GAME/HUBEX research activity

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1. Main research topics

The energy and water cycle in the subtropical monsoon region of East Asia is characterized largely by the Baiu/Changma/Meiyu front in summer. It extends eastward from the eastern edge of the Tibetan Plateau and brings a huge amount of rainfall in East Asia in early summer. Its formation and maintenance processes are largely affected by the Southeast Asian summer monsoon (SEAM), the western North Pacific summer monsoon (WNPM), the mid-latitude westerly systems, and so on. It is interesting that the very humid and the dry climate regions are adjacent to each other just around the Meiyu front in China, affected by the Tibetan Plateau.

Various scale of cloud/ precipitation systems are formed in this frontal zone and play a major role in the energy and water cycle in the zone. The purpose of GAME/HUBEX is to make clear the role of mesoscale cloud systems in time variation of regional scale energy and water cycle, and to reveal their evolution and response to time variation of land surface conditions.

In 1998, HUBEX group performed meteorological observation during the period from May to August. During the intensive field observation, a record-breaking flood occurred in the Yangtze River region. A large amount of important data was obtained by the field observation. Following 1998, HUBEX group also performed meteorological observation in 1999: surface flux observations and the intensive field observation of meteorology and hydrology in June and July. Synoptic scale situation was largely different from the last Meiyu season. The long term monitoring of flux has been conducted since 1998.

2. Continental scale Asian monsoon variability

We analyzed the global precipitation data to study long-term variation of seasonal change of precipitation during the period from June to August in East Asia and the Western Pacific Ocean. Seasonal variations of precipitation can be classified into three patterns A, B and C (Fig. 1). The pattern A is that the intense precipitation area showed no northward shift and its amount decreased from June to August. The pattern B is characterized by a continuous northward shift of intense precipitation from 5 N to 15 N with increasing amount. The pattern C showed a shift from 15 N to 25 N with large amount of precipitation in June and August while less amount in July. These patterns are related to water vapor flux and have strong correlation with precipitation of Meiyu in China and Baiu in Japan.

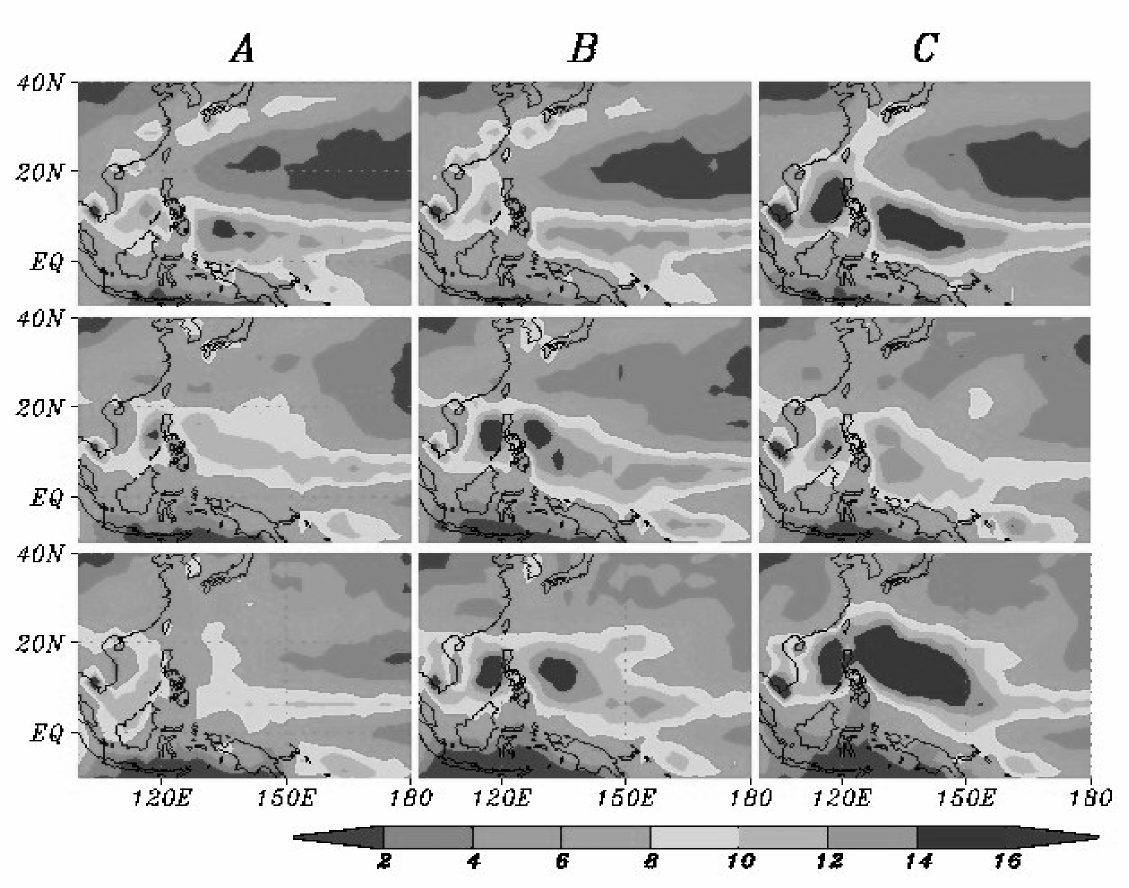


Fig. 1. Averaged monthly precipitation amount in the patterns A, B and C from June to August.

3. Regional scale energy and water cycles

Land-atmosphere interaction and its role in the formation of mesoscale precipitation systems are one of the most important research targets of GAME-HUBEX. We tested the JSM-SiBUC model using GAME reanalysis data as initial and boundary conditions. Figure 2 shows simulated and observed rainfall for the Huaihe River Basin (11 deg.× 5 deg.) from 27 to 30 June 1998. This model can predict the rainfall area rather well, but the predicted rainfall amount is larger than the observed one (especially on 27 June).

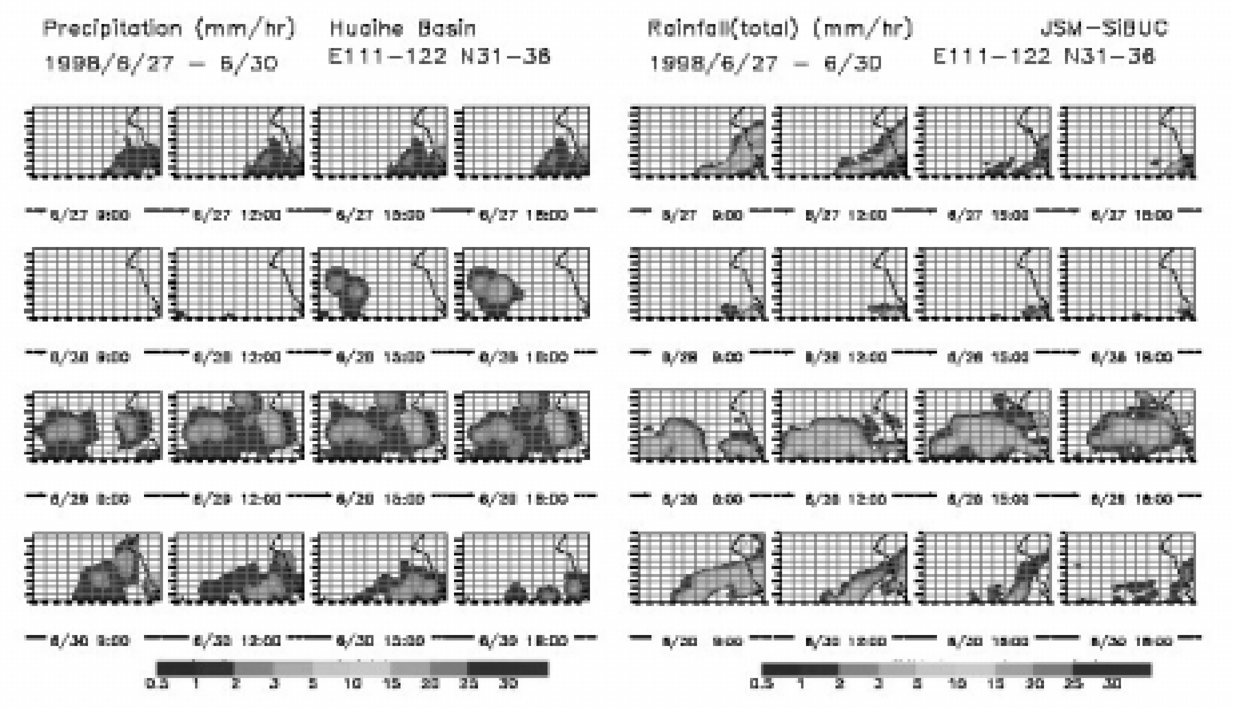


Fig. 2. Simulated and observed (surface station's data) precipitation in Huaihe River Basin (ll deg. × 5 deg.)

4. Frontal-scale characteristics of cloud systems

Frequent appearance of mesoscale convective cloud systems results in the persistent heavy rainfall area in the Meiyu frontal scale. It is interesting that such convective clouds are sometime associated with meso-scale circulation and interact with that circulation system strongly. As for the meso-scale lows, so-called the southwest vortices appear frequently around the Meiyu front in China, initiated around the eastern foot of the Tibetan Plateau.

It is noted that the Meiyu frontal rainfall area became organized into a meso-scale clouds, and a meso-scale low was generated after that. Distribution of the negative relative vorticity at 500 hPa level suggests that persistent generation of the instability associated with the strong low-level southerly wind around the shear line initiated and sustained the heavy rainfall area, resulting in the formation of the meso-low. It is interesting that the synoptic scale low-pressure area near the surface level extended to the northwest of the Meiyu frontal zone around the Huaihe River Basin. This low-pressure area seemed to be associated with the heating from the ground. In relation to this low-pressure area, the low-level southerly wind component reached to penetrate further northward around Fuyang (32.5 N/ 116 E), where cloudless area existed just to the north of the Meiyu cloud zone. Due to such change in the low-level wind field, the destabilization of stratification for deep moist convection was brought there through the differential advection of the equivalent potential temperature. The present study illustrates an example that the activation of the Meiyu frontal rainfall due to the synoptic scale system would result in the initiation of the meso-scale low.

Cloud clusters are important cloud activity of the Meiyu front over the China continent. Precipitation within cloud cluster over the continent is important for the water cycle in this region. A diurnal variation of cloud activity including cloud clusters was significant over the continent during HUBEX IOP. Most of cloud clusters began to develop at the late evening and attained maximum of the lowest cloud area at midnight (Fig. 3.). This is a significant diurnal variation of cloud clusters over the continent. We are trying to simulate the features of cloud clusters by using several mesoscale models (MRI-NHM, ARPS, RSM, etc.)

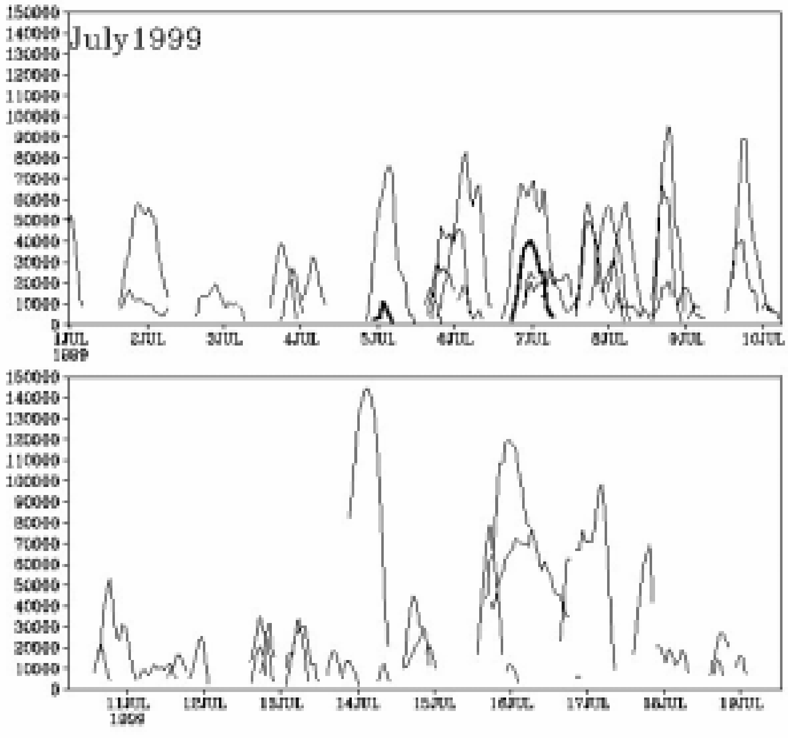


Fig. 3. Time variation of area of cloud clusters with Tbb lower than -60 C.

5. Mesoscale cloud systems

In the Doppler radar observation range, main precipitation systems were observed from 29 June to 3 July, 1998 (Uyeda et al., 1999). It is quite interesting that the Meiyu front moving to the north (south) showed a warm (cold) frontal-like structure as shown in Fig. 4. In addition, the front had three types of sub-structures, that is, warm frontal, cold frontal and meso-vortex types (Maesaka and Uyeda, 1999, 2000a). Warm frontal type of precipitation was in the morning of 29 June 1998 and cold frontal type in the afternoon of the day (Maesaka and Uyeda, 1999, 2000a) (Fig. 5.). Meso-γ scale vortices were observed in the precipitation systems on 2 July (Fig. 6.). Wind fields and divergence profile in and beside the precipitation systems are analyzed with VAD winds by Fujiyoshi et al. (1999, 2000). Evolution of meso-β scale precipitation systems was studied by using Fuyang radar (Xu and Xu, 1999) (Fig. 7.). Water budget in the Fuyang radar observation range (r = 250 km) was analyzed by using sounding data at 7 stations by Maesaka and Uyeda (2000a). Structure and development processes of the precipitation system of cold frontal type are analyzed from a different point of view (Kato et al., 1999; Geng et al., 2000; Maesaka and Uyeda, 2000b). In cold frontal type southwesterly inflow in the low altitude and condensation in the low altitude ahead of the precipitation area were prominent. In meso-vortex type, condensation above 3 km and ahead of the precipitation system, and evaporation behind it are analyzed.

After the main precipitation period, diurnal variation of convective clouds is recognized under the subtropical high from 11 to 15 July, 1998 (Uyeda *et al.*, 2000). On July 13 1998, a deeply developed and long-lived cumulonimbus cloud was observed by Doppler radars. It developed in the atmospheric situation of weak vertical wind shear and its primary updraft was situated in the rear portion relative to the storm motion. It seems that the presence of the broad downdraft observed around the region of low to mid-levels northeasterly inflow contributed to the development and maintenance of downdraft. It is interesting that, under the influence of low-level inflow from the northeast side, interaction between convective-cells occurred and long-lasting and very deeply cumulonimbus cloud was formed in the atmospheric condition of weak vertical wind shear. On 16 July a squall line passed over the Doppler radar sites (Tsuboki *et. al.*, 2000). An intense convection was located along the leading edge and decaying convection behind the edge. A parallel component of relative velocity was significant at every level of the squall line. Convective cells successively developed on the downshear side of this parallel component. As a result, a long line was formed.

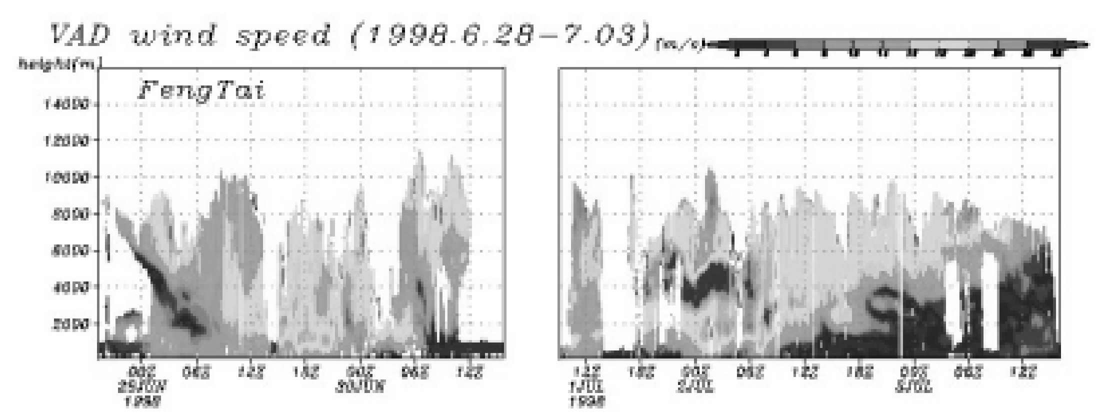
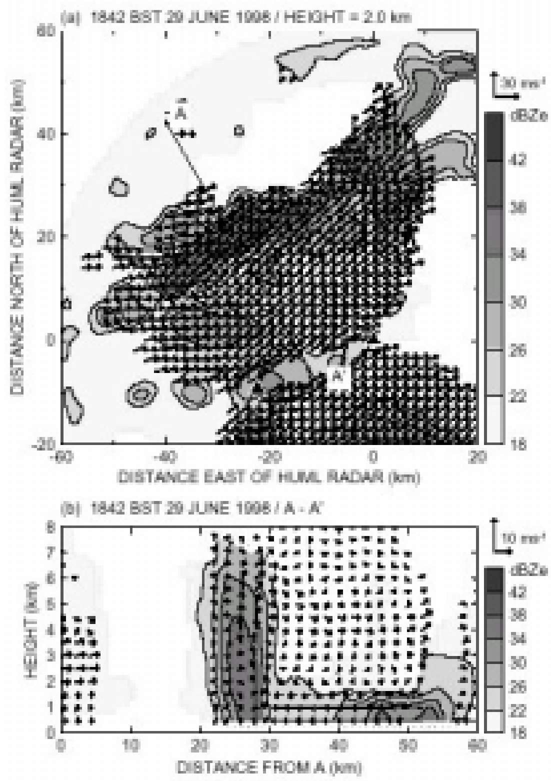


Fig. 4. Time-height cross section of wind speed measured by a Doppler radar at Feng Tai. The left panel (from 29 to 30 June) showed a warm frontal structure and the right panel (from 1 to 3 July) showed a cold frontal structure.



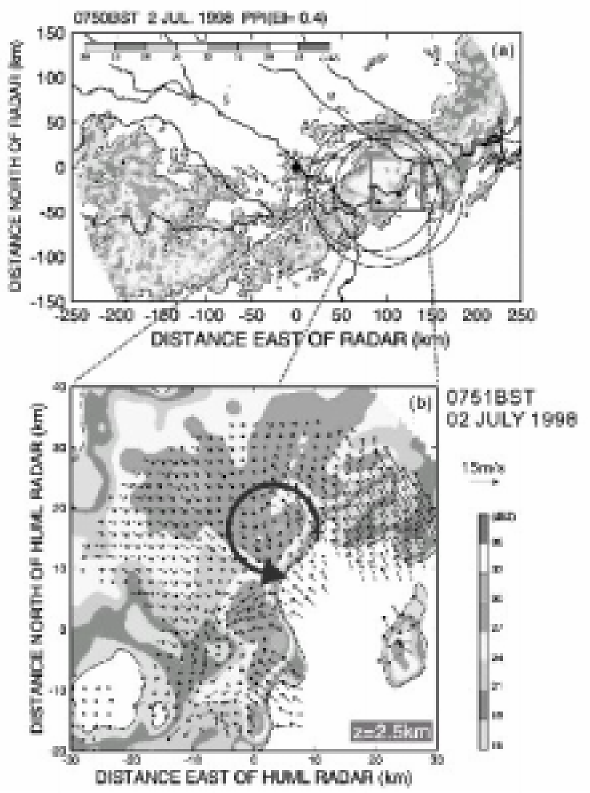


Fig. 5. Dual-Doppler radar analysis for 1842 BST on 29 June 1998. a) Horizontal plane at 2.0 km in height. b) Vertical cross-sections along A-A' lines in (a). The vector denotes the wind on the plane. Vectors of (b) are subtracted from the averaged wind. The shading denotes the radar reflectivity.

Fig. 6. The reflectivity(PPI, EI=0.4) of Fuyang radar at 0750 BST on 2 July 1998 (top panel). Horizontal plane of dual-Doppler radar analysis at 2.5 km in height (bottom panel). The round arrow indicates the vortex.

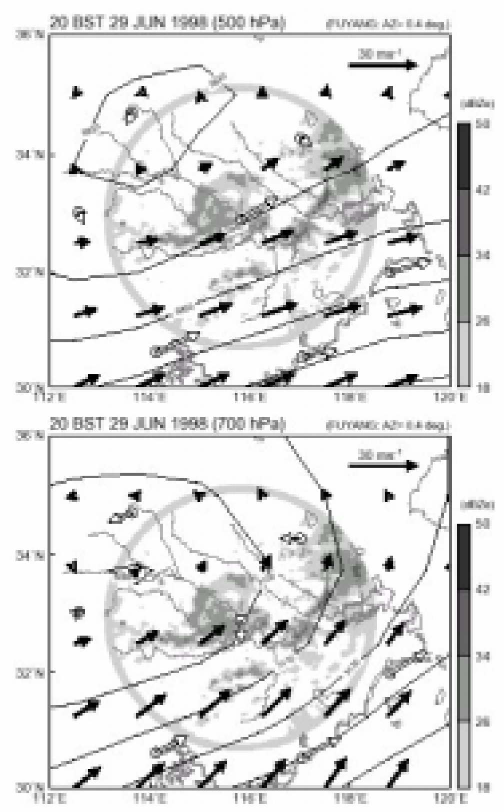


Fig. 7. GANAl wind (solid arrows) and geopotential height (contoured every 10 m) superimposed Fuyang radar reflectivity (0.4 PPI scan) at 700 hPa and 500 hPa (20 BST 29 June 1998). Open circle shows the sounding point and open arrows denote the wind by sounding at the level.

6. Study of land-surface hydrological processes

To predict floods, droughts and future water resources for a large river basin, a macro scale distributed hydrological model is an indispensable tool. For modeling water movement of a large river basin, modeling procedures such as basin partitioning, hydrological process modeling for a sub-basin, linking sub-basin models together to make a total runoff model require heavy tasks. Thereby, automatic procedures for processing hydrological modeling are necessary so that a model is transferable to various large catchments. In automatic modeling procedures, processing channel network linkages should also be included to incorporate a river flow routing model efficiently.

To satisfy such modeling requirements, a macro scale grid based distributed hydrological modeling system using OHyMoS, Object-oriented Hydrological Modeling System (Takasao et al.,1996, Ichikawa et al., 2000) is developed and applied to the Huaihe River basin in China. In the system, a watershed basin is subdivided into grid boxes according to a grid system of a meso-scale atmospheric model to incorporate atmospheric model outputs. By using the values of model parameters identified at the Shigan River basin (Fig. 8), the hydrological simulations for the Huaihe River basin were conducted.

A basic framework for building a macro scale distributed hydrological simulation system is as follows:

i) division of a river network into several sub-networks by rectangular grid boxes set by a numerical atmospheric model,

ii) modeling of hydrological processes in each grid box (runoff element modeling),

iii) modeling of channel flow routing in each grid box (flow routing element modeling),

iv) building a total simulation system by connecting subsystem models composed of the runoff element models and the flow routing element models.

To test the simulation model for working correctly, hypothetical precipitation was given to the system. This simulation shows that time lag of the peaks between two hydrographs is about three days. It is important to consider the effect of river flow routing.

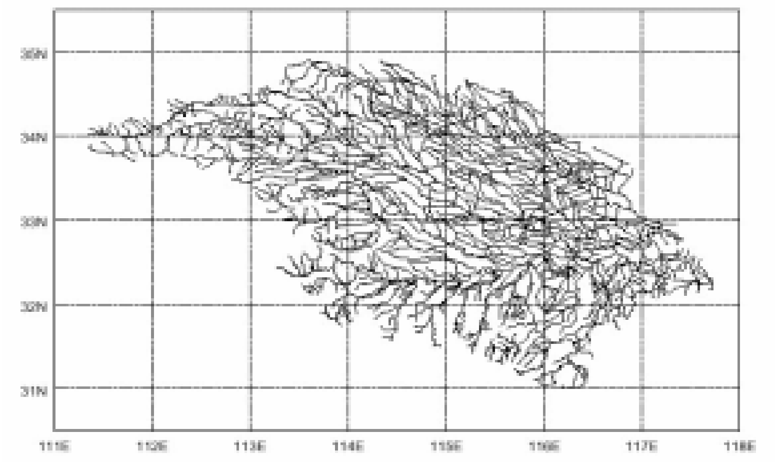


Fig. 8. Channel network for the Huaihe River above Bengbu

7. Concluding remarks

Many studies have been done on the structure and characteristics of precipitation systems during the intensive observation period of the GAME/HUBEX. Although a large number of reports were made on the structure of each precipitation system, the study of interaction between meso-α and meso-β scale systems is few. Combination of Doppler radar data, conventional weather radar data, sounding data, satellite data and surface data is expected. We should utilize objective analysis data and proceed to 4DDA. Only a few studies with numerical simulation are reported; for a squall line on 16 July by Tsuboki et al. (2000) and for an isolated convective cloud on 14 July by Shinoda et al. (2000). We are also encouraged to do numerical simulation for understanding the structure of precipitation systems and water circulation in and around the systems.

For HUBEX area, moisture budget analyses with objective analysis data as Peng and Song (1999) and moisture sink analyses with sounding data as Lin et al. (1999) would give information on the background of the precipitation systems. Doppler radar data are fully used for analyses of three dimensional wind fields in precipitation systems. However grid data of wind velocity available for statistical analyses are not ready. If we have time series of updraft field it will be very useful.

Reflectivity data of three Doppler radar need careful calibration and consideration of attenuation (Xu *et al.*, 1999). Reflectivity data of Fuyang radar is very useful for understanding the structure of precipitation systems (Xu and Xu, 1999; Geng *et al.*, 2000). Classification of precipitation types such as convective or stratiform are tried with Fuyang radar data (Zhang *et al.*, 1999). However Fuyang radar data had fluctuation of reflectivity and its value is compared with TRMM precipitation radar data and disdrometer (Uyeda *et al.*, 1999). Satellite data are very useful for the study of precipitation systems as follows. Estimation of precipitation amount using TRMM TMI is tested by Li *et al.* (1999). Further studies on the principle of satellite infrared rainfall estimation and passive microwave measurement, applied to the strong convective systems during the IOP by Zhang *et al.*, (1999) would be hopeful. Retrieval of water vapor above 500 hPa by using GMS-5 WV (water vapor) channel during the IOP by Osaki *et al.* (1999) would be useful for comparison with precipitation systems. Comparison with GMS IR data and hourly surface rainfall data, as shown by Zheng *et al.* (1999), is also necessary. Analyses with objective analysis data and GMS data as Tuboki and Monoe (2000) would be important.

As many studies on the structure of precipitation systems are made with Doppler radar data and Fuyang radar, we know what kind of precipitation systems we had during the IOP. However surface data is not used well and further use of satellite data should be encouraged for the study of large scale characteristics of Meiyu frontal precipitation systems at the same time with objective analysis data. 4DDA with observational data is expected for better understanding. Numerical experiments with synoptic model and cloud resolving model are also important. Combination of all of the analyses and investigation on the multi-scale structure and multi-processes of precipitation systems would be the most important target of the study.

For the comparison with precipitation systems in another areas, studies on the statistical feature of precipitation system are required; precipitation types, averaged vertical profile of reflectivity (rainfall intensity), updraft and non-adiabatic heating, and averaged precipitation efficiency. As basic data set for various studies are ready and provided, further processed data set such as grid rainfall amount and updraft distribution are expected.

It would be important for HUBEX researchers to reach to mutual understandings on a few focal points to study in a few years and present situation of studies. At the same time we have to provide better community data as soon as possible. Submission of each paper to scientific journals and publishing of special issue of HUBEX would be necessary. It would be important to continue collaboration in the study of the GAME/HUBEX for understanding precipitation systems during the IOP and Meiyu/Changma/Baiu frontal precipitation systems from China and Korea to Japan.

Most papers cited in this report are found in the following Proceedings.

- Proc. of Workshop on Meso-scale Systems in Meiyu/Baiu front and Hydrological Cycle. Xi'an, China (3-9 November, 1999) (GAME Publication No. 25)
- Proc. of International Conf. on Mesoscale Convective Systems and Heavy Rain in East Asia, Seoul, Korea (24-26 April, 2000)
- Proc. of 13th International Conf. on Clouds and Precipitation, Reno, Nevada, USA, (2000)
- Proc. International GAME/HUBEX Workshop, Sapporo, Japan (12-14 September, 2000) (GAME Publication No. 23)