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RADAR OPERATIONS AND DATA COLLECTION IN  
SUPPORT OF METEOROLOGICAL RESEARCH IN NORTHEASTERN ILLINOIS

by

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FINAL REPORT

Contract: ATM78-12350  
for  
National Science Foundation

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April 30, 1979

## INTRODUCTION

Five meteorological research projects focusing on studies of precipitation and severe local storms in the Chicago area are being conducted (Changnon and Semonin, 1978). This particular project concerned operations of a 10-cm radar system, identified as the HOT (Hydrometeorological Tool) radar, to aid in the field operations of two projects and to provide 3-dimensional reflectivity data desired for use in the analyses of all projects. The HOT radar is equipped with a digital integrator and it recorded quantitative reflectivities on digital magnetic tape. These data have been used on several research studies. For example, studies of the morphology of individual cells and entire storm systems, often lines of multiple storms, have depended heavily on the 3-dimensional HOT data.

This reports presents a description of the operations, data collected, data shared with other scientists, and the use of the data in Water Survey research. Following is a description of the five projects which have used the HOT radar.

## PROJECTS INVOLVED WITH THIS RADAR EFFORT

### Northern Illinois Meteorological Research on Downbursts

Project NIMROD (Northern Illinois Meteorological Research on Downbursts) was conducted in northeastern Illinois during May-June 1978. It was a comprehensive study of convective storms. The Illinois State Water Survey, Argonne National Laboratory, the University of Chicago, the National Center for Atmospheric Research, and Governors State University all participated in the observations under the general direction of Professors T. T. Fujita and Ramesh Srivastava of the University of Chicago. The observing instruments

deployed were: 1) a network of 315 raingages and hailpads, 2) a surveillance radar (HOT radar), 3) two radiosondes, 4) three Doppler radars, 5) the portable automated meso-network of NCAR, 6) Lear jet and U-2 aircraft for cloud photography, and 7) rapid scan SMS/GOES satellite. The array of most of these instruments is shown in figure 1.

The research addressed basic issues concerning the dynamics of convective storms, some of which are: 1) the origin and mechanism of downdrafts in convective clouds and severe storms; 2) the role of overshooting updrafts and their subsequent collapse in generating sustained damaging downdrafts; 3) the momentum and water substance transports by updrafts and downdrafts which influence the life cycle and motion of convective storms; and 4) the morphology and mechanisms that lead to severe hailstorms and intense flood-producing rainstorms.

The HOT radar was operated during all convective storm periods in May and June 1978 to provide surveillance of the area and the information needed in the real-time decision-making related to the operations of the three Doppler radars. The Dopplers focused on activity in the triangular area they formed (figure 1), and the Water Survey's HOT radar provided information relevant to the approaching storm entities, including their growth and motion.

#### Urban and Lake Influences on Precipitation

The second project that sought the radar echo data resulting from the May-July operations is entitled "Causes and Impacts of Urban and Lake Influences on Precipitation." This NSF-supported research project (ENV77-15375) is being conducted by the Illinois State Water Survey. It includes the study of local precipitation anomalies in the Chicago and downwind areas (Lake Michigan with radar) so as 1) to identify their presence (space and time), and 2) to investigate their causes (lake and/or urban influences) through case type investigations.

The causative research is heavily dependent on the study of 3-dimensional echo data needed to investigate the time and space behavior of echoes, from their inception until dissipation. A major goal is to compare the results relating to urban influences with those obtained at St. Louis under METROMEX (Metropolitan Meteorological Experiment) (Braham et al., 1975). This Chicago-focused project is using all available historical data plus the echo data emanating from this radar system.

#### Chicago Hydrometeorological Area Project

The third study which benefitted from the HOT radar echo data was CHAP (Chicago Hydrometeorological Area Project) (Changnon and Huff, 1976). This 4-year project has focused on various hydrometeorological studies including 1) the use of a weather radar system to furnish real-time rainfall estimates to the city to aid in the operation of the water resources network, and 2) the gathering of rainfall data over a large rural-suburban-urban area so as to better understand the regional differences in design values for heavy rainfall. This project included the installation and operation of this HOT radar. It also involved the installation and operation of a dense raingage network. The 1978 raingage and HOT radar data have been studied using State of Illinois and NSF (ASRA) resources to derive the best means for rainfall estimation. Various techniques are under investigation. This radar-indicated rainfall data from 1978 materially increased the sample size and was of great value to the research on this project. The demonstration phase including real-time rain measurement over Chicago will be performed in June-August 1979.

#### Precipitation Augmentation for Crops Experiment

The pre-experimental phase of PACE (Precipitation Augmentation for Crops Experiment), involving Water Survey and NOAA scientists and facilities, began

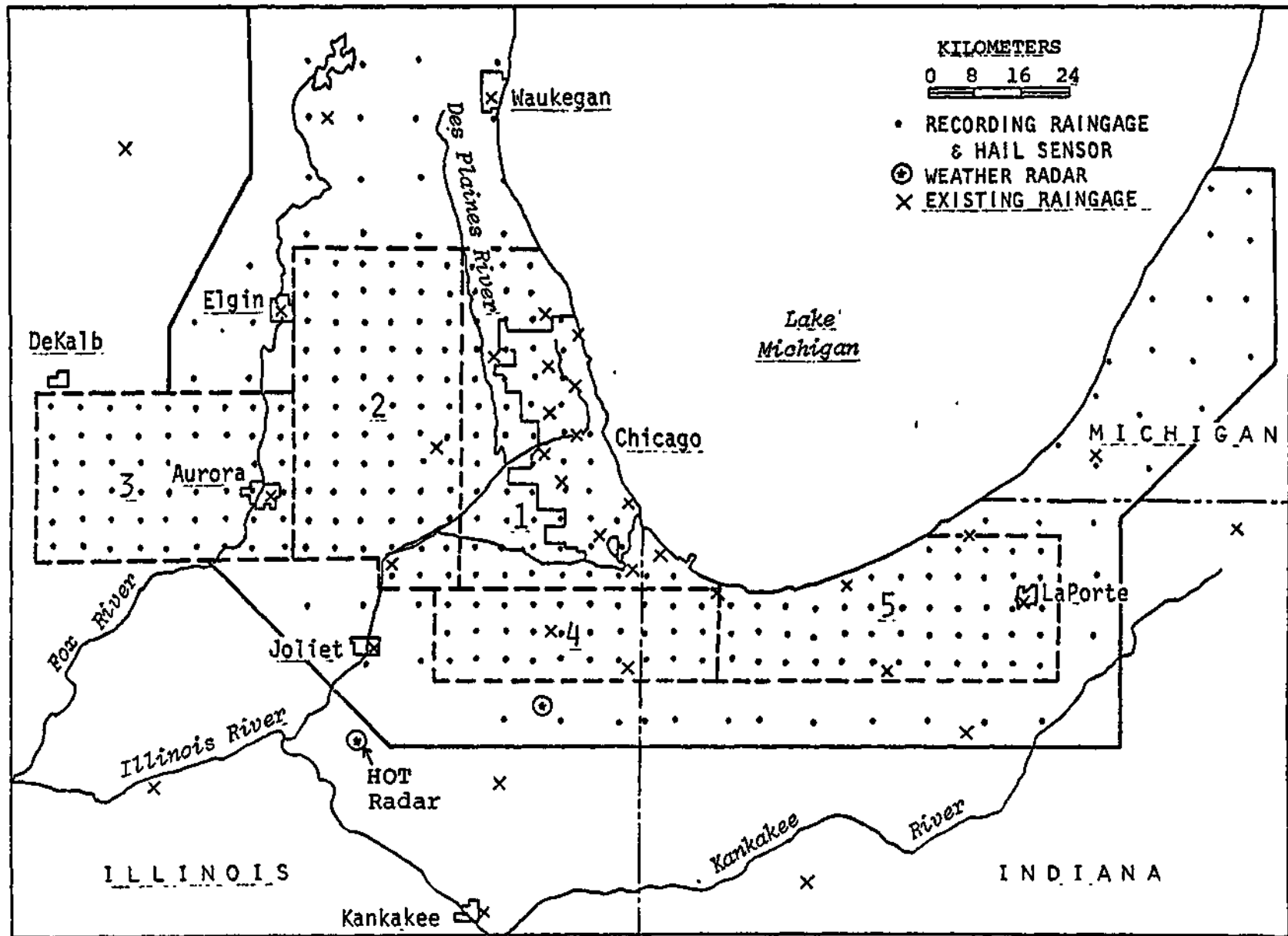


Figure 1. Location of HOT radar in 1978.

in 1978. This project aims to determine the potential for summer rain enhancement in Illinois (and the Midwest). It was oriented in 1978 primarily to aircraft and radar measurements of clouds and cloud systems.

The NOAA P-3 meteorological aircraft was flown from the University of Illinois Willard Airport in Champaign-Urbana during the 14-30 June 1978 period, and the HOT radar was a desired source of data on the life histories of many of the 40 storms the aircraft penetrated in northern Illinois. The radar data for 2 of the good flight days have been reduced and are under study by Water Survey scientists. Scientific papers concerning this research are to be presented at the Weather Modification Conference in 1979.

#### Wind Shear Incidents at O'Hare Airport

Scientists of NOAA Environmental Research Laboratory (WPL) were involved, under FAA sponsorship, in the study of turbulence and gustiness at O'Hare Airport in Chicago. They installed, in 1977, a network of pressure sensors and wind sets to measure these perturbations in a test of methods to detect local shear conditions (with inexpensive systems) as an aid in aircraft operations. In their analysis of several events at O'Hare, NOAA scientists concluded they needed detailed echo data (from a 10-cm wavelength radar) collected in a 3-dimensional manner. NOAA and Water Survey scientists (Al Bedard and Neil Towery) have researched echo behavior on 12 storm incidents. The data was supplied to NOAA for use in their final report to FAA. A scientific paper has been submitted for consideration at the Severe Local Storms Conference in 1979.

The primary focus in the joint analyses was to determine the location of strong radar echoes and heavy rainfall in time and space relative to O'Hare Airport. Presumably, the information could be used in establishing warning criteria for aircraft. For example, it might be established that echoes of

a given intensity and within a certain distance of the airport might produce severe wind conditions. Preliminary examination of the data suggested that:

- 1) At times, no storms existed, meaning the wind shear conditions were caused by other forces (such as passage of a cold front);
- 2) At times the radar echoes were weak and surface rainfall was light;
- 3) At other times, the strong radar echoes were 20 to 25 miles away from O'Hare;
- 4) Strong storms were located within 10 miles of O'Hare at the time of the wind shear event on about 50 percent of the occasions.

#### RADAR DESCRIPTION

The HOT radar system was located at a site southwest of Chicago. The radar site allows for adequate study of approaching precipitation systems from the western quadrant and those developing over the city. The radar site includes a building to house the radar components, a large reinforced concrete base for the radar antenna, the power installation for the radar system and a radome over the 20-foot diameter antenna.

Since its installation in the fall of 1976, the radar has undergone continuous development. Basically, the HOT radar is a greatly modified FPS-18 system with a  $1.2^\circ$  beam width, and was operated in a variety of sophisticated scanning modes to accommodate the many projects being served. A TI-980 micro-computer controls the antenna in addition to the accessing of significant variables such as current antenna position, scan program status, and time of day. The TI-980 computer has 28,000 words of memory. A high speed interface permits the radar processor data to be dumped into the computer memory independent of the other computer activity. The processor dumped data every

96 milliseconds. Each dump provided 1024 8-bit bytes at the rate of 750,000 bytes per second. This computer system includes two tape drives and a Cathode ray tube terminal as well as an ASR33 teletype terminal. The radar has a digital video processor that provides the function of digitizing the radar echoes in 1024 range bins, short-term averaging of this signal, and threshold type data compression prior to archiving the data on magnetic tape. Software necessary to process the resulting data exists.

#### COMPUTER PROGRAMMING

Several programs were developed to aid in the HOT radar data collection and analysis.

Calibration Program. This program was used to simplify the radar calibration process. The operator injected a signal into the waveguide and inputs the amplitude of the signal to the computer. After the desired number of points have been entered, the computer plots all the points on the graphic display terminal. The operator could then exclude one or more points and have the computer calculate the slope and intercept of the calibration curve. This saved considerable time over the previous process which involved picking calibration points out of tape dumps and plotting them manually.

Data Check Program. This program was developed to check data quality as it was being recorded. On a signal from the radar operator, the computer backs up the data collection tape and reads the last block written. The format of the block is checked and any errors logged. The operator could have the program printout time and reflectivity and housekeeping information from



the tape. This program was also used after the data collection period was completed to inspect any part or all of a data tape.

Tape Reading Program. A general purpose tape reading subroutine was written to facilitate post-analysis of the HOT data. This routine read the radar tapes and reconstructed the digitized video. Options were provided for converting the returned power to reflectivity, applying a calibration, doing range averaging, and applying sector limits. This program provided Fortran analysis programs easy access to the radar data.

Contour Mapping Program. This developed program read the radar tapes and generated PPI contour maps of the radar reflectivity. The analyst defines the area to be contoured, the values of the contour lines, and the units of distance to be used (km, miles, etc.). The program plots on the Tektronix 4012 graphics display until one elevation scan is complete. It then pauses to allow the operator to examine the plot and make a hard copy if needed. The analyst may then proceed to the next scan, skip to the next elevation scan, or instruct the computer to skip down the tape until a specific time is reached. The viewing area need not be centered on the radar location, and the scale is variable. This allows small regions to be expanded to fill the screen. Data on computer tape has been traditionally difficult for meteorologists to relate to under operational conditions. This program is a valuable tool to facilitate the utilization of the computer data.

#### OPERATIONS AND DATA COLLECTION

The effort on this project did not stand alone as a research project. It essentially was an operational and data collection effort designed to support

NIMROD, CHAP, and PACE operations and to provide 3-dimensional reflectivity data in usable format to a wide range of scientists involved in five research projects.

During the period of 8 May to 1 July 1978, 38 rain periods (on 32 days) with rain  $>0.15$  in. occurred. The HOT radar was operational during most of these rain periods. These operations were closely coordinated with the three operational efforts.

The NIMROD project manager, using echo information provided by the HOT radar operating in a 3-D surveillance mode, directed three Doppler radars to simultaneously scan a selected storm and coordinated scan frequencies to maximize the useful data recorded. The HOT radar was the surveillance radar for other storms, while the Doppler radars were "working" a storm. It supplied information on the overall storm system and could be used to alert scientists that other storms were moving into the Doppler area of interest.

During periods when integrated data were not being collected for the NIMROD project, the radar was used to record data for the CHAP and PACE research projects. It was also used to collect data and provide guidance for the PACE aircraft operations.

A summary of the data collection for various projects is shown in Table 1. The radar operated 549 hours during 25 operational periods. (A project could have been served twice during one period). The minimum operational period was 2 hours and the maximum was 124 hours with continuous operations. The average operational period was almost 22 hours and the median was approximately 13 hours. Furthermore, on 8 occasions, the radar was operated continuously for more than 24 hours, and four of those lasted more than 48 hours.

Table 2 provides some information on the operational dates in May and June. As can be seen, 53 digital tapes, 28 rolls (4200 feet) of 35-mm film, and 749 Polaroids were collected.

Table 1. Summary of HOT Radar Operations During 1978 for Different Projects

<u>Project Applications</u>	<u># of Times Operations Served</u>	<u>Total Hours</u>
NIMROD Only	14	270
NIMROD and PACE	3	4
PACE Only	2	7
PACE and CHAP	2	123
CHAP Only	10	145

The radar tape and film data were totally checked, and available to all interested scientists within three months after the end of operations (by October 1978). Some of the data were given to the research scientists at the University of Chicago, Governors State University, and the Illinois State Water Survey. The data (tapes and scope photographs) are available to anyone else in the scientific community who wish to use it.

#### RADAR-RAINFALL RESEARCH

Some project research concerned investigations of the Brandes (1975) technique of radar-rainfall adjustment. The research was completed and results were found satisfactory. The effect of reduced raingage density ( $1/2$ ,  $1/4$ ,  $1/6$ ,  $1/9$ ,  $1/12$  of full network density) on the accuracy of the radar-rainfall adjustment with the Brandes technique was analyzed using area-depth relations. This method has been adopted for future radar-rain estimations in Illinois during the summer of 1979.

The Cain and Smith (1977) Sequential Analysis technique was also explored. Computer-generated results indicated that although the Cain and Smith technique is useful for some applications, it is unsuitable for real-time rain estimates for urban hydrologic operations. Also, an in-depth investigation and modification of the Florida Area Cumulus Experiment (FACE) echo tracking program was done as the first step in preparing for 1979 real-time operational efforts in CHAP. The program will be used to track echoes, accumulate statistics on important parameters, and make predictions of the parameters.

Table 2. Summary of Operations for May and June 1978  
(including 1 July)

<u>Operational Dates</u>	<u>Total Days</u>	<u>Total Hours</u>	<u>Number of Tapes</u>	<u>Number of Film Rolls</u>	<u>Number of Polaroids</u>
MAY: 8, 11, 12, 19, 20, 21, 22, 23, 27, 28, 29, 30, 31	13	140	17	8	144
JUNE- 1, 6, 7, 11, 12 JULY 14, 15, 16, 17, 1 18, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30 and 7/1	23	409	36	20	605
Total	36	549	53	28	749

DATA EXCHANGE

The major research applications of the 1978 HOT radar data have been described in earlier sections. The specific distribution and use of data, is itemized in Table 3.

Review of this reveals that the HOT radar data, from operations and data collection performed in this project, have been and are being used in operational forecasts (real-time), and research relating to severe local storms, heavy rain prediction methods, and in planned and inadvertent weather modification.

PERSONNEL

The staff involved in this project, in addition to the Principal Investigator Professor Stanley A. Changnon, were:

Neil G. Towery	Chief Meteorologist
Douglas M. A. Jones	Meteorologist
Donald W. Staggs	Radar Engineer
David Brunkow	Electronics Engineer
Phyllis Stone	Meteorological Aide
Edna Anderson	Meteorological Aide

Several students who were employed and involved in the radar operations and data processing and analysis. These included:

Melanie Wetzel  
Paul Merzloch  
Scott Truett

Table 3. Distribution and Uses of the HOT Radar Data

<u>Data</u>	<u>Supplied To</u>	<u>Purpose</u>
Digital tapes for 17 June and 24 June and 30 June	Water Survey Scientists	Studies of echo properties for clouds under aircraft study for PACE
Digital radar tape for May-July	Water Survey Scientists	Study of radar-rain relations and for simulation testing of prediction of rainfall over Chicago
15 minute radar echo maps for 12 days and echo activity descriptions	NOAA and Water Survey Scientists	NOAA-DOT-FAA study of severe gust and turbulence over O'Hare Airport
All radar film and Polaroids	Prof. T. Fujita, U. of Chicago and Prof. R. Srivastava, U. of Chicago	To study general echo behavior
Radar echo data for 17 June	Dr. John Moses NESS	Extensive case study of satellite detection of severe storms

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