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RESEARCH ARTICLE

A STUDY ON MEIYU BOUNDARY LAYER CHARACTERSTICS OVER DONGSHAN CHINA USING WIND PROFILER RADAR

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ABSTRACT

In order to understand the formation mechanism and vertical structure of precipitating cloud systems associated with the Meiyu/Baiu frontal cyclone, special observational campaigns have been conducted in the downstream of the Yangtze River during June-July 2001 and 2002. We deployed a Lower Atmospheric Wind Profiler (LAWP) with Radio Acoustic Sounding System (RASS) at the Meteorological Observatory, Dongshan, China to observe the inner structure of precipitating cloud systems seen frequently in the observational area. The LAWP provides vertical profiles of three-dimensional wind, convective boundary layer (CBL) and temperature from the lower atmosphere with a height resolution of 58 m to 202 m and a time resolution of about 1 to 60 minutes. LAWP had been operated in two modes: low mode and high mode up to 4 km and 11 km height during non-rainy and rain conditions, respectively. A study was carried out during intensive observational period 2002 (IOP-2002) to understand the pre-convective environments in the boundary layer during pre-Meiyu and Meiyu convective days to find out whether there is any precursor before the convection triggering. The LAWP observations demonstrate that during Meiyu period the average CBL is below < 1 km and whereas, pre- and post-Meiyu period the average CBL height above 1 km. The results show that distinguishable CBL evolution was noticed during pre-Meiyu and Meiyu period. LAWP observed eleven precipitating cloud systems in the vicinity of Meiyu frontal zone during IOP-2002. Each precipitating cloud system was divided into three rain types: convective, mixed convective-stratiform, and stratiform rain based on the LAWP observation data from the echo intensity above melting layer and the difference of the fall speed of precipitation particles between 3 and 6 km altitude. In the passage of the cloud system, convective systems embedded within a wide stratiform precipitation were observed. The observed precipitating cloud systems showed a diurnal variation with a peak in the late evening and nighttime. Boundary layer winds often shows strong South/southwesterly flow when the Meiyu precipitating cloud systems passes overhead of the LAWP.

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INTRODUCTION

In the Yangtze RiverValley, the rain period from mid-June to July is widely known as Meiyu (or Baiu in Japan, Changma in Korea) or Plum rain. During this rainy period, the quasi-stationary Meiyu front can extend from western China to western Japan and characterized by a weak temperature gradient, strong vertical wind shear, and large moisture gradient across the front at low levels (*Ninomiya*, 2000). Precipitation systems imbedded in the Meiyu front are essentially convective in nature. Several field experiments have been carried out over KyushuIslands and over the East China Sea (*Yoshizaki et al.*, 2000). *Chen et al*., (1998) investigated heavy precipitation caused by low-level jet along the western side of the central mountain range of Taiwanunder the Taiwan Area Mesoscale Experiment (TAMEX). *Lau et al*. (2000) carried out an international field experiment during the South China Sea Monsoon Experiment (SCSMEX) with the objective for better understanding the key physical processes for the onset and evolution of the summer monsoon over Southeast Asia and southern China aiming to improve monsoon predictions. The experimental field study, Huaihe River Basin Experiment (HUBEX), was performed around Huaihe River basin in China to investigate energy and hydrological processes of multi-scale cloud systems in the Meiyu front and their interaction with land surface hydrology by utilizing data from the Doppler radars, radiosonde and

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surface meteorological stations (*Shinoda and Uyeda*, 2002). The Meiyu frontal cyclones play a major role not only in the energy and water cycle in the Asian monsoon regions, but also causes flood disasters in the East Asia region. Elucidating the behavior of the systems is important for understanding and predicting regional climate changes, as well as global climate changes. A joint field experiment by the Frontier observational Research System for Global Change (FORSGC), Japan and Chinese Academy of Meteorological Sciences (CAMS), China on heavy rainfall in the downstream of the Yangtze River was conducted during 2001 and 2002. During the intensive observational period (IOP) weather radars, wind profiler radar, automated weather stations and a network of soundings are utilized to reveal the features of precipitating cloud systems (*Yamada et al*. 2003). For the first time lower atmospheric wind profiler (hereafter LAWP or wind profiler) with radio acoustic sounding system (RASS) was used to study the three-dimensional wind field and vertical structure of the precipitating cloud systems associated with Meiyu frontal cyclones. In particular, the wind profiler can directly measure the vertical wind component within a convective environment (*Gage et al*. 1994). Several researchers (*Gage et al*. 1994; *Reddy et al*. 2002; *Atlas and Williams*, 2003) have used LAWP to reveal details about the vertical structure of precipitating cloud systems. Since the vertical distribution of diabatic heating depends on the vertical structure of the convective system, it is important to study the vertical structure of the precipitating clouds occurring during Meiyu frontal cyclones in the downstream of Yangtze River.

Experimental set up

The LAWP/RASS was deployed along with an automatic weather station (AWS), the Institute of Low Temperature Sciences of Hokkaido University Doppler radar and micro rain radar in the premises of the Dongshan Meteorological Observatory, in the Jiangsu province, about 80 km west to Shanghai, PR China. Dongshan (31^{o}4′47″ N; 120^{o}26′3″ E) site is ideal because of the surrounding vegetation and some rural houses. The site is in the peninsula of the Taihu Lake, which is the largest in China with 2425 sq km area. About 3 km to the west side of the site there are few hills of 200 m high. Two intensive observational campaigns were conducted during Meiyu season between June and July 2001 and 2002.

The LAWP has an electronically steered phased array antenna capable of producing five beams. Normally, three beam directions are north, east, and vertical. The off-vertical beams are at an elevation of 74.5 degrees (15.5 degrees down from vertical). The dwell time on each beam was approximately 28 sec. The wind profiler was operated in two modes: low mode with 58-m vertical resolution to understand Atmospheric Boundary layer and in high mode with 202-m vertical resolution for detecting precipitating cloud systems. For the present study, the LAWP/RASS data from 11 June – 31 July during intensive observation period 2002 (hereafter, IOP-2002) has been utilized. An Automatic Weather Station (AWS) is in continuous operation since its installation and provides valuable data of surface parameters viz., wind, temperature, air pressure, relative humidity, solar and net radiation, and rainfall accumulation. During IOP-2002, the LAWP/RASS captured several convective systems in association with Meiyu frontal precipitating cloud systems. The objective of this paper is to investigate wind patterns, convective boundary layer and vertical structure of the precipitating cloud systems near the Meiyu front using LAWP/RASS, AWS and Geo-stationary Meteorological Satellite (GMS IR) data.

RESULTS AND DISCUSSION

The atmospheric boundary layer (ABL) is critical to the studies of both climate and weather. The relatively warm, humid air in the ABL provides a majority of the thermodynamic energy responsible for convective storms in the Meiyu period. The evolution of the thermodynamic state of ABL is therefore of great importance in forecasting the convective storm initiation. The ABL is also the mediator of land-atmosphere interactions that can influence weather and climate. For example, ABL conditions alter surface-atmosphere exchange processes such as evaporation and transpiration and are in turn altered by these fluxes. Thus the patterns of interaction between the land and the atmosphere drive the local and thus climatological patterns of weather development. High-resolution wind profilers have begun to revolutionize our ability to observe the ABL. Convective Boundary Layer (CBL) height is one of the important parameters, which can be used to characterize the ABL. CBL height also serves as basic scaling parameter for fluxes and variances. Therefore, CBL height measurements are a part of the experiments designed to elucidate atmospheric boundary layer structure and its behavior.

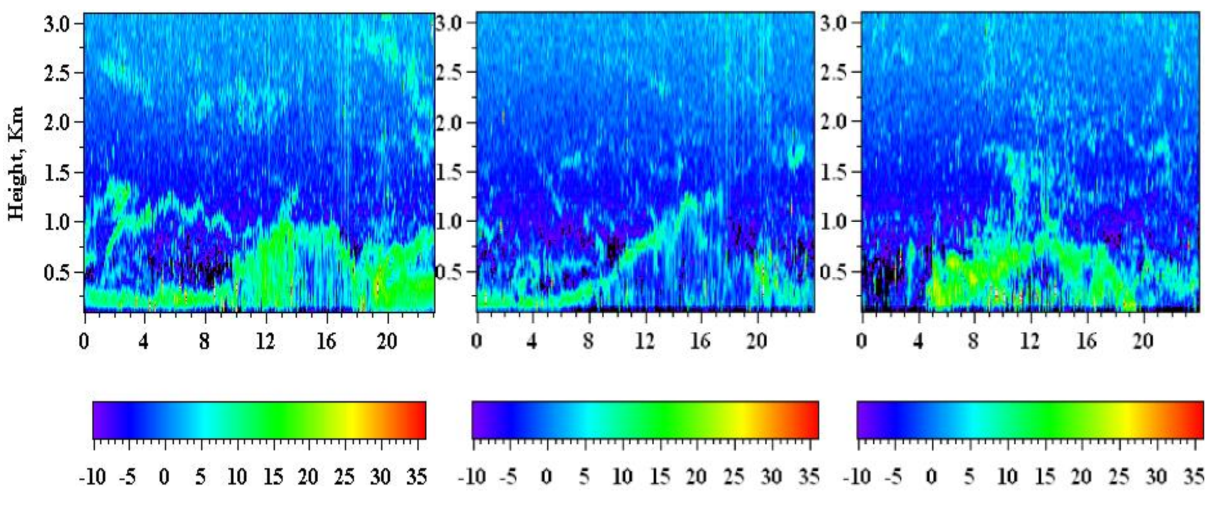

Fig.1 Time-height section of Radar Reflectivity (SNR), dB observed during (a) non-precipitating day, (b) pre-Meiyu convection and (c) Meiyu convective day

One of the exciting potentials of the wind profiler is, its ability to infer the CBL height. The CBL height measurements using the wind profilers are pioneered by *white et al.* (1991). The LAWP observations of range-corrected signal to noise ratio and RASS derived virtual temperature data has been used to infer the CBL height. The height profiles of the range corrected signal to noise ratio show a well-defined sharp peak at the CBL top. Even though, considerable amount of work has been reported on CBL, so far there is no work relating the evolution of CBL and convection triggering. In this regard, the present study aims to closely monitor the evolution of CBL prior to convection triggering using LAWP/RASS observations during Meiyu season. In particular, this study was carried out to understand the pre-convective environments in the boundary layer during Meiyu periods to find out whether there is any precursor before the convection triggering (Figure 1).

growing after 1200 hrs, BST also. The CBL heights are also very high with an increasing trend up to 1500 hrs BST, after which precipitation was observed over the wind profiler site. The deepening of the CBL is observed in the late afternoon in the present case, whereas it is observed exactly at the midday on the non-convective days. Figure 1(c) shows the evolution of CBL on convective days during the Meiyu period. On this day, a different ABL structure has been observed. A shallow CBL confined below 1 km is observed. It is well known that during the Meiyu precipitation, boundary layer will be rich in moisture. So, most of the radiation from the surface will be utilized for the evaporation process, which results in a shallow CBL. Enhanced soil moisture probably contributes to increase the latent heat fluxes and thus decreasing the surface sensible flux locally and suppress the CBL growth, as compared to the deeper CBL that develops with reduced soil moisture level on pre-Meiyu days.

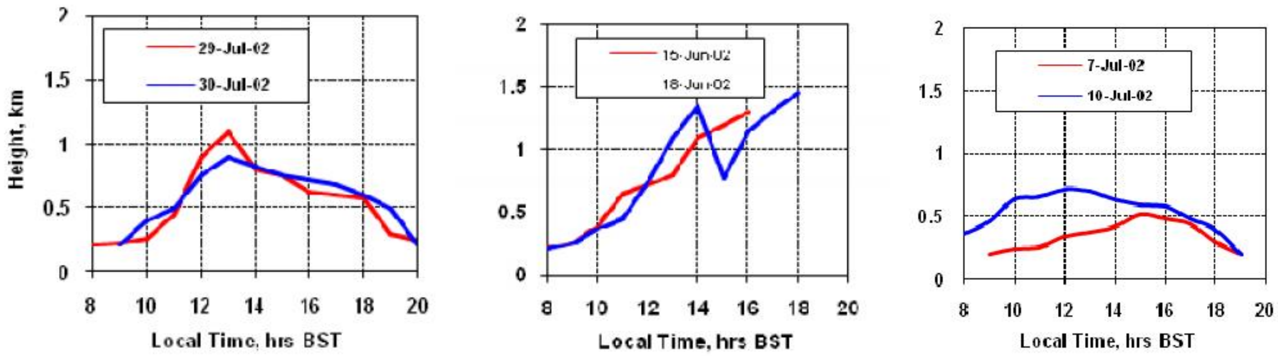

Fig. 2. Evolution of CBL during (a) non-precipitating days, (b) pre-Meiyu and (c) Meiyu convective days

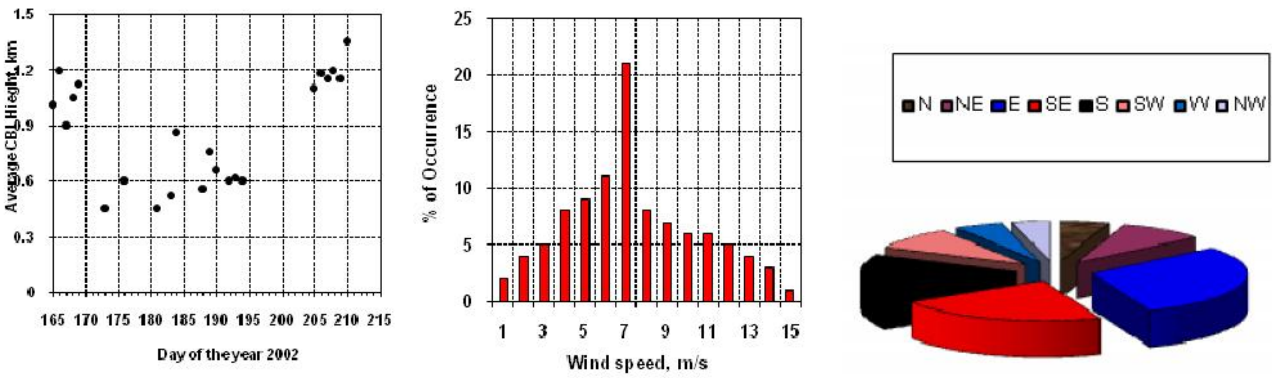

Fig. 3 (a) Boundary layer heights from LAWP measurements. Heights shown are the average over 1200-1500 LT BST for each day during IOP-2002, (b) Boundary-layer wind speed statistics and (c) wind rose showing the predominant wind direction (excluding Precipitation days)

The data obtained during IOP-2002 was categorized as non-precipitating, pre-Meiyu and Meiyu convective days. Figure 2 (a) shows the evolution of CBL on non-precipitating days. This plot readily reveals that on all these days a shallow CBL is forming at morning 0800 hrs BST and afterwards, the CBL grows steadily and reaching its peak at 1200-1300 hrs BST and coming down thereafter. The interesting feature observed on these days is that the CBL is coming down to the lower heights drastically after 1200-1300 hrs. This happens when buoyancy flux at the surface decreases rapidly which in turn results in poor surface forcing and the shallow CBL. Figure 1(b) shows the evolution of CBL on pre-Meiyu convective days. On these days, in the morning hours, the CBL shows more or less similar features like the non-precipitating days. The striking feature in the present case is that the CBL is continuously

Convective boundary layer (CBL) observations using wind profiler over China are rare compared to tropics [*Reddy et al. 2002*] and other mid-latitude regions [*Angevine et al., 1998*]. The wind profiler can measure the height of the CBL, which is also described as the mixing depth or boundary layer depth. Figure 3(a)shows the midday boundary layer height for all the days with well-formed CBL during IOP-2002. The height shown for each day is the average of four hours in early afternoon (11:00 – 15:00 hrs, BST) of the boundary layer heights determined for each hour by subjective examination of the results of a peak-finding algorithm run on the reflectivity. The depth of the planetary boundary layer and the intensity of the turbulence within it have a strong impact on the development of precipitating cloud system in the Meiyu period. The boundary layer height variation mostly depends on temperature and humidity. The low boundary layer heights during IOP 2002 could be due to low relative humidity. Figure 3(b) shows statistics of the daytime boundary layer winds during IOP-2002 days. These are averages of winds over all heights within the CBL. The boundary layer wind speed distribution was sharply peaked at approximately 7 m/s. These results suggest that the moderately strong wind speeds are favorable for the CBL development. During these days, horizontal winds are moderately strong and most of the time blow from easterly or southeasterly direction [Fig.3(c)].

Figure 4(a) shows zonal winds averaged in the height range of 2-3 km every one hour observed with LAWP, (b) AWS observed Rain fall accumulation over Dongshan, and Figure 6(c) shows the time-longitude cross section of T_{BB} at 31° N latitude near wind profiler site during 15 June to 15 July 2002. We find that the lower-tropospheric wind direction tends to become westerly, when the (super) cloud clusters located generated along the Meiyu front. The primary importance of this section is to obtain vertical air motion and inferences on microphysical structure during Meiyu period.

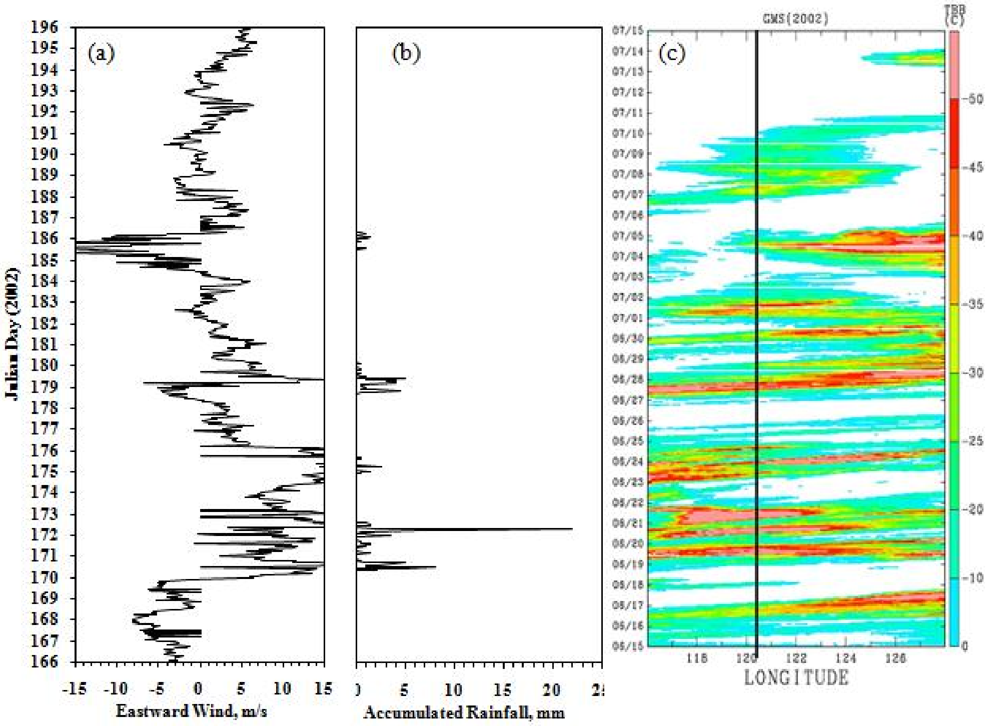

Fig. 4 (a) Zonal winds averaged over the height range of 2-3 km every one hour observed with the LAWP, (b) AWS rainfall accumulation from 15 June to 15 July 2002 at Dongshan site and (c) Longitude and time cross section of the T_{BB} along the 31° N latitude near the wind profiler site obtained from the 1-hourly GMS IR data from 15 June to 15 July 2002. The vertical line in (b) indicates the longitude of the wind profiler site and

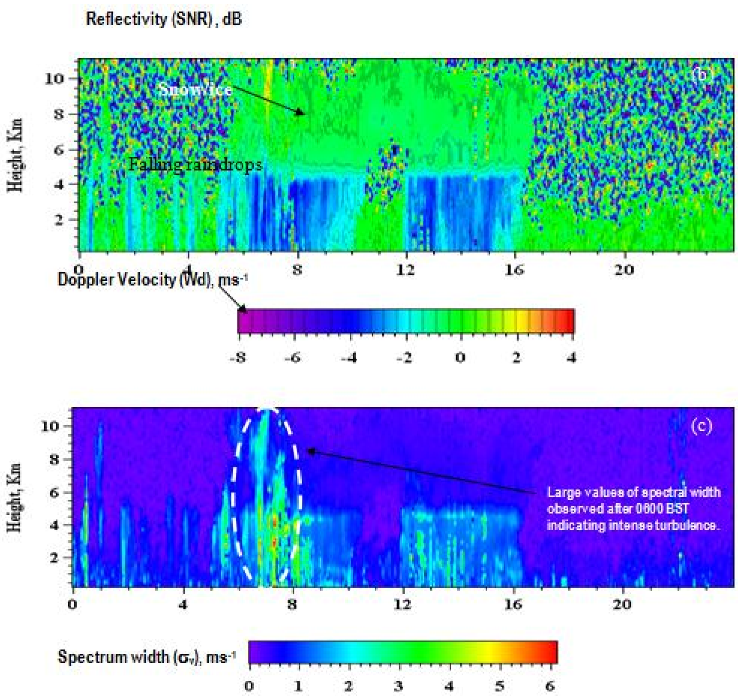

Fig. 5. Time-height section of (a) return power expressed as a signal to noise ratio (SNR, dB), (b) Doppler vertical velocity (W_d, m/s), and spectrum width ($\pm_v$ m/s) during the passage of Meiyu/Baiu frontal precipitating cloud systems 21 June 2002. In Figure 4(a) C, T, and S indicate convective, transition, and stratiform cloud types, respectively

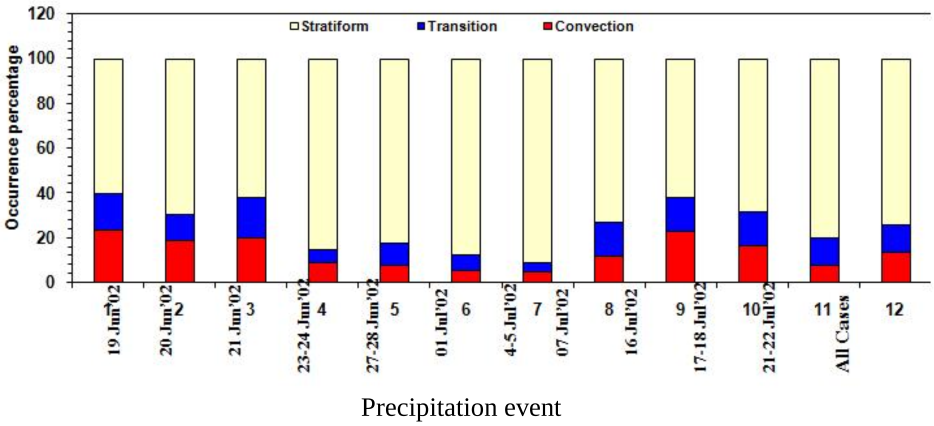

Fig. 6. Occurrence frequency of each rain type in 11 precipitating cloud systems observed during IOP-2002

During IOP-2002, many interesting characteristics of the mesoscale convection in this region were found.On 21 June 2002, a long-lived mesoscale convective system associated with the stationary Meiyu front produced heavy rain over the experimental region. This cloud system was persisted for 16-hours and the boundary layer winds are predominately blowing from south/southeasterly and tropospheric wind moved towards southwest direction. An example of deep convection, followed by a transition to mature stratiform rain, was observed on 21 June 2002 and is shown in Figure 4. Convection begins with a series of intermittent erect convective cells. Above 5 km there is evidence of updrafts and downdrafts extending up to about 12 km. Note, however, the large values of spectral width extended up to 11 km after 0530 hrs BST. The largest values of spectral width appear to well correlate with the most intense rain shafts, judging from the reflectivities shown in Fig. 5(a). Following the most active convection on 21 June 2002, there is a transition to mature stratiform rainfall. The mature stratiform rainfall commences around 1200 hrs BST and can be recognized by the bright band in reflectivities at the melting level below 5.0 km. Above the melting level, Doppler velocities of 1-2 ms^{-1} associated with falling ice and snow, and small spectral width indicative of, at most, weak vertical motions and turbulence characterize the period of stratiform precipitation. Note the rain shaft of approximately 25-min duration that begins after 1245 hrs BST.

The ability of the LAWP to clearly resolve the melting layer when it is present also provides a means of differentiation between stratiform and convective precipitation. From the vertical structure of the precipitating cloud systems, we have classified each profile into convective, transition (mixed convective-stratiform) and stratiform rain based on a modified version of *Williams et al*. (1995). This algorithm is based on judgment of the presence of a melting layer and the presence of turbulence or hydrometeors above the melting layer. During IOP-2002, LAWP noticed eleven precipitating cloud systems with tropical nature (Fig. 6). During onset of Meiyu period, from 19 to 24 June 2002, taller radar reflectivity (SNR) extending up to 12 km in height was found at the beginning part of the precipitating cloud system.

Summary

A study was carried out to understand the evolution of CBL in non-precipitating and precipitating days during Meiyu convective days. A well-distinguishable feature is observed in the pre-convective environments, which can be used as precursor for the convection triggering. In the non-precipitating environments, the CBL has peaked in the mid-day and suddenly descended to lower altitudes and showed decreasing trend thereafter. During pre-Meiyu convective environments, the CBL has continued to grow after mid-day also and shallow CBL has been observed during the Meiyu convective days. The intriguing result from these studies is the distinguishable CBL evolution observed in the pre- and post-Meiyu precipitation environments during Meiyu period. During IOP-2002 the statistical analysis shows of wind speed shows that the boundary layer winds are easterly/ southeasterly with wind speeds 4 - 8 m/s and the average CBL height varies between. 5 and 1.4 km indicating the low-level convective activity. In the passage of the cloud system, convective systems embedded within a wide stratiform precipitation were observed during IOP-2002

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REFERENCE

Angevine, W. M., A.W. Grimsdell, L.M.Hartten, and A.C.Delany, The Flatland boundary layer experiments, *Bull. Am. Meteorol. Soc.*, *79*, 419-431, 1998.

Atlas, D., and C.R.Williams, The Anatomy of a continental tropical convective storm, *J. Atmos. Sci*.,60, 3-15, 2003.

Chen, C., W.K.Tao, P.L.Lin, G.S.Lai, S.F.Tseng and T.C.C.Wang, The intensification of the low-level jet during the development of mesoscale convective systems on a Mei-Yu front, *Mon. Wea. Rev*., 126, 349-371, 1998.

Ding, Y., *Monsoons over China*, 419 pp., Kluwer Academic, Norwell, Mass., 1994.

Gage, K. S., C. R. Williams, and W. L. Ecklund, UHF wind profilers: A new tool for diagnosing tropical convective cloud systems, *Bull. Am. Meteorol. Soc.*, *75*, 2289–2294, 1994.

Lau, K.M., Y.Ding, J.T. Wang, R. Johnson, T. Keenan, R. Cifelli, J. Gerlach, T. Rickenbach, S.C. Tsay, and P.H. Lin, A report of the field operations and early results of the South China Sea Monsoon Experiment (SCSMEX), *Bull. Amer. Meteorol. Soc*., 81, 1261-1270, 2000.

Ninomiya, K., Large- and meso-α-scale characteristics of Meiyu/Baiu front associated with intense rainfalls in 1-10 July 1991, *J. Meteorol. Soc. Japan*, 78, 141-157, 2000.

Reddy, K. K., T. Kozu, Y.Ohno, K. Nakamura, A.Higuchi, K.Madhu Chandra Reddy, P.Srinivasulu, V.K.Anandan, A.R.Jain, P.B.Rao, R.Ranga Rao, G.Viswanthan, and D.N.Rao, Planetary boundary layer and precipitation studies using Lower atmospheric wind profiler over Tropical India, *Radio Sci.*, 37, doi:10.1029/2000RS002538, 2002.

Shinoda, T., and H.Uyeda, Effective factors in the development of deep convective clouds over the west region of Eastern China during the summer monsoon season, *J. Meteorol. Soc. Japan*, 80, 1395-1414, 2002.

White, A.B., C.W.Fairall, and D.W.Thompson, Radar observations of humidity variability in and above the marine atmospheric boundary layer, *J. Atmos.Ocean. Tech*., 8, 639-658, 1991.

Williams, C.R., W.L.Ecklund, and K.S.Gage, Classification of precipitating clouds in the tropics using 915 MHz wind profilers, *J. Atmos.Ocean. Tech*., 12, 996-1012, 1995.

Yamada, H., B.Geng, K.K.Reddy, H.Ueyda, and Y.Fujiyoshi, Three-dimensional structure of a meosocale convective system in a Baiu-Frontal depression generated in the downstream region of the Yangtze River, *J. Meteorol. Soc. Japan*, 81, 1243-1271, 2003.

Yoshizaki, M., T.Kato, Y.Tanaka, H.Takayama, Y.Shoji, H.Seko, K.Aro, K.Manbe and members of the X-BAIU-98 Observation, Analytical and numerical study of the 26 June 1998 orographic rainband observed in Western Kyushu, Japan, *J. Meteorol. Soc. Japan*, 78, 835-856, 2000

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