A case study of bow echo storm using WSR-98D data

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1 Introduction

A typical bow echo occurred in Shandong province, China, on 12 July 2005. In the first hour of the case, due to the cold air flow at mid-high level, the storm developed strongly and hail disaster occurred in GAOTANG and YUCHENG county. Thereafter the bow echo formed and moved in ESE direction with damage wind in JINAN, TAIAN, LAIWU, YIYUAN county, because of the down draft of the cold air on the back of the storm. Before the bow echo reached to LAIWU, a mini supercell developed in LAIWU plain and hail spawned because of special terrain. When the bow echo moved to LAIWU county, the supercell merged into bow echo. When the bow echo approaching the supercell, the intensity of both the storm weakened, due to the opposite direction of air flow at low level. After the combination, the storm developed and the hail disaster occurred again.

2 Synoptic Analysis

A cold vortex was located over the northeast China at 0000 UTC July 12, A trough lie from the vortex extended southwestward to HEBEI province, Shandong Province is located in the south of the trough. Afterward the trough turned with the vortex anticlockwise. When the trough turned, the storm developed.

Two cells of cumulus occurred over the boundary of Shanxi and Hebei province 0000 UTC, then they move southeastward, and several cells developed, reached Gaotang, Yucheng near the boundary of Hebei and Shandong province 0230UTC, the max reflectivity factor attains 62 dbzs. The echo top reach 13km, hail occurred about walnut size at 0330-0400UTC.

After 0400UTC the cells became into the alignment like a arc, the bow echo formed. Then the front of the bow echo became tidy and the middle of the bow echo protruded. When the bow echo passed along, the max wind reached to 18.3 m/s at JINAN CITY 0500 UTC, 18.3 m/s at LAIWU 0530 UTC, 29.2 m/s at YIYUAN 0630UTC, After 0700 UTC, the bow echo expand southward and northward at both end, wind velocity and echo reduced gradually. The bow echo change into stratiform gradually.

3 Hail fall on XINZAI village in YUCHENG county

Figure 1 The 0.5° reflectivity image from the Jinan radar of echo A, B, at 0314 UTC 12 July 2005.

There were several convective cells moved to GAOTANG and YUCHENG in the morning, then they merged each other into two large echo A and B in fig.1 at 0300UTC, hereafter the echo B developed rapidly, hailstone walnut size fell to ground 0330-0400UTC.
Based on analysis of radial mean velocity, the reason of cell B developed and hail occurrence is due to the cold air injection at about 5km level. Figure 2 is time series the velocity cross section (VCS) of echo A and B. The white line is the position of VCS, the time of b-f is 0332, 0338, 0344, 0350, 0356UTC respectively. It can be seen that there is a jet of strong wind from northwest to southeast. In the jet the maximum wind behind echo B, correspond to the rear of velocity bear. In Fig c, d, e, f, where the arrow F pointed to the velocity reached 50m/s. The strong wind jet reach the maximum at 0344UTC. In Figure 3, the northweshe wind appear at 5km level at 0438UTC. Then the axis of the northwest wind decent continuously, fell to 2.5km at 0509UTC. The maximum wind at 5km level is 20m/s. In Fig.3 the wind speed out of the jet is also about 20m/s. The time that strong middle level wind appeared is 1h later than Gaotang. It is approximate to the time that storm moved from Gaotang to radar station.

In the other hand speed up the rear of echo B made it caught the front of the echo, so that the echo B developed rapidly and the hail occurred.

4 The Formation of the bow echo.

The middle level cold air made echo B developed, the echo top reached 14km. The PPI echo formed like a arc protruding southward, this is the prelude to the bow echo. Then the heavy precipitation and hail fall draw the cold air down, formed the arc shaped out flow line, the echoes developed along the line rapidly, the bow echo formed. The speed of the storm movement speedup from 20km/h to 35km/h, the direction of the movement changed form southeast to ESE (Fig.4).

After the bow echo formed, the core of the intense reflectivity moved to the front of the echo band, stratiform formed behind the band. On the apex of the bow echo, the wind became more strong (Fujita, 1978), at 2km level reached 39m/s (Fig.5). The more to approaching the front of the bow echo, the lower the max strong wind core is. When the wind line passed by Jinan, Tai’an, Laiwu, the damage wind occurred: Jinan 18.3m/s at 0458UTC, Laiwu 22.4m/s at 0630UTC, Yiyuan 29.3 m/s at 0700UTC.
SuperCell and Hail in Laiwu city

Before the bow echo formed, there is a supercell storm developed in Laiwu. This supercell made serious damage of hail. The source of the supercell can be go back to 0130UTC. Before the echo A, B formed, a line of cumuli can be seen on PPI of radar. This line is weak, so that it is hard to be seen at radar when it moved eastward, but it is clear on the image of satellite FY2C(Fig.6). When the line moved to the plain of Tailai, the cell at the end of the north developed suddenly. According to (Biyuan Lin., 2002), because of the special terrain of mountain in middle Shandong, there is often a convergent vortex over Tailai plain. When the weak convective line meet the vortex, the supercell developed quickly.

When the supercell developed, it moved northeastward at the speed of 10 km/h. The bow echo on the west moves in ESE direction at about 40km/h. At 0600UTC the bow echo caught up the supercell. They merged together. During the procedure of merging. The echo became weak and the top low down for about 20min. Afterward the echo developed strongly again, the Top reached 15.5km. It made damage wind and hail in east of Laiwu and west of Yiyuan.

The weakening of the echo before the combination of bow echo and supercell can be seen in Fig.9. In Fig.9, a1 is refractivity PPI of $1.5^\circ$ at 0551UTC before combination, a2 show the RCS of a1, white line is the position of RCS, a3 is the PPI of mean velocity in $1.5^\circ$, a4 show the VCS, the white line in a3. Fig9b1-9b4, and Fig 9c1-9c4 just like Fig9a1-9a4, the time of Fig9b is 0603UTC corresponding to the combination, the time of 9c is 0621UTC, the combination is complete.

It can be seen in Fig.9 a4, b4, c4, when the bow echo approaching the supercell, the air flow between the two meso system are in opposite direction. It made the two convective cell weak so that the echo became spread around and two core became several core(b2). But when the two system combination is complete, the air flow became organized, and the echo enhanced again(c2). The hail and damage wind occurred again.

6 summary

The storm developed in Gaotang and Yucheng and hail occurrence is due to the cold air injection at about 5km level behind the storm.

After the storm developed strongly, heavy precipitation and hail fall drew the cold air down, formed the out flow line. The bow echo formed along the line. When the bow echo formed and moved forward, damage wind occurred in Jinan, Tai’an, Laiwu.
The supercell storm developed in Laiwu. made serious damage of hail. During the combination of bow echo and supercell, the echo became weak and spread around for about 20min. After the combination is completed, the echo developed strongly, the damage wind and hail occurred again.

References
Fujita, T.T., 1978: Manual of downburst identification for project NIMROD.