P1.2 PROBING INTO THE HAIL FORMATION MECHANISM ON THE NORTHEASTERN BORDER OF QINGHAI-XIZANG PLATEAU AND ITS NEIGHBORHOOD

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1 INTRODUCTION

Hail formation and growth is a complex problem. Langmuir (1948) and Schaefer (1953) were seeding smashed dry ice in super-cooled cloud , the hole was appeared in the cloud, and snow was falling, which is an index of modern weather modification . From that time on , a series of precipitation modification and hail prevention projects were put in practice all over the world (List, 2004).Through a series of field observational studies, theoretical (laboratory) studies and numerical modeling studies, many conceptual models were set up as the base of operation on hail suppression (Klemp et al.1987;Heymsfield 1980).But these hypotheses have theirs limitation, such as "beneficial competition" is for growth-limiting competition among hail embryos, issued in "WMO statement on the status of weather modification" .This hypothesis was based on G.K.Sulakvelidze's (the former Soviet Russia, Georgia) "accumulation zone of super-cooled rainwater in the hailstorm" theory (G.K.Sulakvelidze 1967) i.e.,that the maximal vertical velocity decreasing area is accumulation zone of super-cooled rainwater in the hailstorm, once the temperature is between 0～－25℃,the hail will be forming. Here is the source of hail. However , the numerous hail slices show that there are many layers and bubbles in the hailstone , which means that hail formation and growth goes through different environment .And there are many other questions (Xu Huanbin et al.,2000). Xu huanbin et al issued a "cave channels "theory, a new hail formation and growth theory(Duan Ying and Liu Jingbo,1998, Wang Siwei and Xu Huanbing,1989,Xu Huanbin,et al, 1988,2001,2002) , combining a two –dimension hail cloud model with large hail moving trajectory and growth model Which answers many questions about the former hail suppression hypotheses, the main conclusions as following:(1) Due to the strong convective airflow of hailstorm there must be a core of main-updraft (MUD) and an area by the core of MUD in which the horizontal wind-speed relative to hailstorm equals zero. In the vertical section, there is a zero-line from the edge to core of MUD. Below this line wind blows towards the core, and upon this line wind blows away. The growth-travel trajectories of cloud particles are rotating by this line and can enter the core of MUD circle by circle while forming hailstones. (2) In hailstorm there is a "cave channel"(CC), whose location is close to the core of MUD and below the zero area. Its volume is about 6% or even smaller of total of hailstorms. The region of embryo formation is in the entrance-end of CC, and the region of hail formation is in the exit-end of CC close to or in the core. Once the particle enters CC, it cannot escape the attraction of CC, just like a trap, until it becomes large stone and falls down from exit-end. As long as the artificial particles are seeded in CC and their trajectores may cross with natural ones, the "beneficial competition" between the natural and the artificial embryos can be realized equally. (3) The existence of CC and its location depend on the airflow, and the rate of hailstone's growth and the length of trajectories depend on the field of super-cold hydrometeor. The real time observation dada support this idea(Tian Liqing,Xu Huanbin and Wang Angsheng,2005).In this paper , using a 3D cloud model with hail-bin microphysics developed by Institute of Atmospheric Physics, Chinese Academy of Sciences(Xueliang Guo ,Meiyuan Huang ,2002) , the hail formation and growth mechanism in each bin of hail from large to ice crystal scale is studied for probing into hail suppression principle further , and therefore providing a theory for hail suppression operations in northwest part of China.

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Fig.1 The radar RHI at 16：21：35,8,July,2003 (BJT) on Yongdeng,Gansu,China

Fig.2 Comparing the real time probing with that of model output at 08 O'clock ,08July2003 (BJT) on Minqing, Gansu, China

Top: the real time soundings data at 08 O'clock,8,July,2003(BJT) at Minqing station. y-axis：hPa，abscissa：temperature（℃）and velocity（m/s） the dot line is dewdrop temperature and radial wind separately, real line is temperature and latitudinal wind.

Bottom: MM5V3 output, others like top.

2 SIMULATION AND ANALYSIS

4.1 The General Situation

The temporal distribution of the maximal special water content in various hydrometeors as figure 4. The temporal distribution of the hail(rain) fall intensity and the accumulative fall hail(rain) as figure 5. The simulation results showed on the hail disaster fact .

Fig.4 The temporal distribution of each hydrometeors maximal special water content , as hail/graupel(qgmax), cloud(qcmax),rain(qrmax),ice(qimax)and snow(qsmax) , unit:k/kg ,abscissa is time ,unit :minutes

Fig.5 The temporal distribution of the fall hail(rain) intensity (unit : mm/hr) and the temporal distribution of the accumulative fall hail(rain) (unit : mm) at surface ,where the dot curve is for hail/graupel, another is for rain.

We can infer that t he whole process can be divided into 2 phases , before 32 min for developing and then dissipating . Then the space distribution of each hydrometeors was showed as following .

4.2 The Water Species Evolvement

It is true that hail formation and growth need the proper dynamical and heat conditions . Now it was the velocity and each water species scheme when the cloud was changing , as figure 6.

The water resource was profusion in cloud for cloud water at 2 min ,rain at 10 min ,and ice crystal at 20 min over -20 ℃, meanwhile rain was falling to ground . The air flow was updraft in the center of cloud , but there were two hypo-circulation beside the center updraft until 26 min when the hail/graupel and snow appeared near 0℃ level , below the maximal updraft level ,where many micro-physical processes involved in rain and snow occurred easily to form hail , at the same time over the maximal updraft level the maxim ice crystal content center was in 10km level at temperature -40℃, where many micro-physical processes involved in ice crystal occurred easily to form hail ,and also natural seeding became true . At 30 min as rain ,hail ,snow falling ,in 0℃ level (5 km height) there was a circle downdraft area, which persisted in 6 min and very well fitted to the maxim hail/graupel content. The proper dynamical conditions was the necessary to hail formation and growth , which provided enough time to take place

Fig.6 Left: the vertical velocity(unit: m/s) .right: the special water content of various hydrometeors (unit: g/kg) and speed cross X－Z transect at y＝17km at 26,30 and 40 minutes form top to bottom , where blue solid is hail/graupel, green longer dash is rain, yellow short dash is cloud, red short dash is snow, blue dot is ice.

Fig.7 The temporal distribution of the maximal updraft and downdraft (unit : m/s)

various micro-physical processes under the good water matter conditions and temperature conditions . Once the hail was big enough to leave cloud to ground , the downdraft reached on ground ,the hail fall was being .When the vertical velocity was the maxim , the downdraft reached the maxim almost at the same time ,as figure 7.This was another fact to show that the vertical velocity was an important factor to hail formation . From now on , as the velocity (updraft /downdraft)was smaller and smaller , the hailstorm was dissipating .

After inner downdraft formatting , the level (4.5 － 7km) of up and down velocity occurred on alternately was the center of the maximal hail/graupel special water content, so where was the center of latent releasing ,which induced a new convection on this level ,then updraft over this level and downdraft under it coexisted. The lifetime of hail cloud was delayed .

At the same time , it was remarkable that there was a inverse temperature level on the top of the cloud from 20 min to 90 min, which was the prime environment of Bergeron process.

4.3 The Time Evolvement Of Each Bin Hail Particle

In this model ,hail particle was divided into 4 bins : large hail (over 25 mm in diameter),classical hail (10< D <25mm).small hail （5mm<D<10mm）, graupel and hail embryo （1mm< D <5mm ）,small

ice crystal （D <1mm ）,and the microphysical processes related to hail were drop freezing due to homogeneous ice nucleation under -40 ℃ (HNUrg), hail from large frozen rain(GNUrg), hail from collisions between super-cooled rain and ice （FRrg ）, hail from heavy riming of snow （Rgaut）,hail from snow-rain collisions（CLrsg）, accretion of snow water by hail（Clsg）, accretion of rain water by hail （Clrg） ,accretion of cloud ice by hail (Clig) , accretion of cloud water by hail(Clcg) , melting of hail（Gmlgr） , Dep/Sub of vapor by hail(vdgv) , Cond/Evap of hail(GMVDgv) .

The dependence of the denary logarithm for each bin maximal hail density (unit:1/l) of time (unit:min) was showed as figure 8 .The small particle was large number , the large particle was small number , which was true in real time . The dependence of each logarithm value of microphysical processes conversion rate(g/g/s) of time (unit:min) was figure 9.

Fig.10 is the each bin hail particle water content(left : from top to bottom :left are small ice particles, graupel and embryos, small hailstones, typical hailstones and large hailstones) and 5 water hydrometeors (right: cloud, ice, snow, rain and hailstones) (unit: g/kg) cross X－Z transect at y ＝17km at 24 minutes, where the fine line with arrows is streamline and without arrows is vertical velocity(unit: m/s), environmental temperature (>0 ℃ middle coarse solid line, <0℃middle coarse spot line) and v-velocity zero line(coarse spot line), u-velocity zero line(coarse solid line). The air flow and temperature showed on symmetry almost, the center of the maximal vertical velocity and maximal temperature in cloud was identical . It was very notable that in the distribution of each hail bin , the former 3 bins hail particle had two high value regions, in the center of the maximal vertical velocity was the least classical hail water content and the large hail was around the center of the vertical velocity.

4.4 The Space Distribution Of Each Bin Hail Particle

Fig.8 The dependence of the denary logarithm for each bin maximal hail density (unit:1/l) of time (unit:min).

Fig.9 The dependence of each logarithm value of microphysical processes conversion rate(g/g/s) of time (unit:min)

Fig.10 The water content (unit: g/kg) cross X－Z transect at y＝17km at 24 minutes of 5 categories hail(left) and 5 hydrometeors(right) from top to bottom :left are small ice particles, graupel and embryos, small hailstones, typical hailstones and large hailstones, right are cloud, ice, snow, rain and hailstones, where the fine line with arrows is streamline and without is vertical velocity(unit: m/s), environmental temperature (>0℃ middle coarse solid line, <0℃middle coarse spot line) and v-velocity zero line(coarse spot line), u-velocity zero line(coarse solid line).

Fig.11 The vertical distribution of temperature(℃),vertical speed(m/s) and each logarithm value of microphysical processes conversion rate(g/g/s) in(18，18)point at 36 minutes，the symbol as text.

By the collocations of temperate, vertical velocity, horizontal wind speed zero lines and water hydrometeors , 5 bins hail particle and the each related microphysics, we can infer that the two high value centers of the former 3 hail bins had different physical mechanisms. The center at low was more effective on hail formation and growth for water hydrometeors movement feature in here . ”Cave channels ” was true .

Figure 11 includes same information as the vertical distribution of temperature(℃),vertical speed （m/s） and each logarithm value of microphysical processes conversion rate(g/g/s) in （18，18）point at 36 minutes , and also each bin hail species water content （g/g）. Compared fig.10 and fig.11 , we find that the high value center of the former 3 bins hail particle in the high level is corresponding to the extensive temperature -40~-5℃,where is the vertical velocity convection region too , hail from collisions between super-cooled rain and ice（FRrg）,accretion of snow water by hail（Clsg）,accretion of rain water by hail （Clrg） ,accretion of cloud ice by hail (Clig) , accretion of cloud water by hail(Clcg) etc. microphysical processes is here with abundant water vapor , ice . These are the cause of high value center in the high level . The high value center in the low level is crossing the temperature 0℃ level ,where is the maximal vertical velocity region too , here the main microphysical processes are hail from snow-rain collisions （CLrsg）,hail from collisions between super-cooled rain and ice(FRrg) , Dep/Sub of vapor by hail(vdgv) , Cond/Evap of hail (GMVDgv), melting of hail (Gmlgr). Here just is the classical hail and large hail region through the horizontal speed zero line .All these shows that there is a “cave channel ” in this region . The water hydrometeors are moving and growing into classical and large hail in this region .

At integral 36 min , we analysis each factor like at 24 min . The meaning of the figure 12 and 13 is the same as figure 10 and 11 respectively. Firstly , it is remarkable that the horizontal wind speed zero line is shifted . The ice particle （D <1mm ）is congregating in the horizontal convection and air flow updraft region , temperature range is 0 ~ -20℃, at 4-6.5 km, where the horizontal wind speed zero line can be found . Compared with the water

species , here is not abundantly the cloud water ,cloud ice but snow. Here the main microphysical processes are connected with snow . At 10 km height , -40℃ the ice and supper- cooled water coexist which is natural seeding source . It is the similar to graupel or hail embryo except for the center lower . To the small hail particle ,its maximal water content center is not in the middle of the cloud ,but in the side of the maximal downdraft . We think that it is related with its growth region . To classical and large hail , the water content center is more and more closer to the middle of the cloud . Obviously , in the hail fall process ,the melting of hail (Gmlgr) is the most physical process .

Fig.12 The same as Fig.10 except for at 36 minutes.

Fig.13 The same as Fig.11 except for at 36 minutes.

3 Conclusion and discuss

Firstly , the results show that the "accumulation zone of super-cooled rainwater " theory , proposed by G.K.Sulakvelidze only respond the hail depleting super-cooled cloud water , the other microphysical processes occurred in the hailstorm are not clarity. The "accumulation zone of super-cooled rainwater " appeared only at the former stage of hailstorm , and the maximal cloud water content is below 0℃ level where the many hail related microphysical processes take place. As hail and rain falling away cloud, the water content in cloud is reducing, the height of the maximal cloud water content is higher and higher, at last it occurs in the two besides of the maximal vertical velocity , where is the air flow in the middle of the cloud acclivitous convection to the center and the near of the zero horizontal speed line. Other water hydrometeors are not like these .

Secondly , the results supply the "cave channels " theory with different hail-bin particle formation and growth processes. Throughout the whole hailstorm life time , each bin of hail-bin has the different maximal value center . For ice crystal content , during the initial hail formation at the height of -20~-50 ℃ the vertical air flow decreasing area is its maximum. A s hail falling and rain falling , cloud water decreasing and vertical velocity weakening , its height is lower and lower , at last it joins the "cave channel " at lower height .The same as the graupel and hail embryo , except for the time of its joining the "cave channel " at lower level is more early then ice crystal 's . For small hail , during the initial hail formation there are two large content centers ,at high and low level . For classical hail and large hail , the most important center is "cave channel " . That is to say , the larger the hail particle is , the more well and truly the "cave channel " theory is , and as the hailstorm developing , the smaller hail particle content is more and more approaching "cave channel ". The results supply a gap of the former " cave channel " that only one particle moving in Lagrange manner and growth with various hail-bin growth and its related microphysics .

Lastly, during the dissipating period of the hailstorm there is all downdraft at "cave channel " ,but where is till the maximal water content center.

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