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METHODOLOGY OF RADAR-RAINFALL QUANTITATIVE STUDIES

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This is a summary of the methods used in solving an existing problem of meteorology and climatology. The problem concerns efforts to measure more accurately areal rainfall amounts resulting from high variability type precipitation. For many areas of the world subject to the thunderstorm type of rainfall, our present climatological data concerning rainfall amounts cannot give a true areal presentation of the occurrence nor the quantity.

Ordinary rain gage networks cannot provide detailed information on the distribution of thunderstorm rainfall, and the cost of establishing rain gage networks for this purpose over large areas would be prohibitive. A few scientific groups, associated with related state and federal government agencies, after World War II began to investigate the ability of radar to provide the detailed information on storm rainfall.

World War II introduced radar, a radio-wave detection apparatus, which has since been adapted to detect precipitation. Preliminary studies have concerned the use of radar for determining the mechanism of rainfall. However, more recent studies using specialized analytical methods and radar modifications are proving that radar can also be used for quantitative measurements of rainfall. To this end such research in Illinois has shown that results from one radar set are at least as accurate as data obtained from a network having one gage to 200 square miles, and often as accurate as one gage to 50 square miles. Since December 1950, Illinois has had one gage for every 230 square miles.

The Illinois State Water Survey, to compare radar and rain gages, has used during the past five years three small watersheds in Illinois for research studies. During 1951 the Goose Creek watershed lying 20 miles west of Champaign was used as a pilot study area. It totaled 49 square miles, and had 33 recording rain gages resulting in a ratio of one gage per 1.5 square miles all located in a radial geometric pattern (fig. 1). Detailed comparative studies of rain gage and radar results were made in the following manner.

Radar search was run 24 hours daily during the summer months on 120 mile range viewed on a Plan-Position Indicator scope, which is a presentation resembling a map view of the studied area with the radar set at the center. When rainfall echoes appeared, 35 mm photos, one frame per minute, were taken of the PPI scope for use in later analysis.

Immediately, the question arises concerning how radar evaluates rainfall amounts in the rain echoes. A radar beam is basically a radio wave signal which is sent out from the radar set, and if reflected back by rain or large metallic objects creates a 'blip' on the scope, correct for distance and azimuth from the radar set. When the receiver sensitivity is

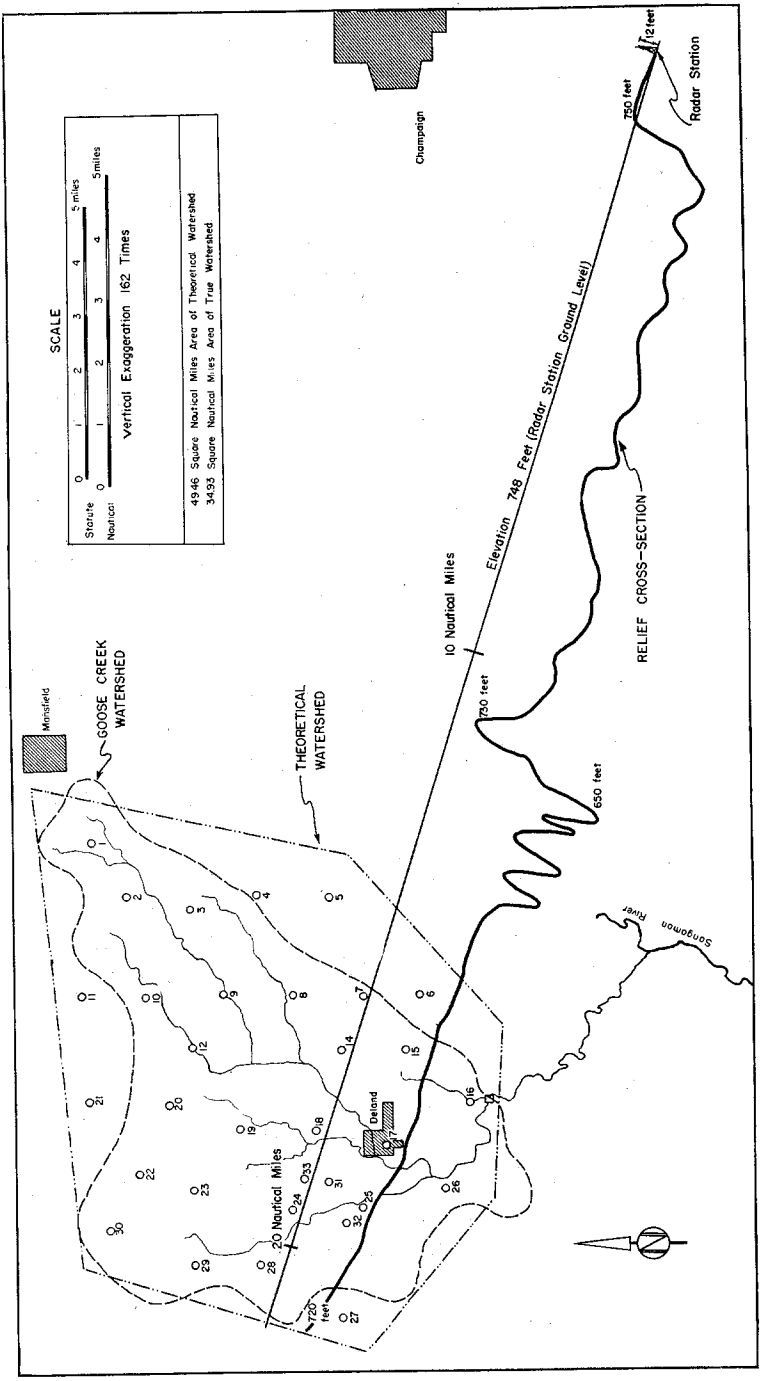

FIG. 1.—Map of radar station and rain gage location in respect to Goose Creek watershed.

decreased, it takes bigger targets to get an echo on the radar scope, and for rainfall these increased targets must be higher rainfall rates and/or larger raindrops. Consequently, by decreasing the receiver sensitivity in measured 'steps' rain echoes can be described and analyzed quantitatively (fig. 2). These electronic 'step' values are related to known rainfall rates. A picture frame is taken of each step every minute including the total number of steps necessary to eliminate even the most intense rain-

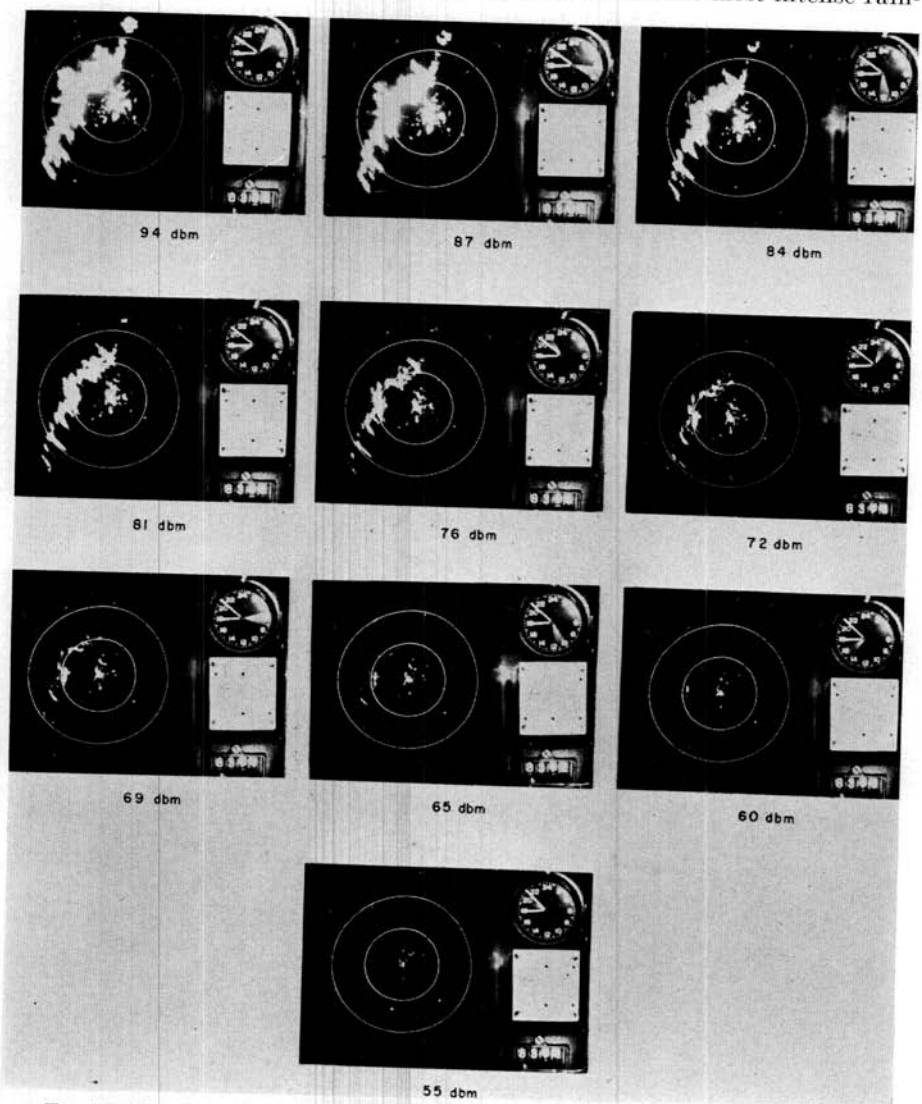

FIG. 2.—Isoecho contours obtained from ten steps of reduction with automatic sensitivity control. Smaller echoes represent areas of heavier rainfall rates.

fall core in the echo. From the film of each storm, each individual frame must be projected upon a large base map of the watershed, and isoecho (contour) lines traced off for each series of 'steps'. For each storm there are several hundred frames, and the aforementioned tracing process, isoecho map planimetering, plus final statistical calculation becomes a time-consuming process.

The Storm of September 26, 1951

Over a period of 40 minutes during the evening of September 26, 1951, a long, narrow cold front squall line with several individual thunderstorm cells moved across the Goose Creek watershed from the northwest (fig. 3). Excellent rain gage and radar data were collected with 0.79 inches of rainfall representing the maximum rain gage catch. The radar calculations indicated 9 percent less total rainfall than the total rain gage accumulation. Analysis proved that for this storm radar was as accurate as one rain gage per 22 square miles (11).

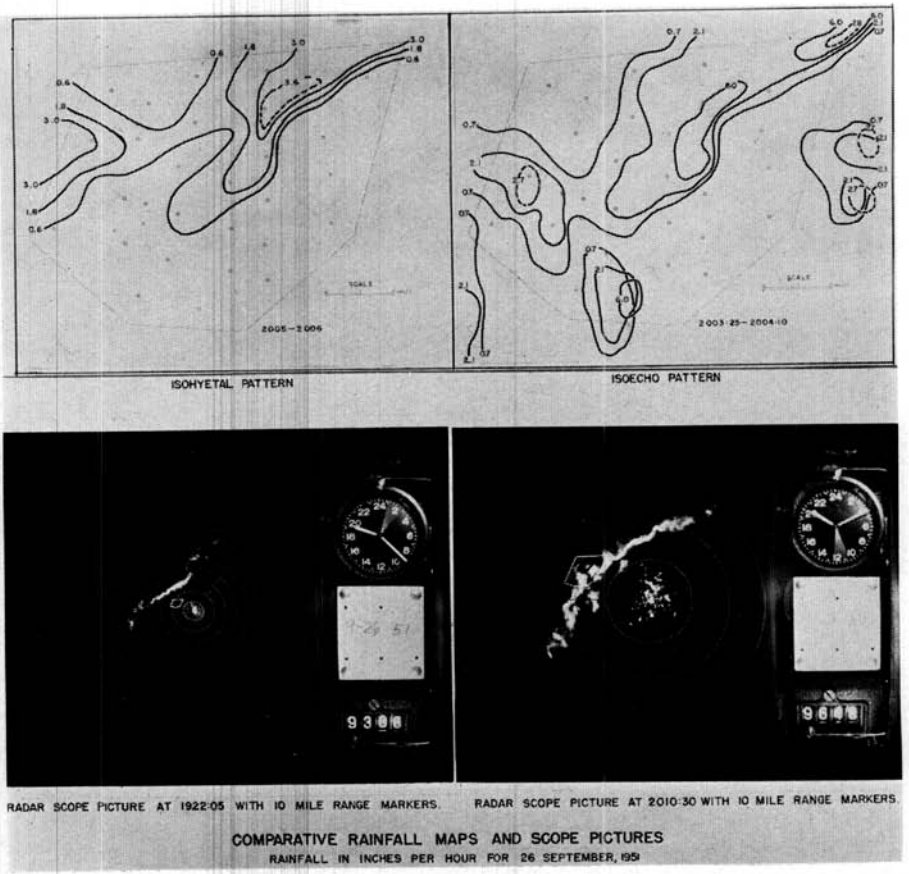

Fig. 3.

Comparison of the isoecho and isohyetal map patterns (fig. 3), which were mapped at similar time intervals while the storm was over the watershed, indicates two relevant factors common to most comparisons of radar-rain gage patterns. The first is that the leading edges of most patterns, the eastern side, are the best criteria for comparison. The second concerns the lack of exact correspondence between patterns and rainfall rates, most of which can be attributed to present limitations of radar's utility in rainfall detection.

Limitations of Radar-Rainfall Detection

Since radar signals are straight line-of-sight waves unable to remain at the same elevation owing to the earth's curvature, only high-level rainfall patterns are viewable at distances much beyond 80 miles from the radar. Consequently, rain from lower-level clouds will be missed at the longer ranges. Furthermore, it must be realized that the signal plane intersecting falling rain at a certain distance aloft is related to distance, and consequently actual rainfall patterns on the ground are often different because of wind drift, change in drop size, and evaporation occurring below the radar observation level.

Radar reflection is a direct result of size of raindrop, and the present lack of detailed knowledge on raindrops limits precise evaluation of rainfall rates. Stabilization and standardization of present radar equipment is lacking and must be accomplished before accurate comparable data can be expected. Much present-day equipment tends to be unavoidably variable in electronic accuracy.

Possibly the greatest limitation in the use of radar in measuring rainfall quantitatively is the aforementioned time-consuming procedure of analysis. However, work is being done on an instrument which will do the complete analysis and computation process electronically. With so many limitations the utility of radar may appear questionable, but it must be remembered that the present status of this research represents only the initial phases of work. Many of the other limitations have foreseeable solutions, and will be eliminated as research moves foreward. The outlook for using radar in quantitative rainfall study is very promising.

Geographic Qualities and Summary

In meteorology and hydrology, and therefore in some aspects of geography, many problems require determination of the total or average amount of rainfall in a given area. The data available for such determinations have usually been the collection of rainfall in rain gages spaced rather sparsely over the area for which estimates have been desired. The question arises then as to how well the average precipitation in an area is measured by gages. This problem is especially acute in measuring precipitation for the thunderstorm type of rainfall.

The pioneer work done on radar usage for investigating isolated precipitation seems to be proving significant in obtaining the data desired. This significance directly and indirectly relates to many research and applied phases of geography. In

respect to agricultural groups, large corporations and government agencies interested in water resources, this radar-rainfall areal analysis and measurement find relevance. The study of areal variability of rainfall definitely has a significance from place to place on the earth's surface and a resulting geographic usefulness.

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