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RAIN SCAVENGING STUDIES - DATA ANALYSIS,
SYNTHESIS, AND INTERPRETATION

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I. INTRODUCTION

The period March 1, 1965 to May 1, 1966 was devoted to research on several problems associated with deposition of atmospheric particulate matter by convective storms. Main areas of inquiry were:

1. Sources of input to convective storms. Can low-altitude inflow account for observed deposition of contaminants?
2. Storm mechanisms responsible for observed variations of contaminant concentration in rain. Can observed concentration-rainfall rate relationships be explained physically? How important is the role of raindrop evaporation?
3. Use of debris from the second Chinese nuclear explosion as a high altitude tracer. What mechanisms are involved in the deposition of high-altitude debris by intense thunderstorms?

There was significant progress in some of these areas. The main effort during the year was reported in Scientific Report No. 1 (Gatz, 1966), which is referred to in this report as "(G)".

Because (G) is limited to analysis of the severe storms which occurred in Oklahoma on May 9 and 10, 1964, several additional items are reported here.

This report presents (Section II) the remaining unreported data collected in 1964, as well as those collected during April and May, 1965, the second season of operation at Chickasha.

Additional work on raindrop evaporation as a concentrating mechanism is reported in Section III.

Section IV describes our data on the Chinese bomb-test fallout of May 1965. Section V summarizes conclusions from the year's efforts, and Section VI reports on the spring, 1966, field data gathering phase.

II. CONTAMINANT CONCENTRATION VARIATIONS WITHIN RAINS

Four additional sets of high-resolution data collected in Oklahoma during 1964 and 1965 are now available for study. One of these sets is our first example of a rain event containing three successive moderate showers. Two of the data sets show how the concentration of contaminant varies in short but moderately intense showers. These three data sets are derived from convective showers, but less intense and less persistent ones than those that occurred in Oklahoma on May 10, 1964. The fourth set shows variations which occurred in a case of light (< 7.5 mm/hr) steady rain.

The procedures for rain collection and analysis were unchanged from those reported in (G) except for the addition of strontium-90 determinations to some samples. A fuming nitric acid precipitation was used for the strontium-90 determinations. Strontium-85 was used as a tracer to evaluate the chemical recovery.

A. RESULTS

1. A Relatively Steady Rain

On the afternoon and evening of May 29, 1964, a light but persistent rain occurred and yielded 249 mm over a period of 4 1/2 hours. The rainfall intensity, sampling and scavenging data are presented in Figure 1. Detailed synoptic data are not given here, but will be collected for a more complete study in a later report. A comparison of the overall average rainfall rate (~ 6 mm/hr) to the mean of the major maxima (~ 7 mm/hr) indicates the uniformity of this rainfall.

In earlier work (Dingle and Gatz, 1966; Gatz, 1966) we have focussed upon the study of primarily convective-type rains. The pattern of scavenging shown by this relatively uniform light rain event indicates a rather long period from the most contaminated to the least contaminated sample, but the sequence of variations still tends to reflect trends such as those observed in showery rain. Because the rainfall rates were consistently low, the time resolution of the contaminant analyses is relatively poor, and details of the concentration curves are therefore lacking. It is worthy of note that the strontium-90 concentrations do not uniformly follow in parallel with the total-beta concentrations. The counting error for Sr-90 is about $\pm 10\%$ at the 95% confidence level, whereas that for total beta is $\pm 5\%$, so where they differ in detail, we prefer to use the latter.

Figure 1. Rainfall intensity, sampling, and scavenging data for the rainfall of the evening hours, May 29, 1964.

Because this event approximated the "steady-state" rainfall model, it may be especially useful for further analytical study.

2. Small, Isolated Showers

Two sets of data were derived from rain events characterized by very brief, widely separated showers of moderate maximum intensity. These occurred respectively (1) during the early morning hours of May 29, 1964, and (2) on the evening of April 24, 1965.

The data for these events are presented in Figures 2 and 3, respectively. Referring to Figure 2, the maximum intensity rain shaft at 0345 achieved nearly 60 mm/hr for a very short time, allowing us to collect 3 samples in 2 minutes, even though the last of these was closed, after the shower had passed, in rain of less than 5 mm/hr intensity. The sharp drop of contaminant concentration that is usually associated with shower maxima is observed here. Although the third of these closely taken samples is partly derived from the heavy rainfall portion, the contribution of post-maximum-intensity rain is evidently sufficient to increase the Sr-90 and beta counts from the minimum concentrations.

The second shower in Figure 2 was preceded by about ten minutes of rain averaging about 6 mm/hr intensity. Here the decreases of contaminant concentration in the samples are spread over an extended period of the order of twenty minutes, and the

Figure 2. Rainfall intensity, sampling, and scavenging data for the early morning showers of May 29, 1964.

minimum occurs just after the heaviest rain (31 mm/hr) with an increase indicated to the end of the rain. Again we choose to read the details from the total beta count rather than the Sr-90 count because of the larger error in the latter.

Figure 3 shows a somewhat similar sequence of total beta and pollen concentrations in relation to the showers of April 24, 1965. The rain shaft of 48 mm/hr maximum intensity passed quickly over the station giving an abrupt drop of contaminant concentrations similar to that observed in the 0345 shower of May 29, 1964. The more gradual reduction of concentrations associated with the second shower (maximum intensity 15 mm/hr) also appears consistent with trends and rainfall intensities observed in the 0455 shower of May 29, 1964 (Figure 2). The pollen counts are considered preliminary at this point. Further counting will be done to improve their accuracy.

3. A Moderate Shower of Three Cells

The weather situation of May 9, 1965 produced a sustained light rain over a period of 3 1/2 hours (Figure 4), in the middle of which moderate showers were recorded. The total rainfall was 13.7 mm, and the maximum intensity attained was 57 mm/hr. In the 20-minute period from 1400 to 1420 CST, three shower cells of nearly equal intensity passed over the station, their duration varying from 5 to 7 minutes.

CONCENTRATION

Figure 3. Rainfall intensity, sampling, and scavenging data for the showers of April 24, 1965.

Figure 4. Rainfall intensity, sampling, and scavenging data for the rain event of May 9, 1965.

The pollen counts given in Figure 4 are again considered to be preliminary. Within the limits of resolution of the data, the total beta concentrations vary with rainfall intensity according to the now familiar pattern. Whereas the trends of beta activity and pollens are nominally parallel, it is clear that the details of these curves are not the same. The differences can be partly ascribed to differences in particle size. The pollens range from 15 to 100 μ in diameter, and although the sizes of the radioactive particles are unknown, it is assumed that they are attached to mixed tropospheric nuclei ranging up to about 3 μ in diameter. We anticipate that further analysis of these differences for certain carefully chosen cases may lead to an improved understanding of the particle attachment mechanisms.

B. DISCUSSION

Of the rain events reported above, one, that of May 9, 1965, is highly similar to the event of May 9, 1964, which is studied in detail in (G). The steady rain case of the evening of May 29, 1964, stands alone and deserves special study in relation to steady state rain models. The other two events are characterized by brief, widely separated, but moderately intense showers (pre-dawn May 29, 1964, and evening April 24, 1965).

At this writing it is not clear how these new data will affect the classification scheme proposed by us (Dingle and Gatz, 1966), on the basis of five events observed in southeastern Michigan. Obviously this scheme will be modified as new data are procured and analyzed, and the principal challenge is to relate the classification scheme appropriately to the physical processes involved. In this case, whereas the second shower on April 24, 1965 (Figure 3) might qualify as a "diffuse" system (Dingle and Gatz, 1966), and the second shower on May 29, 1964 (Figure 2) is evidently at the border between "diffuse" and "well-organized", all the other shower events should probably be classed as "well-organized" systems. At this point it is not clear whether this or a different classification system will be most functional, but we propose to continue and extend our efforts toward the development of a meaningful scheme.

In regard to scavenging effectiveness, it is probably appropriate to point out that four of the events reported by Dingle and Gatz (1966) were probably affected by fresh tropospheric (intermediate fallout) debris from the Russian tests of September, 1961, and the United States tests in the spring of 1962. The Chinese tests have introduced fresh debris in May 1965 and 1966 (see Section III, this report), but this debris has not affected our April-May observations materially to date. Thus, the course

of the scavenging of beta-radioactivity as reported here and in (G) probably gives a more valid picture of the deposition of stratosphere-stored test debris than that of the 1962 data.

In addition to the above considerations, it is appropriate to observe that we have among our data, one storm that fits the "SR" model proposed by Browning (1964). This is the storm of May 10, 1964, which is presented in (G). The scavenging pattern of this storm is quite different from that of our "well-organized" showers, further emphasizing Browning's point that the circulation in an "SR" storm is different from that in less severe convective systems. We have found special interest in the mid-troposphere influx of air to these storms that feeds the strong downdraft, and necessarily involves an intense evaporative effect.

A mechanism to explain the pattern observed in "well-organized" showers was suggested and shown to be feasible in (G). The proposed mechanism consists in the early precipitation of radioactivity-bearing particles, which have been used as condensation nuclei, from a rising air parcel.

Hicks (1966) has shown theoretically that radioactive particles should be effective as condensation nuclei. Furthermore, the size spectrum of radioactive particles in ground-level air has been found nearly identical to that of non-radioactive particles. One infers from this and consideration of atmospheric mixing processes that the original radioactive particles are attached to the tropospheric aerosol spectrum. The tropospheric particles

are largely mixed nuclei; that is, they have soluble component particles, and the association of these with inert material gives them large size, the combined effects of size and hygroscopicity being to make them efficient as condensation nuclei.

The pattern of change of the concentration of contaminant in relation to rainfall rate which we have described has also been observed by others. In some cases, however, other investigators have worked with different radioactive species. Direct comparison of results using different species is not generally convincing because of differences in calibration and counting errors.

That the main features of the total beta concentration profiles approximate some other bomb debris radionuclides has already been mentioned. For the first time in our program we have made strontium-90 determinations for the purpose of cross-calibrating with the University of Oklahoma group (AEC Contract No. AT(40-1)-3083). Simultaneous determinations of strontium-90 and total beta radioactivity were made for most samples taken on May 28 and 29, 1964. The concentration curves are very similar; (Figures 1 and 2). Because the errors of measurement are smaller for the total beta radioactivity counts than for strontium-90, it is our view that our detailed evaluations can best be based upon total beta counts.

III. THE ROLE OF RAINDROP EVAPORATION IN CONCENTRATION FLUCTUATIONS - A QUANTITATIVE EVALUATION.

As raindrops fall through unsaturated sub-cloud air, each drop loses some water through evaporation. Thus, the trace constituents present in the water at cloud level are concentrated during the fall to the ground. Some investigators (Bleichrodt, et al., 1959; Salter, et al., 1962) have attributed observed temporal variations in concentration to variations in the fraction of total water which is lost by evaporation.

Best (1952) and Abraham (1962) have computed the amount of water lost by evaporation from individual falling drops. Several drop sizes and several sets of environmental conditions were studied. Natural rain, however, consists of a spectrum of drop sizes, and evaporation should be computed for the entire spectrum. This is a lengthy and tedious computation if done manually. Fortunately, a computer program written and used by Hardy (1963) is available.

Hardy's program was used in (G) to estimate the effect of raindrop evaporation on concentration variations in a real situation. The program was used to compute enhancement of concentration by evaporation for a series of 1-minute periods in the light rain at the beginning of the rain of May 9, 1964.

Such use of the program requires data on the temporal variations of ceiling height and of temperature and humidity profiles. Because of data limitations in the May 9, 1964, case, it was possible to conclude only that evaporation processes could have contributed significantly to the observed variations.

In view of the difficulty of providing adequate data in individual cases, a computational study was undertaken. The results of this study show what changes in environmental conditions are necessary to produce certain specified changes in concentration.

This chapter describes computations of water loss over the complete drop-size spectrum for a large number of different combinations of drop size, fall distance, and temperature and humidity profiles. Actual cases can then be evaluated individually to see how effective sub-cloud evaporation is.

A. THE COMPUTATION

The quantity computed is the factor by which concentration increases owing to evaporation of the falling drop. This is the concentration factor, K , which is defined as

$$K = \frac{L_c}{L_g}$$

where L_c and L_g are liquid water concentrations (g/m^3) at the cloud base and ground, respectively. This analysis neglects any

loss of contaminant from the rain water sample which occurs if drops evaporate completely before reaching the ground. L_c is computed from the drop-size distribution (assumed) at the cloud base. L_g is computed from the distribution at the ground which results from the combined effects of evaporation and coalescence during fall.

Evaporation was computed using the equations of Kinzer and Gunn (1951). Details of the computation have been given by Hardy (1963).

In the present experimental study, the raindrop-size distributions at cloud base are assumed to be exponential (Marshall and Palmer, 1948). They are described by the equation:

$$N_D = N_0 \exp(-\lambda D)$$

where D is drop diameter, $N_D dD$ is the number of drops between D and $D + dD$ in unit volume of air, N_0 is the value of N_D at $D = 0$ and is found to be $8000 \text{ m}^{-3} \text{ mm}^{-1}$, and

$$\lambda = 41 R^{-0.21} \text{ cm}^{-1}$$

where R is rainfall rate in mm/hr. The largest drop diameter D_L is a function of R and is chosen so that the rainfall rate computed from a spectrum is consistent with the R used in computing the spectrum. The variation of D_L with R is shown in Figure 5.

Figure 5. The variation of the largest drop diameter, D_L , as a function of the rainfall intensity, R . D_L is chosen here so that the rainfall intensity, R_c computed using a Marshall-Palmer drop-size distribution is equal to R .

The temperature profile used in the computations is that of the U.S. Standard Atmosphere (1962). All heights are referred to mean sea level (MSL).

Computations were made for rainfall rates between 1 and 10 mm/hr, relative humidities between 40 and 90% (constant with height), and ceiling heights up to 3 km.

B. RESULTS

Results of the computation at 40% and 90% relative humidity are presented in Figure 6. These values illustrate the results for reasonable limits of relative humidity. The value of 40% represents an atmosphere drier than one expects under rainy conditions. The value of 90% represents a high humidity, but one at which some evaporation still occurs.

C. DISCUSSION

Figure 6 shows that the computed relationships between K and the independent variables are those which should be expected qualitatively. Namely, K varies inversely with rainfall rate and relative humidity, and directly with ceiling height.

More important, the results bear on the question of whether observed concentration variations can be caused exclusively by variation in raindrop evaporation.

In broad terms, we must consider two types of variations. A very rapid variation occurs in shower situations, (see above, Fig. 2 and 3) and a slower variation is associated with light

Figure 6. Values of K , the concentration factor, in relation to humidity, ceiling height, and rainfall rate.

steady rain (Fig. 1, 3, and 4). In showers, the concentration may change by a factor of 3 or more within 10 min. or less as the rainfall rate increases from less than 2 to more than 50 mm/hr. During the same time, changes of temperature and humidity (at all levels) and of ceiling height should be in such a direction as to reduce evaporation. However, short period changes in temperature and humidity profiles are difficult to measure. Before the 1966 season a ceiling measuring system was not available locally. Therefore, we have been forced to consider a limiting condition.

We require the smallest concentration enhancement (in the light rain) from the evaporation mechanism if we assume that the minimum observed concentration (in the heavy rain) is identical to the concentration in the cloud (i.e., no evaporation in heavy rain). If the minimum concentration is partly the result of evaporation, then a greater degree of evaporation of the cloud water is required to produce the concentration observed in the light rain at the beginning.

On the assumption that no evaporation occurs in the heavy rain, can evaporation in the light rain account for the observed differences 3-fold or more in contaminant concentrations?

Figure 6 shows that under the conditions of Hardy's model (steady-state rain) concentration enhancements of greater than 5-fold can result entirely by evaporation only in the case of a ceiling higher than 3 km, a rainfall rate less than 1 mm/hr,

and a relative humidity less than 40%. Such a combination could possibly occur at the beginning of a rain, but it is unlikely that such a high ceiling or low humidity will occur soon after some heavy rain has fallen. Consequently, concentration increases before second or succeeding showers are difficult to explain by evaporation.

The highest concentration in multiple showers ordinarily occurs in the light rain before the first shower. A large evaporative influence is likely in this case, especially if there is a considerable period of rain at rates less than 1 mm/hr.

In the slower variations of steady rain, concentration changes of 10-fold or more are observed to occur within 2 hours, as environmental conditions also change slowly. Figure 1 is an example of a slow concentration variation in steady rain. Large concentration enhancements are again possible if considerable rain falls at less than 1 mm/hr.

Evaporation can be a significant factor in both types of variations, but data (including raindrop-size spectra) from actual cases are needed to evaluate the effect.

IV. RAIN SAMPLING FOR FALLOUT FROM THE SECOND CHINESE NUCLEAR TEST - MAY, 1965

Fallout cases such as those of List, et.al. (1964) suggest that penetration of high-altitude debris layers by thunderstorms

can result in locally large surface deposition. This is an apparent contradiction to the result (G) that most thunderstorms deposit activity which enters the storm primarily from low levels. Dingle (1965) and others have suggested possible mechanisms to explain such cases, but these suggestions remain untested for lack of appropriate data.

The Chinese nuclear explosion of May 14, 1965, offered a possible source of high-altitude tracer. Because the leading edge of a fresh high-altitude debris plume presents a stepwise change, precipitation collected near that leading edge may provide special insights into the scavenging process.

As the upper troposphere debris cloud approached North America, our information indicated that its trajectory would carry it mostly over Canada. By special arrangements with Dr. P.M. Bird, Chief, Radiation Protection Division, Department of National Health and Welfare, Canada, we were able to obtain rain samples collected at several sites in Canada. Samples were obtained from Vancouver, British Columbia; Edmonton, Alberta; Saskatoon, Saskatchewan; Winnipeg, Manitoba; Ottawa, Ontario; and Truro, Nova Scotia.

The samples were evaporated to dryness in the usual manner (G) and counted for total beta radioactivity. A second count was made 10 days later to date the debris.

The average age of the debris at collection time was computed from the relationship $AT^{1.2} = \text{constant}$, where A is radioactivity

at time T after detonation. Results of the age determinations are listed in Table 1 and plotted with the concentrations in Figure 7. The samples were also analyzed with the gamma spectrometer, and determinations of $Ce^{144} + Pr^{144}$, Sb^{125} , Cs^{137} , and $Zr^{95} + Nb^{95}$ concentrations were made. These results are also given in Table 1.

Beta concentrations and rainfall rates appear in Figure 7 for Vancouver, Edmonton, Saskatoon, and Winnipeg. These stations are the only ones for which more than two samples were analyzed.

The position of these stations relative to the path of the upper tropospheric debris is shown in Figure 8. The debris trajectory was prepared by the Atmospheric Radioactivity Research Branch, U.S. Weather Bureau (see Krey and Rosa, 1965). According to the trajectory analysis of this group, the high-altitude debris passed over the U.S. and southern Canada on May 18-19, 1965.

Figure 7 shows that samples were collected at Vancouver and Edmonton on those days. The first sample at Vancouver shows an average age of 40 days; this would seem to indicate the presence of some fresh debris. No Zr^{95} was detected, however. Both Edmonton samples were old (> 100 days); furthermore, the approximate cloud path shown in Figure 8 indicates that the cloud did not pass over Edmonton.

Fresh fission products were detected in air at Helena, Montana (U.S. Public Health Service, Radiation Surveillance

TABLE 1

RADIOACTIVITY IN RAIN SAMPLES COLLECTED IN CANADA DURING MAY, 1965

Sample Code ¹	Time, May, 1965 (CST)		Radioactivity		Concentration (pc/l) ^{2, 3}			Average Age at Collection (days)
	Start	End	Ce ¹⁴⁴ Pr ¹⁴⁴	Sb ¹²⁵	Cs ¹³⁷	Zr ⁹⁵ Nb ⁹⁵	Beta	
V1	1100/19	1500/19	0.15	0.012	0.042	-	0.412	40
V2	1700/19	0900/20	0.11	0.006	0.025	0.165	0.211	>100
V3	2100/21	2300/21	-	0.019	0.033	-	0.198	>100
V4	1100/29	1600/30	0.072	0.008	0.014	-	0.098	>100
S1	1200/23	1500/24	0.14	0.010	0.012	0.17	0.264	>100
S2	2330/24	0745/25	-	-	0.033	0.40	0.598	43
S3	0844/25	1945/25	0.94	-	0.18	0.92	1.54	>100
S4	1300/28	1400/28	0.18	0.016	0.018	-	0.275	>100
S5	2030/30	0930/31	0.13	0.011	0.013	0.11	0.280	60
E1	1830/18	2053/18	0.20	0.012	0.037	-	0.182	>100
E2	1200/19	1200/20	0.24	0.020	0.065	-	0.251	>100
E3	1147/23	1335/23	0.18	0.006	0.028	0.29	0.236	>100
E4	1335/23	1350/23	0.050	-	0.014	0.13	0.221	94
E5	1350/23	2130/23	0.043	0.006	0.012	0.011	0.077	>100
E6	2130/23	0545/24	0.017	-	0.006	0.022	0.053	>100
E7	0545/24	1145/24	-	-	0.004	0.001	0.039	37
E8	1145/24	1410/24	-	-	-	0.024	0.057	32
E9	1410/24	1550/24	-	-	0.008	-	0.054	97
E10	1550/24	2250/24	0.043	-	0.008	0.050	0.078	>100
E11	2250/24	0245/25	0.041	-	0.005	0.048	0.111	71
W1	2000/20	2200/20	0.67	0.015	0.050	1.24	1.88	3
W2	2200/20	0800/21	0.075	-	-	-	0.295	>100
W3	0000/24	0600/24	0.13	0.005	0.015	0.18	0.381	24
W4	0630/24	1515/24	0.202	0.016	0.051	0.19	0.381	>100
W5	1515/24	0815/25	0.071	-	0.024	0.065	0.343	>100
W6	0815/25	1506/25	0.18	0.011	0.021	0.094	0.358	>100
W7	0745/26	1530/26	0.101	0.004	0.014	0.15	0.353	33
W8	1730/26	2000/27	0.135	0.009	0.021	0.055	0.237	>100
O1	/19	/19	0.066	0.010	0.017	-	0.146	70
O2	/27	/27	0.301	0.010	0.029	0.060	0.376	>100
T1	2200/20	0100/21	0.153	0.020	0.017	0.031	0.269	>100

1. Code letter indicates city: V = Vancouver; S = Saskatoon; E = Edmonton; W = Winnipeg; O = Ottawa; T = Truro.

2. Decay-corrected to collection time.

3. 95% confidence limits on beta concentrations: $\pm$ 3% on individual radio-nuclides; $\pm$ 1 - 100%.

Figure 7. Beta concentrations and rainfall rates for Vancouver, Edmonton, Saskatoon and Winnipeg during the period when the debris cloud from the second Chinese nuclear test explosion moved across North America in the 30,000-40,000 ft. layer. Numbers indicate average age in days of the scavenged radioactive materials.

Figure 8. Rain sample collection stations and path of upper tropospheric debris cloud as projected by trajectory analysis applied to the 30,000-40,000 ft. layer (After Krey and Rosa, 1965).

Network station) in the May 18-19 sample, and at most other RSN stations in the western U.S. in the May 19-20 sample (U.S. Public Health Service, 1965). Fresh fallout was detected in rain that fell at Fort Collins, Colorado, (Johnson, et. al. 1966) on May 23-25, although it was not observed there in ground-level air until May 28. Fresh fallout was detected in Seattle and New York City ground-level air on May 22-23. (Krey and Rosa, 1965).

Obviously these data are extremely sketchy. The indication of fresh debris in the rain of the 19th at Vancouver is clear, and tells us that, by some mechanism which we cannot evaluate without fairly comprehensive study of that rain-producing situation, some fresh debris was scavenged by the rain. The debris plume, however, reached Vancouver on the 18th and by the 19th had moved on some hundreds of miles to the east. This does support the idea that downward mixing from the 30,000-40,000 ft. layer into lower, slower-moving air had occurred prior to the scavenging rainfall of the 19th.

According to the trajectories, the edge of the plume passed over Saskatoon and Winnipeg on the 19th and missed Edmonton. The shower at Edmonton on the 19th contained no fresh debris as nearly as we can tell, but on the 24th rain collected at Winnipeg and Edmonton contained some of the fresh debris. That collected at Saskatoon on the 24th contained none, but here, on the 25th some fresh debris turned up.

In each case, the rain scavenging of the fresh debris is delayed at least one day, and in some cases up to 5 or 6 days from the date that the high level debris plume is believed to have passed the station. Obviously our evaluation depends upon the coincidence of rain and the leading edge of the high level plume, and no such coincidence is present in these data.

The third Chinese test of May, 1966, may provide additional useful clues.

V. CONCLUSIONS

The year's work, as described both in (G) and in this report, yielded several important conclusions on problems of rain scavenging of aerosols by convective storms. The conclusions are listed below.

1. Low-altitude (below 650 mb) inflow to the convective storm of May 10, 1964, provided sufficient fallout radioactivity to account for observed deposition.
2. A newly-proposed physical mechanism can explain observed concentration--rainfall rate relationships. The process involves the deposition of large amounts of contaminant in the first rain to fall at a point from a moving shower and the subsequent depletion of contaminants in the heavy rain.
3. It is possible that the raindrop evaporation process contributes to concentration fluctuations, and especially to the high concentrations in the light rain at the start of a shower.

4. Concentration variations in "SR" storm cells appear to be significantly different from those in less severe convective systems in that only small decreases occur with the onset of heavy rain from the one "SR" storm observed to date. This observation is consistent with the suggestion that "SR" storms contain continuous deep downdrafts in which evaporation from drops may greatly concentrate contaminants in the heavy rain. This effect tends to eliminate those differences in concentration between light and heavy rain which result from the first precipitation mechanism (conclusion 2).

VI. FIELD PHASE, 1966.

The field data collection period for Spring, 1966, was agreed upon by our group in conference with NSSL, Norman, Oklahoma, and other groups. Accordingly our station has been manned and operated during April and May. Special features of this year's operation pertain both to our activities and those of others associated in the cooperative program.

A. Our Operation.

1. In addition to our previously established level of activity we have undertaken to collect samples from the ten distributed stations formerly operated by the University of Oklahoma group.
2. We have arranged with Dr. Dieter Ehhalt of NCAR to analyze our rain samples for deuterium (D), tritium (T), and oxygen-18. For this purpose we are collecting special small samples at our principal station.

3. We have improvised a ceilometer from which we hope to obtain information about ceiling heights for use in our evaporation computations.
4. We attempted to launch some pin-pointed artificial tracer studies using silver iodide, but to this date (24 May) we have been unable to procure the needed materials.

B. Operations of Others.

1. Dr. Roger Lhermitte of NSSL has succeeded in establishing his doppler radar station within a mile of our station. We anticipate a fruitful coordination of his effort with ours particularly as it pertains to the evolution of drop sizes. His measurements of drop-size spectra near the melting level will be related to ours near the ground through the coalescence and accretion processes of growth, and through drop breakup and evaporation.
2. Dr. John Hallett of the Imperial College of London and Dr. Keith Browning of the Air Force Cambridge Research Laboratories have joined the effort this year especially to study hail. Their work and ours are likely to be importantly related if the right weather situations develop.

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