Evolution of the Four Heavy Rainfall Cells Structure in the Leading Line Meso-scale Convective System and Lightning Activity

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Abstract--The data from the Doppler radar, SAFIR3000 lightning location system and high-density automatic meteorological stations observations are used to design a variety of radar quantitative parameter and analyze the evolution of cells structures, lightning activity and electrical vertical structure of the four severe rainfall cells structure in a LL-MCS. The conclusions are as follows.At first, the four cells in(Guan in Hebei, Shunyi and Fangshan in Beijing, Baodi in Tianjin) in the single squall respectively brought rainfall of about 23 mm, 50 mm, 27mm and 70mm in one hour. In the Fangshan-cell, two smaller cells were merged.**Secondly**, the radar parameters of V_{40}(40dBZ echo volume range), $V_{40UP\text{-}6}$ (40dBZ echo volume range above height of 6km) and ***Set11*** (echo area range at 11km level) could describe the 3D quantitative structure evolution of cells,and Fcg(cloud-to-ground lightning frequency) and Fic(intracloud flashes frequency) were closely related to the radar parameters, such as its correlation coefficient with $V_{40UP\text{-}6}$ being between 0.63 and 0.97.The ***Fic*** was more sensitive than that of ***Fcg*** when echo structure change.**Thirdly**, the lightning parameter H(height of the radiant point maximum concentration area(main positive charge area) in the Gu'an-cell was below 6km, which was far lower than the other cells at the same stage. **At last**, the feature of Fcg and Fic and H increased significantly after the merger in convective cell and the characteristics of lightning frequency increase showing relationship with the rainfall intensity increasing as well as the lightning frequency peak leading the maximum of rainfall intensity have positive significance for warning of disaster weather.

Key words--LL-MCS; γ-meso-scale convective cell;structure evolution;radar parameter;lightning activity

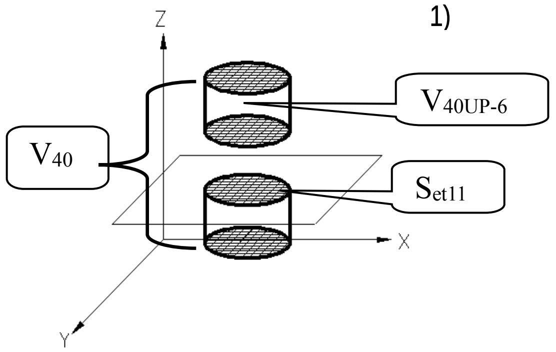
I. INTRODUCTION

In the Leading Line Meso-scale Convective System (LL-MCS),the convective zone are composed of numerous convective cells which are tens of kilometers scale assembling in the way of lateral arrangement (by Houze,et al.[1990]). And these convective cells are limited by the larger scale LL-MCS, as well as have respective independence in the aspect of spatial structure, life cycle and movement. The contact of thunderstorm gale, radar echo characteristics and lightning activity in LL-MCS shorted than the super cell, due to the interaction between multiple convective cells embedding in the LL-MCS, was considered by Steiger et al. [2007]. With advances in small and medium scale monitoring technology, the studying scale is from the β meso-scale of hundreds of kilometers to the γ meso-scale of tens of kilometers, especially the convective cells embedding in the LL-MCS and causing severe weather. The charge structure, the physical process and dynamic action in the cells were studied by Lang et al.[2008] using the radar and lightning data, who chose the squall line systems within one convective cell causing gale and two convective cells causing hail. The charge distribution of four convective cells in the β meso-scale convective system was researched by Weiss et al.[2008] using Lighting Mapping Array(LMA) and E electric field sounding data, and the results were found that the charge distribution of each cell is different from the others, the charge structure layer is not the same from 2 to 6 layers, and the lightning activity is very complex. The charge vertical structure of the γ meso-scale convective zone in the meso-scale severe rain belt was studied by Zheng et al. [2010a] applying SAFIR3000 lightning data. Yuan and Qie [2010] also focused on the cell-scale in a squall line while studying the relationship between lightning activity and precipitation structure in the South China. Compared with previous research upon LL-MCS,the decrease of the scale highlights the cell evolution characteristics and laws in the different development stage and its relationship with hail, thunderstorm gale, heavy rain, etc., also covers the shortage of the multiple convective cells common impact The non-inductive charge mechanism in the work of Takahashi[1978] and Saunders[1993] indicate that lightning activity not only has relationship with convective system structure and its changes, exactly as the lightning activity having a significantly positive correlation with the area of the convective clouds,but also has relationship with the convective region precipitation, such as the precipitation represented by RPF (Rainyields Per Flash) which is 2.65 x 10^7 kg in the Beijing by Zheng et al.[2010b] and 0.72-2.04 x 10^7kg in Spain by Soula et al.[2001], based on the SAFIR3000 data.

II. DATA AND METHODOLOGY

Reflectivity data from the Weather Radar88 Doppler of Beijing and Tianjin.Lightning data from Safir3000 in Beijn.Weather element data from automatic meteorological stations observations network.

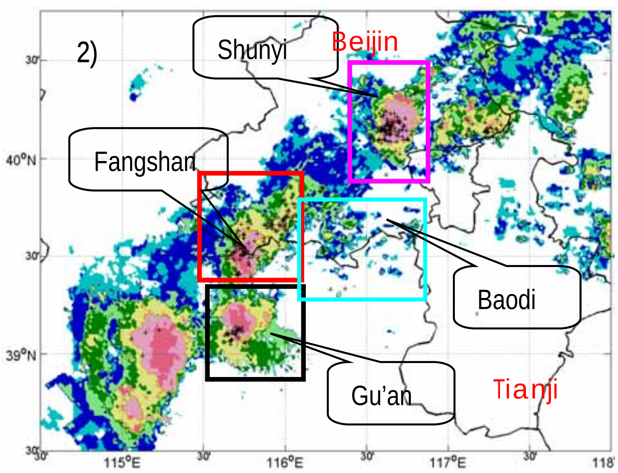
Figture1 is the schematic diagram of calculating radar parameter using radar data in orthogonal coordinates.



III. RESULTS AND DISCUSSION

A.Separation and determination of severe rainfall cells

Figure2 is a horizontal distribution of the echo top (shaded) and IC lightning(sign "+") at 6:36BT 18 July 2007.(Pink,red and blank panes indicate the severe rainfall cells in Sunyi,Fangshan,
Gu'an and Baodi respectively.



B.Relationship between radar parameters V_{40UP-6} and lightning frequency

Table1 is correlation coefficients between Fcg[and Fic] with radar parameters(V_{40UP-6})

Correlation coefficient	Shunyi-cell	Fangshan-cell	Gu'an-cell	Baodi-cell
Rcg	0.63	0.874	0.952	0.894
Ric	0.772	0.819	0.929	0.974

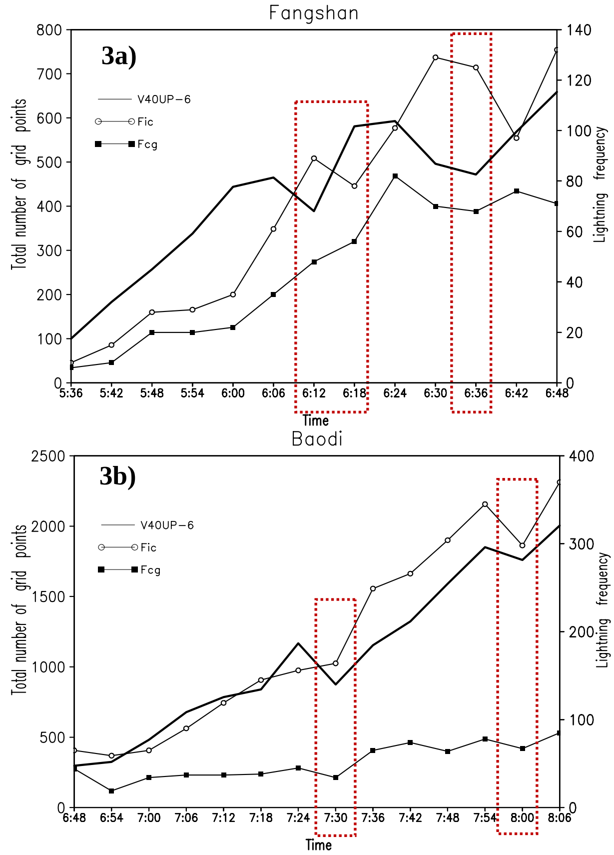


Fig.3 Time series of radar parameter V_{40}40up(solid curve) and frequencies for IC(circle curve) and CG(triangle curve) respectively in Fangshan-cell(a) and Baodi-cel(b)l.

Figure3a shows at 6:12BT,the two cells happened to merge in Fangshan-cell, with the V_{40UP-6} curve assumed low value, then the value increased rapidly.At 6:36BT,the V_{40UP-6} curve assumed valley again, and at this time appeared two cores in the cell.Fic is corresponding to the appearance of troughs and peaks after 6-12min when the curve showed valleys at 6:12BT,6:36BTand peaks at 6:06BT,6:18BT.The results showed that the activity of lightning from cloud lagged after the structure changes of convective cells over 6km.

Figure3b show at 7:30BTand 8:00BTin Baodi-cell, the V_{40UP-6} curve appears low values, both at 7:30BT and 8:0BT,the gale(greater than 17.2m/s) and squall (i.e.,the phenomenon of the temperature lapsed with the pressure surging, instantaneous wind surging and mutations in the wind) were recorded by the automatic stations,whether these small fluctuations were related to other weather disasters needs to be confirmed.

C.Relationship between radar parameters V_{40} and lightning frequency

The analysis as figure4 show:

1)Active period of the lightning corresponded to the peaks of V_{40},With the increase of V_{40}(i.e.,V_{40} color gradually deepened),Fic and Fcg increased rapidly except Shunyi -cell,which indicate the lightning activity intensity with the convective cloud volume increase.

2)Large value center of V_{40} appeared after the rapid rising or peaks of the lightning, which shows the strongest precipitation comes after the lightning fast growing or peaks.Rutledg and MacGorman[1988],Holle[1994],Soula [1998] also found the phenomenon that the lightning peak appeared ahead of rain rates peak.The reason is: Lightning activities leads to the changes of electric field. The rising speed was increased by the electric field force, which strengthen the collection of Ice-phase particles, also in order to accelerate and strengthen the precipitation by Williams et al.[1989] and by Zhang et al.[1995].

D.Characteristics of the main positive charge area height

Notes: Because positioning accuracy of the radiation source is limited, We don't research on radiation source specific height,This paper just focuses on the evolution of the positive charge region (the maximum radiation source where the height of vertical density.

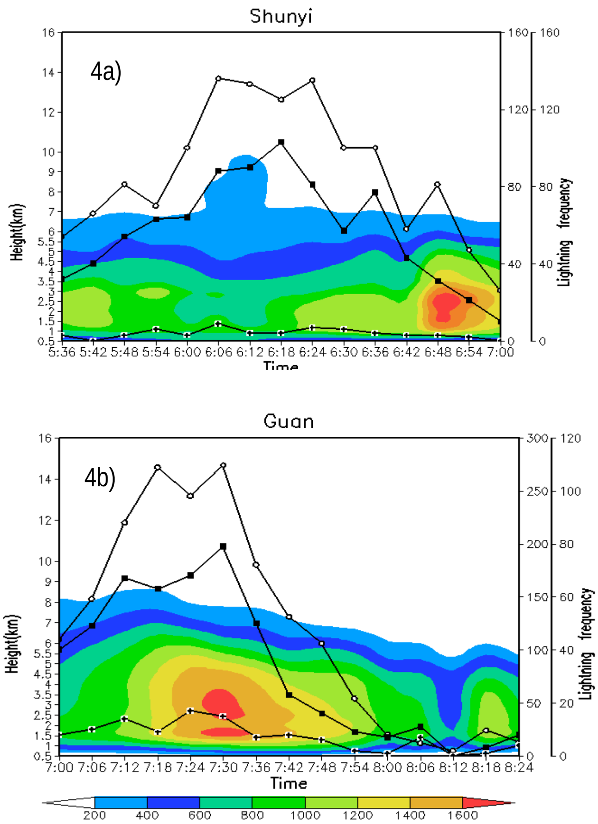


Fig.4 Time-height of radar parameter V_{40}(shade,unit is number of grids) and evolution of Fic, Fcg and positive CG frequencies respectively in Shunyi-cell(a) and Gu'an-cell(b).

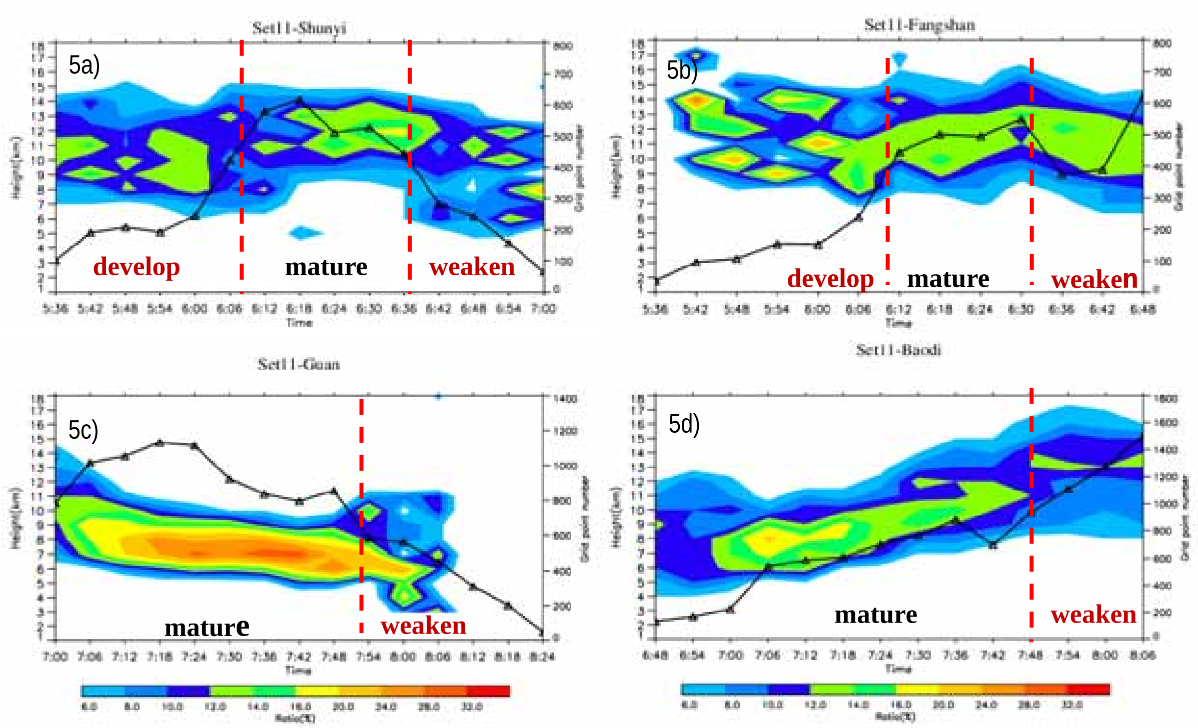


Fig.5 a)Time-height of radiant points ratio (shade) and time series of radar parameter Set11(curve line)in Shunyi-celll. Fig.5b, Fig.5c and Fig.5d same as Fig.5a but for Fangshan-cell,Gu'an-cell and Baodi-cell respectively.

Figure5a and Figure5b show that the positive charge region maintained a high level in each stage of Fangshan-cell and Shunyi-cell. In Figure5d, from the development to the booming stage of Baodi-cell,the lightning parameter H was significantly increased.The result is similar to the conclusion in the work of Hansen [2010], the main positive charge region height increased with the development of thunderstorms, and decreased with the weakening of the thunderstorms.

However,the figure5c show that the evolution of the positive charge region in Gu'an-cell is different from the other three cells:the height of the positive charge region maintained at a relatively low level in the vigorous stage, which has the same features with the work of Zheng [200] about hail.

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