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Investigation of Supercells in China : Environmental and Storm Characteristics

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Abstract

Based on the Doppler weather radar data, More than 200 supercell events in China were identified during eight-year period from 2002 to 2009. Their spatial distribution, seasonal and diurnal variations are given. Using routine sounding and surface observational data, several important parameters representing the major features of the environment in which these supercells occurred were investigated, these parameters include convective available potential energy (CAPE), 0-6km deep layer vertical wind shear, 700-500hPa temperature difference, and surface dewpoints. The results show that the value ranges corresponding to the peak frequencies for the CAPE and the 0-6km wind vector difference distributions are from 1000 to 2500 J/kg and from 15 to 25m/s, respectively. With the base data from more than 50 Doppler weather radars, the characteristics describing the intensity, structure, and evolution of China's supercells were analyzed. The average diameter of mesocyclones associated with supercells is 6.2 km, with the range of the peak frequency for diameter distribution being between 4km and 7km. The value ranges corresponding to peak frequencies for mesocyclone rotational speed and duration are from 15 to 20m/s and 40 to 50 minutes, respectively. About 63% of supercells display the BWER structure, and the value range of peak frequency for supercell maximum reflectivity distribution is between 65 dBz and 70dBz， with the extreme reflectivity value being 76 dBz.

1 Introduction

Supercell storms are the severe convective storms possessing deep and persistent mesocyclones (Doswell and Burgess, 1993; Doswell,2001) and they are responsible for most of extreme hail events, significant tornado events and part of the significant damaging straight wind events (Johns and Doswell, 1992). Up to now, most studies on supercells are done in United States, so in this paper we will give an overview on the supercells in China, with emphasis on their environmental conditions and storm characteristics detected by the Doppler weather radar.

2. Spatial and Temporal Distribution

During the eight-year period from 2002 to 2009, we have identified 224 supercell events，a supercell event means a convective storms process in which a single or multiple supercells have been identified during a 24h period and over an area of a single radar umbrella. China Meteorological Administration (CMA) began to deploy its operational Doppler weather radar network from 1999, up to now, over 160 Doppler weather radars have been put into operation. Figure 1 gives spatial distribution of these supercell events. The supercell events have been identified nearly in all parts of China except the large part

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of the Tibetan Plateau, Xinjiang and Mongolia Gobi. Most of the supercell events occurred in eastern, central, southern and north-eastern China. It is necessary to point out that 224 events are not complete, many supercell events occurred during the 8-year period in China have not been identified, for some areas were not coverage by the Doppler weather radar umbrellas. For eastern, central and southern China, where relative denser radar networks have been built, the replay of Doppler weather radar base data revealed that in these areas the frequency of the supercell events is on the order of 2.0 to 3.0 events per 10^5 square kilometers per year.

Figure 1 Spatial distribution of 224 supercell events from 2002 to 2009 in China.

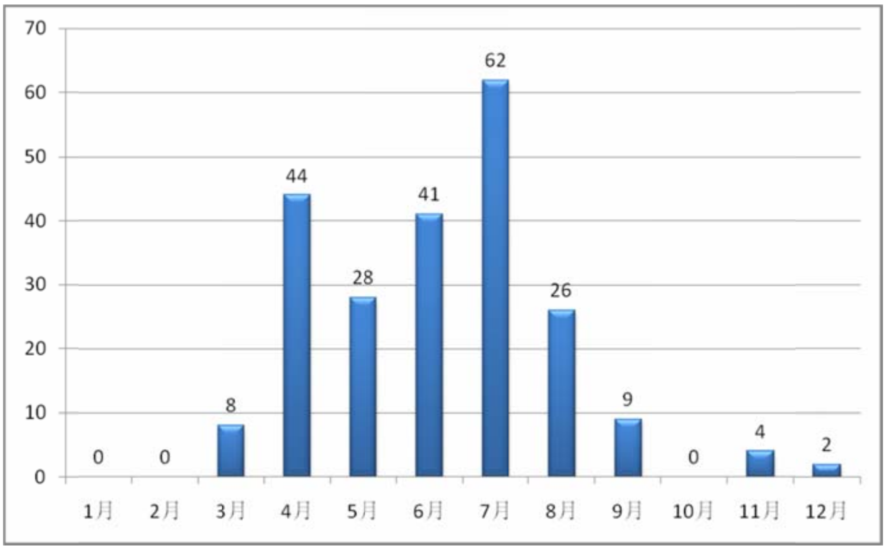

Figure 2 Annual variation of supercell events in China

Figure 2 shows the annual variation of supercell occurring frequency in China, with the peak frequency in July, with the great majority of supercells occurring from March to September. No supercell events have been identified in October, January and February.

January and February are the coldest period in China, it is understandable that during the this period no supercell event occurs. However, it is not reasonable that no supercell event occurs in October, and we believe that the absence of supercell events in our data set is duo to the incompleteness of our supercell events data set.

Figure 3 gives the diurnal variation of the supercell events. The time had been corrected to the local time. The supecell events occur the most frequently from 14:00 to 21:00 local time, with peak value during the period 15:00 to 16:00 local time. The lowest frequency time period for supercell occurrence is between 00:00 to 12:00 local time.

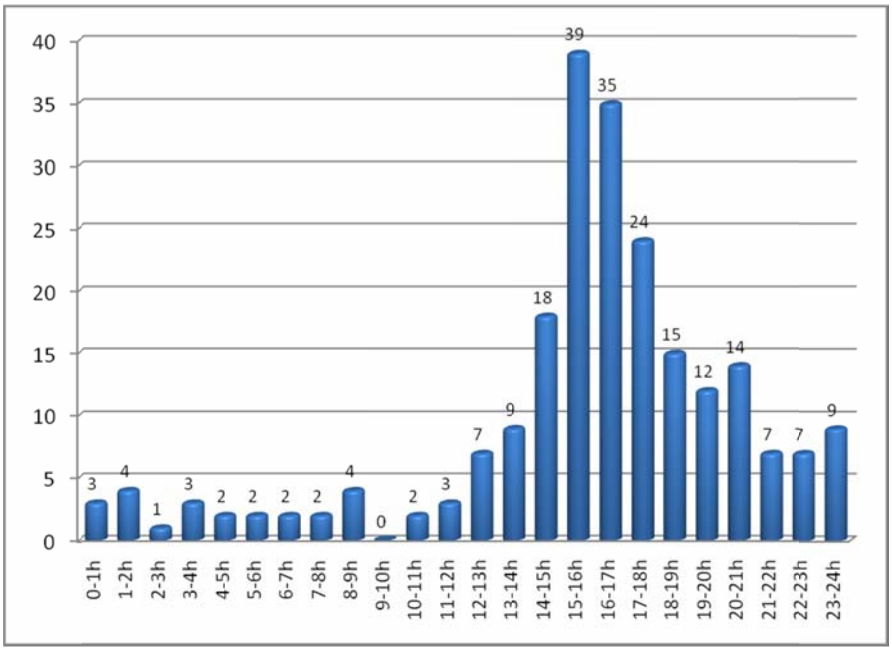

Figure 3 The diurnal variation of the supercell events.

3 Environmental Conditions

The most significant two parameters representing the environmental conditions for convective storms are Convective Available Potential Energy (CAPE) and 0-6km wind vectors difference (deep layer vertical wind shear).

It shows that for large majority of supercell events, the CAPE value is between 500 to 3500 J/kg, the extreme value is over 6000 J/kg (Figure 4), the peak frequencies of the CAPE distribution is between 1000 to 2500 J/kg.

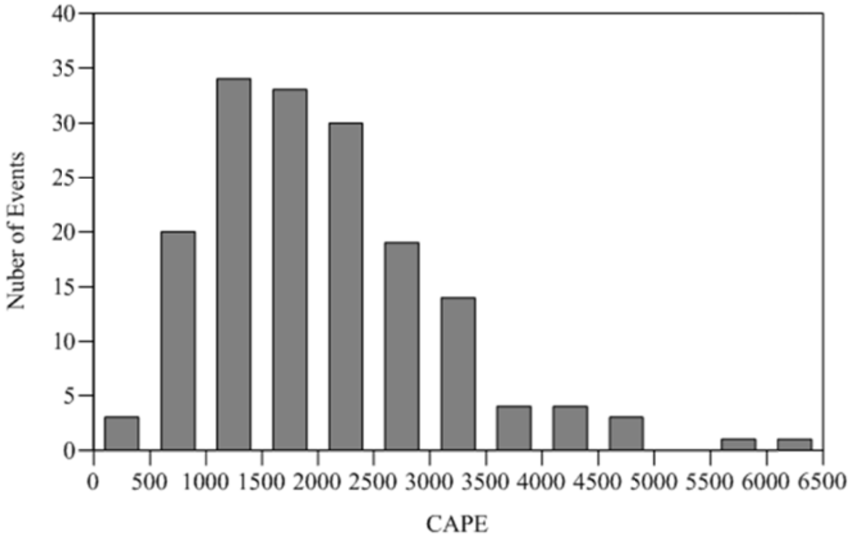

Figure 4 CAPE distribution for the 224 supercell events.

In general, 0-6 km wind vectors difference is used to represent the deep layer vertical wind shear. Figure 5 shows that the high frequencies range for 0-6km wind vector difference is between 15 to 25 m/s, with extreme value near 45m/s. For most majority of the supercell events, the 0-6km wind vector difference value is between 10 to 35 m/s.

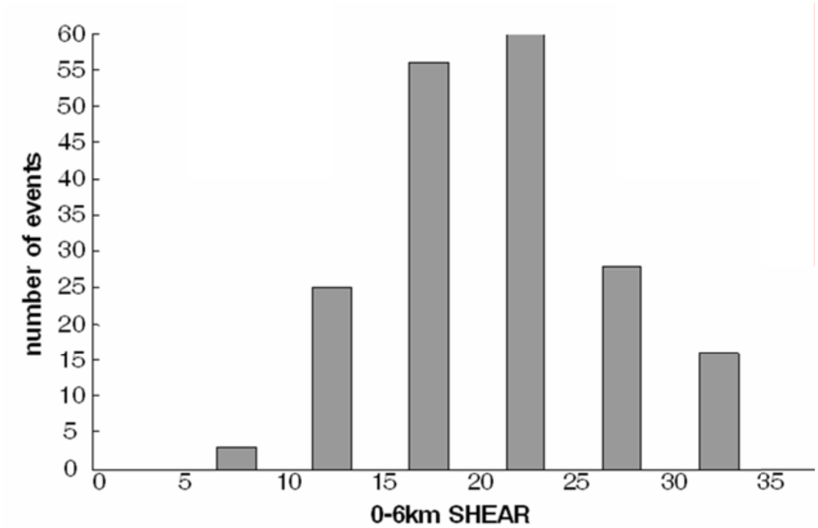

Figure 5 Distribution of 0-6km wind vector difference for the 224 supercell events.

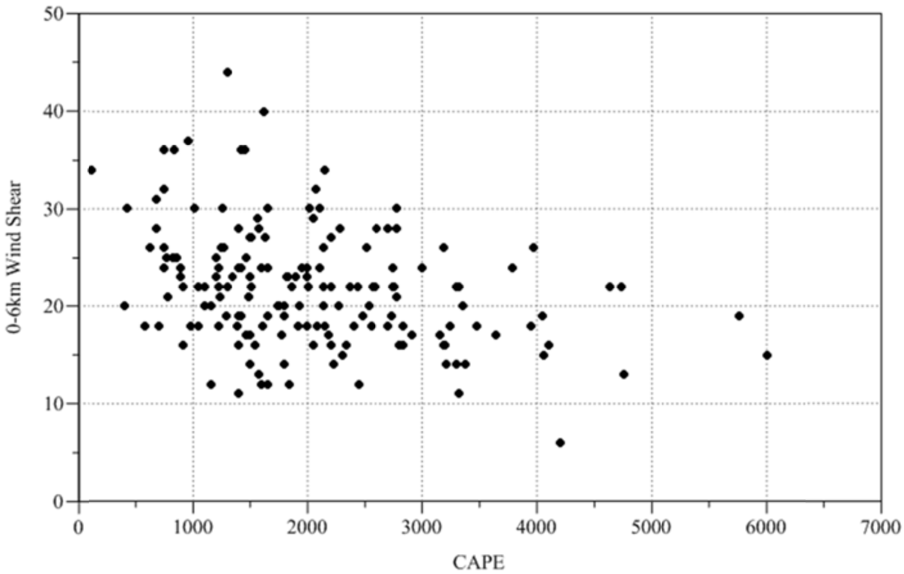

Figure 6 Scattering diagram of CAPE and 0-6km wind vector difference for the 224 supercell events.

From Figure 6, we see that most of the supercell events occurred in an environment with the CAPE between 500 to 3000 J/kg and 0-6 km wind shear between 10 to 30m/s. The value ranges corresponding to the peak frequencies for both the CAPE and the 0-6km wind vector difference distributions are from 1000 to 2500J/kg and from 15m/s to 25m/s, respectively.

4 Supercell Characteristics

The characteristics of supercell storms can be described by many parameters, among them most significant parameters including mesocyclone rotation speed (and corresponding vertical vorticity), diameter, duration, maximum reflectivity within supercell, supercell moving speed and whether or not a BWER can be identified.

For over 85% supercells, their mesocyclones rotation speed is between 15 to 25 m/s, with extreme value as high as 35m/s (Figure 7). The majority of mesocyclones diameter is between 4 to 7km, with minimum, average, and maximum value being 2.0, 6.1 and 14.5 km, respectively (Figure 8). Correspondingly, the vertical vorticity for the great majority of mesocyclones is between 0.5 to 2.5×10^{-2} s^{-1} , with maximum value over 4.0×10^{-2} s^{-1} (Figure 9).

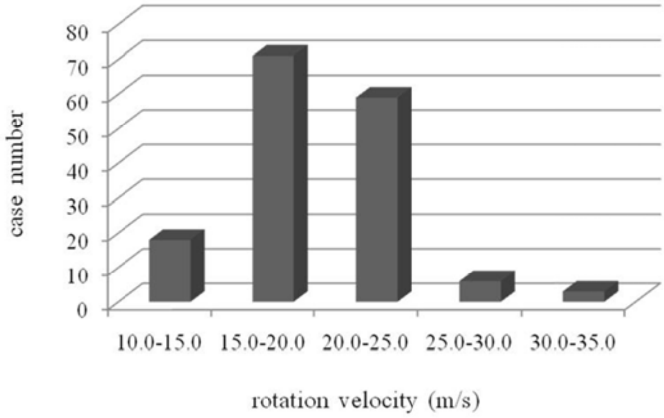

Figure 7 The rotation velocity distribution of the mesocyclones associated with supercells.

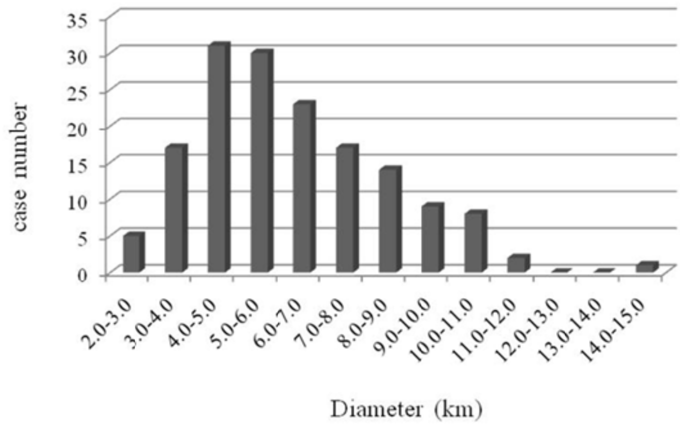

Figure 8 The diameter distribution of mesocyclones associated with supercells

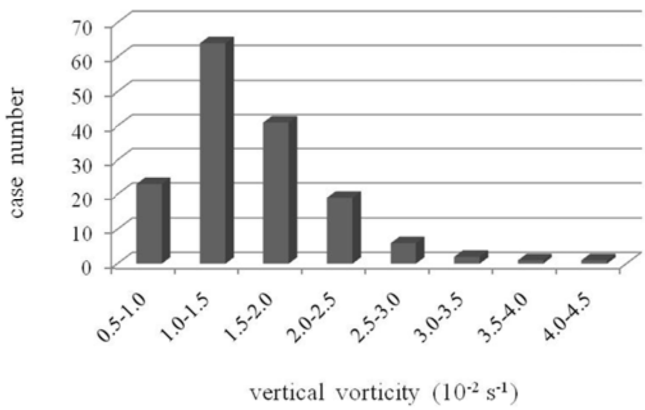

Figure 9 The vertical verticity distribution of mesocyclones

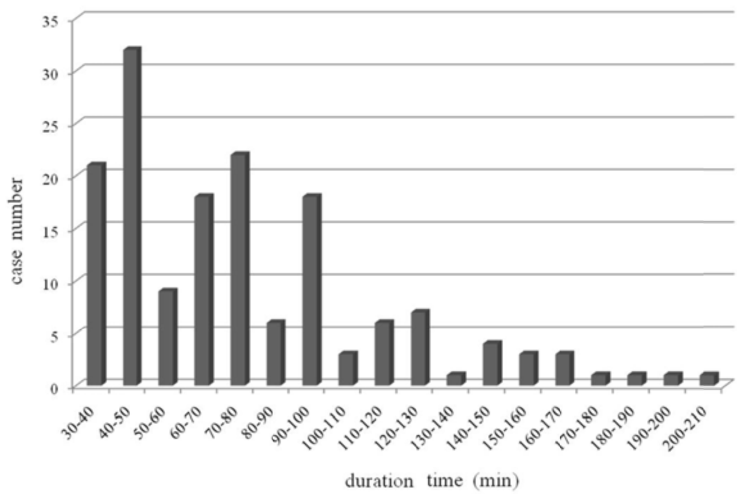

Figure 10 The life span distribution of the supercell storms.

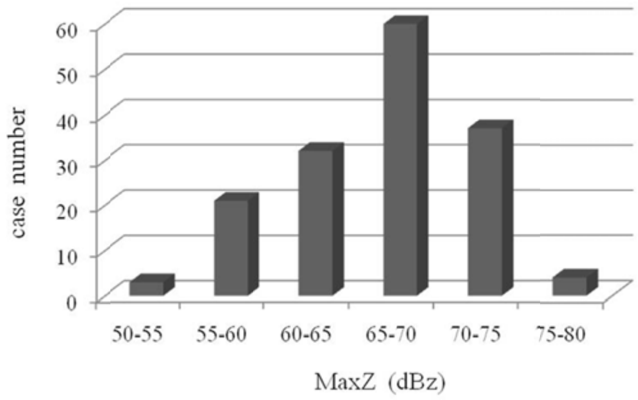

Figure 11 The distribution of maximum reflectivity within supercell storms.

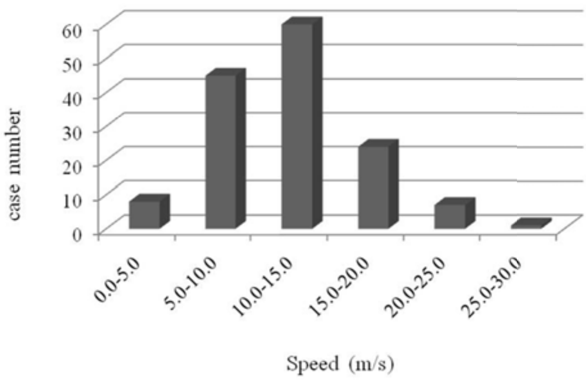

Figure 12 The distribution of moving speed of supercell stroms.

The great majority of supercell storms have a life span of 30 to 130 minutes, with several peak frequencies being 40 to 50 minutes, 70 to 80 minutes and 90 to 100 minutes. The longest supercell duration among the 224 supercell events is nearly 3.5 hours (Figure 10).

The most of supercells have a maximum reflectivity of 55 to 75 dBz, with peak frequency range from 65 to 70 dBz. The highest value is 76dBz. About 63% of supercell storms display the BWER structure and 37% of supercells have not shown clear BWER. The moving speed is between 5.0 to 20.0 m/s for the great majority of supercells, with peak frequency range being from 10.0 to 15.0 m/s, that is, 36 to 48 km/h. The highest value of moving speed is 25m/s, corresponding to 90km/h.

5. Organization Modes of China's Supercell Storms

As in the United States, the organization modes of the supercells in China can be divided into three categories (Smith et al., 2012): 1) discrete cells, 2) cell in clusters, and 3) cell in quasi-linear convective systems (QLCSs).

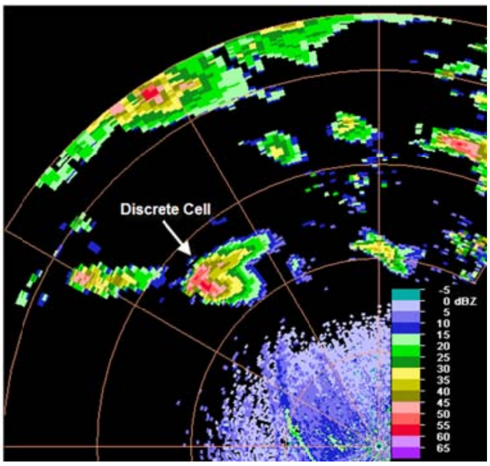

Figure13 0.5° elevation reflectivity at 15:06 on 31 May 2005 from the S-band Doppler weather radar (WSR-98D) located in Tianjin.

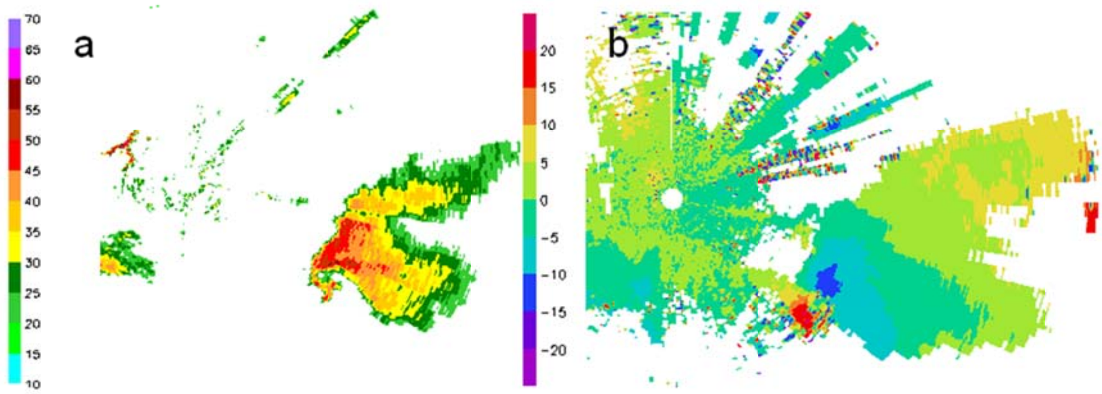

Figure 14 2.4° elevation reflectivity and radial velocity at 15:10 on 31 May 2005 from the C-band Doppler weather radar located in Beijing.

An example of the discrete supercells is displayed in Figure 13, the supercell is isolated from other convective storms, located in south-eastern Beijing . The more clear reflectivity and radial velocity images of this isolated supercell are shown in Figure 14, the hook echo, mesocyclone and even BWER are evident for this classic supercell (Moller, 1994). It produced the most severe hail in Beijing urban area in 20 years, the maximum hail size was 60mm.

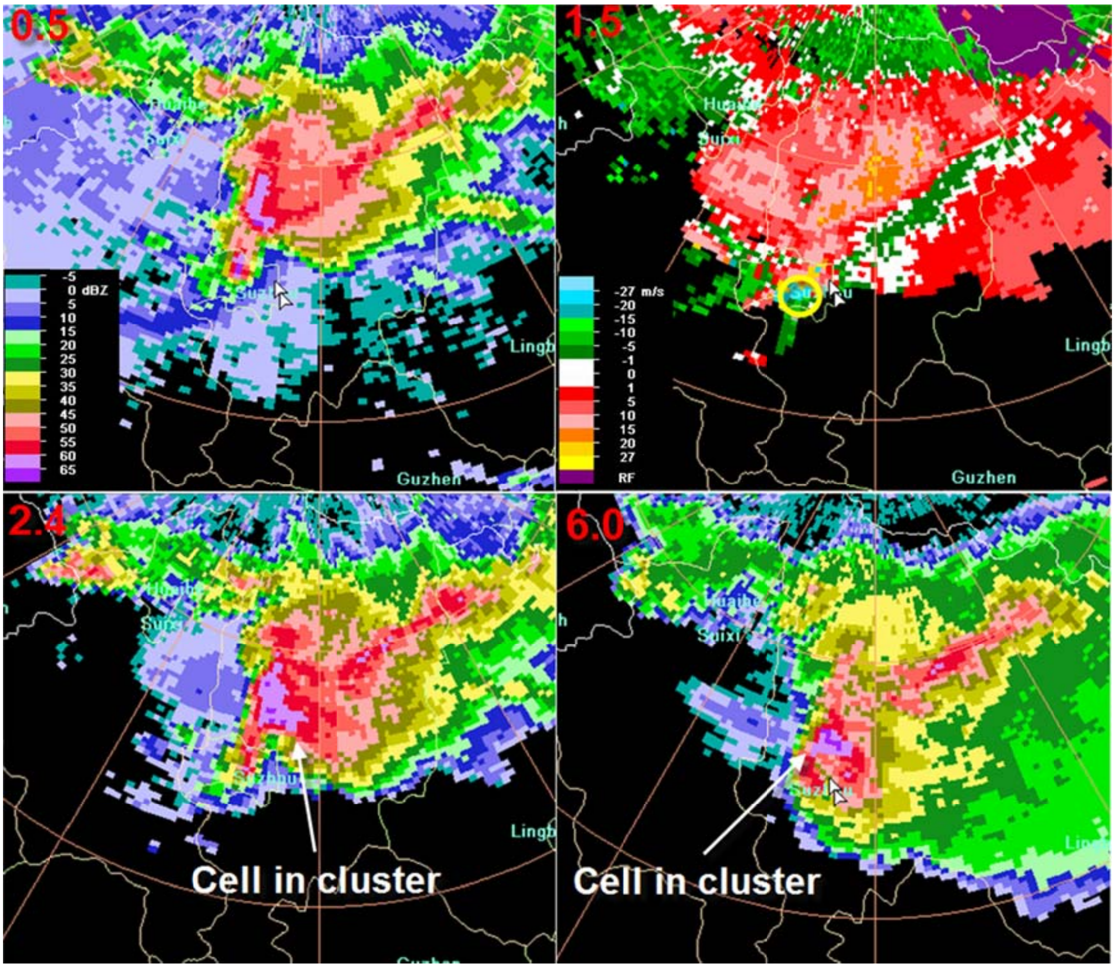

Figure 15 0.5°, 2.4°, 6.0°elevation reflectivity and 1.5°elevation radial velocity images at 23:52 BST on 14 June 2005 from the Xuzhou S-band Doppler weather radar (WSR-98D).

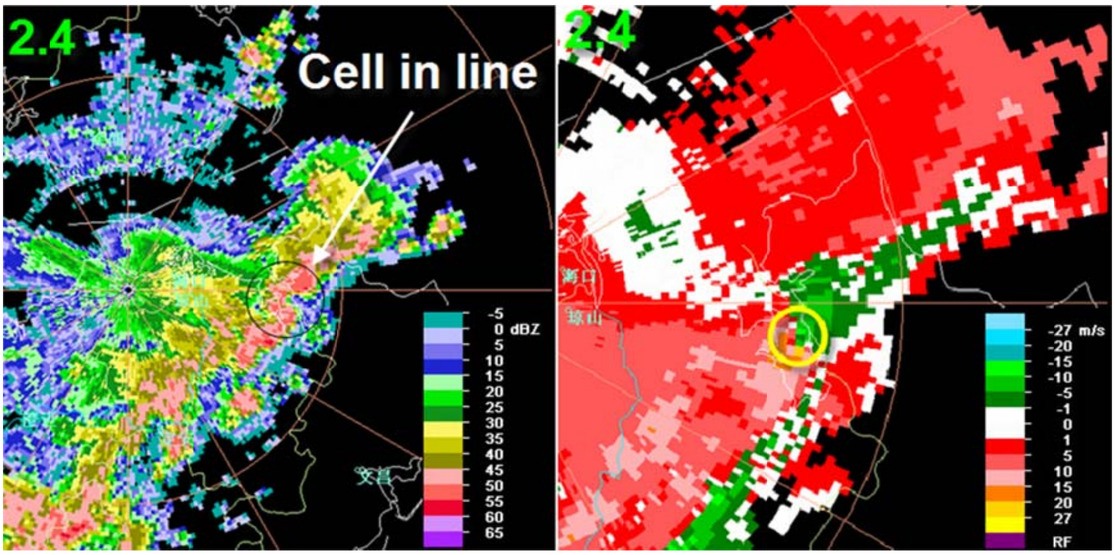

Figure 16 2.4°elevation reflectivity and radial velocity images at 16:35 BST on 29 May 2008 from the Haikou S-band Doppler weather radar (WSR-98D). The scale and image center position are different between the reflectivity and velocity images.

One example of the supercell embedded in the cluster of convective stroms is given in Figure 15. The supercell event occurred around mid-night on 14 June 2005 in Anhui province, it produced 120mm size hail and damaging wind. The figure shows the supercell constitutes the front part of a cluster of convective storms, with a mesocyclone of moderate strength, inflow notch, arc shape outflow boundary and BWERs, as well as three body scattering spike and side lobe echoes due to the large hail in the supercell.

Figure 16 shows an example of supercell embedded in a squall line in Hainan Island, the south end of Chinese continent, occurring in the afternoon on 29 May 2008. It looks like a HP supercell with a front inflow notch and a mesocyclone of moderate strength, having produced a F1 tornado.

Similar to the situation in the United States (Doswell 2001), nearly 100% of the convective storms that produced 50 mm or larger hail and significant tornadoes (F2 or above) are supercell storms. The peak frequency for significant tornadoes occurs in July, most of them were produced by the supercells in cluster or supercells in QLCSs, usually accompanied by flash heavy rain (30mm or greater for one hour). The discrete supercells produce large hail, straight line damaging wind, and occasionally tornadoes.

6. Summary and Conclusion

Based on the Doppler weather radar data, More than 200 supercell events in China were identified during eight-year period from 2002 to 2009. Their spatial distribution, seasonal and diurnal variations are given. Using routine sounding and surface observational data, several important parameters representing the major features of the environment in which these supercells occurred were investigated. And based on the Doppler weather radar data, the characteristics of supercells were studied. The following conclusion are obtained.

1) Most of the supercell events occurred in eastern, central, southern and north-eastern China; The great majority of supercells occurring from April to August and no supercell has been identified in January and February; The supecell events occur the most frequently from 14:00 to 21:00 local time, with peak value during the period 15:00 to 16:00 local time. The lowest frequency time period for supercell occurrence is between 00:00 to 12:00 local time; For eastern, central and southern China, the frequency of the supercell events is on the order of 2.0 to 3.0 events per 10^5 square kilometers per year.

2) Most of the supercell events occurred in an environment with the CAPE between 500 to 3000 J/kg and 0-6 km wind vector difference between 10 to 30m/s. The value ranges corresponding to the peak frequencies for both the CAPE and the 0-6km wind vector difference distributions are from 1000 to 2500J/kg and from 15m/s to 25m/s, respectively.

3) For over 85% supercells, their mesocyclones rotation speed is between 15 to 25 m/s, with extreme value as high as 35m/s; The majority of mesocyclones diameter is between 4 to 7km, with minimum, average, and maximum value being 2.0, 6.2 and 14.5 km, respectively; Correspondingly, the vertical vorticity for the great majority of

mesocyclones is between 0.5 to 2.5×10^{-2} s^{-1} , with maximum value over 4.0×10^{-2} s^{-1} .

4) The great majority of supercell storms have a life span of 30 to 130 minutes, with several peak frequencies being 40 to 50 minutes, 70 to 80 minutes and 90 to 100 minutes, the longest supercell duration among the 224 supercell events is nearly 3.5 hours; The most of supercells have a maximum reflectivity of 55 to 75 dBz, with peak frequency range from 65 to 70dBz; About 63% of supercell storms display the BWER structure and 37% of supercells have not shown clear BWER; The moving speed is between 5.0 to 20.0 m/s for the great majority of supercells, with peak frequency range being from 10.0 to 15.0 m/s, that is, 36 to 48 km/h; The highest value of moving speed is 25m/s, corresponding to 90km/h.

5) As in the United States, the organization modes of the supercells in China can be divided into three categories: 1) discrete cells, 2) cell in clusters, and 3) cell in quasi-linear convective systems (QLCSs); Similar to the situation in the United States, nearly 100% of the convective storms that produced 50 mm or larger hail and significant tornadoes (F2 or above) are supercell storms; The peak frequency for significant tornadoes occurs in July, most of them were produced by the supercells in cluster or supercells in QLCSs, usually accompanied by flash heavy rain (30mm or greater for one hour). The discrete supercells produce large hail, straight line damaging wind, and occasionally tornadoes.

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