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UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

COLORADO-ILLINOIS OPERATIONAL AND ANALYTICAL PROGRAM UTILIZING A DUAL WAVELENGTH RADAR FACILITY

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Contract NCAR 186/71

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TABLE OF CONTENTS

INTRODUCTION

The immediate goals of this program were to develop and operate a dual wavelength radar system in Illinois and Colorado and to analyze the data so as 1) to evaluate the system's capabilities to detect hail, 2) to evaluate the system's capabilities to measure and map the liquid water content of storms, and 3) to interpret the data for various forms of hailstorm and rainfall research. The major efforts relating to this radar project during the annual contract period, 1 June 1971 thru 31 May 1972, concerned two basic areas of activity: development of the radar system to an operational level, and, secondly, plans for the analysis of resulting data. Unfortunately, the radar could not be made operational sufficiently soon in the 12-month period to provide data to actually launch the planned analyses. We had hoped to obtain operations in Illinois during the spring of 1972 and to gather data for comparison with the surface rain and hail data from the Eastern Illinois Network operated by the Water Survey under NSF GA-16917.

DEVELOPMENT OF DUAL WAVELENGTH RADAR SYSTEM

In general, the dual wavelength radar system was under development for the entire period. Much of the system design work of the Survey was accomplished on a prior NSF Grant, GA-18909. However, very little construction work was accomplished during that 18-month grant period, mostly as a result of the late delivery of many radar components.

The concrete pad for erection of the 10-cm antenna and associated equipment was completed in January 1971, but the antenna did not arrive in

Illinois until 20 September 1971. The description of the developmental work that was accomplished under this contract is listed according to the basic components of the system.

Various phases of the developmental work were conducted jointly with personnel of the Laboratory of Atmospheric Probing of the University of Chicago, who was also involved in a NCAR contract involving the radar system. The close cooperation of this group and our allowed the work to progress as rapidly as possible.

M-33 Radar

The 3-cm radar was modified to produce a 1-microsecond pulse. This change permitted a better matching of the 3-cm to the 10-cm radar. The modification consisted of changing power supplies, frequency modulator, and the pulse delay line. These modifications, in turn, required a change of the duty cycle of the magnetron, and as a result required considerable testing before the operation was successful. Power supplies of the M-33 were modified to provide power for just the 3-cm tracking radar which allowed the acquisition radar portion of the M-33 to be deleted but this did not change the loading of the power supply.

The M-33 also had to be changed from a 60 MHz IF system to a 30 MHz IF system in order to match the receiver in the automatic processor built by Control Data Corporation for the University of Chicago. This modification required the change of the automatic frequency control circuit from 60 to 30 MHz as well as changing receiver IF strips. A modified FPS-18 preamp was incorporated to provide a balanced radar system with the FPS-18 radar. The antenna for the M-33 has been regridded to allow its operation in higher winds. Digital encoders were installed on both axes of the M-33 radar to obtain digital antenna information to be available for use in the antenna pointing system. The M-33 triggering circuits also were modified to permit synchronization with the processor output signal.

FPS-18 Radar System

The FPS-18 10-cm radar system of the University of Chicago had been mounted in their 40-ft trailer prior to this contract. This work had been done by our staff under a subcontract from the University of Chicago. Some modification and maintenance were performed on the FPS-18 during the period of this contract. Specifically, difficulties were had with the water cooler, and a number of parts of the water cooler had to be changed. The FPS-18 was modified to accept the trigger from the CDC processor. This allowed it to be synchronized with the processor at a prf of 1/102 microseconds. This prf resulted in an unambiguous radar range of 83 nautical miles.

Pata-Control System

A van containing the data-control system was completely renovated during the contract period. This van was originally a spare parts van from a M-33 radar system. The original cabinets were all removed from the van, the walls painted, and new equipment installed.

Two VK-5 PPI repeaters, two VE PPI repeaters, and one VL-1 RHI repeater were installed in the van. Three of these scopes were fixed for routine photography and recording of data. Two VE's and one VK-5 which are to be photographed using 35-mm cameras and Polaroid cameras installed and attached to them. The camera mounts and hoods were designed and manufactured during the past year. The other two scopes were intended for real-time operator control scopes. Racks of the power supplies for the VK-5 scopes have been placed in the FPS-18 radar which provides more room in the data van at the expense of more cabling requirements.

Additional installations in the data-control van included the tape recorder, the CDC processor, the antenna-position controller, the antenna control system to keep the two antennas pointed in the same direction, and two cabinets for storage of film and magnetic tapes. Some of these components will be discussed further in other parts of this report.

A 36,000 btu/hr air conditioner was also installed in the van to provide the cool air required by the CDC processor. The data-control van also has heaters that were installed for wintertime operation.

Processor and Tape Unit. Although the CDC processor was not completed, it was delivered to the Illinois radar site on 17 March 1972. Following that time, engineers from the Control Data Corporation have worked to complete the processor through the end of this reporting period.

Difficulty was also experienced with the tape recorder purchased from Potter Instruments Company. This tape recorder was recommended by CDC and was the fastest one available at the time of the purchase. However, it has been found to be very erratic in its operation and has not been reliable. Potter technicians have been called and have worked on the equipment three different occasions.

At the end of May 1972 the processor was in the following condition: the hail processor was operating properly; the liquid water content processor was operating correctly; the Doppler processor had some operational difficulties; the quadrature detector was not operating; the in-phase detector was operating properly and some spectra could be observed.

Operations of radar system in Colorado during May 1972 have shown that the contour circuits from the processor were not as valuable as had been desired for real time evaluation of storm reflectivity values. This is partially due to the need for moving the antenna more rapidly than the integration times permit, and also due to the inadility of the radar operator to distinguish a sufficient number of contours. To obtain an immediately useful real time measurement of Z, an A-scope has been provided. It takes the output of the processor and displays it in an A-scope manner on a memory scope. It can be turned on and off at appropriate azimuths and allows an adequate measurement of the storm Z. Engineers from CDC continued to work on the processor during the May radar operations in Colorado.

FPS-1B Antenna and Radome

A number of difficulties were experienced with the 10-cm antenna, as delivered in Illinois by Radiation Systems, Inc.

A majority of the diffiuclties were a result of the pedestal drive system that was installed. When the equipment was originally delivered it was noted that a key in the azimuth drive coupling had fallen out and that one of the motors was free to turn without driving the antenna. On further inspection, and in attempting to repair this difficulty, it was noted that both of the azimuth brakes of the antenna had been burned out prior to delivery and our access to the radar. Initially, the antenna was installed in Illinois without azimuth brakes. The keyway and keys were reinstalled with a groove cut in the key for the set screw to engage. It was felt that this would satisfy the difficulty of keys falling out. However, this has proven to be an incorrect solution and keys are still a problem in the coupling. Later, a representative from ESCO who brought the pedestal for the antenna was available for one week. He installed roll pins in the shaft which prohibit the upper key from working loose. This indeed has been effective. However, the result of maintaining the key in the keyway has been that the wear has been transferred to the keyway itself. During May 1972 in Colorado, one of the coupler's keyway had work until it was 3/4" wide instead of 1/4" wide. This excessive play in the coupler allowed the antenna drive motor to pick up speed before engaging to the mechanical load of the antenna, resulting in very erratic antenna motions.

During the winter season of 1972, the shafts and couplings will be replaced. In addition, the patterns of the antenna, as delivered by RSI, have not been up to specifications. Pattern measurements both at RSI (Virginia) and in Illinois were accomplished. These pattern measurements indicate that the gain of the antenna is in excess of the 42-db specified, but the side lobes are much poorer than specified.

Much difficulty was experienced in assembling the antenna the first time (in Illinois) because RSI failed to provide spacers. The antenna was assembled without spacers, and thus it is not appropriate to tighten the antenna to the back structure. As time permits during the next contract year, the antenna pattern will be improved by careful measurements similar to those which have been accomplished by the National Center for Atmospheric Research with their comparable large antenna.

The radome was installed in Illinois on 2 December 1971. Figure 1 is a sequence of photographs showing the radome erection, a difficult task. In Illinois, the tie downs used for the radome were ground anchors which were driven into the ground. This was not an ideal method of tying the radome down, as the ground anchors have tended to drift outward under the applied load of the radome. Nonetheless, the structure was satisfactory in Illinois. On 10 December 1971, a storm system with winds approaching 90 mph occurred (record high values). The only radome damages were to the D-rings for the upper

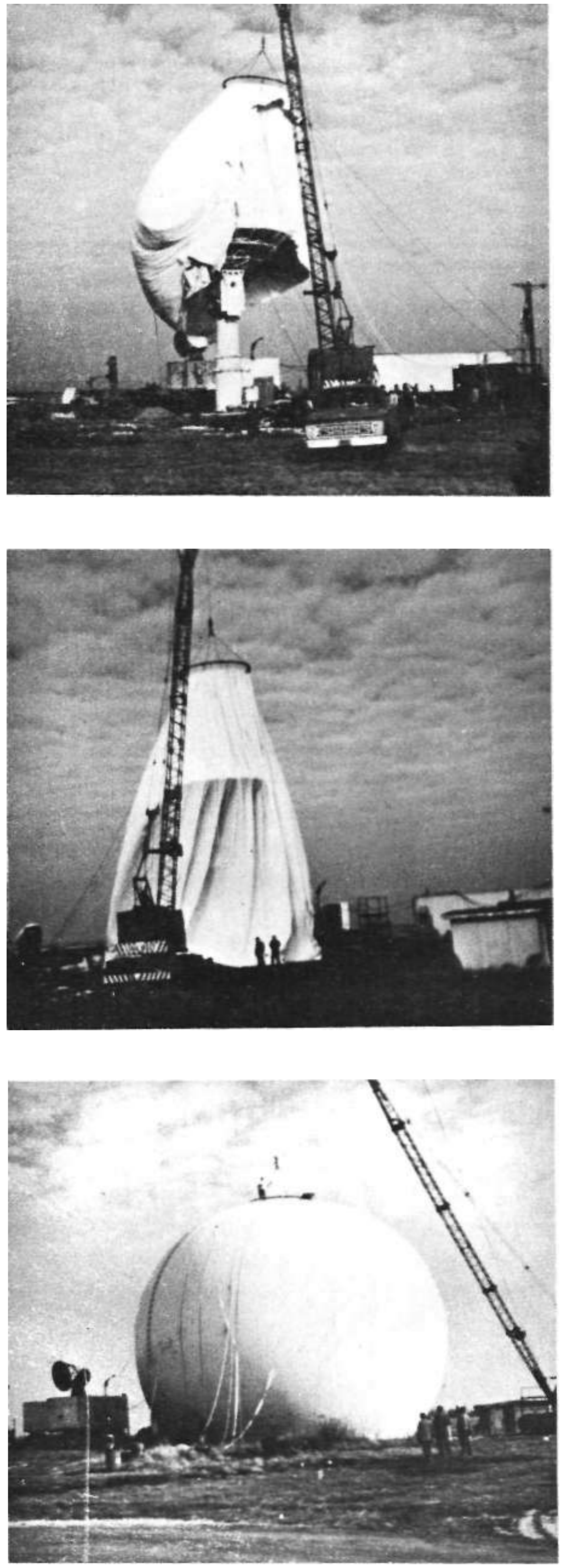


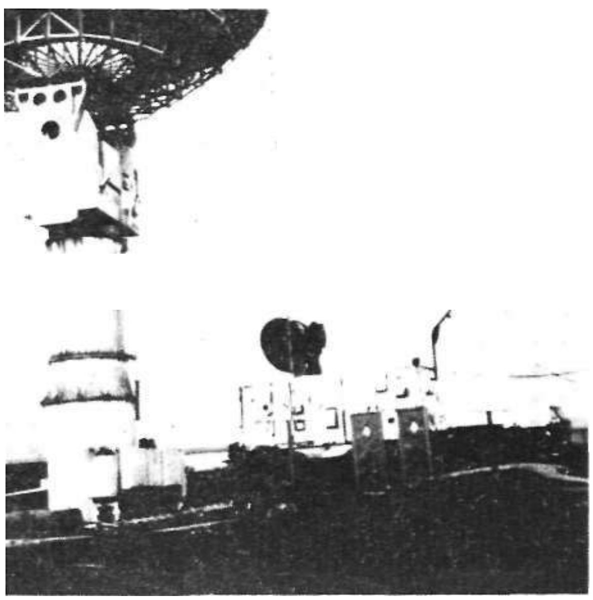
Figure 1. Sequence of photographs showing the erection of the radome over the 10am antenna in Illinois

guy wires. These rings were broken and the inner door of the airlock was damaged extensively. The inner door also tore a part of the radome material at that point. It is our belief that the entranceway of the radome is not appropriately designed, and a new design has been fabricated allowing the airlock entrance to be moved 6 feet further out from the radome. During the windstorm of 10 December, another comparable air structure was destroyed at a location 8 miles away from the radome and a second inflatable structure was destroyed in an adjoining county. These circumstances indicate that, in general, the Illinois radome installation is adequate to withstand winds of this area.

Control systems for the blowers to inflate the radome were designed and incorporated into the system. Under this control system, there are two blowers, each with different speeds: the low-speed blower normally runs continually and maintains 2.00 inches of water pressure internal to the radome. If at any time the pressure drops to below 1.25 inches of water, the second, high-speed blower automatically turns on and both blowers continue to run until reset manually. If any failure occurs with the first blower, such as motor or intake blockage, the second blower will run until serviced. In addition, it has been noted that high and gusty winds produce sufficient changes of pressure internally that the second blower is occasionally turned on. This is also a desirable situation and provides protection from high winds without an anemometer control, as is usually used.

The 1971-72 array of equipment of the radar system, as disposed at the Illinois installation (which was on University of Illinois property at the University Airport) is shown on Figure 2. The array includes the inflated radome, the trailer with M-33 antenna, the van containing the control and data

L. to R. M-33 trailer and antenna, FPS-18 trailer, spare parts truck, and 10am antenna



L. to R. 10 cm antenna, M-33 trailer and antenna, and data-control system van

Figure 2. Showing the radar system components, as positioned in Illinois

recording equipment, the 40-ft trailer containing the FPS-18, and a repair van used to house spare parts and to perform repair work.

Dismantling, Shipping and Erection in Colorado

On 1 April 1972 the packing of the system was begun for its shipment to Ft. Morgan, Colorado, the designated site for its use in NHRE. To fulfill NHRE commitments, this was begun before any operations and data collection were accomplished in Illinois.

All of the equipment was ready for shipment on 12 April, and two of the pull-away vans were shipped on the 12th. The data-control van was shipped on 13 April. The M-33 van and the repair van were consigned on 12 April to the railroads for shipment. The 8-day period required for dismantling and packing of the equipment of this system, as the first attempt, was longer than is anticipated for any future packing and shipping operations. In the future it is felt that 6 days will suffice, provided that weather is appropriate for dismantling the radome and antenna.

The equipment arrived in Colorado in satisfactory condition. The truck vans arrived on 114-15 April. The equipment that had been consigned to the railroads took much longer, arriving on 1 May. In the future, we will attempt to send all equipment by truck.

The 10-cm antenna was assembled on 18 April and erected on 19 April. The radome was erected on 3 May. The installation at Colorado was made in a very calm wind condition with a hydraulic crane, and the installation was more easily accomplished than the first time in Illinois. The Colorado pad design is not only adequate but much superior to the design originally envisioned by AIRTEK. By 15 May, the 10-cm part of the system was operating correctly and through the processor.

PREPARATIONS FOR RADAR DATA ANALYSES

Initial steps preparatory to the various envisioned analyses were made prior to 1 June 1971, and were reported to NCAR at that time. These involved simulating the dual wavelength radar data with digitized photographic data taken with the TPS-10 radar. This simulation, plus any real dual wavelength results which become available, will be reported on in a paper for the Fifteenth Weather Radar Conference in Urbana in October 1972.

The essential analytical approach will be to describe the life history of a storm on the basis of: 1) its total water mass; 2) the vertical distribution of the water mass; 3) the horizontal distribution of the vertically integrated mass of water; 4) the radar echo volume and its vertical distribution (by layers); 5) the height and other linear dimensions of the storm; 6) the horizontal areas of the echo; and 7) the interrelationships between the above and the environmental temperatures and deduced in-cloud temperatures (for example, the distribution with height of storm water mass may be transformed, through knowledge of the temperature-height data, into a distribution of water mass vs. temperature). At the same time, the hail echo will be described from the moment of its initiation in terms of its heights, volume, etc. Relationships between its history and the storm water mass history also will be sought.

The data format for the tapes recorded by the signal processor has only recently become available, and has been turned over to the Water Survey staff programmers. Dr. James C. Neill has taken charge of the program-preparation portion of the analysis work, and, with Morgan, will generate the set of programs to produce the computer displays of the information listed above.

Simultaneously with the above, diagnostic studies comparing the dual wavelength results with results at single wavelengths will be pursued.

ACKNOWLEDGMENTS

This work was accomplished under the general direction of Stanley A. Changnon, Jr., Head of the Atmospheric Sciences Section. Certain Illinois State Water Survey staff members worked on the radar system throughout the contract period. These included Ed Silha, engineer, and Roy Reitz, technician, and their exceptional efforts and contributions are gratefully acknowledged. Other Survey staff members who materially assisted in the developmental work were Donald Staggs and Joe Coons, and those who contributed to the analytical-computer efforts included Robert Beebe, Carl Lonnquist, Robert Sinclair, Phyllis Stone, and Barbara Binch.

The close interaction with the staff of the Laboratory for Atmospheric Probing of the University of Chicago, under the direction of Dr. David Atlas, was important to the successful pursuance of this project. In particular, Dick Fetter of that group materially aided in the developmental phase of the project.

The advice and cooperation extended by Dr. Peter Eccles of the NCAR staff was also of great value.

PUBLICATIONS

A paper entitled "Liquid Water Content Estimation by Dual-Wavelength Radar" written by Dr. Peter Eccles, of the NCAR staff, and Dr. Eugene A. Mueller was published in the Journal of Applied Meteorology (Vol. 10, p. 1252-1259). They also authored an NCAR Technical Report (71/1) NHRE entitled X-Band Attenuation and Liquid Water Content Estimation of Dual-Wavelength Radar.

Mr. Griffith M. Morgan, Jr., wrote a paper entitled "On the Growth of Large Hail" which appeared in the Monthly Weather Review (Vol. 100, p. 196-205). Although based on NSF-sponsored research (NSF GA-16168), it has direct relevance to the research being pursued in this contract.