SOME COMMENTS ON THE GROSSVERSUCH IV HAIL SUPPRESSION EXPERIMENT

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Abstract. The results of the Grossversuch IV hail suppression experiment have been widely used in assessment of the possibilities of hail control actions, particularly those based on the concept developed in the USSR. Also, some general scientific conclusions from this experiment have been derived.

In our opinion, however, a few failures in organization of this experiment were made which could influence the results obtained. Elaboration of this point of view is the subject of the present note.

1. INTRODUCTION

The Grossversuch IV experiment was organized in central Switzerland in several phases in order to study the possibility of suppressing hail by cloud seeding. The last, fourth phase was performed in order to test the Soviet hail suppression method. The experiment was conducted in the period 1977 - 1981 and went on in 1982 as well. The results of this experiment were widely used in the assessment of present possibilities of hail suppression in general, as well as in making far-reaching decisions concerning existing hail suppression systems. Due to these reasons, the Grossversuch IV experiment will be critically analyzed in this paper.

2. THE AIM OF EXPERIMENT

Some parts of Switzerland, France and Italy regularly suffered hail damage so the interest for hail suppression has been present in these countries for a long time. Hail suppression has been attempted for decades, but all efforts to make it efficient were without demonstrated success. That is why so much attention was paid to the highly effective results claimed in the USSR. So, there was a wish to test the USSR hypothesis in Switzerland.

The hypothesis is based on a theory of a so-called accumulation zone sustained by the updraft where the hail is thought to grow from the embryos of large supercooled raindrops. Artificial production of higher numbers of small hailstones instead of low natural numbers of large ones was called the "embryo competition". Mass seeding was performed by rockets carrying a large quantity of seeding material.

Interest in verifying this hypothesis occurred in other western countries as well. The Americans were the first to establish an experiment (NHRE) to test the hypothesis on which the hail suppression in the USSR is based. This experiment, however, was not a real copy of the Soviet hail suppression system. Because of that and probably due to the lack of accumulation zones in hailclouds in Colorado and some other reasons, this experiment did not answer the basic question (Foote and Knight, 1979). Thus, the possibility of successful hail suppression still remained open.

These were the reasons for organization of a new experiment for the verification of the Soviet hail suppression hypothesis. It was decided that this time the verification of the Soviet method should be done on European storms, and also to apply the original Soviet system. Thus in 1975 it was decided to organize a randomized experiment near Luzern (central part of Switzerland). This project, called Grossversuch IV, was carried out by the Ministries of Agriculture in Switzerland, France and Italy, the Federal Institute for Technology in Switzerland and the French and Swiss Insurance Companies.

3. ORGANIZATION OF EXPERIMENT

The geographical position of the experimental area, as well as the location of weather radars and hail suppression stations, are presented in Figure 1. The experimental area is about 800 square kilometers, rather long in shape, with SW-NE orientation. The area is more than 50 km long and on average about 15 km wide. The largest width is 17.5 km near Wolhusen launching site and the smallest is 10 km in the northeastern part. Five hail suppression stations were located along the longer axis of the area and their ranges covered nearly the whole experimental area. The radar was installed near Luzern so that a 20 km range, which is consider not to be proper for clouds observation, covered almost half the experimental area.

The experiment became operational in May 1977 and lasted till September 1981. A five-year period was used in order to have a sufficient statistical reliability to verify a 60% potential decrease of kinetic energy of hail falling to the ground. A 10 cm wave-length weather radar was used in the experiment, as well as the Soviet hail suppression rockets "Oblako", while the personnel was trained by the Soviet experts.

4. RESULTS OF EXPERIMENT

Before the beginning of the experiment a program of execution and assessment was precisely defined (Federer et al., 1978/79). According to this program, using the Soviet criteria for hail cloud identification and seeding of certain of its zones, there were 76 days with experimental clouds in the five-year period. There were 33 seeded days,

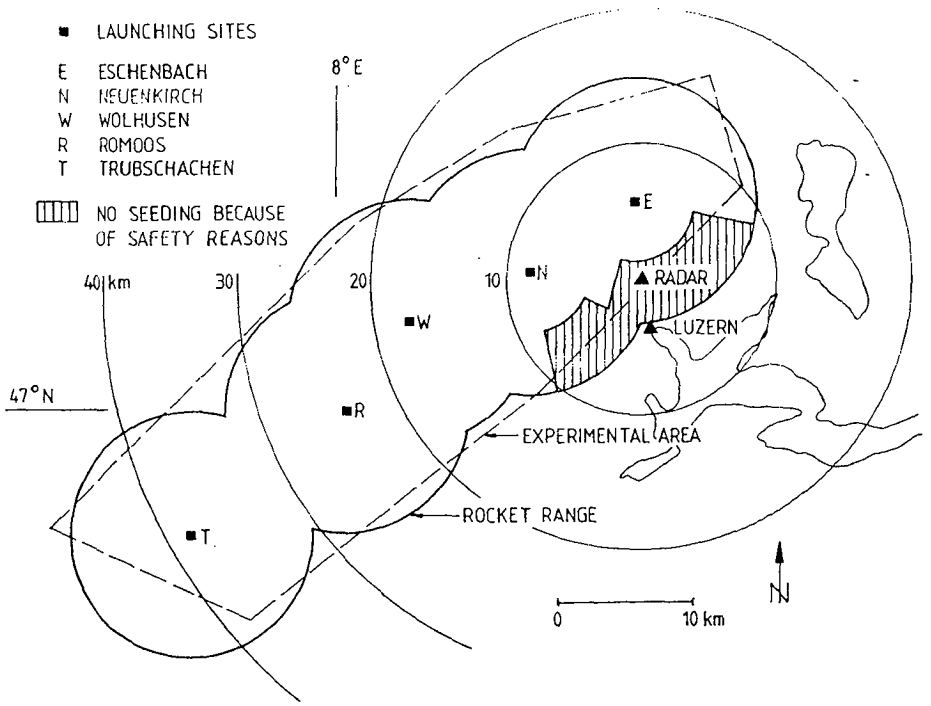

Figure 1. The geographical location of the experimental area of Grossversuch IV with the rocket launching sites. (Federer et al., 1986).

and in 43 days the cloud development was observed without any seeding activity. During the seeded days, a total of 122 individual cells were treated while in the non-seeded days, 94 cells were observed.

Statistical adaptation of these two series of events gave numerous results. Thus, on the basis of radar data, a 90% reliability conclusion was made that the effects of seeding might be anywhere in the range from a 30% decrease of hail-falling kinetic energy to a factor of ten increase. Furthermore, on the basis of the data obtained from a dense network of hailpad (one hailpad per 4 sq. km) a 90 reliability conclusion was made that seeding might cause any effect between a 66% decrease to a 75% of increase of kinetic energy of fallen hail for some hail cells. Thus, various estimates within very wide limits were the result of different statistical methods and tests applied.

On the basis of these and many other results, conclusion was made that the results of the Grossversuch IV experiment did not statistically confirm the Soviet hail suppression method in the central part of Switzerland. These results were considered scientifically credible by numerous experts and other interested persons, so that as a result the reports concerning the efficiency of the Soviet hail suppression and their method of verification became looked at with an increased skepticism.

5. FAILURES OF EXPERIMENT

Since the results obtained in the Grossversuch IV experiment represent not only the effect of applied methodology but the location of the experiment as well, it is necessary to consider whether the experiment was well designed from this point of view. In this regard, we shall consider the geographical position and the shape of the area where the experiment was performed.

In similar experiments in the USSR (Sulakvelidze, 1967; Gayvoronsky and Seregyn, 1969), the experimental area was of a round shape, 35 km in diameter. It was divided into a boundary zone where the occurrence of hail formed outside the experimental area could be expected, and a central zone where the hail could be expected only in case the hail suppression system was not efficient. In case of the Grossversuch IV experiment, the whole experimental area was in fact a boundary zone, since a zone only 15 km wide can suffer damage from hail formed outside that area.

According to the Instruction for Hail Suppression Organization and Activity in the USSR (Bibilashvily, Burcev and Seregyn, 1981, page 18) it was regulated that a boundary zone 6-10 km wide should exist around the protected area, and in case hail clouds moved faster than 50 km per hour this zone should be 12 km wide. Hail clouds are to be treated within this boundary zone in order to prevent hail forming in that zone which might otherwise be carried by the hail clouds into the protected area. This means that seeding effects in the boundary zone are not shown in it, but further downwind, on the protected area; i.e., there is a shifting in space between the seeding activity and the hail reduction.

In hail suppression in Greece, where highly effective results have been recently reported, there is a boundary zone around the protected area (Rudolf et al., 1987). According to the estimation of the executives of hail suppression in Greece, a boundary zone should be 15 km wide as the hailclouds often move with speed of 40 km per hour (Rudolf et al., 1987, page 6).

The experimental area Grossversuch IV by its width strictly corresponds to the boundary zone recommended in Greece. Therefore, one can expect that hail formed outside the experimental area might fall inside it. In the same time, the effect of cloud seeding in the protected area could be found further downwind out of the experimental area Grossversuch IV.

This matter was not considered at all in the program and results of the experiment, so one can get the impression that an unrealistic supposition was used: that the hailstorm clouds which reached the 15 km wide experimental area from the outside delivered the whole quantity of hail they were carrying before entering it, and started a hailstone forming process from the beginning once they entered the 15 km wide zone.

Another point is the orientation of the experimental area given that the area was of an elongated shape. It is not clear what was the idea of the organizers when they designed the orientation of the area. They did not submit any climatological and synoptic analysis that might justify the orientation they had chosen.

For the success of the experiment it is desirable to position the experimental area so that most of the hailstorm clouds have a complete evolution cycle within the area. The Grossversuch IV experiment was apparently not designed to achieve this. Namely, according to climatological data, the predominant mid-tropospheric mean flow over the Grossversuch IV experimental area is NW or W (Palmen and Newton, 1969). This is associated with activity of polar-front jet stream of NW or W direction (Riehl, 1962). For example, studying the orographic effects of the Alps on cold fronts, Petkovšek (1963) identified 75 cold-air penetrations from NW and W directions in 1957 to the Alpine region.

This and some other evidence suggests that it might be expected that most of the hailstorm clouds coming to the experimental area are of the frontal type since the thermal development on the northern side of the Alps is less pronounced. On the other hand, the cold-air penetration from the northwest are probably the most frequent since that direction is topographically exposed to the experimental area shown in Figure 1.

Having this in mind, the northwest direction from which most hailstorm clouds are expected to come coincides with the shorter axis of the experimental area that is only 15 km long. Hailstorm clouds coming with cold-air penetration in many cases already carry formed hail, so the hail will occur in the experimental area regardless of the cloud seeding.

Since the clouds often move across the narrowest part of the area, they stay over it for a short time (15-30 minutes). It is important to emphasize that frontal clouds move much faster than the clouds formed within the air mass. These frontal clouds, with respect to dimensions of their cells, could be seeded by one or two hail suppression stations, at maximum. According to the methodology, if a cloud is not seeded enough, the appropriate hail suppression station should launch one hail suppression rocket every 5 minutes. Finally, if there is any seeding effect, it will in most cases be seen only outside the observed area, due to the narrow shape of the experimental area and fast movement of the cloud. Justification of this expectation is clearly illustrated by the example shown in Figure 2, taken from the paper by Federer et al. (1986).

Southwest to northwest is probably the second most frequent direction of hailstorm cloud movement in central Switzerland. This corresponds to the development of hailstorm clouds in unstable air

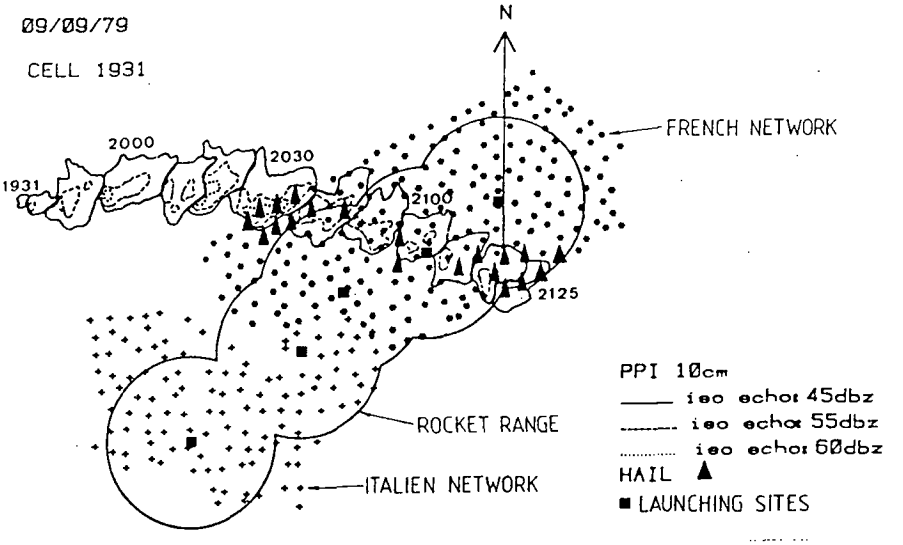

Figure 2. French and Italian hailpad networks covering the experimental area. Radar reflectivity contours (PPI 5°) of hailcell 1931 from 9 September 1979 associated with impacted hailpads. (Federer et al., 1986).

masses in front of a cold air penetration; that is in southwesterly flow. These clouds move parallel to the longer axis of the experimental area.

However, since the experimental area is very narrow, the clouds moving parallel to the longer axis will move more often along one or the other border than over the middle of the protected area. Therefore, it might be expected that these clouds could be only partially treated, since they will be partially within the area and partially out of it. This is also clearly illustrated by the example given in Figure 3 taken from the paper by Federer et al. (1986). We believe that examples represented here in Figures 2 and 3 are selected by Federer et al. as typical cases.

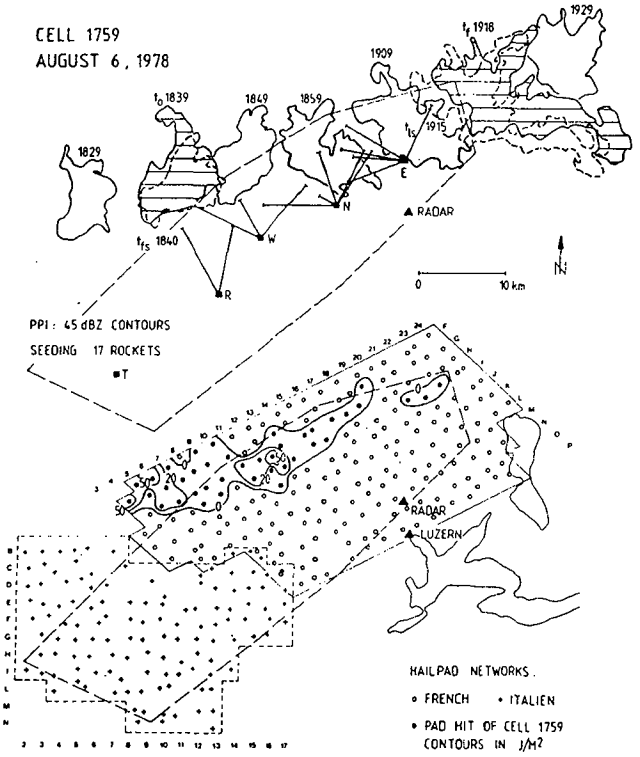

Figure 3. The seeded cell 1759 from 6 August 1978. The 45 dBZ contours in intervals of 10 min are shown, as are the trajectories of the rockets fired into this cell. Two of the fifteen trajectories have to be counted twice because two rockets were launched into the same direction. The figure on the bottom gives the isolines of the kinetic energy measured by the hailpads for 0, 20 and 50 J m^{-2}. (Federer et al., 1986).

6. CONCLUSIONS

This brief examination of the Grossversuch IV experiment indicates that most probably only a small percentage of hailstorm clouds went through a complete life cycle within the observed area so that they could be seeded in the right place and time. That suggests that the Grossversuch IV experiment did not provide the necessary conditions to perform the experiment in an adequate way to obtain the results credible from the point of view of confirming or refuting the efficiency of the USSR hail suppression method. On the other hand, by using a refined statistics the experiments left an impression of a high credibility of their conclusions. We emphasise however that the non-representativity of the data does not justify using the Grossversuch IV experiment results widely and with no reservations in making key feasibility statements and decisions concerning hail suppression.

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