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Investigation of the Efficiency of Hail Protection using Cloud Seeding Technique

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Abstract: The cloud model has been used to investigate the efficiency of hail protection. Fifteen weather situations in which favorable conditions existed for hailstorm development have been analyzed. For these situations the cloud development in natural condition (unseeded case) and the cloud development in the case when artificial agent injected in cloud (seeded case) has been analyzed. In the model's seeding points the agent-mixing ratio was increasing for amount X... (the agent-mixing ratio) which was varying from 3×10^{-10}kg/kg to 3×10^{-8}kg/kg. In that way, injection of agent in cloud was simulating. The seeding has been performed between -8ºC and -12ºC isotherm levels. The mixture of silver-iodide and silver-chlorate particles has been used for cloud seeding. It has been found that the rain and hail fields are sensitive to agent amount injected in cloud. The optimum value of variable X_{smax} is 3×10^{-9} kg/kg. For that value of X_{smax} the reduction of final hail precipitation at the ground is the highest.

Kay words: seeding agent, numerical model, numerical simulation, seeding, hydro-meters, mixing ratio.

Introduction

During the development, the plants are exposed to different unfavorable weather conditions (frost, drought, flood, storm-wind etc.).

Every year, these conditions cause enormous damages in agriculture and economy.

By their intensity and frequency, hail damages are the most threatening, compared to all the other natural disasters, because the hail appears every year, especially in the period when plants are the most sensitive. Negative thunderstorm consequences are significant, especially in large-scale fruit production. Only undamaged fruit products can be characterized as top and first quality.

The technique and method of active influence on the thunderstorm are developing at the same time. The seeding of cloud that is injection of artificial agent particles in cloud is the mostly used method of active influence on the thunderstorm. The agents that are used for cloud seeding are different by their chemical structure and by the dimensions of the particles used in seeding.

We can study effects of cloud seeding by performing experiments in nature and by performing numerical experiments with numerical cloud models.

The mostly used cloud research method in the last few years is numerical simulation of cloud development. Numerical experiments have an advantage over experiments in nature, because numerical experiments give us overlook of development of seeded and unseeded cloud at same time and because this research method is also less expensive.

Materials and Methods

Fifteen data were collected on the days with favorable conditions for hailstorm development and used in this study. A method used was numerical simulation of thunderstorm development. Numerical experiments have been performed by numerical cloud model developed by Curic (1978), Curic and Janc (1988, 1993), Vuckovic (1995) and Music (1998).

Regarding these fifteen situations, cloud development in natural conditions (unseeded case) and with artificial agent injected in cloud (seeded case), have been simulated. The mixture of silver-iodide and silver-chlorate particles has been used for cloud seeding. Characteristics of particles (size distribution, nucleating efficiency) and their generation are described by DeMott (1990, 1994).

Cloud seeding has been performed between 25dBz and 45dBz radar reflectivity contours, and between -8°C and -12°C isotherms. That criterion is in use in operational hail suppression project in Serbia.

In the seeding point, the agent mixing ratio- X_s (agent mass per unit dry air mass) was increasing for amount $X_{smax}= 3\times10^{-9}$ kg/kg and in that way injection of agent in cloud was simulating.

Results and Discussion

The cloud model used for numerical experiments has been divided in two regions: The vertical core and the environment. The core interacts with the environment by organized turbulence mixing (Curic, 1978).

Water content of the model is divided into five categories: vapor water, cloud water, cloud ice, rain water and hail. This content is described, using variables: r -the vapor-water mixing ratio (a vapor mass per unit dry air mass), l_{cw}-the cloud water mixing ratio (a cloud water mass per unit dry air mass) l_{ci} -the cloud ice mixing ratio (a cloud ice mass per unit dry air mass), l_R, -the rain water mixing ratio (a rain water mass per unit dry air mass), l_H -the hail mixing ratio (a hail mass per unit dry air mass).

All mentioned variables have been calculated from the model continuity equations, which describe all the possible processes, which have an influence on these variables.

During the performance of numerical experiments it was observed a dependence of final rain and hail production on agent quantity injected in the cloud (that is on variable X_{smax})

From the above mentioned fifteen situations we have separated ten which enable reduction of the final hail precipitation on the ground. These ten situations have been analyzed by varying value X_{smax}. In that way we have found that the optimum value of X_{smax}, for which the reduction of final hail precipitation on the ground is the greatest, amounts to 3×10^{-9}kg/kg. This value of variable X_{smax} is likely to decrease a final hail and rain precipitation in six situations; in three situations, the final hail and rain precipitation have been increased by seeding; in three situations, the final rain precipitation has been decreased while, at the same time, the final hail precipitation has increased. In remaining three situations both, final hail and rain precipitation on the ground have increased.

Values of final hail and rain precipitation on the ground in seeded and unseeded case are shown in Tab. 1.

Tab.1. Final rain (R) and hail (H) precipitation in seeded (a) and unseeded case (b) for fifteen chosen situations ($X_{smax} = 3\times10^{-9}$kg/kg)

	R (kgm^{-2})	H (kgm^{-2})	R (kgm^{-2})	H (kgm^{-2})	R (kgm^{-2})	H (kgm^{-2})	R (kgm^{-2})	H (kgm^{-2})
a	64.13	3.25	43.11	1.44	16.43	0.11	35.87	0.26
b	67.67	2.11	36.61	0.38	16.57	0.12	32.14	0.37
date	26.07.1984.		29.06.1982.		12.07.1980.		18.06.1981.	
a	36.51	3.46	65.93	1.99	8.17	0.08	23.11	0.26
b	50.43	3.25	30.62	1.32	8.99	0.23	20.94	0.35
date	19.08.1977		28.05.1971.		17.08.1982.		27.05.1982.	
a	39.65	0.71	37.09	1.66	26.22	0.17	17.98	0.23
b	40.62	0.61	29.55	1.09	26.31	0.18	16.76	0.36
date	20.05.1978.		12.06.1974.		11.08.1981.		13.07.1982.	
a			19.32	0.98				
b			15.34	0.48				
date			11.08.1981.					
a			42.35	0.84				
b			24.73	0.74				
date			26.06.1980.					
a			25.93	0.28				
b			24.15	0.23				
date			04.08.1982.					

When the variable X_{smax} is decreasing, changes in the final hail and rain precipitation are similar (have the same trend) to those mentioned above, therefore, the changes are smaller. When we decreased X_{smax} for one order of magnitude ($X_{smax} = 3\times10^{-10}$kg/kg) we observed that the cloud seeding has provoked negligible changes in the cloud.

Tab. 2. Final rain (R) and hail (H) precipitations in seeded (a) and unseeded case (b) for fifteen selected situations ($X_{smax} = 3\times10^{-8}$kg/kg)

	R (kgm^{-2})	H (kgm^{-2})	R (kgm^{-2})	H (kgm^{-2})	R (kgm^{-2})	H (kgm^{-2})	R (kgm^{-2})	H (kgm^{-2})
a	64.13	3.25	43.11	1.44	16.43	0.11	35.87	0.26
b	96.59	5.66	42.16	12.82	24.21	0.42	36.30	0.43
date	26.07.1984.		29.06.1982.		12.07.1980.		18.06.1981.	
a	36.51	3.46	65.93	1.99	8.17	0.08	23.11	0.26
b	43.89	4.58	67.64	7.58	13.23	0.87	22.40	3.54
date	19.08.1977		28.05.1971.		17.08.1982.		27.05.1982.	
a	39.65	0.71	37.09	1.66	26.22	0.17	17.98	0.23
b	36.06	9.75	36.04	8.72	34.63	0.34	24.50	1.20
date	20.05.1978.		12.06.1974.		11.08.1981.		13.07.1982.	
a			19.32	0.98				
b			20.84	1.12				
date			11.08.1981.					
a			42.35	0.84				
b			35.90	13.75				
date			26.06.1980.					
a			25.93	0.28				
b			37.11	0.64				
date			04.08.1982.					

The situation is considerably different when we increased X_{smax} for one order of magnitude ($X_{smax} = 3\times10^{-8}$kg/kg): the final hail precipitation has increased in all the sixteen situations, while the final rain precipitation has increased in ten situations.

Values of final hail and rain precipitation on the ground in seeded and unseeded case for $X_{smax} = 3\times10^{-8}$ kg/kg are shown in Tab. 2.

Conclusion

Numerical simulation of thunderstorm development makes it possible to analyze processes in the hailstorm in the case when clouds are developing in natural conditions, and in the case when agents are in the cloud.

Changes in final rain and hail precipitation on the ground caused by injection of AgJ-AgCl agent in the cloud, have been studied.

It has been found that the rain and hail fields are sensitive to agent amount injected in the cloud.

The optimum value of variable X_{smax} is 3×10^{-9}kg/kg. For that value of X_{smax} the reduction of final hail precipitation on the ground is the greatest.

References

Ćurić, M. (1978): Modeliranje termodinamičkih i dinamičkih procesa vezanih za razvoj kumulonimbusnih oblaka. Doktorska disertacija, Institut za meteorologiju PMF-a,Beograd

Ćurić, M., Janc, D. (1988): A forced 1-D Convective Cloud Model. Meteorol. Atmos. Phys. 39, 51-62.

Ćurić, M. (1989): Numerical Modeling of Thunderstorm. Theor. Appl. Climatol. 40, 227-235.

Ćurić, M., Janc, D. (1990): Numerical study of cloud seeding effects. Meteorol. Atmos. Phys. 42, 145-164.

Ćurić, M., Janc, D. (1988): Predictive Capabilities of a One-Dimensional Convective Cloud Model with Forced Lifting and a New Entrainment Formulation. J. Appl. Meteor. 32, 1733-1740.

Ćurić, M., Janc, D. (1988): Dependence of the Simulated Seeding Effects of Cb Cloud on Types of the AgJ Agents. Meteorol. Atmos. Phys. 52, 91-100.

DeMott, P.J. (1990): Quanifying ice nucleation by silver iodide aerosols. PhD. Dissertation, Department of Atmospheric Science, Colorado State University, 259 pp.

DeMott, P.J. (1994): Quantitative description of ice formation mechanisms of silver iodide-type aerosols. Atmos. Res., 38, 63-99.

Musić, B., 1998: Primena DeMottovih jednačina za nukleaciju leda u numeričkom modeliranju zasejavanja oblaka. Magistarska teza, Institut za meteorologiju Fizičkog fakulteta, Beograd.

Vučković, V. (1995): Promene karakteristika kumulonimbusnog oblaka zasejavanjem: Magistarska teza, Institut za meteorologiju Fizičkog fakulteta, Beograd.

ISPITIVANJE EFIKASNOSTI ZAŠTITE OD GRADA KORISTEĆI TEHNIKU ZASEJAVANJA OBLAKA

-originalni naučni rad-

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Rezime

Grad svake godine nanosi velike štete poljoprivredi, a samim tim i celoj privredi. Već više od trista godina čovek pokušava da smanji štete od grada koristeći različite tehnike delovanja na gradonosne oblake. Poslednjih nekoliko decenija koristi se tehnika zasejavanja oblaka: pomoću protivgradnih raketa u oblak se unosi izvesna količina veštačkog reagensa. Reagensi koji se koriste u protivgradnoj zaštiti se međusobno razlikuju po svom hemijskom sastavu.

Korišćenjem numeričkih modela oblaka može se simulirati razvoj gradonosnog oblaka u slučaju kada se oblak zasejava i kada se ne zasejava. Na taj način moguće je ispitati efikasnost zaštite od grada u slučaju kada se veštački deluje na gradonosne oblake.

U okviru ovog rada simuliran je razvoj oblaka za petnaest situacija u kojima su postojali povoljni uslovi za razvoj gradonosnih oblaka u okolini Beograda. Na osnovu rezultata numeričkih eksperimenata utvrđena je optimalna vrednost odnosa smeše reagensa za smešu srebro jodida i srebro hlorida (AgJ-AgCl) sa kojom treba vršiti zasejavanje da bi efikasnost zaštite od grada bila maksimalna ($X_{smax} = 3\times10^{-9}$kg/kg).