Onset of the East Asia Monsoon in 1991 Simulated by an AGCM

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Abstract

CCSR/NIES/FRCGC joint modeling group made a 20-year simulation for 1979-1998 by an AGCM (primitive equation spectrum model T106L56; the triangular spectral truncation at wave-number 106 with 56 sigma levels) with the annually and seasonally varying observed sea surface temperature. This study presents the features of the onset and seasonal evolution of the East Asia summer monsoon simulated for 1991 in comparison with features found by observational studies for various years. The AGCM can simulate the onset of the East Asia summer monsoon, which precedes the onset of the Indian summer monsoon by ~1 month. The onset of the East Asia summer monsoon occurs in association with the change in large-scale circulation over the continent heated by the sensible heat supply from the surface.

Keywords: Onset of the East Asia summer monsoon. An AGCM simulation of the East Asia summer monsoon. Formation of the Meiyu and Baiu frontal zone.

1. Introduction

Although the onset and the seasonal change of the East Asia monsoon are closely related with the evolution of the Indian summer monsoon, many observational studies showed that the onset of the East Asia monsoon precedes the onset of the Indian summer monsoon about one month. It is also known that the Meiyu and Baiu frontal precipitation zone begins to shift northward around the early July while the Indian monsoon westerlies are sustained at the almost same latitude. Since the AGCM (atmospheric general circulation model) simulation on the East Asia summer monsoon has not been studied yet in detail, it will be informative to compare the onset of the East Asia summer monsoon simulated in the present AGCM with the onset described in observational studies. This simulation study will further our understanding on the East Asia summer monsoon.

2. Model and experiment

The model used in the present study is a primitive equation spectral model, which has 56 sigma-levels and triangular spectral truncation at wave-number 106 (T106L56). It is a high-resolution version of the CCSR/NIES T42L20 that is developed by the Center for Climate System Research and the National Institute for Environmental Sciences (Numaguchi et al., 1997). Although the physical processes of T106L56 are almost same to these of T42L20, some tuning is needed when the resolution is increased to simulate reasonable large-scale circulation systems. Special tuning is not done for the simulation of the East Asia monsoon.

The 20-year integration for 1979-1998 with the annually and seasonally varying observed sea surface temperature is performed by CCSR/NIES/FRCGC joint modeling group. The simulated data of the basic atmospheric and land

surface variables recorded at 1-day interval, and additional variables averaged for each month are used for the present study.

3. Observed features of the East Asia summer monsoon

The onset and the seasonal change of the East Asia monsoon are closely related with the evolution of the Indian summer monsoon. However, many observational studies (Ding (1994), Kato (1985), Kato and Kodama (1992), Matsumoto (1997), Ninomiya and Kobayashi (1998)) showed complicated onset process of the East Asia monsoon. Although there are significant differences among individual years, the following processes are found commonly in many years;

(1) Pre-summer rainfalls over Thailand begin in middle-late April.

(2) The Meiyu-Baiu frontal precipitation zone begins to extend from the south China to the Japan Islands in late April-early May.

(3) Meridional thermal gradient over China decrease rapidly in May in association with the rapid warming in the middle-northern latitudes due to the sensible heat supply from the surface.

(4) The vertical stability over China decrease rapidly in May.

(5) Precipitations over the Indochina Peninsula, Bay of Bengal and the South China Sea increase in middle-late May.

(6) Precipitations over East Asia are intensified in association with the increase of the Indian monsoon westerly in middle June.

(7) The Meiyu and Baiu frontal precipitation zone begins to shift northward early July, while Indian monsoon westerlies are sustained along ~15°N.

4. Features of the East Asia summer monsoon simulated in the AGCM

The onset and the seasonal changes of the East Asia monsoon simulated in the AGCM are consistent with the observed features mentioned above. Figure 1 and Fig. 2 show the 10-day averaged precipitation and 850-hPa wind velocity simulated for 21-30 April and 21-30 June 1991, respectively.

The simulated East Asia summer rain season begins ~1 month before the onset of the Indian monsoon. The 850-hPa circulations in the onset phase are characterized large-scale cyclonic flows over the continent. During 21-30 June, precipitations over the East Asia increase in association with the increase of the Indian monsoon westerly.

Figure 3 and Fig. 4 show the 10-day averaged surface temperature and the vertical stability (the difference of equivalent potential temperature between 850 and 500 hPa) for 21-30 April and 21-30 June 1991, respectively. The decrease of the meridional thermal gradient over China is owing to the rapid warming due to large sensible heat flux of ~75 W m^{-2} over the dry regions in the middle-northern latitudes (figure is not shown). In contrast to the decrease of the thermal gradient over China, fairly large thermal gradient is sustained around the Baiu frontal zone nearby the Japan Islands. The vertical stability over the China continent also decreases rapidly.

The Indian monsoon westerlies indicate maximum intensity during June and July. In this phase, the precipitations over the whole monsoon regions attain maximum intensity. Strong anticyclonic circulation at ~200 hPa with the largest heat source at ~500 hPa appears over ~27°N and 90°E (figure is not shown). The Meiyu-Baiu frontal precipitation zone in the

model indicates the maximum extension and maximum precipitation in June. The Meiyu and Baiu frontal precipitation zone in the model begins to shift northward around the early July, while the Indian monsoon westerlies are sustained at the almost same latitude (figure is not presented).

5. Conclusion

The AGCM can simulate the onset of the East Asia summer monsoon, which precedes the onset of the Indian summer monsoon by ~1 month. The onset of the East Asia summer monsoon occurs in association with the change in large-scale circulation over the continent warmed by the sensible heat supply from the surface.

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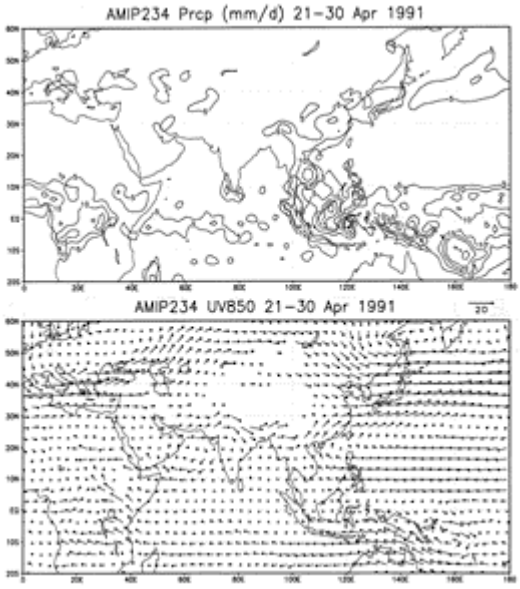

Fig.1: The 10-day averaged precipitation and 850-hPa wind velocity simulated for 21-30 April, 1991.

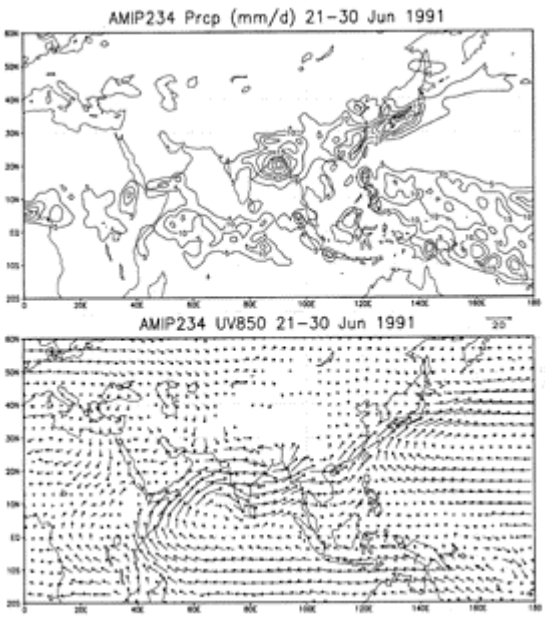

Fig. 2: The 10-day averaged precipitation and 850-hPa wind velocity simulated for 21-30 June, 1991.

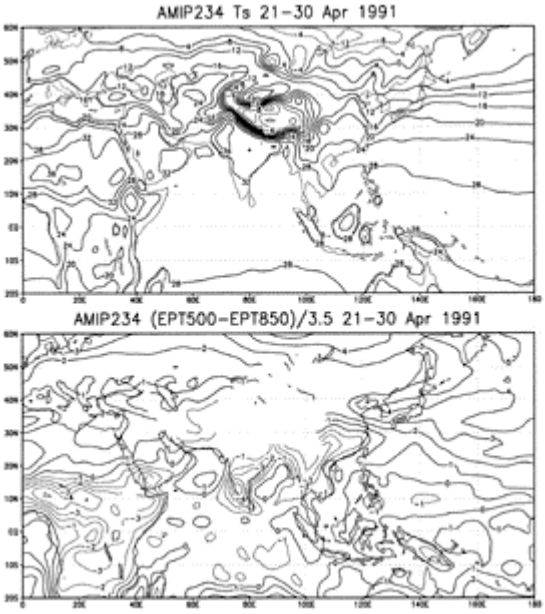

Fig. 3: The 10-day averaged surface temperature and the vertical stability between 850 and 500 hPa for 21-30 June,1991.

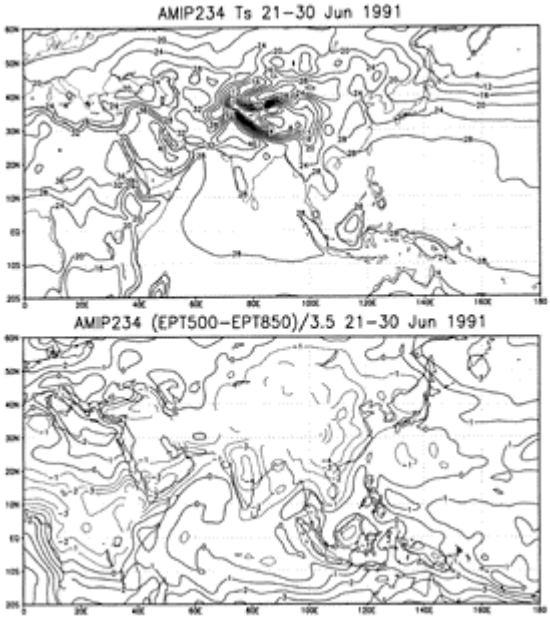

Fig. 4: The 10-day averaged surface temperature and the vertical stability between 850 and 500 hPa for 21-30 Juln, 1991