SHORTER CONTRIBUTIONS

NOTE ON COMPARISON OF LIQUID WATER CONTENT OF AIR WITH RADAR REFLECTIVITY

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This study compares quantitative measurements of liquid water content of the air with radar reflectivity data obtained by the Massachusetts Institute of Technology Weather Radar Research Project during the period September 1947 through April 1949.

Liquid water content of the air was measured in flight with a large capillary collector (5). Radar controlled flights were made during periods of inclement weather and numerous *runs* were made through precipitation cells. (A *run* is defined as a single pass through a portion of a storm cell on an azimuth directly toward or away from M.I.T.) During a run, simultaneous data were recorded on all flight instruments and by the ground radar for that portion of the cell through which the plane was flying at the time. Liquid water content readings were taken in the airplane at intervals of approximately 10 seconds. In this study 357 separate points were considered, from 47 runs, during 18 flights. More detailed descriptions of the flight operations are given in (2).

Radar reflectivity per unit volume is a measure of the fraction of power returned to the radar by the precipitation and is equal to the sum of the individual radar-scattering cross sections of the drops in a unit volume of air. The data used in this study were obtained from an SCR 615-B radar (10 cm).

If all drops are considered equal in size, the relation between the radar reflectivity, η, and the liquid water content of the air is given by (1)

$$\eta \propto M_d d^3,$$

where

η = radar reflectivity per unit volume (mm^2/m^3),
M_d = liquid water content of the air (gm/m^3), and
d = drop diameter (mm).

When the precipitation contains drops of various sizes (1),

$$\eta \propto \sum_d M_d d^3,$$

where the summation is carried out over all drop diameters d.

If the drop size is uniform, or the drop size distribution remains constant through any given period of measurement, then the relation between the liquid water content of the air ($M = \sum_d M_d$) and the radar reflectivity, η, is a linear function.

An attempt was made to make a point to point correlation of M and η, using all 357 cases. The correlation coefficient was 0.20, a rather low value. As a next step the cases were arranged in groups according to type of precipitation, *i.e.*, thunderstorms, showers, and continuous rain. This roughly divided the drop sizes into relatively large, medium, and small sizes. The graph of these points showed demarcation between the types of precipitation, but the correlations within each group were not as high as expected, probably due to sampling errors. Sampling errors may be of two types. First, the echo measured by the radar is returned by a large volume of precipitation due primarily to beam width, whereas the capillary collector samples a relatively infinitesimal volume of air stretched along the line of flight. Second, any errors in space-time coordination between air and ground

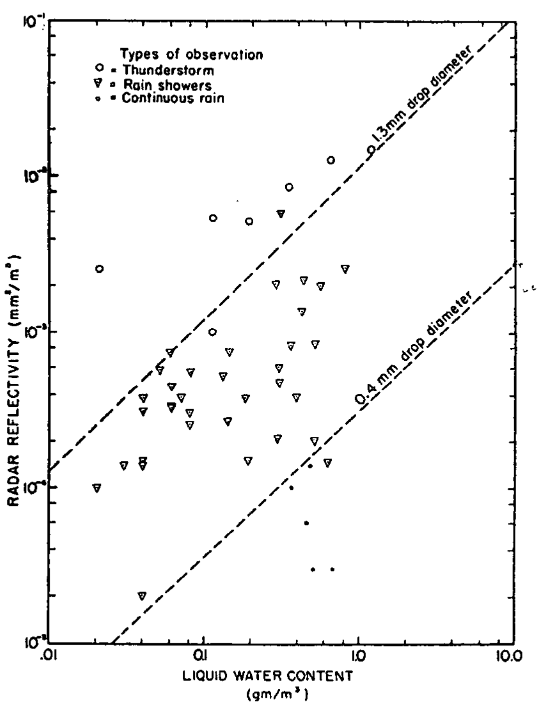

FIG. 1. Relation between liquid water content of the air and radar reflectivity for different types of precipitation.

[1] Based on a study by the Weather Radar Research Project under Contract No. W36-039-sc-32038 with Evans Laboratory, Signal Corps Laboratories, Belmar, New Jersey.

measurements will appear as sampling errors. Because of these uncertainties, small time corrections were applied arbitrarily so as to bring the radar reflectivity maximum into coincidence with the liquid water maximum within each run, and these maximum values were then used in the correlation study. These points, 47 in number, gave a correlation coefficient of 0.54. Although this correlation is significant, the most important result appears to be the separation of measured points into groups according to types of precipitation (fig. 1).

The slope of the diagonal lines in fig. 1 corresponds to the linear relationship discussed above. These particular lines were calculated for uniform drop sizes of 1.3 mm and 0.4 mm.[2] The results suggest that the reflectivity is more dependent on the type of precipitation (diameter of drops) than on the actual amount of liquid water.

This study indicates, then, that any comparison of radar return with liquid water content, or precipitation rate, should consider the type of precipitation, instead of averaging all storms together. Earlier studies [(3), (4), (6)] which compare precipitation rates with radar return have made some allowance for differences in drop sizes by using average drop size distribution for each precipitation rate, but more significant correlations might result if the data were reconsidered according to precipitation type.

[2] These values of drop diameters seem rather small. Later studies have indicated that all the measured values of radar reflectivity are low by a constant factor. The relative values, however, are believed trustworthy.

REFERENCES

1. Austin, P. M., 1948: A group of graphs showing estimated radar return from precipitation. *M.I.T. Weather Radar Research Project Tech. Report No. 6.*
2. Cunningham, R. M., and Miller, R. W., 1948: Five weather radar flights: measurements and analysis. *M.I.T. Weather Radar Research Project Tech. Report No. 7.*
3. Hooper, J. E. N., 1948: Measurement of radar echo intensities from precipitation. *T.R.E. Report T 2116.*
4. Marshall, J. S., Langille, R. C., and Palmer, W. McK., 1947: Measurement of rainfall by radar. *J. Meteor.*, 4, 186–192.
5. Vonnegut, B., 1948: A capillary collector for measuring the deposition of water drops on a surface moving through clouds. *Rev. of sci. Instrum.*, 20, 110–114.
6. Wexler, R., 1948: Rain intensities by radar. *J. Meteor.*, 5, 171–173.