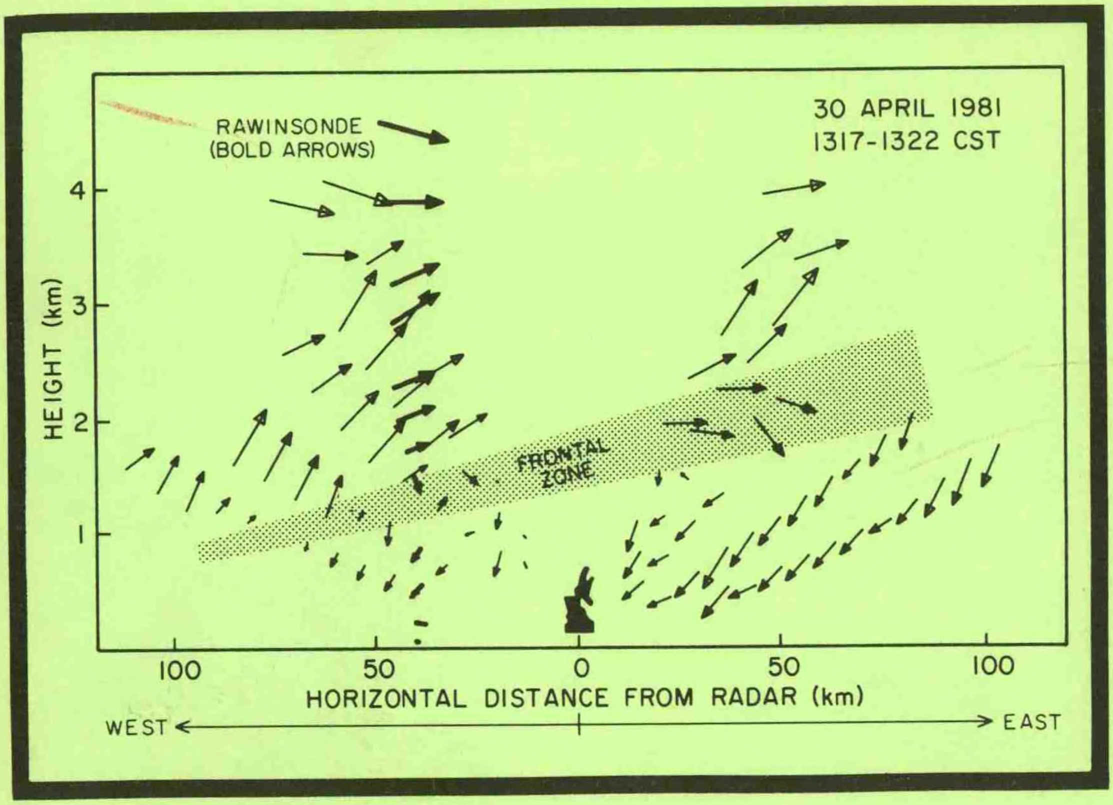
National Severe Storms Laboratory

ANNUAL REPORT FY-84



UNITED STATES DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Environmental Research Laboratories

COVER

Horizontal wind vectors in a west-east vertical cross section across a frontal zone. The frontal zone separates northeasterly winds below 1 km from southwesterly winds above. The bold arrows along the vertical line 40 km west of the radar are horizontal wind vectors measured by a rawinsonde; thin arrows are winds deduced from single Doppler velocity data.

NATIONAL SEVERE STORMS LABORATORY

ANNUAL REPORT - FISCAL YEAR 1984

October 1, 1983 - September 30, 1984

National Severe Storms Laboratory
1313 Halley Circle
Norman, Oklahoma 73069
March 1985

UNITED STATES
DEPARTMENT OF COMMERCE

Malcolm Baldrige,
Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

Environmental Research
Laboratories

Vernon E. Derr,
Director

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W. DAVID RUST*

*AFTER 1 APRIL 1984

VALID FY84

NATIONAL SEVERE STORMS LABORATORY

PERSONNEL STATISTICS

FY-1984

October 1, 1983 - September 30, 1984

	October 1, 1983		September 30, 1984	
	Full-time	Part-time	Full-time	Part-time
Professional	27	2	26	5
Technical	8	3	8	2
Clerical	5	4	5	4
TOTAL	40	9	39	11

Number of full-time holding doctoral degrees on September 30, 1984: 12

In addition to the above, the Laboratory employs 13 U. of Oklahoma (OU) students part time; they are assigned to NSSL staff who are Adjunct Professors at OU. The Cooperative Institute for Mesoscale Meteorological Studies employs nine Graduate Research Assistants, four computer programmers, one drafts-person, and two part-time secretaries supported by NSSL.

NATIONAL SEVERE STORMS LABORATORY

FY-1984 Budget and Funding

NOAA Operations Research and Facilities....................$2,924,200

Support...373,000

Other Agencies: (FY-1984 New Funds)

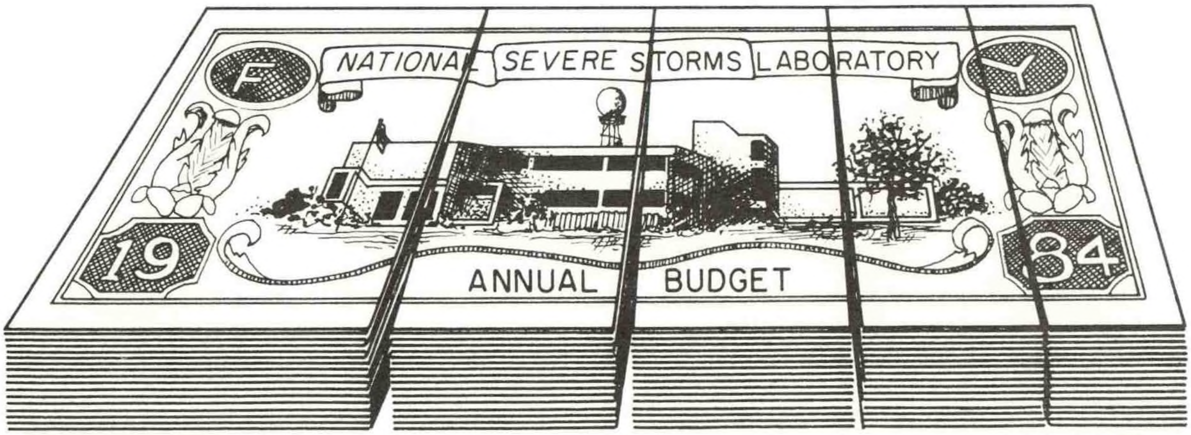
Army	$ 45,000
Air Force	37,800
Federal Aviation Administration	165,000
National Aeronautics & Space Admin.	130,800

Total Other Agencies...............................378,600

TOTAL.....$3,675,800

Proportional allotment of funds*

Storm Evolution & Analysis	16%
Modeling & Dynamics	19%
Computer & Engineering Support	32%
Storm Electricity	14%
Doppler Radar	19%
	100%



32%	19%	19%	16%	14%
COMPUTER AND ENGINEERING SUPPORT	MODELING AND DYNAMICS	DOPPLER RADAR	STORM EVOLUTION AND ANALYSIS	STORM ELECTRICITY

*A portion of administrative costs is included in each percentage.

PROGRAM AREAS

NATIONAL SEVERE STORMS LABORATORY

INTRODUCTION

Edwin Kessler, Director

The Laboratory staff studies severe-storm circulations and the processes through which they develop, and investigates techniques for improved storm detection and prediction, in support of NOAA's operational mission as carried out by the National Weather Service. Our work during 1984 included the following highlights:

(1) Substantial advances in depiction and understanding of thunderstorm and tornado processes. These have come through refinement of methods for retrieving fields of perturbation pressure, buoyancy, and water substance from the time series of velocity distributions detailed in three dimensions by Doppler radars.

(2) New insights into controls on hail production, through interpretation of data gathered in the field, with the aid of diagnostic models for retrieving hail parameters from a base in Doppler observations.

(3) Development and implementation of a system for compressing Doppler radar data and transmitting it with lightning data over a high-grade (9600 baud) land line. Data on velocities and lightning locations were transmitted on an experimental basis to the Oklahoma City Weather Service Forecast Office during spring 1984, where it was an effective aid to the forecasts.

(4) Substantial contributions to NEXRAD, a system of meteorological Doppler radars scheduled for deployment across the United States during the late 1980s:

(a) We demonstrated significant forecasting utility of winds defined by single Doppler radar.

(b) We developed theoretical bases for two signal processing methods for markedly improved target discrimination.

(c) We developed new algorithms for automatic identification of meteorological features.

(5) Publication of two books originated in NSSL. The Thunderstorm in Human Affairs, edited by Edwin Kessler, became available from the University of Oklahoma Press during December 1983. This second edition is handsomely manufactured in hard cover and contains a chapter on lightning damage and lightning protection not present in the first edition published by the U.S. Govt. Printing Office. Doppler Radar and Weather Observations by Richard J. Doviak and Dusan S. Zrnic' of NSSL was published by Academic

Press. Its 458 pages thoughtfully complement existing texts while presenting a wealth of new materials from the cutting edge of modern research. The book is well arranged for use as either reference or text. In addition to these two books, 14 publications by NSSL staff appeared in the peer-reviewed literature during the year, and there were more than 50 printed conference papers and reports.

NSSL's historical antecedents in the former U.S. Weather Bureau and its former National Severe Storms Project are described in an NSSL Special Report prepared in 1976. From early emphasis on use of aircraft for storm investigations related to flight safety, the focus at NSSL has moved to theoretical and empirical studies based on data from a multitude of sensors for new insights into storm mechanics, and new applications to storm warning and prediction and safety of flight.

About one-fourth of NSSL's budget is devoted to maintenance and operation of comprehensive instrumentation for sensing meteorological parameters. Instrumentation includes two 10-cm Doppler radars on a 42-km baseline, the tallest meteorologically instrumented tower in the United States, a network of solar-powered surface stations, and a broad range of sensors for mapping lightning processes in clouds, locating ground strike points of lightning, and measuring electric field parameters.

NSSL, the Interim Operational Test Facility of NEXRAD, the Weather Service Forecast Office at Oklahoma City, and several meteorological groups at the University of Oklahoma and elsewhere in the State are working closely together to help realize benefits inherent in our diverse expertise. All groups are represented in a not-for-profit corporation, The Applied Systems Institute (ASI), formed at the University of Oklahoma. The ASI is a vehicle for facilitating beneficial development such as the planned move of the Oklahoma City WSFO to a place near NSSL on the OU North Campus.

METEOROLOGICAL RESEARCH GROUP

Peter S. Ray, Group Leader

INTRODUCTION

The Meteorological Research Group seeks to improve thunderstorm forecast and warning capabilities by developing conceptual, numerical, and laboratory models of major thunderstorm phenomena and of the prestorm atmosphere. Analysis and interpretation of storm flow fields expand our understanding of external and internal forcing, thermodynamics, cloud physics, and cloud dynamics, which contribute to intense thunderstorms and their attendant phenomena. Subsets of the group objective are addressed by two projects: Modeling and Dynamics led by Carl E. Hane, and Storm Evolution and Analysis led by Rodger A. Brown.

RECENT ACCOMPLISHMENTS

MICROPHYSICAL PROCESSES IN STORMS

Insights into severe thunderstorms, ranging from hail growth and separation of electrical charge to production of heavy rainfall, emerge from a clear understanding of the physics of water substance in clouds. A new diagnostic model has been developed to produce microphysical and thermal variables within observed thunderstorms (Ziegler, 1984a). The technique proceeds from Doppler airflow measurements and an environmental sounding, through the relevant thermodynamic and microphysical processes, to calculate fields of potential temperature, water vapor, and the concentrations and mixing ratios of both liquid water and ice in their various forms within storms. The diagnosed internally consistent storm structure reveals the modulation of precipitation cores by recycling of millimeter-sized ice, graupel, and drops as well as the overwhelming influence of advection (Ziegler, 1984b). The microphysical retrieval can also indicate when errors exist in analyzed fields. When comparing observed and retrieved radar reflectivities, the presence of localized bias errors in the wind analysis is sometimes suggested. These biases lead to anomalous precipitation content and thermal structure by means of the continuity principles within the model. When the wind field errors are corrected, the resulting implied and observed reflectivities are in much better agreement.

Studies of hail growth modes help to reveal how hail growth is related to storm structure, intensity, and evolution. Such a recent study of an individual storm by Knight et al. (1984), incorporates Doppler-derived wind fields, a numerical model, and information from surface hailstone collection. Analysis of hailstone structure revealed that almost all growth was in the wet mode. The model results indicate that two major growth trajectories existed in the storm, and that the fall-out position of one trajectory was coincident with the position of hailfall as documented by the collection vehicle. In agreement with the results of the hailstone structure analysis, all the mass of the modeled hailstones that fell in the collection area was accreted in the wet mode. The wet mode growth in the model occurred at ambient temperatures $\geq$-17°C.

The microphysical structure and general evolution of storms may be studied using the high spatial and temporal resolution of Doppler velocity spectra collected at vertical incidence. The accuracy with which vertical air velocity and drop size distributions can be estimated has traditionally been limited by the interdependence involved in calculating each. However, a new dual wavelength technique has allowed for the determination of vertical velocity independent of drop size distribution. In application the technique requires cautious attention to hardware quality and configuration, since results are sensitive to data quality (Sangren and Ray, 1984).

TORNADIC STORMS

Improved understanding of the fields of velocity, pressure, temperature, and water quantities within storms that contain tornadoes should lead to greater understanding of tornadogenesis and ultimately improved warning criteria. The tornadic Binger, Oklahoma, storm of 1981 has undergone extensive analysis to determine the origin of its echo weak hole within the mesocyclone region. Following calculation of the wind field from dual-Doppler radar data, a microphysical retrieval method has been utilized to provide added information on the water and thermal fields (Johnson and Ziegler, 1984). Major reflectivity features such as hook echo, main precipitation shaft, gust front cell core, slanted reflectivity ridge from hook echo to gust front cell core, and bounded weak echo regions were well retrieved (see Fig. 1). Recycling of millimeter-sized graupel and raindrops in the updraft were important in the formation of the precipitation core. The echo weak hole within the mesocyclone is likened to a soda straw--the sides are impervious to radial influx of precipitation, while the top and bottom of the tube draw in little precipitation because of low precipitation content and downward air motion, respectively.

In a theoretical study of rotation in thunderstorms, Davies-Jones (1983) showed that streamwise vorticity (in the storm's reference frame) causes the updrafts of supercell storms to rotate cyclonically. Streamwise vorticity (i.e., vorticity along the wind direction) is present in the environment when the storm-relative winds veer with height. Convection generates vertical motions and vertical vorticity through the tilting term in such a way that vertical velocity and vertical vorticity are positively correlated when streamwise vorticity is present. Thus, on average, updrafts rotate cyclonically, downdrafts anticyclonically, when the storm-relative winds veer with height.

Methods for retrieval of pressure and buoyancy have been applied to Doppler velocity data from the Del City tornadic storm (20 May 1977). Pressure gradients in the pre-tornadic stage were found to maximize across the updraft maximum approximately in the direction of the environmental wind shear vector at each altitude (see Fig. 2). In the tornadic stage a pronounced pressure minimum (~3-4 mb below ambient) coincides with the low-level

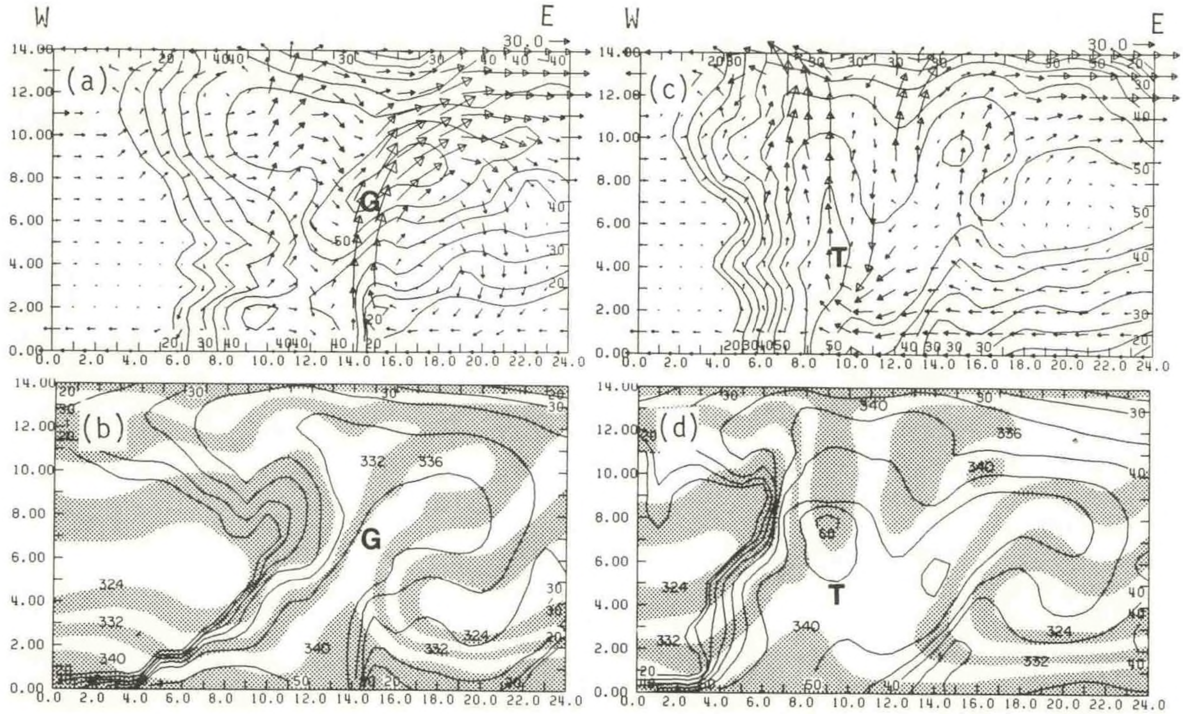


Figure 1. Observed winds and reflectivity (a,c) and retrieved potential temperature θ_e and reflectivity (b,d) in vertical west-east cross sections through the Binger storm at 1909 CST. Section (a,b) is 4 km south of (c,d). The cores of the gust front cell are labeled G and the tornadic cell is labeled T. Velocities (m s^{-1}) are scaled according to the vector at upper right. Reflectivity (dBZ) is contoured in 5-dBZ increments. The θ_e field is indicated by light stippling; alternate stippled-unstippled layers represent a difference of 4°, and key contour values are indicated. All coordinates are in kilometers relative to the origin of the retrieval domain.

mesocyclone (Hane and Ray, 1983). The vorticity-induced pressure deficit near the surface reverses the vertical gradient of perturbation pressure (Brandes, 1984), resulting in sudden formation of rear downdrafts which are commonly observed in tornadic thunderstorms. An investigation applying the same approach to a second tornadic storm (8 June 1974) revealed that the restructured pressure forces create a flux of air parcels into the mesocyclone from higher levels on the storm's rear. Downdrafts fill the mesocyclone in final stages, and updrafts weaken in nearby regions (Brandes, 1984).

The evolution of tornadic thunderstorms that formed over northwest Oklahoma on 2 May 1979 has been investigated using dual-Doppler radar observations. The advance of a rainy downdraft behind the Lahoma gust front contributed to enhanced low-level convergence for the development of a possible gust front tornado. Perturbations in the updraft and vertical vorticity produced the long-lived Lahoma mesocyclone. Analyses of air parcel trajectories within the storms provide details of dissipation of both the Lahoma mesocyclone and first Orienta tornado. These trajectories show that during the mature stages air parcels enter the mesocyclone from low levels and rise cyclonically within the updraft. Separation of the mesocyclone and updraft, infiltration of downdrafts into the mesocyclone, and vertical

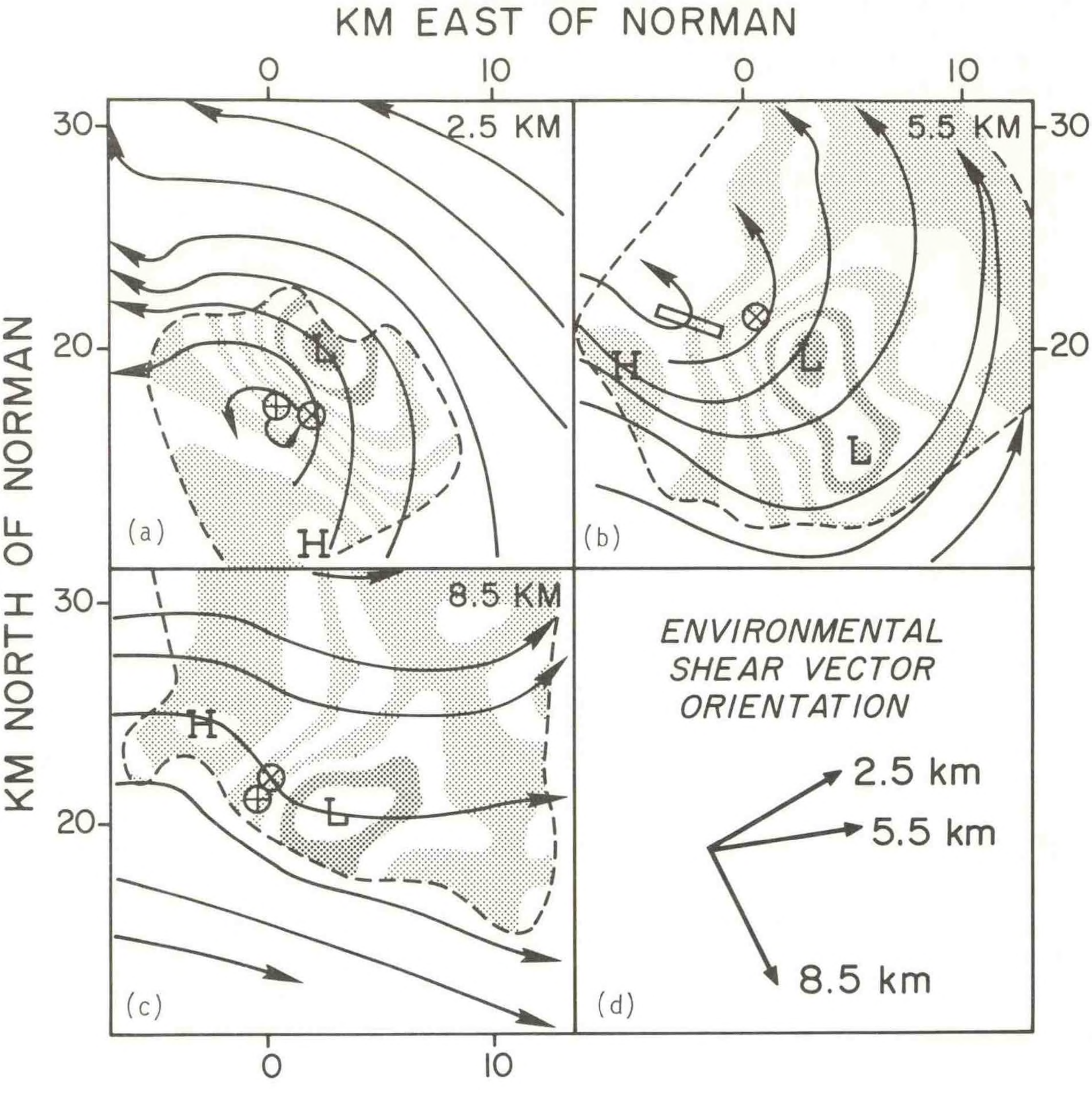


Figure 2. Horizontal flow and pressure field within the Del City storm at 1833 CST. Storm-relative streamlines are superimposed upon the deviation of perturbation pressure from its horizontal average at heights of (a) 2.5, (b) 5.5, and (c) 8.5 km. Pressure is contoured at 0.5-hPa (mb) intervals; negative and positive deviations are denoted by heavy and light stippling, respectively. Updraft maxima are denoted by ⊗ and vorticity maxima by ⊕ (or the bar symbol in (b)). In (d) the orientation of the environmental shear vector at each altitude is shown.

vorticity reduction are the major dissipative features of the Lahoma mesocyclone. The Orienta tornado dissipated as downdraft air reduced the buoyancy of the mesocyclone inflow (Johnson et al., 1983).

Visual and photographic observations of severe storms by intercept teams provide important adjunct information on storm structure and evolution during NSSL's Spring Programs. Four tornadoes were observed by team members during the spring, including a cyclonic-anticyclonic tornado pair concurrently observed by Doppler radar. Attempts to deploy TOTO (Totable Tornado Observatory) in tornado paths were hampered by erratic tornado movement and abrupt changes in intensity.

THUNDERSTORM EVOLUTION AND STRUCTURE

Important forecast and warning insights may often be gained by investigation of the smaller convective entities, which may evolve to produce or maintain larger storm complexes. Doppler data collected on 19 June 1980 reveal that a group of small cells evolved into an isolated supercell storm. The storm initially propagated to the right of the mean wind, and as the size and intensity of the individual cells increased (with center-to-center spacing remaining constant), the reflectivity structure appeared to become steady state. The increase in size and intensity was attributed to an increase in potential buoyant energy in the storm inflow and a slight increase in the storm-relative vertical wind shear. During the 2 1/2 hours that dual-Doppler data were collected, maxima in reflectivity and updraft speed increased dramatically with transition to a supercellular structure (Vasiloff and Brandes, 1984).

A large squall line produced strong outflow winds, frequent cloud-to-ground lightning, and locally heavy rainfall on 19 May 1977. A study of mechanisms responsible for the maintenance of strong convection in this squall line has revealed that small rain-producing cells preceding the line are an integral part of the line's mesoscale organization and contribute strongly toward maintaining the intensity of preferred sections of the line. Description of this work along with that of other recent and past work is included in a comprehensive review of extratropical squall lines and rainbands (Hane, 1984).

FORECASTS AND WARNINGS

A striking relationship has been found between maximum hailsize produced by a storm and the strength of the single Doppler velocity signature of divergence near storm top (Witt and Nelson, 1984). Initially, single Doppler velocity components were computed from multiple Doppler derived wind fields to confirm that radar viewing angle did not significantly bias the maximum Doppler velocity difference across the signature. A least squares relationship, based on eight multiple Doppler data sets, was established (straight line in Fig. 3). The relationship was tested using 18 independent single Doppler data sets (data points in figure) and found to be equally applicable. The relationship thus appears to hold great promise for hailstorm

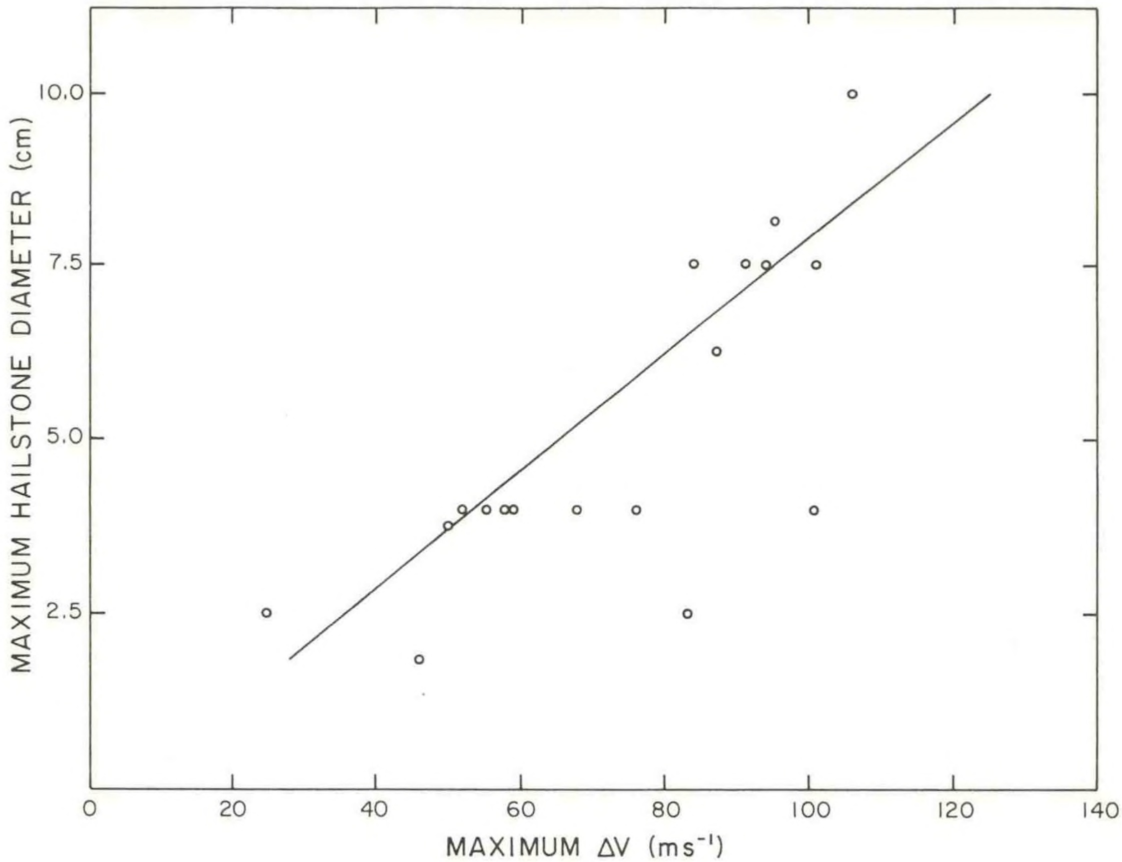


Figure 3. Relationship between maximum reported hailstone diameter and the maximum velocity difference within the upper level divergent outflow region (Δv). The straight line is a least squares fit derived from eight multiple-Doppler cases (1974 to 1980). The open circles are an independent data set obtained from single-Doppler measurements (1984). (Witt and Nelson, 1984).

warnings by distinguishing between storms that produce very large hail (diameters of 7 to 10 cm) and those that produce relatively small hail (2 to 4 cm).

An atlas of single Doppler velocity signatures has been prepared to aid radar operators with Doppler scope interpretation (Wood and Brown, 1983). The signatures include simulated Doppler velocity patterns in the optically clear atmosphere or in widespread precipitation (see Fig. 4) and patterns found within severe thunderstorms. The idealized velocity fields are shown to be good approximations to actual Doppler velocity measurements.

NSSL continues to support development of a modernized Weather Service office by PROFS (Program for Regional Observing and Forecasting Services). Don Burgess participated in an experiment by PROFS to evaluate Doppler velocity and reflectivity displays as part of the severe weather warning process.

A theoretical model has been developed that predicts potential storm intensity and rotation given environmental rawinsonde data and observed storm

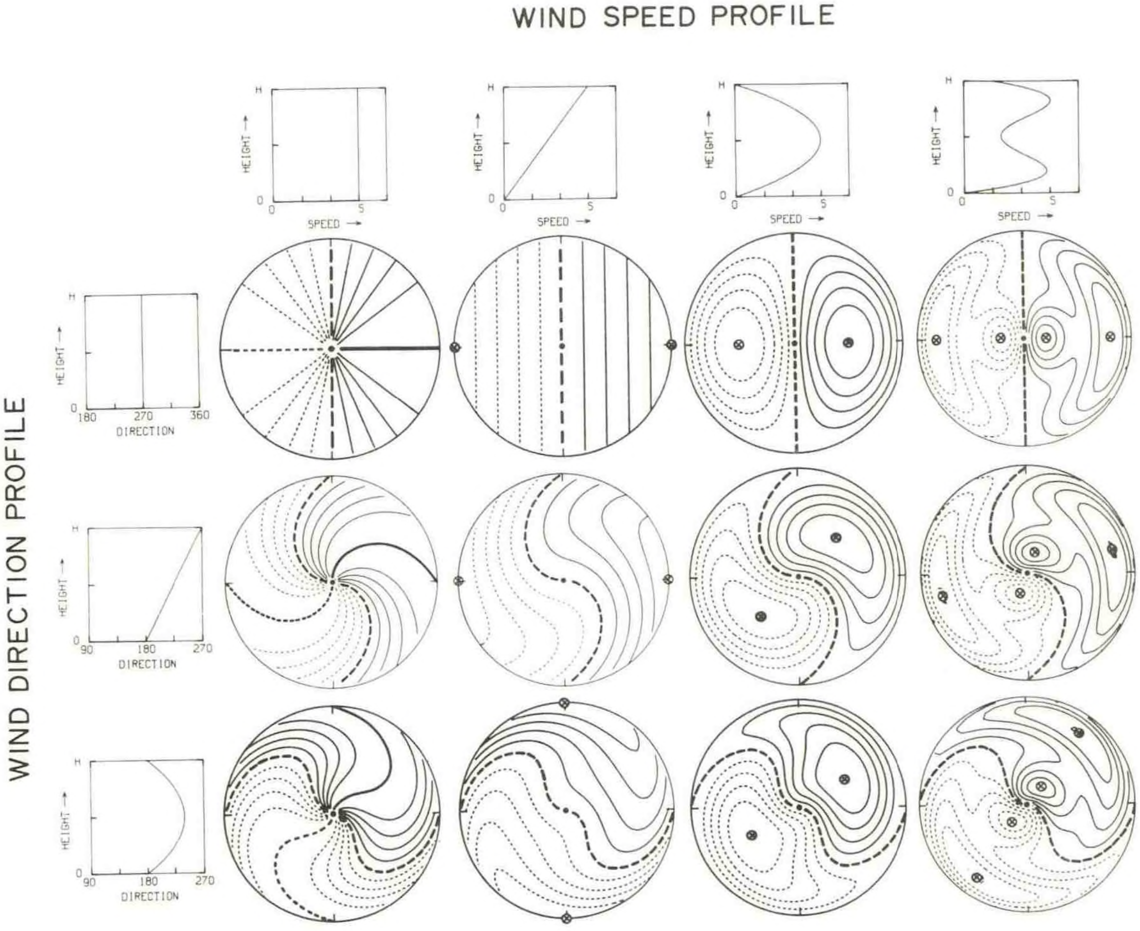


Figure 4. Simulated Doppler velocity patterns (PPI scans at constant elevation angle) for some vertical profiles of wind speed and direction. Doppler velocity contours (as seen on circular radar display) have solid lines for flow away from radar (at center of the display), short dashes for flow toward radar, and heavy long dashes for zero Doppler velocity. Heavier solid and short dashed lines indicate locations of extreme velocity values. Circled x's refer to locations of maximum and minimum Doppler velocity values within the display. (Wood and Brown, 1983)

motion (Davies-Jones et al., 1984). Tests conducted thus far indicate that the technique has potential for improved short-term forecasts when appropriate environmental data are available.

NSSL is working toward gaining understanding of how the mesoscale environment localizes convective systems that produce severe weather and heavy rain. An in-house version of the Penn State (Anthes-Warner) meso-model is operational and being used to study high plateau heat-driven circulations in the presence of baroclinicity. Results show that circulations develop which concentrate low-level convergence and favorable vertical shear to enhance severe storm possibilities in regions of limited size. An independent effort will evaluate 6 to 12-hour forecasts from initial fields based on high resolution satellite-derived fields. The scheme that conserves the gradient structure of the satellite data substantially reduces bias errors produced by direct insertion of satellite data.

DATA ACQUISITION AND PROCESSING

Multiple Doppler radar studies of severe thunderstorms during the past decade have revealed details of kinematic and dynamical structure that otherwise would remain unknown. The ability to follow evolving vertical velocity fields has been an especially revealing contribution. However, researchers are starting to realize that errors in the reconstructed vertical velocity components can be significantly greater than those explained theoretically from radar geometry. A study of potential error sources is under way using actual data sets (Nelson et al., 1984). Thus far, incorrect storm advection, incomplete sampling of low-level divergence, and high Doppler velocity variance have all been rejected as dominant error sources. Work is continuing in order to isolate and study other possible error sources.

Given high quality three-dimensional velocity components derived from multiple Doppler radar measurements, a number of important investigations can be conducted. One application is the retrieval of pressure and density (potential temperature) fields within the planetary boundary layer. Heat flux profiles that have been calculated from these data show encouraging agreement with independent tower measurements in northeast Colorado (Gal-Chen et al., 1984).

The NOAA P-3 aircraft, equipped with a Doppler radar that scanned orthogonal to the aircraft track, was flown in Oklahoma as part of the NSSL Spring Program. Sometimes the only available radar was on the aircraft, and sometimes the airborne radar supplemented the data from one or both the NSSL ground-based 10-cm radars. In one instance, through the use of a ground-based radar and the P-3, we expect to be able to document the life cycle of a tornadic storm that simultaneously produced cyclonic and anticyclonic tornadoes. In cooperation with NASA we collected data with a NASA aircraft equipped with downward-looking sensors while the P-3 collected additional data for more quantitative interpretation. Data gathered from a sea-breeze-induced storm in Florida by the P-3 were analyzed (Ray et al., 1984) to determine the sensitivity of the data to different analysis methods. Differences in the analyses could be explained by statistical error propagation and evolution effects.

Rawinsonde measurements provide important information about the thermodynamic and wind structure of the atmosphere in which severe storms form. As rawinsonde coordinator, Mr. Les Showell supervised the 1984 four-station rawinsonde network operated by the U.S. Army at Fort Sill and the U.S. Air Force Sixth Mobile Weather Squadron from Tinker Air Force Base. For several years, the data from this network have been sent by phone line to NSSL, where soundings are plotted for forecasting purposes. For the first time in 1984, field personnel transmitted data directly to a minicomputer at NSSL that generated plotted soundings. Raw data also were sent directly to ERL's CDC 750 computer in Boulder for archiving.

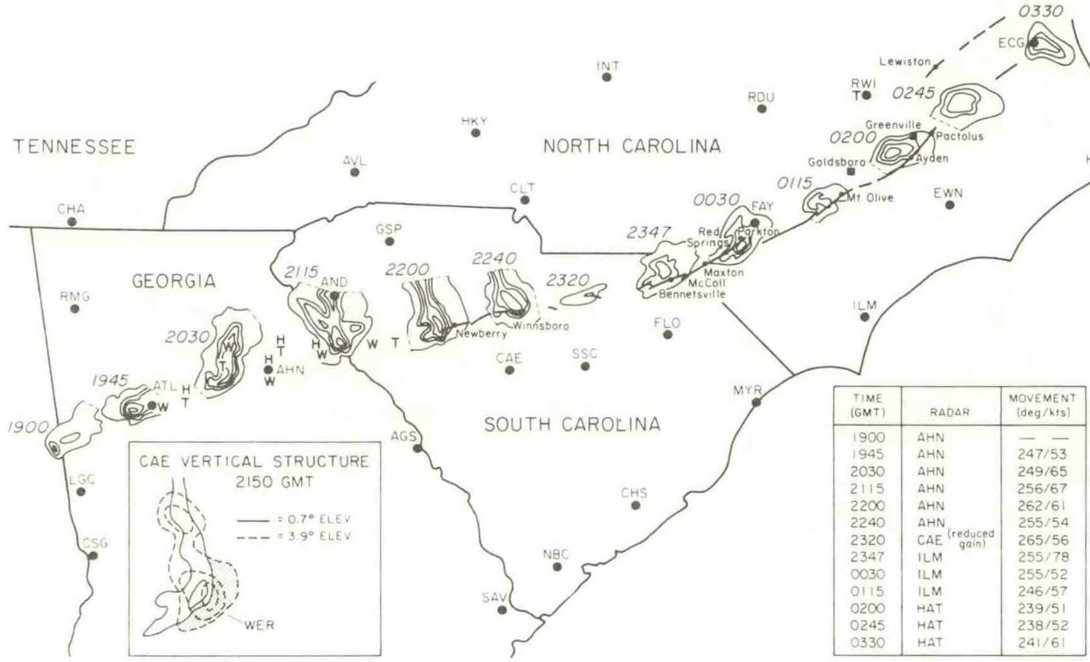
MISCELLANEOUS

With the phasing out of the NWS teletype data circuits, NSSL has been converting to the Paradyne system, which includes a computer display terminal. Dr. Kenneth Johnson has completed a users' reference guide to assist NSSL users of the system.

Several staff members prepared and presented course materials for the AMS Intensive Course on Mesoscale Meteorology and Forecasting, held in Boulder, Colorado, during July 1984. Enrollment for the two-week series of lectures and laboratories was 177 students, including 66 from the National Weather Service. Other participants came from the Canadian Weather Service, National Center for Atmospheric Research, Environmental Research Laboratories, universities, Department of Defense, and private sectors. The course was judged by the participants and organizers alike to be a success in the transfer of technical information, the compilation of a quality set of notes on the mesoscale, and better understanding between those primarily engaged in research and those whose activities are in operational meteorology.

Thunderstorm electrification was the main focus of a multiagency observing program centered at the Langmuir Laboratory and hosted by New Mexico Institute of Mining and Technology. NSSL scientist Peter Ray, was co-investigator on a grant that brought four Doppler radars to complement an extensive network of field mills, a spheric locating device based on interferometry, three aircraft, rawinsondes, etc. Conrad Ziegler alternated with Peter Ray in directing the radar data collection. Thunderstorms usually form over the mountains in response to surface heating and move slowly; they are thus ideal for study over their one-hour lifetime. The data collected during this experiment will provide the first opportunity to relate retrieved microphysical parameters and temperatures with in situ measurements. It is expected that the data will also be used as a verification source for dynamic modeling and electrification studies.

In addition to studying tornadic storms that occur in Oklahoma, NSSL meteorologists occasionally assist with tornado disaster surveys in other parts of the country. Don Burgess was a member of the NOAA Natural Disaster Survey Team that investigated the Carolina tornado outbreak of 28 March 1984. The team found that most of the tornadoes were produced by one supercell storm that took nine hours to cross Georgia, South Carolina, and North Carolina (Fig. 5).



TIME (GMT)	RADAR	MOVEMENT (deg/kts)
1900	AHN	— —
1945	AHN	247/53
2030	AHN	249/65
2115	AHN	256/67
2200	AHN	262/61
2240	AHN	255/54
2320	CAE (reduced gain)	265/56
2347	ILM	255/78
0030	ILM	255/52
0115	ILM	246/57
0200	HAT	239/51
0245	HAT	238/52
0330	HAT	241/61

Figure 5. History of the supercell echo responsible for most of the Carolina tornado outbreak, 28 March 1984. Contours are NWS radar VIP levels 2 through 6. Times are GMT and all elevation angles are 0°. Hail and wind are indicated by H and W, and short-track tornadoes by T. Solid lines indicate long-track tornadoes. The radar whose contours are drawn at each time and echo speeds are listed in lower right. Higher elevation angle (3.9°) is overlaid with the low-level echo from Columbia, South Carolina (CAE) in lower left; weak echo region (WER) indicative of strong updraft is shaded.

EXPECTATIONS FOR FY 1985

The work projected for 1985 is of several kinds:

We will complete and extend case studies of storm morphology and dynamics, already started:

a) Binger tornadic storm
b) 19 May 1977 squall line
c) 20 May 1977 tornadic storm
d) 6 June 1979 splitting storm at Agawam, Oklahoma.

We will continue with theoretical studies of mesocyclone formation.

Studies with a mesoscale numerical model will concentrate on development of techniques for initializing the model, and use of data from 9 May 1979 to investigate convective forcing and boundary layer changes.

Miscellaneous investigations will include participation in analysis of data from the 1984 TRIP (Thunderstorm Research International Experiment) experiment in New Mexico; design experiments to optimize sensor placement in field programs; development of techniques to combine radiance data from satellites with rawinsonde data for better description of detailed atmospheric structures; and development of a search for new techniques for objective analysis of Doppler radar data.

Preparation of review articles will be carried out to organize and present accumulated knowledge so that investigators new to the field can effectively continue the work of their predecessors.

DOPPLER RADAR AND STORM ELECTRICITY RESEARCH (DRASER)

Richard J. Doviak, Group Leader

The NSSL facility to observe electrical and kinematical processes contemporaneously with precipitation phenomena has no parallel. Major objectives of Doppler Radar and Storm Electricity Research (DRASER) include (1) determining relationships between processes of lightning, thermodynamics, and precipitation in thunderstorms in order to develop improved indicators of thunderstorm severity and hazards; (2) developing and refining remote-sensing techniques for locating, tracking, and predicting thunderstorms and their attendant hazards; (3) defining lightning and kinematic characteristics of storms to serve as design criteria for aircraft and ground facilities, and for environmental models; (4) providing ground truth and supportive data for development of new instrumentation and refinement of observational techniques.

These objectives are addressed through both theoretical and observational studies. The Doppler Radar Group focuses its efforts on interpretation of prestorm and stormy weather phenomena, using Doppler radar data for both. The Storm Electricity Group concentrates its analyses on data simultaneously obtained with Doppler radar and storm electricity sensors.

RECENT ACCOMPLISHMENTS

DOPPLER RADAR

Storm Initiation: An analysis of convective development along a frontal zone (30 April 1981) has demonstrated the utility of single Doppler radar in short range forecasting. Winds obtained from single Doppler radar data using the Volume Velocity Processing (VVP) technique, under the assumption of uniform wind, compare quite well with rawinsonde measurements (Cover). The location of the frontal zone aloft (clearly defined in the wind field) was coincident with a layer of upward air motion (measured from Velocity Azimuth Display [VAD] techniques). Storms developed with the onset of warm air advection and increased vertical motion, both of which were detected by radar. The locations of storm formation and tracks (Fig. 6) were displaced eastward from the surface frontal position. However, the regions where storms began and subsequent storm motions could have been predicted from detailed thermodynamic analysis and a map derived from Doppler data analysis (Rabin et al., 1984).

Prestorm cloud formation has been related, with the cooperation of NASA Goddard Space Flight Center, to boundary layer convergence in the vicinity of a dry line (17 May 1981). A cluster of dense clouds and strong convergence on a scale of 10 km preceded severe storm development by only about 30 minutes. Moreover, widespread vertical motion was not observed prior to this development.

In general, evolution of Doppler divergence measured with data from a single radar can provide significant clues to subsequent storm development (Rabin and Zawadzki, 1984). It has been found that divergence measured by a

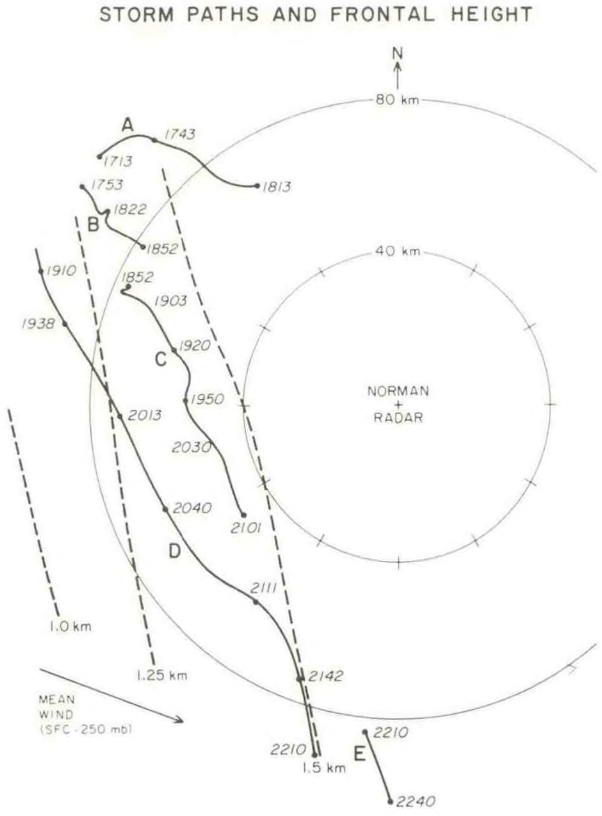


Figure 6. Tracks (solid lines) of five thunderstorms. Times along the tracks are in CST. Dashed lines are the frontal positions at altitudes of 1, 1.25, and 1.5 km during the period 1300-1600. The mean wind direction in the troposphere is indicated by the vector in the lower left corner.

single radar agrees well with dual Doppler analysis. However, the position of cumulus clouds is not always well correlated with convergence areas of the scale resolvable with the VVP analysis (~40 km). Research has begun into using variance of radial velocities obtained from a single radar to estimate convective regions associated with the individual cumulus clusters. This affords much improved resolution over the linear wind methods.

Analysis of radar data has begun to examine the relationship between reflectivity and precipitable water in the boundary layer (using radiometer data of the Wave Propagation Laboratory). Data analyzed to date reveal an enhancement of reflectivity at the top of the mixed layer starting at about noon. The enhancement is attributed to intermittent mixing of cool moist air with warm dry air at the inversion. We are investigating how much of the increased boundary layer moisture can be attributed to latent heat flux (evaporation).

Enhancement of Observing Capabilities: A technique to whiten the sidelobe powers of an array antenna has been developed (Sachidananda et al., 1984). Its purpose is to reduce sidelobe interference with measurements of Doppler shifts in the mainlobe. The method employs antenna pattern switching so that, ideally, the sidelobes contribute incoherently to the Doppler spectral moments while the mainlobe power adds coherently. First calculations suggest that the average nonwhite power residue in the sidelobes can be 14 dB below the average sidelobe power of an equivalent nonswitched pattern (Fig. 7). Furthermore, it is shown that with additional signal processing the power from sidelobes can be canceled.

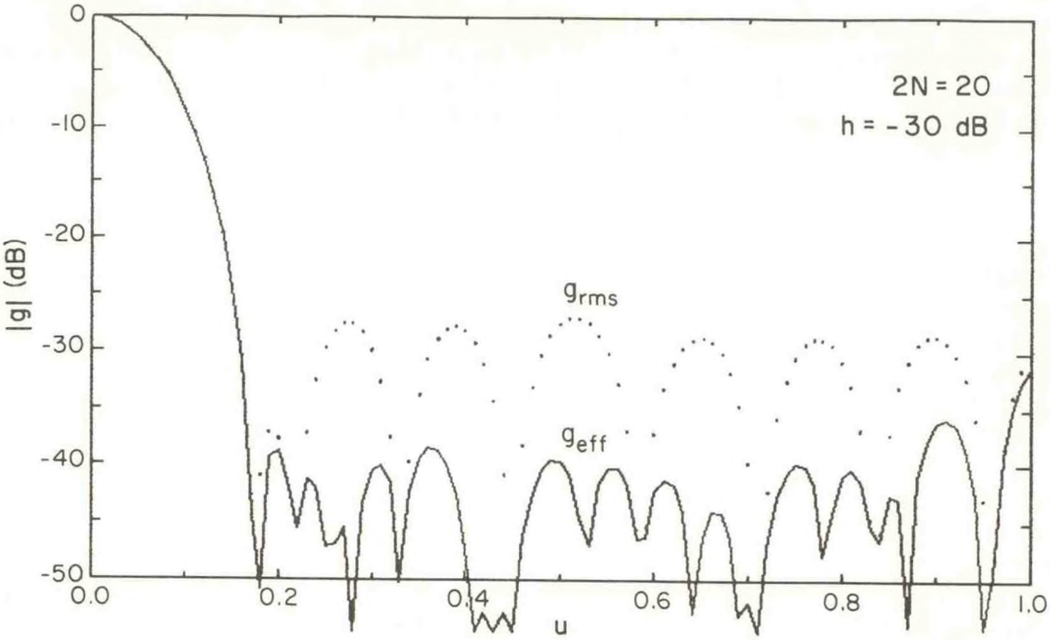


Figure 7. Reduction of sidelobe gain that contributes to coherent power The dotted curve is the gain pattern in the absence of pattern switching; the solid curve is the effective gain pattern that contributes to coherent power. 2N is the number of antenna elements colinearly aligned and spaced $\lambda/2$ apart; $h = -30$ dB is the designed maximum sidelobe gain of the symmetric and antisymmetric pattern components; g_{rms} is the nonswitched pattern gain; g_{eff} is the sidelobe gain for targets contributing to the coherent power observed in the mainlobe.

Performance of a weather Doppler radar with a staggered pulse repetition time has been compared with one using a random (but known) phase of the transmitted pulse. As a standard for this comparison, the specifications of the forthcoming Next Generation Weather Radar (NEXRAD) have been used. Random phase processing offers a better overall performance with an advantage of at least 13 dB in the removal of overlaid echoes. But the staggered scheme allows for automatic velocity dealiasing and is much simpler to implement.

Practical algorithms for mean velocity estimation in pulse Doppler weather radar using a small number of samples have been examined (Mahapatra and Zrnic', 1983). For low signal-to-noise ratios it is shown that the peak of a histogram obtained from the maxima of Doppler spectra is a preferred estimator (Shirakawa and Zrnic', 1983).

The effects of natural shields on Gaussian-shaped antenna patterns have been quantified (Doviak and Zrnic', 1984c). The solution of ensuing diffraction integrals for the pattern shape is expressed in terms of complex error functions. It is shown that ground clutter can be reduced by as much as 20 dB by proper choice of antenna site. This finding has significance for radars that are meant to observe low-level wind shear in and around airports. In a related study (Smith and Doviak, 1984) Doppler velocity bias due to beam blockage by ground targets has been quantified.

Theoretical investigation of various schemes to measure differential reflectivity has begun. We have found that switching between electric field polarizations offset from the vertical by +45° and -45° should provide considerable reduction of dwell time required for estimating differential reflectivity.

A conceptual study of how to track balloons with a NEXRAD type radar has been completed. It is suggested that computer-controlled scan over a small azimuth-elevation sector should produce good quality velocity estimates if the balloon's position is derived from a least squares fitting of its observed echo power to a theoretical model of echo power variation in azimuth and elevation.

We have assessed the accuracy of techniques that estimate the wind components from Doppler velocity data of a profiling radar and have developed a theory that explains reflection and scatter for anisotropically turbulent air (Doviak and Zrnic', 1984b). We are continuing the study of methods to obtain winds transverse to the direction of a Doppler radar beam. For that reason we have examined Fourier spectra of mean Doppler velocities on a circle centered at the radar. For a 50 km radius we have found that velocity harmonics with wavelength less than 50 km are at least 60 dB below the longer wavelength harmonics.

Radar-Lidar Investigation of Quiescent and Stormy Weather: Wind fields obtained with a lidar aboard the NASA CV-990 aircraft have been compared with those synthesized from two Doppler radars (Doviak et al., 1984). It was determined that errors in lidar-derived wind speed and direction came from a Schuler resonance in the inertial navigation system, which caused an indication of erroneous aircraft velocity perpendicular to the heading. This led to an erroneous subtraction from the lidar measured radial velocities. When this Schuler resonance was accounted for, differences between lidar and radar indications were less than 0.75 $m \cdot s^{-1}$. Lidar and single Doppler radar radial velocities collected on another day agreed within 1 $m \cdot s^{-1}$ through a full 360° circle around the Norman Doppler radar. Fig. 8 shows observations of a gust front with this lidar system.

Research on the structure of the convective atmospheric boundary layer observed with the instrumented NSSL/KTVY tall tower, airborne Doppler lidar, and ground-based radars established that the vertically averaged winds in the boundary layer are insensitive to baroclinicity, supporting the hypothesis advanced in J. Atmos. Sci. by Arya and Wyngaard in 1975. However, the computed momentum flux profiles are affected by baroclinicity. A persistent peak in the spectrum of turbulence observed with lidar, radar, and tower is consistent with the presence of horizontally symmetric cells with a horizontal wavelength four times the boundary layer height, as suggested by theory (Eilts et al., 1984).

Real-Time Weather Data Processing: Much of NSSL's work in this area relates closely with the NEXRAD project, whereby a new national radar system for severe storm warning is to replace the current WSR-57 radars toward the end of this decade. We have completed a program that displays heights of constant reflectivity, from which we identify Areas of Deeper Convection (ADC). The locations of ADC are a basis for short term forecasts of convective precipitation. This program together with our real time divergence measurement (Koscielny, 1983) will be used to explore prestorm conditions in Oklahoma.

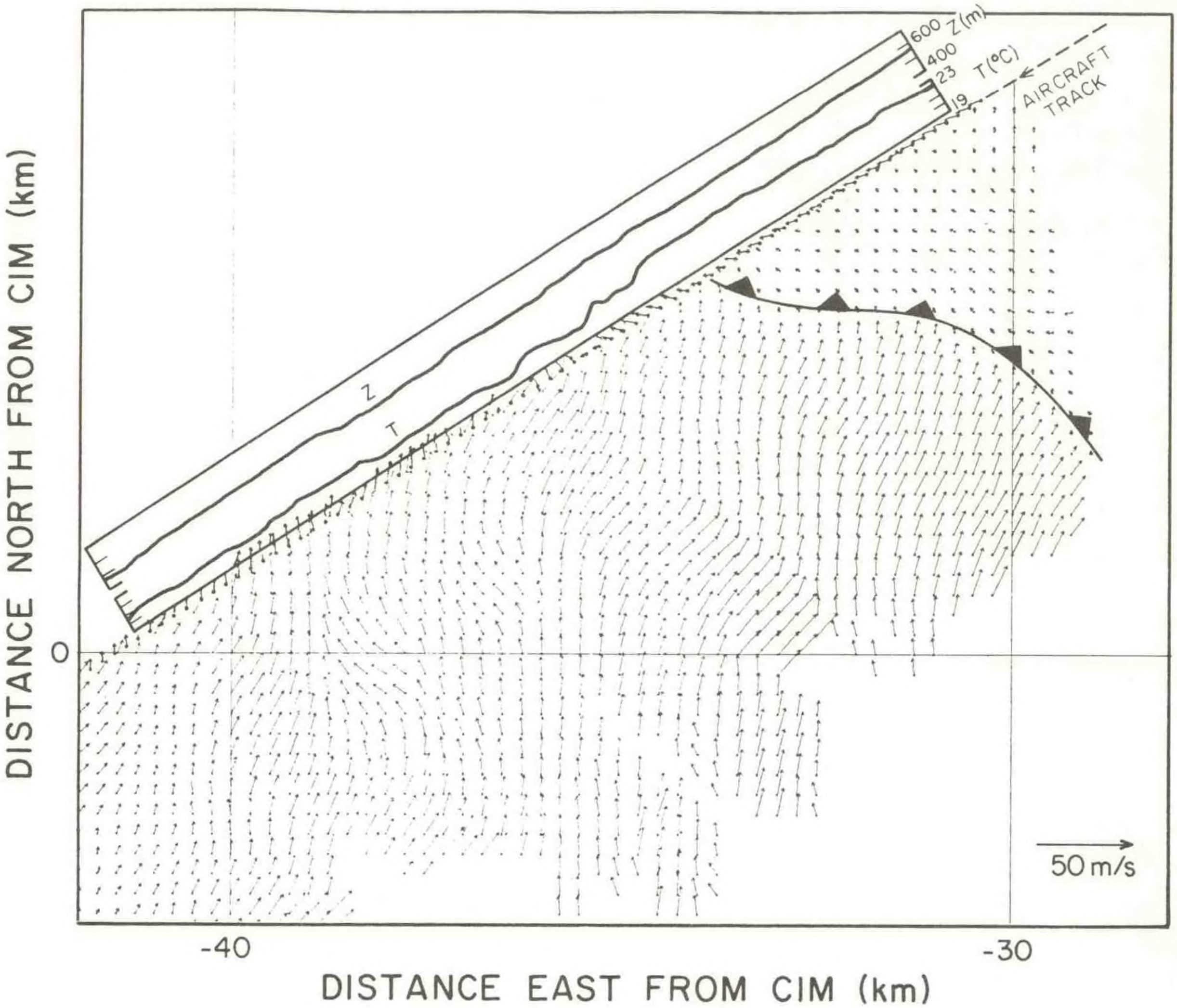


Figure 8. Horizontal winds derived from airborne Doppler lidar observations. The leading edge of a gust front and the gravity current behind it are visible in cloud-free air. Height above ground is 500 m, and horizontal distances are in kilometers from the Cimarron radar in Oklahoma City. Scaled vector wind is indicated in the lower right corner. The line graph indicates height Z (m) of the aircraft above ground and the temperature T (°C), showing drop as aircraft penetrates the gravity current. The line of broad vectors along the aircraft track (from NE to SW) is the INS-derived wind vector.

Computer software was developed to transmit displays of Doppler velocity and lightning data to the National Weather Service in Oklahoma City. Data were thresholded, color categorized, and assigned correct ranges on the Perkin-Elmer 3242 computer. During the 1984 spring data collection period, such data were sent over a 9600 baud line to a Chromatics 1999 color terminal at the National Weather Service office and monitored on a Chromatics 7800 at the Norman Doppler site. Through this project (DOPLIGHT '84), which involved staff in all of NSSL's components and was coordinated by Rodger Brown of the Meteorological Research Group, the forecaster in charge had available a quantitative idea of mesocyclone strength and could prepare appropriate warnings.

An algorithm to detect and track gust fronts has been developed and tested. The algorithm contains two procedures that operate independently on the data. In one, locations of maximum radial convergence are detected and grouped into gust lines, so that fronts with strong radial velocity components can be identified readily. When fronts are aligned along radar radials, the mesocyclone-shear algorithm is used (Zrnic' et al., 1984a,b,c). Tracking with both procedures is accomplished by a least squares fitting procedure and projecting in time a second-order polynomial in range or angle. It seems possible to project the front's position 10 minutes into the future with rms errors of only a few kilometers. A similar algorithm to estimate divergence in storm tops was tested on a limited number of storms (Zrnic' and Gal-Chen, 1984).

Gust Fronts and Downburst: Several cases have been selected for study of the symmetry of intense local downdrafts (downbursts) from convective storms. A downdraft on 27 May 1984 was found to produce a horizontal velocity change as large as 22 $m \cdot s^{-1}$ over a distance of 4 km (Fig. 9). The outflow was elongated (10 km x 5 km) and rotated anticyclonically. Investigation continues of several gust front episodes from 1982 through 1984 (Zrnic' and Lee, 1983). Initial inspection of some Doppler data point to a possible wave phenomenon at both sides of the gust front. Rawinsonde and tower observations are used together with vertical cross sections of reflectivity, velocity, and Doppler spectrum width to understand the structure of these fronts and waves (Doviak and Ge, 1984a,b).

The evolution of gust fronts and downdrafts is being studied to identify the source region and to determine if characteristics of areas where these phenomena originate can be used to forecast the timing and magnitude of subsequent weather hazards.

A feasibility study of a Doppler Downburst Detector has been completed. It seems that a wide-beam radar scanning overhead could detect downward-moving air if spectral processing were utilized.

Thunderstorm Turbulence: A study of the turbulent energy budget in a severe storm from its onset to maturity was completed, and various terms of the turbulent kinetic energy equation have been evaluated. From the time of the first echo, the average kinetic energy density increases considerably, and the total kinetic energy of the storm increases to a steady state value near the equivalent of 230 kilotons of TNT. Convergence of the horizontal energy flux contributes significantly to the energy change within the 20-dBZ storm envelope. Even though the storm is evolving, the mean winds over the storm at

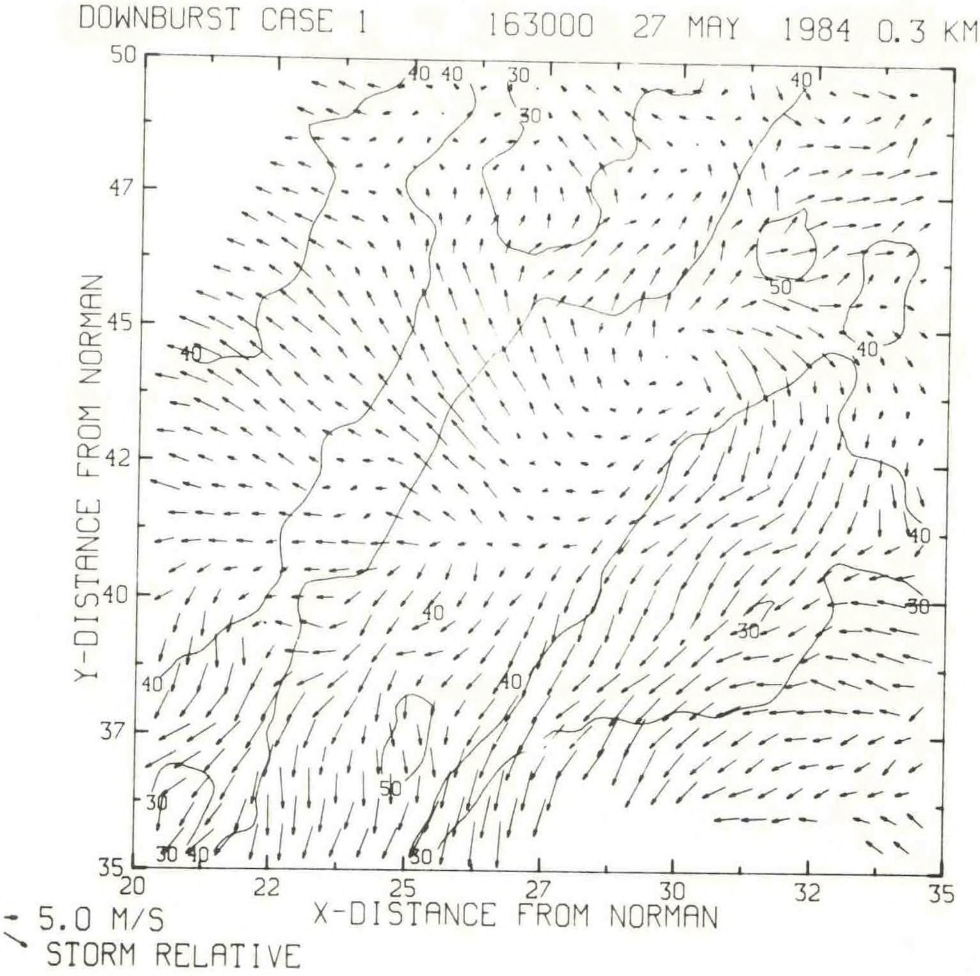


Figure 9. Downburst's horizontal wind field 300 m above ground. Scaled velocity vector is drawn in the lower left corner. Velocity vectors are relative to a frame moving with the storm. Contours show radar reflectivity factor in dBZ.

various heights hardly change from the environmental values over the period of observations.

Data acquired in thunderstorm penetrations by the NASA F-106 aircraft and concurrent Doppler radar data fields have reinforced statistics showing a correlation between Doppler spectrum widths (the square root of the second moment of the Doppler velocity) and aircraft-measured turbulence. Thus the role of NEXRAD in aircraft navigation and safety will be enhanced (Mahapatra and Lee, 1984).

NASA Langley Research Center and NSSL are sharing 1981 Doppler radar and F-106 aircraft turbulence measurements. This is part of a continuing study concerning storm turbulence (Lee, 1984). We have concluded, first, that

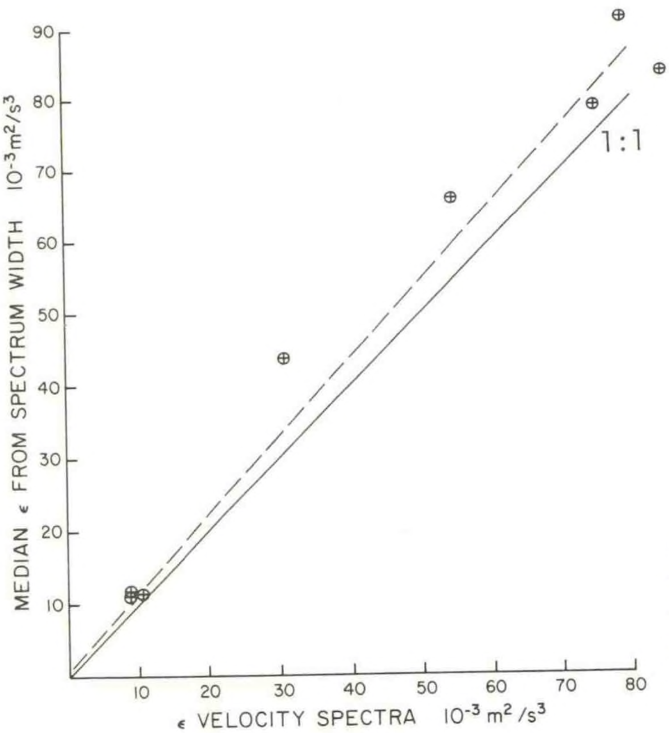


Figure 10. Eddy dissipation rates computed from spectrum width estimates are plotted against rates computed from the spatial spectra of Doppler velocities. Dotted line is a linear fit to the data.

Doppler spectrum widths are independent of the viewing angle of the radars--widths measured from two radars with orthogonal beams agree within 1 $m \cdot s^{-1}$--, and second, there is extremely good consistency between eddy dissipation rates calculated from the Doppler spectrum width and those estimated from the spatial spectra of mean velocities (Fig. 10).

An investigation of the effects of a bilinear velocity height profile on the Doppler velocity and spectrum width shows good agreement between the model-predicted and measured widths.

Investigation into turbulence and the structure constant of refractive index in a solitary wave has established links among Doppler spectrum width, vertical profiles of refractive index deduced from tall tower measurements, and radar reflectivity.

OTHER ACTIVITIES

Research results from work performed at the National Climatic Center concerning multivariate and univariate autoregressive modeling of quasibiennial oscillation have been published (Koscielny and Duchon, 1984).

Effects of charge and electric field on the shape of raindrops, with implications for interpretation of differential reflectivity measurements, have been presented (Zrnic' et al., 1984).

Doppler Radar and Weather Observations has been published by Academic Press (Doviak and Zrnic', 1984). The book blends the theory of weather radar and its signals with weather observations; it is suitable for reference as a graduate textbook for students of atmospheric science and engineering.

STORM ELECTRICITY

Assessment of Errors in Automatic Ground Strike Location: Use of ground strike locating systems continues to increase rapidly within the continental United States. Because about two-thirds of the contiguous United States is now covered by such systems, and because the systems are used daily, it is important to know their accuracy. We completed a study of systematic site errors and detection efficiency in the NSSL system using both a simple statistical technique and comparison with actual ground truth data obtained with the University of Mississippi/NSSL mobile laboratory for lightning out to ranges of 200-300 km (Mach, 1984). We found site errors, i.e., locally caused errors in azimuths, of up to 12 degrees. We have successfully determined correction curves for our data collected prior to 1984.

System detection efficiencies that are quite high have been reported, but undocumented, for ground strike locating systems. We have found that our system detects about 70% of flashes within 300 km. Although this is somewhat lower than efficiencies of some other systems, it is more than adequate for many applications, such as storm identification and tracking.

Mobile Balloon Launches to Measure Electric Fields: Using the mobile storm electricity laboratory and a second vehicle for transporting and launching balloons into storm inflow regions, we joined with scientists from the University of Mississippi in developing storm intercept and balloon-launching techniques for serial balloon ascents in the same storm. The balloons are instrumented to measure electric fields in addition to standard meteorological sounding parameters. A half-dozen successful flights were made into severe and tornadic storms during spring 1984 to learn about the distribution of storm processes and hazards. We also analyzed the electric field and the charge-screening layer in a severe storm anvil and compared them with features of a small, nonsevere orographic thunderstorm (Marshall and Rust, 1983). These results document rather clearly that the charge within the cloud, positive in anvils, attracts opposite polarity from the clear air as hypothesized several decades ago. The screening layer in the severe storm had four times the charge density of the orographic storm (Marshall et al., 1984).

Cloud-to-Ground and Intracloud Lightning in Tornadic Storms: Research continued on lightning rates in tornadic storms on 17 and 22 May 1981 (MacGorman et al. 1983a, 1984b; Horsburgh et al., 1983). It was found that intracloud lightning rates are highest during the tornadic stage, but that cloud-to-ground (CG) lightning rates increase significantly in the vicinity of the mesocyclone after the tornadic stage of a storm ends. We continue to study a possible exception involving positive CG flashes correlated with tornadic production (MacGorman et al., 1983b; Rust et al., 1983, 1984). This investigation extends and supports the research on tornadic storms reported in the FY 1983 annual report.

We have continued our use of NASA's 70- and 10-cm wavelength radars at Wallops Island, Virginia, to investigate the distribution of lightning within thunderstorms and squall line cells (Fig. 11). The long (70 cm) wavelength

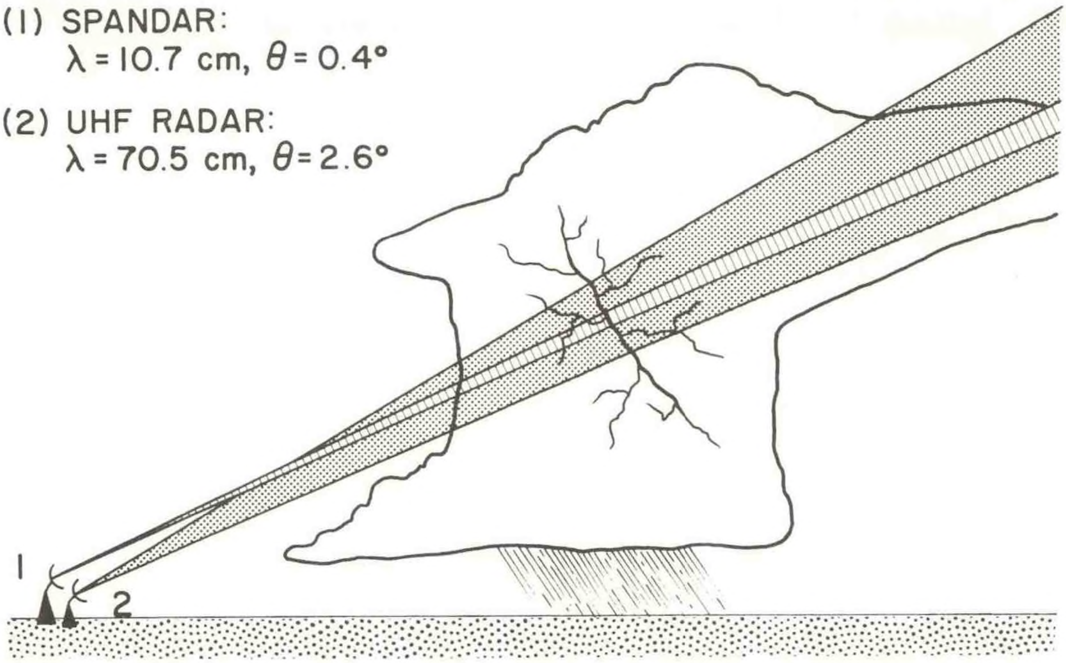


Figure 11. Schematic of storm structure and lightning being probed by two radars. Each radar scans vertically; the narrower beam of the 10 cm wavelength radar for lightning is kept within the beam of the 70 cm weather radar.

makes that radar unique for its ability to locate lightning even in intense precipitation. By combining vertical scan data from both radars, we have found two centers of lightning activity, separated vertically (Fig. 12). The lower center is at about 7 km above ground and the upper one at about 13 km (Mazur et al., 1983a, 1984a). This is independent corroboration of our findings of two such lightning "cores" in Oklahoma storms (Taylor et al., 1983; 1984). New understanding gleaned from these studies is being incorporated into operational procedures used in research on lightning hazards to aircraft. In addition, the finding of such a lightning distribution will provide physical constraints to be incorporated into thunderstorm models.

We started investigating lightning plasma properties through lightning echo variation, correlation between appearance of lightning echo in the radar sampling volume and VHF radiation sources associated with the lightning flash, and lightning effects on precipitation structure and hydrometeor velocities. The studies combine observation with vertically pointing Doppler radars, with the VHF mapping system, and with E-field charge-measuring instruments at Norman. Early results (Mazur et al., 1983b, 1984b) indicate (a) presence of continuous current in the lightning channel of intra-cloud flashes, (b) short-term (a few hundred milliseconds) increase in precipitation echo power at the moment of lightning echo in the sampling volume, and (c) absence of a speedy shift toward downward velocities of precipitation particles after the flash (related to the so called "rain gush phenomenon"). This work is continuing.

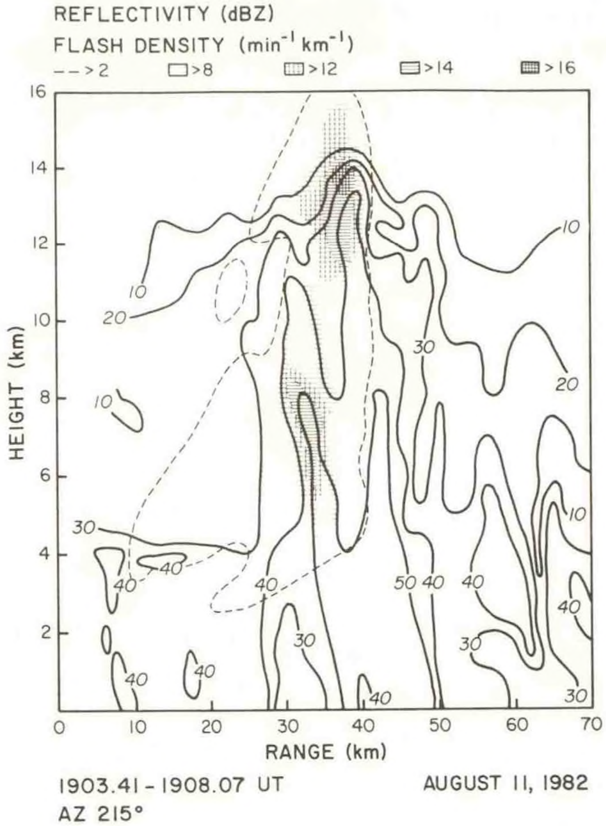


Figure 12. Lightning flash density and precipitation reflectivity on 11 August 1982, 1903-1908 UT. Notice the two centers of lightning activity, separated vertically, and note that one segment of the 50-dBZ core is devoid of lightning. Flash density is the number of lightning echoes detected per minute per kilometer along the beam of the UHF radar.

<u>Lightning Hazards to Aviation</u>: As part of the continuing program involving several agencies and the National Interagency Coordinating Group (NICG) on atmospheric electricity hazards, we have continued to make measurements of lightning involved in direct strikes to an instrumented NASA F-106B research airplane. We found that the F-106 triggered lightning to itself but never intercepted an existing flash during penetrations through upper parts of storms. Radar measurements of the direct lightning strikes show that the channel usually propagates bidirectionally outward from the airplane. This observation on lightning within storms is the first experimental evidence indicating that streamer development is not the unidirectional process reported in some laboratory studies.

Another aspect of our work with the NICG included Dr. MacGorman's participation as the chairman for meteorology on the steering committee for organization of the 9th International Aerospace and Ground Conference on Lightning and Static Electricity held in Orlando, Florida, in June. There were approximately 330 registrants at this conference. Up-to-date results in basic and applied research were presented in about 60 pages.

<u>Equipment Improvements</u>: In response to our verification of large site errors in the NSSL CG ground strike locating system, we moved the Norman site, which was the major contributor to these errors. In addition, data acquisition and "quick-look" playback of the ground strike locations have been improved with additional hardware.

A modification to our VHF lightning mapping system was completed to allow continuous all-hemispheric mapping of lightning within storms.

Lightning Ground Strike Climatology: A final report entitled "Lightning Strike Density for the Contiguous United States from Thunderstorm Duration Records" (MacGorman et al., 1984a) was completed. Thunderstorm duration data were compiled from 450 weather stations for a 30-year period, and lightning strike data from Oklahoma and Florida were analyzed to determine a relationship between thunderstorm duration and lightning strike density. The resulting maps of lightning strike density in the United States, such as shown in Fig. 13, present significantly better estimates of strike density than similar maps based on thunderstorm day data.

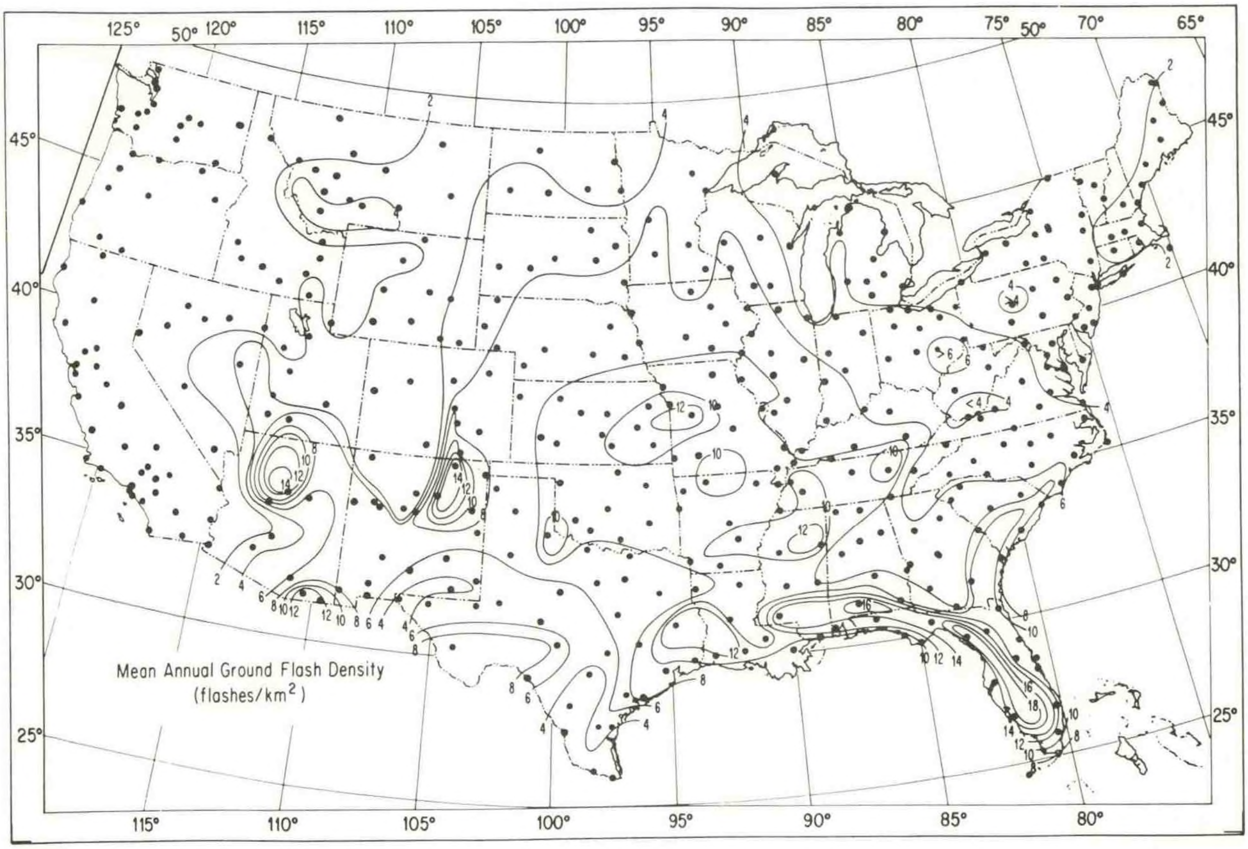


Figure 13. Lightning ground strike climatology. Dots show locations of 450 air weather stations, whose records provided thunderstorm duration data. Ground strike densities are estimated from ground strike data obtained in Oklahoma and Florida and the relationship $N=0.054H^{1.1}$. *N is the number of strikes per* km^2 *and H the thunderstorm duration in hours.*

EXPECTATIONS FOR FY 1985

In order to develop improved operational capabilities for forecasting the locations of storms and their intensity, we shall continue indepth examinations of the prestorm radar data with other data sources and theory. Variance of Doppler (radial) velocity fields will be related to development of cumulus clouds.

To predict downdrafts and gust fronts, a study of their origin and evolution will continue and NEXRAD algorithms for detection and tracking of hazardous weather will be improved.

Wind-profiling capability of weather radars will be examined both theoretically and experimentally. A polarization capability on the Cimarron Doppler radar will be implemented, and signal-processing techniques to estimate differential reflectivity will be examined. Studies of advanced techniques to reduce velocity and range ambiguities in Doppler radar will be conducted.

Relationships between microphysical and electrical processes will be investigated using dual-polarized and vertically pointing Doppler radar with electrical measurements.

The VHF lightning mapping system will be modified for greater simplicity and reliability in acquisition of high quality data.

We will continue to contribute to the National Interagency Coordinating Group on atmospheric electricity hazards, including analysis of in-flight lightning strike data.

We will be analyzing physical characteristics of +CG flashes and analyzing mesoscale and synoptic conditions associated with a storm having an unusually high percentage of +CG flashes; and we will complete analysis of flash type and rates and mesocyclone development for two tornadic storms.

COMPUTER AND ENGINEERING SUPPORT AND DEVELOPMENT

Dale Sirmans, Group Leader

This group (CESD) develops techniques and equipment, maintains the NSSL observational facilities, and supports the observational programs associated with the meteorological research. The NSSL base facilities consist of two 10-cm meteorological Doppler radars, a WSR-57 (surveillance radar), a tall (444 m) tower, a 52-station surface network, an air traffic control facility, and equipment for measuring electrical phenomena in the atmosphere. The group also provides engineering support for the NEXRAD/JSPO Interim Operational Test Facility of NWS.

RECENT ACCOMPLISHMENTS

COMPUTING AND DATA PROCESSING

An award was made to purchase a DEC VAX 11/780 computer system consisting of 12 Mb of memory, 1778 Mb of disk storage, and three magnetic tape drives. This system will be used for interactive editing of Doppler radar data, for editing and archiving of other NSSL collected data, and as a remote job entry link to the CDC 750 in Boulder.

NSSL's Perkin-Elmer 3242 was upgraded to 8 Mb of memory and continues to drive a color graphics unit for the display of real-time radar products as well as being used for quality control of radar data, lightning data, surface data, and tower data.

Universal format tapes were produced for Doppler radar data and distributed to one university for evaluation. During the spring collection program 477 Doppler radar data tapes were recorded.

NSSL supplied data sets to these users:

Alberta Hail Project	(G. Strong)
CIMMS	(G. Lesins)
NASA	(G. Heymsfield)
NASA, Huntsville, Ala.	(S. Goodman)
NWS, Silver Spring, Maryland	(K. Shreeve)
Oklahoma University	(H. Bluestein)
Parks College	(R. Pasken)
Sperry Corporation	(W. Heiss)
Systems and Applied Sciences	(G. Smythe)
Texas A&M	(G. Sickler)
Texas Tech University	(K. Mehta)
University of Arizona	(N. Feldman)
University of Tennessee	(M. Abidi)
University of Wisconsin	(R. Ferrare, R. Mower)

FACILITIES ENGINEERING

B-52 Strategic Radar Evaluation: During the first quarter of FY 1984 the CESD Group participated in a radar data acquisition program with the Air Force for evaluation of the weather detection capability of the B-52 strategic radar. Weather data from the NSSL ground-based radars were used as the benchmark for this comparison and evaluation.

Commercial Carrier Weather Radar Evaluation: The radar system configuration necessary for the ground-based testing of an airborne radar for commercial carriers manufactured by Sperry Corporation was established during the last quarter of FY 1984. Data will be acquired and evaluated through comparison with the NSSL ground-based radar during the first quarter of FY 1985.

Doppler Radar Data to WSFO/WR: Quasi-real-time data were routinely transferred from the Doppler radar at Norman to the WSFO at Will Rogers Airport during the Spring Program. These data proved useful to the duty forecaster and provided an opportunity for gradual technology transfer and examination of minimal Doppler radar products in an important National Weather Service office.

Radar Ground Clutter Canceller Design: Design, fabrication, and testing of both the coherent and incoherent radar ground clutter cancellers were completed. Data needed for a comprehensive performance evaluation have been acquired but analysis has been postponed because of other program demands.

Dual Polarization Radar: Preliminary engineering for an antenna dual-polarization capability (system design, antenna testing, data archiving techniques, etc.) has been completed without receipt of the microwave hardware necessary to implement the capability. The stringent design requirements for NSSL hardware, particularly the switchable ferrite circulator, have presented a challenge to the manufacturer.

EXPECTATIONS FOR FY 1985

COMPUTER SUPPORT

The VAX 11/780 will be installed early in the year, and this additional support equipment will be added: electrostatic plotter, seven-track magnetic tape drive, and a two-monitor color graphics system. By mid-year a Class VI supercomputer should be operational in Gaithersburg, Maryland, and a data communication link will be established between NSSL and the Class VI. By the end of FY 1985, all major computing will be shifted to the Class VI machine.

FACILITIES ENGINEERING

Radar Dual Polarization: Assuming delivery of critical microwave hardware, NSSL will establish a Doppler radar dual-polarization capability on the Cimarron radar system during the second quarter of FY 1985. The dual-polarization radar measurement has potential for improving the radar rainfall estimates, identifying hail, and studying physical processes attending electrification and hydrometeor deformation.

PreSTORM Program: During the third quarter of FY 1985 NSSL will be host for the PreSTORM Program, a prologue to the STORM Central Program in 1988. Major facility changes will be the deployment and operation of a 42-station surface observational network covering the state of Oklahoma and expansion of the cloud-to-ground lightning location network to cover a large portion of the southern Great Plains. Other research plans include a hail study program, dual Doppler radar studies, storm electricity studies, and preliminary evaluation of dual polarization Doppler radar potential.

General Facilities: General facilities expansion and modification plans include the commissioning of a second generation data logger on the NSSL Instrumented Tower; design, fabrication and installation of a radar signal preprocessor and expanded real time display terminal on the Cimarron radar; design and installation of a real time differential reflectivity calculator; and design and installation of a microwave data link between the Cimarron and Norman radars.

COOPERATIVE INSTITUTE FOR MESOSCALE METEOROLOGICAL STUDIES

Y. Sasaki, Director, U. of Okla.; P. S. Ray, Associate Director, NSSL

The Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) is a joint venture of the University of Oklahoma (OU) and ERL through the National Severe Storms Laboratory. CIMMS received first funding in late FY 1978 and began major efforts during FY 1979. The program objectives and activities of CIMMS complement and supplement those of NSSL and the University through research conducted by Visiting Fellows, NOAA and University staff members, and student appointees. The present Council of Fellows, which helps formulate policy, includes two members from NSSL, both of whom hold adjunct professorial appointments at OU, and two members from OU. The Advisory Council, which includes representatives from OU, NOAA, and outside organizations, meets annually.

During 1984 CIMMS was host to researchers from China, South Africa, Japan, and France who undertook studies in mesoscale meteorological models and development of optimization analysis in Doppler radar meteorology. A CIMMS research scientist has continued his work on the Alpine Experiment and satellite-based analysis techniques. In March 1984 he traveled to China to present a paper at the International Symposium on Tibetan Plateau and Mountain Meteorology held in Beijing. Another CIMMS scientist developed a mesoscale variational temperature analysis scheme and tested this scheme using the CIMMS Mesoscale Model. This research was performed under a NASA contract, and the results were presented in April 1984 at the NASA Goddard Space Flight Center Program Review. A CIMMS scientist developed a variational optimization method to obtain two-dimensional wind field information from single-Doppler radar data. Approximately 14 students employed by CIMMS are engaged in research studies toward advanced degrees; 4 are undergraduate students. A CIMMS Research Associate worked in the NEXRAD program. Three postdoctoral Fellows on multiyear appointments work in cloud physics, mesoscale modeling, mesoscale dynamics, and convective instability.

CIMMS research results were reported in approximately 10 reports and publications during FY 1984.

Construction of new facilities for CIMMS and the School of Meteorology in the OU College of Geosciences is still an ongoing project.

In 1985 CIMMS will be host to a NEXRAD Conference in Norman on 2-4 April, and to the "International Symposium on Variational Methods in Geosciences" in September.

ADMINISTRATIVE GROUP

Loyce Tillman, Administrative Officer

The Administrative Management Group provides services related to communications, budget, procurement, project reporting, security, employee utilization, personnel administration, and library. The major responsibilities involve interaction with NSSL staff, with educational institutions and commercial concerns, and with administrators at ERL headquarters and in other agencies (such as FAA, DOE, USAF) and other components of NOAA.

PERSONNEL

At the end of FY-1984 the NSSL total staff included 39 full-time, 6 part-time, and 5 intermittent employees.

The work of our staff continues to be supplemented by means of contracts with the University of Oklahoma, Applied Computer Systems, and the NEXRAD/Interim Operational Test Facility.

LAND AND BUILDINGS

Leases on land and buildings utilized by NSSL during FY-1984 were renewed and entered into on 1 January 1983.

NSSL continues to occupy a two-story reinforced concrete and glass building leased from the University of Oklahoma. The building contains about 20,000 square feet and is situated on approximately 1.5 acres of land.

NSSL rents five other tracts of land from the University of Oklahoma:

(1) A warehouse containing 3,840 square feet of storage space.

(2) Ground space for the Doppler Radar Laboratory Building owned by NSSL, plus a tower supporting a rangefinder.

(3) Ground space across the street from NSSL, with the following facilities:

  (a) Small modulator building

  (b) WSR-57 radar atop a 20-meter tower

  (c) A second tower with UHF and VHF radio antenna

  (d) A third tower with IFF equipment (MPX-7 radar) to interrogate transponders aboard aircraft to determine aircraft position.

(4) Ground space, one-half acre south of and adjacent to the laboratory, occupied by a "benchmark" weather station. (This facility represents cooperation among NSSL, the University of Oklahoma, and the City of Norman, Oklahoma).

(5) Ground space used for placement of sensors to measure various parameters of storm electricity. Located on ground space is an 800-square-foot portable building used by NSSL personnel for observations and data acquisition.

Total cost for all the leases in items (1) through (5) is approximately $122,000 annually.

NSSL leases this additional space:

(6) One acre of land at Cimarron, Oklahoma, about 45 km northwest of Norman, occupied by a second Doppler radar unit.

(7) Levels at the 457 meter KTVY (Television Systems, Inc.) tower, Oklahoma City, Oklahoma, 40 km north of Norman. During most of FY-1983, wind and temperature sensors were operated at seven levels on the tower. Vertical wind data were obtained at the top and bottom, and digital data were obtained for pressure, rainfall, and solar radiation. An analog strip chart recorder and digital magnetic tape operate at the tower site, with simultaneous telephone-line telemetry of digital data for real-time displays at NSSL headquarters.

(8) Land for 28 network sites.

Total annual cost for items (6) through (8) above is approximately $25,600.

GRANTS AND CONTRACTS

FY-1984

Grants and contracts administered by NSSL during FY-1984 are listed below. These were funded both directly from the NSSL budget and from funds of other agencies.

Description	Number	NSSL Cognizant Officer	Start Date	Term Date
Applied Computer Systems "Services for Facilities Management to Operate NSSL Computer Equipment"	NA84RAE05057 ($37,900)	Bumgarner	10/1/83	12/31/84
University of Illinois "Observational Analysis in Conjunction with Storm Modeling"	NA84RAD05050 ($12,500)	Ray	2/1/84	1/31/85
University of Oklahoma Cooperative Agreement "Cooperative Institute for Mesoscale Meteorological Studies (CIMMS)" (Sasaki)	NA80RAH00004 ($324,625)	Kessler	7/1/84	6/30/85
University of Washington "Studies of Severe Convective Storms" (Houze)	NA84RAD00025 ($10,400)	Ray	10/1/83	9/30/84

In addition to the above Grants and Contracts, 110K is disbursed annually for recurring services and maintenance agreements.

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~7 FULL OR PART-TIME PERSONNEL

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PTP - PART-TIME PERMANENT, FIXED WORK SCHEDULE
FTT - FULL-TIME TEMPORARY, FIXED WORK SCHEDULE
PTT - PART-TIME TEMPORARY, FIXED WORK SCHEDULE
WAE - INTERMITTENT TEMPORARY, NO FIXED WORK SCHEDULE. UNDESIGNATED WAE'S ARE TEMPORARY
WAE(P) - INTERMITTENT PERMANENT, NO FIXED WORK SCHEDULE. (P) DESIGNATES PERMANENT WAE EMPLOYEE

AS OF SEPTEMBER 30, 1984

NATIONAL SEVERE STORMS LABORATORY

The NSSL Technical Memoranda, beginning at No. 28, continue the sequence established by the U.S. Weather Bureau National Severe Storms Project, Kansas City, Missouri. Numbers 1-22 were designated NSSP Reports. Numbers 23-27 were NSSL Reports, and 24-27 appeared as subseries of Weather Bureau Technical Notes. These reports are available from the National Technical Information Service, Operations Division, Springfield, Virginia 22151, a microfiche version for $4.00 or a hard copy, cost dependending upon the number of pages. NTIS numbers are given below in parenthesis.

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No. 2 The Development of Aircraft Investigations of Squall Lines from 1956-1960. Brent B. Goddard. 34 p. (PB-168208)

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No. 4 On the Mechanics of the Tornado. J. R. Fulks. February 1962. 33 p. (PD-168210)

No. 5 A Summary of Field Operations and Data Collection by the National Severe Storms Project in Spring 1961. Jean T. Lee. March 1962. 47 p. (PB 165095)

No. 6 Index to the NSSP Surface Network. Tetsuya Fujita. April 1962. 32 p. (PB-168212)

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No. 13 500-Kc./Sec. Sferics Studies in Severe Storms. Douglas A. Kohl and John E. Miller. April 1963. 36 p. (PB-168218)

No. 14 Field Operations of the National Severe Storms Project in Spring 1962. L. D. Sanders. May 1963. 71 p. (PB-168219)

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No. 20 Field Operations of the National Severe Storms Project in Spring 1963. J. T. Lee, L. D. Sanders, and D. T. Williams. January 1964. 68 p. (PB-168224)

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No. 26 Probing Air Motion by Doppler Analysis of Radar Clear Air Returns. Roger M. Lhermitte. May 1966. 37 p. (PB-170636)

No. 27 Statistical Properties of Radar Echo Patterns and the Radar Echo Process. Larry Armijo. May 1966. The Role of the Kutta-Joukowski Force in Cloud Systems with Circulation. J. L. Goldman. May 1966. 34 p. (PB-170756)

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No. 34 Note on Probing Balloon Motion by Doppler Radar. Robert M. Lhermitte. July 1967. 14 p. (PB-175930)

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No. 37 Preliminary Quantitative Analysis of Airborne Weather Radar. Lester P. Merritt. December 1967. 32 p. (PB-177188)

No. 38 On the Source of Thunderstorm Rotation. Stanley L. Barnes. March 1968. 28 p. (PB-178990)

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No. 42 A Rainfall Rate Sensor. Brian E. Morgan. November 1968. 10 p. (PB-183979)

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No. 44 A Study of a Severe Local Storm of 16 April 1967. George Thomas Haglund. May 1969. 54 p. (PB-184970)

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