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OBSERVATIONAL ANALYSIS OF A MULTICELL HAILSTORM AND LIGHTNING ACTIVITY ON WEST COAST OF BOHAI BAY

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1. Introduction

Multi-cell thunderstorms consist of convective cells which have short lives and different stages of developments. Incorporated in continuously by new monomers, thunderstorms strengthen and lead to severe weathers such as strong lightning, hail and tornado. Multi-cell thunderstorms are used to be accompanied by single neonates and merges, and have a few strong cores. The developments of them are complex and non-linear processes which contain the changes of vertical motion and microphysical structure. So the research is quite difficult.

Since the early 70’s, with the development of radar detective technology, some observational facts of thunderstorms mergence have been gradually recognized. Dennis et al. (1970) proposed the feeder cells-consolidating process which was a few kilometers away from the ground and not far from the old generation. When a new unit developed, it would merge with the old one soon. Simpson et al. (1980) mentioned the phenomena of Cloud Bridge. When monomers were merging, due to the convergence of Downdraft in low layer, new echoes were inspired between two monomers and Cloud Bridge would appear in about 1km. However, Cunning et al. (1982) mentioned that should appear in about 9km. Westcott (1984,1994) concludes that: the maximum reflectivity, the high ceilings of thunderstorms and areas of the echo are strengthened after the mergence of monomers, while these changes are related to the lives and development trends of echo nuclear before mergence, but the synergy among merged monomers is not very notable. However, using radar observations to reveal the consolidation process of thunderstorms is rare in China.

Meiying Huang et al. (1987) used 2D numerical models to simulate the mergence and interaction with Cumulus in result which merged cloud is larger than singe cloud. Danhong Fu et al. (2007) used MM5 numerical models to simulate the detail changes of a Cumulus cloud in consolidation process and pointed that Could Bridge and Downdraft play an important role during the consolidation which enhance downdraft and water vapor transforming to product lots of super cooled cloud water and ice particles. The adequate number and size ice particles with updraft which make them climb to a certain altitude are the primary condition of hail and severe lightning occurring. Muhong Yan et al.(1996) simulated non-electric mechanism and pointed out that strong upward air only through -20 ☐ temperature layer and there would be strong lightning; The change of vertical structure of ice particles makes the spatial and temporal distribution of electricity rate and charge change. Using 3D power-electric coupled mode, Yijun Zhang and Anping Sun et al.

(2004) mentioned that electric activities in thunderstorm are able to change the landing speed during the process of water into property particle (maybe it is the following reaction of touch or melting sublimation). Besides, the micro-physical process of phases conversion among water-borne materials and spatial and temporal distribution increases latent heat releasing in clouds, and enhance the upward air flow areas and intensity. So we can see that there are quite close relationships among merge, updraft, ice particles, hail and lightning, but this conclusion is based on the numerical simulation results, lacking of basis of facts.

Since the 20th century, more and more people have concerning about the relationship between mergence of thunderstorms and severe weathers such as hail, Tornado, lightning. Carey's researches show that 97% of precipitation and mixed-phase ice mass, and 100% cloud-ground lightning are caused by combined convective systems. They (2003) analysis F4 tornado, the hail which occurred on May 30th, 1998, in South Dakota of United States and they found that the mergence of super-cells and squall line tails contributed to the enhancement the hazard level. Lee et al. (2006) studied the role of merger in the evolution of convection during the April 1996, in Illinois of United States when tornado happened and he pointed that 54% of tornadoes occurred in 15mins before or after merger. He used 3 kinds of cases to prove that mergence enhances the reflectivity. It was to say that updraft strengthened and the number of particles in per volume unit increased. At the same time, the rotations in thunderstorms were enhanced as well. Tessendorf et al.(2007), Gauthier et al. (2010) found that flashing spikes and ground lightning surged in 10 minutes after the mergence. During the recent years, we set up kinds of new detection equipments (radar, lightning detection, microwave radiometer and automatic stations) and get much higher-resolution monitor data which provide us the premise of the qualitative study on small and medium-size and even the conditions of quantitative analysis. This article aims to analyze the evolution of multi-monomer structure which is about sea breeze front and descript the structure and changes of the thunderstorms system by radar parameters such as Zmax, Zmean, V40, V50, upFv40, downFv40 and ETs11. Then we get the information of the water-borne materials and updraft to recognize the correlation of the merger and hail and lightning activities. It provides the scientific basis for the warning of thunderstorms development trend and disaster weathers.

2. Data and methods

Radar data is from Doppler radar in Tanggu of Tianjin (39º02′38 ″ N,117 º43′01″E). From 14:00 to 16:00BT (Beijing, the same below), it tracks the evolution of multiple single Hailstorm per 6mins. Radar data is rectangular coordinate system data, with horizontal resolution 0.01 ° × 0.01 °(a unit of area). For vertical direction which is 21 layers, we divide 0.5-5.5km into 11 levels, with interval 0.5km, and 6-10km is divided into 5 levels, with interval 1km, and 11-20km is divided into 5 levels, with interval 2km.

Microwave radiometer observatories locate in the southern suburb of Beijing. We use MP3000 radiometer which could better represent the sounding information that includes radiant brightness temperatures of the atmosphere above the site 200km. Then we use inversion of neural network method to get atmospheric profile. We use microwave radiometer data in Beijing to confirm the height of temperature layers(0□,-10□,-20□.etc) at 14 o'clock and compare them with sounding data at 08 o'clock to revise. The result is that the heights of 0□, -10□, -20□, -40□ respectively are 4.077km, 5.494km, 6.897km and 9.48km.

Encryption automated observations provide data which include wind direction and speed, temperature, humidity and air pressure per 10mins wind direction, wind speed, air pressure.

At present, the main sources of national lightning data are TRMM satellite lightning imager (LIS) (Tie Yuan et al., 2010); National ground lightning location network information (such as Guili Feng et al., 2006) and Safir3000 full Flash location data (Zheng Dong et al., 2010; Liu et al., 2011). The lightning data of this article is from three dimensional lightning location system of Safir3000. This system use interferometry to measure the radiation signals of very high frequency VHF(110-118MHz) caused by lightning and provide the three dimensional distribution of radiation and the data of cloud Flash of lightning; then we combine it with that of low frequency LF (300Hz-3MHz) to get ground flash data. It includes 3 detection stations (Yongqing, Fengring, Huairou) and one central station (Beijing). In theory, error is less than 2km during 200km from network center and detective efficiency is up to 90%. Study area within the allowable range. To get the Flash frequency information, we have to follow these rules when we deal with lightning data: (1) Each record that is a point of radiation. When two radiant records meet distances ≥7km and time≥ 100ms, we consider it as another lightning, otherwise as the same lightning; (2) During these radiant records, we consider the 13th column from right to left and 4 as the first return and 5 as the second one. Then 4 and 5 are marked as ground flash. (3)If the value of electronic intensity is greater than 10KA, we would consider it as positive flash. Otherwise, it is the cloudy flash.

3. Results

a. Cases and background

There was a large hail event in offshore sea on August 28, 2008 at 15o'clock (in Beijing, the same below) and the maximum diameter is 35mm, with active lightning, no heavy precipitation. Hailstorm was manufactured by multi-cell thunderstorms. Because there always new thunderstorms generated and incorporated, lives of them are 2 hours(14:12BT-16:42BT).

Figure 1 shows us the curve of the total Flash frequency (cloud Flash and Flash), cloud flash frequency, positive and negative frequency, that is the number of lightning in 6mins. Lightning activities concentrated during 14:00BT-16:00BT and the total number of flash is 713, while flash was minimal, only 3.6%; Cloud flash took 96.4% and was 687. 14:48BT and 15:30BT respectively were the times for merging of thunderstorms, and 15:00BT was the

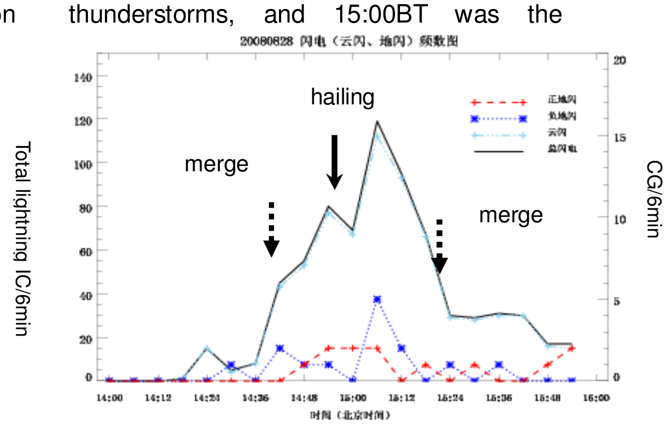

Fig.1 Evolution series of frequencies of total flash, cloud flash, positive and negative flash
(Virtual arrow lines shows the merger times and solid arrow lines show hail times)

beginningtime. Thunderstorms insignificantly impact on the trend of cloud flash frequency, while hail leaded to the frequency of cloud flash slightly decreasing. Subsequently, the peaks of frequencies of negative-ground lightning and cloud flash came out. After the hail, these frequencies sharply dropped. Hail occurred before the lightning peak came out. The formationorganization and development of thunderstorm in coastal areas are close to sea-breeze(ShufenWang,1990;Carey,etal.,2000;Gauthier,et al.,2010).Because of the temperature difference between land and sea，eastern wind dominants the west coast of Bohai in the afternoon, and there are large differences in temperature and humidity between coastal areas in Tianjin and the western areas.

Table1 shows us there was 5.0℃ temperature difference between the observations in Tanggu of Tianjin and southwestern offshore sea at 13o' clock and the difference of relative humidity was 28%. It showed a humid and cold airflow was going from Bohai to inland. From table 2, we could see that the discontinuous front of meteorological elements of humid and cold air mass is sea breeze front.

Table1 Compare in temperature and relative humidity from Tanggu(at seaside) to Jinghai(at southwest area of Tianjin).

element	STATION	13:00 BT	14:00 BT	15:00 BT
temperature℃	TANGGU	25.8	26.6	27.5
	JINGHAI	30.8	31.5	31.9
Temperature difference℃	//	-5.0	-4.9	-4.4
Humidity(%)	TANGGU	82	71	75
	JINGHAI	54	53	47
Humidity difference (%)	//	28	18	28

Using the sounding data on 8 o'clock in Beijing and the data of 6 elements automatic observations during 12~15 o'clock to calculate SWEAT—energy index map of comprehensive thermodynamic instability (Figure 2a-c).

SWEAT contain humidity, temperatures and wind data of high and low layer, considering the vertical rotation of the environmental wind. S means the spin of the wind direction difference of 500hPa and 850hPa; T and Td instead the temperatures and dew points of different altitudes.

$$SWEAT = [12T_d^{850} + 20(T^{850} + T_d^{850}) - 2T^{500} - 49]$$
$$+2V^{850} + V^{500} + 125(S + 0.2)$$

The chart shows there is a low value belt which have being from 12o' clock from Bohai Bay to the island and Jinghai district is unstable high value center during 12~15o' clock and it even reaches 400 on 13o' clock. In highly unstable regions, there is convergence line formed by sea breeze. Compared to 2D-f, the chart shows us that multiple γ meso-scale convective cells were born on 14:18 in coastal wind fronts and convergence line developed into hail storm in high unstable zone by 15:00 and the instability weakened (SWEAT fall to 320) on 15:18 and hail storm was split from a single supercell of single echo core to a multi-cell thunderstorm of multi cores. Comparing with 2A-c, we can see that sea breeze convergence line in high unstable region triggered a γMeso-scale thunderstorm and warning time was about 2hours; γMeso-scale convective cells further developed with the energy provided by high unstable region and ground dynamic convergence uplift. Using sounding and automatic station data, we analyze the distribution of unstable regions and terrestrial convergence lines. Focusing on sea breeze front location is an effective means of early warning of severe convective weather.

b. Multi-cell hail storm evolution

There were 3 particularities of multi-cell hail storm on 28th, Aug. 2008.

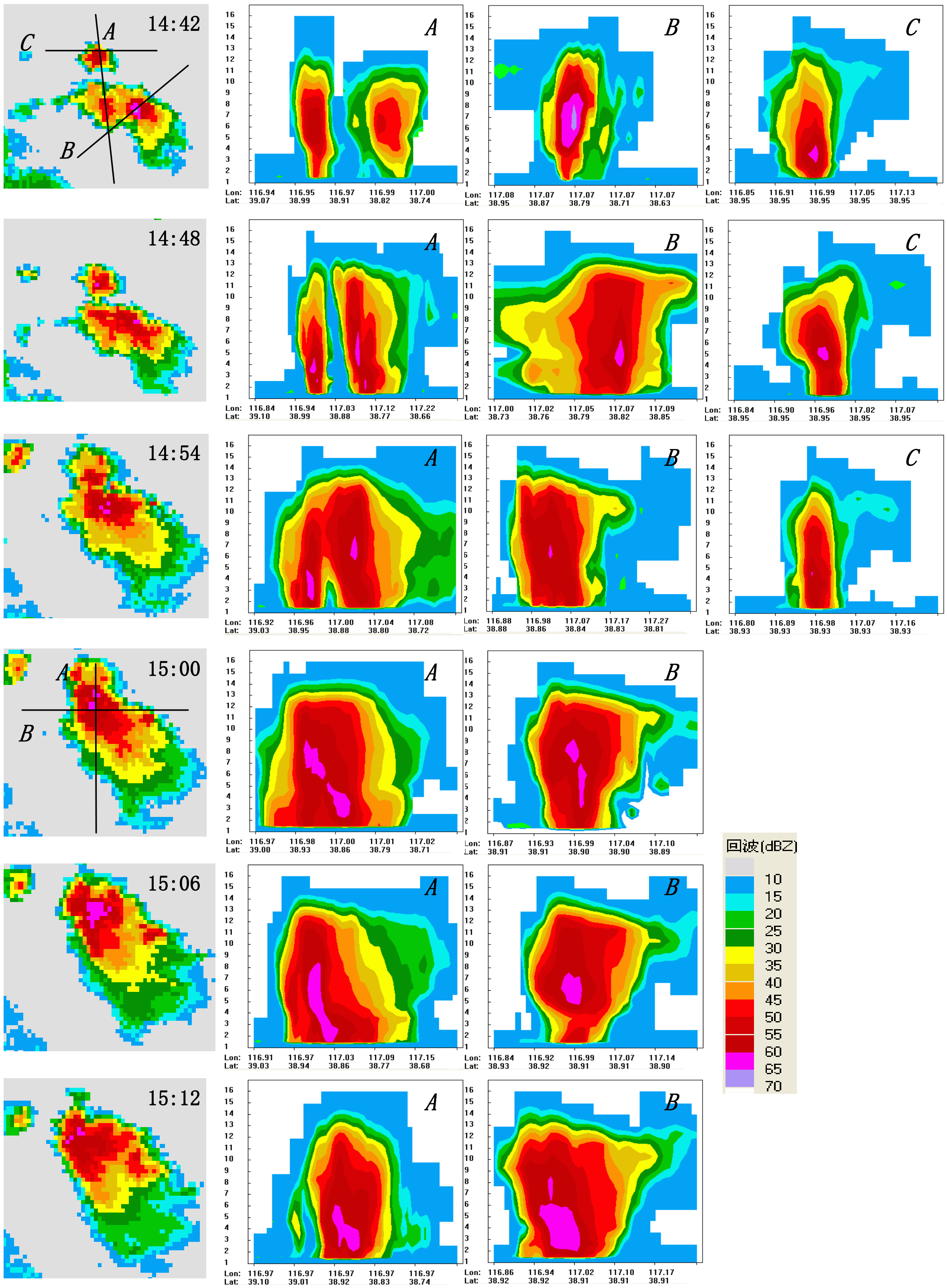

Fig.3-1 Radar reflectivity echoes at temperature height of -15℃ and RHI cross section along line A,B,C respectively from 14:42 to 15:12BT on 28 August 2008.

1) The evolution was with multiple consolidation processes;

2)The conversion of multi-cell thunderstorms and super-cell thunderstorms;

3) Multiple units have their own lives cycle and multiple reflectivity echo cores.

(1980)' results, but it is similar to Cunning (1982)'s. The merger almost begins from the monomers heads, which is perhaps something to do with theirs vertical cycles (we will discuss and explain it in the conclusion of the 5th section). On 15:00BT

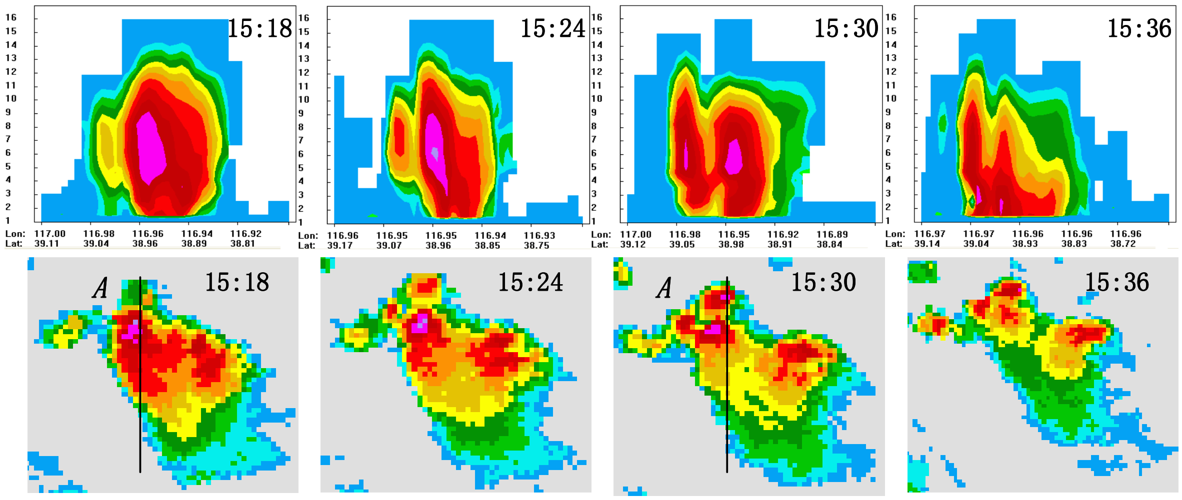

Fig.3-2 As in Fig.3-1 but from 15:18 to 15:36BT.

There are 2 types merge processes below

The first column of graph3-1 is the reflectivity CAPPI image of -15□ temperature layers (height:6km). Figure A, B, C are the RHI images got respectively along A, B, C straight lines sections of gragh3-1. We can see the detail changes of the single structures when these thunderstorms are merging.

During 14:42-15:00BT, two independent thunderstorm monomers were merging and the formation time and intensity of them were nothing to do with each other. We call it independent merger. From the column A of Figure 3-1, we can see that north and south monomers get closer while the intensity of cores are strengthening. The altitude is 6km and intensity is 55dBZ on 14:42BT and it is up to 65dBZ, while the height is 5km on 14:48BT; On 14:54BT, the monomers start merging, with 6~10ykm height and echo intensity greater than 45dBZ; The junction is not in low air, which is different with Simpson (start of hail), monomer merged into the only core and 65dBZ core scope increases and they ascend to about 9km; From microwave radiometer data on 14 o'clock, we get that the environmental temperature is around -35□,with 9km height, in which case the thunderstorm contains large amounts of ice particles. Column B show us the visible pendant shaped echo, which explains updraft is very powerful at this time; There is Cyclonic meso-cyclone in radial velocity chart; The relative radial velocity is 25m/s (positive radial velocity 10m/s, negative radial velocity 15m/s) with 3.1km height, which shows rotational motion is also very strong then. Merged thunderstorms have the characteristics of supercell thunderstorm and ascending motion and rotational motion are being strengthened. On 15:06BT, chart B still shows pendant features, which are 65dBZ core strength, and suspended in 7km height (environmental temperature is about -20□)which is 2km lower before 6mins; The meso-cyclone with3.2km height strengthen and radial velocity reaches 30m/s (positive radial velocity 10m/s, negative radial velocity 20m/s). Chart A shows 65dBZ strong echoes have landed and it corresponds to surface hail. On 15:12BT, charts A, B shows if echoes cores fall to 3~4km (ambient temperature is about 0 ° c) and 65dBZ strong echoes reach the ground, Cyclone radial velocity will significantly reduced, only 11M/s.Water-borne materials in thunderstorm clouds are mainly water particles.65dBZ strong echoes reach the ground, Cyclone radial velocity will significantly reduced, only 11M/s. Water-borne materials in thunderstorm clouds are mainly water particles.

Main characteristics of thunderstorm cell merging is the cloud bridge building, and the reason why cloud bridge location is low is the outflow cold air caused by merge single Downdraft and it uplift the around warm and moist air.

When the Cloud bridge is higher, like this case, the reason why is the top is probably mainly because if the monomers get closer, subsiding air between them will enhance.

According to equation (**DENSITY×SPEED = CONSTANT)** in fluid mechanics, we get when density between monomers reduced and pressure decreases and the pressure difference of single area and outside area increases , the merge is speeded up. Especially the top, because its pressure difference larger than that of its other parts, so head becomes lower and closer firstly and then merge to form clouds bridge. But this is only inferred and need further confirmation.

As image 15:12BT of Figure 3-1, a small monomer of which maximum albedo is 30dBZ outbreaks in 3~6km height, where is about 3km far from the large one, and it is formed by downdraft in large monomer uplift the warm and moist air mass which is in front of it.

1) There is strong updraft in powerful parent unit, up which there is divergence and it is local and small scale, which is large enough to cover a few kilometers around, even around a dozen kilometers; this local divergence is conductive to promote the development of updraft and supply the dynamic background for new nearby monomer formation.

2) Due to strong parent unit, rainfall or hail makes the humidity of the local environment increase, which provides adequate moisture conditions for development of child monomers. However, both of dynamic and humidity conditions affect small scope, so local energy is provided for child monomers, while the parent unit is gradually weakening without larger scale energy supplement.

From 15:00BT, we can see that the cores of multi-cell thunderstorm echo (strong echoes of 45dBZ) are not the only and they are in a thunderstorm. On 15:36BT, with two cores as leader, it was divided into two thunderstorm monomers, which is eastern and the other one is northern. Obviously, multi-cell thunderstorms have multi-cores, which merge to promote their development and devise to accelerate extinction.

c. Radar parameters of quantitative hailstorm structure and evolution

In China, radar is the most effective tool of obtaining the data of thunderstorm structure currently and we set up the relationship between system structure and hail and lightening activities basing on radar echoes during the research on hazard weathers. For example, for banded MCS, Zhiqiang Cao et al.(2005),Guili Feng et al. (2006), Tie Yuan et al. (2010), Liu et al.(2010)

horizontally overlaid lightning and radar echo and got that lightning mainly concentrated on the area with 6km high and echo intensities within 35-50dBZ; The distribution of lightning was sparse in the vast clouds region, where flash exists. For supercell thunderstorms, Dong Zheng et al. (2010) analyzed the vertical stack of lightning and radar echoes and got that lightning concentrated at the places where the contour gradients of echo intensity was large. In the studies above, they both tried to apply the parameters of radar to reflect effectively the special change of thunderstorms, inner dynamic and water-bored materials and so on. Aiming at achieving the quantitative problems, we apply some new parameters of radar. For the vertical distribution of these quantities, the higher the parameters are and the stronger the updraft is, and vice versa. Echo at the temperature level determines the nature of water particles, that is, it mainly is drops or ice crystals. The height of the echo center reflected the height of the water particles in cloud sets. Except these, we get the results below:

Zmax: during the specified study area, the maximums of each reflectivity (unit: dBZ) sometime reflect the height of the center of the maximum reflectivity.

Zmean15: during the specified study area, the average of the reflectivity of each layer with 15dBZ in a certain time reflects the strength of the development in clouds and partly reflects the number of the particles as well.

V40, V50: during the specified study area, at a time the echo area or volume of each layer with 40dBZ and 50 dBZ (unit: lattice point, individual, a lattice point is 0.01 ° 0.01 °) or volume (area x height, height is identified as 1km, unit: Individual km) reflects the size of the core of strong echo and its height and partly reflects the spatial size of the convective clouds set and intensity of precipitation.

Figure 4a-d respectively shows the change of the vertical distribution of parameters referred to above of radar , and it is a overlay map formed by Zmax, Zmean15, V40, V50 (shadow) and lightning frequency (solid line: cloud Flash; Circle dashed line: negative ground flashes; Dash: Flash); It also partly reflects the complex spatial structure in hailstorm and updraft strength and aqueous particle number and phase.

Figure 4a is Zmax and lightning frequency sequence. The following analysis:

On 14:12-16:00BT, there is always 50dBZ echo above -20 ° c, particularly at 14:36-15:12BT, the maximum reflectivity is up 55dBZ (shaded yellow) above.-40 ° c. According to flash and flash frequency curve, we can see the frequency of flash significantly increase and 55dBZ echo through the height of -40 layer(9.48km) and lasts 36 miniuts; after it reaches the peak, the peaks of flash and frequency of flash occur. This shows that ice is transports to the high air by updraft and maintain a while, which contributes to the frequency of lightning activities. This can be proved by the interpretation of non-electric mechanism.

Around 14:36-14:42BT and 15:24BT, from the perspective of vertical distribution of Zmax, the characteristic which is the higher and the values larger of vertical structure shows updraft was quite strong during the two times when 64 echo reached the height of -10℃ layer.

During 14：48-15:06BT and15:30-15:36BT, there is strong intensity echo with 64dBZ, while the hail with 35mm was only recorded at 15:00BT by ground observations; Around 15:30BT, there was no record of hail. The vertical distribution of Zmax is changing with time to describe the process of appearance

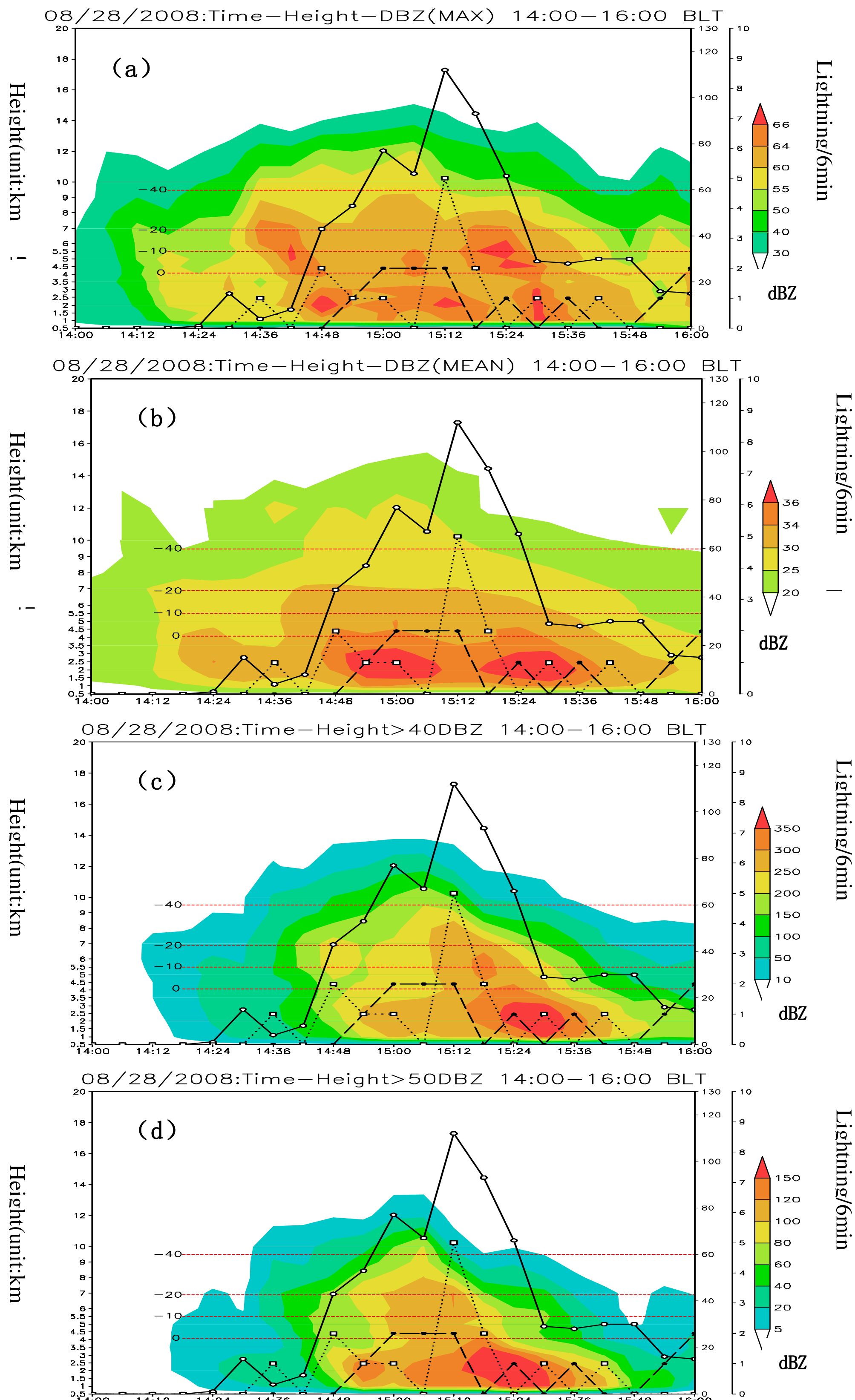

Fig.4 Time–height cross sections of (a) maximum reflectivity(*Z*max, dB*Z*),(b) mean reflectivity (*Z*mean15, dB*Z*), (c) high-reflectivity (v40 dB*Z*) echo volume (*V*40, km3), and (d) 50-dB*Z*reflectivity(v40 dB*Z*) echo volume (*V*40, km3). of overhang ice(hail)-dropping and mounts The 6-min-average lightning flash rate is repeated for comparison. The height several key temperature levels are indicated (*H*(*T* = 0℃)= 4.077 km; *H*(*T* = -10℃)=5.494 km; *H*(*T* = -20℃)= 6.897 km; *H*(*T* = -40℃)= 9.48 km)

of water drops.

Figure 4b is sequence of Zmean15 and lightning frequency. The analysis is below:

① The maximum of entire average intensity of echo reached above 36dBZ in this hail process; the appearance of the shadow of echo with 34dBZ during 14:48-15:42BT shows that the water-borne materials was the most during this period when the lightening was the most active and it took 82.7% of the entire process. So it illustrates that lightening activities and water-borne materials are related.

□ the average strength of echo above -20℃ layer is 25dBZ, which shows updraft is strong then.Shadow zone of 25dBZ consistent with the trend of the change of cloud flash frequency; Especially, the 2 peaks appears in the 14:48BT and 15:00BT correspond to the peaks of flash frequences respectively which appears after 12mins.

Figure 4c、d are sequences of V40、V50h respectively and lightning frequency. The analysis is below:

① V40 also reflects the overhanging structures of the hailstorm about 14:48BT and the nuclear of the strong echo at other times are rendered Tower-like structure. The peaks of the volume and height of the strong echo nuclear corresponds to the peak of the flash frequency. After 15:06BT when the hail finished, V40 increased from 200 to 250 points and the heights of the 200 and 250 point line extended to -20 ° c to-40 ° c layers above 0□ layer. This indicates that after the hail, cumulus clouds is still evolving and the scale of it is large and the core of strong convection cloud is high and there is amounts of ice crystals and upward air currents are very strong, therefore, there is lightning activity peaks. This further explains why the peak of the lightning frequency occurs after hail; also shows hail and the level of lightning activity reflect the evolution of the inner structure of the thunderstorm system.

② V40 V50 ≥ and ≥ 150 60 gridded shadows corresponds to lightning frequency-changing very well. Shadow steep rose and strong echoes developed rapidly during 14:42-15:06BT when it reached peak. Besides, the centers of the maximums (350 and 150) of V40 and V50 appeared below 0 ° c layer during 15:18BT-15:30BT when rain particles dominated within the clouds and the strength of the precipitation was enhanced, while corresponding lightening activities sharply decreased. After the frequent lightening activities, the precipitation was strengthened, which means the data of lightening is meaningful on warning for short-time strong precipitation or not. It needs further research.

d. The warning of hazard weathers with the parameters of radar

This section provides two parameters of radar which are meaningful to warning; they are the variability of volume and the range size of height of the top of echo. As -10 ° c to-20 ° c layers are electromotive layers, so we use -15□ layer as boundary to calculate the variability.The variability of volume is the difference of the next two V40, which reflects the location of nuclear of the strong echo and size-changing.

up*FV40* 、up*FV50:* The variability of volume of V40、V50 above -15□ layer; the following is the variability of volume of V40（Figure. 5a）.

ETS11: The sum of grids of the top which is above 11km of echo (Figure. 5b) not only reflects the development height of the thunderstorm system, but also reflects the size of the system, and it is a parameter of describing development of the system.

From figure 5a，we can see that before

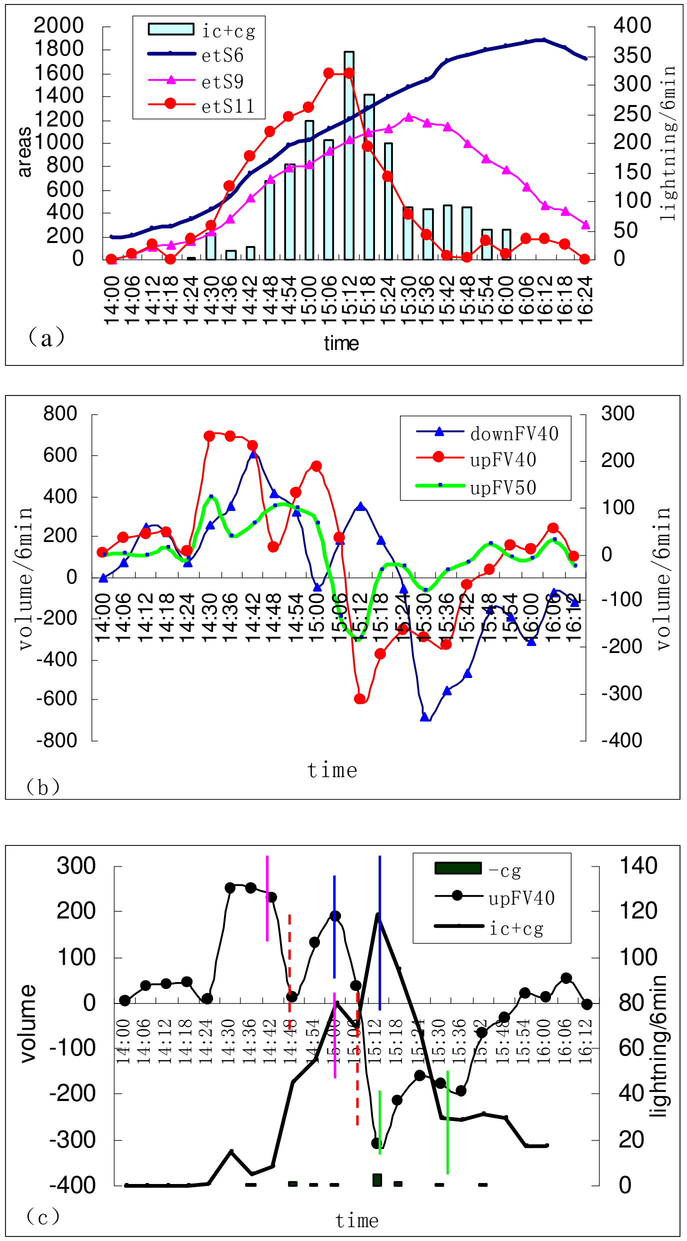

Fig.5 (a)Curves for time sequence of radar-parameter on *upFV40,downFV40 and upFV50.*(b) Time sequence of total lightning frequency, radar-parameter on *etS6,etS9,etS11.*(c) Time sequence of total lightning frequency(solid line), negative lightning frequency(column) and radar-parameter on *upFV40*(Color lines are compare for now-forecasting).

14：48BT，the curves of upFV40 and down FV40 are nearly the same and this demonstrates that the entire muti-monomer develops strongly during this period；during 14:48-14:54BT， the curve of upFV40 is in trough， while variability is positive； Compounding to figure 1，we confirm this the merger time. At this point, the volume of strong echo changes little above -15□ layer, from which we can deduce V40 has not increased rapidly when two thunderstorms merger, while the value of upFV50 reaches the peak, with 103 units; This shows merger has an impact on the structure of thunderstorms, while a little on its strength.

About 12 minites after the merger, that is 15:00-15:06BT (at this time began to hail), upFV40 and upFV50 have reached the highest points, which shows the nuclear of strong echo rise and volume sharply increases as well. Corresponding to figure 3-1, we can see multi-cell thunderstorms at this time had evolved as a supercell thunderstorm and pendant feature is obvious and ice particle content is the most and most powerful updraft. However, down FV40 is in the negative trough, which fully shows strong echo develops powerfully only above -15 ℃ layer and this match the pendant features very well. At 15:06-15:12BT, three curves above were turning, with the value of upFV40 collapsing as a peak to a negative one, which showed V40 significantly drop above -15℃ layer; Down FV40 increasing showed the volume of V40 increase while the height of strong echo unclear significantly decrease with hail falling above -15 ℃ layer. Until the 15:12BT, downFV40 reaches the peak while upFV40 is down to the minimum value. Obviously, the change of volume and location o f strong echo unclear displayed by upFV40 and downFV40 achieve the moments when merger (6-12min) and hail occurs.

Figure 5b shows the sum of the grid points the echo top heights which respectively are above 6km, 9km, 11km are represented by ETS6, ETS9, ETS11; columns represent the total Flash frequency (for contrasts, frequency expanded 3 times). From the trend changing of the curves and total Flash frequency, we can see ETS11 best matches the total flash change; From the times when the curves reaches the peak, we can see ETS11 firstly occur, following by ETS9 and ETS6; and ETS11 changing-trends is ahead of the lightning, so it is the most meaningful for the warning.

When Xiaoyuan Yi et al.(2008) analysis three of convective system of squalls, he got the conclusion that ETS11 is related to flashing frequency. ETS11 is more advanced on describing the history and context of the multi-cell thunderstorms which ease at 15:42BT. It and the gravity potential (2008) can divided development of thunderstorms into different stages.

Figure 5C shows upFV40 (curve) and total Flash (solid line), negative ground flashes in frequency (column chart). From the perspective of two curves of peak-Valley, there are 4 times corresponding to the time when (marked different line styles), and upFV40 ahead of the lightning 12min, the upFV40 also has warning significance to lightning activity.

4. Conclusion

Radar, SAFIR3000 3D lightning location systems, microwave radiometer and observation data of encryption automated stations help us to further recognize the structure of meso-scale convective systems and detailed processes such as merge, and provide the basis for complex relationship between severe weathers such as hail, lightning and evolution of thunderstorm system structure.

This article analysis the local background of a multi-cell monomer hailstorm which is related to the convergence line of sea breeze in the West coast of the Bohai; we study a number of features of different types when they are merging and use the parameters of evolution of radar to quantify vertical structure and physical processes such as mergers, hail, and then we compare the relationship between change of structures and lightning activity and propose radar parameters which is significant to early warning. Get the following main conclusions:

1. Combining local instability of the ground with wet and cooling sea breeze convergence line is the promoting mechanisms of thunderstorms generation and background provides warning time 2hours. Therefore, early warnings of severe convective weather in West coast of the Bohai Sea area, paying attention to the corporation of humid sea breeze convergence line and local highly instability areas is the useful meco-scale condition of inspiring ordinary thunderstorm, the developing of ordinary thunderstorm to multi-cell monomer one or super monomer thunderstorm..

2. There are two types when β or γ-meso-scale monomer merges. They are independent mergence and feeding mergence; During the mergence, cloud bridges occur sometimes in 4~6km and sometimes in 9~10km height among monomers.

3. Cloud flash occupies 96.4% in all flash during this hailstorm process. Thunderstorms mergence has no impact on cloud flash frequency trends and the peak of hail and lightning both occur after the independent mergence. At the beginning of hail, cloud flash frequency is slightly down; hail occur before the appearance of peaks of negative ground lightening and cloud flash frequency. Upward trend is limited at the moment of mergence (12min), while it strengthens again after the mergence. However, feeding mergence is in the dying stage and lightening frequency declines steadily.

4. Radar parameters such as Zmax, Zmean15, V40, V50 are able to much better reflect changes in the evolution and structure of hailstorm; they also reflect the relationship among updraft intensity, the number of water-borne materials and its nature and sever weathers. UpFV40, down FV40, ETS11 can be well described the change of thunderstorms when they merge with hail. Those radar parameters are meaningful to warning of lightening activities, ahead of 12mins.

5. Acknowledgement

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