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USE OF RADAR AS A SUPPLEMENT TO RAINGAGE NETWORKS

by

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INTRODUCTION

The USDA Southwest Rangeland Watershed Research Center (SRWRC) is investigating the possible use and additional USDA need of a proposed National Weather Service (NWS) radar to be located in Tucson, Arizona. The radar might serve to supplement rainfall data being collected on the USDA Walnut Gulch experimental watershed near Tombstone, Arizona, and the Santa Rita experimental range south of Tucson. The 98-gage Walnut Gulch network of recording raingages has been operated for over 20 years, and the 8-gage network at Santa Rita for 4 years. The networks were established to identify characteristics of the high intensity, short duration thunderstorm rains of limited areal extent that dominate rainfall-runoff relationships in much of the southwestern United States. Based on data collected from these networks, the SRWRC has contributed many publications on thunderstorm rainfall characteristics to the scientific and engineering community. However, little work has been done to relate the development and movement of storm systems to runoff-producing rainfall.

The SRWRC has recently developed, and continues to work on, a combined 3 parameter occurrence and depth-area rainfall model for the Southwest (Osborn and Davis, 1977; Osborn et al., 1980). The model is based on data from USDA raingage networks and NWS weather stations in Arizona and New Mexico. The model parameters are latitude, longitude, and elevation. The model simulates rainfall "cells" and accumulates rainfall from the cells at selected watershed locations (raingages or dummy points) to simulate total storm rainfall. Although there appears to be a weak, but identifiable, preference for northwesterly (downslope, as well as prevailing wind direction) cell propogation at Walnut Gulch, we currently assume in our model that the propogation is random. We do not know if Walnut Gulch is typical of a larger region or is subject to local, possibly topographic, effects. If we can tie the apparent movement of storms based on our raingage networks to that suggested by radar echoes, we might be able to develop meaningful directional preferences to replace the random component in our model. Such a change could have significant effects, since runoff from a specific watershed may be affected significantly by how runoff-producing rain develops or "moves" on the watershed.

Also, operating a network of recording raingages for research purposes is becoming more and more expensive, and because radar has been shown to give quantitative statements as to thunderstorm location over watersheds (Kuo and Orville, 1973), radar might help us reduce the number of field trips we make during the thunderstorm season. In this paper, we investigate the need for and value of a proposed NWS radar for our, as well as other, work on rainfall.

RELATED STUDIES

In the early 1960's, the SRWRC obtained a 3-cm horizontal scanning radar unit from air base salvage at Davis-Monthan Air Force Base (DMAFB), Arizona. The radar was installed at the field station in Tombstone and was used for several years. We had hoped that the radar would help in quantifying thunderstorm rainfall (Osborn, 1962). It did not. We did feel that a more sophisticated unit, which would include a vertical scanning unit located at some distance from the watershed, might tell us more about storm dynamics, but we could not justify the cost of such a unit.

Several studies have been reported on the use of radar in combination with raingage measurements to improve thunderstorm rainfall estimates. For example, Wilson (1963, 1967, and 1970) reported on a study in which Oklahoma thunderstorm data were used to determine how the estimation of area rainfall by radar can be improved by using one or several raingages. He found that the error of radar measurements of storm rainfall amounts for a 1000 mi^2 area was reduced by 40% after the radar was calibrated with only one raingage. Similar studies might be appropriate in Arizona using the proposed NWS weather radar and the Walnut Gulch raingage network.

Complete 24-hour weather radar coverage has been available in Arizona since 1970, when a unit was installed at the Phoenix airport (approximately 175 air miles from Tombstone). Hales (1972) made a study of radar echo distribution in Arizona for July-August, 1971 based on the Phoenix radar. He found that in the Phoenix area "there is a surprisingly well organized pattern of diurnal distribution of convective activity, and that thunderstorms which begin in the mountains early in the day move gradually toward the deserts." Unfortunately, this study has not been repeated with more data. We assume that a 24-hour weather radar in Tucson would help to identify similar patterns (or the lack of such patterns) in southeastern Arizona, particularly in the region of Walnut Gulch.

Hales also found a high correlation between radar echoes and rainfall occurrence, but warned against using radar to predict rainfall intensities and areal extent. He published figures showing state-wide frequencies of hourly radar echo distribution for July and August, 1971. From these figures, we developed an hourly radar echo detection curve for Tombstone, and then plotted hourly rainfall occurrences (0.01 in. or more) at Tombstone for the same two months (Fig. 1). The two curves are highly correlated, suggesting that for ungaged areas radar could be useful in estimating seasonal rainfall occurrence.

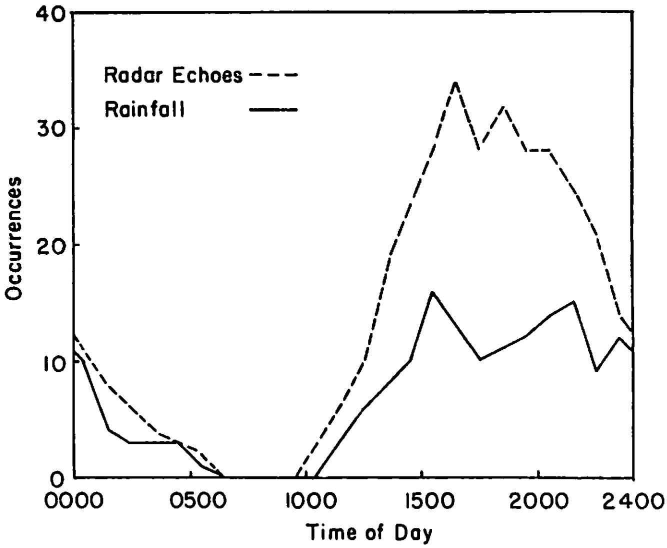

Figure 1. Comparison of radar echoes and rainfall occurrences at Tombstone, Arizona, July-August, 1971.

ANALYSES OF AVAILABLE DATA

At present, DMAFB operates the only weather radar in southeastern Arizona. The purpose of the DMAFB radar unit is to supply accurate weather information for aircraft operation, and busiest periods at DMAFB often are the same as those most interesting to us. Weather data is logged on an hourly basis at DMAFB (sometimes every half hour) during storm periods. Data include: storm system, type of precipitation, precipitation intensity, and the height, direction, and distance to the highest cloud top at the observation time as well as direction and distance (but not height) of other radar echoes.

Early in 1979, we contacted the DMAFB group responsible for radar operation, and they agreed to share their weather logs with us. We were unable to correlate echo intensity levels with rainfall intensity from the available data, but the summer of 1979 was relatively dry. Based on cloud top data (a less satisfactory rainfall indicator) one major event at Walnut Gulch was identified in the DMAFB logs. On 27 July (1610 hrs), a cloud top of 59,000 ft was indicated almost directly over Tombstone. Our raingage records showed that rain was falling on Walnut Gulch on that date at that time.

The time and duration of runoff-producing rainfall on Walnut Gulch are shown in Fig. 2. An isohyetal map of total storm rainfall for 27 July is shown in Fig. 3. Two storm "cells" are indicated, and the radar reading was made during the maximum runoff-producing period of the storm. Unfortunately, this is a small sample from which to reach any conclusions, but it is encouraging that the only recorded cloud top of over 50,000 ft above Walnut Gulch was simultaneous with intense recorded rainfall. This suggests that a continuously operating radar in Tucson not connected with military operation might be quite valuable in tracing storm development and movement in the vicinity of Tombstone.

We also used the radar data to correlate rainfall occurrences to clouds whose tops were 50,000 ft or higher. We then plotted these locations on an Arizona map and determined from Climatological Data publications (NOAA) the closest reporting precipitation station. Because of the limited areal extent of

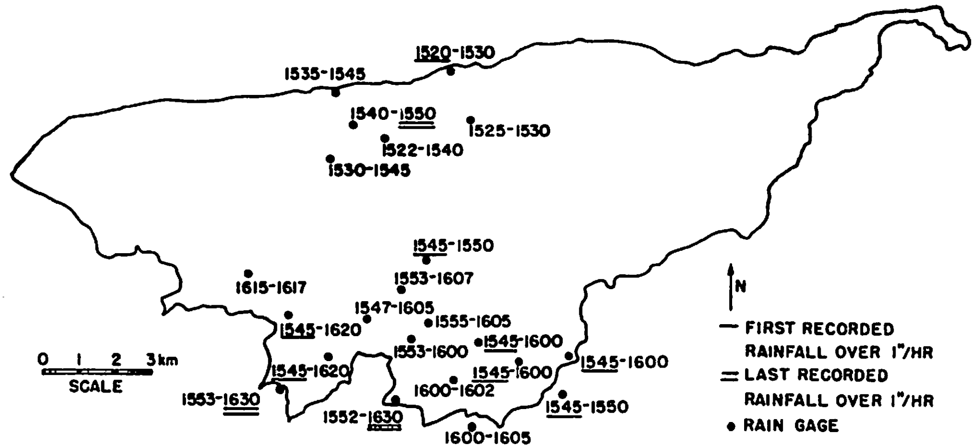

Figure 2. Periods of intense rainfall on Walnut Gulch, 27 July, 1979.

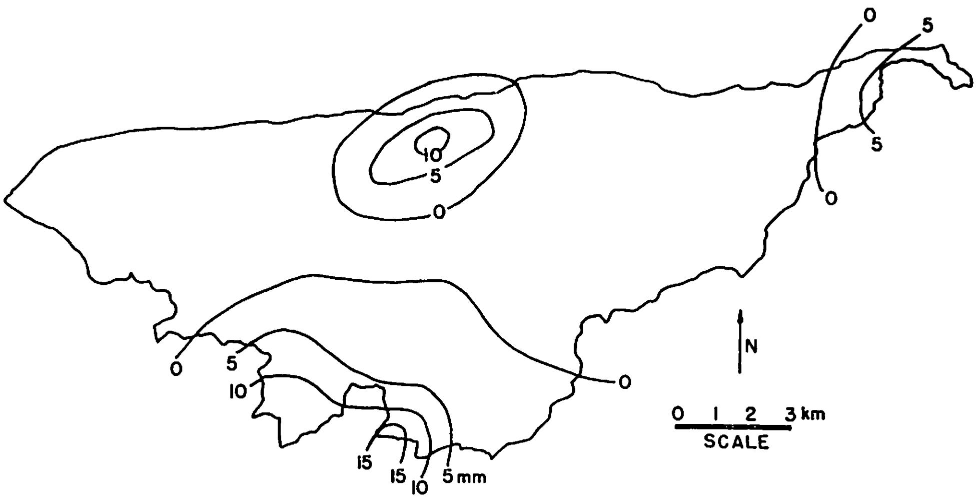

Figure 3. Total storm rainfall on Walnut Gulch, 27 July, 1979.

thunderstorms and the inherent problems in determining exact cloud location, the precipitation station had to be within a 10-mile radius of the cloud location. Of the 37 cloud locations determined in southern Arizona during the 1979 summer thunderstorm season, 26 or 70% had daily rainfall for the particular event-day. These preliminary results are promising, considering that the DMAFB radar is strictly for aircraft control and warning, and again suggest that a full-time weather radar could be valuable for our research program.

CONCLUSIONS

Analyses of available data and information suggest that a 24-hr weather radar located in Tucson would be of value to the USDA and, possibly, others involved in research on thunderstorm characteristics in the Southwest. In particular, the radar could be valuable in improving a regional rainfall occurrence, depth-area model developed by the USDA, SRWRC. Also, we may be able to improve rainfall estimates for ungaged areas by comparing the intensity of radar echoes with Walnut Gulch rainfall data. Finally, if we can pinpoint the location of runoff-producing rainfall, we may be able to operate our research watersheds more efficiently. The limited data from DMAFB suggests this is a distinct possibility. The radar could aid in relating large-scale regional storm development to rainfall-runoff relationships on relatively small rangeland watersheds. If 24-hr weather radar coverage is established in Tucson, we would hope to develop a mutually beneficial cooperative effort with the NWS to this end.

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