HAIL SUPPRESSION IN MENDOZA (ARGENTINA)

by

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ABSTRACT

In the province of Mendoza (Argentina), the hail precipitation affects the agrarian production seriously, and causes substantial damages to agriculturists. One of the main characteristics of the zone is that the most violent storms are those which originate after the sunset; it is relatively easy to find that the reflectivities measured by the radar reach values of over 65 dBZ.

The authors of this article describe the history of hail suppression in Mendoza from the 1950s until today, especially emphasizing the techniques developed by Antigrad Latinoamericana, currently in charge of the hail suppression operations.

1. History of Hail Suppression in Mendoza

The hail suppression in this Argentinian province began as an alternative to the agrarian insurance, whose huge deficit made it impossible to maintain. In 1958, a series of experiments started with the seeding system which was being used in the South of France at the time. For this purpose, 120 generators were installed to burn a coal which was previously impregnated with an acetonic solution of AgI (Grandoso and Iribarne, 1963; Iribarne and Grandoso, 1965).

Later, in 1974, the National Hail Suppression Program was created and three stages were proposed for the developing of the system:

- 1970 to 1978: developing of systems for the observation and analysis of hail precipitation and damages caused in agriculture.
- 1979 to 1981: creation of the organization and construction of the systems which allowed seeding by means of rockets containing lead iodide.
- 1982 to 1983: the Committee responsible for the Program changed the nucleant material and started using AgI.

In 1983, the experiments stopped due to the lack of money and the meager confidence in the rockets made in Argentina.

In 1984, the new authorities of the Province of Mendoza took up the process and came to an agreement with the USSR for the provision of equipment, technical assistance and the transference of technology. All these steps led to the beginning of the hail suppression campaigns - in accordance with a low passed therefore - in three areas centered around Tunuyán, San Martín and San Rafael. MRL-5 radars and several launching pads for the Alazán

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rockets, which are made in Russia, were installed in each of these areas.

The Hail Suppression Program was active in the period 1985-1991. The economic support came from the governmental budget, but the Government collected taxes among the agriculturists. Due to the huge deficits accumulated in 1990 - only 4% of the agriculturists paid the rates - the authorities of the province of Mendoza decided to remove the subsidy and transfer the costs of the system to the so called Regional Consortia, even though by law they reserved themselves the right of administration and control of the system. The Consortia held a plebiscite in order to solve the continuity of the Hail Suppression Program. The results of the elections showed ample popular support for the continuation of the campaign only in the area of San Martín. It is very difficult to determine to what extent wrong management or the results provoked the abandonment of the Program in the other two areas.

In the campaigns of 1993-1994 and 1994-1995, the hail suppression proceedings were in charge of a private company, Antigrad Latinoamericana S.A., which was formed by Russian and Argentinian organizations, as well as by organizations of other countries. The planning of the proceedings was designed by Dr. Abshaev, from the Institute for Geophysics in Nalchik.

In 1995, financial difficulties again led the Government to transfer the system's administration to a Foundation formed by Management Chambers, vinegrower societies, electrification cooperatives, and agriculturists, who had historically supported the system.

2. Target Area

2.1 General characteristics

The province of Mendoza is located in the western part of Argentina, on the border with Chile, and it is crossed by the Andes (Figure 1).

The Hail Suppression Program is designed to protect an area of 1,900 km²; approximately half of which is cultivated. 85% of this surface is dedicated to vines and 12% to wooden cultures (olive trees and fruit trees). The resting 3% are plantations without a definite dedication. The agricultural farms are of a small size and mostly familial. However, there are also big wine companies which produce wine of an excellent quality.

This area is a plain at an average altitude of 600 meters above the sea level. It is called Northern Oasis, for there is enough water coming from the overflowing waters of the Andes for the crops.

Figure 1. Location of target area.

2.2 Climate in the area.

The annual rainfalls usually oscillate between 300 and 500 mm. The climate is dry and continental, with warm summers and mild winters, where the frost days are scarce. In fact, the month of June has an average temperature of 6°C and the month of January 31°C.

The presence of the Andes and the winds cause the *föhn effect*, which leads to a wind called in that zone the "zonda wind". Therefore, humidity is frequently scarce. This fact, together with the sudden temperature changes between day and night, conditions the distribution of the crops.

The observation of the storm cells with the radars shows that the frequency of hail precipitation increases when the storms move between 70 and 90 km away from the mountains. That is to say, the data taken during the last 15 years indicate that the hail precipitation is more frequent in the plains than in the mountains. This can be attributed to the combination of several factors, among which we can point out the entrance of cold air masses from the Antarctic, the heat during the day and the dynamic influence of the orography. On the other hand, the hail precipitation tends to occur after the sunset.

The province of Mendoza has a very high frequency of storms. For example, according to the final report of the campaign 1994-1995, between 22 October 1994 and 23 April 1995; all in all, 94 days with storm phenomena were recorded, 60 of which presented hail storms. On 113 occasions, hailstorms were recorded, 49 of which were supercells. It was also relatively frequent to find a reflectivity intensity over 65 dBz.

The damages caused by the hail precipitation are analyzed following a procedure which has been passed by the parliament with no change regarding methodology. According to the data provided by the Ministry of Economy, the losses reach 14% of the total agrarian production, although the data compiled during the last years show that there has been an important decrease coinciding with the projects of the Hail Suppression Program.

3. General Methodology of the Seeding System

3.1 Introduction

The results obtained by the Grossversuch IV and, above all, the feeling of pessimism it led to, reduced many of the expectations the Russian system had created, a system which had been rather promising until that moment. Thus, most of the scientific groups operating projects in wide territories of the ex-USSR adopted a very restrictive position when it came to provide technical or scientific information. But it is necessary to remember that the methodologies employed in the Grossversuch IV and the results founded, made the Managers of the Sovietic Projects reflex and deepen the research. "Their" system worked properly, but it did not provide satisfactory results in experiments outside their own country.

The linguistic barriers have not favored the exchange of information; therefore, it is difficult to get a detailed knowledge of the evolution of the seeding method. Tens of thousands of square kilometers had Hail Suppression Programs in Moldavia, Ukraine, Russia. Now we can say that the Institute for Geophysics in Nalchik has had an enormous influence in the development of the Hail Suppression Methodology. Thus, we know that the theory of hail accumulation was abandoned, as it was presented at the time of the Grossversuch IV, and it has been substituted by another one which strives to find the zones where hail is formed. Currently, the seedings attempt to accelerate the process of precipitation. New rockets equipped with a better technology have been designed. Computers and software developed for these purposes have improved the knowledge and have facilitated the analysis of the procedures.

3.2 Launching pads

In general, storms enter the target area by its western part. Therefore the seeding area is a little bigger than the target area, so that it is possible to act a few kilometers before the storm enters the area.

The seeding system consists of 29 stations where 2 or 3 launcher pads are installed, ready to be ignited. Each pad can hold 12 rockets, so that there are 24 or 36 rockets ready to be launched. Moreover, there are between 60 and 90 rockets in stock in every station. There is an employee day and night in each of the stations, who is in charge of maintaining the launching systems in perfect condition, as well as receiving and transmitting the corresponding information to Headquarters.

The high degree of difficulty the seeding involves requires specially trained staff able to make decisions in a few seconds about:

1. the precise moment when the proceedings should be started, taking into account the information provided by the systems of observation (radar - computer);
2. the selection of the launching pads which will be used, taking into account, among other things, the forbidden zones;
3. the number and type of rockets which are going to be employed; and,
4. the seeding area of the storm cells, and therefore the orientation of the launching-ramps.

In addition, they have to take into account the information provided by the airport about the air traffic.

3.3 Rockets

It is well known that the Russian system makes use of rockets to carry the seeding material to the interior of the storm cells. When the Manager considers the appropriate moment has arrived, he decides from which launching pads the operation is going to be carried out, as well as the kind of Alazan or Kristall rocket that is going to be employed. Both types are made in Russia and they are regularly imported by the company which is in charge of the project. It is necessary to point out that the Alazan rockets are being substituted by the Kristall ones, but in Mendoza both are still employed. In Table 1 we show some of the most important characteristics they present. The nucleant material is a mixture of AgI to which we have added a combination of K salts to

- improve the combustion of the pyrotechnic substance
- get the AgI to reach the highest degree of efficiency
- add hygroscopic properties which improve the efficiency of the crystallization of the AgI.

The content of AgI does not reach 4% of the total pyrotechnic mixture employed.

Table 1: The main characteristics of the Alazan and Kristall rockets employed in the anti-hail operations.

ALAZAN	
length	890 mm
weight	6.8 Kg
reactive material	1.0 Kg
AgI	16.8 g
maximum height of elevation	4300 m
KRISTALL	
length	2027 mm
weight	11.5 Kg
AgI	7g (estimated)
maximum height of elevation	8000 m (estimated)

Once the rocket launching has been decided, three of them are ignited simultaneously, thus forming an angle of 5° between them, so that they leave a wake of nucleant material which will spread them in the zones chosen to be seeded. Every rocket contains a self-destruction system, which has avoided any relevant incidents from happening.

In the campaigns, several thousands rockets are sent, which require very strict safety norms–keep in mind, this is explosive material.

4. Criteria for the Estimation of Risk Situations

Taking into account the meteorological conditions observed, the height of the 0°C level is established, which we will call H_0. When we observe a cell with the help of the radar (band S) , the values of the following variables are established:

H_{45} is the maximum altitude in which the 45 dBZ contour is located.

H_{15} is the maximum altitude in which the 15 dBZ contour is located.

Once these data are established we calculate:

$$H_{15} - H_0 = \mathbf{\Delta\ H_{15}}$$
$$H_9 - H_0 = \mathbf{\Delta\ H_{45}}$$

The establishing of the risk that the cells detected by the radar may lead to hail precipitation is done according to the data provided by the radar. The risk is estimated in accordance with the classification of the cells in 4 categories depending on the risk, so that the system will indicate "null risk" for class I and "maximum risk" for class IV. The classes are delimited according to the following criteria:

Class I: When the following conditions are found:

$$15 < \mathbf{Z_{max}} < 35 \text{ dBZ}$$
$$\mathbf{\Delta\ H_{max}} \geq 2 \text{ km}$$

where $\mathbf{\Delta\ H_{max}}$ is the altitude between the isotherm 0°C and the place when reflectivity reaches the highest point.

Class II: When the following conditions are found:

$$35 \text{ dBZ} < \mathbf{Z_{max}} < 55 \text{ dBZ}$$
$$\mathbf{\Delta\ H_{45}} \geq 2.5 \text{ km}$$

Class III: When the following conditions are found:

$$\mathbf{Z_{max}} \geq 55 \text{ dBZ}$$
$$\mathbf{\Delta\ H_{45}} \geq 3.0 \text{ km}$$

Class IV: When the following conditions are found:

$$\mathbf{Z_{max}} \geq 65 \text{ dBZ}$$
$$\mathbf{\Delta\ H_{45}} \geq 4.0 \text{ km}$$

The model used to evaluate the risk is based on the observations carried out by the Institute of Geophysics in Nalchik, which Dr. Abshaev considered ics in Nalchik, which Dr. Abshaev considered equally suitable for Mendoza (Magomet et al., 1994).

5. Choice of the Seeding Area Inside the Cells

The rocket launching system is activated when a cell reaches the level of class II, III or IV, and approaches the target area or enters it. To delimit the zones we want to treat, the radar images are analyzed. In accordance with these images, the position of the ascending currents and the new developments are estimated, to determine the general structure of the cell and its evolution in time. The seeding system establishes that the seeding material shall be placed in a zone of weak ascending currents (3-5 m/s). The hypothesis we were working with was based on the fact that "the seeding material is expected to increase the number of ice crystals and accelerate or provoke the precipitation" (Abshaev, 1994b).

The ideal seeding level is located at an altitude of -6°C ±3°C.

The cases analyzed by the authors of this article indicate clearly that the choice of the seeding area has nothing to do with the criteria employed in the Grossversuch IV. It has sometimes been observed that the seeding material is located in the zones which are next to the new developments. It has also been observed that the more asymmetric the structure of the cell, the more rockets were launched.

The speed at which storms are formed and grow in Mendoza and the difficulty of the operations may contribute to put even more pressure on the people who are responsible for the operations. Those factors could also explain why sometimes the seeding starts in cells with low reflectivity. We have to consider the fact that the project is effective and the main objective is that no hail falls to destroy crops.

The observation of the analyzed cases shows that the seeding operations stop when the reflectivity of the storm has decreased considerably and/or the RHI image shows a vertical structure with a good symmetry. According to the Manager of the project, Dr. Victor Markitov, the "trace" left by the seeding material when it has been effective is evident when a storm with previously asymmetric structure was treated, and a few minutes later a sudden change is observed. The result is that the subsequent radar images present a symmetric structure.

6. Control of the Procedures

It was settled by law that international experts who were not involved in the project must be called to carry out a quality control of this program. Thus, in 1994, the authorities of the province of Mendoza named an International Commission of Evaluation, formed by Dr. Roger Reinking, Dr. Leonid Dinevich and Dr. Petio Simeonov. Later, in 1995, a second Commission was named formed by the former experts, excepting Dr. Reinking, and including Dr. Jean Dessens and J.L. Sánchez. This same Commission had consultative functions in 1997.

The Scientific Manager of the Project, Dr. Abshaev proposed from the beginning a Hail Suppression Program where the economic evaluation of the results played an important role. The starting point was the data base concerning the damages caused to the crops which were mentioned by the Agrarian Insurance in force between 1952 and 1965, that is to say, before the hail suppression procedures were carried out. The evaluation designed by Abshaev is based on a comparison between the damaged area of the series and the target area in each campaign. This planning also takes into account what happens in the Northern Oasis - where the procedures are carried out - as well as the Central and Southern Oasis, where there is no seeding activity at all.

In memoranda presented by Dr. Abshaev to the sponsors of the project, it is pointed out that while the Hail Suppression Program has been taking place, a decrease in damages of more than 54% has been observed. It was also said that the effectiveness of the hail suppression system could be far superior (Abshaev 1994c).

Even though the "evaluation method" looks more like a formula of "how the system is working" than like an irrefutable scientific reasoning, the results seem to be interesting and promising. The technology employed is appealing and it has been developed to improve the objectivity in the application of the seeding criteria. The size of the storm cells and the importance of the storming activity in this zone of Argentina suggest that the research of these phenomena should be encouraged, for they have stopped being so episodic and have become severe and frequent.

The actual carrying out of this type of Hail Suppression Program which makes use of the 'Russian system" is technically complex. The analysis of the procedures has shown that the number of errors is very low, which proves the operator's skill and the liability of the technology employed. The social pressure is extremely strong, too.

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