ILLINOIS STATE WATER SURVEY
METEOROLOGIC LABORATORY
at the
University of Illinois
Urbana, Illinois

INVESTIGATION OF THE QUANTITATIVE DETERMINATION OF POINT AND AREAL PRECIPITATION BY RADAR ECHO MEASUREMENTS

FIRST QUARTERLY TECHNICAL REPORT

1 October 1961 - 31 December 1961

Sponsored by
U. S. ARMY SIGNAL RESEARCH and DEVELOPMENT LABORATORY
Fort Monmouth, New Jersey

CONTRACT NO. DA-36-039 SC-87280
DA Task 3A99-07-001-01

DMA Jones

AD______________________Accession No.______
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Signal Corps Contracts DA-36-039 SC-87280

DA Task 3A99-07-001-01

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Signal Research and Development Laboratory
Fort Monmouth, New Jersey

To record and analyze data on raindrop-size distribution in various parts of the world. These data will be correlated with appropriate radar parameters in order to improve the capability of radar in measuring surface rainfall intensities for Army applications such as radioactive rainout prediction, trafficability, and communications.

Prepared by

R. M. Johnson
Meteorologist

E. A. Mueller
Project Engineer

G. E. Stout
Project Director

William C. Ackermann, Chief
Illinois State Water Survey

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PURPOSE

The object of this research is to study the utility of radar equipment in measuring surface precipitation and to improve radar techniques in measuring precipitation for application by the Army to radioactive rainout prediction, trafficabllity, and communications. Considerable effort is being directed toward determining the correlation between radar variables and actual rainfall quantities by means of raindrop-size distribution.

ABSTRACT

The raindrop camera, previously installed at Mt. Withington, New Mexico, was installed at the Meteorology Laboratory in Illinois for the routine collection of data during the winter months. Data collection at the New Jersey and North Carolina sites is proceeding at a normal rate. Measurement of raindrop data from Indonesia and New Mexico has been completed and drop camera film from North Carolina is now being measured. Preliminary results of the analysis of the Majuro data are compared with the Miami data and show that Majuro rainshowers differ significantly from those at Miami, while continuous rains are the same. Due to the great abundance of low rainfall rates existing in the Oregon data, it was found necessary to re-examine the Z-R regression analysis. The rounding of Z values to the nearest 100 adversely effected the intercept and slope of the resultant regression line and also produced variances in excess of those expected. Computations of the regression

lines using calculated rainfall rates to the nearest 0.1 millimeter and calculated reflectivity values to the nearest 10 mm^6m^{-3} are being done to minimize this error for Oregon. A comparison between drop size distributions obtained by a Doppler radar and the drop camera are presented.

PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES

Messrs. G. E. Stout, E. A. Mueller, R. M. Johnson, and M. Fujiwara attended the Ninth Weather Radar Conference held at Kansas City, Missouri from 23-26 October 1961. The following papers were presented at the conference: "Attractive Forces Between Charged Drops and Their Effect on the Coalescence Process" by M. Fujiwara and E. A. Mueller; "Uncertainty in Rainfall Measurements Due to Drop Size Distributions" by E. A. Mueller; and "Effects of Stability on Drop Size Distributions" by R. M. Johnson.

RAINDROP CAMERAS

Island Beach, New Jersey

Fourteen rolls of 70-mm raindrop data were received from Island Beach during the quarter. Transmissometer data was also received at regular intervals. Both the raindrop camera and the transmissometer are operating in a satisfactory manner with only routine maintenance being required. Measurement of the New Jersey data has not as yet been started.

Franklin, North Carolina

During the period, fourteen rolls of film were also received from the North Carolina location. As yet, no trouble has been experienced with the gasoline driven generator, such as those that hampered operations the previous winter. Measurement of the North Carolina data commenced in the early part of November.

Champaign, Illinois

The raindrop camera used in the collection of data at the Mt. Withlngton site the past summer was reassembled at the Meteorology Laboratory during the first part of October. During periods of moderate to heavy rainfall the streak camera is being run simultaneously for evaluation purposes. Since data collection began on October 13, 12 rolls of 70-mm raindrop camera film and 4 rolls of 35-mm streak camera film have been exposed. The majority of the storms occurred with low rainfall rates. None of the Illinois film has been measured.

In summary, 40 rolls of 70-mm raindrop film and 4 rolls of streak camera film were exposed during the quarter and a total of 19 rolls were measured — 2 from New Mexico, 1 from Indonesia and 16 from North Carolina.

DATA ANALYSIS

Majuro, Marshall Islands

The majority of the analysis of the Majuro data has been completed. The data was grouped first into rain types and then into synoptic types. Z-R regression equations were calculated for each rain type and synoptic type. Comparison of Z-R relationships observed at Majuro and Miami for two rain types are shown in Figures 1 and 4. Thunder showers are not illustrated because of the small sample size (5 minutes) observed at Majuro.

As can be seen from Figure 1, the Z-R relationship for Majuro rainshowers differs considerably from the relationships found for Miami. Although the slope of the Miami and Majuro lines are almost identical, the intercepts are quite different. For a given rainfall rate the Z values for Miami are consistently larger than those for Majuro. This difference can possibly be explained by the difference in geographic location. Majuro is located in the maximum shower precipitation belt of the Pacific Ocean, sufficiently far downstream in the Trade Winds, such that few thunderstorms occur. The fact that thunderstorms are scarce would tend to indicate that insufficient instability exists for showers to grow to thunderstorm proportions. In addition, the coalescence process would not be as effective due to smaller vertical motions. A comparison of the average raindrop size distributions for the two stations would appear to confirm this conclusion.

Two typical average distributions for rainshowers are shown in Figures 2 and 3. It can be seen that for similar rainfall rates, the distributions from Majuro have a greater number of total drops but fewer large drops and have the mode of the distributions shifted to the left. It may not be noted from Figure 2, for a rainfall rate of approximately 2 millimeters per hour, the

Majuro distribution with a mode at 1.0 millimeter contains over three times as many drops as the Miami distribution with a mode at 1.3 millimeters. In Figure 3 for a rainfall rate of approximately 82 millimeters per hour, the Majuro distribution with the mode again at 1.0 millimeter has twice as many drops as the Miami distribution with a mode at 1.9 millimeters.

Figure 4 which compares Z-R relationships for continuous rains does not show such a striking difference. The observer at Majuro indicated that most of the continuous rains occurred with alto-stratus clouds so that knowledge of conditions higher were unknown. The observation of similarity of continuous rains leads one to suspect that in both cases the same process was active, namely the Bergeron process, and the efficiency of generation were nearly the same. For rainfall rates less than approximately 2© millimeters per hour the Z values for Miami are slightly greater than those found at Majuro. For rates greater than this, the Z values for Majuro become slightly larger than those for Miami. Figures 5 and 6 are average distributions for continuous rains for both stations. For a rainfall rate of approximately 1 millimeter per hour, Figure 5 shows a greater number of total drops for Majuro but a lesser number of large drops. Figure 6, representing a rainfall rate of approximately 32 millimeters per hour, also shows a large number of total drops for Majuro, but unlike the previous examples, the distribution for Majuro also shows a slightly larger number of drops larger than 2.0 millimeters than does Miami. Since the reflectivity values are dependent upon the sum of the sixth power of the drop diameters, these results are consistent with the crossover of the reflectivity values in Figure 4. Figures 2, 3, and 5 consistently show a greater number of larger drops (greater than 2.0 millimeters) for the Miami distributions.

Table 1 is a summary of the regression analyses for the rain types and synoptic types for Majuro. It is interesting to note that the regression equation for the easterly wave is identical to the one found for the intertropical convergence zone.

TABLE 1

STATISTICS OF MAJURO DROP SIZE DATA

Rain Type	Number of Samples	Regressions	Correlation	% Standard Error of Estimates of Z
RW	1491	$Z=146R^{1.42}$	.97	9.98
R	952	$Z=226R^{1.46}$	.92	16.25
Synoptie Type				
Tropical Depression or Trough	51	$Z=120R^{1.38}$	.93	16.53
Easterly Wave	1126	$Z=196R^{1.38}$	.95	11.99
Intertropical Convergence Zone	1136	$Z=196R^{1.38}$	.95	15.00
Trade Wind Showers	239	$Z=126R^{1.47}$	.98	8.48

In order to compare stability values with those of Miami and also to classify the samples according to the PASI (Positive Area Stability Index), radiosonde cards for Majuro are on order from National Weather Records Center. Results of this analysis should aid in determining the relative importance of the coalescence process for these two stations.

Corvallis, Oregon

Z-R regression equations were also computed for the Oregon data but because of the abundance of low rainfall rates the results became unrealistic. These results occurred from rounding of rainfall rates to the nearest millimeter per hour and radar reflectivity values to the nearest 100 mm^6m^{-3}. In areas of relatively high rainfall rates such as Miami and Majuro this technique has little effect upon the equation of least squares. However, when the majority of the Z-R values are small and rounded a? previously stated, the slope and intercept of the resultant equation are greatly effected by the rounding. Figure 7 illustrates this effect. Figure 8, on the other hand, is the resultant Z-R regression equation using the same data where R is only rounded to* the nearest one-tenth of a millimeter and Z to the nearest 10 mm^6m^{-3}. The straight line fit is obviously much better in the latter case. In addition, the correlation coefficient increased from .75 to .94 when the rounding is reduced to 0.1 mm/hr. The remainder of the Oregon data is being reprocessed using this technique in an effort to calculate more realistic regression equations.

Mt. Withington, New Mexico

Analysis of the drop size distributions from Mt. Withington have continued. The changes of drop size distributions as time progresses appear to be the most interesting feature of this data. Particularly, since the amount of data does not permit statistically valid results for Z-R analysis.

During the period a communication with Mr. Rodney Rogers of Cornell Aeronautical Laboratory contained a graph of drop size distributions inferred from Doppler radar measurements made on the mountain. Since the radar was not calibrated for total power return, only relative distributions were inferable. However, the comparisons between the distributions from the drop camera and the radar are quite favorable. This is particularly true when it is realized that the radar sampled about 10^5 cubic meters at about 0.8 kilometer above the drop camera. The relative distribution from the radar showed a mode at 1.2 mm and the average camera distribution showed a mode at 1.3 mm. The radar showed 0.20 of the mode value at 0.6 mm and the camera showed about 0.15 of the mode value at 0.6 mm. The correspondence is poorer for the large drops where the drop camera values were much higher than the radar values. At 2.5 mm the camera distribution was about 8 times as large as the radar. Since, in general, one would expect better agreement between the two methods of large drops, a better normalization might have been made which would set the number of large drops equal. This has not been attempted since only one set of concurrent data were obtained. In the future investigations of drop-size distributions with simultaneous recordings of Doppler frequency spectra would be very valuable in deducing variations of drop-size distributions with height.

SUMMARY AND CONCLUSIONS

Raindrop data collection and processing is proceeding at a normal rate. Only routine maintenance was required at the three camera sites during the last quarter.

Analyses of the Majuro data shows that, in general, drop size distributions from the Marshall Islands contain a much larger number of total drops per unit volume but a fewer number of large drops than the Miami distributions. The only exception noted was the higher rainfall rates in continuous rains in which case the number of large drops in the Majuro distributions were slightly larger than in the Miami distributions. Prom the resultant Z-R relationships, the reflectivity values for Majuro were consistently less than those for Miami in the case of rain showers. The same was true for rainfall rates less than 20 millimeters per hour. At higher rates, Z values for Majuro were slightly higher than those for Miami.

Oregon data is being reanalyzed in an effort to eliminate the unrealistic regression equations obtained.

PROGRAM FOR NEXT INTERVAL

Operations of raindrop cameras at the present locations will continue during the winter months. It appears that by next spring enough data will have been collected at Island Beach, New Jersey and Franklin, North Carolina, to allow the disassembly of the cameras and to have them relocated for summer data collection. The transmissometer at Island Beach will be available for relocation.

Analysis will continue on the Majuro data with the acquisition of the radiosonde cards for this station. Regression equations will be computed for the different stability classifications. Oregon Z-R relationships will be recalculated for rain type, synoptic type, and stability classifications. Upon completion, work will commence on the analyses of the Alaskan distributions.

PERSONNEL

All key personnel engaged in this research were active under previous Signal Corps contract DA-36-039 SC-75055. A brief sketch of the qualifications and background of each follows;

Glenn E. Stout has been Project Director on the above contract. He received a B.S. Degree from Findlay College, Findlay, Ohio in 1942 and then took special training in meteorolory at the University of Chicago. He has been engaged in meteorology as an instructor for 2 and 1/2 years, served as an Aerological Officer in the Navy for 2 and 1/2 years and employed by the

Illinois State Water Survey as a Research Meteorologist for 13 years.

Eugene A. Mueller was awarded a B.S. and M.S. Degree in electrical engineering from the University of Illinois in 1951 and 1952 respectively. Since 1952 he has been employed by the Illinois State Water Survey in radar weather research.

Robert M. Johnson was awarded a B.S. Degree in chemistry from Ohio State University in 1951 and a B.S. Degree in meteorology from the U.S. Navy Postgraduate School in 1957. He served in the U.S. Navy from 1951 to 1960 including 2 and 1/2 years as a Weather Service Officer. He has been employed by the Illinois State Water Survey since December, 1960, as a meteorologist.

The following personnel were engaged during the first quarter:

Name and Title	Starting Date	Hours Worked	Terminated
G. E. Stout Project Director	10/1/61	126	
Eugene A. Mueller Electronic Engineer	10/1/61	510	
Miyuki Fujiwara Research Assistant	10/1/61	510	
Robert M. Johnson Meteorologist	10/1/61	510	
Edna M. Anderson Meteorological Aide I	10/1/61	510	
Dorothy A. Gurney Meteorological Aide I	10/1/61	510	
Charles P. Medrow Electronics Technician I	10/1/61	510	

Name and Title	Starting Date	Hours Worked	Terminated
Don H. Summers Electronics Technician II	11/1/61	340	
Ronald K. Tibbetts Statistical Clerk	10/1/61	504	12/30/61
Vernon D. Ashmore Laboratory Assistant	10/1/61	98	
Nazir A. Ansari Statistical Clerk	10/1/61	256	
John M. Bobicz Statistical Clerk	10/1/61	190	
David S. Boge Statistical Clerk	10/1/61	214	
Ruth V. Eadie Meteorological Aide I	11/13/61	120	
Victor E. Schulze Student Assistant	10/1/61	253	

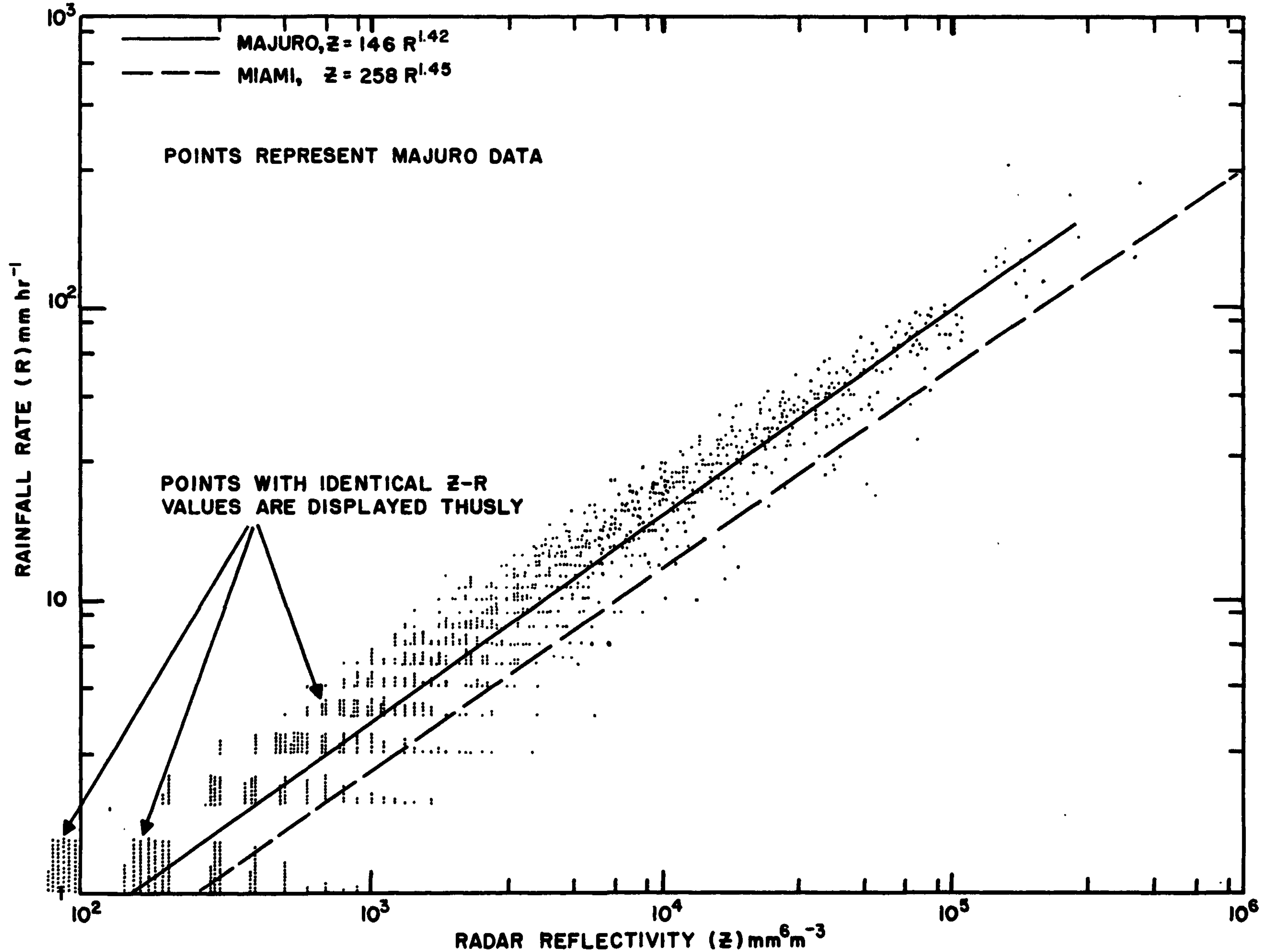

FIG. 1 Z-R RELATIONSHIPS IN RAINSHOWERS AT MAJURO

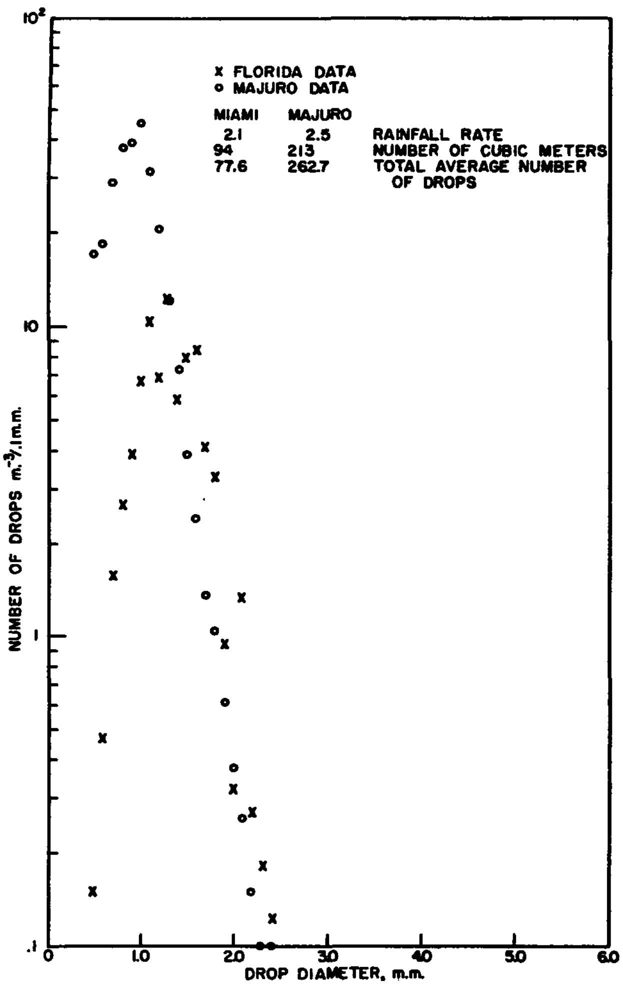

FIG. 2 RAINSHOWER

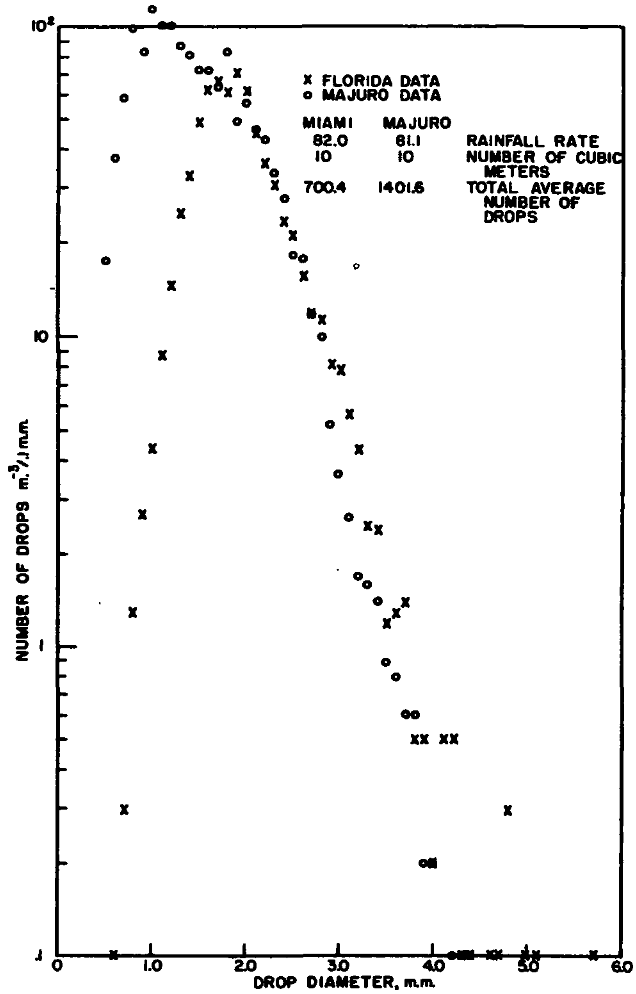

FIG. 3 RAINSHOWER

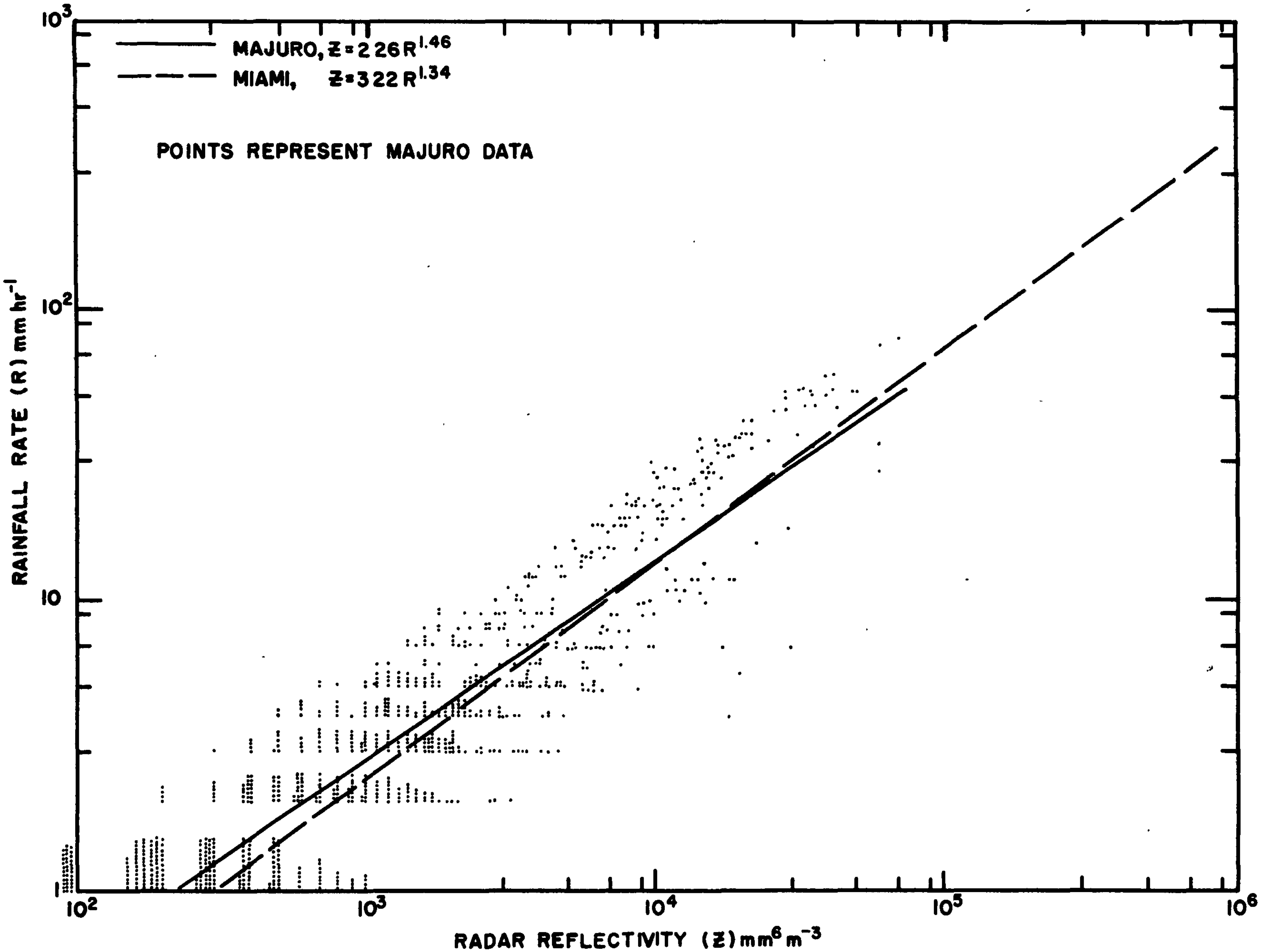

FIG.4 Z-R RELATIONSHIPS IN CONTINUOUS RAINS AT MAJURO

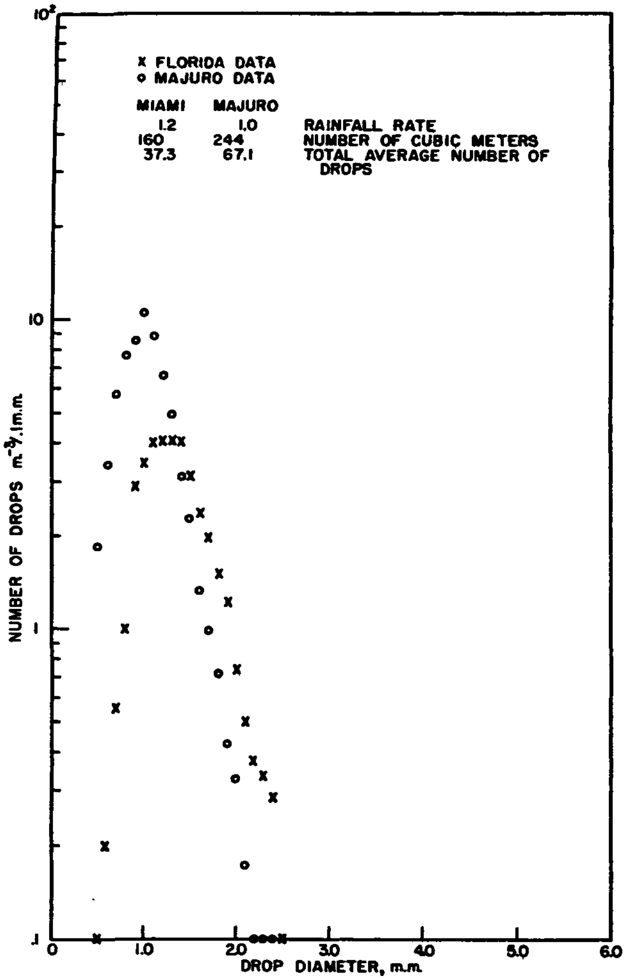

FIG. 5 CONTINUOUS RAIN

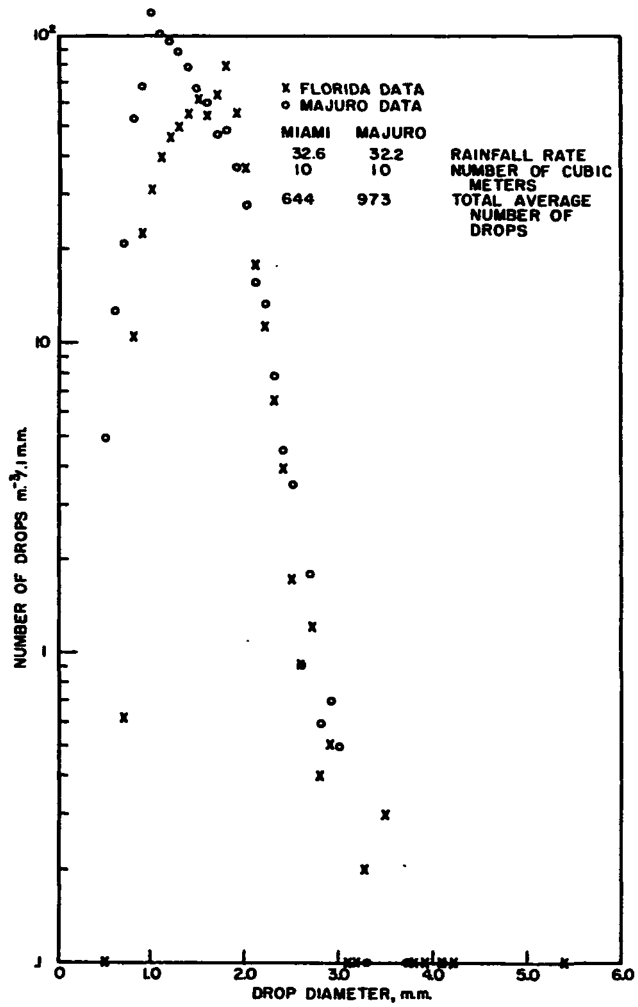

FIG.6 CONTINUOUS RAIN

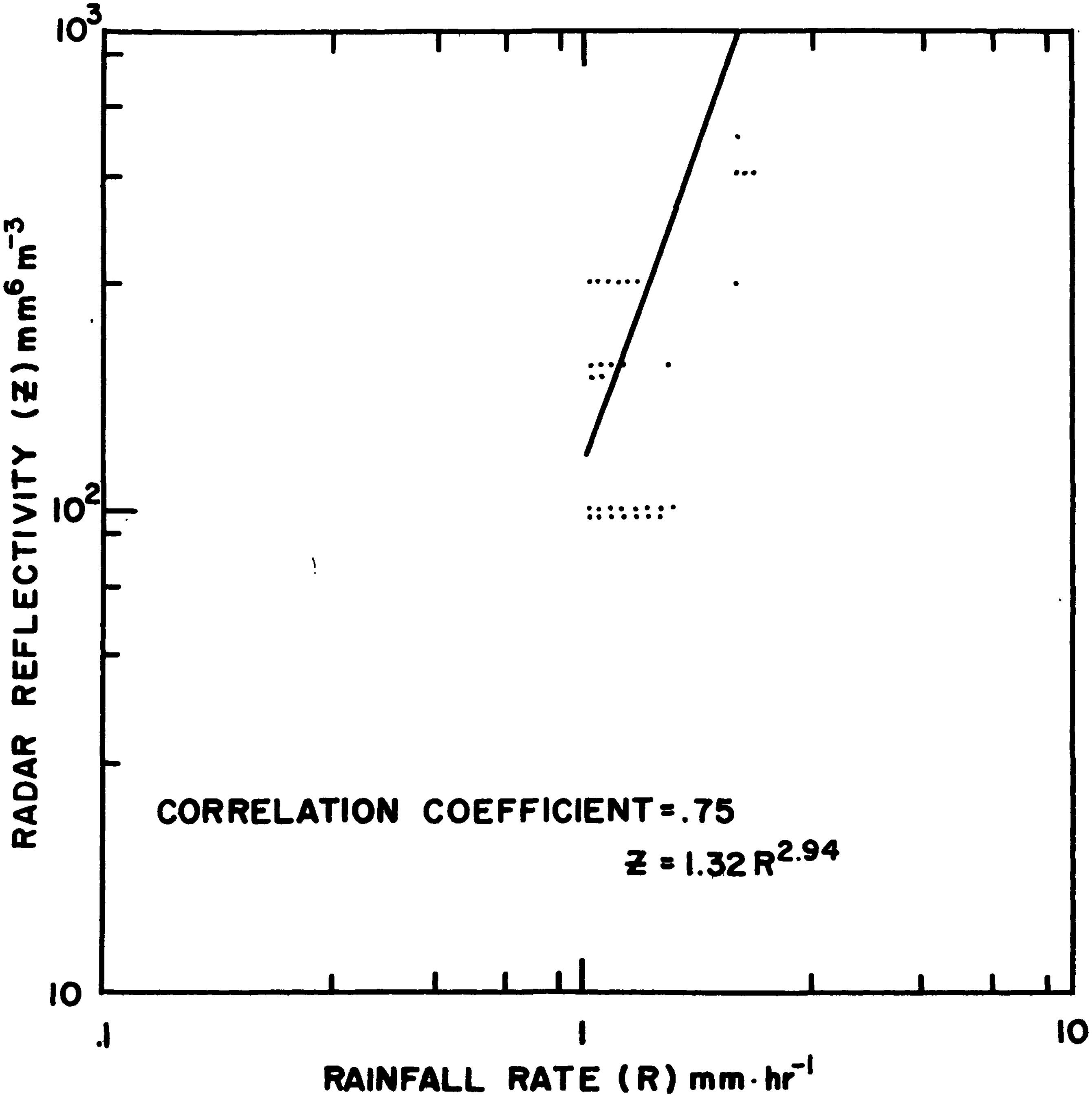

FIG. 7 EXAMPLE OF REGRESSION ANALYSIS WITH (R) ROUNDED TO NEAREST mm/hr

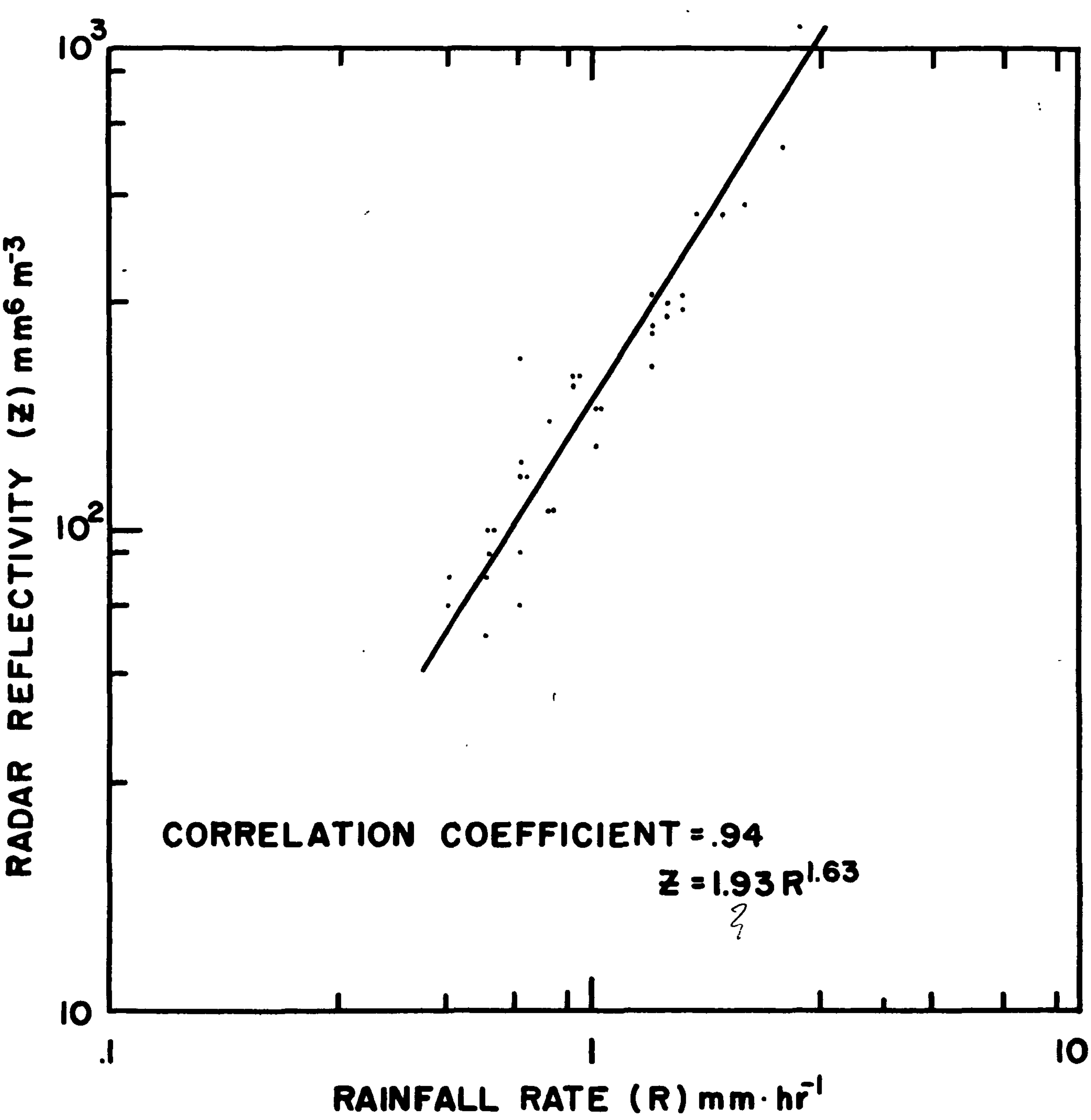

FIG. 8 EXAMPLE OF REGRESSION ANALYSIS WITH (R) ROUNDED TO NEAREST 1/10 mm/hr

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Library, U.S. Weather Bureau, Washington 25, *B.C.*	1
Brookhaven National Laboratories, Camp Upton, New York	1
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