EVALUATION OF THE McLEAN COUNTY RAINFALL MODIFICATION PROJECTS IN 1977 AND 1978

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INTRODUCTION

A central area of research and services of the Atmospheric Sciences Section of the Illinois State Water Survey is planned weather modification. As part of our broad program, we attempt to evaluate, when time and skilled personnel permit, the efforts of certain operational weather modification projects in Illinois (Changnon and Towery, 1977). These attempts help us develop better evaluation capabilities and help us learn whether various modification techniques may work in Illinois. The results of our limited evaluations are also useful to Illinois citizens interested or involved in weather modification.

'This report discusses the highlights of an evaluation of the McLean County Project. Although this project is as yet a very limited, in time, effort to enhance rainfall in central Illinois, it has the portent for future longer operations and thus a more meaningful evaluation. Cloud seeding occurred over McLean County in two 1-month summer periods, one in 1977 and one in 1978. According to the project permit filed with the State, all seedablc rain events (save those weather periods forbid by State law as too dangerous for modification) were to be seeded by project aircraft using one or both common seeding techniques (Agl released at cloud base or at mid-cloud levels).

The written records of the operations in McLean County are adequate, under State Law, to define and describe the daily operations. The sponsors

and county extension service worked together at our suggestion to install an excellent fencepost type raingage network to help define the rainfall patterns inside the county. There were 107 gages with,data available in 1977 and 90 gages in 1978. These rain data, coupled, with that routinely collected by the National Weather Service at locales in and around McLean County are available for evaluation.

However, one of the key data sources for evaluation, the photographs of the project radar scope, has been a major problem. A major evaluation approach, as used in a 5-county project in central Illinois (Changnon and Towery, 1977), involves the use of radar echo histories coupled with the detailed in-target rainfall data. Unfortunately, the radar scope photographs from the McLean County project in 1977 were so poor they could not be interpreted. The photographs in the 1978 project were of better quality but there were no suitable photographic data on 3 of the 10 seeding days and on most of the other 7 days, camera operations were so iimited (turned on too late or off too soon) that the desired echo histories (birth to death of echoes, both those seeded and those not seeded) could not be followed for most echoes. This posed a considerable dilemma. However, a desire to still attempt some form of evaluation led us to try a limited echo investigation.

Two Key Factors

The reader must appreciate two factors relevant to evaluating these two, 1-month modification projects.

First, evaluations of two 1-month seeding projects, even with the best data, can not furnish hard proof of rain modification and the degree of rainfall change indicated is likely not to be statistically significant. The

sample of seeded events is too small to make meaningful evaluations of sub-divisions of the data such.as results for squall line storms, cold front storms, etc. Further, the lack of quality of available,radar, data for much of the two seeding periods limits our analyses so that the: results are-much less conclusive than they might; have been. At best, the results could only be indications of seeding induced effects and must be, considered as preliminary.

The. second fact that any reader should realize (given the above problems) is that practically any. evaluation of an operational seeding project such as this one rests on some form of comparison of seeded cases with nonseeded cases.' This is often called target (seed) versus control; (nonseeded) comparisons. Basically this target (T) versus control (C) comparisons can be done in space or time. That is, the rain in the target area, say McLean County, during a seeded period could be compared with that either in prior years (a time, or historical control) or in adjacent unseeded areas (area control).

Target-control comparisons and evaluation can be improved upon in operational seeded projects if definitive operational seeding criteria are used'. That is, "when weather and cloud conditions are of type Y, we will seed by approach X; and when conditions are type A, we will seed by appraoch B," etc. The seeding criteria used in the McLean County effort were not sufficiently defined and recorded on a day-to-day basis; hence, without this type of specification, the evaluation could not be improved.

Data and Evaluation Approaches Used

The limitations due to the generally poor radar data (and the lack of well specified seeding criteria) led us to use two data sets that are far less than ideal. First, we used the rainfall data, as measured solely by the National

Weather Service raingage stations in and around McLean County. These data were used in target-control comparisons of both one-month efforts. There arc not too many such stations (4 in McLean County and a similar density in surrounding areas),but they offer a way to get comparable area average rainfall. ' Comparing the McLean County rain, as based on the 90 (1978) or'107 (1977) fencepost gages,with that of surrounding areas based on 3 or 4 gages- would be an unfair procedure. It should be realized that 3 or 4 rainfali stations in a 1200. square-mile area can provide an unrepresentative measure of the rain over the area on any summer day, but when the area rain is measured that way over several months, the estimate is usually much better. The operational period area average rainfall in McLean County in 1977 was 3:78 inches based on the 4 National Weather Service (NWS) gages, as compared to 3.66 inches from the 107 gages. The 1978 values were 1.62 inches from the NWS, 4 gages, as compared to 1.65 inches from the 90 gages. Hence, the 4-gage data appear to be good area estimates for McLean County. Much of the rain research was performed by Dr. Hsu.

The second evaluation approach we used was based on the limited radar data available to us from 1978. The areal extent of echoes that were seeded were compared before and after the seeding. Meaningful evaluations of seeded echoes and nonseeded echoes could not be pursued because life histories of so many echoes were not recorded. This phase of the research was conducted by Mr. Towery with assistance from Dr. Hsu.

EVALUATION OF SURFACE RAINFALL DATA IN 1977-1978

Introduction

Possible effects of cloud seeding to increase rainfall in McLean County, located in central Illinois, during the summers of 1977 and 1978 were investigated using comparisons of target (McLean County) area rainfall and control area rainfall. McLean County is an area of about 1200 mi^2 and contains four rainfall stations (Fig. 1). Four "control" areas were defined, as shown in figure 1, to include a north control area (3 stations), a west control area (7 stations), a south control area (3 stations), and an east control area (4 stations). The west and east areas were of comparable size, and the north and south were nearly equal areas.

Two kinds of data sets were used in these evaluations. The first data set used was based on seasonal totals of each station. Stations shown in figure 1 report daily precipitation totals, either based on early morning or late afternoon observations. For the morning stations, the seasonal totals were summed from 0700 on July 15 to 0700 on August 5, 1977; and from 0700 on July 12 to 0700 on August 1, 1978. For the evening measurement stations, seasonal totals were from 1800 on July 14 to 1800 on August 5, 1977; and from 1800 on July 11 to 1800 on August 1, 1978. These time spans included all the seeding activities conducted in the McLean County in these two years.

Figures 2 and 3 show the take off and landing times of seeding airplanes in 1977 and 1978, respectively. There was a total of 40.4 hours and 14 hours of seeding flight times in 1977 and 1978, respectively.

The second data studied comprised the daily precipitation values. In figures 2 and 3 it can be seen that a "seeded day" could be well defined as a

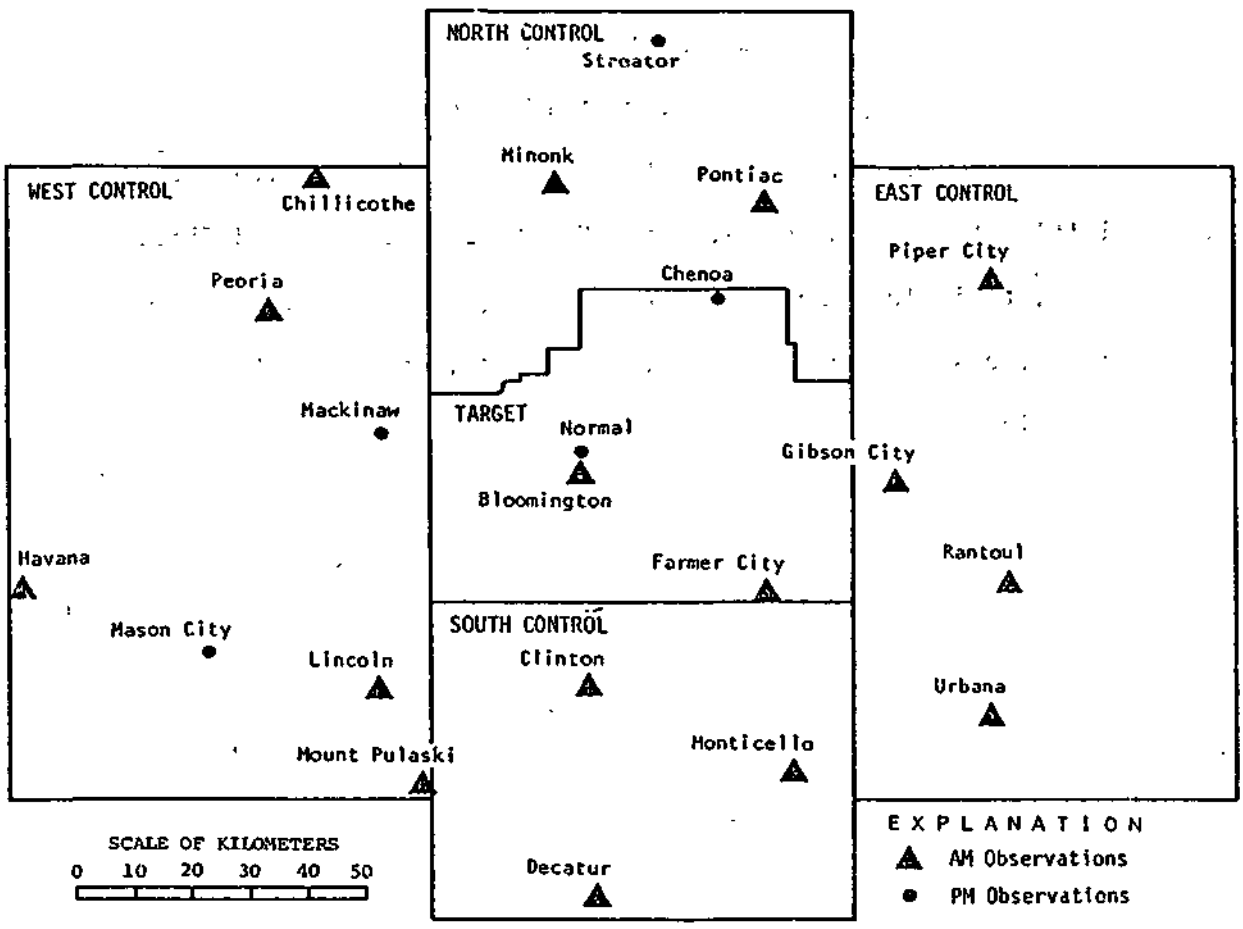

Figure 1. Target and Control areas and raingage stations used to evaluate McLean County Weather Modification Project, 1977-1978

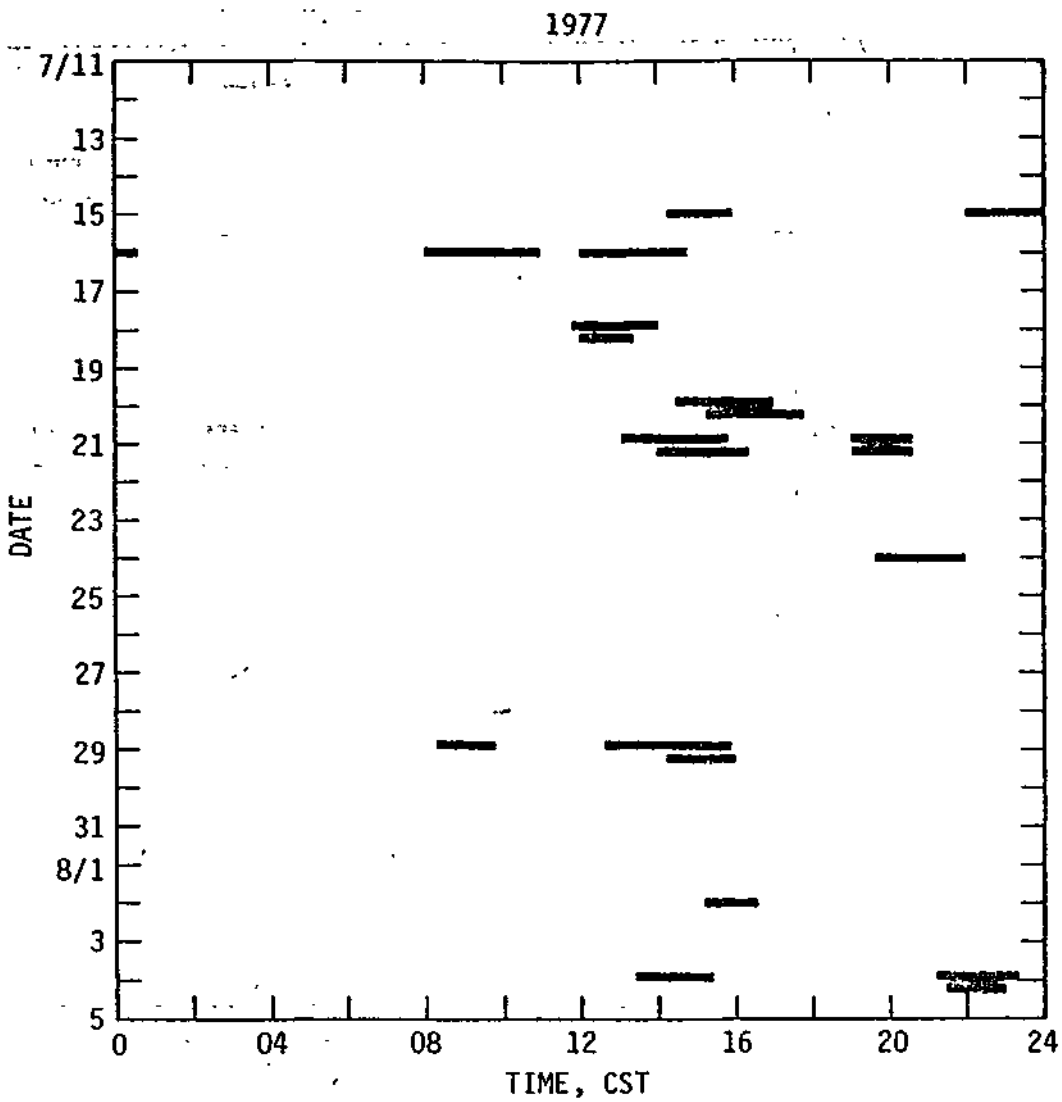

Figure 2. Takeoff and landing times of seeding airplane/s in 1977

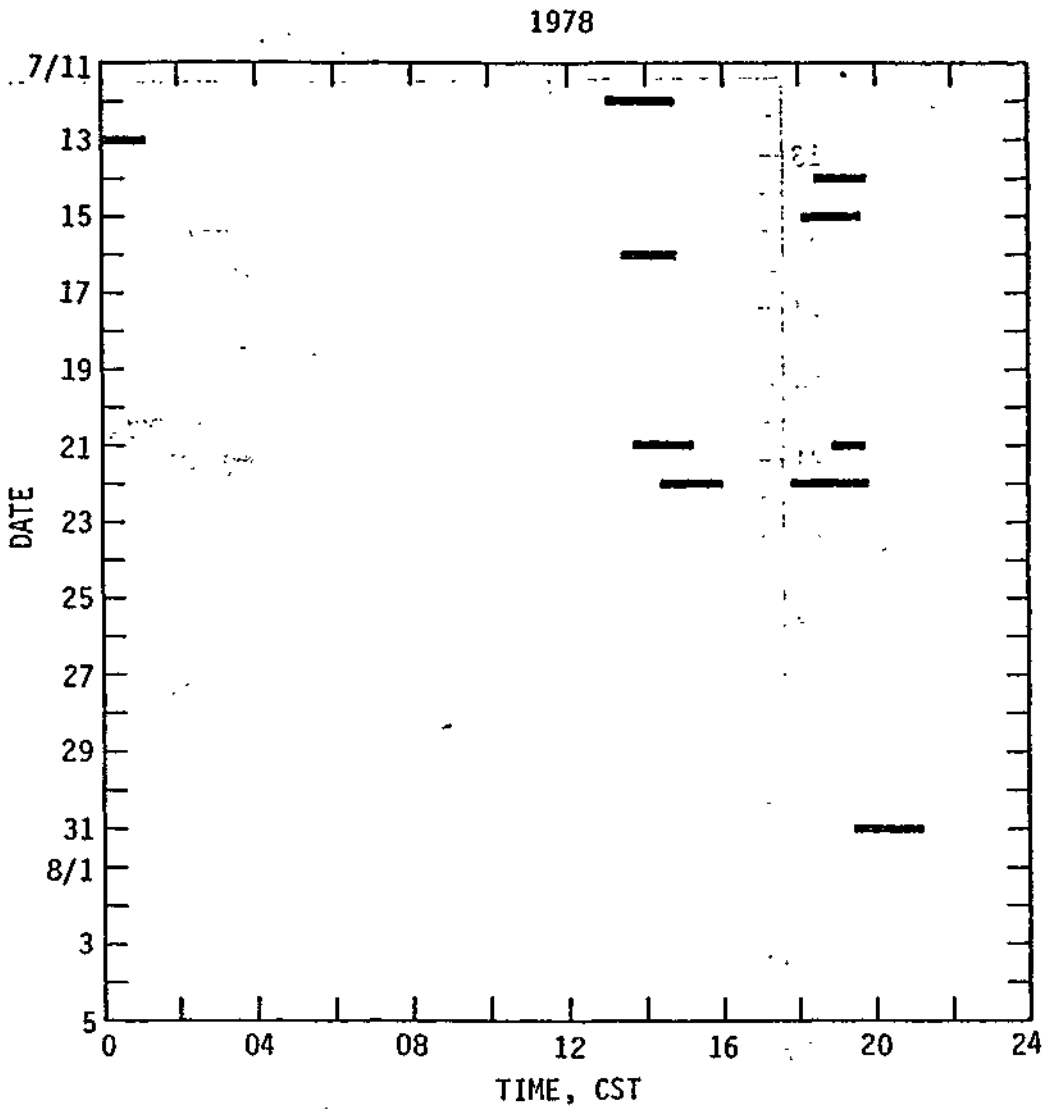

Figure 3.. Takeoff and landing times of seeding airplane/s in 1978

24-hour period starting from 0700 on one day to 0700 on the following day. For this reason, only stations reporting at 0700 were chosen to be included in the analyses for the daily precipitation. The reporting times of stations are revealed in figure 1.

Results for Monthly Totals

Average total precipitation of all stations in the target and in each control area was calculated for 1977, 1978, and both years combined (Fig. 4). In 1977, the target area had approximately regional average (target plus control) precipitation. In 1978, the target had average precipitation much below that of the surrounding controls. When 1977 and 1978 were combined, the target had precipitation a little below the average of the surrounding control areas. The ratio of target value over the average value of the four control areas was 0.94 in 1977, 0.'58 in 1978, and, 0.79 in 1977+1978. These ratios are all less than 1, an indication that when the areal controls were used, the precipitation in the target area (McLean County) was below what one would expect.

A two-sample Wilcoxon rank sum test was performed for 1977+1978, and the target had a rank sum of 9, based on a rank of 2 in 1978 (second lowest) and rank 7 in 1977. There were 10 possible ranks (5 areas and 2 years). The rank sum of 9 for the target area corresponds to a 1-sided significance level of 0.733. In other words, precipitation in the target area was not significantly greater than the control areas when areal monthly totals were used in the evaluation. In addition, for the binomial test with a parameter equal to half (which is the probability that precipitation in the target area is larger than the rainfall in the control), the significance level is 0.855, which again is

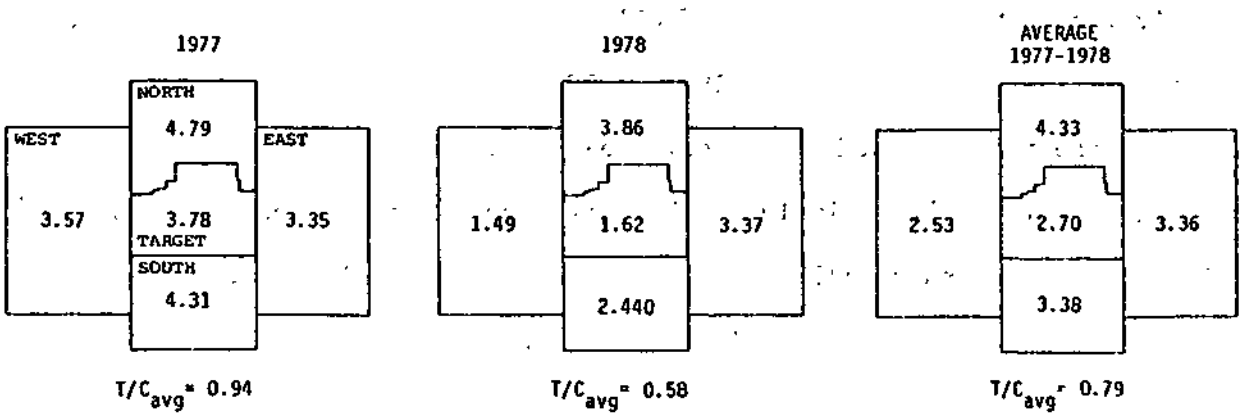

Figure 4. Average total rainfall (inches) of all stations in each area

not significant. The area averages showed less in the target, but these two tests indicated the 2-year differences were not significantly different.

To compare the two years fairly (and remove a possible yearly influence, or difference in the precipitation between 1977 and 1978) the "normalized" average total rainfall of each area was calculated (Fig. 5). The normalization was based first on calculation of the 5-area mean and standard, deviation of each year; then subtracting the 5-area mean from the average of each area (Fig. 4); and then dividing by the standard deviation. Precipitation (normalized) in the target area was below the 5-area average in both years, -0.31 and -0.90 (Fig. 5). Also, a two-sample Wilcoxon rank sum test for the 1977 and 1978 results was calculated. The target had a rank sum statistic of 8 (3 in 1978, 5 in 1977) corresponding to a 1-sided significance level of 0.800. This indicates the target area rain differences were not statistically significant departures.

Individual stations were also used to perform two-sample Wilcoxon tests and the results are shown in Table 1. Station values in the target area were compared and ranked with stations in each control — west, north, south, and east; and with all controls combined. Comparisons of their ranks indicate that none of the rank sum statistics are very significant. All have asignificance level larger than 0.2. The difference in 1977 appears greater than in 1978. The target vs. west control differences suggest more significance than those for other controls. The north control-target differences show the least significant results.

Overall, when seasonal totals were used to evaluate the seeding .effort, the target precipitation was not statistically significantly more than the control values-^ precipitation.

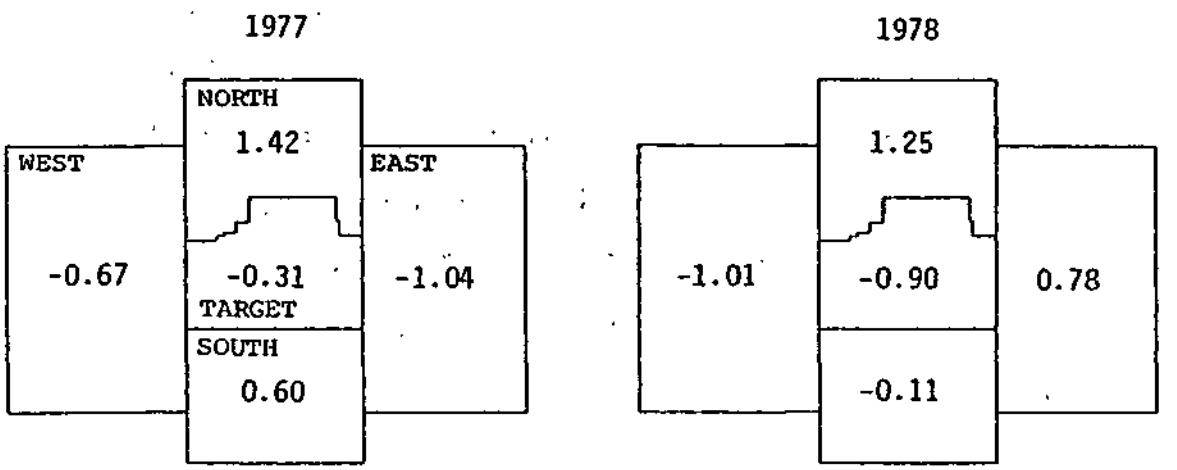

Figure 5. Normalized area average total rainfall index

Table 1. Wilcoxon 2-sample rank sum test, all stations.

			Number of Stations in Target	Number of Stations in Control	Rank Sum	Significance Level
1977	T vs.		4	7	26	0.394
		N	4	3	17	0.972
		S	4	3	13	0.686
		,E	4	4	21	0.243
		Combined Controls	4	17	43	0.5173
1978	T vs.	W	4	7	25	0.464
		N	4	3	18	1.000
		S	4	3	16	0.943
		E	4	4	12	0.971
		Combined Controls	4	17	29	0.8987
1977-1978	T vs.	W	8	14	96	0.4077
		N	8	6	62	0.990
		S	8	6	50	0.755
		E	8	8	60	0.809
		Combined Controls	8	34	146	0.7893

Results for Daily Precipitation

Figure 6 shows the average total rainfall in each area based on the 0700 observing stations. Although .these averages are not exactly identical to those in figure 5, the ratio of target over average control (of all 4 areas) is essentially the same.

Daily rainfall values were classified into seeded or nonsceded days according to the occurrence of seeding. That is, if seeding occurred at 1600 on 15 July, the associated rain at 1600 was that amount reported at 0700 on 16 July, the following day. Table 2 presents daily means and standard deviations of each area using the 0700 daily data for 1977, 1978, and 1977+1978. There were 16 seeded rain days and 25 nonseeded days in the 2-year sample.

Also shown in Table 2 are ratios of target over average control for the seeded days and nonseeded days. For seeded days, the ratios are 0.99, 0.48, and 0.79, for years 1977, 1978, and 1977+1978, respectively. For nonseeded days, the ratios are 0.88, 0.65, and 0.83, for 1977, 1978, and 1977+1978, respectively. All' ratios are less than 1, which is consistent with the seasonal rainfall findings of the previous section (target values less than control).

When the ratios of target over average control in the seeded days are divided by the ratios in the nonseeded days (Table 2), one gets double ratios of 1.13, 0.74, and 1.06, for 1977, 1978, and 1977+1978, respectively. These findings indicate that there is a 13% rain increase in 1977 on seeded days, 26% rain decrease in 1978 on seeded days, and a 6% increase of rainfall on the seeded days when 1977 and 1978 were combined.

To further analyze the target and control area differences, the double ratios of target over each individual control area were calculated (Table 3).

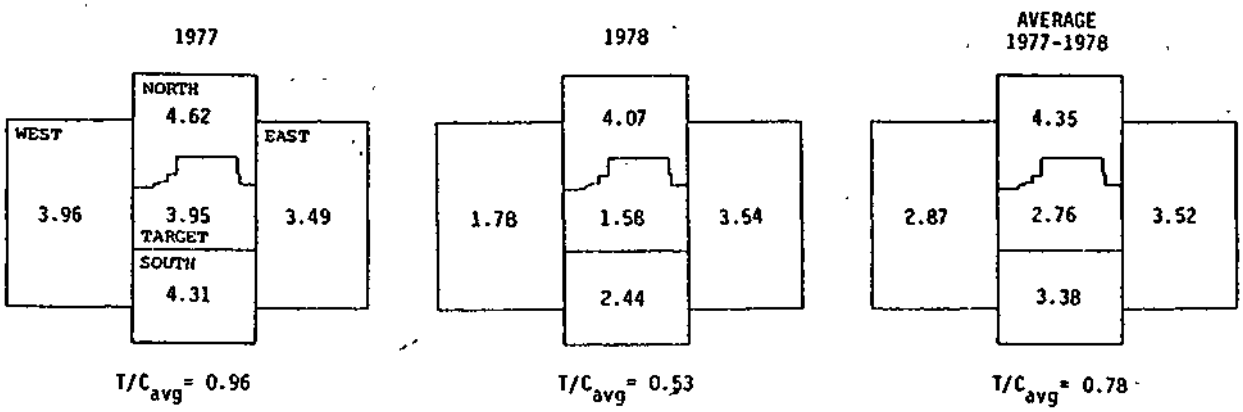

Figure 6. Average area total rainfall (inches) based on AH (usually 0700) observing stations

For example, the double ratio of target over west (upwind) control is 2.15 in 1977, 1.86 in 1978, and 2.05 in 1977+1978. From these results, we see that when the west control is used to evaluate the target, there is relatively much more rainfall on the seeded days than on the nonseeded days. Furthermore, except when east control was used, all double ratios in 1977 are larger than 1.00, which could indicate a positive (increase) seeding effect. In 1978, double ratios of the west and south were larger than 1.0, whereas those of the east and north were less than 1.0. When 1977 and 1978 were combined, the results were mixed. Results suggest a positive seeding effect in the target with respect to the west and south control areas, but a negative seeding effect based on comparisons with the north control and east control areas. When the east control is used, the results show a great decrease in the target. This might be due to downwind (east) influences. On the other hand, when the west, or upwind, control was used, it shows a very significant increase. This could indicate a positive seeding effect, but on the other hand, it may also be due to the below average precipitation in the west control when no seeding was carried out.

EVALUATION OF THE 1978 RADAR ECHO DATA

Data

The echo evaluation was based on data collected by the Atmospheric, Inc. radar used as part of the seeding operations in McLean County. The radar is a quality, commercially available 5-cm weather radar commonly used by many firms. It had a company installed camera system for routinely photographing the scope of the radar.

Table 2. Mean and standard deviation of 0700 reporting stations in each area.

	1977	1978	1977 plus 1978
Number of seeded days	9	7*	16
areas	Mean rainfall (and standard deviation) inches		
W	0.29 (0.33)	0.11 (0.17)	0.21
N	0.40 (0.58)	0.41 (0.71)	0.41
S	0.37 (0.46)	0.17 (0.39)	0.28
E	0.37 (0.46)	0.43 (0.88)	0.40
T	0.35 (0.42)	0.13 (0.28)	0.26
T/C average	0.99	0.48	0.79
Number of non-seeded days	12	13*	25
areas	Mean rainfall (and standard deviation) inches		
W	0.11 (0.35)	0.08 (0.22)	0.09
N	0.08 (0.18)	0.09 (0.33)	0.09
S	0.08 (0.27)	0.10 (0.23)	0.06
E	0.01 (0.05)	0.04 (0.12)	0.03
T	0.06 (0.15)	0.05 (0.15)	0.06
T/C average	0.88	0.65	0.75
Double ratio**	1.13	0.74	1.06

*13 July 1978 was classified as nonseeded day

** $\left(\frac{T_{\text{seeded}}/C_{\text{average seeded}}}{T_{\text{nonseeded}}/C_{\text{average nonseeded}}}\right)$

Table 3. Ratios and double, ratios of daily rainfalls (seeded vs. nonseeded).

	1977	1978	1977+ 1978
Seeded/Nonseeded			
West Control	2.57	1.47	2.24
North Control	4.86	4.45	4.67
South Control	4.40	1.77	3.11
East Control	26.36	11.13	14.20
Target	5.52	2.73	4.59
$T_S/T_{NS}/W_S/W_{NS}$	2.15	1.86	2.05
$T_S/T_{NS}/N_S/N_{NS}$	1.14	0.61	0.98
$T_S/T_{NS}/S_S/S_{NS}$	1.26	1.54	1.48
$T_S/T_{NS}/E_S/E_{NS}$	0.21	0.25	0.32

The radar was located at the Bloomington-Normal Airport. The particular location was convenient for operational purposes; however, its location in the center of the target area hampered the analyses of the radar data. This problem relates to the fact that the base angle (0.7° antenna angle above the horizon) of most scans had large areas of ground clutter which made it difficult to distinguish the precipitation echoes. Furthermore, echoes which passed through the center of the target area (and directly over the.radar) could not be viewed well because of certain radar characteristics and operational considerations. Nonetheless, an analyses and evaluation were pursued. The primary point is: the data, because of the location of the. radar, has deficiencies.

The radar operational procedure was generally to operate in a surveillance mode prior to the launching of the aircraft. Filming of the radar scope generally began about the time the aircraft were launched which was generally not soon enough to get the development and origin ,of many echoes in and around the target. Each sweep of the scope was then photographed continuously until about the time the plane/s landed after seeding. This choice of ending the photography was often too soon with echoes of interest still apparent. The sequence of the radar antenna operation was not well established; however, a full-gain scans at elevation angles of 0.7° and 3.0° were provided on the average every 6 minutes but no longer than every 15 minutes, in addition to scans at other elevation angles. The "full gain" scans refer to the fact that the radar receiver power was such that all echoes were presented on the scope.

The data used in this study came; from seven of the ten seeding dates in July 1978. Table 4 provides some pertinent information concerning the data.

There were two seeding periods which could not be used in the evaluation. On July 21, a seeding event occurred in the mid-afternoon; however, the seeded

echo somehow did not appear in the scope photographs. On July 22, a seeding event occurred near 1830; however, the echoes could not be tracked because of the ground clutter and their proximity to the Bloomington radar site. On July 13; no film was collected. All the radar data for the other 7 days was of poor quality; but could be analyzed.

A major factor which limited the study of the echoes was that the operation of the scope camera' rarely allowed an opportunity to study an echo over its complete life history; that is, from its formation to its dissipation. The available data present only portions of most echo histories. More often than not, the seed and no-seed echoes existed when the camera was either turned on or when it was turned off. Most meaningful echo analyses was sought to perform for comparing seeded and nonseeded echoes depended on having life histories of the echoes. Desired studies rested on knowing at what point, in their total lifetime, the echoes were actually seeded. We could have then fairly compared echoes. Because of this "limited" data problem, only the 11 seeded echoes were studied.

Analysis Procedure

The general goal of the evaluation was to study the areal extent of the echoes, both before (control) and after the seeding time (target). The period of time over which all the echoes existed on film were divided into before- and after-seeding periods. The "after-seeding" period began when the seeding material was first released for a given seeding period.

Many calculations were performed on the basic echo data set, including total area covered by each echo over the time it was tracked, change in echo size from the time of one photograph to the next time, and the average size of.

Table 4. Information concerning data used in evaluation of radar echoes in 1978. Time (CDT) is from a 24-hour clock.

Date	Time of Scope Photography Begin	Time of Scope Photography End	Seeding Time Begin	Seeding Time End	Number of Echoes Seeded	Rain in Target
7/12	1239	1440	1345	1412		No
7/14	1828	1918	1850	1854		No
7/15	1800	1943	1838	1902	1	No
7/16	1320	1507	1340	1405		No
7/21	1850	1939	1914	1920		No
7/22	1435	1611	1453	1525	3	Yes
7/31	1830	2123	1940	2040	3	No
TOTAL					11	

an echo over the time period. The area covered by an echo from one measurement (called a tracing) to the next was obtained by averaging the echo size at the two times, then multiplying by the time (number of minutes) between the tracings or measurements. These accumulated 1-minute "area" were then summed for a particular time period (before or after) to obtain the total area covered by the echo.

The average echo size (AES) over the time period was the parameter then calculated. It was considered to be the most representative of actual echo size. It was obtained by dividing the total area covered by an echo by the total duration of the echo for that period.

The procedure was to make tracings of the radar echoes from each photographed sweep of the antenna — no matter what the elevation angle or the receiver setting. However, only those tracings of "full gain" with a 3° antenna elevation angle were used in the analysis. The echoes on the base angle (0.70) scan were often obscured by ground clutter, and other elevation scans were not nearly as reliably collected (on photographs) or consistent as the ,30 "full gain" scan. A point of caution is that due on the data used from the 3° antenna elevation angle. A scan at that elevation means that the sampled portion of an echo is at different heights above the ground, depending on its distance from the radar. For instance, the center of the radar beam is at 8,000 feet above the ground at 20 miles from the radar; and at 50 miles from the radar site, the radar beam center is 15,000 feet above the ground (well into the cloud).

The position of the aircraft during seeding was then plotted on the radar tracings. This allowed identification of the echoes which were seeded.

The next step was to overlay the tracings and "track" an echo as long as possible prior to and after seeding time. The procedure was to identify, or

label, the primary echo with a number; and all echoes which split from, or merged with, the primary echo were assigned the same number. This was the most reasonable method of echo identification.

A grid (2 miles by 2 miles) was then used to measure the area of the echoes? The grid was placed under the tracings and all squares (or portions) which contained echoes were counted. The number of squares was then multiplied by 4 (2x2) to obtain the area of the echo(es) for each tracing. Thus, the area of each echo was determined at the time of all the full-gain, 3° elevation angle tracings.

Seeded Echo Sizes

Table 5 presents, in chronological order, the echo sizes obtained from the radar echo tracings for all the 11 seeded echoes in 1978. The individual times of the tracings are not shown; however, the average time between tracings was = 6'minutes. The word "seeded" was inserted at the first point (in time) when seeding began during a seeding period. Examination of the values in this table allows one to determine whether an echo grew or decreased in size after seeding occurred, as well as to study the echo size tendencies prior to seeding. The values would indicate that at some point in the after-seeding period, seven echoes (Nos. 1, 3, 6, 7, 9, 10, 11) were larger in size than the maximum size in the before-seeding period. However, seven echoes (Nos. 1, 2, 4, 5, 8, 9, 10) were also smaller at some point in time after the seeding began. No strong conclusion comes from this analysis.

The average echo size of the seeded echoes before and after seeding times occurred were 71 mi^2 and 54 mi^2, respectively. The before- and after-seeding values of the seeded echoes reveal that except for one echo which grew

Table 5. Chronological listing of seeded echo sizes (n. mi^2) obtained from radar echo tracings for given dates. Times are beginning and ending times of the echo tracings. The word "seeded" appears between the last size before and the first size after seeding. On July 31, seeding was in process when an echo (#11) formed.

Date (1978)	7/12	7/14	7/15	7/16	7/21	7/22	7/22	7/22	7/31	7/31	7/31
Time	1239-1440	1836-1913	1800-1854	1320-1450	1850-1921	1435-1538	1435-1611	1442-1515	1830-2112	1932-2112	1950-2040
Echo #	1	2	3	4	5	6	7	8	9	10	11
	112	148	48	356	88	12	16	16	324	12	
	144	152	40	340	60	12	12	16	316	36	Seeded
	144	96	44	324	76	12	32		328		
	164		78	296	64			Seeded	352	Seeded	28
	232	Seeded	56	304	80	Seeded	Seeded		332		24
	300		80		88			16	348	28	28
	212	84	72	Seeded		28	28	12	384	52	36
	480	48	80		Seeded	28	32		384	52	40
	560	32		292		36	16		384	48	40
		8	Seeded	216:	52	20	64			52	24
	Seeded	8		292	52	12	68		Seeded	68	20
			96	236	64		72			84	20
	516		***88***	228	36		68		396	96	32
	512		92	184			80		336	.72	8
	464			156			68		412	92	
	540			148					320	92	
	508			164					264	92	
	808			80					268	80	
	672			80					148	92	
	800			32					176	80	
	672			16					140	84	
				8					140	80	
									116	88	
									104	40	
									116	48	
									72		
									68		
									48		
									60		
									28		

considcrably, the size of seeded echoes after seeding were smaller than those before seeding. The before and after ratio of the seeded echoes medians has a ratio of 0.76. This represents a 24% decrease in echo size after seeding. This reduction of echo size might be duo to (1) seeding, or (2) natural conditions which reduced echo size after seeding materials were released.

SUMMARY

As part of their required project activities in 1977 and 1978, the cloud seeding firm (Atmospherics Incorporated) furnished project ending reports to the State of Illinois and to the local project sponsors, Rain-Gain, Inc. The firm's evaluations of their modification results are of interest. The evaluation of the 1977 seeding project led them to conclude 1) that the target (McLean County) had received 15 to 20% more rainfall than control areas (locale unspecified); 2) that seeded echoes, as compared to nonseeded echoes, lasted 46% longer and produced 51% more areal coverage (Atmospherics Incorporated, 1977). We did not judge the 1977 radar data to be suitable for such analysis. The modification firm's assessment of its 1978 efforts leads to a conclusion that, "there is again a suggestion that individual clouds and systems which were treated with silver iodide did produce precipitation which covered a larger area and lasted a longer time period than precipitation echoes in adjacent areas of a similar size" (Atmospherics Incorporated, 1978). However, no percentage changes in echoes or rainfall are offered for 1978. Our analysis did not agree, generally suggesting either no change or a decrease in rain area and amount in 1978.

Our evaluations based on the seasonal rainfall totals for 1977, for 1978, and for 1977-1978 combined essentially show no seeding effect. The target

area average rainfall in 1977-1978 is lower than the average of the four., surrounding control areas. Two statistical tests (2-sample Wilcoxon and Binomial) were applied to the 1977+1978 area totals, and the rainfall in the target was not significantly greater than that in the 4-area control. Comparisons of seasonal-values, between the target and individual control areas also showed no significant differences, although the differences in 1977 were greater" than those in 1978.

Assessments based on daily rainfall values essentially gave similar results, but with some suggestions of both increases and decreases in rainfall on seeded days. Comparison of target/control area rainfall ratios on the 16 seeded days with those for the 25 nonseeded days provides informative double ratios. These indicate a 13% rain increase in 1977 (similar to that claimed by the seeding firm), a. 26% decrease in the target in 1978, and a net 2-ycar increase of 6%. Comparisons of the target rain with the various control area values suggest an increase in target rainfall (on seeded days) in relation to the west (upwind) area, but a decrease in the target rain versus the east area rain. Two sample tests of these target-control differences showed none to be significant at the 5% level.

The radar film data from the 1978 seeded period were analyzed to evaluate the effect of the seeding bystudying the sizes of the seeded echoes before and after seeding. No other echo characteristics (lifetime, echo intensity, and echo height)or comparisons to nonseeded echoes could be evaluated satisfactorily because of the limitations in the operations and hence data. However, Water Survey studies, have shown that echo size is a reasonably good estimate of rainfall yield.

Comparison; of the; behavior of seeded echoes before and after seeding, was revealing. Half of the. seeded, echoes decreased in size after seeding.

The average echo size of echoes was 71 mi before seeding but 54 mi^2 after seeding, a 24% decrease.

The limited echo analyses indicated that seeding had little or no effect for increasing echo sizes, and suggest an effect leading to a decrease in echo size. This agrees with the daily rain analyses for 1978 which also suggests a decrease in rainfall in the target area on seeded days.

The 1978 echo size results, indicating a decrease in echoes after seeding, do not agree with the 1976 echo studies from the .5-county modification project (Changnon and Towery, 1977). There, the seeded echoes grew relatively more than nonseeded echoes and were 30 to 35% larger after seeding. However, it is critically important to realize that the rain and echo samples from 1977-1978 are woefully small. The size is too small to develop conclusive statistical indications of a seeding effect.

Two factors are important in deriving a generalized interpretation of the results of the McLean County modification project. First, most percentage changes discerned in the several S versus NS comparisons are small, less than 25%, and are well within the "noise" of normal rain variability. Importantly, they do not indicate a sizeable shift (in rain or echoes) that would suggest statistically significant (major) changes (in a small, 2-month sample) were achieved. The second relevant factor relates to the mixed sign of the rain and echo percentages, some were pluses (increases) and some were minuses (decreases). Collectively, these two factors indicate little or no effect in changing the rainfall in a consistent fashion in McLean County in the 1977 and 1978 periods.

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