Department of Environment and Conservation (NSW)

SYDNEY CATCHMENT AUTHORITY

- F I N A L D R A F T R E P O R T -

Workshop on Cloud Seeding

Hosted by the NSW Department of Environment and Conservation (DEC)
and the Sydney Catchment Authority (SCA)

Wednesday 31st January 2007
Department of Environment and Conservation
59-61 Goulburn St Sydney

Introduction

A one-day workshop was held to review the current state of knowledge on cloud seeding for rainfall enhancement, and the role of aerosols and air pollution on precipitation. The workshop was jointly hosted by the NSW Department of Environment and Conservation (DEC) and the Sydney Catchment Authority (SCA), and independently facilitated by Professor Gary Jones, CEO of the eWater Cooperative Research Centre. Nineteen scientists and senior managers (see appendix) participated in the workshop, with formal presentations given by Neville Fletcher (Australian National University), Michael Manton (Monash University), Roger Stone (Queensland Climate Centre), Greg Ayers (CSIRO Marine and Atmospheric Research) and Keith Bigg (The Rainmaker Team).

Participants discussed key issues relating to the scientific evidence for the effectiveness of cloud seeding. Participants briefly reviewed the experience of cloud seeding activities in Australia, current and planned cloud seeding projects and the effect of pollutants on precipitation. The following summary presents a consensus position of attendees at the workshop, expressed as Q&A.

Consensus position

1. **Are scientists convinced that cloud seeding works**? It is generally agreed that targeted cloud seeding can modify precipitation from individual clouds under specific local conditions. The characteristics of clouds that will respond to seeding are well documented. In favourable circumstances cloud seeding has been demonstrated to increase precipitation from individual clouds, but it can also decrease precipitation from individual clouds if applied haphazardly. The extent to which the seeding of individual clouds can be scaled up to enhance precipitation over a large area is unclear. To provide reasonable scientific certainty, scientists require a viable physical model based on cloud physics and direct observational evidence as well as robust statistical validation of the results.

2. **What are the main difficulties?** One major problem is that is it difficult, if not impossible, to quantify the impact of a cloud seeding operation over a wider area, without expensive, time-

consuming and detailed experimentation and evaluation. Natural variability in rainfall is high, both in spatial and temporal terms, and it is difficult to predict what would have happened in an area had cloud seeding not taken place, despite the use of controlled experiments. It is difficult to design a practical cloud seeding campaign that has sufficient statistical rigour to prove or disprove the effectiveness of the seeding. Experiments using appropriate statistical design criteria may need to run for many years in order to detect with reasonable certainty a rainfall enhancement signal against the 'noise' of the natural variability of rainfall. Many cloud seeding trials have suffered because of the inability of the design to produce unequivocal signals of the effect of cloud seeding. In addition, clouds amenable to seeding may not be present for a significant fraction of the time - for example the 1979-1980 Victorian experiment was abandoned due to a lack of suitable clouds.

3. **What has previous experience in Australia shown?** Cloud seeding experiments have been conducted by CSIRO in Australia since 1947, with experiments in the 1950s and 1960s in South Australia, Queensland, the Snowy Mountains, Central Plateau of Tasmania, the New England district of NSW and the Warragamba catchment west of Sydney. Of these experiments, only the Snowy Mountains and Tasmanian studies produced statistically significant increases in rainfall, although the apparently positive result of the Snowy Mountains experiment was disputed by some of the parties involved. Other experiments, conducted by various State Governments in the late 1950s and 1960s, were inconclusive because the experimental design was not robust enough to provide certainty on cause and effect. Further studies of the potential for cloud seeding to increase agricultural productivity conducted in the 1970s and early 1980s did not demonstrate that seeding would be economical or reliable for this purpose.

   The most promising results have been obtained where clouds are formed by air forced up over mountain systems such as Central Tasmania, where results show with reasonable statistical significance that cloud seeding had increased precipitation over target areas (albeit with some anecdotal evidence for decreases downwind – there is not sufficient data to assess this possibility definitively). Cloud seeding is also being conducted by Snowy Mountains Hydro for snow pack enhancement, with the NSW Natural Resources Commission charged with supervision of the trial and reporting on the environmental impact of the trial[1]. The success or otherwise of the Snowy experiment will not be known until sufficient statistical data have been obtained several years hence at the end of the experiment. A 4-year, $7.5m cloud seeding investigative project in south-east Queensland has recently been announced. This will have a rigorous statistical design to test the effectiveness of the seeding in increasing precipitation. It should be noted that different types of clouds form at different latitudes and the Queensland experimental technique may differ from that used elsewhere.

4. **Can findings from one area be transported to another?** Not readily – each area has different topographic and climatological features that respond differently to cloud seeding. Detailed studies

[1] Snowy Mountains Cloud Seeding Trial Act 2004.

are required in specific areas to identify and assess cloud types in different seasons that may be amenable to seeding. Carefully designed experiments are required to separate signal (additional precipitation attributed to seeding) from noise (natural variability and sampling errors), test and verify models and predictions, and then iteratively improve the experimental design before progressing to operational design. Numerical modelling and prediction, in association with advanced measurement techniques, are also integral to the design and testing of specific hypotheses in modern cloud seeding.

5. **What are the types of cloud seeding?** There are two basic types of cloud seeding – warm and cold. *Warm* cloud or hygroscopic seeding involves the introduction of small droplets such as salt spray or large hygroscopic[2] aerosols into the base of continental convective clouds which cause raindrops to form and may cause the cloud to grow due to release of latent heat and/or due to enhanced coalescence of drops. *Cold* cloud seeding creates additional ice crystals that grow at the expense of supercooled liquid water using nucleating agents such as dry ice pellets or crystalline silver iodide nuclei released from ground burners or aircraft. The ice crystals then grow, fall and become raindrops below the freezing level. Currently much of the cloud seeding worldwide is operational hygroscopic seeding in warm cumulus clouds in sub-tropical and tropical areas, carried out without rigorous scientific validation.

6. **How do you tell if a cloud is suitable?** Modern direct and remote sensing techniques can give detailed information on cloud structure and physical quantities such phase (water-vapour-ice) and wind speed and direction. Doppler and polarisation radar can be used to study non-precipitating clouds and evolving cloud cells, microwave radiometer profilers measure liquid water content, and satellite data can be used to interpolate between detailed measurement points. These data can be fed into detailed cloud models for prediction and verification of seeding impacts.

7. **Can cloud seeding be used to break a drought?** No - cloud seeding cannot make clouds where none exist, nor can cloud seeding increase precipitation from clouds that do not have the relevant characteristics. Drying trends cannot be managed or offset by cloud seeding. If effective at all, seeding is most applicable in years of moderate rainfall.

8. **Are there any long-term impacts from cloud seeding?** Some studies have suggested the existence of "persistence effects". A recent hypothesis is that the silver iodide used to seed clouds affects the microflora in soils and causes microorganisms to be released from soils. These are hypothesised to be carried into clouds and form nuclei that will lead to precipitation. This effect may last for a long period following the end of actual cloud seeding activities. If such effects are real, they will confound quantitative studies of cloud seeding effectiveness, but the overall effect could be a further increase in rainfall. Persistence effects have to date received narrow coverage in the peer-reviewed scientific literature.

[2] Hygroscopic particles attract moisture from the atmosphere

9. **Are there any downsides to cloud seeding?** The main disadvantage with cloud seeding is the high operational cost without commensurate assurance of success or economic return. Other issues include the possibility of downwind effects (decreased rainfall downwind from the target area), possible ecological impact of minute traces of seeding chemicals on sensitive terrestrial ecosystems, legal challenges, and overselling the technology without supporting scientific understanding and robust evidence. Experience has shown the importance of community engagement and consultation.

10. **Does pollution influence rainfall?** There is abundant physical evidence that aerosols (fine particles) emanating from human activity from industry, transport, landuse or fire does affect cloud physics, i.e. the characteristics of clouds are altered by introduction of these particles. Human activity is known to increase the concentration of airborne aerosols, particularly of smaller size. However there is limited, conflicting evidence on the impact of pollution on rainfall – increases, decreases and nil impact have been reported. The level of natural variability due to other causes is probably much higher than possible changes attributed to pollution. Importantly, low clouds that are particularly susceptible to microphysical changes due to aerosols emanating from the ground are generally not the main sources of annual rainfall in mid-latitude regions. If pollution effects were to be demonstrated in a particular region, then the preferred approach would be to reduce pollution at its source.

10 April, 2007

Appendix 1 – Workshop participants

Facilitator: Professor Gary Jones, Chief Executive of eWater Cooperative Research Centre

Participants

Dr Brian Spies, Manager Science, Sydney Catchment Authority (co-convenor)
Dr Klaus Koop, Director of Environment & Conservation Science and Chief Scientist, NSW EPA (co-convenor)
Dr Greg Ayers, Chief of Marine and Atmospheric Research, CSIRO
Dr Doug Shaw, Mathematics and Information Sciences, CSIRO
Prof Roger Stone, Director, Australian Centre for Sustainable Catchments, Queensland
Prof Neville Fletcher, Research School of Physical Sciences & Engineering, Australian National University
Prof Michael Manton, School of Mathematical Sciences, Monash University
Dr E Keith Bigg, Rainmaker Team
Prof Andy Pitman, Professor and Network Convenor & ARC Earth System Science Network, Macquarie University
Ms Jane Gibbs, Manager Policy, Metropolitan Water Directorate, NSW Cabinet Office
Mr Derek Elmes, Manager Strategic Science Section, DEC
Dr Henk Heijnis, Scientific Program Manager, Sydney Catchment Authority
Mr Mahes Maheswaran, Strategic Supply Planning Manager, Sydney Catchment Authority
Mr Jason Martin, Strategic Supply Planning Manager, Sydney Catchment Authority
Mr Barrie Turner, General Manager Environment & Planning, Sydney Catchment Authority
Ms Katrina van Lint, Natural Resource Analyst, Natural Resource Commission
Dr David Rissik, Natural Resource Analyst, Natural Resource Commission

Presentations

- Neville Fletcher (Australian National University) – Clouds, rain and rainmaking
- Michael Manton (Monash University) – Statistical design and evaluation of cloud seeding experiments in Australia
- Roger Stone (Queensland Climate Centre) – initial investigation of the potential application of scientific systems for cloud seeding in Queensland
- Greg Ayers (CSIRO Marine and Atmospheric Research) – Pollution and precipitation: evidence for Australia
- Keith Bigg (The Rainmaker Team) – A new look at cloud seeding suggests better and cheaper methods