HAIL SUPPRESSION IN THE HUDSON VALLEY, 1956 AND 1957*

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ABSTRACT. From July to September 1956 and May to September 1957, a hail suppression program was conducted over the Hudson Valley area in New York, sponsored by The Hudson Valley Crop Services Co-op. Voluntary contributions from apple growers throughout the Hudson Valley, and others, supported operations of the Weather Modification Company of San Jose during both seasons. Equipment included one cloud seeding aircraft, a network of 75 to 77 ground generators, and a 3cm radar system. Within these two seasons, a total of 69 storms moved through the Hudson Valley area and 700 individual cells were logged by the radar. Major hail events were produced by cells embedded in frontal associated squall lines in 1956 and mostly from air mass thunderstorms in 1957. Hail damage was reported over some 1% of the total target area in 1956 and about 6% in 1957.

1. BACKGROUND

The first cloud seeding project, intended to reduce hail east of the Mississippi River, was conducted in the Hudson River Valley of New York, just south of Albany, in 1956 and 1957. This was only a decade after the discovery of dry ice and silver iodide as nucleating agents by Drs. Vincent Schaefer and Bernard Vonnegut, working at the General Electric Research Laboratory in Schenectady, NY. The first operational programs, designed to increase precipitation principally in the Catskill Mountains as an aid to the water supplies of New York City, had been conducted in 1950-51.

In May of 1956 a group, composed principally of apple growers, formed the Hudson Valley Crop Services Co-op. Mr. Walter Schreiber and Mr. Elmore Fraleigh, both of Red Hook, were elected President and Secretary-Treasurer. The Weather Modification Company, a commercial cloud seeding group in San Jose, CA, was hired by the Co-op to conduct operations to reduce hail. The designated project area was roughly 21 x 70 miles in Duchess, Ulster, Columbia and Orange counties (Figure 1).

2. THE WEATHER

The general climate of New York State is of the humid continental type which prevails over most of northeastern United States. However, there is a great diversity within the state itself. The global atmospheric circulation brings a variety of air masses to New York. Cold dry air frequently arrives from the northern interior of the continent, and prevailing clouds from the south and southwest transport warm humid air which has been conditioned by the Gulf of Mexico and adjacent subtropical waters. These two air masses provide the dominant continental characteristics of the climate. A third air mass flows inland from the Atlantic Ocean and produces cool damp weather, but this maritime influence is secondary to the more prevalent air masses from the continent.

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Nearly all storm and frontal systems moving eastward across the continent pass through or in close proximity to New York State. Storm systems often move northward along the Atlantic Coast and have an important influence on the weather and climate in the lower Hudson Valley. Frequently, areas deep in the interior of the state feel the effects of such coastal storms. Lengthy periods of abnormally warm weather can result from the movement of great high pressure systems into and through the eastern United States. When a high pressure system moves just off the Atlantic Coast and becomes more or less stagnant for several days, a persistent air flow from the southwest or south affects the state. This circulation brings the very warm, often humid weather of the summer season.

New York State has a fairly uniform distribution of precipitation during the year. No distinctly dry or wet seasons are regularly repeated on an annual basis. Minimum precipitation occurs in winter with an average monthly accumulation of about three inches in the Hudson Valley. Maximum amounts in summer are about four inches. Of course, variations in precipitation amounts from month to month, or in the same month in different years, can be extreme for any individual area. Almost any calendar month has the potential of having the lightest, or heaviest, monthly accumulation of precipitation within a calendar year at a given location.

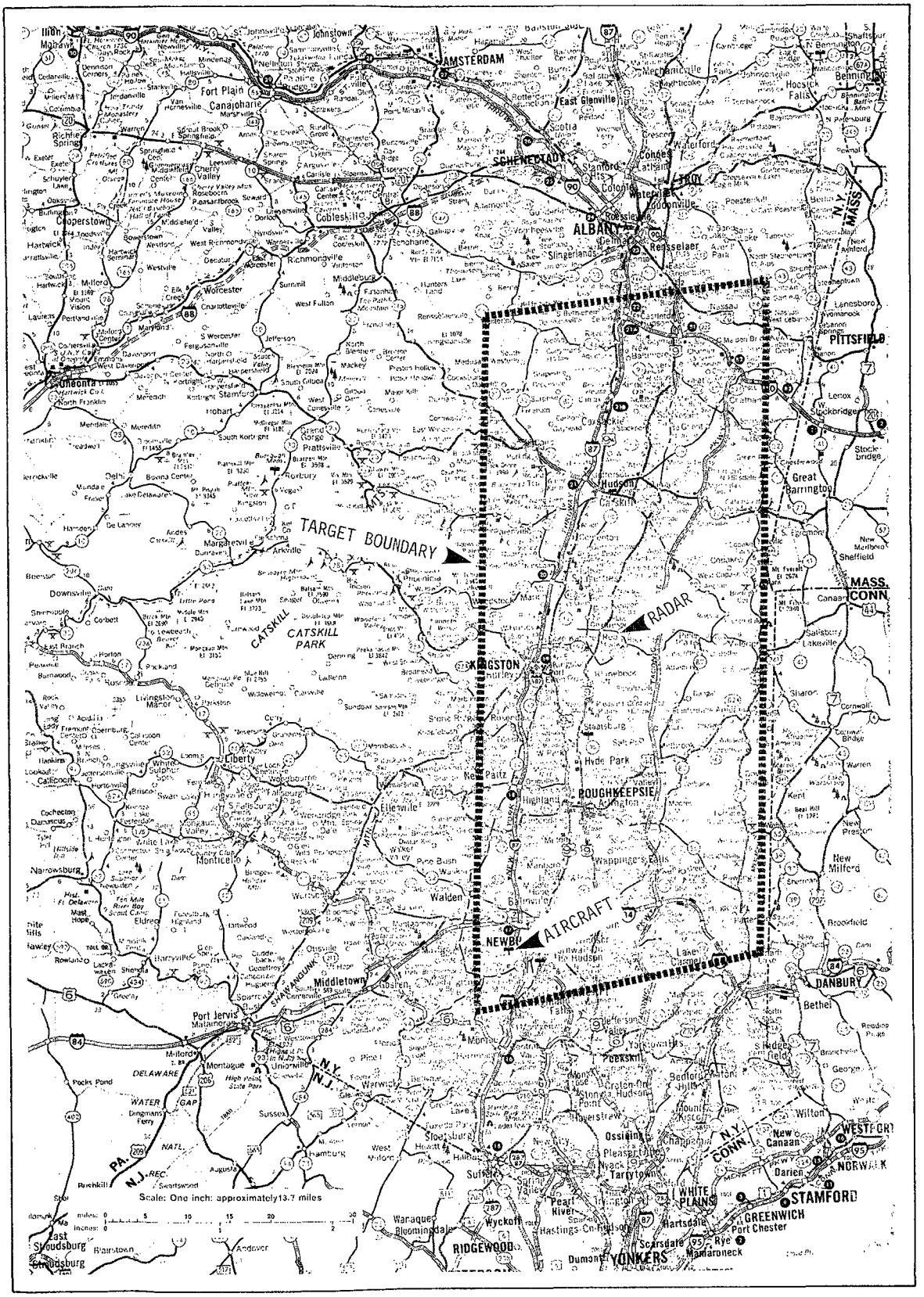
The prevailing wind is generally from the west in New York State, with southwest component during the warmer months. Occasionally a well-developed storm system moving across the continent or along the Atlantic Coast can produce winds strong enough to cause considerable property damage.

Thunderstorms occur on an average of about 30 days per year throughout most of the Hudson Valley. Destructive winds and lightning strikes in local areas are common with the more vigorous warm season thunderstorm. Locally, hail occurs with more severe thunderstorms, but extensive losses to property and crops are less than the damage found in the hail areas of the Great Plains.

"REVIEWED"

FIGURE 1.

Target Boundary
Hudson Valley Hail Suppression Project
- 1956-1957 Season -



Tornadoes are not common, but three or four strike limited, localized areas within the state each year.

The general climate throughout the Hudson Valley supports diversified agriculture including a nationally important production area of apples and other tree fruits. This important Hudson Valley agriculture also includes corn, small grains, grapes and a wide variety of truck crops. Although not a major hail area in the U.S., the Hudson Valley can sustain significant hail damage to crops in some years.

3. PROJECT DESIGN

The original design of the Hudson Valley hail suppression program focused primarily on total operations concepts. No randomization was included because the sponsor desired to minimize hail damage by total application of a technology believed to be effective. However, nothing was implied in this design concept which rejected the desire to acquire data necessary for evaluations and program improvements in future years.

The physical hypothesis for hail suppression was not much different from operational programs as they are conducted throughout the world today; i.e., competition for hail embryo formation and growth through the application of silver iodide as an efficient ice nucleus.

The primary source of silver iodide in both seasons was a network of ground generators established within and adjacent to the lower Hudson Valley area on both sides of the river, essentially from Newburgh on the south to Albany on the north. One P-40 cloud seeding aircraft was based at the airport near Poughkeepsie. A 3 cm weather system (50 kW peak power), with maximum range of 160 statute miles, was located atop Turkey Hill about four miles east of Red Hook and nearly in the geographic center of the target area. Silver iodide nuclei dispensed from both aircraft and ground generators were generated from 5% silver iodide (by weight) in a sodium iodide/acetone solution. Silver iodide use rates were designed for about 50 grams per hour from each ground generator and about 400 grams per hour from an airborne generator.

4. OPERATIONS

4.1 Radar

In 1956 a radar system was considered by some operators as essential to the most effective operation of any weather modification program. Current weather forecasting techniques at that time provided insufficient information for launching cloud seeding aircraft and activating the ground generator network.

The radar system utilized on the Hudson Valley project was a surplus military APS-15 airborne system modified for weather surveillance from a ground level locations. A 30-inch parabolic antenna provided a 3° pencil beam radiation pattern. The 160-mile range was sufficient to detect precipitation echoes well beyond the target area boundary. During 1957, the most distant precipitation cells were logged southwest of the area around Newton, PA, (south of Port Jervis) and near Saratoga Springs, (north of Albany). These echoes were 25 to 35 miles beyond the target boundary.

In 1956 the radar was operated for a total of 384 hours during the various storm periods, an average of about 13.2 hours per storm. In 1957 the radar was operated for about 251 hours during a longer time period, an average of about 6 hours per storm. This wide variation in radar operation per storm period between the two years is explored in the final Section.

4.2 Ground Generators

All ground generators used during the 1956 and 1957 seasons were standard propane/acetone types which burn a solution of silver iodide/sodium iodide/acetone in a propane flame. This mixture of chemical and gas was burned in flame chambers at about 980 C. During operations, the mixture is combined and both the liquid and gas are forced through a spray nozzle to produce liquid solution droplets about 30 micrometers in diameter.

In 1956 a total of 77 ground generators logged 1,632 hours. In 1957 a total of 75 ground generators logged a total of 2,061 hours. In each season an average of 16 generators was operated per storm.

4.3 Aircraft

During both seasons the Hudson Valley Program used a surplus World War II P-40 fighter aircraft, equipped with two airborne liquid fuel silver iodide generators, each using approximately 8 liters per hour of 5% silver iodide (by weight) in the acetone/sodium iodide solution. Propane was used to pressurize the system and as an additional fuel for combustion, much like the ground generators. All airborne cloud seeding was accomplished near cloud base within the strong inflow areas associated with either the air mass type thunderstorms or embedded cells within squall lines.

In 1956 the aircraft flew a total of 28 hours during 14 seeding flights. In 1957 there were 79 hours logged during a total of 37 seeding flights. At the time this program was designed, an aircraft was considered an indispensable supplement in hail suppression work.

5. SUMMARY AND CONCLUSIONS

Thunderstorms logged during the two operational periods differed significantly. In 1956 almost all of the severe storms developed from embedded cells within squall lines associated with cold or occluded fronts. These fronts extended southwest from low pressure areas in southeast Canada or northeast United States, ultimately moving east or southeast across the Hudson Valley. As

in the case of other hail areas, the Great Plains, cold dry air aloft and warm moist air on the surface were the main ingredients for hail production. In 1957 the weather pattern changed dramatically. Very few hail events came from cells embedded in squall lines. Most of the severe activity occurred from air mass thunderstorms not associated with frontal zones, but rather from the extremely unstable conditions of warm moist air on the surface coupled with steep temperature lapse rates. Often the moisture at 500 mb was in strong support of the overall unstable conditions.

An operational summary of events during 1956 and 1957 (Table 1) shows an average of 13.2 hours of radar operation per storm in 1956, and 6 hours per storm in 1957. This supports the belief that air mass storms with shorter life cycles were the dominant type in 1957, while the longer duration cells embedded in relatively slow moving frontal zones were dominant in 1956. Hail suppression technology in 1956 and 1957 did not recognize that the locations of inflow areas important to the formation of hail are very different in each of the two storm types.

The areas with hail, expressed as a percentage of the total area protected, were 1% in 1956 and 6% in 1957. The figure was established after a liberal analysis of the significant hail damage boundaries. Another investigation of the total area covered by precipitation cells having hail potential indicated that precipitation from hail potential cells passed over about 90% of the total target area in 1956 and about 65% of the total target area during 1957.

The outlook on evaluations of operations during the two seasons can best be summarized in quotations from actual reports prepared at the end of the 1956 and 1957 seasons.

> "The evaluation of any weather modification program is always the most difficult portion of the entire operation and necessarily open to the most severe criticism by those directly connected with the program as well as those scientific groups viewing it with more than casual interest from distant points. These evaluation problems are particularly amplified in the case of hail suppression work."

> "The major difficulty in any analysis of this type is to determine how much hail or resultant crop damage might have been expected if the program had not been operated. An answer satisfactory to the scientist or statistician is still not possible at this time."

Table 1. Hudson Valley Hail Suppression Program Operations Summary

WEATHER	1956	1957
Total periods of operation	29	40
Hail bearing storms	16	22
Total cells	282	418
Hail in Target (storms)	4	7
Area hit by hail (% of total area)	1%	6%
GROUND GENERATOR OPERATION		
Number in field	77	75
Total hours logged	1632	2061
Average number per storm	16	16
AIRCRAFT OPERATION		
Total flights	14	37
Total hours	28	79
RADAR OPERATION		
Total hours	384	251
Average hours per storm	13	6