Progress in understanding of precipitation systems along the Meiyu/Baiu front during GAME and GAME II

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Abstract

Intensive field experiments on precipitation systems around the Meiyu front during the GAME/HUBEX and the following observational projects are revealing the characteristics of cloud and precipitation processes over China continent. The field experiment in the downstream of Yangtze River, after the GAME/HUBEX, revealed a significant development of precipitation systems in the region and their maintenance over East China. Another independent field experiments over China and East China Sea are helping to have linked concept on the Meiyu/Baiu frontal precipitation systems. At the same time, importance of understanding on the development of convective clouds in the south of the Meiyu/Baiu front is emphasized because the cloud development in a very moist condition is the significant characteristics of cloud and precipitation of East Asia. Relation between moist land surface and cloud development is becoming one of the important topics in GAME and GAME II. We aim to give a brief summary of these recent field experiments on precipitation systems relating to the Meiyu/Baiu front in order to have synthesized understandings on cloud and precipitation over Asian Monsoon regions.

Keyword: Meiyu front, cloud and precipitation systems, diurnal variation of convection, field experiments.

1. Introduction

Meiyu (in Chinese) or Baiu (in Japanese) frontal precipitation is one of the most prominent phenomena in Asian monsoon. Structure and development processes of the precipitation systems around the Meiyu/Baiu front are studied for better understanding of the land-atmosphere interactions in continental scale during the GAME and GAME II. Our main concerns are related to heavy rainfalls in the Yangtze River Basin because recent studies related to climate change are paid attention to an increase trend of annual rainfall amount in the region (Nitta and Hu, 1996; Gong and Ho, 2002). Coherent variations are suggested between summer rainfall in the middle-lower reaches of the Yangtze River and in the western part of Japan. Heavy rainfalls in the Yangtze River Basin in 1991, 1998 and 2003 are within our recollection.

Heavy rainfalls in the Huaihe River Basin in 1991 led the field experiment of GAME/HUBEX (GEWEX Asian Monsoon Experiment / Huaihe River Basin Experiment) to the region (Zhao and Takeda, 1998; Ding, 2001). The research area of heavy rainfalls was shifted to the downstream of Yangtze River Basing during GAME II. At the same time, but with different purposes from the GAME, intensive field experiments at the east part of the East China Sea were carried out (Yoshizaki et al., 2002). During GAME II field experiments on cloud and precipitations started around the GAME regions. A brief review of field experiments on cloud and precipitation systems are given in this paper for discussing the design of Post GAME.

2. GAME/HUBEX

The first intensive field experiments on the Meiyu frontal precipitation systems with Doppler radars in the network of sounding were carried out in 1998 and 1999 over the Huaihe River Basin during the GAME/HUBEX. Maesaka and Uyeda (2004a,b) showed two types of precipitation systems identified with the radar data of IOP in 1998 (Fig. 1): one without a temperature gradient in the subtropical air mass and the other with a temperature gradient as a result of a merger with the cold front.

In the case of no strong temperature gradient on 29 June 1998, two dominant precipitation systems were recognized. One was the pair made up by the convective precipitation system on the convergence line near the ground and the stratiform precipitation system. The other was the linear convective precipitation system to the south of the convergence line near the ground. As for the linear convective precipitation system to the south of the convergence line, the precipitation generation at 2.0 km in height and the inflow to the convective cells below 1.5 km in height were noted as a result of the dual Doppler radar synthesis. The numerical simulation indicated that this system was formed on the eastern edge of a shallow cold pool. Around this region, the air near the ground was very moist (95 % in relative humidity). A weak cold pool was sufficient to cause the condensation to create a successive linear convective precipitation system. A weak stratiform precipitation system was formed to the east of the linear convective precipitation and released large amount of latent heat to contributed for the development of meso-a-scale precipitation system.

In the case with a temperature gradient on 2 July 1998, the precipitation band which aligned from west to east was observed around the Huaihe River Basin. This precipitation band consisted of two parts: one was the convective precipitation region in the southern edge of the

precipitation band, and the other was the stratiform precipitation region to the north of the convective precipitation region. In the southern convective region, the inflow to the convective cell located in the layer from 2.0 km to 4.0 km ASL and that most of precipitation was generated around the 0 ℃ layer.

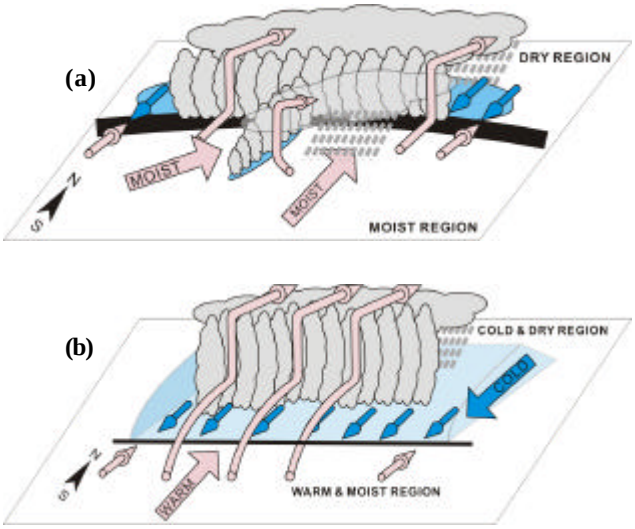

Fig.1: Conceptual models of the precipitation systems associated with the Meiyu front (a) in the subtropical air mass and (b) on the polar front. The arrows indicate the air flow. The thick line indicates the shear line which corresponds to the Meiyu front. The warm and moist air, and cold and dry air distribute to the south and north of the shear line, respectively. (Maesaka et al., 2004a,b)

Through the studies in GAME/HUBEX the role of the moist atmospheric boundary layer in the south of the Meiyu front is emphasized for understanding the development of precipitation systems. Development process of convective clouds on the moist surface in the south of the Meiyu front was studied by Shinoda and Uyeda (2002).

3. Surrounding regions of GAME/HUBEX

3.1. Downstream of Yangtze River

In order to investigate precipitations in the main regions of Meiyu, intensive field experiments in the downstream of Yangtze River were carried out with Doppler radars and wind profilers in 2001 and 2002 in the network of sounding (Geng et al., 2004; Yamada et al., 2003). This experiment was cooperative research with one of the Chinese Key Projects (Ni, 2002). Yamada et al. (2003) revealed one of the mechanisms on the development of the meso-a-scale convective system along the east coast of China: convergence of strong southwesterly inflow to the Meiyu frontal system and the low altitude easterly flow from ocean. Geng et al. (2004) and others are revealing the variety of precipitation systems around the Meiyu front.

A few field experiments on cloud and precipitation systems are going on and a few new experiments are planed in China continent. Continuous observation is expected for understanding of annual variation of convection and precipitation.

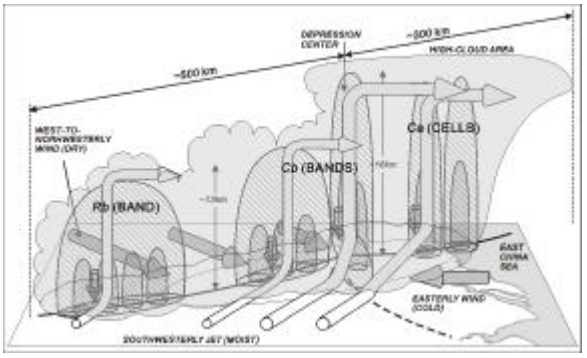

Fig.2: Schematic illustration of the three-dimensional structure of the Mesoscale Convective Systems developed in the downstream of Yangtze River near the coast. (Yamada et al., 2003)

3.2. East part of East China Sea

Intensive field experiments in the east part of East China Sea and the west part of Kyushu were carried out from 1998 to 2002 (Yoshizaki et al. 2002) with Doppler radars, wind profilers, airplane and research vessels on board radar. One of the interesting results is the finding of the water vapor front (Moteki et al, 2004a,b). They found a convergence line with the large water vapor gradient distinct from the Baiu front about 100 km south of the Baiu front. This gave an approach to reveal the Baiu frontal precipitation systems over the East China Sea. Characteristics of precipitation systems along the west coast of Kyushu Island are studied by Yoshizaki et al. (2000), Kato et al. (2003) and others.

These recent studies and previous studies in the east part of Kyushu Island facing to East China Sea are giving detailed features on precipitation systems associated with the Baiu front in the east part of East China Sea. Now we are at the stage to have a unified feature of the Meiyu/Baiu front from Continent China, East China Sea to the west part of Japan.

3.3. Out of GAME regions

Observational studies on diurnal variations of convective activities in GAME-Tibet and GAME-Tropics provided good comparison with convective activities around the Meiyu/Baiu front. Characteristics of convective clouds on Tibetan Plateau during GAME-Tibet IOP were investigated using Doppler radar data (Uyeda et al., 2001).

In the out of the GAME regions, field experiments relating to cloud and precipitation systems were made

during GAME and GAME II. Mori et al. (2004) examined the diurnal cycle of rainfall and its regional variation over Sumatera Island, Indonesia using Tropical Rainfall Measuring Mission (TRMM) satellite precipitation radar (PR) and intensive rawinsonde sounding data. Islam et al. (2004) studied the diurnal variations of cloud activity in Bangladesh and north of the Bay of Bengal in 2000 using GMS IR data and radar data of Bangladesh Meteorological Department. Katsumata and Yoneyama (2004) described the characteristics of the observed internal structure of the internal structure of the ITCZ precipitating system and related environmental factors in the western Pacific using C-band Doppler radar data. Hirose and Nakamura (2002) depicted features of seasonal variations of the vertical gradient of rainfall rate over monsoon Asia using TRMM PR data from 1998 to 2000.

4. Characteristics of cloud clusters

To understand the formation and maintenance mechanism of Meso-scale Convective Systems (MCSs) around the Meiyu/Baiu front, characteristics of Cloud Clusters (CCs) which appeared around the front over Continent China and East China Sea during June and July of five years (1998-2002) were investigated by using infrared TBB data of GMS (Geostationary Meteorological Satellite (Sakamoto and Uyeda, 2002).

Diurnal variation of convective activity is predominant over land during warm season in East Asia. The magnitude of the diurnal variation is known to be different over different geography like a plain, mountains, ocean, etc. However few researchers have investigated the relationship between the appearance characteristics of CC and the geography. In this study, analysis areas containing the eastern part of China and East China Sea, where CC appears frequently along the Meiyu/Baiu front, were classified into four domains: Yangtze River Basin, Southeast Mountains, northern part of East China Sea, southern part of East China Sea. Characteristics of CC were investigated for each of the four domains and surrounding areas. An algorithm to detect and identify CC automatically was developed and 2044 CCs were tracked objectively. Following characteristics of CC around the Meiyu/Baiu front in the four domains were clarified.

Diurnal appearance of CC having an afternoon peak on Tibetan Plateau and Yungi Highland and Southeastern Mountains is clear. In comparison of June and July for four domains, diurnal appearance of CC having an afternoon peak was predominant in Yangtze River basin in July, and Southeast Mountains in both June and July. However, it was not predominant in Yangtze River basin in June. CCs in Southeast Mountains had shorter lifetime and smaller maximum area than those in Yangtze River Basin on average. Over East China Sea, a lot of CCs appeared around 6 o'clock (local time) in the northern part in both June and July. They had longer lifetime and larger maximum area than those over land. Though CCs in the southern part were smaller and lived shorter, some of them appeared simultaneously nearby each other and developed to a huge cluster. Diurnal variation of surface temperature calculated from an objective analysis data provided by Japan Meteorological Agency was consistent with the diurnal appearance of CC in each domain. These findings would contribute for the improvement of forecasting CCs and associated heavy rainfalls.

By tracking CCs objectively, a generation area of CCs, which develop to meso-a low and produce heavy rainfalls, was recognized around the downstream of Yangtze river and the west pat of East China Sea. The trends shown by Takeda and Iwasaki (1987) and Iwasaki and Takeda (1993) are confirmed. The relation between characteristics of CC in the Meiyu/Baiu front and structure of rainfall systems is discussed in comparison with Doppler radar analyses on a few intensive field experiments.

5. Discussion

Recent field experiments on the precipitation systems in the Meiyu/Baiu frontal zone acquired data sets to estimate the water mass besides the data for the study on the structure of the system. The detailed structures of the Meiyu/Baiu frontal precipitation system, which is a unique system in the mid-latitude Asia, are revealed. However the unified understanding of the system from the west of Continent China to Japan is still on the way. Understanding on the role of the convection in the moist environment in the south of the Meiyu/Baiu front would help the understanding on the precipitation systems around Bangladesh and Bay of Bengal, and over Indo China Peninsula. As for the development of convective precipitation system in the moist environment, treatment of boundary layer would be very important as shown by Shinoda and Uyeda (2002). Method to analyze the characteristics of cloud clusters with GMS infrared data would help to reveal the characteristics of precipitation systems in East Asia in combination with another satellite data.

6. Summery

Recent field experiments on the Meiyu/Baiu frontal precipitation systems revealed the development processes of precipitation in the moist environment. Detailed studies on the systems showed that rapid development of convective cloud below the melting layer in the south of the Meiyu/Baiu front plays an important role for development of meso-ß and meso-a precipitation systems along the Meiyu/Baiu front. Studies on the annual variation of precipitation systems along the Meiyu/Baiu front would help the understanding on monsoon. Further studies on development of precipitation systems with cloud resolving model are expected.

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