MITIGATION OF HAIL DAMAGES BY CLOUD SEEDING IN FRANCE AND SPAIN

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I. INTRODUCTION

The state of hail prevention is described in two recent overall reports published by the American Society of Civil Engineers and by the World Meteorological Organization (ASCE 2003, WMO 2006). Three methods are described in the reports, all based on the dispersion of silver iodide nuclei, with rockets, aircraft, or ground-based generator networks. In France and Spain, due to air traffic regulations and financial considerations, the only practical method appears to be ground seeding. The method is presently operated in several areas of the two countries by the ANELFA and the University of León.

II. SCIENTIFIC BASIS OF HAIL PREVENTION WITH GROUND GENERATORS.

It has taken more than 50 years of research in North America and Europe to state that silver iodide seeding from the ground should reduce hail intensity. This can be summarized in four stages:

1) More ice forming nuclei in the atmosphere leads to less hail. Three years of measurements in France have shown that an increase in the ice forming nuclei concentration between -11 and -21°C goes with a decrease in hail damage (Soulage, 1963). Numerical simulation of cloud seeding also shows that when numerous artificial hailstone embryos are present in a hail cell, they compete beneficially for the available supercooled water resulting in the formation of numerous small hailstones, many of which melt before reaching the ground (Farley et al., 1996).

2) Seeding from silver iodide ground generators increases the atmospheric concentration in ice forming nuclei. During hail prevention experiments in France, the ice forming nuclei content has been measured to increase by a factor of a few units to ten (Soulage, 1957), even using low efficiency charcoal generators. A same conclusion was obtained in Canada during the Alberta experiment, with average concentrations above a ground generator network found to be 2-4 times over background (Grandia and Davison, 1977).

3) Silver iodide nuclei emitted at the ground are ingested by the storm. Soulage (1968) measured the number of ice forming nuclei at the submit of the Puy de Dôme, in the middle of a plain seeded with ground generators: the generator nuclei are first concentrated in the surface layer, then this layer is drawn up in limited time and space inside the storm. The Alberta field project consisting in aircraft tracing missions also gave evidence of surface-released transport to cumulonimbus areas (Heimbach, 1978). Numerical simulations have recently confirmed this schema (Yuter and House, 1995; Lascaux and Richard, 2006).

4) Preventive seeding of hailstorms with ground generators reduces hail intensity.

A study based on French insurance data has revealed a 41% decrease in crop damage in seeded areas compared to non-seeded ones (Dessens, 1986). Treating the cells early in their lifetimes appears crucial for successful hail suppression, in agreement with the simulations (Farley et al., 1996). Daily correlations between the running time of the generators and the intensity of point hailfalls measured with hailpads have confirmed the decrease in the hail kinetic energy due to ground seeding (Dessens, 1998). An independent study based on data from the Spanish Agricultural Ministry has shown a significant decrease in hailfall crop damage due to hail prevention with ground generators in the north of Spain (Balash et al., 2004).

III. ADMINISTRATIVE ORGANIZATION OF THE PROJECTS

FRANCE: The ANELFA was born in 1951. It is a non-profit association federating a dozen of regional entities (département) located in hail damaged areas. Each local association collects the funding for its participation to the ANELFA project. The members of the local associations and of the ANELFA are politicians, agronomists, and leaders of agricultural organizations. In the départements covered by this association, 660 seeding stations are spread out in local networks with an odd 10 km mesh. The area is distributed over four regions and represents a total of 66,000 km².

SPAIN: The "Consorcio por la Lucha Antigranizo de Aragon" has the responsibility of managing the seeding operations. The Project is developed in two areas situated in Zaragoza and Teruel (Ebro Valley area).The first area named Valjalón, is in a mountainous region with frequent hailstorms and comprises 30 remote ground generators with an odd 20 km mesh. This target area represents about 6,500 km². The second area, named Bajo Aragón, is placed in a part of Teruel and Zaragoza over a mountainous area and has 21 remote ground generators for seeding operations. The protected area is about 2500 km².

IV. SEEDING AND MEASUREMENTS

FRANCE: Each station is equipped with a manual vortex ground generator which burns a 1% solution of AgI-0.5 NaI in acetone. The hail forecast is made by Météo-France according to a special agreement with the ANELFA. The non-randomized seeding begins at least 3 hours before forecast hailfalls and lasts until the end of the risk period. There are some 20 days with hail warning per year for each local network, an event lasting around 10 hours.

In the ten past years, the 660 stations have released a mean amount of 740 kg of silver iodide per hail season (April-October).

Since 1988, more than 1000 hailpads with a density of 1 hailpad every 8 km have been recording the physical parameters of hailfalls in the area.

SPAIN: Each station is equipped with an automatic ground generator which burns a 1.2 % solution of AgI-0.5 NaI in acetone. The hail forecast is made by the University of León which is in charge of the scientific aspect of the project. The non-randomized seeding begins at least 1 hour before forecast hailfalls and lasts until the end of the risk period. The seeding period starts around May 15 and ends by September 30. There are about 50 days with hail warning per campaign. These past years, stations have released a mean amount of 250 kg of silver iodide per hail season.

100 hailpads with a density of 1 hailpad every 5 km are distributed homogeneously in the area and the network was set up in 2003.

A 5 cm radar in Zaragoza is used both for forecast and storm analysis.

V. FIELD EVALUATION OF THE PROJECTS.

The evaluation of the French and Spanish projects is based on correlations between the running time of the generators and the intensity of point hailfalls as indicated by hailstone number determined with hailpads. A normalization of these two parameters by their daily mean values allows the aggregation of hail days, and the setting-up of larger data samples for a statistical examination in which the random nature of hail becomes less important (Dessens et al., 2006).

The most recent results for 24 major hail days give a 48% decrease in the hail energy of the well seeded cells (Dessens et al., 2009), due to a reduction in the hailstone number in all diameter ranges (FIG.1).

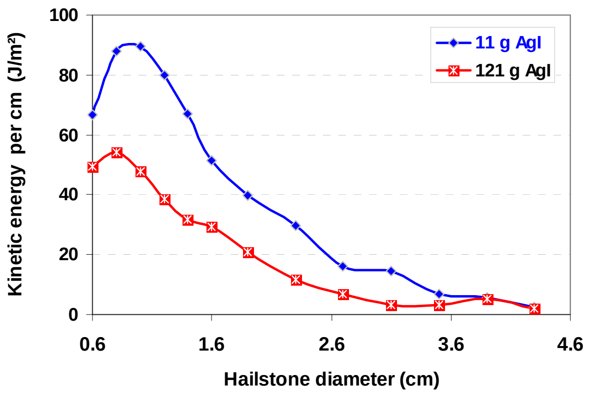

FIG.1. Distributions of the kinetic energy of hailstones as a function of their diameter range for barely and correctly seeded hail cells.

The curves are relative to hailfalls seeded more or less than average on 24 severe hail days. The mean seeding amount of 121 g corresponds to 4.7 generators running during the 3 hrs preceding the hail in a 13 km radius area centred in the cell developing areas. The apparent low seeding effect on hailstones larger than 3 cm may be due to the small case number.

VI. CONCLUSION

The ANELFA and the University of Leon have designed a ground seeding hail prevention system adapted to their respective countries. In France, settlement and farming types allow operation of manual generators, while in Spain the installation of remote controlled generators is necessary. The evaluation of the seeding effect, based on hailfall measurement with hailpad networks as well as with radar observations, shows that the hail prevention ground method is efficient when the generators are operated on time at the right location.

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