NEW ZEALAND METEOROLOGICAL SERVICE

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PROSPECTS FOR WEATHER MODIFICATION

These notes reviewing the present prospects for artificially modifying the weather, and in particular for increasing the rainfall, are circulated for general information.

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1. INTRODUCTION

Ever since the discovery in 1946 that it is possible and practicable to induce the liquid water droplets in certain clouds to change to ice crystals, scientists have been seeking ways to utilize this ability to influence the natural rainfall in some way, either to increase it, to inhibit it, or perhaps to vary its timing or location.

Early attempts around the world to increase rainfall for power generation or to decrease the severity of drought conditions proved inconclusive. It became evident that the problem is not a simple one. It is now clear that many of these well-intentioned attempts actually resulted in a decrease in rainfall.

The goal of beneficial weather modification has provided the stimulus for an enormous research effort in the atmospheric sciences during the last two decades. In the U.S.A., for example, federal agencies alone spent over 35 million dollars in the fiscal years 1961-67 on research and investigations directly related to the problem. Australia must have spent something like 200 to 300 man-years of scientific effort in the quest for satisfactory techniques for increasing rainfall. Figures are not available from the USSR, but the effort there has been on a large scale and has made extensive use of military facilities including aircraft, radar, and rocket equipment.

2. NEW ZEALAND INTEREST

From the beginning of cloud modification experiments scientists in the Meteorological Service have been alert to the possible economic benefits to New Zealand if rainfall could be stimulated or augmented successfully at the right place and at the right time. The present Director attended a symposium on the subject in New York in 1949, and he and other senior scientists have continued to keep in touch with subsequent developments by attendance at conferences, by scrutiny of the scientific literature, and by personal contact at every opportunity with leading workers in this field. This year the Assistant Director in charge of the Research Division participated in the Fifth Session of the Commission for Atmospheric Sciences (World Meteorological Organization) where the current state of the subject was discussed, and the Meteorologist in charge of Physical Meteorology visited the Division of Radiophysics, Commonwealth Scientific and Industrial Research Organization, Sydney, to keep up with the latest developments in the Australian investigations.

With an eye to exploiting any favourable developments that might occur, the Meteorological Service has from time to time made special studies of the occurrence in different parts of New Zealand of clouds that seemed favourable for treatment according to the best views of the time. It has also made detailed studies of the variability of natural rain in the most critically water-deficient areas.

Because of the very great amount of research that has been conducted elsewhere, it has been growing increasingly more difficult for a small country like New Zealand with limited scientific resources to make any major contribution to the problem of artificially augmenting rainfall. However the Meteorological Service at present has one of its research scientists working in a leading research group in Canada studying, with the aid of computer analyses, the processes for the growth of cumulus clouds and the formation of precipitation.

3. PROGRESS TO DATE

By seeding clouds with appropriate innoculants (such as silver iodide or lead iodide crystals) or by inducing local cooling with frozen carbon dioxide, the growth of ice crystals can be encouraged. In most cases this tends to disperse the cloud. The only reasonably established operational form of artificial weather modification is intended to do just this; in parts of North America, Scandinavia and the USSR seeding techniques are used in winter to make temporary holes in fog or low cloud sheets over airfields.

In some countries, notably Italy, France, and the USSR, cumulus clouds are seeded by means of rockets in an attempt to dissipate them before they can produce hail. The cost is high, and the system is likely to be practicable only where there is a concentrated high-value crop like grapes to be protected. The results of these operations are not yet very certain, but claims for a significant reduction in hail damage are made in the USSR.

The other hoped for application of cloud seeding in influencing and preferably increasing the rainfall, has proved to be very difficult. Because of imperfect knowledge of the physical and dynamical processes involved, and because the necessary information (temperatures and humidities inside and outside different parts of a cloud, the numbers of natural freezing nuclei present, the strengths of the updrifts, etc.) is not obtainable from the normally-available observational data, it has been impossible to predict exactly how any particular cloud or storm will behave. Unless this could be done it would be impossible to predict the effect of artificially varying any of the conditions such as increasing the numbers of freezing nuclei in the air. An artificial increase in nuclei in the wrong cloud, or even in the wrong part of the right cloud, would inhibit rather than encourage the formation of rain. It is now clear that this has happened in many seeding trials.

Faced with the enormous variability of natural rainfall from place to place, storm to storm, and cloud to cloud, meteorologists have been forced to use statistical techniques to determine whether sustained or repeated seeding operations have had any effects. Experiments have been confused by the fact that some seedings probably gave an increase, others a decrease in the rain, but it has been impossible to distinguish in retrospect which conditions gave which result.

The World Meteorological Organization has from time to time had panels of experts review the progress in the field of weather modification. The most recent of these reports was published a few months ago. Some of the findings were:

> " It has been established by experiments both in the laboratory and in the field that the character of certain types of cloud, specially those consisting of liquid drops at temperatures lower than $0^{\circ}C$, can be transformed. Whether the consequences of this transformation produce the effects aimed at constitutes a question which in most applications remains unanswered. For dissipation of supercooled fog or stratus cloud for short periods, to permit landing of aircraft, the answer usually is favourable. For increase or decrease of precipitation, suppression of hail, reduction of lightning, or decrease of destructive winds accompanying thunderstorms, the evidence is either contradictory or uncertain."
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> " One of the factors which contribute to this uncertainty about effects on the amount of precipitation is the fact that the quantity of precipitation is governed not only by the microphysics of individual clouds, but also by the dynamic processes involved in the larger-scale circulations. The amount of water substance in a vertical air column is usually of the order of two or three grammes per square centimetre. One can expect the process of condensation and drop growth to lead to precipitation of only a small fraction of this amount, so that unless there are processes which are constantly replenishing the supply of water vapour and leading to further condensation and drop growth, only a few millimetres of precipitation at most would result. To influence the amount of precipitation to any extent, it would appear necessary to change the flow patterns which determine the amount of moisture being fed into the system and control the cloud forming processes."

More recently the Commission for Atmospheric Sciences (one of the technical commissions of the World Meteorological Organization) discussed progress with weather modification at its Fifth Session held in Washington in August this year (Dr J.F. de Lisle was the New Zealand delegate). In a statement prepared at the Session the Commission said:

> ".... The varied and controversial results of seeding experiments appear to be due to the complexities of the dynamics and microphysics of the precipitation process. An encouraging beginning in the understanding of these processes has been made through the development of numerical models which incorporate both the dynamics and microphysics and their interactions ..... Although some experiments have evidently yielded positive results in spite of inadequate knowledge of the workings of the atmosphere, the possible practical benefits of weather modification can be realised only through an increased research effort. This research should be directed primarily at cloud dynamics and the interactions of the dynamics with the microphysics....".

On the subject of increasing rainfall or snowfall the statement said:

> "Of the many experiments conducted in this field only few have clearly demonstrated that seeding has increased the precipitation; in some cases there is even evidence of a decrease in the precipitation. However, there is some evidence that orographic precipitation can be modestly increased by seeding, particularly during the winter over the mountain ranges of the western U.S.A. ....."

The statement included a warning:

> "It is important to emphasize that weather modification is still largely in the research stage. For this reason, operational efforts should be undertaken only after the most careful study of the particular situation by experts and with the understanding that the desired end results may not always be achieved."

4. FUTURE POSSIBILITIES

One of the leading figures in elucidating the processes leading to the formation of rain is Dr B.J. Mason, F.R.S., Director-General of the U.K. Meteorological Office, previously Professor of Cloud Physics at Imperial College, London, and author of the books "The Physics of Clouds" and "Clouds, Rain and Rainmaking". In an address to the Royal Meteorological Society in April this year on "Future Developments in Meteorology : An Outlook to the year 2000", he remarked:

> " I can hardly conclude this address without hazarding a few words about the future prospects of modifying weather and climate. This is one area in which I do not expect any very startling development in the next 30 years, not only because

of the inherent difficulties, but because it would be irresponsible and, I hope, politically unacceptable, to attempt large-scale interference with the balance of natural processes until we can understand, predict, and agree upon the likely consequences. The scientific understanding and assessment of weather modification experiments, as distinct from purely statistical evaluation, is essentially the same problem as weather prediction.

So far, weather modification has been largely, but not entirely, associated with cloud seeding. In my view, 20 years of considerable world-wide effort has produced little convincing evidence that large increases (or decreases) in precipitation can be produced over large areas. Although marginal effects of order 10 per cent may be possible, it has proved very difficult to distinguish induced changes of this magnitude from the natural variation in rainfall. Accordingly, there is a growing awareness that continued repetition of the same methods, in the hope that something will turn up in the statistics, is unlikely to be profitable, and that we must re-examine the underlying processes and philosophy.

The greatly exaggerated claims made by the early cloud-seeding operators are now largely discredited: current claims are much more modest and the difficulties of executing and evaluating cloud-seeding operations are now much more clearly and widely recognized. Statistical assessments of these operations are continually revealing features in the rainfall patterns that are difficult to interpret and explain, even qualitatively, in meteorologically convincing terms. The formulation of reliable numerical models of cloud growth and development, capable of predicting important and readily-observed characteristics of seeded and unseeded (control) clouds, offers the best long-term prospect of assessing the potentialities and results of cloud-modification experiments and should provide deeper physical insight into the problem than the purely statistical approach. However, it would be optimistic to expect the early development of models capable of predicting precipitation amounts with sufficient accuracy to detect the changes of 10-20 per cent that are currently being attributed to cloud-seeding operations. Assessment of such experiments will therefore continue to depend on a combination of statistical and physical criteria, but it is on the latter that the greatest effort is now required. Little further progress is likely until we have acquired a much deeper understanding of the physical, and particularly the dynamical processes that control the release, duration and

intensity of precipitation from the major types of cloud systems."

It is clear to the leading scientists engaged on this problem that the most urgent need is not for more seeding operations but for a better understanding of the cloud dynamics and precipitation mechanisms. There is need for measurements of the right sort in and around clouds. These will need very sophisticated instrumentation such as that being prepared for the U.K. Meteorological Office C-130 aircraft, as well as ground-based radar in the right place. Computer studies such as those in which the New Zealand meteorologist in Canada is engaged will also be necessary.

At the present state of knowledge the most hopeful possibility for weather modification in New Zealand appears to be to induce a small percentage increase from winter storms over high-rainfall mountain areas. If present ideas are substantiated, this might in the future become an economic proposition where suitable storage was available.

For other parts of the country the prospects are poor. Drought conditions are the result of persistent sinking motions of air in anticyclones or in the lee of ranges, and in these conditions no beneficial effects can be expected from seeding. Even on other occasions, however, because of the properties of the maritime air passing over the country, the prospects for influencing the rainfall one way or the other are generally believed to be much less than, for example, in air that has spent some time over a continent.

5. CONTROL

To undertake indiscriminate cloud seeding in a time of water shortage and risk inhibiting critically-needed natural rainfall would be regarded by many people as irresponsible. Many countries are adopting legislation to prevent this. In Australia the State of Victoria, for example, already has legislation requiring that every cloud seeding operation be individually authorized by the Minister, be conducted under the supervision of an authorized scientist, and have the details fully recorded. A penalty of $1000 per day is provided for breach of these conditions.

6. CONCLUSION

Practical weather modification in New Zealand conditions would seem to be some distance away. Researches currently in progress are throwing fresh light on the processes involved and are likely to define more clearly the circumstances in which artificial treatments will or

will not produce favourable effects. In the present view successful application is more likely to be achieved in enhancing winter rains and snows over the mountains than in ameliorating drought conditions over farmlands. In the present imperfect state of knowledge there is considerable risk of producing adverse effects.

New Zealand scientists are keeping closely in touch with progress of research in this field and are watching for any developments that might have beneficial application in New Zealand.

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