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

FOURTH QUARTERLY TECHNICAL REPORT

1 July 1962 - 30 September 1962

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

AD________________________Accession No.______

Illinois State Water Survey Division, Urbana, Illinois. INVESTIGATION OF THE QUANTITATIVE DETERMINATION OP POINT AND AREAL PRECIPITATION BY RADAR ECHO MEASUREMENTS - E. A. Mueller

Q. Tech. Report No. 4, 1 July 1962 - 30 Sept. 1962 11 pps. (Contract DA-36-039 SC-87280] DA Task 3A99-07-001-01, Unclassified Report.

The summer raindrop data collection at Mt. Withington, New Mexico, was undertaken and completed. The installation and data collection from the raindrop cameras in the east central Illinois area are progressing satisfactorily. The computer program for processing of the data in an IBM 7090 computer was completed but not proven as the computer is not presently available to researchers. A summary of the coalescence curve-fitting technique used for the Oregon raindrop data ls presented along with the results obtained with its use. In general, the coalescence curve fitting was considerably better than expected considering the type of rain occurring at Oregon.

UNCLASSIFIED

1. Radar Meteorology
2. Drop Size Distribution
3. Coalescence Theory
4. Contract DA-36-039 SC-87280

AD________________________Accession No.______

Illinois State Water Survey Division, Urbana, Illinois. INVESTIGATION OF THE QUANTITATIVE DETERMINATION OF POINT AND AREAL PRECIPITATION BY RADAR ECHO MEASUREMENTS - E. A. Mueller

Q. Tech. Report No. 4, 1 July 1962 - 30 Sept. 1962 11 pps. (Contract DA-36-039 SC-87280) DA Task 3A99-07-001-01, Unclassified Report.

The summer raindrop data collection at Mt. Withington, New Mexico, was undertaken and completed. The installation and data collection from the raindrop cameras in the east central Illinois area are progressing satisfactorily, The computer program for processing of the data in an IBM 7090 computer was completed but not proven as the computer is not presently available to researchers. A Bummary of the coalescence curve-fitting technique used for the Oregon raindrop data is presented along with the results obtained with its use. In general, the coalescence curve fitting was considerably better than expected considering the type of rain occurring at Oregon.

UNCLASSIFIED

1. Radar Meteorology
2. Drop Size Distribution
3. Coalescence Theory
4. Contract DA-36-039 SC-87280

AD________________________Accession No.______

Illinois Water Survey Division, Urbana, Illinois. INVESTIGATION OF THE QUANTITATIVE DETERMINATION OF POINT AND AREAL PRECIPITATION BY RADAR ECHO MEASUREMENTS - E. A. Mueller

Q. Tech. Report No. 4, 1 July 1962 - 30 Sept. 1962 11 pps. (Contract DA-36-039 SC-87280) DA Task 3A99-07-001-01, Unclassified Report.

The summer raindrop data collection at Mt. Withington, New Mexico, was undertaken and completed. The installation and data collection from the raindrop cameras in the east central Illinois area are progressing satisfactorily. The computer program for processing of the data in an IBM 7090 computer was completed but not proven as the computer is not presently available to researchers. A summary of the coalescence curve-fitting technique used for the Oregon raindrop data is presented along with the results obtained with its use. In general, the coalescence curve fitting was considerably better than expected considering the type of rain occurring at Oregon.

UNCLASSIFIED

1. Radar Meteorology
2. Drop Size Distribution
3. Coalescence Theory
4. contract DA-36-039 SC-87280

AD________________________Accession No.______

Illinois State Water Survey Division, Urbana, Illinois. INVESTIOATION OF THE QUANTITATIVE DETERMINATION OF POINT AND AREAL PRECIPITATION BY RADAR ECHO MEASUREMENTS - E. A, Mueller

Q. Tech. Report No. 4, 1 July 1962 - 30 Sept. 1962 11 pps. (Contract DA-36-039 SC-87280) DA Task 3A99-07-001-01, Unclassified Report.

The summer raindrop data collection at Mt. Withington, New Mexico, was undertaken and completed. The installation and data collection from the raindrop cameras in the east central Illinois area are progressing satisfactorily. The computer program for processing of the data in an IBM 7090 computer was completed but not proven as the computer is not presently available to researchers. A summary of the coalescence curve-fitting technique used for the Oregon raindrop data is presented along with the results obtained with its use. In general, the coalescence curve fitting was considerably better than expected considering the type of rain occurring at Oregon.

UNCLASSIFIED

1. Radar Meteorology
2. Drop Size Distribution
3. Coalescence Theory
4. Contract DA-36-039 SC-87280

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

Q. Tech. Report No. 4, 1 July 1962 - 30 Sept. 1962 11 pps. (Contract DA-36-039 SC-87280) DA Task 3A99-07-001-01, Unclassified Report.

The Bummer raindrop data collection at Mt. Withington, New Mexico, was undertaken and completed. The installation and data collection from the raindrop cameras in the east central Illinois area are progressing satisfactorily. The computer program for processing of the data in an IBM 7090 computer was completed but not proven as the computer is not presently available to researchers. A summary of the coalescence curve-fitting technique used for the Oregon raindrop data is presented along with the results obtained with its use. In general, the coalescence curve fitting was considerably better than expected considering the type of rain occurring at Oregon.

UNCLASSIFIED

1. Radar Meteorology
2. Drop Size Distribution
3. Coalescence Theory
4. Contract DA-36-039 SC-87280

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

Q. Tech. Report No. 4, 1 July 1962 - 30 Sept. 1962 11 pps. (Contract DA-36-039 SC-87280) DA Task 3A99-07-001-01, Unclassified Report.

The summer raindrop data collection at Mt. Withington, New Mexico, was undertaken and completed. The installation and data collection from the raindrop cameras in the east central Illinois area are progressing satisfactorily. The computer program for processing of the data in an IBM 7090 computer was completed but not proven as the computer is not presently available to researchers. A summary of the coalescence curve-fitting technique used for the Oregon raindrop data is presented along with the results obtained with its use. In general, the coalescence curve fitting was considerably better than expected considering the type of rain occurring at Oregon.

UNCLASSIFIED

1. Radar Meteorology
2. Drop Size Distribution
3. Coalescence Theory
4. Contract DA-36-039 SC-87280

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

Q. Tech. Report No. 4, 1 July 1962 - 30 Sept. 1962 11 pps. (Contract DA-36-039 SC-87280) DA Task 3A99-07-001-01, Unclassified Report.

The summer raindrop data collection at Mt. Withington, New Mexico, was undertaken and completed. The installation and data collection from the raindrop cameras in the east central Illinois area are progressing satisfactorily. The computer program for processing of the data in an IBM 7090 computer was completed but not proven as the computer is not presently available to researchers. A summary of the coalescence curve-fitting technique used for the Oregon raindrop data is presented along with the results obtained with its use. In general, the coalescence curve fitting was considerably better than expected considering the type of rain occurring at Oregon.

UNCLASSIFIED

1. Radar Meteorology
2. Drop Size Distribution
3. Coalescence Theory
4. Contract DA-36-039 SC-87280

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

Q. Tech. Report No. 4, 1 July 1962 - 30 Sept. I962 11 pps. (Contract DA-36-039 SC-87280) DA Task 3A99-07-001-01, Unclassified Report.

The summer raindrop data collection at Mt. Withington, New Mexico, was undertaken and completed. The Installation and data collection from the raindrop cameras in the east central Illinois area are progressing satisfactorily. The computer program for processing of the data in an IBM 7090 computer was completed but not proven as the computer is not presently available to researchers. A summary of the coalescence curve-fitting technique used for the Oregon raindrop data is presented along with the results obtained with its use. In general, the coalescence curve fitting was considerably better than expected considering the type of rain occurring at Oregon.

UNCLASSIFIED

1. Radar Meteorology
2. Drop Size Distribution
3. Coalescence Theory
4. Contract DA-36-039 SC-87280

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

FOURTH QUARTERLY TECHNICAL REPORT

1 July 1962 - 30 September 1962

Signal Corps Contracts DA-36-039 SC-87280

DA Task 3A99-07-001-01

Sponsored by

U. S. Army
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

E. A. Mueller
Project Engineer

G. E. Stout
Project Director

William C. Ackermann, Chief
Illinois State Water Survey

TABLE OP CONTENTS

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

The summer raindrop data collection at Mt. Withington, New Mexico, was undertaken and completed. The installation and data collection from the raindrop cameras in the east central Illinois area are progressing satisfactorily. The computer program for processing of the data in an IBM 7090 computer was completed but not proven as the computer is not presently available to researchers. A summary of the coalescence curve-fitting technique used for the Oregon raindrop data is presented along with the results obtained with its use. In general, the coalescence curve fitting was considerably better than expected considering the type of rain occurring at Oregon.

PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES

During July 1962, E. A. Mueller visited Mt. "Withington, New Mexico and installed a raindrop camera on top of Mt. Withington.

Research Report 9B entitled "Raindrop Distributions at Miami, Florida™ by E. A. Mueller was printed and distributed in July.

RAINDROP CAMERAS

East Central Illinois Network

An East Central Illinois network of three raindrop cameras was initiated during the period. Two cameras were placed in operation in July. The first two cameras are one-half mile apart with the northern one designated "A". The second camera has been designated "B". The two cameras have been linked together by means of telephone field wire so that the two cameras will operate at the same time. A third camera, "C", will be placed one and one-half miles south of "A" during the next quarter. The shelters and the concrete pillars have been erected for this camera, and wiring has been performed to allow power service for the drop camera to be connected. Installation of the camera and optical units have been delayed since the 30-inch paraboloidal mirror has not as yet been shipped from New Mexico.

New Mexico Installation

Five rolls of interesting raindrop camera data representing 7 days were obtained from the Mt. Withington, New Mexico, installation during the later part of July and August. The summer at Mt. "Withington was an exceedingly dry season. At least two of the rolls of film contain histories of storms which produced hail at the ground. The camera has been disassembled and shipped to

Illinois with the exception of the mirror and the two raingages which are being shipped during October.

The shelters from this camera unit have been disassembled and stored in the warehouse in Magdalena, Hew Mexico. In event a raindrop camera is set up in Flagstaff, Arizona, in 1963, these shelters will be transported to Arizona for use there.

RADAR OPERATIONAL PROGRAM

CPS-9

The CPS-9 radar has been operating satisfactorily with the exception of the compressor for the waveguide. This compressor has been rebuilt around a one-third horsepower induction motor. The previous compressor motor was a universal motor with brushes. As the motor has become older and the commutator turned down several times, the brush life in the motor has been reduced to about two weeks. The change to the induction motor should reduce the amount of routine maintenance required to maintain pressure in the waveguide.

TPS-10

The TPS-10 radar has not been operated during the period due to a lack of a modulating thyratron. These tubes have now been received and the radar will be put back into operating condition in the coming period.

DATA ANALYSIS

Raindrop Data Reduction

During the period 22 rolls of raindrop data have been measured. This data has not all been reduced due to a change in computing facilities at the University. Considerable effort has been expended on rewriting the data processing programs for the new IBM 7090 computer. These programs have now been completed but have not been tested. Therefore, minor errors may still exist within the program. The 7090 will become available for program checking within the next period. At present there remains approximately 110 rolls of raindrop data to be measured from Island Beach, New Jersey; Franklin, North Carolina; Mt. Withington, New Mexico; and East Central Illinois Raingage Network.

Coalescence Distributions From the Oregon Raindrop Camera

Even though it was recognized that most of the rainfall in Oregon would not be of the warm rain type, attempts were made to fit these distributions to coalescence curves. It has been apparent from inspection of the data that the average drop size distributions could be easily fitted by means of the curves.

The curve-fitting technique finally selected as the most practical involved preparation of a number of overlays for various values of ß in the coalescence expression;

$$N_D = \alpha D^2 e^{-\beta D^3}$$

TABLE 1

COALESCENCE COEFFICIENTS FROM OREGON DATA

* = Two coalescence curves necessary - mode location refers to first coalescence curve.

= No fit possible with coalescence curves.

Rain Rate R (mm/hr)	Coalescence Coefficients α	β	Maximum ^{N}D (no./m^{a}mm)	Mode Location D (mm)	Synoptic Type
1	242	1.00	95	0.85	Air Mass
3	154	.50	76	1.10	Air Mass
6	99	.30	86	1.30	Air Mass
9	#		-	-	Air Mass
1	184	1.00	72	.91	Air Mass Orographic
2	294	LOO	117	1.15	Air Mass Orographic
6	500	1.00	200	1.32	Air Mass Orographic
8	#		-	-	Air Mass Orographic
1	#		-	-	Cold Frontal
2	440	1.00	180	.90	Cold Frontal
1	#		-	-	Post Cold Frontal
2	400	.50	200	.80	Post Cold Frontal
6	1560	1.00	620	.95	Post Cold Frontal
1	136	1.00	54	1.15	Post Cold Frontal Orographic
3	249	1.00	96	1.10*	Post Cold Frontal Orographic
6	400	1.00	160	1.20*	Post Cold Frontal Orographic
8	755	1.00	305	1.10*	Post Cold Frontal Orographic
14	3700	1.20	1250	1.09	Post Cold Frontal Orographic
1	122	.50	62	.90	Overrunning Orographic
2	249	.50	125	1.00	Overrunning Orographic
6	329	.50	161	1.20*	Overrunning Orographic
8	440	.50	220	1.25*	Overrunning Orographic
12	1590	1.20	550	1.05*	Overrunning Orographic
24	3190	.16	4l5	1.18	Overrunning Orographic
26	590	.30	520	1.25	Overrunning Orographic
1	1000	3.00	190	1.25	Warm Front
3	740	2.00	180	1.20	Warm Front
6	790	1.00	335	1-20	Warm Front

TABLE 1 (Cont'd)

Rain Rate R (mm/hr)	Coalescence Coefficients α	β	Maximum N_D (no./m^amm)	Mode Location D (mm)	Synoptic Type
1	128	1.00	52	1.15	Warm Frontal Orographic
3	205	1.00	82	1.15*	Warm Frontal Orographic
6	560	3.00	148	1.10*	Warm Frontal Orographic
9	2200	1.20	760	1.06*	Warm Frontal Orographic
13	1970	1.20	680	1.15*	Warm Frontal Orographic
1	258	1.20	90	1.00	Warm Occlusion Concurrent
1	130	1.00	52	.93*	Warm Occlusion Orographic
3	245	1.00	100	1.24	Warm Occlusion Orographic
6	302	1.00	120	1.60*	Warm Occlusion Orographic
10	400	1.00	160	1.60	Warm Occlusion Orographic
12	460	1.00	220	1.65	Warm Occlusion Orographic
24	#	-	-	-	Warm Occlusion Orographic
1	277	1.20	96	1.05	Pre-Warm Occlusion
2	179	1.00	72	1.25	Pre-Warm Occlusion
6	150	.50	76	1.55	Pre-Warm Occlusion
8	#		-	-	Pre-Warm Occlusion
1	125	.50	57	.90	Pre-Warm Occlusion Orographic
2	409	1.20	146	1.25	Pre-Warm Occlusion Orographic
1	195	1.50	59	1.60	Post-Warm Occlusion
3	425	1.20	150	1.20	Post-Warm Occlusion
5	310	1.00	120	1.30	Post-Warm Occlusion
10	#	-	-	-	Post-Warm Occlusion
1	210	1.00	84	.95	Post-Warm Occlusion Orographic
3	370	1.00	143	1.02	Post-Warm Occlusion Orographic
6	950	1.50	280	1.10*	Post-Warm Occlusion Orographic
8	590	1.00	230	1.13*	Post-Warm Occlusion Orographic
11	340	.50	170	1.35*	Post-Warm Occlusion Orographic
19	4080	1.20	1410	1.18	Post-Warm Occlusion Orographic

These overlays were made from 1/16-Inch plexiglass, and were used on the plotted distributions curves to adjust for the best "eye" fitting. Figure la and lb are examples of some of the better fitted curves. Figures lc and ld are examples of some of the distributions which are labeled in Table 1 as being "no fit", and Figures le and If represent distributions that it was felt had to be represented by two of the coalescence curves.

In general, very excellent fitting was obtained. Table 1 summarizes the parameters that were required to fit a number of the average distributions from Oregon. The fitting is most easily accomplished at the low rainfall rates with B equal to 1.0. As the rainfall rates increase, the tendency is for the B to decrease, the α to Increase, and a need arises for two coalescence curves to fit the data properly. Since it Is probable that a great deal of the rain growth in the Oregon area was due to an ice phase growth it is not surprising that a second mode would be required whenever the rainfall rates became appreciable.

The average distributions that were obtained prior to attempting to fit the curves by a coalescence distribution were obtained from the data as separated by synoptic conditions. The last line in Table 1 shows the synoptic type that was assigned to each of the individual samples. In order to test the significance of this type of sorting, a final group of distributions were obtained by choosing a set of original data points at random from among the total sample. From these it was found that very little significance can be attached to the synoptic conditions as listed in the last column of Table 1. Nonetheless, this represents a fair averaging method for obtaining a number of average distributions from the sampling locations. In this respect, it seems quite surprising that the curves were fit as well as they are by coalescence distributions. Since it would seem that the orographic rains, which are quite prevalent in the area, should have primary growth as ice phase, they should exhibit drop size distributions more nearly as illustrated in Figures lc and Id.

Cloud Droplet Size Spectra

Considerable information may be obtained from cloud droplet size distributions in the vicinity of the raindrop cameras. The Cornell optical disdrometer, a cloud droplet size spectrometer which was on loan from the Cambridge Air Force Research Center and being used on a National Science Foundation grant, was used to collect several samples of cloud droplet size spectras. Figure 2 is an example of the droplet distributions that can be obtained from this cloud droplet size spectrometer. At present, the instrument has not been fully calibrated so values for the relative size and the relative number have not been obtained. This instrument obtains a cumulative drop size spectra running from approximately 100 microns diameter to approximately 4 microns diameter. These curves are obtained by measuring the amount of light scattered from individual particles as they pass through the sensing volume of the instrument. The instrument requires two seconds to obtain a full droplet size spectra. Since the airplane is traveling at approximately 50 meters per second, it requires 100 meters of air space in order to obtain a complete droplet size spectra.

It is hoped that this aircraft will be flown in a cloud over the East Central Illinois raindrop cameras and cloud droplet size spectra obtained at the same time that the drop cameras are registering the raindrop size distributions. This will permit concurrent analysis of the changes in spectra that may be occurring in moving from liquid water in cloud size spectra to the liquid water in raindrop size spectra.

SUMMARY AND CONCLUSIONS

The raindrop data collection program for the East Central Illinois Network is proceeding as planned. The problems that have arisen in obtaining coordinated time pictures from the two cameras and with the radars are solved and the cameras will be operated during the rainfall in the Pall season. The third drop camera has been partially installed in the East Central Illinois Network and as soon as the rest of the equipment arrives from New Mexico, the installation will be completed. The 30-inch paraboloidal mirror from New Mexico will be resurfaced during the winter when little rain normally occurs in central Illinois.

The drop analysis program is proceeding with the inventory of unmeasured film slowly being reduced. The program for processing of the raindrop camera data on IBM 7090 has been completed but not proven on the machine.

PROGRAM FOR NEXT INTERVAL

Emphasis will be placed in obtaining concurrent radar and dropsize data from the East Central Illinois Network. The data from Mt. Vithington will be measured and the distributions scanned for further information on the manner in which the hail spectra enters the distributions. The computer program for the IBM 7090 will be proven during the coming month and the measured, but un-analyzed, data will be processed as soon as the program is ready.

Continued attempts to decide whether coalescence fitting curves are significant with respect to the type of raindrop distributions actually measured will be made. Curves will be fitted to the Majuro data which, in general, should have been of a warm rain type and would be expected to show the best coalescence fitting of any of the data so far attempted.

A case study will be made on at least one of the storms obtained over the East Central Illinois Network during the late summer or early fall. The case study will include as detailed a radar analysis and wind field plots as is possible from the existing data.

PERSONNEL

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

Name and Title	Starting Date	Hours Worked	Terminated
G. E. Stout Project Director	10/l/6l	40	

Name and Title	Starting Date	Hours Worked	Terminated
Eugene A. Mueller Electronic Engineer	10/l/6l	4.08	
Edna M. Anderson Meteorological Aide I	10/l/6l	510	
Dorothy A. Gfurney Meteorological Aide I	10/l/6l	510	
Charles P. Medrow Electronics Technician	10/l/6l	510	
Vernon D. Ashmore Laboratory Assistant	10/l/61	52	8/17/62
Nazir A. Ansari Statistical Clerk	10/l/6l	502	
Victor E. Schulze Student Assistant	10/1/61	163	9/l4/62
James R. Poling Laboratory Assistant	5/21/62	125	8/24/62
Alfred S. Davis Research Assistant	6/11/62	213	8/21/62
Mary S. Spreckelmeyer Statistical Clerk	6/25/62	157	8/31/62
Janet M. Grimes Statistical Clerk	6/25/62	169	9/11/62
Marian E. Adair Meteorological Aide I	9/24/62	17	
Ileah W. Trover Statistical Clerk	9/10/62	60	
Margaret A. Coy Laboratory Assistant	9/4/62	69	
Ruth V. Eadie Meteorological Aide I	ll/l3/6l	510	

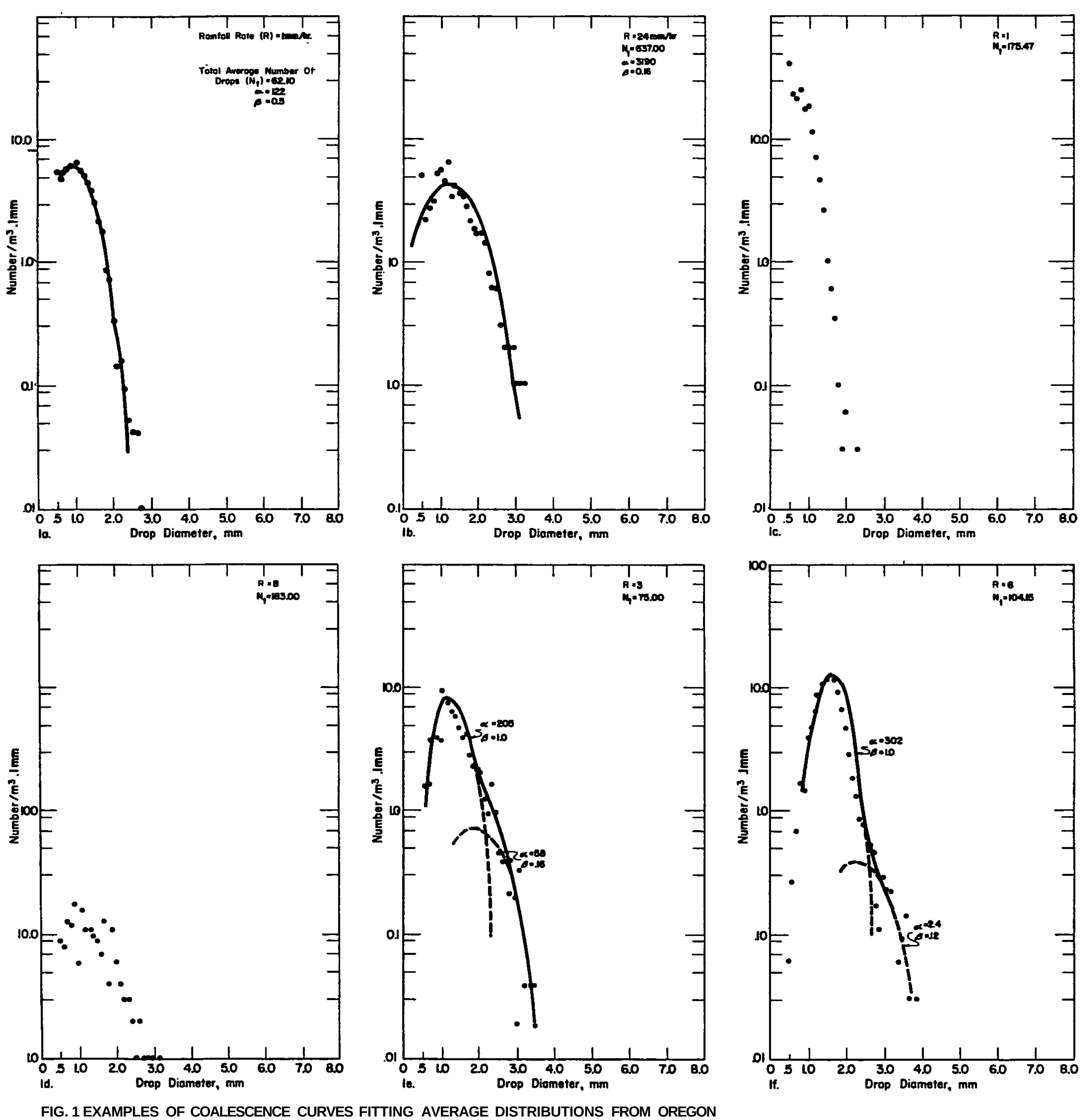

FIG. 1 EXAMPLES OF COALESCENCE CURVES FITTING AVERAGE DISTRIBUTIONS FROM OREGON

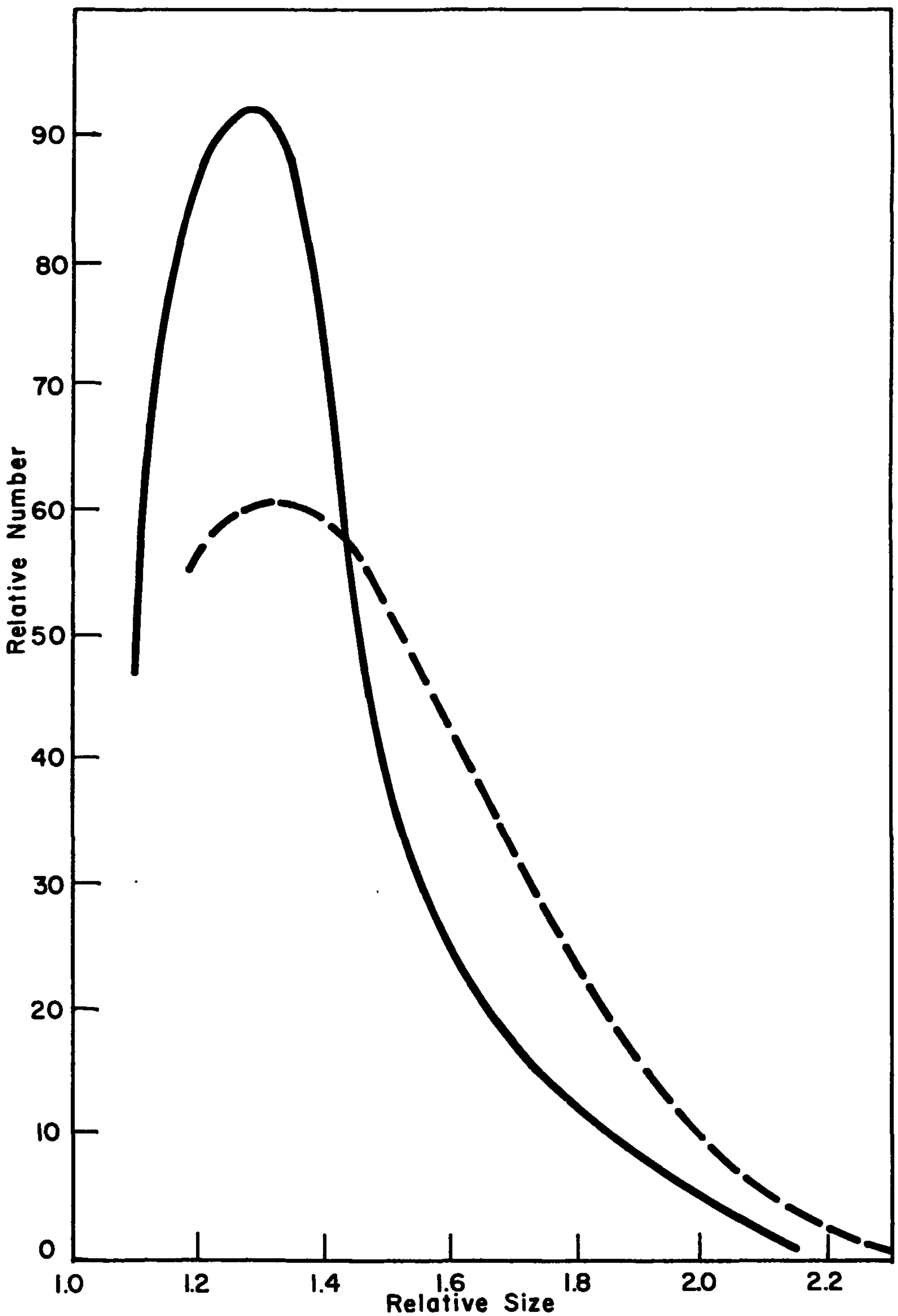

FIG. 2 TWO ADJACENT CLOUD DROPLET SPECTRA OBTAINED ON 9-27-62 WITH DISDROMETER IN CUMULO-STRATUS CLOUDS.