

CLOUD SEEDING

A Method of Increasing Catchment Runoff.

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Introduction

The first Australian cloud seeding experiment was conducted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in February 1947. In a spectacular demonstration near Bathurst in New South Wales, a single cumulus cloud seeded with 225 kg of dry ice produced an average of 13 mm of rain over an area of about 130 km² while neighbouring clouds produced none. The Hydro-Electric Commission of Tasmania (HECT) first became involved with cloud seeding in 1964, jointly sponsoring a 5-year experiment with CSIRO which resulted in a statistically significant rainfall increase of about 23%. Recent discoveries in the field of atmospheric physics have prompted a re-analysis of CSIRO's early cloud seeding experiments with startling results. Some of their efforts including the New England Experiment, appear to have been far more successful at putting extra rain on the ground than at first thought. Three separate cloud seeding projects sponsored by HECT in Tasmania spanning 14 years, have contributed further to our understanding and have confirmed that cloud seeding can routinely enhance runoff into Tasmanian storages by 10 - 20%.

Cloud Physics

Clouds are mostly composed of tiny droplets of distilled water typically 0.02 mm in diameter (figure 1). One million of the tiny cloud droplets must amalgamate to form a single raindrop of 2.0 mm diameter. The natural processes of droplet growth by condensation and coalescence are often so slow, that many clouds containing large reserves of water produce little or no rain.

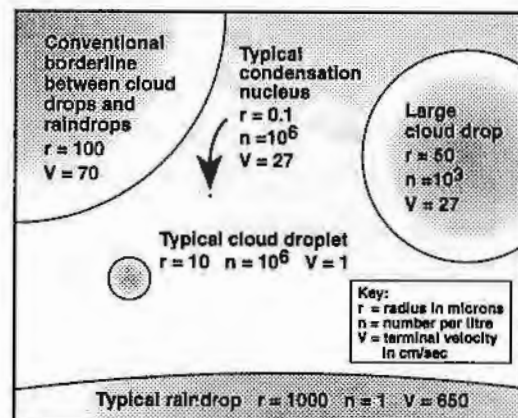


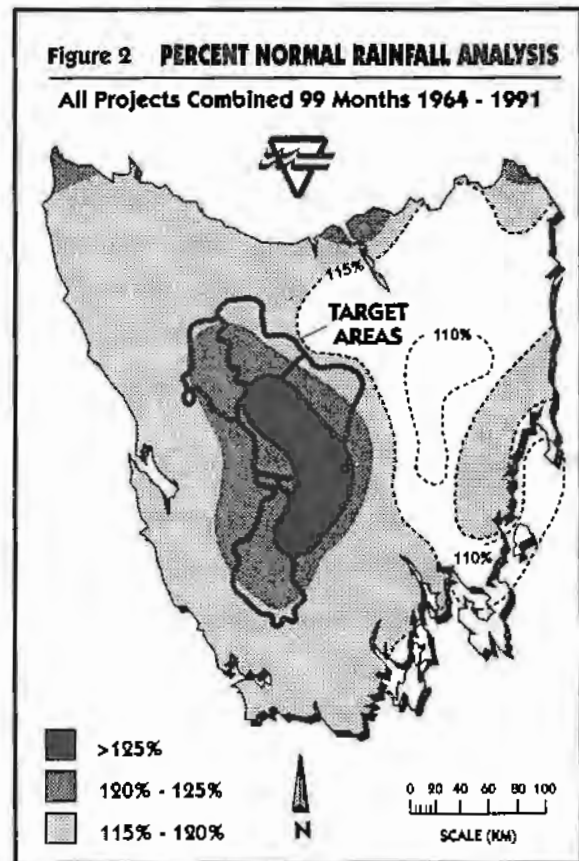
Figure 1: Comparative sizes of cloud particles (Mc Donald 1958)

Some clouds reach high into the atmosphere where the temperature falls below 0°C, commonly but erroneously called the freezing level, where snowflake growth might be expected to begin. By an oddity of nature, it is common, to find cloud water still in the form of liquid droplets at temperatures far below freezing, perhaps as cold as -20°C. To initiate the freezing of cloud droplets, suitable particles known as ice nuclei are required on which ice crystals may grow. It is possible to seed clouds with microscopic ice nuclei to start the process of glaciation.

Current Status of Cloud Seeding

The HECT has concluded two 5-year scientific experiments, both strictly controlled and designed for rigorous statistical analysis. Another project lasting 4 years (1988-1991) was conducted as a drought relief measure when HECT storages fell to unacceptably low levels. Each project has resulted in increased catchment runoff varying from 10 - 20%, and extra water in storage valued at more than ten times the cost of production. Figure 2 shows the effect of 14 years of cloud seeding on Tasmanian rainfall using percent normal analysis, where the normal is the median rainfall from 30 unseeded years. A third experiment is currently underway in Tasmania testing the relative merits of dry ice as a seeding agent.

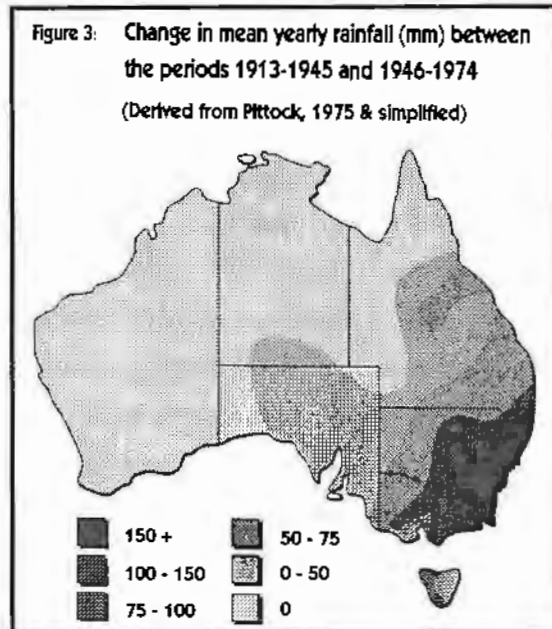
In 1990 cloud seeding was being practised in 23 countries around the world. In California alone, 18 cloud seeding operations were being conducted, some of which have now been running for 40 years. Of the 92 projects, more than 70 were being run by water authorities in operational mode for commercial advantage rather than for experimental purposes.



Will Cloud Seeding Work in NSW?

In the years between 1957 and 1973, an average of 334 hours of cloud seeding per year were conducted in eastern Australia. Coincident with this rainmaking effort,

rainfall in the seeded areas and in areas downwind was 10 - 20% higher than in the 33 year period 1913 - 1945 (figure 3), before the discovery of cloud seeding.



When the cloud seeding ceased in 1973, annual rainfall totals returned to their previous levels. Attempts have been made to explain away the substantial increases in rainfall shown in figure 3 while widespread and at times intensive cloud seeding was in progress, but none of the explanations were considered by the Australian Academy of Science to be totally satisfactory (AAS 1976).

In the years 1958 - 1963, CSIRO conducted a randomised cross-over

design cloud seeding experiment in two New England catchments. The northern target area included the Macintyre and Severn river catchments, and the southern target area included the catchments of the Manilla, Namoi and Peel rivers. Clouds judged suitable were seeded with small amounts of silver iodide, released as an invisible smoke from an aircraft. There appeared to be a spectacular and statistically significant increase in rainfall of about 30% in the first year, but results mysteriously declined in subsequent years (Smith, Adderley and Bethwaite, 1965).

Investigations by Bigg (1985) of the CSIRO Cloud Physics Division into several Australian experiments which all displayed similar patterns of declining results, brought to light an apparent carry-over seeding effect which progressively affected rainfall in unseeded control areas. It also affected target area rainfall on unseeded days. These persistence effects confused the traditional types of statistical analyses and hid the real effects of seeding from view. When the persistence effects of cloud seeding are identified and accounted for, the 6-year New England experiment for example, shows a 19% increase in rainfall on the days of seeding, 10 - 14% for 1 to 10 days after seeding, and 3 - 8% for the subsequent period extending to day 50. A highly successful operation, (Bell 1985).

In 1992, a CSIRO report commissioned by the Department of Primary Industries and Energy Cotton Research and Development Corporation into the statistical

feasibility of cloud seeding in the New England area concluded that there is good potential for increased rainfall by cloud seeding, (Chambers and Long 1992).

Costs and Benefits

The HECT cloud seeding experiments have cost less than one million dollars per year to run, and have returned an average of about 55 mm of extra rain in each 6 month experimental season. In the 3250 km² target area alone, the additional water conserved in storages amounts to about 180,000 Ml per year. Using conservative figures from the most reliable HECT experiments and ignoring the benefits of persistence effects and increased rainfall in neighbouring catchments, the costs and benefits of commercial cloud seeding in Tasmania can be easily calculated. Table 1 lists the assumptions, system characteristics and likely gains obtainable from a single aircraft cloud seeding operation in Tasmania, expanded to cover an area of 6600 km² and to operate for 8 months per year.

Table 1. GAINS OBTAINABLE FROM CLOUD SEEDING

ASSUMPTIONS - Based on Stage 2 Experimental results

Area of Target	6600 km ²
Average number of suitable days per season	30 days
Average increase per seeded day	3.0 mm

SYSTEM CHARACTERISTICS

Runoff ratio (Winter & Spring)	1.0
Average regulation:	85%
Average Power Factor (kW/m ³ /sec)	3800

STORAGE AND ENERGY GAINS

Volume	505,000 Ml total, or an average flow of 16 m ³ /sec
Energy	60 MW average, or 323 GWh/year

COST OF A SINGLE AIRCRAFT CLOUD SEEDING OPERATION

8 month season - approx.	\$ 645,000/year (Tasmania only)
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RESULT

Extra water in storage costs less than	\$1.30 /Ml
Energy in storage gained costs less than	0.2 c/kWh

Environmental Impacts

Vast amounts of scientific effort and finance have been spent on researching the environmental impacts of cloud seeding, particularly in the USA where many hundreds of technical papers have been published. Almost all researchers agree, that there is little or no adverse environmental impact because the seeding agents

are dispersed in minute quantities and are apparently harmless when fed to sensitive species such as rainbow trout. After an intensive study, Klein (1977) summarised the impact of silver iodide on a target area environment as follows; "There appears to be no real threat to humans, plants or animals from silver iodide seeding agents in the study area." Fears that cloud seeding might precipitate floods, devastate wildlife habitats or increase soil erosion by increasing the frequency of extreme weather conditions also appear to be unfounded and can best be placed in perspective by recognising that Australia's recurring droughts are vastly more destructive of the natural environment and the economy than rainfall increases of 10 or 20% could ever be.

Other Issues

In Tasmania the target catchments are sparsely populated and the water resources are under the control of a single authority. There is little or no dispute over rights to the extra water obtained by cloud seeding, or over responsibility for distribution and cost recovery. In more developed and densely populated areas however, these and related issues will need to be addressed. State authorities responsible for the management of water resources have a vital role in coordinating activities and protecting the rights of residents and water users. Because the beneficiaries of a successful cloud seeding project are likely to include more than one interest group, initial funding should logically come from government and cost recovery from sales of water.

Recent Action

On 16 September 1992, representatives of the cotton industry convened an informal meeting in Sydney to urge consideration of a cloud seeding project in northern NSW to augment critically low water levels in several dams. Three ministers of the State Government and 5 ministerial advisers were present, plus the HECT Senior Cloud Seeding Officer from Hobart. On 6 October 1992 copies of a detailed submission entitled "A Proposal for a Pilot Cloud Seeding Project in Northern New South Wales" (HECEC 1992) were mailed to four ministers of the NSW Government. Unofficial advice suggests that although there were no serious environmental objections, the proposal was rejected.

On 31 October 1992, the Murray Darling Basin Commission advertised the availability of funds as part of its Natural Resources Management Strategy, and the HECT submitted a proposal for partial funding of a cloud seeding experiment to be conducted in the New England area. This was also rejected on 2 February 1993.

The Way Ahead

Given the chronic shortage of clean, fresh water in much of Australia in recent years, it is surprising that cloud seeding has not been seriously reconsidered outside of Tasmania, with the exception of an experiment in a small catchment east of Melbourne. In the light of recent discoveries and a new appreciation of the results of the early experiments conducted by CSIRO, the time is right to conduct new experiments in the catchments of New England, the Snowy Mountains and Warragamba Dam where the chances of success are greatest. The greatest need is to re-open the case for cloud seeding with State and Federal Governments, with a view to obtaining their endorsement of a series of well designed experiments and funding of between 1 and 2 million dollars per project per year.

Conclusion

- * There are excellent reasons to believe that cloud seeding is a viable option for enhancing catchment yields in Northern NSW.
- * Suitable technology, equipment, and trained staff are currently available.
- * There are no significant adverse impacts.
- * The benefits of enhanced catchment yields should far outweigh costs.

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