

# ANALYSIS ON THE PRECIPITATION ENHANCEMENT POTENTIAL AREA OF CYCLONE

Yilin Wang

Shangdong Research Institute of meteorology , Jinan, P.R.China, 250031,

Email: qxwyl@sohu.com

Potential area is the main problem in precipitation enhancement operation. In foreign countries, various atmosphere-detecting apparatus are adopted to detect the precipitation enhancement potential area before it is operated. In China, the use of radar, particle measuring system (PMS), radiosonde, etc. plays a vital role in detecting the potential area and making commands before the precipitation enhancement operation. It is our contention that the ice crystal should primarily be at the state of ice-saturation ( $e-E_{ice}>0$ ) and there must be sufficient supply of vapor to increase the condensation or deposition of the ice crystal, according to which potential areas are judged. Based on most statistic analyses, we believe that the precipitation enhancement potential area in cold clouds must have three conditions, namely, the ice-saturation area, the area in which vapor integral below  $0^{\circ}\text{C}$  is greater than 9mm and vertical transportation of water vapor. Analyses on potential area of cyclone are conducted as follows.

## 1. SYNOPTIC SITUATION

From March 3 to March 4 in 2007, a cyclonic weather process influences Shandong Province. At 8:00(Beijing time) on March 3, the foreside of the cyclone influences the province and it starts to rain. At 2:00 on March 4, it advances to the Yellow Sea. After 8:00 on March 4, the raining area recedes out of Shandong

Province and the raining process ends.

## 2. ANALYSIS ON THE POTENTIAL AREA

### 2.1 The Ice-saturation Area

According to the ice-water transformation theory, in order to get the ice crystal to grow, seeding with silver iodide requires that the cold cloud achieves the ice-saturation state. Therefore, the existence of the ice-saturation area is the first condition of the existence of the potential area. Adopting the MM5 model, forecasting figures of the ice-saturation area are drawn every  $5^{\circ}\text{C}$  during the level of  $0-30^{\circ}\text{C}$ . Figure 1 shows the changes of the ice-saturation area at the level of  $-10^{\circ}\text{C}$  from 5:00 on March 3, 2007 to 8:00 on March 4, 2007. It is seen from Figure 1 that at 5:00 on March 3, 2007 the ice-saturation area (shadow area in Figure 1) is located in the western periphery of Shandong Province and at 8:00 on March 3, 2007, it goes into its western area and expands to the eastern area, then it advances into its eastern area at 8:00. on March 4, 2007. From 8:00 on March 3, 2007 to 8:00 on March 4, 2007, the cloud at the level of  $-10^{\circ}\text{C}$  above Shandong Province is at the ice-saturation state from west to east, which is fit for the growth of ice crystal and fulfils the first condition of the precipitation enhancement potential area.

### 2.2 Vapor Integral below $0^{\circ}\text{C}$ (W)

It is pointed out in the numerical simulation that the introduction of ice crystal will convert some of the super ice-saturated vapor into rain. Vapor plays an important

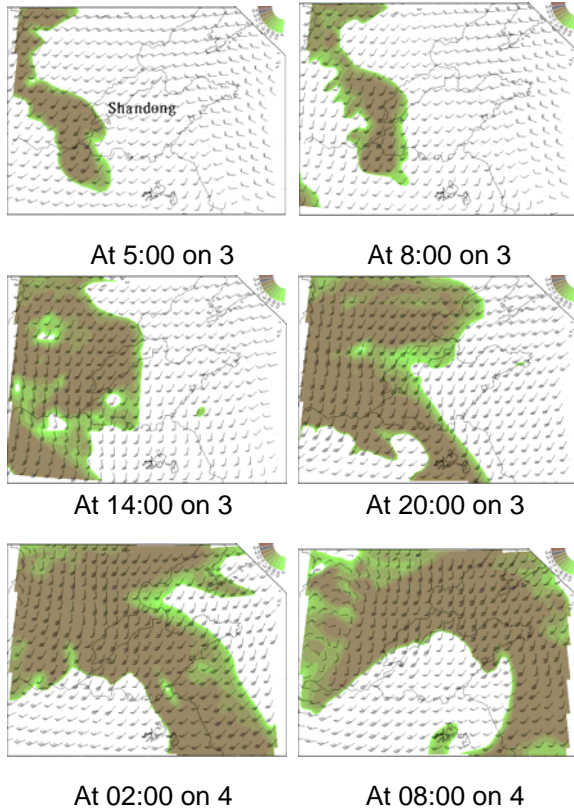


Fig.1 Distribution ice-saturation (shaded areas)on  $-10^{\circ}\text{C}$  from 5:00 on 3 to 8:00 on 4 March 2007

role in the Bergeron theory. The growth speed of the ice crystal in cold clouds is directly related to the amount of vapor in its environment. As a result, the amount of vapor in cold clouds, in a sense, reflects the enhancement potential of the clouds. Statistics show that in cold cloud raining, the vapor integral amount between  $0^{\circ}\text{C}$ – $-30^{\circ}\text{C}$  (W) is closely related to rainfall on the ground. W increases rapidly before raining and decreases rapidly after it. When W attains 9mm, it is preferable for precipitation enhancement operation. Thus, that W is greater than 9mm becomes the second condition of the potential area. Figure 2 indicates the distribution of W at the level of  $-10^{\circ}\text{C}$  from 5:00 on March 3, 2007 to 8:00 on March 4, 2007. At 5:00 on March 3, 2007, the area where the W is 9mm (shadow area of the graph) is located in the west of

Shandong Province and expands from west to east. At 8:00 on March 4, 2007, the area is located in the east of Shandong Province and recedes out of it thereafter (The figure is omitted.). From 5:00 on March 3, 2007 to 8:00 on March 4, 2007, the area of Shandong Province fulfils the second

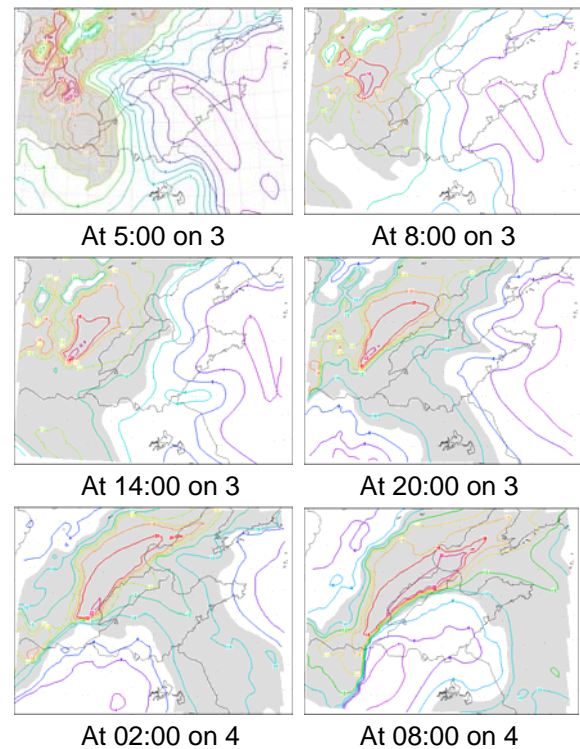


Fig.2 Distribution integral vapor value below  $0^{\circ}\text{C}$  from 5:00 on 3 to 8:00 on 4 March 2007(vapor integral value in shaded areas is bigger than 9mm.)

condition of the precipitation enhancement potential area from west to east.

### 2.3 Vertical Transportation of Water Vapor

As is known to all, in every raining process, the amount of static vapor in the atmosphere is far lower than that of the rainfall and the raining process requires consecutive supplies of vapor. The transportation of vapor in the potential area will increase the density of vapor and fulfils the vapor condition for the growth of ice crystal and water drops through condensation and deposition. In order to get

sufficient vapor in the potential area, a great amount of vapor should be transported upward through the level of  $0^{\circ}\text{C}$  to make the ice crystal and water drops grow. In the mid-lower part of the atmosphere, vapor decreases from downside to upside. The vertical transportation of water vapor is indicated by the multiplication of relative humidity and ascending speed, which is the third condition of the potential area. Figure 3 is the distribution of the area of vertical transportation of water vapor from 5:00 on March 3, 2007 to 8:00 on March 4, 2007 at

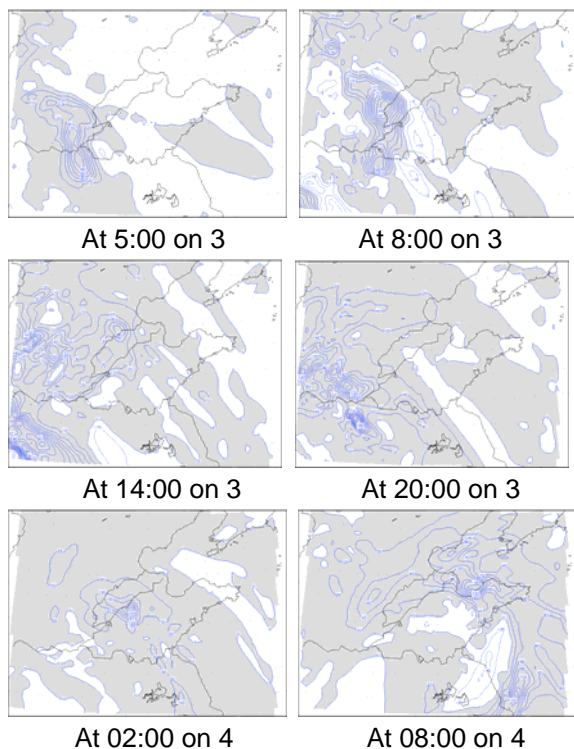


Fig.3 Distribution vertical water vapour transportation from 5:00 on 3 to 8:00 on 4 March 2007(water vapour in shades areas was transported upwards)

the level of  $-10^{\circ}\text{C}$  (The shadow area indicates the area of vertical transportation of water vapor.). At 5:00 on March 3, 2007, the area advances into Shandong Province and expands from west to east. From 5:00 on March 3, 2007 to 8:00 on March 4, 2007, the area of Shandong Province fulfils the

third condition of the precipitation enhancement potential area from west to east.

### 3. APPLICATION OF THE CONDITIONS

#### 3.1 Area and Time of Precipitation Enhancement Operation

The area that fulfils the above three conditions is the preferable area for precipitation enhancement. As is seen from Figure 1 to Figure 3, from 5:00 on March 3, 2007 to 5:00 on March 4, 2007, the area of Shandong Province fulfils the conditions of the potential area from west to east. Therefore, in Shandong, precipitation enhancement should be operated in potential area from west to east.

#### 3.2 Height of Precipitation Enhancement Operation

The area that fulfils the equation of  $T - T_d \leq 2^{\circ}\text{C}$  is the quasi-saturation area. The vertical distribution of the quasi-saturation area helps to locate the vertical scope of the cloud area. Thick quasi-saturation areas provide a fine environment for the growth of rain particles, while lower height of the bottom of clouds decrease the evaporation of raindrops which drop out of clouds. Figure 4 is a vertical section graph of the quasi-saturation area and ice-saturation area at 17:00 on March 3 at  $36^{\circ}30'\text{N}$ . As is seen from figure 4 (on the left), the quasi-saturation area extends to the ground. From the grounds of the western area of Shandong Province to level  $-15^{\circ}\text{C}$  is the quasi-saturation area, which provides a fine environment for the growth of rain particles. In choosing the height of the operation, it should be taken into consideration of the temperature at which the silver iodide forms nucleus and the height to which the apparatus is capable of conveying. As is seen from Figure 4 (on the right), at 17:00 on

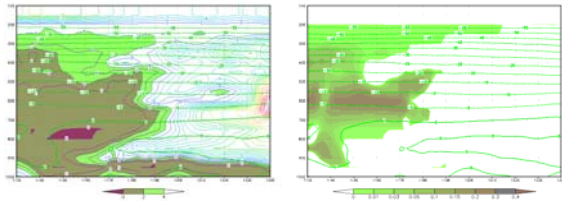


Fig.4 Cross-section along 36°30'N, quasi-saturation (shaded areas) (left) , ice-saturation (shaded areas) (right), at 17:00 on 3 March 2007

March 3, the west of Shandong Province at the level of 0--15°C is at the state of ice-saturation (Shandong Province is roughly located at 115--123°E). There is a center of the ice-saturation area which exceeds 0.15pa at the level of -5--10°C. As is seen from Figure 1 to Figure 4, the best height of enhancement operation is at the level of -5°C in the west of Shandong Province.

### 3.3 Cloud water and rain water

Super-cooled water is the main condition of the precipitation enhancement area. The amount of water contained in cold clouds directly reflects the potential of precipitation enhancement. Figure 5 (on the left) demonstrates the vertical distribution of cloud water at 36°30'N at 17:00 on March 3.

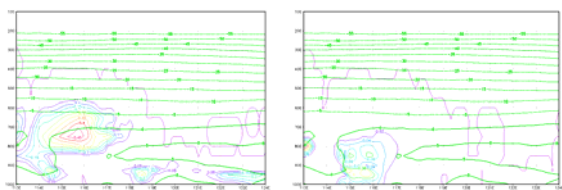


Fig.6 Cross-section along 36°30'N, cloud-water (left), rainfall-water (right) at 17:00 on 3 March 2007

It shows that the maximum area of cloud

water lies above the west of Shandong Province and there is a center of cloud water at the 0--10°C level. Seen from the distribution of rainfall (Figure 5 on the right), the rain has reached the ground at 17:00, which means it is raining. Besides, the center is situated in the west of Shandong Province, which provides a good opportunity for precipitation enhancement.

## 4. OPERATION OF PRECIPITATION ENHANCEMENT

According to the distribution of the potential areas, 70 rockets and 18 Guns in 14 regions of Shandong Province conducted precipitation enhancement from 8:00 on March 3 to 5:00 on March 4, 2007 and fine results are achieved. It also proves that this cyclonic weather process has great potential of precipitation enhancement in Shandong Province.

## 5. CONCLUSIONS

(1) Under the synoptic situation which facilitate precipitation enhancement, it is preferable to conduct the process when the potential area fulfils the three conditions of the ice-saturation area, the area in which vapor integral below 0°C is greater than 9mm and vertical transportation of water vapor.

(2) The height of operation should be chosen at the ice-saturation area, the area of vertical transportation of water vapor and the quasi-saturation area. It should be taken into consideration of the temperature at which the silver iodide forms nucleus and the height to which the apparatus is capable of conveying.