Why CSIRO has stopped cloud-seeding

After nearly 30 years of experiments, CSIRO has closed down its cloud-seeding operations. The decision was taken after research findings showed that clouds suitable for seeding are less common than previously thought.

Other considerations were the increasing cost of mounting large-scale aerial operations, and the high variability of rainfall in Australia (which makes it difficult to measure changes induced by cloud-seeding).

However, CSIRO will maintain its expertise in cloud physics and fields related to weather modification, and continue to be a source of advice for other groups using cloud-seeding.

The fortunes of cloud-seeding began well when, in February 1947, a CSIRO DC-3 dumped 70 kg of dry ice into the top of a cloud west of Lithgow, N.S.W. Within 16 minutes, rain fell from the base of the cloud and continued to fall for hours afterwards. No other rain was observed within 150 km of the plane.

It was the world's first documented case of 'man-made' rain wetting the soil. A year before a similar feat had been attempted in Massachusetts, U.S.A., but evaporation had prevented any rain from reaching the ground.

Encouraged by their initial success, CSIRO scientists carried out further trials near Sydney, mostly using RAAF bombers to carry the heavy loads (sometimes hundred of kilograms) of dry ice up to the required altitudes. Further positive results convinced them that, under suitable cloud conditions, this technique could be relied upon to produce rain that would not normally have fallen.

Natural rainfall—not so easy to bring on artificially.

Measuring the long-term success of cloud-seeding is difficult.

In the early 1950s, the CSIRO rainmakers pioneered the use of silver iodide smoke as a cheaper and less cumbersome substitute for dry ice. This is still the accepted means of cloud-seeding today.

Whether with silver iodide or dry ice, the attractively simple theory behind cloud-seeding remains the same: when injected into a suitably cold cloud, the chemical provides particles around which rain-producing ice crystals can form.

Cold clouds are those with tops extending to altitudes where the temperature falls well below freezing point. Such clouds can produce rain, but only if ice crystals form in them.

The supercooled water droplets in a cold cloud deficient in natural ice crystals are generally too small to form into larger raindrops by themselves, but these same droplets can evaporate to supply moisture to an artificial ice crystal introduced by the cloud-seeder. Provided the cloud is sufficiently deep for these crystals to grow to raindrop size before they evaporate, rain on the ground can result.

Trials conducted during the 1950s and early '60s demonstrated that seeding could increase the amount of rain deposited by individual clouds by a factor as large as three or four.

But the task of measuring the long-term success of cloud-seeding over large areas is much more difficult, owing to the extreme variability of Australian weather.

Scientists now consider 3 years — and, more typically, 5 years — to be the bare minimum period required to obtain a reliable result from an area-seeding trial in Australia. And the maximum increase in average rainfall produced by cloud-seeding is probably no more than 10–20%.

The usefulness of cloud-seeding depends crucially upon how often suitable clouds present themselves for seeding. Originally scientists believed this hap-

Clouds worth seeding are extremely rare.

pened on dozens of occasions a year. Experience has steadily whittled down that expectation, until in CSIRO's most recent experiment, in the Victorian Wimmera, the number has been estimated at one or two!

It is interesting to look into the fortunes of the Wimmera experiment more closely, as it offers a vivid picture of the difficulties facing cloud-seeders and helps to explain why they have called it quits, for the time being at least.

Rare clouds

Dr Warren King of the Division was one of the prime organizers of the experiment, which was carried out with support from the Victorian Department of Agriculture. In his summing up of this work, he relates how the participating scientists expected, before the trials began, that 5 years' effort would show results.

They believed that the clouds formed in cold fronts (which dominate the weather patterns of southern Australia) could be profitably seeded. Since the Wimmera is a prominent wheat-growing area, extra rain from the frontal clouds passing through the region would be welcome.

The researchers compiled 50 years of wheat-yield data and rainfall figures and calculated that a 10% seasonal increase in rainfall would be worth about $1 million (1978 dollars) to wheat-farmers. This amount was about five times the cost of staging the seeding experiment.

However, as experiments proceeded, they found that clouds worth seeding were actually extremely rare, and 25 years' work would be needed to show a statistically significant effect of seeding.

If one factor can be singled out as leading to a fall in the number of apparently suitable opportunities for cloud-seeding, it must be the development of a precision instrument for measuring the amount of supercooled water in clouds. The instrument, developed by Dr King, is a probe that determines liquid water content by measuring the heat loss from a hot wire as water droplets wet it. The defice's usefulness lies in its ability to ignore ice crystals: they bounce off the wire. Other instruments are available for measuring ice-crystal numbers and other cloud properties.

Laboratory studies have now made clear that, for successful seeding, a cloud must have a particularly narrow range of physical properties. For instance, it must have a liquid water content of more than 0·1 g per m^3; it must contain few ice-crystals — less than 10 per litre (if they're already numerous, there's no point in adding more); and cloud temperature should be below −8°C to allow ice crystals to grow.

From August to November (the growing season for wheat) in the 4 years 1975 to 1978, the scientists built up some 385 flying hours in simply measuring the properties of Wimmera clouds (no cloud-seeding was attempted at this stage). These observations showed that frontal clouds are not seedable. Ahead of a front, the clouds are too thin. At the front and behind it, the clouds already contain more than enough ice crystals to initiate rain.

However, all was not lost. Some clouds suitable for seeding were found in rain depressions ('closed lows'). These large-scale weather systems occur much less frequently than fronts, but produce about 30% of the season's rainfall.

Mountainous areas could be the most promising for cloud-seeding.

Few opportunities

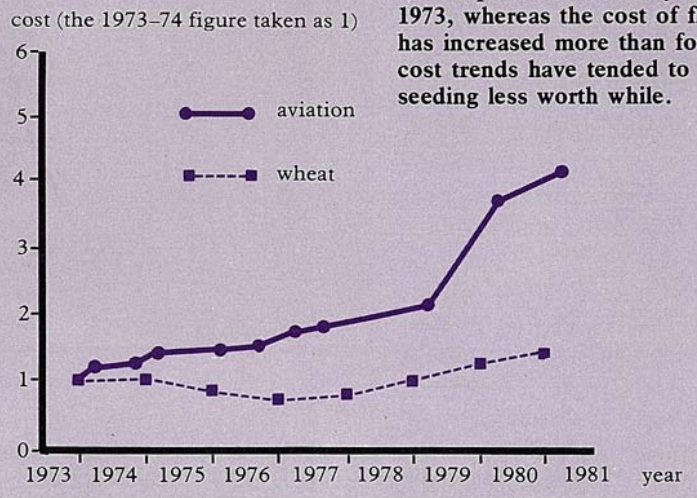
Cloud-seeding began in 1979 and continued in 1980. Seven closed lows came by, but, disappointingly, none was suitable for seeding — they all had an abundance of natural ice cyrstals.

It became apparent that the numbers of seeding opportunities associated with closed lows had been badly over-estimated. Although most of the closed lows encountered in the surveillance flights had brought suitable clouds, this was exceptional.

Suitable cloud occurs in only a fraction, perhaps one-third, of closed lows, according to the scientists' later studies. That would mean only one, or perhaps two, suitable opportunities per season. The rosy prospects of bygone days had vanished.

Cost rises and the benefits of cloud-seeding

Wheat prices have hardly altered since 1973, whereas the cost of flying aircraft has increased more than fourfold. These cost trends have tended to make cloud-seeding less worth while.



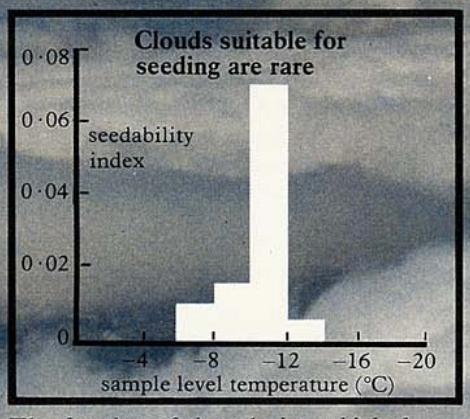
In three of the five closed lows encountered, the clouds were eminently suitable for seeding, with liquid-water contents of 0·1 to 0·3 g per m^3. Of the other two, one was marginally suitable and the other completely full of ice crystals.

An examination of 20 years of weather records showed that the scientists could expect five rain-bearing closed lows per season within the target area. Calculations indicated that seeding could increase the generally low rainfall from these systems by about 50%. This would lead to a 15% increase in seasonal rainfall, which should have been readily detected and statistically validated.

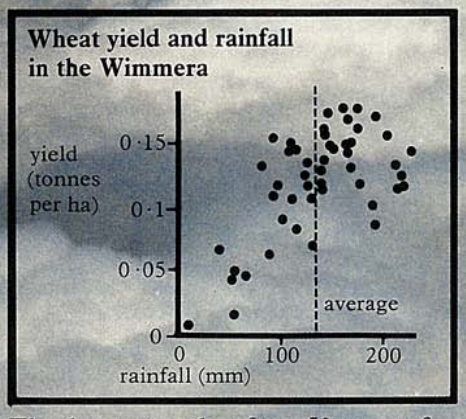
The scientists developed an 'index of seedability' from data acquired during the 1980 flights, and this showed even more clearly how rarely suitable clouds occur. The index is calculated as the fraction of the time when an aircraft flying through cloud (at a given height) encounters conditions suitable for seeding. The average index for temperatures lower than −8°C was only 0·0056 — that is, only about half of 1% of the in-cloud time. Even then, most of the favourable conditions were met in isolated patches of clouds, and seeding these is not much use.

Data on cloud properties were obtained in this aircraft.

Victoria's Wimmera district—scene of recent cloud-seeding experiments.



The fraction of time during which the aircraft flew through clouds worth seeding, 'the seedability index', was very low. Only clouds colder than −8°C can be seeded with silver iodide. Data came from the Wimmera experiment.



The data were taken from 50 years of records. In an average year, increased rainfall due to cloud-seeding should increase yields. However, very high rainfall tends to reduce yields.

Although the seedability index is small, it is not zero, and on three occasions seeding seemed worth while. Because of a randomization scheme, only one occasion was utilized for seeding; the others were 'controls'.

One further point: if the number of real opportunities for seeding is only about one a year then the economic benefits of the scheme work out to be no greater than its cost. The situation becomes bleaker when it is noted that aviation costs have increased by roughly 25% per year, and wheat returns to the farmer have increased by only 5% per year.

Where to next?

Western Victoria was chosen for cloud-seeding because its meteorology and agriculture are broadly representative of those in south-eastern Australia, so it follows that the inland plains of Victoria, South Australia, and New South Wales don't look particularly suitable for seeding.

Further north the rainfall varies so much that it becomes very difficult to discern the effects of a seeding experiment.

The cloud-seeding potential of the Western Australian wheat belt is currently being investigated by a team from the West Australian Institute of Technology, supported by the State government and local farmers, with CSIRO acting as a consultant. After 2 years, results do not look particularly promising, but firm conclusions await at least another year of study.

In Tasmania, the Hydro-Electric Commission is continuing to seed the central catchment area. Again, CSIRO is acting as consultant, having conducted experiments in central Tasmania from 1964 to 1971.

Mountainous areas could be the most promising for cloud-seeding. Experiments in the Snowy Mountains from 1950 to 1960 produced the most statistically sound result: a 19% increase. It is possible that the strong uplift over mountains may induce water to accumulate in the air at temperatures where there are few natural ice crystals. If this is so, cloud-seeding undertakings have extra chances of success. The Division of Cloud Physics is planning an investigation of the rain-forming processes over the Grampians as part of a program of fundamental research into the effect of mountains on rainfall.

Nevertheless, it will take a large economic stimulus to get cloud-seeding experiments going again. The scientists have learnt a lot about the physics of clouds, but the cost of running a cloud-seeding experiment has now become prohibitive.

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More about the topic

'Cloud Seeding in Australia: Experiments 1948–1981 and Prospects for Future Developments.' W. D. King. (CSIRO Division of Cloud Physics: Sydney 1982.)

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