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On the effect of continuous diffusion of salt nuclei into the atmosphere on local rainfall*

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ABSTRACT. It is generally recognised that the presence of salt nuclei in clouds has a powerful influence on rain formation. It is with a view to find out whether continuous diffusion of salt nuclei into air from a powerful atomizer, placed at a height of 60 ft above ground, which is fed by salt solution and worked by compressed air at 20 atmospheres would have any effect on local rainfall, that experiments were undertaken at the Jadavpur University in 1958 and 1959. The atomizer was kept in continuous action throughout the day-light hours during April to October of 1958 and during July to October of 1959.

During 1958 and 1959, West Bengal had deficient monsoon rainfall. The departures of rainfall from the normal in each of the months, during which the experiments were done, were plotted and the lines of equal departures were drawn. These showed that the curves of least negative departures and in some cases highest positive departures were generally oval-shaped extending from north of Calcutta to a distance of about 100 miles towards the prevailing wind direction in all the months in which the experiments were done. This suggested that this oval-shaped area received more rainfall than the neighbouring areas. As this area came under the influence of the salt nuclei which permeated into the air and a fair proportion of which reached cloud levels after a travel of short distance from south Calcutta, it is considered that this factor may have contributed to the increase in rainfall.

1. Introduction

It is known that the presence of salt nuclei in saturated air has profound influence on rain formation. Observations show that the drops formed on hygroscopic nuclei have sizes generally larger than those formed on other types of nuclei. The disparity in sizes thus introduced amongst cloud particles leads to further growth of the larger sized drops both as a result of vapour pressure effect and collision with other drops during their fall through the cloud. The usual process of rain formation in warm type clouds is thus set up.

Observations show that while a fair number of salt nuclei are introduced into the atmosphere over the coastal regions as a result of sea-spray, the number rapidly decreases as one moves into the interior of the country. It was with a view to study the effect on the local rainfall of continuous diffusion of salt nuclei artificially introduced into the atmosphere that experiments were undertaken at the Jadavpur University during 1958 and 1959, according to a plan which was formulated by Prof. S. K. Banerji several years ago.

Experiments on cloud seeding by salt particles have been carried out by Mason in England, by Davies, Hepburn and Samson in East Africa, by Dessens in France, by Fournier D' Albe, Lateef, Rasool and Zaidi in Pakistan. While this paper was under preparation, an account of experiments with salt nuclei carried out at Delhi appeared in this journal (Roy *et al.* 1961).

A powerful atomizer worked by compressed air at 20 atmospheres was fixed at a height of about 60 ft above ground. The feed to the atomizer was from a reservoir of 80 gallon capacity containing half the normal ($\frac{1}{2}$N) solution of NaCl. The compressor was worked by a 2 H. P. electric motor. About 16 lbs of salt were consumed per day. The

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fine spray, on evaporation of the moisture within a few feet of the nozzle, gives rise to an enormous number of salt nuclei per minute diffusing and spreading horizontally and vertically in the windward direction of the atmosphere.

Experiments were carried on during the months April to October 1958. To test the results obtained, the experiments were repeated during the months July to October 1959. Rainfall in West Bengal in 1958 and 1959 was below normal. The actual monthly departures of available rainfall data were plotted against the stations in Bengal, Bihar, Orissa and Assam for all the months, April to October 1958 and July to October 1959. In all the months, the lines of equal departure were all closed curves, generally oval-shaped, the axis extending from Calcutta in the direction of the prevailing wind during the month. The innermost line of equal departure was the line of least negative departure and very often a line of positive departure and the area covered generally extending about 100 miles in the direction of the prevailing wind over the month as a whole.

The similarity of features in the rainfall departure charts in all the months in which the experiments were carried out is suggestive of a tendency of a small increase of rainfall of the order of 10 to 15 per cent in the windward direction due to the injection of salt nuclei.

2. Role of salt nuclei in rain formation

The role of sea-salt nuclei in the formation of large cloud droplets essential for accretional growth of rain-drops is well recognised.

In recent years, Russian scientists have done considerable work on condensation nuclei. Collection of large numbers of supercooled cloud droplets and chemical analysis of the water have shown that on the average they contained $2 \cdot 4 \times 10^{-15}$ gm of NaCl, the chloride concentration in cloud elements being about 8·0 mg per litre. Inferences drawn on mechanism of drop growth indicate that coalescence begins when the radii of the drops attain sizes of about 15 microns and becomes the dominant mechanism when the radii become 25 microns or more.

It is now generally agreed that for a cloud to precipitate by the process of coalescence of cloud droplets, a basic requirement is that a moderately large number of cloud particles of radius 15 to 40 microns be continually generated well above the base of the cloud. Droplets of such large sizes can be produced by the condensation and absorption of water vapour by giant salt nuclei. But the known population density is very small (much less than one salt particle per cubic centimetre) and consequently the salt nuclei do not ordinarily constitute the main contributing factor in natural rain formation. In natural clouds under favourable conditions, there are other processes which lead to growth of large drops of 15 to 40 microns. But it is clear that if by artificial means a large number of salt nuclei can be introduced into the cloud layer, rain formation will be greatly facilitated.

3. Experimental arrangement

The experimental arrangement consists of an atomizer, which is fixed at a height of about 20 ft above the roof of the three-storeyed chemical engineering building of the Jadavpur University on a wooden platform on the top of the reinforced concrete water reservoir, the total height of the atomizer above the ground surface being about 60 ft. The accessibility to the atomizer is arranged by a wooden ladder fixed on the top of the water reservoir on the roof of the building. On the top of the wooden platform also stands a galvanized iron tank of 80 gallon capacity containing salt solution, to feed the atomizer with saline water. The atomizer is worked by an air compressor, which is kept in the room below and connected to the atomizer by airtight galvanized iron pipes. A picture of the atomizer and its connections is given in Fig. 1. The compressor is worked by a 2 H.P. motor and maintains the air flow at a pressure of 20 atmospheres. The connection of the atomizer with the galvanized iron tank is made with thick rubber tube which has to be changed periodically due to the damage done to the rubber by saline water.

The atomizer is CUE Type No. 13577 manufactured by Biasch Bair Brush Co., Chicago. As an atomizer in continuous action with salt solution requires periodical cleaning due to incrustation of salt, another atomizer of the same type was brought into use to facilitate cleaning without interruption of spraying.

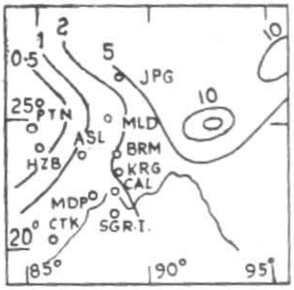
Agitation of sea surface is known to produce giant salt nuclei of mass equal to or greater than 10^{-12} gm and these salt nuclei are effective in rain formation. Sea salt particles are cubic crystals at relative humidities of 71 per cent or less. They change phase at 74 per cent and are completely liquified at 77 per cent.

After a careful consideration of the strength of salt solution to be used it was decided to use solution of the same strength as in sea water. This gave fine sprays, resulting in production of particles of diameters varying from 6 microns to 14 microns. The quantity of salt in sea-water is about 30 per cent by weight. As the weight of a gallon of water is 10 lbs, this means that 3 lbs of salt are to be dissolved in a gallon of water. This is nearly equivalent to half the normal solution of NaCl. Salt solution was prepared on this basis. With this concentration, the salt content of a particle of diameter 10 microns is of the order 10^{-10}gm and this can be taken as the average salt content of the sprayed particles. As the relative humidity at the level of the atomizer was very often less than 71 per cent, the sprayed particles were observed to dry up at a distance of a few feet from the atomizer. Consequently the method gave rise to an enormous number (about 10^{10}) of giant salt nuclei per minute each with an average weight of the order 10^{-10} gm and became airborne in the windward direction.

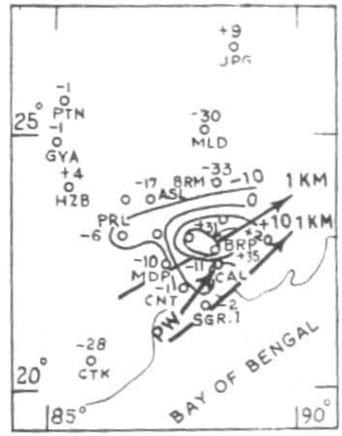
The atomizer was kept in continuous operation during the day-light hours in the months of April to October 1958, and July to October 1959. It was considered that this non-stop feeding of salt nuclei during daylight hours would enable them to take full advantage of convectional and other ascentional currents to reach the cloud level after a horizontal drift of a few miles and play an effective role in rain formation.

Fig. 1

To form an idea of the concentration of salt nuclei per cubic metre of air in different locations during a day's operation of about 10 hours, we have to note that the travel of the nuclei will be determined mainly by the prevailing air currents and that the ordinary slow process of diffusion will play a small part. The source of emanation is a point source and if we assume the air currents to have a horizontal velocity of about 10 m.p.h., the nuclei will spread along a cone of a complicated pattern to a distance of about 160 km. For simplicity, we shall assume the cone to have a length of 160 km and to have horizontal and vertical sections of 2 km each at the far-end. The volume of air within such a cone is about 2×10^{11} cubic metres and the number of salt nuclei

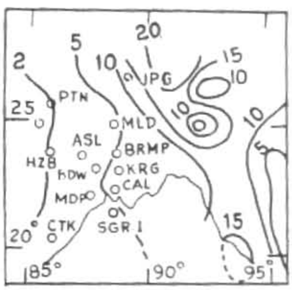


NORMAL RAINFALL (in)
APRIL

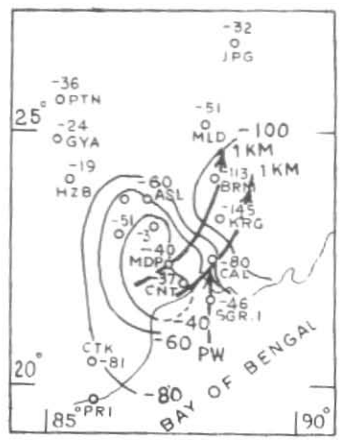


OBSERVED RAINFALL (mm)
APRIL 1958
Continuous lines represent departure from normal

Fig. 2



NORMAL RAINFALL (in)
MAY



OBSERVED RAINFALL (mm)
MAY 1958
Continuous lines represent departure from normal

Fig. 3

dispersed in 10 hours is 6×10^{12}. If the nuclei be assumed to be uniformly distributed within this cone then the number of nuclei per cubic metre is 30. Due to the complex nature of the air stream involving rapid horizontal motion and also slow vertical motion at different places, the concentration of the nuclei will not be uniform; their concentration will be more in some parts of the tongue and less in other parts. As such in several parts of the cloud, they would constitute significant additions to the very small number of natural nuclei and play an important role in producing increased rainfall.

4. Analysis of rainfall data

As a consequence of the continuous nucleation of the atmosphere with giant

TABLE 1

(a) Actual monthly rainfall (mm) and (b) Departure from normal—1958

Stations	April		May		June		July		August		September		October	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
Saugor Island	27	—2	69	—46	36	—259	329	—64	177	—161	566	+303	92	—113
Calcutta	33	—11	60	—80	101	—196	343	+17	180	—148	274	+21	72	—42
Dum Dum	40	—11	53	—65	133	—127	219	—90	230	—94	312	—31	92	—41
Barrackpore	86	+35	70	—59	93	—217	185	—134	288	—14	281	+64	112	+13
Krishnagar	72	+14	26	—145	211	—51	214	—72	219	—44	154	—48	130	+23
Berhampur	5	—33	23	—113	88	—158	332	+56	244	—46	151	—81	170	+77
Midnapore	33	—10	80	—40	68	—191	348	+24	187	—137	519	+303	82	—15
Burdwan	80	+31	72	—80	69	—198	282	—43	198	—105	229	+5	97	+14
Bankura	24	—8	101	—3	137	—131	190	—140	346	+38	318	+118	94	+15
Asansol	4	—17	14	—60	86	—156	135	—212	231	—107	247	+38	212	+101
Contai	32	—1	88	—37	173	—88	281	—70	262	—71	472	+196	159	—24
Malda	0	—30	66	—51	25	—224	401	+109	480	+200	143	—150	74	—37
Jalpaiguri	102	+9	269	—32	953	+294	437	—381	1518	+876	396	—143	184	+43
Purulia	18	—6	25	—51	75	—163	277	—58	250	—82	37	+160	78	—3
Dhanbad	40	—24	4	—47	120	—75	270	—52	300	—50	313	+108	112	+24
Jamshedpur	13	—7	0	—70	82	—109	338	+4	148	—244	393	+212	96	+29
Hazaribagh	18	+4	31	—19	150	—62	281	—50	344	+9	316	+119	40	—39
Patna	6	—1	0	—36	14	—167	234	—60	236	—97	199	—19	63	+5
Gaya	5	—1	0	—24	54	—110	203	—132	271	—78	177	—14	49	0
Cuttack	0	—28	10	—81	101	—152	260	—67	297	—43	293	+45	206	+70

salt nuclei of average diameter of nearly 10 microns, travelling and dispersing in the windward direction, a fair proportion of which would reach the cloud level, the expectation is that these would assist in producing an increase of rainfall in the windward sector over a few hundred square miles. How far this expectation has been realised will be apparent from the rainfall charts given in Figs. 2 to 8.

The actual monthly rainfall and departure from normal of all the India Met. Dep. stations in the experimental area for the experimental months of the years 1958 and 1959 are given in Tables 1 and 2.

In both the years 1958 and 1959 in which experiments were carried out, the monsoon rainfall had been deficient in West Bengal. It was, therefore, considered that the best method of bringing out the effect, if any, of permeation of the local atmosphere with salt nuclei in the windward direction would be to plot the departures of the actual monthly rainfall from the normal monthly rainfall as well as the average monthly prevailing wind direction near the ground surface and also at 1-km level, and compare the trends of the actual departure lines with the normal isohyets. Consequently the departure lines, the mean prevailing wind directions near ground surface and also at 1 km and normal isohyets have been given in Figs. 2 to 8.

In drawing the rainfall departure lines many more stations were plotted than are shown on the chart. The wind direction that has been plotted is the normal wind direction for the month of the prevailing wind near ground surface and at 1-km level. The mean wind direction at 1-km

TABLE 2

(a) Actual monthly rainfall (mm) and (b) Departure from normal—1959

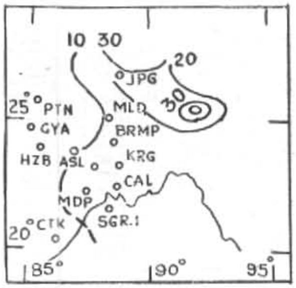
Stations	April		May		June		July		August		September		October	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
Saugor Island	3	—27	32	—83	185	—110	243	—149	244	—93	596	+333	529	+324
Calcutta	85	+40	110	—30	352	+55	167	—159	251	—77	519	+266	474	+360
Dum Dum	58	+8	124	+7	328	+77	197	—113	471	+147	615	+342	340	+206
Barrackpore	29	—22	78	—51	392	+82	273	—46	412	+110	583	+366	557	+458
Krishnagar	17	—41	137	—34	265	+3	240	—46	316	+52	349	+147	525	+418
Berhampur	20	—18	125	—10	187	—59	232	—44	426	+136	253	—21	423	+330
Midnapore	59	+16	63	—57	173	—86	336	+12	269	—55	419	+203	323	+227
Burdwan	3	—46	77	—75	137	—130	130	—196	384	+82	163	—60	483	+399
Bankura	61	+29	17	—86	128	—140	226	—103	249	—59	299	+100	226	+147
Asansol	6	—15	14	—61	237	—4	269	—79	373	+36	550	+341	394	+283
Contai	20	—13	44	—81	243	—18	201	—150	160	—173	380	+104	562	+379
Malda	25	—5	125	—9	179	—71	236	—20	317	+37	179	—114	439	+329
Jalpaiguri	148	—54	163	—137	511	—147	692	—126	231	—44	487	—52	412	—271
Purulia	69	+45	94	—18	252	—14	333	—2	[illegible]	—27	404	+185	137	+166
Dhanbad	5	—11	59	+8	185	—10	387	—65	319	—31	321	+116	402	+314
Jamshedpur	42	—19	48	—22	191	—1	347	—12	237	—155	322	+141	225	+157
Hazaribagh	14	0	74	—24	266	—55	478	—147	366	+30	314	+87	209	+131
Patna	29	+22	84	—48	50	—131	278	—16	291	—41	180	—39	187	+129
Gaya	2	—4	3	—20	107	—57	302	—34	417	+63	149	—41	121	+72
Cuttack	81	+54	102	+12	95	—158	255	—73	326	—14	163	—84	244	+108

in most of the months for which data have been plotted differed very little from the normal wind direction for the month. It has to be remembered that the wind direction that determines the dispersion of the salt nuclei is not the mean wind direction near the ground surface or at 1-km level for the month or the normal wind direction for the month at these levels but the actual wind direction prevailing at the time of dispersion in the levels reached by the nuclei during their travel. It is easier to picture the region covered by the nuclei if it is stated that in lower Bengal, these actual wind directions from the surface up to about 1·5-km level lie within 30 degrees on either side of the monthly normal wind direction. In interpreting the charts this variability in wind direction should be kept in mind. Normally the effect of the nuclei would extend towards some northerly direction from Calcutta, but in July, August and September when depressions form in the north Bay of Bengal and wind tends to become northerly to easterly, some southward extension of nuclei becomes possible. This feature is particularly conspicuous in September 1958 in which month several depressions formed in north Bay of Bengal.

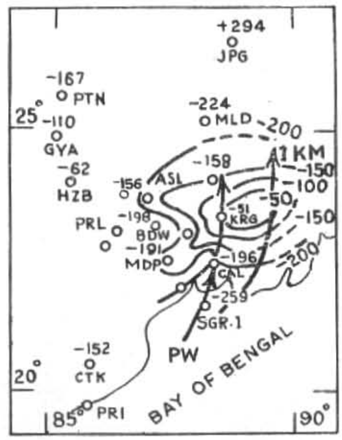
No great accuracy in plotting these charts is claimed. They are intended to bring out the broad features only.

(1) *Rainfall in April 1958 (Fig. 2)*

The diffusion of salt nuclei commenced in this month. It is a month in which strong convectional currents develop. The drift near the ground surface is generally towards northnortheast but owing to convection the salt nuclei would be expected to reach cloud



NORMAL RAINFALL (in)
JUNE



OBSERVED RAINFALL (mm)
JUNE 1958
Continuous lines represent departure from normal

Fig. 4

level within a short distance from Calcutta. The departure lines show an increase from a negative to significant positive value round about Barrackpore in the windward direction towards north of Calcutta. The normal map shows a general increase of rainfall towards the northeast, but the departure map indicates that rainfall had been in excess of this normal over a small oval-shaped area with its longest axis extending from Barrackpore to Burdwan. The northwesterly extension appears to have been dominated by updraft over the dry air tongue from Bihar.

(2) *Rainfall in May 1958* (*Fig.* 3)

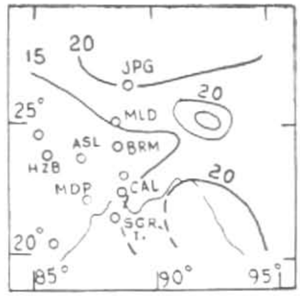
In this month too the rainfall is mainly convectional. The amount of rainfall has been appreciably below normal over the whole area. Although the normal wind at 1 km is towards NNE, the wind nearer the surface was more towards the NNW particularly in the afternoon. There is a gradient of increase in rainfall from Calcutta towards Asansol. The oval-shaped area of least deficiency in rainfall lies towards the west of Calcutta. This location of the oval-shaped area has apparently been influenced by the updraft of moist southerly air over the westerly dry air tongue from Bihar, which is a dominant process of convectional activity in this month leading to the development of thunderstorms.

(3) *Rainfall in June 1958* (*Fig.* 4)

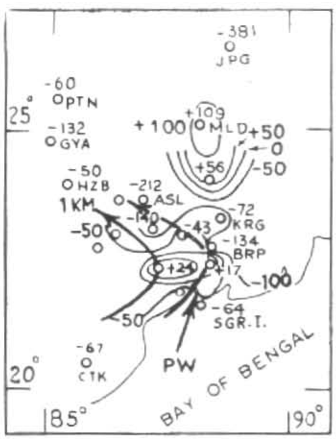
In this month again, there was a large deficiency of rainfall in West Bengal; the deficiency was least over a small oval-shaped area extending from Krishnagar northeastwards in the direction of the wind. The southwest monsoon commenced late in this month, and the rainfall in the month was generally convectional. There is a significant decrease in the deficiency of rainfall in the windward direction northeast of Calcutta. The normal chart shows an increase of rainfall in this direction, but the deficiency recorded has been obtained after taking due account of this increase in normal at individual stations. Here again the increase in rainfall recorded is in the direction towards which the nucleation is expected to have spread.

(4) *Rainfall in July 1958 and July 1959* (*Fig.* 5)

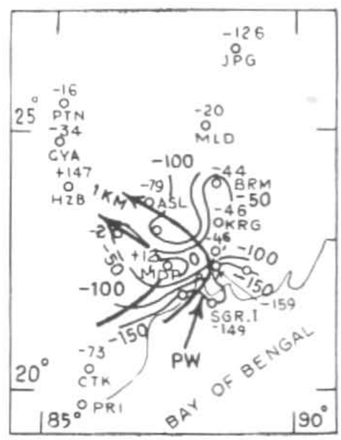
The rainfall departure charts for July 1958 and for July 1959 are shown side by side. The difference between the two months is that while in July 1958, the nucleation was a continuous process since



NORMAL RAINFALL (in)
JULY



OBSERVED RAINFALL (mm)
JULY 1958



OBSERVED RAINFALL (mm)
JULY 1959

Continuous lines represent departure from normal

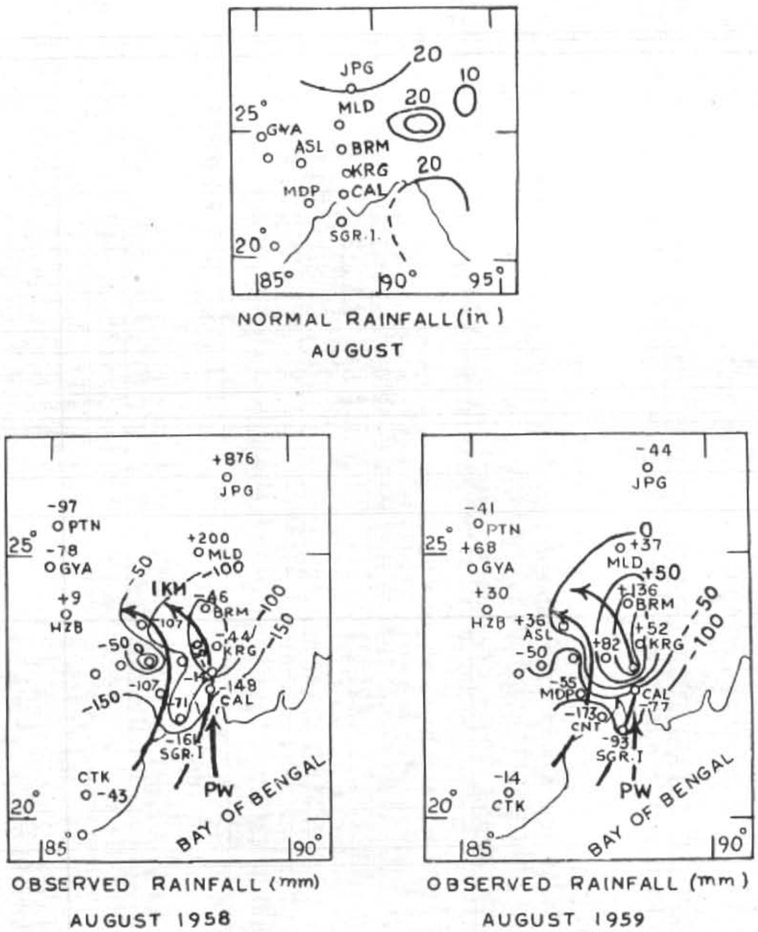
Fig. 5

April 1958 and the atmosphere was greatly permeated with salt nuclei over the whole of the month, in July 1959, the nucleation had just commenced and a few days must have passed before the atmosphere got surcharged with salt nuclei. In both years, there is a general deficiency of rainfall, but there is a small area round about Midnapore over which there is no deficiency. The contrast between the two areas of increased rainfall in July 1958 and July 1959, compared with the normal rainfall chart and also the general similarity of their features is particularly striking. In both months the increase of rainfall is in the direction in which the nucleation has extended.

In July 1958, there was a second localised area of excess rainfall extending from Berhampur to Malda. It is not possible to say whether salt nuclei permeated over this area due to the long continued diffusion.

(5) *Rainfall in August 1958 and August 1959* (*Fig.* 6)

There is a general deficiency of rainfall in West Bengal in these two months; the deficiency is very marked in August 1958 while in August 1959 the deficiency is generally confined to lower Bengal. The departure chart for August 1958 shows an oval-shaped area of least deficiency along a tract extending from Calcutta to Berhampur



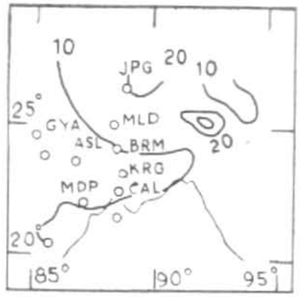
Continuous lines represent departure from normal

Fig. 6

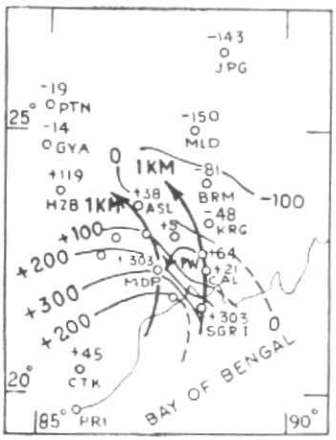
in the windward direction. In August 1959, however, there is a marked excess of rainfall over a tract again extending from Calcutta to Berhampur. In these two months, a feeble southerly wind nearer the surface and stronger wind at higher level helped spreading of the nuclei in an elongated region from a little south of Calcutta towards Berhampur. The locations of the area of least deficiency in August 1958, as well as the area of excess rainfall in August 1959, are striking and would appear to be regions which would be expected to have come under the action of salt nuclei. The excess rainfall in August 1958 at Bankura appears to be a purely local phenomenon.

(6) *Rainfall in September 1958 and September 1959* (*Fig.* 7)

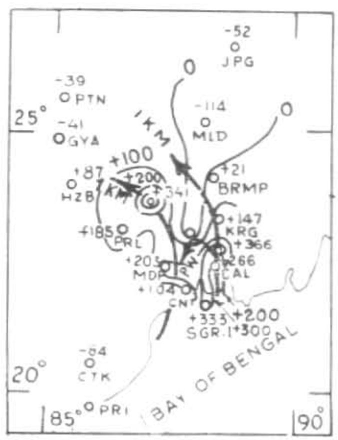
These two months show special features in the two years. In September 1958, there is a deficiency of rainfall in the northern part of Bengal and excess rainfall in the south. This was due to the development of a number of deep depressions in the north Bay of Bengal. As a result, the wind very often became northerly and thereafter easterly. The passage of these depressions across the Orissa coast has caused an excess of rainfall in the area southwest of Calcutta. There is a significant increase in the departure from +21 mm in Calcutta to +303 mm in Midnapore



NORMAL RAINFALL (in)
SEPTEMBER



OBSERVED RAINFALL (mm)
SEPTEMBER 1958



OBSERVED RAINFALL (mm)
SEPTEMBER 1959

Continuous lines represent departure from normal

Fig. 7

and Saugor Island and then a decrease to + 200 mm in Contai and further decrease to + 45 mm in Cuttack. This is suggestive of stimulation by salt nuclei westsouthwestwards of Calcutta up to Midnapore. In September 1959, there is again deficiency of rainfall in north Bengal, but the excess in south Bengal is not as marked as in September 1958. There were fewer depressions in north Bay of Bengal. There was a concentrated area of excess rainfall, round about Asansol in the normal windward direction (Asansol had an excess of +341 mm). But the depressions had their effect in causing, as in September 1958, an excess towards Midnapore (+203 mm) and Saugor Island (+333 mm). Again as in September 1958 there is a significant decrease to + 104 mm at Contai and —84 mm at Cuttack.

(7) *Rainfall in October 1958 and October 1959 (Fig. 8)*

The southwest monsoon had generally withdrawn during the month. Rainfall during the month was mainly of convectional type. In October 1958 the deficiency of rainfall was local in West Bengal but in October 1959, there was marked excess. In October 1958, the rainfall in Calcutta was in deficiency, but an elongated area of

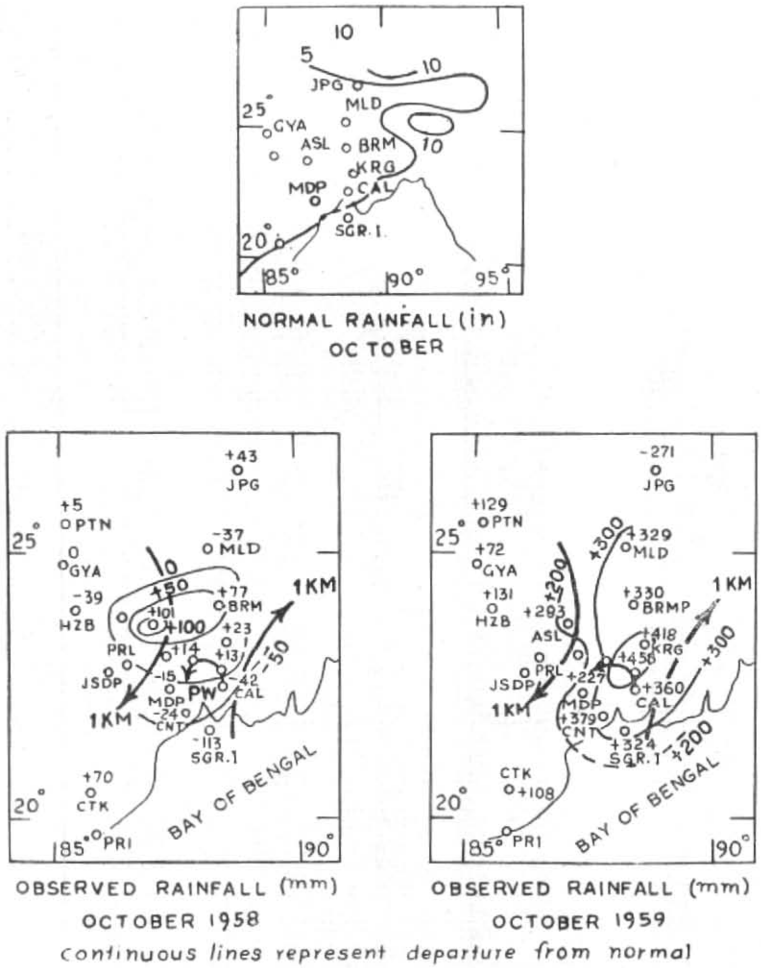


Fig. 8

excess rainfall extended from Asansol to Berhampur and at Asansol rainfall was markedly in excess. Similarly in October 1959, a small area of markedly excess rainfall existed slightly to the north of Calcutta between Barrackpore, Burdwan and Krishnagar. Winds at 1 km are variable in this month, sometimes blowing towards some northerly direction and sometimes towards some southerly direction. These areas of marked excesses have locations where under the wind conditions such as prevailed in the two months, the nucleation might be expected to have extended.

5. Conclusion

In the experiments that were carried out with salt nuclei from April to October in 1958 and were repeated from July to October in 1959, the departure charts of rainfall show a trend of increased rainfall in the direction in which the salt nuclei had travelled. The observed fact that in all the months under investigation, except September 1958 and September 1959, the belt of area adjoining sea coast between Calcutta and Saugor Island, had greater deficiency of rainfall than the area to the north of Calcutta, would seem to suggest that the artificially introduced nuclei (as an addition to natural salt nuclei) had an influence in causing the increased rainfall. In September, special conditions prevailed. The depressions which formed in this month in the north Bay of Bengal, affected the wind system and made the nuclei very often to travel westwards and southwards. Although the cause and the effect has not been firmly correlated, the broad factual indications lend support to the view that the permeation of salt nuclei into the atmosphere tends to increase the total rainfall in a month over the area in which the salt nuclei moved by the prevailing wind system, have been operative by 10 to 15 per cent.

This estimate is based on the assumption that the deficiency of rainfall would in the ordinary circumstances be expected to be very nearly the same within the oval-shaped area as just outside it and that the decrease in the deficiency is mainly the result of permeation of salt nuclei. It may be argued that other factors such as orography may have had some effect in causing the increase, but as the oval-shaped area has taken different positions in the different months over an area with a plane topography, the differential effect of such a factor as orography in regard to the oval-shaped area compared to the area outside it is not obvious. In any case, the analysis is based on the departure from the normal and the 'normal' had taken due account of orography. But depressions which form in the north Bay of Bengal and travel westwards or northwestwards, may cause localised rainfall within their fields of influence, such as they obviously did in September 1958 and September 1959. Even in these cases special features are present to indicate the further augmentaticn of rainfall caused by the permeating salt nuclei.

To illustrate the method of calculation, we can take the month of April 1958. The normal rainfall in the oval-shaped area north of Calcutta is 5 cm. The deficit outside this area is zero and within the oval area, the average excess is +15 mm. Therefore the average increase within the oval-shaped area is 15 mm which is 30 per cent of the normal. Calculated in this way the excess within the oval-shaped areas in the different months are as follows: 1958—April 30 per cent, May 23 per cent, June 20 per cent, July 10 per cent, August 13 per cent, September 40 per cent and October 30 per cent; 1959—July 20 per cent, August 20 per cent, September 16 per cent and October 25 per cent. There was a positive excess in every case, but as these calculations are based on circumstantial evidence, it was considered that the lowest figures, 10 to 15 per cent could be taken as a measure of the increase, even if other factors, beside the salt nuclei, had come into operation to cause the increase.

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