PROGRESS REPORT

OPERATION AND USE OF THE M-33 RADAR IN THUNDERSTORM STUDIES

by

John D. Marwitz

Civil Engineering Section
Colorado State University
Fort Collins, Colorado

Research Supported By
Great Western Sugar Company
National Science Foundation
Colorado State University Research Foundation

October 1963

CER63JDM43

OPERATION AND USE OF THE
M-33 RADAR IN
THUNDERSTORM STUDIES

by

John D. Marwitz

ABSTRACT

An M-33 Fire Control System, obtained through an equipment grant from the National Science Foundation was modified for use in tracking no-lift balloons and observing thunderstorms. The M-33 was located on a knoll about 1/2 mi. east of the CSU Engineering Research Center, Foothills Campus.

A method of launching no-lift balloons to a preselected height was developed. Serial launchings of no-lift balloons were attempted on 2 different days. They were successful on one day. No-lift and rawin balloons were tracked on other days.

Thunderstorms were observed by the M-33 to determine the modifications required to observed thunderstorms. The capability of the equipment was determined and a system was developed to use in observing thunderstorms.

OBJECTIVES

1. Develop a system to launch no-lift balloons to preselected altitudes and to track the no-lift balloon for 20-40 miles with the M-33.

2. Modify the M-33 radar for thunderstorm observation and develop a system for optimum utilization of equipment in observing thunderstorms.

3. Operate radar to determine general operating characteristics, manpower requirements, and operational costs.

PROCEDURES

1. Radar equipment

A M-33, Fire Control System, was acquired by Colorado State University in February 1963. The components acquired were:

2 - Fire Control Trailers
1 - Acquisition Radar Trailer
1 - 400 cycle, 30 kw, gasoline engine generator
1 - Test van (acquired June 1963)

The U. S. Forest Service at Colorado State University acquired three Fire Control Trailers to be used for trailers. We were allowed to cannibalize 2 of the trailers for spare parts. Spare magnetrons have been acquired through various sources.

For general characteristics of the M-33 system see Reference 2.

2. Radar modifications

a. 16 mm camera

A 16 mm Keystone movie camera modified to have a normally open lens was mounted in a rack above the PPI scope near the plotting console. It was fired manually. The PPI scope, a remote elevation indication dial, and an Oldsmobile 12 hr. clock were positioned to be in the field of view of the camera.

b. Plotting boards

The x-y predicting plotter and the upper right-hand plotter were disconnected. The x-y position plotter was used for x-y plotting. The lower right-hand plotter was used for range versus height plotting.

c. Attenuators

Two 25 db attenuators were connected in series with the 25 db attenuator already connected to the PPI scope on the control console. An echo can now be attenuated from 0 to-75 db by increments of 5 db.

d. AGC voltage versus time

An Esterline-Angus recorder was used to give a plot of automatic gain control (AGC) voltage versus time.

e. Air conditioner

A 5000 BTU air conditioner was mounted on an outside stand in front of the left-hand escape portal. This air conditioner proved to be inadequate and was replaced by a 14,500 BTU unit. The 14,500 BTU air conditioner was mounted on a bracket attached to the radar. The portal was enlarged for the larger air conditioner.

f. Copper screen

A 4 ft by 4 ft copper screen was mounted behind the lobing amplifier on the radar antenna. This was done in order to decrease the amount of back-scattering since the signal is projected through the antenna.

g. Telephone exchange

The telephone exchange console was completely removed from the radar.

h. Remote plotter control

A remote plotter control dial was connected in series from the plotting console to the control console.

3. Balloon equipment

Balloons were of two types: Rawin balloons and no-lift balloons. The rawin balloon was a 30 gm neoprene balloon which was inflated with helium to yield 400 to 500 feet per minute rate of rise. A radar reflector was attached to the balloon to permit radar tracking. The developed reflector consisted of a 16 to 18-inch diameter loop of baling wire to which four 3-ft strips of household aluminum foil were taped. The aluminum foil strips were taped together at the bottom so as to maintain the shape of a cylinder of dimension 18 inches in diameter and three feet in length during flight. Rawin balloons were released at the radar site and tracked visually with the periscope until the radar could be switched to automatic tracking. (Usually within 1 to 2 minutes after launch.)

The no-lift balloon assembly was towed to a preselected altitude by a tow balloon and separated by a fuse. The 30 gm neoprene "tow" balloon was filled with helium and weighed to determine the amount of lift in ounces (one ounce of lift produces approximately 100 feet per minute rate of rise). The no-lift balloon assembly consisted of a 30 gm neoprene balloon, radar reflector as described above, a pint plastic freezer bag of gravel for ballast, and 5 feet of cotton string to attach the no-lift assembly to the fuse and tow balloon. The fuse consisted of a 2 to 4-inch length of woven cotton clothesline cord. The cord burned at approximately 5 minutes per inch. As the cord burned by the wire, it would pull out and separate the tow balloon from the no-lift balloon assembly. Separation was readily observed through the periscope.

4. Balloon operation

The A scope was attenuated to -25 db. The antenna (periscope) was pointed downwind at a low elevation angle. The balloon launcher would light the fuse, walk to a position about 75 feet in front of the antenna, check the fuse to insure that it was still burning, and release the balloon on an even minute. He would then return to the tracking console to assist the radar operator in the "lock-on" procedure. Once the radar was locked onto the target, the plotter was activated and readings of time, elevation, azimuth, and range were made every one minute until separation and every 5 minutes thereafter. If the plotter was inoperative, readings were taken every 2 minutes. Five minute time hacks were recorded on both plotters. As the target moved away the attenuation was decreased to produce the proper "grass" on the A scope. The balloons were tracked until the radar broke track. It was possible to manually track a balloon through some interference or return to a track if the elevation and azimuth readings were known. This was done at ranges in excess of 30,000 yards.

5. Thunderstorm operation

Attempts were made to track the hail or rain spikes as described by Wilk (1). This was not possible because the thunderstorms were too homogeneous in structure. Generally, the radar would track downward and lock onto the ground.

Echoes were tracked with either the elevation, azimuth, or range control set to manual or a slow scan. The echoes were much too homogeneous for the radar to seek out the most intense portion.

When a thunderstorm came overhead, the antenna was pointed upward, and bases, and tops were recorded from the expanded A scope.

Scope overlays were made and the same 6 parameters as taken by the LRY CPS-9 (3) were recorded on the scope overlays. When scope overlays were not being taken the radar was placed in a slow scan with the 16 mm camera operating.

RESULTS

1. No-lift system

A reliable system was developed with which to place a no-lift balloon assembly at any desired altitude. The M-33 radar was found to be capable of tracking the no-lift assembly to ranges in excess of 40,000 yards.

Several good no-lift tracks were accomplished. Tracks were made at 6 hourly increments on one day. Those balloons which failed to separate gave good rawin sounding data.

2. Thunderstorm system

The optimum utilization of the M-33 radar was found to be in taking the same six parameters as observed by the CPS-9 with the additional capability of looking vertically upward at overhead thunderstorms.

3. M-33 operation characteristics

The M-33 was found to be a very sophisticated and intricate system which requires constant tuning and balancing of components. The system requires two full-time operators; one radar technician and one meteorologist. They must work very closely for maximum effect. The radar draws about 5 or 6 kilowatts of power. The gasoline engine generator uses 2 to 3 gallons of gasoline per hour.

DISCUSSION OF RESULTS

1. Problems: Balloons

The reflector used by Pennsylvania State University (2) was not large enough. Strips of aluminum foil taped to the balloon would break the balloon as it expanded at higher altitudes.

The cotton string and Jetex separation mechanism used by Pennsylvania State University was not reliable. Placing black powder or match heads in the cotton string failed to work satisfactorily.

The M-33 radar has such a large antenna that during windy periods it would not remain locked onto the balloon. The problem was helped considerably by placing the trailer on its jacks.

The voltage regulator on the gasoline engine generator would not always operate properly so that a constant monitoring of it was required.

Many "angels" were observed on the A scope when tracking balloons. These were normally "spiked" echoes within 10,000 yards of the radar. They were observed at the same location on different days. They were stationary echoes. On certain occasions another angel could be located by turning the antenna 180^0 at the same range and elevation angle. When an attempt was made to lock onto the echo the antenna immediately went to the ground even though the sharpest spike was well above ground. Because of these facts it is believed that they were back scatter from the antenna. Some decrease in the number of "angels" were observed after the 4 ft by 4 ft copper screen was placed over the lobing amplifier.

2. Problems: Thunderstorms

When the radar was locked onto a thunderstorm it invariably would wander through the echo and track the far side of the thunderstorm.

If considerable precipitation was reaching the ground, the radar would usually track into the ground or some stationary target such as mountain peaks, water towers, and radio towers.

An attempt was made to monitor the AGC voltage as a measure of reflectivity. The AGC voltage was tapped at several locations. The voltage was found to fluctuate too much to yield any meaningful data.

3. Accuracy of data

The no-lift balloon data are accurate to within $\pm$ 50 feet (2). The no-lift balloon plots should all be checked for accuracy and adjusted accordingly.

The accuracy of the thunderstorm data is unknown.

RECOMMENDATIONS FOR FUTURE USE OF THE M-33

1. Operate the M-33 radar from the top of the "skyline" road which is parallel to Horsetooth Reservoir.

2. Track balloons and thunderstorms as per the developed systems on on operational basis.

3. Make serial no-lift balloon tracks on certain days.

4. Use the "one camera" method of Quinsland (4) to locate cloud streets.

5. Mount 16 mm PPI camera to ceiling.

6. Modify camera to be fired as the antenna passes a particular azimuth.

7. Tune and balance all spare components using the test van.

8. Mount a radio or telephone in radar for communication.

LIST OF REFERENCES

1. Wilk, K. E. Research concerning analysis of severe thunderstorms. Illinois State Water Survey, Final Report, Contract No. AF 19 (604)-4940, December 1961.
2. Hosler, C. L., L. G. Davis and D. R. Booker, The role of orographic barriers of less than 3000 feet in the generation and propagation of showers, Progress report, Dept. of Meteorology, Penn. State Univ., December 1962.
3. Schleusener, R. A. and J. D. Marwitz, Characteristics of hailstorms in the high plains as deduced from 3-cm radar observations, 10th Wea. Radar Conference, 1963.
4. Quinsland, Donald E. Plane position representation of clouds using a one-photograph technique. Unpublished report prepared under sponsorship of Natural Sciences Research Center Summer Institute at Colorado State University, summer, 1963.