SWISS RANDOMIZED HAIL SUPPRESSION EXPERIMENT, GROSSVERSUCH IV

Bruno Federer

Swiss Federal Institute of Technology, ETH
Zurich/Switzerland

Grossverusch IV is a collaborative project, coordinating under the direction of the Institute for Atmopsheric Physics of ETH in Zurich, the participation of universities and government agencies of France, Italy and Switzerland. Each participating group will contribute its particular expertise to the following defined objective of the project: to test whether a hail suppression method similar to the one proposed by scientists in the USSR, using their high altitude rockets, can successfully be applied in Central Europe, taking into account the climatic and logistic boundary conditions of our regions. The requirements for carrying out such an experiment are 1 a test area with no air-traffic, a high hail frequency, no valuable crops and no people's problem; 2 a 3 cm radar with PPI and RHI for measuring the parameters needed for the seeding criterion; 3 6 launchers for Oblako rockets to cover the area of 100'000 ha (+ 1000 km^2) with sufficient overlap; 4 a 10 cm radar with PPI to measure precipitation quantitatively and; 5 a ground network of hailpads with sufficient density to measure kinetic energy and mass of hail in the test area. The area, which conforms to point 1, lying between Lucerne and Langnau, is depicted in Figure 1 together with the horizontal range of the Soviet rockets and boundaries of the French and Italian ground networks.

In this area an average of 35 thunderstorm days per year occur with 16 being also haildays. This means that in a randomized experiment about 8 seeding days/yr can be expected in the experimental area. If the randomization is made on the basis of 50 % Go : 50 % No-Go days, a duration of 5 years should be sufficient to detect a hail-decrease of 50%, which can be expected if the Russian reports are correct.

In the operational headquarter two radars are used to determine the seeding criterion and to measure the precipitation quantitatively The 3 cm radar, beamwidth 2.4^0 with attenuator is mainly used in the RHI-mode to measure the height and value of the maximum reflectivity of a thunderstorm cell, the height of "accumulation zone" (Z_{max} -10 dBZ) and cloud top and the diameter of the accumulation zone (Kartsivadze and Salukvadze, 1974). These values and the temperatures from a sounding corresponding to these heights are used to calculate in real time a hail probability and the number of rockets to be fired. The firing order is transmitted two minutes after the measurements to a favorably located rocket station by radio.

In seeding an attempt is made to introduce into the accumulation zone 10^5-10^6 active ice nuclei per m^3 of air at the -5^0C level. The Oblako rocket containing 5.2 kg of seeding material will be used. It consists of a head, an engine, a parachute compartment and a remote control mechanism and it costs US $1022. a piece. During the rocket's flight, a time

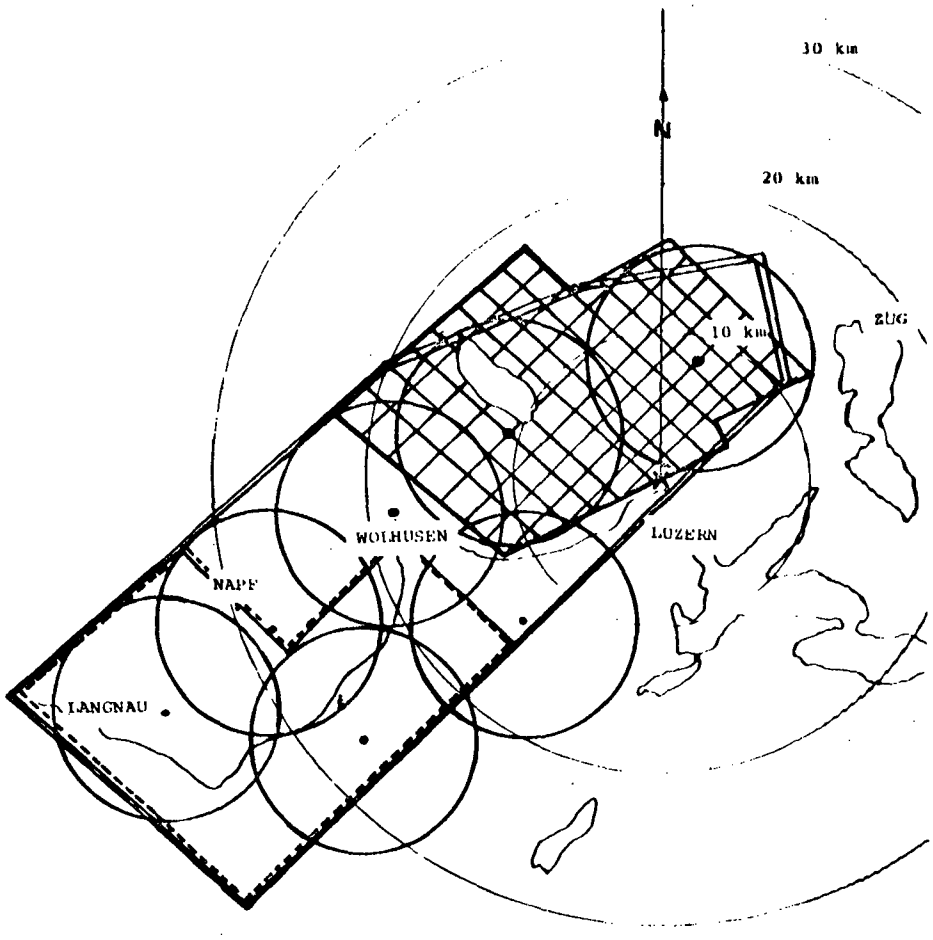

FIGURE 1

Schematic map of the Swiss experimental area (1000 km^2, double line) with hailpad networks and rocket stations. The thick circles are the effective diameters of the Oblako + PGIM-rocket system. The rectangular networks are supplied and serviced by French (North) and Italian (South) workers. Hailpads are spaced by 2.0 km. The Swiss graupelpads, spaced by 500 m are situated along the road from Luzern-Wolhusen to the western end and between Wolhusen and Langnau. The command post with the radars (X) is in the center of the large distance circles.

fuse causes the pyrotechnic composition to begin burning 5 seconds after launching. Ice nuclei are released for 45 sec of the flight and 5.2 kg of pyrotechnic mixture is distributed over ca. 8 km of the rocket path. The rocket launcher TKB-04 is designed to hold 4 rockets. The single-stage PGIM rockets which reach an altitude of 4200 m are used for zones in the immediate vicinity of the launcher and the Oblako which reaches a maximum altitude of 8 km (at 85^0 elevation) is used for distances greater than 2,5 km. The 5.2 kg of pyrotechnic mixture releases about 3 kg of PbI_2-smoke which yields $5 \cdot 10^{15}$ ice nuclei active at -10^0C ($1\text{-}2 \cdot 10^{12}$ active nuclei per g of PbI_2). In 1976 a pyrotechnic mixture containing only 2% of AgI but having an equivalent output of active nuclei will be available in the USSR.

The 10 cm radar, beamwidth 1.6^0 is used to measure precipitation below the freezing level. The PPI is photographed in steps of 5 dBZ provided by an IEC. A continuous effort is made to determine the hail-threshold. If it will be verified that reflectivities above 55 dBZ are hail on the ground and lower reflectivities only liquid precipitation, this threshold can be used to evaluate the suppression effect. The integral

$$\int_{t_o}^{t} \int_{A_{55}} (dBZ_{max} - 55) \, \partial A \partial t$$

for unseeded and seeded storms will be compared and the null hypothesis is that it has the same magnitude in both ensembles. t_o is the time of the first seeding, t the time when a particular contour disappears. The second test variable will be the kinetic energy of hail falling on the 300 hailpads provided and serviced by the French and Italian workers. Kinetic energy should be drastically reduced if the diameters of the hailstones decrease due to seeding. As forecast variables will use a thunderstorm index and the hail probability calculated from a 1-D numerical model.

An alarm day will be declared according to the synoptic situation at 0900 in the morning. If during the day the seeding criterion is met this day will also be a hailday. Seed and no-seed days are declared according to a random table at 0900, when the launching sites will also be altered. Since the decision whether to seed or not is known to everybody the decision of the hailday declarer must be controller. This is done by taking pictures of the PPI during the determination of the parameters of the criterion. Since the accurate targetting of the seeding material is a basic requirement the azimuth and elevation of the launchers at the moment of firing will be remotely controlled with cameras. In this way the experiment will be basically free of subjective influences.

Research will be continued with the instrumented vehicles which measure spectra of raindrops and hailstones and collect stones for various analyses. Whether this supporting research can be extended to other areas depends on the level of commitment with which France and Italy participate in the experiment. Their main interest in coming to Switzerland is to test the French hail core theory with hailpaid and radar data and to see whether it is possible to detect an effect of the heavy and accurately targetted seeding. But the overall goal of this joint effort is to test whether an operation shaped according to the Soviet scheme and using their material, really leads to a damage reduction and could be introduced in regions with moderate air traffic.