DROUGHT AND WEATHER MODIFICATION : A REVIEW

by K. R. RAMANATHAN*, FNA, *Physical Research Laboratory, Navrangpura, Ahmedabad-380009*

(*Received 18 October 1975*)

Variations of rainfall occur from year to year in many countries of the world, and India is no exception. People in India are familiar with the so-called *vagaries* of the Indian monsoon. In a highly populated and mainly agricultural country like India, a significant deficiency in the monsoon rains causes great hardship to the population, particularly in areas where the normal annual rainfall is less than about 60 cm and the deficiency of rainfall can be 40 per cent or more in some years.

The chronic drought areas of the country inculde Kutch, parts of Saurashtra, Rajasthan and adjoining parts of Punjab, Haryana and West Uttar Pradesh, and parts of Maharashtra, Karnataka and Rayalaseema lying in the plateau region of the Deccan between the Western and Eastern Ghats (Rao, *et al.* 1971).

Is it possible to make any substantial change in the weather of drought affected areas apart from transporting water from areas less affected by drought, or arranging better ways of storing and conserving water in years of surplus rainfall? To what extent can "weather", by which we mean "rainfall" in this context, be modified in any part of the World? A limited answer to a small part of this question is coming from the study of the natural physical processes responsible for the formation of rain from clouds, and from experiments that are being carried out in different countries including India, to stimulate certain types of clouds to give rain.

There is a far larger area on earth covered by non-raining clouds than by raining clouds. What makes some clouds to rain? This depends on the temperature and humidity structure of the atmosphere above and below the cloud, the generation of updraft of moist air and the presence of some kind of nuclei on which water vapour can condense.

As early as 1911, A. Wegener in his *"Thermodynamik der Atmosphäre"*, suggested that at temperatures of —10°C to —20°C, cloud droplets could exist as supercooled water together with a few crystals of ice which are spontaneously formed at such temperatures, and owing to the difference in the saturation vapour pressure of ice and water, condensation of vapour would take place preferentially on the ice crystals and the liquid water droplets would evaporate. This point was worked out in detail by T. Bergeron (1933) of Sweden in his paper on "The Physics of Cloud and Precipitation" presented at the Lisbon meeting of the International Association of Meteorology. Some time later, a similar suggestion was made by W. Findeisen (1939) of Germany. Observations made in India had also shown that drizzle or light rain could fall from pure water clouds, strato-cumulus or cumulus, during noon and afternoon hours when the cloud top temperatures were well above 0°C.

*Convener.

D. Langmuir (1948) showed that rain could form by a chain reaction in cumulus clouds at temperatures above freezing.

B. Vonnegut (1947) showed that silver iodide smoke introduced in a cloud with super-cooled water at the top, could promote ice-crystal growth, because of the similarity of their crystal structure. V. Schaefer (1950) used dry ice (solid CO_2) pellets for dissipating cold fog over airports.

Beginning from 1947, scientists in USA, Australia, France, and other countries have carried out many field experiments on the artificial nucleation of both "cold" and "warm" clouds using aircraft for seeding the clouds and observing the resulting growth or dissipation of the seeded clouds in comparison with the behaviour of similar unseeded clouds in the same area (Patterssen *et al.* 1957).

Experimental work on cloud modification in the Indo-Pakistan sub-continent began in 1954 when a ground seeding project was carried out at Lahore in July–September of that year using the dispersal of well-dried salt-powder by a high pressure blower during afternoons from the top of a tall building and measuring the rainfall distribution in the windward and leeward directions and comparing it with the normal distribution. Although a small positive effect of increased rainfall in the direction towards which the low-level winds were blowing, the results could not be considered conclusive.

It has already been mentioned that Indian meteorologists were taking interest in the physical processes responsible for the formation of rain-drops from pure water clouds. In 1953, a Symposium on 'Artificial Rain' was organized by the Atmospheric Research Committee of the CSIR and the India Meteorological Department, at which a number of papers were presented and the whole subject was reviewed. Recommendations were made for the organization of a Rain Research Unit at Delhi for undertaking experiments on cloud seeding. Dr. S. S. Bhatnagar and Prof. K. S. Krishnan agreed to set up such a unit in the National Physical Laboratory, Delhi. Besides providing necessary staff and laboratory facilities, it was decided to equip the Unit with one or two centimetre radars to watch the formation and growth of rain drops in clouds and to requisition the help of the IAF for the seeding of clouds.

Shortly after, Shri A. K. Roy, a Senior Meteorologist of the India Meteorological Department who had been taking great interest in Weather Modification problems was appointed as Scientist-in-Charge of the Rain and Cloud Research Centre in the NPL, and arrangements were made to recruit Research Officers, Research Assistants, instrument mechanics and other auxiliary staff. Dr. Bh. V. Ramana Murty, Dr. R. C. Srivastava, Shri L. V. Khemani and Shri C. R. Biswas were among the earliest to join the group.

An initial survey was made of the normal distribution of rainfall during monsoon months around Delhi and its dependence on the direction of winds from ground up to 1.5 km. Additional raingauges were installed within a radius of 25 km around Delhi. After acquiring equipment and making some laboratory experiments, it was decided to spray a solution of common salt into the atmosphere with power sprayers for a few hours around noon in the months June–September, on days when there were rising cumulus clouds but no marked weather disturbance. Daily weather reports were received from the local forecasting office of the India Meteorological Department. Even if the weather conditions were favourable for seeding, the decision

to seed or not to seed was taken by randomization, so that there were nearly as many seeded days as non-seeded days and the effect of seeding could be critically compared with the normal natural conditions (Roy 1955).

The results of seeding trials made at Delhi in the monsoon of 1957–1959 (Roy *et al.* 1961) showed an over-all effect of increased rainfall in the sector towards which the 1 to 1.5 km wind was blowing. But there were days when the effect was indefinite or was even negative. In order to get sufficient data within a few years, two more ground seeding stations were started one at Agra and the other at Jaipur and observations were continued till the end of the monsoon season in 1965. In 1961, a 3.2 cm weather radar was acquired from Japan and installed near the Laboratory and it was used till 1966 to monitor the formation and growth of rain-drops in growing cumulus clouds (Chatterjee *et al.* 1969). The conclusion from the observations made at the three stations during the years 1957 to 1965 was that there is a net positive effect of increased rainfall in the target sector covering an area of about 450 km^2 (Biswas *et al.* 1967).

Cloud seeding experiments using IAF aircraft for seeding individual cumulus clouds near their base and watching the effect by the 3.2 cm radar were also made in the Delhi area in 1962 (Roy *et al.* 1964). The results confirmed the results of the ground-seeding ex-periments.

In October 1960, the India Meteorological Department, CSIR and IAF organized a comprehensive symposium on "Cloud and Rain in the Tropics" at the Meteorological Office, Poona. Among the participants were meteorologists and scientists from the Indian Air Force and the Department of Atomic Energy. Among the topics of discussion were:

1) atmospheric nuclei, cloud and raindrop size spectrum and atmospheric chemistry;

2) radar studies of cloud and rain; and

3) cloud modification studies.

The results of the discussions at the 1960 symposium were by Shri A. K. Roy as follows:

"The experiments should be scientifically designed and conducted on a rigidity randomized basis, to enable proper evaluations being made by separating as far as possible, the effects of variations in rainfall due to natural causes."

Shri A. K. Roy retired from the NPL Rain Research Centre in 1964. By that time, the India Meteorological Department in collaboration with WMO and UNDP, had established the Institute of Tropical Meteorology in Poona with Dr. P. R. Pisharoty as Director. Included in its programme were studies in Physical Meteorology, development of observational techniques, and researches in medium and long term weather forecasting. Dr. Ramana Murty and some of his colleagues, who were working on problems of weather modification at the Delhi Centre, joined the new Institute and with additional new associates continued and expanded their work, particularly in the area around Poona.

The present symposium on "Droughts in the Asiatic Monsoon Area and their relation to abnormalities in the general circulation of the atmosphere" is an outcome of the interest of the Indian National Science Academy, the India Meteorological

Department, IITM, CSIR, ICAR and Universities. Some recommendations for a programme of research in this field in the next 5 to 10 years have been made at the end of the symposium.

Before I conclude, I should make a brief reference to some major developments in the field of Weather Modification, which are taking place in USA. Besides dynamic seeding of cloud complexes spread over a wide area, using aircraft and different nucleating agents, large-scale experimental work has been organised by US Weather Bureau and US Navy on a project called "Stormfury". The operating group have been using many instrumented aeroplanes capable of flying above the highest levels of cumulo-nimbus clouds and seeding them with silver-iodide smoke from large capacity pyrotechnic generators. Detailed study has been made of the effects of the pyrotechnic seeding on the structure and movement of tropical hurricanes in the Atlantic Ocean.

Another significant development that has taken place is that large concentrations of aircraft have been used in military operations in a limited area of the tropical atmosphere in the Pacific. They generate large amounts of aerosols which can act as nucleating agents and increase the rainfall in the particular region, and also set up disturbances in the general pattern of atmospheric circulation. Developments in science and technology can thus be used not only for the alleviation of distress due to droughts, but produce harmful effects as during the Viet-Nam War. A reference may be made in this connection to the article on "The Cratering of Indo-China" by A. H. Westing and E. W. Pfeiffer in the '*Scientific American*' of May 1972.

I have every hope that we, in the Asiatic Monsoon region, will use whatever knowledge we have of hydro-meteorology and Weather modification for peaceful humanitarian purposes.

References

Bergeron, T.(1933). On the physics of cloud and precipitation. *Proc. int. Assoc. Met. IUGG, Lisbon.*

Bergeron, T.(1949). The problem of artificial control of rainfall on the globe. *Tellus*, **1**, p. 32.

Bergeron, T. (1965). *Proc. Int. Conf. Cloud Physics*, Tokyo and Sopporo.

Biswas, K. R., Kapoor, R. K., and Ramana Murty, Bh. V. (1967). Cloud seeding experiment using common salt, 1957 to 1965. *J. appl. Met.*, **6**, 914.

Bowen, E. G. (1952). A new method of stimulating convective clouds to produce rain and hail. *Q. J. R. met. Soc.*, **78**, 37.

Breham, R. R. (1966). Final Rep. to NSF on *Project Whitetop.*

Chatterjee, R. N., Biswas K. R., and Ramana Murty, Bh. V. (1969). Result of cloud-seeding experiment at Delhi as assessed by radar. *Indian J. Met. Geophys.*, **20**, 11.

CSIR (1953)—Symposium on Artificial Rain.

Findeisen, W. (1939). Raindrop formation in pure water clouds. *Met. Zeit*, **56**, 365.

Fournier D'Albe, E. M., Lateef, A. M. A, Rasool, S. I., and Zaidi, I. M. (1955). The cloud-seeding trials in the Central Punjab in July-August 1954. *Q. J. Roy met. Soc.*, **81**, 574.

Langmuir, I. (1948*a*). The growth of particles in smokes and clouds and the production of snow from supercooled clouds. *Proc. Am. Phil. Soc.*, **92**, 107.

Langmuir, I. (1948*b*). The production of rain by a chain reaction in cumulus clouds at temperatures above freezing. *J. Met.*, **5**, p. 175.

Met. Office, Poona (1962). Papers presented at the Symposium on 'Physics' of Cloud and Rain in October-November 1960. *Indian J. Met., Geophys.*, Special number **13**.

Petterssen, S. and eight other scientists (1957). Meteorological Monograph on cloud and weather modification, Vol. 2. No. 11 of Am. Met. Soc.

Ramana Murty, Bh. V., and Biswas, K. R. (1968). Weather modification in India. *J. met. Soc. Japan*, **46**, 160.

Rao, K. N., Raman, C. R. V., George, C. J., and Misra, R. K. (1971). *Scientific Report on "Rainfall and Droughts" in India.* India met. Dept.

Roy, A.K. (1955). *Rain-making, its Present Position and Future Possibilities.* CSIR Publication, New Delhi.

Roy, A.K. (1959). Weather modification in India. *J. scient ind. Res., CSIR*, **18**, A, p. 422.

Roy, A. K., Ramana Murty, Bh. V., Srivastava, R. C., and Khemani L. V. (1961). Cloud seeding trials at Delhi during monsoon months July–September 1957-1959. *Indian J. Met. Geophys.*, **12**, 401.

Roy, A. K., Ramana Murty, Bh. V., Biswas, K. R., and Khemani, L. T. (1964). Cloud seeding experiments around Delhi using aircraft. *Indian J. scient. ind. Res.*, **23**, 326.

Schaefer, V. I. (1946). The production of ice-crystals in a cloud of super-cooled water droplets. *Science*, **104**, 457.

Symposium at Poona on "Physics of Cloud and Rain in the Tropics" held in Oct–Nov 1960. *Indian J. Met. Geophys.*, Special No. **13** (1962).

Vonnegut, B. (1947). The nucleation of ice-formation by silver iodide. *J. appl. Phys.*, **18**, 593.

Weickmann, H. K., and Anfm Kampe (1953). Physical properties of cumulus clouds. *J. Met.*, **10**, 204.

FORM IV

(*See Rule* 8)

1.	Place of Publication	New Delhi
2.	Periodicity of its Publication ..	Bi-monthly
3.	Printer's Name	B. V. SUBBARAYAPPA
	Nationality	Indian
	Address	Indian National Science Academy Bahadur Shah Zafar Marg, New Delhi-110002
4.	Publisher's Name	B. V. SUBBARAYAPPA
	Nationality	Indian
	Address	Indian National Science Academy Bahadur Shah Zafar Marg, New Delhi-110002
5.	Editor's Name	L. S. KOTHARI
	Nationality	Indian
	Address	Indian National Science Academy Bahadur Shah Zafar Marg, New Delhi-110002
6.	Names and address of individuals who own the Newspaper and partners or shareholders holding more than one per cent of the total capital.	—

I, B. V. SUBBARAYAPPA, hereby declare that the particulars given above are true to the best of my knowledge and belief.

Sd/- B. V. SUBBARAYAPPA

Dated 1 *March* 1976 *Signature of Publisher*