REVIEW OF THE SOUTH AFRICAN HAIL SUPPRESSION PROJECT

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The Nelspruit South Africa Project is supported by the Tobacco Farmers Cooperative and run by the Colorado International Corporation of the United States. The manager is Graeme Mather and the company president is Larry Davis. My relation to this work is that of an impartial external reviewer. I visited and repoted on the project for the U.S. National Science Foundation and the National Hail Research Experiment, as a part of a four-program survey.

Davis and Mather have also kindly permitted me to summarize their latest results which have not yet even been issued in the form of a project report.

These results have been carefully checked by statistician P. W. Mielke, of the Colorado State University, who is a consultant to the project and by myself together with him, removing some apparent minor inconsistencies in the hail data. Nevertheless, the results should be regarded as preliminary. I only briefly summarize them here with the kind permission of the project leaders because I believe that these results and the method of obtaining them are of considerable value to the hail modification community.

In May 1975 the project completed its fourth year of operations. Nelspruit at 25°S is located in the Lowveld, at an altitude of 2500 ft. The hailstorm breeding ground is over the 5000 ft. Heghveld, lying to the west and northwest. The project area experiences about 30-40 hail days per year, in rough similarity to the conditions in Alberta, except for the much lower latitude and generally warmer air temperatures.

The suppression program is operational and does not presently include a randomized target. Nevertheless, a serious physical and statistical evaluation effort is underway to estimate the effects of seeding upon both hail and rain. Only the hail results are discussed here. The rain evaluation is still in progress.

This project has six outstanding and somewhat unique features. These are:

1. On top seeding of feeder towers, executed by jet aircraft. The seeding altitude varies between 20,000 ($T \approx -6^{\circ}C$) and 35,000 ft. ($T \approx -39^{\circ}C$). The aircraft carries a total of 208 50-gm pyrotechnic flares; about 6-20 are dropped into each tower.

   This Lear Jet can climb as rapidly as 6000 ft. per minute and can sustain up to 4.4 g's acceleration. The high maneuverability enables the aircraft to reach the towers when they pass through the

-12°C level and to hit the same tower repeatedly as it rises. It should be noted that estimated updrafts in these tropical hailstorms rarely exceed 20-25 m/sec.

2. The very close interaction between numerical hailstorm models with both the decision and evaluation processes. Thus a "test of concepts" opportunity is provided for the models and a potential for multi-variate analyses in evaluation.

3. The use of objectively assessed hail damage to tobacco plants as a key variable in evaluation. Tobacco is raised on about 1 percent of the 8000 km^2 target area in three main valleys and several smaller ones. The average farm size is 17 hectares. Comparing that hail sampling with the pad method, 27 1 sq. ft. pads in one square mile cover one one-millionth of the area.

4. The 5.6 cm radar is integrated with a minicomputer. The aircraft position is presented on the scope, with either a PPI or RHI display. Hard copies are instantly available with contoured echo patterns, and a strobe on the position of maximum reflectivity, the value of which is printed out.

5. The use of special distribution functions fitted to hail damage and hail severity data. With these functions, adapted by Mielke, tests for the magnitude, nature and significance levels of differences between seeded and unseeded cases are readily made. The unseeded population for this analysis is composed mainly of historical hail damage records for the target and some comparisons with other areas. A few unseeded days during the seeded period are included.

6. A hail damage insurance plan incorporates the weather modification program as an integral part. The plan is underwritten by Lloyd's of London. The 7.5% premium is not only far lower than other tobacco insurance in South Africa but also is lower that the 10.7% average annual crop loss due to hail-prior to the beginning of the seeding program.

Turning to evaluation and results, the criterion for a "hail day" is that the 45 dBZ radar contour be at or above 25,000 ft. elevation. Owing to lack of randomization, all seeded days with no assessed hail damage must be discarded from the seed - no seed comparisons. This is because there was no radar to declare a hail day during the preceding period from which the control days are taken as comprising those days with assessed hail damage. Omitting zero damage seed days leads to more than a factor of two reduction in the seeded sample. Although this is surely a serious handicap, its effect is to render estimates of the seeding effect more conservative. This difficulty brings home the desirability of radar monitored, preferably random, control days in the evaluation of hail suppression.

Now let us look at the current estimate of the results of the hail suppression effort. The primary statistics are:

Hectares damaged to 100%

and

$$\text{Severity ratio} = \frac{\text{Hectares damaged to 100\%}}{\text{Total hectares damaged}}$$

Preliminary results are summarized in Table 1.

Conclusions:

With the present evidence, my conclusion is that the results of the Nelspruit Project justify at least cautious optimism. The tobacco farmers involved have a high degree of belief in the efficacy of the project, as does a major insurance company. Among meteorologists and statisticians, there is a trend for many persons to regard this type of inference from a non-randomized project as virtually conclusive in favor of a hail suppression effect. More conservative types, particularly among statisticians, will not accept the results of any weather modification effort unless a randomized, statistically significant experiment has been conducted.

This is generally not feasible in a customer-supported commercial program.