1. INTRODUCTION
Cloud seeding activities for convection cloud by rain enhancement using cannon are carried out in Weining, the western area of Guizhou province of China. In the convection area the hailstone affects the agrarian production seriously, and causes substantial damages to agriculture every year. One of the main characteristics of the zone is that the convection clouds are those which originate after the noon; it is relatively easy to find that the reflectivity measured by the radar reach values of over 30 dbz. The purpose of convection cloud by rain enhancement is to affect the micro-physical structure of convection cloud by inducing artificial freezing nuclei to the clouds. The principle of convection cloud by rain enhancement by seeding is to produce a large of ice crystals by inducing artificial freezing nuclei to the supercooled clouds to consume supercooled water, so hail growth is restrained because of no enough water. According to this principle, some numerical simulations for supercooled cloud seeding are done. It is very important to study mechanisms of convection cloud by rain enhancement by seeding using the three-dimensional model of convection cloud because convection clouds have three-dimensional structure. Especially in China, convection cloud by rain enhancement work is blind and has no objective criterion on selecting seeding methods. In this paper, using the three-dimensional fully elastic numerical model of convection cloud developed by Institute of Atmospheric Physics (IAP), a convection cloud occurred in Guizhou province, is simulated seeding by AgI and no seeding for this convection. This study can supply optimal seeding scheme, it is beneficial to development of convection cloud by rain enhancement.

2. MODEL
The model contains more detail bulk-water parameterized microphysics, including forty-six warm and ice phase micro-physical processes such as condensation (sublimation), collection, nucleation, multiplication, melting, melting-evaporation and auto-conversion. The model contains vapor, cloud water, rain, cloud ice, snow, graupel and hail. The simulation area moves with the simulation convection cloud simultaneously to enable the convection cloud located in the central area of the simulation area. The time-splitting numerical integral technique is adopted to improve computation efficiency of fully elastic model. The model contains eighteen equations which predict motion field, atmospheric pressure, temperature, mixing ratios (vapor, cloud water, rain, cloud ice, snow, graupel, hail and AgI particles), concentrations of rain and ice phase particles. The standard spatially staggered mesh system is used in the model where three components of velocity are located in normal boundary center of mesh unit and others in the center of mesh unit. Radiation lateral and rigid top boundary conditions are adopted and sponge zone is added in the top boundary to restrain vertical fluctuation of internal gravity wave. The influence of underlying surface ignored, the value of turbulent exchange item is assumed to zero. The model uses the fourth order difference scheme for advection terms and second order leapfrog scheme for time terms and other space terms. The formation mode of initial convection includes thermodynamic disturbance and humidity disturbance et. al. The mechanisms by which AgI can produce the ice phase are as follows: 1) Deposition nucleation: by converting vapor to solid at ice supersaturation. 2) Contact freezing nucleation (including immersion freezing nucleation): by converting cloud water and rain to cloud ice and graupel.

3. NUMERICAL STUDY
The numerical study of convection cloud by rain enhancement by AgI shows that the principle of hail formation and growth conforms to the theory of accumulation zone. The basic theory of convection cloud by rain enhancement by
seeding is “competitive principle”. A series of seeding experiments are done to seek optimal seeding methods.

3.1 SIMULATION OF CONVECTION CLOUD

The seeding and natural (no seeding) experiment is a simulation of moist convection initiated by a warm, moist bubble. The integration domain is 40 km in both horizontal directions and 14.0 km in vertical, with grid intervals \( \triangle x = \triangle y = 1000 \text{m} \) and \( \triangle z = 500 \text{m} \). The sounding data is used as the initial fields of temperature, moisture and velocity. To initiate disturbance, a warm moist bubble is inserted in the center of the domain at a height of 2 km. The initial impulse is 10 km wide and 4 km deep, with a maximum disturbance temperature of 4.5°C. Fig.1 (omitted) shows Vertical cross section of total water content in natural simulation through the center of convection at \( t = 2, 4, 8, 12, 16, 20, 28, 48 \text{ min} \). The convection derived from simulation is similar to that measured by radar (radar map omitted). From Fig.1, it can be seen that the center of water content of convection is located 2 km high at two minutes from the beginning of the developing convection and it is becoming higher with the developing convection. Seven minutes later, it is 3 km high, ten minutes, 4 km. Then sixteen minutes later, the convection becomes weaker. In addition, during the period of convection developing, the total water content is always located in the maximum updraft area. In simulation, the top of convection reach 14.0 km high, the body of convection leans southwest, rain begin on surface at thirteen minutes, the total rainfall on surface is 956.48 ton.

3.2 SIMULATION OF CONVECTION CLOUD BY RAIN ENHANCEMENT

On the basis of the simulation of convection on 20, May, 2007, A series of experiments simulated seeding by AgI for this convection has been done. In this paper, the seeding effect \( (E) \) is defined by the percentage of decreasing of rainfall on surface. The simulation of convection cloud by rain enhancement are shown in Fig.2 (omitted), from which it can be seen the seeding effect at second minute at height 2 km, 3 km, 4 km, 5 km and 6 km separately (shadow area denotes \( E > 8\% \)). Shown as Fig 2, seeding activities with different height, or different site, or different amount of agents can all get the effect more than 50%. For the same seeding agents, the shadow area increases with height from 2 km to 4 km, while decreases from 4 km to 6 km. But it is possible for the total rainfall to increase at height 6 km. The shadow area extends to southwest, it has the consistency with the convection southwest leaning. At the same height, the shadow area by 300g AgI seeding is larger than that by 50g. The convection cloud by rain enhancement can be taken with the best effect of 16%.

\[
\begin{align*}
\text{AgI} & \quad TQ \uparrow \quad TQ \uparrow \quad TNCL \uparrow \quad TNCL \uparrow \quad TQ \uparrow \quad TQ \uparrow \quad TNCL \uparrow \quad TNCL \uparrow \quad P_{托} \downarrow \quad P_{托} \downarrow \quad TQ \uparrow \quad TQ \uparrow \\
5.5\% & \quad 36\% & \quad 42\% & \quad 7\% & \quad 49\% & \quad 31\% & \quad 12\% & \quad 52\% & \quad 29\% \quad \Rightarrow E \quad 16\% 
\end{align*}
\]

This formula indicates that:

1) Because of seeding by AgI for the convection cloud, in the 21 minute, the quantity and the quality of ice in the simulation cloud have a little change. The ice changes to graupel become more and more weak and to snow become more and more strong.

2) The number of the snow is increasing, and the quality of the snow is decreasing.

3) The number of the graupel increase obviously, and its quality have a little change. The collision of the super-cooled water with ice and the super-cooled water with the snow is more than the ice and the snow change to graupel; this is the reason of the increasing quantity and quality of the graupel.

4) By the reason of the quantity increasing more than the quality increasing of the graupel, the graupel change to hail is weak, so the rainfall on surface is increasing.

4. CONCLUSION

The simulation results of convection cloud by AgI seeding with cannon are as follows: The simulation results of rain enhancement by AgI seeding are as follows: the optimal seeding position is located at 3-5 km height in the updraft area and the optimal seeding time is made at 2-6 minutes before an intense echo centre formation. Other things being equal, rain enhancement ratio increases with seeding amount of AgI. This study can supply optimal seeding strategy of rain enhancement.
FIG. 1. Vertical cross section of total water content in natural simulation through the center of hail cloud at t=2, 4, 8, 12, 16, 20, 28, 48 min
Fig. 2 simulation of hail suppression by AgI seeding at two minutes (different height, different location and different amount of seeding agents, 300g in maps of left column, 50g in right, shadow area denotes E>8%)