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WARM CLOUD MODIFICATION: A VIEWPOINT

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Many of the potential rain-producing clouds in the tropical or semi-tropical countries are convective in nature and their tops often do not exceed the height of the freezing level. The possibility of increasing rainfall from warm clouds has generated considerable interest to augment water resources among the nations in these regions. The physical processes involved in the initiation and development of rain in warm clouds are condensation, collision-coalescence and break-up. The physical hypothesis of rain enhancement from warm clouds is based on the modification of the rain processes through seeding the clouds with either a hygroscopic material (e.g. artificial CCN) or with small water drops thereby tapping the potential precipitation efficiency of the cloud systems. Many field programmes have been conducted in several countries either on experimental basis or on operational basis. The experiments for rain enhancement from warm clouds conducted up to the present time, do not have the necessary physical observations for clear-cut evaluation and possible technology transfer (WMO 1995). Some of the important issues of weather modification technology are addressed in this report. The need for the physical understanding of sequential development, predictor variables and an interdisciplinary approach was pointed out.

In a review paper by Cotton (1982) it was concluded that the major problem in establishing the efficacy of warm cloud precipitation enhancement is that randomized field experiments do not clearly establish that observed precipitation anomaly is physically linked to seeding. Hence, scientists heavily depend on the use of theoretical or numerical prediction models to establish a cause and effect relationship between a treatment and an observed rainfall anomaly. However, one must be cautious in interpreting the results produced by such models as being representative of the real world.

Simpson (1978) stated that successful weather modification experiments share three outstanding features, namely, persistence through at least two phases, often requiring more than a decade; some type of predictive tool or stratification; and a relatively uncomplicated cloud and/or evaluation situation, or by strong target-control correlations. The classical approach to obtain statistical significance in the face of high natural variability is to increase the sample size. However, programs where either the understanding of the complex processes and/experimental design were poor, even a hundred years of unevolving randomized experimentation would produce additional inconclusive or uninterpretable statistics. A supplementary alternative which can mitigate sample size requirement is to make use of information relating to the concomitant variables, i.e., early identification of stratifications, covariates or predictors. Without early identification of concomitant variables, the randomization or operational evaluation would probably fail. Incorporation of a stratification in experiment design can often make the difference between significant versus inconclusive results in a fixed time limit experiment, or alternatively save years of expensive experimentation.

Most of the success in weather modification owe a large part of their achievement to identification of concomitant variables, either at the outset or after an exploratory phase of the experiment. It would be satisfying if the predictor or stratification variables arise either from clearly understood physics or model simulations. The results of the 11-year Indian Warm Cloud Modification Experiment (Murty, 1989, 1995) and the model simulation studies (Vijayakumar, 1997) have clearly emphasized the need for the physical understanding, sequential development (stepwise programs to test the applicability of warm cloud modification hypothesis), predictor variables, model simulations. An interdisciplinary approach could be essential for successful warm cloud modification experiments. The results of the Indian field experiments suggested that the warm cloud responses to salt seeding are critically dependent on the cloud physical characteristics, e.g., vertical thickness and liquid water content (Murty, 1989). Clouds with vertical thickness > 1 km, LWC > 0.5 gm m^{-3} when seeded with salt particles (modal size 10 µm), concentration 1 per litre of cloud air) produced increase in rainfall of 24 per cent significant at 4 per cent level. Shallow clouds (vertical thickness < 1 km, LWC < 0.5 gm m^{-3}) when seeded showed tendency for dissipation. The cloud physical observations made in not seeded (Control) and seeded (Target) have provided the physical evidence in support of the statistical evaluation (Murty, 1989). Numerical simulation experiments carried out using the 2DTD cloud model (Orville and Kopp, 1977) suggested that hygroscopic seeding of warm clouds under favourable dynamical conditions (convergence at the cloud-base level) would accelerate the collision-coalescence process resulting in the enhancement of rainfall. Moderate convergence at the cloud-base has been found essential for the cloud growth and development of precipitation in the real world (Vijayakumar, 1997). For achieving success of the Indian warm cloud modification experiment, it is essential to prove the persistence of the seeding result through at least two phases with the supporting step wise programs to test the applicability of the warm cloud modification hypothesis and cloud simulation studies.

The recent South African hygroscopic cloud seeding experiment (1991-1995) offers a hope of increasing precipitation from convective storms (Bigg, 1997). This experiment differed from the earlier hygroscopic cloud seeding in that relatively modest amounts of more finely dispersed particles (mainly Potassium Chloride) were dispensed in the updrafts below the cloud base from flares carried on aircraft (Mather et al., 1996). The radar – estimated arithmetical mean rain masses, in seeded and control storms as a function of time from the moment when the decision to seed or not to seed (decision time) was used to assess the effects of seeding.

The research in the area of land weather modification has moved away from the statistical evaluations for seeding effects to studies oriented towards monitoring processes under natural and seeded conditions. The development of a scientifically acceptable weather modification technology is many years away, barring of course some major break through (Czys, 1995). However, some experiments have provided evidence to convincingly establish that seeding has worked as expected in atleast a few steps of the physical chain of events hypothesized in the conceptual models. The number of scientifically well planned weather modification experiments has diminished considerably during the recent past due to the changing perceptions of the weather modification technology.

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