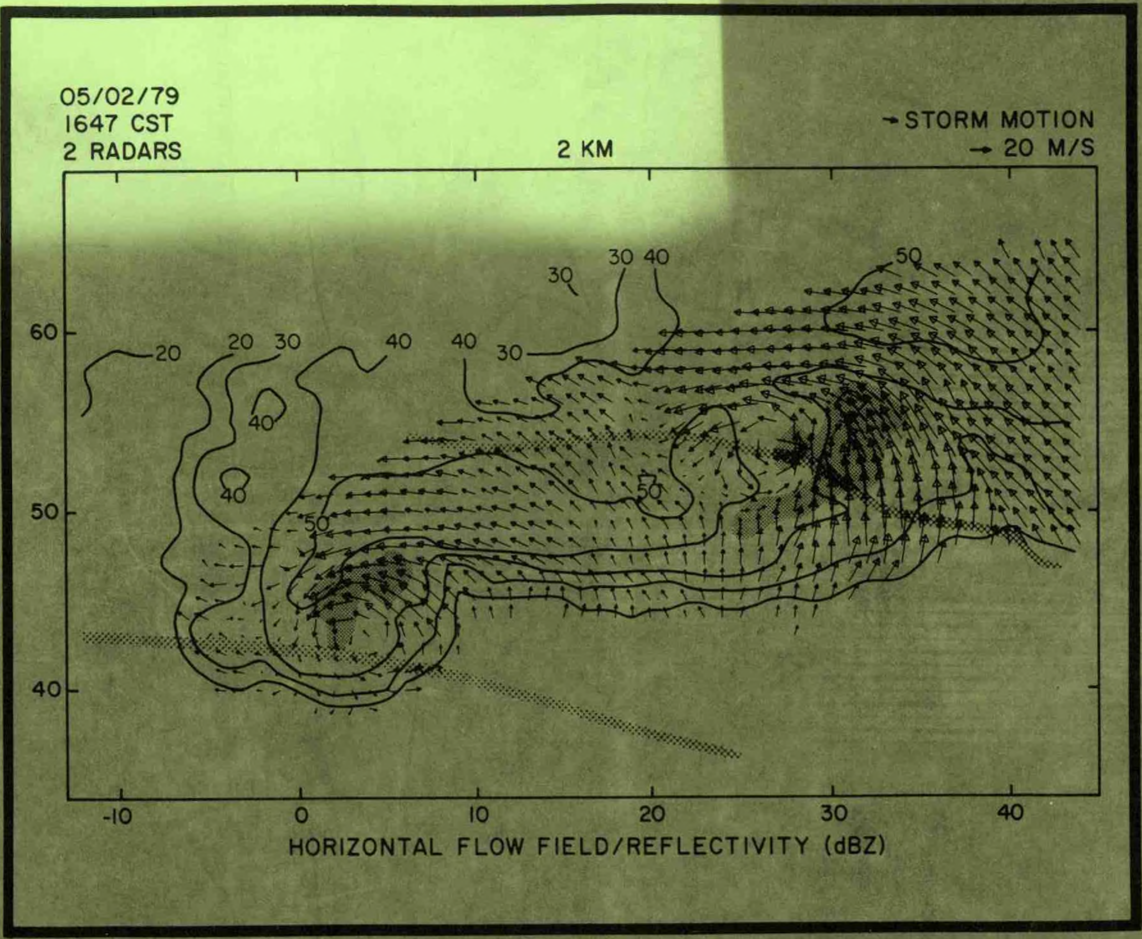
National Severe Storms Laboratory

ANNUAL REPORT FY-82



UNITED STATES DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Environmental Research Laboratories

COVER

Wind flow at 2 km elevation in Orienta and Lahoma tornadic thunderstorms, observed with multiple Doppler radars at 1647 CST on 2 May 1979. Horizontal flow is shown by vectors (scale at upper right) and significant updrafts are shaded. Paths of the two simultaneously occurring tornadoes are indicated by the hatched areas. The data are being studied in a cooperative effort with researchers from NCAR and the University of Chicago to promote understanding of severe thunderstorm morphology and the interaction between tornadoes and the larger cyclonic circulation.

NATIONAL SEVERE STORMS LABORATORY

ANNUAL REPORT - FISCAL YEAR 1982

October 1, 1981 - September 30, 1982

National Severe Storms Laboratory
1313 Halley Circle
Norman, Oklahoma 73069
April 1983

**UNITED STATES
DEPARTMENT OF COMMERCE**

**Malcolm Baldrige,
Secretary**

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

John V. Byrne,
Administrator

Environmental Research
Laboratories

George H. Ludwig
Director

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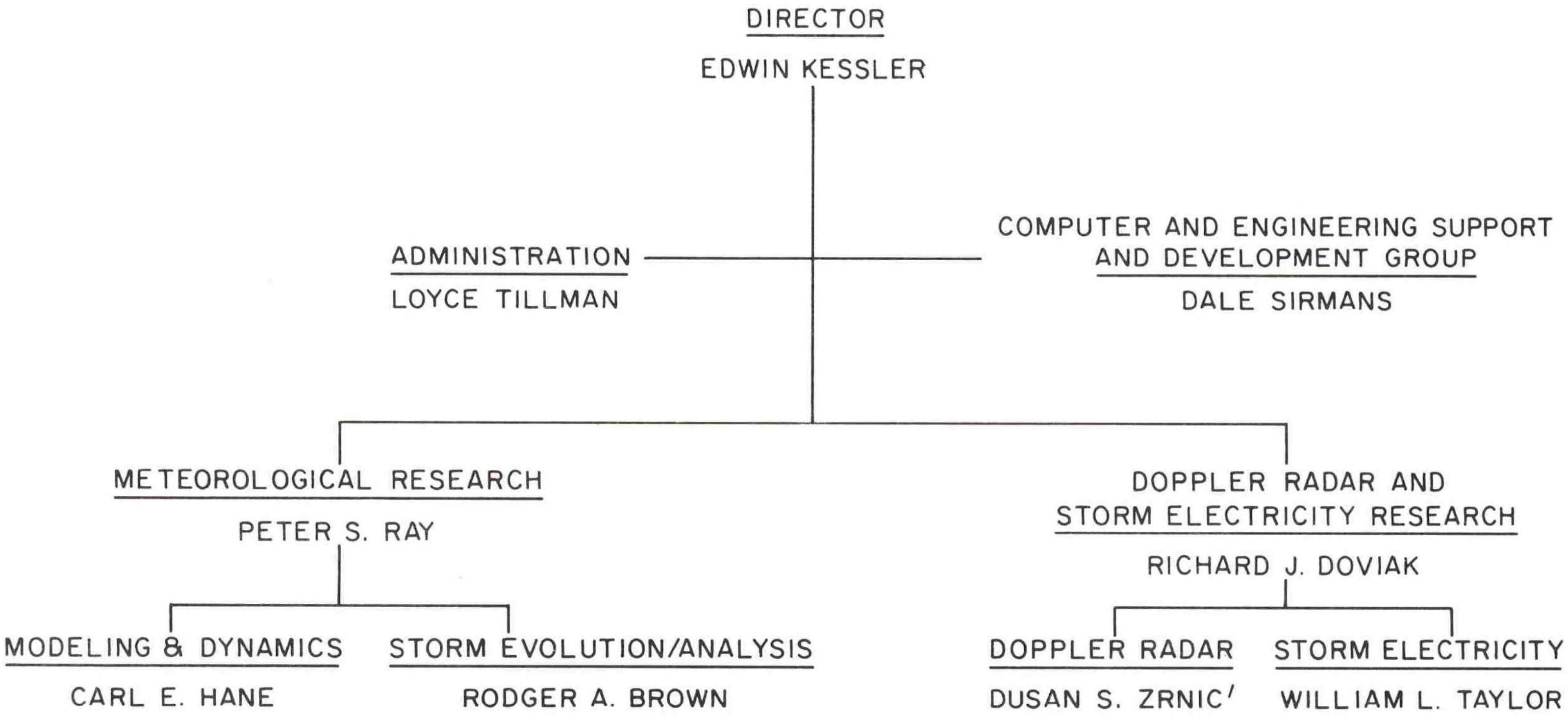

As of September 30, 1982

NATIONAL SEVERE STORMS LABORATORY

PERSONNEL STATISTICS

FY-82

October 1, 1981 - September 30, 1982

	October 1, 1981		September 30, 1982	
	Full-time	Part-time	Full-time	Part-time
Professional	27	1	26	2
Technical	9	2	8	3
Clerical	6	3	5	4
TOTAL	42*	6	39	9

Number of full-time holding doctoral Degrees on October 1, 1981	12*
Number of full-time holding doctoral Degrees on September 30, 1982	11

In addition to the above, the Laboratory employs 17 OU students having assignments with NSSL staff who are Adjunct Professors at OU. The Cooperative Institute for Mesoscale Meteorological Studies employs nine Graduate Research Assistants, two Computer Programmers, one Draftsperson, and a part-time Secretary supported by NSSL.

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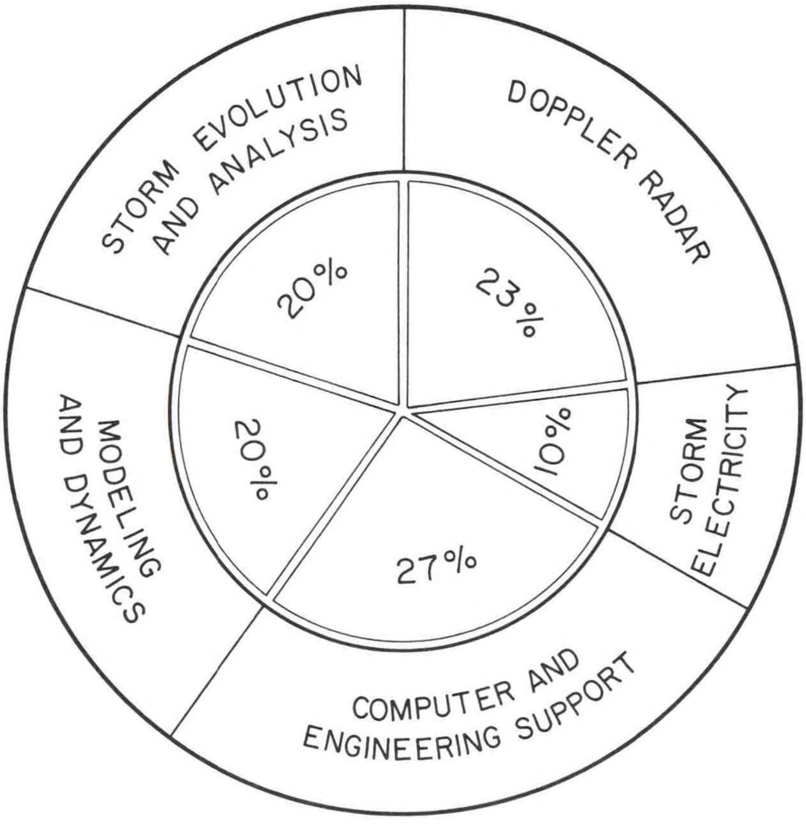
*Includes two post-doctoral research associates of the National Research Council.

NATIONAL SEVERE STORMS LABORATORY

FY-1982 Budget and Funding

NOAA Operations Research and Facilities		$2,856,500
Support		300,000
Other Agencies: (FY-82 New Funds, in thousands)		
AFGL	$ 55.0	
Federal Aviation Administration	160.0	
National Aeronautics & Space Administration	105.4	
U.S. Department of Energy	18.5	
Total Other Agencies		339,000
TOTAL		$3,495,000

Funding by Project*



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*A portion of administrative costs is included in each of the percentages shown.

PROGRAM AREAS

NATIONAL SEVERE STORMS LABORATORY

Edwin Kessler, Director

INTRODUCTION

The Laboratory staff studies severe storm circulations and dynamics and investigates techniques for improved storm detection and prediction, in support of NOAA's operational mission, carried out by the National Weather Service. Progress during FY 82 in research and its applications was remarkable.

1. Mechanisms by which rotation is much intensified in some severe storms were substantially clarified. Improved applications of sounding data and radar data for predicting storm characteristics are indicated.

2. Substantial progress was made in deriving distributions of temperature, pressure, and moisture from detailed fields of three-dimensional winds and reflectivity observed by Doppler radar. This new area of study opens up uses for Doppler radar in numerical prediction, provides insight to hail growth processes, and helps us to understand how weather-creating forces are replenished and modified during development of precipitating weather systems.

3. It was demonstrated that satellite radiance data, widely available but now largely unused in numerical prediction, can provide diagnoses of the vertical air velocity substantially better than those defined by conventional surface and upper air observations alone. Areas of substantial updrafts are often identified with severe storm outbreaks. Means are being developed to improve storm forecast accuracy through detailed wind data which may be provided by future sounding systems, including Doppler radars, profilers, and windsat.

4. A role of outflow boundaries in storm initiation, propagation, and intensification, long inferred from satellite cloud photographs, is being elucidated through studies of satellite data and corresponding detailed velocity fields defined by Doppler radar. As techniques for describing several important characteristics of outflow boundaries become available, better prediction of thunderstorm events should result.

5. A conceptual model of the evolution of mesocyclones (which sometimes harbour tornadoes) has evolved from examination of data on mesocyclones collected at NSSL since 1971. This model, as a stock-in-trade of meteorologists presented with sequential data from the future Doppler radar system (NEXRAD), will help produce more accurate warnings.

6. Although a Doppler radar measures directly only the radial component of air motion, we have been improving several methods for using single Doppler radar to measure the flow of air more fully. In particular, we have optimized single Doppler radar methods for calculating horizontal divergence estimates in the prestorm atmosphere. It has long been known that persistent horizontal convergence of air at low altitudes is a precursor of storm development and capability to measure this quantity accurately and remotely should facilitate the prediction of storm outbreaks.

7. Characteristics of lightning discharges that transfer positive charge to ground have been documented in studies conducted at NSSL. The positive flashes tend to have single return strokes rather than the more common multiple strokes, and a large fraction of flash events have a destructive continuing current. Their extremely short (submicrosecond) rise times documented at NSSL indicate their significance for damage to avionics systems through inductive coupling. Variations in the frequency of occurrence of positive flashes have been associated with features of thunderstorm life cycles.

8. New techniques have been developed by NSSL staff to map lightning discharges and associated fields of air velocity and precipitation in storms. Lightning studies are an essential component of aircraft hazard investigations by NSSL staff supported by all of the FAA, US Air Force, US Navy, and NASA. These studies are also contributing to development of a lightning mapping system to be deployed on a satellite at geosynchronous altitudes.

NSSL has historical antecedents in the former U.S. Weather Bureau and its former National Severe Storms Project, located in the early 1960's in Kansas City, Missouri. As described more fully in a 1976 special report (NSSL History and 1976 Program), the NSSL mission has changed little over the years, but approaches have changed considerably, in response to scientific discoveries, technological developments, and new requirements. From an early emphasis on use of aircraft for storm investigations related to problems of flight safety, the Laboratory has moved to emphasis on examining data from a multitude of sensors for new insights into storm mechanics, and improved sensors and their applications to storm warning and prediction. The Laboratory has consistently supported operational agencies with technologies to improve effectiveness of weather radar and safety of flight.

The Laboratory maintains a 50-station network capability for digital recording of surface meteorological parameters, and maintains instrumentation on the tallest tower in the United States that is equipped to record boundary layer parameters. Two 10-cm Doppler radars on a 42-km baseline provide unique capability for recording atmospheric circulations both in precipitating weather systems and in the optically clear boundary layer. A comprehensive range of instrumentation for recording electrical parameters provides accurate mapping of lightning discharges and measurement of electrical parameters, so that distributions of wind, water and electric fields can be recorded contemporaneously, and their interactions examined. All these supporting facilities devoted primarily to support of research are maintained for less than a third of NSSL's budget.

Through numerous relationships with other government agencies and universities, the NSSL supplies severe storm data that are examined by researchers around the country and overseas. During FY-82 the archiving of data collected on the NSSL Surface Network during the large field program, SESAME 1979, was completed. Data analyses are being undertaken at NSSL and at other research centers around the country. NSSL is pleased to have a colocated office of the NEXRAD program--NEXRAD's Interim Operational Test Facility is using NSSL's Doppler radar to test procedures for identifying storm phenomena. New warnings techniques would be applied with new radars expected to become available in the mid-1980's. The Oklahoma University-NOAA Cooperative Institute for Mesoscale Meteorological Studies developed substantially and well during FY-82; its activities are discussed in a separate section.

In the near future, research at NSSL will be focused in promising areas indicated above. The NEXRAD program will continue to have our strong support, and NSSL staff will contribute techniques having operational promise. Retrieval of thermodynamic parameters from kinematic data, and elucidation of lightning processes in the context of storm circulations and distributions of water substance represent meteorological frontiers to which NSSL should be contributing until our nation's operational weather observing and forecasting system has achieved needed accuracy in warning and predictions, and safety in flight and on the ground.

The meteorological research and applications program of our country has advanced remarkably in the decades since World War II. This is clearly demonstrated in a three-volume publication on thunderstorms completed at NSSL during 1982. The work covers more than 1150 pages, arranged in 37 chapters contributed by 51 authors. The volumes show that the public investment in research on thunderstorms and related phenomena since 1950 has produced a vast increase in our knowledge about them, with impressive new methods for early identification of storms and dissemination of information about their location, movement, and intensity, significant reduction in death rates from tornadoes, and marked decline in the rate of weather-related aircraft accidents. The technologies that are new in the 1980's, and a continually renewed cadre of brilliant and enthusiastic scientists and engineers, constitute the paths by which this remarkable progress can continue.

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

Theoretical Studies

Theory: An attempt to show by linear, inviscid, shallow convection theory that clockwise turning of the environmental shear vector with height produces storms with cyclonically (anticyclonically) rotating updraft (downdrafts) was inconclusive. Further work suggests that the veering of storm relative winds with height is a more fundamental parameter than hodograph curvature.

A physical interpretation of the diagnostic pressure equation was made to show that the dynamic component of pressure can be decomposed into two parts: deformational and rotational. The deformational (rotational) component cannot have a local minimum (maximum) in the interior of a flow domain.

An accurate theoretical approximation for adiabatic condensation temperature was obtained. The approximate solution lies within 0.01 K of the corresponding iterative solution for dewpoint depressions up to 40 K. This finding represents a refinement in data processing accuracy.

A review article by Davies-Jones (1982b) on tornado dynamics has been included in a comprehensive book on thunderstorms (E. Kessler, ed.). Work on observational and theoretical aspects of tornadogenesis has been completed by Davies-Jones (1982a,c).

Modeling: Progress has been made on the application of a method to retrieve pressure and temperature perturbations in convective circulations (Gal-Chen and Hane, 1981)[1]. An investigation into the effect of estimating water vapor in connection with these retrievals and a preliminary application of the method to the convective boundary layer have been completed by Hane and Gal-Chen (1982). Boundary layer pressure retrievals appear promising in that continuity in time is maintained and magnitudes are in agreement with previous modeling estimates. Application of the method to a tornadic storm case where Doppler-derived winds are available also is producing quite favorable results. The analysis of the 19 May 1977 squall line utilizing both Doppler-derived winds and a two-dimensional cloud model has yielded some interesting relationships between discrete production of upward motion along the gust front and maintenance of the strong highly convective region of the squall line (Kessinger *et al*., 1982). Progress in these areas means that Doppler radar data become a more significant part of numerical models, and that better forecasts will probably result.

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[1] Monthly Weather Review, Vol. 109, 564-576. References not given in footnotes are included in the list of FY82 publications and published abstracts starting on p. 37.

A numerical model is being developed to study mesocyclone evolution as a function of storm updraft strength and environmental wind shear. The procedure employs a kinematic iterative technique that utilizes only the three-dimensional wind field and a vertical air density profile. The model is initialized with a simulated axisymmetric updraft that suddenly is subjected to a vertically sheared ambient wind field. Response of the updraft to the winds is determined by iterating the three-dimensional wind field with time. This study should help us to understand the development of airflow patterns revealed by Doppler radar and other sensors.

Work is continuing on the study of the sensitivity of hail growth to storm flow fields determined from multiple Doppler radar measurements and microphysical parameters determined from a numerical model (Nelson, 1982; Pflaum et al., 1982). We hope through this approach to arrive at a more accurate assessment of means for modifying hail and the likelihood of success.

A study is near completion which involves the use of both observations and modeling to investigate a sea-breeze-induced thunderstorm which occurred in southern Florida during the 1978 TRIP experiment. A two-dimensional axisymmetric cloud model was developed and many experiments conducted using sounding data to specify initial conditions and single-Doppler radar data for comparison with modeling results. After systematic alterations of low level environmental conditions and structure of the initial perturbation, a prototype model run was selected which produced the best match with the height and width of the observed storm. Radial velocities were then calculated from the model velocities to reproduce Doppler radar observations. Good qualitative agreement was obtained in the velocity fields, and storm growth rates, evolution, and duration agreed quite well. The small amount of environmental wind shear produced significant differences in the reflectivity field, especially at later stages of storm evolution, but did not result in great changes in the radial velocity from the axisymmetric case. This study is a contribution to the interpretation and utilization of single-Doppler radar data.

Observational Studies

Mesoscale Observations: In the realm of the large scale, a study by McGinley (1982) focused on the events occurring during lee cyclogenesis. The process involves mesoscale to synoptic scale interaction to produce cyclone development. Three or more identifiable stages of development occur where the cyclone passes from a barotropic to a baroclinic structure. Such a transition may be important for development of severe storms in the Great Plains.

Further work defining the mesoscale severe storm environment involved the use of satellite radiance data. By exploiting the ability of radiance data to define thermal and moisture gradients, mesoscale analyses are obtainable. These fields, derived from assimilating rawinsonde and satellite data in an objective variational analysis scheme, were then used to compute vertical motions and these were compared with observed clouds, fronts, and meso-weather systems. In all cases, correlations were better than when rawinsondes alone were used. This scheme will be a framework for development of a mesoscale model initialization scheme, now an important goal of NSSL.

Severe Storms: During the past 12 months a considerable effort has been made to edit and complete preliminary analyses of dual-Doppler data sets obtained on 2 May 1979 and 19 June 1980. Data from 2 May are being used to study tornadic storm morphology and the interrelationships between tornadoes and their parental circulations. The storm relative windfield at 2 km height with the reflectivity (dBZ) contoured is shown on the front cover and described inside the front cover. The strong divergence (implying strong updrafts) at the storm top and the evolution of the low level mesocyclone are shown in Fig. 1. Data from 19 June are being studied statistically to determine life times of storm elements and to examine the transition from multi-cellular to supercell storms.

The Del City and Fort Cobb tornadic storms of 20 May 1977 are being examined to study the evolution of reflectivity, vertical velocity, vorticity and vorticity generation. The data set for this day is unique in that Doppler observations of these tornadic storms exist for a time period of 2 hours for the Del City storm and one hour for the Fort Cobb storm. A general morphology of these storms and descriptions of the analysis technique have been given by Ray et al. (1981)[2]. Comparisons of the tornadic stage of the Del City storm to model simulations have been presented by Klemp et al. (1981)[3]. Present work includes examinations of the vector vorticity field for possible verification of the diagnostic and evolutionary theories of storm rotation presented by Davies-Jones (1982a,c), and the melding of surface observations, rawinsonde data and aircraft observations of the inflow and surface features to aid in trajectory analysis.

An investigation of severe storms that occurred on 23 May 1974 revealed interesting information on the multifaceted role of thunderstorm-produced gust fronts. Thunderstorm gust front boundaries appear to be responsible for storm initiation, propagation and intensification. An especially interesting aspect was one storm's explosive growth and formation of a tornado near the intersection of two outflow boundaries. This study indicates that improved techniques for sensing outflow boundaries may allow better predictions of location, timing, and intensity of thunderstorm events (Weaver and Nelson, 1982).

A paper discussing the utility of using radar to estimate rainfall was completed. A review of thunderstorm rainfall measurement by rain gage and radar was completed (Brandes and Wilson, 1982). The principal conclusions were these:

- Errors in radar rainfall estimates result from errors in estimating radar reflectivity factor and variation in Z-R relationships.
- Co-existing thunderstorms may have distinct radar error patterns.
- There is a tendency to overestimate light rainfalls and to underestimate heavy rainfalls with radar.

NSSL Doppler radars documented portions of the life cycle of the disastrous Wichita Falls tornadic storm (10 April 1979) as it moved from 310 km southwest of Norman to 75 km southeast of Norman. Single Doppler velocity measurements prior to the time of the Wichita Falls tornado revealed the presence of two mesocyclones about 20 km apart; the northeastern-most mesocyclone was associated with the earlier Seymour, Texas, tornado and the second mesocyclone would produce the Wichita Falls tornado. By the time the second tornado formed, the first mesocyclone had dissipated. In general, the Wichita Falls storm followed the long recognized supercell characteristics of motion, shape, and evolution common to tornadic storms (Burgess, 1982).

A conceptual model of mesocyclone evolution is emerging from NSSL's data set of Doppler radar measurements that have been made in severe thunderstorms since 1971. Mesocyclone lifetime can be described as having three stages (Figs. 2 and 3).

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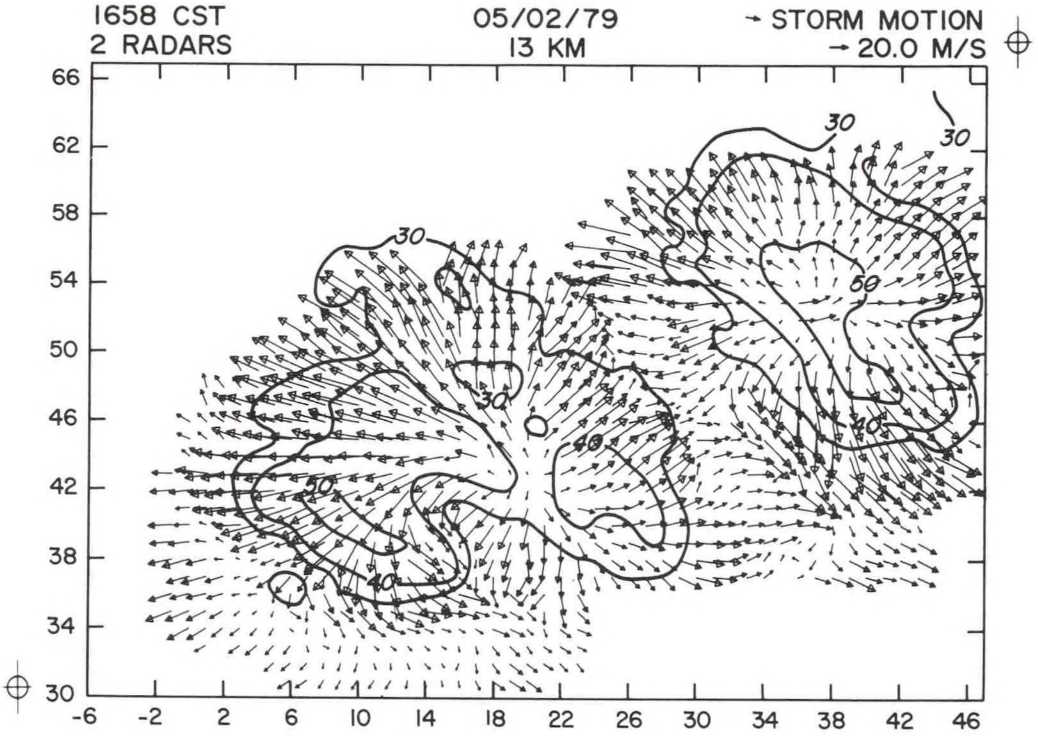
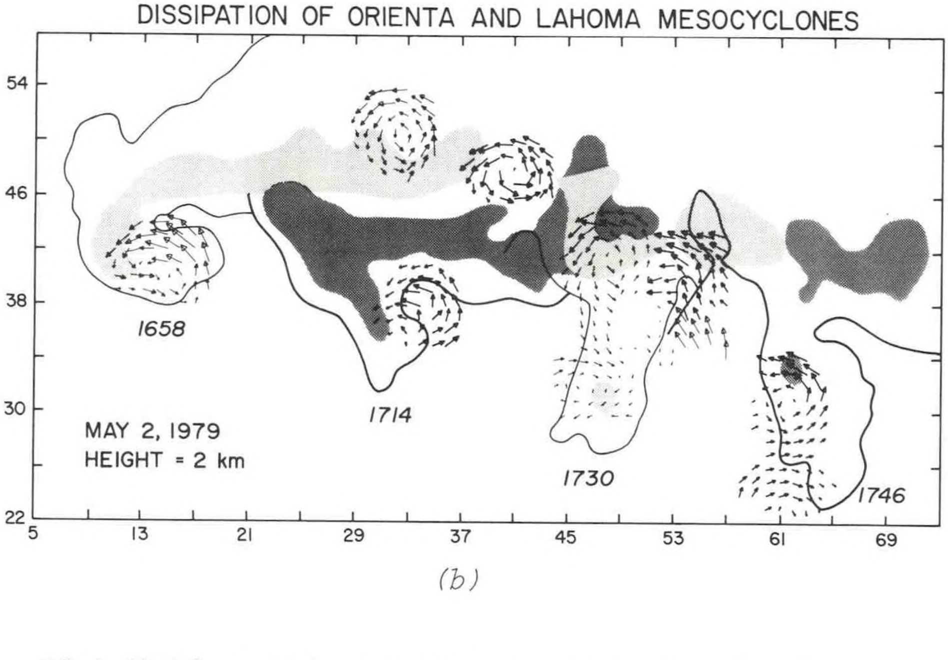
[2] Journal of Atmospheric Sciences, Vol. 38, 1643-1663. [3] Journal of Atmospheric Sciences, Vol. 38, 1558-1580.



(a)



(b)

Figure 1(a). Wind field at 13 km height in the Orienta and Lahoma tornadic thunderstorm at 1658 (11 minutes later than wind field at 2 km height illustrated on the front cover) on 2 May 1979. (b) The evolution of the mesocyclones from 1658 through 1746 is shown at a height of 2 km. The arrows and stippling (for reflectivities greater than 50 dBZ)are shown alternately light and dark for each time. The outer contour is 30 dBZ. In (a) the reflectivities are labeled in dBZ.

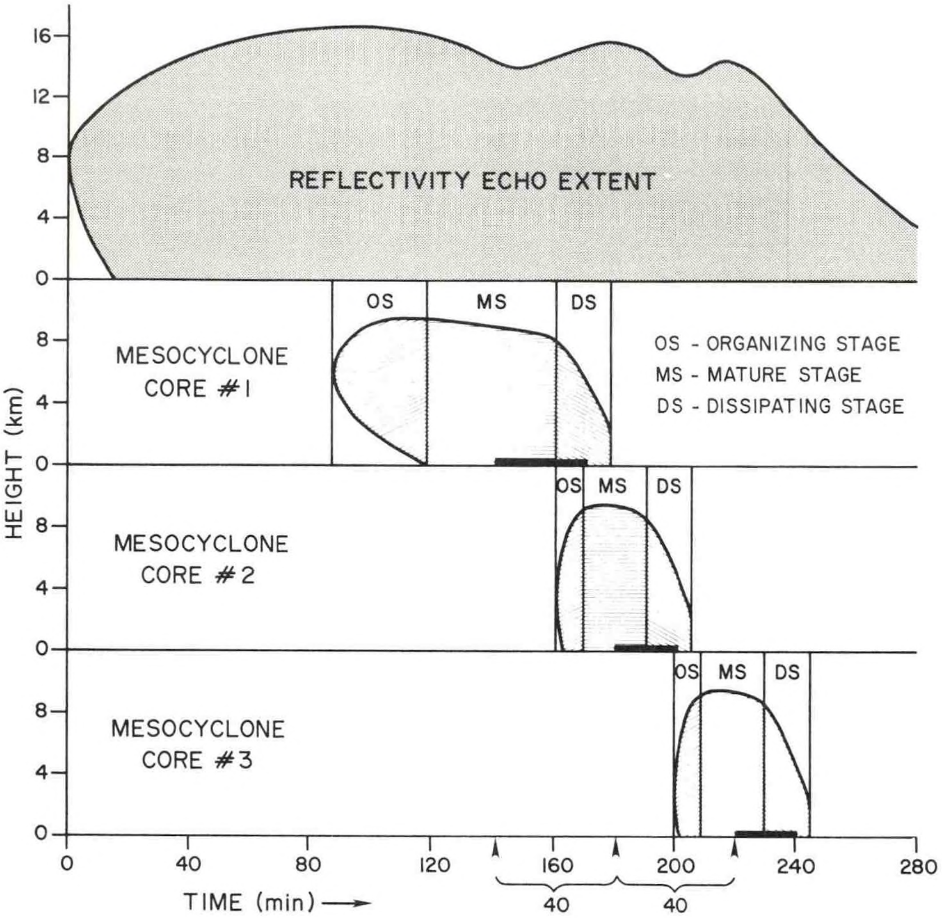


Figure 2. Time-height schematic model of mesocyclone evolution in a supercell storm based on single Doppler mesocyclone signatures collected 1971-1977. Mesocyclone starts forming aloft about 90 minutes after the first radar echo in the storm appears. It takes the circulation about 30 minutes to descend to the ground--marking beginning of mature stage. Midway through the 40-minute-long mature stage a tornado (if one forms)--indicated by horizontal bar--touches the ground; during this stage, echo top decreases. During the 20-minute-long dissipation stage, the mesocyclone core rapidly decreases in depth and disappears; the tornado lifts midway through this stage. The mesocyclone dissipates because its central updraft has been choked off by a gust front occlusion process (see Fig. 3). If a new updraft forms at the occlusion point (discrete propagation), a new mesocyclone core center rapidly forms (in less than 10 minutes compared with 30 minutes for the first core) taking advantage of the pre-existing mesoscale vorticity. The second (and subsequent, if any) mesocyclone lasts only half as long as the first core; all stages are shorter, especially the organizing and mature stages. Sequential tornadoes form within the series of mesocyclone cores at roughly 40-minute intervals. From Burgess et al. (1982).

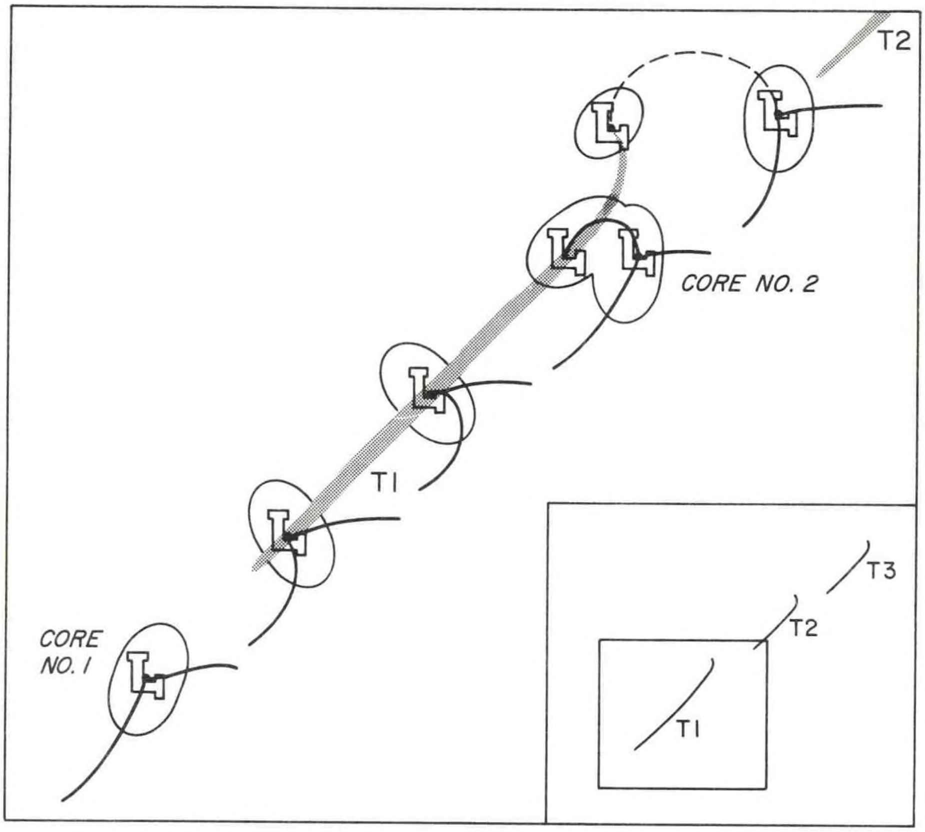


Figure 3. Plan view of mesocyclone core evolution relative to surface tornado tracks (shaded paths labeled T1, T2, T3); time increases from SW toward NE. Core is indicated by surface low pressure area (L) and associated "warm front" and gust front ("cold front"). Note that core 1 occludes and core 2 forms at the point of occlusion while the first tornado still is on the ground. Insert shows the tracks of the tornado family, and the small rectangle is the region expanded in the figure. From Burgess et al. (1982).

In the organizing stage, the mesocyclone--that starts at storm midlevels--grows upward and downward toward the ground. During the mature stage, the mesocyclone is strongest and extends from the ground to heights of 8 to 10 km. During the dissipating stage, the top of the mesocyclonic circulation quickly descends to the ground as the circulation weakens.

If a mesocyclone has more than one (sequential) circulation core, subsequent cores develop much faster and remain mature for shorter periods of time. When a severe storm produces a series of sequential tornadoes, each tornado forms during the mature stage of the core circulation and decays during the dissipation stage (Burgess et al., 1982). This model is illustrated in Figs. 2 and 3.

It is well known that the right-moving member (looking downwind) of a splitting storm pair contains a mesocyclone with a closed counterclockwise circulation. NSSL has been successful in making single Doppler velocity measurements in two left-moving members of a split pair. Meso-anticyclones (clockwise circulation) were found to coincide with the left-moving storm updrafts. However, the meso-anticyclone is more limited in its vertical extent and duration compared with its mesocyclone counterpart (Burgess, 1982).

Tornadoes: A review article on interception of tornadoes by mobile teams has been included in a comprehensive book on thunderstorms (Davies-Jones, 1982d). During the 1982 Spring Program the NSSL Tornado Intercept Team encountered six tornadoes, and in a joint effort with Oklahoma University deployed TOTO (described in the FY81 Annual Report) within 3 km of two tornadoes and under the edge of two rotating wall clouds. A pressure fall of 3 mb and a wind gust of 33 m s^{-1} were measured in association with one of the tornadoes. Descriptions of 1981 intercepts are contained in the 1981 Spring Program Summary (Taylor, 1982).

NSSL Doppler radar measurements in the supercell storm that produced the unusually large Binger tornado (22 May 1981) revealed unusual features. The Doppler velocity tornadic vortex signature (TVS) extended from the ground to within 1 km of storm top--indicating that the tornado itself existed throughout the same depth. Even more interesting is the finding that a weak echo hole coincides with the TVS. This is the first time that a marked reflectivity feature has been associated with a TVS (Lemon *et al.*, 1982).

GENERAL STUDIES

Present efforts in experimental design and optimal network siting for mesoscale sampling ha~~s~~ve centered around the estimation of time-space autocovariances and cross covariances using mesonet surface data. The optimal siting technique currently under consideration is a statistical technique which, when combined with covariance data and mathematical programming algorithms, will provide coordinates for the optimal arrangement of sensors in a network. The present work is confined to surface networks and sampling in an (x,y,t) space. However, this technique should be extendable to four-dimensional sampling by multivariate sensors and is expected to be capable of allowing physical, dynamical and economic constraints to influence the sampling strategy.

To provide quality data for future analysis of severe storms, programs were developed to aid in the quality control and archiving of the 1979 SESAME Stationary Automated Mesonetwork (SAM) data. Owing to temperature sensitive pressure units, pressure corrections were statically determined by using data collected from these units when subjected to varying conditions in an environmental chamber. The spatial integrity of the surface data was checked by use of a program developed to read the data archived in universal format and objectively analyze it. All surface data for days when storms were present within the mesonetwork for the years 1973 through 1977 were archived in the universal format.

A software package was written for use on the CDC Cyber 750 to interface the NSSL plotting package with the DISSPLA plotting package residing on the 750. This eliminated the need to rewrite the NSSL graphics programs to be used on the 750 when the conversion to the 750 took place at the beginning of FY-82. This package has benefited nearly all projects in the analysis of severe storms.

EXPECTATIONS FOR FY-83

Theoretical and observational investigations of tornadogenesis will continue.

Analysis and modeling of the 19 May 1977 squall line case will be completed.

Study of the 20 May 1977 storms will be completed and submitted for publication.

Computation of severe storm statistics from surface data for use in objective analysis and experimental design techniques will be completed.

Techniques for the design of mesoscale field experiments will be further developed.

Case study of application of the thermodynamic retrieval techniques to a tornadic storm will be completed.

DOPPLER RADAR AND STORM ELECTRICITY RESEARCH (DRASER)

Richard J. Doviak, Group Leader

INTRODUCTION

The NSSL facility to observe electrical and kinematical processes contemporaneously with precipitation phenomena has no parallel elsewhere. DRASER deals with the many complex aspects of storm kinematics, precipitation and electricity. Major objectives include (1) determining relationships between lightning discharge processes and the dynamics and precipitation structure of thunderstorms, (2) evaluating storm electricity and Doppler radar data for indicators of thunderstorm severity and hazards, (3) developing and refining remote sensing techniques for predicting, locating and tracking thunderstorms, and for improved warnings of their hazards, (4) defining lightning and kinematic characteristics of storms for inputs into engineering criteria for hazards to aircraft and ground facilities, and into models used in environmental studies, (5) measuring effects of electric fields and lightning on radar-derived meteorological parameters, (6) providing ground truth and supportive data for development of new instrumentation and refinement of observational techniques, (7) developing techniques applicable to NEXRAD for the real-time identification and display of storm hazards, and (8) evaluating the potential of Doppler radar to improve the short-term prediction of severe storm development.

These objectives are addressed through both theoretical and observational studies. The improvement of our observational techniques and the development of new instrumentation keep us at the very frontier of storm research. Simultaneous observations of storm parameters and cooperative efforts in the analysis and interpretation of storm data make NSSL unique in this research area.

The Doppler Radar Group focuses its efforts on interpretation of atmospheric phenomena with Doppler radar both for prestorm and stormy weather. The Storm Electricity Group focuses on observations of electric fields and lightning in and around thunderstorms in order to determine the interaction between storm processes, especially microphysical processes, and the storm's electrical field.

RECENT ACCOMPLISHMENTS

Doppler Data Collection Program 1982

The 1982 spring data collection effort was quite intense in spite of the fact that fewer storms developed in the dual Doppler areas than did the previous year. Some very interesting data were collected.

Severe gust front cases passed over the surface network including the LLWSAS system installed at Will Rogers Airport and winds in excess of 60 kn were recorded. Dual Doppler data, also recorded, are being analyzed.

Several unique data sets of lightning echoes at vertical incidence were obtained. This time the pulse duration was only 0.25 μs with a corresponding range resolution of 37 m (cf. 1 μs and 150 m in use on previous occasions). Fine resolution and comparison of reflectivities with different resolutions should facilitate accurate determination of the cross section of lightning elements. An analysis similar to the one reported by Zrnic' et al. (1982c) is underway.

VHF lightning mapping sites, ELF installations, electric field change devices, direction of arrival network, video cameras, photographic and visual techniques, L-band radar, instrumented balloons, specially equipped aircraft, various other storm electricity sensors, and 10-cm Doppler radars were closely coordinated for data acquisition during the 1982 thunderstorm season.

The VHF lightning mapping equipment at our two sites was modified to extend the observable azimuthal sector from 60° to 120°. Observations using the larger 120° sector were conducted during the NSSL Spring Program. Thunderstorms within our dual mapping region were very sparse--good dual mapping data were obtained on only one day. Single site observations were made on several storms, and the Norman VHF mapping equipment was switched into the vertical looking mode for a few storms passing overhead.

Data were collected from the lightning ground strike locator during the NSSL spring operation with particular emphasis on evaluating its performance for detection of positive cloud-to-ground (+CG) lightning. One promising data set was obtained from several instruments on 30 May 1982 when there appeared to be many +CG flashes. Data collection from the ground strike locator and television video systems continued through the rest of the year as part of our effort to document +CG flashes.

In cooperation with the FAA, the evaluation experiment comparing airborne Doppler radar with NSSL's ground-based Doppler was resumed in May. By the end of June, the Collins C-Band and the Bendix X-Band systems had been flown and data obtained on several storms. The Collins X-Band system test was completed in July. The airborne systems display reflectivity and turbulence, as indicated by the Doppler velocity spectrum width.

In support of NASA's work to develop a satellite system for lightning detection, considerable emphasis during the spring data collection period was placed on acquiring measurements at the ground as an instrumented NASA U2 overflew storms in Oklahoma. On several days, simultaneous cloud-to-ground lightning and surveillance radar data were recorded while the U2 flew over storms more than 100 km west of NSSL. On 27 May, 9 flight passes were made over a squall line as it moved toward and over NSSL. These data are the first set of multisensor ground truth measurements made below the U2 in Oklahoma. Storm tops extended to 17 km on this day and lightning activity was often intense.

Another significant accomplishment during the spring was the successful test flight into a severe storm of a free balloon instrumented to record the electric field vector inside the storm. This cooperative program with the University of Mississippi demonstrated the feasibility of making such measurements to obtain electric field profiles in severe Oklahoma storms.

Prestorm Studies

In the prestorm study area, efforts have been completed to convert existing programs for signal Doppler estimates of wind fields to the CDC Cyber computer.

The VVP (Velocity Volume Processing) algorithm has been applied to prestorm radar data in order to obtain fields of horizontal divergence over large regions of the planetary boundary layer (Doviak, 1982). The results were tested against divergence obtained using dual Doppler radar data and have been published by Koscielny et al., 1982. In order to extend the comparison over larger areas, a new algorithm was developed to calculate divergence directly from radial velocity components of two Doppler radars (using Stokes' Theorem). The residual variance of the VVP data fit was found to be a useful criterion in accepting divergence estimates. The effect of beam blockage at low elevations was found to significantly bias VVP divergence estimates. A study has been made to determine the effective radar beam height as a function of azimuth and elevation when the beam is partially blocked by ground obstacles. Meanwhile some testing of the VVP program showed that decreasing the sector size does not appreciably improve the degree of fit to a linear wind, while the possible error in divergence estimation increases exponentially. Thus, VVP results cannot be improved by using sector sizes much less than 40 degrees.

The VVP program was added to the Perkin Elmer (PE 3242) data processor and tested. A subroutine has been developed to average radial velocities before the VVP analysis, which should reduce VVP processing time by at least 80 percent, suitable for real-time processing.

A routine was developed to plot and directly contour data obtained on polar grids (without interpolation to Cartesian grid). This is being used to analyze the divergence fields obtained from the VVP for a two-hour period before development of tornadic thunderstorms ahead of a dry line (17 May 1981).

Another algorithm computes vertical profiles of divergence at different ranges using the VAD method. The first analysis of one case (19 June 1980) reveals a rapid development of low level convergence about two hours before the development of thunderstorms in the area (Rabin and Doviak, 1982: Figure 4). The effect of beam smoothing on the vertical profiles of divergence has also been examined and a routine was developed for use on the CDC 750 to deconvolve and plot, with better resolution, the height profiles of divergence and vertical velocity.

Some time series data were analyzed to determine the structure constant C_n^2 for the prestorm environment (Doviak and Rabin, 1981). Values of 10^{-14}-10^{-15} were found in the PBL, with $C_n^2 \leq 10^{-15} m^{-2/3}$ for heights above about 2.3 km. Studies have begun to relate vertical profiles of reflectivity in clear air to turbulent fluxes of sensible heat and moisture. Fluxes have been computed from the KTVY tower data for a few cases of coincident radar measurement. However, there appears to be considerable uncertainty in the absolute value of these fluxes.

Results of radar measurements of momentum flux and the turbulent kinetic energy budget terms in the boundary layer were published (Rabin et al., 1982).

VHF Lightning Mapper

Analyses of the VHF data from prior seasons continued with emphasis placed on initial location and progression speeds of a lightning flash, and on relating lightning location mapped by the passive VHF system with other storm electricity parameters and with storm reflectivity and internal wind structure mapped by radar (Taylor, 1982). Detailed analyses of VHF mapped lightning flashes and 10-cm Doppler radar data were completed for four storms occurring on June 19, 1980 (Taylor, 1981). In these storms, VHF sources from lightning processes for cloud-to-ground (CG) and for intracloud (IC) flashes were confined to an altitude below about 10 km. The average height of VHF sources was 4-5 km for CG flashes and

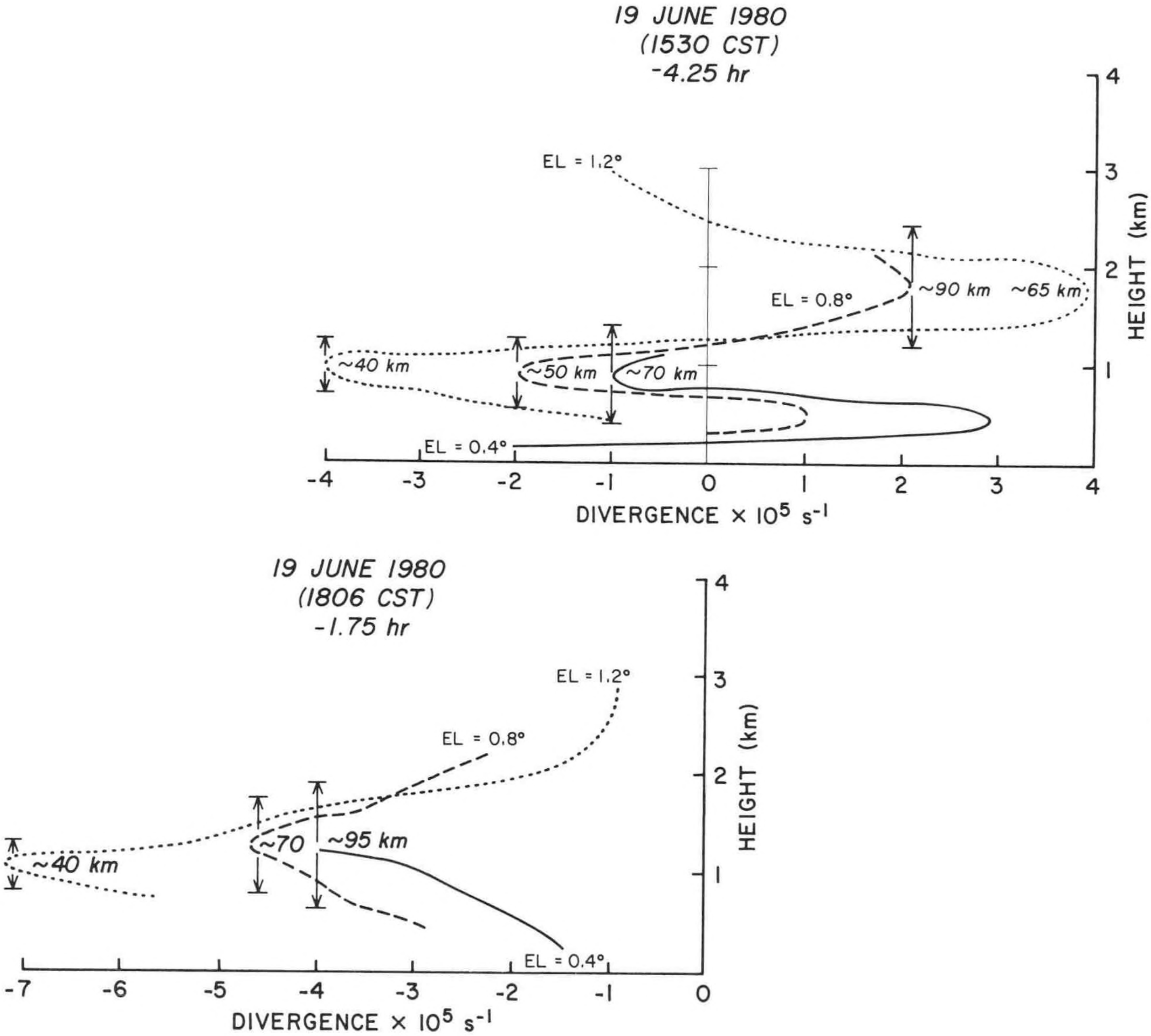


Figure 4. Divergence profiles 4.25 and 1.75 hours before local thunderstorm development. Divergence is determined from Doppler radar data using the VAD algorithm at the noted elevation and range.

5-6 km for IC flashes which placed most lightning in the -15°C to -20°C region. Both CG and IC lightning activity was centered on the main high reflectivity region of a storm and downwind from strong updraft regions (Rust _et_ _al_., 1982).

Another class of IC flashes was discovered that produced a splattering of VHF sources within the main electrically active regions of these four storms and also in a large canopy over the main discharge regions to altitudes of 16 km or more. There was almost a continuum of activity on a second-to-second time scale from many small volumes within the cloud, but each volume produced a very low VHF impulse source rate. Consequently, in our previous analyses of other storms, these relatively minor flashes were ignored relative to the major flashes that occurred sporadically but produced very high impulse rates. The altitude distribution of VHF sources from one small storm is shown in Figure 5, comparing the minor and major discharges. Note that more sources were produced by the minor discharges centered at a height of 12 km than by the major discharges centered at about 5.5 km. The lightning activity producing the upper portion of the minor discharges tended to be centered on the main reflectivity column in the cloud. There seemed to be no temporal association between the minor discharges at high altitudes and

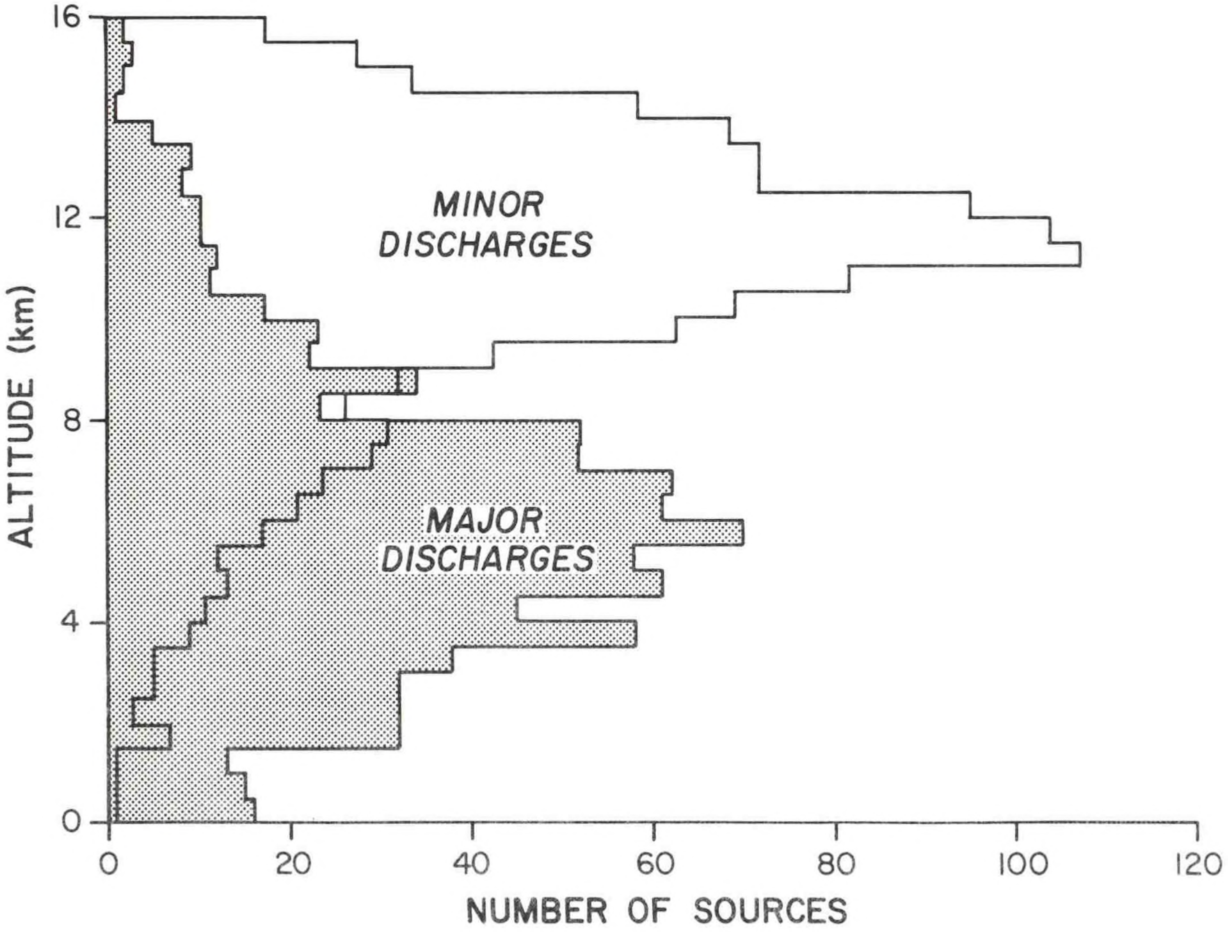


Figure 5. Altitude distribution of VHF impulses storm I, 6/19/80.

the major discharges in the lower portions of the storm. This means we are probably dealing with two classes of lightning, which may indicate different charging mechanisms and different discharging processes and which may pose different levels of hazard to aircraft.

Turbulence Studies

Eddy dissipation rates inferred from the Doppler spectrum width are being compared with rates measured from the spatial spectra of Doppler velocity. It appears that dissipation rates inferred from the spectrum width are consistently higher.

A related study shows that the residuals between a least-squares-fitted linear shear model and actual velocities are largest at locations in storms where the turbulent contribution to spectrum width is large. It appears that intense buoyant mixing at scales larger than the resolution volume causes these residuals, and that the large scale turbulent energy at these locations cascades down to the subresolution volume scales which in turn causes the observed large spectrum widths.

Gust Fronts

Several gust fronts detected by the Norman radar have been examined to build a data base on reflectivity, peak winds, heights, etc. These data should help specify requirements for ground clutter canceller design and the location of radar sites near airports. A particularly interesting gust front occurred on May 11, 1980 (Lee and Doviak, 1981). A bow-shaped discontinuity in velocities extended over 100 km away from the storm that produced it (Figure 6). Data show this solitary gust to have been a cylindrical pool of cool air that propagated southeastward (Figure 7).

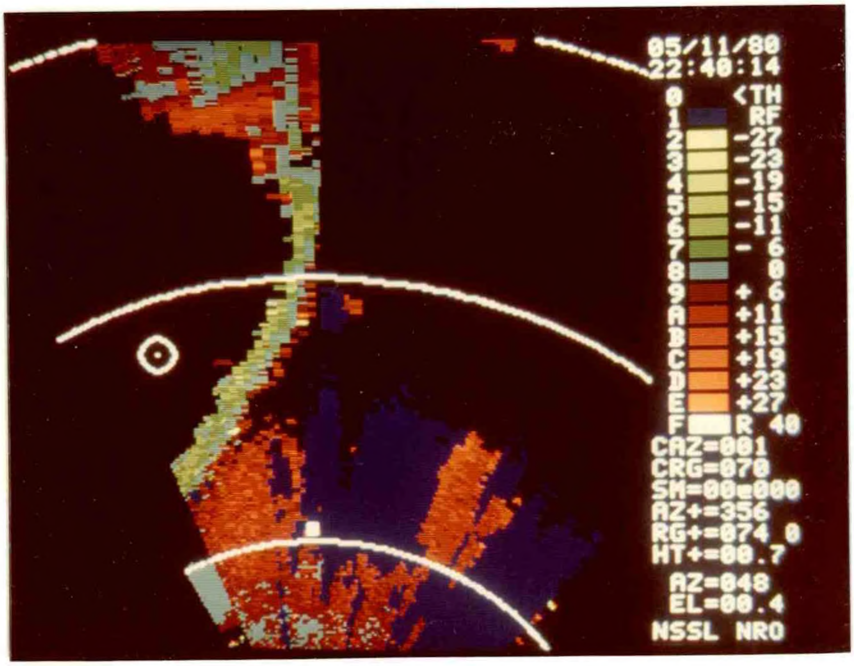


Figure 6. Radial velocities in a bowed gust line produced by thunderstorm outflow at ground level. Red (green) colored areas are radial velocities away from (towards) the radar. The shades from dark to light correspond to median radial velocities 6, 11, 15, 19, 23 and 27 m·s^{-1}. The gray hue is for a median value 0 m·s^{-1}. Dark blue areas indicate presence of overlaid echoes. Elevation angle is 0.40° and range marks are at 40 and 80 km.

Doppler Spectra of Tornadoes

An analysis of the spectra from the Binger tornado that occurred on 22 May 1981, has been completed (Hennington et al., 1982). Direct measurements of maximum velocities from Doppler spectra yielded values of over 90 m·s^{-1} at the location of tornado damage path. Houses were completely destroyed, and large missiles were generated at the time of the Doppler measurements. This tornado extended to within 1 km of the storm top (Lemon et al., 1982).

NASA-NSSL Joint Experiments

i) ELF Cloud-to-Ground Lightning Detection

A new sensor for observing extremely low frequencies (ELF) was developed and installed at NSSL and at NASA/Marshall Space Flight Center in Huntsville, Alabama. The receiving system is wideband, 6 dB down at 15 Hz and 6 kHz, and employs a novel design to eliminate 60 Hz and all harmonics from a.c. power line noise. Simultaneous data from both sites were obtained for cloud-to-ground (CG) flashes out to ranges of about 1000 km. Sample waveforms observed at Norman and Huntsville are shown in Figure 8. Note the similarity in the waveforms produced by the negative lightning return stroke #46, although the amplitude at Huntsville was small because of the greater range to the source. Waveforms for the positive stroke #35 are also very similar and comparable in amplitude since the range from each observing site is about the same. One advantage of using ELF observations for identifying the polarity of CG flashes is the preservation of the initial polarity for the return stroke regardless of range. At higher frequencies, the measured return stroke polarity varies with the distance between the event and sensor.

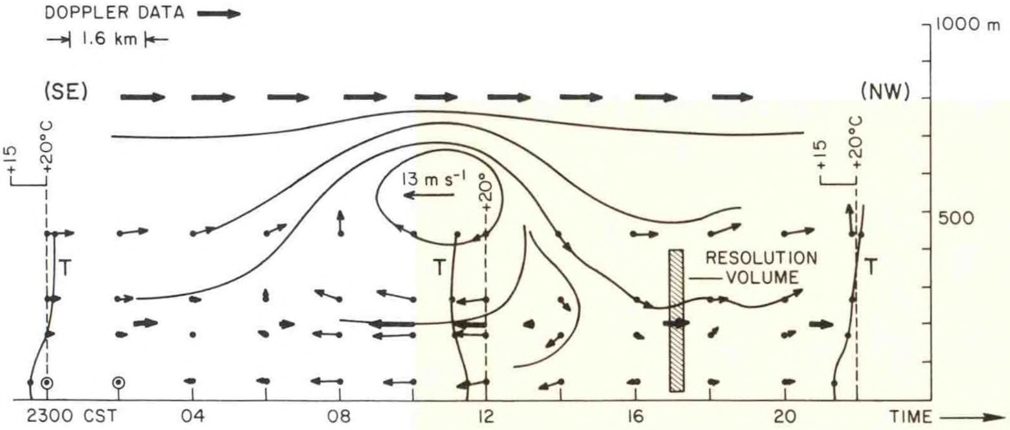


Figure 7. SE-NW cross-section of a gust, comparing pulsed Doppler radar and tower velocity data. Lightly traced arrows are the tower measured winds projected onto this plane, bold arrows the Doppler velocity; vertical lines labeled are temperature profiles. The hatched area shows the radar's resolution volume cross-section in the plane of the beam axis. (From Rust and Doviak, 1982.)

This ELF system will be evaluated for possible use in a combined ground-and satellite-borne lightning mapper to be developed by NASA. The ELF system was also used to augment our ongoing research on positive cloud-to-ground (+CG) flashes. A unique data set on +CG flashes was obtained with the ELF sensors, photographic and television cameras, electric field change sensors, the VHF mapping system, and the lightning ground strike locating system. Positive CG flashes appear to be more hazardous than negative CG flashes and may be better correlated with storm severity.

ii) Radar-Lidar Investigation of the Atmosphere

The Doppler group is cooperating with CIMMS and NASA on joint studies. of the atmosphere by means of an airborne lidar, Doppler radar and other instruments. Preliminary comparisonsbetween instruments have been made and spectra of turbulent velocities have been obtained.

Profiling with the 10-cm Radar

A theoretical study of the feasibility to obtain winds up to tropospheric height with moderately powerful radars has been completed. Radars with a 10 dB edge over the present NSSL system should be capable of measuring winds to about 12 km when eddy dissipation rates exceed 10^{-3} m^2 sec^{-3}. An experiment was designed to verify this hypothesis using a NASA radar at Wallops Island. Two trips to Wallops Island provided evaluation of equipment in place and a basis for a forthcoming experimental study.

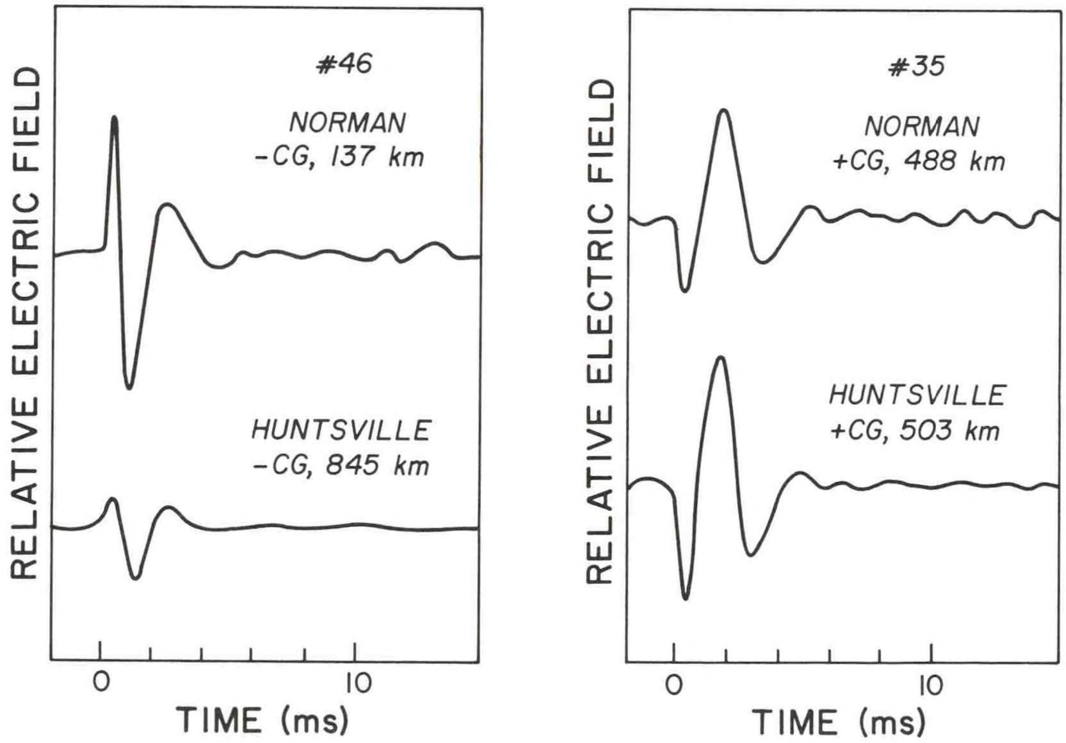


Figure 8. Examples of ELF waveforms from negative and positive return strokes.

Simultaneous Radar Observations of Lightning and Precipitation

Reflectivity, mean velocity, and Doppler spectra were obtained with our vertically-looking Doppler radar for approximately 60 lightning flashes over NSSL. The motion of lightning channels are fixed relative to the air motion providing true wind measurements. In some cases, changes in reflectivity indicate that hydrometeors, aligned by strong electric fields, may have changed orientation due to electric field changes caused by lightning. Widths of the Doppler velocity of lightning channels were often less than 0.5 m/s, suggesting that shear or turbulence within the radar beams were minimal during these observations. These data are being analyzed in our continuing effort to develop the use of lightning as a tracer of air motions and in assessing electric field, lightning and precipitation development interactions (Zrnic' et al., 1981).

We also have a cooperative experiment with Dr. Mazur of CIMMS using radars at Wallops Island, Virginia, to determine the lightning distribution in various storm types (Mazur and Rust, 1981) and to provide information to help guide NASA's instrumented F106 into regions where the aircraft could be struck by lightning. NASA's lightning-hazards-to-aviation program was helped by our capability to detect lightning in real time with radar, and more than 130 strikes to the F106 were recorded. This is more than 10 times the number in previous years.

Also, during this year, measurements of lightning were made in cooperation with the University of Oklahoma, CIMMS, and the Office of Naval Research (Rust and Doviak, 1982).

Effects of Charge and Electric Fields on the Shape of Raindrops

Closed form theoretical solutions have been obtained that relate the eccentricity of raindrops to charge and electric fields (Zrnic' et al., 1982a). The dependence of drop shape on electric field is highly nonlinear; it appears that commonly observed electric fields in clouds have little effect on drop shape whereas for somewhat stronger fields, the growth in distortion is explosive (Figure 9). This is true irrespective of the charge on the drops. In the absence of electric field, the natural oblateness of drops is enhanced by the presence of charge. This increase in eccentricity might be detected as an enhancement of the differential radar reflectivity. With increasing vertical electric field, drops elongate vertically starting from oblate shape and pass through spherical and prolate shapes before breaking up. The role of charge in this process is to enhance preexisting oblateness or prolateness.

Siting of NEXRAD for Airport Surveillance and Lifetimes of Hazardous Weather Features

We have studied NEXRAD radar siting relative to airports for optimum weather surveillance in air terminal areas (Mahapatra et al., 1982a). The location that meets most FAA requirements (volume coverage, resolution, etc.) is about 10 km from the center of runways. It is shown that the most stringent requirement is the detection of low level wind shear (Mahapatra et al., 1982b).

Detailed studies on the lifetimes of storm features based on photointerpretation and computer correlation have been conducted, with the final aim of using the data to arrive at an optimum scan strategy for NEXRAD. It is found that the storms studied did not contain features that might have been missed by a 5-minute

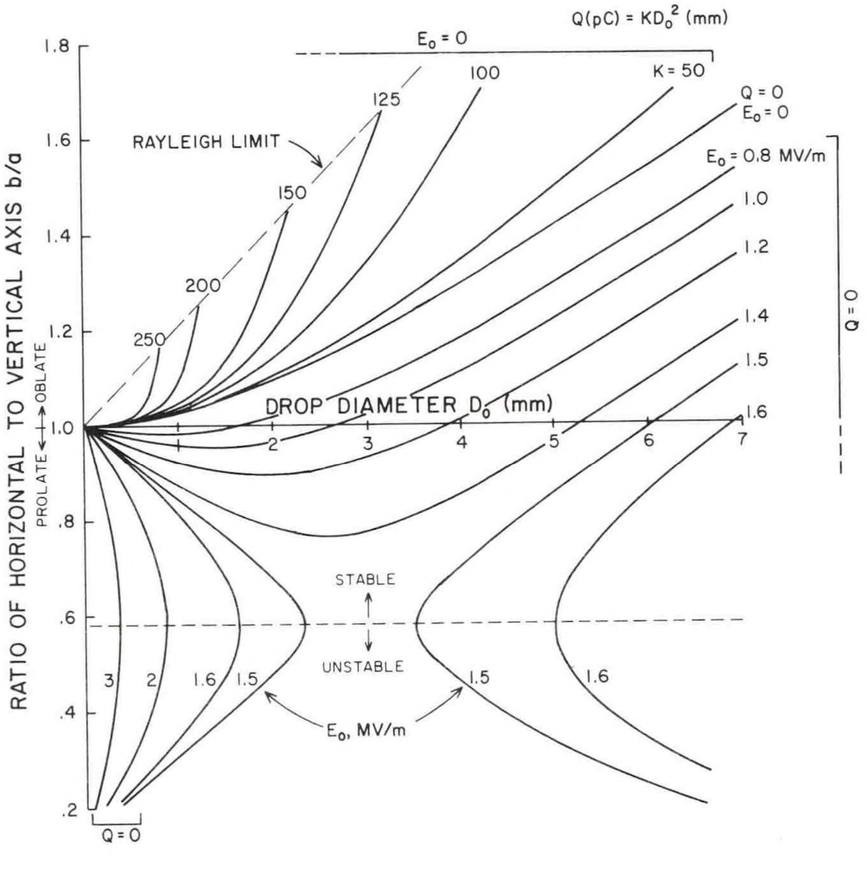


Figure 9. Ratio of horizontal to vertical axis for a spheroidal drop versus storm electric field E_0 and drop charge Q and equivalent spherical diameter D_0. The unstable region for prolate drops and the Rayleigh limit in the oblate region (for equivalent spherical drops) are shown. Charge Q and electric field E_0 are indicated.

scan cycle provided that data from all the three-moment fields (reflectivity, radial velocity and Doppler spectrum width) at several elevations are utilized in the detection of hazardous phenomena.

Processing and Display of Doppler Weather Data

An algorithm to detect mesocyclones automatically has been developed. The algorithm operates on two radials of Doppler velocities at a time and thus is suitable for real time processing. Quantitative estimates of the location of mesocyclones or shear lines and their sizes are provided as outputs from the algorithm (Hennington and Burgess, 1981).

A color display terminal (Chromatics 7900) to be used for compositing weather hazards and to help real time interpretation of Doppler data has been provided.

An algorithm to estimate the mean velocity of the Doppler power spectrum from the peak of that spectrum was developed, along with a theory to estimate the probability density of the estimates. Simulated histograms at low signal-to-noise ratios indicate that algorithm outperforms other conventional methods.

A recent article by Hennington (1981) describes how the effects of range and velocity ambiguities are dealt with in real time on the Norman Doppler range.

Studies concerning ground clutter characteristics (Hamidi and Zrnic', 1981) and filtering methods have been completed (Zrnic et al., 1982).

Numerical Evaluation of Radiation Fields of Modeled Lightning

We completed the development of numerical solutions of Maxwell's equations pertaining to lightning. This new numerical technique allows us to incorporate any return stroke current model and channel geometry. A part of this project includes a Ph.D. dissertation entitled. "The effects of channel tortuosity on electromagnetic radiations from lightning", by Mary Liaw, an OU graduate student in our project. From both theoretical and experimental studies, it has been concluded that the magnitude of the effect of lightning tortuosity on electric fields is highly dependent upon the channel current model used and the range to the flash. Possible application of our results include an assessment of errors in different cloud-to-ground lightning location systems presently in use and the modelling of lightning for study of lightning hazards to aircraft.

Cloud-to-Ground Lightning Studies

Our four-station crossed-loop direction-finding network used to locate lightning ground strikes was modified to locate +CG as well as -CG strike points within about 400 km of NSSL. Much of our effort during the first half of the year was devoted to converting and developing programs to run on the CDC Cyber 750 in Boulder. Serious problems were encountered in reading our data tapes, but these have been mostly overcome.

Analysis was begun on variations in CG flashing rates during tornadic storms (MacGorman, 1981). In a storm that passed through Binger, Oklahoma, on 22 May 1981, there was no obvious minimum in the CG flash rates of the whole storm during the time tornadoes were on the ground, as suggested by previous observations. However, the average number of strokes per flash did increase after the tornadic stage ended, and the fraction of positive CG (i.e., flashes that have lower positive charge) was generally larger before and during tornadoes. Within 10 km of the mesocyclone center, ground flash rates were lower before and during tornadoes and increased after the tornadic stage of the storm ended. In nonsevere summer storms the fraction of CG flashes that are positive varies diurnally from 0.03 to 0.3 and peaks later than the maximum occurrence of the predominant negative CG flashes.

Other Activities

In December one of us attended a meeting of the National Interagency Coordinating Group (NICG) of the National Atmospheric Electricity Hazardous Protection Program and presented an overview of work entitled "Lightning Research at the National Severe Storms Laboratory". As a result of that meeting NOAA has subsequently become a member of the NICG. Our NSSL work in both basic and applied research relating to aviation hazards should make our contribution to this interagency research an important one.

We also presented papers and/or chaired sessions in various scientific meetings such as the Fall Meeting of the AGU (Arnold and Rust, 1981; MacGorman, 1981; Mazur and Rust, 1981; Rust and Taylor, 1981); the 12th Conference on Severe Local Storms (Goodman et al., 1982; Orville et al., 1982; Rabin and Doviak, 1982), the 20th Conference on Radar Meteorology (Zrnic' et al., 1981) the URSI/Nuclear EMP Meeting (Taylor, 1982), the National Aerospace Meeting of ION (Mahapatra et al., 1982b), and anURSI Open Symposium on Multiple-Parameter Radar Measurements of Precipitation (Zrnic' et al., 1982a).

Some effort was also spent on completing previous work such as a study of layered lightning activity (MacGorman et al., 1981), electrical measurements using tethered balloons (Willett and Rust, 1981), and 1981 Spring Program Summary (Taylor, 1982b). In addition, we provided data acquisition support to staff of New Mexico Tech, who simultaneously measured other lightning parameters during the U2 overflights.

Field program operations and experiments related to aircraft operations in the terminal area are described by Lee and Doviak (1981) and Lee (1982) whereas detection of weather hazardous to aviation is presented in Zrnic' and Lee (1982).

The last two chapters, 10 and 11, for the book on Doppler weather radar have been completed. The Chapter "Weather Radar" (Doviak et al., 1982) has been published in Vol. III of Dr. Kessler's comprehensive documentation on thunderstorms.

EXPECTATIONS FOR FY-83

We expect to continue to analyze storm electricity data obtained from severe storms in 1982 and prior years to determine relationships between storm electricity and the spatial and temporal factors of precipitation, kinematics and dynamics inferred from Doppler radar and numerical models.

We will continue pursuit of electrical indicators of storm severity and develop and evaluate lightning flash-type identification techniques. We will also correlate lightning location and flash type with mesocyclone evolution. In addition, we will continue development of techniques to detect, track, and warn of lightning hazards and of other severe weather hazards through the use of lightning observations.

We expect to determine the ELF characteristics of lightning, to evaluate the ELF system capability for detecting positive and negative CG flashes, and to test the feasibility of an ELF satellite hybrid system for lightning detection and classification.

We will evaluate the +CG flash location capability of the modified lightning strike locating system and will analyze the unique set on +CG flashes that was obtained during 1982.

We plan to improve the instrument site for several electric field sensors, improve instrumentation for photographic and television recording of CG flashes, and improve the VHF mapping system to increase accuracy and range by installing new low-noise antenna coupler and making other renovations.

One of the few new NOAA postdoctoral research scientists will be with our group. The scientist will investigate electric field profiles in severe storms using instrumented free balloons.

We expect to cooperate again with several groups including NASA/MSFC, NASA/Langley Research, University of Oklahoma, University of Mississippi, and Rice University. We will continue to participate in various scientific committees and working groups and will be active in the National Interagency Coordinating Group.

We expect to undertake in-depth examination of prestorm radar data from 17 May 1981. VVP divergence will be tested further and dual Doppler analysis will be used extensively. Satellite data will be examined for information on low level moisture variations. We anticipate collaboration with researchers at Penn State University regarding this. Programs for single Doppler estimates of wind fields may be tested on real time data next spring with the possibility of a data collection program including instrumented aircraft.

The book on Doppler weather radar will be submitted to Academic Press.

Testing of the mesocyclone algorithm will be completed. A similar algorithm to detect and measure divergence in storm tops will be developed and tested.

A study of the evolution of turbulent kinetic energy from first echo until mature stage will be undertaken. In this process an attempt will be made to budget the storm's energy.

An experiment will be conducted at Wallops Island to determine how often and to what height are the turbulent fluctuations of C_n^2 in the inertial subrange at scales of 5 cm.

Composite display of hazardous weather will be developed and data from interlaced elevation scans will be processed to determine if there is loss of accuracy in hazard identification when such a scanning strategy is employed.

A study of the evolution and origin of gust fronts will continue as a prelude to determining the predictability of such events.

COMPUTER AND ENGINEERING SUPPORT AND DEVELOPMENT GROUP

Dale Sirmans, Group Leader

INTRODUCTION

This group provides engineering development, maintenance and equipment operation support for the NSSL as well as operation of the principal computer system, development of application software for engineering and meteorological support, data quality control and archiving and dissemination of data to outside groups. The Group also supports the NEXRAD JSPO/Interim Operational Test Facility of the National Weather Service which is located at NSSL.

Major research facilities of NSSL incude two 10 cm Doppler weather radars, a WSR-57 surveillance radar, an ATCBI-3 Aircraft Beacon radar, a meteorologically instrumented 1500' tower(KTVY), and a surface observational network (52 stations). Research computer support is provided by the CDC 750 at Boulder and a limited in-house capability with the Perkin Elmer 3242 computer.

RECENT ACCOMPLISHMENTS

Facilities Engineering

Much of the CESD Group effort centers around support of the Spring Program both in terms of engineering and computer development and in operations support and data handling. In 1982 the full program ran from 15 April until 15 June and elements of the program were extended through July in support of the Airborne Doppler Radar testing and evaluation. As in previous years all NSSL Facilities were utilized for the data acquisition program.

One engineering project during and after the Spring Program was the flight testing and evaluation of the airborne Doppler radars developed by Bendix Avionics and Collins Radio. In this experiment, data from NSSL's Doppler radar at Norman (NRO) were used as a benchmark for performance evaluation of the airborne systems. Systems comparison, performance evaluation, and recommendations for the airborne radars were made in a study by Robert Trotter of ERL's Weather Modification Project Office under FAA contract.

During FY 1982, the NSSL entered into a two-part contract with the NEXRAD/Joint Systems Program Office (JSPO), for engineering development in support of NEXRAD. One phase of this contract was the design and implementation of a closely spaced dual frequency meteorological Doppler radar using the NRO Doppler as the testbed. "Closely spaced" in this context means that both carrier frequency emissions are to be contained in one Radar Spectrum Width as defined by the FCC under the Radar Spectrum Emission Criteria.

The tested design used carrier frequencies of 2750 MHz and 2757.5 MHz in a dual channel scheme as shown in Figure 10. Final test results (Sirmans and Anderson, 1982) indicate that this choice of system characteristics and the NRO Doppler radar hardware could provide an isolation between frequency channels of about 50 dB as illustrated in Figure 11. This isolation is sufficient for parallel operation of the channels, i.e., same type of signal parameter estimation and transmitted waveform in both channels, but is insufficient for an estimate segregation operation, i.e., different signal parameter estimation and different transmitted waveforms in the

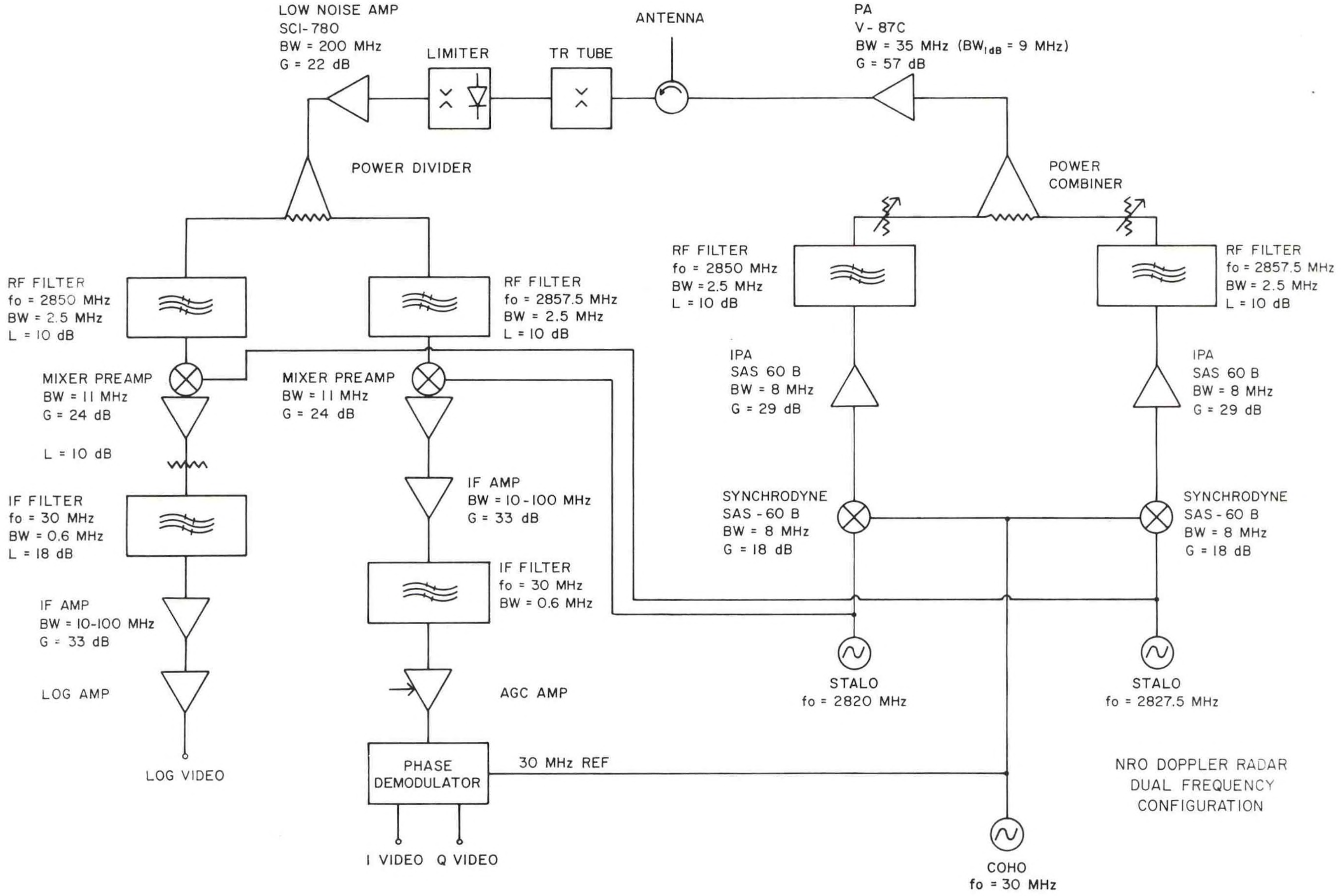
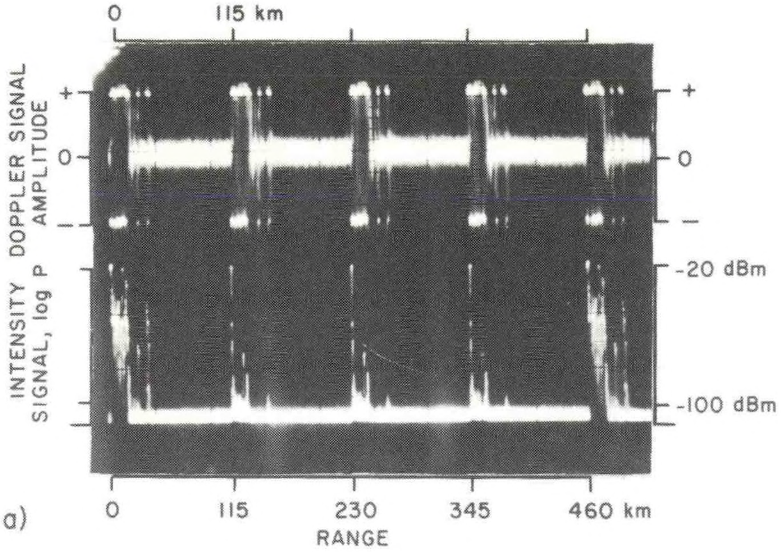
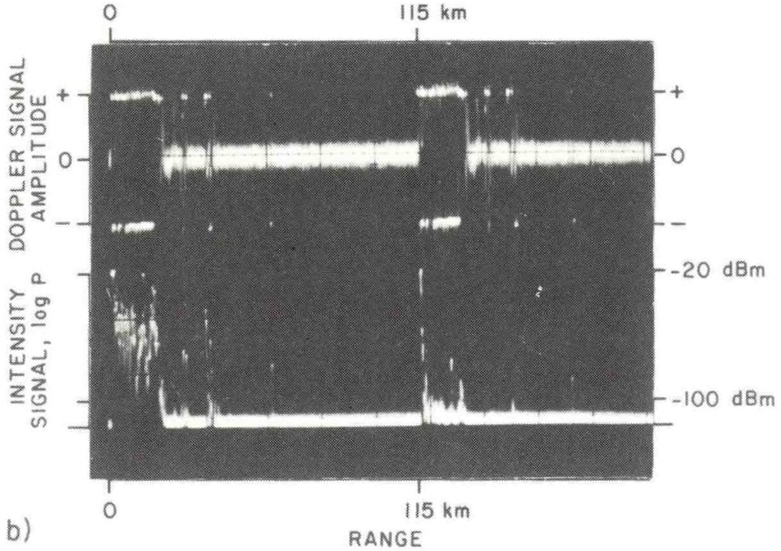


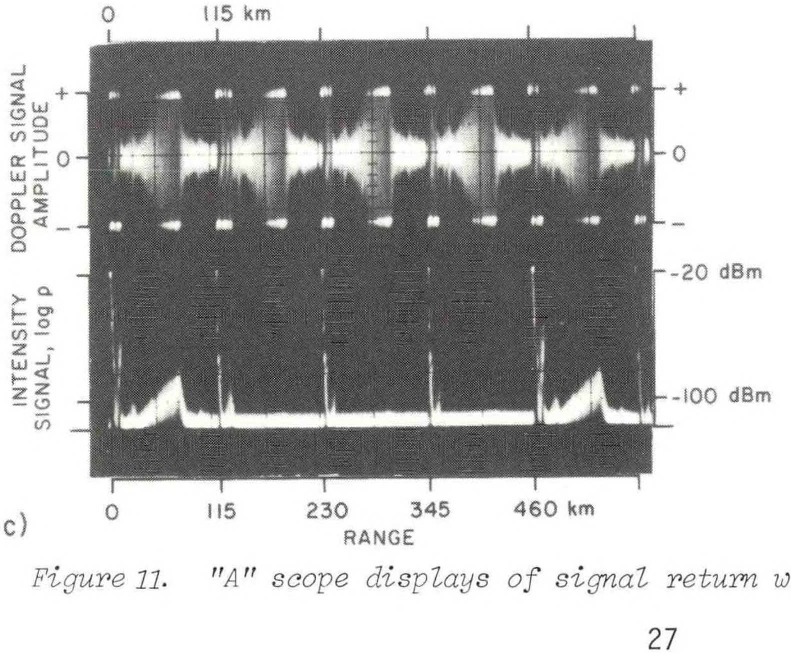
Figure 10. NRO Radar as configured for the dual frequency testing. Other arrangements were examined but most data presented were taken in this configuration.



Complete system period with ground clutter only, strong target at 40 km range is KTVY TV Tower complex.



Detail of cross coupling from Doppler to Intensity Channel, ground clutter only. Resolution is given by ratio of intensity signal with main bang (range = 0) to apparent intensity signal from Doppler Channel (range = 115 km).



Example of meteorological signal as viewed with dual frequency radar. Note absence of cross coupling at this signal level.

Figure 11. "A" scope displays of signal return with dual frequency radar system.

two channels. It is possible to achieve satisfactory estimate segregation operation by the use of high power filters (filter after the final power amplifier) but the high cost of this hardware makes the technique cost effective only for select NEXRAD sites and not the entire network. The dual frequency system development task of the JSPO/NSSL contract was completed in FY-82.

The second task of the JSPO/NSSL contract concerns the design, fabrication and evaluation of a Doppler weather radar ground clutter canceller. A third-order high-pass elliptic filter scheme was chosen. During FY-82 a design was made (Figure 12) and the major portion of the device was fabricated. It is planned to incorporate the clutter canceller into the NRO Radar for testing and evaluation during FY-83.

Another type of radar ground clutter suppression device is being developed in cooperation with the Techniques Development Laboratory of the NWS. This device operates on the return signal envelope and can be utilized in both coherent and incoherent radars. It does not provide as much suppression of clutter as the coherent method does, but has the advantage of having suppression independent of mean velocity. The device is under construction at TDL; completion is expected in early FY-83.

A major step in the improvement of the NSSL air traffic control facility was made with the completion of the preliminary design and fabrication of a color display terminal capable of providing mosaics of weather radar data with aircraft beacon data.

Development of a photovoltaic power system for use on the surface observational network continues with the receipt and testing of all components of the 52 station system. The two wind-powered electrical generators being evaluated as alternate sources for this type power system are still under test.

Computer Support

In June 1981, installation of a Perkin Elmer 3242 computer system and an array processor was completed. This system will allow real-time quality control of data and provide the necessary computer power to generate real-time products for display on a high-resolution color graphics terminal. During FY-82 the number of asynchronous ports was increased from eight to sixteen and the Doppler radar was interfaced to the PE 3242. Orders were placed for a seven-track tape drive, a second nine-track drive, and a 300 megabyte disk drive.

During August 1981, a CDC Cyber 18 RJE station and sixteen-channel statistical multiplex were installed and connected via a dedicated 9600 baud phone line to allow access to the CDC Cyber 750 at Boulder. On 1 October 1981, the in-house SEL 8600 computer system was unplugged and general research was shifted to the CDC 750. Conversion of software to the CDC 750 began in August and continued throughout FY-82. Within the constraints of allocated computer resources, production usage peaked during July 1982. Program conversion time and usage of the CDC 750 have far exceeded projected values and a request for more than double the FY82 CDC 750 usage has been made for FY-83.

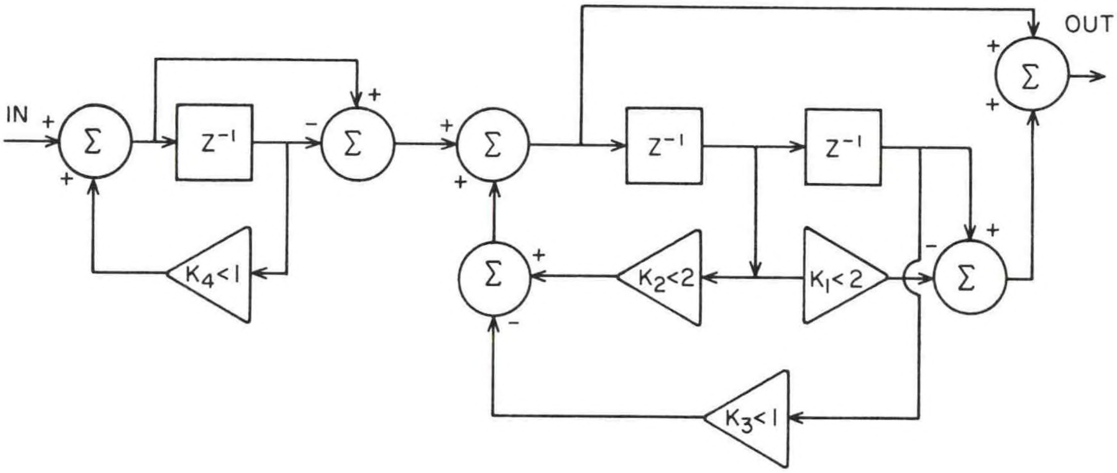


Figure 12.1. Block diagram of the third-order high-pass elliptic filter.

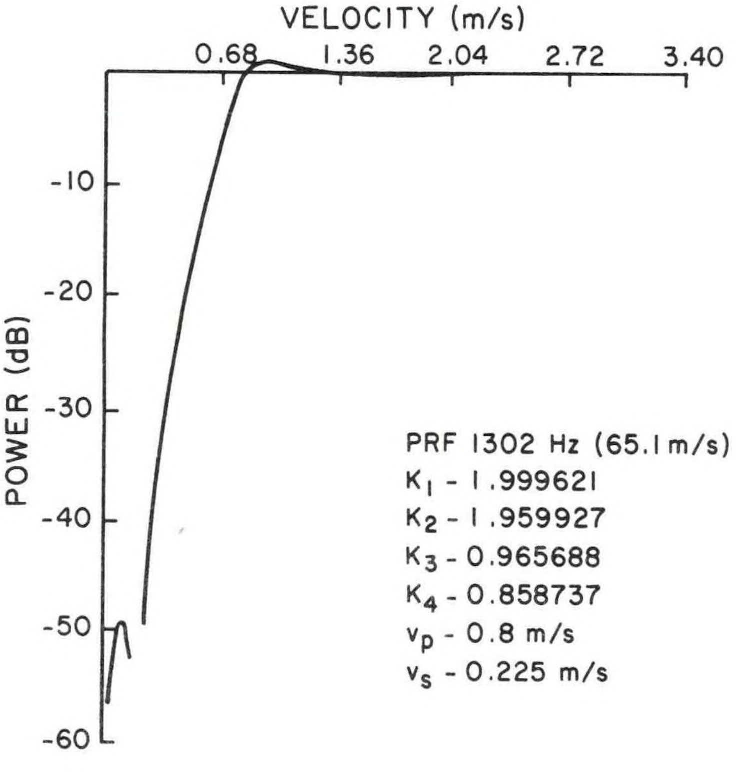


Figure 12.2. Frequency (Doppler velocity) response characteristic of the recursive Filter 1. The Nyquist interval is 65.1 $m \cdot s^{-1}$; in subsequent simulations it is slightly reduced to 64 $m \cdot s^{-1}$

The 1979 SESAME surface data set was archived in the Universal Exchange Format and is available for distribution. This archiving could not be accomplished on the SEL 8600 but was possible with the large on-line disk storage of ERL's CDC 750.

EXPECTATIONS FOR FY83

Facilities Engineering

During the Spring of 1983 the major NSSL facilities will be configured to support a real-time radar operational experiment for the IOTF/JSPO in addition to a research experiment period. For the IOTF, the NRO Doppler Radar will be operated routinely (7 days a week, 10 hours a day) and data products from this system will be transmitted to NWS' Oklahoma City Office and to the Base Weather Station at Tinker Field for use by weather forecasters. Facilities expansion in direct support of this NEXRAD work includes the ground clutter suppresser for the NRO Radar and expansion of the Perkin Elmer 3242 Computer Terminal. The Surface Network and Tall Tower will be specifically configured and operated for support of this experiment.

The Spring Program will also include a period devoted to meteorological research. Related facilities development includes the commissioning of the weather radar-aircraft beacon data display terminal for air traffic control evaluation, modification of the tall tower data logger, modification of TOTO (Totable Tornado Observatory) and improvement in the clear air detection capability of the NRO and CIM Radar.

Engineering development plans include development of a fast deployable meteorological sensor package for measurements in severe storms, completion of the radar clutter suppression testing and evaluations, and evaluation of alternate power sources for the NSSL surface network.

Computer Support

All upgrades ordered for the Perkin Elmer 3242 will be installed and made operational. Usage of the PE 3242 by both NSSL and NEXRAD will increase, full real-time capability being reached during Spring 1983. A decision will be made on placement of a minicomputer at NSSL in FY-84. The lack of in-house capability to perform quality control, archiving and display of existing data is slowing NSSL's research efforts.

Outside individuals receiving substantial NSSL data sets during FY 1982 were:

Aeromet, Tulsa, Okla.	(Phillip Stickel)
Battelle, Richland, Wash.	(Allen Miller)
Florida State University Tallahassee, Fla.	(Jerry Stephens)
MIT - Cambridge, Mass.	(Kerry Emanuel)
MIT Lincoln Laboratory Lexington, Mass.	(John Anderson) (James Evans)

NCAR, Boulder, Colo.	(Andrew Heymsfield)
NASA, Marshall Space Flight Center Huntsville, Ala.	(Stephen Goodman)
NASA, Greenbelt, Md.	(Jerry Heymsfield)
National Weather Service Silver Spring, Md.	(Kenneth Shreeve)
Texas A&M University College Station, Tex.	(Dennis Regan)
University of Illinois Champaign, Ill.	(Robert Wilhelmson)
University of Wisconsin Madison, Wis.	(Charles Anderson)
Ohio State University Columbus, Ohio	(Thomas Seliga)

COOPERATIVE INSTITUTE FOR MESOSCALE METEOROLOGICAL STUDIES

Edwin Kessler

The Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) is a joint venture of the University of Oklahoma and NOAA/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 at NSSL and the University through research conducted by Visiting Fellows, NOAA and University staff, and student appointees.

CIMMS was first led by Interim Director Rex L. Inman, then Head of the Department of Meteorology at the University of Oklahoma. During 1980, Dr. Yoshi K. Sasaki, George Lynn Cross Professor of Meteorology at O.U., was appointed Acting Director and subsequently Director. During 1982, Dr. Peter Ray of NSSL was appointed Associate Director of CIMMS, and the University of Oklahoma provided funds for an Administrative Assistant position filled by Elvira Aguayo on September 12. The present Council of Fellows, which helps formulate policy, includes Associate Director Ray and Dr. Dusan Zrnic' of NSSL, both of whom hold adjunct professorial appointments at O.U., and Director Sasaki and Prof. Inman of O.U. The Advisory Council, which includes representatives from O.U., NOAA, and outside organizations, meets annually.

During 1982, CIMMS activities expanded substantially. CIMMS hosted Dr. M. Shirakawa of Japan, Dr. Francois Xavier Le Dimet of France, and Dr. Isztar Zawadski of Canada, who undertook research studies at CIMMS in radar meteorology and mesoscale dynamics, for periods from three months to a year, with principal financial support from their universities or governments. Post-doctoral Fellow Dr. John McGinley represented CIMMS in the ALPEX field program during March and April 1982, and Dr. Vladislav Mazur joined CIMMS as a post-doctoral Fellow engaged in investigations on lightning. Drs. Ananth Sundararajan, James Goerss, and L.P. Chang are post-doctoral Fellows on multi-year appointments, working in areas of boundary layer dynamics and mesoscale numerical modeling. Approximately ten students employed by CIMMS are engaged in research studies toward advanced degrees; there are also five undergraduate students variously employed and a research associate working in the NEXRAD program; most of these are related also to NSSL and the OU Department of Meteorology.

Approximately ten reports and publications authored or coauthored by CIMMS personnel appeared during FY 82.

CIMMS hosted a Symposium on Mesoscale Modeling during June 1-2, and the NCAR/UCAR Storms Workshop/Symposium during June 3-4 1982, with nearly 200 in attendance. During September 22-24, CIMMS hosted a Symposium/Workshop on NEXRAD with approximately 100 attendees. Finally, Director Sasaki was a member of the International Organizing Committee of the 4th International Symposium on Finite Element Methods in Flow Problems, held in Tokyo during July 26-29, with more than 400 scientists and engineers in attendance.

CIMMS base funding provided through NSSL continues at $100,000 per year and additional funds through NSSL, principally to support employment of students, amounted to another $100,000 during FY 1982. Although the base funds from NOAA have not kept pace with inflation, CIMMS has received contracts and grants from other agencies to the extent of about $700,000 in FY 82 and CIMMS also received over $100,000 from the University. This funding has enabled CIMMS to obtain some significant computer facilities and to expand its activities to a scale that is probably large enough to be self sustaining. CIMMS is a center of excellence and a vital administrative component of the triad which includes the University of Oklahoma Department of Meteorology and the NOAA National Severe Storms Laboratory.

Although there have been some financial shocks to plans for building a new "Energy Center" at the University of Oklahoma, these have resulted only in a scaling down of projections. Construction of new facilities for CIMMS and the Department of Meteorology in the College of Geosciences is scheduled to start during spring 1983.

Prominent in future plans is a Symposium at Norman on Mesoscale Modeling, scheduled for 31 May to 3 June 1983, to be jointly sponsored by CIMMS and the American Meteorological Society. During 1985, there is planned a Symposium at Norman on Variational Methods in Geosciences, to be jointly sponsored by CIMMS and the University of Clermont, France.

ADMINISTRATIVE GROUP

Loyce Tillman, Administrative Officer

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

PERSONNEL

At the end of FY-82 the NSSL total staff included 39 full-time, two part-time, one Junior Fellow and 17 intermittent employees.

Our personnel staff continues to be supplemented by contracts with the University of Oklahoma, Applied Computer Systems, and the NEXRAD/IOTF.

LAND AND BUILDINGS

Leases on land and buildings utilized by NSSL during FY-82 were substantially unchanged from FY-81.

In August, 1972, NSSL occupied a new two-story reinforced concrete and glass building leased from the University of Oklahoma at a cost of approximately $120,000 annually. The building contains about 20,000 square feet and is situated on approximately one and one-half acres of land.

Two relocatable structures (14' x 46' workspace) are also located on the above leased land. One building is used as a central facility adjacent to the Doppler Radar Laboratory Building. The other one is used to house lightning equipment for our Storm Electricity Project.

Other space rented from the University of Oklahoma includes:

a. A warehouse containing 3,840 square feet of usable space
b. Ground space of 718 square feet formerly leased for a rawinsonde facility was relinquished during FY-82
c. Ground space of 17,280 square feet adjacent to the new quarters, with the Doppler Radar Laboratory Building owned by NSSL, plus a tower supporting a rangefinder
d. Ground space of 17,820 square feet north and across the street from the NSSL, with the following facilities:
    1. small modulator building
    2. WSR-57 radar atop a 20-meter tower
    3. a second tower with UHF and VHF radio antenna
    4. a third tower with IFF equipment (MPX-7 radar) to interrogate transponders aboard aircraft to determine aircraft position

e. Ground space, one-half acre south and adjacent to the Laboratory which contains a "benchmark" weather station. (This facility represents cooperation among NSSL, the University of Oklahoma, and the City of Norman, Oklahoma
f. Ground space of 120,000 square feet 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 of the leases in items a through f above is approximately $6,300 annually.

Additional leased space includes:

g. One acre of land leased from Will Rogers Airport Trust at Cimarron, Oklahoma, about 45 km northwest of Norman, containing a second Doppler radar unit
h. Leased space at Chickasha, Oklahoma, containing a rawinsonde site and mesonetwork equipment
i. Levels at the 457 meter KTVY (Television Systems, Inc.) tower, Oklahoma City, Oklahoma, 40 km north of Norman. During most of FY-80, wind and temperature sensors were operated at seven levels on the tower with vertical wind at top and bottom, and digital data on pressure, rainfall, and solar radiation. An analog strip chart recorder operates at the tower site, with simultaneous telephone-line telemetry of digital data for real-time displays and magnetic tape recording at NSSL headquarters
j. During the NSSL's 1981 Spring Program, an additional 0.5 acre of land was leased at Cimarron, Oklahoma, for use as a storm electricity data collection site
k. Land agreements for 52 network sites.

Total annual cost for all items g through k above is approximately $28,000.

OTHER

In 1978, the NSSL acquired from GSA surplus, a one-acre parcel of land in Garfield County to be used as an observational site. An existing building (22' x 16') serves to store supplies needed for rawinsondes and operational office area.

The lease agreement effective when NSSL occupied new quarters in August 1972 was for a term of 10 years, and included an option to renew. Renewal is being negotiated with the University of Oklahoma at this writing.

GRANTS AND CONTRACTS
FY-82

Grants and contracts administered by NSSL during FY-82 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"	NA81RAE00036 ($47,500)	Bumgarner	10-01-81	09-30-82
Florida State University "Longitudinal Convective Rolls in the Clear Atmospheric Boundary Layer"	NA82RAA00125 ($6,868)	Ray	08-06-82	05-05-83
University of Illinois "Observational Analysis in Conjunction with Storm Modeling"	NA82RAA00124 ($10,000)	Ray	08-15-82	07-31-83
University of Mississippi "Storm Electricity in Severe Convective Storms" (Arnold)	NA79RAD00007 ($19,925)	Rust	03-31-82	03-31-83
University of Oklahoma Cooperative Agreement "Cooperative Institute for Mesoscale Meteorological Studies (CIMMS)" (Sasaki)	NA80RAH00004 ($460,700)*	Kessler	06-30-82	06-30-83
University of Oklahoma Cooperative Agreement "Research on Severe Local Storms" (Golden)	NA82RAH00003 ($18,211)	Rust	09-01-82	08-31-83

*This represents funding for two years, all of which was provided within the Federal 1982 fiscal year, related to a one-time administrative adjustment.

PUBLICATIONS AND REPORTS OF THE LABORATORY
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[1] Published Abstracts are given in a separate list starting on p. 40.

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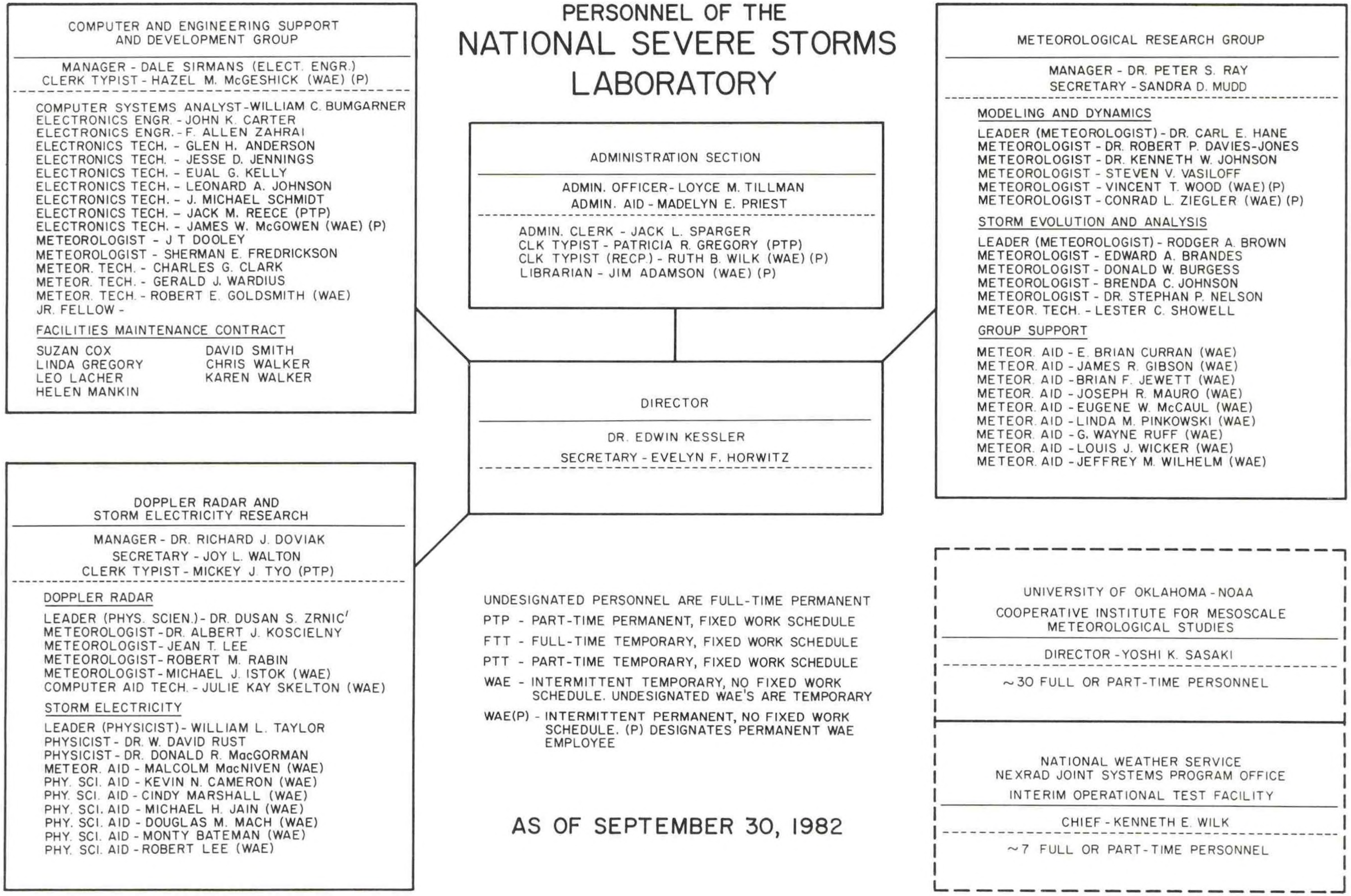
PERSONNEL OF THE NATIONAL SEVERE STORMS LABORATORY



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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, 1982

UNIVERSITY OF OKLAHOMA - NOAA

COOPERATIVE INSTITUTE FOR MESOSCALE METEOROLOGICAL STUDIES

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NATIONAL WEATHER SERVICE
NEXRAD JOINT SYSTEMS PROGRAM OFFICE

INTERIM OPERATIONAL TEST FACILITY

CHIEF - KENNETH E. WILK

~7 FULL OR PART-TIME PERSONNEL

STAFF OF NSSL, CIMMS AND NEXRAD INTERIM OPERATIONAL TEST FACILITY

CIMMS and NEXRAD are administratively separate from NSSL but all work closely together and share use of some facilities.

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 depending upon the number of pages. NTIS numbers are given below in parenthesis.

No. 1 National Severe Storms Project Objectives and Basic Design. Staff, NSSP. March 1961, 16 p. (PB-168207)

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

No. 3 Instability Lines and Their Environments as Shown by Aircraft Soundings and Quasi-Horizontal Traverses. D. T. Williams. February 1962. 15 p. (PB-168209)

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

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

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

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