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# Study of hailstorms cells producing big damages in Mendoza (Argentina)

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## 1 Introduction

The Provincial Government of Mendoza (Argentina), had protected the local crops from the hail damage during five seasons (1999-2004) by contracting an operational service. These operations consisted in silver iodide seeding (AgI) methodology by means of several aircrafts. The aircrafts were provided with meteorological instruments and probes, which allowed obtaining an important amount of data about the hailstorm in this region. A cloud seeding program is normally developed to augment precipitation or to suppress (or reduce) hail by means of a glaciogenic seeding agent, such as the above mentioned AgI. The seeding agent nucleate ice crystals in clouds containing supercooled cloud liquid water to generate high concentrations of ice crystal competing with the existing supercooled cloud liquid water, therefore a massive dose of seeding agents are needed to obtain a beneficial ratio. This process depletes the cloud water, allowing only a modest growth of the ice sizes.

Meteorology of the area.

The city of Mendoza, (33S, 68W, 750 m a.s.l., 900,000 inhabitants), is located at the east side of the Andes Mountains in western Argentina (Figure 1). The Cordillera close to Mendoza, reaches an average height of 5000m with peaks up to 7000 m. The city is located in an arid to semi-arid zone of low rainfall: 120–400 mm/a, mean 230 mm/a, which occurs specially during the summer months (November to March). The annual mean wind intensity is 2.6 m/s, with 19% of calm days, the predominant wind directions are: S-SW, 30%, E-SE, 24%, N-NE: 14%, W-NW, 8%. Due to its closeness to the mountains, Zonda winds similar to Föhn or Chinook winds, prevail in the higher layers most of the year. This is a warm and dry NW wind with speeds ranging 5–6 m/s, and gust up to 12 m/s. Zonda winds and anticyclone situations in the winter months (May to October) with high probability of frost, thermal inversion layers. The area presents low relative humidity (50%), low incidences of fog and few days with covered skies (65–75 days/annum). The bulk of the summer precipitation comes very late in the day and at night. Clouds with low activity during the day often explode near sunset. In some cases the clouds are initiated on the east slopes of the Andes and move eastward on westerly winds aloft that can be quite strong well above the crest of the Andes, which is usually above the 500-mb level. In other cases the storms are initiated out on the plains. The moisture source for these storms usually comes from the east and north and rises as it approaches the east slopes of the Andes. Strong instability, a source of moisture from the east, great depths of supercooled water and strong shearing winds aloft provide the ingredients for these hail-producing storms. Cloud bases typically were at about 10ºC with updrafts often exceeding 7 m/sec. The cloud updrafts increased with height, exceeding 25 m/sec at heights of 7 km and higher. Thermal buoyancy of 5-8ºC was measured in convective towers at heights of 8-10 km. The vertical wind shear was weak below 6 km, but increased strongly above that level as the west winds cleared the Andes barrier, see Rosenfeld et al. (2000, 2001). According to Woodley et al, (2001), the clouds of Mendoza, Argentina have very little coalescence with only isolated small supercooled raindrops. Nearly adiabatic cloud water was maintained up to the level of homogeneous freezing. Up to 5 $g/m^3$ was observed at –38ºC, abruptly vanishing at colder temperature.

## 2 . Material and Methods

The most important equipment is the meteorology radar and its associated systems. They can measure the different variables and parameters of the hailstorms. The information gathered so far by our team is as follow:

*The WR100 radar*

The main information has been obtained with the radar WR100 of C band automated with the TITAN systems, during all seasons of active defence (1999-2004). During this period, approximately 300 days of hailstorms data were collected. Each day has an average of seven hailstorms cells sample, thus obtaining approximately 2100 hailstorms cells. Each cell is considered as a sample, which contains the variables and parameters measured by the radar.

*Parameters and Variables*

The main data sources used were: a) Images of the TITAN system and WM100 C band radar, b) Parameters and variables files with ".txt" format that record the TITAN system, c) The damage hail-report that produce of the Direction of Contingency Prevention (DCP) of Economy Ministry of Mendoza, d) The daily sounding and forecast provided by WMI (Weather Modification Inc.). From the measured variables, we selected only those relevant to explain the Physics and Dynamics changes inside the cells when it is seeding with AgI. These variables are:

**Zmax:** It is a C band radar parameter (dbz.) the maximal reflectivity of the hailstorm cell echo.

**Hzmax:** It is a C band radar parameter that measures the Zmax. height (km.) of the hailstorm cell echo.

**HTope:** It is a C band radar parameter that measures the Top height (km) of the hailstorm cell echo.

**Vol:** It is a TITAN system variable, which represent the volume value of the hailstorm cell ($Km^3$**)** calculated from the 40 dbz. value.

*Methodology for the selection of the data*

For the evaluation of the efficiency of the AgI seeding procedure, it is usually accepted by most scientists the implementation of a random procedure, by taking statistical samples observed form seeded cells, compared to non seeded events, and then evaluating the consequences of such decision, resembling the entire process from a black box point of view. However, the randomize method do not consider the physical and dynamic changes in the processes of hail formation. On the other hand, as said above, the available data was gathered during five operative seasons from 1999-2004. From an operative point of view, all hailstorm cell that had entered into the cultivate oasis was (or should be) seeded. Therefore, it was not possible to use a random selection process to systemize and characterize the hailstorms cells in Mendoza, that is, to analyse seeded and not seeded cells independently. The short comes of the randomise methods, and the impossibility to design such procedure, required to develop some criteria to select the hailstorm cells, allowing the collection of relevant and significant samples. From the measured data, an Evidence Seeding Index (ESI) was build, which captures the physical and dynamical changes occurring during the seeding process. The temporal changes in this index represent a typical signature of the evolution of the hailstorm, which was then correlated to the efficiency and consequences of the hailstorm. Perez, (2004), Perez and Martínez (2004) and Perez (2005) reported the technical and statistical detail on the ESI.

To build a relevant statistical samples of hailstorm cells, an *ad hoc* criterion of similarity was adopted, which may be defined by the three main selection steps: a) all hailstorm cells that have the same genesis zone at the same hour are initially added to the sample; b) from all selected cells in point a) only those with the same displacement direction are overtaken. c) From the data in b) only those hailstorm cells groups with similar meteorology and C band radar parameters are finally adopted. Second, the corresponding C band radar parameter, TITAN variables and sounding data were processed using the Statgraphics software. This software was used to characterize the set of big hailstorm cells, implementing a multiple regression method with the C band radar parameters. In all cases, we used the statistical estimators normally required to validate the statistical studies, such as pi-value, Fisher test, the Durbin-Watson test, R-squared and the standard error of estimation.

## 3 Results

The first interesting result was that only the Hzmax and Vol parameters measured at the C band radar were sensible to changes when the hailstorm cell was seeded. Therefore the study was reduced only to these parameters, on the other side this agrees with the conceptual model. A surprising and unexpected result about the seeding cells in Mendoza is related to hail size on the ground, which appear closely correlated to the Vol. C band radar parameter (Table 1); this parameter is calculated by the TITAN system using the 40 Dbz. zone volume for each hailstorm cell. Moreover, when the data are observed in more detail, it is possible to distinguish a threshold value to this parameter (Table 1). The 2000 $km^3$ Vol. value divide the data in two different behaviour: a) When Vol. value of the hailstorm cell is bigger than the threshold; always big hail was present on the ground; and b) in all the other case, when the Vol. value was smaller than 2000 $km^3$, there is never hail on the ground, or in some few cases only a little hailstone were present. Following these first results, we concentrated our study to the hailstorm cells with a Vol. bigger than 2000 $km^3$, to get a deepen knowledge about of these cells.

*Analysis of hailstorm cells by Vol. value.*

Table 1 show a summary for forty-six (46) seeded hailstorm cells. The table show the different parameters and variables measured on the C band radar and the precipitation information provide by Direction of Contingency Prevention (DCP). The number of study cells was limited only to those with complete information used in our study. Unfortunately, there were a big amount of cells with incomplete data which were not able to been used. The analysis of each cell, allow us to derive important conclusions on the seeding procedure using aircrafts. As said before, two groups arises clearly from Table 1:

1. Cells with Vol. value smaller than 2000 $Km^3$.
2. Cells with Vol. value bigger than 2000 $Km^3$.

*Cells with Vol. value smaller than 2000 $km^3$*, were present almost 80% of the cases (32 cells), where only one of them (3%) had big hail (2 cm. diameter on ground) and four had small hailstone (12%). In other words, the seventy eight percent (78%) of these cells had not produced hailstone on the ground when they were seeded. When the cells precipitated hail on the ground, the maximal reflectivity height was superior to five kilometres. It can be first concluded that for these cases the seeding method using aircraft was very efficient.

*Cells with Vol. value bigger than 2000 $Km^3$* (40 Dbz. Zone) represent only the 20% of the study cases, they always had produced big size hail on the ground and big damage each time that these cells over flown the cultivated oasis of Mendoza. Table1 show important information on this cells class, which allow us to arrive to the following knowledge: *a)* All cells that pertain to this classification always had produced big hailstone (diameter bigger than 2 cm.) accompanied of big damage on the ground, b) They have a low annual occurrence frequency in the Mendoza cultivate oasis, about two event per season. c) The Central oasis never had this type of cells in five operative years. d) The Northern oasis was the region with more cells with Vol. value bigger than 2000 $km^3$ (Figure1). e). Theses cells are responsible for almost 80% of damage by hail per season in Mendoza although they present a low frequency rate. Of course, theses results also indicate that the seeding procedure over cells with Vol. value bigger than 2000 $km^3$ has very low efficiency.

*Additional Statistics Results*

The statistics studies with the C band radar parameters and the TITAN system data had given the following additional knowledge about the bigger than 2000 $km^3$ hailstorm cell. It is possible to distinguish a genesis zone as the beginning of the life cycle of theses cell class. All cells have a trajectory in agree with the Viktor Makitov´s study whose path is showed in the Figure. The first Tops never had the height lower than 10 Km., and the initial reflectivity was always bigger than 42 Dbz. The Zmax average value of these hailstorm cells was 56 Dbz. The sounding data study with the RAOB software allowed finding a typical hologram to theses hailstorm cells.

The forecast system used in the five season was very precise (it had presented an efficiency around 80%), but for the cases of hailstorm cells with Vol. bigger than 2000 $km^3$, the forecast had a very low predictions efficiency on the supercell presence (only the 16%). Thus, these cells class were hard to prediction by the forecast system.

## 4 Conclusions

From the present study it is possible to derive the following conclusions:

a. The Vol. parameter is a threshold value in order to study the cell seeding efficiency with aircraft in Mendoza, because when Vol. value was lower than 2000 $Km^3$ the seeding had elevated efficiency (around of 80%), on other hand, when Vol. value was bigger than 2000 $km^3$ the efficiency was very low, because these hailstorm cell (seeded or not) had always produced big hailstone on the ground (diameter bigger than 2 cm.) and were responsible for 80% of the crop damage in the five season.

b. The big cell with Vol. value bigger than 2000 $km^3$ has a low annual apparition rate, in the order of two or three events per season inside the Mendoza cultivate oasis (South and North). In the Central oasis in five years of study there were not event of big hailstorm cells present.

c. The big cells are currently hard to forecast, but is possible to distinguish a genesis zone for these cells.

d. The statistical study using a C band radar parameters value showed to be very useful in order to take operating decisions in the hailstorm cell seeding procedure. So, if a hailstorm cell start in the genesis zone described, and its first value are Zmax bigger than 42 Dbz. and Top bigger than 10 km., then it must be seeded intensively because there is a high probability that this cell will be a big cell with its Vol. value bigger than 2000 $km^3$ and it will probably produce a big damage.

Given these summarized facts, it is necessary to further research on the atmospheric and geographical conditions of genesis area of the big cells, to better understand the physical and dynanical process that govern its genesis and development, and with this knowledge study a new methodology to mitigate its consequences

## 5. References

Brimelow J., Krauss, T., Reuter G, 2001: Application of a One-Dimensional Cloud and Hail Model to Forescat Maximum Hailstone Diameter for Mendoza, Argentina. *15th Conference on Planned and Inadvertent Weather Modification. Albuquerque (New Mexico).American Meteorologycal Society.*

Foote, B. (2001): Aspects of Cumulonimbus Classification Relevant to the Hail Problem. J. *Rech. Atmos. Vol.19.*

Krauss, T., Makitov, V. 2000: An Overview of Mendoza Hail Suppression Program 2000”. *Weather Modification Inc. Fargo, North Dakota.*

Krauss, T., Renick, J. 2003: Preliminary Economic Results of Hail Suppression Programs in Alberta, Canada and Mendoza, Argentina. *Eighth WMO Scientific Conference on Weather Modification Research. Casablanca, Morocco.*

Makitov, V., 2003: Durations of Seeding Effect Manifestation in Potentially Hail and Hail Clouds. *Eighth WMO Scientific Conference on Weather Modification Research. Casablanca, Morocco.*

Pérez, R., Martinez, H. 2004: An Experience to Validate The Conceptual Model of Seeding Clouds with IAg in Mendoza. *European Congress of Severe Storm (ECSS).*

Pérez, R., Martinez, H. 2005: A Seeding Evidence Index (IES) of Hailstorm Clouds in the Province of Mendoza using de C band radar. *Annual Meeting de la Unión Europea de Geociencias (EGU)*.

Pérez, R., Martinez, H., Sánchez, J. 2003: Data Concerning Hailstorms and Hail Supression Activities in Mendoza, Argentina between 1999 and 2002. *Eighth WMO Scientific Conference on Weather Modification Research. Casablanca, Morocco*.

Puliafito, E., Guevara, M., Puliafito, C. 2003: Characterization of urban air quality using GIS as management system. *Environmental Pollution. Vol 122, pp 105-117*.

Rosenfeld, D., Woodley W., Krauss T. 2000: Aircraft Measured Microstructure of Severe Hailstorms in Argentina from Cloud to –40°C". *Hebrew University of Jerusalem, Israel; Woodley Weather Consultantas, Colorado, USA and Weather Modification Inc. Fargo, North Dakota*.

Rosenfeld, D., Woodley W., Krauss T. 2001: Satellite Observations of the Microstructure of Natural and Seeded Severe Hailstorms in Argentina and Alberta. *15th Conference on Planned and Inadvertent Weather Modification. Albuquerque (New Mexico), American Meteorologycal Society.*

Woodley W., Rosenfeld D., Krauss T. 2001: Aircraft Documentation of Microphysical Seeding Signatures in Argentina Clouds. *15th Conference on Planned and Inadvertent Weather Modification. Albuquerque (New Mexico). American Meteorologycal Society*.