Australian Rain

Trials of the Atlant ionisation rainfall-enhancement technology in Australia

Rainfall enhancement technologies have been deployed widely in countries and regions where water resources are scarce and climates are generally dry and rainfall patterns quite variable. In particular, cloud seeding programs are in place throughout much of the western United States, and in Israel, China and Australia.

Conclusive experimental evidence which confirms that these technologies are effective remains elusive. Detecting a relatively small enhancement signal amongst the natural spatial and temporal variability in rainfall is challenging, and control of the necessary experimental conditions for providing this evidence is extremely difficult. However, there is still a high level of interest in these technologies because of the size of the payoff for a relatively small level of enhancement. Even with a modest probability of enhancement, the expected return from a well-targeted program can be many times greater than costs. Given Australia's historical record of extended periods of adverse climatic conditions, and the limited options available to adapt to climate change in non-urban environments, a strong case can be made for continued trials of rainfall enhancement technologies in Australia, and for large-scale deployment of any cost effective technology which demonstrates even a relatively small enhancement.

Atlant is an alternative to chemical-based cloud seeding. It is a ground-based ionisation system, designed to charge naturally occurring aerosols, which are then carried into the cloud layer through local winds and uplift. The technology is low-cost, quickly and easily deployed and has no discernible negative impact on the environment.

While it is generally accepted that introducing electrically charged droplets into a naturally occurring cloud will affect the collision probabilities and hence the rate of droplet coalescence to produce raindrops, the overall outcome of this effect will depend upon the nature of the cloud and the concentration of charged droplets. There is no record of a systematic scientific program designed to evaluate the effectiveness of the technology when it was first developed. One of the principal issues which needs to be addressed in this context is whether the system can deliver a sufficient concentration of charged aerosols to affect droplet formation and growth within a cloud mass. Another, obvious, question is whether it is possible to observe a measurable increase in rainfall on the ground following operation of Atlant.

Australian Rain Technologies (ART) undertook to do this evaluation, initially with assistance from the Federal Government and then independently with technical assistance from two Australian universities. Over the past 18 months, the evaluation has been guided by a Scientific Reference Panel (SRP) made up of experts in the field of atmospheric physics, statistics and water management.

Measurements were taken to establish the levels of ion concentrations released by the Atlant system into the atmosphere. An atmospheric model was then used to simulate the transport of ions emitted from the Atlant and to estimate the approximate concentration and location of a hypothetical ion plume when it reached the cloud layers. While this helped to establish basic

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elements of how the system physically operates, two major research questions remained. The first related to the interactions between the released ions and aerosols present in the lower atmosphere. The second was whether the potential concentration of the ions or charged aerosols at the cloud layer would be sufficient to initiate or facilitate the formation of rain droplets.

In order to justify what would be a significant program of research to address these questions, ART has focused on a series of field trials, the first two in Queensland. A simple comparison of average rainfall for the trial period with historical records indicated there were elevated levels of rainfall within the target areas in both of these trials. However, rainfall levels both within and outside of the trial areas were still well within historical bounds, and it became clear that a more sophisticated statistical approach would need to be developed if the field trials were going to be able to establish whether ground-based ionisation could deliver discernible rainfall enhancement. The statisticians on the SRP have similarly concluded that any analysis based on simple statistical models is unlikely to be conclusive, a view that is becoming the consensus view regarding rainfall enhancement trials more generally.

ART engaged Professor Ray Chambers of the Centre for Survey and Statistical Methodology at the University of Wollongong to develop such an approach, drawing on his recent and ongoing research into statistical analysis using models which explicitly recognise the spatial and temporal characteristics of observed data, as well as analysis of experimental data where there is limited capacity to control experimental conditions. Central to the application of these techniques is:

- The use of statistical models for daily rainfall readings from individual rain gauges within the trial target area. These models allow for rainfall variation due to local meteorological conditions, local topographical variation and the correlation between gauge readings which are nearby in space and in time. Note that this correlation is important in establishing how much additional information is obtained by using data from individual gauges, compared with the more conventional approach of basing analysis on average rainfall over the target area; and
- The dynamic definition of the target area on a given day based on prevailing wind directions and speeds.

This work was investigative in nature, starting with an analysis of the data from the second Queensland trial, and suggested a positive enhancement effect which shifted with prevailing wind directions. The statistical techniques and experimental designs have subsequently been reviewed and refined in two successive field trials in the Mount Lofty Ranges in South Australia in 2008 and 2009. This trial area was selected to test the efficacy of the Atlant system under meteorological and topographic conditions considered to be favourable for a ground-based system. There was also the possibility that a successful trial would substantively increase rainfall over the drought-affected Lower Lakes of South Australia and the urban water catchment of Adelaide.

The results from the 2008 Mount Lofty Ranges trial were again suggestive of a positive downwind enhancement effect. However, the experimental design of this trial involved only one Atlant site, and the complexity of the correlation structure between nearby gauges limited the inferences that could reliably be drawn from it.

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The 2009 Mount Lofty Ranges trial employed a randomised crossover design with two sites located in similar topographic conditions, separated by a distance of 58 km. The analysis of data from this trial included significant advances in statistical methodology which allowed for spatiotemporal correlation in the gauge-level data. Within a target area defined by two overlapping 60-degree wedges downwind of the devices, the resulting analysis indicated that operation of the Atlant system was associated with a more than nine per cent increase in gauge-level rainfall. The confidence bounds about the estimate suggest a reasonable level of confidence that there was a positive enhancement effect over the trial period. However, the confidence bounds of the estimate are still under investigation as the correlation between gauge level observations needs to be taken fully into account to avoid overstating their precision.

The statisticians on the SRP felt there had been an open, honest and thorough implementation of the trial design. This design was noted as having a number of good features, although there remains room for improvement in future trials.

The investigative nature of the statistical analysis, and the use of models to account for the impact of meteorological and topographic conditions not controllable by the experimental design, does mean that these results suggest a positive Atlant effect exists rather than prove its existence. The statisticians on the SRP have highlighted the suggestive rather than the conclusive nature of the results from a scientific perspective. They have also recommended investigation of alternatives to the particular modelling approach that we adopted. The use of other methods of statistical analysis with the same data could lead to different results which may be more or less favourable. This is an unavoidable caveat when dealing with complex environmental systems, and it extends to consideration of how effective the Atlant technology might be under different meteorological conditions and in different locations. The SRP has noted that addressing this uncertainty will require trialling the Atlant system under a wide range of meteorological and topographic conditions. This would allow the collection of sufficient data for an appropriate physical understanding of its operating characteristics.

The statistical techniques developed for the analysis of data collected in the Atlant trials to date provide a powerful set of tools for similar investigations of induced changes in other local climates. In this context, we note that the statistical methods used in the analysis of the 2008 trial were presented at the Statistical Modelling and Inference Conference held at the Queensland University of Technology, February 1 - 4, 2010, while further techniques developed for the statistical analysis of the 2009 trial were presented at the Australian Statistical Conference, Perth, December 6 - 10, 2010. In addition, results from the 2008 trial were published in the 2010 issue of the Journal of Weather Modification and subsequently presented at the 2010 Weather Modification Association annual meeting in Santa Fe, New Mexico. Results from the 2009 trial have been provisionally accepted for publication in the 2011 issue of the Journal of Weather Modification.

Dr Stephen Beare of Analytecon conducted a cost-benefit analysis of the results from the 2009 Mount Lofty Ranges trial. Gauge-level rainfall was converted to an area-weighted average over the Lower Lakes of South Australia and the urban water catchments of Adelaide, with each gauge being given a weight proportional to the area surrounding the gauge for which it was the closest available observation. The value of additional water into the Lower

Lakes was calculated using the annualised equivalent cost of water entitlements purchased by the Commonwealth in the region. The value of additional water into the Adelaide catchments was derived from an estimate of variable operating costs of a desalinisation plant at current electricity prices. No value was attributed to additional rainfall outside these catchments.

Over the 2009 trial the estimated value of the additional rainfall attributed to the operation of the Atlant system was almost four million dollars. Extrapolating these results to a full year based on seasonal rainfall patterns, this value rises to $11 million generating an expected benefit-cost ratio of almost three to one. Given the uncertainty in the estimated increase in rainfall, this led to the conclusion that the probability that a full-year trial would have broken even was more than 90 per cent and the probability of achieving a 100 per cent rate of return on the cost of such a trial was more than 80 per cent. Return on investment would be several times higher against lower cost, long-term operations.

Extrapolating the benefits from the 2009 Mount Lofty trial to other catchments in the Murray Darling Basin and other regions of Australia indicated that the magnitude of the benefits would, in most instances, be substantially greater. Climatic conditions vary across Australia and future climate conditions are expected to be subject to large and persistent variation. However, should the level of enhancement in these alternative locations turn out to be substantially lower, and the associated uncertainty substantially greater, than the figures estimated for the South Australian trial, the proposed trials still offer a very attractive profile of probable returns (see proposal for such trials later in this document).

ART believes that a case has been made for Australia to invest in establishing whether the Atlant technology is an effective and useful tool which will allow water managers and users to better adapt to current and future climatic conditions in Australia. The SRP is in general agreement that any uncertainty regarding the physical impacts and efficacy of Atlant should be weighed against the level of economic benefits which the results to date suggest might be possible. In this context it concluded further research is justified. Such research will also allow direct experimental evaluation of Atlant's effect in different locales in Australia, as the effect is likely to depend strongly upon local air mass and cloud conditions.

ART recognises the need to establish the scientific links between ground-based ionisation and the physical processes taking place in clouds which could lead to increased precipitation. Significant progress has been made recently in the use of new generation radars to measure microphysical processes within clouds in the context of chemical cloud-seeding experiments. An example would be the work done by the U.S. National Center for Atmospheric Research as part of the Southeast Queensland Cloud Seeding Research Program which was presented at the 2011 American Meteorological Society annual meeting. An independent program of this nature over an extended period at one or two prospective sites is likely to be the best means of establishing whether there is in fact a causal link between operation of Atlant and increased precipitation. In this context, ART would provide open access to the technology.

At the same time, there is an opportunity to continue to conduct field trials in different locations within Australia with a reasonable expectation that benefits of the trials will exceed the costs. Given the low cost of the Atlant system, the fact that the statistical evaluation techniques are well advanced, and the likelihood that dry conditions will persist in Australia over the coming years, such trials seem an opportune investment.

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Proposal for trials in Murray Darling Basin and Western Australia

Australian Rain Technologies is putting forward a proposal to conduct concurrent trials across the Murray Darling Basin and in Western Australia. The trails have been designed to exploit the low-cost minimal footprint of the technology and test fully implemented systems under a variety of climatic conditions. The proposed trial sites were also selected to reflect a range of competing demands for water resources and levels of climatic variability.

The proposed trials in the Murray Darling Basin are across up to eight catchments. Three are in the northern tributary catchments of the Darling River, three are in major tributary catchments of the Murray River, as well as the Lachlan catchment in NSW and the Lower Lakes of South Australia.

To assess the potential benefits of these trials the results form the 2009 Mount Lofty Ranges trial were scaled back and the level of uncertainty increased. The hypothetical level of rainfall enhancement was five per cent, a reduction of more than 45 per cent from the Mount Lofty estimate, and the standard error associated about the effect was doubled.

In calculating the benefits, the level of additional run-off into storages takes evaporative and seepage losses into account and was valued on the basis of water entitlement values and yields. The value of additional rainfall on dry-land agriculture was imputed from an estimated relationship between average rainfall and agricultural land values. Environmental and incidental benefits were not included.

The estimated economic benefits for each of the catchments are set out in the table below. The total estimated benefit of a trial across all eight areas over a single year is $100 million from an additional volume of useful runoff into storages of almost 390GL and the additional on-farm rainfall.

The estimated trial cost of $34 million includes the fixed and operating costs of the system as well as the independent monitoring and evaluation of the results. The cost also include more extensive rainfall measurements in areas where current coverage of the Bureau of the Meteorology network needs to be augmented. The estimated benefit cost ratio for the trial is three to one. Given the assumed level of uncertainty about the estimated there would a more than 70 per cent probability of breaking even and about a 60 per cent chance of a 100 per cent return or greater.

As an indication of the potential benefits of the Atlant in the longer term, costs were scaled back to $10 million reflecting what the might be the costs of commercial implementation of the system. This shows a benefit cost ratio of 10 to one. Given the assumed level of uncertainty about the estimated there would be almost a 75 per cent chance of a 100 per cent return or greater. The average cost of the additional water into storages alone is less than $30/ML.

Thus enhancement at levels considerably below those estimated in trials to date would yield a considerable proportion of the water necessary to be returned to the environment under the draft MDB Plan at a fraction of the cost of repurchasing irrigations entitlements. This would

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avoid the economic and social disruption of such repurchase and provide much additional value in additional direct rainfall to pastures and crops and to environmental areas.

Location	Additional Inflow (GL)	Value of Inflows	Additional Returns to Dry Land Agriculture	Total Benefit
Lower Lakes, Coorong and Adelaide metro	38.9	$9,823,712	Not calculated	$9,823,712
Hume- Dartmouth	169.5	$11,993,750	$5,128,906	$17,122,656
Gwydir Valley	11	$1,156,959	$6,241,720	$7,398,679
Namoi	8.8	$890,820	$8,559,307	$9,450,127
Macquarie-Castlereagh	24.3	$2,456,825	$10,800,856	$13,257,681
Lachlan	9.5	$964,045	$6,449,432	$7,413,477
Murrumbidgee	39.3	$3,970,239	$9,800,478	$13,770,718
Goulbourn-Broken	76.2	$7,697,564	$14,504,836	$22,202,399
Total	377.5	$38,953,914	$61,485,535	$100,439,449

The trial in Western Australia addresses whether the Atlant system is a viable option to facilitate adaptation to severe climatic shifts and longer-term climate change. CSIRO predicts rainfall in the northern wheat belt will remain depressed to 2030, with rainfall expected to fall by 5-10 per cent from the historical average. Beyond that period the Western Australian Department of Food and Agriculture has predicted that adverse climate in the region could reduce crop yields in the order of 10-20 per cent.

The benefits were calculated on the basis of partially restoring crop yields in the region. A five per cent increase in effective rainfall was assumed, resulting in a roughly equivalent increase in average crop yields. The estimated benefit for a 5 per cent increased in effective rainfall the northern wheat belt was over $20million. Assuming trial costs in the order of $5 million this would generate a cost benefit ratio of four to one.

Open access

ART maintains an open-access policy to its analysis of the results of completed trials and the associated economic analysis, including the data obtained from trials and independent reviews.

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ART's Scientific Reference Panel is an advisory group whose members have their own opinions about the design and the results of these trials, and they can be contacted directly. The experts engaged to conduct the analysis may also be contacted on the same basis. Information requests in the first instance should be directed to:

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