ROYAL METEOROLOGICAL SOCIETY: AUSTRALIAN BRANCH MEETING

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Rainmaking Reviewed

J. Warner

Mr Warner, Chief of the CSIRO Division of Cloud Physics, began by pointing out that cloud seeding with a view to stimulating rainfall has been practised for a quarter of a century, but up to the present there is no general agreement as to the scientific basis for the effectiveness of this activity. If the physical processes involved were understood, it would be possible to predict effects and justify assumptions. In the absence of complete understanding it is necessary to resort to statistically based experiments requiring some decision, based on physical evidence, as to the confidence level that will be regarded as acceptable. The theme of the address was what are the aspects of such experiments that make them acceptable to the scientific community?

There is little argument about the fact that it is possible to significantly affect individual clouds by seeding. However, this is of little practical value as rainfall enhancement is required over a large area if it is to be useful. Thus the discussion concentrated on area seeding. The first area seeding in Australia was commenced in the Snowy Mountains in 1955 by releasing silver-iodide smoke from aircraft to produce an increase of ice crystal concentration in cloud and stimulate rainfall by the Bergeron process. Although this experiment was well designed for knowledge at that time, Warner considers its results, along with most other such experiments, unacceptable in the sense of being unproven.

To illustrate this he referred to a table reproduced here as Table 1.

Table 1 Summary of results of selected rainmaking experiments

Site	Number of years	Ratio	Significance level	
Unacceptable				
Snowy Mountains (NSW)	5	1.9	0.05	
South Australia	3	0.95	0.7	
New England (NSW)	6	1.04	0.1	
Warragamba (NSW)	4	0.97	0.6	
India -				
Delhi	8	1.42	0.02	0.02
Agra	6	1.58	0.03	
Jaipur	4	1.19	0.3	

Table 1 (contd)

Site	Number of years	Ratio	Significance level
Acceptable			
Colorado -			
Climax I	5	1.85	0.2
Climax II	5	1.74	0.03
Israel	6	1.15	0.009
Tasmania (Aut-Winter)	4	1.19	0.03

The ratio referred to in this table is the ratio between target rainfall and control rainfall on seeded and unseeded occasions. If this ratio is greater than one at an acceptable statistical confidence level then the seeded clouds will have produced statistically significantly more rain. The experiments had differing methods of defining target and control areas and seeded and unseeded periods, but the general results are compatible. It will be noted that the first group of experiments is classified as unacceptable and the latter acceptable, even though in some of the first group quite reasonable statistical significance is observed.

Warner's main reason for not accepting the early experimental results in Australia was that statistical levels of significance were, at the best, marginal. The Indian experiments on the other hand do not suffer this defect. He used these latter experiments to make the point that the statistical result should be considered in conjunction with good physical evidence. The Indian experimenters seeded clouds with salt from ground based generators with the aim of increasing the coalescence of water droplets. When the details of the experiment were examined Warner claimed that there were only just sufficient nuclei released to have caused the indicated increase and natural large nuclei were already present in comparable numbers. Additionally, radar evidence indicated that only 2 per cent of the natural rainfall was due solely to the coalescence process which the seeding was intended to stimulate.

The acceptable list of experiments in the table, which Warner feels probably is nearly complete, satisfy his two basic criteria: good statistical design and sound physical basis. For example, in the Colorado experiment the cloud physics enabled the results to be divided into two groups, one with the 500 mb temperature below $-20^{o}C$ in which no difference between seeded and unseeded clouds would be expected on physical grounds and the second with the temperature above $-20^{o}C$. The results were based on this second group. In the Israeli experiments the clouds were particularly homogeneous with small drops and low nuclei concentrations, just the conditions required for the seeding to have most effect. The Tasmanian experiments had a good back up of measurements in clouds also allowing a stratification of data and a finding that statistically positive results occurred when physical conditions were appropriate.

In summary, Warner listed the following criteria for an acceptable rainmaking experimental design:

(1) Good statistical design and analysis.

(2) Long duration of experiment (typically greater than 4 or 5 years).

(3) Uniformity of cloud during the experiment, or the ability to separate the regimes in the analysis.

(4) Preponderance of cloud suitable for techniques being used.

(5) An adequate background knowledge of the meteorological and microphysical factors involved in order to be able to appreciate acceptable confidence levels of the statistical results obtained.

On this basis the question might be raised as to whether non-ideal experiments should be carried out. Warner felt they should be, but the experimenters then have the responsibility not to make such strong claims for their success. What then of operational programs? He felt these should also proceed, but that since they cannot meet any of the above criteria no claims for success are possible, even if the seeding had in fact resulted in additional rainfall.

Turning to recent developments, two fields were noted. The numerical simulation of cloud seeding experiments using past rainfall data, on which hypothetical results of seeding operations are superimposed, enable a better understanding of the basic requirements for statistical design of specific experiments. Secondly, the numerical modelling of clouds is showing promise, although at the present stage they do not give fully reliable results for the effects of seeding on rainfall.

Finally, the speaker outlined the steps required to plan a modern experiment. First, past records should be examined using numerical simulation to determine how long the experiment would need to run, then the cloud physics of the site should be studied to determine the best approach. The statistical design should be sound and numerical models used if possible. He noted that the proposed World Meteorological Organization's Precipitation Enhancement Project is being formulated along these lines. Therefore, although the earlier experiments have often been inconclusive they have contributed to a better understanding of the requirements.

During the discussion that followed Mr Warner was asked why the seemingly good results for the Snowy Mountains had not been followed up using improved experimental techniques. In reply it was stated that this was an attractive proposition, but the priorities of the Division and the apparent interest of the Snowy Mountains Authority were such that this was not done. However, he did feel that world-wide experience appeared to indicate that mountainous terrain offered the best prospects for rain-making. Mr K.T. Morley asked if measuring silver iodide in rainfall might not give more accurate results than the measurement of precipitation. To answer this it was pointed out that the raindrops may in fact capture the silver iodide crystals, without the latter actually having acted as freezing nuclei; hence silver iodide in rainwater is no proof that the seeding caused the rain. Dr J.W. Zillman asked whether Warner agreed with the hypothesis that rain made at one area deprived some other area. Warner felt this was not proved. Mr I.C. McIlroy asked whether the 'cyclic' and long-term effects of artificial seeding were still in vogue. Mr Warner said that he thought that they were of rather doubtful validity, but the design of the Tasmanian experiment had tried to allow for them.

R.R.B.