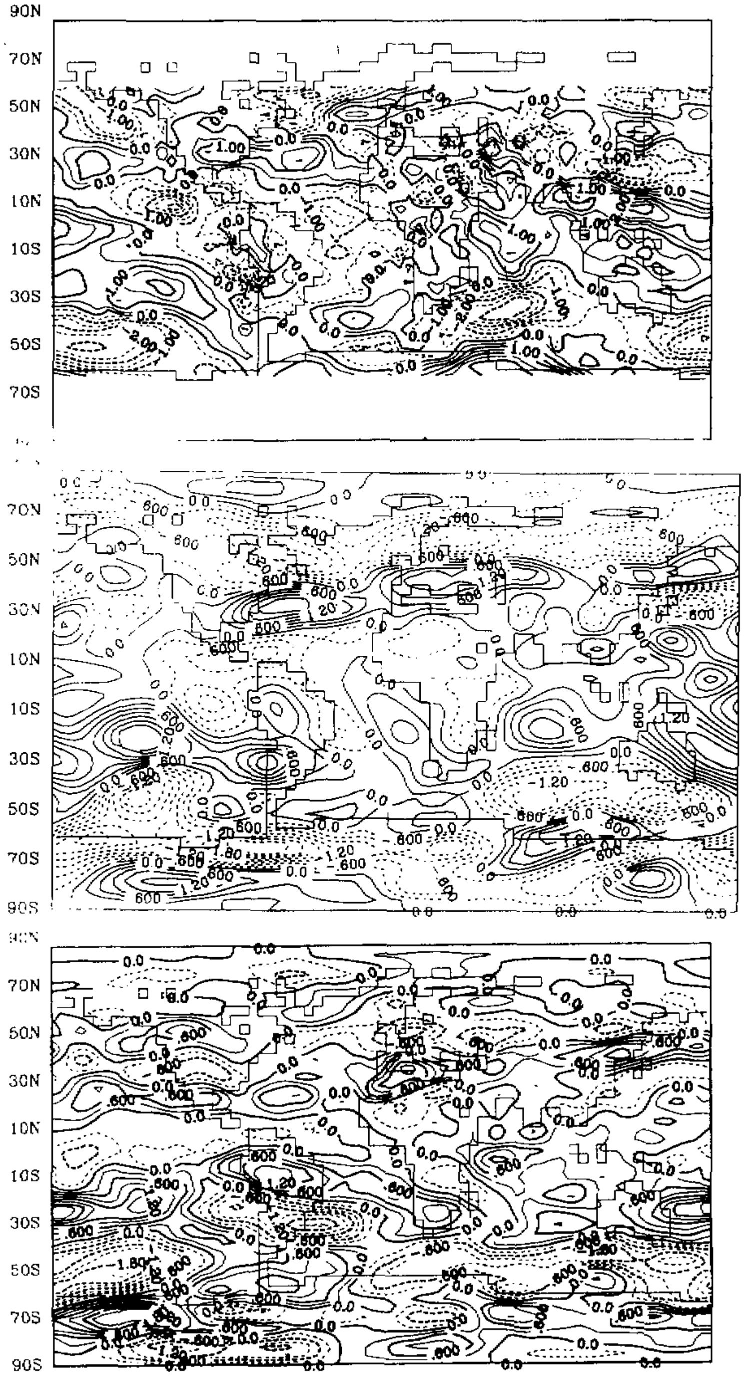

Fig. 1. The global distribution of July u850 differences for strong and weak EAM composite for the observation (a) and simulation (b for the 2-L AGCM and c for the 9-L AGCM).

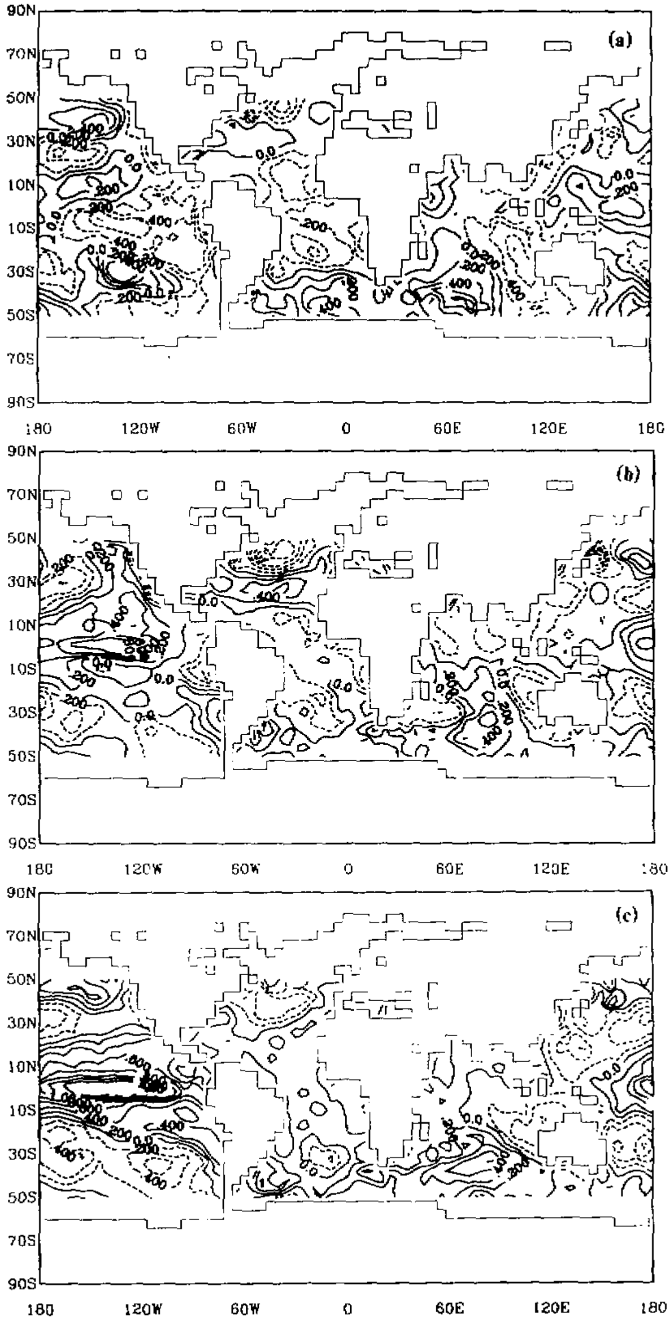

Fig. 2. The seasonal mean SST differences between strong and weak EAM composite for spring (a), summer (b) and autumn (c).

Both 2–L and 9–L models show strong abilities to reproduce the observed global distribution of 850 hPa zonal wind differences for strong and weak EAM composites. We find that the major feature is the weakness of the tropical trade wind over the Indian Ocean and the Central and Western Pacific ($\Delta u850 > 0$) and the models' results are quite realistic despite the smaller magnitude of the difference compared to the observation. The global distribution of July 850 differences for strong and weak EAM composite for the observation and simulation is presented in Fig. 1. Meanwhile the tropical Eastern Pacific SST difference for strong and weak EAM case is positive and develops from spring through autumn. The maximum SST difference at Eastern Pacific is 0.2°C in spring, 0.8°C in summer and 1.4°C in autumn (see Fig.2).

As for the precipitation difference in summer, negative value exists in Yangtze and Huaihe River vally and positive value exists in north and northeast China in ECMWF analysis. The model results are so realistic and the 2–L model shows an even better simulation than the 9–L model.

IV. SIMULATION OF REGIONAL PRECIPITATION OVER CHINA

In most cases, the two models can give resonable simulation of the large–scale pattern of seasonal mean precipitation anomaly over East China, but models' abilities in simulating the regional details of precipitation anomalies are weak. Low horizontal resolutions and models' failure to reproduce the interannual variation of EAM reasonably are two major reasons for this inability.

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