Contract 36

Illinois State Water Survey
Meteorologic Laboratory
at the
University of Illinois
Urbana, Illinois

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

Fifth Quarterly Technical Report

1 October 1962 - 31 December 1962

Sponsored by
U. S. Array Signal Research and Development Laboratory
Port Monmouth, New Jersey

CONTRACT NO. DA-36-039 SC-87280

DA Task 3A99-07-001-01

AD__________________________Accession No.________
Illinois State Water Survey Division, Urbana, Illinois. INVESTIGATION OP THE QUANTITATIVE DETERMINATION OP POINT AND AREAL PRECIPITATION BY RADAR ECHO MEASUREMENTS - E. A. Mueller

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2. Drop Size Distribution
3. Coalescence Theory
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FIFTH QUARTERLY TECHNICAL REPORT

1 October 1962 - 31 December 1962

Signal Corps Contract: DA-36-039 SC-87280

DA Task 3A99-07-001-01

Sponsored by

U. S. Army
Signal Research and Development Laboratory
Port 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

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, trafficability, 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

During the quarter there was no data collection. The cameras are being readied for data collection during the coming spring and summer.

The processing of the raindrop camera data, which have been previously measured and have not been analyzed due to the University's change-over of computer facilities, has been initiated on the computer. The computer program has been proven and the choice has been made to submit the raw data cards to an IBM 1401 computer and obtain the distribution cards from this computer. The distribution cards will then be resubmitted to an IBM 7090 computer and the summary cards will be obtained. This will require a little more data handling than previously but will be considerably less expensive.

The average distributions from Majuro, Marshall Islands, are presented in this quarterly. In general, the coalescence curves

fit the majuro distributions very satisfactorily. The general trend which was observed earlier in Miami is preserved in that as the rainfall rate increases the coalescence distributions tend to become broader until the higher values of rainfall rate are obtained in which case the need for two coalescence curves is strikingly evident. Initial results of stratifying the data as to the condensation level are presented and appear promising.

PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES

During the last period there has been no publications, lectures, reports, or conferences that have been performed under this contract. Research Report No. 8 entitled "Raindrop Size Distributions with Rainfall Types and Weather Conditions" has been completed and has been sent to the printers.

RADAR OPERATIONAL PROGRAM

CPS-9

There has been no collection of data since the raindrop cameras were not operative and no need for winter type precipitation is now evident. The CPS-9 has been operating satisfactorily with the exception of the waveguide pressurizing system. This system is being rebuilt during the winter and should operate more satisfactorily during the coming data collection period.

TPS-10

The TPS-10 radar has not been used in the collection of data during the period. The TPS-10 radar is being reconditioned so that its operation during the coming data collection periods may be satisfactory,

RAINDROP CAMERAS

None of the three raindrop camera installations are at present operative,, Since the majority of our wintertime precipitation comes as frozen precipitation and since frozen precipitation, particularly snow, is not capable of interpretation by the camera technique, the raindrop cameras have not been kept operative during the winter months. The cameras have been returned to the laboratory and have been examined for wear and possible part failures. The cameras seem in good condition. One of the 30-inch mirrors will be resurfaced during the winter period as the surface quality has deteriorated to the point where high definition pictures are impossible. The mirror will be surfaced with stainless steel instead of aluminum which should produce a more serviceable surface. The installations on the East Central Illinois Network can be put back into service with very little effort.

DATA ANALYSIS

Raindrop Data Reduction

During the quarter a total of 14. rolls of raindrop data has been measured. Seven of these rolls have been from the Coweeta

North Carolina installation and seven of them have been from the Island Beach, New Jersey, installation,,

The data that has been previously measured is being processed by the computers at present. This initial processing consists of calculating the rainfall rate, the radar reflectivity, the radar attenuation cross-section, the liquid water content, the medium volume diameter, the medium Z diameter, and a coded distribution type number,, In August of 1962, the University made a change in the computer facilities. Formerly, an Illiac and an IBM 650 were available for research usage. In August of 1962, these computers were retired and replaced by an IBM 1401 and an IBM 7090. Some difficulties were experienced by the computer laboratory in providing the monitoring systems and the interpretive routines for the IBM 7090 so that this machine has not been in general research usage until this quarter. During this past quarter the computer programs which were written previously have been submitted to the machine and have had the errors corrected and are now operative. The major program for the 7090 does not calculate all of the variables at present, but the machine processing of the data has been reinitiated. It has been found to be more economical to submit the raw data to the 1401 to obtain the geometrical mean of the horizontal and vertical measurements of the drops and tabulating the frequency table. The 1401 then outputs a frequency table on two distribution cards. These distribution cards are then submitted to the 7090 which performs the necessary matrix multiplications to obtain the other variables of interest. It appears that the new computers and the rates which are being charged to the contract will result in a considerable economy in computer usage,

Majuro Average Distributions and Coalescence Equations

The raindrop data from Majuro, Marshall Islands, was first stratified according to the rain type as reported by the Weather Bureau observer in charge of the camera, After this stratification it was found there was only a single day's data in the thunderstorm class and therefore this class is being ignored. There were 6ij. days of rainshowers and 26 days of continuous rain which were introduced into this analysis. In total there were 1389 individual one-minute samples of rainshower rains and 931 individual one-minute samples of continuous rain that went into the analysis. The highest rainfall rate for the rainshowers was in excess of 175 millimeters per hour* The highest rainfall rate which went into the continuous rain situation was in excess of 75 millimeters per hour$_e$ Average distributions for the different rainfall rates were obtained by arbitrarily choosing limits on the rainfall rate which went into each group$_c$ The limits were chosen as follows: all the samples which had rainfall rates between 0.5 mm/hr and 1.5 mm/hr were placed into group one. Those between 1.5 and 3.5 were put in group two, those between 3*5 and 5.5 were put in the next group, and then in groups of 3 mm/hr until the 24 mm/hr rate was reached. At this point the sparsity of the data indicated that a better technique would be to choose the same number of samples in each group and therefore a sample size of 10 cubic meters was considered to be appropriate and the rest of the data consisted of grouping the next ten consecutive rainfall rates together. The average distributions were then obtained by adding together the number in each of the class intervals and dividing this number by the total number of samples in the group. The average distributions were then plotted on a graph and Figures 1, 2, and 3 show the results of every other graph for the rainshower situation. The rainfall rate that is indicated on the figure as R is a calculated rate from the average distribution itself and does not refer to the stratification grouping of the data by the individual sample rates.

N_S on the figure is the number of individual one-minute, one-cubic meter samples that are included in the average. N_T is the number per cubic meter in the sample.   and   are the parameters of the coalescence equation which is being used to fit the curve and the coalescence equation is indicated by the solid line on the graph. N_{T2} is the number of drops represented by the coalescence distributions. The fitting of the coalescence equation to these curves is quite good. It can be noticed that at a rainfall rate of approximately 50 mm/hr it is necessary to use two coalescence equations to well fit the data. In fact, as one examines Figure 2, one notices that there is a tendency for the extra curve to show even earlier in rate than drawn by the analysts. These curves have been fit by moving plexiglass slide to the best by-eye fit. The previous quarterly report reported the technique that was used in more detail and also the results from fitting the data at Oregon. At that time, the appearance of these curves suggested that as the rainfall rate at Oregon became high it was necessary to use a second coalescence curve at the high end of the scale in order to appropriately fit that data. However, it seems that on the Majuro data when a second coalescence distribution is necessary, the second one or the auxiliary distribution is the one at the lower portion of the drop diameter,, The curves were much easier to fit than those from Oregon. Figures 4. and 5 indicate the results of fitting the continuous rain situations for Majuro. It can be noticed that for equivalent rainfall rates the continuous rain situation at Majuro showed a distribution which was always narrower than for the same rainfall rate out of rainshowers. This would indicate possibly that the continuous rain situation had been undergoing coalescence for a longer period of time than had the rainshowers. Certainly, this would appear to be true at the higher rainfall rates.

Table 1 is a table of coalescence coefficients and as well as the rainfall rate and the diameter of the mode maximum, the number of the mode maximum and the total number in a distribution for all of the data so that these could be more easily compared with those from Oregon from the previous quarterly report. It can be noted that it would seem that on the basis of this limited distribution from Majuro in terms of the number of distributions of a particular rainfall rate that the Majuro distributions were generally somewhat narrower than the equivalent rainfall rates at Oregon, This is evidenced by noting that at an equivalent rate, the from Majuro is less than or equal to that shown in the Oregon tables. The Majuro data was also stratified by synoptic types and again the stratification does not seem to produce much differences

TABLE 1

COALESCENCE COEFFICIENTS FROM MAJTJRO DATA

Rainfall Rate R (mm/hr)					Mode Location (mm) *D_1	*D_2	Max N_D (N./m3mm) *N_1	*N_2	N_{T_1}	N_{T_2}	N_T	N	Rainfall Type
1.0	637		1.5		.85		180		11+0		140	119	RW
2.5	1100		1.2		0.95		390		305		305	263	"
4.4	220		2.0		1.05		520		357		357	350	"
6.5	270		2.0		1.10		660		445		1+1+5	432	"
8.9	300		2.0		1.10		730		500		500	501	"
13.7	24.50		1.2		1.10		900		717		717	717	"
17.7	2500		1.2		1.15		900		721		721	722	"
22.6	2650		1.2		1.10		920		760		760	785	"
31c1	2300		1.0		1.25		900		770		770	923	"
32.5	2530		1.0		1.25		1000		850		850	947	"
33.4	1380		.3		1.3		720		900		900	890	"
34.8	1700		.5		1.25		840		910		910	984	"
35.8	1750		.5		1.35		860		960		960	966	"
37.9	2170		1.0		1.30		860		71+0		740	921	"
39.2	1600		.5		1.30		800		880		880	983	"
1+2.3	11+50		.3		1.25		760		960		960	1025	"
1+3.9	1950		.5		1.3		960		1060		1060	1124.	"
45.5	14+20		.3		1.3		740		952		952	1033	"
1+8.1	2550		.7		1.25		1220		1250		1250		"
4.9.1	1350		.3		1.4		720		948		948	1056	"
50.7	600		.2	.	1.35		690		1000		1000	1015	"
53.2	320	1550	3.0	.3	1.0	1.4	590	800	350	1035	1385	1173	"
59.1	315	1700	3.0	.3	1.0	1.4	580	900	345	1130	1470	1351	"
63.0	1600		.3		1.45		860		1080		1080	1189	"
69.1	300	660	2.0	.2	1.0	1.5	700	760	480	1100	1580	1519	"

TABLE 1
(cont'd)

Rainfall Rate R (mm/hr)					Mode Location (mm) *D_1	*D_2	Max N_D ($N^o/m^3 mm$) *N_1	*N_2	*T_1	NT_2	$\underline{N_T}$	N	Rainfall Type
73.8	1*10	580	2.0	.2	1.0	1.6	1000	660	680	950	1630	1649	RW
81.1	250	650	2.0	.2	1.0	1.6	600	740	420	1050	1470	1402	"
87.4	235	530	2.0	.1	.9	1.3	920	780	380	1450	1830	1424	"
93.1	4100	1780	1.0	.3	.75	1.7	1700	860	1400	1100	2500	2363	"
113.0	230	340	2.0	.1	.85	1.65	550	630	380	1150	1530	1423	"
172.8	2800	440	1.0	.1	1.0	1.6	1100	800	950	1470	2420	2150	"
1.0	315		1.5		1.5		91;		67		67	69	R
2.4	440		1.2		1.5		150		128		128	128	"
4.1	730		1.2		1.55		260		209		209	209	"
6.3	840		1.2		1.1		295		244		244	244	"
8.6	1680		1.5		1.1		490		370		370	377	"
12.4	1180		1.0		1.15		470		397		397	426	"
17.6	2000		1.2		1.25		720		584		584	587	"
22.1	2100		1.0		1.2		840		700		700	657	"
26.7	2220		1.0		1.2		880		750		750	867	"
32.2	2520		1.0		1.25		1000		850		850	973	"
36.1	275	1800	3.0	.5	1.0	1.3	500	900	310	960	1270	1172	"
47.4	440	560	3.0	.16	1.0	1.25	810	740	480	1170	1650	1273	"
56.1	420	1850	3.0	.3	1.05	1.35	690	960	420	1220	1640	1418	"
78.2	540	540	3o0	.16	1.05	1.5	1000	730	600	1120	1720	1628	"

TABLE 2

COALESCENCE COEFFICIENTS FOR AVERAGE CURVES
PROM DIFFERENT CONDENSATION LEVELS

Condensation Level 400 - 800 feet			Condensation Level 1600 - 2000 feet		
Rainfall Rate R (mm/hr)	Coalescence Coefficients		Rainfall Rate R (mm/hr)	Coalescence Coefficients	
1.0	50	2,0	1.0	160	3,0
2.5	800	1.5	2.6	305	3.0
4.3	257	2,0	4.4	310	3.0
6.4	21+00	2.0	6.6	450	3.0
8.8	1950	1.5	9.0	2600	1.5
13.1	2500	1,5	18.0	3200	1.5
17.4	2230	1.2	17.3	3700	1.5
22.8	2100	1.0	22.7	1980	1.0
25.4	1750	.5	27.6	2700	1.0
31.3	2000	1.0	33.0	1480	.5
33.4	1880	.5			

in the drop size distributions and therefore is not considered to be significant in obtaining drop size coalescence fitting.

Effect of Condensation Level on Drop Size Distribution

Following a suggestion from Dr. Helmut Weickmann of the U. S. Army Signal Research and Development Laboratory, Port Monmouth, New Jersey, the effect of the condensation level on drop size distribution was initiated.

Previous work in attempting to find better means of stratifying the data for prediction of the R-Z equation had indicated that the conditions aloft might be important in the drop size distributions and so a program for an IBM 650 had been written which obtained a positive stability index. This computer program was required to obtain the condensation level as a by-product of determining the instability and therefore this level was brought out on cards from the computer and no great effort was required to sort the raindrop data into various levels according to the condensation level. Since the Majuro data had produced such well fitted coalescence equations, it was decided that this would be an appropriate place to test the hypothesis of the variations in the drop size distributions with the height of the condensation levels. It was expected that if the condensation level were high a longer time for the coalescence process would be available and therefore the distributions at the ground should have higher values of than those distributions which had a low condensation levelo Prom the limited data, that went into the trial sample, this does appear to be the case. An example is given in Figure 6 of two average distributions at approximately the same rainfall rate obtained from data which had condensation levels of 400 to 800 feet and of 1600 to 2000 feet. Table 2 shows the comparisons of the resulting coalescence coefficients. There is a considerable difference in the width of the spectra as evidenced by equal or higher values at all times for the high group. This is in agreement with the assumption that the coalescence process should be effective for longer periods of time for a high condensation level than for a low condensation level. Figure 6 shows three distributions for both the low and the high sort. This work will be continued and reported on more fully during the next quarterly report.

SUMMARY AND CONCLUSIONS

Data processing is once again on a routine basis with the data being measured and submitted to the computer for preliminary analysis and calculations as it is being measured. There is some back log data which will be submitted to the computer during the coming quarter. The raindrop cameras are being refurbished for the coming summer's data collection. The radars are not being used at present but are being put into good operating condition for the coming data collection.

Data analysis has indicated that coalescence distributions are very good fits for the Majuro data. The data is fit better at this location than any other drop size data that has been examined in the past. The dependence of the coalescence parameters with the condensation level appears to be promising and further work in this direction is indicated and will be performed during the coming quarter.

PERSONNEL

The following personnel were engaged in the research during the fifth quarter:

Name and Title	Starting Date	Hours Worked	Terminated
G, E. Stout Project Director	10/1/61	51	
Eugene A. Mueller Electronic Engineer	10/1/61	408	
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	10/1/61	510	
Marian E. Adair Meteorological Aide I	9/24/62	270	
Ileah W. Trover Statistical Clerk	9/10/62	260	
Margaret A. Coy Laboratory Assistant	94/62	124	
Ruth V. Eadie Meteorological Aide I	11/31/61	510	
Ronald G. Custer Scientific Assistant	10/15/62	85	
Gerald W. Swanson Statistical Clerk	10/31/62	131	
Nazir Ansari Statistical Clerk	10/1/61	277	

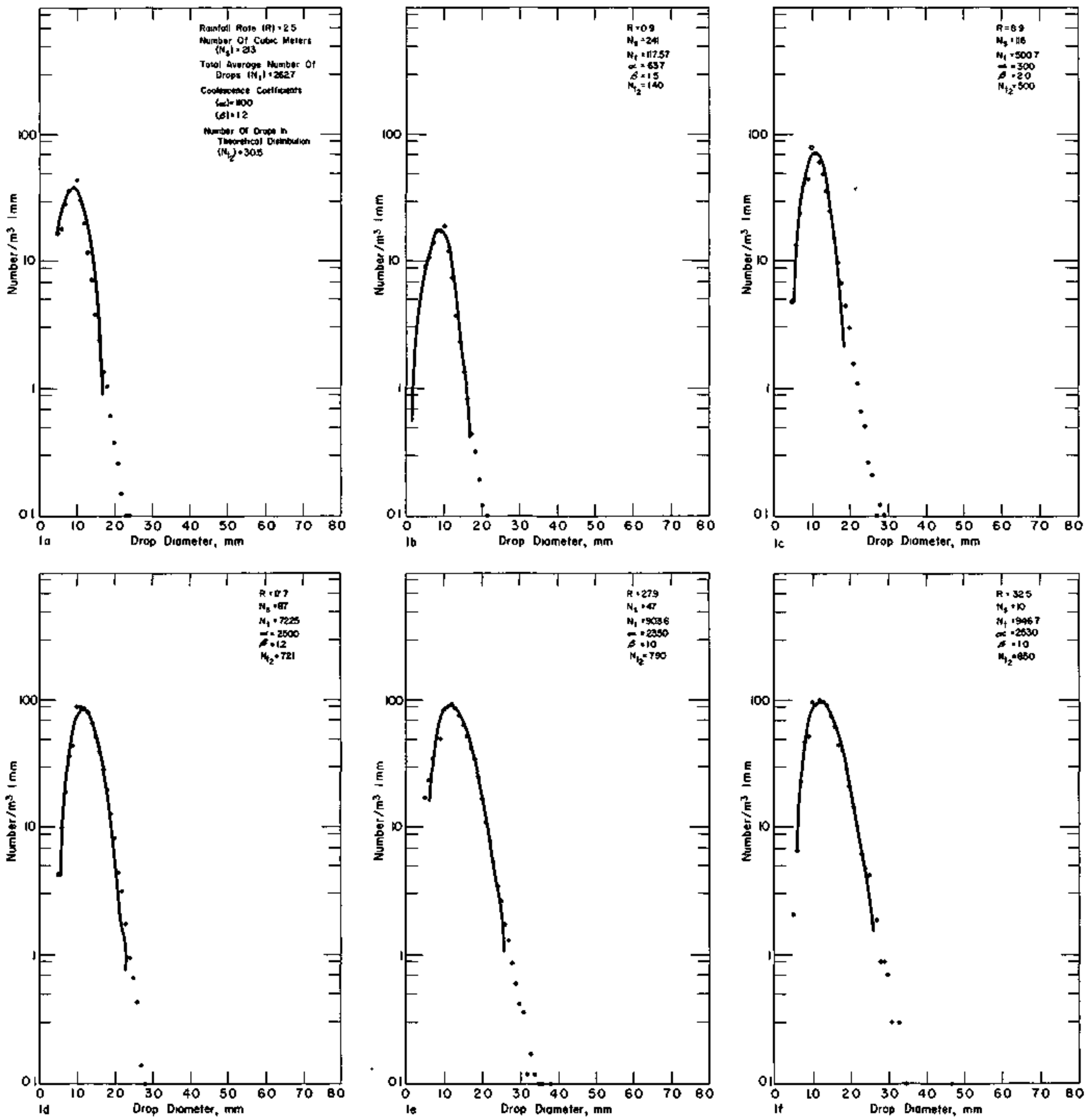

FIG. I EXAMPLES OF COALESCENCE CURVES ON MAJURO AVERAGE RAINSHOWER DISTRIBUTIONS (0<R<33)

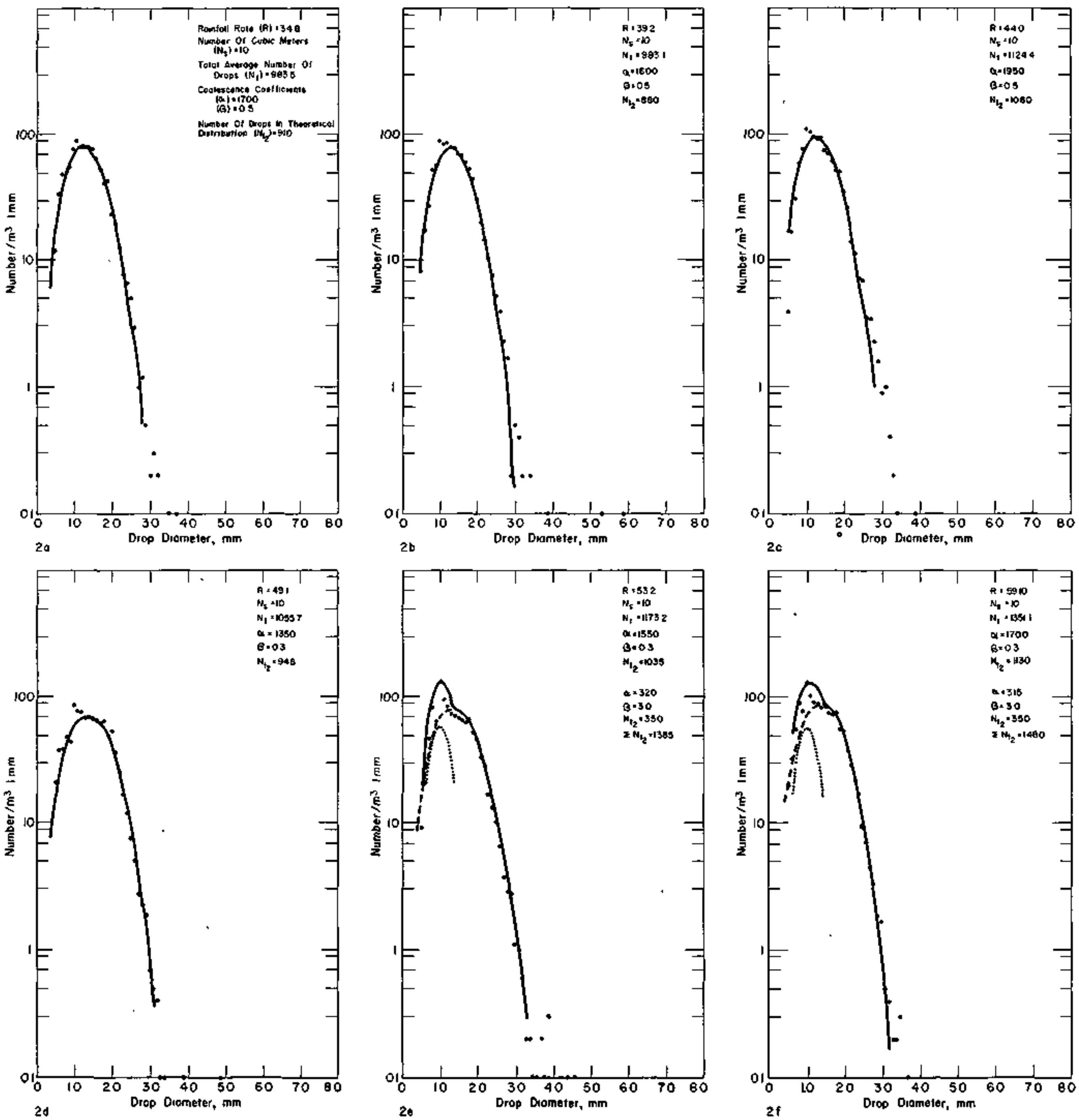

FIG 2 EXAMPLES OF COALESCENCE CURVES ON MAJURO AVERAGE RAINSHOWER DISTRIBUTIONS (33<R<60)

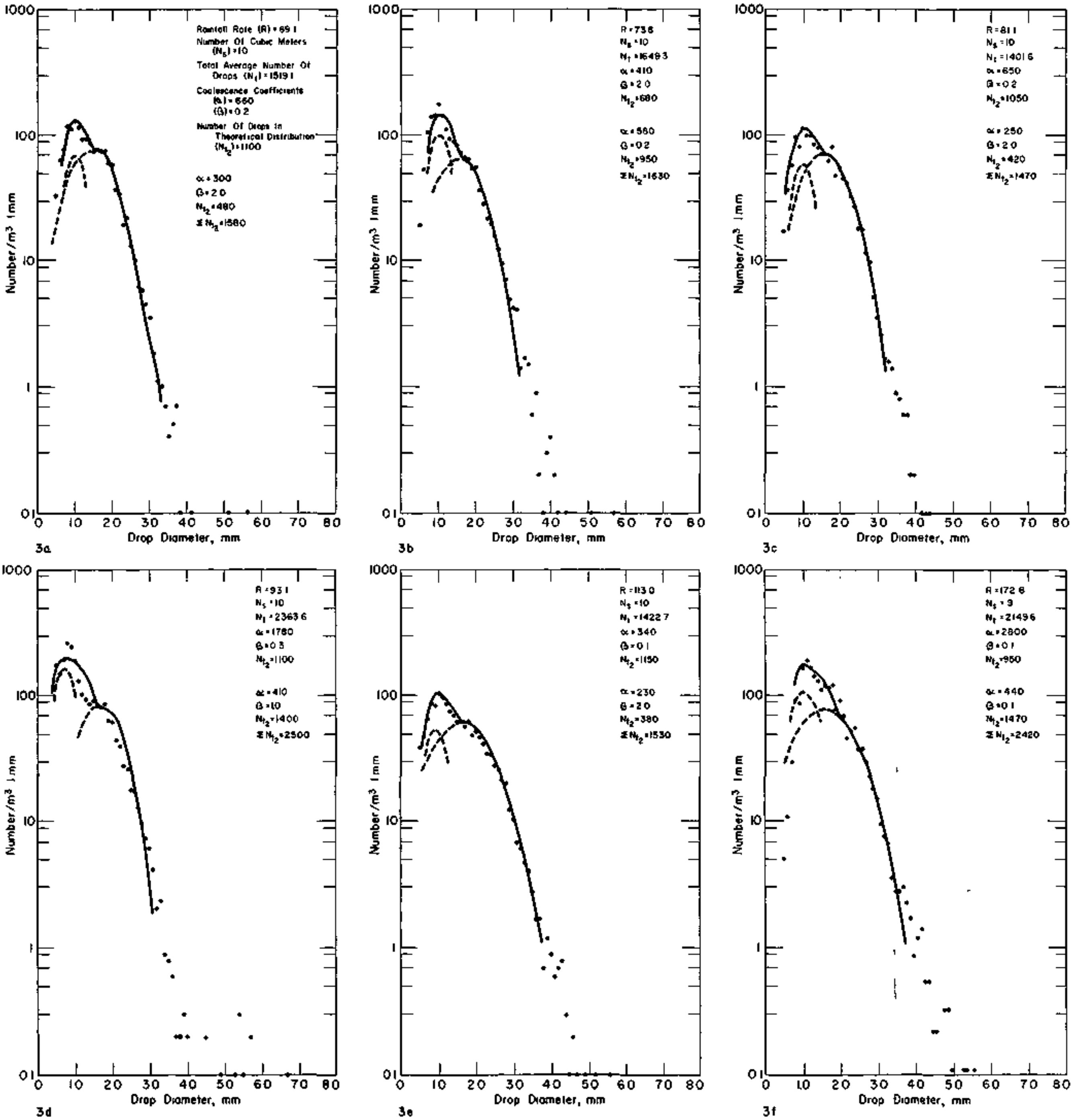

FIG. 3 EXAMPLES OF COALESCENCE CURVES ON MAJURO AVERAGE DISTRIBUTIONS (60<R<175)

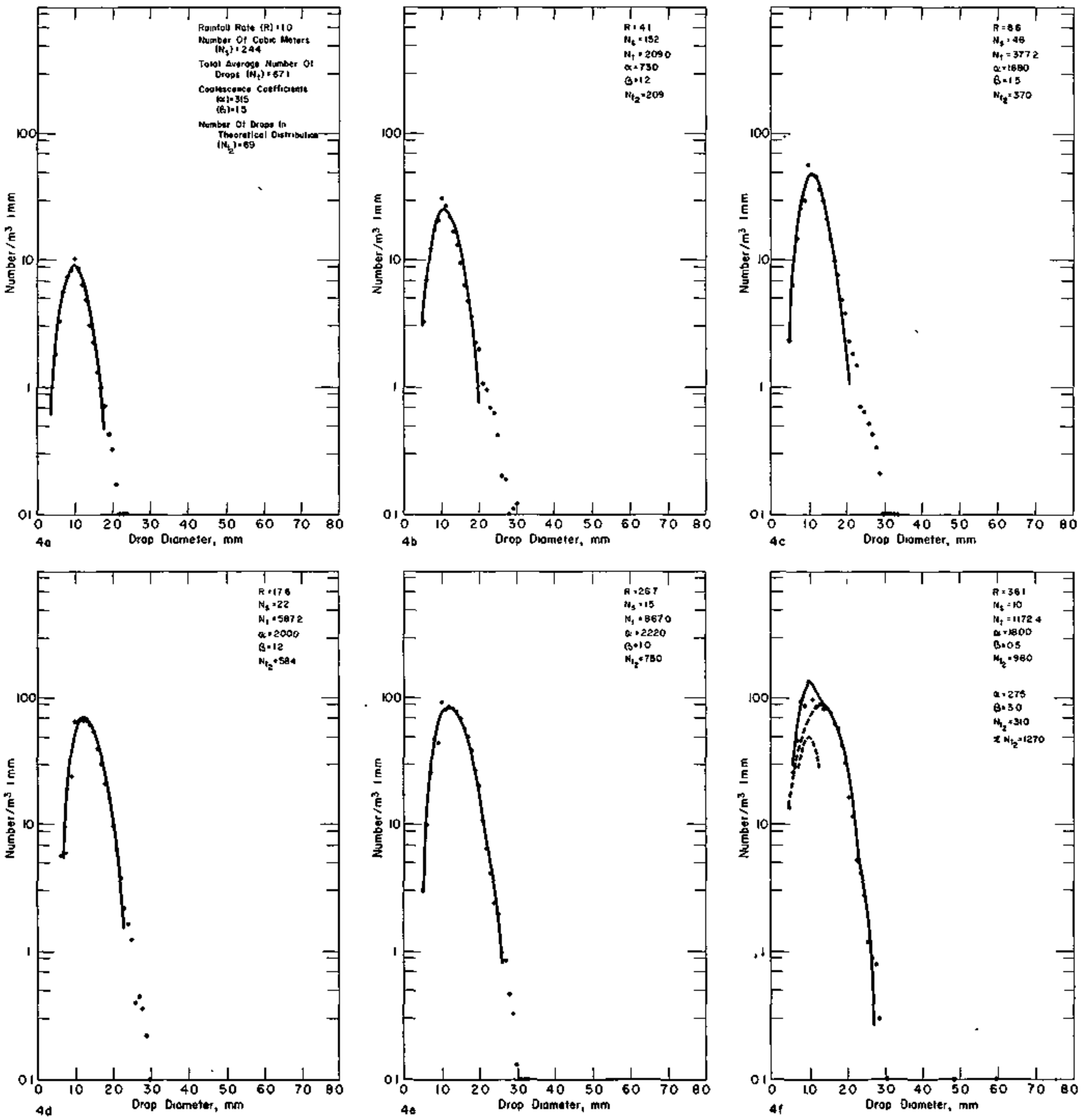

FIG. 4 EXAMPLES OF COALESCENCE CURVES ON MAJURO AVERAGE CONTINUOUS RAIN DISTRIBUTIONS (0 < R < 37)

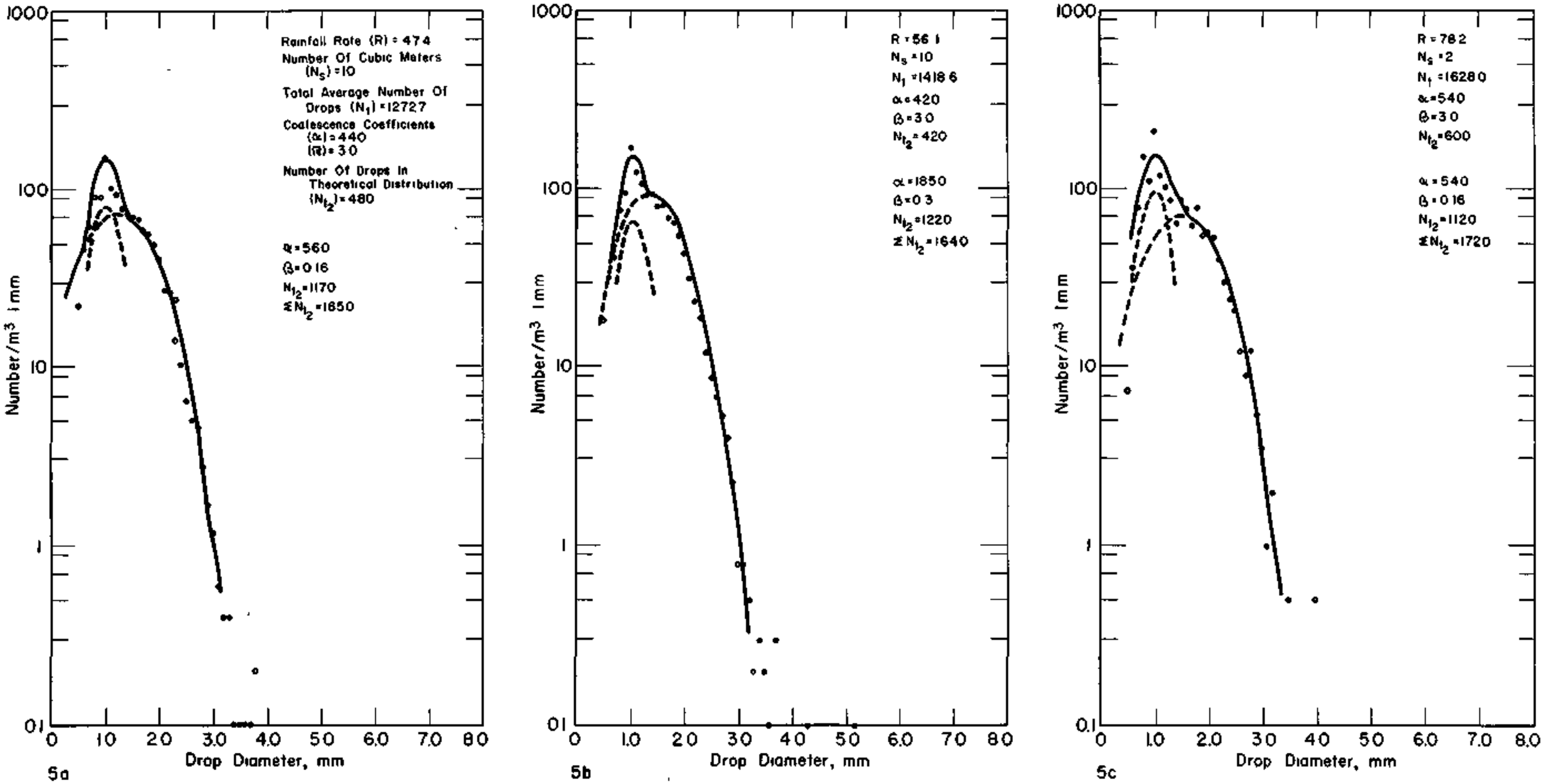

FIG. 5 EXAMPLES OF COALESCENCE CURVES ON MAJURO AVERAGE CONTINUOUS RAIN DISTRIBUTIONS (37<R<80)

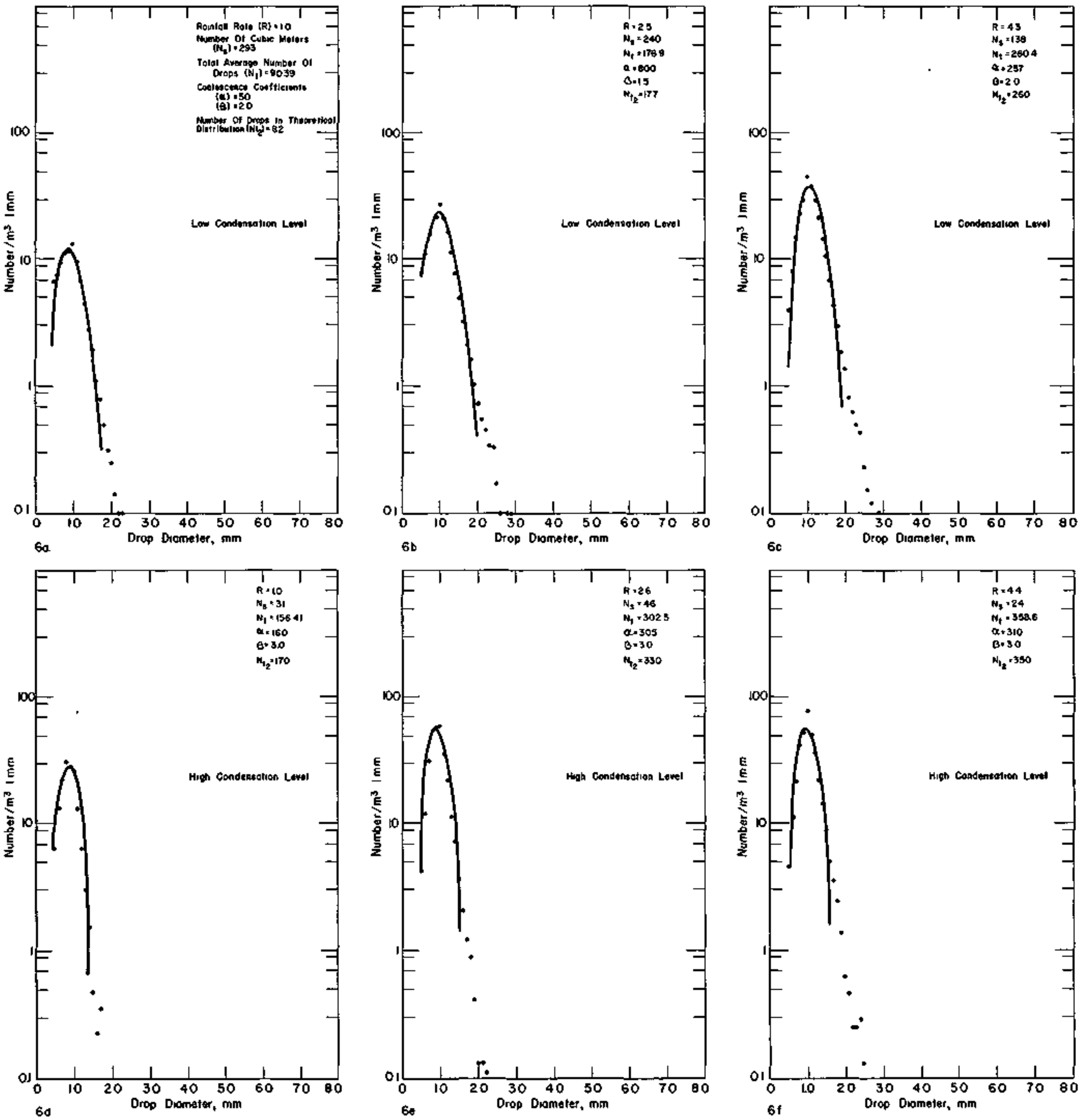

FIG 6 COMPARISON BETWEEN DISTRIBUTIONS OBSERVED FROM LOW CONDENSATION LEVEL AND HIGH CONDENSATION LEVEL FROM MAJURO