THE CHARACTERISTICS OF WEATHER PATTERN ASSOCIATED WITH MESOSCALE CONVECTIVE SYSTEM/TORRENTIAL RAIN IN TAIWAN AREA DURING THE MEI-YU PERIOD

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ABSTRACT

Torrential rainfall forecast is a very difficult problem. Quantitative precipitation forecast is more difficult because it results from different scale interactions. The forecast of torrential rainfall associated with mesoscale convective system (MCS) is the most important goal in regional forecasts.

This paper utilized satellite imagery, rain gauges, surface and upper air observations to analyze the characteristics of synoptic environmental weather pattern and their relationship to low-level jet(LLJ), equivalent potential temperature(θe) ridge , precipitable water(PW) and relative stability based on daily rainfall over 130 mm during the Mei-Yu (May-June) period from 1991 to 1995. The final goal was to identify the characteristic of the composite chart of the weather pattern associated with MCSs/torrential rainfall in Taiwan area and to develop an operational quantitative precipitation forecast technique in the near future .

Preliminary results showed that there are five weather patterns (front type, post-front type, synoptic type, overrunning type and mesoscale type) that are associated with the MCSs/torrential rainfall. Some of them are similar to those of Maddox et al.(1979) , but some of them are different due to local effects at Taiwan island. We need more case studies to clearly identify the general characteristics of the weather patterns, such that one can establish the weather pattern recognition for future quantitative precipitation forecast.

I. INTRODUCTION

Many MCSs take place in southern and eastern China during the Mei-Yu period. Some of them can last long enough and bring heavy or torrential rainfall to Taiwan when they move toward the Taiwan area. Generally, the rainfall amounts associated with MCSs are significant.

The MCSs associated with heavy rain during the Mei-Yu period can be roughly classified into two types with two different forcing mechanisms. In the first type, the MCS is triggered and maintained by large scale forcing such as a front or short-wave trough(strong forcing). The second type of MCS is generated by mesoscale forcing(weak forcing) such as land/sea breeze,meso-low and orographic lifting. There were many studies of the environmental conditions of MCSs. Three weather patterns(synoptic type, front type, mesohigh type) were recognized by Maddox et al.(1979) based on 100 flash flood events. Chiou and Lin(1985) studied 10 larger MCSs cases occurred in southern China area and came up with three type(front-short trough , meso-low, and southwesterly flow surge pattern). Sheih et al.(1994) documented the weather patterns associated with heavy/torrential rainfall over various area in Taiwan .

Funk(1991) recently documented some of the techniques used by the Forecast Branch of National Meteorological Center(NMC) to make quantitative precipitation forecasts of the convective rainfall. He emphasized the importance of conceptual models such as those developed by Maddox et al. (1979) and others as important tools in the forecast process. Accurate forecasts of quantitative precipitation are needed to anticipate potential flood and flash-flood situations.

The purpose of this study is to reanalyze the characteristics of weather patterns and cloud patterns associated with MCSs/torrential rainfall(daily rainfall amount over 130 mm)in order to build various conceptual models for operational requirement.

II. DATA AND ANALYSIS

Using satellite imagery, rain gauges data, surface and upper air observations during the Mei-Yu(May-June) period from 1991 to

1995, with the criteria threshold of daily rainfall amount >130 mm, there were 25 cases being studied. We composite different vertical level weather situations(such as surface front, 850 hpa wind shear line ,LLJ, 500 hpa trough, etc.) based on the surface front and 500 hpa short trough location and their relative orientation. We made composite chart for each weather pattern, mean daily rainfall distribution and the accompanied cloud patterns.

III. RESULTS AND DISCUSSION

1. Categories of weather patterns

Table 1 shows the characteristic of twenty-five cases of torrential rainfall(daily rainfall > 130 mm) in Taiwan area during the Mei-Yu period

Table 1. Cases of torrential rainfall (daily rainfall > 130mm) in Taiwan area during the Mei-Yu period from 1991 to 1995.

Cases	Date	Relative Maximum Rainfall Area	Weather Situation	Weather Pattern
(1)	1991.6.19	NE,N	M	Meso-scale Type
(2)	1991.6.20	S	F1	Front Type
(3)	1991.6.21	N,S	F1/F	Synoptic Type
(4)	1991.6.22	S	F	Front Type
(5)	1991.6.23	S	F	Front Type
(6)	1991.6.24	N,S	F	Front Type
(7)	1992.5.21	N	F2	Overrunning Type
(8)	1992.5.31	E	F2	Front Type
(9)	1993.5.26	C,S	F	Front Type
(10)	1993.5.27	C,S	F	Front Type
(11)	1993.6. 2	C,S	F	Front Type
(12)	1993.6. 3	S	F2	Front Type
(13)	1993.6. 5	N	F1/F	Synoptic Type
(14)	1993.6.11	S	M	Meso-scale Type
(15)	1994.5. 3	C	F1/F	Synoptic Type
(16)	1994.5. 4	C,S	F	Front Type
(17)	1994.5.31	S,NE	F	Front Type
(18)	1994.6. 1	S,SE	F2	Front Type
(19)	1994.6.18	N,C	F1/F	Synoptic Type
(20)	1995.5.13	SE	F	Front Type
(21)	1995.5.17	N	F2	Overrunning Type
(22)	1995.6. 8	C,S	F1/F	Synoptic Type
(23)	1995.6. 9	C,S	F	Front Type
(24)	1995.6.11	C,S,SE	F	Front Type
(25)	1995.6.12	S	F	Front Type

F1 : Pre-front
F :Front
F2 :Post-front
M :None-Front in Taiwan area
N :Northern Taiwan;
C:Central Taiwan
S:Southern Taiwan
E:Eastern Taiwan
NE:Northeastern Taiwan
SE:Southeastern Taiwan

from 1991 to 1995. It is evident that most of the cases are related to the front situation(pre-front, front, post-front), only some of the cases were caused by mesoscale forcing(weak forcing). It is noted that different weather patterns may results in similar rainfall pattern due to torrential effect. The same weather pattern may result in small difference in the locations of relative maximum rainfall area. Four types of weather patterns were summarized(Table 2) based on twenty-five cases. The first is front type(64%) similar to the east-west front type of Maddox et al.(1979);

Table 2. The characteristics of various weather patterns associated with MCSs/torrential rainfall in May-June from 1991 to 1995.

TERM / CASES	FRONT TYPE	SYNOPTIC TYPE	OVERRUNNING TYPE	MESO-SCALE TYPE	TOTAL
TOTAL	16 (64%)	5 (20%)	2 (8%)	2 (8%)	25 (100%)

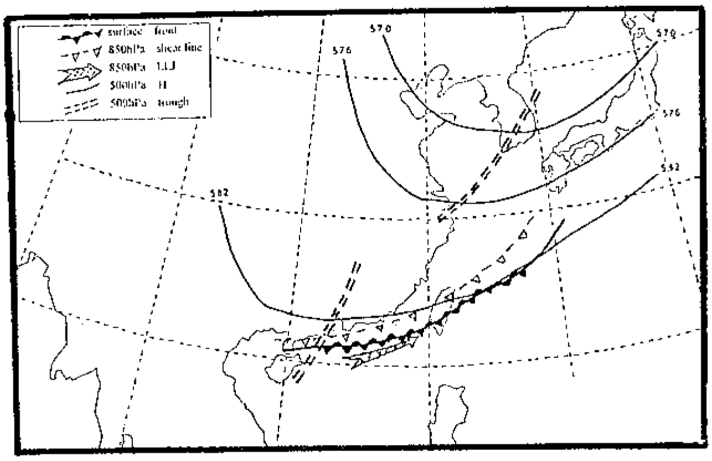
the second is synoptic the type(20%) which is also similar to that of Maddox et al.(1979); the third is overrunning type(8%); the fourth is mesoscale type(8%).The mean weather chart of the front type associated with torrential rainfall is shown in Fig. 1a. A stationary front(moving at the mean speed of 5 knots) appeared in the surface level. A wind shear line closely followed the surface front. A LLJ existed in 850 hpa . In some cases there was a meso-low occurred west of Taiwan area, with a strong deep trough being perpendicular to the surface front or with a pronounced short wave trough in 500 hpa level, and with a strong diffluence in the 300 hpa level. The cloud type associated with this front type was convective cloud band. There was another front type (post-front type) as shown Fig. 1b. when the front has passed Taiwan area, but the 850 hpa wind shear line still existed in the Taiwan area, low pressure in middle level or short trough located at the west of Taiwan area, A typical synoptic type (Fig.1c)associated with torrential rainfall had a well defined vertical structure of baroclinic wave. The meso-ß scale convective cloud clusters regenerated along the surface front. The above-mentioned front type and synoptic type constituted 84% of the cases in twenty five torrential rainfall events. The overrunning type (Fig.1d)showed that the rainfall occurred behind the surface stationary front. An 850 hpa shear line was located behind the front. A shallow convection developed along this line. The cloud type associated with the overrunning type was stratiform with a warm-top cloud band existing over large area. In the mesoscale type (Fig.1e)there were generally no front over Taiwan or a front was far from Taiwan area, shear line was nonexistent in 850 hpa level . The LLJ may or may not be present. There can be a ridge or a very week trough in 500 hpa level . The southwestly flow is dominant in this type. This type usually occurred in the afternoon, which is categorized as a weak forcing type preferably produced by land-sea breeze, thermal heating , orographic lifting effect.

2. Rainfall distribution of various weather patterns

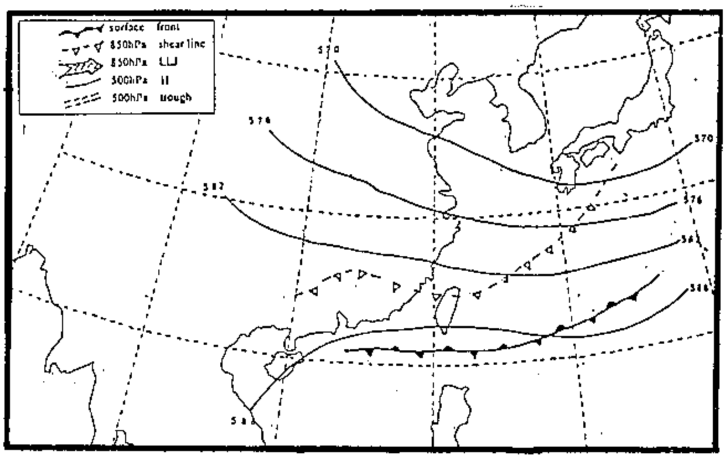
The mean daily rainfall distribution of above-mentioned weather patterns are shown in Fig. 2. It was very evident that the distribution of mean daily rainfall of the front type(11 cases) was similar to that of the post-front type(5 cases), but the local maximum of former was larger than that of the later. The distribution of the mean daily rainfall of the front type was different from that of the synoptic type(5 cases) ,such as the western onshore part of central Taiwan and the northeastern and northwestern part of Taiwan area. The distribution of mean daily rainfall of the overrunning type(2 cases) was appeared northern part of Taiwan, but that of mesoscale type(2 cases) was occurred western onshore part and mountain area of southern Taiwan. It is noted that the terrain of Taiwan plays an important role in the generation of relative maximum rainfall centers.

3. Cloud pattern of various torrential rainfall events

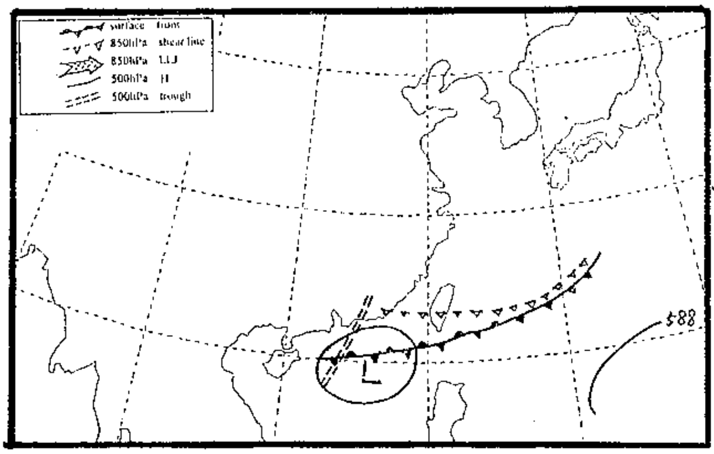
Fig. 3 shows the cloud patterns along with various weather patterns with torrential rainfall events. It was very clear that there were cloud patterns that generated torrential rainfall during the Mei-Yu period. The cloud pattern of the synoptic type with MCSs/torrential rainfall is spiral band which is similar to that of mid-latitude cyclone. Some MCSs existed in the cloud band, sometimes the cloud pattern of the synoptic type (Fig. 3a) may transform into that of the front type. The cloud patterns of the front type can be roughly summarized into two types. One is shown in Fig. 3c, with a comma cloud band associated with a short trough located west of Taiwan area. Another was related to southwestly moist zone(Fig. 3d). The cloud pattern of meso-low type evidently showed low pressure center located in west of Taiwan area. The spiral cloud band arround the low pressure center was similar to the cloud pattern of the tropical disturbance .



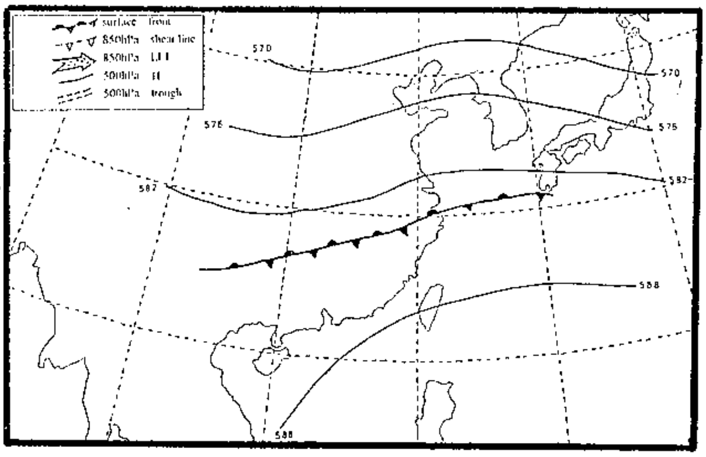
(a)Front type



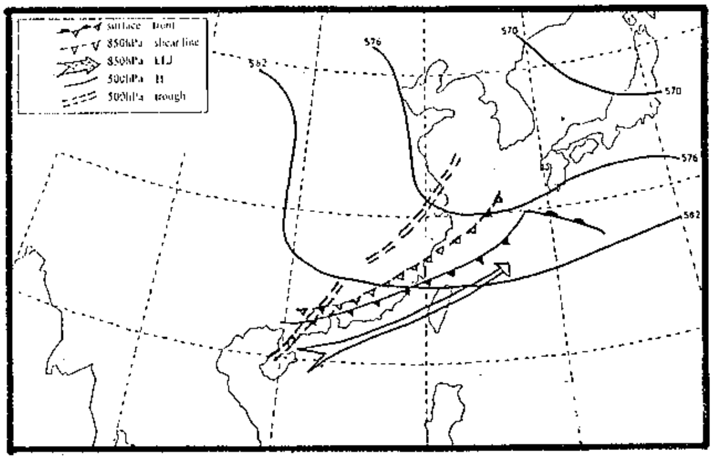
(d)Overrunning type



(b)Post-front type



(e)Meso-scale type



(c)Synoptic type

Figure 1. The composite charts of synoptic weather patterns with MCS/torrential rainfall during the Mei-Yu period from 1991 to 1995

(a)Front type

(b)Post-front type

(c)Synoptic type

(d)Meso-scale type

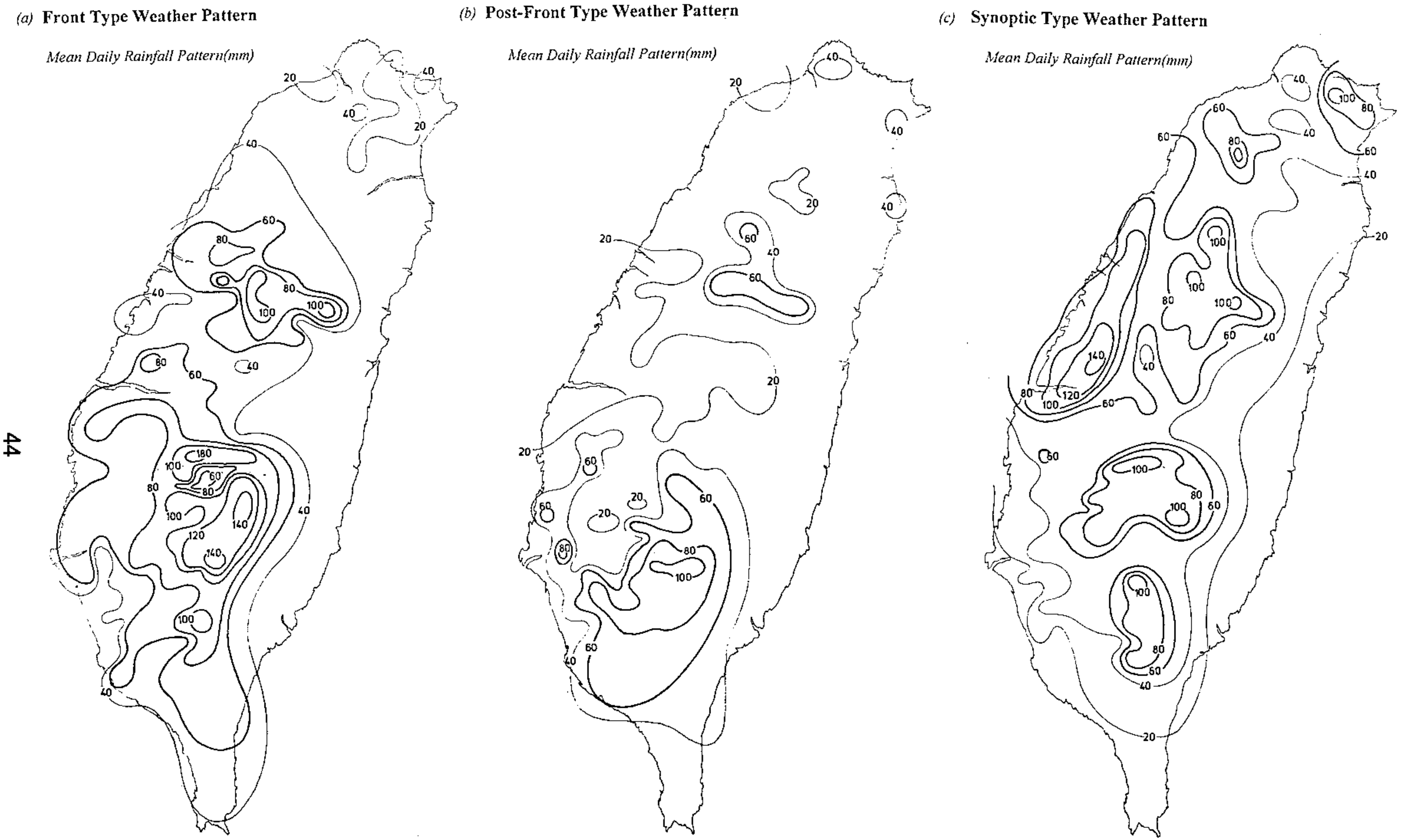


Figure 2. The mean daily rainfall distribution of various weather patterns associated with MCSs/torrential rainfall events.

(d) **Overrunning Type Weather Pattern**

Mean daily rainfall pattern(mm)

(e) **Meso-Scale Type Weather Pattern**

Mean Daily Rainfall Pattern(mm)

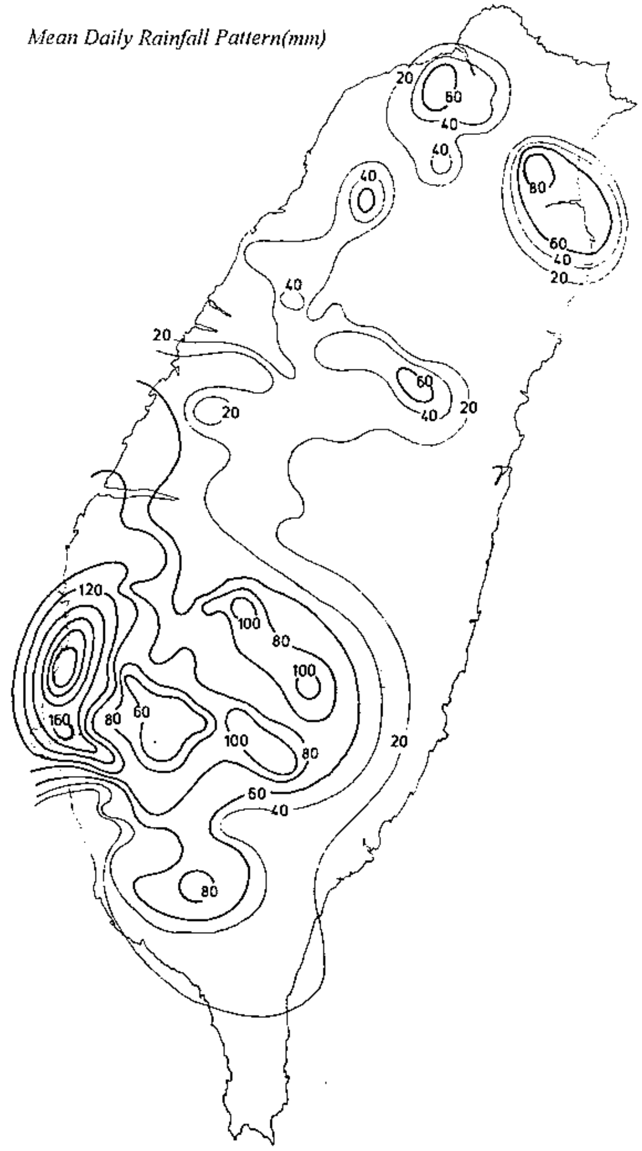


Fig 2. (continued)

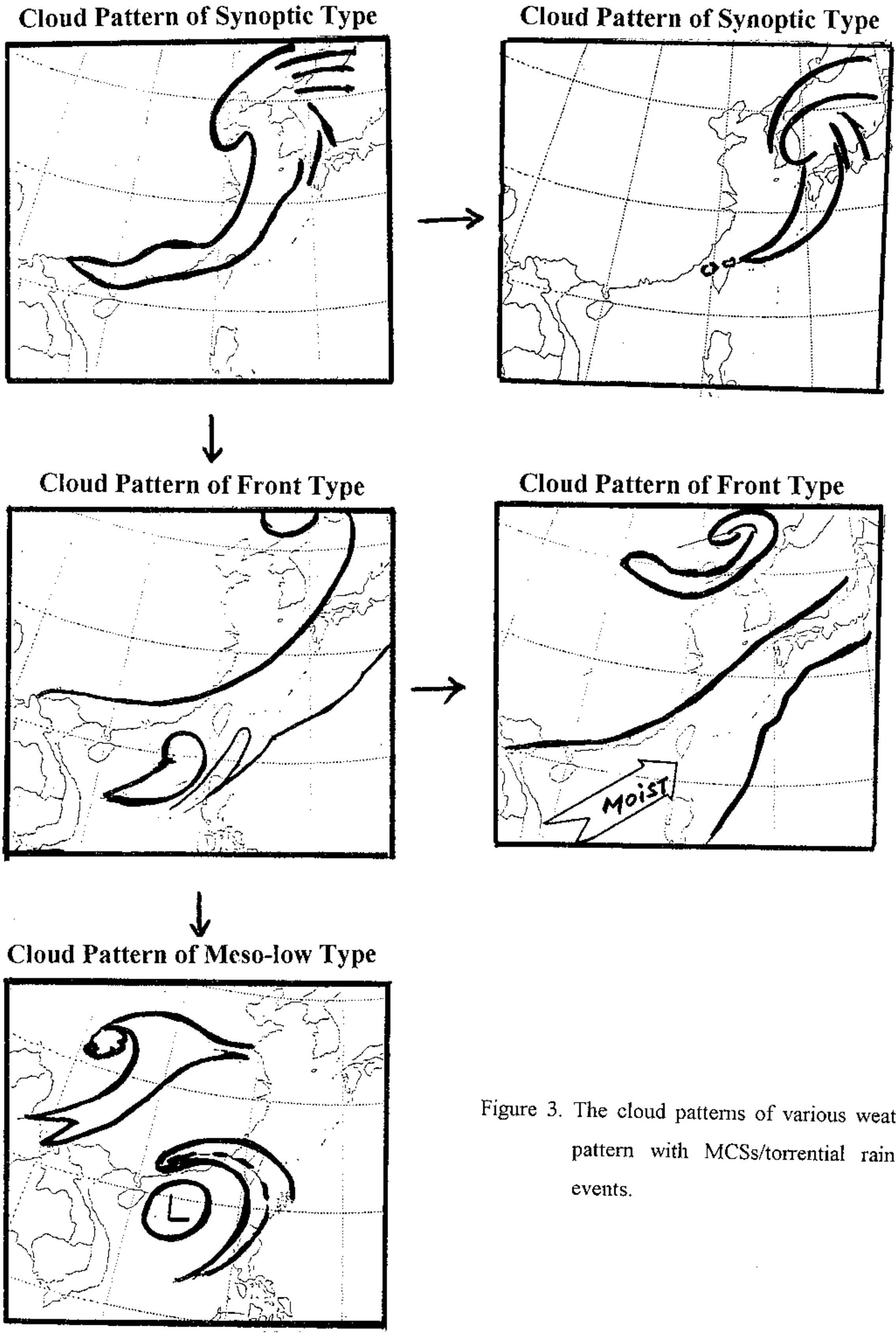


Figure 3. The cloud patterns of various weather pattern with MCSs/torrential rainfall events.

4. Environmental conditions and thermal characteristics

Table 3 shows the synoptic environmental condition and thermal characteristic of eight MCSs/torrential rainfall events in 1993. Most of the cases were related to the front situation(strong forcing). Two of them were not. The important contributing factors to the torrential and excessive rainfall events are lower level θ e ridges axis and the LLJ. Results also showed that the favorable conditions of the

Table3. The synoptic condition and thermal characteristic of 8 torrential rainfall cases on May-June in 1993 (sw/20 indicate 20 knots southwesterly flow,Y yes,N none, F,F1,M indicate front , pre-front ,and none-front in Taiwan area)

	SFC	850HPa					700Hpa			Thermal condition				
TIME (GMT)	front location	LLJ	θe ridge	warm adv.	θe adv.	moisture cov.	LLJ	ridge	posit vor.	PW	TI	KI	LI	CAPE
May 2600-2612	F	SW/20	Y	Y	Y	Y	SW/25	Y	Y	66	44	36	− 3.1	1224
2700-2712	F	SW/25	Y	Y	Y	Y	SW/30	Y	Y	76	49	42	− 4.7	2997
June 0112-0200	F1	SW/35	Y	Y	Y	Y	SW/35	Y	N	62	45	38	− 4.5	2053
0200-0212	F	N	Y	N	N	Y	SW/35	Y	Y	68	44	39	− 2.0	1010
0500-0512	F1	SW/30	Y	Y	Y	Y	SW/40	Y	Y	68	43	39	− 4.1	1978
1100-1012	F1	SW/25	Y	N	Y	Y	SW/25	Y	Y	62	41	34	− 2.7	1147
1600-1612	M	SW/25	Y	N	N	Y	SW/30	N	N	56	49	37	− 7.9	3309
1700-1712	M	SW/25	Y	N	N	,Y	SW/25	Y	N	57	46	33	− 5.7	2666
TOTAL		Y (81 %)	Y (100 %)	Y (50 %)	Y (63 %)	Y (100 %)	Y (100 %)	Y (81 %)	Y (63 %)	> 56 mean 64	> 41 mean 45	> 33 mean 37	mean -4.3	> 1147 mean2048

frontal type in the synoptic environment were a surface front associate with a LLJ(in 850 hpa or 700 hpa), a nearby θe ridge axis and a moisture convergence zone. The average thermal condition with torrential rainfall events were precipitable water(PW)=64 mm, TI=45, KI=37, LI=-4 and Convective Available Potential Energy(CAPE) =2048 wm-2.

IV. SUMMARY

The GMS satellite imagery, dense rain gauge network, surface and upper air observations were used to study the weather patterns with MCSs/torrential rainfall during the Mei-Yu period from 1991 to 1995. Preliminary results reveal the characteristics of four weather patterns (front type, synoptic type , overrunning type and mesoscale type) generating MCSs/torrential rainfall. Some of them were similar to those of Maddox et al.(1979), some of them were different on various area at Taiwan island. We need more case studies to conclusively identify the general characteristics of the weather patterns, such that it is possible for us to establish the weather pattern recognition techniques for future quantitative precipitation forecasts.

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台灣梅雨季中尺度對流系統/豪雨之天氣類型特徵

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摘　　要

豪雨的預報，是一個非常困難的題目，要能定量預報，更是不容易，因爲它牽涉到大尺度，中尺度到小尺度以及彼此相互間的關係，而導致豪雨之中尺度對流系統（ MCS ）的預報又是區域性豪雨預報最重要的一環。

本文乃就 1991-1995 年 5-6 月台灣附近所發生的 MCS/豪(大)雨個案資料，分析 MCS 生成發展及移動與綜觀及中尺度環境天氣類型及其相關低層噴流、θe 脊線、 1000-300hpa 可降水量及不穩定度大小之關係，以建立台灣地區 MCS/豪(大)雨之不同綜觀天氣類型及特徵，以期作爲發展一套豪（大）雨定量降水預報方法之參考。

研究結果顯示台灣地區伴隨 MCS 降水之天氣類型可分成綜觀型、鋒面型、超越型以及中尺度型，有一些與美國 MCC 綜觀環境類型相似但仍存在一些差異，並且北、中及南部之區域發生 MCS 天氣類型特徵亦有不同。