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Numerical Study of Thunderstorm Development in Seeded and Unseeded Case

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Abstract: By numerical cloud model we have calculated a change in hydrometeors distribution in the cloud for the day 29th June 1981 when in Belgrade existed favorable condition for hailstorm development. Two case have analyzed: a development of hailstorm in natural conditions (unseeded case) and in the case when artificial agent has injected in the cloud (seeded case). The seeding agent was silver-iodide and silver-chlorate mixture (AgJ-AgCl).

From the results of this investigation we can conclude that the cloud seeding accelerates the cloud development: the rain and hail precipitations on the ground in seeded case are appearing and finishing earlier in comparison to unseeded case. In seded case a hail appeared at the ground in initial phase of cloud development and a hail do not appeared at the ground in later phase of cloud development. So, the duration of hail precipitation at the ground has reduced. The reduction of finally amount of hail precipitation on the ground is consequence of that.

Kay words: numerical model, numerical simulation, seeding, hydrometers, mix-ing ratio.

Introduction

Hail causes considerable damage to crops and property. Many hypotheses have been proposed for suppressing hail. The most common has been creating enhanced competition among hailstones and their embryos for available moisture. This hypothesis is known as "beneficial competition" (Sulakvelidze, 1967). Under this concept the total amount of super cooled water available for hailstone growth is considered fixed. If the number of hailstones could be increased, then the share of the super cooled water that each would receive would be reduced and hailstone sizes would be reduced accordingly. Smaller hailstones would fall more slowly and lose a larger fraction of their ice mass by melting, thereby decreasing the total hail mass.

A hail suppression project based on the Russian method has been in operation in Serbia for 30 years.

Curic and Janc (1990, 1993), Vuckovic (1995), Music (1998) developed a microphysical model and applied it in the temperature interval between -8°C and -12°C which is considered to be the seeding zone in the operational hail suppression program in Serbia.

The research, which has reported here, gives us possibility to understand processes in the hailstorm and thereby it can increase effectiveness of the hail suppression.

Materials and Methods

The Belgrade sonde data of 29th June 1981, when has existed favorable condition for hailstorm development, has used in this investigation.

One-dimensional time-dependent numerical cloud model has applied to simulate hailstorm cloud development. The model has developed by Curic and Janc (1990, 1993), Vuckovic (1995), Music (1998).

By that model it is possible to calculate a changes in hydrometeors (cloud water, cloud ice, rain water and hail) distribution in time and height.

Two cases have analyzed: a development of hailstorm in natural conditions and in the case when artificial agent has injected in the cloud. The injection of the artificial agent in the cloud has signified by term-cloud seeding. The seeding is performed in the seeding zone when it is located between radar reflectivity contours of 25dBz and 45dBz. Seeding agent has consisted of silver-iodide and silver-chlorate mixture (AgJ-AgCl).

Agent amount, which had been injecting in cloud is expresses by agent mixing ratio -X_s (agent mass per unit dry air mass). The available value of agent mixing ratio in the seeding point is increasing by seeding for value $X_{smax}=3\times10^{-9}$kg/kg. That value has tacked because for them the reduction of final hail precipitation at the ground is the greatest (Music, 1998).

Water content in the model has divided in five categories (vapor water, cloud water, cloud ice, rain water and hail) and expressed by mixing ratio variable (r, l_{cw}, l_{ci}, l_R, l_H). The mixing ratio is defined as water mass per unit dry air mass.

Results and Discussion

The field, which has analyzed first is cloud water field. The cloud water field is consists of small cloud droplets which have negligible fall velocity in comparison to airflow velocity. In that way the cloud water droplets are adrift by airflow i.e. the velocity of cloud droplets is equivalent to airflow velocity.

The cloud water fields in unseeded case (the cloud develop in natural conditions) and in seeded case (the AgJ-AgCl agent is injected in cloud) is shown in Fig. 1, and Fig. 2, respectively.

By comparison Fig.1 to Fig.2 it can be conclude that the amount of cloud water is reducing by seeding. The maximum value of cloud water mixing ratio (l_{cwmax}) in unseeded case is 0.020 kg/kg and located between 6000m and 8000m height levels. In seeded case the maximum value of cloud water mixing ratio is 0.016kg/kg and located between 4000m and 6000m. Also, in this case the cloud water practically does not exist above the height of 6000m after five minutes time of cloud development.

The cloud ice field is consists of small ice particles which have negligible fall velocity in comparison to air flow velocity that is the cloud ice particles are adrift by air flow.

Cloud ice fields in unseeded and seeded case is shown in Fig. 3 and Fig. 4, respectively. From these figures we can see that the seeding of cloud provokes the increasing of cloud ice amount in the cloud. The maximum value of cloud ice mixing ratio has increased from 1×10^{-4}kg/kg to 5×10^{-4}kg/kg.

So, seeding of cloud cause increase in cloud ice quantity and decrease in cloud water quantity in the cloud. Namely, the part of available cloud water is transforming to cloud ice. A large number of small size hailstone instead small number of large size hailstone is consequence of that transformation. A smaller hailstones fall slowly and lose a larger fraction of their ice mass by melting, thereby decrease of total hail mass are appearing.

The rain water field is consists of drops with diameter in the range from 50μm to 5mm, which have notable fall velocity. Analogize the hail water field is consists of particles with diameter larger then 50μm which have notable fall velocity.

The rain and hail water fields in unseeded and seeded case shown on Fig. 5, Fig. 6, Fig. 7 and Fig. 8, respectively. As can seen from Fig. 5 (the hail field in unseeded case) the hail mixing ratio have a maximum at the height $z = 4000$m and in times $t = 5$min, $t = 15$min and $t = 30$min. The hail appear at the ground between $t = 15$min and $t = 20$min and around the time $t = 33$min.

In the seeded case the hail appears at the ground in time $t = 5$min (Fig. 6). The duration of hail precipitation is shorter in comparison to unseeded case. The hail do not appears in later phase of cloud development .

In all, the finally amount of hail precipitation on the ground has reduced by seeding. By comparison Fig.7 to Fig.8 we can see that in seeded case the raining has appeared on ground earlier and earlier finished as well as the rain precipitation is intensifier in time around $t = 7$min. After time $t = 7$min the intensity of rain precipitation has reduced.

By comparison the rain field with the hail field we can see that these fields was correlated that is the consequence of hail intensifier at higher levels in first several minutes is rain precipitation intensifier at the ground.

The decrease of rain precipitation intensity after $t = 9$min has caused by decrease of hail mixing ratio on higher level (around $z = 4000$m height) which appears after $t = 8$min.

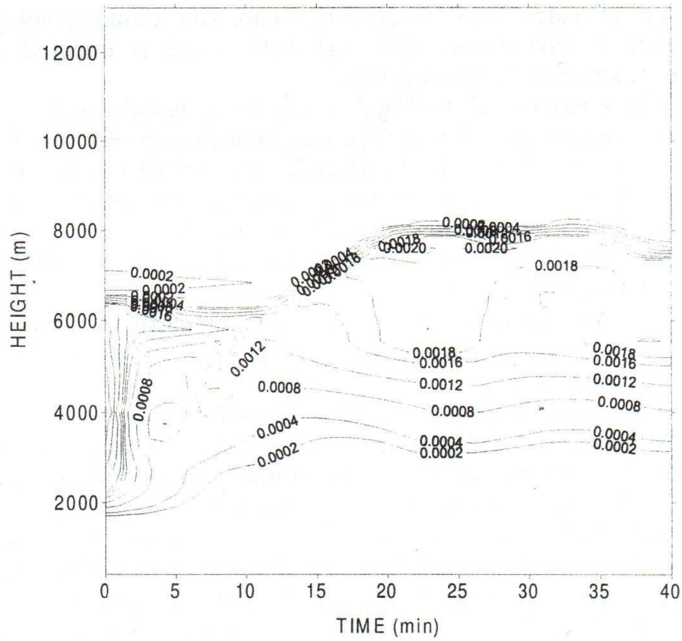

Fig. 1. Cloud water mixing ratio (kg/kg) in unseeded case

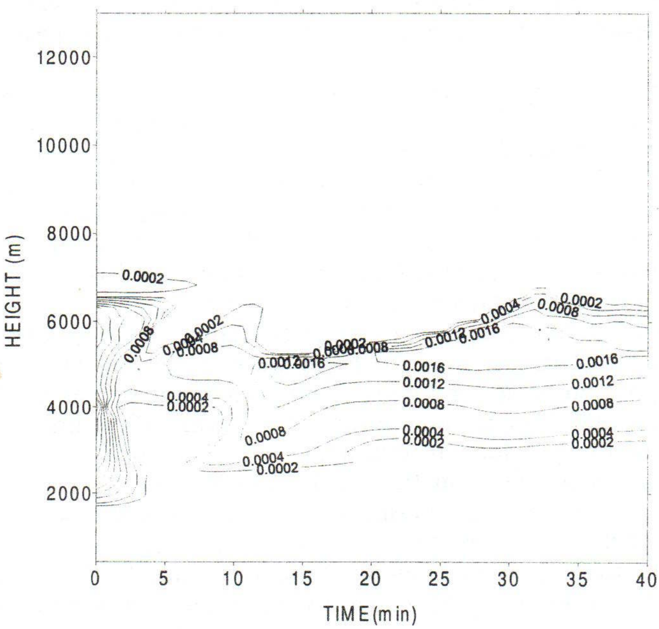

Fig. 2. Cloud water mixing ratio (kg/kg) in seeded case

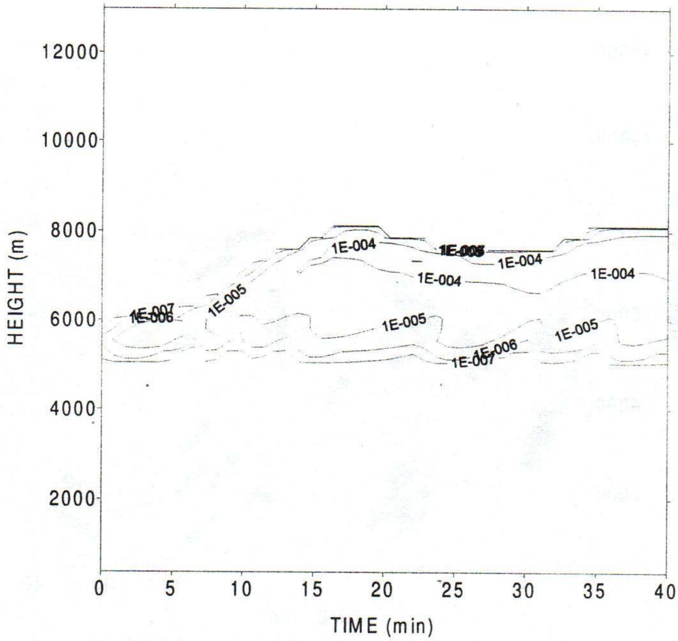

Fig. 3. Cloud ice mixing ratio (kg/kg) in unseeded case

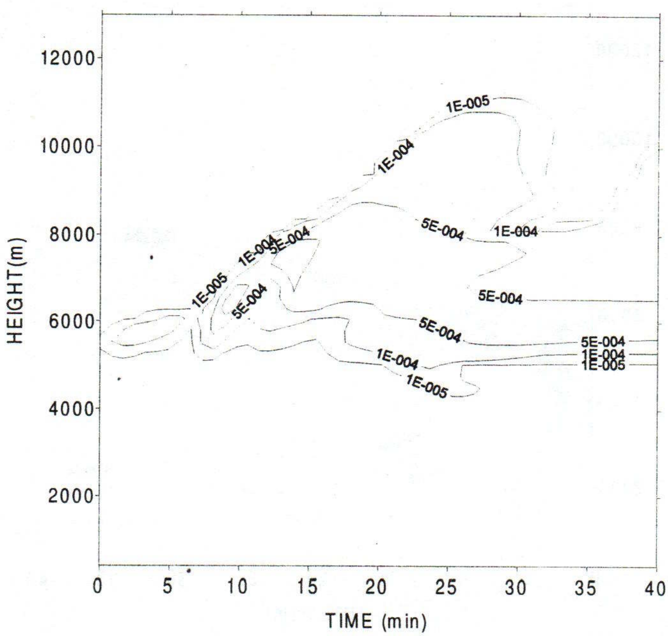

Fig 4. Cloud ice mixing ratio (kg/kg) in seeded case

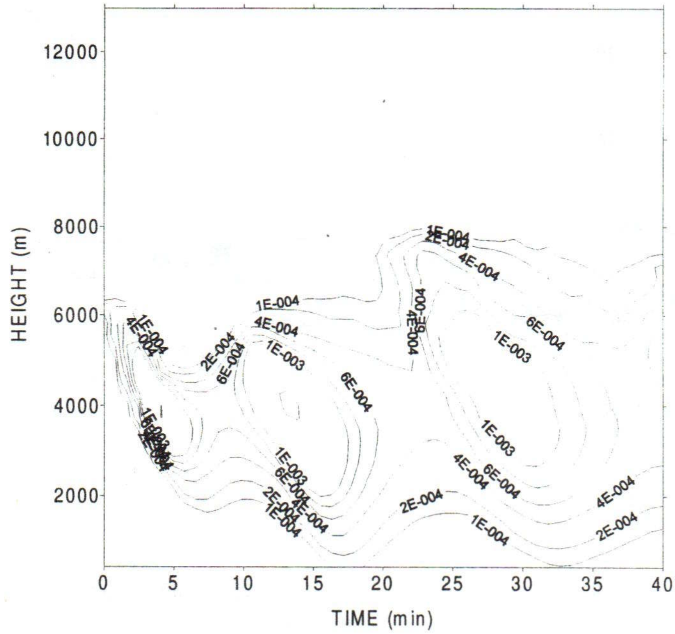

Fig. 5. Hail mixing ratio (kg.kg) in unseeded case

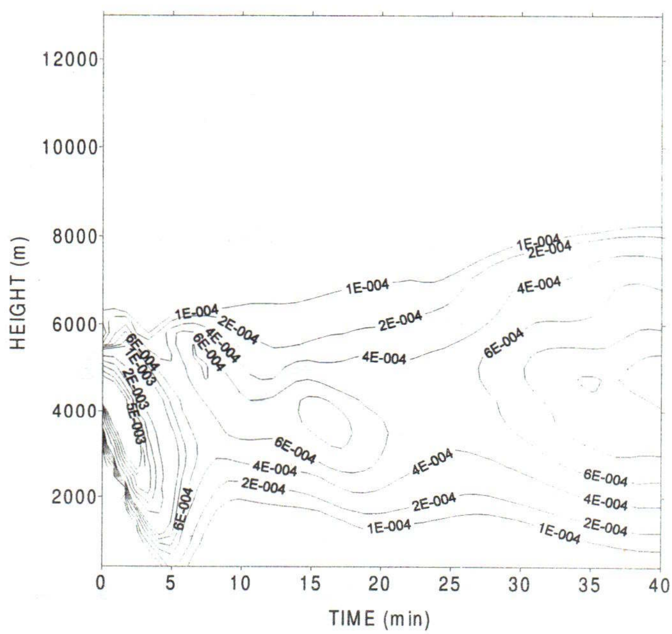

Fig. 6. Hail mixing ratio (kg/kg) in seeded case

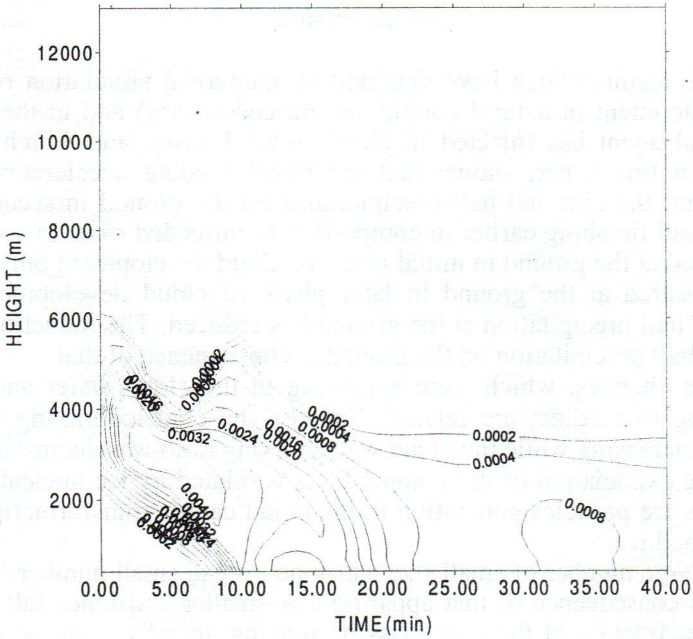

Fig. 7. Rain mixing ratio (kg/kg) in unseeded case

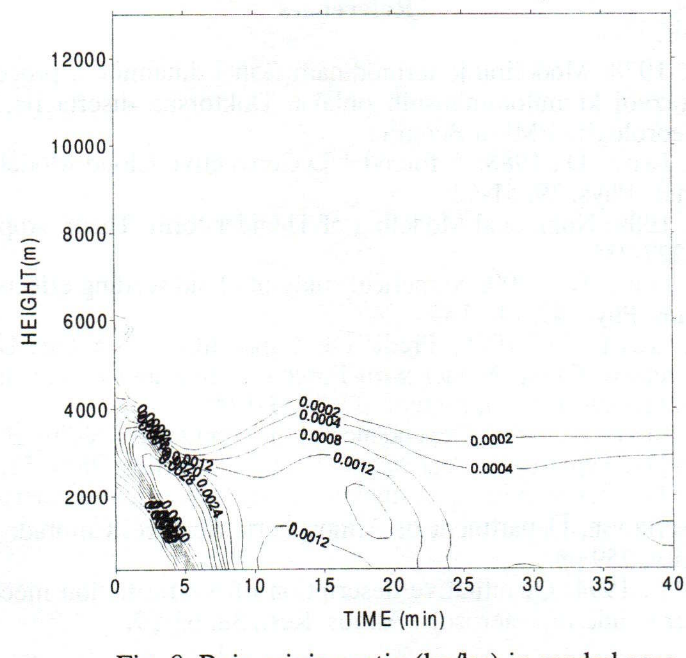

Fig. 8. Rain mixing ratio (kg/kg) in seeded case

Conclusion

The results which have obtained by numerical simulation of hailstorm cloud development in natural conditions (unseeded case) and in the case when the artificial agent has injected in cloud (seeded case), and which have been presented in this paper, shown that the cloud seeding accelerates the cloud development: the rain and hail precipitations on the ground in seeded case are appearing and finishing earlier in comparison to unseeded case. In seeded case a hail appeared at the ground in initial phase of cloud development only, and a hail do not appeared at the ground in later phase of cloud development. So, the duration of hail precipitation at the ground has reduced. The reduction of finally amount of hail precipitation on the ground is consequence of that.

The changes, which were appearing in the cloud water and cloud ice fields owing to seeding, are related. Namely, the clod ice-mixing ratio in the cloud was increasing while the cloud water-mixing ratio was decreasing.

The explanation of these apparitions is related by ice nucleation mechanism that is ice particles generation in the cloud causes transformation of cloud water to cloud ice.

A large number of small size hailstone instead small number of large size hailstone is consequence of that apparition. A smaller hailstones fall slowly and lose a larger fraction of their ice mass by melting, thereby decrease of total hail mass are appearing.

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NUMERIČKO PROUČAVANJE RAZVOJA GRADONOSNOG OBLAKA U ZASEJANOM I NEZASEJANOM SLUČAJU

-originalni naučni rad-

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Rezime

Gradonosni oblaci redovno nanose velike štete poljoprivrednim dobrima. Grad može da ošteti ne samo rod poljoprivrednih dobara u godini kada se pojavi, već može da izazove takva oštećenja na zasadima da se prinos smanji ili potpuno izostane i narednih nekoliko godina. Zato je veoma važno proučiti razvoj gradonosnih oblaka u prirodnim uslovima razvoja kao i razvoj gradonosnih oblaka u slučaju kada se veštački deluje na njih. U ovom radu vršeno je ispitivanje razvoja gradonosnog oblaka dana 29.06 1982. god. Pomoću numeričkog modela oblaka. Kada se u oblak unose određena količina reagensa (smeša srebro jodida i srebro hlorida) dolazi do obrazovanja velikog broja manjih kristalića leda. Na taj način u oblaku se formira veši broj sitnijih zrna grada umesto manjeg broja krupnijih zrna grada. Veći deo sitnih zrna grada se istopi dok stigne do tla. Zasejavanje oblaka ubrzava razvoj oblaka. Padavine pri tlu (grad i kiša) ranije se javljaju i ranije završavaju. Grad koji se u nezasejanom slučaju javljao pri tlu u kasnijoj fazi razvaja oblaka, u zasejanom slučaju se ne javlja. Dužina trajanja grada i ukupna količina grada koja padne na tlo, je smanjena.