Outlook

Rainmaking; the state of the art

For thousands of years in Australia, conjuring up drought-breaking rain was a spiritual art, practised in Aboriginal rain-making ceremonies. Then, for a short time after February 5, 1947, when the first rain produced by cloud seeding fell near Bathurst, N.S.W., science was hailed as the instrument that would rid Australia of its recurring droughts. But, of course, it hasn't happened.

The scientists involved always had lower expectations, for the simple reason that clouds capable of producing rain are rare things during droughts. It is hardly surprising, however, that the announcement of a success in scientific rain-making was greeted with rather wild enthusiasm in this driest of all continents.

Research into cloud seeding has continued without break since the first successful experiments were carried out after World War II. The scientists involved, from the CSIRO Division of Cloud Physics in Sydney (formerly part of the Division of Radiophysics), have shown that the amount of rain produced by some individual clouds can be increased greatly, and that modest increases in average rainfall can be produced in some areas. But they have also made the surprising discovery that cloud seeding can sometimes reduce rainfall.

Last year, drought-stricken farmers in Western Australia raised about $100 000 to pay for cloud seeding in their districts. Help was requested from CSIRO, and the Division provided a technician to assist in preparations for the seeding. Earlier, scientists from the Division had trained people in the State Department of Agriculture, along with people from other States, in cloud-seeding techniques and recognition of clouds that might respond favourably.

No guarantee

However, the Chief of the Division, Mr Jack Warner, had to point out to the people seeking help that there was no certainty that their efforts would have any useful outcome. He also had to tell them that there would be no way of judging afterwards whether seeding had indeed produced extra rain.

Mr Warner.

A large single cloud discharges its burden.

At present it is possible to predict the impact of seeding in any area only after a research effort lasting 5 years or more, and no such research has been carried out in Western Australia. Because rainfall varies so widely in the natural course of events, lengthy controlled experiments are needed to show what effect, if any, seeding is having. The scientists hope that increased understanding of how clouds work and improvements in techniques for gathering information about them will, in the not too distant future, make cloud seeding less of a gamble than it is now in most parts of Australia.

Clouds form when water that has evaporated from oceans, lakes, vegetation, and moist ground rises and cools to the point where it condenses. Tiny particles that are always present in the atmosphere serve as nuclei for the water to condense around.

The droplets that form have a diameter of less than one-thousandth of a millimetre, and are much too small to fall as rain. Raindrops are a millimetre or more across, and different clouds produce them in two different ways.

In warm clouds, the droplets grow into raindrops as they collide and coalesce. The other process occurs in clouds, such as the tall cumulus clouds often seen over Australia, that reach altitudes where temperatures are below freezing. Ice crystals form and grow. Then they fall and melt into raindrops.

The crystals can only form, however, if particles are present that can act as ice nuclei. Sometimes in this type of cloud, potential nuclei are either absent or sparsely scattered, and water at the top of the cloud remains liquid despite the sub-zero temperatures.

Those are the circumstances in which cloud seeding can work. By adding particles, such as silver iodide smoke, rain-makers can initiate the development of the ice crystals that turn into rain. They can produce the same effect by adding very cold substances such as dry ice. Warm clouds are not susceptible to seeding.

Early trials

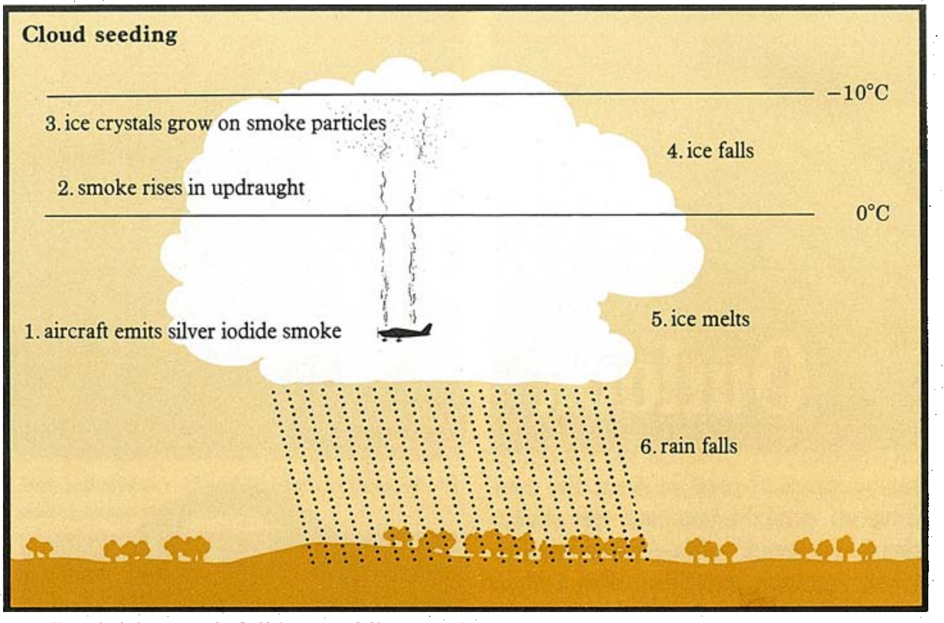
Australian rain-making research began close on the heels of two pioneering experiments conducted in the United States in 1946. In the first of these, dry ice was dropped into a cold fog generated in a laboratory. Ice crystals, resembling those that take part in the rain-producing process in tall clouds, formed in the fog. In the second experiment, dry ice was dropped from an aeroplane into clouds over Pittsfield, Massachusetts. Ice crystals formed as hoped, demonstrating that the process worked in the field. But evaporation prevented any rain or snow from reaching the ground.

The CSIRO experiment at Bathurst the following year was the first in the world in which induced rain actually wet some soil. In this, and follow-up trials near Sydney that continued until 1950, dry ice was dropped into the tops of clouds in quantities ranging from tens to hundreds of kilograms. Large aircraft were needed to take the dry ice loads to the required altitudes, and RAAF bombers were used in most cases. The results were most encouraging; the scientists concluded that, when cloud conditions were suitable, this method worked reliably in initiating rain that would not otherwise have fallen.

But dropping dry ice into clouds was expensive and difficult, and attention turned to the use of silver iodide, a material that had been suggested by American research workers. In the early 1950s, the CSIRO team pioneered the silver iodide seeding technique that is still in use. Light aircraft fitted with burners on their wings are flown into clouds; there, updraughts lift the silver iodide smoke particles to the cold cloud tops where they can act as ice nuclei.

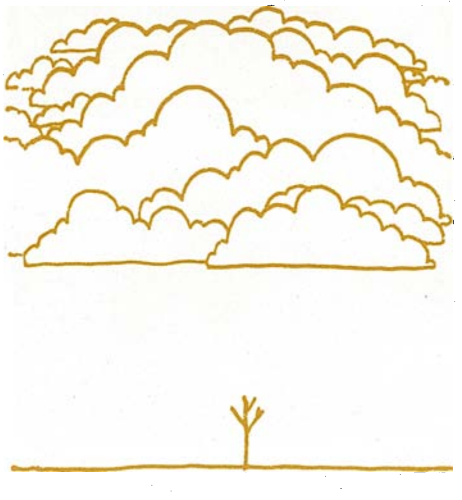
Seeding trials using this technique were carried out on individual clouds between 1953 and 1956, with results similar to those achieved with dry ice. Another series of trials, from 1961 to 1965, again produced similar results. This series was carefully planned to make possible accurate comparisons between rainfall from clouds randomly selected for seeding and that from similar unseeded clouds. The scientists concluded that there was only a 2% probability that the higher rainfall from the seeded clouds was due to chance.

The results of these trials, and of similar experiments overseas, indicate that seeding can increase the amount of rain deposited by individual clouds by a factor as large as three or four. Experiments aimed at finding out what effect a continuing seeding program can have on average rainfall over an area have, however, produced much less dramatic results. A 20% increase seems to be near the upper limit.



Seeding initiates rainfall by providing particles on which ice crystals can grow.

A cloud's ice crystals under the microscope.



Rainfall over an area

Between 1955 and 1963, the scientists conducted rain-making experiments, each lasting 3–6 years, in the south-east of South Australia, the Warragamba catchment that supplies water to Sydney, the Snowy Mountains, and the New England district of northern New South Wales. They estimated the effects of seeding from rainfall measurements in seeded and unseeded parts of the study areas.

They expected to achieve their best results in the Snowy Mountains and New England areas, as these were on the western slopes of the Great Dividing Range and affected mainly by continental rather than maritime air masses. Clouds that develop over the continent are more likely than those developing over the sea to be the cold-topped type susceptible to seeding. The South Australian and Warragamba test areas were exposed to more maritime air.

The results confirmed the scientists' prediction, and in fact no change in average rainfall was detected at the South Australian site or Warragamba. But the rainfall increase recorded in New England was very small, just 4%, and there was a one-in-ten chance that it was merely part of the natural rainfall variation. The Snowy Mountains site produced a more conclusive result — an average increase of 19%.

These experiments provided the first evidence that seeding can sometimes cause rainfall to decrease. Although no reduction in average rainfall was detected in any of the experiments, seeding appeared to increase precipitation in some periods and reduce it in others. Unfortunately, the design of the experiments was too simple to show what conditions produced rainfall rises and falls.

The CSIRO team conducted a more complex rain-making experiment in Tasmania between 1964 and 1970. They did not detect any change in rainfall in spring and summer. In autumn, however, they measured an increase of about 30%. In winter, rainfall seems to have increased in periods of light to moderate natural rain, but some evidence suggests that it decreased in periods of heavy natural rain.

The scientists used complex statistical techniques developed by the Division of Mathematics and Statistics to analyse the results of the experiment, and gained new information on the conditions under which seeding increases rainfall. For example, they found that, in Tasmania's predominantly maritime air, seeding stratiform clouds produced additional rain while seeding cumuliform clouds did not. They also found that they would have to increase the complexity of rain-making experiments still further if the conditions that produce increases, and decreases, in rainfall were to be fully defined.

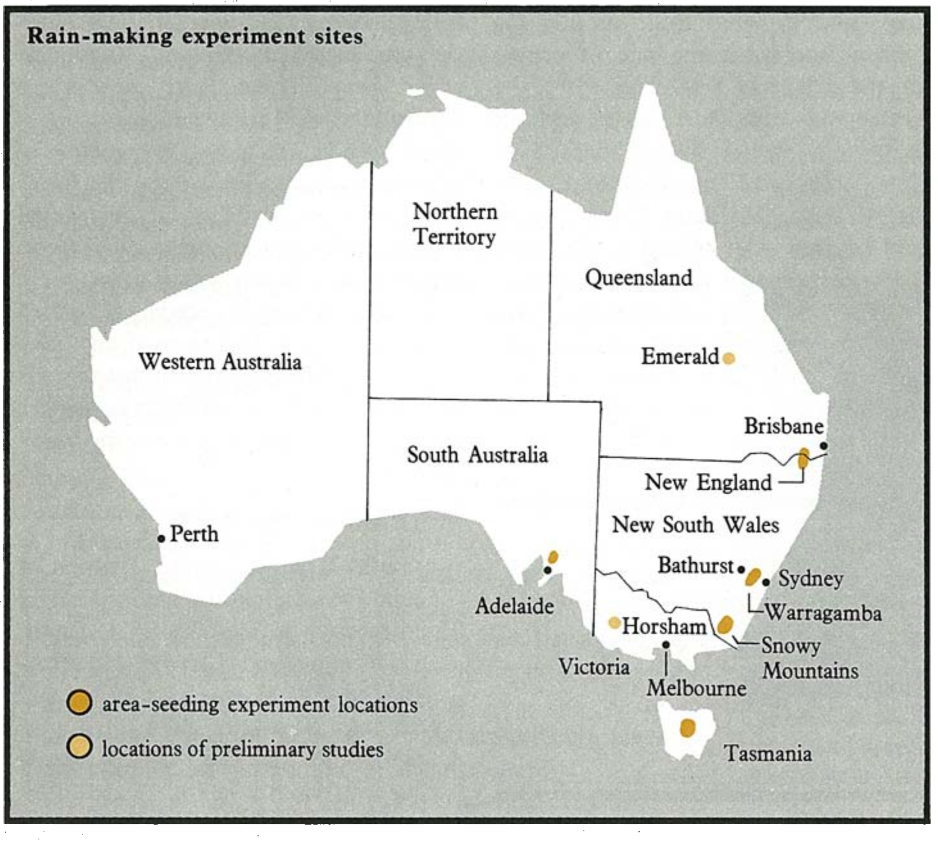
Before an experiment

Mr Warner and his Cloud Physics colleagues now believe that a preliminary study, lasting probably 3 years, should be carried out before any future area-seeding experiment begins. This should enable the researchers to make a realistic prediction as to whether a seeding program would be successful and whether any increase produced could be detected against the natural rainfall variation.

If the value of cloud seeding over large parts of the world, and Australia, is to be known in the reasonably near future, much more rapid assessment procedures will be needed.

In this study, measurements would be made from light aircraft flown through clouds to find out how often, and under what synoptic conditions, clouds suitable for seeding appeared over the area.

A simple way to find out whether a cloud contains the supercooled water needed for seeding to be effective (i.e., water colder than 0°C but still liquid) is to fly through its top layers. If the plane ices up, the answer is yes. However, temperature readings have to be taken, because the supercooled water needs to be at least as cold as −5° and preferably about −10°. For research purposes, of course, the scientists use much more sophisticated techniques than mere observation of aircraft icing.



Near the top of the cloud, information also has to be gathered on the amount of supercooled water present and the numbers and sizes of ice crystals in it. At the base of the cloud, measurements of water droplets are needed to ensure that ice formation and not droplet coalescence is the cloud's main rain-producing mechanism.

Once the relation between synoptic conditions and the appearance of suitable clouds has been worked out, the area's weather records can show how often and when, in an average year, clouds likely to respond to seeding will appear overhead. From all this information, it should be possible to make useful forecasts about the outcome of the seeding experiment.

One thing that needs to be estimated is how many years of seeding will be required before firm results show up against the background of natural rainfall variation. Obviously it is desirable to keep experiments as short as possible. Studies of the variability of natural rainfall show that for most areas of Australia an experiment lasting 5 years would be necessary, and in some parts the required time would be much longer.

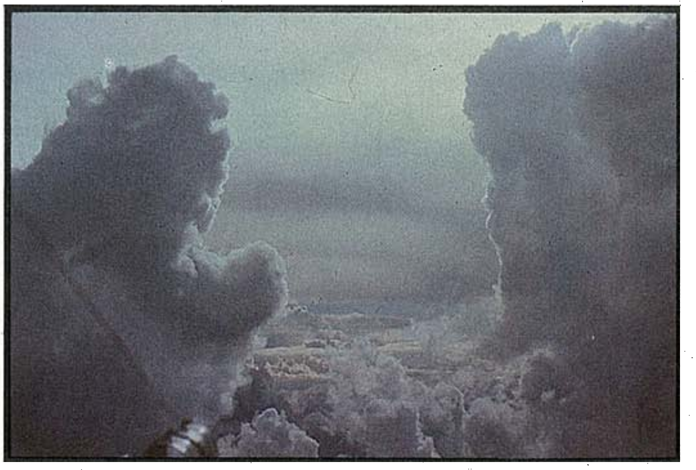
Between 1971 and 1975, the scientists carried out a preliminary study along these lines over the catchment of the Fairbairn dam near Emerald, central Queensland. They found that seeding would probably increase rainfall from the large tropical cumulus clouds common in the area. However, largely because natural rainfall varies greatly there — cyclonic disturbances come inland as far as Emerald in some years and not in others — they concluded that only a very lengthy experiment could show just what impact seeding was having. They decided not to go ahead with it.

Seasonal rains

Since 1975, the Cloud Physics team has been examining the prospects for a successful seeding experiment over wheat-growing country near Horsham, western Victoria. The fact that it is an agricultural area complicates matters. If rainfall is being increased over catchment areas for reservoirs, as it was in the Tasmanian experiment and would have been in Queensland, the times of year when additional rain falls and how heavy individual falls are will be minor considerations. In agricultural areas, on the other hand, they can be matters of great importance.

Around Horsham, winter rains are usually adequate, but rainfall during the spring growing season is often insufficient. So the scientists have been looking

Above the clouds.



A view often encountered by cloud seeders.

at the prospects for increasing spring rains. They have also been gathering as much information as they can on the relation between rainfall and crop yield. Some difficult questions need answers; for example, is extra rainfall likely to be beneficial or harmful on days when natural rainfall is already moderate to heavy?

The preliminary study shows that a 5-year experiment should be sufficient to reveal what impact a continuing seeding program could have in the area. It indicates that seeding could increase average spring rainfall by perhaps 15–20%.

On days when conditions are likely to be most suitable for seeding, increases of at least 50% could be expected. These are days when low-pressure systems produce stratiform clouds extending upwards to an altitude of more than 8000 m. The scientists have found that these clouds often contain extensive regions of supercooled water and low concentrations of ice crystals.

A decision on whether a full-scale rain-making experiment should go ahead in the Horsham district will be made in conjunction with the Victorian government.

The pre-experiment procedures worked out by the CSIRO team have been adopted by the World Meteorological Organization in its preparations, now under way, for an internationally sponsored Precipitation Enhancement Project. The aim is to carry out a rain-making experiment, taking about 5 years, in a semi-arid part of the world where prospects are good for producing extra rain in economically beneficial quantities.

As part of its contribution to the project, the Division of Cloud Physics, with assistance from the Division of Mathematics and Statistics, is examining rainfall data from six countries chosen as possible sites. The WMO hopes the results of the experiment will provide information helpful in assessing the prospects for rain-making in other semi-arid areas.

Help from satellites?

Clearly, however, if the value of cloud seeding over large parts of the world, and Australia, is to be known in the reasonably near future, much more rapid assessment procedures will be needed. Mr Warner points out that, after 30 years of rain-making research in Australia, the effects of seeding operations can be predicted confidently in only a few small portions of this country.

In the long term, information obtained from instruments carried by satellites may be the key to extending the coverage. If these could provide the information about clouds now gathered from aircraft, the problem would become one of coping with the deluge of data. This should be possible with computers. Three years of observations would still be needed to achieve the state of knowledge now reached in the Horsham district, but it could be knowledge related to the whole country instead of a very limited area.

Already, satellites can provide the information needed on cloud temperatures. However, they can't reveal whether clouds are just liquid or contain ice crystals, nor can they give necessary information about particle sizes and concentrations.

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Scientists at the Division are developing equipment intended to supply this information from satellites. Its method of detection will depend upon a spectral analysis of scattered radiation. The first tests of the equipment, installed in aircraft, should be made this year. Its output will be compared with the results of measurements taken in the usual way from aircraft flying through clouds. If these tests are successful, the equipment will need to be developed for satellite use — a program likely to take some years.

Meanwhile, cloud seeders continue to be called into action when rain is short, despite the lack of real knowledge about effects in most parts of the country. In the early years of rain-making research, these operations were carried out by the CSIRO team. Between 1965 and 1970 the Division conducted a series of courses at which people from State government departments were trained in techniques of cloud seeding, including recognition of promising clouds. Since then, the States have taken responsibility for operational seeding, with CSIRO accepting a responsibility to help in any way it can.

In these operations, seeding is carried out when conditions look as if they may be suitable. It is unfortunate that there is no way of telling, if rain follows, whether any of it was produced by the rain-makers.

More about the topic

'Research Activities.' CSIRO Division of Cloud Physics. (CSIRO: Sydney 1976.)

Cloud seeding in Australia. E. J. Smith. In 'Weather and Climate Modification', ed. W. Hess. (John Wiley and Sons Inc.: New York 1974.)

A closer look at rain clouds. *Rural Research* No. 82, 1973.