State Water Survey Division
METEOROLOGY SECTION
AT THE
UNIVERSITY OF ILLINOIS

Illinois Institute of Natural Resources

Miscellaneous Publication 59

ASSESSMENT OF SUMMER 1980 WEATHER MODIFICATION EFFORT IN SOUTHEASTERN ILLINOIS

by
Chin–Fei Hsu
and
Stanley A. Changnon, Jr.

October 1981
Champaign, Illinois

ASSESSMENT OF SUMMER 1980 WEATHER MODIFICATION EFFORT IN SOUTHEASTERN ILLINOIS

Chin-Fei Hsu and Stanley A. Changnon, Jr

State Water Survey Division
Illinois Institute of Natural Resources
Champaign, IL 61820

1 INTRODUCTION

During the dry summer of 1978, a group of citizens in southeastern Illinois became interested in the possibility of obtaining additional rainfall through the use of a weather modification program. By the latter part of the summer, they had formed a corporation called Southeastern Rain Incorporated; raised funds; and launched a cloud seeding project carried out by a weather modification firm (Atmospherics Incorporated) in August and early September. No scientific assessment of this hurriedly assembled effort was attempted. The regional interest in this endeavor, and the potential for agricultural benefits deriving from additional summer rainfall in this area of Illinois, led the group to plan for a second summer season project in 1979 and a third in 1980. A local fund raising program was conducted in each year.

Interactions between the local county cooperative extension advisors and staff of the Illinois State Water Survey, which was providing scientific and technical information on weather modification, led to the decision that the State Water Survey would plan and perform an assessment of the rainfall for the 1979 and 1980 projects. This would provide information to local groups and state officials. This effort would also test the evaluation techniques and concepts being evolved on an NSF-sponsored project concerned with operational projects (Hsu et al., 1981; Hsu and Chen, 1981). The 1980 "target area" (Fig. 1) of about 2600 square km was defined as that area in which funds were raised and was identified as the site for cloud seeding operations, based upon the contract between Southeastern Rain Inc., and Atmospherics Incorporated. The target area embraced most of Saline and Gallatin Counties, and parts of Franklin, Hamilton, White, and Williamson Counties (Fig. 1). No dense raingage network like that in 1979 was established in 1980.

Results from evaluating the 1979 cloud seeding effort were reported elsewhere (Changnon and Hsu, 1980; Hsu and Changnon, 1981). The results reported here pertain only to the 1980 project. It is important to appreciate that the assessment of 1980 summer rainfall, which involved comparisons of the rainfall patterns and amounts in the target (seeded) area with those in the surrounding (non-seeded) areas, should not lead to the inference that the rainfall in the target area was either increased or decreased because of seeding. We *stress* that it is very unlikely due to the great natural variability of summer rainfall in southern Illinois, that one could decide whether cloud seeding during a period of a few weeks altered the rainfall or not.

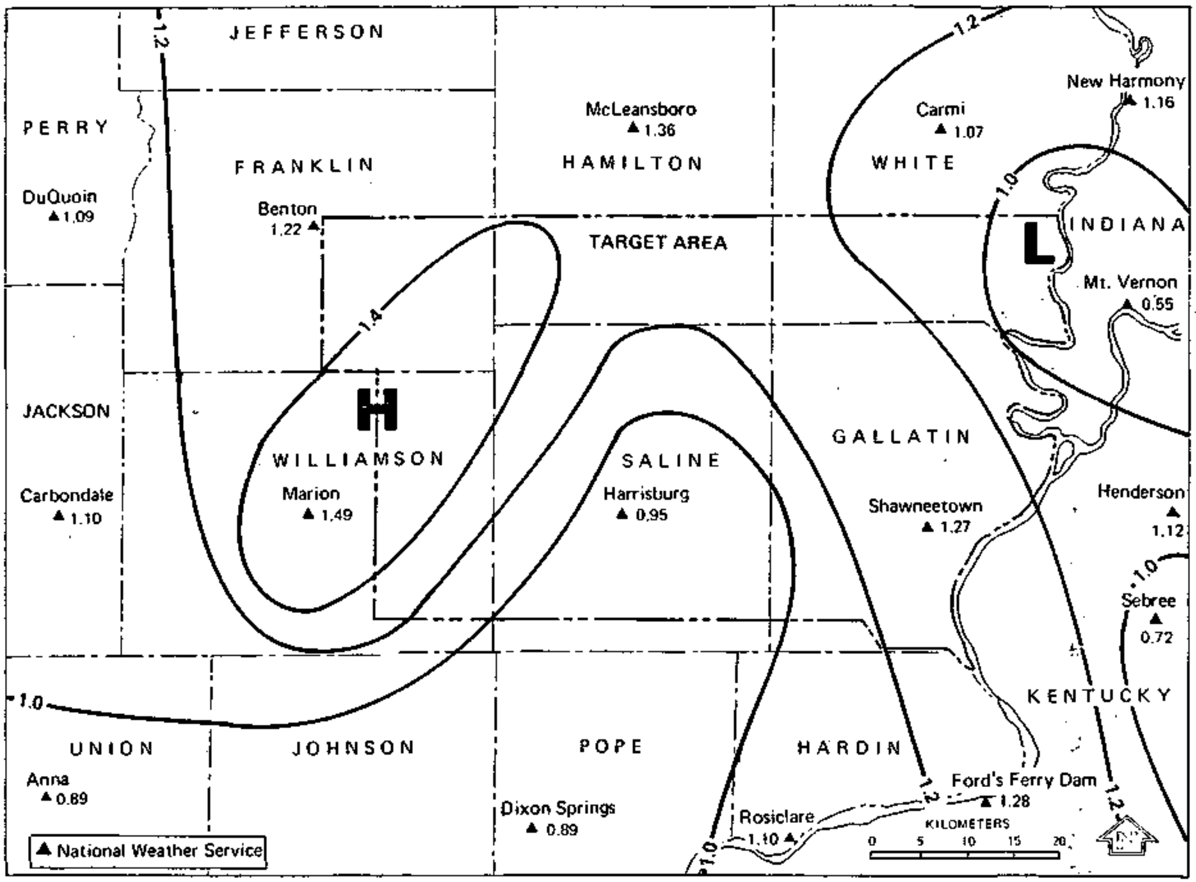

Fig. 1. Rainfall ratio pattern for 1980 rainfall compared to 1949-1978 average.

Rather, these statistics are presented with these *cautions* to achieve the following objectives: 1) to describe the rainfall in and around the target area, and 2) to compare three of many statistical evaluation techniques being investigated by the authors (Changnon et al., 1980). The second objective is emphasized here in interpretating the subsequent results. From a scientific standpoint, these data will become a part of a larger bank of data, including radar echo data and cloud seeding operational data for 1980 (and other years and other projects), which later may provide sufficient information to allow some assessment of whether cloud seeding in Illinois actually 1) altered clouds and their behavior, and 2) altered rainfall *with some high degree of certainty.*

2 DATA

The official raingages of the National Weather Service in the area are shown on Fig. 1, each denoted by a small triangle. Typically, there is only one such station per county in this region of Illinois, Indiana and Kentucky. Rainfall at these National Weather Service stations was measured once daily, typically at 0700 CDT. Data were collected from late June until late August. The daily rainfall data of the National Weather Service observations were available in the published records of that agency.

The cloud seeding company was available and ready to seed clouds from 23 June through 2 July 1980 (period 1), and then, after a pause because local conditions were too wet with lowland flooding, the operations were available again from 14 July through 20 August 1980 (period 2). Thus, cloud seeding could have been conducted, if suitable weather conditions were available, for a total of 48 days within this 23 June-20 August period. This period of 23 June-2 July and 14 July-20 August was subsequently called the operational period.

A chronicle of weather events which occurred during the 1980 operational period is shown in Table 1. There was 1 seeded (S) day during period 1, and 15 seeded days during period 2. Three days were designated as "severe storm" (X day) when a severe storm warning was issued. There were 2 C days when the aircraft was aloft for cloud surveillance but no seeding was conducted.

3 ANALYSIS OF SURFACE PRECIPITATION

A time-honored approach to rainfall evaluation of a specific area has been to compare the rainfall in the area of interest with that in regions surrounding it. The surrounding regions are typically called "control areas" for comparison with the "target area". The only NWS gages in the target area were at Harrisburg and Shawneetown. Prior to the seeding project, control areas to the north, west, south, and east of the target area were defined, and

Table 1• Chronicle of Weather Events That Occurred in the 1980 Seeding Operations
(S: seeded; C: not seeded, with airborn cloud observation; X: severe weather warning; U: suspended)

	0	1	2	3	4	5	6	7	8	9
					June					
20				S					C	X
30										
					July					
0				U	U	U	U	U	U	U
10	U	U	U	U						
20		S					S	S		
30										
					August					
0		X	X			S	S	S		S
10		S		S	S			S	S	C
20										

each included two to five National Weather Service gages. They were areas of a size equivalent to the target area, and each had the same general raingage density of approximately one gage per 1300 square km. The grouping of these gages into various controls appears in Appendix A. The station values in the target area and in each of the four control areas, were combined to form areal averages. For example, the north control area comprised the rainfall values from the station gages at McLeansboro, Carmi and New Harmony.

Assessemnts using only National Weather Service station data from 1949 to 1980 (excluding 1979) in and around the target area were pursued. All NWS stations used possess continuous rainfall records during the 31-year period. The 1979 data were excluded from the present evaluation mainly because seeding also occurred in 1979 and the operational periods were different in 1979 and 1980. In the following, we first present the 1980 areal rain comparison; then the areal rain comparison of each year in 1949—1980; historical comparison using individual National Weather Service station values; historical comparison using areal rains; and finally historical target-control comparison by using three evaluation techniques.

3.1 Target-Control Comparisons of 1980 Areal Rains

Rainfall totals were defined to be that total during the operational period (June 23 to July 2 and July 14 to August 20). Total rainfall values at each area for the seed and no seed occasions during period 1 (23 June-2 July) and period 2 (14 July-20 August) as well as the entire period are shown in Table 2.

During the 1980 operational period,, the target area received 5.48 inches on the seeded occasions (Table 2c), and the average rainfall for all 4 control areas on the seeded occasions was 3.82 inches. Their difference, labeled T-C (or target minus control), was equal to +1.66 inches. This difference, expressed as a percent of the control average rainfall, represented 43.5% more rainfall in the target area on the seeded occasions than in the control areas.

Similar comparisons for the two individual periods appear in Tables 2a and 2b. They show that the target area also received more rainfall on the seed occasions during each period than did the average of the four control areas. The rainfall increases on seeded occasions for periods 1 and 2 were respectively +.35 and +1.31 inches; and the percentage increases were respectively +20.0%, and +63.3%. However, these values cannot be used alone as indication of any seeding effect, as a certain "selection bias" may have been introduced by the seeding operator in favor of more natural rainfall on occasions chosen for seeding. More reliable and more bias-free evaluation involves use of the historical target-control comparison, which is discussed below.

On no-seed occasions, the target area received less rainfall in either period than did all four control areas, except the north and east control during period 1, and the south control during period 2. The differences (T-C) between the target and the averaged control represented 0.36, 0.69, and 1.05 inches less respectively in periods 1, 2 and the combined period; or -31.0%, -43.9%, and -38.5% respectively.

Table 2. Areal Rainfall in the Target and Control Areas, 1980

	North	West	Control South	East	Control Avg	Target Area	T-C	% Increase
			a. 23 June-2 July (Period 1)					
Seed	2.37	1.13	2.50	.98	1.75	2.10	+.35	+20.0%
No Seed	.33	1.75	1.90	.67	1.16	.80	-.36	-31.0%
Total	2.70	2.88	4.40	1.65	2.91	2.90	-.01	-0.3%
			b. 14 July-20 August (Period 2)					
Seed	2.07	2.32	1.55	2.35	2.07	3.38	+1.31	+63.3%
No Seed	1.49	2.82	.50	1.48	1.57	.88	-.69	-43.9%
Total	3.56	5.14	2.05	3.83	3.64	4.26	+.62	+17.0%
			c. Period 1 and Period 2 Combined					
Seed	4.44	3.45	4.05	3.33	3.82	5.48	+1.66	+43.5%
No Seed	1.82	4.57	2.40	2.15	2.73	1.68	-1.05	-38.5%
Total	6.26	8.02	6.45	5.48	6.55	7.16	+.61	+9.3%

Rainfall totals in the target indicated that there was .01 inch less rain (-.30%) than the surrounding controls during period 1; on the other hand, there was .62 inches more rain (17%) in the target during period 2.

The total 1980 rains (Table 2c) show that the rainfall in the target area (7.16 inches) easily exceeded the averages of four control areas (6.55 inches), and was larger than each control areal rainfall except that of the west control. The T-C difference was +.61 inches, or +9.3%. Thus our first effort of assessment revealed that there was a "crude" rainfall increase, though small, in the target area.

3.2 Target-Control Comparison by Year

To further assess the 1980 target-control comparison, the five areal rains in each year of 1949-1980 (except 1979) were ranked so that the lowest rain was assigned rank 1, and so on (Table 3). The mean of the 30 historical ranks in the target area was 3.33, and those in the north, west, south, and east controls were 2.35, 3.08, 3.13, and 3.10 respectively. The ratio of the 1980 rank to the mean historical rank in the target area was 1.20. This rank-ratio was the second largest among the five rank-ratios. The west control had the largest rank-ratio (2.60), which indicated that its 1980 rain was much above its historical average. Similarly, the rank-ratio of the east control (.32) indicated that its 1980 rain was much below its historical mean, a phenomenon contrary to what was observed in the east control area during the 1979 seeding operation (Hsu and Changnon, 1981). Then, the east control had heavy rains.

3.3 Historical Comparison Using Individual NWS Stations

For each NWS gage, a ratio of 1980 rain to the 1949-1978 averaged rain was calculated for periods 1, 2, and the combined period (Table 4). It is obvious that rainfall during period 1 in 1980 was much above historical average for most gages except 2 gages, namely, Mt. Vernon and Sebree, both in the east control. The above-normal rain in the target during period of 1980 was probably due to a general meteorological persistence of the above-normal rainfall over the entire region, rather than due to the 1-day seeding operation during this period.

On the other hand, rainfall during period 2 of 1980 was below the historical average for most gages except four gages, all of which were only slightly (5-20%) above the historical average. One gage with slightly above-normal rainfall was located at Shawneetown (inside the target). The rain during period 2 of 1980 might conceivably have resulted from the seeding, bearing in mind that there were 15 days being seeded during this period of 1980. However, rains at Harrisburg, the other target gage, during the same period were much below the historical average. The other three gages with above-normal rains during period 2 were located to the west and north of the target area.

Table 3. Rank of Areal Rains in Each Year*

Year	Control North	Control West	Control South	Control East	Target
1949	2	3	1	5	4
1950	1	5	3	2	4
1951	3	2	4	1	5
1952	5	4	1	2	3
1953	1	5	3	2	4
1954	5	2	1	3	4
1955	2	3	5	1	4
1956	3	5	1	2	4
1957	2	1	4	3	5
1958	2	4	5	3	1
1959	1	2	4	5	3
1960	4	2	1	5	3
1961	5	3	2	1	4
1962	3	1	4	5	2
1963	1	5	4	2	3
1964	2	1	5	3	4
1965	5	4	1.5	1.5	3
1966	1	5	4	2	3
1967	1	2	4	5	3
1968	4	3	2	5	1
1969	1	5	4	2	3
1970	1.5	1.5	3	5	4
1971	2	3	5	4	1
1972	1	5	4	2	3
1973	2	4	3	5	1
1974	1	2	5	3	4
1975	1	3	2	4	5
1976	3	4	2	1	5
1977	1	2	3	4	5
1978	4	1	3	5	2
1980	2	5	3	1	4
1949-1978 Mean	2.35	3.08	3.13	3.10	3.33
Ratio of 1980 to historical	.85	2.60	.96	.32	1.20

* Smallest value was assigned rank 1 and so on.

Table 4. Ratio of 1980 Rain to Historical Rain for Each NWS Station

Station	Area	Period 1	Period 2	Combined Period
Harrisburg	Target	2.48	.61	1.04
Harrisburg Disposal Pl.	Target	2.11	.46	.86
Shawneetown	Target	1.77	1.11	1.27
Carmi	North	1.78	.89	1.07
McLeansboro	North	2.31	1.12	1.36
New Harmony (IN)	North	2.66	.66	1.16
Anna	West	1.97	.59	.89
Benton	West	1.31	1.19	1.22
Carbondale	West	2.75	.51	1.10
DuQuoin	West	1.60	.94	1.09
Marion	West	3.04	1.05	1.49
Dixon Springs	South	2.86	.34	.89
Fords Ferry Dam (KY)	South	3.93	.53	1.28
Rosiclare	South	3.38	.44	1.10
Henderson (KY)	East	2.46	.77	1.12
Mt. Vernon (IN)	East	.70	.51	.55
Sebree (KY)	East	.87	.68	.72

Corresponding ratios for the combined periods (Table 4) did not reveal results as clear-cut as each individual period. It can be seen that there was a region of high rainfall ratios located to the west of the target area (Fig. 1). The 1980 total rainfall amount of Harrisburg (inside the target) was close to its historical average, with a ratio of 0.95; while the 1980 total rainfall amount of Shawneetown was above its historical average, with a ratio of 1.27. However, a band of high rainfall ratios also occurred to the west, north and southeast of the target area, which discounted the significance of this above-normal rainfall ratio at Shawneetown.

3.4 Historical Comparison Using Areal Rains

The ranked areal precipitation values of 1949-1978 and 1980 for each area are shown in Table 5. The ranks of 1980 rainfall values for the north, west, south, east controls and the target were respectively 20, 26, 20, 16, and 20. In general, the 1980 areal rainfall was above the median values (16th observation). the rank of the target rainfall, 20, was not statistically significant and was rather close to the averaged rank of the four control areas' rainfall, 20.5; and it was not as extreme as that, 26, in the 1979 analysis (Changnon and Hsu, 1980).

3.5 Historical Target-Control Comparison

In the following, rainfall values from 1949 to 1978 were used as "historical control" to compare with the 1980 rainfall values. Three statistical evaluation techniques were chosen before the actual evaluation efforts were undertaken; namely, the principal component regression (PCR), multiple regression (MR), and double ratio (DR). The choice of evaluation techniques was largely based upon findings from our NSF-funded research, which investigated performance of various statistical-physical techniques in evaluating operational weather modification projects (Hsu, 1979b; Changnon *et al*., 1980; Hsu and Chen, 1981; Hsu *et al*., 1981). The decision to use three techniques undoubtedly will raise the question of multiplicity, but the evaluation efforts are basically exploratory rather than to confirm the effectiveness of cloud seeding over southeastern Illinois.

3.5.1 Principal Component Regression.

First, a principal component analysis for the four control areas using 1949-1978 historical data was performed and the first component was retained, which was used in turn as an independent variable to run a regression on the target area value. The (historical) principal component regression equation was used to forecast precipitation in the target area, which in turn was compared to the observed 1980 target area precipitation. The use of one component in the regression is also due to findings from our research (Hsu and Chen, 1981; Hsu *et al*., 1981). The resulting forecasted rain for the 1980

Table 5. Distribution of Ordered Areal Precipitation, 1949-1980 (Excluding 1979)

No.	North	West	South	East	Target
1	1.53	1.40	2.26	2.19	1.84
2	2.49	1.83	2.67	2.67	2.81
3	2.72	2.62	3.19	3.21	3.17
4	3.01	3.14	3.22	3.35	3.22
5	3.08	3.92	3.50	3.55	3.41
6	3.36	4.00	4.08	3.67	3.53
7	4.00	4.37	4.18	3.98	3.70
8	4.09	4.45	4.30	4.07	4.04
9	4.15	4.46	4.45	4.60	4.29
10	4.45	4.58	4.82	4.64	4.46
11	4.48	4.93	4.85	4.92	4.48
12	4.53	5.04	4.98	5.30	4.70
13	4.61	5.13	5.07	5.31	4.99
14	4.92	5.43	5.13	5.33	5.97
15	5.17	5.47	5.18	5.34	6.28
16	5.21	5.74	5.87	5.48*	6.36
17	5.32	5.75	6.04	5.76	6.38
18	5.51	5.93	6.35	5.95	6.39
19	5.65	6.05	6.44	6.09	7.09
20	6.26*	6.57	6.45*	6.44	7.16*
21	6.37	6.96	6.48	6.51	7.38
22	6.42	7.06	6.82	7.07	7.47
23	6.46	7.36	7.06	7.46	7.56
24	6.49	7.59	7.14	7.69	7.77
25	6.86	7.90	7.47	7.82	8.02
26	6.91	8.02*	7.94	7.82	8.07
27	7.64	8.65	8.79	8.32	8.41
28	8.18	8.89	8.92	10.17	8.75
29	8.35	10.29	9.46	10.35	9.38
30	8.85	10.57	11.43	10.68	11.29
31	10.01	10.58	12.77	13.15	12.17

*1980 value

target area by using the 1949-1978 PCR equation was 6.88 inches. The difference between this and the actual rain value (7.16-6.88), gave an estimated rainfall increase of 0.28 inches, or +4.1%.

To assess the significace of this rainfall increase, a re-randomization (repeated) principal component regression was pursued. (For more information on re-randomization testing, see Hsu, 1979a; Gabriel and Hsu, 1980, 1981.) One year from 1949 to 1978 was randomly selected as a hypothetical seeded year, and all other years (including 1980) were used as historical "control" years. Then a principal component regression was performed on this seeded-historical data, and a forecasted precipitation was obtained, from which a rainfall increase was computed. This process was repeated by selecting another year as "seeded" and so on, until a distribution of rainfall increases was obtained. The randomization distribution of rainfall increases, 31 in all, was obtained and is shown in a "stem-and-leaves" display (Table 6a). Among these estimated rainfall increases twelve were larger than the 1980 value (indicated by an asterisk in the Table), and the significance was thus 0.42 (=13/31)- That is, the chance that this increase is due to nature (rather than to cloud seeding) is nearly half. But again, whether the cause of this is due to cloud seeding or not can not be completely ascertained.

3.5.2 Multiple Regression.

The four control areas values were used as independent variables to regress on the target area values using 1949-1978 data. The resulting (historical) regression equation was used to forecast 1980 target area rainfall. The forecasted value, 7.14 inches, and the difference between this and the actual 1980 target area rainfall (7.16-7.14), give an estimated rainfall increase of 0.02 inches, or 0.3%. A randomization multiple regression was performed similarly to that using principal component regression. Table 6b shows a "stem-and-leaves" display of the randomization distribution of estimated rainfall increases using MR. The significance level i3 found to be 0.48.

3.5.3 Double Ratio.

For 1980 as seeded year, a double ratio is calculated as follows:

$$DR = T_sC_{ns}/T_{ns}C_s$$

where T_s is the rainfall total of the target area in the year 1980, T_{ns} is the averaged rainfall total of the target area in the non-seeded years (1949-1978), and similarly for C_s and C_{ns}. A randomization double ratio procedure was performed, and a "stem-and-leaves" display of the randomization distribution is shown in Table 6c. The double ratio corresponding to 1980 is 1.045, or an estimated rainfall increase of 0.31 inches, and the significance level is 0.39.

Table 6. Randomization Distributions of Estimated Rainfall Increases

3a Principal Component Regression (1 PC)

Stem	Leaves	Cumulative No.	Cumulative %
-2.00	03,95	2	6.5
-1.00	00,34,55,71,97	7	22.6
-0.00	04,15,18,20,29,51,54,56,98	16	51.6
0.00	03,05,28*,46,50,68,75,92,93	25	80.6
1.00	10,19,26,99	29	93.5
2.00	45,76	31	100.0

3b Multiple Regression

Stem	Leaves	Cumulative No.	Cumulative %
-3.00	29	1	3.2
-2.00		1	3.2
-1.00	10,34,40,66,86,96	7	22.5
-0.00	25,46,46,52,54,68,84,96	15	48.4
0.00	01,02*,16,30,51,59,64,78,82	24	77.4
1.00	16,34,49,50	28	90.3
2.00	48,61,77	31	100.0

3c Double Ratio

Stem	Leaves	Cumulative No.	Cumulative %
.400	69	1	3.2
.600	50	2	6.5
.700	32,73,79,83	6	19.4
.800	34,55,90,94	10	32.3
.900	20,47,66,76,80,87,99	17	54.8
1.000	05,34,45*,94	21	67.7
1.100	40,46,73,89,89	26	83.9
1.200	03,47,69,91	30	96.8
1.300		30	96.8
1.400	92	31	100.0

*1980 value

Note that the above three evaluation techniques give non-identical significant levels to their respective 1980 estimated rainfall increases. All the estimated rainfall increases using PCR, MR or DR are not statistically significant.

4 SUMMARY

The target area received more rainfall (based on only three gages to determine the area average) during the 1980 48-day operational period than did the surrounding areas. This was particularly true when one compared the target area rainfall with the surrounding control rainfall based solely on the seed rain occasions. Investigation of the 1980 areal rainfall in the target area, as compared to the control areas, reveals an estimated rainfall increase of 44% on seed occasions, and an estimated rainfall decrease of 39% on no seed occasions.

However, the 1980 rainfall data alone cannot be construed as evidence of any cloud seeding effect. The differences when one compares the seed rainfall values with the no-seed values, particularly as revealed in Table 2, do suggest a localized high in the target area on seed occasions which was not present on no-seed occasions. As one final caution, one expects that cloud seeding in the target area would be attempted under conditions that were locally favorable for heavier rainfall there, and a "selection bias" might have occurred.

A more bias-free evaluation using surrounding control areas and historical data shows a non-significant rainfall increase in the neighborhood of 4% - 5% in the target area during the 1980 cloud seeding period. The probability that this is due to chance is approximately .40.

5 ACKNOWLEDGMENTS

We wish to acknowledge the assistance of Phillis Stone who carefully compiled the rain data and segregated it into discrete rain occasions, and Julia Chen for providing computer programming assistance. John Brother aided with the drafting of the illustration. Part of this research was done under the support of grant ATM 79-05007 from the National Science Foundation. The findings do not necessarily reflect NSF beliefs or policy.

6 REFERENCES

Changnon, S. A., Jr., K. R. Gabriel, and C. F. Hsu, 1980: Evaluating operational cloud seeding projects. Third WMO Scient. Conf. on Wea. Mod., Clermont-Ferrand, France, 21-25 July, 494-499.

---, and C. F. Hsu, 1980: Assessment of summer 1979 rainfall in southeastern Illinois with special reference to weather modification efforts. Misc. Publ. 56, Illinois State Water Survey, Champaign, IL, 18 pp.

Gabriel, K. R., and C. F. Hsu, 1980: Power studies of re-randomization tests. Third WMO Scient. Conf. on Wea. Mod., Clermont-Ferrand, France, 21-25 July, 507-513.

---, and C. F. Hsu, 1981: Evaluation of the power of re-randomization test, with application to weather modification experiments. Submitted to J. Amer. Statist. Assoc.

Hsu, C. F., 1979a: Two methods of computing statistical powers with application to weather modification (preliminary results). Proc. Statist. Comp. Sec., Amer. Statist. Assoc, 243-246.

---, 1979b: Monte Carlo Studies of statistical evaluation techniques for weather modification projects. Seventh Conf. on Inadv. and Planned Wea. Mod., Amer. Meteor. Soc, Banff, Canada, 8-12 Oct., J3-J4.

---, and J. Chen, 1981: Performance comparison of statistical techniques in evaluating weather modification projects. Eighth Conf. on Inadv. and Planned Wea. Mod., Amer. Meteor. Soc, Reno, Nevada, 5-7 Oct., 128-129.

---, and S. A. Changnon, Jr., 1981: Assessment of summer of 1979 weather modification efforts in southeastern Illinois. J. Wea. Mod., 13(1), 132-140.

---, S. A. Changnon, Jr., F. A. Huff, and K. R. Gabriel, 1981: The assessment of statistical-physical techniques for evaluation of weather modification operations. Final Report, NSF ATM79-05007, Illinois State Water Survey, Champaign, IL.

APPENDIX A

NWS Stations Used in the Evaluation of 1980 Southeastern Illinois Cloud Seeding Project

Area	Station	Index	County	Latitude	Longitude
Target	Harrisburg	3879	Saline	37 44	88 32
	Harrisburg Disposal Pl	3884	Saline	37 45	88 32
	Shawneetown	7859	Gallatin	37 43	88 11
North Control	Carmi	1296	White	38 10	88 12
	McLeansboro	5515	Hamiton	38 05	88 32
	New Harmony (IN)	6179	Posey	38 08	87 56
West Control	Anna	0187	Union	37 28	88 14
	Benton	0608	Franklin	38 00	88 55
	Carbondale	1265	Jackson	37 44	89 12
	DuQuoin	2483	Perry	37 59	88 14
	Marion	5342	Williamson	37 44	88 57
South Control	Dixon Springs	2353	Pope	37 26	88 40
	Ford Ferry Dam (KY)	2961	Crittendon	37 28	88 06
	Rosiclare	7487	Hardin	37 25	88 21
East Control	Henderson (KY)	3762	Henderson	37 45	87 38
	Mt. Vernon (IN)	6001	Posey	37 57	87 53
	Sebree (KY)	7234	Webster	37 36	87 32