A Cloud-Seeding Experiment in the Snowy Mountains, Australia

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ABSTRACT

A cloud-seeding experiment was conducted in the Snowy Mountains of Australia from 1955–1959 inclusive. The objective was to determine if silver-iodide smoke released from an aircraft into clouds could increase the precipitation over a selected area. The method involved a comparison of the precipitation in a target area and that in a control area during randomized periods of seeding and no seeding. Over the five years, the ratio of the precipitation in the target to that in the control area was higher in seeded than in unseeded periods. Three statistical tests are presented which show that the seeded periods are different from the unseeded periods at significance levels of 0.03, 0.09 and 0.03 (one sided). This supports a positive seeding effect. Other analyses both detract from and support this contention. The net result is that the experiment is inconclusive. Further, improved experiments are proposed.

1. Introduction

An experiment took place during the five years 1955 to 1959 inclusive, in the Snowy Mountains of Australia, in which clouds were seeded with silver-iodide smoke released from an aircraft. The intention was to determine if this procedure could produce an increase in precipitation over a catchment area which is associated with important hydro-electric and irrigation works.

The experiment was carried out jointly by the Snowy Mountains Hydro-Electric Authority (SMHEA) and the Commonwealth Scientific and Industrial Research Organization (CSIRO). A preliminary report of the form of the experiment and the first year's precipitation figures have already been published (Adderley and Twomey, 1958).

2. Design of the experiment

The method used involved seeded and control areas, and seeded and unseeded periods. Time was divided into periods, in about half of which clouds were seeded as they approached the target area; the choice of seeded periods being on the basis of a series of radom numbers (Fisher and Yeates, 1948) in order to satisfy one of the main requirements of satistical analysis. The precipitation in the seeded area was compared with that in a climatologically and geographically similar control area, unaffected by the seeding, the object of the analysis being to determine if this comparison differed for the seeded and unseeded periods. Near the center of the seeded area there was a smaller "Target" area, where he effects of seeding should have been more pronounced.

The use of a control area greatly reduces the duration of an experiment, and the use of unseeded periods for the control data has advantages over the use of historical data—the effect of climatic variations is reduced and it has been possible to obtain an improved estimate of precipitation by the use of a closely spaced network of precipitation gauges installed for the experiment (see Fig. 1.)

Length of period. The choice of a suitable length of period for on-off seeding depended on many factors, one of the more important being that it should at least be possible to read most of the precipitation gauges when the periods changed, an operation which took up to two days. Also in the inaccessible terrain of the Snowy Mountains, this could only be done in fine weather.

In southeast Australia during autumn, winter and spring, there is a fairly regular procession of atmospheric pressure systems from west to east, with an average period of six to seven days. Fine weather in the Snowy Mountains areas is usually associated with the passage of anti-cyclones, whereas the frontal surfaces which are the main sources of cloud and rain are generally located between anti-cyclonic centers. It was decided therefore to change the periods whenever the center of an anti-cyclone crossed the meridian, 150E.

Time of year. The experiment ran, each year, from 15 March to 1 December, or the change of period closest to these dates (except in 1955 when the starting date was 8 June). During this time of the year, the drift of clouds associated with precipitation usually has a westerly component, whereas in the summer months the cloud drift may be in any direction due to frequent

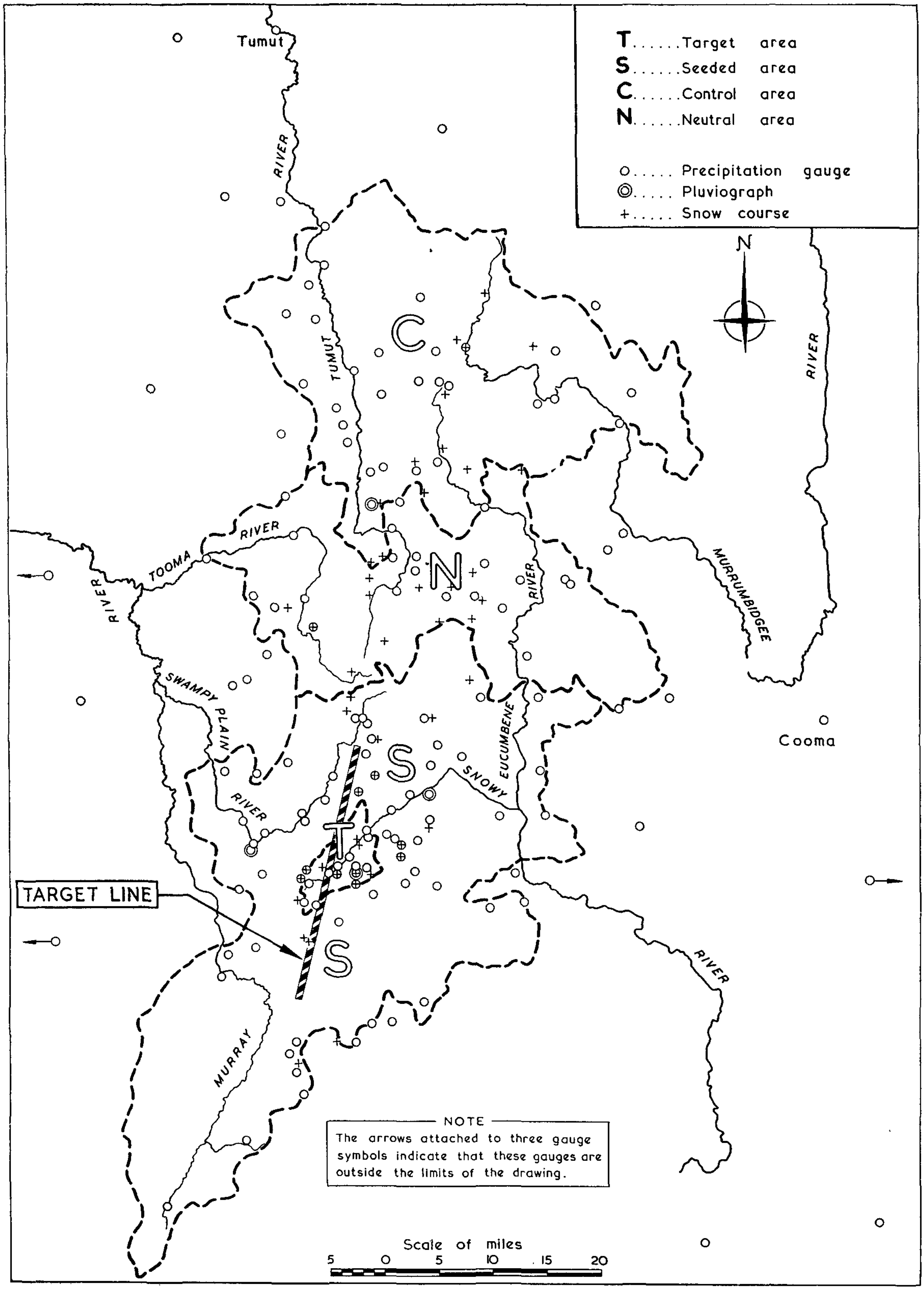

FIG. 1. The experimental areas showing precipitation gauges.

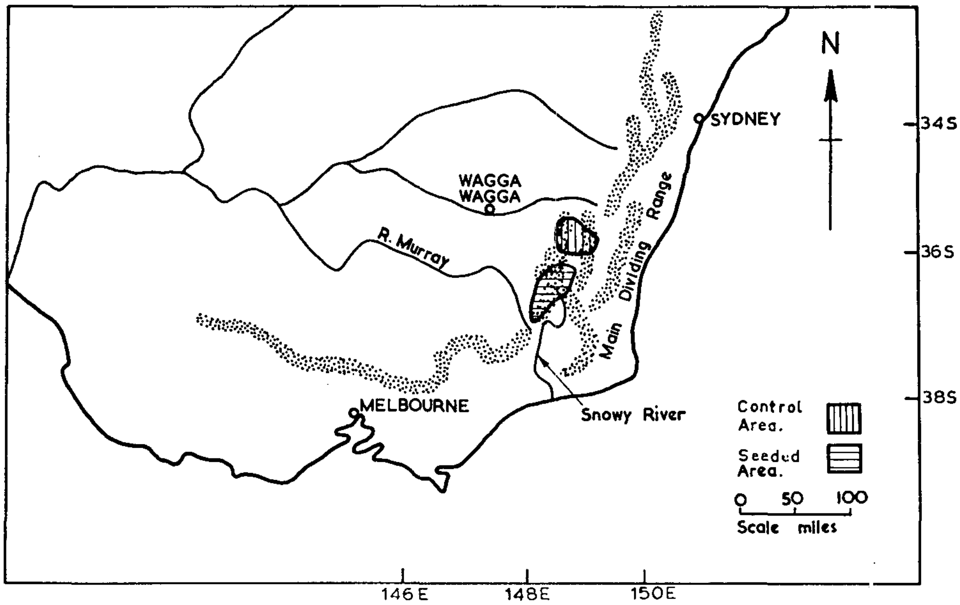

FIG. 2. The general area and surroundings.

invasions of easterly air and penetration of monsoonal air from the tropics.

Estimation of precipitation. In this experiment an estimate of the mean precipitation was required for each of the three areas for each period. The raw data were provided from a total of 147 precipitation gauges, 8 pluviographs (later increased to 25) and 57 snow courses, the locations of which are indicated on Fig. 1. Some of the pluviographs were unreliable. Reasonably reliable records were only available from four: three in the seeded area (one of them in the target area) and one in the control area. Much of the precipitation was in the form of snow, particularly in the months of June-July-August-September. At the conclusion of each period, personnel of the Hydrology Branch of the Snowy Mountains Authority read as many of the gauges as possible, drew isohyetal patterns for the period, and calculated the mean precipitation for each area by integration of the isohyets.

The decision to use isohyets as the means of assessing the results of the experiment was taken before the experiment began. There were two reasons: first, it was not always possible to read all the gauges at each period change, so some means had to be adopted of allowing for the missing gauge readings, in an area where, for reasons of topography, precipitation exhibits marked spatial variation. Secondly, much of the precipitation is in the form of snow, which was measured by snow-courses. These require judgment in interpretation, particularly when their readings differ from those of adjacent rain gauges, which frequently under-read seriously during snow. The best meteorological advice available suggested that the most reliable measure of precipitation in these circumstances would be obtained by the use of isohyets.

At the conclusion of the experiment it was decided that the isohyets should be redrawn in order to make them more acceptable statistically since the person who drew them was aware of the seeding sequence. As a result they were redrawn by a meteorologist who had no knowledge of which periods were seeded and final precipitation figures were computed from these. Both the original and final precipitation figures are given for comparison at the end of the paper as an Appendix.

On the whole they are well correlated. Such discrepancies as occur are most frequent in the target area and have been found to be due to differences in interpretation of the original data, particularly when snow courses indicated more precipitation than was recorded by the rain gauges.

3. Area of operations

The general area and its relation to the surroundings are shown in Fig. 2, the details being shown on a large scale in Fig. 1.

The following considerations influenced the choice of the seeded and control areas. Major construction works were in progress in the control area, consequently attempts to increase precipitation there were not desirable until the works were finished. The seeded area is to the south of the control area. Most construction for this region was planned not to commence before 1960, so that it was available for seeding in the period

1955–1959. Increased precipitation in both areas will eventually be of value when the construction is complete.

Orography and climatology. The Snowy Mountains form part of the Great Dividing Range, which extends for nearly 2000 miles in a north-south direction about 100 miles inland from the coast of Eastern Australia. At the latitude of the Snowy Mountains, approaching from the west, the land rises rapidly (6000 ft in 20 miles) and then slopes more gently down towards the east. The control, seeded and target areas are situated on the crest of this range, the target area being at the highest point. They are disposed across the path of the precipitation-bearing clouds, which during the operational period usually move with winds between southwest and northwest.

4. Equipment

Silver-iodide smoke was generated by burners on the wings of the aircraft, each producing 10^{17} nuclei per hour active at -17C. The burners, seeding materials and their performance have been described by Smith *et al.* (1958).

Four aircraft types, Avro Anson, Lockheed Hudson, DC-3 and Cessna 310 were employed at different stages of the experiment. All aircraft were equipped with complete navigational aids so that accurate position finding was possible.

5. Operational procedure

The operational procedure was designed on the basis of experiments which had been carried out by the CSIRO, in which single clouds were seeded with silver-iodide smoke released from an aircraft. The object of these experiments was to determine appropriate cloud seeding procedures and the conditions in which they were effective. Some of these experiments have been described by Warner and Twomey (1956). In the case of cumulus clouds, precipitation was usually stimulated provided that the cloud top was colder than -5C and that the cloud was compact and at least several thousand feet in vertical extent. The precipitation usually appeared at the cloud base 20–30 min after the seeding. Less information was available concerning the seeding of layer clouds, but the time between seeding and the onset of precipitation was 20 to 50 min. These considerations led to the following design of seeding procedure.

The aircraft took off from its base at Wagga Wagga (90 miles NNW of the seeded area) when either visual inspection or the prevailing meteorological situation indicated that suitable cloud conditions might be found near the seeded area. "Suitable" clouds were defined as having tops colder than -5C and thickness exceeding half the terrain clearance of the bases. Most of the flights were in the daytime.

Wind and temperature meaurements were made as the aircraft approached the seeded area, to augment the information provided by the Meteorological Office at Wagga Wagga. The cloud conditions were assessed and a decision made on the suitability of the clouds for seeding. In case of doubt as to their suitability they were seeded.

If conditions were considered suitable for seeding, the track of the seeding flight was determined. The "target line" at which the aircrew aimed is shown in Fig. 1: it was 32 miles long and ran nearly north and south through Mount Kosciusko, and straddled the target area. It is considered probable that the turbulent air, which is characteristic of the region and diffuses the seeding agent, caused much of the seeded area to be also affected. The seeding track was equal in length to this line and parallel to it, but was spaced upwind from it in order to allow for the expected time interval between seeding and the arrival of precipitation on the ground. The time assumed was 30 min in the case of cumulus clouds or 60 min for layer clouds; when the height of the cloud base exceeded 6000 ft, $1\frac{1}{2}$ min were added for each 1000 ft excess height. Cumulus clouds were usually seeded at the base, while stratus clouds were seeded at the -6C level when possible. When the wind direction was such that seeded air might flow over the control area, no seeding was carried out.

The burners were ignited and a number of passes made along the predetermined track. If weather conditions prevented complete passes being made, the accessible part of the track was traversed. Continuous checks were made on wind velocity at the seeding height and appropriate adjustments made to the seeding track.

The seeding continued for as long as the opportunity existed or until aircraft endurance dictated return or silver-iodide solution was exhausted. The intention was to seed for as high a proportion as possible of the time during which suitable conditions prevailed. Practical difficulties imposed limits on this proportion, particularly in the early stage of the experiment.

6. Changes after first year's operation

The experiment started in June 1955 and its initial form has been described by Adderley and Twomey (1958). After the close of the first season's operations (December 1955) certain changes were introduced as a result of practical experience in carrying out the experiment. These changes are described below; since the beginning of the 1956 operation, the experiment ran unchanged.

These modifications were all made for operational reasons entirely unconnected with the precipitation figures. Therefore it is considered reasonable to analyze the results of all five years together.

Control area. The control area shown in Fig. 1 differs from the original area in that the southern end was omitted to make room for a neutral area, which reduced the possibility of silver-iodide being carried over the southern end of the control area. The recomputed control area precipitation figures quoted for 1955 (original isohyets) are therefore less than those in the Adderley-Twomey paper.

Target line. For the same reason, the target line was shortened by eight miles at its northern end.

Definition of areas. In the Adderley-Twomey report, what is now called the seeded area was referred to as the target area. Owing to a misunderstanding, the precipitation figures quoted in that report for the Target area were not those for what is now called the seeded area, but for an annular space surrounding the area now called the Target area. Thus the precipitation figures quoted in the Appendix for the seeded area in 1955 differ from those quoted by Adderley and Twomey.

Length of period. In 1955, the period was defined as the duration between the passage of successive anticyclone centers. This led to certain periods being as short as four days and also to unfavorable conditions for the reading of the gauges. Therefore, a minimum period length of eight days, and period changes only taking place in fine weather, were stipulated.

Precipitation gauges. The precipitation gauge network was increased.

7. Clouds encountered

The following remarks on clouds and weather are based on the seeding crew's observations. They may not be fully representative of the area since the aircraft only flew when there was reasonable expectation of the incidence of seedable clouds.

Clouds suitable for seeding occurred mainly with cold fronts and in westerly stream weather. Occasionally clouds suitable for seeding occurred during incursions of easterly air. Seedable clouds sometimes occurred in southerly air streams associated with low pressure systems to the east of the area, but were not seeded because the effect of seeding might have drifted over the control area.

During the autumn and spring, clouds were mainly cumulus which grew as they approached the main range and typically appeared to have lives well in excess of 30 min. Altostratus was occasionally encountered. In winter the clouds were mainly stratocumulus or nimbostratus with bases at 4000 ft and tops extending to heights in excess of 10,000 ft, unless, as frequently happened, an inversion at 8000 to 9000 ft limited the growth. In the case of the deeper cloud it frequently appeared that large cumuli were embedded in the stratus. Freezing levels were typically 5000 ft in winter and 8000 ft in autumn and spring.

8. Precipitation figures

The mean precipitation depths in each period are given in the Appendix at the end of the paper for the target area (T), the seeded area (S) and the control area (C).

Two sets of figures are given. The final precipitation figures, upon which subsequent statistical analyses are based, are given in regular type. The original precipitation figures are given in *italics* and are included for completeness only. The beginning and end dates of periods and the duration of seeding are also given.

Bad weather prevented the reading of the gauges at the end of periods 9, 11, 13, 24, and 40 and therefore the pairs of periods 9 and 10, and 40 and 41 (unseeded) and 11 and 12, 13 and 14, and 24 and 25 (seeded) have been combined and treated as single periods.

The four gaps in dates during the operational time of the year, 27 March 56 to 11 April 56, 13 April 57 to 26 April 57, 3 April 58 to 9 April 58 and 25 March 59 to 7 April 59 were breaks due to Easter. The dates 26 March 56, 12 April 57, 2 April 58 and 24 March 59 were ends of periods within the given definition.

Table 1 gives the total precipitation during the five years in the various areas, for seeded and unseeded periods, in inches of water.

TABLE 1. Precipitation totals.

Target area (seeded periods)	ΣT_s	238.23
Seeded area (seeded periods)	ΣS_s	119.34
Control area (seeded periods)	ΣC_s	100.02
Target area (unseeded periods)	ΣT_u	221.54
Seeded area (unseeded periods)	ΣS_u	119.23
Control area (unseeded periods)	ΣC_u	110.57

A cursory inspection of these figures shows that the total precipitation in the seeded area was the same (119 inches) whether it was seeded or not. However, the precipitation in the control area was lower in seeded periods (100 inches) than in unseeded periods (111 inches). Similarly, while the target area precipitation was higher when seeded, this should be considered in comparison with the lower precipitation in the control area in seeded periods.

The total precipitations in the target and seeded areas may be examined in comparison with those in the control area.

Thus

$$\sum T_s/\sum C_s = 2.382,$$
$$\sum T_u/\sum C_u = 2.004,$$

and

$$\sum S_s/\sum C_s = 1.193,$$
$$\sum S_u/\sum C_u = 1.079.$$

It is then clear that increases in precipitation appear to have occurred in the target and seeded areas during the seeded periods. The ratio of total precipitation in the target area to that in the control area during seeded periods exceeds by 19 per cent the similar ratio during unseeded periods. The corresponding increase for the seeded area is 11 per cent. Similar comparisons may be made for each of the individual years and are shown in Table 2.

TABLE 2. Percentage precipitation difference from expectation.

Period	Percentage values $\left[\frac{\Sigma T_s/\Sigma C_s}{\Sigma T_u/\Sigma C_u}-1\right]100$	Percentage values $\left[\frac{\Sigma S_s/\Sigma C_s}{\Sigma S_u/\Sigma C_u}-1\right]100$
1955	26.4	19.0
1956	26.8	11.9
1957	12.3	−3.9
1958	16.0	10.4
1959	3.2	−1.3
1955–1959	19.0	10.7

TABLE 3. Regression analysis statistics.

Variate[a]	Transformation	"t" test significance level	Difference of means[b]	90% confidence band[c]
T	Cube root	0.03	17.0%	3.1% to 32.1%
	Square root	0.03	17.2%	3.1% to 32.2%
	Logarithmic	0.05	15.5%	0.2% to 33.0%
S	Cube root	0.18	5.6%	−4.2% to 16.0%

[a] Periods 51, 96 and 97 in which there was zero precipitation in one or more areas, were excluded from these analyses.
[b] The "difference of means" is the difference between the arithmetic values of the transformed seeded precipitation means adjusted for the slope of the regression line and the unseeded mean, expressed as a percentage of the unseeded mean.
[c] There is a 90 per cent chance that the true difference of the means, obtained as in (b) will be in the range given.

9. Statistical analysis

Three methods of analysis are presented:

a) Regression analysis of T and S using C as the concomitant variable;
b) An order test using the period values of the ratios T/C and S/C;
c) An experimental sampling test using the ratios of the cumulative sums, $\sum T/\sum C$ and $\sum S/\sum C$, as variables.

All methods test the null hypothesis that the difference between the precipitation balance in the areas during seeded and unseeded periods is no greater than would be expected by chance. The tests used were all of the one-sided form.

There are *a priori* reasons (see Section 6) for regarding the first year's results as non-homogeneous with the results of the remaining four years. Since this does not affect the distribution-free methods the five years' results have been treated together. A case could possibly be made for excluding the first year's results from the regression analysis, but there is no internal evidence that they differ significantly from those of the remainder and they have been included.

Regression analyses. The distribution of the precipitation is markedly non-normal and a normalizing transformation is necessary. Various transformations including logarithmic, square root and cube root were examined, the latter being the best with respect to normal distribution and homoscedasticity about the regression line.

A "t" test (Kendall, 1946) applied to the difference of the means of departures from the regression line gave significance levels and other relevant statistics noted in Table 3.

A graph of the cube root transformed values of T plotted against those of C is included as Fig. 3.

Order tests on period ratios. The values of T/C for each period, excluding those periods for which T, S and C are zero, were arranged in order of magnitude and a Wilcoxon (Mann and Whitney, 1947) test applied to the array divided into seeded and unseeded ratios, giving a significance level of 0.09. The same test was also applied to the period ratios S/C, giving a significance level of 0.24.

Random sampling on cumulative sums. The ratios of cumulative sums $\sum T/\sum C$ and $\sum S/\sum C$ differ in seeded and unseeded periods (Section 8), and a random sampling test (Adderley, 1961) performed on an electronic computor using 10,000 samples gives the significance levels of these differences. They are 0.03 for $\sum T/\sum C$ and 0.04 for $\sum S/\sum C$.

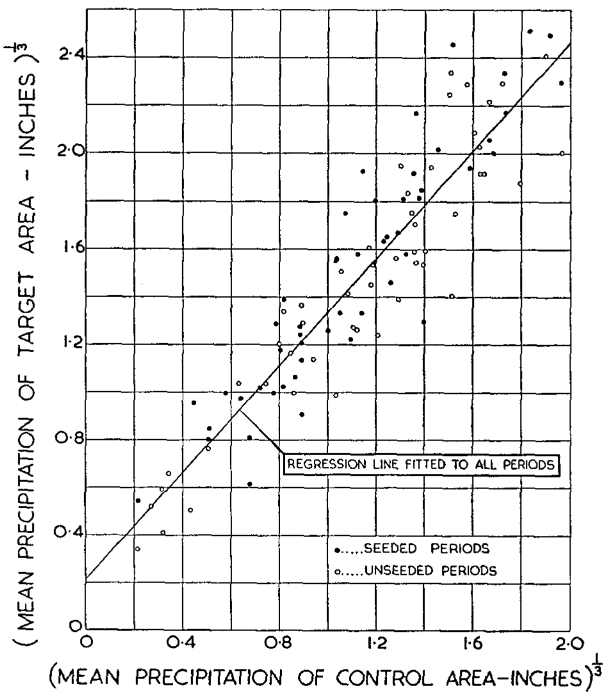

FIG. 3. Graph of cube root transformed values of T against C.

TABLE 4. Summary of results.

Method	Significance levels Target area	Seeded area
Regression	0.03	0.12
Wilcoxon tests on period ratios	0.09	0.24
Random sampling	0.03	0.04

Discussion of statistical analysis. The three methods of analysis give different results because they test different properties of the variates. The regression method because of the transformation and the order test on the ratios, gives greater weight to the low precipitation values; the random sampling test, because it uses totals, gives greater weight to high values.

All methods show with a marginal significance level that it is unlikely that the difference between the precipitation relationships in the target and control areas in the seeded and unseeded periods is due to chance. The same is true to a lesser extent of the seeded and control areas. The only obvious systematic difference between the seeded and unseeded periods is the seeding, suggesting that the seeding has caused an increase.

10. Further analyses

Further analyses were undertaken which were not included in the original design.

A search was made for systematic differences other than the seeding, which could have contributed to the difference between the seeded and unseeded precipitations. The control area precipitation was higher in the unseeded than in the seeded periods, and there was a negative correlation of T/C with C. These could effect the results of the analyses. Of the tests presented, the Wilcoxon test on period ratios appears to be the only one appreciably affected. The magnitude of the control area precipitation difference is 10 per cent and its significance level by Wilcoxon test is 0.24.

Examination of the data from the four pluviographs which gave reasonably reliable records, suggested that precipitation was increased very little if at all, in the periods commencing half an hour after seeding started and terminating two and four hours after the cessation of seeding. The data from the eight daily read rain gauges which were available for the whole of the experiment did not suggest any effects of seeding although this analysis necessarily used statistically biased data. These analyses reduced confidence in an inference that seeding caused precipitation increases. (The same pluviographs and rain gauges showed increases of about the same magnitude as the isohyetal data in the seeded periods as compared with the unseeded periods.)

On the other hand, some analyses (also biased), supported an inference that seeding increased precipitation; for example, the difference appears to have been most pronounced in spring when there was the highest incidence of clouds of the type (cumulus) regarded as the most suitable for seeding.

The two participating organizations place differing weights on the results of these subsidiary analyses. To the SMHEA they suggest that the increase due to seeding was substantially less than the sample difference of 19 per cent. To the CSIRO the limitations of these subsidiary analyses appear such as to prevent the drawing of meaningful conclusions.

11. Conclusions

The marginal significance of the difference between seeded and unseeded period precipitations, together with the subsidiary analyses, lead to an overall result of the experiment which, while encouraging, is inconclusive. Therefore, further and improved experiments in this area are indicated and it is hoped that these will be commenced shortly.

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REFERENCES

Adderley, E. E., 1961: Non-parametric methods of analysis applied to large-scale cloud-seeding experiments. *J. Meteor.*, **18**, 692–694.

——, and S. Twomey, 1958: An experiment on artificial stimulation of precipitation in the Snowy Mountains regions of Australia. *Tellus*, **10**, 275–280.

Fisher, R. A., and F. Yeates, 1948: *Statistical tables for biological agricultural and medical research.* London, Oliver and Boyd, p. 104.

Kendall, M. G., 1946: *The advanced theory of statistics 2.* London, Charles Griffin, p. 110.

Mann, H. B., and D. R. Whitney, 1947: On a test of whether one of two random variables is larger than the other. *Ann. math. Stat.*, **15**, 50.

Smith, E. J., K. J. Heffernan and W. J. Thompson, 1958: The decay of the ice-nucleating properties of silver-iodide released from an aircraft. *Quart. J. R. meteor. Soc.*, **84**, 162–165.

Warner, J., and S. Twomey, 1956: The use of silver-iodide for seeding individual clouds. *Tellus*, **8**, 453–459.

APPENDIX

TABLE 1. Seeded periods.

Period No.	Duration From	To	Mean precipitation—inches Final T	Final S	Final C	Original T	Original S	Original C	Hours seeded Hr:Min
	1955								
3	28 Jun.	2 Jul.	0.51	0.23	0.13	0.28	0.10	0.08	1:15
6	20 Jul.	26 Jul.	1.08	0.43	0.54	0.56	0.33	0.45	0:58
7	27 Jul.	31 Jul.	3.97	1.90	2.31	2.86	2.01	2.06	0:36
8	1 Aug.	5 Aug.	1.64	0.68	0.52	0.73	0.39	0.40	1:35
11/12	19 Aug.	28 Aug.	8.23	4.83	4.80	7.31	3.78	4.26	3:29
13/14	29 Aug.	11 Sept.	7.17	1.77	1.50	3.47	1.44	0.90	1:20
17	27 Sept.	30 Sept.	0.99	0.50	0.46	0.40	0.24	0.17	2:00
20	14 Oct.	19 Oct.	5.39	2.22	1.23	4.71	1.87	1.12	0:26
22	27 Oct.	3 Nov.	3.12	2.16	2.04	2.72	1.76	1.70	1:42
23	4 Nov.	10 Nov.	2.39	1.65	1.17	2.14	1.42	0.99	2:40
24/25	11 Nov.	20 Nov.	2.09	1.11	0.70	2.46	1.03	0.72	3:42
26	21 Nov.	27 Nov.	3.78	1.69	1.11	4.18	1.76	0.92	1:48
	1956								
35	12 Apr.	30 Apr.	15.55	9.14	7.06	14.92	8.06	6.39	3:38
36	1 May	9 May	2.40	1.46	1.49	2.28	1.58	1.75	—
39	20 Jun.	10 Jul.	12.12	6.67	7.53	9.46	6.31	6.63	2:27
43	17 Aug.	30 Aug.	14.87	3.20	3.48	11.23	3.82	3.00	15:22
44	31 Aug.	13 Sept.	4.36	2.38	1.87	4.42	2.44	1.81	10:37
45	14 Sept.	26 Sept.	6.32	3.28	2.66	6.22	3.76	2.38	8:55
49	6 Nov.	20 Nov.	5.96	2.74	2.26	4.94	2.46	2.09	12:00
50	21 Nov.	1 Dec.	0.99	0.31	0.19	0.59	0.22	0.11	5:18
	1957								
52	29 Mar.	12 Apr.	0.92	0.54	0.26	0.71	0.42	0.20	—
53	27 Apr.	6 May	4.50	2.41	1.92	3.91	1.96	1.59	4:10
57	6 Jun.	2 Jul.	12.79	6.42	5.17	11.19	6.30	4.42	16:15
58	3 Jul.	16 Jul.	6.00	3.88	2.60	2.01	3.58	2.33	4:15
60	27 Jul.	14 Aug.	7.07	2.21	2.49	5.59	2.05	2.21	15:08
62	28 Aug.	6 Sept.	1.47	0.70	0.71	1.52	0.60	0.56	—
65	4 Oct.	17 Oct.	3.68	2.07	1.69	3.46	2.08	1.49	17:37
67	26 Oct.	9 Nov.	1.83	1.67	1.32	1.96	1.62	1.26	10:02
68	10 Nov.	21 Nov.	2.01	1.15	1.03	1.82	0.98	1.01	7:30
69	22 Nov.	5 Dec.	1.76	1.06	0.70	1.60	0.95	0.69	4:02
	1958								
72	10 Apr.	18 Apr.	2.68	2.13	0.54	2.58	1.95	0.45	3:40
75	7 May	19 May	8.19	3.88	3.09	7.23	3.14	2.88	18:25
77	30 May	10 Jun.	5.91	2.64	1.72	5.10	2.58	1.61	5:20
78	11 Jun.	18 Jun.	1.92	1.25	0.69	1.51	0.85	0.53	2:00
81	9 Jul.	23 Jul.	15.85	6.12	6.15	12.71	5.54	5.70	25:27
83	5 Aug.	21 Aug.	10.26	5.59	5.21	8.80	5.45	5.14	27:16
85	2 Sept.	9 Sept.	2.13	1.09	0.49	1.25	0.95	0.53	2:00
86	10 Sept.	23 Sept.	4.66	2.24	2.15	2.21	1.75	1.79	21:25
89	14 Oct.	27 Oct.	10.21	4.42	2.57	8.45	3.21	2.33	20:32
90	28 Oct.	6 Nov.	0.87	0.26	0.09	0.46	0.16	0.04	—
	1959								
93	13 Mar.	23 Mar.	0.23	0.19	0.31	—	—	—	—
95	18 Apr.	28 Apr.	1.07	0.57	0.37	0.86	0.42	0.32	3:00
96	29 Apr.	6 May	—	—	—	—	—	—	—
98	15 May	22 May	0.74	0.30	0.71	0.69	0.24	0.58	5:15
100	2 Jun.	11 Jun.	1.25	0.53	0.65	0.98	0.43	0.54	9:45
101	12 Jun.	28 Jun.	7.33	4.83	4.00	6.16	4.60	3.86	19:07
102	29 Jun.	6 Jul.	0.61	0.43	0.13	0.53	0.42	0.10	—
106	19 Aug.	26 Aug.	0.16	0.03	0.01	—	—	—	22:01
108	4 Sept.	11 Sept.	0.53	0.19	0.31	0.37	0.09	0.21	7:30
109	12 Sept.	23 Sept.	8.72	5.80	4.63	7.20	5.25	4.30	43:12
111	2 Oct.	14 Oct.	3.96	2.71	1.42	3.71	2.62	1.15	20:41
113	24 Oct.	2 Nov.	3.80	2.13	1.11	3.39	2.04	0.97	21:09
116	19 Nov.	1 Dec.	2.19	1.55	2.73	1.86	1.49	2.64	24:43

TABLE 2. Unseeded periods.

Period No.	Duration From	Duration To	Final T	Final S	Final C	Original T	Original S	Original C
	1955							
1	8 Jun.	20 Jun.	8.30	4.12	4.29	*7.80*	*4.31*	*3.82*
2	21 Jun.	27 Jun.	7.39	2.52	2.19	*3.33*	*2.21*	*1.93*
4	3 Jul.	12 Jul.	1.12	0.49	0.41	*0.67*	*0.30*	*0.45*
5	13 Jul.	19 Jul.	3.80	1.95	2.10	*2.13*	*1.80*	*1.86*
9/10	6 Aug.	18 Aug.	13.95	6.72	6.85	*13.20*	*5.86*	*6.15*
15	12 Sept.	19 Sept.	0.45	0.27	0.13	*0.34*	*0.19*	*0.07*
16	20 Sept.	26 Sept.	4.01	2.25	2.49	*3.70*	*2.27*	*2.50*
18	1 Oct.	4 Oct.	2.07	1.39	1.35	*2.56*	*1.30*	*1.58*
19	5 Oct.	13 Oct.	4.97	2.34	2.53	*3.87*	*1.72*	*2.13*
21	20 Oct.	26 Oct.	7.04	4.35	4.35	*6.04*	*3.47*	*3.80*
27	28 Nov.	5 Dec.	1.91	1.36	1.76	*1.69*	*1.34*	*1.53*
	1956							
34	11 Mar.	26 Mar.	7.05	4.42	4.43	*6.23*	*4.38*	*4.15*
37	10 May	28 May	6.64	4.49	5.76	*7.64*	*5.49*	*5.27*
38	29 May	19 Jun.	8.07	7.02	7.60	*8.77*	*6.88*	*7.10*
40/41	11 Jul.	28 Jul.	11.99	3.92	3.93	*8.34*	*4.37*	*3.68*
42	29 Jul.	16 Aug.	11.34	4.79	3.39	*17.77*	*6.67*	*3.53*
46	27 Sept.	12 Oct.	7.32	3.58	2.90	*5.00*	*3.10*	*2.60*
47	13 Oct.	24 Oct.	5.36	2.45	3.54	*4.02*	*2.45*	*3.33*
48	25 Oct.	5 Nov.	5.40	2.73	2.43	*3.97*	*1.64*	*2.40*
	1957							
51	18 Mar.	28 Mar.	0.53	0.10	—	*0.28*	*0.04*	—
54	7 May	15 May	1.12	0.55	0.25	*0.83*	*0.47*	*0.19*
55	16 May	27 May	0.97	0.80	1.09	*0.59*	*0.58*	*0.84*
56	28 May	5 Jun.	0.13	0.06	0.08	*0.11*	*0.02*	*0.04*
59	17 Jul.	26 Jul.	2.54	1.69	0.70	*0.98*	*1.64*	*0.54*
61	15 Aug.	27 Aug.	2.02	1.92	1.41	*1.79*	*1.79*	*1.29*
63	7 Sept.	20 Sept.	3.69	1.68	2.56	*2.07*	*1.39*	*2.34*
64	21 Sept.	3 Oct.	4.16	2.41	1.61	*3.50*	*2.16*	*1.60*
66	18 Oct.	25 Oct.	3.42	2.21	1.18	*3.09*	*2.17*	*1.12*
	1958							
70	17 Mar.	25 Mar.	0.29	0.27	0.04	*0.18*	*0.16*	*0.03*
71	26 Mar.	2 Apr.	2.16	0.99	0.72	*1.47*	*0.82*	*0.66*
73	19 Apr.	27 Apr.	0.14	0.09	0.02	*0.16*	*0.03*	—
74	28 Apr.	6 May	2.41	1.03	0.54	*1.92*	*0.68*	*0.42*
76	20 May	29 May	12.80	5.88	3.43	*9.70*	*5.09*	*2.81*
79	19 Jun.	26 Jun.	0.04	0.04	0.01	—	—	—
80	27 Jun.	8 Jul.	3.62	1.97	1.68	*2.68*	*1.93*	*1.64*
82	24 Jul.	4 Aug.	10.87	4.65	4.61	*10.03*	*4.90*	*4.37*
84	22 Aug.	1 Sept.	3.05	1.52	1.64	*2.31*	*1.31*	*1.44*
87	24 Sept.	1 Oct.	4.05	2.48	2.76	*3.80*	*2.03*	*2.52*
88	2 Oct.	13 Oct.	9.08	4.91	4.14	*8.59*	*4.77*	*3.94*
91	7 Nov.	17 Nov.	6.18	3.01	2.36	*4.96*	*2.78*	*2.44*
92	18 Nov.	3 Dec.	2.68	1.86	2.16	*1.95*	*1.63*	*1.98*
	1959							
94	8 Apr.	17 Apr.	1.48	0.68	0.83	*1.11*	*0.55*	*0.74*
97	7 May	14 May	—	—	—	—	—	—
99	23 May	1 Jun.	0.07	0.07	0.03	—	—	—
103	7 Jul.	17 Jul.	0.21	0.14	0.03	*0.15*	*0.10*	*0.03*
104	18 Jul.	29 Jul.	3.63	2.68	2.72	*2.27*	*2.32*	*2.00*
105	30 Jul.	18 Aug.	12.06	6.30	5.08	*6.17*	*5.08*	*4.21*
107	27 Aug.	3 Sept.	1.75	0.94	0.51	*1.28*	*0.74*	*0.44*
110	24 Sept.	1 Oct.	1.58	0.94	0.60	*0.96*	*0.68*	*0.45*
112	15 Oct.	23 Oct.	2.79	3.81	3.45	*2.68*	*3.52*	*3.33*
114	3 Nov.	10 Nov.	2.85	1.98	1.27	*2.40*	*1.84*	*1.17*
115	11 Nov.	18 Nov.	0.99	0.51	0.63	*0.69*	*0.42*	*0.57*

(Mean precipitation—inches)