A COMPARISON OF RAINDROP SIZE SPECTRA BETWEEN MIAMI, FLORIDA, AND CORVALLIS, ORGEON

ROBERT CATANEO
Illinois State Water Survey

ABSTRACT.—Corvallis, Oregon, and Miami, Florida, two locations where raindrop data have been collected using the raindrop camera, a device which photographs raindrops as they fall, have been compared with respect to the raindrop spectra that have been determined with the camera. The spectra were contrasted with respect to total number of drops (N_T) per average rain rate, per cubic meter of sample, geometric mean diameter (D_G), which is associated with a log-normal distribution, mode diameter (D_M), and the diameter of drops at which half the liquid water content lies above that diameter and half below (D_L). Results indicate that, for similar rainfall rates, Corvallis, Oregon has more of the relatively small drops as well as more of the relatively large ones, than Miami, Florida. As a consequence of this, it is found that greater radar reflectivities exist at Corvallis than at Miami for the same or similar rainfall rates.

Much data have been collected with the raindrop camera, as described by Jones and Dean (1953) and Mueller (1960). These data include drop-size distributions for rains in several climatic regions throughout the world, and were obtained in an attempt to establish relationships between radar reflectivity and rainfall rate for these regions.

In the following discussion, a drop-size distribution is characterized by the number of drops in each 0.1 mm size interval from 0.5 mm - 7.9 mm in diameter. To date, all of the analyses have not been completed, although radar-rainfall relationships have been determined for most of the locations. Of course, statements concerning relationships involving rainfall rate (R), and the radar reflectivity factor (Z) must necessarily involve a discussion of the kinds of drop-size distributions that exist during the rains, since Z is directly dependent on D^6, the sixth power of the drop diameters, where:

$$Z = \sum_{D=0.5}^{D=7.9} n_D D^6 \qquad (1)$$

n_D being the number of drops of diameter D. If unique distributions existed in nature for various climatic areas, then unique Z-R relationships would follow. Unfortunately, this is not the case. However, an examination of the raindrop-size spectra that do exist would certainly be of interest and value in any attempt to establish Z-R relationships. Two locations where raindrop data were collected, Miami, Florida, and Corvallis, Oregon, have been compared with respect to their drop-size distributions, and the results are presented herein.

Method of Analysis

Briefly, the raindrop camera takes seven pictures, approximately 1½ seconds apart, at the beginning of a minute, and then becomes inactive for the remainder of the minute. Each frame represents a volume of about 1/7 cubic meter, so one minute of data represents approximately one cubic meter. The drops are measured individually, and their number and size are punched onto data cards.

In order to discover general trends and characteristics associated with the distributions, it was necessary to examine average drop-size spectra in the two locations, rather than individual minutes of data. The averages were determined as follows. The data from each of the two locations were sorted in ascending order according to rainfall rate, and then grouped into intervals 1.0 mm/hr wide at the lowest rates, increasing in size at higher rates. The average number of drops per cubic meter in each 0.1 mm increment of drop diameter from 0.5-7.9 mm, along with other related parameters, was calculated by a computer. For this study, all types of rains were grouped together; there was no stratification of the data according to various rain types or synoptic types, for example, since the purpose of this study was to make general comparisons between the two locations. At Miami, a total of 2506 cubic meter samples were collected, and 1703 cubic meter samples were collected at Oregon. It may be of interest to note that approximately 65 percent of the samples collected at Miami were associated with convective type precipitation, while Oregon samples were on the order of 33 percent convective in nature.

One method of comparing two groups of distributions is to examine the N_T's for the same or similar rainfall rates from the two locations on log-log coordinates, where N_T is the total number of drops per cubic meter of sample for a particular rain rate. Fig. 1 is an example of this where the ordinate represents Oregon, and the abscissa represents Miami. Each point then represents the average total number of drops for each location for the same average rain rate. Now, it is somewhat difficult to point to one parameter and state that it alone, or together with another, describes a particular drop-size spectrum completely, so we should also examine other factors. In Figs. 2A, 2B, and 2C, three comparisons are made between the two areas, on semi-log coordinates, with average rainfall rate as abscissa and D_G, D_M and D_L respectively as ordinate. D_M is the diameter of the mode of the spectrum, which is the

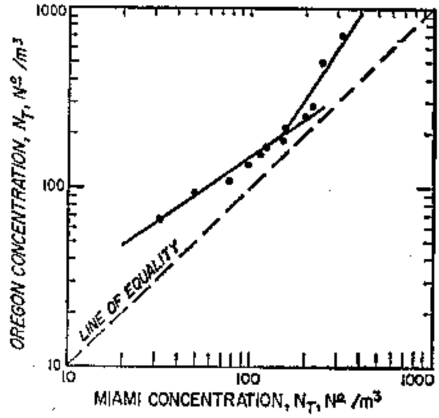

FIGURE 1. Drop concentrations for Miami and Oregon (from average spectra for all data, no stratification).

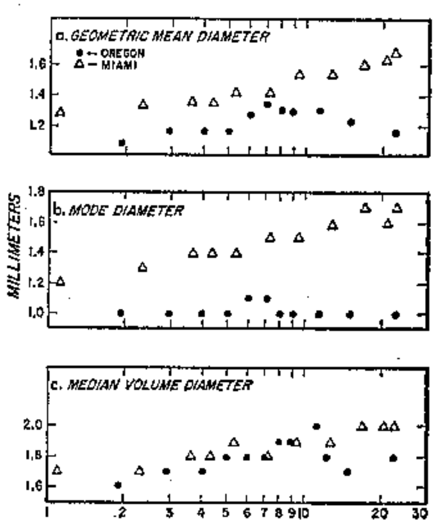

FIGURE 2. The mode diameter, the geometric mean diameter, and median volume diameter as a function of rainfall rate for Miami and Oregon.

diameter of the size drop that occurs in the largest numbers. D_G is the geometric mean diameter with:

$$\ln D_G = \frac{\sum_{i=1}^{i=n} n_i \ln D_i}{N_T} \qquad (2)$$

as described in an equation for a log normal distribution fit for the drop-size spectra, and D_L is the median volume diameter which is the diameter of the drop-size where half of the liquid water content of the distribution, for the one cubic meter sample, lies above that drop-size and half below. One should also examine the relationship between N_D and D, as in Figs. 3 and 4, where N_D is the number of drops of diameter D. There are other means of comparing spectra, but it is felt that the ones used in this discussion are the most directly related to the distributions.

Results of Analysis

Examination of the N_T comparison between the two locations (Fig. 1) reveals that, for the same rainfall rate, Oregon consistently has more drops than Miami. This would imply that Oregon has smaller drops than Miami, or more specifically, that some average drop-size parameter, such as D_G, D_M or D_L is greater for Miami for the same or similar rainfall rates. In Figs. 2A and 2B this seems to be the case when R is compared with D_G and D_M, respectively; both parameters are consistently higher for Miami for the same or similar rainfall rates. However, D_L for Miami is only slightly higher than for Oregon. (Fig. 2C)

To state flatly that Oregon has smaller drops than Miami would not be describing the situation completely; a more detailed examination is necessary. Figs. 3 and 4 are comparisons of spectra for similar rates from both locations. The particular spectra that were used appear to be representative of their respective areas. These figures indicate that Oregon has more of the smaller size drops, but also more of the larger drops, with a temporary reversal in the vicinity of the Miami mode. This reversal, incidentally, is the reason why the rates are very nearly equal, for, quite obviously, if Oregon had more drops of every size, the rates wouldn't be similar. Therefore, a more accurate statement concerning the two areas would be that Oregon has both more of the relatively small and relatively large drops, rather than that Oregon has smaller drops.

In addition, an examination of the Z-R relationship from both locations reveals that for equal rainfall rates, Oregon has greater reflectivities for R greater than 0.8 mm/hr. The actual Z-R equations for both regions are as follows; for Oregon,

$$Z = 301 \ R^{1.64} \qquad (3)$$

for Miami,

$$Z = 286 \ R^{1.43} \qquad (4)$$

where Z is in units of mm^6/m^3 and R is in mm/hr. On a plot of R vs. Z on log-log coordinates, the linear relationship for Oregon has a greater slope and a greater Z-intercept (at R = 1.0 mm/hr) than Miami, as is revealed in Fig. 5. This means that for equal rainfall rates the reflectivities for Oregon are indeed greater. It may be concluded from this, that Oregon has larger drops than Miami, which agrees with the above analyses, although it was

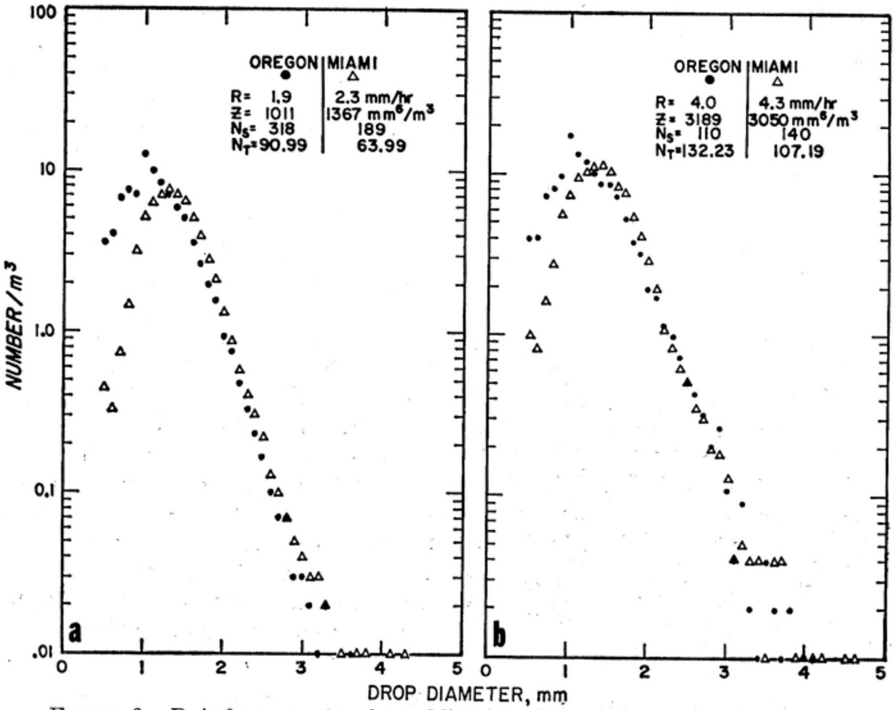

FIGURE 3. Raindrop spectra from Miami and Oregon.

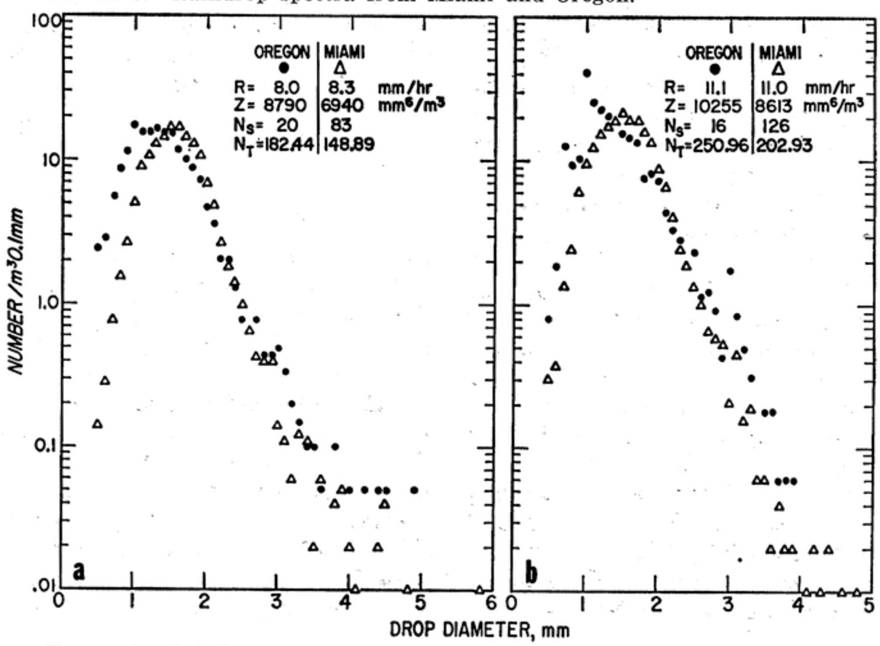

FIGURE 4. Raindrop spectra from Miami and Oregon.

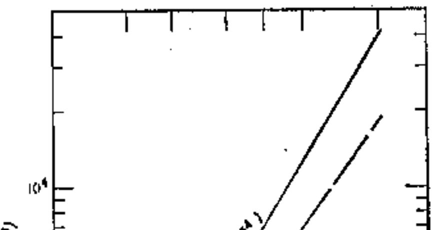

FIGURE 5. Z-R regression lines for Miami, Florida and Corvallis, Oregon.

found upon examining the actual drop distributions that in addition, Oregon has more of the smaller drops. So apparently, the greater number of larger drops in Oregon represents a sufficient enough difference to result in greater reflectivities, since Z depends directly on D^6, but not large enough to produce greater D_0, D_M and D_L values which are linearly dependent upon D. This agrees with the fact that the N_T's at Oregon are greater than at Miami for the same or similar rates. The standard error of estimate for the Miami regression line in Fig. 5 is 0.198 and for Oregon it is 0.136. A standard error of estimate of 0.136 on R means that for a given measurement of Z an error of less than $\pm$ 37 percent on R can be expected 68 percent of the time.

It should be pointed out that the number of samples (N_S) used from both areas in Figs. 3 and 4 varied substantially, with Miami having four times the number of Oregon in Fig. 4A, and eight times the number in Fig. 4B. There are two reasons for this. First, more data were collected at Miami, and secondly, much of the data taken at Oregon were rains of very low rates; for example, approximately 70 percent were rates of less than 2 mm/hr. It is believed, however, that the number of samples taken at Oregon is adequate for a valid comparison. It should also be noted that many of the corresponding N_T's for the relationship in Fig. 1 were arrived at by interpolating between rates on a R-N_T curve in order to obtain the same rainfall rate for both locations when attempting to establish a point on the N_T-N_T curve.

SUMMARY

The drop-size spectra at Oregon and Miami were compared with respect to D_0, D_M, D_L and N_T. The investigation revealed that Oregon rains have larger numbers of drops for the same rainfall rates. Upon closer examination, it was found that the Oregon rains have more of the smaller drops as well as more of the larger ones. The parameters used for the comparison are not necessarily the only ones that are available for valid analyses, but to date appear to be the most appropriate. A similar type of study is under-

way for the other locations where raindrop-size distribution data have been collected, and the results from those will be available in the near future.

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