An Analysis of a Meso-β System in a Mei-yu Front Using the Intensive Observation Data During CHeRES 2002

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ABSTRACT

The conventional and intensive observational data of the China Heavy Rain Experiment and Study (CHeRES) are used to specially analyze the heavy rainfall process in the mei-yu front that occurred during 20–21 June 2002, focusing on the meso-β system. A mesoscale convective system (MCS) formed in the warm-moist southwesterly to the south of the shear line over the Dabie Mountains and over the gorge between the Dabie and Jiuhua Mountains. The mei-yu front and shear line provide a favorable synoptic condition for the development of convection. The GPS observation indicates that the precipitable water increased obviously about 2–3 h earlier than the occurrence of rainfall and decreased after that. The abundant moisture transportation by southwesterly wind was favorable to the maintenance of convective instability and the accumulation of convective available potential energy (CAPE). Radar detection reveals that meso-β and -γ systems were very active in the MCS. Several convection lines developed during the evolution of the MCS, and these are associated with surface convergence lines. The boundary outflow of the convection line may have triggered another convection line. The convection line moved with the mesoscale surface convergence line, but the convective cells embedded in the convergence line propagated along the line. On the basis of the analyses of the intensive observation data, a multi-scale conceptual model of heavy rainfall in the mei-yu front for this particular case is proposed.

Key words: mei-yu front, heavy rainfall, mesoscale convergence line, conceptual model, Doppler radar

1. Introduction

It is well known that the majority of heavy rainfall is produced by mesoscale convective systems (MCSs). Since Maddox (1980) defined a relatively large-scale and severe convection system as a mesoscale convective complex (MCC), meteorologists have paid more attention to studying MCCs. Liang and Fritsch (2000) investigated the environmental conditions for the development of MCCs in Africa, Australia, China, South America, and the USA. They indicated that MCCs are initiated in the baroclinic region and that vertical wind shear in the lower troposphere and large convective available potential energy (CAPE) are favorable to the development of MCCs. Heavy rainfall events during the mei-yu season usually appear in relation to the passage of MCSs. The floodings due to heavy rainfall over the Huaihe River basin in 1991 and over the Yangtze River basin in 1998 were produced by MCSs; in particular, the severe heavy rainfall in Wuhan City and Huangshi City, Hubei Province, China, during 20–21 July 1998 resulted from MβCSs (Zhang et al., 2002; Bei and Zhao, 2002). The MβCSs that produced heavy rainfall in 1991 developed along the shear line and mei-yu front, and some MβCSs are associated with vortices (Ding, 1993). Only conventional data have been employed to analyze the synoptic conditions of vortices and MCSs that occurred along mei-yu fronts in China in previous studies (Zhang et al., 2002; Zhang and Zhao, 2004), in addition, some simulation results have been used to study the structure (Bei et al., 2002; Xu and Gao, 2002; Cheng and Feng, 2001).

Several field experiments have been carried out during recent years in East Asia to study the structure and mechanism of MCSs that produce heavy rainfall, such as the observation of the structure of a mei-yu-
Fig. 1. The observed 36-h precipitation of 0800 LST 20 June–2000 LST 21 June 2002. The cross marks indicate the location of Shouxian, Hefei, Feixi and Anqing stations. The dashed circle shows the observation area by the Hefei radar. (units: amm)

frontal convective system during the Taiwan Area Mesoscale Experiment (TAMEX, Kuo and Chen, 1990). Intensive field experiments were also conducted on Kyushu Island and in the East China Sea between 1998 and 2002 (Yoshizaki et al. 2002). In particular, the China Heavy Rain Experiment and Study (CHERES) field experiment on heavy rainfall in the mei-yu front, which was to acquire intensive observational data for studying the structure and evolution of mesoscale convective systems, was conducted in the middle and lower reaches of the Yangtze River in June and July in 2001 and 2002.

The CHERES field experiment in China covers two regions: the middle reaches of the Yangtze River, including southern Hunan Province and most of Hubei Province, and the lower reaches of the Yangtze River, including most of Anhui Province, southern Jiangsu Province, and northern Zhejiang Province. The field experiment includes 15 radiosondes, 120 surface intensive observation stations, 9 weather Doppler radars, 8 GPS stations, 2 wind profilers, 1 boundary layer observation system, and 114 automatic weather stations (AWS). The Yichang and Jingzhou Doppler radars in Hubei Province and the Wuwei and Ma’anshan Doppler radars in Anhui Province provided two dual Doppler radar observations systems, respectively (Ni, 2001). During the field experiment, a severe MCS with a life cycle longer than one day developed over southern Anhui Province during 20–21 June 2002, which produced heavy rainfall in southern Anhui Province and Jiangsu Province (Fig. 1) with a maximal rainfall of 180.8 mm d⁻¹ occurring over Huangshan. In this paper, intensive observation data—especially the radar data of Hefei station, GPS, and wind profiler data—are used to reveal the features of the MCS.

2. The synoptic conditions for MCS development

The synoptic weather patterns at 2000 LST 20 and 0800 LST 21 June 2002 are shown in Fig. 2. At 200 hPa, the northeastern rim of the South Asia high is located at the Yangtze River basin (Figs. 2a, b), which is the upper-level divergence area. At 500 hPa, a trough is located in the western part of China at 2000 LST 20 June and travels eastwards a little by 0800 LST 21 June (Figs. 2c, d). The MCSs developed in the warm region to the south of the shear line (Figs. 2e, f), which is located between the southern edge of the westerlies and the northern periphery of the western Pacific subtropical high. At the same time, the mei-yu front is located at the Yangtze River basin to the north of 30°N, which is the left side of the exit of the lower level jet (LLJ) and the right side of the entrance of the upper level jet (ULJ). Development of the convective system in the mei-yu front seems to be significantly related to the moisture transported by the LLJ. Backward propagation or redevelopment of the cell occurs when unstable moist air continuously feeds into the southwest boundary of the active convection. In conclusion, the weather pattern and synoptic condition over the middle and lower reaches of the Yangtze River basin are favorable to the formation and development of convective systems from 20 to 21 June 2002. The convection along the mei-yu front is extraordinarily active, especially over the lower reaches of the Yangtze River basin.

3. The formation and development of the MCS

3.1 MCS features

It can be seen in Fig. 3 that the MCS formed in southern Anhui Province (near Dabie Mountains) at 2000 LST 20 June and developed into a meso-α system at 0200 LST 21 June with a minimum TBB (black body temperature) less than −70°C. The system produced weak rainfall at that time, and afterwards, the hourly rainfall during 0200–0800 LST 21 June was greater than 10 mm. The system split at 0900 LST 21 June, and consequently, it weakened gradually and part of the severe convection stagnated over southern Anhui Province. Almost at the same time, a new meso-β convective system was generated at (116°E, 31.5°N) (Dabie mountains), and merged with the old convection at 1600 LST 21 June. This system dissipated at 2000 LST 21 June over southern Anhui