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Is the incidence of unusually dusty weather over Delhi in May and June for the two consecutive summers of 1952 and 1953 an indication that the Rajasthan Desert is advancing towards Delhi ?*

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Introduction

Incidence of prolonged spells of dusty weather over Delhi during the summer months of May and June for the two consecutive years 1952 and 1953 has led to the apprehension that this may be indicative of an extension of the Rajasthan desert conditions towards Delhi. This apprehension has naturally been followed by suggestions for remedial measures. One suggestion, which seems to have attracted much attention, is that Government should take steps to increase rainfall over the arid and semi-arid regions in and around the Rajasthan desert by artificial stimulation of clouds, and thereby check spread of desert conditions. The object of the present note is to examine whether there has been any progressive increase, in recent years, in the incidence of dust-phenomena over the Delhi State which could be taken as indicative of desert conditions approaching the State. The associated question of the possibility of obtaining increased rainfall by 'seeding' clouds over an arid or semi-arid region with a view to prevent spread of desert conditions, has also been touched in the note.

To enable a proper appreciation of the incidence of dust phenomena, it is necessary to go into their genesis, keeping in view the synoptic situations which favour the occurrence of such phenomena. This is briefly discussed in the following paragraphs.

Hot and dry dust-raising high winds (*Loo*)

High winds caused by steep pressure gradients due to a deep low pressure area or depression over an arid or semi-arid region can raise clouds of dust to considerable heights and fill the whole atmosphere over the region with dust, giving sometimes a reddish yellow colour to the sunlight and reducing visibility in various degrees depending on the prevalent conditions. The clouds of dust, at times, may be suffocatingly dense and the air aloft so charged with dust that the sun becomes almost invisible. To aviation, dust-laden high winds with poor seeing conditions constitute one of the major hazards, because they last for hours, cover wide areas and cannot be avoided as localised hazards associated with thunderstorms or duststorms (Andhi) can be. Moreover, dust-cloud or dust-fog, once created in the atmosphere by high winds

* This article was written in reply to the specific enquiry but it is hoped that the subject matter dealt with in the article will be of interest to meteorologists and airmen.—*Editor*

over a large tract of arid land, can be drifted to long distances by the prevailing winds so as to widen the area of the hazard.

In the summer months, dry and hot dust-raising high winds often blow from a westerly direction continuously for hours over northwest India, including Uttar Pradesh, where they are popularly known as "Loo". The high winds are occasioned by steep pressure gradients due to the deepening of the seasonal trough of low pressure over the region, usually under the influence of western disturbances which originate in the Mediterranean region and, travelling eastwards through Iran, Afghanistan, Baluchistan and West Pakistan, enter northwest India.

Although the incidence of high winds due to steep pressure gradients is an essential condition for the occurrence of high dust-raising winds in a region, other conditions have also to be taken into account to obtain a full physical understanding of the raising of dust in the air by the winds. One of the conditions is obviously that the region should be arid or semi-arid, and that the rainfall there should be scanty so that the surface soil is not compacted by moisture to prevent high winds to carry it away. This condition obtains in the arid and semi-arid regions of northwest India in the summer months of May and June in a very favourable form, particularly during the years of scanty seasonal rainfall. The raising of dust aloft requires the presence of uprising convection currents or a high degree of turbulence in the air or both. It is well known that convection of air results from the occurrence of superadiabatic lapse of temperature between the ground surface and the air above due to the insolation of the ground during the day. Such superadiabatic lapse rates of temperature in the air occur frequently in northwest India during the day in summer above the heated ground, occasionally up to a height of several thousand feet under favourable conditions. It is also known that turbulence in air near the ground surface is caused by ground obstacles and roughness of its surface. Turbulence is present in all air-movement, and increases in magnitude with increase in wind speed. But wind alone does not determine the degree of turbulence. High lapse rate of temperature in the lower atmosphere, as occurs in summer during the day due to insolation, also contributes to the growth of turbulence. Further, under typical atmospheric conditions, there may be powerful descending air currents to produce turbulence of exceptional magnitude, as in the case of squalls associated with thunderstorms and duststorms (Andhi).

Observations of high dust-raising winds during the summer months in northwest India, as in other arid and semi-arid regions of the globe, show that they occur mostly during the day, commencing within a few hours of the sunrise and weakening usually in the afternoon a few hours before the sunset, although the dust may not settle down till late in the night. It is also significant to note that the atmospheric obscurity in the lower layers of air near the ground is not always at its worst during the hours of prevalence of high winds but the obscurity may worsen later after the winds have died down. Persistent dust-fog, so often observed after the cessation of high winds in the afternoon, is due to the slow settling down of dust.

The reason why dust-raising hot and dry winds (Loo) occur mostly in the day time is obvious from the foregoing considerations. High lapse rate of temperature of air above the ground, so essential for the creation of strong convection currents and pronounced turbulence to raise dust in the air, can occur only by insolation of the ground during the day time. Moreover, during the night and in the early morning hours there is an inversion of temperature in the air above the ground, extending to a height of several hundred feet. As a result of this inversion the high winds during the night exist only above the inversion level with calm or very gentle breeze near the ground. With the sunrise, the inversion disappears as a result of turbulence and convection, and high winds again re-appear at the ground level. This explains why high winds occur during the day time consecutively for days together while nights remain less windy or even calm.

The length of a spell of high winds naturally depends on the persistency of the seasonal low as a deep depression, and consequently of the steep pressure gradients which cause high winds.

Dust-laden high winds in the summer are not peculiar to northwest India. Under similar synoptic situations, dust-laden high winds or gales are known to occur in summer in other parts of the globe, such as the arid and semi-arid regions of China, Australia, Arabia and Persia. Northwesterly dust-raising gales in Persia are locally known as " Shamal " which often carry dust well into the Persian Gulf and render shipping operation impossible off the entrance to the Shatt-el-Arab.

Dry Thunderstorms or Duststorms (*Andhi*)

Dry thunderstorms or duststorms (Andhi) are distinct from the dust-laden hot and dry high winds or gales (Loo). Duststorms are essentially thunderstorms in a dry region. They are local instability phenomena, exactly like thunderstorms and are associated with the growth of large cumulus or cumulonimbus clouds. Duststorms (Andhi) like thunderstorms are attended by powerful squalls of short duration ranging from a few minutes to half an hour or so, in which individual gusts may attain in exceptional cases a velocity as high as 100 miles per hour. Because of the comparatively dry conditions associated with the genesis of duststorms and the high degree of turbulence produced by the powerful descending currents associated with the passage of squalls, large quantities of dust are raised in the air to a considerable height. The walls of dust advancing with the squalls reduce the visibility to a very low value. At times the squalls may be so turbulent and air so loaded with dust that the darkness produced could be matched only by that of the blackest night, making it practically impossible to do anything inside a house without the aid of lamps or some other artificial lights. This is why duststorms are called " Andhi " in India. Although the amount of precipitation reaching the ground is not usually measurable, the passage of an Andhi is generally followed by drizzle and large drops of muddy rain. A marked cooling of air usually takes place with the occurrence of an Andhi. This cooling is due mainly to the evaporation in the dry hot atmosphere of precipitation which fails to reach the ground. Sometimes, when synoptic situations permit the incursion of streams of sufficiently humid air to feed the duststorms, they manifest all the characteristics of the thunderstorm phenomena including shower. Under such favourable conditions, an Andhi may be followed by a thunderstorm attended by claps of thunder, lightning flashes and heavy showers of rain. In an Andhi, lightning is usually invisible because of the dust-cloud and claps of thunder inaudible because of the roaring of the squall winds.

Although local in character, a duststorm must be reckoned as a greater hazard to aviation than a thunderstorm because of the visibility conditions in a duststorm in addition to the common hazard due to violent squalls and associated turbulence. In exceptional cases, duststorm squalls (Andhi) equal in violence the Nor'wester thunder-squalls in Bengal and other parts of northeast India occurring in the months of April and May and locally known as *Kal-Baisakhi*. Andhi and Kal-Baisakhi are essentially of the same origin, the only difference between the two being that the amount of moisture in the mass of humid air feeding an ' Andhi ' in northwest India is generally small with reference to its usual environment of very hot and dry air, while the amount of moisture in the humid air feeding a Nor'wester in northeast India is generally sufficiently high to cause copious precipitation. For their genesis, both the phenomena require the presence of a western disturbance or other synoptic situations to cause an incursion of humid air of maritime origin from the Indian Seas in juxtaposition to the comparatively hot and dry air over the land so as to give rise to thermodynamic instability or latent instability in the atmosphere. In an atmosphere thermodynamically unstable, it requires only a " trigger " action to cause dynamic instability to start in the atmosphere with consequent rise of moist air, leading to condensation of water vapour and formation of thunderstorm and duststorm clouds. A "trigger" action may be provided in many conceivable ways, such as (*i*) the creation of superadiabatic lapse of temperature in the lower atmosphere by the insolation of the ground during a summer day, (*ii*) under-cutting of moist air by cold air as in a cold-front, (*iii*) over-running of moist air by dry air and (*iv*) convergence of dry and moist air. "Trigger" (*i*) can be operative only in the day time, mostly in the afternoon. But duststorms (Andhi) are known to occur in the night as well as at other times of the day. So, there can be little doubt that other "triggers" are also operative in the genesis of duststorms.

With the foregoing explanations about the genesis of high dust-raising winds, duststorms and dust-fog, we pass on to consider the incidence of these phenomena over the Delhi area in recent years.

Incidence of high dust-raising winds (*Loo*), Duststorms (*Andhi*) and Dust-fog in summer over the Delhi State during the period 1945-53

Prolonged spells of dusty weather in the summer months of May and June of 1952 and 1953 were not peculiar to the Delhi State, but were equally noteworthy also in north and west Rajasthan and the adjoining areas of the Punjab and Uttar Pradesh. But in the present context, it is sufficient if considerations are confined to the data for the Delhi State. Reliable hourly observations of duststorms and dust-fog are available for 9 years, 1945-53, of the Airport Observatory at Palam, Delhi. Data for high dust-raising winds for the same period have been collected by an examination of the anemographs of the Airport Observatory, Safdarjung, Delhi. The Palam duststorm data have been verified on each occasion by a reference to the Safdarjung anemographs. These data are tabulated in Table I for the month of May and in Table II for the month of June, together with the number of western disturbances which affected weather over the Delhi State and the adjoining areas of Rajasthan, the Punjab and Uttar Pradesh during each May and June of 1945-53. Columns (2) and (3) under (*a*) of Tables I and II give the number of hours during a month when the visibility due to dust-fog at Palam was observed to be limited to (*i*) 1,100 yards and (*ii*) $1\frac{1}{4}$ miles. Column (4) under (*b*) gives the number of occasions of duststorms (Andhi) in a month when the wind speed in individual gusts of the associated squalls exceeded 25 miles an hour with visibility limited to 1,100 yards. Column (5) under (*c*) gives the number of hours of high dust-raising winds in a month with average wind speed 25 miles per hour or more. Column (6) under (*d*) gives the number of western disturbances during a month affecting weather over the Delhi State and adjoining areas of Rajasthan, the Punjab and Uttar Pradesh.

It will be seen from Table I that during the period 1945-53, the month of May in 1953 had the worst dusty weather,—dust-fog, duststorms (Andhi) and high dust-raising winds, over the Delhi State. May 1946 was also nearly as bad in this respect. It will be further observed that the frequency of western disturbances affecting weather over Delhi and its neighbourhood was high in May 1946 and 1953. May 1951 was the best from the point of view of dusty weather over Delhi ; and the number of western disturbances during this month was also the least. It is thus obvious that the incidence of dusty weather is closely related to the frequency of western disturbances, although the two are not connected by a simple rule of ratio and proportion. This is not difficult to understand. For example, one individual western disturbance may be associated with more than one duststorm at Delhi and another with none. In the same way, the existing synoptic situation on one occasion may favour the occurrence of high dust-raising winds for a prolonged period under the influence of a western disturbance, whereas the situation may be altogether unfavourable on another occasion for a disturbance to cause high winds.

Incidence of dust-fog is an integrated effect of the incidence of duststorms and high dust-raising winds, as is clear from the figures in Table I.

OBSERVATIONS OF (*a*) POOR VISIBILITY, (*b*) DUSTSTORM (ANDHI) AND (*c*) HIGH DUST-RAISING WINDS AT DELHI (PALAM AIRPORT) DURING MAY 1945-1953 AND (*d*) THE FREQUENCY OF WESTERN DISTURBANCES DURING THIS PERIOD.

(*a*) Number of hours during a month when the Visibility was observed to be limited to (*i*) 1,100 yds. & (*ii*) $1\frac{1}{4}$ miles, due to Dust-fog.

(*b*) Occasions of Duststorms (Andhi) during a month when the windspeed in individual gusts of the associated squall exceeded 25 miles/hr with visibility limited to 1,100 yds.

(*c*) Number of hours of high dust-raising winds in a month with average windspeed 25 miles/hr or more.

(*d*) Number of Western Disturbances during a month affecting weather over the Delhi State and the adjoining areas of the Punjab, Rajputana and Uttar Pradesh.

TABLE I (MAY)

Year	(*a*) VISIBILITY Number of hours		(*b*) DUST-STORMS (ANDHI)	(*c*) HIGH DUST-RAISING WINDS	(*d*) FREQUENCY OF WESTERN DISTURBANCES
	Limited to 1,100 yds.	Limited to $1\frac{1}{4}$ miles	Occasions	Number of hours	
(1)	(2)	(3)	(4)	(5)	(6)
1945	**18** (6^D, 12^N)	**42** (16^D, 26^N)	**11** (6^D, 5^N)	**6** (4^D, 2^N)	**6**
1946	**33** (26^D, 7^N)	**63** (46^D, 17^N)	**8** (4^D, 4^N)	**19** (12^D, 7^N)	**8**
1947	**12** (10^D, 2^N)	**53** (47^D, 6^N)	**5** (5^D, 0^N)	**6** (6^D, 0^N)	**7**
1948	**9** (8^D, 1^N)	**19** (17^D, 2^N)	**5** (4^D, 1^N)	**5** (4^D, 1^N)	**5**
1949	**16** (7^D, 9^N)	**34** (21^D, 13^N)	**6** (3^D, 3^N)	**8** (4^D, 4^N)	**6**
1950	**12** (11^D, 1^N)	**20** (18^D, 2^N)	**3** (3^D, 0^N)	**6** (5^D, 1^N)	**6**
1951	**5** (3^D, 2^N)	**6** (3^D, 3^N)	**4** (2^D, 2^N)	**2** (1^D, 1^N)	**4**
1952	**18** (13^D, 5^N)	**42** (34^D, 8^N)	**11** (9^D, 2^N)	**7** (5^D, 2^N)	**7**
1953	**45** (29^D, 16^N)	**73** (38^D, 35^N)	**12** (7^D, 5^N)	**27** (18^D, 9^N)	**10**
Mean for the period 1945-53	**19** (13^D, 6^N)	**39** (27^D, 12^N)	**7** (5^D, 2^N)	**10** (7^D, 3^N)	**7**

D=Day time (0001 G.M.T. to 1400 G.M.T.) N=Night time (1401 G.M.T. to 0000 G.M.T.)

OBSERVATIONS OF (*a*) POOR VISIBILITY, (*b*) DUSTSTORM (ANDHI) AND (*c*) HIGH DUST-RAISING WINDS AT DELHI (PALAM AIRPORT) DURING JUNE 1945-1953 AND (*d*) THE FREQUENCY OF WESTERN DISTURBANCES DURING THIS PERIOD.

(*a*) Number of hours during a month when the Visibility was observed to be limited to (*i*) 1,100 yds. & (*ii*) $1\frac{1}{4}$ miles, due to Dust-fog.

(*b*) Occasions of Duststorms (Andhi) during a month when the windspeed in individual gusts of the associated squall exceeded 25 miles/hr with visibility limited to 1,100 yds.

(*c*) Number of hours of high dust-raising winds in a month with average windspeed 25 miles/hr or more.

(*d*) Number of Western Disturbances during a month affecting weather over the Delhi State and the adjoining areas of the Punjab, Rajputana and Uttar Pradesh.

TABLE II (JUNE)

Year	(*a*) VISIBILITY Number of hours		(*b*) DUST-STORMS (ANDHI)	(*c*) HIGH DUST-RAISING WINDS	(*d*) FREQUENCY OF WESTERN DISTURBANCES
	Limited to 1,100 yds.	Limited to $1\frac{1}{4}$ miles	Occasions	Number of hours	
(1)	(2)	(3)	(4)	(5)	(6)
1945	14 (10^D, 4^N)	69 (25^D, 44^N)	11 (7^D, 4^N)	18 (13^D, 5^N)	6
1946	13 (13^D, 0^N)	18 (17^D, 1^N)	6 (6^D, 0^N)	10 (9^D, 1^N)	5
1947	14 (11^D, 3^N)	31 (22^D, 9^N)	7 (6^D, 1^N)	11 (10^D, 1^N)	5
1948	4 (3^D, 1^N)	26 (25^D, 1^N)	4 (3^D, 1^N)	11 (10^D, 1^N)	5
1949	4 (4^D, 0^N)	38 (25^D, 13^N)	4 (4^D, 0^N)	11 (11^D, 0^N)	3
1950	7 (5^D, 2^N)	50 (39^D, 11^N)	3 (1^D, 2^N)	17 (14^D, 3^N)	6
1951	10 (9^D, 1^N)	38 (24^D, 14^N)	5 (5^D, 0^N)	15 (15^D, 0^N)	6
1952	31 (25^D, 6^N)	87 (74^D, 13^N)	10 (6^D, 4^N)	24 (17^D, 7^N)	9
1953	12 (8^D, 4^N)	38 (32^D, 6^N)	2 (1^D, 1^N)	13 (11^D, 2^N)	4
Mean for the period 1945-53	12 (10^D, 2^N)	44 (32^D, 12^N)	6 (4^D, 2^N)	14 (12^D, 2^N)	5

D=Day time (0001 G.M.T. to 1400 G.M.T.) N=Night time (1401 G.M.T. to 0000 G.M.T.)

A reference to Table II will show that the month of June 1953 cannot be considered to be exceptional from the point of view of dusty weather compared to 1945, 1946, 1947, 1951 and 1952. June 1952 had the worst dusty weather during the period under consideration in conformity with the high frequency of western disturbances during this month. Statistics for dust phenomena over Delhi in June given in Table II, clearly indicate a general correspondence between the incidence of dusty weather and frequency of western disturbances. But, as stated before, all western disturbances are not equally effective in causing duststorms, dust-raising winds and dust-fog. Their efficacy depends largely on the nature of the disturbances themselves as also on the existent synoptic situations in northwest India when they affect weather there. Moreover, in the month of June an eastern depression from the head of the Bay of Bengal, generally known to the meteorologist as monsoon depression, may, in exceptional cases, travel westwards as far as Gujarat or even Sind and profoundly affect the pressure field in northwest India concurrently with the entry of a western disturbance into the region. Also, a western disturbance may at times cause a deepening only of the seasonal low pressure area over northwest India, and at other times only of the seasonal trough of low pressure area over the Gangetic Valley, and occasionally deepening of both, with the result that the effect of a western disturbance varies greatly according to the existing synoptic situation.

Tables I and II, when studied with the foregoing considerations in view, seem to be sufficient to show that it is not necessary to assume that the Rajasthan desert conditions are spreading towards Delhi to explain the incidence of bad dusty weather there for the consecutive summers of 1952 and 1953. The period, for which requisite data for duststorms, dust-raising winds and dust-fog are available, is too short for dealing with the issue of a climatic change from the point of view of dusty weather. It is true that the summers of 1952 and 1953 have been bad at Delhi in this respect, but there is no reason to believe that such bad or even worse spells of dusty weather did not occur in the past. In any case, the annual fluctuations as seen from Tables I and II, do not suggest any progressive increase in dusty weather over Delhi. Such fluctuations are quite common in weather elements all over the globe.

Table III gives the annual rainfall at Delhi for more than 100 years. The mean annual rainfall at Delhi is 26·75″. It is most interesting to note from this Table how variable the annual rainfall can be at a station like Delhi. The highest annual rainfall at Delhi was as large as 60·36″ in 1933, the next highest being 50·40″ recorded in 1862. The lowest annual rainfall was 8·10″ in 1868, other low amounts recorded being 11·78″ in 1928 and 10·35″ in 1929. The annual rainfall in 1952 was 20·50″ and the rainfall in 1953 from 1st January to 30th September totals 27·1″. The annual rainfall figures for the years 1952 and 1953 do not indicate any abnormal or abrupt climatic change in Delhi in recent years. What is most important in the present context is to note that there is no progressive decrease of rainfall in the Delhi area. As is well known, fluctuations in annual rainfall are due to variations in synoptic situations from year to year. Exceptionally low amounts of rainfall recorded in 1868, 1928 and 1929 as also the exceptionally high amounts recorded in 1933 and 1862 are explainable on the basis of the peculiarities of the synoptic situations in these years. It will be unduly increasing the body of the present note to go into the details of those synoptic situations in the present context.

Just to illustrate how a particular synoptic situation may be responsible for the occurrence of a prolonged spell of widespread dusty weather in northwest India in summer, a set of weather maps for the period June 25 to June 28, 1953, is given on pages 9-12.

(*a*) Continuous lines on the Pressure, Wind and Dust-fog maps give lines of equal atmospheric pressure in millibars (isobars).

TABLE III

Annual rainfall at Delhi for the period 1845-1952

Year	Annual Rainfall in inches	Year	Annual Rainfall in inches	Year	Annual Rainfall in inches
1845	23·68	1885	39·21	1920	23·20
1846	20·92	1886	29·58	1921	27·21
1847	28·62	1887	38·99	1922	23·86
1848	14·31	1888	32·23	1923	31·20
1849	25·63	1889	28·88	1924	33·91
1850	18·93	1890	29·38	1925	21·22
1851	24·78	1891	35·50	1926	27·68
1852	27·18	1892	25·56	1927	21·92
1853	23·26	1893	33·26	1928	11·78
1854-59	No records	1894	41·11	1929	10·35
1860	43·50	1895	19·30	1930	24·69
1861	23·60	1896	23·57	1931	24·17
1862	50·40	1897	21·23	1932	20·91
1863	36·80	1898	18·02	1933	60·36
1864	27·70	1899	12·12	1934	30·19
1865	29·70	1900	33·65	1935	28·10
1866	35·80	1901	21·07	1936	41·84
1867	23·00	1902	27·25	1937	21·39
1868	8·10	1903	13·19	1938	12·67
1869	23·50	1904	30·42	1939	17·66
1870	24·20	1905	12·02	1940	21·71
1871	32·20	1906	31·49	1941	13·65
1872	32·70	1907	12·24	1942	36·68
1873	34·20	1908	40·27	1943	17·34
1874	22·30	1909	37·94	1944	38·67
1875	38·20	1910	30·96	1945	29·35
1876	20·58	1911	24·07	1946	25·56
1877	18·98	1912	33·43	1947	20·24
1878	29·18	1913	17·41	1948	36·98
1879	35·95	1914	32·25	1949	29·37
1880	27·05	1915	24·87	1950	34·30
1881	26·30	1916	29·43	1951	17·48
1882	24·89	1917	32·67	1952	20·50
1883	17·05	1918	12·33	1953 (Jan.-Sept.)	27·10
1884	36·85	1919	17·23		

Mean annual rainfall at Delhi .... 26·75″

(*b*) Arrow-heads show the directions of wind and feathers on the arrows indicate speed as shown below :—

 westerly 5 knots *i.e.* 6 miles/hour.

 westerly 10 knots *i.e.* 12 miles/hour.

 westerly 15 knots *i.e.* 17 miles/hour.

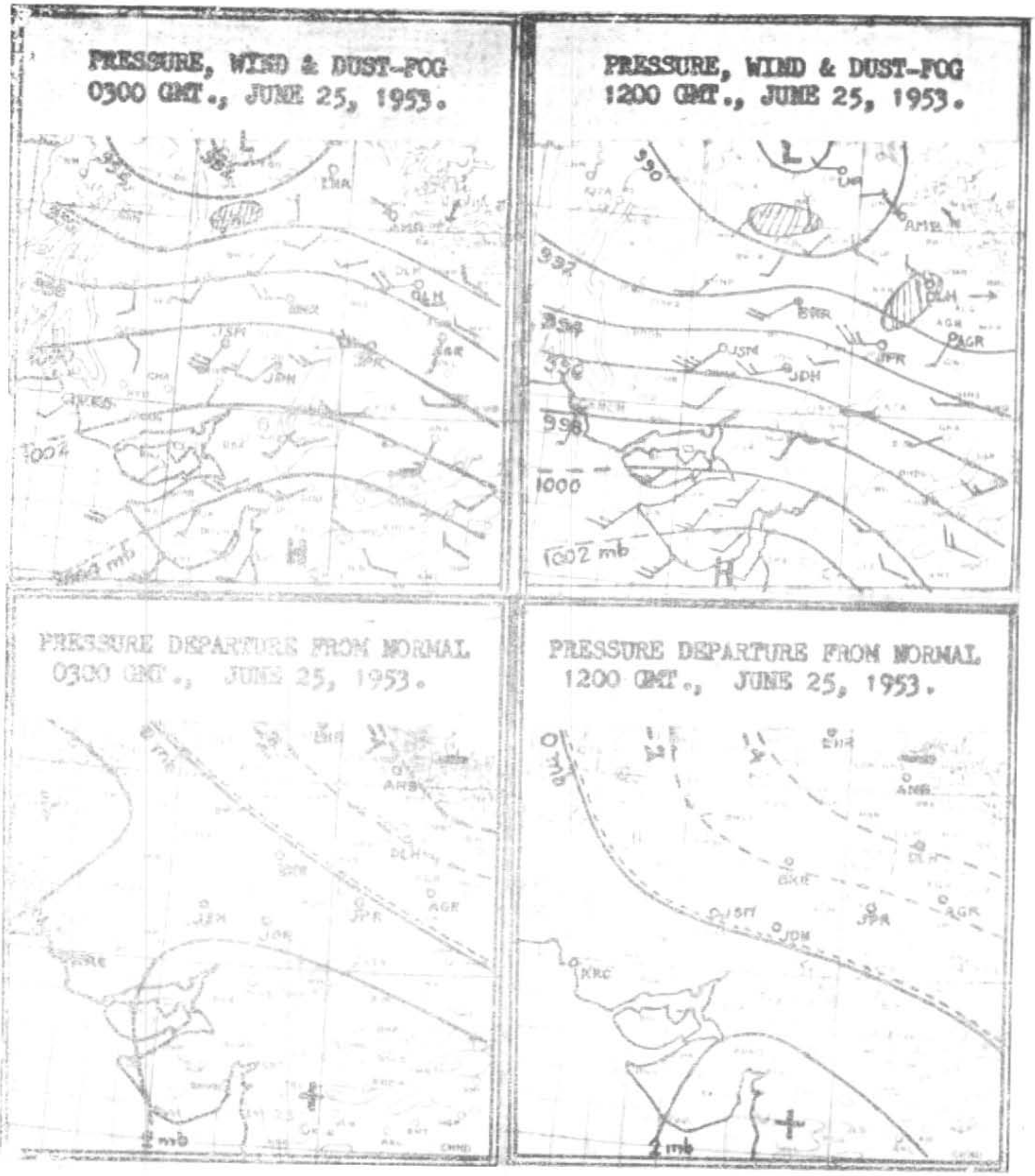
 westerly 40 knots *i.e.* 46 miles/hour.

 westerly 45 knots *i.e.* 52 miles/hour.

 westerly 50 knots *i.e.* 58 miles/hour.

(*c*) L denotes low pressure area or depression and H denotes high pressure area on the Pressure, Wind and Dust-fog maps.

(*d*) Dotted areas on the Pressure, Wind and Dust-fog maps indicate the region where dust-fog prevailed with visibility limited to 1,100 yards. Striped areas indicate the region where visibility was limited to $1\frac{1}{4}$ miles.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0300 GMT., JUNE 25, 1953.
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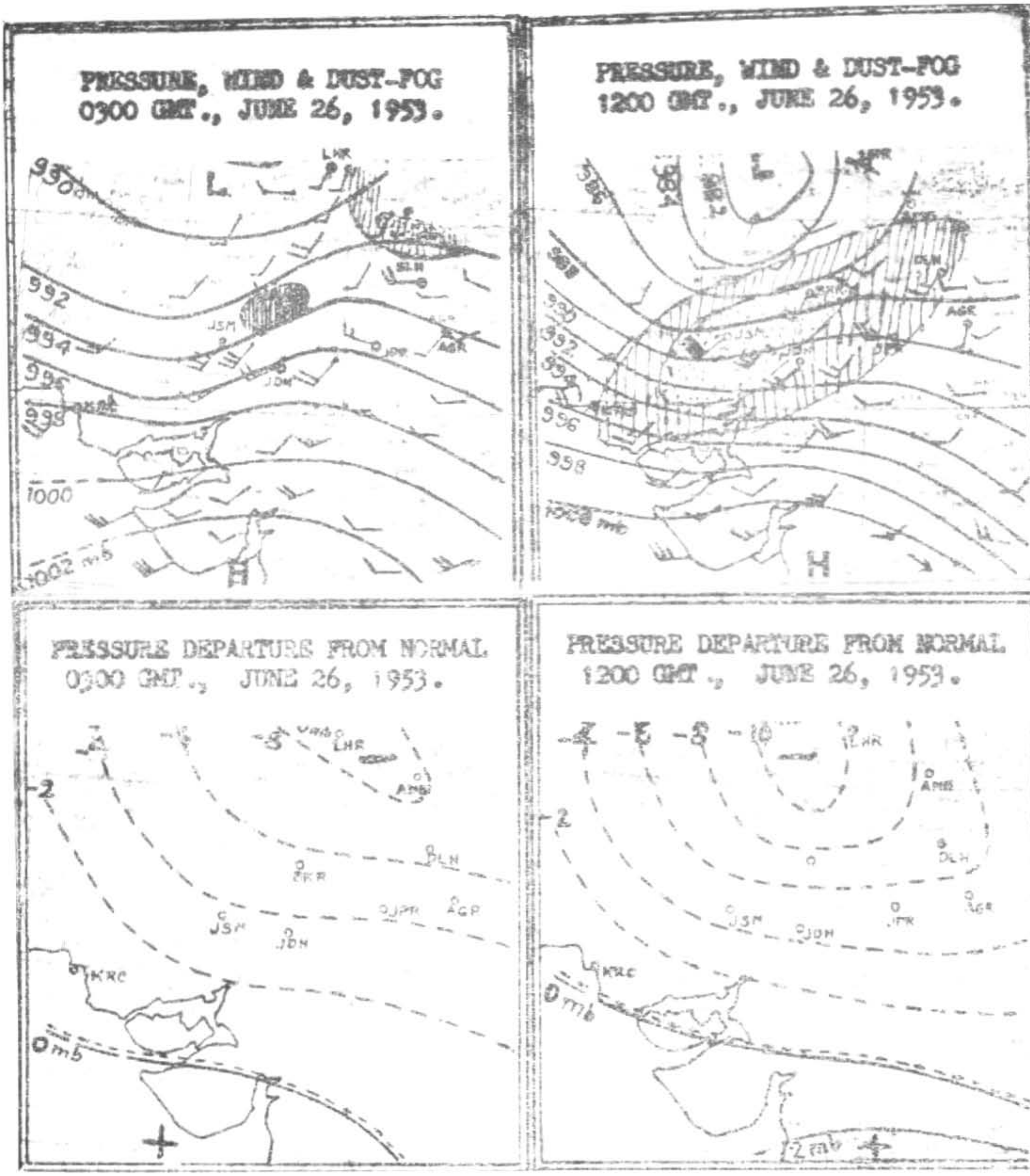
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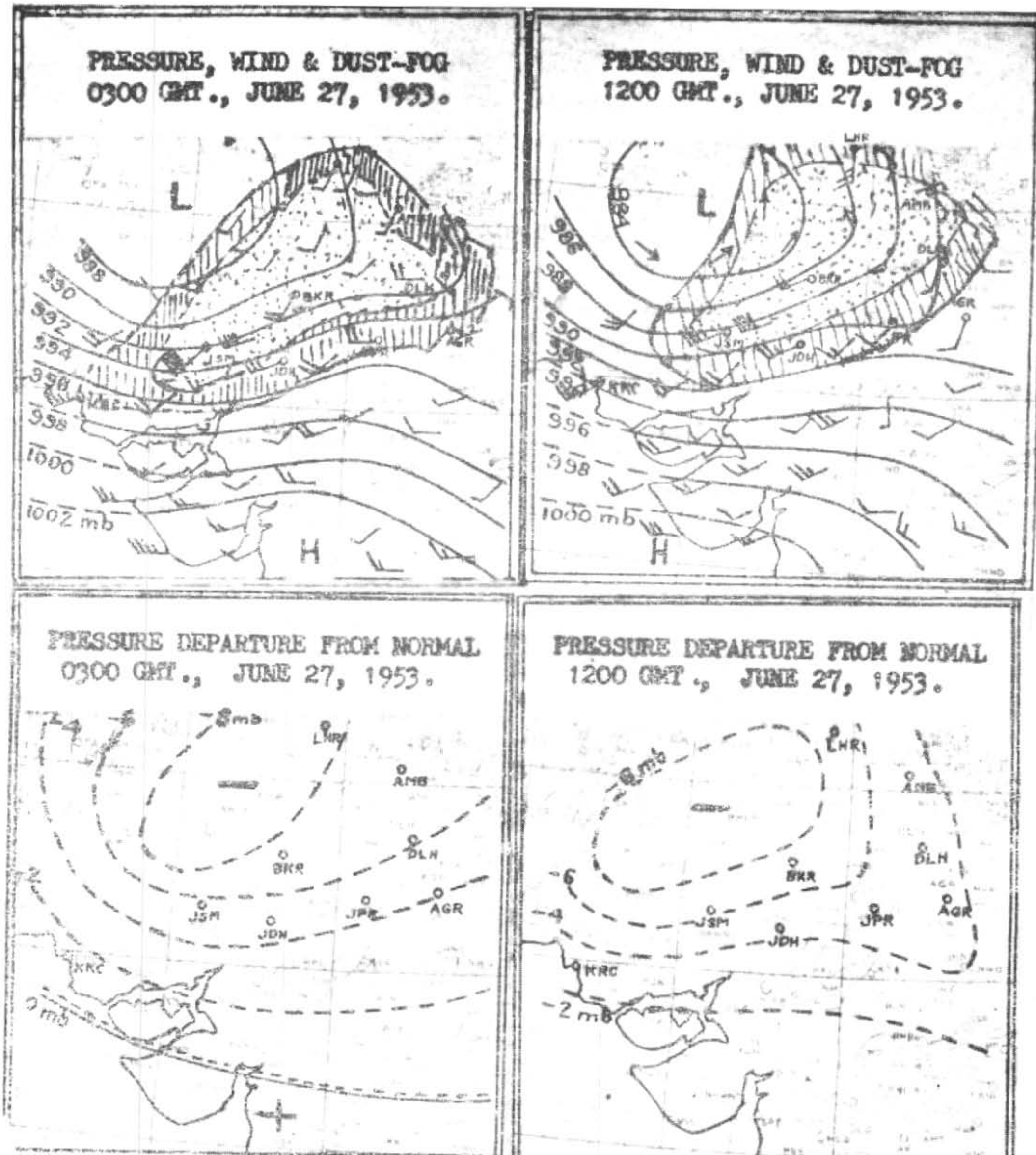
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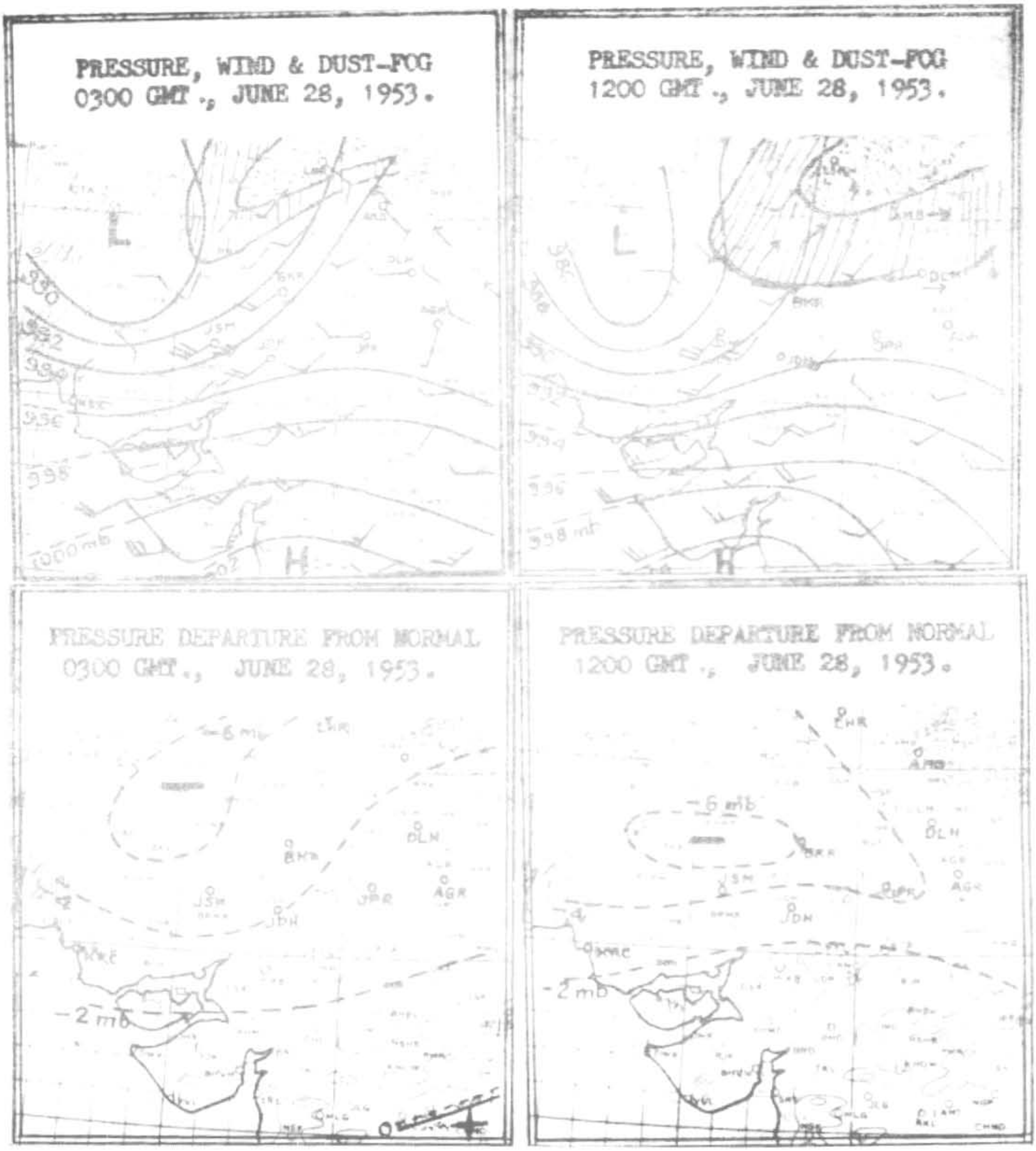
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0300 GMT., JUNE 28, 1953.
PRESSURE, WIND & DUST-FOG
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DLH
BKR
JSH
AGR
JDH

(*e*) Pressure Departure maps show the areas where the pressure is below normal or above normal.

(*f*) Lines on the Pressure Departure maps are drawn at intervals of 2 millibars both on the negative as well as on the positive side.

(*g*) Positive sign (+) on the Pressure Departure chart means that the pressure is above the normal value and negative sign (—) means that the pressure is below the normal.

It is clear from the weather charts that the incidence of dust-fog over the Delhi State during June 26 to June 28 was not local in character. During the period 1200 GMT (1730 IST) on June 26 to 1200 GMT on June 27 dust-fog covered a wide area stretching from Karachi to Delhi, a distance of about 700 miles.

It may be recalled that the month of June this year was a comparatively good one up to the 25th from the point of view of incidence of dusty weather. There were only a few occasions of duststorms and high dust-raising winds before the 26th June. A monsoon depression, which formed over the northwest angle of the Bay of Bengal off the Orissa coast on the 18th morning, was about 12 millibar deep with centre near Puri on the 19th morning. It moved rapidly westwards, being centred over Madhya Pradesh on the 20th, over north Bombay Deccan on the 21st and over Kathiawar coast on the 22nd, where it remained stationary for a day and filled up very rapidly by the 24th morning. This monsoon depression followed a westerly track a little too far to the south. Although it caused fairly heavy rain along its track and strong monsoon on the Bombay coast during the period 19th to 23rd June, it failed to give any rain on the desert tracts of Rajputana and the adjoining areas of the Punjab and Sind. It was, however, able to cause an incursion of the monsoon along and near the western Himalayas where a good amount of rain fell on the 22nd and 23rd. Palam airport recorded a heavy shower of 2·5″ and Safdarjung 1·6″ on the 24th morning with no rain to the west of the line joining Delhi and Patiala. In spite of the heavy fall of rain over the Delhi State between the 23rd and 24th June, Delhi became enveloped in a thick dust-cloud for a prolonged period from the 25th to 28th June. The synoptic situation which was responsible for the spell of dusty weather at Delhi is clearly seen from the weather maps for the period. Following the filling up of the monsoon depression over Kathiawar on the 24th, atmospheric pressure started falling over the Punjab on the 24th under the influence of a western disturbance, and by the 25th morning a marked low pressure area about 4 millibar deep appeared over that region. The Indo-Gangetic trough of low pressure along the Himalayas also became well marked. By the 26th afternoon the low pressure area over the Punjab concentrated into a deep depression with a pressure deficiency of about 12 millibars near Montgomery. This deep depression caused an unusually steep pressure gradient over the desert tracts of Rajputana giving rise to moderate to strong westerly or southwesterly gales on the 26th and 27th, particularly over the Jaisalmer-Phalodi-Bikaner-Jodhpur area. Jaisalmer experienced strong southwesterly gales of about 58 miles per hour for hours during this period. Phalodi also had gales of 45 to 50 miles per hour in the same period, while Jodhpur was gusting at speeds varying from 40 to 50 miles per hour. The depression weakened on the 28th and merged into the seasonal trough of low pressure in northwest India by the 29th.

The desert tracts of Rajasthan had little or no rain before this disturbance and the soil there was in a very favourable condition to be raised aloft by the strong gales. The amount of dust raised and carried away from place to place by the strong gales in the districts of Jaisalmer and Bikaner was enormous. It is seen from newspaper reports that many heads of cattle were buried under sand carried by the dust-raising winds. Rail tracks between Bikaner and Jodhpur were under thick layers of sand at several places, causing dislocation of train services. Other arid regions of the globe have also experienced occasionally fierce dust-raising gales. In the spring of 1902 when rainfall was scanty over a large area in the northern parts of Victoria in Australia, many carefully worked fallow lands were practically swept bare by fierce dust-raising winds of " the loose soil mulch which had been so laboriously prepared by cultivation to conserve moisture and provide plant food for the next year's crop. Many a boundary fence was obliterated and lanes filled to depth of several feet by wind borne sand and loam during this year. In New South Wales the same occurred over large areas of purely pastoral country ".

A glance at the weather maps will show how the extensive cloud of dust moved day by day from the Sind area towards the western Himalayas during the period 26th to 28th June. Hill stations like Mussorie, Dharampur, Dharamsala, Muktesar, Simla and even Jammu in Kashmir were enveloped in this dust-cloud during the period 27th to 28th. It is thus clear that the dust-fog over Delhi from the 26th to 28th was not just a local phenomenon. The dust was really carried to Delhi by the dust-cloud drifting from the southwest. This is not an unprecedented phenomenon. Carrying of dust by wind from place to place must have been going on over arid and semi-arid regions of the globe from the prehistoric times. Just as house-floors are liable to be covered with thick layers of dust if left uncared for a long time, so also areas round an arid and semi-arid region, particularly on the windward side, would have been covered with heavy deposit of dust if nature did not do its duty of regular cleaning. This the nature does by giving rain periodically and washing away the dust to the rivers and then to the sea. Incidence of bad spells of dusty weather need cause no apprehension that desert conditions are advancing towards Delhi. New Delhi itself was more or less a barren semi-arid region before the Capital was developed. Now it is a green belt. If man helps nature, more semi-arid areas can be gradually made green by adopting the known ways of conservation and storage of water, use of underground water and adoption of the modern methods of irrigation and cultivation.

Feasibility of increasing rainfall by "seeding" clouds over an arid or semi-arid region to combat genuine drought

The topic of making rain artificially by "seeding" clouds has been greatly publicised in recent years in the United States of America, Australia and other countries as also in our own homeland. The glare of publicity has sometimes led to most extravagant and unreal claims of success without adequate scrutiny and proper assessment of the results of the operations carried out. All the same, the un-suspecting public has been tuned to the expectation that any technological miracle is purchasable at a price. The incidence of bad spells of dusty weather over the Delhi State for two consecutive summers of 1952 and 1953 has naturally reinforced the idea of calling in the aid of artificial stimulation of clouds as a measure to augment rainfall over Rajasthan and the adjoining areas to reduce the incidence of dusty weather and prevent the apprehended spread of desert conditions. For reasons stated in the following paragraphs, it seems unlikely that rain to break drought in an arid or semi-arid region can be had by the use of any cloud "seeding" technique.

To have an appreciation of the problem it is important to bear in mind what cloud modifications are accepted as feasible by Meteorologists and Scientists in general as a result of theoretical and practical researches carried out during the past. The important scientific conclusions on the subject of cloud modifications are stated below :—

(*a*) " Seeding " of a super-cooled cloud with " dry ice " or silver iodide will usually convert at least a portion of it to ice-crystal cloud if the temperature is below —5°C.

(*b*) " Seeding " of a thin layer-type or stratus cloud can create holes or channels in the cloud deck so that the ground below could be seen. This is obviously of interest to both military and commercial aviation for making landings and parachute drops. As, however, the water content of stratus clouds is small, little rain can be expected to occur and actually reach the ground as a result of " seeding " such a cloud.

(*c*) " Seeding " of an inactive fair-weather cumulus cloud can only result in partial or complete dissipation of the cloud without any significant rain reaching the ground.

(*d*) " Seeding " of an active large cumulus cloud may often result in ' virga ' or light precipitation but significant rain can fall only if the synoptic situation is favourable for a sustained flow of moist air, and for the requisite cloud forming processes for the continuous replenishment of the seeded cloud.

(*e*) Weather control on a small scale, such as cloud modifications mentioned above and local dissipation of fog, is known to be possible. There is no evidence and no scientific reason to think that the cloud " seeding " technique has provided us the ability to modify or control large scale atmospheric processes which are responsible for our general weather and climatic patterns.

The amount of precipitation obtainable in an area from clouds, whether by natural processes or by artificial stimulation, is obviously dependent on the horizontal transport of water vapour, feeding the clouds over the area. This transport of moist air of maritime origin can be maintained or augmented only by the creation or intensification of a circulation of the size of a cyclone, several thousand square miles in area. Although various theories have been put forward in support of the idea that " seeding" can have cumulative effect, there is yet no acceptable ground for the belief that " seeding " can locally increase convection circulation in a cloud cell so as to permit vertical growth of the cell. Even granting that " seeding " can increase local convective activity inside a cloud, there is no evidence or rational theoretical basis that such an increase will start cyclogenesis on a large scale. It is, therefore, extremely unlikely that any " seeding " of clouds would result in a net increase of rainfall in an area afflicted by genuine drought. In this context, it is important to remember that precipitation is only one side of the hydrological cycle. A net increase in rainfall in an area is impossible without a greater transport of water vapour into that area, which can be achieved only by acquiring the power to start big scale cyclogenesis. Further, supposing that " seeding " of inactive cumuliform cloudlets usually occurring in genuine drought conditions, is able to extract a few drops of rain from the clouds to reach the ground at one spot, it is not difficult to see that other spots would be deprived of their share of drops, which natural processes might have provided in due course without the artificial stimulus. There is, therefore, little possibility of obtaining relief by cloud " seeding " in times of drought, since at such times clouds are of unfavourable type and air so dry that rain which may possibly be induced by " seeding " would evaporate before reaching the ground ; and when conditions are favourable, nature takes care of making it rain.

The problem is in a way akin to that of a Finance Minister who is called upon to provide financial assistance in various forms to a large famine-stricken area with his purse practically empty and with no prospect of getting increased revenues or loans from inside or outside the country. The Finance Minister can use all his ingenuity to make an equitable distribution of financial assistance to the famine-stricken people but he can do so only to the extent his purse will permit. This is the reason why a Finance Minister builds up a reserve year by year, which can be drawn upon to combat emergencies of this type in future years. It would be a real miracle if cloud " seeding " technique could come to the aid of mankind to solve the problem of water famine in arid and semi-arid regions. It looks as though we shall have to depend for many more years on the old known methods of tackling the problem of drought and water famine.