春雨個案研究

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Introduction

In springtime there are several cold fronts passed through Taiwan area. Sometime it caused heavy rainfall in local area. There were also papers to study the spring front and climate. Such as Hwu and Wang (王作台、胡志文 1994) use Singular Value Decomposition (SVD) method to understand the large scale circulation of spring time in East Asia. Shiao and Juang (蕭志惠、莊漢明 2002) use the NECP region model to simulate the short term climate on spring time and Mei-Yu period. And these above mentioned papers have given some better understanding to the spring climate. In this study a weak cold front passed through north Taiwan that brought morning rainfall associated with thunder lightning. With radar echo, satellite image, and conventional data, which the mechanism of the cold front caused morning rainfall associated with thunder lightning can be analyzed and realized. Finally a result of simulation was given and examined to compare with the data analysis.

Data analysis

At 00Z 9 April 2008a, low pressure was located near the coast of Mainland China north part. The cold front extended from the center of low pressure to the south part of Mainland China. As the low moved to the East China Sea the cold front came and covered the off shore of north Taiwan Strait at 12Z 10 April 2008 showed the low moved to the Japanese Sea the cold front passing through the north Taiwan and caused morning thunder lightning and rainfall at 00Z 10 April 2008.

Table 1 was the list of metrological element before and after the front crossed north Taiwan. The observation stations include three stations that are Keelung, Taipei, and Hsinchu. The time is from 4 o'clock to 10 o'clock of 10 April 2008 in local time. The data contain wind, rainfall, and temperature.

Table1 The variation of meteorological element of 10 April 2008

		4 hour	5 hour	6 hour	7 hour	8 hour	9 hour	10 hour
Keelun 基隆	wind(m/s)	SSW /3.8	SSE/ 2.2	N /4.9	NNE/5.3	NNE/4.6	N/4.1	N/4.2
	rainfall(mm)	0	0	Trace	22	4.5	0	0
	Temperature(℃)	25.9	25.9	20.7	19.7	20.5	20.3	20.2
Taipei 台北	wind(m/s)	Calm	SE/ 0.5	SSE/ 1	ENE/ 4.8	ENE/6.8	ENE/4.7	ENE/6.2
	rainfall(mm)	0	0	Trace	4.5	13	Trace	0
	Temperature(℃)	25.1	23.7	23.5	20.8	20	20.4	20.4
Hsinch 新竹	wind(m/s)	WNW/1.7	NNW/0.9	WNW/1.5	WNW/1.2	NE/ 2	ENE/2.1	NNE/2.4
	rainfall(mm)	0	0	0	0	10	1	0.5
	Temperature(℃)	25.6	25.3	25.3	25.4	20.7	21.3	21.9

At the time 4 o'clock of local time before the front arrived Taiwan all the temperature of the three stations were over 25℃. Then the temperature fall down to 20℃ when the front passed the individual stations. The time, which the front passed by, the temperature of Keelunng station fall down and the wind component turned from south to north at 6 o'clock. The time, which the front passed by, the temperature of Taipei station fall down and the wind component turned from south to north at 7 o'clock. And the temperature of Hsinchu station fall down and the wind component turned from west to east at 8 o'clock. But for the rainfall amount decreased when the cold front moved southward. The total rainfall of Keelunng station was 26.5 mm. The total rainfall of Taipei station was 17.5 mm. And the total rainfall of Hsinchu station was only11.5 mm. From the temperature change and rainfall pattern, the pattern of this front is very similar a katafront. That is said the temperature dropped first, and then has apparently rainfall after temperature change, especially on the windward of spring time. And that katafront often associated with thunderstorm in north Taiwan.

Rainfall accumulation

The rainfall amount of the cold front across Taiwan area began at 6, and rain started from the top of north Taiwan and moved southward. The rainfall area expanded parallel to the movement of the cold front. At 06h of 10 April 2008 it was just the front that touches the north Taiwan. At

07h of 10 April 2008 showed that when the front crossed over the mountain of windward and the intensity of rainfall increased. At 8 o'clock of 10 April 2008 the rainfall area moved southward. And at 9 o'clock of 10 April 2008 the rainfall area was almost not increase that represented the cold front was decreasing respectively.

Radiosonde Analysis

The analysis of Skew-T Log-P diagram could understand the stability of local area. The curve of radiosonde of Taipei at 00Z 9 April 2008, in the low level from the ground to 900 hpa there was a dry lid (inversion) which was advantage for the development of convective system (Carlson 1980). From the bottom to the top, the entire wind field was almost west wind. During the daylight because of the surface heating the bottom of the inversion layer was lift from surface to 900 hpa. And the surface humidity dropped from 77%(00Z 9 April) to 54%(12Z 9 April).

When the cold front arrived to Taipei the humidity became 88%, between 900 hpa and 850 hpa level there was an inversion, the inversion stable layer it similar as a gravity duct (Lindzen, Tung 1976). And the wind speed about 700 hpa level was decrease very evident at 00Z 10 April 2008. And below the 900 hpa the wind direction turn from west wind to east wind that means the high pressure after the front has crossed Taipei which was match with the temperature of Taipei in table 1.

Radar echo and satellite

Radar echo and satellite image showed very match. And the time of the figures were presented from 16Z 9 April to 02Z 10 April. These pictures showed the development of line convective cloud that caused morning thunder in north Taiwan. An arc line appeared in satellite image and the arc line was increased both in radar reflectivity and satellite cloud image. The line in radar echo organized gradually. And ahead the arc line the cloud amount also increased apparently.

At 19Z 9 April 2008, the line echo moved southward that caused the line echo was very close to the Taiwan island. At the south of line echo, which was on the satellite image and the intensity of the cloud was increase. When the line cloud arrived the north part of Taiwan at 21Z 9 April 2008, the intensity and width of the line cloud were also increase.At the windward the intensity of line cloud increased continuality. And at 22Z 9 April 2008 the line cloud moved southward. At 23Z 9 April 2008 the cloud on the right hand of Taiwan Island, and before the line echo were also moved southward. At 00Z 10 April 2008 the line echo came to Hsinchu. Because of the mountain block the intensity of the line echo began decrease. And the cloud over the off shore on the right hand of Taiwan and also moved southward but the intensity started loosen gradually. As the line echo went down southward the intensity of the line echo reduce continuity and then disappeared gradually.

Discussion and conclusion

At 9 April 2008 a weak front, which associated with line cloud, passed through Taiwan from Mainland China, and brought morning thunder rainfall in northern Taiwan. Before the front arrived Taiwan the sounding of Taipei presented an inversion and jet stream in the low level of the atmosphere. At that time the wind which around Taiwan was southwest winds that could bring the warm advection to Taiwan easily. Both the inversion and low level jet played an important role for the server weather (Yang, shu 1985) (Uccellini, Johnson 1979). Simpson (1983) described that if there is a low level jet before the surface front that will not benefit to the deep convection. And the other reason was the weather system of 10 April 2008 that the title of the trough from the low level to the high level was only a little which was not favor to the deep convective storm. In addition to the cold air mass was very thin and the cold high moved very fast. Therefore as the front moved to Taiwan that only caused a broad area rain fall associated with shallow thunder lightning in the morning, especially in the windward of upslope the precipitation was larger than the plain.

Moncrieff & Miller (1976) named the positive area of thermal dynamic diagram as CAPE (Convective available potential energy), which is particularly useful to measure the statically unstable air parcel. Colby(1984) offered convective inhibition (CIN) energy for the convective forecast. And Resmussen & Blanhard (1998) used the CIN as a parameter of low level thermal dynamics to investigate the isolated super cell thunderstorm. In this study we also examined the value both CAPE and CIN. At 00Z 9 April 2008, from Skew-T Log-p diagram of Taipei showed that there was a cap from the ground level to 900 hpa and the value of CAPE and CIN were 298.5 $J \cdot kg^{-1}$ and 302.2 $J \cdot kg^{-1}$ respectively. Because of the value of CIN was greater than the value of CAPE that represents the air parcel was stable at 00Z. Until 12Z the value of CAPE and CIN turn to381 $J \cdot kg^{-1}$ and 275.1 $J \cdot kg^{-1}$ respectively. Due to the values of CAPE and CIN became opposite. That was said the value of CAPE was greater than the value of CIN at 12Z. Thus, the air parcel has the potential to overcome the convective inhibition (CIN) and advantaged for the convective system development. Due to the front passed through

Taiwan accompanied with line cloud, the instability was explosive and then the cloud line was strengthened that formed a convergence line in north Taiwan.The convergence of streamlines in low level that was one of the major mechanism of thunder rain and produced upward motion.

As the convergence line of the front moved to Taiwan the front instability triggered the potential unstable of low boundary and forced the unstable layer became convective system and the front went forward along the upslope of windward area. So the weak front was enhanced. Then following the rainfall happened and associated with thunder lightning in the morning. And that case was a special case which the thunder rainfall occurred in the morning not in the afternoon.

As the low center moved eastward sequentially, and the weak cold high pressure moved southward. The cold north wind was blocked by the Ling-Lan terrains at the coast of south Mainland China. Then the wind turned into northwest direction. As the low pressure center and high pressure center moved on the same latitude as a pressure dipole. The speed of north wind was increase between the dipole. There were two effects that caused the north wind increase. One is that between the low pressure and high pressure, the wind field was confluence then there were stronger north wind. The other is as the north wind moved along Ling-Lan terrains and the flow was squeezed by the topographic effect. Therefore the wind speed was forced increase. Those two effects generated a low level northly jet. When the low level northly jet encountered the low level southwestly jet at the northern part of Taiwan and at the windward place the system were enhanced especially. As shown in fig.1 the dash line is northly jet. The dots line is southwestly jet. The cross of above two lines was the thunder rainfall area. At first the low center moved eastward, cold high moved southward. And the cold air was also pushed southward by the north wind. Before 09Z 09 April 2008, the cold temperature was blocked by the Ling-Lan terrains. After 09Z 09 April 2008, the north wind shifted to eastward. Therefore a group of cold air through Ling-Lan terrains and moved down along the coast of Mainland China, and then the flow directly crossed the isobar that also induced gravity wave and ageostrophic wind (Chang, Millard 1983). At 21Z 09 April 2008, the gravity wave moved to the north part of Taiwan. From the Skew-T Log-p diagram of 00Z 10 April 2008, there was an inversion between 900 hpa and 850 hpa which was just like a duct. And the duct could keep the gravity wave not disappear so quickly. According to Raymond (1976) wave –CISK theory, the convergence of gravity will force the convective development. And the maximum rainfall was occurred after the trough and before the ridge. That was another mechanism to product the thunder rainfall in the morning of 00Z 10 April 2008.

Reference

王作台、胡志文 1994：ENSO年後春季東亞大氣特性之分析，大氣科學第 22 期第 3 號，339－360。

蕭志惠、莊漢明 2002：台灣地區春梅雨期短期氣候之模擬研究，大氣科學第 30 期第 4 號，291－312。

洪景山 2002：武夷山地形和海洋邊界層在梅雨鋒南下過程中扮演的角色，大氣科學第 30 期第 3 號，3275－290。

Carlson T.N. 1980：Analysis and prediction of severe storms environment. Bull. Amer. Met. Soc., 61(9)1018-1032.

Chang C.P., J.E. Millard, G.T.J.Cjem 1983：Gravitational character of cold surges during Winter MONEX. Mon. Wea. Rev., 107, 812-829.

Colby F. P. 1984：convective inhibition of convection during ACE- SESAME-2. Mon. Wea. Rev., 112, 2239-2252.

Linzen, R.S., K. K. Tung 1976 Banded convective activity and ducted gravity wave, Mon, Wea, Rev., 104, 1602-1617.

Moncrieff M.W., M.J. Miller 1976：The dynamics and simulation of tropical cumulonimbus and squall lines. Quart. J. .Meteor. .Soc., 102, 373-394.

Resmussen E.N., D.O. Blanhard, 1998：A baseline climatology of sounding-derived supercell and tornado forecast parameters. Wea. Forecasting. 13, 1148-1164.

Raymond,D.J., 1976. Wave-CISK and convective mesosystem, J. Atmos.Soci., 33, 2992-2398.

Shipro M A 1983. Mesoscale weather system of the central United State.The National STORM program. 80307,3.1－3. 7.

Uccellini L W., D R Johnson 1979. The coupling of upper and lower tropospheric jet streamsand implications for the development of severe convective storms. Mon. Wea. Rev. 107, 682－703.

Yang G., C. Shu 1985. Large scale environmental conditions for thunderstorm development. AAS ,2(4), 508－521.

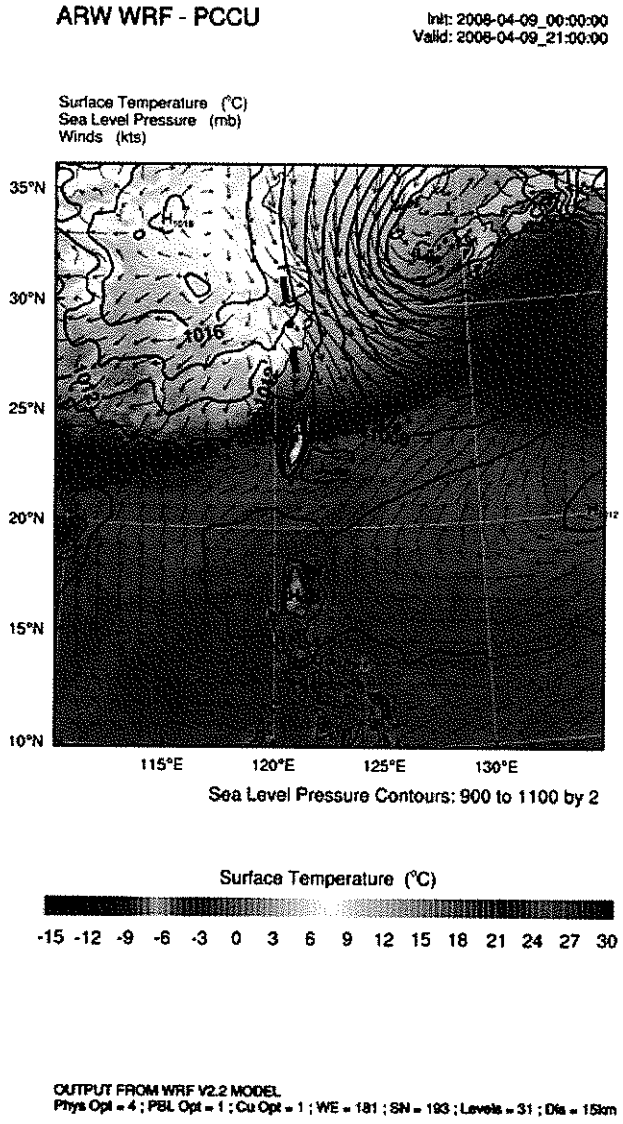

Fig. 1 The intersection between northly jet and southwestly jet at Taiwan area.